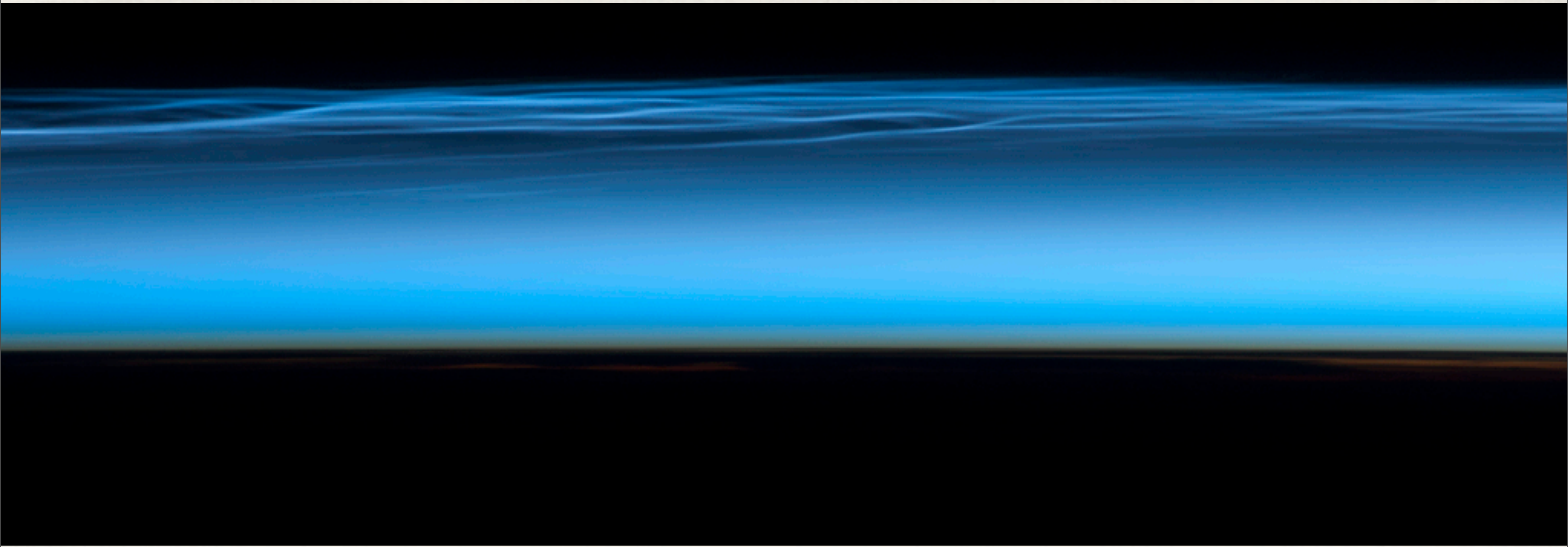
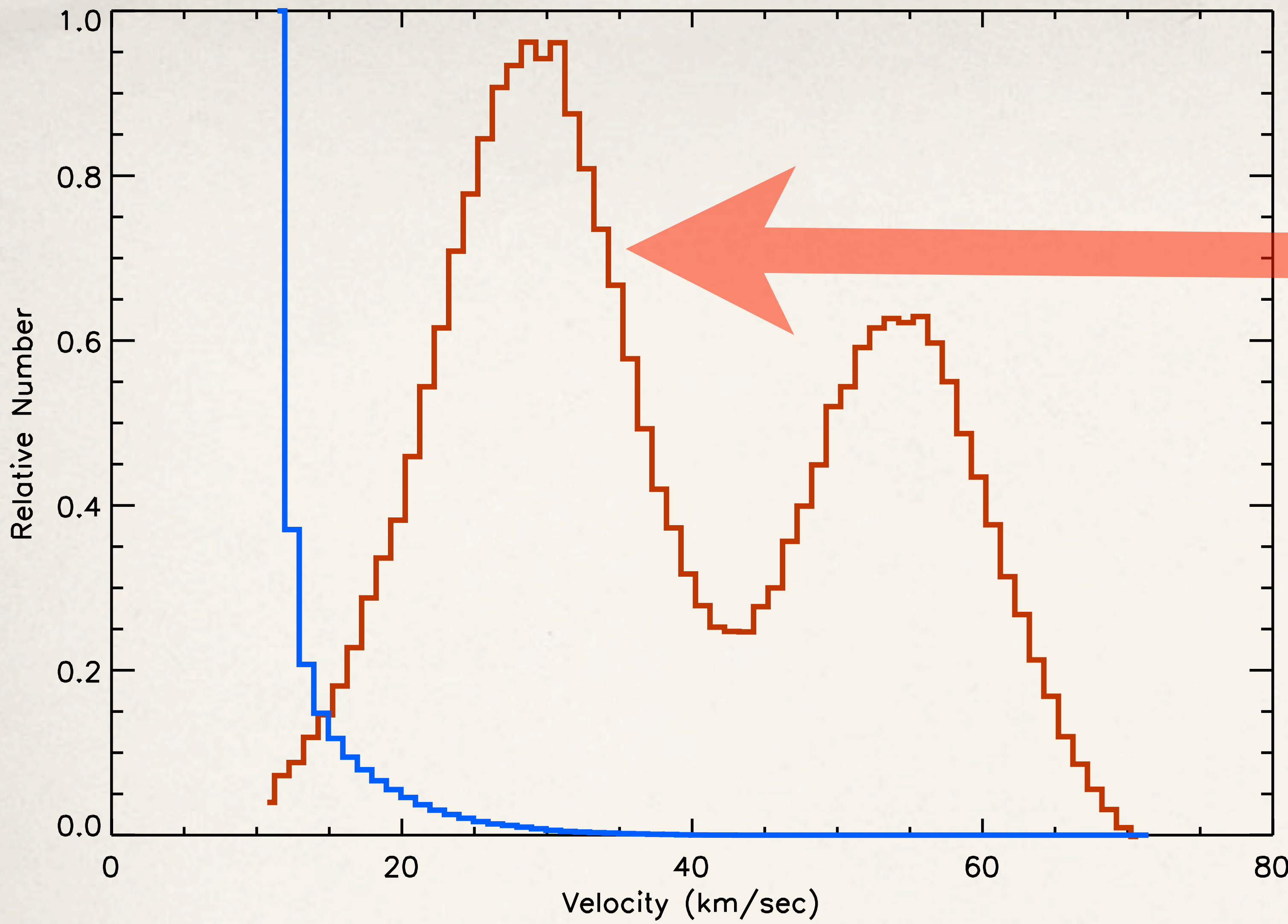


# Radar detectability studies of slow and small Zodiacal Dust Cloud Particles

**D. Janches**

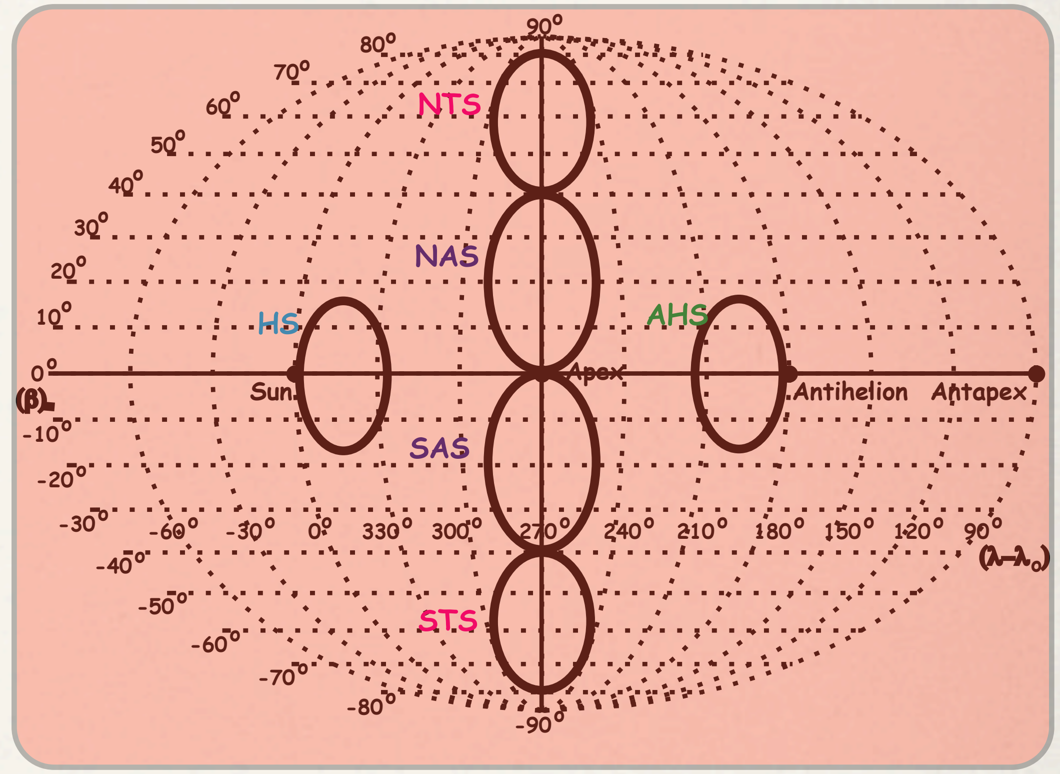
**J.M.C. Plane, W. Feng, D. Nesvorný, M.J. Nicholls and D. Marsh, N. Swarnalingam**

*MST Workshop, INPE, Sao Jose Dos Campos, May 25-30, 2014*



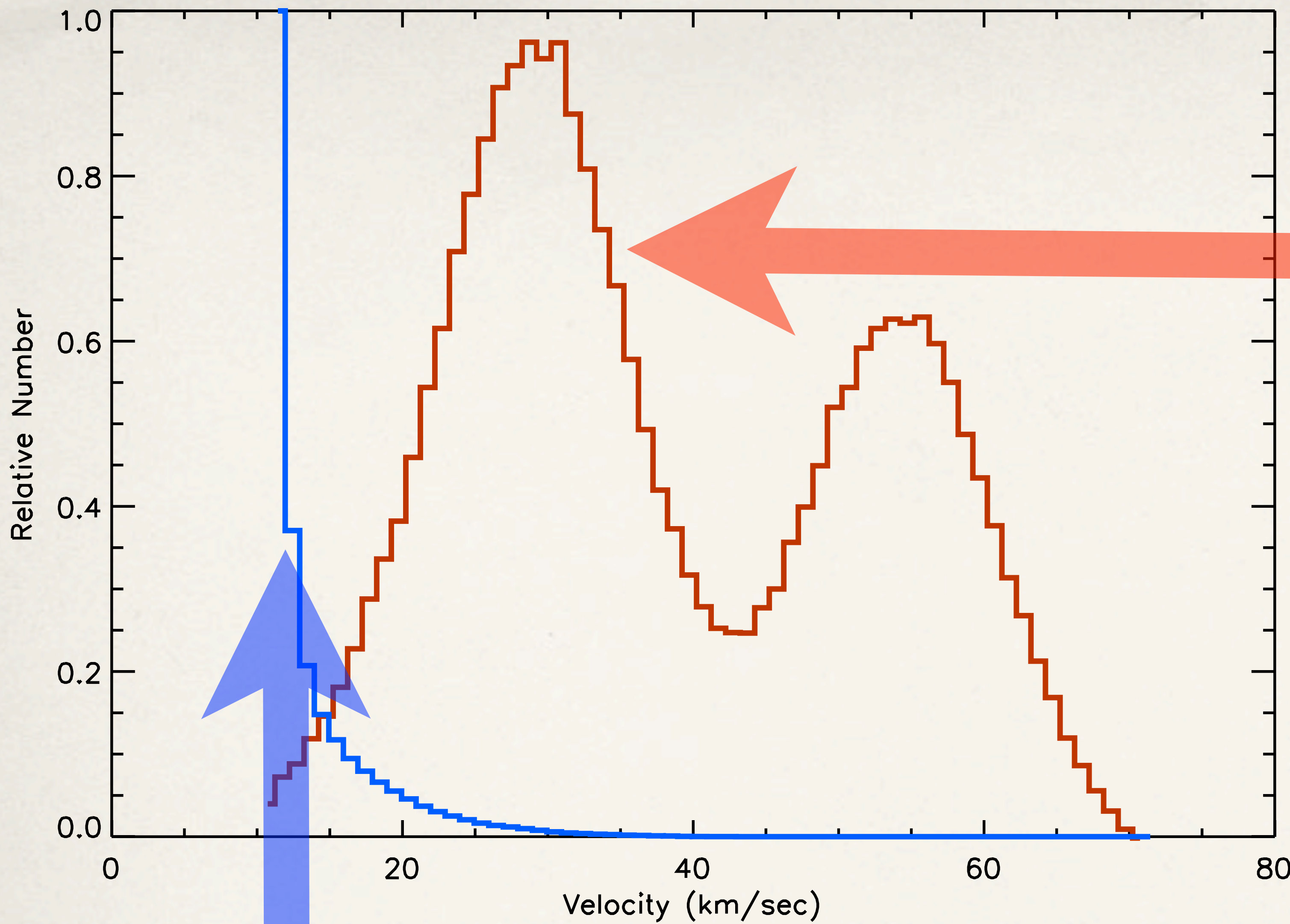

MIF (HPLA radars), Meteor Radars Apparent Sporadic Sources (~10 daily tons) ~70% H, AH, NT and ST, ~30% NA and SA

