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ASTRONOMICAL TABLES OF *ZĪJ-I MUḤAMMAD SHĀHĪ* AND THEIR RELATION TO *TABULAE ASTRONOMICAE* OF DE LA HIRE

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Sawai Jai Singh (1688-1743), widely known for his masonry and stone observatories also wrote an astronomical text, *Zīj-i Muḥammad Shāhī*. The astronomical tables of the *Zīj* consist of mean planetary parameters in three subsets: first, the yearly motion of parameters for 30 Arabic years beginning with the epoch date of the *Zīj*, 20 February 1719; second, tables of the motion of the parameters for 30,60, ..., 300 Arabic years in increments of 30 years, followed by the motion for 600,900, and 1200 Arabic years in increments of 300 years; and third, tables of monthly motions. The paper reconstructs a number of these tables from the daily motions of the parameters.

Jai Singh acquired *Tabulae Astronomicae* of de La Hire from Europe and had it translated into Sanskrit. Since the publication of the *Zīj-i Muḥammad Shāhī*, it has been asserted that the planetary tables of *Zīj* are based on the *Tabulae Astronomicae* and not on Jai Singh's own observations. The paper calculates the daily motions of the mean planetary parameters for both, the *Zīj* and the *Tabulae Astronomicae* and arrives at the conclusion that indeed a strong case can be built that the planetary tables of the *Zīj* are an adaptation of the *Tabulae Astronomicae* of de La Hire.

Key words: *Zīj*, *Zīj*-i *Muḥammad Shāhi*, Muḥammad Shāh, Astronomical tables, *Tabulae*, *Tabulae Astronomicae*, de La Hire, Virendra Sharma, Virendra N. Sharma, Virendra Nath Sharma, Jai Singh, Sawai Jai Singh, Jaipur, Planetary parameters, Oriental Research Institute of Baroda, Sawai Man Singh II Museum, *Dṛkpakṣasāraṇyam Sūryagrahṇam*, Bhandarkar Oriental Research Institute, Du Bois, Medieval Astronomical Tables, Raymond Mercier, Benno van Dalen, Keval Ram, David Pingree.

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Sawai Jai Singh (1688-1743), the eighteenth century ruler of Jaipur, India, is known for his masonry and stone instruments, and observatories which he erected in cities of north India. Jai Singh also prepared a set of astronomical tables, *Zīj-i Muḥammad Shāhī*, around1733 or so. Jai Singh's *Zīj* is a Persian text of planetary tables and of information useful to an astronomer, or astrologer preparing almanacs and horoscopes for his clientele. Nearly two dozen copies of *Zīj-i Muḥammad Shāhī* (ZMS) survive to this day in libraries and archives around the globe.[1] This paper is based on the MS of the British Library, London.[2]

In addition to erecting observatories, Jai Singh assembled a fine library of astronomical books acquired from far and wide. He acquired books from Europe on varied subjects and had some of them translated into Sanskrit or Hindi. Since the publication of the *Zīj-i Muḥammad Shāhī*, doubts have been raised about the originality of its tables and suggestions made that the *Zīj* is based on the *Tabulae Astronomicae* of Phillip de La Hire. Pons, a Jesuit priest, who visited the Raja in 1734, wrote in 1740 to a friend in Europe, that the Raja would publicize or popularize the *Tabulae Astronomicae* of de La Hire under his own name or patronage.[3] Hunter, the first European to study the *Zīj-i Muḥammad Shāhī* around 1785, also suspected the originality of the *Zīj's* contents.[4] Furthermore, recently, it has been pointed out that all the planetary tables of the *Zīj* are mere adaptation of de La Hire's Tabulae Astronomicae and that they "in no way depend on observations made in India." [5, 6]

These doubts contrast with Jai Singh's claims about his own work. In the preface to the *Zīj*, he writes:

> ". . . in this place [Delhi], . . . astronomical instruments were constructed with all the exactness that the heart can desire, and the motions of the stars constantly observed with them for a long period of time. . . . (And then) mean motions and equations were established which were consistent with observation. He [Jai Singh] found the calculations [with these] agreed perfectly with the observation. . . . A table under the name of His Majesty [*Muḥammad Shāhī*], . . . comprehending the most accurate rules and most perfect methods of computation was constructed. . . ."[7]

In Fig.1 we reproduce a page from the *Zīj* representing the parameters for the planet Venus. In order to verify the validity of Jai Singh's claim, as well

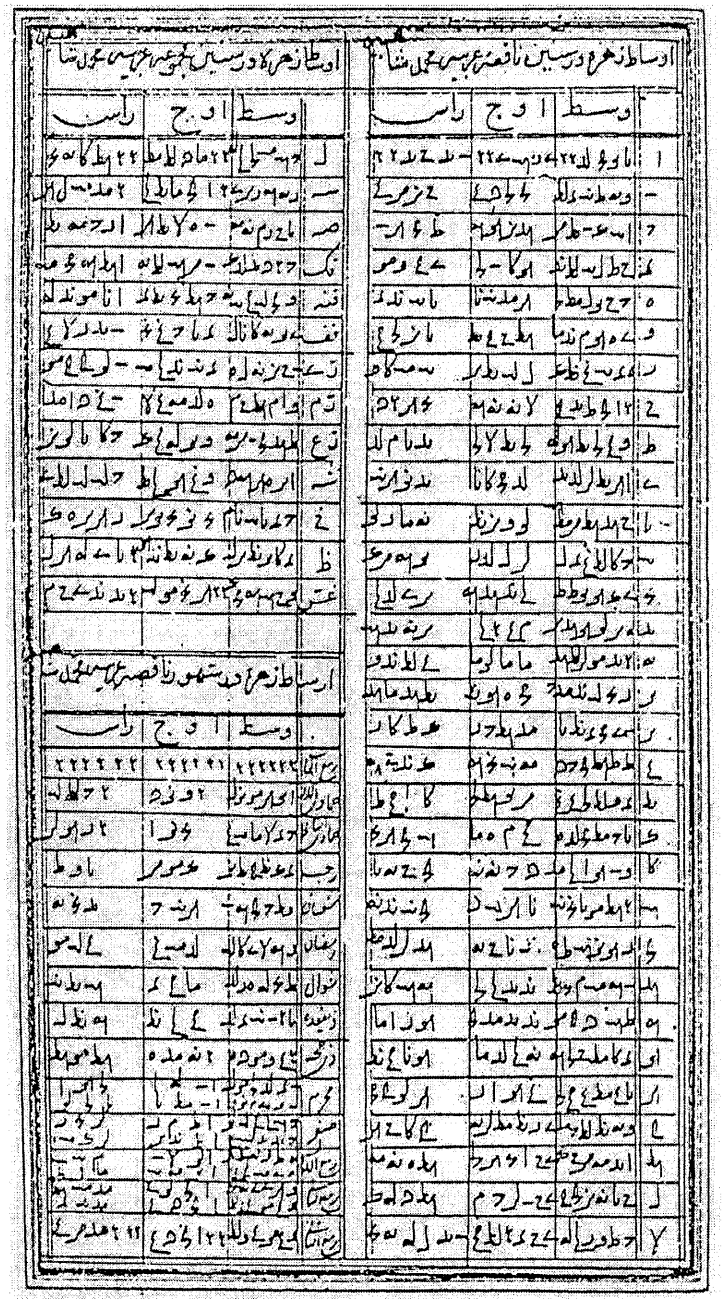
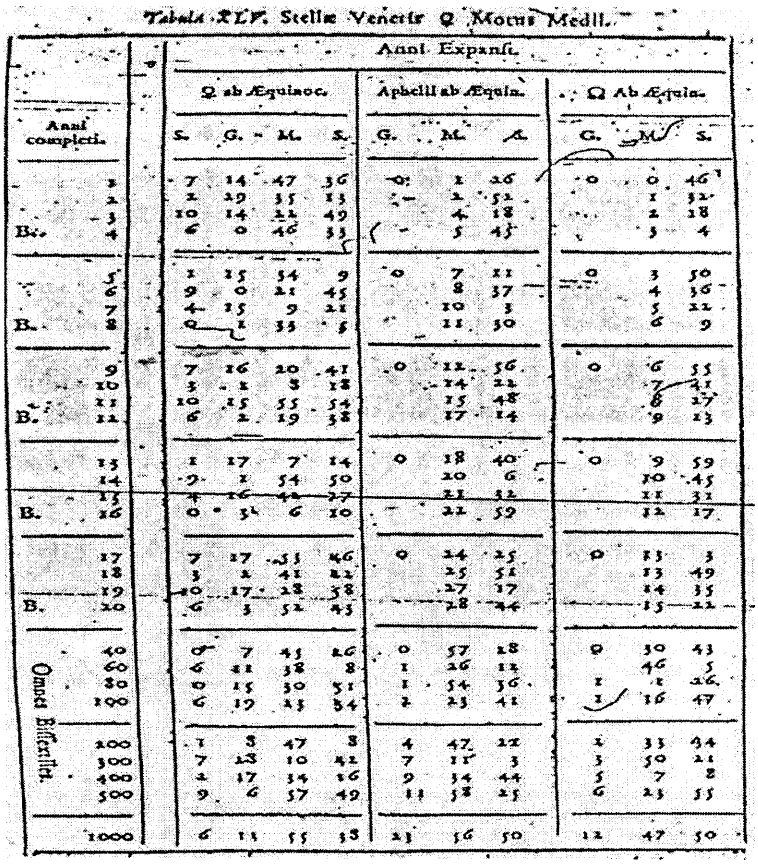


Fig. 1. A page from *Zīj Muḥammad Shāhī*, The Parameters for the Planet Venus. (Curtesy, The British Library)


Tabula XLV. Stellæ Veneris ♀ Motus Medii.

