THE SUN'S DUST DISK – DISCOVERY POTENTIAL OF THE NEW HORIZONS MISSION DURING INTERPLANETARY CRUISE. M. Landgraf, *ESA/ESOC, Robert-Bosch-Strasse 5, 64293 Darmstadt, Germany (Markus.Landgraf@esa.int).*

1 Introduction

When the Pioneer 10 spacecraft entered the interplanetary space beyond Jupiter's orbit, it detected an almost constant flux of impacts by dust particles (Humes, 1980) larger than $10\ \mu m$. This was unexpected, as the dust from comets, which were the only potential sources of dust known at the time, is believed to be less concentrated at larger heliocentric distances. At the time, an exotic distribution of cometary orbits had to be introduced in order to explain the Pioneer data. Dust from outside the solar system can not explain the constant flux detected by the Pioneer experiments, because the interstellar flux of dust particles large enough to be detectable by the Pioneer instruments is at least an order of magnitude lower than the detected flux (Landgraf *et al.* , 2000). The discovery of objects in the Edgeworth-Kuiper belt (EKB) (Jewitt & Luu, 1993) offered the possibility for another dust source: The objects in the EKB should produce dust by mutual collisions and by collisions with interstellar dust particles (Yamamoto & Mukai, 1998), forming a disk of dust around the Sun. Modelling the evolution of the orbits of dust grains from the EKB Landgraf *et al.* (2002) showed, that indeed the Pioneer data can only be explained by dust migrating in from the EKB under the influence of the Poynting-Robertson drag.

Unfortunately the Pioneer dust measurements extend only to a heliocentric distance of $18\ AU$, where the instrument ceased function. Consequently, Pioneer detected merely the inner edge of the solar system dust disk. Here the question arises, what the radial density profile of the solar system dust disk is and what processes govern the evolution of the dust grains after the release from the parent body. Because we do not know the collisional lifetime of dust grains from the EKB, it is unclear, what fraction of EKB dust grains survives the evolution to inside the orbit of Uranus, where Pioneer 10 made its far most measurements. We present a prediction of the dust detection rate of the planned New Horizons mission using the same model that was employed to analyse the Pioneer data. We show what the signature of different dust lifetimes will be in the data collected by this mission.

2 Modelling the Solar System Dust Disk

The evolution of a dust grain released by an EKB object depends mainly on two parameters: it's collisional lifetime, and its susceptibility to solar radiation pressure, which is parameterised by the constant ratio β of radiation pressure force to gravity. Here we assume values of β of 0.03, 0.08, 0.2, and 0.5. The value of β is mainly controlled by the grain size (van de Hulst, 1957). Assuming a homogeneous spherical grain with a bulk mass density of $1\,g\,cm^{-3}$, the value $\beta = 0.03$ corresponds to a grain diameter of $16\ \mu m$, $\beta = 0.08$ to a diameter of $6\ \mu m$, $\beta = 0.2$ to a diameter of $3\ \mu m$, and $\beta = 0.5$ to a diameter of $1\ \mu m$. For the sources of the dust grains we assume all 420 trans-Neptunian objects listed with the Minor Planet Center of the IAU that have been observed at more than one opposition. Upon release the dust grains acquire orbits different from those of their parent bodies due to the effect of solar radiation pressure (Kresak, 1976).

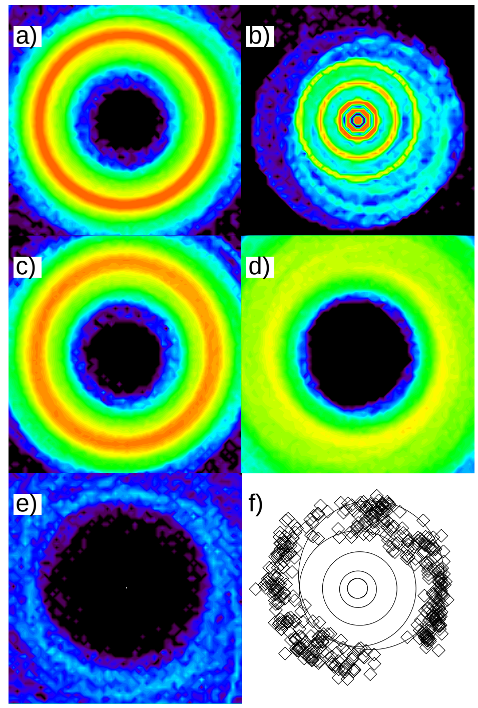

Figure 1: Spatial density distribution of dust from EKB objects (normalised logarithmic colour scale: blue=0.001, red=1) in a $120\,AU \times 120\,AU$ sub-plane of the ecliptic. Panels a), c), d), and e) show the distribution of grains with $\beta = 0.03$, 0.08, 0.2, and 0.5 respectively for a collisional lifetime of $10^6\ a$. In panel b) the distribution for grains with $\beta = 0.03$ is shown if no collisions are considered. Panel f) shows the orbits of Jupiter, Saturn, Uranus, Neptune, and Pluto, and the positions of EKB objects predicted for the epoch of the planned fly-by of Pluto by the New Horizons mission in 2016.

The grain's orbits evolve under the effect of the Poynting-Robertson drag towards the inner solar system (Liou *et al.* , 1996). On the way inwards they can be trapped in mean motion resonances (MMRs), or can be destroyed by a collision with an interstellar or another EKB dust grain. Using the same method as Liou *et al.* (1996) we have simulated the evolution of grains with $\beta = 0.03$ for a lifetime of 1×10^6 years. In order to determine the effects of the frequency of grain destruction by collisions on the distribution of dust in the disk we simulate grains with $\beta = 0.03$ from one representative source object without considering collisions. In this case the end of life of the dust grains is determined by ejection from the solar system by a close encounter with a giant planet or by falling into the Sun. Figure 1 shows the spatial density distributions for the different values of β and also for the case without collisions.

