HISTORICAL PATRON OF ASTRONOMY, SHOGUN YOSHIMUNE TOKUGAWA, WHO LED FEUDAL JAPAN TO A MODERNIZED SOCIETY

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Abstract: Because astronomy as science has been furthermost from monetary business and profit, the existence of its patrons and patronage has played important roles for the development of astronomy. From such a viewpoint, this paper introduces the eighth Shogun Yoshimune Tokugawa as the most prominent patron of astronomy throughout the history of Japan. In the background of his activities in astronomy there was a firm self-consciousness that the top leader of a country was responsible for giving people the correct calendar, similar to the ancient traditional ideology of Chinese emperors. Thus, Yoshimune continued to embrace an ambition for calendar reform but this did not come true during his lifetime. For this purpose, Yoshimue founded a new astronomical observatory, observed various celestial objects from it, and made opticians produce a large astronomical telescope. Hence he should be recognised as an astronomer or scientist.

Another one of Yoshimune's historic contributions was that he relaxed the century-long import ban on Chinese books unrelated to Christianity. Thanks to this epoch-making decision, the Japanese people were given chances to learn about Western science and culture through foreign books. As a result, Japan was ready to accept the flood of knowledge and information from the Western world when Japan removed the Sakoku (national seclusion) policy in 1868. Therefore, we may safely say that today we Japanese owe much to Yoshimune's farsighted policy.

Keywords: patron of astronomy; Yoshimune Tokugawa; shogun; telescope; Yogaku.

1 INTRODUCTION

The history of astronomy mainly consists of past stories describing major discoveries in astronomy, theories, observational instruments, and lifetimes of the people directly relating to this discipline who achieved them. These long-term achievements often involved huge budgets and wealthy patrons with expensive telescopes and large observatories. On the other hand, astronomy as a pure science has been most remote from the pursuit of mundane business and profit. This means that the existence of patrons and patronage supporting astronomical studies is an inevitably important factor in development of this discipline throughout its history. We easily recall such historic patrons of astronomy as Frederick II of Denmark (1534–1588) who totally supported Tycho Brahe's work on the island of Hven, Ulugh Beg (1394–1449) the founder of Samarkand Observatory, and King Sejong the Great (1392–1450) of the Choseon Kingdom in Korea.

As such, this paper describes the lifetime and achievements of the eighth Shogun Yoshimune Tokugawa (1684–1751), who was a great patron of astronomy, and played an important role in subsequently influencing the modernization of Japanese society after the eighteenth century. In Section 2, we will provide a summary of Japanese history from ancient times to the eighteenth century in order to explain why Yoshimune had to make superhuman efforts in order to overcome the pre-modern traditions and rules of Samurai feudal society.

2 JAPANESE FEUDALISM AND ITS CHARACTERISTICS

The history of the establishment of unified Japan goes back to the middle of the seventh century, where a supreme ruler with actual power named Tenno (Emperor) first emerged by gathering and conquering local powerful families. Tenno's politics was conducted by the Government in the Imperial Court located at Kyoto. Court nobles controlled actual political administration there. By the end of the seventh century, the Tenno Government accomplished a nation-wide governing regime referred to as the Ritsuryo system, involving criminal laws, taxes, administrative organization and working rules for the official employees.

The basic structure of this national system was nearly completed in about the 680s at the time of the two Emperors Tenji and Tenmu, who largely borrowed from the bureaucratic governments of the Sui and Tang Dynasties in China.[1] Aristocratic officers serving Emperors would continue to sustain Japan under the Ritsuryo system without fatal political disorder until the end of the eleventh century.

However, in the course of these several hundred years, warriors originally hired to guard court nobles and governmental officers gradually rose in political and social status because of the backgrounds that they had, especially with weapons such as swords. They were so-called Samurai or Bushi, and later they grew into many family groups. The largest of these were called the Heishi and Genji. These two groups soon were involved in a 10-year long nation-wide civil war, with the Genji eventually defeating the Heishi.

As a result, in 1192 the first feudalistic Samurai Government, the Kamakura Bakuhu, was established in Kamakura, a small town near Tokyo. Around this time, the position of Emperors had declined, and they were only symbolic and had no influence or power in politics. After the Kamukra Bakuhu, another Samurai Government, the Muromachi Bakuhu in Kyoto, ruled over Japan. Their leader was called the Shogun. This feudal Government continued for fifteen generations, down to the first half of the fifteenth century. Thereafter however, the controlling power of the Bakuhu weakened, so that regional authorities (called Daimyo, or feudal warlords) within the Bakuhu began to battle each other for territory. This nation-wide turmoil also gave rise to conflicts between Buddhist sects and rich merchants. Thus, this confusing time was known as the Sengoku (Warring) Period. Regarding astronomy, for several hundred years after the Medieval period, a few Chinese calendar systems were used in Japan without any modification,[2] mainly for astrological purposes, to cure the painful hearts of war-damaged peoples.

In 1603, Ieyasu Tokugawa (Totman, 1967), the head of the Tokugawa Family, seized power. By defeating other Daimyos and ruling over all Japan, he established a new national feudal Government, called the Tokugawa Bakuhu, whose top authorities were also called Shoguns. From this time down to 1868 for about 270 years Japanese people at last enjoyed a peaceful life, though within the Samurai regime. Following is the story of the eighth Shogun, Yoshimune, and this Tokugawa Shogunate.

3 YOSHIMUNE'S LIFE BEFORE HE BECAME A SHOGUN

Yoshimune Tokugawa, the eighth Shogun of the Tokugawa Bakuhu Government (Figure 1) was born in 1684 in the Wakayama Prefecture of current Japan, then called the Kishu han (domain). He was the fourth son of his father, warlord Mitsusada Tokugawa. Because at that time non first-born sons had very little chance of being nominated as the next warlord, it seemed that Yoshimune would have a simple daily life, without any ambition of promotion, by eagerly exercising Samurai martial arts and reading many books on various topics. However, fortune smiled upon this frugal young man. Just by chance, all three of his older brothers had died by the time Yoshimune was only 22 years of age, so he became the next Daimyo of the Kishu han.

In an attempt to improve the financial situation of this han he streamlined the administration by hearing opinions from lots of officials, and he then went and employed people with high ability, without taking account of their social status. As a result, Yoshimune's political fame gradually spread, even among feudal lords of other regions.

