# ORBITAL EVOLUTION OF MICRON-SIZED DUST GRAINS COMING FROM THE KUIPER BELT;

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Since the discovery of the first trans-Neptune object [1,2] and the still ongoing discoveries of such objects, it has been proposed that micron-sized dust particles produced from those so-called "Kuiper belt objects" may contribute significantly to the interplanetary dust population that constitutes the zodiacal cloud [3]. We report here preliminary results from numerical calculations of the orbital evolution of such dust particles. Due to Poynting-Robertson (PR) drag and solar wind drag, micron-sized dust particles will spiral toward the Sun once they are released from their large parent bodies. This motion leads dust particles to pass by planets as well as encounter numerous mean motions resonances (MMRs) associated with planets. Trapping into exterior MMRs with Neptune and, to a lesser extent, Uranus dominates the orbital evolution of those particles. Gravitational scattering by Saturn or Jupiter usually controls their final fate. Sixteen out of twenty particles in our numerical modeling eventually were scattered out of the Solar System. The remaining four particles were able to complete their journeys all the way to the Sun.

**Methods:** We assume dust particles are released (with zero relative velocity) from parent bodies located at 45 AU, with proper eccentricities and inclinations equal to 0.1 and 10°, respectively. The initial forced elements are calculated by the secular perturbation theory [4] using the osculating orbital elements of 7 planets (we exclude Mercury and Pluto). The initial proper longitudes of ascending node, proper longitudes of the pericenter, and the mean longitudes of dust particles (before they left their parent bodies) are each randomly chosen between 0° and 360° to simulate their collisional origin. The forced and proper orbital elements are combined to form the initial osculating orbital elements of the parent bodies. The ratio of radiation pressure force to solar gravitational force acting on a dust particle, $\beta$, is set equal to 0.1, corresponding to spherical particles 4 $\mu$m in diameter with material density 3 g cm$^{-3}$ [5]. Solar wind drag is assumed to be 35% that of the PR drag. The equations of motion of 7 planets, which gravitationally interact with one another, and 20 dust particles are integrated by the implicit Runge-Kutta integrator, RADAU [6], on an HP 9000 715/75 workstation.

**Results and Discussion:** To summarize: (1) Dust grains spend much of their evolutionary history trapped in one or another of the exterior MMRs with Neptune or Uranus. All particles are trapped in at least one of those resonances for many millions of years. The consequence of this is the formation of dust rings like the ring of dust of asteroidal origin near the Earth's orbit [7,8]. All particles eventually get out of the resonances through close encounters with Neptune or Uranus and continue their journey toward the Sun. (2) Gravitational scattering by either Saturn or Jupiter usually dominates the final destiny of dust particles. Among all twenty particles, one was ejected by Neptune, eight by Saturn, and seven by Jupiter. (3) A significant fraction of the particles (the remaining 4 particles, or, 20% of our sample) were able to pass by Saturn and Jupiter and make their journey all the way to the Sun.

The PR drag life time [4] of our test particles, with no planets, is about 7 million years. However, their actual lifetimes (Fig. 1) are longer than that, due to the trapping process. The evolution in semimajor axis of one typical particle is shown in Fig. 2. This particle started its

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journey from about 51 AU (the effect of solar radiation pressure force increases the semimajor axis of a dust particle upon its release from the parent body). It passed through several exterior MMR locations with Neptune and one Laplace resonance location with Neptune and Uranus before it was trapped in the 4:3 MMR with Neptune for about 7.8 million years. After it escaped the resonance via close encounters with Neptune, it was trapped briefly in the 6:5 and 1:1 MMRs with Neptune, a 5:3 MMR with Uranus, and a 2:1 MMR with Saturn. When this particle was removed from the last resonance, close encounters with Saturn eventually made the particle's orbit hyperbolic, ejecting it out of the Solar System.

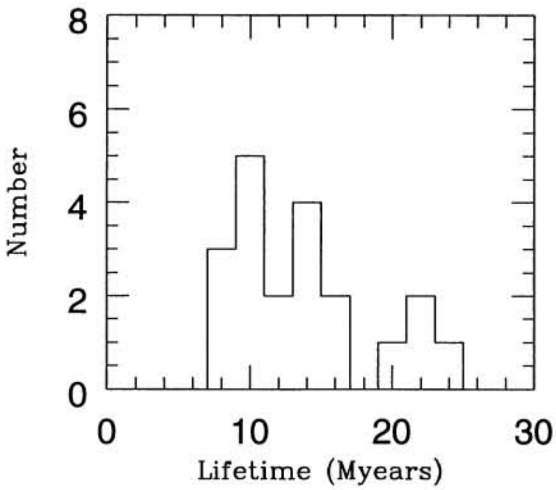


Fig. 1

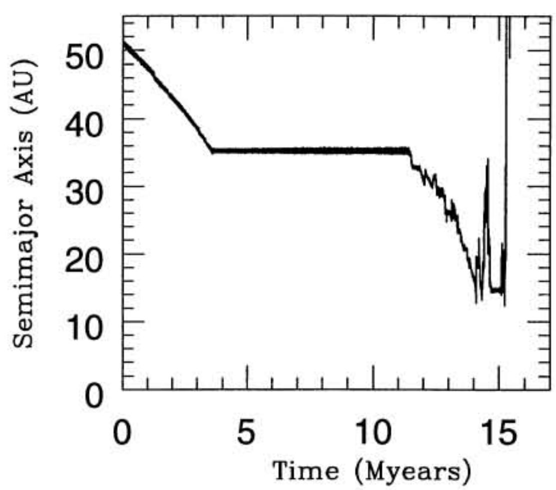


Fig. 2

The four particles that were able to pass by Saturn and Jupiter had small eccentricities (~0.2) and inclinations (~15°) when they approached the Earth. This makes them behave more like asteroidal than cometary-type particles. Our dynamical study has not yet determined whether these Kuiper belt dust particles play a significant role in interplanetary space. Our study does show, however, that a fraction of them are capable of evolving toward the inner part of the Solar System. In order to determine their abundance in interplanetary space, two additional questions must be answered: (1) What is the dust production rate in the region of the Kuiper belt?, and (2) What is the collisional lifetime of those dust particles when interstellar dust grains are considered?

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