Anomalous Forbush effects associated both with remote western and eastern sources

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The 9th Hellenic Astronomical Conference
20-24 September 2009, Athens

Russian Academy of Science
IZMIRAN

Abstract

Solar wind disturbances near Earth, as a rule, dominate the magnitude, shape and other properties of Forbush effects (FE). At specific cases though, an inconsistency in the relation between the characteristics of the interplanetary disturbance and Forbush effect is observed, when a large decrease of cosmic ray intensity may correspond to a small disturbance of the near Earth solar wind. Most often such cases occur when the source of disturbance is a large release of solar substation in the eastern part of the solar disk. The study of the Forbuch effect on 16-17 July 2005 has shown that an anomaly in the relation of the interplanetary magnetic field (IMF) intensity and the FE magnitude may not be caused by eastern but by far western sources. We analyzed the events from the database of IZMIRAN, which contains several thousands interplanetary disturbances and Forbush effects in order to search for anomalous Forbush decreases associated with both remote western and eastern sources. Analysis of such events testifies that Cosmic Ray (CR) variations are able to provide information on sufficiently remote heliospheric phenomena and thus, play a significant role to the understanding of space environment.

What is a Forbush Effect ?

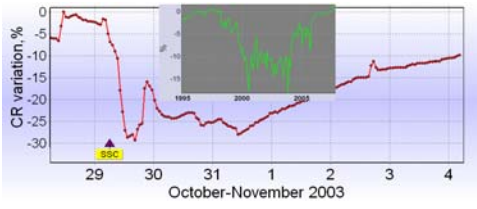

Figure 1: 10 GV cosmic ray variations during the giant Forbush effect in October 2003 (hourly data) and in 23th solar cycle (monthly data).

Forbush effect (FE) is often said to be a storm in CRs and this is correct. During the FE we see mostly disturbed galactic CRs. During the FE the CR often happen to be most modulated, and the magnitude of the largest FEs is higher than 11-year CR variation. It is shown in Fig. 1, where CR variation during an FE and long-term CR modulation during the solar cycle for rigidity of 10 GV are plotted on the same magnitude scale but on two different time scales. CR variations in solar cycle 23 did not exceed 19%, whereas in one FE at the end of October 2003 they made about 28%. And finally, during the FE galactic CR flux may be the most anisotropic. FE is a storm in CRs and a manifestation of heliospheric storm. Perhaps, it is reasonable to give the definition of the FE basing on its origin. It may look as follows: **"Forbush effect is a result of the influence of coronal mass ejections (CMEs and ICMEs) and/or high speed streams of the solar wind from the coronal holes on the background cosmic rays".** Thus, interplanetary disturbances that created the FEs are both of sporadic and recurrent nature. It would be desirable to leave only one class of sources and not consider recurrent phenomena as the FEs. But this is practically impossible because the solar wind disturbance is often a result of interaction of different factors, both of sporadic (flares, filament disappearances, coronal ejections) and recurrent (coronal holes, streamer structure) origin.

When does a Forbush Effect occur ?

Fig. 2a demonstrates quasi 11-year cycles in the behavior of the FE magnitude averaged monthly and yearly. 11-year periodicity appears also in the variations of numbers of different magnitude FEs (Fig. 2b). Since all sufficiently large FEs (e.g., >5%) are connected with CMEs, by studying the variations in the number of large FEs we can get information about CMEs during those time periods when there were no CME observations

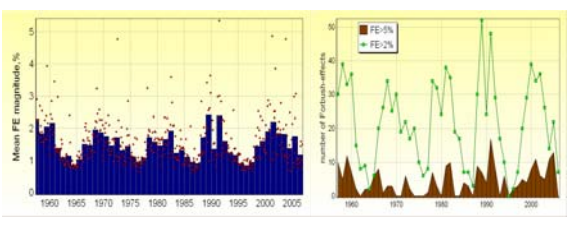

Figure 2: (a) left panel – monthly (points) and yearly (columns) mean FE magnitudes over 1957-2006; (b) right panel –Annual number of FEs with magnitude > 3 % & > 5 % in the same time period

Anomalous Forbush Effects

Among all FEs we distinguished a subclass of events characterized by relatively unsettled interplanetary and geomagnetic conditions (IMF<15 nT, Kp<6), gradual decrease of the CR intensity on the main phase of FE and slow recovery phase. It turned out that all these events were caused by far eastern or western solar sources and have very characteristic features in a behavior of CR variations

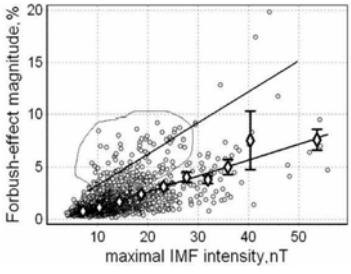

Figure 3: FE magnitude (A_F) vs maximal IMF intensity Bm. Diamonds are the A_F values averaged by the equal Bm intervals

We are focusing at the events (circled group – Fig. 3) where small and moderate values of IMF corresponded to large A_F . It looks as a result of more effective influence of a disturbance on the CR. A degree of such the efficiency might be estimated as $K_F = A_F / Bm$, (%/nT).

