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The Korean Adaptation of the Chinese-Islamic Astronomical Tables

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Contents

List of abbreviations

CCSNP	*Ch'ilchôngsan naep'yôn*
CCSOP	*Ch'ilchôngsan oeap'yôn*
HHLF	*Huihui lifa*
HHLF–M	"Huihui lifa" (section of the *Ming shi*)
QZTB	*Qizheng tuibu*
TSC	"True solar calendar", a calendar adopted in the practical applications of the astronomical tables of the *HHLF*.
j.	*juan*, Chinese term for chapter or volume
k.	*kwon*, Korean term identical with the Chinese *juan*

Preliminary remarks: Chinese dates are given in the usual system of dynastic eras, and the sexagesimal cycle applied to the numeration of the successive days and years of the Chinese calendrical and chronological system is used without warning. Explanation of these subjects, however, are easily found in a large number of Western sources mentioning the Chinese calendar in one way or another[1].

[1] For example, Kenneth 1992 (at a very general level) and Hoang 1968 (more specific).

1. Introduction

Around 1384, by the order of the first Ming emperor Zhu Yuanzhang, a set of Islamic astronomical tables, together with practical instructions, was translated from some unknown Arabic or Persian sources into Chinese by Mashayihei and Wu Bozong. The former was a Muslim astronomer in service of the Ming dynasty whose name is only known in Chinese transliteration but not in the Arabic original, and the latter a Chinese scholar-official. During the Ming dynasty and later, the resulting astronomical tables became known under the generic title of *Huihui lifa* (*HHLF*), literally "Muslim System of Calendrical Astronomy"[2]. Although the original version of the tables is not extant, later re-editions of these have been preserved: the first is known as the *Qizheng tuibu* (*QZTB*) and the second is the "Huihui lifa" section (*HHLF-M*) of the standard history of the Ming dynasty *Ming shi*.

The *QZTB* (literally "Calculations of the Seven Governors", i.e. of the sun, the moon and the five classical planets known in imperial China: Mercury, Venus, Mars, Jupiter and Saturn)[3] was compiled by Bei Lin[4] (*fl.*1456–1477), vice-director of the Bureau of Astronomy at Nanjing, then the "southern capital" of the Ming dynasty, presumably on the basis of the original *HHLF*. The process of compilation initiated in 1470, took no less than seven years and came to an end in 1477. The title *Qizheng tuibu* is not the original title of Bei Lin's treatise, but a new one given to the 18th century edition of the text by the editors of the famous *Siku quanshu* (Complete Library of the Four Treasuries) collection. In fact, in the *Siku caijin shumu* (A List of the Books Collected for the Compilation of the *Siku quanshu*), three Chinese treatises of Islamic astronomy are mentioned: two *Huihui lifa* "in four *juan* by Bei Lin" and another one, described as "originally bearing no title", but registered under the new title of *Qizheng tuibu*[5]. In addition, the *Daming xianzong chunhuangdi shilu* (True Records of the Ming Pure Emperor Xianzong)[6] notes that Bei Lin finished his re-edition of the *HHLF* precisely on the 56th sexagesimal day (*jiwei*) of the 10th month of the 13th year of the *Chenghua* era (6 November 1477), and that he called the resulted book *Huihui li*. Presumably, in such a context the title *Huihui li* is identical with that of the lost *Huihui lifa.*

In its turn, the *HHLF-M* was compiled by a group of early Qing scholars, among which were the two historians Wu Renchen (1628–1689) and Huang Zongxi (1610–1695) and the astronomer Mei Wending (1633–1721). It is basically an abbreviated version of the *QZTB*, but with a considerable number of revisions and additions[7].

Most importantly, during the reign of King Sejong (1418–1450) of the Chosôn dynasty, the *HHLF* was brought to Korea and eventually adapted to local usage by Korean

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[2] For recent study of the *HHLF*, cf. Yabuuchi 1954, 1964, 1969, 1987 and 1997; Chen Meidong 1987, Martzloff 1988; and Chen Jiujin 1996, pp. 106–230.

[3] An English translation and commentary of the *QZTB* is presently being prepared by Benno van Dalen.

[4] On Bei Lin, cf. Chen Jiujin 1996, pp. 122–130.

[5] Wu Weizu 1960, p. 115 and p. 271.

[6] Zhang Mao et al. 1491, j. 101, p2b.

[7] Cf. Mei Wending *ca.* 1703, pp. 7–8 and Zhang Tingyu et al. 1730, j. 37, p. 1ab.

astronomers. This Korean adaptation, entitled *Ch'ilchông san oep'yôn* (*CCSOP*)[8], has raised a considerable interest among modern scholars but systematic research has still not been carried out. The two historians who have most studied the work, Yabuuchi Kiyoshi[9] and Chen Jiujin[10], have left many important points unanalyzed. For example, neither of them has given answers to the following two questions:

(1) On what Chinese source(s) was the Korean adaptation based?
(2) Are the astronomical tables of the *HHLF* really adapted to practical usage?

As regards the first question, both Yabuuchi and Chen Jiujin have tacitly supposed that the Korean adaptation of the *HHLF* was based on a single Chinese source, which they refer to as the *Huihui lifa*. In fact, however, as I will show in the sequel, a Korean astronomer who took part in the adaptation also mentions another Chinese source. Is this second source still extant, and if so, what was its influence on the Korean adaptation? With regard to the second question, as I will show later, it seems that the astronomical tables of the original *HHLF* have been unsuitable for practical use because of chronological difficulties, consciously or not left in the translation by the original compilers, and linked to the problem of the determination of the time-interval between a given day and the epoch of the tables. Hence two further questions arise: were Korean astronomers aware of these difficulties? And if yes, what was their approach and what were its consequences?

In the first part of this article, I will first describe the general background of the Korean adaptation of the *HHLF* and its practical function during the Chosôn dynasty. Secondly, I will demonstrate that the Korean adaptation of the *HHLF* was not based on a single Chinese source. Then, in parts 2 and 3, I will concentrate my analysis on the algorithm for the determination of the time-interval between a given day and the epoch of the astronomical tables in the *HHLF* and I will focus on the Korean re-adjustments of the tables, including both the invention of a procedure for the calculation of the time-interval between a given day and the epoch of the tables and the re-determination of various astronomical constants relating to the sun, the moon and the five major planets. I will also give a general assessment of the validity of these re-adjustments. In addition, I will show that the Korean adaptation of the *HHLF* contains some other elements that may shed light on the circumstances of their compilation. The most important of these is a two-lines-in-one note appended to the star catalogue in the book. The note has formerly been used by Yabuuchi, Pan Nai and Chen Jiujin to fix the date of compilation of the catalogue and the geographical site where the needed observations were conducted. However, no general agreement has been attained. I will reexamine the question in the light of newly discovered materials related to the early activities of the Bureau of

[8] The literal meaning of this title will be explained in the sequel.
[9] Yabuuchi 1997, p. 19 and pp. 38–39.
[10] Chen Jiujin 1996, pp. 134–141 and Chen Jiujin 1997.

Astronomy of the Ming dynasty and thus provide a new clue to the problem of the Chinese source of the star catalogue of the *HHLF*. This last result will confirm the fact that the Korean adaptation of the *HHLF* was based on more than one Chinese source.

2. Background and Chinese sources

During the late Koryo dynasty (1303–1304) the most sophisticated Chinese system of calendrical astronomy, the *Shoushi li*[11], was introduced in Korea[12]. It appears, however, that Koryo computists and astronomers could not wholly take advantage of the totality of the new techniques made available to them because, while they could use the easiest part of the *Shoushi li* for calculating their yearly civil calendar, they did not use its more complex techniques for solar and lunar eclipse calculations. Instead, they employed the older and out of date eclipse techniques of the *Xuanming li*[13], a system of mathematical astronomy composed five century earlier, in *ca.* 806, by Xu Ang, an official astronomer of the late Tang dynasty[14]. It seems that their inability to take advantage of the new techniques in this respect was due to a lack of knowledge of root extraction needed for eclipse calculations[15]. Furthermore, the *Shoushi li* techniques for the determination of the positions of the planets also remained out of their reach and the situation remained unchanged until King Sejong's period in the first half of the 15th century[16].

In order to develop calendrical astronomy in his own kingdom, King Sejong personally studied the new Chinese techniques and ordered his astronomers to carry out a systematic research into the *Shoushi li*[17]. Meanwhile, some competent astronomers were sent to China in order to study astronomy, instrument making and to collect astronomical books[18]. To the full satisfaction of the king, these specialists not only acquired a considerable knowledge, but also brought back home important Chinese astronomical works published at the beginning of the Ming dynasty, such as the *HHLF* and the *Datong*

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[11] Literally "Season Granting System of Calendrical Astronomy", an officially adopted system of calendrical astronomy composed between 1276 and 1281 by Guo Shoujing, the most important astronomer of the Yuan dynasty. This system is often believed to be the most advanced in China before the 16th century.

[12] Shi Yunli 1998, p. 312.

[13] Literally "Great Brightness System of Calendrical Astronomy".

[14] Shi Yunli 1998, p. 314.

[15] Shi Yunli 1998, p. 314.

[16] Shi Yunli 1998, pp. 314–315.

[17] Shi Yunli 1998, pp. 315

[18] Yi Kungik 1800, vol. 3, p. 109.

lifa tonggui[19] (literally "Comprehensive Canons of the *Datong li*[20]"), a work composed in 1384 on the basis of *Shoushi li* by Yuan Tong (*fl.* 1384), an officer of the Ming Bureau of Astronomy.

As soon as these works were imported from China, in 1432, King Sejong assigned two scholars to the study of the *Datong lifa tonggui* and three others to the *HHLF*. The former were the historian and astronomer Chông Inji (1396–1478) and the astronomer Chông Ch'o (*fl.* 1437) and the latter the three astronomers Chông Hûmji, Yi Sunji (1406–1465) and Kim Tam (*fl.*1442)[21]. In 1442, two new treatises on calendrical astronomy resulted from their work. They were published two years later under the titles *Ch'ilchông san naep'yôn* (Calculations of the Seven Governors, Main Part[22]) (*CCSNP*) and *Ch'ilchông san oep'yôn* (Calculations of the Seven Governors, Supplementary Part[23]) (*CCSOP*), respectively. The first was based on both the *Datong lifa tonggui* and on Guo Shoujing's *Shoushi li*[24] and the second was actually an adaptation of the *HHLF*[25]. Several years later, two other books followed, namely, the *Ch'ilchông san naep'yôn chôngmyonyôn kyosik karyông* (Eclipse Calculations Using the *CCSNP* Techniques with Examples of Solar and Lunar Eclipses from the [Sexagesimal] Year *Dingmao* [no. 4 of the sexagesimal cycle] [1447]) and the *Ch'ilchông san oep'yon chôngmyonyôn kyosik karyông* (Eclipse Calculations Using the *CCSOP* Techniques with Examples of Solar and Lunar Eclipses from the [Sexagesimal] Year *Dingmao* [1447]), which give the details of the calculating techniques for solar and lunar eclipses, respectively according to the *CCSNP* and *CCSOP*.

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[19] A series consisting of six individual books: (1) *Liri tonggui* (canon for [the calculations of] the yearly civil calendar), (2) *Taiyang tonggui* (canon for [the calculations of] the sun), (3) *Taiyin tonggui* (canon for [the calculations of] the moon), (4) *Jiaoshi tonggui* (canon for [the calculations of] the eclipses), (5) *Wuxing tonggui* (canon for [the calculations of] the five [major] planets) and (6) *Siyu tonggui* (cannon for [the calculations of] the four excesses). Here the "four excesses" (*siyu*) are four celestial positions with periodical variation, namely, *ziqi* (purple vapor, of which the astronomical meaning is unclear), *yuebei* (lunar apogee), *jidu* (Ketu, the ascending lunar node) and *luohou* (Rāhu, the descending lunar node). They all bear special significance in traditional Chinese astrology. These six books were all revised and republished in Korea during King Sejong's reign. Cf. Lee Eun-Hee 1997.

