29th ASI Meeting
ASI Conference Series, 2011, Vol. 3, pp 69 – 74
Edited by Pushpa Khare & C. H. Ishwara-Chandra

Study on solar and cosmic ray activities and their periodic behaviour

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Abstract. This thesis studies the short and mid-term periodicities of different solar indices and galactic cosmic ray data from different neutron monitor stations and their time-variability for cycles 21-23. Hysteresis effects between solar and cosmic ray data also have been investigated. Possible explanations of detected periodicities are discussed.

Keywords : Sun: flares – Sun: oscillations

1. Introduction

Solar activity exhibits both periodic and quasi-periodic variations in different time scales from minutes to centuries and even beyond. For a long term periodicity the Suns 11-year sunspot cycle (Schwabe cycle) and for a short term 27 days periodicities are most prominent. The former is related to the polarity reversal of solar magnetic field while the latter reflects rotational modulation. The regime between these extremes of time scales (27 days and 11 years) is called the midrange (Bai, 2003). Investigation of mid-term periodicities using solar activity indicators has been explored starting with the discovery of a ~154 days periodicity in energetic solar flare occurrence around the maxima of cycle 21 (Rieger et al. 1984). Solar wind, the magnetized plasma composed of charged particles flowing away from the Sun, perturbs the upper atmosphere of the Earth, changes its composition, temperature, and affects the modern communication system (Clark 2006). On the other hand, the Earth is permanently bombarded by energetic charged particles coming from our own galaxy like black holes, rotating neutron stars etc and are called Galactic Cosmic Rays (hereafter GCRs). GCRs has profound effect on the cloud formation, atmospheric ozone depletion etc (Bazilevskaya et al. 2008). Therefore, predicting the timing and strength of

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such eruptions is very important, which is hampered by the fact that the inner dynamics of the Sun is not fully understood. In view of this, the main aim of the present thesis is to study the short and mid-term quasi-periodicities of various solar and cosmic ray activities during different solar cycles. A number of short and intermediate term periodicities including the well known 150-160 days fluctuation is detected in different data sets during different intervals. Along with it, the correlation effect between solar parameters and GCRs has also been investigated. Possible explanations of the observed periodicities are given in terms of r-mode oscillations inside the Sun.

2. Data and analysis methods

We have used the data of solar flare with energy of electrons in different energy bands viz. low (> 0.6 MeV), medium (> 2 MeV) and relativistic (> 10 MeV) recorded by IMP-8 satellite for cycles 21-23.The other solar indices studied were daily sunspot no. and area, separately for the whole solar disk, northern and southern hemisphere; 10.7 cm. radio flux and coronal Fe lines taken from National Geographical Data Centre. GCRs data has been considered from Moscow and Oulu neutron monitor stations. Intermediate term periods were detected by using FFT, Maximum entropy, Lomb-Scargle periodogram and Wavelet techniques.

3. Results and discussions

Power spectral analysis exhibited prominent peaks around 150–155 days during cycles 21and 23 in electron flares of all energy bands (Chowdhury & Ray 2006; Chowdhury et al. 2008). During solar cycle 22, the prominent periods in low and medium energy electron flares were ~ 330 days and ~ 640 days (~1.66 yr). We have found significant periods of ~152 days and ~176 days in the same data sets during ascending phase including maxima of cycle 23 (Fig.1). But in case of relativistic flares we found ~ 155 day period during cycle 22 (Fig.2) (Chowdhury et al. 2009a). During cycle 22, for whole solar disc data of sunspot areas, we have found significant periods of 27-36 days, ~106, ~175 and ~389 days (Fig.3). Similar type time variable quasi periodicities are also found in northern and southern hemispheres of the Sun (Chowdhury et al. 2009b). The well-known Reiger periodicity was present in sunspot area data during cycle 22, but prominent mainly in the southern hemisphere. Period ~1.3 yr is detected in the whole disc as well as southern hemisphere (Chowdhury et al. 2009b). During solar cycle 23 along with rotational period ~27 days we also detected other quasi-periods like 150-160 days, 350-380 days and ~1.3 years in different time-intervals (Fig. 4). We have further investigated the periodic behavior of both sunspot numbers and areas from 2003 to 2007, covering only the deep descending phase of solar cycle 23 using wavelet technique. In case of daily sunspot numbers, we have found that periods corresponding to solar rotation and its close are most stable. Other short-term periodicities like 40-50 days, 60-70 days,

