Art. XVIII.—*Notes on Hindu Astronomy and the History of our Knowledge of it.* By James Burgess, C.I.E., LL.D., M.R.A.S., etc.

1. The following notes are perhaps somewhat miscellaneous, but they may help to re-direct attention to an interesting subject, recalling the history of European studies of it with some of the results obtained. And since the scheme arranged by Mr. Whitley Stokes for cataloguing the Sanskrit works in Indian libraries, private and other, and for obtaining copies of the rarer ones has yielded such excellent results in all departments, it will perhaps be possible for Orientalists now to publish and translate some of the more important *Siddhântas* and *Karaṇas* hitherto inaccessible, and which would be most useful in tracing the origins and history of this Indian science.

2. We cannot trace the study of the heavens by the Hindus to any very early date. Strabo says[1] the Pramnai (which is, perhaps, only another form of Σαρμαναι), "ridicule the Brachmanes as boasters and fools for occupying themselves with physiology and astronomy." This statement may, of course, refer to the time of Alexander's invasion, or it may be based on later reports which Strabo (*cir.* A.D. 1) had collected. In Âpastamba's *Dharmasûtra* (II. iv. 8, 11) it is stated that astronomy is one of the six *aṅgas* of the *Veda*. But of the character of this early Hindu astronomy we learn, what we do know, chiefly from the *Jyotisha*

[1] Strabo, *Geograph.* lib. xv. cap. i. § 70 (Casaub. p. 719); conf. Lassen, *Rhein. Mus. für Phil.* Bd. I. S. 183, and *Ind. Alterthumsk.* (2nd ed.), Bd. I. S. 1002 n.; Weber, *Hist. Ind. Lit.* p. 28.

Vedaṅga of the *Yajur* and *Rigveda*, from which it seems to have been mainly concerned with the lunar motions,[1] connected as they were with the proper times for sacrificial acts, and otherwise to have been of a very elementary and chiefly astrological nature.[2]

3. It is now generally conceded that Hindu astronomy, as we know it, has been originally based on that of the Alexandrian Greeks, who had brought the study with them from the Ionian lands, where it had been early cultivated by Thales (*cir.* B.C. 636–570) its founder; by Anaximander (610–547), who declared the earth moved round its axis, that the moon reflects the sun's light, invented the gnomon, observed the solstices and equinoxes, measured the obliquity of the ecliptic, noted the morning setting of the Pleiades on the twenty-ninth day before the equinox, and made the first geographical charts; by Pythagoras (*cir.* 570–490 B.C.); by Anaximenes (*cir.* 550–470), who taught gnomonics; and by Anaxagoras (499–427), who ascribed the cosmical adjustments to intelligent design. Eudoxos of Knidos (*cir.* 370 B.C.) introduced the sphere, described the two colures, observed and recorded the places of fixed stars, and determined the tropical year at 365$\frac{1}{4}$ days. Phaenos, Euktemon, and Meton (B.C. 432) observed the solstices, laid down the places of the four tropical circles, and introduced the cycle

[1] See Prof. Weber's paper *Über den Veda Kalendar, Namens Jyotisham,* (*in Abhandlung. d. Königl. Akad. der Wissensch. zu Berlin*, 1862) and an important paper by Dr. Thibaut in *Jour. As. Soc. Beng.* vol. xlvi. (1877), pt. i. pp. 411–437, cited below, § 34.

[2] Dr. Rhys Davids has called my attention to the following passage in the *Tevijja Sutta*, Mahâ-Sîlaṁ, 4: "Or, whereas some Samaṇa-Brâhmans, who live on the food provided by the faithful, continue to gain a livelihood by such low arts and such lying practices as these: that is to say, by predicting—'There will be an eclipse of the moon.' 'There will be an eclipse of the sun.' 'There will be an eclipse of a planet.' 'The sun and the moon will be in conjunction.' 'The sun and the moon will be in opposition.' 'The planets will be in conjunction.' 'The planets will be in opposition.' 'There will be falling meteors, and fiery coruscations in the atmosphere,' etc. . . . He [the recluse] on the other hand, refrains from seeking a livelihood by such low arts, by such lying practices."—See the whole passage in Rhys Davids' *Buddhist Suttas* (*Sacred Books of the East*, vol. xi. pp. 197–8). The work is supposed to be an early one in Buddhist literature and the reference it contains, condemnatory of the practices of astrology, is of interest. It reminds us of "the dividers of the heavens, the star-gazers, the monthly prognosticators" of ancient Chaldea (*Isaiah*, xlvii. 13).

of 19 years and 235 lunations. Plato proposed the representation of celestial motions by circles, which has been so prolific of scientific results. Aristotle wrote a work on astronomy, now lost. Kallippos (B.C. 330), who helped Aristotle in his investigations, proposed the Kallippic period of 76 years, consisting of 27,759 days and 940 lunar months, and wrote on the heliacal risings of the planets. Autolykos wrote two works—the earliest that have come down to us—on the motion of the sphere, and the risings and settings of the fixed stars; they had been translated into Arabic, but are as yet unpublished in Greek. Eudemos, a disciple of Aristotle's, wrote on the history of astronomy, but we know only that he stated in it that the axes of the ecliptic and equator are 24° distant. Aristarkhos, of Samos (*cir.* 275 B.C.), seems to have held that the earth revolves round the sun—a hypothesis which has also been ascribed to Philolaos (*cir.* 430). Pytheas of Massilia, and Artemidoros of Ephesos, contributed to the study; and Euclid, in his *Phainomena*, gives twenty-five propositions on the doctrine of the sphere. Aratos (*cir.* 270) wrote a poem—the *Phainomena*, based on the earlier prose works of Eudoxos, and supplying a popular introduction to a knowledge of the stars, and of the circles of the sphere, with rules for the risings and settings of the constellations, etc. Eratosthenes (B.C. 276–196) measured the obliquity of the ecliptic at 23° $51\frac{1}{3}'$, and made the first scientific attempt to determine the magnitude of the earth and the distance of the sun.[1] Hipparkhos, of Bithynia (*cir.* B.C. 160–120), "the lover of truth and labour," made his observations at Rhodes, but except his commentary on the poem of Aratos, all his works have perished, and it is to Ptolemy, his great admirer, that we owe our information as to the extent and importance of his researches: to him

[1] He seems to have considered the measurements made for the earth's circumference as only approximate, and put it at 250,000 or 252,000 stadia. The distance of the sun he made 804,000,000 stadia; but what stadium did he use? If $8\frac{4}{7}$ stadia be taken as equal to an English mile, then the first would be 29,200 miles, and the sun's distance 93,800,000 miles: not very far from the truth.

is due the reconciliation of observation and theory, the precession of the equinoxes—which he estimated at 48″ per annum—and the distinction between the sidereal and tropical motions. After him, Geminos, Kleomedes, Theodosios, Menelaos, Hypsikles, Strabo, Cicero, Hyginos, and Pliny all bear testimony to the continuity of astronomical research down to the time of Klaudios Ptolemy (*cir.* 100–160 A.D.), whose *Syntaxis*, with the commentary on it by Theon, was so long the standard text-book on the subject. This position it probably owed in a large measure to its comprehensive character and the great mathematical merits of his methods. Later astronomical writers we know there were: indeed it would be absurd to suppose that the science should have suddenly stopped short on the publication of a great work, which suggested so many matters for investigation, especially by further observations; and we know that even as late as the fifth century, Ammonios was taking observations of the places of the stars. Smaller works, containing important corrections of the elements, would have little chance of long surviving in competition with so masterly and complete a work as Ptolemy's, even although his constants were known to be somewhat inaccurate. Whatever works of the kind may have been published, however, have been lost—destroyed, probably, in the fourth and seventh centuries, when the Alexandrian libraries perished. They would naturally be small handbooks for popular use, containing constants and rules, similar to the Hindu *Karaṇas*, and it is not altogether impossible that the original *Pauliśa Siddhânta* may have been a translation of one of them.

How far, however, during the first five or six centuries of our era, such works of the later Greek astronomers reached India, we shall never probably know for certain. We do know this, that the terms and methods of the Hindu *Siddhântas* are so evidently borrowed from Greek sources, that, apart from the admissions in some of these works respecting the teaching of the Yavanas, there could be no doubt as to their source.

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4. The Greek astronomers sought for a period in which different planetary revolutions were completed. The use of this *exeligmos* or period of evolution[1] is a marked feature in the Hindu astronomy also. Their later and usual *exeligmos*, however, is a much longer one than any we know of the Greeks having used:[2] it is the *Mahâyuga*, *Chaturyuga*, or simply *Yuga* of 4,320,000 sidereal years; still later works employ also the *Mahâkalpa* of 1000 *Chaturyugas*. In terms of one or other of these periods nearly all astronomical elements or revolutions are expressed in whole numbers—the number of days, revolutions of the moon and planets, of their nodes and apsides, etc. These constants supply the place of tables for each *Siddhânta*; they are not too numerous for a person frequently using them to retain in his memory, and nearly all computations can be performed by means of them and a short table of sines. This exactly suited the convenience of the Brâhmaṇ Jyotishas. The different *Siddhântas*, too, are readily recognized by the various values given to these elements: thus, the number of days divided by the years in the

[1] The astronomical use of the word ἐ̆ξελιγμὸς is not given in Liddell and Scott's *Lexicon*. Ptolem. *M. Syntaxis*, lib. iv. cap. 2; Geminos, *Eisag. eis ta Phainom.*

[2] Censorinus (A.D. 238) has the following passage (*de Die Natali*, cap. xviii. ed. Nisard, p. 377), to which my attention has been called by Prof. H. Jacobi, of Bonn: "Est præterea annus, quem Aristoteles maximum potius, quam magnum, adpellat: quem solis, lunæ, vagarumque quinque stellarum orbes conficiunt, cum ad idem signum, ubi quondam simul fuerunt, una referuntur, cuius anni hiems summa est κατακλυσμὸς, quam nostri diluvionem vocant; æstas autem ἐκπύρωσις, quod est mundi incendium. Nam his alternis temporibus mundus tum exignescere, tum exaquascere videtur. Hunc Aristarchus putavit esse annorum vertentium duum millium CCCCLXXXIV; Aretes Dyrrachinus quinque millium DLII; Heraclitus et Linus decem millium CC∞ (10,800); Dion X.M.CC∞ XXCIV (10,884); Orpheus CMXX (120,000); Cassandrus trecies sexies centum millium (360,000). Alii vero infinitum esse, nec unquam in se reverti existimarunt."

Here we have a fair counterpart of the Hindu theory of *Yugas*; and, as Prof. Jacobi also points out, so far, at least, as Aristotle is concerned, Usener has shown (*Rheinische Museum*, Bd. xxviii. Ss. 392 f.) that the statement of Censorinus is correct. The *annus maximus* of Aristotle is mentioned by Tacitus (*Dial.* 16, in ed. Nisard, p. 481): "Ut Cicero in Hortensio scribit, is est magnus et verus annus, quo idem positio cœli siderumque, quæ quum maxime est, rursum existet, isque annus horum quos nos vocamus annorum XII M.DCCCCLIV (12,954), complectitur." In this period a precession of 50″·023 annually would carry the equinoctial points round just 180°.

exeligmos gives the length of the sidereal year for each authority. Thus :

	Days in a *Yuga*.		Year. *d.*	*h.*	*m.*	*s.*
Romaka Siddhânta	1,577,865,600	or	365	5	55	12.
Laghu Ârya Siddhânta	1,577,916,450	„	365	6	12	30.
Parâśara Siddhânta	1,577,917,570	„	365	6	12	31·50.
Pauliśa Siddhânta	1,577,917,800	„	365	6	12	36.
Sûrya Siddhânta	1,577,917,828	„	365	6	12	36·56.
Second *Ârya Siddhânta*	1,577,917,542	„	365	6	12	36·84.
Brahma Siddhânta	1,577,816,450	„	365	6	12	9.
Siddhânta Śiromaṇi	1,577,916,450	„	365	6	12	9.
Modern Science	1,577,907,465	„	365	6	9	9·3.

By comparison with the last it will be seen that all the Hindu values are too large, except that given by the *Romaka Siddhânta*, which coincides exactly with Ptolemy's value for the tropical year, and is too small for the sidereal one; Ptolemy's sidereal year was of 365*d.* 6*h.* 9*m.* 48·59*s.* The *Yuga*, or divisor, it will be noted, being the product of the factors—60, 60, 60, and 20, is an exceedingly convenient one in a system where the sexagesimal subdivision is applied throughout to every element.

5. Curiously enough the first definite information respecting the Hindu system of astronomy, came to Europe from Siam, where, in the early centuries of our era, there was a flourishing Hindu state. In 1687 Louis XIV. sent M. de la Loubére on an embassy to Siam, and he brought back with him a portion of a manuscript containing rules for computing the places of the sun and moon. This was submitted to the celebrated John Dominic Cassini, the Italian astronomer, whom Louis had brought to Paris to take charge of his observatory. In his hands the calculations described, without indication of the meaning of the constants employed, were lucidly explained. His memoir was published in 1691, in De la Loubére's *Relation de Siam* (tome ii.), and afterwards reprinted with other papers by Cassini, in the eighth volume of

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the *Mémoires de l'Academie Royale des Sciences*, for 1666 to 1699 (pp. 279–362).

