International Journal of Innovative Research & Growth
A Peer Reviewed Journal
ISSN: 2455-1848
Journal homepage: http://www.ijirg.com/ijirg/
Volume: 11 Issue: 4, October 2022

Cosmic ray intensity variation in relation with solar wind plasma parameters during the period of 1997-2007

Jaipal Singh Lodhi[1], Shushil Sharma[2], P. L. Verma[3*]
[1,2]Research Scholar, Department of Physics, Govt. Autonomous P. G. College, Satna, M.P., India
[2]Department of Physics, Govt. Vivekanand P.G. College Maihar, Satna, M.P., India
E-mail: plverma2010@gmail.com
* Corresponding Author

Article Info
Received 18 August 2022
Received in revised form 15 October 2022
Accepted for publication 15 November 2022
DOI: 10.26671/IJIRG.2022.4.11.106

Citation:
Lodhi, J. S., Sharma, S., Verma, P. L. (2022). Cosmic ray intensity variation in relation with solar wind plasma parameters during the period of 1997-2007. *Int J Innovat Res Growth*, 11, 155-160.

Abstract
In this investigation we have analyzed yearly average values of cosmic ray intensity (CRI) with yearly average of solar wind plasma parameters interplanetary magnetic field (IMF B) ,solar wind plasma temperature (SWPT) ,solar wind plasma pressure (SWPP)observed during the period of 1997-2007 to explore the possible relationship amongst cosmic ray intensity variation and yearly average values of interplanetary magnetic field (IMFB) solar wind plasma temperature (SWPT) and solar wind plasma pressure (SWPP) .We have observed that yearly average values of cosmic ray intensity (CRI) are anti-correlated with yearly average values of interplanetary magnetic fields (IMFB) a large negative correlation with a correlation coefficient of (-0.85) has been determined amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of interplanetary magnetic fields (IMFB). Further, the yearly average values of CRI are negatively correlated with yearly average values of solar wind plasma temperature (SWPT) and solar wind plasma pressure (SWPP). Negative correlation with a correlation coefficient of (-0.32) has been observed amongst yearly average values of CRI and yearly average values of solar wind plasma temperature (SWPT)and (-0.41)amongst yearly average values of CRI and yearly average values of solar wind plasma pressure (SWPP).It is also seen that yearly average values of solar wind plasma parameter solar wind plasma temperature, solar wind plasma pressure and interplanetary magnetic field are positively correlated with yearly average values of sunspot numbers. Positive correlated with correlation coefficient (0.81) are determine amongst yearly average value of interplanetary magnetic fields (IMFB) and yearly average values of SSN, (0.27)amongst yearly average values of solar wind plasma pressure (SWPP) and yearly average values of SSN and (0.48)amongst yearly values of solar wind plasma temperature (SWPT) and yearly average values sunspot numbers(SSN).
Keywords:- Cosmic ray intensity (CRI), Solar wind plasma parameters, interplanetary magnetic fields (IMFB), solar wind plasma temperature (SWPT), solar wind plasma pressure (SWPP), sunspot numbers (SSN).

1. Introduction

Cosmic ray observations from numerous locations amongst 1937 and 1955 are being investigated by S. E. Forbush and H. V. Neher and cosmogenic ^{10}Be data are merged with the neutron monitor data since 1951 to study the long- and short-term variations in the galactic cosmic radiation intensity for the interval 1428–2005 (McCracken & Beer, 2007). The diurnal variation has been shown to be universal phenomenon, demonstrating the anisotropy of an initial radiation and its correlate to the sunspot, auroral, and geomagnetic activity (Venkatesan, 1985).The strong, confined magnetic fields cause the light emitted by the Sun to weaken, resulting in sunspots, which serve as an independent indicator of the magnetic activity of the Sun. Although the Sunspots do not cause modulation. They are rather an indication of the time variation of other solar activity parameters such as the solar and helio-spheric magnetic fields, solar wind velocity, density temperature, pressure, turbulence in the helio-spheric magnetic fields, and episodic disturbances in the heliosphere caused by solar flares, coronal mass ejections, corotating interaction regions, merged interactions regions, and globally merged interaction regions. The main objective of cosmic-ray modulation studies is to determine quantitatively how these variables create the propagation conditions that explain the cosmic-ray modulation. It is important to understand these time variations in detail during the technological era since about 1950, because it allows one to extrapolate solar and helio-spheric conditions back into the past in two ways (Caballero-Lopez, 2019). First, solar activity has been observed for up to 400 years in several parameters. It clearly shows the well-known 11-yearactivity cycle and the differences from one cycle to the next. Over the past two decades, there has been much debate about different reconstructions of the sunspot numbers (SSN). There are mainly two

