

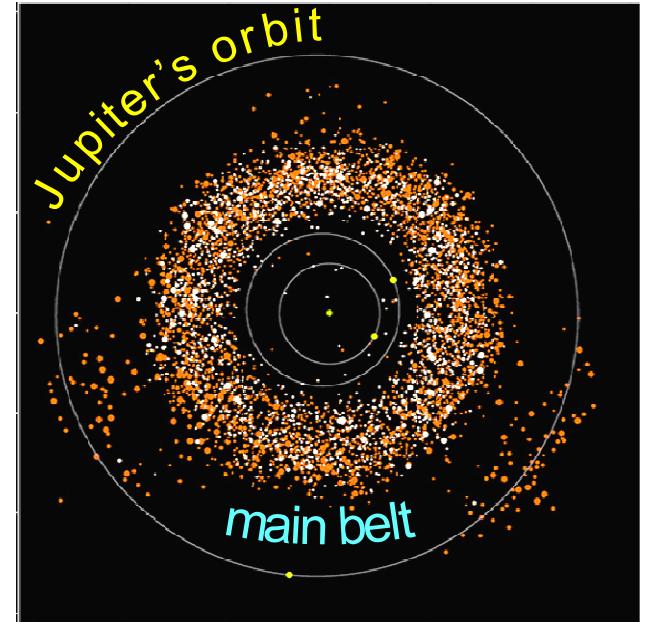
High Ecliptic Latitude Survey for Sub-km Asteroids

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Subaru Users Meeting 2012

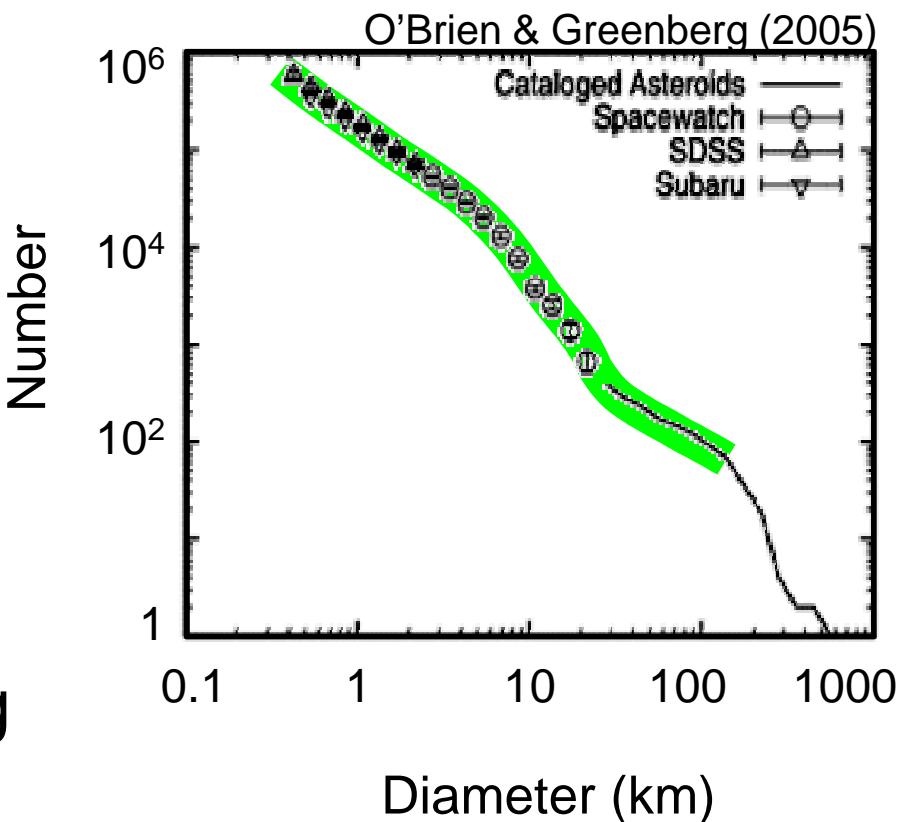
Main-Belt Asteroids

- Asteroid belt between the Mars and Jupiter orbits on the ecliptic plane
- Fragments of surviving planetesimals
- Tracer of the formation and migration of planets
- The distributions of their orbits, body size, and taxonomic classes have been explored by previous extensive asteroid surveys such as
 - Spacewatch → 60000 asteroids in 3700 deg^2 (Jedicke & Metcalfe 1998)
 - SDSS → 13000 asteroids in 500 deg^2 (Ivezić et al. 2001)
 - Subaru → 1100 asteroids in 3 deg^2 (Yoshida et al. 2003)

