SPITZER IMAGING OF COMETS: SPATIALLY EXTENDED CO+CO_2 EMISSION AND DUST TRAILS.

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Introduction: Comet nuclei formed beyond the protoplanetary disk frost line at $r_h > 5$ AU, among the giant planets and were scattered into the Kuiper Belt (KB) and beyond into the Oort Cloud (OC) [1]. Since their formation, the interiors and surfaces of most comets have remained at temperatures below 140 K while in "cold storage" in the KB or the OC and most nucleus surfaces have remained below 400 K even during perihelion passage [2]. At such low temperatures, dust mineralogy remains stable and each comet nucleus retains a record of the minerals, ices, and volatiles extant in the comet agglomeration zones in the early solar system. Here we present *Spitzer Space Telescope* IRAC and MIPS images that enable studies of the spatial distribution of volatiles and dust in the comae of OC and ecliptic comets including: C/2003 K4 (LINEAR), 71P/Clark, 41P/Tuttle-Giacobini-Kresak, 37P/Forbes and 21P/Giacobini-Zinner; discussing detailed analysis of 21P (the parent body of the Daconid meteor stream) observations obtained during its 2005 apparition.

Volatiles CO+CO_2: Cometary activity occurs when volatile gases are released through sublimation or through the exoergic crystallization of amorphous water ice. Some molecular species (e.g., CO) are released not only from the nucleus (native source), but also from within the coma ("distributed" or "extended" source). The IRAC 4.5μm bandpass encompasses the CO and CO_2 fundamental bands at 4.67 and 4.26μm, respectively. The CO+CO_2 bands are the dominate emission components at 4 to 5μm in excess of the dust continuum emission in *ISO* spectra of C/1995 O1 (Hale-Bopp) and 103P/Hartley, and in the ambient coma of 9P/Tempel. After removing the dust continuum emission and scattered solar light the IRAC 4.5μm images can be used to map the CO and CO_2 spatial distributions in comet comae; emission from the two molecules can be decoupled as CO and CO_2 have different lifetimes in the coma and therefore produce different radial distributions. The excess emission in 21P (r_h = 2.4 AU post-perihelion) exhibits a ρ^{-1} surface brightness distribution out to ≈10^5 km from the nucleus (Fig. 1), consistent with derived lengths scales of 7.7 10^6 km (CO) and 2.9 10^6 km (CO_2) expected for outflow velocities of ~1 km s^{-1} assuming lifetimes of CO = 89 days and CO_2 = 34 days at 2.4 AU [3].

Dust Trails: Comets lose a large fraction of their mass in dust grains > 100μm. These grains weakly respond to solar radiation pressure and form distinct dynamical structures known as dust trails [5]. Our 21P MIPS 24μm image at 2.4 AU exhibited no evidence for a trail (1σ upper limit 0.074 MJy sr^{-1} $pixel^{-1}$, resulting an optical depth of 4.5 10^{-10}), suggesting that the number density of trail particles (typical particle size ~1 mm) is < 2 10^{-11} m^{-3}. For comparison, the dust trail number density is respectively ~10^{-11} m^{-3} and ~10^{-9} m^{-3} for 67P/Churyumov-Gersimenko and 81P/Wild [5,6].

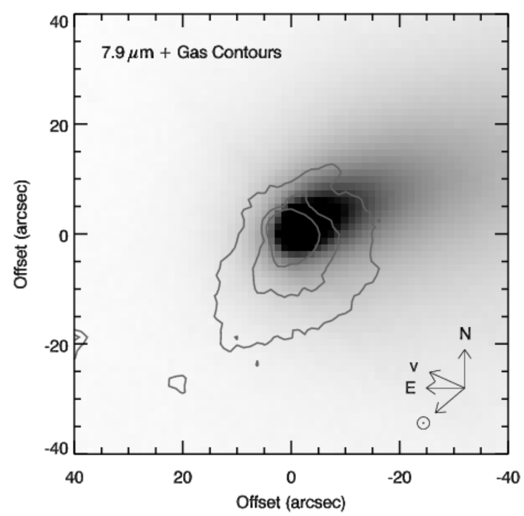

Figure 1: Comet 21P/Giacobini-Zinner *Spitzer* IRAC 7.9μm image (1.79 to 7.08 MJy sr^{-1} gray-scale range) with *contours* (0.05, 0.10, and 0.15 MJy sr^{-1}) of the excess emission (CO+CO_2 gas) derived from the IRAC 4.5μm image [4].

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