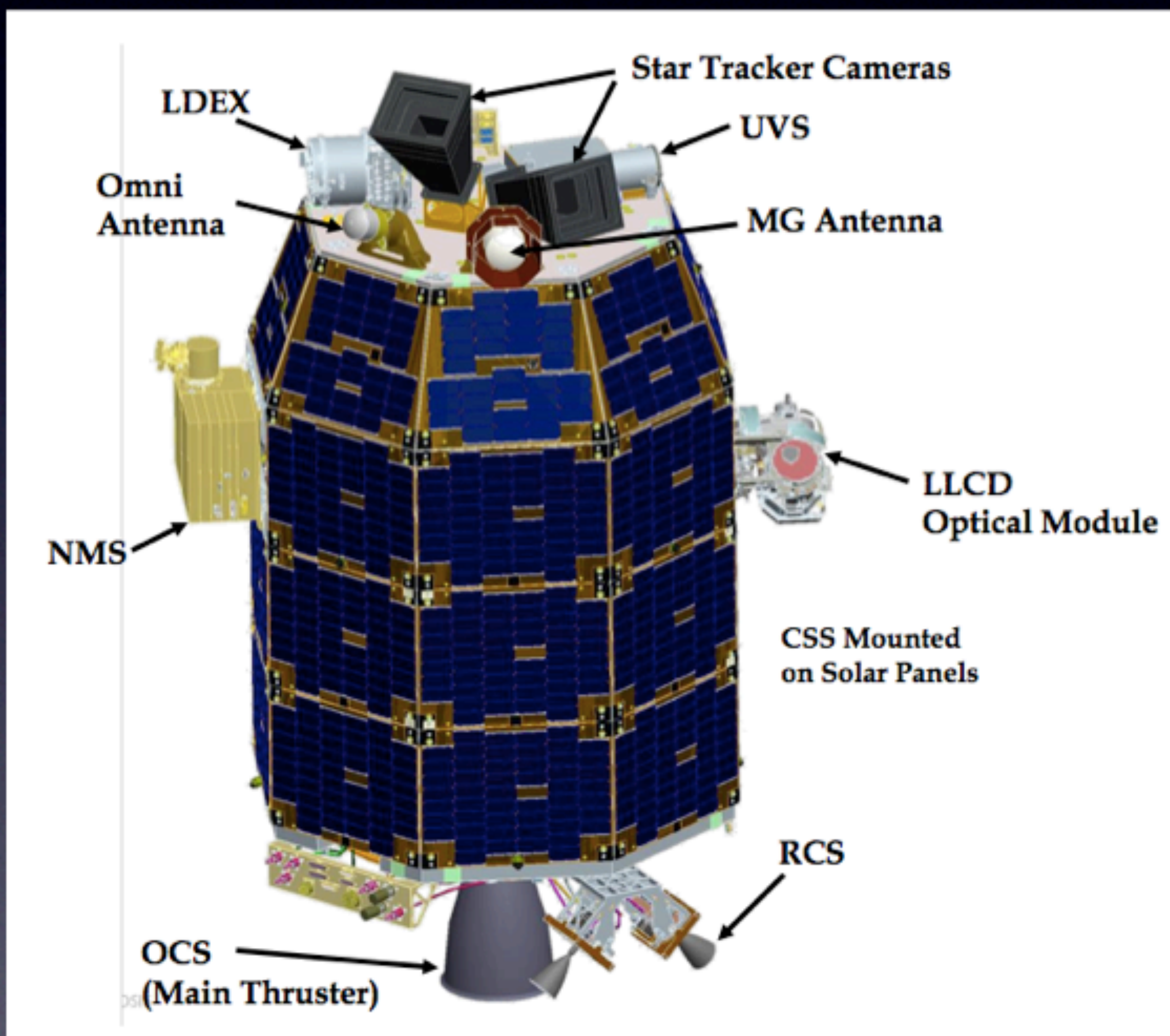
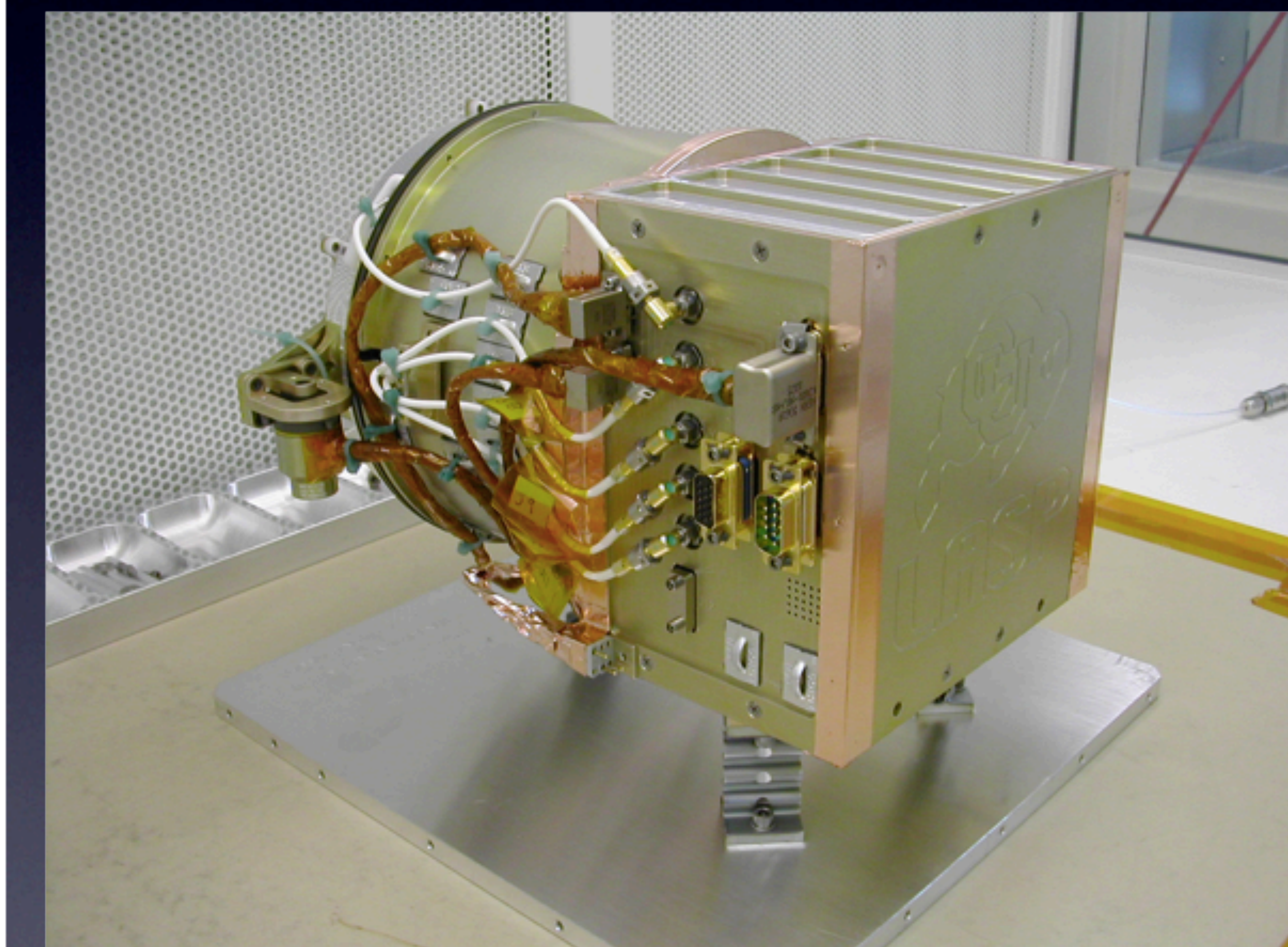
The Lunar Dust Cloud

Sascha Kempf[1,2], Mihaly Horanyi[1,2], Zoltan Sternovsky[1,2], Jürgen Schmidt[3], and Ralf Srama[4]

LDEX on LADEE

Lunar Dust Experiment

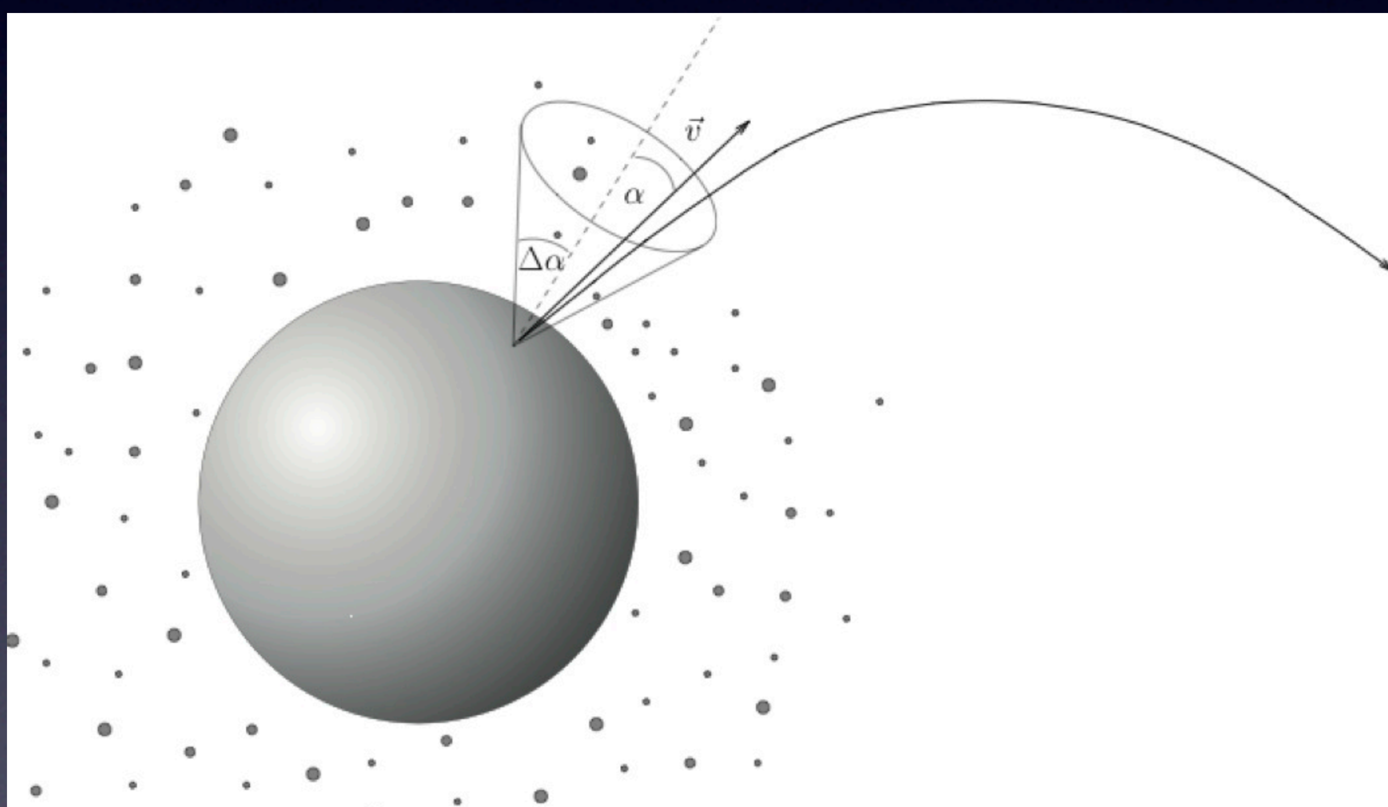




How is the Lunar dust produced?

