STM JOURNALS

Research & Reviews: Journal of Physics
ISSN: 2278-2265 (Online), ISSN: 2347-9973 (Print)
Volume 7, Issue 3
www.stmjournals.com

Variation in Diurnal Phase of Cosmic Ray Intensity during 1986–2017

Arvind Dubey[1,]*, Santosh Kumar[2], S. K. Dubey[3]
[1]Department of Physics, Seva Sadan College, Burhanpur, Madhya Pradesh, India
[2]Department of Physics, Jabali Dant Chikitsalaya, Survey of India Chouraha, Jabalpur, Madhya Pradesh, India
[3]Department of Physics, Govt. Model Science College, Jabalpur, Madhya Pradesh, India

Abstract
Variations of cosmic ray diurnal phase for Oulu, Apatity, Kiel and Moscow neutron monitoring stations through harmonic analysis by Fourier technique have been investigated in the present study. The period of investigation has been taken to be the period of solar cycle 22, 23 and major portion of solar cycle 24; i.e. 1986 to 2017. Diurnal phase is found have tendency to shift towards later hour direction during 1989, 2000 and 2014, which are the years of maximum solar activity; as compared to the phase values found in minimum solar activity period; i.e., during years 1986, 1996 and 2008.

Keywords: *Cosmic ray intensity, solar cycle, earlier hour, later hour, diurnal phase*

****Author for Correspondence*** E-mail: arvinddubey3768@gmail.com

INTRODUCTION
The foremost harmonic of the Fourier dissection (event of sunlight based diurnal anisotropy in cosmic ray intensity) is ascribed to the clarification based on an outward spiral convection and an internal field adjusted dispersion along the IMF. The harmony amongst convection and dispersion produces a vitality autonomous anisotropic stream of infinite beam particles from the 270° corotational bearing [1].

This simple picture was appreciated to explain the average behaviour of solar daily variations. But in the steady state equilibrium conditions, the particles must corotate with IMF therefore generating an amplitude of ≃0.6% in space [2, 3]. Many other important effects such as excessive diffusion or convection, drifts due to density gradients, curvature of the IMF, gradients in the IMF and/or the changes in the level of solar activity may also change the level of anisotropy to a great extent.

It had been observed from the critical analysis of diurnal variation, calculated on a day-to-day basis from ground based data [4–6], as well as on the average basis for extended periods [7–9] that the simple corotation picture was inadequate to account for all the observed features. In particular, the shift in the diurnal phase to earlier hours observed in 1971 by detectors responding to a wide range of rigidities had indeed provided an evidence for additional effects contributing to the diurnal anisotropy.

From the analysis of ground based neutron monitoring station data, McCracken *et al.* and Rao *et al*. have found that the average diurnal anisotropy [1, 10]:
(a) has a maximum flux incident from $(89\pm1.6)^0$ east of the Sun-Earth line i.e. 1800 hour local time;
(b) has time invariant amplitude of (0.3±0.002)%;
(c) varies with the angle of declination; and
(d) remains rigidity independent in the rigidity range 1–100 GV.

The modulation of cosmic ray intensity on different scales together with these parameters has been studied by many researchers from time to time [11–19]. Periodicities and quasi-periodic variations of solar flares, coronal observations and solar wind parameters have also been observed by many researchers [20–28]; while the oscillatory trend in geomagnetic indices was observed by many others [23, 27–31].

Changing behaviour/variations in solar and interplanetary magnetic activity are strongly related with periodicities and fluctuations in the cosmic ray intensity [11, 13, 15, 32].

DATA ANALYSES

In this work, we have utilized the hourly pressure-corrected data of cosmic-ray intensity from the Oulu neutron monitor (location 67.57°N, 33.4°E, cut-off rigidity: 0.65 GV), Apatity neutron monitor station (location: 43.28°N, 42.69°E, cut-off rigidity: 5.6 GV), Kiel neutron monitor (location: 54.3°N, 10.1°E, cut-off rigidity: 2.36 GV) and Moscow neutron monitor (location: 55.4°N, 37.3°E, cut-off rigidity: 2.39 GV) for the duration 1986–2017. The pressure-corrected data are used for diurnal variation of cosmic rays intensity by harmonic analysis using Fourier technique. The data are taken for Oulu neutron monitor http://cr0.izmiran.ru/oulu/main.htm, Apatity neutron monitor http://cr0.izmiran.ru/apty/main.htm, Kiel neutron monitor http://cr0.izmiran.ru/kiel/main.htm and Moscow neutron monitor http://cr0.izmiran.ru/mosc/.

