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Geochemistry of Vesta and Ceres: In-flight calibration of Dawn's Gamma Ray and Neutron Detector

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The purpose of the Dawn mission is to investigate processes that contributed to the formation and early evolution of solid bodies in the solar system by exploring Vesta and Ceres, which are the two largest bodies in the main astreroid belt. Because they were formed at different heliocentric distances, Vesta and Ceres incorporated different amounts of water and other volatiles, which strongly influenced their thermal evolution. Vesta, which is thought to be the source of the basaltic, Howardite, Eucrite, and Diogenite (HED) meteorites, is dry and underwent igneous differentiation. In contrast, low-temperature, aqueous processing must have played an important role in the evolution of Ceres, which is rich in water and other volatiles, and may still contain subsurface liquid water. By exploring both Vesta and Ceres, the gradient in the composition of the solar nebula and role of water in planetary evolution can be investigated.

The Dawn payload includes redundant framing cameras (FC), a visible and infrared spectrometer (VIR), and a gamma ray and neutron detector (GRaND), which, along with radio science, will measure surface geomorphology, composition, and mineralogy, and provide constraints on the internal structure of Vesta and Ceres. For both Vesta and Ceres, global mapping data will be acquired from circular polar orbits. In low altitude orbits, GRaND will map the elemental composition of Vesta and Ceres to depths less than one meter, including major rock forming elements and light elements (such as H, C, and N), which are the primary constituents of ices.

GRaND consists of 21 radiation sensors, which measure the spectrum of neutrons and gamma rays originating from interactions between galactic cosmic rays and the material constituents of the asteroids and, separately, backgrounds from spacecraft materials. GRaND uses a bismuth germanate (BGO) scintillator for gamma ray spectroscopy, which has high efficiency, enabling the measurement of gamma rays up to 10 MeV, including capture gamma rays from Fe and Ti. Below 3 MeV, the BGO sensor works in combination with a 16-element array of CdZnTe semiconductors, which have relatively high resolution, enabling accurate measurement of the densely populated, low energy region of the gamma ray spectrum, which contains gamma rays from radioactive decay (K, Th, and U) and from nuclear reactions (for example, with Mg, Si, and H). Thermal, epithermal, and fast neutrons are measured using a combination of boron-loaded plastic and lithium-loaded glass scintillators.

At Vesta, gamma ray and neutron spectroscopy will be used to determine geochemical trends that can be compared with HED data. For example, a scatter plot of the average atomic mass (determined from fast neutrons) and magnesium number can be used to tell the difference between diogenite and eucrite compositions, which are HED end-members. Correlations with MgO (for example, with FeO or SiO2) also strongly differentiate between diogenite and eucrite, and, in combination with optical spectroscopy, can be used to determine whether an olivine-rich mantle is exposed in Vesta's large south polar crater. At Ceres, neutron spectroscopy can be used to determine water abundance and layering (for example, ice may be present in the shallow subsurface at high latitudes), which will provide constraints on recharge and loss mechanisms (for example, emplacement via water volcanism vs. gradual replenishment from a subsurface acquifer). In addition, nuclear spectroscopy can be used to determine the possible presence of CO2 and NH3 ices on the surface of Ceres as well as the composition of non-icy materials, including the hydration state and composition of surface minerals.

GRaND was calibrated in the laboratory prior to delivery to the spacecraft. In addition, the response of the instrument to the space radiation environment was measured during Earth-Mars cruise, which followed launch in September of 2007. Because the data were acquired when the energetic particle flux was minimal, the measurements are ideal for determining the background from galactic cosmic rays under conditions that would be ideal for science data acquisition at Vesta and Ceres. In February of 2009, the spacecraft will fly by Mars. At closest approach, the spacecraft will be within 500 km of Mars, providing GRaND with a strong source of planetary neutrons and gamma rays, which will be used to cross-calibrate GRaND against elemental abundance data acquired by the Mars Odyssey Gamma Ray Spectrometer instrument suite. Here, we describe the instrument response model and its application to the analysis of the space radiation background during cruise and cross-calibration against Odyssey data at Mars. The model is applied to determine the expected performance of GRaND at Vesta and Ceres.