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WHEN AND WHERE TO LOOK TO OBSERVE MAJOR SOLAR FLARES?

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Abstract

When and where to look is an important issue to observers planning to observe major solar flares. Prediction of major flares is also important because they influence the Earth's environment. This paper discusses how to utilize recently discovered solar "hot spots" and a solar activity periodicity of about 154 days in determining when and where to look to catch major flares.

HOT SPOTS FOR FLARE ACTIVITY

It has been discovered that solar flares are not uniformly distributed in longitude, but that there exist "hot spots" or "active zones," where flare activity is much higher than elsewhere (Bai 1987, 1988). Figure 1 shows the longitude distribution of major flares of the Northern Hemisphere in a system rotating with a synodic period of 26.72 days (from Bai 1988). Here major flares mean flares with comprehensive flare indices (CFI) greater than 5 for cycle 19 and those with CFIs greater than 6 for the 1965-1979 period. Compilation and indexing of CFIs are given by Dodson and Hedeman (1971, 1975, 1981). For the period since the launch of the *Solar Maximum Mission* (*SMM*), major flares mean flares with peak rates greater than 1000 count/s measured by the Hard X-Ray Burst Spectrometer (HXRBS). In this figure we find two longitude intervals where the flare distribution is higher than the average; they are called "hot spots" or "active zones." One around 120° is very prominent for cycles 20 and 21; the other around 300° is not very distinctive for cycle 20, nevertheless four superactive regions appeared in the 270-330° interval during cycle 20. These two hot spots were about 180° apart in longitude and remained at the same locations during cycles 20 and 21. They rotated with a synodic period of 26.72 days.

For this figure, the Central Meridian at 00:00 UT on January 1, 1965 was taken as the zero longitude. With this convention, the relationship between Carrington longitude, l_c, and the relative longitude, l_n, of Figure 1 is given by

$$l_n = 1.021 l_c - (N_{cr} - 1489)\, 7.48 + 106 + 360 m_1 , \quad (1a)$$

or

$$l_n = 1.021 l_c - (N_{cr} - 1812)\, 7.48 + 210 + 360 n_1 \quad (1b)$$

where N_{cr} is the Carrington rotation number and m_1 and n_1 are integers to make l_n be in the 0-360° range.

Figure 2 shows the longitude distribution of major flares of the Southern Hemisphere in a system rotating with a synodic period of 26.61 days (from Bai 1988). Here also we find two longitude intervals, 10-60° and 170-260°, where the flare distribution is higher. The enhancement in the first interval is very prominent for cycle 21, weak for cycle 19, and nonexistent for cycle 20. The enhancement in the second interval can be seen through all three cycles. These two hot spots in the Southern Hemisphere rotated with a synodic period of 26.61 days, and they were also separated by about 180° in longitude. Here the same convention was used for the zero longitude as for Figure 1. The relation between l_c, and l_s of Figure 2 is given by

$$l_s = 1.025 l_c - (N_{cr} - 1489)\, 9.00 + 105 + 360 m_2, \qquad (2a)$$

or

$$l_s = 1.025 l_c - (N_{cr} - 1812)\, 9.00 + 78 + 360 n_2, \qquad (2b)$$

where m_2 and n_2 are integers to make l_s be in the 0-360° range.

It is of great interest to find out what causes hot spots lasting two or three solar cycles. Whatever the physical mechanism is, the hot spots may be useful in determining where to point our instruments to observe major flares. It is often criticized with a hind sight that we have not done well in pointing *SMM* detectors to very prolific active regions. Before relying on hot spots, let us see the longitude distribution of major flares in cycle 22. Figure 3 shows the longitude distribution of major flares with HXRBS peak count rates above 1000 counts/s for the period from January 1, 1986 to March 31, 1989. We find a huge concentration of flares in the 90-150° interval. This is due mainly to flares from three superactive regions: AR 5278, AR 5355, and AR 5395. The last one produced 27 major flares. AR 5470, which produced a series of major flares in early May (private communication, Don Neidig; Bill Marquett) was located at (N30, l_c=263°). It was right at the prominent hot spot with l_n=96°. AR 5528 produced an X-class flare in early June, and its relative longitude is l_n=275°, putting it squarely in the less prominent hot spot of the Northern Hemisphere for cycles 20 and 21 (see Figure 1).