The phase (Hr) of the diurnal anisotropy for Oulu, Apatity, Kiel and Moscow neutron monitor have been plotted against year in Figures 1 and 2 showing the variation in the phase (Hr) during 1986–2017.

CONCLUSION

The direction of the daily vector (phase angle) shifts towards earlier hours. Oh *et al*. concluded that higher energy NM stations contribute more to the 11 year phase variation due to the diffusion of galactic CRs along the

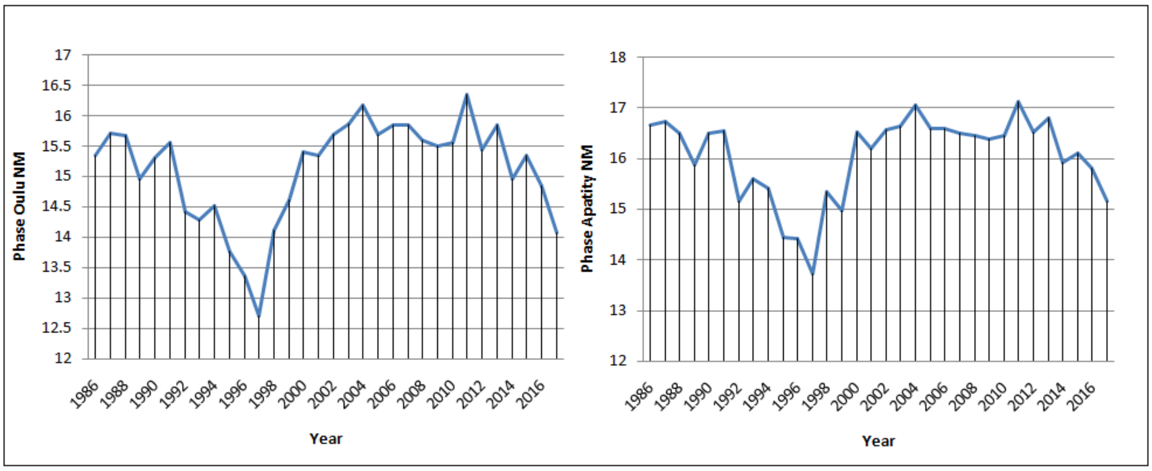

Fig. 1: *Shows the Plot between Diurnal Phase and Year for Duration 1986–2017 (Oulu and Apatity Neutron Monitor Stations).*

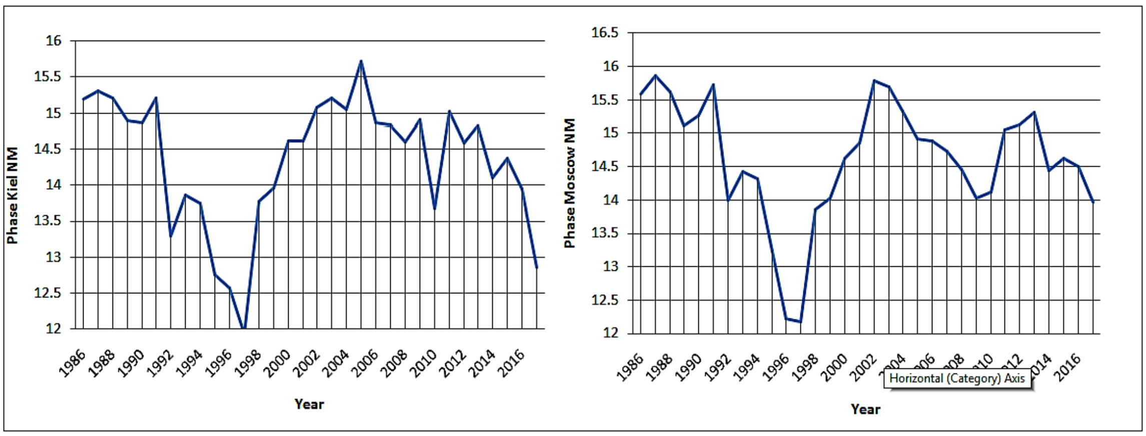

Fig. 2: *Shows the Plot between Diurnal Phase and Year for Duration 1986–2017 (Kiel and Moscow Neutron Monitor Stations).*

IMF lines [33]. The phase angle of higher rigidity station shifts towards earliest hours; this shift is due to outward convection by solar wind that increases the radial component of daily variation more than the east-west component [34].

