draw other circles through the standard-time lines, as indicated in Figure 2, at points where the corrections to standard time (to get sun-time) are 0 and 20 minutes, respectively. These points are indicated by the crossing of the standard-time and the sun-time lines. By interpolation the circles at five-minute intervals, as shown in Figure 2, may be drawn. If time-lines 10 minutes apart are used, then these correction circles may be at two-minute intervals. Next construct a figure eight for the date scale as shown in Figure 3. The small loop of the figure eight is governed by the corrections on May 10 and July 20, as an inspection of Figure 3 will show. The other dates of the year can now be plotted around the figure eight as indicated by column 3 of Table B and illustrated in Figure 3. If desired, the solar-time lines may be left inside the inner circle as has been done in Figure 3. The shadow will then give both local apparent solar time and standard time. Figure 3 shows the finished dial graduations. To set the sun-dial for operation, it is necessary only to level the bottom surface by level-bubbles and then to turn it about a vertical axis until the shadow reads correct time. This is best done near noon.

THE PENNSYLVANIA STATE COLLEGE, STATE COLLEGE, PENNSYLVANIA.

A Statistical Survey of Solar Eclipses in Chinese History*

By WEN SHION TSU

Throughout the Chinese history there were 920 solar eclipses properly recorded, only seven of them were in error and did not take place. These eclipses which were carried down to the present time makes a good reference to study of the history of Chinese astronomy. Since Shih Ching, Book of Poetry, interestingly informed that "the eclipse of the moon is a common matter and the eclipse of the sun is a bad thing," therefore the first standard history, Shih Chi, written by Szu Ma Chien, the celebrated historian of the Han Dynasty about 90 B.C., rejected the lunar eclipses and recorded the solar ones. It is interesting to note that the history gave the dates of the solar eclipses always with their positions in the sky. When the total eclipse occurred, the history also gave the expressions as the day became dark as night, the stars appeared, and the birds and hens went back their nests, etc.

The earliest record of solar eclipse in China was found in Shu Ching, Book of Historical Documents, a Chinese classic. This eclipse was well known to the Chinese and Europeans, and has been fully discussed by a number of eminent authorities. The Punitive Expedition of Yin, the

*The author requested that his phraseology be changed so as to conform more nearly to accepted English usage. We have refrained from doing so, except in cases of obvious misspelling and omissions, in order that the personality of the writer might be preserved. As the meaning is clear, the value of the paper is in no way lessened by the style which is unconventional in places.—ED.

prince of Hsia, is the title of a chapter in Shu Ching, and recorded as follows: "In the first day of the last month of autumn the sun and the moon did not meet harmoniously in Fang. The blind beat their drums, the inferior officers galloped, and the common people ran about." The definite year was not given in the record, and the word Fang was sometimes used as the name of a lunar cycle, and sometimes as a small constellation including the stars β, δ, π, and ρ Scorpii. From this point of view there is some ambiguity. The Buddhist priest named I-Hang, a famous astronomer of the Tang Dynasty about 720 A.D., computed the date at the 5th year Ping Yin of Chung Kang (2155 B.C.). Kuo Shou Ching, the astronomer of the Yuan Dynasty about 1276 A.D., fixed the same date at the 5th year of Chung Kang, but the year cycle was Koei Se (2128 B.C.), which was 27 years behind Ping Yin as referred to by I-Hang. Chung Kang reigned only 13 years. Before the reform period of the Chou Dynasty at 841 B.C. the chronology was in confusion and not accepted by the historians and astronomers. Moreover, for the above referred dates there were no eclipses which could be seen in China. Oppolzer fixed the date at October 22, 2137 B.C. which was 10 years earlier than that of Kuo Shou Ching, while Schligel and Kühnert calculated another date at May 7, 2165 B.C. which was 10 years earlier than that of I-Hang. Such a remote eclipse was practically falling into confusion.

The next ancient eclipse of the sun whose date can be accurately fixed was preceded by an eclipse of the moon. In Shih Ching, as referred to above, there was a record which stated as follows: "The conjunction in the tenth month, the new moon on the first day Sing Mao, the sun was eclipsed, it was very bad." The record also mentioned the eclipse of the moon as quoted above. Dr. Mitchell determined the exact date and explained clearly: "The eclipse of the sun referred to took place on September 6, 776 B.C., the eclipse of the moon on August 21. The solar eclipse was visible only as a partial eclipse in China while that of the moon was nine-tenths." The eclipse of the sun could be seen in Lo-Yang, the capital of Chou, about two-tenths. It is interesting to note that the period from this eclipse to that of October 11, 668 B.C., over 108 years, 39512 days, is just twice of three Saroses. The evidence of the first reliable date of the solar eclipse in the Chinese history stands more firmly without doubt.