6. Cassini's principal deductions from the Siamese manuscript were—(1) That the sidereal year employed was of 365*d*. 6*h*. 12*m*. 36*s*., being the 800th part of 292,207 days; (2) That the epoch of the constants was Saturday, 21st March, 638 A.D. at new moon (the mean conjunction occurring at Siam about 3*h*. 15*m*. A.M.) and when there was a considerable eclipse of the sun at 5*h*. 19*m*. P.M.,[1] which eclipse, however, could not have been visible to the east of Orissa; (3) That since a correction to that effect is applied to the results, the rules and data were originally arranged for a place about 18¼° to the west of Siam: this he conjectures to have been "Narsinga,"[2] which Bailly places "in Orissa" in lat. 17° 22′ N., that is, about Piṭṭapuram in the Godâvarî district; but Bailly suggests Benares as a more probable place, and "having about the same longitude";[3] (4) That at the epoch the sun's apogee was at 20° of Cancer, and the moon's at 21° of Capricorn; (5) That to the revolution of the moon's apsis a period of 3232 days was allowed; (6) That the greatest equation of the centre for the sun was 2° 12′, though he gives a short table from the manuscript on the same page, which states it at 2° 14′, while Bailly, professing to quote Cassini's figures, says[4] he found it to be 2° 10′ 32″—which is the value assigned in the *Sûrya Siddhânta*, and which Bailly himself had obtained from another Indian work.[5] The moon's greatest equation of the centre Cassini found to be 4° 56′; (7) That the civil year began with the month of Kârttika; (8) And that the constants employed made the artificial day or *tithi*

[1] I have revised the times from modern tables, assuming the longitude of Siam at 6*h*. 42*m*. E. from Greenwich; Cassini (*Mém. de l'Acad.* tome viii. p. 311) adopted 6*h*. 34*m*. E. from Paris, which is only 1½*m*. in excess of this.

[2] *Mém. de l'Acad.* 1666–1699, tome viii. p. 309.

[3] *Astron. Indienne et Orientale*, p. 12.

[4] *Astron. Indienne*, pp. viii. 7, 44.

[5] *Mém. de l'Acad.* tome viii. p. 304.

bear to the civil or natural day the ratio of 692:703; hence 703 lunar months are equal to 20,760 days, and the synodical month was 29*d.* 12*h.* 44*m.* 2·39*s.*; and as 228 solar months were made equal to 235 lunar ones, he concluded that in 13,357 years there are 165,205 lunar months and 487,860 days, whence he deduced a tropical year of 365*d.* 5*h.* 55*m.* 13·77*s.*, or almost exactly the same as Ptolemy's value.

7. With respect to these results, it may be noted—(1) That the sidereal year of 365*d.* 6*h.* 12*m.* 36*s.* is exactly that of the now missing *Pauliśa-Siddhânta*, and, from Al-Berûnî's account of it, we learn that it used the same numbers as the Siamese to determine the year, viz. 292,207 days as the measure of 800 years.[1] (2) The ratio of the *tithi* to the natural day is a usual approximation in Hindu astronomy, giving 1 *kshaya tithi* in $64-\frac{1}{11}$ or $63\frac{10}{11}$ days.[2] (3) But the ratio of 228 solar months (6939·9165 days) as equal to 235 lunar months (6939·6871 days), is introduced in the computations only where so close an approximation could produce no sensible error in the results; and Cassini has, perhaps, been misled here by the natural supposition that a tropical year must be as material an element in Hindu as it is in European astronomy. (4) From Al-Berûnî, again, we learn that Puliśa assigned 488,219 revolutions of the moon's apsis to a *Chaturyuga*,[3] or almost exactly 3232 days to a revolution. We might infer, then, that the other elements used were also taken from the *Pauliśa-Siddhânta*—that the lunar month, for example, was of 29*d.* 12*h.* 44*m.* 2·75*s.*—but that they had been engrossed in a *Karaṇa* for the calculation of horoscopes and almanacs. This points, however, to Siam and the Eastern Peninsula as a promising field of search for the

[1] Al-Berûnî's *India*, Sachau's transl. vol. ii. p. 58; see below § 38.

[2] Wilkinson's *Siddhânta S'iromaṇi*, *Golâdhyâya*, iv. 12, where it is misprinted $64\frac{1}{11}$ for $64-\frac{1}{11}$; conf. also Al-Berûnî's *India*, Sachau's tr. vol. ii. pp. 37, 47, 52, and 54.

[3] Al-Berûnî's *India*, vol. ii. p. 18; the exact value with this element is 3231·98752 days, the difference between this and 3232 days amounts only to one day in 80·2 revolutions, or 686 years.

Pauliśa[1] and possibly others of the *Siddhântas* that have been lost in India.

8. The next contribution to our knowledge of this subject is to be found in an appendix to the *Historia Regni Græcorum Bactriani* of T. S. Bayer (1694–1738), and is titled "Christophori Theodosii Waltheri *Doctrina Temporum Indica ex libris Indicis et Brahmanum institutione, A.C. cIↄIↄccxxxiii Trangambarae digesta, simul cum Paralipomenis recentioribus.*"[2] The author remarks that Ptolemy alone divided the day into sixty parts, as the Hindus do, and these again sexagesimally. He cites the Hindu divisions of time from Amarasiṁha; gives the names of the nine *graha* in Sanskrit and Tamil; of the days of the week; of the months; the signs of the zodiac; the *nakshatras*, *yogas*, *karaṇas*; of the *tithis* in Sanskrit, Persian, and Dekhani; and an account of the *yugas*, and of the *Panchâñga* or kalendar. To this curious tract is added a long note by Leonard Euler on the Hindu year of 365*d.* 6*h.* 12*m.* 30*s.*

9. Beschi had also given some account of the Indian almanac in his Tamil Grammar, published in 1738;[3] but no contribution of real importance to Hindu astronomy was made for about eighty years after Cassini's paper. M. Le Gentil had gone to Pondicheri, however, to observe the transit of Venus in 1769, and he remained there for twenty-three months busying himself in acquiring some further knowledge of Indian astronomy, which he communicated to the Academy of Sciences in a *Mémoire* presented early in 1773.[4] It is amusing to read his prefatory remarks on the prejudices of the Brahmans, whose conduct he compares to that of the Egyptian priests, as described by Strabo.[5] He succeeded, however, in obtaining

[1] This portion of the paper was written before Thibaut's *Pañchasiddhântikâ*, of Varâha Mihira, reached this country. It contains an outline of the *Pauliśa Siddhânta*.

[2] Petropoli, 1738.

[3] Beschi (†1742) also published *Tiruchabei Kanidam*, a Tamil work on astronomy.

[4] *Histoire de l'Academie Royale des Sciences*, 1772, 2nde Partie,—*Mémoires*, pp. 169–189; suite, pp. 190–214, 221–266.

[5] *Ib.* pp. 169, 170; conf. Strabo, *Geog.* lib. xvi. c. i. § 20, ed. Casaub. p. 805.

a good deal of information from these contemned Brahmans. He gives a pretty full account of the principal elements and the methods of computation, with the tables used. These are based on the *Laghu Ârya-Siddhânta*, which is generally employed in the south of the Madras Presidency. In a continuation of this *Mémoire*,[1] he gives in full the computations of eclipses, both of the sun and moon, according to what is known as the Vâkyam process,[2] in use among the Tamil Jyotishas. The processes were adapted to the position of Trivalur (long. 79° 8′ E. lat. 10° 44′ N.). They had been derived from others, probably originally having the epoch of A.D. 499, but adapted to 1413. The constants, tables, and processes are exactly those employed by Warren in his account of the same operations.[3] The period of the revolution of the moon's node is 6792·36 days, the equation of the sun's centre (deduced by Bailly) was 5° 1′ or precisely that of Ptolemy and the Persian astronomers;[4] and the equation of the sun's centre was that of the *Sûrya Siddhânta*. Le Gentil also gives the lengths of the different solar months according to the *Laghu Ârya-Siddhânta.*

The arrangement of the planetary names of the week-days he considered singular, as Sukravâra was reckoned as 0, and passing to Sanivâra as 1,[5] not noticing that the names are arranged just as in the Roman kalendar, and the numerals attached are determined by the epoch of the Kaliyuga being Friday. He got the names of the 27 *Nakshatras*, and with the help of his paṇḍit, he gave a representation of twenty-four of them, with approximate identifications of the principal stars in the different groups[6] —being the first attempt of the kind. But sickness interrupted these studies. The numbers of stars, forming several of the groups which he gives, differ from the usual

[1] *Mém. de l'Acad.* pp. 221 ff.
[2] See Warren's *Kala Saṅkalita*, p. 118, etc. Probably this was the method of the *Pauliśa Siddhânta.*
[3] *Kala Saṅkalita*, pp. 118 ff. 340, and Tables xxvi. ff.
[4] *Astron. Indienne*, pp. 87, 245.
[5] *Mém. de l'Acad.* 1772, pt. ii. pp. 187, 188.
[6] *Mém.* ut sup. pp. 209 ff.

lists, many containing more stars than are generally assigned to them; but whether this is entirely due to his paṇḍit's teaching or not is uncertain. He mentions that at Benares and in Bengal a method called "sittandum" was in use;[1] this is probably connected with Beschi's "sittandij," and with a year of 365*d.* 6*h.* 12*m.* 36*s.*,—the same as is employed in the *Pauliśa Siddhânta.*[2]

10. Le Gentil's examples of the computations, with his explanations, made the methods clearly intelligible. They attracted the attention of the brilliant but unfortunate Jean Sylvain Bailly (1736–1793), and he was so carried away by the new study that he stretched his ingenuity to reconcile the data of Indian astronomy with the results of the most advanced knowledge of his day. He considered that it had been founded on accurate observations made thousands of years B.C.; and that it had been the source of the Greek science, only Ptolemy had altered its results for the worse.[3] In 1787 he published his *Traite de l'Astronomie Indienne et Orientale*—a quarto, of over 600 pages, intended to form the second volume of his History of Ancient Astronomy. In this he discussed anew the

[1] *Mém. de l'Acad.* p. 221.

[2] The word (except *Sittandij*, as used by Beschi) seems to have been unknown to Warren; conf. *Kala Saṅkalita*, pp. 7, 51–56, 83, Le Gentil says it means 'ancient,' and *Vâkyam* means 'new'; but his meanings and derivations are not to be trusted—*Kaliyuga*, for example, he says is from *Kaly* an 'epoch,' and *ugam* 'misfortune'! *Sittandij* is probably a Dravidian derivative of *Siddhânta*, i.e. following the Siddhânta rules; conf. Waltheri, *Doctr. temp. Indica*, in Bayeri, *Hist. Reg. Græc. Bactriani*, pp. 184, 198.

[3] Bailly, *Astron. Ind.* p. 296:—"L'antiquité des Chaldéens n'auroit pas suffi aux 2500 ans. La plus ancienne date des Chaldéens en Astronomie est de l'an 2234 avant notre ère, 2100 ans. environ avant Hypparque. D'ailleurs j'ai remarqué plus haut que les observations d'éclipses, du moins les observations exactes, ne paroissent pas remonter à Babylone au-delà de Nabonassar; il faut donc que ces observations aient été faites ailleurs, et on ne peut guères se refuser à croire qu'elles ont été faites dans l'Inde où les Chaldéens semblent avoir emprunté les premiers éléments de leur Astronomie." And, p. 300,—"Il semble que ce n'est point sur une suite d'observations d'éclipses qu' Hypparque à établi la période de 126,007j. 1h., mais sur les Tables indiennes. Il en résulte par consequent que les Astronômes d'Alexandrie tiennent des Indiens les connoissances primitives et fondamentales de la théorie de la lune." See also pp. 303, 306, etc.

M. Bailly's attempt in behalf of the originality of the Hindu astronomy has found almost a parallel in the *Uranographie Chinoise* of M. Gustave Schlegel (La Haye, 1875), in which the author attempts to prove that the early astronomy is originally Chinese, and has been imported by Chaldeans, Greeks, Indians, etc., from China.

information published by Cassini and Le Gentil, together with two other manuscripts that had been received from India by the astronomer, M. Joseph de Lisle (1688–1768). The first of these had been sent from India in 1750 by the Père Patouillet, and was headed "Panchânga Śiromaṇi,"[1] the other had also been obtained in 1750 by Père Xavier du Champ, S.J., and sent from Pondicheri to Père Gaubil, in China, and by him transmitted to M. de Lisle in 1760. The latter were said to come from Kṛishṇâpuram, a place located by D'Anville in long. 75° 10′ or 75° 15′ E.[2] from Paris, lat. 14° 30′ N. But from the length of the shadow of the gnomon, Bailly derived a latitude of 16° 16′, which[3] would place it near the Kṛishṇâ; he suggests Masulipatnam or Narsâpur. The epoch he derived was 10th March, 1491, but the constants had been derived from others whose epoch was A.D. 499; the equations of the sun and moon were those of the *Sûrya-Siddhânta;* and tables[4] were added identical with those afterwards published by Davis and Warren. Calculations of the lunar eclipse of 29th July, 1730, the places of Jupiter and Mercury for the same date, and of the solar eclipse of 4th July, 1731, were given in full.

The tables procured by M. Patouillet were called by Bailly those of "the Brahmans of Narsâpur,"[5] though he

[1] *Astron. Ind.* pp. iii. xi. 49 and 391.

