TRANSLATION

OF THE

SURYA SIDDHA'NTA.

CONTENTS.

TRANSLATION OF SU'RYA-SIDDHA'NTA.

CHAPTER I.

Called MADHYA-GATI *which treats of the Rules for finding the mean places of the planets.*

Invocation.

1. Salutation to that Supreme Being which is of inconceivable and imperceptible form, void of properties (of all created things), the external source of wisdom and happiness, and the supporter of the whole world in the shapes (of BRAHMÁ, VISHNU and SIVA.)

Introductory.

2 & 3. Some time before the end of the KRITA YUGA, a great Demon named MAYA, being desirous of obtaining the sound, secret, excellent, sacred and complete knowledge of Astronomy, which is the best of the six sciences subordinate to the VEDA, practised the most difficult penance, the worship of the Sun.

4. The self-delightful Sun, being gratified at such (difficult) penance of MAYA, bestowed on him the knowledge of the science of Astronomy which he was inquiring after.

The illustrious Sun said.

5. (O MAYA,) I am informed of your intention (of attaining the knowledge of the science of Astronomy) and pleased with your penance. I, therefore will grant you the great knowledge of Astronomy which treats of time.

6. (But since) nobody can bear my light and I have no time to teach you (the science,) this man who partakes of my nature will impart to you the whole of the science.

7. The God Sun, having thus spoken to, and ordered the man born from himself (to teach MAYA), disappeared. That man spoke to MAYA, who stood bending and folding his hands close to his forehead, in the following manner.

8. (O MAYA), hear attentively the excellent knowledge (of the science of Astronomy) which the Sun himself formerly taught to the great saints in each of the YUGAS.

9. I teach you the same ancient science, which the Sun himself formerly taught. (But) the difference (between the present and the ancient works) is caused only by time, on account of the revolution of the YUGAS.

Kinds of time.

10. Time is of two kinds; the first (is continuous and endless which) destroys all animate and inanimate things (which is also the cause of creation and preservation), the second is that which can be known. This (latter kind of time) is also of two kinds; the one is called MÚRTA (measurable) and the other is AMÚRTA (immeasurable, by reason of bulkiness and smallness respectively).

Pala and Ghatiká.

11. The time called MÚRTA, begins with PRÁṆA (a portion of time which contains four seconds,) and the time called AMÚRTA begins with TRUṬI (a very small portion of time which is the $\frac{1}{33750}$th part of a second.) The time which contains six PRÁṆAS is called a PALA, and that which contains sixty PALAS is called a GHAṬIKÁ.

Day and Month.

12. The time, which contains sixty GHAṬIKÁS is called a NÁKSHATRA AHORÁTRA (a sidereal day and night) and a NÁKSHATRA MÁSA (a sidereal month) consists of thirty NÁKSHATRA AHORÁTRAS. Thirty SÁVANA (terrestrial) days (a terrestrial day being reckoned from sun-rise to sun-rise) make a SÁVANA month.

The lunar and solar month and the Divine Day.

13. Thirty lunar days make a lunar month, and a solar month is the time which the Sun requires to move from

one sign* of the Zodiac to the next. A solar year consists of twelve solar months; and this is called a day of the Gods.

The length of the year of the Gods and Demons.

14. An AHORÁTRA (day and night) of the Gods and that of the Demons are mutually the reverse of each other, (viz. a day of the Gods is the night of the Demons; and conversly, a night of the Gods is the day of the Demons). Sixty AHORÁTRAS, multiplied by six, make a year of the Gods and Demons.

The length of a great YUGA.

15 & 16. The time containing twelve thousand years of the Gods is called a CHATURYUGA (the aggregate of the four YUGAS, KRITA, TRETÁ, DWÁPARA and KALI).

These four YUGAS including their SANDHYÁ† and SANDHYÁNS'A contain 4,320,000 solar years.

The numbers of years included in these four small YUGAS are proportional to the numbers of the legs of DHARMA‡ (virtue personified).

The length of the four small YUGAS.

17. The tenth part of 4,320,000 the number of years in a great YUGA, multiplied by 4, 3, 2, 1 respectively make up the years of each of the four YUGAS, KRITA and others, the years of each YUGA include their own sixth part, which is collectively the number of years of SANDHYÁ and SANDHYÁNS'A, (the periods at the commencement and expiration of each YUGA).

The length of a period called MANU and that of its SANDHI.

18. (According to the technicality of the time called MÚRTA,) 71 great YUGAS (containing 306,720,000 solar years) constitute a MANWANTARA (a period from the beginning of a

* It is to be observed here that the signs Aries, Taurus, &c., are reckoned from the star REVATÍ (ζ Piscium,) and a solar year corresponds to a sidereal year. B. D.

† These two words will be explained in the sequel. B. D.

‡ It is stated that Dharma stands with four legs in the KRITA, with three legs in the TRETÁ, with two legs in the DWÁPARA and with one leg in the KALI. Therefore the number of the years of the KRITA, TRETÁ, DWÁPARA, and KALI are proportional to 4, 3, 2 and 1 respectively. B. D.

Manu to its end) and at the end of it, 1,728,000 the whole number of the (solar) years of the KṚITA, is called its SANDHI; and it is the time when a universal deluge happens.

The length of a KALPA.

19. Fourteen such MANUS with their SANDHIS (as mentioned before), constitute a KALPA, at the beginning of which is the fifteenth SANDHI which contains as many years as a KṚITA does.

The lengths of a day and night of the God BRAHMÁ.

20. Thus a thousand of the great YUGAS make a KALPA, a period which destroys the whole world. It is a day of the God BRAHMÁ, and his night is equal to his day.

The period of his life and that of his passed age.

21. And the age of BRAHMÁ consists of a hundred years—according to the enumeration of day and night (mentioned in the preceding S'LOKA). One half of his age has elapsed, and this present KALPA is the first in the remaining half of his age.

22. Out of this present KALPA six MANUS with their SANDHIS, and twenty-seven YUGAS of the seventh Manu called VAIVASWATA have passed away.

23. Of the twenty-eighth great YUGA, the KṚITA YUGA has passed away. Let (a calculator,) reckoning the time from the end of the KṚITA compute the number of years passed.

24. 47,400 years of the Gods have elapsed in the creation of the God BRAHMÁ, of animate and inanimate things, of the planets, stars, Gods, Demons, &c.

How the planets move eastward.

25. Now the planets (such as the Sun) being on their orbits, go very rapidly and coutinnally with the stars towards the west and hang down (from their places towards east) at an equal distance, (i. e. they describe equal spaces daily towards the east,)* as if overpowered by the stars (by reason of their very rapid motion caused by the air called PRAVAHA.)

* The Hindu Astronomers suppose that all the planets move in their orbits with the same velocity. B. D.

26. Therefore, the motions of the planets appear towards the east, and their daily motions determined by their revolutions (by applying the rule of proportion to them) are unequal to each other, in consequence of the circumferences of their orbits; and by this unequal motion, they pass the signs (of the Zodiac.)

Bhagaṇa or a sidereal revolution.

27. The planet which moves rapidly, requires a short time, to pass the signs (of the Zodiac,) and the planet that moves slowly, passes the signs (of the Zodiac) in a long time. BHAGAṆA means that revolution through the signs (of the Zodiac which a planet makes by passing round) up to the end of the true place of the star called REVÁTI (ζ Piscium, from which end they set out.)

The circular measures.

28. Sixty VIKALÁS (seconds) make a Kalá (a minute) and sixty minutes constitute an ANS'A (a degree.) A RÁSÍ (a sign) consists of thirty degrees and just twelve RÁS'IS (signs) make a Bhagaṇa (revolution.)

The number of revolutions of the Sun, Mercury, Venus, and the S'íghrochcha of Mars, Saturn and Jupiter in a great YUGA.

29. In a great YUGA each of the planets, the Sun, Mercury, Venus and the S'ÍGHROCHCHA (i. e. the farthest point from the centre of the Earth in the orbit of each of the planets) of Mars, Saturn and Jupiter moving towards the east make 4,320,000 revolutions (about the Earth).

Of Moon and Mars.

30. There are 57,753,336 revolutions of the Moon and 2,296,832 revolutions of the planet Mars.

Of Mercury's S'íghrochcha and Jupiter.

31. There are 17,937,060 revolutions of the S'ÍGHROCHCHA of the planet Mercury* and 364,220 revolutions of the planet Jupiter.

* The revolutions of the Síghrochchas of Mercury and Venus correspond to their revolutions about the Sun. B. D.

Of Venus's S'ighrocheha and of Saturn.

32. There are 7,022,376 revolutions of the S'IGHROCHCHA of the planet Venus* and 146,568 revolutions of the planet Saturn.

Of Moon's Apogee and Node.

33. In a great YUGA, there are 488,203 revolutions of the Moon's MANDOCHCHA (apogee,) and the number of the retrograde revolutions of the Moon's ascending node is 232,238.

Number of sidereal revolutions and the mode of finding the number of risings of the planets in a YUGA.

34. There are 1,582,237,828 sidereal revolutions in a great YUGA (a sidereal revolution is the time from one rising of a star to the next at the equator and it is a sidereal day as mentioned in the twelfth S'LOKA.) These sidereal revolutions diminished by each planet's own revolutions (before mentioned) are its own risings in a great YUGA.

The mode of finding the No. of Lunar months and that of the additive months in a YUGA.

35. The number of Lunar months is equal to the difference between the revolutions of the Moon and those of the Sun; and the remainder of the Lunar Months lessened by the Solar months is the number of ADHIMÁSAS (additive months.)

The mode of finding the No. of subtractive days in a YUGA and the definition of a terrestrial day.

36. If the SAVANA (terrestrial) days be subtracted from the Lunar days, the remainder constitute the days called the TITHI-KSHAYA (subtractive days.) There the SAVANA days are those in which a SÁVANA day or terrestrial† day is equal to the time from sun-rise to sun-rise (at the equator).

No. of terrestrial and lunar days.

37. There are 1,577,917,828 terrestrial days and 1,603,000,080 lunar days in a great YUGA.

* The revolutions of the Sighrochchas of Mercury and Venus correspond to their revolutions about the Sun. B. D.

† A terrestrial day is that which the English call a solar day. B. D.

No. additive months and that of subtractive days.

38. (In a great YUGA) there are 1,593,336 additive months and 25,082,252 subtractive days.

No. of Solar months in a YUGA and the way to know the No. of terrestrial days.

39. There are 51,840,000 Solar months in a great YUGA, and the terrestrial days are the sidereal days diminished by the Sun's revolutions.

40. The revolutions of the planets, the additive months, the subtractive days, the sidereal days, the lunar days and the terrestrial days (mentioned above) separately multiplied by 1000 make the revolutions, the additive months &c., in a KALPA, (because a KALPA consists of 1000 great YUGAS.)

Nos. of Revolutions of the Apogees of the planets.

41 & 42. In a KALPA, there are 387 revolutions of the Sun's Apogee (about the Earth), 204 of Mars' apogee, 368 of Mercury's apogee, 900 of Jupiter's apogee, 535 of Venus' apogee and 39 of Saturn's apogee.

Now we proceed to mention the retrograde revolutions of the Nodes (of the planets Mars, &c.)

43 & 44. There are 214, 488, 174, 903, 662 revolutions of the Nodes of the planets Mars, Mercury, Jupiter, Venus and Saturn respectively. We have already mentioned the revolutions of the apogee and node of the Moon.

The number of the solar years elapsed from the time when the planetary motions commenced, to the end of the last KRITA YUGA.

45, 46 & 47. Collect together the years of the six MANUS, with their six SANDHIS, and the SANDHI which lies in the beginning of the KALPA, those of twenty-seven great YUGAS of the present MANU named VAIVASWATA and those of the KRITA YUGA; and subtract from the sum, the said number of years of the Gods, reduced to solar years, required (by the God Brahmá) in the creation of the universe, (before the commencement of the planetary montions,) and the remainder 1,953,720,000 is the number of solar years before the end of the KRITA YUGA.

To find the AHARGANA or the No. of terrestrial days from the time the planetary motions commenced to the present mid-night.

48. To 1,953,720,000 the number of elapsed years, add the number of years elapsed (from the end of the last KRÍTA YUGA to the present year;) reduce the sum to months (by multiplying it by 12;) to the result add the number of lunar months from the beginning of the light half of the CHAITRA* (of the current year to the present lunar month.)

49. Write down the result separately; multiply it by the number of additive months (in a YUGA) and divide the product by the number of solar months (in a YUGA); the quotient, (without the remainder,) will be the elapsed additive months. Add the quotient (without the remainder) to the said result, reduce the sum to days (by multiplying it by thirty) and increase it by the number of (lunar) days (passed of the present lunar month).

50 and 51. Write down the amount in two places; (in one place,) multiply it by the number of subtractive days (in a YUGA); divide the product by the number of lunar days (in a YUGA) and the quotient (without the remainder) will be the number of elapsed subtractive days. Take the number of these days from the amount (which is written in the other place) and the remainder will be the number of elapsed terrestrial days (from the time, when the planetary motions commenced) to the present midnight at LANKÁ.†

* That lunar month which ends, when the Sun is in MESHA (stellar Aries) the first sign of the Zodiac, is called CHAITRA, and that which terminates when the Sun is in VRISHABHA (Taurus) the second sign of the Zodiac, is called VAIS'ÁKHA and so on. Thus the lunar months corresponding to the twelve signs Mesha (Aries,) VRISHABHA (Taurus,) MITHUNA (GEMINI,) KARKA (Cancer,) SINHA (Leo,) KANYÁ (Virgo,) TULÁ (Libra,) VRIS'CHIKA (Scorpio,) DHANU (Sagittarius,) MAKARA (Capricornus,) KUMBHA (Aquarius) and MÍNA (Pisces,) are CHAITRA, VAIS'ÁKHA, JYESHTHA, ÁSHÁDHA, S'RÁVANA, BHÁDRAPADA, ÁS'WINA, KÁRTIKA, MÁRGAS'IRSHA, PAUSHA, MÁGHA and PHÁLGUNA.

If two lunar months terminate when the Sun is only in one sign of the Zodiac, the second of these is called ADHIMÁSA (an additive or intercalary month.) The 30th part of a lunar month is called Tithi (a lunar day.) B. D.

† The proof of the process for finding the AHARGANA stated in the S'LOKAS from 48th to 51st will be clearly understood from the following statement.

In order to find the AHARGANA, let the number of the Solar years elapsed be multiplied by 12; and the product is the number of elapsed solar months to the last mean MESHA SANKRÁNTI (i. e. the time when the mean Sun enters the first stellar sign of the Zodiac called stellar Aries;) to this let the number of passed

From the number of these elapsed days, the Rulers of the present day month and year can be known (by reckoning the order of them) from the Sun.

To find the Ruler of the present day.

Divide the number of elapsed terrestrial days by 7, and reckoning the remainder from the sun-day, the Ruler of the present day will be found.

To find the Rulers of the present terrestrial month and year.

52. Divide the number of elapsed terrestrial days by the number of days in a month and by that in a year (i. e. by 30 and 360) multiply the quotients (rejecting the remainders) by 2 and 3 respectively, and increase the products by 1. Divide the results by 7, and reckoning (the order of the Rulers) from the Sun, the remainders will give the Rulers of the present (terrestrial) month and year respectively.

lunar months CHAITRA, &c., considering them as solar, be added: the sum is the elapsed solar months up to the time when the Sun enters the stellar sign of the Zodiac corresponding to the present lunar month. To make these solar months lunar, let the elapsed additive months be determined by proportion in the following manner.

As the number of solar months in a YUGA
: the number of additive months in that period
:: the number of solar months just found
: the number of additive months elapsed.

If these additive months with their remainder be added to the solar months elapsed, the sum will be the number of lunar months to the end of the solar month; but we require it to the end of the last lunar month. And as the remainder of the additive months lies between the end of the lunar month and that of its corresponding solar month, let the whole number of additive months, without the remainder, be added to the solar months elapsed; and the sum is the number of the lunar months elapsed to the end of the last lunar month.

This number of lunar months elapsed, multiplied by 30 and increased by the number of the passed lunar days of the present lunar month, is the number of lunar days elapsed. To make these lunar days terrestrial, the elapsed subtractive days should be determined by proportion as follows.

As the number of lunar days in a YUGA
: the number of subtractive days in that period
:: the number of lunar days just found
: the number of subtractive days elapsed.

If these subtractive days be subtracted with their remainder from the lunar days, the difference will be the number of terrestrial days elapsed to the end of the last lunar day; but it is required to the present mid-night. As the remainder of the terrestrial days lies between the end of the lunar day and the mid-night, the whole number of the subtractive days, (without the remainder) should be subtracted from the lunar days elapsed, and the difference is, of course, the number of terrestrial days elapsed from the time, when planetary motions commenced, to the present mid-night at LANKÁ. B. D.

To find the mean places of the planets at a given midnight at LANKÁ.

53. Multiply the number of elapsed terrestrial days by the number of a planet's revolutions (in a KALPA); divide the product by the number of terrestrial days (in a KALPA); and the quotient will be the elapsed revolutions, signs, degrees &c. of the planet. Thus the mean place of each of the planets can be found.

To find the places of the S'ighrochchas, apogees and nodes of the planets.

54. In the same way, the mean places of the S'ÍGHROCHCHA and MANDOCHCHA (apogee) whose direct revolutions (in a KALPA) are mentioned before, and those of the nodes of the planets can be found. But the places of the nodes, thus found, must be subtracted from twelve signs, because their motions are contrary to the order of the signs.

To find the present SAMVATSARA.

55. Multiply the number of elapsed revolutions of Jupiter by 12; to the product add the number of the signs from the stellar Aries to that occupied by Jupiter; divide the amount by 60, and reckoning the remainder from VIJAYA,* you will find the present SAMVATSARA.

An easy method for finding the mean places of the planets.

56. These processes are mentioned (from 45th S'LOKA to 54th) in detail, but, for convenience' sake, let (an astronomer) computing the elapsed terrestrial days from the beginning of the TRETÁ YUGA, find easily the mean places of the planets.

57. At the end of this KRÍTA YUGA the mean places of all the planets, except their nodes and apogees, coincide with each other in the first point of stellar Aries.

58. (At the same instant) the place of the Moon's apogee= nine signs, her ascending node=six signs, and the places of the other slow moving apogees and nodes, whose revolutions are mentioned before, are not without degrees (i. e. they contain some signs and also degrees).

* Astrologers reckon 60 SAMVATSARAS, VIJAYA &c., which answer successively to the periods required by mean Jupiter to move from one sign to the next. B. D.

The lengths of the Earth's diameter and its circumference.

59. The diameter of the Earth is 1600 YOJANAS. Multiply the square of the diameter by 10, the square-root of the product will be the circumference of the Earth.

The rectified circumference of the Earth, and DES'ÁNTARA* correction in minutes.

60. The Earth's circumference multiplied by the sine of co-latitude (of the given place) and divided by the radius is the SPHUṬA or rectified circumference (i. e. the parallel of latitude) at that place.

Multiply the daily motion (in minutes) by the distance of the given place from the Middle Line of the Earth, and divide the product by the rectified circumference of the Earth.

61. Subtract the quotient in minutes from the place of the planet (which is found at the mid-night of LANKÁ, as mentioned in S'LOKA 53,) if the given place be east of the Middle Line, but if it be west, add the quotient to it, and (you will get) the planet's place at (the mid-night of) the given place.

Middle Line of the Earth.

62. (The cities named) ROHÍTAKA, UJJAYINÍ, KURUKSHETRA &c. are at the line between LANKÁ and the north pole of the Earth, (this line is called the Middle Line of the Earth.)

To find the terrestrial longitude of a place.

63, 64 and 65. At the given place if the Moon's total darkness (in her eclipse) begins or ends after the instant when it begins or ends at the Middle Line of the Earth, then the given place is east of the Middle Line, (but if it begins or ends) before the instant (when it begins or ends at the Middle Line, then) the given place is west of the Middle Line.

Find the difference in GHAṬIKÁS between the times (of the beginnings or ends of the Moon's total darkness at the given place and the mid-night, which difference is called the DES'ÁNTARA GHAṬIKÁS.)

* DES'ÁNTARA is the correction necessary to be applied to the place of a planet in consequence of the longitude of a place, reckoned from the Middle Line of the Earth or the Meridian of LANKÁ. B. D.

Multiply the rectified circumference of the Earth by this difference and divide the product by 60. The quotient will be the east or west distance (in YOJANAS) of the given place from the Middle Line.

Apply the minutes, found by this distance, to the places of the planets (as directed before in S'LOKAS 60 and 61).

To find the instant when a day of the week begins.

66. A day of the week begins at the DES'ÁNTARA GHAṬIKÁS after or before the mid-night at the given place according as it is east or west of the Middle Line.

To find the mean place of a planet at a given time.

67. (If you want to know the place of a planet at a given time after or before a given mid-night,) multiply the daily motion of the planet by the given time in GHAṬIKÁS, divide the product by 60, and add or subtract the quotient, in minutes, to or from the place of the planet found at the given (mid-night,) and you have the place of the planet at the given time after or before the given mid-night. The place of the planet, thus found, is called its TÁTKÁLIKA or instantaneous place.

68. The Moon's deflection to the north and south from the end of the declination of her corresponding point at the Ecliptic is caused by her node. The measure of her greatest deflection is equal to the $\frac{1}{8}\frac{1}{0}$th part of the minutes in a circle.

69. The measures of the greatest deflections of Jupiter and Mars caused by their nodes are respectively $\frac{2}{3}$ and $\frac{3}{4}$ of that of the Moon, and that of Mercury, Venus and Saturn is $\frac{1}{2}$ of the Moon's greatest deflection.

70. Thus the mean greatest latitudes of the Moon, Mars, Mercury, Jupiter, Venus and Saturn are declared to be 270, 90, 120, 60, 120 and 120 minutes respectively.

