Indian Journal of History of Science, 17 (2) : 244—251 (1982)

JAGANNATH SAMRAT'S OUTSTANDING CONTRIBUTION TO INDIAN ASTRONOMY IN EIGHTEENTH CENTURY A.D.

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Jagannath Samrat was the Chief Pandit Astronomer in the court of Maharaja Savai Jaisingh II, the founder of Modern Jaipur and of five astronomical observatories at Jaipur, Delhi, Muttra, Ujjain and Varanasi[1]. We do not know about his life in detail. He was born in 1652 A.D.[2]. About his life Sudhakar Dwivedi says that in 1672 when Maharaja Savai Jaisingh was on a defence mission to south India he met Jagannath, who was then only twenty and very well-versed in *Śāstras*. He brought Jagannath to Jaipur to teach him Arabic and Persian. This perhaps he did to meet the challange from the Emperor of Delhi that Sanskrit Pandits cannot learn Arabic and Persian. In a short period Jagannath became well-versed in Arabic and Persian and also in Astronomical works in those languages. The Maharaja then took him to Delhi and presented him to the Emperor. The emperor was so pleased with Jagannath that he immediately appointed him his court Paṇḍit. But later on Maharaja Jaisingh requested the return of Jagannath who thereafter became the court Astronomer of Maharaja Jaisingh[3]. Jagannath Samrat in the introduction of his work *Siddhānta Samrāṭ* praises Maharaja Jaisingh and states that the work was written at the request of the Maharaja[4]. He refers to the Maharaja elsewhere also in that work. In the same book he mentions some astronomical observations made in śaka 1651 (1729 A.D.) and 1652 (1730 A.D.)[5].

The object of the paper is to clear misunderstandings about his works and to explain the methods of his observations and analysis.

HIS WORKS

It is commonly believed that Jagannath Samrat translated two books from Arabic into Sanskrit—*Rekhāgaṇita* and *Samrāṭ Siddhānta*. Sudhakar Dwivedi mentions only these two translated books in his *Gaṇaka-Taraṅginī*[6]. S. B. Dikshit holds the same view[7]. Strongly enough the same view is expressed in '*A concise History of Science in India*' which quotes:

'Jagannatha at the instance of his patron mastered Arabic and Persian and translated Ptolemy's *Almagest* and Euclid's *Elements* from their Arabic version into

*Since deceased.

Sanskrit. The *Samrāṭ Siddhānta,* the Sanskrit title of *Almagest* contains 13 chapters, 141 sections and 196 geometrical propositions: The *Rekhāgaṇita* was the name given to the *Elements.* In our opinion this view is not correct and we shall discuss this topic at length.

First we shall discuss the book commonly known as *Samrāṭ Siddhānta.* A book with this title was edited by Ram Swarup Sharma and published by Indian Institute of Astronomical and Sanskrit Research, New Delhi, hereafter to be denoted by S.S.R.S. From editing point of view this publication is very corrupt. However it gives us an opportunity to see the whole text as commonly understood to be *Samrāṭ Siddhānta,* because it begins with the statement:

> *Arabi Bhāṣaya Grantho Mijasti Nāmaka Sthitah chvāṇakānam Subodhāya Gīrvāṇya Prakaṭikṛtah.*

In Arabic language there is a work named *Mijasti.* For the sake of those, not knowing Arabic it is translated into Sanskrit. It further states 'This book has 13 chapters, 141 sections and 196 theorems to be proved with geometrical figures (*Kṣetrāṇi*)[8]. Then there are thirteen chapters and one additional chapter *Yantrādhyāya.* Sudhakara Dwivedi quotes *Yantrādhyāya* as a part of *Samrāṭ Siddhānta*[9]. S. B. Diksit also mentions *Yantrādhyāya* and its other sections (chapters) in the copy lying in MSS collection of Ānandāśrama, Poona[10]. But we think that the first thirteen chapters mentioned in S.S. R.S. as *Samrāṭ Siddhānta* are really *Siddhānta Sāra Kaustubha* for the following reasons :

(*a*) In the beginning of the book just after the title *Samrāṭ Siddhāntaḥ* it is written in the form of a title '*Sri Siddhanta Sara Kaustubha*'.

