though certainly not devoid of sensibility, Kangxi's policy towards the Jesuits, as towards most other matters, was overwhelmingly dictated by sense.

* * *

A historian, rather than siding with one of two parties of a quarrel, and passing moral judgment on the other, will see in all that I have discussed evidence of the complexity of the Jesuits' situation in China. Here the conflicts of loyalties on the European side — in Pereira's case, to his country and to his religious order — have been emphasised. Other elements are needed to fully grasp this complexity. In particular, the tensions between the Chinese and their Manchu rulers need to be taken into account.

Further, a historian of science, rather than blame those whom they see as having prevented the glorious progress and diffusion of science — represented here by the work of Verbiest and the French Jesuits —, will conclude, I hope, that Pereira's life and career, and above all his attitude towards the sciences highlight the political, social and cultural intricacies in which the sciences, their developments and their circulation, are inevitably caught — as is the case with all human activity.

THE *YUZHI LIXIANG KAOCHENG HOUBIAN* IN KOREA

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1. Introduction

In 1742, a new canonical book on calendrical astronomy was completed at the Beijing Bureau of Astronomy under the directorship of Ignatius Kögler (1680–1746) and Andre Pereira (1689–1743). The book was entitled the *Yuzhi lixiang kaocheng houbian* 御製曆象考成後編 (*Later Volumes of the Thorough Investigation of Calendrical Astronomy Imperially Composed*, hereafter LKH), named after the famous *Yuzhi lixiang kaocheng* 御製曆象考成 (*Thorough Investigation of Calendrical Astronomy Imperially Composed*, hereafter LK), another canon of official astronomy of the Qing dynasty published about twenty years earlier. The new book comprised ten *juan*, which can be divided into three major parts, in the same way as the LK. The first part, *juan* 1 to 3, is the "theoretical"[1] section devoted to the so-called *shuli* 數理, or mathematical principles, wherein the motions of the sun and the moon as well as the process of their eclipses are demonstrated to reveal the underlying principles for practical calculations. The second part, *juan* 4 to 6, is the "practical" section devoted to so-called *bufa* 步法 or computational methods, wherein two sets of different but identically functioning methods are given for the predictive calculations of the sun, the moon and lunar and solar eclipses: firstly a set of algorithms derived from the principles explained in the first part of the book, and then the procedures based on pre-calculated tables. The third part, *juan* 7 to 10, contains the pre-calculated tables needed in the second set of methods introduced in the "practical" portion.

The most outstanding feature of the new book is that it includes some elements of Newton's astronomy, namely (1) Newton's value for the length of a tropical year; (2) all the equations of the moon included in Newton's *Theory*

[1] In this article, I propose a dichotomy between the techniques (or technical aspect) and theories (or theoretical aspect) of calendrical astronomy in the following way: while techniques refer to the algorithms for concrete calculations, theories denote the underlying principles of these algorithms, especially the demonstrations, with geometrical models if needed, of various motions and processes involving the sun, the moon and the five major planets.

of the Moon's Motion (hereafter TMM); (3) the procedures for calculating these equations except that for calculating the equation of center of the moon; (4) lunar tables that rely on these equations. As an indispensable basis of Newton's astronomy, the first two laws of Kepler are adopted to describe the motions of the sun and moon, while Kepler's equation and some of its approximate solutions are also introduced in great detail and applied in practical calculations.

Besides, various important results obtained by Gian Domenico Cassini (1625–1712) are also incorporated in the book with clear acknowledgement of his name, including (1) his value of the ecliptic obliquity, (2) his theory and table of atmospheric refraction, (3) his method for measuring the solar parallax and the measured result, and (4) his procedures for the calculations of eclipses and the related tables. In short, the LKH was equipped with the most up-to-date achievements of contemporary Europe in predictive astronomy related to the positional calculation of the sun and the moon.[2]

Since the book took advantage of such important European achievements from Kepler to Newton's time, positional astronomy of the sun and moon thus witnessed a very remarkable advancement: as compared with the theory of the LK, the precision of the positional calculation of the sun improved more than ten times, whereas the lunar theory became over four times more accurate in longitudinal calculation and nearly ten times more accurate in latitudinal calculation, which directly laid down a sound foundation for the improvement of the predictive calculation of solar and lunar eclipses.[3]

Although the new book was adopted together with the LK as the infrastructure of Qing official astronomy, its reception among literati and astronomers

[2] For the compilation of and the new knowledge in the LKH, see Hashimoto Keizô 橋本敬造, Daenhô no tenkai. Rekishô kôsei kôhen no naiyô ni tsuite 楕円法の展開——《曆象考成後編》の内容について (The Development of elliptical Methods. On the contents of the *Later Volumes of the Established System of Calendrical Astronomy*), *Tôhô gakuhô* 東方學報 (Journal of Oriental Studies), vol.42 (1971), pp.245–272; Lu Dalong, *Guimao yuan Calendar* (1742–1911) and Isaac Newton's Theory of the Moon's Motion, in Celina A. Lértora Mendoza *et al.*, *The Spread of the Scientific Revolution in the European Periphery, Latin America and Eastern Asia, Proceedings of the XX^th International Congress of History of Science* (Liège, 20–26 July 1997), Volume V, Turnhout, Belgium: Brepols Publishers, 1999, pp.169–179; Han Qi, "The Compilation of the *Lixiang kaocheng houbian*", in Luis Saraiva (ed.), *History of Mathematical Sciences: Portugal and East Asia II*, Lisboa: EMAF-UL, 2001, pp.147–152; Shi Yunli and Xing Gang, "The First Chinese version of the Newtonian Tables of the Sun and the Moon", in Chen, K-Y., Orchiston, W., Soonthornthum, B., and Strom, R. (eds.), 2006, *Proceedings of the Fifth International Conference on Oriental Astronomy*, Chiang Mai: Chiang Mai University, 2006, pp.91–96.

[3] Shi Yunli 石云里, "Lixiang kaocheng zhong de zhongxincha suanfa ji qi ri yue lilun de zongti jingdu 曆象考成中的中心差算法及其日月理論的總體精度" (The calculation of the equation of center in the *Later volumes of the thorough investigation of calendrical astronomy* and the accuracy of its theory of the sun and moon), *Zhongguo keji shiliao* 中国科技史料 (China historical materials on science and technology), 24 (2003), pp.132–146.

outside the Bureau of Astronomy was not without problem. The most important issue incurred was the incoherence between the geometrical models applied in the two books: while a combination of circular motions was adopted in the LK for the description of the motions of the sun, the moon and the five planets, the schemes employed in the LKH for the description of both solar and lunar motions were elliptic orbits. The issue became even more unsettled after the French Jesuit Michel Benoist (1715–1774) openly suggested in his *Diqiu tushuo* 地球圖說 (*Explanation of the World Map*, presented to the throne in 1760 and published outside the court in 1799) that the heliocentric scheme was a more reasonable arrangement of the celestial bodies. To the leading Chinese minds of the time, the inconsistency of the Jesuit astronomers in cosmological models convincingly disproved the reliability of the Western approach of astronomical studies. They thus concluded that the right way of pursuing astronomy was not to study the true arrangement of the celestial bodies and the shape of their orbits as the Western astronomers did, but only to observe the heavenly motions in order to achieve accurate techniques of calculation.[4] In other words, the issue of inconsistency determinately changed the Chinese understanding of astronomy as a science — both its goal and its methodology.

Since the LKH was very soon introduced into Korea, where the LK had long been officially promulgated as well, it is very interesting to see how Korean astronomers responded to the new book. Did they notice the same issue as their Chinese counterparts did? If so, what would their response be? This paper gives a review of the Korean reception of the book in an attempt to answer these questions. In general, I would like to present the paper both as a case study of the indirect circulation of Western learning in East Asia, *i.e.* the circulation through books from China, and as a comparative study of the reception of the Western learning in different countries of the same area.

2. The Transmission of Western Astronomy from China to Korea

In most periods up to the twentieth century, the Chinese social and cultural systems were taken as models by Korean rulers. As in China, every Korean dynasty set up its own institution in charge of astrological, calendrical and time-keeping service for the king. This institution played a very important role in traditional Korean society. For this reason, astronomy became a highly developed field of knowledge.

[4] Shi Yunli 石云里 and Lü Lingfeng 吕凌峰, "Cong 'gouqiu qigu' dao 'danqiu wubi': shiqi-shiba shiji Zhongguo tianwenxue fazhan de yitiao guiji 从'苟求其故'到'但求'无弊': 17–18 世纪中国天文学发展的一条轨迹" (From "While Seeking for the Reasons" to "Only Seeking to be Blameless": A Trajectory of the Development of Astronomical Thought in Seventeenth and Eighteenth Century China), *Kexue jishu yu bianzhengfa* 科学技术与辩证法 (Science, Technology and Dialectics) 2005, 1: 36–40.

