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ZĪJ-i MUHAMMAD SHĀHĪ AND THE TABLES OF DE LA HIRE

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The planetary tables of *Zīj-i Muhammad Shāhī* compiled by Sawai Jai singh, the astronomer-king of India have been compared with those of the *Tabulae Astronomicae* of de La Hire, and a conclusion has been drawn that the tables of the *Zīj* are independent of the *Tabulae Astronomicae*.

INTRODUCTION

Sawai Jai Singh (1688-1743), the astronomer-king of the eighteenth century India, designed astronomical instruments and built observatories in five different cities of north India with a purpose of updating the existing astronomical tables. He completed his tables shortly after 1730 and dedicated them to the reigning monarch Muhammad Shah. The tables known as *Zīj-i Muhammad Shāhī* are still extant, and about 20-25 copies of them survive to this day in libraries and archives around the world. Recently, Mercier has asserted that the tables of Jai Singh are not based on his own observations conducted at his observatories but merely modified versions of the *Tabulae Astronomicae* of de La Hire, which Jai singh had acquired from Europe.[1]

In this paper we report finding that the planetary tables of the *Zīj-i Muhammad Shāhī* are independent of the *Tabulae Astronomicae* and that, there is little to substantiate Mercier's contention.[2]

ASTRONOMICAL TABLES OF DE LA HIRE

De La Hire (1640-1718), a highly competent observer and a member of the Academie de Sciences at paris, published his *Tabulae Astronomicae* in 1687. The second edition of the text came out in 1702 and a reprint 25 years later in 1727.[3] The second edition of the *Tabulae* is in two books. Its first book describes how to use the tables given in book II for solving problems, such as the calculations of solar and lunar eclipses. The second book has a wide variety of charts or tables, beginning with the table of coversion of arc to time, equation of time and the geographical coordinates of some 126 cities and towns around the globe. These are next followed by extensive tables for the mean longitude, aphelion and the ascending node of the moon and for the planets. A typical table, such as that for the planet Saturn is given in Tables 1 and 2.

Table 1

Mean Parameters for the planet Saturn in *Tabulae Astronomicae* of de La Hire.

Julian Years B.C.	Mean Tropical Longitude, λ				Longitude of Aphelion, Γ				Longitude of Ascending Node, Ω			
	Sign	Deg.	Min.	Sec.	Sign	Deg.	Min.	Sec.	Sign	Deg.	Min.	Sec.
300	0	5	10	9	7	13	52	3	2	12	14	45
200	4	28	29	33	7	16	8	11	2	14	13	50
100	9	21	48	7	7	18	24	19	2	16	12	55
Jan.1, A.D.1	2	15	8	21	7	20	40	27	2	18	12	0
A.D.												
100	7	8	27	45	7	22	56	35	2	20	11	5
200	0	1	47	9	7	25	12	43	2	22	10	10
300	4	25	6	33	7	27	28	51	2	24	9	16
400	9	18	25	57	7	29	44	59	2	26	8	21
500	2	11	45	21	8	2	1	7	2	28	7	17
600	7	5	4	45	8	4	17	15	3	0	6	32
700	11	28	24	9	8	6	33	23	3	2	5	37
800	4	21	43	33	8	8	49	31	3	4	4	43
900	9	15	2	57	8	11	5	39	3	6	3	48
1000	2	8	22	21	8	13	21	47	3	8	2	54
1100	7	1	41	45	8	15	37	55	3	10	1	59
1200	11	25	1	9	8	17	54	3	3	12	1	4
1300	4	18	20	33	8	20	10	11	3	14	0	10
1400	9	11	39	57	8	22	26	19	3	15	59	15
1500	2	4	59	21	8	24	42	27	3	17	58	21
1600	6	28	18	45	8	26	58	35	3	19	57	25
1600	6	27	58	39	8	26	58	33	3	19	57	24
1700	11	21	16	1	8	29	14	41	3	21	56	29

