1986 DA AND 1986 EB: IRON OBJECTS IN NEAR-EARTH ORBITS; J.C. Gradie, Planetary Geosciences Division, Hawaii Institute of Geophysics, University of Hawaii, Honolulu, HI 96822 and E.F. Tedesco, Jet Propulsion Laboratory, Pasadena, CA 91109.

The estimated 1,500 asteroids, with diameters larger than a few hundred meters, which cross or closely approach the Earth's orbit are divided into three orbital classes: the Aten asteroids with semi-major axes less than 1 AU and which cross the Earth's orbit near aphelia, the Apollo asteroids with semi-major axes greater than or equal to 1 AU and with perihelia greater than 1.17 AU, and the Amor asteroids with perihelia between 1.17 and 1.3 AU (1). These asteroids which have orbits stable against collision with or ejection by a planet on the order of 10^7 to 10^8 years must be derived from either extinct cometary nuclei (2) or the asteroid belt (c f. 1).

These near-Earth asteroids are important for several diverse reasons: they represent a group of objects from which at least some of the meteorites are derived, they may harbor extinct cometary nuclei thought to contain some of the most primitive and, perhaps, pristine material in the solar system, occasionally collide with the Earth, and are among the most accessible objects in the solar system.

Study of the physical properties of the Earth-approaching asteroids is constrained by the generally long time between close approaches and poorly known orbits. Of the 88 Aten, Apollo, and Amor class asteroids discovered through 1985 only 47 have orbital elements sufficiently reliable to permit their routine recovery (3). Therefore, the timely announcement of the discovery of 1986 DA, an Amor asteroid, by M. Kizawa (IAU Circ. 4181) and of 1986 EB, an Aten asteroid, by E. Shoemaker and C. Shoemaker (IAU Circ. 4191) allowed for quick follow-up physical observations of the 10 and 20 micron thermal flux at the NASA IRTF and the spectral reflectance characteristics from ECAS photometry at KPNO (4). The albedos and diameters on the IRAS system (5) are 0.14 and 2.3 km and 0.19 and 2.0 km, respectively. UBV colors are U-B = 0.21 and 0.24 and B-V = 0.70 and 0.71, respectively. On the TRIAD system the albedos are 0.12 and 0.17, respectively. The classification of M for both objects is firmly established since the combination of UBV color and albedo is unique to this class (6). The spectral reflectance properties and geometric albedos of the M-class asteroids are consistent with compositions analogous to the metallic (iron-nickel) meteorites since radar observations of the M-class asteroids (7) show radar reflectivities indicative of a body nearly entirely metallic in composition.

Where is the source region for metallic objects like 1986 DA, 1986 EB and other near-Earth asteroids? An asteroidal source region would imply a compositonal distribution for near-Earth asteroids similar to that seen in the asteroid belt. McFadden, et al. (8) concluded that the similarity between the spectral reflectance of seven near-Earth asteroids and some main-belt asteroids argued that a sizeable fraction must come from the main belt, in particular the 5:2 Kirkwood gap. Wisdom (9,10) has calculated

that the 3:1 Kirkwood gap is a possible source region as well. Tedesco and Gradie (4) have used the classification of 38 near- Earth asteroids to conclude that the distribution of types (C, S, M, etc.) is remarkably similar to that found in both the 3:1 and 5:2 resonances and that compositions indicative of cometary material are rare. The source of the near-Earth asteroids is primarily asteroidal.

If the source of the near-Earth asteroids is primarily asteroidal, then to account for the lack of extinct cometary nuclei in the population, one must postulate that either the cores of comets are remarkably similar in compositions to the asteroids in the 3:1 and 5:2 resonances, that the end product of at comets is simply dust, meteor streams, or objects too small to be easily detected, i.e., the majority of comets lack volatile-free cores, or that the core of a comet is so friable that it cannot survive intact as long as asteroidal material.

1986 DA and 1986 EB may be near-Earth sources for some of the iron-nickel meteorites. The long cosmic-ray exposure ages (approx. 10^9 years) argue that the sources of iron meteorites must be orbits with lifetimes longer than the Aten, Apollo, and Amor population (11, 12). The source must be in the asteroid belt for only there can strong meter- sized objects survive collisions for a 10^9 years (13). Using the Greenberg and Chapman model (13) for meteorite production from a strong, km-sized body, we calculate that 1986 DA and 1986 EB should produce about 20% of the meteorites that come from all near-Earth asteroidal sources or about 1% of all meteoritic material. Since about 2% of all meteorites are irons (14), we would expect that fully half of the iron meteorites should have cosmic-ray exposure ages less than 10^8 years. This discrepancy is either the result of experimental bias (15), inappropriate application of models describing the production of meteorites from near- Earth iron objects, or that statistical under representation of specific meteoritic source bodies.

REFERENCES: 1) Shoemaker, E.M., J.G. Williams, J.G. Helin, and R.F. Wolfe, Asteroids, edited by T. Gehrels (Univ. Arizona Press, Tucson), 253, 1979; 2) Opik, E.J., Proc. Roy. Irish Acad. 54A, 165, 1951; 3) Hahn, G., Uppsala Astronomical Observatory Report No. 38, 1986; 4) Tedesco, E.F. and J.C. Gradie, Astron. J., in press, 1987; 5) Lebofsky, L.A., M.V. Sykes, E.F. Tedesco, G.J. Veeder, D.L. Matson, R.H. Brown J.C. Gradie, M.A. Feierberg, and R.J. Rudy, Icarus, 68, 239, 1986; 6) Gradie, J.C. and E.F. Tedesco, Science 216, 1405, 1982; 7) Ostro, S.J., D.B. Campbell, and I.I. Shapiro, Science 229, 442, 1985; 8) McFadden, L.A., M.J. Gaffey, and T.B. McCord, Science 229, 160, 1985; 9) Wisdom, J., Meteoritics 18, 422, 1983; 10) Wisdom, J., Nature 315, 731, 1983; (11) Wetherill, G.W. and J.G. Williams, J. Geophys. Res. 73, 635, 1968; 12) Wetherill, G. W., Geochim. Cosmochem. Acta 40, 1297, 1976; 13) Greeneberg, R. and C.R. Chapman, Icarus 55, 455, 1983; 14) Antartic Meteorite Newsletter 8, 15-40, 1986; 15) Wasson, J., Meteorites, (W.H. Freeman and Company, New York), 1985.