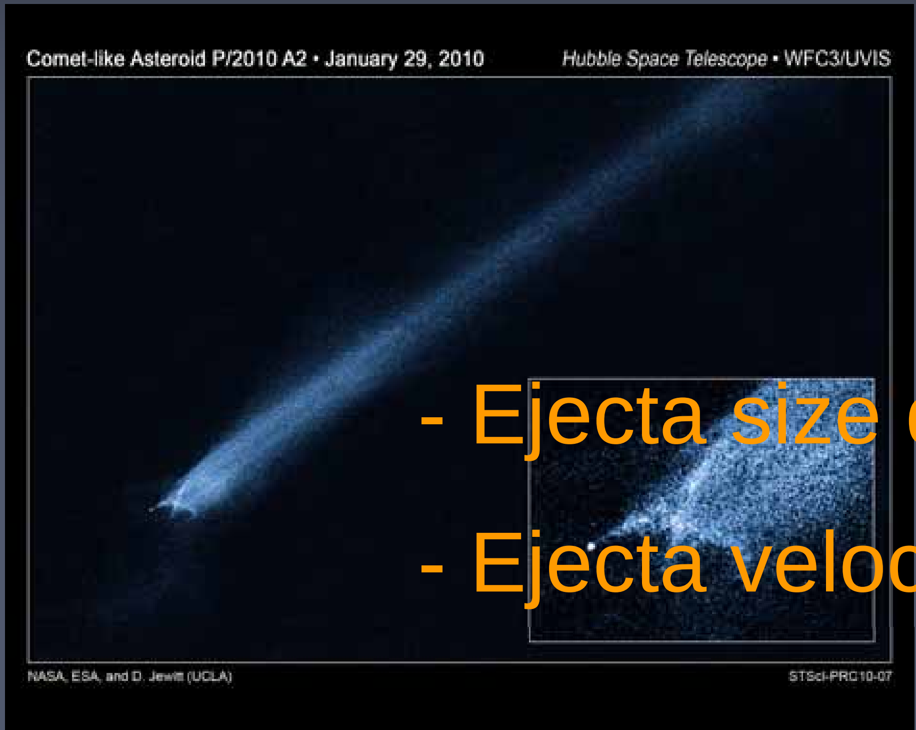
Dust From Collisions at Various Relative Velocities



- Ejecta size distribution
- Ejecta velocity

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Ejecta size distribution

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Kadono et al. 2010,
J. Geophys. Res., **115**, E04003

size distribution

mass distribution

$$n(s)ds \propto s^{-\gamma}\, ds$$

$$N(>s) \propto s^{-\gamma+1} ds$$

$$M(>s) \propto s^{-\gamma+4} ds$$

$$n(m)dm \propto m^{-\beta}\, dm$$

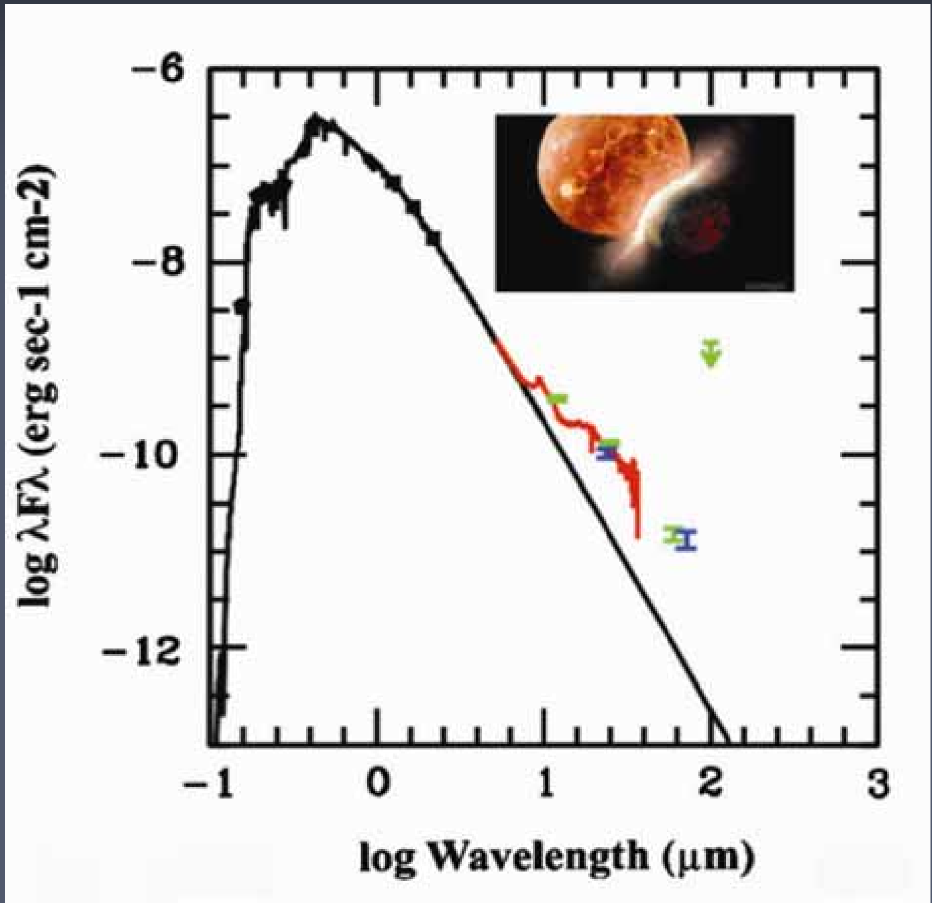
$$N(>m) \propto m^{-\beta+1} da$$

$$\gamma = 3\beta - 2$$

$\gamma = 3.5$ *(at collision cascade)*

(Dohnanyi 1969, Tanaka et al. 1996)

Debris disc - HD172555



IR excess detected by Spitzer

HD172555 is a very young A5V star (age~ 12 Myr). (Zuckerman & Song 2004)

Large IR excess is due to fine dust particles created by a hypervelocity (>10 km/s) impact (Lisse et al. 2009).

$$\gamma = 3.95$$

dust mass ~ 4×10^{19} kg

Ejecta size distribution from cratering

$$\gamma = 3.47$$

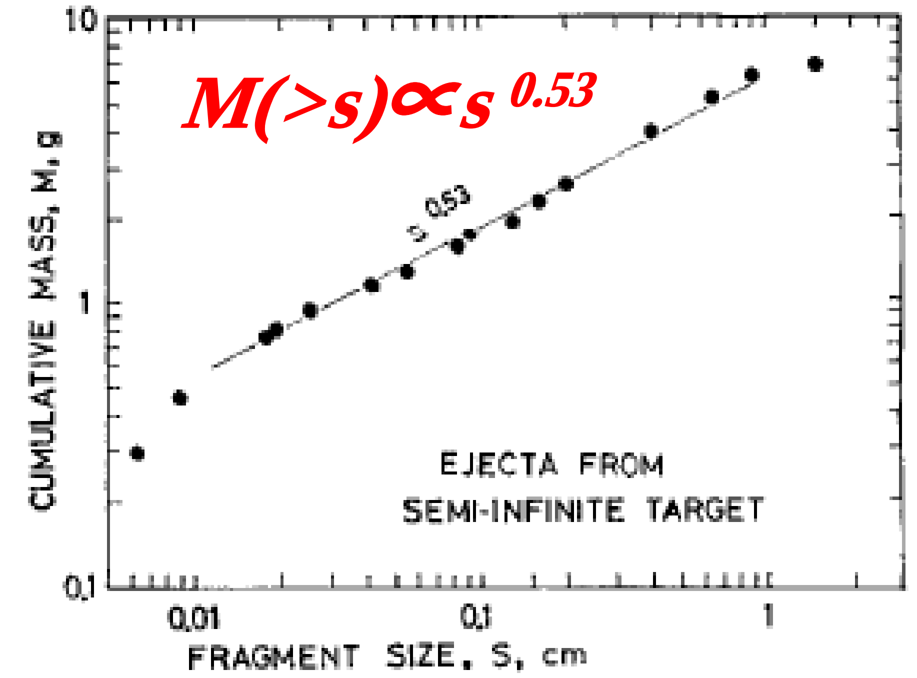


FIG. 9. Size distribution of fragments of semi-infinite target.

Velocity ~2.6 km/s

(Fujiwara et al. 1977)

