next day. This is why the Tamil month *Tai*, corresponding to Bengal Solar *Mâgha*, A.D. 1910–11 is shown in Table XII as having commenced on 14 January 1911, *i.e.*, the day after the Sankrânti.

145. The authors of the "Indian Calendar" also state that in Malabar, when the Sankrânti occurs after 18 ghaṭikas, the Solar month commences on the next day. If this were so, Malayâlam *Dhanus* in A.D. 1910–11 would commence on 16th December 1910. As a matter of fact, however, all the Malayâlam Panchângams show *Dhanus*, A.D. 1910–11, as commencing on the same day as the Tamil *Mârgali*, i.e., on 15 December 1910. This fact imports an element of doubt into the so-called "Malabar rule" laid down by Messrs. SEWELL & DIKSHIT; and till the contrary is shown to be the case, we must assume that the Tamil rule is followed in Malabar.

146. The Bengal rule laid down by the same authorities is practically applied in Table XII, page 136 (Ephemeris for Bengal). Whatever may be the rules as regards the commencement of a civil month *in any part of India*, the data given in Table XII and the Eye-Table will enable any one to apply his own *civil* rule with certainty. The dates entered in Table XII for the commencement and end of Solar months apply in strictness only to Southern India and to the *Arya Siddhânta.* For the *Sûrya Siddhânta* and for tracts where a different *civil* rule from that in force in Southern India is followed, suitable corrections may have to be applied, as in Table XII, page 136 (Ephemeris for Bengal).

147. To illustrate the difference between Sankrântis according to Ârya and Sûrya Siddhântas, we will give a practical example from a case which recently came under the author's notice. A person produced a Tamil horoscope which contained among other data the following note on the date of his birth :—

"A.D. 1856, June 28, *Ani* 16."

A reference to the Tamil panchângams of the year A.D. 1856 showed that according to *all* of them, 28 June 1856 A.D., corresponded to 17th, not to 16th *Ani.*

The apparent discrepancy was explained by the sole fact that the person, though now residing in Southern India, was born at *Belgaum* where the Sûrya Siddhânta is followed, and where presumably the horoscope was cast by a Tamil Astrologer.

The Solar year corresponding to A.D. 1856 commenced on 11 April A.D. 1856, at 14 ghaṭ. 6 palas according to Sûrya Siddhânta (Table X) and at 7 ghaṭ. 55 palas according to Ârya Siddhânta. (Table XII.)

For *Ani* Sankrânti by the Tables II and XIX, we have to add 62 days 21 ghaṭ. 20 palas according to Sûrya Siddhânta, and 62 days 19 ghaṭ. 34 palas according to Ârya Siddhânta.

∴ According to Sûrya Siddhânta, *Ani* Sankranti occurred on the 73rd day (reckoned from 1 April 1856) at 35 ghaṭ. 26 palas (*i.e.*, after 30 ghaṭ.)

According to Ârya Siddhânta, *Ani* Sankrânti occurred on the 73rd day (reckoned from 1 April 1856) at 27 ghaṭ. 29 palas (*i.e.*, before 30 ghaṭikas).

148. In accordance with the *civil* rules for Solar months current in the Tamil country (Sec. **144** *supra*) the month of *Ani* in A.D. 1856 began (according to Sûrya Siddhânta) on the 74th day reckoned from 1 April 1856, *i.e.*, on the 13th June 1856 (*vide* Table VIII), and the 16th *Ani* was 13 + 15 = 28th June 1856.

According to *Arya Siddhânta*, the month of *Ani* in A.D. 1856 began on the 73rd day reckoned from April 1856, *i.e.*, on 12th June 1856 (*vide* Tab. VIII) and the 17th of *Ani* was 12+16 = 28th June 1856.

149. This example shows that there could easily be a difference of 1 day between Solar dates in one part of the country and another.

It also shows that such differences cannot be accounted for by the ordinary *Jantris* and *Panchângams* but must be explained by recourse to the fundamental principles of the Indian Calendar.

CHAPTER XX.

USE OF EPHEMERIS OR TABLE XII for Lunar Tithis.

150. Even in those parts of the Indian Continent where the Solar Calendar is used for *civil* purposes, lunar tithis are observed for *religious* purposes: elsewhere the civil as well as the religious calendar is *lunar* and is regulated by tithis, instead of by days of the month.

151. Like the lunar calendar of the Jews, and unlike that of the Muhammadans, the Hindu calendar may be described as luni-solar since all its periods of time, though regulated by the movements of the moon, are made to fit in with divisions of the Solar Year. A lunar tithi is not counted at all unless the Sun rises upon it. A Tithi, Nakshatra, or Yoga may begin, or end, at any moment of the day, but the Tithi, Nakshatra, or Yoga pertaining to a day is that which is current *at sunrise*. A lunar month takes its name from the next following *Solar* Sankrânti : if there are two lunar months entitled to derive their name from a single Solar Sankrânti, they both receive the same name and one, the first, is called *adhika*. On the other hand, if a new moon is followed by two Sankrântis before it is followed by another new moon, the lunar month which would ordinarily have been derived from the second of the two Sankrântis is suppressed and is said to be *Kshaya*, that is, in defect. Lastly the lunar year, beginning in the month of *Solar* Chaitra, which is itself the last month of the *Solar* year, is named after the *next Solar Year*. These considerations suffice to prove that the Hindu lunar year is properly a luni-solar year.

152. Lunar periods of time are characterized by an element of certainty or rather of palpable evidence, not found in solar periods, and in another sense the actual moments of lunar phases are marked by much greater uncertainty than Solar Sankrântis. We will explain each of these propositions.

153. *Palpable evidence of lunar periods.*—We cannot visibly perceive in the heavens the fact that the sun has completed any definite stage in his annual course: but new moon, when the moon's longitude is the same as the sun's, is a patent fact: so are full moon and each quarter of the lunar month. There cannot be a difference of a whole day between the moment of new moon in one part of the country, and the same moment in another part, just as we saw there might be in the commencement of a solar month. If an inscription states that a certain tithi fell on a Monday, and by calculating backwards we trace the tithi to a Saturday we may be quite certain that there is some error in the inscription.

154. On the other hand, there are greater fluctuations in the moon's than in the sun's movements, in the sense that the actual time of new moon may be as much as 14 hours before or 14 hours after the time of *mean* new moon. Two calculations are therefore necessary to determine the time at which the moon reaches any particular stage of her course: we must first ascertain the *mean* time, which is simply the expected time, taking an average over very long periods; and then we must calculate the *actual* time by making a correction to the mean time according to the moon's and sun's *anomaly* at the particular moment. Both these operations can be performed very easily and very accurately, that is to say, in exact accordance with the Siddhântas, by means of the tables in the present work. The correction is called a correction for the sun's and moon's *equation of the centre*. There are also one or two other minor corrections recognized in modern astronomy, but the Siddhântas do not make them. (See sections **121** to **127** *supra*.)

155. In the case of new moons from A.D. 1840 to A.D. 1920, it was thought best not to give the reader even the slight trouble of calculating the anomaly and the equation of the centre; and the exact moment of each new moon during these eighty years as well as the *exact* day of its occurrence, where it differs from the mean date, is entered in separate columns, in Table XII "General Ephemeris." Here, however, the day and fraction of a day marking the occurrence of *mean* new moon, and the sun's and moon's anomalies at the moment of mean new moon are also given, as they are necessary for the calculation of tithis between one new moon and another.

156. Supposing now the reader wishes to ascertain the exact time of new moon in July 1910. He finds the following entries:—

(Tab. XII) A.D. 1910.

Date and fraction of day of **Ashadha** new moon.	Actual moment of new moon.
(**5**) July 7, 10 ghaṭikas 57 palas;	July **6, 49 ghatikas 55 palas.**

Moon's and Sun's anomaly in days, ghatikas and palas.

Sun's anomaly: 84 days 58 ghaṭikas 29 palas.

Moon's anomaly: 4 days 29 ghaṭikas 13 palas.

157. As regards the *exact* moment of occurrence of new moon in July 1910, there is no difficulty at all; for it is Wednesday, 6th July 1910 (the **date** of mean moon as well as the *week-day* has to be diminished by one, by reason of the anomalies) and the time of day is **49 ghatikas 55 palas**.

158. This, as explained already, is mean Lankâ time. If now you wish to know the *true local time* of the *actual* moment of new moon in July 1910, and if you happen to be at one of the 30 places named in Table XIII, all you have to do is to apply to Lankâ time the correction indicated in the column "Total correction" for the day of the solar year entered under the new moon date in Table XII.

159. Supposing you are at Tanjore, the correction for the 84th day is + 2478 seconds of time, *i.e.*, 103 palas or + 1 ghaṭika 43 palas. Adding this to Lankâ time, 49 ghaṭikas 55 palas, we have **51** ghaṭikas **38** palas, exact time at Tanjore according to Sûrya Siddhânta. If now you wish to know how far this time agrees with modern astronomical computation, you have merely to look at the time of new moon according to the Tiruvâdi Almanac (Mr. Srauti's Panchângam) which is calculated from the English Nautical Almanac and is reduced to the latitude of Tanjore, and you find there "6th July 1910, **52** ghaṭikas **10** palas", showing a difference of 32 palas. This difference of 32 palas is due to lunar acceleration which has changed since the date of the Sûrya Siddhânta. (*Vide* Sec. **2**.)

160. If you are at Madras (lat. 13°) you will find the correction according to Table XIII to be + 2200 seconds of time, *i.e.*, + 92 palas or + 1 ghaṭika 32 palas. Adding this to mean Lankâ time, you get (49 ghat. 57 palas + 1 ghat. 32 palas =) 51 ghat. 29 palas. The time according to the "College" Panchângam (Mr. Raghavachari's) is 52 ghaṭikas 33 palas, showing a difference of 1 ghaṭika 4 palas. The increased difference, as compared with Mr. Srauti's Panchângam, is mainly due to two facts, (1) The correction for Madras local time is less than that for Tanjore local time by 11 palas, (2) Madras standard time, which is shown in the College Panchângam, is nine minutes or 22½ palas in advance of Madras Local time. There is still, however, an unexplained difference of a few palas between our tithi and that of the College Panchângam.

161. Next, suppose the reader wishes to know the ending moment of the 8th tithi or *ashtamî* in the bright fortnight following the new moon of 6th July 1910. For this we have to calculate first of all the *mean* ending moment of the 8th tithi, and then its *actual* ending moment. The mean ending moment is given by adding the collective duration of 8 tithis according to the Eye-table to the *mean* moment of new moon.

(Tab. XII) Mean moment of new moon	...	A.D. 1910. 7 July 10 ghat. 57 palas.
Add collective duration of 8 tithis according to the Eye-table.	...	7 days 52 ghat. 29 palas.
		A.D. 1910 15 July 3 ghat. 26 palas.

162. This, then, is the *mean* ending moment of the 8th tithi or *ashtamî*. For the *actual* ending moment of the same tithi, we first of all add the collective duration of 8 tithis to the moon's and sun's anomaly noted in Table XII under the new moon of 7 July 1910.

	Moon's anomaly			Sun's anomaly		
	4 days	29 ghat.	13 palas	84 days	58 ghat.	29 palas.
Add collective duration of 8 tithis.	7 days	52 ghat.	29 palas	7 days	52 ghat.	29 palas.
	12 days	21 ghat.	42 palas	92 days	50 ghat.	58 palas.
Deduct ☉'s Eqn.		–2 ghat.	20 palas			
Net ☾'s anom.	12 days	19 ghat.	22 palas			

163. According to the Eye-table we find the Sun's Equation for an anomaly of 92 days, 51 ghat. to be *minus* 2 ghat. 20 palas, and we deduct this equation from the moon's anomaly already found. The Equation of the centre for the moon's net anomaly of 12 days 19 ghat. 22 palas is, by the Eye-table, *minus* 9 ghaṭikas.

164. The sum of moon's and sun's Equations :

– 2 ghat.	20 palas.
– 9 ghat.	
– 11 ghat.	20 palas.

165. If 11 ghaṭikas be deducted from the mean ending moment of the 8th tithi, we obtain, as the *actual* ending moment of *sukla ashtamî*, 14 July A.D. 1910, 52 ghaṭikas after sunrise.

166. This is Lankâ time. If now we wish to know the ending moment of the tithi in true local time, say at Madras (Lat. 13°), all we have to do is to apply the figure entered in the column "Total correction" under Madras (Lat. 13°) against the 92nd day of the Solar Year in Tab. XIII. The correction being + 2095 seconds or + 87 palas, that is + 1 ghat. 27 palas, the ending moment of **Sukla ashtami,** 14 July 1910, at Madras, is (52 ghat. + 1 ghat. 27palas =) 53 ghat. 27 palas. The "College" Panchângam gives 52 ghat. 33 palas.

167. We will now show the reader how to calculate successive tithis from the Eye-table and Table XII combined. The duration of 1 tithi, according to the Eye-table, is 59 ghaṭikas 4 palas, that is, 1 day less 1 ghaṭika *plus* 4 palas. Bearing this in mind, we shall proceed to calculate the successive tithis after new moon, 7 July 1910 ; the mean time of which is 10 ghat. 57 palas, or nearly 11 ghaṭikas.

Details for determining the ending moments (in Madras Time) of 30 tithis, Lunar Ashadha, A.D. 1910.