Dust Production

Meteoroid Impacts Produce Ejecta



Sremcevic et al., Icarus, 2005

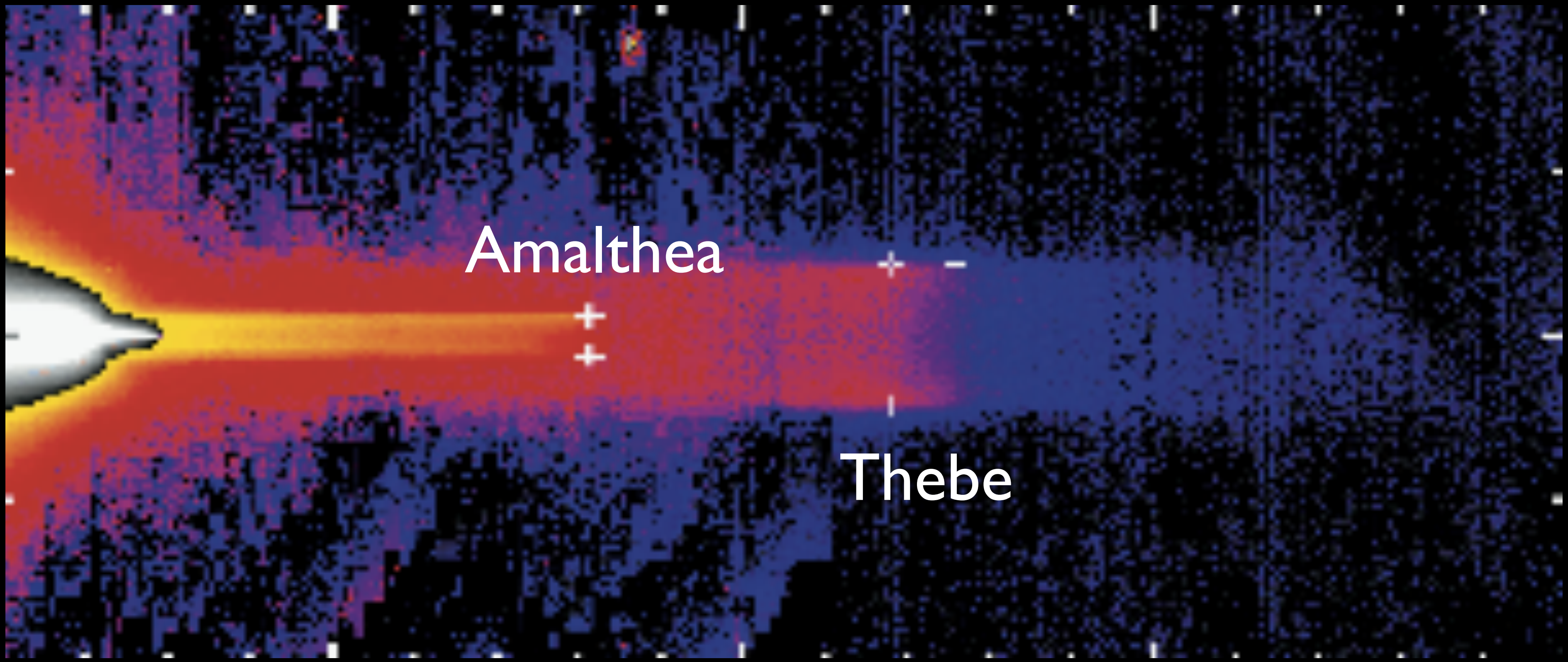
- Gravitationally Bound Ejecta Populate Cloud
- Some Ejecta Escape:
  - Feed Rings
  - Moon Mass Loss Mechanism

Lunar Mass Yield ~ 1000

Koschny & Grün, Icarus, 2001; Krivov et al., Icarus, 2003

Dust Moon „at Work"

Jupiter ʻs Gossamer Rings



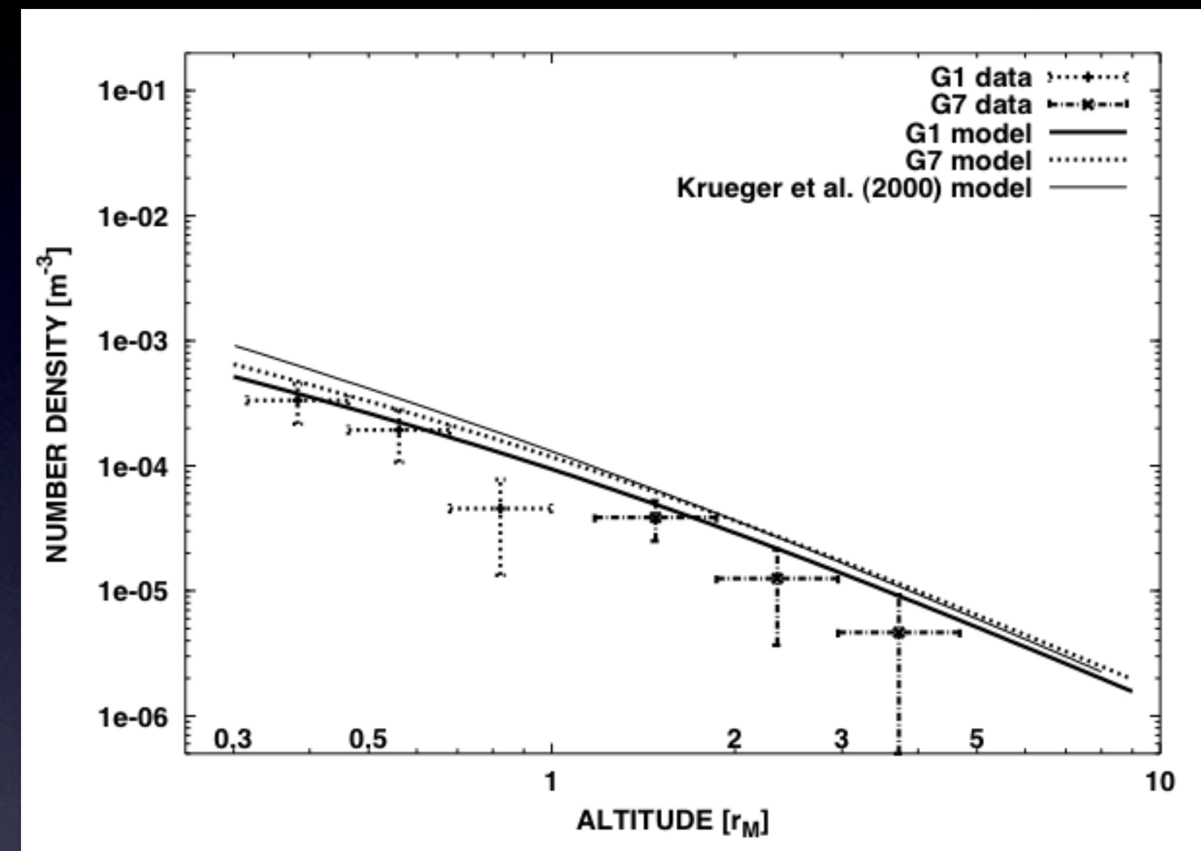
Burns et al., Science, 1999

Ejecta Clouds

Galileo Dust Detector: Galilean Satellites Wrapped in Dust Clouds

(Krüger et al., Nature, 1999)