(*b*) Jagannath Samrat has a style of mentioning the name of his Patron, his own name and that of the book and the number of the chapter at the conclusion of a chapter in his works. For example at the end of 15th chapter of *Rekhāgaṇita* he writes—*Srīmadrājādhirāja prabhuvara Jayasiṃhasya tuṣṭyai Dvijendrah, Srīmat Samrāṭ Jagannātha iti Samabhidharudhitenpraṇite. Granthesmin namni Rekhāgaṇititi Sukoṇāvabodhapradataryadhyāyaodhyetri Mohāpaha iha Viratimghasrasainogatobhut*[11]. We find such mentions at the end of almost all chapters in which the name of the book is given as *Siddhānta Sāra Kaustubha.* For example we quote the verse at the end of first chapter.

> ***Rājādhirāja prabhutoṣaṇarthe Samrāṭ Jagannāth kṛte Sug'ilpe Siddhāntasare khalu Kaustubhesmindhyāya ādyoviratim Jagama.***

(*c*) As we have already stated, the socalled *Samrāṭ Siddhānta* has 13 chapters, 141 sections and 196 theorems to be proved with geometrical figures. From the study of *S.S.R.S.*[12] we find:

1st	Chapter	has	14	sections	16	figures (kstras)
2nd	,,	,,	13	,,	25	,,
3rd	,,	,,	10	,,	20	,,
4th	,,	,,	11	,,	9	,,
5th	,,	,,	19	,,	20	,,
6th	,,	,,	10	,,	7	,,
7th	,,	,,	5	,,	nil	,,
8th	,,	,,	6	,,	4	,,
9th	,,	,,	11	,,	10	,,
10th	,,	,,	10	,,	18	,,
11th	,,	,,	12	,,	24	,,
12th	,,	,,	9	,,	18	,,
13th	,,	,,	11	,,	25	,,
Total 13 Chpt.			141	,,	196	,,

Thus we see that the whole book is covered in first 13 chapters and the chapter (book) given under the caption of *Yantrādhyāya* is not a part of the book translated from *Mijasti* or *Almagest.*

(*d*) As regards the subject of the first thirteen chapters of *S.S.R.S.* and *Yantrādhyāya,* it is common in nature, but their treatment is quite different. While the former part is clearly a translation, the latter part is written on traditional Indian style. For example, in the first chapter in the table of places for the maximum length of day, latitude etc.[13] We find that none of them is situated in India. Similarly in the list of constellations[14] which is bigger than any such list in traditional literature the famous *Saptarṣi* constellation in translated as *Bara Bhalu* (big bear). The arrangement of the subject is in prose and in a foreign style whereas in *Yantrādhyāya* the subject is discussed in Indian style and in verses with an explanation in prose, as we find in most of *Siddhānta* texts. Thus we see that there is no similarity in these two parts of a book. The whole of *SSRS* is more than a book.