Thus, so far, the Northern Hemisphere flare distribution for cycle 22 looks very similar to those for cycles 20 and 21.

The longitude distribution of major flares of the Southern Hemisphere is shown in Figure 4 for the same period as for Figure 3. This distribution does not resemble that of Figure 2 at all. It is too early to say whether the Southern Hemisphere will develop hot spots at new locations or at the same locations as in earlier cycles.

From the above discussions, the Northern Hemisphere hot spot around $l_n=100^\circ$ is the most promising place to look. This hot spot rotates with a 26.72-day synodic period and crossed the Central Meridian on May 31, 1989. It should be remembered that a hot spot is not active continuously, but major flare activity comes and goes every several months. A hot spot that has been quiet for several months does not burst suddenly into violent flare activity, but it becomes very active usually one or two rotations after forming interesting active regions (see Figures 5, 9, and 13 of Bai 1988). If an interesting active region begins to develop in a hot spot, therefore, we should pay attention.

A 154-DAY PERIODICITY

It has been recently discovered that solar activity exhibits a periodicity of about 154 days. This periodicity appears not only in the rate of occurrence of solar flares but also in various indicators of solar activity (Rieger *et al.* 1984; Kiplinger *et al.* 1984; Bogart and Bai 1985; Ichimoto *et al.* 1985; Bai and Sturrock 1987; Lean and Brueckner 1989; Droege *et al.* 1989).

This periodicity can be used in determining when to observe the Sun to catch major flares. Between June 1980 and December 1983, the increase of flare activity with the 154-day period was very regular (Rieger et al 1984; Bogart and Bai 1985; Bai and Sturrock 1987). If such a regularity is repeated in the future, the 154-day periodicity is going to be a good guide in planning for major solar flare observations. However, a recent analysis of the occurrence of proton flares (Bai, Cliver, and Kile 1989) shows that the periodicity is intermittent by appearing in the interval between April 1957 and December 1971 and in the interval between April 1978 and October 1983. My analysis of the occurrence of HXRBS major flares shows that the periodicity is not present in the interval from January 1984 to June 1989 (Fig. 5). Therefore, the observations so far are not so encouraging.

But we have to wait for the reappearance of the periodicity. If we see a great increase of flare activity in early August, five months after the burst of major flares in AR 5395 in March 1989, we may expect a reappearance of the 154-day periodicity.

TYPES OF ACTIVE REGIONS

Predicting major solar flares based on the periodicity and hot spots is like predicting the weather based on the climate. It is good for long-term predictions and for the average behavior. For short-term predictions, knowing the types and development histories of active regions on the solar disk is necessary, because more than 99% of flares occur in active regions. Therefore, it is important to know what types and morphology of sunspot groups produce large numbers of major flares. There has been a large amount of work on this subject, and a proper review is beyond the scope of this paper (see McIntosh 1981; Sawyer, Warwick, and Dennett 1986; references therein).

Since January 1972 a revised Zurich classification scheme has been adopted by the *Solar Geophysical Data* (McIntosh 1981). The first letter in this three-letter classification scheme indicates whether the group is unipolar or bipolar and what is the longitudinal extent in the case of a bipolar group. The second letter indicates the area of the largest sunspot in the group. The third letter indicates the sunspot distribution in the group. It is of interest to find out what classes superactive regions belong to. Bai (1988) gives three-letter classifications of superactive regions at the peak of their development. Table 1 gives the frequencies of different classes among the superactive regions given by Bai (1988). We find that 37 of the 49 superactive regions for the 1972-1985 period have "E" or "F" as their first letters of the classification. This means that for a large majority of superactive regions their longitudinal extents are greater than 10^{o}. Forty four of the 49 superactive regions have "k" as their second letters of the three-letter classification. This means that for a large majority of superactive regions the penumbral diameters of their largest sunspots are greater than 5^{o} in heliographic angle ($>6\times10^{4}$ km). Twenty five of the 49 superactive regions have "c" as their third letter of the three-letter classification. This means that superactive regions are compact, which indicates that the magnetic field gradient is large somewhere in superactive regions. Therefore, if an active region belongs to Ekc or Fkc class, it is more likely to produce major flares.