End of the 1st chapter of SÚRYA-SIDDHÁNTA called MADHYÁGÁTI (which treats of the Rules for finding the mean places of the planets.)

CHAPTER II.

Called SPHUṬA-GATI *which treats of the Rules for finding the true places of the planets.*

Cause of the planetary motions.

1. The Deities, invisible (to human sight), named S'ÍGHROCHCHA, MANDOCHCHA (Apogees) and PATA (Nodes,) consisting of (continuous and endless) time, being situated at the ecliptic, produce the motions of the planets.

2. The Deities, (S'ÍGHROCHCHA and MANDOCHCHA) attract the planets (from their uniform course) fastened by the reins of winds borne by the Deities towards themselves to the east or the west, with their right or left hands according as they are to their right or left.*

3. (Besides this) a (great) wind called PRAVAHA carries the planets (westward) which are also attracted towards their apogees. Thus the planets being attracted (at once) to the east and west get the various motions.

4. The Deity called UCHCHA (apogee) draws the planet to the east or west (from its uniform progress) according as the Deity is east or west of the planet at a distance less than six signs.

5. As many degrees &c., as the planets, being attracted by their apogees, move to the east or the west, so many are called additive or subtractive (to or from their mean places).

6. In the same way, the Deity node named RÁHU by its power deflects the planet, such as the Moon, to the north or to the south from (the end of) the declination (of its corresponding

* The place of a planet rectified by the 1st or 2nd equation is nearer to its higher apsis (MANDOCHCHA or S'ÍGHROCHCHA) in its orbit, than the planet's unrectified place. The cause of this is that the Deities have hands furnished with reins of winds and by them they attract the planet towards themselves.
This will explain the meaning of the 2nd S'LOKA. B. D.

points at the ecliptic). This deflection is called VIKSHEPA (celestial latitude).

7. The Deity node draws the planet to the north or to the south (from the ecliptic) according as the node is west or east of the planet at a distance less than six signs.

8. (But in respect of Mercury and Venus) when their PÁTAS (or nodes) are in the same direction at the same distance (as mentioned in the preceding SLOKA) from their S'ÍGHROCHCHAS, they deflect in the same manner (as mentioned before) by the attractions of their S'ÍGHROCHCHAS.

9. The attraction of the Sun (by its apogee) is very small by reason of the bulkiness of its body, but that of the Moon is greater than that of the Sun, on account of the smallness of the Moon's body.

10. As the bodies of the (five) minor planets, Mars, &c. are very small, they are attracted by the Deities S'ÍGHROCHCHA and MANDOCHCHA very violently.

11. And for this reason, the additive or subtractive equation of the minor planets caused by their movement (which is produced by the attraction by their UCHCHAS) is very great. Thus, the minor planets, being attracted by their S'ÍGHROCHCHA and MANDOCHCHA and carried by the wind PRAVAHA, move in the heavens.

Kinds of motion.

12. (And therefore) the motion of the planets is of eight kinds, i. e.

I. VAKRÁ (decreasing retrograde motion).

II. ATIVAKRA (increasing retrograde motion).

III. VIKALA (stationary).

IV. MANDÁ (increasing direct motion less than the mean motion).

V. MANDATARÁ (decreasing direct motion less than the mean motion).

VI. SAMA (mean motion).

VII. S'ÍGHRATARA or ATIS'ÍGHRA (increasing direct motion greater than the mean motion).

VIII. S'ÍGHRA (decreasing direct motion greater than the mean motion).

13. Of these kinds, the five motions ATIS'ÍGHRA, S'ÍGHRA, MANDA, MANDATARA and SAMA are direct and the two motions VAKRA and ATIVAKRA are retrograde.

14. (Now) I explain carefully the Rules for finding the true places (of the planets) in such a manner that the places found by the Rules coincide with those, determined by observation, of the planets which move constantly with various motions.

The Rule for finding the sines for every $3\frac{3}{4}°$ in a quadrant of the circle whose Radius=3438.

15. The eighth part of the number of minutes contained in a sign (i. e. 1800) is the first sine. Divide the first sine by itself, subtract the quotient from that sine, and add the remainder to that sine: the sum will be the second sine.

16. In the same manner, divide successively the sines (found) by the first sine; subtract (the sum of) the quotients from the divisor and add the remainder to the sine last found and the sum will be the next sine.* Thus you will get twenty-

* This method is proved thus.

Let sin. A—sin. O $= d_1$;
sin. 2 A—sin. A $= d_2$;
sin. 3 A—sin. 2 A $= d_3$;
&c. $=$ &c.
sin. n A—sin. $(n-1)$ A $= d_n$;
sin $(n+1)$ A—sin. n A $= d_n + 1$.

Then since $d_1 - d_2 =$ 2 vers A. sin A $\div$ R;
$d_2 - d_3 =$ 2 vers A. sin 2 A $\div$ R;
$d_3 - d_4 =$ 2 vers A. sin 3 A $\div$ R;
&c. $=$ &c.
$d_n - d_{n+1} =$ 2 vers A. sin n A $\div$ R;

we have by addition

$$d_1 - d_{n+1} = \frac{2 \text{ vers A}}{R} (\text{sin. A} + \text{sin. 2 A} + \ldots\ldots + \text{sin. } n\text{ A}) \text{ or,}$$

$$\text{sin. A} + \text{sin. } n\text{ A} - \text{sin. } (n+1)\text{ A} = \frac{2 \text{ vers A}}{R} (\text{sin A} + \text{sin. 2 A} \ldots\ldots + \text{sin. } n\text{ A})$$

$$\therefore \text{sin. } (n+1)\text{ A} = \text{sin. } n\text{ A} + \text{sin. A}$$

$$\frac{2 \text{ vers A}}{R} (\text{sin. A} + \text{sin. 2 A} \ldots\ldots + \text{sin. } n\text{ A.})$$

Here, A $= 3° 45'$, $\therefore \frac{2 \text{ vers A}}{R} = .9042822 = \frac{1}{233.5}$, which is roughly given in the text $= \frac{1}{225}$.

four sines (in a quadrant of a circle whose radius is 3438). These are as follows.

The sines.

17 to 22. 225, 449, 671, 890, 1105, 1315, 1520, 1719, 1910, 2093, 2267, 2431, 2585, 2728, 2859, 2978, 3084, 3177, 3256, 3321, 3372, 3409, 3431, 3438.

Subtract these sines separately from the Radius 3438 in the inverse order, the remainders will be the versed sines (for every $3\frac{3}{4}°$).

The versed sines.

23 to 27. There are 7, 29, 66, 117, 182, 261, 354, 460, 579, 710, 853, 1007, 1171, 1345, 1528, 1719, 1918, 2123, 2333, 2548, 2767, 2989, 3213, 3438, versed sines (in a quadrant).

28. The sine of the (mean) greatest declination, (of each of the planets)=1307 (the sine of 24°).

The Rule for finding the planet's (mean) declination from its longitude.

Multiply the sine (of the longitude of a planet) by the said sine 1307; divide the product by the radius 3438; find the arc whose sine is equal to the quotient. This arc is the (mean*) declination (of the planet required).

29. Subtract the place of the planet from those of the MANDOCHCHA† and S'IGHROCHCHA: and the remainders‡ are the KENDRAS. From the KENDRA determine the quadrant (in which the Kendra ends,) and the sines of the BHUJA and KOTI§ (of the KENDRA).

30. The sine of the BHUJA (of the arc which terminates) in an odd quadrant (i. e. 1st and 3rd,) is the sine of that part of

* The mean declination of a planet is the declination of its corresponding point in the ecliptic: but the Sun's mean declination is the same as his true declination. B. D.

† MANDOCHCHA is equivalent to the higher apsis. The Sun's and Moon's MANDOCHCHAS (higher apsides) are the same as their apogees while the other planets' MANDOCHCHAS are equivalent to their aphelions. B. D.

‡ The first remainder is called the first KENDRA which corresponds with the anomaly, and the second, the second KENDRA which is equivalent to the commutation added to or subtracted from 180° as the second KENDRA is greater or less than 180°. B. D.

§ The BHUJA of any given arc is that arc, less than 90°, the sine of which is equal to the sine of that given arc; and the KOTI of any arc is the complement of the BHUJA of that arc. B. D.

the given arc which falls in the quadrant where it terminates, but the sine of the KOṬI (of that arc) is the sine of that arc which it wants to complete the quadrant where the given arc ends; and the sine of the BHUJA (of the arc) which ends in an even quadrant (i. e. 2nd and 4th) is the sine of that arc which it wants to complete the quadrant where the given arc ends; but the sine of the KOṬI (of that arc) is the sine of that part of the given arc which falls in that quadrant where it terminates.

To find the sine of the given degrees &c.

31. (Reduce the given degrees &c., to minutes.) Divide the minutes by 225: and the sine (in S'LOKAS 17—22) corresponding to the quotient is called the GATA (the past) sine, (and the next sine is called the GAMYA to be past sine): multiply (the remainder in the said division) by the difference between the GATA and GAMYA sine and divide the product by 225.

32. Add the quotient to the sine past: (the sum will be the sine required). This is the Rule for finding the right sines (of the given degrees &c.) In the same way, the versed sines (of the given degrees &c.) can be found.

Given the sine to find its arc.

33. Subtract the (next less) sine (from the given sine); multiply the remainder by 225 and divide the product by the difference (between the next less and greater sines): add the quotient to the product of 225, and that number (which corresponds to the next less sine); the sum will be (the number of minutes contained in) the arc (required).

Dimensions of the 1st epicycles of the Sun and Moon in degrees of the deferent or concentric.

34. There are fourteen degrees (of the concentric) in the periphery of the MANDA or first epicycle of the Sun, and thirty-two degrees (in the periphery of the 1st epicycle) of the Moon, when these epicycles are described at the end of an even quadrant (of the concentric or on the Line of the Apsides.) But when they are described at the end of an odd quadrant (of the concentric, or on the diameter of the concentric perpendicular to the Line of the Apsides) the degrees in both are

diminished by twenty minutes; (then the degrees in the periphery of the Sun's epicycle=13° 40′ and in that of the Moon's=31° 40′.)

Dimensions of the 1st epicycles of the Mars &c., in degrees of the concentric.

35. There are 75, 30, 33, 12 and 49, (degrees of the concentric in the peripheries of the first epicycles of Mars, Mercury, Jupiter, Venus and Saturn respectively) at the end of an even quadrant (of the concentric, but) at the end of an odd quadrant, there are 72, 28, 32, 11, 48 (degrees of the concentric.)

Dimensions of the 2nd epicycles of Mars &c.

36. There are 235, 133, 70, 262 and 39 (degrees of the concentric) in the peripheries of the S'ÍGHRA or second epicycles of Mars &c., at the end of an even quadrant (of the concentric).

37. At the end of an odd quadrant (of the concentric,) there are 232, 132, 72, 260, 40 degrees of the concentric in the peripheries of the second epicycles of Mars &c.

Given the KENDRA of a planet, to find the dimensions of the rectified periphery of the epicycle.

38. Take the difference between the peripheries of epicycles of a planet at the ends of an even and an odd quadrant; multiply it by the sine of the BHUJA (of the given KENDRA of the planet,) and divide the product by the radius. Add or subtract the quotient to or from the periphery which is at the end of an even quadrant according as it is less or greater than that which is at the end of an odd quadrant: the result will be the SPHUṬA or rectified periphery (of the epicycle of the planet.)

Given the 1st or 2nd KENDRA of a planet, to find the 1st or 2nd BHUJA-PHALA and KOṬI-PHALA and the 1st equation of the planet.

39. Multiply the sines of the BHUJA and KOṬI (of the given 1st and 2nd KENDRA of a planet) by the rectified periphery (of the 1st and 2nd epicycle of the planet), and divide the products by the degrees in a circle or 360° (the quotients are called the 1st or 2nd BHUJA-PHALA and KOṬI-PHALA respectively). Find the arc whose sine is equal to the 1st BHUJA-PHALA: the number of the minutes

contained in this arc is the MANDA-PHALA* (or the 1st equation of the planet.)

To find the 2nd equation of the minor planets Mars &c.

40. Find the 2nd KOṬI-PHALA (from a planet's 2nd KENDRA as mentioned before:) it is to be added to the radius when the Kendra is less than 3 signs or greater than 9 signs, but when the KENDRA is greater than 3 signs and less than 9, (then the 2nd KOṬI-PHALA) is to be subtracted (from the radius).

41. Add the square of the result (just found) to that of the sine of the 2nd BHUJA-PHALA: the square root of the sum is the S'ÍGHRA-KARṆA or 2nd hypothenuse.†

Find the (2nd) BHUJA-PHALA of the planet (as mentioned in S'LOKA 39th;) multiply it by the radius and divide the product by the 2nd hypothenuse (above found).

42. Find the arc whose sine is equal to the quotient (just found); the number of the minutes contained in the arc is called the S'ÍGHRA-PHÀLA‡ (or 2nd equation of the planet.)

The 2nd equation of Mars &c. is employed in the first and fourth operations (which will be explained in the sequel).

To find the true places of the Sun, the Moon and other planets.

43. (In order to find the true places of the Sun and Moon,) a single operation called MANDA (or operation of finding the first equation,) is to be employed (that is to say, when you want to find the true places of the Sun and Moon, find their first equation and apply it, as will be mentioned in 45th S'LOKA, to their mean places: thus you have the true places of the Sun and Moon).

But in respect of Mars &c. 1st S'ÍGHRA operation (or operation of finding the 2nd equation,) 2nd MANDA operation, 3rd MANDA operation, and 4th S'ÍGHRA operation, are to be employed successively.

* MANDA-PHALA is the same as the equation of the centre of a planet. B. D.

† The S'ÍGHRA-KARṆA or 2nd hypothenuse is equivalent to the distance (in minutes) of the planet from the Earth's centre. B. D.

‡ SÍGHRA-PHALA or 2nd equation is equivalent to the annual parallax of the superior planets; and the elongation of the inferior planets. B. D.

44. Find the second equation (from the mean place of a planet:) apply the half of it to the mean place, and (to the result) apply the half of the first equation (found from that result; from the amount) find the 1st equation again, and apply the whole of it to the mean place of the planet and (to that rectified mean place)* apply the whole of the 2nd equation (found from the rectified mean place: thus you will find the true place of the planet).

How the 1st and 2nd equations of the planets are to be applied.

45. In the S'ÍGHRA and MANDA operations, the (second or first) equation of a planet in minutes is to be additive when the (second or first) KENDRA (of the planet) is less than 6 signs; but when it is greater than 6 signs, the (2nd or 1st) equation is to be subtractive.

The BHUJÁNTARA† correction in minutes.

46. Multiply the diurnal motion of a planet by the number of minutes contained in the first equation of the Sun, and divide the product by the number of minutes contained in a circle or 21600′: add or subtract the quotient, in minutes, according as the Sun's equation is additive or subtractive, to or from the place of the planet (which is found from the AHARGAṆA at the mean mid-night at LANKÁ, the result will be the place of the planet at the true mid-night at LANKÁ.)

47. Subtract the diurnal motion of the Apogee of the Moon from her mean diurnal motion; (the remainder will be the Moon's motion from her apogee;) from this remainder find the 1st equation of her motion (by the rule which will be explained further on). This equation is to be subtractive or additive to her mean motion (for finding the true motion of the moon).

* The rectified mean place of a planet is called its MANDA SPHUṬA place. The MANDA-SPHUṬA places of Mars, Jupiter and Saturn correspond with their heliocentric places. B. D.

† The BHUJÁNTARA correction is to be applied to the place of a planet found from the AHARGAṆA for finding the place of the planet at the true mid-night at LANKÁ, arising from that portion of the equation of time which is due to the unequal motion of the Sun in the Ecliptic. B. D.

To find the true diurnal motions of the Sun and Moon and the MANDA-Sphuṭa motions of the others.

48. In the MANDA operation, find the (first) equation of a planet's diurnal motion from the motion itself, in the same way in which the planet's first equation is found.

(Take the difference between the GATA and GAMYA sines which have been found in finding the sine of the first KENDRA of the planet); by the difference between the sines (GATA and GAMYA) multiply the (planet's mean) motion (from its apogee) and divide the product by 225.

49. The quotient multiplied by the (rectified) periphery of the first epicycle of the planet and divided by 360° (becomes the first equation of the planet's motion) in minutes. Add this equation (to the mean diurnal motion of the planet) when the first KENDRA is greater than 3 signs and less than 9; but when the first KENDRA is greater than 9 signs or less than 3, subtract the equation of the motion from it: (thus you have the true diurnal motions of the Sun and Moon, and the MANDA-SPHUṬA motions of the others which are equivalent to their heliocentric motions.)

To find the true diurnal motion of a minor planet.

50. Subtract the MANDA-SPHUṬA diurnal motion of a (minor) planet from its S'ÍGHROCHCHA's diurnal motion, and multiply the remainder by the difference between the radius* and the 2nd hypothenuse found in the 4th operation for finding the 2nd equation.

51. Divide the product by the (said) 2nd hypothenuse, add the quotient (to the MANDA-SPHUṬA motion of the planet) when the 2nd hypothenuse is greater than the radius;* but when it is less than the radius subtract the quotient (from the MANDA-SPHUṬA motion, the result will be the true motion of the planet). (But in the latter case), if the quotient be greater (than the MANDA-SPHUṬA motion,) subtract (the MANDA-SPHUṬA motion from the quotient); the remainder will be the retrograde motion of the planet.

* Notes on 50 and 51. Some commentators of the SÚRYA SIDDHÁNTA understand by the term radius the cosine of the 2nd equation found in the 4th operation. B. D.

The cause of the retrogression of the planets.

52. When a planet is at a great distance (more than 3 signs) from its S'ÍGHROCHCHA and (therefore) its body is attracted by the loose reins (borne by the S'ÍGHROCHCHA,) to its left or right, then the planet's motion becomes retrograde.

When the planets began to retrograde and when they leave their retrogression.

53 and 54. The planets Mars, and others (i. e. Mars, Mercury, Jupiter, Venus and Saturn) get the retrograde motion about the same time when the degrees of (their 2nd) KENDRAS, found in the 4th operation, are equal to 164, 144, 130, 163 and 115 (respectively) : and when the degrees of (their 2nd) KENDRAS are equal to the remainders (196, 216, 230, 197 and 245,) found by subtracting the (said) numbers (164, 144, 130, 163 and 115,) from 360° (separately,) the planets leave their retrogression.

55. Venus and Mars (leave their retrogression about the same time) when (their 2nd KENDRA) is equal to 7 signs, on account of the greatness (of the rectified dimension) of their 2nd epicycle : so Jupiter and Mercury (leave their retrogression) when (their 2nd KENDRA)=8 signs, and Saturn leaves its retrogression when (its 2nd KENDRA)=9 signs.

To find the latitude of a planet.

56. Add or subtract the 2nd equations of Mars, Saturn and Jupiter (found in the 4th operation) to or from their nodes according as the 2nd equations applied to the (rectified mean) places of the planets : but in respect of Mercury and Venus add or subtract their 1st equations (found in the 3rd operation, to or from their nodes) according as their 1st equations are subtractive or additive respectively (the results are the rectified nodes).

57. (For the argument of latitude of each of the planets‡ Mars, Jupiter and Saturn) take its rectified node from its true place : but for (the argument of latitude of) Mercury or Venus take its rectified node from its S'ÍGHROCHCHA ; find the sine (of

‡ Notes on 56 and 57. It is evident that the argument of latitude of each of the planets, found here, equals the heliocentric place of the planet diminished by the place of its node. B. D.

the argument of latitude of a planet); multiply it by the (greatest) latitude of the planet (mentioned in SLOKA 70th of 1st Chapter) and divide the product by the 2nd hypothenuse found in the 4th operation; but in respect of the Moon divide it by the radius: the quotient will be the latitude (of the planet).

To find the true declination of a planet.

58. The (mean) declination (of a planet or the declination found by computation from its corresponding point in the ecliptic) increased or diminished by its latitude, according as they are both of the same or different denominations, becomes the true (declination of the planet). But the Sun's (true declination) is (the same as) his mean declination.

To find the length of a planet's day.

59. Multiply the diurnal motion (in minutes) of a planet by the number of PRÁṆAS which the sign, in which the planet is, takes in its rising (at a given place;) divide the product by 1800′ (the number of minutes which each sign of the ecliptic contains in itself,) add the quotient, in PRÁṆAS, to the number of the PRÁṆAS contained in a (sidereal) day: the sum will be the number of PRÁṆAS contained in the day and night of that planet (at the given place).

Given the declination, to find the radius of the diurnal circle.

60. Find the right and versed sines of the declination (of a planet): take the versed sine (just found) from the radius, the remainder will be the radius of the diurnal circle south or north of the equinoctial. (This radius is called DYUJYÁ).

To find the ascensional difference.

61. Multiply the sine of declination (above found) by the length (in digits) of the equinoctial shadow,* divide the product by 12, the quotient is the KUJYÁ:† The KUJYÁ multiplied by the radius

* The equinoctial shadow is the shadow of a vertical gnomon of 12 digits when the Sun is in the equinoctial at the mid-day at a given place. B. D.

† KUJYÁ is the sine of that arc of a diurnal circle which is intercepted between the Horizon and the six o'clock line. B. D.

and divided by the DYUJYÁ (above found) becomes the sine of the ascensional difference. The arc of that sine (in minutes) is the ascensional difference in PRAṆAS.

To find the lengths of the day and night of a planet and a fixed star.

62. Add and subtract the ascensional difference to and from the fourth part of the length of the day and night of the planet (as found in S'LOKA 59) separately, the results will be lengths of the half day and half night respectively of the planet when its declination is north.

