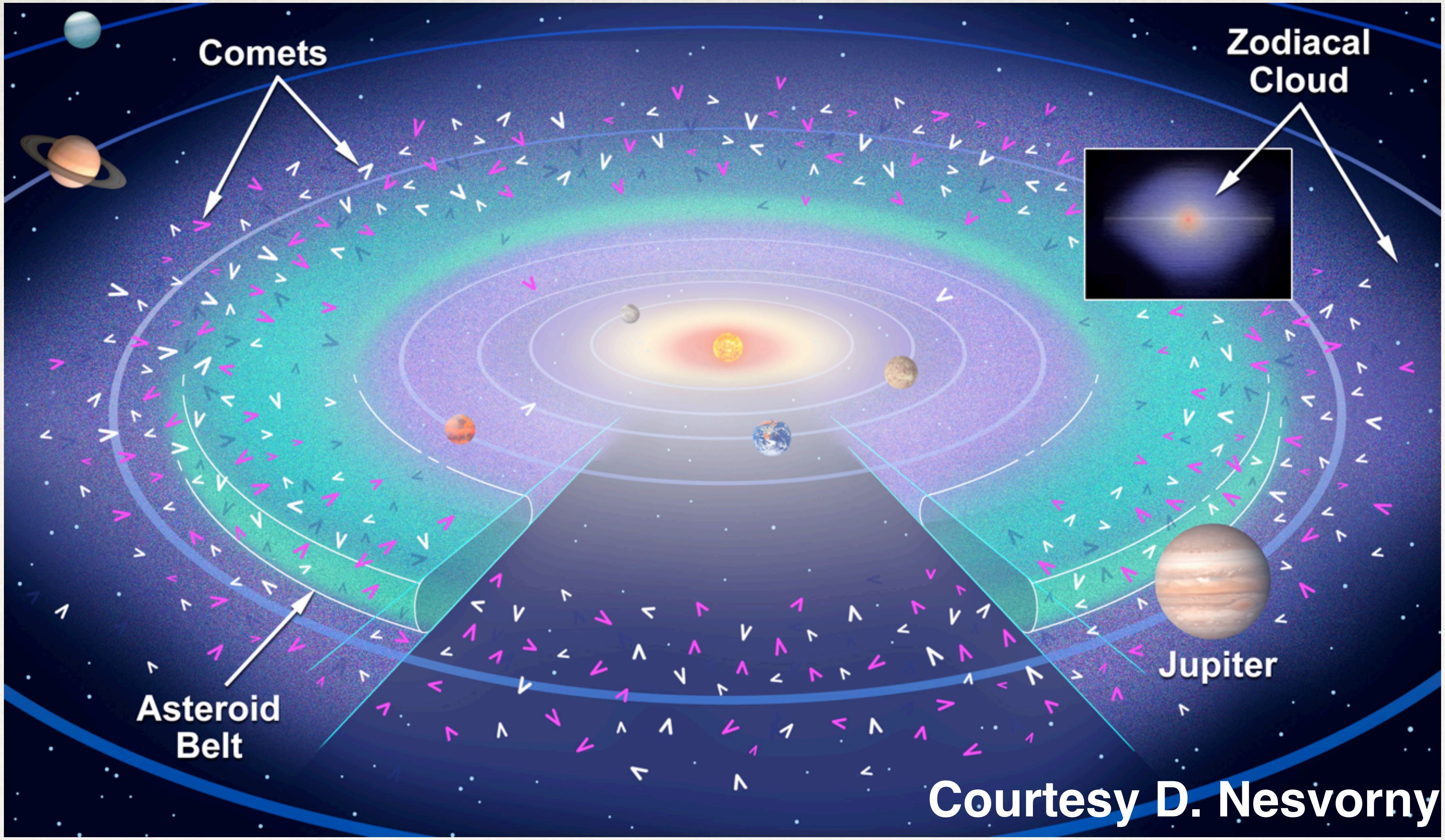
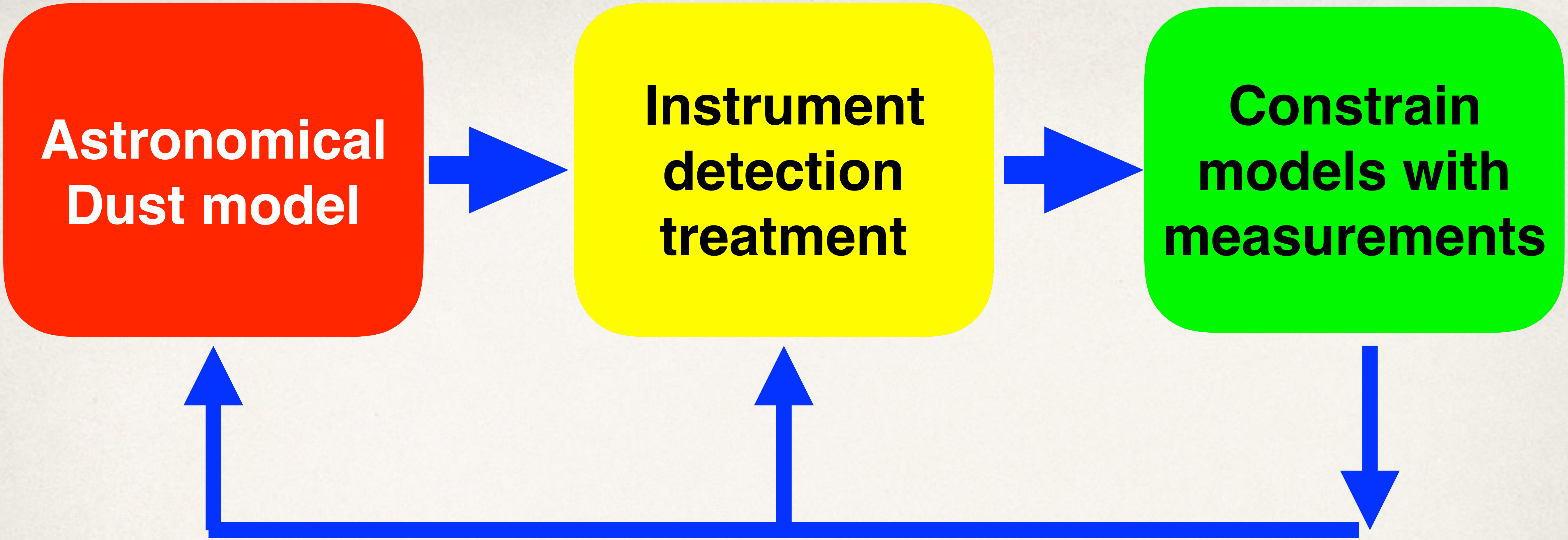


