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The observation and modeling of Galactic Cosmic Rays in the nuclear planetology applications

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For several decades, a lot of science missions have explored Solar system planets and their moons. The list of primary science goals for many of them include studying bulk elemental composition of the planet subsurfaces. Gathered information may help to understand geochemical processes influencing on their evolution in the past and to answer questions on the origin and evolution of Solar system, planets, their satellites, asteroids and comets.
One of most useful method of studying bulk elemental composition remotely is the usage of gamma-ray and neutron spectrometers on board of orbital and landing spacecraft. Using data gathered by these instruments one may map abundances of major rock-forming elements along the planetary surface and investigate distribution of water in the shallow subsurface.
The neutron and gamma-ray radiation of planets and their satellites, such as Mars, Mercury, and the Moon, is caused by the charged particles of the Galactic Cosmic Rays (GCR) which bombard surfaces of the airless or with thin atmosphere like on Mars celestial bodies. The GCR charged particles collide with the nuclei of basic rock-forming elements in the subsurface layer and produce secondary high-energy particles – neutrons, protons, gamma-rays, heavy ions and other particles. Neutrons are slowing down and before escaping from subsurface may interact with the soil nuclei via elastic, inelastic and capture reactions. The excitation of nuclei in these reactions produces monoenergetic emission of gamma-rays typical for a given nucleus. Thus, the surface emits a spectrum of gamma-rays with a set of nuclear lines indicating the chemical composition of the soil. It is known that the light element's nuclei, such as hydrogen, effectively moderate neutrons. Therefore, amount of these elements may be determined from the monitoring of the neutron spectrum variations.
The gamma-rays and neutron spectroscopy of the planets is informally called as a nuclear planetology. Summarizing our experience obtained from the HEND (Mars Odyssey), DAN (Curiosity), BTN (ISS), LEND (LRO) and FREND (TGO) experiments one may conclude that the nuclear planetology methods require not only a knowledge of the instrument sensitivity but also accurate prediction and modeling of the GCRs. From other side, if for a long time instruments are observing subsurface area with well known properties one could reverse the problem and evaluate GCR flux and its variations on different time scales.
In this study, we have presented summary of different observations including usage of space neutron spectrometers as GCR monitors as well as discussed the general problems related with numerical modeling of GCR interaction with celestial bodies and spacecraft in application of the neutron planetology experiments.