SOME CHARACTRISTIC FEATURES OF SOLAR ACTIVITY DURING SOLAR CYCLE 21

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Abstract

An analysis of monthly cosmic-ray data of the Inuvik station over the period 1975-1984 is carried out for the study of some solar cycle phenomena related to the cosmic-ray modulation. A remarkable large time-lag of one-half year between cosmic-ray intensity and solar activity (as indicated by sunspot number, solar flares and high-speed plasma streams) is appeared for first time. This lag indicate the very high activity level of the 21st solar cycle where the size of the modulation region at a first approximation is estimated to the value of 180 AU. The hysteresis-effect is considerably increased in the 21st cycle, whereas a periodicity of the lag, cycle per cycle, is also presented.

1. Introduction. It is known that the solar activity presents many strange features from cycle to cycle and have been examined in detail from several researchers. For example, Legrand and Simon (1985) have noted that there are series of cycles with very high activity level (cycles 18, 19, etc.) as well as quite low activity level (cycles 5, 6, 12, and 14). Xanthakis et al. (1981) have showed that the amplitude of modulation in the 20th solar cycle is smaller than that in the 19th cycle.

In this work in order to study the characteristics of the 21st solar cycle, we examined the 11-year modulation of cosmic-ray intensity from several solar, interplanetary and geomagnetic indices. The variation of cosmic-ray intensity over a solar cycle bears a close inverse relationship to the actual solar activity cycle (Forbush, 1958). It has been shown that the differences between the shapes of the curves representing the variation of these quantities introduce a hysteresis-like phenomenon. Dorman and Dorman (1967) have developed a mathematical model in which the magnetic inhomogeneites that regulate the transport of cosmic-ray particles are related to the sunspot numbers and the dimensions of the solar cavity are in the range of 80-160 AU. Hatton (1980), Mavromichalaki and Petropoulos (1984) have shown that the phase-lag between cosmic-ray intensity and solar activity can be removed by choosing a different index for solar activity.

The remarkable large time-lag between cosmic-ray minimum which occurred in August 1982 and the sunspot maximum which was in September 1979 (Fig. 1) led us to examine the characteristics of this cycle in the light of phase-lag between cosmic-rays and various kinds of solar, interplanetary and geophysical parameters.

2. Method of Study. In order to study the long-term cosmic-ray modulation for solar cycle 21st, we applied a method of data analysis which appeared by Mavromichalaki and Petropoulos (1984).

So, we used neutron monitor data of Inuvik station (Super NM-64, threshold rigidity 0.18 GV) for the interval 1965-1984, which were normalized so as the intensities at solar minimum are taken equal to 1.00 and those at solar maximum equal to zero.

Also for this analysis monthly values of relative sunspot number (Zürich Observatory), the flares of importance ≥ 1N, the flares at importance ≥ 1B, and the geomagnetic index A_p have been used (Solar Geophysical Data). For the same period we have found and identified the two categories of high-speed streams of solar plasma. The first one is the slow undisturbed wind of "quite days" emitted by coronal holes and called "Corotating streams", and the second one is the stable high-speed wind streams associated with strong active regions emiting solar flares and producing Forbush decreases in the Earth and so called "Flare generated streams" (Burlaga, 1975;1979). The solar-wind streams have been taken from J. King available through the National Space Science Data Center (King, 1979,1983,1986).

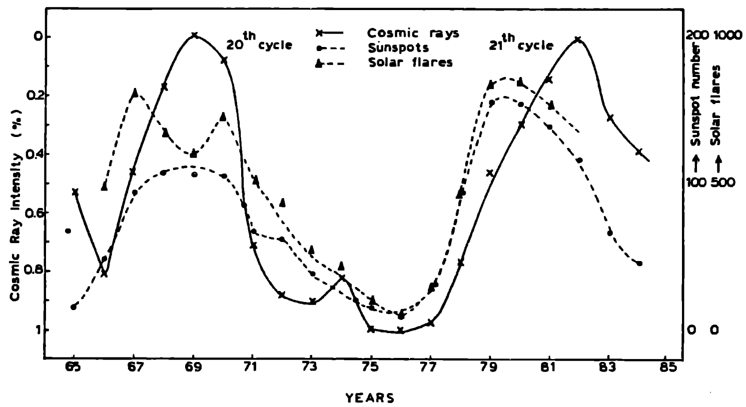

Fig. 1 Neutron monitor data, sunspot number and solar flares during the 20th and 21st solar cycles

A correlation analysis of cosmic-ray intensity with all these series of data for different time-lags between the cosmic-ray intensity and each of the above mentiones parameters is carried out (Figs 2 and 3). The time-lag of cosmic-ray intensity