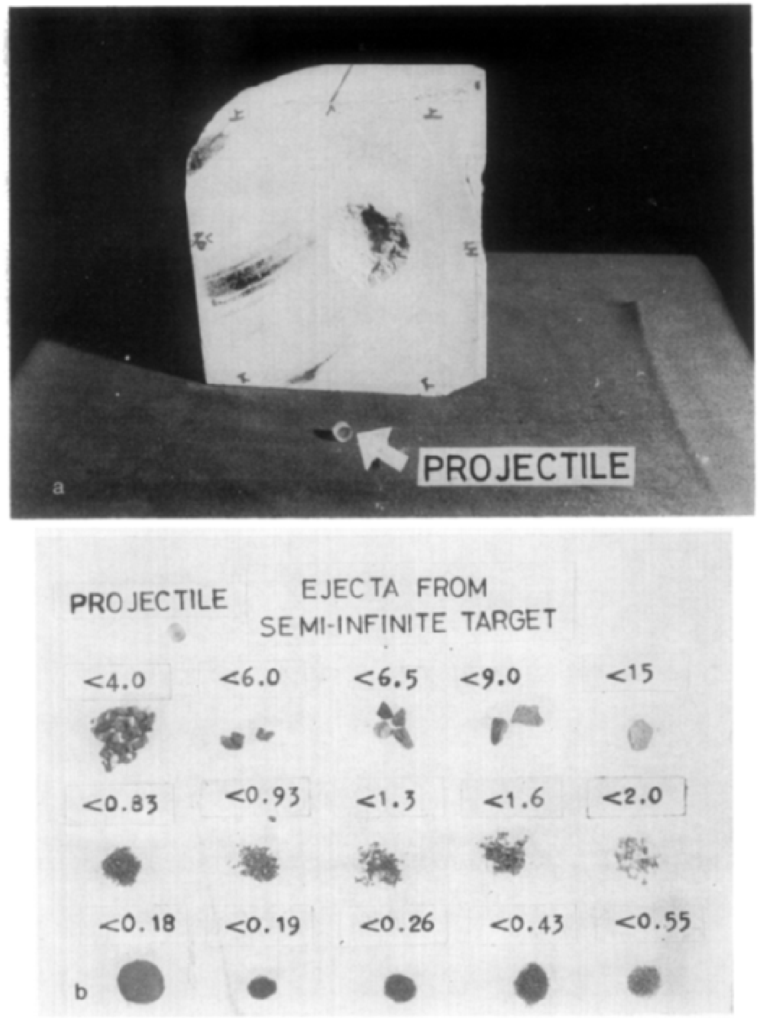
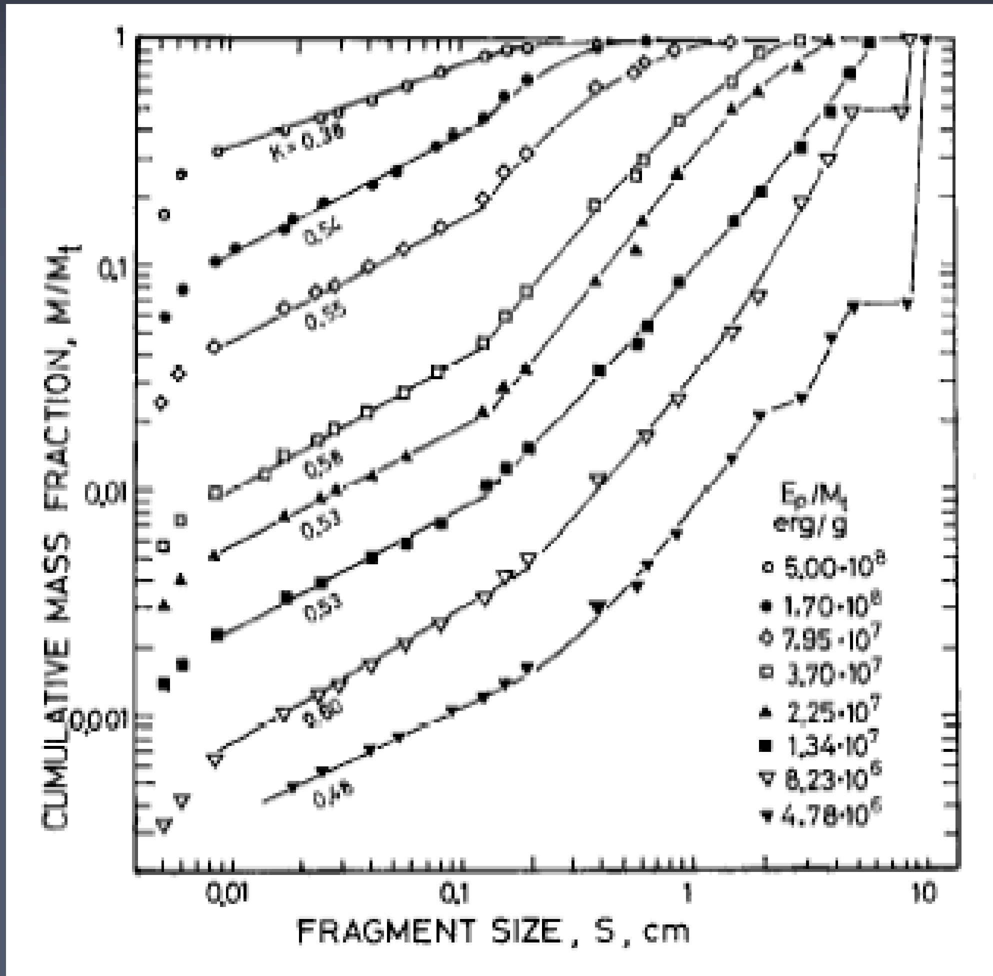


FIG. 5. Class 4 impact. Impact crater (a) and its ejecta (b).

Ejecta size distribution from catastrophic disruption

Cumulative mass $M(>m)/M_t$



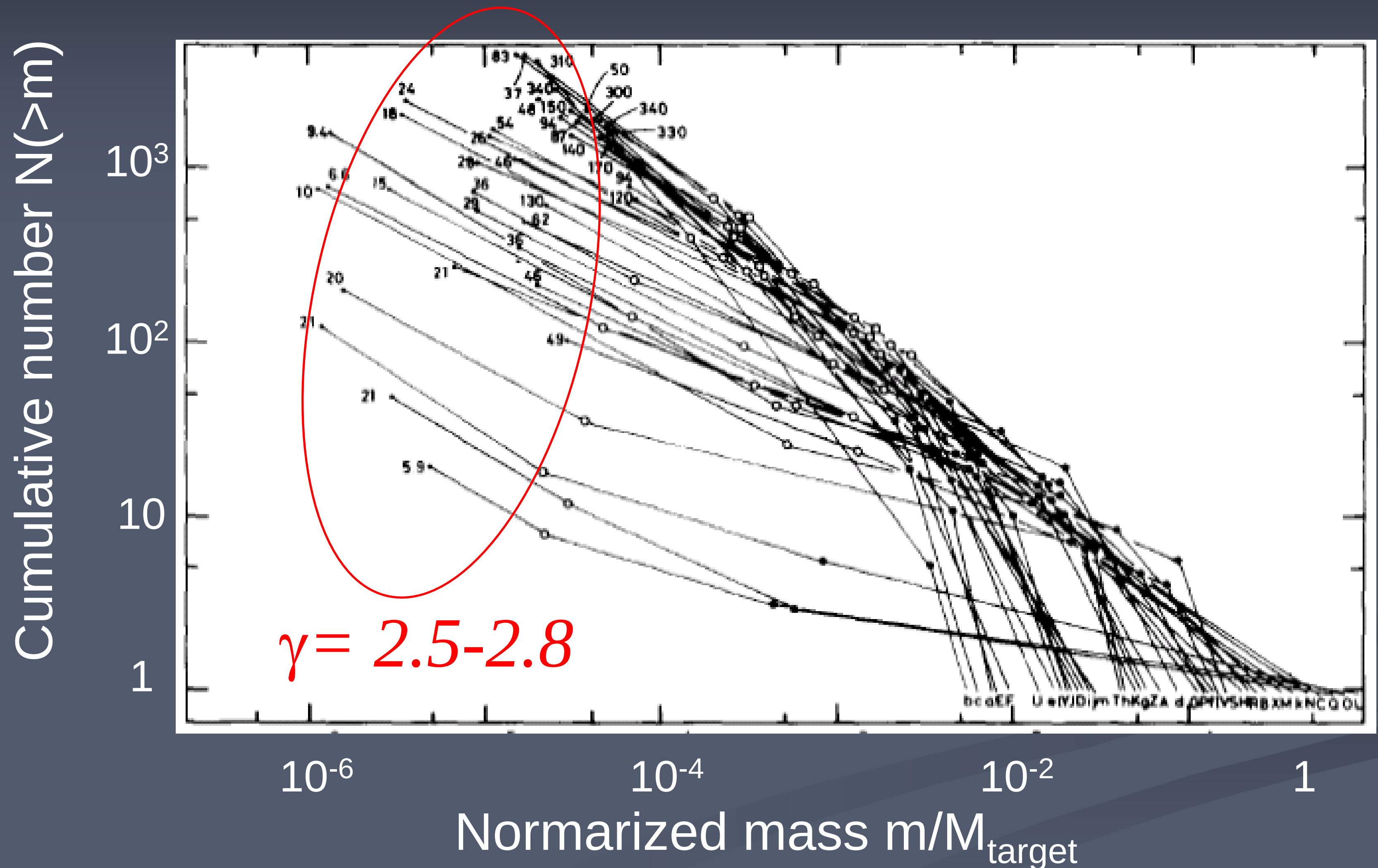
$\gamma = 3.4\text{-}3.6$

Normarized mass m/M_{target}

Velocity ~2.6 km/s

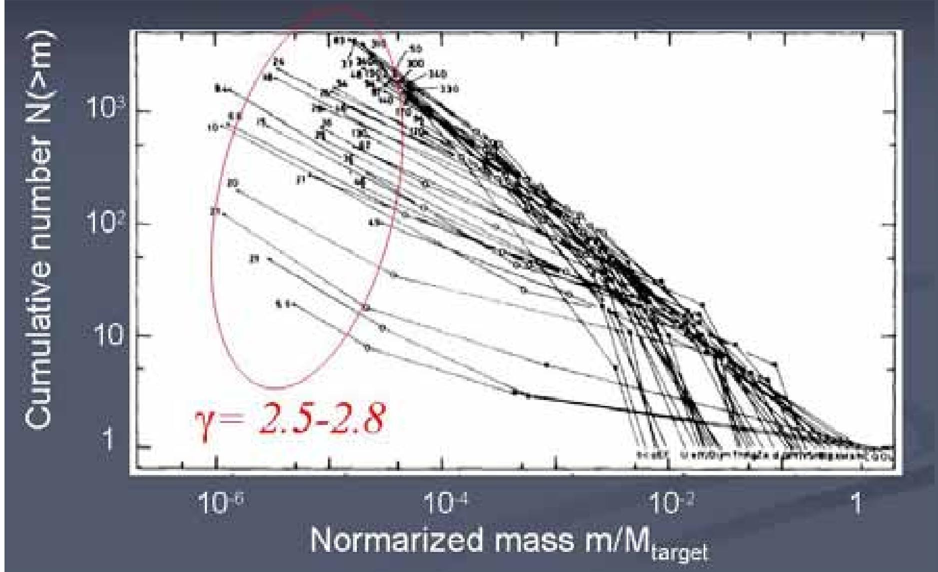
(Fujiwara 1977)