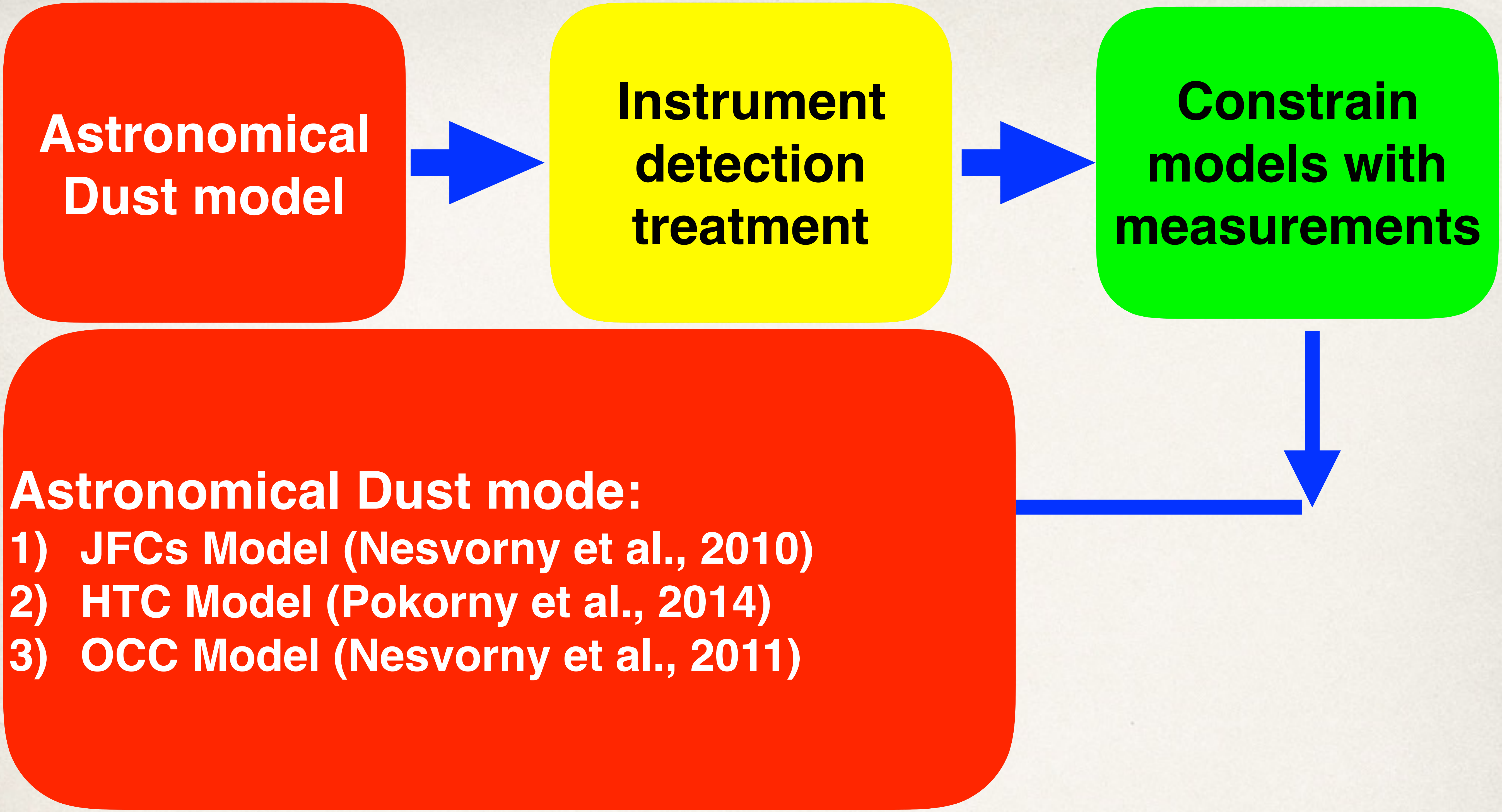
Radar Detectability of meteor head echoes and its implication on the Zodiacal Dust Cloud populations

D. Janches (SWL-NASA/GSFC)
N. Swarnalingam (CUA), P. Pkorný (UWO), J. M.C. Plane(University of Leeds), D. Nesvorný (SWRi), W. Feng (University of Leeds), J. D. Carrillo - Sanchez (University of Leeds), and D. Vokrouhlický (Charles University)

Meteoroids 2016, Noordwijk, The Netherlands, June 6-10, 2016


Astronomical Dust model
Instrument detection treatment
Constrain models with measurements

Approach


Astronomical Dust model
Instrument detection treatment
Constrain models with measurements
Astronomical Dust mode:
1) JFCs Model (Nesvorny et al., 2010)
2) HTC Model (Pokorny et al., 2014)
3) OCC Model (Nesvorny et al., 2011)

Approach

Astronomical Dust model

Instrument detection treatment

Constrain models with measurements

Astronomica

1) JFCs Model
2) HTC Model
3) OCC Model

Constrain models with measurements:

1) Specifically HPLA Radar Measurements
2) Specifically Arecibo 430 MHz
3) Specifically Daily Rates and Radial Velocity distributions

Approach

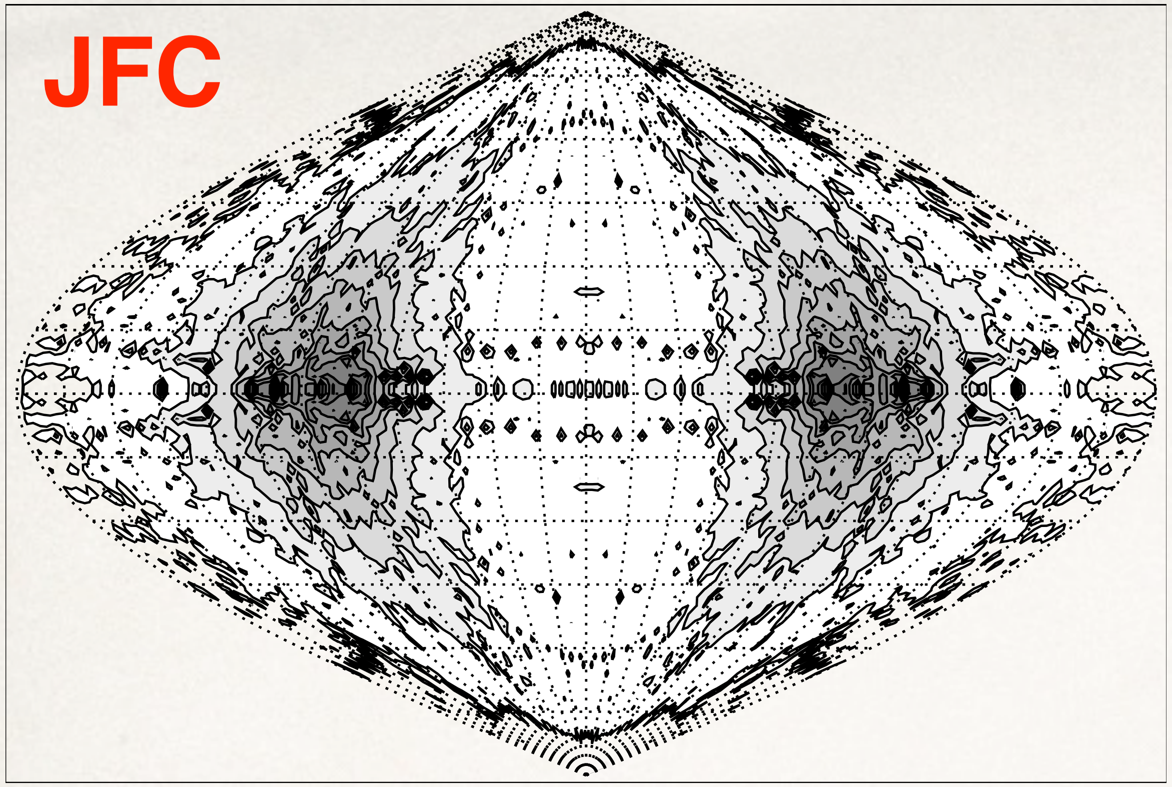
Astronomical Dust model → **Instrument detection treatment** → **Constrain models with measurements**