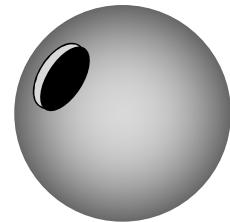
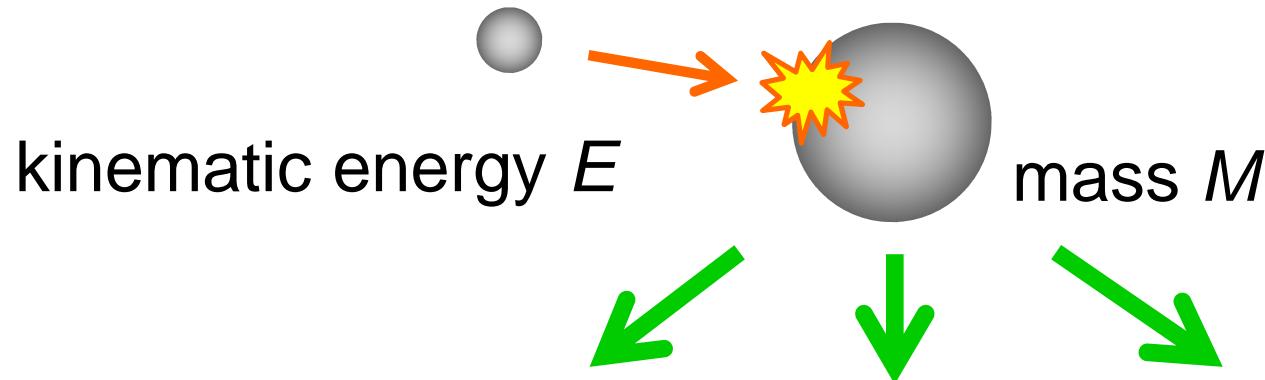


Size Distribution

- Power-law distribution
- Produced by collisional evolution
- Meaningful clues for investigating
 - Post-accretion inner planetesimal disk
 - Collisional lifetime of asteroids
 - Population of near-Earth asteroids
 - Crater distribution on the moon and Mars
 - Dust production (interplanetary dust, debris disks)

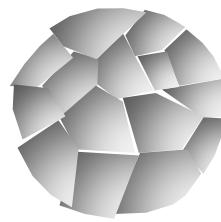


Impact Events



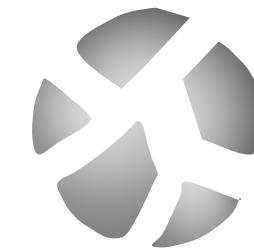
Cratering

$$E / M < Q_s$$



Gravitational
reaccumulation

$$Q_s < E / M < Q^*_D$$



Catastrophic
disruption

$$E / M > Q^*_D$$

→ E

Impact strength against disruption Q^*_D :

