DOI: 10.31401/WS.2021.proc.10



# Temporal Analysis of the GCR Flux Obtained from the Liulin-MO Instrument in Orbit around Mars

Krastev[1] K., Semkova[1] J., Koleva[1] R., Benghin[2] V., Drobyshev[2] S.

[1]Space Research and Technology Institute, Bulgarian Academy of Sciences
[2] Institute of Biomedical Problems of Russian Academy of Sciences

**Abstract.**

In this article we present the results of measurements of the radiation environment obtained from the Liulin-MO instrument on ExoMars Trace Gas Orbiter (TGO) in orbit around Mars for the last three years. Special attention is paid to two interesting events that occur with a rapid change in the flux of cosmic rays, measured by the instrument. The possible connection between these two events and the increased solar activity for the respective time intervals, characterized by the manifestation of coronal mass ejections and solar flares, is shown.

## Introduction

The radiation field in interplanetary space is complex, composed of galactic cosmic rays (GCR) and solar energetic particles (SEP). The GCR - charged particles that originate from sources beyond the Solar System - represent a continuous radiation source. The variations of the GCR flux is determined mainly by its interaction with interplanetary magnetic field (IMF). The interplanetary magnetic field is formed by the solar wind (solar plasma flow), which carries away the frozen magnetic fields (regular and random) into the interplanetary space. The depth of the modulation of this interaction depends on several factors - the size and direction of the regular component, the size of the random component of the magnetic field, i.e. from its disturbance, from the speed of the solar wind, etc. (Toptygin., 1985). All these events are in one way or another related to the cycles of solar activity.

The dosimetric telescope Liulin-MO for measuring the radiation environment onboard the ExoMars TGO (Semkova et al, 2018) is a module of the Fine Resolution Epithermal Neutron Detector (FREND), (Mitrofanov et al. 2018). The parameters that Liulin-MO measures are energy deposition spectra, particle flux and dose rate in 2 perpendicular direction. TGO was inserted into Mars science orbit (circular orbit with about 400 km altitude, $74^0$ inclination, ~ 2 hours orbit period) on 9 April 2018. On 16 April 2018 Liulin-MO was switched on and since then operates almost continuously (Semkova et al, 2021). The relatively short period of our data obtained in Mars orbit (three years) allows us to trace only part of the 11-year variation of galactic cosmic rays, but it allows us to observe short term variations in the charged particles flux, caused by large-scale disturbances of the solar wind (Forbush effect). There are two main types of solar wind disturbances: recurrent and sporadic (Belov., 2008). Recurrent Forbush decreases are caused by high speed solar wind streams flowing from coronal holes. Non-recurrent Forbush effects are associated with coronal mass ejections (CME) that pass into an interplanetary cloud (ICME).

## Observations

The data for the entire period during which the Liulin –MO instrument is in scientific orbit around Mars are shown in Figure 1.