(*e*) Like the beginning of first Chapter, the first thirteen chapters of *SSRS, Yantrādhyāya* has introductory verses of prayer and the statement that the author is writing *Samrāṭ Siddhānta* at the request of Maharaja Jaisingh. These verses are the same which are quoted in the beginning of the first chapter except verse 7, of that chapter. But there are three additional verses No. 4, 7 and 9 and verse No. 6 of the first chapter is deleted in *Yantrādhyāya*. This shows that it is a separatė book and not a part of the translated book. Moreover *Yantrādhyāya* is divided into chapters like those in other *Siddhāntas* as *Madhyamādhikāra Spaṣṭādhikāra Tripraśnādhikāra* etc. If *Yantrādhyāya* is a chapter of the main book, there should be no division of chapters (*adhyāyas*) in a chapter. In the chapter of *Jyotpatti* in the socalled *Yantrādhyāya* the treatment is like one found in other *Siddhānta* texts and not like the one given in the first chapter of the main book. Like other *Siddhānta* texts it deals with sines and versed sines of an arc. In *Jyotpatti* the use of a theorem is made with the statement '*Atha Mijasti Granthaya Prathamādhyāyasya Dwitīyakṣetre Idamupapannam*'[15] which means that it is proved in the second theorem of first chapter of *Mijasti*, which is the part of the translation of *Mijasti*. If *Yantrādhyāya* is a part of the same book the statement should have been different. Therefore it is proved beyond doubt that the chapter given at the end of *SSRS* is not the part of the book given in the first thirteen chapters. It is a separate work divided into many chapters like *Yantrādhyāya*, *Jyotpatti*, *Madhyamādhikāra* etc. The first thirteen chapters bear a separate heading of *Siddhānta Sāra Kaustubha* in the beginning and end of every chapter. But there is no such thing in the other book. (*Yantrādhyāya*). Therefore we conclude that the book mentioned under caption *Yantrādhyāya* is real *Samrāṭ Siddhānta* and the translation of *Almagest* is *Siddhānta Sāra Kaustubha*. It appears that by the misjudgment of a copyist the introductory verse stating that Jagannātha is writing the work of *Samrāṭ Siddhānta* was written in the beginning of *Siddhānta Sāra Kaustubha* alongwith some other verses and the fact could not be examined because the work is very big having more than a thousand pages and is very corrupt. I think Sudhākara Dwivedi on the basis of these verses in the beginning of *Siddhāntā Sāra Kaustubha* termed the whole work as *Siddhānta Samrāṭ*. Since he was a great authority on the subject his version was taken for granted and the mistake was perpetuated. On critical examination of the work the mistake was discovered and now M. D. Chaturvedi, a younger colleague of mine, has edited the socalled *Yantrādhyāya* with its real title *Samrāṭ Siddhānta (SSMC)* which is published by the Sanskrit Parisad of Sagar University. Hereafter by the word *Samrāṭ Siddhānta* we will mean SSMD and not SSRS.

Thus we see that Jagannath Samrat wrote three books *Rekhāgaṇita*, *Siddhāntā Sāra Kaustubha* and *Samrāṭ Siddhānta*. Of these the first two are translations of books from Arabic and the third one is his own contribution to the subject. Before coming to discuss the outstanding features of *Samrāṭ Siddhānta* we shall first give a brief summery of these books. *Rekhāgaṇita*—it is a translation of *Elements of Euclid* from some Arabic work. The first chapter has 48 theorems, second 14, third 37, fourth 16, fifth 25, sixth 33, seventh 39, eighth 25, ninth 38, tenth 109, eleventh

41, twelfth 15, thirteenth 21, fourteenth 10 and fifteenth 6. Since these subject matter is the same as that of *Elements of Euclid* we are not describing it.

Siddhānta Sāra Kaustubha: It is a translation of an Arabic work *Mijasti* which is popularly known as *Almagest*. It has 13 chapters, 141 sections and 196 propositions requiring geometrical proof. Subject matter of the first chapter is a general description of geocentric sphere, theorems on chords, tables of chords and halfchords, spherical astronomy, tables of shadow, declination, etc. The second chapter describes maximum day length, latitude midday shadow of a gnomon of given length on equinoxes and solstices of some places and some other tables connected with the diurnal motions of the sun. It is noteworthy that the places mentioned in these tables are situated in the middle east or Europe. Third chapter deals with the motions of sun. It is noteworthy that months mentioned in this chapter are Egyptian and Persian. An astronomer named Batul Mayus is mentioned in this chapter. In connection with an epoch the names of Alexander and Dus'manassar are also mentioned. Chapter four deals with the motions of moon and connected tables. Chapter five deals with celestial sphere, equation of centre, parallax, distance of moon and connected tables. Chapter six deals with Eclipses and their projections. Chapter seven deals with stars and constellations, tables of co-ordinates of different stars of constellations. Chapter eight also deals with stars and milky way. Chapter nine deals with the orbits of planets, their mean motions, equation of centre and reduction of geocentric longitude. Chapter ten also deals with the equation of centre and reduction to geocentric positions and motions of Mercury. Chapter eleven deals with the motions of Venus, Mars, Jupiter and Saturn and connected tables. Chapter twelve deals with retrograde motions. Chapter thirteen deals with celestial latitude of planets and heliacal rising and setting of planets.