Ejecta size distribution from catastrophic disruption

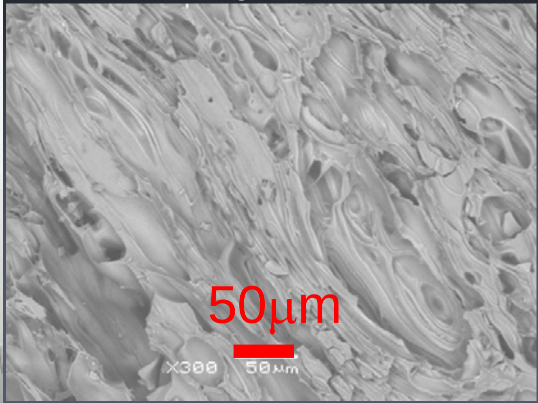


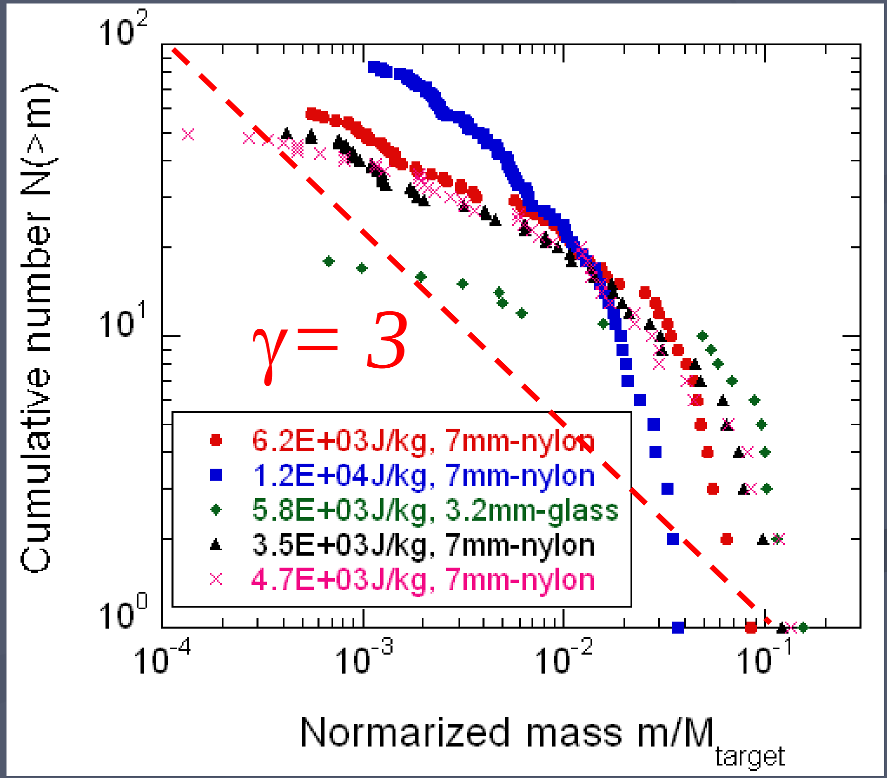
Velocity ~70-990 m/s (Takagi et al. 1984)

Ejecta from pumice

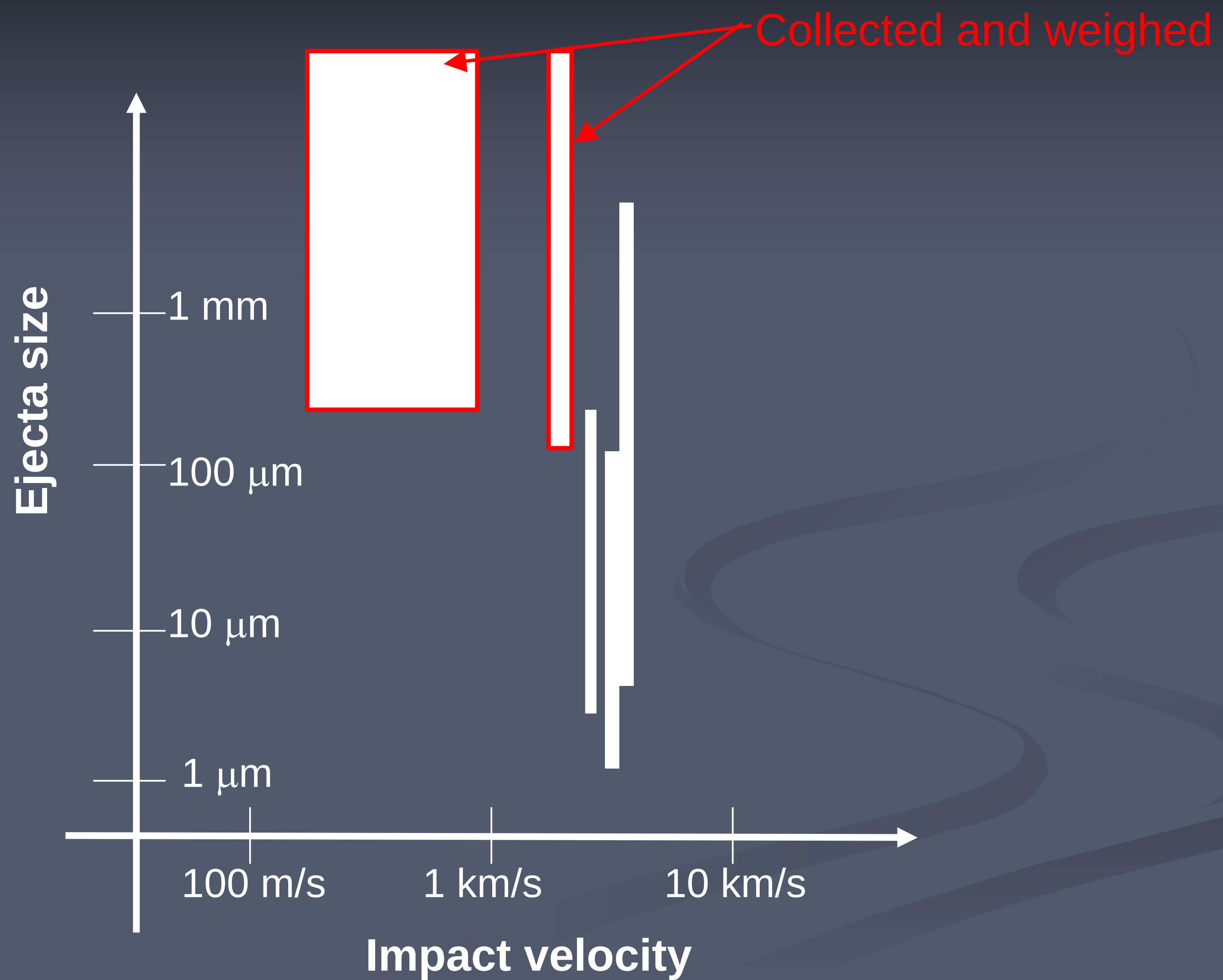


Porosity ~ 73%

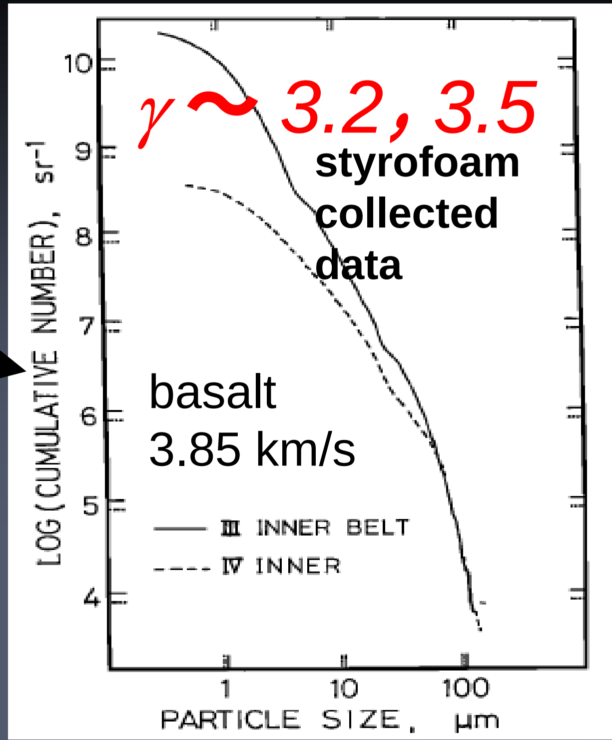




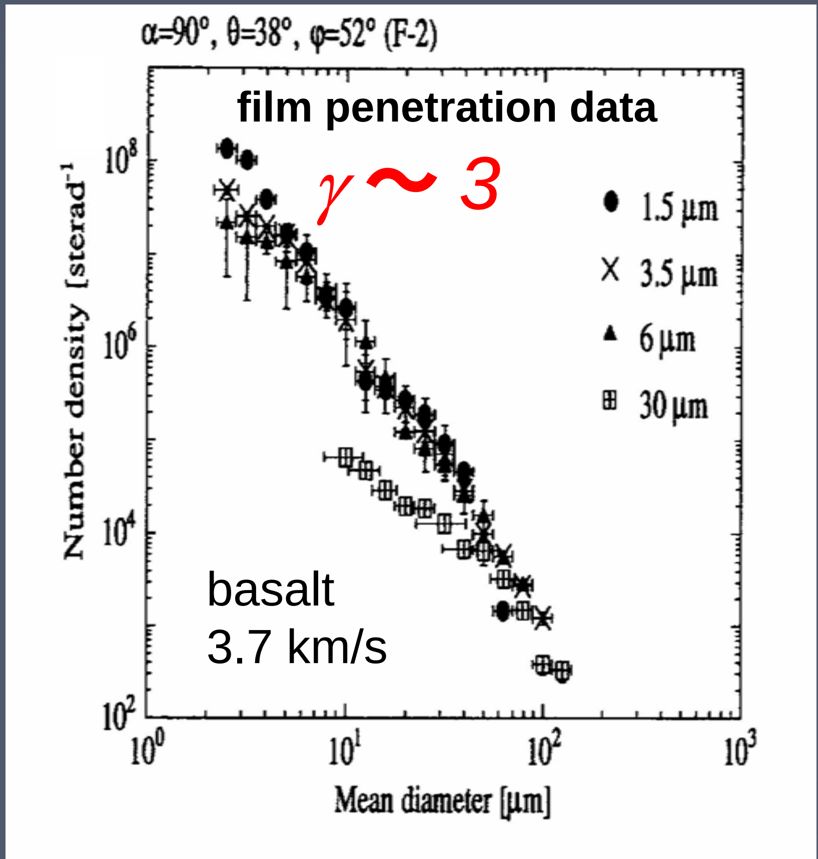
Ejecta size distribution from silicates

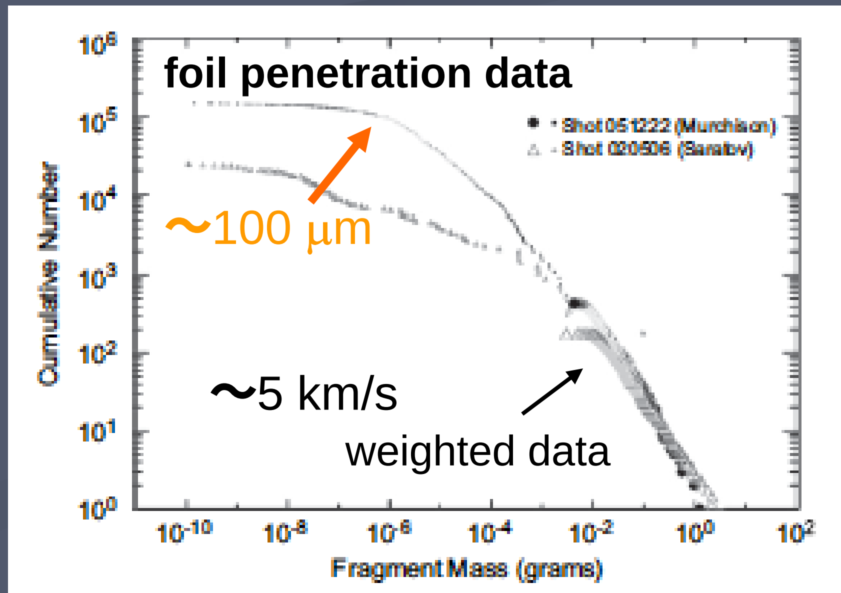


Grain size 30-300 μm



(Asada. 1985)