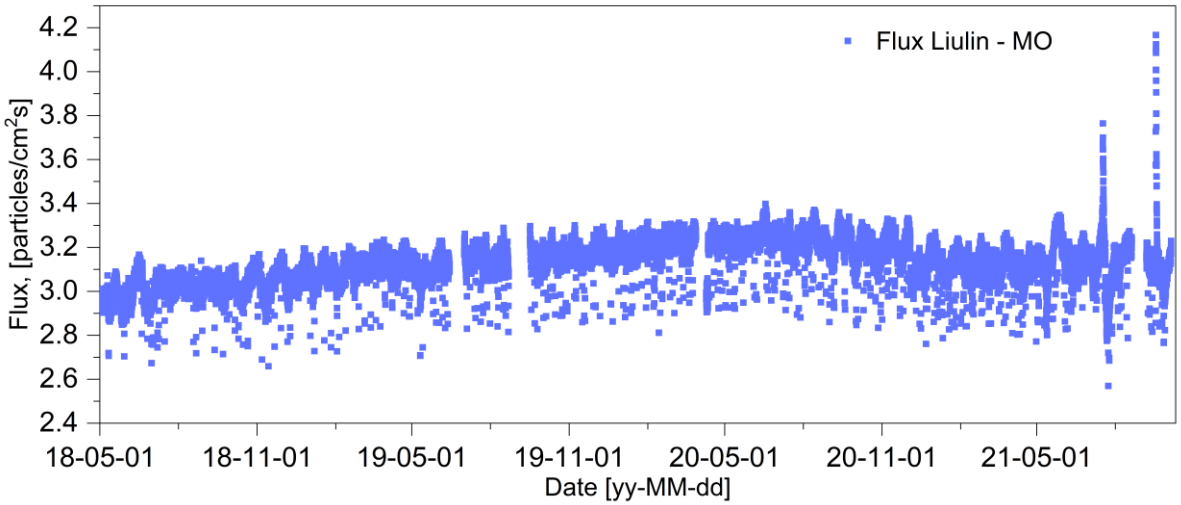


*Figure 1. Data for the period 1 May 2018 to 30 September 2021, measured by the Liulin-MO instrument.*

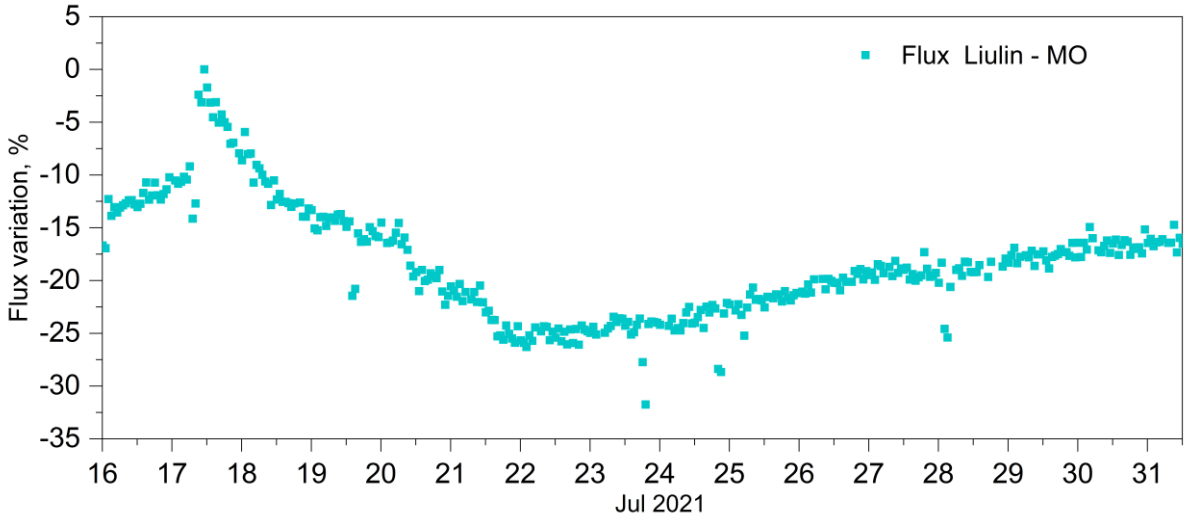


*Figure 2. The July, 2021 event.*

The two events of 17 July and 17 September 2021 stand out clearly. The event of July 17 is expressed in an initial increase in the charged particle flux followed by a decrease of about four days (see Figure 2). This event has a typical time profile of an Forbush effect caused by coronal mass ejection. First the instrument is hit by the accelerated by the wave front to high energies solar material - SEP, forming the pick in the particle flux. After several days to Mars arrive the dense solar plasma which causes the Forbush depression. Unlike the July event, the september event lacked a Forbusch decrease. The time profiles of the two spikes are identical. Initially for about 5-7 hours there is an increase in the flux and then within 30 hours it reaches the initial values.

**Analysis**

Figure 2 shows that the Forbusch decrease was most likely caused by several CMEs separated in time. In the interval 13-17 July, several CMEs were registered. As an illustration, three events from the CACTus/LASCO database are shown, which we can relate to our

measurements (see Figure 3, 4, 5). The SPE preceding Forbusch effect was most likely caused by CME from 17.07.

