Theories of Solar Motion in *Chongzhen Lishu*, *Yuzhi Lixiang Kaocheng* and *Lixiang Kaocheng Houbian*

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At the end of the Ming Dynasty (1368-1644) and in the early Qing Dynasty (1616-1911), Four Chinese Calendrical Books, of which the titles are *Chongzhen Lishu* (revised and compiled as *Xiyang Xinfa Lishu* in 1645 and as *Xinfa Suanshu* in *Qinding Siku Quanshu* in 1784), *Kangxi Yongnian Lifa* in 1668, *Yuzhi Lixiang Kaocheng* in 1724 and *Yuzhi Lixiang Kaocheng Houbian* in 1742, are of great significance to the introduction of western astronomy into China.

Based upon textual interpretation of the theories in *Xinfa Suanshu* and *Yuzhi Lixiang Kaocheng*, the following conclusions have been reached. The characters of the leap years in the former three calendrical books are consistent. The geometrical models for calculating the Sun's equation of center were an equidistant eccentric orbit in *Xinfa Suanshu* and an oblique-epicyclic orbit in *Yuzhi Lixiang Kaocheng*. The secular variation of the obliquity of the ecliptic was distinctly expressed in *Xinfa Suanshu*, of which the retarding rate is 45″.454545 per 100 years, being slightly smaller than the numerical value 46″, and the obliquity of the ecliptic was 23°31′30″ in *Xinfa Suanshu* and 23°29′30″ in *Yuzhi Lixiang Kaocheng*.

In the second year of the Chongzhen Emperor (1629), astronomical solar eclipse was not correctly predicted by the Qintianjian (Royal Observatory), and the Ministry of Rites of the Ming Dynasty presented a memorial about repairing the calendar, which was approved by the Emperor. Xu Guangqi (1562-1633), Li Zhizao (1565-1630), Li Tianjing (1579-1659) and the Jesuits Nicolas Longobardi (Long Huamin, 1559-1654), Jean Terrenz (Deng Yuhan, 1576-1630), Jacques Rho (Luo Yagu, 1593-1638), Johann Adam Schall von Bell (Tang Ruowang, 1591-1666) and some Chinese astronomers had put forward time after time ideas to reform the calendar and compile new calendrical books. At the end of the seventh year of Chongzheng Emperor (1634), the Books, which were called *Chongzhen Lishu*, *Chongzhen reign-period Treatise on Calendrical Science*, which form the first Jesuit astronomical encyclopaedia, were classified five times with a total of 46 entries in 137 volumes. They were been presented to the Emperor for his consideration and judgment. Today, this original version of the Books is no longer complete, but is scattered both at home and abroad. [1]

In the second year of the Shunzhi Emperor (1645) of the Qing Dynasty, Johann Adam Schall von Bell presented a revised version of *Chongzhen Lishu* with a new title: *Xiyang Xinfa*

Lishu, *Treatise on Calendrical Science According to the Western Method*, of 32 entries in 103 volumes to the Emperor. Then the official almanacs of Chinese tradition, based on the calendrical books, were put into use. In 1784, *Xiyang Xinfa Lishu* was renamed as *Xinfa Suanshu*, *Mathematical Treatise According to the new Method*, in order to respect the Qinglong Emperor's style name *Hongli*, and compiled into *Qinding Siku Quanshu*, *Complete Books in Four Treasuries Royally Determined.* All the above-mentioned treatises select the year of 1628 as the epoch of the Calendar and give the astronomical parameters for 200 years from 1628 to 1827[2], though some of the main parameters for the solar motion were revised (Fig. 1).

In 1669, *Kangxi Yongnian Lifa*, *Eternal Calendrical Method for the Kangxi Emperor*, was compiled by Ferdinand Verbiest (Nan Huairen, 1623-1688). It gives the astronomical parameters from 1828 to 3827 in 32 volumes, 4 volumes each for the Sun, the Moon, Five Planets (Saturn, Jupiter, Mars, Venus and Mercury) and Eclipses. [3]

In 1683, *Jiaoshi Lishu*, *The Calendrical Book of Eclipses*[4], was compiled by Ferdinand Verbiest. It was of historic significance in the development of Chinese Calendars in the early Qing Dynasty, and has not been meticulously investigated until now, and is not even mentioned in volume 3 of *Science and Civilisation in China* (Cambridge University Press, 1959) and the volume of astronomy in *The History of Science and Technology in China* (Beijing, Science Press, 2003). [5,6] *The Calendrical Book of Eclipses* consisted of *Huangdao Jiushidu Biao*, *Tables of Ninety Degrees of the Ecliptic*, and *Taiyang Gaodu Biao*, *Tables of Solar Latitude*,

