Multi-point observations of Forbush decreases at Earth and at Mars: a statistical comparison

A. Papaioannou¹, A. Belov², J. Guo³, M. Abunina², A. Anastasiadis¹, R. Wimmer-Schweingruber³, E. Eroshenko²
A. Melkumyan², A. Abunin², B. Heber³, K. Herzst³, C. T. Steigies³

¹ Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Greece
² Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), 42092 Troitsk, Moscow Region, Russia
³ Christian-Albrechts-Universitaet zu Kiel, Olshausenstrasse 40, D-24098 Kiel, Germany

Abstract: During their travel from the Sun to Earth, coronal mass ejections (CMEs) and their interplanetary (IP) counterparts (interplanetary coronal mass ejections, ICMEs) interact with Galactic cosmic rays (GCRs) that fill the IP space. The leading shock wave of the ICME (if any) and the following ejecta modulate GCRs, which results in a reduction in the cosmic ray (CR) intensity, known as the Forbush decrease (FD). On the other hand, high-speed streams (HSS) from coronal holes (CHs) rotate with the Sun, forming Corotating Interaction Regions (CIRs). These can also modulate GCRs and result to FDs. In this work we present FD events that have been recorded at Earth by neutron monitors and at Mars by the Radiation Assessment Detector (RAD) instrument on the Mars Science Laboratory (MSL). We have compiled a catalogue of 424 FDs at Mars using RAD dose rate data, from 2012 to 2016. Furthermore, we applied, for the first time, a comparative statistical analysis of the FDs measured at Mars, by RAD, and at Earth, by NMs, for the same time span. A carefully chosen sample of FDs at Earth and at Mars, driven by the same ICME, led to a significant correlation (cc=0.71) and a linear regression between the sizes of the FDs at the different observing points. We show that the amplitude of the FD at Mars is higher on average by a factor of 1.5–2 compared to the size of the FD at Earth. Finally, almost identical regressions were obtained for both the Earth and Mars FDs as concerns the dependence of the maximum hourly decrease of the CR density to the size of the FD.

Forbush Decreases (FDs)

- FDs are short term (s few days) depressions of the Galactic Cosmic Ray (GCR) intensity.
- Some FD events are not local phenomena but are interplanetary ones.
- FDs are often related to geomagnetic storms.
- FDs are caused by energetic galactic cosmic rays, solar cosmic rays (with high energy) and solar energetic particles.
- FDs are not detectable by silicon and plastic detectors.

Measurements of Forbush Decreases

@ Earth
Neutron Monitors Since 1950’s

|Mars| MSL/RAD Since 2012

- RAD is an energetic particle detector designed to measure solar energetic particles, secondary neutrons, and other secondary particles.
- RAD contains six detectors, three of which (A, B, and C) are silicon diodes arranged as a telescope. The other three (D, E, and F) are scintillators.
- Dose rates are measured in both silicon and plastic detectors.

FDs @Mars & @Earth

Statistical comparisons:

<table>
<thead>
<tr>
<th>FDs</th>
<th>@Earth</th>
<th>Median of 50 years</th>
<th>Mean of 50 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>541</td>
<td>1.43</td>
<td>1.10</td>
<td>2.74</td>
</tr>
<tr>
<td>410</td>
<td>1.37</td>
<td>2.74</td>
<td>2.74</td>
</tr>
</tbody>
</table>

Conclusions

- FDs at Mars and Earth have almost identical dependencies of the values of the maximum hourly decrease of the CR density (DmE) to the size of the FD (Figure 6).
- The MSL/RAD data allow the identification of FDs with a magnitude exceeding 1.5-2% while the mean amplitude of the identified FDs at Mars is 3.17% (Figure 5).

References: Papaioannou et al., A catalogue of Forbush decreases recorded on the surface of Mars from 2012 until 2016: comparison with terrestrial FDs, Astron. Astrophys., under review, 2018
Guo et al., Measurements of Forbush decreases at Mars: both by MSL on ground and by MAVEN in orbit, Astron. Astrophys., DOI: 10.1051/0004-6361/201732087, 2017

Acknowledgement: RAD is supported by NASA (HEOMD) under JPL subcontract #1273039 to Southwest Research Institute and in Germany by DLR and DLR’s Space Administration grant numbers 50MM0511, 50MM1011, and 500MM1011 to the Christian Albrechts University, Kiel. We acknowledge the NMDB database (www.nmdb.eu), founded under the European Union’s FP7 programme (contract no. 213007) for providing data.

Contact: atpapaio@astro.noa.gr