critical specific energy required for catastrophic disruption

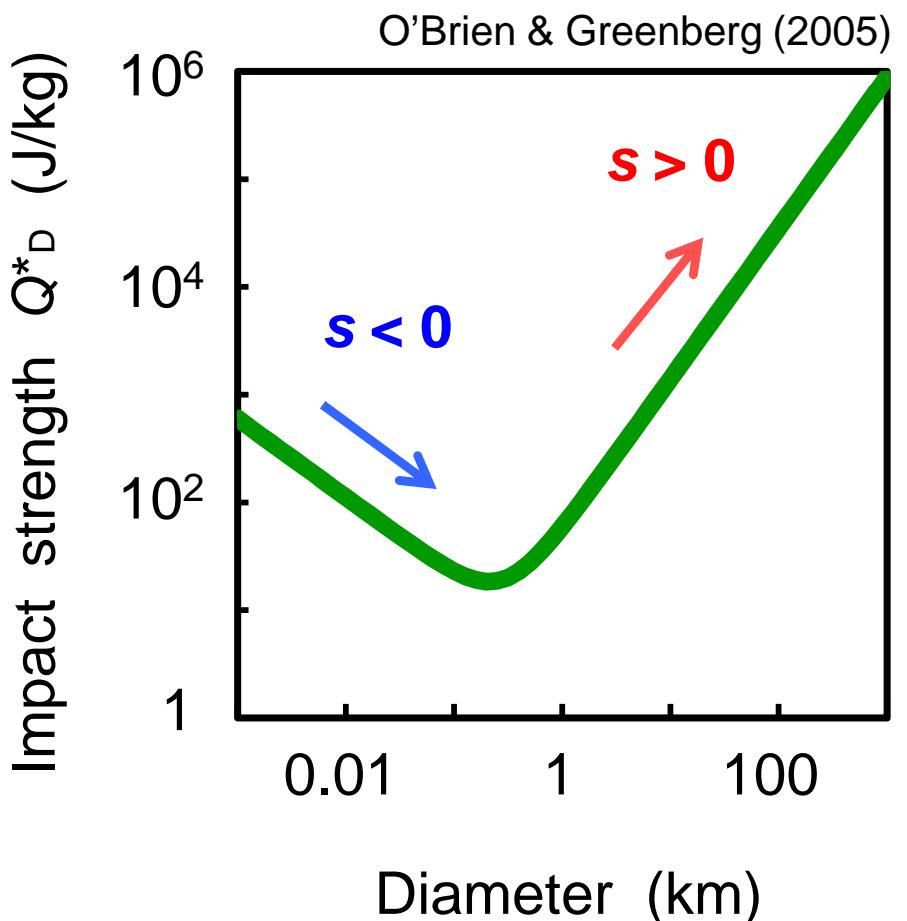
Impact Strength

- Represented by a power law

$$Q^*_D \propto D^s$$

(D : diameter, s : power-law index)

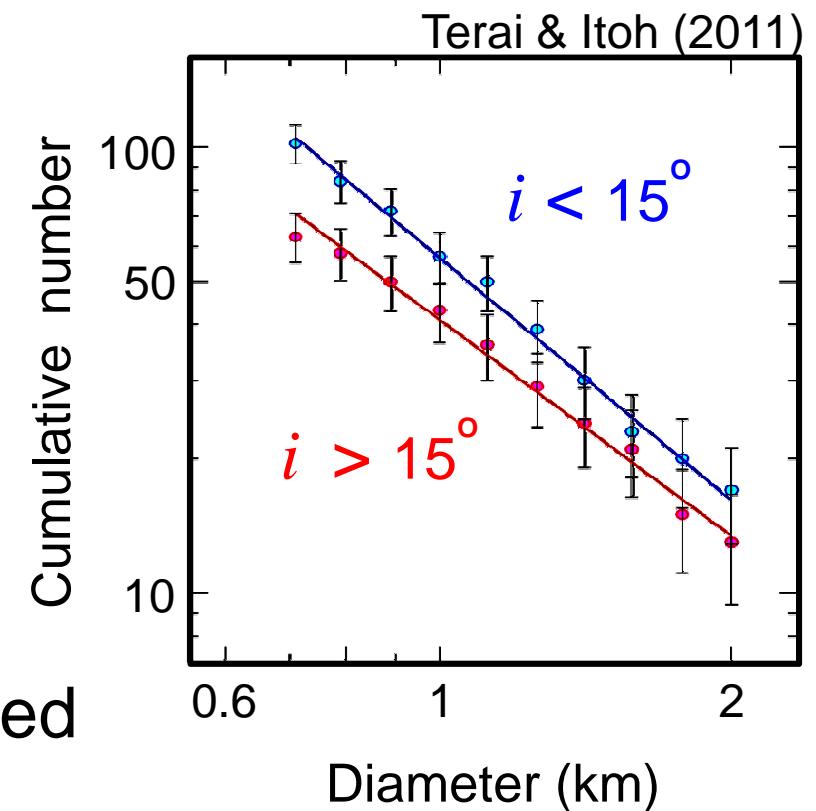
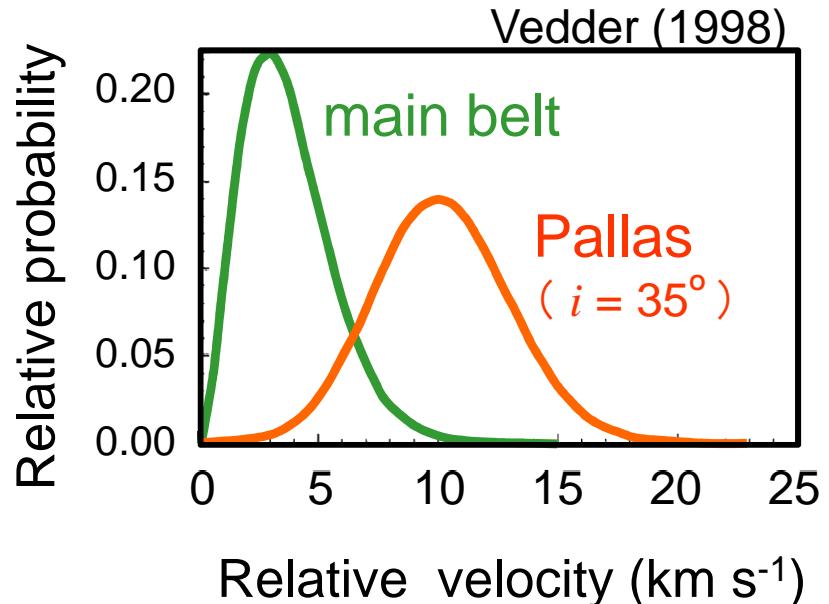
- Small-size bodies ($D < \sim 1$ km)
 - Decreases with size ($s < 0$)
- Large-size bodies ($D > \sim 1$ km)
 - Increases with size ($s > 0$)
- **The power-law slope s of Q^*_D primarily determines the size distribution slope** (O'Brien & Greenberg 2003)