A.D. 1910 Tithi	July.	Mean ending moment of tithi.	☉'s Anom.	☉'s Equation.	☾'s Anom. at mean end of tithi.	Add or subtract ☉'s Equation.	☾'s Equation.	Sum of ☉'s & ☾'s Equations.	Actual end of tithi, Lanka time.	Correction for Madras time.	Ending moment of tithi, Madras time.	Ending moment, "College" Panchangam.	Ending moment Kanjanur Panchangam	Difference between Surya Siddhanta and Naut. almanac.	Full name of tithi.
		gh. p.	d. gh.	gh. p.	d. gh. p.	d. gh. p.	gh. p.	gh. p.	July gh.p.	gh. p.	July gh.p.	July gh. p.	July gh. p.	gh.p.	
Amavasya *Sukla paksha.*	7	10,57	84,58	−0, 50	4 29,13	4 28,23	−20,12	−21,2	6 49,55	+1,31	6 51,26	6 52,33	6 53,11	−1,7	
															Sukla Paksha.
1	8	10, 1	85,57	−1, 0	5 28,17	5 27,17	−22,48	−23,48	7 46,13	+1,31	7 47,44	7 47, 7	7 49,41	+0,37	Pratipada.
2	9	9, 5	86,56	−1,12	6 27,21	6 26, 9	−24,23	−25,35	8 43,20	+1,30	8 45, 0	8 42,52	8 47,16	+2, 8	Dvitiya.
3	10	8, 9	87,55	−1,23	7 26,25	7 25, 2	−24,47	−26,10	9 41,59	+1,29	9 43,28	9 40,10	9 45,58	+3,18	Tritiya.
4	11	7,13	88,54	−1,34	8 25,29	8 24,55	−23,59	−25,33	10 41,40	+1,29	10 43, 9	10 39,13	10 45,55	+3,56	Chaturthi.
5	12	6,17	89,53	−1,45	9 24,33	9 22,48	−21,55	−23,40	11 42,37	+1,28	11 44, 5	11 40,10	11 47, 7	+3,55	Panchami.
6	13	5,21	90,52	−1,56	10 23,37	10 21,41	−18,36	−20,32	12 44,49	+1,27	12 46,16	12 43, 1	12 46,36	+3,15	Shashti.
7	14	4,25	91,51	−2, 7	11 22,41	11 20,34	−14,11	−16,18	13 48, 7	+1,27	13 49,34	13 47,25	13 52,56	+2, 9	Saptami.
8	15	3,29	92,50	−2,17	12 21,45	12 19,28	− 8,52	−11, 9	14 52,20	+1,26	14 53,46	14 52,59	14 57,23	+0,47	Ashtami.
9	16	2,33	93,49	−2,28	13 20,49	13 18,21	− 2,59	− 5,26	15 57, 7	+1,26	15 58,33	15 59,12	15 60, 0	−0,39	Navami.
												Navami	16 2,16		
10	17	1,37	94,48	−2,39	14 19,53	14 17,14	+ 3,11	+ 0,32	16 60, 0		16 60, 0	16 60, 0			Dasami
								Dasami	17 2, 9	+1,25	17 3,34	17 5,22	17 7,11	−1,48	Dasami.
11	18	0,41	95,47	−2,50	15 18,57	15 16, 7	+ 9, 4	+ 6,14	18 6,55	+1,24	18 8,19	18 10,56	18 11,46	−2,37	Ekadasi.
12	18	59,45	96,46	−3, 0	16 18, 1	16 15, 1	+14,22	+11,22	19 11, 7	+1,24	19 12 31	19 15,24	19 15,44	−2,53	Dvadasi.
13	19	58,49	97,45	−3,11	17 17, 5	17 13,54	+18,45	+15,34	20 14,23	+1,23	20 15,46	20 18,35	20 18,44	−2,49	Trayodasi.
14	20	57,53	98,44	−3,21	18 16, 9	18 12,48	+22, 1	+18,40	21 16,33	+1,23	21 17,56	21 20,10	21 20,34	−2,14	Chaturdasi.
15	21	56,57	99,43	−3,32	19 15,13	19 11,41	+24, 4	+20,32	22 17,29	+1,22	22 18,51	22 20,24	22 21,31	−1,33	Paurnami.
Krishna Paksha															*Krishna Paksha*
1	22	56, 1	100,42	−3,42	20 14,17	20 10,35	+24,48	+21, 6	23 17, 7	+1,22	23 18,29	23 17,10	23 20,34	+1,19	Pratipada.
2	23	55, 5	101,41	−3,52	21 13,21	21 9,29	+24,21	+20,29	24 15,34	+1,21	24 16,55	24 16,53	24 18,43	+0, 2	Dvitiya.
3	24	54, 9	102,40	−4, 2	22 12,25	22 8,23	+22,43	+18,41	25 12,50	+1,21	25 14,11	25 13,41	25 15,46	+0,30	Tritiya.
4	25	53,13	103,39	−4,12	23 11,22	23 7,17	+20, 4	+15,52	26 9, 5	+1,20	26 10,25	26 9,44	26 11,49	+0,41	Chaturthi.
5	26	52,17	104,38	−4,22	24 10,33	24 6,11	+16,34	+12,12	27 4,29	+1,20	27 5,49	27 5,18	27 7,11	+0,31	Panchami.
6	27	51,21	105,37	−4,32	25 9,37	25 5, 5	+12,23	+ 7,51	... 59,12	+1,19	28 0,31	28 0,29	28 1,47	+0, 2	Shashti.
7	28	50,25	106,36	−4,42	26 8,41	26 3,59	+ 7,40	+ 2,58	28 53,23	+1,19	... 54,42	... 55,22	.. 54, 8	−0,40	Saptami.
8	29	49,29	107,35	−4,52	27 7,45	27 2,53	+ 2,40	− 2,12	29 47,17	+1,19	29 48,36	29 50, 5	29 49,48	−1,29	Ashtami.
9	30	48,33	108,34	−5, 2	0 33,32	0 28,30	− 2,29	− 7,31	30 41, 2	+1,18	30 42,20	30 44,37	30 43,44	−2,17	Navami.
10	31	47,37	109,33	−5,11	1 32,36	1 27,25	− 7,31	−12,42	31 34,55	+1,18	31 36,13	31 39, 6	31 37,49	−2,53	Dasami.
	Aug.								Aug.		Aug	Aug.	Aug.		
11	1	46,41	110,32	−5,21	2 31,40	2 26,19	−12,14	−17,35	1 29, 6	+1,18	1 30,34	1 33,34	1 32,10	−3,10	Ekadasi.
12	2	45,45	111,31	−5,30	3 30,44	3 25,14	−16,27	−21,57	2 22,48	+1,17	2 25, 5	2 28,11	2 27, 3	−3, 6	Dvadasi.
13	3	44,49	112,30	−5,39	4 29,48	4 24, 9	−19,58	−25,37	3 19,12	+1,17	3 20,29	3 23,14	3 22,38	−2,45	Trayodasi.
14	4	43,53	113,29	−5,49	5 28,52	5 23, 3	−22,39	−28,28	4 15,25	+1,17	4 16,42	4 18,57	4 19, 4	−2,15	Chaturdasi.
15	5	42,57	114,28	−5,58	6 27,56	6 22, 2	−24,19	−30,17	5 12,40	+1,16	5 13,56	5 15,24	5 16,33	−1,28	Amavasya.
Amavasya															

168. The reader is presented in the above table with a full decursus of tithis for a whole lunar month, calculated in accordance with the Sûrya Siddhânta; and he is also furnished in the same table with the ending moments of the same tithis, as arrived at by two standard Panchângams current in Southern India, namely, (1) the Kanjanûr Panchângam of Annâvaiyangâr, commonly called "No. 28 Panchângam", and (2) the Nungambaukum Panchângam by Mr. Râghavachâri and his son, commonly called "The College Panchângam." The former of these panchângams is typical of the class known as "Vâkya Panchângams".

169. A *vâkyam* (meaning in Tamil a sentence) is simply a phrase or series of phrases, employed in accordance with a very ancient "Transnumeration" table, called "Kadapayadi", closely analogous to the present writer's Transnumeration Table, published at page 37 of his "Secret of Memory". It is generally believed that the vâkya process is based on the Ârya Siddhânta, but this is by no means well established.

Only solar dates in Southern India seem to follow the Ârya Siddhânta, but for lunar tithis and nakshatras, that Siddhânta, as proved by the above, as well as by the next, table, seems to have been given up long ago, even in Southern India, in favour of the more accurate Sûrya Siddhânta. If the Kanjanûr Panchângam had followed the Ârya Siddhânta, all mean tithis, including *Amâvâsyâs*, would have occurred according to that Panchângam 3 ghaṭikas 42 palas later than by the Sûrya Siddhânta, whereas the above table, and more especially the next table of nakshatras, shows a much smaller difference as a rule between that panchângam and the results arrived at on strict Sûrya Siddhânta principles.

170. The Nungumbaukum or "College" Panchângam belongs to the class of what are called in Southern India *Drig-ganita* panchângams, *i.e.*, those in which computation is checked by observation, the observation being understood to be that carried on at a modern standard observatory, like those at Greenwich, Paris and New York.

171. Practically, all the *Drig-ganita* panchângams are based on the Greenwich Nautical Almanac, which is published some three years in advance for each year. It is not to be supposed that the moon's and sun's places given in the Nautical Almanac are those observed then and there, for they are also calculated on the best available data, which include several elements of the lunar theory, neglected in the Siddhântas.

N.B.—For the manner in which Drig-ganita tithis are computed, see Section **121** *Supra*.

172. The reader will observe that in our specimen table the difference between Sûrya Siddhânta tithis and what we may call Nautical Almanac tithis, does not exceed 2 ghaṭikas at new moon or 4 ghaṭikas at other times. (The extreme difference between the two systems may amount at times to as much as 17 ghaṭikas, or 7 hours.) This no doubt is a disadvantage of the Sûrya Siddhânta system for strictly astronomical purposes (*i.e.*, on the assumption that Hindu Astronomy *must* agree with the most accurate results of European Astronomy); but if it is remembered that a Nautical Almanac panchângam cannot be constructed unless one has in hand the Nautical Almanac of the particular year, whereas a Siddhânta panchângam can be constructed in a few hours' time for any year, past, present or future, without any other materials than those furnished by Tables VI, VII, VIII and IX of this work, it will be seen that a panchângam on the purely Indian system is a great convenience.

Moreover, the Indian panchângam is not a thing of to-day or yesterday, but has been constructed on the lines now followed for at least 1500 years, and no person, unacquainted with the system, can hope to understand the thousands of inscriptions scattered all over India, on the proper reading of which the reconstruction of scientific Indian history largely depends.

173. *Adhika* or *Trisparsa* Tithis and *Kshaya* Tithis: A tithi which begins on one day, is current for the whole of the next day and ends in the morning of the third day is called an *Adhika* or *Trisparsa* tithi. *Trisparsa* means "touching three days." An example is furnished in the above table by *sukla navami* of the Kanjarûr Panchângam, and *sukla dasamî* of our own and the College Panchângam. The fact that a tithi is current for the whole of a day is indicated in the panchângams by entering '60 ghat' as its ending moment, *i.e.*, it does not come to an end all that day. On the other hand, a tithi which begins and ends *between* one sunrise and another is *kshaya* or in defect and is suppressed. Such a tithi is *krishna saptamî* by all three Panchângams in the above table.

N.B.—If the reader wishes to apply to the Siddhanta results, the corrections necessary to bring them up to the Nautical Almanac standard, he is enabled to do so in Chapter XVII of Part I of this work, Sections **116** to **122**.

CHAPTER XXI.

Use of Tables XII and XI—A.

(NAKSHATRAS.)

174. We next suppose the reader to be desirous of calculating the *nakshatras* in order for a particular lunar month. The longest interval between each mean new moon and the mean ending moment of each of the 27 nakshatras following new moon is given in Table XI-A (pp. 134, 135) in days, ghaṭikas and palas. The interval is subject to a single correction which holds good for the whole of a Solar Year. For the years A.D. 1840 to A.D. 1920 the corrections for Nakshatras are shown in the last column of Table XII "Deduct for Nakshatras". The deduction for the solar year A.D. 1910-11 is 1 day 56 ghaṭikas 18 palas. Taking, for example, Lunar Âshâdha in this year, we find at p. 134 that the first Nakshatra for Âshâḍha from which the deduction can be made is No. 7 Punarvasu, and we proceed to determine the mean ending moment of Punarvasu Nakshatra.

		d.	gh.	p.
(Table XI-A, p. 134.) Interval for Punarvasu, No. 7 Nak. in "Âshâḍha"		2	49	41
(Table XII, p. 151.) *Deduct* for the year 1910-11		—1	56	18
		0	53	23
Add mean ending moment of Âshâḍha New moon. (Table XII, p.151.)	July	7	10	57
Mean ending moment of No. 7 Punarvasu Nakshatra	July	8	4	20

175. Starting from this point, the following Table illustrates the whole of the processes for determining the ending moment of every nakshatra in the series of 27 from 6th July to 2nd August A.D. 1910. As in the last table, a comparison is also instituted between the ending moments of nakshatras, recorded in the "No. 28" and "College" Panchângams respectively, and those arrived at in the present table on the principles of Sûrya Siddhânta. The reader will note that the agreement among the different panchângams is, in this particular month, closer in regard to nakshatras than in regard to tithis. However, an extreme variation of 5 ghaṭikas has to be looked for even under nakshatras between Sûrya Siddhânta and Nautical Almanac results.

Table showing mean and actual ending moment (Lanka time and Madras local time) for each Nakshatra from 6th July 1910 to 2nd August 1910.

Name of Nakshatra.	English month and day.	Mean ending moment of Nakshatra.	Moon's mean anomaly	Nakshatra equation (Tab. IX-I).	Actual ending moment of Nakshatra, Lanka time.	Correction for Madras (Tab. XIII).	Actual ending moment of Nakshatra, Madras time.	Kanjanur No. 28 Panchangam.	College Panchangam.	Surya Siddhanta compared with Nautical Almanac.
A.D. 1910	M.	d. gh. p.	d. gh. p.	gh. p.	M. d. gh. p.	gh. p.	M d. gh. p.	gh. p.	gh. p	gh. p.
Punarvasu ...	July	8 4 20	5 12 25	-20 35	July 7 43 45	+1 30	July 7 45 15	46 0	42 50	+2 25
Pushya	July	9 5 3	6 13 8	-22 20	July 8 42 43	+1 30	July 8 44 13	45 23	40 27	+3 46
Aslesha	July	10 5 46	7 13 51	-22 59	July 9 42 47	+1 29	July 9 44 16	45 54	39 36	+4 40
Magha	July	11 6 29	8 14 34	-22 23	July 10 44 6	+1 29	July 10 45 35	47 38	40 28	+5 7
Purva Phalguni ...	July	12 7 12	9 15 17	-20 35	July 11 46 37	+1 28	July 11 48 5	50 36	43 13	+4 52
Uttara Phalguni ..	July	13 7 55	10 16 0	-17 33	July 12 50 22	+1 28	July 12 51 50	54 47	47 47	+4 3
Hasta	July	14 8 28	11 16 43	-13 25	July 13 55 3	+1 27	July 13 56 30	52 57	53 48	+2 42
Chitra	July	15 9 11	12 17 26	- 8 22	July 15 0 49	+1 26	July*15 2 15	5 56	0 56	+1 19
Svati	July	16 9 54	13 18 9	- 2 45	July 16 7 9	+1 25	July 16 8 34	12 16	8 33	+0 1
Visakha	July	17 10 37	14 18 52	+ 3 5	July 17 13 42	+1 25	July 17 15 7	18 40	16 9	-1 2
Anuradha ...	July	18 11 20	15 19 35	+ 8 42	July 18 20 2	+1 24	July 18 21 26	24 41	23 1	-1 35
Jyeshtha ...	July	19 12 3	16 20 18	+13 42	July 19 25 45	+1 23	July 19 27 8	30 3	28 53	-1 45
Mula	July	20 12 46	17 21 1	+17 47	July 20 30 33	+1 23	July 20 31 56	34 26	33 15	-1 19
Purva Ashada ...	July	21 13 29	18 21 44	+20 45	July 21 34 14	+1 22	July 21 35 36	37 17	36 11	-0 35
Uttara Ashada ...	July	22 14 12	19 22 27	+22 29	July 22 36 41	+1 21	July 22 38 2	39 43	37 42	+0 20
Sravana	July	23 14 55	20 23 10	+22 58	July 23 37 53	+1 21	July 23 39 14	40 29	37 59	+1 15
Sravishta ...	July	24 15 38	21 23 53	+22 15	July 24 37 53	+1 20	July 24 39 13	40 5	37 13	+2 0
Satabhisaj ...	July	25 16 21	22 24 36	+20 26	July 25 36 47	+1 20	July 25 38 7	38 47	35 38	+2 29
Purva Bhadrapada ...	July	26 17 4	23 25 19	+17 39	July 26 34 43	+1 20	July 26 36 3	36 15	33 25	+2 38
Uttara Bhadrapada ...	July	27 17 47	24 26 2	+14 5	July 27 31 52	+1 19	July 27 33 11	33 16	30 44	+2 27
Revati	July	28 18 30	25 26 45	+ 9 54	July 28 28 24	+1 19	July 28 29 43	29 34	27 45	+1 58
Asvini	July	29 19 13	26 27 28	+ 5 14	July 29 24 27	+1 19	July 29 25 46	25 35	24 27	+1 19
Bharani	July	30 19 56	27 28 11	+ 0 25	July 30 20 21	+1 18	July 30 21 39	21 32	21 0	+0 39
Krittika	July	31 20 39	0 45 37	- 3 40	July 31 16 59	+1 18	July 31 18 17	17 30	17 29	+0 48
Rohini	Aug.	1 21 22	1 56 20	- 9 9	Aug. 1 12 13	+1 18	Aug. 1 13 31	13 43	13 55	-0 24
Mrigasira ...	Aug.	2 22 5	2 57 3	-13 24	Aug. 2 8 41	+1 17	Aug. 2 9 58	10 20	10 27	-0 29
Ardra	Aug.	3 22 48	3 57 46	-17 8	Aug. 3 5 40	+1 17	Aug. 3 6 57	7 36	7 19	-0 22

CHAPTER XXII.