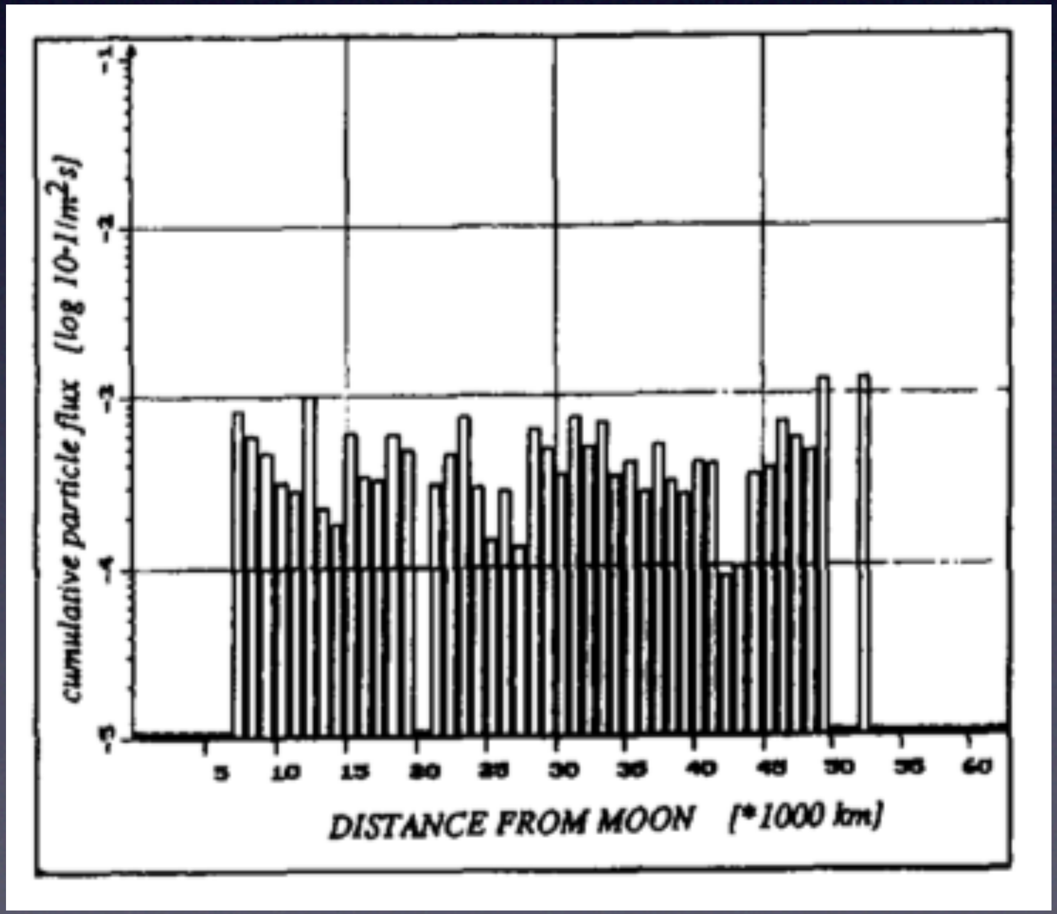
Krivov et al., PSS, 2003

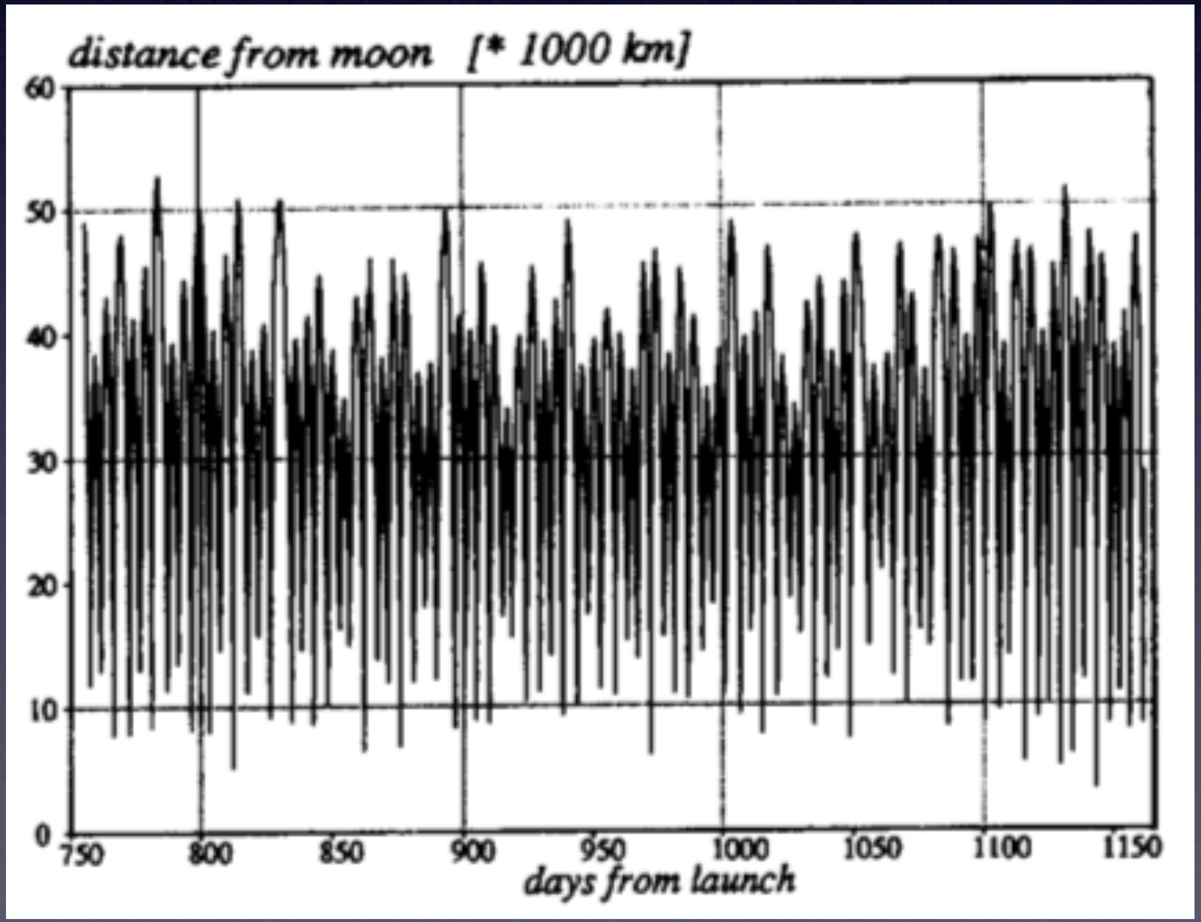


Almost Isotropic Clouds Composed of Surface Ejecta

Evidence Lunar Exosphere?

- Hiten was the only Lunar orbiter equipped with a dust detector (MDC)
- Orbit was not favourable for detecting Lunar ejecta (Altitude: 10000 km ... 50000 km)

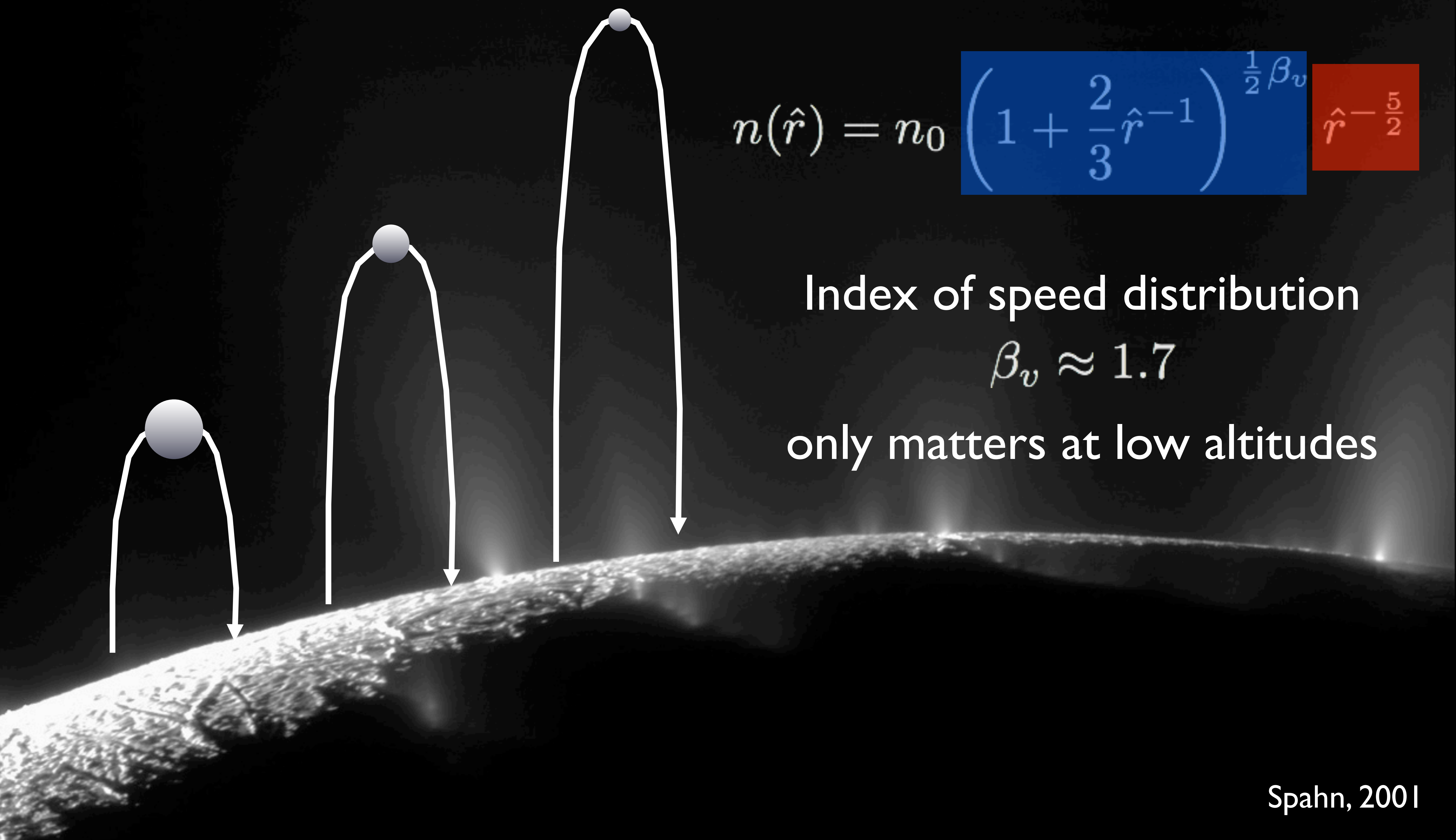




Iglseder et al., 2006, Adv. Space Res.

Trajectory and dust data are lost!

Ballistic Dust Clouds



$$n(\hat{r}) = n_0 \left(1 + \frac{2}{3}\hat{r}^{-1}\right)^{\frac{1}{2}\beta_v} \hat{r}^{-\frac{5}{2}}$$

