THE

# PAÑCHASIDDHÂNTIKÂ

THE ASTRONOMICAL WORK

OF

## VARÂHA MIHIRA.

THE TEXT, EDITED WITH AN ORIGINAL COMMENTARY IN SANSKRIT AND AN ENGLISH TRANSLATION AND INTRODUCTION

BY

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AND

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# PREFACE.

There is some reason to fear that the feeling of any one who may examine in detail this edition and translation of Varâha Mihira's astronomical work will, in the first place, be wonder at the boldness of the editors. I am indeed fully conscious that on the imperfect materials at our disposal an edition in the strict sense of the word cannot be based, and that what we are able to offer at present deserves no other name but that of a first attempt to give a general idea of the contents of the Pañchasiddhântikâ. It would, in these circumstances, possibly have been wiser to delay an edition of the work until more correct Manuscripts have been discovered. Two considerations, however, in the end induced us no longer to keep back the results, however imperfect, of our long continued endeavours to restore and elucidate the text of the Pañchasiddhântikâ. In the first place we were encouraged by the consideration that texts of purely mathematical or astronomical contents may, without great disadvantages, be submitted to a much rougher and bolder treatment than texts of other kinds. What interests us in these works, is almost exclusively their matter, not either their general style or the particular words employed; and the peculiar nature of the subject often enables us to restore with nearly absolute certainty the general meaning of passages the single words of which are past trustworthy emendation. And, in the second place, we feel convinced that even from that part of the Pañchasiddhântikâ which we are able to explain more is to be learned about the early history of Sanskrit Astronomy than from any other work which has come down to our time.

Imperfect and fragmentary as text and translation are, we may assert at any rate that, in our endeavours to overcome the quite unusual obstacles, which the corrupt and bare text of the Pañchasiddhântikâ opposes to the interpreter, we have spared no trouble. The time and thought, devoted to the present volume, would, I may say without exaggeration, have amply sufficed for the editing and explaining of twenty times the amount of text presenting only normal difficulties. This I mention, not of course in order to extol what we have been able to do, but only as an excuse for what we see ourselves obliged to leave undone.

Next to the lamentable state of the text as appearing in the two Manuscripts at our disposal, the greatest disadvantage under which we laboured was the absence of a Commentary. Commentaries can be hardly done without in the case of any Sanskrit astronomical work; much less so, when the text, as that of the Pañchasiddhântikâ, describes many mathematical pro-

cesses more or less diverging from those commonly employed. Commentaries probably existed formerly, and possibly exist even now; but we have failed to procure any. The Commentary published in the present volume is an entirely original composition by my Collaborator. A mere translation of the text with notes would, indeed, have sufficed for the European reader; we however, wished to make the results of our labour accessible to Paṇḍits also who understand no English. And a full ṭîkâ giving full demonstrations in the ordinary Hindû style will, in many cases, be useful to the European student also.

The right hand columns of the text give the emended text; the left hand columns the text of the better one of our two Manuscripts which we thought advisable to exhibit in extenso. Some remarks on the Manuscripts and the mode of emendation of the text will be found at the end of the Introduction.

As this preface is signed by myself only, I may, I think, here acknowledge—in a somewhat more explicit way than the mere association of names on the title page is capable of doing—the great obligations under which I am to my collaborator Paṇḍit Mahâmohopâdhyâya Sudhâkara Dvivedî. His constant assistance was altogether indispensable to me, and all the more welcome as among the Jyautishas of my acquaintance I know of no other, fully equal to work of this kind and at the same time equally ready to devote himself to a task which in certain aspects is so entirely unremunerative. I may express the hope that the Paṇḍit, who is already so well known for his efforts to spread a knowledge of modern higher Mathematics among his countrymen, will continue to devote a part at least of his learning and talents to the elucidation of the ancient history of science in this country.

I further wish to express my best thanks to the Bombay Government and to Professor R. G. Bhandarkar, who with great liberality have allowed me the use, for lengthened periods of time, of all those Manuscripts in their charge which I required for the present edition. Nor must I omit to record my obligations to Professor G. Buehler to whose activity, when in charge of the search for Sanskrit Manuscripts in parts of the Bombay Presidency, we are indebted for the discovery of the two Manuscripts on which this edition is based.

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ALLÁHABÁD:
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# INTRODUCTION.

The Pañchasiddhântikâ by Varâha Mihira occupies a marked position of its own in Indian astronomical literature. As a rule works treating of that branch of science claim either to be directly revealed, as *f. i.* the Sûrya Siddhânta in that form which has come down to our time; or else to base in all essential points on some older work of divine origin, as *f. i.* the Siddhântas by Brahmagupta and Bhâskarâchârya, both of which are reproductions, however greatly amplified and improved, of an old Paitâmaha Siddhânta. One of the consequences of this is, that these works claim for themselves direct or derived infallibility, propound their doctrines in a calmly dogmatic tone, and either pay no attention whatever to views diverging from their own, or else refer to such only occasionally, and mostly in the tone of contemptuous depreciation. The latter attitude is assumed *f. i.* by Brahmagupta who indeed devotes a special chapter to the task of reviewing those astronomical systems which were opposed to the teaching of the Brahma Siddhânta, but who would have rendered that part of his work much more valuable and interesting, had he been less anxious to criticize and ridicule than to impart information. The astronomical writers, it is true, therein only exemplify a general mental tendency which displays itself in almost every department of Hindû Literature; but mere dogmatic assertion appears more than ordinarily misplaced in an exact science like astronomy, and the absence of all appreciative reference to the views of preceding authors is particularly vexatious, when we have to do with a branch of Hindû Learning which shows clear traces of having been remodelled under the influence of Greek teaching.

To the general rule the Pañchasiddhântikâ forms a striking exception. As far as we can judge at present, Varâha Mihira was the only one among Hindû writers on astronomy who thought it worth while to give an exposition of all the more important forms of astronomical doctrine which were current at his time. Not that he was unable to judge of the relative value of the systems which offered themselves to his examination; for, as we shall see further on, he knew very well in what order of merit the five Siddhântas whose teaching he summarizes are to be arranged. But he seems ready to acknowledge that even inferior systems deserve a certain amount of attention, as long as they continue to occupy in certain circles a position of authority; and he appears not to be altogether incapable of taking a purely intellectual interest in examining the various, more or less perfect, methods which may be applied to the solution of scientific problems. At the same time he seems to have no hesitation to acknowledge the connexion of the

modern phase of Hindû astronomy with Greek science. Although directly stating that the Hindûs learned from the Greeks, he at any mentions certain facts and points of doctrine which suggest the depend of Indian astronomy on the science of Alexandria; and, as we know alr from his astrological writings, he freely employs terms of undoubted G origin. The Pañchasiddhântikâ thus becomes an invaluable source for who wishes to study Hindû astronomy from the only point of view w can claim the attention of the modern scholar, *viz.* the historical one.

Regarding its form the Pañchasiddhântikâ belongs to the class of so-called karaṇagranthas *i. e.* compendious astronomical treatises whic not set forth the theory of the subject at comparative length as Siddhântas do, but merely supply a set of concise—and often only app mately correct—rules which suffice for the speedy performance of all the important astronomical calculations. It however contains a few cha whose contents lie outside the limits of a mere karaṇa and resemble the responding chapters of the best known Siddhântas; notably the chapter w describes the general constitution of the universe, and the 15th chapter c Jyotishopanishad. And it of course decidedly distinguishes itself fro ordinary karaṇas by the fact that it does not base on any one parti Siddhânta, but undertakes to reproduce the more important doctrines of different Siddhântas.