**Asteroidal, Halley Type Comets and Oort Cloud Comets**



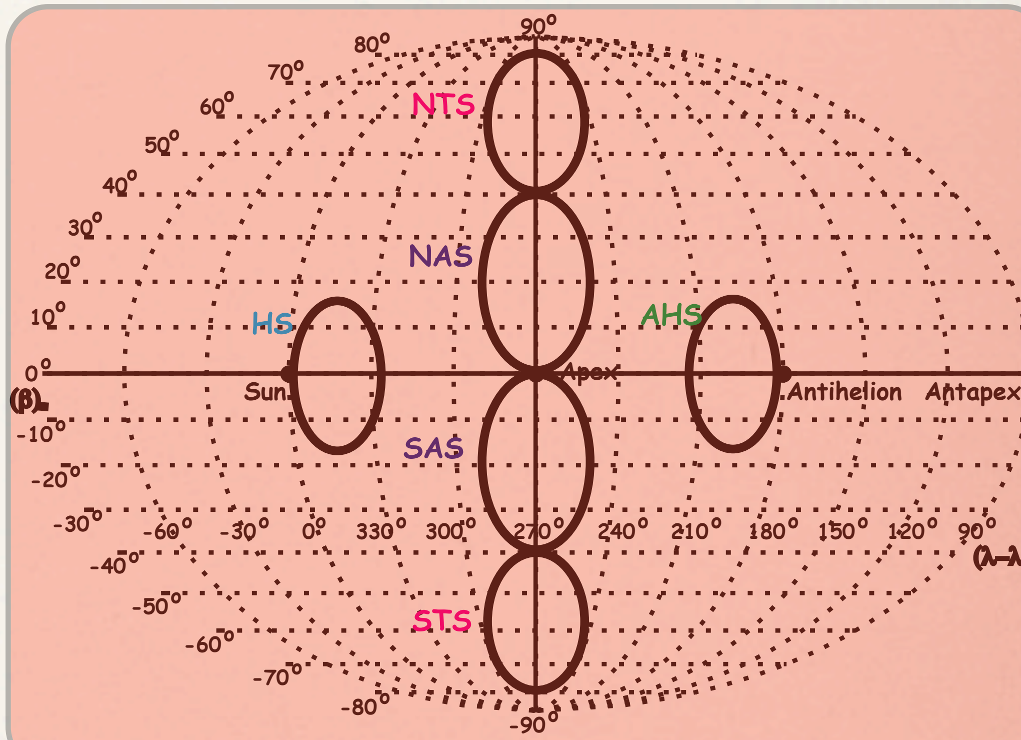

**No differential ablation**: Marsh et al (2013) ~6 d.t. to model Na, while Feng et al. (2013) 2 d.t. to model Fe

# Velocity Input Model




MIF (HPLA radars), Meteor Radars Apparent Sporadic Sources (~10 daily tons) ~70% H, AH, NT and ST, ~30% NA and SA

**Asteroidal, Halley Type Comets and Oort Cloud Comets**



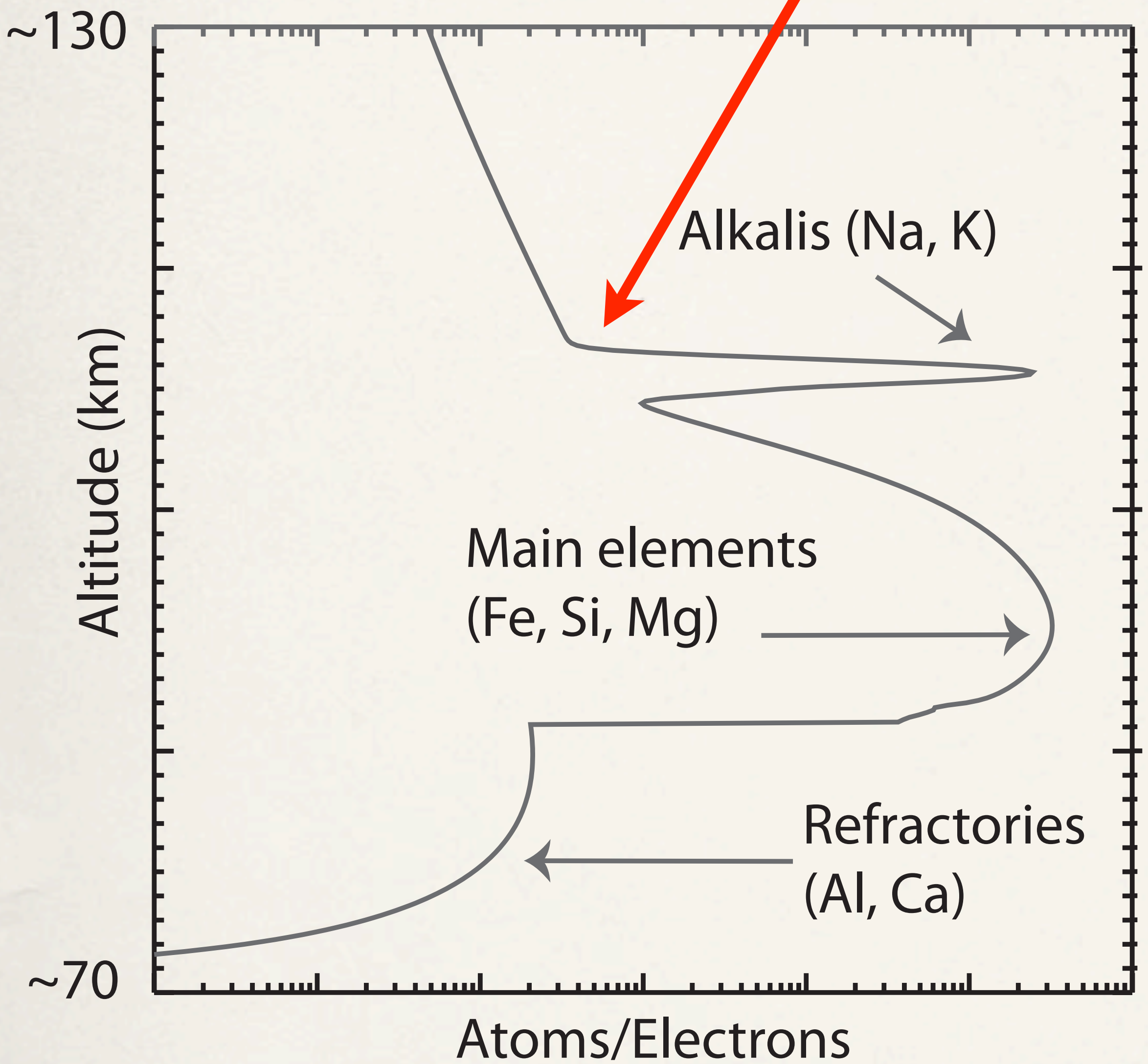

Nesvorny et al. (2010, 2011)
~32 daily tons (most of the flux onto Earth) with 90% IDP originating from **Jupiter Family Comets**, i.e. very slow velocity distribution (12 km/sec) undetected by meteor radars (AMOR,CMOR)

**No differential ablation**: Marsh et al (2013) ~6 d.t. to model Na, while Feng et al. (2013) 2 d.t. to model Fe

# Velocity Input Model

# Meteor head-echo scattering cross-section

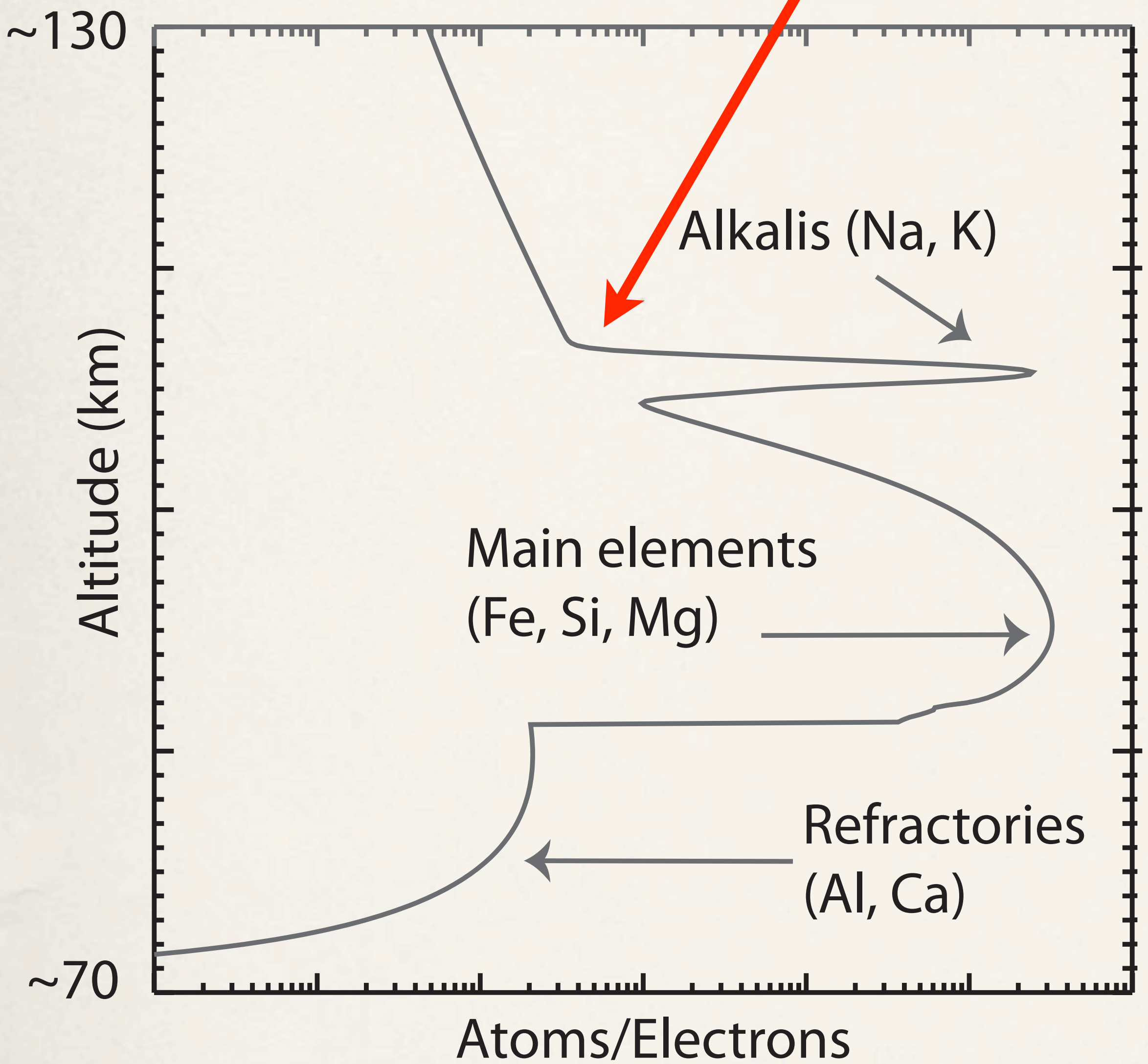
$$\sigma(V,\alpha,m) = 4\pi N(V,\alpha,m)^2 r_e^2$$