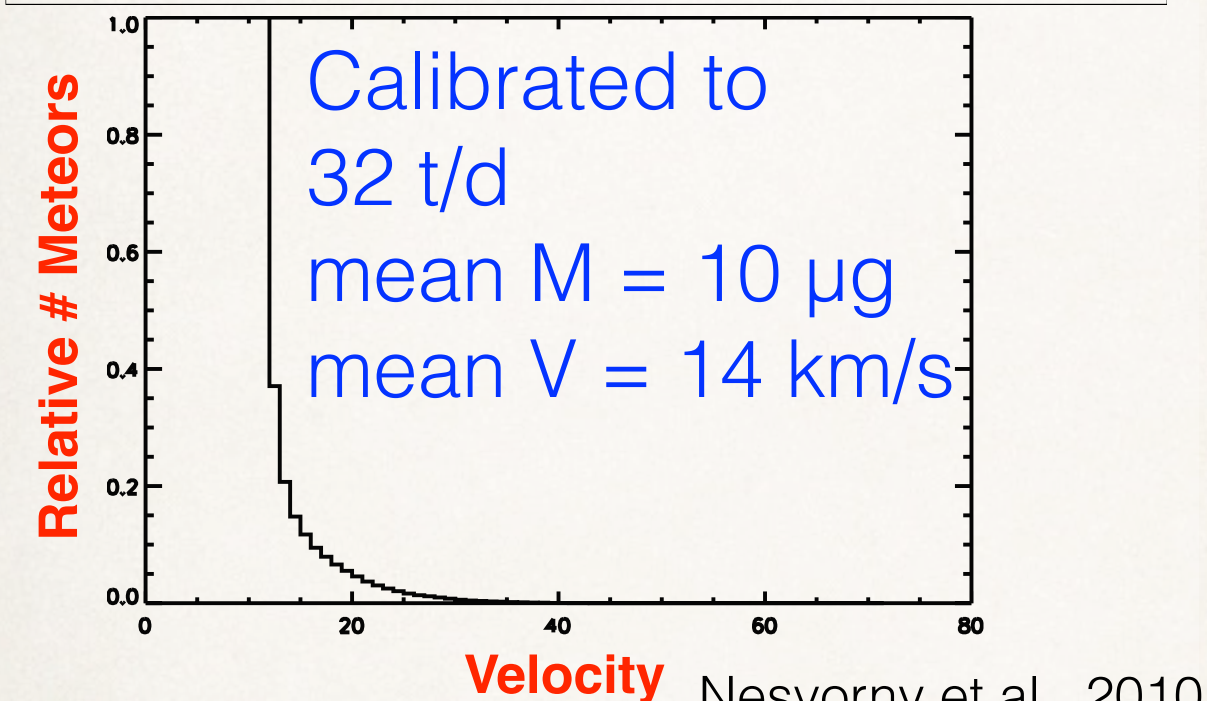
Instrument detection treatment as a function of m,V and α:

1) **Understanding the ablation and electron production**
2) **Understanding the characteristics of the meteor head echo (i.e. size and shape)**
3) **Understanding how radar signal strength depends on 1 and 2 (SNR)**