Anni Expansi.

Anni completi.	♀ ab Æquinoc. S.	G.	M.	S.	Aphelii ab Æquin. G.	M.	S.	☊ Ab Æquin. G.	M.	S.
1	7	14	47	36	0	1	26	0	0	46
2	2	29	35	13		2	52		1	32
3	10	14	22	49		4	18		2	18
B. 4	6	0	46	33		5	43		3	4
5	1	15	54	9	0	7	11	0	3	50
6	9	0	21	45		8	37		4	36
7	4	15	9	21		10	3		5	22
B. 8	0	1	33	5		11	30		6	9
9	7	16	20	41	0	12	56	0	6	55
10	3	1	8	18		14	22		7	41
11	10	15	55	54		15	48		8	27
B. 12	6	2	19	38		17	14		9	13
13	1	17	7	14	0	18	40	0	9	59
14	7	1	54	50		20	6		10	45
15	4	16	42	27		21	32		11	31
B. 16	0	31	6	10		22	59		12	17
17	7	17	53	46	0	24	25	0	13	3
18	3	2	41	22		25	51		13	49
19	10	17	28	58		27	17		14	35
B. 20	6	3	52	45		28	44		15	22
40	0	7	45	26	0	57	28	0	30	43
60	6	11	38	8	1	26	12		46	5
80	0	15	30	51	1	54	56	1	1	26
100	6	19	23	34	2	23	41	1	16	47
200	1	3	47	8	4	47	22	2	33	44
300	7	23	10	42	7	11	3	3	50	21
400	2	17	34	16	9	34	44	5	7	8
500	9	6	57	49	11	58	25	6	23	55
1000	6	13	55	38	23	56	50	12	47	50

Annui Bissextili.

Fig. 2. A page from the *Tabulae Astronomicae* of de La Hire: The Parameters for the Planet Venus.

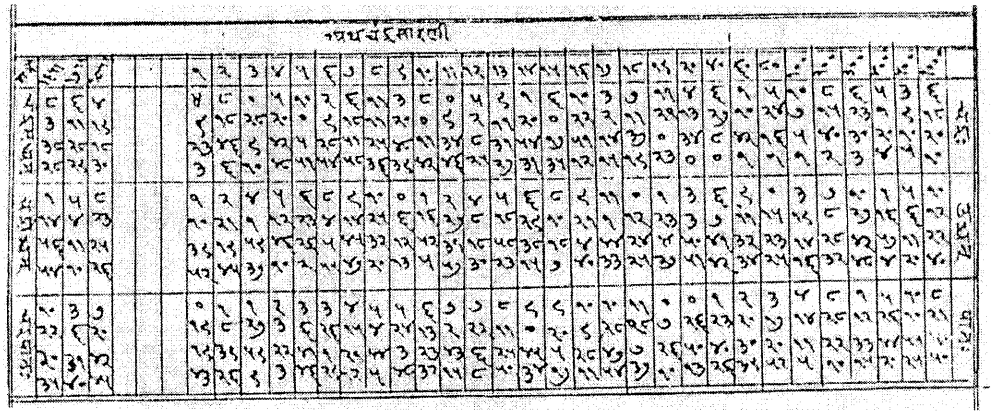


Fig. 3. A page from *Dṛkpakṣa Sāraṇī*, the Parameters for the Moon.

as to confirm the doubts cast on it by others, we analyzed the planetary tables of the *Zīj* in detail. On the basis of our analysis, we believe that indeed a strong case can be built that the planetary tables of the *Zīj* are an adaptation of the *Tabulae Astronomicae* of de La Hire.[8]

TABULAE ASTRONOMICAE 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.[9] The second edition of the *Tabulae* is in two books. Its first book describes how to apply the tables given in book II for solving astronomical problems, such as the calculations of solar and lunar eclipses. The second book has a wide variety of charts and tables, beginning with the table of conversion of arc to time, equation of time, and geographical coordinates of 126 cities and towns around the globe. These are followed by extensive tables for the mean longitude, aphelion and the ascending node of the moon and of the planets. We reproduce a page from the *Tabulae Astronomicae* in Fig. 2.

Sawai Jai Singh had acquired perhaps both editions of the *Tabulae Astronomicae* of de La Hire. His assistants most likely brought the first edition in 1731 from Portugal,[10] and then du Bois copied the second edition a year later in 1732 at Jaipur.[11] The manuscript of du Bois may still be seen at the Sawai Man Singh II Museum of Jaipur. Du Bois writes that Jai Singh ordered the translation of the *Tabulae* as soon as it reached Jaipur and that Jai Singh entrusted him to complete the task. The Sawai Man Singh II Museum preserves an incomplete translation of the *Tabulae Astronomicae* in Sanskrit under the title *Firaṅgī Candravedhopayogī Sāraṇī*.[12]

The Oriental Research Institute of Baroda also preserves a copy of the translation listed under the title *Dṛkpakṣa Sāraṇī*.[13] This manuscript is also incomplete and includes tables and explanatory text only. In Fig. 3 we reproduce a table for the parameters of the moon. A section of the translation called *Dṛkpakṣasāraṇyam Sūryagrahaṇam* is located at the Bhandarkar Oriental Research Institute of Pune.[14] The Pune copy, as its name accurately describes it, concerns with only the calculations of solar eclipses and has no tables.

PLANETARY TABLES OF *TABULAE ASTRONOMICAE* OF DE LA HIRE

Tabulae Astronomicae's planetary tables consist of mean tropical longitude of planets, longitude of the aphelion, and longitude of the ascending node in two alternating sets of tables. The first set of *Tabulae* compiles planetary parameters at 100-year intervals for the period beginning with 300 BC to 1700 AD. The second set consists of tables for the same parameters for 1, ..., 20, ..., 80, 100, ..., 500, and 1000 Julian years. It also gives monthly variations of the parameters in the second set.

The author examined DLH's (*Tabulae Astronomicae's*) planetary tables, particularly the subset of tables for 20 to 1000 Julian years in details. The tables are modulo 360^0, and their first number indicates complete number of signs of the zodiac elapsed, followed by degrees, minutes and seconds. According to this scheme, an entry such 5, 20;16, 30 will be 170;16, 30 according to sexagesimal scheme or $170^0.267$ according to the decimal format. The author noticed that these tables have been compiled by multiplying base values of parameters by appropriate factors or by dividing the 1000-year values of the parameters by appropriate divisors. The author found only three errors in the dLH tables when he reconstructed them from their yearly motions obtained from 1000-year values. However, he found that the errors due to improper rounding off of angles to the nearest second of arc were numerous.

PLANETARY TABLES OF *ZĪJ-I MUḤAMMAD SHĀHĪ* [15]

The planetary tables of the ZMS consist of three subsets: first, the yearly motion of parameters for 30 Arabic years beginning with the epoch date of the *Zīj*, 20 February 1719; second, tables of the motion of the parameters for 30, 60, ..., 300 Arabic years in increments of 30 years, followed by the motion for 600, 900, and 1200 Arabic years in increments of 300 years; and third, tables of monthly motions.

The entries of the ZMS tables are in *abjad* notation, and as such they are read from right to left.[16] Similar to the dLH tables, the first entry of these tables indicates the number of signs elapsed, followed by degrees, minutes, seconds, and fractions of seconds according to the sexagesimal scheme often carried to the sixth place. The data in the tables are modulo 360^0, i.e., the complete numbers of revolutions have been omitted.

We reconstructed these tables from daily motions of the parameters. The daily motions, as a first step, were obtained from 30 Arabic-year motions given in the ZMS, and then readjusted by trial and error to best fit the tables. The reconstructed tables are given in Tables 1-14. In these Tables, wherever our computer generated results differ from the ZMS entries, we give the computer-results in parentheses. Any differences between the ZMS and the computer values should be presumed as an error in the ZMS tables. We noticed that errors in the ZMS tables are of two kinds, scribal and computational. A scribal error is easy to spot in general. In the *abjad* notation of numbers, 10s and 30s differ only by the length of a vertical bar, and similarly, the 10s and 50s differ by a dot above the numbers. Thus a scribe could easily misread a number or make an error of his own in transcribing.