63. But when the planet's declination is south, the reverse of this takes place (i. e. the results, just found, will be the lengths of the half night and half day of the planet respectively). (In both cases,) twice the results are the lengths of the day and night (respectively).

In the same way, the lengths of the day and night of any fixed star can be determined from its declination which is to be found by adding or subtracting its latitude to or from the declination (of its corresponding point in the ecliptic).

The BHOGA of a NAKSHATRA and TITHI.

64. The BHA-BHOGA (or the space of a NAKSHATRA or an Asterism) contains 800′ minutes, and the BHOGA of a TITHI (or the space which the Moon describes from the Sun in tithi or lunar day) contains 720′ minutes.

To find the NAKSHATRA in which a planet is at a given time.

The place of a planet, reduced to minutes, divided by the BHABHOGA or 800′, gives the number of those NAKSHATRA or Asterisms (counted from AS'WINÍ which are passed by the planet; and the remainder is that portion of the present NAKSHATRA which is passed by the planet.) (This remainder divided) by the diurnal motion (of the planet) gives the quotient in the days, GHATIKAS, &c. which the planet has taken to pass that portion of the present NAKSHATRA.

To find the YOGA* at a given time.

65. The sum of the places of the Sun and Moon (found at a given time,)

* YOGA is a period of time in which the sum of the places of the Sun and Moon increases by 13° 20′ or 800′. B. D.

reduced to minutes, is to be divided by the BHA-BHOGA (or 800'.) The quotient is the number of the elapsed YOGAS (counted from VISHKARUBHA): (The remainder is called the GATA of the present YOGA, and the BHA-BHOGA (or 800') diminished by the GATA is called the GAMYA of that YOGA.) The GATA and GAMYA of the present YOGA multiplied by 60 and divided by the sum of the diurnal motions (of the Sun and Moon) become the numbers of the past and to be past GHAṬIKA'S (respectively of the present YOGA at the given time.)

To find the lunar day at a given time.

66. Take the place of the Sun from that of the Moon (found at a given time); divide the remainder, reduced to minutes, by the BHOGA (of a TITHI or 720'; the quotient is the number of the elapsed tithis or lunar days.) (The remainder is the GATA of the present TITHI, and the BHOGA of a TITHI diminished by the GATA is the GAMYA of the present TITHI.) The GATA and GAMYA of the present TITHI, multiplied by 60 and divided by the difference between the diurnal motions (of the Sun and Moon) become the numbers of the past and to be past GHAṬIKA'S (respectively of the present TITHI at the given time).

Invariable KARAṆAS.

67. The four invariable KARAṆAS called S'AKUNI, NAGA, CHATUSHPADA and KINSTUGHNA (always appropriate to themselves successively the halves of the TITHIS,) from the latter half of the fourteenth TITHI of the dark half (of a lunar month to the first half of the first TITHI of the light half of the next lunar month inclusive).

Variable KARAṆAS.

68. And the seven variable KARAṆAS, BAVA* &c. afterwards succeed each other regularly, through eight repetitions in a (lunar) month.

* 1. BAVA. 2. BÁLVA. 3. KAULAVA. 4. TAITILA. 5. GARAJA. 6. VANIJA. 7. BHADRÁ. B. D.

69. It is to be known that all the KARAṆAS answer successively to half of a TITHI.

(O MAYA,) thus I have explained to you the Rules for finding the true places of the heavenly bodies, the Sun &c.

End of the 2nd Chapter of the SŪRYA-SIDDHĀNTA.

CHAPTER III.

Called the TRIPRAS'NA, *which treats of the Rules for resolving the questions on Time, the position of places, and directions.*

To determine the meridian and east and west lines and the points of the Horizon.

1. On the surface of a stone levelled with water or on the levelled floor of chunam work, describe a circle with a radius of a certain number of digits.

2 and 3. Place the vertical Gnomon of 12 digits at its centre and mark the two points where the shadow (of the Gnomon) before and after noon meets the circumference of the circle: these two points are called the west and the east points (respectively).

Then, draw a line through the TIMI* formed between the

* To draw a line perpendicular to and bisecting the line joining two given points, it is usual to describe two arcs from the two given points as centres with a common radius, intersecting each other in two points: the line passing through the intersecting points is the line required. In this construction, the space contained by the intersecting arcs is called TIMI "a fish," on account of its form. It is evident that the line drawn through the TIMI formed between two given points, must be perpendicular to and bisect the line which joins the given points. B. D.

(said) east and west points, and it will be the north and south line or the Meridian Line.

4. And thus, draw a line through the TIMI formed between the north and south points of the Meridian Line; this line will be the east and west line.

In the same manner, determine the intermediate directions through the TIMIS formed between the points of the determined directions (east, south &c.).

Given the Gnomonic shadow and its BHUJA, to find the direction of the shadow.

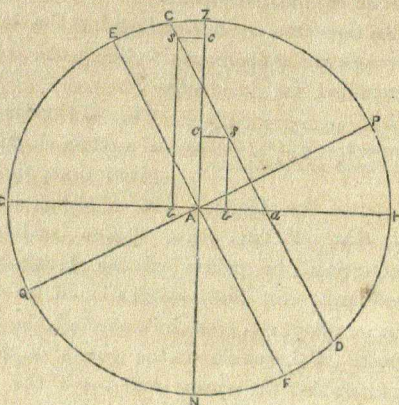
5. (In order to find the direction of a given shadow of the Gnomon at a given time, describe a circle in the plane of the Horizon with a radius whose length is equal to that of the given shadow and at its circumference determine the points of the Horizon, the Meridian and east and west lines as mentioned before:) Then describe a square about the said circle through the lines drawn from the centre (of the circle to the points of the Horizon, in such a manner that the square shall touch the circle at the cardinal points) and in this circle (towards the western or eastern part of it according as the given time is before or after noon), draw a line (as a sine,) equal to BHUJA* (of the given shadow and perpendicular to the east and west line towards the north or south according as the BHUJA is north or south. To the end of this perpendicular, draw a line from the centre). This (line) will denote the direction of the given shadow (at the given time).

6. The line representing the Prime Vertical, the six o'clock line or the equinoctial, passes through the east and west points of the Horizon.

* The distance (in digits) of the end of the shadow of the Gnomon (which is placed at the intersecting point of the Meridian and east and west line) is called the BHUJA (of the shadow north or south according as the end of the shadow is north or south of the east and west line: and the distance of the end of the shadow from the Meridian Line is called the KOTI (of the shadow) east or west according as the end of the shadow is east or west of the Meridian Line. B. D.

To find the sine of amplitude reduced to the hypothenuse of the given shadow.

7. (In the said circle)* from the east and west line (to its north) at a distance equal to the equinoctial shadow, draw another line parallel to the former; the distance between the end of the



* Note on the 7th S'LOKA.

Let Z G N H be the plane of the Meridian of the given place of north latitude; and in that plane let G A H be the diameter of the Horizon, Z the zenith, P and Q the north and south poles, E A F the diameter of the Equinoctial, P A Q that of the six o'clock line, Z A N that of the Prime vertical, C a D that of one of the diurnal circle in which the Sun is supposed to revolve at the given day and *s* the projection of the Sun's place: and let *s c*, *s b* be the perpendiculars to Z N, G H respectively.

Then, A *a* = AGRÁ or the sine of the Sun's amplitude;

S *b* = SÁNKU or the sine of the Sun's altitude;

c s or A *b* = BHUJA or the sine of the distance of the Sun from the Prime Vertical measured on a great circle passing through the Sun and at right angles to the Prime Vertical.

a b = S'ANKUTALA or the distance of the perpendicular drawn from the Sun's place to the horizontal plane, from the line (called the UDAYÁSTA-SÚTRA in Sanskrit) in which the plane of the Horizon intersects that of the diurnal circle: and it is evident from the figure that

$$A\,a = ab \pm A\,b;$$

or

AGRÁ = S'ANKUTALA ± BHUJA:

in this the upper or lower sign must evidently be used according as the Sun is north or south of the Prime Vertical.

Now if these AGRÁ, S'ANKUTALA and BHUJA which are in terms of the radius of a great circle, be reduced to the hypothenuse of the gnomonic shadow at the given time, it is clear that the reduced BHUJA will be equal to the distance of the end of the shadow from the east and west line, but the reduced SÁNKUTALA will equal the Equinoctial shadow. It is showed thus:

let R = the radius of a great circle:

h = the hypothenuse of the shadow;

then, $h : R = 12 : s\,b, \therefore s\,b = \frac{12\,R}{h}$;

Now, in the triangle *s a b* $\because \angle\, a\,s\,b$ = the latitude of the given place;

$$\therefore \frac{a\,b}{s\,b} = \frac{\text{the sine of latitude}}{\text{the cos. of latitude}} = \frac{\text{the Equinoctial shadow}}{12};$$

given shadow and the latter line is equal to the sine of amplitude (reduced to the hypothenuse of the given shadow).

Given the shadow to find its hypothenuse.

8. The square-root of the sum of the squares (of the lengths) of the Gnomon and the given shadow is called the hypothenuse of the shadow: from the square of the hypothenuse subtract the square of the Gnomon; the square-root of the remainder will be equal to the shadow; and the length of the Gnomon is to be known (from the shadow) by the inverse calculation.

The precession of the equinoxes.

9. The circle of Asterisms librates 600 times in a great YUGA (that is to say, all the Asterisms, at first, move westward 27°. Then returning from that limit they reach their former places. Then from those places they move eastward the same number of degrees; and returning thence come again to their own places. Thus they complete one libration or revolution, as it is called. In this way the number of revolutions in a YUGA is 600 which answers to 600,000 in a KALPA).

Multiplying the AHARGAṆA (or the number of elapsed days) by the said revolutions and dividing by the number of terrestrial days in a KALPA; the quotient is the elapsed revolutions, signs, degrees, &c.

10. (Rejecting the revolutions), find the BHUJA of the rest (i. e. signs, degrees &c. as mentioned in S'LOKA 30th of the 2nd Chapter). The BHUJA (just found) multiplied by 3 and divided by 10* gives the degrees &c. called the AYANA (this is the same with the amount† of the precession of the equinoxes).

$$\text{or } a\,b \times \frac{h}{12\,R} = \frac{\text{the Equinoctial shadow}}{12};$$

$$\therefore a\,b \times \frac{h}{R} \text{ or the reduced S'ANKUTALA} = \text{the Equinoctial shadow};$$

∴ The reduced sine of amplitude = the Equinoctial shadow ± the reduced BHUJA; this explains the 7th S'LOKA. B. D.

* 27° : 90°. B. D.

† This is the distance of the Stellar Aries from the vernal equinox. B. D.

Add or subtract the amount of the precession of the equinoxes (according as the asterisms are moving eastward or westward at the given time) to or from the place of a planet: from the result (which is equivalent to the longitude of the planet) find the declination, the shadow of the Gnomon, the the ascensional difference &c.

This motion of the asterisms (or the precession of the equinoxes) will be verified by the actual observation of the Sun when he is at the equinoctial or the solstitial points.

11. According as the Sun's true place found by computation (as stated in the 2nd Chapter) is less or greater than that which is found by observation (i. e. the longitude of the Sun), the circle of asterisms is to the east or west (from its original place) as many degrees as these are in the difference (between the Sun's true place and the longitude).

The equinoctial shadow.

12. At a given place, when the Sun comes to the equinoctial, the shadow (of the Gnomon of 12 digits) cast on the Meridian Line at noon is called the PALABHÁ or the equinoctial shadow (for that place).

Given the equinoctial shadow, to find the co-latitude and latitude.

13. The Radius multiplied by the Gnomon (or 12) and the equinoctial shadow (separately) and divided by the equinoctial hypothenuse* gives the cosine and sine of the latitude (respectively). The arcs of these sines are the co-latitude and the latitude which are always south† (at the given place from whose zenith the equinoctial circle is inclined to the south).

Given the Gnomon's shadow at noon and Sun's declination, to find the latitude of the place.

14 and 15. The BHUJA of the shadow of the Gnomon at noon is the same as the shadow itself. Multiply

* The equinoctial hypothenuse is the hypothenuse of the equinoctial shadow found by taking the square-root of the sum of the squares of the equinoctial shadow and the Gnomon (or 12). B. D.

† The south latitudes of Sanskrit correspond to the north latitudes of the Europeans. B. D.

the Radius by that BHUJA and divide the product by the hypothenuse of the said shadow; the quotient will be the sine of the zenith distance: the zenith distance, found from that sine in minutes, is north or south according as the BHUJA is south or north respectively (at a given place). Find the sum of the zenith distance and the Sun's declination in minutes when they are both of the same name, but when they are of contrary names, find the difference between them. This sum or difference is the latitude in minutes (at the given place).

To find the equinoctial shadow from the latitude.

16. Find the sine of the latitude, (just found); take the square of that sine from that of the Radius; the square root of the remainder is the cosine of the latitude. The sine of the latitude multiplied by 12 and divided by the cosine of the latitude gives the PALABHA or the equinoctial shadow.

Given the latitude of the place and the Sun's zenith distance at noon, to find his declination and longitude.

17. Find the difference between the degrees of the latitude (at a given place) and those of the Sun's zenith distance at noon when they are both of the same name, but when they are of contrary names find the sum of them; the result will be the Sun's declination: multiply its sine by the Radius.

18. Divide the product by the sine of the Sun's greatest declination (or 1397): find the arc (in signs &c. whose sine is equal to the quotient, just found); this arc will be the longitude of the Sun when he is in the first quarter of the Ecliptic: but when he is in the second or third quarter, subtract or add the signs &c. (contained in the arc) from or to 6 signs; (the remainder or the sum will be the longitude of the Sun).

19. And when the Sun is in the fourth quarter of the Ecliptic subtract the signs &c. (which compose the arc) from 12 signs; the remainder will be the true longitude of the Sun at noon.

(To the longitude, just found, apply the amount of the precession of the equinoxes inversely for the Sun's true place.)

To find the Sun's mean place from his true place.

(In order to find the mean place of the Sun from his true place above found,) find the 1st equation from the true place of the Sun and apply it inversely to the place repeatedly, the result is the mean place of the Sun (that is, assume the true place as his mean place, find the Sun's first equation from it and add this equation to the true place if the equation be subtractive, but if it be additive, subtract it from the true place; the result will be somewhat nearer to the exact mean place of the Sun at the given noon; assuming this result as the Sun's mean place apply the said mode of calculation, and repeat the process until you get the exact mean place of the Sun).

Given the latitude of the place and the declination of the Sun, to find his zenith distance at noon.

20. Find the sum of the latitude of a given place and the Sun's declination when they are of the same name, but when they are of contrary names find the difference between them; the result will be the zenith distance of the Sun (at noon). Find the sine and cosine of the (found) zenith distance.

Given the Sun's zenith distance at noon, to find the shadow and its hypothenuse.

21. The sine (just found) and the Radius multiplied by the length of the Gnomon in digits (or by 12) and divided by the cosine (above found) give the shadow of the Gnomon and its hypothenuse (respectively) at noon.

Given the Sun's declination and shadow, to find his amplitude and the sine of amplitude reduced.

22. The sine of the Sun's declination multiplied by the equinoctial hypothenuse and divided by 12 gives the sine of the Sun's amplitude. This sine multiplied by the hypothenuse of the Gnomonic shadow at noon, and divided by the Radius, becomes the sine of amplitude reduced to the shadow's hypothenuse.

Given the equinoctial shadow and the reduced sine of amplitude, to find the BHUJA.

23. To this reduced sine of the Sun's amplitude add the equinoctial shadow; the sum will be the north BHUJA (of the shadow at the given time) when the Sun is

the southern hemisphere, but when he is in the northern hemisphere, take the reduced sine of amplitude from the equinoctial shadow, and the remainder will be the north BHUJA.

24. In the latter case, when the reduced sine of amplitude is greater than the equinoctial shadow, subtract this shadow from the reduced sine; the remainder will be the south BHUJA between east and west line and the end of the shadow at the given time. Every day the BHUJA at noon equals the Gnomon's shadow at that time.

Given the latitude and the Sun's declination, to find the hypothenuse of the shadow at the time when the Sun reaches the Prime Vertical.

25. Multiply the cosine of the latitude by the Equinoctial shadow or the sine of the latitude by 12; the product (which is the same in both cases) divided by the sine of the Sun's declination gives the hypothenuse of the gnomonic shadow at the time when the Sun reaches the prime vertical.*

Otherwise.

26. When the (Sun's) north declination is less than the latitude, the hypothenuse of the shadow at noon multiplied by the equinoctial shadow and divided by the reduced sine of amplitude at noon, gives the (same) hypothenuse† (which is found in the preceding S'LOKA).

* This is shown thus,
Let l = latitude of the place;
e = the equinoctial shadow;
d = the sine of the Sun's declination;
p = ... altitude; } when the Sun reaches the prime vertical.
x = the hypothenuse of the shadow;
Then, sin $l : d = R : p$;
and $R : p = x : 12$;

$$\therefore x = \frac{12 \sin l}{d} = \frac{e \cos l}{d} \text{ (because } \cos l : \sin l = 12 : l \text{ and } \therefore e \cos l = 12 \sin l\text{)}.$$

† This is proved thus.
Let h = the hypothenuse of the shadow at noon;
a = the sine of amplitude reduced to that hyp.

$$\therefore \frac{a R}{h} = \text{the sine of amplitude in terms of the radius.}$$

27. The sine of the declination (of the Sun) multiplied by the radius and divided by the cosine of the latitude becomes the sine of amplitude. Multiply this sine by the hypothenuse of the shadow at a given time and divide the product by the radius: the quantity obtained is the sine of amplitude in digits (reduced to the hypothenuse of the shadow at the given time).

Given the equinoctial shadow and the Sun's amplitude, to find his altitude when situated in the vertical circle of which the azimuth distance is 45°.

28 and 29. Subtract the square of the sine of amplitude from the half of the square of the radius; multiply the remainder by 144; divide the product by the half of the square of the gnomon (i. e. 72) increased by the square of the equinoctial shadow. Let the name of the result be the KARAṆÍ. Let the calculator write down this number (for future reference).

30. Multiply twelve times the equinoctial shadow by the sine of amplitude and divide the product by the former divisor (i. e. 72 added to the square of the equinoctial shadow). Let the result be called the PHALA. Add the square of the KARAṆÍ to the PHALA and take the square-root of the sum.

31 and 32. The square-root, (just found), diminished or increased by the PHALA according as the Sun is south or north of the equinoctial, becomes the Kona-s'anku* or the sine of

Then $\frac{a\,\mathrm{R}}{h} : p$ (the sine of the Sun's altitude when he is at the prime vertical)

$= \cos l : \sin l = e$ (equinoctial shadow) : 12;

$$\therefore \quad p = \frac{12\,a\,\mathrm{R}}{h\,e};$$

and $\therefore p : \mathrm{R} = 12 : x$ (the hypothenuse of the Sun's shadow when he reaches the prime vertical):

$$\therefore x = \frac{12\,\mathrm{R}}{p} = 12\,\mathrm{R} \times \frac{h\,e}{12\,a\,\mathrm{R}} = \frac{h\,e}{a};$$

supposing the Sun's declination to undergo no change during the day.

* This is demonstrated thus.
Let e = the equinoctial shadow,
a = the sine of amplitude,
h = the KARAṆÍ,
f = the PHALA,
and x = the KONA S'ANKU.

altitude of the Sun when situated at an intermediate vertical (intersecting the Horizon at the N. E. and S. W. or N. W. and S. E. points). If the sun be south of the prime vertical, then the KOṆA-S'ANKU will be south-east or south-west, but if he be north of it, then it will be north-east or north-west. The square-root of the difference between the square of the KOṆAS'ANKU and that of the radius, is called the DṚIGJYÁ or the sine of the zenith distance.

33. Multiply the (said) sine of the zenith distance and the radius by 12 and divide the products by the KOṆA-S'ANKU (above found); the quotients will be the shadow (of the gnomon) and its hypothenuse (respectively, when the Sun will come on an intermediate vertical) at the proper place and time.

Then, $12 : e = x : \frac{e}{12} x =$ S'AUKUTALA (as shown in the note on 7th S'LOKA);

and since it is manifest from the same note that the S'AUKUTALA applied with the sine of amplitude by addition or subtraction according as the Sun is south or north of the equinoctial, becomes BHUJA (i. e. the sine of the Sun's distance from the prime vertical),

$$\therefore \frac{e}{12} x \pm a = \text{BHUJA};$$

but when the Sun is N. E., N. W., S. E., or S. W., it is equidistant from the prime vertical and the meridian. Therefore the hypothenuse of a right-angled triangle, of which one side is the BHUJA and the other equal to it, is the sine of the zenith distance.

$$\therefore \text{hyp.})^2 = 2 \left(\frac{e}{12} x \pm a\right)^2 = \frac{e^2}{72} x^2 \pm \frac{a e}{3} x + 2 a^2.$$

Now, since the square of the sine of the zenith distance added to the square of the sine of the altitude is equal to the square of the radius,

$$\therefore x^2 + \frac{e^2}{72} x^2 \pm \frac{a e}{3} x + 2 a^2 = R^2;$$

$$\text{or } (e^2 + 72)\, x^2 \pm 24\, a e\, x = 72\, R^2 - 144\, a^2;$$

$$\therefore x^2 \pm \frac{24\, a e}{e^2 + 72} x = \frac{72\, R^2 - 144\, a^2}{e^2 + 72} = \frac{144\, (\frac{1}{2} R^2 - a^2)}{e^2 + 72}.$$

Now, in the foregoing equation it will be observed that the value of the side containing the known quantities is what has been already spoken of under the name of KARAṆÍ, and that the half of the co efficient of x is what has been already spoken of under the name of PHALA,

$$\therefore x^2 \pm 2 f x = k,$$

which gives $\quad x = \sqrt{f^2 + k} \pm f.$ B. D.

