System Dust Detection from Swarm Navigation Cameras – A Potential Science Add-On

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micro Advanced Stellar Compass µASC on Swarm and Juno

Solar system dust may be observed directly from spacecraft using a unique detection method first demonstrated on NASA's Juno spacecraft [Benn et al 2017 & Jorgensen et al 2020]. Data from Juno demonstrated that dust tails from comets are observable in a similar fashion.

During the five year deep space trajectory from Earth to Jupiter, the micro Advanced Stellar Compass, part of the Juno MAG investigation delivered accurate attitude measurements for the science magnetometer. The microASC uses its cameras to image the sky for attitude determination, its primary function, but also logs objects appearing in the camera FOV that are not stars. The Swarm satellites carry a microASC identical to Juno and could thus be used as a dust detector in near Earth space.

microASC capabilities:

- Fully autonomous, inertial attitude determination instrument
- Optical imaging of solar system bodies
- Autonomous detection and tracking of non stellar objects
- Characterization of the hypervelocity dust impact on the spacecraft
- Detecting high energy particles (>15MeV e^- and >80MeV p^+)

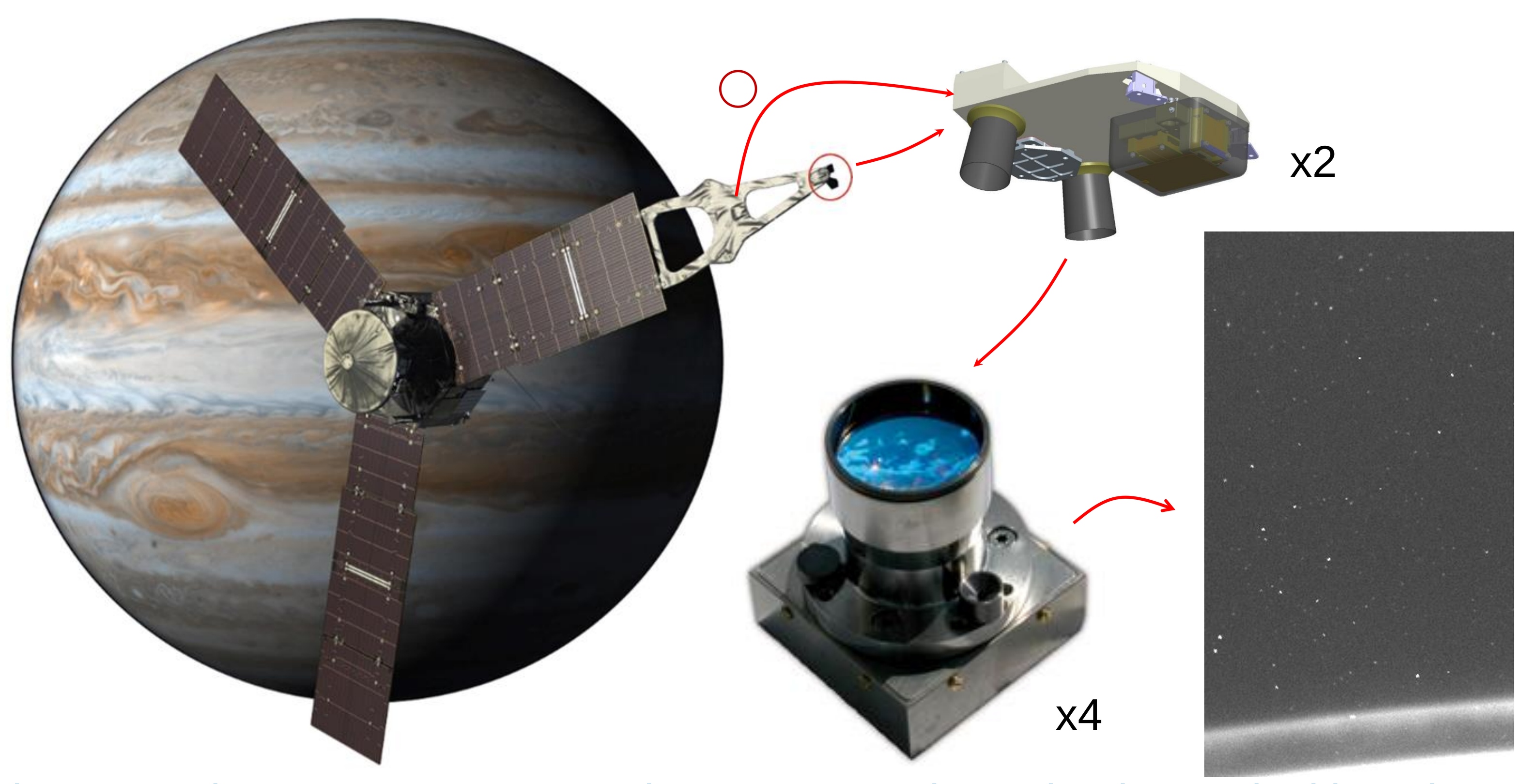

Figure 1: microASC cameras on the Juno MAG investigation optical benches. Image Credit NASA, DTU