# Head-Echo SNR

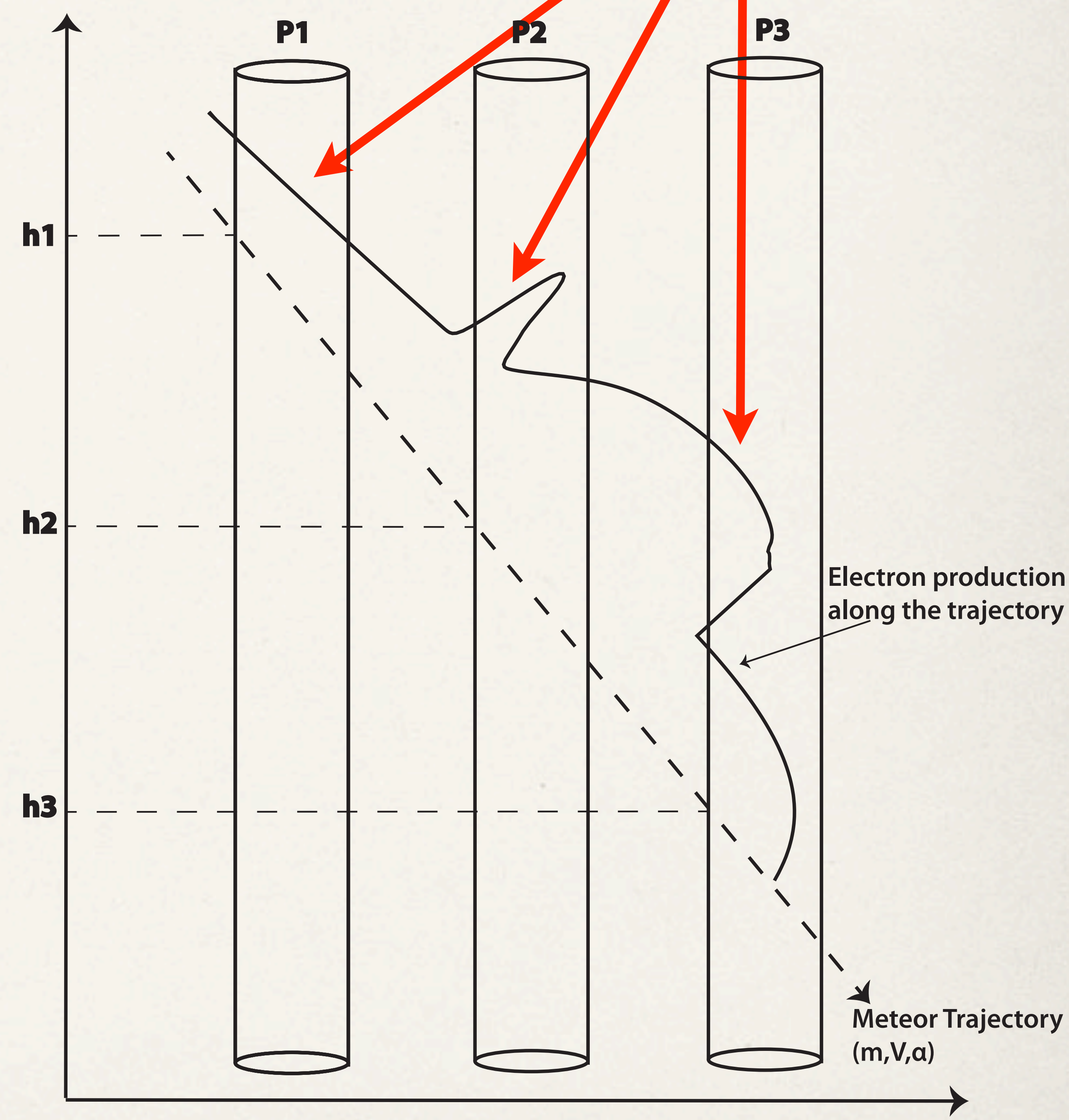
## Meteor head-echo scattering cross-section

$$\sigma(V,\alpha,m) = 4\pi N(V,\alpha,m)^2 r_e^2$$

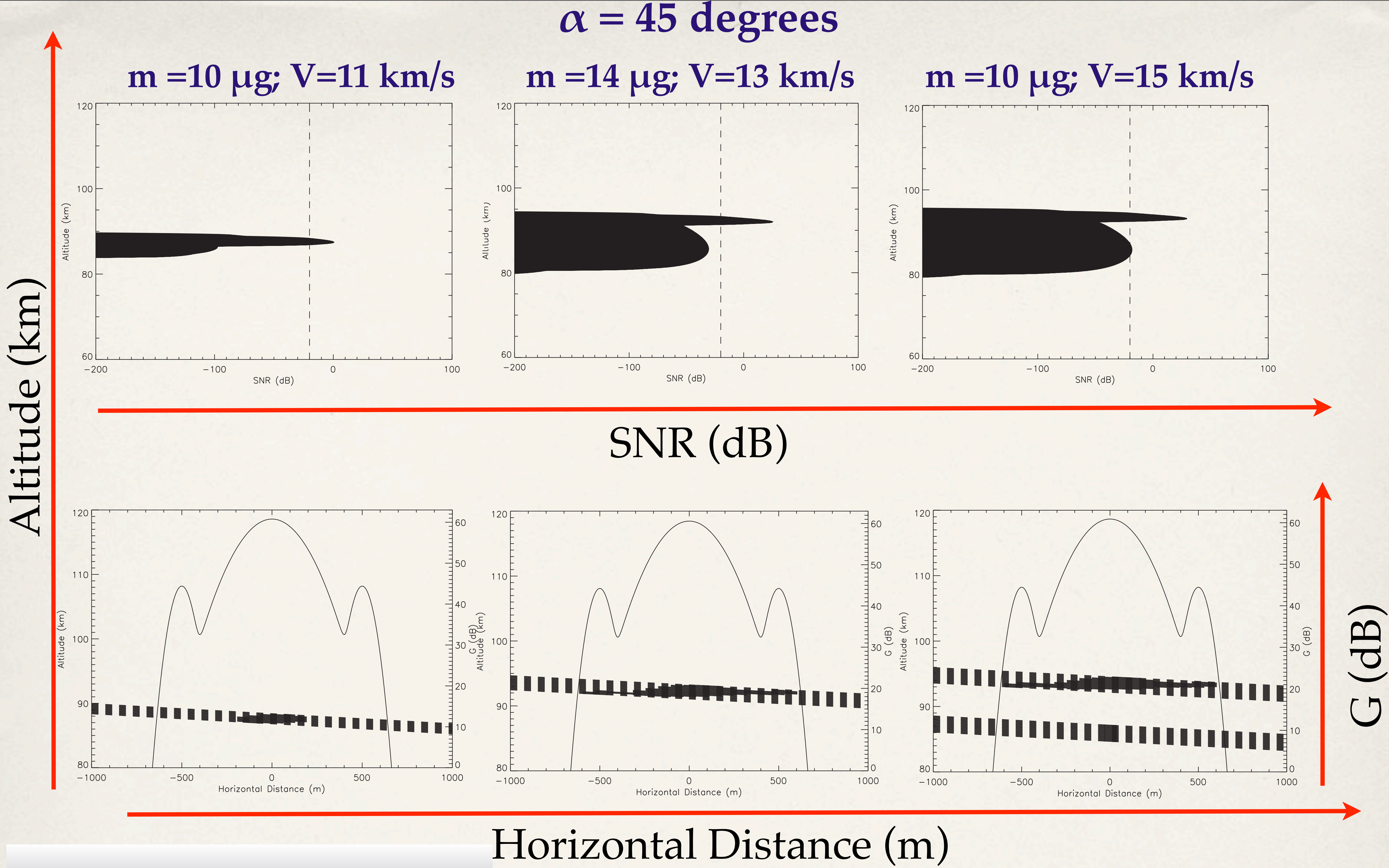



## Meteor head-echo detected SNR

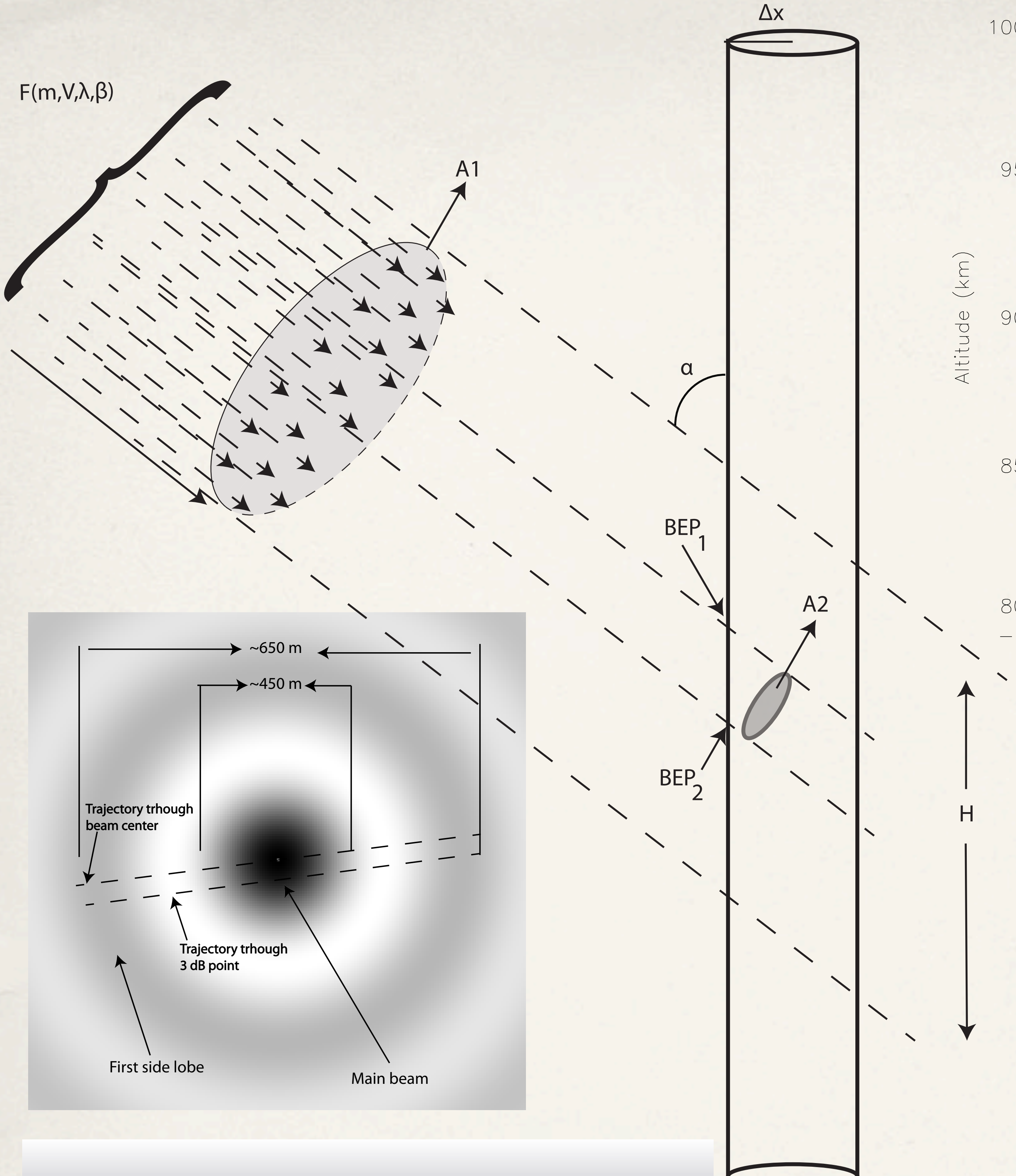
$$SNR = \frac{P_t \lambda^2 G^2 \sigma}{(4\pi)^3 P_n R^4}$$