[20] *Datong li*, literally "Great Union System of Calendrical Astronomy", is a system of calendrical astronomy officially adopted by the Ming Bureau of Astronomy. Its computational techniques and basic parameters, as codified in the *Datong lifa tonggui*, are basically identical with those of the *Shoushi li* except the following two respects: (1) the adoption of a new epoch, i.e. the winter solstice of the sexagesimal year *jiazi* (first year of the sexagesimal cycle applied to the enumeration of solar years) of the *Hongwu* era (1384), rather than that of the sexagesimal year *xinji* (no. 18 of the sexagesimal cycle) of the *Zhiyuan* era (1281); (2) the renunciation of the technique of secular variation of the tropical year, formerly needed to calculate the time elapsed since epoch with an incredible and totally illusory precision. Cf. Nakayama 1982.

[21] Lee Eun-Hee 1997.

[22] Literally "inner chapters".

[23] Literally "outer chapters".

[24] Lee Eun-Hee 1997; Shi Yunli 1998, pp. 315–317.

[25] Jeon Sangwoon 1974, p. 80; Chen Jiujin 1996, pp. 134–141 and 1997, pp. 105–111.

Later, the *CCSOP* was continuously used by official Korean astronomers in parallel with the *CCSNP* for the eclipse prediction[26], even after European astronomy was officially adopted in Korea in the mid-17th century. In the official annals of the Astronomical Board of the Chosôn dynasty composed in 1818, the author Sông Chudôk (1759-?), a court astronomer of the late Chosôn dynasty, describes the routine works of the Board in relation to the eclipse prediction as follows:

> Seven days before an eclipse, the results calculated with methods taken from four treatises are required to be compared with each other and reported [to the throne]. . . . These four are the [*Ch'ilchôngsan*] *naep'yôn*, the [*Ch'ilchôngsan*] *oep'yôn*, the *Shixian*[27] and the *Datong lifa*[28,29].

From this, it appears that traditional Chinese-Islamic astronomy survived up to at least the early 19th century in Korea, whereas it was officially abandoned in China in 1659[30].

But which sources were exactly used in the compilation of the *CCSOP*? A priori, it would seem that the *HHLF*, published in China *ca.* 1384, is the only source available to the compilers of the *CCSOP*. This inference sounds more plausible if we take into account the following note in front of the *CCSNP* and *CCSOP* section of the *Sejong sillok* (Veritable Record of King Sejong):

> Therefore, King Sejong assigned Chông Inji, Chông Ch'o and Chông Hûmji to conduct a research into [the *Shoushi li*]. These [astronomers] grasped almost all the secrets of the original and the King in person resolved all the remaining obscurities. Since the content of other treatises of Chinese origin such as the *Taiyin* and the *Taiyang tonggui*[31], happened to be a little different from that of the *Shoushi li*, the [*CCSNP*] was compiled using these together with the *Shoushi li*. The *Huihui lifa* was also brought from China and the King ordered Yi Sunji and Kim Tam to study it. Some discrepancies and mistakes of Chinese astronomers were found and consequently the [*CCSOP*] was compiled on the basis of these various revisions and corrections[32].

Here, only three sources for the compilation of both the *CCSNP* and *CCSOP* are mentioned: the *Shoushi li*, *Datong lifa tonggui* and *Huihui lifa*, among which the *Huihui lifa* is the only title that has connection with the *CCSOP*. However, when Yi Sunji recounts the genesis of the *CCSNP* and *CCSOP*, he explicitly numerates another Chinese source:

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26 Lee Eun-hee 1997.

27 Here the expression *Shixian* refers to the European system of calendrical astronomy translated into Chinese by the German Jesuit missionary Adam Schall von Bell (1592–1666) and other Jesuit astronomers.

28 The *Datong lifa* is an equivalent of *Datong li*. For the *Datong li*, cf. footnote 20.

29 Sông Chudôk 1818, k. 2, p. 17a–18b.

30 Huang Yilong 1993.

31 Two individual books belonging to the *Datong lifa tonggui*. Cf. footnote 19.

32 Chông Inji et al. 1454, k. 156, p. 1a.

> Books from the Great Ming dynasty such as the *Shoushi li, Huihui li, Tonggui* and the *Tongjing* have been all studied and revised before the *CCSNP* and *CCSOP* were eventually compiled[33].

Hence we now have four possible sources in all: the *Shoshi li*, the *Huihui li*, the *Tonggui* and the *Tongjing*. Presumably, *Huihui li* and the *Tonggui* mentioned here refer to the *Huihui lifa* and the *Datong lifa tonggui*: such loose designations are commonly met in Chinese and Korean, especially non-bibliographical, works. The expression *Tongjing* (literally "A Comprehensive Guide") must also refer to another technical source, perhaps cited in abbreviated form, which is worth to be identified.

Searching through the Bibliographical Section of the *Ming shi* (Standard History of the Ming Dynasty), we can find the record of a book in four *juan* called *Lifa tongjing* (literally "A Comprehensive Guide to the System of Calendrical Astronomy") by a certain Liu Xin[34]. It also happens that an incomplete manuscript with a quite similar title *Xiyu lifa tongjing* (literally "A Comprehensive Guide to the System of Calendrical Astronomy from Western Areas"), but limited to *juan* 11 to 14 and 21 to 24, is preserved at the National Library of China[35]. At the beginning of each *juan* of the *Xiyu lifa tongjing*, the following "byline" is repeated:

> Edited by Liu Xin from Ancheng[36], Gentleman for Fostering Virtue[37] and Summer Officer Chief[38] of the Bureau of Astronomy.

Given the similarity of the book titles and the fact that the mentioned author, Liu Xin, is the same as the one mentioned by the *Ming shi*, the *Xiyu lifa tongjing* probably does not differ from the *Lifa tongjing*.

As seen from the remaining parts of the book, *Xiyu lifa tongjing* is probably a new edition of the *HHLF*. But Liu Xin, the new editor, had apparently access to more numerous Arabic and/or Persian sources than his two predecessors, Mashayihei and Wu Bozong, the authors of the initial translation of the Chinese Muslim astronomical tables. And it seems that Liu Xin has reworked the texts and even added new astronomical tables because, for example, the extant copy of the *Xiyu lifa tongjing* explains the calculation of the *fancha* (general equations) of the five major planets by using tables called *Yue wuxing fancha licheng* (quick tables for the general equations of the moon and five [major] planets)[39], absent from the texts of the other two reedited versions of the *HHLF*, namely, the *QZTB* and *HHLF-M*.

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[33] Yi Sunji 1445, k. 4, p. 25b.

[34] Zhang Tingyu et al. 1730, j. 98, p. 13b.

[35] Call No.CBM/ND1416/610. These preserved parts have been reproduced in Ma Mingda and Chen Jing 1996, pp. 42–307.

[36] Presently Anfu County, Jiangxi Province.

[37] In Chinese "Chengde lang", a prestige title for officials of rank 6a. Cf. Hucker 1985, p. 129, no. 514.

[38] In Chinese "Xiaguan zheng". In the ancient Chinese bureau of astronomy, names of the four yearly seasons, i.e. spring, summer, autumn and winter, were used as official titles. Each name was applied to two officers, one chief and the other associate. Also cf. Hucker 1985, p. 230, no. 2296.

[39] Liu Xin *ca.* 1436–1450, j. 14, p. 1a.

Further evidence about the existence of the person of Liu Xin and his works on astronomy, especially his re-edition of the Chinese-Islamic astronomical tables, appears in other historical sources. The *Kangxi Anfu xianzhi* (Annals of the Anfu County Edited During the *Kangxi* Era) notes that Liu Xin "was promoted to the position of Summer Officer Chief of the Bureau of Astronomy during the *Zhengtong* era (1436–1450) of the Ming dynasty for he was versed in astronomy"[40]. The *Daming yingzong ruihuangdi shilu* (True Records of the Intelligent Ming Emperor Yingzong)[41] tells us that Liu Xin observed the altitude of the north pole in 1447 and was killed two years later during a eunuch rebellion.

Moreover, in an anthology of the famous official Xu Youzhen (1407–1472), we can find the following preface for a certain *Xiyu lishu* (Treatise on Calendrical Astronomy from Western Areas) written by Xu Youzhen:

> [...] The Muslim system of calendrical astronomy is said to have been authored by an extraordinarily talented man named Mahamute [Muhammad] in the *Aerbi* [Arabic] year[42], in a western place called *Make* [Mecca] [...]. Calendar makers believed it to be the most accurate system for the calculation of the longitudes, latitudes as well as ominous motions [of the Seven Luminaries], but it did not spread eastward before the Yuan era. When the first emperor [of the present dynasty] inaugurated the composition of the *Datong li*, he summoned to his court [several] westerners expert in calendar making and ordered the Bureau of Astronomy to adopt the Muslim astronomical techniques as a supplement [to the orthodox *Datong li*]. It has remained in use since then. My friend Liu Zhongfu [Liu Xin] has an excellent knowledge of stars and astronomical tables. He has comprehensively studied all sorts of [Chinese astronomical] methods and is also proficient in western [i.e. Islamic] ones. He noticed that the Muslim system of calendrical astronomy is somewhat inconsistent and devoid of uniform rules, and would therefore become more and more confusing with the passage of time. Consequently, he translated the Muslim text precisely, prescribed rules for its usage, and pre-calculated the essential quick tables. The resulting procedures are brief, simple and clear. They form an orderly book devoted to the [Muslim] school of astronomy that is to be used indefinitely and to remain essential to students of calendrical astronomy[43].

Since Xu Youzhen is a apparently a contemporary of Liu Xin and given that no scholar called Liu is known to have studied Islamic astronomy as deeply as Liu Xin has, it may be assumed that the Liu Zhongfu mentioned here designates Liu Xin by using

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[40] Quoted from Beijing tianwentai edt. 1989, p. 167.

[41] Sun Jizong et al. 1467, j. 160, pp. 7b–8a; j. 181, pp. 2b–3a.

[42] Xu Youzhen obviously only had quite limited knowledge about the history of astronomy in the Islamic world, and therefore owed the original authorship of the *HHLF* to the founder of the Islamic religion. Moreover, since the epoch of the *HHLF* was known by most Chinese scholars as in the "*Aerbi* year", presumably the year of Hegira, he also dates the compilation of the *HHLF* back to the same year. Similar misunderstanding can also be found in the *HHLF-M* (Zhang Tingyu et al. 1730, j. 37, p. 1).

[43] Xu Youzhen 1439–1472, j. 2, pp. 21a–23a.

his scholarly name, Zhongfu, instead of Xin. Consequently, the *Xiyu lishu* is probably a loose designation of the *Xiyu lifa tongjing*[44].

All in all, it seems reasonable to conclude that the *Xiyu lifa tongjing* is identical with the *Tongjing* mentioned by Yi Sunji. Unfortunately, since the extant version of the *Xiyu lifa tongjing* is too fragmented, we are unable to assess precisely its influence on the *CCSOP*. Yabuuchi has observed that "the tables [of the *CCSOP*] are intermingled with the explanatory text describing their use", and such a characteristic is very different from the style of the *HHLF-M* and *QZTB*[45]. But on the other hand, we noticed that the extant part of the *Xiyu lifa tongjing* is also arranged in such a way. Therefore, it might have been the prototype followed by Korean astronomers in designing the content arrangement of the *CCSOP*.