sunspot records: the Wolf SSN, and the group SSN (Cliver & Herbst 2018). These two series differ from one another before ≈1885. However, in the past century, they are similar, except for the period of very high solar activity (Cliver & Herbst 2018). The use of different reconstructions leads to different results. However, because our study covers about the last five decades of observations, we only use the Wolf SSN. We study that the correlations of the force-field parameter with these two sunspot records will not differ from each other. Due to the supersonic expansion of the solar wind (SW), the heliosphere resembles a giant irregular bubble filled with a large number of energetic particles. These particles are the main source of the cosmic radiation environment, (Mertens & Slaba 2019). With the support of suitable solar indices and geophysical characteristics, many research teams have attempted to describe this long-term change in the galactic cosmic ray intensity, including Nagashima and Morishita (1980a), Other scholars, like Xanthakis, Mavromichalaki, and Petropoulos (1981), considered how multiple parameters (solar or geophysical) contributed to the modulation process. It is now clear that there exists an anti-correlation amongstgalactic cosmic rays'intensity and the level of solar activity over a cyclic 11-year period, with perhaps some time lag (Forbush,1958; Parker 1965, Van Allen2000;).When cosmic rays enter the atmosphere, they interact with atmospheric atoms and produce cascades of secondary particles, which at ground level are primarily neutrons and muons. Neutron monitors and muon detectors located at different locations on Earth have been used since the 1950s to observe galactic cosmic rays. Information on galactic cosmic rays prior to the modern epoch of neutron monitors and muon detectors, and the space age, rely on the studies of cosmogenic isotope records from ice cores and tree rings (Owens and Forsyth, 2013). The intensity of galactic cosmic rays is influenced by several solar and interplanetary phenomena, such as coronal mass ejection, interplanetary impact, number of sunspots, and perturbations of solar wind plasma parameters. Foremost classes of solar activity tend to track sunspot numbers throughout the solar cycle, including solar flares, filaments, and coronal mass ejections (CMEs) (Webb, et al. 1994, Eddie Rossm and William J. Chaplin 2019). This activity is transmitted to the Earth by the solar corona and propagates to the heliosphere as the solar wind. Amongst all these solar activities, it is widely believed that Though sunspots do not directly affect cosmic-ray intensity, surface magnetic activity, especially large and long-lived active regions, can cause perturbations in the properties of the solar wind (Stansby et al., 2021) modulates heliosphere galactic cosmic ray's transport. In this paper we tried to explore relation amongst galactic cosmic rays and solar wind plasma parameters, solar wind plasma temperature (SWPT), solar wind plasma pressure (SWPP), interplanetary magnetic fields B (IMF B) over the period of 1997-2007.

2. Observational Data

In this study yearly average values of cosmic ray intensity (CRI) with solar wind plasma parameters, interplanetary magnetic field (IMFB), solar wind plasma temperature (SWPT), solar wind plasma pressure (SWPP)over the period of 1997 to 2007. For this study yearly average values of cosmic ray intensity (CRI) data of Oulu Super Neutron monitor over the period 1997-2007 has been used. For the data of solar sunspot numbers (SSN), solar geophysical data report U. S. Department of commerce; NOAA monthly issue and solar STP data (http://www.ngdc.noaa.gov/solar/solardataservices) are used. For the data of solar wind plasma temperature, pressure and interplanetary magnetic field (IMF B)Omni web data have been used.

Years	Cosmic ray Intensity (CRI)	Sunspot Numbers (SSN)	IMF B	SWPT	SWPP
1997	6181	20.3	5.5	61643	2.2
1998	5977	61.6	6.9	91386	2.19
1999	5555	96.1	6.9	109583	20.7
2000	5647	123.3	7.2	1052057	2.31
2001	5581	123.3	6.9	100619	2.17
2002	5544	109.4	7.6	117541	2.34
2003	5853	65.9	7.6	170693	2.72
2004	5900	43.3	6.5	113652	2.09
2005	6182	30.2	6.2	119395	2.33
2006	6309	15.4	5	88491	1.98
2007	6329	7.9	4.5	91542	1.79

3. Data Study and Results

In this study, we have performed correlative study amongst yearly average values of cosmic ray intensity (CRI) with yearly average values of solar wind plasma parameter, solar wind plasma temperature (SWPT), solar wind plasma pressure (SWPP), interplanetary magnetic fields (IMFB) and sunspot numbers(SSN) over the period 1997-2007.

