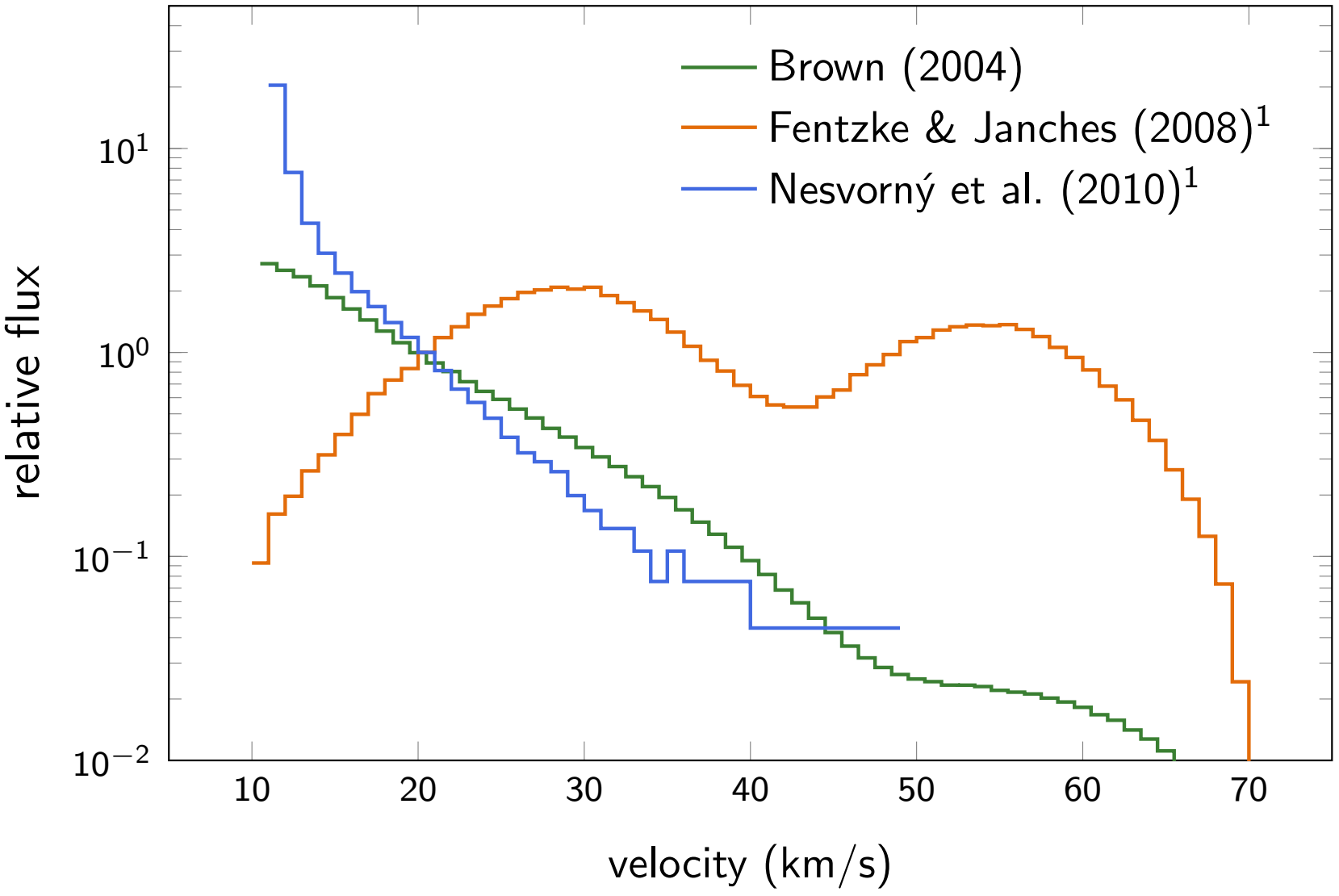
Optical and radar measurements of the meteor speed distribution

Althea Moorhead, Bill Cooke
NASA Meteoroid Environment Office

Peter Brown, Margaret Campbell-Brown
University of Western Ontario

Meteoroids 2016
June 7, 2016

Meteoroid speed distribution(s)



[1] As represented in Janches et al. (2014)

Goals

Have: Start with the meteor speed distribution to constant limiting radar amplitude

Improve: Re-weight the radar speed distribution to constant limiting KE

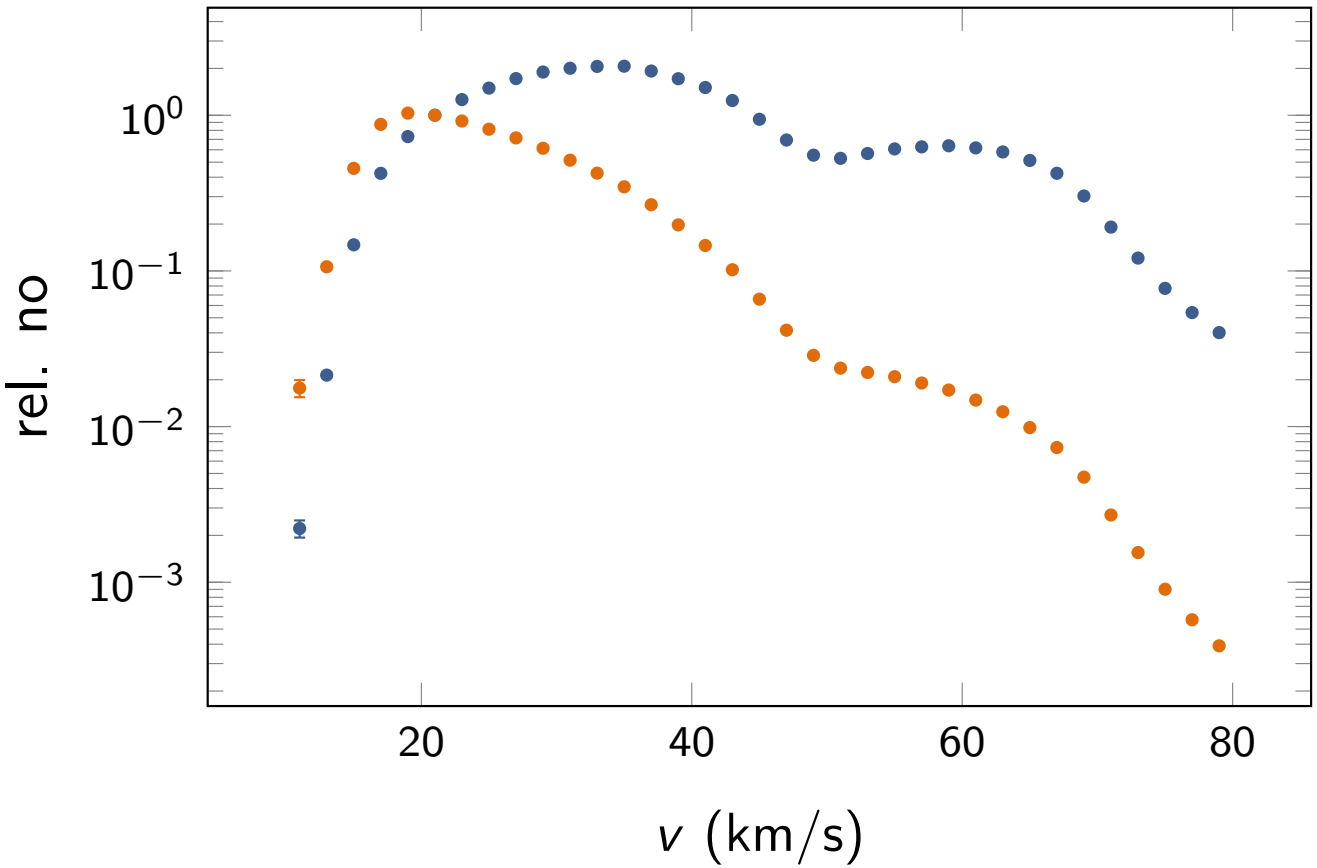
- Use improved bias estimations
- Use modern forms of β

