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Solar wind modulation of galactic cosmic rays observed on board of ExoMars TGO

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Abstract

The FREND dosimeter Liulin-MO on board ExoMars TGO [6] in 2016 – 2017 measured GCR fluxes during TGO transit to Mars and on Mars high ecliptic orbit. During the interplanetary transit of TGO a good agreement between the fluxes provided by Liulin-MO and those measured by SIS instrument aboard ACE is observed. On high elliptic Mars orbit (31.10.2016 – 07.03.2017) Liulin-MO data match SIS data “delayed” by 5 days in average. During these periods no CME hit the Earth but multiple HSS were observed. We investigate the relation of GCR short-term variations to the observed solar wind parameters as measured aboard ACE to find how the flux depletions are related to the particular HSS.

1. Introduction

The 27 day variations in GCR intensities have been observed for many decades since the first announcement by Forbush [1]. On a short-term scale the GCR flux is modulated by interaction with non-homogeneous structures – high speed streams (HSS) and the interplanetary manifestations of coronal mass ejections that could be magnetic clouds (MC) and interplanetary coronal mass ejections (ICME) (e.g. [2], [3], [4]). These effects have been studied extensively using data from ground-based neutron monitors. Thus recorded GCR fluxes bear the effects of their interaction with the magnetoshere and the interaction of the primary and secondary particles with the atmosphere.

We focus on GCR variations caused by HSS and the leading them corotating interaction regions (CIRs). Different mechanisms were proposed to cause the onset of GCR depression, including solar wind speed increases at stream edges, magnetic sector boundaries, magnetic field enhancements, and stream interfaces. Richardson [5] studied the effects of CIRs on GCR fluxes using data from several space probes. He concluded that interfaces between fast and slow solar wind streams and the leading edges of CIRs are responsible for the depression onset.

2. Data and results

Liulin-MO GCR fluxes in two perpendicular directions and the proton flux > 30 MeV by SIS instrument on ACE satellite [7] (located at L1 libration point at about 1 500 000 km from Earth) obtained from 22.04.2016 to 07.03.2017 are compared in Fg. 1. Note that Liulin-MO is not able to measure protons with energies below 30 MeV due to the shielding of its detectors. During the interplanetary transit of TGO a good agreement between the fluxes provided by the two instruments is observed. In high elliptic Mars orbit (31.10.2016 – 07.03.2017) Liulin-MO data match SIS data “delayed” by 5 days in average

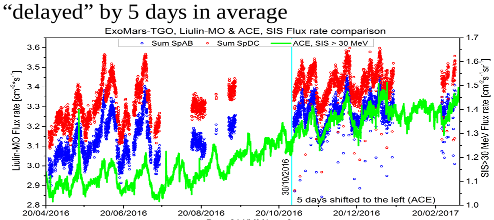

Figure 1. Liulin-MO GCR fluxes in two perpendicular directions and proton flux > 30 MeV by SIS instrument on ACE satellite obtained from 22.04.2016 to 07.03.2017

During the plotted period no CME hit the Earth but multiple HSS were observed according to NOAA Preliminary Reports and Forecasts of Solar Geophysical Data. Therefore it were HSS, which modulated SIS and Liulin-MO fluxes. As a first step we used the WSA-Enlil model (http://iswa.ccmc.gsfc.nasa.gov/) to look at the propagation of a possible HSS. During April – first half of July the Earth and Mars are located on near-by magnetic field lines ant the HSS fronts reach both planets (and TGO still nearer to Earth than to Mars) roughly simultaneously. During November 2016 a possible HSS reaches Mars first and only after approximately 4 days reaches the Earth. At the end of the period – the beginning of March 2017 this delay is already about 6 days. In the scale of Fig. 1. an average delay of 5 days of ACE SIS data gives an admissible agreement with Liulin-MO GCR fluxes. The overall increase of the fluxes in both instruments observed from 22.04.2016 to 07.03.2017 can be attributed to the increase of GCR intensity during the declining phase of the solar activity.

We investigate the relation between GCR small-scale variations recorded by Liulin-MO on TGO transit to Mars and ACE SIS and solar wind (SW) disturbances - CIR and HSS - recorded on board ACE. To identify the SW disturbed regions we used velocity, density, proton temperature, module and components of IMF, proton thermal pressure, proton plasma β parameters (ratio of thermal and magnetic field pressures) and the method described in [8]. We identified about 15 regions with HSS. Usually CIRs/corotating high-speed streams depress the cosmic ray intensity, but there were two regions of HSS where no GCR flux depression was observed. The average depression in our cases is ~4%. In individual streams, the cosmic ray intensity and solar wind speed tend to be highly anti-correlated but exceptions occur. The recovery phase is more gradual than the onset phase. The depression onset is observed in different regions of the HSS – sometimes it is associated with the leading edge of the stream and the stream interface; with the leading or trailing edge of the CIR; or even inside the HSS. The depression maximum occurs around the maximum of SW speed, but it is rarely located in the vicinity of CIR trailing edge.

3. Summary and Conclusion

We presented a comparison between GCR fluxes measured aboard TGO by the FREND dosimeter Liulin-MO and those measured by SIS instrument on ACE. Modelling of interplanetary medium during the investigated period showed that GCR small-scale variations observed by both instruments at different locations in the heliosphere are caused by one and the same HSS. Analyses of SW parameters measured on ACE showed that the onset of GCR flux depletions occur in different regions of the HSS. This does not give ground to make any conclusions about the mechanism of GCR-HSS interaction.

Acknowledgements

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