3.1 Yearly Average Values of Cosmic Ray Intensity (CRI) with Yearly Average Values of Interplanetary Magnetic Fields (IMFB)

For the study about yearly average values of cosmic ray intensity (CRI) with yearly average values of Interplanetary magnetic field (IMFB).We have performed correlative study amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of interplanetary magnetic field, for the period of 1997-2007. We have plotted a liner graph amongst yearly average values of cosmic ray intensity (CRI) besides yearly average values of solar interplanetary magnetic field (IMFB), shown in fig. [1]. From the figures it is observed that inverse correlation has been found amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of interplanetary magnetic fields (IMFB).Large negative correlation with correlation coefficient (-0.85) has been found amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of interplanetary magnetic field (IMF B) for the period of 1997-2007.

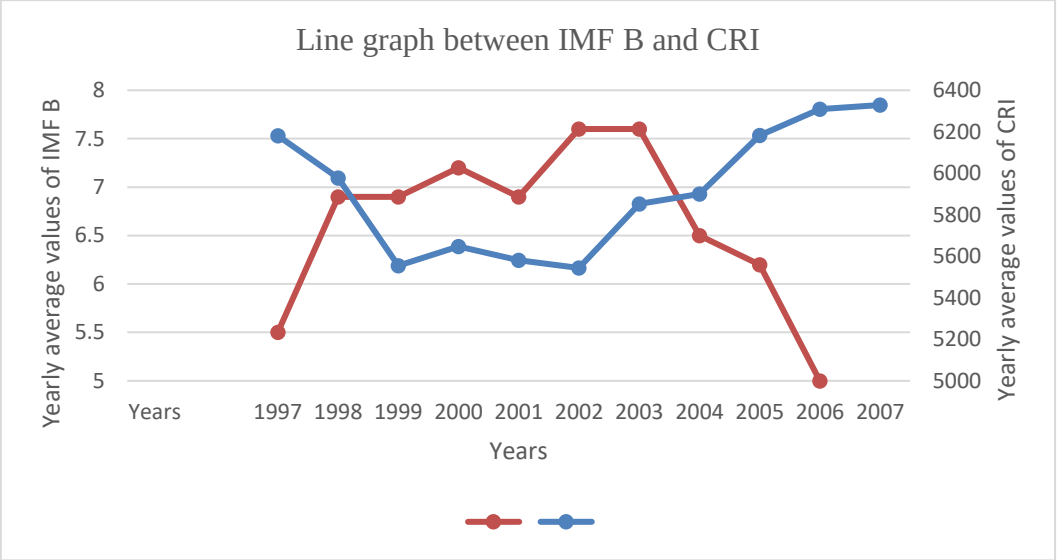

Figure-1 Shows line graph amongst yearly average values of CRI and yearly average values of interplanetary magnetic field (IMF B), over the period of 1997-2007.

3.2 Yearly Average Values of Cosmic Ray Intensity (CRI) with Yearly Average Values of Solar Wind Plasma Temperature (SWPT)

For the study about yearly average values of cosmic ray intensity (CRI) with solar wind plasma temperature (SWPT),we have performed correlative study amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of solar wind plasma temperature (SWPT), over the period of 1997-2007. We have plotted a liner graph amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of solar wind plasma temperature (SWPT) which is shown in fig. [2]. From the figures it is observed that negative correlation has been found amongst yearly average values of cosmic ray intensity (CRI) and yearly average value of solar wind plasma temperature (SWPT). Negative correlation with correlation coefficient (-0.32) has been found amongst yearly average values cosmic ray intensity (CRI) and yearly average values of solar wind plasma temperature (SWPT)for the period of 1997-2007.

