circle through that pole. Thus, in the figure, the declination (*krânti*) of S would be *c a*, or the distance of *a* from the equator at *c* : its latitude (*vikshepa*) is *a* S, or its distance from *a*. We have, accordingly, the same term used here as before. To designate the position in longitude of *a*, on the other hand, we have a new term, *dhruva*, or, as below, (vv. 12, 15), *dhruvaka*. This comes from the adjective *dhruva*, "fixed, immovable," by which the poles of the heaven (see below, xii. 43) are designated; and, if we do not mistake its application, it indicates, as here employed, the longitude of a star as referred to the ecliptic by a circle from the pole. We venture, then, to translate it by "polar longitude," as we also render *vikshepa*, in this connection, by "polar latitude," it being desirable to have for these quantities distinctive names, akin with one another. Colebrooke employs "apparent longitude and latitude," which are objectionable, as being more properly applied to the results of the process taught in the last chapter (vv. 7–10).

The mode of statement of the polar longitudes is highly artificial and arbitrary : a number is mentioned which, when multiplied by ten, will give the position of each asterism, in minutes, in its own "portion" (*bhoga*), or arc of 13° 20′ in the ecliptic (see ii. 64).

This passage presents a name for the asterisms, *dhishnya*, which has not occurred before ; it is found once more below, in xi. 21.

2. Forty-eight, forty, sixty-five, fifty-seven, fifty-eight, four, seventy-eight, seventy-six, fourteen,

3. Fifty-four, sixty-four, fifty, sixty, forty, seventy-four, seventy-eight, sixty-four.

4. Fourteen, six, four; Uttara-Ashâḍhâ, (*vâiçva*) is at the middle of the portion (*bhoga*) of Pûrva-Ashâḍhâ (*âpya*); Abhijit, likewise, is at the end of Pûrva-Ashâḍhâ; the position of Çravaṇa is at the end of Uttara-Ashâḍhâ;

5. Çravishthâ, on the other hand, is at the point of connection of the third and fourth quarters (*pada*) of Çravaṇa: then, in their own portions, eighty, thirty-six, twenty-two,

6. Seventy-nine. Now their respective latitudes, reckoned from the point of declination (*apakrama*) of each: ten, twelve, five, north; south, five, ten, nine;

7. North, six; nothing; south, seven; north, nothing, twelve, thirteen; south, eleven, two; then thirty-seven, north;

8. South, one and a half, three, four, nine, five and a half, five; north, also, sixty, thirty, and also thirty-six;

9. South, half a degree; twenty-four, north, twenty-six degrees; nothing—for Açvinî (*dasra*), etc., in succession.

The text here assumes that the names of the asterisms, and the order of their succession, are so familiarly known as to render it unnecessary to rehearse them. It has been already noticed (see above, i. 48–51, 55, 56–58, etc.) that a similar assumption was made as regards the names and succession of the months, signs of the zodiac, years of Jupiter's cycle, and the like. Many of the asterisms have more than one appellation: we present in the annexed table those by which they are more generally and familiarly known; the others will be stated farther on. Nearly all these titles are to be found in our text, occurring here and there; a few of the asterisms, however, (the 5th, 6th, 9th, and 17th), are mentioned only by appellations derived from the names of the deities to whom they are regarded as belonging, and one (the 25th) chances not to be once distinctively spoken of. We append to the names, in a tabular form, the data presented in this passage; namely, the position of each asterism (*nakshatra*) in the arc of the ecliptic to which it gives name, and which is styled its "portion" (*bhoga*), the resulting polar longitudes, and the polar latitudes. And since it is probable (see note to the latter half of v. 12, below) that the latter were actually derived by calculation from true declinations and right ascensions, ascertained by observation, we have endeavored to restore those more original data by calculating them back again, according to the data and methods of this Siddhânta—the declinations by ii. 28, the right ascensions by iii. 44–48—and we insert our results in the table, rejecting odd minutes less than ten.

Positions of the Junction-Stars of the Asterisms.

No.	Name.	Position in its Portion.	Polar Longitude.	Polar Latitude.	Right Ascension.	True Declination.	Interval in Longitude.	Interval in R. A.
		° ′	° ′	° ′	° ′	° ′	° ′	° ′
1	Açvinî,	8 0	8 0	10 0 N.	7 30	13 20 N.	12 0	11 0
2	Bharaṇî,	6 40	20 0	12 0 "	18 30	20 0 "	17 30	16 50
3	Kṛttikâ,	10 50	37 30	5 0 "	35 20	19 20 "	12 0	12 0
4	Rohiṇî,	9 30	49 30	5 0 S.	47 20	13 0 "	13 30	13 40
5	Mṛgaçîrsha,	9 40	63 0	10 0 "	61 0	11 20 "	4 20	4 40
6	Ârdrâ,	0 40	67 20	9 0 "	65 40	13 0 "	25 40	27 30
7	Punarvasu,	13 0	93 0	6 0 N.	93 10	30 0 "	13 0	14 0
8	Pushya,	12 40	106 0	0 0	107 10	23 0 "	3 0	3 20
9	Âçleshâ,	2 20	109 0	7 0 S.	110 30	15 40 "	20 0	20 40
10	Maghâ,	9 0	129 0	0 0	131 10	18 20 "	15 0	15 0
11	P.-Phalgunî,	10 40	144 0	12 0 N.	146 10	25 50 "	11 0	10 40
12	U.-Phalgunî,	8 20	155 0	13 0 "	156 50	22 50 "	15 0	13 50
13	Hasta,	10 0	170 0	11 0 S.	170 40	7 0 S.	10 0	9 20
14	Citrâ,	6 40	180 0	2 0 "	180 0	2 0 "	19 0	17 40
15	Svâtî,	12 20	199 0	37 0 N.	197 40	29 20 N.	14 0	13 10
16	Viçâkhâ,	13 0	213 0	1 30 S.	210 50	14 20 S.	11 0	11 0
17	Anurâdhâ,	10 40	224 0	3 0 "	221 50	19 20 "	5 0	5 0
18	Jyeshṭhâ,	2 20	229 0	4 0 "	226 50	21 50 "	12 0	12 0
19	Mûla,	1 0	241 0	9 0 "	238 50	29 50 "	13 0	14 0
20	P.-Ashâḍhâ,	0 40	254 0	5 30 "	252 50	28 30 "	6 0	6 30
21	U.-Ashâḍhâ,	....	260 0	5 0 "	259 20	28 40 "	6 40	7 0
22	Abhijit,	....	266 40	60 0 N.	266 20	36 0 N.	13 20	14 30
23	Çravaṇa,	....	280 0	30 0 "	280 50	6 20 "	10 0	10 40
24	Çravishṭhâ,	....	290 0	36 0 "	291 30	13 30 "	30 0	30 40
25	Çatabhishaj,	13 20	320 0	0 30 S.	322 10	15 40 S.	6 0	6 0
26	P.-Bhâdrapadâ,	6 0	326 0	24 0 N.	328 10	10 50 N.	11 0	10 30
27	U.-Bhâdrapadâ,	3 40	337 0	26 0 "	338 40	16 50 "	22 50	21 10
28	Revatî,	13 10	359 50	0 0	359 50	0 0	8 10	7 40

Fig. 31.


0°
360°
1. Açvinî.
2. Bharaṇî.
3. Kṛttikâ.
4. Rohiṇî.
5. Mṛgaçîrsha.
6. Ârdrâ.
7. Punarvasu.
8. Pushya.
9. Âçleshâ.
10. Maghâ.
11. P.-Phalgunî.
12. U.-Phalgunî.
13. Hasta.
14. Citrâ.
1. A.
—1. Açvinî.
2. Bh.
—2. Bharaṇî.
3. K.
—3. Kṛttikâ.
4. R.
—4. Rohiṇî.
5. M.
—5. Mṛgaçîrsha.
—6. Ârdrâ.
6. Â.
7. P.
—7. Punarvasu.
8. P.
—8. Pushya.
—9. Âçleshâ.
Â.
10. M.
—10. Maghâ.
11. P.-Ph.
—11. P.-Phalgunî.
12. U.-Ph.
—12. U.-Phalgunî.
13. H.
—13. Hasta.
14. C.
—14. Citrâ.
180°
28. Revatî—
28 R.
27 U.-Bh
27. U.-Bhâdrapadâ—
26 P.-Bh
26. P.-Bhâdrapadâ—
25. Çatabhishaj—
25 Çat.
24. Çr
23
24. Çravishthâ—
Ç
23. Çravaṇa—
22. A
22. Abhijit—
21 U.-A.
21. U.-Ashâḍhâ—
20. P.-Ashâḍhâ—
20. P.-A.
19. Mûla—
19 M
18. Jyeshthâ—
18. J.
17. Anurâdhâ—
17 A.
16. Viçâkhâ—
16 V.
15. Svâtî—
15. S.
14. Citrâ—
180°
27. Revatî.
26. U.-Bhâdrap.
25. P.-Bhâdrap.
24. Çatabhishaj.
23. Çravishthâ.
22. Çravaṇa.
21. U.-Ashâḍhâ.
20. P.-Ashâḍhâ.
19. Mûla.
18. Jyeshthâ.
17. Anurâdhâ.
16. Viçâkhâ.
15. Svâtî.
14. Citrâ.

Our calculations, it should be remarked, are founded upon the assumption that, at the time when the observations were made of which our text records the results, the vernal equinox coincided with the initial point of the Hindu sidereal sphere, or with the beginning of the portion of the asterism Açvinî, a point 10′ eastward on the ecliptic from the star ζ Piscium: this was actually the case (see above, under i. 27) about A. D. 560. The question how far this assumption is supported by evidence contained in the data themselves will be considered later. To fill out the table, we have also added the intervals in right ascension and in polar longitude.

The stars of which the text thus accurately defines the positions do not, in most cases, by themselves alone, constitute the asterisms (*nakshatra*); they are only the principal members of the several groups of stars—each, in the calculation of conjunctions (*yoga*) between the planets and the asterisms (see below, vv. 14–15), representing its group, and therefore called (see below, vv. 16–19) the "junction-star" (*yogatârâ*) of the asterism.

It will be at once noticed that while, in a former passage (ii. 64), the ecliptic was divided into twenty-seven equal arcs, as portions for the asterisms, we have here presented to us twenty-eight asterisms, very unequally distributed along the ecliptic, and at greatly varying distances from it. And it is a point of so much consequence, in order to the right understanding of the character and history of the whole system, to apprehend clearly the relation of the groups of stars to the arcs allotted to them, that we have prepared the accompanying diagram (Fig. 31) in illustration of that relation. The figure represents, in two parts, the circle of the ecliptic: along the central lines is marked its division into arcs of ten and five degrees: upon the outside of these lines it is farther divided into equal twenty-sevenths, or arcs of 13° 20′, and upon the inside into equal twenty-eighths, or arcs of 12° 51$\frac{3}{7}$′; these being the portions (*bhoga*) of two systems of asterisms, twenty-seven and twenty-eight in number respectively. The starred lines which run across all the divisions mark the polar longitudes, as stated in the text, of the junction-stars of the asterisms. The names of the latter are set over against them, in the inner columns: the names of the portions in the system of twenty-seven are given in full in the outer columns, and those in the system of twenty-eight are also placed opposite the portions, upon the inside, in an abbreviated form.

The text nowhere expressly states which one of the twenty-eight asterisms which it recognizes is, in its division of the ecliptic into only twenty-seven portions, left without a portion. That Abhijit, the twenty-second of the series, is the one thus omitted, however, is clearly implied in the statements of the fourth and fifth verses. Those statements, which have caused difficulty to more than one expounder of the passage, and have been variously misinterpreted, are made entirely clear by supplying the words "asterism" and "portion" throughout, where they are to be understood, thus: "the asterism Uttara-Ashâḍhâ is at the middle of the portion styled Pûrva-Ashâḍhâ; the asterism Abhijit, likewise, is at the end of the portion Pûrva-Ashâḍhâ; the position of the asterism Çravaṇa is at the end of the portion receiving its name from Uttara-Ashâḍhâ; while the asterism Çravishṭhâ is between the third and fourth quarters of the portion named for Çravaṇa." After this interruption to the regularity of correspondence of the two systems—the asterism Abhijit being left without a portion, and the portion Çravishṭhâ containing no asterism—they go on again harmoniously together to the close. The figure illustrates clearly this condition of things, and shows that, if Abhijit be left out of account, the two systems agree so far as this—that twenty-six asterisms fall within the limits of portions bearing the same name, while all the discordances are confined to one portion of the ecliptic, that comprising the 20th to the 23d portions. If, on the other hand, the ecliptic be divided into twenty-eighths, and if these be assigned as portions to the twenty-eight asterisms, it is seen from the figure that the discordances between the two systems will be very great; that only in twelve instances will a portion be occupied by the asterism bearing its own name, and by that alone; that in sixteen cases asterisms will be found to fall within the limits of portions of different name; that four portions will be left without any asterism at all, while four others will contain two each.

These discordances are enough of themselves to set the whole subject of the asterisms in a new light. Whereas it might have seemed, from what we have seen of it heretofore, that the system was founded upon a division of the ecliptic into twenty-seven equal portions, and the selection of a star or a constellation to mark each portion, and to be, as it were, its ruler, it now appears that the series of twenty-eight asterisms may be something independent of, and anterior to, any division of the ecliptic into equal arcs, and that the one may have been only artificially brought into connection with the other, complete harmony between them being altogether impossible. And this view is fully sustained by evidence derivable from outside the Hindu science of astronomy, and beyond the borders of India. The Pârsis, the Arabs, and the Chinese, are found also to be in possession of a similar system of division of the heavens into twenty-eight portions, marked or separated by as many single stars or constellations. Of the Pârsî system little or nothing is known excepting the number and names of the divisions, which are given in the second chapter of the Bundehesh (see Anquetil du Perron's Zendavesta, etc., ii. 349). The Arab divisions are styled *manâzil al-kamar*, "lunar mansions, stations of the moon," being brought into special connection with the moon's revolution; they are marked, like the Hindu "portions," by groups of stars. The first extended comparison of the Hindu asterisms and the Arab mansions was made by Sir William Jones, in the second volume of the Asiatic Researches, for 1790: it was, however, only a rude and imperfect sketch, and led its author to no valuable or trustworthy conclusions. The same comparison was taken up later, with vastly more learning and acuteness, by Colebrooke, whose valuable article, published also in the Asiatic Researches, for 1807 (ix. 323, etc.; Essays ii. 321, etc.), has ever since remained the chief source of knowledge respecting the Hindu asterisms and their relation to the lunar mansions of the Arabs. To Anquetil (as above) is due the credit of the first suggestion of a coincidence between the Pârsî, Hindu, and Chinese systems: but he did nothing more than suggest it: the origin, character, and use of the Chinese divisions were first established, and their primitive identity with the Hindu asterisms demonstrated, by Biot, in a series of articles published in the Journal des Savants for 1840: and he has more recently, in the volume of the same Journal for 1859, reviewed and restated his former exposition and conclusions. These we shall present more fully hereafter: at present it will be enough to say that the Chinese divisions are equatorial, not zodiacal; that they are named *sieu*, "mansions"; and that they are the intervals in right ascension between certain single stars, which are also called *sieu*, and have the same title with the divisions which they introduce. We propose to present here a summary comparison of the Hindu, Arab, and Chinese systems, in connection with an identification of the stars and groups of stars forming the Hindu asterisms, and with the statement of such information respecting the latter, beyond that given in our text, as will best contribute to a full understanding of their character.

The identification of the asterisms is founded upon the positions of their principal or junction-stars, as stated in the astronomical text-books, upon the relative places of these stars in the groups of which they form a part, and upon the number of stars composing each group, and the figure by which their arrangement is represented: in a few cases, too, the names themselves of the asterisms are distinctive, and assist the identification. The number and configuration of the stars forming the groups are not stated in our text; we derive them mainly from Colebrooke, although ourselves also having had access to, and compared, most of his authorities, namely the Çâkalya-Sanhitâ, the Muhûrta-Cintâmani, and the Ratnamâlâ (as cited by Jones, As. Res., ii. 294). Sir William Jones, it may be remarked, furnishes (As. Res., ii. 293, plate) an engraved copy of drawings made by a native artist of the figures assigned to the asterisms. For the number of stars in each group we have an additional authority in al-Bîrûnî, the Arab savant of the eleventh century, who travelled in India, and studied with especial care the Hindu astronomy. The information furnished by him with regard to the asterisms we derive from Biot, in the Journal des Savants for 1845 (pp. 39–54); it professes to be founded upon the Khanda-Kataka* of Brahmagupta. Al-Bîrûnî also gives an identification of the asterisms, so far as the Hindu astronomers of his day were able to furnish it to him, which was only in part: he is obliged to mark seven or eight of the series as unknown or doubtful. He speaks very slightingly of the practical acquaintance with the heavens possessed by the Hindus of his time, and they certainly have not since improved in this respect; the modern investigators of the same subject, as Jones and Colebrooke, also complain of the impossibility of obtaining from the native astronomers of India satisfactory identifications of the asterisms and their junction-stars. The translator, in like manner, spent much time and effort in the attempt to derive such information from his native assistant, but was able to arrive at no results which could constitute any valuable addition to those of Colebrooke. It is evident that for centuries past, as at present, the native

* The true form of the name is not altogether certain, it being known only through its Arabic transcription: it seems to designate rather a chapter in a treatise than a complete work of its author.

tradition has been of no decisive authority as regards the position and composition of the groups of stars constituting the asterisms: these must be determined upon the evidence of the more ancient data handed down in the astronomical treatises.

In order to an exact comparison of the positions of the junction-stars as defined by the Hindus with those of stars contained in our catalogues, we have reduced the polar longitudes and latitudes to true longitudes and latitudes, by the following formulas (see Fig. 30):

$$(1 \div \cos Aa) \cot ELC = \tan Sab$$
$$\sin Sab \sin Sa = \sin Sb$$
$$\tan Sb \cot Sab = \sin ab$$

ELC = ω   Aa = λ'
Sab = A   Sa = β'
Sb = β
ab = λ-λ'

Aa being the polar longitude as stated in the text ($= La + 180°$), Sa the polar latitude, ELC the inclination of the ecliptic, Sb the true latitude, and ab a quantity to be added to or subtracted from the polar longitude to give the true longitude. The true positions of the stars compared we take from Flamsteed's Catalogus Brittanicus, subtracting in each case 15° 42′ from the longitudes there given, in order to reduce them to distances from the vernal equinox of A. D. 560, assumed to coincide with the initial point of the Hindu sphere. There is some discordance among the different Hindu authorities, as regards the stated positions of the junction-stars of the asterisms. The Çâkalya-Sanhitâ, indeed, agrees in every point precisely with the Sûrya-Siddhânta. But the Siddhânta-Çiromaṇi often gives a somewhat different value to the polar longitude or latitude, or both. With it, so far as the longitude is concerned, exactly accord the Brahma-Siddhânta, as reported by Colebrooke, and the Khaṇḍa-Kaṭaka, as reported by al-Bîrûnî. The latitudes of the Brahma-Siddhânta also are virtually the same with those of the Siddhânta-Çiromaṇi, their differences never amounting, save in a single instance, to more than 3′: but the latitudes of the Khaṇḍa-Kaṭaka often vary considerably from both. The Graha-Lâghava, the only other authority accessible to us, presents a series of variations of its own, independent of those of either of the other treatises. All these differences are reported by us below, in treating of each separate asterism. The presiding divinities of the asterisms we give upon the authority of the Tâittirîya-Sanhitâ (iv. 4. 10. 1–3), the Tâittirîya-Brâhmaṇa (iii. 1. 1, 2, as cited by Weber, Zeitsch. f. d. K. d. Morg., vii. 266 etc., and Ind. Stud., i. 90 etc.), the Muhûrta-Cintâmani, and Colebrooke: those of about half the asterisms are also indirectly given in our text, in the form of appellations for the asterisms derived from them.

The names and situations of the Arab lunar stations are taken from Ideler's Untersuchungen über die Sternnamen: for the Chinese mansions and their determining stars we rely solely upon the articles of Biot, to which we have already referred.

It has seemed to us advisable, notwithstanding the prior treatment by Colebrooke of the same subject, to enter into a careful re-examination and identification of the Hindu asterisms, because we could not accept in the bulk, and without modification, the conclusions at which he arrived. The identifications by Ideler of the Arab mansions, more thorough and correct than any which had been previously made, and Biot's comparison of the Chinese *sieu*, have placed new and valuable materials in our hands: and these—together with a more exact comparison than was attempted by Colebrooke of the positions given by the Hindus to their junction-stars with the data of the modern catalogues, and a new and independent combination of the various materials which he himself furnishes—while they have led us to accept the greater number of his identifications, often establishing them more confidently than he was able to do, have also enabled us in many cases to alter and amend his results. Such a re-examination was necessary, in order to furnish safe ground for a more detailed comparison of the three systems, which, as will be seen hereafter, leads to important conclusions respecting their historical relations to one another.

1. *Açvinî;* this treatise exhibits the form *açvini;* in the older lists, as also often elsewhere, we have the dual *açvinâu, açvayujâu,* "the two horsemen, or Açvins." The Açvins are personages in the ancient Hindu mythology somewhat nearly corresponding to the Castor and Pollux of the Greeks. They are the divinities of the asterism, which is named from them. The group is figured as a horse's head, doubtless in allusion to its presiding deities, and not from any imagined resemblance. The dual name leads us to expect to find it composed of two stars, and that is the number allotted to the asterism by the Çâkalya and Khanda-Kataka. The Sûrya-Siddhânta (below, v. 16) designates the northern member of the group as its junction-star: that this is the star β Arietis (magn. 3.2), and not α Arietis (magn. 2), as assumed by Colebrooke, is shown by the following comparison of positions:

Açvinî	long., A. D. 560,	11° 59′	lat.	9° 11′ N.
β Arietis . . .	do.	13° 56′	do.	8° 28′ N.
α Arietis . . .	do.	17° 37′	do.	9° 57′ N.

Colebrooke was misled in this instance by adopting, for the number of stars in the asterism, three, as stated by the later authorities, and then applying to the group as thus composed the designation given by our text of the relative position of the junction-star as the northern, and he accordingly overlooked the very serious error in the determination of the longitude thence resulting. Indeed, throughout his comparison, he gives too great weight to the determination of latitude, and too little to that of longitude: we shall see farther on that the accuracy of the latter is, upon the whole, much more to be depended upon than that of the former.

Considered as a group of two stars, Açvinî is composed of β and γ Arietis (magn. 4.3); as a group of three, it comprises also α in the same constellation.

There is no discordance among the different authorities examined by us as regards the position of the junction-star of Açvinî, either in latitude or in longitude. The case is the same with the 8th, 10th, 12th, and 13th asterisms, and with them alone.

The first Arab *manzil* is likewise composed of β and γ Arietis, to which some add α: it is called ash-Sharatân, "the two tokens"—that is to say, of the opening year.

The Chinese series of *sieu* commences, as did anciently the Hindu system of asterisms, with that which is later the third asterism. The twenty-seventh *sieu*, named Leu (M. Biot has omitted to give us the signification of these titles), is β Arietis, the Hindu junction-star.

2. *Bharaṇî;* also, as plural, *bharaṇyas;* from the root *bhar*, "carry": in the Tâittirîya lists the form *apabharaṇî*, "bearer away," in singular and plural, is also found. Its divinity is Yama, the ruler of the world of departed spirits; it is figured as the *yoni*, or pudendum muliebre. All authorities agree in assigning it three stars, and the southernmost is pointed out below (v. 18) as its junction-star. The group is unquestionably to be identified with the triangle of faint stars lying north of the back of the Ram, or 35, 39, and 41 Arietis: they are figured by some as a distinct constellation, under the name of Musca Borealis. The designation of the southern as the junction-star is not altogether unambiguous, as 35 and 41 were, in A. D. 560, very nearly equidistant from the equator; the latter would seem more likely to be the one intended, since it is nearer the ecliptic, and the brightest of the group—being of the third magnitude, while the other two are of the fourth: the defined position, however, agrees better with 35, and the error in longitude, as compared with 41, is greater than that of any other star in the series:

Bharaṇî	24° 35′	11° 6′ N.
35 Arietis (*a* Muscæ)	26° 54′	11° 17′ N.
41 Arietis (*c* Muscæ)	28° 10′	10° 26′ N.

The Graha-Lâghava gives Bharaṇî 1° more of polar longitude: this would reduce by the same amount the error in the determination of its longitude by the other authorities.

The second Arab *manzil*, al-Buṭain, "the little belly"—i. e., of the Ram—is by most authorities defined as comprising the three stars in the haunch of the Ram, or ε, δ, and ϱ^3 (or else ζ) Arietis. Some, however, have regarded it as the same with Musca; and we cannot but think that al-Bîrûnî, in identifying, as he does, Bharaṇî with al-Buṭain, meant to indicate by the latter name the group of which the Hindu asterism is actually composed.

The last Chinese *sieu*, Oei, is the star 35 Arietis, or α Muscæ.

3. *Kṛttikâ;* or, as plural, *kṛttikâs:* the appellative meaning of the word is doubtful. The regent of the asterism is Agni, the god of fire. The group, composed of six stars, is that known to us as the Pleiades. It is figured by some as a flame, doubtless in allusion to its presiding divinity: the more usual representation of it is a razor, and in the choice of this symbol is to be recognized the influence of the etymology of the name, which may be derived from the root *kart*, "cut;" in the configuration of the group, too, may be seen, by a sufficiently prosaic eye, a broad-bladed knife, with a short handle. If the designation given below (v. 18) of the southern member of the group as its junction-star, be strictly true, this is not Alcyone, or η Tauri (magn. 3), the brightest of the six, but either Atlas (27 Tauri: magn. 4) or Merope (23 Tauri: magn. 5): the two latter were very nearly equally distant from the equator of A. D. 560, but Atlas is a little nearer to the ecliptic. The defined position agrees best with Alcyone, nor can we hesitate to regard this as actually the junction-star of the asterism. We compare the positions below:

Kṛttikâ	39° 8′	4° 44′ N.
Alcyone	39° 58′	4° 1′ N.
27 Tauri	40° 20′	3° 53′ N.
23 Tauri	39° 41′	3° 55′ N.

The Siddhânta-Çiromaṇi etc. give Kṛttikâ 2′ less of polar longitude than the Sûrya-Siddhânta, and the Graha-Lâghava, on the other hand, 30′ more: the latter, with the Khaṇḍa-Kaṭaka, agree with our text as regards the polar latitude, which the others reckon at 4° 30′, instead of 5°.

The Pleiades constitute the third *manzil* of the Arabs, which is denominated ath-Thuraiyâ, "the little thick-set group," or an-Najm, "the constellation." Alcyone is likewise the first Chinese *sieu*, which is styled Mao.

4. *Rohiṇî*, "ruddy"; so named from the hue of its principal star. Prajâpati, "the lord of created beings," is the divinity of the asterism. It contains five stars, in the grouping of which Hindu fancy has seen the figure of a wain (compare v. 13, below); some, however, figure it as a temple. The constellation is the well-known one in the face of Taurus to which we give the name of the Hyades, containing ϵ, δ, γ, ϑ, α Tauri; the latter, the most easterly (v. 19) and the brightest of the group—being the brilliant star of the first magnitude known as Aldebaran—is the junction-star, as is shown by the annexed comparison of positions:

Rohiṇî	48° 9′	4° 49′ S.
Aldebaran	49° 45′	5° 30′ S.

The Siddhânta-Çiromaṇi etc. here again present the insignificant variation from the polar longitude of our text, of 2′ less: the former also makes its polar latitude 4° 30′: the Graha-Lâghava reads, for the polar longitude, 49°. All these variations add to the error of defined position.

The fourth Arab *manzil* is composed of the Hyades: its name is ad-Dabarân, "the follower"—i. e., of the Pleiades. We would suggest the inquiry whether this name may not be taken as an indication that the Arab system of mansions once began, like the Chinese, and like the Hindu system originally, with the Pleiades. There is, certainly, no very obvious propriety in naming any but the second of a series the "following" (*sequens* or *secundus*). Modern astronomy has retained the title as that of the principal star in the group, to which alone it was often also applied by the Arabs.

The second Chinese *sieu*, Pi, is the northernmost member of the same group, or ϵ Tauri, a star of the third to fourth magnitude.

5. *Mṛgaçîrsha*, or *mṛgaçiras*, "antelope's head": with this name the figure assigned to the asterism corresponds: the reason for the designation we have not been able to discover. Its divinity is Soma, or the moon. It contains three stars, of which the northern (v. 16) is the determinative. These three can be no other than the faint cluster in the head of Orion, or λ, φ^1, φ^2 Orionis, although the Hindu measurement of the position of the junction-star, λ (magn. 4), is far from accurate, especially as regards its latitude:

Mṛgaçîrsha	61° 3′	9° 49′ S.
λ Orionis	63° 40′	13° 25′ S.

In this erroneous determination of the latitude all authorities agree: the Graha-Lâghava adds 1° to the error in polar longitude, reading 62° instead of 63°.

Here again there is an entire harmony among the three systems compared. The Arab *manzil*, al-Hak'ah, is composed of the same stars which make up the Hindu asterism: the third *sieu*, named Tse, is the Hindu junction-star, λ Orionis.

6. *Ârdrâ*, "moist:" the appellation very probably has some meteorological ground, which we have not traced out: this is indicated also by the choice of Rudra, the storm-god, as regent of the asterism. It comprises a single star only, and is figured as a gem. It is impossible not to regard the bright star of the first magnitude in Orion's right shoulder, or α Orionis, as the one here meant to be designated, notwithstanding the very grave errors in the definition of its position given by our text: the only visible star of which the situation at all nearly answers to that definition is 135 Tauri, of the sixth magnitude; we add its position below, with that of α Orionis:

Ârdrâ	65° 50′	8° 53′ S.
α Orionis	68° 43′	16° 4′ S.
135 Tauri . . .	67° 38′	9° 10′ S.

The distance from the sun at which the heliacal rising and setting of Ârdrâ is stated below (ix. 14) to take place would indicate a star of about the third magnitude; this adds to the difficulty of its identification with either of the two stars compared. We confess ourselves unable to account for the confusion existing with regard to this asterism, of which al-Bîrûnî also could obtain no intelligible account from his Indian teachers. But it is to be observed that all the authorities, excepting our text and the Çâkalya-Sanhitâ, give Ârdrâ 11° of polar latitude instead of 9°, which would reduce the error of latitude, as compared with α Orionis, to an amount very little greater than will be met with in one or two other cases below, where the star is situated south of the ecliptic; and it is contrary to all the analogies of the system that a faint star should have been selected to form by itself an asterism. The Siddhânta-Çiromaṇi etc. make the polar longitude of the asterism 20′ less than that given by the Sûrya-Siddhânta, and the Graha-Lâghava 1° 20′ less: these would add so much to the error of longitude.

Here, for the first time, the three systems which we are comparing disagree with one another entirely. The Chinese have adopted for the determinative of their fourth *sieu*, which is styled Tsan, the upper star in Orion's belt, or δ Orionis (2)—a strange and arbitrary selection, for which M. Biot is unable to find any explanation. The Arabs have established their sixth station close to the ecliptic, in the feet of Pollux, naming it al-Han'ah, "the pile": it comprises the two stars γ (2.3) and ξ (4.3) Geminorum: some authorities, however, extend the limits of the mansion so far as to include also the stars in the foot of the other twin, or η, ν, μ Geminorum; of which the latter is the next Chinese *sieu*.

7. *Punarvasu*; in all the more ancient lists the name appears as a dual, *punarvasû*: it is derived from *punar*, "again," and *vasu*, "good, brilliant": the reason of the designation is not apparent. The regent

of the asterism is Aditi, the mother of the Âdityas. Its dual title indicates that it is composed of two stars, of nearly equal brilliancy, and two is the number allotted to it by the Çâkalya and Khanda-Kataka, the eastern being pointed out below (v. 19) as the junction-star. The pair are the two bright stars in the heads of the Twins, or α and β Geminorum, and the latter (1.2) is the junction-star. The comparison of positions is as follows:

Punarvasu	92° 52′	6° 0′ N.
β Geminorum . . .	93° 14′	6° 39′ N.

The Graha-Lâghava adds 1° to the polar longitude of Punarvasu as stated by the other authorities.

Four stars are by some assigned to this asterism, and with that number corresponds the representation of its arrangement by the figure of a house: it is quite uncertain which of the neighboring stars of the same constellation are to be added to those above mentioned to form the group of four, but we think ι (magn. 4) and υ (5) those most likely to have been chosen: Colebrooke suggests ϑ (3.4) and τ (5.4).

The determinative of the fifth *sieu*, Tsing, is μ Geminorum (3), which, as we have seen, is reckoned among the stars composing the sixth *manzil*: the seventh *manzil* includes, like the Hindu asterism, α and β Geminorum: it is named adh-Dhirâ', "the paw"—i. e., of the Lion; the figure of Leo (see Ideler, p. 152 etc.) being by the Arabs so stretched out as to cover parts of Gemini, Cancer, Canis Minor, and other neighboring constellations.

8. *Pushya*; from the root *push*, "nourish, thrive"; another frequent name, which is the one employed by our treatise, is *tishya*, which is translated "auspicious"; Amara gives also *sidhya*, "prosperous." Its divinity is Bṛhaspati, the priest and teacher of the gods. It comprises three stars—the Khanda-Kataka alone seems to give it but one—of which the middle one is the junction-star of the asterism. This is shown by the position assigned to it to be δ Cancri (4):

Pushya	106° 0′	0° 0′
δ Cancri	108° 42′	0° 4′ N.

The other two are doubtless γ (4.5) and ϑ (6) of the same constellation: the asterism is figured as a crescent and as an arrow, and the arrangement of the group admits of being regarded as representing a crescent, or the barbed head of an arrow. Were the arrow the only figure given, it might be possible to regard the group as composed of γ, ϑ, and β (4), the latter representing the head of the arrow, and the nebulous cluster, Præsepe, between γ and ϑ, the feathering of its shaft: ϑ (105° 43′—0° 48′ S.) would then be the junction-star.

The Arab *manzil*, an-Nathrah, "the nose-gap"—i. e., of the Lion—comprises γ and δ Cancri, together with Præsepe; or, according to some authorities, Præsepe alone. The sixth *sieu*, Kuei, is ϑ Cancri, a star which is, at present, only with difficulty distinguished by the naked eye. Ptolemy rates it as of the fourth magnitude, like γ and δ; perhaps it is one of the stars of which the brilliancy has sensibly diminished during the past two or three thousand years, or else a variable star of very long period. The possibility of such changes requires to be taken into account, in comparing our heavens with those of so remote a past.

9. *Âçleshâ ;* or, as plural, *âçleshâs;* the word is also written *âçreshâ:* its appellative meaning is "entwiner, embracer." With the name accord the divinities to whom the regency of the asterism is assigned, which are *sarpâs,* the serpents. The number of stars in the group is stated as five by all the authorities excepting the Khaṇḍa-Kaṭaka, which reads six: their configuration is represented by a wheel. The star α Cancri (4) is pointed out by Colebrooke as the junction-star of Âçleshâ, apparently from the near correspondence of its latitude with that assigned to the latter, for he says nothing in connection with it of his native helpers: but α Cancri is not the eastern (v. 19) member of any group of five stars; nor, indeed, is it a member of any distinct group at all. Now the name, figure, and divinity of Âçleshâ are all distinctive, and point to a constellation of a bent or circular form: and if we go a little farther southward from the ecliptic, we find precisely such a constellation, and one containing, moreover, the corresponding Chinese determinative. The group is that in the head of Hydra, or η, σ, δ, ε, ϱ Hydræ, σ and ϱ being of the fifth magnitude, and the rest of the fourth: their arrangement is conspicuously circular. There can be no doubt, therefore, that the situation of the asterism is in the head of Hydra, and ε Hydræ, its brightest star (being rated in the Greenw. Cat. as of magnitude 3.4, while δ is 4.5), is the junction-star:

Âçleshâ	109° 59′	6° 56′ S.
ε Hydræ	112° 20′	11° 8′ S.
α Cancri	113° 5′	5° 31′ S.

The error of the Hindu determination of the latitude is, indeed, very considerable, yet not greater than we are compelled to accept in one or two other cases. The Khaṇḍa-Kaṭaka increases it 1°, giving the asterism 6° instead of 7° of polar latitude. The Siddhânta-Çiromaṇi etc. deduct 1° from the polar longitude of the Sûrya-Siddhânta, and the Graha-Lâghava deducts 2°: both variations would add to the error in longitude.

The Arab *manzil* is, in this instance, far removed from the Hindu asterism, being composed of ξ Cancri (5) and λ Leonis (5.4), and called aṭ-Ṭarf, "the look"—i. e., of the Lion. The seventh Chinese *sieu,* Lieu, is, as already noticed, included in the Hindu group, being δ Hydræ.

10. *Maghâ ;* or, as plural, *maghâs;* "mighty." The *pitaras,* Fathers, or *manes* of the departed, are the regents of the asterism, which is figured as a house. It is, according to most authorities, composed of five stars, of which the southern (v. 18) is the junction-star. Four of these must be the bright stars in the neck and side of the Lion, or ζ, γ, η, and α Leonis, of magnitudes 4.5, 2, 3.4, and 1.2 respectively; but which should be the fifth is not easy to determine, for there is no other single star which seems to form naturally a member of the same group with these: ν (5), π (5), or ϱ (4) might be forced into a connection with them. This difficulty would be removed by adopting, with the Khaṇḍa-Kaṭaka, six as the number of stars included in the asterism: it would then be composed of all the stars forming the conspicuous constellation familiarly known as "the Sickle." The star α Leonis, or Regulus, the most brilliant of the group, is the junction-star, and its position is defined with unusual precision:

Maghâ	129° 0′	0° 0′
Regulus	129° 49′	0° 27′ N.

The tenth *manzil*, aj-Jabhah, "the forehead"—i. e., of the Lion—is also composed of ζ, γ, η, α Leonis.

The eighth, ninth, and tenth *sieu* of the Chinese system altogether disagree in position with the groups marking the Hindu and Arab mansions, being situated far to the southward of the ecliptic, in proximity, according to Biot, to the equator of the period when they were established. The eighth, Sing, is α Hydræ (2), having longitude (A. D. 560) 127° 16′, latitude 22° 25′ S.

11, 12. *Phalgunî;* or, as plural, *phalgunyas;* the dual, *phalgunyâu*, is also found: this treatise presents the derivative form *phâlgunî*, which is not infrequently employed elsewhere. The word is likewise used to designate a species of fig-tree: its derivation, and its meaning, as applied to the asterisms, is unknown to us. Here, as in two other instances, later (the 20th and 21st, and the 26th and 27th asterisms), we have two groups called by the same name, and distinguished from one another as *pûrva* and *uttara*, "former" and "latter"—that is to say, coming earlier and later to their meridian-transit. The true original character and composition of these three double asterisms has been, if we are not mistaken, not a little altered and obscured in the description of them furnished to us; owing, apparently, to the ignorance or carelessness of the describers, and especially to their not having clearly distinguished the characteristics of the combined constellation from those of its separate parts. In each case, a couch or bedstead (*çayyâ*, *mañca*, *paryanka*) is given as the figure of one or both of the parts, and we recognize in them all the common characteristic of a constellation of four stars, forming together a regular oblong figure, which admits of being represented—not unsuitably, if rather prosaically—by a bed. This figure, in the case of the Phalgunîs, is composed of δ, ϑ, β, and 93 Leonis, a very distinct and well-marked constellation, containing two stars, δ and β, of the second to third magnitude, one, ϑ, of the third, and one, 93, of the fourth. The symbol of a bed, properly belonging to the whole constellation, is given by all the authorities to both the two parts into which it is divided. Each of these latter has two stars assigned to it, and the junction-stars are said (v. 18) to be the northern. The first group is, then, clearly identifiable as δ and ϑ Leonis, the former and brighter being the distinctive star:

Pûrva-Phalgunî . . .	139° 58′	11° 19′ N.
δ Leonis	141° 15′	14° 19′ N.
ϑ Leonis	143° 24′	9° 40′ N.

The Siddhânta-Çiromaṇi etc., and the Graha-Lâghava, give Pûrva-Phalgunî respectively 3° and 4° more of polar longitude than the Sûrya-Siddhânta. These are more notable variations than are found in any other case, and they appear to us to indicate that these treatises intend to designate ϑ, the southern member of the group, as its junction-star: we have accordingly added its position also above.

In the latter group, the junction-star is evidently β Leonis:

Uttara-Phalgunî . . .	150° 10′	12° 5′ N.
β Leonis	151° 37′	12° 17′ N.

This star, however, is not the northern, but the southern, of the two composing the asterism: its description as the southern we cannot but regard as simply an error, founded on a misapprehension of the composition of the double group. To al-Bîrûnî, β Leonis and another star to the northward, in the Arab constellation Coma Berenices, were pointed out as forming the asterism Uttara-Phalgunî. The Çâkalya gives it five stars, probably adding to β Leonis the four small stars in the head of the Virgin, ξ^1, ν, π, and o, of magnitudes four to five and five.

The regents of Pûrva and Uttara-Phalgunî are Bhaga and Aryaman, or Aryaman and Bhaga, two of the Âdityas.

The two corresponding Arab mansions are called az-Zubrah, "the mane"—i. e., of the Lion—and as-Sarfah, "the turn": they agree as nearly as possible with the Hindu asterisms, the former being composed of δ and ϑ Leonis, the latter of β Leonis alone. The Chinese *sieu*, named respectively Chang and Y, are υ^1 Hydræ (5)* and α Crateris (4).

13. *Hasta*, "hand." Savitar, the sun, is regent of the asterism, which, in accordance with its name, is figured as a hand, and contains five stars, corresponding to the five fingers. These are the five principal stars in the constellation Corvus, a well-marked group, which bears, however, no very conspicuous resemblance to a hand. The stars are named—counting from the thumb around to the little finger, according to our apprehension of the figure—β, α, ϵ, γ, and δ Corvi. The text gives below (v. 17) a very special description of the situation of the junction-star in the group, but one which is unfortunately quite hard to understand and apply: we regard it as most probable, however (see note to v. 17), that γ (3) is the star intended: the defined position, in which all the authorities agree, would point rather to δ (3):

Hasta	174° 22′	10° 6′ S.
γ Corvi	170° 44′	14° 29′ S.
δ Corvi	173° 27′	12° 10′ S.

The Hindu and Chinese systems return, in this asterism, to an accordance with one another: the eleventh *sieu*, Chin, is the star γ Corvi. The Arab system holds its own independent course one point farther: its thirteenth mansion comprises the five bright stars β, η, γ, δ, ϵ Virginis, which form two sides, measuring about 15° each, of a great triangle: the mansion is named al-Auwâ', "the barking dog."

14. *Citrâ*, "brilliant." This is the beautiful star of the first magnitude α Virginis, or Spica, constituting an asterism by itself, and figured as a pearl or as a lamp. Its divinity is Tvashtar, "the shaper, artificer." Its longitude is very erroneously defined by the Sûrya-Siddhânta:

Citrâ	180° 48′	1° 50′ S.
Spica	183° 49′	2° 2′ S.

All the other authorities, however, saving the Çâkalya, remove this error, by giving Citrâ 183° of polar longitude, instead of 180°. The only variation from the definition of latitude made by our text is offered by the Siddhânta-Çiromani, which, varying for once from the Brahma-Siddhânta, reads 1° 45′ instead of 2°.

* It is, apparently, by an original error of the press, that M. Biot, in all his tables, calls this star ν^1.

Spica is likewise the fourteenth *manzil* of the Arabs, styled by them as-Simâk, and the twelfth *sieu* of the Chinese, who call it Kio.

15. *Svâti*, or *svâti*; the word is said to mean "sword." The Tâittirîya-Brâhmana calls the asterism *nishṭyâ*, "outcast," possibly from its remote northern situation. It is, like the last, an asterism comprising but a single brilliant star, which is figured as a coral bead, gem, or pearl. In the definition of its latitude all authorities agree; the Graha-Lâghava makes its polar longitude 198° only, instead of 199°. The star intended is plainly α Bootis, or Arcturus:

Svâtî	183° 2′	33° 50′ N.
Arcturus	184° 12′	30° 57′ N.

In this instance, the Hindus have gone far beyond the limits of the zodiac, in order to bring into their series of asterisms a brilliant star from the northern heavens: the other two systems agree in remaining near the ecliptic. The fourteenth Chinese *sieu*, Kang, is $\varkappa$ Virginis (4.5): the Arab *manzil*, al-Ghafr, "the covering," includes the same star, together with ι, and either λ or φ Virginis.

16. *Viçâkhâ*, "having spreading branches": in all the earlier lists the name appears as a dual, *viçâkhe*. The asterism is also placed under the regency of a dual divinity, *indrâgnî*, Indra and Agni. We should expect, then, to find it composed, like the other two dual asterisms, the 1st and 7th, of two stars, nearly equal in brilliancy, and two is actually the number assigned to the group by the Çâkalya and the Khanda-Kataka. Now the only two stars in this region of the zodiac forming a conspicuous pair are α and β Libræ, both of the second magnitude, and as these two compose the corresponding Arab mansion, while the former of them is the Chinese *sieu*, we have the strongest reasons for supposing them to constitute the Hindu asterism also. There are, however, difficulties in the way of this assumption. The later authorities give Viçâkhâ four stars, and the defined position of the junction-star identifies it neither with α nor β, but with the faint star ι (4.3) in the the same constellation. Colebrooke, overlooking this star, suggests α or $\varkappa$ Libræ (5): the following comparison of positions will show that neither of them can be the one meant to be pointed out:

Viçâkhâ	213° 31′	1° 25′ S.
ι Libræ	211° 0′	1° 48′ S.
α Libræ	205° 5′	0° 23′ N.
$\varkappa$ Libræ	217° 45′	0° 2′ N.

The group is figured as a *toraṇa*: this word Jones and Colebrooke translate "festoon," but its more proper meaning is "an outer door or gate, a decorated gateway." And if we change the designation of situation of the junction-star in its group, given below (v. 16), from "northern" to "southern," we find without difficulty a quadrangle of stars, viz. ι, α, β, γ (4.5) Libræ, which admits very well of being figured as a gateway. Nor is it, in our opinion, taking an unwarrantable liberty to make such an alteration. The whole scheme of designations we regard as of inferior authenticity, and as partaking of the confusion and uncertainty of the later knowledge of the Hindus respecting their system of asterisms. That they were long ago doubtful of the position of Viçâkhâ is shown by the fact that al-Bîrûnî was obliged to mark it in his list as "unknown." Very probably the Sûrya-Siddhânta, in calling ι the northern member of the group, intended to include with it only the star 20 Libræ (3.4), situated about 6° to the south of it. Upon the whole, then, while we regard the identification of Viçâkhâ as in some respects more doubtful than that of any other asterism in the series, we yet believe that it was originally composed of the two stars α and β Libræ, and that later the group was extended to include also ι and γ, and, as so extended, was figured as a gateway. The selection, contrary to general usage, of the faintest star in the group as its junction-star, may have been made in order to insure against the reversion of the asterism to its original dual form.

The variations of the other authorities from the position as stated in our text are of small importance: the Siddhânta-Çiromaṇi etc. give Viçâkhâ 55′ less of polar longitude, and the Graha-Lâghava 1° less; of polar latitude, the Siddhânta-Çiromaṇi gives it 10′, the Graha-Lâghava 30′ less; the Khaṇḍa-Kaṭaka agrees here, as also in the two following asterisms, with the Sûrya-Siddhânta.

The sixteenth Arab *manzil*, comprising, as already noticed, α and β Libræ, is styled az-Zubânân, "the two claws"—i. e., of the Scorpion: the name of the corresponding Chinese mansion, having for its determinative α Libræ, is Ti.

17. *Anurâdhâ*; or, as plural, *anurâdhâs*: the word means "success." The divinity is Mitra, "friend," one of the Âdityas. According to the Çâkalya, the asterism is composed of three stars, and with this our text plainly agrees, by designating (v. 18) the middle as the junction-star: all the other authorities give it four stars. As a group of three, it comprises β, δ, π Scorpionis, δ (2.3) being the junction-star; as the fourth member we are doubtless to add ϱ Scorpionis (5.4). It is figured as a *bali* or *vali*; this Colebrooke translates "a row of oblations"; we do not find, however, that the word, although it means both "oblation, offering," and "a row, fold, ridge," is used to designate the two combined: perhaps it may better be taken as simply "a row;" the stars of the asterism, whether considered as three or four, being disposed in nearly a straight line. The comparison of positions is as follows:

Anurâdhâ	224° 44′	2° 52′ S.
δ Scorpionis . . .	222° 34′	1° 57′ S.

The Siddhânta-Çiromaṇi and Graha-Lâghava estimate the latitude of Anurâdhâ somewhat more accurately, deducting from the polar latitude, as given by our text, 1° 15′ and 1° respectively: the Siddhânta-Çiromaṇi etc. also add the insignificant amount of 5′ to the polar longitude of the Sûrya-Siddhânta.

The corresponding Arab *manzil*, named al-Iklîl, "the crown," contains also the three stars β, δ, π Scorpionis, some authorities adding ϱ to the group. The Chinese *sieu*, Fang, is π (3), the southernmost and the faintest of the three.

18. *Jyeshṭhâ*, "oldest." The Tâittirîya-Sanhitâ, in its list of asterisms, repeats here the name *rohiṇî*, "ruddy," which we have had above as that of the 4th asterism: the appellation has the same ground in this

as in the other case, the junction-star of Jyeshṭhâ being also one of those which shine with a reddish light. The regent is Indra, the god of the clear sky. The group contains, according to all the authorities, three stars, and the central one (v. 18) is the junction-star. This is the brilliant star of the first magnitude α Scorpionis, or Antares; its two companions are σ (3.4) and τ (3.4) in the same constellation:

Jyeshṭhâ	230° 7′	3° 50′ S.
Antares	229° 44′	4° 31′ S.

The constellation is figured as a ring, or ear-ring; by this may be understood, perhaps, a pendent ear-jewel, as the three stars of Jyeshṭhâ form nearly a straight line, with the brightest in the middle.

The Siddhânta-Çiromaṇi and Graha-Lâghava add to the polar longitude of the junction-star of the asterism, as stated in our text, 5′ and 1° respectively, and they deduct from its polar latitude 30′ and 1° respectively, making the definition of its position in both respects less accurate.

Antares forms the eighteenth *manzil*, and is styled al-Kalb, "the heart"—i. e., of the Scorpion: σ and τ are called an-Niyât, "the *præcordia*." The Chinese *sieu*, Sin, is the westernmost of the three, or σ.

19. *Mûla*, "root." The presiding divinity of the asterism is *nirṛti*, "calamity," who is also regent of the south-western quarter. It comprises, according to the Çâkalya, nine stars; their configuration is represented by a lion's tail. The stars intended are those in the tail of the Scorpion, or $\varepsilon, \mu, \zeta, \eta, \vartheta, \iota, \varkappa, \upsilon, \lambda$ Scorpionis, all of them of the third, or third to fourth, magnitude. Other authorities count eleven stars in the group, probably reckoning μ and ζ as four stars; each being, in fact, a group of two closely approximate stars, named in our catalogues μ^1 (3), μ^2 (4), ζ^1 (4.5), ζ^2 (3). The Khanda-Kataka alone gives Mûla only two stars, which are identified by al-Bîrûnî with the Arab *manzil* ash-Shaulah, or λ and υ Scorpionis. The Tâittirîya-Sanhitâ, too, gives the name of the asterism as *vicṛtâu*, "the two releasers": the Vicṛtâu are several times spoken of in the Atharva-Veda as two stars of which the rising promotes relief from lingering disease (*kshetriya*): it is accordingly probable that these are the two stars in the sting of the Scorpion, and that they alone have been regarded by some as composing the asterism: their healing virtue would doubtless be connected with the meteorological conditions of the time at which their heliacal rising takes place. Our text (v. 19) designates the eastern member of the group as its junction-star: it is uncertain whether the direction is meant to apply to the group of two, or to that of nine stars: if, as seems probable, λ is the star pointed out by the definition of position, it is strictly true only of the pair λ and υ, since ι, $\varkappa$, and ϑ are all farther eastward than λ:

Mûla	242° 52′	8° 48′ S.
λ Scorpionis . . .	244° 53′	13° 44′ S.

The Graha-Lâghava gives a more accurate statement of the longitude, adding 1° to the polar longitude as defined by all the other authorities; but it increases the error in latitude, by deducting 1° from that presented by our text: the Siddhânta-Çiromaṇi, in like manner, deducts 30′, while the Khaṇḍa-Kaṭaka adds the same amount.

The Tâittirîya-Sanhitâ makes *pitaras*, the Fathers, the presiding divinities of this asterism, as well as of the tenth.

Bentley states (Hind. Astr., p. 5) that Mûla was originally reckoned as the first of the asterisms, and was therefore so named, as being their root or origin; also that, at another time, or in a different system, the series was made to begin with Jyeshṭhâ, which thence received its title of "eldest." These statements are put forth with characteristic recklessness, and apparently, like a great many others in his pretended history of Hindu astronomy, upon the unsupported authority of his own conjecture. It is, in many cases, by no means easy to discover reasons for the particular appellations by which the asterisms are designated: but we would suggest that Mûla may perhaps have been so named from its being considerably the lowest, or farthest to the southward, of the whole series of asterisms, and hence capable of being looked upon as the root out of which they had grown up the heavens. It would even be possible to trace the same conception farther, and to regard Jyeshṭhâ as so styled because it was the first, or "oldest," outgrowth from this root, while the Viçâkhe, "the two diverging branches," were the stars in which the series broke into two lines, the one proceeding northward, to Svâtî or Arcturus, the other westward, to Citrâ or Spica. We throw out the conjecture for what it may be worth, not being ourselves at all confident of its accordance with the truth.