TABLE 1
SUNSPOT GROUP CLASSES OF SUPERACTIVE REGIONS

First Letter	A	B	C	D	E	F	H
No. of A. R.	0	0	1	11	22	15	0

Second Letter	x	r	s	a	h	k
No. of A. R.	0	0	3	1	1	44

Third Letter	x	o	i	c
No. of A. R.	0	4	20	25

SUMMARY

We have discussed how to utilize the 154-day periodicity and the existence of hot spots in determining when and where to look to observe major flares. The two Northern Hemisphere hot spots that persisted at the same locations through cycle 20 and 21 seem to persist at the same locations until now (June 1989). Therefore, the Northern Hemisphere hot spots---especially the prominent one---are good places to watch to observe major flares. Especially when complex active regions appear within the hot spots, we should expect major flares from there. The longitude distribution of southern hemisphere flares for cycle 22 until now is different from those of the preceding cycles. It is not certain at this time whether or not the distribution for the Southern Hemisphere will resemble those of the preceding cycles as more flares are produced. Therefore, southern hemisphere hot spots are, as of now, less reliable.

The 154-day periodicity does not appear in the occurrence rate of major flares for the time interval from the beginning of 1984 until now. A recent study shows that the periodicity is intermittent appearing in certain epochs and not appearing in other epochs. Therefore, when the 154-day periodicity resumes its regularity, we can use it for planning observations of major solar flares.

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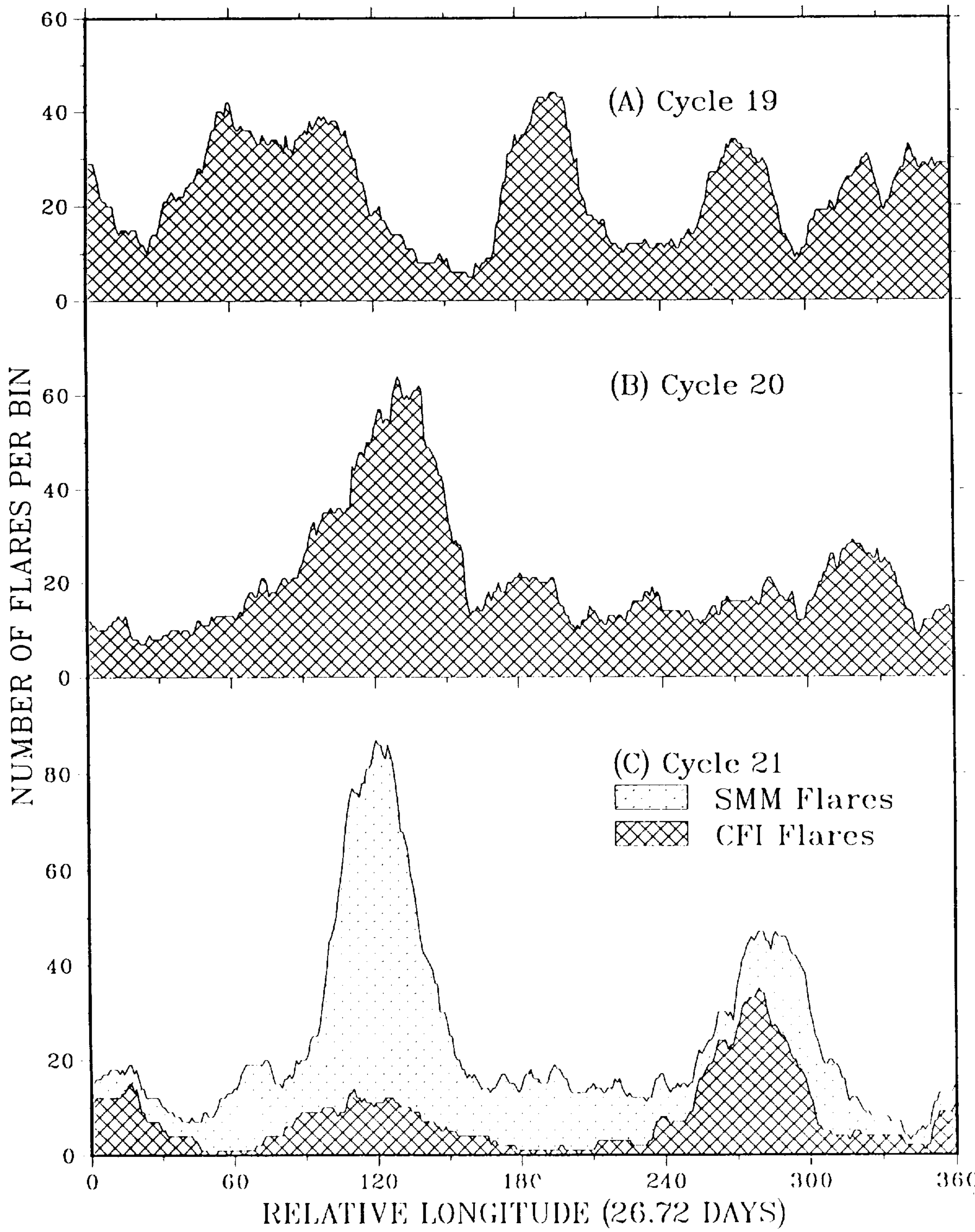