[2] *Ib.* pp. 31, 32 ff. 317 ff. 319 n. There is a small village of the name in long. 77° 40′ E. lat. 14° 30′ N. about twelve miles south of Anantapur; but there are several other Kṛishṇapurams, one in N. Arkaḍ, long. 78° 28½′ E., lat. 12° 53′ N.; another on the Kṛishṇâ, long. 79° 16′ E., lat. 16° 21′ N.; a fourth in Trichinapalli, long. 78° 51′ E., lat. 11° 23′ N.; a fifth on the Kâverî, long. 77° 1′ E., lat. 12° 13′ N.; a sixth in Tinnevelli, long. 77° 51′ E., lat. 8° 41′ N.; a seventh in Travankoḍ, long. 76° 35′ E., lat. 9° 9′ N. It is very unlikely that the tables of P. DuChamp came from the first, as Bailly assumes, simply because it is the only Kṛishṇapuram on D'Anville's map.

[3] *Ib.* p. 32.

[4] *Ib.* pp. 336, 337.

[5] Here, again, we have no definite locality, for there are several towns of the name of Narsâpur, and others named Narsipur. Narsâpur in long. 73° 28′ E., lat. 18° 59′ N.; another in long. 78° 19′ E., lat. 19° 2′ N.; a third in long. 83° 41′ E., lat. 18° 35′ N.; and a fourth in long. 81° 44′ E., lat. 16° 26′ N.; and a fifth in long. 79° 1′ E., lat. 15° 4′ N., which is perhaps meant by Bailly. Narsipur in long. 76° 18′ E., lat. 12° 47′, a pretty large town on the Hemâvatî in Maisur; another in long. 78° 4′ E., lat. 13° 8½′ N.; a third on the Kâverî in long. 76° 58′ E., lat. 12° 12′ N.; a fourth in long. 81° 50′ E., lat. 16° 21′ N., etc.

suggested that they might come from Narasiṁhapur "under the same meridian as Benares,"[1] and further concludes that the original of these, and also of the Siamese ones, must have come from Benares. Their epoch he computed to be 1569 A.D., but of some elements 1656,[2] and that they were based on the Kṛishṇâpuram data. The year was of 365*d.* 6*h.* 12*m.* 30*s.*; the greatest equation of the sun's centre was 2° 10′ 34″, and of the moon's 5° 2′ 26″, and tables of their values for every degree of anomaly were given. Bailly also added an account of a diagram that had been sent by M. d'Hancarville, who had obtained it through Mr. Broughton-Rouse, giving the Hindu scheme of the solar system, with the diameter of the earth put down as 1600 *yojans,* and the circumferences of the orbits of the moon, sun, and planets, as they are given in the astronomical works. In this scheme the circumferences, that is, the distances, are made proportional to the times of revolution of each planet,[3] the distance of the moon being approximately determined, as it had been by the Greeks,[4] and the planets arranged on the supposition that they all have the same velocity.

Bailly's work at once attracted the attention of European astronomers and mathematicians. Even Laplace

[1] The longitude of Benares is 83° E. from Greenwich: which Narasiṁhapuram he means is uncertain.

[2] *Astron. Indienne*, pp. 49, 55, 60. The *Graha Lâghava*, according to Warren (*Kala Sankalita*, p. 365), was written about 1556 A.D., but Whitney says it was the composition of Ganeśa, and dated S'ake 1442 (A.D. 1520). The *Siddhânta Sundara* of Jñânarâja also belongs to the beginning of the sixteenth century. The *Siddhânta Rahasya* was written in S'. 1513 (A.D. 1591); Ranganâtha completed his commentary on the *Sûrya-Siddhânta* in S'. 1525 (A.D., 1603); and his son Muniśvara wrote the *Siddhânta-Sârvabhauma* and a commentary on the *Siddhânta-S'iromaṇi* of Bhâskara-Âchârya. The *Graha Taraṅgini* was written in 1618, the *Siddhânta Manjari* in 1619, and Kamalâkara wrote the *Siddhânta Tattva-Viveka* about 1620 (*Jour. Amer. Or. Soc.* vol. vi. p. 422). It thus appears that during the century 1520–1620, after intercourse with Europe had been established, there was considerable activity in the compilation of new astronomical text-books.

[3] *Astron. Ind.* pp. 204 f.; Burgess' *Sûrya-Siddhânta*, xii. 80–90: Al-Berûnî's *India* (Sachau's tr.), vol. ii. pp. 67–73; Gladwin's *Âyin-Akbari* (8vo. ed.), vol. ii. p. 306; also Bâpu Deva S'âstri in *Trans. Benares Institute*, 1865, pp. 18–27.

[4] Ptol. *Syntaxis*, lib. v. cap. xv. and *Arkhai* (ed. Halma, *Hypoth*, etc.), p. 61.

was at first carried off by the ingenious exposition; and, having discovered the long inequality in the motions of Jupiter and Saturn, he wrote, in 1787:[1] "I find by my theory, that at the Indian epoch of 3101 years before Christ, the apparent and annual mean motion of Saturn was 12° 13′ 14″, and the Indian tables make it 12° 13′ 13″. In like manner, I find that the annual and apparent mean motion of Jupiter at that epoch was 30° 20′ 42,″ precisely as in the Indian astronomy." The scholarly Professor John Playfair, of Edinburgh University, wrote an eloquent paper in exposition of Bailly's views, which appeared in the *Transactions of the Royal Society of Edinburgh* in 1789.[2]

11. In the same year, Mr. Samuel Davis, having, through Sir Robert Chambers (1737-1803), obtained a copy of the *Sûrya-Siddhânta*, contributed an excellent analysis of that work, with extracts from a commentary on it, referring to the *Brahma Siddhânta* contained in the *Vishṇu-Dharmottara Purâṇa*, and mentioning the *Paulastya*, *Soma*, *Vasishṭha*, *Ârya*, *Romaka*, *Parâśara*, and *Ârsha Siddhântas*, the *Graha Lâghava*, the *Sâkalya Saṁhita*, the *Siddhânta Rahasya*, the tables of Marakanda, and other astronomical works,—thus bringing to notice a considerable literature on the subject previously unheard of.[3] Mr. Davis seems, however, to have believed that the obliquity of the ecliptic must have been observed when it was actually 24°, which he reckoned had been the case about 2050 B.C.[4] Bailly had already applied LaGrange's latest formula to show that Aristarkhos (B.C. 280) was in error in making it so much in his time, but that about 4300 B.C. it was of this amount, and must have been so observed by the Brahmans at that date.[5] How the latter could observe to a second—while Aristarkhos, Eratosthenes, Hipparkhos, and Ptolemy confessed their instruments were not sufficiently delicate to

[1] *Esprit des Journeaux*, Nov. 1787, p. 80.
[2] *Trans. R. Soc. Edinb.* vol. ii. pp. 135–192.
[3] *Asiat. Res.* vol. ii. pp. 225–287.
[4] *Asiat. Res.* vol. ii. p. 238.
[5] *Astron. Ind.* pp. xli. xlii. 165, 166.

observe to within less than 5′ or 6′—does not seem to have occurred to Messrs. Bailly and Playfair to explain. In remarking on the distance of 51,570 *yojans* ascribed to the moon, Mr. Davis deduces from it an absolute distance of 220,184 geographical miles, noting that this is nearly the truth,[1] but he overlooks the fact that this is 64½ times the radius of the earth, whereas Ptolemy had determined her distance in apogee at 64 radii, while he made her mean distance 59 radii, or within $\frac{1}{60}$ of the truth. The fact, which Davis noted, that the precession of the equinoxes is treated as a libration in the *Sûrya-Siddhânta*,[2] might have cautioned him against supposing the system could have originated before the present *pâda* of such a precession began. Mr. Davis's paper, however, was the first analysis of an original Hindu astronomical treatise, and was a model of what such an essay ought to be.

12. Davis's essay was immediately followed up by the versatile Sir William Jones, who, following Bailly, tried to defend the originality of the Hindu Zodiac[3]—a thesis that has since been more seriously debated. Soon afterwards he followed this by another paper, being a continuation of a previous one on Indian Chronology, and suggested by a passage from the *Varâha-saṁhita*, cited by Mr. Davis.[4] In it he concluded that as the equinoctial points were stated to have been at one time in Mesha and Tula, there must have been observations of this fact, and these could only have been made about 1181 B.C., and hence that Parâśara—whose authority was cited for this—must have flourished within twelve centuries before Christ. He further replies to Bailly's question why the Hindus counted the precession as beginning from A.D. 499, by admitting the erroneousness of the theory that this motion was a libration.[5]

[1] *As. Res.* vol. ii. p. 262. Pandit Bâpu Deva S'âstri gives the distance of 51566 yojanas as equal to 468,780 miles: *Trans. Benares Institute*, 1865, p. 21.
[2] *Ib.* pp. 266, 270; Burgess' *Sûrya Siddhânta*, iii. 9–12 and notes.
[3] *Ib.* vol. ii. pp. 289–306.
[4] *Ib.* pp. 389–403.
[5] The Hindu astronomers teach "that the vernal equinox oscillates from the third of Mîna to the twenty-seventh of Mesha and back again in 7200 years;

13. In 1790, William Marsden (1754–1836) contributed to the *Philosophical Transactions*[1] a paper "On the Chronology of the Hindus." Written in London, without access to original sources, however, it was hardly to be expected that even so able an orientalist as its author was, should add materially to the information already published. He called in question Bailly's assumption that a conjunction of all the planets was actually observed at the epoch of the Kaliyuga, B.C. 3102,[2] pointing out how widely miscalculated the places of some of them had been for that epoch. In his account of the cycle of sixty years, Marsden's information being only from Southern India,[3] he was misled by it to suppose that the Bârhaspati saṁvatsara coincided with the common year;[4] and this mistake attracted the attention of Mr. Davis, who contributed his second paper, in 1791,[5] expounding this cycle of sixty years from the *Sûrya-Siddhânta*, with references to Âryabhaṭa, Varâha Mihira, the *Jyotistattva*, and *Siddhânta Śiromaṇi*. In this paper, which showed like ability with the former, he gave the first account of the twelve-year cycle of Jupiter, as mentioned by Varâha Mihira.

14. Mr. Davis pointed out that the rule given in the *Jyotistattva* and by Varâha Mihira for determining the years of the Bṛihaspati-chakra is based on the constants of the *Arya Siddhânta*.[6] The years of this cycle are measured by the mean motion of Jupiter through one sign or 30°

which they divide into four *pâdas*, and consequently that it moves, in the two intermediate *pâdas*, from the first to the twenty-seventh of Mesha, and back again, in 3600 years; the colure cutting their ecliptic in the first of Mesha, which coincides with the first of Aświnî, at the beginning of every such oscillatory period." *Ib.* p. 392, also pp. 394 and 398.

[1] *Phil. Trans.* vol. lxxx. pt. ii. (1790), pp. 560–584.

[2] His principal authorities seem to have been Beschi's *Tamil Grammar* (1738); Abraham Roger's *Mœurs des Brames* (1670); and Bailly's *Astron. Indienne*, p. 326.

[3] *Astron. Ind.* pp. xxviii. 184, etc.

[4] *Phil. Trans.* vol. lxxx. pt. ii. p. 583.

[5] *Asiat. Res.* vol. iii. pp. 209–227.

[6] *Asiat. Res.* vol. iii. pp. 215, 219; Varâha Mihira makes the fraction $\frac{8589}{3750}$, the equivalent of 8° 42′·72 of Jupiter's motion, which takes place in 104·840987 days (*J.R.A.S.* N.S. Vol. V. p. 48). Varâha's is the only rule known by Al-Berûnî (A.D. 1030); *India*, (ed. Sachau), vol. ii. p. 123.

of mean heliocentric longitude, being a little over 361 days.[1] The rule is expressed by the formula—

Jupiter's mean place (in signs) for S elapsed (Śaka) sidereal

$$\text{years} = S + \frac{22\,S + 4291}{1875}.$$

Hence, for the commencement of the Śaka era, or when $S = 0$, we have for the mean place—

$$\frac{4291}{1875} = 2 + \frac{541}{1875} = 2^{\text{signs}}\ 8^\circ\ 39'\ 31''\cdot 6.$$

That is, 2 signs (or 2 years of the cycle) had elapsed and 8° 39′ 21″·6 of the third year, Śukla. Now the *Ârya Siddhânta* value for the cycle year is 361·022681 days for 30° of motion or 1° in 12·034089 days, so that 8° 39′ 21″·6 represents 104·16708[2] days by which the Śukla saṁvatsara had advanced when the Śaka era began.

If we adapt this formula to the Kaliyuga reckoning by putting K—3179 = S, and then add 270 revolutions or 3240 signs, to get rid of the negative quantity, we have—

$$K - 3179 + \frac{22\,(K - 3179) + 4291}{1875} = K - 1 + \frac{22\,(K - 1)}{1875} + 27.$$

This gives exactly the same results as the other formula; but K—1 might point to only 3178 years between the Kaliyuga

[1] Delambre says the Hindus knew nothing of heliocentric longitudes, *Hist. Astron. Anc.* tome i. p. 481. This is true scientifically, but the mean motion of a superior planet is its equivalent, conf. *As. Res.* vol. iii. p. 212.

[2] Warren, *Kalasankalita*, p. 203, has made a mistake in converting the fraction on the supposition that Jupiter moves through 30° only in 360 *saura* days. Both Mr. Davis and Col. Warren have rather complicated their operations by the introduction of *saura* time, which is quite unnecessary; the heliocentric longitudes saving confusion. The simple nature of the fractions will readily appear when we take the cycle year of the *Jyotistattva*, or *Ârya Siddhânta*, of 361·02268 days; $\frac{22}{1875}$ of this is 4·23600 days; and the sum of these numbers is 365·25868 days, or exactly the solar year. For the mean motion of Jupiter, also, we have 30° in one year of the cycle; $\frac{22}{1875}$ of 30° is 21′·12; and the sum 30° 21′·12 is the mean motion of the planet in one solar year.

and Śaka epochs, but really to the fact that the Hindu astronomers, when they referred the Bṛihaspati cycle back to the Kaliyuga reckoning, found that it did not commence with the Kaliyuga era. To show this:—in the last formula,[1] if we put $K=3179$, $\frac{22(K-1)}{1875}$ becomes $37+\frac{541}{1875}$, and—

$K-1$	$=3178$ solar years	1160792·0868 days.
$(K-1)+37$	$=3215$ cycle years	1160687·9197
$\frac{541}{1875}$ of 361·02268 days . .		104·1671,[2] as above.

