Comet C/2012 S1 (ISON)'s Carbon-rich and Micron-size-dominated Coma Dust

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Comet C/2012 S1 (ISON) was unique in that it was a dynamically new comet derived from the Nearly Isotropic Oort cloud reservoir of comets with a sun-grazing orbit. We present thermal models for comet ISON ($r_h \sim$1.15 AU, 2013-Oct-25 11:30 UT) that reveal comet ISON's dust was carbon-rich and dominated by a narrow size distribution dominated by ~micron-sized grains. We constrained the models by our SOFIA FORCAST photometry at 11.1, 19.7 and 31.5 μm and by a silicate feature strength of ~1.1 and an 8–13μm continuum greybody color temperature of ~275–280 K (using $T_{bb} \propto r_h^{-0.5}$ and $T_{bb} \sim$260–265 K from Subaru COMICS, 2013-Oct-19 UT)[1,2]. N-band spectra of comet ISON with the BASS instrument on the NASA IRTF (2013-Nov-11-12 UT) show a silicate feature strength of ~1.1 and an 11.2μm forsterite peak.[3] Our thermal models yield constraints the dust composition as well as grain size distribution parameters: slope, peak grain size, porosity. Specifically, ISON's dust has a low silicate-to- amorphous carbon ratio (~1:9), and the coma size distribution has a steep slope (N$\simeq$4.5) such that the coma is dominated by micron-sized, moderately porous, carbon-rich dust grains. The N-band continuum color temperature implies submicron- to micron-size grains and the steep fall off of the SOFIA far-IR photometry requires the size distribution to have fewer relative numbers of larger and cooler grains compared to smaller and hotter grains. A proxy for the dust production rate is $\epsilon f \rho \sim$1500 cm,[4] akin to $A f \rho$. ISON has a moderate-to-low dust-to-gas ratio.[5] Comet ISON's dust grain size distribution does not appear similar to the few well-studied long-period Nearly Isotropic Comets (NICs), namely C/1995 O1 (Hale-Bopp)[6,7,8,9] and C/2001 Q4 (NEAT)[10] that had smaller and/or more highly porous grains and larger sizes, or C/2007 N4 (Lulin) [11] and C/2006 P1 (McNaught)[12] that had large and/or compact grains. Radial transport to comet-forming disk distances ($\geq$ 20 AU) is easier for smaller grains ($\leq$1 μm) than for larger grains (~20 μm like Stardust terminal particles).[13] The presence of predominantly micron-sized and smaller grains suggests comet ISON may have formed either earlier in disk evolution whereby larger grains did not have the time to be transported to distances beyond Neptune, or the comet formed so far out in the disk that larger grains did not traverse such large radial distances. The high carbon-content of ISON's refractory dust appears to be complimented by the presence of limited-lifetime organic (CHON-like) grain materials: preliminary analyses of near-IR and high-resolution optical spectra indicate that gas-phase daughter molecules C_2, CN, and CH were more abundant than their parent molecules (C_2H_2, C_2H_6, measured in the near- IR).[14] Dust composition as well as grain size distribution parameters (slope, peak grain size, and porosity) give clues to comet origins.[15,16]

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