曆元後二百恒年表

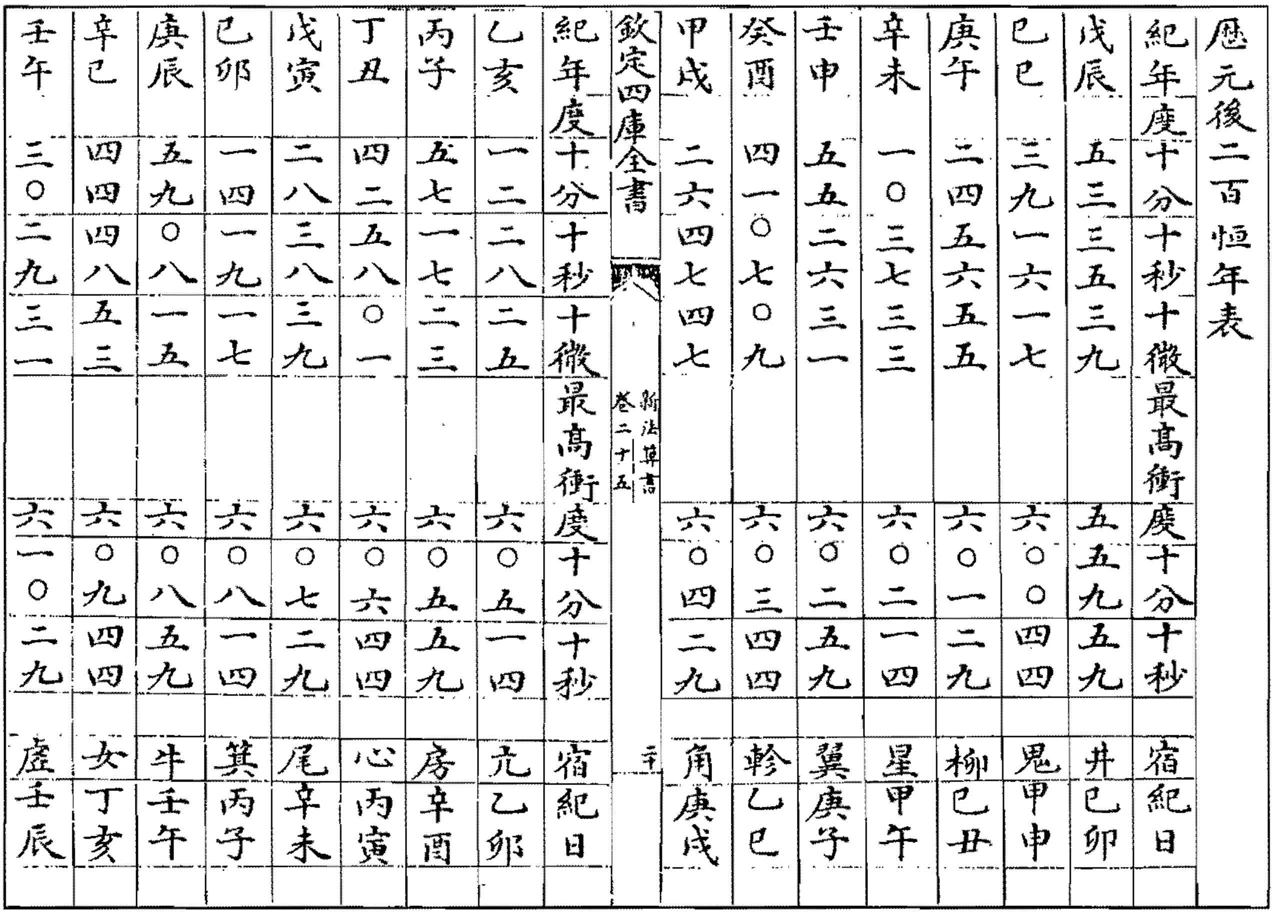
紀年	度十分十秒十微	最高衝度十分十秒	宿紀日
戊辰	五二三九五〇	五五九五九	井己卯
己巳	三八二〇二八	六〇〇四四	鬼甲申
庚午	二四〇一〇七	六〇一二九	柳己丑
辛未	〇八五〇〇五	六〇二一四	星甲午
壬申	五四三〇三三	六〇二五九	翼庚子
癸酉	四〇二〇二一	六〇三四四	軫乙巳
甲戌	二五五二〇〇	六〇四二九	角庚戌

日躔表一卷 曆元後二百恒年 十一

紀年	度十分十秒十微	最高衝度十分十秒	宿紀日
乙亥	一〇四〇五八	六〇五一四	亢乙卯
丙子	五六二一三六	六〇五五九	房辛酉
丁丑	四二〇二一四	六〇六四四	心丙寅
戊寅	二七四二五三	六〇七二九	尾辛未
己卯	一二三二五一	六〇八一四	箕丙子
庚辰	五八一二四九	六〇八五九	牛壬午
辛巳	四三五三〇八	六〇九四四	女丁亥
壬午	二八三三四六	六一〇二九	虛壬辰