Table 2

Mean Parameters for the planet Saturn in *Tabulae Astronomicae.*

Julian Years	Mean Tropical Longitude, λ				Longitude of Aphelion, Γ				Longitude of Ascending Node, Ω			
	Sign	Deg.	Min.	Sec.	Sign	Deg.	Min.	Sec.	Sign	Deg.	Min.	Sec.
1	0	12	13	29	0	0	1	22	0	1	12	
2	0	24	26	59	0	0	2	44	0	2	23	
3	1	6	40	28	0	0	4	6	0	3	34	
4	1	18	55	59	0	0	5	27	0	4	46	
5	2	1	9	28	0	0	6	49	0	5	57	
6	2	13	22	57	0	0	8	11	0	7	9	
7	2	25	36	26	0	0	9	33	0	8	20	
8	3	7	51	57	0	0	10	54	0	9	32	
9	3	20	5	26	0	0	12	16	0	10	43	
10	4	2	18	55	0	0	13	38	0	11	54	
11	4	14	32	24	0	0	15	0	0	13	6	
12	4	26	47	56	0	0	16	21	0	14	17	
13	5	9	1	25	0	0	17	43	0	15	29	
14	4	21	14	54	0	0	19	5	0	16	40	
15	6	3	28	23	0	0	20	27	0	17	52	
16	6	15	43	54	0	0	21	48	0	19	3	
17	6	27	57	23	0	0	23	10	0	20	15	
18	7	10	10	52	0	0	24	32	0	21	26	
19	7	22	24	21	0	0	25	54	0	22	37	
20	8	4	39	53	0	0	27	14	0	23	49	
40	4	9	19	45	0	0	54	27	0	47	38	
60	0	13	59	38	0	1	21	41	1	11	27	
80	8	18	39	31	0	1	48	54	1	35	16	
100	4	23	19	24	0	2	16	8	1	59	5	
200	9	16	38	48	0	4	32	16	3	58	10	
300	2	9	58	12	0	6	48	24	5	57	16	
400	7	3	17	36	0	9	4	32	7	56	21	
500	11	26	37	0	0	11	20	40	9	55	27	
1000	11	23	14	0	0	22	41	20	19	50	54	

Sawai Jai Singh and the Tables of de La Hire

Sawai Jai singh had acquired both editions of the *Tabulae Astronomicae* of de La Hire. The first edition was brought over to him in 1730 by his assistants from Portugal,[4] and the second edition was copied two years later in 1732 by Du Bois at Jaipur.[5] The manuscript of Du Bois may still be seen at the Sawai Man Singh II Museum of Jaipur, where most of the books of Jai Singh's library are located these days. Du Bois writes that Jai Singh had the *Tabulae* translated as soon as it reached Jaipur and that it was he who was entrusted with the task of translating. An incomplete translation of the *Tabulae Astronomicae* in Sanskrit is preserved at the Museum under the title *Firangī grahavedhopayogī sāraṇī.*[6] The Oriental Research Institute of Baroda has a copy of the translation listed under the title *Dṛkapakṣasāraṇi.* The manuscript includes tables and explaining text, from which a table for the parameters of the moon is reproduced in Figure 1.[7] A section of the translation called *Dṛkapakṣasāraṇyām sūryagrahaṇam,* is preserved at the Bhandarkar Oriental Research Institute of Poona[8]. The Poona copy, as its name indicates, concerns with the calculations of solar eclipse only and has no tables.

The Tabulae Astronomicae and Zīj-i Muhammad Shāhī

The *Zīj-i Muhammad Shāhī* is an astronomical text written in the style of Islamic *Zījes* of the Middle Ages. Its planetary tables include mean elements for the months of an Arabic year, for 30 Arabic years following the date of the epoch at yearly intervals, and for 390 Arabic years at 30-year intervals. A typical table of the *Zīj-i Muhammad Shāhī* is shown in Figure 2.

In order to verify Mercier's assertion that the planetary tables of the *Zīj-i Muhammad Shāhī* are based on the de La Hire's *Tabulae Astronomicae,* we calculated the mean parameters of the planets from the *Tabulae Astronomicae* for a number of Arabic years following the date of the *Zīj's* epoch, February 20, 1719.

