RESONANCE TRAPPING OF COMET AND ASTEROID DUST PARTICLES BY THE EARTH AND MARS

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We recently discovered the existence of,and have described certain features of, orbit-orbit resonance trapping of dust grains by the earth. The dust particles were assumed to range from 10 to 100 microns in radii moving under gravitational, radiation and solar wind forces [1,2]. Analysis has been extended to new initial orbits with the same size particles. We have numerically integrated the motion of particles from comet Encke and from asteroids that may give rise to the interesting IRAS (Infrared Astronomical Satellite) dust bands such as those described by Dermot, et. al. [3]. We also examine some new consequences of the resonance trapping phenomenon.

For the calculations two kinds of computation have been made. In one scheme the equations of motion in inertial cartesian coordinates are solved as a Cowell formulation, with the planets propagated in Keplerian orbits. The other formulation is for three bodies in a frame that rotates with the orbit of the perturbing body. In both cases the implicit Runge-Kutta integrator with the Gauss-Radau spacing of Edgar Everhart [4] is used. The particle is assumed to be a spherical back body of density 1 gm/cc subject to gravitational forces, pressure due to radiation, and drag due to solar wind and the Poynting-Robertson effect [5].

The first case to be reported here is shown in figure 1. A 60 micron particle started with initial zero relative velocity at asteroid Koronis (initial semimajor axis, a = 2.9 a.u., eccentricity, e = .06 and inclination, i = 1.0 degrees, note that q and Q label perihelion and aphelion respectively). The orbital history was followed for nearly 300,000 years. The gravitational perturbers are Jupiter, Mars, Earth, and Venus. In its passage through various gravitational regimes it undergoes resonance trapping at Mars, the Earth and at Venus. Trapping resonances usually occurs with dust-planet orbital period ratio of the type $j/(j+1)$ (where j is an integer).In Fig 1 these are respectively , Mars 9/10, the earth 2/3, and Venus 7/8. The surprising feature is the resonance trap at Mars. In many earlier simulations of orbital decay from the asteroid belt we had not seen such a resonance.

Figure 2 displays the corresponding time history of a 100 micron particle from comet Encke. The particle was released at perihelion from Encke's orbit (a = 2.21 a.u., e = .847, i = 12.4 degrees), with zero relative velocity. It moves under the gravitational influence of Jupiter, Mars, Earth and Venus. Its history is followed for 55,000 years. Initial radiation pressure moves the particle's aphelion, after release, out to about 4.5 au. It's semimajor axis shrinks smoothly to near the earth's orbit where it is trapped at almost exactly one a.u., for 10,000 years. Examination of its motion in a coordinate frame rotating with the earth, in figure 3. , shows that the particle is snared into a one - one resonance with the earth. The particle moves in the bean-shaped curve around the earth in a clockwise sense while the curve librates slowly in a counterclockwise sense.

An important facet of this capture of a particle from comet Encke is that the eccentricity and inclination at the time of capture were .75 and 10 degrees respectively. While the eccentricity decreased a small amount during capture, the particles inclination remained almost constant.

As a continuation of the work as described in Jackson and Zook [1,2] we plot in figure 4 the time history, in a coordinate system rotating with the earth, of a thirty micron radius particle evolving in a resonance capture with the earth. A three body orbit propagation suffices here to show important features of the motion. This simulates the capture of many particles with ascending nodes uniformly distributed in heliocentric longitude. The resulting pattern is always the same. The particle falls into resonance such that the points form a lobe pattern which librates. The earth however is always in a trough of the lobes. Thus there would be a longitudinal variation in spatial density, relative to the earth's position, as projected onto the plane of its orbit.

In summary we see several important new phenomena associated with resonance trapping of dust particles. (1) It is possible for Mars to trap particles into orbit-orbit resonance. (2) Dust particles in highly eccentric orbits from comets can sometimes be trapped into resonance with a planet. (3) Particles trapped into resonance with the earth will display a longitudinal dependence in density as viewed from the earth.