New: Characterize associated uncertainties

New: Re-weight the radar speed distribution to constant limiting magnitudes and compare with optical measurements

Correcting to a limiting mass

$q \propto m^a v^b$, flux $\propto m^- \alpha \rightarrow N_{>m_{ref}} = N v^{-b\alpha/a}$ (Taylor, 1995)

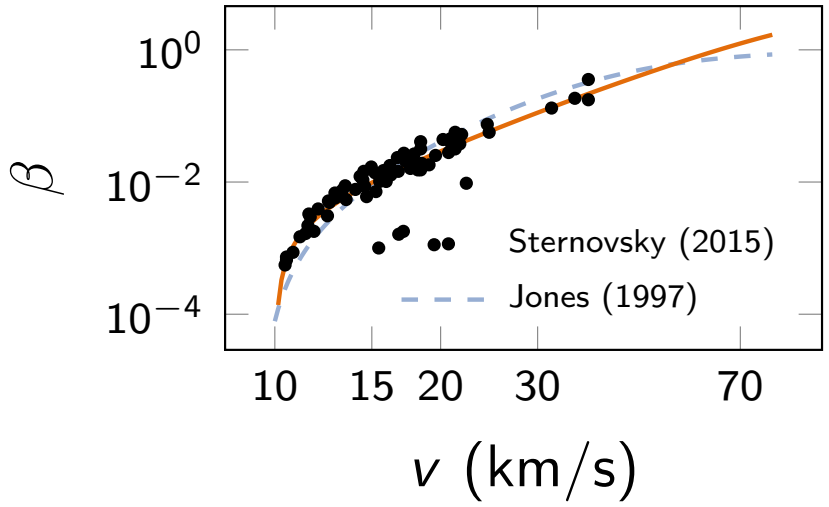


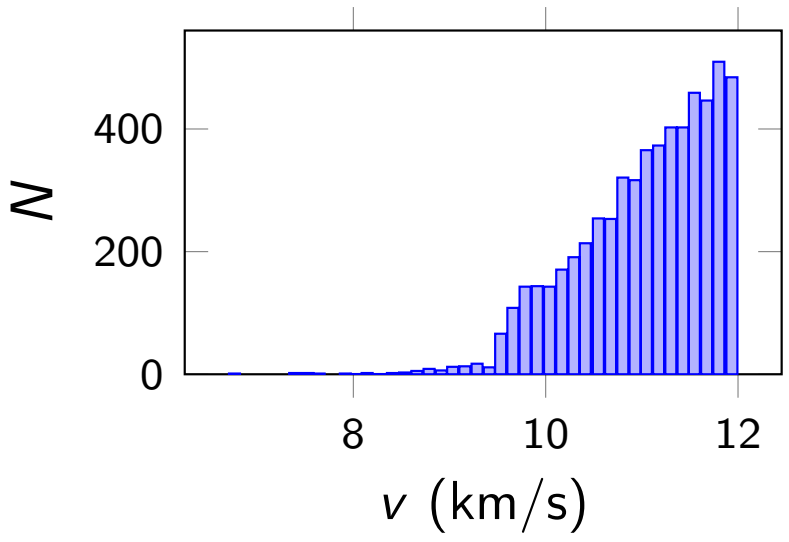
Ionization efficiency

- Jones (1997) predicts $q \propto v^b$
- Experiments confirm this for iron (Sternovsky, 2015)
- Radar detections show a "cliff" near 9.5 km/s

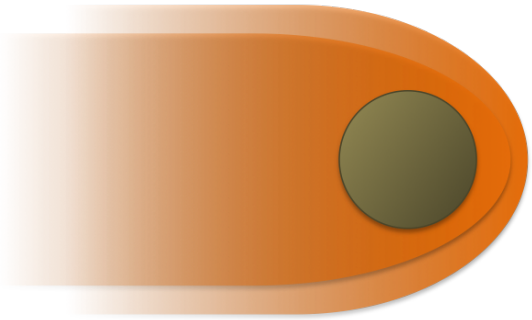
~~$q \propto m^a v^b$~~

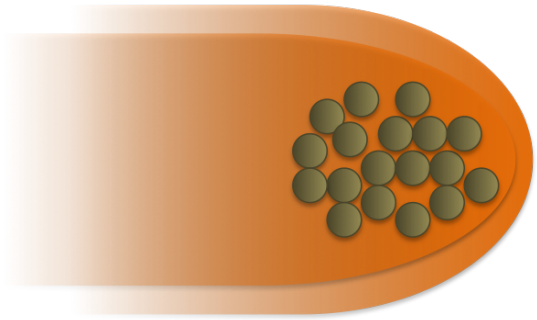
$$q = -\frac{\beta(v)}{\mu v}\frac{dm}{dt}$$





Mass ablation rate





$$\frac{dm}{dt} \propto m^{2/3}$$

$$\frac{dm}{dt} \propto m$$

$$\frac{dm}{dt} = -\frac{\Lambda A}{2\xi}\left(\frac{m}{m_{frag}}\right)^{x}\left(\frac{m}{\rho_m}\right)^{2/3}\rho_a v_m^3$$

