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Long–term relationship between the tilt of the heliospheric neutral current sheet and cosmic ray intensity variation

Umakant Sharma[a], G.N. Singh[b] and Pankaj K. Shrivastava[c]
(a) Department of Physics, A.P.S. University, Rewa, 486 003, India
(b) Department of Physics, Sudarshan Degree College, Lalgaon, Distt. Rewa, 486 115, India
(c) Department of Physics, Govt. Model Science College, Rewa, 486 001, India
Presenter: Umakant Sharma (uks_2005@rediffmail.com), ind-sharma-UK-abs1-sh34-oral

A correlative analysis has been done between the monthly values of tilt angle α and monthly mean values of cosmic ray data of Kiel neutron monitor station for $A > 0$ and $A < 0$ epochs of solar magnetic field for the period of 1980 to 1999. We observed negative and high correlation cosmic rays and tilt angle α for both the $A > 0$ and $A < 0$ epochs. Higher correlations are found for the ascending phases of solar cycles 21 and 22.

1. Introduction

A number of solar parameters such as sunspot number, Ground solar flares, Coronal index of solar activity are being used to explain the long–term cosmic ray modulation in relation with solar activity [1]. In recent years, the general structure of the magnetic field has been classified on the basis of neutral current sheet. During the years around the sunspot maxima, the magnetic field is organised into two hemisphere separated by a current sheet. In each hemisphere the field is very well approximated by a Parker – Archimedean spiral with the tense of the field being outward in one hemisphere and inward in the other. The field direction in each hemisphere alternates in each 11–year sunspot cycle. At the solar minimum the current sheet is nearly equatorial, with the northern hemisphere field being in one direction, and the southern field having the opposite sign. Inside the hemisphere, the intensity of galactic cosmic rays of energies less than about 10 GeV continuously changes in response to changes in solar activity. Cosmic ray modulation studies have to explain these variations, consisting of 22 year, 11 year and solar rotation. It is known that sunspot numbers are not directly related with cosmic ray particles, but the waviness of heliospheric neutral current sheet or tilt angle α certainly provides us atleast physical mechanism to understand the long–term cosmic ray modulation. A number of research have considered tilt angle α in long–term cosmic ray modulation studies [2–4]. In a correlative studies, it has been reported that cosmic rays negatively correlated with tilt angle α for the different epochs of solar magnetic field [5]. Now further values of tilt angles have become available till 1999. We therefore extended the analysis to include these new data sets.

2. Discussion

To investigate the relationship between cosmic rays and tilt angle α during $A > 0$ epochs of solar magnetic field, we have done a correlative analysis for the two intervals (i) April 1976 to January 1980 (ii) May 1991 to September 1999. These two periods represent $A > 0$ epochs of solar magnetic field, when the northern hemispheric magnetic field is directed outward. The monthly mean values of Kiel neutron monitors data are plotted against the monthly values of tilt angle α for $A > 0$ epochs as depicted in Fig. 1. Lower panel of Fig.1 shows the correlation between tilt angle α and cosmic rays for the period of 1976 to January 1980. We observed negative and high correlation (Correlation coefficient $\approx$ - 0.91) for the ascending phase of solar cycle 21. Upper panel of figure shows the scatter plot for the next $A > 0$ epoch (May 1991 to September 1999) between CR and tilt angle α. Result of figure shows a negative and high correlation (correlation

coefficient ≈ 0.51). Comparatively low correlation is observed for this period in comparison to the period of 1976 to 1980. Similar analysis has been done for the epochs of A < 0 of solar magnetic field. The analysis has been performed for the intervals (i) July 1980 – February 1987 (ii) March 1987 – August 1990. These two intervals show negative magnetic polarity in northern hemisphere or A < 0 epochs of solar magnetic field. High and negative correlations are seen in scatter plots of Fig. 2. –0.83 and – 0.95 correlation coefficients are found for the periods of (i) July 1980 – February 1987) and March 1987 – August 1990 respectively. It is clear from the distribution of points and best tilt lines that correlations are found higher during the periods of April 1976 – January 1986 (A > 0) and March 1987 to December 1990 (A < 0). Both of these period fall in the ascending phases of solar cycles 21 and 22 respectively.