We also noted that computational errors in the ZMS fall in the fourth or fifth sexagesimal places, and as such, they should have not caused any serious problems to the astronomers consulting the *Zīj*. It should be pointed out that Jai Singh's instruments were accurate only down to a minute of arc at best, or down to the first place of the sexagesimal, and therefore the data beyond the first sexagesimal place were, in fact, superfluous.

THE *TABULAE ASTRONOMICAE* AND *ZĪJ-I MUḤAMMAD SHĀHĪ*

In order to verify the assertion that Jai Singh based his planetary tables of the *Zīj-i Muḥammad Shāhī* on de La Hire's *Tabulae Astronomicae*, we calculated, first, the parameters for the epoch date of the *Zīj* from the *Tabulae*, taking the longitude difference of 73:30 between Paris and Delhi.[17,18]. We found that the mean longitude, λ of the planets, for the epoch date of the *Zīj-i Muḥammad Shāhī*, agrees with the calculated values from the *Tabulae*. However, for the longitude of aphelion, Γ, and for the longitude of ascending node, Ω, there was a difference of about one arc-second for some of the planets.[19] We also noticed that the compilers of *Zīj*, did not apply any longitude correction for a number of parameters, particularly, when such a correction had been small.

Next, we calculated the daily mean motions of parameters of the planets in the *Tabulae Astronomicae* as well as in the *Zīj-i Muḥammad Shāhī*. The results of our calculations are given in Tables 15 and 16. The daily motions reported for the *Zīj* in the Table are the ones that best fit the *Zīj* data as pointed out earlier. A close inspection of this Table would reveal that the ZMS values match with the *Tabulae* values up to fourth sexagesimal place and not beyond. A simple explanation for this discrepancy may lie in the very process of conversion itself. For one, it is not known with certainty as to what entries of the *Tabulae* tables were used by Jai Singh's astronomers for their conversion exercise. There are essentially two steps involved in the conversion exercise: one, converting the sexagesimal entries of the *Tabulae* into a decimal format; two, dividing the result thus obtained by appropriate number of days to obtain the daily motion for the ZMS tables. It is not known with certainty as down to how many places after the decimal point, the compilers of the *Zīj* tables carried out their calculations for each step of conversion. We have reasons to believe, however, that the mathematicians of Jai Singh carried out their calculations down to18 or more places after the decimal point, for at least some of the parameters.

TABLES IN THE *ZĪJ-I MUḤAMMAD SHĀHĪ* FROM *TABULAE ASTRONOMICAE*

The author has found two other tables which were copied from de La Hire's *Tabulae*. Islamic *Zījes*, by and large, lack refraction-correction tables, but the *Zīj-i Muḥammad Shāhī* has such a table. Jai Singh borrowed this table directly from the *Tabulae Astronomicae*.[20] There is no evidence that the Raja himself determined any refraction correction data for his *Zīj*. Another table that he could have adapted from the *Tabulae Astronomicae* is the equation of time. In the *Zīj*, the equation of time is in *ghaṭikā* and *pala* units, which, after transformation into minutes and seconds, becomes identical with the table of the *Tabulae Astronomicae*. We should point out, however, that tables for equation of time are not unique to European works; they are also found in just about every *Zīj* written in the Islamic world during the middle ages.

TABLES OF MEAN PLANETARY PARAMETERS IN THE *ZĪJ-I MUḤAMMAD SHĀHĪ*

We have divided the tables for the mean planetary parameters into two groups. The Group A of tables elaborates yearly motions of a parameter following the epoch date of February 20, 1719 A.D. The yearly motions in Table A have been calculated by multiplying the daily motions either by 354 or by 355 days of an Arabic year. The years with 355 days are leap-years, and they are indicated by a letter x in the column "years after the epoch". The ZMS does not record the complete number of revolutions of parameters, but we are indicating them in the tables with a letter *r* following the number of revolutions. The Group B, on the other hand, elaborates tables with 30 - 1200 yr motions of the parameters in 30 yr or 300 yr steps. The numerical values in this group of tables have been calculated from 30-yr motions.

Wherever our computer generated values differ from the ZMS entries, we denote the computer generated results in parentheses as pointed out earlier. Any difference between the ZMS entries and our calculated results may be presumed as errors in the ZMS tables.

Group A: Yearly Motion of the Parameters of Planets

Table 1 Yearly Motion of the Parameters of the Sun

	Mean Longitude λ	**Longitude of Aphelion Γ**
	Daily Motion 0r,0,0;59,8,19,46,50,57,27,40 **Epoch Date** 0r,10,29;36,1,0,0,0	**Daily Motion** 0r,0,0;0,0,10,6,34,34,11,22 **Epoch Date** 0r,3,8;26,4,0,0
	Yearly Motion after the Epoch Date	**Yearly Motion after the Epoch Date**
Years after the epoch date: 1x	1r,10,19;30,18,2,11,30	0r,3,8;27,3,48,55
2	2r,10,8;25,26,44,36,9	0r,3,8;28,3,27,42(43)
3	3r,9,27;20,35,27,0,48	0r,3,8;29,3,6,30
4 x	4r,9,17;14,52,29,12,18	0r,3,8;30,2,55,25
5	5r,9,6;10,1,11,36,57	0r,3,8;31,2,34,13
6 x	6r,8,26;4,18,13,48,27	0r,3,8;32,2,23,8
7	7r,8,14;59,26,56,13,6	0r,3,8;33,2,1,55
8	8r,8,3;54,35,38,37,45	0r,3,8;34,1,40,43
9 x	9r,7,23;48,52,40,49,15	0r,3,8;35,1,29,38
10	10r,7,12;44,1,23,13,54	0r,3,8;36,1,8,26
11	11r,7,1;39,10,5,38,33	0r,3,8;37,0,47,14
12 x	12r,6,21;33,27,7,50,3	0r,3,8;38,0,36,9
13	13r,6,10;28,35,50,14,42	0r,3,8;39,0,14,57
14	14r,5,29;23,44,32,39,21	0r,3,8;39,59,53,44
15 x	15r,5,19;18,1,34,50,51	0r,3,8;40,59,42,17(39)
16	16r,5,8;13,10,17,15,30	0r,3,8;41,59,21,27
17 x	17r,4,28;7,27,19,27,0	0r,3,8;42,59,10,22
18	18r,4,17;2,36,1,51,49(39)*	0r,3,8;43,58,49,10
19	19r,4,50(5);57,44,44,16,28(18)	0r,3,8;44,58,27,58
20 x	20r,3,25;52,1,46,27,58(48)	0r,3,8;45,58,6(16),45(52)
21	21r,3,14;47,10,28,52,37(27)	0r,3,8;46,57,55,40
22	22r,3,3;42,19,11,17,16(6)	0r,3,8;47,57,34,28
23 x	23r,2,23;36,36,13,28,46(36)	0r,3,8;48,57,23,16(22)
24	24r,2,12;31,44,55,53,25(15)	0r,3,8;49,57,2,10(11)
25 x	25r,2,2;26,1,58,4,55(45)	0r,3,8;50,56,40(51),59(5)
26	26r,1,21;21,10,40,29,34(24)	0r,3,8;51,56,29,54
27	27r,1,10;16,19,22,54,13(3)	0r,3,8;52,56,8,42
28 x	28r,1,0;10,36,25,5,43(33)	0r,3,8;53,54(55),47(57),30(35)
29	29r,0,19;5,45,7,30,22(12)	0r,3,8;54,55,36,24
30	30r,0,8;0,53,49,55(54),1(51)	0r,3,8;55,55,15,12

* A difference of 10 in the last digit from 18 yr down to 30 yr, for the parameter λ, indicates an error in calculations.