Kinetic energy distribution

- Impact experiments are KE-limited

$$p = 5.24 \times d^{19/18} \mathrm{BH}^{-1/4} \left(\frac{\rho_p}{\rho_t}\right)^{1/2} \left(\frac{v_p \cos\beta}{c_s}\right)^{2/3}$$

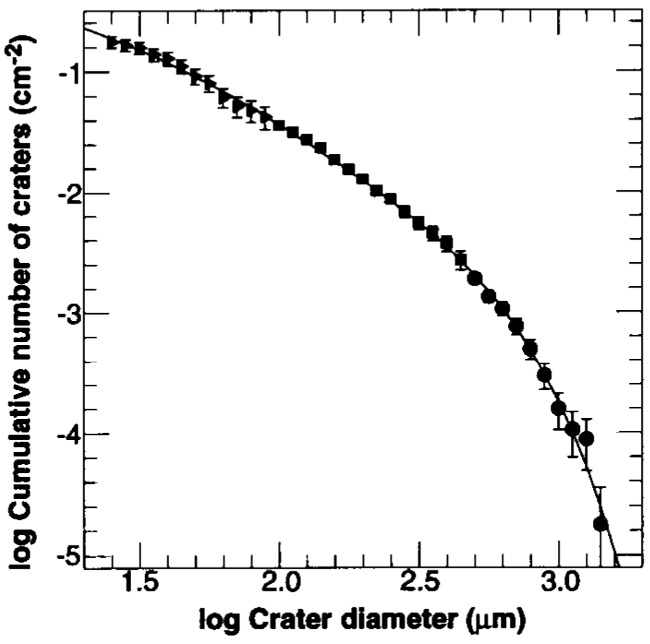
$$= 0.739 \times \mathrm{KE}^{19/54}\, \mathrm{BH}^{-1/4} \frac{\rho_p^{4/27}}{\rho_t^{1/2}} v_p^{-1/27} \left(\frac{\cos\beta}{c_s}\right)^{-2/3}$$