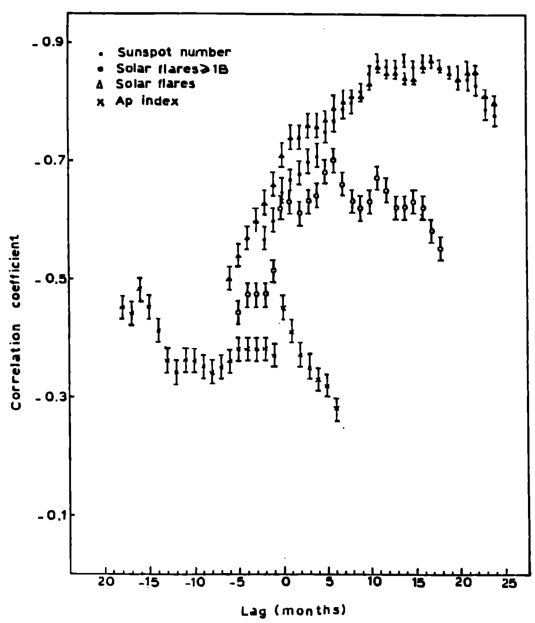

Fig. 2 Correlation coefficient between the monthly cosmic-ray intensity and sunspot number, solar flares, solar flares at importance >1B and A_p index as a function of cosmic-ray intensity-lag with respect to these indices for the 21st cycle

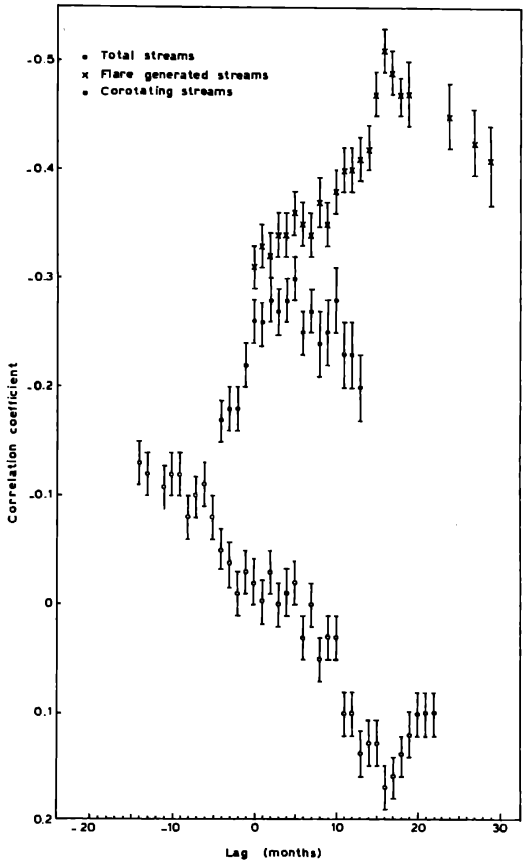

Fig. 3 Correlation coefficient between the monthly cosmic-ray intensity and total streams, flare-generated streams, and corotating streams as a function of cosmic-ray intensity lag with respect to these indices for the 21st cycle. The errors are also appeared

which corresponds to the cross correlation coefficient of each parameter for the cycles 21st and 20th is given in Table 1.

Table 1

Cross correlation coefficient and the corresponding time-lags for the solar cycles 20 and 21

Indices	r	Lag (months)			Lag (months)	
Sunspot number	-0.87	16		0.88	2	
Solar flares $>$1N	-0.87	17		-0.76	4	
Solar flares $>$1B	-0.70	6				
Streams	-0.30	5	21 cycle			20 cycle
Flare-generated streams	-0.51	16		-0.30	3	
Corotating streams	+0.17	16				
A_p index	-0.45	0		-0.20	0	
	-0.48	-16		+0.33	12	

3. Discussion and Conslusions

From the above analysis we can conclude the followings:

It is interesting to note the large time-lag of cosmic rays with respect to sunspot number and solar flares $\geq$1N. The cross correlation coefficient for these parameters is at a maximum for a time-lag of 16 months which is appeared for first time during a solar cycle. It was known that the time-lag of cosmic-ray intensity with respect to solar activity varies from several to twelve months (Nagashima and Morishita, 1980). The large lag of cosmic-ray during the present cycle was also noted by Legrand and Simon (1985) correlating the cosmic-ray intensity and the shock event activity.

The corresponding lag of cosmic rays during the 20th cycle was only two months for the sunspot number and 4 months for the solar flares. It means that the present cycle was a very active cycle comparing with the previous one and the size of the modulating region around the sun during the 21st cycle is estimated to the value of 180 AU in a first order approximation. It confirms the fact that the dimensions of the heliosphere are not constant but depend upon the level of activity during a given solar cycle. That is the heliosphere has a large size during the more active cycles.

On the other hand, looking at the time lags of previous cycles, we see that the hysteresis effect appears a periodicity. The phase-lag of cosmic-rays with respect to the sunspot number gives large values during the odd cycles and short values during cycles 17,18,19,20 and 21 the corresponding time-lags are 9, 1.10-11.2 and 16 months. Perhaps, it is due to the superposition of 11-year and 22-year modulation.

The cosmic ray intensity appears a short relatively lag (6 months) with respect to the most important solar flares (≥1B) as it is shown in Fig.2, which means that this parameter of solar activity affected mainly the cosmic-ray modulation (Legrand and Simon, 1985) and not the sunspot number as it was believed.

The correlation analysis between cosmic-ray intensity recorded at the Earth with respect to geomagnetic index A_p has shown that there is no pronounced phase lag. A negative correlation is appeared before sixteen months (Balasubrahmanyan, 1967).

The same correlation analysis between monthly cosmic-ray intensity and the two categories of high-speed solar wind streams has shown that a large time-lag of 16 months is introduced into the streams data. This large lag indicate that the influence of fast streams on cosmic rays is extended to large regions around the sun.

4. Acknowledgements. Thanks are due to all experimental groups which provided all these data and to the director of WDC-A of Solar-Terrestrial Physics.

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