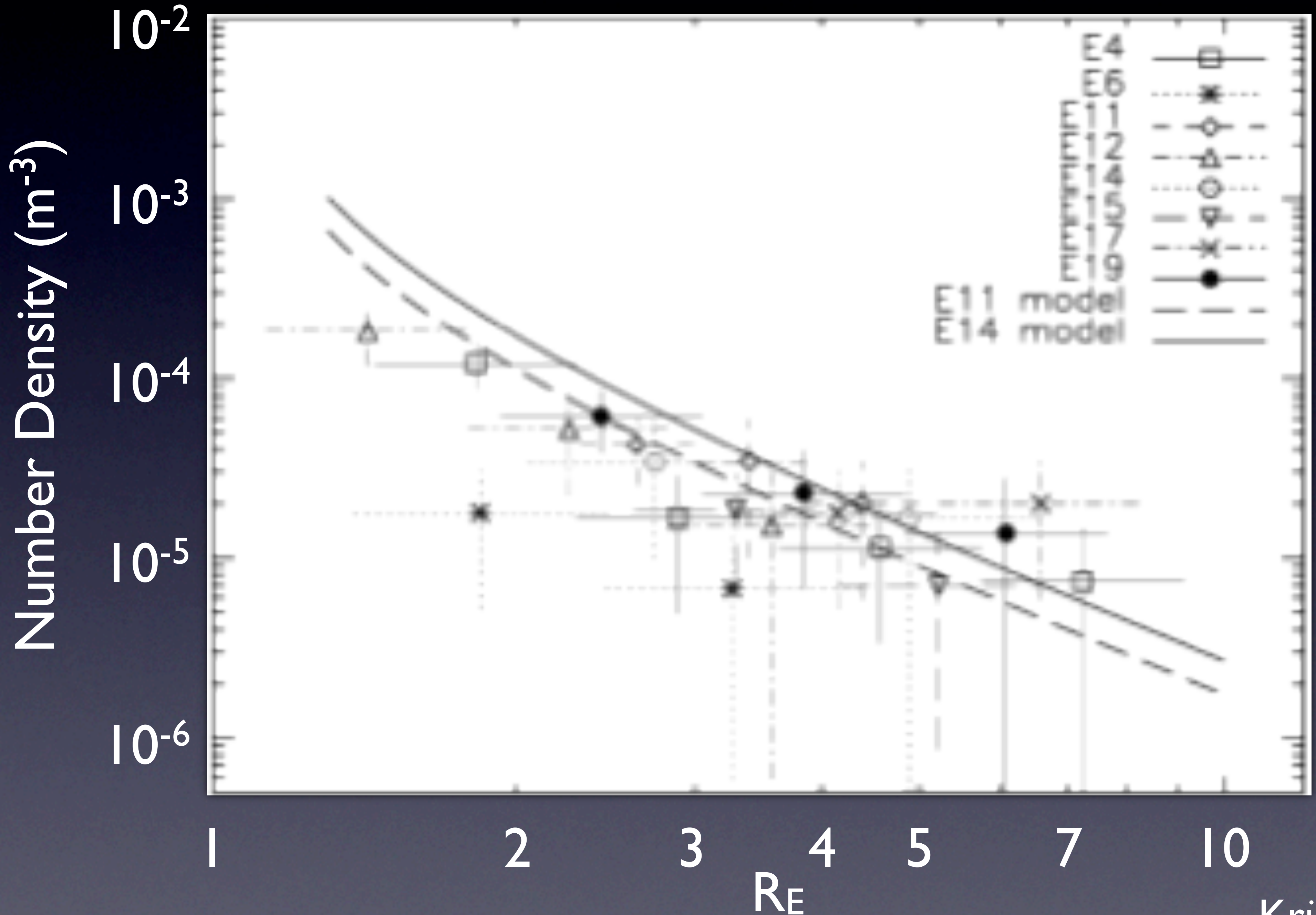
Index of speed distribution

$\beta_v \approx 1.7$

only matters at low altitudes

Spahn, 2001

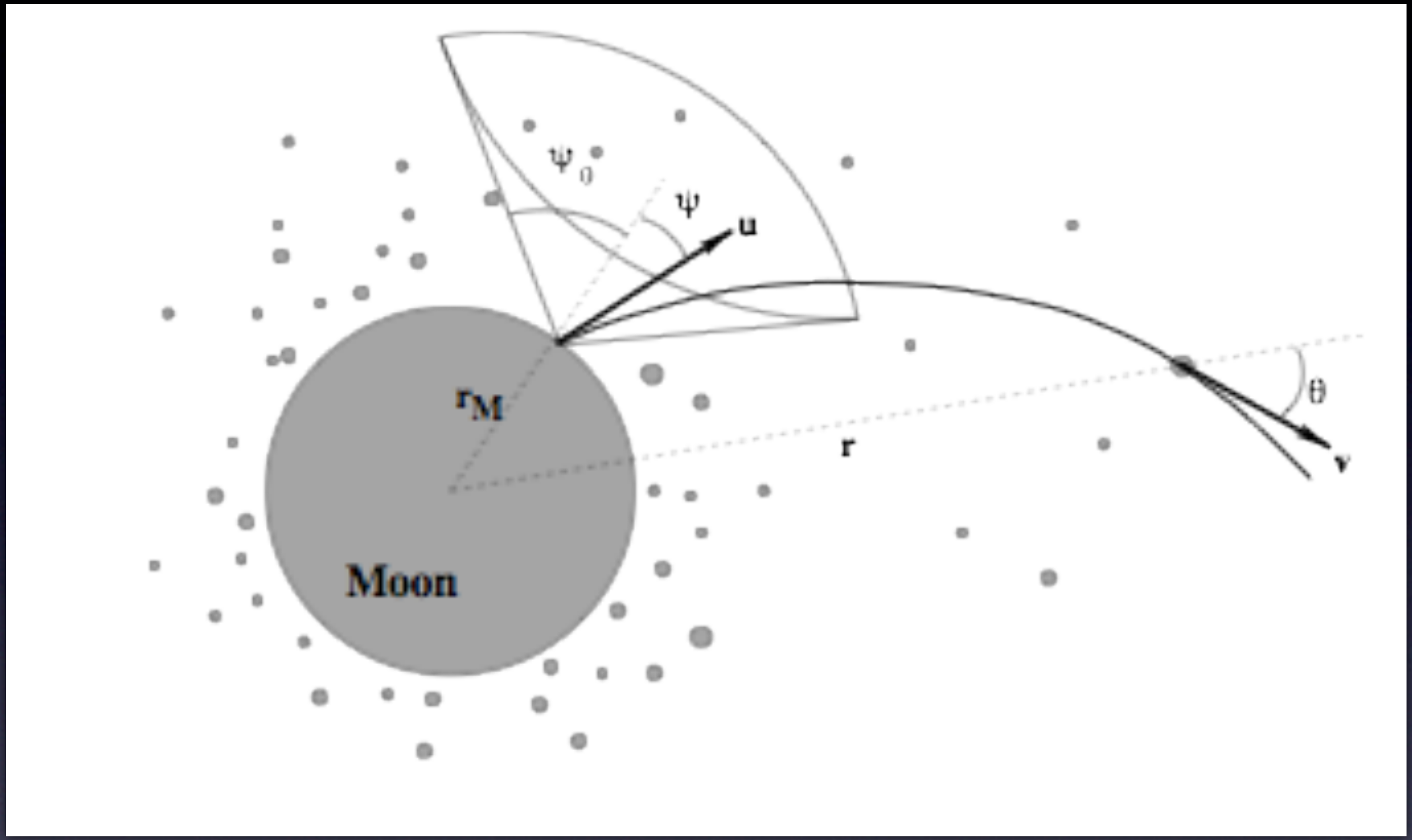
Reproduces Cloud Data



Krüger et al., PSS, 2003

General Case

Include ejectas ‘ angular distribution:



$$n(r, v, \theta) = \frac{N^+}{8\pi^2}\frac{1}{r^2}\frac{1}{|\dot{r}|}\frac{1}{v^2 sin\theta} f(u, \psi)\left|\frac{\partial(u, \psi)}{\partial(v, \theta)}\right|$$

Krivov et al., 2003 Sremcevic et al., 2003, 2005

Ejecta Cloud Profile

Bound Ejecta:

$$n_b(r) = \frac{N^+}{2\pi r_M^2 v_{esc}} \gamma u_0^\gamma r^{-5/2} K_b(r)$$

Unbound Ejecta:

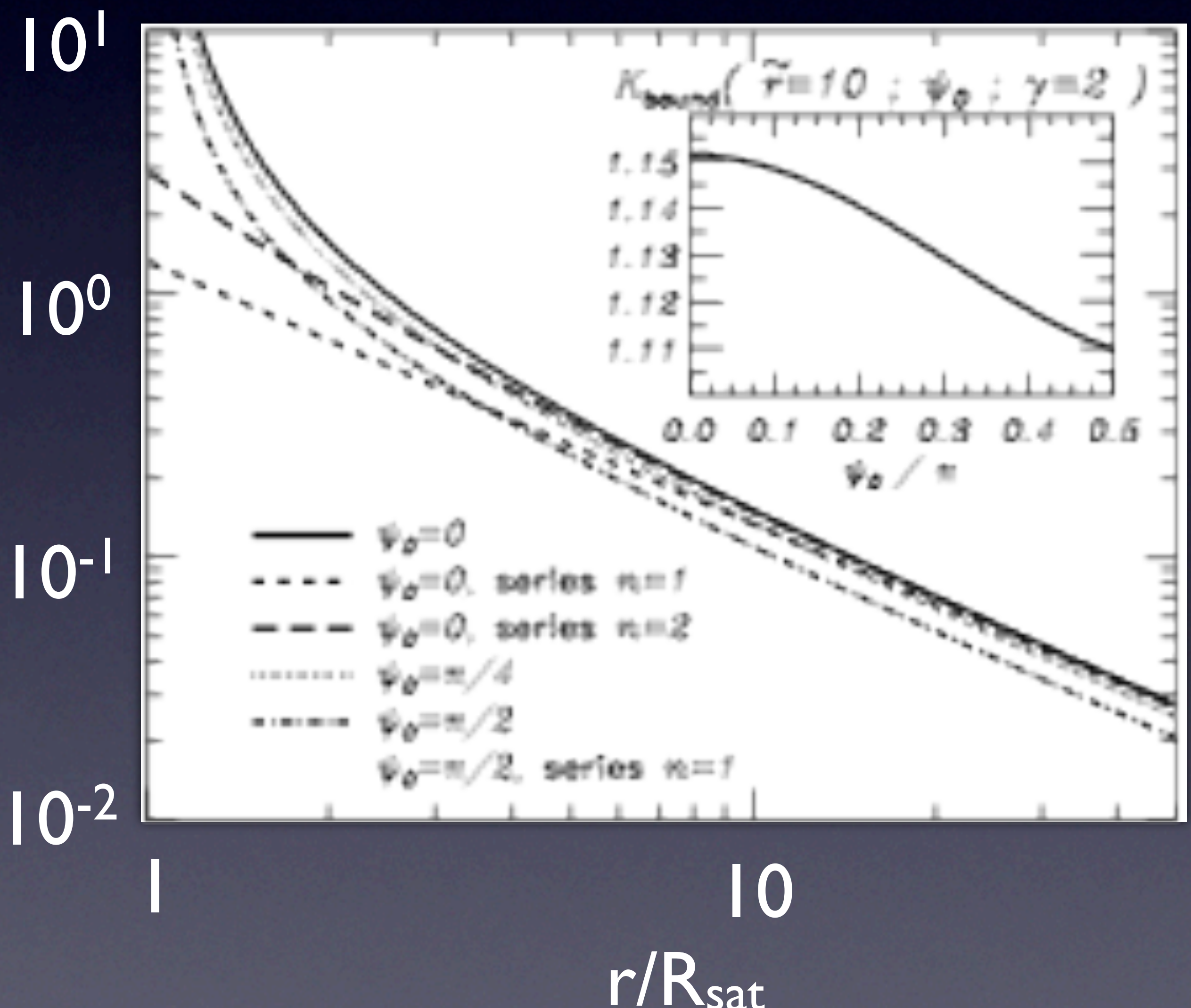
$$n_u(r) = \frac{N^+}{4\pi r_M^2 v_{esc}} \gamma u_0^\gamma r^{-2} c_0(\gamma) K_b(r)$$