The long term trend and the impact of inversion of extremity of the sunlight based attractive field on the diurnal anisotropy of astronomical beam (CR) power have been accounted for by Kumar *et al*. [35]. They have discovered that the period of the diurnal anisotropy fundamentally moves to early hours when the PSMF in the northern side of the equator (NH) is sure amid the periods 1971–79 and 1992–95 when contrasted with that amid the periods 1964–70 and 1980–89 when the PSMF in the NH is negative, affirming again the prior consequences of 22 year periodicity.

We have investigated diurnal phase on annual average basis from 1986 to 2017 which covers three phases of solar maximum; i.e. 1989, 2000 and 2014 as well as three phases of solar minimum; i.e., during years 1986, 1996 and 2008.

We have found:

(i) Shifted diurnal phase of cosmic rays towards later hours; for Oulu, Apatity, Kiel and Moscow stations observed in year 1989, 2000 an 2014; i.e., during maxima of solar cycle 22, 23 and 24.

(ii) The diurnal phase direction is observed to shift towards earlier hours in 1986, 1996 and 2008; i.e., during minimum solar activities phases of solar cycle 21, 22, 23; and a trend of large shift towards earlier hours found in 2016–2017 and onwards during declining phase of solar cycle 24.

(iii) The phase shows a tendency to shift towards earlier hours from 1992 with a little increase towards corotational direction during 1993, 2011 and again adopts a consistent trend of shifting towards early hours during later period.

(iv) With the comparative study of diurnal variation on different stations for different geometric conditions, it is observed that there are no significant difference in Oulu, Apatity, Kiel and Moscow neutron monitor stations.

ACKNOWLEDGEMENTS

We thankfully acknowledge Oulu, Apatity, Kiel and Moscow neutron monitor stations to provide cosmic ray intensity data.

REFERENCES

1. McCracken KG, Rao UR. A survey of the diurnal anisotropy. *Proc. 9th Int Cosmic Ray Conf*, London. 1965; 1: 213p.
2. Pomerantz MA, Duggal SP. The cosmic ray solar diurnal anisotropy *Space Sci Rev.* 1971; 12: 75p.
3. Rao UR. Solar modulation of galatic cosmic radiation *Sp Sci Rev*. 1972; 12: 719p.
4. Ananth AG, Agrawal SP, Rao UR. Study of cosmic ray diurnal variation on a day to day basis. *Parmana.* 1974; 3: 74p.
5. Kane RP. Mechanism of the diurnal anisotropy of cosmic ray radiation. *J Geophys Res.* 1974; 79: 1321p.
6. Kane RP. A study of days showing nonfield aligned diffusion vectors of cosmic ray diurnal anisotropy. *J Geophys Res.* 1975; 80: 3509p.
7. Agrawal SP, Singh RL. Critical study of the diurnal and semi diurnal variation of cosmic ray intensity on day to day basis. *14th Int Cosmic Ray Conf,* Munchen. 1975; 4: 11293p.
8. Kumar S, Yadav RS, Agrawal SP. Daily variation of galatic cosmic ray intensity during quiet days. *17th Int Cosmic Ray Conf,* Paris. 1981a; 10: 242p.
9. Ahluwalia HS, Riker JF. Solar wind velocity and daily variation of cosmic rays. *19th Int Cosmic Ray Conf,* La Jolla. 1985; 5: 116p.
10. Rao UR, McCracken KG, Venkatesan D. Asymptotic cones of acceptance and their use in the study of the daily variation of cosmic radiation. *J Geophys Res.* 1963; 68: 345p.
11. Mavromichalaki H, Preka-Papadema P, Liritzis I, *et al.* Short-Term Variations of Cosmic-Ray Intensity and Flare Related Data in 1981–1983. *New Astron.* 2003; 8: 777–94p.
12. Singh YP, Gautam S, Badruddin. Temporal Variations of Short- and Mid-Term Periodicities in Solar Wind Parameters and Cosmic Ray Intensity. *J Atmos Sol Terr Phys*. 2012; 89(1): 48–53p.

