АСТРОФИЗИКА

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TRANSIENT PHENOMENA IN COSMIC RAY INTENSITY DURING EXTREME EVENTS

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In the present work an analysis has been made for the extreme events occurred during July 2005. Specifically, rather intense Forbush decrease was observed at different neutron monitors all over the world during 16 July 2005. An effort has been made to study the effect of this unusual event on cosmic ray intensity as well as various solar and interplanetary plasma parameters. It is noteworthy that during 11 to 18 July 2005 the solar activity ranged from low to very active. Especially low levels occurred at the 11, 15 and 17 July whereas high levels took place on the 14 and 16 July 2005. The Sun is observed active during 11 to 18 July 2005 and the interplanetary magnetic field intensity lies within 15 nT and solar wind velocity was limited to ~500 kms^{-1}. The geomagnetic activity during this period remains very quite, *Kp* index did not exceed 5, the disturbance storm time D_{st} index remains ~-70 nT and no sudden storm commencement has been detected during this period. It is noted that for majority of the hours, the north south component of interplanetary magnetic field, *Bz* remains negative and cosmic ray intensity increases and shows good/high correlation with *Bz* and as the polarity of *Bz* tends to shift from negative to positive values, the intensity decreases and shows good/high anti-correlation with *Bz*. The cosmic ray intensity tends to decrease with the increase of interplanetary magnetic field strength (*B*) and shows anti-correlation for majority of the days.

Key words: *cosmic rays: interplanetary magnetic cloud*

1. *Introduction.* Modulations of galactic cosmic ray (GCR) intensity, which recur at the solar rotation period and are associated with corotating high-speed streams from coronal holes are presumably caused by deviations from the average solar wind properties associated with these streams. It is found by Richardson et al. [1] that the cosmic ray intensity tended to be anti-correlated with the solar wind speed within individual events, suggesting that enhanced convection of cosmic rays from the inner heliosphere in streams contributes to the depression. Richardson et al. [2] reported a 22-year dependence in the size of recurrent modulations observed by neutron monitors and spacecrafts during the last five solar minima, with larger modulations during the $A>0$ cycles (when the solar global magnetic field points outward on the northern hemisphere).

The transient disturbances in the interplanetary space usually are accompanied by the short period decreases - Forbush effects of the galactic cosmic ray (GCR) intensity [3-7]. Generally, two types of the Forbush effects of the GCR intensity are distinguished - sporadic and recurrent. The sporadic

Forbush effects are characterized with a rapid decrease phase during the one-two days and by a subsequent recovery phase lasting for few days. Solar flares and coronal mass ejections (CMEs) produced large variations in cosmic ray intensity. A lot of attempts have been made in the past to explore the relation between these phenomena as well as their impact on cosmic rays [8-10].

Nowadays, the analysis of spacecraft data reveals that these events are common in the solar wind. About 30% of CMEs observed in the solar wind exhibit internal field rotations, characteristic of magnetic flux rope. However, the relationship between the CMEs observed near the Sun and magnetic clouds is poorly understood.

Forbush decreases associated with shock-associated cloud are caused by magnetic field variations associated with interplanetary disturbances [11]. Badruddin et al. [12] have reported a possible correlation between magnetic clouds and cosmic ray intensity decrease while Kudo et al. [13] have reported an increases in cosmic ray intensity that may be related to the geomagnetic D_{st} index and Iucci et al. [14] have found short term increase in CR intensity occurring inside the Forbush decrease that possibly may be associated with magnetic clouds. Zhang and Burlaga [15] infer that the cosmic rays are mainly modulated by fluctuation rather than by drifting in the strong smooth field in the magnetic cloud.