The latitude of the place and the Sun's declination being given, to find the Sun's altitude, Zenith distance &c. at given time from noon.

34. Add or subtract the sine of the ascensional difference to or from the radius according as the Sun is in the northern or southern hemisphere. The result is called the ANTYÁ. From the ANTYÁ subtract the versed sine of the time from noon (reduced to degrees); Multiply the remainder by the cosine of the declination.

35 and 36. Divide the product, (thus found), by the radius; the quotient is called the CHHEDA; the CHHEDA multiplied by the cosine of latitude and divided by the radius becomes the S'ANKU* or the sine of the Sun's altitude (at the given time). Subtract the square of the S'ANKU from that of the radius; the square root of the remainder is DRIG-JYÁ or the sine of the zenith distance (at the given time). (From the S'ANKU and the DRIG-JYÁ) find the shadow and its hypothenuse as mentioned before (in S'LOKA 32).

Given the gnomonical shadow and its hypothenuse, to find the time from noon.

Multiply the radius by the given shadow (of the gnomon) and divide the product by the shadow's hypothenuse.

* This will be manifest thus.
Let l = latitude of the place north of the equator;
d = the Sun's declination;
a = the ascensional difference,
t = the time from noon in degrees,
and x = the Sun's altitude.
Then we have the equation which is very common:

$$\sin x = \frac{\cos t \cdot \cos l \cdot \cos d \pm \mathrm{R} \cdot \sin l \cdot \sin d}{\mathrm{R}^2};$$

$$= \frac{(\cos t \pm \frac{\tan l \cdot \tan d}{\mathrm{R}}) \cos l \cdot \cos d}{\mathrm{R}};$$

$$= \frac{(\cos t \pm \sin a) \cos l \cos d}{\mathrm{R}^2};$$

$$\text{or} = \frac{(\mathrm{R} \pm \sin a - \text{vers } t) \cos d}{\mathrm{R}} \cdot \frac{\cos d}{\mathrm{R}}.$$

It is to be observed here, that when the latitude of the place is north, the sin a becomes plus or minus according as the declination is north or south. B. D.

37. The quotient is the DRIG-JYÁ; the square-root of the square of the radius diminished by that of the DRIG-JYÁ (just found), is the S'ANKU: multiply it by the radius and divide the product by the cosine of latitude (of the place).

38 and 39. The result (thus found) is the CHHEDA; multiply the CHHEDA by the radius; divide the product by the cosine of the declination. Subtract the quotient from the ANTYÁ and take the remainder. From the versed sines (given in S'LOKAS 23—27 of the second chapter) find the arc whose versed sine equals the remainder: The minutes contained in the arc are the PRÁṆAS in the time before or after noon.*

Given the latitude of the place and the reduced sine of amplitude, to find the Sun's declination and longitude.

Multiply the cosine of latitude by the given reduced sine of amplitude and divide the product by the given shadow's hypothenuse (at a given time).

40. The quotient, (thus found), is the sine of the Sun's declination; multiply it by the radius and divide the product by the sine of the greatest declination; find the arc in signs, degrees, &c.; from this arc and that quarter of the ecliptic in which the Sun is situated at the given time the Sun's longitude can be determined (as mentioned before in S'LOKAS 18 and 19 of this Chapter).

To draw a line in which the Gnomonic shadow's end revolves.

41. On any day place a vertical gnomon on an horizontal plane; mark the end of the shadow at three different times on the plane, and describe a circle passing through these points. Then the end of the shadow of that gnomon will revolve in the circumference of this circle through that day.†

* This Rule is the converse of the preceding one. B. D.

† This Rule is refuted by BHÁSKARÁCHÁRYA in his GOLADHYÁYA, and he is right, because the end of the gnomonical shadow revolves in an hyperbola in the places between the arctic and antarctic circles. B. D.

To find the right ascensions of the first three signs of the Ecliptic.

42. (In order to find the right ascensions of the ends of the three first signs of the ecliptic i. e. Aries, Taurus and Gemini, find the declinations of the said ends) then multiply the sines of one, two, and three sines by the cosine of the greatest declination of the Sun separately, and divide the products by the cosines of the declinations (above found), respectively: The quotients will be the sines of the arcs; find the arcs in minutes. (These arcs will be the right ascensions of the ends of the three first signs of the ecliptic).

To find the rising periods of those signs at the Equator.

43. The number of minutes contained in the first right ascension, (above found), is the number of PRÁṆAS which Aries takes in its rising at LANKÁ (or the equator); then take the first right ascension from the second and the second from the third; the remainders in minutes will denote the numbers of PRÁṆAS in which Taurus and Gemini rise at the equator.

(The numbers of the PRÁṆAS, thus found, contained in the rising periods of Aries, Taurus and Gemini at the equator are) 1670, 1795 and 1935 (respectively).

To find the rising periods of those signs at a given place.

(In order to find the rising periods of the first three signs of the ecliptic at a given place of N. L., find at first the ascensional differences of the ends of the said signs at that place and subtract the first ascensional difference from the second and the second from the third. The first ascensional difference and these remainders are severally called the CHARAKHAṆḌAS of the said signs for the given place). Subtract the CHARAKHAṆḌAS (of the first three signs) for the given place from their rising periods at the equator: the remainders will be the rising periods in PRÁṆAS of the said signs at the given place.

To find the rising periods of the rest.

44. The rising periods of the first three signs of the ecliptic at the Equator successively increased by their CHARAKHAṆḌAS give in

a contrary order the rising periods of the following three signs (i. e. Cancer, Leo and Vergo). The rising periods of the first 6 signs, thus found, answer in an inverse order to those of the latter six Libra, &c. for the given place.

To find the Horoscope or the point of the ecliptic just rising at a given time from sunrise.

45. From the Sun's longitude ascertained at the given time, find the BHUKTA and BHOGYA times in PRANAS, (in the following manner. Find the sign in which the Sun is and find the BHUKTA degrees or the degrees which the Sun has passed and the BHOGYA degrees or those which he has to pass). Multiply the numbers of the BHUKTA and BHOGYA degrees (separately) by the rising period of the said sign (at the given place) and divide the products by 30. (The first quotient is the BHUKTA time in PRAṆAS in which the Sun has passed the BHUKTA degrees, and the latter is the BHOGYA time in PRÁṆAS in which he has to pass the BHOGYA degrees.)

46 and 47. From the given time in PRÁṆAS (at the end of which the Horoscope is to be found) subtract the BHOGYA time in PRAṆAS and the rising periods of the next signs (to that in which the Sun is, as long as you can, then at last, you will find the sign, the rising period of which being greater than the remainder you will not be able to subtract, and which is consequently called the AS'UDDHA sign or the sign incapable of being subtracted, and its rising period the AS'UDDHA rising). Multiply the remainder thus found by 30 and divide the product by the AS'UDDHA rising period: add the quotient, in degrees, to the preceding signs (to the AS'UDDHA sign) reckoned from Aries: (and to the sum apply the amount of the precession of the equinoxes by subtraction or addition according as it will be additive or subtractive): the result, (thus found), will be the place of the Horoscope* at the eastern horizon. If the time at the end of which the Horoscope is to be found,

* Thus there are two processes for finding the Horoscope, one when the given time is after sun-rise and the other when it is before sun-rise, and which are consequently called KRAMA or direct and VYÚTKRAMA or indirect processes respectively. B. D.

be given before sun-rise, then take the BHUKTA time (above found) and the rising periods of the preceding signs, to that which is occupied by the Sun) in a contrary order from the given time; multiply the remainder by 30 and divide the product by the AS'UDDHA rising period; subtract the quotient, in degrees, from the signs (reckoned from Aries to the AS'UDDHA sign inclusive); the remainder (inversely applied with the amount of the precession of the equinoxes) will be the place of the Horoscope at the eastern horizon.

To find the culminating point of the Ecliptic at the given time from noon.

48. From the time, in GHAṬIKAS, from noon, before or after, the Sun's place found at the given time, and the rising periods of the signs ascertained for the equator, find the arc, in signs, degrees, &c. (intercepted between the Sun and the meridian at the given place) subtract or add the signs &c. (just found) from or to the Sun's place (according as the given time is before or after noon); the result will be the place of the culminating point of the ecliptic (at the given time).

Given the place of the Horoscope and that of the Sun, to find the time from sun-rise.

49. (Of the given place of the Horoscope and that of the Sun), find the BHOGYA time in PRÁṆAS, of the less and the BHUKTA time, in PRÁṆAS of the greater, add together these times and the rising periods of the intermediate signs (between those which are occupied by the Sun and the Horoscope); and you will find the time (from sun-rise at the end of which the given place of the Horoscope is just rising in the eastern horizon).

50. When the given place of the Horoscope is less than that of the Sun, the time (above found) will be before sun-rise, but when it is greater, the time will be after sun-rise.

And when the given place of the Horoscope is greater than that of the Sun increased by 6 signs, the time found (as mentioned before) from the place of the Horoscope and that of the Sun added to 6 signs will be after sun-set.

End of the third Chapter called the TRIPRAS'NA.

CHAPTER IV.

On the Eclipses of the Moon.

The diameters of the Sun and Moon in YOJANAS and their rectification.

1. The diameter of the Sun's orb is 6,500 YOJANAS and that of the Moon's is 480 YOJANAS.

2 and 3. The diameters of the Sun and Moon multiplied by their true diurnal motions and divided by (their) mean diurnal motions become the SPHUTA or rectified diameters.

To find the Sun's diameter at the Moon and their diameters in minutes.

The rectified diameter of the Sun multiplied by his revolutions (in a KALPA) and divided by the Moon's revolutions (in that cycle), or multiplied by the periphery of the Moon's orbit and divided by that of the Sun, becomes the diameter of the Sun at the Moon's orbit.

The diameter of the Sun at the Moon's orbit and the Moon's rectified diameter divided by 15, give the numbers of minutes contained in the diameters (of the discs of the Sun and the Moon respectively).

To find the diameter of the Earth's shadow at the Moon.

4 and 5. Multiply the true diurnal motion of the Moon by the Earth's diameter (or 1,600) and divide the product by her mean diurnal motion; the quantity obtained is called the SÚCHÍ. Multiply the difference between the Earth's diameter and the rectified diameter of the Sun by the mean diameter of the Moon (or 480) and divide the product by that of the Sun (or 6,500); subtract the quotient from the SÚCHÍ the remainder will be the diameter (in YOJANAS) of the Earth's shadow (at the moon); reduce it to minutes as mentioned before (i. e. by dividing it by 15).

To find the probable times of the occurrences of eclipses.

6. The Earth's shadow (always) remains at the distance of 6 signs from the Sun. When the place of the Moon's ascending node equals the place of the shadow or that of the Sun, there will be an

eclipse (lunar or solar). Or when that node is beyond or within the place of the shadow or that of the Sun, by some degrees, the same thing will take place.

7. The places of the Sun and the Moon found at the time of the new moon are equal (to each other) in signs, (degrees) &c. and at the instant of the full moon they are at the distance of 6 signs from each other.

To reduce the places of the Sun, the Moon and her ascending node as given at mid-night to the instant of the syzygy.

8. (Find the changes of the places of the Sun, the Moon and her ascending node in the instant from midnight to the instant of the syzygy as mentioned in S'LOKA 67th of 1st Chapter). To the places of the Sun and the Moon (as found at the midnight) apply by subtraction or addition their changes according as the instant of the syzygy is before or after midnight: the results are called the SAMA-KALA places of the Sun and the Moon: But increase the place of the node (at midnight) by its change, if the instant of the syzygy be before midnight, or diminish it if it be after midnight.

What covers the Sun and the Moon in their eclipses.

9. The Moon being like a cloud in a lower sphere covers the Sun (in a solar eclipse); but in a lunar one the Moon moving eastward enters the Earth's shadow and (therefore) the shadow obscures her disc.

To find the magnitude of an eclipse.

10. Take the Moon's latitude (at the time of syzygy) from half the sum of the diameter of that which is to be covered and that of the coverer (in a lunar or solar eclipse); the remainder is the greatest quantity of the eclipsed part of the disc.

To ascertain the occurrence of a total, partial or no eclipse.

11. If this quantity should be greater than the diameter of the disc which is to be eclipsed, the eclipse will be a total one, otherwise it will be partial. But if the Moon's latitude be greater than half the sum (mentioned in the preceding S'LOKA) there cannot be an eclipse.

To find the half duration of the eclipse and that of the total darkness.

12. Find the halves separately of the sum and difference of the diameter of that which is to be covered and that which is the coverer. Subtract the square of the (Moon's) latitude (as found at the time of the syzygy) severally from the squares of the half sum and the half difference and take the square-roots of the results.

13. These roots multiplied by 60 and divided by the diurnal motion of the Moon from the Sun give the STHITYARDHA the half duration of the Eclipse and MARDÁRDHA the half duration of the total darkness in GHAṬIKÁS (respectively).

To find the exact STHITYARDHA and MARDÁRDHA.

14 and 15. The diurnal motions (of the Sun, the Moon and her ascending node) multiplied by the STHITYARDHA (above found) in GHAṬIKÁS and divided by 60 give their changes in minutes. Then to find the first exact STHITYARDHA, subtract the changes of the Sun and the Moon from their places and add the node's change to its place; from these applied places find the Moon's latitude and the STHITYARDHA. This STHITYARDHA will be somewhat nearer the exact one, from this find the changes and apply the same mode of calculation (as mentioned before) and repeat the process until you get the same STHITYARDHA in every repetition. This STHITYARDHA will be the exact first STHITYARDHA. But to find the latter STHITYARDHA add the changes of the Sun and Moon to their places and subtract the node's change from its place; from these applied places find the Moon's latitude and the STHITYARDHA again and repeat the same process until the exact latter STHITYARDHA be found. In the same manner determine the first and second exact MARDÁRDHAS by repeated calculations.

To find the times of the phases of an eclipse.

16. At the end of the true lunar day (i. e. at the time of the full moon) the middle of the eclipse takes place; this time diminished by the exact first STHITYARDHA leaves the time of the beginning,

and increased by the latter exact STHITYARDHA gives the time of the end.

17. In the same manner, the time of the middle of a total eclipse diminished and increased (separately) by the exact first and second MARDÁRDHAS gives the times of the beginning and end of the total darkness (respectively).

To find the KOṬI or the portion of the coveror's path from the middle of the eclipse to a given time.

18. Multiply the diurnal motion of the Moon from the Sun by the (first) STHITYARDHA diminished by given GHAṬIKÁS and divide the product by 60, the quotient is the KOṬÍ in minutes (or the perpendicular of the right angled triangle of which the Moon's latitude is the base and the distance between the centres of that which is the coveror and that which is to be covered is the hypothenuse).

19. In an eclipse of the Sun, the KOṬI in minutes (above found,) multiplied by the mean STHITYARDHA and divided by the apparent* STHITYARDHA becomes the SPHUṬA or apparent KOṬI in minutes.

To find the quantity of the eclipsed part at a given time during the first half of an eclipse.

20. The Moon's latitude is the BHUJA (or base) and the square-root of the sum of the squares of the KOṬI and BHUJA is the hypothenuse (of the triangle as mentioned before in S'LOKA 18th). Subtract the hypothenuse from half the sum of the diameters (as stated in S'LOKA 10th); the remainder will be the quantity of the eclipsed part (of the disc) at the time (at which the KOṬI and BHUJA are ascertained).

To find the quantity of the eclipsed part at a given time during the latter half of an eclipse.

21. If it be required to know the KOṬI &c. at a given time after the middle of the eclipse, subtract the GHATIKAS (between the given time and the end of the eclipse) from the second STHITYARDHA; from the remainder find the KOṬI &c. as mentioned before. The obscured part found from the second STHITYARDHA is the portion of the disc yet in obscurity.

* The mean and apparent STHITYARDHAS will be explained in the next chapter. B. D.

Given the quantity of the eclipsed part, to find its corresponding time.

22 and 23. Subtract the minutes contained in the given eclipsed part from half the sum of the diameter of that which is covered and that which is the coveror; from the square of the remainder subtract the square of the Moon's latitude at that time. The square-root of the remainder is the KOṬI in minutes (in the lunar eclipse). But in the solar one the remainder (thus found) multiplied by the apparent STHITYARDHA and divided by the mean STHITYARDHA gives the KOṬI in minutes. From the KOṬI find the time in GHATIKA'S in the same way that you found the STHITYARDHA (from the square-root as mentioned in S'LOKA 13). At this time (before or after the middle of the eclipse,) the quantity of the eclipsed part is equal to the given one.

To find the VALANAS used in the projection of eclipses.

24. Find the zenith distance* (in the prime vertical of the body which is to be eclipsed), multiply its sine by the sine of the latitude of the place, and divide the product by the radius. Find the arc whose sine is equal to the quotient; the degrees contained in this are called the degrees of the (AKSHA or the latitudinal) VALANA: they are north or south according as the body is in the eastern or western hemisphere of the place.

25. From the place of the (said) body increased by 3 signs find the declination, (which is called AYANA or solstitial VALANÁ). Find the sum or difference of the degrees of this declination and those of the latitudinal VALANÁ, when those valanas are of the same name or of contrary names: (the result is called sphuṭa or true VALANÁ). The sine of the true VALANÁ divided by 70 gives the VALANA in digits.†

* The distance of the circle of position (passing through the body) from the zenith of the place is called the zenith distance in the prime vertical of the body. The rough amount of this can be easily found by the following simple proportion.

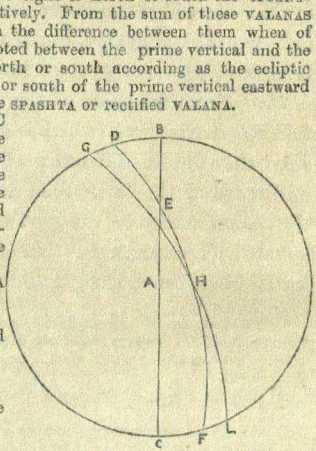
As half the length of the day of the body
: 90.
:: the time from noon of the body at a given time
: the zenith distance in the prime vertical at the given time. B. D.

† In the projection of eclipses, after drawing the disc of the body to be eclipsed, the north and south and the east and west lines, which lines will of

To find the ANGULAS or digits contained in the Moon's latitude, diameter, eclipsed part, &c. at a given time during an eclipse.

26. Find the length of the day (of the body which is to be eclipsed as mentioned in ślokas 62 and 63 of the second Chapter): to this length add its half and the UNNATA time (or the half length diminished by

course represent the circle of position passing through the body (supposed on the ecliptic) and the secondary to that circle at the given place, to find the direction of the line representing the ecliptic in the disc of the body on which the knowledge of the exact directions of the phases of the eclipses depends, it is necessary to know the angle formed by the said secondary and the ecliptic. This angle or that arc of a great circle, 90° from the place of the body which is intercepted between the said secondary or the prime vertical and the ecliptic is called the VALANA or variation (of the ecliptic). And as it is very difficult to find this arc at once, it is divided into two parts of which the one is that portion of the great circle (90° from the place of the body) which is intercepted between the Prime vertical and the Equinoctial and the other is that portion of the same circle which is intercepted between the Equinoctial and the ecliptic; these two portions are called the *Akṣha* VALANA and the *Ayana*-VALANA respectively. The *Akṣha* VALANA is called the north or south according as the Equinoctial circle meets the great circle (90° from the place of the body) on the north or south of the prime vertical eastward of the body; and it is evident from this that on the northern latitudes when the body is in the eastern or western hemisphere the *Akṣha* VALANA will be the north or south respectively. And the *Ayana*-VALANA is called the north or south according as the ecliptic meets the said great circle on the north or south of the Equinoctial to the east of the body, and hence it is evident that when the declination of the body's place increased by 3 signs is north or south the *Ayana*-VALANA will be the north or south respectively. From the sum of these VALANAS when they are of the same name or from the difference between them when of contrary names the arc which is intercepted between the prime vertical and the ecliptic is found and hence it will be north or south according as the ecliptic meets the said great circle on the north or south of the prime vertical eastward of the body and it is sometimes called the SPASHTA or rectified VALANA.



Let A be the place of the body; B G C L the great circle 90° from it; B A C the ecliptic; D E F the Equinoctial; E the Equinoctial point; G H L the prime vertical; H the intersecting point of the prime vertical and the Equinoctial, and hence the east or west point of the Horizon and therefore G H equivalent to the zenith distance in the prime vertical.

Then the arc G D = the *Akṣha* VALANA,

D B = the *Ayana*-VALANA,

and G B = the SPASHTA or rectified VALANA.

These arcs can be found as follows,

Let L = latitude of the place,

n = the zenith distance in the prime vertical,

l = the longitude of the body,

e = the obliquity of the ecliptic,

d = the declination of the body,

x = the *Akṣha* VALANA,

the given time from the midday of the body); and by the quotient divide the Moon's latitude, diameter &c. in minutes; the results are the digits contained in the latitude &c.

(End of the fourth Chapter.)

y = the ÁYANA-VALANA,
and z = the rectified VALANA.
Then in the spherical triangle D H G
sin G D H : sin D H G = sin G H : sin G D;
here, sin G D H = sin B D E = cos d,
sin D H G = sin L;
and sin G H = sin n,
$\therefore$ cos d : sin L = sin n : sin x.

$\therefore$ sin x or the sine of the ÁKSHA VALANA $= \frac{\text{sin L. sin } n}{\cos d}$ in which the Radius is used for cos d in the text

This VALANA is called north or south according as the point D be north or south of the point G.

And in the triangle D E B
sin B D E : sin B E D = sin B E : sin D B,
or cos d : sin e = cos l : sin y

$\therefore$ sin y or the sine of the ÁYANA VALANA $= \frac{\sin e \times \cos l}{\cos d}$ in which the Radius is used for cos d in the text.

This VALANA is called north or south; according as the point B be north or south of the point D.