It is likely that in this process he nurtured an early desire to become a patron of science and astronomy. For instance, the Museum of Wakayama Prefecture now preserves seven old 2.7m × 5.0m maps of his castle town (Nakamura, 2014: 155) that were produced by Yoshimune's order, each of which includes elaborate drawings of not only each building but also roads, rivers and bridges, with detailed numerical sizes measured by a land survey method. The author infers that past experience made him consider compiling a map of the whole Japan archipelago at a later time (see Section 4.2).

Figure 1: Portrait of the eighth Shogun Yoshimune Tokugawa in formal dress wearing a ceremonial skullcap, a scepter and a Japanese sword (Tokugawa Memorial Foundation, Wikimedia commons).

In 1716 the seventh Shogun passed away at the age of ten without a proper successor among the main Tokugawa family. Hence Yosimune was recommended by senior retainers of the Tokugawa Shogunate to be the next Shogun, both because Yoshimune was most akin by blood to the main Tokugawa family and he had a good reputation for his successful administration of the Kishu han. Consequently, he soon moved to Edo (present-day Tokyo), the then capital of Japan, accompanied by many competent vassals who had served him in the Kishu han.

4 SHOGUN YOSHIMUNE: PATRON OF ASTRONOMY

4.1 Yoshimune's Disposition

Yoshimune was rather different from the other 14 Shoguns during the history of the Tokugawa Shogunate, between 1603 and 1868. All Shoguns except Yoshimune were only nominal top rulers and almost all political affairs were controlled by high-ranking Shogunal bureaucrats. Thus, the ordinary activities of the Shoguns were mainly limited to painting and calligraphic works, poetry, art literature and the tea ceremony.

On the other hand, Yoshimune was not interested in most things that the Medieval Court nobles enjoyed, but preferred knowledge and practice based on corroborative experience. In particular, he took great interest in all fields of natural science, including astronomy, and applied his mathematical talent to the administration. Yoshimune was a top ruler, and his political achievements (especially his various reforms during the Kyoho Period of the 1720s) were recorded much more frequently than those of other Shoguns. For instance, see the *Tokugawa Jikki* (*Biographical Collected Works of Tokugawa Shoguns*, originally completed in 1844) (Kuroita, 1999), that related to other books and documents at that time.

Another aspect of Yoshimune's unique personality was that when he dealt with his vassals or ordinary people he did so very fairly, regardless of their social position. *Tokugawa Jikki* introduces an anecdote (ibid.) where a *ronin* (a retired or dismissed Samurai) sent a letter to the Shogun's office strongly complaining about defects in the Kyoho reforms. Although many of the Bakuhu retainers worried that the *ronin* would be severely punished, Yoshimune's reaction was very different. He praised the *ronin's* letter by showing it to his vassals, saying that this man's words were at least partly correct.

4.2 Desire for Calendar Reform and Two Science Advisers

Soon after the nomination of the eighth Shogun in 1716, Yoshimune recognized calendar reform as one of the most important jobs of the Tokugawa Government—this may have been one of the reasons why Yoshimune had a strong interest in astronomy and calendar science. In fact, the official biography of the Shoguns, *Tokugawa Jikki*, describes the situation (ibid.; Nakamura, 2014: 157) as:

> Honorable Shogun Yoshimune considered that astronomy and calendrical science are the most fundamental discipline for "giving people a correct calendar" (観象授時, *guanxiang shoushi* in Chinese), which had been a long holy tradition for the Chinese Empire in the Chinese history. For the purpose he himself studied not only Chinese and Japanese books and materials relating to national calendars but also relevant Western astronomy through the translated literature into Chinese as well. Our Shogun made inquiries to ask a Shogunal astronomer whether or not the Japanese calendar currently in use was accurate enough, but the official could not respond with satisfactory answers. Therefore, Shogun Yoshimune directed the same question to his science advisor Katahiro Takebe.

From this story we can well understand that Yoshimune's attitude to prioritize astronomy came not from his personal interest or taste for it, but from a much wider self-consciousness as a top administrator.

Katahiro Takebe (1664–1739) was an eminent mathematical scholar from the Samurai class, who had been serving the Bakuhu Government since the times of the sixth Shogun. Takebe had then been known as one of the authors of books that collected mathematical studies in Japan (called *Wasan*). Hearing of his fame, Yoshimune requested that Takebe become his science advisor. The *Tokugawa Jikki* records that following Yoshimune's invitation Takebe made more than ten contributions in various fields. This indicates that Yosimune put high confidence on Takebe's abilities.

A good example is how Takebe spent six years preparing a nation-wide map of Japan (named the *Kyoho Nihonzu*), and this was completed in 1723. This was the first Japanese map based on the trigonometric survey approach (Kawamura, 2010). Takebe's case was quite exceptional among other Shoguns because they never adopted scientists like Takebe as political consultants.

In the astronomical history of Japan relating to Yoshimune, the most important topic with a long-term influence was calender reform. The lunisolar calendar used in Japan during Yoshimune's reign was the *Jokyo Calendar*, which civil astronomer Harumi Shibukawa (1639–1715) proposed in 1684 by learning the *Shoushi Calendar* that was in use at the time during the Yuan Dynasty in China. Owing to this successful achievement Shibukawa was appointed as the first official astronomer of the Bakufu Government (called Tenmonkata).

Incidentally, Yoshimune questioned how accurate the *Jokyo Calendar* really was when compared to the *Shixian Calendar*, which was then used in China. In fact, a local museum near Tokyo founded by Yoshimune's descendants now preserves a draft of the letter without a signature inquiring about Japanese and Chinese calendars

(Nakamura and Ito, 2009). It is very likely that this document was written by Yoshimune himself and was to a special subordinate, probably Takebe. Certainly, any Shogun other than Yoshimune would not ask such specific questions about calendars; it included about ten different lines of enquiry, such as the mathematical difference between the *Jokyo* and *Shixian Calendars*, and how to utilize solar eclipse observations for the purpose of improving the calendar.

There was a reason why Yoshimune asked these questions. He had already learnt through Chinese literature that the *Shixian Calendar* was the best one. This was produced in 1645, and was the first to apply knowledge of Western astronomy, which Jesuit missionaries from Europe brought to China during the Ming Dynasty.