The Chun Chiu, or Spring and Autumn, written by Confucius, is best known as the Annals of Lu, his native state. The chief events that took place in the state are briefly summarized in the period of 242 year, 722 to 481 B.C. In the Annals there were 37 eclipses of the sun, 33 of which have been identified with certainty. Two eclipses of September 19, 552 B.C. and July 18, 549 B.C. were in error and did not take place, and two of them on February 4, 645 B.C. and April 9, 518 B.C. were not visible in China.

At the end of the Chou Dynasty the feudal states in Chinese empire were separated and attacked each other. After Chun Chiu there were

seven big states in feudal times from B.C. 460 to 220, which disturbed the peace of the country. The old calendars were said to have been lost, and the astronomical observations have not been properly recorded, or there were even no observations to be taken at all. When the Chou Dynasty was ruined in 255 B.C. Shih Huang Ti, the first emperor of Tsin Dynasty, conquered the whole empire and reigned a short time from B.C. 246 to 210. During the period from B.C. 460 to 210 about 250 years there were only nine eclipses of the sun recorded in the history and the most of them were written without the months and days. According to Oppolzer the one on April 20, 443 B.C. was a partial eclipse and that on August 5, 301 B.C. could be seen in China not more than three-tenths, while the history described these two eclipses in "the dark daylight." This expression was often used for a total eclipse in the Chinese history. These records must be in error, and the eclipse on March 14, 247 B.C. was also in error that could not be visible in China.

The historical eclipse of the sun in Shu Ching told us that the emperor Chung Kang ordered the prince Yin to execute the astronomers Hi and Ho who failed to predict the solar eclipse. This unfortunate story also told us that the ancient Chinese astronomers were in the duty of predicting eclipses more than 4,000 years ago. But up to the time of the Han Dynasty (204 B.C.) forty-eight solar eclipses were mentioned above, the method how to predict the eclipse of the sun could not find any clue in the history. Even in the Han Dynasty from 204 B.C. to 220 A.D. with a long period of 425 years, 141 eclipses of the sun were recorded in the Annals of Han, the calendars which have been used then showed how to calculate the eclipse of the moon but not of the sun. Therefore the solar eclipses described in the Annals of Han were actually seen, only two out of 141 eclipses were in error and did not occur in the time. This is perhaps the mistake in writing or printing as so far the history was carried down about two thousand years ago. There is an important fact that the solar eclipses in the Annals of Han did not always take place on the first day of the calendar month. It was usually one day before, or sometimes one day after which was due to the fact that the new moon did not fall exactly into the first day of the calendar month, because the calendars of Han used the mean new moon and did not apply the apparent new moon to match the first day of the month.

The empire of Han was divided by three states from A.D. 222 to 265. The leading one was Shuh, which had its capital at Chengtu, and comprised all the region west of Hupeh; the next was Wei, whose king Tsao Pi ruled at Loh-yang and swayed most of the region north of the Yangtze River; the third was Wu whose king Sun Küen was invested by the preceding at Nanking, and ruled all the eastern provinces. Each state had its own calendars which sometimes might have one day difference. The eclipses of the sun were recorded in the Annals of Wei in the History of Three States. They were twenty in number. It is interesting to note that in the state of Wei an astronomer Yang Wai established a calendar called Chin Ch'u about A.D. 237, and gave a method

to determine the direction angles at the first contact of the solar eclipse. This was supposed to be the first method to predict the eclipse of he sun.

Tu Yu, a historian of classic research in the Tsiu Dynasty about 280 A.D., determined the solar eclipses of Chun Chiu, the Annals of Lu, by ten calendars, and worked out the data to compare discriminatingly. In the Annals of Tsin there were 83 eclipses of the sun, of which 20 were already recorded in the Annals of Wei as referred to above. The sixty-three solar eclipses properly belonged to the Tsin Dynasty from A.D. 266 to 419. Three of them could not be identified with certainty which must be in error.