Since the original version of the *HHLF*, published *ca.*1348, is not extant and the manuscript of the *Xiyu lifa tongjing* preserved in the National Library of China is extremely incomplete, the *CCSOP* constitutes the most ancient full re-edition of the *HHLF* still extant. But when comparing the *CCSOP* with the *QZTB* and *HHLF-M* – the other two complete re-editions of the *HHLF* still available – various differences are noticeable. For example, Yabuuchi has already pointed out that the astronomical tables and the corresponding algorithms needed to use them are essentially the same in the three treatises, whereas the arrangement of the content in the *CCSOP* is quite different from that of the *QZTB* and *HHLF-M*[46]. Most importantly, however, the *CCSOP* contains a fundamental computational procedure, concerning the determination of the time-interval between a given day and the epoch, which is absent from both the *QZTB* and *HHLF-M*. Some astronomical constants also differ in both cases. In the sequel, we shall discuss these important but hitherto unconsidered variations.

3. The problem of the determination of the time-interval between a given day and the epoch

To begin with, we shall first define the following special operators:

a ***Div*** *b*: divide the integer *a* by the integer *b* and keep the integer part of the quotient. For example, 102 *Div* 30 = 3.

a ***Mod*** *b*: divide the integer *a* by the integer *b* and return the remainder. For example, 102 *Mod* 30 = 12.

a ***DivMon***: subtract 30, 29, 30, 29 . . . (i.e. the number of days of each successive lunar month of the *hijra* lunar calendar[47]) successively, always beginning with

[44] In ancient China, authors often asked friends or famous people to write prefaces to their works. Sometimes, books mentioned in prefaces were not given their exact title but only an approximate or abridged title. Therefore, when a book title is mentioned in a preface, it should not be always taken *verbatim* as an exact bibliographical reference.

[45] Yabuuchi 1997, p. 19.

[46] Yabuuchi 1997, p. 19.

[47] The length of the *hijra* lunar year is 354 days in a normal year, divided into 12 lunar months with 30 in every odd month, 29 days in every even month. In the case of a leap year, one leap day should be added to the 12th month, which will also have 30 days.

30, from a given integer *a* until the remainder becomes smaller than the upcoming subtrahend and return the number of subtractions performed. This operation supplies the greatest number of integer lunar months included in a given number of days. For example, 102 *DivMon* = 3 means that 102 days consists of 3 lunar months.

a ***ModMon:*** subtract 30, 29, 30, 29 ... (i.e. the number of days of each successive lunar month of the *hijra* lunar calendar) successively, always beginning with 30, from a given integer *a* until the remainder becomes smaller than the upcoming subtrahend and return the remainder. This operation supplies the number of days left after subtracting the greatest possible number of integer months from a given number of days. For example, 102 *ModMon* = 13 means that after taking 3 lunar months from 102 days, 13 days are left.

As can been seen from the *CCSOP*, *QZTB* and *MMLF-M*, the astronomical tables of the *HHLF* are based on some version of the *hijra* lunar calendar. But the application of the tables is made complex owing to the fact that a special true solar calendar (TSC) is adopted for practical calculations.

In the TSC, the day is defined from noon to noon, and the new year day corresponds to the day on which the sun passes the vernal equinoctial point[48]. The theoretical value of the length of the year it adopts is equal to $365\frac{31}{128}$ days[49] but a plain year consists of 365 days and twelve months successively having 31, 31, 31, 32, 31, 31, 30, 30, 30, 29, 29, 30 and 30 days, bearing the names of the twelve zodiacal signs in such a way that the first month of the calendar corresponds to Aries. For convenience, we will express a date in this calendar by using the following special format: day number (from 1 to 29, 30, 31 or 32) + zodiacal name of the corresponding month + (when necessary) corresponding Christian year number. For example, in this system, the new year day of any year is noted 1 Aries.

The insertion of the TSC in calendrical calculations based on the Chinese Islamic tables raises the question of the determination of the time-interval between a day in the TSC and the epoch of the *hijra* lunar calendar. This is a fundamental and unavoidable problem of date-conversion between the solar and lunar chronological scales of the Chinese Islamic tables. As the astronomer Li Rui (1768–1817) comments, "no one could use [the Chinese Islamic tables] without knowing [how to convert solar and lunar dates]"[50]. In fact, the question was probably trivial for Muslim astronomers of the Ming Bureau of Astronomy. But for other Chinese and Korean computists or astronomers, not necessarily versed in Islamic culture beyond the Chinese or Korean adaptations of Islamic materials, the question was probably all but obvious.

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48 For detailed descriptions and discussions of this calendar, cf. Yi Sunji and Kim Tam 1442, k. 1; Bei Lin 1477, j. 1, pp. 1a–2b and p. 3ab; Xu Youzhen 1439–1472, j. 2, pp. 21b–22a; Zhang Tingyu et al. 1730, j. 37, pp. 3a–4a; Mei Wending 1703, j. 1. pp. 7b–9a and p. 11ab; Chen Jiujin 1996, pp. 144–149. According to Chen Jiujin (1996, pp. 154–161), up to the early 20th century the TSC was still used in parallel with the *hijra* lunar calendar by Muslims in northwest China.

49 Cf. Chen Jiujin 1996, p. 147.

50 Ruan Yuan 1799, j. 29, p. 352.

Unfortunately, the earliest available Chinese version of the *HHLF*, the *QZTB*, remains silent on the matter and this was perhaps also the case of the text of the original *HHLF* and of Liu Xin's *Xiyu lifa tongjing*, both works being anterior to the edition of the *QZTB*.

In the *QZTB*, the problem is left unmentioned: Bei Lin, the author of the book, completely overlook the question. The absence of a development which seems so crucial to us is perhaps the consequence of some rivalry between astronomers respectively attached to the Chinese and Muslim Departments of the Bureau of Astronomy. This hypothesis appears all the more plausible because no Chinese astronomer is known to have been able to correctly convert *hijra* dates into the TSC chronological system prior to the first half of the 16th century, when the astronomer Tang Shunzhi (1506–1560) propounded two algorithms to solve the question, which were eventually incorporated in the *HHLF-M* a century later. However, it turns out that neither of these algorithms is correct (see the appendix). Consequently, later Chinese astronomers from the Qing period frequently accused Muslim astronomers of "trickily hiding the root numbers" of Chinese-Muslim astronomical and calendrical systems in order to "fool the eyes and ears" of their rivals[51].

Recently, historians of Chinese astronomy have often depicted the highly competitive tension which opposed astronomers from various ethnic origins and belonging to different sections of the Bureau of Astronomy during the Ming and Qing dynasties[52]. But the phenomenon was not new since it already manifested itself earlier, as soon as the Yuan dynasty, when Muslim and Chinese astronomers worked independently and uncooperatively in the service of their Mongolian patrons[53]. Given that a few Chinese astronomers and a majority of the Muslim Astronomers in the early Ming Bureau of Astronomy came from the Yuan Bureau[54], the perpetuation of such a situation is not surprising. Under such conditions, it is quite plausible that the Muslim compilers of the *HHLF* have deliberately omitted the conversion techniques in order to barr the access to the correct use of Muslim tables[55].

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51 Ruan Yuan 1799, j. 29, p. 352; Mei Wending 1703, j. 1, p. 7b–9a.

52 Huang Yilong 1991 and 1993; Chen Jiujin 1996, p. 248–258.

53 In the early Yuan Dynasty, two Bureaus of Astronomy, a Chinese and an Islamic one, were set up. In 1275, however, the two Bureaus were transformed into a single structure. From that time, more cooperation between Chinese and Islamic astronomers might have been expected. But it was not the case. According to Wang Shidian (j. 7, p. 13–14 and 16), both still worked separately.

54 Shortly after the founding of the Ming dynasty in 1367, between 1368 and 1369, ten Chinese and fifteen Muslim astronomers from the former Yuan Observatory were summoned to serve in the Bureau of Astonomy of the Ming dynasty in Nanjing (Xia Yuanji et al. 1418, j. 35, p. 5b–6a and j. 41, pp. 2a). They continued to work separately in two independent Bureaus of Astronomy until 1398 when the two Bureaus were again combined into a single unit. The two Bureaus were sited miles apart, the Chinese one on the summit of the *Zijinshan* (Purple Golden Mountain) and Muslim one at *Yuhuatai* (Pavilion of Flowery Rains), "to isolate astronomers of the two Bureaus and prevent them from mutual communication" (Tan Xisi 1619, j. 7 p. 6b).

55 According to *Ming huidian* (Xu Pu 1502, j. 176, p. 2a), "those Muslim officers and apprentices [of astronomy] also subordinate to the Bureau of Astronomy. Their progenies inherit their techniques as well as positions. [They] use the dust-board computus of their original country in the [astronomical] calculations". The *Mingshi* (Zhang Tingyu et al. 1730, j. 37, p. 2a) also explains

The Korean compilers of the *CCSOP*, however, became fully aware of the problem and remarked that they had found "some discrepancies and mistakes" in the *HHLF*. Hence the compilation of the *CCSOP* "on the basis of these various revisions and corrections"[56]. Eventually, they explicitly propounded another algorithm.

In order to appreciate the approach of the *CCSOP*, we shall first explain how dates in TSC could have been converted into the *hijra* lunar calendar. The following explanation is based on the *CCSOP*, *QZTB* and *HHLF-M*. But, first of all, we have to answer the following two questions:

A. What is the epoch of the *hijra* lunar calendar (*hijra* epoch) used in the above versions of the Chinese Islamic tables (and presumably in the original *HHLF*)?
B. What is the *hijra* lunar date of the epoch of the TSC?

First, we examine question A. The *hijra* lunar calendar, on which the Chinese Islamic astronomical tables are based, may have two different epochs[57]:

(1) The "astronomical" epoch based on the mean lunar crescent of Thursday, 15 July 622.
(2) The "civil" epoch determined by the first visibility of the new moon on Friday, 16 July 622.

From the section *Qiu gongfen runri* (Calculation of the intercalary days of the true solar years) and *Qiu yuefen runri* (Calculation of the intercalary days of the [*hijra*] lunar years) of the *QZTB* and *HHLF-M*, we understand that the *hijra* epoch is on a Friday, while the TSC epoch on a Thursday[58]. Therefore, the "civil" epoch may be the one originally used in the Chinese Islamic tables. To confirm this induction, we applied the procedures of the *CCSOP*, *QZTB* and *HHLF-M* to calculate the longitude of the moon at the *hijra* epoch and obtained the same result: $144^\circ 54' 43''$. We select the moon because, among the celestial positions computable with the procedures of the three treatises, the lunar longitude is the most sensitive to the time variations. Using relevant formulae presented by Jean Meeus[59], we have found that the apparent lunar longitude at sunset around local time 7:00 p.m. on 16 July 622 at the Ming capital city Nanjing is $143^\circ 37' 53''$, a result very close to the above one. As a month in the *hijra* lunar calendar usually begins from sunset, the sunset on 16 July 622 is probably the *hijra* epoch used by the Chinese Islamic tables.

But due to the fact that a day in the TSC is defined as from noon to noon, a *hijra* epoch at sunset would certainly cause inconvenience in the practical applications of these tables without any special adjustment.

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that Muslim astronomers from the Ming Bureau of Astronomy still "use the dust-board calculating method and original books of their original country". In other words, as a book compiled on the mandate of a Chinese emperor (Zhu Yuanzhang), the *HHLF* was intended, by its Muslim compilers, only for Chinese astronomers. The Muslim astronomers in China did not rely on it at all.

[56] Chông Inji et al. 1454, k. 156, p. 1a.

[57] Blois and Dalen 2000; Taqizadeh 1937–1942.

[58] Bei Lin 1477, j. 1, pp. 3a–4a; Zhang Tingyu 1730, j. 37, pp. 3b–4b. For modern explanation of these two sections, cf. Chen Jiujin 1996, pp. 142–149.

[59] Meeus 1979.

