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First Results from the Lunar Lander Neutron and Dosimetry Experiment (LND) on China's Chang'E 4 mission to the far side of the Moon

Robert F. Wimmer-Schweingruber (1,2), Shenyi Zhang (2), Jia Yu (1), Stephan I. Böttcher (1), Sönke Burmeister (1), Henning Lohf (1), Bin Yuan (2), G. Shen (2), C. Wang (2), Jingnan Guo (1,3), Zigong Xu (1), Thomas Berger (4), Christine Hellweg (4) Daniel Matthiäe (4)

(1) Institute of Experimental and Applied Physics, Kiel University, Germany, (2) National Space Science Center, Chinese Academy of Sciences, Beijing, China, (3) CAS Key Laboratory of Geospace Environment, Dept. of Geophys. &Planet Sci., University of Science and Technology of China, Hefei 230026, China, (4) Institute of Aerospace Medicine, German Aerospace Center, Linder Höhe, D-51147 Cologne, Germany

Abstract

Chang'E 4 is the Chinese mission which landed on the far side of the Moon at 02:26 UTC on January 3, 2019. It consists of a lander, a rover, and an relay spacecraft. We will present first results from the Lunar Lander Neutron and Dosimetry (LND) Experiment aboard Chang'E 4. LND has obtained first active dosimetric measurements on the surface of the Moon, both of the charged as well as neutral radiation component. The latter is the result of the interaction of high-energy particle radiation with the lunar regolith and contributes to the total dose experienced by astronauts on future missions to the Moon.

1. Introduction

Chang'E4, the Chinese mission to the Moon, was launched on December 8, 2018 and landed on the far side of the Moon in the von Karman crater on January 3, 2019. The mission consists of a lander, a rover, and a communication relay. In this presentation we will describe first data from the Lunar Lander Neutron & Dosimetry experiment (LND) which is placed on the lander. LND consists of a stack of 10 segmented Si solid-state detectors (SSDs) which forms a particle telescope to measure charged particles (electrons from 0.5 MeV to several MeV, protons 8-35 MeV, and heavier nuclei 17-75 MeV/nuc). A special geometrical arrangement allows observations of fast neutrons (and γ-rays) which are also important for dosimetry and cosmic-ray exposure of lunar soils. Thermal neutrons are measured using a very thin Gd conversion foil which is sandwiched between two SSDs. Thermal neutrons are sensitive to subsurface water and important to understand lunar surface mixing processes. Despite the aim of landing humans on the Moon in the not too distant future, radiation measurements in the vicinity of the Moon are remarkably scarce. Fairly recent measurements in lunar orbit were provided by the Radiation Dose Monitor (RADOM) on board Chandrayaan-1 [1]. The spacecraft reached its operational 100 km circular orbit on November 12, 2008. Measurements showed a dose rate of 0.23 mGy per day averaged over 3545 hours of measurement time (20/11/2008 to 18/5/2009). Newer measurements have been provided by the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) instrument [2] on board the Lunar Reconnaissance Orbiter (LRO). CRaTER measured a radiation exposure of about $0.22 - 0.27$ mGy per day in its 50 km orbit. In comparison with these meager orbital data, there is a real dearth of data on the lunar surface. The current knowledge about the radiation environment on the surface of the Moon is based exclusively on calculations using radiation transport models with input parameters from models for the galactic cosmic ray spectra and for solar particle events. This is highly questionable, especially since we know that these models are fraught with uncertainties [3]. Measurements of the lunar neutron density at depths of 20 - 400 g/cm2 within the lunar subsurface were performed during the Apollo 17 mission [4]. LND has now been measuring for five lunar "days" (as of May 7, 2019) and two publications have been submitted to the scientific literature [5], [6]. As all payload of Chang'E 4, LND can measure during lunar "day-time" and is switched off during lunar "nights" to conserve energy.

2. Science and Measurement Objectives

LND's chief purpose is to prepare for human exploration of the Moon by providing time series of dose rate and linear energy transfer (LET) spectra from the surface of the Moon. A secondary science objective is to investigate small-scale variations in the particle fluxes in conjunction with other near-Earth assets such as SOHO, ACE, etc. In addition, LND has two "lunar" science objectives, i.e., to measure the very local subsurface a) water and b) FeO content and to compare them with a larger average. To improve our knowledge of the surface radiation field on the Moon, LND measures at three time cadences 1) 1 minute: low energy resolution electrons, protons, neutrals, dosimetric quantities, 2) 10 minutes: thermal neutrons, electrons, heavy ions at low energy resolution 3) one hour: high-resolution data for ions, electrons, neutrons, dosimetric quantities.

3. Instrument Description

LND consists of a sensor head viewing the zenith direction and a separate electronics box. It is housed in the instrument compartment of the Chang'E4 lander. The sensor head houses a stack of 10 segmented SSDs, a single LND detector has a geometric factor of 28.3 cm^2sr, which allows for a high count rate of $\sim$35 counts/sec per single detector. The inner segments of the top two detectors have a geometric factor of 0.58 cm2sr and we expect approximately 0.5 counts/sec in coincidence. This high count rate allows to determine statistically significant variations in the dose rate during solar particle events, and to determine particle spectra with high time resolution (see next section). LND can stop 30 MeV protons and relativistic electrons.

4. Outlook

LND on Chang'E 4 has - at the time of writing this sbastract - been measuring for nearly five lunar "days". Because of the current low solar activity, we have not seen any solar particle event and variations in the dosimetric quantities have been small. We appear to be in a deep solar activity minimum with the galactic cosmic rays (GCRs) thus being the main contribution to the measured dose rate.

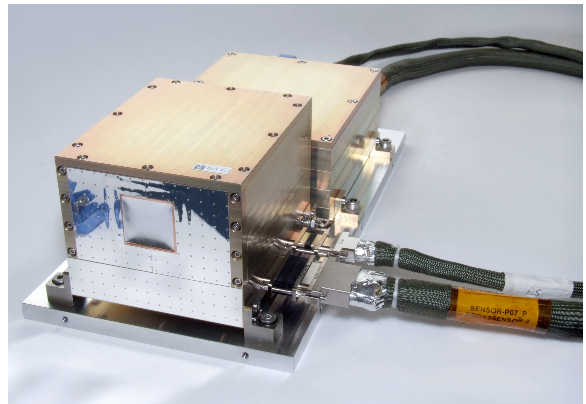

Figure 1: The LND sensor head (front) and electronics box (back) have been measuring the lunar radiation environment since the landing of Chang'E 4 on the far side of the Moon on January 3, 2019.

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