五八二

(a) [1]:582



歷元後二百恒年表

欽定四庫全書　新法算書　卷二十五

紀年	度十分	十秒	十微	最高衝 度十分	十秒	宿	紀日
戊辰	五三	三五	三九	五五九	五九	井	己卯
己巳	三九	一六	一七	六〇〇	四四	鬼	甲申
庚午	二四	五六	五五	六〇一	二九	柳	己丑
辛未	一〇	三七	三三	六〇二	一四	星	甲午
壬申	五五	二六	三一	六〇二	五九	翼	庚子
癸酉	四一	〇七	〇九	六〇三	四四	軫	乙巳
甲戌	二六	四七	四七	六〇四	二九	角	庚戌
乙亥	一二	二八	二五	六〇五	一四	亢	乙卯
丙子	五七	一七	二三	六〇五	五九	房	辛酉
丁丑	四二	五八	〇一	六〇六	四四	心	丙寅
戊寅	二八	三八	三九	六〇七	二九	尾	辛未
己卯	一四	一九	一七	六〇八	一四	箕	丙子
庚辰	五九	〇八	一五	六〇八	五九	牛	壬午
辛巳	四四	四八	五三	六〇九	四四	女	丁亥
壬午	三〇	二九	三一	六一〇	二九	虛	壬辰

(b) [2],788:402

Fig. 1　The main parameters for the solar motion in (*Chongzhen Lishu* and *Xinfa Suanshu*)

though both of them have distinctive page numbers. *Tables of Ninety Degrees of the Ecliptic*, specifically called *Shengjing Jiushidu Biao*, *Tables of Ninety Degrees for Shengjing* in *Qingshigao*, *the Miscellany on the History of the Qing Dynasty* was ordered by imperial edict *to be eternally followed* (*Yongyun Zunshou*). It has two parts, *Huangdao Jiushidu Biao Tushuo*, *the Explanation through Diagrams*, in three leaves, and the relative tables in six leaves. *Tables of Solar Latitude* are on 11 leaves without explanation. As examined, *the Explanation through Diagrams* only revealed the three main calculating steps for the compilation of *Tables of Ninety Degrees of the Ecliptic* (Libiaofa zhiyao yi you san), but the eight steps are absolutely necessary. The obliquity of the Ecliptic of 23°32′ was applied in *Tables of Ninety Degrees of the Ecliptic* and otherwise the obliquity of the Ecliptic of 23° 30′ (Er shi san du ban) was permutated in *Tables of Solar Latitude*. Furthermore, the methods of calculation and permutation in *Tables of Solar Latitude*, of which the error is 4′, and *Tables of Solar Latitude* in *Yuzhi Lixiang Kaocheng*, *Through Investigation of Calendrical Astronomy Imperially Composed*, in which the obliquity of the Ecliptic is 23°29′30″, are rather different. *Yuzhi Lixiang Kaocheng* was issued in the second year of the Yongzheng Emperor (1724) in 3 parts of 42 volumes and is usually called *Jiazi Yuanli*. It selected the year 1684 as the epoch of the Calendar and gave astronomical parameters for 300 years from 1684 to 1983. [7]

In the seventh year the Qianlong Emperor (1742), *Yuzhi Lixiang Kaocheng Houbian*, *Supplement to Through Investigation of Calendrical Astronomy Imperially Composed*, was issued in 10 volumes and is usually called *Guimao Yuanli*. It selected the year 1723 as the epoch of the calendar and gave astronomical parameters for 300 years from 1723 to 2022. [8]

Therefore, from 1645 to 1742, the four calendrical books, *Xiyang Xinfa Lishu*, *Kangxi Yongnian Lifa*, *Yuzhi Lixiang Kaocheng* and *Yuzhi Lixiang Kaocheng Houbian*, which are abbreviated *XYXFLS*, *KXYNLF*, *LXKC* and *LXKCHB*, were successively put into use. All the almanacs during the Qing Dynasty were imperially given a general name, *Shixianli*, which included *Jiazi Yuanli* and *Guimao Yuanli*.

In 1959, Dr. Joseph Needham pointed out:

> The historical vicissitudes of the Chinese calendar will, indeed, remain a matter of some difficulty, as the definitive monograph on this subject has not yet been written, either in Chinese or a western language. Fortunately, however, it is not of primary scientific importance. The various shifts to which the calendar experts were put by their inaccurate knowledge of precession, planetary cycles, etc., need not delay us too much. What seem really interesting in Chinese astronomy are such questions as the ancient and medieval cosmic theories, the mapping of the heavens and the coordinates used, the understanding of the great circles of the celestial sphere, the use of circumpolar stars as indicators of the meridian passages of invisible equatorial constellations, the study of eclipses, the gradual development of astronomical instruments (which by the +13th century had attained a level much higher than that of Europe), and the through recording of observations of important celestial phenomena. [5]

The characters of the leap year, the equation of the center of the Sun and the secular variation of the obliquity of the ecliptic discussed below could be regarded as a definitive monograph on the calendrical science in the Qing Dynasty and give a preparatory resolution of the fifth "question", the study of eclipses.