Krivov et al., 2003   Sremcevic et al., 2003, 2005

Angular Distribution

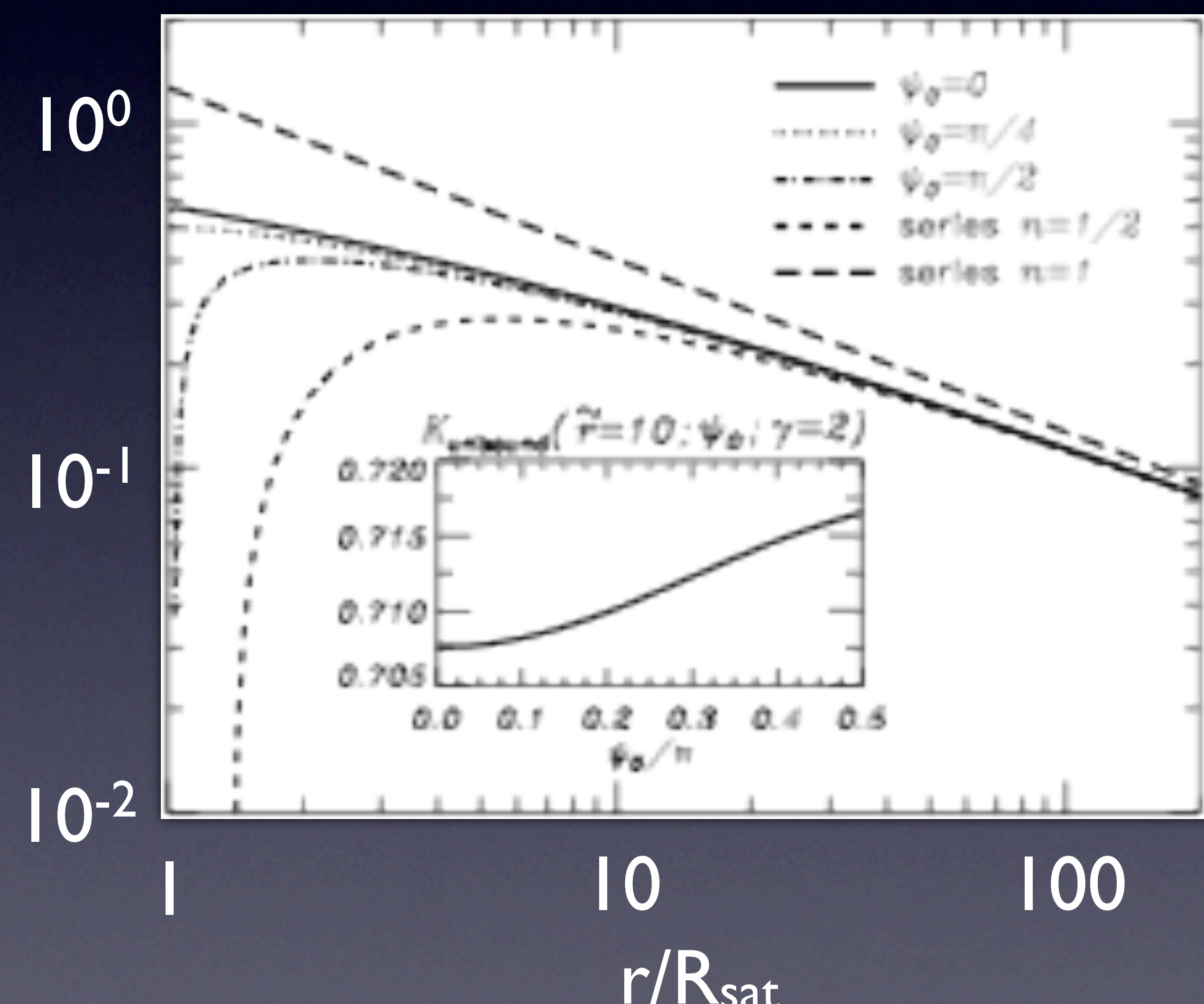
Bound Ejecta:

$K_{bound}-1$



Unbound Ejecta:

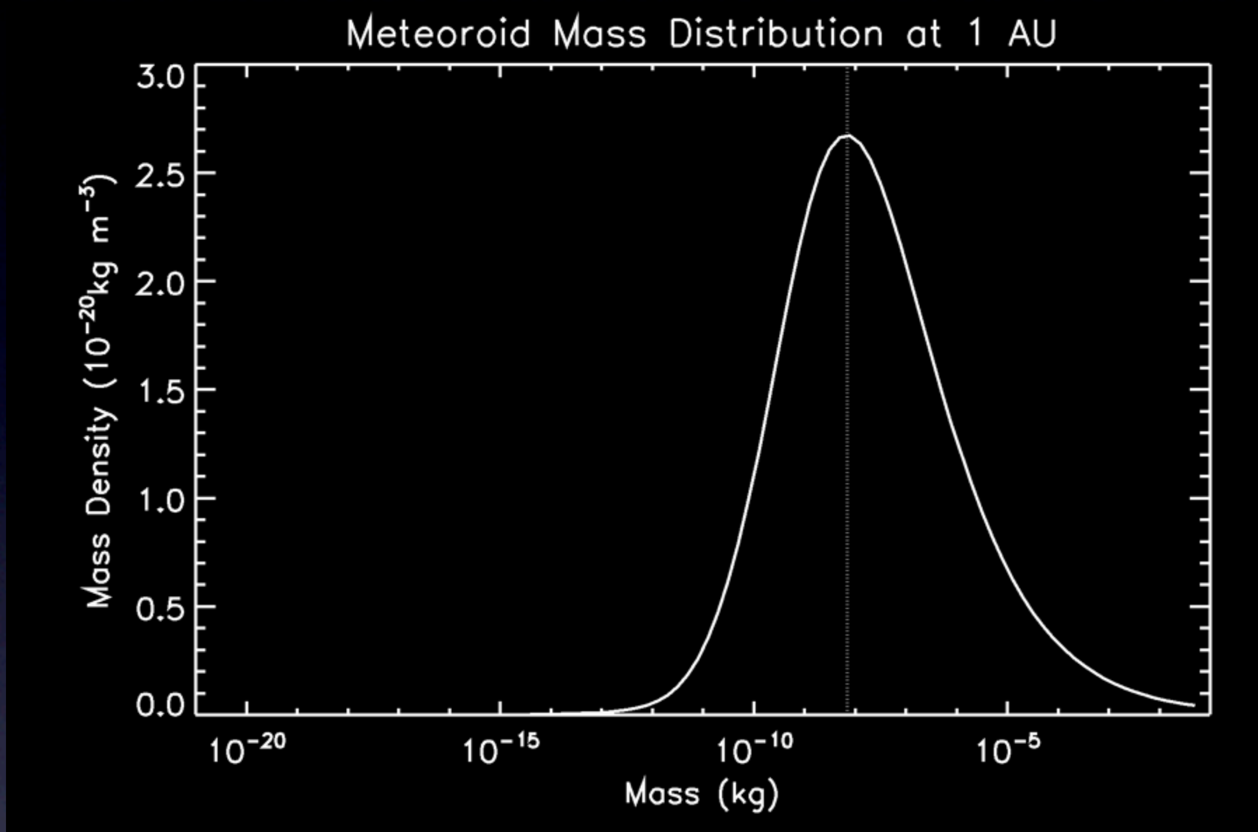
$1-K_{unbound}$

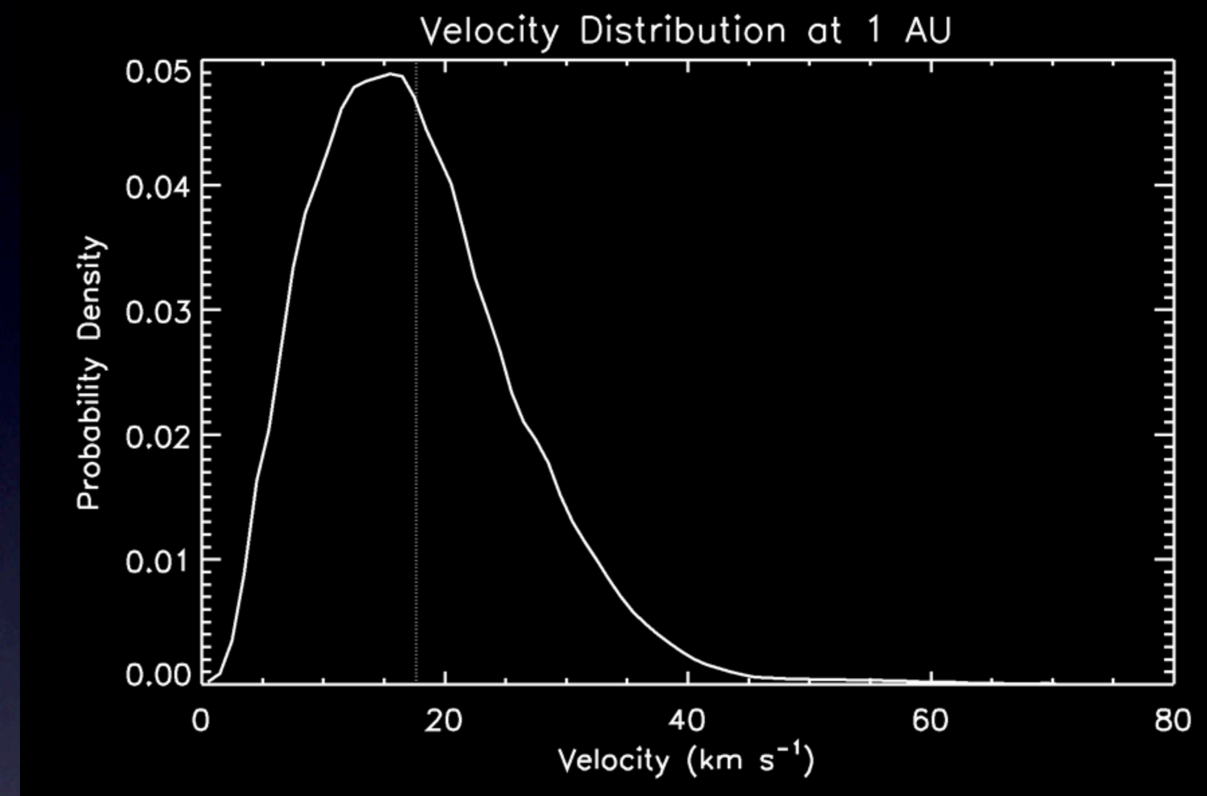


Angular Distribution can be Deduced from Density Profile

How About the Impactor Flux?