Fig. 1. Longitude distribution of northern hemisphere major flares for cycle 19(a), cycle 20(b), and cycle 21(c) in a system rotating with a synodic period of 26.72 days. For cycle 19, flares with CFI>5 are selected, and for the 1965—1979 period, flares with CFI>6 are selected. For years from 1980, *SMM* flares with peak HXRBS rate >1000 counts/s are selected. (Figure from Bai 1988)

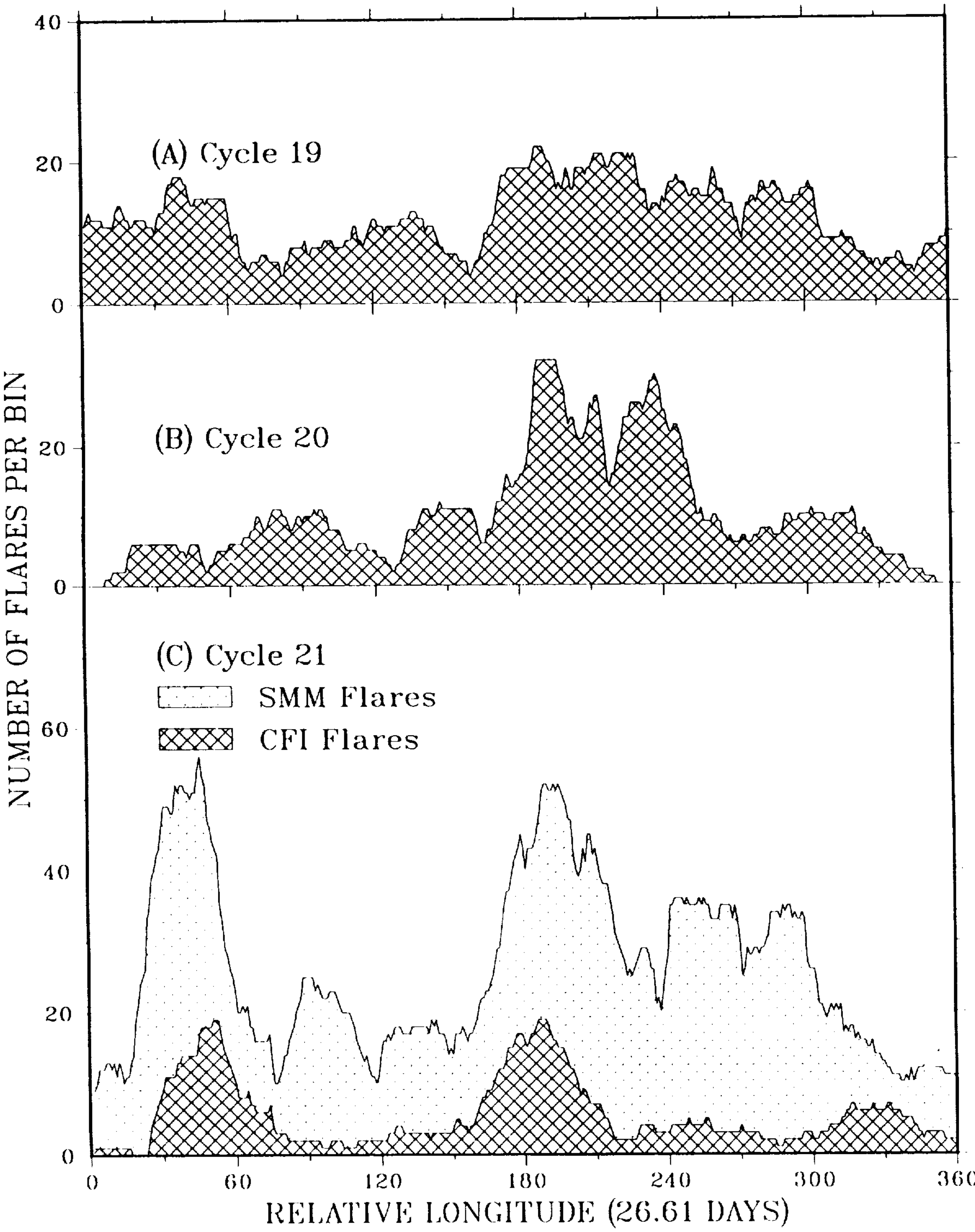

Fig. 2. Longitude distribution of southern hemisphere major flares for cycle 19(a), cycle 20(b), and cycle 21(c) in a system rotating with a synodic period of 26.61 days. The same selection criteria for major flares were used as for Fig. 1. (Figure from Bai 1988)