The nineteenth Arab *manzil* is styled ash-Shaulah, "the sting"—i. e., of the Scorpion—and comprises, as already noticed, υ and λ Scorpionis. The determinative of the seventeenth *sieu*, Uei, is included in the Hindu asterism, being μ^2 Scorpionis.

20, 21. *Ashâḍhâ;* or, as plural, *ashâḍhâs;* this treatise presents the derivative form *âshâḍhâ*, which is not infrequent elsewhere: the word means "unsubdued." Here, again, we have a double group, divided into two asterisms, which are distinguished as *pûrva* and *uttara*, "former and latter." Their respective divinities are *âpas*, "the waters," and *viçve devâs*, "the collective gods." Two stars are ordinarily allotted to each asterism, and in each case the northern is designated (v. 16) as the junction-star. By some authorities each group is figured as a bed or couch; by others, the one as a bed and the other as an elephant's tusk; and here, again, there is a difference of opinion as to which is the bed and which the tusk. The true solution of this confusion is, as we conceive, that the two asterisms taken together are figured as a bed, while either of them alone is represented by an elephant's tusk. The former group must comprise δ (3.4) and ε (3.2) Sagittarii, the former being the junction-star; this is shown by the following comparison of positions:

Pûrva-Ashâḍhâ	254° 39′	5° 28′ S.
δ Sagittarii	254° 32′	6° 25′ S.

The Graha-Lâghava gives Pûrva-Ashâḍhâ 1° more of polar longitude, and 30′ less of polar latitude, than the Sûrya-Siddhânta: the Siddhânta-Çiromani etc. give it 10′ less of the latter.

The latter of the two groups contains, as its southern star, ζ Sagittarii (3.4), and its northern and junction-star can be no other than σ (2.3) in the same constellation, notwithstanding the error in the Hindu determination of its latitude, which led Colebrooke to regard τ (4.3) as the star intended: we subjoin the positions:

Uttara-Ashâḍhâ	260° 23′	4° 59′ S.
σ Sagittarii	262° 21′	3° 24′ S.
τ Sagittarii	264° 48′	5° 1′ S.

The only variation from the position of the junction-star of this asterism as stated in our text is presented by the Graha-Lâghava, which makes its polar longitude 261° instead of 260°.

The Çâkalya (according to Colebrooke: our MS. is defective at this point) and the Khaṇḍa-Kaṭaka assign four stars to each of the Ashâḍhâs, and the former represents each as a bed. It would not be difficult to establish two four-sided figures in this region of the constellation Sagittarius, each including the stars above mentioned, with two others: the one would be composed of γ^2 (4.3), δ, ε, η (4—the star is also called β Telescopii), the other of φ (4.3), σ, τ, and ζ: such is unquestionably the constitution of the two asterisms, considered as groups of four stars; they are thus identified also, it may be remarked, by al-Bîrûnî. The junction-stars would still be δ and σ, which are the northernmost in their respective constellations; nor is there any question as to which four among the eight are selected to make up the double asterism, since δ, ε, ζ, and σ both form the most regular quadrangular figure, and are the brightest stars.

The determinatives of the eighteenth and nineteenth mansions of the Chinese, Ki and Teu, are γ^2 and φ Sagittarii, which are included in the two quadruple groups as stated above. The twentieth *manzil* comprehends all the eight stars which we have mentioned, and is styled an-Na'âim, "the pasturing cattle": some also understand each group of four as representing an ostrich, na'âm. The twenty-first *manzil*, on the other hand, al-Baldah, "the town," is described as a vacant space above the head of Sagittarius, bounded by faint stars, among which the most conspicuous is π Sagittarii (4.5).

22. *Abhijit*, "conquering." The regent of the asterism is Brahma. The position assigned to its junction-star, which is described as the brightest (v. 19) in a group of three, identifies it with α Lyræ, or Vega, a star which is exceeded in brilliancy by only one or two others in the heavens:

Abhijit	264° 10′	59° 58′ N.
Vega	265° 15′	61° 46′ N.

The other authorities compared (excepting the Çâkalya) define the position in latitude of Abhijit more accurately, adding 2° to the polar latitude given by the Sûrya-Siddhânta: the Graha-Lâghava also improves the position in longitude by adding 1° 20′, while the Siddhânta-Çiromaṇi etc. increase the error by deducting 1° 40′.

The Tâittirîya-Sanhitâ (iv. 4. 10) omits Abhijit from its list of the asterisms: the probable reason of its omission in some authorities, or in certain connections, and its retention in others, we shall discuss farther on.

Abhijit is figured as a triangle, or as the triangular nut of the *çrngâṭa*, an aquatic plant; this very distinctly represents the grouping of α Lyræ with the two other fainter stars of the same constellation, ϵ and ζ, both of the fifth magnitude.

In this and the two following asterisms—as once before, in the fifteenth of the series—the Hindus have gone far from the zodiac, in order to bring into their system brilliant stars from the northern heavens, while the Chinese and the Arab systems agree in remaining in the immediate neighborhood of the ecliptic. The twentieth *sieu* is named Nieu, and is the star β Capricorni (3), situated in the head of the Goat: the twenty-second *manzil*, Sa'd adh-Dhâbiḥ, "felicity of the sacrificer," contains the same star, the group being α (composed of two stars, each of magnitude 3.4) and β Capricorni.

23. *Çravaṇa*, "hearing, ear"; from the root *çru*, "hear": another name for the asterism, *çroṇâ*, found occurring in the Tâittirîya lists, is perhaps from the same root, but the word means also "lame." Çravaṇa comprises three stars, of which the middle one (v. 18) is the junction-star: they are to be found in the back and neck of the Eagle, namely as γ, α, and β Aquilæ; α, the determinative, is a star of the first to second magnitude, while γ and β are of the third and fourth respectively:

Çravaṇa	282° 29′	29° 54′ N.
α Aquilæ . . .	281° 41′	29° 11′ N.

All the authorities agree as to the polar latitude of Çravaṇa: the Siddhânta-Çiromaṇi etc. give it 2° less of polar longitude than our treatise, and the Graha-Lâghava even as much as 5° less.

The regent of the asterism is Vishṇu, and its figure or symbol corresponds therewith, being three footsteps, representatives of the three steps by which Vishṇu is said, in the early Hindu mythology, to have strode through heaven. The Çâkalya, however, gives a trident as the figure belonging to Çravaṇa. Possibly the name is to be regarded as indicating that it was originally figured as an ear.

The Chinese *sieu* corresponding in rank with Çravaṇa is called Nü, and is the faint star ϵ Aquarii (4.3). The Arab *manzil* Sa'd Bula', "felicity of a devourer," or al-Bula', "the devourer," etc., includes the same star, being composed of ϵ, μ (4.5), ν (5) Aquarii, or, according to others, of ϵ and 7 (6) Aquarii, or of μ and ν.

24. *Çravishṭhâ*; the word is a superlative formation from the same root from which came the name of the preceding asterism, and means, probably, "most famous." Another and hardly less frequent appellation is *dhanishṭhâ*, an irregular superlative from *dhanin*, "wealthy." The class of deities known as the *vasus*, "bright, good," are the regents of the asterism. It comprises four stars, or, according to the Çâkalya and Khaṇḍa-Kaṭaka, five: the former, which is given by so early a list as that of the Tâittirîya-Brâhmana, is doubtless the original number. The group is the conspicuous one in the head of the Dolphin, composed of β, α, γ, δ Delphini, all of them stars of the third, or third to fourth, magnitude, and closely disposed in diamond or lozenge-form: they are figured by the Hindus as a drum or tabor. The junction-star, which is the western (v. 17), is β:

Çravishṭhâ	296° 5′	35° 33′ S.
β Delphini	296° 19′	31° 57′ S.

The only variation from the position assigned in our text to the junction-star of Çravishṭhâ is presented by the Graha-Lâghava, which gives it 286°, instead of 290°, of polar longitude. Perhaps its intention is to point out ζ (5) as the junction-star: this is doubtless the one added to the other four, on account of its close proximity to them, to make up the group of five; it lies only about half a degree westward from β.

The name of the twenty-fourth *manzil*, Sa'd as-Su'ûd, "felicity of felicities"—i. e., "most felicitous"—exhibits an accordance with that of the Hindu asterism which possibly is not accidental. The two are, however, as already noticed, far removed in position from one another, the Arab mansion being composed of the two stars β (3) and ξ (5.4), in the left shoulder of Aquarius, to which some add also 46, or c^1, Capricorni (6). The corresponding *sieu*, Hiü, is the first of them, or β Aquarii.

25. *Çatabhishaj*, "having a hundred physicians": the form *çatabhishâ*, which seems to be merely a corruption of the other, also occurs in later writings. It is, as we should expect from the title, said to be composed of a hundred stars, of which the brightest (v. 19) is the junction-star. This, from its defined position, can only be λ Aquarii (4):

Çatabhishaj	319° 51′	0° 29′ S.
λ Aquarii	321° 33′	0° 23′ S.

The rest of the asterism is to be sought among the yet fainter stars in the knee of Aquarius, and the stream from his jar: of course, the number one hundred is not to be taken as an exact one, nor are we to suppose it possible to trace out with any distinctness the figure assigned to the group, which is a circle. The Khaṇḍa-Kaṭaka, according to al-Bîrûnî, gives Çatabhishaj only a single star, but this is probably an error of the Arab traveller: he is unable to point out which of the stars in Aquarius is to be regarded as constituting the asterism.

The regent of the 25th asterism, according to nearly all the authorities, is Varuṇa, the chief of the Âdityas, but later the god of the waters: the Tâittirîya-Sanhitâ alone gives to it and to the 14th asterism, as well as to the 18th, Indra as presiding divinity: this is perhaps mere blundering.

The Graha-Lâghava places the junction-star of Çatabhishaj precisely on the ecliptic: the Siddhânta-Çiromaṇi etc. give it 20′, instead of 30′, of polar latitude south.

The corresponding lunar mansion of the Arabs, Sa'd al-Akhbiyah, "the felicity of tents," comprises the three stars in the right wrist and hand of the Water-bearer, or γ (3), ζ (4), η (4) Aquarii, together with a fourth, which Ideler supposes to be π (5). Since, however, the twenty-third Chinese determinative, Goei, is α Aquarii (3), a star so near as readily to be brought into the same group with the other three, we are inclined to regard it as altogether probable that the mansion was, at least originally, composed of α, γ, ζ, and η.

26, 27. *Bhâdrapadâ*; as plural, *bhâdrapadâs*: also *bhadrapadâ*; from *bhadra*, "beautiful, happy," and *pada*, "foot." Another frequent appellation is *proshṭhapadâ*: *proshṭha* is said to mean "carp" and "ox"; the latter signification might perhaps apply here. We have here, once more, a double asterism, divided into two parts, which are distinguished from one another as *pûrva* and *uttara*, "former" and "latter." All authorities agree in assigning two stars to each of the two groups; but there is not the same accordance as regards the figures by which they are represented: by some the one, by others the other, is called a couch or bed, the alternate one, in either case, being pronounced a bi-faced figure: the Muhûrta-Cintâmaṇi calls the first a bed, and the second twins. It admits, we apprehend, of little or no question that the Bhâdrapadâs are properly the four bright stars β, α, γ Pegasi, and α Andromedæ—all of them commonly reckoned as of the second magnitude—which form together a nearly perfect square, with sides measuring about 15°: the constellation, a very conspicuous one, is familiarly known as the "Square of Pegasus." The figure of a couch or bed, then, belongs, as in the case of the other two double asterisms, already explained, to the whole constellation, and not to either of the two separate asterisms into which it is divided, while, on the other hand, either of these latter is properly enough symbolized by a pair of twins, or by a figure with a double face. The appropriateness of the designation "feet," found as a part of both the names of the whole constellation, is also sufficiently evident, if we regard the group as thus composed. The junction-star of the former half-asterism is, by its defined position, clearly shown to be α Pegasi:

Pûrva-Bhâdrapadâ	334° 25′	22° 30′ N.
α Pegasi	333° 27′	19° 25′ N.

The Graha-Lâghava gives the junction-star 1° less of polar longitude, which would bring its position to a yet closer accordance, in respect to longitude, with α Pegasi: the error in latitude, which is common to all the authorities, is not greater than we have met with several times elsewhere. But we are told below (v. 16) that the principal star of each of these asterisms is the northern, and this would exclude β Pegasi altogether, bringing in as the other member of the first pair some more southern star, perhaps ζ Pegasi (3.4). The confusion is not less marked, although of another character, in the case of the second asterism: in the definition of position of its junction-star we find a longitude given which is that of one member of the group, and a latitude which is that of the other, as is shown by the following comparison:

Uttara-Bhâdrapadâ	347° 16′	24° 1′ N.
γ Pegasi	349° 8′	12° 35′ N.
α Andromedæ	354° 17′	25° 41′ N.

If we accept either of these two stars as the one of which the position is meant to be defined, we shall be obliged to admit an error in the determination either of its longitude or of its latitude considerably greater than we have met with elsewhere. Nor is the matter mended by any of the other authorities: the only variation from the data of our text is presented by the Graha-Lâghava, which reads, as the polar latitude of Uttara-Bhâdrapadâ, 27° instead of 26°. There can be no doubt that the two stars recognized as composing the asterism are γ Pegasi and α Andromedæ, but there has evidently been a blundering confusion of the two in making out the definition of position of the junction-star. We would suggest the following as a possible explanation of this confusion: that originally α and γ Pegasi were designated and described as junction-stars of the two half-groups, of which they were respectively the southern members; that afterward, for some reason—perhaps owing to the astrological theory (see above, vii. 21) of the superiority of a northern star—the rank of junction-star was sought to be transferred from the southern to the northern stars of both asterisms: that, in making the transfer, the original constitution of the former group was neglected, while in the latter the attempt was made to define the real position of the northern star, but by simply adding to the polar latitude already stated for γ Pegasi, without altering its polar longitude also. Al-Bîrûnî, it should be remarked, was unable to obtain from his Hindu informants any satisfactory identification of either of these asterisms, and marks both in his catalogue as "unknown."

The view we have taken of the true character of the two Bhâdrapadâs is powerfully supported by their comparison with the corresponding members of the other two systems. The twenty-sixth and twenty-seventh *manzils*, al-Fargh al-Mukdim and al-Fargh al-Mukhir, "the fore and hind spouts of the water-jar," comprise respectively α and β Pegasi, and γ Pegasi and α Andromedæ; the determinatives of the twenty-fourth and twenty-fifth *sieu*, Che and Pi, are α and γ Pegasi.

The regents of these two asterisms are *aja ekapât* and *ahi budhnya*, the "one-footed goat" and the "bottom-snake," two mythical figures, of obscure significance, from the Vedic pantheon.

28. *Revatî*, "wealthy, abundant." Its presiding divinity is Pûshan, "the prosperer," one of the Âdityas. It is said to contain thirty-two stars, which are figured, like those of Çravishthâ, by a drum or tabor; but it would be in vain to attempt to point out precisely the thirty-two which are intended, or to discover in their arrangement any resemblance to the figure chosen to represent it. The junction-star of the group is said (v. 18) to be its southernmost member: all authorities agree in placing it upon the ecliptic, and all excepting our treatise and the Çâkalya make its position exactly mark the initial point of the fixed sidereal sphere. The star intended is, as we have already often had occasion to notice, the faint star ζ Piscium, of about the fifth magnitude, situated in the band which connects the two Fishes. It is indeed very near to the ecliptic, having only 13′ of south latitude. It coincided in longitude with the vernal equinox in the year 572 of our era.

At the time of al-Bîrûnî's visit to India, the Hindus seem to have been already unable to point out distinctly and with confidence the situation in the heavens of that most important point from which they held that the motions of the planets commenced at the creation, and at which, at successive intervals, their universal conjunction would again take place; for he is obliged to mark the asterism as not certainly identifiable. He also assigns to it, as to Çatabhishaj, only a single star.

The twenty-sixth Chinese *sieu*, Koei, is marked by ζ Andromedæ (4), which is situated only 35′ east in longitude from ζ Piscium, but which has 17° 36′ of north latitude. The last *manzil*, Batn al-Hût, "the fish's belly," or ar-Rishâ, "the band," seems intended to include the stars composing the northern Fish, and with them probably the Chinese determinative also: but it is extended so far northward as to take in the bright star β Andromedæ (2), and to this star alone the name of the mansion is sometimes applied, although its situation, so far from the ecliptic (in lat. 25° 56′ N.), renders it by no means suited to become the distinctive star of one of the series of lunar stations.

We present, in the annexed table, a general conspectus of the correspondences of the three systems; and, in order to bring out those correspondences in the fullest manner possible, we have made the comparison in three different ways: noting, in the first place, the cases in which the three agree with one another; then those in which each agrees with one of the others; and finally, those in which each agrees with either the one or the other of the remaining two.

Correspondences of the Hindu, Arab, and Chinese Systems of Asterisms.

No.	Hindu Name.	Hindu with Arab and Chinese.	Hindu with Arab.	Hindu with Chinese.	Arab with Chinese.	Hindu with Arab or Chinese.	Arab with Hindu or Chinese.	Chinese with Hindu or Arab.
1	Açvinî,	1	1	1	1	1	1	1
2	Bharaṇî,	2*	2*	2	2*	2	2*	2
3	Kṛttikâ,	3	3	3	3	3	3	3
4	Rohiṇî,	4	4	4	4	4	4	4
5	Mṛgaçîrsha,	5	5	5	5	5	5	5
6	Ârdrâ,	..	..	..	†	..	..	..
7	Punarvasu,	..	6	..	†	6	6	†
8	Pushya,	6‡	7	6	..	7	7	6
9	Âçleshâ,	..	..	7	..	8	..	7
10	Maghâ,	..	8	..	..	9	8	..
11	P.-Phalgunî,	..	9	..	..	10	9	..
12	U.-Phalgunî,	..	10	..	..	11	10	..
13	Hasta,	..	..	8	..	12	..	8
14	Citrâ,	7	11	9	6	13	11	9
15	Svâtî,	..	..	..	7	..	12	10
16	Viçâkhâ,	8	12	10	8	14	13	11
17	Anurâdhâ,	9	13	11	9	15	14	12
18	Jyeshṭhâ,	10	14	12	10	16	15	13
19	Mûla,	11‡	15	13	..	17	16	14
20	P.-Ashâḍhâ,	12	16	14	11	18	17	15
21	U.-Ashâḍhâ,	..	..	15	..	19	..	16
22	Abhijit,	..	..	..	12	..	18	17
23	Çravaṇa,	..	..	..	13	..	19	18
24	Çravishṭhâ,	..	..	..	14	..	20	19
25	Çatabhishaj,	..	..	..	15	..	21	20
26	P.-Bhâdrapadâ,	13	17	16	16	20	22	21
27	U.-Bhâdrapadâ,	14	18	17	17	21	23	22
28	Revatî,	..	..	..	18§	..	24§	23§

* This supposes the second *manzil* to be composed of the stars in Musca, as defined by some authorities. † The sixth *manzil* includes, according to many authorities, the fifth *sieu*, but as there is, at any rate, a discordance in the order of succession, we have not reckoned this among the correspondences. ‡ We reckon these two as cases of general coincidence, because, although the Chinese *sieu* is not contained in the Arab mansion, the Hindu asterism includes them both, and the virtual correspondence of the three systems is beyond dispute. § Here we assume the Chinese *sieu* to be comprised among the stars forming the last *manzil*, which is altogether probable, although nowhere distinctly stated.

Owing to the different constitution of the systems, their correspondences are somewhat diverse in character: we account the Hindu asterisms and the Arab mansions to agree, when the groups which mark the two are composed, in whole or in part, of the same stars: we account the Chinese system to agree with the others, when the determinative of a *sieu* is to be found among the stars composing their groups. We have prefixed to the whole the numbers and titles of the Hindu asterisms, for the sake of easy reference back to the preceding detailed identifications and comparisons.

After this exhibition of the concordances existing among the three systems, it can, we apprehend, enter into the mind of no one to doubt that all have a common origin, and are but different forms of one and the same system. The questions next arise—is either of the three the original from which the others have been derived? and if so, which of them is entitled to the honor of being so regarded? and are the other two independent and direct derivatives from it, or does either of them come from the other, or must both acknowledge an intermediate source? In endeavoring to answer these questions, we will first exhibit the views of M. Biot respecting the origin and character of the Chinese *sieu*, as stated in the volumes for 1840 and 1859 of the Journal des Savants.

According to Biot, the *sieu* form an organic and integral part of that system by which the Chinese, from an almost immemorial antiquity, have been accustomed to make their careful and industrious observations of celestial phenomena. Their instruments, and their methods of observation, have been closely analogous with those in use among modern astronomers in the West: they have employed a meridian-circle and a measure of time, the clepsydra, and have observed meridian-transits, obtaining right ascensions and declinations of the bodies observed. To reduce the errors of their imperfect time-keepers, they long ago selected certain stars near the equator, of which they determined with great care the intervals in time, and to these they referred the positions of stars or planets coming to the meridian between them. The stars thus chosen are the *sieu*. Twenty-four of them were fixed upon more than two thousand years before our era (M. Biot says, about B. C. 2357: but it is obviously impossible to fix the date, by internal evidence, within a century or two, nor is the external evidence of a more definite character); the considerations which governed their selection were three: proximity to the equator of that period, distinct visibility—conspicuous brilliancy not being demanded for them—and near agreement in respect to time of transit with the upper and lower meridian-passages of the bright stars near the pole, within the circle of perpetual apparition: M. Biot finds reason to believe that these circumpolar stars had been earlier observed with special care, and made standards of comparison, and that, when it was afterward seen to be desirable to have stations near the equator, such stars were adopted as most nearly agreed with them in right ascension. The other four, being the 8th, 14th, 21st, and 28th, the accession of which completed the system of twenty-eight, were added in the time of Cheu-Kong, about B.C. 1100, because they marked very nearly the positions of the equinoxes and solstices at that epoch: the bright star of the Pleiades, however, which had originally been made the first of the series, from its near approach to the vernal equinox of that remoter era, still maintained, as it has ever since maintained, its rank as the first. Since the time of Cheu-Kong the system has undergone no farther modification, but has been preserved unaltered and unimproved, with the obstinate persistency so characteristic of the Chinese, although many of the determinative stars have, under the influence of the precession, become far removed from the equator, one of them even having retrograded into the preceding mansion.

If the history of the Chinese *sieu*, as thus drawn out, is well-founded and true, the question of origin is already solved: the system of twenty-eight celestial mansions is proved to be of native Chinese institution—just as the system of representation of the planetary movements by epicycles is proved to be Greek by the fact that we can trace in the history of Greek science the successive steps of its gradual elaboration. That history rests, at present, upon the authority of M. Biot alone: we are not aware, at least, that any other investigator has gone independently over the same ground; and he has not himself laid before us, in their original form, the passages from Chinese texts which furnish the basis of his conclusions. But we regard them as entitled to be received, upon his authority, with no slight measure of confidence: his own distinguished eminence as a physicist and astronomer, his familiarity with researches into the history and archæology of science, his access to the abundant material for the history of Chinese astronomy collected and worked up by the French missionaries at Pekin, and the zealous assistance of his son, M. Édouard Biot, the eminent Sinologist, whose premature death, in 1850, has been so deeply deplored as a severe loss to Chinese studies—all these advantages, rarely united in such fullness in the person of any one student of such a subject, give very great weight to views arrived at by him as the results of laborious and long-continued investigation. Nor do we see that any general considerations of importance can be brought forward in opposition to those views. It is, in the first place, by no means inconsistent with what we know in other respects of the age and character of the culture of the Chinese, that they should have devised such a system at so early a date. They have, from the beginning, been as much distinguished by a tendency to observe and record as the Hindus by the lack of such a tendency: they have always attached extreme importance to astronomical labors, and to the construction and rectification of the calendar; and the industry and accuracy of their observations is attested by the use made of them by modern astronomers—thus, to take a single instance, of the cometary orbits which have been calculated, the first twenty-five rest upon Chinese observations alone: and once more, it is altogether in accordance with the clever empiricism and practical shrewdness of the Chinese character that they should have originated at the very start a system of observation exceedingly well adapted to its purpose, stopping with that, working industriously on thenceforth in the same beaten track, and never developing out of so promising a commencement anything deserving the name of a science, never devising a theory of the planetary motions, never even recognizing and defining the true character of the cardinal phenomenon of the precession.

Again, although it might seem beforehand highly improbable that a system of Chinese invention should have found its way into the West, and have been extensively accepted there, many centuries before the Christian era, there are no so insuperable difficulties in the way as should destroy the force of strong presumptive evidence of the truth of such a communication. It is well known that in very ancient times the products of the soil and industry of China were sought as objects of luxury in the West, and mercantile intercourse opened and maintained across the deserts of Central Asia; it even appears that, as early as about B. C. 600 (Isaiah xlix. 12), some knowledge of the Sinim, as a far-off eastern nation, had penetrated to Babylon and Judea. On the other hand, we do not know how much, if at all, earlier than this it may be necessary to acknowledge the system of asterisms to have made its appearance in India. The literary memorials of the earliest period, the Vedic period proper, present no evidence of the existence of the system: indeed, it is remarkable how little notice is taken of the stars by the Vedic poets; even the recognition of some of them as planets does not appear to have taken place until considerably later. In the more recent portions of the Vedic texts—as in the nineteenth book of the Atharva-Veda, a modern appendage to that modern collection, and in parts of the Yajur-Veda, of which there is reason to believe that the canon was not closed until a comparatively late period—full lists of the asterisms are found. The most unequivocal evidence of the early date of the system in India is furnished by the character of the divinities under whose regency the several asterisms are placed: these are all from the Vedic pantheon; the popular divinities of later times are not to be found among them; but, on the other hand, more than one whose consequence is lost, and whose names almost are forgotten, even in the epic period of Hindu history, appear in the list. Neither this, however, nor any other evidence known to us, is sufficient to prove, or even to render strongly probable, the existence of the asterisms in India at so remote a period that the system might not be believed to have been introduced, in its fully developed form, from China.

If, now, we make the attempt to determine, upon internal evidence, which of the three systems is the primitive one, a detailed examination of their correspondences and differences will lead us first to the important negative conclusion that no one among them can be regarded as the immediate source from which either of the other two has been derived. It is evident that the Hindu asterisms and the Arab *manâzil* constitute, in many respects, one and the same system: both present to us constellations or groups of stars, in place of the single determinatives of the Chinese *sieu;* and not only are those groups composed in general of the same stars, but in several cases—as the 7th, 10th, 11th, and 12th members of the series—where they differ widely in situation from the Chinese determinatives, they exhibit an accordance with one another which is too close to be plausibly looked upon as accidental. But if it is thus made to appear that neither can have come independently of the other from a Chinese original, it is no less certain that neither can have come through the other from such an original; for each has its own points of agreement with the *sieu*, which the other does not share—the Hindu in the 9th, 13th, and 21st asterisms, the Arab in the 15th, 22nd, 23rd, 24th, and 25th mansions. The same considerations show, inversely, that the Chinese system cannot be traced to either of the others as its source, since it agrees in several points with each one of them where that one differs from the third. It becomes necessary, then, to introduce an additional term into the comparison; to assume the existence of a fourth system, differing in some particulars from each of the others, in which all shall find their common point of union. Such an assumption is not to be looked upon as either gratuitous or arbitrary. Not only do the mutual relations of the three systems point distinctly toward it, but it is also supported by general considerations, and will, we think, be found to remove many of the difficulties which have embarrassed the history of the general system. It has been urged as a powerful objection to the Chinese origin of the twenty-eight-fold division of the heavens, that we find traces of its existence in so many of the countries of the West, geographically remote from China, and in which Chinese influence can hardly be supposed to have been directly felt. And it is undoubtedly true that neither India nor Arabia has stood in ancient times in such relations to China as should fit it to become the immediate recipient of Chinese learning, and the means of its communication to surrounding peoples. The great route of intercourse between China and the West led over the table-land of Central Asia, and into the north-eastern territory of Iran, the seat of the Zoroastrian religion and culture: thence the roads diverged, the one leading westward, the other south-eastward into India, through the valley of the Cabul, the true gate of the Indian peninsula. Within or upon the limits of this central land of Iran we conceive the system of mansions to have received that form of which the Hindu *nakshatras* and the Arab *manâzil* are the somewhat altered representatives: precisely where, and whether in the hands of Semitic or of Aryan races, we would not at present attempt to say. There are, as has been noticed above, traces of an Iranian system to be found in the Bundehesh; but this is a work which, although probably not later than the times of Persia's independence under her Sassanian rulers, can pretend to no high antiquity, and no like traces have as yet been pointed out in the earliest Iranian memorial, the Zendavesta. Weber (Ind. Literaturgeschichte, p. 221), on the other hand, sees in the *mazzaloth* and *mazzaroth* of the Scriptures (Job xxxviii. 32; II Kings xxiii. 5)—words radically akin with the Arabic *manzil*—indications of the early existence of the system in question among the western Semites, and suspects for it a Chaldaic origin: but the allusions appear to us too obscure and equivocal to be relied upon as proof of this, nor is it easy to believe that such a method of division of the heavens should have prevailed so far to the west, and from so ancient a time, without our hearing of it from the Greeks; and especially, if it formed a part of the Chaldaic astronomy. This point, however, may fairly be passed over, as one to be determined, perhaps, by future investigations, and not of essential importance to the present inquiry. The question of originality is at least definitely settled adversely to the claims of both the Hindu and the Arab systems, and can only lie between the Chinese and that fourth system from which the other two have together descended. And as concerns these, we are willing to accept the solution which is furnished us by the researches of M. Biot, supported as we conceive it to be by the general probabilities of the case. Any one who will trace out, by the help of a celestial globe or map,* the positions of the Chinese determinatives, cannot fail to perceive their general approach to a great circle of the sphere which is independent of the ecliptic, and which accords more nearly with the equator of B. C. 2350 than with any other later one. The full explanations and tables of positions given by Biot (Journ. d. Sav., 1840, pp. 243–254) also furnish evidence, of a kind appreciable by all, that the system may have had the origin which he attributes to it, and that, allowing for the limitations imposed upon it by its history, it is consistent with itself, and well enough adapted to the purposes for which it was designed. With the positions of its determinative stars seem to have agreed those of the constellations adopted by the common parent of the Hindu and Arab systems, excepting in five or six points: those points being where the Chinese make their one unaccountable leap from the head to the belt of Orion, and again, where the *sieu* are drawn off far to the southward, in the constellations Hydra and Crater: and this, in our view, looks much more as if the series of the *sieu* were the original, whose guidance had been closely followed excepting in a few cases, than as if the asterisms composing the other systems had been independently selected from the groups of stars situated along the zodiac, with the intention of forming a zodiacal series. It is easy to see, farther, how the single determinatives of the *sieu* should have become the nuclei for constellations such as are presented by the other systems; but if, on the contrary, the *sieu* had been selected by the Chinese, in each case, from groups previously constituted, there appears no reason why their brightest stars should not have been chosen, as they were chosen later by the Hindus, in the establishment of junction-stars for the asterisms.

We would suggest, then, as the theory best supported by all the evidence thus far elicited, that a knowledge of the Chinese astronomy, and with it the Chinese system of division of the heavens into twenty-eight mansions, was carried into Western Asia at a period not much later than B. C. 1100, and was there adopted by some western people, either Semitic or Iranian. That in their hands it received a new form, such as adapted it to a ruder and less scientific method of observation, the limiting stars of the mansions being converted into zodiacal groups or constellations, and in some instances altered in position, so as to be brought nearer to the general planetary path of the ecliptic. That in this changed form, having become a means of roughly determining and describing the places and movements of the planets, it passed into the keeping of the Hindus—very probably along with the first knowledge of the planets themselves—and entered upon an independent career of history in India. That it still maintained itself in its old seat, leaving its traces later in the Bundehesh; and that it made its way so far westward as finally to become known to, and adopted by, the Arabs. The farther

* We propose to furnish at the close of this publication, in connection with the additional notes, such a map of the zodiacal zone of the heavens as will sufficiently illustrate the character and mutual relations of the three systems compared.

modifications introduced into it by the latter people all have in view a single purpose, that of establishing its stations in the immediate neighborhood of the ecliptic: to this purpose the whole Arab system is not less constantly faithful than is the Chinese to its own guiding principle. The Hindu sustains in this respect but an unfavorable comparison with the others: the arbitrary introduction, in the 15th, 22nd, 23rd, and 24th asterisms, of remote northern stars, greatly impairs its unity, and also furnishes an additional argument of no slight force against its originality; for, on the one hand, the derivation of the others from it becomes thereby vastly more difficult, and, on the other, we can hardly believe that a system of organic Indian growth could have become disfigured in India by such inconsistencies; they wear the aspect, rather, of arbitrary alterations made, at the time of its adoption, in an institution imported from abroad.

It might, at first sight, appear that the adoption by the Arabs of the *manzil* corresponding to Açvinî as the first of their series indicated that they had derived it from India posterior to the transfer by the Hindus of the first rank from Kṛttikâ, the first of the *sieu*, to Açvinî: but the circumstance seems readily to admit of another interpretation. The names of many of the Arab mansions show the influence of the Greek astronomy, being derived from the Greek constellations: the same influence would fully explain an arrangement which made the series begin with the group coinciding most nearly with the beginning of the Greek zodiac. The transfer on the part of the Hindus, likewise, was unquestionably made at the time of the general reconstruction of their astronomical system under the influence of western science. The two series are thus to be regarded as having been brought into accordance in this respect by the separate and independent working of the same cause.

M. Biot insists strongly, as a proof of the non-originality of the system of asterisms among the Hindus, upon its gross and palpable lack of adaptedness to the purpose for which they used it; he compares it to a gimlet out of which they have tried to make a saw. In this view we can by no means agree with him: we would rather liken it to a hatchet, which, with its edge dulled and broken, has been turned and made to do duty as a hammer, and which is not ill suited to its new and coarser office. Indeed, taking the Hindu system in its more perfect and consistent form, as applied by the Arabs, and comparing it with the Chinese *sieu* at any time within the past two thousand years, we are by no means sure that the advantage in respect to adaptation would not be generally pronounced to be upon the side of the former. The distance of many of the *sieu* during that period from the equator, the faintness of some among them, the great irregularity of their intervals, render them anything but a model system for measuring distances in right ascension. On the other hand, to adopt a series of conspicuous constellations along the zodiac, by their proximity to which the movements of the planets shall be marked, is no unmotived proceeding: just such a division of the ecliptic among twelve constellations preceded and led the way to the Greek method of measuring by signs, having exact limits, and independent of the groups of stars which originally gave name to them. M. Biot's error lies in his misapprehension, in two important respects, of the character of the Hindu asterisms: in the first place, he constantly treats them as if they were, like the *sieu*, single stars, the intervals between whose circles of declination constituted the accepted divisions of the zodiac; and in the second place, he assumes them to have been established for the purpose of marking the moon's daily progress from point to point along the ecliptic. Now, as regards the first of these points, we have already shown above that the conversion of the Chinese determinatives into constellations took place, in all probability, before their introduction to the knowledge of the Hindus: there is, indeed, an entire unanimity of evidence to the effect that the Hindu system is from its inception one of groups of stars: this is conclusively shown by the original dual and plural names of the asterisms, or by their otherwise significant titles—compare especially those of the 13th and 25th of the series. The selection of a "junction-star" to represent the asterism appears to be something comparatively modern: we regard it as posterior to the reconstruction of the Hindu astronomy upon a truly scientific basis, and the determination, by calculation, of the precise places of the planets: this would naturally awaken a desire for, and lead to, a similarly exact determination of the position of some star representing each asterism, which might be employed in the calculation of conjunctions, for astrological purposes; the astronomical uses of the system being no longer of much account after the division of the ecliptic into signs. And the choice of the junction-star has fallen, in the majority of cases, not upon the Chinese determinative itself, but upon some other and more conspicuous member of the group originally formed about the latter. Again, there is an entire absence of evidence that the "portions" of the asterisms, or the arcs of the ecliptic named from them, were ever measured from junction-star to junction-star: whatever may be the discordance among the different authorities respecting their extent and limits, they are always freely, and often arbitrarily, taken from parts of the ecliptic adjacent to, or not far removed from, the successive constellations.

As regards the other point noticed, it is, indeed, not at all to be wondered at that M. Biot should treat the Hindu *nakshatras* as a system bearing special relations to the moon, since, by those who have treated of them, they have always been styled "houses of the moon," "moon-stations," "lunar asterisms," and the like. Nevertheless, these designations seem to be founded only in carelessness, or in misapprehension. In the Sûrya-Siddhânta, certainly, there is no hint to be discovered of any particular connection between them and the moon, and for this reason we have been careful never to translate the term *nakshatra* by any other word than simply "asterism." Nor does the case appear to have been otherwise from the beginning. No one of the general names for the asterisms (*nakshatra*, *bha*, *dhishnya*) means literally anything more than "star" or "constellation": their most ancient and usual appellation, *nakshatra*, is a word of doubtful etymology (it may be radically akin with *nakta*, nox, νύξ, "night"), but it is not infrequently met with in the Vedic writings, with the general signification of "star," or "group of stars": the moon is several times designated as "sovereign of the *nakshatras*," but evidently in no other sense than that in which we style her "queen of night"; for the same title is in other passages given to the sun, and even also to the Milky Way. When the name came to be especially applied to the system of zodiacal asterisms, we have seen above that a single one of the series, the 5th, was placed under the regency of the moon, as another, the 13th, under that of the sun: this, too, by no means looks as if the whole design of the system was to mark the moon's daily motions. Naturally enough, since the moon is the most conspicuous of the nightly luminaries, and her revolutions more rapid and far more important than those of the others, the asterisms would practically be brought into much more frequent use in connection with her movements: their number, likewise, being nearly accordant with the number of days of her sidereal revolution, could not but tempt those who thus employed them to set up an artificial relation between the two. Hence the Arabs distinctly call their divisions of the zodiac, and the constellations which mark them, "houses of the moon," and, until the researches of M. Biot, no one, so far as we are aware, had ever questioned that the number of the asterisms or mansions, wherever found, was derived from and dependent on that of the days in the moon's revolution. It was most natural, then, that Western scholars, having first made acquaintance with the Arab system, should, on finding the same in India, call it by the same name: nor is it very strange, even, that Ideler should have gone a step farther, and applied the familiar title of "lunar stations" to the Chinese *sieu* also; an error for which he is sharply criticised by M. Biot (Journ. d. Sav., 1859, p. 480). The latter cites from al-Bîrûnî (Journ. d. Sav. 1845, p. 49; 1859, pp. 487–8) two passages derived by him from Varâha-mihira and Brahmagupta respectively, in which are recorded attempts to establish a systematic relation between the asterisms and the moon's true and mean daily motions. One of these passages is exceedingly obscure, and both are irreconcilable with one another, and with what we know of the system of asterisms from other sources: two conclusions, however, bearing upon the present matter, are clearly derivable from them: first, that, as the "portions" assigned to the asterisms had no natural and fixed limits, it was possible for any Hindu system-maker so to define them as to bring them into a connection with the moon's daily motions: and secondly, that such a connection was never deemed an essential feature of the system, and hence no one form of it was generally recognized and accepted. The considerations adduced by us above are, we think, fully sufficient to account for any such isolated attempts at the establishment of a connection as al-Bîrûnî, who naturally sought to find in the Hindu *nakshatras* the correlatives of his own *manâzil al-kamar*, was able to discover among the works of Hindu astronomers: there is no good reason why we should deprive the former of their true character, which is that of zodiacal constellations, rudely marking out divisions of the ecliptic, and employable for all the purposes for which such a division is demanded.

The reason of the variation in the number of the asterisms, which are reckoned now as twenty-eight and now as twenty-seven, is a point of no small difficulty in the history of the system. M. Biot makes the acute suggestion that the omission of Abhijit from the series took place because the mansion belonging to that asterism was on the point of becoming extinguished, the circle of declination of its junction-star being brought by the precession to a coincidence with that of the junction-star of the preceding asterism about A. D. 972. But it has been shown above that M. Biot's view of the nature of a *nakshatra*—that it is, namely, the arc of the ecliptic intercepted between the circles of declination of two successive junction-stars—is altogether erroneous: however nearly those circles might approach one another, there would still be no difficulty in assigning to each asterism its "portion" from the neighboring region of the ecliptic. Again, this explanation would not account for the early date of the omission of Abhijit, which, as already noticed, is found wanting in one of the most ancient lists, that of the Tâittirîya-Sanhitâ. It is to be observed, moreover, that M. Biot, in calculating the period of Abhijit's disappearance, has adopted τ Sagittarii as the junction-star of Uttara-Ashâdhâ, while we have shown above that σ, and not τ, is to be so regarded: and this substitution would defer until several centuries later the date of coincidence of the two circles of declination. According to the Hindu measurements, indeed (see the table of positions of the junction-stars, near the beginning of this note), Abhijit is farther removed from the preceding asterism, both in polar longitude and in right ascension, than are five of the other asterisms from their respective predecessors: nor does the Hindu astronomical system acknowledge or make allowance for the alteration of position of the circles of declination under the influence of the precession: their places, as data for the calculation of conjunctions, are ostensibly laid down for all future time. For these various reasons, M. Biot's explanation is to be rejected as insufficient. A more satisfactory one, in our opinion, may be found in the fact, illustrated above (see Fig. 31, beginning of this note), that the asterisms are in general so distributed as to accord quite well with a division of the ecliptic into twenty-seven equal portions, but not with a division into twenty-eight equal portions; that the region where they are too much crowded together is that from the 20th to the 23rd asterism, and that, among those situated in this crowded quarter, Abhijit is farthest removed from the ecliptic, and so is more easily left out than any of the others, in dividing the ecliptic into portions. We cannot consider it at all doubtful that Abhijit is as originally and truly a part of the system of asterisms as any other constellation in the series, which is properly composed of twenty-eight members, and not of twenty-seven: the analogy of the other systems, and the fact that treatises like this Siddhânta, which reckon only twenty-seven divisions of the ecliptic, are yet obliged, in treating of the asterisms as constellations, to regard them as twenty-eight, are conclusive upon this point. The whole difficulty and source of discordance seems to lie in this—how shall there, in any systematic method of division of the ecliptic, be found a place and a portion for a twenty-eighth asterism? The Khanda-Kataka, as cited by al-Bîrûnî—in making out, by a method which is altogether irrespective of the actual positions of the asterisms with reference to the zodiac, the accordance already referred to between their portions and the moon's daily motions—allots to Abhijit so much of the ecliptic as is equivalent to the mean motion of the moon during the part of a day by which her revolution exceeds twenty-seven days.

Others allow it a share in the proper portions of the two neighboring asterisms: thus the Muhûrta-Mâlâ, a late work, of date unknown to us, says: "the last quarter of Uttara-Ashâḍhâ and the first fifteenth of Çravaṇa together constitute Abhijit: it is so to be accounted when twenty-eight asterisms are reckoned; not otherwise." Ordinarily, however, the division of the ecliptic into twenty-seven equal "portions" is made, and Abhijit is simply passed by in their distribution. After the introduction of the modern method of dividing the circle into degrees and minutes, this last way of settling the difficulty would obviously receive a powerful support, and an increased currency, from the fact that a division by twenty-seven gave each portion an even number of minutes, 800, while a division by twenty-eight yielded the awkward and unmanageable quotient $771\frac{3}{7}$.

Much yet remains to be done, before the history and use of the system of asterisms, as a part of the ancient Hindu astronomy and astrology, shall be fully understood. There is in existence an abundant literature, ancient and modern, upon the subject, which will doubtless at some time provoke laborious investigation, and repay it with interesting results. To us hardly any of that literature is accessible, and only the final results of wide-extended and long-continued studies upon it could be in place here. We have already allotted to the *nakshatras* more space than to some may seem advisable: our excuse must be the interest of the history of the system, as part of the ancient history of the rise and spread of astronomical science; the importance attaching to the researches of M. Biot, the inadequate attention hitherto paid them, and the recent renewal of their discussion in the Journal des Savants; and finally and especially, the fact that in and with the asterisms is bound up the whole history of Hindu astronomy, prior to its transformation under the overpowering influence of western science. In the modern astronomy of India, the *nakshatras* are of subordinate consequence only, and appear as hardly more than reminiscences of a former order of things: from the Sûrya-Siddhânta might be struck out every line referring to them, without serious alteration of the character of the treatise.

Before bringing this note to a close, we present, in the annexed table, a comparison of the true longitudes and latitudes of the junction-stars of the twenty-eight asterisms, as derived by calculation from the positions stated in our text, with the actual longitudes and latitudes of the stars with which they are probably to be identified. In a single case, (the 27th asterism), we compare the longitude of one star and the latitude of another; the reason of this is explained above, in connection with the identification of the asterism. We add columns giving the errors of the Hindu determinations of position: in that for the latitude north direction is regarded as positive, and south direction as negative.

Upon examining the column of errors of latitude presented in this table, it will be seen that they are too considerable, and too irregular, both in amount and in direction, to be plausibly accounted for otherwise than as direct errors of observation and calculation. The grossest of them, as has already been pointed out, are committed in the measurement of southern latitudes, when of considerable amount, and they are

Positions, and Errors of Position, of the Junction-Stars of the Asterisms.

No.	Name.	Longitude, A. D. 560. Hindu.	Longitude True.	Longitude Hindu error.	Latitude. Hindu.	Latitude True.	Latitude Hindu error.	Star compared.
		° ′	° ′	° ′	° ′	° ′	° ′	
1	Açvinî,	11 59	13 56	– 1 57	9 11 N.	8 28 N.	+ 0 43	β Arietis.
2	Bharaṇî,	24 35	26 54	– 2 19	11 6 "	11 17 "	– 0 11	35 Arietis, *a* Muscæ.
3	Kṛttikâ,	39 8	39 58	– 0 50	4 44 "	4 1 "	+ 0 43	η Tauri, Alcyone.
4	Rohiṇî,	48 9	49 45	– 1 36	4 49 S.	5 30 S.	+ 0 41	α Tauri, Aldebaran.
5	Mṛgaçîrsha,	61 3	63 40	– 2 37	9 49 "	13 25 "	+ 3 36	λ Orionis.
6	Ârdrâ,	65 50	68 43	– 2 53	8 53 "	16 4 "	+ 7 11	α Orionis.
7	Punarvasu,	92 52	93 14	– 0 22	6 0 N.	6 39 N.	– 0 39	β Gemin., Pollux.
8	Pushya,	106 0	108 42	– 2 42	0 0	0 4 "	– 0 4	δ Cancri.
9	Âçleshâ,	109 59	112 20	– 2 21	6 56 S.	11 8 S.	+ 4 12	ε Hydræ.
10	Maghâ,	129 0	129 49	– 0 49	0 0	0 27 N.	– 0 27	α Leonis, Regulus.
11	P.-Phalgunî,	139 58	141 15	– 1 17	11 19 N.	14 19 "	– 3 0	δ Leonis.
12	U.-Phalgunî,	150 10	151 37	– 1 27	12 5 "	12 17 "	– 0 12	β Leonis.
13	Hasta,	174 22	173 27	+ 0 55	10 6 S.	12 10 S.	+ 2 4	δ Corvi.
14	Citrâ,	180 48	183 49	– 3 1	1 50 "	2 2 "	+ 0 12	α Virginis, Spica.
15	Svâtî,	183 2	184 12	– 1 10	33 50 N.	30 57 N.	+ 2 53	α Bootis, Arcturus.
16	Viçâkhâ,	213 31	211 0	+ 2 31	1 25 S.	1 48 S.	+ 0 23	ι Libræ.
17	Anurâdhâ,	224 44	222 34	+ 2 10	2 52 "	1 57 "	– 0 55	δ Scorpionis.
18	Jyeshṭhâ,	230 7	229 44	+ 0 23	3 50 "	4 31 "	+ 0 41	α Scorp., Antares.
19	Mûla,	242 52	244 33	– 1 41	8 48 "	13 44 "	+ 4 56	λ Scorpionis.
20	P.-Ashâḍhâ,	254 39	254 32	+ 0 7	5 28 "	6 25 "	+ 0 57	δ Sagittarii.
21	U.-Ashâḍhâ,	260 23	262 21	– 1 58	4 59 "	3 24 "	– 1 25	σ Sagittarii.
22	Abhijit,	264 10	265 15	– 1 5	59 58 N.	61 46 N.	– 1 48	α Lyræ, Vega.
23	Çravaṇa,	282 29	281 41	+ 0 48	29 54 "	29 19 "	+ 0 35	α Aquilæ, Atair.
24	Çravishṭhâ,	296 5	296 19	– 0 14	35 33 "	31 57 "	+ 3 36	β Delphini.
25	Çatabhishaj,	319 50	321 33	– 1 43	0 28 S.	0 23 S.	– 0 5	λ Aquarii.
26	P.-Bhâdrapadâ,	334 25	333 27	+ 0 58	22 30 N.	19 25 N.	+ 3 5	α Pegasi.
27	U.-Bhâdrapadâ,	347 16	349 8	– 1 52	24 1 "	25 41 "	– 1 40	γ Peg. & α Androm.
28	Revatî,	359 50	359 50	0 0	0 0	0 13 S.	+ 0 13	ζ Piscium.

all in the same direction, giving the star a place too far to the north. The column of errors in longitude, on the other hand, shows a very marked preponderance of *minus* errors, their sum being 33° 54′, while the sum of *plus* errors is only 7° 52′. Upon taking the difference of these sums, and dividing it by twenty-eight, we find the average error of longitude to be – 56′, the greatest deviation from it in either direction being – 2° 4′ and + 3° 27′.* So far as this goes, it would indicate that the Hindu measurements of position were made from a vernal equinox situated about 1° to the eastward of that of A. D. 560, and so at a time seventy years previous to the date we have assumed for them, or about A. D. 490. In our present ignorance of the methods of observation

* In a comparison in which a high degree of exactness was desired, and was not, in the nature of the case, unattainable, it would of course be necessary to take into account the proper motions of the stars compared. This we have not thought it worth while, in the present instance, to do. We may remark, however, that the junction-star of the 15th asterism, Arcturus, has a much greater proper motion than any other in the series; and that, if this were allowed for, according to its value as determined by Main (Mem. Roy. Astr. Soc., vol. xix, 4to, 1851), the Hindu error of longitude would be diminished about 22′, but that of latitude increased about 35′.

employed by the Hindus for this purpose, such a determination of date cannot, indeed, be relied upon as exact or conclusive, yet it is the best and surest that we can attain. The general conclusion, at any rate, stands fast, that the positions of the junction-stars of the asterisms were fixed not far from the time when the vernal equinox coincided with the initial point of the Hindu sidereal sphere, or during the sixth century of our era.

Since, according to the Hindu theory, the initial point of the sidereal sphere is also, for all time, the mean place of the vernal equinox, which always reverts to it after a libration of 27° in either direction (see above, iii. 9–12), we are not surprised to find the positions of the asterisms primarily defined upon the supposition of their coincidence. But it is not a little strange that the effect of the precession in altering the direction of the circles of declination drawn through the junction-stars, and so the polar longitudes and latitudes of the latter, should be made no account of (see, however, the latter half of v. 12, below, and the note upon it), and that directions for calculating the conjunctions of the planets with the asterisms according to their positions as thus stated should be given (vv. 14–15), unaccompanied by any hint that a modification of the data of the process would ever be found necessary. This carelessness is perhaps to be regarded as an additional evidence of the small importance attached, after the reconstruction of the Hindu astronomy, to calculations in which the asterisms were concerned; although it also tends strongly to prove what we have suggested above (note to iii. 9–12), that in the construction of the Hindu astronomical system the precession was ignored altogether. It is to be noticed that the two systems of *yogas* (see above, ii. 65, and additional note upon that passage), originally founded upon actual conjunctions with the asterisms, have been divorced from any real connection with them. A like consideration might restrain us from accepting the determinations of position here presented as the best results which Hindu observers and instruments were capable of attaining; yet, in the absence of other tests of their powers, we cannot well help drawing the conclusion that the accuracy of a Hindu observation is not to be relied on within a degree or two.

10. Agastya is at the end of Gemini, and eighty degrees south; and Mrgavyâdha is situated in the twentieth degree of Gemini;

11. His latitude (*vikshepa*), reckoned from his point of declination (*apakrama*), is forty degrees south: Agni (*hutabhuj*) and Brahmahrdaya are in Taurus, the twenty-second degree;

12. And they are removed in latitude (*vikshipta*), northward, eight and thirty degrees respectively. . . .

In connection with the more proper subject of this chapter we also have laid before us, here and in a subsequent passage (vv. 20–21), the defined positions of a few fixed stars which are not included in the system of zodiacal asterisms. The definition is made in the same manner as before, by polar longitudes and latitudes. It is not at all difficult to identify the stars referred to in these verses; they were correctly pointed out by Colebrooke, in his article already cited (As. Res., vol. ix). Agastya is α Navis, or Canopus, a star of the first magnitude, and one of the most brilliant in the southern heavens. Its remote southern position, only 37° from the pole, renders it invisible to an observer stationed much to the northward of the Tropic of Cancer. Its Hindu name is that of one of the old Vedic *ṛshis*, or inspired sages. The comparison of its true position with that assigned it by our text—which, in this instance, does not require to be reduced to true longitude and latitude—is as follows:

Agastya	90° 0′	80° 0′ S.
Canopus	85° 4′	75° 50′ S.

The error of position is here very considerable, and the variations of the other authorities from the data of our text are correspondingly great. The Siddhânta-Çiromaṇi and (according to Colebrooke) the Brahma-Siddhânta give Agastya 87° of polar longitude, and 77° of latitude, which is a fair approximation to the truth; the Graha-Lâghava also places it correctly in lat. 76° S., but makes its longitude only 80°, which is as gross an error as that of the Sûrya-Siddhânta, but in the opposite direction. The Çâkalya-Sanhitâ agrees precisely with our treatise as respects the positions of these four stars, as it does generally in the numerical data of its astronomical system.