These calculations were carried out in more than one ways. The *Tabulae Astronomicae* has tables with the mean values of the parameters for 1-20 years calculated for each and every planet. We reasoned that if Jai Singh and his astronomers had, in fact, decided to transform the tables of the *Tabulae Astronomicae* for their own *Zīj,* the simplest approach for them, for atleast some of their data, would have been to use de La Hire's 1-20 year tables directly. By applying a simple equation they could have obtained their desired results. For example, the mean longitude of the sun for the nth year after the epoch year would be obtained as follows.

$$\text{Mean } \lambda \text{ for the nth year} = (\text{mean } \lambda \text{ in the } \textit{Tabulae} \text{ for n years}) \times (354;22)/(365;15) + 329;36, 1$$

In the above equation the 354;22 is the number of days in an Arabic year, 365;15 is the length of a Julian year used by de La Hire, and 329;36, 1 is the mean λ at the epoch

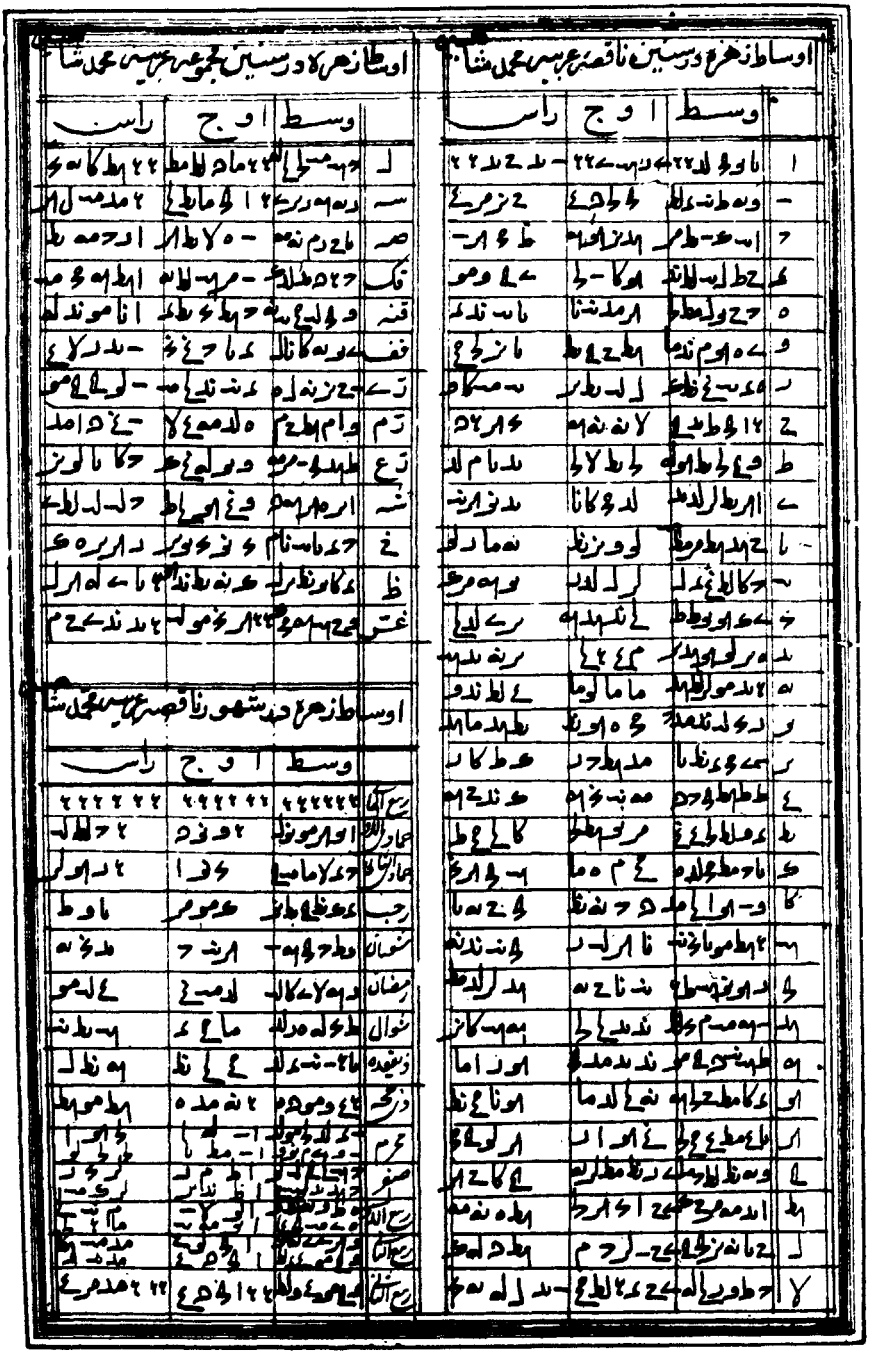

FIG. 1. Mean Parameters for the planet Venus in the *Zīj-i Muhammad Shāhī*. The entries in the table follow a modified *Abjad* notation, and they are read from right to left.

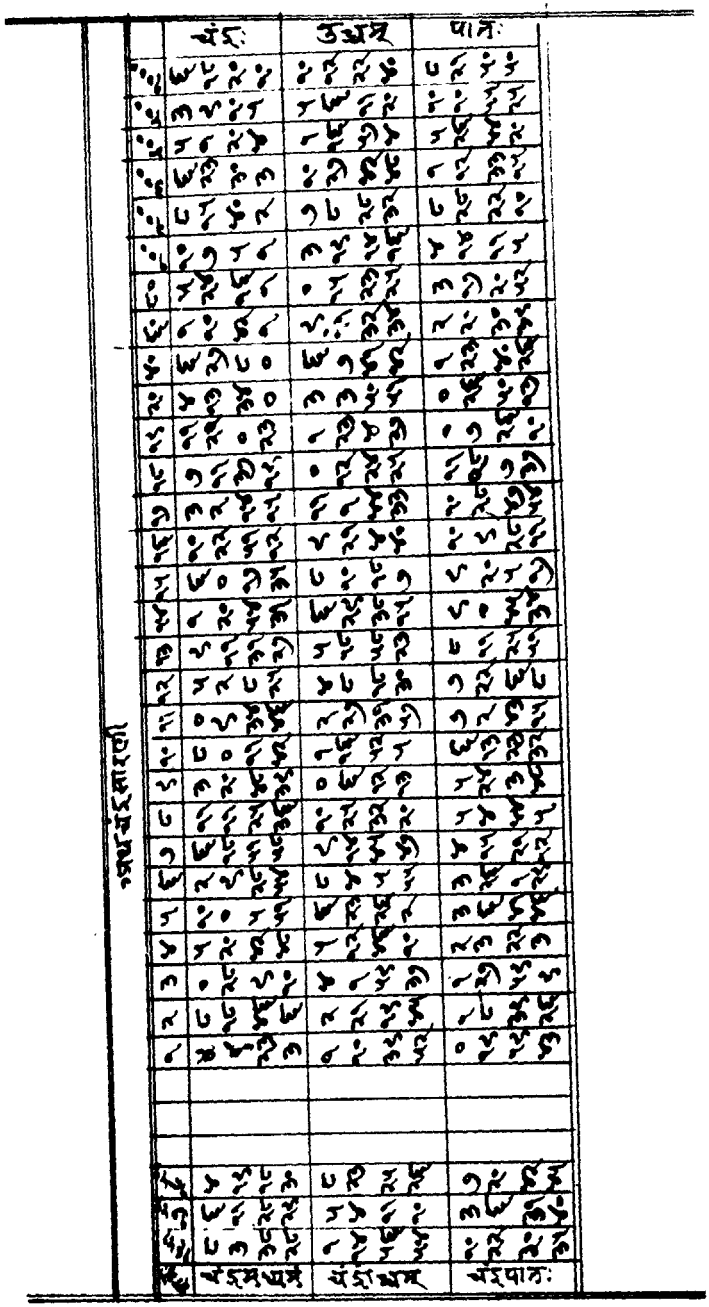

FIG. 2. Mean Parameters for the Moon in the *Drkapakṣa Sāraṇī*. The *Sāraṇī* is a translation of the *Tabulae Astronomicae* of de La Hire first published in 1687.