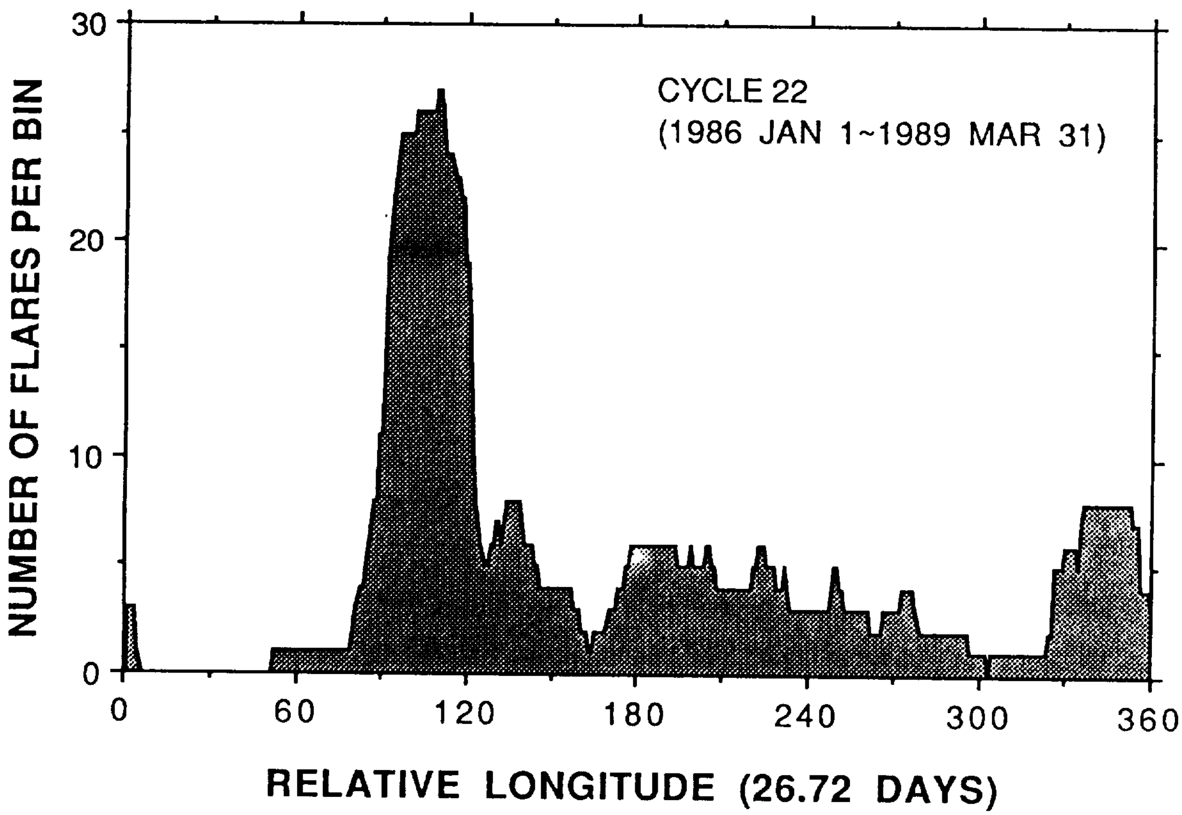

Fig. 3. Longitude distribution of northern hemisphere major flares for cycle 22 in a system rotating with a synodic period of 26.72 days.

