STM JOURNALS

Research & Reviews: Journal of Physics
ISSN: 2278-2265 (Online), ISSN: 2347-9973 (Print)
Volume 6, Issue 1
www.stmjournals.com

Heliospheric Modulation of Galactic Cosmic Rays during Solar Minimum of SC 23/24

***B.K. Tiwari*[1,*], *B.R. Ghormare*[2]**
[1]Department of Physics, A.P.S. University, Rewa, Madhya Pradesh, India
[2]Department of Physics, Rewa Engineering College, Rewa, Madhya Pradesh, India

Abstract

Galactic cosmic ray (GCR) flux at earth is modulated by the heliospheric magnetic field. Heliospheric modulation potential during grand solar minimum is observed using an open solar flux (OSF) model, with OSF source based on Sunspot number. Structure of the heliosphere controls the solar outputs and their variability, and produces changes in cosmic ray intensity. Observation was based on the data taken from Omniweb data centre for solar-interplanetary data and yearly mean count rate of cosmic ray intensity (CRI) variation data from Oulu (Rc = 0.80 GV) and Moscow (Rc = 2.42 GV) neutron monitors during 1996–2016. It was observed that slow decline of solar cycle 23 and slow rise of solar cycle 24 resulted in prolonged low solar activity that lasted from about 2006 to 2009 with 2008 and 2009 being sun remarkably quiet. Therefore, solar minimum between cycle 23 and 24 was very extended and deep in contrast to previous solar minima's and the strength of the interplanetary magnetic field (IMF) has been falling off to new low levels, reducing the GCR entering inner-heliosphere and it was high anti-correlation between sunspot number and GCR flux. The correlation between the count rate of cosmic ray intensity with solar indices and heliospheric parameters was also found.

Keywords: *Interplanetary magnetic field (IMF), galactic cosmic ray intensity (GCRI), interplanetary coronal mass ejections (ICMEs), solar activity*

****Author for Correspondence*** E-mail: btiwari70@yahoo.com

INTRODUCTION

The photosphere magnetic flux and heliospheric magnetic flux (HMF), both have varied approximately in phase with the sunspot cycle. On longer time scales, HMF has been evaluated using geomagnetic activity as a proxy indicator (Luckwood et, al., 2009 and Owens, 2011) [1]. The HMF modulates the galactic cosmic ray (GCR) flux incident on the terrestrial atmosphere, allowing HMF properties to be inferred from GCR records. During the solar minimum of solar cycle 23, ideal condition observe the solar modulation of GCR and the expected charge–sign dependence. The intensity of GCRs is modulation as they transverse the turbulent magnetic field embedded into solar wind particles scattered by its declaration in the expending solar wind. The slow decline of solar cycles 23 and slow rise of solar cycles 24 resulted in prolonged and deep contrast to previous solar minima. The sun was remarkably quiet and the strength of interplanetary magnetic field (IMF) has been falling off to new low levels; dependence of the heliosphere and cosmic ray modulation due to solar activity was supported by space and ground-based experiments [2, 3]. The mean sunspot number occurred minimum in August 2009 and maximum of cosmic ray intensity was observed in October 2009, dependence of the cosmic ray intensity time-lag behind the sunspot number about two months. During this period of minimum solar activity, sunspot nearly disappeared and solar magnetic field is reduced, about half as those observed during the previous solar minimum. The average solar wind speed (SWV) during this period (minimum of solar cycle 23/24) was 380 km/sec, i.e. about 8% slower than in previous solar minimum (SC 22/23) and 15% slower than earlier ones (SC 21/22). This might be caused by the polar coronal holes were smaller than in previous solar cycles. The mean value of the IMF was recorded between 2007–2009 falling off to new low levels as