Responding to Yoshimune's enquiry, Takebe recommended another mathematician, Genkei Nakane (1662–1733). Nakane used to be an employee working at the Bakuhu silver mint in Kyoto, whose faculty Takebe highly appreciated. After an interview with Nakane, Yoshimune was well satisfied and adopted him as another science advisor, like Takebe. At a later meeting Yoshimune frankly confessed to Nakane his desire that the Bakuhu Government should adopt a new lunisolar calendar that accommodated Western astronomy, instead of the *Jokyo Calendar*. The *Tokugawa Jikki* (Kuroita, 1999) says that Nakane was impressed by Yoshimune and answered his opinions honestly:

> Traditional calendars used in China have followed reforms of many times during the past 2000 years, because they often failed to predict correctly astronomical events like solar or lunar eclipses. After the coming of Christian missionaries into China with knowledge of Western science the situation was drastically improved, and one of the results is also reflected in adoption of the Shixian calendar. On the other hand in Japan, Christianity had long been prohibited by law since the 1630s. People were not allowed to import Chinese books that European missionaries in China authored or translated. If you His Majesty wish to make a calendar reform using results of Western astronomy, it will be a good idea to alleviate the import ban of Chinese books at least non-relating to Christianity, such as books of astronomy, geography and pure science.

Yoshimune once again found that Nakane's opinions were reasonable and correct. In 1720 a Shogun's order was sent from the Bakuhu Government to Nagasaki Bugyou (Magistrate), notifying that from now on the import or sales of Chinese books irrelevant to Christianity need not be subject to strict regulation.

In addition, as Yoshimune successfully practiced innovative efforts in political, economic, cultural and social fields, he was often recognised as the *Chuko no so* (the *Restorer of the Tokugawa Shogunate*) in Japanese history. However, we will not go any further into this theme, which is covered in many books (e.g., see Kuroita, 1999; Oishi, 1989, 2001; Totman, 1967; Tsuji, 1985), since the main purpose of this paper is to discuss Yoshimune the scientist, as well as aspects of his patronage of astronomy.

5 YOSHIMUNE AS AN ASTRONOMER AND A SCIENTIST

In this section, we will concentrate on how Yoshimune contributed to the development and modernization of Japanese astronomy, both directly and indirectly. We have already seen Yoshimune's political attitudes toward astronomy and science as an enlightened ruler. On the other hand, there is no doubt that he was also strongly attracted to astronomy personally. The following topics demonstrate that Yoshimune was not only the patron of astronomy but was also an astronomer and scientist.

5.1 Yoshimune's Strong Interest in Astronomy

An example of Yoshimune's early interest in Western astronomy can be found in the business diary written by a manager of the Deshima Office in Nagasaki of the Dutch East India Company[3] (Nakamura, 2008). It says that in 1717, when the Manager went to Edo (Tokyo) from Nagasaki and visited Yoshimune for a formal greeting, Yoshimune asked a few technical questions by showing an astrolabe that he owned: how Dutch people use the astrolabe for astronomical purposes, and what are the observational errors of the instrument. As the Manager could not give correct answers to these inquiries he wrote he felt embarrassed. Because Japan had adopted a national seclusion policy (called Sakoku) from the 1630s on, people were prohibited from sailing abroad by strict law. So the Japanese were not interested in the astrolabe since there was no chance that they would use it on ocean voyages. The only exception was made by Yoshimune himself: his log books record astronomical observations made at Edo with the title *Kohu Nikkei* during 1732–1738. These include measurements of the Sun using an astrolabe. The *Kohu Nikkei*[4] will be mentioned again later.

Another episode that took place in 1736 is more surprising; namely when another Dutch manager from Nagasaki met Yoshimune in Edo, Yoshimune asked him to dispatch to Japan from his home country an astronomer who could teach Western astronomy. But contrary to Yoshimune's

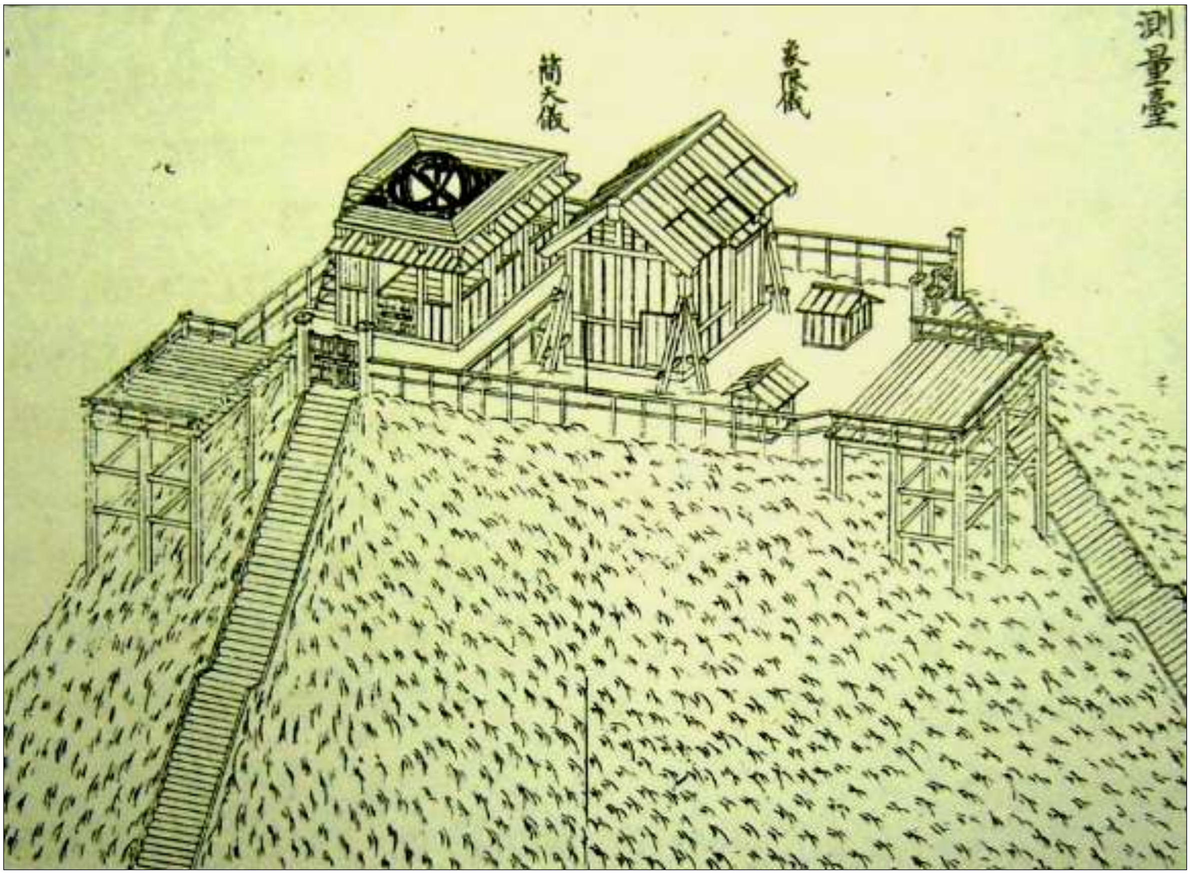

Figure 2: The astronomical observatory of the Bakuhu Tenmonkata established at Asakusa in Edo city in 1782. The height of the hill is about 10m, and on top several observational instruments were installed. One can see the simplified armillary sphere invented by Yoshimune on the left. This drawing is in the *Kansei Rekisho* (after Shibukawa, 1844).

plan, this request was not fulfilled. Had this been realized, it is very likely that the subsequent history of Japanese astronomy would have been quite different from what we now know of it.