- Meteor observations are *closer* to being KE-limited than mass-limited

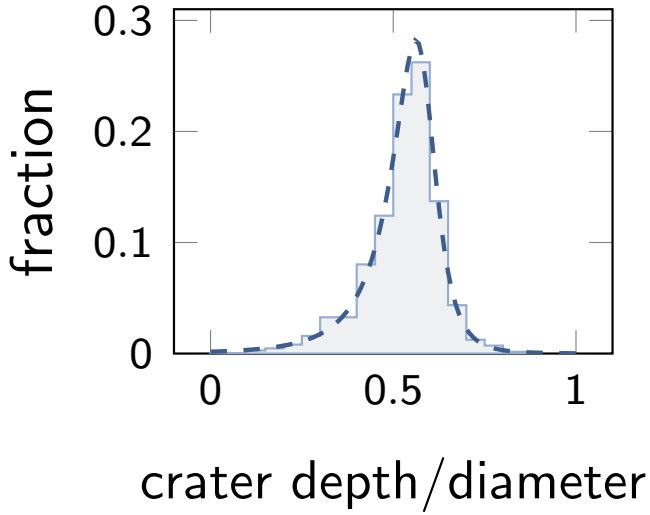
$$q \sim m\ v^{3.5}$$

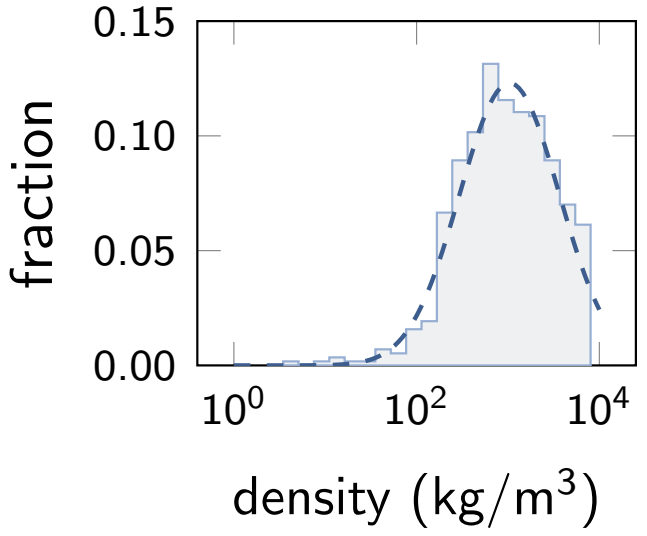
$$\sim \mathrm{KE}\ v^{1.5}$$

Kinetic energy distribution

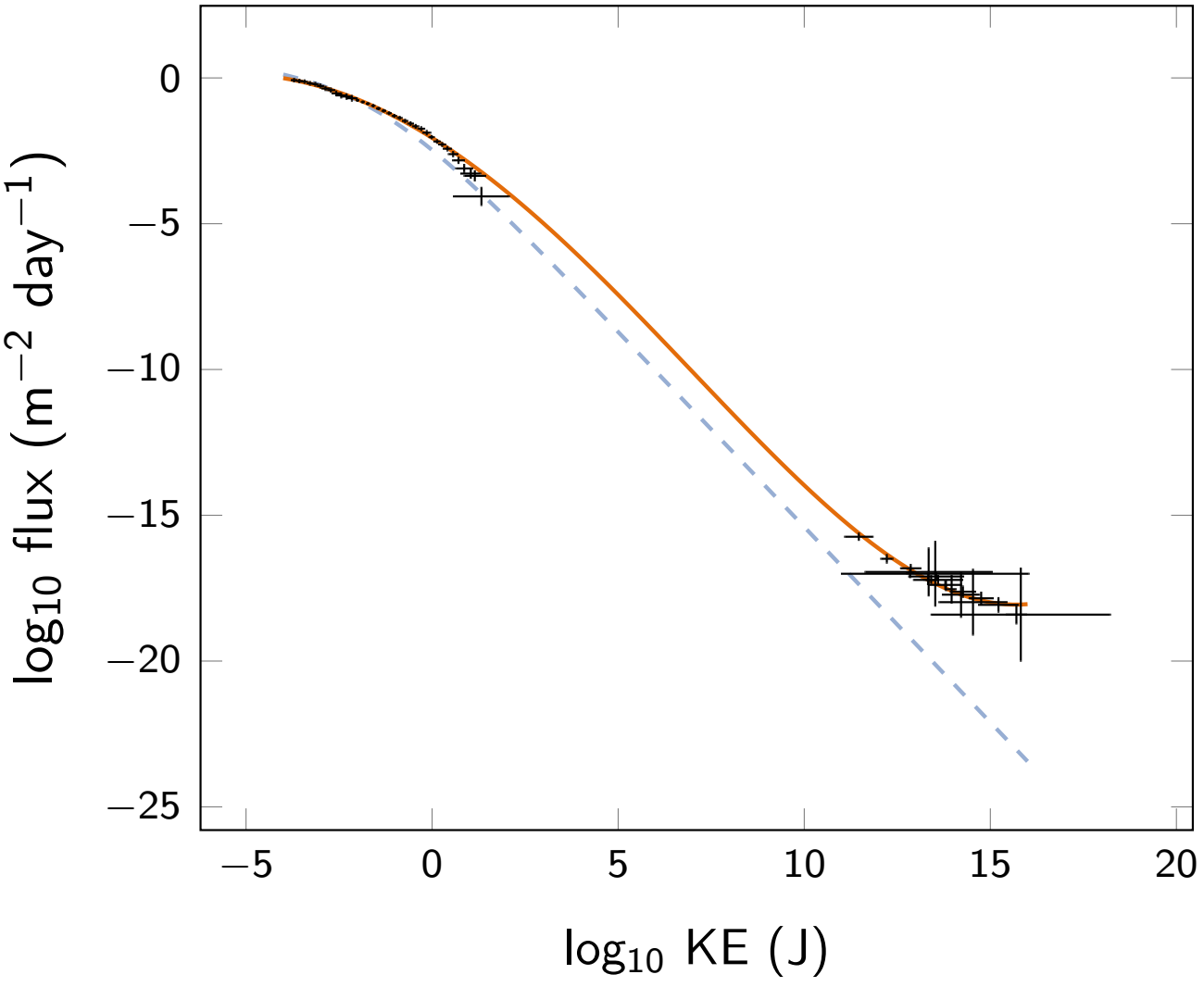


+



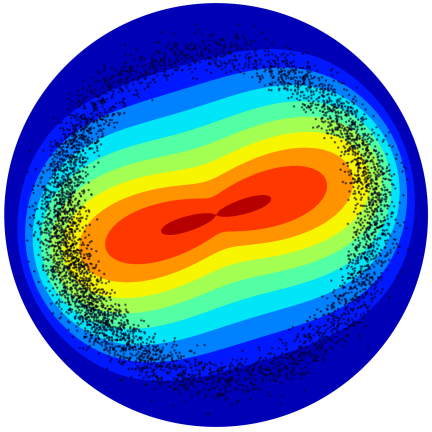


