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Water on Vesta: First Results from Dawn's Survey Orbit

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Abstract

For over a decade, and especially since 2009, hydrogen, hydroxyl and water have been reported to exist on and beneath the surface of the Moon, in spite of early studies of returned lunar samples indicating a dry Moon. Vesta is a similar object to the Moon in the inner Solar System. The Dawn mission in orbit around Vesta since summer 2011 is searching for these molecules. We report on the initial findings and their implications.

1. Introduction

Water and other volatiles on airless solid surfaces in the inner solar system seem to be short-lived due to high temperatures, low pressures, high-energy irradiation and bombardment. These molecules could exist in the interior but high temperature formation and differentiation processes seem to work against this. The Moon is the most studied of these objects. Samples of the Moon returned in the early 1970s were reported to show little or no evidence of volatiles that could not be explained by terrestrial or solar wind contamination, and thus the Moon was thought to be very "dry." However, during the past decade or so, a series of observations were reported to indicate the presence of H, OH, H_2O and other volatiles, perhaps from several different sources and processes (for a summary see [1]). Vesta is similar to the Moon in that it is in the inner solar system, differentiated, basaltic in composition and has little or no atmosphere. Thus, the findings for the Moon might apply to Vesta and provide another example for study of the processes involved [2, 3]. The Dawn mission [4] is to orbit both Vesta and Ceres, with capture into Vesta orbit during the summer of 2011. Dawn carries several instruments useful for detection and mapping of volatiles: the Gamma Ray and Neutron Detector (GRaND), for detection and mapping of hydrogen, and the Visual-Infrared (VIR) imaging spectrometer, sensitive to OH, H_2O and other volatile molecules. The multispectral imaging system provides geologic and topographic context for these observations. These instruments are sensitive to different properties and build their results on different time scales, and so their findings have to be integrated into a broader discussion, partly with this presentation.

2. Volatiles on/in the Moon

Volatiles can come from at least three different sources: 1) indigenous, *i.e.*, from the original material; 2) infall, from comets and some asteroidal material; and 3) surface chemistry, from solar wind implantation. There is recent evidence reported that could indicate that all three of these are sources. Excess H near the poles was reported from neutron spectrometers on Lunar Prospector and Lunar Reconnaissance Orbiter (LRO). The molecular form of H could not be determined, but trapped water in permanently shadowed polar regions was suggested. This could come from any or all the possible sources. The Moon Mineralogy Mapper (M^3) imaging spectrometer on Chandrayaan-1 reported widespread spectral signatures of OH and perhaps H_2O (Fig. 1) [5], confirmed by reanalysis of older Cassini Visual and Infrared Mapping Spectrometer (VIMS) calibration observations and by new EPOXI spectrometer observations. These observations seemed most consistent with solar wind proton implantation and hydroxylation [1]. Observations of the plume from the impact of part of the booster rocket for LRO into the lunar surface were reported to show evidence of volatiles, including water, CO_2 and a variety of organic molecules, seeming to confirm the sources suspected from the H detection. Finally, there is increasing number of reports of water in lunar sample material, suggesting indigenous water up to that similar with the Earth's mantle.

3. The Vesta case

Vesta could have volatiles from all three of the possible sources: indigenous, infall and solar wind induced chemistry, following the lunar experience [2, 3]. Vesta should also retain water more easily, including just below the surface, than the Moon, given its colder environment. Vesta is basaltic in composition and apparently has differentiated, like the Moon. It may have had more water originally than the Moon, considering their different origin hypothesis, the Moon from giant impact by a third body into the Earth and Vesta from accretion and radioactive heating. If originally existing, some water should survive Vesta's evolution. Vesta should be impacted at least as much as the Moon by "wet" asteroidal and cometary material and perhaps more so. The solar wind also strikes the exposed surface of Vesta with about the same energy per particle as for the Moon, although the flux density should be lower by about the square of the difference in distance from the Sun (~1/4.5). Thus, the same chemical reactions could take place on Vesta as for the Moon but at a slower rate. Observations of Vesta so far show little or no evidence of volatiles (*e.g.*, Fig 1), although these observations are very difficult from the Earth. Dawn has a huge advantage by being in orbit for a relatively long period. The VIR spectrometer should detect any spectral signatures similar to those for the Moon rather quickly and begin studying their relationship with Vesta physical properties, just as was done for the Moon (Fig 1) [1]. GRaND, however, will require repeated global observations at the lowest possible altitude to build up the global map of H for all surface elements simultaneously and so will required a longer time for results to become available. GRaND and VIR are sensitive to different materials (H *versus* volatile molecules) and measure over different depths (upper meter or so *versus* upper few mm). VIR should rather quickly indicate if volatiles are present on/in the upper surface, probably due to the solar wind implantation hydroxylation, but subsurface volatiles, perhaps from interior outgassing or to trapped infall may require the entire mission at Vesta for GRaND to detect them. The first result from the initial phase of the Dawn mission at Vesta will be reported here.

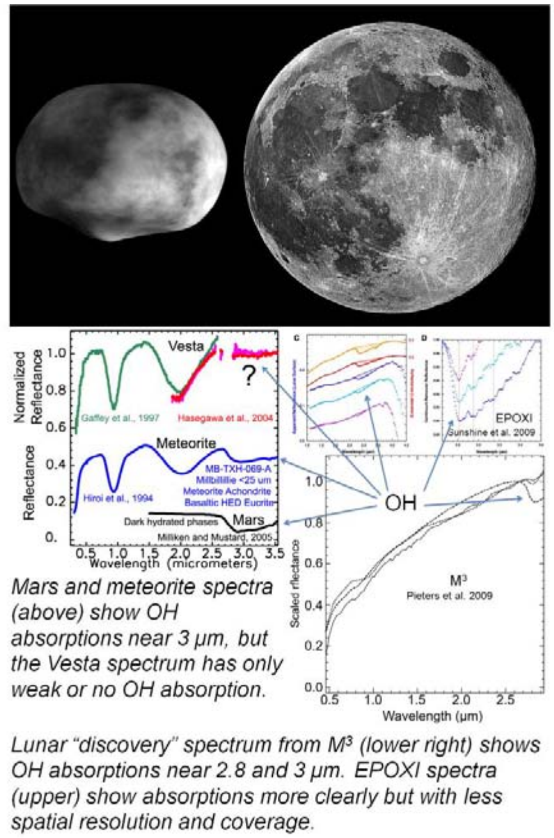

Figure 1: Examples of OH/H_2O detections [2].

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