5.2 A New Astronomical Observatory

The *Tokugawa jikki* (Kurita, 1999), *Kousho koji* (Kondou, 1976, and Watanabe, 1987) mention that when Yoshimune entered the Edo Castle as the Shogun, he found some old astronomical instruments in storehouse, but none of them was of any practical use. So, he thought of establishing an astronomical observatory. Initially, the whereabouts of the Yoshimune's new observatory was unknown, but in 2011 a hand-written old map of the Castle's central garden (*Fukiage Gyoen*) was discovered (Matsuo, 2014), in which the observatory was drawn. It consisted of a small hill with an armillary sphere designed by Yoshimune located on the top, and beside it there was a house for observatory staff, that also had a library. It is interesting to note that the function of this facility was close to that of the modern astronomical observatory.

After Yoshimune's death this facility was removed from the garden, so this would be the reason why information about its whereabouts was lost. But in 1782 Shogunal astronomers reconstructed an observation site by taking account of Yoshimune's observatory as a model, whose picture and explanation are recorded in the *Kansei Rekisho* (*Reports of Kansei Calendar Reform*) (Figure 2). Hence, we now know the outline of Yoshimune's astronomical observatory.

5.3 Instruments Designed by Yoshimune

Tokugawa Jikki writes that soon after becoming the Shogun Yoshimune constructed a large armillary sphere in the Edo Castle by taking skillful craftsmen from the Kishuu han. It also notes that since the body of this instrument was coated in leather painted with *urushi*-lacquer, the distortion caused by the wet outdoors air was kept small (Nakamura, 2008: 63). Figure 3 is a photograph of an armillary sphere recently reproduced by modeling the one made by Yoshimune. This was for a TV program about his lifetime. Compare the size with the height of a man standing nearby.

At a later time, Yoshimune invented a different type of the armillary sphere and named it *Kantengi* (simplified armillary sphere). He had recognized that the armillary spheres developed in China had a structure and functions that were too complicat-

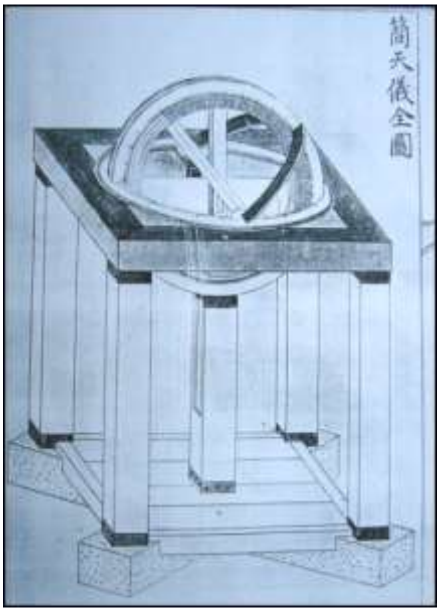

Figure 3 (left): Replica of the large armillary sphere made by Yoshimune and used in the central garden of the Shogun's Castle in Edo city. This model shown here was reproduced for an NHK TV program on Yoshimune's life and achievements, broadcast in 2013. The diameter of the armillary sphere is 2.4m, the same as the original one made by Yoshimune (photograph: the author).

Figure 4 (right): Kantengi (simplified armillary sphere) by Yoshimune,. *Kansei Rekisho* notes that the armillary sphere in this figure is the one invented by Yoshimune, which was later moved from Edo Castle to Asakusa Observatory in the suburbs for the project of the Kansei Calendar reform at the end of the eighteenth century. This drawing is in the *Kansei Rekisho* (after Shibukawa, 1844).

ed to enable measurements of coordinates in the equatorial, ecliptic and azimuth-altitude systems. Thus, he considered improving the traditional armillary sphere into a simplified one that was limited to measuring only equatorial latitude and longitude. In the *Kansei Rekisho* (*Reports of Kansei Calendar Reform*) one can see *Kantengi*, that was made by Yoshimune (Figure 4).

Another astronomical instrument invented by Yoshimune was *Sokugohyo*. This instrument was intended to allow observers to measure altitudes and transit times simultaneously when celestial objects came on the meridian plane. The timing of the meridian transit was recorded by reading the dials of a mechanical clock. Watanabe (1987: 518–521) points out that despite the novelty, the measuring accuracy was no better than Yoshimune initially planned.

5.4 Observational Records by Yoshimune

What kinds of celestial objects did Yoshimune and his subordinates observe using the above-mentioned astronomical instruments at the Observatory in Edo Castle, and how were they recorded? Unfortunately, we cannot know the details since the ninth Shogun destroyed lots of Yoshimune's records after his death. And it is also likely that Edo Castle, which was located in the center of Tokyo city, suffered damage from the great Kanto Plain Earthquake of 1923.

The only records left are observational logbooks titled *Kohu Nikkei*, which means sundial observations at the capital Edo. Despite the title, they actually include many continuous records other than those of the Sun, covering the six years from 1718 to 1724. Moreover, they compare observations of the Sun made from two sites, namely Yoshimune's Castle and a place in the suburbs of Edo.

The main contents of the *Kohu Nikkei* were observations made with the large armillary sphere and *Sokugohyo*, in addition to those of the astrolabe already mentioned in Section 5.1. Furthermore, it is worth noting that they also record the appearance of some comets and auroral phenomenon, and occultations of Jupiter by the Moon. Considering that later Shogunal astronomers used to observe celestial bodies for a year or so only for the purpose of calendar reform, Yoshimune's astronomical observations extending for a much longer period should be regarded as an important achievement (Nakamura, 2014: 161–162 and 166).

