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Dawn Discovery Mission: Symbiosis with 1 AU Observations

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Abstract. The Dawn mission, the ninth in the series of NASA Discovery missions, is scheduled for launch in late May 2006 on a voyage to both Vesta and Ceres. The mission carries a framing camera, visible and infrared mapping spectrometer, gamma ray and neutron spectrometer, laser altimeter and magnetometer to understand and contrast these two very different bodies. Vesta apparently accreted dry, differentiated, and formed an iron core. Ceres apparently contains much water and ice and has remained relatively cool over its lifetime. The community of 1AU observers can help optimize the Dawn mission by improving the knowledge of Vesta and Ceres rotation axes, thus improving our knowledge of when regions and features will be best illuminated. The detection of any satellites would not just identify a potential hazard, and a secondary target of interest, but would also determine the mass of the primaries, enabling better mission planning. Characterization of the surface in any way, including identifying potential targets for detailed study, is also most welcome.

1. Introduction

The current paradigm for the formation of the solar system is that it began in a solar nebula, a rotating disk of gas and dusk about 4.6 Ga b.p. In a period that now is thought to be about 3 million years (e.g., Jacobson 2003) the dust accreted into rocks and the planetary embryos, similar in size to Vesta and Ceres. When Jupiter formed, gravitational stirring in the asteroid belt countered the accretional process, but in the inner solar system accretion continued, forming the larger terrestrial bodies, Mars, Earth, Venus and Mercury, over about 30 million years. The Earth's Moon is thought to be due to the collision of a Mars-sized object with the proto-Earth in which much of the material of the two colliding bodies remained with the Earth and a small portion remained in orbit later accreting into the present Moon. This scenario is summarized in Fig. 1.

The solar nebula itself was decidedly heterogeneous varying in physical and chemical properties as a function of heliocentric distance. Near the Sun materials that would condense and solidify at high temperature, such as iron, are believed to have been more prevalent. Further from the sun the temperature and pressure were less and lower temperature materials formed. Perhaps between Vesta at 2.34 AU and Ceres at 2.77 AU the dew line was passed and the accreted material was much richer in water and organics as the temperature dropped further, with distance as illustrated in Fig. 2.

This hypothesis is supported in the case of Vesta by the association with Vesta, of a group of meteorites, the Howardites, Eucrites and Diogenites, or HED

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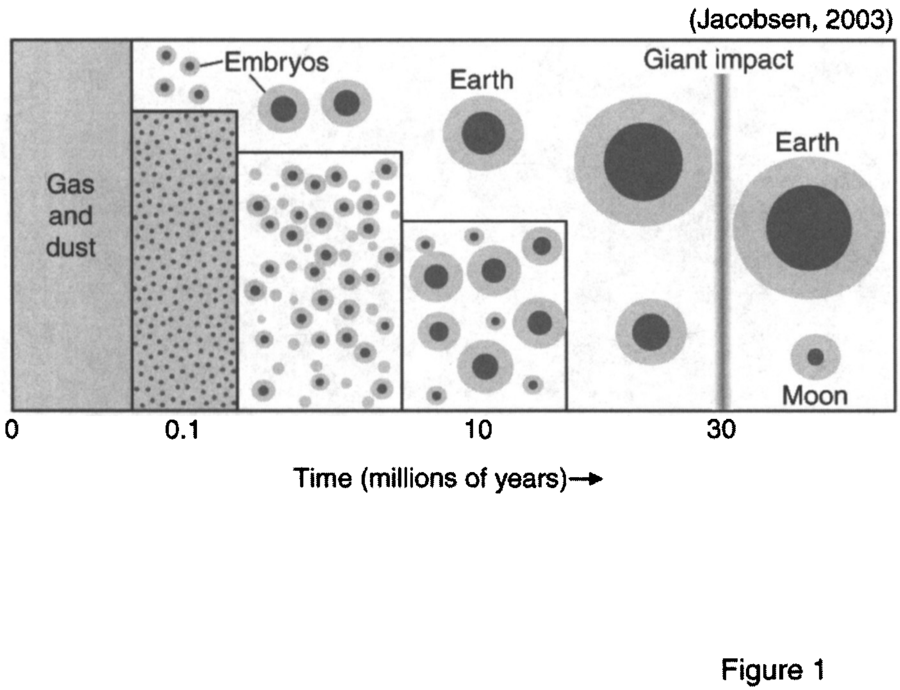

Figure 1. Schematic illustration of the sequence of formation of the inner solar system (after Jacobsen 2003).

