A SOLAR SYSTEM DUST RING: THE EARTH AS ITS SHEPHERD

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We have studied the problem of dust particles with low inclinations and eccentricities approaching the earth under the action of Poynting-Robertson (PR) drag and the gravitational influence of the earth. These particles have been shown to undergo a set of complex motions [1,2]. As pointed out by Greenberg [3] and Weidenschilling and Davis [4] particles experiencing a dissipative force with a decaying orbit can be trapped in an orbit resonant with the more massive perturbing body.

Our method was to calculate explicitly by a numerical method the evolving orbits of particles in the size range of 10 to 100 microns. The three dimensional elliptic three body motion with radiation pressure and Poynting-Robertson drag, are integrated with the implicit Runge-Kutta procedure of Everhart using Gauss-Radau spacings [5]. The particles are taken to be idealized spheres with the optical property that they are black body absorbers.

The results of numerical orbit evolution for a 30 and a 60 micron particle are respectively displayed in Figure 1 and Figure 2. Plotted here are the semi-major axis(in AU) and eccentricity of the particle versus time in Julian centuries. The particles were started at 1.5 AU with orbital eccentricity of zero. It is evident that after an initial slow decay under PR drag orbital evolution for the 30 micron particle stops roughly in a 7:8 resonance at 1.08 AU for about 20,000 years . The 60 micron particle stops at a 5:6 resonace for about 90,000 years. While the semimajor axis oscillates with small amplitude the eccentricity is forced to slow growth by the resonance until after some time the resonance is broken. The length of trapping and its location depend on the size of the particle. It is interesting to note that the 30 micron particle is briefly stoped in a resonance just inside the earth's orbit.

Consider particles initially in the dust bands seen by IRAS[6]. As the particles evolve under PR (and plasma) drag their orbits will tend to circularize. Many low inclination particles will approach the earth on near circular orbits and be trapped in resonance for a period of time. This phenomena will give rise to a concentration of particles at the resonances with the earth and hence ring of dust near one astronomical unit.

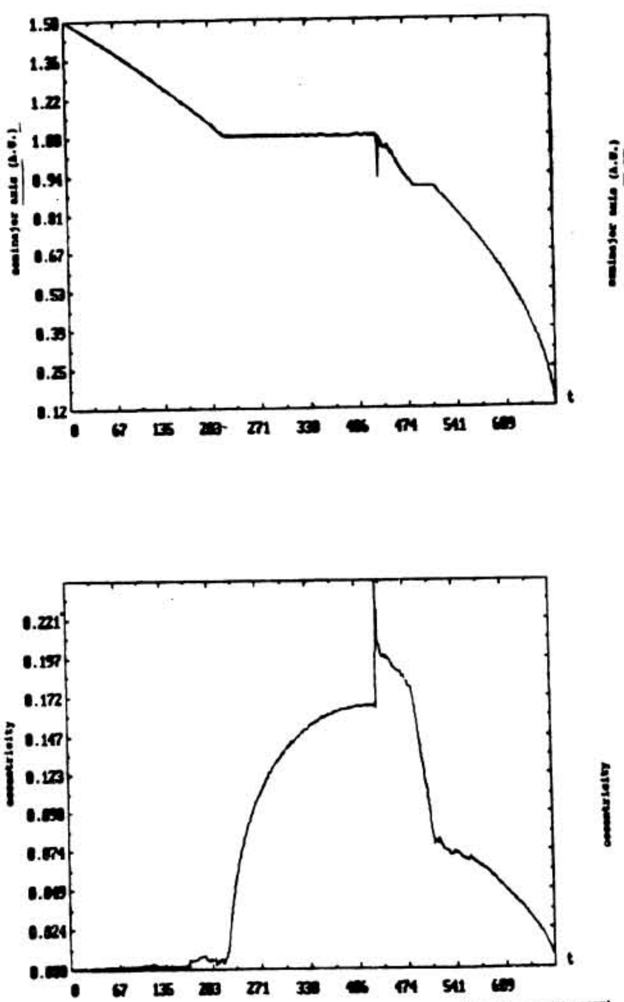
The question now arises as to whether or not any observational evidence exists for a dust ring that we deduce should be near the orbit of the earth. Zodiacal light studies have not , as yet, reported any such evidence [7,8]. But it is possible that the low intensity narrow ring near the Earth would not be easily detected by the Helios spacecraft zodiacal light photometers , as they do not observe along the ecliptic plane [7]. There may, however be some significance in the fact that the zodiacal light brightness within 1 AU varies as r to the -1.3 power [7] while it varies as -1.5 outside of 1 AU [8]. A dust ring near the earth might give rise to such a result.