5.5 Astronomical Telescope and Mounting

In this Subsection we will introduce the aspects of Yoshimune himself as an astronomer and scientist. Needless to say, Yoshimune clearly recognized the importance of the telescope in astronomy. Although he eagerly wanted to make telescopes

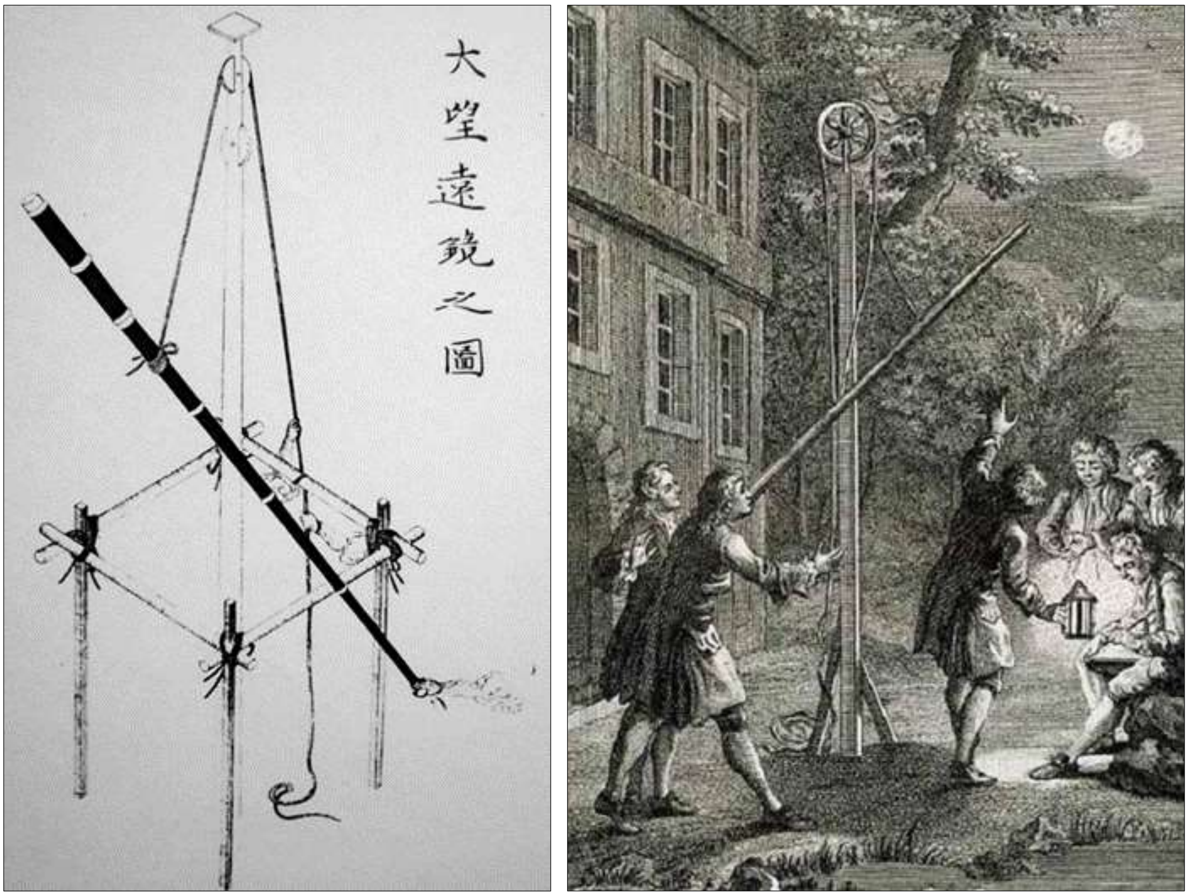

Figure 5(a) (left): A long telescope hung from a mounting with a pulley mechanism, drawn in the *Kansei Rekisho* (after Shibukawa, 1844). One can see that the telescope consists of five stage draw-tubes. The square-shaped horizontal bars drawn in the lower part of the figure were newly devised for the purpose of easy pointing of the telescope to each of azimuthal directions. Figure 5(b) (right): An example of a European telescope mounting with a pulley mechanism (after Zuidervaart, 1999: 118).

of better performance for astronomical studies, it is clear that he and his staff at Edo Castle could not do this work themselves. Therefore, following suggestions made by Takebe and Nakane (Section 4.2) Yoshimune employed Nizaemon Mori from Nagasaki, who was a famous official Bakuhu optician. Currently we know of three existing telescopes with Mori's signature; all of them are of the Schyrlean-type, which consists of four convex lenses.[5]

The largest one, which is now owned by a citizen of Nagasaki, has an objective lens of 91mm diameter, with a five-stage telescopic tube that extends to 3.4m, and a magnification power measured by the author of about 10. Mori's two other telescopes are much smaller. Meanwhile, the *Shusei Houreki Ganreki* (*Reports of the Modified Houreki Calendar Reform in 1769*) includes a section titled "Large astronomical telescope", which was made by Yoshimune's order. Figure 5(a) shows the telescope drawn in this report. Because of the following reasons, the author judges that the telescope in Figure 5(a) is the one made for Yoshimune:

(1) the five-stage telescopic tubes and sizes of the extended lengths are the same for both the telescopes,
(2) at that time there was no commercial need for such a large telescope for purposes other than astronomy, from the viewpoint of production technology and cost, and
(3) as seen in Figure 5(a), without an appropriate mounting one cannot point such a large and heavy telescope at a celestial object in the sky just by hand.

The telescope drawn in Figure 5(a) is intriguing in that one could control its aiming direction by using the mounting with a pulley mechanism at the top. It is well known that during the seventeenth century amateur astronomers in Europe often adopted similar mountings (see Figure 5(b)). But Yoshimune's mounting is unique in having the horizontal square bars that are shown in the lower part of the telescope. Probably they were a good idea, as they easily allowed adjustment of the azimuthal direction of the telescope and helped keep it stable.

The following story makes us appreciate Yoshimune as an astronomer and scientist (Nakamura, 2008: 70). One day a staff member at Edo Castle Observatory confessed to Yoshimune that it was difficult for him to point a large telescope at a star so that it was exactly at the center of the circular field-of-view. Yoshimune understood that in order to make exact measurements the aiming cross-hairs had to be placed somewhere on the optical axis of the telescope. But the problem was to put them where? Should they be between the objective lens and the eyepiece—the place must be *in focus* as seen simultaneously with the eye for both a star and the cross-hairs.[6] Yoshimune made various experiments in order to resolve this difficulty, and eventually he found the appropriate position for the cross-hairs. This anecdote indicates that Yoshimune was surely an astronomer or an optical scientist in the modern sense.