Mṛgavyâdha, "deer-hunter"—it is also called Lubdhaka, "hunter"—is α Canis Majoris, or Sirius, the brightest of the fixed stars:

Mṛgavyâdha	76° 23′	39° 52′ S.
Sirius	84° 7′	39° 32′ S.

Here, while all authorities agree with the correct determination of the latitude of Sirius presented by our text, the Siddhânta-Çiromaṇi etc. greatly reduce its error of longitude, by giving the star 86°, instead of 80°, of polar longitude: the Graha-Lâghava reads 81°.

The star named after the god of fire, Agni, and called in the text by one of his frequent epithets, *hutabhuj*, "devourer of the sacrifice," is the one which is situated at the extremity of the northern horn of the Bull, or β Tauri: it alone of the four is of the second magnitude only:

Agni	54° 5′	7° 44′ N.
β Tauri	62° 32′	5° 22′ N.

The very gross error in the determination of the longitude of this star is but slightly reduced by the Graha-Lâghava, which gives it 53°, instead of 52°, of polar longitude. The Siddhânta-Çiromaṇi and Brahma-Siddhânta omit all notice of any of the fixed stars excepting Canopus and Sirius.

Brahmahṛdaya, "Brahma's heart," is α Aurigæ, or Capella:

Brahmahṛdaya	60° 29′	28° 53′ N.
Capella	61° 50′	22° 52′ N.

The Graha-Lâghava, leaving this erroneous determination of latitude unamended, adds a greater error of longitude, in the opposite direction to that of our text, by giving the star 4° more of polar longitude.

We shall present these comparisons in a tabular form at the end of the chapter, in connection with the other passage of similar import.

12. . . . Having constructed a sphere, one may examine the corrected (*sphuṭa*) latitude and polar longitude (*dhruvaka*).

What is the true meaning and scope of this passage, is a question with regard to which there may be some difference of opinion. The commentator explains it as intended to satisfy the inquiry whether the polar longitudes and latitudes, as stated in the text, are constant, or whether they are subject to variation. Now although, he says, owing to the precession, the values of these quantities are not unalterably fixed, yet they are given by the text as they were at its period, and as if they were constant, while the astronomer is directed to determine them for his own time by actual observation. For this purpose he is to take such a sphere as is described below (chap. xiii)—of which the principal parts, and the only ones which would be brought into use in this process, are hoops or circles representing the colures, the equator, and the ecliptic—and is to suspend upon its poles an additional movable circle, graduated to degrees: this would be, of course, a revolving circle of declination. The sphere is next to be adjusted in such manner that its axis shall point to the pole, and that its horizon shall be water-level. Then, in the night, the junction-star of Revatî (ζ Piscium) is to be looked at through a hole in the centre of the instrument, and the corresponding point of the ecliptic, which is 10′ east of the end of the constellation Pisces, is to be brought over it; after that, it will be necessary only to bring the revolving circle of declination, as observed through the hole in the centre of the instrument, over any other star of which it is desired to determine the position, and its polar longitude and latitude may be read off directly upon the ecliptic and the movable circle respectively.

Colebrooke (As. Res., ix. 326; Essays, ii. 324) found this passage similarly explained in other commentaries upon the Sûrya-Siddhânta to which he had access, and also met with like directions in the commentaries on the Siddhânta-Çiromaṇi.

There are, however, very serious objections to such an interpretation of the brief direction contained in the text. It is altogether inconsistent with the whole plan and method of a Hindu astronomical treatise to leave, and even to order, matters of this character to be determined by observation. Observation has no such important place assigned to it in the astronomical system: with the exception of terrestrial longitude and latitude, which, in the nature of things, are beyond the reach of a treatise, it is intended that the astronomer should find in his text-book everything which he needs for the determination of celestial phenomena, and should resort to instruments and observation only by way of illustration. The sphere of which the construction is prescribed in the thirteenth chapter is not an instrument for observation: it is expressly stated to be "for the instruction of the pupil," and it is encumbered with such a number and variety of different circles, including parallels of declination for all the asterisms and for the observed fixed stars, that it could not be used for any other purpose: it will be noticed, too, that the commentary is itself obliged to order here the addition of the only appliances—the revolving circle of declination and the hole through the centre—which make of it an instrument for observation. The simple and original meaning of the passage seems to be that, having constructed a sphere in the manner to be hereafter described, one may examine the places of the asterisms as marked upon it, and note their coincidence with the actual positions of the stars in the heavens. And we would regard the other interpretation as forced upon the passage by the commentators, in order to avoid the difficulty pointed out by us above (near the end of the note on the last passage but one) and to free the Siddhânta from the imputation of having neglected the precessional variation of the circles of declination. M. Biot pronounces the method of observation explained by the commentators "almost impracticable," and it can, accordingly, hardly be that by which the positions of the asterisms were at first laid down, or by which they could be made to undergo the necessary corrections. Another method, more in accordance with the rules and processes of the third chapter, and which appears to us to be more authentic and of higher value, is described by Colebrooke (as above) from the Siddhânta-Sarvabhâuma, being there cited from the Siddhânta-Sundara; it is as follows:

"A tube, adapted to the summit of the gnomon, is directed toward the star on the meridian: and the line of the tube, pointed to the star, is prolonged by a thread to the ground. The line from the summit of the gnomon to the base is the hypothenuse; the height of the gnomon is the perpendicular; and its distance from the extremity of the thread is the base of the triangle. Therefore, as the hypothenuse is to its base, so is the radius to a base, from which the sine of the angle, and consequently the angle itself, are known. If it exceed the latitude [of the place of observation], the declination is south; or, if the contrary, it is north. The right ascension of the star is calculated from the hour of night, and from the right ascension of the sun for that time. The declination of the corresponding point of the ecliptic being found, the sum or difference of the declinations, according as they are of the same or of different denominations, is the distance of the star from the ecliptic. The longitude of the same point is computed; and from these elements, with the actual precession of the equinox, may be calculated the true longitude of the star; as also its latitude on a circle passing through the poles of the ecliptic."

The Siddhânta-Sarvabhâuma also gives the true longitudes and latitudes of the asterisms, professedly as thus obtained by observation and calculation, and they are reported by Colebrooke in his general table of data respecting the asterisms.

If we are not mistaken, the amount and character of the errors in the stated latitudes of the asterisms tend to prove that this, or some kindred process, was that by which their positions were actually determined.

13. In Taurus, the seventeenth degree, a planet of which the latitude is a little more than two degrees, south, will split the wain of Rohiṇî.

The asterism Rohiṇî, as has been seen above, is composed of the five principal stars in the head of Taurus, in the constellation of which is seen the figure of a wain. The divinity is Prajâpati. The distances of its stars in longitude from the initial point of the sphere vary from 45° 46′ (γ) to 49° 45′ (α): hence the seventeenth degree of the second sign—the reckoning commencing at the initial point of the sphere, taken as coinciding also with the vernal equinox—is very nearly the middle of the wain. The latitude of its stars, again, varies from 2° 36′ (ε) to 5° 47′ (ϑ) S.; hence, to come into collision with, or to enter, the wain, a planet must have more than two degrees of south latitude. The Siddhânta does not inform us what would be the consequences of such an occurrence; that belongs rather to the domain of astrology than of astronomy. We cite from the Pañcatantra (vv. 238–241) the following description of these consequences, derived from the astrological writings of Varâha-mihira:*

"When Saturn splits the wain of Rohiṇî here in the world, then Mâdhava rains not upon the earth for twelve years.

"When the wain of Prajâpati's asterism is split, the earth, having as it were committed a sin, performs, in a manner, her surface being strewn with ashes and bones, the *kâpâlika* penance.

"If Saturn, Mars, or the descending node splits the wain of Rohiṇî, why need I say that, in a sea of misfortune, destruction befalls the world?

"When the moon is stationed in the midst of Rohiṇî's wain, then men wander recklessly about, deprived of shelter, eating the cooked flesh of children, drinking water from vessels burnt by the sun."

Upon what conception this curious feature of the ancient Hindu astrology is founded, we are entirely ignorant.

14. Calculate, as in the case of the planets, the day and night of the asterisms, and perform the operation for apparent longitude (*dṛkkarman*), as before: the rest is by the rules for the conjunction (*melaka*) of planets, using the daily motion of the planet as a divisor: the same is the case as regards the time.

15. When the longitude of the planet is less than the polar longitude (*dhruvaka*) of the asterism, the conjunction (*yoga*) is to come; when greater, it is past: when the planet is retrograding (*vakragati*), the contrary is to be recognized as true of the conjunction (*samâgama*).

The rules given in the preceding chapter for calculating the conjunction of two planets with one another apply, of course, with certain modifications, to the calculation of the conjunctions of the planets with the asterisms. The text, however, omits to specify the most important of these modifications—that, namely, in determining the apparent longitude of an asterism, one part of the process prescribed in the case of a planet, the *ayanadṛkkarman*, or correction for ecliptic deviation, is to be omitted altogether; since the polar longitude of the asterism, which is given, corresponds in character with the *âyana graha*, or longitude of the planet as affected by ecliptic deviation, which must be ascertained by the *ayanadṛkkarman*. The commentary notices the omission, but offers neither explanation nor excuse for it. The other essential modification—that, the asterism being fixed, the motion of the planet alone is

* Our translation represents the verses as amended in their readings by Benfey (Pantschatantra etc., 2r Theil, nn. 234–237). In the third of the verses, however, the reading of the published text, *çaçi*, "moon," would seem decidedly preferable to *çikhi*, "descending node"; since the node, being always necessarily in the ecliptic, can never come into collision with Rohiṇî's wain.

to be used as divisor in determining the place and time of the conjunction—is duly noticed.

The inaccuracies in the Hindu process for determining apparent longitudes, which, as above noticed, are kept within bounds, where the planets alone are concerned, by the small amount of their latitudes, would be liable in the case of many of the asterisms to lead to grave errors of result.

16. Of the two Phalgunîs, the two Bhâdrapadâs, and likewise the two Ashâḍhâs, of Viçâkhâ, Açvinî, and Mrgaçîrsha (*sâumya*), the junction-star (*yogatârâ*) is stated to be the northern (*uttara*):

17. That which is the western northern star, being the second situated westward, that is the junction-star of Hasta; of Çravishṭhâ it is the western:

18. Of Jyeshṭhâ, Çravana, Anurâdhâ (*maitra*), and Pushya (*bârhaspatya*), it is the middle star: of Bharaṇî, Kṛttikâ (*âgneya*), and Maghâ (*pitrya*), and likewise of Revatî, it is the southern:

19. Of Rohiṇî, Punarvasu (*âditya*), and Mûla, it is the eastern, and so also of Âçleshâ (*sârpa*): in the case of each of the others, the junction-star (*yogatârakâ*) is the great (*sthûla*) one.

We have had occasion above, in treating of the identification of the asterisms, to question the accuracy of some of these designations of the relative position of the junction-stars in the groups containing them. We do not regard the passage as having the same authenticity and authority with that in which the determinations of the polar longitudes and latitudes are given; and indeed, we are inclined to suspect that all which follows the fifteenth verse in the chapter may be a later addition to its original content. It is difficult to see otherwise why the statements given in verses 20 and 21 of the positions of certain stars should be separated from those presented above, in verses 10–12. A designation of the relative position of the junction-star in each group ought also properly to be connected with a definition of the number of stars composing each, and a description of its configuration—such as are presented along with it by other treatises, as the Çâkalya-Sanhitâ. The first is even in some points ambiguous unless accompanied by the others, since there are cases in which the same star has a different position in its asterism according as the latter is to be regarded as including a less or a greater number of stars. In this respect also, then, the passage looks like a disconnected fragment. Nor is the method of designation so clear and systematic as to inspire us with confidence in its accuracy. Upon a consideration of the whole series of asterisms, it is obvious that the brightest member of each group is generally selected as its junction-star. Hence we should expect to find a general rule to that effect laid down, and then the exceptions to it specially noted, together with the cases in which such a designation would be equivocal. Instead of this, we have the junction-stars of only two asterisms containing more than one star, namely Abhijit and Çatabhishaj, described by their superior brilliancy, while that of the former is not less capable of being pointed out by its position than are any of the others in the series. Again, there are cases in which it is questionable which star is meant to be pointed out in a group of which the constitution is not doubtful, owing to the very near correspondence of more than one star with the position as defined. And once more, where, in a single instance, a special effort has apparently been made to fix the position of the junction-star beyond all doubt or cavil, the result is a failure; for it still remains a matter of dispute how the description is to be understood, and which member of the group is intended. The case referred to is that of Hasta, which occupies nearly all of verse 17. That Colebrooke was not satisfied as to the meaning of the description is clear from the fact that he specifies, as the star referred to, "γ or δ Corvi." His translation of the verse, "2nd W. of 1st N. W.", conveys to us no intelligible meaning whatever, as applied to the actual group. He evidently understood *paçcimottaratârâyâ* as a single word, standing by euphony for *-târâyâs*, ablative of *-târâ*. Our own rendering supposes it divided into the two independent words *paçcimottaratârâ yâ*, or the three *paçcimâ uttaratârâ yâ*. This interpretation is, in the first place, supported by the corresponding passage in the Çâkalya-Sanhitâ, which reads, "of Hasta, the north-western (*vâyavî*): it is also the second western." Again, it applies without difficulty to one of the stars in the group, namely to γ, which we think most likely to be the one pointed out—and mainly, because either of the others would admit of being more simply and briefly designated, δ as the northern, β as the eastern, α as the southern, and ε as the western star. We should, then, regard the description as unambiguous, were it not for what is farther added, "being the second situated westward;" for γ is the first or most westerly of the five in longitude, and the third in right ascension, while the second in longitude and in right ascension respectively are the two faint stars ε and α. We confess that we do not see how the difficulty is to be solved without some emendation of the text.

We conceive ourselves to be justified, then, in regarding this passage as of doubtful authenticity and inferior authority: as already partaking, in short, of that ignorance and carelessness which has rendered the Hindu astronomers unable, at any time during the past thousand years, to point out in the heavens the complete series of the groups of stars composing their system of asterisms. None of the other authorities accessible to us gives a description of the relative places of the junction-stars, excepting the Çâkalya-Sanhitâ, and our manuscript of its text is so defective and corrupt at this point that we are able to derive from it with confidence the positions of only about a third of the stars. So far, it accords with the Sûrya-Siddhânta, save that it points out as the junction-star of Pûrva-Ashâdhâ the brightest, instead of the northernmost, member of the group; and here there is a difference in the mode of designation only, and not a disagreement as regards the star designated.

20. Situated five degrees eastward from Brahmahṛdaya is Prajâpati: it is at the end of Taurus, and thirty-eight degrees north.

21. Apâmvatsa is five degrees north from Citrâ: somewhat greater than it, as also six degrees to the north of it, is Âpas.

The three stars whose positions are defined in this passage are not mentioned in the Çâkalya-Sanhitâ, nor in the Siddhânta-Çiromaṇi and (according to Colebrooke) the Brahma-Siddhânta; only the latter of them, Âpas, is omitted by the Graha-Lâghava, being noticed in the Sûrya-Siddhânta alone. It may fairly be questioned, for the reason remarked above, whether the original text of our treatise itself contained the last two verses of this chapter: moreover, at the end of the next chapter (ix. 18), where those stars are spoken of which never set heliacally, on account of their high northern situation, Prajâpati is not mentioned among them, as it ought to be, if its position had been previously stated in the treatise. Still farther on (xiii. 9), in the description of the armillary sphere, it is referred to by the name of Brahma, which, according to the commentary on this passage, and to Colebrooke, it also customarily bears. Perhaps another evidence of the unauthenticity of the passage is to be seen in the fact that the two definitions of the polar longitude of Prajâpati do not, if taken in connection with verse 11, appear to agree with one another: a star which is 5° east from the position of Brahmahṛdaya, as there stated, is not "at the end of Taurus," but at its twenty-seventh degree: this may, however, be merely an inaccurate expression, intended to mean that the star is in the latter part, or near the end, of Taurus. The Graha-Lâghava, which defines the positions of all these stars directly, by degrees of polar longitude and latitude, and not by reference either to the signs or to other stars, gives Prajâpati 61° of polar longitude, or 5° more than it assigned to Brahmahṛdaya: it also adds 1° to the polar latitude as stated in our text. The star referred to can hardly be any other than that in the head of the Wagoner, or δ Aurigæ (4):

Prajâpati	67° 11′	36° 49′ N.
δ Aurigæ	69° 54′	30° 49′ N.

The error of latitude is about the same with that which was committed with reference to Brahmahṛdaya, or Capella. Why so faint and inconspicuous a star should be found among the few of which the Hindu astronomers have taken particular notice is not easy to discover.

The position of the star named Apâmvatsa, "Waters' Child," is described in our text by reference to Citrâ, or Spica Virginis: it is said to be in the same longitude, 180°, and 5° farther north; and this, since Citrâ itself is in lat. 2° S., would make the latitude of Apâmvatsa 3° N. The Graha-Lâghava gives it this latitude directly, and also makes its longitude agree with that of Spica, which, as already noticed, it places at the distance of 183° from the origin of the sphere. Âpas, "Waters" (the commentary, however, treats the word as a singular masculine, Âpa), is put 6° north of Apâmvatsa, or in lat. 9° N. It is identified by Colebrooke with δ Virginis (3), and doubtless correctly:

Âpas	176° 23′	8° 15′ N.
δ Virginis	171° 28′	8° 38′ N.

Colebrooke pronounces Apâmvatsa to comprise "the nebulous stars marked b 1, 2, 3" in Virgo. We can find, however, no such stars upon any map, or in any catalogue, accessible to us, and hence presume that Colebrooke must have been misled here by some error of the authority on which he relied. There is, on the other hand, a star, ϑ Virginis (4), situated directly between Spica and δ, and at such a distance from each as shows almost beyond question that it is the star intended:

Apâmvatsa . . . . 178° 48′ . . . . 2° 45′ N.
ϑ Virginis . . . . 178° 12′ . . . . 1° 45′ N.

It is not less difficult in this than in the former case to account for the selection of these stars, among the hundreds equalling or excelling them in brilliancy, as objects of special attention to the astronomical observers of ancient India. Perhaps we have here only the scattered and disconnected fragments of a more complete and shapely system of stellar astronomy, which flourished in India before the scientific reconstruction of the Hindu astronomy transferred the field of labor of the astronomer from the skies to his text-books and his tables of calculation.

The annexed table gives a comparative view of the positions of the seven stars spoken of in this and a preceding passage (vv. 10–12) as defined by our text and as determined by modern observers:

Positions of certain Fixed Stars.

Name.	Hindu position:				True position:		Star compared.
	pol. long.	pol. lat.	long.	lat.	long.	lat.	
	° ′	° ′	° ′	° ′	° ′	° ′	
Agastya,	90 0	80 0 S.	90 0	80 0 S.	85 4	75 50 S.	α Argûs, Canopus.
Mṛgavyâdha,	80 0	40 0 S.	76 23	39 52 S.	84 7	39 32 S.	α Canis Maj., Sirius.
Agni,	52 0	8 0 N.	54 5	7 44 N.	62 32	5 22 N.	β Tauri.
Brahmahṛdaya,	52 0	30 0 N.	60 29	28 53 N.	61 50	22 52 N.	α Aurigæ, Capella.
Prajâpati,	57 0	38 0 N	67 11	36 49 N.	69 54	30 49 N.	δ Aurigæ.
Apâmvatsa,	180 0	3 0 N.	178 48	2 45 N.	178 12	1 45 N.	ϑ Virginis.
Âpas,	180 0	9 0 N.	176 23	8 15 N.	171 28	8 38 N.	δ Virginis.

The gross errors in the determinations of position of these stars give us a yet lower idea of the character of Hindu observations than we derived from our examination of the junction-stars of the asterisms.

The essay of Colebrooke in the ninth volume of the Asiatic Researches, to which we have already so often referred, gives farther information of much interest respecting such matters connected with the Hindu astronomy of the fixed stars as are passed without notice in our treatise. He states the rules laid down by different authorities for calculating the time of heliacal rising of Agastya, or Canopus, upon which depends the performance of certain religious ceremonies. He also presents a view of the Hindu doctrine of the Seven Sages, or *ṛshis*, by which name are known the bright stars in Ursa Major forming the well-known constellation of the Wain, or Dipper. To these stars the ancient astronomers of India, and many of the modern upon their authority, have attributed an independent motion about the pole of the heavens, at the rate of 8′ yearly, or of a complete revolution in 2700 years. The Sûrya-Siddhânta alludes in a later passage (xiii. 9) to the Seven Sages, but it evidently is to be understood as rejecting the theory of their proper motion, which is also ignored by the Siddhânta-Çiromaṇi. That so absurd a dogma should have originated and gained a general currency in India, and that it should still maintain itself in many of the astronomical text-books, is, however, too striking and significant a circumstance to be left out of sight in estimating the character of the ancient and native Hindu astronomy.

CHAPTER IX.

OF HELIACAL RISINGS AND SETTINGS.

CONTENTS:—1, subject of the chapter; 2–3, under what circumstances, and at which horizon, the planets rise and set heliacally; 4–5, method of calculating their distances in oblique ascension from the sun; 6–9, distances from the sun at which they disappear and re-appear; 10–11, how to find the time of heliacal setting or rising, past or to come; 12–15, distances from the sun at which the asterisms and fixed stars disappear and re-appear; 16–17, mode of determining their times of rising and setting; 18, what asterisms and stars never set heliacally.

1. Now is set forth the knowledge of the risings (*udaya*) and settings (*astamaya*) of the heavenly bodies of inferior brilliancy, whose orbs are overwhelmed by the rays of the sun.

The terms used for the heliacal settings and risings of the heavenly bodies, or their disappearance in the sun's neighborhood and their return to visibility, are precisely the same with those employed to denote their rising (*udaya*) and setting (*asta*, *astamaya*, *astamana*) above and below the horizon. The title of the chapter, *udayâstâdhikâra*, is literally translated in our heading.

2. Jupiter, Mars, and Saturn, when their longitude is greater than that of the sun, go to their setting in the west; when it is less, to their rising in the east: so likewise Venus and Mercury, when retrograding.

3. The moon, Mercury, and Venus, having a swifter motion, go to their setting in the east when of less longitude than the sun; when of greater, to their rising in the west.

These specifications are of obvious meaning and evident correctness. The planets which have a slower motion than the sun, and so are overtaken by him, make their last appearance in the west, after sunset, and emerge again into visibility in the east, before sunrise: of those which move more rapidly than the sun, the contrary is true: Venus and Mercury belong to either class, according as their apparent motion is retrograde or direct.

4. Calculate the longitudes of the sun and of the planet—in the west, for the time of sunset; in the east, for that of sunrise—and then make also the calculation of apparent longitude (*dṛkkarman*) of the planet.

5. Then the ascensional equivalent, in respirations, of the interval between the two (*lagnântaraprâṇâs*) will give, when divided by sixty, the degrees of time (*kâlânçâs*); or, in the west, the ascensional equivalent, in respirations, of the interval between the two when increased each by six signs.

Whether a planet will or will not be visible in the west after sunset, or in the east before sunrise, is in this treatise made to depend solely upon the interval of time by which its setting follows, or its rising precedes, that of the sun, or upon its distance from the sun in oblique ascension; to the neglect of those other circumstances—as the declination of the two bodies, and the distance and direction of the planet from the ecliptic—which variously modify the limit of visibility as thus defined. The ascertainment of the distance in oblique ascension, then, is the object of the rules given in these verses. In explaining the method of the process, we will consider first the case of a calculation made for the eastern horizon. The time of sunrise having been determined, the true longitudes and rates of motion of the sun and the planet in question are found for that moment, as also the latitude of the planet. Owing to the latter's removal in latitude from the ecliptic, it will not pass the horizon at the same moment with the point of the ecliptic which determines its longitude, and the point with which it does actually rise must be found by a separate process. This is accomplished by calculating the apparent longitude of the planet, according to the method taught in the seventh chapter. There is nothing in the language of the text which indicates that the calculation is not to be made in full, as there prescribed, and for the given moment of sunrise: as so conducted, however, it would evidently yield an erroneous result; for, the planet being above the horizon, the point of the ecliptic to which it is then referred by a circle through the north and south points of the horizon is not the one to which it was referred by the horizon itself at the moment of its own rising. The commentary removes this difficulty, by specifying that the *akshadṛkkarman*, or that part of the process which gives the correction for latitude, is to be performed "only as taught in the first half-verse"—that is, according to the former part of vii. 8, which contains the rule for determining the amount of the correction at the horizon—omitting the after process, by which its value is made to correspond to the altitude of the planet at the given time. Having thus ascertained the points of the ecliptic which rise with the sun and with the planet respectively, the corresponding equatorial interval, or the distance of the planets in oblique ascension, is found by a rule already given (iii. 50). The result is expressed in respirations of sidereal time, which are equivalent to minutes of the equator (see above, i. 11–12); they are reduced to degrees by dividing by sixty: and the degrees thus found receive the technical name of "time-degrees" (*kâlânçâs, kâlabhâgâs*); they are also called below "degrees of setting" (*astânçâs*), and "degrees of visibility" (*dṛçyânçâs*).

If the planet for which the calculation is made has greater longitude than the sun, the process, being adapted to the time of sunset, and to the western horizon, requires a slight modification, owing to the fact that the equivalents of the signs in oblique ascension (iii. 42–45) are given only as measured at the eastern horizon. Since 180 degrees of the ecliptic are always above the horizon, any given point of the ecliptic will set at the same moment that another 180° distant from it rises; by adding, then, six signs to the calculated positions of the sun and the planet, and ascertaining, by iii. 50, the ascensional difference of the two points so found, the interval between the setting of the sun and that of the planet will be determined.

Before going on to explain how, from the result thus obtained, the time of the planet's disappearance or re-appearance may be derived, the text defines the distances from the sun, in oblique ascension or "degrees of time," at which each planet is visible.

6. The degrees of setting (*astânçâs*) are, for Jupiter, eleven; for Saturn, fifteen; for Mars, moreover, they are seventeen:

7. Of Venus, the setting in the west and the rising in the east take place, by reason of her greatness, at eight degrees; the setting in the east and the rising in the west occur, owing to her inferior size, at ten degrees:

8. So also Mercury makes his setting and rising at a distance from the sun of twelve or fourteen degrees, according as he is retrograding or rapidly advancing.

9. At distances, in degrees of time (*kâlabhâgâs*), greater than these, the planets become visible to men; at less distances they become invisible, their forms being swallowed up (*grasta*) by the brightness of the sun.

The moon, it will be noticed, is omitted here; her heliacal rising and setting are treated of at the beginning of the next following chapter.

In the case of Mercury and Venus, the limit of visibility is at a greater or less distance from the sun according as the planet is approaching its inferior or superior conjunction, the diminution of the illuminated portion of the disk being more than compensated by the enlargement of the disk itself when seen so much nearer to the earth.

Ptolemy treats, in the last three chapters (xiii. 7–9) of his work, of the disappearance and reappearance of the planets in the neighborhood of the sun, and defines the limits of visibility of each planet when in the sign Cancer, or where the equator and ecliptic are nearly parallel. His limits are considerably different from those defined in our text, being, for Saturn, 14°; for Jupiter, 12° 45′; for Mars, 14° 30′; for Venus and Mercury, in the west, 5° 40′ and 11° 30′ respectively.

10. The difference, in minutes, between the numbers thus stated and the planet's degrees of time (*kâlânçâs*), when divided by the difference of daily motions—or, if the planet be retrograding, by the sum of daily motions—gives a result which is the time, in days etc.

11. The daily motions, multiplied by the corresponding ascensional equivalents (*tallagnâsavas*), and divided by eighteen hundred, give the daily motions in time (*kâlagati*); by means of these is found the distance, in days etc., of the time past or to come.

Of these two verses, the second prescribes so essential a modification of the process taught in the first, that their arrangement might have been more properly reversed. If we have ascertained, by the previous rules, the distance of a planet in oblique ascension from the sun, and if we know the distance in oblique ascension at which it will disappear or re-appear, the interval between the given moment and that at which disappearance or re-appearance will take place may be readily found by dividing by the rate of approach or separation of the two bodies the difference between their actual distance and that of apparition and disparition: but the divisor must, of course, be the rate of approach in oblique ascension, and not in longitude. The former is derived from the latter by the following proportion: as a sign of the ecliptic, or 1800′, is to its equivalent in oblique ascension, as found by iii. 42–45, so is the arc of the ecliptic traversed by each planet in a day to the equatorial equivalent of that arc. The daily rates of motion in oblique ascension thus ascertained are styled the "time-motions" (*kâlagati*), as being commensurate with the "time-degrees" (*kâlânçâs*).

12. Svâtî, Agastya, Mṛgavyâdha, Citrâ, Jyeshṭhâ, Punarvasu, Abhijit, and Brahmahṛdaya rise and set at thirteen degrees.

13. Hasta, Çravana, the Phalgunîs, Çravishṭhâ, Rohiṇî, and Maghâ become visible at fourteen degrees; also Viçâkhâ and Açvinî.

14. Kṛttikâ, Anurâdhâ (*mâitra*), and Mûla, and likewise Âçleshâ and Ârdrâ (*râudrarksha*), are seen at fifteen degrees; so, too, the pair of Ashâḍhâs.

15. Bharaṇî, Pushya, and Mṛgaçîrsha, owing to their faintness, are seen at twenty-one degrees; the rest of the asterisms become visible and invisible at seventeen degrees.

These are specifications of the distances from the sun in oblique ascension (*kâlânçâs*) at which the asterisms, and those other of the fixed stars whose positions were defined in the preceding chapter, make their heliacal risings and settings. The asterisms we are doubtless to regard as represented by their junction-stars (*yogatârâ*). The classification here made of the stars in question, according to their comparative magnitude and brilliancy, is in many points a very strange and unaccountable one, and by no means calculated to give us a high idea of the intelligence and care of those by whom it was drawn up. The first class, comprising such as are visible at a distance of 13° from the sun, is, indeed, almost wholly composed of stars of the first magnitude; one only, Punarvasu (β Geminorum), being of the first to second, and having for its fellow one of the first (α Geminorum). But the second class, that of the stars visible at 14°, also contains four which are of the first magnitude, or the first to second; namely, Aldebaran (Rohiṇî), Regulus (Maghâ), Deneb or β Leonis (Uttara-Phalgunî), and Atair or α Aquilæ (Çravana); and, along with these, one of the second to third magnitude, δ Leonis (Pûrva-Phalgunî), three of the third, and one, ι Libræ (Viçâkhâ), of the fourth. In this last case, however, it might be possible to regard α Libræ, of the second magnitude, as the star which is made to determine the visibility of the asterism. Among the stars of the third class, again, which are visible at 15°, is one, α Orionis (Ârdrâ), which, though a variable star, does not fall below the first to second magnitude; while with it are found ranked six stars of the third magnitude, or of the third to fourth. The class of those which are visible at 17°, and which are left unspecified, contains two stars of the fourth magnitude, but also two of the second, one of which, α Andromedæ or γ Pegasi (Uttara-Bhâdrapadâ), is mentioned below (v. 18) among those which are never obscured by the too near approach of the sun. The stars forming the class which are not to be seen within 21° of the sun are all of the fourth magnitude, but they are no less distinctly visible than two of those in the preceding class; and indeed, Bharaṇî is palpably more so, since it contains a star of the third magnitude, which is perhaps (see above) to be regarded as its junction-star. Since Agni, Brahma, Apâmvatsa, and Âpas are not specially mentioned, it is to be assumed that they all belong in the class of those visible at 17°, and they are so treated by the commentator: the first of them (β Tauri) is a star of the second magnitude; for the rest, see the last note to the preceding chapter.

Some of the apparent anomalies of this classification are mitigated or removed by making due allowance for the various circumstances by which, apart from its absolute brilliancy, the visibility of a star in the sun's neighborhood is favored or the contrary—such as its distance and direction from the equator and ecliptic, and the part of the ecliptic in which the sun is situated during its disappearance. Many of them, however, do not admit of such explanation, and we cannot avoid regarding the whole scheme of classification as one not founded on careful and long-continued observation, but hastily and roughly drawn up in the beginning, and perhaps corrupted later by unintelligent imitators and copyists.

16. The degrees of visibility (*dṛçyânçâs*), if multiplied by eighteen hundred and divided by the corresponding ascensional equivalent (*udayâsavas*), give, as a result, the corresponding degrees on the ecliptic (*kshetrânçâs*); by means of them, likewise, the time of visibility and of invisibility may be ascertained.

This verse belongs, in the natural order of sequence, not after the passage next preceding, with which it has no special connection, but after verse 11. Instead of reducing, as taught in that verse, the motions upon the ecliptic to motions in oblique ascension, the "degrees of time" (*kâlânçâs*) may themselves be reduced to their equivalent upon the corresponding part of the ecliptic, and then the time of disappearance or of re-appearance calculated as before, using as a divisor the sum or difference of daily motions along the ecliptic. The proportion by which the reduction is made is the converse of that before given; namely, as the ascensional equivalent of the sign in which are the sun and the planet is to that sign itself, or 1800′, so are the "degrees of visibility" (*dṛçyânçâs*, or *kâlânçâs*) of the planet to the equivalent distance upon that part of the ecliptic in which it is then situated. The technical name given to the result of the proportion is *kshetrânçâs*: *kshetra* is literally "field, territory," and the meaning of the compound may be thus paraphrased: "the limit of visibility, in degrees, measured upon that part of the ecliptic which is, at the time, the territory occupied by the planets in question, or their proper sphere."

17. Their rising takes place in the east, and their setting in the west; the calculation of their apparent longitude (*dṛkkarman*)

is to be made according to previous rules; the ascertainment of the time, in days etc., is always by the daily motion of the sun alone.

This verse should follow immediately after verse 15, to which it attaches itself in the closest manner. The dislocation of arrangement in the latter part of this chapter is quite striking, and is calculated to suggest a suspicion of interpolations.

The directions given in the verse require no explanation: they are just such an adaptation of the processes already prescribed to the case of the fixed stars as that made in verse 14 of the last chapter. The commentary points out again that the calculation of the correction for latitude (*akshadṛkkarman*) is to be made only for the horizon, or as stated in the first half-verse of the rule.

18. Abhijit, Brahmahṛdaya, Svâtî, Çravaṇa (*vâishṇava*), Çravishṭhâ (*vâsava*), and Uttara-Bhâdrapadâ (*ahirbudhnya*), owing to their northern situation, are not extinguished by the sun's rays.

It may seem that it would have been a more orderly proceeding to omit the stars here mentioned from the specifications of verses 12–15 above; but there is, at least, no inconsistency or inaccuracy in the double statement of the text, since some of the stars may never attain that distance in oblique ascension from the sun which is there pointed out as their limit of visibility. We have not thought it worth the trouble to go through with the calculations, and ascertain whether, according to the data and methods of this treatise, these six stars, and these alone, of those which the treatise notices, would never become invisible at Ujjayinî. It is evident, however, as has already been noticed above (viii. 20–21), that the star called Brahma or Prajâpati (δ Aurigæ) is not here taken into account, since it is 8° north of Brahmahṛdaya, and consequently can not become invisible where the latter does not.

CHAPTER X.

OF THE MOON'S RISING AND SETTING, AND OF THE ELEVATION OF HER CUSPS.

CONTENTS:—1, of the heliacal rising and setting of the moon; 2–5, how to find the interval from sunset to the setting or rising of the moon; 6–8, method of determining the moon's relative altitude and distance from the sun at sunset; 9, to ascertain the measure of the illuminated part of her disk; 10–14, method of delineating the moon's appearance at sunset; 15, how to make the same calculation and delineation for sunrise.

1. The calculation of the heliacal rising (*udaya*) and setting (*asta*) of the moon, too, is to be made by the rules already given. At twelve degrees' distance from the sun she becomes visible in the west, or invisible in the east.

In determining the time of the moon's disappearance in the neighborhood of the sun, or of her emergence into visibility again beyond the sphere of his rays, no new rules are required; the same methods being employed as were made use of in ascertaining the time of heliacal setting and rising of the other planets: they were stated in the preceding chapter. The definition of the moon's limit of visibility would have been equally in order in the other chapter, but is deferred to this in order that the several processes in which the moon is concerned may be brought together. The title of the chapter, *çrngonnatyadhikâra*, "chapter of the elevation of the moon's cusps" (*çrnga*, literally "horn"), properly applies only to that part of it which follows the fifth verse.

The degrees spoken of in this verse are, of course, "degrees of time" (*kâlânçâs*), or in oblique ascension.

2. Add six signs to the longitudes of the sun and moon respectively, and find, as in former processes, the ascensional equivalent, in respirations, of their interval (*lagnântarâsavas*): if the sun and moon be in the same sign, ascertain their interval in minutes.

3. Multiply the daily motions of the sun and moon by the result, in nâdîs, and divide by sixty; add to the longitude of each the correction for its motion, thus found, and find anew their interval, in respirations;

4. And so on, until the interval, in respirations, of the sun and moon is fixed: by so many respirations does the moon, in the light half-month (*çukla*), go to her setting after the sun.

5. Add half a revolution to the sun's longitude, and calculate the corresponding interval, in respirations: by so many respirations does the moon, in the dark half-month (*krshnapaksha*), come to her rising after sunset.

The question here sought to be solved is, how long after sunset upon any given day will take place the setting of the moon in the crescent half-month, or from new to full moon, and the rising of the moon in the waning half-month, or from full to new moon. The general process is the same with that taught in the last chapter, for obtaining a like result as regards the other planets or fixed stars: we ascertain, by the rules of the seventh chapter—applying the correction for the latitude according to its value at the horizon, as determined by the first part of vii. 8—the point of the ecliptic which sets with the moon; and then the distance in oblique ascension between this and the point at which the sun set will measure the required interval of time. An additional correction, however, needs to be applied to the result of this process in the case of the moon, owing to her rapid motion, and her consequent perceptible change of place between the time of sunset and that of her own setting or rising: this is done by calculating the amount of her motion during the interval as first determined, and adding its equivalent in oblique ascension to that interval; then calculating her motion anew for the increased interval and adding its ascensional equivalent—and so on, until the desired degree of accuracy is attained.

The process thus explained, however, is not precisely that which is prescribed in the text. We are there directed to calculate the amount of motion both of the sun and moon during the interval between the setting of the sun and that of the moon, and, having applied them to the longitudes of the two bodies, to take the ascensional equivalent of the distance between them in longitude, as thus doubly corrected, for the precise time of the setting of the moon after sunset. In one point of view this is false and absurd; for when the sun has once passed the horizon, the interval to the setting of the moon will be affected only by her motion, and not at all by his. In another light, the process does not lack reason: the allowance for the sun's motion is equivalent to a reduction of the interval from sidereal (*nâkshatra*) time to civil, or true solar (*sâvana*) time, or from respirations which are thirty-six-hundreths of the earth's revolution on its axis to such as are like parts of the time from actual sunrise to actual sunrise. But such a mode of measuring time is unknown elsewhere in this treatise, which defines (i. 11–12) and employs sidereal time alone, adding (ii. 59) to the sixty nâḍîs which constitute a sidereal day so much sidereal time as is needed to make out the length of a day that is reckoned by any other method. It seems necessary, then, either to suppose a notable blunder in this passage, or to recognize in it such a departure from the usual methods of the treatise as would show it to be an interpolation. Probably the latter is the alternative to be chosen: it is, at any rate, that which the commentator prefers: he pronounces the two verses beginning with the second half of verse 2, and ending at the middle of verse 4, to be spurious, and the true text of the Siddhânta to comprise only the first half of verse 2 and the second of verse 4; these would form together a verse closely analogous in its method and expression with verse 5, which teaches the like process for moon-rise, in the waning half-month. Fortified by the authority of the commentator, we are justified in assuming that the Sûrya-Siddhânta originally neglected, in its process for calculating the time of the moon's setting, her motion during the interval between that time and sunset, and that the omission was later supplied by another hand, from some other treatise, which reckoned by solar time instead of sidereal. This does not, however, explain and account for the second half of the second verse; which, if it has any meaning at all, different from that conveyed in the former part of the same verse, seems to signify that when the sun and moon are so near one another as to be in the same sign, the discordance between distances on the ecliptic and their equivalents upon the equator may be neglected, and the difference of longitude in minutes taken for the interval of time in respirations.

If the time is between new and full moon, the object of the process is to obtain the interval from sunset to the setting of the moon; as both take place at the western horizon, the two planets are transferred to the eastern horizon, in order to the measurement of their distance in ascension: if, on the other hand, the moon has passed her full, the time of moonrise is sought; here the sun alone is transferred, by the addition of 180° to his longitude, to the eastern horizon, as taught in verse 5. The equation to be applied to the longitude of both planets is found by the familiar proportion—as sixty nâḍis are to the given interval in nâḍis, so is the true daily motion of the planet to its actual motion during that interval.

6. Of the declinations of the sun and moon, if their direction be the same, take the difference; in the contrary case, take the sum: the corresponding sine is to be regarded as south or north, according to the direction of the moon from the sun.

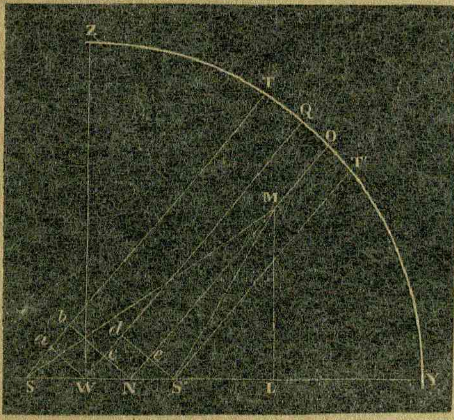
7. Multiply this by the hypothenuse of the moon's mid-day shadow, and, when it is north, subtract it from the sine of latitude (*aksha*) multiplied by twelve; when it is south, add it to the same.

8. The result, divided by the sine of co-latitude (*lamba*), gives the base (*bhuja*), in its own direction; the gnomon is the perpendicular (*koṭi*); the square root of the sum of their squares is the hypothenuse.

In explaining the method of this process, we shall follow the guidance of the commentator, pointing out afterwards wherein he varies from the strict letter of the text: for illustration we refer to the accompanying figure (Fig. 32).

The figure represents the south-western quarter of the visible sphere, seen as projected upon the plane of the meridian; Z being the zenith, Y the south point, W Y the intersection of the horizontal and meridian planes, and W the projection of the west point. Let Z Q equal the latitude of the place of observation, and let Q T and Q O be the declinations of the sun and moon respectively, at the given time: then W Q, S T, and N O will be the projections of the equator and of the diurnal circles of the sun and moon. Suppose, now, the sun to be upon the horizon, at S, and the moon to have a certain altitude, being at M: draw from M the perpendicular to the plane of the horizon M L, and join M S: it is required to know the relation to one another of the three sides of the triangle S L M, in order to the delineation of the moon's appearance when at M, or at the moment of sunset.

Fig. 32.



Now M L is evidently the sine of the moon's altitude at the given time, which may be found by methods already more than once described and illustrated. And S L is composed of the two parts S N and N L, of which the former depends upon the distance of the moon in declination from the sun, and the latter upon the moon's altitude. But S N is one of the sides of a right-angled triangle, in which the angle N S *b* is equal to the observer's co-latitude, and N *b* to the sum of the sine of declination of the sun, *c b* or W *a*, and that of the moon, N *c*. Hence

$$\sin b\,S\,N : b\,N :: R : S\,N$$

or $$\text{sin co-lat.} : \text{sum of sines of decl.} :: R : S\,N$$

and $$S\,N = (R \times \text{sum of sines of decl.}) \div \text{sin co-lat.}$$

In like manner, since, in the triangle M N L, the angles at M and N are respectively equal to the observer's latitude and co-latitude,

$$\sin M\,N\,L : \sin L\,M\,N :: M\,L : N\,L$$

or $$\text{sin co-lat.} : \text{sin. lat.} :: \text{sin alt.} : N\,L$$

and $$N\,L = (\text{sin alt.} \times \text{sin lat.}) \div \text{sin co-lat.}$$

We have thus found the values of M L and the two parts of S L in terms of the general sphere, or of a circle whose radius is tabular radius: it is desired farther to reduce them to terms of a circle in which M L shall equal the gnomon, or twelve digits. And since the gnomon is equal to the sine of altitude in a circle of which the hypothenuse of the corresponding shadow is radius (compare above, iii. 25–27 etc.), this reduction may be effected by multiplying the quantities in question by the hypothenuse of the shadow and dividing by radius. That is to say, representing the reduced values of S N and N L by $s\,n$ and $n\,l$ respectively,

$$R : \text{hyp. shad.} :: M\,L : \text{gnom.}$$
$$R : \text{hyp. shad.} :: S\,N : s\,n$$
$$R : \text{hyp. shad.} :: N\,L : n\,l$$

Substituting, now, in the second and third of these proportions the values of S N and N L found for them above, and substituting also in the third the value of the hypothenuse of the shadow derived from the first, we have

$$R : \text{hyp. shad.} :: \frac{R \times \text{sum sin decl.}}{\text{sin co-lat.}} : sn, \text{ and } R : \frac{R \times \text{gnom.}}{\text{sin alt.}} :: \frac{\text{sin alt.} \times \text{sin lat.}}{\text{sin co-lat.}} : nl$$

which reduce to

$$sn = \frac{\text{hyp. shad.} \times \text{sum sin decl.}}{\text{sin co-lat.}}, \text{ and } nl = \frac{\text{sin lat.} \times \text{gnom.}}{\text{sin co-lat.}}$$

Hence, if the perpendicular M L be assumed of the constant value of the gnomon, or twelve digits, we have

$$SL = \frac{(\text{hyp. shad.} \times \text{sum sin decl.}) + (\text{sin lat.} \times \text{gnom.})}{\text{sin co-lat.}}$$

In the case thus far considered the sun and moon have been supposed upon opposite sides of the equator. If they are upon the same side, the sun setting at S′, or if their sines of declination, S′*d* and N *c*, are of the same direction, the value of S′N, the corresponding part of the base S′L, will be found by treating in the same manner as before the difference of the sines, S′*e*, instead of their sum. In this case, too, the value of S′*e* being north, S′N will have to be subtracted from N L to give the base S′L. Other positions of the two luminaries with respect to one another are supposable, but those which we have taken are sufficient to illustrate all the conditions of the problem, and the method of its solution.

It is evident that, in two points, the process as thus explained by the commentator is discordant with that which the text prescribes. The latter, in the first place, tells us to take, not the sum or difference of the sines of declination, but the sine of the sum or difference of declinations, as the side *b* N of the triangle S N *b*. This seems to be a mere inaccuracy on the part of the text, the difference between the two quantities, which could never be of any great amount, being neglected : it is, however, very hard to see why the less accurate of the two valuations of the quantity in question should have been selected by the text ; for it is, if anything, rather less easy of determination than the other. The other discordance is one of much more magnitude and importance : the text speaks of the "hypothenuse of the moon's mid-day shadow" (*madhyâhnenduprabhâkarṇa*), for which the commentary substitutes that of the shadow cast by the moon at the given moment of sunset. The commentator attempts to reconcile the discrepancy by saying that the text means here the moon's shadow as calculated after the method of a noon-shadow ; or again, that the time of sunset is, in effect, the middle of the day, since the civil day is reckoned from sunrise to sunrise : but neither of these explanations can be regarded as satisfactory. The commentator farther urges in support of his understanding of the term, that we are expressly taught above (vii. 11) that the calculation of apparent longitude (*dṛkkarman*) is to be made in the process for finding the elevation of the moon's cusps; while, if the hypothenuse of the moon's meridian-shadow be the one found, there arises no occasion for making that calculation. It seems clear that, unless the commentator's understanding of the true scope and method of the whole process be erroneous, the substitution which he makes must necessarily be admitted. This is a point to which we shall recur later.

9. The number of minutes in the longitude of the moon diminished by that of the sun gives, when divided by nine hundred, her illuminated part (*çukla*) : this, multiplied by the number of digits (*angula*) of the moon's disk, and divided by twelve, gives the same corrected (*sphuṭa*).

The rule laid down in this verse, for determining the measure of the illuminated part of the moon, applies only to the time between new moon and full moon, when the moon is less than 180° from the sun : when her excess of longitude is more than 180°, the rule is to be applied as stated below, in verse 15. As the whole diameter of the moon is illuminated when she is half a revolution from the sun, one half her diameter at a quarter of a revolution's distance, and no part of it at the time of conjunction, it is assumed that the illuminated portion of her diameter will vary as the part of 180° by which she is distant from the sun ; and hence that, assuming the measure of the diameter of her disk to be twelve digits, the number of digits illuminated may be found by the following proportion : as half a revolution, or 10,800′, is to twelve digits, so is the moon's distance from the sun in minutes to the corresponding part of the diameter illuminated : the substitution, in the first ratio, of 900 : 1 for 10,800 : 12, gives the rule as stated in the text. Here, it will be noticed, we have for the first and only time the Greek method of measuring the moon's diameter, by equal twelfths, or digits : from this scale a farther reduction is made to the proper Hindu scale, as determined by the methods of the fourth chapter (see above, iv. 2–3, 26), by another proportion: as twelve is to the true diameter in digits, so is the result already found to the true measure of the part of the diameter illuminated.

It is not to be wondered at that the Hindus did not recognize the ellipticity of the line forming the inner boundary of the moon's illuminated part: it is more strange that they ignored the obvious fact that, while the illuminated portion of the moon's spherical surface visible from the earth varies very nearly as her distance from the sun, the apparent breadth of the bright part of her disk, in which that surface is seen projected, must vary rather as the versed sine of her distance.

10. Fix a point, calling it the sun: from that lay off the base, in its own proper direction; then the perpendicular, toward the west; and also the hypothenuse, passing through the extremity of the perpendicular and the central point.

11. From the point of intersection of the perpendicular and the hypothenuse describe the moon's disk, according to its dimensions at the given time. Then, by means of the hypothenuse, first make a determination of directions;

12. And lay off upon the hypothenuse, from the point of its intersection with the disk, in an inward direction, the measure of the illuminated part: between the limit of the illuminated part and the north and south points draw two fish-figures (*matsya*);

13. From the point of intersection of the lines passing through their midst describe an arc touching the three points: as the disk already drawn appears, such is the moon upon that day.

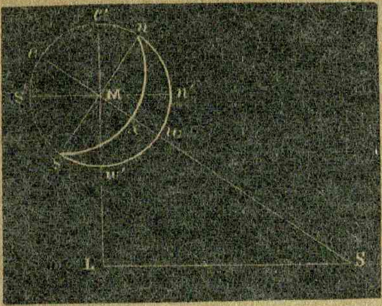
14. After making a determination of directions by means of the perpendicular, point out the elevated (*unnata*) cusp at the extremity of the cross-line: having made the perpendicular (*koṭi*) to be erect (*unnata*), that is the appearance of the moon.

15. In the dark half-month subtract the longitude of the sun increased by six signs from that of the moon, and calculate, in the same manner as before, her dark part. In this case lay off the base in a reverse direction, and the circle of the moon on the west.

Having made the calculations prescribed in the preceding passages, we are now to project their results, and to exhibit a representation of the moon as she will appear at the given time. The annexed figure (Fig. 33) will illustrate the method of the projection.

We first fix upon a point, as S, which shall represent the position of the sun's centre upon the western horizon at the moment of sunset, and we determine, in the manner taught at the beginning of the third chapter, the lines of cardinal direction of which it is the centre. From this point we then lay off the base (*bhuja*) S L, according to its value in digits as ascertained by the previous process, and northward or southward, according to its true direction as determined by the same process. From L, its extremity, is laid off the perpendicular (*koṭi*), which has the fixed value of twelve digits. This, being a line perpendicular to the plane of the horizon, may be regarded as having no proper direction of its own upon the surface of projection: but the text directs us to lay it off westward from L, apparently in order that the observer, standing upon the eastern side of his base S L, and looking westward toward the setting sun, may have his figure duly before him. The western extremity of the perpendicular, M, represents the moon's place, and from that as a centre, and with a radius equal to the semi-diameter of the moon in digits, as ascertained by calculation for the given moment, a circle is described, representing the moon's disk. Next we are to prolong the hypothenuse, S M, to *e*, and to draw, by the usual means, the line *s n* at right angles to it: the directions upon the disk thus determined by the hypothenuse, as the text phrases it, are called by the commentary "moon-directions" (*candradiças*). The sun being at S, the illuminated half of the moon's circumference will be *s w n*, the cusps will be at *s* and *n*, and *w* will be the extremity of the diameter of greatest illumination. From *w*, then, lay off upon the hypothenuse an amount, *w x*, equal to the measure in digits of the illuminated part of the diameter, and through *s*, *x*, and *n* describe an arc of a circle, in the manner already more than once explained (see above, vi. 14–16); the crescent *s w n x* will represent the amount and direction of the moon's illuminated part at the given time. Now we once more make a determination of directions upon the disk according to the perpendicular L M; that is to say, we prolong L M to *e'*, and draw *s' n'* at right angles to it: the directions thus established are styled in the commentary "sun-directions" (*sûryadiças*), although without obvious propriety: they might rather be called "apparent directions," or "directions on the sphere," since *s' n'* should represent a line parallel with the horizon, and *w' e'* one perpendicular to it. The line *s' n'* is called in the text the "cross-line" (*tiryaksûtra*), and whichever of the moon's cusps is found upon that line is, we are told, to be regarded as the elevated (*unnata*) cusp, the other being the depressed one (*nata*). Whenever there is any base (*bhuja*), as S L, or whenever the moon and sun are not upon the same vertical line M L, there will take place, of course, a tilting of the moon's disk, by which one of her cusps will be raised higher above the horizon than the other; the relative value of the base to the perpendicular will determine the amount of the tilting, and of the deflection of the points of direction *n e s w* from *n' e' s' w'*; and the elevated cusp will always be that upon the same side of the perpendicular on which the base lies. What is meant by the latter half of verse 14 is not altogether clear. The commentator explains it in quite a different manner from that in which we have translated it: he understands *koti* as meaning in this instance "cusp," which signification it is by derivation well adapted to bear, and does actually receive, although not in any other passage of this treatise: and he explains the verb *krtvâ*, "having made," by *drshtvâ*, "having seen": the phrase would then read "beholding the elevated cusp." We cannot accept

Fig. 33.



this explanation as a plausible one: to us the meaning seems rather to be that whereas, in the projection, the perpendicular (*koṭi*) L M is drawn on a horizontal surface, we are, in judging of the projection as an actual representation of the moon's position, to conceive of that line as erected, set up perpendicularly.