Another piece of evidence derives from the measurements of beta-meteoroids taken by the Pioneer 8 and 9 spacecraft. Zook [9] noted from the beta-meteoroid measurements that the parent meteroid spatial density must be increasing with increasing heliocentric distance near one AU rather than decreasing as would be the case for a particle distribution resulting from the influence of PR drag only. A dust ring that peaks in spatial density just outside the orbit of the earth could give rise to such a result. Whipple [10] noted that most beta meteroids observed at 1 AU must have been created outside of 0.5 AU in order to give the azimuthally observed distribution of beta-meteroids. This is consistent with Zook's observations.

Dust Ring
Jackson and Zook

In summary , although there does not appear to be any definitive observational evidence for a dust ring near the earth there are theoretical reasons to expect such a ring near the earth . The spatial density in the ring , compared to the nearby meteortic complex is not yet known.

References:[1]Gustafson, B., and Misconi,(1986) N.Y.,Icarus,v66,280 [2]Jackson, A.(1987),presented at Cosmic Dust Collection Facility Workshop,Carmel in press,
[3]Greenberg,R,(1978)Icarus,v33,62.[4]Weidenschilling,S.andDavis,D.,Icarus, [5]Everhart,E.(1985)Dynamics of Comets(Carusi and Valsecchi,eds),185-202.[6] Low,.et al. (1984), Astrophys. J., 278, 119 [7] Leinert, L. et. al.,(1981) Astro. and Astrop. , 103, 177. [8] Hanner, M., et.al., (1976) Interplanetary Dust and Zodical Light,p.29-35 (H. Elsasser and H. Fechtig, Eds.). [9] Zook, H. (1975) Planet Space Sci. 23, 1391. [10]Whipple, F. (1976) Interplanetary Dust and Zodical Light (H. Elasser and H. Fechtig, Eds.),p 403 - 415.



(Time is per 100 years)

Figure 1. From the trajectory of a 30 micron particle started at 1.5 A.U.

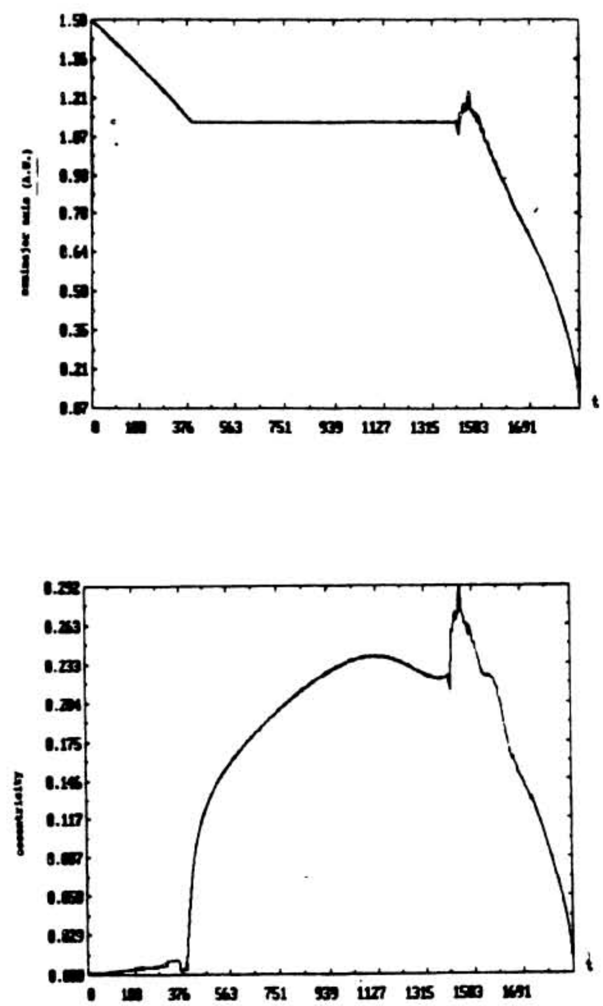


Figure 2. From the trajectory of a 40 micron particle started at 1.5 A.U.