Best-fit model of Q^*_D law
for main-belt asteroids

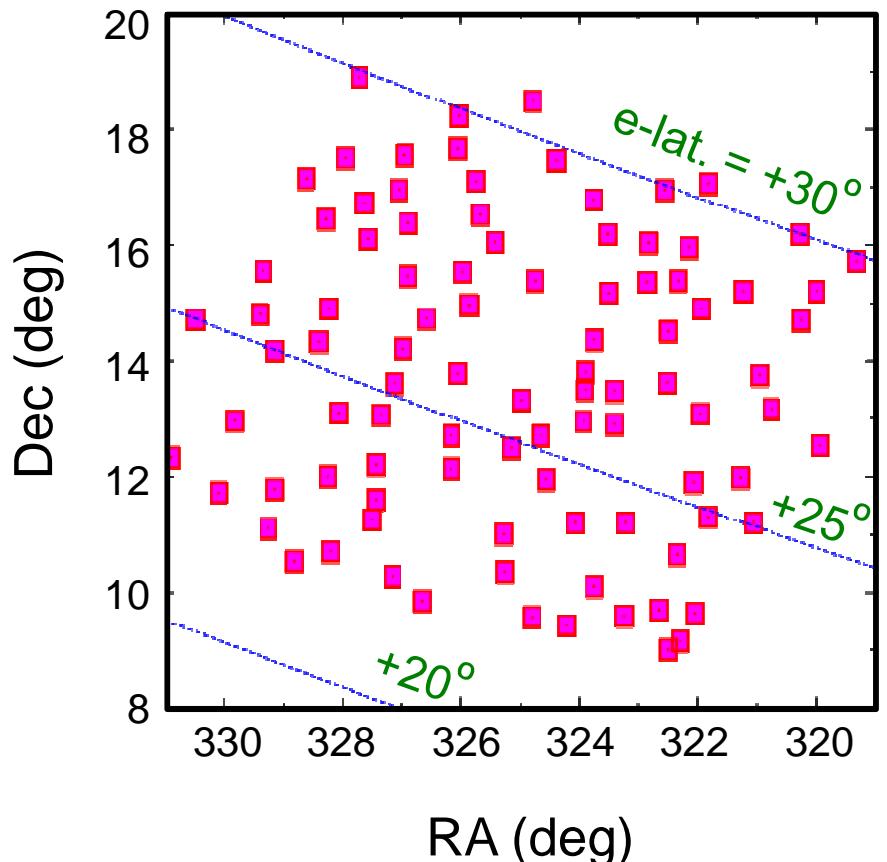
Impact Velocity

- High-inclination asteroids and near-Earth asteroids have hyper-velocity collisions ($> \sim 10 \text{ km s}^{-1}$)
- Velocity dependency of Q^*_D slope remains unknown
- Our previous survey with S-Cam
 - High-inclination asteroids have a shallower size distribution
- More precise measurement is needed