Samrāṭ Siddhānta—This book is not a translation of any Arabic or Persian book but is an original contribution of the author to Indian Astronomy. It is written in a traditional *Siddhānta* text style of verse cum prose. It consists of five chapters; *Yantrādhyāya, Jyotpatti, Madhyamādhikāra, Spaṣṭādhikāra* and *Tripraśnādhikāra*. The book as it is available now and published by M. D. Chaturvedi is not complete. Many important chapters like those on the eclipse of moon, the eclipse of sun on shadow, heliacal rising and setting of planets etc. are missing. The author himself refers his readers to see the method of *construction* of *Samrāṭyantra* in *Yantra Rachanādhyāya: 'Tatkaraṇaprakāro vedhaprakarsca yantra racanādhyāye draṣṭavyah'*[16].

In *Yantrādhyāya* the author describes main features and method of observation from the following instruments: (*i*) *Nadīvalaya* or *Nadīyantra,* (*ii*) *Golayantra,* (*iii*) *Digaṃṣayantra,* (*iv*) *Dakṣinodak bhitti yantra,* (*v*) *Vṛtta Ṣaṣṭhaṃśa yantra,* (*vi*) *Samrāṭ yantra—Jaiprasa yantra* and (*vii*) *Kranti vṛtta yantra.* Besides these *yantras* a very useful *yantra, Jarakuli,* is described in *Spaṣṭadhikara* and *Yamyottara yantra* and *Nadivalaya* are described in *Tripraśna.* The author also gives reasons for the preference of masonary instruments against brass instruments. In *Jyotpatti* the writer starts the subject in traditional manner, but gives advance knowledge of the subject. He gives methods of finding sines of sum and difference of two arcs, sines of a double arc, sine of 3 times of an arc, sine of one third of an arc, sine of 5 times of an arc and sine of 1/5th of an arc, sine of of an arc, sines of 30°, 45°, 18°, 72°. He also gives Uluk-Beg's method for finding sine of 1/3rd of an arc. He also gives rules for finding versed sines. In *Madhyamādhikāra* he describes traditional nine measures of time, time measures in a *Kalpa*, *Bhagana* (complete revolutions) of planets etc. in a *Kalpa*, calculation of *Ahargaṇa*, finding of mean planets, mean motions of planets, *Khakakṣa*, orbits of planets, measures of discs of planets, madhya and spaṣṭa circumference of earth, standard meridian of India, equation of time, and *Gola spaṣṭadhyāya* deals with finding numerical values of sines, *manda* and *śīghra* epicycles, *mandoccas*, *spaṣṭa* epi-cycles (*Paridhi*), *Bhujaphala*, *Koṭiphala*, *Śīghra Karṇa*, *Śīghra phala*, true places of planets, true motions of planets, calculation of celestial latitude of planets, to know the sun by observation etc. *Jarkali yantra* and methods of determination of various elements with its help. *Tripaśnādhyāya* deals with finding direction, *Palabhā*, *Palakarṇa*, description of *Yanyottarayantra* and *Nadīvalaya*, method of making *Gola*, *Akṣakṣetras*, methods for determining declination, R.A., shadow of *Gnomon*, *cara*, *svodaya*, *Lagna*, *Dasama*, *kala*, *Ayana Dṛkkama Akṣa Dṛk Karma*, altitude and azimuth, length of a day, *Bhavas Natkala*, latitude in Southern hemisphere and celestial latitude. It is to be noted that he quotes verses from Bhāskara, Kamatākara and *Sūrya Siddhānta* at several places.

To understand the importance of his work we must note the position of Indian Astronomy, before and after his time. After Bhāskarcaryā II, the only astronomer who wanted to evolve methods of calculation of planets tallying with observed position was Gaṇeśa (b. 1507 A.D.) the author of *Grahalāghava*. Other astronomers were either contented with writing commentaries on old texts or writing texts on old patterns suggesting minor corrections on the basis of their improved knowledge of mathematics. One such astronomer was Kamalākara. But he was very orthodox in astronomical matters. He regarded *Sūrya Siddhānta* like Veda and could not tolerate any deviation from its principles. After Jagannāth Samrāṭ we do not have any astronomer of his calibre.