compared with 1985–1987 and in 1995–1997. This decrease in interplanetary magnetic field is due to either weaker input of solar polar magnetic flux or less input from the Interplanetary coronal mass ejection (ICME). The changes in the solar winds magnetic field over the solar cycle, affect GCRs, in the inner solar system. During higher solar activity (when sunspot number are large), is correlated with increased IMF strength, which in turn reduces the GCR entering the inner heliosphere and it is strong & steady anti-correlated between sunspot number and GCR flux. This decrease in IMF is due to either weaker input of solar polar magnetic flux or less input from the interplanetary coronal mass ejection (ICME). The changes in solar winds magnetic field over the solar cycle affect GCRs in the inner solar system. During higher solar activity (when sunspot number are large), it is correlated with increased IMF strength, which in turn reduces the GCR entering the inner heliosphere and it is strong and steady anti-correlated between sunspot number and GCR flux. Modulation in the solar wind plasma and its fluctuation flows through the interplanetary medium that creates weaker solar magnetic field and the tilt of the heliospheric current sheet is also responsible for drift effect on GCR [3]. The slow decline of solar cycle 23 and slow rise of solar cycle 24 resulted in prolonged low solar activity which lasted from about 2006 to 2009 with sun being remarkably quiet in 2008 and 2009. Therefore, solar minimum between cycle 23 and cycle 24 was very extended and deep in contrast to previous solar minima's with tens of months instead of few months. Solar cycle dependence of cosmic ray intensity time lag behind the sunspot number; for cycle 17–23, the mean value of this time lag was about 2.4±1.9 months for even cycles and 12.4±7.2 months for odd cycles [4,5]. The strength of IMF and solar wind density reduced by about 28% at the end phase of solar cycle 23, whereas solar wind speed remained unchanged as compared to previous solar minimum [6, 7].

DATA ANALYSIS

In the present study, yearly mean data of solar activity and heliosphere indices data with count rate of cosmic ray intensity as observed by Oulu, and Moscow (R_c=0.80 GV, and R_c= 2.42GV) neutron monitors and solar-interplanetary data from Omni web database were used (Figure 1).

RESULTS AND DISCUSSION

Studying the relationship between changes in GCR intensity (I) and solar wind velocity (V), I & B (magnitude) of IMF and I & tilt angle (TA) during the period 2008–2010, showed (i) an anticorrelation between I & V with maximum magnitude of correlation coefficient (r = 0.68±0.09) for zero delay time—a decrease of V causes a reduction of convection

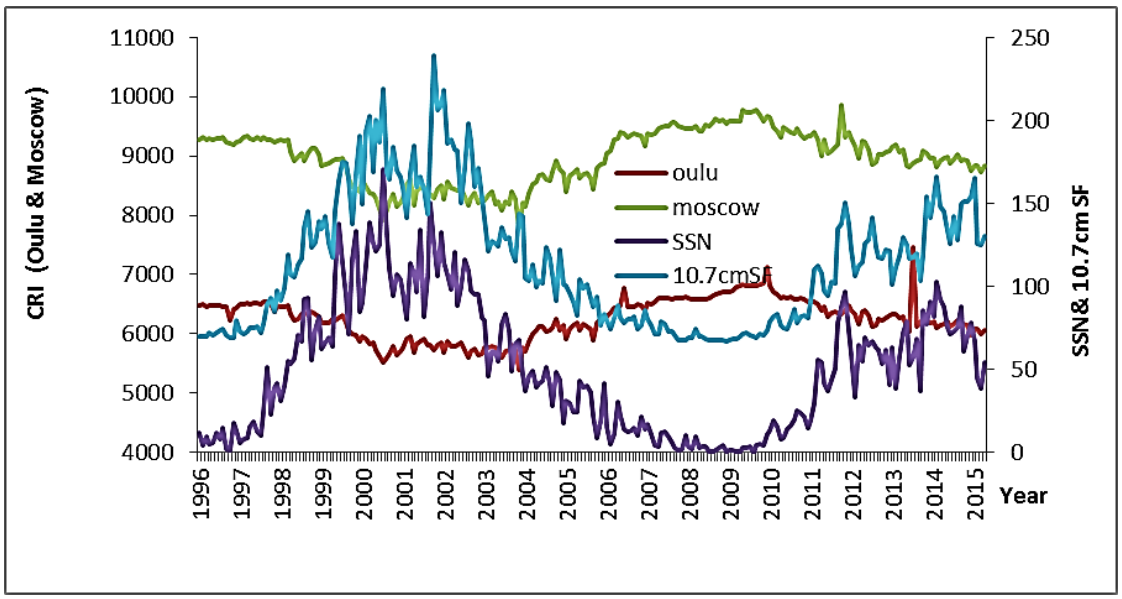

Fig. 1: *Monthly Mean Count Rate of CRI (Oulu & Moscow) with Sunspot Number (SSN) and 10.7 cm Solar Radio Flux (SRF).*