USE OF TABLE X.

176. Table X, which covers more than a hundred and thirty pages of the present work is intended to serve the epigraphist and the historian in somewhat the same manner as Table XII is intended to serve the general reader. If Table X is used in conjunction with the Eye-Table, nothing else is needed for the determination of the ending moments of tithis, correct to two places of decimals of a day, for any of the 2000 years between B.C. 1 and A.D. 2000. The manner of using Table X will be obvious to the reader who knows how to use Table XII.

* *Chitra* Nakshatra extends from 56 gh. 30 p. on 13th July 1910 to 2 gh. 15 p. on 15th July 1910. No *Nakshatra* comes to an end on 14th July 1910, and this fact is indicated in the panchangas by entering *Chitra* as adhika Nakshatra and showing it against *July 14, 60 gh. no palas* as well as against July 15th, 2 gh. 15 p. The first entry means simply that on 14th July 1910, *Chitra* was current for the whole of the civil day.

177. Suppose for example that the date corresponding to "*Saka Samvat 999, Phâlguna Sukla 3*", is to be ascertained, we proceed as follows :—

Śaka 999 expired

This is how the two head-lines of Table X should be used for ascertaining ☉'s and ☾'s anomalies.

	Days of S. Year.	☾'s Anom.	
First New Moon in Solar Year ...	3·28	2·67	
Add collective days up to Phalguna New Moon, and remember there was an adhika month earlier in the year.	324·84	21·74	
Collective duration of 3 tithis (by Eye-Table)	2·95	2·95	
	331·07	27·36	+ ·165 (☉'s Eqn.) = 27·53
Sun's Eqn. (by Eye-Table) for	331·07 days =		+ ·165 day
Moon's do. do. for	27·53 days =		+ ·002 day

Sum of ☉'s and ☾'s Equations. + ·167 day
(Table X) Phalguna New Moon, Saka 999, A.D. 1078 (4) Feb. 14·78 } **Mean tithi.**
(Eye-Table) Duration of 3 tithis (2) 2·95 }

Add mean tithi to sum of ☉'s and ☾'s Eqn. (7)* Feb. 17·90

The ending moment of the tithi is therefore ·90 of a day, *i.e.*, (according to Eye-Table 54 ghat. on Saturday, 17 February A.D. 1078 ; which, so far as ghaṭikas are concerned, is the result arrived at by Dr. Fleet by applying Prof. Chhatre's table—*Ind. Antiq.*, Vol. XVII, p. 162.

178. In the above process the *mean ending moment* of the tithi is given in the *two* lines bracketed "**Mean tithi**", and *all the rest* of the process is directed to ascertaining the sum of the sun's and moon's equations of the centre.

179. A further simplification could have been effected by using Table VIII for ascertaining the sun's and moon's anomaly, thus :—

	☉'s An. days.	☾'s An. days.
(Table X) Śaka 999 expired. Anomaly of sun and moon at first new moon in Solar Year	3·28	2·67
(Table VIII) Phâlguna śukla 3, increased by 1 month (see Sec. **220** *infra*) because of an adhika month in the year : i.e., *Chaitra sukla* 3.	327·79	24·69
	331·07	27·36
	☉'s Eqn.	+ ·165
		27·53

We thus obtain the sun's and moon's anomalies by the additionof *two*, instead of *three*, set of figures, and we may proceed as before to determine the equations for these anomalies.

Solar Dates by Table X.

180. Supposing the Kumbha Sankrânti for the same Śaka Samvat 999, expired, was wanted : we proceed as follows :—

Commencement of solar year, Śaka 999 : Mr. 23·6638
Kumbha Sankrânti (by Eye-Table) 305·0850

Mr. 328·7488, *i.e.*, 44 ghat. 56 p. (Tab. XIX.)

* Since the sum of the several fractions of a day which go to make up the ending moment of the tithi exceeds unity, we increase the week-day by 1.

Now, by Table VIII (see Sec. **216** *infra*) 328 days from Mr. 1, A.D. 1077 is **22 Ja. 1078**.

By Table IV (see Sec. **231** to **241** *infra*) the week day of 22 Ja. 1078 was 3 + 6 + 6 + 22 = 37, which divided by 7 leaves remainder 2, *i.e.*, **Monday**. This result agrees with that arrived at by Dr. Fleet *loc. cit.* except as regards the moment of Sankrânti, which he puts down as about 47 ghat. 52 palas.

181. To take another example, suppose we want the third Panguni of the Viśvâvasu year which was current in or after the Śaka year 1347 (expired.)

By Table X, Śaka 1347 (exp.) was A.D. 1425.

By Table I, the Viśvâvasu of that epoch was A.D. 1425.

By Table X, the commencement of Śaka 1347 (exp.) was	Mr. 26·7111
By the Eye-Table, the addition for the commencement of Panguni =	334·9053
	361·6164 days.

By Table VIII, 361 days from 1 Mr. A.D. 1425 was 24th Feb. A.D. 1426.

Now, since ·6164 of a day exceeds ·5, that is, goes beyond sunset, therefore, by the rule in force in South India, [*vide* Sec. **144** (3)] the first Panguni in the year in question was 25th Feb. 1426.

Therefore the 3rd Panguni (Śaka 1347, Viśvâvasu) was 27th Feb. 1426.

And by Table IV the week day of 27th Feb. 1426 was 6 + 4 + 2 + 27 = 39 ,which, divided by 7, leaves remainder 4 (i.e.) *Wednesday*. This agrees with the result arrived at by Professor Kielhorn at page 83 of Appendix to Vol. VII, *Epigraphia Indica*.

Nakshatras concurrent with Tithis.

182. A tithi is often cited along with a Nakshatra ending on the same day. In such cases the *ending moment* of the Nakshatra can be most easily determined by Table XI. (For merely finding the *concurrent* Nakshatra, we may proceed much more expeditiously as in Section **185** or Section **186**.)

Thus in the case dealt with in sections **177** to **179**, the Nakshatra correction for Śaka 999 (A.D.1077) was (Tab. XI) that corresponding to argument 3·279, *i.e.*, ·2394 + ·0059 = ·2453. Deducting this from the interval for Revatî in the 12th lunar month (the year 999 Śaka contained an adhika month, and therefore Phâlguna was the 12th month), we have, as net interval for Revatî, 3·1860 *minus* ·2453 = 2·9407. Add this to New moon, Feb. 14·78 we have Feb. 17·72. ☾'s Anom. 2·67 + 21·74 + 2·94 = 27·35. Eqn. for Nak. (Tab. IX-*k*) = + ·016. Absolute ending moment of Nakshatra, Feb. 17·72 + ·016 or Feb. 17·74, *i.e.*, 44 ghaṭikas after sunrise on 17 Feb. A.D. 1078. This agrees with Mr. Dikshit's calculation, cited by Dr. Fleet at p. 162 of *Ind. Ant.*, Vol. XVII.

183. In South Indian inscriptions a solar date, a lunar tithi and the corresponding *nakshatra* are often cited together.

The following example shows how the citation should be verified.

Ep. Indica, Supplt. to Vol. VII, p. 132. "Śaka 1106: on the day of Satabhîshaj, which was the 14th *tithi* of the first fortnight and a Wednesday, the 26th solar day of the month of Simha".

Now by Table X, Śaka 1106 commenced on March 24·3508, A.D. 1184.

By Eye-Table, Simha begins and Karkata ends 125·4755 days after commencement of solar year.

∴ Simha Sankrânti of Śaka 1106 was on 149·8263 days of the solar year.

That is, by the rule in Southern India already adverted to, the 1st day of Simha was the 150th day reckoned from 1st March 1184.

∴ the 26th day of Simha would be 150 + 25 or the 175th day from 1st March which by Table VIII, was 22 August.

In order that the 26th day might be the 14th tithi of the first fortnight, the new moon must have occurred 13 days before, *i.e.*, about 9 August.

In Table X we find Bhâdrapada new moon on Aug. 8·56 of A.D. 1184 (Wednesday).

By Eye-Table, 14 tithis = 13·78 days.

∴ the mean 14th tithi ended on August 22·34, A.D. 1184.

The day of the week was Wednesday: since the new moon was on Wednesday, the addition of 14 days or 2 whole weeks to the day of the week would still give us the same day, Wednesday.

184. If we want the actual ending moment of the 14th tithi, we proceed as follows :—

		☾'s Anom.
First new moon in solar year, A.D. 1184	19·0909	1·191 days.
By Table VIII, 14th tithi of Sukla Bhâdrapada	131·9033	21·685
	150·9942	22·876
By Tab. IX, ☉'s Eqn. for 150·99 days = —·1672		—·1672
" " ☾'s Eqn. for 22·709 days = + ·3550		22·709
Sum = + ·1878	+ ·1878	
	151·1820	
Add commencement of solar year, Mr.	24·3508	
	175·5328	days from 1st Mr. A.D. 1184.

By Table XIX ·5328 day = 31 ghaṭikas 58 palas.

The actual ending moment of Bhâdrapada śukla 14, Saka 1106, was 31 ghat. 58 palas after mean sunrise on Wednesday, 22 Aug., A.D. 1184.

185. For the Nakshatra corresponding to this tithi we proceed as follows :—

	Lunation space.
By Table VIII (last column) Sun's longitude for Nak. on 151st day =	12·0321
" V (last column) do. do. ·18 day =	·0145
Add 14 tithis (by Table II)	13·7809
	25·8275

By Table III, the lunation space last arrived at, 25·8275 corresponds to No. 24 Satabhishaj whose ending space is 26·2404

Our inscription is therefore correct in all respects.

186. An equally simple method of ascertaining the Nakshatra concurrent with the above tithi is the following, where, however, we use degrees of sun's and moon's longitude.

Ending moment of tithi in days of solar year was 150·99 + ·19 (Sum of eqns.) = 151·18 days.
By Tab. XVII-A & XVII-C., ☉'s Long. and Eqn. for 151·18 days = 146·69° − 2·04° + ·18 = 144·83°
Add Moon's Elongation, *i.e.*, No. of tithi × 12° = 14 × 12° = 168·00°

312·83°

By Eye-Table the longitude is that of Nakshatra *Satabhishaj*.

CHAPTER XXIII.

THEORY OF ANOMALIES AND EQUATIONS OF THE CENTRE.

CONSTRUCTION OF TABLE IX.

187. The uses of Table IX, to which we come after discussing Tables XI and X, will be sufficiently obvious from examples already worked out. We therefore give in this place in popular language a theory of anomalies and their equations.

188. From the fact that the orbit of the moon as well as that of the earth is elliptical, not circular, it follows that the motions of these bodies cannot be uniform from day to day or from hour to hour. This irregularity is called the *eccentricity* of the orbit and the correction to be applied on this account is called the equation of the centre.

189. The following extract from Prof. Jacobi's Table in Vol. I of *Epigraphia Indica* will serve to introduce the reader to the general theory of Solar and Lunar anomalies, and it will also show how the material furnished by the Siddhântas has been worked into Table IX of the present work :—

Surya Siddhanta.

☾'s Eqn. +; ☉'s Eqn. −				☾'s Eqn. −; ☉'s Eqn. +				Moon's Equation of the centre.			Sun's Eqn. of the centre.		
Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.	Deg.	Min.	Sec.	Deg.	Min.	Sec.
0	0	180	0	180	0	360	0	0	0	0	0	0	0
30	0	150	0	210	0	330	0	2	32	0	1	6	3
60	0	120	0	240	0	300	0	4	22	30	1	53	26
90	0	90	0	270	0	270	0	5	2	46	2	10	31

190. Let us try to interpret in detail the meaning of this table. We are supposed to measure the moon's rate of progress, beginning from perigee, the point when she is nearest the earth, and at every step we must distinguish the moon's mean position, *i.e.*, the position which she would have attained at a uniform rate of motion equal to the mean, and the actual position which she attains on account of the eccentricity of her orbit.

191. The mean and actual positions are the same at 0° or 360°, *i.e.*, at perigee and at 180°, *i.e.*, at apogee.

When the moon's mean position is 30° from perigee, her actual position has advanced by 2 degrees 32 minutes.

When her mean position ought to be 60°, we find her actually at 64° 22′ 30″ from perigee.

When her mean position ought to be 90°, that is half way between perigee and apogee, she is actually 95° 2′ 46″ from perigee.

From this point she begins to move more slowly, though her actual position is still in advance of the mean.

At 120° from perigee, she is 4° 22′ in advance of the mean position, that is, exactly as she was at mean 60°.

At 150° from perigee she is only 2° 32′ in advance of the mean position.