These five Siddhântas, named by Varâha Mihira in the first cha are the Paitâmaha, Vâsishṭha, Romaka, Pauliśa and Saura Siddhâ Varâha Mihira there also states his view as to their order in importa assigning the first place to the Sûrya Siddhânta, placing next the Romaka Pauliśa Siddhântas as about equally correct, and declaring the two remai works to be greatly inferior to the three mentioned. In agreement with estimate very different amounts of space are allotted to the individual dhântas in the body of the work, the Sûrya Siddhânta and Pauliśa Siddh being treated at some length, next to these the Romaka, and very little a tion being paid to the Paitâmaha Siddhânta, and, although this is a somewhat difficult to decide, to the Vasishṭha Siddhânta.

In addition to the general character of the five Siddhântas, this d ence of treatment is owing to a special cause, mentioned by Varâha M in the first chapter *viz.* his wish to devote the Pañchasiddhântikâ chief the task of setting forth the calculation of solar eclipses, the most dif

I now proceed shortly to discuss the teaching of each of the five Siddhântas as represented by Varâha Mihira. This, however, requires the preliminary settlement of two questions.

In the first place we must attempt to ascertain with accuracy which chapters of the Pañchasiddhântikâ are devoted to each of the five works in question.—This is a task beset by considerable difficulties, as we have no commentary to assist us, and as the indications to be met with in the text as well as in the colophons of the chapters, as exhibited by the two Manuscripts at our disposal, do not, in all cases, enable us to arrive at definite conclusions.

I begin with those chapters, fortunately constituting the majority, which allow themselves to be referred to their respective sources with confidence.—The very short twelfth chapter is, in its colophon, called Paitâmaha Siddhânta, and is in its first stanza declared by Varâha Mihira himself to base on the teaching of Pitâmaha; it is the only chapter in the whole work which is concerned with that Siddhânta.—The eighth chapter treats, according to its colophon, of the calculation of solar eclipses according to the Romaka Siddhânta; and that this really is so, we again have no reason to doubt, as the first stanza refers to the Romaka by name, and as, moreover, the contents of the chapter agree with the statements made in the first chapter about the yuga and the ahargaṇa of the Romaka Siddhânta.—The ninth, tenth and eleventh chapters undoubtedly summarize the doctrines of the Sûrya Siddhânta, as is stated in the colophon, indicated in the first stanza of chapter IX, and borne out by the general agreement of the contents of the three chapters with the Sûrya Siddhânta as known at present. The sixteenth chapter contains, according to the colophon and to stanza 1, the rules of the Sûrya Siddhânta for finding the mean places of the planets; and the seventeenth chapter which teaches how to calculate their true places we may without hesitation refer to the same Siddhânta.

Among the remaining chapters of the work I at first single out those in which Varâha Mihira apparently does not intend to reproduce specific features of one particular Siddhânta, but rather to summarize doctrines held by all the more advanced astronomers of his time, and most probably set forth, with greater or less variations, in three of his five Siddhântas, *viz.*, the Sûrya, Pauliśa and Romaka Siddhântas. To this class of chapters, in which we discern more of the individual Varâha Mihira than in the remainder of the work, I feel inclined to reckon three or perhaps four sections. In the first place the thirteenth chapter, designated in the colophon as 'trailokya-samsthâna', which gives a popular exposition of the sphericity of the earth and the different aspects of the celestial sphere which are due to difference of

terrestrial latitude. The mode of treatment of these questions is no doubt Varâha Mihira's own, as also the interesting criticisms passed on some astronomical schools. In the same way the fourteenth chapter, which is chiefly engaged in showing how certain results may be obtained not only by calculation but more directly by observation and the inspection of certain mechanical contrivances, appears, on the whole, to be Varâha Mihira's own, although the more scientific of his five Siddhântas no doubt treated of those topics in a similar manner. The same remarks apply to the fifteenth chapter which is even more distinctly individualistic, and contains interesting references to other astronomers. I am more doubtful about the position of chapter IV. which in the colophon is merely counted as such, without any special designation. The matter of the chapter corresponds to what in the best known astronomical works is set forth in the so-called tripraśnâdhikâra, with the addition, however, of rules for calculating the table of sines (which ordinarily are given in the spashṭâdhikâra). It is not improbable that here also Varâha Mihira sums up, in his own fashion, whatever he found of value in the corresponding chapters of the Romaka, Pauliśa and Sûrya Siddhântas. On the other hand, as the fourth chapter follows and precedes chapters specially devoted to the Pauliśa Siddhânta, it is not impossible that its contents are meant to sum up the teaching of that Siddhânta only. The decision in this case is however of no very great importance, as the rules given in the fourth chapter on the whole closely agree with the general Siddhânta doctrine.

Among the chapters not yet discussed we first notice the sixth chapter which the colophon states to treat of solar eclipses according to the Pauliśa Siddhânta. I see no reason for rejecting this statement; for although the text of the chapter itself does not refer to the Pauliśa Siddhânta, it most probably actually bases on the teaching of this latter work, since the two other chapters (VII and VIII) which teach the theory of solar eclipses certainly refer to the Sûrya and Romaka Siddhântas. From this again it follows with great probability that also the sixth chapter, which treats of lunar eclipses, represents the teaching of the Pauliśa Siddhânta; and if so, then likewise the fifth chapter merely designated as Śaśidarśanam. These assumptions are confirmed by the fact that these three chapters treat only of the calculation of eclipses in the narrower sense, to the exclusion of all preliminary operations, such as the ascertainment of the mean and true longitudes etc. of sun and moon, so that an introductory chapter setting forth those latter topics is required. Now, a chapter of this nature is supplied by the third one of the Pañchasiddhântikâ which gives rules for finding the mean and true places of the sun (and of the moon?) and for similar operations, and

which, in its colophon at least, is said to represent the teaching of the Pauliśa Siddhânta. The relation, however, of the third chapter to the one immediately preceding is puzzling. The second chapter is, in the colophon, merely designated as "nakshatrâdichchheda," but its contents comprise firstly a rule or set of rules for finding the mean (and perhaps also true?) places of the moon (stanzas 1—7), and, secondly, a set of rude, approximative rules for calculating the length of the day at any time of the year, the length of the shadow of the gnomon, and, from the latter, the mean place of the sun, and the lagna (and vice versâ; stanzas 8—13). The chapter concludes with the words "This is the (calculation of the) shadow according to the concise Vâsishṭha Siddhânta." The question now is, whether this whole chapter has to be viewed as epitomizing the Vasishṭha Siddhânta, or whether that work is represented only by its latter part. The rules contained in stanzas 8—13 are of a very rough character, and can, for that reason, hardly come from the Pauliśa Siddhânta; their character, on the other hand, agrees very well with the criticism passed by Varâha Mihira, in the first chapter, on the imperfections of the Vasishṭha Siddhânta. It is more difficult to arrive at a conclusion regarding the rules embodied in stanzas 1—7. If they do not belong to the Vasishṭha Siddhânta, it would follow that the Pañchasiddhântikâ, which after all promises to render us acquainted with the doctrines of all the five Siddhântas, however imperfect some of them may be, does not even inform us how the place of the moon is calculated according to the Vasishṭha Siddhânta, while it yet gives the corresponding rules from the, certainly not more advanced, Paitâmaha Siddhânta, very concisely indeed but yet with sufficient fulness. On the other hand there appears to be some reason for tracing the rules to the Pauliśa Siddhânta. The third chapter, which, as we have seen above, we may connect with the Pauliśa Siddhânta with a very high degree of probability, gives in stanzas 1—3 the required rules for finding the mean and true places of the sun, and then continues, in stanzas 4—9, to give certain rules about the moon. Now these rules have unfortunately remained obscure to us; but yet so much appears certain that they are somehow connected with the rules concerning the moon given in the former half of chapter II, constituting, as it seems, a kind of continuation, or more accurate version of the latter. But again, on this latter hypothesis no reason is apparent why the two sets of rules should be separated from each other by the altogether heterogeneous matter treated of in the latter half of chapter II. I therefore see myself obliged to leave this point undecided, and only wish to suggest, as a third not impossible alternative, that the method for calculating the places of the moon which is set forth in chapter II belonged, in its essential features at least, to the Pauliśa as well as to the Vasishṭha Siddhânta,

and that stanzas 8-13 of the third chapter add certain details which were peculiar to the former of the two Siddhântas. It is greatly to be regretted that the introductory stanza of chapter II, which possibly would throw some light on the position of the chapter, has remained altogether obscure to us.