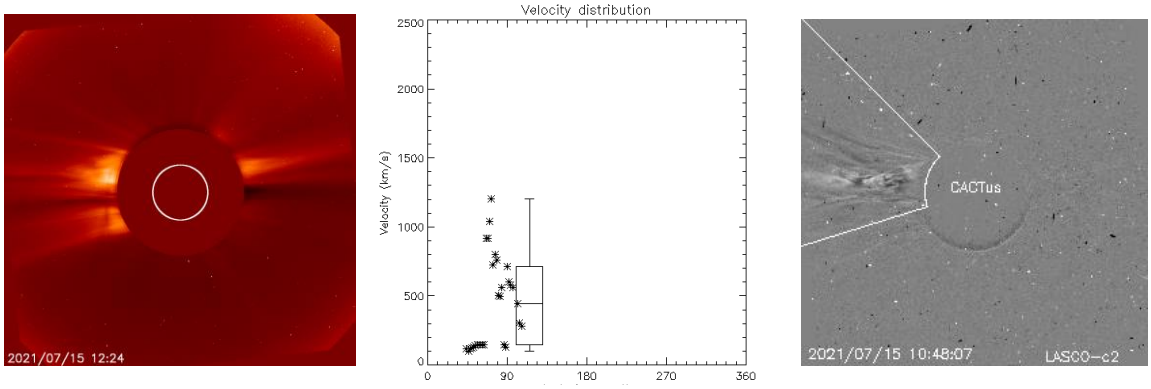


*Figure 3. The CME (0035) from July 15, 2021 and its velocity distribution.*

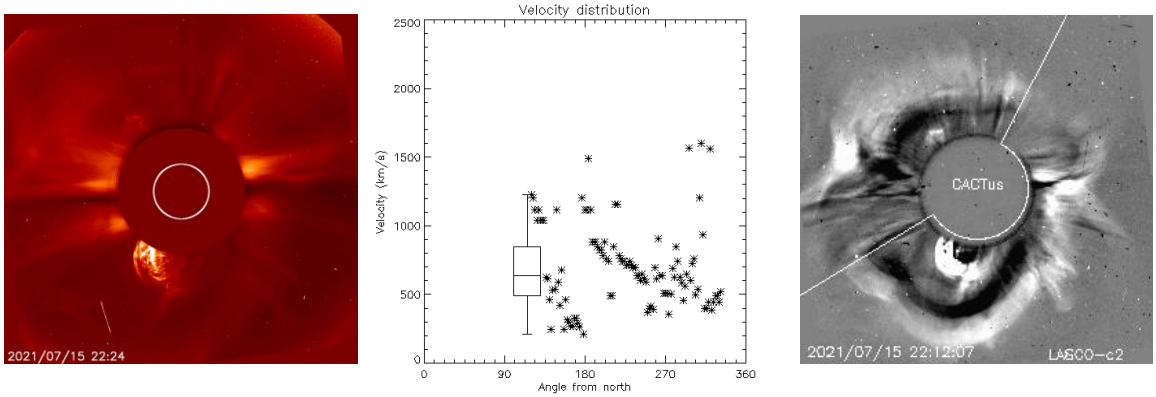


*Figure 4. The CME (0036) from July 15, 2021, and its velocity distribution.*

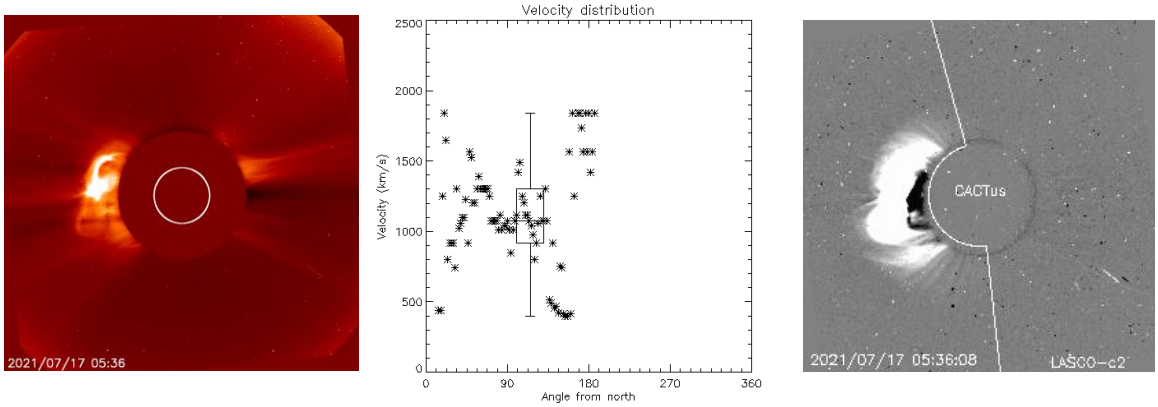


*Figure 5. The CME from July 17, 2021 and its velocity distribution.*

It is now widely agreed that SEPs come from two different sources with different acceleration mechanisms working: the flares themselves release impulsive events while the coronal mass ejection (CME) shocks produce gradual events. It is not excluded that the event we observe on September 17 (Figure 6) is the so-called hybrid event (Papaioannou at al, 2016). The solar flare that we associate with the increase in the CR flux is shown in Figure 7.