Approach

NASA HSD



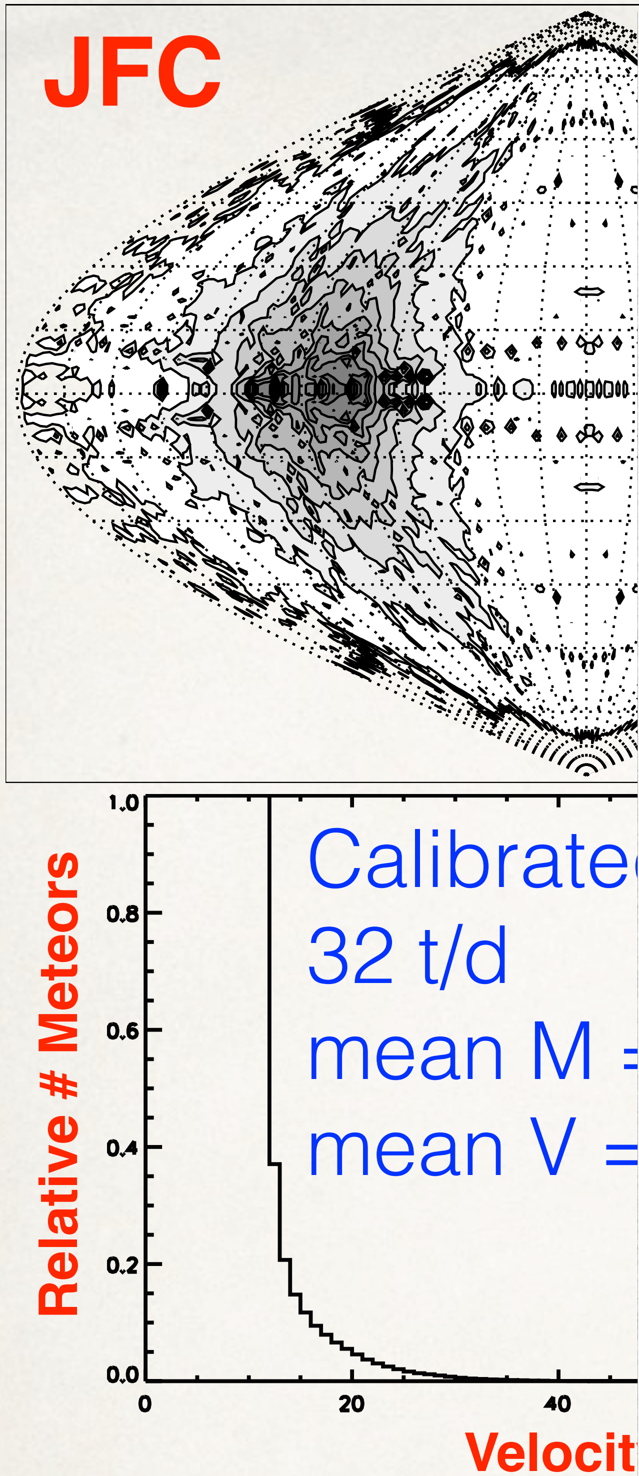


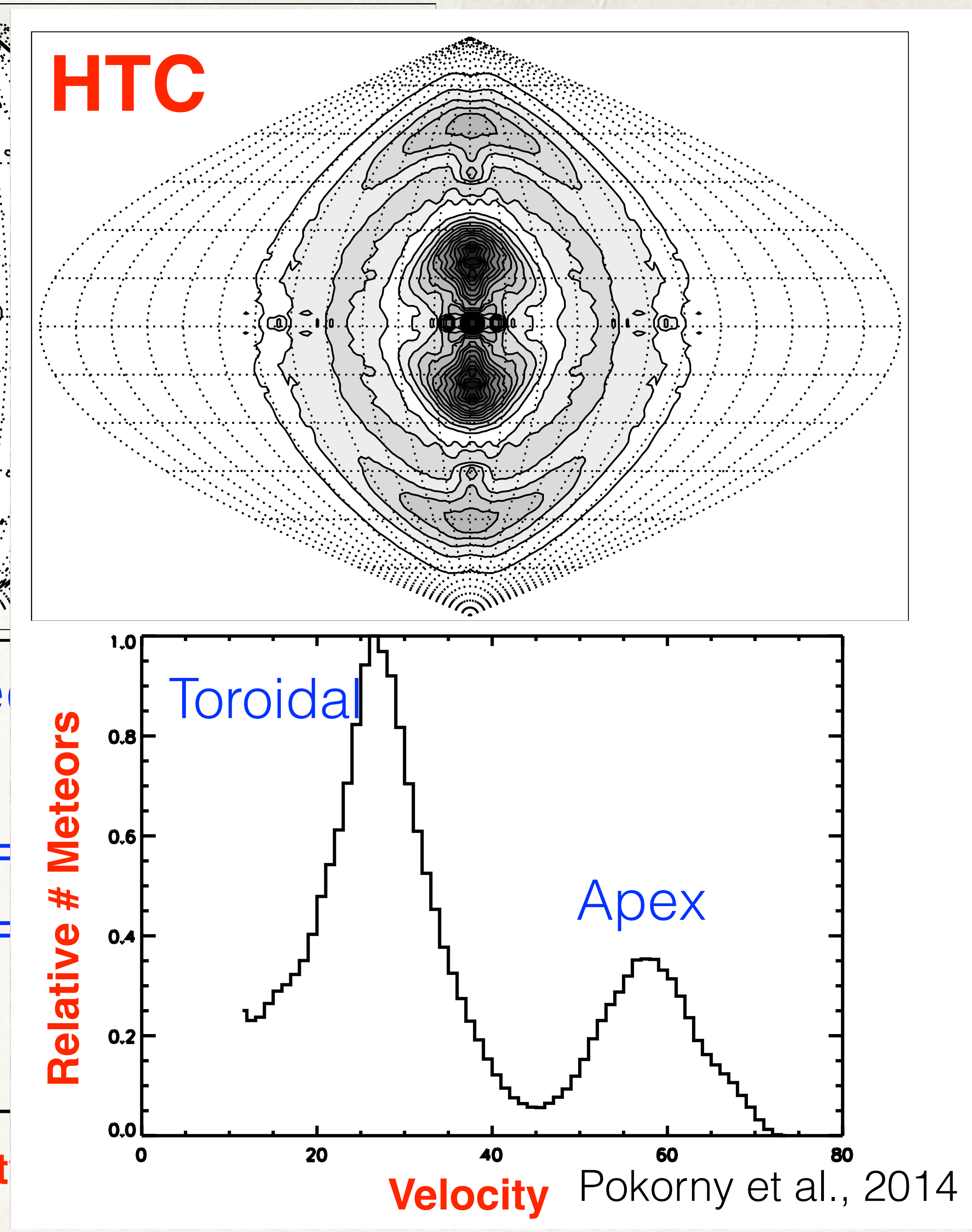
Nesvorny et al., 2010

One of the work's main hypothesis is that most of this flux is undetected by radars due to its small velocity

A main goal of this work is to show if this is in fact true for Arecibo 430 MHz Head Echo (HE) Meteor Observations

Astronomical Models





work's main
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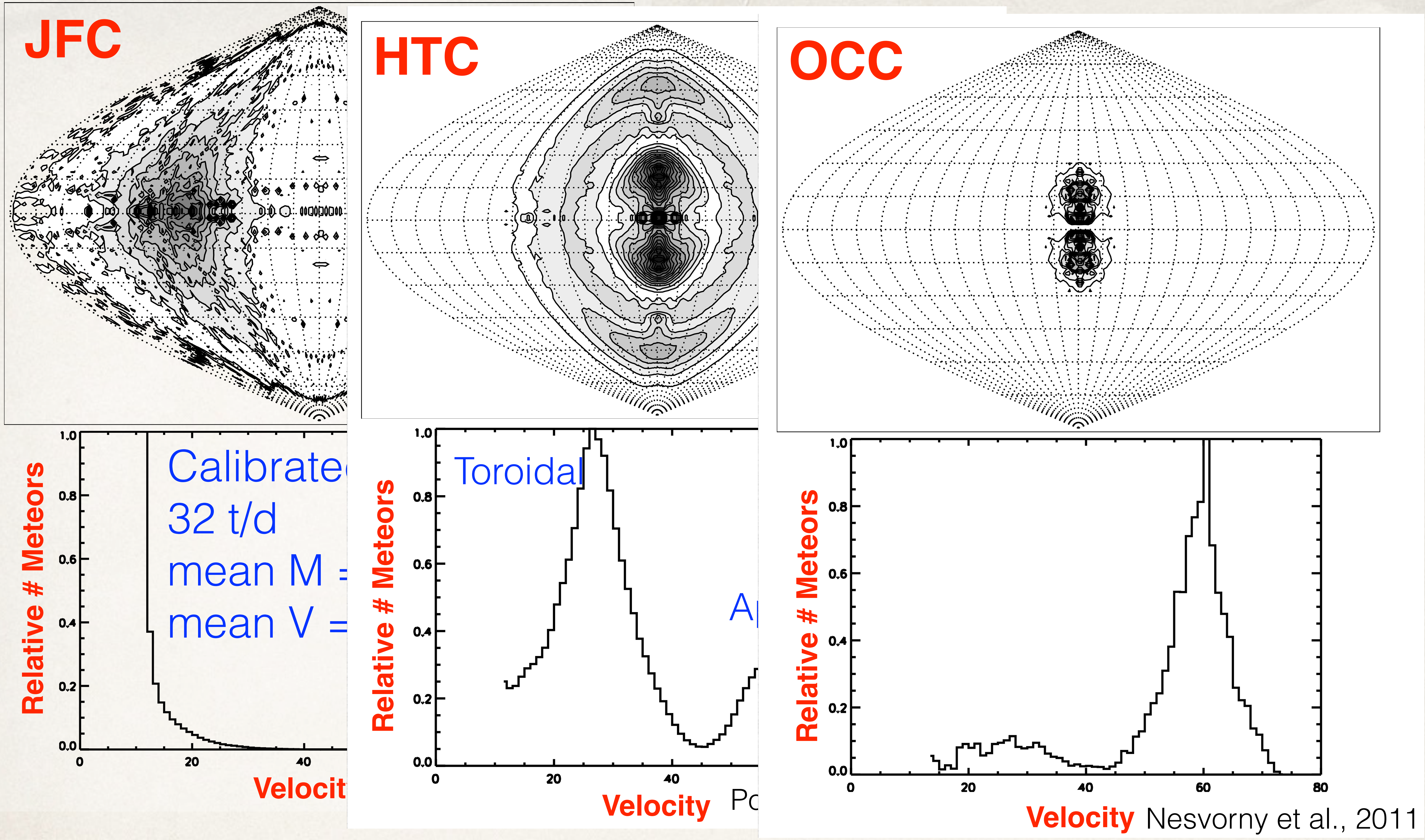
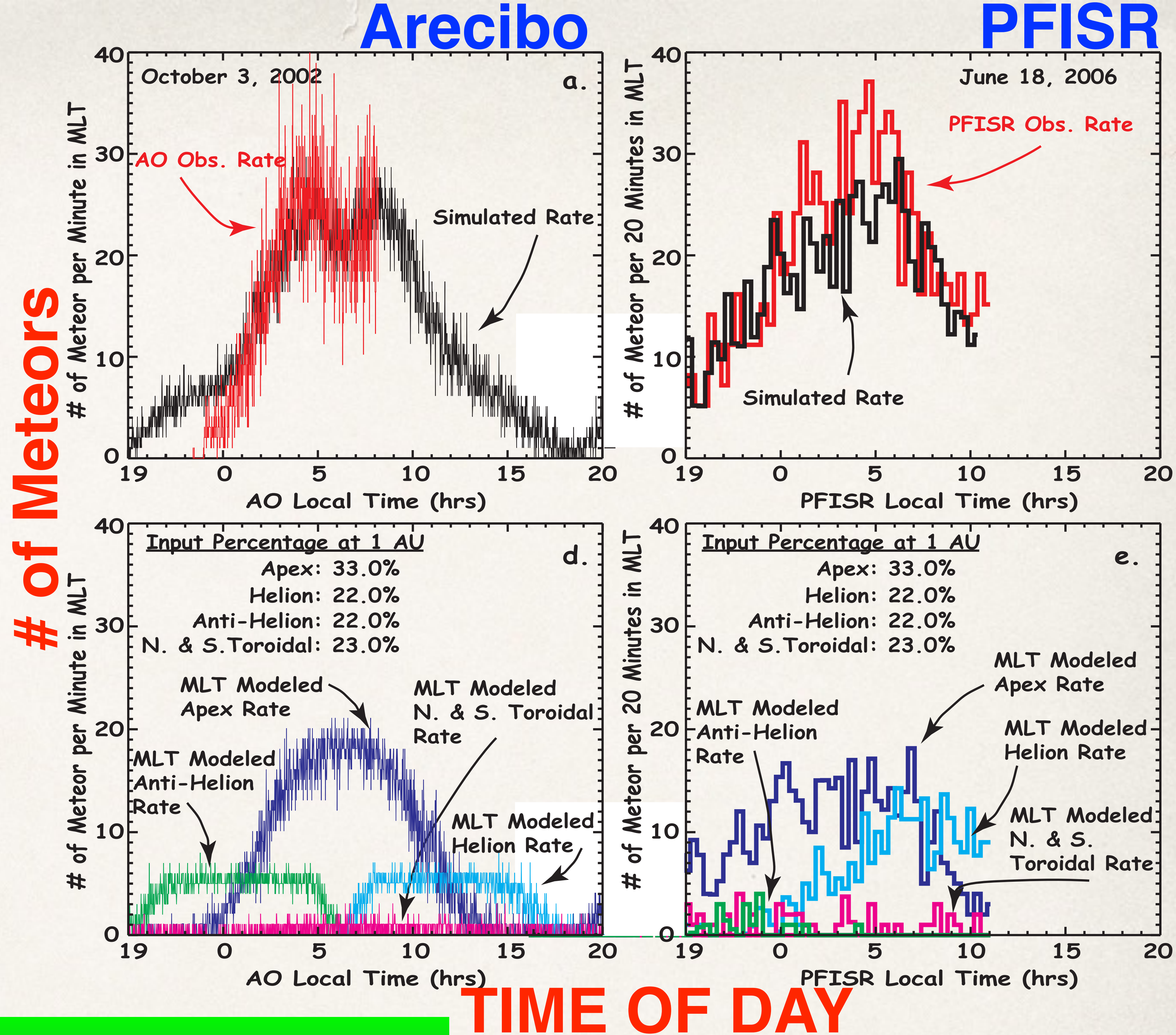
Astronomical Models