Table 2. Yearly Motion of the Parameters of the Moon

	Mean Longitude λ	Longitude of Perihelion Γ	Longitude of Ascending Node Ω
	Daily Motion 0r,0,13;10,35,1,22,11,28,46 **Epoch date** 0r,11,11;17,6,0,0	**Daily Motion** 0r,0,0;6,41,4,29,35,16,10 **Epoch Date** 0r,11,24;50,57,0,0	**Daily Motion** 0r,0,0;3,10,38.18,4,54,30,0 **Epoch Date** 0r,5,7;16,14,0,0
	Yearly Motion after the Epoch Date	**Yearly Motion after the Epoch Date**	**Yearly Motion after the Epoch Date**
Years after the epoch date: Ix	13r,11,8;54,19,6,18	1r,1,4;23,58,35,1(4)	4,18;28,17,23,1
2	26r,10,23;20,17(57),11,14	1r,2,13;50,19,5,37(38)	3,29;43,31,24,20
3	39r,10,7;47,35,16,8(9)	1r,3,23;16,39,36,13(12)	3,10;58,45,25,39
4 x	52r,10,5;24,48,22,27	1r,5,2;49,41,11,13(16)	2,22;10,48,48,40
5	65r,9,19;51,26,27,23	1r,6,12;16,1,41,50	2,3;26,2,49,59
6 x	78r,9,17;28,39,33,41	1r,7,21;49,3,16,50(53)	1,14;38,6,13,0
7	91r,9,1;55,17,38,37	1r,9,1;15,23,47,26(27)	0,25;53,20,14,19
8	104r,8,16;21,55,43,44(32)	1r,10,10;41,44,18,2(1)	0,7;8,34,15,38
9 x	117r,8,13;59,8,49,50	1r,11,20;14,45,53,3(5)	11,18;20,37,38,39
10	130r,7,28;25,46,54,58(46)	2r,0,29;41,6,23,39	10,29;35,51,39,58
11	143r,7,12;52,24,59,48(42)	2r,2,9;7,26,54,15(13)	10,10;51,5,41,17
12 x	156r,7,10;29,38,6,0	2r,3,18;40,28,29,15(17)	9,22;3,9,4,18
13	169r,6,24;56,16,11(10),1(55)	2r,4,28;6,48,59,51	9,3;18,23,5,37
14	182r,6,9;22,54,16(15),4(51)	2r,6,7;33,9,30,26(25)	8,14;33,37,6,56
15 x	195r,6,7;0,7,22,9	2r,7,17;6,11,5,28(29)	7,25;45,40,29,57
16	208r,5,21;26,45,27,18(5)	2r,8,26;32,31,36,3	7,7;0,54,31,16
17 x	221r,5,19;3,58,33,23	2r,10,6;5,33,11,5(7)	6,18;12,57,54,17
18	234r,5,3;30,36,38,32(18)	2r,1(11),15;31,53,41,40(41)	5,29;28,11,55,36
19	247r,4,17;57,14,43,18(14)	3r,0,24;58,14,12,16(15)	5,10;43,25,56,55
20 x	260r,4,15;34,27,49,32	3r,2,4;31,15,47,17(18)	4,21;55,29,19,56
21	273r,4,0;1,5,54,32(28)	3r,3,13;57,36,17,53	4,3;10,43,21,15
22	286r,3,14;27,43,59,36(24)	3r,4,23;23,56,48,28(27)	3,14;25,57,22,34
23 x	299r,3,12;4,57,5,41	3r,6,2;56,58,23,30	2,25;38,0,45,35
24	312r,2,26;31,35,10,37	3r,7,12;23,18,14(54),5(4)	2,6;53,14,46,54
25 x	325r,2,24;8,48,16,55	3r,8,21;56,20,29,6(8)	1,18;5,18,9,55
26	338r,2,8;35,26,21,51	3r,10,1;22,40,59,42	0,29;20,32,11,14
27	351r,1,23;2,4,26,47	3r,11,10;49,1,30,18(16)	0,10;35,46,12,33
28 x	364r,1,20;39,17,33,4(5)	4r,0,20;22,3,5,18(20)	11,21;47,49,35,34
29	377r,1,5;5,55,38,0	4r,1,29;48,23,35,55(54)	11,3;3,3,36,53
30	390r,0,19;32,33,42,56	4r,3,9;14,44,6,41(28)	10,14;18,17,38,14(12)

Table 3. Yearly Motion of the Parameters of Planet Mercury

	Mean Longitude λ	**Longitude of Aphelion Γ**	**Longitude of Ascending Node Ω**
	Daily Motion 0r,0,4;5,32,35,20,32, 52,36,10 **Epoch date** 0r,6,23;22,21,0,0	**Daily Motion:** 0r,0,0;0,0,16,14,27,56,41,50 **Epoch Date** 0r,8,13;33,32,0,0	**Daily Motion** 0r,0,0;0,0,14,0,39,27,10,0 **Epoch Date** 0r,1,15;19,1,0,0
	Yearly Motion after the Epoch Date	**Yearly Motion after the Epoch Date**	**Yearly Motion after the Epoch Date**
Years after the epoch date: 1x	4r,7,6;10,10,6,34	0r,8,13;35,8,5,35	0r,1,15;20,23,53,54(53)
2	8r,7,14;52,26,37,48	0r,8,13,36,43,54,56	0r,1,15;21,46,33,46
3	12r,7,23;34,43,9,2	0r,8,13;38,19,44,17	0r,1,15;23,9,13,39
4 x	16r,8,6;22,32,15,35(37)	0r,8,13;39,55,49,52	0r,1,15;24,32,7,33(32)
5	20r,8,15;4,48,46,51	0r,8,13;41,31,39,13	0r,1,15;25,54,47,25
6 x	24r,8,27;52,37,53,24(25)	0r,8,13;43,7,44,48(49)	0r,1,15;27,17,41,19
7	28r,9,6;34,54,24,39	0r,8,13;44,43,34,10	0r,1,15;28,40,21,11
8	32r,9,15;17,10,55,53	0r,8,13;46,19,23,30	0r,1,15;30,3,1,4
9 x	36r,9,28;5,0,2,26(28)	0r,8,13;47,55,29,6	0r,1,15;31,25,54,58
10	40r,10,6;47,16,33,42	0r,8,13;49,31,18,27	0r,1,15;32,48,34,50
11	44r,10,15;29,33,4,55(56)	0r,8,13;51,7,7,47	0r,1,15;34,11,14,43
12 x	48r,10,28;17,22,11,28(30)	0r,8,13;52,43,13,22(23)	0r,1,15;35,34,8,37
13	52r,11,6;59,38,42,44	0r,8,13;54,19,2,44	0r,1,15;36,56,48,29
14	56r,11,15;41,55,13,58	0r,8,13;55,54,52,5	0r,1,15;38,19,28,22
15 x	60r,11,28;29,44,20,31(33)	0r,8,13;57,30,57,39(40)	0r,1,15;39,42,22,16
16	65r,0,7;12,0,51,46(47)	0r,8,13;59,6,47,1	0r,1,15;41,5,2,8
17 x	69r,0,19;59,49,58,19(21)	0r,8,14;0,42,52,36	0r,1,15;42,27,56,2
18	73r,0,28;42,6,29,35	0r,8,14;2,18,41,57	0r,1,15;43,50,35,54
19	77r,1,7;24,23,0,49	0r,8,14;3,54,31,18	0r,1,15;45,13,15,37(47)
20 x	81r,1,20;12,12,7,22(24)	0r,8,14;5,30,36,53	0r,1,15;46,36,9,30(41)
21	85r,1,28;54,28,38,35(38)	0r,8,14;7,6,26,14	0r,1,15;47,58,49,33
22	89r,2,7;36,45,9,51(52)	0r,8,14;8,42,15,35	0r,1,15;49,21,29,26
23 x	93r,2,20;24,34,16,24(26)	0r,8,14;10,18,21,10	0r,1,15;50,44,23,20
24	97r,2,29;6,50,47,40	0r,8,14;11,54,10,31	0r,1,15;52,7,3,12
25 x	101r,3,11;54,39,54,13(15)	0r,8,14;13,30,16,7	0r,1,15;53,29,57,6
26	105r,3,20;36,56,25,29	0r,8,14;15,6,5,27	0r,1,15;54,52,36,59
27	109r,3,29;19,12,56,44(43)	0r,8,14;16,41,54,48	0r,1,15;56,15,16,51
28 x	113r,4,12;7,2,3,17	0r,8,14;18,18,0,24	0r,1,15;57,38,10,45
29	117r,4,20;49,18,34,32(31)	0r,8,14;19,53,49,45	0r,1,15;59,0,50,38
30	121r,4,29;31,35,5,46(45)	0r,8,14;21,29,39,5	0r,1,16;0,23,30,30

