

STUDENT DUST COUNTER: STATUS REPORT AT 42 AU. M. Piquette^{1,3}, A. R. Poppe², E. Bernardoni^{3,4}, J. R. Szalay⁵, D. James³, M. Horányi^{3,4}, S. A. Stern⁶, H. Weaver⁷, J. Spencer⁶, C. Olkin⁶, J. Parker⁶, A. Verbiscer⁸, and the New Horizons P&P Team

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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 of mass $> 10^{-12}$ g, or approximately $0.5 \mu\text{m}$ in radius. New Horizons was launched on January 19th 2006 and performed fly-bys of the Pluto and Ultima-Thule systems in 2015 and 2019, respectively and continues to explore the Kuiper Belt [9]. SDC has nearly continuously mapped the dust density distribution along the trajectory of New Horizons from Earth to 42 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 $28 \mu\text{m}$ thick polyvinylidene fluoride (PVDF) plastic film sensors, each with dimensions of $14.2 \times 6.5 \text{ cm}$ [10]. 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 [11,12]. PVDF displays both pyroelectric and piezoelectric properties and is affected by temperature variations and mechanical vibrations [11].

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' sensors, providing a baseline of 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' sensors, recording both dust impacts and noise events.

SDC Measurements: SDC has taken near continuous dust measurements from Earth to 42 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 [10,12,13]. The customary analysis assumes that IDPs follow circular Kepler orbits, modified by radiation pressure, with a mass density of 2.5 g/cm^3 .

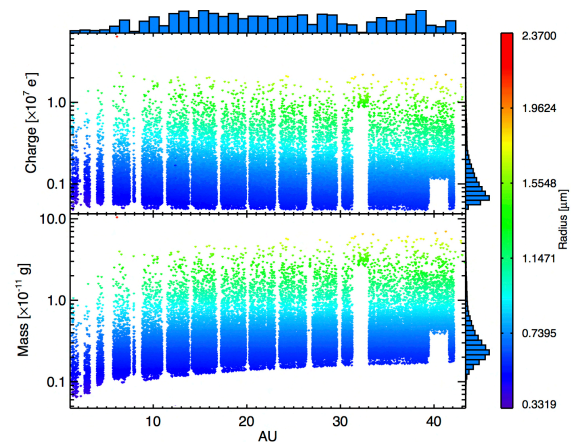


Figure 1. The impact charges *top* and mass estimates *bottom* of all events recorded by SDC from Earth to 42 AU that were not coincident with thruster firings. Data gaps are periods when SDC was turned off. Color represents size estimates assuming 2.5 g/cm^3 .

Dust impact rates were calculated by subtracting the average number of counts recorded by the reference sensors from the average number of counts recorded by the science sensors. Due to the electronics layout of SDC, the 14 sensors are divided into two channels A and B, each with their own reference sensor. The uncertainty in counts was calculated by adding the standard deviation of the reference and science sensors in quadrature for each channel. 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 three different size cuts at 0.63, 0.85, and 1.47 μm . For grains $> 0.63 \mu\text{m}$, the density initially increases from 4-15 AU then remains fairly constant. The density of larger grains (> 0.85 and $1.3 \mu\text{m}$) has been nearly constant, agreeing with Pioneer measurements [14].

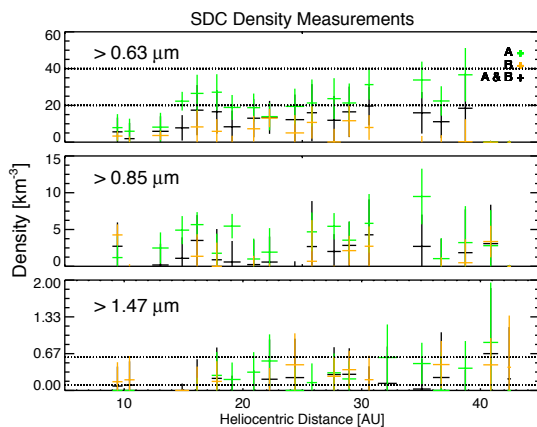


Figure 2. Interplanetary dust density for grains with radii $> 0.6, 0.85,$ and $1.47 \mu\text{m}$. One sigma error bars were calculated by adding the standard deviation of hits from the reference and science sensors in quadrature. Horizontal lines represent density estimates from the Voyager and Pioneer missions in the top and bottom panels, respectively.

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 [6,15,16]. 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 mass measure by SDC with the predicted distribution from the model.

The model predicts a lower count of smaller grains ($< 0.7 \times 10^{-11} \text{ g}$) and a higher count of larger grains ($> 2 \times 10^{-11} \text{ g}$) than detected by SDC. In fact, SDC measurements of particles $> 5 \times 10^{-11} \text{ g}$ are consistent with zero detections.

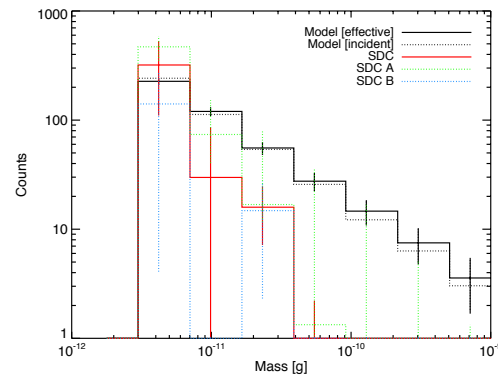


Figure 3. Predicted and measured mass distributions. The difference between the incident and effective model predictions stems from the assumption of grains being on circular Kepler orbits.

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 42 AU and compare these measurements to existing theoretical models.

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