6 YOSHIMUNE'S LEGACY: THE MODERNIZATION OF FEUDAL JAPAN

6.1 Unsuccessful Calendar Reform

The two science advisers to whom Yoshimune gave high trust, Takebe and Nakane died in 1739 and 1733 respectively. This must have been a regretful loss to Yoshimune, since completion of a calendar reform based on a knowledge of Western astronomy had been his eager aim for a long time. To compensate for the deaths of Takebe and Nakane, Yoshimune appointed Masayoshi Nishikawa as the new Shogunal astronomer. Masayoshi had taught non-professional astronomy at his private school in Edo city using the famous Chinese textbook of astronomy *Tenkei Wakumon* (*Tianjing Huowen* in Chinese).[7]

Following Yoshimune's orders, Nishikawa began preparing to reform the calendar by supporting one of the Shogunal astronomers in Edo, in collaboration with the Imperial Court astronomer Tsuchimikado, who was based in Kyoto and was responsible for the new calendar. However, Nishikawa was no more than a teacher of general astronomy and he had neither knowledge of nor experience in practical matters of calendrical astronomy. In the course discussions he disagreed a few times with Tsuchimikado regarding ceremon ial matters on how to propose the calendar reform to the Emperor. As a result, because of Tsuchimikado's strong opposition Nishikawa was eventually fired by the Bakuhu Government. By this time, Yoshimune had already passed away, in 1751.

After such scandalous troubles the new luni–solar calendar, named *Houreki Reki*, was at last released in 1754. But this calendar failed to predict the solar eclipse of 1763, just nine years later. On the other hand, some local amateur astronomers had calculated that this predicted solar eclipse would not actually take place. Then in 1769 the Bakuhu Government ordered the Shogunal astronomers to make a new calendar by modifying the *Houreki Calendar*, which was the *Shusei Houreki Calendar* mentioned in Section 5.5. Nonetheless, even this Calendar did not accomplish substantial improvements since its theory was borrowed directly from a traditional Chinese calendar. Because of this series of problems, Japan had to wait until after Yoshimune's death to see his dream come true, and calendrical reform based upon knowledge of Western astronomy only came about in 1798.

6.2 The Start of Studying Books Written in European Languages

Before Yoshimune relaxed the strict regulation that prevented the importing or sale of Chinese books in 1720, Japanese people could not read books written in European languages. Even Japanese interpreters working for the Dutch East India Company in Nagasaki were in the same situation, because their jobs only allowed communication with Dutch officers primarily for the import–export business.

Soon after the removal of the book import ban by Yoshimune some retired Japanese interpreters in Nagasaki began to translate Dutch books into Japanese, but they must have found this very difficult without access to a Dutch dictionary or knowledge of Dutch grammar. One example was Ryoei Motoki (1735–1794) who translated nearly ten books, mainly about astronomy and geography. Motoki's most important contribution through this translation work was that he introduced the Copernican heliocentric system of the Solar System to the Japanese for the first time.

Another translator of Dutch books was Tadao Shizuki (1761–1806). He translated a 1798 Dutch physics book that originally had been published by the British author John Keill in 1741, and he spent four years completing the *Rekisho Shinsho* (*New Book on the Calendar and Astronomy*). Through this book the Japanese for the first time learnt about Keplerian motions of the planets using the theory of Newtonian dynamics. A unique feature of Shizuki's book was that in the appendix he publicized his original idea about the nebular hypothesis to explain the origin of the Solar System.

6.3 Yoshimune's Dream Comes True at Last

There was another group of people in Osaka who tried to understand and utilize Western astronomy through Chinese books. The leader of the group was Goryu Asada (1734–1799), originally a medical doctor, who in 1767 ran a small private school to teach astronomy to the public. He and two talented students, Yoshitoki Takahashi (1764–1804) and Shigetomi Hazama (1756–1816) eagerly studied the recently imported *Lixiang Kaocheng Houbian* (*Consideration of Calendrical As-*

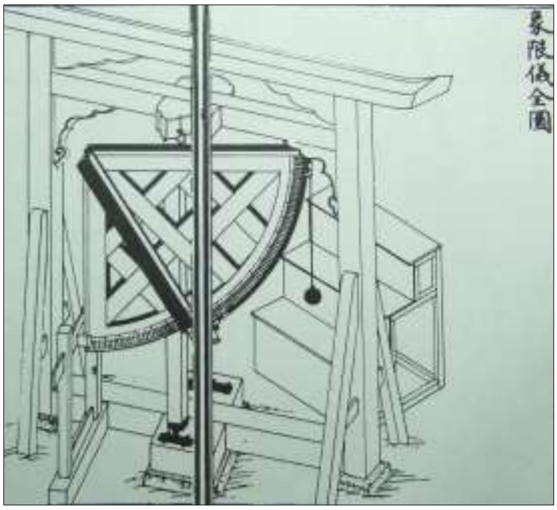

Figure 6: A *shogengi* (astronomical quadrant) used at the time of the Kansei Calendar reform Note that a sighting telescope is attached. Drawn in the *Kansei Rekisho* (after Shibukawa, 1844).

tronomy, Later Part), and managed to master most contents of the book, including Keplerian motions. This book was originally written in 1742 by the Jesuit missionary Ignatius Koegler, with editing support from Chinese Court Astronomers. This book discussed advanced Western astronomy, as represented by mathematical theories of the elliptical motions of the Sun and Moon.