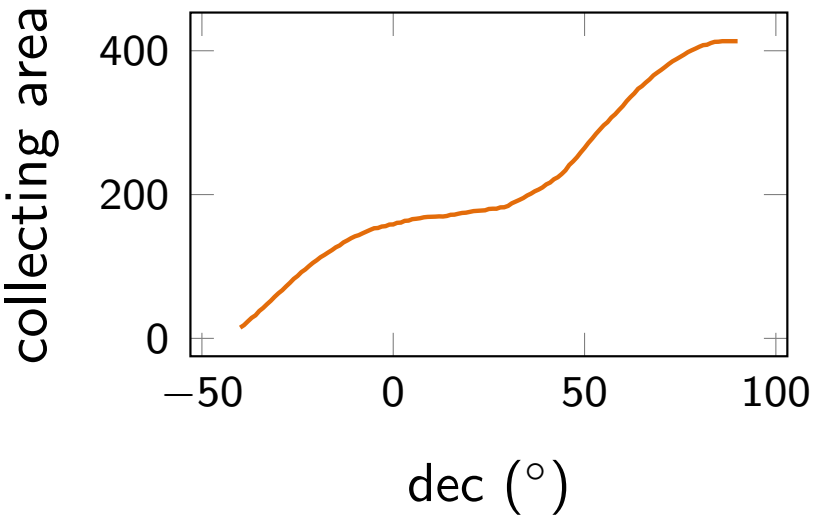
Kinetic energy distribution



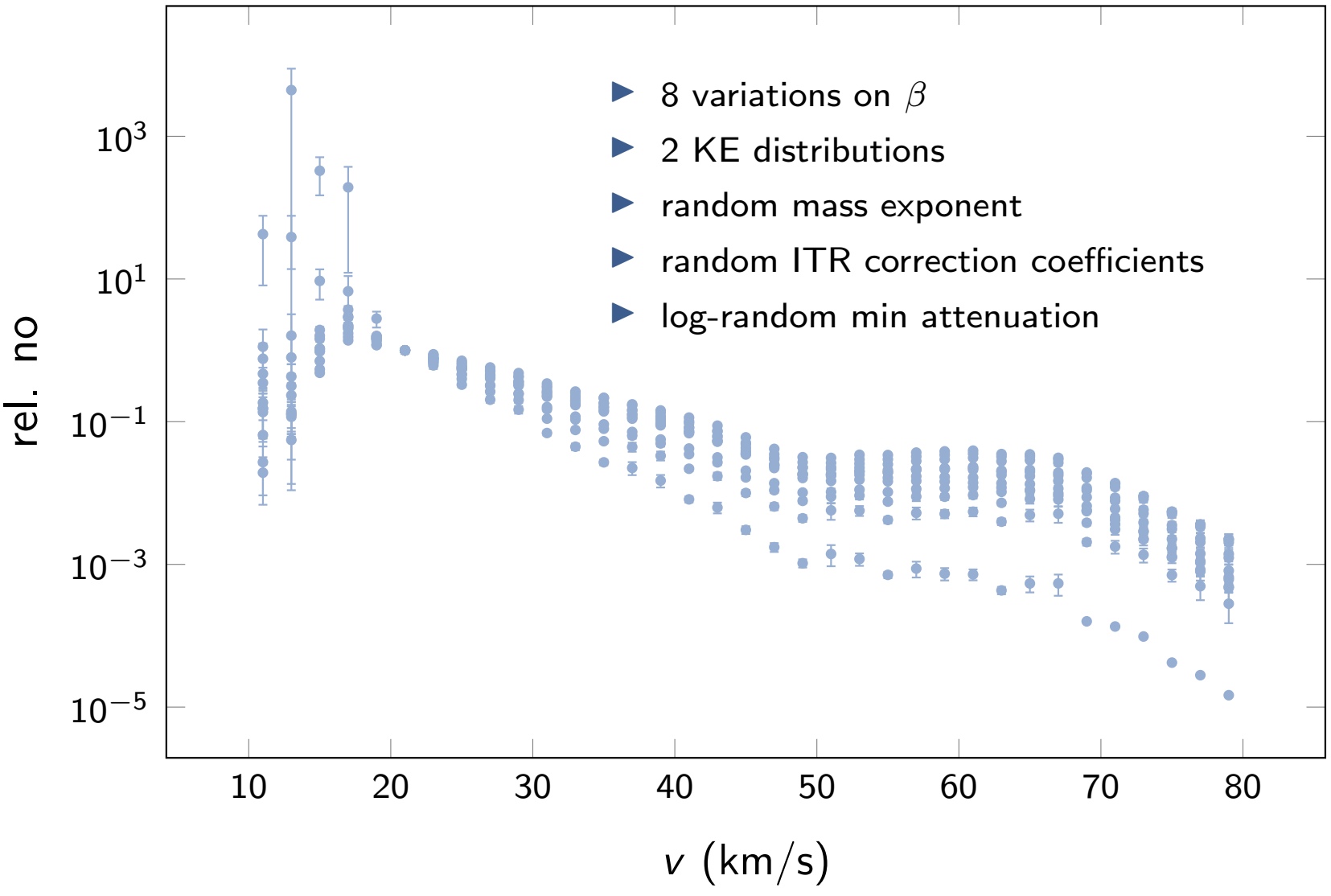
Radar bias corrections

- Pulse repetition effect
- Finite velocity effect
- Initial trail radius effect
  - Empirical relation (with uncertainties!) from Jones & Campbell-Brown (2005)
- Beam pattern/radiant visibility