Rulers and astronomers were always very keen to learn astronomy from China. At latest from the sixth century on, Chinese astronomy was introduced into Korea with eagerness and had very profound impact on the development of science and civilization in Korea.[5]

In 1603, a world map published by the Jesuit missionary Matteo Ricci (1552–1610) in Chinese was brought back to Korea from Beijing by Yi Kwang-jŏng 李光庭, a diplomat.[6] In the notes printed around the map, basic knowledge of astronomy from Europe such as the structure of the universe according to the Ptolemaic model, the sphericity of the Earth, the sizes of different celestial spheres and bodies, as well as the reason for lunar and solar eclipses, was presented with simple illustrations.[7] Response to this knowledge soon appeared in a book by Yi Su-gwang 李晬光 (1563–1628) completed in 1614, where the author recalls:

> "Once I saw the diagram of the heavens drawn by the European Feng Baobao 馮寶寶, which indicates that the heavens are in nine layers. The highest heavens are those of the fixed stars and planets, and then we have the heaven of the sun. The lowest is the heaven of the moon. The doctrine seems to be quite reasonable."[8]

Besides, he also mentioned some geographical knowledge about such European countries as England and Portugal,[9] which was obviously acquired from the notes around Ricci's map as well. Here the name "Feng Baobao" must be the Chinese name of Matteo Ricci, Li Madou 利瑪竇, misread by Yi Su-gwang presumably because of both the resemblance of the Chinese characters in the names (*ma* 瑪 and *feng* 馮, *bao* 竇 and *dou* 竇) and the bad quality of printing on the map. No matter what the reason actually was, this marked the beginning of a new era in the history of astronomy in Korea — the era under the influence of "Sino–European astronomy" — although more substantial transmission of Western astronomy into Korea did not happen until 1631 when Chŏng Tu-wŏn 鄭斗源 (1581~?) and Yi Yŏng-hu 李榮後 contacted João Rodrigues (Lu Ruohan 陸若漢, 1561–1634), a Jesuit missionary in China, and brought back to Korea a number of books on Western astronomy and a few astronomical instruments of

[5] For a survey of the transmission of astronomy from China to Korea before the 20th century, see Shi Yunli 石云里, "Gudai Zhongguo tianwenxue zai Chaoxian bandao de liuchuan he yingxiang 古代中國天文學在朝鮮半島的流傳和影響", *Da ziran tansuo* 大自然探索, 16 (1997), pp.119–124.

[6] Jeon Sang-woon, *A history of Science in Korea*, Seoul: Jimoondang Publishing Company, 1998, p.356.

[7] Zhu Weizheng 朱維錚, *Li Madou zhongwen zhuyi ji* 利瑪竇中文著譯集 (Matteo Ricci's Collected Works and Translations in Chinese), Shanghai, Fudan daxue chubanshe, 2001, pp.169–226.

[8] Yi Su-gwang 李晬光, Chibong yusŏl 芝峰類說 (Classified Notes of Yi Su-gwang), Seoul: Chosŏn Kosŏ Kanhaenghoe, 1916, k.1, 21a.

[9] Park Seong-Rae, "Portugal and Korea: Obscure Connections in the Pre-Modern Sciences before 1900", in: Luís Saraiva (ed.), *History of Mathematical Sciences: Portugal and East Asia II*, Singapore, World Scientific Publication Co. Pte. Ltd., 2004, pp.166–174.

European origin.[10] In this era, China became the most important, if not the only, window for the Korean reception of astronomical knowledge from Europe.[11]

In 1644 when the Korean authorities learnt from an emissary returning from China that the new Qing dynasty had adopted a civil calendar based on the "Western method", they ordered the Bureau of Astronomy, *Kwansanggam* 觀象監, to study the details of the new calendar as well as its underlying theories and calculation techniques. Groups of astronomers were dispatched to Beijing for this purpose; the task, proved very difficult because the Qing government forbade their own astronomers to teach astronomy to foreigners. After nearly ten years, Korean official astronomers finally grasped the necessary techniques and in 1651 they began to calculate their own civil calendar for the following year with the new system.[12]

By then, however, they still had no idea about the techniques for the calculation of planetary motions. In addition, they often ran into technical difficulties in astronomical computations. Therefore more astronomers were sent to Beijing for new knowledge whenever it was thought necessary and a new practice was formed soon. Every year, a number of "Officials going to Beijing" (*puyŏngwan* 赴燕官) from the Bureau of Astronomy, selected by examination, were dispatched to study astronomy in China. Around 1741, this practice became a somewhat fixed rule. In 1762, the rule underwent an amendment: from then on the "Officials going to Beijing" should be sent every three years. Eight years later, it was stated that the "Officials going to Beijing" could be sent whenever the Bureau of Astronomy ran into any difficulty and was in need of a consultation with astronomers in China. In 1791, the frequency of the trips was fixed to every other year. Usually the "Officials going to Beijing" would consult officials from the Qing Bureau of Astronomy privately. They also had the opportunity to visit different churches in Beijing and to meet Jesuit astronomers there. For example, Hong Tae-yong 洪大容 (1721–1783) left a very detailed description of such a meeting between an "Official going to Beijing" and Augustin von Hallerstein (1703–1774) that he had witnessed by himself. Other Jesuit astronomers who had contacts with Korean astronomers in the early and mid-Qing period include Johann Adam Schall von Bell (1592–1666), Ignatius Kögler and Andre Pereira. Besides, the Chosŏn government also encouraged their emissaries to Beijing

[10] Park Yong-dae 朴容大 *et al.*, *Chŭngbo munhŏn pigo* 增補文獻備考 (Documents for Reference; enhanced and supplemented version, 1908), reprint, 1957, Seoul: Kojŏn Kanhaenghoe, *k.* I and 242; Park Seong-Rae, "Portugal and Korea".

[11] For a general survey of the history of the transmission of Western astronomy into Korea, see Shi Yunli 石云里, "*Xifa chuan Chao kao (shang) (xia)* 西法傳朝考（上）（下）", *Guangxi minzu xueyuan xuebao* 廣西民族學院學報, 10 (2004), pp.30–38 and 42–48.

[12] Shi Yunli, "*Xifa chuan Chao kao*".

to buy astronomical books and instruments. Those who made remarkable contributions in this respect were officially praised and rewarded.[13]

The system of "Officials going to Beijing" turned out to be very beneficial to the development of Chosŏn calendrical astronomy. In 1705 and 1708, the royal astronomer Hŏ Wŏn 許遠 was sent to Beijing and eventually learnt from an officer at the Beijing Bureau of Astronomy techniques hitherto unknown to Korean astronomers, including the techniques for calculating the positions of the sun, the moon and the five planets, as well as those for calculating lunar and solar eclipses.[14] In 1706, the techniques that he had thus learnt were applied to the calculation of civil calendars by royal astronomers. In 1710, he completed the first Korean work on Western techniques of calendrical astronomy, the *Sech'o yuhwi* 細草類彙 (*Categorized Collection of Detailed Workings*); it is basically a set of instructions for calculating a civil calendar using the tables provided in the *Xiyang xinfa lishu* 西洋新法曆書 (*Treatises on Calendrical Astronomy According to New Western Method*, 1629–1644), without touching upon any theoretical aspect of the "Western method" introduced in the latter.

If it had taken more than sixty years for Korean royal astronomers to take up the technical aspect of the *Xiyang xinfa lishu*, some more decades were still needed for them to command the theoretical aspect of the compendium. This can be seen from their response to the LK. Largely a compact version of the *Xiyang xinfa lishu*, this work was promulgated in 1724 by the Qing government as the official version of calendrical astronomy. The first Korean response to this change was not seen until four years later when the Bureau of Astronomy memorialized the king, asking that someone should be sent to China to buy the book and to learn the new system. In the following year, a copy of the book was purchased from Beijing and the king agreed that the book be reprinted in Korea. If the Korean royal astronomers had obtained a good understanding of the theoretical part of the *Xiyang xinfa lishu*, they should have encountered no difficulty in digesting the LK. However, after a few days of study, the officials of the Bureau of Astronomy found that "the new method is so difficult that [they were] not able to understand it although [they had] spent so many days and nights on it". Therefore, they petitioned that more astronomers should be sent to Beijing to learn it.[15]

[13] Shi Yunli, "Xifa chuan Chao kao".
[14] Hŏ Wŏn 許遠, *Hyŏnsang sinbŏp sech'o yuhwi* 玄象新法細草類彙 (Classified Collection of New Methods for Calculating Celestial Phenomena), pp.3–4, reprint in Yu Kyŏng-no 俞景老 (ed.), Han'guk kwahak kisul charyo taegye ch'ŏn*munhakp'yŏn* 韓國科學技術資料大系天文學篇 (A Great Compilation of Korean Historical Works in Science and Technology, Astronomy Volumes), Seoul: Yŏgang Ch'ulp'ansa, 1986, vol.9.
[15] Wu Han 吳晗, *Chaoxian Lichao shilu zhong de Zhongguo shiliao* 朝鮮李朝實錄中的中國史料, Beijing: Zhonghua shuju, 1980, p.4429 and 4431.