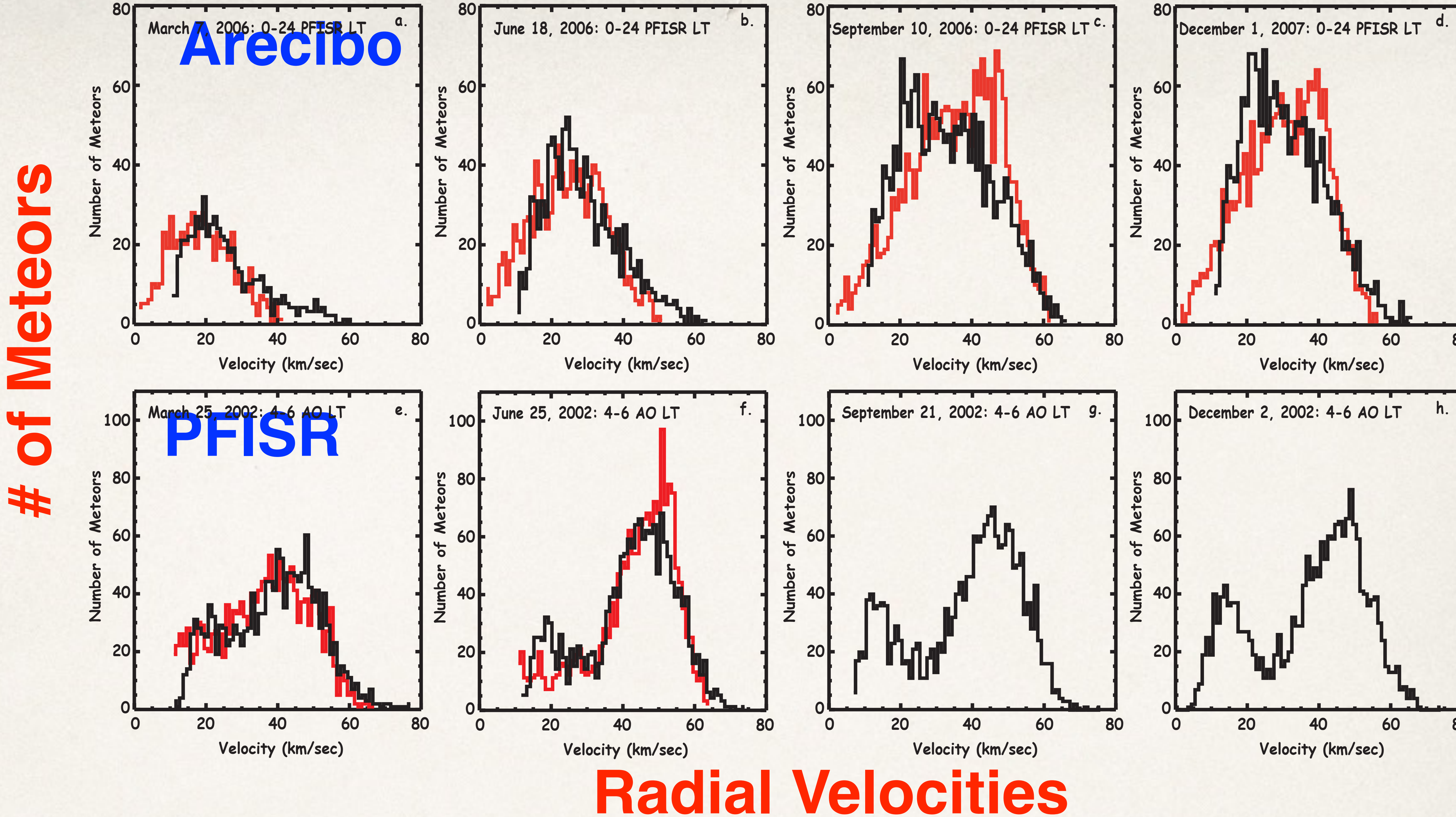


Astronomical Models

Assuming we know the astronomical input and the manner is detected we can then use the measurements to constrain the amount of particles needed from each source