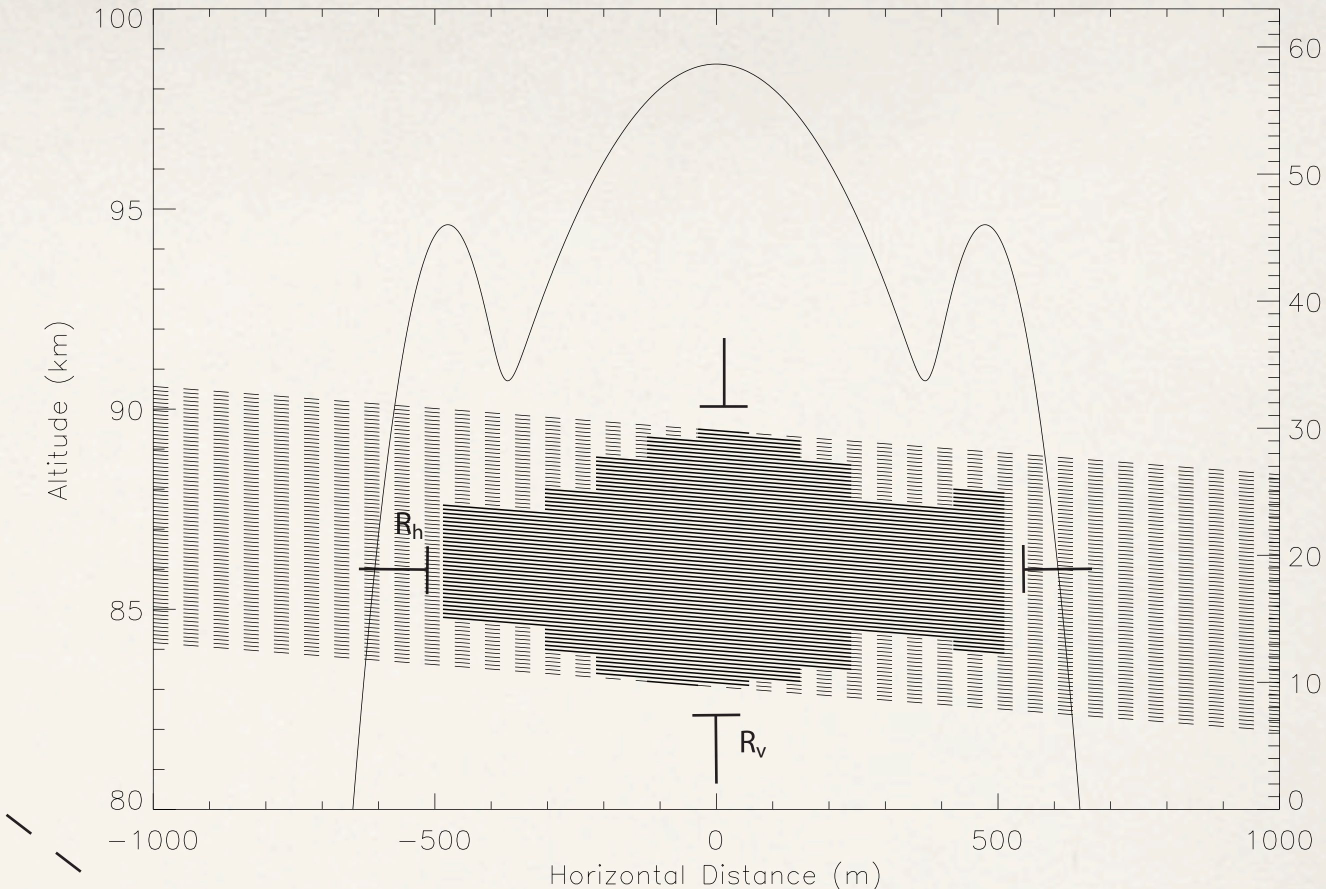


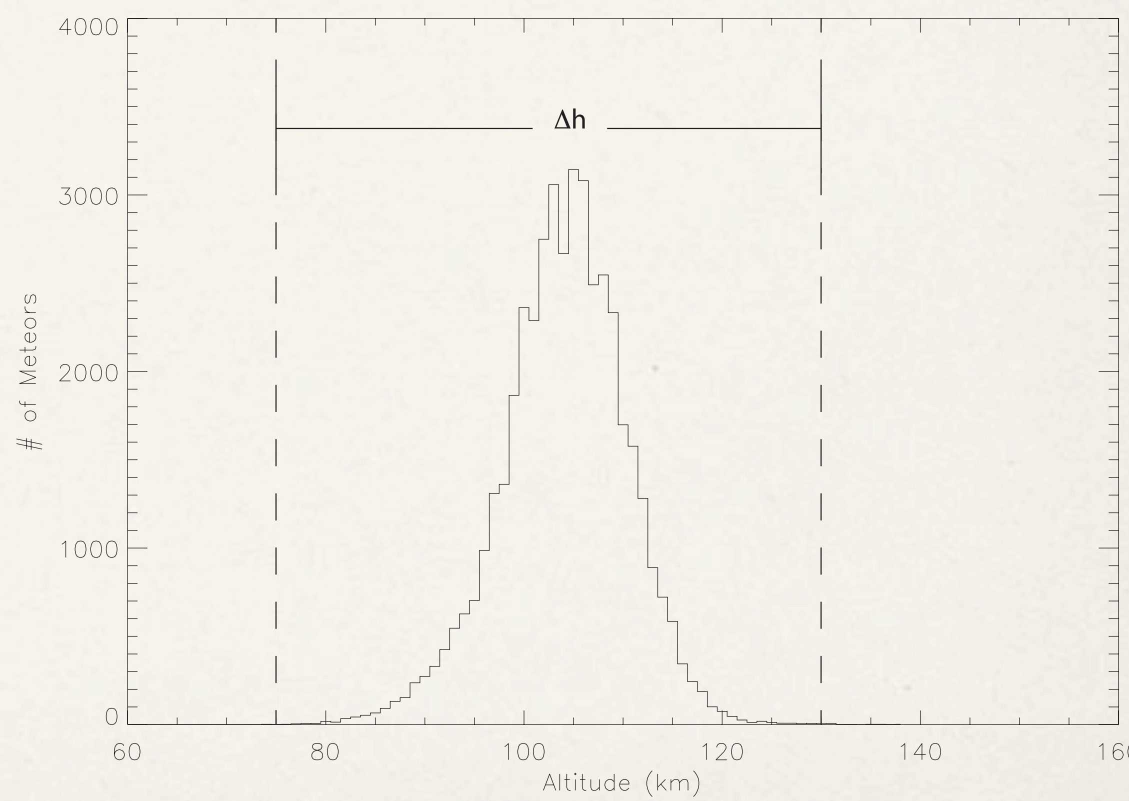

# Head-Echo SNR


α = 45 degrees
m =10 μg; V=11 km/s
m =14 μg; V=13 km/s
m =10 μg; V=15 km/s
Altitude (km)
SNR (dB)
G (dB)
Horizontal Distance (m)

