Dynamics of the Cosmic Ray Current Behaviour During Large-Scale Solar Wind Disturbances

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Abstract

By using treatment results of world net neutron monitor data by the global survey method, the behaviour of cosmic ray current (anisotropy) during Forbush-effects for the 1965 to 1999 period is analyzed. Peculiarities of the current behaviour before the shock wave arrival are investigated depending on the value of intensity decrease effect and heliocoordinates of disturbance sources on the Sun. Data of the Yakutsk underground complex of muon telescopes are also used in the analysis. Possibilities to predict the arrival of large-scale disturbances of interplanetary medium at the Earth by the behaviour of the observed cosmic ray anisotropy are discussed.

1. Introduction

The mean current of galactic cosmic rays (GCRs), $\overrightarrow{W}$, caused by the convection-diffusion model, is oriented to the east-west direction and is of ∼0.5 % [3]. However, at the periods of solar wind disturbances the direction and value of $\overrightarrow{W}$ may be strongly differed from the mean ones [4]. If these changes begin before the Forbush-decrease onset then they may be the precursors of the entry of the Earth in the region of interplanetary disturbance. Krymsky et al.[3] have calculated the current structures defined by the disturbance source heliolongitude. According to these calculations, it is assumed that before the arrival of interplanetary shock waves the stable current component to the Sun from western flares and from the Sun for eastern flares appears. Further it was shown [1] that there was qualitative agreement of the observed average current structure with the expected one for disturbances from the regions of $\Phi < 45^0$ E heliolongitudes.

2. Results and Discussion

Based on the treatment of hourly values of neutron monitor world network by the global survey method for the 1966-1994 period, the current structures observed before Forbush-decreases are analyzed. We consider 97 Forbush-decreases with the amplitudes A $\geq$ 4% identified with the heliocoordinates of their sources

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[2]. It is shown [4] that the most likely geophysical effect is observed from solar flares occurring 1.5- 2 days before the arrival of corresponding disturbance in interplanetary space to the Earth. Taking into account this, the Table lists statistical analysis results in a behaviour of average 3-hour vectors $\overrightarrow{W}$ 2 days before the above Forbush-decreases divided to 4 groups according to heliolongitudes of the disturbance source. For each group the relationships of characteristic current structure with the current components from and to the Sun in the azimuth east - west direction in per cent are presented.
Table.

Regions of heliolongitudes	30 - 60^0E	0 - 30^0E	0 - 30^0W	30-60^0W
Currents from the Sun	$\approx$ 44%(7)	$\approx$ 62%(21)	$\approx$ 40%(7)	$\approx$ 23%(3)
Currents to the Sun	$\approx$ 13%(2)	$\approx$ 21%(7)	$\approx$ 30%(5)	$\approx$ 31%(4)
Azimuth currents	$\approx$ 43%(7)	$\approx$ 17%(6)	$\approx$ 30%(5)	$\approx$ 46%(6)

From the Table the following can be found: 1. For current structures before Forbush-effects from eastern flares (Φ <30^0E) the appearance of GCR current directed from the Sun is characteristic ($\approx$ 62%). For the flares from the heliolongitude region of $30 < \Phi < 60^0$ E the number of current structures with the component from the Sun decreases and is $\approx$ 44%. Fig.1a presents an example for the behaviour of hourly values of the isotropic intensity I and GCR current vectors $\overrightarrow{W}$ with a radial component from the Sun observed in the period of Forbush-decrease on November 9,1969 from the solar flare (14^0N; 11^0E). The arrow is the beginning of Forbush-decrease. 2. Before Forbush-effects from western flares ($\Phi < 30^0$ W) the relative increase ($\approx$ 30%) of current structures with the current component directed to the Sun is observed in comparison with the behaviour of current before the arrival of disturbances from the eastern sources. Much the same per cent of currents to the Sun is observed before disturbances from the flares from the region of heliolongitudes of $30 < \Phi < 60^0$ W. Fig.1b gives the behaviour of I and $\overrightarrow{W}$ during the Forbush-decrease on January 4, 1988 from the flare (35^0S; 18^0W). It is evident from the Table that there is only the partial agreement between observed and expected [3] current structures before the arrival of interplanetary disturbances both from eastern and western flares.