And the rectified VALANA G B = G D + D B, when the point D lies between the points G and B, but if the point D be beyond them, the rectified VALANA will be equal to the difference between the Aksha and Ayana VALANAS. This also is called north or south as the point B be north or south of the point G.

To mark the sine of the SPASHTA VALANA in the projection of the eclipse it is reduced to the circle whose radius is 49 digits in the text.

i. e. R : sin z = 49 : reduced sine of the VALANA:

$\therefore$ reduced sine of the VALANA $= \frac{49 \sin z}{\text{R}} = \frac{49 \sin z}{3438} = \frac{\sin z}{70}$

This reduced sine in digits is denominated the VALANÁ in the text. B. D.

CHAPTER V.

On the Eclipses of the Sun.

Where the parallax in longitude and that in latitude is nothing.

1. There is no parallax in longitude of the Sun when his place equals the place of the nonagesimal. And when the (north) latitude (of the place) and the north declination of the nonagesimal are equal to each other (i. e. when the nonagesimal coincides with the zenith) there will be no parallax in latitude.

2. Now I will explain the rules for finding the parallax in latitude which takes place when the connection of the place and time is different from that which is mentioned (in the preceding S'LOKA,) and the parallax in longitude which arises when the Sun is east or west (of the nonagesimal).

To find the sine of amplitude of the horoscope.

3. At the end of the time of conjunction (from sunrise) in GHATIKA'S find the place of the horoscope through the rising periods at a given place (and apply it with the amount of the precession of the equinoxes.) Its sine multiplied by the sine of greatest declination (or sin 24°) and divided by the cosine of latitude gives a quantity called the UDAYA (or the sine of amplitude of the horoscope).

To find the sine of the zenith distance of the culminating point of the ecliptic.

4. Then find the place of the culminating point of the ecliptic through the rising periods at the equator as mentioned before, and find the sum of the declination of the culminating point and the latitude of the place when they are of the same name, otherwise find the difference between them.

5. The result (thus found) is the zenith-distance of the culminating point of the ecliptic. The sine of this zenith-distance is called the MADHYAJYA or the middle sine.

To find the sine and cosine of the zenith-distance of the nonagesimal.

Multiply the MADHYAJYA by the UDAYA (above found,) divide the product by the radius and square the quotient.

6. Subtract the square from the MADHYAJYA: the square-root of the remainder is (* nearly equal to) the DRIKSHEPA or the sine of the zenith-distance of the nonagesimal (or the sine of the latitude of the zenith). The square-root of the difference between the squares of the DRIKSHEPA and the radius is the S'ANKU or the sine of the altitude of the nonagesimal. This sine is called the DRIGGATI.

Otherwise.

7. (Or) the sine and cosine of the zenith-distance (of the culminating point of the Ecliptic,) are the rough DRIKSHEPA and DRIGGATI (respectively.)

To find the Moon's parallax in longitude from the Sun reduced to GHAṬIKAS.

Dividing the square of the sine of one sign (or 30°) by the DRIGGATI (above found,) the quantity obtained is called the CHHEDA or the divisor.

8. The sine of the difference between the place of the Sun and the nonagesimal divided by the CHHEDA gives the Moon's parallax in longitude from the Sun reduced to (sávana) GHAṬIKAS, whether the Sun be east or west (of the nonagesimal.†)

* For, the square-root of the remainder multiplied by the radius and divided by the cosine of the celiptical part intercepted between the nonagesimal and the culminating point becomes the exact DRIKSHEPA or the sine of the latitude of the Zenith. B. D.

† All Hindu astronomers suppose that every planet daily traverses 12000 YOJANAS nearly in its orbit and as the part of a planet's orbit intercepted between the sensible and rational horizon is equal to the earth's semi-diameter (or 800 YOJANAS which $= \frac{1}{15}$ th of 12000) therefore, the extreme or horizontal parallax of a planet is thought to be equal to $\frac{1}{15}$ part of its diurnal motion: thus the Moon's horizontal parallax is 52′ 42″ nearly and the Sun's 3′ .. 56″ and hence the horizontal parallax of the Moon from the Sun is $= (52' .. 42'') - (3' .. 56'') = 48' .. 46''$. And four GHAṬIKÁS in which the Moon describes 48′ .. 46″ from the Sun is the horizontal parallax in time.

Now, let

l = the latitude of a planet (the Sun or Moon),
d = the difference between the places of the planet and the nonagesimal,
a = the altitude of the nonagesimal,
p = the horizontal parallax,
x = the parallax in longitude,
y = the parallax in latitude.

Then we have the equation,

$$x = p \frac{\sin a . \sin (d + x)}{\text{R. cos. } (l \pm y)}$$

which is common in astronomy.

To find the accurate parallax, and the apparent time of conjunction.

9. Subtract the parallax in time (just found) from the end of the true time of conjunction if the place of the Sun be beyond that of the nonagesimal; but if it be within, add the parallax. At this applied time of conjunction find again the parallax in time and with it apply the end of the true time of conjunction and repeat the same process of calculation until you have the same parallax and the applied time of conjunction in every repetition. (The parallax lastly found is the exact parallax in time and the time of the conjunction is the middle of the solar eclipse.)

To find the Moon's parallax in latitude from the Sun.

10. Multiply the DṚIKSHEPA (or the sine of the zenith-distance of the nonagesimal) by the mean diurnal motion of the Moon from the Sun, and divide the product by fifteen times the radius: the quotient is the parallax in latitude of the Moon from the Sun.

Otherwise.

11. Dividing the DṚIKSHEPA by 70, the quotient is the same amount of parallax (found in the preceding S'LOKA) or multiplying the DṚIKSHEPA by 77 and dividing by the radius (i. e. 3438), the quotient is the same.

To find the apparent latitude of the Moon.

12. The amount of the parallax in latitude (just found) is south or north according as the nonagesimal is south or north (of the zenith). Add this amount to the Moon's latitude if they are of the same

In this, if we take for convenience's sake $\sin d$ for $\sin (d + x)$ and R. for $\cos (l \pm y)$ on account of the smallness of x, y and l in an eclipse, then we have

$$x = p \frac{\sin a . \sin d}{R^2}$$

Now, it is evident that if p be assumed, the horizontal parallax of the Moon from the Sun in time (or $p = 4$ GHAṬIKÁS) x will be the Moon's parallax in longitude from the Sun, and then

$$x = \frac{4 \sin a \sin d}{R^2} = \frac{\sin d}{(\frac{1}{4} R^2)} = \frac{\sin d}{\text{chheda.}}$$

$$\text{sin. } a$$

B. D.

name, but if of contrary names, subtract it. (The result is the apparent latitude of the Moon).

13. (In the solar eclipse) through the apparent latitude of the Moon (just found) find the STHITYARDHA* MARDARDHA magnitude of the eclipse &c. as mentioned before : the VALANÁ, the eclipsed portion of the disc at any assigned time &c. are found by the rule mentioned in the Chapter on the lunar eclipses.

To find the apparent STHITYARDHAS and MARDÁRDHAS in solar eclipses.

14, 15, 16 and 17. Find the parallaxes in longitude (converted into time) by repeated calculation at the beginning of the eclipse found by subtracting the first STHITYARDHA (just found) from the time of conjunction, and at the end found by adding the second STHITYARDHA. If the Sun be east of the nonagesimal and the parallax at the beginning be greater and that at the end be less than the parallax at the middle, or if the Sun be west, and the parallax at the beginning be less and that at the end be greater than the parallax at the middle, add the difference between the parallaxes at the beginning and the middle, or at the end and the middle to the first or the second STHITYARDHA (above found) : otherwise subtract the difference. It is then when the Sun is east or west of the nonagesimal at the times both of the beginning and the middle or of the middle and the end, otherwise add the sum of the parallaxes (at the time of the beginning and middle or of the end and the middle) to the first or the second STHITYARDHA (Thus you have the apparent STHITYARDHAS and from these the times of the beginning and the end of the eclipses of the Sun.)

In the same manner, find the apparent MARDARDHAS (and the times of the beginning and end of the total darkness in the total eclipses of the Sun).

End of the fifth Chapter.

* This STHITYARDHA is called the mean STHITYARDHA in the solar eclipse. B. D.

CHAPTER VI.

On the Projection of Solar and Lunar Eclipses.

Object.

1. Since the phases of the lunar and solar Eclipses cannot be exactly understood without their projection, I therefore explain the excellent knowledge of the projection.

To describe the circle in which the valaná is to be marked.

2. Having marked at first a point on the floor levelled with water, describe, on the point as centre with 49 digits as radius, a circle in which the VALANÁ (as found in the fourth Chapter) is to be marked.

Other two circles concentric with the first.

3. (On the same centre,) describe a second circle named the SAMASA with the radius equal to half the sum of the diameters of that which is to be covered and that which is the coveror, and a third circle with the radius equal to the semi-diameter of that which is to be covered.

The directions of the beginning and end of the lunar and solar eclipses.

4. (In these circles determine the north and south, and the east and west lines* as mentioned before (in the 3rd Chapter).

In a lunar eclipse, the obscuration first begins to the east and it ends to the west, (but) in a solar one the reverse of this takes place. (Therefore in the projection of the lunar eclipse, the VALANA is to be marked as sine to the eastern or western side of the outer circle above described according as it is found at the beginning or end of the eclipse, but in the projection of the solar eclipse, the VALANA found at the beginning or the end of the eclipse is to be marked to the western or eastern side of the circle respectively.)

* It is evident that these lines will represent the circle of position, and the secondary to it passes through the body which is to be eclipsed. B. D.

To mark the VALANÁ in the first circle.

5. In a lunar eclipse mark the VALANÁ (as directed in the preceding S'LOKA) to the eastern side of the outer circle from the east and west line to its north or south according as the VALANÁ is north or south, when it is found at the beginning of the eclipse; but when it is found at the end of the eclipse, mark it to the western side of the outer circle from the east and west line to the south or north according as the VALANÁ is north or south. And in a solar eclipse mark the VALANÁ inversely (i. e. mark it at the beginning or end of the eclipse to the western or eastern side of the outer circle respectively in the same manner as mentioned before).

To mark the latitudes found at the beginning and end of the eclipse in the second circle.

6. From the end of the VALANÁ (as drawn before) draw a line to the centre. From this line draw another line (perpendicular to the former and) as the sine in the circle called the SAMASA, equal to the Moon's latitude found at the beginning or end of the eclipse, (to the north or south of the former line according as the latitude is north or south).

To find the direction of the beginning and end of the eclipse in the disc of the body which is to be covered.

7. Again, draw a line from the end of the latitude (as drawn before) to the centre. Then the point, where the body which is to be covered begins to be obscured or quits the obscuration, is the same where the line drawn before cuts the circle representing the disc of the body which is to be covered.

To determine the directions of the latitudes of the Moon in the projections.

8 and 9. In the projection of the solar eclipse, the latitudes of the Moon are always designated by their normal name, but in the projection of the lunar one they are designated reversely.

To mark the VALANÁ at the middle of the eclipse.

And in the lunar projection to the northern or southern side of the outer circle above described, according as the latitude of the Moon

found at the middle of the eclipse is considered north or south, mark the VALANA determined at the middle of the eclipse from the north and south line to its east, when the VALANA and the latitude are of the same name; but when they are of different names, mark the VALANA to the west of the north and south line. And in the solar projection the reverse of this takes place.

To find the magnitude of the eclipse.

10. From the end of the VALANA (just marked) draw a line to the centre. On this line mark the latitude (found at the middle of the eclipse) from the centre towards (the end of) the VALANA.

11. With the end of the latitude (just marked) as a centre, and the radius equal to the semi-diameter of the coveror, describe a circle. The part of the third circle (as described before with the radius equal to the semi-diameter of that which is to be eclipsed) contained in the circle above described will be eclipsed.

12. In the projection (of the lunar or solar eclipse) described on the floor or board, reverse the positions of the points of the eastern and western halves of the horizon.

The limit of the magnitude of the eclipsed portion which is invisible in the solar or lunar eclipse.

13. To the 12th part of the Moon's disc the obscured portion is invisible on account of the brightness of the Moon's disc; and owing to the dazzling flash of the Sun's disc its eclipsed part when not exceeding 3 minutes, is not visible.

To find the path of the coveror.

14, 15 and 16. Call the points at the ends of the latitude (found at the beginning, middle and the end) (as marked before,) the first, the middle, and the last points respectively, describe the TIMIS between the first and middle points and the middle and the last and draw two lines through these two TIMIS; with the intersecting point of these two lines as a centre, describe such an arc as will pass through the three points. This arc will be the path of the coveror through which it will move.

To project a given eclipsed portion.

17, 18 and 19. [When you want to project the eclipsed portion, the magnitude of which is given at the time before or after the middle of the eclipse] subtract the given portion (in digits) as found before from half the sum of the coveror and that which is to be covered. From the centre (of the three circles as described before) draw a line equal to the remainder towards the direction of the beginning or end of the eclipse according as the given time is before or after the middle, in such a manner that the end of that line may be on the path of the coveror: then with the end of that line as a centre, at the distance equal to the semi-diameter of the coveror, describe a circle: then that portion of the third circle which falls within the circle (above described) will be obscured.

To find the direction of the beginning of total darkness by the projection.

20 and 21. From the centre of the three circles, towards the direction of the beginning of the eclipse, draw a line equal to half the difference between the diameters (of the coveror and that which is to be covered) in such a manner that its end fall on the coveror's path. About the end of that line describe a circle with an extent equal to the semi-diameter of the coveror. Then you will find the direction of the beginning of total darkness where the third circle touches internally the circle above described.

To find the direction of the end of the total darkness.

22. In the same way draw the said line towards the end of the eclipse and describe a circle as above. Then you will find the direction of the end of total darkness just as mentioned before.

The colour of the eclipsed portion of the Moon.

23. When the eclipsed portion of the Moon's disc is less than the half, it appears of a smoky colour, when it is greater than the half, it appears of a black colour: and when the Moon's eclipsed portion is greater than $\frac{3}{4}$ths of the whole it appears of a dusky copper hue, and in a total eclipse it appears of a tawny hue.

This science is very secret.

24. (O Maya) this science, secret even to the Gods, is not to be given to any body, but to the well-examined pupil who has attended one whole year.

End of the sixth Chapter.

CHAPTER VII.

On the conjunction of the planets.

Kinds of conjunction.

1. The conjunction of the five minor planets is considered their fight or association with each other (according to their light and position as will be explained afterwards) : but their conjunction with the Moon, is considered their association with her and with the Sun is their ASTAMANA disappearance.

To find whether the time of conjunction is past or future.

2. The conjunction of two planets, both moving eastward, is past when the place of the quick moving planet is beyond that of the slow-moving one, otherwise (i. e. when the place of the quick-moving planet is within that of the slow-moving) their conjunction is future. But when both the planets have retrograde motions, the reverse of this takes place.

3. When, of the two planets, (only) one is moving eastward and its place is beyond that of the other (which move to the west) their conjunction is past : but when the place of the retrograde is beyond that of the other (i. e. the east-moving) the conjunction is future.

To find the time of conjunction from a given time.

(When you want to know the exact time of conjunction of two planets, find their true places at any given time near the time of conjunction :) (then) multiply the difference in minutes between

the places (above found) by the diurnal motions of the planets in minutes (separately),

4. And divide the two products by the difference between the diurnal motions, when the motions of the planets are both direct or both retrograde; but when of the planets one is retrograde, divide the two products (above found) by the sum of the diurnal motions: (the results are the changes of the planets.)

5. From the places of these two planets (found at the given time) subtract their changes when the conjunction is past, but when it is future add the changes to the places. (This rule applies when the planets move eastward,) but when they retrograde, the reverse of this takes place. When one of the two planets is retrograde, add or subtract its change to or from its place (according as the conjunction is past or future).

6. Thus the places of the planets on the ecliptic applied with their changes become equal (to each other): divide the difference between the places of the planets (found at the given time) by the divisor which is taken before in finding their changes, the quotient will be the interval in days, GHAṬIKÁS &c. (between the given time and the time of conjunction).

7. Having found the lengths of the day and night of the places of the planets (found at the time of conjunction) and their latitudes in minutes, (determine for that time), the time* from noon (i. e. from the time when the planet's place comes to the meridian) and that from rising or setting of the place of each of the two planets with the horoscope (at that time according as the planet's place is east or west of the meridian of the place).

The correction called the AKSHA DRIKKARMA.

8. Multiply the latitude of the planet by the equinoctial shadow and divide the product by 12; the quantity obtained being multiplied by the time in GHAṬIKÁS from noon of the planet's place

* The time can be found by the Rule mentioned in S'LOKA 49th of the 3rd Chapter. B. D.

and divided by half the length of the day of the planet's place (as found before), gives the correction called the AKSHA DRIK-KARMA.

9. Subtract the correction from the planet's place when it is east of the meridian, and add when it is west: this holds when the latitude of the planet is north, but when it is south add the correction to the planet's place when it is east of the meridian and subtract when it is west.

The correction called the AYANA DRIKKARMA.*

10. Add 3 signs to the planet's place and find the declination from the sum. Then the number of minutes contained in the planet's latitude multiplied by the number of degrees contained in the declination (above found) gives the correction in seconds (called the AYANA DRIKKARMA). Add or subtract this correction (to or from the place of the planet) according as the declination (above found) and the planet's latitude are of the same name or of different names.

The use of the DRIKKARMA in finding the conjunctions &c.

11. In finding the times of conjunctions of the stars and planets and those of rising and setting of the planets and in finding the phases of the Moon, this DRIKKARMA correction must be applied (to the place of the planet) at first.

To find the distance of two planets in the same circle of position.

12. (Thus apply the two portions of the DRIKKARMA correction above found, to the equal places of the two planets as found in 6th SLOKA of this Chapter, and from these places applied, find the apparent time of conjunction by the Rule as mentioned in the SLOKAS 2nd to 6th: and repeat the operation until you get the time at which the places of the two

* DRIKKARMA is the correction requisite to be applied to the place of a planet, for finding the point of the ecliptic on the circle of position which passes through the planet. This correction is to be applied to the place of the planet by means of its two portions, one called the AYANA DRIKKARMA and the other the AKSHA DRIKKARMA. The place of a planet with the AYANA DRIKKARMA applied, gives the point of the ecliptic on the hour circle which passes through the planet: and this corrected place of the planet again, with the AKSHA DRIK-KARMA applied, gives the point of the ecliptic on the circle of position which passes through the planet. B. D.

planets with the two portions of the DRIKKARMA applied become equal to each other. This time is the exact apparent time of conjunction of those two planets.) Find again the places of the planets (at the time of their exact apparent time) and their latitudes from them: then find the difference between the latitudes when they are of the same name and the sum when they are of different names; the result will be the north and south distance (between those two planets at that time).

The apparent diameters of the planets in minutes.

13. The diameters of Mars, Saturn, Mercury, Jupiter and Venus reduced to the Moon's orbit are 30, 37½, 45, 52½ & 60 (yojanas respectively).

14. These diameters multiplied by 2 and the radius and divided by the sum of the radius and the hypothenuse found in the fourth operation (as mentioned in the 2nd Chapter) become their rectified diameters. Divide these rectified diameters by 15, the quotients are the minutes contained in the apparent diameters of the planets.

Observation of the planets.

15. On the levelled floor (place a gnomon &) mark the shadow (found at any assigned time from the bottom of the gnomon) to the opposite side of the planet: then show the planet in the mirror placed at the end of the shadow (just marked): the planet will be seen in the direction passing through the end of the shadow and the reflected end of the gnomon.

16. (When, at the time of conjunction of two planets, they will be above the horizon) erect two styles, five cubits long, one cubit buried in the ground, in the north and south line, at the distance equal to that of the two planets (as found in the 12th SLOKA of this Chapter, (reduced to digits by the Rule as mentioned in SLOKA 26th of the 4th Chapter).

17. Mark the shadows from the bottoms of the styles (as mentioned in SLOKA 15th) and draw lines from the ends of the shadows to those of the styles: then the astronomer may show the planets in the lines (above drawn).

18. (Thus) the planets will be seen in the heaven at the ends of the styles.

The fight and association of the planets.

In the conjunction of any two minor planets, there is their fight called the ULLEKHA (paring) when their discs only touch each other: but when the discs cross each other, the fight is called the BHEDA (breaking).

19. When in the conjunction, the rays of the two planets mix with each other, it is their fight, called the ANS'UVI-MARDA (the mixture of the rays).

When in the conjunction of the two planets, their distance (found in s'LOKA 12th) is less than one degree, it is their fight called the APASAVYA (the contrary) if one of the two planets be smaller; (otherwise the fight is not distinct).

20. (In the conjunction) when the distance of the planets is greater than one degree, it is their association, if the discs of the planets are both large and bright; (otherwise the association is indistinct).

Which planet is conquered in the fight.

In the fight called APASAVYA that planet is conquered which is obscure, small and gloomy.

21. And that planet is overcome which is rough, discoloured or south (of the other).

Which is the conqueror.

And that is the conqueror of which the disc is the brighter and larger, whether it be north or south (of the other).

Kinds of fight.

22. If (in the conjunction) the planets both be very near to each other and bright, then their fight is called the SAMÁGAMA: If both the planets be small or overpowered, then the fight is called the KÚṬA or VIGRAHA (respectively).

23. (In the fight of Venus with any other minor planet,) Venus is usually the conqueror whether she be north or south (of the other).

Find the time of conjunction of the moon with any of the minor planets in the same way as mentioned before.

24. This (i. e. the association and fight of the planets) is (only) imaginary, intended to foretel the good and evil fortune people, since the planets being distant from each other move in their own (separate) orbits.

End of the Seventh Chapter called the GRAHAYUTI or the planetary conjunctions.

CHAPTER VIII.

On the conjunction of the planets with the Stars.

To find the longitudes of the principal stars of the Asterisms.