[1] Jackson, A. A. and Zook, H.A. , Lunar and Planetary Science XIX, 539-540, Lunar and Planetary Institute, Houston (1988)
[2] Jackson, A. A. and Zook, H.A., in press Nature, (1989).
[3] Dermot , S.F., Nicholson, P.D., Burns, J.A., and Houck, J.R., Nature, 312, 505-509, (1984)
[4] Everhart, E. Dynamics of Comets: Their Origin and Evolution,(eds. Carusi, A. and Valsecci, G.B.) 185 - 202 (D. Reidell , Dordrecht, Holland, 1985)
[5]Burns, J.A. , Lamy, P.L., and Soter, S. , Icarus, 40, 1-48 (1979)

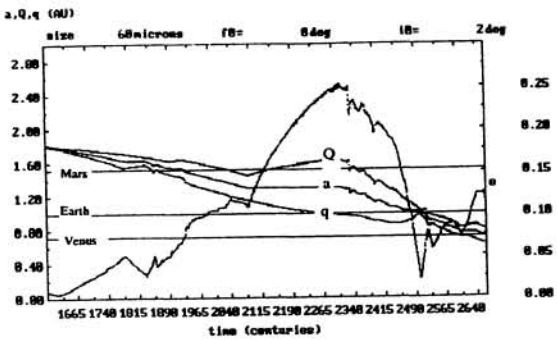

Fig. 1. Time history of a 60 micron particle started from orbit of asteroid Kornois. Semimajor axis , a, aphelion Q and perhelion q are in A.U..

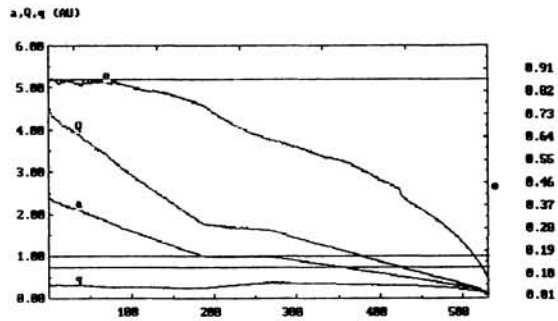

Fig. 2. Time history of a 100 micron particle released with zero relative velocity from comet Encke.

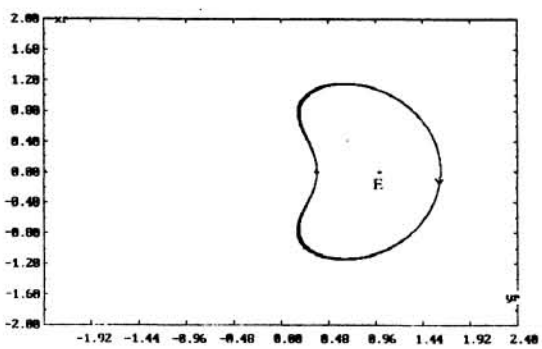

Fig. 3. For the particle in fig. 2 a relative motion plot of the orbit in a frame rotating with the orbital angular motion of the earth. The X and Y axes are in units of A.U. The location of the earth is at E (1,0) and the sun is at (0,0).

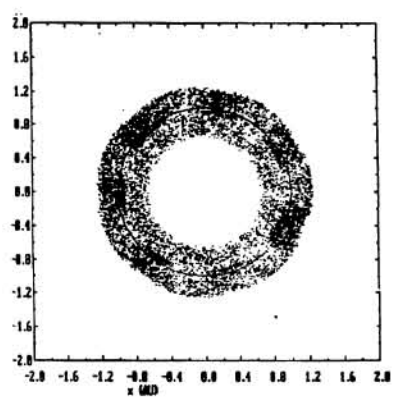

Fig. 4 A 30 micron particle trapped in resonance with the earth , 1000 points of its time history 2.77 years apart. The earth is located at (1,0) and the sun at (0,0).