HPLA Measurements

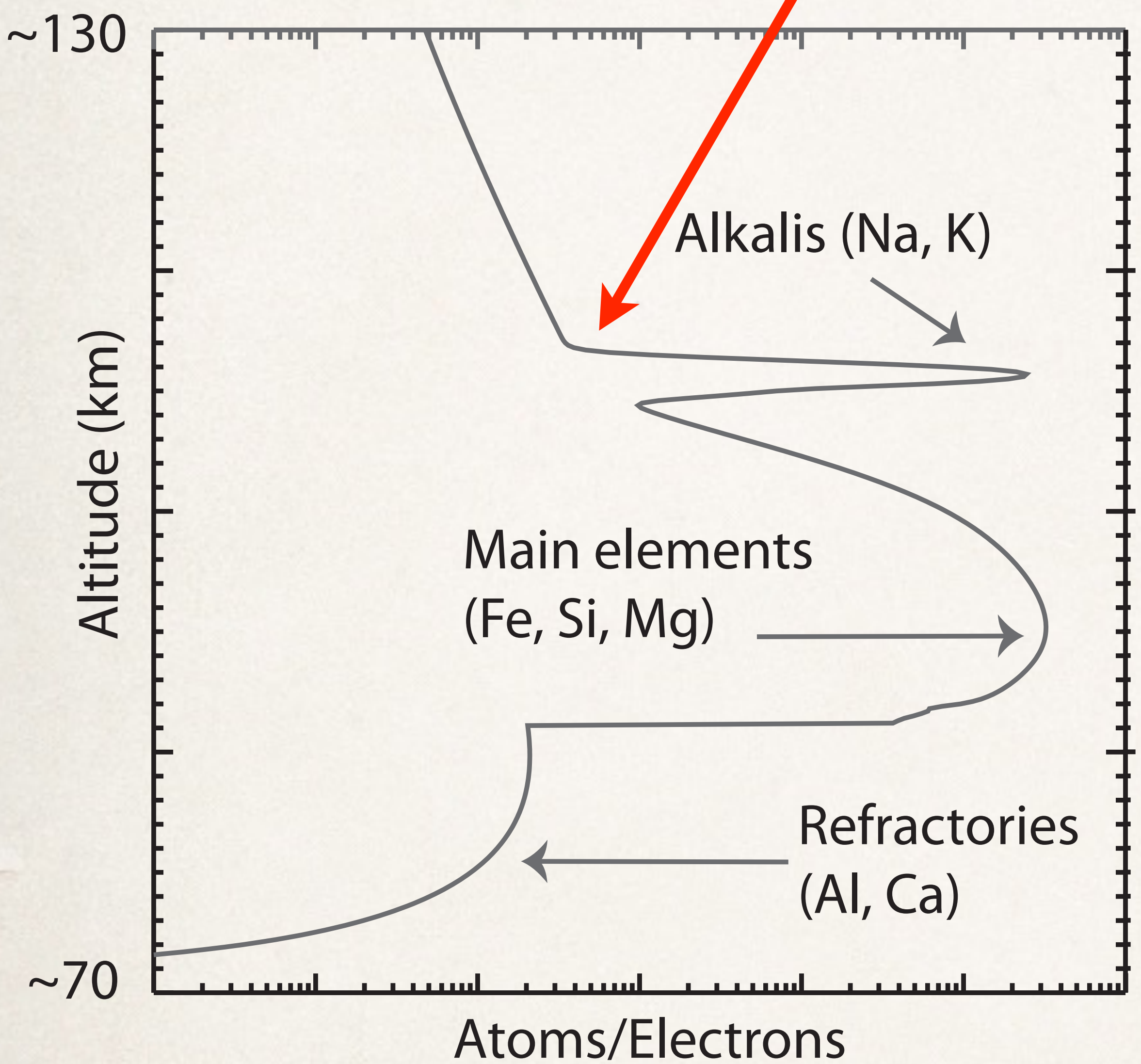


Line of sight velocities help to constrain the aspect sensitivity dependance of the meteor detection

HPLA Measurements

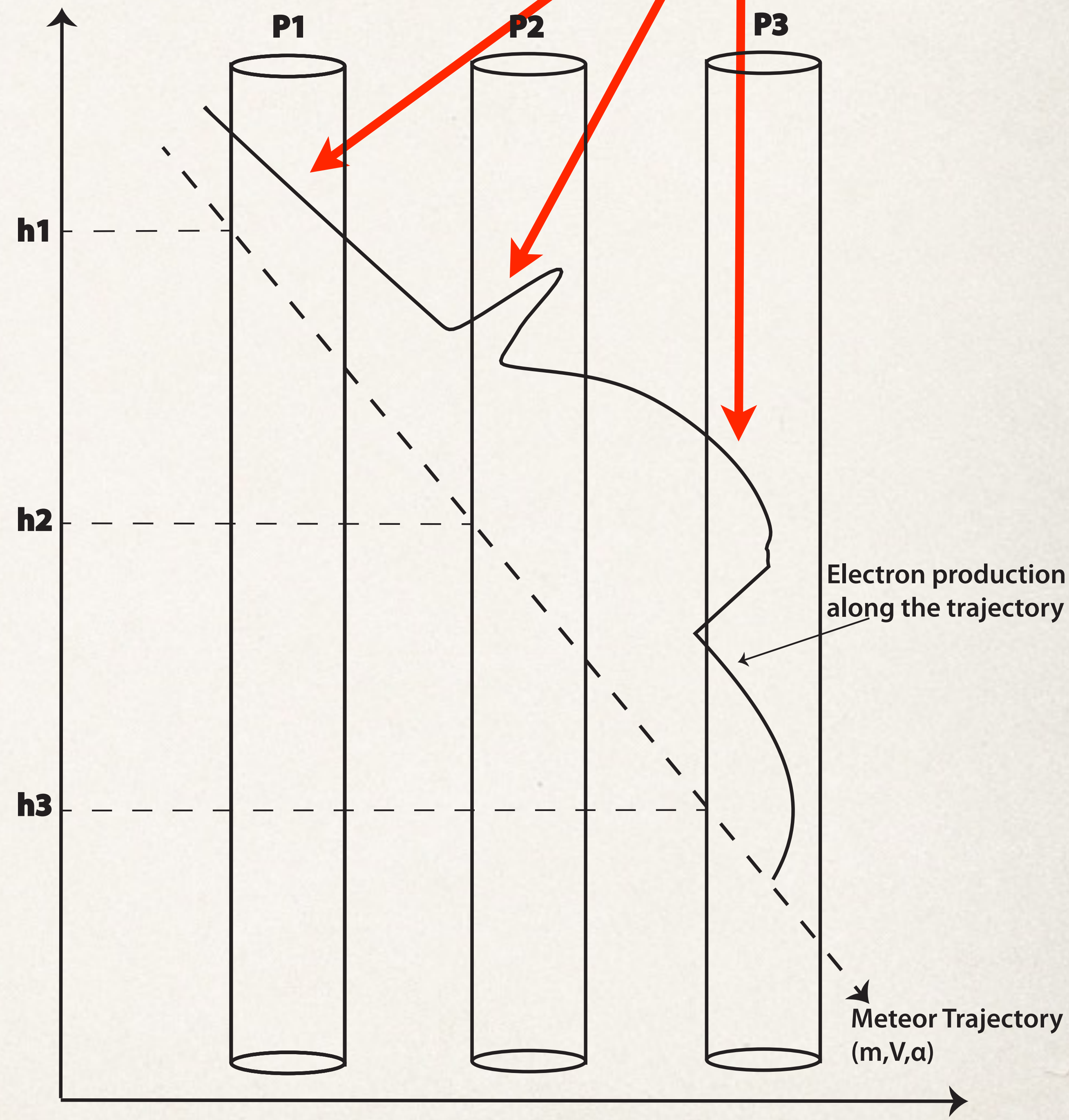
Meteor head-echo scattering cross-section