We have thus far only supposed a case in which the calculations are made for the moment of sunset, the situation of the moon being in the western hemisphere of the heavens. In the text, however, there is nothing whatever to limit or determine the time of calculation, and it is evident that the process of finding the base and perpendicular will be precisely the same, if S (Fig. 32) be taken upon the eastern horizon, and the triangle S L M in the eastern hemisphere. The last verse supposes these to be the conditions of the problem, and lays down rules for determining in such a case the amount of illumination, and for drawing the projection. As regards the measure of the illuminated part, we are to follow the same general method as before, only substituting for the moon's distance in longitude from the sun her distance from the point of opposition, and regarding the result obtained as the measure of that part of the diameter which is obscured (*asita*, "black"); since, during the waning half-month, darkness grows gradually over the moon's face in the same manner as illumination had done during the crescent half-month. But why the base (*bhuja*) is now to be laid off in the opposite to its calculated direction, we find it very hard to see. The commentator says it is because all the conditions of the problem are reversed by our having to calculate and lay off the obscured, instead of the illuminated, part of the moon's disk: but the force of this reason is not apparent. The establishment in the projection of a point representing the position of the sun is, in effect, the one condition which sufficiently determines all the rest: if we are to make a projection corresponding to that drawn in illustration of the other case, we ought, it should seem, to draw the base in its true direction, and, stationing the observer upon the western side of it, looking eastward, to lay off the perpendicular away from him, toward the east; and then to proceed as before, only measuring the obscured part of the diameter from its remoter extremity, instead of from that next the sun. This latter direction is regarded by the commentator as actually conveyed in the final clause of verse 15: he interprets "the circle (*mandala*) of the moon" to mean the dark part of the moon's disk, or that which is to be pointed out as increasing during the waning half-month, and "on the west" to mean on the western side of the complete disk, which is the side now turned away from the sun. It seems to us exceedingly questionable whether the passage fairly admits of this interpretation, but we have no other explanation of it to offer—unless, indeed, it is to be looked upon as a virtual repetition of the former direction to lay off the perpendicular, which determines the position of the moon's disk, towards the west.

We must confess that we feel less satisfied with our comprehension of the scope and methods of this chapter than of any that precedes it. We are disappointed at finding the result arrived at one of so indefinite a character, and of so little significance. The whole laborious calculation seems to be made simply for the sake of delineating the appearance of the moon at a given moment, and pointing out which of her two horns has the greater altitude. No determination is made of the amount of angular deflection, upon which any consequences, meteorological, astrological, or of any other character, could be founded; nor is any hint given of the way in which the results of the process are to be turned to account. Moreover, while the object aimed at seems thus to be merely a projection, a time is selected at which the moon is not ordinarily visible, so that she can not be seen to exhibit an accordance with her delineated appearance! Once more, the whole process is an extremely faulty one: it is, in fact, only when the moon is herself at the horizon that her visible disk can be regarded as in the same plane with lines parallel with and perpendicular to the horizon, or that *e′ w′* and *n′ s′* (Fig. 33) represent actual directions upon her face: anywhere else, the relations of the moon's disk at M in the first figure (Fig. 32) and at M in the other figure (Fig. 33) are so different that the latter cannot fairly represent the former. It would seem, indeed, as if the moment of the moon's own setting or rising were the one for which such a calculation and projection as this would have most significance: at that time, the disappearance or appearance of one of her horns before the other would be such a phenomenon as might seem to a Hindu astronomer worth the trouble of delineating, as a decisive proof of the accuracy of his scientific knowledge. We have not found it possible, however, to make the rules of the text apply to such a case, and the commentary is explicit in its definition of the time of the calculation, as sunset or sunrise alone, to the exclusion of any other moment. But the discordance existing at more than one point in the chapter between the text and the commentary suggests the conjecture that the original design of the one and the traditional interpretation of it represented by the other may be at variance, and we are not without suspicions that the text may have been altered, so as not now fairly and accurately to represent any one consistent process. A better understanding of the general object of the calculation and the use made of its results, and an acquaintance with the solutions of the problem presented by other astronomical treatises, might throw additional light upon these points; but we are not able at present fully to avail ourselves of such assistance, nor is the importance of the subject such as to render incumbent upon us its fuller elucidation.

CHAPTER XI.

OF CERTAIN MALIGNANT ASPECTS OF THE SUN AND MOON.

Contents:—1–5, definition and description of the malignant aspects of the sun and moon, when of equal declination; 6–11, to find the longitude of the sun and moon when their declinations are equal; 12–13, to ascertain the corresponding time; 14–15, to determine the duration of the aspect, and the moment of its beginning and end; 16–18, its continuance and its influences; 19, when such an aspect may occur more than once, or not at all; 20, occurrence of the yoga of like name and character; 21, of unlucky points in the circle of asterisms; 22, caution as to these unlucky aspects and points; 23, introductory to the following chapters.

1. When the sun and moon are upon the same side of either solstice, and when, the sum of their longitudes being a circle, they are of equal declination, it is styled *vâidhṛta*.

2. When the moon and sun are upon opposite sides of either solstice, and their minutes of declination are the same, it is *vyatîpâta*, the sum of their longitudes being a half-circle.

3. Owing to the mingling of the nets of their equal rays, the fire arising from the wrathfulness of their gaze, being driven on by the provector (*pravaha*), is originated unto the calamity of mortals.

4. Since a fault (*pâta*) at this time often causes the destruction of mortals, it is known as *vyatîpâta*, or, by a difference of title, *vâidhṛti*.

5. Being black, of frightful shape, bloody-eyed, big-bellied, the source of misfortune to all, it is produced again and again.

Of all the chapters in the treatise, this is the one which has least interest and value. It is styled *pâtâdhikâra*, "chapter of the *pâtas*," and concerns itself with giving a description of the malignant character of the times when the sun and moon have equal declination, upon the same or opposite sides of the equator, and with laying down rules by which the time of occurrence of those malignant aspects may be calculated. The latter part alone properly falls within the province of an astronomical treatise like the present: the other would better have been left to works of a professedly astrological character. The term *pâta*, applied to the aspects in question, means literally "fall," and hence also either "fault, transgression," or "calamity." We have often met with it above, in the sense of "node of a planet's orbit"; as so used, it was probably first applied to the moon's nodes, because they were the points of danger in her revolution, near which the sun or herself was liable to fall into the jaws of Râhu (see above, iv. 6); and it was then transferred also, though without the same reason, to the nodes of the other planets. As it is employed in this chapter, we translate it simply "aspect." Why the time when the sun and moon are equally distant from the equator should be looked upon as so especially unfortunate is not easy to discover, notwithstanding the lucid explanation furnished in the third verse. For the "provector" (*pravaha*), the wind which carries the planets forward in their orbits, see above, ii. 3. When the equal declinations are of opposite direction, the aspect is denominated *vâidhṛta*, or *vâidhṛti*. This word is a secondary derivative from *vidhṛti*, "holding apart, withholding," or from *vidhṛta*: it has been noted above (under ii. 65) as the name of the last *yoga*; and its use here is not discordant with that, since the twenty-seventh yoga also occurs when the sum of the longitudes of the sun and moon is 360°. The title of the other aspect (*pâta*), which occurs when the sun and moon are equally removed from the equator upon the same side of it, is *vyatîpâta*, which may be rendered "very excessive sin or calamity." This, too, is the name of one of the yogas, but not of that one which occurs when the sum of longitudes of the sun and moon is 180°: the discordance gives occasion for the ex-

See Bouché-Leclercq p. 165

planation contained in verse 20, below. The specification of the text, that the aspects take place when the sum of longitudes equals a circle or a half-circle respectively, or when the two luminaries are equally distant from either solstice, or either equinox, is not to be understood as exact: this would be the case if the moon had no motion in latitude; but owing to that motion, the equality of declinations, which is the main thing, occurs at a time somewhat removed from that of equality of distance from the equinoxes: the latter is called in the commentary *madhyapâta*, "the mean occurrence of the aspect." The terms translated by us "upon the same and upon the opposite sides of either solstice" are *ekâyanagata* and *viparîtâyanagata*, literally "situated in the same and in contrary *ayanas*"; *ayana* being, as already pointed out (end of note to iii. 9–12), the name of the halves into which the ecliptic is divided by the solstices.

6. When the longitudes of the sun and moon, being increased by the degrees etc. found for the coincidence of the solstice with its observed place, are together nearly a circle or nearly a half-circle, calculate the corresponding declinations.

7. Then, if the declination of the moon, she being in an odd quadrant, is, when corrected by her latitude (*vikshepa*), greater than the declination of the sun, the aspect (*pâta*) is already past;

8. If less, it is still to come: in an even quadrant, the contrary is the case. If the moon's declination is to be subtracted from her latitude, the rules as to the quadrant are to be reversed.

As in other processes of a similar character (see above, iv. 7–8; vii. 2–6), we are supposed to have found by trial, for the starting-point of the present calculation, the midnight next preceding or following the occurrence of the aspect in question, and to have determined for that moment the longitudes and rates of motion of both bodies, and the moon's latitude. In finding the longitudes, we are to apply the correction for precession; this is the meaning of the expression in verse 6, *dṛktulyasâdhitânçâdi*, which may be literally translated "degrees etc. calculated for accordance with observed place"; the reference is to the similar expression for the precession contained in iii. 11. Next the declinations are to be found, and that of the moon as corrected for her latitude. And since, in the odd quadrants—that is to say, the first and third, counting from the actual vernal equinox—declination is increasing, while in the others it is decreasing, if the declination in an odd quadrant of the moon, the swifter moving body, is already greater than that of the sun, the time of equality of declination is evidently already past, and the converse. But if, on the other hand, the moon's declination (using that term in its Hindu sense) is so small, and her latitude so great, being of opposite directions, that her actual distance from the equator is measured by the excess of the latter above the former, and so is of direction contrary to that of her declination, then, as declination increases, distance from the equator diminishes, or the contrary, and the conditions as formerly stated are reversed throughout.

9. Multiply the sines of the two declinations by radius, and divide by the sine of greatest declination: the difference of the arcs corresponding to the results, or half that difference, is to be added to the moon's longitude when the aspect (*pâta*) is to come;

10. And is to be subtracted from the moon's longitude when the aspect is past. If the same quantity be multiplied by the sun's motion and divided by the moon's motion, the result is an equation, in minutes, which is to be applied to the sun's place, in the same direction as the other to the moon's.

11. So also is to be applied, in the contrary direction, a like equation to the place of the moon's node. This operation is to be repeated, until the declinations of the two bodies come to be the same.

By this process are ascertained the longitudes of the sun and moon at the time when their declinations are equal. Its method may be briefly explained as follows. At the midnight assumed as the starting-point of the whole calculation there is found to be a certain difference in the two declinations: we desire to determine how far the paths of the two luminaries must be traced forward or backward, in order that that difference may be removed; and this must be effected by means of a series of approximations. We commence our calculation with the moon, as being the body of more rapid motion. By a proportion the inverse of that upon which the rule for deriving the declination from the longitude (ii. 28) is founded, we ascertain at what longitude the moon would have the sun's actual declination, and at what longitude she would have her own actual declination, as corrected by her latitude: the difference between the two results is a measure of the amount of motion in longitude, forward or backward, by which she would gain or lose the difference of declination, if the sun remained stationary and her own latitude unchanged. Since, however, that is not the case, we are compelled to calculate the corresponding motion of the sun, and also the moon's latitude in her new position; and in order to the latter, we must correct the place of the node also for its retrograde motion during the interval. The motions of the sun and node are found by the following proportion: as the moon's daily motion is to that of the sun, or to that of the node, so is the correction applied to the moon's place to that which must be applied to the place of the sun, or to that of the node. A new set of positions in longitude having thus been found, the declinations are again to be calculated, and the same approximative process repeated—and so on, until the desired degree of accuracy is attained.

The text permits us to apply, as the correction for the place of the moon, either the whole or the half of the difference of longitude found as the result of the first proportion: it is unessential, of course, in a process of this tentative character, what amount we assume as that of the first correction, provided those which we apply to the places of the sun and node be made to correspond with it: and there may be cases in which we should be conducted more directly to the final result of the process by taking only half of the difference.

12. The aspect (*pâta*) is at the time of equality of declinations; if, then, the moon's longitude, as thus increased or diminished, be less than her longitude at midnight, the aspect is past; if greater, it is to come.

13. The minutes of interval between the moon's longitude as finally established and that at midnight give, when multiplied by sixty and divided by the moon's daily motion, the time of the aspect, in nâḍîs.

We had thus far found only the longitudes of the sun and moon at the time of equality of declination, and not that time itself: the latter is now derived from the former by this proportion: as the moon's daily motion is to a day, or sixty nâḍis, so is the difference between the moon's longitude at midnight and at the time of the aspect to the interval between the latter time and midnight.

14. Multiply the half-sum of the dimensions (*mâna*) of the sun and moon by sixty, and divide by the difference of their daily motions: the result is half the duration (*sthiti*), in nâḍîs etc.

15. The corrected (*sphuta*) time of the aspect (*pâta*) is the middle: if that be diminished by the half-duration, the result is the time of the commencement; if increased by the same, it is the time of the end.

16. The time intervening between the moments of the beginning and end is to be looked upon as exceedingly terrible, having the likeness of a consuming fire, forbidden for all works.

The continuance of the centres of the sun and moon at the point of equality of declination is, of course, only momentary; but the aspect and its malignant influences are to be regarded as lasting as long as there is virtual contact of the two disks at that point, or as long as a central eclipse of the sun would last if it took place there. Its half-duration, then, or the interval from its middle to its beginning or end respectively, is found by a proportion, as follows: if in a day, or sixty nâḍis, the two centres of the sun and moon become separated by a distance which is equal to the difference of their daily motions, in how many nâḍis will they become separated by a distance which is equal to the sum of their semi-diameters? or

diff. d. motions : 60 : : sum semi-diam. : half-duration

And if this amount be subtracted from and added to the time of equality of declination, the results will be the moments at which the aspect will begin and end respectively.

Such is the plain and obvious meaning of the text in this passage. The commentator, however, in accordance with his interpretation of the next following verse (see below), declares that the aspect actually lasts as long as any portion of the moon's disk has the same declination with any portion of that of the sun; and that, accordingly, it commences—the moon's declination being supposed to be increasing—whenever her remoter limb comes to have the same declination with the nearer limb of the sun, and ends when her nearer limb comes to have the same declination with the remoter limb of the sun—the contrary being the case when her declination is decreasing. He acknowledges that the text does not seem to teach this, but puts in the plea which is usual with him when excusing a palpable inaccuracy in the statements or processes of the treatise; namely, that the blessed author of the work, moved by pity for mankind, permitted here the substitution of difference of longitude for difference of declination, in view of the greater ease of its calculation, and the insignificance of the error involved. That error, however, is quite the reverse of insignificant; it is, indeed, so very gross and palpable that we cannot possibly suppose it to have been committed intentionally by the text; we regard it as the easier assumption that the conditions of the continuance of the aspect are differently estimated in the text and in the commentary, being by the former taken to be as we have stated them above, in our explanation of the process. The view of the matter taken by the commentator, it is true, is decidedly the more natural and plausible one: there seems no good reason why an aspect which depends upon equality of declination should be determined as to continuance by motion in longitude, or why the aspect should only occur at all when the two centres are equally distant from the equator; why, in short, there should not be partial aspects, like partial eclipses of the sun. If the doctrine of the commentary is a later development, or an independent form, of that which the text appears to represent, it is a naturally suggested one, and such as might have been expected to arise.

17. While any parts of the disks of the sun and moon have the same declination, so long is there a continuance of this aspect, causing the destruction of all works.

18. So, from a knowledge of the time of its occurrence, very great advantage is obtained, by means of bathing, giving, prayer, ancestral offerings, vows, oblations, and other like acts.

We have translated verse 17 in strict accordance with the interpretation of it presented in the commentary, although we must acknowledge that we do not see how that interpretation is to be reconciled with the actual form of the text. The term *ekâyanagata*, which the commentator renders "having equal declination," is the same with that which in the first verse signified "situated in the same *ayana*"; *mandala*, although it is sometimes used with the meaning "disk," here attributed to it by him, is the word employed in that same verse for a "circle," or "360°"; and *antara*, which he explains by *ekadeça*, "any part," never, so far as we know, is properly used in that sense, while it is of frequent occurrence elsewhere in this treatise with the meaning "interval." The natural rendering of the line would seem to be "when there is between the sun and moon the interval of a circle, situated in the same *ayana*." This, however, yields no useful meaning, since such a description could only apply to an actual conjunction of the sun and moon. We do not see how the difficulty is to be solved, unless it be allowed us, in view of the discordance already pointed out as existing between the plain meaning of the previous passage and that attributed to it by the commentator, to assume that the text has been tampered with in this verse, and made to furnish a different sense from that it originally had, partly by a forced interpretation, but partly also by such an alteration of its readings as disables it from yielding any other intelligible meaning.

19. When the equality of declinations of the sun and moon takes place in the neighborhood of the equator, the aspect may then again occur a second time: in the contrary case, it may fail to occur.

Near the equinox, where declination changes rapidly, the moon, as the swifter moving body, may come to have twice, in rapid succession, the same declination with the sun, and upon the opposite sides of the equator. Near the solstice, on the other hand, where the ecliptic and equator are nearly parallel, the moon—if she happens to be nearer the equator than the sun is, owing to her latitude—may pass the region in which the aspect would otherwise be liable to occur, without having had a declination equal in amount to that of the sun.

20. If the sum of the longitudes of the sun and moon, in minutes, on being divided by the portion (*bhoga*) of an asterism (*bha*), yields a quotient between sixteen and seventeen, there is another, a third, *vyatîpâta*.

This is simply a special application of the rule formerly given (ii. 65), for finding, for any given time, the current period named *yoga*. The seventeenth of the series, as is shown by the list there given, has the same name, *vyatîpâta*, with one of the aspects treated of in this chapter: judging from verse 22, below, it is also regarded as possessing a like portentous and malignant character.

21. Of the asterisms (*dhishṇya*) Âçleshâ (*sârpa*), Jyeshṭhâ (*âindra*), and Revatî (*paushṇya*), the last quarters are junctions of the asterisms (*bhasandhi*); the first quarter in the asterisms following these respectively is styled *gaṇḍânta*.

22. In all works, one must avoid the terrible trio of *vyatîpâtas*, as also the trio of *gaṇḍântas*, and this trio of junctions of asterisms.

The division of the ecliptic into twenty-sevenths, or asterisms, coincides with its division into twelfths, or signs, at the ends of the ninth, eighteenth, and twenty-seventh asterisms, which are also those of the fourth, eighth, and twelfth signs respectively. To this innocent circumstance it seems to be owing that those points, and the quarters of portions, or arcs of 200′, on either side of them, are regarded and stigmatized as unlucky and ominous. Hence the title *bhasandhi; sandhi* is literally "putting together, joint," and *bha* is, as has been noticed elsewhere (note to iii. 9–12), a name both of the asterisms and of the signs. In which of its various senses the word *gaṇḍa* is used in the compound *gaṇḍânta*, we do not know.

23. Thus hath been related that supreme, pure, excellent, mysterious, and grand system of the heavenly bodies: what else dost thou desire to know?

In this verse re-appears the personality of the revealer of the treatise, the incarnation of a portion of the sun, which has been lost sight of since near the beginning of the work (i. 7). The questions addressed to him, in answer to this appeal, by Maya, the recipient of the revelation, introduce the next chapter, which, with the two that follow it, contains the additional explanations and instructions vouchsafed in reply. The last three chapters confessedly constitute a separate portion of the work, which is here divided into a *pûrva khanḍa* and an *uttara khanḍa*, or a "former Part" and a "latter Part." It is by no means impossible that the whole second Part is an appendix to the text of the Siddhânta as originally constituted.

The title of the next following chapter is *bhûgolâdhyâya*, "chapter of the earth-globe": in the second part of the treatise the chapters are styled *adhyâya*, "lection," instead of, as hitherto, *adhikâra*, "heading."

CHAPTER XII.

COSMOGONY, GEOGRAPHY, DIMENSIONS OF THE CREATION.

CONTENTS:—1–9, inquiries; 10–28, development of the creative agencies, of the elements, and of the existing creation; 29–31, form and disposition of the stellar and planetary systems; 32–44, situation, form, structure, and divisions of the earth; 45–72, varying phenomena of night and day in different latitudes and zones; 73–77, revolutions of the stars and planets; 78–79, regents of the different divisions of time; 80–90, dimensions of the planetary, stellar, and ethereal orbits.

1. Then the demon Maya, prostrating himself with hands suppliantly joined before him who derived his being from the part of the Sun, and revering him with exceeding devotion, inquired as follows:

2. O blessed one! of what measure is the earth? of what form? how supported? how divided? and how are there in it seven interterranean (*pâtâla*) earths?

3. And how does the sun cause the varying distinction of day and night? how does he revolve about the earth, enlightening all creatures?

4. For what reason are the day and night of the gods and of the demons opposed to one another? or how does that take place by means of the sun's completion of his revolution?

5. Why does the day of the Fathers consist of a month, but that of mortals of sixty nâḍîs? for what reason is not this latter everywhere the case?

6. Whence is it that the regents of the days, years, months, and hours (*horâ*) are not the same? How does the circle of asterisms (*bhagaṇa*) revolve? what is the support of it with the planets?

7. The orbits of the planets and stars, uplifted from the earth one above another—what are their heights? what their intervals? what their dimensions? and what the order in which they are fixed?

8. Why are the rays of the sun hot in the summer, and not so in the winter? how far do his rays penetrate? How many modes of measuring time (*mâna*) are there? and how are they employed?

9. Resolve these my difficulties, O blessed one, creator of creatures! for there is not found besides thee another resolver, who beholdeth all things.

The proper answers to these inquiries commence at about the twenty-seventh verse of the chapter, the preceding philosophical history of the development of the existing creation being apparently volunteered by the revelator. All the questions then find their answers in this chapter, excepting that as to the methods of measuring time, which is disposed of in the fourteenth and concluding chapter. The subject of the thirteenth chapter also seems not to be contemplated in the laying out, in this passage, of the scheme of subjects to be treated of in the remainder of the treatise.

10. Having heard the words thus uttered with devotion by Maya, he then again promulgated this mysterious and supreme Book (*adhyâya*):

11. Listen with concentrated attention: I will proclaim the secret doctrine called the transcendental (*adhyâtma*): there is nothing which may not be bestowed on those who are exceedingly devoted to me.

12. Vâsudeva, the supreme principle of divinity (*brahman*), whose form is all that is (*tat*), the supreme Person (*purusha*), unmanifested, free from qualities, superior to the twenty-five principles, imperishable,

13. Contained within matter (*prakṛti*), divine, pervading everything, without and within, the attractor—he, having in the first place created the waters, deposited in them energy.

14. That became a golden egg, on all sides enveloped in darkness: in it first became manifested the unrestrained, the everlasting one.

15. He in the scripture (*chandas*) is denominated the golden-wombed (*hiraṇyagarbha*), the blessed; as being the first (*âdi*) existence, he is called Âditya; as being generator, the sun.

16. This sun, likewise named Savitar, the supreme source of light (*jyotis*) upon the border of darkness—he revolves, bringing beings into being, the creator of creatures.

17. He is extolled as natural illuminator, destroyer of darkness, great. The Hymns (*ṛcas*) are his disk, the Songs (*sâmâni*) his beams, the Liturgy (*yajûnshi*) his form.

18. He, the blessed one, is composed of the trio of sacred scriptures, the soul of time, the producer of time, mighty, the soul of the universe, all-penetrating, subtle: in him is the universe established.

19. Having made for his chariot, which is composed of the universe, a wheel consisting of the year, and having yoked the seven metres as his steeds, he revolves continually.

20. Three quarters are immortal, secret; this one quarter hath become manifest. In order to the production of the animated creation, he, the mighty one, produced Brahma, the principle of consciousness (*ahânkara*).

21. Bestowing upon him the Scriptures (*veda*) as gifts, and establishing him within the egg as grandfather of all worlds, he himself then revolves, causing existence.

22. Then Brahma, wearing the form of the principle of consciousness (*ahankâra*), produced mind in the creation: from mind was born the moon; from the eyes, the sun, the repository of light;

23. From mind, the ether; thence, in succession, wind, fire, waters, earth—these five elements (*mahâbhûta*) were produced by the successive addition of one quality.

24. Agni and Soma, the sun and moon: then Mars etc. were produced, in succession, from light, earth, ether, water, wind.

25. Again, dividing himself twelve-fold, he, the mighty one, produced what is known as the signs; and yet farther, what has the form of the asterisms (*nakshatra*), twenty-seven-fold.

26. Then he wrought out the whole animate and inanimate creation, from the gods downward, producing forms of matter (*prakṛti*) from the upper, middle, and lower currents (*srotas*).

27. Having produced them in succession, as stated, by a difference of quality and function, he fashioned the distinctive character of each, according to the showing of the Scripture (*veda*)—

28. That is, of the planets, asterisms, and stars, of the earth, and of the universe, he the mighty one; of gods, demons, and mortals, and of the Perfected (*siddha*), in their order.

We do not regard ourselves as called upon to enter into any detailed examination of this metaphysical scheme of development of the creation, or to compare it critically with the similar schemes presented in other Hindu works, as Manu (chap. i), the Purâṇas (see Wilson's Vishṇu Purâṇa, Book I), etc. We will merely explain a few of its expressions, and of the allusions it contains. Vâsudeva is an ordinary epithet of Vishṇu, and its use in the signification here given it seems indicative of Vaishṇava tendencies on the part of the author of the scheme. The twenty-five principles referred to in verse 12 are those established by the Sânkhya philosophy. The reference in verse 15, first half, is to Rig-Veda x. 121. In the second half of the same verse we have a couple of false etymologies: *âditya* comes, not from *âdi*, "first," but from *aditi*, "eternity"; and to derive *sûrya*, "sun," from the root *sû*, "generate" (from which *savitar* actually comes), is beyond the usual measure of Hindu theologico-philosophical etymologizing. The Hymns, Songs, and Liturgy are the three bodies of scripture commonly known as the Ṛig-Veda, Sâma-Veda, and Yajur-Veda. The "seven metres" (v. 19) are those which are most often employed in the construction of the Vedic hymns: in parts of the Veda itself they are personified, and marvellous qualities and powers are ascribed to them. The obscure statement contained in the first half of verse 20 comes from verses 3 and 4 of the *purusha*-hymn (Ṛig-Veda x. 90: the hymn is also found in others of the Vedic texts). The second half of verse 22 also nearly coincides with a passage (v. 13) in the same hymn. Of the five elements assumed by the Hindu philosophers, the first, ether, is said to be endowed only with the quality of audibleness; the second, air, has that of tangibility also; the third, fire, has both, along with color; to these qualities the fourth element, water, adds that of savor; the last, earth, possesses audibility, tangibility, color, savor, and odor: this is according to the doctrines of the Sânkhya philosophy. In verses 24 and 25 we have specifications introduced out of consideration for the general character and object of this treatise: as also, in the part assigned to the sun in the history of development, we may perhaps recognize homage paid to its asserted author. For the beings called in verse 28 the "perfected" (*siddha*), see below, verses 31 and 40.

29. This Brahma-egg is hollow; within it is the universe, consisting of earth, sky, etc.; it has the form of a sphere, like a receptacle made of a pair of caldrons.

30. A circle within the Brahma-egg is styled the orbit of the ether (*vyoman*): within that is the revolution of the asterisms (*bha*); and likewise, in order, one below the other,

31. Revolve Saturn, Jupiter, Mars, the sun, Venus, Mercury, and the moon; below, in succession, the Perfected (*siddha*), the Possessors of Knowledge (*vidyâdhara*), and the clouds.

The order of proximity to the earth in which the seven planets are here arranged is, as noticed above (i. 51–52), that upon which depends the succession of their regency over the days of the week, and so also the names of the latter. So far as the first three and the last are concerned, it is a naturally suggested arrangement, which could hardly fail to be hit upon by any nation having sufficient skill to form an order of succession at all: the order in which the sun, Mercury, and Venus are made to follow one another is, on the other hand, a matter of more arbitrary determination, and might have been with equal propriety, for aught we can see, reversed or otherwise varied. Of the supernatural beings called the "possessors of knowledge" (*vidyâdhara*) we read only in this verse: the "perfected" we find again below, in verse 40, as inhabitants of a city on the earth's surface.

32. Quite in the middle of the egg, the earth-globe (*bhûgola*) stands in the ether, bearing the supreme might of Brahma, which is of the nature of self-supporting force.

33. Seven cavities within it, the abodes of serpents (*nâga*) and demons (*asura*), endowed with the savor of heavenly plants, delightful, are the interterranean (*pâtâla*) earths.

34. A collection of manifold jewels, a mountain of gold, is Meru, passing through the middle of the earth-globe, and protruding on either side.

35. At its upper end are stationed, along with Indra, the gods, and the Great Sages (*maharshi*); at its lower end, in like manner, the demons (*asura*) have their place—each the enemy of the other.

36. Surrounding it on every side is fixed next this great ocean, like a girdle about the earth, dividing the two hemispheres of the gods and of the demons.

37. And on all sides of the midst of Meru, in equal divisions of the ocean, upon islands (*dvîpa*), in the different directions, are the eastern and other cities, fashioned by the gods.

38. At a quadrant of the earth's circumference eastward, in the clime (*varsha*) Bhadrâçva, is the city famed as Yamakoṭi, having walls and gateways of gold.

39. To the southward, in the clime Bhârata, is in like manner the great city Lankâ: to the west, in the clime called Ketumâla, is declared to be the city named Romaka.

40. Northward, in the clime Kuru, is declared to be the city called that of the Perfected (*siddha*); in it dwell the magnanimous Perfected, free from trouble.

41. These are situated also at a distance from one another of a quadrant of the earth's circumference; to the north of them, at the same distance, is Meru, the abode of the gods (*sura*).

42. Above them goes the sun when situated at the equinoxes; they have neither equinoctial shadow nor elevation of the pole (*akshonnati*).

43. In both directions from Meru are two pole-stars (*dhruvatârâ*), fixed in the midst of the sky: to those who are situated in places of no latitude (*niraksha*), both these have their place in the horizon.

44. Hence there is in those cities no elevation of the pole, the two pole-stars being situated in their horizon; but their degrees of co-latitude (*lambaka*) are ninety: at Meru the degrees of latitude (*aksha*) are of the same number.

In these verses we have so much of geography as the author of the chapter has seen fit to connect with his astronomical explanations. For a Hindu account of the earth, it is wonderfully moderate, and free from falsehood. The absurd fictions which the Purâṇas put forth as geography are here for the most part ignored, only two or three of the features of their descriptions being retained, and those in an altered form. To the Purâṇas (see especially Wilson's Vishṇu Purâṇa, Book II., chap. ii–vi), the earth is a plain, of immense dimensions. Precisely in the middle of it rises Mount Meru, itself of a size compared with which the earth, as measured by the astronomers, is as nothing: it is said to be 84,000 yojanas high, and buried at the base 16,000 yojanas; it has the shape of an inverted cone, being 32,000 yojanas in diameter at its upper extremity, and only 16,000 at the earth's surface. Out of this mountain the astronomical system makes the axis of the earth, protruding at either extremity, indeed, but of dimensions wholly undefined. As the Purâṇas declare the summit of Meru, and the mountains immediately supporting it, to be the site of the cities inhabited by the different divinities, so also we have here the gods placed upon the northern extremity of the earth's axis, while their foes, the spirits of darkness, have their seat at the southern. The central circular continent, more than 100,000 yojanas in diameter, in the midst of which Meru lies, is named Jambûdvîpa, "the island of the rose-apple tree": it is intersected by six parallel ranges of mountains, running east and west, and connected together by short cross-ranges: the countries lying between these ranges are styled *varshas*, "climes," and are all fully named and described in the Purâṇas, as are the mountain-ranges themselves. The half-moon-shaped strips lying at the bases of the mountains on the eastern, southern, western, and northern edges of the continent, are called by the same names that are given by our text to the four insular climes which it sets up. Bhârata is a real historical name, appearing variously in the early Hindu traditions; Kuru, or Uttara-Kuru, is a title applied in Hindu geography of a less fictitious character to the country or people situated beyond the range of the Himâlaya; the other two names appear to be altogether imaginary. The Purâṇas say nothing of cities in these four climes. Lankâ, as noticed above (i. 62), is properly an appellation of the island Ceylon; and Romaka undoubtedly comes from the name of the great city which was the mistress of the western world at the period of lively commercial intercourse between India and the Mediterranean: the other two cities are pure figments of the imagination. Our treatise, it will be observed, ignores the system of continents, or *dvîpas*, and simply surrounds the earth with an ocean in the midst, like a girdle: the Purâṇas encompass Jambûdvîpa about with six other *dvîpas*, or insular ring-shaped continents, each twice as vast as that which it encloses, and each separated from the next by an ocean of the same extent with itself. Of these seven oceans, the first, which washes the shores of Jambûdvîpa, is naturally enough acknowledged to be composed of salt water: but the second is of syrup, the third of wine, the fourth of clarified butter, the fifth of whey, the sixth of milk, and the last of sweet water. Outside the latter is an uninhabited land of gold, and on its border, as the outmost verge of creation, is the monstrous wall of the Lokâloka mountains, beyond which is only nothingness and darkness.

The author of the Siddhânta-Çiromaṇi, more submissive than the writer of our chapter to the authority of tradition, accepts (Golâdhy., chap. ii) the series of concentric continents and oceans, but gives them all a place in the unknown southern hemisphere, while he regards Jambûdvîpa as occupying the whole of the northern.

The *pâtâlas*, or interterranean cavities, spoken of in verse 33, are also an important feature of the Puranic geography. If our author has not had the good sense to reject them, along with the insular continents, he at least passes them by with the briefest possible notice. In the Purâṇas they are declared to be each of them 10,000 yojanas in depth, and their divisions, inhabitants, and productions are described with the same ridiculous detail as those of the continents on the earth's surface.

It will be observed that the text, although exhibiting in verse 41 a distinct apprehension of the fact that the pole is situated to the northward of all points of the equator alike, yet, in describing the position of the four great cities, speaks as if there were a north direction from Meru, in the continuation of the line drawn to the latter from Lankâ, and an east and west direction at right angles with this.

For the terrestrial equator, considered as a line or circle upon the earth's surface, there is no distinctive name; it is referred to simply as the place "of no latitude" (*niraksha*, *vyaksha*).

45. In the half-revolution beginning with Aries, the sun, being in the hemisphere of the gods, is visible to the gods: but while in that beginning with Libra, he is visible to the demons, moving in their hemisphere.

46. Hence, owing to his exceeding nearness, the rays of the sun are hot in the hemisphere of the gods in summer, but in that of the demons in winter: in the contrary season, they are sluggish.

47. At the equinox, both gods and demons see the sun in the horizon; their day and night are mutually opposed to each other.

48. The sun, rising at the first of Aries, while moving on northward for three signs, completes the former half-day of the dwellers upon Meru;

49. In like manner, while moving through the three signs beginning with Cancer, he completes the latter half of their day: he accomplishes the same for the enemies of the gods while moving through the three signs beginning with Libra and the three beginning with Capricorn, respectively.

50. Hence are their night and day mutually opposed to one another; and the measure of the day and night is by the completion of the sun's revolution.

51. Their mid-day and midnight, which are opposed to one another, are at the end of each half-revolution from solstice to solstice (*ayana*). The gods and demons each suppose themselves to be uppermost.

52. Others, too, who are situated upon the same diameter (*samasûtrastha*), think one another underneath—as the dwellers in Bhadrâçva and in Ketumâla, and the inhabitants of Lankâ and of the city of the Perfected, respectively.

53. And everywhere upon the globe of the earth, men think their own place to be uppermost: but since it is a globe in the ether, where should there be an upper, or where an under side of it?

54. Owing to the littleness of their own bodies, men, looking in every direction from the position they occupy, behold this earth, although it is globular, as having the form of a wheel.

55. To the gods, this sphere of asterisms revolves toward the right; to the enemies of the gods, toward the left; in a situation of no latitude, directly overhead—always in a westerly direction.

55. Hence, in the latter situation, the day is of thirty nâḍîs, and the night likewise: in the two hemisphéres of the gods and demons there take place a deficiency and an excess, always opposed to one another.

57. During the half-revolution beginning with Aries, there is always an excess of the day to the north, in the hemisphere of the gods—greater according to distance north—and a corresponding deficiency of the night; in the hemisphere of the demons, the reverse.

58. In the half-revolution beginning with Libra, both the deficiency and excess of day and night in the two hemispheres are the opposite of this: the method of determining them, which is always dependent upon situation (*deça*) and declination, has been before explained.

59. Multiply the earth's circumference by the sun's declination in degrees, and divide by the number of degrees in a circle: the result, in yojanas, is the distance from the place of no latitude where the sun is passing overhead. $\frac{C.\ \delta}{360}$

60. Subtract from a quarter of the earth's circumference the number of yojanas thus derived from the greatest declination: at the distance of the remaining number of yojanas

61. There occurs once, at the end of the sun's half-revolution from solstice to solstice, a day of sixty nâḍîs, and a night of the same length, mutually opposed to one another, in the two hemispheres of the gods and of the demons.

62. In the intermediate region, the deficiency and excess of day and night are within the limit of sixty nâḍîs; beyond, this sphere of asterisms (*bha*) revolves perversely.

63. Subtract from a quarter of the earth's circumference the number of yojanas derived from the declination found by the sine of two signs: at that distance from the equator the sun is not seen, in the hemisphere of the gods, when in Sagittarius and Capricorn; $\frac{C}{4}$ –

64. So also, in the hemisphere of the demons, when in Gemini and Cancer: in the quarter of the earth's circumference where her shadow is lost, the sun may be shown to be visible.

65. Subtract from the fourth part of the earth's periphery (*kakshâ*) the number of yojanas derived from the declination found by the sine of one sign: at the distance from the place of no latitude of the remaining number of yojanas,

66. The sun, when situated in Sagittarius, Capricorn, Scorpio, and Aquarius, is not seen in the hemisphere of the gods; in that of the demons, on the other hand, when in the four signs commencing with Taurus.

67. At Meru, the gods behold the sun, after but a single rising, during the half of his revolution beginning with Aries; the demons, in like manner, during that beginning with Libra.

68. The sun, during his northern and southern progresses (*ayana*) revolves directly over a fifteenth part of the earth's circumference, on the side both of the gods and of the demons.

69. Between those limits, the shadow is cast both southward and northward; beyond them, it falls toward the Meru of either hemisphere respectively.

70. When passing overhead at Bhadrâçva, the sun is rising in Bhârata; it is, moreover, at that time, midnight in Ketumâla, and sunset in Kuru.

71. In like manner also he produces, by his revolution, in Bhârata and the other climes, noon, sunrise, midnight, and sunset, reckoning from east to west.

72. To one going toward Meru, there take place an elevation of the pole (*dhruva*) and a depression of the circle of asterisms; to one going toward the place of no latitude, on the contrary, a depression of the former and an elevation of the latter.

This detailed exposition of the varying relations of day and night in different parts of the globe is quite creditable to the ingenuity, and the distinctness of apprehension, of those by whom it was drawn out. It is for the most part so clearly expressed as to need no additional explanations: we shall append to it only a few brief remarks.

How far, in verse 46, a true statement is given of the cause of the heat of summer and the cold of winter, may be made a matter of some question: the word which we have translated "nearness" (*âsannatâ*) has no right to mean "directness, perpendicularity," and yet, when taken in connection with the preceding verse, it may perhaps admit that signification. The second chapter shows that the Hindus knew very well that the sun is actually nearer to the whole earth in winter, or when near his perigee, than in summer.

The expression *ayanânta*, "at the end of an *ayana*," employed in verses 51 and 61, and which we have rendered by a paraphrase, might perhaps have been as well translated, briefly and simply, "at either solstice." Probably *ayana*, as used in the sense of "solstice" (see above, end of note to iii. 9–12), is an abbreviated form of *ayanânta*, like *jyâ* for *jyârdha* (ii. 15–27), and *aksha* for *akshonnati* (i. 60).

In verse 55, we have translated by "toward the right" and "toward the left" the adverbs *savyam* and *apasavyam*, which mean literally "leftwise" and "right-wise"; that is to say, in such a manner that the left side or the right side respectively of the thing making the revolution is turned toward that about which the revolution is made, this being the Hindu mode of describing the passing of one person about another person or thing, especially in respectful salutation and in religious ceremonial.

The natural measure of the day and of the night is assumed in verse 56 etc. to be the half of a whole day, or thirty nâḍis, and any deviation from that norm is regarded as an excess (*dhana*, *vṛddhi*) or a deficiency (*ṛṇa*, *hâni*, *kshaya*). The former processes referred to at the end of verse 58 are those taught in ii. 60–62.

We have already above (note to i. 63–65) called attention to the fact that all the Hindu measurements of longitude and latitude upon the earth's surface are made in yojanas, and not in degrees.

The expression "perversely" (*viparîta*) in verse 62 is explained by the commentator to mean "in such manner that the rules as already given cannot be applied"; since the sine of the ascensional difference (*cara*—see ii. 61) as found by them would be greater than radius.

The latter half of verse 64 is obscure: its meaning seems to be, as explained by the commentator, that over a corresponding portion of the earth's surface in the contrary hemisphere the sun is continuously visible during the same period, the shadow of the earth, which is the cause of night, not covering that portion.

73. The circle of asterisms, bound at the two poles, impelled by the provector (*pravaha*) winds, revolves eternally: attached to that are the orbits of the planets, in their order.

74. The gods and demons behold the sun, after it is once risen, for half a year; the Fathers (*pitaras*), who have their station in the moon, for a half-month (*paksha*); and men upon the earth, during their own day.

75. The orbit (*kakshâ*) of one that is situated higher up is large; that of one situated lower down is small. Upon a great orbit the degrees are great; so also, upon a small one, they are small.

76. A planet situated upon a small circuit (*bhramaṇa*) traverses the circle of constellations (*bhagaṇa*) in a little time; one revolving on a large circle (*maṇḍala*), in a long time.

77. The moon, upon a very small orbit, makes many revolutions: Saturn, moving upon a great orbit, makes, as compared with her, a much less number of revolutions.

The connection and orderly succession of subjects is by no means strictly maintained in this part of the chapter. The seventy-fourth verse is palpably out of place, and is, moreover, in great part superfluous; for the statement contained in its first half has already twice been made, in verses 45 and 67, and in the latter passage in nearly the same terms as here: its last specification, too, is of a matter too obvious to call for notice. Nevertheless, the verse cannot well be spared from the chapter, since it contains the only answer which is vouchsafed to the question of verse 5, above, respecting the day and night of the Fathers. In the assignment of the different divisions of time, as single days, to different orders of beings, the month has been given to the *pitaras*, "Fathers," or manes of the departed, and they are accordingly located in the moon, each portion of whose surface enjoys a recurrence of day and night once in each lunar month. The next following verses, 75 to 77, are a rather unnecessary amplification of the idea already expressed in i. 26–27; but they answer well enough here as special introduction to the detailed exhibition of the measurements of the planetary orbits which is to follow. Before that is brought in, however, we have the connection again broken, by the intrusion of the two following verses, respecting the regents of years, months, days, and hours.

78. Counting downward from Saturn, the fourth successively is regent of the day; and the third, in like manner, is declared to be the regent of the year;

79. Reckoning upward from the moon are found, in succession, the regents of the months; the regents of the hours (*horâ*), also, occur in downward order from Saturn.

This passage appears to be introduced here as answer to the inquiry propounded in verse 6, above. Instead, however, of explaining why the different divisions of time are placed under the superintendence and protection of different planets, the text contents itself with reiterating, in a different form, what had already been said before (i. 51–52) respecting the order of succession of the regents of the successive periods; but adding also the important and significant specification respecting the hours, or twenty-fourths of the day. We have sufficiently illustrated the subject, in connection with the other passage; we will only repeat here that, the planets being regarded as standing in the order in which they are mentioned in verse 31, above, their successive regency over the hours is the one fundamental fact upon which all the rest depend, each planet being constituted lord also of the day whose first hour is placed under his charge, and so likewise of the month and of the year over whose first hour and day he is regent—neither the month nor the year, any more than the hour itself, being divisions of time which are known to the Hindus in any other uses, and the name of the hour, *horâ*, which is the Greek ὥρα, betraying the source whence the whole system was introduced into India.

80. The orbit (*kakshâ*) of the asterisms (*bha*) is the circuit (*bhramaṇa*) of the sun multiplied by sixty: by so many yojanas does the circle of the asterisms revolve above all.

81. If the stated number of revolutions of the moon in an Æon (*kalpa*) be multiplied by the moon's orbit, the result is to be known as the orbit of the ether: so far do the rays of the sun penetrate.

82. If this be divided by the number of revolutions of any planet in an Æon (*kalpa*), the result will be the orbit of that planet: divide this by the number of terrestrial days, and the result is the daily eastward motion of them all.

83. Multiply this number of yojanas of daily motion by the orbit of the moon, and divide by a planet's own orbit; the result is, when divided by fifteen, its daily motion in minutes.

84. Any orbit, multiplied by the earth's diameter and divided by the earth's circumference, gives the diameter of that orbit; and this, being diminished by the earth's diameter and halved, gives the distance of the planet.

85. The orbit of the moon is three hundred and twenty-four thousand yojanas: that of Mercury's conjunction (*çîghra*) is one million and forty-three thousand, two hundred and nine:

86. That of Venus's conjunction (*çîghra*) is two million, six hundred and sixty-four thousand, six hundred and thirty-seven: next, that of the sun, Mercury, and Venus is four million, three hundred and thirty-one thousand, five hundred:

87. That of Mars, too, is eight million, one hundred and forty-six thousand, nine hundred and nine; that of the moon's apsis (*ucca*) is thirty-eight million, three hundred and twenty-eight thousand, four hundred and eighty-four:

88. That of Jupiter, fifty-one million, three hundred and seventy-five thousand, seven hundred and sixty-four: of the moon's node, eighty million, five hundred and seventy-two thousand, eight hundred and sixty-four:

89. Next, of Saturn, one hundred and twenty-seven million, six hundred and sixty-eight thousand, two hundred and fifty-five: of the asterisms, two hundred and fifty-nine million, eight hundred and ninety thousand, and twelve:

90. The entire circumference of the sphere of the Brahma-egg is eighteen quadrillion, seven hundred and twelve trillion, eighty billion, eight hundred and sixty-four million: within this is the pervasion of the sun's rays.

We present below the numerical data given in these verses, in a form easier of reference and of comparison with the like data of other treatises:

Planet etc.	Orbit, in yojanas.
Moon,	324,000
" apsis,	38,328,484
" node,	80,572,864
Mercury (conjunction),	1,043,209
Venus (conjunction),	2,664,637
Sun,	4,331,500
Mars,	8,146,909
Jupiter,	51,375,764
Saturn,	127,668,255
Asterisms,	259,890,012
Universe,	18,712,080,864,000,000

43 315 002

We have already more than once (see above, notes to i. 25–27, and iv. 1) had occasion to notice upon what principles the orbits of the planets, as here stated, were constructed by the Hindus. That of the moon (see note to iv. 1) was obtained by a true process of calculation, from genuine data, and is a tolerable approximation to the truth: all the others are manufactured out of this, upon the arbitrary and false assumption that the mean motion of all the planets, each upon its own orbit, is of equal absolute amount, and hence, that its apparent value in each case, as seen by us, is inversely as the planet's distance, or that the dimensions of the orbit are directly as the time employed in traversing it, or as the period of sidereal revolution. These dimensions, then, may be found by various methods: upon dividing the circumference of the moon's orbit by her time of sidereal revolution, we obtain as the amount of her daily motion in yojanas 11,858.717 nearly (more exactly 11,858.71693+); and multiplying this by the time of sidereal revolution of any planet, we obtain that planet's orbit. This is equivalent to making the proportion

moon's sid. rev.: planet's sid. rev. : : moon's orbit: planet's orbit

And since the times of sidereal revolution of the planets are inversely as the number of revolutions made by them in any given period, this proportion, again, is equivalent to

planet's no. of rev. in an Æon : moon's do. : : moon's orbit : planet's orbit

This is the form of the proportion from which is derived the rule as stated in the text, only the latter designates the product of the multiplication of the moon's orbit by her number of revolutions as the orbit of the ether (*âkâça*), or the circumference of the Brahma-egg, within which the whole creation, as above taught, is enclosed. This is the same thing with attributing to the outermost shell of the universe one complete revolution in an Æon (*kalpa*), of 4,320,000,000 years.

There is one feature of the system exposed in this passage which to us is hitherto quite inexplicable: it is the assignment to the asterisms of an orbit sixty times as great as that of the sun. This, according to all the analogies of the system, should imply a revolution of the asterisms eastward about the earth once in each period of sixty sidereal years. The same orbit is found allotted to them in the Siddhânta-Çiromaṇi (Gaṇitâdhy., iv. 5), and it is to be looked upon, accordingly, as an essential part of the general Hindu astronomical system. We do not see how it is to be brought into connection with the other doctrines of the system, or what can be its origin and import—unless, indeed, it be merely an application to the asterisms, in an entirely arbitrary way, of the general law that everything must be made to revolve about the earth as a centre. We have noticed above (note to iii. 9–12) its inconsistency with the doctrine of the precession adopted in this treatise.

The dimensions of the several orbits stated in the text are for the most part correct, being such as are derived by the processes above explained from the numbers of sidereal revolutions given in a former passage (i. 29–34). There is, however, one exception: the orbit of Mercury, as so derived, is 1,043,207.8, and the number adopted by the text—which rejects fractions throughout, taking the nearest whole number—should be, accordingly, –208, and not –209. If we took as divisor the number of Mercury's revolutions in an Æon as corrected by the *bîja* (see note to i. 29–34), we should actually obtain for his orbit the value given it by the text; the exact quotient being 1,043,208.73. But as none of the other orbits given are such as would be found by admitting the several corrections of the *bîja*, it seems preferable to assume that the text has at this point become corrupt, or else that the author of the chapter made a blunder in one of his calculations.*

The value of a minute of arc upon the moon's orbit being fifteen yojanas (see note to iv. 2–3), the value, in minutes, of any planet's mean daily motion may be readily found from its orbit by the proportion of which the rule given in verse 83 is a statement, as follows: as the distance, or the orbit, of the planet in question is to that of the moon, so is the moon's mean motion in minutes, or 11,858.717 ÷ 15, to that of the planet.

In verse 84 we are taught to calculate the distance of any planet from the earth's surface: in order to this, we are first to find the diameter of the planet's orbit, adopting, as the ratio of the diameter to the circumference, that of the diameter to the circumference of the earth—the former, of course, as calculated (i. 59) by the false ratio of $1 : \sqrt{10}$. After being guilty of so gross an inaccuracy, it is quite superfluous, and a mere affectation of exactness, to take into account so trivial a quantity as the radius of the earth, in estimating the planet's distance from the earth.

In the doctrine of the orbits of the planets, as here laid down, we have once more a total negation of the reality of their epicyclical motions, and of their consequently varying distances from the earth in different parts of their revolutions. ?

CHAPTER XIII.

OF THE ARMILLARY SPHERE, AND OTHER INSTRUMENTS.

CONTENTS:—1–13, construction and equipment of the armillary sphere; 13–15, position of certain points and sines upon it; 15–16, its adjustment and revolution; 17–25, other instruments, especially for the determination of time.

1. Then, having bathed in a secret and pure place, being pure, adorned, having worshipped with devotion the sun, the planets, the asterisms (*bha*), and the elves (*guhyaka*),

2. Let the teacher, in order to the instruction of the pupil—himself beholding everything clearly, in accordance with the knowledge handed down by successive communication, and learned from the mouth of the master (*guru*)—

3. Prepare the wonder-working fabric of the terrestrial and stellar sphere (*bhûbhagola*) . . . .

* The last six verses of the chapter, which contain the numerical data, may very possibly be a later addition to its original content: the Âyîn-Akbari (as translated by Gladwin), in its account of the astronomy of the Hindus, which it professedly bases upon the Sûrya-Siddhânta, gives these orbits (8vo. edition, London, 1800, ii. 306), but with the fractional parts of yojanas, as if independently derived from the data and by the rules of the text: the orbit of Mercury it states correctly, as 1,043,207¾ yojanas.

We have already remarked above (note to xii. 1–9) that the subject of this chapter is one respecting which no inquiries were addressed at the beginning of the preceding chapter by the recipient to the communicator of the revelation, and that the chapter accordingly wears in some measure the aspect of an interpolation. It comes in here as furnishing a means of illustrating to the pupil the mutual relations of the earth and the heavens as explained in the last chapter—and yet not precisely as there explained; for it gives a representation only of the earth and of the one starry concave upon which the apparent movements of all the heavenly bodies are to be traced, and not of the concentric spheres and orbits out of which the universe has been declared to be constructed. The chapter has a peculiar title, unlike that of any other in the treatise: it is styled *jyotishopanishadadhyâya*, "lection of the astronomical Upanishad." Upanishad is the name ordinarily given to such brief treatises, of the later Vedic period, or of times yet more modern, as are regarded as inspired sources of philosophical and theological knowledge, and are looked upon with peculiar reverence: its application to this chapter is equivalent to an assumption for it of especial sanctity and authority. It may possibly also indicate that the chapter is originally an independent treatise, incorporated into the text of the Sûrya-Siddhânta.

