CARBON WITHIN CERES' REGOLITH: CONSTRAINTS FROM NUCLEAR SPECTROSCOPY.

T. H. Prettyman[1], N. Yamashita[1], E. Ammannito[2], J. C. Castillo-Rogez[3], B. L. Ehlmann[3,4], H. Y. McSween[5], S. Marchi[6], C. M. Pieters[7], N. Schorghofer[1], M. J. Toplis[8], C. T. Russell[9], C. A. Raymond[3], [1]Planetary Science Institute, Tucson AZ (prettyman@psi.edu), [2]Italian Space Agency, Rome, Italy, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA, [4]California Institute of Technology, Pasadena, CA, [5]University of Tennessee, Knoxville, TN, [6]Southwest Research Institute, Boulder, CO, [7]Brown University, Providence, RI, [8]CNRS/IRAP, University of Toulouse, Toulouse, France, [9]University of California, Los Angeles CA.

Introduction: Measurements of the surface composition of dwarf planet Ceres by the NASA Dawn mission and ground-based observations provide new insights into processes that shaped the largest body in the main asteroid belt. Dawn's Visible-to-Infrared Mapping Spectrometer (VIR) revealed a global surface containing aqueous alteration assemblages, including ammoniated phyllosilicates, carbonates, and opaques (e.g. magnetite or iron sulfides) [1, 2]. The surface mineralogy is similar to that of the CM and CI chondrites, which were subjected to extensive aqueous alteration within their parent bodies [3]. In addition, aliphatic organic compounds were detected in a broad (200 km) region in and around Ernutet crater [4]. The analysis of telescopic UV spectra indicates the presence of graphitized carbon, which could be produced by the exposure of organics on the surface to ionizing particles and UV radiation [5]. If the organic molecules have endogenic origin, then they may be more widespread within Ceres' subsurface than indicated by VIR. The presence of carbon within Ceres' aqueously-altered regolith provides further clues about interior evolution and offers potential opportunities for future studies of pre-biotic chemistry.

Elemental constraints: Measurements by Dawn's Gamma Ray and Neutron Detector (GRaND) were analyzed to determine the elemental composition of Ceres' subsurface to depths of a few decimeters on broad spatial scales [6]. Ice stability models imply that equatorial regions are representative of Ceres' ice-free composition. These regions contain more hydrogen and less iron than the CI chondrites. The meteorites have similar composition to the solar nebula, which indicates they experienced aqueous alteration in a closed system. The differences between the elemental composition of the CI chondrites and Ceres regolith suggest that ice and rock fractionated within Ceres' interior to form a chemically differentiated body.

GRaND data indicate that Ceres' regolith is carbon rich. The inferred presence of super-chondritic concentrations of carbon (e.g. Fig. 1) is consistent with ice-rock fractionation, with a crust enriched in light elements relative to the interior; although, accretion from a more-volatile rich source cannot be excluded. Here, we present the latest analyses of gamma ray and neutron spectra acquired during Dawn's primary and extended missions to determine the carbon content of Ceres' regolith.

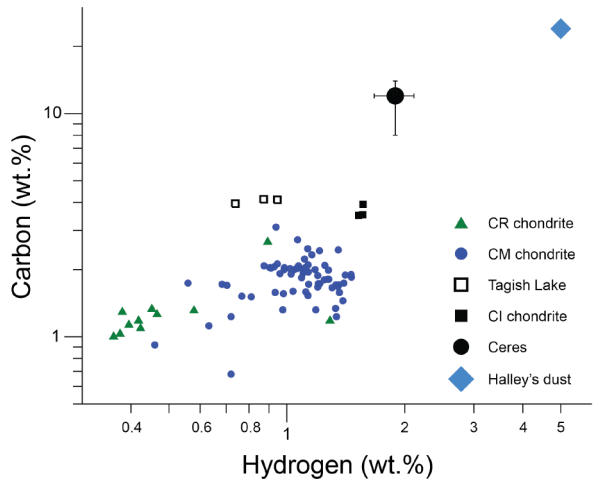

Figure 1. The concentrations of carbon and hydrogen within Ceres' ice-free regolith are compared with that of dust from comet Halley [7] and aqueously-altered carbonaceous chondrites [8]. The concentration of hydrogen on Ceres was determined by neutron spectroscopy [6]. The concentration of carbon was determined by fitting GRaND measurments of iron and hydrogen by adding carbonates and organics to a representative CI chondrite composition. Error bars give the variation of carbon and hydrogen within the ice-free regolith.

Elemental measurements combined with optical spectroscopy and meteorite studies provide constraints on carbon chemistry and processes underlying Ceres' formation and evolution.

Acknowledgements: This work was funded by the NASA Dawn mission, under contract with the Jet Propulsion Laboratory, and by NASA's Solar System Exploration Research Virtual Institute.

References: [1] De Sanctis M. C. *et al.* (2015), *Nature, 528*, 7581, 241-4. [2] Ammannito E. *et al.* (2016), *Science, 353*, 6303. [3] McSween H. Y. *et al.* (2017), *Meteoritics & Planetary Science*. [4] De Sanctis M. C. *et al.* (2017), *Science, 355*, 6326, 719-722. [5] Hendrix A. R. *et al.* (2016), *Geophysical Research Letters, 43*, 17, 8920-8927. [6] Prettyman T. H. *et al.* (2017), *Science, 355*, 6320, 55-59. [7] Jessberger E. K. *et al.* (1988), *Nature, 332*, 691-695. [8] Alexander C. M. O. D. *et al.* (2012), *Science, 337*, 6095, 721-723.