From 180° onwards she begins to slow down, and when she ought to be 210° from perigee, or 30° from apogee, we find she has reached only 210° *minus* 2° 32′ or 207° 28′. When she ought to be 270° from perigee, she is only 270° *minus* 5° 2′ 46″ or 264° 57′ 14″.

From 270° onwards she begins to move quicker, though she is still behind her mean position. At 300° she is behind by 4° 22′ 30″ and at 330° she is behind her mean position by only 2° 32′ and at 360° or at perigee she is even with her mean position.

192. In like manner we might trace the Sun's mean and actual positions from perigee through apogee back to perigee, using the figures in the last column of the above table, from which we see that the maximum equation of the centre for the sun is 2° 10′ 31″.

193. In our tables (except under Planets' Tables XVII, XVIII) we do not refer to the sun's or moon's position by degrees, but by days, which is more readily intelligible and handier for purposes of calculation.

194. Our Table IX with its numerous divisions (*a*) to (*l*) is simply the result of a careful expansion of the smaller tables from which the figures in Section **196** have been extracted, and we shall see presently how far our Table IX agrees with the original.

We saw that when the moon is actually 32° 32′ from perigee, she is 2° 32′ in advance of her mean position.

We turn the first of these figures into days with the help of Subsidiary Table VII (*a*) and for turning 2° 32′ into days we use Subsidiary Table VI (*a*).

By Sub. Table VII (*a*)	30°	=	2·2962 days.
	2°	=	·1531 day.
	32′	=	·0408 day.
	32° 32′	=	2·4901 days.
By Sub. Table VI (*a*)	2°	=	·1641 day.
	32′	=	·0437 day.
	2° 32′	=	·2078 day. ... (1)

195. We now turn to Table IX (*a*), and look up the equation for an anomaly of 2·4901 days. We there find,

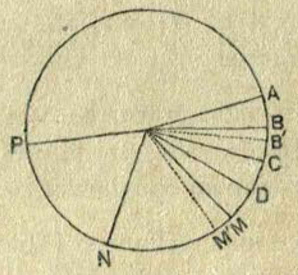
☾'s Anomaly.	Equation.
2·479 days	·207 day.
2·493 days	·208 day.
·014 day	·001 day.

(·490 *minus* ·479 =) ·011 day ; $\frac{\cdot 011}{\cdot 014} \times \cdot 001 = \cdot 008$ day.

∴ The equation for 2·490 days = ·2078 day. . . . . (2)

Our result (2) according to Table IX (*a*) is in exact agreement with result (1) deduced from the Siddhânta Table, which shows the anomaly and the equation of the centre in degrees minutes and seconds.

196. The reader will naturally ask why we turned the *anomaly* 32° 32′ into days by means of Table VII (*a*) and the *equation* 2° 32′ by means of Table VI (*a*). We proceed to explain.



197. Let us suppose the sun and the moon to move in the same plane and in circular orbits, describing equal spaces in equal times. Let AB, BC, CD be the mean spaces described by the sun in three successive tithis, and let AM, MN, NP be the corresponding mean spaces described by the moon in the same tithis.

198. If there were no irregularity or eccentricity in the sun's and moon's motions, the first tithi would be the time taken by the moon to gain 12°, that is, the space BM over the sun ; similarly the second and third tithis would be the periods in which the moon gains (MN *minus* BC) and (NP *minus* CD) over the sun.

199. But owing to the eccentricity of their orbits we will suppose the sun to be at B′ (actual position) when he ought to be at B (mean position) and the moon to be at M′ (actual position) when she ought to be at M (mean position).

200. Then in the period of a mean tithi (·9843 day) the moon gains over the sun the space B′M′ but our tithi is the period during which the moon actually gains over the sun 12°, *i.e.*, we must cut off from B′M′ a space equal to BM and determine the time during which that space is gained by the moon. Our problem would be solved if we knew the time during which B′M′ *minus* BM was gained by the moon.

201. Now B′M′ *minus* BM = MM′ *minus* BB′. The time during which MM′ − BB′ is gained, is evidently the time during which MM′ is gained *minus* the time during which BB′ is gained. The times during which MM′ and BB′ are respectively gained are obtained by turning MM′ and BB′ into days according to Sub. Table VI (*a*). This is the reason why in the Tables for the moon's and also the sun's equation of the centre we turn the equation into days invariably by Table VI (*a*). For Nakshatra and Yoga equations other scales which it was unnecessary to give in detail, were used for converting degrees into days.

202. As the equation for the sun as well as the equation for the moon is sometimes positive and sometimes negative, and for *tithis* we have to take the *difference* between the two equations, some confusion would result from our having to change signs so often. Therefore the sun's equations are tabulated, as in the extract given above, with the signs *reversed*. That is why the sun's eccentricity, starting from perigee, is shown in the table in Sec. **189** as negative whereas it is really positive.

203. The reader will also observe that the moon's equation in the above table is, as it should be, positive between perigee and apogee, whereas in Table IX (*a*) it is negative for the same period. The reason is that when the moon does in a given time *more* than the mean space, this is equivalent to a given space being done in *less* than mean time. This is why in Table IX, which derives equations of time from equations of space, the signs of space-equations are reversed. In the case of the sun's equations, a double reversion of signs takes place, first a reversion in order to make the operation of combining the sun's and moon's equations always an addition, and secondly a reversion in order to derive equations of time from equations of space. As a final result, the sun's equation of time is shown in Table IX (*c*) as positive after perigee and negative after apogee. A third reversion takes place in calculating sunrise, where we have to derive equations of space from equations of time. (*Vide* Sec. **255** *infra*.)

204. In calculating tithis, all we have to do, is to sum up the equations of the sun and the moon according to Table IX, whether they are positive or negative. Before taking the moon's equation, however, we in practice add to or deduct from the moon's anomaly the sun's equation and we determine the equations for the net moon's anomaly. The reason is that when the effect of the Sun's anomaly is to diminish or increase the mean time that would be necessary for a tithi, it is necessary to take the moon's anomalies for the altered mean time.

205. Conversely, in calculating *Yogas*, where we have to take sum of the proper anomalistic equations of the sun and the moon, our Yoga equations in Table IX (*i*) [p. 20 (*a*),] have had to be suitably altered as to their signs.

206. For *Nakshatras*, we have to convert the moon's eccentricity, in other words her equation of the centre, into days at the rate of the moon's sidereal motion, *i.e.*, 360° for 27·32166 days and this has accordingly been done in Table IX (*j*), (*k*), and (*l*).

207. The sun's anomaly in Tables IX (*c*), (*f*) and (*h*) is expressed, not in days of the *anomalistic* year, but as days of the *solar* year, and this is done for convenience of use, as explained in Part III, Sec. **253**.

208. For instance, in the above table, the sun's equation for an anomaly of 270° is entered as 2° 10′ 31.″

Now by Table VII (*b*) 270° = 202·92 + 71·02 = 273·94 days.
And by Table VI (*a*) 2° = ·1641 day.
10′ = ·0137 day.
31″ = ·0007 day.

2° 10′ 31″ = ·1785 day.

Since the solar year always begins with a mean anomaly of 102·0802 days, an anomaly of 273·94 days of the anomalistic year really belongs to 273·94 *minus* 102·08, *i.e.*, the 171·86th day of the solar year.

Accordingly we find in Table IX (*c*) the equation ·1785 day set down against the 171·86th day of the solar year.

209. The length of the modern anomalistic year is 365·2596 days while that of the Hindu solar year is 365·2587 days. There is no practical error in adopting, as the Indian Siddhântis have done, an identical period for the anomalistic and solar (sidereal) years. The modern anomalistic lunar month is, like the Hindu anomalistic month, 27·5546 days. In converting degrees of anomaly into days we, therefore, put—

Sun's anomaly : [Sub. Table VII (*b*)] 360° = 365·258756484 days.

Moon's anomaly : [Sub. Table VII (*a*)] 360° = 27·45459999 days.

210. The above theory of anomalies and equations is subject to an important variation in practice, which we alluded to briefly in Sec. **208**, but which it is now necessary to dwell on specially. Supposing a mean tithi is accomplished at A days of the solar year, when the Moon's anomaly is B days, then, if the ☉'s equation for A days is—*a*, this means that the tithi would be accomplished (supposing for the moment that the ☾'s anomaly had no influence) in *A*—*a* days of the solar year, at a moment when the moon's anomaly would be *B*—*a*. Now we proceed to determine the influence of this moon's anomaly *B*—*a* and find the moon's equation to be, let us suppose, —*b*. We then put down, as the actual ending moment of the tithi, *A*—*a*—*b* days of the solar year.

211. Strictly speaking, we ought to take (1) the sun's equation for *A* + *b* + *a* days of the solar year, where *b* is the equation (positive or negative) of the moon for anomaly B, and *a* is the ☉'s equation, positive or negative, for A days of the solar year, (2) the moon's equation for anomaly of *B* + *a* days, and then add the equations so found.

212. But in practice this refinement is not necessary for the sun's equation since the maximum value of *b* + *a* is (·4138 + ·1784 =) ·5922 day, and the maximum variation of the sun's equation for this period is about ·0018 day or 6 palas only. We may note, however, that in the test example, worked by Prof. Jacobi for Âshâḍha Śukla 12, K.Y. 3585, and by ourselves in sections **228** and **259** to **262** *infra*, a difference of 4 palas does occur between his method and Mr. Dikshit's, and the learned Professor rightly surmises in a footnote (*Ep. Ind.* Vol. I, p. 430) that the difference must be due to an abridgment in the Hindu method. We now see what the abridgment consists in.

CHAPTER XXIV.

USE OF TABLE VIII.

213. Table VIII is a very comprehensive as well as a very useful table. It is designed to convey some very useful information by itself and taken with Tables VI and VII, it enables us to take the first and most important step in calculating tithis, that is, to ascertain the exact mean ending moment of a tithi in any year, past, present or future.

Let us interpret the table, taking the entries for a particular day, say the 340th day of the solar year, A.D. 1908 (Kaliyuga 5009).

214. Column 1. "Week day 4", *i.e.*, if the first day of the year was 1, the 340th day of the year would be the 4th day of the week, *i.e.*, an addition of 3; the first day of the year being 4, Wednesday, the 340th day would be 3 + 4 = Saturday.

215. Column 2. "Days reckoned from Jan. 1: 5, 6 Decr." and there is the following footnote: "When two dates are given in any of these columns, use the first in a leap year: otherwise use the second".

The meaning of these entries is that the 340th day of the English Calendar year, reckoned from 1 January, is 5 December if it was a leap year, otherwise it would be the 6 December. By the expression "if it was a leap year", we mean, "if in the course of reckoning we have had to pass a 29th February".

The entry in this column is meant to be of use only with reference to the English Calendar. If we want to know, for instance, how many days there are between 15 March and 23 Oct. we take the corresponding figures from col. 2 of Table VIII, *i.e.*, 74 and 296, and we know the interval to be 222 days. We should always remember that the meaning of such problems and their solution is: "From a particular hour on 15th March *to the same hour* on 23rd Oct. there are 222 whole days". (*Vide* note prefixed to Sec. **128**.)

216. Column 3. The third column means: "The 3rd Feb. is the 340th day reckoned from 1 March". This column is useful for ascertaining the A.D. equivalent of dates in Indian Solar Years which began in March, *i.e.*, up to and inclusive of expired Kaliyuga 4853, A.D. 1752, see the examples in Sections **142, 180** and elsewhere, and rules in Sec. **144**.

217. Column 4. The fourth column means: "The 5th March is the 340th day reckoned from 1st April, if we have passed 29th February in our reckoning: otherwise the 340th day reckoned from 1st April is the 6th March of the following year". This column is useful in ascertaining the A.D. equivalent of days in solar years, subsequent to A.D. 1752. See examples worked out in Chapters VI, VII and elsewhere.

218. Column 5. The fifth column means:—

"The 340th day of the Hindu Solar Year is, *more or less*, the 6th Panguni (Tamil), the 6th Meenam (Malabar) or the 6th Chaitra (Bengal Solar)". We say "*more or less*", because if we want to know exactly what day in the solar year corresponds to 6th Panguni, 6th Meenam, or 6th solar Chaitra, we should first of all determine the beginning of these months, according to (1) the moment of Sankrânti, and (2) the rule of practice followed in the respective provinces. See examples worked out in Sec. **181** and elsewhere.

In the present case, supposing we are concerned with the Solar Year 5011 Kaliyuga, A.D. 1910 the year began as follows:—

	Surya Siddhanta.	
(Tab. VI) A.D. 1900 ...	Ap. 12·6204	
(Tab. VII) Add for 10 years.	·5876	
	Ap. 13·2080	
Moment of Solar *Chaitra* Sankrânti according to Sûrya Siddhânta which is followed in Bengal (by Tab. VI.)	334·9053 days.	
	335·1133 days of Solar year.	

	Arya Siddhanta.	
	Ap. 12·5139	
	·5868	
	Ap. 13·1007	
Moment of *Panguni or Meenam* Sankrânti, according to Ârya Siddhânta, which is followed in the Tamil country and in Malabar (by Tab. II.)	334·9200 days.	
	335·0207 days of Hindu Solar year.	

According to the rule followed in Malabar and the Tamil country, the month begins on the same day on which the Sankrânti occurs, if the Sankrânti occurred before ·50 of a day. [Sec. **144** (3)]. Therefore the 1st Panguni or 1st Meenam in the year, expired Kaliyuga 5011, was the 335th day of the Solar year and the 340th day would be the 6th Panguni or 6th Meenam.

In Bengal the month begins the day after Sankrânti, if the Sankrânti is before ·75 of the day. Therefore in Bengal the first Chaitra in the Solar year K.Y. 5011 (expired) will be the 336th day of the Solar year and the 340th day of the Solar year will only be the 5th Chaitra.

219. **Column 6**. The 6th column is the central column of the whole Table. The figure 340 in the present case is the guide in using the other columns.

220. **Column 7**. The 7th column should be read with the 8th. The two columns mean; "In a year where there is no *adhika mâsa*, the 1*st* tithi of the *dark* fortnight (indicated by *dark* figures) of Chaitra, which is called *bahula prathamâ* or *badi* 1, ends on the 340th day of the Lunar Year at ·5861 of the day". If we find out the beginning of the lunar year, which we can do from Tables VI and VII, or Tab. X, all we have to do is to add to it the ending moment of a tithi, as given in Table VIII, and then we know the day and fraction of day of the Solar Year or of the English Calendar year, when the mean tithi ends. Examples of this process are given throughout the work. If there has been an *adhika mâsa* during the year, which we can ascertain from Table X or XII, the tithi is advanced one month.