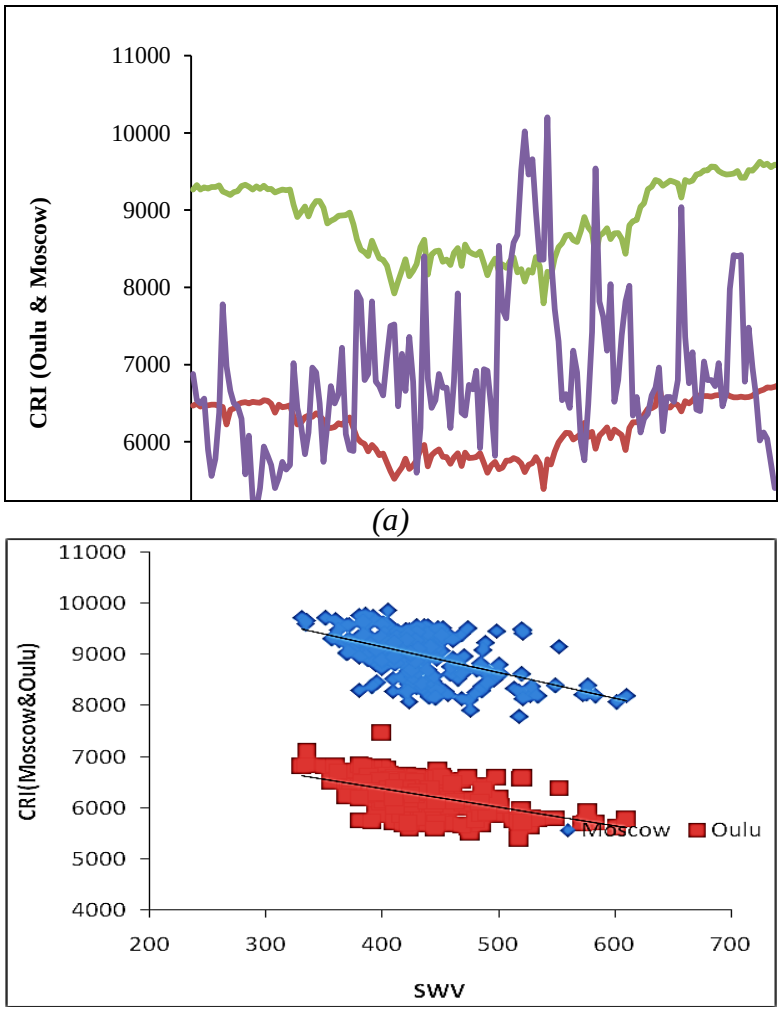

Fig. 2: *(a) Monthly Mean Count Rate of CRI (Oulu & Moscow) with Solar Wind Velocity (SWV); (b) Correlation Between Monthly Mean Count Rate of CRI (Oulu & Moscow) with Solar Wind Velocity (SWV).*

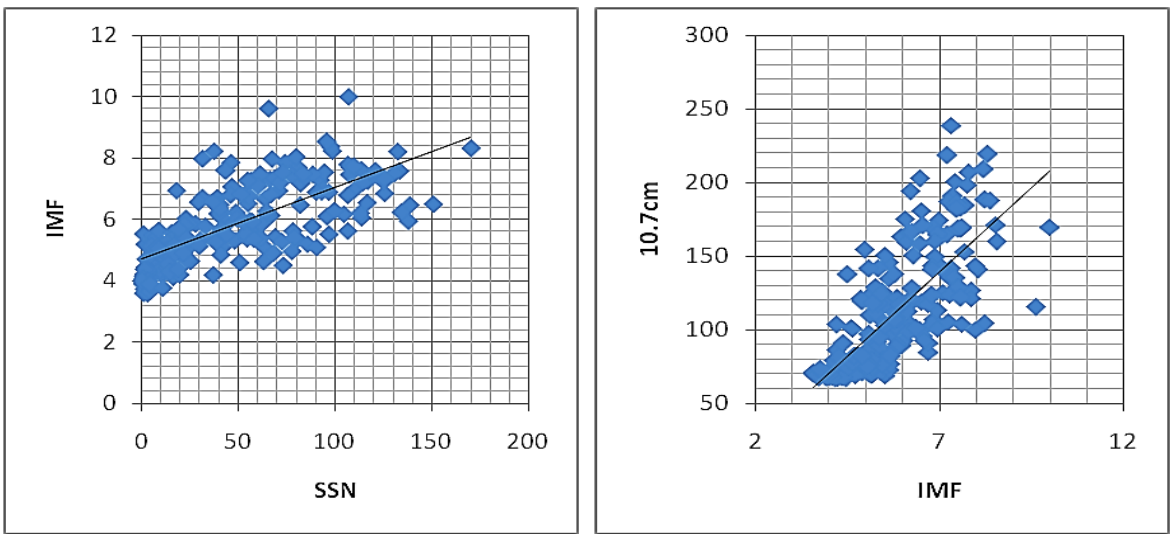

Fig. 3: *Correlation Between (a) Monthly Mean Sunspot Number (SSN) with IMF; and (b) Montly Mean IMF and 10.7 cm Solar Radio Flux (SRF).*