Interplanetary Dust @ 1 AU



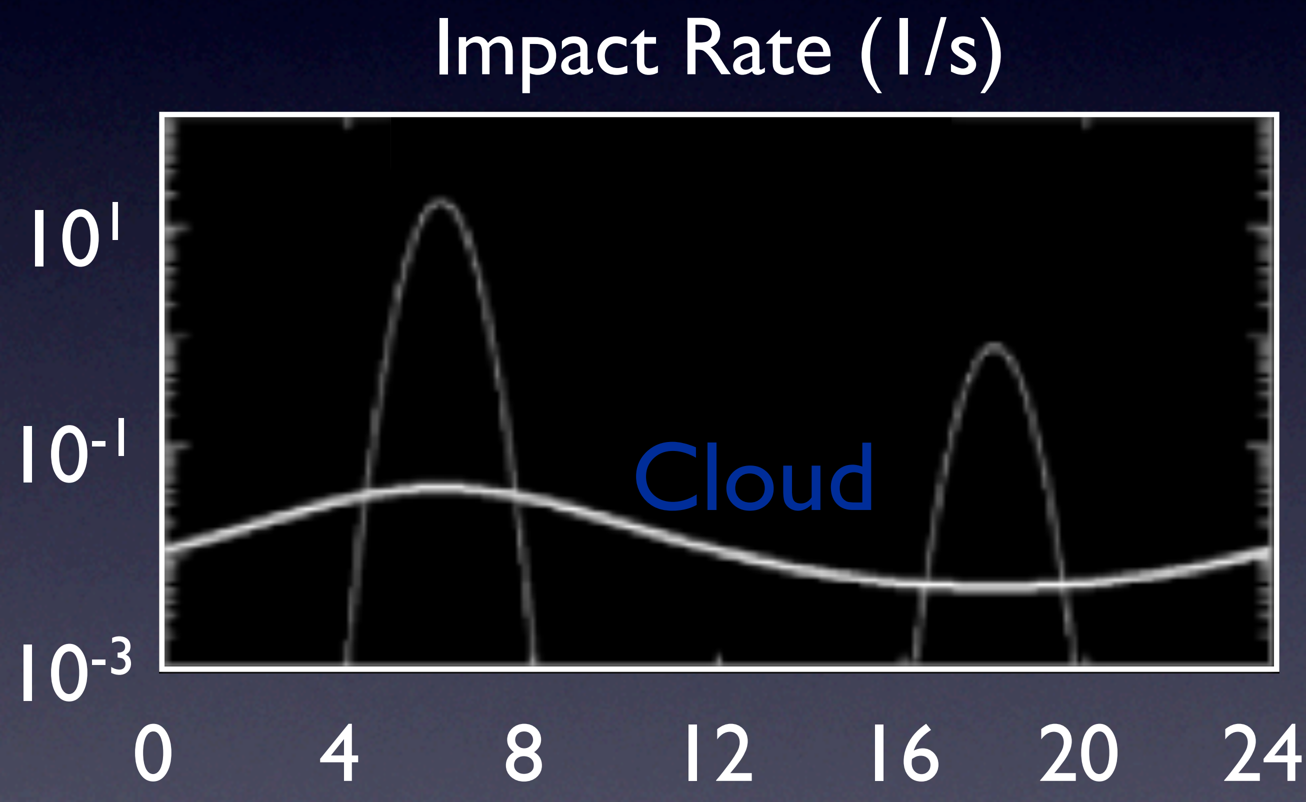


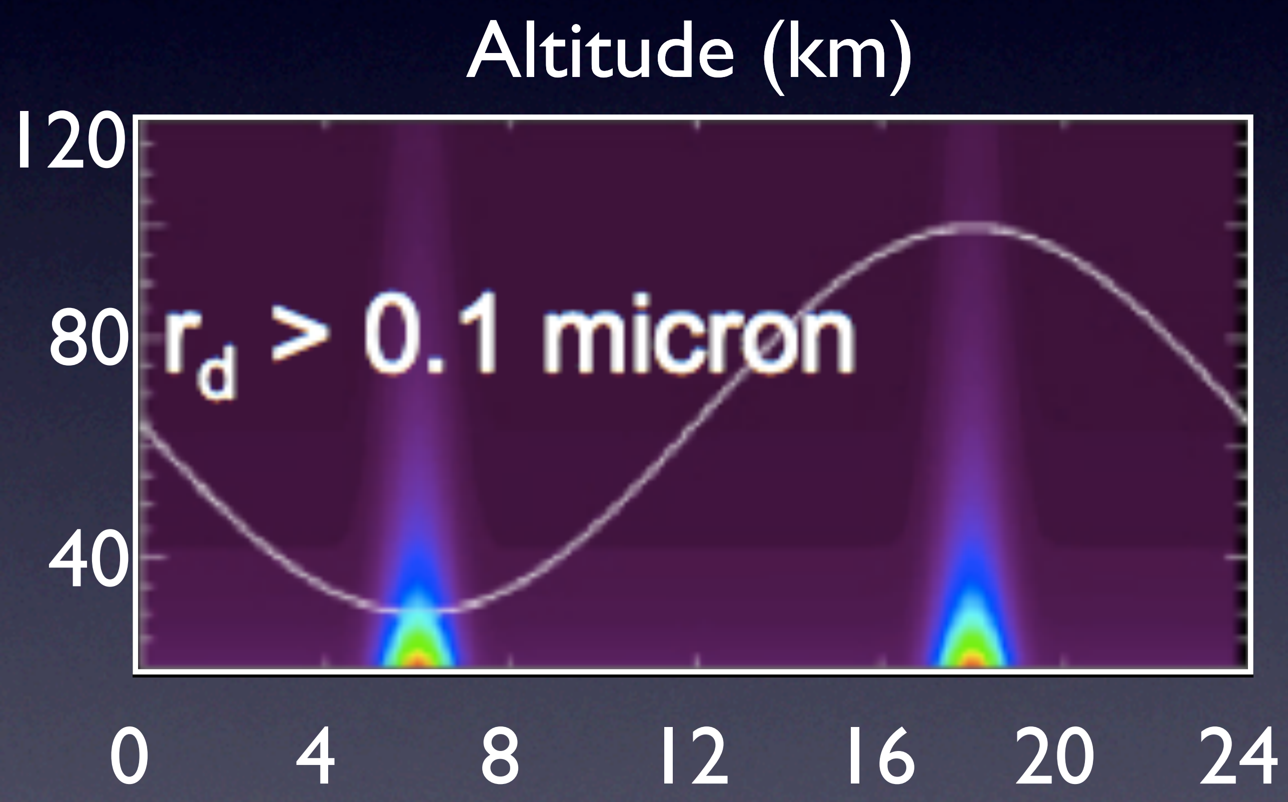
Taylor, Adv. Space Res., 1995

- Differential mass flux on plate spinning orthogonally to ecliptic plane
- based on spacecraft data and lunar crater size distribution
- based on spacecraft data,