date in the *Zīj-i Muhammad Shāhī*. For calculating the mean λ, the number of complete revolutions calculated from the sidereal period of the planet should also be taken into account.

Following this procedure, we calculated yearly mean parameters for the sun, the moon and the planets and compared them with those in the *Zīj*. A typical set of calculations, for the planet Venus, is given in Table 3. In literally scores of such calculations that we carried out for our investigation, there was not a single entry in the *Zīj* that agreed with our calculated results.

Next we calculated from de La Hire's 1600-year motions the parameters for a number of years following the epoch date. We reasoned that, perhaps, the yearly date from the *Tabulae Astronomicae,* described earlier, were ignored by Jai Singh, and instead, the data for a larger number of years, such as 1600 Julian years preferred.[9] Mercier also, in a way, alludes to Jai Singh having calculated his tables in the basis of the 1600 Julian year readings. However, with the 1600-year data also we found no agreements. The procedure was repeated with much smaller number of years such as 20. Once again the results were in the negative. We also converted the yearly difference for the parameters of de La Hire into those for the Arabic years of the *Zīj*, but could find no agreement there either.

Table 3

Mean λ for the planet Venus for the Arabic years following the epoch date of the *Zīj-i Muhammad Shāhī* (ZMS) calculated from *Tabulae Astronomicae* of de La Hire. The very first number in the columns represents the number of the signs elapsed. The numbers after the semicolon follow the sexagesimal scheme of expressing angles.

Julian Years	Mean Motion in *Tabulae*	Arabic years following the epoch ZMS	Mean Motion Computed from *Tabulae*	Mean Motion in ZMS
		0	------	11,16;23,34
1	7,14;47,36	1	6,13;45,40	6,15;9,52
2	2,29;35,13	2	1,11;7,47	1,12;20,20
4	6,0;46,33	4	3,7;25,14	3,8;16,31
5	1,15;34,9	5	10,4;47,20	10,5;26,41
7	4,15;9,21	7	11,29;31,32	0,1;23,9
10	3,1,;8,18	10	8,23;11,6	8,24;27,48
15	4,16;42.27	15	7,11;34,52	7,13;32,55
17	7,17;53,46	17	9,7;52,19	9,9;29,23
19	10,17;28,58	19	10,21;52,54	11,3;49,44
20	6.3;52,43	20	6,1;31,54	6,2;26,2

Our investigations thus left little choice but to suspect that the parameters in the *Zīj* and in the *Tabulae Astronomicae* have been obtained from two different sets of elements. Our suspicions were confirmed when we calculated the mean yearly motions of the elements from the two texts. The results of these calculations are given in Table 4. In the table the mean elements have been tabulated from the 300-year Julian year data in the *Tabulae Astronomicae* and the 300-Arabic-year data of the *Zīj*. In the table the fractions beyond the seconds of arc have been displayed merely to point out the

Table 4

Mean Planetary Elements per Arabic Year calculated from the *Tabulae Astronomicae* and the *Zīj-i Muhammad Shāhī* (ZMS). The entries in the columns are according to the sexagesimal scheme.