In a *tîkâ* to the *Sûrya Siddhânta* a rule is given, modelled on the preceding, and, in fact, identical with the second form, only by substituting K for $K-1$ in the fractional part, and altering the constants to suit those of the treatise, it brings the results into accord with the proper years. Ârybhaṭa's revolutions of Jupiter were 364224 in a Mahâyuga, and $\frac{364224\times12}{4320000}=1+\frac{22}{1875}$. The *Sûrya Siddhânta* text value of 364220 revolutions, requires $\frac{364220\times12}{4820000}=1+\frac{211}{18000}$; and with the *bîja* value of 364212,—$\frac{364212\times12}{4320000}=1+\frac{117}{10000}$, as the coefficient.

The formulæ are,—(1) with the text value—

$$K+26+\frac{211K}{18000},$$

and (2) for the value corrected by *bîja*,—

$$K+26+\frac{117K}{10000};$$

[1] To bring out the exact values of the fractions in this and the other rules, we must assume that the solar and *chakra* reckoning commence from the same point, and not at 2·14757 days apart, during which Jupiter's motion would be 10′ 42″·45. The rules immediately following, however, show that the Hindu writers were not particular about even larger discrepancies in the position of the planet.

[2] If we compute by the formula with $K=3179$ complete, instead of $K-1$, we get $3\frac{563}{1875}$ signs$=3^s$ 9° 0′ 28″·8, or 3 years of the cycle and 108·4031 days expired; or a whole cycle year and 4·236 days, that is exactly one solar year, too great.

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in both of which the 26 is inserted to bring out the proper cycle year when dividing the integers of the values by 60. The actual revolutions are found by dividing $K+\frac{211K}{18000}$ by 12; for $K=3179$, we have—

$$\text{the place}=3179+37\tfrac{4769}{18000} \text{ or } 3216^s\ 7^\circ\ 56'\cdot 9,$$

or 268 revolutions $0^s\ 7^\circ\ 56'\cdot 9$. But to obtain the cycle year, reckoned from Prabhava, we add 26 to 3216, making 3242, and divide by 60, the remainder being 2 expired and Śukla current. That is, this reckoning begins with the Kaliyuga solar year, and with the 27th year of the cycle, or Vijaya.

These may be converted, to suit the Śaka reckoning, into—

$$(1)\ S+2+\frac{211S+4769}{18000};\ \text{and}\ (2)\ S+\frac{117S+21943}{10000}.$$

And, for the Vikrama saṁvat, reckoning by solar years from Mesha saṁkrânti—

$$(1)\ V+45+\frac{211V+12284}{18000};\ \text{and}\ (2)\ V+45+\frac{117V+6148}{10000}.$$ [1]

In all cases, the sum of the integers divided by 60, gives the cycles elapsed, and the *remainder* is the last elapsed saṁvatsara, or, with 1 added, it indicates the current cyclic year. The fraction is of the current sign (30°) of Jupiter's mean place.

The *Sûrya Siddhânta* values applied to $K=3179$ or $S=0$ give, as above, $2^s\ 7^\circ\ 56'\ 54''$, or 95·65202 days elapsed of Śukla saṁvatsara; and with the *bîja* formula—$2^s\,5^\circ\,49'\,44''\cdot 4$, which at the rate of 12·03449 days to 1° gives 70·14903 days previous to March 15·19*d.* A.D. 78.[2] That is, the Śukla

[1] These, for the *Jyotistattva* rule, would become $V+45+\frac{22V+1321}{1875}$.

[2] Conf. Warren's *Kalasankalita*, pp. 202–204; *Ind. Ant.* vol. xviii. pp. 198–201 and 380 f. The differences in the mean places of Jupiter for different dates

saṁvatsara began, according to the *Jyotistattva* rule, A.D. 77, Dec. 1·03*d.*; according to the *Sûrya Siddhânta* text, Dec. 9·54*d.*; and as corrected by the *bîja*, A.D. 78, Jan. 4·04*d.*

Further, the remainders in the three formulæ may be converted into civil days elapsed at the following Mesha-saṁkrânti, by multiplying the remainders by 361·0227, 361,0267, or 361·0347 respectively, and dividing by 1875, 18000, or 10000, according to the formula used.

The periods of recurrence of Kshaya saṁvatsaras is indicated by the reciprocals of the above fractions, viz. $\frac{1875}{22} = 85\frac{5}{22}$, $\frac{18000}{211} = 85{\cdot}308$, and $\frac{10000}{117} = 85{\cdot}47$ years respectively, according to the different authorities. And the fractions themselves indicate a *kshaya* saṁvatsara whenever the remainder in $\frac{22S+4291}{1875}$ exceeds 1852. Thus for Śaka 60, the fraction becomes $2\frac{1861}{1875}$, and as 1861 exceeds 1852, this indicates that a cycle year (the fourth) begins and ends in Ś. 60, and Ś. 61 will begin in the fifth of the cycle; the

may be tabulated thus (the remainder on dividing the expired cycle year by 12, giving the sign completed) :—

Years.		Cycle year expired.	Jupiter's place in the current sign.		
				Sûrya Siddhânta.	
Kaliyuga.	S'aka.		*Jyotistattva.*	Text.	With *bîja.*
3100		42	10° 50′·88	10° 10′·0	8° 6′·00
3179	0	2	8 39·36	7 56·9	5 49·74
3200	21	23	16 2·88	15 20·0	13 12·00
3751	572	40	30 0·00	29 6·1	26 36·06
4000	821	52	27 38·88	26 40·0	24 0·00
4500	1321	18	26 38·88	22 30·0	19 30·00
5000	1821	44	19 38·88	18 20·0	15 0·00
Ann. increm.		1	30 21·12	30 21·10	30 21·06

The S′. year 573, by the *Jyotistattva*, thus began with the 42nd year of the cycle; the formula of Varâha Mihira would have given 5ˢ 0° 3′·36 elapsed, making the saṁvatsara begin 0·67*d.* before the Saṁkrânti.

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fourth being *kshaya*.[1] With the other fractions, there will, according to the *Sûrya Siddhânta* text, be a *kshaya* saṁvatsara whenever the fraction $\frac{211K}{18000}$ reduced leaves a numerator greater than 17788; and with the *bîja*, when in $\frac{117K}{10000}$ the same term is greater than 9882.[2]

15. In 1792 Professor Playfair addressed to the Asiatic Society a series of six questions and remarks, on the original literature of the subject,[3] directing attention to the search for, and publication of, works on Hindu Geometry and Arithmetic; pressing the desirability of the complete translation of the *Sûrya-Siddhânta* by Mr. Davis; suggesting the compilation of a Catalogue *raisonné*, containing an enumeration and a short account of the Sanskrit books on Indian astronomy; the value of an actual examination of the heavens in company with a Hindu astronomer to determine the stars and constellations mentioned in the Sanskrit works, reminding Sir Wm. Jones of a sort of promise he had made to attempt this; and, lastly, the importance of descriptions and drawings of the astronomical buildings[4] and instruments still to be found in India.

[1] The S'aka years, in which expunged years of the Bṛihaspati chakra oocur, according to the Jyotistattva rule, are given by the formula—

$$60\tfrac{8}{22}+n\times 85\tfrac{5}{22},$$

n being any suitable integer. Thus putting $n=12$, we have—

$$60\tfrac{8}{22}+12\times 85\tfrac{5}{22}=60\tfrac{8}{22}+1022\tfrac{16}{22}=1083\tfrac{2}{22}:$$

an expunged year occurred in S'. 1083, by the *Jyotistattva* rule.

Similarly, for the rules applicable to the *Sûrya Siddhânta*, we obtain

$$(1)\ 3071\tfrac{19}{211}+n\times 85\tfrac{65}{211};\ \text{and}\ (2)\ 3076\tfrac{108}{117}+n\times 85\tfrac{55}{117},$$

for Kaliyuga dates when expunged cycle years occur, (1) according to the text, and (2) with the *bîja*.

[2] In Southern India the Saṁvatsara is made to coincide with the year beginning with Mesha-saṁkrânti, and is eleven in advance of the northern reckoning. Hence they must have coincided before the *Kshaya* saṁvatsara which occurred in S'aka 827, when, probably they began to diverge. The formula for the South Indian reckoning is (K+12)÷60, which gives the elapsed cycles and years.

[3] *Asiat. Res.* vol. iv. pp. 159–163.

[4] Sir Robt. Barker had given an account of the observatory at Benares in *Phil. Trans.* vol. lxvii. pp. 598 ff.: see also Bernoulli's ed. of Tieffenthaler's *Desc. de l'Inde*, tome i. pp. 316 f. and 347 f. for those at Jaypur and Ujjain; conf. also *As. Res.* vol. v. pp. 190–211. But little has been done since to describe oriental instruments: see *Jour. As. Soc. Beng.* vol. viii. pp. 831–838;

These questions were doubtless influential in directing the researches of Colebrooke and others immediately afterwards. In his remarks on them Sir Wm. Jones stated that he had recently received a Sanskrit work from Benares containing the names, figures, and positions of all the asterisms known to ancient or modern Hindus, not only in the Zodiac, but in both hemispheres, and almost from pole to pole. That work he had "translated with attention," and "consigned it to Mr. Davis."[1] But Davis does not seem to have utilized this translation, and Sir William died 27th April, 1794.

Professor Playfair next read a paper to the Royal Society of Edinburgh, in April, 1795, on the Trigonometry of the Brahmans, based on Davis's first essay.[2] What had most attracted Playfair's attention was the rule for the construction of the table of sines, viz.—that if 225 (the sine of 3° 45′) be divided by 225, the quotient, 1, deducted from it, and the remainder, 224, added to the first sine, we shall have the second 449, as the sine of 7° 30′; and if this again be divided by 225, and the quotient, 2, deducted from 224, already found, the second remainder added to 449 will give the third sine, 671; and so on. He pointed out that the 47th proposition of Euclid's book of *Data* was closely related to the theorem from which he thought this rule was deduced; that Ptolemy's theorem embraced Euclid's, and that the Hindu one was only a particular case of it, which had, however, been noticed first in Europe by Fr. Vieta (1540–1603) in his *Treatise on Angular Sections*. But it does not seem to have occurred to Playfair to test the Hindu rule further than was given in the statement of it. Had he done so he would have found that though it gives the first few values correctly enough, it does not hold for those farther down the table; and if a table were con-

on a Persian astrolabe, *ib.* vol. x. pp. 759–765, and vol. xi. pp. 720–722; also conf. *ib.* vol. ii. pp. 251 ff. Paṇḍit Bâpû Deva Sâstri described the Mânmandra observatory at Benares, in the *Trans. Benares Institute*, 1865, pp. 191–196.

[1] *As. Res.* vol. iv. p. 163. Mr. Davis was afterwards a Director of the Hon. E. India Co., and was the father of the late Sir John Francis Davis, Bart.

[2] *Trans. R. Soc. Edin.* vol. iv. pp. 83–106.

structed by this rule, the sine, for example, of 45° would be found to be 2423′, instead of 2431′, and the error would rapidly increase in the upper half of the quadrant. If the table had been constructed by the rule, then, evidently the sum of the sines up to any point divided by 225, and the quotient subtracted from that constant should give the difference between the last of those added and the next; thus the sum of the first sixteen sines, or to 60° inclusive, is 27,744′, and this divided by 225, gives 123 and only a small fraction; taking 123 from 225, leaves 102 as the next difference, whereas the table requires 106. Delambre also noticed the rule in 1806,[1] and showed that the divisor should not be equal to the sine of the first arc, but that for arcs of 3° 45′ it should be 233·527, and he suggested that 225 might be an error of the press. But the *Sûrya Siddhânta* directs to divide "the tabular sines in succession by *the first*," and designates the first by the words "*Tattvâśvina*,"[2] which renders any such mistake impossible. When the table had been computed by other and much simpler means, therefore, the author had noticed that such a process would answer in computing the first few sines, and inferred that it would serve for all. Had he attempted

[1] *Connaissance des Tems*, 1808, pp. 447-453; and *Phil. Mag.* vol. xxviii. (1807) pp. 18-25. Delambre computed a table of the sines for every 3° 45′ of the quadrant with 233·5 as the divisor, which agrees practically with the *Siddhânta* table; four of the sines only differing by more than half a minute from the Hindu values. Had the author of the *Siddhânta*, however, known the property used by Briggs, he would have seen that as the second differences have a constant relation to the sines, the sum of any number of sines of equidistant arcs divided by the sum of their second differences must give the constant divisor.

[2] *Tattva* stands for 25, and *aśvina* for 2, and all such numbers are written down from right to left. That the divisor should be equal to the first sine, the arcs would require to have been multiples of 3° 47′ 48″·48—values which would have been of no use in a table, even had the Hindus possessed the means of computing it. Again, the divisor 225 is correct only for multiples of 3° 49′ 13″·54 (or with the correct value of π, 3° 49′ 14″·22), which are equally unsuitable. The Hindu sines are expressed in minutes, the radius being made equal to 3438′, which gives 3·14136 for the value of π, or 57° 18′ for radius. How this value was arrived at we know not. Archimedes, about 250 B.C., had determined the ratio of the diameter to the circumference to lie between 1 to $3\frac{10}{70}$ and 1 to $3\frac{10}{71}$. These give respectively 57° $16\frac{4}{11}$′ and 57° $18\frac{13}{23}$′; and, rejecting the fraction, the latter might readily be adopted as lying *between* the limits, though very near the second.