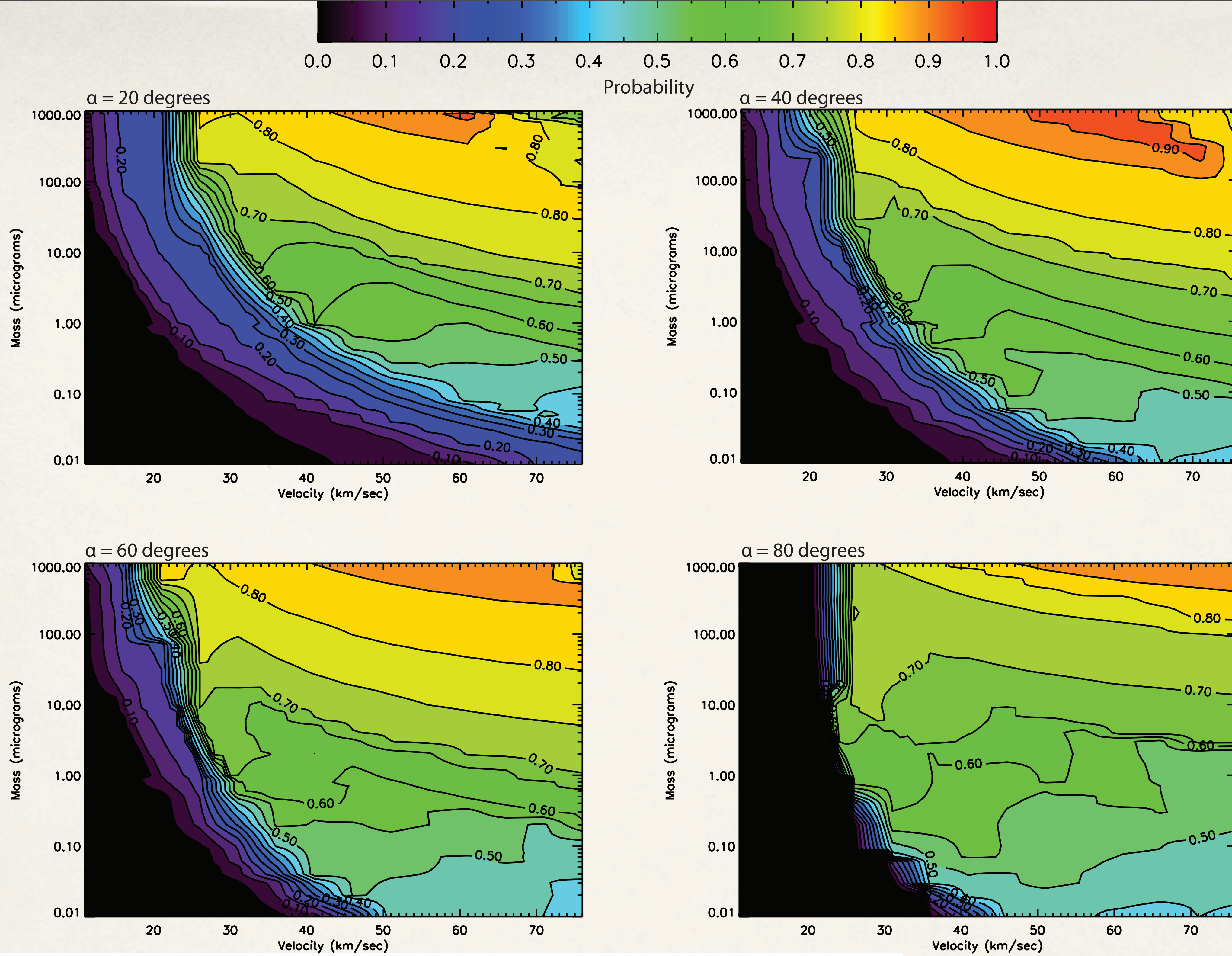
# SNR Results



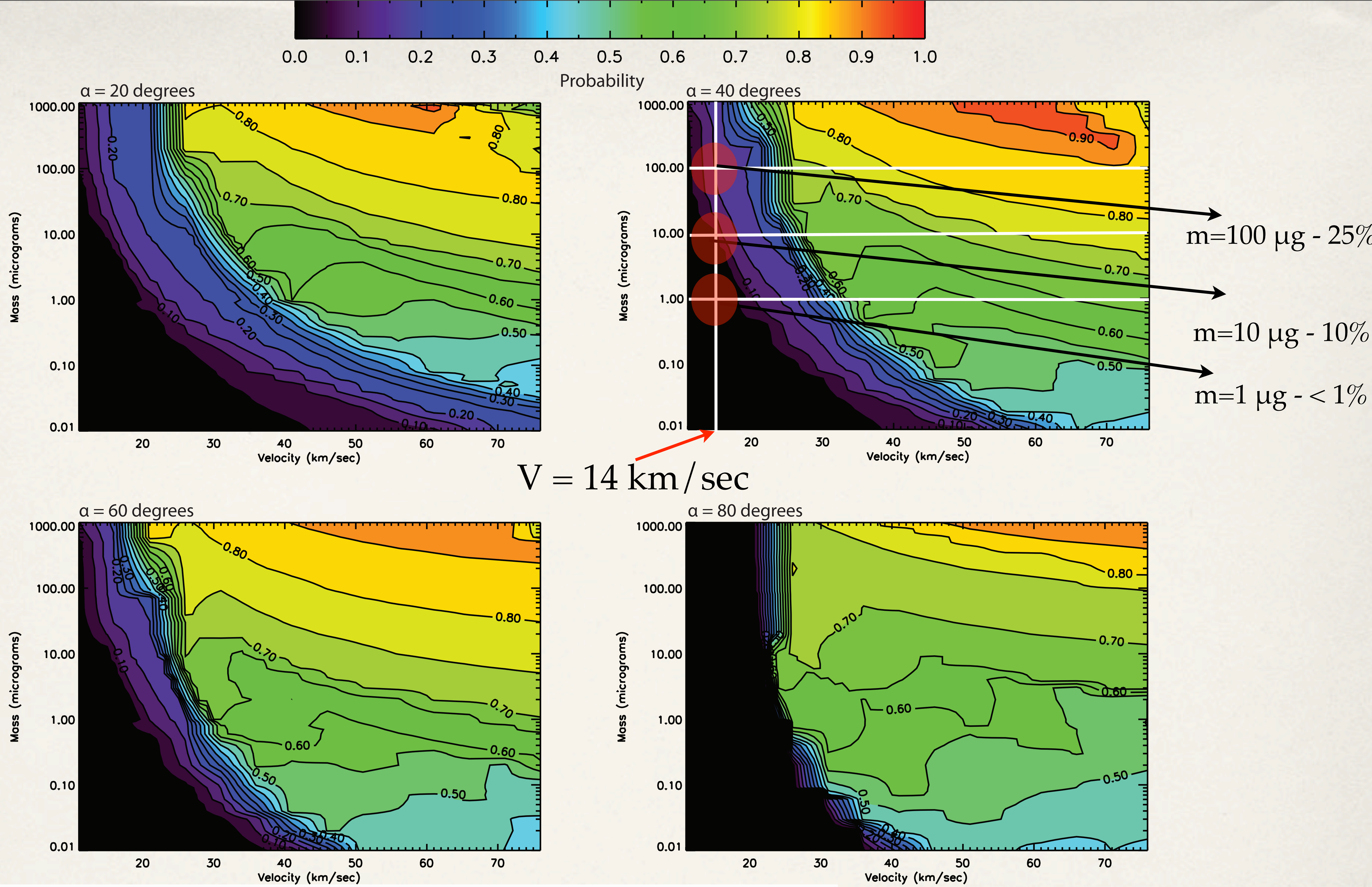



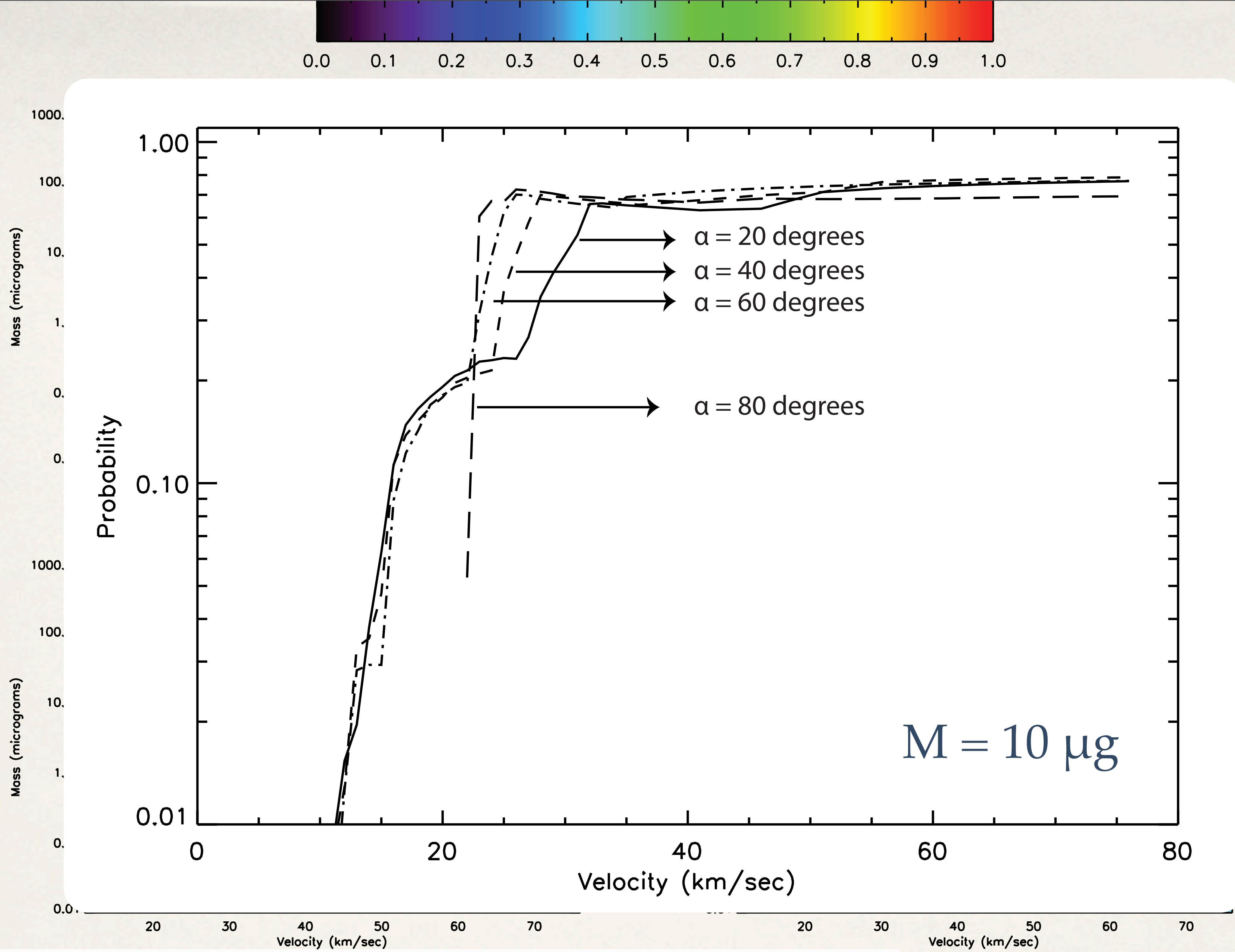

# Probability




# P(α,m,V), SNR=-20 dB




# P(α,m,V), SNR=-20 dB



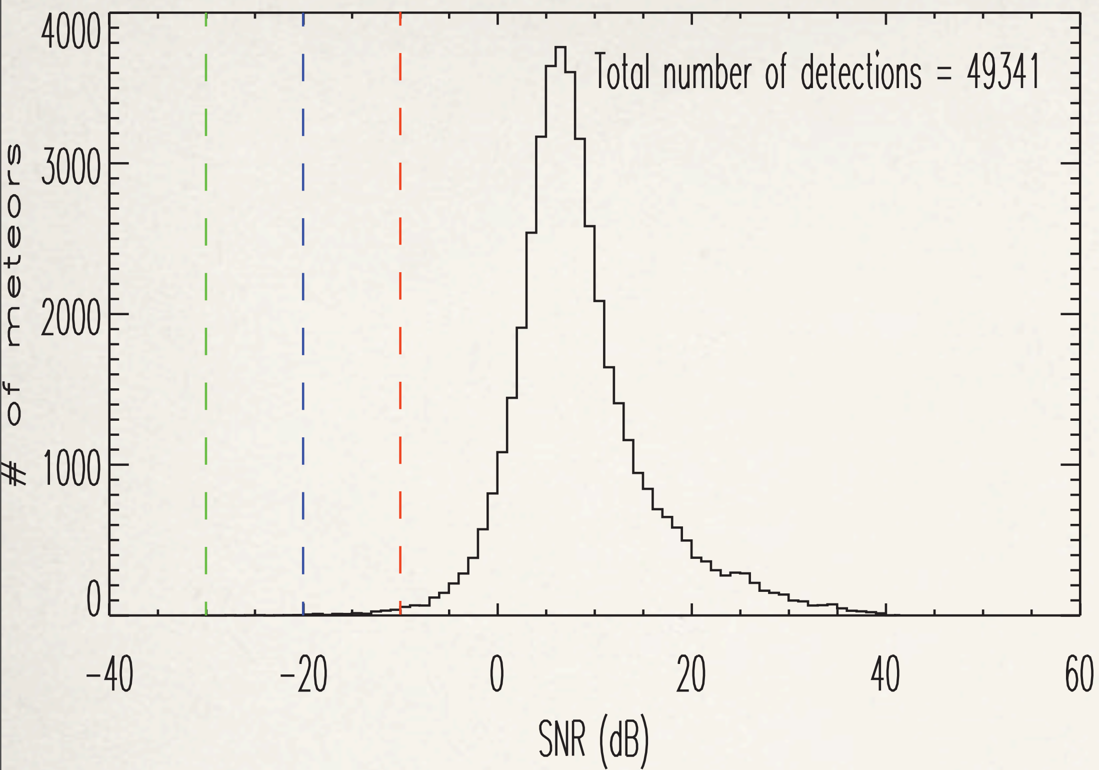

m=100 µg - 25%

m=10 µg - 10%

m=1 µg - < 1%

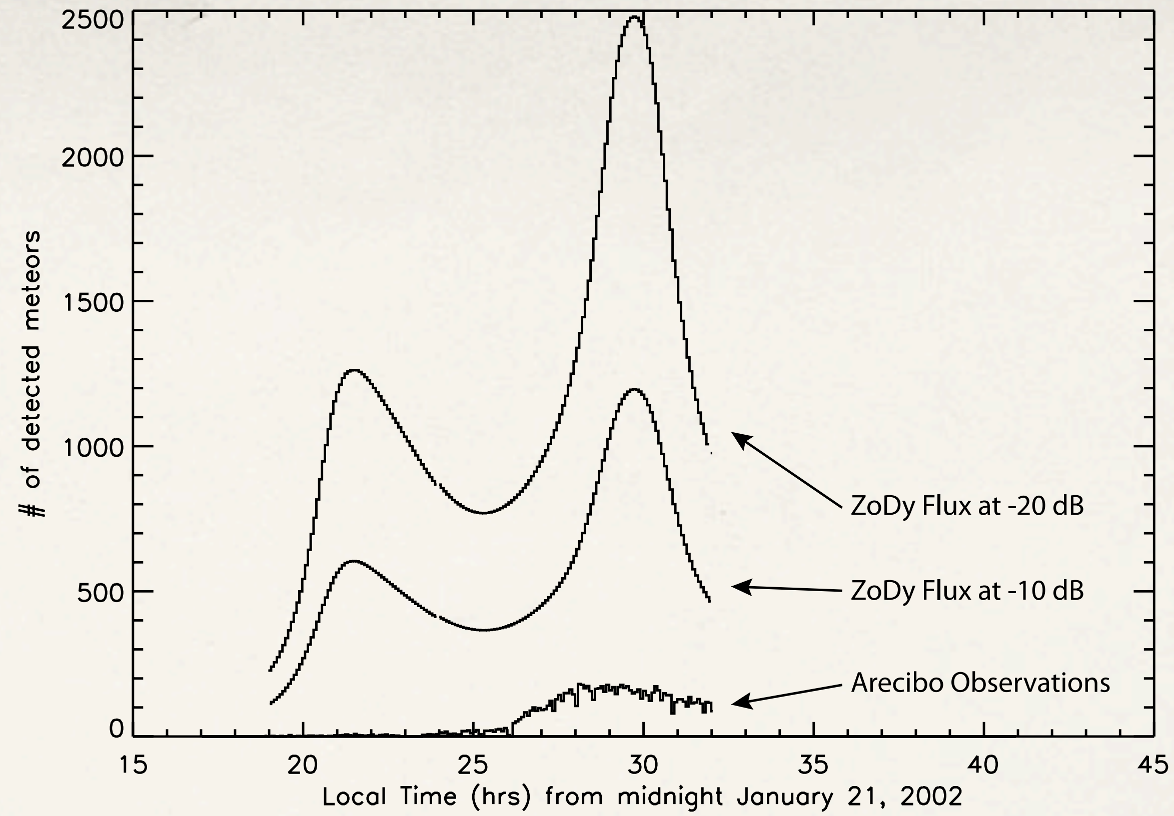
# P(α,m,V), SNR=-20 dB

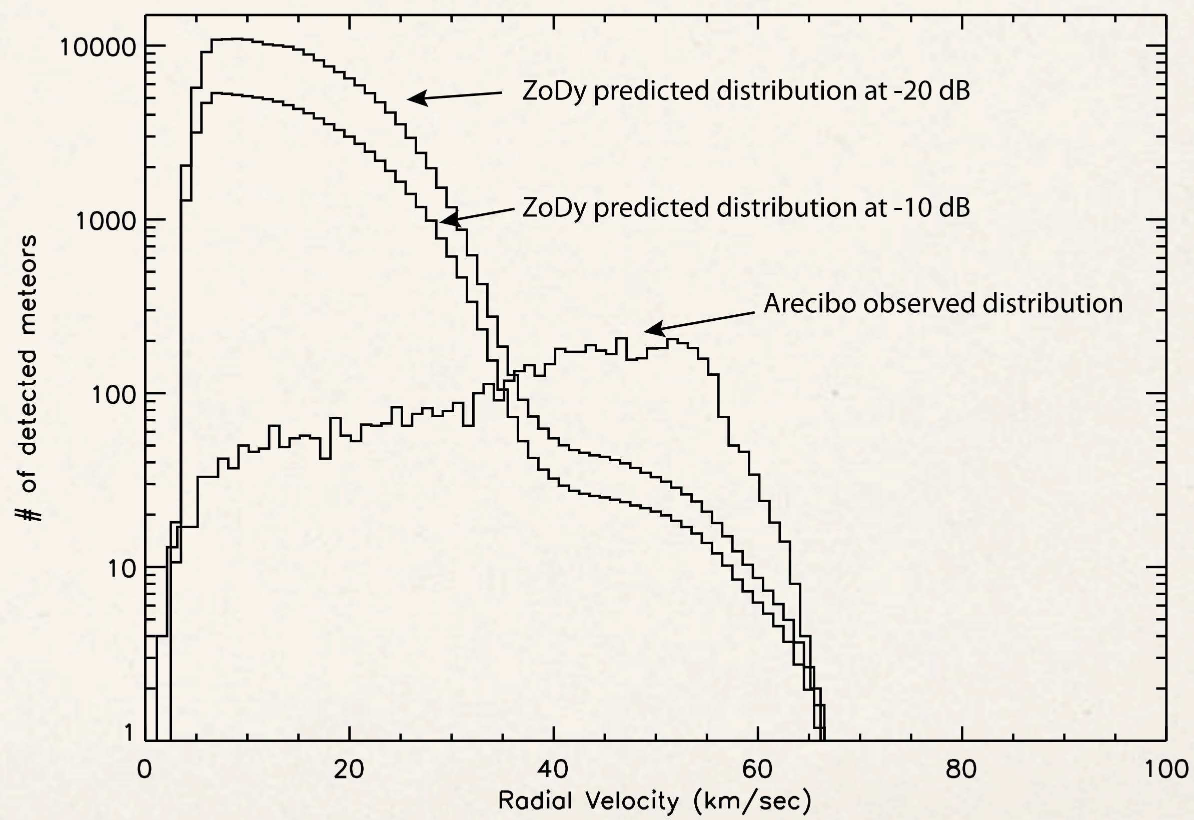
# Results

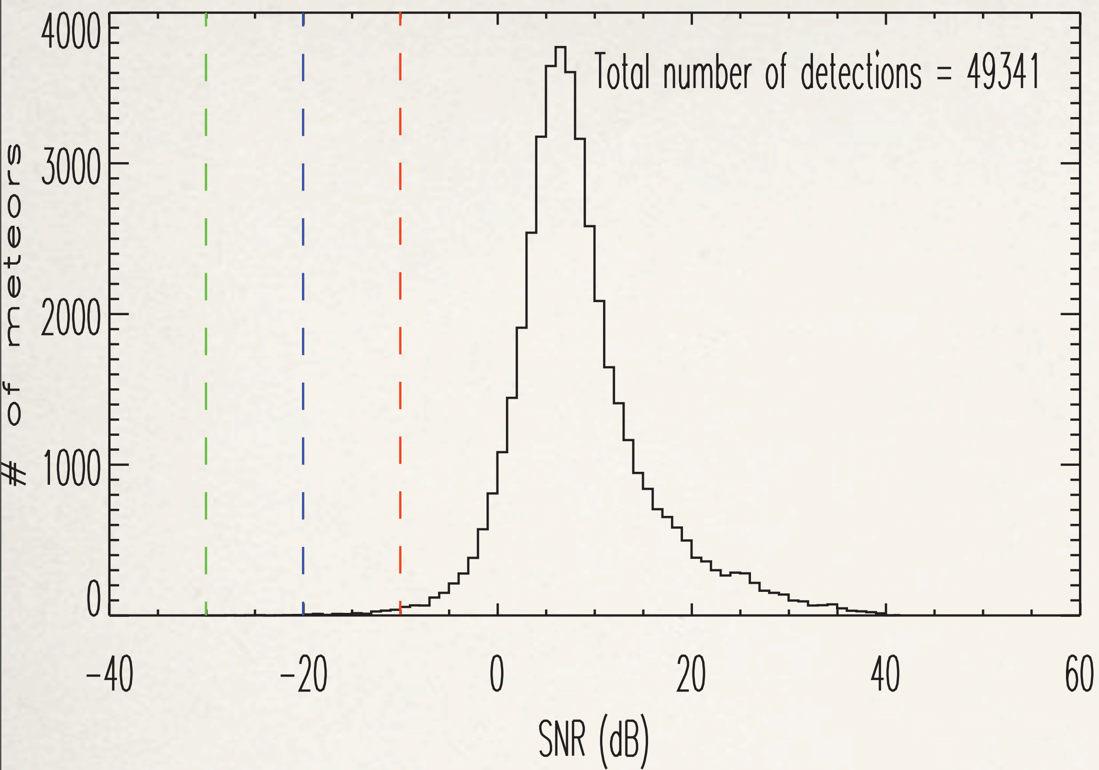


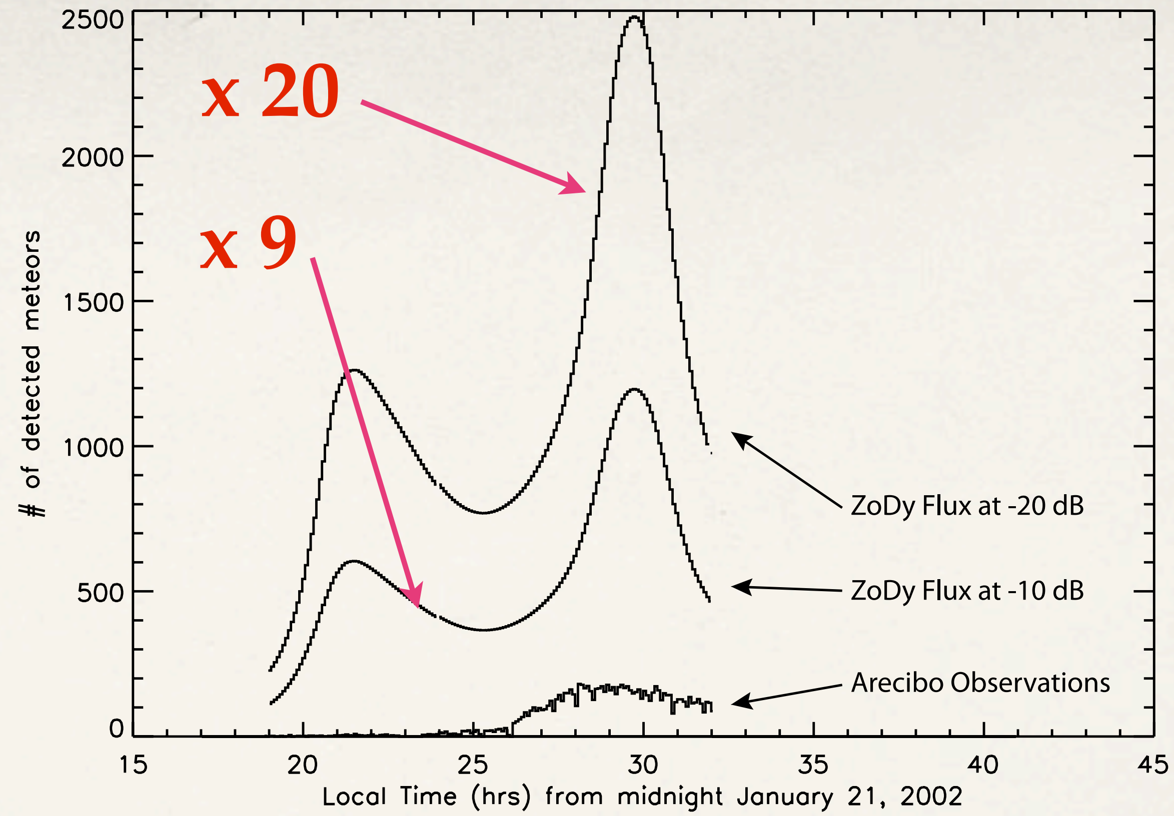

-30 dB
-20 dB
-10 dB