The word *bha*, in verse 1, may mean either the asterisms proper (*nakshatra*), or the signs (*râçi*), and is explained by the commentator as intended to include both. The *guhyakas*, "secret ones," are a class of demigods who attend upon Kuvera, the god of wealth, and are the keepers of his treasures: why they are mentioned here, as objects of especial reverence to the astronomical teacher, is not obvious. The commentator explains the word by "Yakshas etc., lesser divinities." In our translation of verse 3 we have followed the reading of the published text, which Colebrooke also appears to have had before him; our own manuscripts read, instead of *bhûbhagola*, *bhûmigola* and *bhûmer gola*, "sphere of the earth" simply.

Colebrooke, in his essay On the Indian and Arabian Divisions of the Zodiac (As. Res., ix. 323 etc.; Essays, ii. 321 etc.) to which we have already so often had occasion to refer, gives a translation of part of this chapter, from the beginning of the third to the middle of the thirteenth verse, as also a brief sketch of the armillary sphere of which the construction is taught in the Siddhânta-Çiromaṇi. He farther furnishes a description, and a comparison with these, of the somewhat similar instruments employed by the Greeks, the Arabs, and the early European astronomers. It has not seemed to us worth while to extract these descriptions and comparisons, or to draw up others from independent and original sources: the object of the Hindu instrument is altogether different from that of the others, since it is intended merely as an illustration of the positions and motions of the heavenly bodies, while those are meant to subserve the purposes of astronomical observation; and its relation to them is determined by this circumstance; while it, of course, possesses some of the circles which enter into the construction of the others, it is, upon the whole, a very different and much more complicated and cumbersome structure. There is nothing in the way of supposing that the first hint of its construction may have been borrowed from the instruments of western nations: but, on the other hand, it may possibly admit also of being regarded as an independent Hindu device.

3. . . . Having fashioned an earth-globe of wood, of the desired size,

4. Fix a staff, passing through the midst of it and protruding at either side, for Meru; and likewise a couple of sustaining hoops (*kakshâ*), and the equinoctial hoop;

5. These are to be made with graduated divisions (*angula*) of degrees of the circle (*bhagaṇa*). . . .

The fixing of a solid globe of wood, representing the earth, in the midst of this instrument, is of itself enough to render impracticable its application to purposes of astronomical observation. For Meru, the axis and poles of the earth, see verse 34 of the preceding chapter. We are not informed of what relative size the globe and the encompassing hoops are to be made; probably their relation is to be such that the globe will be a small one, contained within an ample sphere. The two "supporting hoops," to which are to be attached all the numerous parallels of declination hereafter described, are, of course, to be fastened to the axis at right angles to one another, and to represent the equinoctial and solstitial colures. The commentary directly prescribes this, and the text also assumes it in a later passage (v. 10).

Colebrooke, following the guidance of the commentators, treats the former half of verse 5 as belonging to the following passage, instead of the preceding. It can, however, admit of no reasonable question that the connection as established in our translation is the true one: it is demanded by the natural construction of the verses, and also yields a decidedly preferable sense.

5. . . . Farther—by means of the several day-radii, as adapted to the scale established for those other circles,

6. And by means of the degrees of declination and latitude (*vikshepa*) marked off upon the latter—at their own respective distances in declination, according to the declination of Aries etc., three

7. Hoops are to be prepared and fastened: these answer also inversely for Cancer etc. In the same manner, three for Libra etc., answering also inversely for Capricorn etc.,

8. And situated in the southern hemisphere, are to be made and fastened to the two hoop-supporters. . . .

The grammatical construction of this passage is excessively cumbrous and intricate, and we can hardly hope that the version which we have given of it will be clearly understood without farther explanations. Its meaning, however, is free from ambiguity. We have thus far only three of the circles out of which our instrument is to be constructed, namely those intended to represent the two colures and the equator: we are next to add hoops for the diurnal circles described by the sun when at the points of connection between the different signs of the zodiac. Of these there will be, of course, three north of the equator, one for the sun at the end of Aries and at the beginning of Virgo, one for the sun at the end of Taurus and at the beginning of Leo, and one for the sun at the end of Gemini and the beginning of Cancer, or at the solstice: also, in the southern hemisphere, three others corresponding to these. The dimensions of which they must be made are to be determined by their several radii (which are called day-radii—see above, ii. 60), as ascertained by calculation and reduced to the same scale upon which the colures and equator were constructed. They are then to be attached to the two general supporting hoops, or colures, each at its proper distance from the equator; this distance is ascertained by calculating the declination of the sun when at the points in question, and is determined upon the instrument by the graduation of the two supporting hoops. This graduation is in the text called that for declination (*krânti*) and latitude (*vikshepa*): it will be remembered that, according to Hindu usage, the latter means distance from the ecliptic as measured upon a circle of declination.

8. . . . Those likewise of the asterisms (*bha*) situated in the southern and northern hemispheres, of Abhijit,

9. Of the Seven Sages (*saptarshayas*), of Agastya, of Brahma etc., are to be fixed . . . .

If the orders given in these verses are to be strictly followed, our instrument must now be burdened with forty-two additional circles of diurnal revolution, namely those of the twenty-seven junction-stars (*yogatârâ*) of the asterisms and of that of Abhijit—which is here especially mentioned, as not being always ranked among the asterisms (see above, p. 352 etc.)—those of the seven other fixed stars of which the positions were stated in the eighth chapter (vv. 10–12 and 20–21), and also those of the Seven Sages, or the conspicuous stars in Ursa Major (see end of the last note to the eighth chapter). Such impracticable directions, however, cannot but inspire the suspicion that the instrument may never have been constructed except upon paper.

9. . . . Just in the midst of all, the equinoctial (*vâishuvatî*) hoop is fixed.

10. Above the points of intersection of that and the supporting hoops are the two solstices (*ayana*) and the two equinoxes (*vishuvat*) . . . .

We have already noticed (note to iii. 6) that the celestial equator derives its name from the equinoxes through which it passes. It seems a little strange that the adjustment of the hoop representing it to the two supporting hoops, which we should naturally regard as the first step in the construction of the instrument, is here assumed to be deferred until after all the other circles of declination are fixed in their places.

The word translated "above" (*ûrdhvam*) in verse 10 requires to be understood in two very different senses, as is pointed out by the commentator, to make the definitions of position of the solstices and of the equinoxes both correct: the latter are situated precisely at the intersection of the equinoctial colure with the equator; the former at a distance of 24° above and below the intersection of the equator with the other colure, or at the intersection of the colure with the third parallel of the sun's declination, on either side of the equator.

We are next taught how to fix in its proper position the hoop which is to represent the ecliptic.

10\. . . . From the place of the equinox, with the exact number of degrees, as proportioned to the whole circle,

11\. Fix, by oblique chords, the spaces (*kshetra*) of Aries and the rest; and so likewise another hoop, running obliquely from solstice (*ayana*) to solstice,

12\. And called the circle of declination (*krânti*): upon that the sun constantly revolves, giving light: the moon and the other planets also, by their own nodes, which are situated in the ecliptic (*apamaṇḍala*),

13\. Being drawn away from it, are beheld at the limit of their removal in latitude (*vikshepa*) from the corresponding point of declination. . . .

Instead of simply directing that a circle or hoop, of the same dimensions as those of the equator and colures, be constructed to represent the ecliptic, and then attached to the others at the equinoxes and solstices, the text regards it as necessary to fix, upon the six diurnal circles of the sun of which the construction and adjustment were taught above, in verses 5–8, the points of division of all the twelve signs, before the ecliptic hoop can be added to the instrument. In the compound *tiryagjyâ*, in verse 11, which we have rendered "oblique chords," we conceive *jyâ* to have its own more proper meaning of "chord," instead of that of "sine," which, by substitution for *jyârdha* (see note to ii. 15–27, near the end), it has hitherto uniformly borne. We are to ascertain by calculation the measure of the chord of 30°, to reduce it to the scale of dimensions adopted for the other great circles of the instrument, and then, commencing from either equinox, to lay it off, in an oblique direction, to the successive diurnal circles, northward and southward, thus fixing the positions upon them of the initial and final points of the twelve signs; and through all these points the ecliptic hoop is to be made to pass.

It does not appear that separate hoops for the orbits of the other planets, attached to the ecliptic at their respective nodes, are to be added to the instrument.

In verse 12 we have a name for the ecliptic, *apamaṇḍala*, which does not occur elsewhere in the treatise. The word might be literally translated "off-circle," and regarded as designating the circle which deviates in direction from the neighboring equator; but it is more probably an abbreviation for *apakramamaṇḍala*, which would mean, like the ordinary terms *krântimaṇḍala*, *krântivṛtta*, "circle of declination."

13\. . . . The orient ecliptic-point (*lagna*) is that at the orient horizon; the occident point (*astamgachat*) is similarly determined.

14\. The meridian ecliptic-point (*madhyama*) is as calculated by the equivalents in right ascension (*lankodayâs*), for mid-heaven (*khamadhya*) above. The sine which is between the meridian (*madhya*) and the horizon (*kshitija*) is styled the day-measure (*antyâ*).

15. And the sine of the sun's ascensional difference (*caradala*) is to be recognized as the interval between the equator (*vishuvat*) and the horizon. . . .

These verses contain an unnecessary and fragmentary, as also a confused and blundering, definition of the positions upon the sphere of a few among the points and lines which have been used in the calculations of the earlier parts of the treatise. We are unwilling to believe that the passage is anything but a late interpolation, made by an awkward hand. For the point of the ecliptic termed *lagna*, or that one which is at any given moment passing the eastern horizon, or rising, see iii. 46–48, and note upon that passage. The like point at the western horizon, which the commentator here calls *astalagna*, "*lagna* of setting," and which the text directs us to find "in a corresponding manner," has never been named or taken into account anywhere in the treatise: we have seen above (as for instance, in ix. 4–5) that all its processes into which distance in ascension enters as an element are transferred for calculation from the occident to the orient horizon. For *madhyalagna*, the point of the ecliptic situated upon the meridian, see above, iii. 49 and note. Although we have ordinarily translated the term by "meridian ecliptic-point," this being a convenient and exact definition of the point actually referred to, we do not regard the word *madhya*, occurring in it, as meaning "meridian" in the sense in which it is used in modern astronomy, namely the great circle passing through the observer's zenith and the north and south points of his horizon. For it deserves to be noted that the text has no distinctive name for the meridian, and nowhere makes any reference to it as a circle on the sphere: it will be seen just below that, while the position of the horizon is defined, the meridian is not contemplated as a circle of sufficient consequence to require to be represented upon the illustrative armillary sphere. The commentator not very infrequently has occasion to speak of the meridian, and styles it *yâmyottaravṛtta*, "south and north circle," or *ûrdhvayâmyottaravṛtta*, "uppermost south and north circle." In the latter half of verse 14, where we have translated *madhya* by "meridian," it would have been more exact to say "mid-heaven," or "the sun at the middle of his visible revolution," or "the sun when at the point called *madhyalagna*." For the "day-measure" (*antyâ*), see above, iii. 34–36. Its definition given here is as bad as it could well be: for, passing over the fact that the line in question is not properly a sine, and moreover that the text does not tell us in which of the numberless possible directions it is to be drawn from the meridian to the horizon, the line which it is attempted to describe is not the one which the treatise regards as the *antyâ*, but the correspondent of the latter in the small circle described by the sun. That is to say, the text here substitutes the line D A in Fig. 8, above (p. 232), for the line E G. A similar blunder is made in defining the sine of the sun's ascensional difference (*carajyâ*): the line A B in the same figure, which is the "earth-sine" (*kujyâ, kshitijyâ*), is taken, instead of its equivalent in terms of a great circle, C G. Moreover, the text reads "equator" (*vishuvat*—E C in the figure) here for "east and west hour-circle" (*unmaṇḍala*—C P): the commentator restores the latter, and excuses the substitution by a false translation of the latter half of iii. 6, making it mean "the east and west hour-circle is likewise denominated the equinoctial circle."

In verse 14, *lankodayâs* is substituted for the more usual term *lankodayâsavas* (see above, iii. 49, and note), in the sense of "equivalents of the signs in right ascension," literally, "at Lankâ."

15. . . . Having turned upward one's own place, the circle of the horizon is midway of the sphere.

16. As covered with a casing (*vastra*) and as left uncovered, it is the sphere surrounded by Lokâloka. . . .

The simple direction to turn upward one's own situation upon the central wooden globe which represents the earth does not, it is evident, contemplate any very careful or exact adjustment of the instrument.

Verse 16 is very elliptical and obscure in its expressions, but their general meaning is plain, and is that which is attributed to them by the commentator. The proper elevation having been given to the pole of the sphere, a circle is by some means or other to be fixed about its midst, or equally distant from its zenith and nadir, to represent the horizon. Then the part below is to be encased in a cloth covering, the upper hemisphere alone being left open. As thus arranged, the sphere is, as it were, girt about by the Lokâloka mountains. Lokâloka is, as we have seen above (note to xii. 32–44), the name of the giant mountain-range which, in the Puranic geography, is made the boundary of the universe: it is apparently so called because it separates the world (*loka*) from the non-world (*aloka*); and as out of the Puranic Meru the new astronomical geography makes the axis and poles of the earth, so out of these mountains it makes the visible horizon.

The "wonder-working fabric of the terrestrial and stellar sphere" is now fully constructed, and only requires farther, in order to its completion as an edifying and instructive illustration of the relations of the heavens to the earth, to be set in motion about its fixed axis.

16. . . . By the application of water is made ascertainment of the revolution of time.

17. One may construct a sphere-instrument combined with quicksilver: this is a mystery; if plainly described, it would be generally intelligible in the world.

18. Therefore let the supreme sphere be constructed according to the instruction of the preceptor (*guru*). In each successive age (*yuga*), this construction, having become lost, is, by the Sun's

19. Favor, again revealed to some one or other, at his pleasure. . . .

Here we have another silly mystification of a simple and comparatively insignificant matter, like that already noticed at the end of the sixth chapter. The revolution of the machine of which the construction has now been explained, in imitation of the actual motion of the heavens about the earth, is something so calculated to strike the minds of the uninitiated with wonder, that the means by which it is to be accomplished must not be fully explained even in this treatise, lest they should become too generally known: they must be learned by each pupil directly from his teacher, as the latter has received them by successive tradition, from the original and superhuman source whence they came. It is perfectly evident that such a fabric could only be made to revolve in a rude and imperfect way; that it should have marked time, and continued for any period to correspond in position with the actual sphere, is impossible.

The word which, upon the authority of the commentator, we have rendered "water," in verse 16, is *amṛtasrâva*, literally "having an immortal flow": perhaps the phrase should be translated rather, "by managing a constant current of water."

19. . . . So also, one should construct instruments (*yantra*) in order to the ascertainment of time.

20. When quite alone, one should apply quicksilver to the wonder-causing instrument. By the gnomon (*çanku*), staff (*yashṭi*), arc (*dhanus*), wheel (*cakra*), instruments for taking the shadow, of various kinds, .

21. According to the instruction of the preceptor (*guru*), is to be gained a knowledge of time by the diligent. . . .

The commentator interprets the first part of verse 20 in correspondence with the sense of the preceding passage: the application of mercury to a revolving machine, in order to give it the appearance of automatic motion, must be made privately, lest people, understanding the method too well, should cease to wonder at it. The instruments mentioned in the latter half of the same verse are explained in the commentary simply by citations from the *yantrâdhyâya*, "chapter of instruments," of the Siddhânta-Çiromaṇi (Golâdhy., pp. 111–136, published edition). We will state, as briefly as may be, their character:

The gnomon (*çanku*) needs no explanation: its construction and the method of using it have been fully exhibited in the third chapter of our treatise. The "staff-instrument" (*yashṭiyantra*) is described as follows. A circle is described upon a level surface with a radius proportioned to that of the sphere, or to tabular radius. Its cardinal points are ascertained, and its east and west and north and south diameters are drawn. From the former, at either extremity, is laid off the sine of amplitude (*agrâ*) ascertained by calculation for the given day: the points thus determined upon the circumference of the circle represent the points on the horizon at which the sun rises and sets. Another circle, with a radius proportioned to that of the calculated diurnal circle of the day (*dyujyâ*), is also described about the centre of the other, and is divided into sixty equal parts, representing the division of the sun's daily revolution into sixty nâḍîs. Into a depression at the centre, the foot of a staff (*yashṭi*), equal in length to the radius of the larger circle, is loosely inserted. When it is desired to ascertain the time of the day, this staff is pointed directly toward the sun, or in such manner that it casts no shadow; its extremity then represents the place of the sun at the moment upon the sphere. Measure, by a stick, the distance of that extremity from the point of sunrise or of sunset: this will be the chord of that part of the diurnal circle which is intercepted between the sun's actual position and the point at which he rose, or will set: the value of the corresponding arc in nâḍîs may be ascertained by applying the stick to the lesser graduated circle. The result is the time since sunrise, or till sunset.

The "wheel" (*cakra*) is a very simple instrument for obtaining, by observation, the sun's altitude and zenith-distance. It is simply a wheel, suspended by a string, graduated to degrees, having its lowest point and the extremities of its horizontal diameter distinctly marked, and with a projecting peg at the centre. When used, its edge is turned toward the sun, so that the shadow of the peg falls upon the graduated periphery, and the distances of the point where it meets the latter from the horizontal and lowest points of the wheel respectively are the required altitude and zenith-distance of the sun. From these, by the methods of the third chapter (iii. 37–39), the time may be derived.

The "arc" (*dhanus*) is the lower half of the instrument just described —or, we may also suppose, a quadrant of it; since only a quadrant is required for making the observations for which the instrument is employed.

21. By water-instruments, the vessel (*kapâla*) etc., by the peacock, man, monkey, and by stringed sand-receptacles, one may determine time accurately.

22. Quicksilver-holes, water, and cords, ropes (*çulba*), and oil and water, mercury, and sand are used in these: these applications, too, are difficult.

The instruments and methods hinted at in these verses are only partially and obscurely explained by the commentator. The *kapâla*, "cup" or "hemisphere," is doubtless the instrument which is particularly described below, in verse 23. The *nara*, "man," is also spoken of below, in verse 24, and is simply a gnomon; it is perhaps one of a particular construction and size, and so named from having about the height of a man. The peacock and monkey are obscure. The "sand-vessels" (*reṇugarbha*), which are "provided with cords" (*sasûtra*), are probably suspended instruments, of the general character of our hour-glasses. The commentator connects them also with the "peacock," as if the latter were a figure of the bird having such a vessel in his interior, and letting the sand pour out of his mouth. In illustration of the "quicksilver-holes" (*pâradârâ*) a passage is cited from the Siddhânta-Çiromaṇi (as above), giving the description of an instrument in which they are applied. It is a wheel, having on its outer edge a number of holes, of equal size, and at equal distances from one another, but upon a zig-zag line: these holes are filled half full of mercury, and stopped at the orifice: and it is claimed that the wheel will then, if supported upon an axis by a couple of props, revolve of itself. The application of this method may well enough be styled "difficult": if a machine so constructed would work, the Hindus would be entitled to the credit of having solved the problem of perpetual motion. The descriptions of one or two other somewhat similar machines are also cited in the commentary from the Siddhânta-Çiromaṇi: the only new feature worthy of notice which they contain is the application of the siphon, or bent tube, in emptying a vessel of the water it contains.

It will have been noticed that, throughout the whole of this chapter, the different parts or passages end in the middle of a verse. In the twenty-first verse the coincidence between the end of a passage and the end of a verse is re-established, but it is at the cost of such an irregularity as is nowhere else committed in the treatise: the verse is made to consist of three half-çlokas, instead of two, the whole chapter being thus allowed to contain an uneven number of lines. There are two or three very superfluous half-verses at the beginning of the chapter, the omission of any one of which would seem an easier and preferable method of restoring the regular and connected construction of the text.

23. A copper vessel, with a hole in the bottom, set in a basin of pure water, sinks sixty times in a day and night, and is an accurate hemispherical instrument.

This instrument appears to have been the one most generally and frequently in use among the Hindus for the measurement of time: it is the only one described in the Âyîn-Akbari (ii. 302). One of the common names for the sixtieth part of the day, *ghaṭî* or *ghaṭikâ*, literally "vessel," is evidently derived from it: the other, *nâḍî* or *nâḍikâ*, "reed," probably designated in the first place, and more properly, a measure of length, and not of time. A verse cited in the commentary to this passage gives the form and dimensions of the vessel used: it is to be of ten *palas'* weight of copper, six digits (*angula*) high, and of twice that width at the mouth, and is to contain sixty *palas* of water: the hole in the bottom through which it is to fill itself is to be such as will just admit a gold pin four digits long, and weighing three and a third *mâshas.* The description of the Âyîn-Akbari does not precisely agree with this; and it is, indeed, sufficiently evident that an instrument intended for such a purpose could not be accurately constructed by Hindu workmen from measurements alone, but would have to be tested by comparison with some recognized standard, or by actual use.

24. So also, the man-instrument (*narayantra*) is good in the day-time, and when the sun is clear. The best determination of time by means of determinations of the shadow has been explained.

We have already noticed above, under verse 21, that the *nara* was a simple gnomon. The explanations here referred to are, of course, those which are presented in the third chapter.

The concluding verse of the chapter is an encouragement held out to the astronomical student.

25. He who thoroughly knows the system of the planets and asterisms, and the sphere, attains the world of the planets in the succession of births, his own possessor.

CHAPTER XIV.

OF THE DIFFERENT MODES OF RECKONING TIME.

CONTENTS:—1–2, enumeration of the modes of measuring time, and general explanation of their uses; 3, solar time; 4–6, of the periods of eighty-six days; 7–11, of points and divisions in the sun's revolution; 12–13, lunar time; 14, time of the Fathers; 15, sidereal time; 15–16, of the months and their asterisms; 17, of the twelve-year cycle of Jupiter; 18–19, civil, or mean solar, time; 20–21, time of the gods, Prajâpati, and Brahma; 22–26, conclusion of the work.

1. The modes of measuring time (*mâna*) are nine, namely those of Brahma, of the gods, of the Fathers, of Prajâpati, of Jupiter, and solar (*sâura*), civil (*sâvana*), lunar, and sidereal time.

2. Of four modes, namely solar, lunar, sidereal, and civil time, practical use is made among men; by that of Jupiter is to be determined the year of the cycle of sixty years; of the rest, no use is ever made.

This chapter contains the reply of the sun's incarnation to the last of the questions addressed to him by the original recipient of his revelation (see above, xii. 8). The word *mâna*, which gives it its title of *mânâdhyâya*, and which we have translated "mode of measuring or reckoning time," literally means simply "measure": it is the same term which we have already (iv. 2–3) seen applied to designate the measured disks of the sun and moon.

3. By solar (*sâura*) time are determined the measure of the day and night, the *shaḍaçîtimukhas*, the solstice (*ayana*), the equinox (*vishuvat*), and the propitious period of the sun's entrance into a sign (*sankrânti*).

The adjective *saura*, which we translate "solar," is a secondary derivative from *sûrya*, "sun." It is applied to those divisions of time which are dependent on and determined by the sun's actual motion along the ecliptic. The "day and night" measured by it are probably those of the gods and demons respectively; see above, xii. 48–50. The solar year, as already noticed (note to i. 12–13), is sidereal, not tropical; it commences whenever the sun enters the first sign of the immovable sidereal zodiac, or when he is 10 minutes east in longitude from the star ζ Piscium. The solar month is the time during which he continues in each successive sign, or arc of 30°, reckoning from that point. The length of the solar year and month is subject only to an infinitesimal variation, due to the slow motion, of 1′ in 517 years, assumed for the sun's line of apsides (see above, i. 41–44); but it is, as has been shown above (note to i. 29–34, near the end), somewhat differently estimated by different authorities. The precise length of the solar months, as reckoned according to the Sûrya-Siddhânta, is thus stated by Warren (Kâla Sankalita, p. 69):

Duration of the several Solar Months.

No.	Name.	Duration.					Sum of duration.				
		d	n	v	'''	''''	d	n	v	'''	''''
1	Vâiçâkha,	30	55	32	2	39	30	55	32	2	39
2	Jyâishṭha,	31	24	12	2	41	62	19	44	5	20
3	Âshâḍha,	31	36	38	2	44	93	56	22	8	4
4	Çrâvaṇa,	31	28	12	2	42	125	24	34	10	46
5	Bhâdrapada,	31	2	10	2	40	156	26	44	13	26
6	Âçvina,	30	27	22	2	38	186	54	6	16	4
7	Kârttika,	29	54	7	2	35	216	48	13	18	39
8	Mârgaçîrsha,	29	30	24	2	33	246	18	37	21	12
9	Pâusha,	29	20	53	2	31	275	39	30	23	43
10	Mâgha,	29	27	16	2	32	305	6	46	26	15
11	Phâlguna,	29	48	24	2	33	334	55	10	28	48
12	Câitra,	30	20	21	2	36	365	15	31	31	24

The former passage (i. 12–13) took no note of any solar day; in this chapter, however, such a division of time is distinctly contemplated: it is also recognized by the Siddhânta-Çiromaṇi (Gaṇitâdhy., ii. 8), and seems to be, for certain uses, generally accepted. The solar day is the time during which the sun traverses each successive degree of the ecliptic, with his true motion, and its length accordingly varies with the rapidity of his motion: three hundred and sixty such days compose the sidereal year. In order to determine the solar day corresponding to any given moment, it is, of course, only necessary to calculate, by the methods of the second chapter, the sun's true longitude for that moment. Hence it is a matter of very little practical account: all the periods regarded as determined by it may be as well derived directly from the sun's longitude, without going through the form of calling its degrees days. It is thus with the equinoxes, solstices, and entrances of the sun into a sign (*sankrânti*, "entrance upon connection with"): for the latter, and for the continuance of the propitious influences which are believed to attend upon it, see below, verse 11. The *shaḍaçîtimukhas* form the subject of the next following passage.

The manuscript without commentary inserts here the following verse: "the day and night of the gods and demons, which is determined by the sun's revolution through the circle of asterisms (*bhacakra*), and the number of the Golden (*kṛta*) and other Ages, as already stated, is to be known."

4. Beginning with Libra, the *shaḍaçîtimukha* is at the end of the periods of eighty-six (*shaḍaçîti*) days, in succession: there are four of them, occurring in the signs of double character (*dvisvabhâva*);

9-26
11-22
2-18
5-14

5. Namely, at the twenty-sixth degree of Sagittarius, at the twenty-second of Pisces, at the eighteenth degree of Gemini, and at the fourteenth of Virgo.

6. From the latter point, the sixteen days of Virgo which remain are suitable for sacrifices: anything given to the Fathers (*pitaras*) in them is inexhaustible.

We have not been able to find anywhere any explanation of this curious division of the sun's path into arcs of 86°, commencing from the autumnal equinox, and leaving an odd remnant of 16° at the end of Virgo. The commentary offers nothing whatever in elucidation of their character and significance. The epithet "of double character" (*dvisvabhâva*) belongs to the four signs mentioned in verse 5; judging from the connection in which it is applied to them by Varâha-Mihira (Laghujâtaka, i. 8, in Weber's Indische Studien, ii. 278), it designates them as either variable (*cara*) or fixed (*sthira*), in some astrological sense. The term *shadaçîtimukha* is composed of *shadaçîti*, "eighty-six," and *mukha*, "mouth, face, beginning." We do not understand the meaning of the compound well enough to venture to translate it.

7. In the midst of the zodiac (*bhacakra*) are the two equinoxes (*vishuvat*), situated upon the same diameter (*samasûtraga*), and likewise the two solstices (*ayana*); these four are well known.

8. Between these are, in each case, two entrances (*sankrânti*); from the immediateness of the entrance are to be known the two feet of Vishṇu.

9. From the sun's entrance (*sankrânti*) into Capricorn, six months are his northern progress (*uttarâyaṇa*); so likewise, from the beginning of Cancer, six months are his southern progress (*dakshiṇâyana*).

10. Thence also are reckoned the seasons (*ṛtu*), the cool season (*çiçira*) and the rest, each prevailing through two signs. These twelve, commencing with Aries, are the months; of them is made up the year.

The commentator explains *samasûtraga*, like *samasûtrastha* above (xii. 52), to mean situated at opposite extremities of the same diameter of the earth, or antipodal to one another.

The technical term for the sun's entrance into a sign of the zodiac is, as noticed already, *sankrânti* (the commentary also presents the equivalent word *sankramana*); of these there take place two between each equinox and the preceding or following solstice. The latter half of verse 8 is quite obscure. The commentator appears to understand it as signifying that, in each quadrant, the entrance (*sankrânti*) immediately following the solstice or equinox is styled "Vishṇu's feet." In the earliest Hindu mythology, Vishṇu is the sun, especially considered as occupying successively the three stations of the orient horizon, the meridian, and the occident horizon; and the three steps by which he strides through the sky are his only distinctive characteristic. These three steps, then, appear under various forms in the later Vâishṇava mythology, and there is plainly some reference to them in this designation of the sun's entrances into the signs. It would seem easiest and most natural to recognize in the three signs intervening between each equinox and solstice Vishṇu's three steps, and to regard the two intermediate entrances as the marks of his feet; this may possibly be the figure intended to be conveyed by the language of the text.

The word *ṛtu* means originally and literally any determined period of time, a "season" in the most general sense of the term; but it has also been employed from very early times to designate the various divisions of the year. They were anciently reckoned as three, five, six, or seven; but the prevailing division, and the only one in use in later times, is that into six seasons, named Çiçira, Vasanta, Grîshma, Varsha, Çarad, and Hemanta, which may be represented by cool season, spring, summer, rainy season, autumn, and winter. Çiçira begins with the month Mâgha, or about the middle of January (see note to i. 48–51, and the table given below, under vv. 15–16), and each season in succession includes two solar months.

11. Multiply the number of minutes in the sun's measure (*mâna*) by sixty, and divide by his daily motion: a time equal to half the result, in nâḍîs, is propitious before the sun's entrance into a sign (*sankrânti*), and likewise after it.

The propitious influences referred to above, in verse 3, as attending upon the sun's entrance into a sign, are regarded as enduring so long as any part of his disk is upon the point of separation between the two signs. This time is found by the following proportion: as the sun's actual daily motion, in minutes, is to a day, or sixty nâḍîs, so is the measure of his disk, in minutes, to the time which it will occupy in passing the point referred to.

12. As the moon, setting out from the sun, moves from day to day eastward, that is the lunar method of reckoning time (*mâna*): a lunar day (*tithi*) is to be regarded as corresponding to twelve degrees of motion.

13. The lunar day (*tithi*), the karaṇa, the general ceremonies, marriage, shaving, and the performance of vows, fastings, and pilgrimages, are determined by lunar time.

14. Of thirty lunar days is composed the lunar month, which is declared to be a day and a night of the Fathers: the end of the month and of the half-month (*paksha*) are at their mid-day and midnight respectively.

For the *tithi*, or lunar day, see above, ii. 66: for the karaṇa, see ii. 67–69. For the month considered as the day of the *pitaras*, or manes of the departed, see note to xii. 73–77. Manu (i. 66) pronounces the day of the Fathers to be the dark half-month, or the fortnight from full moon to new moon, and their night to be the light half-month, or the fortnight from new moon to full moon. With this mode of division might be made to accord that stated in the latter part of verse 14, by rendering *madhye* "between," instead of "at the middle point of": we have translated according to the directions of the commentator.

15. The constant revolution of the circle of asterisms (*bhacakra*) is called a sidereal day. The months are to be known by the names of the asterisms (*nakshatra*), according to the conjunction (*yoga*) at the end of a lunar period (*parvan*).

16. To the months Kârttika etc. belong, as concerns the conjunction (*samayoga*), the asterisms Kṛttikâ etc., two by two: but

three months, namely the last, the next to the last, and the fifth, have triple asterisms.

The subject of sidereal time, although one of prominent importance in the present treatise, since the subdivision of the day is regulated entirely by it, is here very summarily dismissed with half a verse, while we find appended to it in the same passage matters with which it has nothing properly to do.

We have already (note to i. 48–51) had occasion to notice that the months are regarded as having received their names from the asterisms (*nakshatra*) in which the moon became full during their continuance. According to Sir William Jones (As. Res., ii. 296), it is asserted by the Hindus "that, when their lunar year was arranged by former astronomers, the moon was at the full in each month on the very day when it entered the *nakshatra*, from which that month is denominated." Whether this assertion is strictly true admits of much doubt. Our text does not imply any such claim: it only declares that the month is to be called by the name of that asterism with which the moon is in conjunction (*yoga*) at the end of the *parvan*: this latter word might mean either half of a lunar month, but is evidently to be understood here, as explained by the commentary, of the light half (*çukla paksha*) alone, so that the end of the *parvan* (*parvânta*) is equivalent to the end of the day of full moon (*pûrṇimânta*), or to the moment of opposition in longitude. Now it is evident that, owing to the incommensurability of the times of revolution of the sun and moon, as also to the revolution of the moon's line of apsides, full moon is liable to occur in succession in all the asterisms, and at all points of the zodiac; so that although, at the time when the system of names for the months originated and established itself, they were doubtless strictly applicable, they would not long continue to be so. Instead, however, of being compelled to alter continually the nomenclature of the year, we are allowed, by verse 16, to call a month Kârttika in which the full of the moon takes place either in Kṛttikâ or in Rohiṇî, and so on; the twenty-seven asterisms being distributed among the twelve months as evenly as the nature of the case admits.

At what period these names were first introduced into use is unknown. It must have been, of course, posterior to the establishment of the system of asterisms, but it was probably not much later, as the names are found in some of the earlier texts which contain those of the *nakshatras* themselves. We can hardly suppose that they were not originally applied independently to the lunar months; and certainly, no more suitable derivation could be found for the name of a lunar period than from the asterism in which the moon attained during its continuance her full beauty and perfection. In later times, as we have already seen (note to i. 48–51), the true lunar months are entirely dependent for their nomenclature upon the solar months, according to the determination of the latter, as regards their commencement and duration, by the data and methods of the modern astronomical science. There has been handed down another system of names for the months (see Colebrooke in As. Res., vii. 284; Essays, i. 201), which have nothing to do with the asterisms: whether they are to be regarded as more ancient than the others we do not know. They are—commencing with the first month of the season Vasanta, or with that one which in the other system is called Câitra—as follows: Madhu, Mâdhava, Çukra, Çuci, Nabhas, Nabhasya, Isha, Ûrja, Sahas, Sahasya, Tapas, Tapasya.

For the sake of a clearer understanding of the relations of the asterisms, months, and seasons, we present their correspondences below in a tabular form:

	Season.	Month.	Asterisms in which full moon may occur.
	Çarad.	Kârttika. (Oct.-Nov.)	Krttikâ. Rohiṇî.
3.	Hemanta.	Mârgaçîrsha. (Nov.-Dec.)	Mrgaçîrsha. Ârdrâ.
		Pâusha. (Dec.-Jan.)	Punarvasu. Pushya.
	Çiçira.	Mâgha. (Jan.-Feb.)	Âçleshâ. Maghâ.
		Phâlguna. (Feb.-Mar.)	P.-Phalgunî. U.-Phalgunî. Hasta.
1.	Vasanta.	Câitra. (Mar.-Apr.)	Citrâ. Svâtî.
		Vâiçâkha. (Apr.-May.)	Viçâkhâ. Anurâdhâ.
2.	Grîshma.	Jyâishtha. (May-June.)	Jyeshthâ. Mûla.
		Âshâdha. (June-July.)	P.-Ashâdhâ. U.-Ashâdhâ.
	Varsha.	Çrâvaṇa. (July-Aug.)	Çravaṇa. Çravishthâ.
		Bhâdrapada. (Aug.-Sept.)	Çatabhishaj. P.-Bhâdrapadâ. U.-Bhâdrapadâ.
3	Çarad.	Âçvina. (Sept.-Oct.)	Revatî. Açvinî. Bharaṇî.

Davis (As. Res., iii. 218) notices that some of the ancient astronomers have divided the asterisms somewhat differently, giving to Çrâvaṇa the three beginning with Çravaṇa, to Bhâdrapada the three beginning with Pûrva-Bhâdrapadâ, and to Âçvina only Açvinî and Bharaṇî. It seems, indeed, that the selection of the three months to which three asterisms, instead of two, were assigned, must have been made somewhat arbitrarily.

It will be noticed that in this passage Kârttika is treated as the first of the series of months, while above (v. 10) Çiçira was mentioned as the first season, and while in practice (see note to i. 48–51) Vâiçâkha is treated as the first of the solar months, and Câitra of the lunar. Another name for Mârgaçîrsha, also, is Agrahâyaṇa, which appears to mean "commencement of the year." How much significance these variations of usage may have, and what is their reason, is not known to us.

As regards Vâiçâkha and Câitra, indeed, the case is clear, and we may also regard the rank assigned to Kârttika as due to the ancient position of Kṛttikâ, as first among the lunar mansions.

17. In Vâiçâkha etc., a conjunction (*yoga*) in the dark half-month (*kṛshṇa*), on the fifteenth lunar day (*tithi*), determines in like manner the years Kârttika etc. of Jupiter, from his heliacal setting (*asta*) and rising (*udaya*).

We have already, in an early part of the treatise (i. 55), made acquaintance with a cycle of the planet Jupiter, composed of sixty years; in this verse we have introduced to our notice a second one, containing twelve years, or corresponding to a single sidereal revolution of the planet. The principle upon which its nomenclature is based is very evident. Jupiter's revolution is treated as if, like that of the sun, it determined a year, and the twelve parts, each quite nearly equalling a solar year (see note to i. 55), into which it is divided, are, by the same analogy, accounted as months, and accordingly receive the names of the solar months. The appellations thus applied to the years, in their order, we are directed to determine by the asterism (*nakshatra*) in which the planet is found to be at the time of its disappearance in the sun's rays, and its disengagement from them: for it would, of course, set and rise heliacally twelve times in each revolution, and each time about a month later than before. The name of the year, however, will not agree with that of the month in which the rising and setting occur, but will be the opposite of it, or six months farther forward or backward, since the month is named from the asterism with which the sun is in opposition, but the year of the cycle from that with which he is in conjunction. The terms in which the rule of the text is stated are not altogether unambiguous: there is no expressed grammatical connection between the two halves of the verse, and we are compelled to add in our translation the important word "determines," which links them together. The meaning, however, we take to be as follows: if, in any given year, the heliacal setting of Jupiter takes place in the month Vâiçâkha, then the asterism with which the moon is found to be in conjunction at the end of that month—which will be, of course, the asterism in which the sun is at the same time situated—will determine the name of the year, which will be Kârttika: and so on, from year to year. The expression "in like manner," in the second half of the verse, is interpreted as implying that to the years of this cycle is made the same distribution of the asterisms as to the months in the preceding passage: the second and third columns of the last table, then, will apply to the cycle, if we alter their headings respectively, from "month" to "year of the cycle," and from "asterisms in which full moon may occur" to "asterisms in which Jupiter's heliacal setting and rising may occur."

There is one untoward circumstance connected with this arrangement which is not taken into account by the text, and which appears to oppose a practical difficulty to the application of its rule. The amount of Jupiter's motion during a solar year is not precisely one sign, but perceptibly more than that, so that the mean interval between two successive heliacal settings is a little more than a solar month; and this difference accumulates so rapidly that the thirteenth setting would take place about four degrees farther eastward than the first, so that, without some system of periodical omissions of a month, the correspondence between the names of the years, if applied in regular succession, and the asterisms in which the planet disappeared would, after a few revolutions, be altogether dislocated and broken up. If the cycle were of more practical consequence, or if it were contemplated as one of the proper subjects of this treatise, we might expect to find some method of obviating this difficulty prescribed. Warren, however, in his brief account of the cycle of twelve years (Kâla Sankalita, p. 212 etc.), states that he knows of no nation or tribe making any use of it, but only finds it mentioned in the books. According to both him and Davis (As. Res., iii. 217 etc.), the cycle of twelve years is subordinate to that of sixty, the latter being divided into five such cycles, to which special names are applied, and of each of which the successive years receive in order the titles of the solar months. The appellations of the cycles themselves are those which properly belong to the years of the lustrum (*yuga*), or cycle of five years, by which, as already noticed (note to i. 56–58), the Hindus appear first to have regulated time, and effected by intercalation the coincidence of the solar and lunar years: they are Samvatsara, Parivatsara, Idâvatsara, Idvatsara, (or Anuvatsara), and Vatsara (or Idvatsara, or Udravatsara). It would appear, then, either that the cycle of sixty years was derived from and founded upon the ancient lustrum, being an imitation of its construction in time of the planet Jupiter, of which a month equals a solar year, or else that the already existing cycle had been later fancifully compared with the lustrum, and subdivided after its model into sub-cycles for years, and years for months: of these two suppositions we are inclined to regard the latter as decidedly the more probable.

18. From rising to rising of the sun, that is called civil (*sâvana*) reckoning. By that are determined the civil days (*sâvana*), and by these is the regulation of the time of sacrifice;

19. Likewise the removal of uncleanness from child-bearing etc., and the regents of days, months, and years: the mean motion of the planets, too, is computed by civil time.

The term *sâvana* we have translated "civil," as being a convenient way of distinguishing this from the other kinds of time, and as being very properly applicable to the day as reckoned in practical use from sunrise to sunrise: in the more general sense, as denoting the mode of reckoning the mean motions of the planets, and the regency of successive periods, *sâvana* corresponds to what we call "mean solar" time. The word itself seems to be a derivative from *savana*, "libation," the three daily *savanas*, or the sunrise, noon, and sunset libations, being determined by this reckoning.

20. The mutually opposed day and night of the gods (*sura*) and demons (*asura*), which has been already explained, is time of the gods, being measured by the completion of the sun's revolution.

21. The space of a Patriarchate (*manvantara*) is styled time of Prajâpati: in it is no distinction of day from night. An Æon (*kalpa*) is called time of Brahma.

It may well be said that the mode of reckoning by time of the gods has been already explained: the length of a day of the gods, with the method of its determination, has been stated and dwelt upon, in almost identical language, over and over again (see i. 13–14; xii. 45–50, 67, 74; and the interpolated verse after xiv. 3), almost as if it were so new and striking an idea as to demand and bear repeated inculcation. For the Patriarchate (*manvantara*), or period of 308,448,000 years, see above, i. 18: this is the only allusion to it as a unit of time which the treatise contains. For the Æon (*kalpa*), of 4,320,000,000 years, as constituting a day of Brahma, see above, i. 20.

The remaining verses are simply the conclusion of the treatise.

22. Thus hath been told thee that supreme mystery, lofty and wonderful, that sacred knowledge (*brahman*), most exalted, pure, all guilt destroying;

23. And the highest knowledge of the heaven, the stars, and the planets hath been exhibited: he who knoweth it thoroughly obtaineth in the worlds of the sun etc. an everlasting place.

24. With these words, taking leave of Maya, and being suitably worshipped by him, the part of the sun ascended to heaven, and entered his own disk.

25. So then Maya, having personally learned from the sun that divine knowledge, regarded himself as having attained his desire, and as purified from sin.

26. Then, too, the sages (*rshi*), learning that Maya had received from the sun this gift, drew near and surrounded him, and reverently asked the knowledge.

27. And he graciously bestowed upon them the grand system of the planets, of mysteries in the world the most wonderful, and equal to the Scripture (*brahman*).

The Sûrya-Siddhânta, in the form in which it is here presented, as accepted by Ranganâtha and fixed by his commentary, contains exactly five hundred verses. This number, of course, cannot plausibly be looked upon as altogether accidental: no one will question that the treatise has been intentionally wrought into its present compass. We have often found occasion above to point out indications, more or less distinct and unequivocal, of alterations and interpolations; and although in some cases our suspicions may not prove well-founded, there can be no reasonable doubt that the text of the treatise has undergone since its origin not unimportant extension and modification. Any farther consideration of this point we reserve for the general historical summary to be presented at the end of the Appendix.

APPENDIX:

CONTAINING ADDITIONAL NOTES AND TABLES, CALCULATIONS OF ECLIPSES, A STELLAR MAP, ETC.

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1. p. 142. The name *siddhânta*, by which the astronomical text-books are generally called, has, by derivation and original meaning, nothing to do with astronomy, but signifies simply "established conclusion;" and it is variously applied to other uses in the Sanskrit literature. It may not be uninteresting to present here a summary view of the existing astronomical literature of the Hindus, as derived from such sources of information upon the subject as are accessible to us, even though such a view must necessarily be imperfect and incomplete. We commence by giving a list of works furnished to the translator, at his request, by the native Professor of Mathematics in the Sanskrit College at Pûna, and which may be taken as representing the knowledge possessed, and the opinions held, by the learned of Western India at the present time. Along with it is offered the list of nine treatises given in the modern Sanskrit Encyclopedia, the Çabdakalpadruma, as entitled to the name of Siddhânta. The longer list was intended to be arranged chronologically; the remarks appended to the names of treatises are those of its compiler.

1. Brahma-Siddhânta.	1. Brahma-Siddhânta.
2. Sûrya-Siddhânta.	2. Sûrya-Siddhânta.
3. Soma-Siddhânta.	3. Soma-Siddhânta.
4. Vâsishṭha-Siddhânta.	4. Bṛhaspati-Siddhânta.
5. Romaka-Siddhânta.	5. Garga-Siddhânta.
6. Pâulastya-Siddhânta.	6. Nârada-Siddhânta.
7. Bṛhaspati-Siddhânta.	7. Pârâçara-Siddhanta.
8. Garga-Siddhânta.	8. Pâulastya-Siddhânta.
9. Vyâsa-Siddhânta.	9. Vasishṭha-Siddhânta.

10. Pârâçara-Siddhânta.
11. Bhoja-Siddhânta; earlier than the Çiromaṇi.
12. Varâha-Siddhânta; earlier than the Çiromaṇi.
13. Brahmagupta-Siddhânta; earlier than the Çiromaṇi.
14. Siddhânta-Çiromaṇi; *çake* 1072 [A.D. 1150].
15. Sundara-Siddhânta; about 400 years ago.
16. Tattva-Viveka-Siddhânta; in the time of the reign of Jaya Sinha, about 250 [years ago.
17. Sârvabhâuma-Siddhânta; in the time of the reign of Jaya Sinha.
18. Laghu-Ârya-Siddhânta } earlier than the Çiromaṇi.
19. Bṛhad-Ârya-Siddhânta } earlier than the Çiromaṇi.

It is obvious that these lists are uncritically constructed, and that neither of them is of a nature to yield valuable information without additional explanations. The one is most unreasonably curt, and seems founded on the principle of allowing the title of Siddhânta to no work which is the acknowledged composition of a merely human author, while the other contains treatises of very heterogeneous character and value: and neither list distinguishes works now actually in existence from those which have become lost, and those of which the existence at any period is questionable. A more satisfactory account of the Siddhânta literature may be drawn up from the notices contained in the writings of Western scholars, and especially from the various essays of Colebrooke. For what we shall here offer, he is our main authority.

In the present imperfect state of our knowledge of the subject, there is perhaps no better method of classifying the Hindu astronomical treatises than by dividing them into four classes, as follows: first, those which profess to be a revelation on the part of some superhuman being; second, those which are attributed to ancient and renowned sages, or to other supposititious or impersonal authors; third, those regarded as the works of actual authors, astronomers of an early and uncertain period; fourth, later texts, of known date and authorship, and mostly of a less independent and original character.

I. The first class comprises the Brahma, Sûrya, Soma, Bṛhaspati, and Nârada Siddhântas.

1. *Brahma-Siddhânta.* The earliest treatise bearing this name is said to have formed a part of the Vishṇudharmottara Purâṇa, a work which seems to be long since lost, and scarcely remembered except in connection with the Siddhânta. The latter, too, is only known by a few citations in astronomical writings, and by the treatise of Brahmagupta (see below, third class) founded upon it. Another work laying claim to the same title is that which we have many times cited above as the Çâkalya-Sanhitâ. Sanhitâ, "text, comprehensive work," is a term employed to denote a complete course of astronomy, astrology, horoscopy, etc.: this treatise, according to the manuscript in our possession, forms the second division (*praçna*) of such a course. It professes to be revealed by Brahma to the semi-divine personage Nârada. Of its relation to the Sûrya-Siddhânta we have spoken above (note to viii. 10–12). It does not appear to be referred to as an independent work in either of the native lists we have given.

2. *Sûrya-Siddhânta.* This is the treatise of which the translation has been given above, and of which, accordingly, we do not need to speak here more particularly.

3. *Soma-Siddhânta.* Judging from its title, this work must profess to derive its origin from the moon (*soma*), as the preceding from the sun (*sûrya*). Bentley speaks of it as following in the main the system of the Sûrya-Siddhânta. There is a manuscript of it in the Berlin Library (Weber's Catalogue, No. 840), and Colebrooke seems also to have had it in his hands.

4. *Bṛhaspati-Siddhânta.* Bṛhaspati is the name of a divine personage, priest and teacher of the gods, as also of the planet Jupiter. No work bearing this name is mentioned, so far as we can ascertain, by any European scholar, although Bṛhaspati is not infrequently referred to in native writings as an authority in astronomical matters.

5. *Nârada-Siddhânta.* A Nâradî-Sanhitâ, or course of astrology, in the Berlin Library (Weber, No. 862), and an occasional reference to

Nârada, among other divine or mythical personages, as an astronomical authority, are all the indications we find justifying the introduction of this name into the list of the Çabdakalpadruma.

II. In the second class we include the Gârga, Vyâsa, Pârâçara, Pâuliça, Pâulastya, and Vâsishtha Siddhântas. Garga, Parâçara, Vyâsa, Pulastya, and Vasishtha are prominent among the sages of the ancient period of Hindu history: the two latter are of the number of those who give name to the stars in Ursa Major (they are β and ζ respectively). They cannot possibly have been the veritable authors of Siddhântas, or works presenting the modern astronomical system of the Hindus: but—and this seems to be especially the case with regard to Garga and Parâçara—one and another of them may have distinguished themselves in connection with the older science, and so have furnished some ground for the part attributed to them by the later tradition, and for the fathering of astronomical works upon them.

1. *Garga-Siddhânta.* Astronomical treatises and commentaries upon them occasionally offer citations from Gârga (see, for instance, Colebrooke's Essays, ii. 356; Sir William Jones in As. Res., ii. 397), but of a Siddhânta, or text-book of astronomy, bearing his name, we find nowhere any mention excepting in these lists.

2. *Vyâsa-Siddhânta.* This name, too, is known to us only from the list above given.

3. *Pârâçara-Siddhânta.* According to Bentley, the second chapter of the Ârya-Siddhânta contains an extract from this work, in which are stated the elements of the mean motions of the planets adopted by it. The work itself appears to be lost; unless, indeed, it may have been contained in a manuscript of the Mackenzie Collection, which in Wilson's Catalogue (i. 120) is called Vriddha-Parâsara, and said to be "a system of astrology, attributed to Parâsara, the father of Vyâsa."

4. *Pâuliça-Siddhânta.* The planetary elements of this treatise also are preserved in later commentaries, and are stated by Bentley and Colebrooke. We have noticed above (note to i. 4–6) that al-Bîrûnî attributes it to Paulus the Greek; whence Weber (Ind. Lit., p. 226) conjectures that it was founded upon the *Εἰσαγωγή* of Paulus Alexandrinus. If this account of its origin be correct, the Puliça to whom the later Hindus attribute it is a fictitious personage, whose name is manufactured out of Pâuliça. The work, it will be seen, is not mentioned in either of the lists we have given, its place appearing to be taken by the Pulastya-Siddhânta. According to the Hindu tradition, the school represented by the Pâuliça-Siddhânta was the rival of that of Âryabhaṭṭa.

5. *Pulastya-Siddhânta.* Of this Siddhânta we find mention only in such native lists as omit the preceding. Hence we are led to conjecture that the two names may indicate the same work; an attempt, founded upon the similarity of the names, having been made by some to attribute the Pâuliça-Siddhânta to a known and acknowledged Hindu sage.

6. *Vasishṭha-Siddhânta.* This work is spoken of as actually in existence by both Colebrooke and Bentley, and the latter states its system to correspond with that of the Sûrya-Siddhânta. More than one treatise bearing the name is referred to, the older one being of unknown authorship, and the other a later compilation founded upon this, by

Vishnu-candra, who is said also to have derived his material in part from Âryabhaṭṭa. A copy of a Vṛddha-Vasishṭha-Siddhânta formed a part of the Mackenzie Collection (Wilson's Catalogue, i. 121).

III. To the third class may be assigned the Siddhântas of Âryabhaṭṭa, Varâha-mihira, and Brahmagupta, and the Romaka-Siddhânta, as well as the later version of the Vasishṭha-Siddhânta, last spoken of. The first three names are those of greatest prominence and highest importance in the history of Hindu astronomical science, and there is every reason to believe that the sages who bore them lived about the time when the modern system may be supposed to have received its final and fully developed form, or during the fifth and sixth centuries of our era.

1. *Ârya-Siddhânta.* The two principal works of Âryabhaṭṭa appear to have been originally entitled the Âryâshṭaçata, "work of eight hundred verses," and Daçagîtikâ, "work of ten cantos." Colebrooke knew neither of them excepting by citations in other astronomical text-books and commentaries. Bentley had in his hands two treatises which he calls the Ârya-Siddhânta and the Laghu-Ârya-Siddhânta, which are possibly identical with those above named.* The Berlin Library also contains (Weber, No. 834) a work which professes to be a commentary on the Daçagîtikâ.

2. *Varâha-Siddhânta.* The only distinctively astronomical work of Varâha-mihira appears to have been his Pañca-siddhântikâ, or Compendium of Five Astronomies, of which we have already spoken (note to i. 2–3), and which was founded upon the Brahma, Sûrya, Pâuliça, Vasishṭha, and Romaka Siddhântas. It is supposed to be no longer in existence, although the astrological works of the same author have been carefully preserved, and are without difficulty accessible.