Table 4. Yearly Motion of the Parameters of Venus

	Mean Longitude λ	**Longitude of Aphelion Γ**	**Mean Longitude Ω**
	Daily Motion	**Daily Motion**	**Daily Motion**
	0r,0,1;36,7,49,32,3,17,24,55	0r,0,0;0,0,14,10,11,30,15,0	0r,0,0;0,0,7,34,11,30,25,19
	Epoch date	**Epoch Date**	**Epoch Date**
	0r,11,16;23,34,0,0	0r,10,7;22,10,0,0	0r,2,14;8,14,0,0
	Yearly Motion after the Epoch Date	**Yearly Motion after the Epoch Date**	**Yearly Motion after the Epoch Date**
Years after the epoch date: 1x	2r,6,15;9,52,4,39	0r,10,7;23,33,50,18	0r,2,14;8,57(58),47,18
2	4r,1,12;20,2,19,47	0r,10,7;24,57,26,25	0r,2,14;9,43,27,2
3	5r,8,9;30,12,39(34),54	0r,10,7;26,21,2,33	0r,2,14;10,28,6,46
4 x	7r,3,8;16,30,39,33(34)	0r,10,7;27,44,52,51(52)	0r,2,14;11,12,54,4
5	8r,10,5;26,40,54,41	0r,10,7;29,8,29,19(0)	0r,2,14;11,57,33,48
6 x	10r,5,4;12,58,59,20(21)	0r,10,7;30,32,19,17(18)	0r,2,14;12,42,21,6
7	12r,0,1;23,9,14,28	0r,10,7;31,55,55,25(26)	0r,2,14;13,27,0,50
8	13r,6,28;33,19,29,35	0r,10,7;33,19,31,33(34)	0r,2,14;14,11,40,34
9 x	15r,1,27;19,37,34,14(15)	0r,10,7;34,43,21,51(52)	0r,2,14;14,56,27,52
10	16r,8,24;29,47,49,22	0r,10,7;36,6,58,59(0)	0r,2,14;15,41,7,36
11	18r,3,21;39,58,4,30	0r,10,7;37,30,34,7	0r,2,14;16,25,47,20
12 x	19r,10,20;26,16,9,9	0r,10,7;38,54,24,25	0r,2,14;17,10,34,38
13	21r,5,17;36,26,24,17	0r,10,7;40,18,0,38(33)	0r,2,14;17,55,14,22
14	23r,0,14;46,36,39,24	0r,10,7;41,41,36,41	0r,2,14;18,39,54,6(5)
15 x	24r,7,13;32,54,44,3(4)	0r,10,7;43,5,26,59	0r,2,14;19,24,41,24
16	26r,2,10;43,4,59,11	0r,10,7;44,29,3,7	0r,2,14;20,9,21,7
17 x	27r,9,9;29,23,3,50	0r,10,7;45,52,53,25	0r,2,14;20,54,8,25
18	29r,4,6;39,33,18,58	0r,10,7;47,16,29,33	0r,2,14;21,38,48,9
19	30r,11,3;49,43,34,5	0r,10,7;48,40,5,41	0r,2,14;22,23,27,53
20 x	32r,6,2;26(36),1,38,44	0r,10,7;50,3,55,59	0r,2,14;23,8,15,11
21	34r,0,29;46,11,53,52	0r,10,7;51,27,32,7	0r,2,14;23,52,54,55
22	35r,7,26;56,22,9,0	0r,10,7;52,51,8,15	0r,2,14;24,37,34,39
23 x	37r,2,25;42,40,13,39	0r,10,7;54,14,38(58),33	0r,2,14;25,22,21,57
24	38r,9,22;52,50,28,46	0r,10,7;54,14(38),44(34),23	0r,2,14;26,7,1,41
25 x	40r,4,21;39,8,33,25(26)	0r,10,7;55(57),38(2),34(24),41(59)	0r,2,14;26,51,48,59
26	41r,11,18;49,18,48,33	0r,10,7;58,26,1,7	0r,2,14;27,36,28,43
27	43r,6,15;59,29,3,41	0r,10,7;59,49,37,15	0r,2,14;28,21,8,27
28 x	45r,1,14;45,47,8,20	0r,10,8;1,13,27,33	0r,2,14;29,5,55,45
29	46r,8,11;55,57,23,28	0r,10,8;2,37,3,40	0r,2,14;29,50,35,20(29)
30	48r,3,9;6,7,38,35	0r,10,8;4,0,39,48	0r,2,14;30,35,15,13

Table 5. Yearly Motion of the Parameters of Planet Mars

	Mean Longitude λ	Longitude of Aphelion Γ	Longitude of Ascending Node Ω
	Daily Motion 0r,0,0;31,26,39,13,58,18,30 **Epoch Date** 0r,7,24;32,42,0,0	**Daily Motion** 0r,0,0;0,0,10,57,32,3,39,35 **Epoch Date** 0r,5,0;55,32,0,0	**Daily Motion** 0r,0,0;0,0,6,4,55,56,15 **Epoch Date** 0r,1,17;36,29,0,0
	Yearly Motion after the Epoch Date	**Yearly Motion after the Epoch Date**	**Yearly Motion after the Epoch Date**
Years after the epoch date: 1x	1r,2,0;35,24,7,40	0r,5,0;56,36,50,25	0r1,17;37,4,59,11
2	1r,8,6;6,39,36,6	0r,5,0;57,41,29,52	0r,1,17;37,40,52,17
3	2r,2,11;37,55,4,32	0r,5,0;58,46,9,19	0r,1,17;38,16,45,23
4 x	2r,8,17;40,37,12,12	0r,5,0;59,50,59,43(44)	0r,1,17;38,52,44,34
5	3r,2,23;11,52,40,38	0r,5,1;0,55,39,11	0r,1,17;39,28,37,40
6 x	3r,8,29;14,34,48,38(18)	0r,5,2(1);0,29,25(36),11	0r,1,17;40,4,36,51
7	4r,3,4;45,50,16,44	0r,5,1;3,5,9,43(3)	0r,1,17;40,40,29,57
8	4r,9,10;17,5,45,10	0r,5,1;4,9,48,30	0r,1,17;41,16,23,3
9 x	5r,3,16;19,47,52,50	0r,5,1;5,14,13(38),10(55)	0r,1,17;41,52,22,14
10	5r,9,21;51,3,21,16	0r,5,1;6,19,18,22	0r,1,17;42,28,15,20
11	6r,3,27;22,18,49,42	0r,5,1;7,23,57,49	0r,1,17;43,4,8,26
12 x	6r,10,3;25,0,57,22	0r,5,1;8,28,48,14	0r,1,17;43,40,7,36(37)
13	7r,4,8;56,16,25,48	0r,5,1;9,33,27,41	0r,1,17;44,16,0,43
14	7r,10,14;27,31,54,14	0r,5,1;10,38,7,8	0r,1,17;44,51,53,49
15 x	8r,4,20;30,14,1,54	0r,5,1;11,42,57,32(33)	0r,1,17;45,27,53,0
16	8r,10,26;1,29,30,20	0r,5,1;12,47,36,60	0r,1,17;46,3,46,6
17 x	9r,5,2;4,11,38,0	0r,5,1;13,52,27,24	0r,1,17;46,39,45,17
18	9r,11,7;35,27,6,26	0r,5,1;14,57,6,52	0r,1,17;47,15,38,23
19	10r,5,13;6,42,34,52	0r,5,1;16,1,46,19	0r,1,17;47,51,31,29
20 x	10r,11,19;9,24,42,32	0r,5,1;17,6,36,43	0r,1,17;48,27,30,40
21	11r,5,24;40,40,10,58	0r,5,1;18,11,16,11	0r,1,17;49,3,23,46
22	12r,0,0;11,55,39,24	0r,5,1;19,15,55,38	0r,1,17;49,39,16,52
23 x	12r,6,6;14,37,47,4	0r,5,1;20,20,46,2	0r,1,17;50,15,16,3
24	13r,0,11;45,53,15,30	0r,5,1;21,25,25,30	0r,1,17;50,51,9,9
25 x	13r,6,17;48,35,23,10	0r,5,1;22,30,15,54	0r,1,17;51,27,8,20
26	14r,0,23;59(19),50,51,36	0r,5,1;23,34,55,22	0r,1,17;52,3,1,26
27	14r,6,28;51,6,20,2	0r,5,1;24,39,34,49	0r,1,17;52,38,54,32
28 x	15r,1,4;53,48,27,42	0r,5,1;25,44,25,13	0r,1,17;53,14,53,43
29	15r,7,10;25,3,56,8	0r,5,1;26,49,4,41	0r,1,17;53,50,46,49
30	16r,1,15;56,19,24,34	0r,5,1;27,53,44,8	0r,1,17;54,26,39,55