221. Thus, supposing we want the 3rd *bahula* tithi of Mâgha in expired K. Y. 5010 (A.D. 1909) when there was an adhika Śrâvana, we proceed as follows:—

Commencement of Solar year, A.D. 1909	Ap. 12·9492	(1)
First new moon in Solar year.	7·2745	(2)
18th Mâgha (for which we take from Table VIII the figures against the 18th of the next lunar month, *Phâlguna*)	313·0242	(3)
(1) + (2) + (3), omitting 12 Ap.	321·2479 (Solar Year).	
(1) + (2) + (3), including 12 Ap.	333·2479 (days reckoned from 1 Ap.)	

Our mean tithi, *Mâgha bahula tritiyâ*, ended on the 321st day of the Solar Year at ·2479 of the day or on the 333rd day of the English Calendar year, reckoned from 1st April (*i.e.*, 27 Feb. 1910) at ·2479 of the day.

222. Column 8. The 8th column, as we have just seen, gives the order of tithis in each lunar month, beginning with the bright fortnight (light figures) and ending with the dark fortnight (heavy figures).

223. Column 9. The 9th column gives the moon's anomaly at the ending moment of each tithi The figure in this column should be added to the moon's anomaly at the moment of the first new moon in the solar year. The moon's anomaly at the first new moon in the solar year is given in the appropriate column of Table X. Tables VI and VII combined give only the moon's anomaly *at the commencement of the solar year* and if we are using Tables VI and VII to determine the moon's anomaly, we should take care to add the interval *between the commencement of the solar year* and *the first new moon in the solar year.* Thus, suppose we want the exact ending moment of the 12th tithi of the bright fortnight of Âshâḍha in the year A.D. 484 (K.Y. 3585 expired) and we wish to use Tables VI, VII, and VIII ; we proceed as follows :—

	Commencement of Solar year.	First new moon in solar year.	Moon's anomaly.
(Table VI) A.D. 400	Mr. 17·4857	23·8447 d.	21·748 d.
(Table V) *Add* for 84 years.	·7355	0·5453	13·466
	Mr. 18·2212	24·3900	35·214
Add interval between commencement of solar year and first new moon in solar year		..	24·390
			59·604
Deduct two whole anomalistic months (Table II)		...	55·109
			4·495
Add (from Table VIII), for ending moment of Âshâḍha *Sudi* 12 (*no* Adhika masa)		... 70·8734	15·764
		95·2634	20·259
⊙'s Eqn. for 95·26 days (Table IX-*c*) :	−·0455 *		− ·045
☾'s Eqn. for 20·214 days (Table IX-*b*) :	+ ·4138		20·214
	+ ·3683	+ ·3683	
Add commencement of solar year A.D. 484		March 18 ·2212	
		March 113·8529 days	

reckoned from 1 Mr. A. D. 484, etc., as in Sec. **260** *infra.*

224. Column 10. The tenth and last column gives the sun's sidereal longitude for Nakshatras and Yogas: that is, it gives the sun's longitude by putting 365·25875 days = 29·5306.

* If we re-calculated the ⊙'s eqn. for ⊙'s anom. of 95·26 + ·37 (☾'s + ⊙'s eqns.), we shall find it to be— 0466 which is the ⊙'s eqn. adopted by Prof. Jacobi in Vol. I, *Ep. Ind.* We have noted however in Sec. **212** *supra*, as well as in Sec. **260** *infra*, that this is a refinement seldom required in practice.

The method of using this column is explained in the chapters of the Text, headed "Nakshatras" and "Yogas" and also under "Use of the Tables", *vide* Sections **36**, **49**, **185**, etc.

This column gives the sun's longitude for whole days: for fractions of days, when necessary, we should add the equivalent from Table V (last column). The use of this column is not necessary if we prefer to take the Sun's longitude in degrees from Tables XVII-A and XVII-C. See examples in Secs. **186, 287** and elsewhere.

CHAPTER XXV.

USE OF TABLES VII, VI AND TABLE V—LUNAR CYCLES.

225. The uses of these important tables will have become familiar from the explanation of Table VIII, contained in Sec. **223** and elsewhere. They enable us in fact to use Table VIII, whether for the Sûrya Siddhânta or for the Ârya Siddhânta, and whether for Solar or for Luni-Solar dates. Instead of giving constants, as Prof. Jacobi has done, for K.Y. 3100, 3200, etc., we have given constants for K.Y. 3101, 3201, etc., being the equivalents of A.D. century years. We thereby arrive at a very simple, and at the same time handy, method of determining the A.D. month, day and fraction of day, *marking the commencement of any Hindu solar year*. We believe it is the first time that this method has been used for this particular purpose.

226. At the end of Table VII are given constants for any period of 100, any period of 200, any period of 300 years, etc., up to a period of 3000 years. These figures lead us to a knowledge of the principal lunar cycles in the Indian Calendar, that is, periods of years after which new moons happen on the same day and more or less at the same hour of the Indian solar year. Thus we find from Table VII that, according to the Sûrya Siddhânta, a new moon after 19 complete S. Yrs. recurs on the same day of the S.Y. but 5 hrs. 24' earlier.

Do.	122	do.	do.	do.	do.	2 ,,	8' later.
Do.	385	do.	do.	do.	do.		55' ,,
Do.	648	do.	do.	do.	do.		17' earlier.
Do.	1315	do.	do.	do.	do.	6 ,,	,,
Do.	2329	do.	do.	do.	do.		4½' later.

N.B.—2300, and 1300 years are the two most important lunar cycles according to Dr. Grattan Guinness, but he takes for comparison the *tropical* year and the Synodical month.

227. Under moon's anomaly the most important cycle is that of 43 years, as after 43 years, the anomaly increases by only ·00458 of a day, *i.e.*, 6 minutes and 3½ seconds.

228. After 46 years, mean new moons occur just 1 day 2 minutes and 3 seconds later. This is a useful fact to remember.

TABLE V.

229. The exact method of using Table V for determining the *ending moments* of Nakshatras and Yogas is not explained, because the first two-thirds of this table are hardly necessary if Table XI is used. The third portion of Tab. V "Sun's Longitude for Nakshatras and Yogas" may be used in combination with the last column of Tab. VIII for determining the nakshatra *concurrent* with a tithi. Numerous examples of this method are given in

Secs. **36**, **49** and elsewhere, but our readers will probably prefer to use the alternative method provided by Tables XVII-A and XVII-C.

230. *Multiplication Table for Jupiter's Samvatsara.*—According to the Sûrya Siddhânta, Jupiter makes 364,220 revolutions (without *bîja* or correction) and 364,212 revolutions (with *bîja* or correction) in a yuga of 4,320,000 years. This means that the mean period of revolution of Jupiter is, with *bîja*, 4332·41581277 days, and without *bîja*, 4332·32065235 days. Each of these periods is nearly 12 years and a Jovian month or $\frac{1}{12}$ of the period of Jupiter's revolution is very nearly equal to a solar year. The Jovian month is therefore called in ordinary language a Jovian year and there are 1·0117 Jovian years in a solar year. Also a mean solar day = ·00277 of a Jovian year.

The multiplication table of Jupiter's samvatsaras is merely the multiplication of each of these quantities from 1 to 99. For further particulars regarding Jovian years, see sections **97** to **106** *supra.*

CHAPTER XXVI.

USE OF TABLE IV (VARA OR WEEK-DAY), TABLES III, II AND I.

231. The *vâra* or week-day is almost invariably quoted in Indian dates. The fact that week-days are the same in European and Indian reckoning (*e.g.*, a Monday in a date a thousand years ago corresponded, as it does to-day, to an Indian *Soma-vâra*, Tamil *Tingal*) is a striking proof of the common origin of the Indo-European mode of reckoning the week. This identity becomes all the more striking when we consider that everything else in the two reckonings (year, month, day of month, hour of day, etc.) is different. The week-day is, therefore, an important link between the two systems and it is well that we have an easy and at the same time a thoroughly accurate and reliable mode of identifying the week-day of any date, however remote, in the past. The ordinary rule laid down in Indian works on astronomical computation is to count the days from the beginning of Kaliyuga (18 Feb., 3102 B.C.) and cast off sevens—a truly formidable operation which few of our readers will venture upon.

N.B.—The number of days from the beginning of Kaliyuga up to any moment under consideration is called the *Aharganâ*. This is constantly alluded to in Hindu works on astronomical computation and we have therefore given an *Ahargana* Table (Table XXII, last page of this work), but the reader will have no occasion to use it unless to verify allusions.

232. Table IV of the present work supplies an easy method of verifying the day of the week of the European Calendar. An equally simple, if not a simpler, method might be devised for discovering the week-day of any date of an Indian solar year, but inasmuch as all operations in the present work are directed towards ascertaining the A.D. or B.C. date corresponding to an Indian date, it will be enough if we are able to verify week-days, through the B.C. or A.D. equivalents of Indian dates.

233. The reader will observe in Table IV three lines in heavy type, consisting of the figures

1, 2, 3, 4, 5, 6, 7, or 0.

These are called co-efficients. Each century, year of a century and month of a year has its co-efficient which is shown in Table IV, and all we have to do is to add up the co-efficients for the component elements of a date, the day of the month being itself an additional co-efficient. Thus if we want to know the week day of 15 July 1910 we proceed as follows :

(Table IV) co-effiicent of 1900	**2**
„ „ of 1910	**5**
„ „ of July	**5**
Day of month	15
Total	27

Dividing 27 by 7, we have as remainder 6, which is equivalent to Friday, the 6th day of the week.

The 15th July 1910 was, therefore, a **Friday**.

It will simplify the operation if we cast off sevens in the very act of summing up the figures. Thus $2+5$ being 7, we might neglect the first two figures, and 15 being $2\times7+1$, we need only add $5+1$ which is 6 or Friday.

234. This method is applicable to any date, A.D. or B.C., **Old Style** or **New Style**, but the student should first understand the negative character of B.C. dates and also the difference between **Old Style** and **New Style**.

235. **B.C. dates.** All B.C. dates are negative. B.C. 44 is really the year "*minus* 44" in relation to A.D. 1. In determining week-days of B.C. dates, we should first of all convert the dates into positive figures: that is, for the century, we should take the next previous century increased by 1, and for the odd year we should take 101 *minus* the odd year we are dealing with.

Thus, supposing we want the week-day of 18 February 3102 B.C., the first day of Kaliyuga we proceed as follows :—

(Table IV). Co-efficient of 3201 B.C. (the century preceding 3102)............	**3**
„ „ 101 *minus* 2 (the odd year before us) = 99.........	**4**
„ „ February (in an ordinary year)............................	**2**
Day of month	18
Total	27

Now, 27 divided by 7 leaves 6, *i.e.*, **Friday** which, according to all accounts, was the first week-day of Kaliyuga.

236. **Old Style.**—At present every fourth year A.D. is a leap year, but century years 1700, 1800, 1900, 2000 A.D. are leap years only if the first two figures are divsible by **4**.

This rule about century years was adopted, in most European countries (except Russia which still follows the Old Style) under the authority of a decree of Pope Gregory XIII, dated 1582, and in English speaking countries, under the authority of an Act of the British

Parliament, dated 1752. It was ordered by the same Act of Parliament (in order to correct the principal error of the Old Style,) that the day following 2 September 1752 (Wednesday) should be called the "14 September 1752" (Thursday) not the "3 September" (Thursday). This is the famous "dropping of 11 days" by Act of Parliament. **Wednesday, 2 September, A.D. 1752** was therefore the last day of the Old Style in English-speaking countries and **Thursday, 14 September**, A.D. **1752** is the first day of the English New Style.

For Old Style dates, *i.e.*, dates down to, and inclusive of, 2 Sep. A.D. 1752, the reader should use the co-efficients of centuries appearing under "Old Style" in Table IV.

237. The reader will note that 1600 and 1700 appear under both Old Style and New Style. The reason is that in most European countries, except the United Kingdom and Russia, the New Style came into use in 1582, whereas 1600 and 1700 were Old Style in England.

238. Coming down to the co-efficients of odd years, we note that odd years of centuries have the same co-efficient, whether the style be Old or New, A.D. or B.C : only a B.C. odd year should first be deducted from 101 so as to render it positive. (*vide* Sec. **235**.)

239. Lastly, under co-efficients of months, we notice that the co-efficient of January in a leap year is 5, while in an ordinary year it is 6; and likewise February has 2 for its ordinary co-efficient, and 1 for its co-efficient in leap-years. The co-efficients of the other months do not change for leap-year.

240. In ordinary years, the week-day of the 1st of January is the co-efficient of the year. Thus the co-efficient of the year A.D. 1910 is 7 or 0, and the week-day of 1st January A.D. 1910 is also 7 or 0, *i.e.*, **Sunday**. The reason is that in ordinary years, the week-day of 1st January is the co-efficient of the year *plus* 6 + 1 ; and the addition of 7, *i.e.*, of a whole week, does not of course change the week-day.

In leap-years the week-day of 1st January is the co-efficient of the year *plus* 5 + 1 ; *i.e.*, in leap-years the week-day of 1 January is 1 less than the co-efficient of the year.

241. The student who has read the author's "Secret of Memory" will be able to dispense altogether with the use of Table IV for verifying week-days. For particulars of this interesting method, see "**Secret of Memory** *" Chapter **XIV**, p. 108.

Tables III, II, and I.

242. The uses of these Tables will be self-evident. Tables II and III will be constantly handled by the reader, and their principal contents have, therefore, been included in a condensed form in the Eye-Table at the end of the book.

243. The "Limits of Adhika and Kshaya months" which form the middle portion of Table II present the whole of this intricate subject in a veritable nutshell. For explanation, See Sections **18** to **30**. When mean intercalations are required, that is, when Adhika months have to be determined without reference to anomalies, we should apply the "Limits of Adhika months" just as they are.

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PART III.—CONSTRUCTION OF THE TABLES.

[This part is intended to be of use in criticizing the method employed in the present work as well as in suggesting further improvements. It will be of immediate interest to those readers who are acquainted with one or other of the existing methods connected with the well-known names of JACOBI, KIELHORN, SCHRAM, SEWELL AND DIKSHIT, CHHATRE, etc., besides the older and less known names of WARREN and JERVIS. The general reader who makes his first acquaintance with the subject in the pages of this work will find the present part thoroughly intelligible and exceedingly interesting, provided he has mastered the first two Parts.]

CHAPTER XXVII.

TABLES FOR CONVERTING SPACE INTO TIME.

244. The method of calculating and verifying Indian dates, presented in this work, is intended to be of service to the general reader as well as to the scientific expert, the epigraphist, the archæologist, and the historian. The method is perfectly simple and at the same time absolutely correct according to the Siddhântas, so that it has become possible for the first time to dispense with all manner of approximations and rough and ready methods which, however valuable in the hands of an expert, are apt to mislead and confuse, more often than they assist, the general reader. The principal device by which this combination of extreme simplicity with accuracy and absolute fidelity to the original authorities, has been accomplished, is the reduction of all quantities required for calculation to whole days and fractions of a day.