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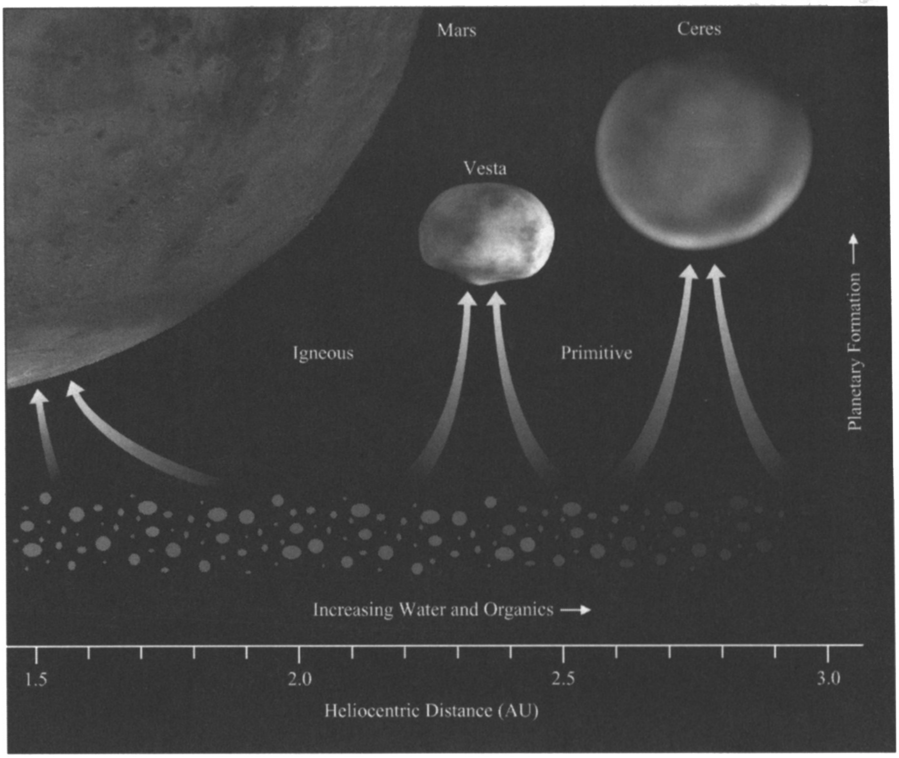

Figure 2

Figure 2. Schematic illustration of the role of the compositional gradient in the early solar nebula in affecting the composition of Mars, Vesta and Ceres (Courtesy M. Sykes, 2002).

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meteorites, that constitute 5meteorites have a unique reflectance spectrum that matches the reflectance spectrum of both Vesta and those asteroids, that may be pieces of Vesta, known as vestoids. These meteorites indicate that Vesta melted, formed a central iron core, and material derived from Vesta's interior flowed across the surface similar to flows on the lunar mare. This would make Vesta the smallest known body that accreted and differentiated, the smallest of the terrestrial-type planets. Thus, studying Vesta enables us to better understand the primordial accretion and differentiation of planets. It enables us to understand the role and timing of collisions in the early solar system and what were the heat sources that contributed to planetary thermal evolution. Further Vesta data will contribute to the understanding of the generation of magnetic fields in planetary cores.

Ceres is believed to be very different than Vesta, forming a bridge between the inner rocky bodies of the inner solar system and the icy bodies of the outer solar system. Presently it is believed that Ceres began as a silicate-ice organic mixture that is melted by long-lived radio-nuclides in all but a thin ice crust. The warm water circulates, diapirs form in the ice crust, surface topography forms and reforms. Presently Ceres may be completely frozen but most probably it contains a global ocean of water. Thus Ceres is strikingly different than Vesta and enables us to study the role and emergence of water on a planetary scale and how it controlled planetary evolution. Further, the surface of Ceres may teach us much about low temperature aqueous alteration, a process we believe common in the early solar system.