Many workers have shown the structure and dynamics of interplanetary magnetic clouds and their effects on the magneto sheath and magnetosphere. The association of geomagnetic activity to magnetic clouds and other IMF features are given by Farrugia et al. [16] and Tsurutani and Gonzalez [17]. Farrugia et al. [18] have shown that a major geomagnetic storm and associated aurora were produced by the extended interval of the negative Bz in the front part of magnetic cloud. As the magnetic cloud moved past the Earth, the magnetic field slowly rotated northward giving an extended interval with positive Bz in which the geomagnetic activity subsided.

2. *Data and analysis.* The temperature and pressure corrected hourly data (counts of neutrons) of cosmic ray intensity from Moscow neutron monitor have been used, where the long-term change from the data has been removed by the method of trend correction. The days of Forbush decreases have also been removed from the analysis to avoid their influence in cosmic ray variation. Interplanetary magnetic field and solar wind plasma data have been taken from the interplanetary medium data book.

3. *Results and Discussion.* In the present work we have rigorously studied the extreme events occurred during July 11 to 17, 2005. The hourly

data of cosmic ray neutron monitor of Moscow for these events have been plotted in Fig.1. As depicted in figure, a series of Forbush effects took place from 12 July causing a decrease in cosmic ray intensity of about 2%, by the 16 July 2005. As a result an intensive Forbush decrease of cosmic ray, on 16[th] July is evident. A sharp enhancement of cosmic ray intensity occurred right after the main phase of the Forbush decrease on 16[th] July, was followed by a second decrease within less than 12 hours. The characteristics of this event indicate that it does not comprise a ground level enhancement of solar cosmic rays neither a geomagnetic effect in cosmic rays. The

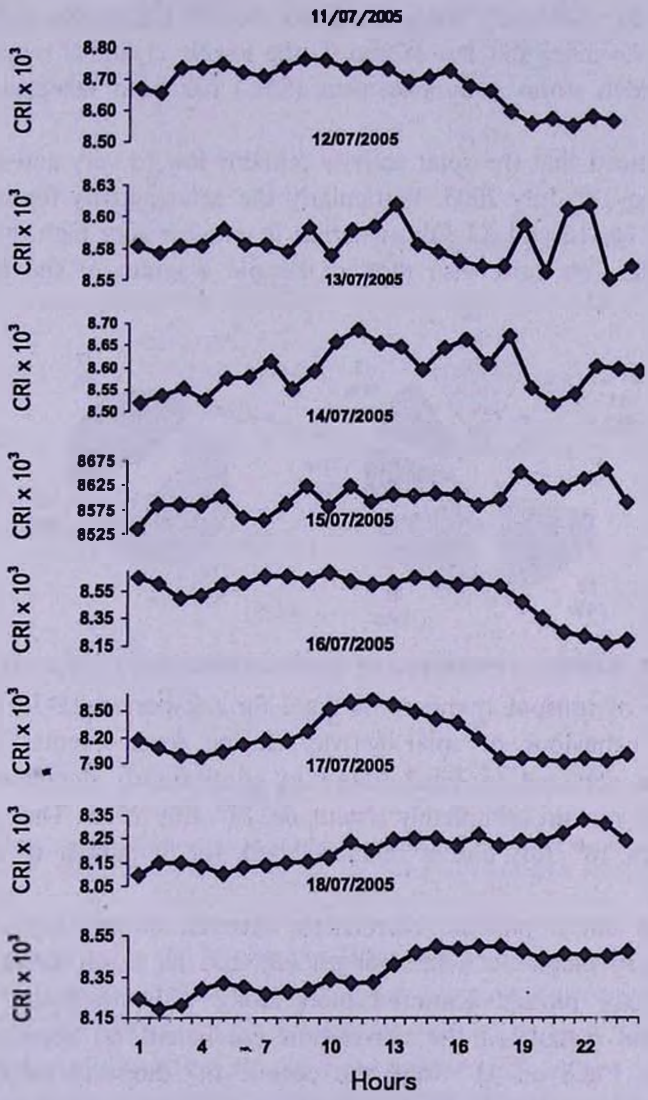

Fig.1. Cosmic ray intensity variation during July 11-18 2005.

event seems to be caused by the interplanetary disturbances in the inner heliosphere at the time when Earth crossed a periphery of a giant Forbush effect started after the flare on 14th July and play a significant role for the solar activity of the previous days.

