Abstract

In this work, which is based on the cosmic ray solar modulation in the heliosphere, we have examined the variations of cosmic ray intensity with various solar parameters and tilt angle of the heliospheric current sheet in detail. For this purpose we have used cosmic ray intensity data from Climax neutron monitor station and Oulu neutron monitor station. This study is based on the detailed analysis of time lags and hysteresis between cosmic ray intensity and solar parameters/tilt angle, extending over several solar cycles (19–23) and during periods of different polarity states of the heliosphere ($A < 0$ and $A > 0$). The Ph.D. thesis based on this work has been divided into four chapters. Brief abstracts of these chapters are given below.

In first chapter, basics of the heliosphere, heliospheric current sheet and modulation of cosmic rays in heliosphere have been discussed. Role of solar wind in the shaping of heliosphere, its structure and size, heliospheric magnetic polarity and its periodicity
have also been given. Discussion of heliospheric current sheet, tilt angle and its influence on the incoming galactic cosmic rays preludes the second half of the chapter that is modulation of cosmic rays intensity in heliosphere. Here the modulation models, transport equation of galactic cosmic rays, its implications, role of drift in modulation and long term variations in cosmic ray intensity have been discussed. Also the hysteresis effect and the importance of estimation of time lag (between observed cosmic ray intensity and solar activity parameters) in the study of cosmic ray modulation are conversed.

In second chapter, a detailed analysis of the time lags and hysteresis effects between cosmic ray intensity and three solar activity indices (sunspot number, 10.7 cm. solar radio flux, and solar flare index) has been carried out. The cosmic ray neutron monitor data and solar data extending over a period of 55 years covering five solar activity cycles (19–23) for alternating solar polarity states (two \( A > 0 \), and three \( A < 0 \)) have been examined. We determined (a) time lag between the cosmic ray intensity and the solar variability, (b) area of the cosmic ray intensity versus solar activity modulation loops, and (c) dependence of the cosmic ray intensity on the solar variability, during different solar activity cycles and polarity states of the heliosphere. The hysteresis plots between the cosmic ray intensity and solar indices show differences in their relationship during similar phases in odd and even cycles. Moreover, the relationships between cosmic ray intensity and solar indices show dependence on polarity states of solar magnetic cycle. The area of the hysteresis loops, the time lag between cosmic ray intensities and solar indices, and the rate of cosmic ray intensity decrease during even and odd numbered cycles.
have also been determined: they show considerable differences for different solar cycles. The consequences of observed differences have been discussed. Significant difference between time lags during opposite polarity states of the solar magnetic field and the heliosphere (A > 0 and A < 0) has been noticed. Difference in cosmic ray intensity decrease rate with solar activity during A > 0 epoch and A < 0 epoch has also been found. The difference appears to be related to magnetic polarity states of the heliosphere and particle drifts in the heliosphere. The work discussed in this chapter has been published in “Journal of Atmospheric and Solar-Terrestrial Physics”, 70, 169, (2008).

In chapter 3, we have dealt with modulation loops, time lags and relationship between cosmic ray intensity and tilt of the heliospheric current sheet. We aimed to study certain aspects of the solar modulation of galactic cosmic ray intensity during different solar activity cycles and in different polarity states of the heliosphere. For this purpose we have plotted modulation loops between the cosmic ray intensity and the tilt angle of the heliospheric current sheet during three solar activity cycles 21, 22, and 23 and obtained the area of the modulation loops. The time lag between the tilt angle and the cosmic ray intensity in odd and even cycles and during A > 0 and A < 0 polarity states of the heliosphere are determined using correlation analysis. Rate of intensity decrease with tilt angle during different solar and magnetic cycles are estimated from best fit method. Marked differences during the two odd and one even solar cycle, as well as during different polarity states of the solar magnetic field are found. We found that the time lag in even cycle (22) is much different from that in odd cycles (21 and 23). Moreover, considerable differences in time lags are also observed during A > 0 and A < 0 polarity states of
the heliosphere. We also found that the cosmic ray intensity decreases at much faster rate (and with better correlation) with increase in tilt angle during $A < 0$ than $A > 0$, indicating stronger response to the tilt changes during $A < 0$. These results are discussed in the light of three dimensional modulation models including the gradient and curvature drifts and the tilt of the heliospheric current sheet. The work and results discussed in this chapter are published in “Astronomy & Astrophysics”, 466, 697, (2007).

In chapter 4, we have summarized our work of cosmic ray modulation study using tools like hysteresis, time lag, correlation coefficients etc. and have discussed the important results and conclusions drawn from it.