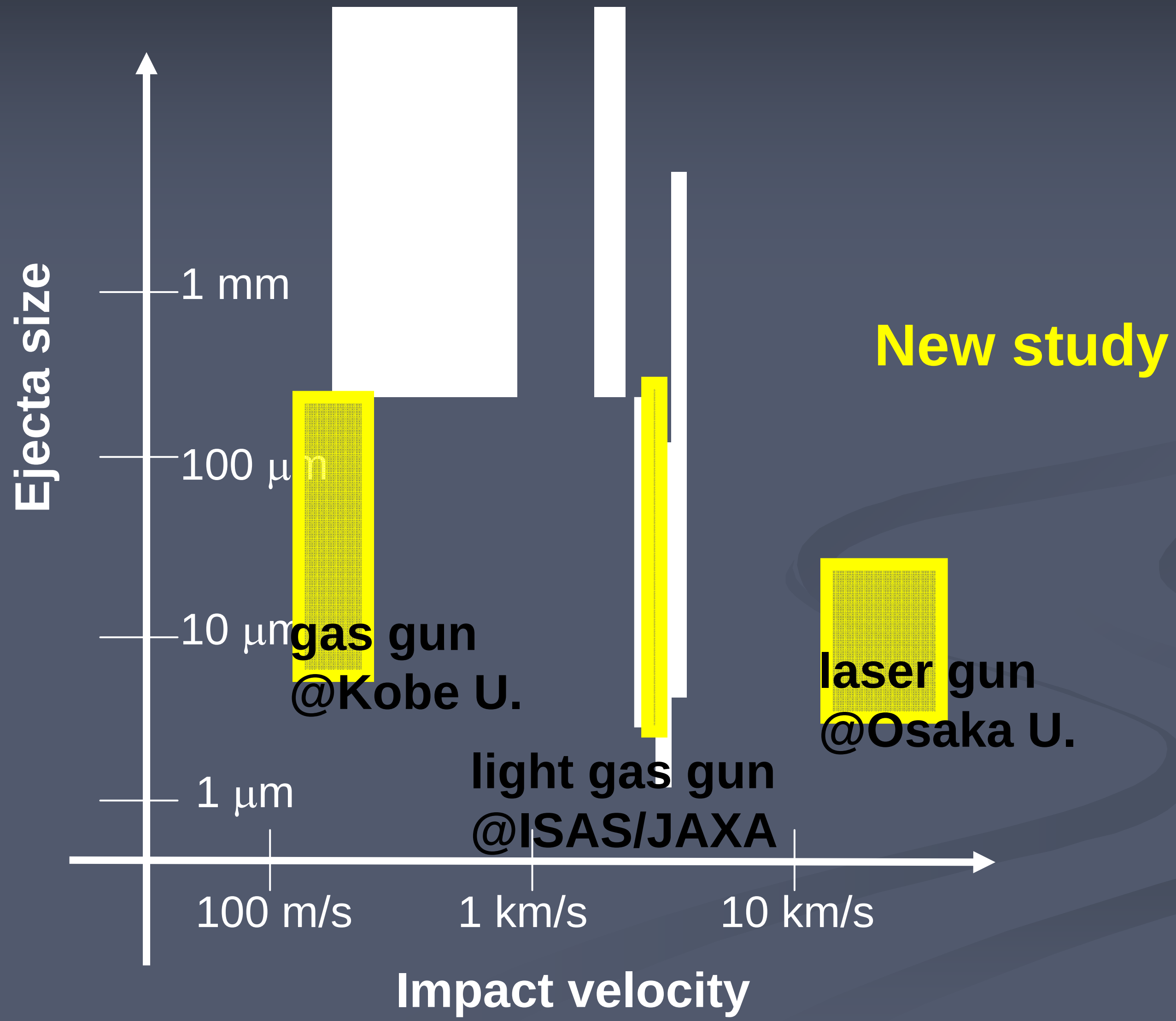




(Nakamura et al., 1994)

(Flynn et al., 2008)

Ejecta size distribution from silicates



Hyper velocity impact experiments

Projectile

Velocity: 13 ~ 61 km/s
Diameter: 80 ~ 250 μm
Material: Al

Laser

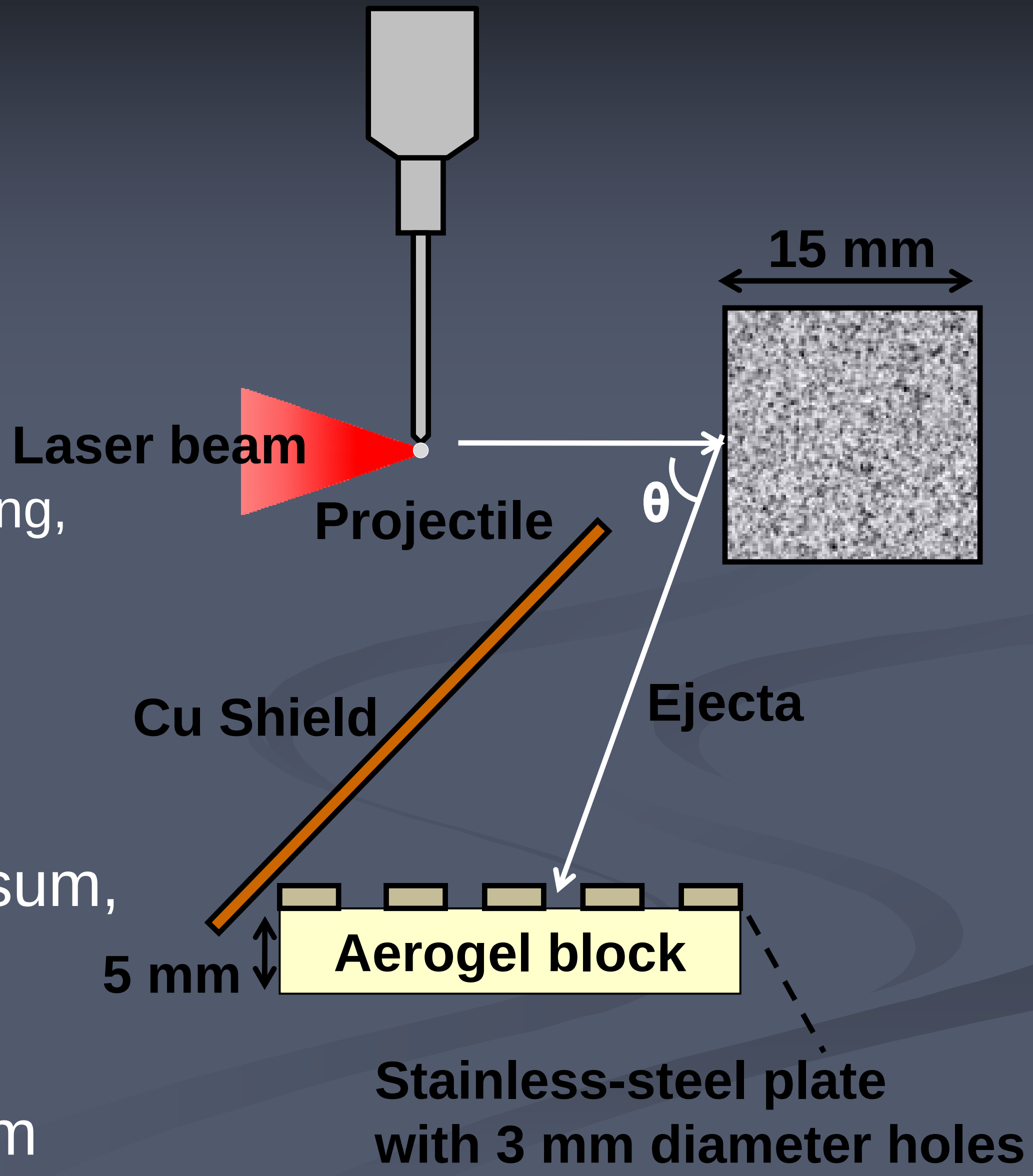
GEKKO XII - HIPER
at Institute of Laser Engineering, Osaka University
λ∼1.05 μm, ∼5000J

Target

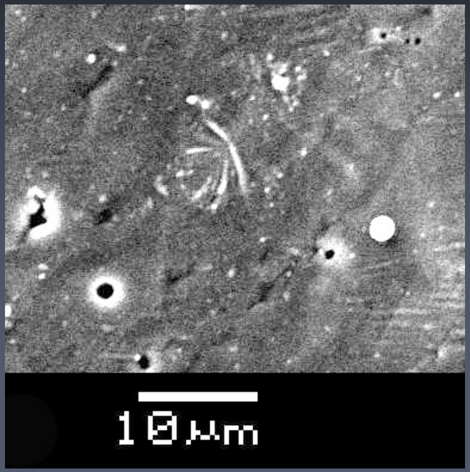
basalt, dunite, anhydrate($CaSO_4$), gypsum, sintered silica particles

