**THE DETECTION, LOCALIZATION, AND DYNAMICS OF LARGE ICY PARTICLES SURROUNDING COMET 103P/HARTLEY 2.**

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**Introduction:** The Deep Impact Spacecraft flew past comet 103P/Hartley 2 on November 4$^{th}$, 2010 at 12.3 km/s, reaching a minimum distance of 694km [1]. Hartley 2 produces water at a faster rate than should be possible from surface sublimation alone, and is therefore an example of a hyperactive comet. During the encounter, the High Resolution (HRI) and Medium Resolution Instruments (MRI) captured images of a field of debris composed of fine grain dust and ice, and hundreds of discrete larger particles enveloping the comet. While clouds of large particles have previously been reported in radar data [2], this swarming of individual grains in the near-nucleus environment of Hartley 2 has not been directly observed in any other comet to date. In this study, we present a preliminary analysis of the identification, localization, and dynamics of particles present in the encounter images. The goal of this work is to identify and locate the brightest particles surrounding Hartley 2 with the aim of understanding their positions and possible motions.

**Observations:** Hundreds of golf ball to basketball-sized particles were detected near the nucleus (Fig. 1). These larger particles, interpreted to be composed primarily of water ice [3,4] were detected at a high density near the nucleus. The vast majority of these particles are consistent with point sources in the MRI camera and are therefore interpreted to be <~7m at closest approach. They are also consistent with point sources in the HRI images, which yields an even smaller upper-limit on their possible sizes. Many of these particles can be visually observed throughout the encounter images. The brightness of each individual "chunk" is highly variable between images however, with many particles appearing and disappearing several times during the flyby. This behavior hints at a faceted or irregular surface to exhibit this degree of phase variability.

**Determination of Particle Position and Motion:** Due to the large number of images taken during the approach (providing a high degree of time resolution), many of the particles are present in multiple frames as the spacecraft flies past. The motion of the spacecraft instruments relative to the comet nucleus (including not only spacecraft velocity but pointing adjustments) provides a metric to reconstruct the location and displacement of these particles from Hartley 2 by stereoscopic reconstruction of particle locations in successive frames. The technique employed here draws on uncalibrated stereo photogrammetry techniques and particle tracking algorithms to locate the particles in Euclidian space. By using features on the surface as fiducial points (as already required by the shape model), we can use the comet as a "calibration plate in space" to determine camera projection matrices for each image.

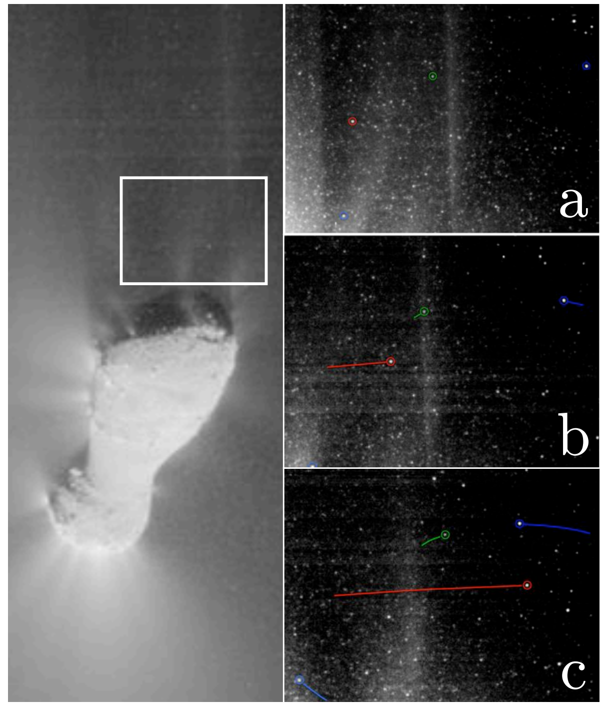


**Figure 1.** MRI clear filter encounter image near closest approach of Hartley 2 (left; approximately 800 km from nucleus). Image is stretched to illustrate jets and an icy particle cloud. White box corresponds to the approximate position of the sub-frames on the right (a,b,c), which identify and track four particles over three successive images. Solar direction is from the bottom.