- derived from radio meteors data
- mean speed: ~ 17 km/s

LDEX Prediction

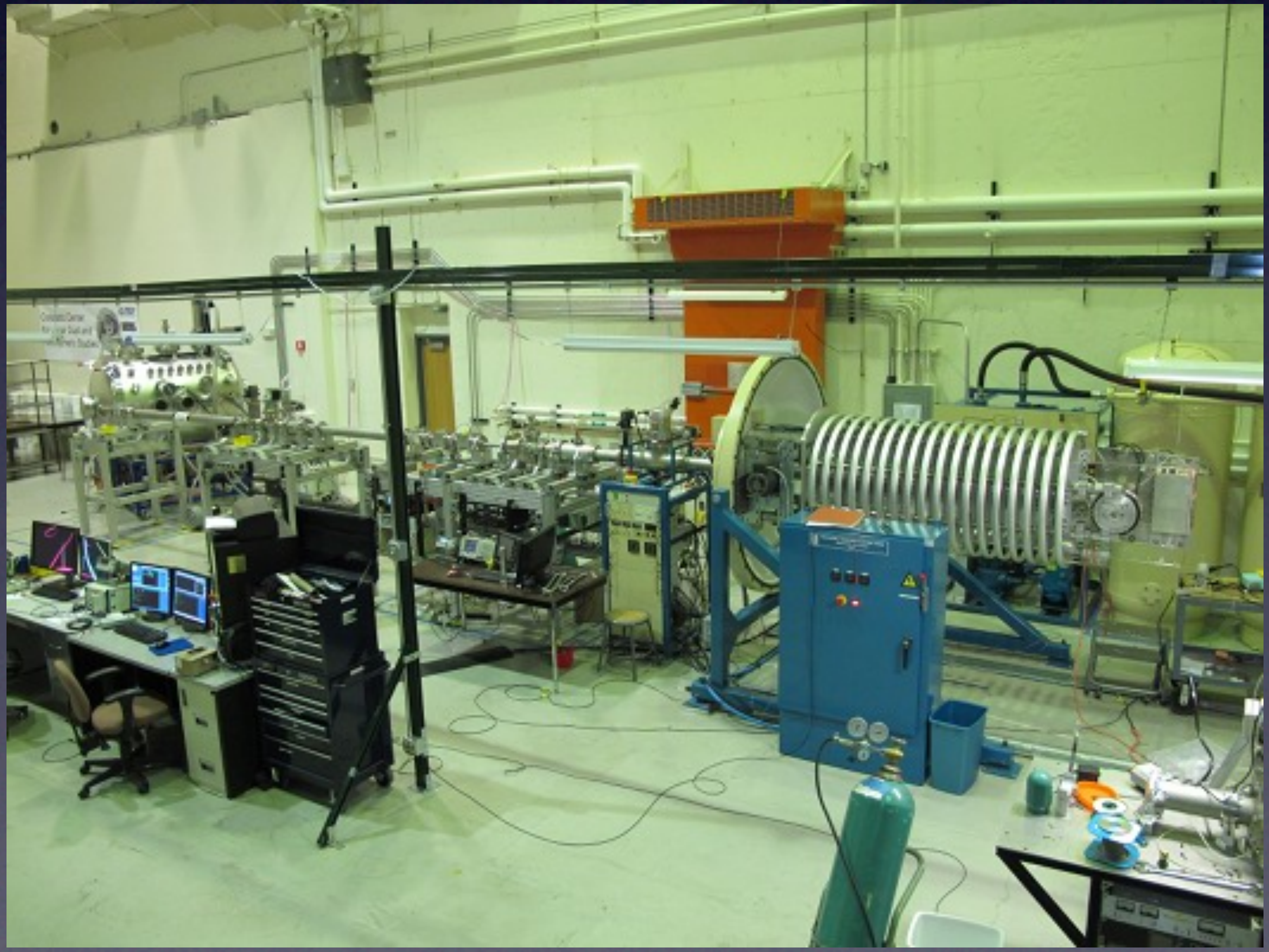


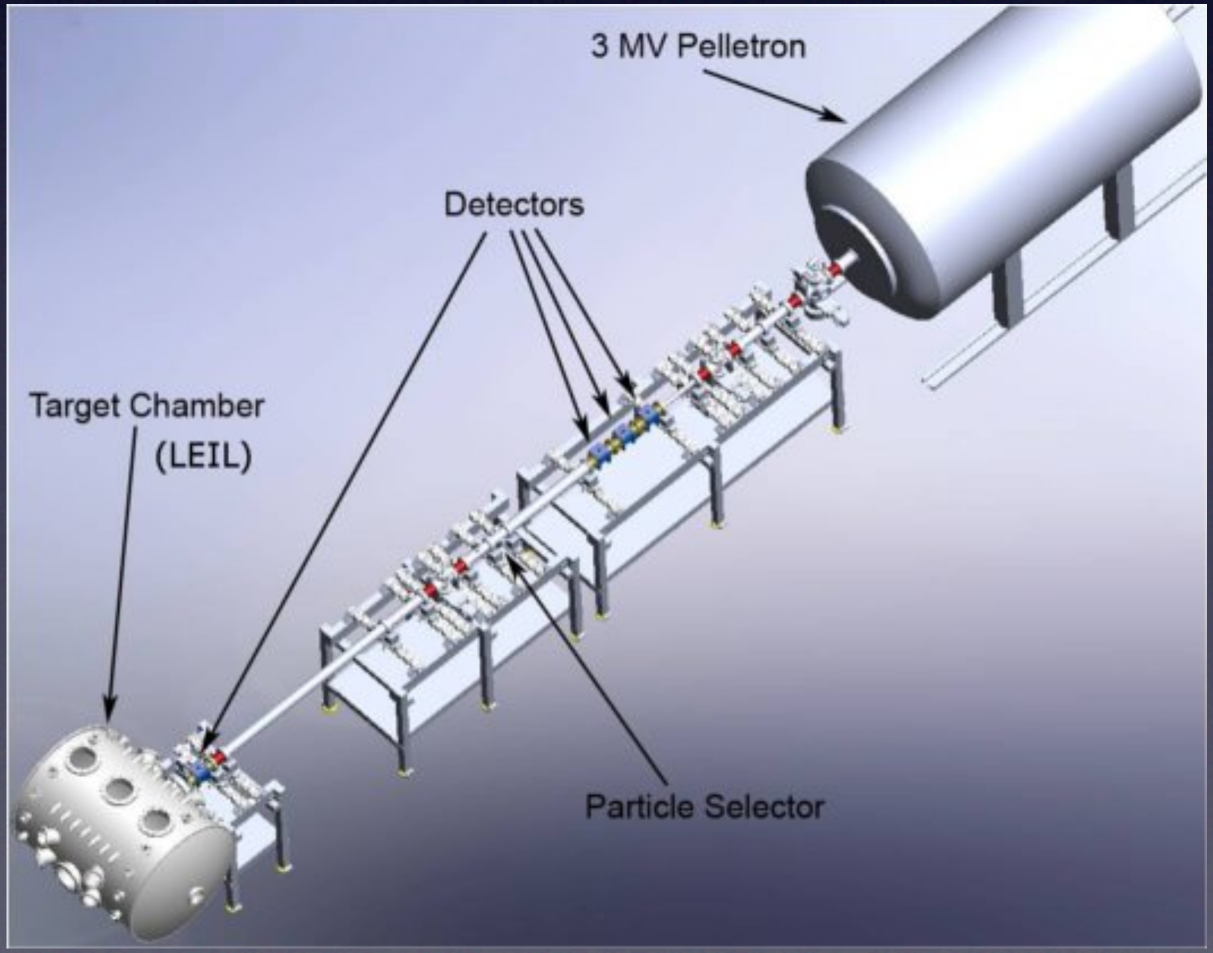


Sternovsky, NLSI Meeting, 2009

CCLDAS Accelerator at CU Boulder

3 MV Pelletron

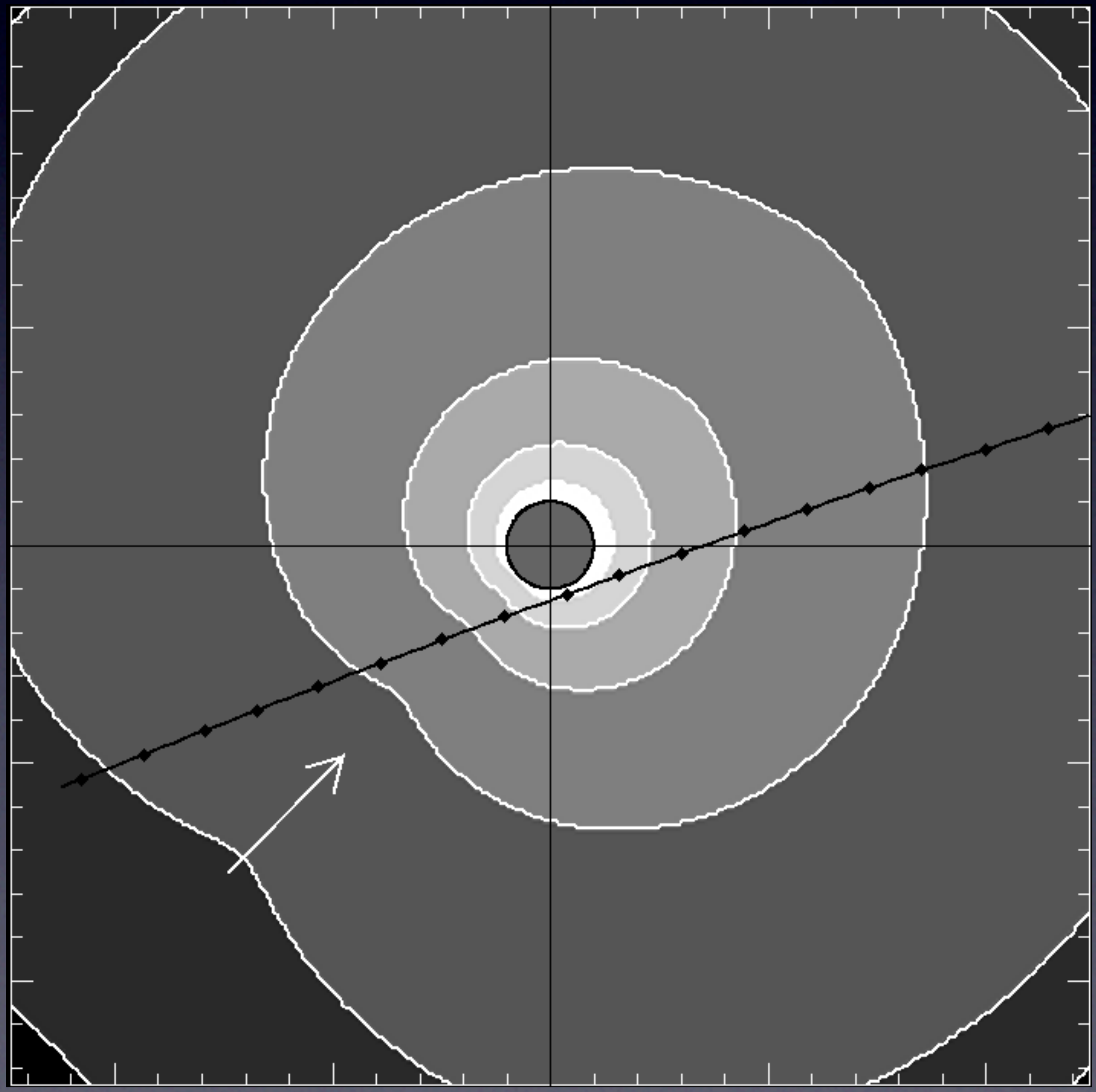




Summary

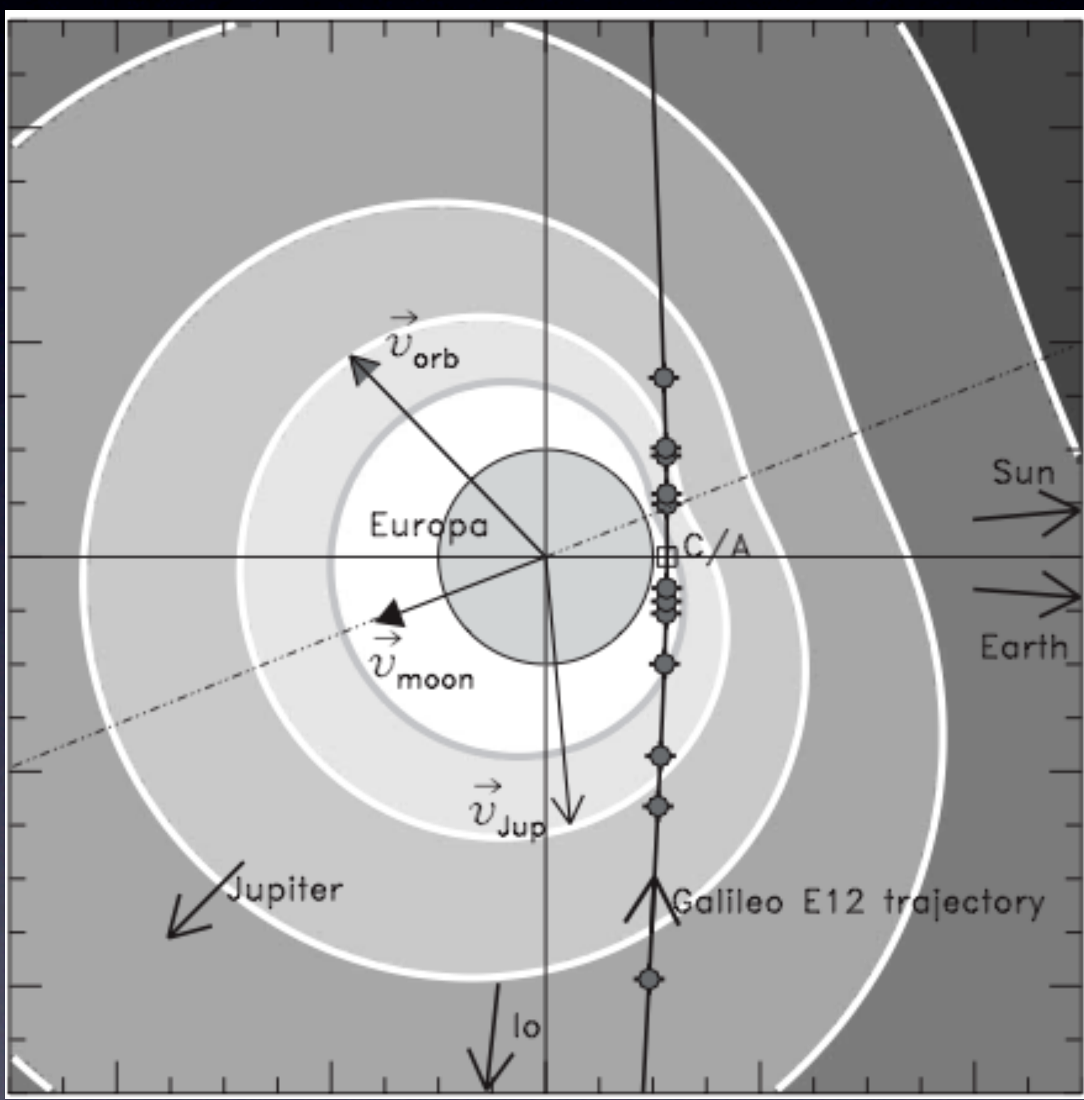
- Ejecta production is a standard planetary process
- Ejecta clouds have been characterized so far only around the icy Galilean moons
- LADEE/LDEX will be the first measurement of dust ejecta of the Moon (rocky object)
- The detailed mapping by LADEE will fully characterize the ejecta generation process
- Laboratory support measurements are under way at the CCLDAS dust accelerator

Isotropic Impactor Flux - Really?