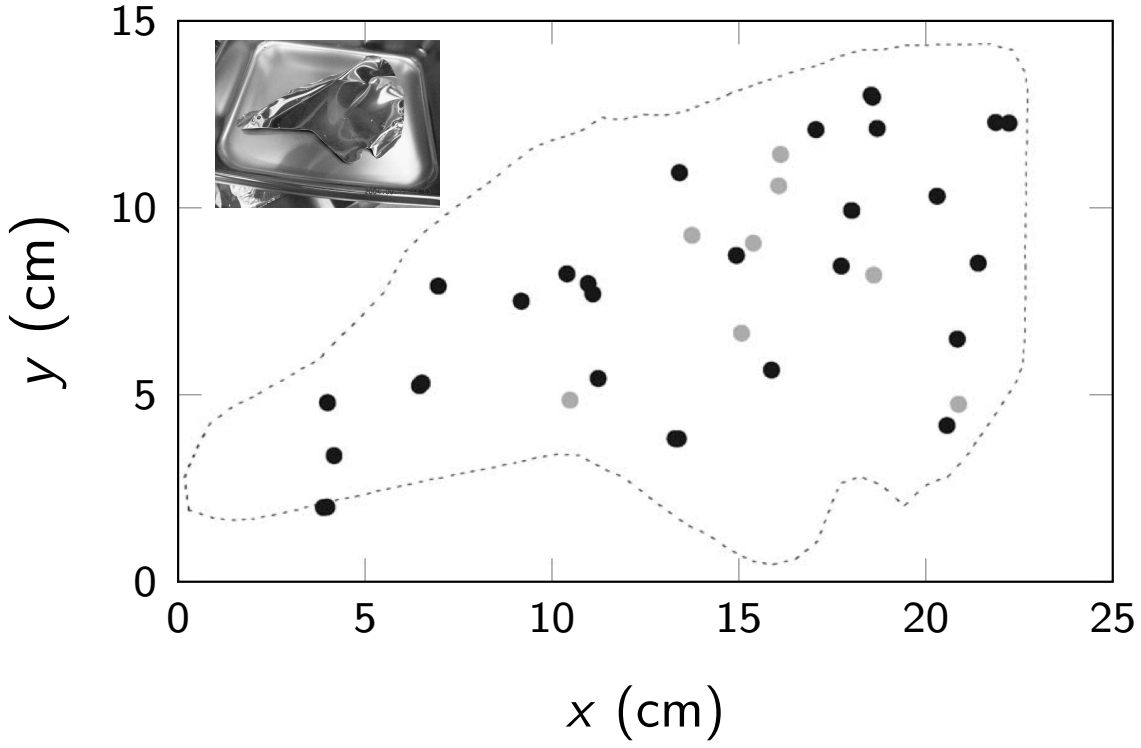




Corrected speed distribution

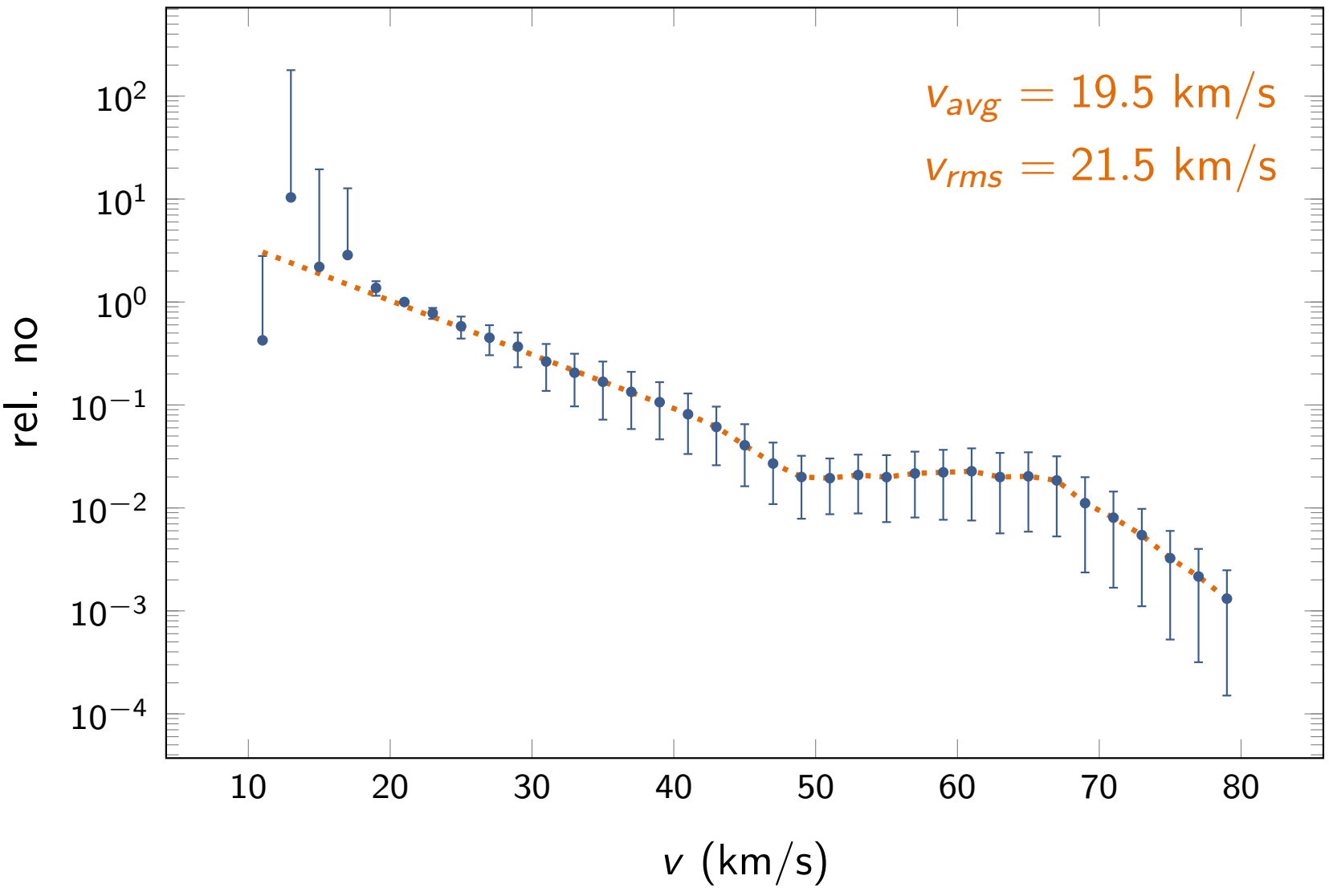


Gravitational focusing constraints

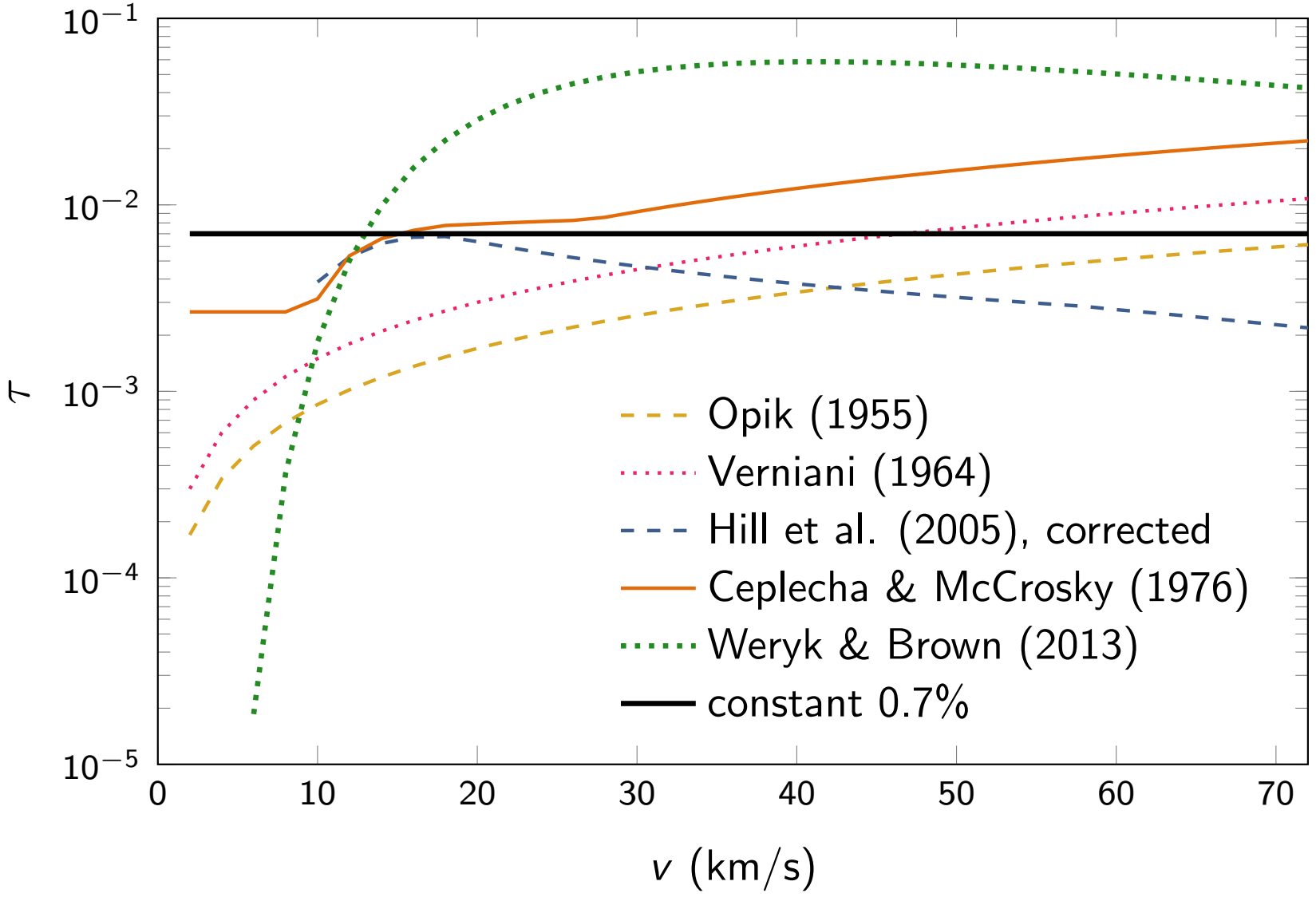


- Cratering rate on Genesis near L1 was within 40% of near-Earth rate (Love & Allton, 2006)