We have no idea how long it took for Korean royal astronomers to grasp both the technical and theoretical respects of the LK. However, thanks to the "Officials going to Beijing" system, they became more and more responsive to new changes in calendrical astronomy in China. This was manifested by the Korean reception of the LKH. The work was known to Korean astronomers very shortly after its publication in China and they adopted it very quickly.

3. Early Reception

The process of the introduction of the LKH into Korea is well documented in the official records of the Chosŏn dynasty:

"[In the 17th year of King Yŏngjo (1743),] the Translator Officials of the last delegation [to Beijing] An Myŏng-yŏl 安命悅, Kim Chŏng-ho 金挺豪 and Yi Ki-hŭng 李箕興 purchased the LKH in ten volumes and presented it to the throne. The Royal Calendar Request Officer purchased a copy of the new method [of calendrical astronomy] of the Qing [*i.e.* the LKH] and presented it to the throne."[16]

In the 7th month of the following year the officials who had contributed to the introduction of the new method were rewarded by the king:

"Since the Translator Officials An Myŏng-yŏl *et al.* purchased and contributed the new method the LKH, and the Astronomer Official An Kuk-pin 安國賓 learnt the newly composed methods [of calendrical astronomy], the King bestowed rewards on them all."[17]

The book was officially adopted immediately, but together with the LK, because the calculation of the five planets is not discussed in the former:

"The new method devised in the LKH was adopted. [...] After the *jiazi* 甲子 year of King Yŏngjo's reign (1744), the calculation of the motion of the sun and moon as well as that of solar and lunar eclipses was done with Dai Jinxian's 戴進賢 [*i.e.* Kögler] method [*i.e.* the method from the LKH], while Mei Juecheng's 梅穀成 method [*i.e.* the method from the LK] was still applied for the calculation of the five planets, except that Dai Jinxian's table of the mean motion of the sun was now used in the computation of the mean motion of Venus and Mercury, because their epicycles are carried on the same deferent as that of the sun."[18]

However, Korean royal astronomers at the time did not go to the trouble of generating new tables by adjusting the tables in the LKH to the longitude and latitude of their own capital. The only thing they did, as they had always done

[16] Park Yong-dae 朴容大 *et al.*, *Chŭngbo munhŏn pigo*, k.1, p.3b.
[17] Wu Han, *Chaoxian... Zhongguo shiliao*, pp.4525–4526.
[18] Sŏ Ho-su 徐浩修 *et al.*, *Kukcho yŏksanggo* 國朝曆象考 (An Investigation of Calendrical Astronomy of the Present Dynasty), reprinted in *Han'guk kwahak kisul charyo taegye ch'ŏnmunhakp'yŏ*, vol.8, p.26.

before with other systems of calendrical astronomy introduced from China, was to make a direct use of the LKH first and then to rectify the results which otherwise would be valid only for Beijing. For example, "when the Bureau of Astronomy needed to calculate the uncorrected time of the maximum phase of a solar eclipse, the time for Beijing was first calculated, and then 42 minutes were added to obtain the time for Hanyang 漢陽",[19] the capital of the Chosŏn dynasty.

Needless to say, the royal astronomers would not always content themselves only with the command of the technical aspect of the "Western method": after several decades of efforts, they gradually acquired a good knowledge of its theoretical side. In the astronomical section of the *Munhŏn pigo* 文獻備考 completed around 1770, a succinct summary of both the cosmological outline and the geometrical models of the motions of the sun, the moon and the five planets as explained in the LK is provided.[20] Up to 1791, the contents of the LK and that of the *Shuli jingyun* 數理精蘊 (*Essential Principles of Mathematics*), which had been commissioned at the same time as the LK, were part of the curriculum for civil examinations[21] for examinees in astronomy; the two works were also used as textbooks for the training of lower officials at the Bureau of Astronomy.[22] This is a convincing indication that by then the LK (including both its technical and theoretical parts) and the knowledge of mathematics necessary for its understanding and application (mostly geometry, trigonometry and logarithms) were mastered at least by the higher officials at the Bureau of Astronomy and thus became the real foundation of official astronomy in Chosŏn Korea.

Equipped with a more competent knowledge of "Sino–European" astronomy, Korean astronomers now began to make efforts to apply it to their local needs. Thus, an equatorial armillary sphere and a horizontal sundial were constructed in 1789 on the basis of the designs provided in such Chinese books on Western astronomy as the *Celiang quanyi* 測量全義 (*Complete Meaning of Measurement*, 1631, a part of the *Xiyang xinfa lishu*), *Lingtai yixiangzhi* 靈臺儀象志 (*An Explanation of the Newly Built Astronomical Instruments of the Imperial Observatory*, 1674) and the *Shuli jingyun*. However the two instruments were adapted to the

[19] Sŏ Ho-su *et al.*, *Kukcho yŏksanggo*, p.56.
[20] Park Yong-dae *et al.*, *Chŭngbo munhŏn pigo*, k.1.
[21] For a general description of the education and civil examination system of Chŏson Dynasty, see Lee Ki-baek, *A New History of Korea*, Cambridge, Massachusetts, Harvard University Press, 1984, pp.180–182. For the education and examination in so-called *chapkwa* 雜科 (miscellaneous disciplines) including astronomy and mathematics, see Horng Wann-Sheng 洪萬生, "Shiba shiji dongsuan yu zhongsuan de yi duan duihua: Hong Jeongha vs. He Guozhu 十八世紀東算與中算的一段對話：洪正夏 vs. 何國柱", *Hanxue yanjiu* 漢學研究, 20, 2 (2002), pp.57–80.
[22] Sŏng Chudŏk 成周悳, *Sŏun'gwanji* 書雲觀志 (Annals of the Bureau of Astronomy), k.1, p.15a and 21b, reprinted in *Han'guk kwahak kisul charyo taegye ch'ŏnmunhakp'yŏ*, vol.8, pp.295–630.

altitude of the North Pole in Seoul.[23] In the same year, a new table indicating the times of the transit of major fixed stars for different fortnightly periods was compiled in accordance with the geographical latitude of Seoul.[24] In 1791, the Bureau of Astronomy re-measured the altitudes of the North Pole in Hanyang and other provincial cities, and recalculated the length of day and night as well as the times of sunrise and sunset in these places.[25]

The first Korean scholar who ever tried to write an independent work on the basis of the LKH was Sŏ Ho-su 徐浩修 (1736–1799). He came from a family belonging to the *yangban* 两班 class (high officials in civil and military services), the aristocratic class in Chosŏn Korea. His father Sŏ Myŏng-ŭng 徐命膺 (1716–1787) was a high rank official.[26] Sŏ Ho-su ranked first (*changwŏn* 狀元) in the Civil Examination of Erudite Level (*munkwa* 文科) in 1765; he became first the Associate-editor (*pukŏi* 副校理) and then Editor (*kŏi* 校理) of the Office of Special Advisors (*Hungmun'gwan* 弘文館), and took part in the compilation of the *Munhŏn pigo*. He visited China twice in 1776 and 1790 as the vice-envoy to Beijing, to congratulate the Qianlong Emperor on his birthday, which enabled him to have personal contacts with a number of Chinese scholars. In 1780, he became an Associate Librarian (*chigchehak* 直提學) of the Palace Library (*Kyujanggak* 奎章閣) and made a significant contribution to the expansion of the library through his effort in systematic purchase of books from China, including the famous Qing encyclopedia *Gujin tushu jicheng* 古今圖書集成 (*A Collection of Books from Antiquity to the Present*). He assumed the position of Minister of Rites (*yecho p'ansŏ* 禮曹判書) for some years, and his *Yulyŏ T'ongŭi* 律呂通義 (*Comprehensive Discussion of Musical Harmony*) in 1793 may have been composed in response to this assignment.[27] He also compiled a royally commissioned book on agriculture entitled *Haedong nongsŏ* 海東農書 (*Treatise on Farming in Korea*, 1798–1799) which has been assessed as an "attempt to systematize the whole range of Korea's agricultural science" by modern historians.[28]

Several of Sŏ Ho-su's unpublished manuscripts bear witness to his good expertise in astronomy, including the *Honkae t'onghŏn tosŏl chipchŏn* 渾蓋通憲圖說集箋 (*Collected Commentaries on the Illustrated Explanation of the Astrolabe and Its Cosmographical Basis*) and *Yŏksang kosŏng pohae* 曆象考成補解 (*Supplementary Explanation of the LK*). His *Yŏksang kosŏng*

[23] Sŏng Chudŏk, *Sŏun'gwanji*, k.4, pp.7a–12b.
[24] Sŏng Chudŏk, *Sŏun'gwanji*, k.4, p.2b; Sŏ Ho-su *et al.*, *Kukcho yŏksanggo*, p.64–142.
[25] Sŏ Ho-su *et al.*, *Kukcho yŏksanggo*, p.28–54.
[26] Lee Ki-baek, *A New History of Korea*, p.235.
[27] Yun Pyŏng-t'ae 尹炳泰 *et al.*, *Han'guk kosŏ mongnok* 韓國古書目錄 (A Catalogue of Ancient Korean Books), Seoul: Taehan Min'guk Kukhoe Tosŏgwan, 1968, p.566.
[28] Lee Ki-baek, *A New History of Korea*, p.241.

hupyŏn pohae 曆象考成後編補解 (*Supplementary Explanation of the LKH*) was probably the first Korean treatise directly connected to the LKH. The manuscript of this last treatise used to be preserved in the *Chunggyŏng mun'go* 中京文庫 (Library of Middle Capital) in *Kaesŏng* 開城 together with those of the two others.[29] However, we do not know whether they are still extant. Fortunately, in the last few years of his life, Sŏ masterminded, and maybe also partly compiled, two other works on astronomy, from which we may have an idea of his contribution to the reception of the LKH.