At the end of Tsin Dynasty China was divided into two empires, the North and the South. The North empire was ruled the region of Yellow River and reigned by two successive dynasties, namely the North Wei (A.D. 386 to 556) and the North Chou (557 to 581). The South empire was ruled along the Yangtze Valley and reigned by successive four dynasties, namely, the Sung (420 to 478), the Zu (479 to 502), the Liang (503 to 556), and the Cheng (557 to 589). The Huai River which ran west of Honan to north of Kiangsu was taken for their boundary line. The history is very difficult and easy to lead to a confusion. The Annals of the North and the Annals of the South were written by the same author, Li Yei Seu. The former recorded 79 eclipses of the sun and the latter only 36. Twenty-seven of them can be identified with the same year but they may not on the same day. Each dynasty also had its own annals which were comparatively more complicated.

When the Siu Dynasty conquered the whole empire, China was then united into one again at 590 A.D. The Annals of Siu recorded the solar eclipses from 420 to 618 A.D. including those of the South dynasties, but not in full. Ma Tuan Ling, a historian of the 13th century, collected 87 solar eclipses during that time. I have carefully examined all the Annals of these dynasties and found 109 eclipses of the sun from 386 to 618 A.D. so Ma Tuan Ling's collection is also not complete. Since the prediction of the solar eclipses had been improved in the Tsin Dynasty, the Huang Chi Calendar of Siu (604 A.D.) gave the methods for finding the first and the last contacts, and the position and the phases of the eclipses. Most of them recorded in the Annals must be predicted then, so there was about one third could not be seen in China.

The astronomers of the Tang Dynasty as Fu Chen Chin, Li Chen Fung and I-Hang calculated their new calendars which were successively adopted by the emperors. I-Hang's calendar was known as the best. From this epoch each emperor practically changed his new calendar, the astronomical observations were much improved then. The eclipses of the sun observed and recorded were 103 in number in the Tang Dynasty from A.D. 619 to 906. The Five Dynasties followed with a short period from A.D. 907 to 960 and twenty-six eclipses of the sun were recorded in the Annals of the period.

In the Sung Dynasty (961 to 1263 A.D.) the prediction and observa-

tion of the solar eclipses had been considered more important as the first duty for the astronomers. The Bureau of History was then established and had its duty to predict the eclipse and to keep the records. The Bureau of Astronomy was established at the same time and had its duty to observe the eclipse and to record the phenomena. If their work be found in error, the officers should be punished with depressing their ranks, or stopping the payments of their salaries. There were 152 solar eclipses during 300 years in the Sung Dynasty. Every one was on the first day of the calendar month. This proves that the Sung calendars have been improved, and also that the beginning and ending of the eclipses were clearly indicated.

Kuo Shuh Ching, the well-known astronomer of the Yuan Dynasty about 1281, made a calendar with actual observations, and overthrew the old method which was supposed to be the sun, the moon, and the five planets in conjunction on the same day as the beginning of the calendar. He showed his calendar as a practical one and explained a method of predicting eclipses. He also calculated back the ancient eclipses, two from Shu Ching and Shih Ching, thirty-six from Chun Chiu, and thirty-five from the other history. There were sixty-one eclipses of the sun recorded in the Annals of Yuan in 104 years from A.D. 1264 to 1368.

When the Yuan Dynasty fell in 1369 the new dynasty Ming had to change the calendar. The new calendar was called Da Tung and revised in 1384. In fact this calendar was copied from the method of Kuo Shuh Ching and omitted his important part of annular acceleration, whence the predicted time of solar eclipses did not accord with the actual observations, usually three of four hours were in difference. The astronomers noticed the mistakes in the calendar, but it could not be changed without the order of the Emperor. In 1554 Tsu Tsai Yuo, the Prince Tching, made a new calendar, and in 1581 he revised it again. By his methods he calculated back 25 eclipses of the sun mentioned in the Annals and showed that the Da Tung calendar was in error. Unfortunately his calendars were not accepted by the Emperor. In 1583 P. Mathieu Ricci, an Italian missionary, introduced the European methods. In 1628 P. Adam Schall proposed a new calendar which was put in use until the fall of the Dynasty. There were 145 solar eclipses in the Annals of Ming, about 50 of them could not be seen in China.

At the opening of the Tsing Dynasty Schall became an imperial astronomer and the calendar was then adopted. In 1645 P. Ferdinal Verbiest revised this calendar and made some improvements. Fifty-two solar eclipses recorded with every detail in the first 150 years of the Tsing Dynasty from 1645 to 1795. It is to be regretted that the records in the 19th century are said to have been lost at the overthrow of the Dynasty in 1911. The following table is a summary from the Chinese history that shows the distribution of the solar eclipses.