3. *Brahma-Siddhânta.* The proper title of the work composed by Brahmagupta, upon the foundation of an earlier treatise bearing this name, is Brahma-sphuṭa-Siddhânta, "corrected Brahma-Siddhânta," but the word *sphuṭa*, "corrected," is frequently omitted in citing it, as has been our own usage in the notes to the Sûrya-Siddhânta. Colebrooke possessed an imperfect copy of it, and it was also in Bentley's possession. Upon it was professedly founded, in the main, the Siddhânta-Çiromaṇi of Bhâskara.

4. *Romaka-Siddhânta.* Of the name of this treatise, the only one we have thus far met with which is not derived from a real or supposed author, we have spoken in the note to i. 4–6. It is said by Colebrooke to be by Çrîshena, and to have been founded in part upon the original Vasishṭha-Siddhânta; its early date is proved by its being one of those treated as authorities by Varâha-mihira. No copy of it seems to have have been discovered in later times.

Our list also mentions a Bhoja-Siddhânta, probably referring to some astronomical work published during the reign, and under the patronage, of Râja Bhoja Deva, of Dhârâ, in the tenth or eleventh century of our era.

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* See an article by Fitz-Edward Hall, Esq., On the Ârya-Siddhânta, in a later part of this volume.

IV. Our fourth class is headed by the Siddhânta-Çiromaṇi, written in the twelfth century by Bhâskara Âcârya, and founded upon the Brahma-Siddhânta of Brahmagupta. Our numerous references to it and citations from it indicate the prominent and important position which it occupies in the modern astronomical literature of India. For a description of the numerous commentaries upon it, see Colebrooke's Hindu Algebra, note A (Essays, ii. 450 etc.).

The longer of the lists given above mentions two or three other works of yet later date. Among them the Siddhânta-Sundara is the most ancient, having been composed by Jñâna-râja at the beginning of the sixteenth century. The Graha-Lâghava is a treatise of the same class, and is highly considered and much used throughout India, although omitted from the Pûna list. It is of nearly the same date with the work last spoken of, being the composition of Ganeça, and dated *çake* 1442 (A. D. 1520). The Siddhânta Tattva-Viveka, more usually styled the Tattva-Viveka simply, is a century later: it was written by Kamalâkara, about A. D. 1620. The Siddhânta-Sârvabhâuma dates from very nearly the same period, and is the work of Muniçvara, who is also the author of a commentary on the Çiromaṇi, and the son of Ranganâtha, the commentator on the Sûrya-Siddhânta.

This class of astronomical writings might be almost indefinitely extended, but the works which have been mentioned appear to be the most authoritative and important.

Of all the treatises whose names we have cited, we know of but three which have as yet been published—the Sûrya-Siddhânta, the Siddhânta-Çiromaṇi, and the Graha-Lâghava; the two latter under the auspices of the School-Book Society of Calcutta. Prof. Hall's edition of the Sûrya-Siddhânta, to which reference is made in our Introductory Note, has been completed by the addition of a fourth Fasciculus since our own publication was commenced, so that we have been able to avail ourselves of its valuable assistance throughout.

2. p. 142. Ranganâtha, in the verses with which he closes his commentary, states it to have been completed on the same day with the birth of his son Muniçvara, in the *çâka* year 1525, or A. D. 1603. For his relationship to other well-known authors or commentators of astronomical treatises, see Colebrooke's Essays, ii. 452 etc. Other commentators on the Sûrya-Siddhânta mentioned by Colebrooke are Nṛsinha, who wrote but a few years later than Ranganâtha, and Bhûdhara and Dâdâ Bhâï, whose age is not stated. The Mackenzie collection (see Wilson's Catalogue, p. 118 etc.) contained commentaries on the whole or parts of the same text by Mallikârjuna, Yellaya, an Âryabhaṭṭa, Mammabhaṭṭa, and Tammaya.

3. p. 143. As no especially suitable opportunity has hitherto offered itself for giving in our notes the synonymy of the names of the planets, we present here all the appellations by which they are known in the text of the Sûrya-Siddhânta.

The sun is called by the following names derived from roots signifying "to shine": *arka, bhânu, ravi, vivasvant, sûrya;* also *savitar*, literally "enlivener, generator"; *bhâskara*, "light-maker"; *dinakara* and

Angâraka

divâkara, "day-maker"; and *tigmânçu* and *tîkshṇânçu*, "having hot or piercing rays."

The moon, besides her ordinary names *indu*, *candra*, *vidhu*, is styled *niçâkara*, "night-maker"; *niçâpati*, "lord of night"; *anushṇagu*, *çîtagu*, *çîtânçu*, *çîtadîdhiti*, *himaraçmi*, *himânçu*, *himadîdhiti*, "having cool rays"; and *çaçin* and *çaçânka*, "marked with a hare": the Hindu fancy sees the figure of this animal in the spots on the moon's disk. The name *soma* nowhere directly occurs, but it is implied in the title *sâumya* given to Mercury.

Mercury is styled *jña* and *budha*, "wise, knowing"; also *çaçija* and *sâumya*, "son of the moon." The reason of neither appellation is obvious. It will be seen below that the moon, the sun, and the earth have each of them one of the lesser planets assigned to it as its son: why Mercury, Saturn, and Mars were selected, and on what grounds their respective parentage was given them, is hitherto entirely unknown.

Venus has one name, *çukra*, "brilliant," which is derived from her actual character: she is also known as *bhṛgu*, which is the name of one of the most noted of the ancient sages, or as *bhṛguja* or *bhârgava*, "son of Bhṛgu."

Mars has likewise a single appellation, *angâraka*, "coal," which is given him on account of his fiery burning light: all his other titles, namely *kuja*, *bhûputra*, *bhûmiputra*, *bhûsuta*, *bhâuma*, mark him as "son of the earth."

Jupiter is known as *bṛhaspati*, which is, as already more than once noticed, the name of a divine personage, priest and teacher among the gods; the word means originally "lord of worship." The planet also receives some of his titles, namely *guru*, "preceptor," and *amarejya*, "teacher of the immortals." The only other name given to it, *jîva*, "living," is of doubtful origin.

Saturn has two appellations, each represented by several forms; namely "son of the sun," or *arkaja*, *ârki*, *sûryatanaya*; and "the slow-moving," or *manda*, *çani*, *çanâiçcara*.

All these names, it will be noticed, are of native Hindu origin, and have nothing to do with the appellations given by other nations to the planets. In the Hindu astrological writings, however, even those of a very early period (see Weber's Ind. Stud., ii. 261), appear, along with these, other titles which are evidently derived from those of the Greeks.

4. p. 146. We have everywhere cited Bentley's work on Hindu astronomy according to the London edition of it (8vo., 1825), the only one to which we have had access.

In a few instances, where we have not specified the part of Bhâskara's Siddhânta-Çiromaṇi to which we refer, the Gaṇitâdhyâya, or properly astronomical portion of it, is intended.

5. p. 161. For the convenience of any who may desire to make a more detailed examination of the elements of the mean motions of the planets adopted in this treatise, and to work out the results deducible from them, we present them in the following table in a more exact form. We give the mean time of sidereal revolution, in mean solar days, and the amount of mean motion, in seconds, during a day, and also during a Julian year, of 365¼ mean solar days.

Mean Motions of the Planets.

Planet.	Time of sidereal revolution.	Mean daily motion.	Mean yearly motion
	d	″	″
Sun,	365.25875648	3,548.16956	1,295,968.931
Mercury,	87.96970228	14,732.34496	5,380,988.996
Venus,	224.69856755	5,767.72702	2,106,662.295
Mars,	686.99749394	1,886.46976	689,033.081
Jupiter,	4,332.32065235	299.14683	109,263.381
Saturn,	10,765.77307461	120.38151	43,969.346
Moon,			
sider. rev.,	27.32167416	47,434.86773	17,325,585.437
synod. rev.,	29.53058795	43,886.69817	16,029,616.507
apsis,	3,232.09367415	400.97848	146,457.389
node,	6,794.39983121	190.74532	69,669.730

6. p. 161. The system of the Sûrya-Siddhânta, so far as concerns the mean motions of the planets, the date of the last general conjunction, and the frequency of its recurrence, is also that of the Çâkalya-Sanhitâ. It is likewise presented, according to Bentley (Hind. Astr., p. 116), by the Soma and Vasishtha Siddhântas. So far as can be gathered from the elements of the Pâuliça and Laghu-Ârya Siddhântas, as reported by Colebrooke and Bentley, these treatises, too, followed a similar system; the revolutions of the planets in an Age, as stated by them, where they differ from those of the Sûrya-Siddhânta, always differ by a number which is a multiple of four. Some of the astronomical text-books, however, have constructed their systems in a somewhat different manner. Thus the Siddhânta-Çiromani, following the authority of Brahmagupta and of the earlier Brahma-Siddhânta, makes the planets commence their motions together at the star ζ Piscium at the very commencement of the Æon, and return to a general conjunction at the same point only after the lapse of the whole period of 4,320,000,000 years. The same is the case with the Ârya and Pârâçara Siddhântas: they too, as reported by Bentley (Hind. Astr., pp. 148, 150), state the revolutions of the planets for the whole Æon only, and in numbers which have no common divisor, so that they assume no briefer cycle of conjunction. But they all, at the same time, take special notice of the commencement of the Iron Age, which they make to begin at the moment of mean sunrise at Lankâ, and manage to effect very nearly a general conjunction at the time of its occurrence, as is shown by the table at the end of this note, in which are presented the positions of all the planets, and of the moon's apsis and node, as stated by them for that moment.

We insert these data here, because they seem to us to furnish ground for important conclusions respecting the comparative antiquity of the two systems. The commencement of the Iron Age, which to the one is of cardinal importance as an astronomical epoch, is to the other simply a chronological era, having no astronomical significance. Now if, as has been shown in our notes to be altogether probable, that epoch is in fact of astronomical origin, being arrived at by retrospective calculation of the planetary motions, we can hardly avoid the conclusion that the system which presents it in its true character is the more ancient and original. This conclusion is strengthened by the notice taken of the epoch by the Siddhânta-Çiromaṇi and its kindred treatises. We do not see how their treatment of it is to be explained, excepting upon the supposition that a general conjunction at that time was already so firmly established as a fundamental dogma of the Hindu astronomy, that they were compelled, even while rejecting the theory of brief cycles and recurring conjunctions, to pay it homage by so constructing their elements that these should exhibit at least a very near approach to a conjunction at the moment. We are clearly of opinion, therefore, that, apart from all consideration of the relative age of the separate treatises, the system represented by the Sûrya-Siddhânta is the more ancient.

Mean Places of the Planets, 6 *o'c A. M. at Ujjayinî, Feb.* 18*th, B. C.* 3102.

Planet.	Siddhânta-Çiromaṇi.				Ârya-Siddhânta.				Pârâçara-Siddhânta.			
	s	°	′	″	s	°	′	″	s	°	′	″
Sun,	0	0	0	0	0	0	0	0	0	0	0	0
Mercury,	11	27	24	29	11	21	21	36	11	21	17	17
Venus,	11	28	42	14	11	27	7	12	11	26	58	34
Mars,	11	29	3	50	0	0	0	0	11	29	14	38
Jupiter,	11	29	27	36	11	27	7	12	11	27	2	53
Saturn,	11	28	46	34	0	0	0	0	11	28	57	22
Moon,	0	0	0	0	0	0	0	0	0	0	10	48
" apsis,	4	5	29	46	4	3	50	24	4	5	12	29
" node,	5	3	12	58	5	2	38	24	5	2	49	12

7. p. 164. We present in the annexed table, in the same form as above (note 5), the elements of the mean motions of the planets as corrected by the *bîja*.

Mean Motions of the Planets, as corrected by the bîja.

Planet.	Time of sidereal revolution.	Mean daily motion.	Mean yearly motion.
	d	″	″
Mercury,	87.96978075	14,732.33182	5,380,984.196
Venus,	224.69895152	5,767.71717	2,106,658.695
Jupiter,	4,332.41581277	299.14026	109,260.981
Saturn,	10,764.89171783	120.39136	43,972.946
Moon's apsis,	3,232.12015592	400.97519	146,456.189
" node,	6,794.28280845	190.74861	69,670.930

8. p. 166. At the time when we wrote our note, we had not observed that Bentley himself explains, in a foot-note to page 117 of his work, this apparent error. In the case of Mercury, since the number of revolutions as stated by the text of our treatise did not yield him the result which he desired, he has quietly taken the liberty of altering it from 17,937,060 to 17,937,024, assuming, as his justification, an error of the copyists which has not the slightest plausibility, and ignoring the fact that the correctness of the former number is avouched by its occurrence in other treatises. It is highly characteristic of Bentley, that he has thus arbitrarily amended one of the data upon which he rests the most important of his general conclusions, a conclusion which, but for such emendation, would be not a little weakened or modified. Any one can see for himself, upon referring to our table given on page 188, with how much plausibility Bentley is able to deduce, from the dates of its fourth column, the year A. D. 1091 as that of the composition of the Sûrya-Siddhânta. We have been solicitous to allow Bentley all the credit we possibly could for his labors upon the Hindu astronomy, but we cannot avoid expressing here our settled conviction that, as an authority upon the subject, he is hardly more to be trusted than Bailly himself, that his work must be used with the extremest caution, and that his determination of the successive epochs in the history of astronomical science in India is from beginning to end utterly worthless.

9. p. 167. We have not fulfilled our promise to recur in the eighth chapter to the subject of the sun's error of position, because we felt ourselves incompetent to cast at present any valuable light upon it. Nothing but a careful and thorough sifting and comparison of all the earliest treatises, together with the traditions preserved by the commentators, and the practical methods of construction of the calendar, is likely to settle the question as to the manner in which the elements of the planetary orbits were originally made up.

10. p. 168. In making out our comparative table of sidereal revolutions, we have calculated the column for Ptolemy as we conceive that he would himself have calculated it, had he been called upon to do so. M. Biot, having in view an object different from ours, has carefully revised Ptolemy's processes (see his Traité Élémentaire d'Astronomie Physique, 3me éd., v. 37–71), and has deduced from the latter's original data what he regards as the true times of sidereal revolution of the primary planets furnished by them; his periods are accordingly slightly different from those presented in our table.

Colebrooke (As. Res., xii. 246 ; Essays, ii. 412) has also given a comparative table of the daily motions of the planets, but has committed in it the gross error of setting side by side the sidereal rates of motion of the Hindu text-books and the tropical rates of Ptolemy and Lalande. Of course, his data being incommensurable, the conclusions he draws from their comparison are erroneous.

11. p. 171. We add, in the following table, a comparison of the positions of the apsides and nodes of the planets as stated in our treatise—being those which are adopted, with unimportant variations, by all the schools of Hindu astronomy—with those laid down by Ptolemy in his Syntaxis. The latter we give as stated by Ptolemy for his own period, without reducing them to their value in distances from the initial point of the Hindu sphere. The actual distance of that point, or of the vernal equinox of A. D. 560, from the vernal equinox of Ptolemy's time, is about $5\frac{1}{2}°$. We should remark also that Ptolemy does not state expressly and distinctly the positions of the nodes: we derive them from the rules given by him, in the sixth chapter of his thirteenth Book, for calculating the latitude of the planets: not being, however, altogether confident of our correct understanding and interpretation of those rules.

Positions of the Apsides and Nodes of the Planets.

Planet.	Sûrya-Siddhânta.		Ptolemy.		Difference.	
Apsides:	°	'	°	'	°	'
Sun,	77	15	65	30	+ 11	45
Mercury,	220	26	190	0	+ 30	26
Venus,	79	49	55	0	+ 24	49
Mars,	130	1	115	30	+ 14	31
Jupiter,	171	16	161	0	+ 10	16
Saturn,	236	38	233	0	+ 3	38
Nodes:						
Mercury,	20	44	10	0	+ 10	44
Venus,	59	45	55	0	+ 4	45
Mars,	40	4	25	30	+ 14	34
Jupiter,	79	41	51	0	+ 28	41
Saturn,	100	25	183	0	− 82	35

It will be perceived that the differences here are not so great as to exclude the supposition of a connected origin. We do not ourselves believe that the Hindus were ever sufficiently skilled in observation, or in the discussion of the results of observation, to be able to derive such data for themselves, or even intelligently to modify and improve them, when obtained from other sources. In order, however, fully to understand the relation of the Hindu to the Greek science in this part, we require to know, first, what were the positions assigned to the apsides and nodes by Greek astronomers prior to Ptolemy, and secondly, what were their actual positions at the periods in question. Upon the first point no information appears to have been handed down to our times; and as regards the other, we have not found any modern determination of the desired data, and are not ourselves at present in a situation to undertake so intricate and laborious a calculation.

12. p. 173. The era of the *kali yuga*, or Iron Age, is not in practical use among the Hindus of the present day: two others, of a less remote date, are ordinarily employed by them in the giving of dates. These are styled the eras of Çâlivâhana and of Vikramâditya respectively, from two sovereigns so named: their origin and historical significance are matters of much doubt and controversy. The years of the era of Çâlivâhana are, according to Warren (Kâla Sankalita, p. 381 and elsewhere), solar years: their reckoning commences after the lapse of 3179 complete years of the Iron Age, or early in April, A. D. 78: the 1782nd year, accordingly, coinciding with the 4961st of the Iron Age, commenced, as is shown by the table on p. 174, April 12th, 1859, and ended April 11th, 1860. The years of this era are generally cited as *çaka* or *çâka* years. In the other era, the luni-solar reckoning is followed (Warren, as above, p. 391 and elsewhere); and its first year began with the 3045th of the Iron Age, or early in 58 B. C.: its 1962nd year, coinciding with the 4961st of the remoter era, commenced (see table on p.

174) April 4th, 1859, and ended March 22nd, 1860. The years of this era are called and quoted as *samvatsara* years, or, by abbreviation, simply *samvat*.

13. p. 183. M. Vivien de St. Martin (in Julien's Mémoires de Hiouen-Thsang, ii. 258) supposes the value of the *li* in use in China during the seventh century to have been about 329 metres, or 1080 English feet. This would make the values of the three kinds of yojana mentioned by the Buddhist traveller to be 8⅙, 6⅕, and 3⅓ English miles respectively.

14. p. 188. In the first table upon this page, we have, by an oversight, given the earth's heliocentric longitude, instead of the sun's geocentric longitude. To the sun's place as stated, accordingly, should be added 180°.

15. p. 196. M. Biot (Journal des Savants, 1859, p. 409) suggests that the Hindus, like Albategnius, obtained their sines directly from the chords of Hipparchus or Ptolemy. This may not be an altogether impossible supposition, but it is at least an unnecessary one, for they certainly had geometry enough, at the time of the elaboration of their astronomical system, to construct their table independently. Our notes have presented Delambre's view of the method of its construction and the reason of its limitation to arcs which are multiples of 3° 45′. We cannot but feel, however, upon maturer consideration, that the correctness of that view is very questionable; that the Hindus could probably have made out a more complete table if they had chosen to do so; and that a sufficient reason is found for their selection of the arc of 3° 45′ in the fact that it is a natural subdivision of a recognized unit, the arc of 30°, while the series of twenty-four sines was sufficiently full and accurate for their uses. We have been at the pains to calculate the complete series of Hindu sines from Ptolemy's table of chords, assuming the value of radius to be 3438′, in order to test the question whether there were any correspondence of errors between them which should prove the one to be derived from the other: our results are as follows. In five of the instances (the 14th, 15th, 19th, 22nd, and 23rd sines of the table) in which the value of the Hindu sine exceeds the truth, Ptolemy supports the error; in the other three cases (the 16th, 17th, and 18th sines), Ptolemy affords the correct value; to the 6th sine, also, which by the Hindus is made too small, Ptolemy's table gives its true value, but the next following sine he makes too great (namely 1520.59, which would give 1521, instead of 1520); this is his only independent error. The evidence yielded by the comparison may be regarded as not altogether unequivocal.

For the benefit of any who may desire to make practical use of the Hindu sines, in calculations conducted according to the processes of the Sûrya-Siddhânta, we give, upon the opposite page, a more detailed table of them than has been presented hitherto, with such sets of differences annexed as will enable the calculator readily to find the sine of any given arc, or the reverse, without resorting to the laborious proportions by which the text contemplates that they should in each case be determined. Such a table we have ourselves found highly useful, and even almost indispensable, in connection with our own calculations.

Table of Hindu Sines, with Differences.

Arc.	Sine.	Diff.	
° ′	′	′	′
0	0		
1	60		
2	120	1	1.000
3	180		
3 45	225		
4	239.93	1	0.996
5	299.67	2	1.991
6	359.40	3	2.987
		4	3.982
7	419.13	5	4.978
7 30	449		
8	478.60	1	0.987
9	537.80	2	1.973
		3	2.960
10	597	4	3.947
11	656.20	5	4.933
11 15	671	1	0.973
12	714.80	2	1.947
13	773.20	3	2.920
14	831.60	4	3.893
		5	4.867
15	890	1	0.956
16	947.33	2	1.911
17	1004.67	3	2.867
18	1062	4	3.822
		5	4.778
18 45	1105		
19	1119	1	0.933
20	1175	2	1.867
		3	2.800
21	1231	4	3.733
22	1287	5	4.667
22 30	1315		
23	1342.33	1	0.911
24	1397	2	1.822
		3	2.733
25	1451.67	4	3.644
26	1506.33	5	4.556
26 15	1520		
27	1559.80	1	0.884
28	1612.87	2	1.769
		3	2.653
29	1665.94	4	3.538
30	1719	5	4.422

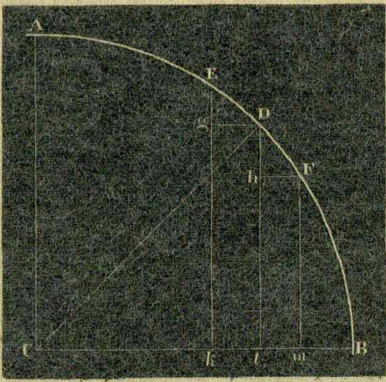
Arc.	Sine.	Diff.	
° ′	′	′	′
30	1719	1	0.849
31	1769.93	2	1.698
32	1820.87	3	2.547
		4	3.396
33	1871.80	5	4.244
33 45	1910		
34	1922.20	1	0.813
35	1971	2	1.627
36	2019.80	3	2.440
		4	3.253
37	2068.60	5	4.067
37 30	2093		
38	2116.20	1	0.773
39	2162.60	2	1.547
		3	2.320
40	2209	4	3.093
41	2255.40	5	3.867
41 15	2267		
42	2299.80	1	0.729
		2	1.458
43	2343.52	3	2.187
44	2387.27	4	2.916
		5	3.644
45	2431		
46	2472.07	1	0.684
		2	1.369
47	2513.14	3	2.053
48	2554.21	4	2.738
		5	3.422
48 45	2585		
49	2594.53	1	0.636
50	2632.67	2	1.271
		3	1.907
51	2670.80	4	2.542
52	2708.93	5	3.178
52 30	2728		
53	2745.47	1	0.582
54	2780.40	2	1.164
		3	1.747
55	2815.33	4	2.329
56	2850.27	5	2.911
56 15	2859		
57	2882.80	1	0.529
		2	1.058
58	2914.53	3	1.587
59	2946.26	4	2.116
60	2978	5	2.644

Arc.	Sine.	Diff.	
° ′	′	′	′
60	2978	1	0.471
61	3006.27	2	0.942
62	3034.58	3	1.413
		4	1.884
63	3062.80	5	2.356
63 45	3084		
64	3090.20	1	0.413
65	3115	2	0.827
66	3139.80	3	1.240
		4	1.653
67	3164.60	5	2.067
67 30	3177		
68	3187.53	1	0.351
69	3208.60	2	0.702
		3	1.053
70	3229.67	4	1.404
71	3250.74	5	1.756
71 15	3256		
72	3269	1	0.289
		2	0.578
73	3286.33	3	0.867
74	3303.67	4	1.156
		5	1.444
75	3321		
76	3334.60	1	0.227
		2	0.453
77	3348.20	3	0.680
78	3361.80	4	0.907
		5	1.133
78 45	3372		
79	3374.47	1	0.164
80	3384.33	2	0.329
		3	0.493
81	3394.20	4	0.658
82	3404.07	5	0.822
82 30	3409		
83	3411.93	1	0.098
84	3417.80	2	0.196
		3	0.293
85	3423.67	4	0.391
86	3429.53	5	0.489
86 15	3431		
87	3432.40	1	0.031
		2	0.062
88	3434.27	3	0.093
89	3436.13	4	0.124
90	3438	5	0.156

In explaining how the Hindus may have arrived at their empirical rule, as laid down in verses 15 and 16, for the development of the series of sines, we have also, as mentioned in our note, followed the guidance of Delambre. Prof. Newton, however, is of opinion that the rule in question was probably obtained by direct geometrical demonstration, in some such method as the following, which is much more in accordance with the mathematical processes exhibited or implied in other parts of the Sûrya-Siddhânta.

In the quadrant A B (Fig. 34), let B F, B D, and B E be three arcs, of which each exceeds its predecessor by the equal increment D F or D E; and let F m, D l, and E k be their sines, increasing by the unequal differences D h and E g. Now as E D and D F are small arcs (they are shown in the figure of three times the proportional length of the arcs of difference of the Hindu table), E D g and D F h may be regarded as plane triangles, and the angles made by C D at D as right angles: hence the angles E D g and C D l are equal, the triangles E D g and C D l are similar, and E D : E g : : C D : C l; or E g = E D.C l ÷ C D. In like manner, D h = E D.C m ÷ C D. Therefore D h − E g = E D.$l\,m$ ÷ C D; and E g, which is the amount by which E k exceeds D l, equals D h − (E D.$l\,m$ ÷ C D). But, by similarity of the triangles C D l and D F h, F h, or $l\,m$, equals E D.D l ÷ C D; and hence E D.$l\,m$ ÷ C D = (E D^2 ÷ C D^2) D l, or (E D ÷ C D)^2 D l. Now when E D equals 225′ and C D 3438′, E D ÷ C D = $\frac{1}{15}$ nearly (or exactly $\frac{1}{15.28}$), and (E D ÷ C D)^2 = $\frac{1}{225}$ nearly (more exactly, $\frac{1}{233.48}$). Hence E k = D l + D h − $\frac{1}{225}$ D l, which is equivalent to the Hindu rule.

Fig. 34.



When we wrote the note to the passage of the text relating to the sines, we assumed that the rule as there stated would give the series of sines, having found upon trial that it held good for the first few terms of the series. But, it having been pointed out to us by Prof. Newton that the adoption of $\frac{1}{15}$ as the value of E D ÷ C D could not but lead to palpably erroneous results, we carried our calculations farther, and found that only five of the sines following the first one can be deduced from it by the processes prescribed; that with the seventh sine begins a discordance between the table and the result of calculation by the rule, which goes on increasing to the end, where it amounts to as much as 70′ in the value obtained for radius.

This untoward circumstance, which may be regarded as a trait highly characteristic of a Hindu astronomical treatise, seems to us rather to favor the opinion that the rule is the result of construction and demonstration, and not empirically deduced from a consideration of the actual second differences. In the latter case we should more naturally suppose that it would have been tested throughout by actual trial; while, if it had been arrived at in the manner above explained, an application of it to the first few members only of the series might more easily have been accepted as a sufficient test of its correctness.

16. p. 203. We are not sure that the name *bhuja* may not originally and properly belong rather to the arc than to its chord or sine. It comes from a root *bhuj*, "bend," and signifies primarily "a bend, curve," being applied also to designate the arm on account of the latter's suppleness or flexibility. The word *koṭi* also most frequently means "the end or horn of a bow." We might, then, look upon the relations of the arc (*dhanus*, *câpa*, *kârmuka*) and its parts and appurtenances as follows. The whole arc taken into account is (Fig. 2, p. 203) Q R S: of this, B R C is the *bhuja*, curve or bow proper, while B Q and C S are its two *koṭis* or horns: B C is the chord or bow-string (*jyâ* etc.), or, more distinctively, the *bhujajyâ;* which name, by substitution for *jyârdha*, is also applied to either of its halves, B H or H C: B F or C L is in like manner the *koṭijyâ;* R H, finally, the versed sine, is the "arrow" (*çara*, *ishu*); by this name it is often known in other treatises, although not once so styled in this Siddhânta. If this view be correct, the terms *bhuja* and *koṭi* as applied to the base and perpendicular of a right-angled triangle, are given them on account of their relation to one another as sine and cosine, while the synonyms of *bhuja*, namely *bâhu* and *dos*, are employed on account only of their agreement with it in the signification "arm," and not in that which gives it its true application. For *koṭi* the treatise affords no synonyms.

17. p. 207. M. Delambre, in his History of Ancient Astronomy (i. 462 etc.), has subjected to a detailed examination the rules of the Sûrya-Siddhânta for the calculation of the equations of the centre for the sun and moon, has reduced them to a single formula, and has calculated for each degree of a quadrant the values of the equations, comparing them with those furnished by the Hindu tables, as reported by Davis (As. Res., ii. 255–256). M. Biot has more recently, in the Journal des Savants for 1859 (p. 384 etc.), taken up the same subject anew, especially pointing out, and illustrating by figures and calculations, the error of the Hindus in assuming the variation of the equation to be the same in all the four quadrants of mean revolution.

18. p. 220. Neither Delambre nor Biot (both as above cited), nor any other western savant who has treated of the Hindu astronomy, has found any means of accounting for the variation of dimensions of the planetary epicycles. In its present form and extent, indeed, it seems to defy explanation: we can only conjecture that it may be an unintelligent and reasonless extension to all the planets, and to both classes of epicycles, of a correction originally devised and applied only in one or two special cases. According to Colebrooke (As. Res., xii. 235 etc.; Essays, ii. 400 etc.), there is discordance among the different Hindu authorities upon this point. Âryabhaṭṭa agrees with the Sûrya-Siddhânta throughout; Brahmagupta and Bhâskara make the epicycles only of Venus and Mars variable; Muniçvara, in the Siddhânta-Sârvabhâuma, regards all the epicycles as invariable.

19. p. 236. Our suggestion of a possible derivation of the term *yoga* from the "sum" of the longitudes of the sun and moon is unquestionably erroneous. That term is to be understood here in the sense of "junction, conjunction," and the conception upon which is founded its application to the periods in question is that of a conjunction (*yoga*) of the moon with the twenty-seven asterisms (*nakshatra*) in their order, or her successive continuance in their respective portions. Only the system is divorced from any actual connection with the asterisms; for while the latter are stellar groups, having fixed positions in the heavens, they are here treated as if the twenty-seven-fold division of the ecliptic founded upon them had no natural limits, but was to be reckoned from the actual position of the sun at any given moment.

According to Warren (Kâla Sankalita, p. 74), the names of the twenty-seven yogas, as given by us on page 236, are also applied by the Hindus to the junction-stars (*yogatârâ*) of the asterisms (with the omission, of course, of Abhijit): for which see the notes to the eighth chapter. This fact we do not find noticed elsewhere; possibly the usage is a local one only.

Of the twenty-eight yogas of the other system, to which the Sûrya-Siddhânta makes no reference, the names are given by Colebrooke as follows:

1. Ânanda.
2. Kâladanda.
3. Dhûmra.
4. Prajâpati.
5. Sâumya.
6. Dhvânksha.
7. Dhvaja.
8. Çrîvatsa.
9. Vajra.
10. Mudgara.
11. Chattra.
12. Mâitra.
13. Mânasa.
14. Padma.
15. Lambaka.
16. Utpâta.
17. Mṛtyu.
18. Kâṇa.
19. Siddhi.
20. Çubha.
21. Amṛta.
22. Musala.
23. Gada.
24. Mâtanga.
25. Râkshasa.
26. Cara.
27. Sthira.
28. Pravardha.

Colebrooke says farther: "The foregoing list is extracted from the Ratnamâlâ of Çrîpati. He adds the rule by which the yogas are regulated. On a Sunday, the nakshatras answer to the yogas in their natural order; viz. Açvinî to Ânanda, Bharaṇî to Kâladaṇda, etc. But, on a Monday, the first yoga (Ânanda) corresponds to Mṛgaçiras, the second to Ârdrâ, and so forth. On a Tuesday, the nakshatra which answers to the first yoga is Âçleshâ; on Wednesday, Hasta; on Thursday, Anurâdhâ; on Friday, Uttara-Ashâḍhâ; and on Saturday, Çatabhishaj."

This is by no means a clear and sufficient explanation of the character and use of the system, yet we seem to see distinctly from it that this, no less than the other system, is cut off from any actual connection with the twenty-eight asterisms, since the succession of the yogas is made to depend upon the day of the week, while the week stands in no constant and definable relation to the motion of the moon.

20. p. 246. In stating that the Sûrya-Siddhânta furnished no hint of the precession excepting in this passage, we failed to notice that in one other place, namely in connection with the rules for finding the time when the declinations of the sun and moon are equal (xi. 6), the precession is distinctly ordered to be calculated, and in terms which contain an evident reference to those in which the fact of the precession is here stated. The exception, however, is one which goes to prove, rather than overthrow, the general rule: the process in which we are for once favored with explicit directions upon the point in question is the one of all others in the work the most trivial, and the chapter which contains it furnishes, as pointed out by us in the notes, good reason to suspect late alterations and interpolations. We do not, then, regard the statement made in our note as requiring to be either retracted or seriously modified. Nor do we, although fully appreciating the difficulty of assuming that the original elaborators of the general Hindu system can have been ignorant of, or ignored, the precession, regret the force and distinctness with which we have stated the circumstances which appear to favor that assumption. Whether it be true or false, there is much in connection with the subject which is strange, and demands explanation: and that can only be satisfactorily given when there shall have been attained a more thorough comprehension of the early history and the varying forms of the science in India.

21. p. 258. The commentary frequently styles the sine of altitude *mahâçanku*, "great gnomon," to distinguish it from the *çanku*, "gnomon."

22. p. 275. Our statement that the Sûrya-Siddhânta employs only the term *graha* to designate the planets requires a slight modification. In one instance (ii. 69) they are called *khacârin*, and in one other (ix. 9) *khacara*, both words signifying "moving in the ether" (see xii. 23, 81).

23. p. 282. This use of the word *prâcî*, "east, east point," appears to be taken from the projections of eclipses, as directed to be drawn in the sixth chapter. Thus, in the figure there given (Fig. 27, p. 301), E M and *v* M represent the directions of the equator and ecliptic with reference to one another at the moment of first contact, and E and *v* are the east-points (*prâcî*) of those lines respectively: the arc E *v*, or the "interval of the two east-points," is the measure of the angle which the two lines make with one another at the given time.

24. p. 285. As promised above, we present here, by way of appendix to the fourth chapter of our translation and notes, a

Calculation, according to the Data and Methods of the Sûrya-Siddhânta, of the Lunar Eclipse of February 6th, 1860,

for the latitude and longitude of Washington.

Bailly, in his work on the Hindu astronomy (p. 355 etc.), presents several calculations of eclipses by Hindu methods, namely of the lunar eclipse of July 29th, 1730, of the lunar eclipse of June 17th, 1704, and of the solar eclipse of Nov. 29th, 1704. But, owing to his imperfect comprehension of the character and meaning of many of the processes, and owing to his incessant use of Hindu terms in the most barbarous transcriptions, without explanations, his intended illustrations are only with difficulty intelligible, and are exceedingly irksome to study. Davis, in his first valuable article in the Asiatic Researches (ii. 273 etc.), has also furnished a calculation of a lunar eclipse, as made by native astronomers, comparing their results, obtained by several different methods, with the actual elements of the eclipse, as given by the Nautical Almanac. As it seemed desirable to give a like practical illustration of the Hindu methods of calculation, in connection with this fuller exposition of their foundation and meaning, and by way of an additional test of the accuracy of the results which the system is in condition to furnish, we have selected for the purpose the partial eclipse of the moon which occurred on the evening of Feb. 6th, 1860. Our calculations are made according to the elements of our text alone, without adding, like Davis, the correction of the *bîja*, since our object is to illustrate the text itself, and not the modern system as altered from it. The course of the successive steps of our processes may not everywhere strictly accord with that which would be pursued by a native astronomer, as we take the rules of the text and apply them according to our own conception of their connection.

We omit the preliminary tentative processes, and conceive ourselves to have ascertained that, at the time of full moon in the month Mâgha, I. A. 4961 (see page 174), or *samvat* 1917 (see add. note 12), the moon will be eclipsed.

I. To find the sum of days (*ahargaṇa, dinarâçi*) for mean midnight next preceding full moon.

The sixth day of February, 1860, being the day of full moon (*pûrnimâ*), is the fifteenth day of the first, or light, half of the lunar month Mâgha, the eleventh month of the year, as is shown by the table on page 174. The time, then, for which we are to find the sum of days, is $4960^y\ 10^m\ 14^d$, reckoning (i. 56) only from the commencement of the Iron Age. For this period the sum of days, as found by the processes already sufficiently illustrated in the notes to i. 48–51, is 1,811,981 days.

II. To find the mean longitude of the sun and moon, and of the moon's apsis.

The proportions (i. 53)

$$1{,}577{,}917{,}828 : 1{,}811{,}981 :: \begin{cases} 4{,}320{,}000 : 4960^{rev}\ 9^s\ 23^\circ\ 17'\ 1'' \\ 57{,}753{,}336 : 66{,}320^{rev}\ 3^s\ 9^\circ\ 44'\ 19'' \\ 488{,}203 : 561^{rev}\ 1^s\ 13^\circ\ 43'\ 1'' \end{cases}$$

give us—rejecting whole revolutions, and deducting 3^s from the motion of the moon's apsis, for its position at the epoch (see note to i. 56–58)—the mean longitudes required. These are for the time of mean midnight at Ujjayinî: to find them for mean midnight at Washington, which is distant from Ujjayinî $1671^y.28$, upon a parallel of latitude $3936^y.75$ in circumference (note to i. 63–65), we add to the position of each $\frac{1671.28}{3936.75}$ or .42453 of its mean motion during a sidereal day. This correction is styled the *deçântaraphala*. We have, then,

	Long. at Ujjay.		Correction.		Long. at Wash'n.
Sun,	$9^s\ 23^\circ\ 17'\ 1''$	+	$25'\ 2''$	=	$9^s\ 23^\circ\ 42'\ 3''$
Moon,	$3^s\ 9^\circ\ 44'\ 19'$	+	$5^\circ\ 34'\ 43''$	=	$3^s\ 15^\circ\ 19'\ 2''$
Moon's apsis,	$10^s\ 13^\circ\ 43'\ 1''$	+	$2'\ 50''$	=	$10^s\ 13^\circ\ 45'\ 51''$

The place of the sun's apsis remains as already found for Jan. 1st (note to ii. 39):

Longitude of sun's apsis,	2s 17° 17′ 24″

In applying here the correction for difference of meridian, as well as in all other processes of the whole calculation into which the amounts of motion of the planets etc. during fractions of a day enter as elements, we have derived those amounts from the motions during a sidereal day, and not, as in the illustrative processes of our notes, during a mean solar day. The divisions of the day given in the text (i. 11–12) are distinctly stated to be those of sidereal time, and all the rules of the treatise are constructed accordingly (see, for instance, ii. 59). It is evident, then, that in making any proportion in which is involved the amount of motion during 60 nâḍis, that amount is to be regarded as the motion during a sidereal day only. In overlooking in our notes the difference between the two, we have followed the example of all the illustrations of Hindu methods of calculation known to us. The difference is, indeed, in a Hindu process, of very small account; but we have preferred, in making this calculation, to follow what we conceive to be the exacter method. The mean motions during a sidereal day of the bodies concerned in a lunar eclipse are as follows:

Sun,	58′ 58″ 28‴ 55⁗
Moon,	13° 8′ 25″ 21‴ 21⁗
Moon's apsis,	6′ 39″ 53‴ 1⁗
Moon's node,	3′ 10″ 13‴ 28⁗

III. To find the true longitudes and motions of the sun and moon:

1. To find the sun's true longitude (note to ii. 39):

Longitude of sun's apsis,	2s 17° 17′ 24″
deduct sun's mean longitude (ii. 29),	9s 23° 42′ 3″
Sun's mean anomaly (*kendra*),	4s 23° 35′ 21″
Arc determining the sine (*bhuja*—ii. 30),	36° 25′
Sine of sun's mean anomaly (*bhujajyâ*),	2040′
Corrected epicycle (ii. 38),	13° 48′
Equation (*bhujajyâphala*—ii. 39),	+ 1° 18′
add to sun's mean longitude,	9s 23° 42′
Sun's true longitude,	9s 25° 0′

2. To find the moon's true longitude (note to ii. 39):

Longitude of moon's apsis,	10s 13° 45′ 51″
deduct moon's mean longitude,	3s 15° 19′ 2″
Moon's mean anomaly,	6s 28° 26′ 49″
Arc determining the sine,	28° 27′
Sine of moon's mean anomaly,	1637′
Corrected epicycle,	31° 50′
Equation,	− 2° 25′
deduct from moon's mean longitude,	3s 15° 19′
Moon's true longitude,	3s 12° 54′

3. To find the sun's true rate of motion (ii. 48–49):

Sun's mean motion in 60 nâḍîs,	58′ 58″
Sine of sun's mean anomaly,	2040′
Difference of sines,	183′
Daily increase of sine of anomaly,	47′ 58″
Equation of motion,	+ 1′ 50″
add to sun's mean motion,	58′ 58″
Sun's true motion,	60′ 48″

4. To find the moon's true rate of motion (ii. 47–49):

Moon's mean motion in 60 nâḍîs,	788′ 25″
deduct motion of apsis (ii. 47),	6′ 40″
Daily increase of moon's mean anomaly,	781′ 45″
Sine of moon's mean anomaly,	1637′
Difference of sines,	199′
Daily increase of sine of anomaly,	691′ 25″
Equation of motion,	+ 61′ 8″
add to moon's mean motion,	788′ 25″
Moon's true motion,	849′ 33″

IV. To find the interval between the given instant of midnight and the end of the half-month, or the moment of opposition in longitude of the sun and moon, which is the middle of the eclipse.

At the instant of mean midnight preceding full moon, we have found the true longitudes of the sun and moon, and their distance in longitude, to be as follows:

Sun's true longitude,	$9^s\ 25^\circ\ 0'$
Moon's do.,	$3^s\ 12^\circ\ 54'$
Distance in longitude,	$6^s\ 12^\circ\ 6'$

Hence we see that the moon has still 12° 6′ to gain upon the sun. We have also found their true rates of motion, and the difference of those rates, to be as follows:

Moon's true motion,	849′ 33″
Sun's do.,	60′ 48″
Moon's daily gain,	788′ 45″

Now we make the proportion: if the moon in 60 nâḍîs gains upon the sun 788′ 45″, in how many nâḍîs will she gain her present distance in longitude from the sun? or

$$788'\ 45'' : 60^n :: 726' : 55^n\ 13^v\ 3^p$$

It thus appears that the time of opposition is $55^n\ 13^v\ 3^p$ after mean midnight of Feb. 5–6. This result, however, requires correction, for the moon's motion has become sensibly accelerated during so long an interval, and we find, upon calculation, that she is then 2′ past the point of opposition. A repetition of the same process shows that it is necessary to deduct $10^v\ 3^p$ from the time stated. Then, at $55^n\ 3^v$ after mean midnight, we have as follows:

Sun's mean longitude,	$9^s\ 24^\circ\ 36'$
Equation of place,	$+\ 1^\circ\ 20'$
Sun's true longitude,	$9^s\ 25^\circ\ 56'$
Moon's mean longitude,	$3^s\ 27^\circ\ 22'$
Longitude of apsis,	$10^s\ 13^\circ\ 52'$
Equation of moon's place,	$-1^\circ\ 26'$
Moon's true longitude,	$3^s\ 25^\circ\ 56'$

By the same process as before, the true motions of the two planets at the moment of opposition are found to be:

Sun's true motion,	$60'\ 48''$
Moon's do.	$854'\ 36''$

It would have been better to adopt, as the starting-point of our calculations, the mean midnight following, instead of that preceding, the opposition of the sun and moon, because in that case, the interval to the moment of opposition being so much less, it might have been found by a single process, not requiring farther correction. The same change would have enabled us to follow strictly the rule given in ii. 66 for finding the end of the lunar day; which rule we were obliged above to apply in a somewhat modified form, because a little more than one whole lunar day was found to intervene between the given midnight and the moment of opposition.

V. To determine the instant of local time corresponding to the middle of the eclipse.

What we have thus far found is the interval between mean midnight and the moment of opposition. But since Hindu time is practically reckoned from true sunrise to true sunrise, we have now, in order to determine at what time the eclipse will take place, to ascertain the interval between mean midnight and true sunrise.

In order to this, we require first to know the equation of time, or the difference between mean midnight and true or apparent midnight, which is the moment when the sun actually crosses the inferior meridian. As concerns this correction, we have deviated somewhat from the method contemplated by the text. It is there prescribed (ii. 46) that, so soon as the sun's equation of the centre has been determined, there should at once be calculated from it, and applied to the longitude of the two planets, a correction representing, in terms of their motion, the equation of time; so that the distance of the moment of opposition from mean midnight does not directly enter into account at all. We have preferred to follow the course we have taken, in order to bring out and illustrate more fully the utter inadequacy of the prescribed method of making allowance for the equation of time, to which we have already briefly referred in the note to ii. 46. The method in question is virtually as follows: the sun being found at the given midnight to be $1^\circ\ 18'$, or $78'$, in advance of his mean place, the equation of time may be ascertained by this proportion: as a whole circle is to a sidereal day, so is the sun's equation of place to the time by which his true transit will precede or follow his mean transit; or, in the present case,

$$21{,}600' : 60_n :: 78' : 0^n\ 13_v$$

which gives us 13 vinâḍîs, or $5\frac{1}{2}$ minutes, as the value of the equation. But this is assuming that the sun's motion takes place along the equator, instead of along the ecliptic, which is so grossly and palpably erroneous that we wonder how the Hindus could have tolerated a process which implied it. Their own methods furnish the means of making a vastly more correct determination of the equation in question. The mean longitude of the sun at the given midnight is—after adding to it the amount of the precession, as determined farther on—$10^s\ 14°\ 7'$: hence, if the sun were $10^s\ 14°\ 7'$ distant upon the equator from the vernal equinox, or if he had that amount of right ascension, mean and true midnight would coincide. But he is actually at $10^s\ 15°\ 25'$ of longitude. If, then, we ascertain what point on the equator will pass the meridian at the same time with that point of the ecliptic, its distance from the sun's mean place in right ascension will be the equation of time required. This may be accomplished as follows. The sun is in the eleventh sign, of which the equivalent in right ascension (iii. 42–45) is 1795^p: his distance from its commencement is $15°\ 25'$, or $925'$. Hence the proportion (ii. 46)

$$1800' : 1795^p :: 925' : 922^p$$

gives us 922^p as the ascensional equivalent of the part of the eleventh sign traversed by the sun (*bhuktâsavas*). Now add together the

Ascensional equivalents	of three quadrants,	$16{,}200^p$
do.	of the tenth sign,	$1{,}935^p$
do.	of the part of the eleventh sign traversed,	922^p
their sum is		$19{,}057^p$

which is equal to $10^s\ 17°\ 37'$; this, then, is the sun's true right ascension. The difference between it and his mean right ascension, $10^s\ 14°\ 7'$, is $3°\ 30'$, of which the equivalent in sidereal time is 210^p or 35^v, or 14 minutes. This, which is more than two and a half times as much as the value formerly found for the equation, is quite nearly correct; its actual amount for Feb. 6th being given by the Nautical Almanac as $14^m\ 20^s$.

There is not, among all the processes taught in the Sûrya-Siddhânta, another one of so inexcusably bungling a character as this, while the means lay so ready at hand for making it tolerably exact.

In going on to calculate the local time of the eclipse, we shall adopt the valuation of the equation of time given by the Hindu method, or 13^v, but we shall reserve the distance of the phases of the eclipse from midnight, free from this constant error of about 10^m, for final comparison with the like data given by our modern tables.

To find the local time, we must first ascertain (ii. 59) the length of the sun's day, from midnight to midnight, and in order to this we need to know in what sign the sun is. Hence we require

1. To determine the amount of precession for the given date.

By iii. 9–12, the proportion

$$1{,}577{,}917{,}828^d : 600^{rev} :: 1{,}811{,}981^d : 0^{rev}\ 8^s\ 8°\ 2'\ 14''.6$$

gives us $248°\ 2'\ 14''.6$ as the part of a revolution accomplished by the movable point. Of this, the part determining the sine is 68° 2′ 14″.6. Then the farther proportion

$$10 : 3 :: 68^\circ\ 2'\ 14''.6 : 20^\circ\ 24'\ 44''$$

gives us 20° 24′ 44″ as the amount of the precession. Now, then, to the

Sun's true longitude,	$9^s\ 25^\circ\ 56'$
add the precession,	$20^\circ\ 25'$
Sun's distance from vernal equinox,	$10^s\ 16^\circ\ 21'$

This quantity is often called *sâyanâ sûrya*; that is to say, "the sun's longitude with the precession (*ayana*) added."

The sun is accordingly in the eleventh sign, of which the ascensional equivalent is 1795^p. His daily motion has been found to be 60′ 48″. Hence the proportion (ii. 59)

$$1800' : 1795^p :: 60'\ 48'' : 60^p.64$$

gives us 61^p, or $10^v\ 1^p$, as the excess of the sun's day over a true sidereal day of 60 nâḍîs: its length is accordingly $60^n\ 10^v\ 1^p$, or $21,661^p$.

Next we desire to know how much of this day passed between midnight and sunrise, and for this purpose we have

2. To find the sun's ascensional difference (*cara*).

a. To ascertain the sun's declination, and its sine and versed sine.

The sun's longitude, with precession added (*sâyana sûrya*),	$10^s\ 16^\circ\ 21'$
Arc determining the sine (*bhuja*),	$43^\circ\ 39'$
Sine,	$2372'$

Now, then, the proportion (ii. 28)

$$3438' : 1397' :: 2372' : 964'$$

gives us 964′ as the sine of declination (*krântijyâ*); the corresponding arc (ii. 33) is 16° 17′ S; its versed sine (ii. 31–32) is 139′.

b. To find the radius of the sun's diurnal circle (ii. 60).

From radius,	$3438'$
deduct versed sine of declination,	$139'$
Radius of diurnal circle (*dinavyâsadala, dyujyâ*),	$3299'$

c. To find the earth-sine (ii. 61).

The measure of the equinoctial shadow at Washington is (see note to ii. 61–63) $9^d.68$. The proportion, then,

$$12^d : 9^d.68 :: 964' :: 778'$$

shows the value of the earth-sine (*kshitijyâ, kujyâ*) to be 778′.

d. To find the sun's ascensional difference (ii. 61–62).

The proportion

$$3299' : 3438' :: 778' : 811'$$

gives the sine of ascensional difference (*carajyâ*), which is 811′. The corresponding arc, or the sun's ascensional difference (*cara, caradala*), is 13° 39′, or 819^p.

3. To find the time from midnight to sunrise.

The sun's declination being south, the ascensional difference is to be added (ii. 62–63) to the quarter of the sun's complete day, to give the length of the half-night. That is to say,

Quarter of sun's complete day (21,661p ÷ 4),	5,415p
Sun's ascensional difference,	819p
Sun's half-night,	6,234p

The interval between true midnight and true sunrise is therefore 6,234p, or $17^n\ 19^v$. That from sunrise till noon (a quantity required in later processes) is found in like manner by subtracting the ascensional difference from the quarter-day: it is 4596p.

Now then, finally,

Time of opposition, reckoned from mean midnight,	$55^n\ 3^v$
deduct equation of time,	13^v
do. reckoned from true midnight,	$54^n\ 50^v$
deduct interval till sunrise,	$17^n\ 19^v$
do. reckoned from sunrise,	$37^n\ 31^v$

The time at which the opposition of the sun and moon in longitude takes place, or the middle of the eclipse, is accordingly, by civil reckoning at Washington, $37^n\ 31^v$.

VI. To determine the diameters of the sun, moon, and shadow.

1. To find the sun's apparent diameter.

The sun's mean motion in a sidereal day being 58′ 58″, his true motion at the time of the eclipse being 60′ 48″, and his mean diameter 6500 yojanas, we find, by the proportion (iv. 2)

$$58'\ 58'' : 60'\ 48'' :: 6500^y : 6702^y.81$$

that the sun covers of his mean orbit, at the time of the eclipse, 6702.81 yojanas. This is reduced to its value upon the moon's mean orbit by the proportion (iv. 2)

$$57{,}753{,}336 : 4{,}320{,}000 :: 6702^y.81 : 501^y.37$$

And upon dividing the result, 501.37 yojanas, by 15 (iv. 3), we find the sun's apparent diameter to be 33′ 25″.

2. To find the moon's apparent diameter.

In like manner as before, the proportion (iv. 2)

$$788'\ 25'' : 854'\ 36 :: 480^y : 520^y.3$$

shows us that the moon's corrected diameter is 520.3 yojanas. This also, divided by 15 (iv. 3), gives the value of the moon's apparent diameter in arc: it is 34′ 41″.

3. To find the diameter of the earth's shadow.

The following proportion (iv. 4),

$$788'\ 25'' : 854'\ 36'' :: 1600^y : 1734^y.3$$

determines the value of the earth's corrected diameter (*sûci*) to be 1734.3 yojanas.