Detecting Interplanetary Dust

The Juno microASC routinely logged spallation products evolving from the impacts of rapid interplanetary dust particles (IDPs) on the spacecraft. The system is capable of detection of IDPs with a diameter larger than ~5µm, with the largest particles measured to be in the 0.1mm range.

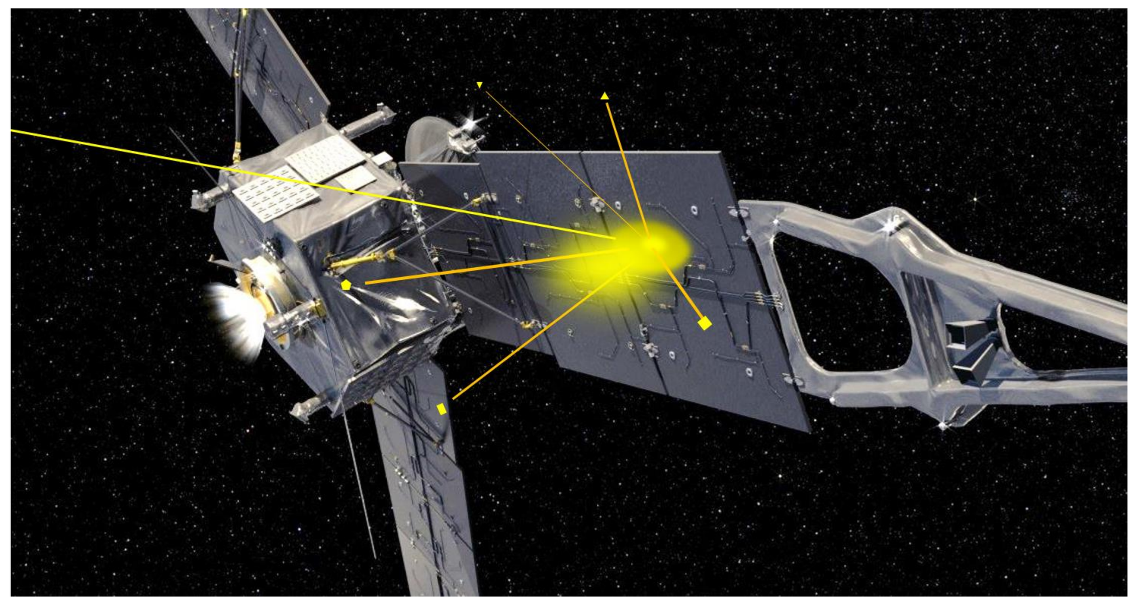

Figure 2: Spallation products from spacecraft dust impacts . Image credit NASA

Observations

These observations by the Juno spacecraft provided measurements of the dust density profile along the trajectory through the solar system from 0,9AU to 5AU (Figure 2). However, at a few occasions, highly elevated dust count for short periods, weeks, indicated a different origin.