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to compute even half the table by it, he would have found that it did not answer; and had he divided the sum of any considerable number of the tabular sines by that of their second differences, he would have obtained the correct divisor, or a very close approximation to it.[1] That he did not shows how little conception he had of the principle on which the rule is based.

16. In 1799 Mr. John Bentley prepared his first paper, *On the Antiquity of the Sûrya Siddhânta and the formation of the Astronomical Cycles therein contained.* This paper was intended to expose Bailly's assumption of the extreme antiquity and accuracy of the Hindu system and observations; and, notwithstanding other mistakes into which he fell, he fully established this point.[2] But he was misled by the statement of Śatânanda, who, in his *Bhâsvatî-Karaṇa*, calls himself the disciple of Varâha Mihira. As Śatânanda composed his work in Śaka 1021, Bentley, believing this misleading statement literally, and that Varâha Mihira was the author of the *Sûrya Siddhânta* which we now possess, ascribed the latter author and his work to the eleventh century A.D. It can hardly be said, however, that he was intentionally unfair in his discussion; his mathematical method was not unsound, but his application of it gave equal 'weights'

[1] Thus in the Hindu table the sum of the sines of 23 arcs is 50795, and of the second differences 218; and dividing the first by the second we have 233 as the approximate value. Had the sines been calculated to decimals we should have 50791·01 ÷ 217·495 = 233·527; and for the 24 arcs 54229 ÷ 232·217 = 233·527—both correct to the third place of decimals. By modern tables we get the true value thus:

$2(1-\cos. 3^\circ 45') = 4 \sin^2 \frac{3^\circ 45'}{2} = \cdot 0042821523 = \frac{1}{233 \cdot 5273583}$; and sine 3° 45' = 0·065403129, multiplied by R' = 3437'·746770785, gives 224'·8393961, instead of 225'—the Hindu value. Log. 233·5273583 = 2·3683377665.

It is evident that the *Sûrya Siddhânta* rule was founded on inspection of the first few sines of the Table, and not the table on the rule. Ranganâtha, in his commentary, makes a similar deduction from a false conclusion. He states that the last second difference is 15' 16'' 48'''—which is evidently found by dividing R = 3438' by 225; then he makes the proportion: As radius to any other sine, so is this difference to the second difference at that sine. This gives a roughly approximate value in a table already formed, but which could not be constructed with this divisor. Even with R = 3438' the second difference at 90° is 14' 43''·322—the correct value being 14' 43''·257567.

[2] *Asiatic Researches*, vol. vi. pp. 537–588. See Colebrooke's *Essays*, vol. ii. pp. 389, 390 (or Cowell's ed. p. 341); Weber's *Sanskrit Literature*, p. 261.

to all errors of motion whether large or so small that their effects could only be detected after very long periods, and he tried to fix the date of the work in question by striking an average between the dates derived from all the errors in position in each case. Had he divided the sum of the errors of position at any assumed date by the sum of the errors in annual motion, they would have been weighted somewhat in proportion to the annual amounts, and a date would have been determined when the errors were most fairly balanced; but if most of the elements given in a text had not been practically determined at or about one time, and also with an approach to accuracy, this would not necessarily fix correctly the date of the work.[1] Bentley did not coax his results into the closest possible agreement with one another, by refinements of computation as Bailly had done on the other side; and his paper showed a large acquaintance with the subject, and laid the basis of a better understanding of it by subsequent writers.

17. In the first number of the *Edinburgh Review* (October, 1802) was given a notice of the sixth volume of the *Asiatic Researches*, concluding with a review of Bentley's paper, and though it extended only to two pages (pp. 42, 43), it was strongly opposed to any reduction of the supposed immense antiquity and accuracy of the *Sûrya Siddhânta.* Though accepting Sir W. Jones's conclusion that Varâha Mihira flourished about 499 A.D., the reviewer insisted that he was a comparatively modern author as compared with the compiler of this *Siddhânta,* and if Parâśara mentions the Śaka era, the passage must be an interpolation.

18. To this prejudiced critique (which was ascribed to Professor Playfair) Bentley replied in a second paper *On the Hindu Systems of Astronomy, and their connection with*

[1] Thus the positions of Mercury, Venus, Jupiter, Saturn, and the moon's apogee yielded dates at which they agreed with Lalande's tables, varying between 887 and 945 A.D., and dividing the sum of the errors at any fixed date by the sum of the errors of annual motion we obtain 924 A.D. as the approximate date at which the *Siddhânta* elements gave generally correct results for these planets. But for Mars the result would be about 1458 A.D., which is

History in ancient and modern times.[1] In this he pursued the same line of argument, as in his first essay, and though not a Sanskrit scholar, he showed considerable acquaintance for the time with the Sanskrit literature of the subject; but still associating Varâha Mihira with the authorship of our present redaction of the *Sûrya Siddhânta*, which he tacitly assumed was based on fairly accurate observations—a great mistake,—and being irritated by the injustice of the anonymous reviewer, he developed prejudices against allowing even a fair antiquity to the Hindu astronomical system, which seriously interfered with the value of his paper.

19. This paper was in turn reviewed in a separate article in the *Edinburgh Review* of July, 1807 (vol. x. pp. 455–471), by Professor Playfair, in which Bailly's superior ability to an 'amateur' like Bentley is paraded; and the argument of the latter is attempted to be turned by an illustration

suggestive of a much later epoch, or a revision of the text. It is with the moon's motions, however, that Hindu astronomy is most concerned, and we might fairly suppose that its elements would form the best test of the age of a *Siddhânta*. Taking from the *Sûrya Siddhânta* the positions relative to the sun, we have:

	Text: errors in 1200 A.D.	Annual error.	When correct.	With *bîja*: errors in 1450 A.D.	Annual error.	When correct.
Moon	+0′ 1′ 36″	0″·72	1067	+0 4′ 55″	0″·72	1067
,, Apogee	—0 24 50	28·9	1251	—0 4 17	27·7	1459
,, Node	+0 13 0	20·3	1162	—0 5 30	18·3	1468
Sums	—0 10 14	49·9	1212	— 4 52	46·7	1456

In the last case it will be seen how little the smaller annual error affects the result, and if the first of the three be omitted the average is 1463 A.D. The mean longitudes of Venus, Mars, and Jupiter, give respectively A.D. 1509, 1455, and 1575, when correct, as computed with the *bîja*, and the mean brought out as above is 1516. As an error of 20′ is perhaps not too much to allow in any observation taken by the Hindus, the *Sûrya Siddhânta* may fairly be ascribed to the thirteenth century, and the *bîja* corrections to the latter half of the fifteenth or even to the sixteenth century A.D.; but the observations on which each edition is based were most probably taken at various dates and never reduced to one epoch.

[1] *Asiatic Researches*, vol. viii. pp. 195–244.

specially constructed for the purpose. Whatever the defects of Bentley's method, this was not, in the case, a fair scientific argument. Bentley might be wrong in ascribing the *Sûrya Siddhânta* to the eleventh century; his argument might not quite prove that, but his critic was far more in error in ascribing to it an antiquity of nearly 5000 years. The application of the *bîja* or correction to the elements of the planets was possibly made in the early part of the sixteenth century A.D.; and the general approximate accuracy of the elements in the text, as compared with those in the oldest works, supports Bentley's argument, for a comparatively modern date for the known redaction, which was really all he contended for. The unfair way in which his papers were treated in the *Edinburgh Review*, seems to have soured Mr. Bentley, and he published nothing more for twenty years.

20. The next contribution was from the pen of the scholarly H. T. Colebrooke, and appeared in the ninth volume of the *Asiatic Researches*. This was *On the Indian and Arabian Divisions of the Zodiac*,[1] and contains a careful analysis of the stars in the different Nakshatras of the Hindus, and in the *manâzil al-gamar* of the Arabs, identifying them with those in European catalogues. He noted the correspondence of the Hindu signs of the Zodiac with those of the Greeks, and of the 36 *dreshkânas*, with the *dekanoi* of the Greeks and the *wujûh* of the Arabs—a term agreeing in sense precisely with *πρόσωπον*, which is similarly used; and finally he suggested an investigation to determine whether 'Yavanâchârya' does not refer to a Greek author. Part of this excellent paper was severely attacked by Bentley, nearly eighteen years after publication, in his *Hindu Astronomy*, apparently for no other reason than that Colebrooke had ascribed Varâha Mihira's age to the sixth century A.D., not having yet discovered that the *Sûrya Siddhânta*, as he knew it, was not Varâha's work at all.

[1] *As. Res.* vol. ix. (1807), pp. 323–376; reprinted in Colebrooke's *Essays*, vol. ii. pp. 321–373.

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21. Nearly nine years elapsed before the publication of Colebrooke's second astronomical paper *On the Notion of the Hindu Astronomers concerning the Precession of the Equinoxes and Motions of the Planets.*[1] It discussed the question scientifically with abundant references to original authorities. In his *Dissertation on the Algebra of the Hindus,* prefixed to his *Algebra,* etc., of Brahmagupta and Bhâskara,[2] he also determines the dates of several of the astronomical works and writers, placing Âryabhaṭa about 360 A.D. (which, however, is too early, the correct date being about 500 A.D.),[3] Brahmagupta, 628 A.D., Bhaṭṭotpala in 968 A.D., etc. The notes and illustrations to this paper also contain much information respecting Hindu astronomy, and conclude with one on the "communication of the Hindus with Western nations on 'Astrology and Astronomy,'" calling attention to the non-Sanskrit origin of such technical words as *horâ, dreshkâṇa liptâ* (λεπτα), *kendra* (κέντρον), *anaphâ, sunaphâ, durudharâ, kemadruma,* etc.

22. In 1817, the same year in which Colebrooke's work just referred to was published, M. Delambre issued his *Histoire de l'Astronomie Ancienne,* in the first volume of which he devotes two long chapters to the history and results of European research in Indian astronomy. They contain a very full *resumé* of the work of Bailly and of the memoirs by Jones, Davis, Bentley, and of Colebrooke's first essay, with frequent comments and explications; but they add nothing to previous knowledge. Bentley's views were substantiated, and those of Bailly and the Edinburgh Reviewer are treated with contempt.[4]

23. But the investigation of the subject had somewhat lost its interest, and for a long period the workers in this

[1] *As. Res.* vol. xii. (1816), pp. 209–250; also in Colebrooke's *Essays,* vol. ii. pp. 374–416.

[2] London, 1817; reprinted in *Essays,* vol. ii. pp. 417–531.

[3] *Essays,* vol. ii. p. 429; Weber's *Sanskrit Literature,* p. 257 n.; see below, § 31.

[4] Professor Playfair must have felt the severity of Delambre's remarks: see his paper "On the Algebra and Arithmetic of the Hindus," *Edinburgh Review,* vol. xxix. (Nov. 1817), pp. 162, 163. In his review (vol. x. p. 456) Playfair apparently implies that he also wrote the first notice in vol. i. pp. 42, 43.

field were few. In 1814 Captain John Warren, one of Colonel Lambton's chief assistants in the Trigonometrical survey, at the suggestion of Mr. F. W. Ellis, prepared a paper on Hindu astronomical computations, and another on the Muhammadan Kalendar. These were afterwards expanded and others added, and finally published together at Madras in a thick quarto volume in 1825, under the name of *Kalasankalita*. It treats almost exclusively of the methods employed by the Brahmans in Southern India, explaining in detail the arithmetical processes for determining chronological and astronomical elements. The author deprecates any charge of trying to support the views of Bentley, or of the partizans of Bailly: his object "is merely to explain the various modes according to which the Natives of India divide *time*, and to render their Kalendars intelligible." As a practical book on the subject it is still a standard, and though it contains some errors and misprints, they are not difficult to detect.

24. In 1825 also, Mr. Bentley, having learnt through friends that Professor Playfair "was not the author of the review, and that he could not, consistently with his character, be the author of any such nonsense,"—though still very irate at the "wanton and insidious attack" made on him by "persons in concealment,"—published his *Historical View of the Hindu Astronomy*. It was written in a state of declining health, his constitution having probably been enervated by a residence of more than forty years in India, and was published after his death. Everywhere it betrays a stubborn animus against all who differed from his opinions, even on minor questions, which did not at all involve his main contention: hence his assumptions are rarely to be trusted, though stated with unqualified confidence. Colebrooke especially, he was furiously opposed to, where a little consideration might have convinced him of the probable accuracy of that great scholar's deductions, and of the support they might lend to his own chief argument. The work, as well as Warren's, made accessible the Hindu Tables of Equations for computing the places

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of the planets, and other data.[1] To Bentley's attack on Colebrooke, that scholar replied in the *Asiatic Journal* for 1826 (vol. xxi. pp. 360 ff.) in language of considerable acerbity. It was not difficult to show that, with certain modifications, Colebrooke was ready to accept the principles of Bentley's methods of dealing with the age of the *Siddhântas*, but that, owing to the inaccuracies of Hindu observations, his computations could only supply approximations to the dates of the treatises,[2] which, on the other hand, had borrowed largely as to theory.