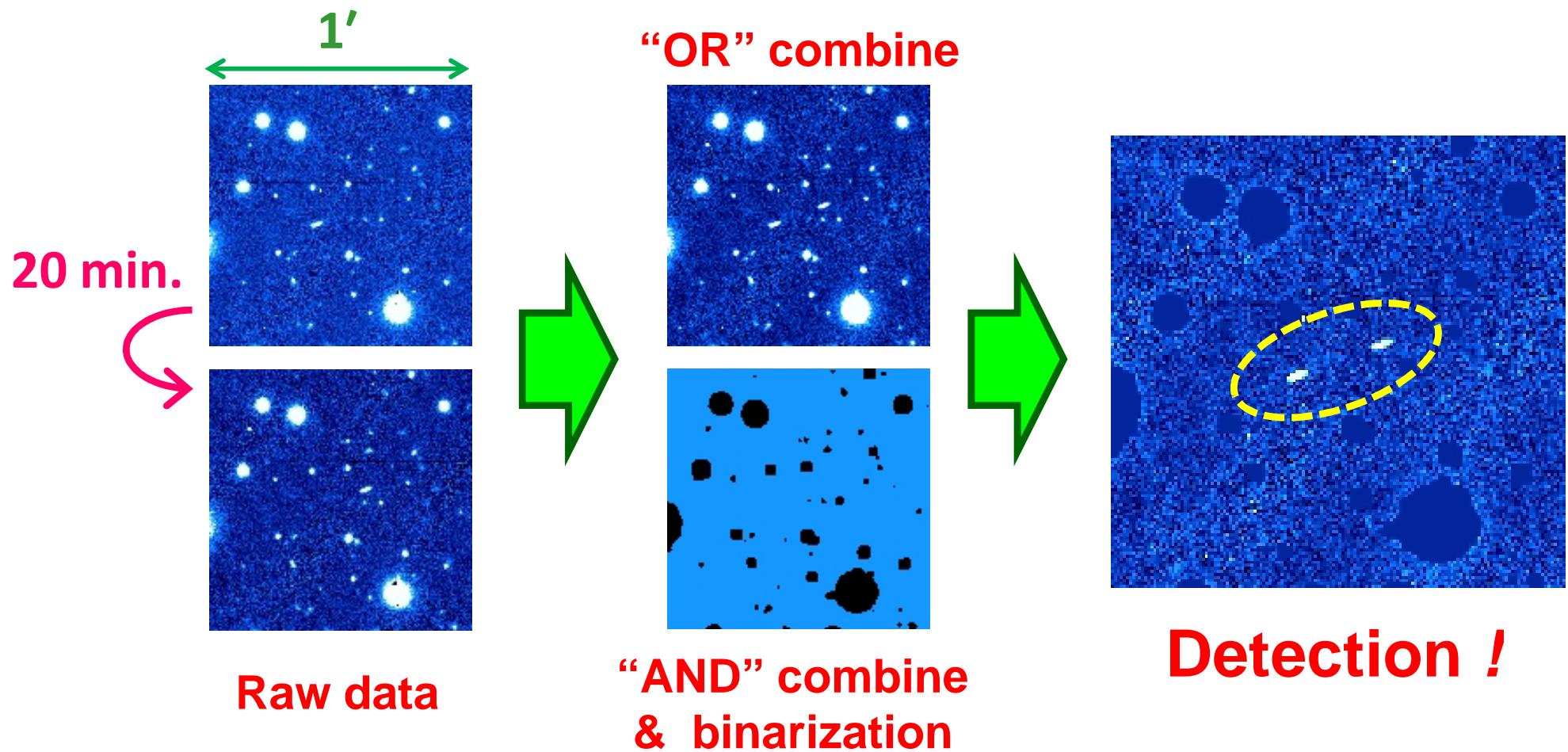


Observation

- Wide-field survey using S-Cam
- High ecliptic latitude ($+20\text{--}30^\circ$)
- Two visits with a 20-min interval
- 240-sec exposure with r -band
- Sky coverage of 26 deg^2 in two nights' observation