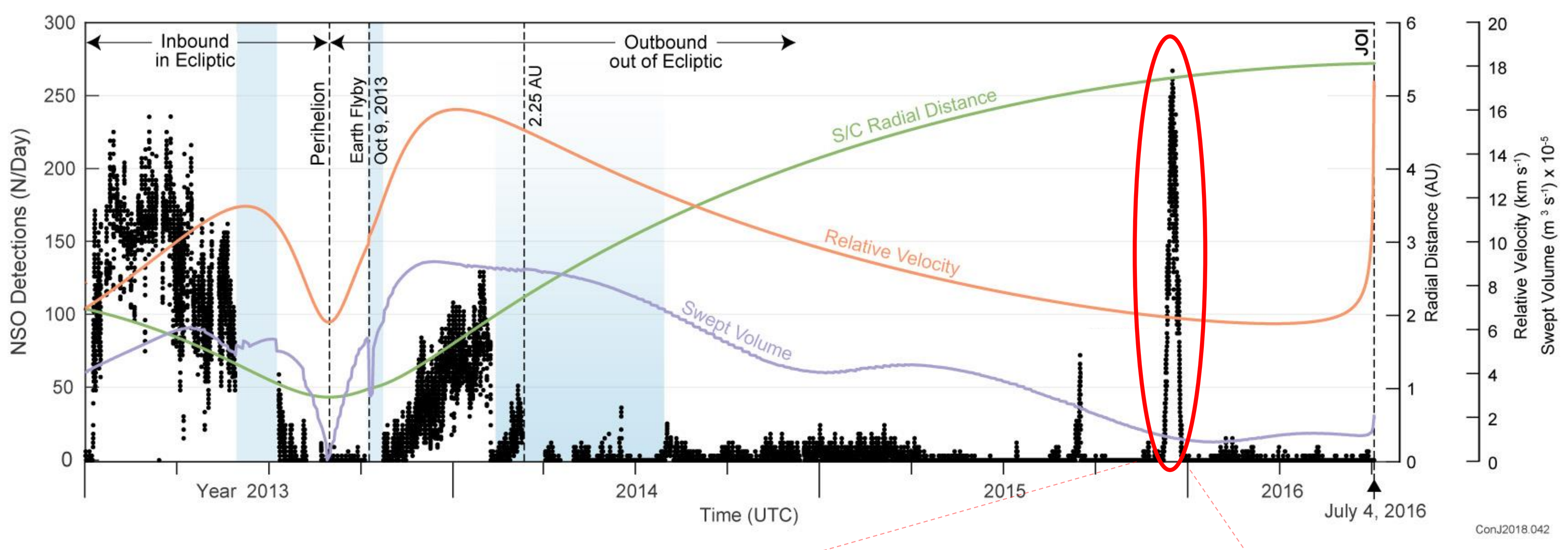

Figure 2: Detections along Juno trajectory out through the solar system. Highly elevated dust count in 2015 December. From Jorgensen et al. 2020.

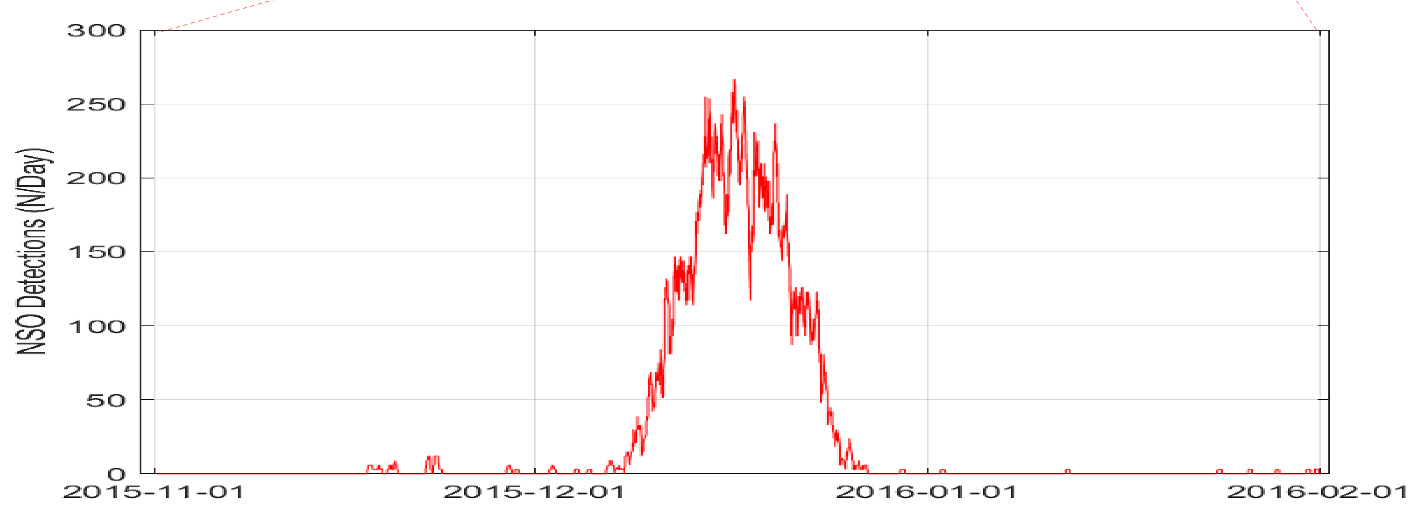

Figure 3: Close-up of the December 2015 peak is confined to 20 days and reveals fine structure in the count rate.