	Element	de La Hire	ZMS	Modern
Sun	λ	349;16,49,51	349;16,49,46	349;16,50,1
	Γ	0;0,59,40	0;0,59,38	0;1,0,3
Moon	λ	12^r 349;16,32,35	12^r 349;16,30,56	12^r 349;16,32,35
	Γ	39;28,47,32	39;28,47,34	39;28,40,25
	Ω	-18;45,55,53	−18;30,7,18	−18;45,54,23
Mercury	λ	4^r 10;12,18,27	4^r 10;12,18,28	4^r 10;12,7,13
	Γ	0;1,35,51	0;1,35,55	0;0,54,20
	Ω	0;1,22,42	0;1,22,45	0;0,41,24
Venus	λ	1^r 207;45,24,59	1^r207;50,51,26	1^r 207;40,18,39
	Γ	0;1,23,38	0;1,23,41	0;0,49,11
	Ω	0;0,44,42	0;0,42,31	0;0,32,0
Mars	λ	185;42,47,4	185;42,47,15	185;42,48,4
	Γ	0;1,4,29	0;0,52,44	0;0,60,48
	Ω	0;0,35,47	0;0,35,55	0;0,26,56
Jupiter	λ	29;27,29,59	29;27,30,8	29;27,29,52
	Γ	0;1,31,36	0;0,55,35	0;0,35,18
	Ω	0;0,13,42	0;0,13,42	0;0,35,18
Saturn	λ	11;52,7,24	11;52,7,14	11;13,54,33
	Γ	0;1,19,15	0;1,7,37	0;1,8,24
	Ω	0;1,9,20	0;1,9,25	0;0,30,30

difference between the mean elements of the two astronomical texts. The instuments of Jai Singh and those of de La Hire as well do not justify even the retentions of seconds. The last column in the table are the modern values provided for comparison purposes.

Mercier's Reasonings

Mercier's assertion that the tables of *Zīj-i Muhammad Shāhī* are based on *Tabulae Astronomicae* rests primarily on his "longitude" argument. He states that, for the *Zīj*, the rates of motion for the mean parameters have been calculated first for the Paris meridian for the epoch date of Februrary 20, 1719, and then, applying a longitude correction, changed for the meridian of Shahjahanabad or Delhi. And since these calculated results "come close" to those in the *Zīj*, the entire planetary data in the *Zīj* must, therefore, have been borrowed from de La Hire. Mercier does not say if he checked out the latter implications of his reasoning.

He goes on to add that the longitude correction for these calculations had been selected as 73;30. However, such a longitude difference is for one single reading only.[10] For others, it varies from 72;13 for the aphelion of the moon to 82;27 for the mean longtide of Saturn. Mercier does not explain this discrepancy. He apparently believes, however, that the discrepancy is due to some carelessness on the part of Jai Singh's mathematicians.[11]

Besides, Mercier does not say where and how Jai Singh obtained the longitude difference between Delhi and Paris. It certainly could not have been from the *Tabulae Astronomicae*. The longitude difference between Paris and Delhi calculated on the basis of the *Tabulae Astronomicae* should be 79;35 and not 73;30.[12] Further, Boudier, a French Jesuit, had determined in 1734 the longitude of Delhi with respect to Paris as 75;0.[13] Boudier had come over to Jaipur at the invitation of the Raja. Mercier does not explain why the Raja did not use this most recently determined longitude by one of his guest astronomers.

Mercier observes that the value 73;30 is closer to the longitude of Jaipur determined in modern times, Which is 73;29. The best measurment of the longtitude of Jaipur in the days of the Raja was due to Boudier, who found it to be 73;30 that Mercier seems to think the Raja used.

Tables in the Zīj-i Muhammad Shāhī from de La Hire

Although the planetary tables, as we have shown above, are independent of the *Tabulae Astronomicae*, it would be erroneous to think that none of the information in the *Zīj* is based on de La Hire's *Tabulae*. Islamic *Zījes* do not carry refraction-correction tables, but the *Zīj-i Muhammad Shāhī* has such a table. This table in the *Zīj-i Muhammad Shāhī* has been obtained directly from the *Tabulae Astronomicae*.[14] There is no evidence that the Raja himself determined any refraction correction data for his *Zīj*. Another table that could have been adapted from *Tabulae*

Astronomicae is the equation of time. The equation of time in the *Zīj* is given in *ghatikās* and *pals* which after transformation into minutes and seconds become identical with the table of the *Tabulae Astronomicae*. It should be pointed out, however, that equation of time is not unique to European tables; it is also found in just about every *Zīj* written in the Islamic world. Further, the geographical coordinates of a number of towns in the *Zīj-i Muhammad Shāhī* are identical with those in de La Hire's *Tabulae Astronomicae*.