1. The Characters of the leap years of calendrical treatises in *XFSS*, *KXYNLF*, *LXKC* and *LXKCHB*

Based upon *Liyuan Hou Erbai Hengnian Biao* of *Richan Biao Juan Yi*, volume 1 of *the Solar Tables* in *Chongzhen Lishu*, abbreviated *CZLS*, and that of *Richan Biao Juan Ershiwu*, volume 25 in *Xinfa Suanshu*, which is abbreviated as *XFSS*, *Jiaoshi Juan Yi*, *Er*, *San* and *Si*, volumes 1, 2, 3, 4, in *KXYNLF*, *Taiyang Niangeng Biao* of *Richao Biao* in *LXKC* and *Taiyang Niangeng Biao* of *Richao Biao* in *LXKCHB*, the leap years, which are related to the tropical year, in the four calendrical Books are outlined as Table 1 and Table 2.

Tab. 1 The leap years in *XFSS*, 1628-1827, in *KXYNLF*, 1828-, and in *LXKC*, 1684-1983

	1644*	1677	1710	1743	1776	1809	1842	1875	1908	1941	1974
	48	81	14	47	80	13	46	79	12	45	78
	52	1685	18	51	84	17	50	83	16	49	82[3)]
	56	89	22	55	88	21	54	87	20	53	86
	60	93	26	59	92	25[1)]	58	91	24	57	90
1631	64	1697	30	63	1796	29[2)]	62	1895	1929*	1962*	1995*
35	68	1701	34	67	1801*	1834*	1867*	1900*	33	66	1999
1639	1673*	1706*	1739*	1772*	05	38	71	04	37	70	2003

The leap years with * have 4 year intervals, and the others are of 3 years

1) For *XYXFLS* 200 years from 1628 to 1827

2) For *KXYNLF* 2000 years (1828-3827), based on the 4 volumes for ecliptic tables

3) For *LXKC* 300 years from 1684 to 1983

Tab. 2 The leap years in *LXKCHB*, 1723-2022[7]

	1743	1776	1809	1842	1875	1908	1941	1974	2007
	47	80	13	46	79	12	45	78	11
	51	84	17	50	83	16	49	82	15
	55	88	21	54	87	20	53	86	2019
1726	59	92	25	58	91	24	57	90	
30	63	1796	29	62	95	28	61	94	
34	67	1800	33	67	1899	32	65	1998	
1739*	1772*	1805*	1838*	1871*	1904*	1937*	1970*	2003*	

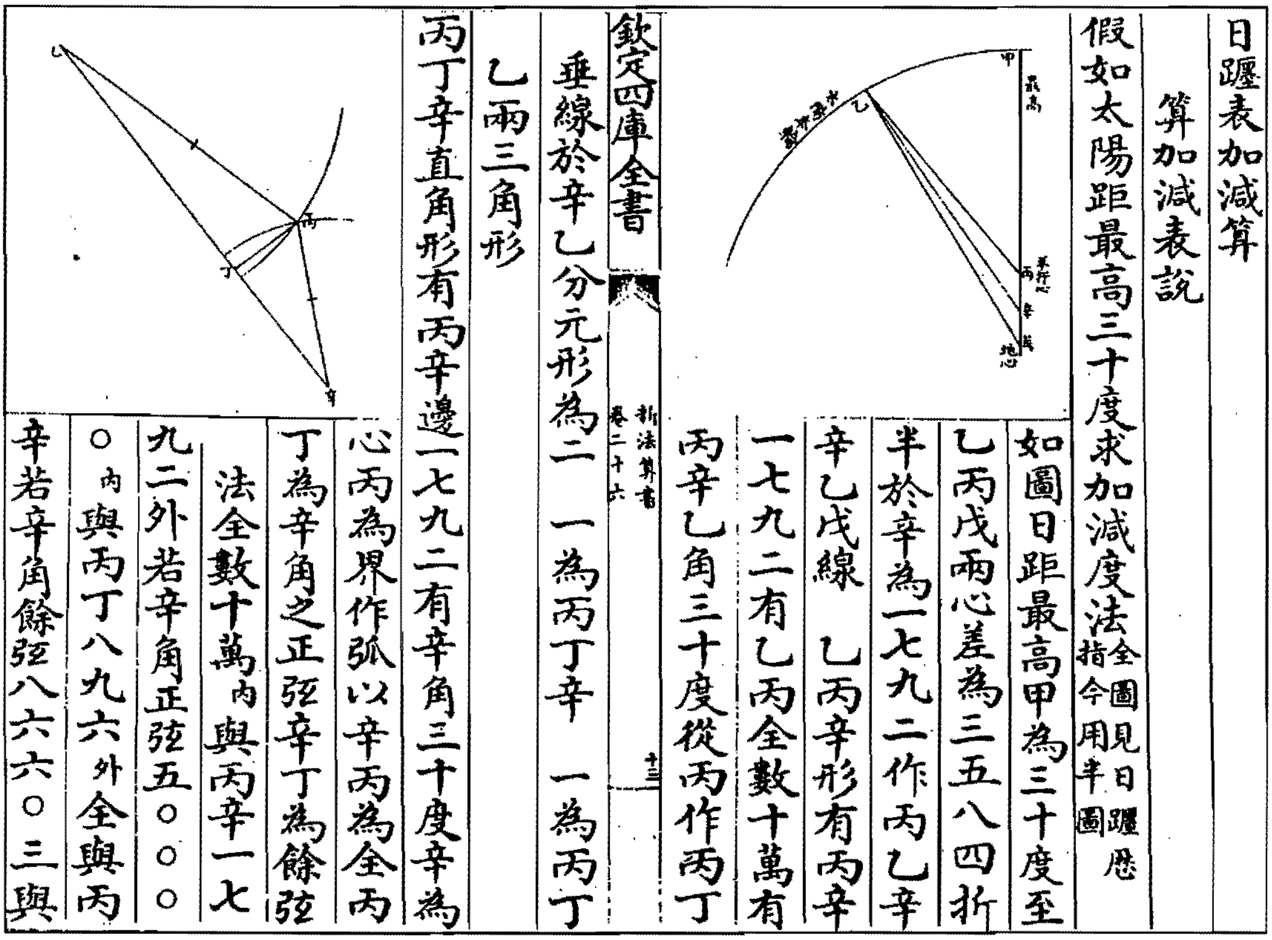
Therefore, the leap years, being intercalated in *XYXFLS* and successively in *KXYNLF* have been duplicated in *LXKC*. *LXKCHB* is based on the 33-year pattern of leap years (there is a rather exact accord between days and years over this interval, with eight days being intercalated per 33 years). 1900 in *KXYNLF* and *LXKC*, and 1800 in *LXKCHB*, were selected as the leap year. So the four calendars are uniquely Chinese creations. [7,8]