There now remain for adjudgment only the first and the last chapters of the Pañchasiddhântikâ. The latter I shall discuss further on. The position of the former is altogether clear; it contains, subsequently to some introductory stanzas, a rule for calculating the ahargaṇa according to the Romaka Siddhânta, an exposition of the principles according to which the intercalation of lunar months and the omission of lunar days are managed in the Pauliśa, Romaka and Sûrya Siddhântas, and finally a set of rules for calculating the so-called Lords of the year, month etc., which rules were most likely given in each of the three Siddhântas last mentioned.

The second question, which must be touched upon before we can review the teaching of the individual Siddhântas, is whether the Pañchasiddhântikâ represents the teaching of the five astronomical works, on which it is professedly based, with absolute accuracy, or rather allows itself certain modifications of the doctrines summarized. This question is one of considerable importance; for before we have settled it one way or other, we are unable to judge of the historical position of the five Siddhântas, and to compare the account, given of them by Varâha Mihira, with what we know about them from other sources. We have, in this part of our investigation, to occupy ourselves almost exclusively with the Sûrya Siddhânta, because that treatise is the only one of the five Siddhântas which has come down to our time, and thus allows of our comparing it with what Varâha Mihira tells us about the Sûrya Siddhânta as known to him. Now a cursory survey of those chapters of the Pañchasiddhântikâ which treat of the Sûrya Siddhânta shows at once that the treatise of that name known to Varâha Mihira agreed with the modern Sûrya Siddhânta in its fundamental features. The methods of the two treatises are essentially the same and, on the other hand, sufficiently different from those of the other Siddhântas summarized by Varâha Mihira, to ensure to the Sûrya Siddhânta in its two fold form a distinct position of its own. At the same time we cannot fail to notice that in certain points the teaching of the old Sûrya Siddhânta (by which name I shall, for shortness sake, designate the Sûrya Siddhânta known to Varâha Mihira) must have differed from the correspondent doctrines of its modern representative. If we, for instance, observe that the old Sûrya Siddhânta assigned to the mean diameters of sun and moon the values 32′ 5″ and 30′ 54″ (P. S. IX. 15. 16), while 32′ 3.″6 and 32′ are the corresponding values according to the modern

treatise; or if we notice the values assigned in XVII 1. 2 to the epicycles of the apogee which altogether differ from those stated in the modern Sûrya Siddhânta; we are driven to the conclusion that in these and similar points the treatise used by Varâha Mihira really differed from the modern one known to us. For we are altogether unable to imagine any reason why Varâha Mihira should have changed, in the details referred to, the doctrines of the book which he aims at epitomizing.

There is however a series of other cases in which the decision is not quite so simple. While, as remarked above, the mathematical processes prescribed in the old Sûrya Siddhânta agree on the whole with those of the modern treatise, it at once appears that Varâha Mihira whose intention it is to write a karaṇa considers himself entitled to represent the teaching of his original in a somewhat condensed form, facilitating the quick despatch of the required astronomical calculations. What he *f. i.* says, in the first chapter, about the yuga of the Sûrya Siddhânta, clearly is an abbreviated statement of the corresponding doctrines of the old Sûrya Siddhânta, and we therefore have no reason to doubt of the old Siddhânta, as well as the modern one, having taught that 4320000 years constitute a great age, and that one thousand such great ages go to a kalpa. The fact is that for all the merely theoretical part of a Siddhânta there is no room in the karaṇa, and that hence the latter does all that is required if, instead of describing the great periods of the world, it states the smallest possible aggregate of years comprising an integral number of lunar months and natural days. So far we have no reason to hesitate in accepting Varâha Mihira's statements as a faithful, though somewhat modified, rendering of the meaning of the old Sûrya Siddhânta; the question however assumes a somewhat different aspect when we compare the number of natural days contained, on the one hand, within the mahâyuga of the modern Sûrya Siddhânta, and, on the other hand, within the corresponding period according to Varâha Mihira. The modern Sûrya Siddhânta teaches that a mahâyuga of 4320000 years comprises 1593336 intercalary months and 25082252 omitted lunar days, whence it follows that the number of sâvana days contained within the same period amounts to 1577917828. Varâha Mihira on the other hand, following *his* Sûrya Siddhânta, states that a period of 180000 years comprises 66389 intercalary months and 1045095 omitted lunar days, so that a mahâyuga ($= 24 \times 180000$ years) consists of 1577917800 sâvana days, *i. e.* 28 days less than according to the modern Sûrya Siddhânta. Here it certainly appears possible that Varâha Mihira should have slightly diminished the number of the sâvana days of the mahâyuga, and implicitly the length of the solar year, in order to be able to reduce

that number, as well as the number of the years of the yuga, by twenty-four and thus to arrive at figures more easy to manipulate; all the more as the inaccuracy involved in that change would affect to an almost insensible degree only the comparatively short periods to which the rules of the karaṇa grantha are meant to be applied. But in spite of this undeniable possibility I am inclined to think that in the present case also Varâha Mihira proceeded with strict accuracy, and that his Sûrya Siddhânta actually assigned to the great yuga twenty-eight days less than the modern treatise does. For in addition to the general consideration that there are several other items in which the old and the new Siddhântas differed beyond any doubt, we have in the present case two special reasons *viz.* firstly that it would have sufficed to diminish 1577917828 by four (instead of twenty-eight) in order to make it divisible by twenty-four; and secondly that the estimation of the length of the solar year implied in the statement of the old Sûrya Siddhânta agrees exactly with that value of the length of the Solar year that results from the elements of that Pauliśa Siddhânta about which Bhaṭṭotpala's commentary on the Bṛihat Saṃhitâ and Pṛithûdaka Svâmin's commentary on Brahmagupta's sphuṭa Brahma Siddhânta furnish some information. As we shall see at once, Varâha Mihira's Sûrya Siddhânta agreed with that Pauliśa Siddhânta in several other points also, and it therefore is not improbable that the two Siddhântas were at one also concerning the length of the solar year. If this is so, the most important item by which hitherto the Sûrya Siddhânta was considered to be distinguished from the Pauliśa Siddhânta (as reported by Bhaṭṭotpala etc.) would vanish; which clearly shows that an accurate investigation of the degree of strictness with which Varâha Mihira reproduces the doctrines of his Siddhântas cannot be dispensed with.

