DUST PARTICLES IN THE JOVIAN SYSTEM. Herbert A. Zook, NASA Johnson
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The rate of penetration of the meteoroid detector panels on the Pioneer
10 and Pioneer 11 (P-10, P-11) spacecraft increased by a factor of nearly 10^ over the nearby interplanetary background rate when these spacecraft flew by
Jupiter (1,2,3). A difficulty arises when one attempts to solely ascribe
this increase in penetration rate to a near-Jupiter gravitational enhancement
of the flux of interplanetary meteoroids. That is, to match a near-Jovian
gravitational enhancement with the observed flux, interplanetary meteoroids
must either be in near-circular, low inclination orbits, or the size distri-
bution of meteoroids must be very steep (with numerous small meteoroids) at 5
AU. The experimental evidence (2,3) indicates that neither condition can be
strictly true. An alternative is to postulate that a cloud of meteoritic
particles are in orbit about Jupiter and that they caused the observed in-
crease in penetration rate. We have studied this latter possibility in some
detail and now summarize some of our results here.

The orbital and size distribution of the eight outer moons of Jupiter (4
in prograde and 4 in retrograde orbits) are consistent with them being the
largest remaining fragments of a previous collision history (e.g., 4). It is
also reasonable to assume that this collision history produced a large but
unobserved population of smaller objects in both prograde and retrograde Jo-
vian orbits. Under interplanetary meteoritic erosion and under mutual col-
lisions with each other, a cloud of micrometer to millimeter sized particles
is postulated to be continuously created from the suggested population of
larger particles. The small particles then drift, under Poynting-Robertson
drag, toward Jupiter. When particles from this cloud reach the Jovian mag-
etosphere at about 100 R (Jovian radii), we find that the plasma ion den-
sity (5) and average plasma atomic weight (6) are such that the co-rotating
magnetospheric plasma drag will dominate P-R drag. Particles in prograde
Jovian orbits will drift no closer to Jupiter but, instead, will increase
their apojoves until it is probable that they escape the Jovian system. Particles in retrograde orbits will have their inward drift velocities in-
creased. Figure 1 shows the drift velocities, under both P-R and plasma
drag, of particles of radius 5 μm whose initial orbits are circular but whose
semi-major axes and inclinations are those of the 4 retrograde Jovian moons.
The inward drift velocity is given in km/s. Plasma drag also acts to lower
the orbit inclination with time. This effect is shown in Figure 2 where or-
bital inclination is plotted versus jovicentric distance for particles in
retrograde orbit. The particle trajectories progress to the left with time.
If the initial inclination is less than about 150° the particles will evolve
into prograde orbits and then expand orbital dimensions. They then progress
away from, rather than toward, Jupiter.

We find that under reasonable assumptions that the 4 retrograde moons
and associated fragments are able to produce enough small particles to ac-
count for the magnitude of the P-10 and P-11 results. This expectation in-
cludes an analysis of the rate of destruction of these particles by col-
lisions with the Galilean moons while the particles drift toward Jupiter.
However, our theoretical results also show that P-10 spacecraft should be
penetrated at a rate 5 to 10 times higher on the approaching leg of the
Jupiter swingby than on the receding leg. This appears to be contrary to the
actual observation that there was little difference between the number of
penetrations during each leg of the swingby. Thus we have the dilemma that
neither the interplanetary meteoroid population nor debris from the outer
Jovian moons can be clearly demonstrated to be responsible for the P-10 pene-
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The data are too limited to provide good statistics, however. There remains the possibility that particles from Amalthea, 1979J2, and possible associated debris could be responsible. The latter possibility would seem to require electromagnetic scattering of the particles out of the Jovian equatorial plane.

References:

Fig. 1: Inward drift velocity vs. Jovicentric distance for particles of radius = 5 μm (ρ = 3 g/cm³)

Fig. 2: Jovicentric orbit inclination vs. Jovicentric distance. Particles evolve to lower left from upper right with time.

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