25. Mr. C. M. Whish, in a paper in the *Transactions of the Madras Library Society* (1827) "On the Antiquity of the Hindu Zodiac," dealt with certain traces of Greek influence. Sir William Jones had treated Montucla's theory,[3] that the Hindu astronomy was based chiefly on the Ptolemaic, with contempt. But Mr. Whish proved most satisfactorily that the zodiacal signs with the figures of the constellations must have been borrowed immediately from the Greeks, and were known even by Greek names. Varâha Mihira, in the sixth century, describes the twelve; Śrîpati in the *Ratnamâlâ* repeats the description;[4] and the commentary on it, the *Prabhodana*, gives the same in twelve verses put into the mouth of Yavaneśvara. Varâha, in the *Vṛihat Jâtaka* (i. 8), enumerates them in the lines—

Kriya Tâvuri Jituma Kulîra Leya Pâthona Jûka Kaurpyâkhyâḥ |
Taukshika Âkokero Hṛidrogaś chântyabhaṁ chetthaṁ || [5]

[1] These tables were reprinted in the Appendix to Rothman's *History of Astronomy* (1834).

[2] Part of this paper was reproduced in the new edition of Colebrooke's *Essays*, edited by his son, vol. ii. pp. 366–374.

[3] *Histoire des Mathématiques* (1758), tome i. pp. 402–404.

[4] *As. Res.* vol. ii. p. 292.

[5] Whish (*Trans. Lit. Soc. Madras*, p. 67) gives a variant reading of this *pâda*, viz.:—*Taukshika Âkokero Hṛidogaś chesthusi kramaśaḥ* ||,—giving Isthusi for Ἰχθύς. Kulîra, though closely resembling κόλουροι, is not connected with it, but, like Karkaṭa also, is a Sanskrit word: Varâha, quoting Yavaneśvara, has —*Karkî kulîrakṛitiramba saṁstho*, etc. Whish also mentions that it is found in the *Horâ S'âstra*, xi. 9.

Here are the Greek names transliterated, and elsewhere the list is repeated with trifling variants. Thus we have—

Greek.	Latin.	
Κριός	Aries	Kriya
Ταῦρος	Taurus	Tâvuri, v.ll.-Tâvuru, Tâmbiru.
Δίδυμος	Gemini	Jituma, Jutuma, Juthuma, Jittama, Jitma.
Καρκίνος	Cancer	Karkin, Karka.
Λέων	Leo	Leya, Liyaya.
Παρθένος	Virgo	Pâthena, Pâthona, v.ll.-Pârtîna, Pârtheya.
Ζυγόν	Libra	Jûka, Dyûka, Jûga.
Σκορπίος	Scorpio	Kaurpya, Korpia, Kaurba, Korpya.
Τοξότης	Sagittarius	Taukshika.
Αἰγόκερως	Capricornus	Âkokera, Âgokîru.
Ὑδροχόος	Aquarius	Hṛidroga, Hṛidoga, Udruvaga.
Ἰχθύς	Pisces	Ittha, Ithusi, Isthusi.

But, again, the names of the planets are similarly given in the *Horâ Śâstra* and elsewhere in Greek forms, *e.g.*—

The Sun—	Heli, for	*Ἥλιος*.
Mercury—	Himna, Hema, Himra, for	*Ἑρμῆς*.
Mars—	Âra,	*Ἄρης*.
Saturn—	Koṇa,	*Κρόνος*.
Jupiter—	Jyau, Jîva, Jyaus, Jyos, Dyupatiḥ Divaspatiḥ,	*Ζεύς*.
Venus—	Âsphujit, Apsujit,	*Ἀφροδίτη*.

26. Colebrooke and subsequent scholars have pointed out other Greek terms connected with geometry, astronomy, and astrology that have been transferred into Sanskrit works,[1] *e.g.*—

anaphâ, *ἀναφή*.

[1] Colebrooke, *Essays*, vol. ii. pp. 364, 526 f. or new ed. pp. 320, 476 f.; J. Muir, *Journ. As. Soc. Beng.* vol. xiv. pp. 810 f.; Weber, *Ind. Stud.* vol. ii. pp. 254, 261; Jacobi, *De Astrologiae Indicae*, etc., pp. 8, 11, 33, 35; Kern, *Bṛihat Saṁhitâ*, int. p. 28. Whish's paper was translated by Lassen, *Zeitsch. f. d. Kunde d. Morgenl.* vol. iv. p. 302.

âpoklima ἀπόκλιμα—declination; ἀπόκλιματα—the 3rd, 6th, 9th, and 12th astrological houses.
dṛikâṇa, dṛikkâṇa, drekkâṇa, dṛishkâṇa, dṛeshkâṇa, δέκανος, decanus—the chief of ten parts (out of thirty) of a sign.[1]
durudharâ, δορυφορία, the 13th yoga.
duśchikya, τυχικόν, name of the 3rd astrological mansion.
dyûnam or dyûtam, δυτόν, the 7th mansion, reckoning from that in which the sun is.
harija, ὁρίζων, the horizon.
hibuka, ὑπογεῖον, the 4th *lagna* or astrological house: Pâtâla.
horâ, ὥρα, hour[2]—the twenty-fourth part of a day.
jâmitra, διάμετρον, diameter; the 7th house.
kemadruma, κενόδρομος.
kendra, κέντρον, distance of a planet from the apsis of its orbit; argument of an equation; κέντρα—the 1st, 4th, 7th, and 10th houses.
koṇa, γωνία, angle; and trikoṇa, τρίγωνον, a triangle.
liptâ, λεπτή, a minute of arc.
meshûraṇa, μεσουράνημα, meridian; the 10th house.
paṇapharâ, ἐπαναφορά, rising; ἐπαναφοραι, the 2nd, 5th, 8th, and 11th houses.
rishphâ, ṛiḥphâ, ῥιφή; the 12th house.
sunaphâ, συναφή, a planetary conjunction.
veśi, φάσις,[3] a phase.

These terms occurring in Varâha Mihira's writings are conclusive proof of the Greek origin of Hindu astronomy and astrology, and Dr. Weber has pointed out that the technical terms among these are all used in the same sense in the *Eisagôgê* of Paulus Alexandrinus. They occur, indeed, in all astrological works after about the commencement of the fourth century A.D.[4]

[1] Firmicus Maternus, *Math.* ii. 4; Salmasii *Plinianæ Exercitationes*, pp. 460 f.; Colebrooke, *Essays*, vol. ii. pp. 364-370.
[2] *Sûrya Siddh.* xii. 79.
[3] The ordinary dictionaries, Greek or Sanskrit, do not explain the precise meaning of these terms in astrology or astronomy.
[4] Conf. Sir G. Lewis, *Survey of the Astronomy of the Ancients*, on the early history of astrology.

27. For some time after Mr. Whish's paper there were but few original contributions to our knowledge of Hindu astronomy.[1] In 1834 Mr. Lancelot Wilkinson, of the Bombay Civil Service, contributed a paper to the *Journal of the Asiatic Society of Bengal* on the use of the *Siddhântas* in native education,[2] followed by an extract with translation from Bhâskar Âchârya's *Siddhânta Śiromaṇi* (A.D. 1150). This was followed, in 1842, by the publication by him of the text of the *Golâdhyâya* section, and subsequently by a translation and notes, afterwards edited by Paṇḍit Bâpu Deva Śâstri for the *Bibliotheca Indica*; and, in 1843, by an edition of Mallâri's *Grahalâghava*.

28. In the same year Capt. J. B. Jervis's *Indian Metrology* was published, containing a long chapter (195 pages) on measures of time, which shows a considerable knowledge of the texts. In it he explains, with Tables from the *Laghu* and *Bṛihach Chintâmaṇi*, the construction of the *Pañchâṅga* or Hindu calendar.[3] Dr. E. Roer, in 1844, also contributed to the *Journal of the Bengal Society*,[4] a Latin version of the third section, or *Gunitadhia* of Bhâskara's *Siddhânta Śiromaṇi*.

29. At Jaffna, in Ceylon, in 1849, the Rev. H. R. Hoisington published a treatise in Tamil, with a translation called *The Oriental Astronomer*, forming a text-book for the usual computations required for native almanacs. It was based chiefly on the work of Uḷḷamuḍayan with the epoch of A.D. 1243, and on Viśvanâtha Śâstri's system of eclipses with the epoch of 1756.

[1] In 1832 was published an *Account of British India*, prepared by Dr. Hugh Murray and others, in three volumes, in the last of which was a chapter (2nd ed. vol. iii. pp. 288–323) on Hindu Astronomy and Mathematics, written by Prof. W. Wallace, of Edinburgh University, giving a good popular account of previous researches.

In 1834 Mr. Rothman, in his *History of Astronomy* (pp. 116–128), gave a brief outline of the subject with Mr. Bentley's tables of the planets. Mountstuart Elphinstone, in his *History of India* (1839), in the first chapter of book iii., also gave a brief summary of what was known up to that time.

[2] *Jour. As. Soc. Beng.* vol. iii. pp. 504–519.

[3] *Indian Metrology*, pp. 174–259.

[4] *Jour. As. Soc. Beng.* vol. xiii. pt. i. pp. 53–66.

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30. In 1858, however, a very valuable work on Hindu astronomy appeared in a translation of the *Sûrya Siddhânta*, by the Rev. E. Burgess, a missionary in the Maraṭha country, first published in the *Journal of the American Oriental Society* (vol. vi. pp. 141–498), with a full commentary and notes, largely by Professor Whitney.[1] This work has placed within the reach of all who are interested in the subject a complete outline of Hindu methods of astronomical calculation as practised for centuries past, together with a clear exposition of the theories on which they are based, and their relations to European science. The book is a model of careful annotation.[2]

31. An important paper on the age and authenticity of the more notable Hindu writers on astronomy was contributed by the late Dr. Bhâu Dâji to the *Journal of the Royal Asiatic Society* in 1864. In this able contribution he agrees with Bentley that the *Mahâ Ârya Siddhânta*[3] is probably of about A.D. 1322. The *Âryabhaṭîya*, or *Laghu Ârya Siddhânta* (composed in 499 A.D.) containing both the *Daśagîti* and *Âryâshṭaśata*[4]—the latter of 108 couplets—he identified as the work of Âryabhaṭa of Kusumapura or Pâṭaliputra, born in A.D. 476, whose peculiar method of expressing numbers by letters was explained by Mr. Whish. This author seems to have used for the ratio of the diameter

[1] It was also issued as a separate volume. Bâpu Deva S'âstri's version was published under the supervision of Archdeacon Pratt, in the *Bibliotheca Indica* in 1860. An English version of the early part of this Siddhânta had also appeared in the *Asiatic Journal*, May, June, 1817; and part of the first and the eighth chapter, with a French translation, in Abbé J. M. F. Guerin's *Astronomie Indienne*, 1847. The text, with Raṅganâtha's commentary, was edited by Dr. Fitzedward Hall, in the *Bibliotheca Indica*, 1859.

[2] A good exposition of the principal steps in the calculation of eclipses is to be found in a paper by the late William Spottiswoode in *J.R.A.S.* Vol. XX. (1863), pp. 345–370.

[3] Dr. Fitzedward Hall, in *Jour. Am. Or. Soc.* (1860), vol. vi. pp. 556–559, and Dr. Whitney in an additional note to the paper (*ib.* pp. 560–564), had discussed Âryabhaṭa and his writings; and Dr. Kern, in *J.R.A.S.* Vol. XX. pp. 371–387, collected the extracts from Âryabhaṭa found in Bhaṭṭa Utpala's commentary on the *Bṛihat Saṁhitâ*.

[4] Dr. Kern has edited the text of these works—*Ârya-bhaṭîya*, with the commentary *Bhaṭadîpikâ* of Paramâdîsvara (Leiden, 1874). A notice of this work by Prof. A. Weber appeared in the *Liter. Central-Blatt*, 1875, No. 7, and was reprinted in his *Indische Streifen*, Bd. iii. pp. 300–302.

to the circumference of a circle that of $1:3\frac{17}{120}$; and his elements are still used in Southern India in astronomical computations. Al-Berûnî (A.D. 1030), however, refers to a still earlier author of the name, distinguishing the second as "of Kusumapura."

Varâha Mihira, the author of the *Pañchasiddhântikâ* and other works, on the testimony of Âmarâja, died in A.D. 587. Brahmagupta, in the *Brahmasphuṭa Siddhânta*, gives his own date, as born A.D. 598, and Al-Berûnî gives 665 as the epoch of his *Khaṇḍakhâdyaka.*[1] Bhaṭṭotpala's date had been discovered by Colebrooke as A.D. 966; and Bhâskara Achârya's date for the *Siddhânta Śiromaṇi*, A.D. 1150, when he was thirty-six years of age, is supported by the evidence of an inscription near Chalisgâṁ.[2]

32. Dr. H. Kern in a preface to his edition of the text of the *Bṛihat Saṁhitâ* (1865), added further to our knowledge of the earlier Hindu writers in this branch, and submitted very important considerations as to their relations.

33. M. J. B. Biot (1775–1862), in the *Journal des Savants* for 1840 and 1845, advanced the theory that the Hindu Nakshatras were only the Chinese *sieu*, introduced into India for astrological purposes. M. Sédillot, in 1849, rejected this view, and claimed for the Arabs the invention of the lunar mansions.[3] Weber, in 1852, expressed the suspicion that the Chinese had rather borrowed the *sieu* from India, and soon after rejected Biot's views, to which the latter replied in the *Journal des Savants* in 1859. Weber then wrote two very elaborate papers on the subject, published in 1860 and 1862,[4] showing their relation to

[1] Sachau's *Al-Berûnî*, transl. vol. ii. p. 7.