Jagannath was very well versed in Indian Astronomy and had mastered Arabic system of Astronomy. He was also in touch with European astronomers. He wanted to evolve correct methods to find the true positions of planets tallying with observed positions. He wanted to know the correct principles for true motions of planets. He says it requires a long time to come to a conclusion. So the kings should establish observations to know the positions of planets, by observations. Enumerating the efforts of Maharāja Jaisingh he says that, besides setting observations at different places in India, he sent a scholar named Mohammad Sarif to western countries (*Phiraṅgdeśa*). He determined latitude at Mahil deva island which was 4° 12′ S. From Surat he sent for *Gola* of European countries. He sent Mohammad Mehandi to collect astronomical data from further islands. Thus he sent astronomers in all countries and in all directions to observe planets and collect observed data. He says such efforts should be continued by other rulers also[17].

He felt that observational instruments were to play an important role in the development of astronomical knowledge. Therefore he gave first importance to instruments in his work *Samrāṭ Siddhānta.* Besides some useful traditional instruments like *Yamyottarayantra* and *Nadīvalaya* he describes the other instruments of observatories set up by his patron Jaisingh. He also describes the method of observation with the help of those instruments.

He was a great observer himself. He determined the obliquity of ecliptic very correctly. He says that at Delhi it was observed by some one to be 23° 39′. In Arabia it was observed to be 23° 51′ 19″ by Astronomer Avarakhas (?) and others. In Greece at latitude 36° it was observed to be 23° 51′ 15″ by astronomer Vatal Majus (?). At Samarkand at latitude 39° 37′ Uluk Beg found it to be 23° 30′ 17″ and he in 1651 *Śaka* (1729 A.D.) observed at Delhi (*Indraprastha*) to be 23° 28′, the result which almost tallies with the modern value of the same. He also observed precession of equinox (*Ayanāṃśas*) to be 19° 37′ in the same year. He determined the rate of precession to be 1° in 70 years. According to him year of zero precession of fixed Hindu sphere was 278 *Śaka* (356 A.D.)[18]. He also tried to know the position of aphelion and eccentricity of the solar (earth's) orbit. For that he made four observations of the Sun on vernal equinox day of the year 1651 *Śaka* at 18 *ghaṭis* and 57 *palas* in the same year when increasing declination of the sun was 22° 19′ again in the same year when the sun was near the other equinox point and in the next year when the sun was near the Vernal equinox. By these observations and mathematical analysis he found the correct value of eccentricity (*Parama Mandaphala*) to be 1° 55′, 58″ 2" and aphelion 3 /6°/42′/48 17"[19].

He does not take anything for granted. He says that Kamalākara takes the value of π to be $\sqrt{10}$ and criticises Bhāskara for having a different value. But this fact was examined by all astronomer technicians carefully and they found that the value of Bhāskara (1150 A.D.) was correct and not of Kamalākara[20].

In connection with *manda phala* he examined the rules of Bhāskara and Kamalākara. He finds that sine of *mandaphala* should have *mandakarṇa* as a divisor and not *trijya.* For this error he criticised Bhāskara, Kamalākara and others[21].

He made an attempt to give a proof of corrections for *manda* and *śīghra phalas* which had never been tried by others. He also suggested many new methods of correct observation by very simple instruments and evolved new rules for calculations specially in the chapter of *Tripraśna.* His work is an attempt to evolve rules for correct calculations of position of planets tallying with the observed positions. He says in *Madhyamādhikāra,* "When in *Siddhāntas* like *Brahma Siddhānta* and *Sūrya Siddhānta* which are supposed to be written by R. Sies calculated planets do not tally with the observed positions, it is clear that the position of sky (planetery rate of motion) undergoes a change. If the sky was fixed then the calculations from all *Siddhāntas* at all times must be the same. Even then we have taken traditional method of finding mean position of planets for the benefit of Society and have calculated them with the application of *Bīja* and other corrections so that they tally with the observed positions[21].

In the conclusion we can say that *Samrāṭ Siddhānta* is different from *Siddhānta Sāra Kaustubha* which is really the translation of *Almagest* and in this work Jagannath Samrat has broken the traditional line of depending on traditional constants and showed the future astronomers to rely on observed results and to base their rules on them.

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[8] *S. S. R. S.* p. 2.

[9] *G. T.* p. 108 and version p. 110.

[10] *B. J.* p. 401.

[11] *G. T.* p. 104.

[12] *S. S. R. S.* p. 116.

[13] *S. S. R. S.* p. 135-140.

[14] *S. S. R. S.* p. 725.

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[16] *S. S. M. C.* p. 39.

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[18] *S. S. M. C.* p. 7.

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