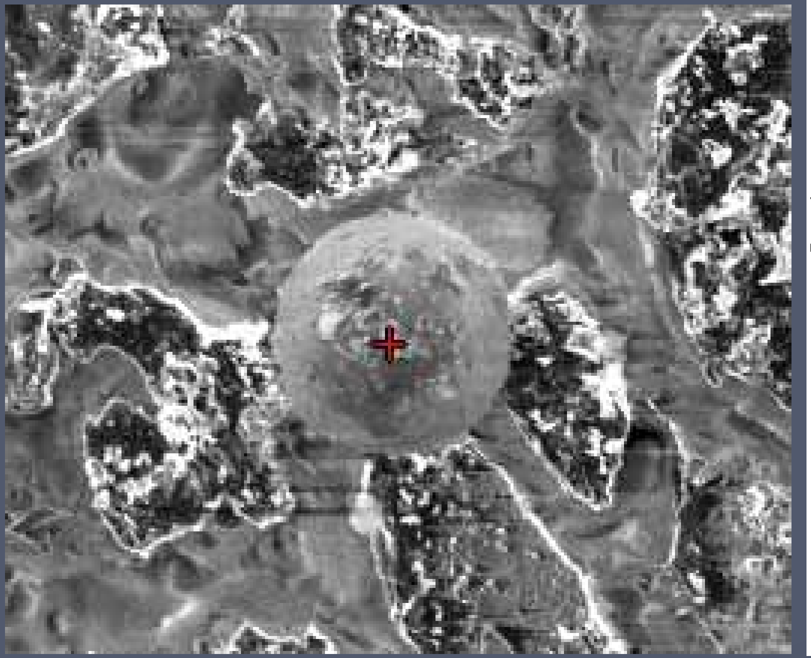
Aerogel block

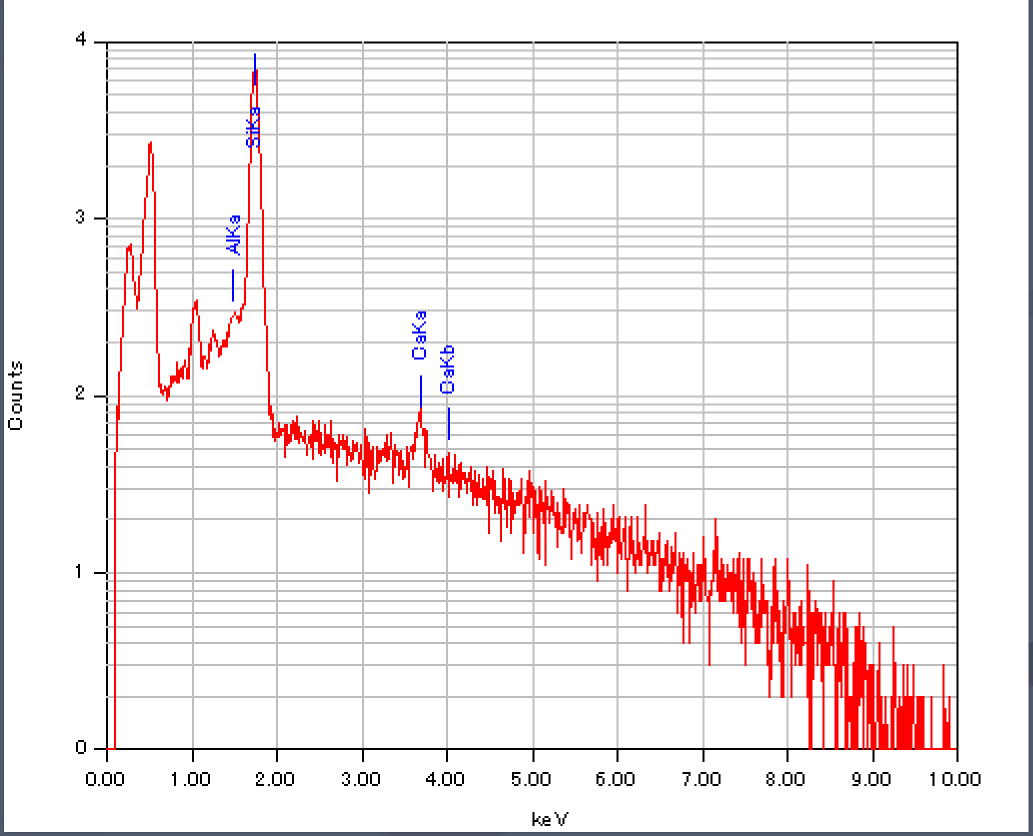
0.11 g/cm³, 25x25x5 mm



First look


10 µm




Counts
keV
SiKa
AlKa
CaKa
CaKb
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00

Experiment conditions

Shot#	Projectile			Target
33364	Al	249 μm	13.3 km/s	basalt
33370	Al	248	16.5	dunite
33372	Al	80	60.8	dunite
33752	Al	121	21.8	dunite

#33364

#33370

15 mm

#33372

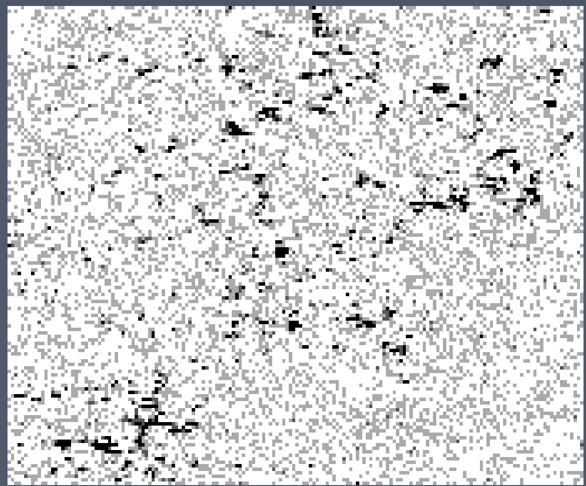
#33752

EPMA (Electron Probe Micro Analyzer) mapping

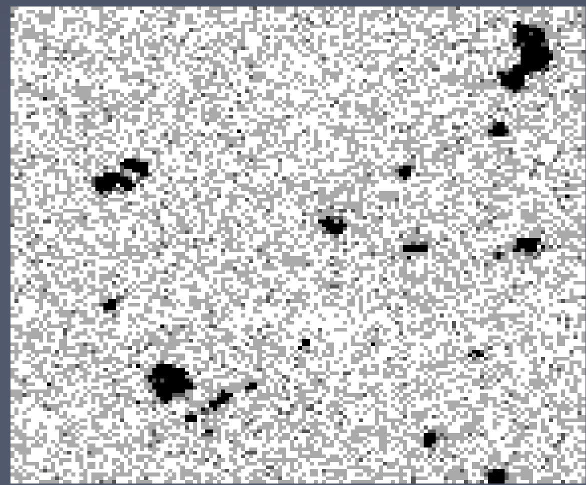
Mapped elements: Dunite : Mg, Al, Si, Fe, Cu
Basalt : Mg, Al, Ca, Si, Fe