Comet morphology

Three distinct tail fractions determined by β, the ratio between solar radiation pressure and solar gravity

$$\beta = \mu - 1 = \frac{F_{rad}}{F_{grav}} = \frac{\kappa Q_{pr}}{\rho s}$$

- s = dust particle radius
- ρ = dust particle density
- Q_{pr} = light pressure efficacy
- κ = Empirical constant

Molecular particles $\beta >> 1$
Medium particles $\beta \sim 1$
Large particles $\beta = \sim 0$

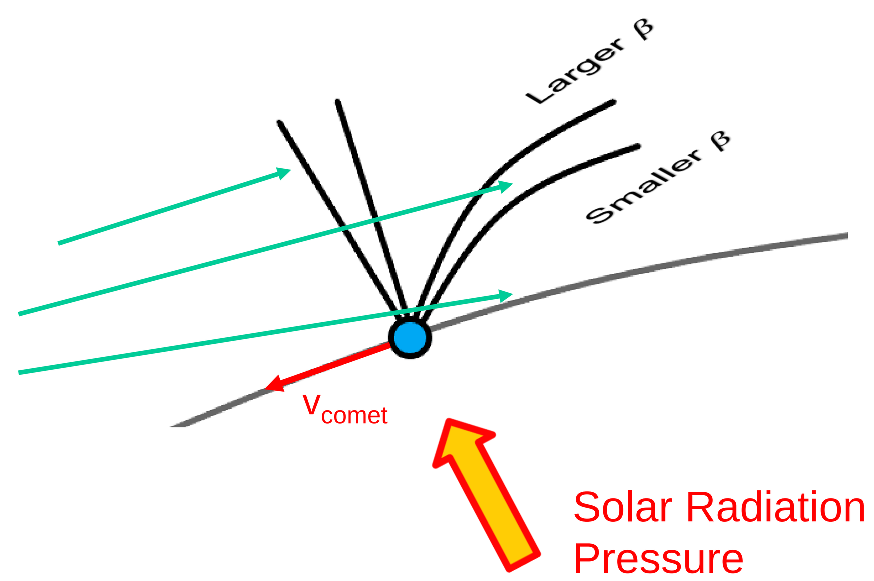

Figure 3: Solar radiation pressure separates comet dust particles by β.

Candidate search

The concentrated occurrence in time indicate a common source for the dust impacts during the events. Comets are a prime dust source candidate, therefore a full search of the existing known comets (3777 unique comets) in NASA JPL's Small-Body Database, was conducted, investigating when Juno crossed comet orbit planes in close vicinity to the comet. The resulting candidates are shown in Figure 5. The orbit of comet P/2019 S3 (PANSTARRS) is crossed at the time of observation and happens in a favorable geometry).

