STUDENT DUST COUNTER: STATUS REPORT AT 38 AU.

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Introduction: Information on the distribution of interplanetary dust particles (IDPs) provides constraints to the origin and evolution of planetary bodies. The distribution of IDPs depends on the sources, sinks, and dynamics of dust grains permeating the solar system. Numerical models have demonstrated that outgassing and outbursts of Jupiter Family Comets (JFCs) dominate the distribution of IDPs in the inner solar system [1,2] while the mutual collisions and bombardment of Edgeworth-Kuiper Belt Objects (EKBOs) by interstellar/interplanetary grains dominate the distribution of IDPs in the outer solar system [3,4,5,6]. IDPs are subject to gravity, radiation pressure, EM forces, and Poynting-Robertson drag. Under these forces, IDPs migrate throughout the solar system, often getting trapped in resonances with or scattered by the giant planets [6,7,8]. Being able to accurately map the distribution of IDPs will provide insight into the parent bodies of the particles as well as the overall evolution of the solar system.

The Student Dust Counter (SDC) is an in-situ dust detector aboard the New Horizons spacecraft observing the distribution of IDPs in the mass range of $10^{-12} < m < 10^{-9}$ g or approximately 0.5 - 5 µm in radius. New Horizons was launched on January 19th 2006 and performed a fly-by of the Pluto system on July 14th 2015. SDC has nearly continuously mapped the dust density distribution along the trajectory of New Horizons from Earth to 38 AU.

SDC Description: The SDC detector plate is mounted in the ram direction of the New Horizons spacecraft. It consists of 14 permanently electrically polarized 28 µm thick polyvinylidene fluoride (PVDF) plastic film sensors, each with dimensions of 14.2 × 6.5 cm [9]. The PVDF detectors operate by detecting a change in the surface charge density on their conducting surfaces due to the cratering of the PVDF films by dust impacts [10,11]. PVDF displays both pyroelectric and piezoelectric properties and is affected by temperature variations and mechanical vibrations [10]. For this reason the instrument was designed with 2 of its 14 sensors attached to the backside of the detector panel, shielded from dust impacts. These two detectors serve as `reference' channels, providing a baseline of the noise events induced by effects other than dust impacts, including the firing of thrusters, mechanical vibrations, and random thermal electronic noise. The 12 forward facing detectors serve as `science' channels, recording both dust impacts and noise events.

SDC Measurements: SDC has taken near continuous dust measurements from Earth to 38 AU. Figure 1 shows all recorded data excluding those coincident with thruster firings or other recorded events. The impact charge measured by SDC is a function of the mass and speed of the impacting particles requiring an assumption about one to obtain the other [9,11,12]. The customary analysis assumes that IDPs follow circular Kepler orbits, modified by radiation pressure, with a mass density of 2.5 g/cm^3.

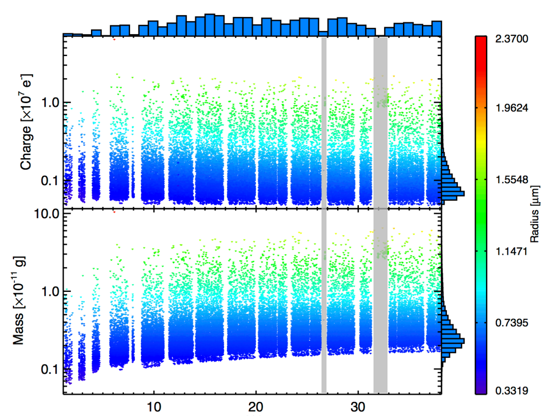

Figure 1. The impact charges *top* and mass estimates *bottom* of all events recorded by SDC from Earth to 38 AU that were not coincident with thruster firings. Data gaps are periods when the New Horizons spacecraft transitioned to three-axis-stabilized mode and SDC was turned off. Gray bars indicate the periods of high spacecraft activity when SDC thresholds were raised during a rehearsal period and the encounter with Pluto.

Dust impact rates were calculated by subtracting the average number of counts recorded by the reference channels from the average number of counts recorded by the science channels. The uncertainty in counts was calculated by adding the standard deviation of the reference and science channels in quadrature. The density of IDPs was derived by dividing the calculated dust count by the volume carved out by a single sensor. Figure 2 shows the dust density estimate for two different size cuts at 0.6 µm and 1.3 µm. For grains > 0.6 µm, the density initially increases from 4-15 AU then remains fairly constant. The density of larger grains (> 1.3 µm) has been nearly constant, agreeing with Pioneer measurements [13].