1. I declare the number of the minutes contained in the BHOGAS* of (all) the Asterisms (AS'WINÍ, BHARAṆÍ, &c. except the UTTARÁSHADHÁ, ABHIJIT, S'RAVAṆA and DHA-

* Dividing the number of minutes contained in the longitude of the principal star of an Asterism by 800 and dividing the remainder by 10, the quotient obtained is here called the BHOGA of the ASTERISM. B. D.

Note on V 2 to 9. For convenience' sake the longitudes of the principal stars of the four Asterisms UTTARÁSHÁDHÁ, ABHIJIT, S'RAVAṆA and DHANISHTHA only are given and the BHOGAS of the others from which the longitudes of the remaining principal stars can easily be found by the rule mentioned in 1st S'LOKA, are given.

The longitudes and latitudes of the stars mentioned here are the apparent ones. The apparent longitude of a star is the distance from the origin of the Ecliptic to the intersecting point of this circle and the circle of declination passing through the star: and the apparent latitude of a star is the sum or difference of its true declination and the declination of the intersecting point of the Ecliptic and the circle of latitude passing through the star, according as the said declinations are of different names or of the same name.

The following table will exhibit the names of the Asterisms and of their principal stars as supposed to be meant, their apparent longitudes as will be found from their BHOGAS, and their apparent latitudes.

NISHPHÁ). Multiply the BHOGA of each Asterism by 10 and to the product add the spaces of the antecedent Asterisms (each of which contains 800 minutes as mentioned in S'LOKA 64th of the second Chapter), the sum is the longitude (of the principal star of the asterism).

The BHOGAS of the Asterisms.

2. (The number of minutes in the BHOGA of the Asterism called A'SWINÍ is) 48, (of BHARAṆÍ) 40, (of KRITTIKÁ) 65, (of ROHIṆÍ) 57, (of MRIGA) 58, (of ARDRÁ) 4, (of PUNARVASU) 78, (of PUSHYA) 76, and (of Á'S'LESHÁ) 14.

3. (The BHOGA, in minutes, of MAGHÁ is) 54, (of PÚRVÁ-PHÁLGUNÍ) 64, (of UTTARÁ-PHÁLGUNÍ) 50, (of HASTA) 60, (of CHITRÁ) 40, (of SWÁTÍ) 74, (of VIS'ÁKHÁ) 78, (and of ANURÁDHÁ) 64.

Asterisms.	YOGA-TÁRÁS *or principal stars.*	*Apparent longitudes,* s ° ′	*Apparent latitudes* °
As'winí,	α Arietis,	0 8 0	10 N.
Bharaṇí,	Musca,	0 20 0	12 N.
Krittiká,	π Tauri, Pleiades,	1 7 30	5 N.
Rohiṇí,	α Tauri, Aldeharan,	1 19 30	5 N.
Mriga,	λ Orionis,	2 3	10 S.
Ardrá,	α Orionis,	2 7 20	9 S.
Punarvasu,	β Geminorum,	3 3	6 N.
Pushya,	δ Cancri,	3 16	0 N.
As'leshá,	α 1 and 2 Cancri,	3 19	7 S.
Maghá,	α Leonis, Regulus,	4 9	0 N.
Purvá-phálguní	δ Leonis,	4 24	12 N.
Uttará-phálguní,	β Leonis,	5 5	13 N.
Hasta,	γ or δ Corvi,	5 20	11 S.
Chitrá,	α Virginis, Spica,	6 0	2 S.
Swátí,	α Bootis; Arcturus,	6 19	37 N.
Vi'sákhá,	α or χ Libra,	7 3	1 30′ S.
Anurádhá,	δ Scorpionis,	7 14	3 S.
Jyeshṭhá,	α Scorpionis, Antares,	7 19	4 S.
Múla,	ν Scorpionis,	8 1	9 S.
Púrváshádhá,	δ Sagittarii,	8 14	5 30′ S.
Uttaráshádhá,	τ Sagittarii,	8 20	5 S.
Abhijit,	α Lyri,	8 26 40′	60 N.
S'ravaṇa,	α Aquilæ,	9 10	30 N.
Dhanishṭhá,	α Delphini,	9 20	36 N.
S'atatáraká,	λ Aquarii,	10 20	0 30′ S.
Púrvábhádrapadá,	α Pegasi,	10 26	24 N.
Uttarábhádrapadá,	α Andromedo,	11 3	26 N.
Revatí,	ζ Piscium,	11 29 5	0 0 N.

B. D.

4. (The BHOGA, in minutes, of JYESHṬHÁ is) 14, (of MÚLA) 6, and (of PÚRVÁSHÁḌHÁ) 4. The principal star of UTTARÁSHÁḌHÁ is in the middle of the space of PÚRVÁSHÁḌHA (i. e. the longitude of the principal star of UTTARÁSHÁḌHA is 8 signs and 20 degrees). The principal star of ABHIJIT is at the end of the space of PÚRVÁSHADHA (i. e. the longitude of the principal star of ABHIJIT is 8 signs, 26 degrees and 40 minutes) and (the principal star of) S'RAVAṆA is situated at the end (of the space) of UTTARÁSHÁḌHÁ (i. e. the longitude of the principal star of S'RAVAṆA is 9 signs and 10 degrees).

5. The principal star of DHANISHṬHA is at the junction of the third and fourth quarters of the space of S'RAVAṆA (i. e. the longitude of the principal star of DHANISHṬHÁ is 9 signs and 20 degrees). (The BHOGA, in minutes, of S'ATATÁRAKA is) 80 (of PÚRVABHÁDRAPADA) 36, (and of UTTARÁBHADRAPADA) 22.

6 to 9. (The BHOGA of REVATÍ is) 79.

The latitudes of the principal stars of the Asterisms AS'WINÍ, &c. from the ends of their mean declinations are 10° N., 12° N., 5° N., 5° S., 10° S., 9° S., 6° N., 0°., 7° S., 0°., 12° N., 13° N., 11° S., 2° S., 37° N., 1°½ S., 3° S., 4° S., 9° S., 5°½ S., 5° S., 60° N., 30° N., 36° N., ½° S., 24° N., 26° N., and 0° respectively.

The longitudes and latitudes of the stars AGASTYA, MRIGAVYÁDHA, AGNI and BRAHMAHRIDAYA.

10, 11 and 12. The star AGASTYA (or Canopus) is at the end of the sign Gemini at a distance of 80° south (from its corresponding point in the ecliptic, i. e. the longitude of AGASTYA is 90° and its latitude is 80° S.) and the star MRÍGAVYADHA or the Hunter (which is evidently Sirius) is situated in the 20th degree of the sign Gemini (i. e. its longitude is 2 signs and 20 degrees) and its latitude from the end of its mean declination (from its corresponding point in the ecliptic,) to the south is 40°.

The stars called AGNI (or β Tauri) and BRAHMAHRIDAYA (or Capella) are in the 22nd degree of the sign Taurus (i. e. the

longitude of both of them is 1 sign and 22°. The latitudes of these two stars are 8° and 30° N. respectively.

Having framed a spherical instrument examine each of the (said) apparent latitudes and longitudes.

Crossing the cart of ROHIṆÍ.

13. That planet will cross the cart (of the Asterism) ROHIṆÍ (i. e. the place of Rohiṇí which is figured as a cart) which is placed at the 17th degree of the sign Taurus and of which the south latitude is greater than 2°.

To find the conjunction of a planet with a star.

14. (When you want to know the time of conjunction of a planet with a star) find the lengths of the day and night of the star as you found those of a planet (in the preceding chapter): and apply the ÁKSHA-DRIKKARMA (only) to the longitude of the star as mentioned before; then proceed just in the same way as in finding them in planetary conjunctions: and find the days (past or future from the given time to that of conjunction of the planet with the star) from the diurnal motion of the planet (only).

To know whether the time of conjunction is past or future.

15. (At a given time), when the longitude of the planet (with the two portions of the DṚIKKARMA applied) is less than that of the star (with the ÁKSHA-DṚIKKARMA applied) the conjunction is future: and when the longitude of the planet is greater than that of the star, the conjunction is past: (this holds when the planet is direct) (but) when it is retrograde the conjunction is contrariwise (i. e. when the longitude of the planet is less or greater than that of the star the conjunction is past or future).

YOGA-TÁRÁS or principal stars of the Asterisms.

16. The north star of (each of the Asterisms) PÚRVAPHALGUNI, UTTARAPHALGUNI, PÚRVÁ BHADRAPADA, UTTARÁ BHÁDRAPADA PÚRVAṢHÁḌHÁ, UTTARAṢHADHÁ, VISÁKHÁ, AS'WINI and MṚÍGA is called its YOGA-TÁRÁ or the principal star.

17. The star which is near to and west of the north-western star of the Asterism HASTA is its YOGA-TÁRÁ; and the western star of the Asterism DHANISHṬHA is its YOGA-TÁRÁ.

18. The middle star of (each of the Asterisms) JYESHṬHÁ, S'RAVAṆA, ANURÁDHÁ, and PUSHYA is its YOGA-TÁRÁ: and the southern star of each of the Asterisms BHARAṆÍ, KṚITTIKÁ, MAGHÁ, and REVATÍ is its YOGA-TÁRÁ.

19. The eastern star of each of the Asterisms ROHIṆÍ, PUNARVASU, MÚLA, and AS'LESHÁ is its YOGA-TÁRÁ and of the remaining Asterisms that is the YOGA-TÁRÁ which is the brightest (in each Asterism).

The longitude and latitude of the star PRAJÁPATI.

20. The star PRAJÁPATI (Aurigæ) is 5 degrees to the east of the star BHRAHMA-HṚIDAYA. Its longitude is 1 sign and 27° and the latitude is 38° N.

Of the stars Apám-vatsa and Ápa.

21. The star APÁM-VATSA (b 1. 2. 3) is situated in the Asterism CHITRÁ five degrees north (of its principal star) (i. e. the longitude of APÁMVATSA is equal to that of the principal star of CHITRÁ or 180°: and its latitude is 3° N.). (And in the same Asterism) the star ÁPA (Virginis), somewhat larger than APÁM-VATSA, is north of it at a distance of 6° (i. e. the longitude of ÁPA is 180° and the latitude 9° N.)

End of the eighth Chapter on the conjunction of the planets with the stars.

CHAPTER IX.

On the heliacal rising and setting of the planets and stars.

1. I now explain the heliacal rising and setting of the bodies (the moon and other planets and stars) which have little light and (consequently) disappear on account of the brilliancy of the sun (when he approaches them).

The planets which set heliacally in the western horizon and rise heliacally in the eastern horizon.

2. Jupiter, Mars and Saturn set heliacally in the western horizon when their places are beyond that of the sun: and they rise heliacally in the eastern horizon when their places are within that of the sun: and the same thing takes place with respect to Venus and Mercury when they have retrograde motion.

The planets which rise in the eastern horizon and set in the western horizon.

3. The moon, whose motion is quicker than that of the sun, and Mercury and Venus when they have quicker motion, set heliacally in the eastern horizon when their places are within the place of the sun: and rise heliacally in the western horizon when their places are beyond it.

To find the time at which a planet rises or sets heliacally.

4. (When you want to determine the time of the heliacal rising or setting of a planet), find (at any given day near to that time) the true places of the sun and the planet at the sun's setting, when the planet's heliacal rising or setting is in the western horizon; (but) when it is in the eastern horizon, determine the places at the rising of the sun: then apply the DRIKKARMA correction to the planet's place (as mentioned in the seventh Chapter).

5. (When the planet's heliacal rising or setting is in the eastern horizon) find the time in PRÁṆAS, from the places (just found) of the sun and the planet (by the rule mentioned in S'LOKA 49th Chapter III.): (It will be the time from the planet's rising to the rising of the sun). But when the heliacal rising or setting of the planet is in the western horizon, find the time, in PRÁṆAS, from the places of the sun and the planet with 6 signs added: (It will be the time from the setting of the planet to that of the sun). The time, in PRÁṆAS, (thus found) divided by 60 gives the KÁLANS'AS, the degrees of time (i. e. the time turned into degrees at the given rising or setting of the sun.)

6. (The degrees of time at which before the sun's rising or after the sun's setting a heavenly body rises or sets heliacally, are called the KÁLÁNS'AS of that body). Thus the KÁLÁNS'AS of Jupiter are 11, of Saturn 15 and of Mars 17. (i. e. when the degrees of time found by the rule mentioned in S'LOKA 5th are 11, 15 or 17 of Jupiter, Saturn or Mars respectively, the planet will rise or set heliacally).

7. Venus sets heliacally in the western horizon and rises in the eastern horizon by its 8 degrees (of time) on account of the greatness of its disc (when it has retrograde motion, but when it has direct motion) and hence its disc becomes small, it sets heliacally in the eastern horizon and rises in the western horizon by 10 degrees (of time).

8. Thus Mercury rises or sets heliacally at the distance of 12 degrees of time from the sun, when it becomes retrograde; but when it is moving quick it rises or sets heliacally at the distance of 14 degrees.

9. When (at a given time) the KÁLÁNS'AS (found from the places of the planets by the rule mentioned in 5th S'LOKA) are greater than the planet's own KÁLÁNS'AS (just mentioned), the planets become visible; (but) when less, the planets having their discs involved in the rays of the sun, become invisible on the earth.

10. Find the difference, in minutes, between the KÁLÁNS'AS (i. e. KÁLÁNS'AS found from the place of the planet at the given time, and those which are the planet's own as mentioned before): and divide it by the difference between the diurnal motions* of the sun and the planet; the quantity obtained is the interval in days, (ghaṭikás) &c., between the given time and that of the planet's heliacal rising or setting. (This holds when the planet is direct; but) when it is retrograde, take the sum of the diurnal motions of the sun and the planet for the difference of the diurnal motions.

* Here motions should first be turned into time (as directed in S'LOKA 1 11th to make the dividend and divisor similar. B. D.

11. The diurnal motions of the sun and the planet multiplied by the numbers of PRÁṆAS contained in the rising periods of the signs occupied by the sun and the planet, and divided by 1,800, become the motions in time. From these motions (turned into time) find the time past or future in days, GHAṬIKÁS &c., from the given time to the time of heliacal rising or setting of the planet.

12. The stars SWÁTÍ (Arcturus), AGASTYA (Canopus) MṚIGAVYÁDHA (Sirius), CHITRÁ (Spica), JYESHṬHÁ (Antares), PUNARVASU (*β* Geminorum), Abhijit (*α* Lyræ) and BRAHMAHRÍDAYA (Capella) rise or set heliacally by 13 degrees of time.

13. The stars HASTA (*δ* Corvi), S'RAVAṆA (*α* Aquilæ) PÚRVAPHÁLGUNÍ (*δ* Leonis), UTTARÁ-PHALGUNÍ (*β* Leonis), DHANISHṬHÁ (*α* Delphini), ROHIṆÍ (*α* Tauri), MAGHÁ (Regulus), VIS'ÁKHÁ (*α* Libræ) and AS'WINÍ (*α* Arietis) rise (or set) heliacally by 14 degrees of time.

14. The stars KṚITTIKÁ (*π* Tauri, Pleiades), ANURADHÁ (*δ* Scorpionis), MÚLA (*ν* Scorpionis), AS'LESHÁ (*α* 1 and 2 Cancri), ÁRDRÁ (*α* Orionis) PÚRVASHÁDHA (*δ* Sagittarii) and UTTARÁSHADHÁ (*τ* Sagellarii) rise (or set) by 15 degrees of time.

15. The stars BHARAṆÍ (Musca), PUSHYA (*δ* Cancri) and MṚIGA (*λ* Orionis), on account of their smallness, rise or set heliacally by 21 degrees of time: and the others [i. e. S'ATATARAKÁ (*λ* Aquarii), PÚRVÁ-BHÁDRAPADÁ (*α* Pegasi), UTTARÁBHÁDRAPADA (*α* Andromedæ), REVATI (*ζ* Piscium), AGNI (*β* Tauri), PRAJÁPATI (*δ* Aurigæ), APÁMVATSA (b 1. 2. 3.) and ÁPA (*δ* Virginis)] rise and set by 17 degrees of time.

16. The KÁLÁNS'AS (of a planet and those which are found at a given time from the place of the planet) multiplied by 1,800 and divided by the rising period of the sign which is occupied by the planet, give the degrees of the ecliptic. (Then in S'LOKA 10th) take the degrees of the ecliptic for their corresponding degrees of time and from them find the time of heliacal rising or setting of the planet.

17. The said stars rise heliacally in the eastern horizon and set heliacally in the western. Apply the AKSHA-DṚIKKARMA to their longitudes and (through them) find the days past or future from the given time to the time of heliacal rising or setting of the stars from the diurnal motion of the sun only (by the rule mentioned in 10th S'LOKA).

18. The stars ABHIJIT (α Lyræ), BRAHMA-HṚIDAYA (Capella), SWÁTÍ (Arcturus), S'RAVAṆA (α Aquilæ), DHANISHṬHÁ (α Delphini) and UTTARÁ-BHADRAPADÁ (α Andromedæ) never disappear owing to the sun's light on account of the greatness of their north latitudes (i. e. these stars having great north latitudes never set heliacally) in the northern hemisphere.

End of the ninth Chapter on the heliacal rising and setting of the planets and stars.

CHAPTER X.

On the phases of the Moon and the position of the Moon's cusps.

1. Find the time also at which the Moon will rise or set heliacally in the same way as mentioned before. She becomes visible in the western horizon and invisible in the eastern horizon by 12 degrees of time.

To find the time of daily setting of the Moon.

2. Find the true places of the Sun and the Moon (at Sun-set of that day of the light half of a lunar month at which you want to know the time of daily setting of the Moon) and apply the two portions of the DṚIKKARMA to the moon's place); from those places, with 6 signs added, find the time in PRAṆAS (just in the same way) as mentioned before (in 5th S'LOKA of the preceding Chapter). At these PRAṆAS after the sun-set, the Moon will set (on that day).

To find the time of daily rising of the Moon.

3. (But when you want to know the time of the Moon's daily rising on a day of the dark half of a lunar month) find the true places of the Sun and the Moon (at sun-set) and add 6 signs to the Sun's place (and apply the two portions of the DṚIKKARMA to the Moon's place); from these places (i. e. from the Sun's place with 6 signs added and from the Moon's place with the DṚIKKARMA applied) find the time in PRAṆAS (in the same way as mentioned before in 5th S'LOKA of the preceding Chapter). At this time in PRAṆAS after sun-set the Moon will rise (on that day).

To find the phases of the Moon.

4. (When you want to know the phase of the moon on a day of the first quarter of a lunar month, find the true declinations of the Sun and the Moon at sun-set or sun-rise of that day) find the difference of the sines of the declinations (just found), when they are of the same name, otherwise find the sum: to this result (the difference or the sum) give the name of the same direction south or north at which the Moon is from the Sun.

5. Multiply the result by the hypothenuse of the gnomonic shadow of the Moon (at the same time as can be found by the rule mentioned in the third Chapter): find the difference between the product and twelve times the equinoctial shadow if the result be north (but) if it be south find the sum of them.

6. The amount (thus found) divided by the sine of co-latitude of the place, gives the BÁHU or base (of a right angled triangle): this is of the same name of which the amount is: and the sine of the altitude of the Moon is the KOṬI (or perpendicular of the triangle). The square-root of the sum of the squares of the BÁHU and KOṬI is the hypothenuse (of the triangle).

7. Subtract the Sun's place from that of the Moon. The minutes contained in the remainder divided by 900 give the illuminated part of the Moon: This part multiplied by the

Moon's disc (in minutes) and divided by 12 becomes the SAMA or rectified illuminated part.

8. (On a board or levelled floor) having marked a point representing the Sun, draw from that point a line equal to the BAHU (above found) in the same direction in which the BAHU is, and from the end of the BAHU a line (perpendicular to it) equal to the KOṬI (as above found) to the west, and draw the hypothenuse between the end of the KOṬI and the point (denoting the Sun).

9. About the point where the KOṬI and the hypothenuse meet, describe the disc of the Moon (found at the given time). In this disc suppose the directions (east, west &c.,) through the line of the hypothenuse (i. e. in the disc suppose the east where the line of the hypothenuse cuts the disc, the west where the same line produced intersects it, and the north and south where a line passing through the centre of the disc and being perpendicular to the line of the hypothenuse cuts the disc).

10. Take a part of the hypothenuse within the disc from the (latter) intersection of the disc and the hypothenuse equal to the (rectified) illuminated part: and between the end of that part and the north and south points of the disc describe two TIMIS.

11. From the intersecting point of the two lines, drawn through the TIMIS, describe the arc which will pass through the three points (the end of the illuminated part and the north and south points of the disc). The disc thus cut by the arc will represent the form of the Moon as it will be seen on the evening of the given day.

12. Marking the directions in the disc through the KOṬI (above drawn), show the horn elevated at the end of the transverse line; this figure will represent the phase of the Moon.

13. In the dark half of the lunar month subtract the place of the Sun with 6 signs added to it, from the Moon's place, and from the remainder find the dark part of the Moon (in the same way as you found the illuminated part in the 7th S'LOKA):

(and in the diagram) change the direction of the BÁHU and show the dark portion of the Moon in the west.

End of the tenth Chapter called S'ringonnatí which treats of the phases of the moon.

CHAPTER XI.

Called PATADHIKARA *which treats of the Rules for finding the time at which the declinations of the Sun and Moon become equal.*

VAIDHRÍTA.

1. It is called VAIDHRÍTA when the Sun and Moon are in the same AYANA (i. e. when they are both in the ascending or descending signs), the sum of their longitudes equal to 12 signs (nearly) and their declinations equal.

VYÁTÍPÁTA.

2. It is called VYATIPATA when the Moon and the Sun are in different AYANAS, the sum of their longitudes equal to 6 signs (nearly) and their declinations equal.

