INVESTIGATING THE HABITABILITY OF CERES.

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Introduction: Ample evidence suggests that water must have played a significant role in the evolution of Ceres. Despite the nearly featureless spectrum of Ceres in the visible and near-infrared (NIR), the weak but mysterious absorption features in the 3-µm region have been variously interpreted as: water ice frost [1], NH_4-bearing phyllosilicate [2], mixture of irradiated organics and crystalline water ice [3], iron-rich clay and carbonates [4], and brucite ($Mg(OH)_2$) [5]. All of these possible compositions require an H_2O-based origin. The density of Ceres is consistent with ~25% water by mass [6]. The HST images [7] and ground-based NIR observations of Ceres [8, 9] show a remarkably homogeneous surface, a possible consequence of relatively recent or even current resurfacing driven by liquid-phase activity and/or volatile sublimation and mass transport [cf 10]. A marginal detection of OH off the northern limb of Ceres was reported [11], although subsequent searches returned negative results [12]. Thermal evolution modeling of Ceres [13, 14] suggests liquid water in the mantle in the past and perhaps even today. Water ice can remain in shallow subsurface at mid- to high-latitude areas on Ceres for the age of the solar system [15, 16].

The potentially large H_2O fraction in Ceres, existence of subsurface liquid water, and active exchange of materials between the surface and subsurface make Ceres an intriguing target for astrobiology. With its much closer proximity to the Earth compared to icy moons, and lower surface gravity relative to Mars and large moons, Ceres could be a prime target for future space missions to study the habitability on or beneath the surface of an ice-rich body.

NASA's Dawn spacecraft will arrive at Ceres in April 2015 for a nominal 5-month mapping rendezvous [17]. With the prospect of obtaining high-resolution maps of Ceres' geology, mineralogy, elemental abundance, and gravity by Dawn, we expect that our understanding of Ceres will be greatly advanced.

Perspectives: The astrobiological potential of Ceres needs to be better understood with a systematic, coordinated study combining observational and theoretical approaches. We envision that this investigation would have several key components: long-term, high-resolution monitoring of the surface of Ceres for its spectral reflectance; continued searches of active water sublimation on Ceres covering a full orbital period; and thermal mapping. These long time-baseline campaigns would be a critical complement to Dawn's detailed portrait of Ceres. Essential for these observations are high-resolution and/or high signal-to-noise. Of particular interest, thermal mapping in the sub-mm wavelengths is an especially powerful technique for directly probing the subsurface thermal properties at or beneath the diurnal thermal skin depth (~1 mm). Ceres shows much larger (~50%) rotational variations in sub-mm flux [18], in contrast to the ~4% variations in visible light, indicating highly heterogeneous subsurface layers that could reflect variations in the relative fractions of water ice mixed in the regolith. The prospect that water ice would be accessible a few centimeters below Ceres' surface is exciting. Further observations, over extended timescales, are necessary to confirm and better interpret the Chamberlain et al. conclusions [18]. The ALMA Observatory would be the best facility to provide the desired angular resolution and would complement the bistatic scattering radar observations to be performed by Dawn.

Input as constraints to theoretical modeling, these new observations would lead to a better understanding of the depth and state of subsurface water ice. In addition to physical observation and modeling, complementary insights about the chemical environment of Ceres' surface and subsurface would be gained from compositional mapping. All in all, such an interdisciplinary investigation would greatly benefit the assessment of Ceres' past and present habitability.

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