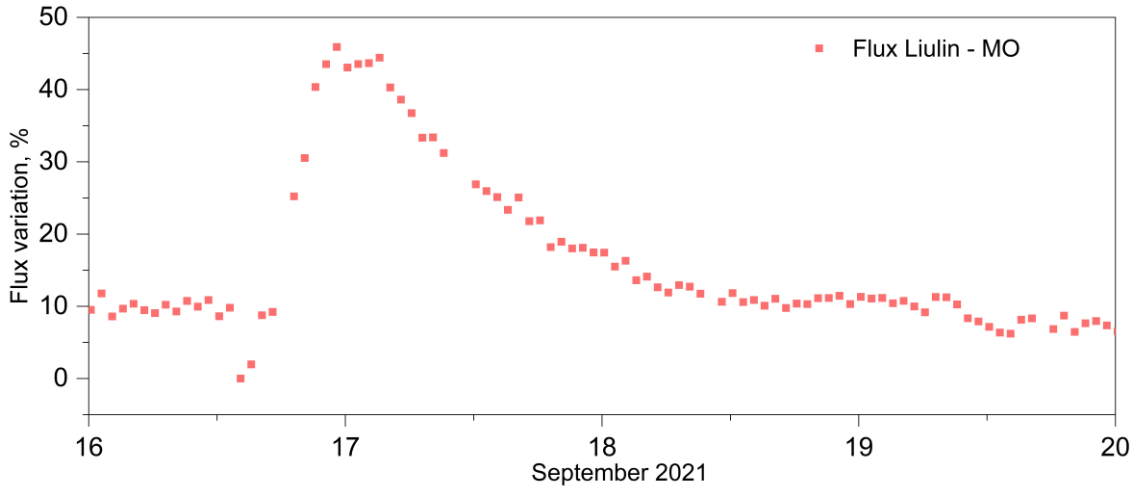


*Figure 6. The event from 17 September, 2021 - rapid increase in the flux of cosmic rays.*

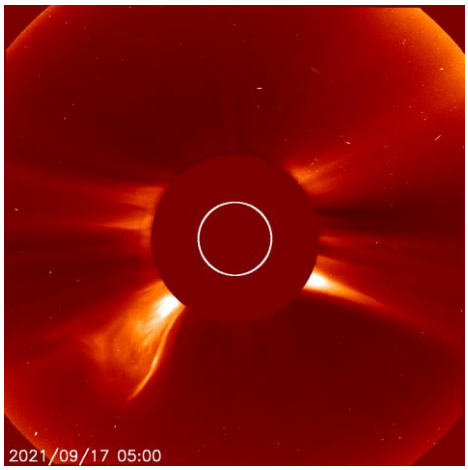


*Figure 7. Solar flare associated with the event from 17 september, 2021.*

## Conclusions

The registration of the two discussed events allows us to trace the propagation in the interplanetary space of sporadic magnetic fields caused by phenomena such as CME and solar flares. This work is in progress. Comparison of the Liulin-MO measurements with the measurements of fluxes of the charged particles by the neutron detectors of FREND instrument, as well as comparison with the parameters of the magnetic field and solar wind in Mars orbit for the discussed events are planned.