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

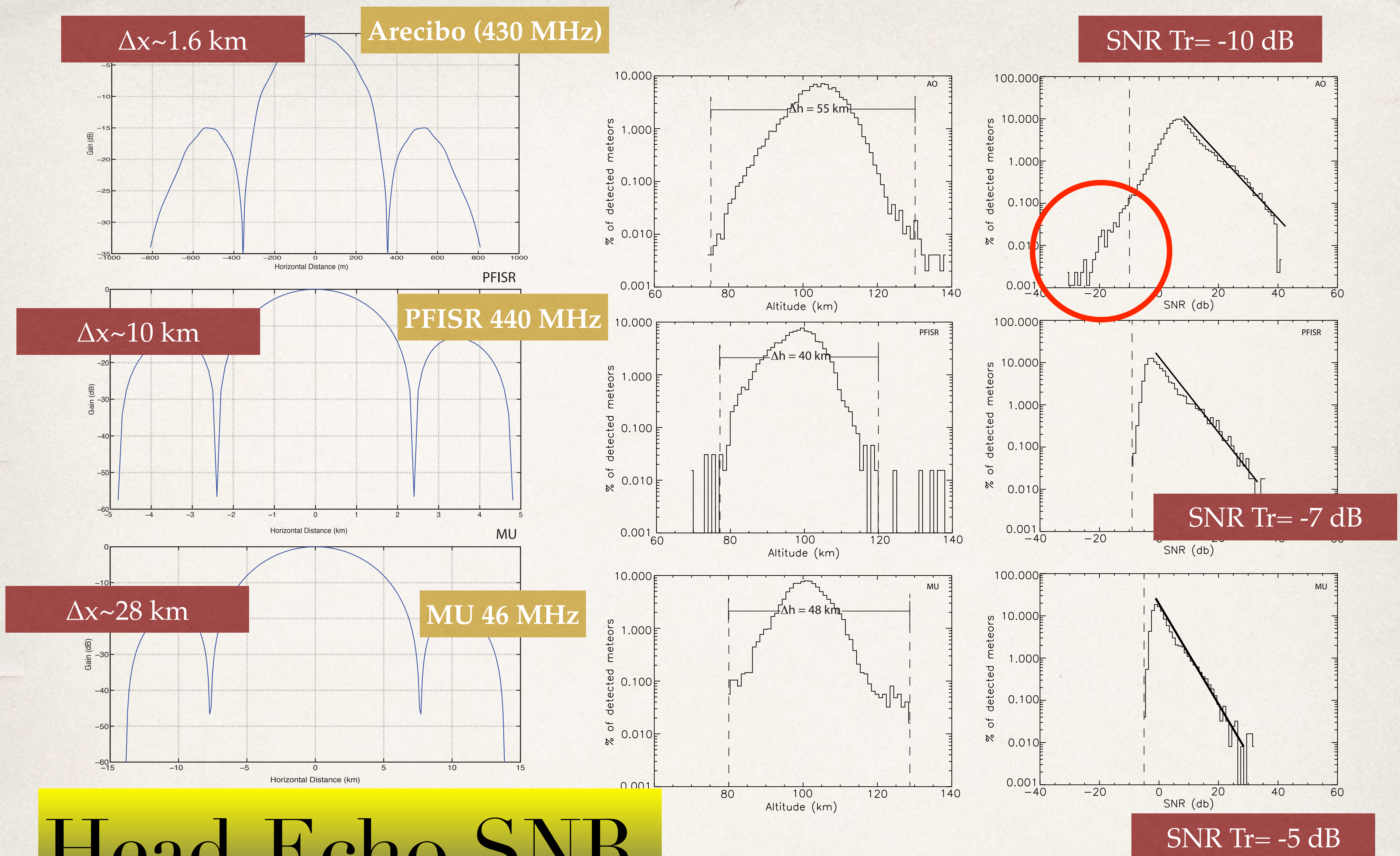


Meteor head-echo detected SNR

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



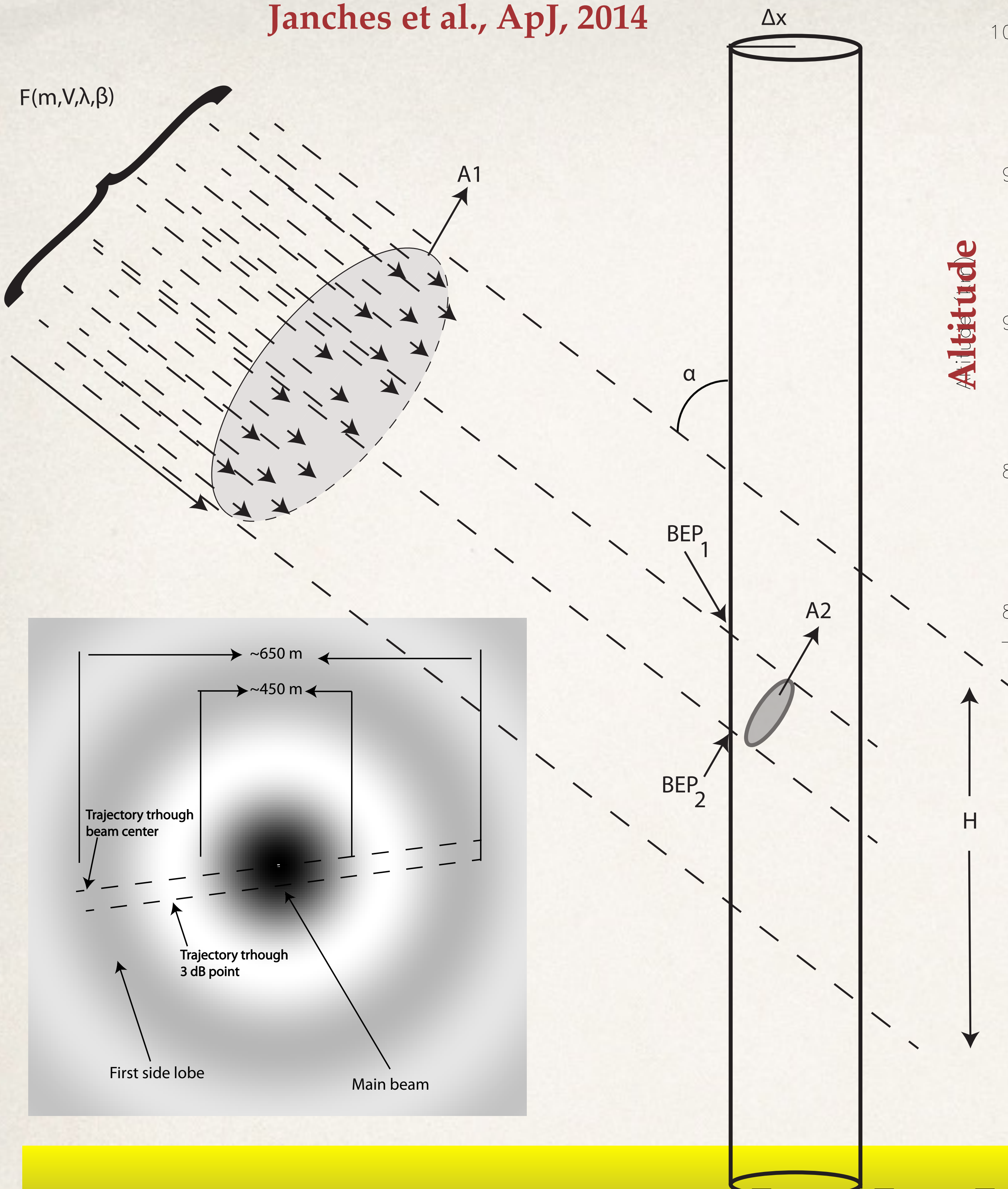