January 2002



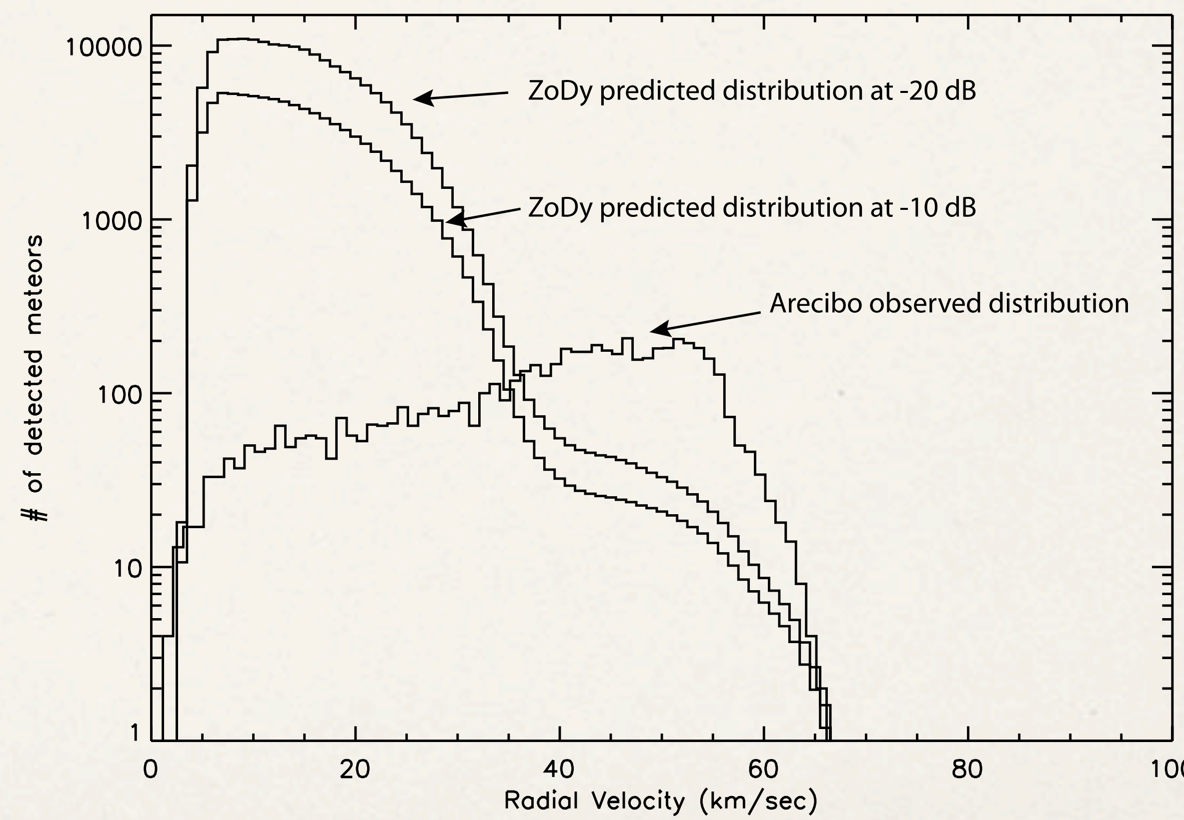



-30 dB

-20 dB

-10 dB




January 2002

# Results

**An input rate of 30 – 40 t/d of slow particles**:

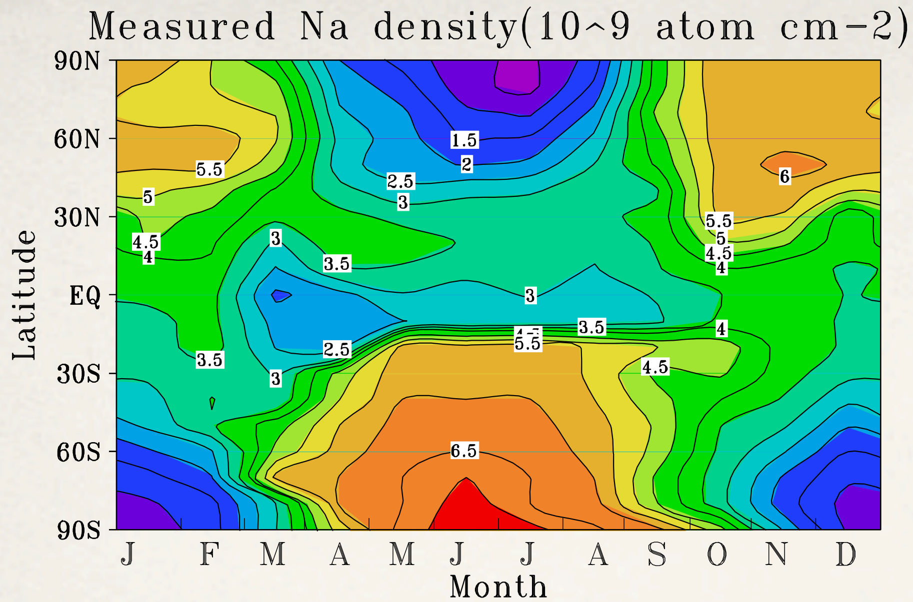
1. Produces the degree of differential ablation required to model the Fe, Mg and Ca layers at the same time as the Na layer, without artificially reducing their injection rates (as done for the WACCM-Fe and -Mg modeling)

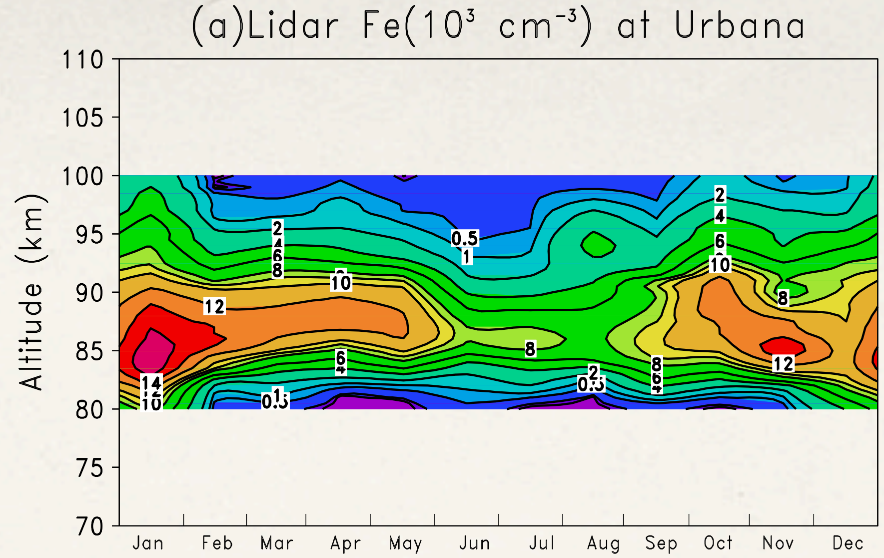
2. Produces a sensible input rate of cosmic spherules