To investigate the possibility of forecast for individual disturbances the behaviour of $\overrightarrow{W}$ taking into account also insufficient ($\sim$ 1%) GCR intensity decrease effect is considered in addition. The analysis results show that there exist a certain current structure associated with the subsequent arrival of disturbance. It is found that the appearance of the stable (2 days and more) and significant radial component of current to the Sun ($\overrightarrow{W}$r > 0.2%) is detected, on the whole, 1-3 days before the beginning of several decreases in the cosmic ray intensity. This effect depending on the GCR current radial component value is also manifested in the muon component. Fig.2 presents the behaviour of the isotropic intensity and daily average vectors of GCR current by using global survey re-

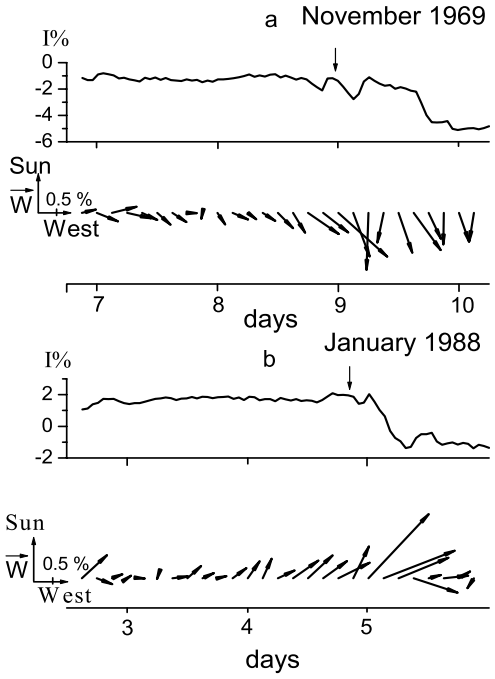

Fig. 1. Behaviour of the isotropic intensity I and GCR currents $\vec{W}$ before and after the arrival of an interplanetary shock wave from eastern (a) and western (b) flares

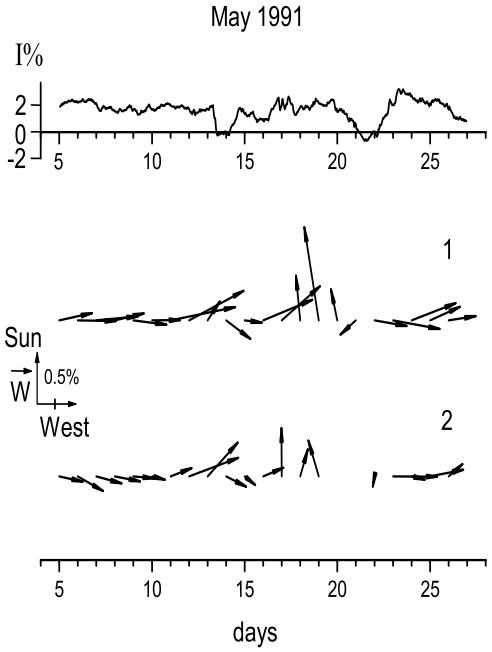

Fig. 2. Isotropic intensity I and GCR currents $\vec{W}$ by global survey data (1) and the ground-based vertical muon telescopy (2) in May 1991

sults (1) and ground-based vertical muon telescope data (2). As seen from Fig.2, the significant component of current to the Sun, $\overrightarrow{W}$r, in the neutron and muon components appears 1-3 days before small ($< 2\%$) GCR intensity disturbances. Based on results obtained, the test of current structures for 1981-1999 has been carried out. Thereby, the cases, when the search condition was observed after the beginning of disturbances, were excluded. From 102 periods detected according to the above condition, ~ 80 periods were observed 1-3 days before even small ($\sim 1\%$) effects in the GCR intensity. Therefore, the probability for the arrival of any disturbance to the Earth after the occurrence of the stable radial component of current to the Sun ($\overrightarrow{W}\mathrm{r} > 0.2\%$) is ~ 0.8. The rest periods found without next significant disturbances in the GCR isotropic intensity were, on the whole, in the periods of solar activity minima. Thus, there exist the close correlation between the occurrence of stable periods (> 2 days) of currents to the Sun ($\overrightarrow{W}\mathrm{r} > 0.2\%$) and the subsequence arrival of some interplanetary disturbances at the Earth.

3. Conclusion

The above analysis of the behaviour of GCR currents shows:

1. The significant association of changes in the behaviour of GCR anisotropy before the beginning of large-scale disturbances in interplanetary space with heliolongitudes of their sources is not found.
2. The appearance of the stable and significant component of GCR current to the Sun can be a precusor for the arrival of some interplanetary disturbances to the Earth at the all phases of solar activity except for minima.

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