[2] He has been confounded with Vitteśvara (A.D. 899), son of Bhadatta, of Al-Berûnî (vol. i. p. 156), author of the *Karaṇasâra*; conf. Weber's *Sansk. Liter.* p. 262. Mallikârjunada, a southern astronomer, is supposed by Warren to have written about A.D. 1178, and used the meridian of Râmeśvaram (79° 22′·1 E. of Greenwich), as did also Balâdityakalu, a Telugu astronomer, who wrote in 1456 A.D. Vâvilâla Kuchchinna, another Telugu astronomer, is said to have written in 1298 A.D. Warren's *Kala Sankalita*, pp. 171, 356, 389–90. Notices, in Sanskrit, of a number of astronomical writers, have of late appeared in *The Paṇḍit*.

[3] *Matériaux pour servir à l'Histoire comparée des Sciences Mathématiques chez les Grecs et les Orientaux*, pp. 467–549.

[4] *Die Vedischen Nachrichten von den Naxatra* (Berlin, 1860 and 1862).

the *manâzil* of the Arabs, as indicative of their derivation from Western Asia. Professor Max Müller next claimed the Nakshatras to be of purely Hindu origin, and that the Jyotisha account of the position of the colures fixed the twelfth century B.C. as the date, not the fourteenth as Colebrooke had concluded.[1] And, again, in the preface to the fourth volume of the *Ṛigveda* he discussed the question of the Indian or foreign origin of the Nakshatras. Professor Whitney, in his notes to the translation of the *Sûrya Siddhânta*, and in separate papers, reviewed the whole question in a very able way.[2]

34. Professor Weber, in 1865 (*Ind. Stud.* vol. x. pp. 264 ff.), directed attention to the *Sûryaprajñapti*—a Jaina astronomical treatise—which, from the resemblance its elements bear to the system of the *Jyotisha-Vedâṅga*, naturally suggests that it preserves for us the main features of Hindu science before it was affected and modified by that of the Greeks. This new line of research was followed up by Dr. G. Thibaut, in a paper in the *Journal of the Bengal Asiatic Society* for 1877 (vol. xlvi. pt. i. pp. 411–437), already referred to, and two on the *Sûryaprajñapti* in the same *Journal* for 1880 (vol. xlix. pt. i. pp. 107–127, and 181–206). The elements of the system there expounded are—that 61 months of 30 civil days each are equal to 62 lunar months, or 67 sidereal revolutions.

These figures give, for the moon's sidereal revolution 27·313433 days, and for the synodical 29·516129*d.*; but, as compared with the *Sûrya Siddhânta*, these periods are both too short, 67 sidereal revolutions being equal to 1830·89645 days, and 62 synodical equal to 1830·55217,—

[1] *Jour. As. Soc. Beng.* vol. xxix. (1860), p. 200.

[2] Conf. Biot, *Jour. des Savants*, 1860; or *E'tudes sur l'Astronomie Indienne et Chinoise* (1862); Sédillot, *Courtes Observations sur quelques Points de l'Hist. de l'Astronomie* (1863); Whitney, *Jour. Amer. Or. Soc.* vol. vi. pp. 325–350, etc.; vol. viii. pp. 1-94, 383–398, and Proc. p. lxxxiii.; Weber, *Ind. Str.* vol. ii. pp. 172, 173; *Ind. Stud.* vol. ix. pp. 424 ff.; vol. x. pp. 213 ff.; E. Burgess, *Jour. Am. Or. Soc.* vol. viii. pp. 309–334, and Proc. pp. lxvii.-lxviii.; Archdeacon Pratt, *Jour. As. Soc. Beng.* vol. xxxi. pp. 49 f.; Whitney, *J.R.A.S.* Vol. I. (N.S. 1864), pp. 316–331; Sir E. Colebrooke, *ib.* pp. 332-338; and Whitney, *Orient. and Linguistic Studies* (1874), vol. ii.

instead of 1830 days for each. This indicates a primitive and rough method of observation, and not even a knowledge of the 19-year period; for we thus have—

	Jyotisha.	*Sûr. Siddh.*	Diffs. or errors.
235 Synodical months,	6939·689*d.*	6936·290*d.*	−3·399*d.*
254 Sidereal „	6937·612	6939·705	−2·093
19 Solar years	6954	6939·916	+14·084

By dividing the *sâvana* day into 60 *nâḍikâs* of $10\frac{1}{20}$ *kalâs* each, or into 603 *kalâs*, the *nakshatra* day or thirtieth part of a sidereal revolution is expressed by 549 *kalâs*, the period during which the moon passes through one *nakshatra* is 610 *kalâs*, and the duration of a *tithi* is $593\frac{17}{62}$ *kalâs*; and from the motion of the moon being to that of the sun as 67 : 5, the sun's motion is 45 parts, while the moon's is 603, in 1 *sâvana* day. In this there is no trace of the Greek sexagesimal division.

The *Sûryaprajñapti* uses 28 *nakshatras* of unequal extent, while the *Vedâṅga* has 27 of equal extent, and uses for the ratio of the circumference to the diameter of a circle, that of $\sqrt{10}:1$; the sun's diameter is made $\frac{48}{61}$ of a yojana; but it accounts for the celestial phenomena by supposing two suns, two moons, etc.

35. The *Nakshatras*, or lunar asterisms, seem to have been first mapped out on the heavens as groups of stars, not far from the ecliptic, readily recognizable, and by which the positions of the moon and planets could be readily indicated. The distances between the leading or distinguishing stars of the successive groups were necessary unequal, and when it was required to indicate the time in which the moon passed through, or continued in the space allotted to the different asterisms, they came to be divided into those of longer, shorter, and average duration. But the lunar sidereal month consists of about $27\frac{193}{600}$ days, or $819\frac{13}{20}$ muhûrtas; if, then, an average of a day is assigned to each Nakshatra, there must be twenty-eight of them, one having a duration of only $9\frac{13}{20}$ muhûrtas. And this was possibly the earlier arrangement with the twenty-seven distributed,

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so that six—the 4th, 7th, 12th, 16th, 21st, and 27th of the series beginning with Áśvinî—were of longer extent, or through each of which the moon passed in $1\frac{1}{2}$ days: other six—the 2nd, 6th, 9th, 15th, 18th, and 25th—were shorter, or of half a day each; and the remaining fifteen (*i.e.* exclusive of Abhijit, the 22nd) were passed through in one day each. But the division of the ecliptic into $27\frac{9}{28}$ parts (or thereabouts) is inconvenient and perplexing, and in astrology would be got rid of if possible; and, as the synodical month of $29\frac{26}{49}$ days was divided into thirty *tithis*, the sidereal revolution could equally readily be divided into twenty-seven *dina* each of 24*hrs.* 17*min.* 9·335*sec.*, in which time the moon traverses 13° 20′. With this arrangement the longer *Nakshatras* would occupy 20° of longitude each; the short 6° 40′; and the rest 13° 20′ or 800′ each; while Abhijit—the additional one of about $4\frac{1}{4}$°—was included in the 21st, or Uttarâshâḍhâ—one of the long ones. This is the arrangement as represented by Garga and in the *Nakshatra-kalpa* brought to notice by Weber.[1] Brahmagupta, however, in his *Uttara-Khaṇḍakhâdyaka* (665 A.D.) adheres to the early arrangement of a separate portion for Abhijit of 4° $14\frac{7}{23}$′, computing the precise arcs moved over by the moon in the long, short, and average spaces for one and a half, half, and one *civil* day respectively.[2] These durations he apparently brought over from a time preceding the knowledge of Greek astronomy in India; for we find in the fragments of Pushkarasârin's work on eclipses,

[1] *Vedische Nachrichten von den Naxatra*, 2nd. Th. p. 390.

[2] Al-Berûnî's *India* (Sachau's tr.), vol. ii. p. 87; conf. *Ind. Ant.* vol. xiv. p. 43; Biot, *E'tudes sur l'Astronomie Indienne* (Ex. du *Jour. d. Sav.*), pp. 81, 82. According to Brahmagupta the moon's sidereal motion in one civil day is 13° 10′ 34″·88, whence the Nakshatra portions or arcs are:—

Six of 19° 45′ 52″·32 each	=	118°	35′	13″·92
Six of 6 35 17·44 ,,	=	39	31	44·64
Fifteen of 13 10 34·88 ,,	=	197	38	43·19
Twenty-seven together (average 13° 10′ 34″·88)	=	355	45	41·75
Abhijit (for 0·3216673 day)		4	14	18·25
		360	0	0

In Al-Berûnî's account, by neglecting a small fraction in the average daily motion, the value left for Abhijit comes out 4° 14′ 18″·60.

recently discovered in Central Asia, that while 810 muhûrtas, or twenty-seven days, were allotted to the other twenty-seven *Nakshatras*, a duration of seven or eight muhûrtas was assigned to Abhijit.[1] And the early character of this work is supported by its beginning the series of *Nakshatras* with Kṛittikâ rather than Aśvinî; it also divides them into four groups, Nos. 3 to 9 (of the following list) belonging to the *East*, Nos. 10 to 16 to the *South*, Nos. 17 to 23 to the *West*, and Nos. 24 to 28, and 1, 2, to the *North*. This is also the arrangement in the *Nakshatra-kalpa*.[2]

When sexagesimal computation came to be depended on rather than observation, the arcs were equalized, and the Nakshatra portions retained the names of the asterisms, just as the zodiacal signs did those of the constellations, without coinciding very closely with them. The twenty-seven Nakshatra arcs were thus made, in later Hindu works, of 800′ each; but Abhijit was still occasionally retained. Thus the *Muhûrta Mâlâ* says, "the last quarter of Uttarâshâḍhâ and the first fifteenth of Śravaṇa together constitute Abhijit." This allows 4° 13′ 20″ for this Nakshatra, or very nearly the value given by Brahmagupta. Most of the later works take 100′ from Śravaṇa, and extend Abhijit to 5°, or from 276° 40′ to 281° 40′.

The number of stars in the different asterisms varies in different works: Al-Berûnî gives the numbers from Brahmagupta,[3] with the positions of the *yogatârâs*, or distinguishing stars, in each. These positions differ in several instances from those of the *Sûrya Siddhânta*, and are given in the following table, along with the periods for each *Nakshatra*, the number of stars, and the determinant star (*yogatárâ*) as identified in our modern lists.[4]

[1] Dr. Hoernle has discussed a portion of the MS. of Pushkarasârin's work in the *Jour. As. Soc. Bengal*, vol. lxii. (1893) part. i. pp. 9–18, See *The Academy*, Aug. 12th, 1893, p. 136.

[2] *Vedische Nachrichten von den Naxatra*, 2nd Th. p. 377.

[3] See Thibaut, in *Ind. Ant.* vol. xiv, p. 43. Where two numbers are given in the following table, the second is from Pushkarasârin's fragment, published by Dr. Hoernle in *Jour. As. Soc. Beng.*, vol. lxii. part i.; see also Colebrooke's *Essays*, vol. ii. p. 322, and table.

[4] Burgess's *Sûrya Siddhânta*, pp. 175–220, or *Jour. Am. Or. Soc.* vol. vi. pp. 319–364.

Names of the Nakshatras.	Duration in Muhûrtas.	No. of Stars mentioned.	Distinguishing Star. Polar Longitude.	Polar Latitude.	Star.
1. As'vinî, or As'vayujau	30	2, 3	8° 0′	10° 0′N.	β Arietis.
2. Bharaṇî, or Apabharaṇî	15	3	20 0	12 0 N.	α Muscæ.
3. Kṛittikâ, or Kṛittikas	30	6	37 28	5 0 N.	23 Tauri.[1]
4. Rohiṇî	45	5	49 28	5 0 S.	Al-Dabarân, α Tauri.
5. Mṛigas'îrsha, Andhakâ, Aryikâ, Invakâ, or Ilvalâ	30	3	63 0	5 0 S.	λ Orionis.
6. Ârdrá, or Bâhu	15	1	67 0	11 0 S.	α Orionis (?)
7. Punarvasû	45	2	93 0	6 0 N.	β Geminorum.
8. Pushya, Tishya, or Sidhya	30	1, 3	106 0	0 0	δ Cancri.
9. Âs'leshâ, Âs'reshâ, or Âsleshâs	15	6, 5	108 0	6 0 S.	ε Hydræ.
10. Maghâ, or Maghâs	30	6, 5	129 0	0 0	Regulus.
11. Pûrva - Phalgunî, or Arjunî	30	2	147 0	12 0 N.	δ Leonis.
12. Uttara-Phalgunî	45	2	155 0	13 0 N.	Al-Ṣarfa, β Leonis.
13. Hasta	30	5	170 0	11 0 S.	γ or δ Corvi.
14. Chitrâ	30	1	183 0	2 0 S.	Spica Virginis.
15. Svâtî, or Nishtyâ	15	1	199 0	37 0 N.	Arcturus.
16. Vis'hâkhâ, or Vis'âkhe	45	2	212 5	1 30 S.	ι Libræ.
17. Anurâdhâ	30	4	224 5	3 0 S.	δ Scorpionis.
18. Jyeshṭhâ or Rohiṇî	15	3	229 5	4 0 S.	Antares.
19. Mûla, or Vichṛitau	30	2, 4	241 0	9 30 S.	λ Scorpionis.
20. Pûrva - Ashâḍhâ, or Âpya	30	4, 3	254 0	5 20 S.	δ Sagittarii.
21. Uttara-Ashâḍhâ, Vais'va	45	4	260 0	5 0 S.	σ Sagittarii.
22. Abhijit	8 (7)[2]	3	265 0	62 0 N.	Al-Nasr Al-wâqi', Vega.
23. S'ravaṇa, S'roṇa, or As'vattha	30	3	278 0	30 0 N.	Al-Nasr Al-ṭâ'ir, α Aquilæ.
24. S'ravishṭhâ, or Dhanishṭhâ	30	5, 4	290 0	36 0 N.	β Delphini.
25. S'atabhishaj	15	1	320 0	0 18 S.	λ Aquarii.
26. Pûrva-Bhâdrapadâ, Proshṭhapadâ, or Pratishâna	30	2	326 0	24 0 N.	α Pegasi.
27. Uttara-Bhâdrapada, etc.	45	2	336 0	26 0 N.	γ Pegasi or, α Andromedæ.
28. Revatî	30	1	360 0	0 0	ζ Piscium.