In 1795, Sŏ Ho-su was appointed Director of the Bureau of Astronomy. After taking office, he designed a new program to train the lower officials of the Bureau of Astronomy. He also organized the compilation of the *Kukcho yŏksanggo* 國朝曆象考 (*An Investigation of Calendrical Astronomy of the Present Dynasty*), which was completed in 1796. The book was intended to be a detailed record of the development in calendrical astronomy during the Chosŏn dynasty, with a stress on the most recent improvements. In the part devoted to lunar and solar eclipses, several steps of the algorithms from the LKH were discussed in detail, because they were deemed problematic by the authors of the book. Without basic knowledge of the underlying theory of eclipse calculation in the LKH, it is impossible for an astronomer to spot these errors and inadequacies and to provide his own remedies. The book does not attribute this part of the work to any specific author as it does in a number of other passages. It is very likely, however, that this part of the work was authored by Sŏ Ho-su himself, considering both his familiarity with the LKH and his leading role in the compilation of the book.[30]

Also under the directorship of Sŏ Ho-su, another book entitled *Ch'ilchŏng poppŏp* 七政步法 (*Calculating Methods for the Seven Governors, i.e.* the sun, the moon and the five planets) was completed by a group of astronomers at the Bureau of Astronomy in 1798. Just like the *Sech'o yuhwi* compiled by Hŏ Wŏn in 1710, the book is also a manual prescribing the detailed steps of the necessary calculations in calendrical astronomy on the basis of the pre-calculated tables given in both the LK and the LKH. This book gives us a very clear concept about how the techniques from these two books were used in combination by Korean royal astronomers at the time. Exactly as shown above, the algorithms and tables of the LKH are applied to the calculation of the positions of the sun and moon as well as to the predictive calculation of both solar and the lunar eclipses. All the Newtonian equations of the moon as introduced in the LKH are adopted in the calculation of the motion of the moon. The book was revised with a few additions by Nam Pyŏng-gil 南秉吉 (1820–1869) in 1861 under a new title, *Ch'ubo*

[29] Yun Pyŏng-t'ae *et al.*, *Han'guk kosŏ mongnok*, p.1153 and 1413.
[30] See the prefaces to the book in Sŏ Ho-su *et al.*, *Kukcho yŏksanggo*, pp.3–11.

ch'ŏmnye 推步捷例 (*Succinct Routines for Astronomical Calculations*), but its core content never changed.[31]

That competent command of both technical and theoretical aspects of the "Western method" brought obvious confidence to the Korean royal astronomers in this period is exemplified by the following anecdote. After Sŏ Ho-su finished his *Honkae t'onghŏn tosŏl chipchŏn*, he sent the manuscript to the Chinese scholar-official Weng Fanggang 翁方綱 (1733–1818) in an attempt to obtain a preface from him. Weng enjoyed high prestige for his alleged expertise in calendrical astronomy because he was said to devote himself to the study of the calendar behind the chronology of the *Spring and Autumn Annals* (*Chunqiu,* 春秋). After he had seen Sŏ Hŏ-su's book, however, he only wrote a short colophon on a separate sheet of paper, rather than in front of the book, as a way to express his "sentiment of modest prudence in not daring to write a preface". His excuse was that he "had never invested serious efforts in the study of calendrical astronomy", and "generally no one would dare to write any preface to a book the topic of which he had not learnt in detail". While expressing his own opinion on this affair, Sŏ Ho-su criticized Weng and the emptiness of contemporary scholarship in China:

> "Both Minister Ji [Yun 紀昀 (1724–1805)] and Vice-Minister Tie [Bao 鐵保 (1752–1824)] said that Mr. Weng has profound expertise in calendrical astronomy. At the very beginning, however, when I learnt that he was devoting himself to the study of the arrangement of the syzygies and intercalary months during the *Spring and Autumn* period, I already had the suspicion that he does not understand the new method. Now when I see his colophon, the emptiness and shallowness of his scholarship is testified. Generally speaking, nowadays scholars and officials in China only use prosody, calligraphy and painting as ladders to fame and promotion. The study of the rites, harmonics and mathematics is only a fashionable guise for them. Those who do have the slight will to pursue true studies also never do more than pick up the trivial parts of Gu Yanwu 顧炎武 (1613–1682) and Zhu Yizun's 朱彝尊 (1629–1709) scholarship. From this I realize that the pureness and soundness seen in the scholarship of Li Guangdi 李光地 (1642–1718) or the delicateness and profoundness seen in the scholarship of Mei Wending 梅文鼎 (1633–1721) only occur in every other generation, and you cannot expect anything more than this. It is said that the director of the [Chinese] Bureau of Astronomy Chang Xi 常喜 and the Western scholar An Guoning 安國寧, (André Rodrigues, 1729–1796) are both very eminent for the study of calendrical astronomy. But to them I did not have an opportunity to pay a visit. How regrettable!"[32]

[31] Yu Kyŏng-no (ed.), *Han'guk kwahak kisul charyo taegye ch'ŏnmunhakp'yŏn*, vol.9, Front Matters, pp.4–6.
[32] Sŏ Ho-su 徐浩修, *Yŏnghaenggi* 燕行記 (Record of a Trip to Beijing), reprint in *Yŏnghaengnok sŏnjip* 燕行錄選集 (Selected Records of Trips to Beijing), Seoul: Sŏngyun'gwan Taehakkyo Taedong Munhwa Yŏn'guwŏn, 1962, p.514.

Although Sŏ's criticism was not directed against professional Chinese astronomers, his words still reflected his confidence in his knowledge of the "Western method".

4. Further Appropriation

During the first half of the nineteenth century, Korean astronomers began a more profound assimilation of the "Sino–Western" astronomy as they tried to work more independently. They began to blend what they had learnt from both China and their own tradition to create something that could be properly claimed to belong to themselves. During this period, the LKH was largely appropriated in the writings of Ch'oe Han-gi 崔漢綺 (1803–1874).

Ch'oe Han-gi was from a low *yangban* family, and was famous for his thirsty eagerness in purchasing and reading a wide variety of books from China. He was more a generalist thinker than a specialist in astronomy. His broad interest in science and technology can be seen from the range of his works, which include *Nongjŏng hoeyo* 農政會說 (*General Explication of Agriculture*, 1830), *Ŭisang isu* 儀象理數 (*Principles and Constants of Calendrical Astronomy*, 1839), *Sŭpsan chinbŏl* 習算津筏 (*Ferry for Learners of Mathematics*, 1850), *Simgi tosŏl* 心機圖說 (*Illustrated Explication of Intelligent Devices*, 1842) and *Chigu chŏnyo* 地球典要 (*Description of the Nations of the World*, 1857). However, his major pursuit in scholarship seems to have been the establishment of a general system of natural philosophy on the basis of an ontology constructed around the central concept of *qi* 氣, which can be seen from his *Ch'uch'ŭngnok* 推測錄 (*Discourses on Epistemology*, 1836), *Kihak* 氣學 (*The Study of Qi*, 1857), *Unhwa ch'ŭkhŏm* 運化測驗 (*On the Measurement and Test of the Motions and Changes*, 1860) and *Sŏnggi unhwa* 星氣運化 (*On the Motions and Changes of the Stars and of Qi*, 1867).[33]

The *Ŭisang isu* was Ch'oe Han-gi's only book on mathematical astronomy. It was not published and has been preserved only as an incomplete manuscript. The author's preface is dated to late 1835, which must have been the date of the basic completion of the work. From the "Conventions" (*pŏmnye* 凡例) following this preface, we know that the book must have consisted in three parts: (1) Preparatory knowledge on plane and spherical trigonometry excerpted from the *Shuli jingyun* and the LK, and on the geometry of ellipse adapted from the LKH; (2) Section on the sun, the moon and lunar and solar eclipses based chiefly on the LKH; (3) Section on the five planets based on the LK. Unfortunately, the last part is obviously missing from the manuscripts known to us.