The simulation shows that the larger grains (with smaller values of β) are concentrated in a ring near the source region. For larger values of β the disk becomes more extended and distributed with lower peak densities. This is because the grains with higher β exhibit high eccentricities and large semi-major axes (typically $150\ AU$ for $\beta = 0.5$) immediately after their release. If there were no collisions even these grains would ultimatively circle towards the Sun. The case without collisions (figure 1 b)) demonstrates this effect. The inner solar system is well populated, especially MMRs with the giant planets, which show up as concentric rings in the figure.

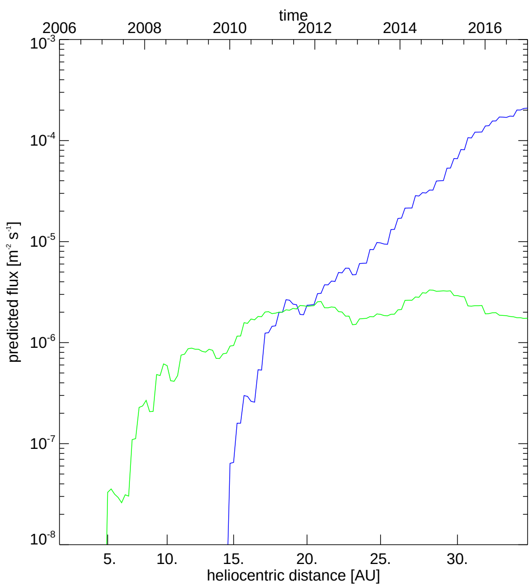

Figure 2: Prediction of impactor flux (normalised) onto the dust instrument of the New Horizons mission. The blue curve shows the prediction for dust grains with $\beta = 0.03$ and a collisional lifetime of $10^6\ a$, and the green curve for grains with $\beta = 0.03$ that are not subject to collisional destruction.

3 Prediction of Impact Flux for New Horizons

It is planned to launch New Horizons in early 2006 on a high-energy trajectory towards Jupiter. The fly-by of Jupiter will send the spacecraft onto an almost radial trajectory towards Pluto, the fly-by of which will then occur in 2016. Here we assume that the target area of the dust instrument is mounted on the side of the spacecraft opposite to the main antenna, which is assumed to point towards the Sun. The simulation described above allows us to determine the flux vector of dust from the Kuiper belt relative to the sensitive target area along the spacecraft's trajectory. The resulting impactor flux can thus be predicted as a function of time and heliocentric distance. In order to fix the absolute value of the dust concentration we scale the prediction so that the flux of grains with $\beta = 0.03$ (larger than $16\ \mu m$) at $18\ AU$ is $2 \times 10^-6\ m^{-2}\ s^{-1}$ as was measured by Pioneer 10. The prediction shown in figure 2 shows that the profiles of the dust flux curves depend strongly on the collisional lifetimes of the grains. For the case with no collisions (or collisional lifetime longer than the Poynting-Robertson lifetime) the flux curve remains relatively flat outside the orbit of Uranus. In the case where collisions lead to a destruction of the grain after, on average, 10^6 years, the predicted flux increases steeply with heliocentric distance.

4 Conclusion

We have simulated the evolution of the distribution of cosmic dust generated by EKB objects using realistic initial orbits and considering various values for the strength of radiation pressure and the collisional lifetime. The simulation together with the measurements of dust by the Pioneer spacecraft allows a prediction of the expected impactor flux on the future New Horizons mission.

New Horizons will be able to distinguish two different kinds of dust evolution in the EKB: driven by collisions or orbit migration under Poynting-Robertson drag. The main unknown here is the rate of collisions with interstellar dust particles. If not collisions but Poynting-Robertson dominate the evolution of EKB dust, the dust flux measured by New Horizons beyond $20\ AU$ can be expected to be constant at the level that was measured by Pioneer 10. If, on the other hand, the flux of interstellar dust grains larger than $1\ \mu m$ is $10^{-4}\ m^{-2}\ s^{-1}$ in the outer solar system, equal to the flux measured by the Ulysses mission (Grün *et al.* , 1994) inside the orbit of Jupiter, then the average collision rate on a EKB dust grain with a diameter of $16\ \mu m$ is about one every 10^6 years. The curve in figure 2 shows that the dust population detected by Pioneer 10 at a heliocentric distance of $18\ AU$ is then merely a tiny fraction of the dust that is more abundant by two orders of magnitude outside $30\ AU$, closer to its sources. In that case New Horizons can expect to find a very high flux of more than $10^{-4}\ m^{-2}\ s^{-1}$, or about 10 hits per day for each square meter of sensitive area.

References

GRÜN, E., ET AL., 1994. *A&A*, **286**, 915–924.
HUMES, D. H. 1980. *JGR*, **85**(A/II), 5841–5852.
JEWITT, ET AL. 1993. *Nature*, **362**, 730–732.
KRESAK, L. 1976. *Bull. Astronom. Inst. Czech.*, **27**, 35–46.
LANDGRAF, M., ET AL. 2000. *JGR*, **105**(A5), 10343–10352.
LANDGRAF, M., ET AL. 2002. *AJ*, **123**(5), 2857–2862.
LIOU, J.-C., ET AL. 1996. *Icarus*, **124**, 429–440.
VAN DE HULST, H. C. 1957.*Light scattering by small particles*. Dover Publications Inc., New York.
YAMAMOTO, S., & MUKAI, T. 1998. *A&A*, **329**, 785–791.