Moving Object Detection



→ 441 moving objects were detected

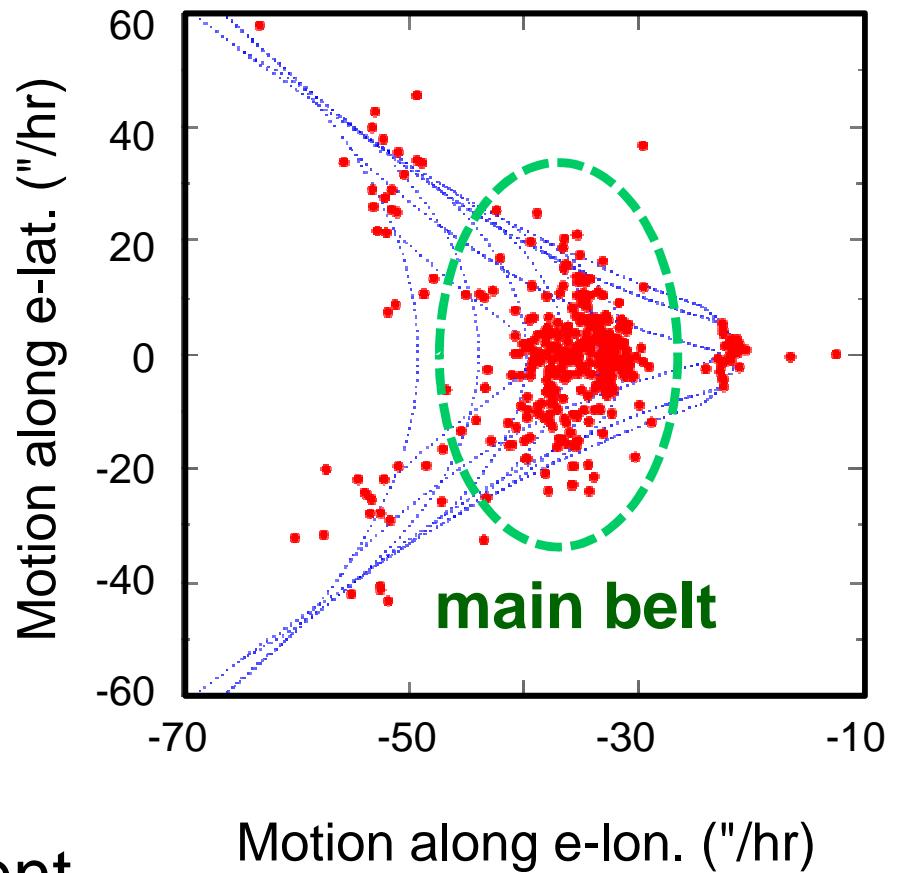
Orbit/Size Estimations

Orbits

- Orbital elements are estimated from motion velocities
- Assuming circular orbits

Asteroid size

- Diameter is converted from apparent magnitude and helio/geocentric distances
- Assuming albedo of 0.09 – 0.17 derived from the ratio between S-type (bright) and C-type (dark) asteroids



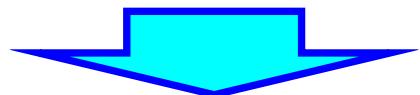
Sample Selection

Data

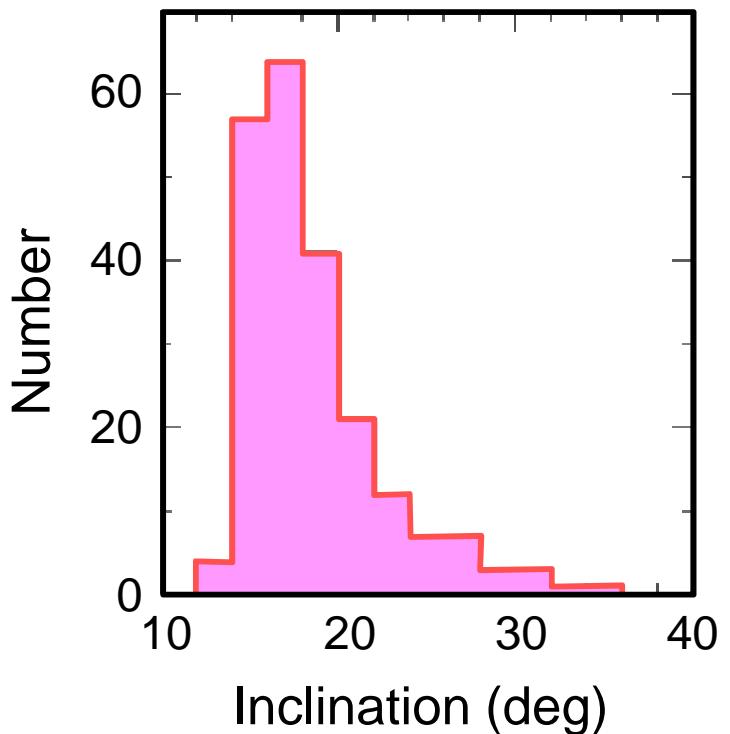
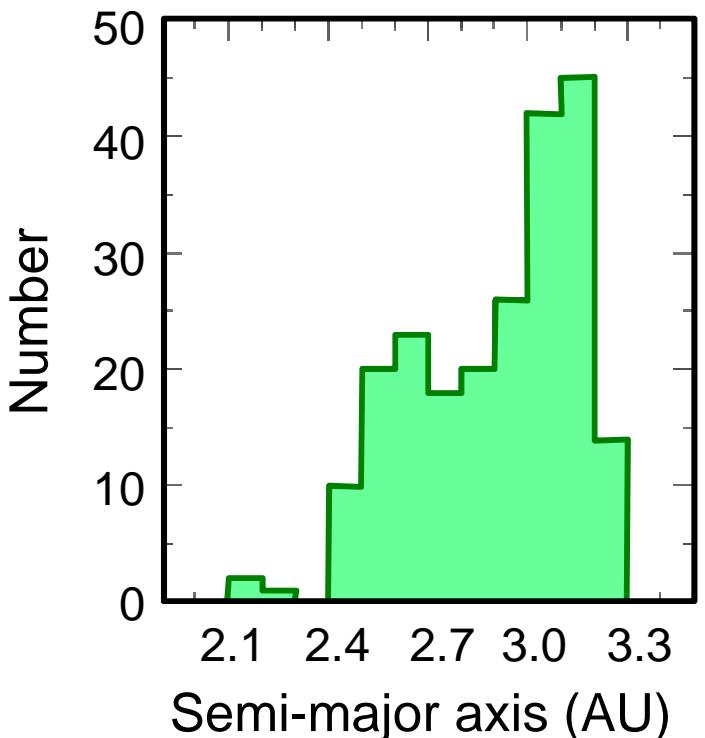
- 50% detection limit $r > 24.4$ mag