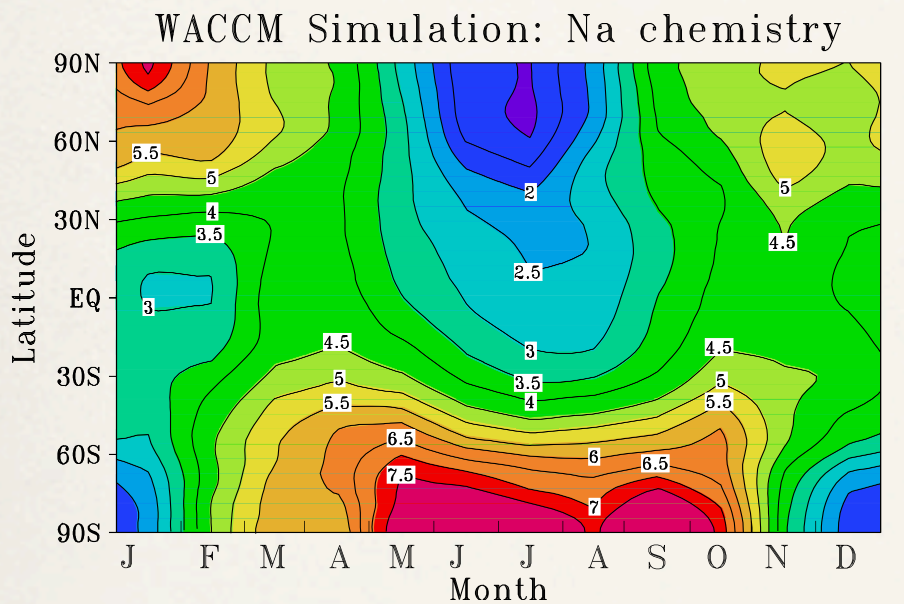
3. Produces the correct optical extinction of meteoric smoke in the mesosphere

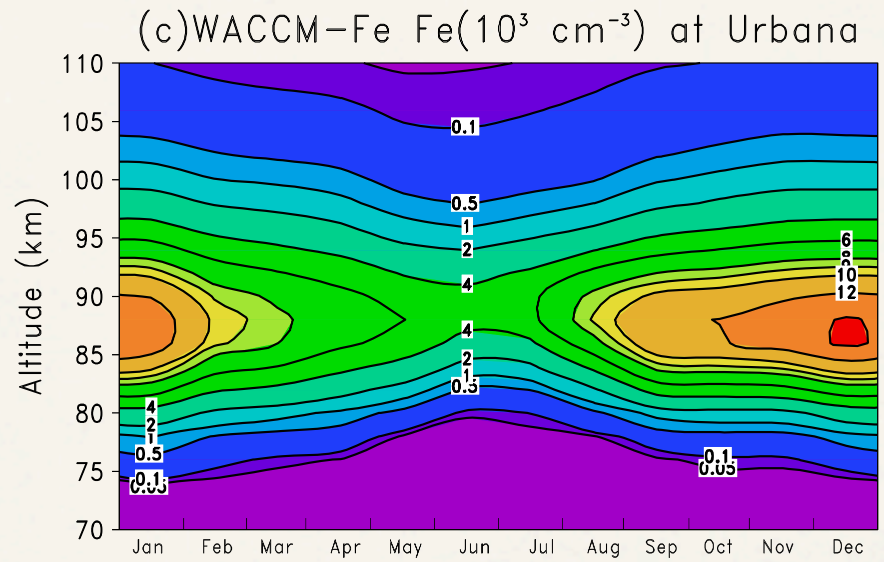
Reducing the total by a factor of 2 means that points 2 and 3 would no longer hold. Increasing the average speed to above 18 km s/1 means that point 1 would not hold.

# Problem



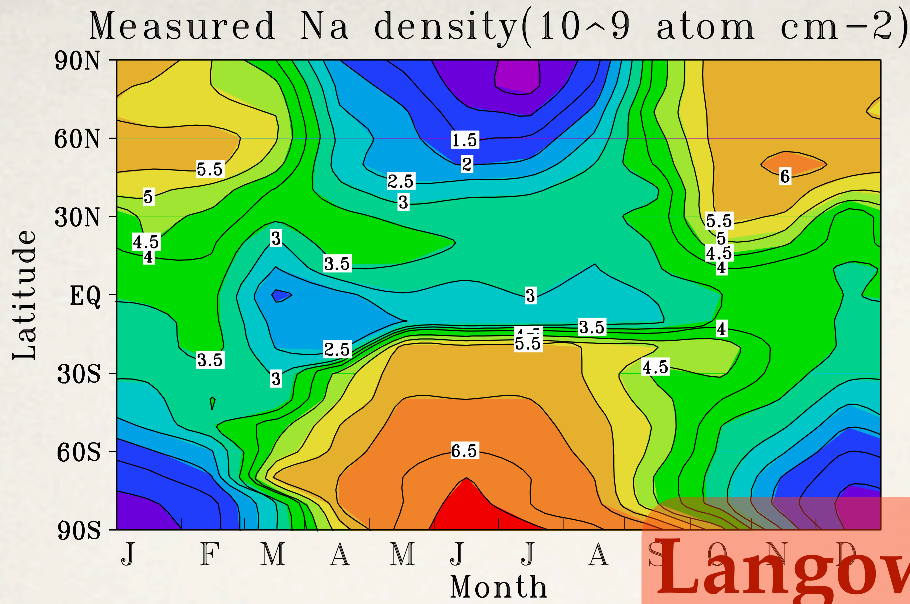



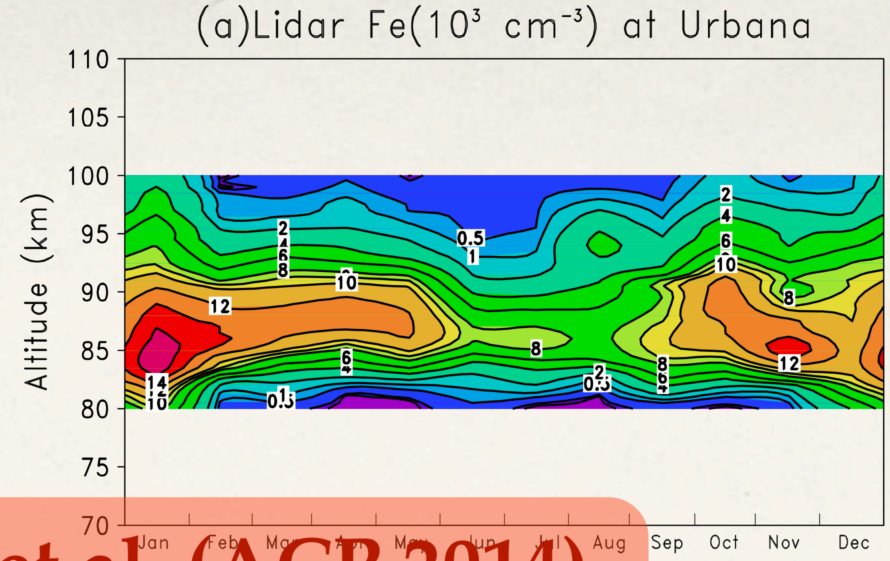




**Marsh et al (JGR 2013)**
**Na MIF 4.6 t/d**

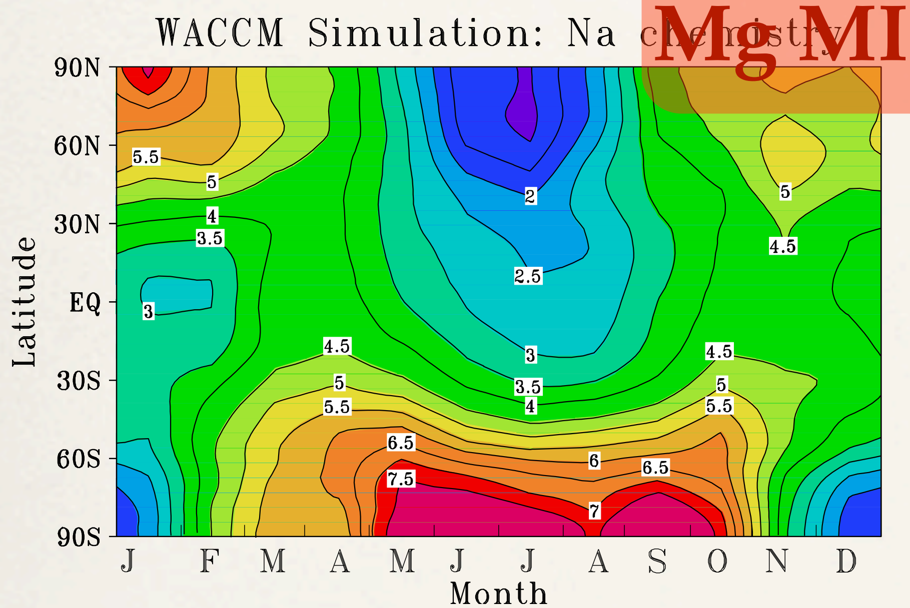
**Feng et al (JGR 2013)**
**Fe MIF 2.6 t/d**

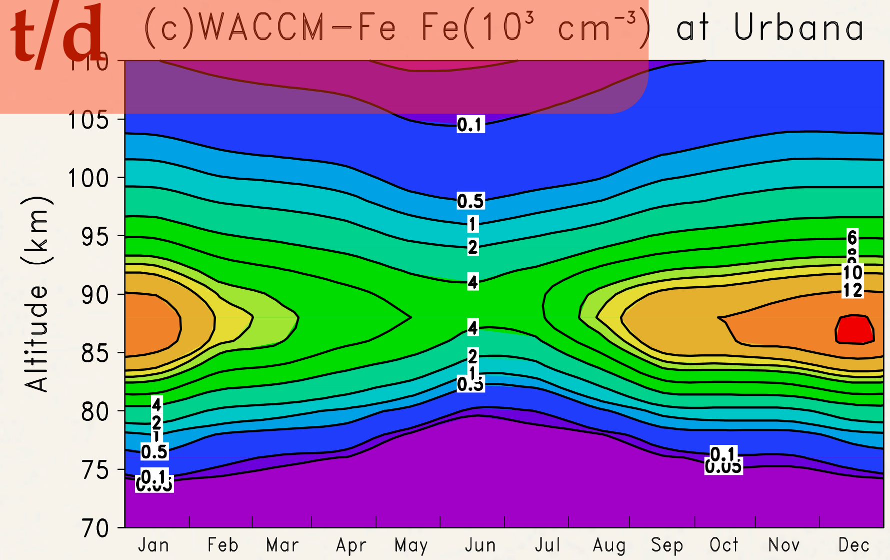
# MIF & Mesospheric Metal




Langowski et al. (ACP 2014)
Mg MIF 0.4 t/d




Marsh et al (JGR 2013)
Na MIF 4.6 t/d

Feng et al (JGR 2013)
Fe MIF 2.6 t/d

# MIF & Mesospheric Metal

Based on firing high velocity iron particles into a chamber of "air" at low pressure, and measuring electron production along the particle track (Friichtenicht et al., 1973 – a NASA report, not published in the literature)

Indirect way of measuring ionization efficiency (rate of ablation of Fe inferred from the deceleration of the particles).

Nevertheless, Jones used these experiments combined with data on meteor luminosity and radar scattering to derive expressions for the ionization efficiency of the major elements. His expressions **overpredicted** the ionization efficiency by an order of magnitude. The abstract concludes "***The observational ionization coefficients are much lower than predicted by the present theory and we provisionally explain this as a consequence of transfer of charge from the meteoric ion to a molecule of the air.***"

# Jones 1997 Calculation of of β

Cuderman (1972) reported measurements of the ionization cross section of K atoms over the full range of collision energies. Charge transfer to O2 is much more important than to N2.

Although much of the product is O2- rather than free electrons, the O2- is produced with sufficient translational speed to auto-detach the electron. Assuming that the final products are K+ and e- and using quantum chemistry trajectory calculations the collision cross section between K and O2 or N2 can be found (enough interaction to vibrationally excite the diatomics).

