PHOTOMETRY ANALYSIS OF COMET 81P/WILD 2 FROM STARDUST DATA. Jian-Yang Li[1], Michael, F. A'Hearn[1], Lucy A. McFadden, [1]Department of Astronomy, University of Maryland, College Park, MD 20742, jyli@astro.umd.edu.

Introduction: To date four cometary nuclei have been directly imaged by spacecraft from close distances, including 1P/Halley, 19P/Borrelly, 81P/Wild 2, and 9P/Tempel 1, all displaying a distinctive look. Of them the latter three are the Jupiter Family Comets (JFCs). The photometric properties of Comet Borrelly and Comet Tempel 1 have been studied in great detail from disk-resolved images and show surprisingly different properties for these two dynamically similar JFCs [1,2].

Comet 81P/Wild 2 is the target of NASA's comet sample return mission Stardust [3]. It is believed to have a different dynamical history from Borrelly and Tempel 1, and thought to have been captured to its current orbit for only several apparitions [4]. The 72 disk-resolved images of the nucleus returned in January 2004 with pixel scales up to 14m, and phase angles from 11° to 102°, make an excellent dataset to study the photometric properties of this cometary nucleus, and compare the photometric properties of three JFCs.

Data Reduction: All Stardust images of Comet Wild 2 are collected through a wideband filter centered at ~700nm with total bandwidth ~500nm. These images have been calibrated to *V*-band reflected radiance as received by the detector, in the unit of (W m^{-2} sr^{-1}). We further took the solar flux at 1 AU, 156 (W m^{-2}), as provided by Stardust calibration team (Kirk, priv. comm.) to convert radiance to the standard reflectance unit, I/F, such that I is the reflected radiance and πF is the incident solar flux.

During the encounter, Stardust executed some long exposure to image the inner coma and jets, but saturated the nucleus. Those images have been discard in our analysis. Due to their low spatial resolution and low signal to noise, some images taken at the beginning and the end of the encounter sequence were also discarded. Specifically, we used images with pixel scales <100m in the disk-integrated analysis, and <30m for the disk-resolved case. To avoid dust hit on the telescope mirror, Stardust spacecraft is equipped with a periscope, which caused double-image when the periscope mirror angle is <19°. We marked such data points, and discarded them in our analysis too.

Disk-Integrated Phase Function: To measure the total magnitude of the nucleus, all pixels inside the boundary of the nucleus are integrated. The total foreground coma flux is estimated from a half of the intensity of the ambient coma 5-10 pixels outside the nucleus, and subtracted out. The total brightness of the nucleus is then converted to magnitude (Fig. 1). The difference between inbound and outbound legs is due to the cross-section change of the nucleus, reflecting part of the rotational lightcurve.

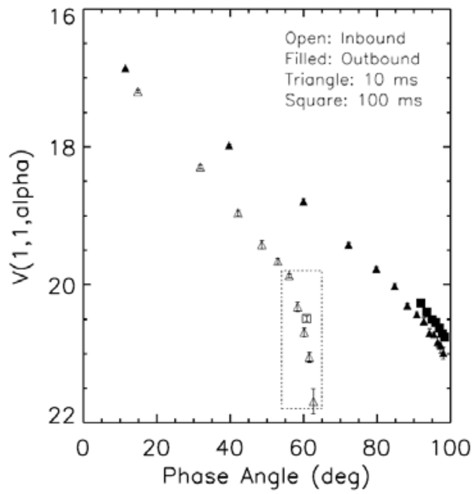

Fig. 1. V-band magnitude of the nucleus of Comet Wild 2 from Stardust images. Data in the dashed rectangular area have periscope mirror angle <19° where double-image appears.

To construct a phase function that is suitable for modeling, we calculate the averaged intensity over the illuminated and visible part of the nucleus, then factor it to a spherical shape by [1+cos(α)]/2, where α is the phase angle, and then convert to magnitude using the size of the best-fit ellipsoidal shape model (Kirk, priv.

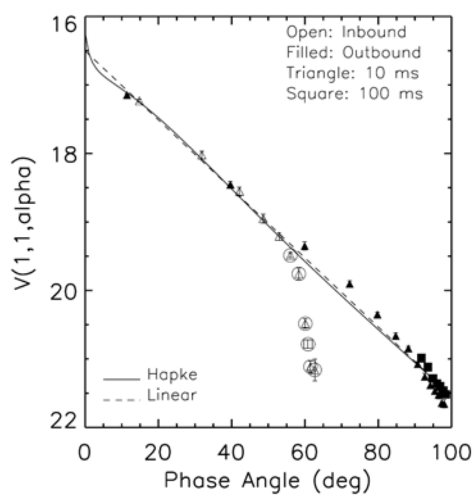

Fig. 2. Adjusted phase function of Comet Wild 2 from Stardust images. Data in circles have periscope mirror angle <19° and are disregarded in modeling.

comm.) (Fig. 2).