245. The civil day (with its multiple, the week,) is the one measure of time that is common to European and Indian reckoning, everything else (year, month, ghaṭikas, palas hours, minutes, seconds,) being different in the two systems. Accordingly, the civil day and decimals of a day have been adopted throughout this work for expressing all manner of Indian dates as well as for working out ending moments of *tithis*, etc., and also for verifying the correspondence of English and Indian dates. Any decimal of a day can be converted readily into Indian *ghaṭikas* and *palas* (Tamil, *naligais* and *vinâdis*) or English hours, minutes, and seconds by means of Tables XIX and XX. To assist the reader in very exact computation, the fractions expressing minutes have been carried far enough to show the recurring places. If, for instance, we wish to know how many hours, minutes, and seconds are equivalent to ·40490 of a day, we turn to Table XX and find that ·40486 of a day is equal to 9 hours 43 minutes. The remainder of the decimal fraction is ·00004 which, the same table informs us, is between 3 and 5 seconds. So the answer is, 9 hours 43 minutes 4 seconds. The same decimal fraction is equivalent in Indian time (as we may see from Table XIX) to 24 ghaṭikas 18 palas. Ghaṭikas and hours, as fractions of a day, are also shown in the Eye-table at the end of the book.

246. The reader will notice that in the first three parts of the present work as well as in the connected tables (except the Subsidiary Tables VI-*a*, VII-*a*, and VII-*b*, which are intended mainly for purposes of comparison between the present tables and those of previous writers on the same subject,) measures of time alone are used, and that measures of space, *i.e.* (*degrees* of celestial longitude, *degrees* of mean anomaly of the sun and moon, etc.) have been altogether excluded. This is the principle known as Largeteau's method, which was first applied to Indian astronomical computation by Professor Jacobi in 1888. Messrs. Sewell and Dikshit have applied the same principle in their "*Indian Calendar*" (1896).

247. The present method is founded on Largeteau's principle, but differs essentially from it as well as all previous applications of it in one important respect. Instead of using Largeteau's method to discover how much *space* has been accomplished at a particular moment of time, the present writer has used the method of day-spaces or space days to discover the *moment of time* at which a particular extent of space has been accomplished. Thus, instead of determining the expired portion of a tithi, corresponding to a given moment of time (*i.e.*, generally, to mean sunrise on a particular day,) as is done by Messrs. Jacobi and Sewell, and then calculating the unexpired portion of the tithi by means of successive approximations, the present writer investigates, directly and once for all, the *ending moment of a tithi*, the very thing required by Indian usage.

248. By setting this object steadily in view, the author has been enabled to reduce to two or three very simple and easy steps, Messrs. Sewell and Dikshit's method, which covers a page and a half (pp. 81, 82) of their "Indian Calendar"; likewise he has considerably abridged Professor Jacobi's process, which consists, in the first place, of an approximation, on Largeteau's method, and thirteen or fourteen *subsequent* steps (*a*) to (*m*), as expounded in Volumes I and II of "*Epigraphia Indica*". As regards Mr. Dikshit's own *very accurate* but *very tedious* method, covering *several pages* of the introduction to Dr. Fleet's "*Gupta Inscriptions*", the present writer has been successful in arriving at *absolutely the same result* as Mr. Dikshit in two lines of working. (See Sections **223**, **259**.)

249. The principles upon which space was converted into time for the purposes of the present work are set forth in the following paragraphs.

The principal measure of space, the distance of the moon from the sun, was converted into days in the ratio of 29·530587946 days to 360° in the case of the Sûrya Siddhânta and 29·5305925 days to 360° in the case of the Ârya Siddhânta. Subsidiary Table VI-A is the conversion Table for Sûrya Siddhânta.

The increase of the moon's age, according to the *Sûrya Siddhânta*, for each solar year is according to the above rate of conversion, 10·891701134 days. Instead of reckoning the increase of the moon's age, however, the present method reckons directly the *retardation in the date of appearance of the first new moon* in each solar year, for which purpose it is, of course, necessary to deduct 10·891701134 days from 29·530587946 days: result, 18·638886812 days. This, then, is the number of days by which the appearance of the first new moon is retarded each year, and the first thing to do every year is to calculate the interval of retardation for that year. The interval (if we take the retardation for one year) will, *ipso facto*, be the date of appearance of the first or *Vaisâkha* new moon in solar year 1 of Kaliyuga (expired). From this date all other mean new moons for that or any subsequent solar year may be found by the successive addition of multiples of 29·53059 days; and the mean ending moment of every *tithi* is given by the addition of the *tithi* equivalent in days (according to the Eye-Table) to the date of mean new moon. Precisely the same method was followed for the Ârya Siddhânta, Lalla's corrections being introduced at the appropriate date.

250. The mean anomaly, in the case of the moon as well as that of the sun, was reckoned from perigee, as in Professor Jacobi's article in the *Indian Antiquary* (1888), and not from apogee, as in his articles in Volumes I and II of *Epigraphia Indica*. For the purpose of Table IX, the moon's mean anomaly was converted into days in the ratio of 27·554599899 days to 360° in the case of the Sûrya Siddhânta, and of 27·554566936 days to 360° in the case of the Ârya Siddhânta. The increase of the moon's mean anomaly for a single solar year is thus :—

Sûrya Siddhânta, 7·048957797 days.
Ârya Siddhânta, 7·049310381 days.

The anomaly of the moon at the first moment of Kaliyuga was taken as 90° from perigee, that being the figure according to all the authorities. Subsidiary Table VII *(a)* is the conversion table for moon's anomaly according to the Sûrya Siddhânta. From the year A.D. 1600, the corrected period of the anomalistic month (27·55459797 days) has been adopted for Sûrya Siddhânta calculations.

251. The moon's mean anomaly, as entered in Table IX, corresponds to the *tithi* or space accomplished, while the equation is the addition to or deduction from the tithi, to be made in order to arrive at the *time* or *ending moment* of the tithi. Consequently, the equation in degrees was in every case added to or deducted from the mean anomaly, and the result, converted into days at the rate of 27·5546 days to 360°, is entered as the anomaly in Table IX.

252. For the purpose of Table IX–*c*, *f*, and *h*, the sun's mean anomaly, reckoned from perigee, was converted into days at the rate of 365·25875 days to 360° [Subsidiary Tab. VII (*b*)] and the sun's equation of the centre was converted at the same rate as the distance of moon from sun (29·53059 days to 360°), because the principal use of the sun's equation of the centre is to correct the mean into the true distance of the moon from the sun. The moon's equation of the centre in Table IX-*a*, *b*, *d*, *e*, *g*, was converted at the same rate, and for the same reason, from degrees into decimals of a day.

N.B.—In the Nakshatra and Yoga Equation Tables, IX–*i*, *j*, *k*, *l*, equations in degrees were converted into days at the rate of 27·32167 days for 360° in the case of Nakshatras, and of 25·4202 days for 360° in the case of Yogas.

253. The actual sun's anomaly, as entered in Table IX, is the result of a series of transformations which had to be carefully executed for each of the 680 stages of the anomaly. According to the Sûrya Siddhânta, the mean anomaly of the sun at the commencement of each solar year, neglecting the slow motion of the perigee which is allowed for in that Siddhânta but not in the others, is 102° 45′ or, in solar days, 104·25093 days. This amount has therefore to be added to the number of days expired in the solar year at a given moment in order that the sun's anomaly for that moment may be correctly expressed in days. From the sum, 2·1707 days have to be deducted for Sodhya. Thus the equation entered in Table IX (*c*) against the 182nd day of the solar year is the equation which really belongs to the following mean anomaly : *viz.*, 182 days *plus* 104·25093 days *minus* 2·1707 days, that is, an anomaly of 284·0802 days: the latter figure, which is not required in practice, has wholly disappeared from Table IX (*c*), and the equation is simply entered against the day of the solar year for which, in practice, it is likely to be required.

254. For *nakshatras*, the following formula was used: (moon's longitude *minus* sun's longitude) *plus* sun's longitude = moon's longitude for *nakshatras*. As moon's *minus* sun's longitude is expressed according to the ratio 360° = 29·53059 days, the sun's longitude is expressed in the same ratio. Solar days are thus expressed in terms of the synodical month and the result of the reduction, after allowing for śodhya, is exhibited for whole days in the last column of Table VIII, "Sun's longitude for Nakshatras". *Fractions* of solar days can be converted into lunation-longitude by means of the third multiplication table in Table V. The first two multiplication tables in Table V were originally intended to be of use in determining the ending moment of a yoga or nakshatra, but in practice, either Table XI or Tables XVII-A and XVII-C will be found much easier and handier than Table V for the investigation of all kinds of problems connected with nakshatras and yogas. Table XI is referred to in Secs. **263** to **265** *infra* and Tables XVII-A and XVII-C in Sec. **266** *infra*.

255. The moment of *sunrise* for any latitude and longitude in India can be ascertained by means of Table XIII, based on the rules and table of *asus* given by Professor Jacobi in Volume I of the *Epigraphia Indica*. Professor Jacobi has himself given detailed tables for sunrise in Volume II of the same publication, but the results achieved by means of those tables can, it is believed, be more easily arrived at by the present Table XIII. For the purpose of determining the equation of time for each day of the solar year, the sun's equation of the centre, according to Table IX (*c*), was used, with the sign changed: likewise the *asus* given in Professor Jacobi's table and reproduced in Sec. **76** *supra*, had to be suitably modified.

Thus (according to Professor Jacobi's table) in the 10th degree of Northern latitude 30 degrees of Sign 1 of the Zodiac take 1544 *asus* or 1544 × 4 seconds of time to rise;

or in lunation-longitude,

$\left(\frac{30}{360}\right) \times 29{\cdot}53059$, or 2·46088 units of space take 1544 × 4 seconds of time to rise;

$$\therefore 1 \text{ unit of space takes } \frac{1544 \times 4}{2{\cdot}46088} = 1544 \times 1{\cdot}62 = 2510 \text{ seconds.}$$

This 2510, then, is the factor by which each day's equation of the centre according to Table IX (*c*) should be multipled (so long as the sun is in the first Sign) in order to give that day's equation of time.

And generally, all the *asus* in Professor Jacobi's table were multiplied by $\frac{4}{2{\cdot}46088} = 1{\cdot}62$, and the factors thus obtained were multiplied again by each day's equation according to Table IX (*c*) in the present work: the result was each day's equation of time in seconds as entered in Table XIII of this work. The same result could of course have been arrived at directly from Table XVII-A, "Sun's Equation in degrees for each day of Solar Year".

256. For using the tables in *Epigraphia Indica*, Vol. II, the sun's longitude (first sidereal and then tropical), corresponding to a given day of the solar year, has to be first determined from special tables in Vol. I, *Epigraphia Indica*; then the *vinâdis* given under each degree of latitude and for each Sign of the Zodiac in Vol. II, *ibid.*, have to be multiplied by the equation of the centre, which in turn has to be calculated from the sun's mean anomaly, applied with proportional parts to Special Table XXIV-B in Vol. I, *Epigraphia Indica*: only then can the moment of sunrise for a given day in the solar year be ascertained.

257. In the present Table XIII on the other hand, the moment of sunrise for any day of any solar year is obtained by simply adding a figure in the column "Tropical Longitude" to the figure opposite the given day of the solar year in the column "Equation of Time"; and the result is the correction, in seconds of time, to be applied to mean sunrise at Lankâ (6 a.m.) to determine the local sunrise for the given latitude.

258. Column 3 under each degree of latitude in Table XIII is a further step towards simplification, for it gives, for the 80 years ending 1920, the *total* correction to be applied to mean Lankâ time in order to arrive at the local time, for each of 30 important places, including Calcutta, Madras and Bombay. In this column the difference in time corresponding to the longitude of each place, measured from Ujjain, is added to the correction for sunrise for each day of the solar year and for each degree of latitude.

Example.—Ashâdha Sukla 12, *Kaliyuga* 3585 (*expired*) A.D. 484.

259. A single test problem, the same as that selected by Mr. Dikshit in his Introduction to *Dr. Fleet's Gupta Inscriptions* as well as by Professor Jacobi in Vol. I of *Epigraphia Indica*, will suffice to demonstrate the absolute reliability and extreme simplicity of the above processes as carried out in the present work. The problem is to determine the ending moment of *Ashâdha sukla dvâdasî* in *Kaliyuga* 3585 (expired), A.D. 484. The ending moment has to be determined (*a*) for Lankâ and (*b*) for the latitude and longitude of Eran (Lat. 24°, Long. 78° 15'). Lastly, the problem has to be worked out, first according to the *Sûrya Siddhânta*, and then according to the *First Arya Siddhânta*.

SURYA SIDDHANTA.

References to Tables.	Days of Solar Year.	Moon's mean Anomaly in days.
(Table X): Kaliyuga 3585 ; A.D. 484 ; * March 18·2212.		
First New Moon in Solar year ...	24·3900	4·494
(Table VIII): Âshâḍha śukla 12 ...	70·8734	15·764
	95·2634	20·258
		(☉'s Eqn.)— ·0455
Table IX (*c*): ☉'s Eqn. for 95·26 days of Solar Year =	−·0455	
Table IX (*b*): ☾'s Eqn. for anom. of 20·212 days =	+·4138	20·212
	+·3683 + ·3683	
* English month, day, and fraction of day marking commencement of solar year ...	95·6317 *March 18·2212	
	113·8529	

Our result is: the tithi ended at ·8529 of a day, *i.e.*, at 51 ghaṭikas 11 palas on the 113th day of the English Calendar, counting from 1st March.

The reader will be pleased to note that this absolutely correct result for the ending moment of a tithi is obtained by *simply adding* up six or seven figures from Tables VIII, IX, and X, and that absolutely no other process is required for any tithi in any year.

260. Now, by Table VIII, the 113th day of the English Calendar, counting from 1st March, is 21st June ;

by Table XIX, ·8529 of a day = 51 ghaṭikas 11 palas ;

by Table IV we arrive at the week-day as follows :—

Co-efficient of 400 A.D.	...	2
Co-efficient of odd year 84	...	0
Co-efficient of June	...	3
Day of the month	...	21
		26

Since 26, divided by 7, leaves remainder 5 = THURSDAY, the final answer is THURSDAY, 21st JUNE, A.D. 484, 51 GHATIKAS 11 PALAS after mean sunrise at Lankâ.

NOTE.—This is the absolutely correct ending moment, according to Mr. Dikshit ; but Professor Jacobi arrives at a result which is 4 palas short. To arrive at the latter result, ☾'s + ☉'s Eqn. must be added as in foot-note to p. (83) to ☉'s Anom. before ascertaining ☉'s Eqn., just as ☉'s Eqn. is in the actual working *supra*, added to ☾'s anom. before ascertaining ☾'s Eqn. This extra step, however, is a nicety seldom required in practice, since the error on this account can never exceed 6 palas. See Sec. **212** *supra*.

