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Recent results for the space radiation environment aboard ExoMars TGO provided by FREND's Liulin-MO dosimeter

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Abstract

We present recent results from measurements of the charged particle fluxes, dose rates, linear energy transfer spectra and estimation of dose equivalent rates in the interplanetary space, in high elliptic Mars's orbit and first data in TGO science orbit, provided by Liulin-MO dosimeter of FREND instrument aboard TGO.

The obtained data show that during the cruise to Mars and back (6 months in each direction), taken during the declining of solar activity, the crewmembers of future manned flights to Mars will accumulate at least 60% of the total dose limit of 1 Sv for the cosmonauts/ astronauts career in case their shielding conditions are close to the average shielding of Liulin-MO detectors - about 10 g cm^{-2}.

The comparison of flux and dose rate measurements curried out by Liulin-MO dosimeter during the cruise of TGO to Mars with calculation based on galactic cosmic rays (GCR) models show surplus of measured flux and dose rate on calculated.

The dosimetric measurements in high elliptic Mars' orbit were used to estimate the flux shadow by Mars effect. Results of 23 TGO pericenter crossing were investigated. The "shadow effect" amounted to 30%, but as a rule was less than calculated one.

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

1. Introduction

The estimation of the radiation effects for a long-duration manned space mission requires: i) Knowledge and modeling of the particle radiation environment; ii) Calculation of primary and secondary particle transport through shielding materials; and iii) Assessment of the biological effect of the dose.

The FREND's dosimetry module Liulin-MO provided information about the radiation environment during the cruise stage and now - on Mars' orbit.

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]. Each pair of the dosimetric telescopes consists of two 300 μm thick, 20x10 mm area rectangular Si PIN photodiodes. 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.

3. Liulin-MO data during the TGO cruise, in high elliptic Mars'orbit and first data in Mars' science orbit

The average flux from GCR during the transit to Mars for the period April 22 - September 15, 2016 is 3.12 cm^{-2} s^{-1} and 3.29 cm^{-2} s^{-1} in two perpendicular directions. For November 01, 2016 - January 17, 2017 in MCO1 it is 3.26 and 3.42 cm^{-2} s^{-1} in two perpendicular directions. In the pericenter the average decrease of the particle flux is 0.77 cm^{-2} s^{-1}. The flux for February 24, 2017 - March 07, 2017 in MCO2 is slightly higher.

The dosimetric measurements in high elliptic Mars' orbit demonstrate strong dependence of the GCR fluxes near the TGO pericenter on satellite's field of view shadowed by Mars.

The average flux from GCR for April 16-May 13, 2018 in Mars science orbit is 2.96 and 3.06 cm^{-2} s^{-1} in two perpendicular directions.

The measured flux and dose rate during the TGO transit to Mars were compared with calculations based on galactic cosmic ray models. The results show surplus of measured on calculated values.

Table 1 summarizes the dose rate in silicon, the quality factors and dose equivalent rates obtained during the different phases of TGO flight.

Table 1. Dose rate in Si D (Si), quality factors Q and dose equivalent rates H during different TGO phases

Time frame/TGO phase	D (Si) (AB)/ D (Si) (DC) μGy d^{-1}	Q (AB)/ Q (DC)	H (AB)/ H (DC) mSv d^{-1}
April 22 - September 15, 2016/ Cruise	372 ± 37/ 390 ± 39	4.08 ± 0.3/ 4.02 ± 0.3	1.97± 0.4/ 2.04± 0.4
November 01, 2016 - January 17, 2017/ MCO1	405.6 ± 41/ 422 ± 42	4.23 ± 0.33/ 4.12 ± 0.3	2.23± 0.5/ 2.26± 0.5
February 24 - March 07, 2017/ MCO2	410 ± 41/ 425 ± 42.5	4.31 ± 0.33/ 4.17 ± 0.3	2.3± 0.55
April 16 – May 13, 2018/ Mars Science Orbit	337± 34/ 354± 35	3.5±0.26	1.53±0.3/ 1.61±0.32

4. Summary and Conclusions

The increase of the charged particles dose rate and flux measured from April 22, 2016 to March 07, 2017 corresponds to the increase of GCR intensity during the declining phase of the solar activity.

The obtained data show that during the cruise to Mars and back (6 months in each direction), taken during the declining of solar activity, the crewmembers of future manned flights to Mars will accumulate at least 60% of the total dose limit of 1 Sv for the cosmonauts/ astronauts career in case their shielding conditions are close to the average shielding of Liulin-MO detectors - about 10 g cm^{-2}.

Very first Liulin-MO data in Mars' Science Orbit show that close to the Solar activity minimum the dose equivalent rate is about 1.2÷1.6 mSv d^{-1}.

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 on the Surface Platform is under preparation for ExoMars 2020 mission.

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References

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