In addition to understanding theoretical astronomy, Asada and this two disciples devised a quadrant and a meridian transit instrument with a pendulum clock that allowed high-precision measurements of celestial objects (Figure 6). In these developments they consulted various figures drawn in another famous Chinese book, the *Lingtai Yixiangzhi* (*Observational Instruments of Astronomical Observatories*) that originally was published in Beijing in 1674 by the Belgian missionary

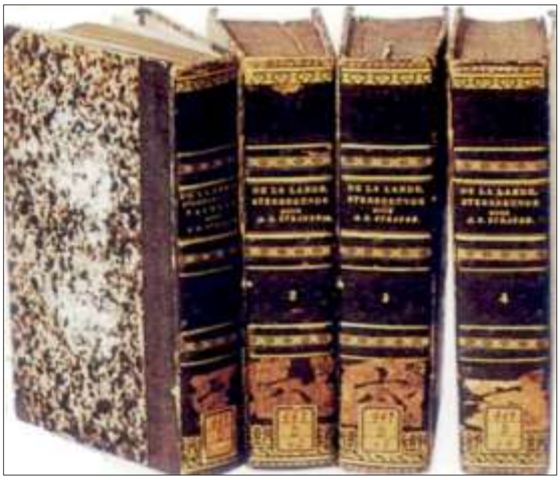

Figure 7: *Astronomia of Sterrekunde,* Volumes 2–5 (1773–1775). These copies are now in the Library at the National Astronomical Observatory of Japan. Note that Volume 1 is missing (photograph: the author).

Ferdinand Verbiest. Incidentally, it is known that this Chinese book accommodated the achievements of the Danish astronomer Tycho Brahe (1546–1601) (see Nakamura, 2014: 181). Up to that time in China astronomers tended to develop universal observing instruments like the traditional armillary sphere that could measure a few kinds of data at the same time, but at the sacrifice of data quality. Tycho, on the other hand, concentrated his efforts on inventing or improving astronomical instruments in order to increase observational accuracy. Maybe the Asada group subconsciously followed Tycho's revolutionary approach.

The reputation of the Asada group's activities regarding the latest astronomy soon reached the Shogun's ears. As the top of Councilors (*Roju*) of the Bakuhu Government at that time happened to be a grandson of Yoshimune, he had good knowledge of Yoshimune's unsuccessful calendar reform plan, and he also understood his grandfather's regret in this regard. Soon an order from the Shogun was sent to Takahashi and Hazama saying that the two must come up to Edo to be involved in the calendar reform that was then in progress. One year after their arrival in Edo, Takahashi was appointed the new Shogunal astronomer (*Tenmonkata*) with responsibility for calendar reform, because he was seen to have more ability in understanding advanced Western astronomy.

Referring to the two Chinese books and some European ephemerides then imported to Japan, in 1797 Takahashi and Hazama eventually succeeded in completing a new calendar incorporating traditional astronomy with Western astronomy. It was named the Kansei Calendar. The Bakuhu Government adopted it for public use from the following year (*Kansei Rekisho*). At that moment, Yoshimune's long-standing dream of a new calendar based on Western astronomy was at last realized. Owing to this distinguished achievement the Bakuhu Government promoted Takahashi to the top of Shogunal astronomers. However, he was not satisfied. What caused his dissatisfaction was that in the Kansei Calendar the Keplerian theory of elliptical orbital motion was applied only to the Sun and the Moon but not to the five planets. This was inevitable because the *Lixiang Kaocheng houbian* did not provide detailed astronomical constants of the five planets. For this reason, Takahashi made it a rule to look for up-to-date data among astronomy books imported from Europe.

6.4 Subsequent Progress and a Completed Calendar

In 1803 Takahashi was asked by his supervisor to look into a set of five recently obtained books with the title *Astronomia of Sterrekunde* (1773–1775) (Figure 7). This was a Dutch translation of the book

Astronomie written in 1771 by Paris Observatory's Jerome Lalande (Figure 8).

Carefully scanning the pages, and figures, diagrams and numerical tables in particular, Takahashi was convinced that this book must be one of the best ever published thus far on astronomy, even though he had never learnt the Dutch language and therefore could not read the book.[8] Spending half a year, he diligently devoted himself to copying in Japanese those contents of the book that he could understand or considered to be important, and he left eight notebooks filled with extracts before his death in 1804. Later, Takahashi's second son Kagesuke Shibukawa (1787–1856) succeeded in finishing his father's work. Kagesuke not only completed the translation of Lalande's book, which he published as *Shinko Rekisho* in 1836, but he also utilized the results in perfecting the last lunisolar calendar used in Japan from 1842, the Tenpo Calendar.

On the other hand, the overall report of the Kansei Calendar reform, the *Kansei Rekisho*, was published by Kagesuke in 1844. In the Preface of the report, he said:

> We could finally complete the Kansei lunisolar calendar fully taking account of knowledge from Western astronomy, the long-standing dream of the Honorable Shogun Yoshimune. So I believe that we could at last answer his holy wishes at least partially, and we now feel a great relief.

These cited sentences indicate that Yoshimune's enthusiasm for calendar reform continued to influence the people from the Bakuhu Government like Kagesuke, even almost a century after Yoshimune's death.

7 CONCLUDING REMARKS

Relaxation of the import ban on Chinese books by Yoshimune meant that Japanese people could read books written in European languages, not in translations but directly. We have seen that one of these rare examples occurred when Shogunal astronomers were able to study Lalande's book *Astronomia of Sterrekunde*. Another example occurred in the 1770s when some medical practitioners in Edo city were engaged in deciphering the Dutch anatomy book, *Ontleedkundige Tafelen* (1734). Much later, in 1815, one of the translators, Genpaku Sugita wrote an essay titled *Rangaku kotohajime* (*Birth of Rangaku*, Ogata, 1959), recalling their difficult challenges at that time. In this book Sugita coined the new word Rangaku, which the next paragraph explains.

Afterwards, these activities gradually expanded to almost all the fields of Western culture and technology. We now call these scholastic efforts Rangaku (Dutch Learning) or Yogaku (Western Learning) (Numata et al, 1984). And when the national seclusion policy, Sakoku, forced on us from the 1630s, was removed by the Meiji Ishin (political revolution of the Meiji period) in 1868, Western culture and technology flooded into Japan. Thanks to Yogaku, the Japanese managed to catch up with the world-wide trends in modernization by themselves. In other words, we can say that the Japanese people owe much to Yoshimune's farsighted policy.

8 NOTES

1. During this era, Japan, located in the isolated archipelagos of the Far East, was under the strong influence of foreign migrants from China and Korea (called Toraijin) in almost every field. Many of them worked in Japanese Governmental offices helping and teaching Chinese technology and culture to Japanese colleagues.

Figure 8: French astronomer Jerome Lalande (Wikimedia commons).