Similar to the case just discussed is that of the mean revolutions of the planets, as reported, according to the Sûrya Siddhânta, in the 16th chapter of the Pañchasiddhântikâ. As appears from the notes to the translation and the latter part of this Introduction, the periods assigned to the mean revolution by the old Sûrya Siddhânta differed more or less from the corresponding values stated in the modern treatise. There, however, the hypothesis of Varâha Mihira having for some reason or other modified the elements of the work with which he had to deal seems altogether excluded. If he had chosen to state the length of the revolutions of the planets in the ordinary form *i. e.* by establishing periods within which the planets perform integral numbers of complete revolutions, he might possibly have had reason to manipulate the traditional numbers to a certain extent, so as to reduce them to more manageable terms. But in the case under discussion he follows another plan *viz.* of at first stating the time of one revolution in round numbers, and then directing

us to apply a certain correction, in order to make up for the inaccuracy involved in the employment of those round numbers. Now it is easy to see that, if Varâha Mihira's Sûrya Siddhânta had exhibited the same figures as the modern Siddhânta, the amount of the corrections would differ from that actually stated by him, and we therefore are entitled to conclude that regarding the revolutions of the planets also the old Sûrya Siddhânta actually differed from the modern one; a conclusion moreover made more acceptable by the circumstance that several of the values assigned to the mean revolutions by Varâha Mihira's Siddhânta agree with the teaching of the Pauliśa Siddhânta known to Bhaṭṭotpala, and with that of Âryabhaṭa.

That the difference, observed between the numbers of the natural days of the yuga as stated by the two Sûrya Siddhântas, is due to a real discrepancy of the two books, is further confirmed by the rule given in Chapter X 2 and 4 for finding the mean place of the moon. This rule is based on the elements of the yuga as stated in chapter I, but for the sake of greater facility of calculation employs reduced numbers. Instead of multiplying the given ahargaṇa by $\frac{2406389}{65746575}$ (the numerator of which fraction are the sidereal revolutions of the moon during the period of 180000 years, and the denominator the sâvana days comprehended within the same time), it directs us to employ the expression $\frac{900000}{24589506}$, and thereupon—in order to make up for the error involved in this substitution—to deduct from the mean place of the moon thus found $\frac{51''}{3120}$ for each revolution. In other words, Varâha Mihira is unwilling to allow to pass an error in the mean position which amounts to no more than one sixtieth of a second of space for each revolution. But if he, on the other hand, had purposely, for mere convenience of calculation, lessened the length of the mahâyuga by twenty-eight days, he would thereby have reduced the length of each sidereal month by about four hundreths of a second of time, which in its turn would have implied an error in the moon's mean place amounting to about one fiftieth of a second of space for each revolution. So that, while anxious to correct one small error, he would have allowed another greater one to pass; an assumption which we have absolutely no right or reason to make.

The investigation of special cases thus certainly favours the conclusion that the changes which the old Sûrya Siddhânta has undergone in Varâha Mihira's representation are purely formal, and that convenience of calculation is held by him to be a consideration of altogether secondary importance.

We therefore, and this is the most important conclusion to be drawn from the preceding enquiry, may hold ourselves entitled to look in the same light upon Varâha Mihira's rendering of the other Siddhântas which we can

check neither by means of the originals nor with the assistance of modern recasts. There also we must hold Varâha Mihira to have closely followed the elements and methods of the authors of the Siddhântas, and to have permitted himself only minor changes, such as facilitate calculation without affecting the fundamental character of the rules. General principles, enabling us to judge with certainty how far those changes may extend, can however not be laid down; we rather must judge each given case on its own merits. When we *f. i.* find that the yuga of the Romaka Siddhânta comprised, according to Varâha Mihira, only 2850 years, we may raise the question whether this yuga is the true yuga of the Romaka, or only represents a subdivision of the true yuga, analogous to the 180000 years of the Sûrya Siddhânta which, as we have seen above, must be considered as the smallest fraction of the mahâyuga with which the calculation of the ahargaṇa can be effected. But we shall without much hesitation decide in favour of the former alternative, in the first place because the yuga of the Romaka Siddhânta is expressly called a yuga of the sun and moon, for the formation of which a comparatively small number of years was sufficient, and in the second place because Brahmagupta, in a passage to be quoted later on, testifies that the Romaka Siddhânta did not conform to the traditional views concerning the large periods of time. If, again, we find that according to the Pañchasiddhântikâ the Pauliśa Siddhânta made no use of yugas of any kind to the end of calculating the ahargaṇa and the mean positions of the planets, but employed for those purposes a peculiar system of its own, we certainly must conclude that system to have been actually taught in the original Pauliśa Siddhânta, and not constructed, as indeed it might have been, by Varâha Mihira on the elements of the Pauliśa Siddhânta. For why, we must ask ourselves, should he have transformed in that way the elements of the Pauliśa Siddhânta rather than those of the other Siddhântas which without any difficulty might have been thrown into the same form? And, to single out one further point, if we find that the Pañchasiddhântikâ gives a rule how to calculate, according to the Sûrya Siddhânta, the equation of the centre of sun and moon for any given anomaly, while it represents the Pauliśa and Romaka Siddhântas as merely stating the amount of those equations for a certain series of anomalies, without teaching us how to calculate the equations for the intervening anomalies; we must again suppose that Varâha Mihira faithfully renders characteristic features of the original Siddhântas as he found them; for if he had held the opinion (which as the writer of a karaṇa he indeed might have held) that the practical astronomer knows enough, if be can assign the equations of the centre for, let us say, each fifteen degrees of anomaly, he would no doubt not have given the general rule from the Sûrya

Siddhânta, but calculated from it the amounts whose knowledge he considered indispensable, and inserted them ready calculated in his text.

We therefore arrive at the conclusion that Varâha Mihira has in no case obliterated the characteristic features of the Siddhântas he had to deal with, and that whatever distinguishes those works from one another in the text of the Pañchasiddhântikâ really distinguished them in their original form. We may note in conclusion that there is one interesting circumstance which furnishes a kind of counterproof to this conclusion. According to VII. 1. and VIII. 9 the Pauliśa and Romaka Siddhântas calculated the parallax in longitude at a solar eclipse in exactly the same manner. Now Varâha Mihira accentuates this agreement of the two works by stating the rule each time in exactly the same words. But an author, who is so evidently desirous to mark the points in which the different authorities on which he draws are at one, may certainly be supposed to be no less scrupulous in stating the details in which they diverge.

After having thus cleared the way, I proceed to give short summaries of the doctrines of the five Siddhântas, beginning with that one which, owing to the existence of a modern recension, is best known, *viz.* the Sûrya Siddhânta.

Sûrya Sidd

According to I. 14 the Sûrya Siddhânta of Varâha Mihira taught that 180000 years contain 66389 intercalary months, and 1045095 omitted lunar days. The number 180000 is the twenty-fourth part of the years of a mahâyuga; if we therefore, for comparison's sake, multiply the figures given above by twenty-four, and deduce from them the number of the sâvana days of a yuga, we obtain 1577917800; while the corresponding figure for the modern Siddhânta is 1577917828. The length of the sidereal year resulting from these figures is $365^d\ 6^h\ 12'\ 36''{\cdot}56$ in the case of the modern, and $365^d\ 6^h\ 12'$ $36''$ in the case of the old Sûrya Siddhânta. The latter value exactly agrees with that which, according to Bhaṭṭotpala and others, was assigned to the solar year in the Pauliśa Siddhânta.

What the old Sûrya Siddhânta taught about the mean motions of the sun and moon, is immediately apparent from the above statement concerning the nature of the yuga. The number of the moon's sidereal resolutions during the yuga is the same as in the modern Siddhânta; whence it follows that each revolution is a little shorter (the yuga of the old Siddhânta counting twenty-eight days less than that of the modern one). Rules how to calculate the mean positions of the sun and moon are given in chapter IX; they however call for no special remarks, as they follow immediately from the constitution of the yuga.—The duration of the revolution of the moon's apogee may

be derived without difficulty from stanzas 3 and 4 of the same chapter. From stanza 3 it follows that one resolution is performed in $3231^{d}\ 23^{h}\ 42'\ 16''{\cdot}76$; while the duration resulting from the elements of the modern Siddhânta amounts to $3232^{d}\ 2^{h}\ 14'\ 53''{\cdot}4$. And if, accommodating ourselves to the general Siddhânta practice, we determine the number of revolutions performed within one mahâyuga, we obtain 488219 for Varâha Mihira's Sûrya Siddhânta; while the modern Siddhânta gives 488203 only. We note that according to Âryabhaṭa also the apogee performs 488219 revolutions within one mahâyuga.