Sremcevic et al., (2003, 2005)

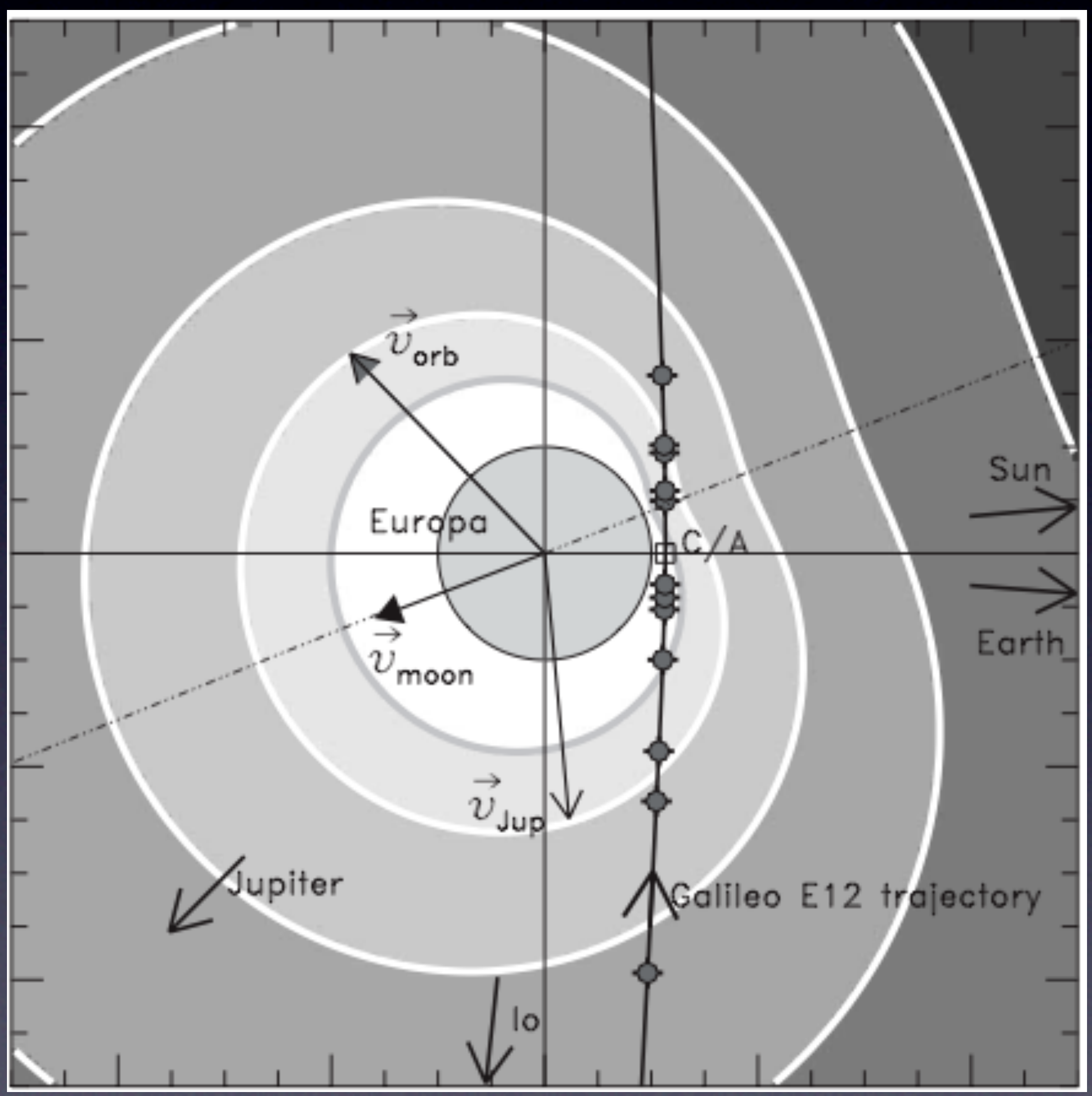
Induced Dust Cloud Anisotropy



Sremcevic et al., *PSS* **53**, 2006

- Anisotropic impactor flux causes anisotropic ejecta clouds:
- Anisotropy provides information about the directionality of the impactor flux
- Example: Ejecta cloud of the Jovian moon Europa:
  - generated by IDPs with an isotropic speed distribution and by IDPs in retrograde orbits

Cloud Anisotropy

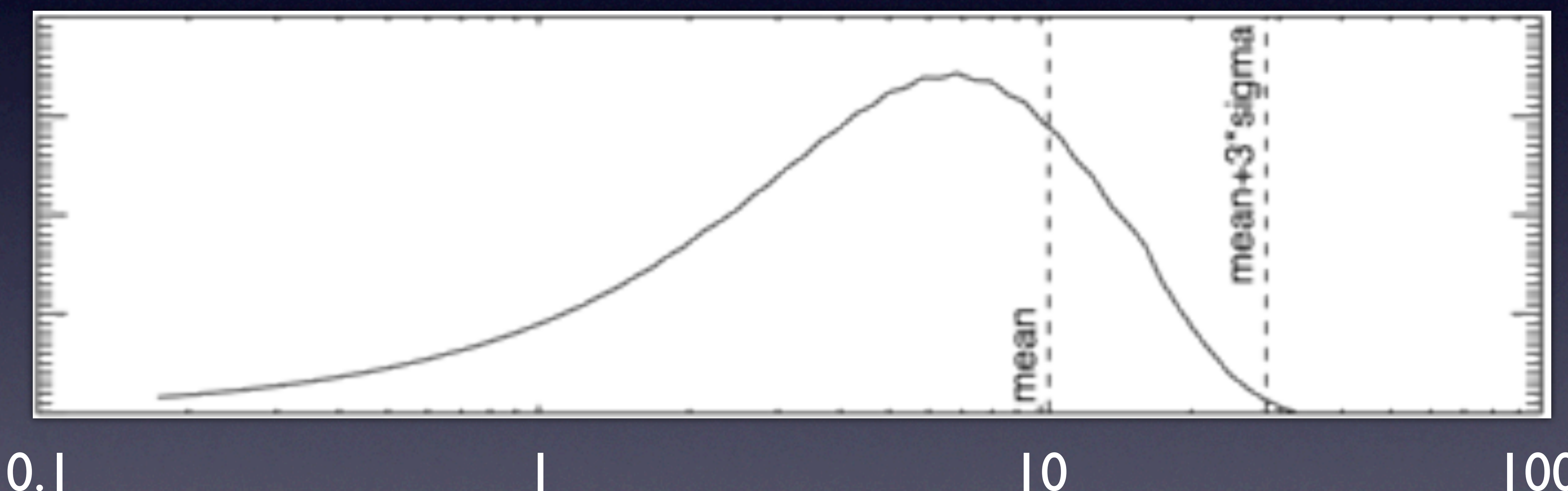


Sremcevic et al., *PSS* **53**, 2006

- Moon „magnifies“ weak impactor streams
- Acts as an large area dust detector
- Galactic dust streams should appear in LDEX data

Ejecta Production Map (Erosion Map)

Ejecta detected by LDEX at 100 km altitude



Distance from most probable ejection point (km)

Postberg et al., Plan. Space Sci., subm.

Weakness: Ejecta Production

Ejecta mass production:

$$M^{+} = F_{imp} Y S_{sat}$$

Ejecta Yield:

$$Y = 2.85 \cdot 10^{-8} \cdot 0.0149^{G_{sil}} \left(\frac{1 - G_{sil}}{927} + \frac{G_{sil}}{2\,800} \right)^{-1} m_{imp}^{0.23} v_{imp}^{2.46}$$

Koschny & Grün, 2001

Ejecta Production

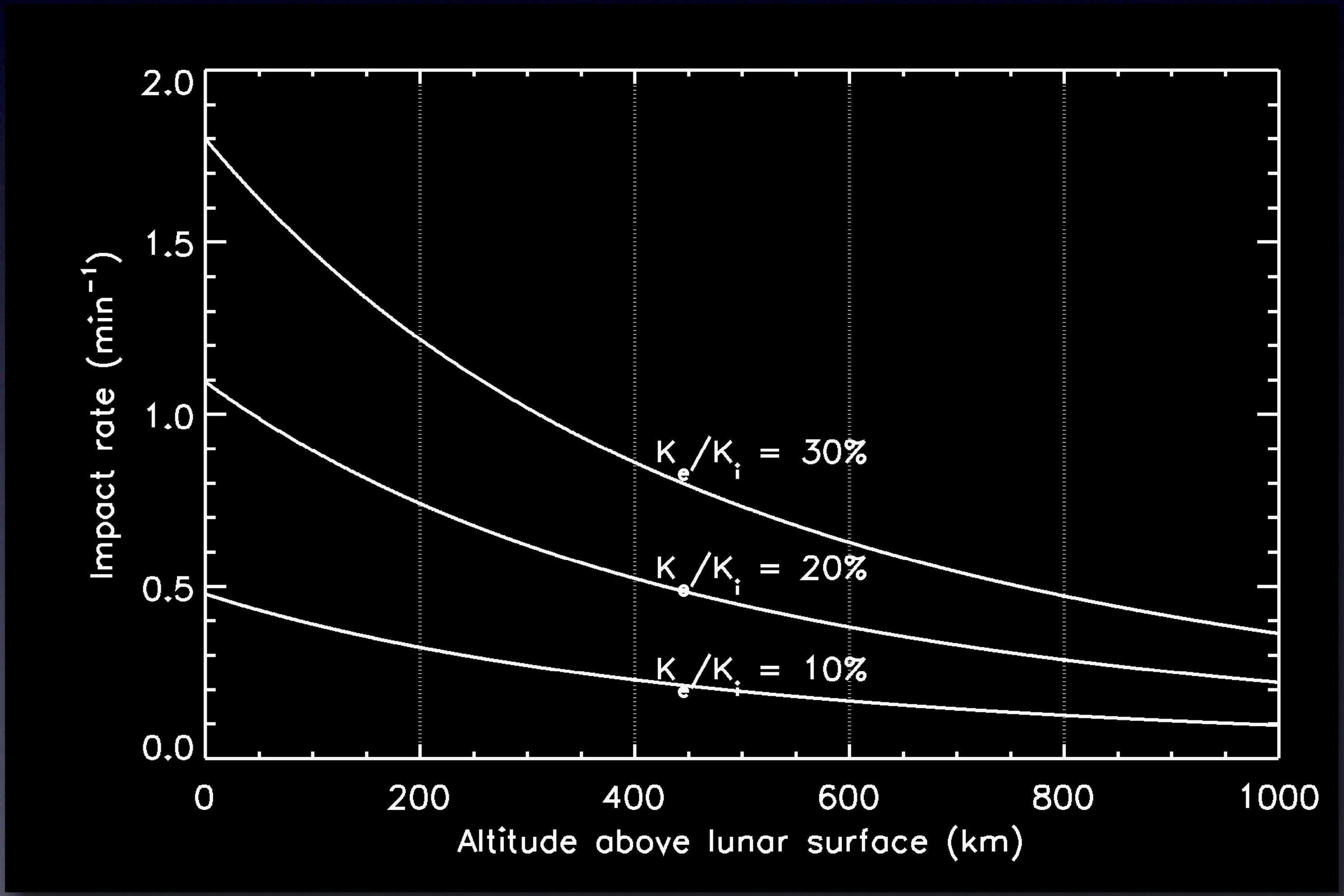
Production Rate of Ejecta > s:

$$N^+(> s) = \frac{3-\gamma}{\gamma}\frac{M^+}{m_e^{max}}\left(\frac{s_e^{max}}{s_e}\right)^\gamma$$

Energy Transfer:

$$K_e/K_i = Y\left(\frac{v_e^{min}}{v_{imp}}\right)^2 \begin{cases} \frac{\beta-1}{3-\beta}\left[\left(\frac{v_e^{min}}{v_e^{max}}\right)^{\beta-3} - 1\right] & \beta < 3, \\ 2\ln\left(\frac{v_e^{min}}{v_e^{max}}\right) & \beta = 3 \end{cases}$$

Lunar Dust Cloud



- Grains > 0.5μm
- 0.1m^2 detector
- 100 km orbit:
  - 100 000 / 3 month