Table 6. Yearly Motion of the Parameters of Jupiter

	Mean Longitude λ	**Longitude of Aphelion Γ**	**Longitude of Ascending Node Ω**
	Daily Motion 0r,0,0;4,59,16,0 **Epoch Date** 0r,4,26;54,6,0,0	**Daily Motion** 0r,0,0;0,0,15,30,25,23,54 **Epoch Date** 0r,6,10;45,43,0,0	**Daily Motion** 0r,0,0;0,0,2,19,4,13,50,10 **Epoch Date** 0r,3,7;15,59,0,0
	Yearly Motion after the Epoch Date	**Yearly Motion after the Epoch Date**	**Yearly Motion after the Epoch Date**
Years after the epoch date: Ix	0r,5,26;24,45,40,0	0r,6,10;47,14,45,0	0r,3,7;16,12,42,50
2	0r,6,25;50,26,4(3),0(59)	0r,6,10;48,46,14,30	0r,3,7;16,26,23,21
3	0r,7,25;16,6,28(27),0(59)	0r,6,10;50,17,44(43),0(59)	0r,3,7;16,40,3,52
4 x	0r,8,24;46,46,8,0	0r,6,10;51,49,29,0	0r,3,7;16,53,46,42
5	0r,9,24;12,26,32,0	0r,6,10;53,20,58,30	0r,3,7;17,7,27,13
6 x	0r,10,23;43,6,12,0	0r,6,10;54,52,43,30	0r,3,7;17,21,10,3
7	0r,11,23;8,46,36,0	0r,6,10;56,24,13,0	0r,3,7;17,34,50,34
8	1r,0,22;34,27,0,0	0r,6,10;57,55,42,30	0r,3,7;17,48,31,5
9 x	1r,1,22;5,6,40,0	0r,6,10;59,27,27,30	0r,3,7;18,2,53(13),15(55)
10	1r,2,21;30,47,4,0	0r,6,11;0,58,57,0	0r,3,7;18,15,54,26
11	1r,3,20;56,27,28,0	0r,6,11;2,30,26,30	0r,3,7;18,29,34,57
12 x	1r,4,20;27,7,8,0	0r,6,11;4,2,11,30	0r,3,7;18,43,17,43(47)
13	1r,5,19;52,47,32,0	0r,6,11;5,33,41,0	0r,3,7;18,56,58,18
14	1r,6,19;18,27,56,0	0r,6,11;7,5,10,30	0r,3,7;19,10,38,49
15 x	1r,7,18;49,7,36,0	0r,6,11;8,36,55,30	0r,3,7;19,24,21,39
16	1r,8,18;14,43(48),0,0	0r,6,11;10,8,25,0	0r,3,7;19,38,2,10
17 x	1r,9,17;45,27,40,0	0r,6,11;11,40,10,0	0r,3,7;19,51,45,0
18	1r,10,17;11,8,4,0	0r,6,11;13,11,39,30	0r,3,7;20,5,25,31
19	1r,11,16;36,48,28,0	0r,6,11;14,43,9,0	0r,3,7;20,19,6,2
20 x	2r,0,16;7,28,8,0	0r,6,11;16,14,54,0	0r,3,7;20,32,48,52
21	2r,1,15;33,8,32,0	0r,6,11;17,46,23,30	0r,3,7;20,46,28(29),23
22	2r,2,14;58,48,56,0	0r,6,11;19,17,53,0	0r,3,7;21,0,9,54
23 x	2r,3,14;29,28,36,0	0r,6,11;20,49,38,0	0r,3,7;21,13,52,44
24	2r,4,13;55,9,0,0	0r,6,11;22,21,7,30	0r,3,7;21,27,33,15
25 x	2r,5,13;25,48,40,0	0r,6,11;23,52,52,30	0r,3,7;21,41,16,5
26	2r,6,12;51,29,4,0	0r,6,11;25,24,22,0	0r,3,7;21,54,56,36
27	2r,7,12;17,9,28,0	0r,6,11;26,55,51,30	0r,3,7;22,8,37,7
28 x	2r,8,11;47,49,8,0	0r,6,11;28,27,36,30	0r,3,7;22,22,19,57
29	2r,9,11;13,29,32,0	0r,6,11;29,59,6,0	0r,3,7;22,36,0,28
30	2r,10,10;39,9,56,0	0r,6,11;31,30,35,30	0r,3,7;22,49,40,19(59)

Table 7. Yearly Motion of the Parameters of Planet Saturn

	Mean Longitude λ	**Longitude of Aphelion Γ**	**Longitude of Ascending Node Ω**
	Daily Motion 0r,0,0;2,0,34,24,39,26,53 **Epoch date** 0r,7,3;6,57,0,0	**Daily Motion** 0r,0,0;0,0,13,28,46,1,54 **Epoch Date** 0r,8,29;39,23,0,0	**Daily Motion** 0r,0,0;0,0,11,45,12,20,21 **Epoch Date** 0r,3,22;18,5,0,0
	Yearly Motion after the Epoch Date	**Yearly Motion after the Epoch Date**	**Yearly Motion after the Epoch Date**
Years after the epoch date: 1x	0r,7,15;0,20,35,53	0r,8,29;40,42,45,13(12)	0r,3,22;19,14,32,28
2	0r,7,26;51,43,37,22	0r,8,29;42,2,16,56	0r,3,22;20,23,13,52(53)
3	0r,8,8;43,6,38,51(50)	0r,8,29;43,21,48,40(39)	0r,3,22;22(21),52(33), 46,(13),23(53)
4 x	0r,8,20;36,39(30),14,44	0r,8,29;44,41,33,52	0r,3,22;23(22),52(42),7(46),6(22)
5	0r,9,2;27,53,16,33(13)	0r,8,29;46,1,5,35	0r,3,22;23,52,7,6(4)
6 x	0r,9,14;21,16,52,6	0r,8,29;47,20,50,48	0r,3,22;25,1,39,34(32)
7	0r,9,26;12,39,53,35	0r,8,29;48,40,22,31	0r,3,22;26,11,0,17(15)
8	0r,10,8;4,2,55,4	0r,8,29;49,59,54,15	0r,3,22;27,20,20,59(58)
9 x	0r,10,19;57,26,30,57	0r,8,29;51,19,39,28(27)	0r,3,22;28,29,53,27(26)
10	0r,11,1;48,49,32,26	0r,8,29;52,39,11,11	0r,3,22;29,39,34(14),10(9)
11	0r,11,13;40,12,33,55	0r,8,29;53,58,42,54(55)	0r,3,22;30,48,34,53(52)
12 x	0r,11,25;33,36,9,48	0r,8,29;55,18,28,7	0r,3,22;31,58,7,20
13	1r,0,7;24,59,11,17	0r,8,29;56,37,59,50	0r,3,22;33,7,28,3(2)
14	1r,0,19;16,22,12,46	0r,8,29;57,57,31,34	0r,3,22;34,16,48,46(45)
15 x	1r,1,1;9,45,48,39	0r,8,29;59,17,16,47(46)	0r,3,22;35,26,21,14(13)
16	1r,1,13;1,8,50,8	0r,9,0;0,36,48,30	0r,3,22;36,35,41,57(56)
17 x	1r,1,24;54,32,26,1	0r,9,0;1,56,33,42	0r,3,22;37,45,14,25(24)
18	1r,2,6;45,55,27,30	0r,9,0;3,16,5,26	0r,3,22;38,54,35,38(7)
19	1r,2,18;37,18,28,59	0r,9,0;4,35,37,10	0r,3,22;40,3,50(55),15(50)
20 x	1r,3,0;30,42,4,52	0r,9,0;5,55,22,22	0r,3,22;41,13,28,18
21	1r,3,12;22,5,6,21	0r,9,0;7,14,54,5	0r,3,22;42,22,49,1(0)
22	1r,3,24;13,28,7,50	0r,9,0;8,34,25,49	0r,3,22;43,32,9,44(43)
23 x	1r,4,6;6,51,43,43	0r,9,0;9,54,11,2(1)	0r,3,22;44,42(41),41(42),11
24	1r,4,17;58,14,45,12	0r,9,0;11,13,42,45	0r,3,22;45,51,2,54
25 x	1r,4,29;51,38,21,5	0r,9,0;12,33,27,58(57)	0r,3,22;47,0,35,22
26	1r,5,11;43,1,22,34	0r,9,0;13,52,59,41	0r,3,22;48,9,56,0(5)
27	1r,5,23;34,24,24,3	0r,9,0;15,12,31,24(25)	0r,3,22;49,19,16,48
28 x	1r,6,5;27,47,59,56	0r,9,0;16,32,16,37	0r,3,22;50,28,49,15(16)
29	1r,6,17;19,11,1,25	0r,9,0;17,51,48,20	0r,3,22;51,38,9,58
30	1r,6,29;10,34,2,54	0r,9,0;19,11,20,4,3	0r,3,22;52,47,30,41

Group B: The 30-1200 Arabic-Year Tables

Explanation

The mathematicians compiling the 30 - 1200 yr tables of the ZHS often carried out their calculations to the fifth or sixth places of the sexagesimal notation for the 30 yr motion, but recorded only down to the fourth or fifth in the text. We are indicating the extra places not recorded in the ZHS with an asterisk. The computer generated results differing from the ZHS entries are displayed in parentheses. The ZHS does not record the complete number of revolutions of parameters, but we are showing them in the following tables with a letter r after the number of revolutions.

Table 8. Planetary Parameters of the Sun

Multiplier	Arabic years	Mean Tropical Longitude λ	Longitude of Aphelion Γ
1	30	29r,1,8;24,52,49,54,51	0r,0,0;29,51,15,12,20
2	60	58r,2,16;49,45,39,50,0 [1]	0r,0,0;59,42,30,24,40
3	90	87r,3,25;14,38,29,45,0	0r,0,1;29,33,45,37,30(0)
4	120	116r,5,3;39,31,19,39,0	0r,0,1;59,25,0,49,20
5	150	145r,6,12;4,24,9,34,0	0r,0,2;29,16,16,1,40
6	180	174r,7,20;29,16,59,29,0	0r,0,2;59,7,31,14,0
7	210	203r,8,28;54,9,49,24,0	0r,0,3;28,58,46,26,20
8	240	232r,10,7;19,2,39,19,0	0r,0,3;58,50,1,38,40
9	270	261r,11,15;43,55,29,14,0	0r,0,4;28,41,16,51,0
10	300	291r,0,24;8,48,19,8,0	0r,0,4;58,32,32,3,20
20	600	582r,1,18;17,36,48(38),17,0	0r,0,9;57,5,4,6,40
30	900	873r,2,12;26,24,57.25,0	0r,0,14;55,37,36,10,0
40	1200	1164r,3,6;35,13,36(16),34,0	0r,0,19;54,10,8,13,20

[1] The mathematicians compiling the tables of ZMS quite often rounded off the last digits to zeros.
Therefore, zeros in the last sexagesimal place in this table do not necessarily mean that the they are the results of actual calculations.