From stanza 5 of the same chapter we learn that the old Sûrya Siddhânta agreed likewise with Âryabhaṭa in reckoning 232226 revolutions of the moon's node to one mahâyuga; while the modern Siddhânta counts 232228.—In estimating the greatest latitude of the moon at 270 minutes (stanza 6) the old Sûrya Siddhânta agreed with the modern one.

According to stanza 7 the old Sûrya Siddhânta assigned to the sun's apogee the longitude of eighty degrees. Âryabhaṭa gives 78° only, and a calculation of the place of the apogee for the epoch of the Pañchasiddhântikâ, based on the elements of the modern Sûrya Siddhânta, gives about 77°. The Pañchasiddhântikâ says nothing about the revolutions of the apogees of the sun and planets, and it hence is possible that the old Sûrya Siddhânta was not yet acquainted with the theory held, on entirely insufficient grounds, by the modern treatise, and modern Hindû astronomers in general, that the apogees of the sun and the planets perform a certain number of revolutions within a mahâyuga or kalpa. On the other hand it might be supposed that Varâha Mihira, although acquainted with that doctrine, yet confined himself to stating the places which the apogees occupied at his time, since so much is sufficient for the purposes of a karaṇa-writer.—The rules for finding the true places of the sun and moon, which are given in stanzas 7 and 8, are analogous to those of the modern Sûrya Siddhânta, with the one important difference that, while the latter assumes epicycles of different size for the even and odd quarters of the revolution of the two bodies, Varâha Mihira's Sûrya Siddhânta knows of one epicycle only for the sun as well as for the moon. The rules for finding the true motion, etc. given in stanzas 13 and 14 agree with those of the modern work.

The rules for calculating solar and lunar eclipses agree with the modern rules as far as general methods are concerned, but at the same time show many deviation in details; so *f. i.* in the calculation of the parallax in solar eclipses. Some of these rules we have, moreover, not been able to elucidate to our full satisfaction.

The mean motions of the planets (apart from sun and moon) are given in chapter XVI. The following statement shows the numbers of complete revolutions during one mahâyuga according to the old and modern Sûrya Siddhântas.

| | Old Sû. Si. | Modern Sû. Si. |
|---|---|---|
| Mercury | 17937000 | 17937060 |
| Venus | 7022388 | 7022376 |
| Mars | 2296824 | 2296832 |
| Jupiter | 364220 | 364220 |
| Saturn | 146564 | 146568 |

The two Siddhântas thus agree concerning Jupiter only, and disagree therein from Âryabhaṭa, according to whom Jupiter's revolutions amount to 364224 in one mahâyuga. The old Sûrya Siddhânta agrees with Âryabhaṭa and the Pauliśa Siddhânta (according to Bhaṭṭotpala), as far as Venus, Mars and Saturn are concerned, while it agrees with the Pauliśa Siddhânta only concerning Mercury and Jupiter.

The positions of the apogees and the dimensions of the epicycles of the apsis and the conjunction are given in XVII, 1—3. If will be observed that, as regards the numbers indicating the size of the epicycles of the apsis of Venus and Saturn, the translation diverges from the corrected text given by us. The manifestly corrupt text was at first emendated on the basis of the dimensions stated in the modern Sûrya Siddhânta, the hypothesis of the agreement of the two Siddhântas in this detail being resorted to in the absence of evidence decidedly favouring any other assumption. But I afterwards discovered that such evidence exists. The statements which Brahmagupta in his Khaṇḍakhâdyakakaraṇa makes about the places of the apogees and the dimensions of the epicycles agree with those made in the sixteenth chapter of the Pañchasiddhântikâ, in all those details in which the text of the latter work needs no emendation, and it therefore may be presumed that the agreement extended also to the epicycles of Venus and Saturn. And examining the traditional text of the Pañchasiddhântikâ from this point of view, we find that instead of the 'Surâs' of stanza 1 we have to read not 'śarâs' but 'svarâs' and that the 'triṃśâḥ' is correct without any further addition. It is true that thus the Âryâ remains defective; but the word, or words, missing were most probably expletive rather than essential to the sense. Brahmagupta maintains his karaṇa to be founded on Âryabhaṭa, or at any rate to give re-

sults equal to those to be derived from Âryabhaṭa ;* it is then a somewha curious circumstance—into the discussion of which I cannot enter in this plac —that the dimensions of the epicycles and the positions of the apogees assume in the Khaṇḍakhâdyaka (as well as in the sixteenth chapter of the Pañcha siddhântikâ) differ, all of them, more or less from those recorded in the Laghu Âryabhaṭîya.†

The method, taught in chapter XVII, of calculating the equations o the apsis and of the conjunction agrees on the whole with that prescribed i the modern Sûrya Siddhânta, although there are several divergences in details Peculiar are the special rule given for Mercury in stanza 10, and the correctio to be applied to Venus' place according to stanza 11. The statements as t the distance from the sun at which the planets become visible differ to som extent from those made in the modern Siddhânta; so also the greatest latitude of the planets given in stanzas 13 and 14.

An omission which might make us suppose that the chapter as give in our Manuscripts is not complete is that nothing whatever is said about th places of the planets' nodes.

Paitâmaha Siddhânta.

We next turn to the Paitâmaha Siddhânta which indeed has not com down to our time, but whose teaching throughout agrees with that of a wel known section of Hindû astronomical literature.

Of this Siddhânta there treats only one very short chapter, of th Pañchasiddhântikâ *viz.* the twelfth one ; but its five stanzas manifestly suffice t reproduce everything of importance contained in that very primitive treatise The Paitâmaha Siddhânta, known to Varâha Mihira, represents Hindû Astro nomy as not yet affected by Greek influences,‡ and thus belongs to the sam category as the Jyotisha-Vedâṅga, the Garga Saṃhitâ, the Sûryaprajñapti an similar works. From what Varâha Mihira says about its contents, we migh almost identify it with the Jyotisha Vedâṅga. The yuga on which the calcu lations of the Paitâmaha Siddhânta base is the well known quinquennial on

* Brahmagupta's Khaṇḍa-khâdyaka begins with the following stanza

प्रणिपत्य महादेवं जगदुत्पत्तिस्थितिप्रलयहेतुं ।
वक्ष्यामि खण्डखाद्यकमाचार्यार्यभटतुल्यफलम् ॥

† It is also worthy of notice that Âmaśarman, one of the Commentators of the Khaṇḍ khâdyaka, quotes some stanzas from a Pauliśa tantra which make the same statements about th dimensions of the epicycles as the Khaṇḍakhâdyaka itself, and, moreover, seems generally to tre the doctrines of Âryabhaṭa and the Pauliśa as equivalent.

‡ As already pointed out by me in my paper on the Jyotisha-vedâṅga, Journal of th Asiat. Soc. of Bengal 1878.

which consists of five solar years of 366 days each, and contains sixty solar months, sixty-two synodical months, and sixty-seven so-called nâkshatra months *i. e.* sidereal revolutions of the moon. The beginning of the yuga is marked by a conjunction of the sun and moon at the first point of the nakshatra Dhanishṭhâ. The duration of the longest day of the year amounts to eighteen muhûrtas, that of the shortest to twelve muhûrtas; in the intervening periods the days increase or decrease by the same daily quantity.—The Paitâmaha Siddhânta refers to two points only which appear not to be mentioned in the Jyotisha Vedâṅga, as far as I have hitherto succeeded in making out the meaning of that difficult treatise. It, in the first place, gives a rule for calculating the so called vyatîpâta yogas (st. 4); and in the second place, fixes a period from which the quinquennial yugas are to be counted. In st. 2 Varâha Mihira directs us to deduct two from the Śâka date, and to divide the remainder by five; which implies that a new yuga is supposed to begin with the third year of the Śâka Era, or two Śâka elapsed.

