Title: Comet Mineralogy as Inferred from Infrared Spectra of Comets
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Abstract:

For most comets, infrared (IR) spectroscopy (remote sensing) is the method through which we diagnose the mineralogy and size distribution of dust in their comae. The shape and contrast of the IR spectral features depend on the particle size: optically active minerals (absorbing of visible and near-IR solar photons) and submicron solid grains or highly porous (> 90% vacuum) grains primarily contribute to the shapes of the observed resonances. Comet mineralogies typically are determined by fitting thermal emission models of ensembles of discrete mineral grains to observed IR spectral energy distributions. The absorptivities (Q_abs) and scattering efficiencies (Q_scat) of the discrete mineral grains are computed using Mie scattering, Maxwell-Garnet mixing, Discrete Dipole Approximation, and Multi-Layered Sphere codes. These techniques when applied to crystalline minerals, specifically olivine (Mg_x, Fe_1-x)2 SiO4, x>0.9, require the use of ellipsoidal shaped particles with elongated axial ratios or hollow spheres to produce the shapes of the resonances observed both from comet comae and laboratory samples. The wavelength positions of the distinct resonances from submicron-radii crystalline silicates, as well as their thermal equilibrium temperatures, constrain the crystalline olivine to have a relatively high Mg-content (x>0.9, or Fo>90). Only resonances computed for submicron Mg-rich crystalline olivine and crystalline ortho-pyroxene match the observed IR spectral features. However, this has led to the interpretation that micron-radii and larger crystals are absent from comet comae. Furthermore, the mass fraction of silicate crystals is dependent upon whether just the submicron portion of the size distribution is being compared or the submicron crystals compare to the aggregates of porous amorphous silicates that are computationally tractable as porous spheres. We will discuss the Deep Impact results as examples of these challenges to interpreting mid-IR spectra of short-period comets.

In contradiction to these model-dependent results that indicate that only submicron silicate crystals exist in comets, Stardust samples contain micron-size, and larger, nearly pure-Mg crystalline olivine and pyroxene crystals. The measurements of IR spectra of crystalline olivine in Stardust samples will provide a data set against which we can compare our scattering codes results and thereby improve our capability of assessing the cometary silicate crystalline fraction using remote sensing techniques.

In addition to the challenge of the deducing the silicate mineralogy, organic species known from Halley flybys and present in Stardust samples as a solid-state component of comet dust have eluded spectroscopic detection in the near- and mid-IR. The organic species in IDPs are observed to be the `glue' that holds aggregate porous grains together. A possible link between the organic species and comet observations is the `extended sources' of molecular species `distributed' into comet comae by grains. Within IDP aggregates, the subgrains primarily are composed of silicates, FeS and (now from Stardust) Ca-Al minerals. It is our current challenge to model the IR spectra obtained for Stardust samples using scattering codes for aggregate grains composed of multiple minerals, such as Multi-Layered Spheres. The greatest challenge is to incorporate silicate crystals into these aggregates and assess their thermal equilibrium temperatures and spectral shapes.