[33] Ch'oe Han-gi 崔漢綺, *Chŭngbo myŏngnamnu ch'ongsŏ* 增補明南樓叢書 (A Collectanea of Ch'oe Han-gi's Works), reprint, Seoul: Sŏngyun'gwan Taehakkyo Taedong Munhwa Yŏn'guwŏn, 2002.

Ch'oe Han-gi held a progressivist view of the development of mathematical astronomy. As a philosophically oriented scholar, he attached heavy intellectual and moral values to this progress. So he argued:

> "What can [recent developments in astronomy] add to the ancient studies? It is nothing but the new understanding of principles that prevents people from remaining negligent, as well as the knowledge of the predictability of [celestial] events that prevent people from being trapped in heterodoxy. Therefore, after you understand the secrets [of celestial events], you will not see any miracle in them; after you exhaust their origins, you will see them as ordinary things. Now that calendrical astronomy has been cultivated in a very clear way and conforms very well to practical measurements, there is no space left for those who used to attribute astrological significance to celestial events. It can also help those who have obstacles in their intelligence to widen their sight of knowledge. How can a blockhead understand its benefits for the culture and administration of a nation?"[34]

It must have been for the same reason that he decided that he would "confine [the book] to the explanation of the principles and constants, rather than devote it to the tables and calculations".[35] Accordingly, the book does not contain a so-called "practical" section as both the LK and the LKH. None of the tables from these two books were incorporated in it either. Since the third part of the manuscript is lost, we have no idea how the theory of the five planets was presented. As for the part devoted to the sun, the moon and the lunar and solar eclipses, it is basically a copy of the "theoretical" section of the LKH except for some comments by Ch'oe Han-gi himself and various deletions of diagrams, paragraphs and passages deemed unnecessary. Another difference is that the part of the LKH devoted to the discussion of basic properties of ellipses as well as to the derivation and solution of Kepler's equation was moved to the first part of the book as preparatory knowledge in geometry concerning the ellipse.

As far as the cosmological system is concerned, the Tychonic scheme of the universe from the LK still remains in the book. By the time he wrote the preface to the book, however, Ch'oe Han-gi had become convinced that the earth was rotating daily on its axis, and that the orbits of the sun and of the five planets were elliptic. He expressed his opinion on these two issues very clearly in his *Ch'uch'ŭngnok*. In a section titled "The right rotation of the earth", he remarked:

> "How superb is the doctrine of the [rotating] earth. It clarifies the correct arrangement of the universe, and makes the long night of thousands of years break into daylight. Calendar makers say that the heaven has a leftward rotation, but it is

[34] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.5, p.219.
[35] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.5, p.219.

only for the convenience of mathematical treatment. Despite this, a scholar must know the rightward rotation of the earth so that to see the internal connection of the celestial motions. [...] After the importation of the world map into China, people there were skeptical about the roundness of the earth at first but ended up believing in it. And gradually they realized that it was an unchangeable truth. However, they are now still adhering so stubbornly to the [old] theories of calendrical astronomy that they do not feel easy with the argument for the mobility of the earth. The Western countries also have the rotating earth theory, which has been applied in their calendrical astronomy for a long time. Some scholars in China discussed this doctrine. It does not seem easy to account for the motions of the Seven Governors from the standpoint of a rotating earth as compared with accounting for them from the perspective of a stationary earth. In fact, however, this is nothing more than a replacement of the diurnal rotation of the heaven with the daily rotation of the earth. Although a talk about it provides no benefit [for calendrical astronomy], its principle cannot be left without discussion. The doctrine of the diurnal rotation of the earth is really more reasonable in accounting of the fact that the further a heavenly body is, the slower its motion appears and *vice versa*. Besides, rotation is particularly pertinent in the explanation of the mechanism of tides."[36]

This point of view reflects the influence of previous Korean advocates of the geo-kinetic doctrine from Kim Sŏk-mun 金錫文 (1658–1735) to Hong Tae-yong 洪大容 (1731–1783).[37] On the other hand, it also reflects the new contemplation of Ch'oe Han-gi himself on the issue, especially the connection between the rotation of the earth and the mechanism of the tides. In his "Notes on the Contents" of the *Ŭisang isu*, he singled out the issue again:

> "There is an old doctrine advocating that the left rotation of the Seven Governors is not the result of their own daily motion, but is rather due to the rotation of the earth from west to east, one circle a day. Recently there are quite a few exponents of this doctrine. They try to account for the motions of the

[36] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.1, p.119.

[37] For the development of the geo-kinetic idea in late Chosŏn dynasty, see *e.g.* Yabuuti Kiyosi 薮内清, "Richô gakusha no chikyû kaitensetsu 李朝科學者の地球回轉説" (Chosŏn Scholars' Theory of the Earth's Rotation), *Chôsen gakuhô* 朝鮮學報 (Journal for Chosŏn Studies), 49 (1968), pp.427–445; Ogawa Haruhisa 小川晴久, "Higashi Ajia ni okeru chitensetsu no seiritsu 東アジアにおける地轉說の成立" (The Development of the Theory of the Earth's Rotation in East Asia), *Tongbang Hakchi* 東方學志 (Journal of Korean Studies), 23–24 (1980), pp.375–387; Shi Yunli 石云里 "Cong Huang Daozhou dao Hong Taewong: shiqi shiji Zhong-Chao didongshuo de bijiao yanjiu 从黄道周到洪大容——十七世纪中朝'地动说'的比较研究" (From Huang Daozhou to Hong Taewong: a Comparative Study of the Geo-kinetic Theories in Seventeenth an Eighteenth Century China and Korea), *Ziran bianzhengfa tongxun* 自然辩证法通讯 (Journal of Natural Dialectics of Nature), 19 (1997), pp.60–65; Chen Hui 陳輝, "Chaoxian didongshuo gailun 朝鮮地動說概論" (An Introduction of the Geo-kinetic Doctrines of Chosŏn Korea), in: Jin Jianren 金建仁 (ed.), *Hanguo yanjiu* 韓國研究 (Korean Studies), no.7, Beijing, Xueyuan chubanshe, 2004, pp.274–293.

luminaries with the doctrine, but do not end up in success. Perhaps the doctrine has a long history. There are still some scholars who believe it more reasonable. Although presently we adopt the view of a resting earth for the convenience of mathematical treatment, those who want to pursue mathematical astronomy should explore in that direction as well after they understand this book. In such a way we can reach not only more deliberated theories in mathematical astronomy, but also a guarantee that our study is not unbalanced."[38]

In other words, he was reminding his readers not to concentrate too much on mathematical astronomy at the cost of ignoring the real mechanism of the universe.

He adopted a similar approach to the issue of the shape of planetary orbits. In the section entitled "Elliptic shape of the orbits of the sun and the planets" of his *Ch'uch'ŭngnok*, he argued for the generality of the ellipticity of planetary orbits and highlighted its significance for cosmological discourse:

> "The orbits of the sun and the planets are all ellipses. Hence we can know that the heaven is not in an exactly spherical shape. Since the sun is at a different distance from the earth at the summer and winter solstices, we can therefore believe that the earth is not at the center [of the universe]. According to the LKH, Westerners such as Cassini and Lalande were keen on calendrical astronomy and versed in the measurement and test of the orbits of the various luminaries. When these astronomers tested the elliptic orbits with practical observations, it was found that the two are mostly in conformity. We can know from them that the heaven is not exactly spherical in shape."[39]

In fact, the LKH did not say anything concerning the shape of the orbits of the five planets. It also seems that by the time he wrote neither *Ŭisang isu* nor *Ch'uch'ŭngnok*, Ch'oe Han-gi had yet read Michel Benoist's *Diqiu Tushuo*, where the elliptic shape of all planetary orbits is introduced, together with the heliocentric model of the universe.[40] Therefore the generalization of the elliptic orbit among the planets might have been worked out by Ch'oe Han-gi himself. In the *Ŭisang isu*, he also suggested that one could apply the elliptic orbits to the five planets instead of the deferent-epicycle models. He argued that "these methods are different but their underlying principle is identical",[41] though he did not give further deliberation on how this might be obtained, especially when a geocentric system was used.

[38] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.5, pp.215–216.

[39] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.1, p.120.

[40] Sivin, Nathan, "Copernicus in China", in *Science in Ancient China, Researches and Reflections*, IV, Variorum (revision of an earlier version published in 1973 in *Studia Copernicana* 6, Warsaw, Institute for the History of Science, Polish Academy of Sciences); Chen Meidong, 陳美東, *Zhongguo kexue jishu shi. Tianwen juan* 中國科學技術史天文學卷 (The History of Science and Technology in China, Astronomical Volume), Beijing, Kexue chubanshe, pp.720–721.

[41] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.5, p.222.