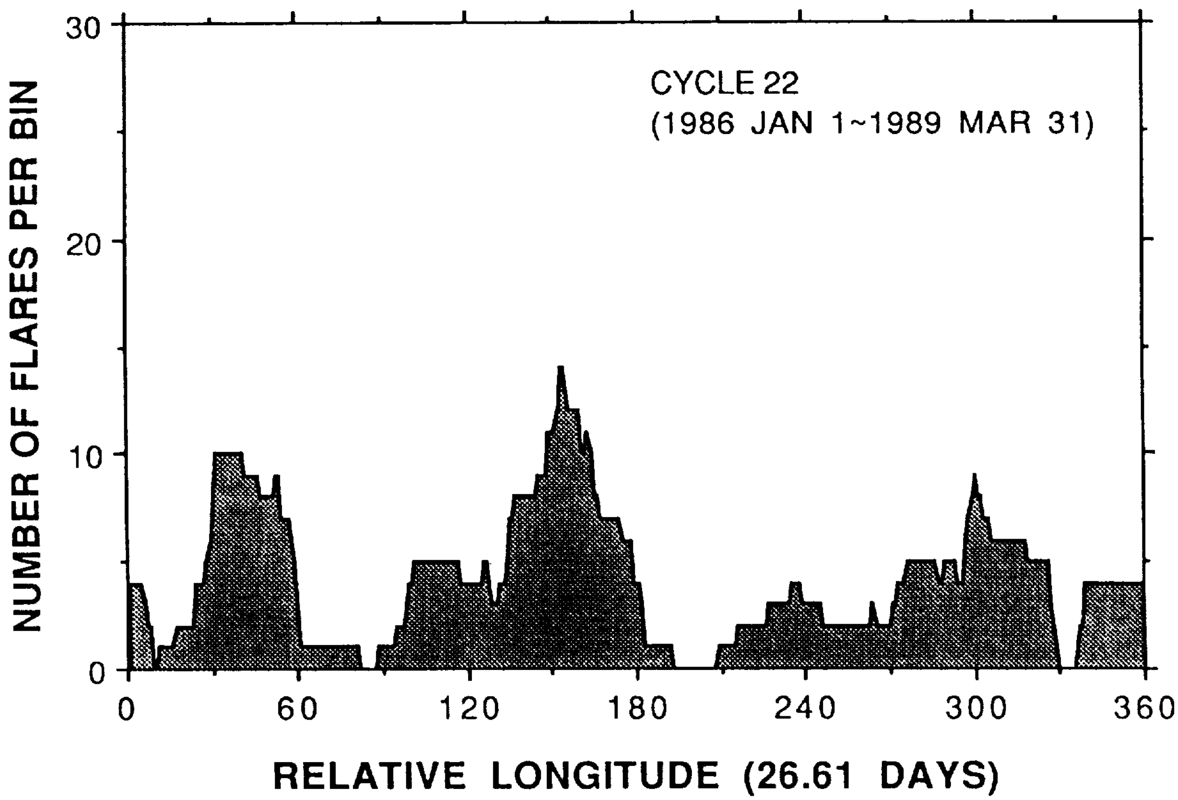

Fig. 4. Longitude distribtuion of southern hemsiphere major flares for cycle 22 in a system rotating with a synodic period of 26.61 days.