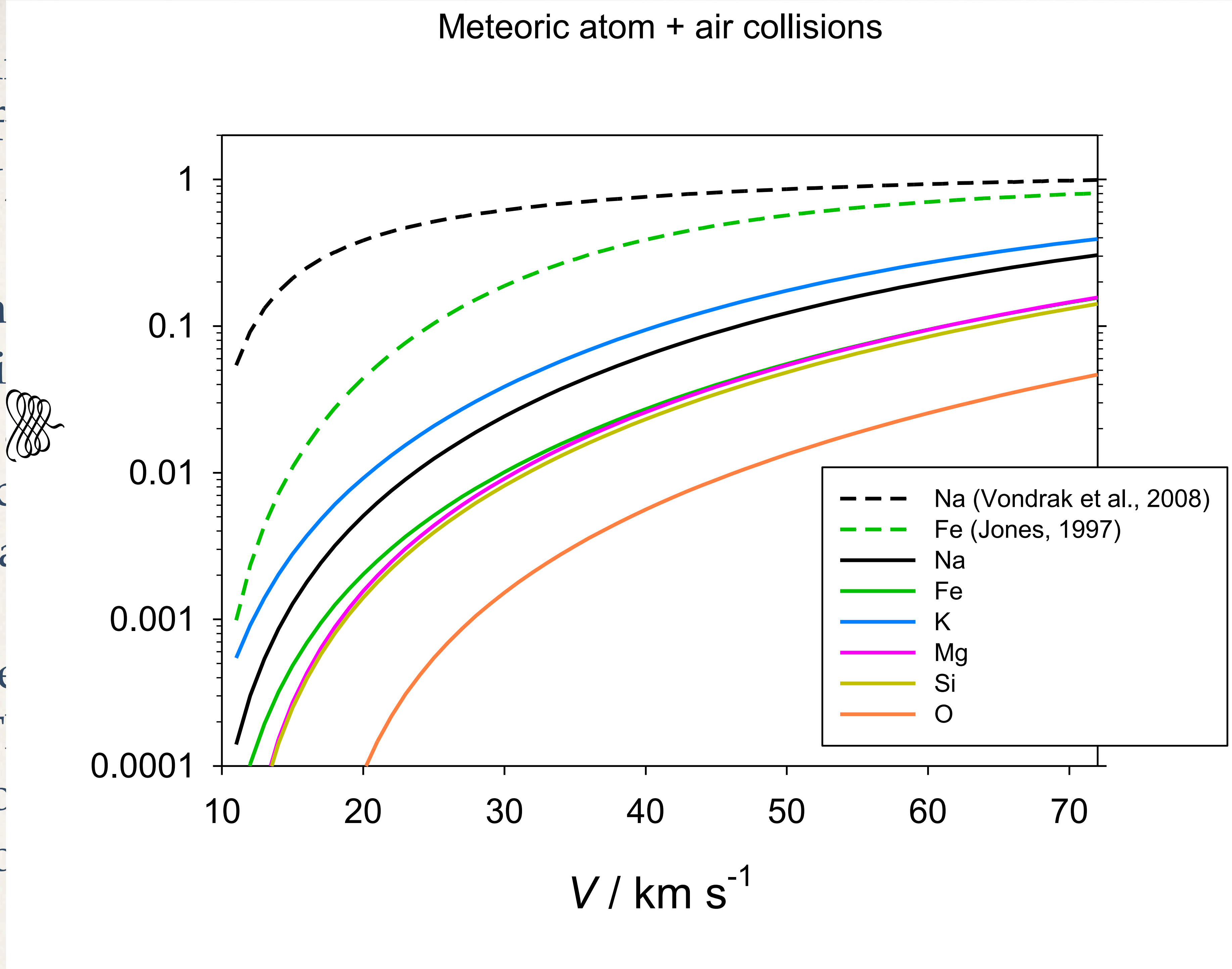
Beta is then the ionization cross section from Cuderman divided by the collision cross section. The Beta factors for the other metals and O are then calculated by scaling their relative ionization cross sections (which scale as their ionization potential squared relative to K).

# Revision of β

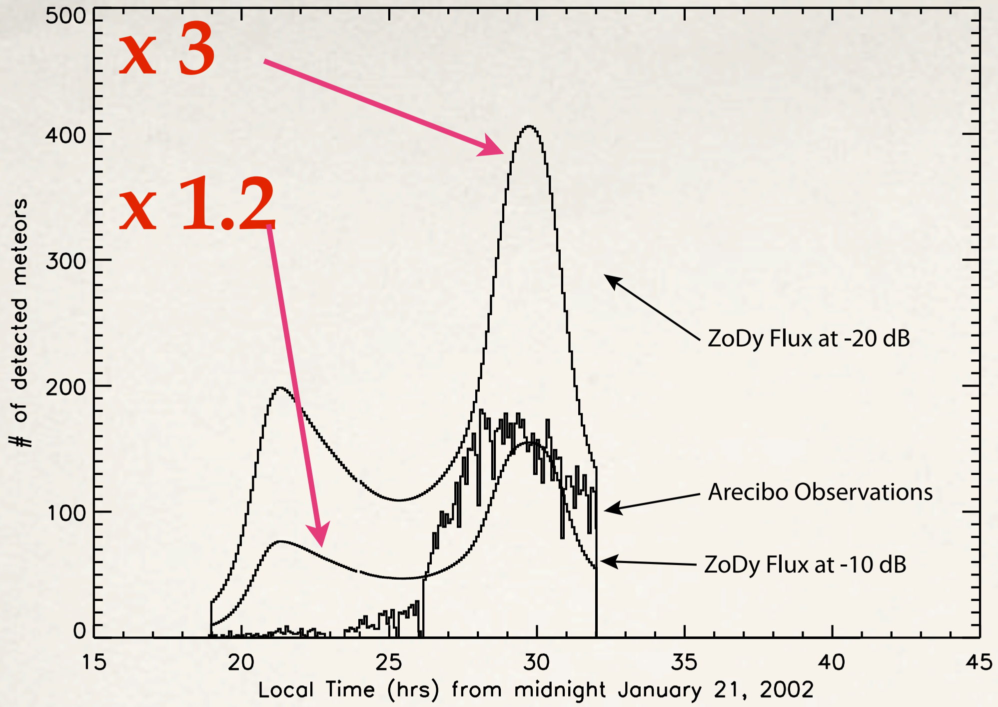
Cuderma[...] on of K atoms
over the f[...] more important
than to N[...]

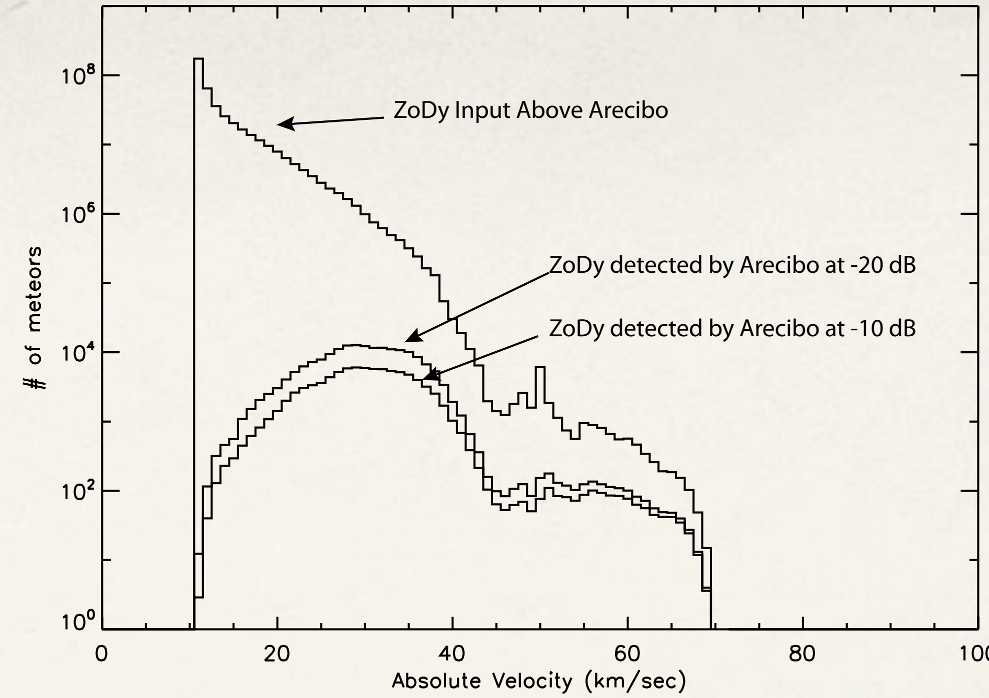
Although [...] 2- is produced
with suffi[...] ing that the final
products [...] lations the
collision [...] interaction to
vibrationa[...]

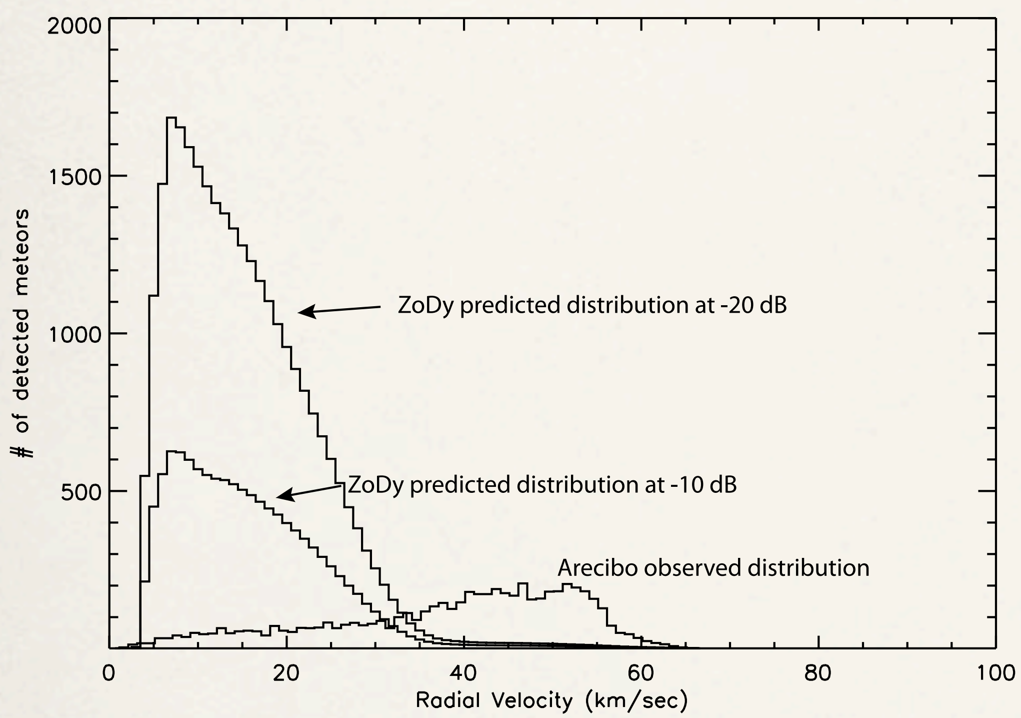
Beta is the [...] ne collision cross
section. T[...] d by scaling their
relative ic[...] ntial squared
relative to[...]

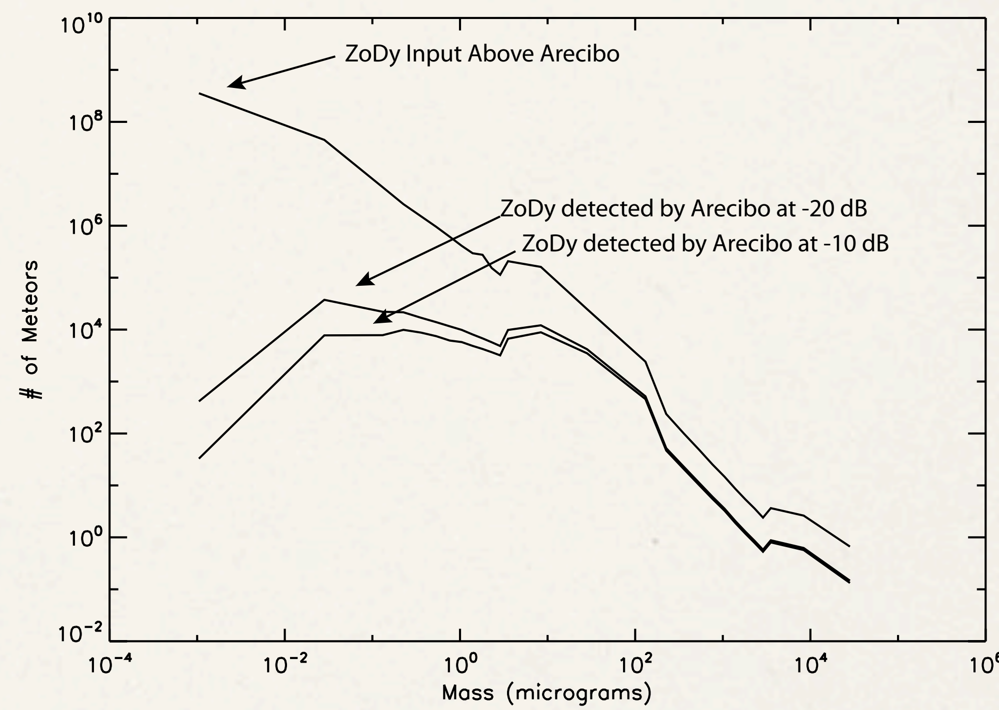



# Revision of β




# Revised Results

- Developed new approach to estimate the detection probability of meteor head echoes as a function of particle m, V and $\alpha$ based on differential ablation

- At low velocities, detection is strongly dependent on particle composition

- Demonstrate the need to revise treatment of $\beta$

- When applied to the ZDC Model developed by Nesvorny et al. and compared to Arecibo observations, our results suggests the radar should detect at least an order of magnitude more slower particles

- ZoDy only includes slow JFCs so when other faster populations are included (HTC, OCC and Asteroidal) disagreement will worsen

# Conclusions