In fact, this adjustment can be detected from the *Taiyin jingdu zongnian licheng* (*Quick tables of lunar longitudes complete years*)[60]. This table supplies the initial mean lunar longitudes at the beginnings of every intercalary cycle of the *hijra* lunar calendar, each cycle consisting of 30 *hijra* lunar years and the first year of each cycle being called a *zongnian* (complete year)[61]. Just as the *HHLF-M* suggests[62], these longitudinal values can be calculated from the following equation:

$$\overline{\lambda}_i = \overline{\lambda}_1 + \frac{i}{30} \times 38^\circ 15'.$$

In this equation, $38^\circ 15'$ is the amount by which the initial mean lunar longitude will increase every time an intercalary cycle of 30 *hijra* lunar years completes, $\overline{\lambda}_1$ the mean lunar longitude at the *hijra* epoch that is given as $148^\circ 49'$ in the initial column of the table, whereas $\overline{\lambda}_i$ is the mean lunar longitude of the complete year *hijra* i, and i, the year number of a complete year, is always an integer multiple of 30.

Checking the table with the equation, we find that each tabulated value differs from our calculated result for the same complete year by a negative amount of $5^\circ 10'$. And if we subtract $5^\circ 10'$ from $\overline{\lambda}_1$ and use the remainder to calculate the lunar longitude at the *hijra* epoch, the resulting lunar longitude becomes equal to $139^\circ 44' 43''$. This result is very close to the value $139^\circ 30' 28''$ which is obtained when applying Jean Meeu's formulae to the case of the 16 July 622 at 12:00 p.m., Nanjing local time. This means that in the *HHLF* the *hijra* epoch has been practically shifted from sunset to noon.

In order to double check whether the "final" epoch of the *hijra* lunar calendar in the *HHLF* is on 16 July 622 and at noon, we have also calculated the solar longitude at the epoch with the procedures of the *CCSOP*, *QZTB* and *HHLF-M*. As a result, we have found $114^\circ 51' 53''$, a value quite near to the theoretical solar longitude $114^\circ 54' 44''$ at Nanjing local time 12:00 p.m. 16 July 622, calculated with Jean Meeus' formulae. Therefore there is no doubt that the *hijra* epoch as used in the *HHLF* and its three descendant versions is at noon 16 July 622 at the Ming dynasty capital Nanjing (Julian Day 1948439.6701).

It remains that in the procedural instructions of the *CCSOP*, *QZTB* and the *HHLF-M* a mistake due to a confusion between lunar and solar years occurs.

In fact, the *hijra* epoch is located 786 *hijra* lunar years before the sexagesimal year *jiazi* (no. 1 of the sexagesimal cycle) of the *Hongwu* era of the Ming dynasty (1384) or in 622, a year which corresponds to the sexagesimal year *renwu* (no. 19 of the sexagesimal cycle) of the *Wude* era of the Tang dynasty when expressed in the Chinese classical chronological system. But the *CCSOP*, *QZTB* and *HHLF-M* mistake these 786 *hijra* lunar years for 786 true solar years. Precisely for that reason the epoch they give becomes located 786 solar years before 1384, or in 599. In the classical Chinese way of

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[60] Bei Lin 1477, j. 2, pp. 9–10. The corresponding table can be found in the *CCSOP* (Yi Sunji and Kim Tam 1442, k. 1, pp. 32–34) and *HHLF-M* (Zhang Tingyu et al. 1730, j. 38, pp. 7b–10a) as well.

[61] This cycle results from the fact that the length of 30 *hijra* lunar years gives an integer number of days, i.e. $30 \times 354\frac{11}{30} = 10631$. For the intercalary rule of the *hijra* lunar calendar as used in the *HHLF*, cf. footnote 66 and 69.

[62] Zhang Tingyu et al. 1730, j. 38, p. 9b.

expressing dates, this *hijra* epoch corresponds to the sexagesimal year *jiwei* (no. 56 of the sexagesimal cycle) of the *Kaihuang* era of the Sui dynasty. There is no doubt that this mistake needs being corrected in the present discussion. In the sequel, the actual *hijra* epoch is taken equal to the noon 16 July 622.

Now let us turn to the question of the epoch of the TSC (question B). According to the procedural instructions of the *CCSOP*, *QZTB* and *HHLF-M*, the TSC epoch must verify two conditions:

(1) It must fall on the day (from noon till noon) of vernal equinox, mean or true;
(2) Its week day number must be equal to 5 (Thursday)[63].

From the *Ri wuxing zhongxing zongnian licheng* (*Quick table of the mean solar and planetary longitudes for complete years*)[64], the mean solar longitude of the *hijra* epoch is $116°5'8''$ with respect to Aries 0° (vernal equinoctial point). Since the accurate length of a year in the TSC is $365\frac{31}{128}$ days, as already mentioned at the beginning of this section, the mean sun of this calendar moves about $59'8''$ per day. Therefore the value $116°5'8''$ corresponds to the mean solar motion in about 117.787 days since its last passing of the vernal equinoctial point. This indicates that the mean vernal equinoctial day and the *hijra* epoch are 118 days apart. Since 118 *DivMon* = 4 and 118 *ModMon* = 0, the sought day should be 2 Ramadan[65] 1 B.H. (B.H.= before the *hijra* epoch, assuming that the year before the year 1 *hijra* is the year 1 B.H., which is a leap year of 355 days [66]).

To check whether the day 2 Ramadan could have been the TSC epoch, let us calculate the corresponding week day number from that of the *hijra* epoch which is equal to 6 (Friday), according to the description of the *QZTB* and *HHLF-M*. Since (6–118) *Mod* 7 = 7 (Saturday) rather than 5 (Thursday, i.e. the week day number of the solar epoch), the day in question does not satisfy the second condition listed above.

Following the procedural instructions of the *CCSOP*, *QZTB* and *HHLF-M*, the true longitudes of the sun at noon on 1 Ramadan and 29 Shaaban[67] 1 B.H. are found equal to $46'42''$ and $359°47'59''$, respectively. This result means that the true sun would enter Aries on 29 Shaaban 1 B.H., 120 days before the *hijra* epoch. Since (6–120) *Mod* 7 = 5 (Thursday), the day 29 Shaaban 1 B.H. is a plausible TSC epoch. This epoch corresponds to the Julian Day 1948319.6701 (= 1948439.6701 – 120), or local time

[63] In the *QZTB* and *HHLF-M,* the seven week days are such that Sunday is the first day, Monday the second and so on. Moreover, the week day number of the solar epoch is 5 (Thursday), whereas that of the *hijra* epoch is 6 (Friday).

[64] *Bei Lin* 1477, j. 2, pp. 1–2. The corresponding tables can also be found in the *HHLF-M* (Zhang Tingyu et al. 1730, j. 38, pp. 1a–7b) and *CCSOP* (Yi Sunji and Kim Tam 1442, k. 1, pp. 1b–4a).

[65] Ramadan is the 9th month in the *hijra* lunar calendar, a month having 30 days. In Christian calendar, this day corresponds to 18 March 622.

[66] This format of dating was suggested by Benno van Dalen. According to the intercalary rule of the *hijra* lunar calendar, the years 2, 5, 7, 10, 13, 16, 18, 21, 24, 26 and 29 are leap years in every 30 years, and a leap day should be added to each of these years. Since the year 1 *hijra* is not a leap year, 1 B.H. should be a leap year.

[67] Shaaban is the 8th month in the *hijra* lunar calendar and consists of 29 days. In the Julian calendar, these two days correspond to 19 and 18 March 622, respectively.

12:00 p.m. 18 March 622 at Nanjing. The corresponding true vernal equinox, retrospectively computed with Jean Meeus' formula, occurs the same day at Nanjing local time 5:18 p.m.

Now let us present the result of our reconstruction of the time-interval between a given day in the TSC and the *hijra* lunar epoch (that of 622), in terms of three variables Y_m, M_m, and D_m defined as follows:

Y_m = number of lunar years from the *hijra* epoch to the beginning of the TSC year to which the given day belongs,
M_m = number of lunar months from the beginning of the lunar year to the beginning of the lunar month to which the given day belongs,
D_m = number of days from the beginning of the given lunar month to the given day.

Let also

Y_s = the number of solar years contained in the time-interval between the solar epoch and the given day,
D_s = the number of days between the given day and the beginning of the solar year to which the given day belongs,
D_s = the number of solar leap days[68] in Y_s years,
d_m = the number of lunar leap days[69] in Y_m years.

Then Y_m, M_m and D_m verify the following equations:

$$Y_m = (Y_s \times 365 + d_s + D_s - 120)\ \mathit{Div}\ 354 \tag{3.1.1}$$

$$d_m = [Y_m \times 11 + 14]\ \mathit{Div}\ 30 \tag{3.1.2}$$

$$M_m = [(Y_s \times 365 + d_s + D_s - 120)\ \mathit{Mod}\ 354 - d_m]\ \mathit{DivMon}, \tag{3.1.3}$$

$$D_m = [(Y_s \times 365 + d_s + D_s - 120)\ \mathit{Mod}\ 354 - d_m]\ \mathit{ModMon}, \tag{3.1.4}$$

where $Y_s \times 365 + d_s$ is the total number of solar days in Y_s years. After subtracting 120 from $Y_s \times 365 + d_s + D_s$, the remainder is the number of days separating the *hijra* epoch from the given day. But if $d_m > 354$ days, the correct number of lunar years is obtained by first calculating $Y'_m = Y_m - d_m\ \mathit{Div}\ 354$ and then d_m from (3.1.2) with Y'_m instead of Y_m. When needed, the same technique is also applicable to Eqs. (3.1.5) to (3.1.12) below.

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[68] Since the accurate length of a solar year of the true solar calendar in question is $365\frac{31}{128}$ days, $\frac{31}{128}$ day are left out each year. In addition, according to the *QZTB* and *HHLF-M,* there is a leap constant of $\frac{15}{128}$ day at the solar epoch. Whenever the accumulation of these fractional values amounts to a full day, a solar leap year occurs and a leap day will be added to the last month of the leap year. The accumulated leap days in Y_s should be calculated using $d_s = (Y_s \times 31 + 15)$ *Div* 128.

[69] Since a *hijra* lunar year has exactly $354\frac{11}{30}$days, a lunar leap day should be added periodically to keep the calendar in step with the solar and lunar motion. Since there is a leap constant of $\frac{14}{30}$ day at the *hijra* epoch, the number of lunar leap days in Y_m years should be calculated from $d_m = (Y_m \times 11 + 14)$ *Div* 30.

Nevertheless, as explained above, the actual TSC epoch given in the *CCSOP*, *QZTB* and *HHLF-M* does not correspond to 622, but to the year 599, twenty-three solar years earlier and the equations above have to be modified accordingly: we must calculate the number of days between noon of 1 Aries 599 and the 622 *hijra* epoch. Since the time-interval between the vernal equinoxes of 599 and 622 is equal to 23 solar years, or $23 \times 365 + (23 \times 31 + 15)$ *Div* 128 = 8400 days, the number of solar days before the *hijra* epoch should be equal to 8400 + 120 = 8520 days, or 24 lunar years and 15 days.