Whether this direction is due to Varâha Mihira only, or was already contained in the Paitâmaha Siddhânta, may be considered doubtful; the latter alternative, however, appears to be more probable, as Varâha Mihira, if in any way adding to—or rendering more definite—the teaching of the Paitâmaha Siddhânta, would most likely have adapted it to the same initial date as the other Siddhântas, *viz.* 427 Śâka.

The Paitâmaha (Brâhma) Siddhânta known to Varâha Mihira has thus to be distinguished from the Brahma Siddhânta on which Brahmagupta's Sphuṭa Siddhânta is based. That Brâhma or Paitâmaha Siddhânta is a short treatise in prose, forming part of the Vishṇudharmottara-Purâṇa, and belonging altogether to the modern phase of Hindû Astronomy. The number of Brahma Siddhântas, known at present, thus amounts to four, *viz.* the Paitâmaha Siddhânta summarized in the Pañchasiddhântikâ, the Paitâmaha Siddhânta forming part of the Vishṇudharmottara, the Sphuṭa Brahmasiddhânta by Brahmagupta, and that Brahma Siddhânta whose more ordinary name is Śâkalya Siddhânta.

There now remain the Romaka, Pauliśa and Vasishṭha Siddhântas, for the teaching of none of which we have any other source of importance but the Pañchasiddhântikâ. I begin with the first mentioned of these three treatises.

Romaka

The fifteenth stanza of the first chapter shortly describes the nature of the yuga employed by the Romaka Siddhânta. The yuga is called 'one of the sun and moon' *i. e.* a lunisolar one, and said to comprise 2850 years,

which period is further stated to contain 1050 adhimâsas and 16547 pra
*i. e.* tithipralayas, omitted lunar days. The above numbers of years
intercalary lunar months allow of being reduced by 150, and we thus find
in the opinion of the author of the Romaka, 19 solar years exactly co
seven intercalary months, or—if we take the entire sum of months—th
solar years comprise 235 synodical lunar months. The yuga of the Ro
is thus evidently based on the so-called Metonic period, named afte
Athenian astronomer Meton who, about 430 B. C., showed the mea
improving the Greek Calendar of his time by the assumption of 19 tro
years comprising 235 synodical months.—That the Romaka Siddhânta, in
of making use of the simple Metonic period, employs its one hundre
fiftieth multiple, has a reason not difficult to discern. The author o
Romaka, although manifestly borrowing his fundamental period from the
at the same time wished to accomodate himself to the Indian fashion o
culating the sum of days which has elapsed from a given epoch (the so-
ahargaṇa) by means of a cyclic period comprising integral numbers of
years, lunar months and natural days. Now the simple Metonic period
not represent an aggregate of the nature required, neither if we—with M
himself—estimate the length of the tropical year at $365\frac{5}{19}$ days, nor if we
ourselves of the more accurate determinations by which later Greek ast
mers improved on the work of Meton, and it therefore becomes requis
employ a multiple. What the multiplying number is to be, of course de
on the value assigned to the length of the year, and we therefore have
certain the opinion held on this point by the author of the Romaka.
data supplied in stanza 15 enable us to do so without difficulty. For
multiply the 2850 years of the Romaka yuga by 12 (in order to find the
ber of corresponding solar months), add the 1050 adhimâsas (whereb
obtain the number of synodical lunar months), multiply by 30 (so as t
the lunar days), and finally deduct the 16547 tithi pralayas, the final
amounts to 1040953 natural days; which being divided by 2850 (the nu
of the years of the yuga), we obtain for the length of one year $365^d\ 5^h\ 5$
But in order to form an aggregate of years which contains an integral nu
of days and at the same time is divisible by nineteen, $19 \times 50 = 2850$
have to be taken.

Whence the above determination of the year's length was adopt
the author of the Romaka, there cannot be any doubt. The year
Romaka is, down to seconds, the tropical year of Hipparchus or, if w
of Ptolemy who accepted the determination, considerably faultive as i
made by his great predecessor.

The rule for calculating the ahargaṇa according to the Romaka (I. 8—10), and so likewise the rules for finding the mean places of the sun and the moon (VIII. 1. 4) immediately follow from the constitution of the yuga, and have been elucidated in the notes to the translation. The length of the periodical month would, according to the Romaka, amount to $27^{d}\ 7^{h}\ 43'\ 6.3''$.

To the apogee of the sun the longitude of 75° is ascribed in VIII. 2. —The apogee of the moon and its periods of revolutions are not, in the usual Indian style, treated apart from the moon's motion; the 8th chapter (stanza 5) rather contains a rule for calculating the moon's position with regard to her apogee directly *i. e.* without any preliminary separate calculation of the apogee's place. The kendra mentioned there is the moon's anomaly, and the rule implies that the anomaly revolves 110 times within 3031 days, in other words that the moon returns to her apogee, or performs one anomalistic revolution, in $27^{d}\ 13^{h}\ 18'\ 32''.\ 7$.

By deducting the longitude of the sun's apogee from the mean longitude of the sun we find the sun's anomaly, and may then proceed to calculate his true longitude. For the latter process the Romaka Siddhânta however does not supply any general rule, enabling us to deduce the required equation of the centre for any given anomaly; but contents itself with stating the amounts of the equation from 15 to 15 degrees of anomaly. These amounts are stated in VIII. 3, and it is of interest to note that they agree very closely with the corresponding amounts given by Ptolemy. The greatest equation of the centre, which according to the modern Sûrya Siddhânta amounts to $2°\ 10'\ 13''$, and which in no other Hindû text book known to me greatly differs from this latter value, according to the Romaka amounts to $2°\ 23'\ 23''$, while Ptolemy assigns to it the value of $2°\ 23'$; and also the equations for the smaller anomalies show a pretty close agreement, as appears from the following tabular statement

| Degrees of Anomaly. | 15 | 30 | 45 | 60 | 75 | 90 |
|---|---|---|---|---|---|---|
| Equation of centre according to the Romaka. | $34'\ 42''$ | $1°\ 8'\ 37''$ | $1°\ 38'\ 39''$ | $2°\ 2'\ 49''$ | $2°\ 17'\ 5''$ | $2°\ 23'\ 23''$ |
| According to Ptolemy. | | $1°\ 9'$ | | $2°\ 1'$ | | $2°\ 23'$ |

The values quoted from Ptolemy are those given by him for the quadrants of the apogee. The Romaka Siddhânta apparently makes no distinction of quadrants, but employs the same equations indiscriminately for all.

In an analogous manner stanza 6 states the moon's equations
centre from 15 to 15 degrees of anomaly. These equations do not agre
closely with the corresponding ones of Ptolemy, according to whom the
est equation amounts to 5° 1′.—The length of the revolution of the
node amounts, according to VIII. 8, to $6796^{d}\ 7^{h}$, in pretty close agre
with Ptolemy's determination of the same quantity, *viz.* $6796^{d}\ 14^{h}$ etc.—
cerning the greatest latitude of the moon we have two conflicting state
implied in VIII. 11 and VIII. 14, provided the interpretation of
stanzas given in the translation be right. According to the former it
amount to 240′; according to the latter to 270′, which is the value ordi
met with in Hindû astronomical works. Regarding the explanation gi
the translation of stanza 14 I have to remark that it is an attempt on th
of my colloborator to connect the rule with the usual estimation of the
greatest latitude, while the fraction $\frac{21}{9}$, if its denominator be taken
reduced Radius, would strictly lead back to a greatest latitude of 280′.
different values should be ascribed to the same quantity in one and the
book, might primâ facie appear inadmissible; but it is by no means imp
that in some of the older Siddhântas there were incorporated empirical
borrowed from various sources, the rationale of which was not under

Stanza 13 gives 30′ and 34′ for the mean measure of the diame
sun and moon respectively, and st. 15 gives the ordinary Indian rule fo
ing the true diameters from the mean diameters and the true and
motions.