2. The Mission

The spacecraft carries five instruments and obtains radiometric data for studies of Vesta's and Ceres' gravitational field. A framing camera provided by the Max-Planck-Institut für Aeronomie and DLR in Germany enables us to map the surface in seven colors plus a clear filter. A visible and infrared mapping spectrometer for the classification of the minearology of the surface has been provided by the Italian Space Agency. The Los Alamos National Laboratory is building a gamma ray and neutron spectrometer to detect the elemental compositions of the body and the presence of water. Goddard Space Flight Center is providing the laser altimeter to accurately map the size and shape of the bodies. UCLA is providing a magnetometer to map the crustal remanent magnetic field and to determine the interior electrical conductivity of the bodies. The instruments and their location on the spacecraft are given in Fig. 3.

The spacecraft is launched in late May 2006 and uses ion propulsion to assist it to reach, and then orbit, Vesta and Ceres in 2011 and 2014 respectively. The flight path is shown in Fig. 4. Once at Vesta or Ceres the spacecraft enters a series of circular orbits of varying altitude. The two principal orbits are a high altitude mapping orbit where the framing camera and the mapping spectrometer are used and a low altitude mapping orbit where the laser altimeter, gamma ray spectrometer and magnetometer obtain their prime data. The mission is led by a Principal Investigator, managed by JPL, with the spacecraft being built by Orbital Sciences Corporation.

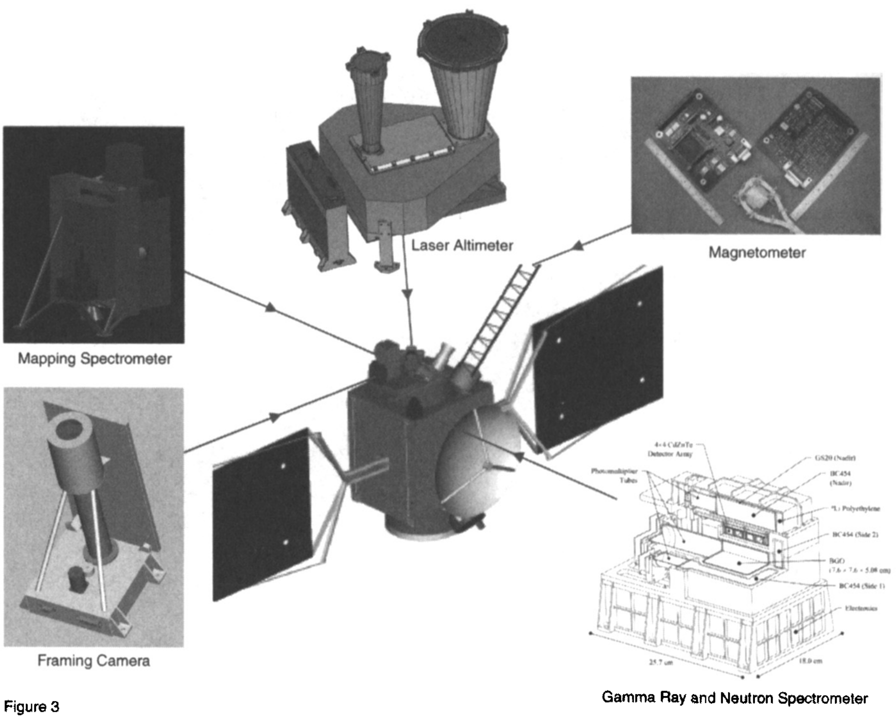

Figure 3. The Dawn payload.

