IDA: DISTRIBUTION AND ORIGIN OF SURFACE BLOCKS

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At least 20 blocks or boulders have been discovered on the surface of Ida in the Galileo high resolution mosaic returned to Earth in September 1993. The block distribution fits a dynamical model in which the blocks are ejecta fragments that entered partial or temporary orbit about Ida before being swept up preferentially onto the leading surfaces. Thus the blocks may represent the first observational evidence of small "moons" of a main-belt asteroid.

Features interpreted as blocks are small, isolated objects with positive relief comparable to their horizontal scale, shown by shadows and illumination. Positive relief features found alongside craters are more likely to be rims and are not included in our mapping. A number of blocks can be unambiguously identified in the stereo pair formed by images 2339 and 2439, but because stereo coverage does not exist over most of Ida, the overall distribution was mapped using monoscopic coverage only. The spatial distribution of these 30 - 150 m diameter blocks is distinctly nonuniform (Fig.1), with most of the blocks found on or near the "leading surfaces" of the asteroid (the two regions which sweep through space as Ida rotates or, more precisely, where the local rotational velocity vector is directed outwards from the surface). None are found on the trailing region despite the excellent illumination and viewing geometry of images of this region (2313, 2326 and 2339). Although different sets of blocks have been identified by several mappers within the Galileo imaging team, depending upon subjective criteria, the spatial distributions have been similar.

The largest cluster is found near the site of two large (~10 km) craters on the leading surface. However, the blocks are not concentrated near the rims of these craters, and few blocks appear to be associated with the large craters near the middle of the mosaic. One or two trails leading to blocks have been tentatively identified; in each case, the implied direction of motion is away from the presumably high gravity potential at the ends of Ida. One small group of blocks visible in stereo images 2339 and 2439 may be the result of disruption of a single parent block.

The blocks were probably never small heliocentric asteroids, which would impact more uniformly over the surface, and most of which would be disrupted on impact at over 3 km/s [1]. Blocks of the observed size might have been ejected by 1-10 km craters [2, 3], but emplacement of blocks near their source craters would not explain their distinctive spatial distribution. Instead, we suggest that the large blocks were ejected at speeds near the escape velocity and went into temporary orbit about Ida, while smaller ejecta fragments were launched at higher velocities and escaped.

We have modeled the orbits of ejecta around a body with elongation similar to Ida's. The body consists of two contacting spheres of variable size and uniform density, connected by a massless cylinder. Tests with more realistic density distributions showed little difference from this model. In each numerical experiment, 10,000 particles are launched from random locations and tracked until they reimpact the surface. The launch direction for each particle can be randomly chosen, or assigned a fixed inclination. In a typical case, the two spheres in the model asteroid are each of radius 15 km and density 4 g cm^{-3} (so average overall density is 2.4 g cm^{-3}), rotating with period of 4.7 hr. All particles are launched at 32 m/s (near the average escape speed), inclined 45^{o} to the surface, the predominant inclination for ejecta according to Melosh [4]. The material goes into temporary orbit around the asteroid for durations that are long in comparison to the rotational period. The fate of these small "moons" is strongly influenced by the irregular shape and rapid rotation of the asteroid.

Fig. 2 shows one side of the model asteroid, with the rotation axis in the plane of the paper and the leading surface on the right. The opposite side is similar by the symmetry of the model. Points show the impact sites of the 4% of particles that have returned to the surface after 10 revolutions of the model asteroid.

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The strong preference for collection on the leading edge is clearly shown. Similar results are found in all cases, except when the launch speed is so low that re-impact is immediate and local.

Blocks on Ida may be eventually destroyed by impacts of m-sized projectiles. Extrapolating the size distribution for small asteroids suggested by the Gaspra cratering record [5] down to 1 m suggests that the blocks survive on Ida for 30-80 million yr. Impacts by 50-350 m objects create the 1-10 km craters [6, 7] with blocky ejecta every 1-100 million yr. Thus block production probably keeps pace with block destruction.

References: [1] Bottke et al., Icarus, in press, 1994. [2] Moore, NASA SP-315, 1972. [3] Lee et al., Icarus 68, 77-86, 1986. [4] Melosh, "Impact Cratering", Oxford, 1989. [5] Belton et al., Science 257, 1647, 1992. [6] Nolan et al., DPS, 1992. [7] Greenberg et al., Icarus, in press, 1994.