The greatest parallax is, as in Indian astronomy generally, su
to be equal to the mean motion during four nâḍikâs; hence the rule gi
st. 9 for calculating the parallax in longitude, the result being the diff
of the parallaxes of the sun and the moon.

The parallax in latitude is calculated on the same principle (stan
—14), the result however not giving the difference of the solar and the
parallaxes, but merely the latter one, the solar parallax being neglected
inaccuracy in the preliminary determination of the zenith distance
nonagesimal is noted in the translation.—The rule for calculating the du
of the eclipse, after the true latitude has been ascertained (st. 16),
usual one.

What remains unexplained of the Romaka Siddhânta are, princ
the different kshepa-quantities met with in the rules for finding the ah
(Chapter I), and the mean places of sun, moon. etc. (Chapter VIII).

of course, are intended to enable us to start in our calculation from the epoch of the Pañchasiddhântikâ (or of *the*, or *some*, Romaka-Siddhânta, about which see below), and their elucidation would probably lead to some interesting results. It will be observed that the rule for calculating the ahargaṇa professes to be adapted to the meridian of Yavanapura, while the rules for finding the places of the sun, moon etc. refer to the meridian of Ujjayinî.* The difference in longitude of those two places is stated by Varâhamihira—following the Pauliśa Siddhânta as it appears—in III. 13.—A further reference to the Romaka which has remained obscure to us seems to be made in III. 73.—Whether any of the rules concerning the planets which are given in the last chapter base on the Romaka Siddhânta, is doubtful.

From this short summary of the contents of the Romaka Siddhânta I pass on to the consideration of its authorship and time of composition, coupling therewith—for reasons which will appear later on—an enquiry as to the date of the Pañchasiddhântikâ itself.

Hitherto it has been generally held, on the authority of Colebrooke and Bhâu Dâjî, that the original Romaka Siddhânta was composed by Śrîsheṇa; an opinion which I myself, when writing my paper on the Pañchasiddhântikâ (Journ. Asiat. Soc. of Bengal) was not prepared to abandon entirely, although then already certain considerations led me to suggest that Śrîsheṇa's work might after all have been a mere recast of an older treatise of the same name. This latter view I now feel inclined to set forth as the only true one.

The authorities for Colebrooke's and Bhâu Dâjî's opinion were Brahmagupta and his commentator Pṛithûdaka Svâmin. Brahmagupta, in a considerable number of passages of his Sphuṭa Siddhânta, refers to Śrîsheṇa by name, and in connexion with those passages his commentator repeatedly remarks that Śrîsheṇa was the author of the Romaka Siddhânta. And in one passage at least Brahmagupta himself mentions Śrîsheṇa in connexion with the Romaka Siddhânta. That passage which is found in the Tantra-parîkshâdhyâya (the 11th chapter of the Sphuṭa Siddhânta) was discussed by me in the paper referred to above (pp. 290 ff.), but owing to the very corrupt form in which the Manuscripts of the Sphuṭa Siddhânta exhibit its text I did not at that time fully understand it, so that the meaning of just its most

* The truth of this remark of course depends, in the first place, on the correctness of the emendation in VIII. 5 owing to which we have substituted ऽस्तगमेऽ वन्त्याम् (read so in the text, instead of ऽस्तगमवन्त्याम्) for the °स्तगमवत्यां of the Manuscript; and in the second place, on the assumption that the clause "at sunset, at Avanti" has to be connected generally with the rules given in stanzas 1—5. But both this assumption and the emendation appear to me well founded.

important clause escaped me, as it seems to have escaped Colebrooke an Bhâu Dâjî. The text of the passage, as appearing in Colebrooke's manuscrip (now in the India Office Library), runs as follows:—

श्रीषेणविष्णुचंद्रप्रद्युम्नार्यभटलाललिंहानां । १
ग्रहणादिविसंवादात् प्रतिदिवसं सिद्धमज्ञत्वम् । २
युक्त्यार्यभटोक्तानि प्रत्येकं दूषणानि योज्यानि । ३
श्रीषेणप्रभृतीनां कानिचिदन्यानि वक्ष्यामि । ४
आर्यान्सूर्यशशांकौ मध्याविंदूच्चचंद्रपातौ च । ५
कुजबुधगीष्पतिसितशीघ्रसनिश्चरान् मध्यान् । ६
युगयातवर्षभगणान्वातिष्टान्विजयनंदिकृतपाठान् । ७
मंदोच्च परिधिपातान्दृष्टीकरणाद्यार्यभटात् । ८
श्रीषेणेन गृहीत्वा रवीन्दुरारोमकृतकर्यः । ९
एतानेव गृहीत्वा वासिष्ठो विष्णुचंद्रेण । १०

The other Manuscripts of the Sphuṭa Siddhânta known to me (or belonging to the Bombay Government; one, a modern copy, in the library o the Benares College; and one in the Royal Library of Berlin) have som important different readings. They all read in line 1 लाट° instead of लाल° an in line 5 लाटासूर्य° instead of आर्यान्सूर्य°. In line 7 the Ben. MS. reads वाशिष्टाद्विज the Berlin MS. has वाशिष्टाञ्जयनंदिकृतपादान्; and the Bom. MS. वसिष्टाभ्येनयुगा कृतपाठात्. In line 8 the Bom. and Ben. MSS. read परिधिपातस्पष्टीकरणाद्यमा°. Lin 9 runs in the Berlin MS. एतानेव गृहीत्वा चंद्ररवोच्चयरोमकः कृतः कंथा. The Ben. MS reads गृहीत्वा रवीन्दुपरोमककृतः कथा, and the Bom. MS. गृहीत्वा रवीचपरोमकात् कृतः कं In line 10, instead of वासिष्ठो the Ben. MS. has विशिष्टो, the Bom. MS. विहितो (not to mention less important differences).

The general purport of this passage is clear. It is meant as a criticis of the performance of Śrîsheṇa, who in composing his astronomical text boo borrowed rules and processes from various sources, and combined them int an incongruous whole. Leaving aside for the present the second half o line 7, and line 10, we may—emendating the text as given above with th help of the varietas lectionis—render the passage as follows.

'From the fact that Śrîsheṇa, Vishṇuchandra, Pradyumna, Âryabhaṭ Lâṭa, and Siṃha contradict one another regarding eclipses and similar topic their ignorance is proved daily. The criticisms which I (in the preceding pa of the chapter) have passed on Âryabhaṭa are, with the requisite modification to be applied to the doctrines of each of those teachers as well. I will howeve make some further critical remarks on Śrîsheṇa and others.

Śrîsheṇa took from Lâṭa the rules concerning the mean motions of th sun and moon, the moon's apogee and her node, and the mean motions

Mars, Mercury's Śîghra, Jupiter, Venus' Śighra and Saturn; from — — the elapsed years and revolutions of the yuga; from Âryabhaṭa the rules concerning the apogees, epicycles and nodes, and those referring to the true motions of the planets; and thus — — — '

Here we are confronted by the latter half of line 9, which seems to state that thus the Romaka (Siddhânta) was composed (kṛitaḥ) by Śrîsheṇa. But this would leave unexplained the last word of the line which three Manuscripts give in the form 'kanthâ.' Keeping therefore this latter reading, and substituting (with the Berlin and Bom. MSS.), 'ratnochchayo' for the four aksharas preceding 'Romakaḥ,' I translate 'and thus the Romaka (Siddhânta) which was (or 'is') a heap of jewels (as it were) has, by Śrîsheṇa, been made into a patched rag (as it were).'