To DETERMINE THE ENDING MOMENT OF THE ABOVE TITHI IN TRUE LOCAL TIME AT ERAN.

261. We first of all find the sun's sidereal longitude for 95·85 days, for which purpose we deduct the *sodhya*, 2·17 days. Remainder, 94 days nearly.

We turn to Table XIII and bring down the entry under Latitude 24° corresponding to the 94th day of the Solar Year, for ☉'s trop.* long. and the entry corresponding to the 95th day for the equation of time.

(1) Equation of time (95th day) : + 148 seconds of time.

(2) ☉'s tropical longitude (94th day): + 2647 seconds of time.

(3) To these figures from Table XIII we add the time-difference for the longitude of Eran (+ 2·53 degrees Ujjain longitude), namely, + 2·53 × 240 or + 608 seconds of time. Total : + 148 + 2647 + 608 = + 3403 seconds of time.

Now 3403 seconds of time, divided by 60, are 56 minutes 43 seconds or ·0393 of a day. Adding this to the mean Lankâ time already arrived at, *viz*., ·8529, we obtain, as TRUE LOCAL TIME at ERAN for Âshâḍha Sukla 12, 3585 Kaliyuga, ·8922 of a day or 53 GHATIKAS 32 PALAS which is exactly the same as Mr. Dikshit's result.

ACCORDING TO 1st ARYA SIDDHANTA.

262. The simplest way of arriving at the ending moment of the above tithi according to the first Ârya Siddhânta—and this was apparently the method adopted by Mr. Dikshit—is to deduct from the ending moment, already arrived at, the difference between the *Sodhyas* of the Sûrya and Ârya Siddhântas (2·1707 days *minus* 2·1476 days = ·0231 day), this being the

* NOTE.—In the solar year, 3585 K.Y. we make no correction for the difference between ☉'s sidereal and tropical longitude because in 3600 K.Y., *i.e.*, only 15 years later, the ☉'s sidereal coincided with the ☉'s tropical longitude.

only difference between the Sûrya and Ârya Calendars at the epoch 3585 K.Y. We thus obtain ·8530 day less ·0231 day = ·8299 day = 49 GHATIKAS 48 PALAS (Table XIX). This is exactly Mr. Dikshit's result for the mean Lankâ time of the ending moment of the tithi according to the 1st Ârya Siddhânta. We may make the same deduction for true local time at Eran according to the same Siddhânta, and obtain Mr. Dikshit's result for this also.

NOTE.—There was also a difference of ·001 of a day, *i.e.*, $1\frac{1}{2}$ minutes or 4 palas between the commencement of the solar year, K.Y. 3585, according to the Surya and Arya Siddhantas (*vide* Tables VI and VII in the present work); but apparently Mr. Dikshit neglected this trivial difference.

CHAPTER XXVIII.

CONSTRUCTION OF TABLE FOR NAKSHATRAS AND YOGAS.

263. Table XI contains a very easy method of calculating directly the absolute ending moment of a *nakshatra* or *yoga*.

The interval between new moon and any particular nakshatra n may be expressed by the formula $\frac{29{\cdot}5306-A}{q}+n\times d.$

where A is the sun's longitude at new moon, expressed in terms of a lunation as in the last column of Table VIII, n is the numerical order of the given nakshatra, counting from Revatî, d is the mean duration of a nakshatra in days, and q is the ratio of the length of the synodical to that of the sidereal month.

The above expression may be expanded into

$$\left\{29{\cdot}5306-\left(f+al-2{\cdot}1707\right)\times m\right\}\times\frac{1}{q}+n\times d,$$

where f is the moment of occurrence of the first New Moon in a Solar Year, as given in Table X, a is the number of lunations completed since the commencement of the Solar Year, l is the period of a lunation in days (*i.e.*, 29·5306 days); 2·1707 days are the *sodhya*, m is the factor for converting Sun's longitude into lunation space, according to Table V (last column); $\frac{1}{q}$ is the factor used in the 1st column of Table V $\left(i.e., \frac{1}{1{\cdot}0808}\right)$ and $n\times d$ is the collective duration in days of Nakshatras counted from Revatî up to the end of the given Nakshatra.

We may expand the above expression again as follows:

$$29{\cdot}5306\times\frac{1}{q}+2{\cdot}1707\times m\times\frac{1}{q}+n\times d-f\times m\times\frac{1}{q}-al\times m\times\frac{1}{q}.$$

Now all these expressions connected by + or −, except, $f\times m\times\frac{1}{q}$ may be calculated *once for all* for every *Nakshatra* in the lunar year, for

$$29{\cdot}5306\times\frac{1}{q}=27{\cdot}32167\ ;$$

$$2{\cdot}1707\times m\times\frac{1}{q}=\ {\cdot}16237\ ;$$

And the expression $({\cdot}16237+n\times d-al\times m\times\frac{1}{q})$, when calculated for each Nakshatra becomes one of the figures given in Table XI under "Interval between New Moon and each Nakshatra".

There remains $f\times m\times\frac{1}{q}$, whose maximum value is $29{\cdot}5306\times m\times\frac{1}{q}=2{\cdot}20891$ (the difference between 29·530587946 and 27·321674163, the lengths of the synodical and sidereal months).

The values of $f \times m \times \frac{1}{q}$, less than the maximum, may be calculated by means of the Nakshatra correction Table in Table XI.

Accordingly all that we have to do, in order to know the mean ending moment of any Nakshatra, is to take the corresponding figure from the "Interval" Table XI and deduct the value of $f \times m \times \frac{1}{q}$ as obtained from the "correction" table in Table XI.

N.B.—The correction tables might have been made additive instead of subtractive, by (1) subtracting all the quantities in the correction tables from 2·20890 in the case of Nakshatras and from 4·11036 in the case of Yogas, and (2) subtracting 2·20890 and 4·11036 respectively from all the intervals in the body of Table XI. This will be attended to in a future edition of the work, should a second edition be called for.

264. Thus, supposing the mean ending moment of *Mûla* Nakshatra in the month of (lunar) *Kârttika* in A.D. 1910, is required :—

The mean ending moment of *Kârttika* New Moon is (by Table X) November	2·30
The integer and first two decimal places of the "Interval" for "*Kârttika* Mûla" (Table XI)	6·13
	Nov. 8·43
Deduct $f \times m \times \frac{1}{q}$, *i.e.*, the equivalent of 25·91 according to the correction table in Table XI; 1·87 + ·07 = 1·94.	−1·94
	Nov. 6·49

This is the mean ending moment of the Nakshatra *Mûla* in Lunar Kârttika, A.D. 1910.

If we want the absolute ending moment, we calculate the anomaly :

		Days.
Moon's mean anomaly at commencement of Solar Year	...	0·535
Add increase of anomaly up to Kârttika New Moon	...	11·866
Add "Interval" less $f \times m \times \frac{1}{q}$	...	4·19
		16·59
Corresponding Equation for Nakshatras (Table IX–*k*)	...	+·246

Adding this equation to the mean ending moment, Nov. 6·49, we have Nov. 6·74 or (by the Eye-Table) 44½ ghaṭikas after mean sunrise on Nov. 6, A.D. 1910. We could, of course, if we had liked, have calculated the absolute ending moment to four places of decimals instead of to two.

265. *Yogas* are worked in the same manner, by using the corresponding portions of Table XI, *i.e.*, by deducting from the "Yoga Interval" (for the given lunar month and given Yoga) the correction for the Solar Year according to the Yoga correction table in Table XI.

266. When a *Yoga* and *Nakshatra* are cited with the *tithi* as in the example in Sec. **98** *supra*, it will generally be enough to ascertain the nakshatra and the yoga which were concurrent with the tithi and this can most easily be done as follows :—

Sun's anomaly at ending moment of tithi, 203·31 days.

By Table XVII–A, the ☉'s longitude corresponding to 203 days is	197·94°
" XVII–C, " " " ·31 day is	·31°
	198·25°
The tithi being the 9th, the moon's elongation was 9 × 12° =	108·00°
Total	306·25°

This (by Eye-Table) is the longitude for Nakshatra *Dhanishtha*.

For *Yoga* we add 2 × Sun's Longitude to Moon's Elongation.

That is, the yoga longitude is $108{\cdot}00° + 2 \times 198{\cdot}25° = 108{\cdot}00° + 396{\cdot}50° = 504{\cdot}50$

Deducting 360° which is one complete revolution, we have $504{\cdot}50° - 360° = 144{\cdot}50°$, which (by Eye-Table) is the Longitude of No. 10 *Ganda* Yoga.

267. When we wish to find the ending moment of a Nakshatra or Yoga, we should apply Table XI as follows :—

In our example, the mean tithi ended at 8·86 days after *Kârttika New Moon*. The age of the first new moon in the solar year being 20·27 days, the corresponding Nakshatra correction is (by Table XI) 1·50 + ·02 = 1·52 = (by Eye-Table) 1 day 31 ghaṭikas and the Yoga correction (by Table XI) 2·78 + ·04 = 2·82 = 2 days 49 ghaṭikas.

From Table XI-A under col. VII Kârttika we obtain—

	Nakshatra. d.	gh.	p.		Yoga. d.	gh.	p.
No. 23 Dhanishtha	10	10	59	No. 11 Vriddhi	11	24	59
Deduct correction	1	31			2	49	
	8	40			8	36	

N.B.—The coincidence of a particular *Yoga* with a particular *Nakshatra* happens only once a year, and we could, by means of this coincidence, discover the month and the tithi even if these were not quoted.

This is the Tithi interval, 8 d. 51½ gh—11½ gh. This is the Tithi interval 8 d. 51½ gh.—15½ gh.

We can, with the last line of corrections, use for the Nakshatra and Yoga the ⊙'s and ☾'s Anomalies already found (Sec. **98**) for the tithi, *i.e.*, ⊙'s Anom. 206 days 18½ gh.; ☾'s Anom. 25 days 16 gh.

Our Nakshatra Eqn. will be that for ☾'s Anom. of 25 d. 16 gh. *less* 11½ gh., or for 25 d. 4½ gh.: Eqn. (Tab. IX-*l*) is + 11½ gh.

Our Yoga ⊙'s Anom. will be 206 d. 18½ gh. *less* 15½ gh. or 206 d. 3 gh., for which ⊙'s Yoga Eqn. (Tab. IX-*i*) is + 7 gh. 42 p.

Our Yoga ☾'s Anom. will be 25 d. 16 gh.—15½ gh. = 25 d. ½gh. for which ☾'s Yoga Eqn. (Tab. IX-*i*) is + 10 gh. 55 p.

The sum of ⊙'s and ☾'s Eqns. for Yoga is + 7 gh. 42 p. + 10 gh. 55 p. = + 18 gh. 37 p.

These equations can be added to the mean ending moments of Nakshatra and Yoga.

The equation being added to Nakshatra mean ending moment, we have, as the absolute ending moment of the Nakshatra, Oct. 19·76, *i.e.*, 42½ gh.—11½ gh. + 11½ gh. = 42½ gh. on 19 Oct. A.D. 1474.

The Yoga ended at 42½ gh. — 15½ gh. + 18½ gh. = 45½ gh., when tithi also ended (*vide* Sec. **98**).

Now Dhanishṭha Nakshatra ends when moon's longitude is 306·7° (Eye-Table) and since the moon is said to have been in Kumbha râśi, her longitude must have been between 300° and 330° (Eye-Table).

Since the event happened between 300 and 306·7 degrees of moon's longitude, the exact hour is defined as being less than 30 ghaṭikas before the end of the Nakshatra (since by Table XVII-D the moon's long. increases by 6·7° in ·50 of a day).

N.B.—With reference to line 5 of Sec. **98**, the Tithi being the 18th, the *karana* (*vide* list in Table III) must have been *Kaulava* and must have ended at the same moment as the 9th tithi (for the reason explained in Sec. **55** *supra*).

CHAPTER XXIX.

INVESTIGATION OF ADHIKA AND KSHAYA MONTHS.

268. *Adhika* months are the cream of the Indian Calendar, while *kshaya* months are its *crème de la crème*. Figures of speech apart, it is certainly true that the success or failure of any computer in deducing *adhika* and *kshaya* months is the measure of his success or failure in dealing, as a whole, with the Indian Calendar. How far the present method satisfies this ordeal, will be for competent judges to decide.

269. Two independent English lists of *adhika* and *kshaya* months are at present in existence, the first by Prof. **Chhatre** (reproduced in *Ind. Antiq.*, Vol. XXIII, pp. 105–108), and the second by Messrs. **Sewell** and **Dikshit**. The lists in **Patell's** *Chronology* and **Cunningham's** *Indian Eras* are obviously copied, without check, from Chhatre whose reputation was and is, sufficient to justify such a procedure.

Messrs. Sewell and Dikshit certainly exercised an independent and erudite judgment in revising Prof. Chhatre's list, and they declare, in several parts of their work, the indubitable superiority of their list to that of *Chhatre*.

270. For the purposes of Table X in the present work, it was necessary to weigh carefully the merits of Mr. Chhatre's and Mr. Dikshit's calculations wherever they differed. The palm must no doubt be awarded, as a general rule, to Mr. Dikshit, but he seems to have failed, by oversight, to take notice of the *kshaya* months in A.D. 507 and A.D. 751 which are investigated below.

Adhika Months.

A.D. 629.

271. In regard to this year Messrs. Sewell and Dikshit are at some pains to explain (under *Additions and Corrections*, p. 150 of " Indian Calendar") that Chhatre's entry of Adhika Kârttika is wrong and that their own entry of Adhika Âśvina is correct. Let us verify this statement, and in so doing, note the comparative brevity and simplicity of our method.

	Days.	☉'s and ☾'s Eqns.	☾'s Anom.	
First New moon in Solar Year A.D. 629,	10·2145		20·456	
Add for 7th New moon	177·1835	−·172	11·856	
		−·342		
	187·3980		32·312	
	−·514	−·514	−·172	☉'s Eqn.
7th or Tulâ Sankrânti 186·9355 :	186·884		32·140	
			27·555	
			4·585	

The 7th new moon was therefore *Asvina*, and obviously the 6th new moon also was an *Asvina*; so that the Adhika month was, as stated by Messrs. Sewell and Dikshit, Âśvina, not as stated by Chattre, Kârttika.

A.D. 979.

272. In each of the next two cases Mr. Chhatre was out of reckoning by a very small margin. For A.D. 979 Messrs. Sewell and Dikshit have given *Srávana* as the Adhika month, whereas *Bhâdrapada* is the Adhika month in that year according to Prof. Chhatre's list. The calculations must in all these cases be made by the *Sûrya Siddhânta* and the foot-note to p. (9) of the text should be applied.