Again, from the

Sun's corrected diameter,	6702y.81
deduct the earth's diameter (iv. 4),	1600
remains	5102y.81

and this remainder, when reduced by the following proportion (iv. 5),

6500y : 480y : : 5102y.81 : 376y.8

gives us the excess of the earth's corrected diameter (*sûci*) over the diameter of the shadow on the moon's mean orbit. Hence, from the

Earth's corrected diameter,	1734y.3
deduct last result,	376y.8
Diameter of shadow,	1357y.5
divide by	15
Diameter of shadow in arc,	90′ 30″

VII. To determine the moon's latitude at the middle of the eclipse, and the amount of greatest obscuration.

The proportion (i. 53)

1,577,917,828 : 232,238 : : 1,811,981 : 266^{rev} 8^{s} 7° 28′ 25″

gives us the amount of retrograde motion of the moon's node since the commencement of the Iron Age. Deducting from this 6^{s}, for the position of the node at that time (note to i. 56–58), and taking the complement to a whole circle, we have

Longitude of moon's node, mean midnight, at Ujj.,	9^{s} 22° 31′ 35″
deduct for difference of meridian,	1′ 21″
Longitude of moon's node, mean midnight, at Wash'n,	9^{s} 22° 30′ 14″
deduct motion during 55^{n} 3^{v},	2′ 55″
Longitude of moon's node at moment of opposition,	9^{s} 22° 27′ 19″
subtract from moon's longitude (ii. 57),	3^{s} 25° 56′
Moon's distance from node,	6^{s} 3° 29′
Arc determining the sine (*bhuja*),	3° 29′
Sine,	209′

Hence the proportion

3438′ : 270′ : : 209′ : 16′ 25″

gives us, as the moon's latitude at the moment of opposition, 16′ 25″ S.

Now, then, by iv. 10–11,

Semi-diameter of eclipsed body (34′ 41″÷2),	17′ 22″
do. of eclipsing body (90′ 30″÷2),	45′ 15″
their sum,	62′ 37″
deduct moon's latitude,	16′ 25″
Amount of greatest obscuration (*grâsa*),	46′ 12″

and since this amount is greater than the diameter of the eclipsed body, it is evident that the eclipse is a total one.

This is a most unfortunate result for the Hindu calculation to yield; for, in point of fact, the eclipse in question is only a partial one, obscuring about four-fifths of the diameter of the moon's disk. The source of the error lies mainly in the misplacement, relatively to the sun and moon, of the moon's node, and the consequent false value found for the moon's latitude. The latter quantity actually amounts, at the time of opposition, to 35′ 42″, or more than twice the value given it by the Hindu processes. And it will be seen, on referring to the table on p. 188, that the relative error in the place of the moon's node, having been accumulating for seven centuries, is now about 3½°, and so reduces, by more than half, the true distance of the moon from her node. We have tried whether the admission of the correction of the *bîja* would better the result, but that is not the case: the error of position is still (see the table) nearly 2°, and the moon's latitude is increased only to 24′ 11″, so that the eclipse still appears to be total. It is evidently high time that a new correction of *bîja* be applied by the Hindu astronomers to their elements, at least to such as enter into the calculation of eclipses.

VIII. To find the duration of the eclipse, and of total obscuration, and the times of contact, immersion, emergence, and separation.

Diameter of the eclipsing body, the shadow,	90′ 30″	90′ 30″
do. eclipsed body, the moon,	34′ 41″	34′ 41″
Sum and difference,	125′ 11″	55′ 49″
Half-sum and half-difference (C M and C N, Fig. 21, p. 277),	62′ 35″	27′ 55″
Squares of do.,	3919′	724′
deduct square of latitude,	269′	269′
remain,	3650′	455′
Square roots of remainders (C A and C B),	60′ 25″	21′ 19″

In order to reduce these quantities to time, we need first to ascertain the difference of the true daily motions of the sun and moon at the given moment:

Moon's true daily motion,	854′ 36″
Sun's do.,	60′ 48″
Moon's gain in a day,	793′ 48″

Hence the proportions (iv. 13)

$$793' \, 48'' : 60^{n} :: \begin{cases} 60' \, 25'' : 4^{n} \, 34^{v} \\ 21' \, 19'' : 1^{n} \, 36^{v} \, 4^{p} \end{cases}$$

give us the half-duration of the eclipse as 4^{n} 34^{v}, and the half-time of total obscuration as 1^{n} 36^{v} 4^{p}, supposing the moon's latitude to remain constant through the whole continuance of the eclipse. We now proceed to correct these results for the moon's motion in latitude. And first, as regards the half-duration. We calculate the amount of motion of the moon and of her node during the mean half-duration by the following proportions (iv. 14):

$$60^{n} : 854' \, 36'' :: 4^{n} \, 34^{v} : 1^{\circ} \, 5' \, 2''$$
$$60^{n} : 3' \, 10'' :: 4^{n} \, 34^{v} : 14''$$

Farther,

To and from moon's long. at opposition,	$3^s\ 25^\circ\ 56'$	$3^s\ 25^\circ\ 56'$
add and subtract motion during half-duration,	$1^\circ\ 5'$	$1^\circ\ 5'$
Moon's long. at end and beginning of eclipse,	$3^s\ 27^\circ\ 1'$	$3^s\ 24^\circ\ 51'$
From and to long. of node at opposition,	$9^s\ 22^\circ\ 27'\ 21''$	$9^s\ 22^\circ\ 27'\ 21''$
subtract and add motion during half-duration,	$14''$	$14''$
Long. of node at end and beginning of eclipse,	$9^s\ 22^\circ\ 27'$	$9^s\ 22^\circ\ 28'$
Moon's distance from node,	$6^s\ 4^\circ\ 34'$	$6^s\ 2^\circ\ 23'$
Arc determining sine,	$4^\circ\ 34'$	$2^\circ\ 23'$
Sine,	$274'$	$143'$
Moon's latitude at end and beginning of eclipse,	$21'\ 31''$ S.	$11'\ 14''$ S.

From these valuations of the latitude we now proceed to calculate anew, in the same manner as before, the half-durations, as follows:

Square of half-sum of diameters,	$3919'$	$3919'$
deduct squares of latitude,	$463'$	$126'$
remain,	$3456'$	$3793'$
Square roots of remainders,	$58'\ 47''$	$61'\ 35''$

And the proportions

$$793'\ 48'' : 60^n :: \begin{cases} 58'\ 47'' : 4^n\ 26^v\ 3^p \\ 61'\ 35'' : 4^n\ 39^v\ 2^p \end{cases}$$

give us the corrected values of the intervals between opposition and contact and separation respectively, or the former and latter half-durations, as $4^n\ 39^v\ 2^p$ and $4^n\ 26^v\ 3^p$.

The text contemplates the repetition of this corrective process, if still greater accuracy be required in the results attained: we have not thought it worth while to carry the calculation any farther, as a second correction would be of altogether insignificant amount.

By a like process, the former and latter half-times of total obscuration, and the moon's latitude at immersion and emergence, are found to be as follows:

Moon's latitude at immersion and emergence,	$14'\ 36''$	$18'\ 13''$
Half-times of total obscuration,	$1^n\ 42^v\ 3^p$	$1^n\ 29^v\ 4^p$

By adding the two halves we obtain

Duration of the eclipse (*sthiti*),	$9^n\ 5^v\ 5^p$
do. of total obscuration (*vimarda*),	$3^n\ 12^v\ 1^p$

And by subtracting and adding the half-times of duration and of total obscuration from and to the time of opposition (iv. 16–17), we obtain the following scheme for the successive phases of the eclipse:

Phase.	Time of occurrence: after mean midnight.	after sunrise.
First contact,	$50^n\ 23^v\ 4^p$	$32^n\ 51^v\ 4^p$
Immersion,	$53^n\ 20^v\ 3^p$	$35^n\ 48^v\ 3^p$
Middle of eclipse,	$55^n\ 3^v\ 0^p$	$37^n\ 31^v\ 0^p$
Emergence,	$56^n\ 32^v\ 4^p$	$39^n\ 0^v\ 4^p$
Last contact,	$59^n\ 29^v\ 3^p$	$41^n\ 57^v\ 3^p$

The proper calculation of the eclipse is now completed. If, however, we desire to project it, we have still to determine the *valana*, or deflection of the ecliptic from an east and west line, for its different phases, as also the scale of projection. We will therefore proceed to calculate them, deferring to the end of the whole process any comparison of the results we have obtained with those given by modern astronomical science.

IX. To calculate the deflection of the ecliptic from an east and west line (*valana*) for the middle, beginning, and end of the eclipse.

1. For the middle of the eclipse.

a. To find the length of the moon's day and night respectively at the given time.

Moon's longitude at opposition,	$3^s\ 25°\ 56'$
Precession,	$20°\ 25'$
Moon's distance from vernal equinox,	$4^s\ 16°\ 21'$
Arc determining sine,	$43°\ 39'$
Sine,	$2372'$

The moon's declination is then found by the following proportion (ii. 28):

$$3438' : 1397' :: 2372' : 964' = \sin 16°\ 17'$$

Now, from

Moon's declination	$16°\ 17'$ N.
deduct her latitude (ii. 58),	$16'$ S.
Moon's true declination,	$16°\ \ 1'$ N.
Sine of do.,	$948'$
Versed sine of do.,	$135'$
deduct from radius (ii. 60),	$3438'$
Moon's day-radius,	$3303'$

Again, to find the earth-sine, we say (ii. 61),

$$12^d : 9^d.68 :: 948' : 765' = \text{earth-sine.}$$

and to find the ascensional difference (ii. 61–62),

$$3303' : 3438' :: 765' : 796' = \sin 13°\ 24' \text{ or } 804'.$$

The excess of the moon's complete revolution over a sidereal day is found by the proportion (ii. 59)

$$1800' : 1795^p :: 849'\ 33'' : 848^p$$

Adding this to a sidereal day, or $21{,}600^p$, we find that the moon's day is of $22{,}448^p$, of which one quarter is 5612^p. Increase and diminish this by the moon's ascensional difference (ii. 62), and the half-day and half-night are found to be 6416^p and 4808^p respectively.

All this laborious process of ascertaining the length of the moon's half-day, or the time which, with the given declination, she would occupy in rising from the horizon to the meridian, is rendered necessary by the correction which the commentary applies to the rule of the text in which the moon's hour-angle is involved, as pointed out in the note to iv. 24–25 (p. 284, above). We now proceed

b. To find the hour-angle, and the corrected hour-angle.

At the moment of opposition, the moon's hour-angle is evidently the same with that of the sun. Hence it may be found as follows:

Time of opposition reckoned from sunrise, $37^n\ 31^v$, or	$13{,}506^p$
deduct the whole day,	$9{,}192^p$
remains	$4{,}314^p$
deduct from the half-night,	$6{,}235^p$
Sun's distance in time from inferior meridian,	$1{,}921^p$

The moon's distance eastward from the upper meridian is accordingly 1921^p. This is corrected, or reduced to its proportional value as a part of the moon's arc of revolution from the horizon to the meridian, by the following proportion:

$$6416^p : 90° :: 1921^p : 26°\ 57'$$

The moon's corrected hour-angle, then, is $26°\ 57'$: its sine is $1557'$.

c. To determine the amount of deflection for latitude (*valanânçâs*, or *âksha valana*—iv. 24).

The sine of the latitude of Washington, $38°\ 54'$, is $2158'$. Hence the proportion

$$3438' : 1557' :: 2158' : 977' = \sin 16°\ 31'$$

gives us $16°\ 31'$ as the value of the quantity sought. The moon being in the eastern hemisphere, it is to be reckoned as north in direction.

d. To determine the amount of deflection for ecliptic-deviation (*âyana valana*—iv. 25).

Moon's distance from vernal equinox,	$4^s\ 16°\ 21'$
add a quadrant,	3^s
their sum,	$7^s\ 16°\ 21'$
arc determining sine,	$46°\ 21'$
sine,	$2486'$

Hence, by ii. 28, the proportion

$$3438' : 1397' :: 2486' : 1010' = \sin 17°\ 6'$$

gives us $17°\ 6'$ as the amount of declination of the point of the ecliptic which is a quadrant in advance of the moon, and this is the deflection required. Its direction is south. We are now ready for the final process.

e. To ascertain the net amount of deflection (*valana*), in digits.

From the ecliptic-deflection,	$17°\ 6'$ S.
deduct the deflection for latitude,	$16°\ 31'$ N.
remains the net deflection, in arc,	$35'$ S.
divide (iv. 25) by	70
Deflection in digits,	$0^d.50$ S.

It thus appears that, at the moment of opposition, the part of the ecliptic in which the moon is situated very nearly coincides in direction with an east and west circle. The amount of deflection is so small that in our projection, given in connection with the sixth chapter, we were obliged to exaggerate it somewhat, in order to make it perceptible.

2. For the beginning of the eclipse.

As, owing to the moon's motion in latitude and longitude, her declination, and so also her ascensional difference, are not precisely the same at the beginning and end of the eclipse as at the moment of opposition, we ought in strictness to repeat the first part of the preceding calculation, determining anew the length of the moon's half-day, as it would be if she made her whole revolution about the earth with those declinations respectively. This we take the liberty of omitting to do, as the modification thus introduced into the process would be of very small importance.

a. To find the moon's corrected hour-angle.

And first, for the sun's hour-angle:

Time of first contact, reckoned from sunrise, $32^{n}\ 51^{v}\ 4^{p}$, or	11,830p
deduct the whole day,	9,192p
remain	2,638p
deduct from the half-night,	6,235p
Sun's distance in time from inferior meridian,	3,597p

This, then, is the hour-angle of the centre of the shadow at the time of contact. The distance of the centre of the moon in longitude from that of the shadow was found above (under VIII) to be 61′ 35″. This is reduced to its value in right ascension by the proportion

$$1800' : 1795^{p} :: 61'\ 35'' : 61^{p}.4$$

Now, then,

from the hour-angle of the shadow,	3,597p
deduct the difference of the moon's right ascension,	61p
Moon's hour-angle at beginning of eclipse,	3,536p

This is virtually an application of the process taught in iii. 50.

The moon's hour-angle is now corrected, as before, by the proportion

$$6416^{p} : 90^{\circ} :: 3536^{p} : 49^{\circ}\ 36'$$

The sine of 49° 36′ is 2617′.

b. To find the deflection for latitude.

The proportion

$$3438' : 2158' :: 2617' : 1643' = \sin 28^{\circ}\ 34'$$

gives us the deflection for latitude as 28° 34′, which is north, as before.

c. To find the ecliptic-deflection.

Moon's distance from vernal equinox at opposition,	$4^{s}\ 16^{\circ}\ 21'$
deduct motion during $4^{n}\ 39^{v}\ 2^{p}$,	$1^{\circ}\ 6'$
do. at time of contact,	$4^{s}\ 15^{\circ}\ 15'$
add a quadrant,	3^{s}
sum,	$7^{s}\ 15^{\circ}\ 15'$
arc determining sine,	$45^{\circ}\ 15'$
sine,	2441′

Next, the proportion

$$3438' : 1397' :: 2441' : 992' = \sin 16^\circ 47'$$

shows us that the ecliptic-deflection is 16° 47′; it is, as in the former case, south.

d. To find the deflection, in digits.

From the deflection for latitude,	28° 34′ N.
deduct the ecliptic-deflection,	16° 47′ S.
remains the net deflection, in arc,	11° 47′ N.
its sine is	702′
divide by	70
Deflection, in digits,	$10^d.03$ N.

3. For the end of the eclipse.

Of this process, which is throughout closely analogous to the last, we shall present only a brief statement of the results.

Hour-angle of the centre of the shadow,	322^p E.
Distance of the centre of the moon in right ascension,	59^p E.
Moon's hour angle,	381^p E.
do. corrected,	5° 20′
Sine,	320′
Deflection for latitude,	3° 21′ N.
Moon's distance from vernal equinox + 3^s,	7^s 17° 24′
Arc determining sine,	47° 24′
Sine,	2530′
Ecliptic-deflection,	17° 24′ S.
Net deflection, in arc,	14° 3′ S.
do. in digits,	$11^d.93$ S.

The mode of application of these quantities in making a projection of an eclipse is sufficiently explained in the notes to the sixth chapter, and illustrated by the figure there given, which is adapted to the conditions of the eclipse here calculated. All the quantities entering into the projection, however, of which the value has been stated in minutes, require also to be reduced to digits, according to a scale determined by the following process.

X. To determine the scale of projection of the disks and latitudes (iv. 26).

This process we will perform only for the moment of opposition, or for the middle of the eclipse. At this time, as has been seen above, we have

Moon's half-day,	6416^p
do. hour-angle (*nata*),	1921^p
do. altitude in time (*unnata*),	4495^p
add $6416^p \times 3$	$19,248^p$
the sum is	$23,743^p$
divide by	$6,416^p$
the quotient is	3.7

At the elevation, then, which the moon has when in opposition, 3′.7 make a digit, and by this amount the values of the disk of the moon, the shadow, and the latitudes, are to be divided, in order to reduce them to a scale upon which they may be plotted. It is evident that, in strictness, the same calculation requires to be made also for the time of contact and the time of separation, or the time of any other phase of which the projection is to serve as an illustration: but it is evident also that this is wellnigh impracticable, since one projection could then be used to illustrate only a single phase, unless several different scales should be employed in the same figure.

It now only remains for us to present a comparison of the elements of the eclipse, as thus calculated, with their true values as determined by modern astronomical science. This is done in the annexed table. The true elements we take from the American Nautical Almanac for 1860. In comparing the time of the middle of the eclipse, we take, as already mentioned, the value of it given by the Hindu process as calculated from mean midnight.

	Sûrya-Siddhânta.	Am. Naut. Almanac.	Hindu error.
Time of opposition in long.,	$9^h\ 57^m\ 35^s$ P. M.	$9^h\ 27^m\ 10^s.8$ P. M.	+ $30^m\ 24^s$
Moon's long. at opposition,	136° 21′	137° 35′ 53″.7	− 1° 15′
" lat. at "	16′ 25″ S.	35′ 42″.1 S.	− 19′ 17″
" hourly motion in long.,	35′ 37″	38′ 0″.6	− 2′ 24″
Semi-diameter of sun,	16′ 42″	16′ 15″.2	+ 27″
do. of moon,	17′ 20″	16′ 42″.6	+ 37″
do. of shadow,	45′ 15″	45′ 16″	− 1″
Amount of obscuration,	1.33	0.812	+ 0.518
Whole duration of eclipse,	$3^h\ 37^m\ 44^s$	$2^h\ 52^m\ 24^s$	+ $45^m\ 20^s$

Lat at opp.

25. p. 299. Our next note is a

Calculation, according to Hindu Data and Methods, of the Solar Eclipse of May 26th, 1854,

for the latitude and longitude of Williams' College, Williamstown, Mass.

As has been already mentioned in the closing note to the fifth chapter, the following calculation of a solar eclipse was mainly made for the translator, while in India, by his native assistant. Some additional calculations have been appended here by us, in order to render the whole process a more complete illustration of the rules as given in the text of our treatise; and we have also had to reject and replace certain parts of the work actually done, on account of their inaccuracy. For the most part, we present the work as it was made, although involving some repetitions which might be regarded as superfluous, after the explanations and illustrations already given in the notes and in the preceding calculation of a lunar eclipse. The eclipse selected is the one calculated and delineated in Prof. James H. Coffin's useful work, entitled "Solar and Lunar Eclipses familiarly illustrated and explained, with the method of calculating them, according to the theory of Astronomy as taught in New-England Colleges" (New York, 1845).

I. To find the sum of days (*ahargana*) from the commencement of the planetary motions to the time of calculation.

The eclipse in question occurs at the close of the month Vâiçâkha, the second month of the luni-solar year, in the 1777th year of the era of Çâlivâhana (see add. note 12). To compute, then, the number of whole years, and to reduce them, with the remaining part of a year, to mean solar days, we proceed as follows :

Sandhi at the beginning of the *kalpa*,	1,728,000
Six *manvantaras*,	1,850,688,000
Twenty-seven *mahdyugas* of the seventh Manu,	116,640,000
	1,969,056,000
deduct the time spent in creation,	17,064,000
From creation to beginning of 28th *mahdyuga*,	1,951,992,000
Kṛta yuga of 28th or current *mahâyuga*,	1,728,000
Tretâ yuga of "	1,296,000
Dvâpara yuga of "	864,000
Kali yuga, to era of Çâlivâhana,	3,179
Complete years elapsed of the era,	1,776
From the creation to end of March, 1854, complete years,	1,955,884,955
to reduce to solar months, multiply by	12
Solar months,	23,470,619,460
add month of current year elapsed,	1
Whole number of solar months,	23,470,619,461

Now, to find the intercalary months, we make the proportion

51,840,000 : 1,593,336 : : 23,470,619,461 : 721,384,701

Then, to

Solar months elapsed,	23,470,619,461
add intercalary months,	721,384,701
Lunar months elapsed,	24,192,004,162
to reduce to lunar days, multiply by	30
Lunar days,	725,760,124,860
add for current month,	29
Whole number of lunar days,	725,760,124,889

Farther, to find the number of *tithikshayas*, or omitted lunar days, in this period, we say

1,603,000,080 : 25,082,252 : : 725,760,124,889 : 11,356,018,362

Next, from

Lunar days elapsed,	725,760,124,889
deduct omitted lunar days,	11,356,018,362
Mean solar days elapsed,	714,404,106,527

This, then, is the required *ahargaṇa*, or sum of days from the commencement of the planetary motions to about the time of new moon, May, 1854. The processes by which it is found are in all respects the same with those illustrated by us in the notes to i. 21–23, 24, 48, 48–51, above. It will be noticed that the Hindu astronomer, at least when working out an illustrative process, like the one in hand, scorns to make use of any of the means for reducing the labor of computation which the text directly or impliedly permits, and of which, in our own calculations, we have been glad to avail ourselves.

II. To ascertain the mean longitudes of the sun, the moon, the sun's apsis, the moon's apsis, and the moon's node, for mean midnight on the Hindu meridian, at the given interval from the creation.

The amount of motion, since the creation, of the bodies named, in their order, is found by the following series of proportions:

1,577,917,828 : 714,404,106,527 :: 4,320,000 : 1,955,884,955^{rev} 1^{s} 12° 14′ 14″
1,577,917,828 : 714,404,106,527 :: 57,753,336 : 26,147,889,118^{rev} 1^{s} 9° 44′ 29″
1,577,917,828,000 : 714,404,106,527 :: 387 : 175^{rev} 2^{s} 17° 17′ 23″
1,577,917,828 : 714,404,106,527 :: 488,203 : 22,134,467^{rev} 2^{s} 21° 56′ 9″
1,577,917,828 : 714,404,106,527 :: 232,238 : 105,146,020^{rev} 10^{s} 17° 11′ 50″

Rejecting whole revolutions, and, in the case of the moon's node, subtracting the fraction from a whole revolution, we have, as the mean longitudes required:

Sun,	1^{s} 12° 14′ 14″
Moon,	1^{s} 9° 44′ 29″
Sun's apogee,	2^{s} 17° 17′ 23″
Moon's apogee,	2^{s} 21° 56′ 9″
Moon's node,	1^{s} 12° 48′ 10″

The Hindu calculator has taken, in the case of the moon's apsis and node, the numbers of revolutions given by the text, omitting the correction of the *bija*. We have not, in order to test the accuracy of his arithmetical operations, worked over again the proportions, excepting in two instances, the first and last: our results differ but slightly from those above given (we find the seconds of the sun's place to be 40″, and the minutes and seconds of the node's motion to be 12′ 43″)—not enough to render any modification necessary.

III. To ascertain the values of the same quantities at mean sunrise on the equator, or 6 o'clock.

In order to this, we must add to each planet's longitude one fourth the amount of its mean motion in a day. We require, then, the mean daily motions. They are found as follows, taking the sun as an example:

1,577,917,828^{d} : 4,320,000^{rev} :: 1^{d} : 59′ 8″ 10‴ 10⁗.4

We omit the other proportions and their results, as the latter have been fully stated in the table of mean motions of the planets (note to i. 29–34). Adding a quarter of the daily motion, we have as follows:

	Long. at midnight.		Correction.		Long. at sunrise.
Sun,	1^{s} 12° 14′ 14″	+	14′ 47″	=	1^{s} 12° 29′ 1″
Moon,	1^{s} 9° 44′ 29″	+	3° 17′ 39″	=	1^{s} 13° 2′ 8″
Sun's apogee,	2^{s} 17° 17′ 23″	+	0	=	2^{s} 17° 17′ 23″
Moon's apogee,	2^{s} 21° 56′ 9″	+	1′ 40″	=	2^{s} 21° 57′ 49″
Moon's node,	1^{s} 12° 48′ 10″	−	48″	=	1^{s} 12° 47′ 22″

IV. To ascertain the values of the same quantities at mean sunrise upon the equator, on the meridian of the given place.

Adopting 75° 50′ as the longitude of the Hindu meridian east from Greenwich, we have, as the interval in longitude of Williams' College from it, 149° 2′ 30″, which is equal to $24^n\ 50^v\ 2^p$. The latitude is 42° 42′ 51″. We have, then, first, to determine the distance of the place in question, upon its own parallel of latitude, from the Hindu meridian.

The equatorial circumference of the earth has been found above (note to i. 59–60) to be 5059.64 yojanas. Its circumference upon the parallel of latitude of Williams' College is found (i. 60) by the following proportion :

$$3438' \ (=R) : 2525' \ (= \cos 42° \ 42' \ 51'') :: 5059^y.64 : 3715^y.97$$

The *deçântara*, or difference of longitude in yojanas, is then determined thus :

$$60^n : 24^n \ 50^v \ 2^p :: 3715^y.97 : 1538^y.41$$

And the *deçântaraphala*, or correction for difference of longitude, is calculated from the daily motion of each body, by such a proportion as the one subjoined, which gives the sun's correction :

$$3715^y.97 : 1538^y.41 :: 59' \ 8'' : 24' \ 27''$$

We omit the other proportions, and merely present their results in the following table :

	Sunrise at Lankâ.		Correction.		Sunrise on giv. merid.
Sun,	$1^s\ 12°\ 29'\ 1''$	+	24′ 27″	=	$1^s\ 12°\ 53'\ 28''$
Moon,	$1^s\ 13°\ 2'\ 8''$	+	5 27 12	=	$1^s\ 18°\ 29'\ 20''$
Sun's apogee,	$2^s\ 17°\ 17'\ 23''$	+	0	=	$2^s\ 17°\ 17'\ 23''$
Moon's apogee,	$2^s\ 21°\ 57'\ 49''$	+	2′ 45″	=	$2^s\ 22°\ 0'\ 34''$
Moon's node,	$1^s\ 12°\ 47'\ 22''$	−	1′ 19″	=	$1^s\ 12°\ 46'\ 3''$

We have already (note to i. 63–65) called attention to the excessively awkward and cumbrous character of this process for making the correction for difference of meridian.

V. To find the sun's true longitude.

From the longitude of the sun's apsis,	$2^s\ 17°\ 17'\ 23''$
deduct sun's mean longitude (ii. 29),	$1^s\ 12°\ 53'\ 28''$
Sun's mean anomaly,	$1^s\ 4°\ 23'\ 55''$
Sine,	1927′

The diminution of the sun's epicycle is now found by the following proportion (ii. 38) :

$$3438' : 20' :: 1927' : 11' \ 12''$$

The dimensions of the epicycle are, then (ii. 34), 14° − 11′ 12″, or 13° 48′ 48″. Next, the proportion (ii. 39)

$$360° : 13° \ 48' \ 48'' :: 1927' : 74' \ 11''$$

gives us the sun's equation of the centre, which, by ii. 45, is additive. Hence to the

Sun's mean longitude,	$1^s\ 12°\ 53'\ 28''$
add the equation,	$1°\ 14'\ 11''$
Sun's true longitude,	$1^s\ 14°\ 7'\ 39''$

This calculation exhibits a rather serious error: the sine of 34° 24′, the anomaly, is 1942′, not 1927′. The final result, however, is not perceptibly modified by it: the equation ought to be 1° 14′ 30″, and the true longitude 1ˢ 14° 7′ 58″.

VI. To find the moon's true longitude.

From the longitude of the moon's apsis,	2ˢ 22° 0′ 34″
deduct moon's mean longitude,	1ˢ 18° 29′ 20″
Moon's mean anomaly,	1ˢ 3° 31′ 14″
Sine,	1898′
Diminution of epicycle,	11′ 2″
Dimensions of epicycle,	31° 48′ 58″
Equation of the centre,	+ 2° 47′

Hence, to the

Moon's mean longitude,	1ˢ 18° 29′ 20″
add the equation,	2° 47′
Moon's true longitude,	1ˢ 21° 16′ 20″

VII. To calculate the true daily motions of the sun and moon.

The equations of motion for the sun and moon have been found by the calculator of the eclipse by the following proportion: as the whole orbit of either planet is to its epicycle, so is its mean daily motion to the required equation. That is to say, for the sun,

360° : 13° 48′ 48″ :: 59′ 8″ : 2′ 16″

which, by ii. 49, is subtractive. Hence the sun's true motion is 59′ 8″ − 2′ 16″, or 56′ 52″.

Again, for the moon,

360° : 31° 48′ 58″ :: 790′ 35″ : 69′ 36″

And the moon's true motion is 790′ 35″ − 69′ 36″, or 720′ 59″.

These calculations are exceedingly incomplete and erroneous, as may readily be seen by referring to the corresponding process in the other eclipse, or to that given as an illustration in the note to ii. 47–49. The actual value of the sun's equation of motion, as fully calculated by the method of our treatise, is only 1′ 51″; that of the moon is only 58′ 49″: whence the true motions are 57′ 17″ and 731′ 46″ respectively. These are elements of so much importance, and they enter so variously into the after operations, that we have hesitated as to whether it would not be better to cancel the whole work of the Hindu calculator from this point onward, and to perform it anew in a more exact manner; but we have finally concluded to present the whole as it is, as a specimen—although, we hope, not a favorable one—of native work; pointing out, at the same time, its deficiences, and cautioning against its results being accepted as the best that the system is capable of affording.

We have thus far found the true longitudes of the sun and moon for the moment of mean sunrise at the equator, upon the meridian of the given place. We desire now farther to find the same data for the moment of sunrise upon the same meridian in latitude 42° 42′ 51″ N.

VIII. To find the longitudes of the sun and moon at sunrise in long. 149° 2′ 30″, lat. 42° 42′ 51″ N.

1. To calculate the precession of the equinoxes (iii. 9–12).

The proportion

$$1{,}577{,}917{,}828^{d} : 600^{rev} :: 714{,}404{,}106{,}527 : 271{,}650^{rev}\ 8^{s}\ 7^{\circ}\ 45'\ 22''$$

gives us the amount of the motion of the equinox in its own circle of libratory revolution, since the beginning of things. Rejecting complete revolutions, and deducting 6^{s} from the fraction of a revolution, we have the distance of the equinox from the origin of the sidereal sphere, in terms of its own revolution, as $67^{\circ}\ 45'\ 22''$: three tenths of this, or $20^{\circ}\ 19'\ 36''$, is the amount of the precession.

2. To calculate the sun's declination.

Sun's longitude,	$1^{s}\ 14^{\circ}\ 7'\ 39''$
Precession,	$20^{\circ}\ 19'\ 36''$
Sun's distance from vernal equinox,	$2^{s}\ 4^{\circ}\ 27'\ 15''$
Sine,	$3101'$

Then, by ii. 28,

$$3438' : 1397' :: 3101' : 1260' = \sin 21^{\circ}\ 31'\ 3''$$

the sun's declination is therefore $21^{\circ}\ 31'\ 3''$.

3. To calculate the sun's ascensional difference.

The radius of the sun's diurnal circle (*dyujyâ*—ii. 60) is $3199'$.

The equinoctial shadow in the given latitude is $11^{d}.07$, being found by the proportion (iii. 17)

$$\text{cos lat.} : \text{sin lat.} :: \text{gnom.} : \text{eq. shad.}$$

or

$$2525' : 2330' :: 12^{d} : 11^{d}.07$$

Again, to find the earth-sine (*kujyâ*—ii. 61),

$$12^{d} : 11^{d}.07 :: 1260' : 1162'$$

And, to find the sine of ascensional difference,

$$3199' : 3438' :: 1162' : 1249'$$

The corresponding arc is $21^{\circ}\ 19'$, or $1279'$; and since a minute of arc is equivalent to a respiration of time, the sun's ascensional difference in time is 1279^{p}, or 213^{v}, or $3^{n}\ 33^{v}$, rejecting the odd respiration.

4. To calculate the length of the sun's day.

The sun being in the third sign, of which the equivalent in right ascension (iii. 42–45) is 1935^{p}, the excess of his day over 60 nâḍîs is found by the proportion

$$1800' : 1935^{p} :: 59'\ 8'' : 63^{p}$$

whence the length of his day is $21{,}663^{p}$.

In this calculation of the length of the sun's day, the operator has taken the mean, instead of the true, motion of the sun, which is obviously less accurate, and which is contrary to the meaning of the rule of the text (ii. 59), as explained by the commentator.

Now, in order to find the difference between the sun's longitude at sunrise on the equator and sunrise on the given parallel of north latitude, we make a proportion, as follows: if in his whole day the sun moves an amount equal to his daily motion, how much will he move during an interval corresponding to his ascensional difference? or

$$21{,}663^{p} : 59'\ 8'' :: 1279^{p} : 3'\ 29''$$

The sun's declination being north, sunrise on the given parallel precedes sunrise on the equator, and hence this result—which is called the *carakalâs*, "minutes (*kalâ*) of longitude corresponding to the ascensional difference (*cara*)"—is to be subtracted from the sun's longitude as formerly found. That is to say,

Sun's longitude at equatorial sunrise,	1s 14° 7′ 39″
deduct the correction (*carakalâs*),	3′ 29″
Sun's longitude at sunrise, lat. 42° 42′ 51″ N., long. 149° 2′ 30″ W. from Lankâ,	1s 14° 4′ 10″

In finding the corresponding value of the moon's longitude we apply first a correction for the sun's equation of place; it is, in fact, the equation of time, calculated after the entirely insufficient method which we have already fully exposed, in connection with part V of the preceding process. The proportion is (ii. 46) as follows:

21,600′ : 790′ 35″ :: 1° 14′ 11″ : 2′ 43″

Here, again, bad is made worse by taking as the second term of the proportion the moon's mean, instead of her true, rate of motion. It is to be noticed that a like correction should have been applied also to the sun's longitude, but was omitted by the calculator. We have, then,

Moon's longitude, mean equatorial sunrise,	1s 21° 16′ 20″
add the correction for the equation of time,	2′ 43″
Moon's longitude, true equatorial sunrise,	1s 21° 19′ 3″

Now we apply farther the correction for the sun's ascensional difference (*carasanskâra*); it is calculated in the same manner with that of the sun, and its amount is found to be 47′ 51″.

Moon's longitude, true equatorial sunrise,	1s 21′ 19′ 3″
deduct the correction for the sun's asc. diff.,	47′ 51″
Moon's longitude at sunrise, lat. 42° 42′ 51″ N., long. 149° 2′ 30″ W. from Lankâ,	1s 20′ 31′ 12″

On comparing the longitudes of the sun and moon, as thus determined, it is seen that the time of conjunction is already past. Hence the calculation is carried a day backward, by subtracting from the longitude of each body its motion during a day. That is to say,

	Longitude, sunrise following eclipse.		day's motion.		Longitude, sunrise preceding eclipse.
Sun,	1s 14° 4′ 10″	−	56′ 52″	=	1s 13° 7′ 18″
Moon,	1s 20° 31′ 12″	−	12° 0′ 59″	=	1s 8° 30′ 13″
Moon's node,	1s 12° 46′ 3″	+	3′ 11″	=	1s 12° 49′ 14″

This is an entirely uncalled-for, and a highly inaccurate proceeding. By the rule given in our text (ii. 66), it is just as easy and regular a process to find from any given time the interval to the beginning of the current lunar day by reckoning backward, as that to the end of the day by reckoning forward. And to assume that the whole calculation may be transferred from one sunrise back to the preceding by simply deducting the amount of motion in a day as determined for the former time is to take a most unwarrantable liberty, and to ignore the change during the interval of many of the elements of the calculation, as the sun's and moon's rates of motion, the sun's declination and ascensional difference, etc. In making the transfer, moreover, the longitude of the moon's node has been taken as found for mean equatorial sunrise, without any correction for the equation of time, or for the sun's ascensional difference.

IX. To find the time of true conjunction, and the longitudes of the sun, moon, and moon's node at that time. By ii. 66, from the

Moon's true longitude,	$1^s\ 8^\circ\ 30'\ 13''$
deduct the sun's do.,	$1^s\ 13^\circ\ 7'\ 18''$
remains	$11^s\ 25^\circ\ 22'\ 55''$
divide by the portion of a lunar day,	$720'$
the quotient is	29^d and $442'\ 55''$
deduct the remainder from a whole portion,	$720'$
remains	$277'\ 5''$

This process shows us that the moon has still $277'\ 5''$ to gain upon the sun, in order to arrive at the end of the thirtieth or last day of the lunar month, or at conjunction with the sun.

Next, from the

Moon's true daily motion,	$720'\ 59''$
deduct the sun's do.,	$56'\ 52''$
Moon's daily gain in longitude,	$664'\ 7''$

Hence the proportion

$$664'\ 7'' : 60^n :: 277'\ 5'' : 25^n\ 2^v$$

gives us the time of conjunction, reckoned from sunrise, as $25^n\ 2^v$.

Now, by iv. 8, we proceed to find the longitudes for that time. The amounts of motion during $25^n\ 2^v$ are found by the following proportions:

$$60^n : 25^n\ 2^v :: \begin{cases} 56'\ 52'' : 23'\ 43'' \\ 720'\ 59'' : 300'\ 48'' \\ 3'\ 11'' : 1'\ 19'' \end{cases}$$

Then, to the

Sun's longitude at sunrise,	$1^s\ 13^\circ\ 7'\ 18''$
add the correction,	$23'\ 43''$
Sun's longitude at conjunction,	$1^s\ 13^\circ\ 31'\ 1''$
Moon's longitude at sunrise,	$1^s\ 8^\circ\ 30'\ 13''$
add the correction,	$5^\circ\ 0'\ 48''$
Moon's longitude at conjunction,	$1^s\ 13^\circ\ 31'\ 1''$
Node's longitude at sunrise,	$1^s\ 12^\circ\ 49'\ 14''$
deduct the correction,	$1'\ 19''$
Node's longitude at conjunction,	$1^s\ 12^\circ\ 47'\ 55''$

The mode of proceeding adopted by us above, in the lunar eclipse, for finding the time of the middle of the eclipse, and the longitudes of the sun and moon at that time, is, as will not fail to be observed, quite different from that of the native calculator of this eclipse. That followed by Davis, or his native assistants (As. Res., ii. 273 etc.), varies considerably from both. Our own method, though varying in some respects from that contemplated by the text, is a not less legitimate application of its general methods than either of the others, and it possesses this important advantage over both, that we were able to verify it, and to show, by calculating the mean and true places for the given instant, that the latter was actually the one at which the system made the opposition of the sun and moon to take place: while, on the contrary, in the process now in hand, so many errors have been involved, that, were the same test to be applied, we should find the centres of the sun and moon many minutes apart at the moment fixed upon as that of conjunction, and the place of conjunction as far removed from the point of longitude above determined for it.

X. To find the apparent diameters of the sun and moon.

These quantities are determined by means of the following proportion: as the mean daily motion in yojanas is to the mean diameter in yojanas, so is the true motion in minutes to the true diameter in minutes. That is to say, for the sun and moon respectively,

$$11{,}858\tfrac{3}{4}^y : 6500^y :: 56' \, 52'' : 31' \, 10''$$
$$11{,}858\tfrac{3}{4}^y : 480^y :: 720' \, 59'' : 29' \, 2''$$

This method is in appearance quite different from that which is prescribed by our text (iv. 2–3), but it is in fact only a simplification, or reduction, of the rules there given. Thus, for the moon, the text gives

m. mot. in minutes : true mot. in min. : : m. diam. in yoj. : true diam. in min. $\times$ 15

Transposing, now, the middle terms, transferring the factor 15 from the fourth term to the first, and noting that the mean motion in minutes, when multiplied by 15, gives the value of the same in yojanas, we have the former proportion, namely,

m. mot. in yoj. : m. diam. in yoj. : : true mot. in min. : true diam. in min.

Again, in the case of the sun, the rules of the text give

m. mot. in min. : true mot. in min : : m. diam. in yoj. : true diam. in yoj.
and true diam. in yoj. = true diam. in min. $\times$ 15 $\times$ (sun's orbit $\div$ moon's orbit)

Now transposing the second and third terms of the proportion, substituting for the fourth its equivalent as here stated, and transferring to the first term the last two factors of that equivalent, we have

m. mot. in min. $\times$ 15 $\times$ $\dfrac{\text{sun's orbit}}{\text{moon's orbit}}$: m. d. in y. : : true mot. in min. : true diam. in min.

But the first term, as thus constructed, is, by the method of determination of the planetary orbits (see xii. 81–83), equal to the sun's mean daily motion upon his orbit reckoned in yojanas: hence the proportion becomes for the sun, as for the moon,

m. mot. in yoj. : m. diam. in yoj. : : true mot. in min. : true diam. in min.

XI. To calculate the parallax in longitude (*lambana*), and the time of apparent conjunction (v. 3–9).

1. To find the orient ecliptic-point (*lagna*) at the moment of true conjunction (iii. 46–48).

In order to this, we require to have first the equivalents in oblique ascension (*udayâsavas*) of the several signs of the zodiac for the latitude of Williams' College, 42° 42′ 51″ N. We present annexed their values as employed by the calculator of the eclipse, and also as calculated by ourselves according to the method taught in our text (iii. 42–45). It will be noticed that the differences are not inconsiderable, and evince much carelessness on the part of the native astronomer; who, moreover, employs vinâḍis only in his processes, rejecting the odd respirations, which is an inaccuracy not countenanced by the Sûrya-Siddhânta.

	Equivalent in oblique ascension: acc. to calculator.	acc. to us.	
1st sign	....	1008^p	12th sign
2nd "	....	1238_p	11th "
3rd "	287^v or 1722^p	1699_p	10th "
4th "	359^v or 2154^p	2171^p	9th "
5th "	387^v or 2322^p	2352^p	8th "
6th "	388^v or 2328^p	2332_p	7th "

The equivalents assigned by the Hindu calculator to the 3rd and 4th signs are moreover, it may be remarked, inconsistent with one another, since the one ought to fall short of 1935^p by as much as the other exceeds that quantity.

Now, then, to the

Sun's longitude at conjunction,	$1^s\ 13°\ 31'\ 1''$
add the precession,	$20°\ 19'\ 36''$
Sun's distance from the equinox,	$2^s\ 3°\ 50'\ 37''$

It appears, accordingly, that the sun is in the 3rd sign, and 26° 9′ 23″ from the beginning of the fourth. Hence the proportion (iii. 46)

$$30° : 287^v :: 26°\ 9'\ 23'' : 250^v$$

give us 250^v as the ascensional equivalent of the part of a sign to be traversed (*bhogyâsavas*). The time of the day, or the sun's distance in time from the eastern horizon, is $25^n\ 2^v$, or 1502^v. Then, from the

Time of conjunction,	1502^v
deduct asc. equiv. of part of 3rd sign,	250^v
remains	1252^v
deduct asc. equiv. of 4th, 5th, and 6th signs,	1134^v
remains	118^v

This remainder of time, or of ascension, is reduced to its value in arc of the ecliptic by the proportion (iii. 49)

$$388^v : 30° :: 118^v : 9°\ 7'\ 25''$$

Add this result to the whole signs preceding, and the longitude of the orient ecliptic-point (*lagna*) is found to be $6^s\ 9°\ 7'\ 25''$: its sine is 544′ (more correctly, 545′).

2. To find the orient-sine (*udayajyâ*—v. 3).

This is found by the proportion

$$2525' : 1397' :: 544' : 301'$$

2525′ being the cosine of the latitude, and 1397′ the sine of the inclination of the ecliptic (ii. 28).

3. To find the meridian ecliptic-point (*madhyalagna*—iii. 49).

In order to this, we must first know the sun's hour-angle (*nata*), or distance in time from the meridian; it is determined as follows:

A quarter of the complete day,	$15^n\ 0^v$
add the sun's ascensional difference,	$3^n\ 33^v$
The sun's half-day,	$18^n\ 33^v$
deduct from time of conjunction,	$25^n\ 2^v$
Sun's hour-angle, west,	$6^n\ 29^v$

The sun's distance from the beginning of the fourth sign was found above to be 26° 9′ 23″. Its equivalent in right ascension (*lankodayâsavas*) is found by the following proportion (iii. 49):

$$30^\circ : 323^v :: 26^\circ\ 9'\ 23'' : 285^v$$

Now, from the

Sun's hour-angle, $6^n\ 29^v$, or	389^v
deduct the result of the last proportion,	285^v
remains	104^v

and this remainder, being less than the equivalent of a sign, is reduced to its value as longitude by the proportion (iii. 48)

$$323^v : 30^\circ :: 104^v : 9^\circ\ 3'\ 57''$$

The longitude of the meridian ecliptic-point is accordingly $3^s\ 9^\circ\ 3'\ 57''$: its sine is 3393′.

In criticism of the process as thus conducted, we would only remark that the quarter of the sun's day should have been called $15^n\ 2^v\ 4^p$ (see above, VIII. 4), and that to take 323^v as the equivalent in right ascension of the third and fourth signs is inaccurate, the value given it by our treatise being 1935^p, or $322\frac{1}{2}^v$.

4. To find the meridian-sine (*madhyajyâ*—v. 4–5).

First, the declination of the meridian ecliptic-point is determined by the proportion (ii. 28)

$$3438' : 1397' :: 3393' : 1378' = \sin 23^\circ\ 39'\ 37''$$

Its value being north, it is deducted from the latitude of the place for which the calculation is made, since this, though by us reckoned as north, is to the Hindu apprehension (iii. 14) always south, being measured south from the zenith to the equator. That is to say,

From the given latitude,	42° 42′ 51″
deduct decl. of merid. ecliptic-point,	23° 39′ 37″
Meridian zenith-distance (*natânçâs*),	19° 3′ 14″

The sine of this arc, which is 1117′, is the meridian-sine.

Here is another blunder of the calculator: the sine of 19° 3′ 14″ is actually 1122′.

5. To find the sine of ecliptic zenith-distance (*dṛkkshepa*), and the sine of ecliptic-altitude (*dṛggati*).

First, by v. 5,

$$3438' : 301' :: 1117' : 97'\ 48''$$

Now, then, by v. 6,

Square of last result,	9,564′
deduct from square of mer.-sine,	1,247,689′
remains	1,238,125′
Square-root,	1113′

This, then, is the sine of ecliptic zenith-distance. The sine of ecliptic-altitude is found by subtracting its square from that of radius, and taking the square-root of the remainder; it is found to be 3253′.

6. To find the divisor (*cheda*), and the sun's parallax in longitude (*lambana*).

The sine of one sign, or 30°, is 1719′.

Square of sin 30°,	2,954,961
divide by	3,253
Divisor (*cheda*),	908

Next, to find the interval on the ecliptic between the sun's place and the meridian:

Longitude of meridian ecliptic-point,	3ˢ 9° 3′ 57″
do. of sun,	2ˢ 3° 50′ 37″
Interval in longitude,	1ˢ 5° 13′ 20″

Of this the sine is 1950′, and, upon dividing it by 908, the divisor (*cheda*) above found, the value of the parallax in longitude (*lambana*) is ascertained to be 2^n 21^v.

Here is some of the worst blundering which we have yet met with. The sine of 35° 13′ is actually 1982′, not 1950′; and upon dividing it by 908, we find the quotient to be only 2^n 11^v.

The calculator assumes the time of apparent conjunction to be determined by this single correction. As the text, however (v. 9), directs that the process be repeated, to insure a higher degree of accuracy, we shall finally quit at this point the guidance of his computations, and go on to apply in full the rules of the Sûrya-Siddhânta.

The sun being west of the meridian, or his longitude being less than that of the meridian ecliptic-point (v. 9), the correction for parallax is additive to the time of true conjunction. Hence, to the

Time of true conjunction,	25^n 2^v
add the correction,	2^n 11^v
Time of conjunction once equated,	27^n 13^v

For the time thus found, we now proceed to calculate again the value of the parallax. The results of the calculation are briefly presented below:

Sun's longitude at corrected time of conjunction,	2ˢ 3° 52′ 41″
Orient ecliptic-point (*lagna*),	6ˢ 18° 50′
Its sine,	1110′
Orient-sine (*udayajyâ*),	614′
Sun's hour-angle,	3103^p

Meridian ecliptic-point (*madhyalagna*),	$3^s\ 21^\circ\ 59'$
Its sine,	$3188'$
Its declination,	$22^\circ\ 9'$ N.
Its zenith-distance,	$20^\circ\ 34'$ S.
Meridian-sine (*madhyajyâ*),	$1207'$
Sine of ecliptic zenith-distance (*dṛkkshepa*),	$1188'$
Sine of ecliptic-altitude (*dṛggati*),	$3226'$
Divisor (*cheda*),	$916'$
Sine of sun's dist. in long. from meridian,	$2558'$
Parallax in longitude (*lambana*),	$2^n\ 48^v$
add to time of true conjunction,	$25^n\ 2^v$
Time of conjunction twice equated,	$27^n\ 50^v$

Once more, we repeat the same calculation; its principal results are as follows:

Orient ecliptic-point,	$6^s\ 21^\circ\ 41'$
Orient-sine,	$702'$
Meridian ecliptic-point,	$3^s\ 25^\circ\ 26'$
Meridian-sine,	$1241'$
Sine of ecliptic zenith-distance,	$1215'$
Sine of ecliptic-altitude,	$3216'$
Divisor,	$919'$
Parallax in longitude,	$2^n\ 55^v$
add to time of true conjunction,	$25^n\ 2^v$
Time of apparent conjunction,	$27^n\ 57^v$

A farther repetition of the process would still yield an appreciable correction, but as so many errors have been involved in the preceding parts of the calculation as to render any exactness of result unattainable, and as enough has been done to illustrate the method of correction by successive approximation and the comparative value of the results it yields, we stop here, and rest content with the last time obtained, as that of the apparent conjunction of the sun and moon, or of the middle of the eclipse, at Williams' College.

XII. To calculate the parallax in latitude (*nati*) for the middle of the eclipse.

This is given us by the proportion (v. 10)

$$3438' : 731'\ 27'' \div 15 :: 1215' : 17'\ 14''\ \text{S.}$$

in which $1215'$ is the sine of ecliptic zenith-distance, as found in the last process.

XIII. To calculate the moon's latitude, and her apparent latitude, for the middle of the eclipse.

We require first to find the longitude of the moon, and that of her node, for the moment of apparent conjunction, by adding to their longitudes, as already found (above, IX) for the time of true conjunction, their motion during $2^n\ 55^v$. The amount of motion is found by the proportions

$$60^n : 2^n\ 55^v :: \begin{cases} 720'\ 59'' : 35'\ 3'' \\ 3'\ 11'' : 0'\ 9'' \end{cases}$$

Now, then, to the

Moon's longitude at true conjunction,	$1^s\ 13^\circ\ 31'\ 1''$
add the correction,	$35'\ 3''$
Moon's longitude at apparent conjunction,	$1^s\ 14^\circ\ 6'\ 4''$

Farther, from the

Node's longitude at true conjunction,	$1^s\ 12^\circ\ 47'\ 55''$
deduct the correction,	$9''$
Node's longitude at apparent conjunction,	$1^s\ 12^\circ\ 47'\ 46''$
deduct from moon's longitude,	$1^s\ 14^\circ\ 6'\ 4''$
Moon's distance from node,	$1^\circ\ 18'\ 18''$
Sine,	$78'$

Hence the proportion (ii. 57)

$$3438' : 270' :: 78' : 6'\ 8''$$

gives us the

Moon's true latitude,	$6'\ 8''$ N.
deduct from parallax in latitude (v. 12),	$17'\ 14''$ S.
Moon's apparent latitude,	$11'\ 6''$ S.

XIV. To find the amount of obscuration (*grâsa*) at the moment of apparent conjunction.

By iv. 10, we add to the

Diameter of the eclipsing body, the moon,	$29'\ 2''$
Diameter of the eclipsed body, the sun,	$31'\ 10''$
Sum of diameters,	$60'\ 12''$
Half-sum of diameters,	$30'\ 6''$
deduct moon's apparent latitude,	$11'\ 6''$
Amount of greatest obscuration,	$19'\ 0''$

This remainder being less than the sun's diameter, the eclipse (iv. 11) is partial only.

XV. To determine the times of the beginning and end of the eclipse respectively.

As the eclipse is a partial one only, we have not to calculate the times of the beginning and end of total obscuration; and indeed, we may well suppose that the Hindus would never venture to calculate those times in a solar eclipse: it is even questionable whether the accuracy of their methods would justify them in ever predicting with confidence that an eclipse would be total.

In the first place, we assume that the moon's apparent latitude, as calculated for the moment of conjunction, remains unchanged during the whole duration of the eclipse, and calculate, by iv. 12–13, what would be, upon that assumption, the interval between the middle of the eclipse and either contact or separation of the disks. That is to say (iv. 12), from the

Square of sum of semi-diameters (30′ 6″),	906′ 1″
deduct square of moon's latitude (11′ 6″),	123′ 13″
remains	782′ 48″
Square root of remainder,	27′ 59″

This result represents the distance, as rudely determined, of the two centres at the moments of contact and separation. To ascertain the corresponding interval of time, we say (iv. 13)

664′ 7″ : 60n :: 27′ 59″ : 2n 32v

Now, then, from and to the

Time of apparent conjunction,	27n 57v
subtract and add the half duration,	2n 32v
Beginning of eclipse,	25n 25v
End of eclipse,	30n 29v

This is as far as the operation was carried by the native calculator, and with data and results somewhat different from those here given, owing to his neglect to repeat the process of determination of the parallax in longitude in finding the time of apparent conjunction. Unfortunately, however, the text (iv. 14–15 ; v. 13–17) prescribes a long and tedious series of modifications and corrections of the results so far obtained, of which we shall proceed to perform at least enough to illustrate the method of the process, and the comparative importance of the corrections which it furnishes.