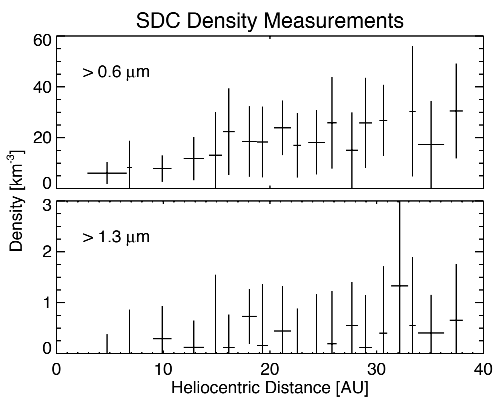

Figure 2. Interplanetary dust density for grains with radii > 0.6 µm and > 1.3 µm. One sigma error bars were calculated by adding the standard deviation of hits from the reference and science channels in quadrature.

Model Comparisons: Recent models have detailed the sources, sinks, and transport of dust particles in the outer solar system allowing for direct comparisons with SDC observations [6,14,15]. These models used a test particle approach, with collisional schemes introduced, integrating the motion of individual grains under the influence of gravity due to the Sun and the giant planets, radiation pressure, Poynting Robertson drag, electromagnetic perturbation due to the interplanetary magnetic fields, and grain-grain collisions.

In all previous analyses, the dust fluxes and densities derived from the SDC measurements assumed that the impacting particles follow circular Kepler orbits adjusted for radiation pressure. However, the numerical dust trajectory integrations show that particles can follow orbits with significant eccentricities and inclinations, contrary to the simplifying assumptions used in our data analysis to date. Figure 3 shows a comparison of the distribution of charges measure by SDC with the predicted distribution from the model.

The model predicts a much higher probability of large impact charges (> ~3×10^6 e^{-1}) than detected by SDC, especially beyond 15 AU.

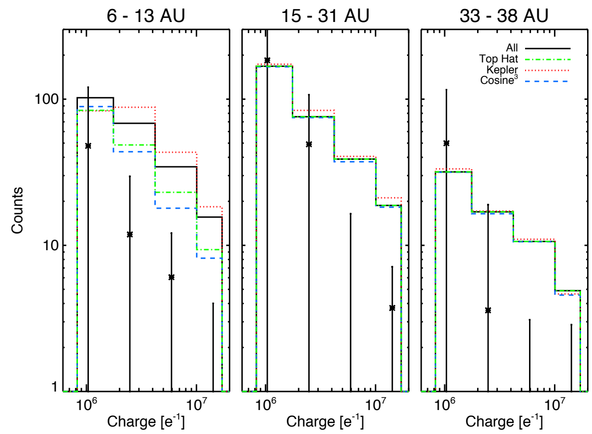

Figure 3. Predicted and measured impact charge distributions at three different heliocentric ranges.

Conclusion: SDC has nearly continuously mapped the dust density distribution along the trajectory of New Horizons, and it continues to operate providing the first ever measurements of a dedicated dust instrument in the Edgeworth-Kuiper Belt. We present results of the dust density distribution from 1 to 38 AU and compare these measurements to existing theoretical models.

References: [1] Nesvorny, D., et al., (2010) *Astronomical Journal,* 713, 816-836. [2] Nesvorny, D., et al., (2011) *Astonomical Journal,* 743. [3] Stern, S. A., (1996) *Astronomy and Astrophysics,* 310, 999-1010. [4] Yamamoto, S., et al., (1998) *Astronomy and Astrophysics,* 329, 785-791. [5] Poppe, A. R., (2015) *Icarus,* 246, 352-359. [6] Poppe, A. R. (2016), *Icarus,* 264, 369-386. [7] Liou, J. C., et al., (1999) *Icarus,* 141, 13-28. [8] Moro-Martin, A., et al., (2002), *Astrophysical Journal,* 124, 2305-2321. [9] Horányi, M. et al., (2008), *Space Sci. Rev.,* 140, 387-402. [10] Simpson, J. A., et al., (1985) *Nucl. Instrum. Methods,* 236, 187-202, [11] Poppe, A. R., et al., (2010) *Nucl. Instrum. Methods,* 622, 583-587. [12] James, D., et al., (2010) *Review of Scientific Instrum.,* 81, 034501. [13] Humes, D. H. (1980) *Journal of Geophysical Research,* 85, 5841-5852. [14] Vitense, C., et al., (2012) *Astronomy and Astrophysics,* 540. [15] Vitense, C., et al., (2014) *Astrophysical Journal,* 147, 154.