ON THE STABILITY OF "METEORITE SWARMS" IN RESONANT ORBITS - A PRELIMINARY STUDY; J. Oberst, Institute for Geophysics, The University of Texas at Austin, Austin, Texas 78751.

Introduction. Meteorite falls are commonly believed to occur as solitaires. This is mainly because our observational data on the temporal distribution of meteorite falls show no clear evidence for the presence of "meteorite streams", groups of meteorites having similar orbital elements a, e, i, Ω, and ω. However, this apparent lack of grouping may be because these observational data are strongly biased.

Further evidence for meteorites being solitaires includes the high radiometric exposure ages of most meteorites, which are much higher ($t \geq 10^6$ years) than what is commonly believed to be the possible dynamic lifetime of streams of meteoroids ($t \leq 10^4$ years). An association with a stream may be the exception in the case of the "Farmington" meteorite (1), which has the uniquely short exposure age of $t < 25{,}000$ years (2). However, for most other meteorites such an association seems impossible.

Nevertheless, under certain circumstances meteorite streams can survive much longer time than is commonly believed to be possible. We now have evidence that these meteorite streams exist and that they may be quite common features in the solar system.

Computer Simulation and Results. Consider an asteroid in an orbit that is in resonance with the orbit of Jupiter; i.e., the two orbits have periods that have a ratio of small whole numbers. Consider that the asteroid breaks up, its fragments being dispersed in arbitrary directions. The disruption is assumed to occur at the asteroid's aphelion, such that at given dispersion velocity a maximum change in the orbital elements occurs. The dispersion velocities are chosen at $v < 200$ m/s, as is typically expected for the outcome of catastrophic collisions (3). As a result, the fragments remain in orbits very similar to that of the parent. I computed the orbital evolution of the fragments after break-up taking into account the gravitational forces in the sun-Jupiter system. Here, Jupiter is assumed to be in a circular orbit about the sun. It is assumed that the fragments do not influence the motion of the two major bodies and that there is no interaction among the fragments. The integrations are done in a two-dimensional rotating coordinate system in which the position of the sun and that of Jupiter are fixed (4).

Figure 1 shows the orbital evolution of these fragments for the first 500 years compared with the case where the parent asteroid was in a non-resonant orbit. Two features are observed: (a) The meteorites do not propagate along their orbital path, as is observed in the non-resonant case. Instead, they cluster around the former location of their parent. We may thus term this feature a meteorite "swarm", which represents the special case of a meteorite "stream" in which all six orbital elements, including the true anomaly ν, of the meteorites are similar. (b) The meteorites appear to librate around this location. It appears that such a meteorite swarm trapped in a resonance will escape dispersion for a longer time than in the general case of meteorites in non-resonant orbits, where Ω and ω will disperse within $t \leq 10^4$ years (not shown in Figure).

Evidence for the Existence of Meteorite Swarms. It is known that resonance mechanisms play an important role in the asteroid-meteorite complex (5). Hence, the described meteorite swarms may well exist and may even represent an important stage in the orbital history of meteorites. We have described in detail that the lunar seismometers have possibly encountered such a meteorite swarm in January 1977 (6). Additional evidence for the existence of meteorite swarms comes from an observed 31-year-periodicity of H-chondrite falls (7). It is obvious that the described meteorite swarms cannot be intercepted by the earth every year, but only in years in which the position of the earth and that of the swarm coincide, which will occur with a certain periodicity. Further evidence comes from the yet unexplained discrepancy of the abundance of different meteorite classes for meteorites found in the Antarctica and in meteorite collections of the Northern Hemisphere (8). This discrepancy may be caused by the earth intercepting different swarms of meteorites having different geocentric radiants at different times of the year.

Further, we may reconsider the fall of the Mazapil iron meteorite which reportedly occurred during the extraordinary display of the Andromedid meteor shower in November 1885 (9, 10). This has hitherto been regarded as a coincidence because of the discrepancy between the expected young ages of showers and the high exposure ages of meteorites mentioned above. However, clustering of meteorites on resonances can offer an alternative explanation for this observation, since the Andromedids are a shower near the 2:1 resonance. Hence, the Mazapil meteorite may indeed have been a member of this shower. It implies that the Andromedids may contain fragments of an asteroidal break-up in the past.

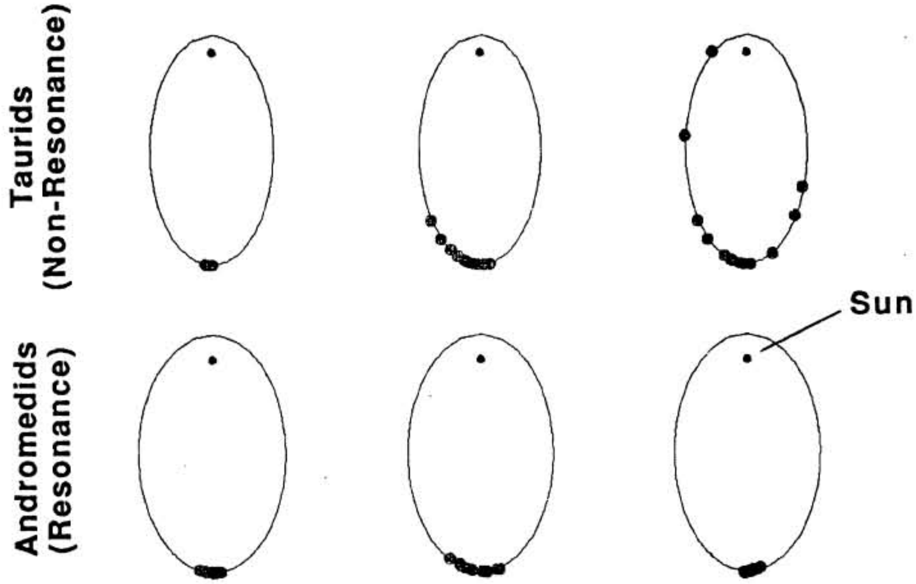

Figure 1: Orbital evolution of meteoritic fragments, from left to right, 5, 250, and 500 years after break-up of a parent asteroid in the non-resonant case (top) and in the case of meteorites in resonant orbits. The typical orbits of two well-known meteor showers are chosen.

References: (1) Oberst, J. and Y. Nakamura (1986) EOS Trans. Am. Geophys. Union 67, 107. (2) DeFelice, J., G. G. Fazio, and E. L. Fireman (1963) Science 142, 673. (3) Davis, D. R., C. R. Chapman, R. Greenberg, S. J. Weidenschilling, and A. W. Harris (1979) in: Asteroids, 528, University of Arizona Press, Tucson, Arizona. (4) Szebehely, V. (1967) Theory of orbits, The restricted problem of three bodies, Academic Press Inc., Orlando, Florida. (5) Wetherill, G. W. (1985) Meteoritics 10, 1. (6) Oberst, J. and Y. Nakamura (1987) Lunar Planetary Science XVIII, this issue. (7) Wood, C. A. (1982) Lunar Planetary Science XIII, 873. (8) Dennison, J. E., D. W. Lingner, and M. E. Lipschutz (1986) Nature 319, 390. (9) Hidden, W. E. (1887) Am. J. Sci. 133, 221. (10) Kresák, L. (1963) Bull. Astron. Inst. Czechosl. 14, 2, 52.