Outcome of impact disruption of iron meteorites at room temperature

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The iron meteorites and some M-class asteroids are generally understood to originate in the cores of differentiated planetesimals or in the local melt pools of primitive bodies. On these primitive bodies and planetesimals, a wide range of collisional events at different mass scales, temperatures, and impact velocities would have occurred. Iron materials have a brittle–ductile transition at a certain temperature, which depends on metallurgical factors such as grain size and purity, and on conditions such as strain-rate and confining pressure [1]. An evolutional scenario of iron meteorite parent bodies was proposed in which they formed in the terrestrial planet region, after which they were scattered into the main belt by collisions, Yarkovsky thermal forces, and resonances [2]. In this case, they may have experienced collisional evolution in the vicinity of the Earth before they were scattered into the main belt. The size distribution of iron bodies in the main belt may therefore have depended on the disruption threshold of iron bodies at temperature above the brittle-ductile transition.

This paper presents the results of impact-disruption experiments of iron meteorite and steel specimens mm-cm in size as projectiles or targets conducted at room temperature using three light-gas guns and one powder gun. Our iron specimens were almost all smaller in size than their counterparts (as targets or projectiles, respectively). The fragment size distribution of iron material was different from that of rocks. In iron fragmentation, a higher percentage of the mass is concentrated in larger fragments, i.e., the mass fraction of fine fragments is much less than that of rocks shown in the Figure (left). This is probably due to the ductile nature of the iron materials at room temperature. Furthermore, the Figure (right) shows that the largest fragment mass fraction f is dependent not only on the energy density but also on the size of the specimens. In order to obtain a generalized empirical relationship for f, we assumed a power-law dependence of f on initial peak pressure P_0 normalized by a dynamic strength, Y, which was defined to be dependent on the size of the iron material. A least-squares fit to the data of iron meteorite specimens resulted in the following relationship: $f \propto (\frac{P_0}{Y})^{-2.1}$. The deformation of the iron materials was found to be most significant when the initial pressure greatly exceeded the dynamic strength of the material.

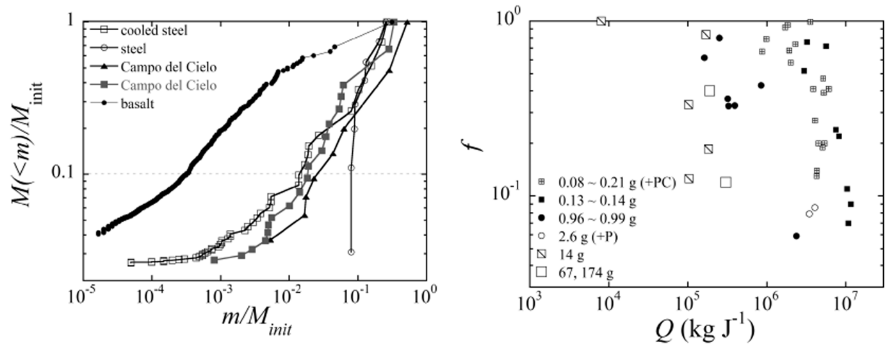

Figure: Left: Total mass of fragments having mass smaller than m normalized by initial mass. Right: The largest fragment mass fraction versus energy density. Different mass ranges of the iron specimens are shown by different marks.

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