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Constraints on the Kuiper belt dust in the outer Solar System

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Abstract

The Edgeworth-Kuiper belt (EKB) and its presumed dusty debris are a natural reference for extrasolar debris disks. The dust in the EKB cannot be seen directly due to the strong foreground emission of the zodiacal cloud but in-situ measurements show that dust is present in the outer solar system. To model the dust distribution we take advantage of the knowledge of the parent bodies of dust, namely the transneptunian objects (TNOs). On the base of [8] we generate the dust with our collisional code to determine the radial and size distribution of the dust using a 50% ice and 50% astrosilicate composition of the particles. In addition we included a simple estimation of the influence of the three outermost planets and sublimation. To calibrate our model we used the in-situ measurements of the New Horizons dust counter [7]. It is shown that the influence of the planets and sublimation on the spectral energy distribution is very small. Our model can reproduce the in-situ measurements the New Horizons and is roughly consistent with the upper limit on the thermal emission flux from the COBE spacecraft [1].

1. Introduction

The Edgeworth-Kuiper Belt (EKB) is the main reservoir of small bodies and dust in the Solar System and constitutes the most prominent part of the Solar System's debris disk. However, the EKB dust has not been unambiguously detected so far. The observational evidence for the EKB dust is limited to scarce in-situ detections of dust in the outer solar system by a few spacecraft, partly with uncalibrated "chance detectors" [2, 6, 7]. Given the lack of observational data, one can only access the properties of the EKB dust by modeling. Such a modeling takes the known EKB populations to be parent bodies for dust and uses collisional models to generate dust distributions. A detailed description of our model and assumed properties of the particles are described in Vitense et al. 2011, in prep.

2. Dust production model

To model the dust produced by the TNOs we populated the EKB with a debiased population of known TNOs, as described in [8]. That population is likely to be nearly complete down to sizes of $\sim 10\,\mathrm{km}$. We assumed that our modeled EKB was entirely devoid of sub-kilometer objects and, in particular, that no dust was present. Since this assumption is obviously unrealistic, we let our collisional code *ACE* (*Analysis of Collisional Evolution*) ([4] , and references therein). run over a timescale that was long enough for the population of large bodies to generate sufficient amount of smaller debris down to dust sizes. Data of the New Horizons dust counter [7] were used to determine that timescale and thus served as a calibrator for our simulations.

3. Planets and sublimation

An important force for small particles is the Poynting-Robertson drag which forces particles to migrate inward. Eventually they have to pass the orbits of the planets where they run the risk of being scattered. To determine the survival rate, we used a numerical code that simulates the orbital evolution of a single particle when including the gravity of planets as well as the stellar wind and Poynting-Robertson drag. Small dust particles can also suffer sublimation. The thermal interaction of dust grains with the solar radiation was investigated [3]. When the assumed 50% ice and 50% astrosilicate particles reach their sublimation distance of $8\,\mathrm{AU} \ldots 16\,\mathrm{AU}$, the fraction of ice in the grains will evaporate and the particle will end as an astrosilicate grain that has half the volume of the original particle. The changes of the number density and in mass and size were included in the radial and size distribution of our model.

4. In-situ measurements and SED

The measurements of the dust counter on board the New Horizons spacecraft indicate dust fluxes up to

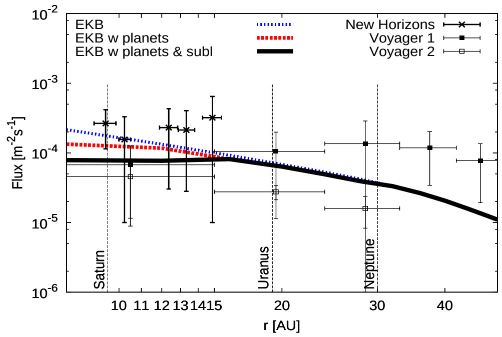

Figure 1: Simulated dust flux and in-situ measurements by New Horizons [7] and Voyager 1 and 2 [2].

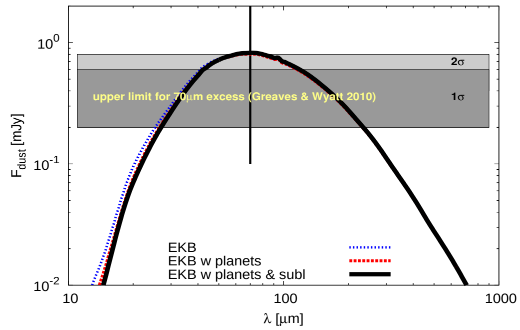

Figure 2: Spectral energy distribution of the EKB as seen from 10 pc. The black solid line is the final result after applying the effects of planets and sublimation.

$1.56 \times 10^{-4}\,\mathrm{m}^{-2}\mathrm{s}^{-1}$ [7] between Saturn and Uranus for $m > 10^{-12}$ g. Including our results of Section 3 we calculated the dust fluxes for the EKB without and with planets and sublimation. The influence of planets and sublimation on the dust flux is minor (Fig. 1).

We used the NextGen grid models for a G2V-star and the procedure of [5] to calculate the spectral energy distribution (SED) of the EKB that would be seen from a distance of 10 pc. The final SED is shown in Fig. 2. It can be seen that planets and sublimation marginally affect the result.

5. Summary and Conclusions

We developed a self-consistent model of the EKB debris disk, in which we modeled the collisional behavior of the TNOs, the influence of the Poynting-Robertson drag (including stellar wind drag), the dust scattering by the three outer planets and the effect of sublimation. Our model can reproduce the in-situ measurements the New Horizons and is roughly consistent with the upper limit on the thermal emission flux from the COBE measurements [1].

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