3. The Fire (named PATA) which arises from the mixture of the rays of the sun and the moon in equal quantities, being burnt by the air called PRAVAHA produces evil to mankind.

4. Since the (said) PATA frequently destroys people at the time (when the declinations of the Sun and Moon become equal) it is called VYATÍPATA. It is also called VAIDHRÍTA.

5. This PÁTA is of black colour and hard body, red eyed and gorbellied, destroyer of all people and horrible: it happens frequently.

To find time at which the true declinations of the Sun and Moon become equal.

6. When the sum of the places of the Sun and Moon, applied with the degrees of the precession of the equinoxes as found by observation, is 12 or 6 signs find their declinations.

7. Now, if the Moon's mean declination (i. e. the declination of her corresponding point in the ecliptic) with her latitude applied (i. e. her true declination) be greater than that of the Sun, when the Moon is in an odd (1st or 3rd) quarter of the ecliptic, the PÁTA (or the instant when the declinations of the Sun and Moon become equal) is past.

8. And (if the Moon's declination be) less, (the PATA is future. But when the place of the Moon is in an even i. e. 2nd or 4th) quarter (of the ecliptic) the reverse of this takes place (i. e. if the Moon's true declination be greater than that of the Sun the PATA is future, and if less the PATA is past).

When the Moon's (mean) declination is subtracted from her latitude (for her true declination change the name of the Moon's quarter.

9. Multiply the sines of the declinations (as found in the 6th S'LOKA) by the radius and divide the products by the sine of the greatest declination (i. e. 24°) : take the arcs whose sines are equal to the quotients, and add the difference or half the difference of the arcs to the Moon's place when the PATA is future. (This result which is just applied to the Moon's place is called the moon's change).

10. But when the PATA is past, subtract the Moon's change from her place. The Moon's change multiplied by the true daily motion of the Sun and divided by that of the Moon gives the Sun's change : apply it to the Sun's place as in the case of the Moon.

11. Find the change of the Moon's ascending node in the same way (i. e. multiply the Moon's change by the daily motion of the node and divide the product by the Moon's true daily motion) : apply this change inversely to the node's place. Find the declinations of the Sun and the Moon again (from their places with their changes applied) and apply the same process (mentioned in the preceding S'LOKAS) repeatedly until you get their declinations equal.

To find when a PÁTA is past or to be past.

12. The PATA is that instant at which the declinations (of the Sun and the Moon) become equal. Now, according as the Moon's true place found at the PATA by applying the Moon's change (as mentioned before) is less or greater than that found at mid-night (of that day), the PATA is before or after (the mid-night.)

To find the true time of the PÁTA.

13. The difference, in minutes, between the Moon's true places found at the PÁTA and the mid-night, multiplied by 60 and divided by the true daily motion of the Moon gives the GHAṬIKA'S between the PATA and the mid-night. (Then you will get the time of the PATA by adding or subtracting the GHAṬIKA'S, just found, to or from the mid-night according as the PATA is past or future).

To find half the duration of the PÁTAKÁLA.

14. (Find the semi-diameters, in minutes, of the Sun and the Moon by the Rule mentioned in the 4th Chapter.) The sum of the semi-diameters of the Sun and the Moon multiplied by 60 and divided by the Moon's true daily motion from the Sun gives half the duration of the PÁTA-KÁLA.*

To find the beginning, middle and end of the PÁTA.

15. The true time of the PATA (found in the 13th S'LOKA) is called the middle of the PÁTA: This time diminished by half the duration of the PÁTA, just found, gives the beginning of the PÁTA and increased by half the duration gives the end of the PÁTA.

16. The interval between the beginning and end of a PÁTA is horrible; being in the form of burning fire, all rites are prohibited during its continuance.

Form of the PÁTA-KÁLA.

17. As long as the distance of any point of the sun's disc (from the equinoctial) is equal to that of any point of the Moon's disc, the

* The PA'TA-KA'LA, or duration of the PA'TA, is the time during which the declination of any point of the Sun's disc and that of any point in the Moon's are equal.—B. D.

PÁTA-KÁLA lasts and destroys the (happy results of) all rites (performed during that time).

18. People get very great religious merits from such (virtuous) acts as bathing, alms-giving, prayers, funeral ceremonies, religious obligations, burnt offerings, &c. (performed in the PÁTA-KÁLA), as well as from the knowledge of that time.

19. When the (mean) declinations of the Sun and the Moon become equal, near the equinoctial points, the PÁTA of the two kinds (i. e. VYATÍPÁTA and VAIDHRÍTA) happens twice: contrariwise (i. e. when the mean declinations become equal near the solstitial points, and the true declination of the Moon is less than that of the Sun) no PÁTA happens.

Third PÁTA.

20. There becomes a third PÁTA called (also) VYATÍPÁTA* when the minutes, contained in the sum of the places of the Moon and the Sun, divided by the BHABHOGA (or 800) give a quotient which terminates in 17 (i. e. which is more than 16 and less than 17).

GANDA'NTA and BHASANDHI.

21. The last quarters of the NAKSHATRAS† AS'LESHA', JYESHTHA' and REVATÍ are called the BHASANDHI (or junctions of NAKSHATRAS) and the first quarter of each of their following ones (i. e. MAGHA', MÚLA and AS'WINÍ) is called the GANDANTA.

22. During the three frightful VYATÍPA'S, GANDA'NTAS and BHASANDHÍS (just mentioned), all (joyful) acts are prohibited.

23. (O Maya,) thus far have I told you the excellent, virtuous, useful secret and great knowledge of Astronomy, what more do you want to hear?

End of the 11th Chapter called PÁTA'DHIKA'RA.

End of the First Part of the SÚRYA-SIDDHÁNTA.

* This is the YOGA or the period of time in which the sum of the places of the Sun and the Moon increases by 800'. This YOGA is the 17th reckoned from VISHKAMBHA. See 65th S'LOKA of the second CHAPTER.—B. D.

† These are the periods 9th, 18th and 27th from AS'WINÍ: they are found from the Moon's place by the Rule mentioned in the 64th S'LOKA of the 2nd CHAPTER.—B. D.

CHAPTER XII.

On Cosmographical Matters.

1. Now, MAYA-ASURA joining the palms of his hands, saluted (his teacher) the man who partakes of the Sun's nature, and worshipping him with his best respects asked this :—

Question about the Earth.

2. (Tell me, O my) omnipotent (master,) What is the magnitude of the Earth? what is its form? what supports it? how is it divided? and how are the seven PÁTÁLA-BHÚMIS or lower regions situated in it?

Question about the sun's revolution.

3. How does the Sun cause day and night? How does he, enlightening (all) the worlds, circumvolve the Earth?

Other questions.

4. Why are the day and night of of the (Gods) and ASURAS mutually the reverse of each other (i. e. why is it day to the Gods when it is night to the ASURAS and vice versâ) : and how is it that the (said) day and night is equal to the time in which the Sun completes one revolution?

5. By what reason does the day and night of the PITṚIS consists of a lunar month and that of man consists of 60 GHAṬIKÁS? why are not the day and night of the same length everywhere?

6. Why are not the rulers of the days, years, months and hours in the same order? how does the starry sphere with the planets revolve, and what is its support?

7. At what distances from the Earth are the orbits of the planets and stars arranged one above the other? what are the distances (between the consecutive) orbits? what are their dimensions? and in what order are they situated?

8. (Why is it that) the Sun's rays are vehement in summer and not so in winter: How far do the Sun's rays reach? How many MÁNAS (i. e. kinds of time as solar, lunar &c.) are there, and what their use?

9. O you omnipotent, who are acquainted with the past, (present and future events) remove my doubts (by answering my questions): (as) no one except you is omniscient and remover (of doubts).

10. Having heard the speech thus addressed by MAYA with his best respects, the man (who partakes of the Sun's nature) related to him the secret Second Part of the work.

11. O Maya, hear attentively the secret knowledge called ADHYATMAN (or means of apprehension) which shall tell you: I have nothing which is not to be given to those who are exceedingly attached to me.

The secret knowledge called ADHYÁTMAN.

12. The Supreme Being is called VÁSUDEVA. The excellent soul (PURUSHA) partaking of the nature of VÁSUDEVA is imperceptible, void of all properties, calm, the spirit or life of the universe and imperishable.

13. (This) all-pervading PURUSHA called God SANKARSHAṆA entering nature made the water and put his influence in it.

14. This (water with that influence) became a golden egg involved in darkness: In this egg the eternal ANIRUDDHA first became manifest.

15. This omnipotent ANIRUDDHA is called HIRAṆYA-GARBHA in the VEDAS (by reason of his situation in the golden egg): He is called ÁDITYA from his first appearance and (also) SÚRYA on account of the production (of the universe from him).

16. This ANIRUDDHA named SÚRYA and (also) SAVITÁ is excellent light for the destruction of darkness. This maker of the three states (UTPATTI birth or production, STHITI life or existence, and SANHÁRA death or destruction) of animate (and inanimate) things, illuminating the world (in the golden egg),—

17. This self light ANIRUDDHA destroyer of darkness is

denominated MAHÁN (intelligence): The RIG-VEDA is his disc, SÁMA-VEDA his rays, and YAJUR-VEDA his body.

18. This omnipotent ANIRUDDHA consisting of the three VEDAS is time itself, cause of time, all-pervading, universal spirit, omnivagous and supreme soul and the whole universe depends on him.

19. Riding on the car of the universe to which are attached the wheel of the year and the horses of the seven metres, this ANIRUDDHA revolves at all times.

20. Three-fourths of ANIRUDDHA are hid in the heavens and one (fourth) is this manifest universe. That able ANIRUDDHA generated BRAHMÁ consciousness (AHANKÁRA) for the creation of the universe.

21. Now having bestowed the excellent VEDAS on BRAHMÁ the grandfather of all people and placed him in the middle of the golden egg, ANIRUDDHA himself revolves and illuminates the universe.

22. Then BRAHMÁ bearing the form of consciousness thought of creation. The Moon sprung from (his) mind, and the Sun, a treasure of lights, from (his) eyes.

23. From BRAHMA'S mind sprung ether, from ether air, (from air) fire, (from fire) water, (and from water) earth successively. Thus the five primary elements were produced by the superposition of quality.*

24. The Sun and Moon are respectively of the nature of fire and water, and the five (minor planets) Mars and others (i. e. Mars, Mercury, Jupiter, Venus, and Saturn) sprung severally from fire, earth, ether, water, and air.

25. Again BRAHMÁ, of subdued passions, divided a circle, invented by himself, into 12 parts, naming it the RAS'I-VRITTA, and the same circle into 27 parts naming it the NAKSHATRA-VRITTA.

* Having produced ether with the quality of sound, air was formed by adding to ether the quality of touch; fire by adding to air the quality of form, water by adding to fire the quality of taste, and earth by adding to water the quality of smell.—B. D.

26. Now having created things of different natures by compounding in various proportions the best, middling, and worst qualities (i. e. principles of truth, passion, and darkness) BRAHMÁ made the universe containing Gods and animate and inanimate things.

27 and 28. Having created (Gods and animate and inanimate things) successively according to their qualities and actions, the able BRAHMÁ arranged the planets, asterisms, stars, the earth, worlds, Gods, Demons, men, and SIDDHAS, regularly at proper places and times in the way mentioned in the VEDAS.

29. This BRAHMANDA (the golden egg sacred to BRAHMÁ) is hollow: in this (the worlds) BHÚR, BHUVAR &c., are situated. It is like a SAMPUṬA (a casket) formed by two KAṬAHAS (frying vessels joined mouth to mouth) and of a spherical shape.

Order of the orbits of the stars and planets situated one below the other.

30 and 31. The circumference of the middle of the BRAHMANDA is called VYOMAKAKSHÁ (the orbit of heaven). In it (i. e. BRAHMÁNDA) all the stars revolve. Beneath them Saturn, Jupiter, Mars, the Sun, Venus, Mercury and the Moon revolve one below the other, beneath them the SIDDHA, the VIDYÁDHARA and clouds are situated.

Answers to the questions stated in 2nd S'LOKA.

32. The terrestrial globe, possessing BRAHMÁ's most excellent power of steadiness, remains in space at the centre of the BRAHMÁNDA (which is) all around.

33. The seven PÁTÁLA BHÚMIS or infernal regions formed by the concave strata of the earth are very beautiful, being inhabited by NÁGAS (serpents) and ASURAS (demons) and having the liquors of the divine plants (which shine by their own light).

The position of MERU.

34. The golden mountain MERU, containing heaps of various precious stones, passes through the middle of the terrestrial globe (as an axis projecting on both sides at the poles).

The inhabitants of the ends of the MERU i. e. of the two poles.

35. The Gods with INDRA and the great holy sages inhabit the top of the MERU (i. e. the north pole) while the ASURAS are at the bottom (i. e. the south pole). They (i. e. the Gods and ASURAS) hate each other.

Situation of the great Ocean.

36. The great Ocean (the Ocean of salt water) encircles the MERU; it is like a girdle (or Zone) to the earth and separates the regions of the Gods and the ASURAS (i. e. it is at the Equator and divides the terrestrial globe into two hemispheres: the north is sacred to the Gods and the south to the ASURAS).

The four cities placed at the Equator.

37. Around the middle of the MERU in the directions of the east &c. and at equal distances in the ocean are the four cities made by the Gods in the different DWÍPAS.

38. To the east of the MERU (i. e. north pole) at a fourth part of the Earth's circumference in the BHADRÁS'WA VARSHA (a division of a continent) is the city called YAMA-KOṬI having golden ramparts and arched gateways.

39. So to the south in the BHÁRATA-VARSHA there is the great city called LANKÁ: to the west in the KETUMÁLA-VARSHA there is the city called ROMAKA.

40. To the north in the KURU-VARSHA there is the city called SÍDDHA-PURÍ (or SIDDHA-PURA). Liberal and devout men being free from pain inhabit that (city).

41. These (four cities) are situated at a distance equal to the fourth part of the Earth's circumference from each other: (and) the MERU sacred to the Gods is north of them at the same distance.

There is no equinoctial shadow at the equator.

42. When the Sun is at the equinoctial, he passes through the zenith of these (cities) and therefore, there is neither equinoctial shadow nor elevation of the terrestrial axis at these cities.

The position of the polar stars.

43. On both sides of the MERU (i. e. the north and south poles of the

Earth) the two polar stars are situated in the heaven at their zenith. These two stars are in the horizon of the cities situated on the equinoctial regions.

44. Since the polar stars are in the horizon of the (said) cities, there is no elevation of the terrestrial axis (but) the co-latitude is 90°; so the latitude at the MERU is 90°.

The beginning of the day to the Gods and ASURAS.

45. When the Sun is above the regions of the Gods* (i. e. the northern hemisphere) he first appears to the Gods at the first point of Aries: but to the ASURAS (he first appears) at the first point of Libra, when the sun is going above the regions of the ASURAS (i. e. the southern hemisphere).

Answer to the question in 8th S'loka.

46. Owing to this (the Sun's going northward and southward) the Sun's rays are vehement in summer in the Gods' regions and in winter in the ASURAS'. Conversely they are weak (in summer in the ASURAS' regions and in winter in the Gods').

47. The Gods and ASURAS behold the Sun in the horizon at the equinoxes. The two periods in which the Sun is in the northern and southern hemispheres are mutually the day and night to the Gods and ASURAS (i. e. when the Sun is in the northern hemisphere it is day to the Gods and night to the ASURAS, and vice versâ).

48. The Sun at the first point of Aries, risen to the inhabitant of the MERU (i. e. to the Gods) and passing the three following signs (i. e. Aries, Taurus and Gemini), completes the first half of the day (of the Gods).

49. So he (the Sun) passing (the three signs) Cancer and others completes the second half of the day. In the same manner (the Sun passing) the three signs Libra, &c. and other three Capricorn, &c. (completes the first and second halves of the day of the ASURAS).

Answer to the questions in the 4th S'LOKA.

50. Therefore their day and night are mutually reverse, and the length of

* See the 36th S'LOKA of this Chapter. B. D.

Their Nycthemeron arises from the completion of the Sun's (one) revolution.

51. Their mid-day and mid-night (happen) at the time of the solstices reversely (i. e. it is mid-day to the Gods when it is the mid-night to the ASURAS, and vice versâ) : The Gods and the ASURAS consider themselves each above the other.

52. The others likewise who are situated diametrically opposed (at the earth's surface) as the inhabitants of the BHADRÁSWA and KETUMÁLA (i. e. of YAMAKOṬI and ROMAKA) and those of LANKÁ and SIDDHAPURA consider (themselves) one below the other.

53. Thus everywhere on (the surface of) the terrestrial globe, people suppose their own place higher (than that of others) : because this globe is in space where there is no above and below.

54. All people around their own place behold the Earth, though globular, of the form of a circular plain, on account of the smallness of their bodies.

Parallel and Right spheres.

55. This starry sphere revolves horizontally (from right) to left to the Gods and (from left) to right to the ASURAS : But at the equator (it) always (revolves) vertically (from east) to west.

56. At the equator, therefore, (the length of) the day is always of 30 GHAṬIKÁS and the length of the night is also the same : and at the regions of the Gods and those of the ASURAS (i. e. at the northern and the southern hemisphere) the day and night (except at the equinoxes) always increase and decrease reversely (i. e. at the northern regions the day increases and the night decreases, while at the southern ones the day decreases and the night increases, and vice versâ).

57. When the Sun is in the (northern) signs Aries &c. the increase of the length of the day and the decrease of the length of the night become more and more (until the Sun arrives at the tropic of Cancer and then they become less and less) at the regions of the Gods : but at those of the ASURAS the reverse of this takes place.

58. (But) when the Sun is in the (southern) signs Libra &c. the decrease and increase both of the day and night are the reverse. The knowledge of this (increase or decrease) at every day from (the equinoctial shadow of) the given place and the Sun's declination is described before (in the 61st S'LOKA of the 2nd Chapter).

59. Multiply the Earth's circumference by the number of degrees of the Sun's declination (of a given day) and divide the product by 360° (and take the quotient). The Sun (at that day) passes through the zenith (of the place, north or south of the Equator according as the declination is north or south) at a distance in YOJANAS equal to the quotient (above found) from the equator.

Determination of the place where the day or night becomes of 60 GHAṬIKÁS.

60 and 61. In the same manner find the number of YOJANAS from the Sun's greatest declination and subtract the number from the fourth part of the Earth's circumference (and take the remainder). Then (when the Sun is) at a solstice, the day or night becomes of 60 GHAṬIKÁS once (in a year) at the distance in YOJANAS equal to the remainder (above found) from the equator (i. e. at the polar circles) in the regions of the Gods and the ASURAS reversely (i. e. when the Sun is at his greatest distance from the equinoctial, the day becomes of 60 GHAṬIKÁS at the polar circle in the northern hemisphere, while the night becomes of the same length at the polar circle in the southern one, and vice versâ).

62. (At places) between them (i. e. the equator and a polar circle on either side of the equator) the day and night increase and decrease within the 60 GHAṬIKÁS. Beyond that (i. e. in the polar regions) the starry sphere revolves in an opposite manner (as regards the north pole and the south).

The positions where some signs are always invisible.

63. Find the YOJANAS (as above) from the declination which arises from the sine of two signs* and subtract the YOJANAS from the fourth

* The sine of two signs (i. e. 60°) multiplied by the sine of the greatest declination and divided by the Radius gives the sine of declination. B. D.

part of the Earth's circumference. At the distance equal to the remaining YOJANAS from the equator in the regions of the Gods, the Sun, situated at Sagittarius and Capricornus, is never seen.

64. But in the regions of the ASURAS (at the same distance from the equator), (he is never visible) when situated in Gemini and Cancer. At that quarter of the Earth's circumference in which the Earth's shadow is destroyed (i. e. never falls) the Sun will be seen.

65 and 66. From the fourth part of the Earth's circumference subtract the YOJANAS found from the declination of one sign (30°). At the distance of the remaining YOJANAS from the equator, the Sun never appears in the regions of the Gods when he is in Sagittarius, Capricornus, Scorpio and Aquarius: but in the regions of the ASURAS (at the same distance from the equator, he is never seen when situated in the four signs Taurus, &c. (i. e. Taurus, Gemini, Cancer, and Leo.).

67. The Gods at the MERU behold the Sun constantly as long as he is in (northern) six signs Aries, &c. so the ASURAS as long as he is in (the southern ones) Libra, &c.

Terrestrial tropic.

68. At the distance of the fifteenth part of the Earth's circumference (from the equator) in the regions of the Gods or the ASURAS (i. e. at the north or south terrestrial tropic) the Sun passes through the zenith when he arrives at the north or south solstitial point (respectively).

Determination of the direction of the gnomonic shadow at noon.

69. (At places) between them (i. e. between the equator and the tropics) the gnomonic shadow may be north or south at noon. Beyond this limit it falls towards the ends of the MERU (i. e. the north and south poles) in the northern and southern hemisphere (respectively).

Answer to the question in the 3rd S'LOKA.

70. The Sun when arrived at the zenith of BHADRÁS'WA (or Yamakoṭi) makes his rising in BHÁRATA (or LANKA), mid-night in KETUMÁLA (or RAMAKA) and setting in KURU (or SIDDAPURA).

71. In the same manner, (the Sun) revolving from east to west, (when he reaches the zenith of BHÁRATA or LANKÁ) makes the mid-day, rising, mid-night and setting in the VARSHAS, BHÁRATA and others, i. e. BHÁRATA, KETUMÁLA, KURU and BHADRÁS'WA respectively).

Oblique sphere.

72. To one who is going to the end of the MERU (i. e. to the north or south pole from the equator) the elevation of the polar star (north or south) and the inclination of the starry sphere increase (more and more as he approaches the MERU :) and to one going towards the equator the reverse is the case with the inclination and elevation.

Answer to the question in the 2nd half of the 6th S'LOKA.