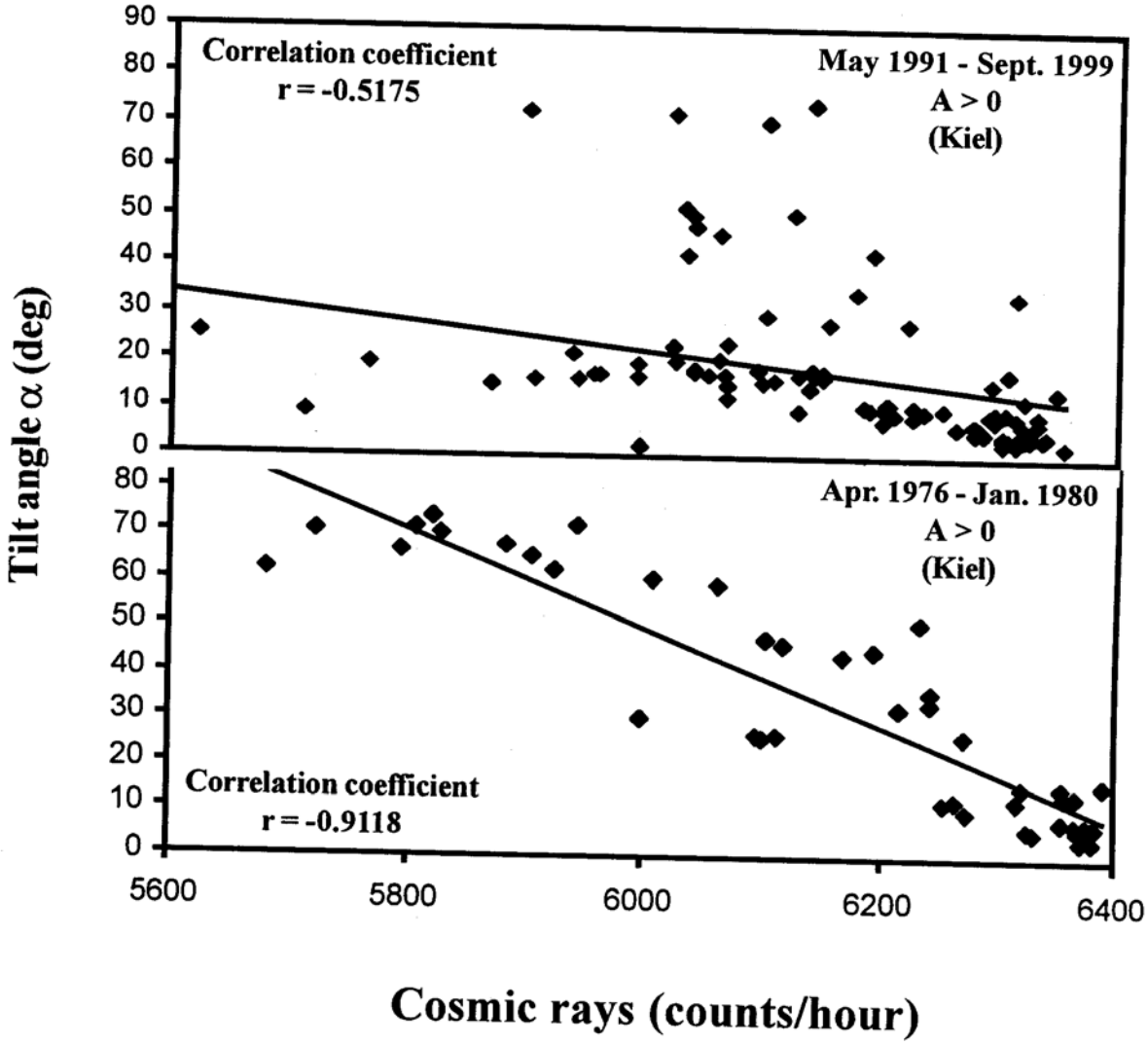

Figure 1. Shows the cross plot between the monthly mean values of cosmic rays (Kiel neutrons) and Tilt angle α for A > 0 epochs of solar magnetic field.

Results of our analysis consistent with a cosmic ray distribution in inner heliosphere in which cosmic ray intensity of neutral sheet is highest, with intensity decreasing with distance laterally from the sheet, when the tilt angle α increases and warp in the neutral sheet becomes more pronounced, the earth spends more time of greater distances from the neutral current sheet and therefore is exposed to a lower cosmic ray intensity at neutron monitor energies.