2. Models for calculating the annual equation of the mean motion of the Sun in *XFSS*, *LXKC* and *LXKCHB*

The theory of solar motion in *XFSS* was derived from the model of an eccentric circle. The distance between its center and another center is 3584, where the mean distance between the Earth and the Moon was taken to be 100 000, the eccentricity of the orbit was assumed to be 0.017 92.

The two illustrative examples were only given in *Suan Jiaojian Biao Shuo*, *Explanation on the calculation of the annual equation of the mean motion of the Sun*, in *Richan Biao Juan Er* of *XFSS*, but were not included in the orginal version of *CZLS*.

As noted in Fig. 2, Yinshu M is measured from the perigee of the Sun assumed to be 30°. Then,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假如太陽距最高三十度求加減度法(全圖見日躔曆指今用半圖)
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乙丙戊丙心差為三五八四折
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辛乙戊線 乙丙辛形有丙辛
一七九二有乙丙全數十萬有
丙辛乙角三十度從丙作丙丁
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垂線於辛乙分元形為二 一為丙丁辛 一為丙丁
乙丙三角形
丙丁辛直角形有丙辛邊一七九二有辛角三十度辛為
心丙為界作弧以辛丙為全丙
丁為辛角之正弦辛丁為餘弦
法全數十萬(內)與丙辛一七
九二(外)若辛角正弦五〇〇〇
〇(內)與丙丁八九六(外)全與丙
辛若辛角餘弦八六六〇三與

Fig. 2 The illustrative model for the calculation of the equation of the center in *XFSS*[2], 788:437

$\alpha = \arcsin(0.01792 \sin M) = 30'48''.1573932$;

$\beta = \mathrm{arctg}\,[0.01792 \sin M \div (\cos\alpha - 2e\cos M)] = 0°.5298216083 = 31'47''.35779$;

$\alpha + \beta = 30'48''.1573932 + 31'47''.35779 = 1°02'35''.5151832.$

The corresponding values are 30′46″, 31′44″, 1°02′30″ in the text[2], 788:437-438 and 1°02′33″ in the Table of *XFSS*[2],788:431. So, the formula for calculating the equation of the mean motion of the Sun in *XFSS* is given as follows:

the equation of the center

$= \arcsin(e \sin M) + \mathrm{arctg}\,\{e \sin M \div [\cos(\arcsin(e \sin M)) - 2e\cos M]\}$.

The relative values calculated by the formula, in the Tables of *XFSS* and in *Tychonis Brahe Astronomiae Instauratae Progymnasmata* (1602) are juxtaposed in Table 3.

