On The Evolution Of The Dust Emitted By Comet 103P/Hartley 2 And Observed By EPOXI.

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The EPOXI close flyby of comet 103P/Hartley 2 at 13:59 UT on 04 Nov 2010 showed clear evidence for a highly active surface emitting refractory dust & solid ice particles into interplanetary space, with multiple jets emanating from localized spots on the surface (Fig. 1). The evidence included a smooth space-filling coma dust distribution shadowed in regions by the nucleus, as well as a distribution of large individual particles detected as discrete spots and streaks.

Discrete Particles. Typical cometary coma dust populations contain particles from 10^{-1} to 10^4 um in size, with the amount of small (0.1 – 10) vs large (10^3 – 10^5) μm sized particles varying from comet to comet [1-4]. Copious large dust particles in Hartley 2's coma were anticipated by 12 cm Arecibo radar return measurements [5]; this group found ~15 times the surface area in large coma dust particles than in the nucleus. Tens of thousands of spots and streaks were detected by EPOXI and found to be variable between images, and thus cannot be due to fixed pattern noise or dust on the camera optics. Nor do they match the spatial signature of a background star field. Simple constraints derived from the EPOXI camera observing circumstances imply that these large particles must be mm to dm in size.

Dust Particle Structure and Composition. "Old" cometary dust is fluffy and porous, as determined indirectly from remote cometary sensing [1-4] and directly from the large dust grain hits on the STARDUST collector [6]. We do not know how solid ices are structured in the nucleus, whether they are separate or interleaved inside the dust, filling its pores. This is important as EPOXI IR spectral measurements indicate water ice reflectance absorption features indicative of small, micron sized ice particles. Thus the nature of Hartley 2's dust is currently somewhat unconstrained: the imagery & IR spectral features could be created by separate populations of small fine icy grains creating the smooth flux and large refractory grains creating the discrete point sources, by large fluffy porous grains and their fragmentary decay products made of mixtures of micron sized ice & refractory material, or some mixture of the two.

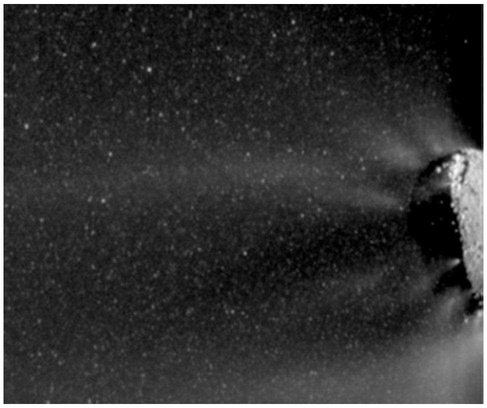

Figure 1. EPOXI HRI-VIS (1024x1024, 2"/pix) C.A. image of the anti-solar end of the 103P/Hartley 2 nucleus. Spatial resolution is ~3 m/pix, & the Sun is to the right. Highly active emission regions are apparent, containing multiple jet structures & their associated rough surface terrain. Also apparent are jets of small dust, a smooth background of small unresolved dust particles, and multiple discrete large (mm to dm sized) dust particles.

Fate of the Dust Emitted by Hartley 2: (1) Fragmentation/Sublimation in the Inner Coma ($\rho < 10^3$ km). The observed decrease in the near-nucleus coma surface brightness is flatter than the canonical $1/\rho$ coma profile expected for acceleration free expansion of released dust. This argues for either a de-acceleration of the dust, or an increase in the $[\pi a^2\ p_v\ \phi(\alpha)]$ product with distance from the nucleus, due to either dust fragmentation or dust brightening. The high activity level of the nucleus and the water ice detected by the EPOXI IR spectrometer argue for sublimation driven fragmentation. The timescale for sublimation of mm to dm-sized icy grains is 0.67 to 67 hrs : τ_d[hrs] = 6.7 a(cm) at r_h = 1.08 AU, assuming $\rho = 0.5$ g cm^{-3} and an ice-to-dust mass ratio $\kappa = 1$ [7] . The distance traveled in this time is on the order of $\tau_d * V_d$ (with $V_d = 0.4$ km/sec $\sqrt{\beta}$, and $\beta = 10^{-3}$ to 10^{-5}, [1]) or 20 to 230 km.

(2) Into the Outer Coma ($\rho > 10^4$ km) & Tail. Ground based observers (e.g. [8]) have found evidence for only warm, $T \sim 1.07 * T_{LTE}$ refractory dust, $dn/da \sim a^{-3.7} + \delta$(mm – cm sized grains), with a 10-20% silicate emission feature, typical of JFC family comets and similar to previous observations of dust emission from Hartley 2 [9-11]. This implies that any emitted water ice must be ephemeral, and/or a minority of all dust surface area emitted into the larger coma. The flat near-nucleus coma argues for extensive fragmentation and ephemeral dust; however it is possible to "hide" a minority fraction of cold icy dust mixed together with a warm refractory dust component.

(3) Into the 103P/Hartley 2 Trail. Millimeter to cm sized dust particles are present in the comet's trail, detected by Spitzer [12] and WISE [13, Fig. 2]. This would seem to imply that many of the large discrete particles found by EPOXI within a few km of the nucleus have to survive to create the observed trail.

In contrast, EPOXI did not see any evidence for discrete large grains near the nucleus comet 9P/Tempel 1 in images obtained from a similar distance during its 2005 *in situ* flyby, [14], arguing for there being few, if any, large bright grains emitted by that comet. Yet Tempel 1 was emitting similar total amounts of dust, and has an even more massive observed trail than Hartley 2 [12], arguing for a larger absolute production rate of large cm-sized grains. These results may imply that refractory trail grains are too dark ($p_v \sim 0.05$, or 6-20 times darker than clean water ice grains) to be easily detectable in either comet.

Figure 2. WISE image of 103P/Hartley 2 coma, tail, and trail at 4.6, 12 and 22 μm (blue, green & red, respectively) taken on May 10, 2010, when the comet was 2.3 AU from the Sun. The extent of the trail seen behind the comet in this view is 1.8×10^6 km, and the Sun is towards the top of the image.

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