Some Further Comments

We noted some minor errors also in Mercier's paper. Mercier erroneously translates the A.H. 1138, the epoch date of the star catalog in the *Zīj*, as 1738 A.D., and from that deduces that the date of completion of the *Zīj-i Muhammad Shāhī* as 1738 A.D. However, 1138 A.H. does not transform into 1738 A.D., but into 1725-26. Hence it does not follow that the *Zīj* was completed in 1738.

Conclusion

In conclusion, we find little evidence in support of Mercier's contention that the planetary tables of the *Zīj-i Muhammad Shāhī* have been borrowed from the *Tabulae Astronomicae* of de La Hire. Our analysis of the two texts reveals that the mean elements used in them are totally different. The table definitely borrowed from the *Tabulae Astronomicae* is apparently that of refraction-correction.

Acknowledgements

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Notes and References

[1]Mercier, Raymond, "The Astronimical Tables of Rajah Jai Singh Sawā'i," Indian J. Hist. Sci., 19, 143-171, (1984). Henceforth this paper would be referred to as "Mercier."

[2]This paper is primarily based on the *Zīj-i Jadīd Muhammad Shāhī*, Add. ms. 14373, of the British Library, on which Mercier's article is also based. In addition, I consulted the copies of the *Zīj* at 1. The Raza Library, Rampur, 2. Azad Library, Aligarh, 3. Khudabaksa Library, Bankipur, 4. Sawai Man Singh Museum, Jaipur, 5. Andhrapradesh Archives, Hyderabad, and 6. Arabic and Persian Institute, Tonk.

[3]*Tabulae Astronomicae Ludovici Magni* ..., of Philippo de La Hire, Paris, (1702); second edition Paris (1727).

[4]For Sawai Jai Singh's delegation to Europe see Sharma, Virendra Nath, "Jai Singh, His European Astronomers and the Copernican Revolution, Indian J. Hist. Sci., vol. 17 (2), 345-352, (1982)

[5]Du Bois, Joseph, Introduction to De La Hire's *Tabulae Astronomicae*, ms., Sawai Man Singh II Museum, Jaipur.

[6]Formerly mislabeled as *Firangī candravedhopayogī Sāraṇī*, Catolog no. 5609, Sawai Man Singh II

Museum. See Bahura, Gopal N., *Literary Heritage of the Rulers of Amber and Jaipur*, p. 63, Jaipur, (1976).

[7]*Dṛkapakṣa Sāraṇī*, Cat. no. 3162, 29 ff, Oriental Institute, Baroda.

[8]*Dṛkapakṣasāraṇyām sūryagrahaṇam*, Bhandarkar Oriental Research Institute, Poona, no. 926 of 1886-92. The translator of the works is Kevalram, a prominent assistant of the Raja.

[9]There is some difference between the data computed on the basis of yearly tables and that on the basis of large number of years such as 1600 Julian years.

[10]Only the mean longitude of the moon for the epoch date differs by 73;30 from the Paris meridian. Mercier, p. 147.

[11]Mercier, p. 146.

[12]*Tabulae Astronomicae* does not list the longitude of Delhi, but it gives the longitude of Agra as 5 h. 20 m, or 81;0, from which the longitude of Delhi turns out to be 79;35. In the list of geographical coordinates of the towns in the *Zīj-i Muhammad Shāhī*, the longitude of Agra (Akabarabad) with respect to Delhi is given as 0;14,10.

[13]Letters Edifiantes et Curieuses des Missions étrangères, Nouville Édition. Memories des Indes, Tome quinzieme, Toulouse, 1810, pp. 269-290.

[14]*Zīj-i Muhammad Shāhī*, f. 146. Ref. 2.