[1] Alcyone is not given in Ptolemy's Star List, and by Ulagh Beg it is mentioned only as "a small star": Atlas (27, Tauri) or Merope (23, T.) is probably intended in the Hindu works.

[2] The MS. of Pushkarasârin's work, found in Central Asia, ascribes 8 (or 7) muhûrtas to Abhijit, which gives 27·267 (or 27·233) days for the moon's sidereal revolution, which is only a rough approximation. Brahmagupta's value is equivalent to $9\frac{13}{20}$ muhûrtas, giving 27·32167 days for the sidereal month as derived from the elements he adopts.

36. Prof. H. Jacobi, in a tract, *de Astrologiae Indicae 'Horâ' appellatae Originibus: accedunt Laghu-Jâtaki, cap. ined. iii-xii.* (Bonnae, 1872),[1] called attention to the circumstance that the system of the twelve astrological mansions occurs first in Firmicus Maternus (A.D. 350), and hence that the Indian Horâ-texts, in which these are of essential importance, cannot be of much earlier date. He also calls attention to the Greek words occurring in Varâha Mihira's and later works, which are employed in the same sense in the *Εἰσαγωγή* of Paulus Alexandrinus (A.D. 378).

37. The publication in 1888 of Dr. E. C. Sachau's version of Al-Berûnî's *India,* supplies us with a good deal of information respecting the Hindu astronomical works in use in the eleventh century, and their methods of computation, compared with the Arab science of that age.

38. In 1874, however, Dr. Bühler discovered the *Pañchasiddhântikâ* of Varâha Mihira, for an account of which we are indebted to Dr. Thibaut (*Jour. As. Soc. Beng.* vol. liii. 1884, pp. 259–293), and subsequently (in 1889) for an edition of the text and translation, based on two MSS. obtained by Dr. Bühler. This work expounded the systems of five early treatises, the *Saura, Pauliśa, Romaka, Vâsishṭha,* and *Brâhma* or *Paitâmaha Siddhântas*—all now lost, so far as we know, in their original forms. The author mentions that the difference of longitude between Yavanapura and Ujjain is $7\frac{1}{3}$ *nâḍîs* or 44°, and between the first and Benares is 9 *nâḍîs* or 54°; if Alexandria is meant, as is almost certainly the case, the correct figures are 46° and 53° 11′, and the closeness to truth of the values in an element so difficult to determine with accuracy before the invention of any sort of chronometer is satisfactory. Varâha makes the starting point of computations in the *Pañchasiddhântikâ* the 1st Chaitra Śaka 427.[2] The sun's mean place is computed, by the *Saura Siddhânta* by multiplying the *ahargaṇa*

[1] This tract (48 pp.) was reviewed by Prof. A. Weber in the *Liter. Central-Blatt,* 1873, No. 25, pp. 786–88, reprinted in *Indische Streifen,* Bd. iii. pp. 165–68; also by Prof. H. Kern in *The Academy,* 1873.

[2] March 18th, A.D. 505, at 33^{gh} 9^{p} after noon.

from the initial date by 800, deducting 442, and dividing by 292207. This makes the year 365*d.* 15*g.* 31′ 30″ as in the *Pauliśa Siddhânta.* Next we have a *yuga* of 180,000 years equal to 65,746,575 days containing 2,226,389 synodical or 2,406,389 sidereal months,[1] which gives values slightly differing from the modern *Sûrya Siddhânta.* The moon's node makes 900 revolutions in 2,908,789 days, as in the *Âryabhaṭîya*, of which 2,260,356 had elapsed at the epoch. So also we find that the period of Jupiter's revolution is taken as 4332·3205754 days.

The *Romaka Siddhânta* employs a *yuga* of $150 \times 19 = 2850$ years or 1,040,953 days, which gives a tropical year of 365*d.* 14*gh.* 48*p.* (365*d.* 5*h.* 55*m.* 12*s.*), exactly as determined by Hipparchus and Ptolemy. In the same period there are 1050 *adhimâsas* and 16,547 suppressed lunar days; hence the lunations are $12 \times 2850 + 1050 = 150 \times 235 = 35250$, and the synodical month 29*d.* 31*gh.* 50′ 5″·617, while the tropical (not sidereal) month is $1040953 \div (35250 + 2850) =$ 27·32160105*d.*[2] For the anomalistic month we have 110 in 3031 days, or $27 \cdot 5\dot{5}\dot{4}$ days; for the node, 24 revolutions in 163,111 days, or $6796\frac{7}{24}$ days for a revolution. The epoch is sunset at Yavanapura at the beginning of the lunar month of Chaitra, Śaka 427, at the beginning of Wednesday, and this counting of the astronomical day from *sunset* was customary among the Greeks. Varâha does not give details respecting the planetary motions, other than the lunar, as treated in the *Romaka Siddhânta.* It places the sun's apogee in longitude 75°, and the greatest equation of the centre amounts to 2° 23′ 23″ or but little in excess of Ptolemy's value.

[1] This is otherwise put as 900,000 revolutions in 24589506 $\frac{746166}{2406389} =$ 24589506·3100775 days, and the rule for the moon's mean place is to multiply the ahargaṇa by 900,000, deduct 670,217, and divide by 24,589,506, and correcting for the fraction by taking $\frac{51}{3120}$ of the elapsed revolutions as seconds to be subtracted.

[2] The almost perfect coincidence of these values with those of Ptolemy, *Math. Syn.* lib. iii. c. 2, has been pointed out by me, *Ind. Ant.* vol. xix. p. 284. The *Romaka Siddhânta* accepts, without modification, the Metonic cycle of 19 years combined with Hipparchus's length of the Tropical year; and this may account for the very slight differences. If, instead of 126007 days *plus* one hour which Ptolemy uses for the lunar equations, we substituted 126007 days *minus* one hour (*or* $1\frac{1}{2}h.$) we should get the *Romaka Siddhânta* values.

The *Paitâmaha S.* is discussed very briefly by Varâha Mihira, but appears to have belonged to the primitive astronomical system of the *Jyotisha, Garga Samhitâ,* etc., employing a *yuga* of 5 years of 366 days each, and one of these *yugas* beginning with the third year of the Śaka era.

The *Vâsishṭha S.* is also treated so briefly, and as of so inferior scientific value, that little can be said about it.

Of the *Pauliśa Siddhânta,* we already knew much from Al-Berûnî and from Hindu writers. Its peculiar methods appear to be the same as those used in Southern India.[1] The longitude of the sun's apogee is made 80°. The year is 43831÷120=365·2583 days.

One peculiarity is the Table of Sines which is given under the heading of this *Siddhânta.* It is constructed for the usual 24 arcs increasing by 3° 45′ each; but instead of using 57° 18′, the length of the radius in arc, as the value of the sine of 90°, it follows the Greek method of Ptolemy who divided the radius or chord of 60° into 60 parts, subdivided sexagesimally, and gave the chords of double arcs in terms of this: thus the chord of 180° or the diameter was 120 parts, and of 60° was 60 parts. Now if we copy out Ptolemy's chords for every 7° 30′ in succession up to 180° we shall have the *Pauliśa Siddhânta* table of sines for each arc from 3° 45′ to 90°.[2] Moreover, if we set down Ptolemy's successive differences, between each pair we shall have the differences given also in this *Siddhânta*—varying only in that Ptolemy gives each quantity to the third degree of sexagesimals, while Puliśa gives the values only to seconds. It need only be added that, as it is to Ptolemy that the sexagesimal division is ascribed,[3] there can be little if any doubt that Paulus or Puliśa was one of those who introduced it and the Greek system of astronomy into India. Dr. Thibaut considers that the *Romaka* and *Pauliśa Siddhântas* must have been composed not later than A.D. 400.

[1] Warren's *Kâla Sankalita,* pp. 118 ff.
[2] See this in *Ind Ant.* vol. xx. p. 228.
[3] Wallis, *Hist. and Prac. Algeb.* c. 7.

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39. At the close of the *Pañchasiddhântikâ*, Varâha Mihira adds some short rules (ch. xviii, śll. 66–79) for the longitudes of the sun and planets. Dr. Thibaut remarks[1] that the durations ascribed in these to the synodical revolutions "are extraordinary," agreeing "neither with those assigned to the synodical motions in Hindu astronomy generally, nor, therefore with the true periods—from which the periods implied in the teaching of the *Siddhântas* differ to a very inconsiderable extent only"; and, he adds, "to meet with a set of numerical quantities widely differing from those generally accepted is indeed so startling that one at first feels strongly inclined to doubt the soundness of the text." But on referring to his translation (p. 103) it appears that Varâha Mihira, speaking of the sun first (śl. 66), uses degrees or *saura* days, and this measure is naturally carried through the following ślokas. We have no other instance, so far as I know, of the synodical revolutions being stated in a Sanskṛit treatise, and we are not to infer that they should be given in civil days, as in European works based on the Copernican system, rather than expressed in degrees or equivalent *saura* time,—as Varâha Mihira has done in this place and with considerable accuracy.

His values are readily derived in the following way:—Employing the *yuga* of 1080000 sidereal solar revolutions, the revolutions of the planets in that period are—Mars, 574206; Jupiter, 91055; Saturn, 36641; Mercury, 4484250; Venus, 1755597; and if we divide the *degrees* in 1080000 revolutions by the difference between 1080000 and the number of heliocentric revolutions of the planet, we obtain the arcs through which the sun moves during the planet's synodical revolution. Thus, for Mars, we have—

$$\frac{1080000^{r} \times 360^{\circ}}{1080000 - 574206} = \frac{388800000^{\circ}}{505794} = 768^{\circ}{\cdot}6924, \text{ or nearly } \frac{3075}{4} \text{ or } 768\tfrac{3}{4},$$

as in the text. Similarly, for the other planets we find—

For Mercury . $114^{\circ}{\cdot}2102$ or very nearly $\frac{3312}{29}$ or $114^{\circ}\frac{6}{29}$;
For Jupiter . . $393^{\circ}{\cdot}146$ „ $\frac{2752}{7}$ or $393\frac{1}{7}$;

[1] *Pañchasiddhântikâ*, Introd. p. xlvii.

For Venus . .	$575^{\circ}{\cdot}491$	nearly	$\frac{1151}{2}$ or $575\frac{1}{2}$;
And for Saturn.	$372^{\circ}{\cdot}6426$	,,	$\frac{1118}{3}$ or $372\frac{2}{3}$;

—the fractional values in each case being those given in the text.[1]

Dr. Thibaut has prefixed an excellent introduction to his edition; but, as he himself allows, the translation admits of emendation, the text of the only copies available being very corrupt; and a commentary much more complete is required to illustrate the version satisfactorily.

40. The only further contributions connected with this branch of Hindu science have been devoted to its relation to chronology. The Hindu calendar is constructed in so peculiar a way, depending on the relations of solar and lunar motions, that it is a complicated problem to fix the date in the Julian calendar corresponding to a given day in the Hindu reckoning. That reckoning, too, not being necessarily quite accurate, but dependent on the system in their astronomical treatises, requires us to work out the coincidence by means of their data.[2] It is very important, however, to be able to determine such coincidences with complete accuracy as a means of fixing the precise dates of inscriptions upon which Indian chronology must be based.

[1] The greatest error is only 3′·4 in the case of Mars, for which the fraction $\frac{9993}{13}$ would have given the more accurate value of $768^{\circ}{\cdot}691$; and for Mercury, the multiplier 2170 and divisor 19, would have been even closer than 3312 and 29. To convert these arcs into civil time, using Varâha Mihira's value for the sidereal year, 365*d.* 15*gh.* 33*p.*, we have to multiply by 1·01460764 or $1\frac{9}{616}$: the results are—Mars, 779·92 days; Jupiter, 398·87; Saturn, 378·08; Mercury, 115·88; and Venus, 583·90 days.

[2] The principal of these papers are :—Jacobi, *Methods and Tables for verifying Hindu Dates, Titles*, etc. in *Ind. Ant.* vol. xvii. pp. 145–181; *The Computation of Hindu Dates in Inscriptions*, etc., with Tables in *Epigraphica Indica*, vol. i. pp. 403–460; *Tables for Calculating Hindu Dates in True Local Time*, in *ibid.* vol. ii.; R. Schram, *Hilfstafeln für Chronologie*, in *Denkschriften d. Kais. Acad. d. Wissensch. mat. nat. Cl. Wien*, vol. xlv. pp. 289–358; and *Ind. Ant.* vol. xviii. pp. 290–300; Kielhorn, *The Sixty year Cycle of Jupiter*, in *Ind. Ant.* vol. xviii. pp. 193–209, and 380–386, and *Abhand. d. K. Gesellsch. d. Wissensch. z. Göttingen*, 1889.