EPSC Abstracts
Vol. 13, EPSC-DPS2019-422-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Results from radiation environment measurements aboard ExoMars Trace Gas Orbiter in Mars science orbit in May 2018-April 2019

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Abstract

The dosimetric telescope Liulin-MO [1] for measuring the radiation environment onboard the ExoMars TGO is a module of the Fine Resolution Epithermal Neutron Detector (FREND) [2].

Here we present recent results from measurements of the charged particle fluxes, dose rates and estimation of radiation quality factors and dose equivalent rates at ExoMars TGO science orbi (circular orbit with 400 km altitude, 74^0 inclination, 2 hours orbit period), provided by Liulin-MO dosimeter from May 01, 2019 to April 30, 2019 and comparison with data from previous periods of its measurements. They must be understood in the context of the shielding from the free-space radiation environment provided by the mass of materials surrounding the instrument's detectors. The average shielding of Liulin-MO detectors integrated over the full shielding distribution by FREND instrument is about 10 g cm^{-2}.

Since now the dosimeter has measured the dosimetric parameters of the galactic cosmic rays (GCR). Solar particle events were not registered. The available measurements were taken during the continuing declining of the Solar activity in 24^{th} Solar cycle.

1. Introduction

The main goal of the Liulin-MO dosimetric experiment is investigation of the radiation conditions in the heliosphere at distances from 1 to 1.5 AU from the Sun. The main scientific objectives of the Liulin-MO investigation are: a) To measure the dose and determine the dose equivalent rates for human explorers during the interplanetary cruise and in Mars orbit; b) Measurement of the fluxes of GCR, solar energetic particles and secondary charged particles during the cruise and in Mars orbit; c) Together with other detectors of the FREND instrument to provide data for verification and benchmarking of the radiation environment models and assessment of the radiation risk to the crewmembers of future exploratory flights.

2. Methodology and measured parameters of Liulin-MO

Liulin-MO contains two dosimetric telescopes - A&B, and C&D arranged at two perpendicular directions [1]. The parameters, provided by Liulin-MO simultaneously for two perpendicular directions have the following ranges: absorbed dose rate from 10^{-7} Gy h^{-1} to 0.1 Gy h^{-1}; particle flux in the range 0 - 10^4 cm^{-2} s^{-1}; energy deposition spectrum and coincidence energy deposition spectrum in the range 0.08 - 190 MeV.

The FREND neutron detectors are oriented along the -Y axis, the Liulin-MO detectors are oriented along the X and Z axes of the satellite. In Mars science orbit (MSO) when TGO is pointed to nadir (along –Y axis), the angles of the dosimeter axes to the nadir are 90^0.

3. Liulin-MO data in Mars' science orbit

Table 1 presents a comparison of the fluxes, dose rates in Si and dose equivalent rates obtained every 3 months since May 01, 2018 to May 01, 2019. An increase of the dose rates and fluxes is observed.

Investigated is the dependence of the flux, measured by Liulin-MO on the distance of TGO from Mars and orientation of dosimeter detectors. A strong dependence of the measured fluxes on the part of the detector's field of view (FOV) shadowed by Mars is observed.

Investigated is the planetary distribution of the flux and dose rate. The planetary distribution of the flux deviations relatively the running average (flux is averaged in bins 5^0 longitude x 4^0 latitude) are less than 0.5%. Nevertheless some small difference in the flux distribution by longitude-latitude coordinates is observed.

Compared are Liulin-MO GCR fluxes, the proton flux with energies > 30 MeV measured by SIS instrument on ACE satellite and Oulu neutron monitor count rate from May, 2018 to April 30, 2019.

Table 1. Flux, dose rate in Si D (Si), quality factors Q and dose equivalent rates H for 3 months periods from May 01, 2018 to May 01, 2019

Time frame	F (AB)/ F (DC) #cm-1s-1	D (Si) (AB)/ D (Si) (DC) μGy h-1	Q (AB)/ Q (DC)	H (AB)/ H (DC) mSv h-1
01.05-31.07.2018	3/3.1	14.26/14.97	3.47/ 3.45	64.33/ 67.14
01.08.-31.10.2018	3.02/3.12	14.35/14.98	3.48/ 3.48	64.92/ 67.77
01.11.2018-31.01.2019	3.06/3.16	14.47/14.98	3.47/ 3.46	65.27/ 67.38
01.02. -01.05.2019	3.11/3.2	14.78/15.32	3.49/ 3.48	67.06/ 69.31

4. Summary and Conclusions

The obtained data from May 2018 to April 2019 show that 1) Slight increase of the flux, dose rate and dose equivalent rate is observed, which corresponds to the increase of GCR intensity during the declining of the solar activity; 2) A strong dependence of the measured fluxes on the part of the FOV shadowed by Mars is observed; 3) There is a slight dependence of the flux distribution on the Martian latitude and longitude; 4) Measurements in two perpendicular directions show that the flux is about 93% (3.05, 3.15 $cm^{-2}s^{-1}$), dose rate is 85% (347±35, 361.4±36 μGy day^{-1}), dose equivalent rate is 70% (1.57±0.33, 1.64±0.34 mSv day^{-1}) of that in February-March 2017 in high elliptic Mars orbit; 5) A reasonable agreement between GCR count rates from different particle detectors in different locations in the heliosphere is observed.

The results are important for future manned mission to Mars radiation risk estimations.

A similar module, called Liulin-ML for investigation of the radiation environment on Mars' surface as a part of the active detector of neutrons and gamma rays ADRON-EM will be flown on the Surface Platform of ExoMars 2020 mission.

Acknowledgements

Thanks: Contracts N 503/2-13 and 63/4-14 between IKI-RAS and SRTI-BAS; Agreement between RAS and BAS on fundamental space research; Contract No. 4000117692/16/NL/NDe Funded by the Government of Bulgaria through an ESA Contract under the PECS.

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