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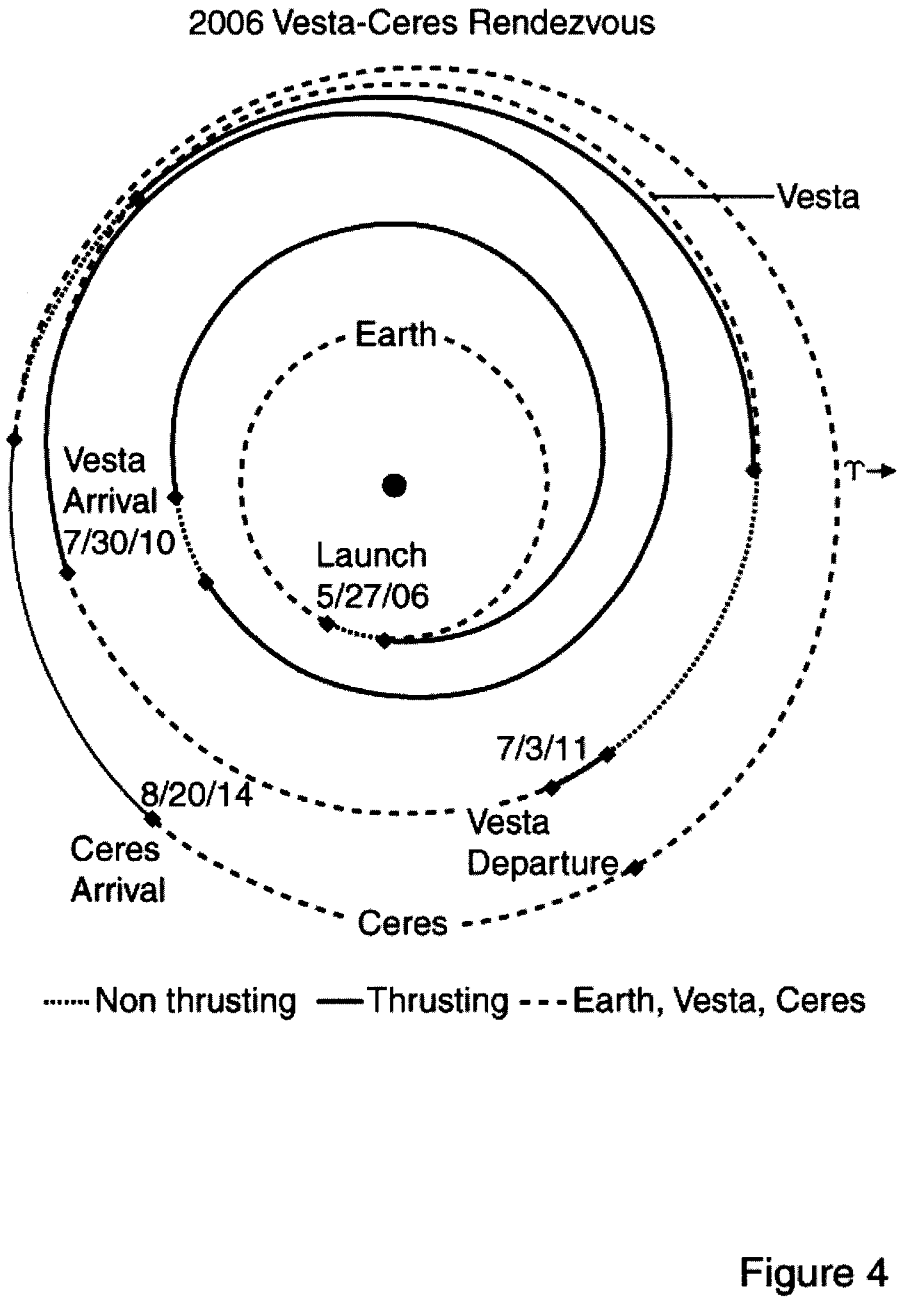

Figure 4. The Dawn trajectory.

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3. Participation

There are numerous ways that the scientific community can participate meaningfully in the Dawn mission, in addition to the original selected core team. Presently, as the mission undergoes detailed design, we need to understand the illumination of the surface while the spacecraft is in orbit. This depends on an accurate knowledge of the axis of rotation of Vesta and Ceres. An improved knowledge of these directions would be most helpful to Dawn. Satellite searches would also be helpful, not simply so that Dawn could avoid hitting the satellite, but because the mass of the primary derived from the satellite's period would help definitize Dawn's trajectory analysis. Identifying features on Vesta and Ceres that need further study would be helpful. Characterizing targets of opportunity along the flight path to Vesta and Ceres is also important. Later in the program there will be a participating scientist program that will add scientists to the team as well as a data analysis program that will provide support for the analysis of data that will be rapidly entered into the public archives.

4. Concluding Remarks

Dawn is a most viable mission under active development and preparing to build hardware for a 2006 launch. It will provide exciting data to the community in 2010 and 2014. In the meantime it would benefit from the attention of the 1 AU observing community.

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References

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