## Acknowledgements

The CME Catalog used in this work is generated and maintained at CACTus/LASC0 CME database: https://wwwbis.sidc.be/cactus/catalog.php. The work in Bulgaria is supported by Project No 129 (Grant KP-06 Russia 24) for bilateral projects of the National Science Fund of Bulgaria and Russian Foundation for Basic Research and by Contract No 4000133961/21/NL/SC funded by the Government of Bulgaria through an ESA Contract under the Plan for European Cooperating States.

## References

Belov, A.V. (2008) Forbush effects and their connection with solar, interplanetary and geomagnetic phenomena, Proceedings of the International Astronomical Union 4(S257):439 – 450, 2008.

Mitrofanov I., A. Malakhov, B. Bakhtin, D. Golovin, A. Kozyrev, M. Litvak, M. Mokrousov, A. Sanin, V. Tretyakov, A. Vostrukhin, A. Anikin, L.M. Zelenyi, J. Semkova, S. Malchev, B. Tomov, Y. Matviichuk, P. Dimitrov, R. Koleva, T. Dachev, K. Krastev, V. Shvetsov, G. Timoshenko, Y. Bobrovnitsky, T. Tomilina, V. Benghin, V. Shurshakov, 2018. Fine Resolution Epithermal Neutron Detector (FREND) onboard the ExoMars Trace Gas Orbiter, Space Science Reviews, August 2018, 214:86, https://doi.org/10.1007/s11214-018-0522-5.

Semkova, J., R. Koleva, V. Benghin, T. Dachev, Yu. Matviichuk, B. Tomov, K. Krastev, St. Maltchev,P. Dimitrov, I. Mitrofanov, A. Maklahov, D. Golovin, M. Mokrousov, A. Sanin, M. Litvak, A. Kozyrev, V. Tretyakov, S. Nikiforov, A. Vostrukhin, F. Fedosov, N. Grebennikova, L. Zelenyi, V. Shurshakov, S. Drobyshev, 2018. Charged particles radiation measurements with Liulin-MO dosimeter of FREND instrument aboard ExoMars Trace Gas Orbiter during the transit and in high elliptic Mars orbit, Icarus, Vol. 303, Pp 53-66, https://doi.org/10.1016/j.icarus.2017.12.034

Semkova, J., R. Koleva, V. Benghin, T. Dachev, Yu. Matviichuk, B. Tomov, K. Krastev, St. Maltchev, P. Dimitrov, I. Mitrofanov, A. Maklahov, D. Golovin, M. Mokrousov, A. Sanin, M. Litvak, A. Kozyrev, S. Nikiforov, D. Lisov, A. Anikin, V. Shurshakov, S. Drobyshev, 2021. "Results from radiation environment measurements aboard ExoMars Trace Gas Orbiter in Mars science orbit in May 2018 - December 2019", Icarus, June 2021, 114264, https://doi.org/10.1016/j.icarus.2020.114264

Papaioannou, A., Sandberg, I., Anastasiadis, A., Kouloumvakos, A., Georgoulis, M., Tziotziou, K., Tsiropoula, G., Jiggens, P., Hilgers, A. (2016) Solar flares, coronal mass ejections and solar energetic particle event characteristics, Space Weather and Space Climate 6(A42), 2016.

Toptygin, I. N. (1985) Cosmic Rays in Interplanetary Magnetic Fields, Springer Netherlands, Geophysics and Astrophysics Monographs 27, 1985, 375 p.