By 1857, Ch'oe Han-gi had become a whole-hearted believer in heliocentrism. This can be seen from his *Chigu chŏnyo*, where the heliocentric system was introduced in great detail.[42] In his *Unhwa ch'ŭngŏm* he argued again for the truth of both the rotation and revolution of the earth.[43] By the time he wrote his *Sŏngki unhwa*, he had even read *Tantian* 談天 (*Discussion about the Heaven*),[44] a Chinese translation of John F. Herschel's *Outlines of Astronomy* (1849) done by the famous scientific translator Li Shanlan 李善蘭 (1811–1882) and the English missionary Alexander Wylie (1815–1887) in 1859.[45] The *Sŏngki unhwa* was actually an attempt at building a system of natural philosophy on the basis the astronomical knowledge contained in *Tantian.*[46] Nevertheless, none of these new developments meant that he would discard the old mathematical astronomy included in his *Ŭisang isu*. In the "Notes on the Contents" of his *Sŏngki unhwa*, he still referred his readers to that book "on the trigonometric calculation of angles and sides in both plane and spherical triangles, as well as the calculation of the angle corresponding to the area of an elliptic segment".[47] In the manuscript of the *Ŭisang isu*, we can see some insertions obviously made long after the book was completed. One insertion is the initial constants for the sun, the moon and the five planets to the epoch of the winter solstice of 1860, which "was transcribed from Nam Pyŏng-gil's *Sihŏn Kiyo* 時憲紀要 (*An Epitome of the Shixian [System of Calendrical Astronomy])*",[48] a work completed in 1860, as we will see later. Another insertion mentioned both the rotation and the revolution of the earth, which indicates that the insertion was made after Ch'oe Han-gi acquired a clear knowledge of the twofold motion of the earth. The handwriting style of both of these insertions evidently differs from that of the other parts of the whole manuscript. This means that Ch'oe kept revising the manuscript whenever he learnt any piece of new knowledge that he thought necessary to add to the manuscript. Obviously, even after his knowledge of general astronomy was updated, he still believed in the validity of the knowledge included in the *Ŭisang isu* in some respects. At least he still treated the book as an indispensable source of calendrical astronomy useful for practical calculations, while the new books such as *Tantian* did not provide enough knowledge in this direction at all.

[42] Chen Hui, "Chaoxian didongshuo gailun".
[43] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.5, pp.77–79.
[44] See his preface to the book; Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.5, p.103.
[45] This work is a typical modern textbook on general astronomy based on modern celestial dynamics. Chen Meidong, *Zhongguo kexue jishu shi*, *Tianwen juan*, pp.749–755.
[46] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.5, pp.103–212.
[47] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.5, p.105.
[48] Ch'oe Han-gi, *Chŭngbo myŏngnamnu ch'ongsŏ*, vol.5, p.220.

5. Final Re-Editions

Ch'oe Han-gi's attitude towards the knowledge in his *Ŭisang isu* foreshadowed the fact that both the LK and the LKH would survive in Korea for another period of time even though new knowledge of astronomy as introduced in such Chinese books as *Tantian* had found its way into the academic circles in Korea. This is even more the case when we move our focus to the Bureau of Astronomy, where the interest was more technically oriented because of the Bureau's responsibility as an institution in charge of an important facet of the royal rites, *i.e.* the calculation of civil almanacs and the prediction of the portentous phenomena such as solar and lunar eclipses. Knowledge from both the LK and the LKH was taken as the only working basis until 1895, when the Gregorian calendar was promulgated in Korea. The best examples of the role of the two works in official Korean astronomy in this period were the works by Nam Pyŏng-gil and his elder brother Nam Pyŏng-ch'ŏl 南秉哲 (1817–1863).

Unlike Ch'oe Han-gi, the Nam brothers belonged to a still prosperous *yangban* family. Nam Pyŏng-gil was successful in the Augmented Civil Examination (*chŭnggwangsi* 增廣試) of the Erudite Level (*munkwa* 文科, *or taekwa* 大科)[49] in 1850, and was promoted to a number of high posts such Acting Minister of Personnel (*Ijo p'ansŏ* 吏曹參判), Minister of Punishments (*Hyŏngjo p'ansŏ* 刑曹判書) and Vice-Councilor of the State Council (*Ŭijŏngbu chwach'amch'an* 議政府左參贊).[50] In about 1860, he was appointed to the Directorship of the Bureau of Astronomy, maybe on account of his great interest in mathematics and astronomy. He wrote quite a number of books on mathematics including *Ch'ŭngnyang tosŏl* 測量圖說 (*Illustrated Explanation of Measurement*), *Sanhak chŏngŭi* 算學正義 (*Exact Meaning of Arithmetic*, 1867), *Kujangsul hae* 九章術解 (*Explanation of the Procedures of the Nine Chapters*), *Mui hae* 無異解 (*Explanation of the Equivalence [of the Chinese and Western Methods for Solving the Quadratic Equation]*), *Kugo sulyo tohae* 勾股述要圖解 (*Illustrated Explanation of the Gougu [i.e. right triangle] Method*), *Kugo sansul sech'o* 勾股算術細草 (*Detailed Demonstration of the Calculation of Gougu*), *Jipko Yŏndan* 緝古演段 (*An Elaboration on the Jigu [suanjing* 算經]), and *Okkyŏng sech'o sanghae* 玉鏡細草詳解 (*A Detailed Explanation of the Ceyuan Haijing*).[51] He also wrote very extensively on astronomy

[49] Lee Ki-baek, *A New History of Korea*, p.181.
[50] Horng Wann-Sheng 洪萬生, "Shuxue wenhua de jiaoliu yu zhuanhua: yi Hanguo shuxuejia Nan Bingji (1820–1869) de 'Suanxue zhengyi' wei li 數學文化的交流與轉化：以韓國數學家南秉吉（1820–1869）的《算學正義》為例" (Transmission and Transformation of Mathematical Cultures: A case study of Korean mathematician Nam Pyŏng Gil's *Sanhak Chongyi*), *Shida xuebao* 師大學報 (Bulletin of the Normal University), vol.48–1 (2003), pp.20–36.
[51] Horng Wann-Sheng, "Sino-Korean Transmission of Mathematical Texts in the 19th Century: A Case Study of Nam Pyŏng-gil's *Kugo Sulyo tohae*", *Historia Scientiarum*, vol.12-2 (2002), pp.87–98.

and left a number of works such as *Chungsŏng sinp'yo* 中星新表 (*New Tables of the Transit Times of Major Stars*, 1864), *T'aeyang kyŏngnup'yo* 太陽更漏表 (*A Table for Measuring the Daily and Nightly Times*), *Ch'unch'u ilsik ko* 春秋日食考 (*A Study of the Solar Eclipses in the Spring and Autumn Annals*), and the *Ch'ubo chopye* mentioned above. On the basis of Mei Wending's work on the application of planispheric projection in the solution of spherical triangles, he even invented an instrument named *yangdoŭi* 量度儀 (Instrument for Angle Measurement) which was actually an mechanical calculator based on Mei Wending's theory. His *Yandoŭi tosŏl* 量度儀圖說 (*Illustrated Description of the Instrument for Angle Measurement)* is a treatise on this instrument.[52] His *Sihŏn kiyo* has been discussed above.

Some historians of mathematics see "no trace of the metaphysical view, a dominant characteristic of the works of *sadaebu* 士大夫 (literati-official) or *yangban* scholars" in Nam Pyŏng-gil's mathematical works.[53] The titles on astronomy above convey to us a similar impression of Nam Pyŏng-gil's preference for tackling technical problems. His approach to the LK and the LKH in the *Sihŏn kiyo* provides us with a more concrete example of the predominantly technical taste in his scholarship in astronomy.

As mentioned above, after the adoption of the Qing dynasty's calendar, the *Shixian li* 時憲曆, in Korea in 1651, the calculation techniques of this system became a requirement in the Civil Examination of astronomy. For a long time, however, there was no standard textbook on Western astronomy for students to use. Although the contents of the LK and *Shuli jingyun* had been adopted in 1791 as requirements for examinations, the standard textbooks available from the Bureau of Astronomy were still those based on outdated traditional Chinese astronomy. Therefore, when Nam Pyŏng-gil took the directorship of the Bureau, he decided to compile a book to fill up this gap, which gave rise to the *Sihŏn kiyo* in 1860.[54]

The work is in two *kwon* 卷 or volumes (Chart 1). It is basically a mixture of theories, elementary constants and algorithms taken from both the LK and the LKH. More specifically, while sections 1.7–1.8, 1.11–1.14 and 2.1–2.5 are based on the LKH, other sections are based on the LK, except that the final values for of the epoch and tropical year in sections 1.5 and 1.6 are adopted from the LKH.

[52] Jeon Sang-woon, *A History of Science in Korea*, pp.104–107.
[53] Horng Wann-Sheng, "Sino–Korean Transmission of Mathematical Texts".
[54] See Nam Pyŏng-gil's own colophon as well as the prefaces to the book by Cho Tu-sun 趙鬥淳 (1796–1870) and Kim Pyŏng-ik 金炳翼, in Nam Pyŏng-gil 南秉哲, *Sihŏn Kiyo* 時憲紀要 (An Epitome of the *Shixian* System of Calendrical Astronomy), reprint in *Han'guk kwahak kisul charyo taegye ch'ŏnmunhakp'yŏ*, vol.10, pp.1–286, esp. pp.3–10 and 285–286.