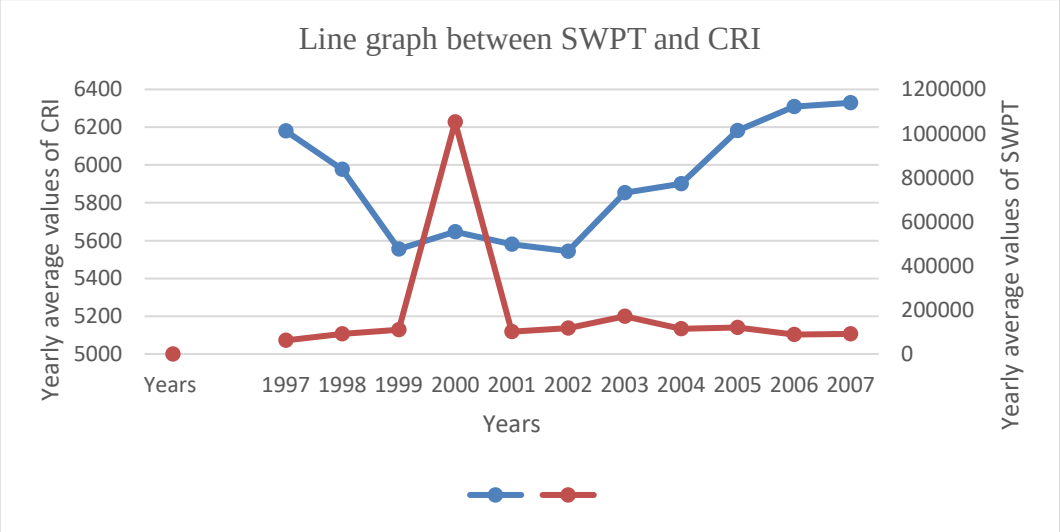

Figure-2 Shows the relationship amongst yearly average values of CRI and yearly average values of solar wind plasma temperature (SWPT) over the period of 1997-2007

3.3 Yearly Average Values of Cosmic Ray Intensity (CRI) with Yearly Average Values of Solar Wind Plasma Pressure (SWPP)

For the study about yearly average value of cosmic ray intensity with solar wind plasma pressure (SWPP), we have performed correlative study amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of solar wind plasma pressure (SWPP), over the period of 1997-2007. We have plotted a liner graph amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of solar wind plasma pressure (SWPP) which is shown in fig. [3]. From the figure it is observed that negative correlation has been found amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of solar wind plasma pressure (SWPP). Negative correlation with correlation coefficient (-0.41) has been found amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of solar wind plasma pressure (SWPP)for the period of 1997-2007.

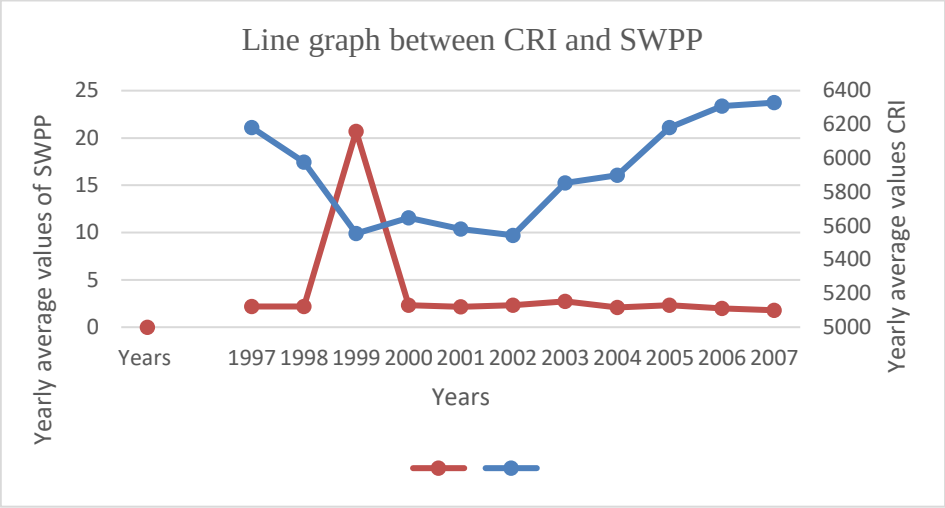

Figure-3 Shows the relationship amongst yearly average values of CRI and yearly average values of solar wind plasma pressure P, for the period of 1997-2007