Table 9. Parameters of the Moon

Multiplier	Arabic Years	Mean Tropical Longitude λ	Longitude of Aphelion Γ	Longitude of Ascending Node Ω
1	30	389r,1,8;15,27,42,56(55),36*	3r,3,14;27(23),47,6,40,54*,30*	2r,-{5,7;2,3,38,11,5*}
2	60	778r,2,16;30,55,25,51	6r,6,28;47,34,13,20(22)	4r,-{10,14;4,7,16,22}
3	90	1167r,3,24;46,23,8,47	9r,10,13;11,21,20,3	5r,-{3,21;6,10,54,33}
4	120	1556r,5,3;1,50,51,42	13r,1,27;35,8,26,44	7r,-{8,28;8,14,32,44}
5	150	1945r,6,11;17,18,34,38	16r,5,11;58,55,33,25	8r,-{2,5;10,18,10,54(55)}
6	180	2334r,7,19;32,46,17,34	19r,8,26;22,42,40,5	10r,-{7,12;12,21,49,7}
7	210	2723r,8,27(37);48,14,0,29	23r,0,10;46,29,46,6(46)	11r,-{5(0),19;14,25,27,18}
8	240	3112r,10,6;3,41,43,29(25)	26r,3,25;10,16,53,27	13r,-{5,26;16,29,5,29}
9	270	3501r,11,14;19,9,26,20	29r,7,9;34,4,0,8	15r,-{11,4(3);18,32,43,40}
10	300	3891r,0,22;34,37,9,16	32r,10,23;57,51,6,49	16r,-{4,10;20,36,21,51}
20	600	7782r,1,15;9,14,18,32	65r,9,17;55,42,13,38	32r,-{8,20;41,12,43,42}
30	900	11673r,2,7;43,51,27,48	98r,8,11;13(53),33,20,27	47r,-{1,1;1,49,5,33(32)}
40	1200	15564r,3,0;18,28,37,4	131r,7,5;51,24,27,36(16)	63r,-{5,11;22,25,27,23}

Table 10. Parameters of the Mercury

Multiplier	Arabic Years	Mean Tropical Longitude λ	Longitude of Aphelion Γ	Longitude of Ascending Node Ω
1	30	120r,10,6;9,14,5,46	0r,0,0;47,57,39,5,20*,46*	0r,0,0;41,22,30,30,15*
2	60	241r,8,12;18,28,11,32	0r,0,1;35,55,18,11	0r,0,1;22,45,1,1
3	90	362r,6,18;27,42,17,18	0r,0,2;23,52,57,16	0r,0,2;4,7,31,31
4	120	483r,4,24;36,56,23,4	0r,0,3;11,50,36,21	0r,0,2;45,30,2,1
5	150	604r,3,0;46,10,28,50	0r,0,3;59,48,15,27	0r,0,3;26,52,32,31
6	180	725r,1,6;55,24,34,26(36)	0r,0,4;47,45,54,32	0r,0,4;8,15,3,2
7	210	845r,1(11),13;4,38,40,22	0r,0,5;35,43,37(33),37	0r,0,4;49,37,33,32
8	240	966r,9,19;13,52,46,8	0r,0,6;23,41,14(12),43	0r,0,5;31,0,4,2
9	270	1087r,7,25;23,6,51,54	0r,0,7;11,38,51,48	0r,0,6;12,22,34,32
10	300	1208r,6,1;32,20,57,40	0r,0,7;59,36,30,53	0r,0,6;53,45,5,3
20	600	2417r,0,3;4,41,55,20	0r,0,15;59,13,1,47	0r,0,13;47,30,10,5
30	900	3625r,6,4;37,2,53,0	0r,0,23;58,49,32,40	0r,0,20;41,15,15,8
40	1200	4834r,0,6;9,23,50,40	0r,1,1;58,26,3,34	0r,0,27;35,0,20,10

Table 11. Parameters of the Venus

Multiplier	Arabic Years	Mean Tropical Longitude λ	Longitude of Aphelion Γ	Longitude of Ascending Node Ω
1	30	47r,3,22;42,33,38,35	0r,0,0;41,50,39,49(48*),51*	0r,0,0;29(22),21,15,13
2	60	94r,7,15;25,7,17,10	0r,0,1;23,41,19,38	0r,0,0;44,42,30,27(26)
3	90	141r,11,8;7,40,55,45	0r,0,2;5,31,19(59),27	0r,0,1;7,3,45,19(39)
4	120	189r,3,0;50,14,34,20	0r,0,2;47,22,39,15	0r,0,1;29,25,43(0),42(52)
5	150	236r,6,23;32,48,12,55	0r,0,3;29,13,19,4	0r,0,1;51,46,54(16),35(5)
6	180	283r,10,16;15,21,51,30	0r,0,4;11,3,58,53	0r,0,2;14,7,31,18
7	210	331r,2,8;57,55,30,5	0r,0,4;52,54,38,42	0r,0,2;36,28,28(46),46(31)
8	240	378r,6,1;40,29,8,40	0r,0,5;34,45,18,31	0r,0,2;58,50,1,44
9	270	425r,9,24;23,2,47,45(15)	0r,0,6;16,35,58,20	0r,0,3;21,11,16(36),57
10	300	473r,1,17;5,27(36),25,50	0r,0,6;58,26,38,9	0r,0,3;32(43),32,39(32),10
20	600	946r,3,4;11,12,51,40	0r,0,13;56,13(53),16,17	0r,0,7;27,17(5),5(4),20
30	900	1419r,4,21;16,59(49),17,30	0r,0,20;55,19,54,26	0r,0,11;10,35(37),27(36),30
40	1200	1892r6,8;22,25,43,20	0r0,0,27;53,46,32(33)	0r0,14;54,10,8,40

Table 12. Parameters of the Mars

Multiplier	Arabic Years	Mean Tropical Longitude λ	Longitude of Aphelion Γ	Longitude of Ascending Node Ω
1	30	15r,5,21;23,37,24,37(34),0*,59*	0r,0,0;32,21,44,7	0r,0,0;17,57,39,46
2	60	30r,11,12;47,14,49,8	0r,0,1;4,43,28,14	0r,0,0;35,55,19,32
3	90	46r,5,4;10,52,13,49(42)	0r,0,1;37,5,12,21	0r,0,0;53,52,59,58(18)
4	120	61r,10,25;34,29,38,16	0r,0,2;9,26,56,28	0r,0,1;11,9(50),39,4
5	150	77r,4,16;58,7,2,50	0r,0,2;41,48,40,35	0r,0,1;29,48,18,50
6	180	92r,10,8;21,44,27,4(24)	0r,0,3;4(14),10,24,42	0r,0,1;47,45,58,36
7	210	108r,3,29;41(45),21,51,58	0r,0,3;46,32,8,49	0r,0,2;5,43,38,22
8	240	123r,9,21;8,59,16,32	0r,0,4;38(18),53,52,56	0r,0,2;23,41,18,8
9	270	139r,3,12;32,36,41,6	0r,0,4;51,15,37,3	0r,0,2;41,38,57,54
10	300	154r,9,3;56,14,5,40	0r,0,4(5);23,37,21,10	0r,0,2;59,36,37,40
20	600	309r,6,7;52,28,11,20	0r,0,10;47,14,42,20	0r,0,5;59,13,15,20
30	900	464r,3,11;48,42,17,5(1)	0r,0,16;10,52,3,30	0r,0,8;58,49,53,0
40	1200	619r,0,15;44,56,22,40(41)	0r,40(0),21;34,29,24,40	0r,0,11;58,26,30,40

Table 13. Parameters of the Jupiter

Multiplier	Arabic Years	Mean Tropical Longitude λ	Longitude of Aphelion Γ	Longitude of Ascending Node Ω
1	30	2r,5,13;45,3,56,0	0r,0,0;45,47,35,30,0*,30*	0r,0,0;6,50,40,59
2	60	4r,10,27;30,7,52,0	0r,0,1;21(31),35,11,0	0r,0,0;13,41,21,58
3	90	7r,4,11;15,11,18(48),0	0r,0,2;17,22,46,30	0r,0,0;20,32,2,57
4	120	9r,9,25;0,15,45(44),0	0r,0,3;3,10,22,0	0r,0,0;27,22,43,56
5	150	12r,3,8;45,19,40,0	0r,0,3;48,57,57,30	0r,0,0,34,13,25(24),54(55)
6	180	14r,8,22;23(30),30(23),36,0	0r,0,4;34,45,33,0	0r,0,0;41,4,5,54
7	210	17r,2,6;15,27,32,0	0r,0,5;20,33,8,30	0r,0,0;47,54,46,53
8	240	19r,7,20;0,31,28,0	0r,0,6;6,20,44,0	0r,0,0;54,45,27,52
9	270	22r,1,8(3);45,34(35),24,0	0r,0,6;52,8,19,30	0r,0,1;1,36,8,51
10	300	24r,6,17;30,39,20,0	0r,0,7;37,55,55,0	0r,0,1;8,27(26),49,50
20	600	49r,1,5;1,58(18),40,0	0r,0,15;15,51,50,0	0r,0,2;16,53,39,40
30	900	73r,7,22;31,58,0,0	0r,0,22;13(53),47,45,0	0r,0,3;25,20,29,30
40	1200	98r,2,10;2,37,20,0	0r,1,0;31,43,40,0	0r,0,4;33,47,19,20