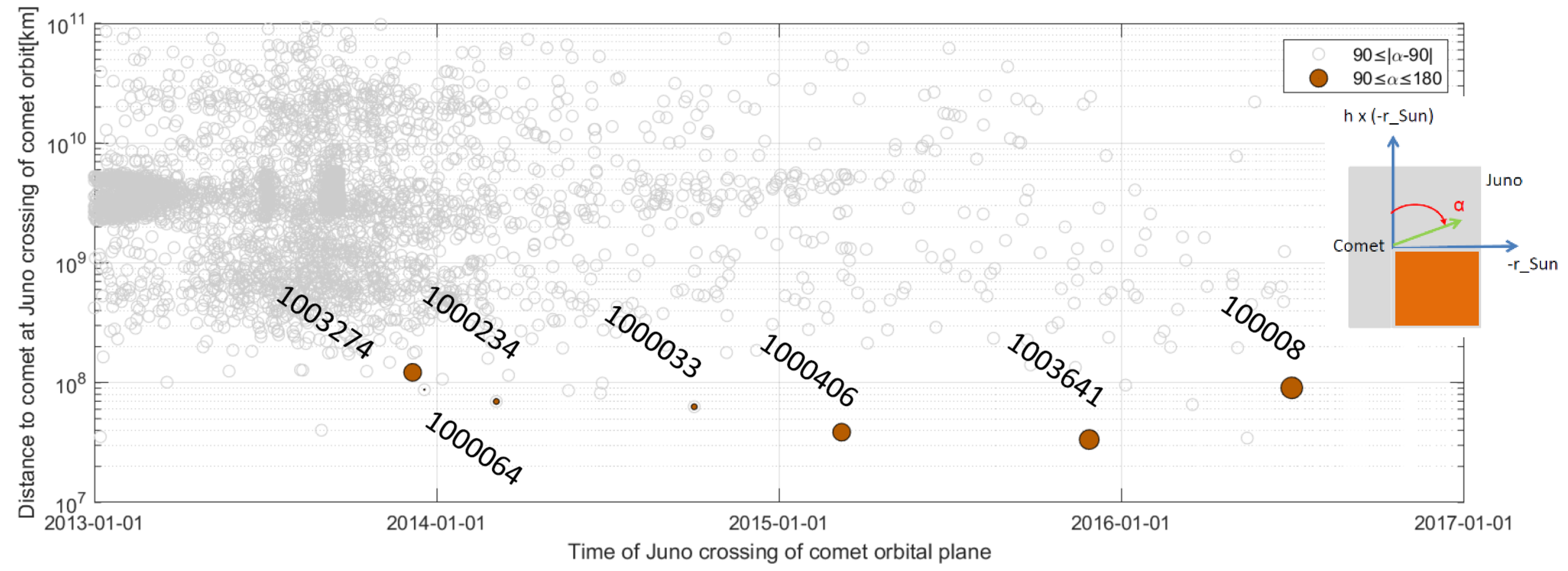

Figure 5: Candidate search. For each comet in NASA JPL SBD the points show the time of Juno's crossing of the comet orbit plane along with the distance to the comet at this time. Candidates must be close and have correct geometry in order for the dust to reach Juno.

Dust Particle Simulations

To understand the dynamics and search for the basic parameters of the detected dust particles, dynamic simulation [Pines 1961] of the dust from release at the comet to detection at Juno is conducted. Forces included are Solar and planetary gravitation, Solar Radiation pressure.

The simulation shows the dust arriving at Juno around the time of observation, with a variation in arrival time based on the combination of beta value and ejection velocity from the comet.

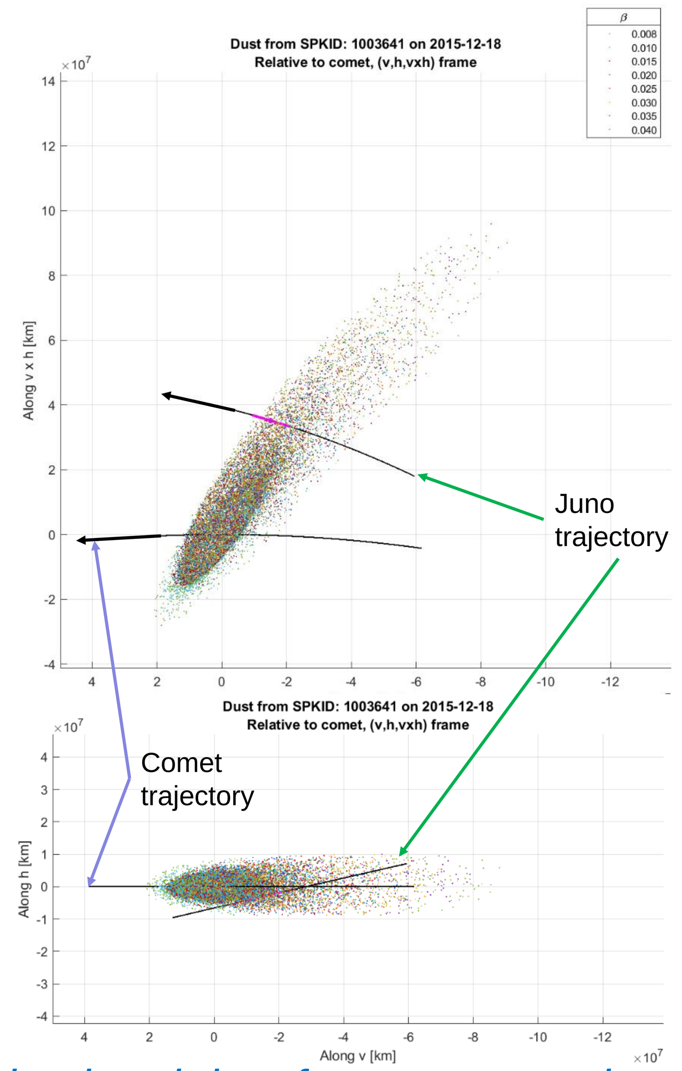

Figure 7: Simulated dust from comet at the time of observation by Juno microASC

References

Benn et al 2017, *Observations of interplanetary dust by the Juno magnetometer investigation*, GRL, doi.org/10.1002/2017GL073186

Jorgensen et al 2020, *Distribution of Interplanetary Dust Detected by the Juno Spacecraft and Its Contribution to the Zodiacal Light*, JGR Planets, doi.org/10.1029/2020JE006509.

Pines 1961, *Variation of Parameters for Elliptic and Near Circular Orbits*, The Astronomical Journal, Vol 66, number 1, p 5-7, 1961

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