and an increase of I; (ii) an anticorrelation between I & B with the maximum magnitude of r (r = 0.73±0.08)—a dropping of B causes an increase of diffusion coefficient, and consequently an increase of I; and (iii) a strong inverse correlation between I & TA with correlation coefficient r (r = 0.92±0.05). Beside the direct roles of diminishing V and B in the increasing of I, the maximum intensity I in 2009 was established by drift effect (Figure 2a, and b).

The changes in solar winds magnetic field over the solar cycle, IMF strength reduces and the strength of IMF has been falling off to new low levels, which in turn reduces the GCRs entering the inner heliosphere, and a record high cosmic ray intensity was observed during minimum period of solar cycle 23 and cycle 24 and it is strength anticorrelation between sunspot number and GCR flux. The variation of cosmic ray intensity is inversely correlated with solar activity indices and these variations are produced by solar wind velocity (V). It is related to convection, diffusion and depends on the interplanetary field strength (B), its fluctuations, and the tilt of the heliospheric current sheet. The sun is remarkably quiet, and record high cosmic ray intensity was observed in 2009 due to reduction in B and TA; thereafter, an unusually rapid increase in the TA was likely related to the weaker polar field (Figure 3a and b)

CONCLUSION

The recurrent variation of the GCR was soft during unusually prolonged, minimum epoch between solar cycle 23 and cycle 24; and hard during the maximum epoch of the listing solar cycle 24. We connected this phenomenon with the changes in the effective sign of the modulation region of the recurrent variation of the GCR intensity in different epochs of solar activity. Solar-interplanetary indices, tilt of the heliospheric current sheet, reduction in solar polar magnetic field and interplanetary magnetic field (IMF) caused modulation in GCR in the inner heliosphere. The sun was remarkably quiet and strength of IMF has been falling off to new low level and record high CRI was observed during the period of minimum solar activity. Changes in the solar winds magnetic field over the solar cycle, affect GCR in the inner heliospheric solar system and strong anticorrelation -0.78 found between SSN and GCR flux. A small time-lag was found between CRI and solar activity, of about two months, with very high correlation during period of minimum of cycle 23 and ascending phase of solar cycle 24.

REFERENCES

1. Lockwood, M., M. J. Owens. Centennial changes in the heliospheric magnetic field and open solar flux: The consensus view from geomagnetic data and cosmogenic isotopes and its implications. *J. Geophys. Res*. 2011; 116. A04109, DOI:10.1029/2010JA016220
2. Modzelewska R, Alania MV. The 27-Days Cosmic Ray Intensity Variation During Solar Minimum 23 and 24. *Solar Phys.* 2013; 286: 593–607p.
3. Tiwari BK, Ghormare BR, Shrivastava PK, *et al*. Modulation in Cosmic ray During the Declining and Minimum Solar Activity Period of Solar Cycle 23. *Res J Physical Sci*. 2014; 2(2): 9–12p.
4. Nagashima K, Morishitha I. Long term modulation of cosmic rays and inferable electromagnetic state in solar modulating regions. *Planetary and Space Sciences*. 1980; 28(2): 117p.
5. Schwadron NA, Body AJ, Kozarev K, *et al*. Galactic cosmic ray radiation hazard in the unusual extended solar between solar 23 and 24. *Space Weather*. 2010; 8: S00E04. DOI:10.1029,2010SW000567.
6. Zhao L, Fisk L. Understand the behavior of the heliospheric magnetic field and the solar wind during the unusual solar minimum between cycle 23 and 24. *Solar Phys*. 2011; 274: 379p.
7. Tiwari BK, Ghormare BR, Shrivastava PK. Study of Variation in Cosmic ray Intensity due to Solar-Interplanetary activity between 1996–2013. *Res J Phys Sci*. 2014; 2(3): 4–8p.

Cite this Article

Tiwari BK, Ghormare BR. Heliospheric Modulation of Galactic Cosmic Rays During Solar Minimum of SC 23/24. *Research & Reviews: Journal of Physics*. 2017; 6(1): 1–4p.