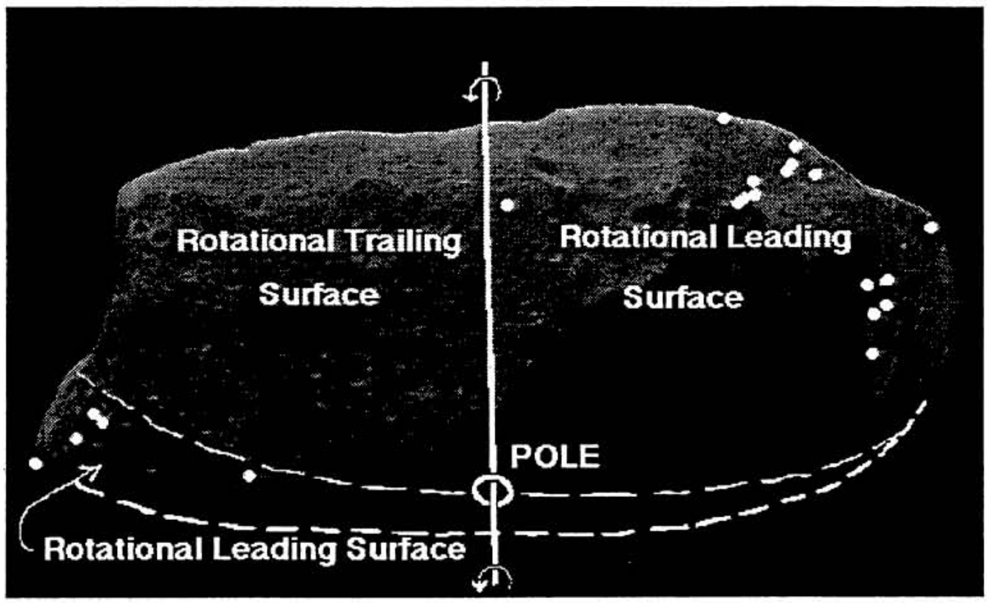

Figure 1: Locations of boulders and approximate boundaries of leading and trailing surfaces.

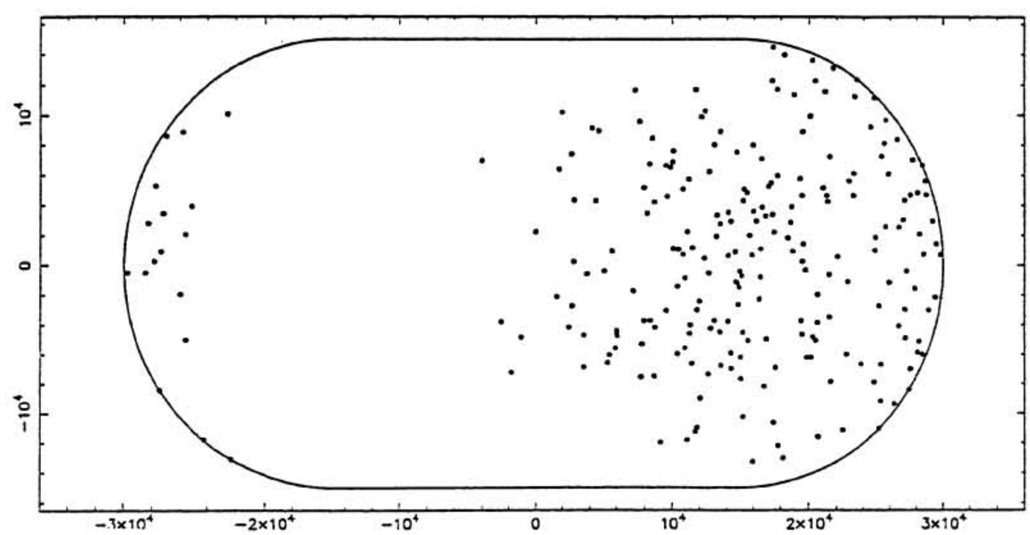

Figure 2: Ejecta launched uniformly from over the model asteroid reimpact predominantly on the leading surfaces.