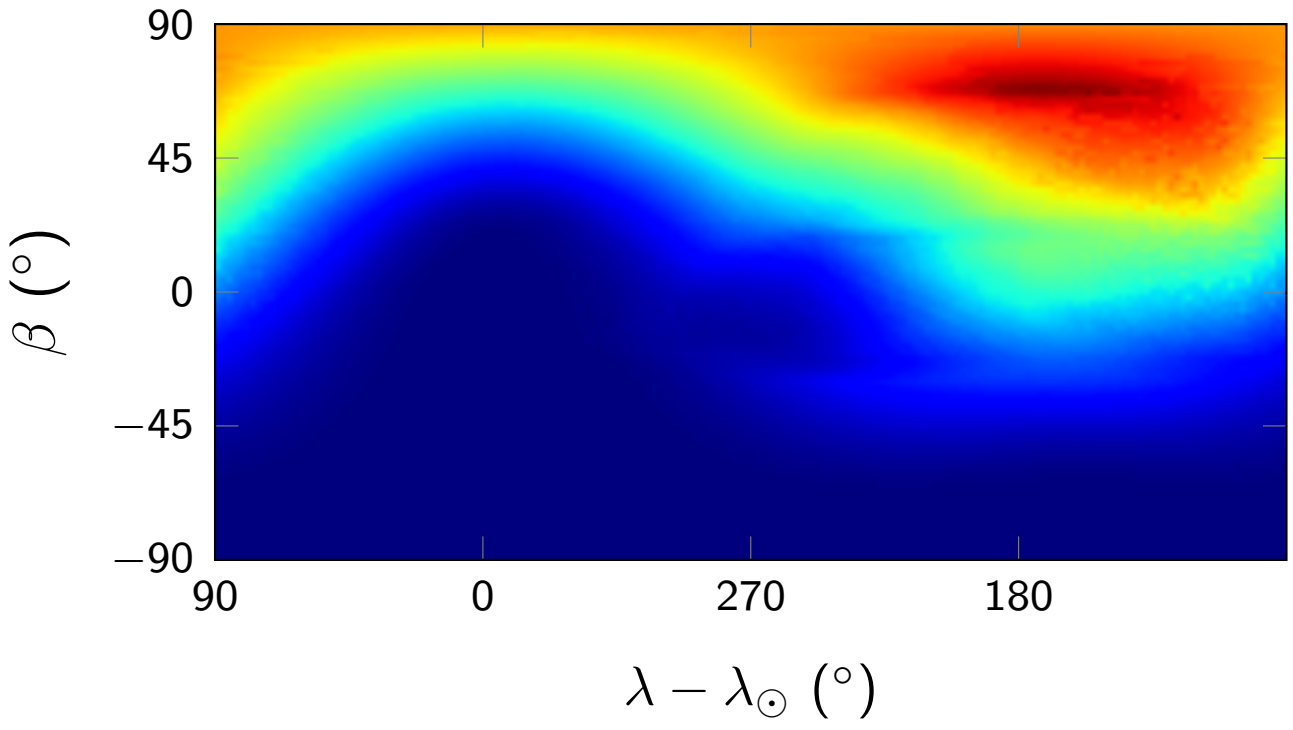
Weighted average speed distribution



Luminous efficiency

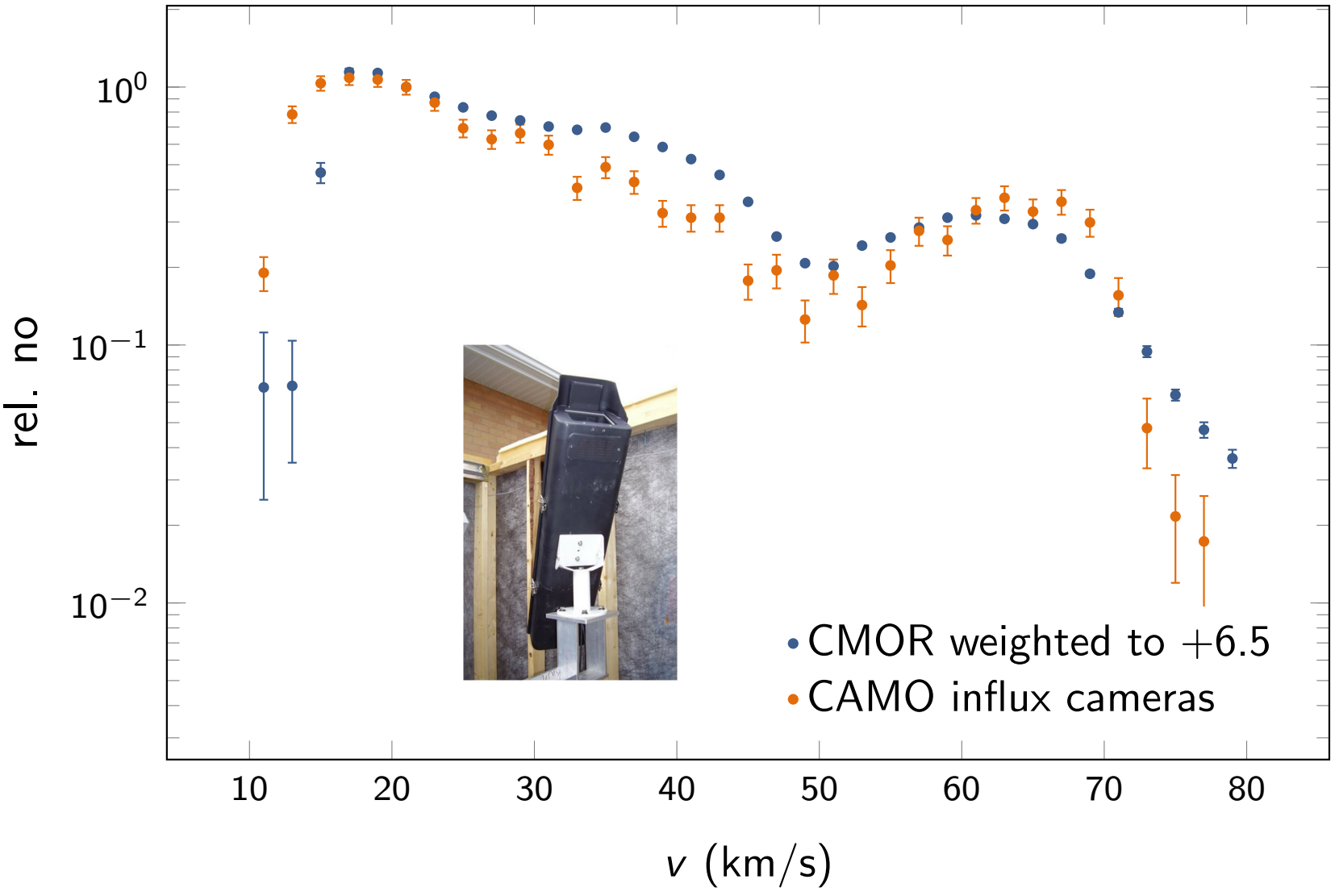


Radiant coverage



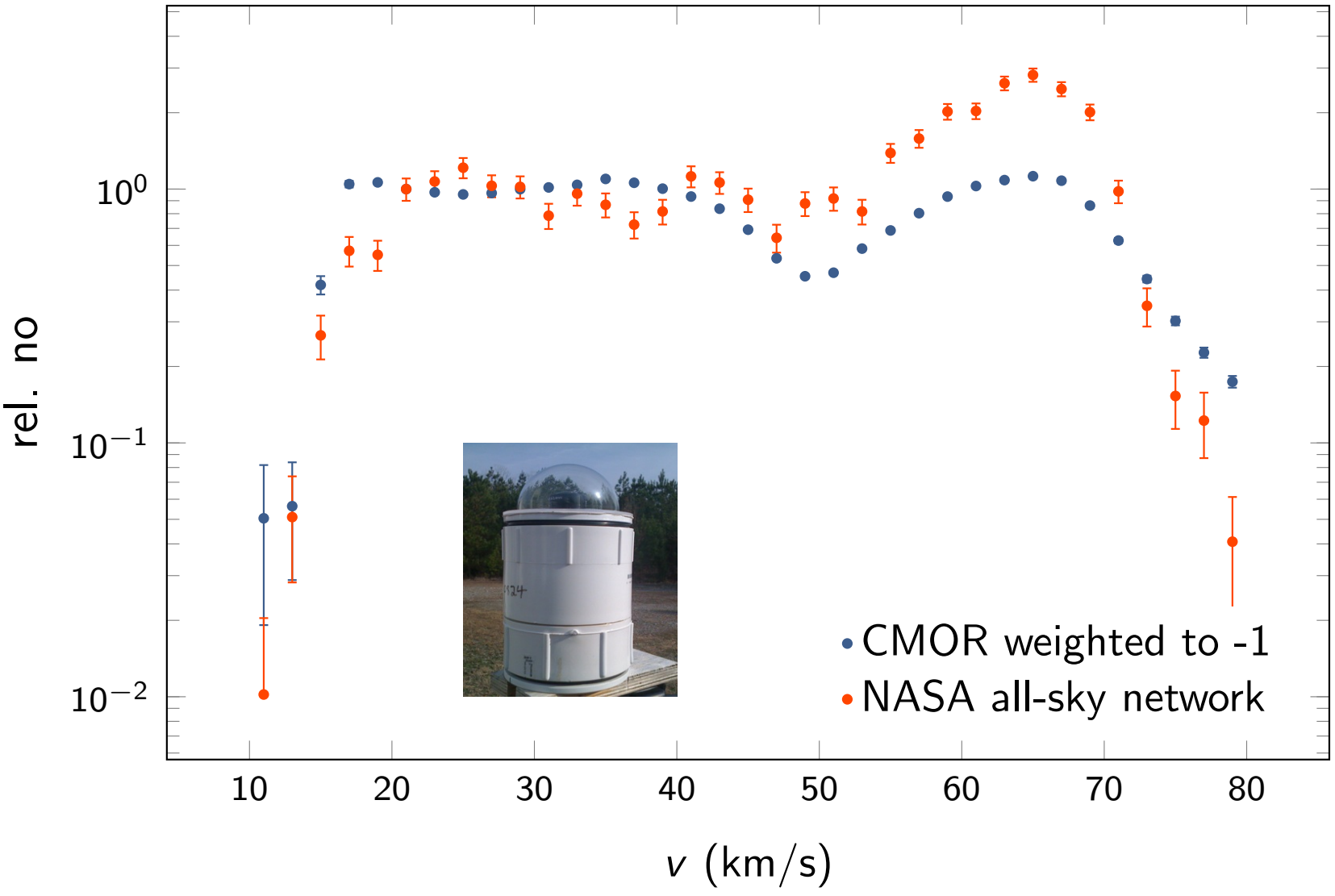
CAMO influx camera speed distribution

Limiting magnitude of +6.5

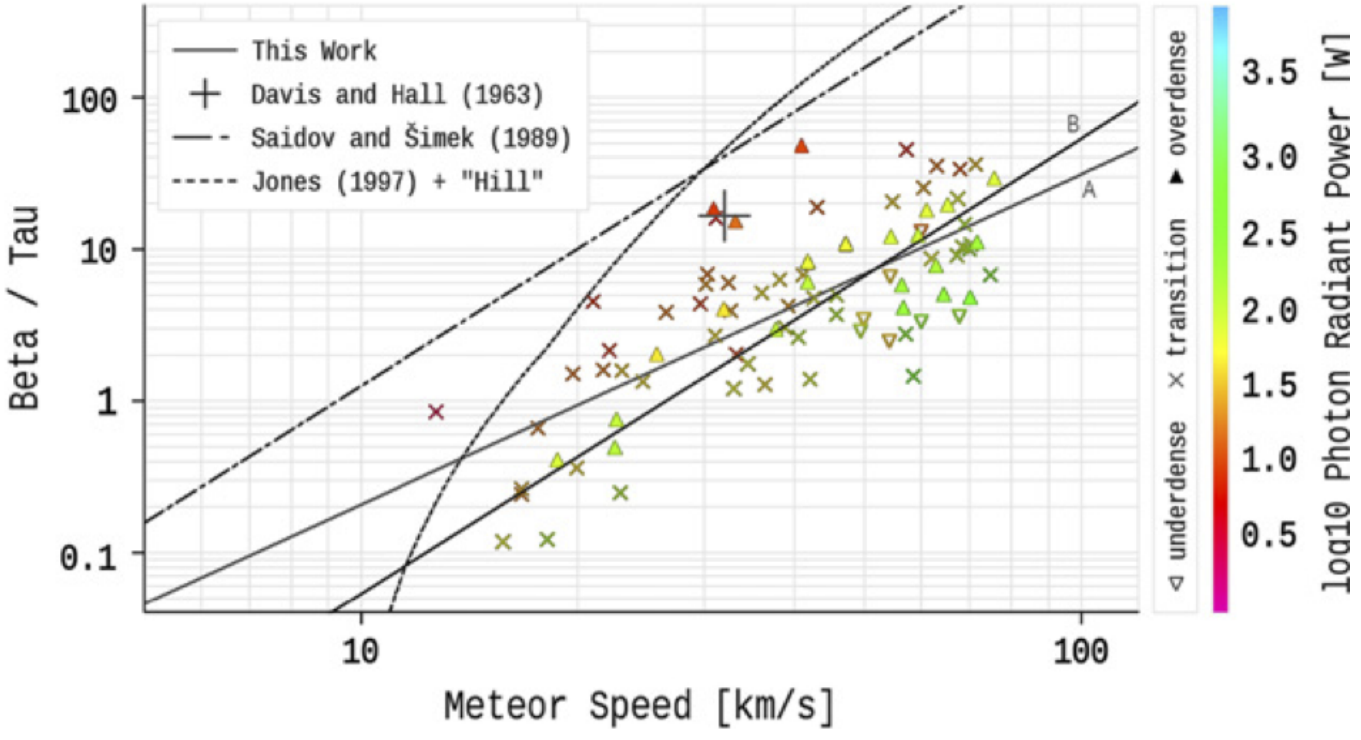


NASA all-sky network speed distribution

Limiting magnitude ~ -1



Luminous efficiency



$$\log_{10}(\beta/\tau) = c_v \log_{10} v - c_L \log_{10} L - c_c$$

Conclusions

Improved: Radar speed distribution to constant limiting KE

- Improved treatment of β yields more slow meteors

New: Characterized associated uncertainties

- Large uncertainty remains for slowest bins

New: Good agreement with video data for some βs

Future: Better characterization of τ, especially at low speed

Future: Refine speed distribution with additional in-situ constraints