Tab. 3 The relative values of the equation of the center by the formula, tables of *XFSS* and Tycho (1602)

M	Values by the formula				Tables of XFSS[1)]	Tycho's Tables[2)]
	α	β	α + β	In °, ′ and ″		
0	0	0	0	0°	0°	0°
15	0. 2657409146	0. 275270404	0. 5410113186	0°32′27″. 6407472	0°32′28″	0°30′48″
30	0. 5133770537	0. 5298216083	1. 043198662	1°02′35″. 5151832	1°02′33″	0°59′44″
45	0. 7260345073	0. 744912064	1. 470946571	1°28′15″. 4076556	1°28′14″	1°24′56″
60	0. 8892189389	0. 905443817	1. 794662756	1°47′40″. 7859216	1°47′40″	1°44′47″
75	0. 99180457	1. 001090286	1. 992894856	1°59′34″. 4214816	1°59′32″	1°57′52″
87	1. 025387991	1. 027314844	2. 052702835	2°03′09″. 730206	2°03′08″	2°02′45″
88	1. 026169766	1. 027454836	2. 053624602	2°03′13″. 0485672	2°03′11″	2°02′55″
89	1. 026638926	1. 027281451	2. 053920377	2°03′14″. 1133572	**2°03′12″**	2°03′03″
90	1. 026795329	1. 026795329	2. 053590658	2°03′12″. 9263688	2°03′10″	2°03′09″
91	1. 026638926	1. 025997205	2. 052636131	2°03′09″. 4900716	2°03′06″	3°03′13″
92	1. 026169766	1. 024887907	2. 051057673	2°03′03″. 8076228	2°03′00″	**2°03′15″**
93	1. 025387991	1. 023468353	2. 048856344	2°02′55″. 8828384	2°02′52″	2°03′13″
105	0. 99180457	0. 9826895156	1. 974494086	1°58′28″. 1787096	1°58′28″	2°00′04″
120	0. 8892189389	0. 8735652558	1. 762784195	1°45′46″. 023102	1°45′46″	1°48′36″
135	0. 7260345073	0. 7080900452	1. 434124553	1°26′02″. 8483908	1°26′02″	1°29′23″
150	0. 5133770537	0. 4979225533	1. 011299607	1°00′40″. 6785852	1°00′40″	1°03′33″
165	0. 2657409146	0. 25684914	0. 5225900546	0°31′21″. 3241968	0°31′20″	0°33′01″
180	0	0	0	0°	0°	0°
210	-0. 513377053	-0. 4979225533	-1. 011299606	-1°00′40″. 6785816	-1°00′40″	-1°03′33″
240	-0. 8892189389	-0. 8735652558	-1. 762784195	-1°45′46″. 023102	-1°45′46″	-1°48′36″
270	-1. 026795329	-1. 026795329	-2. 053590658	-2°03′12″. 9263688	-2°03′10″	-2°03′09″
300	-0. 8892189389	-0. 905443817	-1. 794662756	-1°47′40″. 7859216	-1°47′40″	-1°44′47″
330	-0. 5133770537	-0. 5298216083	-1. 043198662	-1°02′35″. 5151832	-1°02′33″	-0°59′44″
360	0	0	0	0°	0°	0°

1) [2], 788: 431-436

2) *Tychonis Brahe Astronomiae Instauratae Progymnasmata*, Bragae Bohemiae, M. DC. II. , 60-61

In *JiaoShi LiZhi Juan Er* of *CZLS*[1]:241-242, two equivalent formulas for calculating the equation of the mean motion of the Sun were implied, i. e. ,

the equation of the center

$$= \arcsin\ (ze\sin M \div \sqrt{1 + 4e^2 + 2e\cos M}),\ \text{or}$$

$$= 180° - \frac{M}{2} + \text{arctg}\ [\ (1 - 2e)\ \text{tg}\,\frac{M}{2} \div\ (1 + 2e)\ ].$$

The theory of the solar motion in *LXKC* was derived from the model of an eccentric circle, as illustrated in the model of oblique-epicyclic circles (Benlun-Junlun). The diameters of the epicycle and oblique circle are assumed to be 268 812 and 89 604, respectively, when the mean distance between the Earth and the Moon was taken to be 10 000 000. The equation of the mean annual motion of the Sun depends on the eccentricity of the Earth's orbit around the Sun, which is 179 208 of such parts, where the Earth's mean distance from the Sun would be 10 000 000. The maximum value for of the Equation of the Sun's center is 2°03′11″.

the equation of the center = arctg [0.0358416 sin$M$ ÷ (1 − 0.0179208 cos$M$)] .

The theory of solar motion in *LXKCHB* was derived from "the simplified elliptic", not solved in the form of Kepler's equation, and the eccentricity was taken as 0.0169. [9] Then,

$$\text{the equation of the center} = 2\arcsin\left(e\sin M \div \sqrt{1+e^2-2e\cos M}\right) \pm \left[\operatorname{arctg}\left(10000000\times \operatorname{tg}M \div 9998571.85\right) - M\right].$$

The models in *XFSS*, *LXKC* and *LXKCHB* are an eccentrical circle, oblique-epicyclic circles and "the simplified elliptic" . The calculated value for the maximum of the equation of the center of the Sun in *XFSS* is 2°03′14″, and the value given in the table is 2°03′12″, while the calculating and given values are 2°03′11″ in *LXKC* and 1°56′13″ in *LXKCHB*.

