

DETECTION OF H₂O-RICH MATERIALS ON CERES BY THE DAWN MISSION. J.-Ph. Combe¹, T. B. McCord¹, F. Tosi², A. Raponi², M. C. De Sanctis^{2,3}, E. Ammannito^{2,3}, C. A. Raymond⁴, C. T. Russell³, ¹Bear Fight Institute, 22 Fiddlerø Road, P.O. Box 667, Winthrop, WA, 98862, USA (jean-philippe_combe @ bearfightinstitute.com), ²Istituto di Astrofisica e Planetologia Spaziali-Istituto Nazionale di Astrofisica, Rome, Italy. ³Institute of Geophysics and Planetary Physics, University of California Los Angeles, CA, USA. ⁴Jet Propulsion Laboratory, Pasadena, CA, USA.

Introduction: Ceres is the largest object of the asteroid belt (945 km in diameter), with a near spherical body shape (and is now classified as a dwarf planet). H₂O may have played a fundamental role its geological evolution [1-3], therefore the detection of exposed water-bearing materials have been an important quest from Earth-based observations and by the Dawn space mission [4]. Near-infrared reflectance spectra acquired by telescope revealed a surface rich in hydroxylated materials [5- 12] (such as phyllosilicates and carbonates) that may have resulted of aqueous alteration of silicates. Its distance to the sun (between 2.56 and 2.98 Astronomical Units) and shape are consistent with a differentiated interior that is rich in H₂O ice [1- 3]. In addition, possible releases of OH [13] and H₂O molecules [14] have been reported.

Reflectance spectra obtained by the Visible and Infrared Mapping Spectrometer (VIR-MS) [15] during the Survey orbit of the Dawn spacecraft revealed the presence of exposed surficial H₂O on Ceres [16]. The shape of spectra may be due to H₂O ice or mineral hydrates. Further analysis now focuses on determining the nature of the detected compounds. The geological context of the H₂O-rich unit in crater Oxo (Fig. 1) will also be investigated in order to understand its origin. Hypotheses by order of likelihood are 1) release of subsurface materials by eruptions due to hydrothermal activity, 2) exposition of subsurface materials by a meteorite impact or a landslide, 3) deposition of H₂O-rich materials by collision with a comet and 4) formation at the surface by chemical reaction of charged particles from the solar wind and the surface regolith

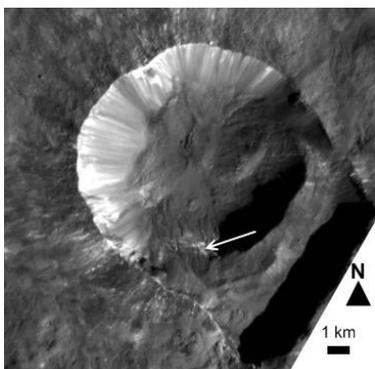


Fig. 1: Crater Oxo observed by the Dawn spacecraft Framing Camera during the Low altitude Mapping Orbit. The white arrow indicates the location of the H₂O detection by VIR.

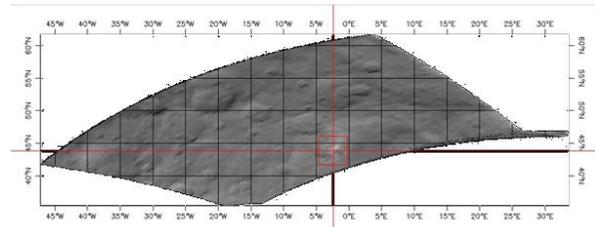


Fig. 2: I/F image at 1.1 μm that shows the first observation of crater Oxo by the VIR imaging spectrometer during Dawn's Survey orbit around Ceres. The red lines cross at the location of the H₂O detection (only two pixels in this image).

