High Ecliptic Latitude Survey for Small Main-belt Asteroids

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Main-belt asteroids (MBAs) located in the asteroid dense zone between Mars and Jupiter orbits continuously collide with one another. Collisional evolution refers to changes in the number-diameter distribution for asteroids, hereinafter called size distribution, as collisions repeat over time. Asteroids larger than ~100 m in diameter have a scaling law that the strength against impact disruption increases with body size. The increasing degree of impact strength is the primary factor that determines the size distribution of MBAs [1]. Therefore, measurements of the size distribution allow us to examine the asteroid strength law The development of collisional evolution models of MBAs is proceeding using the size distributions with a variety of size ranges obtained by a number of previous survey observations.

However, MBA's collisional evolution could have been different in the early solar system because newborn Jupiter dynamically excited asteroid orbits (pumped up eccentricities and inclinations) and sped up their collision velocities much faster than at present [2]. We know very little about the impact strength law under such hypervelocity collisions. To address this question, we focused our research on the size distribution of asteroids with highly inclined orbits, because their collisional velocities are significantly high and can provide information about asteroid collisions with high velocity. No previous observations have measured the size distribution of high-inclination asteroids in the desirable range of several hundred meters to several kilometers which is close to the boundary between the gravity-scaled and strength-scaled regimes. We used Subaru/Suprime-Cam to conduct an optical wide-field observation of small main-belt asteroids with high inclinations. We surveyed 26.5 deg^2 of high ecliptic latitude fields around +25° in two nights using our efficient method for detecting moving object (figure 1).

As a result of our data analysis, 441 moving objects were detected in good-condition data of 13.6 deg^2 [3]. Orbital estimation indicates that about 380 of them are MBA candidates Since the diameters of these asteroids are too small to measure directly, we calculated their size from photometric brightness. Most of the detected asteroids have diameters of 0.6–6 km and inclinations higher than 15°. We found that the slope of the size distribution changes sharply around 1 km in diameter (figure 2). This is the same pattern that a previous study confirmed in MBAs near the ecliptic plane dominated by low-inclination asteroids. A careful comparison of the size distribution in the range of 0.6–5 km with that of asteroids near the ecliptic plane revealed that high-inclination asteroids have a shallower size distribution. We consider that hypervelocity collisions accelerate the rate of increase in the impact strength according to asteroid size. It indicates that large bodies have a higher disruptive strength and longer lifespan relative to tiny bodies than the ecliptic asteroids during the dynamical excitation phase in the early solar system.

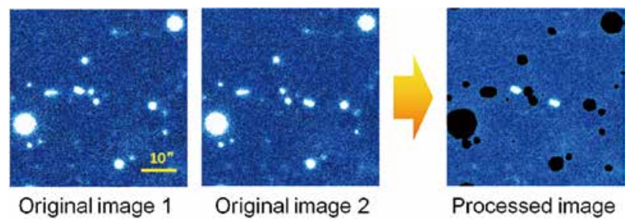

Figure 1: (Left and center) Subaru/Suprime-Cam *r*'-band images obtained at 20-min intervals. (Right) Processed image from the original images. Only the moving asteroid remains after the background objects were masked.

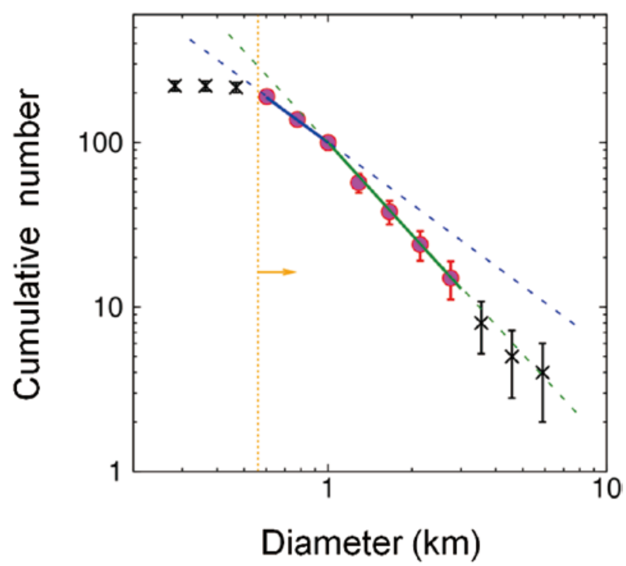

Figure 2: Cumulative size distribution of our MBA sample with the detection limit of 0.56 km in diameter (dotted line). The circles show the diameter range used for evaluation of the distribution slope and the crosses show the excluded range. The blue and green solid lines show the best-fit power laws in the ranges smaller/larger than 1 km, respectively.

References

[1] O'Brien, D. P., Greenberg, R.: 2003, *Icarus*, **164**, 334.
[2] Bottke, W. F., et al.: 2005, *Icarus*, **175**, 111.
[3] Terai, T., Takahashi, J., Itoh, Y.: 2013, *AJ*, **146**, 111.