Objects

- Semi-major axis 2.0–3.3 AU
- Apparent magnitude $r < 24.4$ mag
→ Diameter > 0.56 km



221 asteroids selected

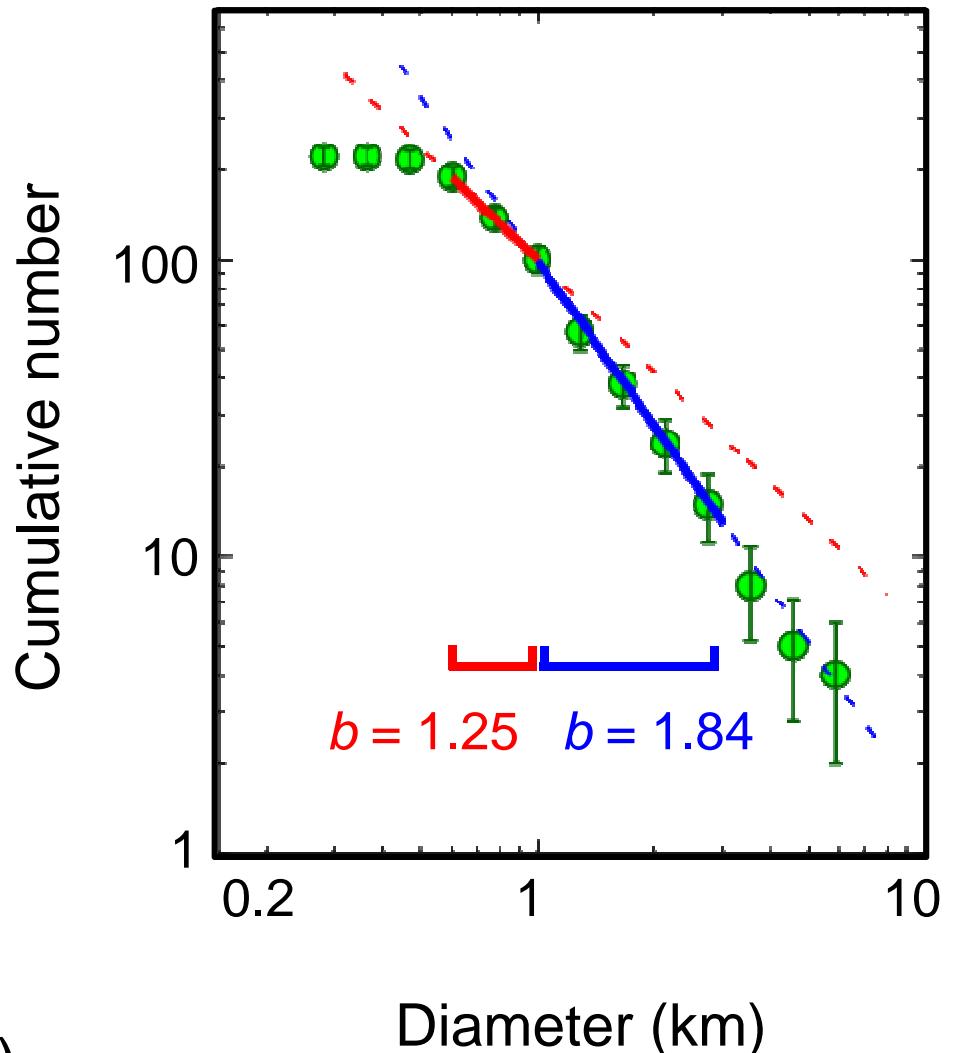


Results

- Cumulative size distribution
- Slope break at $D \sim 1$ km
 - Consistent with Yoshida and Nakamura (2007)
- Power-law fitting with

$$N(> D) \propto D^{-b}$$

(D : diameter, b : power-law index)

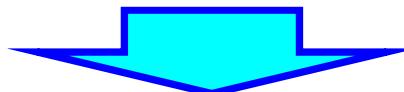


→ $b = 1.25 \pm 0.03$ in $0.6 \text{ km} < D < 1.0 \text{ km}$

$b = 1.84 \pm 0.27$ in $1.0 \text{ km} < D < 3.0 \text{ km}$

Comparison

- Yoshida and Nakamura (2007) :
 - Sub-km asteroid survey near the ecliptic plane
→ Low-inclination asteroids dominate
 - Number ratio of S/C-types $\sim 1:4$ in the outer region
→ **$b = 1.32 \pm 0.02$** ($0.6 < D < 1.0$ km)
- This study (high ecliptic latitude survey)
 $b = 1.25 \pm 0.03$ ($0.6 < D < 1.0$ km)

