THE EMERGENCE OF THE THIRD PARADIGM FOR EXPRESSING ASTRONOMICAL PARAMETERS: ALGEBRAIC FUNCTION

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1. SOLAR EQUATION OF CENTER, WESTERN AND CHINESE

The solar equation of center was the most important problem with which professional mathematical astronomers in ancient times had to deal. Western astronomers traditionally treated it with geometry and trigonometry, while the Chinese generally relied on an entirely different pragmatical and empirical tradition, namely numerical interpolation between values of the midday gnomon-shadow length observed at, say, ten-day intervals. There is, however, another tradition using an algebraic function of second order that seems to have originated in Central Asia some time around the eighth century. This third approach was discovered by the present writer in 1964 and briefly described in English. In this paper, we shall examine more closely the historical context of this innovation, as well as the adoption and development of this third approach in Central Asian and Chinese mathematical astronomy.

2. PROCESS OF DISCOVERY OF THE FUTIAN CALENDAR

The Futian calendrical system (that is, the step-by-step methods for computing the ephemeris) has been known as one of the unofficial calendars compiled in A.D. 780-783 in China. The compiler, Cao Shiwei, apparently an expert in divination as well as a mathematical astronomer, originated in the western part of China. One conjectures that he or his family originally came from Samarkand.

No part of the content of the Futian calendar has survived in China to this day. Tradition says that it was based on an Indian calendar and speaks of it as having entirely altered the old Chinese method. This reputation for novelty is probably due to its adoption of a calendrical epoch in the recent past, in this instance the year 660, rather than placing it conventionally at the time of a grand conjunction. This was a characteristic

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Indian practice. Another innovation of the Futian calendar is its use of decimals rather than traditional fractions. K. Yabuuti has also associated it with astrological practices from India.

H. Momo has shown that the Futian calendar was the major tool of the Buddhist school of astronomy, the productions of which competed with the official Chinese-style ephemerides made by Japanese court astronomers. He has also proven that two extant twelfth-century Japanese horoscopes had been calculated with the Futian calendar. So much for circumstantial evidence.

In 1963, the late J. Maeyama found a text entitled "Futenreki nitten sa rissei" (The Futian calendar table of the solar equation of center, in 1 volume) in the Tenri Library. It was analyzed astronomically by the present writer.

The text, transmitted by the Buddhist school of astronomy, was perhaps preserved in the family of the hereditary court astronomers in Kyoto. When a calendrical reform was projected in the mid-eighteenth century, some able astronomers were called to Kyoto. One of them was Tatara Hoyu, who thus was given access to ancient astronomical works. His project proved to be unsuccessful, but he bequeathed his library to posterity to be used for future calendrical reforms. He edited several collections, one of them entitled "Tenmon hisho" (Esoteric works of astronomy), which includes the fragment of the Futian calendar. This collection was bought by the Tenri Library not long before 1963.

The text consists of a short illustration of calculation and a table of the solar equation of center for each Chinese degree (defined as the mean daily solar motion). Though the explanation of the computational method is somewhat clumsy, analysis of the table clearly showed that the data given are all calculated from the formula:

$$x = (182 - y)y/3300,$$

where x is the equation of center and y is the mean solar anomaly, both expressed in Chinese degrees.

3. A PARADIGM CHANGE AND ITS AFTERMATH

This formula employed in the Futian calendar resembles neither the traditional Chinese empirical (interpolation between observational data) nor the Hellenistic-Indian geometrical or trigonometrical approach. It is an algebraic calculation of second order.

Whether such an algebraic method is superior to empirical or geometrical techniques is hard to judge. It has the advantage of being easily calculated on a counting board, especially in a culture such as China where decimal calculation was widespread. In fact, Chen Meidong has shown that in the course of history this algebraic function became a regular feature of Chinese calendar calculation. It was also employed later for the same purpose in the Uighur calendar.

On the other hand, the algebraic method was not empirically superior. It does not agree as closely with observational data for some days in the cycle as does the traditional Chinese interpolation method.

Thus, when algebraic expression was first used in China, it might have prompted certain psychological restraints, often prevalent at the time of paradigmatic change, among mathematical astronomers. The traditional approach required empirical data for the solar equation of center on any given day, that is, day-to-day observation of the position of the sun. In other words, astronomers are able to check the agreement each day. In contrast, only a few empirical data are needed to determine the coefficients of the algebraic formulas in the Futian calendar — in the case of the second-order equation, only three. The other components are determined by theory and computation.

The algebraic method also sacrifices the psychological satisfaction offered by the rational explanations that geometrical schemes entail, as in the Western astronomical tradition. By improving parameters, algebraic functions may be made to approximate observed positions well enough to satisfy an empirical mind, but they can never satisfy a mind that prefers the theoretical and schematic. The Chinese astronomers who began using European astronomy in the seventeenth century clearly express their appreciation of its ability to explain not only what is, but why it is so.

In conclusion, the algebraic expression introduced into calendrical calculation in the eighth century provided an alternative method, simpler, easier and more convenient for calendar calculators.