Mg

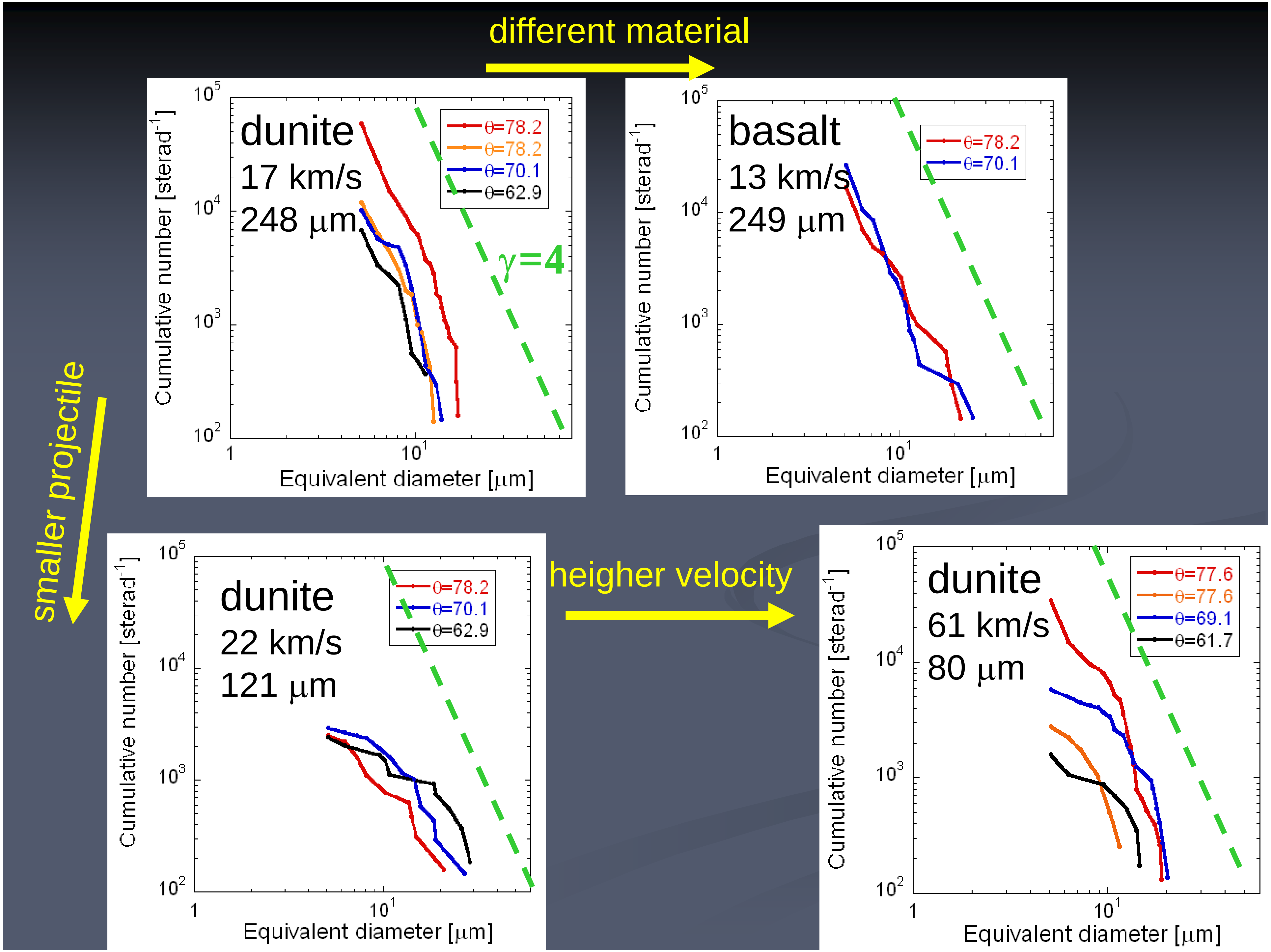
500 μm



Al

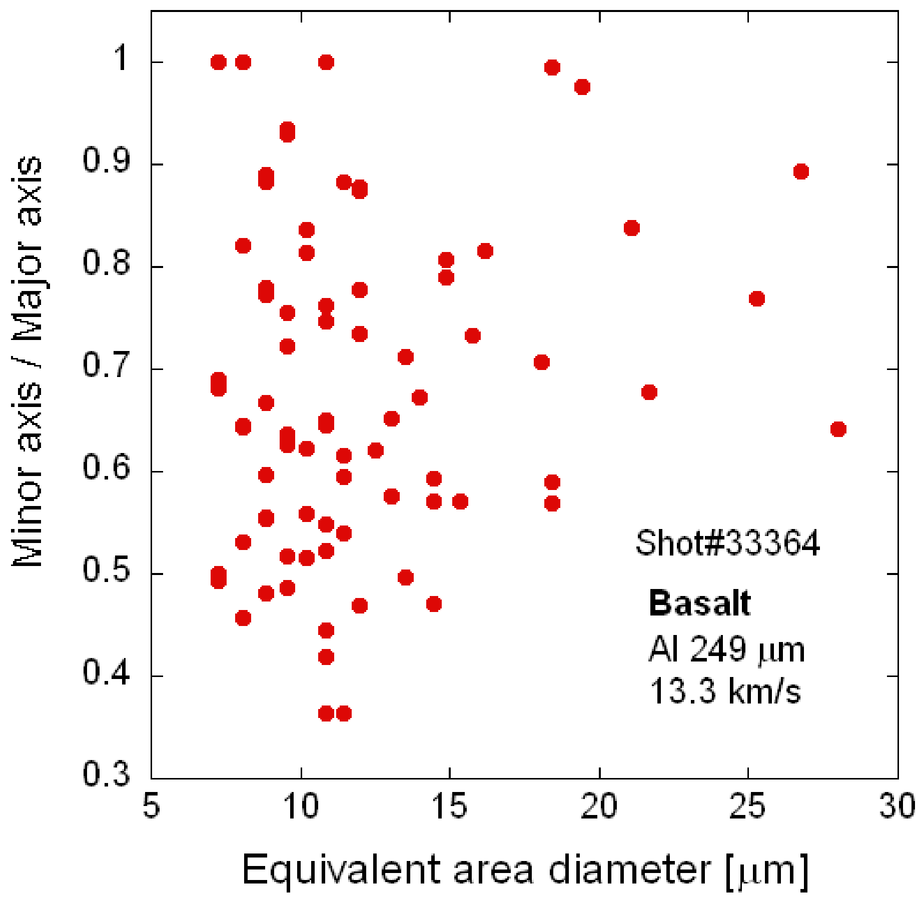


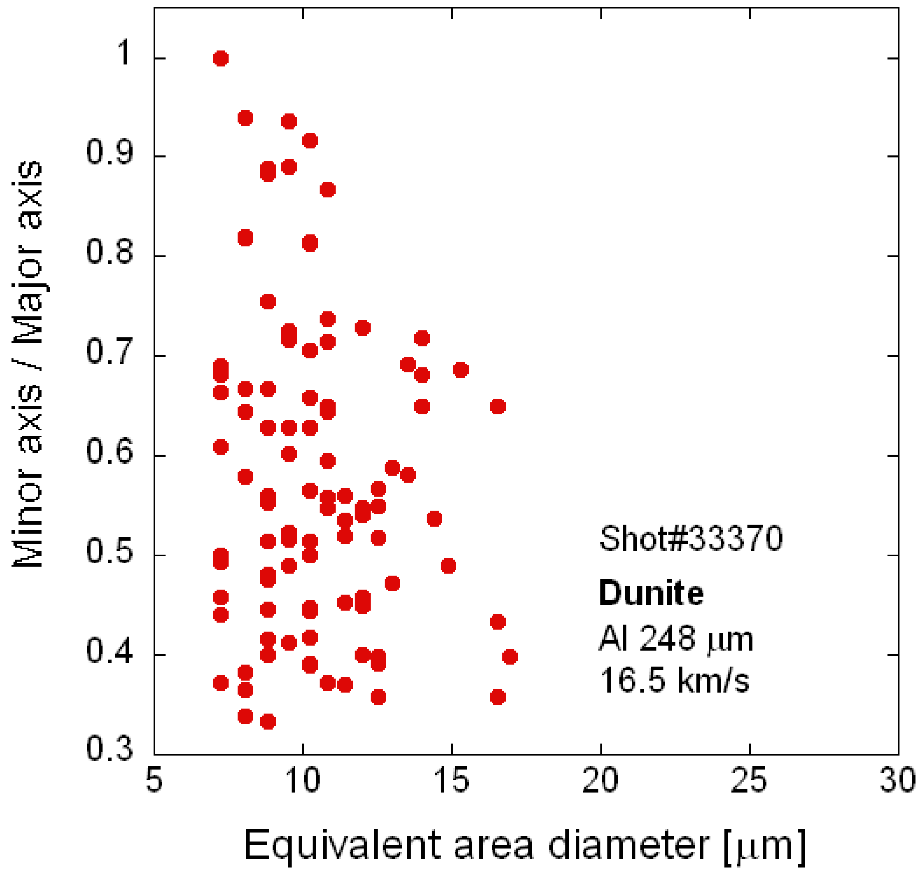
We analyzed the surface of the aerogel blocks at a mapping mode (3.2✕3.2 μm/pixel, 1024✕1024 pixels, 15keV, 50ms/pixel).



different material
smaller projectile
heigher velocity
dunite
17 km/s
248 μm
θ=78.2
θ=78.2
θ=70.1
θ=62.9
γ=4
basalt
13 km/s
249 μm
θ=78.2
θ=70.1
dunite
22 km/s
121 μm
θ=78.2
θ=70.1
θ=62.9
dunite
61 km/s
80 μm
θ=77.6
θ=77.6
θ=69.1
θ=61.7
Cumulative number [sterad⁻¹]
Equivalent diameter [μm]

Ejecta shape
(from 2-D EPMA image)





Summary

- We conducted hypervelocity impact experiments.
  13 ~ 61 km/s

- The range of the slope of ejecta size distribution is wide.
  $\gamma \sim 2 - 5$

- There may be material dependence on ejecta shape.

- A possible source for the dust particles around HD172555?

Ejecta velocity

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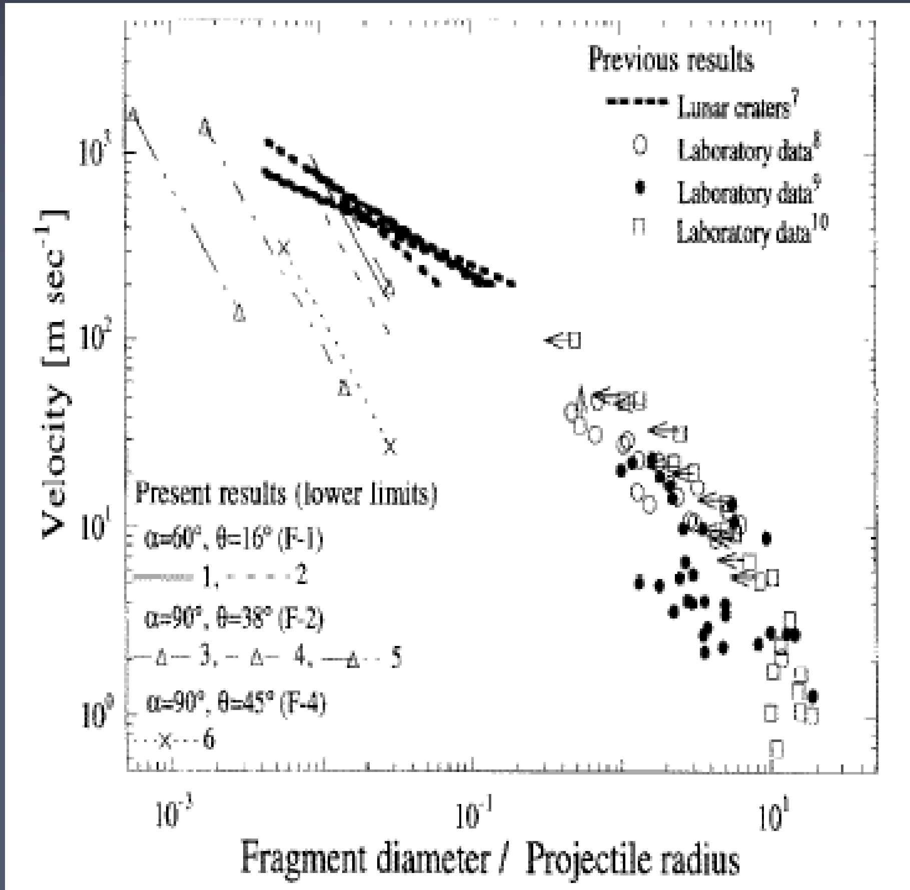
[2] ISAS/JAXA