Because 8400 *Mod* 7 and (8520 – 15) *Mod* 7 are both equal to 0, the week day numbers of 1 Aries and 1 Muharram[70] in 599 are the same as those of 622. In other words, 1 Aries 599 should begin at noon on 16 Dhu al-Hijja[71] 25 B.H., 15 days before the beginning of 24 B.H.. This result corresponds to the Julian Day 1939919.6701 (= 1948319.6701 – 8400) or local time 12:00 p.m. 19 March 599 at Nanjing[72]. With this new data, Y_m, M_m and D_m should be calculated from the following equations:

$$Y_m = (Y_s \times 365 + d_s + D_s - 15)\ \textit{Div}\ 354 \tag{3.1.5}$$

$$d_m = [(Y_m + 24) \times 11 + 14]\ \textit{Div}\ 30 \tag{3.1.6}$$

$$M_m = [(Y_s \times 365 + d_s + D_s - 15)\ \textit{Mod}\ 354 - d_m]\ \textit{DivMon} \tag{3.1.7}$$

$$D_m = [(Y_s \times 365 + d_s + D_s - 15)\ \textit{Mod}\ 354 - d_m]\ \textit{ModMon}, \tag{3.1.8}$$

where Y_s denotes the number of solar years appearing between 1 Aries 599 and the given day, and d_m the number of intercalary lunar days in (Y_m + 24) years. Furthermore, if we select 1 Muharram 25 B.H. as a starting-point of the calculation and neglect the incorrectness of its week day number, these equations can be re-written as follows:

$$Y_m = (Y_s \times 365 + d_s + D_s + 340)\ \textit{Div}\ 354 - 25 \tag{3.1.9}$$

$$d_m = [(Y_m + 25) \times 11 + 14]\ \textit{Div}\ 30 \tag{3.1.10}$$

$$M_m = [(Y_s \times 365 + d_s + D_s + 340)\ \textit{Mod}\ 354 - d_m]\ \textit{DivMon} \tag{3.1.11}$$

$$D_m = [(Y_s \times 365 + d_s + D_s + 340)\ \textit{Mod}\ 354 - d_m]\ \textit{ModMon}. \tag{3.1.12}$$

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70 Murraham is the 1st month of the *hijra* lunar calendar, having 30 days.

71 Dhu al-Hijja is the 12th month in the *hijra* lunar calendar, consisting of 29 days in a normal year but 30 days in a leap year. Since, according to the intercalation rule of the *hijra* lunar calendar (cf. footnote 66), 1 B.H. is a leap year, 25 B.H. would also be a leap year. Therefore, there should be 30 days in this month.

72 According to the method of the *CCSOP, QZTB* and *HHLF-M*, the true solar longitude at this moment is $20'20''$, and hence the approximate time of the true vernal equinox, i.e. about $8^h\ 15^m$ earlier than this moment. The modern theoretical result is 4:15 a.m. 19 March 599 (Julian Day 1939919.3471), or $7^h\ 45^m$ before noon of 16 Dhu al-Hijja 25B.H.at Nanjing, only 30 minutes later than the *HHLF* result.

Here 340 is the interval between the beginning of 25 B.H. and 1 Aries 599, since 25 B.H. happens to be a 355 days leap year[73] and $355 - 15 = 340$.

In the *CCSOP*, Y_m is expressed as the sum of the numbers of *zongnian* (complete year) Y_c and *lingnian* (individual year) Y_i, where

$$Y_c = Y_m \mathit{Div}\ 30,$$

$$Y_i = Y_m \mathit{Mod}\ 30,$$

30 corresponding to 30 lunar years, the intercalation cycle of the *hijra* lunar calendar[74]. Since Y_c and Y_i are the arguments of the most basic tables of the *HHLF* such as the *Ri wuxing zhongxing zongnian licheng* (*Quick table of the mean solar and planetary longitudes for complete years*) and *Ri wuxing zhongxing lingnian licheng* (*Quick table of the mean solar and planetary longitudes for individual years*)[75], the formulation of the results using Y_c and Y_i makes the use of tables more straightforward. The following is the specific procedure for finding Y_c, Y_i, M_m and D_m described in the *CCSOP*:

> Method for calculating the numbers of the complete year, individual year, lunar months and lunar days of each solar month [of a given solar year]: Place [on the counting board] the number of years elapsed since the [TSC] epoch, multiply it by the length of a normal solar year. Add the *zhouying*[76] and the number of solar leap days[77] to the product. Divide the sum by 10631 days and multiply the integer part of the quotient by 30, hence the number of complete years. Divide the remainder of the same division by the length of a lunar year, hence the individual years. Subtract the number of lunar leap days (if any occur during the individual years) from the new remainder, and subtract the number of days of the successive lunar months (30 days for the 1st month, 29 for the 2nd, 30 for the 3rd , and so on). Hence the number of lunar months from the beginning of the lunar year, as well as the number of days from the beginning of the lunar month containing 1 Aries. By successively adding the number of days in each solar month [of the TSC] to the obtained months and days, the lunar months and days for the first day in each solar month are successively obtained[78].

[73] Cf. footnote 71

[74] Cf. footnote 61.

[75] Bei Lin 1477, j. 2, pp. 1a–2b and p. 3ab; Zhang Tingyu et al. 1730, j. 38, pp. 1a–7b; Yi Sunji and Kim Tam (1442), k. 1, pp. 1b–7a.

[76] *zhouying* literally means "the interval constant of the lunar year", referring to the time-interval between the lunar and the solar epochs.

[77] The *CCSOP* (Yi Sunji and Kim Tam 1442, j. 1, p. 12b) uses a new algorithm for calculating the number of solar leap days: "Place the number of solar years (counted from the solar epoch to a given solar year) and add 1 to it. Multiply the result by 31, the intercalation coefficient of the zodiacal signs, and divide the result by 128. The integer part of the quotient gives the number of solar leap days". We can rewrite this algorithm as $d_s = (Y_s + 1) \times 31\ \mathit{Div}\ 128$, where d_s designates the sought number of solar leap days. The difference between this algorithm and the method of the *HHLF* (cf. footnote 68 above) amounts to $\frac{16}{128}$ days, it causes a shift of the order of intercalary solar years, but causes no great difference in the positional calculations of the sun, moon and planets.

[78] Yi Sunji and Kim Tam 1442, k. 1, pp. 12b–13a.

Let

Y_s = the number of solar years occurring between 599 and a given year,
d_s = the number of solar leap days in Y_s years,
Z = the zhouying,
d_i = the number of lunar leap days in the individual years which can be calculated from the intercalation set of the *hijra* lunar calendar.[79]

Then, the above procedure for the calculation of Y_c, Y_i, M_m and D_m of 1 Aries is equivalent to the following set of equations:

$$Y_c = [(Y_s \times 365 + d_s + Z) \, Div \, 10631] \times 30 \tag{3.2.1}$$

$$Y_i = [(Y_s \times 365 + d_s + Z) \, Mod \, 10631] \, Div \, 354 \tag{3.2.2}$$

$$M_m = \{[(Y_s \times 365 + d_s + Z) \, Mod \, 10631] \, Mod \, 354 - d_i\} \, DivMon \tag{3.2.3}$$

$$D_m = \{[(Y_s \times 365 + d_s + Z) \, Mod \, 10631] \, Mod \, 354 - d_i\} \, ModMon. \tag{3.2.4}$$

Furthermore, assuming that each month k ($k = 1, 2, 3, \ldots, 12$) of the TSC contains L_k days, we can represent the procedure for the calculation of the number of lunar months (M_{m+k}) and days (D_{m+k}) of the first day of each solar month as follows:

$$M_{m+k} = M_m + \left(D_m + \sum_{j=1}^{k} L_j \right) DivMon \tag{3.2.5}$$

$$D_{m+k} = \left(D_m + \sum_{j=1}^{k} L_j \right) ModMon. \tag{3.2.6}$$

In Eqs. (3.2.1) to (3.2.4) above, 10631 is the number of days contained in 30 lunar years and Z is said to be equal to 342 at the beginning of the *CCSOP*[80]. Hence, it is quite clear that the lunar epoch here is actually located at the beginning of 25 B.H. because the plus-minus symbol and the value of Z is very close to the coefficient 340 in (3.1.9) to (3.1.12).

No known written source explains how the compilers of the *CCSOP* arrived at the algorithm above. But it is now clear that the algorithm contains an error of 2 days in the calculation of D_m. In addition, another error also occurs in the number of lunar years elapsed from the *hijra* epoch because the extra 25 lunar years have not been subtracted from the sum $Y_c + Y_i$. These two errors obviously result from the ignorance of the exact date of the real *hijra* epoch of the *HHLF*.

We must admit that, despite the two errors mentioned above, the procedure of the *CCSOP* is much clearer, more direct and ingenuous than those of the *HHLF-M* (see appendix below). In particular, its recourse to the 30-year leap-cycle of the *hijra* lunar calendar, which greatly simplified the determination of the number of lunar leap days.

[79] Cf. footnote 66
[80] Yi Sunji and Kim Tam 1442, k. 1, p. 1.

Table 1. Correction constants of the *HHLF* and *CCSOP*

	β_h	β_c
λ_s	$-1'4''$	$266°9'39''$
λ_m	$-14'$	$243°44'$
2η	$-26'$	$315°9'$
φ	$-14'$	$151°$
ω	0	$250°45'$
δ_1	$-3'$	$191°10'$
δ_2	$-1'$	$296°58'$
δ_3	0	$229°58'$
δ_4	$-1'$	$282°46'$
δ_5	$-1'$	$203°1'$

But the most important question is: did these two errors make the *CCSOP* tables unusable? The answer is no, because as I will explain in the next section, the initial errors are eventually cancelled by the modification of various other constants concerning the positional calculations of the sun, the moon and the five planets.

4. The modification of various constants

As can be seen from the *QZTB* and *HHLF-M*[81], various correction constants (β_h in the second column of Table 1) are used by the *HHLF* in the calculations of the

1. mean solar longitude (λ_s),
2. mean lunar longitude (λ_m),
3. double-elongation of the moon (2η),
4. mean anomaly of the moon (φ)
5. mean anomaly of the five planets (δ_i, $i = 1, 2, 3, 4$ and 5, respectively corresponding to Mercury, Venus, Mars, Jupiter and Saturn),
6. retrogradation of Ketu (ω), the ascending node of the moon's path (the longitude of Ketu is calculated as $\rho = 360° - \omega$).

In the *CCSOP*, however, these various constants have been modified as indicated in the third column of Table 1 (β_c). According to Yabuuchi, the constants of the *HHLF* are perhaps the correction factors due to the equation of time[82]. But Benno van Dalen has suggested me that, instead, what is at stake is rather a correction needed in order to account for a difference in geographical longitude between Nanjing and an unknown place where the Persian or Arabic tables were originally composed, a place located approximately $6°.5$ westward from Nanjing. To see is, it suffices to divide the constants for

[81] Bei Lin 1477, j. 1, p. 6a, p. 8a, p. 12; Zhang Tingyu et al. 1730, j. 37, p. 5b, p. 6b, p. 7a, p. 9b.

[82] Yabuuchi 1997, p. 27–28.

the mean solar and lunar longitudes by their respective daily mean motions (the values implicitly used by the *HHLF* are $59'8''$ for the sun and $13°10'36''$ for the moon[83]):

$$(360° \times 1'4'') \div 59'8'' = 6°.4938 \cong 6°.5,$$

$$(360° \times 14') \div 13°10'36'' = 6°.3749 \cong 6°.5.$$

Even so, the new constants of the *CCSOP* are obviously too large to be considered as corrections for either the time equation or a difference in geographical longitude. In fact, I would rather suggest that they can only come from a correction concerning the previously mentioned errors.

To prove this conjecture, let us consider the example of the date 1 Aries of 1432, the year when the compilation of the *CCSOP* began. Since $\mathrm{Y}_s = 1432 - 599 = 833$, we obtain the following values from equations (3.2.1) to (3.2.4) above: $\mathrm{Y}_c = 840, \mathrm{Y}_i = 19$, $\mathrm{M}_m = 6$ and $\mathrm{D}_m = 10$. Then, using the related procedure of the *CCSOP*, we obtain the value of the mean solar longitude at the instant of noon on the day 1 Aries of 1432: $92°26'48''$. Yet the correct value should be around $0°$ because the sun is supposed to enter Aries precisely when its longitude is equal to zero. After adding $266°9'39''$ as listed in the third column and second row of Table 1 to the value above, however, the result becomes $358°35'48''$. From this, the true solar longitude becomes equal to $36'31''$ by simply applying the solar equation as tabulated in the *Taiyang jiajian chafen lichen* (*Quick table of solar equations*)[84].

