Interstellar Probe Observations of the Solar System's Debris Disks

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Introduction. In this paper, we explore the possibilities of using an Interstellar Probe (IP) telescope placed at 1000 AU from the Sun to observe the brightness, shape, and extent of the solar system's debris disk(s).

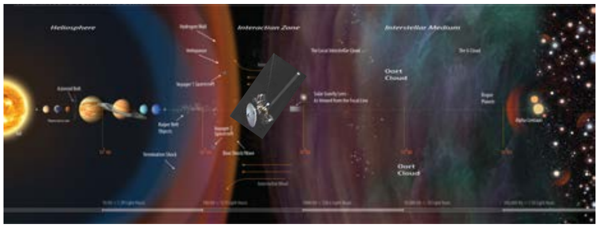

Fig 1. – Location of the Interstellar Probe payload with respect to the planets, the heliopause, Alpha Centauri, and the Oort Cloud.

Planetesimal belts and debris disks full of dust are known as the "signposts of planet formation" in exosystems. The overall brightness of a disk provides information on the amount of sourcing planetesimal material, while asymmetries in the shape of the disk can be used to search for perturbing planets. The solar system is known to house two such belts, the Asteroid belt and the Edgeworth-Kuiper Belt (EKB); and at least one debris cloud, the Zodiacal Cloud, sourced by planetesimal collisions and comet evaporative sublimation.

However, these are poorly understood *in toto* because we live inside of them; i.e., while we know of the two planetesimal belt systems, it is not understood well how much dust is produced from the EKB since the near-Sun comet contributions dominate near-Earth space and only 1 s/c, New Horizons, has ever flown a dust counter through the EKB. Understanding how much dust is produced in the EKB would give us a much better idea of the total number of bodies in the belt, especially the smallest ones, and their dynamical collisional state. Even for the close-in Zodiacal cloud, questions remain concerning its overall shape and orientation with respect to the ecliptic and invariable planes of the solar system - they are not explainable from perturbations caused by the known planets alone.

Discussion. What Can Interstellar Probe mission at 1000 AU do for us with Lookback Imaging and *in Situ* Dust Measurements?

Enable Scientific Studies :

- Produce the 1st Exterior Imaging of the Solar System's Dust Cloud/Debris Disk
- Use the Solar System's known inventory & history as a Rosetta Stone for understanding Exosystem Disks
- Search for unknown/new Solar System objects like Planet X that perturb the cloud
- Improve meaurements of cosmic background light originating from outside the Solar System

Using Interstellar Probe lookback imaging, we should be able to measure the entire extent of the inner, near-earth zodiacal cloud; whether it connects smoothly into an outer cloud, or if there is a second outer cloud sourced by the Kuiper belt and isolated by the outer planets, as predicted by Stark & Kuchner or Poppe et al. [1-5] (Figs 2-3). VISIR imagery will inform us about the dust cloud's density, while MIR cameras will provide thermal imaging photometry related to the cloud's dust particle size and composition. Observing at high phase angle by looking back towards the Sun from 1000 AU, we will be able to perform deep searches for the presence of rings and dust clouds around discrete sources, and thus we will be able to search for possible strong individual sources of the debris clouds - like Planet X, or the Haumea family collisional fragments, or the rings of the Centaur Chariklo, or dust emitted from spallation off the 6 known bodies of the Pluto system. Measurement from an on-board dust counter will provide the first ever *in situ* sampling of dust beyond 200 AU, and calibrated ground truth for models produced from IP imagery.

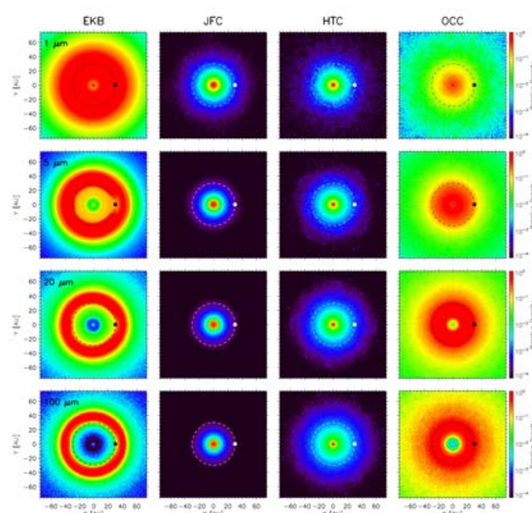

Fig 2. – Predicted dust cloud morphologies for varying grain sizes arising from the EKB and comet sources of our outer debris disk. After [5].

Large-scale structure determination of the cloud should help inform us of ancient events like planetary migration and planetesimal scattering (as in the LHB), and measurement of the cloud's total brightness will allow improved removal of its signal in near-Earth cosmological measurements looking out into the Universe.