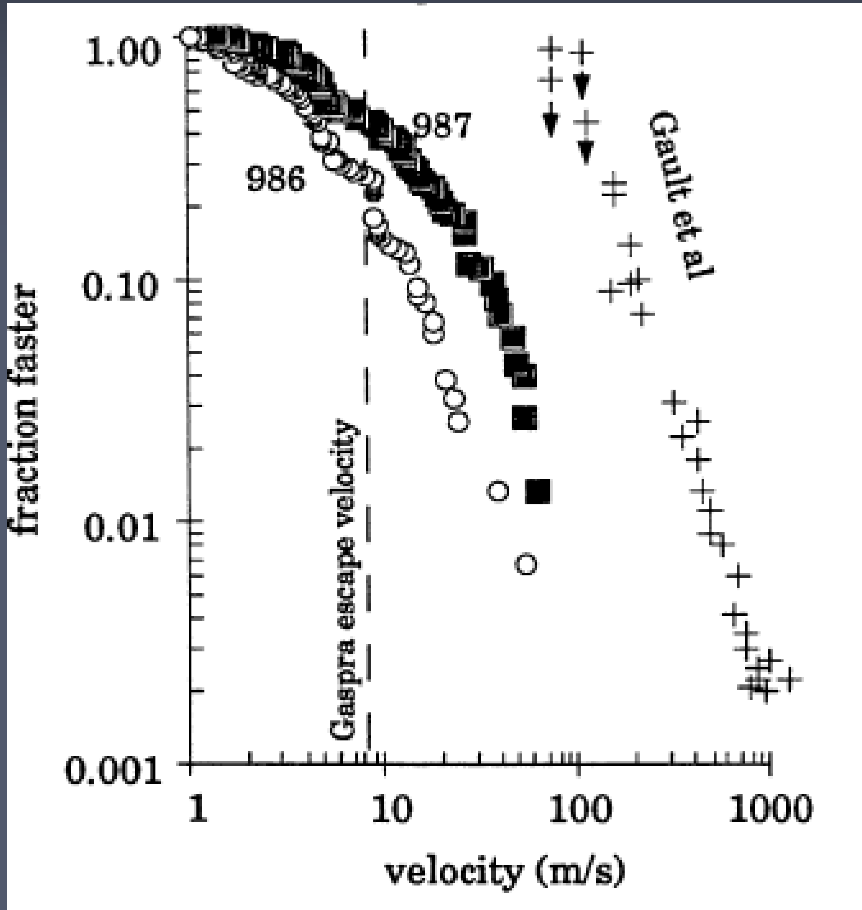
Previous results

Size-(max.) velocity relation



(Nakamura et al., 1994)

Cumulative mass faster than …



(Housen 1992)

Impact experiments

Projectile

Nylon spheres, Iron with/without plastic cylinder

Velocity: 1.7 ~ 7.0 km/s

Diameter: 2.5 ~ 7 mm

Target

Material: Dunite, Serpentinite, Nylon

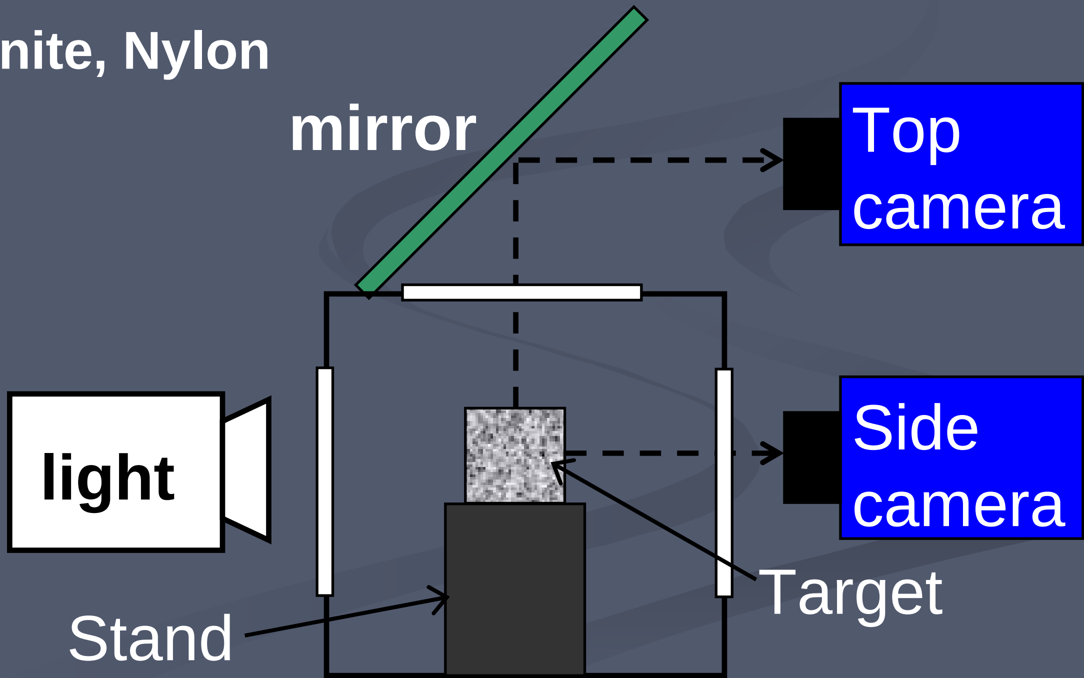
High speed imaging

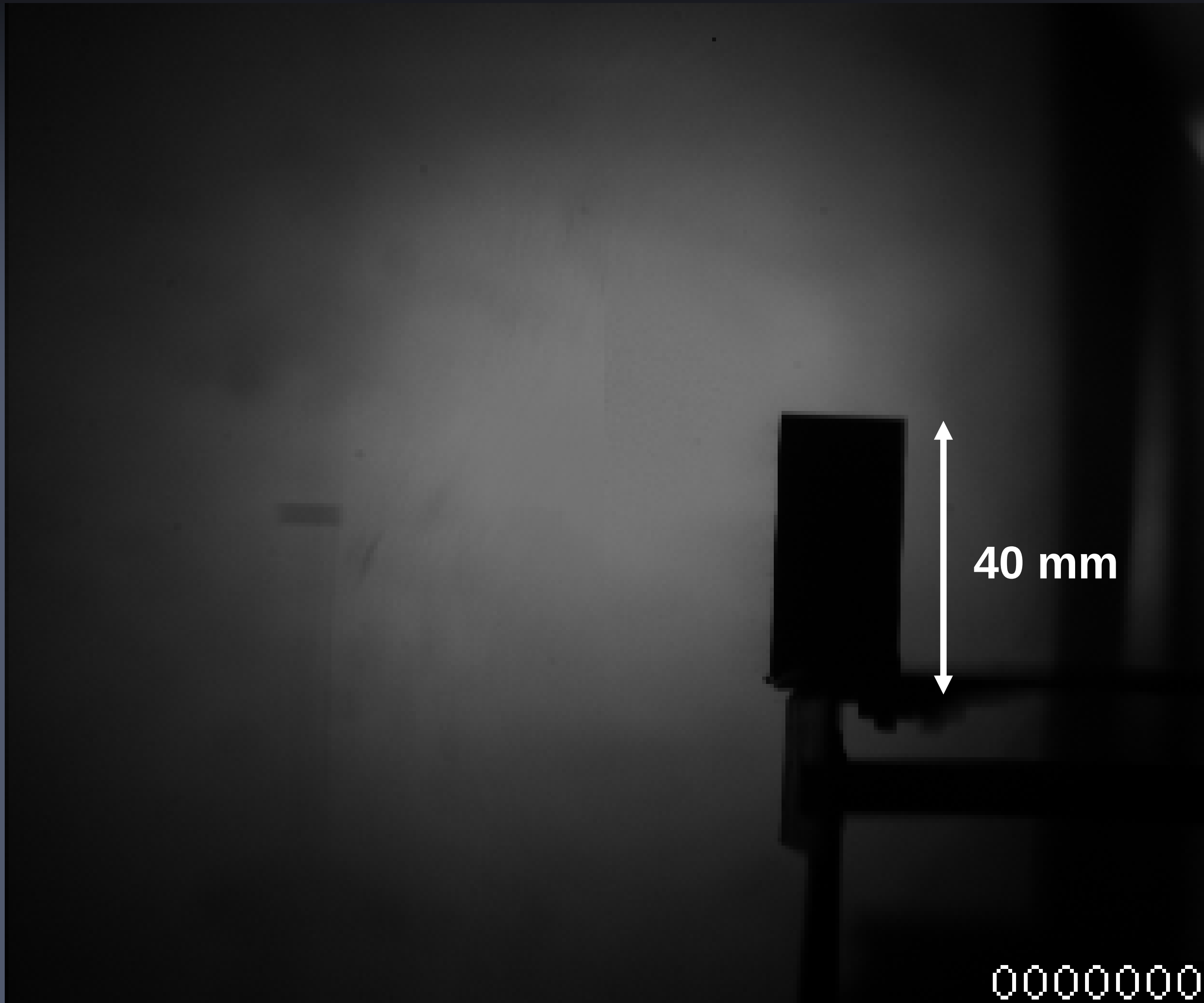
Side camera

- framing interval： 4, 8 μs
- exposure： 2 μs

Top camera

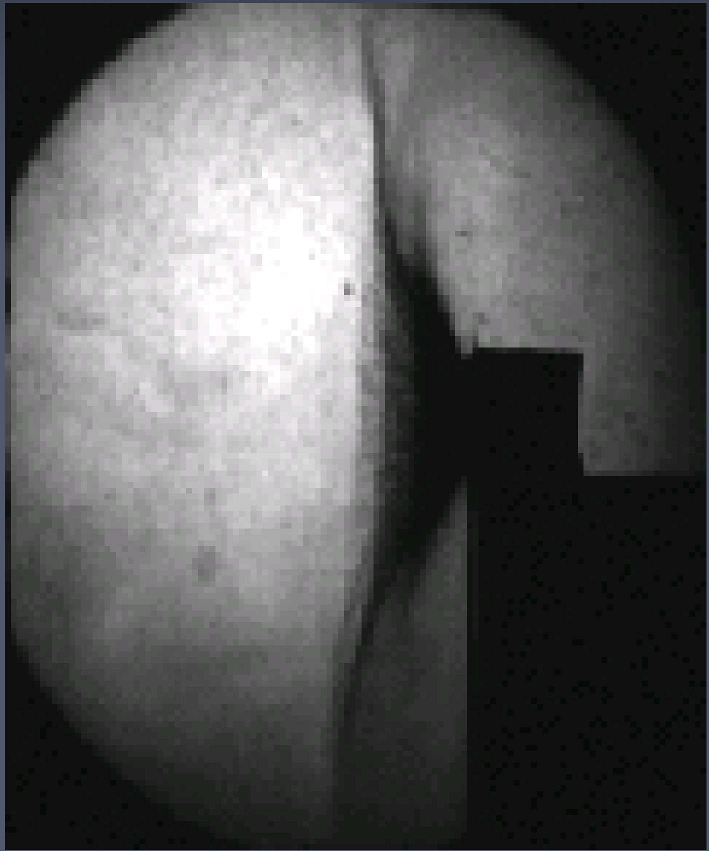
- framing interval： 4 μs
- exposure： 0.5, 1 μs