According to the rules of the *CCSOP* [85] the mean conjunction of the sun and the moon is defined to take place 10 days before 1 Aries 1432. Now let us calculate the solar and lunar longitudes at the instant of noon of this day. Their difference should be less than the difference between the mean daily motions of the moon ($13°11'$[86]) and the sun ($59'8''$[87]), namely, $12°10'42''$.

Applying the same method as above to the calculation of the solar longitude at noon of 1 Aries and again adding the correction of $266°9'39''$, the mean and true solar longitudes at noon 10 days earlier are found to be equal to $348°44'25''$ and $350°42'33''$ respectively. The mean lunar longitude at noon of the day will be $103°36''$ if we do not adopt the correction constant $243°44''$ listed in the third column and third row of Table 1. But the result becomes $347°20'$ when the correction is added. With the correction constants for the double-elongation and the mean anomalies of the moon listed in the same table, we can calculate the true lunar longitude at the same moment and obtain

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[83] Cf. Chen Meidong 1987.

[84] Yi Sunji and Kim Tam 1442, k. 1, pp. 14a–31a.

[85] When calculating the mean solar longitude at the instant of the new moon corresponding to the lunar month to which 1 Aries belongs, Korean astronomers used the following procedure: "place the mean solar longitude of 1 Aries, subtract the changes in mean solar longitude corresponding to the days for 1 Aries (i.e. D_m); the result is the solar longitude corresponding to the day of the new moon." (Yi Sunji and Kim Tam *ca.* 1447, k. 1, p. 13b). This implies that the day of the new moon was defined as D_m days before 1 Aries.

[86] Yi Sunji and Kim Tam 1442, k. 1, p. 39a.

[87] Yi Sunji and Kim Tam 1442, k. 1, p. 8b.

Table 2. Corrections of λ_s, λ_m, 2η, φ and ω at noon of 1 Aries in 1432AD

	θ_1	θ_2	ξ	θ_3	ζ
λ_s	92°26′9″	358°35′48″	93°49′16″	358°36′53″	1′5″
λ_m	235°22′	119°6′	116°2′	119°20′	14′
2η	285°51′	241°	44°26′	241°25′	25″
φ	129°1′	280°1′	208°46′	280°15′	14″
ω	162°49′	53°34′	109°15′	53°34′	0
δ_1	280°37′	111°47′	168°48′	111°49′	2″
δ_2	271°2′	208°	63°1′	208°1′	1″
δ_3	94°51′	324°49′	130°1′	324°50′	1″
δ_4	1°7′	283°53′	77°12′	283°55′	2″
δ_5	211°45′	54°46′	156°58′	54°47′	1″

$344°37'37''$. This result means that the mean conjunction of the sun and the moon would occur about 2 hours and a half after noon, while the true conjunction occurs about 12 hours after noon of the same day.

These two examples clearly indicate that the application of the new constants of the *CCSOP* can in fact bring the calculated longitudes of the sun and the moon from obviously absurd values to theoretically acceptable ones. By analyzing the values of β_c of Table 1, we further notice that the new constants are roughly equal to the changes of λ_s, λ_m, 2η, φ, ω and δ_i in 25 lunar years and 2 days.

The result of this analysis is illustrated in Table 2. In this table, θ_1 represents the values of λ_s, λ_m, 2η, φ, ω and δ_i at the noon of 1 Aries 1432, calculated with the methods of the *CCSOP*, without adding the values of the β_c of Table 1 to the final results; θ_2 represents similar values obtained when β_c is added to the final results; ξ represents the value changes of λ_s, λ_m, 2η, φ, ω and δ_i in 25 lunar years and 2 days, again calculated with the method of the *CCSOP*; lastly $\theta_3 = \theta_1 - \xi$ and $\zeta = \theta_3 - \theta_2$.

It appears that, for each row of data, after θ_1 has been corrected with ξ, the new result θ_3 is very close to the value θ_2 . Moreover, the difference between θ_3 and θ_2 is also very close to the original correction constant of the *HHLF* (β_h in Table 1). In other words, from Table 2, the following relations can be obtained: $\theta_2 = \theta_1 - \xi - \beta_h = \theta_1 + \beta_c$. Therefore $\beta_c = -(\xi + \beta_h)$. The slight differences between β_h and ζ can be accounted for by the approximations used in the computations of the *licheng* (quick tables) and the β_h in the *HHLF*. This result means that the new constants of the *CCSOP* also incorporate the original constants from the *HHLF*.

From the preceding analysis, we realize that by using the new correction constants listed in the third column in Table 1, the compilers of the *CCSOP* have effectively subtracted 25 years and 2 days from Y_m and D_m calculated from Eqs. (3.2.1) to (3.2.4). Thus they actually have moved the original 1 Aries 599 from 13 to 15 Dhu al-Hijja 25 B.H., 15 days before the beginning of the year 24 B.H. This new lunar date for 1 Aries 599 is the same as that of equations (3.1.5) to (3.1.8).

Table 3 shows the longitudes of the sun, moon, planets and Ketu at the noon of 1 Aries 1432, respectively calculated with the methods of the *CCSOP* (expressed as Λ_c)

Table 3. Longitudes of the Seven Luminaries and Ketu at noon of 1 Aries in 1432AD

	Λ_c	Λ_t	$\Delta = \Lambda_c - \Lambda_t$
The Sun	$0°36'31''$	$0°29'17''$	$7'14''$
The Moon	$125°39'36''$	$125°8'49''$	$30'47''$
The Ketu	$306°26'$	$306°35'$	$-9'$
Mercury	$17°6'4''$	$19°13'58''$	$-2°7'54''$
Venus	$319°3'26''$	$317°43'34''$	$1°19'52''$
Mars	$27°7'32''$	$27°9'45''$	$-2'13''$
Jupiter	$69°13'26''$	$69°36'48''$	$-23'22''$
Saturn	$304°10'2''$	$303°11'0''$	$59'3''$

Table 4. Longitudes of the Seven Luminaries and Ketu at noon of 1 Aries in 1910

	Λ_c	Λ_t	$\Delta = \Lambda_c - \Lambda_t$
The Sun	$0°48'17''$	$0°38'28''$	$9'49''$
The Moon	$139°11'4''$	$138°50'28''$	$20'36''$
The Ketu	$61°10''$	$61°5'$	$5'$
Mercury	$345°53'22''$	$346°55'47''$	$-1°2'25''$
Venus	$322°10'22''$	$320°14'20''$	$1°56'2''$
Mars	$66°2'45''$	$64°49'51''$	$1°12'54''$
Jupiter	$190°33'24''$	$190°20'11''$	$13'13''$
Saturn	$24°30'17''$	$25°27'19''$	$-57'4''$

and the relevant formulae of Meeus (expressed as Λ_t)[88]. We have found that the absolute errors in the longitudes of the sun, the moon, Ketu and the three outer planets are less than one degree. From Table 4, we further note that such a level of accuracy remained almost unchanged even until the end of the Chosôn Dynasty in 1910[89], especially for the longitudes of the sun, the moon and Ketu. This may explain why the *CCSOP* had been used by Korean astronomers for predicting solar and lunar eclipses for more than 400 years.

It seems strange to us how the compilers of the *CCSOP* realized that they could obtain correct results by merely adding some new constants to those of the *HHLF*. Considering the time spent by them on completing this book (ten years in all), one can imagine the painstaking work they had done for determining the new corrections.

[88] According to modern theoretical calculation, the noon of 15 Dhu al-Hijja 25 B.H. corresponds to the Julian Day 1939920.6473 at Seoul, capital of the Chosôn Korea. Since the time-interval between 1 Aries 599 and 1432 is equal to $365 \times (1432 - 599) + d_s$ days and $d_s = [(1432 - 599 + 1) \times 31]$ *Div* 128, the Julian Day of noon of 1 Aries 1432 can be determined from the sum 1939920.6473 + 304045 + 201. The result is 2244166.6473 and corresponds to 12:00 p.m. 12 March 1432 at Seoul. The theoretical values of Table 3 are calculated using this date.

[89] To calculate the Julian Day of 1 Aries 1910, it suffices to add $365 \times (1910 - 1432) + [(1919 - 1432 + 1) \times 31]$ *Div* 128 days to 2244166.6473. The result is Julian Day 2418752.6473, corresponding to local time 12:00 p.m. 22 March 1910.

5. The star catalogue

An Islamic catalogue of 277 stars entitled *Huangdao nanbei gexiang neiwai xing jingweidu licheng* (*Quick table of longitudes and latitudes of the stars lying inside and outside northern and southern ecliptic constellations*) appears in both Bei Lin's *QZTB*[90] and the *CCSOP*[91] (the *HHLF-M* contains no such catalogue).

The catalogue lists the longitudes, latitudes and magnitudes of 277 stars, designated under Chinese names. Its interest is great for it provides "entirely new material"[92] for the study of Islamic astronomy. It also constitutes the earliest star catalogue presenting Islamic constellations in a Chinese context. Despite its conspicuous importance, however, no unanimity has so far been reached on the answer to the most basic question: when and where were the stars in the catalogue observed and tabulated? Yabuuchi thought that it was *ca*. 1391 but at an unknown place[93]. On the contrary, Pan Nai asserts that the star catalogue derives from an unknown earlier Arabic or Persian version compiled outside China by simply adding the precession correction to original coordinates[94]. In his turn, Chen Jiujin claims that the star coordinates were directly observed by official Muslim astronomers of the early Ming court[95].

In fact these different views are mainly caused by different interpretations of a two-lines-in-one note[96] inserted below the title of the *CCSOP* catalogue by an unknown author. This controversial text reads as follows:

> Four extra minutes should be added to the longitude of each star every five years. In the [sexagesimal] year *bingzi* [no. 13 of the sexagesimal cycle] of the *Hongwu* era [1396] the number of years [elapsed since the epoch] is equal to 798 and that is why 4 minutes have already been added. With the [sexagesimal] year *xinsi* [no. 18 of the sexagesimal cycle] [1401], the number of years amounts to 803, and 4 more minutes should be added. Adding these repeatedly every 5 years, eternity is reached.[97]

Three different interpretations of this passage have been propounded:

(1) Yabuuchi Kiyoshi's interpretation: The longitudes of the star catalogue are not observed values, but values augmented 4 minutes every 5 years, or 48 seconds per year, in accordance with precession. Since "4 minutes have already been added at the occasion of the [sexagesimal] year *bingzi* of the *Hongwu* era (1396)", it can be conjectured that the observations took place five years earlier, i.e. in 1391. Furthermore, a chronological examination of the longitudes of some stars of the catalogue shows that the stars were observed around 1365. This result is by no means incompatible with the date of the two-lines-in-one note, provided that an error level of 20 minutes in the observations is accepted. Yabuuchi also adds that "because of the

[90] Bei Lin 1477, j. 6, pp. 27a–42b.
[91] Yi Sunji and Kim Tam 1442, k. 5, pp. 54a–79b.
[92] Yabuuchi 1997, p. 38.
[93] Yabuuchi 1997, p. 39.
[94] Pan Nai 1989, p. 366–371.
[95] Chen Jiujin 1996, pp. 134–141.
[96] A note printed in smaller fonts than the text.
[97] Yi Sunji and Kim Tam 1442, k. 5, p. 54a.

disagreement with Ptolemy's star catalogue from the point of view of the ecliptic [latitudes], the star table in the *QZTB* and the *CCSOP* should be considered to be the result of new observations at the end of the 14th century. Whether these observations were carried out in China, or the *Huihui li* reproduces an Islamic star table which had been transmitted to China after the introduction of the dust-board methods in the year 18 of the *Hongwu* era, cannot be decided."[98]

(2) Pan Nai's interpretation: Under the extreme social chaos of the late Yuan dynasty, there was little possibility for the Islamic observatory in China to make systematic observations for the compilation of a star catalogue. Even in the early Ming period, conditions were still not satisfactory because the Bureau of Astronomy of the early Ming dynasty was equipped with out of date instruments inherited from the Yuan dynasty, which were originally designed for the latitude of Beijing and graduated with equatorial coordinates only and not with ecliptic coordinates like those of the Islamic star catalogue. Therefore, the star catalogue "was necessarily produced outside of China and incorporated in some Islamic astronomical treatises, brought eastward by a 'distant foreigner' and eventually presented to the Chinese court. [...] As for the so-called 'longitudes of the year *Hongwu* 24', I feel that certain results were also derived from calculations made around 1391" because "it seems unreasonable to believe that supplementary observations of fixed stars were made after the dust-board system of calendrical astronomy had been imported and the *Huihui lifa* compiled."[99]

(3) Chen Jiujin's interpretation: "Judging from the fact that Madeluding (Mashayihei's father) and Mashayihei once made astronomical observations in Nanjing and the family was thus bestowed the honorific title of *Dacetang* (Great observation hall) by the emperor Zhu Yuanzhang, it is evident that they had sufficiently good conditions to make the observations necessary for the compilation of the star catalogue [of the *HHLF*]. Therefore we can definitely assert that the coordinates of the star catalogue were observed by Mashayihei" in the early Ming dynasty[100].