3. Secular variations in the precession and obliquity in *XFSS*

In the history of observations showing that the precession of the equinoxes and solstices is not uniform, chapter 2, Book Ⅲ of *On the Revolutions*, Nicholas Copernicus pointed out:

> To 1° there will have to be assigned, as will be seen, not 100 years at all, but 66 years. Moreover, in the 741 years from Ptolemy [to Al-Battani], only 65 years are to be assigned to 1°. Finally, if the remaining period of 645 years is compared with the difference of 9° 11′ of my observation, 1° will receive 71 years. Hence in those 400 years before Ptolemy, clearly the precession of the equinoxes was slower than from Ptolemy to Al-Battani, when it was also quicker than from Al-Battani to our times. [10]:122

And Eduard Rosen annotated in his translation and commentary version of *On the Revolutions*, this wholly imaginary nonuniformity in the precession of the equinoxes was discarded by Tycho Brahe. In his *Astronomiae instauratae mechanica* (Wandsbek, 1598; *Opera omnia*, Copenhagen, 1913-1929, V, 113, lines 9-17) the great Danish astronomer remarked:

> I have also noticed that in the longitudes [of the stars] the intricacy of the nonuniformity is not as great as Copernicus believed. For, what he imagined in this regard insinuated itself through defects in the observations, both ancient and recent. Hence the precession of the equinox in these times is also not as slow as he indicated. For at present the fixed stars traverse 1°, not in 100 years in accordance with his computation, but in only 71 1/2 [years] . In the past they always uniformly completed very nearly this [motion], if the observations of [our] predecessors are properly delimited, with only a trivial irregularity, arising accidentally from another source. [10]:384

In *XFSS*, the precession of the equinoxes is given as 51″ per year, i. e. , 1° is assigned to 69 years 91days 73 Ke (1 Ke equals 15 minutes), which is different from that of Copernicus and Tycho Brahe. [11]

The secular variation of the obliquity of the ecliptic once was an issue relative to the precession of the equinox. Nicholas Copernicus pointed out:

> Likewise in the motion of the obliquity a difference is discovered. For, Aristarchus of Samos found the obliquity of the ecliptic and equator to be 23°51′20″, the same as Ptolemy; Al-Battani, 23° 36′; Al-Zarkali the Spaniard, 190 years after him, 23°34′; and in the same way 230 years later, Profatius the Jew, about 2′ less. But in our time it is found not greater than 23°28 1/2′. Hence it is also clear that from Aristarchus to Ptolemy, the motion was a minimum, but from Ptolemy to Al-Battani a Maximum. [10]:122

The corresponding values for the obliquity of Profatius (c. 1236-1305, Ibn Tibbon, Jacob ben Machir) 23°32′, of George von Peurbach (1423-1461) 23°28′, of N. Copernicus 23°28′ 24″ and of T. Brahe 23°31′30″ were included in *XFSS*. [12] Furthermore, the secular variation of the obliquity is implied in *Taiyang Pingxing Yongbiao* (not included in *CZLS*) of *XFSS*, of which the retarding rate is 45″. 454545 per 100 years, i. e. , 1° in 7920 years (132 Jiazi years), being slightly smaller than the numerical value 46″. [13]

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[11] 关于“岁差”,《新法算书・日躔历指》卷首曰:“岁差者, 日与恒星比论乃得之也; 未论恒星, 未可论岁差也。”[2],788: 367

《崇祯历书・恒星历指一卷》“恒星历叙目”对“岁差”的论述是:

黄赤二道, 位置不等, 其各两极不等, 二经二纬, 纵横不等, 交互不等, 故令星行不等, 其差亦不等。有名为有差, 而绝不可谓差者, 黄道之经度是也。恒星依黄道东行, 如载籍相传尧时冬至日躔约在虚七度, 今躔箕四度, 四千年间, 而日退行若干度者, 即星之进行若干度也。古历谓之岁差, 各立年率。郭守敬以为六十六年有奇而差一度, 今者斟酌异同, 辨析微眇, 定为每岁东行一分四十三秒七十三微二十六纤, 六十九年一百九十一日七十三刻而行一度, 凡二万五千二百〇二年九十一

日二十五刻而行天一周，终古恒然也。此立名为差，而实有定法，不可谓差者也。

薄树人．《崇祯历书·恒星历指一卷》“恒星历叙目”．中国科学技术典籍通汇·天文卷（第八分册）．郑州：河南教育出版社，1997．1371-1375，1372.《新法算书·恒星历指卷一》未收录上述的“恒星历叙目”。

[12]