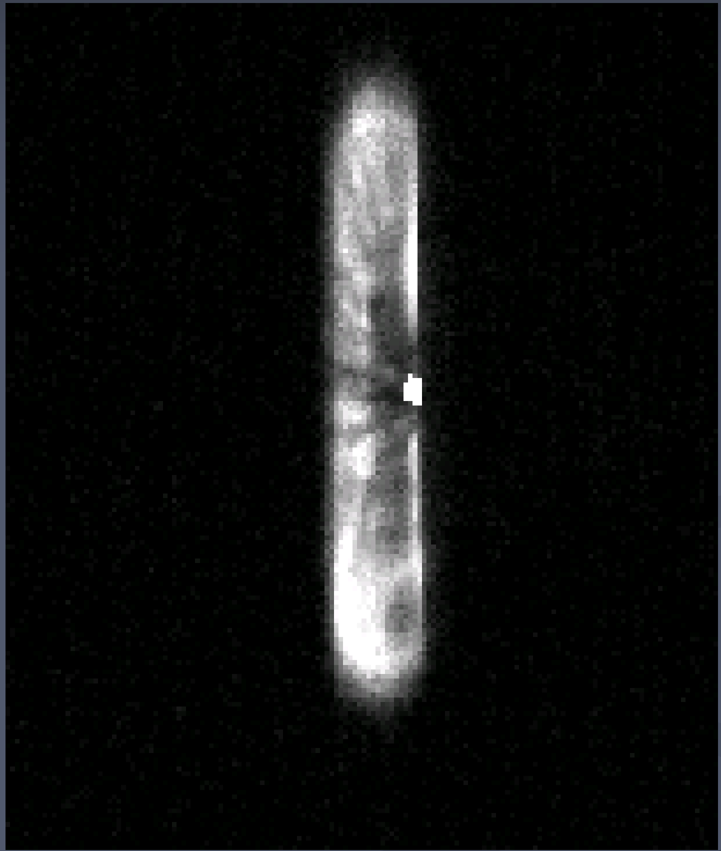


Iron meteorite 2.5ϕx2 → dunite block 40x40x20, 4 μs/frame

Impact experiments

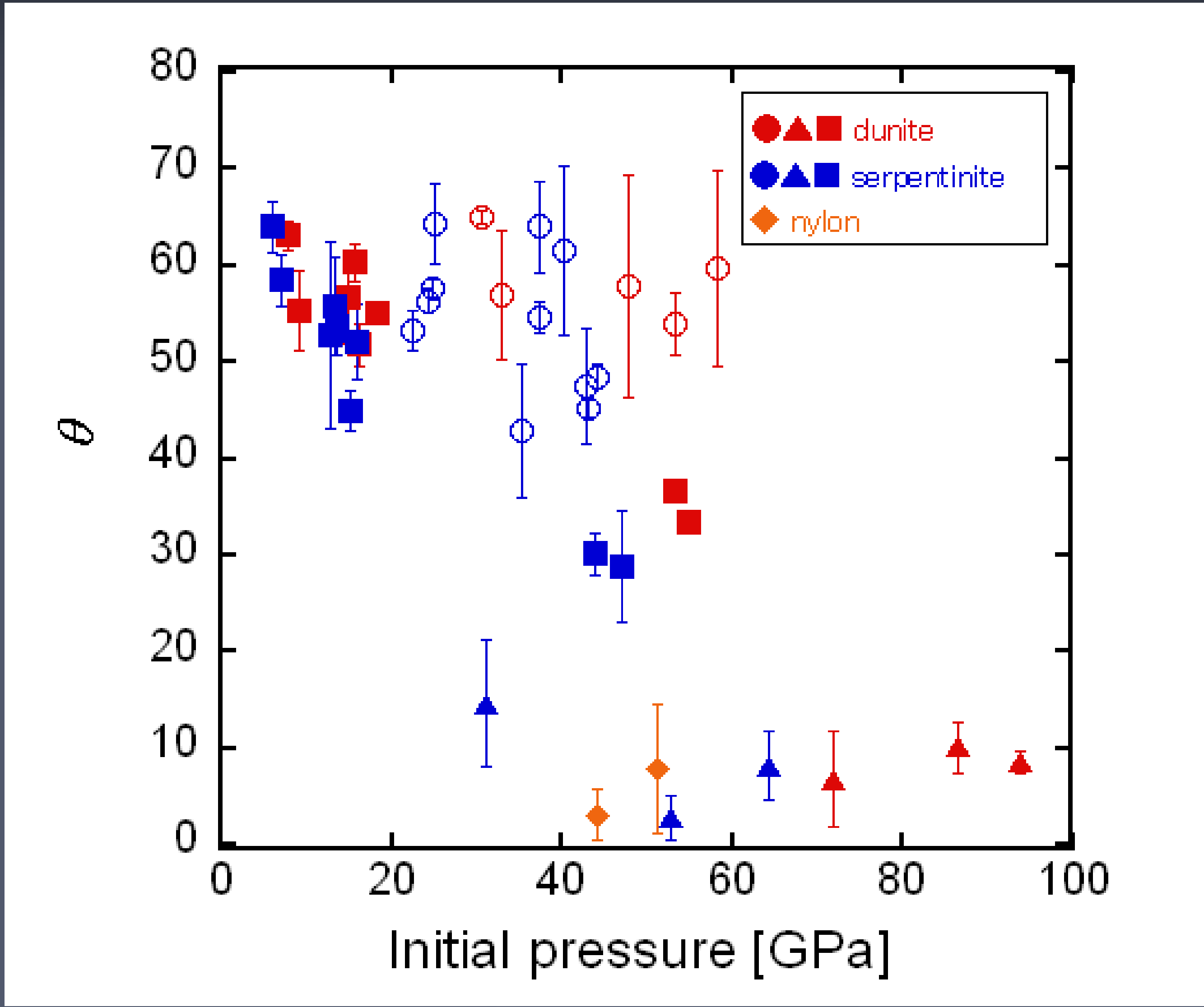


Solid ejecta

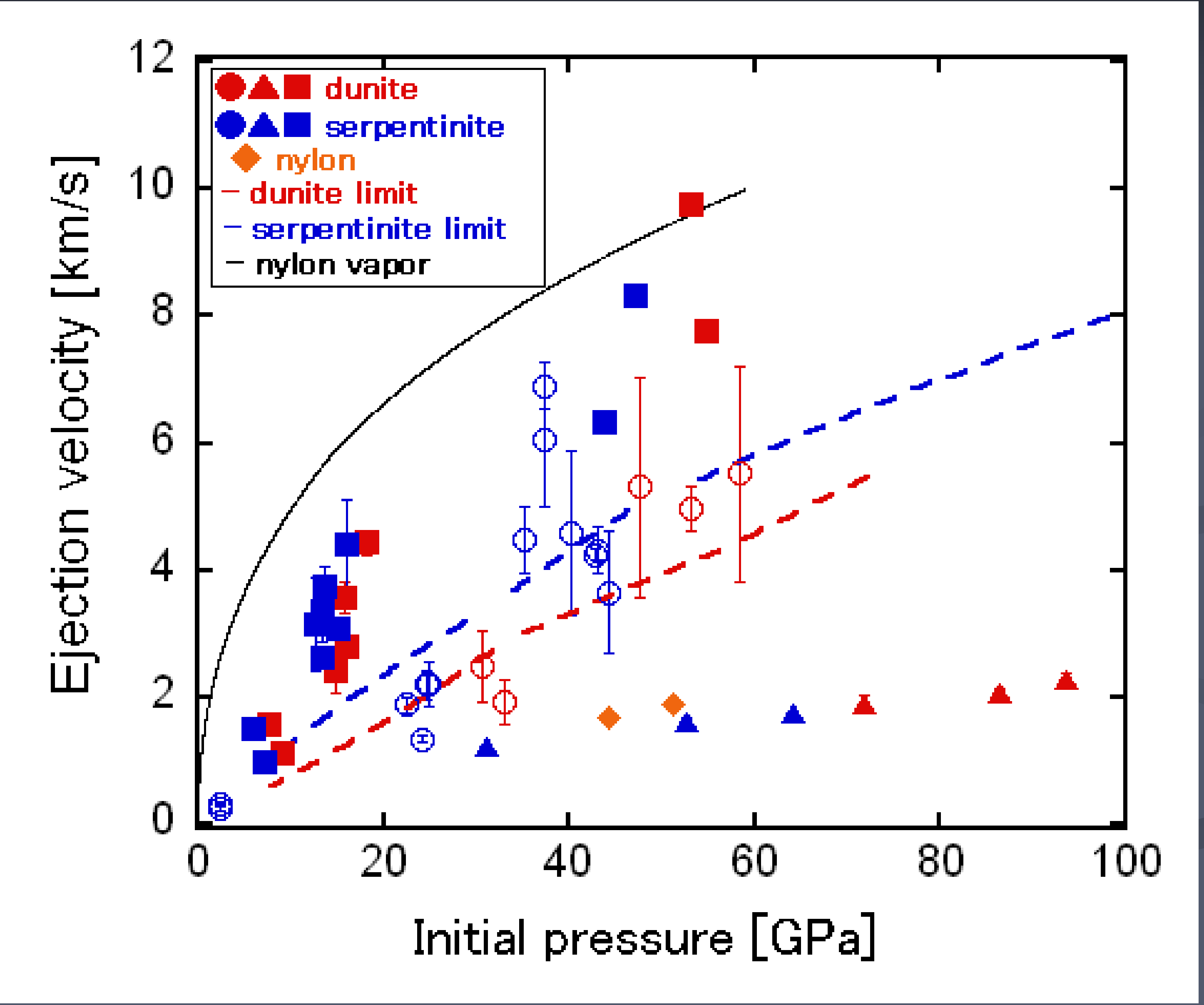


Nylon vapor plume

Ejection angle



Ejection velocity



Summary

- The maximum ejecta velocity and the shape of the ejecta cone is

  - dependent on the initial pressure (initial particle velocity)
  - highly dependent on the projectile material (projectile/target density ratio)

- The motion of the fastest ejecta is affected by impact generated vapor.

Near future work

- Put constraints on the ejecta size and velocity distribution based on the images (information from the extinction)