Table I: Distinction of FEs to Anomalous & Normal events

type	East (E90-E30)	Centre (E30-W30)	West (W30-W90)
$K_F > 0.36$ Anomalous	14	10	9
$K_F < 0.36$ Normal	24	62	13

One can see that in normal events the central sources dominate whereas anomalous FEs are mainly caused by extreme eastern or western sources. All anomalous FEs turned out to be of >3% magnitude and occurred in relatively weakly disturbed interplanetary and geomagnetic conditions (IMF<15 nT, Kp<6), with gradual fall of CR intensity in the main phase of Forbush-effect. We compared the characteristics of CR variations during the FEs from western and eastern sources.

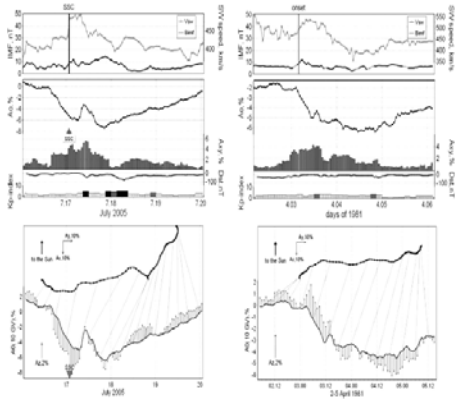

Figure 4: Examples of the FEs in July 2005 and April 1981 caused by the far western solar sources: IMF, solar wind, geomagnetic data (Kp-index and Dst variations), cosmic ray density and anisotropy (A0 and Axy) during the FEs associated with the western solar flares W79 and W52. In the bottom panels vector diagram of CR anisotropy (equatorial component Axy) and density (A0) are presented. Vertical vectors mean north-south component of the CR anisotropy. Thin lines connect equal time points in each 6 hours in vector diagram and density curves

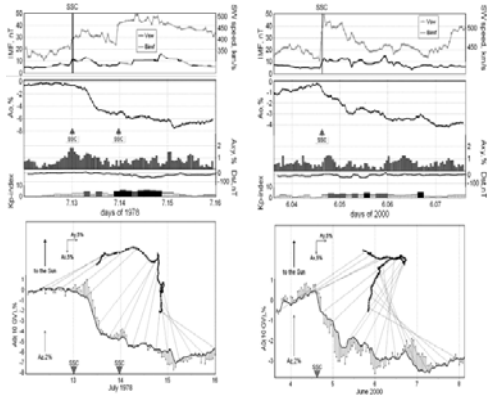

Figure 5: Parameters of the cosmic ray, interplanetary and geomagnetic activity during the FEs associated with far eastern solar flares: in July 1978 (E58) and June 2000 (E60). There designations are the same as in Fig. 4

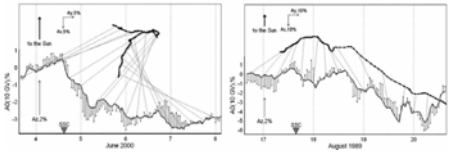

Figure 6: Vector diagrams for equatorial component of CR anisotropy Axy during the FEs associated with eastern (June, 2000, E60) and western (August 1989, W60) solar sources. The designations are the same as in Fig 4.

Conclusions

✓ In the majority of effective events the Earth enters only a periphery of the interplanetary disturbance, the main part of which misses Earth (to the East or to the West).

✓ Those events are preceded by powerful flares on the Sun, which are generally located far from the center of the solar disk. The CMEs and interplanetary disturbances, originating from the near limb longitudes, appear to be of larger size and more complicated structure than is visible near Earth.

✓ It was possible to separate small but very definite groups of large FEs which were not followed by strong interplanetary disturbances near Earth, nor by high geomagnetic activity but seemed to be associated with great solar wind disturbances that missed Earth.

✓ The anomalous eastern FEs have a prolonged descent phase with a later minimum but larger magnitude in CR density than western events. They show a sharp change of the anisotropy direction in the minimum of FE.

✓ The anomalous western FEs strongly differ from typical FEs caused by western sources which are usually not large and very short. They also differ from the anomalous eastern FEs by a bigger size of CR anisotropy and less variability of its direction.

✓ These properties may be used for the inner heliosphere as diagnostics and Space Weather predictions.

✓ In the cases of far sources the CR observations give better information about the real power and size of a disturbance than near-Earth measurements of the solar wind.

✓ Moreover, it may be a useful tool in the cases of events where there is not sufficient data for their identification.

Acknowledgement

The support of the Special Research Account of the University of Athens is gratefully acknowledged.

References

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