Linear fit yields $V(1,1,0)=16.50\pm0.02^m$, and a phase slope of 0.0504±0.0002 mag/°. To carry out Hapke modeling, we adopted a 5-parameter form, with single-scattering albedo w, a single-term single-particle phase function with asymmetry factor g, a roughness parameter θ, and the opposition height B_0 and width h [5]. Due to phase angle limitations, the opposition parameters for Comet Wild 2 cannot be modeled. The roughness parameter and asymmetry factor cannot be distinguished effectively here. Thus we assumed B_0=1.0, h=0.01, and took θ=27° as suggested by the following disk-resolved analysis. The best-fit w is 0.0290±0.002, and g is -0.522±0.003. The modeled $V(1,1,0)=16.23^m$, geometric albedo 0.0484, phase integral 0.191, and Bond albedo 0.00926.

Disk-Resolved Photometry: A shape model of the nucleus of Comet Wild 2 has been developed [6]. The scattering geometry of each pixel in the disk-resolved images can be calculated with this shape model coupled with the spacecraft flyby geometry documented in Stardust SPICE data archived in Planetary Data System Small Bodies Node [7]. We further binned the I/F data points extracted from the seven selected images into 5° incidence angle (i), emission angle (e), and phase angle (α) bins to reduced the alignment error between images and geometry maps. Finally, all data points with i and e greater than 75° are disregarded to avoid pixels too close to limb and/or terminator.

Assuming B_0=1.0 and h=0.01, the three other Hapke parameters are modeled: w=0.0319, g=-0.518, θ=27°. The modeled root mean square (RMS) is about 11% (Fig. 3), indicating a good fit and small photometric variations across the surface of the nucleus of Comet Wild 2. The ratio between measured and modeled I/F is plotted against i, e, and α in Fig. 4.

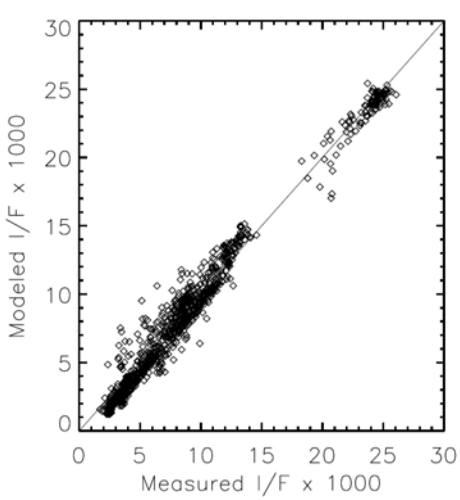

Fig. 3. Goodness of disk-resolved Hapke model. Perfect fit will result in the solid line. Model RMS is 11%.

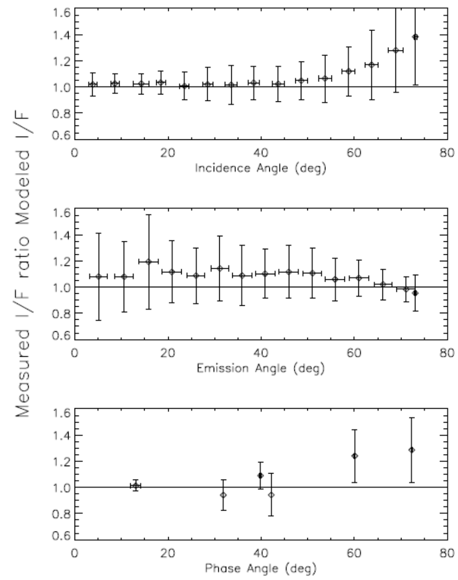

Fig. 4. Ratio of measured and modeled I/F plotted against I (top), e (middle), and α (bottom). Data are binned with the standard deviation in each bin represented by the error bars.

The difference between the modeled w here and that from disk-integrated phase function is possibly due to foreground coma, for which no attempt is made here to remove before disk-resolved modeling. The asymmetry factor g modeled here agrees with the value derived from the disk-integrated phase function very well. Slight systematical bias of the model with i and e is evident. More investigation is needed to reveal the physical indication on the photometric properties or variations over the surface.

Conclusions: The disk-integrated phase function of Comet Wild 2 is constructed from Stardust flyby images. Linear law shows an absolute V magnitude 16.50^m, and a phase slope of 0.050 mag/°.

Disk-resolved analysis results in a good fit with an RMS of 11%, indicating a photometric variation that is comparable to that found on Comet Tempel 1, but much smaller than that observed on Comet Borrelly. Hapke model yields a w 0.032, an asymmetry factor -0.52, and a roughness parameter 27°. Modeled geometric albedo is 0.048.

References: [1] Li, J.-Y., A'Hearn, M.F., McFadden, L.A., Belton, M.J.S. (2007) *Icarus*, in press; [2] Li, J.-Y. et al. (2007) *Icarus* Deep Impact Special Issue, in press; [3] Brownlee, D. E. et al. (2004) *Science* **304**, 1764; [4] Sekanina, Z., Yeomans, D.K. (1985) *AJ*, **90**, 2335; [5] Hapke, B. (1993) *Theory of Reflectance and Emittance Spectroscopy*, Cambridge Univ. Press; [6] Kirk, R.L. (2005), 36th LPSC, abstract #2244; [7] Semenov, B.V. et al. (2004), NASA Planetary Data System.