3.4 Yearly Average of Sunspot Numbers (SSN) with Yearly Average Values of Interplanetary Magnetic Field (IMFB)

For the study about yearly average of interplanetary magnetic field (IMFB)with yearly average values of sunspot numbers (SSN)and we have performed correlative study amongst yearly average values of interplanetary magnetic field (IMFB) and yearly average values of sunspot numbers (SSN), for the period of 1997-2007. We have plotted a liner graph amongst yearly average values of interplanetary magnetic field (IMF B) and yearly average values of sunspot numbers (SSN), shown in fig. [4]. From the figures it is observed that yearly average values of interplanetary magnetic field (IMFB)and yearly average values of sunspot numbers (SSN) are positive correlated and a large positive correlation with coefficient (0.81) has been found amongst yearly average values of interplanetary magnetic field (IMFB)and yearly average value of sunspot numbers (SSN) for the period of 1997-2007.

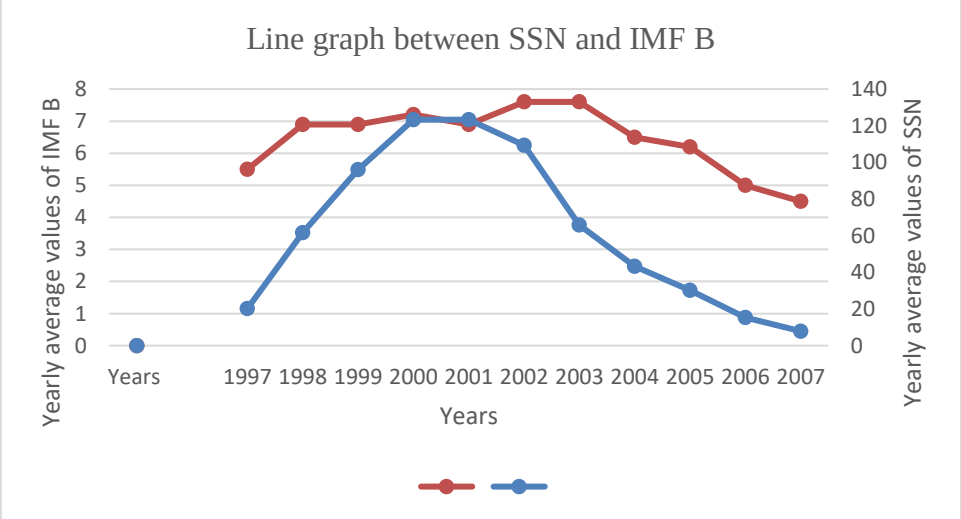

Figure-4 Shows the relationship amongst yearly average values of interplanetary magnetic field (IMF B)and sunspot number (SSN) for the period of 1997-2007

3.5 Yearly Average Values of Sunspot Numbers with Yearly Average Values of Solar Wind Plasma Pressure (SWPP)

For the study about yearly average of values of solar wind plasma pressure (SWPP) with yearly average values of sunspot numbers (SSN),we have performed correlative study amongst yearly average values of solar wind plasma pressure (SWPP)and yearly average values of sunspot numbers (SSN), for the period of 1997-2007. We have plotted a liner graph amongst yearly average values of solar wind plasma pressure (SWPP)and yearly average values of sunspot numbers (SSN), shown in fig. [5]. From the figures it is observed that yearly average values of solar wind plasma pressure (SWPP)and yearly average values of sunspot numbers (SSN), are positively correlated and positive correlation with correlation coefficient (0.27)has been found amongst yearly average values of solar wind plasma pressure (SWPP)and yearly average values of sunspot numbers (SSN) for the period of 1997-2007.

