A probabilistic approach to deriving Ceres average surface composition from Dawn VIR data

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Quantitative determination of the mineral assemblages on the surface is important for the understanding of aqueous alteration on Ceres. Unveiling the aqueous paleoenvironment of Ceres would constrain the formation and evolution processes of Ceres, which is tied to the dynamical history of the early solar system. Infrared spectroscopic observations of Ceres from Dawn/VIR have shown that its dark surface contains Mg-phyllosilicates, ammonium-bearing phases, Mg/Ca carbonates, and dark materials, considered to be organic carbon and/or magnetite. The amount of a given material type present is currently constrained by “best-fits” of spectra with radiative transfer models using optical constants from terrestrial libraries [1].

In order to determine statistically rigorous error bars on quantification of material types present, we applied a Bayesian method to spectral unmixing of Ceres average surface. The Bayesian Markov Chain Monte Carlo method samples the posterior probability distribution function (PDF), i.e. the probability of a given set of mineral abundances and their grain sizes. This approach enables us to derive the mineral abundances on Ceres and the statistical error bars, taking observational errors in the reflectance spectra into account. As previous works [e.g., 1], we utilize the Hapke unmixing model for radiative transfer, which assumes the single-scattering albedo (SSA) spectrum of a surface is the sum of the SSA spectra of the material types comprising the surface, weighted by their cross sectional areas and proportional to abundance. Inputs are optical constants of the end member material types (n,k) as well as abundances range (0-100%) and grain sizes (10 μm-1 mm).

We obtained the best-fit composition of Ceres average surface which is consistent with the previous work utilised VIR data [1]. The Hapke model predicted the large amount of dark materials (proposed to be magnetite and/or amorphous carbon) up to ~80 wt.%, which is inconsistent with the elemental abundances estimated from the Gamma Ray and Neutron Detector (GRaND) [2]. We discuss the possible agents of the darkning of Ceres surface.

[1] De Sanctis et al., 2015, Nature, 528, 241-244. [2] Prettyman T. H. et al., 2017, Science, 355, 6320, 55-59.

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