We have first to find the longitude of the sun, moon, and node, at the moments thus determined as those of contact and separation; they are as follows:

Sun's long. at true conj. (25n 2v),	1s 13° 31′ 1″	1s 13° 31′ 1″
add for his motion	22″	5′ 10″
Sun's long. at beg. and end of eclipse,	1s 13° 31′ 23″	1s 13° 36′ 11″
add the precession,	20° 19′ 36″	20° 19′ 36″
Sun's distance from the vernal equinox,	2s 3° 50′ 59″	2s 3° 55′ 47″
Moon's long. at app. conj.	1s 14° 6′ 4″	1s 14° 6′ 4″
subtract and add motion in 2n 32v,	30′ 26″	30′ 26″
Moon's long. at beg. and end of eclipse,	1s 13° 35′ 38″	1s 14° 36′ 30″
Node's long. at app. conj.,	1s 12° 47′ 46″	1s 12° 47′ 46″
add and subtract	8″	8″
Node's long. at beg. and end of eclipse,	1s 12° 47′ 54″	1s 12° 47′ 38″

To find, then, the moon's true latitude at contact and separation, we have

Moon's distance from node,	47′ 44″	1° 48′ 52″
Sine,	48′	109′
Moon's latitude,	3′ 46″ N.	8′ 34″ N.

Next are calculated the moon's parallax in latitude, and her apparent latitude, at the beginning and end of the eclipse, by a process of which the main results are the following :

Orient ecliptic-point,	6s 10° 28′	7s 3° 59′
Sine,	625′	1921′
Orient-sine,	345′	1063′
Sun's hour-angle,	2455p	4279p
Meridian ecliptic-point,	3s 11° 54′	4s 11° 7′
Sine of do.,	3363′	2590′
Zenith-distance of do.,	19° 16′	24° 53′
Meridian-sine,	1134′	1445′
Sine of ecliptic zenith-distance,	1128′	1374′
Parallax in latitude,	16′ 0″ S.	19′ 29″ S.
deduct true latitude,	3′ 46″ N.	8′ 34″ N.
Moon's apparent lat. at beg. and end of eclipse,	12′ 14″ S.	10′ 55″ S.

Finally, from the

Square of sum of semi-diameters,	906′ 1″	906′ 1″
deduct squares of app. latitude,	150′ 39″	119′ 11″
remain	755′ 22″	786′ 50″
Distance of centres in longitude,	27′ 29″	28′ 3″
Corresponding interval,	2n 29v	2n 32v
Corrected times of beginning and end of eclipse,	25n 28v	30n 29v

It is evidently unnecessary to carry any farther this part of the process; at the time of the eclipse, the increase of the moon's latitude northward, and the increase of her parallax southward, so nearly balance one another, that the additional correction yielded by a new computation would be quite inappreciable—as, indeed, has been, in one of the two cases, that already obtained. In making this corrective calculation we have not followed with exactness the directions given in the commentary under v. 14–17. It is there taught that, after making the first rough determination of the half-duration, based upon the moon's apparent latitude at apparent conjunction, we must turn back to the true conjunction, find the positions of the planets and node at intervals of the half-duration from that point, and make these positions the data of our farther approximative processes. The text itself, as already remarked by us in the notes, shows an utter and provoking want of explicitness with regard to the whole matter, and may be regarded as favoring equally the method of the commentary, our own, or any other that might be devised. We have taken our own course, then, because we were unable to see any sufficient reason for reverting from apparent to true conjunction, as directed by the commentator.

With regard to the next steps, the language of the text is less ambiguous: it distinctly orders us to deduct from and add to the time of true conjunction (*tithyanta*) the intervals found as the former and latter half-duration, and from the moments thus determined to compute anew, by a repeated process, the parallax in longitude. This is a very laborious operation, and not altogether accurate, although perhaps as much so as any which the Hindu methods admit. As we are supposed to have already ascertained how far apart the two centres must be at the moments of contact and separation, the problem is, evidently, to determine at what moment of time they will, allowing for the parallax in longitude, be at that distance from one another. Now as formerly, to find the time of apparent conjunction, we started from that of true conjunction, and arrived at the desired result by a series of approximative calculations of the parallax in longitude, so now, starting from points removed from true conjunction by the given intervals, we shall ascertain, by a similar series of approximations, the times when the distances represented by those intervals will be apparent, or the moments to which contact and separation of the disks will be deferred by parallax in longitude. The results of the calculations, as made by us, are as follows:

Time of true conjunction,	$25^n\ 2^v$	$25^n\ 2^v$
subtract and add,	$2^n\ 29^v$	$2^n\ 32^v$
Times of true contact and separation,	$22^n\ 33^v$	$27^n\ 34^v$
Sun's longitude, with precession,	$2^s\ 3^\circ\ 48'\ 16''$	$2^s\ 3^\circ\ 53'\ 1''$
Orient ecliptic-point,	$5^s\ 27^\circ\ 9'$	$6^s\ 20^\circ\ 27'$
Orient-sine,	$95'$	$664'$
Meridian ecliptic-point,	$2^s\ 25^\circ\ 52'$	$3^s\ 23^\circ\ 56'$
Meridian-sine,	$1107'$	$1226'$
Sine of ecliptic zenith-distance,	$1106'$	$1203'$
Sine of ecliptic-altitude,	$3255'$	$3219'$
Divisor,	908	918
Moon's longitude,	$2^s\ 3^\circ\ 21'$	$2^s\ 4^\circ\ 21'$
Distance from meridian ecliptic-point,	$22^\circ\ 31'$	$1^s\ 19^\circ\ 35'$
Sine,	$1316'$	$2617'$
Parallax in longitude,	$1^n\ 27^v$	$2^n\ 51^v$

Again, we go on to correct these results by repeated calculations of the parallax, in the mode which has already been sufficiently illustrated. Annexed are the results only:

Times of contact and separation,	$22^n\ 33^v$	$27^n\ 34^v$
add correction for parallax,	$1^n\ 27^v$	$2^n\ 51^v$
Times of contact and separation, once equated,	$24^n\ 0^v$	$30^n\ 25^v$
Corresponding parallax,	$1^n\ 54^v$	$3^n\ 20^v$
add to times first obtained,	$22^n\ 33^v$	$27^n\ 34^v$
Times of contact and separation, twice equated,	$24^n\ 27^v$	$30^n\ 54^v$
Corresponding parallax,	$2^n\ 2^v$	$3^n\ 24^v$

Without taking the trouble to carry the calculations any farther, we may accept these as the finally determined values of the parallax in longitude at the times of apparent contact and separation. Then, by v. 16,

Parallax in longitude at contact and separation,	$2^n\ 2^v$	$3^n\ 24^v$
do. at apparent conjunction,	$2^n\ 55^v$	$2^n\ 55^v$
Difference of parallaxes,	53^v	29^v
add to former and latter mean half-duration,	$2^n\ 29^v$	$2^n\ 32^v$
True former and latter half-duration,	$3^n\ 22^v$	$3^n\ 1^v$
subtract and add from and to time of app. conj.,	$27^n\ 57^v$	$27^n\ 57^v$
Times of apparent contact and separation,	$24^n\ 35^v$	$30^n\ 58^v$

The calculation of the elements of the eclipse is thus completed. For the purpose, however, of illustrating the rules of the text (iv. 18–21) for determining, in the case of a solar eclipse, the amount of obscuration at any given moment during the continuance of the eclipse, we add also the following process:

XVI. To find the amount of obscuration of the sun, $2^n\ 38^v$ after first contact.

We make choice of this time, which is equivalent to $27^n\ 13^v$ after sunrise, because the data for finding the parallax in latitude at the moment have already been calculated (see above, XI). By iv. 18, from the

True former half-duration (*sphuṭa sparçasthityardha*),	$3^n\ 22^v$
deduct the given interval,	$2^n\ 38^v$
Interval to apparent conjunction (*madhyagrahaṇa*),	44^v

To reduce this interval in time to distance in longitude of the centres, we say (iv. 18)

$$60^n : 664'\ 7'' :: 44^v : 8'\ 7''$$

This, then, would be the interval in longitude between the two centres at the given moment, if there were no change of the moon's parallax in longitude during the eclipse, or if the moon actually gained in $2^n\ 29^v$, instead of in $3^n\ 22^v$, the distance intervening between her centre and the sun's at the moment of first contact. That, however, being not the case, we must reduce the result thus found in the ratio of $3^n\ 22^v$ to $2^n\ 29^v$, or of the true to the mean half-duration. That is to say (iv. 19),

$$3^n\ 22^v : 2^n\ 29^v :: 8'\ 7'' : 5'\ 59''$$

and this result, $5'\ 59''$, is the true distance of the two centres in longitude, $27^n\ 13^v$ after sunrise.

A briefer and more obvious method of obtaining the quantity in question would have been to make a proportion as follows: if, at the time of the eclipse, the moon gains upon the sun $27'\ 29''$ in $3^n\ 22^v$, what will she gain during 44^v? or

$$3^n\ 22^v : 27'\ 29'' :: 44^v : 5'\ 59''$$

Upon computation, we find the

Moon's parallax in latitude, $27^n\ 13^v$ after sunrise,	$16'\ 51''$ S.
Moon's true latitude,	$5'\ 25''$ N.
Moon's apparent latitude,	$11'\ 26''$
Its square,	$130'\ 43''$
Square of distance in longitude ($5'\ 59''$),	$35'\ 59''$
Their sum (iv. 20),	$166'\ 34''$
Actual distance of centres,	$12'\ 54''$
deduct from sum of semi-diameters,	$30'\ 6''$
Amount of obscuration at given time,	$17'\ 12''$

If it were desired to project the eclipse, we should now have to calculate (by iv. 24–25) the deflection (*valana*) for the moments of contact, conjunction, and separation, and likewise (by iv. 26) the scale of projection. As we do not, however, intend to present here a projection, and as the subject of the deflection has been sufficiently illustrated already, in the notes upon the text and in the calculation of the lunar eclipse, we regard it as unnecessary to go through with the labor required for making the computations in question. Finally, we annex, as in the case of the lunar eclipse formerly calculated, a summary comparison of the principal results of the Hindu processes with the elements of the eclipse in question as determined by Prof. Coffin, in his work referred to above. It must be borne in mind, however, that, owing to the faulty manner in which many of the computations of the native astronomer have been made, the comparison is not entirely trustworthy; a more careful adherence to the methods of the Siddhânta would have given somewhat different results: in the case of the daily motions of the sun and moon, the true calculations, as performed by us (see p. 452), give more correct values; in other instances, the contrary might perhaps have been the case.

	Sûrya-Siddhânta.	Prof. Coffin.	Hindu error.
Time of true conjunction in longitude,	$2^{h}\ 30^{m}$	$3^{h}\ 56^{m}$	$-\ 1^{h}\ 26^{m}$
Sun's and moon's longitude,	63° 50′ 37″	65° 12′ 37″	− 1° 22′
Moon's distance from node,	43′ 6″	4° 12′ 22″	− 3° 29′ 16″
Sun's daily motion in longitude,	56′ 52″	57′ 45″	− 53″
Moon's do. do.	12° 0′ 59″	12° 7′ 12″	− 6′ 13″
Sun's apparent diameter,	31′ 10″	31′ 37″	− 27″
Moon's do. do.	29′ 2″	29′ 45″	− 43″
Time of apparent conjunction,	$3^{h}\ 40^{m}$	$5^{h}\ 32^{m}$	$-\ 1^{h}\ 52^{m}$
Parallax in longitude, in time,	$1^{h}\ 10^{m}$	$1^{h}\ 36^{m}$	$-\ 26^{m}$
Amount of greatest obscuration,	19′	30′ 59″	− 11′ 59″
Time of first contact,	$2^{h}\ 20^{m}$	$4^{h}\ 15^{m}$	$-\ 1^{h}\ 55^{m}$
Time of separation,	$4^{h}\ 50^{m}$	$6^{h}\ 38^{m}$	$-\ 1^{h}\ 48^{m}$
Duration of eclipse,	$2^{h}\ 30^{m}$	$2^{h}\ 23^{m}$	$+\ 7^{m}$

26. pp. 327–344. Prof. Weber, of Berlin, has favored us in a private communication with a number of additional synonyms of the names of the asterisms, derived from the literature of the Brâhmaṇa period.

Mṛgaçiras, the fifth of the series, is also styled *andhakâ*, "the blind," apparently from its dimness; *âryikâ*, "honorable, worthy;" *invakâ*, of doubtful meaning: this latter epithet is also found in some manuscripts of the Amarakoça, as various reading for *ilvalâ*, which is there expressly declared (I. i. 2. 25) to designate the stars in the head of the antelope.

Ârdrâ, the sixth asterism, is called *bâhu*, "arm." Taking this name in connection with that of the preceding group, it seems probable that the Hindus figured to themselves the conspicuous constellation Orion as a running antelope, of which α, γ, β, and $\varkappa$ mark the feet: α, then, is the left fore-foot, or arm. Perhaps the name Mṛgavyâdha, "antelope-hunter," given to the neighboring Sirius (viii. 10), is connected with the same fancy.

The Maghâs are called in a hymn of the last book of the Rig-Veda (x. 85. 13) *aghâs:* the word means literally "evil, base, sinful," and its application to one of the asterisms is so strange that, if not found elsewhere, we should be inclined to conjecture a corrupted reading.

Phalgunî, or the Phalgunîs, forming the eleventh and twelfth groups, are styled also *arjunî*, "bright, shining."

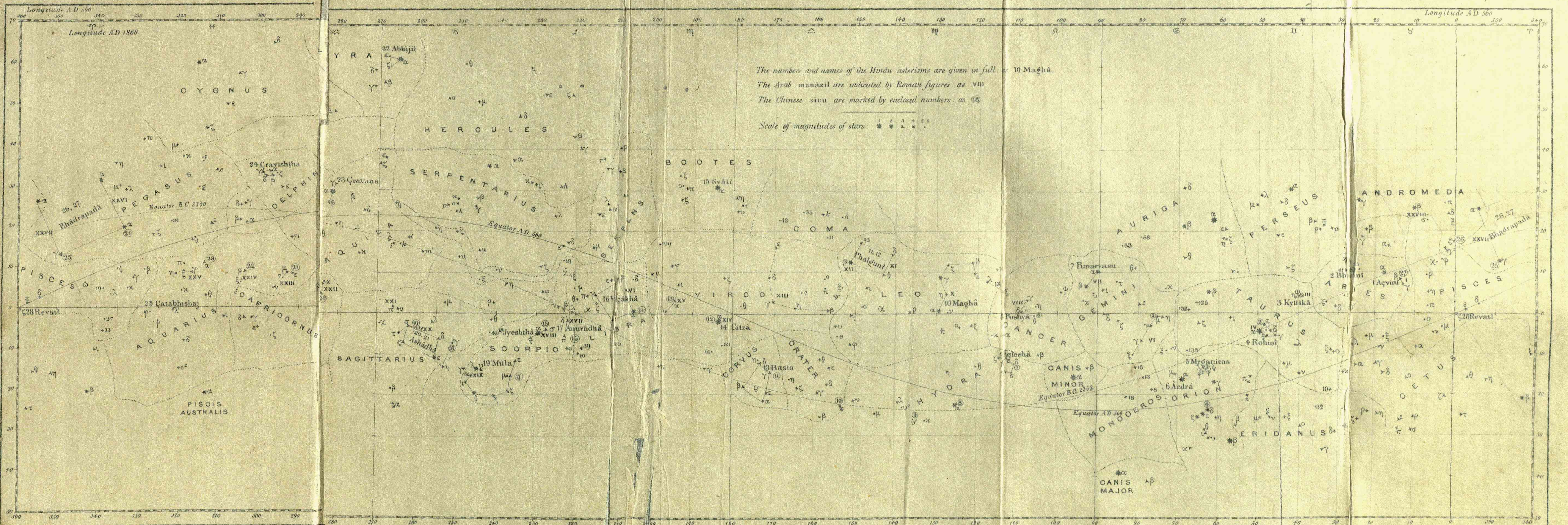
Çravaṇa, the twenty-third asterism, receives the name *açvattha*, which is properly that of a tree, the Ficus religiosa; the reason of the appellation is altogether obscure.

Bhâdrapadâ, the last double asterism, is called *pratishṭhâna*, "stand, support," in evident allusion to the disposition of the four bright stars which compose it, like the four feet of a stand, table, bedstead, or the like.

27. p. 344. We offer herewith the stellar chart to which reference was made in the note on p. 349, and which is intended to illustrate the positions and mutual relations of the Hindu *nakshatras*, the Arab *manâzil al-ḳamar*, and the Chinese *sieu*. We add a brief explanation of the manner in which it has been constructed, and the form in which it is presented.

The form of the map is that of a plane projection, having the ecliptic as its central line. It would have better illustrated the Hindu method of defining the positions of the junction-stars, and the errors of the positions as defined by them, if the equator of A. D. 560, instead of the ecliptic, had been made the central line of the projection. This, however, would have involved the necessity of calculating the right ascension and declination of every star laid down, a labor which we were not willing to undertake. Moreover, the ecliptic is, in fact, the proper central line along which the groups of the Hindu and Arab systems, at least, are arranged, and the form given to the chart also facilitates the laying down of the equator of B. C. 2350, which we desired to add, for the purpose of enabling our readers to judge in a more enlightened manner of the plausibility of M. Biot's views respecting the origin of the Chinese system: it is drawn with a broken line, while the equator of A. D. 560 is also represented, by an entire line. As the zone of the heavens represented is, in the main, that bordering the ecliptic, the distances and the configuration of the stars are altered and distorted by the plane projection to only a very slight degree, not enough to be of any account in a merely illustrative chart, such as this is. As a general rule, we have laid down all the stars of the first four magnitudes which are situated near the ecliptic, or in that part of the heavens through which the line of the asterisms passes; stars of the fourth to fifth magnitude are also in many cases added; smaller ones are noted only when they enter into the groups of the several systems, or when there were other special reasons for introducing them. The positions are in all cases taken from Flamsteed's Catalogue, and the magnitudes are also for the most part from the same authority: in many individual cases, however, we have followed other authorities. We have endeavored so to mark the members of the three different series that these may readily be traced across the map; but, to assure and facilitate the comparison, we also place upon the page opposite it a conspectus of the nomenclature, constitution, and correspondence of the three systems, referring to pages 327–344 for a fuller discussion of these matters, and an exposition of what is certain, and what more or less hypothetical, or exposed to doubt, with regard to them.

Hindu asterism.	Arab *manzil*.	Chinese *sieu*.
1. Açvinî. β and γ Arietis.	1. ash-Sharaṭân. β and γ Arietis.	27. Leu. β Arietis.
2. Bharaṇî. 35, 39, and 41 Arietis.	2. al-Butain. 35, 39 and 41 Arietis.	28. Oei. 35 Arietis.
3. Kṛttikâ. η Tauri, etc. (Pleiades).	3. ath-Thuraiyâ. η Tauri etc. (Pleiades).	1. Mao. η Tauri.
4. Rohiṇî. α, ϑ, γ, δ, ε Tauri.	4. ad-Dabarân. α, ϑ, γ, δ, ε Tauri.	2. Pi. ε Tauri.
5. Mṛgaçiras. λ, φ^1, φ^2 Orionis.	5. al-Hak'ah. λ, φ^1, φ^2 Orionis.	3. Tse. λ Orionis.
6. Ârdrâ. α Orionis.	6. al-Han'ah. η, μ, ν, γ, ξ Geminorum.	4. Tsan. δ Orionis.
7. Punarvasu. β, α Geminorum.	7. adh-Dhirâ'. β, α Geminorum.	5. Tsing. μ Geminorum.
8. Pushya. ϑ, δ, γ Cancri.	8. an-Nathrah. γ, δ Cancri, and Præsepe.	6. Kuei. ϑ Cancri.
9. Âçleshâ. ε, δ, σ, η, ρ Hydræ.	9. aṭ-Ṭarf. ξ Cancri, λ Leonis.	7. Lieu. δ Hydræ.
10. Maghâ. α, η, γ, ζ, μ, ε Leonis.	10. aj-Jabhah. α, η, γ, ζ Leonis.	8. Sing. α Hydræ.
11. Pûrva-Phalgunî. δ, ϑ Leonis.	11. az-Zubrah. δ, ϑ Leonis.	9. Chang. υ^1 Hydræ.
12. Uttara-Phalgunî. β, 93 Leonis.	12. aṣ-Ṣarfah. β Leonis.	10. Y. α Crateris.
13. Hasta. δ, γ, ε, α, β Corvi.	13. al-Auwâ'. β, η, γ, δ, ε Virginis.	11. Chin. γ Corvi.
14. Citrâ. α Virginis.	14. as-Simâk. α Virginis.	12. Kio. α Virginis.
15. Svâtî. α Bootis.	15. al-Ghafr. ι, κ, λ Virginis.	13. Kang. κ Virginis.
16. Viçâkhâ. ι, γ, β, α Libræ.	16. az-Zubânân. α, β Libræ.	14. Ti. α^2 Libræ.
17. Anurâdhâ. δ, β, π Scorpionis.	17. al-Iklîl. β, δ, π Scorpionis.	15. Fang. π Scorpionis.
18. Jyeshthâ. α, σ, τ Scorpionis.	18. al-Kalb. α Scorpionis.	16. Sin. σ Scorpionis.
19. Mûla. λ, υ, κ, ι, ϑ, η, ζ, μ, ε Scorp.	19. ash-Shaulah. λ, υ Scorpionis.	17. Uei. μ^2 Scorpionis.
20. Pûrva-Ashâḍhâ. δ, ε Sagittarii.	20. an-Na'âim. γ^2, δ, ε, η, φ, σ, τ, ζ Sagittarii.	18. Ki. γ^2 Sagittarii.
21. Uttara-Ashâḍhâ. σ, ζ Sagittarii.	21. al-Baldah. N. of π Sagittarii.	19. Teu. φ Sagittarii.
22. Abhijit. α, ε, ζ Lyræ.	22. Sa'd adh-Dhâbiḥ. α, β Capricorni.	20. Nieu. β Capricorni.
23. Çravaṇa. α, β, γ Aquilæ.	23. Sa'd Bula'. ε, μ, ν Aquarii.	21. Nü. ε Aquarii.
24. Çravishṭhâ. β, α, γ, δ Delphini.	24. Sa'd as-Su'ûd. β, ξ Aquarii.	22. Hiü. β Aquarii.
25. Çatabhishaj. λ Aquarii etc.	25. Sa'd al-Akhbiyah. α, γ, ζ, η Aquarii.	23. Goei. α Aquarii.
26. Pûrva-Bhâdrapadâ. α, β Pegasi.	26. al-Fargh al-Mukdim. α, β Pegasi.	24. Che. α Pegasi.
27. Uttara-Bhâdrapadâ. γ Pegasi, α Andromedæ.	27. al-Fargh al-Mukhir. γ Pegasi, α Andromedæ.	25. Pi. γ Pegasi.
28. Revatî. ζ Piscium, etc.	28. Baṭn al-Hût. β Andromedæ, etc.	26. Koei. ζ Andromedæ.



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28. p. 351. We have perhaps expressed ourselves in a manner liable to misconstruction as to the want of reason or authority for giving to the asterisms the name of "lunar mansions," "houses of the moon," and the like. We would by no means be understood as denying that in the Hindu science, especially its older forms, and in the Hindu mythology, they are brought into particular and conspicuous relations with the moon. Indeed, whether they were originally selected and established with reference to the moon's daily progress along the ecliptic, as has been, until lately, the universal opinion, or whether we are to believe with M. Biot that they had in the first instance nothing to do with the moon, and only came by chance to coincide in number with the days of her sidereal revolution—it is at any rate altogether probable that to the Hindu apprehension this coincidence formed the basis of the system. We may even conclude, from the fact that the asterisms are so frequently spoken of in the early literature of the Brâhmaṇa period, while nevertheless there is no distinct mention of the planets until later (Weber, Ind. Lit., p. 222), that for a long time the Hindus must have confined their attention and observations to the sun and moon, paying no heed to the lesser planets: and yet we cannot regard it as in any degree probable—hardly as possible, even—that any nation or people could establish a system of zodiacal asterisms without discovering and taking note of the planets; or that such a system could have been communicated to, and applied by, the Hindus, without a recognition on their part of those conspicuous and ever-moving stars. It may fairly be claimed, then, that the asterisms, as a Hindu institution, are an originally lunar division of the zodiac; but we object none the less to their being styled "lunar mansions," or called by any equivalent name; because, in the first place, the Hindus themselves have given them no name denoting a special relation to the moon, and no name signifying "house, mansion, station," or anything of the kind; and because, in the second place, as soon and as far as the Hindu astronomy extended itself beyond its limitation to observations of the moon, just so far and so soon did it employ the system of asterisms as a general method of division of the ecliptic; so that finally, as pointed out by us above, the asterisms have come to be divested, in the properly astronomical literature of India, of all special connection with the moon. With almost the same propriety might we call the Hindu signs "luni-solar mansions"—since they are, by origin, the parts of the ecliptic occupied by the sun during each successive synodical revolution of the moon—as denominate the *nakshatras* of the Siddhântas "lunar mansions."

29. p. 353. We should have mentioned farther, that an additional inducement—and one, probably, of no small weight—to the reduction of the number of asterisms from twenty-eight to twenty-seven, is to be recognized in the fact that the time of the moon's sidereal revolution in days, though intermediate between the two numbers, is yet decidedly nearer to twenty-seven, exceeding it by less than a third. M. Biot might even claim with some reason that the choice of the number t[illegible]ty-eight tended to prove the whole system not a lunar one by [illegible]: yet it might be replied that, the time of revolution being dis[illegible] more than twenty-seven days, the larger number was fully admissible, and that it was also in some respects preferable, as being one that could be halved and quartered.

30. p. 417. In bringing this work to a close, we deem it advisable to present, in a summary manner, but more distinctly and connectedly than could properly be done in the notes upon the text, our conclusions as to certain points in the history of the Sûrya-Siddhânta, and of the astronomical science which it represents.

In the first place, Bentley's determination of the age of the treatise we conceive to be altogether set aside by the considerations which we have adduced against it (note to i. 29–34); there is no reasonable ground for questioning that the Sûrya-Siddhânta is, as the Hindus have long believed it to be, one of the most ancient and original of the works which present their modern astronomical science. How far the text of which the translation has been given above is identical in substance and extent with that of the original Sûrya-Siddhânta, is another question, and one not easy to solve. That it is not precisely the same is evident enough. Even the modern manuscripts differ from one another in single readings, in details of arrangement, in added or omitted verses. A comparison of the texts adopted and established by the different commentators would be highly interesting, as carrying the history of the treatise a step farther back: but to us only one commentary is accessible, nor do we find anywhere any notices respecting the versions given by the others: in the absence of such, we may conclude that all present substantially the same text, and so are alike posterior to the modelling of the work into its present form and with its present contents. But the indications of addition and interpolation, which we have had in so many cases to point out in our notes, are sometimes too telling to be misinterpreted. Farther than this we may not at present go: any detailed discussion of the subject must remain unsatisfactory, until a fuller acquaintance with other of the ancient treatises, and a more careful comparison of them with one another, shall throw upon it new light. A point of special interest connected with it is, whether the elements of mean motions of the planets do actually date from about the time pointed out by Bentley's calculations. With regard to this we are far from being confident; but we do not regard it as impossible, or even as very improbable, that those elements, as presented by our text, have been the same from the beginning, never having undergone correction until the application of the *bîja*, about A. D. 1500 (p. 163 etc.). And the date of that correction is calculated at least to suggest the suspicion that Muslim science may have had something to do with it. That observation, and the improvement of their system by deductions from observation, were ever matters of such serious earnest with the Hindus that they should have been led to make such amendments independently, is yet to be proved. The most important alteration of which anything like direct proof is furnished is that which concerns the precession of the equinoxes (note to iii. 9–12); and even here we would not undertake to say confidently what is the conclusion to be drawn. All such inquiries must remain conjectural, mere gropings in the twilight, until the position of the Sûrya-Siddhânta in the Siddhânta literature shall be better understood. What has given it so much greater prominence and popularity than are enjoyed by the other works of its class, or from what period its preëminence dates, is unknown. There are treatises, like the Çâkalya-Sanhitâ (add. note 1), which agree with it in all essential features; there are yet others, like the Soma and Vasishtha Siddhântas, which are said (add. note 6) to vary little from it: whether any one among them all is original—and if any, which—whether in each case the relation is one of co-ordination or of subordination—we must be content for the time to be ignorant.

One thing, however, is certain: underneath whatever variety may characterize the separate treatises, there exists a fundamental unity; their differences are of secondary importance as compared with their resemblances; they all represent essentially a single system. And this by no means in the same sense in which all modern astronomical works may be said to represent a single system. For the Hindu system is not one of nature; it is not even a peculiar method of viewing and interpreting nature, from which, after it had once been devised by some controlling intellect, others had not the force and originality to deviate: it is a thoroughly artificial structure, full of arbitrary assumptions, of absurdities even, which have no foundation in nature, and could be invented by one as well as another. We need only to refer, as instances, to the frame-work of monstrous chronological periods (i. 14–23)—to the common epoch of the commencement of the Iron Age (note to i. 29–34), with its exact or nearly exact (add. note 6) conjunction of all the planets—to the form of statement of the mean motions, yielding recurring conjunctions, at longer or shorter intervals—to the assumption of a starting-point for the planets from at or near ζ Piscium (note to i. 27)—to the revolutions of the apsides and nodes of the planets (i. 41–44)—to the double system of epicycles (ii. 34–38)—to the determination of the planetary orbits (xii. 80–90), etc., etc. These are plain indications that the Hindu science emanated from one centre; that it was the elaboration of a period and of a school, if not of a single master, who had power enough to impose his idiosyncracy upon the science of a whole nation. The question, then, of the comparative antiquity of single treatises is lost in the higher interest of the inquiry—when, where, and under what influence originated the system which they all agree in representing?

What our opinions are upon these points will not be a matter of doubt with any one who may have carefully looked through the preceding pages, although they have nowhere been explicitly stated. We regard the Hindu science as an offshoot from the Greek, planted not far from the commencement of the Christian era, and attaining its fully developed form in the course of the fifth and sixth centuries. The grounds of this opinion we will proceed briefly to state.

In considering such a question, it is fair to take first into account the general probabilities of the case. And there can be no question that, from what we know in other respects of the character and tendencies of the Hindu mind, we should not at all look to find the Hindus in possession of an astronomical science containing so much of truth. They have been from the beginning distinguished by a remarkable inaptitude and disinclination to observe, to collect facts, to record, to make inductive investigations. The old belief under the influence of which Bailly could form his strange theories—the belief in the immense antiquity of the Indian people, and its immemorial possession of a highly developed civilization—the belief that India was the cradle of language, mythology, arts, sciences, and religions—has long since been proved an error. It is now well known that Hindu culture cannot pretend to a remoter origin than 2000 B. C., and that, though marked by striking and eminent traits of intellect and character, the Hindus have ever been weak in positive science; metaphysics and grammar—with, perhaps, algebra and arithmetic, to them the mechanical part of mathematical science—being the only branches of knowledge in which they have independently won honorable distinction. That astronomy would come to constitute an exception to the general rule in this respect, there is no antecedent ground for supposing. The infrequency of references to the stars in the early Sanskrit literature, the late date of the earliest mention of the planets, prove that there was no special impulse leading the nation to devote itself to studying the movements of the heavenly bodies. All evidence goes to show that the Hindus, even after they had derived from abroad (p. 348) a systematic division of the ecliptic, limited their attention to the two chief luminaries, the sun and moon, and contented themselves with establishing a method of maintaining the concordance of the solar year with the order of the lunar months. If, then, at a later period, we find them in possession of a full astronomy of the solar system, our first impulse is to inquire, whence did they obtain it? A closer inspection does not tend to inspire us with confidence in it as of Hindu origin. We find it, to be sure, thoroughly Hindu in its external form, wearing many strange and fantastic features which are to be at once recognized as of native Indian growth; but we find it also to contain much true science, which could only be derived from a profound and long-continued study of nature. The whole system, in short, may be divided into two portions, whereof the one contains truth so successfully deduced that only the Greeks, among all other ancient nations, can show anything worthy to be compared with it; the other, the framework in which that truth is set, composed of arbitrary assumptions and absurd imaginings, which betray a close connection with the fictitious cosmogonies and geographies of the philosophical and Puranic literature of India. The question presses itself, then, strongly upon us, whether these two portions can possibly have the same origin: whether the scientific habit of mind which could lead to the discovery of the one is compatible with those traits which would permit its admixture with the other. But most especially, could a system founded—as this, if original, must have been—upon sagacious, accurate, and protracted observation of the heavenly bodies, so entirely ignore the ground-work upon which it rested, and refuse and deny all possibility of future improvement by like means, as does this Hindu system, in whose text-books appears no record of an observation, and no confessed deduction from observations; in which the astronomer is remanded to his text-book as the sole and sufficient source of knowledge, nor ever taught or counselled to study the heavens except for the purpose of determining his longitude, his latitude, and the local time? Surely, we have a right to say that the system, in its form as laid before us, must come from another people or another generation than that which laid its scientific foundation; that it must be the work of a race which either had never known, or had had time to forget, the observing habits and the inductive methods of those who gave it origin. But the hypothesis that an earlier generation in India itself performed the labors of which the later system-makers reaped the fruit, is well-nigh excluded by the absence, already referred to, of all evidence in the more ancient literature of deep astronomical investigation: the other alternative, of derivation from a foreign source, remains, if not the only possible, at least the only probable one. We come, then, next to consider the direct evidences of a Greek origin.

First in importance among these is the system of epicycles for representing the movement, and calculating the positions, of the planets. This, the cardinal feature in both systems, is (ii. 34–45) essentially alike and the same in both. Now, notwithstanding the fact that such secondary circles do in fact represent, to a certain degree, true quantities in nature, there is yet too much that is strange and arbitrary in them to leave any probability to the supposition that two nations could have devised them independently. But there are sufficient grounds for believing the Greeks to have actually created their own system, bringing it by successive steps of elaboration to the form in which Ptolemy finally presents it. In the history of the science among the Greeks, everything is clear and open; they tell us what they owed to the Egyptians, what to the Chaldeans: we trace the conceptions which were the germs of their scheme of epicycles, the observations on which it was based, the inductive and deductive methods by which it was worked out and established. In the Hindu astronomy, on the other hand, all is groundless assumption and absurd pretense: we find, as basis for the system, neither the conceptions—for these are directly or impliedly denied or ignored —nor the observations—for not a mention of an actual observation is anywhere to be discovered—nor the methods: the whole is gravely put forth as a complete and perfect fabric, of divine origin and immemorial antiquity. On the agreement of the two sciences in point of numerical data we will not lay any stress, since it might well enough be supposed that two nations, if once set upon the same track toward the discovery of truth, would arrive independently at so near an accordance with nature and with one another. We will look for other evidences, of a less ambiguous character, to sustain our main argument. The division of the circle, into signs, degrees, minutes, and seconds, is the same in both systems, and, being the foundation on which all numerical measurements and calculations are made, is an essential and integral part of both. Now the names of the first subdivisions, the signs, are the same in Greece and in India (see note to i. 58): but with the Greeks they belong to certain fixed arcs of the ecliptic, being derived from the constellations occupying those arcs; with the Hindus they are applied to successive arcs of 30°, counted from any point that may be chosen: this is an unambiguous indication that the latter have borrowed them, and forgotten or neglected their original significance. But farther, the ordinary Hindu name of that division of the circle which is in most frequent use, the minute, is no Sanskrit word, but taken directly from the Greek, being *liptâ*, which is λεπτόν. Again, the planets are ordinarily named in the Siddhântas in the order in which they succeed one another as regents of the days of the week; and not only has it been shown above that the week is no original Hindu institution, but it has even appeared that, on tracing it to its very foundation, we find there another Greek word, ὥρα, represented by *horâ*. Once more, in the cardinal operation of finding by means of the system of epicycles the true place of a planet, we see that one of the most important data, the mean anomaly, is called by another name of Greek origin, namely *kendra*, which is κέντρον. These three words, occurring where they do, not upon the outskirts of the Hindu science, but in its very centre and citadel, amount of themselves almost to full proof of its Greek origin: taken in connection with the other concurrent evidences, they form an argument which can neither be set aside nor refuted. Of those other evidences, we will only mention farther here that Hindu treatises and commentaries of an early date often refer to the *yavanas*, "Greeks" or "westerners," and to *yavanâcâryâs*, "the Greek (or western) teachers," as authorities on astronomical subjects—that astronomical treatises are found bearing names which come more or less distinctly from the West (note to i. 4–6)—and that floating traditions are met with, to the effect that some of the Siddhântas were revealed to their human promulgators in Romaka-city, that is to say, at Rome. Farther witness to the same truth, deducible from other coincidences of the two systems, we pass unnoticed here, since it is not our object to discuss the question exhaustively, but only to bring forward the main grounds of our opinions.

The question next arises, when, and in what manner the knowledge of astronomy was communicated from Greece to India. In reply to this, only probabilities offer themselves, yet in some points the indications are pretty distinct. It is, in our own view, altogether likely that the science came in connection with the lively commerce which, during the first centuries of our era, was carried on by sea between Alexandria, as the port and mart of Rome, and the western coast of India. Two considerations especially favor this supposition: first, that the chief site of the Hindu science is found to be the city which lay nearest to the route of that commerce (note to i. 62): secondly, that Rome is the only western city or country which is distinctly mentioned in the astronomical geography (xii. 39), and the one with which, as above noticed, the astronomical traditions connect themselves. Had the Hindus derived their knowledge overland, through the Syrian, Persian, and Bactrian kingdoms which stood under Greek government, or in which Greek influence was predominant, and Greek culture known and prized, the name of Rome would have been vastly less likely to stand forth with such prominence, and the capitals of Hindustan proper would more probably have been the cradles of the new science. The absence from the Hindu system of any of the improvements introduced by Ptolemy into that of the Greeks (note to ii. 43–45) tends strongly to prove that the transmission of the principal groundwork of the former took place before his time: nor can we think it likely that the numerical elements adopted by the Hindus would vary so much as in many cases they are found to do from those of the Syntaxis, if the latter had been already in existence, and acknowledged as the principal and most authoritative exponent of Greek astronomy. Whether the information was transmitted through the medium of Hindus who visited the Mediterranean, or of learned Greeks who made the voyage to India, or by the translation of Greek treatises, or by what other methods, we would not at present even offer a conjecture; and the point is one of only subordinate consequence.

Whatever may have been the date of the first communication of the elements out of which the Hindu system was elaborated, there is good reason to suppose that its final reduction to its present form did not take place until some time during the fifth and sixth centuries. That period is distinctly pointed out by the choice of the equinox of A. D. 570 as the initial and principal point of the fixed sphere (note to i. 27), by the definition of position of the junction-stars of the asterisms (p. 355), and by the Hindu traditions which refer to that time the names of greatest prominence and authority in the early history of the science. It is evident that the elaboration of the system must have been a work of time, probably of many generations: what were the forms which it wore in the interval we do not know; here, as in many other departments of the Hindu literature, all record of the steps of development appears to be lost, only the final and fully formed product being preserved and transmitted to us: yet more light upon this point may still be hoped for, from the careful examination of all documents now accessible, or of such as may hereafter be discovered. The process of assimilation and adaptation to Hindu conceptions and Hindu methods was thoroughly and completely performed. Among the changes of method introduced, the most useful and important was the substitution of sines for chords (p. 200); the general substitution of an arithmetical for a geometrical form also deserves particular notice. That no great amount of geometrical science is implied in any part of the system, is very evident: it is distinguished by the constant and dexterous application of a few simple principles: the equality of the square of the hypothenuse to the sum of the squares of the base and perpendicular—the comparison of similar right-angled triangles—the formation and combination of proportions, the rule of three—are the characteristic features of the early Hindu mathematical knowledge, as displayed in the Sûrya-Siddhânta. Of other treatises, of an earlier or later period, as those of Brahmagupta and Bhâskara, which (see Colebrooke's Hindu Algebra) give evidence of knowledge more profound in arithmetic and algebra, we cannot at present speak; but we hope at some future time to be able to revert to the subject of the Hindu astronomy, in connection with these or other of the text-books by which it is represented.

Rev. Mr. Burgess, having placed his translation and notes in the hands of the Committee of Publication for farther elaboration, has very liberally allowed them entire freedom in their work, even where their deductions, and the views they expressed, did not accord with his own opinions. The most important point at issue between us is that discussed in the next preceding pages, or the originality of the Hindu astronomy; upon this, then, he is desirous of expressing independently his dissenting views, as in the following note.

Concluding Note by the Translator.

It may not be improper for me to state, in a closing note, that I had prepared a somewhat extended and elaborate essay on the history of astronomy among the Hindus, to be published in connection with the preceding translation. But the length of this essay is such—the subject matter of it not being material to the illustration of the Siddhânta, and the translation and notes having already occupied so much space—that it was not thought advisable to insert it here.

Yet as my investigations have led me to adopt opinions on some points differing from those advanced by Prof. Whitney in his very valuable additions to the notes upon the translation, truth and consistency seem to require me to present at least a brief summary of the results at which I arrived in that essay in reference to the points in question. By so doing, I free myself from any embarrassment under which I should labor, if hereafter—as I now intend—I shall wish to express the grounds for my opinions on these points, in this Journal or elsewhere.

The points to which I allude bear upon the claims of the Hindus to the honor of original invention and discovery in astronomical science—especially, their claims to such an honor in comparison with the Greeks.

Prof. Whitney seems to hold the opinion, that the Hindus derived their astronomy and astrology almost bodily from the Greeks—and that what they did not borrow from the Greeks, they derived from other people, as the Arabians, Chaldeans and Chinese (see pp. 178, 348, 350, et al.). I think he does not give the Hindus the credit due to them, and awards to the Greeks more credit than they are justly entitled to. In advancing this opinion, however, I admit that the Greeks, at a later period, were the more successful cultivators of astronomical science. There is nothing among the Hindu treatises that can compare with the great Syntaxis of Ptolemy. And yet, from the light I now have, I must think the Hindus original in regard to most of the elementary facts and principles of astronomy as found in their systems, and for the most part also in their cultivation of the science; and that the Greeks borrowed from them, or from an intermediate secondary source, to which these facts and principles had come from India. I might perhaps so far modify this statement as to admit the supposition that neither Greeks nor Hindus borrowed the one from the other, but both from a common source. But with my present knowledge, I cannot concur in the opinion that the Hindus are, to any great extent, indebted to the Greeks for their astronomy, or that the latter have any well grounded claims to the honor of originality in regard to those elementary facts and principles of astronomical science which are common to their own and other ancient systems, and which are of such a nature as indicates for them a single origin, and a transmission from one system to another. For the sake of clearness, it is well that I should state more specifically a few of the more important facts and principles that come under the class above referred to. They are as follows:

1. The lunar division of the zodiac into twenty-seven or twenty-eight asterisms (see transl., ch. viii). This division is common, with slight modifications, to the Hindu, Arabian, and Chinese systems.

2. The solar division of the zodiac into twelve signs, with the names of the latter. These names are, in their import, precisely the same in the Hindu and Greek systems. The coincidence is such that the theory of the division and the names of the parts having proceeded from one original source is unquestionably the correct one.

3. The theory of epicycles in accounting for the motions of the planets, and in calculating their true places. This is common to the Hindu and Greek astronomies. At least, there is such a coincidence in the two systems in reference to the epicycles as almost to preclude the idea of independent origin or invention.

4. Coincidences, and even a sameness in some parts, between the systems of astrology received among the Hindus, Greeks, and Arabians, strongly indicate for those systems, in their primitive and essential elements, a common origin.

5. The names of the five planets known to the ancients, and the application of these names to the days of the week (see notes, i. 52).

In regard to these specifications I remark in general:

First, in reference to no one of them do the claims of any people to the honor of having been the original inventors or discoverers appear to be better founded than those of the Hindus.

Secondly, in reference to most of them, the evidence of originality I regard as clearly in favor of the Hindus; and in regard to some, and those the more important, this evidence appears to me nearly or quite conclusive.

I have not space for detail, nor is it the design of this note to enter into the details of argument on any point whatever. A brief remark, however, for the sake of clearness, seems called for in reference to each of the above five specifications of facts and principles common to some or all of the ancient systems of astronomy and astrology.

1. As to the lunar division of the zodiac into twenty-seven or twenty-eight asterisms. The undoubted antiquity of this division, even in its elaborated form, among the Hindus, in connection with the absence or paucity of such evidence among any other people, incline me decidedly to the opinion that the division is of a purely Hindu origin. This is still my opinion, notwithstanding the views advanced by M. Biot and others in favor of another origin.

2. As to the solar division of the zodiac into twelve parts, and the names of those parts. The use of this division, and the present names of the signs, can be proved to have existed in India at as early a period as in any other country; and there is evidence less clear and satisfactory, it is true, yet of such a character as to create a high degree of probability, that this division was known to the Hindus centuries before any traces can be found in existence among any other people.

As corroborative of this position in part, or at least as strongly favoring the idea of an eastern origin of the division of the ecliptic in question, I may be allowed to adduce the opinions of Ideler and Lepsius, as quoted by Humboldt (Cosmos, Harper's ed., iii. 120, note): "Ideler is inclined to believe that the Orientals had names, but not constellations, for the Dodecatomeria, and Lepsius regards it as a natural assumption 'that the Greeks, at the period when their sphere was for the most part unfilled, should have added to their own the Chaldean constellations from which the twelve divisions were named.'" Whether Ideler meant by "Orientals" the Chaldeans, or some other eastern people, the application of the term in this connection to the Hindus exactly suits the supposition of the Indian origin of the division in question, since in Indian astronomy the names of the signs are merely names of the twelfth parts of the ecliptic, and are never applied to constellations. Humboldt's opinion is, that the solar divisions of the ecliptic, with the names of the signs, came to the Greeks from Chaldea. I think the evidence preponderates in favor of a more eastern, if not a Hindu, origin.

3. The theory of epicycles. The difference in the development of this theory in the Greek and Hindu systems of astronomy precludes the idea that one of these people derived more than a hint respecting it from the other. And so far as this point alone is concerned, we have as much reason to suppose the Greeks to have been the borrowers as the contrary; but other considerations seem to favor the supposition that the Hindus were the original inventors of this theory.

4. As regards astrology, there is not much honor, in any estimation, connected with its invention and culture. The coincidences that exist between the Hindu and Greek systems are too remarkable to admit of the supposition of an independent origin for them. But the honor of original invention, such as it is, lies, I think, between the Hindus and the Chaldeans. The evidence of priority of invention and culture seems, on the whole, to be in favor of the former; the existence of three or four Arabic and Greek terms in the Hindu system being accounted for on the supposition that they were introduced at a comparatively recent period. In reference, however, to the word *horâ*, Greek ὥρα (see notes to i. 52; xii. 78–79), it may not be inappropriate to introduce the testimony of Herodotus (B. II, ch. 109): "The sun-dial and the gnomon, with the division of the day into twelve parts, were received by the Greeks from the Babylonians." There is abundant testimony to the fact that the division of the day into twenty-four hours existed in the East, if not actually in India, before it did in Greece. In reference, farther, to the so-called Greek words found in Hindu astronomical treatises, I would remark that we may with entire propriety refer them to that numerous class of words common to the Greek and Sanskrit languages, which either came to both from a common source, or passed from the Sanskrit to the Greek at a period of high antiquity; for no one maintains, so far as I am aware, that the Greek is the parent of the Sanskrit, to the extent indicated by this numerous class of words, and by the similarity of grammatical inflections in the two languages.

5. As to the names of the planets, I remark that the identity of all of them in the Hindu and Greek systems is not to my mind clearly made out. However this may be, I think the present names of the planets in Greek astronomy originated at least as far east as Chaldea. Herodotus says (B. II, ch. 52) . . . "the names of the gods came into Greece from Egypt." The names of the planets are names of gods. Herodotus's opinion indicates the belief of the Greeks in reference to the origin of these names. Other considerations show for them, almost beyond a question, an origin as far east, to say the least, as Chaldea.

As to the application of the names of the planets to the days of the week, it is impossible to determine definitely where it originated. Respecting this matter, Prof. H. H. Wilson expresses his opinion—in which I concur—in the following language: "The origin of this arrangement is not very precisely ascertained, as it was unknown to the Greeks, and not adopted by the Romans until a late period. It is commonly ascribed to the Egyptians and Babylonians, but upon no very sufficient authority, and the Hindus appear to have at least as good a title to the invention as any other people" (Jour. Roy. As. Soc., ix. 84).

One word on the claims of the Arabians to the honor of original invention in astronomical science. And first, they themselves claim no such honor. They confess to having received their astronomy from India and Greece. They had at an early period some two or three of the first Hindu treatises of astronomy. "In the reign of the second Abbasside Khalif Almansúr . . . (A. D. 773), as is related in the preface to the astronomical tables of Ben-Al-Adami, published . . . A. D. 920, an Indian astronomer, well versed in the science which he professed, visited the court of the Khalif, bringing with him tables of the equations of planets according to the mean motions, with observations relative to both solar and lunar eclipses, and the ascension of the signs; taken, as he affirmed, from tables computed by an Indian prince, whose name, as the Arabian author writes it, was Phíghar" (Colebrooke's Hindu Algebra, p. lxiv). That the Arabians were thoroughly imbued with a knowledge of the Hindu astronomy before they became acquainted with that of the Greeks, is evident from their translation of Ptolemy's Syntaxis. It is known that this great work of the Greek astronomer first became known in Europe through the Arabic version. In the Latin translation of this version, the ascending node (Greek *ἀναβιβάζων σύνδεσμος*) is called *nodus capitis*, "node of the head," and the descending node (Greek *καταβιβάζων σύνδεσμος*), *nodus caudæ*, "node of the tail"—which are pure Hindu appellations (see Latin Translation of Almagest, B. iv, ch. 4; B. vi, ch. 7, et al.). This fact, with other evidence, clearly shows the influence of Hindu astronomy on that of the Arabians. In fact, this latter people seem to have done little more in this science than work over the materials derived from their eastern and western neighbors.

Another fact showing the belief of the Arabians themselves respecting their indebtedness, in matters of science, to the Hindus, should be mentioned here. They ascribe the invention of the numerals, the nine digits (the credit of whose invention is quite generally awarded to the Arabians), to the Hindus. "All the Arabic and Persian books of arithmetic ascribe the invention to the Indians" (Strachey, on the Early History of Algebra, As. Res., xii. 184; see likewise Colebrooke's Hindu Algebra, pp. lii–liii, where the same is shown from a different authority. Strachey's article was published subsequently to the work of Colebrooke).

The above facts and considerations, showing the indebtedness of the Arabians to the Hindus in regard to mathematical and astronomical science, clearly have an important bearing on the question of priority of invention in regard to the lunar division of the zodiac into twenty-eight asterisms, at least so far as the Arabians are concerned. Taking all the facts into account, the supposition that this people were the inventors is altogether untenable.

I close this note—already longer than I intended—with a quotation from that distinguished orientalist, H. T. Colebrooke. In a very valuable essay entitled "On the Notions of the Hindu Astronomers concerning the Precession of the Equinoxes and Motions of the Planets," having stated with some detail some of the more striking peculiarities of the Hindu systems, and likewise coincidences existing between them and that of the Greeks, with the evidence of communication from one people to the other, he says: "If these circumstances, joined to a resemblance hardly to be supposed casual, which the Hindu astronomy, with its apparatus of eccentrics and epicycles, bears in many respects to that of the Greeks, be thought to authorize a belief, that the Hindus received from the Greeks that knowledge which enabled them to correct and improve their own imperfect astronomy, I shall not be inclined to dissent from the opinion" (As. Res., xii. 245–6; Essays, ii. 411).

This is all that so learned and cautious a writer could say in favor of the opinion that the Hindus derived astronomical knowledge from the Greeks. More than this I certainly could not say. After the solar division of the zodiac, with the names of its parts, it is evident, I think, that only hints could have passed from one people to the other, and that at an early period; for on the supposition that the Hindus borrowed from the Greeks at a later period, we find it difficult to see precisely what it was that they borrowed; since in no case do numerical data and results in the systems of the two peoples exactly correspond. And in regard to the more important of such data and results—as for instance, the amount of the annual precession of the equinoxes, the relative size of the sun and moon as compared with the earth, the greatest equation of the centre for the sun—the Hindus are more nearly correct than the Greeks, and in regard to the times of the revolutions of the planets they are very nearly as correct: it appearing from a comparative view of the sidereal revolutions of the planets (p. 168), that the Hindus are most nearly correct in four items, and Ptolemy in six. There has evidently been very little astronomical borrowing between the Hindus and the Greeks. And in relation to points that prove a communication from one people to the other, with my present knowledge on the subject, I am inclined to think that the course of derivation was the opposite to that supposed by Colebrooke—from east to west rather than from west to east; and I would express my opinion in relation to astronomy, in the language which this eminent scholar uses in relation to some coincidences in speculative philosophy and religious dogmas, especially the doctrine of metempsychosis, found in the Greek and Hindu systems, which indicate a communication from one people to the other: "I should be disposed to conclude that the Indians were in this instance teachers rather than learners" (Transactions of the Roy. As. Soc., i. 579). This opinion is expressed in the last essay on oriental philosophy that came from the pen of Colebrooke. E. B.

Boston, May, 1860.

SANSKRIT INDEX.

THE following Index contains all the Sanskrit words, excepting proper names, which have been cited in the text and notes, in connection with their translation or more detailed explanation. It includes many terms of trivial importance, but we prefer to err upon the side of fullness, if upon either. All the cases of occurrence of each word are not given, but it is referred to a characteristic passage, or to the note where it is explained. The references by Roman and Arabic figures are to chapter and verse, and an added *n* denotes the note next following the verse given: Arabic figures when used alone refer to pages.

the wind that moves the planets

GENERAL INDEX.

The references are as in the preceding Index.

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