In other words: Śrîsheṇa incorporated into the old genuine Romaka Siddhânta elements borrowed from various heterogeneous sources, and thereby spoilt it, making it look like a piece of cloth, or dress, made up of various patches.

The Romaka Siddhânta going under Śrîsheṇa's name was thus not the original one, but merely a recast of it, into which new matter borrowed from different astronomical writers had been introduced. This is neither improbable in itself, nor altogether destitute of collateral proof. For if we compare the information concerning Śrîsheṇa's Romaka Siddhânta, given by Brahmagupta, with what we now know about the Romaka Siddhânta epitomized by Varâha Mihira, certain differences between the doctrines of the two works present themselves at once. I here confine myself to two points, the consideration of which does not necessitate a reference to any other passage from the Sphuṭa Brahma Siddhânta but the one quoted above. The first point of disagreement is that Śrîsheṇa, according to Brahmagupta, borrowed his rules for the spashṭîkaraṇa *i. e.* for the calculation of the true places of the planets, from Âryabhaṭa. Now Âryabhaṭa's rules are known to us from the Laghv-âryabhaṭîya, and we observe that they agree in all essential points with the corresponding rules of the Sûrya Siddhânta, specifying, as the latter work does, the dimensions of the paridhi—epicycle of each planet, and teaching how the equation of the centre is to be calculated trigonometrically for any given anomaly. Varâha Mihira's Romaka Siddhânta on the other hand, as we have seen above, makes no mention of epicycles, does not in fact give any generally applicable rule for calculating the equation of the centre, but merely states in a tabular form the equations, howsoever calculated, for each fifteenth degree of the anomalies of sun and moon. That Romaka Siddhânta therefore manifestly had not borrowed its rules from Âryabhaṭa, and

hence cannot be identified with Śrîsheṇa's work. On the other hand it is quite intelligible that Śrîsheṇa, who appears to have followed the old Romaka Siddhânta as far as the mean motions of the planets are concerned, should have borrowed the rules for calculating the true places—which his principal authority was unable to supply—from the work of Âryabhaṭa. A second argument may be drawn from what, in line 7 of the extract quoted above from Brahmagupta, is said about Śrîsheṇa having borrowed from some other work (apparently some Vasishṭha Siddhânta) his theory as to the elapsed years and revolutions of the yuga. Judging from the expressions made use of in that place and from the context in which it stands, Śrîsheṇa's views about the yuga must have been akin to those generally held in the Siddhântas on that point, the yuga being a vast period of time comprising integral numbers of complete revolutions of all the planets. But as we have seen above, the yuga employed in the old Romaka Siddaânta was an altogether different one, of a strictly lunisolar character and hence consisting of a comparatively moderate number of years. When, therefore, Brahmagupta, in the first chapter of the Sphuṭa Siddhânta, animadverts on the non-traditional character of the Romaka Siddhânta,* he manifestly does not refer to the recast by Śrîsheṇa in whose hands the Romaka Siddhânta had assumed a more orthodox form, but to the genuine Siddhânta, which at Brahmagupta's time was no doubt still in existence and duly distinguished from Śrîsheṇa's treatise.

We next have to consider the bearings of a date which, in the first chapter of the Pañchasiddhântikâ, is mentioned in connexion with the Romaka-Siddhânta. Stanzas 8—10 which give a rule for calculating the ahargaṇa (*i. e.* the sum of civil days which have elapsed from an initial epoch up to a given date) direct us first to deduct 427 from the number of the current Śaka year, which means that the initial epoch of the calculation is 427 Śaka. It then proceeds to explain the details of the calculation of the ahargaṇa, and closes with the words 'this is the ahargaṇa in (or, according to) the Romaka Siddhânta.'

That this date—427 Śaka—is mentioned in the Pañchasiddhântikâ, has been known to scholars since a considerable time. The astronomers of Ujjayinî who furnished to Dr. William Hunter the list of astronomers with their dates, published by Colebrooke (Algebra p. XXXIII), gave 427 Śaka as the time of (their second) Varâha Mihira. Albe-ûnî refers to it as the date

of the Pañchasiddhântikâ. Bhâu Dâjî quotes the stanza from the Pañchasiddhântikâ as furnishing the epoch of the Romaka Siddhânta, adopted by Varâha Mihira also. (Journ. Royal Asiat. Soc. New Series Vol. I). Dr. Kern is inclined to look upon 427 Śaka as marking the year of the birth of Varâha Mihira who, as appears from a passage quoted by Bhâu Dâjî, died in Śaka 509.

All these views clearly have no further foundation than the passage of the Pañchasiddhântikâ about the calculation of the aharganа. The view that 427 Śaka is the year of Varâha Mihira's birth we may set aside without hesitation. Dr. Kern was led to that hypothesis partly by the consideration that the Pañchasiddhântikâ, which in one place refers to Âryabhaṭa's views, could hardly have been composed in 505 A. D. when Âryabhaṭa—born in 476 A. D.—was only 29 years old. We now know—from Dr. Kern's edition of the Âryabhaṭîya—that Âryabhaṭa composed his work in 499 A. D. already, so that he might very well have been quoted in a book writtten in 505 A. D. The other argument brought forward by Dr. Kern, *viz.* that Varâha Mihira died in 587, certainly goes some way to prove that the Pañchasiddhântikâ was not written in 505, but not that Varâha Mihira was born in the latter year. The text of the Pañchasiddhântikâ enables us at present to judge of the position of Varâha Mihira with regard to the date 427 Śaka. From the chapters on the Sûrya Siddhânta it appears that Varâha Mihira considers that year to be the epoch of his karaṇagrantha from which all astronomical calculations have to start; for all the kshepa quantities involved in the different rules, given in those chapters for finding the mean places of sun, moon, and planets, can be accounted for satisfactorily on that basis. I have no doubt that also the kshepa quantities stated in the Romaka and Pauliśa Chapters admit of being explained on the same supposition, but unfortunately we have so far not succeeded in finding the clue to their right understanding. Now it would certainly be most satisfactory, if we could assume that the Pañchasiddhântikâ was composed in the very year which it selects for its astronomical epoch, or at any rate within a few years of that year; for as nearness of the epoch tends to facilitate all astronomical calculations and, at the same time, to minimize the inaccuracies resulting from the fact that karaṇa rules are often only approximatively correct, it is the interest and the practice of karaṇa writers to choose for their epoch a year, as little remote as may be from the time of the composition of their treatises. The positive statement, however, made by Âmarâja (as quoted by Bhâu Dâjî) about the date of Varâha Mihira's death does not favour such an assumption; and we moreover find that the deduction of 427 forms part of a rule which in the end is said to be 'in' or 'according to' the Romaka Siddhânta. This

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यस्माच्च रोमके ते स्मृतिबाह्यो रोमकस्तस्मात् ॥

of the Pañchasiddhântikâ. Bhâu Dâjî quotes the stanza from the Pañchasiddhântikâ as furnishing the epoch of the Romaka Siddhânta, adopted by Varâha Mihira also. (Journ. Royal Asiat. Soc. New Series Vol. I). Dr. Kern is inclined to look upon 427 Śaka as marking the year of the birth of Varâha Mihira who, as appears from a passage quoted by Bhâu Dâjî, died in Śaka 509.

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