	Days.	☾'s Anomaly
First New moon in Solar Year A.D. 979,	7·5649	5·023
Add for 5th New moon	118·1223	7·904
	125·6872	12·927
Sum of ☉'s and ☾'s Eqns.: −·1259−·1005=	−·2264	−·126 (☉'s Eqn.)
5th or Simha Sankrânti 125·4755:	125·4608	12·801

The Adhika month was *Srâvana* by ·0147 day, *i.e.*, nearly one ghaṭika, and in this instance Messrs. Sewell and Dikshit are right. Our Table X shows Adhika Srâvana.

A.D. 1199.

	Days.	☾'s Anom.
First New moon in Solar Year	3·3683	8·539
3rd New moon in "	59·0612	3·952
	62·4295	12·491
		+·055 (☉'s Eqn.)
		12·546
Sum of ☉'s + ☾'s Eqns. + ·0555 − ·1261 = − ·0706	− ·0706	
3rd or Mithuna Sankrânti 62·3555:	62·3589	

The Adhika month, 3rd new moon, was *Ashâdha*, as stated by Messrs. Sewell and Dikshit, not *Jyeshtha*, as determined by Chhatre. Our Table X shows Adhika Âshâḍha.

It happens that this very interesting Adhika month, the 3rd lunar month in the year AD. 1199—1200 is quoted in a South Indian inscription, discussed by Dr. Fleet at p. 156 of the *Indian Antiquary*, Vol. XIX (1890). In the inscription itself the Adhika month is identified as *Ashâdha*, not as *Jyeshtha*. Of course the margin of difference is so small (5 minutes), that a calculator might, without being convicted of error, place an *adhika* month of this description on either side of the Sankrânti. If we did not know that the difference was so small, we should be at a loss to account for the discrepancy between the statement in the inscription and Prof. Chhatre's list. As it is, a more striking instance cannot be imagined than this actual one, to demonstrate the value and importance to an epigraphist of a knowledge of how to calculate tithis accurately.

Kshaya Months.

A.D. 507.

	Days.	☉'s and ☾'s Eqns.		☾'s Anom.	
First New moon in Solar Year	10·1256	—·129		14·587	
Add for 8th New moon in Solar Year	206·7141	—·064		13·832	
(1) 8th or Vrischika Sankrânti 216·8289 :	216·8397	—·193	=216·6467	28·419	
				27·555	
				0·864	
				— ·129	(☉'s eqn.)
				0·735	
		+·039		0·864	
Add for 10th New moon	59·0612	—·355		3·952	
(2) 10th or Makara Sankrânti 275·637 :	275·9009	—·316	=275·5849	4·816	
				+ ·039	(☉'s eqn.)
				4·855	
		+·120			
				4·816	
Add for 11th New moon	29·5306	—·412		1·976	
(3) 11th or Kumbha Sankrânti 305·085 :	305·4315	—·292	=305·1395	6·792	
				+ ·120	(☉'s eqn.)
				6·908	

273. From (1) it follows that the 8th new moon was Kârttika and it is apparent from the time of occurrence of that new moon (1 ghaṭika before the end of the solar month) that the 7th new moon also must have been a *Kârttika*.

From (2) it follows that the 10th new moon was Pausha. [Foot-note to p. (9) of Text.]

From (3) it follows that the 11th new moon was Phâlguna. [Do. do.]

∴ The new moon between Pausha and Phâlguna, viz., *Mâgha*, was *kshaya* in this year.

It is also evident from the time of occurrence of this Phâlguna that the 12th new moon also must have been a Phâlguna.

Against this year Messrs. Sewell and Dikshit have noted only "Adhika Phâlguna", whereas Chhatre mentions also a *kshaya* month, Pausha. We have just seen that the kshaya month was really *Mâgha*, which is accordingly noted in our Table X.

Nor would the case have been different under the Ârya Siddhânta, since, as we remarked in the foot-note to Sec. **161** *supra*, the new moons under the Ârya Siddhânta at this epoch occurred only ·0231 of a day before the Sûrya Siddhânta new moons, and this would have made no difference as regards *adhika* and *kshaya* months in the present case.

A.D. 751.

274. Only an *Adhika* Chaitra without a *kshaya* month is noted in this year by Messrs. Sewell and Dikshit, whereas Prof. Chhatre notes *Adhika* Kârttika and *Adhika* Chaitra besides Mârgasîra *kshaya*. Let us work for the different new moons :—

	Days.	⊙'s and ☾'s Eqns.	☾'s Anom.
First New moon in Solar Year A.D. 751:	10·3034	−·172	26·321
Add for 7th New moon	177·1835	−·304	11·856
(1) Beginning of 7th Solar month 186·9355 :	187·4869	−·476 = 187·011	38·177 − ·172 (⊙'s Eqn.) − 27·55 = 10·450
			27·555
		−·128	10·622
Add for 8th New moon	29·5306	−·133	1·976
(2) Beginning of 8th Solar month 216·828 :	217·0175	−·261 = 216·756	12·598 − ·128 (⊙'s Eqn) = 12·470
		−·052	
Add for 9th New moon	29·5306	+·077	1·976
(3) Beginning of 9th Solar month 246·3192 :	246·5481	+·025 = 246·573	14·574 − ·052 (⊙'s Eqn.) = 14·522
		+·040	
Add for 10th New moon	29·5306	+·335	1·976
(4) Beginning of 10th Solar month 275·6369 :	276·0787	+·375 = 276·454	16·550 + ·040 (⊙'s Eqn.) = 16·590
		+·120	
Add for 11th New moon	29·5306	+·385	1·976
	305·6093	+·505	18·526
(5) Beginning of 11th Solar month 305·0850:	305·6093	+·505 = 306·114	18·526 + ·120 (⊙'s Eqn.) = 18·664
		+·169	
Add for 12th New moon	29·5306	+·412	1·976
(6) Beginning of 12th Solar month 334·9053 :	335·1399	+·581 = 335·721	20·502 + ·169 (⊙'s Eqn.) = 20·671
		+·176	
Add for 13th New moon	29·5306	+·357	1·976
(7) End of 12th Solar month 365·25875 :	364·6705	+·533 = 365·203	22·478 + ·176 (⊙'s Eqn.) = 22·654

N.B.—The above is a convenient and concise method of working for *Adhika* and *Kshaya* months.

From (1) and (2) it follows [applying the rule in foot-note to p. (9) of the Text], that the 7th and 8th new moons were both Kârttika, the first of them being *Adhika*.

From (3) it follows that the 9th new moon was *Pausha*.

∴ The new moon between Kârttika and Pausha, viz., *Mârgasîra* was *kshaya* and it is accordingly noted as such in our Table X.

From (4) it follows that the 10th new moon was *Mâgha*.

From (5) it follows that the 11th new moon was *Phâlguna*.

From (6) and (7) it follows that the 12th and 13th new moons were both *Chaitra* the first of them being *adhika*.

It would appear that by oversight Messrs. Sewell and Dikshit failed to take account of these facts, notwithstanding that Prof. Chhatre had mentioned them.

A.D. 1963.

275. Messrs. Sewell and Dikshit, after noting that the last *Kshaya* month before our time was in A.D. 1822, go on to remark: "We are led to suppose that there will be no suppressed month till at earliest A.D. 1944, and possibly not till A.D. 1963".

There is no reason why the matter should be treated as one for conjecture, since anybody familiar with the present method can calculate that the next *Kshaya* month will be in A.D. 1963, as we have indeed noted in Table X. There will be another in A.D. 1982, as noted in the same Table.

CHAPTER XXX.

CONSTRUCTION OF PLANETARY TABLES XVII AND XVIII.

276. The mean sidereal periods, used in Tables XVII and XVIII, are those of modern European astronomy adjusted to the Indian sidereal year. The following table compares the sidereal period of each planet, ordinarily given in Indian astronomical works, with that adopted in this work as well as with the results of modern astronomy.

Planet.	Indian Sidereal period.	Modern Astronomy (Encycl. Brit.)	Figure adopted in this work.
	Days.	Days.	Days.
Mars	686·99749	686·979645	686·98814
Mercury	87·969702	87·969258	87·96939
Jupiter	4332·3206	4332·584821	4332·92322
Venus	224·698568	224·700786	224·70169
Saturn	10765·7730	10759·219817	10761·30664

277. In the first place it was thought unnecessary to observe in regard to planetary sidereal periods the same scrupulous adherence to Indian authorities which is incumbent in the case of the solar year and the moon's synodical month. In the next place, the difference in the length of the sidereal year between Indian and modern astronomy results in a slight displacement of the starting point of Indian celestial longitude, which displacement amounts to 7′ 6·26″

in 50 years and should be added to the precession, amounting, according to modern astronomy, to 41′ 52·27″ for fifty years. The total difference between Indian sidereal and modern tropical longitudes is thus 48′ 58·53″ for 50 years or 59″ per annum, while Bhâskara's estimate of the precession, 59·9007″ per annum, is only slightly larger.

278. If the slight annual displacement of the zero point of Indian longitudes, which is a practical postulate of Indian astronomy, however unrecognized in theory, is applied to the sidereal places of planets, their mean sidereal periods will have to be altered as shown above. In this manner alone will it be possible to apply to the planets the same precession as is applied to the sun, for the purpose of converting sidereal into tropical longitude.

N.B.—By taking this slight liberty with the mean sidereal periods of planets, the exact agreement of the mean place of any planet with its place in modern astronomy is secured, and the serious divergences between the two systems, commented on in Whitney's notes on the *Surya Siddhanta* have been effectually avoided. As a result, the place, whether mean or actual, assigned to any planet in Tables XVII and XVIII, may not tally exactly with Indian calculations, but the difference will generally be found to be very slight, while there is an obvious advantage in having for every possible epoch a mean place for each planet, identical with that assigned to it by modern astronomy.

279. The planetary anomalies and annual equations, which were used for Tables XVII and XVIII of this work, were taken from *Warren's Kâla Sankalita* and are ascribed by that author to a local Telugu Astronomer of the time, called *Vavilâla Kuchinna*. The tables are no doubt old-fashioned, but they are handy and sufficiently accurate for the purposes of Indian horoscope-chronology. This is the main reason for resuscitating them into present-day use.

280. The figures as to longitudes of apses and nodes and the greatest apparent latitudes of planets (Table XVII) are taken, partly from Warren and partly from the Siddhânta Siromani.

PART IV—PLANETS AND PLANETARY CHRONOLOGY.

281. Indian astronomy reckons nine planets, spoken of collectively as *navagrahas*, namely the Sun, Moon, Mars, Mercury, Jupiter, Venus, Saturn, Rahu and Ketu. It will be seen that the first seven are named in the order of the days of the week, and this is always the order in which they are referred to in Indian astronomy. Rahu is another name for the moon's ascending node, one of the points at which the moon's orbit cuts that of the Sun (the ecliptic), the other point, or the descending node, being called Ketu. An eclipse cannot happen except when the moon is at either node and the sun is at the same or the opposite node; hence the popular legend which depicts *Rahu* as a dragon swallowing up the moon or the sun at the time of an eclipse. All the planets, except Rahu and Ketu, move like the Sun, from West to East in their apparent path round the earth. Rahu moves in the opposite direction, and Ketu is always assigned a position 180° from that of Rahu.

282. All the data necessary for calculating the geocentric longitude and latitude of the five planets, Mars, Mercury, Jupiter, Venus and Saturn, are given at pages 200 to 206 of the Tables (Table XVII).

283. The longitude of any planet is its distance, measured in degrees, from an arbitrary point in the ecliptic, which point may perhaps best be defined as the 0 point of the Sun's mean longitude. The Sun's *mean* longitude is always 0 at a certain part of the Indian Solar Year, namely, at 2·1707 days from the commencement of each Indian Solar Year: while *at the moment of commencement* of the Indian Solar Year, the Sun's *actual* longitude is 0. The difference between the Sun's mean and actual longitude at any time is his equation of the centre, and this difference is due to his varying pace at different times of the year as he journeys round the earth. The Sun's mean longitude and equation for every complete day of the Solar Year are given in Table XVII-A (pp. 207, 208), and these are most important data in Indian astronomy. Table XVII-C (p. 209) gives the increase of the Sun's mean longitude for hundredth parts of a day.

284. The Sun's mean longitude at any moment is ascertained by deducting 2·1707 from the number of days and fraction of day elapsed since the commencement of the Indian Solar Year, and applying to the result the Table of Sun's longitude (Table VII-B, p. 8). The difference between the Sun's longitude thus calculated and the longitude for the same moment given in any European *Nautical Almanac*, is the true Indian precession, and this difference should always be added to the longitude of a planet given in this work in order to ascertain the corresponding longitude according to the *Nautical Almanac*. The following table gives the precession to be added to Indian celestial longitudes at various epochs since A.D. 520 (when the European and Indian longitudes coincided), in order to arrive at the European celestial longitude. The rate of precession adopted for this table is 1 degree for every 61¼ years, or 59″ per annum, the rate arrived at in Sec. **277** *supra*.

(The European longitude is called the *tropical* longitude of a planet from its being regulated by the tropical year, whereas the Indian longitude is generally called a *sidereal* longitude from its being regulated by the sidereal year.)

A.D.	Kaliyuga.	Indian Precession in Degrees.	A.D.	Kaliyuga.	Indian Precession in Degrees.	A.D.	Kaliyuga.	Indian Precession in Degrees.
520	3621	0·0	**1040**	4141	8·5	**1561**	4662	17·0
551	3652	0·5	**1071**	4172	9·0	**1591**	4692	17·5
581	3682	1·0	**1102**	4203	9·5	**1622**	4723	18·0
611	3712	1·5	**1132**	4233	10·0	**1653**	4754	18·5
642	3743	2·0	**1163**	4264	10·5	**1684**	4785	19·0
673	3774	2·5	**1194**	4295	11·0	**1715**	4816	19·5
704	3805	3·0	**1225**	4326	11·5	**1745**	4846	20·0
735	3836	3·5	**1255**	4356	12·0	**1775**	4876	20·5
765	3866	4·0	**1285**	4386	12·5	**1806**	4907	21·0
796	3897	4·5	**1316**	4417	13·0	**1837**	4938	21·5
826	3927	5·0	**1347**	4448	13·5	**1867**	4968	22·0
856	3957	5·5	**1377**	4478	14·0	**1898**	4999	22·5
887	3988	6·0	**1408**	4509	14·5	**1929**	5030	23·0
918	4019	6·5	**1439**	4540	15·0	**1960**	5061	23·5
949	4050	7·0	**1469**	4570	15·5	**1990**	5091	24·0
980	4081	7·5	**1500**	4601	16·0	**2020**	5121	24·5
1010	4111	8·0	**1531**	4632	16·5	**2051**	5152	25·0

285. We will now explain briefly how the planetary tables at pages 200 to 206 are to be used in practice.