Table 14. Parameters of the Saturn

Multiplier	Arabic Years	Mean Tropical Longitude λ	Longitude of Aphelion Γ	Longitude of Ascending Node Ω
1	30	0r,11,26;0,37,2,54,27*	0r,0,0;39,48,20,3,15*	0r,0,0;34,42,30,39,29*
2	60	1r,11,22;7(1),14,5,49(48)	0r,0,1;19,36,40,7	0r,0,1;9,25,1,19
3	90	2r,11,18;10(1),51,8,43(42)	0r,0,1;59,25,0,10	0r,0,1;44,7,31,58
4	120	3r,11,14;14,28,11,38	0r,0,2;39,13,20,33(13)	0r,0,2;18,50,2,38
5	150	4r,11,10;18,5,14,32	0r,0,3;19,1,40,16	0r,0,2;53,32,33,7(17)
6	180	5r,11,6;21,42,17,27	0r,0,3;58,50,7(0),20	0r,0,3;28,15,3,57
7	210	6r,11,2;25,19,20,21	0r,0,4;38,38,20,23,	0r,0,4;2,57,34,36
8	240	7r,10,28;28,56,23,16	0r,0,5;18,26,40,26	0r,0,4;37,40,5,16
9	270	8r,10,24;32,33,26,10	0r,0,5;18(58),55(15),0,29	0r,0,5;12,22,35,55
10	300	9r,10,20;36,10,29,5	0r,0,5(6);38,3,20,33	0r,0,5;47,5,6,35
20	600	19r,9,11(10);12,20,58,9	0r,0,13;16,6,41,5	0r,0,11;34,10,13,9(10)
30	900	29r,8,1(0);38(18),31,27,14	0r,0,19;54,10,1,38	0r,0,17;21,15,39(19),44
40	1200	39r,6,22(20);14(24),41,56,18(0)	0r,0,26;32,13,22,10	0r,0,23;8,20,26,0(21)

Table 15. Daily Motion of Planetary Parameters in Tabulae of de La Hire and in the *Zīj*. The daily motions of the *Zīj* are the ones that best fit its tables.

Planet	Parameter	No. of Years in DLH*	Motion in the DLH	Daily Motion in sexagesimal form in the DLH	Daily Motion in the *Zīj-i*
Sun	λ	3	2r,11,29;17,1	0;59,8,19,46,50,57,32,3	0,0;59,8,19,46,50,57,27,40
	Γ	2	0;2;3	0;0,0,10,6,34,31,13,58	0;0,0,10,6,34,34,11,22
Moon	λ	3	40r ,0,28;9,10	13;10,34,51,22,11,30,24,39	0,13;10,35,1,22,11,28,46
	Γ	3	4,1;59,37	6;41,4,29,35,20,32,53	0;6,41,4,29,35,16,10
	Ω	1	-0,19,19,43	-0;3,10,38,18,4,55,53,25	-0;3,10,38,18,4,54,30
Mercury	λ	1	4r ,1,23;43,15	4;5,32,35,20,32,52,36,10	0,4;5,32,35,20,32,52,36,10
	Γ	5	0;8,14	0;0,0,16,13,55,55,31,52,23	0;0,0,16,14,27,56,41,50
	Ω	60	1;25,14	0;0,0,14,0,4,55,41,16**	0;0,0,14,0,39,27,10,0

* Here DLH stands for *Tabulae Astronomicae* of de La Hire.
** Without applying the leap year corrections.

Table 16. Daily Motion of Planetary Parameters in *Tabulae* of de La Hire and in the *Zīj* cont.

Planet	Parameter	No. of Years in DLH*	Motion in the DLH, for the no. years	Daily Motion in sexagesimal form in the DLH	Daily Motion in the ZMS
Venus	λ	3	4r 10.14;22,49	1;36,7,49,32,3,17,15,37	1;36,7,49,32,3,17,24,55
	Γ	5	0;7,11	0;0,0,14,9,43,34,14,19,35	0;0,0,14,10,11,30,15,0
	Ω	40	0;30,43**	0;0,0,7,34,10,35,43,44	0;0,0,7,34,11,30,25,19
Mars	λ	3	1r ,7,3;51,26	0;31,26,39,13,58,21,22,12	0;31,26,39,13,58,18,30,0
	Γ	3	0;3,20	0;0,0,10,57,32,3,17,15,37	0;0,0,10,57,32,3,39,35
	Ω	1	0;0,37	0;0,0,6,4,55,53,25,29	0;0,0,6,4,55,56,15
Jupiter	λ	3	3,1;1,37	0;4,59,16,0	0;4,59,16,0,0,0,0
	Γ	3	0;4,43	0;0,0,15,30,24,39,27,7,24	0;0,0,15,30,25,23,54,0
	Ω	10	0;2,21	0;0,0,2,18,59,32,23,55	0;0,0,2,19,4,13,50,10
Saturn	λ	2	1,6;40,28	0;2,0,34,24,39,27,7,24	0;2,034,24,3926,53
	Γ	1	0,0;1,22	0;0,0,13,28,46,1,38,37,49	0;0,0,13,28,46,1,54
	Ω	2	0;2,23	0;0,0,11,45,12,19,43,33,41,55	0;0,0,11,45,12,20,21

* Here DLH stands for *Tabulae Astronomicae* of de La Hire.
** It seems that here only three digits after the decimal were retained while calculating the daily motion.

Conclusion

The paper reconstructs tables of mean motions for the parameters of planets in the *Zīj-i Muḥammad Shāhī* of Sawai Jai Singh from their daily motions. The daily motions were calculated, as a first step, from the 30 Arabic year motions in the *Zīj* and then readjusted by trial and error to best fit the tabular data of the *Zīj*. The daily motions are compared with the daily motions in *Tabulae Astronomicae* of de La Hire. On the basis of similarity between the two daily motions, the paper concludes that indeed a strong case can be built that *Zīj-i Muḥammad Shāhī*'s tables are based on the *Tabulae Astronomicae* of de La Hire.

Acknowledgement

The computer program for the analysis of the *Zīj-i Muḥammad Shāhī* tables were written by William Bultman. The author appreciates his assistance.

Notes and References

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12. *Firaṅgī Candravedhopayogī Sāraṇī*, Catalog No. 5609, Sawai Man Singh II Museum. Also see Gopal N. Bahura, *Literary Heritage of the Rulers of Amber and Jaipur*, p. 63., Jaipur, 1976. Also Pingree, *Ibid*, pp.150-151.

13. *Dṛkpakṣa Sāraṇī*, Catalog. No. 3162, 29 ff, Oriental Research Institute, Baroda. According to Pingree, *Dṛkpakṣa Sāraṇī* of Kevalrāma is "not a translation of de La Hire, but a weird mixture of bits of de La Hire, often misunderstood, with traditional Indian astronomy. . . ." David Pingree, Brown Univ. Providence, RI, private communication.

14. *Dṛkpakṣasāraṇyam Sūryagrahaṇam* , No. 926 of 1886-92, Bhandarkar Oriental Research Institute, Pune. The translator of the works is Kevalrāma, a prominent assistant of the Rājā.

15. For the contents of *Zīj-i Muḥammad Shāhī* , see *Sawai Jai Singh and His Astronomy, op. cit*, or Mercier, *op. cit.*

16. See *Sawai Jai Singh and His Astronomy,* Appendix III, for *abjad* notion. *op. cit.*

17. Mercier and van Dalen report that Jai Singh used 73;30 as the longitude difference between Paris and Delhi. Mercier and van Dalen, *op. cit.*

18. The procedure is as follows:
Calculation of mean λ for planet Venus for the epoch date, 20 February 1719.

Mean λ from *Tabulae* at 1700 A.D.	= 5,23;55,18
Motion of λ in 18 yrs.	= 3,2;41,22
Motion of λ for January	= 1,19;40,3
Motion in λ 19 days	= 1,0;26,29
Total	= 11,16;23,34
Longitude correction (73;30)	= -0,0;19,38

λ at the epoch date = 11,16;23,34, which agrees with the ZMS value for the epoch date.

19. A difference of one arc-second for the parameter, Γ , was noted for the Moon and Jupiter, and 2 arc-second for Venus. From the British Library copy of the *Zīj,* we suspect that Jai Singh's astronomer might have made a mistake in reading of the parameter Γ in the *Tabulae*. The corrected reading would still leave a difference of 1 arc-second, however. For the parameter,Ω , there was a difference of one arc-second for the Moon, and Jupiter.

20. *Zīj-i Muḥammad Shāhī*,f. 146.