If conditions suitable for astronomical observations were really met with at the beginning of the Ming dynasty, Chen Jiujin's interpretation would be the most plausible. Since it is widely believed, however, that no systematic construction of astronomical instruments was undertaken in the early Ming dynasty, before the capital was moved from Nanjing to Beijing, few scholars believe that serious astronomical observations were then really conducted at the Ming Bureau of Astronomy. Still, Chen Jiujin has found a record in an anonymous book named *Qingzhen shiyi buji* (Supplementary Edition of Analysis of Some Questions about Islamic Religion), indicating that, on the order of Zhu Yuanzhang, the first Ming emperor, Mashayihei had "constructed an armillary sphere to check the correctness of past astronomical observations, and was thus promoted to the position of *Kelou boshi* (Clepsydra Doctor)." The same book also adds that " Mashayihei eventually composed a treatise in several volumes entitled *Faxiang shu* (Book on Astronomical Instruments)". However, the reliability of Chen Jiujin's source is somewhat

[98] Yabuuchi 1997, p. 39.
[99] Pan Nai 1989, p. 366–371.
[100] Chen Jiujin 1996, p. 134–141.

suspicious even in the eyes of Chen Jiujin himself, because the *Qingzhen shiyi buji* was written in the late 19th century[101].

To resolve this problem, the author of the present article has reinvestigated the early history of the Ming Bureau of Astronomy and discovered the following materials related to the construction of astronomical instruments during the *Hongwu* Period:

A. On the [sexagesimal] day *bingwu* (no. 43 of the sexagesimal cycle) of the seventh month of the year *Hongwu* 17 (28 July 1384), "a *Guanxingpan* [star-observing plate] was constructed at the Bureau of Astronomy"[102]. Another source also indicates that "the [Ming] Bureau of Astronomy has a *pan* [plate] for star-observation [*guanxing*], which was constructed in the year *Hongwu* 17."[103]
B. "A *Huntianyi* [armillary sphere] has been constructed on the [sexagesimal] day *wuchen* [no. 5 of the sexagesimal cycle] of the forth month of the year *Hongwu* 24 [15 May 1391]."[104]
C. "In the eleventh month of the year *Hongwu* 29 [1 to 30 December 1396], the emperor ordered the construction of a *Huntianyi* [armillary sphere]." [105]

It is obvious that the *Guanxing pan* in A is not a traditional Chinese instrument, because, so far, nobody has been able to find any record of such a star-observing instrument, shaped like a plate, possibly made by a Chinese astronomer before the Ming period. Therefore, we can safely assert that the *Xingpan* in question should be some sort of Islamic astrolabe. As for the two armillary spheres mentioned in B and C, it is highly possible that one of them was of Islamic type[106] because the Ming Bureau of Astronomy had no need to build simultaneously *two* armillary spheres of the same type at a great cost. More interestingly, as the following chronology shows, the construction of the three instruments has a clear chronological connection with the history of Islamic astronomy, especially in the case of the *HHLF* and its star catalogue:

Hongwu 17 (1384)	– compilation of the *HHLF*.
Hongwu 24 (1391)	– the Islamic catalogue is supposed to have been observed according to the two-lines-in-one note of the *CCSOP*.
Hongwu 29(1396)	– the Islamic catalogue is supposed to have been corrected according the two-lines-in-one note in the *CCSOP*.

[101] Chen Jiujin 1996, p. 119.

[102] Xia Yuanji et al. 1418, j. 163, p. 2a. *Ming dazheng cuanyao* (Tan Xisi 1619, j. 7, p. 6b) also records the event, but gives a different date: the leap month eleven of the year *Hongwu* 17 (14 November to 12 December 1384).

[103] Xu Pu 1502, j. 176, p. 2a.

[104] Xia Yuanji et al. 1418, j. 208, p. 4b; Tan Xisi 1619, j. 9, p. 10b. *Huntianyi* is a generic term designating all sorts of armillary spheres.

[105] Xu Xueju 1601, j. 72, p. 5b. *Ming dazheng cuanyao* (Tan Xisi 1619, j. 10, p. 19b) also record: "In the eleventh month of the year *Hongwu* 29, [the Bureau of Astronomy] constructed a *Huntianyi*".

[106] An Islamic armillary sphere usually bears ecliptic coordinates, whereas a Chinese one usually bears equatorial coordinates.

This chronological proximity between the compilation of the *HHLF* and the related star catalogue cannot merely be a coincidence. It enables us to combine all available fragments and tentatively to reconstitute the following fragmentary scenario:

(a) Since a star catalogue is indispensable in predicting such special heavenly phenomena with astrological significance as the occultation of fixed stars by the moon and the five planets (one of the main motivations at the root of the compilation of the *HHLF*)[107], there must have existed a star table in the first edition of the *HHLF* directly translated from some earlier Islamic source. However a mere translation would have revealed discernible errors. Therefore, a new astrolabe was built in 1384, during the compilation of the *HHLF*. It was intended to re-observe the star positions of the tables. Still, the precision of the new observations was not satisfactory because the astrolabe was too small to guarantee a sufficient accuracy.
(b) In order to get more exact results, a new Islamic armillary sphere was constructed in 1391; and another star table with a better precision was thus established.
(c) Five years later, in 1396, in an attempt to measure the positions of the stars of Chinese constellations, astronomers of the Ming Bureau of Astronomy constructed a Chinese armillary sphere. In response, the Islamic astronomers of the same Bureau also edited a new Islamic star table on the basis of a precession correction of the second table, thus producing the final copy of the Islamic star table of the *CCSOP*. According to the precession rule of the *CCSOP*, the needed correction had to be implemented precisely in 1396. Meanwhile, the date of the next correction, that of the [sexagesimal] year *xinsi* (no. 18 of the sexagesimal cycle)(1401), was designated in advance[108].
(d) Since the completion of the final version of the star catalogue did not coincide with that of the *HHLF*, it follows that it was in no way imported to Korea together with the *HHLF* but very likely with Liu Xiu's *Xiyu lifa tongjing*, which was composed after 1396.

6. Conclusion

(1) The Korean adaptation of Chinese-Islamic astronomical tables is based on more than a single Chinese source. Apart from the *HHLF* edited *ca.* 1438, the *Xiyu lifa tongjing* compiled by Liu Xin in the first half of the fourteenth century is one of its important sources as well.
(2) The purpose of the Korean translation was not merely theoretical but also practical: from 1442 onwards, official Korean astronomers applied the *CCSOP* techniques for

[107] Chen Jiujin 1996, pp. 125, 130 and 140.
[108] If the notes were added after the [sexagesimal] *xinsi* year, the title of the Emperor at the time, namely, Yongle (reigning from 1403 to 1424) rather than that of the first emperor Hongwu who died in 1398, should be attached to the name of this year, and the content of the notes should become "the [sexagesimal] year *xinsi* of the *Yongle* era", just as the earlier year was "the [sexagesimal] year *bingzi* of the *Hongwu* era".

eclipse predictions during more than four hundred years. Hence it was in Korea that the Chinese-Islamic astronomical tables survived for the longest period.

(3) Given that the astronomical tables of the *HHLF* follow the *hijra* lunar calendar but with computations using an underlying solar calendar, the problem of the determination of the time interval between the lunar epoch and a given day in the solar calendar was fundamental for practical purposes. But the original compilers of the *HHLF* failed to present a solution of the problem. Consequently, astronomers who had no knowledge of the epoch of the *hijra* lunar calendar could not use these tables. It remains that the *HHLF* was intensively studied by astronomers such as Liu Xin and Bei Lin but, before the sixteenth century, few Chinese scholars, if any, ever solved the problem. On the contrary, in their *CCSOP*, Korean astronomers independently noticed the severe incompleteness of the *HHLF* and succeeded remarkably well in resolving the problem. Still, the procedure they propounded contains errors, because they also were unaware of the exact date of the *hijra* epoch, but otherwise it was logical, simple and clear. More importantly, using a technique of readjustment of various astronomical constants concerning the mean motion of the sun, moon and planets they remedied these errors satisfactorily. These variations indicate that the *CCSOP* is not a mere reorganization of the texts and tables of the *HHLF* but rather a readjustment and revision of the tables to remove the obstructions for their practical application.

(4) We have found that the star catalogue of the *CCSOP* was most probably first translated around 1384 from an unknown Islamic (Arabic, Persian, or other) source and revised *ca.* 1391 on the basis of observations. Another revision taking precession into account was implemented in 1396 but after that date the table remained unchanged and was finally exported to Korea together with Liu Xin's *Xiyu lifa tongjing*. This provides another evidence that the *CCSOP* was not only based on the *HHLF* but also on other Chinese sources.

Appendix: The algorithms called *jiaci fa*[109]

The two algorithms of the *HHLF-M* for calculating the time-interval between the *hijra* epoch and a given day in the TSC are called *jiaci fa* (the method of *jiaci*), where the time-interval is also expressed in terms of $\mathrm{Y}_m + \mathrm{M}_m + \mathrm{D}_m$.

Mei Wending, a Chinese astronomer in the early Qing dynasty, has given a reasonable explanation of the meaning of the technical terminology "*jiaci*": when the number of solar years (Y_s) between a given day and the TSC epoch is known, the corresponding number of *hijra* lunar years (Y_m) is calculated by simply adding a number of *hijra* lunar years to Y_s. This added number is called "*jiaci*"[110].

The two algorithms of the *HHLF-M* are as follows (the words in parentheses are two-lines-in-one notes in the original text, while those in the square brackets are added by myself):

[109] Dr. Benno van Dalen kindly made his unpublished manuscript on this problem available to me during my study, which gave me many inspirations.

[110] Mei Wending 1703, bk. 1, pp. 7b–9a.