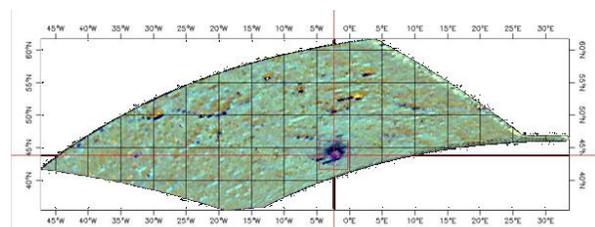


Fig. 3: Color composite of VIR normalized data (Red: 1.86 μm ; Green: 2.00 μm ; Blue: 2.18 μm). The blue unit illustrates the negative spectral slope of high-albedo materials within crater Oxo. H₂O-rich materials are only two pixels within this blue unit.

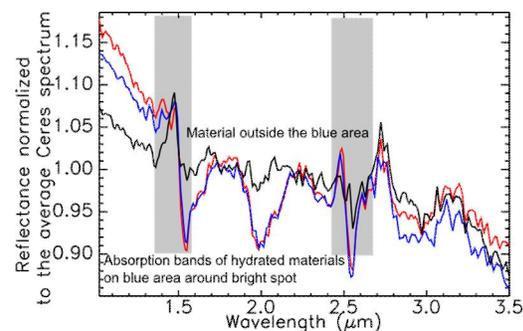


Fig. 4. Example of VIR infrared spectra divided by the average spectrum of Ceres. Colored spectra show absorptions at 2.0 μm and 1.55 μm that are diagnostic of H₂O-rich materials. The relatively negative spectral slope in the infrared may characterize geologically fresh materials. The black curve is a spectrum of materials outside the blue area in Fig. 3, which have a less negative spectral slope. Grey areas define ranges of wavelength where instrument artifacts may affect the data.

Absorption band of H₂O at 2.0 μm in VIR spectra: The Visible and InfraRed Mapping Spectrometer (VIR-MS) [15] onboard the Dawn spacecraft [4] is sensitive to radiance scattered by the surface of Ceres over two wavelength ranges 0.25-1μm and 0.95-5.1-μm with separate detectors. VIR data cover most of the surface of Ceres at low resolution. Spectra acquired during the Survey orbit at 4400 km altitude, with spatial resolution of approximately 1.1 km/pixel indicate that a high albedo unit within Oxo (Fig. 2) with a relatively negative spectral slope (Fig. 3) exhibits absorption bands of the H₂O molecule stretching mode overtone [17, 18] at 2.0 and 1.55 μm (Fig. 4) [16]. Three observations of the same area acquired within 72 hours (nine Cererean days) confirmed the findings. A small (a few square kilometers) high-albedo spot near the southern rim of Oxo seem to correspond to the location of the detection. At the time of VIR observations (near summer solstice and noon local time), the area was illuminated, however the location is likely shaded most of the time because of the proximity of a sharp crater rim.

Candidate H₂O-rich materials: H₂O ice and mineral hydrates such as chlorides, sulfates, and carbonates have spectra shapes that could fit VIR spectra. In order to further constrain the composition, the thermophysical stability of exposed H₂O-rich compounds on Ceres and results from chemical models of Ceres interior are being investigated.

H₂O ice. Pure water ice exposed at the surface may be due to contemporary formation or deposition; an ice-cemented regolith could have been recently exposed by an impact or a landslide. However, H₂O ice would sublime rapidly enough to disappear in a time very short (a few years) compared to geological timescale [19, 20]. Temporal variations in the abundance of H₂O-rich materials would be consistent with H₂O ice. Future observations by VIR are planned for this purpose.

Mineral hydrates. Near-infrared reflectance spectra of H₂O-rich materials show similar absorption bands at 1.55 and 2.0 μm for both pure water ice and various types of mineral hydrates such as chlorides, sodium carbonates, magnesium sulfates, sodium sulfates and ammonium sulfates. Polyhydrated salts are thermodynamically more stable than pure H₂O ice in the conditions of Ceres' surface over geological timescales.

Implication of the presence of H₂O on Ceres:

The detection of exposed H₂O ice would likely indicate contemporary hydrothermal activity, and therefore that internal heating due to radionuclide disintegration is strong enough to trigger eruptions. That would also reinforce the conclusions made earlier about observed releases of water vapor [14] and haze [21].

On the other hand, if absorption bands of H₂O on Ceres are due to polyhydrated minerals, then it would favor a more ancient formation and possible exposure from an impact or a landslide.

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