《日躔历指》西历名家关于“黄道与赤道之距度（黄赤交角）”的测定

	“古今各测”术文[1]	Times	Astronomers	Obliquity
1	周显王二十五年丁丑，迄崇祯元年戊辰为一千九百七十二年，西古史亚理大各	BC 344	（萨摩斯的）阿里斯塔克（Aristarchus，约公元前 310 ~ 约前 230）[3]	23°51′20″
2	秦二世三年甲午，迄崇祯元年戊辰为一千八百四十七年，西史阨（通“厄”）腊多	BC 207	埃拉托色尼（约公元前 276 ~ 前 194，Eratosthenes）	
3	汉景帝中元元年壬辰，迄崇祯元年戊辰为一千七百七十七年，西史意罢阁	BC 149	喜帕恰斯（Hipparchus，约公元前 190 ~ 前 125）	
4	汉光武建武十七年辛丑，迄崇祯元年为一千四百八十八年，西史多勒某，其书为历家之宗。已上四家测定黄赤相距为二十三度五十一分二十〇秒，于中分为二十三度八十五分	AD 40[2]	托勒密（约 90 ~ 168，Claudius Ptolemaeus）[13]	
5	唐僖宗广明元年庚子，迄崇祯元年为七百四十八年，西史亚耳罢德测定二十三度三十五分，于中分为二十三度五十八分三十三秒	AD 880	阿尔—巴塔尼（Al Battani，约 858 ~ 929）	23°35′
6	宋神宗熙宁三年庚戌，迄崇祯元年为五百五十八年，西史亚杂刻测定二十三度三十四分，于中分为二十三度五十六分六十七秒	AD 1070	阿尔—卡尔扎里（约 1029 ~ 1087，Al Zarkali）	23°34′
7	宋高宗绍兴十年庚申，迄崇祯元年为四百八十八年，西史亚尔满测定二十三度三十三分，于中分为二十三度五十五分	AD 1140	Al-Mamun[4]	23°33′
8	元成宗大德四年庚子，迄崇祯元年为三百二十八年，西史波禄法测定二十三度三十二分，于中分为二十三度五十三分三十三秒	AD 1300	普罗法提阿斯（约 1236 ~ 1305，Profatius；Ibn Tibbon，Jacob ben Machir）	23°32′
9	天顺四年庚辰，迄崇祯元年为一百六十八年，西史褒尔罢测定二十三度二十八分，于大统历为二十三度四十六分六十七秒	AD 1460	皮欧巴赫（George von Peurbach，1423 ~ 1461）	23°28′

续表

	"古今各测" 术文[1)]	Times	Astronomers	Obliquity
10	正德十年乙亥，迄崇祯元年为一百一十三年，西史歌白尼测定二十三度二十八分二十四秒，于大统历为二十三度四十八分一十二秒	AD 1515	哥白尼（N. Copernicus，1473～1543）	23°28′24″
11	万历二十四年丙申，迄崇祯元年为三十二年，西史第谷造铜铁测器十具，甚大甚准，又算地半径差及清蒙差，岁岁测侯，定为二十三度三十一分三十〇秒，西土今宗用之，于大统历为二十三度五十二分三十〇秒。第谷覃精四十年，察古史测法，知从来未觉有清蒙之气及地之半径两差，又旧用仪器，体制小、分度粗，窥筒孔大，所得余分不过四分度或六分度之几而已，且古来测北极出地之法未真未确，故相传旧测，俱不足依赖以定太阳躔度	AD 1596	第谷（T. Brahe，1546～1610）	23°31′30″

1）[2]，788：372-373；本表参考：严敦杰．明清之际西方传入我国之历算记录．梅荣照主编．明清数学史论文集南京：江苏教育出版社，1990. 114-181

2）拟应改正为"汉顺帝永和五年庚辰"（A. D. 140）

3）如果这里的数据取自哥白尼的《天体运行论》，哥白尼在此"所犯的历史性错误"，使"亚理大各"指"阿里斯塔科"（或《天体运行论》中译本的"阿里斯塔尔恰斯"），而不是正确的"阿里斯泰拉斯"（Aristyllus）[10]:385

4）[哈里发] Al-Mamun [时代的天文学家] 测定23°33′于830年。时间不一致，汉译时间当伪"（严敦杰，133）。

[13]

太阳平行永表[2]，788:408-409

甲子数	距冬至		最高冲			宿数	纪日
	度	分	宫	度	分		
一	〇	二二	一〇	一七	一二	一四	四〇
二	〇	二二	一〇	一七	五七	〇五	五五
三		二三		一八	四二	二四	一〇
四		二三		一九	二七	一五	二五
五		二四		二〇	一二	〇六	四〇
六五	〇	五一	〇	五	一二	二六	四〇
天启四年							
六六	〇	五二	〇	五	五七	一七	五五
百三一	一	二二	一	二四	四二	二〇	一〇
百三二	一	二二	一	二五	二七	一一	二五

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