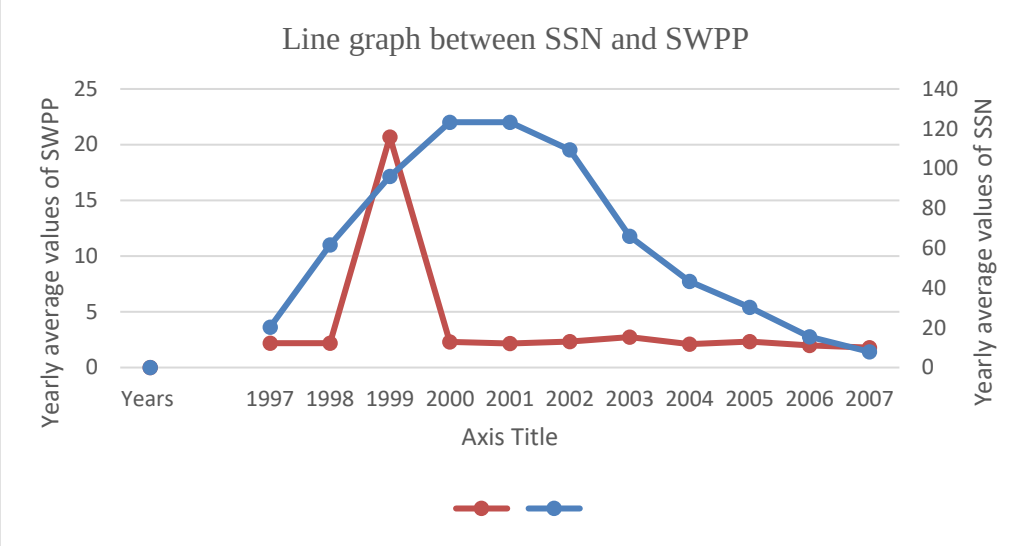

Figure-5 Shows the relationship amongst yearly average values of solar wind plasma pressure (SWPP) and yearly average values of sunspot numbers (SSN) for the period of 1997-2007

3.6 Yearly Average Values of Sunspot Numbers with Yearly Average Values of Solar Wind Plasma Temperature (SWPT)

For the study about yearly average of values of solar wind plasma temperature (SWPT)with yearly average values of sunspot numbers (SSN),we have performed correlative study amongst yearly average values of solar wind plasma temperature (SWPT) and yearly average values of sunspot numbers (SSN), for the period of 1997-2007. We have plotted a liner graph amongst yearly average values of solar wind plasma temperature (SWPT) and yearly average values of sunspot numbers (SSN), shown in fig. [6]. From the figures it is observed that yearly average values of solar wind plasma temperature (SWPT) and yearly average values of sunspot numbers (SSN), are positively correlated and positive correlation with correlation coefficient (0.48) has been found amongst yearly average values of solar wind plasma temperature (SWPT) and yearly average values of sunspot numbers (SSN) for the period of 1997-2007.

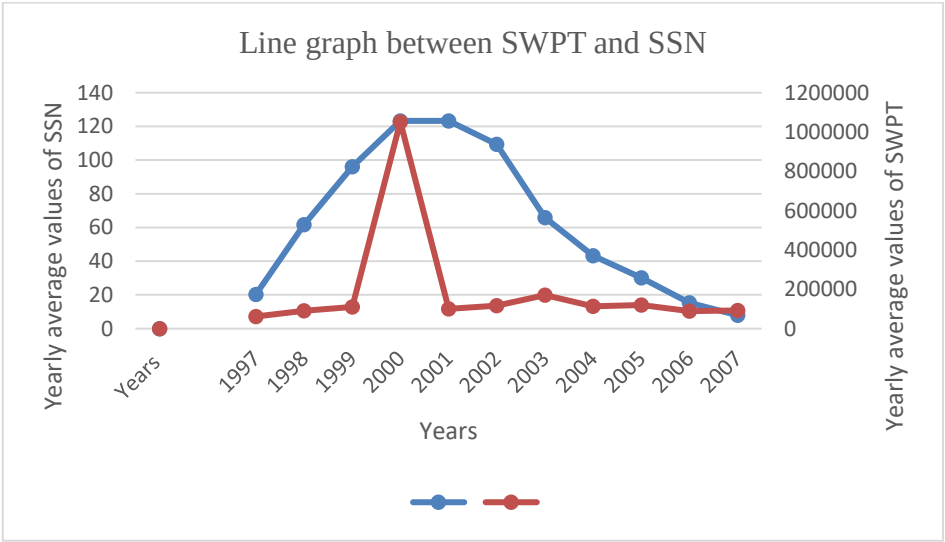

Figure-6 Shows the relationship amongst yearly average values of solar wind plasma temperature (SWPT) and yearly average values of sunspot number (SSN) for the period of 1997-2007