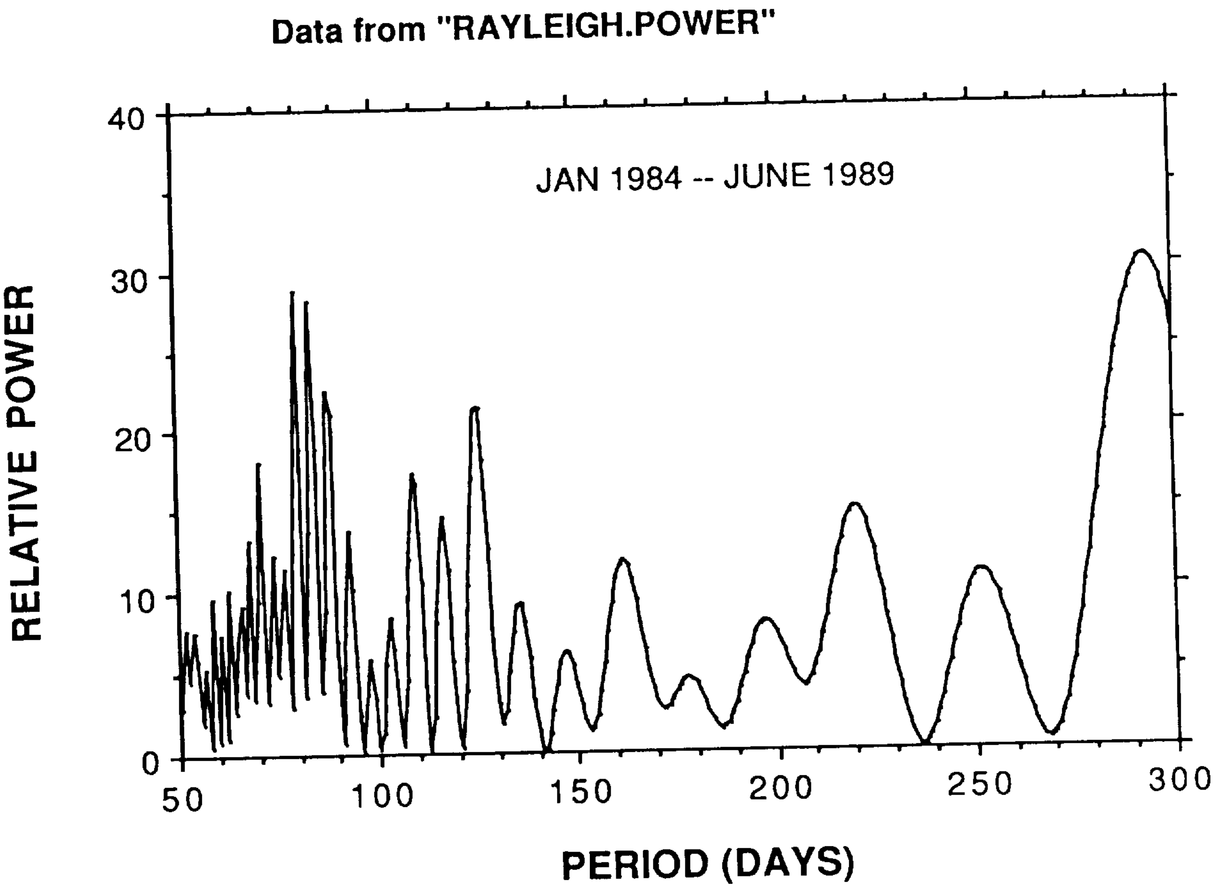

Fig. 5. Fourier power spectrum for the occurrence of major flares for the 1986 January 1 to 1989 June 8 interval. There is no peak at all near 154 days.