The Sun was rather active during this period and we have observed 35 C-class, 13 M-class and 1 X-class solar flares and five halo coronal mass ejections during 11 to 18 July 2005. Though the main flares occurred, the interplanetary space near the Earth was not strongly disturbed during this period. The interplanetary magnetic field intensity lies within 15 nT and solar wind velocity was limited to ~500 kms^{-1}. The geomagnetic activity during this period was also very quite, *Kp* index did not exceed 5, the lowest D_{st} index remains ~-70 nT and no sudden storm commencement (SSC) has been detected during this period.

It is noticed that the solar activity remains low to very active during the period 11 to 18th July 2005. Particularly the solar activity found to remain low during 11, 15 and 17 July, whereas it remains very high during 14 and 16 July 2005. We have also plotted the pie diagram of the frequency of

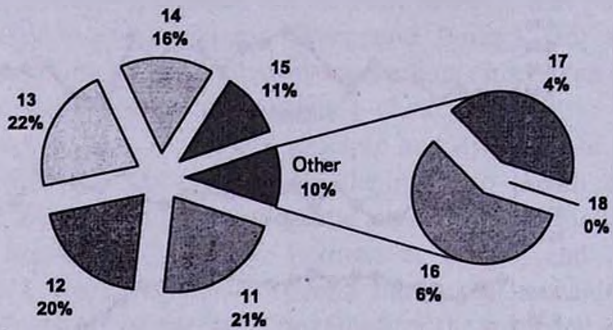

Fig.2. Frequency of occurrence of sunspot numbers during July 11-18 2005.

occurrence of sunspot numbers in Fig.2 for the period 11-18 July 2005 to study the behaviour of solar activity during these events. The sunspot numbers as depicted in Fig.2 found to continuously decreased from 11th July until it remain completely absent on 18th July 2005. Thus a blank Sun appeared on 18th July and it remains blank for a number of days till 22nd July 2005.

To find out a possible correlation between cosmic ray intensity and interplanetary magnetic field strength (*B*) and its north south component (*Bz*), we have plotted scattered plots along with regression equation in Fig.3, 4 and calculated the correlation coefficient (*r*) between them. As depicted in Fig.3 on 11th July, the cosmic ray intensity increases sharply as the *Bz* component of IMF increases and shows a good positive correlation ($r = 0.65$). The cosmic ray intensity seems to remain unaffected for different polarity of Bz on 12th, 14th and 16th July showing very nominal correlation (r=-0.09, 0.13, 0.10) during these days. On 13th July the cosmic ray intensity significantly decreases as the polarity of Bz changes from negative to positive and shows a high anti-correlation (r=- 0.71), however it increases sharply with increase of Bz during 15th July and shows a good positive correlation (r=0.50). The cosmic ray intensity decreases sharply on