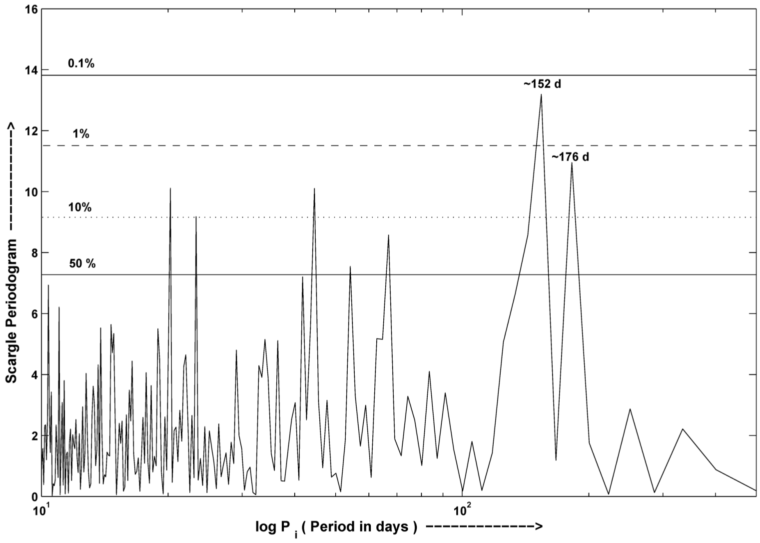

Figure 1. Periodicity of $E > 2$ MeV solar electron flares for cycle 23.

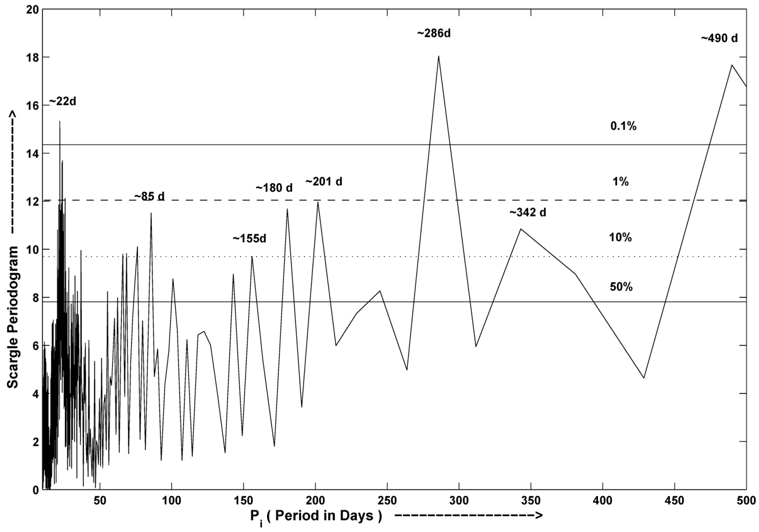

Figure 2. Periodicity of $E > 10$ MeV solar electron flares for cycle 22.

80-90 days, 110-130 days, 140-150 days, 160-170 days and 230-240 days were also found in different hemispheres during declining phase of this cycle (Chowdhury et al. 2010a). Similar kinds of quasi-periodicities were also detected in the daily sunspot area time series. We have studied the cross-correlation coefficient and time- lag between different solar activity indices like sunspot number, area, 10.7 cm. flux, coronal Fe line and GCRs data taken from Moscow neutron monitor station for 1996-2003 and

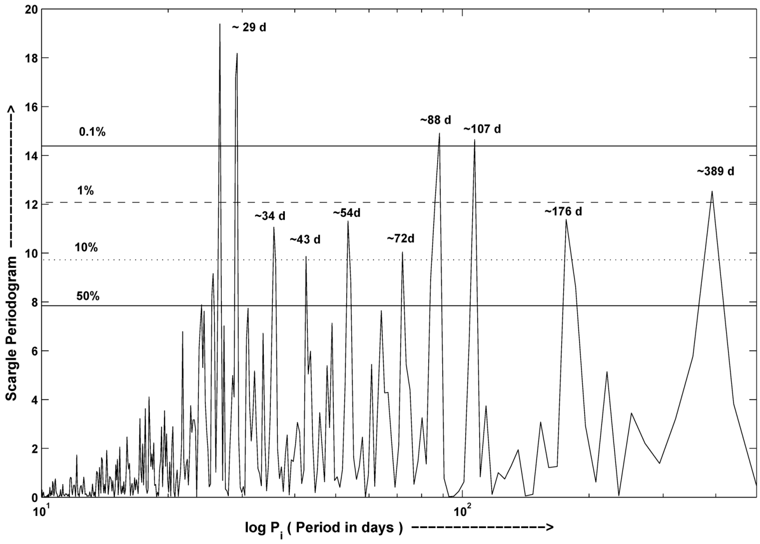

Figure 3. Periodicity of Sunspot area of full solar disk for cycle 22.