Method of calculating the additional number [of lunar years]: Place the number of days between the TSC epoch and the given day (which is the numerical sum of the normal and leap days [of the solar years elapsed since the TSC epoch]). Subtract from it the number of leap days of the *hijra* lunar years [elapsed since the same epoch]. Add to the result 331 days (which is the number of days before the day of vernal equinox of the year *jiwei* [of *Kaihuang* era, namely 599, counted from the beginning of the corresponding lunar year]), and divide the sum by 354 (the length of a [lunar] year). Subtract from the remainder of the division first the previously added 331 days. Then subtract successively from the new result 23 (the number of days that would make up a full lunar year if 331 days was added to it), 24 (the *jiaci* of the [sexagesimal] year *jiazi* of *Hongwu* era [1383]) and 1 (a subtracted day caused by the change of epoch). The result is the actual number of the lunar years (between the [sexagesimal] year *jiwei* of *Kaihuang* era and the given day). [...]

Another algorithm: Place the number of seasonal accumulation (sum up the leap days and the general leap days [of the solar years elapsed since the TSC epoch], you get the number of seasonal accumulation). Subtract from it the corresponding number of lunar leap days (place 11, multiply it by the number solar years [elapsed since the TSC epoch], add 14 to the product and then divide the result by 30, hence the corresponding number of lunar leap days). Divide the result by 354 and subtract from the quotient 24, i.e. the *jiaci* of [the sexagesimal year *jiazi* of] *Hongwu* [era]. Then subtract from the new result 23 days [that would make up one lunar year if 331 days was added to it] and the subtracted 1 day caused by the change of epoch. Hence the same result as can be obtained from the previous method. (To calculate the general leap days, place 11, multiply it by the number of solar years [between the TSC epoch and the given day]. As for the calculation of the leap days of the solar years [elapsed since the TSC epoch], cf. the previously mentioned method.)[111]

This description is very confusing. But by using the same symbols as those of Eqs. (3.1.5) to (4.2.12) above, we can rewrite the first method as follows:

$$\mathrm{A} = \mathrm{Y}_s \times 365 + \mathrm{d}_s + \mathrm{D}_s - \mathrm{d}_m + 331 \tag{6.1.1}$$

$$\mathrm{B} = (\mathrm{A}\ \mathit{Mod}\ 354) - 331 - 23 \tag{6.1.2}$$

$$\mathrm{Y}_m = \mathrm{A}\ \mathit{Div}\ 354 - 24 \tag{6.1.3}$$

$$\mathrm{M}_m = (\mathrm{B}\ \mathit{Mod}\ 354)\ \mathit{DivMon} \tag{6.1.4}$$

$$\mathrm{D}_m = (\mathrm{B}\ \mathit{Mod}\ 354 - 1)\ \mathit{ModMon}. \tag{6.1.5}$$

Here, $\mathrm{Y}_s \times 365 + \mathrm{D}_s$ and d_s are the numbers of the normal and leap days, respectively, of the solar years elapsed since the solar epoch. It is not difficult to see that these equations contain at least five illogical and even mistaken points:

I. According to the text, d_s is calculated with "the previously mentioned method". But we cannot find any word about this calculation either in the *HHLF-M*, or in Bei Lin's *QZTB*. The correct method should be what we introduced in footnote 68 above.

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111 Zhang Tingyu et al. 1730, bk. 37, p. 4b.

II. Since the result of A *Mod* 354 in (6.1.2) is obviously less than 354 days, we cannot subtract another (331+ 23) days from it.

III. In the two-lines-in-one note to the second method, d_m is said to be calculated from $(Y_s \times 11 + 14) \div 30$. But according to the intercalation rule of the *hijra* lunar calendar (cf. footnote 69 above), $(Y_m + 24)$ should be used here instead of Y_s. However, this will give rise to another problem, namely, for the time being Y_m is not known yet.

IV. The two-lines-in-one note of the two methods indicates that the number 24 in (6.1.3), or 24 outside the square brackets in (6.1.6), is the "*jiaci* of the [sexagesimal] year *jiazi* of *Hongwu* era (1384)". This is incorrect. In fact, the origin and function of this value is the same as the number 24 in (3.1.6).

V. The number 24 in the square brackets of Eqs. (6.1.6) to (6.1.9) is actually the time-interval between 1 Aries 599 to 1 Muharram 24 B.H.. But it is 9 days longer as compared to the correct value, namely the 15 days in Eq. (3.1.5).

The reader may have realized that what we obtain from Eqs. (6.1.4) or (6.1.6) is not the so-called "*jiaci*" (additional number of lunar years), but the number of lunar years between the *hijra* epoch and the given day. In the second method, however, the *jiaci* is calculated first. Let Y_a represent the number of the *jiaci*, we can express this method as follows:

$$E = (31 \times Y_s + 15)\ \mathit{Div}\ 128 + 11 \times Y_s - d_m \tag{6.2.1}$$

$$Y_a = E\ \mathit{Div}\ 354 - 24 \tag{6.2.2}$$

$$Y_m = Y_a + Y_s \tag{6.2.3}$$

$$M_m = (E\ \mathit{Mod}\ 354 - 23 - 1)\ \mathit{DivMon} \tag{6.2.4}$$

$$D_m = (E\ \mathit{Mod}\ 354 - 23 - 1)\ \mathit{ModMon}. \tag{6.2.5}$$

Here $(31 \times Y_s + 15)$ *Div* 128 and $11 \times Y_s$ respectively correspond to the leap days and general leap days of the solar years elapsed since the TSC epoch. The latter stems from the difference between the lengths of the solar and lunar years: $365 - 354 = 11$. This method is simpler than the first one, but the problems mentioned above in points I, III, IV and V still remain here.

Obviously, the *jiaci* methods were not invented by the Muslim compilers of the *HHLF*, because there was little possibility for them to commit to the mistakes and illogicalities above. Then who is the inventor?

The clue comes perhaps from the Qing scholar Li Zhaoluo (1769–1841), who had in his possession a manuscript of twelve chapters on mathematics and calendars written by Tang Shunzhi (1507–1560), an astronomer of the late Ming dynasty famous for his study of the *Huihui lifa*[112]. In a colophon to this manuscript, Li Zhaoluo notes that the manuscript contained a paper named *Huihui lifa yi* (A Discourse of the *Huihui lifa*), in which "the *jiaci* method is the genuine secret key (to the use of the *HHLF*)"[113]. This implies

[112] Ruan Yuan 1799, j. 29, pp. 357–359; Chen Jiujin 1996, pp. 258–261.
[113] Li Zhaoluo 1878–1882, bk. 6, pp. 6ab.

that the *jiaci fa* was propounded by Tang Shunzhi. Unfortunately, this manuscript has now been lost for a long time. We cannot find it even in Ma Mingda and Chen Jing's recent book that collects extensively source materials relating to the *HHLF*[114].

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[114] Ma Mingda and Chen Jing 1996, pp. 741–762.

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Glossaries

Names of persons

1/ ancient

Bei Lin, 貝琳
Chông Ch'o, 鄭招
Chông Hûmji, 鄭欽之
Chông Inji, 鄭麟趾
Guo Shoujing, 郭守敬
Huang Kuan, 黃寬
Huang Zongxi, 黃宗羲
Kim Tam, 金淡
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Li Zhaoluo, 李兆洛
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Liu Zhongfu, 劉仲孚
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Tang Shunzhi, 唐順之
Wang Shidian, 王士點
Wu Bozong, 吳伯宗
Wu Renchen, 吳任臣
Xia Yuanji, 夏原吉
Xu Ang, 徐昂
Xu Pu, 徐溥
Xu Xueju, 徐學聚
Xu Youzhen, 徐有貞
Yi Kungik, 李肯翊
Yi Sunji, 李純之
Yuan Tong, 元統
Zhang Mao, 張懋
Zhang Tingyu, 張廷玉
Zhu Yuanzhang, 朱元璋

2/ modern

Chen Jing, 陳靜
Chen Jiujin, 陳久金
Chen Meidong, 陳美東
Huang Yilong, 黃一農

Il-Seong Nha, 羅逸星
Jeon Sang-woon, 全相運
Lee Eun-Hee, 李銀姬
Ma Mingda, 馬明達
Nakayama Shigeru, 中山茂
Pan Nai, 潘鼐
Shi Yunli, 石云里
Yabuuchi Kiyoshi, 藪內清

Technical and other terms

aerbi, 阿爾必
chengdelang, 承德郎
fancha, 汎差
guanxing, 觀星
guanxingpan, 觀星盤
Hongwu, 洪武
huntianyi, 渾天儀
jiaci fa, 加次法
jiazi, 甲子
jidu, 計都
jiwei, 己未
juan, 卷
Kaihuang, 開皇
kwon, 卷
licheng, 立成
lingnian, 零年
luohou, 羅喉
Make, 馬可
pan, 盤
renwu, 壬午
siyu, 四餘
Wude, 武德
xiaguan zheng, 夏官正
xinsi, 辛巳
Yongle, 永樂
yuebei, 月孛
zhouying, 周應
ziqi, 紫氣
zongnian, 總年

Book titles

Ch'ilchông san naep'yôn, 七政算內篇
Ch'ilchông san naep'yôn chôngmyonyôn kyosik karyông, 七政算內篇丁卯年交食假令
Ch'ilchôngsan oeap'yôn, 七政算外篇
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Chega yoksang jip, 諸家曆象集
Chosôn wangjo sillok, 朝鮮王朝實錄
Chouren zhuan, 疇人傳
Chūgoku no tenmon rekihō, 中國 天文曆法
Daming taizu gaohuangdi shilu, 大明太祖高皇帝實錄
Daming xianzong chunhuangdi shilu, 大明憲宗純皇帝實錄
Daming yingzong ruihuangdi shilu, 大明英宗睿皇帝實錄
Datong li, 大統曆
Datong lifa tonggui, 大統曆法通軌
Datong liri tonggui, 大統曆日通軌
Faxiang shu, 法象書
Gudai Chaoxian Xuezhe de shoushili yanjiu, 古代朝鮮學者的授時曆研究
Guochao dianhui, 國朝典彙
Han'guk kwahak kisulsa charyo taegye: Ch'ônmunhakp'yôn, 韓國科學技術史資料大系 天文學篇
Huangdao nanbei gexiang neiwai xing jingweidu licheng, 黃道南北各像 內外 星經緯度立成
Huihui lifa, 回回曆法
Huihui lifa yi, 回回曆法議
Huihui tianwenxueshi yanjiu, 回回天文學史研究
Jiaoshi tonggui, 交食通軌
Jiuzhou xuekan, 九州學刊
Kaikai riki kai, 回回曆解
Kangxi Anfu xianzhi, 康熙安福縣志
Lisuan quanshu, 曆算全書
Ming Dazheng cuanyao, 明大政纂要
Ming huidian, 明會典
Ming shi, 明史
Ming shilu, 明實錄
Mishujian zhi, 祕書監志
Qingchao qintianjian zhong geminzu tainwenjia de quanli qifu, 清朝欽天監中各民族天文家的權力起伏
Qingchu tianzhujiao yu huijian tianwenjia jian de zhengdou, 清初天主教與回教天文家間的爭鬥
Qingzhen shiyi buji, 清真釋疑補輯
Qiu gongfen runri, 求宮分閏日
Qiu yuefen runri, 求月分閏日
Qizheng tuibu, 七政推步
Ri wuxing zhongxing lingnian licheng, 日五星中行零年立成
Ri wuxing zhongxing zongnian licheng, 日五星中行總年立成
Sejong sillok, 世宗實錄
Shoushi li, 授時曆
Siku caijin shumu, 四庫採進書目
Siku quanshu, 四庫全書
Siyu tonggui, 四餘通軌
Sôun'gwanji, 書云觀志
Taiyang jiajian chafen licheng, 太陰加減差分立成
Taiyang tonggui, 太陽通軌
Taiyin jingdu zongnian licheng, 太陰經度總年立成
Taiyin tonggui, 太陰通軌
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Wuan lisuan shuji, 勿菴曆算書記
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Yôllyôsil kisu, 燃藜室記述
Yue wuxing fancha licheng, 月五星汎差立成
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