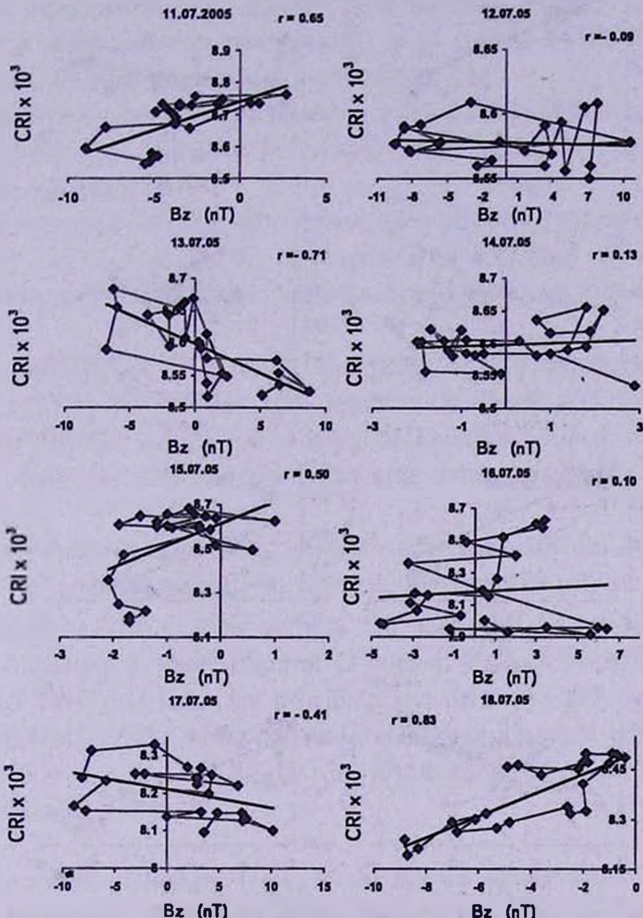

Fig.3. Cosmic ray intensity along with the variation in associated value of north south component of IMF (Bz), the regression line and the observed correlation coefficient (r) during 11-18 July 2005.

17th July as the polarity of Bz changes from negative to positive and shows a good anti-correlation (r=-0.41), whereas it increases significantly with the increase of Bz and shows a high correlation (r=0.83). It is also observed that for majority of the hours Bz remains negative and cosmic ray intensity increases and shows good/high correlation with Bz and as the polarity of Bz tends to shift from negative to positive values, the cosmic ray intensity decreases and shows good/high anti-correlation with *Bz*.

The cosmic ray intensity decreases significantly on 11th July showing high anti-correlation ($r=-0.72$) and increases gradually on 12th July showing some positive correlation ($r=0.32$) with the increase of IMF strength (*B*).

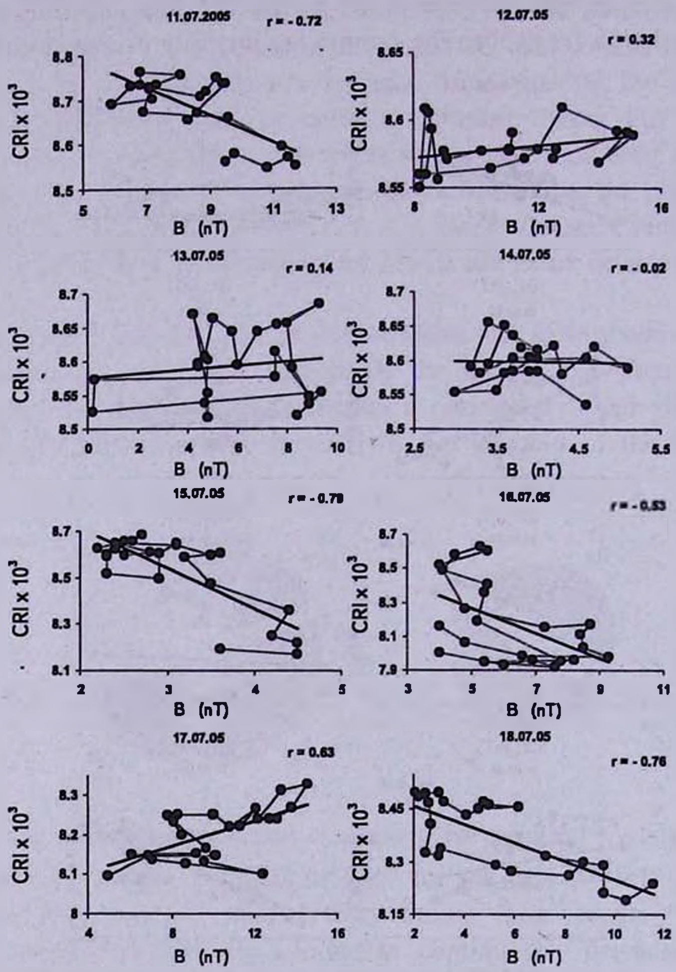

Fig.4. Cosmic ray intensity along with the variation in associated value of IMF strength (*B*), the regression line and the observed correlation coefficient (*r*) during 11-18 July 2005.