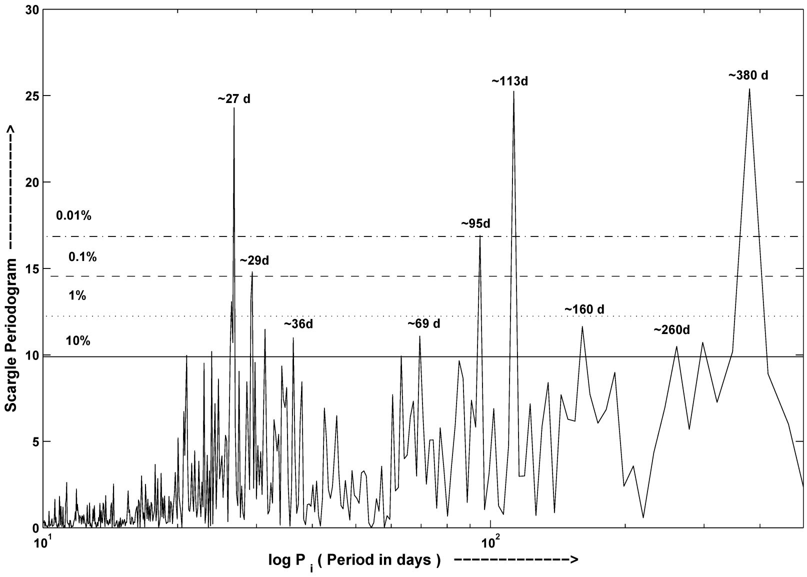

Figure 4. Periodicity of Sunspot area of full solar disk for cycle 23.

found that the lag varies non periodically between -20 to 20 days (Fig. 5) (Chowdhury et al. 2010b). Further study on the periodic behavior of GCRs data taken from Oulu neutron monitor station for cycle 23 noted significant periods of 27-32 days, 120-125

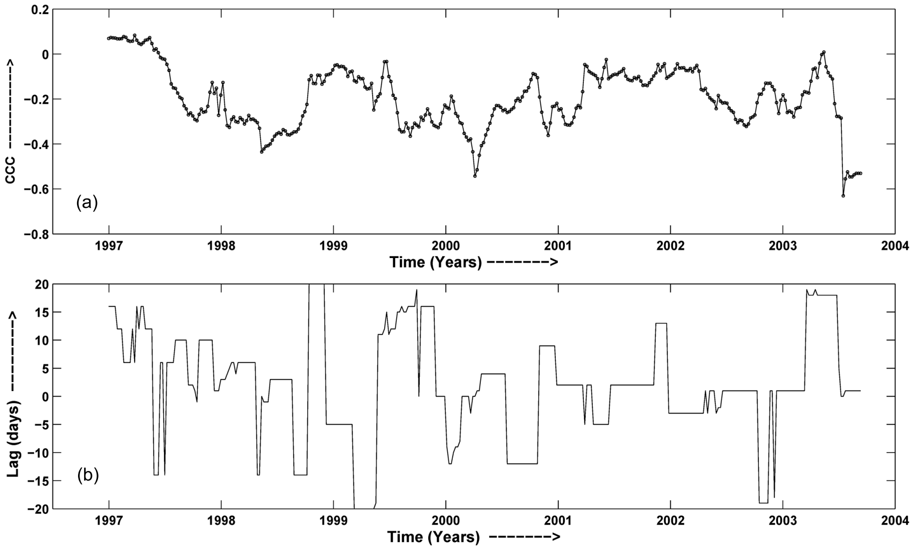

Figure 5. (a) Cross-correlation coefficient between Sunspot area and Moscow GCR for cycle 23. (b) Lag between Sunspot area and Moscow GCR for cycle 23 (1.5.1996–31.12.2003).

days, 150-190 days and ~1.35 yrs. (Chowdhury et al. 2010c). We discussed the GCRs periodicities on the basis of transient phenomenon occurring inside the heliosphere.

4. Conclusions

Sturrock et al. (1999) and Lou (2000) suggested that the Rieger and similar Rieger-type periodicities are related to physical properties of Rossby type waves or r-modes occurring inside the Sun. The r-modes are globally coherent quasi-toroidal oscillations dominated by coriolis force which in small scale approximation reduces to the Rossby waves (Provost et al. 1981) and from the SOHO/MDI instrument, Kuhn et al. (2000) detected signature of long-lived r-modes. We found that our results are consistent with the periods detected theoretically with r-mode oscillations or Rossby type of waves.Probably solar modulation of GCRs within the heliosphere and their interaction with solar wind are the cause of GCRs periodicities and the time lag.

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