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Modeling the peculiar polarization in Comet C/2011 W3 (Lovejoy)

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While grazing the Sun on 16 December 2011 at minimal distance 140,000 km, Comet C/2011 W3 (Lovejoy) was observed with the twin Solar and Terrestrial Relations Observatory (STEREO) spacecrafts in two ranges of phase angle α=30–60° and 85–140° with two red filters [1], revealing an outstanding negative polarization near backscattering compared to what was known previously about all other comets. For instance, in relative vicinity of the cometary nucleus (up to 2 solar radii), the amplitude $|P_{min}|$ of the average negative polarization branch was 15$\pm$3% at α=35°. The same part of the coma produced positive polarization with maximum value P_{max}=45$\pm$5%.

We analyze the values of this polarization first using the agglomerated debris particles. These particles have highly irregular shapes and have been used to model light scattering from comets [e.g., 2]. We examined over 30 different refractive indices m that are representative of various cometary species, such as, ices, silicates, organics, and amorphous carbon. We take into account particle polydispersity by averaging the light-scattering response over particle size using a power-law distribution. We find that the agglomerated debris particles cannot reproduce $|P_{min}|$=15$\pm$3%. We then analyzed seven other types of irregularly shaped particles [e.g., 3, 4] and found that the observed negative polarization can be reproduced only if particles have compact morphology with aspect ratio $\sim$1. This suggests that particles in the coma could have nearly spherical shape.

We computed light scattering by spheres with refractive indices m = 1.6+0.0005i, 1.6+0.05i, 1.6+0.1i, and 1.6+0.15i, that are representative for Mg-rich silicates at the lowest value and for organics at other values of Im(m). We find that spheres with m = 1.6 + 0.0005i and a power-law size distribution r^{-n} of having index n = 4.6–4.8 can simultaneously reproduce $|P_{min}|$ and P_{max} detected in Comet Lovejoy. This finding suggests that the Lovejoy coma consists of Mg-rich silicate particles, which presumably melted in the vicinity of the Sun, acquiring a nearly spherical shape.

References: [1] W.T. Thompson. Icarus, submitted (2015); [2] E. Zubko et al. Mon. Not. Roy. Astron. Soc. 440, 2928–2943 (2014); [3] E. Zubko. Light Scattering Reviews, Vol. 6, 39–74 (2012); [4] E. Zubko et al. J. Quant. Spectrosc. Radiat. Transfer 150, 42–54 (2015)