However it does not shows any significant trend associated with *B* during 13th-14th July having very weak correlation ($r=0.14$, -0.02) on these days. The cosmic ray intensity decreases significantly on 15th and 18th July showing high anti-correlation ($r=-0.79$, -0.76), however it decreases sharply on 16th July and increases on 17th July showing high correlation ($r=-0.53$, 0.63) with *B* on these days. The cosmic ray intensity tends to decrease with the increase of IMF strength (*B*) and shows anti-correlation for majority of the days.

4. *Conclusions.* From the present investigations following conclusions may be drawn:

- A series of Forbush effects took place from 12 July causing a decrease in cosmic ray intensity of about 2%, by the 16 July 2005.

- An intensive Forbush decrease of cosmic ray intensity observed on 16^{th} July 2005.

- The characteristics of this Forbush decrease on 16^{th} July, 2005 indicate that it does not comprise ground level enhancement of solar cosmic rays neither a geomagnetic effect in cosmic rays.

- The Sun is observed active during 11 to 18 July 2005 and the interplanetary magnetic field intensity lies within 15 nT and solar wind velocity was limited to ~500 kms^{-1}.

- The geomagnetic activity during this period remains very quite, *Kp* index did not exceed 5, the disturbance storm time D_{st} index remains ~-70 nT and no sudden storm commencement has been detected during this period.

- For majority of the hours, the north south component of IMF, *Bz* remains negative and cosmic ray intensity increases and shows good/high correlation with *Bz* and as the polarity of *Bz* tends to shift from negative to positive values, the intensity decreases and shows good/high anti-correlation with *Bz*.

- The cosmic ray intensity tends to decrease with the increase of IMF strength (*B*) and shows anti-correlation for majority of the days.

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ПЕРЕХОДНЫЕ ЯВЛЕНИЯ В ИНТЕНСИВНОСТИ КОСМИЧЕСКИХ ЛУЧЕЙ ВО ВРЕМЯ ЭКСТРЕМАЛЬНЫХ СОБЫТИЙ

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В настоящей статье проводится анализ экстремальных событий, имевших место в июле 2005г. Особое внимание уделяется весьма интенсивному форбушевскому спаду, который наблюдался повсюду различными мониторами нейтронов 16 июля 2005г. Делается попытка выявить влияние указанного необычного события на интенсивность космических лучей, а также на значения различных параметров солнечной и межпланетной плазмы. Важно отметить, что в период между 11 и 18 июля 2005г, солнечная активность менялась в широких пределах. Особенно низкой она была 11, 15 и 17 июля, в то время как высокий уровень достигался 14 и 16 июля. В период от 11 до 18 июля интенсивность межпланетного магнитного поля менялась в пределах до 15 нТ, а скорость солнечного ветра - до 500 км $с^{-1}$. Геомагнитная активность в данный период оставалась спокойной. Значение *Kp* индекса не превосходило 5, D_{st}-индекс времени бурего возмущения оставался порядка ~-70 нТ, внезапного начала бури не отмечалось. Следует отметить, что в большую часть времени север-южный компонент межпланетного магнитного поля B_z оставался отрицательным, а интенсивность космического луча показывала хорошую/высокую корреляцию с B_z. Когда полярность B_z обнаруживала тенденцию меняться на положительную, интенсивность падала и показывала хорошую/высокую антикорреляцию с B_z. Интенсивность космических лучей имела тенденцию убывать с усилением межпланетного магнитного поля (*B*) и показывала антикорреляцию большую часть времени.

Ключевые слова: *космические лучи: межпланетное магнитное поле*

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