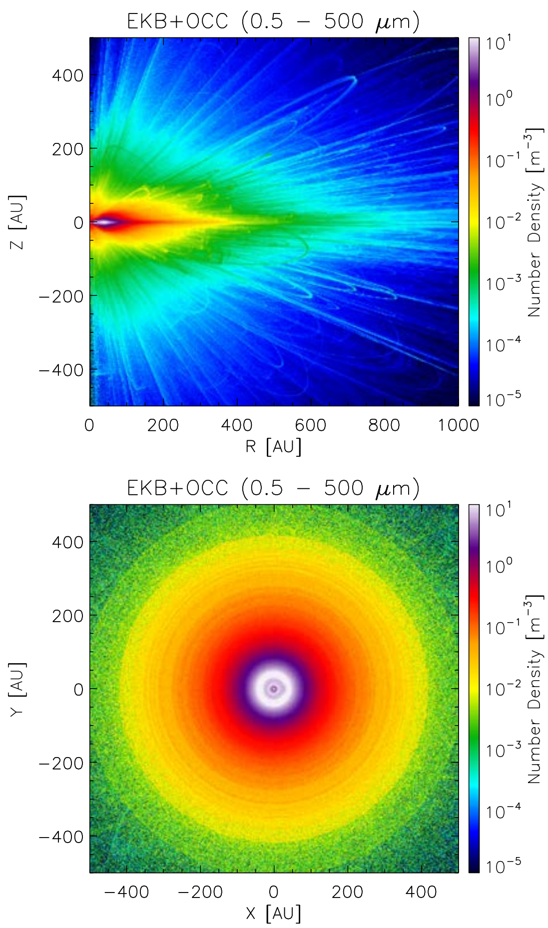

Fig 3. – Expected total outer solar system dust cloud morphology. After [5].

Potential Solar System Resource Utilization :

-Dust, Collisional Family Locations
-Source Characterization - #'s, Masses, Velocities
-Source Loss Rates

At the same time these scientific endeavors are occurring, better understanding of the solar system's dust clouds will help characterize their sources, providing location information for potential future easily exploitable rocky (inner cloud) and icy (outer cloud) materials. Examples of these are the sources of the inner cloud dust bands in the MBA, and the Haumea family members in the EKB.

Exploration:

- Understanding the Dust Distribution Around a G2V Star

Looking out to the future exploration of our first exosystem, the Alpha Centauri system, our closest neighbor beckons. This system also contains a close G2V solar twin of estimated age ~ 5 Gyr, old enough to have formed life as we know it. At 4.3 ly distance, the timescales for reaching this system are prohibitive unless we send probes at near lightspeed velocities, conversely at these speeds impacts with just mm sized dust particles can deliver Petajoules (Megatons of TNT equivalent) energy. Thus, a detailed knowledge of the dust cloud around our G2V star will help Hazard Mitigation for a High-Speed Interstellar Flyby to our neighboring G2V, Alpha Cen A.

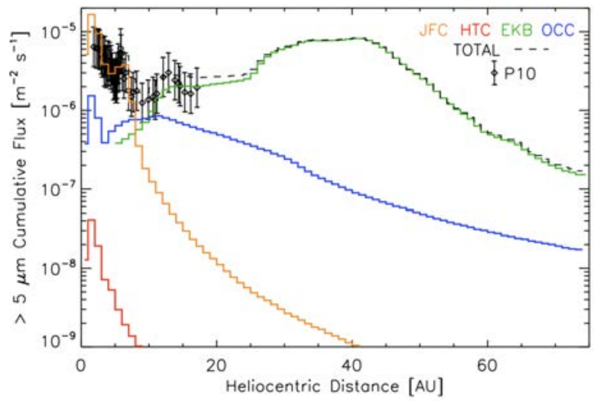

Fig. 4. – Predicted dust flux contributions (colored curves) and in situ measurements (black data pts) for the solar system debris disk cloud [3,4]. Note the predicted crossover from JFC dominated to EKB dominated at ~10 AU, which matches the data well. Will another crossover occur at ~100 AU from EKB dominated to OCC dominated? Can we expect a similar pattern of dust around Alpha Cen A, or does Alpha Cen B severely distort its cloud?

Conclusions. The expected scientific, resource utilization, and mission exploration support value of VISIR imaging of the solar system's dust cloud from 1000 AU remove is large. The contributions from the Edgeworth-Kuiper Belt and the Oort Cloud, normally obscured from the Earth by locally dominant JFC and asteroid belt contributions, should be easily imaged. Models of the inner + outer cloud produced from IP measurements will allow better understanding of the dust hazards we can expect around Alpha Cen A and B and better, safer mission designs to study that system *in situ*.

References: [1] Stark & Kuchner 2009, *ApJ* **707**, 543 [2] Stark & Kuchner 2010, *AJ* **140**, 1007 [3] Poppe+ 2010, *Geophys.Res.Lett.* **37**, L11101 [4] Poppe & Horányi 2012, *Geophys.Res.Lett.* **39**, 1 [5] Poppe 2016, *Icarus* **264**, 369