Table 1. Table of Contents of the *Sihŏn Kiyo* 時憲紀要.

1.	Ch'ilchŏng 七政 (On the Seven Governors)
1.1.	Yŏkpŏp yŏnhyŏk 曆法沿革 (Evolution of the Calendrical System)
1.2.	Ch'ŏnsang 天象 (Configuration of the Heavens)
1.3.	Chich'e 地體 (Geographical Coordinate System)
1.4.	Kyŏngwido 經緯度 (Celestial Coordinate Systems)
1.5.	Yŏkwŏn 曆元 (Epoch)
1.6.	Sesil 歲實 (Tropical Year)
1.7.	Chi pangyŏng ch'a 地半徑差 (Diurnal Parallax)
1.8.	Ch'ŏngmonggi ch'a 清蒙氣差 (Atmospheric Refraction)
1.9.	Hangsŏng haengdo 恒星行度 (Motion of the Fixed Stars)
1.10.	Hangsŏng sallye 恒星算例 (Calculation of the Fixed Stars)
1.11.	T'aeyang haengdo 太陽行度 (Motion of the Sun)
1.12.	Ilchŏn sallye 日躔算例 (Calculation of the Sun)
1.13.	T'aeŭm haengdo 太陰行度 (Motion of the Moon)
1.14.	Wŏlli sallye 月離算例 (Calculation of the Moon)
1.15.	Osŏng sallye 五星行度 (Motion of the Five Planets)
1.16.	T'osŏng sallye 土星算例 (Calculation of Saturn)
1.17.	Moksŏng sallye 木星算例 (Calculation of Jupiter)
1.18.	Hwasŏng sallye 火星算例 (Calculation of Mars)
1.19.	Kŭmsŏng sallye 金星算例 (Calculation of Venus)
1.20.	Susŏng sallye 水星算例 (Calculation of Mercury)
1.21.	Osŏng tanmok sallye 五星段目算例 (Calculation of the Phases of the Five Planets)
2.	Kyosik 交食 (Eclipses)
2.1.	Kyosik ch'ongnon 交食總論 (General Discourse on the Eclipses)
2.2.	Wŏlsik sallye 月食算例 (Calculation of the Lunar Eclipse)
2.3.	Wŏlsik taesik sallye 月食帶食算例 (Calculation of the Lunar Eclipse Occurring Across the Horizon)
2.4.	Ilsik sallye (ponbop; wubop) 日食算例本法、又法 (Calculation of the Solar Eclipse — Original method; other method)
2.5.	Ilsik taesik sallye (ponbop; wubop) 日食帶食算例本法、又法 (Calculation of the Lunar Eclipse Occurring Across the Horizon — Original method; other method)

Although Nam Pyŏng-gil tried to keep a "theoretical" basis for his book as the authors of both the LK and the LKH did, his emphasis was clearly not on this aspect. The sections devoted to the "theoretical" descriptions of the motions of the sun, the moon and the five planets, *i.e.* those sections named "*Haengdo*" 行度 (motion), turn out to be extremely brief. For example, the LKH devotes 156 pages to the explanation of the so-called "Mathematical theory of the sun" (*richan shuli* 日躔數理), including discussions on why and how an elliptic orbit has been adopted since Kepler in the account of the motion of the sun, in what respects this new model was different from and similar to the old Tychonic model, how the mean motion and the equation of center of the sun were defined in the new model, what the relation was between the mean and true motion of the sun in the new system, how to describe this relation quantitatively (*i.e.* how to derive Kepler's equation), how to calculate true motion from mean motion with geometric methods (*i.e.* how to obtain an approximate solution of Kepler's equation), and which method was acceptable in the case of the sun. In the *Sihŏn kiyo*, however, only a little more than two pages with similar density of characters are devoted to the "theoretical" description of the motion of the sun. Similarly, while the LKH devotes another 212 pages on the theoretical discussion of the motion of the moon, *Sihŏn kiyo* devotes only another two pages to the topic. Where the authors of the LKH try very hard and at great length to give justifications for their adoption of any new data, new model or new mathematical treatment, Nam Pyŏng-gil just describes them as accepted facts. On the other hand, however, the algorithms taken from the "practical" sections of both the LK and the LKH for practical calculations in calendrical astronomy are explained step by step in great detail in the sections entitled "*Sannye*" 算例 (exemplifying calculation). Wherever needed, Nam borrows explanations from the "theoretical" sections of both the LK and the LKH when required to make the concept and mathematical procedure involved at every step intelligible to his readers.

Just as in the LK and the LKH, the cosmological framework described in Nam's work is still the geocentric model, with a spherical and immobile earth surrounded by twelve heavens. The Seven Governors are carried on the nine inner heavens, while the three outer heavens are for the fixed stars, the south–north and east–west components of the precession of the equinoxes respectively. The Tychonic scheme of the universe, given at the beginning of the planetary theories of the LK, does not appear in Nam's book. Following the argument of Chinese astronomers such as Mei Wending[55] and the authors of the LK itself, Nam Pyŏng-gil stressed that although "the Western method also indicates that the sun is at the center of the deferents of the five planets, that arrangement is merely a hypothetical scheme (*ch'asang* 借象)".[56] Like Chinese astronomers, he believed that the actual scheme of the five planets was that while each planet was revolving on an epicycle (*seryun* 歲輪), the center of the epicycle was revolving on a geocentric deferent. In his opinion, since the epicycle had the same radius as the geocentric deferent of the sun and its center was always in the same direction as the mean sun, astronomers could replace it with the deferent of the sun by centering the planetary deferents on the sun. In this way, as he insisted, one could say that the supposed geo-heliocentric scheme was equivalent to the real geocentric one.[57]

Also like the compilers of the LKH, Nam Pyŏng-gil kept silent on the issue of how to accommodate the elliptic orbits of the sun and the moon and the deferent-epicycle models of the five planets with one uniform model of the universe, although he argued that "the underlying principle regarding the equation of center [of a planet] is roughly similar to that of the sun and moon".[58] In his mind, the elliptic model was nothing but another mathematical procedure used to deal with the inequality of the motion of the sun:

> "Is it acceptable that the underlying principle [of the elliptic model] in the description of the apogee and perigee is primarily the use of the eccentric heaven, whereas its method in the mathematical treatment of the equation of center is nothing more than Guo Shoujing's 郭守敬 (1231–1316) method of pile summing and interpolation (*t'ajŏk ch'och'a* 垛積招差)?"[59]

However, someone who just hopes to command practical techniques for calculations in calendrical astronomy would have found no problem in following Nam Pyŏng-gil's prescription.

Nam Pyŏng-ch'ŏl was as successful as his younger brother in his career as an official. He passed the Civil Examination at the Erudite Level in 1837, and was then appointed to a number of high positions successively, including those of Minister of Rites (*Yejo p'ansŏ* 禮曹判書), Minister of Military Affairs (*Pyŏngjo p'ansŏ* 兵曹判書), Minister of Personnel (*Ijo p'ansŏ* 吏曹判書) and Official of Special Advisor (*Hongmun'gwan taejaehak* 弘文館大提學). Like Nam Pyŏng-gil, he was very keen on mathematics and astronomy as well. Presumably, his interest in these subjects was influenced by Nam Pyŏng-gil. In mathematics he left a work on the *Ceyuan haijing* 測圓海鏡 (*Sea Mirror of the Circle Measurement*, 1248) entitled *Haegyŏng sech'o hae* 海鏡細草解 (*Explanation of the Exemplifying Calculations in the Sea Mirror*, 1861).

[55] Mei Wending 梅文鼎, *Wu'an lisuan quanshu* 勿庵曆算全書 (Complete Collection of Mei Wending's Works on Calendrical Astronomy and Mathematics), reprint in *Yingyin Wenxian ge Siku quanshu* 景印文淵閣四庫全書, Taipei, Taiwan shangwu yinshuguan, 1986, vol.794, j.16, and j.17.

[56] Nam Pyŏng-gil, *Sihŏn Kiyo*, p.107.
[57] Nam Pyŏng-gil, *Sihŏn Kiyo*, pp.107–108.
[58] Nam Pyŏng-gil, *Sihŏn Kiyo*, p.101.
[59] Nam Pyŏng-chŏl, *Sihŏn Kiyo*, p.17.

In astronomy he published two works. While his *Ŭigi chipsŏl* 儀器輯說 (*Collected Descriptions of Instruments*) describes the structure and use of a number of astronomical instruments, including those designed or constructed by himself and his friends, his *Ch'ubo sokhae* 推步續解 (*Continued Explanation of the Algorithms in Astronomy*) is devoted to calendrical astronomy which is related to our topic. From these works it is clear that he also concentrated on technical aspects of astronomy, presumably also under the influence of Nam Pyŏng-gil, then Director of the Bureau of Astronomy.