4. Conclusion

In this investigation we have performed correlative study of yearly average values of cosmic ray intensity (CRI) with yearly average of solar wind plasma parameters interplanetary magnetic field (IMFB),solar wind plasma temperature (SWPT),solar wind plasma pressure (SWPP) and sunspot numbers (SSN) observed during the period of 1997-2007 .It is determined that that yearly average values of cosmic ray intensity (CRI) are anti-correlated with yearly average values of interplanetary magnetic fields (IMFB) and a large negative correlation with a correlation coefficient of (-0.85) has been determined amongst yearly average values of cosmic ray intensity (CRI) and yearly average values of interplanetary magnetic fields (IMFB) . Further, the yearly average values of CRI are negatively correlated with yearly average values of solar wind plasma temperature (SWPT) and solar wind plasma pressure (SWPP). Negative correlation with a correlation coefficient of (-0.32) has been observed amongst yearly average values of CRI and yearly average values of solar wind plasma temperature (SWPT) and (-0.41)amongst yearly average values of CRI and yearly average values of solar wind plasma pressure (SWPP). Further we have observed that yearly average values of solar wind plasma parameter solar wind plasma temperature, solar wind plasma pressure and interplanetary magnetic field are positively correlated with yearly average values of sunspot numbers. Positive correlated with correlation coefficient (0.81) are determine amongst yearly average value of interplanetary magnetic fields (IMFB) and yearly average values of SSN, (0.27)amongst yearly average values of solar wind plasma pressure (SWPP) and yearly average values of SSN and (0.48)amongst yearly values of solar wind plasma temperature (SWPT) and yearly average values sunspot numbers (SSN).It is concluded that solar wind plasma parameter, interplanetary magnetic field (IMFB), solar wind plasma temperature (SWPT), solar wind plasma pressure (WSPP) play crucial role for the modulation of galactic cosmic rays .

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

i. Caballero, R.A., Lopez, N.E., Engelbert, N.E., Rechardson, J. D. (2019). Correlation of Long-term Cosmic-Ray Modulation with Solar Activity Parameters. *APJ*, 883, 13.

ii. Cliver, E.W., Herbst, K. (2018). Evolution of the Sunspot Number and Solar Wind B Time Series. *Space Sci Rev*, 214, 56. https://doi.org/10.1007/s11214-018-0487-4

iii. Mertens, C.J., Slaba, T.C. (2019). Characterization of Solar Energetic Particle Radiation Dose to Astronaut Crew on Deep-Space Exploration Missions. *Space weather*, 17, 1650-1658.

iv. Venkatesan, D. (1985). Cosmic Ray Picture of the Heliosphere. Johns Hopkins APL Technical Digest, V6, 4-19.

v. Stansby, D., Green, L.M., Gesztelyil, L. van D., Horbury, T.S. (2021). Active Region Contributions to the Solar Wind over Multiple Solar Cycles. *Solar Physics*, 296, 2-15.

vi. Rossm, E., Chaplin, W.J. (2019). The Behaviour of Galactic Cosmic-Ray Intensity during Solar Activity Cycle 24, *Solar Physics*, 294, 5-17.

vii. Forbush, S.E.J. (1958). Cosmic-Ray intensity variations during two solar cycles. *Journal of Geophysical Res*, 63, 651-669.

viii. Allen, J.A.V. (2000). On the modulation of galactic cosmic ray intensity during solar activity cycles 19, 20, 21, 22 and early 23. *Geophysical research latter*, 27, 2453-2456.

ix. McCracken, K. G., Beer, J. (2007). Long-term changes in the cosmic ray intensity at Earth 1428–2005. *J.Geophys Res: Space Physics*, 112, 1-15.

x. Nagashima, K., Morishita, I. (1980a). Long term modulation of cosmic rays and inferable electromagnetic state in solar modulating region. *Planetary and Space Science*, 28, 177-194.

xi. Owens, M.J., Forsyth, R.J. (2013). The helio-spheric magnetic field. *Living Rev, Solar Phys*, 10, 5.

xii. Parker, E. N. (1965). The passage of energetic charged particles through interplanetary space. *P&SS*, 13, 9-49. https://doi.org/10.1016/0032-0633(65)90131-5

xiii. Webb, D.F., Howard, R.A. (1994). The solar cycle variation of coronal mass ejections and the solar wind mass flux. *J. Geophys. Res.*, 99, 4201-4220. https://doi.org/10.1029/93JA02742

xiv. Xanthakis, J., Mavromichalaki, H., Petropoulos, B. (1981). Cosmic-ray intensity related to solar and terrestrial activity indices in solar cycle No. 20. *Astrophysics and Space Science*, 74, 303–317.