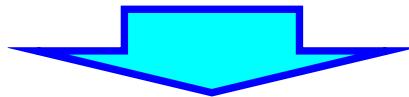


Shallow size distribution

Catalog Data

SDSS Moving Object Catalog

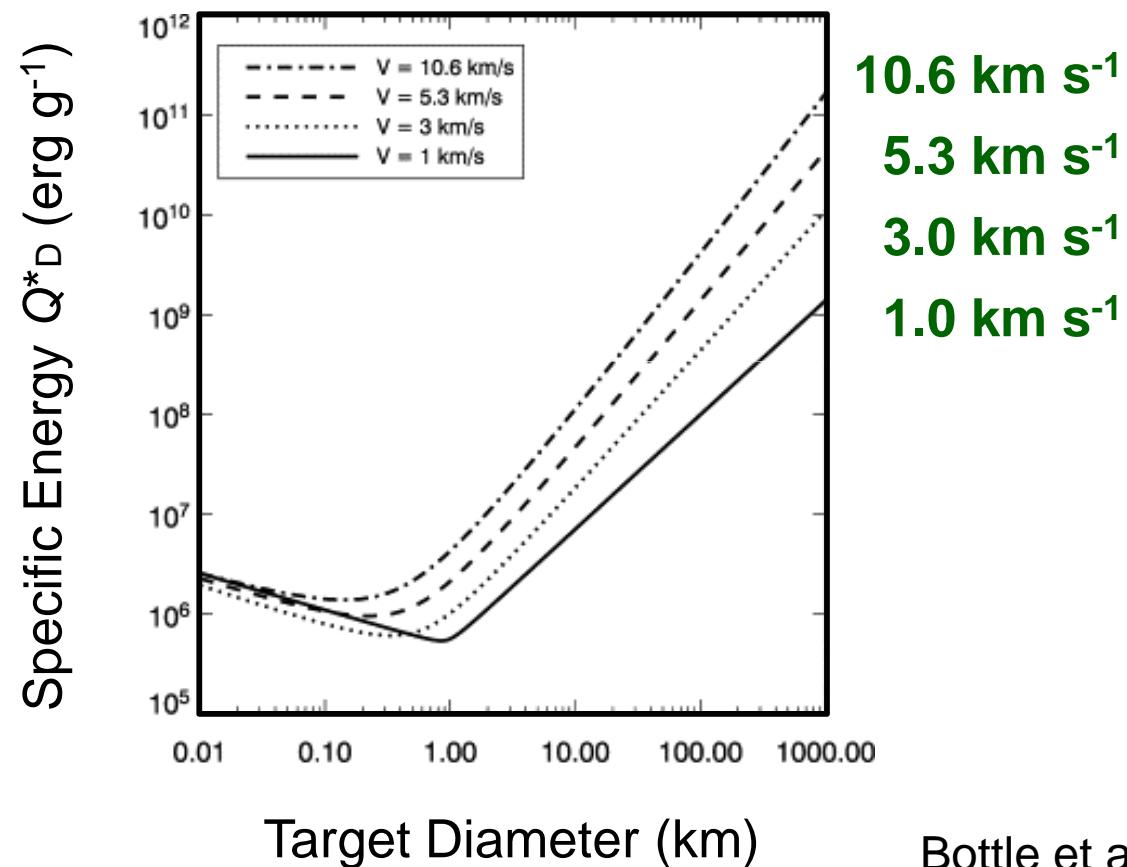
- Main-belt asteroids with inclination $< 15^\circ$
→ $b = 2.49$ ($2 < D < 10$ km)
- Main-belt asteroids with inclination $> 15^\circ$
→ $b = 2.33$ ($2 < D < 10$ km)



High-inclination asteroids have a shallower size distribution from km down to sub-km

Impact Strength Curve

- Shallow size distribution of high-inclination asteroids
 - Steep Q^*_D curve in hypervelocity collisions
 - Consistent with simulations by Bottle et al. (2005)



Bottle et al. (2005)

Summary

- Our high ecliptic latitude survey has detected more than 200 high-inclination small asteroids
- The cumulative size distribution has a slope break at diameter of 1 km
- High-inclination asteroids have a shallow size distribution
 - Large asteroids are more survivable in hypervelocity impacts of $\sim 10 \text{ km s}^{-1}$
- This result is helpful for understanding collisional evolution of inner planetesimals and growth of terrestrial planets