73. The starry sphere, bound at its two poles (north and south), being struck with the PRAVAHA winds revolves constantly : (so) do the orbits of the planets confined within it in regular order.

Answer to the question in 5th S'LOKA.

74. (As) on the Earth the Gods and the ASURAS behold the Sun constantly above the horizon throughout half the year, and men throughout their day, (so) do the PITRIS situated on the upper part of the Moon (behold the Sun) throughout a fortnight.

75. The orbit of the upper (of any two planets) is greater than that of the lower : and the degrees of the greater orbit (in length) are greater than those of the smaller.

76. A planet revolving in a smaller orbit passes the 12 signs in a shorter time and one going in a greater orbit (passes the 12 signs) in a longer time.

77. Therefore the Moon moving in a smaller orbit makes many revolutions while the SANAISCHARA (slow-moving i. e. Saturn) going in a greater orbit makes a few.

Answer to the question in the first half of the 6th S'LOKA.

78. Every fourth of the planets (in the order of their orbits mentioned in S'LOKA 31) reckoning from Saturn is the Ruler of a day (of the week) in succession (thus, the

Sun, who is fourth from Saturn, is the ruler of the 1st day; the Moon, who is fourth from the Sun, is the ruler of the second day; Mars, the fourth from the Moon, is the ruler of the third day, and so on).

In the same manner every third of the planets, reckoning from Saturn (i. e. Mars, Venus, the Moon, Jupiter, &c. successively) is the ruler of a year (of 360 terrestrial days).

79. Reckoning from the Moon, the planets above her (i. e. Mercury, Venus, the Sun, &c.) are called the rulers of the months (of 30 days) successively. And from Saturn (the planets situated) one below the other (i. e. Jupiter, Mars, the Sun, &c.) are successively the rulers of the hours.*

Answer to the question in 7th S'LOKA.

80. The Sun's orbit (in YOJANAS to be stated in S'LOKA 86th) multiplied by 60 gives (the length of) the middle circle of the starry sphere. This circle of the stars of so many YOJANAS revolves above all (the planets).

81. Multiply the number of the said revolutions of the Moon in a KALPA by the Moon's orbit (to be declared in S'LOKA 85th): the product is equal to the orbit of heaven (or the circumference of the middle of the BRAHMANDA): to this orbit the rays of the Sun reach.

Determination of the Dimensions of the orbits of the planets and their daily motion in YOJANAS.

82. The very same (the orbit of heaven) being divided by the number of revolutions of a planet in a KALPA gives the orbit of that planet; (and dividing this orbit) by the number of terrestrial days in a KALPA, the quotient is called the daily motion (in YOJANAS) of all the planets to the east.

Of their daily motions in minutes or angular motions.

83. Multiply this number of YOJANAS of the daily motion (of all the

* v. 78 and 79. It is to be known here that the Ruler of a day (from mid-night to mid-night at LANKA) is the same as that of the first hour of the day: and the Ruler of a month or a year is the same as that of the first day of the month or year. B. D.

planets) by the Moon's orbit and divide the product by the orbit of the planet (of which the daily motion in minutes is to be known): the quotient being divided by 15 gives the number of minutes of the motion (of that planet).

84. The orbits (of the planets) multiplied by the Earth's diameter and divided by the circumference of the Earth give the diameters of the orbits. These (diameters) diminished by the Earth's diameter and divided by 2 give the distances of the planets (from the Earth's centre).

85. The orbit of the Moon is 324,000 (YOJANAS) and that of the SIGHROCHCHA of Mercury, beyond the Moon is 1,043,209.

86. That of the SIGHROCHCHA of Venus is 2,664,637 beyond that, that of the Sun, Mercury and Venus is 4,331,500.

87. That of Mars is 8,146,909 and that of the Moon's apogee is 38,328,484.

88. That of Jupiter is 51,375,764 and that of the Moon's ascending node is 80,572,864.

89. That of Saturn is 127,668,255 and that of the fixed stars is 259,890,012.

90. The circumference of the sphere of the BRAHMÁNDEE in which the Sun's rays spread, is 187120808640000000 YOJANAS.

End of the twelth CHAPTER.

CHAPTER XIII.

On the construction of the armillary Sphere and other astronomical Instruments.

1 and 2. Now the teacher (of MAYA) being in a secret and holy place bathed, pure and adorned, and having worshipped faithfully the Sun, the planets, the asterisms and the GUHYAKAS (a kind of Demigods) explained clearly the knowledge which he had from his preceptor (the Sun) through traditional instruction, for the satisfaction of his pupil (MAYA).

The construction of the armillary Sphere.

3 and 4. Let an astronomer make the wonderful construction of the armillary Sphere with that of the Earth (at its centre).

Having caused a wooden terrestrial globe to be made of any desired size with a staff representing the MERU passing through the (globe's) centre and projecting on both sides. (Let him fix) two circles (on the staff) called the ADHARA KAKSHÁ or the supporting circle (answering to the colures) as also the equinoctial.

The diurnal circles of the 12 signs.

5. Let three circles marked with the number of degrees in the 12 signs (or 360°) be prepared (to represent the diurnal circles at the ends of the 3 signs Aries, Taurus and Gemini) with radii answering to the respective diurnal circles in proportion to the Equinoctial.

6, 7, 8 and 9. Let him fix the three circles for Aries and other signs respectively (on the two supporting circles) marked with the degrees of declinations north and south, at the end of respective declination (north of the Equinoctial) (of the ends of the said signs). The same (circles) answer contrariwise to the (three signs) Cancer and others (at the ends of the respective declinations of the beginnings of the signs). In the same manner, let him fix (other) three circles in the southern hemisphere, for Libra and others (and) contrariwise for Capricorn and the rest. Let him also fix circles on both the supporting circles for the principal stars of the asterisms in both hemispheres as also for ABHIJIT (and Lyræ) and for the seven great saints (i. e. the seven stars composing the constellation of Ursa major), AGASTYA (Canopus). BRAHMÁ (Aurigæ) and other stars. In the very middle of all (these circles) is fixed the Equinoctial circle.

Determination of the places of the 12 signs in the sphere.

10 and 11. Let the two solstices be marked above the intersection of the Equinoctial and one of the two supporting circles (i. e. at the distance of the Sun's greatest

declination from the intersection to the north and south on the supporting circle) and the two equinoxes (at the intersection of the equinoctial and the other supporting circle).

Then from the equinox at the exact degrees of every sign (i. e. at every 30°) the places of Aries and other signs should be determined by the transverse strings (of the circle).

The Ecliptic.

There is another circle passing from solstice to solstice.

12 and 13. (This circle) is called the Ecliptic: in this, the Sun, enlightening the worlds, always revolves.

(But) the Moon and other (planets) being attracted from the ecliptic by their nodes situated in the ecliptic are seen at the ends of (their respective) latitudes.

The Horoscope.

(The point of the ecliptic) in the eastern horizon is called the LAGNA (the horoscope) and (the point) just setting is called the ASTA LAGNA (or the setting LAGNA) on account of its setting.

The MADHYA LAGNA or the culminating point of the ecliptic.

14. The point of the ecliptic in the middle of the visible heaven (or in the meridian i. e. the culminating point of the ecliptic) as determined through the rising periods of the signs ascertained for LANKA (in 48th S'LOKA of the 3rd Chapter) is called the MADHYAMA (Lagna).

The ANTYÁ.

(Suppose a line between the two intersections of the meridian of a given place and a given diurnal circle). The string (or the portion of that line) intercepted between the meridian and the horizon (in terms of the radius of a great circle) is called ANTYÁ.

The sine of the ascensional difference.

15. And a portion (of the same line) intercepted between (the plane of) the six o'clock line and that of the horizon (in terms of the radius of a great circle) is, it is to be known, equal to the sine of the ascensional difference.

The Horizon. (On the terrestrial globe) considering the given place as the highest, surround the sphere with the horizon in its middle (i. e. 90° distant from the given place).

The self-revolving Spheric instrument. 16. Thus having surrounded the sphere (the axis of which should be elevated to the height of the pole) by the horizon (made as level as water) and covered (in its lower half) by wax cloth, make it rotate by the force of the current of water for the knowledge of the passage of time.

17. (Or let an astronomer) make the sphere (a self-revolving instrument) by means of mercury.

The method (of constructing the revolving instrument) is to be kept a secret, as by its diffusion here it will be known to all (and then there will be no surprise in it).

Therefore, from the instruction of the teacher construct the excellent spheric instrument (so that it may be self-revolving).

(The knowledge of) this, the Sun's method is lost at the end of every YUGA.

19. It arises again by the favour of some one (great astronomer) when he pleases.

So let other self-revolving instruments be furnished for measuring time.

20. To (such) a surprising instrument let (an astronomer) alone apply his contrivance, (in secret).

Other instruments for measuring time. Let smart (astronomers) from the instruction of their teacher know the hour (of the day) by the dial instruments gnomon, staff, semicircle and circle in various ways.

21. Let also (astronomers) determine the hour exactly by the water-clocks, clepsydra &c., and the sand-clocks in the shape of peacock, man or monkey.

22. (For the self-revolution of the said instruments) apply the hollow spokes (half filled) with mercury, water, threads, ropes, mixture of oil and water, mercury and sand to them

(i. e. the instruments). These applications are very difficult of attainment.

KAPALA Yantra or Clepsydra.

23. The copper vessel (in the shape of the lower half of a water jar) which has a small hole in its bottom and being placed upon clean water in a basin sinks exactly 60 times in a nycthemeron, is called the KAPÁLA YANTRA.

The Gnomon.

24. As also that instrument the Gnomon is very useful by day when the Sun is clear, and an excellent means of ascertaining time by taking its shadows.

Conclusion.

25. Having known exactly the science of the planets and stars and the spheric, man attains (his residence at) the spheres of the planets (Moon &c.) and becomes acquainted with the spiritual knowledge by his regeneration, attains to spiritual knowledge in a subsequent birth.

End of the thirteenth Chapter called JYAUTISHOPANISHAT.

CHAPTER XIV.

On kinds of time.

Number of kinds of time.

1. There are nine MÁNAS (kinds of time), the BRÁHMA (that of BRAHMÁ), the DIVYA (that of the Gods), the PITRYA, the PRÁJÁPATYA, as also that of Jupiter, the Solar, the Terrestrial, the Lunar and the Sidereal.

The MÁNAS which are used here.

2. The four MÁNAS the solar, the lunar, the sidereal and the terrestrial are (always) in use in this world: the MÁNA of Jupiter is (used

here for knowing the 60 SAMVATSARAS,* and the other MĀNAS are not always (used).

Use of the solar MĀNA.

3. The lengths of the day and night, the SHAḌAS'ÍTI-MUKHAS,† the solstitial and equinoctial times, and the holy time of SANKRÁNTI (i. e. the time of the entrance of the Sun into a sign at which a good action brings good desert to the performer) are determined by the solar MĀNA.

The SHAḌAS'ÍTI MUKHA.

4. Every eighty-sixth (solar‡) day reckoned from the time of TULÁDI (i. e. from the time at which the Sun enters the sign Libra) is called SHAḌAS'ÍTI-MUKHA in succession. These four days lie (in the four solar months) when the Sun is in the four signs of two natures (i. e. Gemini, Virgo, Sagittarius and Pisces).

There are four SHAḌAS'ÍTI MUKHAS in a year.

5. (The first SHAḌAS'ÍTI-MUKHA happens when the Sun is) at the 26th degree of Sagittarius, (the second) at the 22nd degree of Pisces, (the third) at the 18th degree of Gemini and (the fourth) at 14th degree of Virgo.

6. Then (after the fourth SHAḌAS'ÍTI-MUKHA) the remaining 16 solar days of the solar month at which the Sun is in Virgo, are equal to a sacrifice (i. e. good actions performed in these days give great merit equal to that of a sacrifice) and in these days a gift given in honour of deceased ancestors is imperishable (i. e. the gift gives infinite merit).

Four common points of the ecliptic.

7. In the middle of the starry sphere, the two equinoxes are diametrically opposed, so are the two solstices (in the ecliptic); these four points (of the ecliptic) are very common.

Its other points.

8. Again, between every two consecutive points (of them) two SANKRÁN-

* See 55th S'LOKA of the first Chapter. B. D.

† This word will be explained in the following S'LOKA. B. D.

‡ By a solar day is here meant the time in which the Sun moves one degree of the Ecliptic. B. D.

TIS or the beginnings of the signs are situated in the ecliptic: (And of the twelve points of the ecliptic, just mentioned), the points which are next to the (four common) points (i. e. the beginnings of the four signs Taurus, Leo, Scorpio and Aquarius) are called the VISHṆU-PADÍ.

Two halves of a tropical year.

9. From (the time of) the Sun's entrance into Capricorn the six solar months are the UTTARÁYAṆA (the northing of the Sun): in the same manner from the time of the entrance of the Sun into Cancer, the six solar months are the DAKṢHIṆÁYANA (the southing of the Sun).

The seasons, months and year.

10. From that time (i. e. the winter solstice) the periods, in each of which the Sun remains in the two signs are the seasons S'ISIRA (the very cold season) &c.* and the twelve periods in which the Sun remains in the 12 signs Aries, &c., are the solar months and a year is equal to the aggregate of these months.

The holy time of SANKRÁNTI.

11. The number of minutes contained in the Sun's disc multiplied by 60 and divided by (his) daily motion (gives a certain number of GHAṬIKÁS.) Half these GHAṬIKÁS, before as well as after the SANKRÁNTI (or the time of the Sun's passage from one sign into another) is holy.

The lunar MÁNA.

12. The time in which the Moon, being separate from the Sun (after a conjunction), moves daily to the east is the lunar MÁNA. The time in which the Moon describes 12 degrees (from the Sun) is a lunar day.

Use of the lunar MÁNA.

13. The TITHI (lunar day), the KARAṆA (half of a TITHI), the time of marriage, shaving and all other acts, as also (the times of)

* A solar year is divided into six seasons, viz. The S'IS'IRA (the very cold season), the VASANTA (the Spring), the GRÍSHMA (the hot season) the VARSHA (the rainy season), the S'ARAT (the Autumn) and the HEMANTA (the cold season). B. D.

religious acts of obligations, fasts and pilgrimages are regulated by the lunar MÁNA.

The MÁNA of PITṚIS.

14. A lunar month which consists of 30 lunar days, is, as mentioned before, a day and night of the PITṚIS. The end of a (lunar) month and that of the light half of that month take place in the middle of them (the day and night of the PITṚIS) respectively.

* The sidereal MÁNA.

15. A daily revolution of the starry sphere is called a sidereal day.

Naming of the lunar months.

The lunar months are named from the NAKSHATRAS* (or asterisms) which take place (or in which the Moon is) on the 15th day of these months.†

16. On the 15th day of (each of the lunar months) KÁRTIKA and others, (either of every) couple of the NAKSHATRAS reckoned from KṚITTIKÁ takes place successively. (But on the 15th day of each of) the three months such as the last (i. e. Ás'WINA) and that coming before the last (i. e. BHÁDRAPADA) and the fifth (i. e. PHÁLGUṆA) one of three NAKSHATRAS takes place.‡

Years of Jupiter.

17. (As the lunar months are named KÁRTIKA &c. from the union of their 15th day with the NAKSHATRAS KṚITTIKÁ, &c. so) the years of Jupiter are called KÁRTIKA, &c. from the union of the 15th day of the dark half of the months VAIS'ÁKHA, &c. (with the NAK-

* The NAKSHATRAS are found in the 64th S'LOKA of the 2nd Chapter. B. D.

† The first lunar month is named CHAITRA from the NAKSHATRA CHITRA, the 2nd VAIS'A'KHA', from VIS'A'KHA' the 3rd JYESHṬHA, from JYESHṬHA, the 4th ÁSHADHA from PÚRVA'S'HA'DHA', the 5th S'RA'VAṆA, from S'RAVAṆA, the 6th BHA'DRAPADA from PÚRVA'BHA'DRAPADA', the 7th Ás'WINA from Ás'WINÍ, the 8th KA'RTIKA from KṚITTIKA, the 9th MA'RGAS'ÍRSHA from MṚIGAS'ÍRSHA, the 10th PAUSHA from PUSHYA, the 11th MA'GHA from MAGHA' and the 12th PHA'LGUNA from PÚRVA-PHALGUNÍ. B. D.

‡ On the 15th day of the lunar month KA'RTIKA, the NAKSHATRA KṚITTIKA or ROHIṆÍ takes place; of MARGAS'ÍRSHA, MṚIGA or ÁRDRA', of PAUSHA, PUNARVASU or PUSHYA; of MAGHA, Ás'LESHA or MAGHA'; of PHALGUNA, PÚRVAPHALGUNÍ or UTTARAPHALGUNÍ or HASTA; of CHAITRA', CHITRA or SWA'TI; of VAIS'AKHA, VIS'A'KHA' or ANURA'DHA'; of JYESHṬHA, JYESHṬHA' or MÚLA; of ÁSHADHA, PÚRVA'SHADHA' or UTTARA'SHADHA; of SRAVAṆA, SRAVAṆA or DHANISHṬHA; of BHA'DRAPADA, S'ATATA'RA, PÚRVA'BHA'DRAPADA' or UTTARA'BHA'DRAPADA; and of Ás'WINA, REVATÍ Ás'WINÍ or BHARAṆÍ. B. D.

NAKSHATRÁS KRITTIKÁ, &c., when at the said 15th day) Jupiter rises or sets heliacally.

Terrestrial MÁNA.

18. The time from one rising of the Sun to the next is called a SÁVANA or a terrestrial day, from this the number of terrestrial days in a KALPA is determined: By these days the time of sacrifice is calculated.

It's use.

19. Determination of the SÚTAKA (or impurity contracted in consequence of a death or birth in one's family), the rulers of the day, month and year, and the mean motion of a planet are reckoned by SÁVANA (or the terrestrial MÁNA).

The MÁNA of the Gods.

30. It is said before that the day and night of the Gods and the ASURÁS are mutually reverse: This day and night which is found from the completion of the Sun's revolution is DIVYA (or the MÁNA of the Gods).

PRA'JA'PATYA MANA.

21. The duration of a MANU (which, as mentioned before, is equal to 71 YUGAS) is called PRÁJÁPATYA (or the MÁNA of PRAJÁPATI who was the father of MANUS). There is no division of the day and night in this MÁNA.

The BRA'HMA MANA.

The KALPA is called the BRÁHMA (or the MÁNA of BRAHMÁ).

Conclusion.

22. O superior MAYA, I declared this secret and surprisingly excellent (knowledge) to you. This (equivalent to) the holy knowledge is exceedingly meritorious and the destroyer of all sins.

23. Having known this excellent divine knowledge of the stars and the planets which is (just) imported to you, man acquires a perpetual place on the spheres of the Sun &c.

24. Having properly imparted this to MAYA and said this (the meaning of the preceding two verses) and being worshipped by him, the man who partakes of the nature of the Sun, ascended to heaven and entered the disc of the Sun.

25. Then having learned the divine knowledge from the Sun himself, MAYA considered himself as one who had done his duty, and free from sins.

26. Then having known that MAYA had obtained a blessing of the Sun (some) saints approached and asked him respectfully the knowledge.

27. He (MAYA) being delighted gave the great knowledge of the planets to them (the saints) which is very surprising in this world, secret and equivalent to the holy knowledge.

End of the 14th Chapter, of the Second Part, and of the work.

POSTSCRIPT BY THE TRANSLATOR.

It is stated in the SÚRYA-SIDDHÁNTA that a dialogue took place between a man partaking of the nature of the Sun and a Demon called MAYA 2,164,960 years before the present time. But nobody knows who has put this dialogue into verse or the date of this versification. People believe that it is the production of some MUNI (saint), and many are of opinion that it is the oldest of eighteen ancient astronomical works. Its style is easy, and the reading of it, as of the PURÁṆAS, is considered to be meritorious. Every subject is treated more fully in this than in any other of the ancient SIDDHÁNTAS, and the revolutions of the planets are so correctly stated in it that their places can be determined with great accuracy.

The names of the eighteen ancient SIDDHÁNTAS are :—

1. Súrya-siddhánta.
2. Brahma-s.
3. Vyása-s.
4. Vasishṭha-s.
5. Atri-s.
6. Parás'ara-s.
7. Kas'yapa-s.
8. Nárada-s.
9. Garga-s.
10. Maríchi-s.
11. Manu-s.
12. Aṅgiras-s.
13. Lomas'a-s.
14. Pulis'a-s.
15. Chyavana-s.
16. Yavana-s.
17. Bhṛigu-s.
18. S'aunaka or Soma-s.

Although it is generally supposed that the SÚRYA-SIDDHANTA is the oldest, yet some consider the BRAHMA-SIDDHÁNTA to be so: and it is stated in the S'AMBHU-HORÁPRAKAS'A (an astrological work), that the SOMA-SIDDHÁNTA is the first, the BRAHMA-SIDDHANTA the second, and the SÚRYA-SIDDHÁNTA the third in the order of time. But this opinion is not generally received. Of the eighteen ancient Siddhántas only four (viz. Súrya-s., Brahma-s., Soma-s., and Vasishṭha-s.) are now procurable; the others are very rare.

In the translation wherever words are supplied by way of explanation they are included in brackets. In some places the original Sanskrit is so brief and terse, that it is not only obscure, but unintelligible, without the insertion of words to complete the sense: e. g. p. 24, S'LOKA 64.

BAPU DEVA.

Sanskrit College, Benares, 1860.

ERRORS.

Page.	*Line from top.*	*Error.*	*Correction.*
1	7	Properties (of all created things).	Properties,
1	9	Siva.	Síva.
5	13	Revátí.	Revatí.
8	4	Kŕíta yuga.	Kṛita yuga.
12	32	Madhyágatí.	Madhyagatí.

INDEX.