Ch'ubo sokhae was completed in 1862, about two years after Nam Pyŏng-gil's *Sihŏn kiyo*. According to the author, the book was actually a follow-up of the *Tuibu fajie* 推步法解 (*Explanation of the Algorithms in Astronomy*, 1843) by Jiang Yong 江永 (1681–1762), a Chinese scholar whom Nam Pyŏng-ch'ŏl admired very much. He praised the lucidity of the *Tuibu fajie* and acclaimed the book as "a true guide for the students of calendrical astronomy". In his opinion, the most important feature of Jiang Yong's work was its presentation:

> "The book explains the celestial configurations through algorithms, and reveals underlying theories through constants, so that as soon as one reads the texts, one will immediately acquire in one's mind a clear understanding of both the theories of the Seven Governors and the diagrams illustrating mathematical operations involving trigonometry."[60]

The only problem was, as he pointed out, that the algorithms included in Jiang Yong's book were based on the LK, since the book had been completed before the publication of the LKH. Therefore, Nam decided to compile a new book on the calculation of the sun, the moon and the lunar and solar eclipses, using the methods from the LKH but written in the same style and format as the *Tuibu fajie*. That is why he named this new book *sokhae*, or a continued explanation.

This new work is in four volumes (*kwon*), divided into four sections that deal with the calculation of the sun (*kwon* 1), the moon (*kwon* 2), the lunar eclipse (*kwon* 3), solar eclipses and the fixed stars (*kwon* 4). It is basically a commentary on the algorithms of the "practical" part of the LKH, except for the section on the fixed stars, which is in fact a commentary on the relevant algorithms taken from the "practical" part of the LK. Each section begins with the constants to be used, followed by the algorithms. Comments are given on every constant and every step of calculation, clarifying the astronomical meaning and the historical improvements of the constants, as well as the key concepts and mathematical treatments involved at every step. Compared to Nam Pyŏng-gil's book, the *Ch'ubo sokhae* is even less open to the theoretical dimension of Western astronomy.

[60] Nam Pyŏng-chŏl, *Sihŏn Kiyo*, pp.325–326.

One may be able to make one's own calculations by following the prescriptions in the book step by step. It is very doubtful, however, whether by reading it one can really "acquire immediately in one's mind a clear understanding of both the theories of the Seven Governors and the diagrams illustrating the trigonometric operations", especially for a beginner. Although some operations are originally based on very complicated geometrical operations and configurations, not one single diagram is provided throughout the book, let alone any thorough demonstration of the geometrical principles behind all the algorithms.

6. Concluding Remarks

Although the Jesuit compilers of the LKH tried very hard to fill in both the cosmological and mathematical gaps between the LKH and LK to uphold, at least apparently, the coherence of the theories in the two books, they still failed in averting themselves from the criticism of Chinese scholars thereafter. This was true especially after the introduction of the heliocentrism by Michel Benoist. The most famous criticism was that by Ruan Yuan 阮元 (1764–1849), one of the most influential writers within the scientific circles in China after the mid-18th century, who argued:

> "Since the Europeans, attracted by the Emperor's civilizing virtue, came from afar and translated their techniques for pacing the heavens, we have had the mathematics of deferents and epicycles. [...] And then, not very long after, there was a change. For what has all along been called circles they have substituted ellipse techniques, and they hold that the earth moves and the sun is static. This means that the Westerners were unable to firmly maintain their previous arguments. [...] From Tycho's time to the present only somewhat over a century has passed, but how many times have they changed his methods! I cannot imagine how much further they will go. They are certain to surpass these beginnings, boasting of knowledge that only they have, inventing absurd theories."[61]

Finally, an overwhelming majority of Chinese astronomers in Ruan's period accepted a common belief that any geometrical and cosmological model that the Westerners contrived was just a purely mathematical treatment, as Ruan Yuan put it:

> "Generally speaking, these [models] are simply hypothetical figures, used to demonstrate why and how we could use the plus or minus equations [to correct the mean motions of the sun, the moon and the five planets]. However, in view of the capability of these models to tell the reasons for the irregular motions of the heavenly bodies, undiscriminating people mistakenly believe that there are

[61] Ruan Yuan 阮元, *Chouren zhuan* 疇人傳 (Biographies of Mathematicians and Astronomers), Beijing, Zhonghua shuju, 1991, pp.609–610. English translation from Sivin, "Copernicus in China", with my own changes.

truly such circles in the blue heavens. This is really a great delusion! [...] As long as the figure is borrowed for illustrating computational principles, then it is fine to say that the model is an ellipse with the equal area planetary motion on it, and there is also no any impropriety even in saying that the earth moves while the sun is static!"[62]

But even so, Ruan Yuan still thought that the heliocentric system was too absurd. So he continued:

"However, as a doctrine it [*i.e.* the heliocentrism] goes too far to the degree that the proper order of the up-there and the down-here is reversed, and the roles of the kinetic and the static are topsy-turvy. Never has there been any instance worse than this in being so heretical and unedifying."[63]

From the too frequent changes of the Western astronomy in cosmological models and the heresy of the heliocentric model the Westerners ended up with, Ruan Yuan saw the serious risk in following the Western approach in astronomy. So he advised his readers:

"When ancient calendar makers studied the motion of the Seven Governors, they only talked about the inequalities and irregularities of the sun, the moon and the five planets, rather than the reasons for these inequalities and irregularities. This is really because that the way of Heaven is too subtle for human power to spy out. Therefore, they only spoke of what is so rather than pressed further to seek for why it is so. Such was the prudence of the ancient people when they established their teachings. [...] [Western astronomy] being so, you might still say that the Westerners' discourses on celestial phenomena can clarify the reasons. But how can [these discourses] be superior to only talking about the inequalities and irregularities? Only talking about what is so rather than why it is so, which can make us unmistakable forever!"[64]

In other words, the incoherence discerned by Chinese scholars such as Ruan Yuan in Western astronomy convinced them that not only should they withdraw their previous faith in its superiority in revealing the underlying principles of the heavenly motions, but they should even stop pursuing astronomy in the Western way.

Ruan Yuan's argument turned out to be overwhelmingly appealing to contemporaneous literati. Leading mathematicians and astronomers in the period such as Li Rui 李銳 (1768–1817) and Xu Guilin 許桂林 (1778–1821) shared his view.[65]

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[62] Ruan Yuan, *Chouren zhuan*, pp.609–610. English translation from Sivin, "Copernicus in China", with my own changes.

[63] Ruan Yuan, *Chouren zhuan*, pp.609–610. English translation from Sivin, "Copernicus in China", with my own changes.

[64] Ruan Yuan, *Chouren zhuan*, pp.609–610. English translation from Sivin, "Copernicus in China", with my own changes.

[65] Shi Yunli and Lü Lingfeng, "Cong 'gouqiu qi gu' dao dan qiu 'wubi' ".

To them the only acceptable part of Western astronomy was the advanced techniques in instruments and observation. Therefore, Xu Guilin argued that the only way astronomers in China could take for sure was to combine the Western techniques with the old cosmology tenet of the *Xuanye* 宣夜 school which never tried to imagine the possible orbital arrangement of the Seven Governors.[66] For this reason, Western astronomy was adopted and studied by Chinese astronomers and literati of the period only insofar as it provided a set of pure mathematical techniques or even a craft in tackling the practical problems they came across either in calendrical astronomy or in evidential studies (*kaozheng xue* 考證學). This situation would not undergo a substantial change until 1840, when a new bout of transmission of Western science began in the gunpowder smoke of the Opium War.

It seems that the incoherence issue did not trouble Korean astronomers to the same extent. While those who were closely connected to the Bureau of Astronomy such as Sŏ Ho-su, Nam Pyŏng-gil and Nam Pyŏng-chŏl simply concentrated on the technical aspects of both the LK and the LKH without any word about the cosmological gap between the two books, Ch'oe Han-gi, a scholar outside that institution, also seemed to be quite settled even after he was converted to heliocentrism and Newtonian astronomy. It appears that from the very beginning he made a very clear demarcation between the mathematical and physical dimensions of astronomical studies, but he believed that both dimensions had their own functions and therefore could be treated separately. In his opinion, physical and mathematical studies of astronomy were equally important and as a scholar one had to keep a balanced knowledge in both directions. Compared to Chinese scholars such as Ruan Yuan, Li Rui and Xu Guilin, his emphasis on the physical study reveals great open-mindedness, and total independence from the mainstream trend the astronomical thought represented not only by the leading thinkers in astronomy in China, where the only source of Western astronomy lay for Korea, but also by the Korean royal astronomers in the Bureau of Astronomy, who were supposed to be the dominant experts in astronomical issues in the country.

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[66] Shi Yunli and Lü Lingfeng, "Cong 'gouqiu qi gu' dao dan qiu 'wubi' ".