13. Modzelewska R, Alania MV. 27-day Cosmic Ray Intensity Variations during Solar Minimum 23/24. *Sol Phys*. 2013; 286(2): 593–07p.
14. Potgieter MS. Modulation of Galactic Protons in the Heliosphere during the Unusual Solar Minimum of 2006 to 2009. *Sol Phys*. 2014; 289(1): 391–06p.
15. Aslam OPM, Badruddin. Study of Cosmic-Ray Modulation during the Recent Unusual Minimum and Mini-Maximum of Solar Cycle 24. *Sol Phys*. 2015; 290(8): 2333–53p.
16. Howe R, Christensen-Dalsgaard J, Hill F, *et al*. Periodic Variation in the Geomagnetic Activity: A Study Based on the Ap Index. *Science.* 2000; 287: 2456–2460p.
17. Chowdhury P, Kudela K, Moon J. A Study of Heliospheric Modulation and Periodicities of Galactic Cosmic Rays during Cycle 24. *Sol Phys*. 2016; 291(2): 581–02p.
18. Bazilevskaya G, Broomhall AM, Elsworth Y, *et al*. A Combined Analysis of the Observational Aspects of the Quasi-Biennial Oscillation in the Solar Magnetic Activity. *Space Sci Rev*. 2014; 186(1–4): 359–386p.
19. Kudela K, Sabbah I. Quasi-Periodic Variations of Low Energy Cosmic Rays. *Science*. 2016; 59(4): 547–57p.
20. Rieger E, Kanbach G, Reppin C. A 154 Day Periodicity in the Occurrence of Hard Solar flares. *Nature.*1984; 312(5995): 623–25p.
21. Mclntosh PS, Thompson RJ, Willock EC. A 600-day Periodicity in Solar Coronal Holes. *Nature.* 1992; 360(6402): 322–24p.
22. Mursula K, Zieger B. The 1.3 year Variation in Solar Wind Speed and Geomagnetic Activity. *Adv Space Res*. 2000; 25: 1939–42p.
23. Nayar SRP, Radhika VN, Revathy K, *et al*. Wavelet Analysis of Solar Wind and Geomagnetic Parameter. *Sol Phys*. 2002; 208(2): 359–373p.
24. Mclntosh SW, Leamon RJ, Krista LD, *et al*. The Solar Magnetic Activity Band Interaction and Instabilities that Shape Quasiperiodic Variability. *Nat Commun*. 2014; 6: 6491p.
25. Valdes-Galicia JF, Velasco VM. Variations of Mid-Term Periodicities in Solar Activity Physical Phenomena. *Adv Space Res*. 2008; 41(2): 297–05p.
26. Katsavrias C, Preka-Papadema P, Moussas X. Wavelet Analysis on Solar-Wind Parameters and Geomagnetic Indices. *Sol Phys*. 2012; 280(2): 623p.
27. Singh YP, Badruddin. Prominent Short-, Mid-, and Long-Term Periodicities in Solar and Geomagnetic Activity: Wavelet Analysis. *Planet Space Sci*. 2014; 96: 120–24p.
28. Chowdhury P, Choudhary DP, Gosain S, *et al.* Short-Term Periodicities in Interplanetary, Geomagnetic and Solar Phenomena during Solar Cycle 24. *Space Sci*. 2015; 356(1): 7–18p.
29. Dungey IW. Interplanetary Magnetic Field and the Auroral Zones. *Phys Rev Lett*. 1961; 6(2): 47–8p.
30. Gonzalez ALC, Gonzalez WD, Dutra SLG, *et al.* Periodic Variation in the Geomagnetic Activity: A Study Based on the Ap Index. *J Geophys Res*. 1993; 98(A6): 9215–31p.
31. Paularena KI, Szabo A, Richardson JD. Coincident 1.3-year Periodicities in the ap Geomagnetic Index and the Solar Wind. *Res Lett*. 1995; 22(21): 3001–004p.
32. Singh YP, Badruddin. Short-Term Variations of Cosmic Ray Particles during the Recent Deep Solar Minimum and the Previous Four Solar Minima: A Wavelet Analysis. *Sol Phys.* 2015a; 290: 3071–79p.
33. Oh SY, Yi Y, Bieber JW. Modulation Cycles of Galactic Cosmic Ray Diurnal Anisotropy Variation. *Sol Phys*. 2010; 262(1): 199–12p.
34. Sabbah I. Solar Magnetic Polarity Dependency of the Cosmic Ray Diurnal Variation. *J Geo Research Space Phys*. 2013; 118(8): 4739–47p.
35. Kumar S, Shrivastava SK, Dubey SK, *et al*. Effect of Solar Poloidal Magnetic Field Reversal on Diurnal Anisotropy of Cosmic Ray Intensity on Quiet Days. *Indian J Radio Space Phys*. 1998; 27(5): 236–40p.

Cite this Article
Arvind Dubey, Santosh Kumar, Dubey SK. Variation in Diurnal Phase of Cosmic Ray Intensity during 1986–2017. *Research & Reviews: Journal of Physics*. 2018; 7(3): 20–23p.