2. The Chinese calendar used in Japan for the longest period of time was the Senmyo Calendar, during the 868 years from AD 823 to 1684. It was this fact that motivated Harumi Shibukawa to propose a new calendar.
3. 35mm micro-films of *Archief Nederlansche Factorij Japan* (Hdup.6998-1) are available at the Historiographical Institute, the University of Tokyo (https://www.hi.u-tokyo.ac.jp).
4. The manuscript of this document is now preserved in the National Diet Library of Japan (139-63), https://www.ndl.go.jp.
5. The oldest telescope now in Japan is also of the Schyrlean-type, consisting of four convex lenses, and was owned by the youngest son of Ieyasu Tokugawa. It was manufactured in

or before 1650. For details, refer to Nakamura (2008), and Bolton and Korey (2010: 250).

6. In the case of Keplerian telescopes with two convex lenses, it is easy to look for the position where the cross-hairs must be placed; namely at the common focuses of the objecttive and eyepiece lenses. On the other hand, as the Schyrlean telescopes like Yoshimune's large telescope consisted of four convex lenses, it was very difficult to find the appropriate place in which place the cross-hairs without knowledge of modern optics.
7. In China this book was published in 1675 by You Ziliu but attracted very few readers, whereas in Japan it had a very wide readership and was translated into Japanese. The reason for its popularity in Japan was that it explained general astronomy, including Western astronomy, meteorology and geography, at a non-professional level. The first Shugunal astronomer Harumi Shibukawa (Section 4.2) commented that he recognized the motion of the perihelion point of the Earth's orbit for the first time through reading this book.
8. Takahashi's inference was to the point. Lalande's original publication was widely welcome, not only in Europe but also in other countries. For example, the German astronomer Friedrich W. Bessel praised it highly, and subsequently copies were translated into European, Turkish, Arabic and Japanese languages.

9 REFERENCES

Bolton, M., and Korey, M., 2010. The world's oldest surviving telescopes. In van Helden, A., Dupré, S., van Gent, R., and Zuidervaart, H.J. (eds.), *The Origin of the Telescope.* Amsterdam, KNAW Press. Pp. 231–255.

Kawamura, H., 2010. *Edo Bakuhu no Nihon Chizu* (*Maps of Japan Made by Bakuhu Government*). Tokyo, Yoshikawa Kobunkan (in Japanese).

Kondou, S., 1976. Kousho Koji (Bibliographic notes). In *Kondou Seisai Zenshu* (*Collected Works of Kondou Seisai*, *Volume 3*. Tokyo, Daiichi Shobo (https://www.digital.archives.go.jp/file/1234372.html) (in Japanese).

Kuroita, K. (ed.), 1999. Utokuin-dono Go Jikki (Biography of Shogun Tokugawa Yoshimune). In *Kokushi Taikei* (*Collected Works of Japanese National History*), *Tokugawa Jikki, Part 9, Volume 46*. Tokyo, Yoshikawa Kobunkan (in Japanese).

Matsuo, M., 2014. Tenmondai ga egakareta Gyoenzu (Map of Edo castle garden with an astronomical observatory). *Nihon Rekishi* (*Japanese History*), 6(793), 85–95 (in Japanese).

Nakamura, T., 2008. The earliest telescope preserved in Japan. *Journal of Astronomical History and Heritage,* 11(3), 203–212.

Nakamura, T., 2008. *Edo no Tenmongakusha Hoshizora wo Kakeru* (Stories on Japanese astronomers of the Edo period). Tokyo, Gijutsu Hyoronsha (in Japanese).

Nakamura, T., and Ito, S., 2009. Utokuinsama rekisuu otazuneno onhitsu (Shogun Yoshimune's Inquiry Letter on Calendrical Mathematics). In *A History of Japanese Astronomy, Catalogue of Special Exhibition 2009*. Tokyo, University of Tokyo (https://www.lib.u-tokyo.ac.jp/html/tenjikai/tenjikai2009/shiryo/kaisetsu10.html) (in Japanese).

Nakamura, T., 2014. *Toyo Tenmongakushi* (*A History of Oriental Astronomy*). Tokyo, Maruzen (in Japanese).

Nakayama, S., 1969. *A History of Japanese Astronomy*. Cambridge, Harvard University Press.

Numata, J., et al., and the Japan-Netherlands Institute (eds.),1984. *Yougaku-shi Jiten* (*Dictionary of the History of Western Learning*). Tokyo, Yushodo Press (in Japanese).

Ogata, T., 1959. *Rangaku Kotohajime* by Genpaku Sugita (*Birth of Rangaku*). Tokyo, Iwanami (in Japanese).

Oishi, S., 1989. *Tokugawa Yoshimune to Sono Jidai* (*Tokugawa Yoshimune and His Age*). Tokyo, Chuou Kouron Sha (in Japanese).

Oishi, M., 2001. *Yoshimune to Kyoho no Kaikaku* (*Yoshimune and His Kyoho Political ReformTokyo*). Tokyo, Tokyo-do Publications (in Japanese).

Shibukawa, K. et al., 1844. *Kansei Rekisho* (*Reports of Kansei Calendar Reforms*, *Volume 19*. (https://dl.ndl.go.jp/pid/2552879/1/5) (in Japanese).

Tokugawa, Y., and others, 1732–1738. *Kohu Nikkei* (*Sundial Observations at the Capital Edo*). Edo (in Japanese).

Totman, C., 1967. *Politics in the Tokugawa Bakuhu,1600–1843.* Cambridge (Mass.), Harvard University Press.

Totman, C, 1985. *Tokugawa Ieyasu, Shogun: A Biography*. San Francisco, Heian International.

Tsuji, T., 1985. *Tokugawa Yoshimune*. Tokyo, Yoshikawa Kobunkan (in Japanese).

Watanabe, T., 1987. *Kinsei Nihon Tenmonngakushi* (*History of Japanese Astronomy in Early Modern Times*), *2nd Volume*. Tokyo, Koseisha Koseikaku (in Japanese).

Zuidervaart, H., 1999. *Van Konstgenoten en Hemelse Fenomenen.* Roterdam, Erasmus Publishing (in Dutch).

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As for the second field he has published 16 papers in English and 61 in Japanese. His recent books are: *Deciphering the Ancient Starry Sky from the Kitora Tumulus Star Map: A History of Star Maps and Catalogues in Asia* (2018, University of Tokyo Press, in Japanese); *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe* (2017, Springer, co-edited by Wayne Orchiston); and *A History of Oriental Astronomy* (2014, Tokyo, Maruzen Publ., in Japanese).

Asteroid Tsuko (6599), a member of the Flora family, was named after him in 1991. Tsuko is on the Editorial Board of the *Journal of Astronomical History and Heritage*.