The procedure relies on epipolar geometry to locate particles in multiple frames (Figure 2). In any given frame, particles are first located in image space. To solve for their three-dimensional position from stereoscopic parallax, the same particles must be located from at least one more viewing geometry. The search is restricted along epipolar line swaths in the other views. Due to the large number of particles, this search is conducted in a combinatorics routine to locate the particle matches that are located in the same 3-dimensional location in at least three images. The utility of the epipolar geometry in this application is that it is able to handle the temporally varying brightness of individual particles- if one particle falls beneath the threshold brightness for several frames, it can be located again when viewing conditions are more favorable (Figure 3).

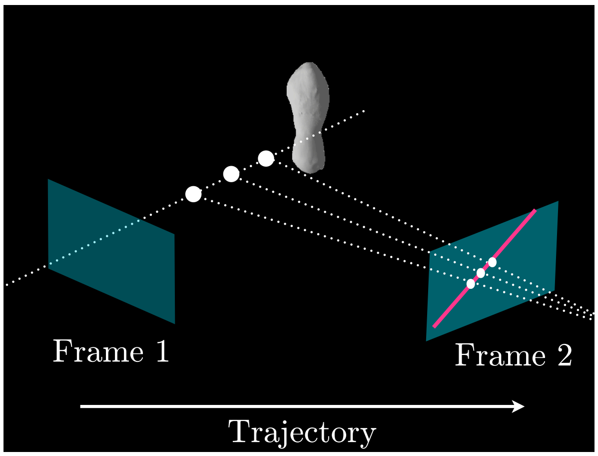


**Figure 2.** Epipolar geometry of particle reconstruction.

**Results and Analysis:** The majority of particles measured so far in the MRI images are located within 10km of the center of the nucleus, with a few detected at approximately 30km. Most of these particles are moving slowly (in the 0.5-2 m/s range); these speeds imply considerable lifetimes of the particles given their distance (~$10^5$ seconds). The dot product of the velocity vectors with the solar direction demonstrates an anti-solar bias in particle trajectories. Derivation of accelerations of these particles require accuracies in position reconstruction above the current state.

The volume of identification is biased toward the anti-solar direction due, at least partially, to the viewing geometry during flyby. A study on the effect of selection biases is currently underway. However, we note that an excess emission of water in the tail direction was measured in both pre-encounter and flyby data. This production was predicted to come from large icy grains accelerated in the anti-solar direction under non-gravitational forces in pre-encounter earth-based observations [5].

**Conclusions:** The encounter images of Hartley 2 reveal a high density of not only fine-grained dust and ice but also a large number of discrete particles surrounding the comet. Analysis of the location and forces acting upon these particles will enhance our understanding of the near-by environment of hyperactive comets and can explain some of their production properties.

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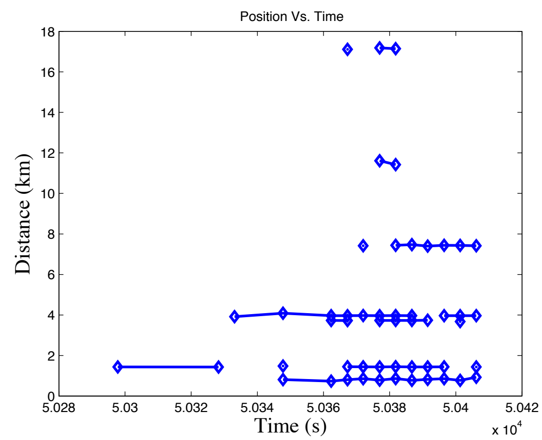


**Figure 3.** Distance of particles from nucleus center vs. time. Note temporally varying nature as particles drop beneath the noise floor only to reemerge at a different viewing geometry.

**References:**

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