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Solar Observations in Ancient China and Solar Variability

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Solar observations in ancient China and solar variability

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In this paper I review both the history of solar observations in ancient China and recent researches on solar variability. The paper consists of three parts. In the first part I describe Sun worship and the early observations of solar phenomena. In the second part I concentrate on sunspot observations and improving the catalogue of naked-eye sunspot records. In the third part I discuss long-term variations of solar activity by using historical sunspot records over 2000 years. The 210-year cycle, which has the largest significance in the power spectrum, may have an important influence on the forecasting of the next cycle (no. 22).

Solar observations in ancient China

Many archaeological materials have shown that in ancient China Sun worship was in vogue and there were daily sacrificial rites for welcoming and seeing off the Sun (see, for example, Xu *et al.* 1985). Clear evidence is found on bone inscriptions of the Shang Dynasty (*ca.* 1500–1050 B.C.). For example: *Yi Si Bu Wang Bin Ri* (Yi Si day, the King received as guest the rising Sun). *Chu Ru Ri Sui San Niu* (sacrifices were offered to the rising and setting Sun and three oxen were killed).

According to the textual researches of several palaeographers, the words *Bin Ri*, *Chu Ri* and *Ru Ri* were all sacrificial rites to the Sun.

The daily worshipping of the Sun certainly caused spontaneous observations of solar phenomena. In fact, from bone inscriptions it is known that the ancient Chinese had already recorded at least four solar phenomena. They are:

(1) *Ri Hui* (the Sun was dark and gloomy);
(2) *Ri Yun* (solar halo);
(3) *Ri Zhi* (no definite explanation);
(4) *Ri Shi* (solar eclipses).

In addition to this evidence, many ancient works of art related to solar phenomena have recently been unearthed in China (see, for example, Xu 1987). Most of them have shown the same solar phenomenon that is known as *Ri Zhong Wu* (a crow – or a three-legged crow – was within the Sun). In fact, they are artistic representations of sunspot phenomena.

Sunspot observations and systematic records

As far as is known, the earliest sunspot observations should be identified by the expression *Ri Zhi* as found in the above mentioned bone inscriptions. This word has been interpreted in different ways, but an explanation in terms of sunspots seems to be most reasonable. In a paper that will be published elsewhere I shall discuss this problem in detail. Sunspot observations were mentioned in one of the famous Chinese classics, the *Book of changes*. In the hexagram of *Feng* ('abundance') there were two specialized terms: *Ri Zhong Jian Dou* ('the *Dou*, which is a

measuring rice tool, was seen within the Sun') and *Ri Zhong Jian Mei* ('a star was seen within the Sun'). It has been established that the two terms essentially mean that sunspots were seen within the Sun (see, for example, Xu 1979). These same expressions have been used for recording sunspot phenomena until the beginning of the Qing dynasty (A.D. 1644).

Systematic recording of sunspot phenomena began from the Han dynasty (206 B.C. to A.D. 220), because just at that time the Chinese official histories started to be compiled. A well-known event is the sunspot record of 10 May 28 B.C. The text states that 'On Ji Wei day the Sun was yellow at its rising and a black vapour as large as a coin was observed at its centre'. After the Han dynasty there were some sunspot records in each dynastic history. In the encyclopaedia *Tu Shu Ji Cheng* (*Imperial Encyclopaedia*) of the Qing dynasty, the previous sunspot records were gathered in a special chapter. To trace sunspot activity back in time, several authors have compiled a limited amount of sunspot records and produced catalogues of sunspot observations. The most famous of these works is Kanda's catalogue. It contains 142 items from Chinese histories with a supplement of some records from Korean and Japanese official histories (see, for example, Kanda 1932). However, there are two shortcomings in these researches. Firstly, it is now known that there are at least seven separate specialized terms for recording sunspot phenomena sighted by the naked eye in ancient times (see, for example, Xu 1990). Because all of these terms were not recognized until recently, some sunspot records were overlooked or misinterpreted. Secondly, apart from the official histories there are also numerous local topographies called *Fang Zhi* ('local gazettes'). These are important supplements to the official histories and equivalent to the latter in the reliability of recording events. The *Fang Zhi* were ignored until Xu & Jiang (1982) explained the importance of seventeenth-century records. Using the above mentioned sources, I have reconstructed a new naked-eye sunspot catalogue that assembled both Western and Oriental records and added a substantial amount of new data (see, for instance, Wittmann & Xu 1987).

Long-term variations of solar activity

The variability of solar activity before A.D. 1700 has for some time been an interesting problem. During this historical period, Chinese sunspot records were direct reflections of solar activity. Some authors have therefore used them to analyse the periodicity of solar activity. However, on the one hand, their sunspot catalogues were incomplete, and on the other hand the statistical weight of different sunspot records was not considered.

To overcome these shortcomings, I used our essentially complete sunspot catalogue, mentioned in the above section. Then according to descriptive differences in sunspot size, number and sighting duration I assigned weights for each sunspot record. Thus I transformed descriptive sunspot records into a numerical time series. From the time series I obtained its power spectrum, details of which are summarized in table 1 (see, for example, Xu *et al.* 1988). These results enable the following conclusions to be deduced.

1. The 10.62-year period, which actually is the mean periodicity of Schwabe's cycle, is quite significant during the past two millenia, even though the ancient sunspot record is not continuous. This means that Schwabe's cycle is a basic regularity of solar activity and such activity has never ceased.

2. The 212-year period is most significant. Recent researches have also shown that a 210-year cycle of solar activity can be obtained from analysing some astrophysical and geophysical

Table 1. Details of the power spectrum

frequency / cycles per year	period/years	phase	amplitude
0.0047	212.77	0.0267	0.2555
0.0038	263.16	1.3251	0.2448
0.0159	62.89	−0.2926	0.1352
0.0024	416.67	−0.7763	0.1279
0.0942	10.62	−1.5087	0.1156
0.1506	6.64	−0.8893	0.0858
0.0090	110.10	−0.0031	0.0856
0.0114	86.96	0.5784	0.0694

data (see, for example, Chistyakov 1986). Hence the 210-year cycle may be a new important regularity of solar activity. If so, it may give valuable guidance in forecasting the level of the next cycle. It seems possible that the maximum sunspot number of the forthcoming no. 22 cycle will be substantially more than 100.

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