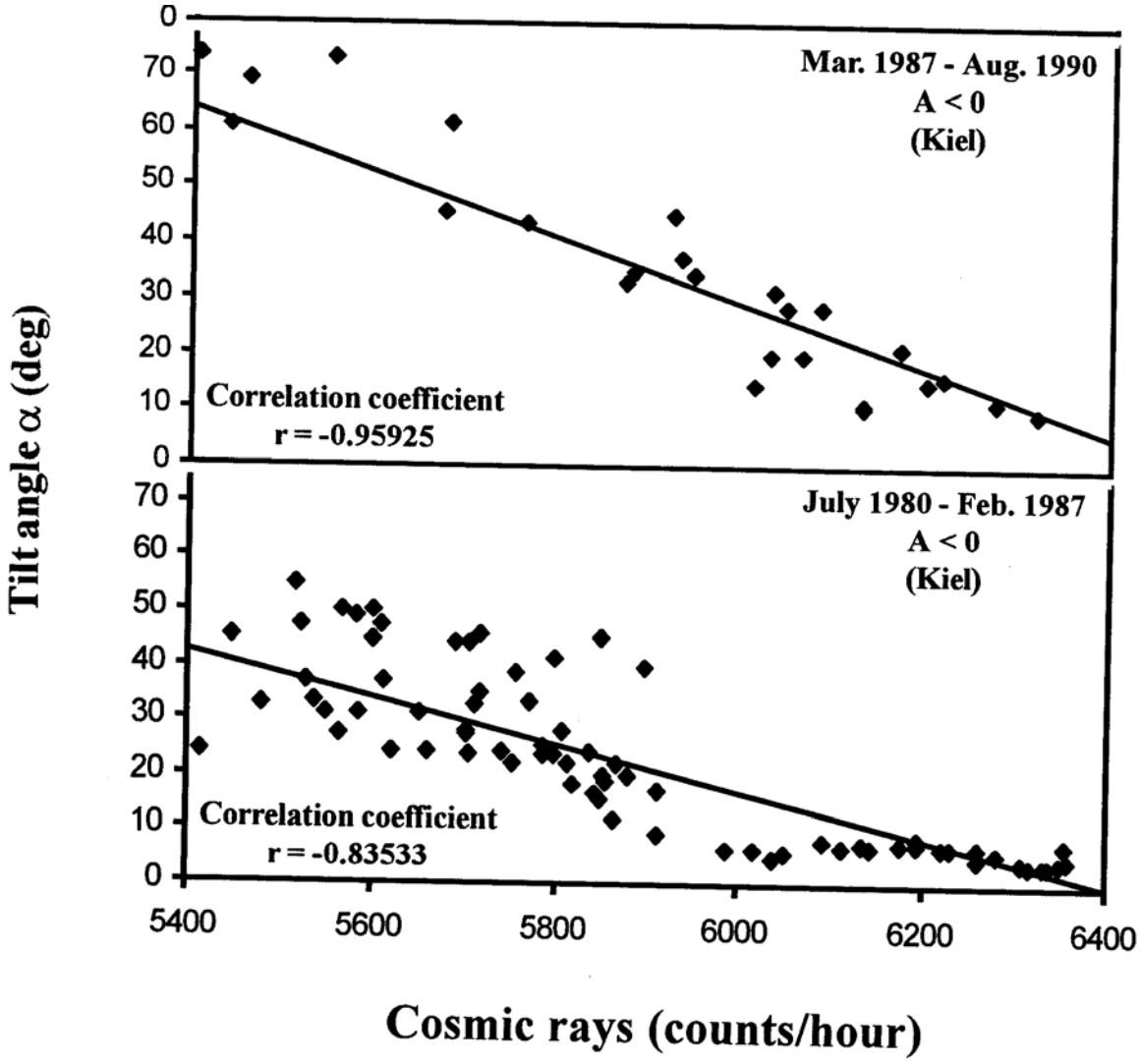

Figure 2. Shows the cross plot between the monthly mean values of cosmic rays and tilt angle α for A < 0 epochs of solar magnetic field when the northern field is directed inward.

Drift depend on the three dimensional topology of interplanetary medium and vary according to solar activity. We know from the predictions of these models that gradient and curvature drift can cause cosmic rays to travel through vastly different regions of the heliosphere in consecutive solar cycles. When the northern heliospheric magnetic field is directed outward (A > 0), particles with positive charge drift inward from the polar regions to the equatorial plane and out along the wavy neutral sheet. The waviness of the neutral sheet, which is indicated by the so called tilt angle α is then expected to play a relative unimportant role in modulation. When the northern field is directed inward (A < 0), positive particles reach the inner heliosphere by drifting in along the neutral sheet and the waviness of the neutral sheet is therefore in this case expected to play a more important role in the modulation processes.

3. Conclusions

Coefficients of correlation are found negative and high for both the epochs (A < 0 and A > 0) of solar magnetic field. The correlations are found comparatively higher during the epochs of A < 0, while the northern field is directed inward. However, higher correlations are found for the period of March 1987 to August 1990 and April 1976 to January 1980, which represent the ascending phases of solar activity cycles 21 and 22, respectively.

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References

[1] P. K. Shrivastava et al., Indian J. of Phys. 75B, 11 (2001).
[2] E.J. Smith and J. Thomas. J. Geophys. Res. 91, 2933 (1986).
[3] P.P. Shukla et al. Acta Ciencia Indica. XX, 3, 63 (1994).
[4] I.G. Usoskin et al., 27th ICRC, Hamburg. 9, 3791 (2001).
[5] M. Singh et al., 25th ICRC, Durban. 2, 33 (1997).