Head-Echo SNR

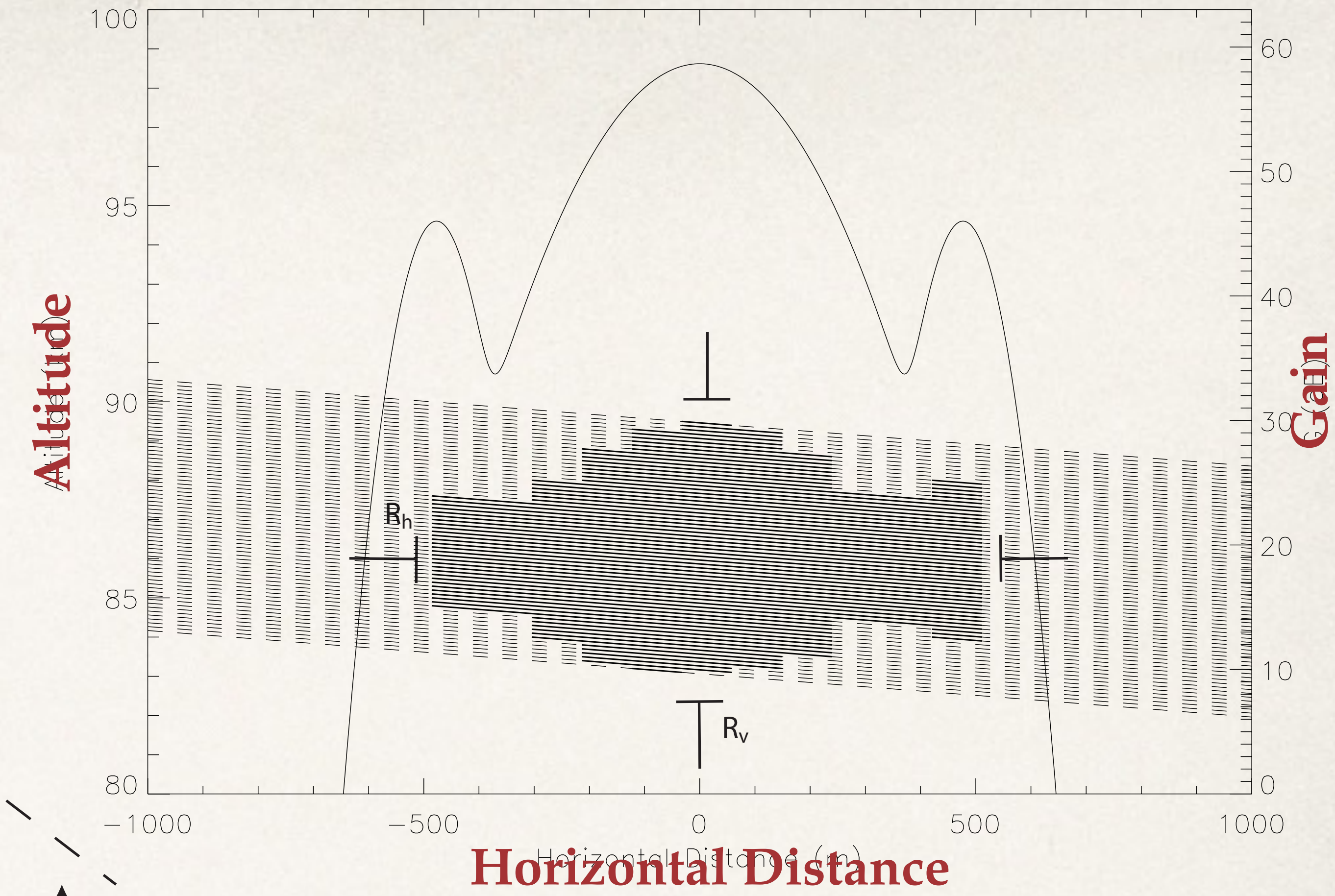


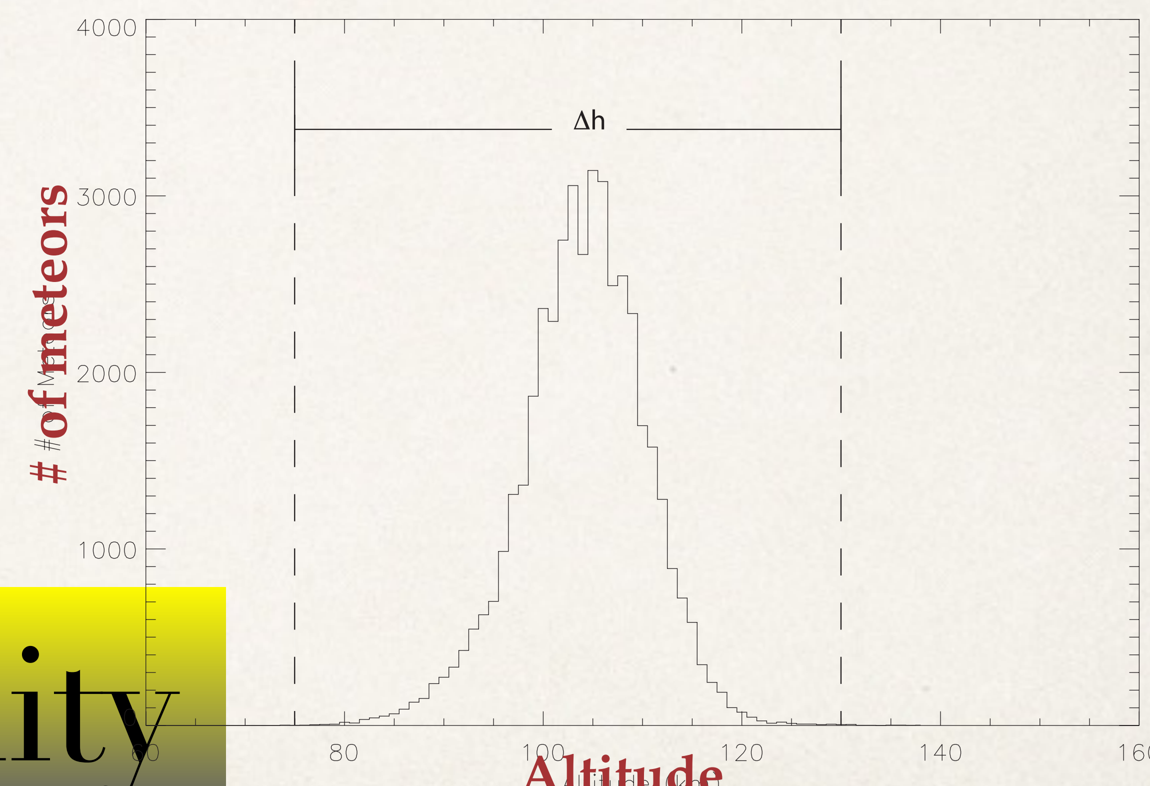
Head-Echo SNR

Janches et al., ApJ, 2015

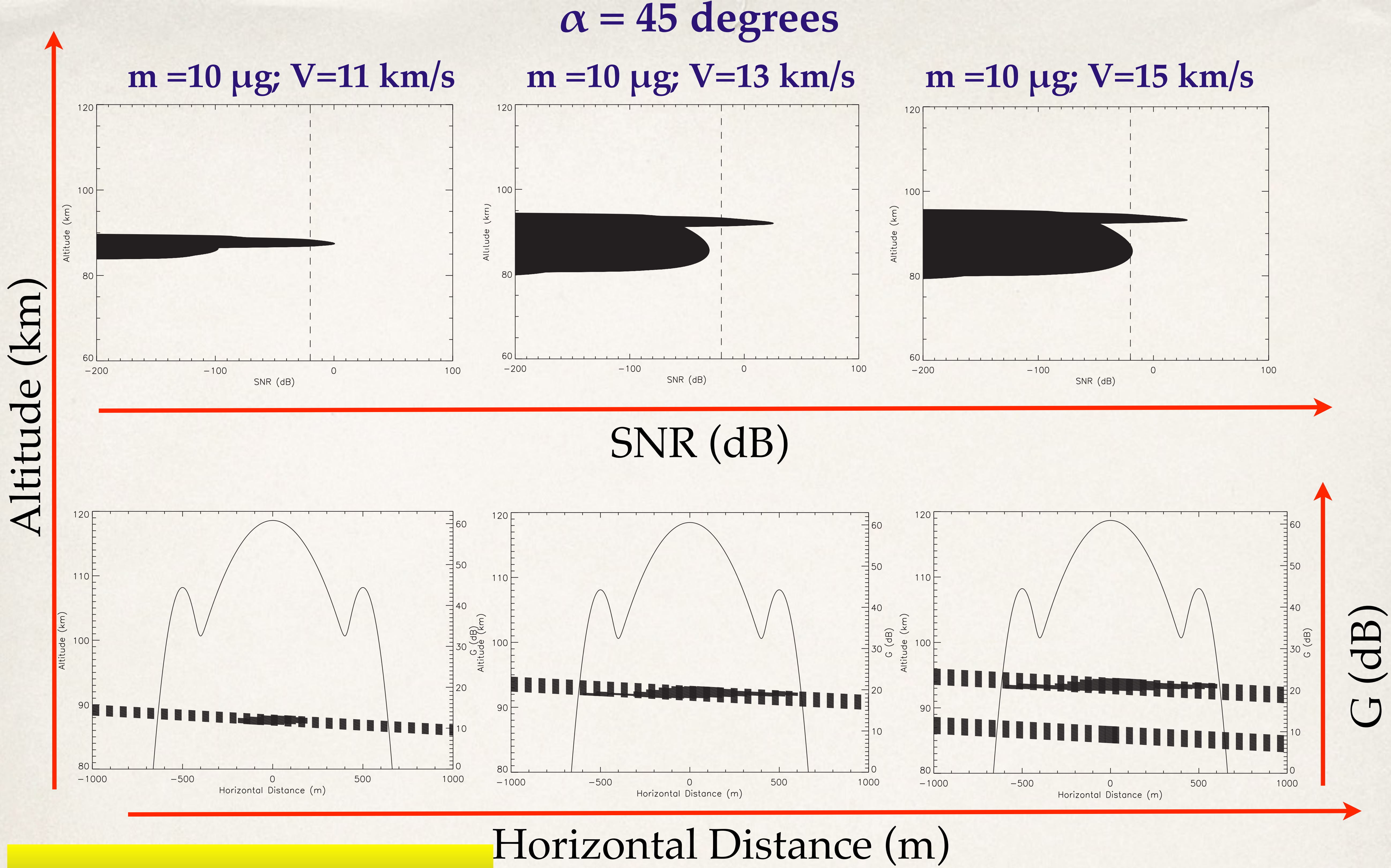
Janches et al., ApJ, 2014





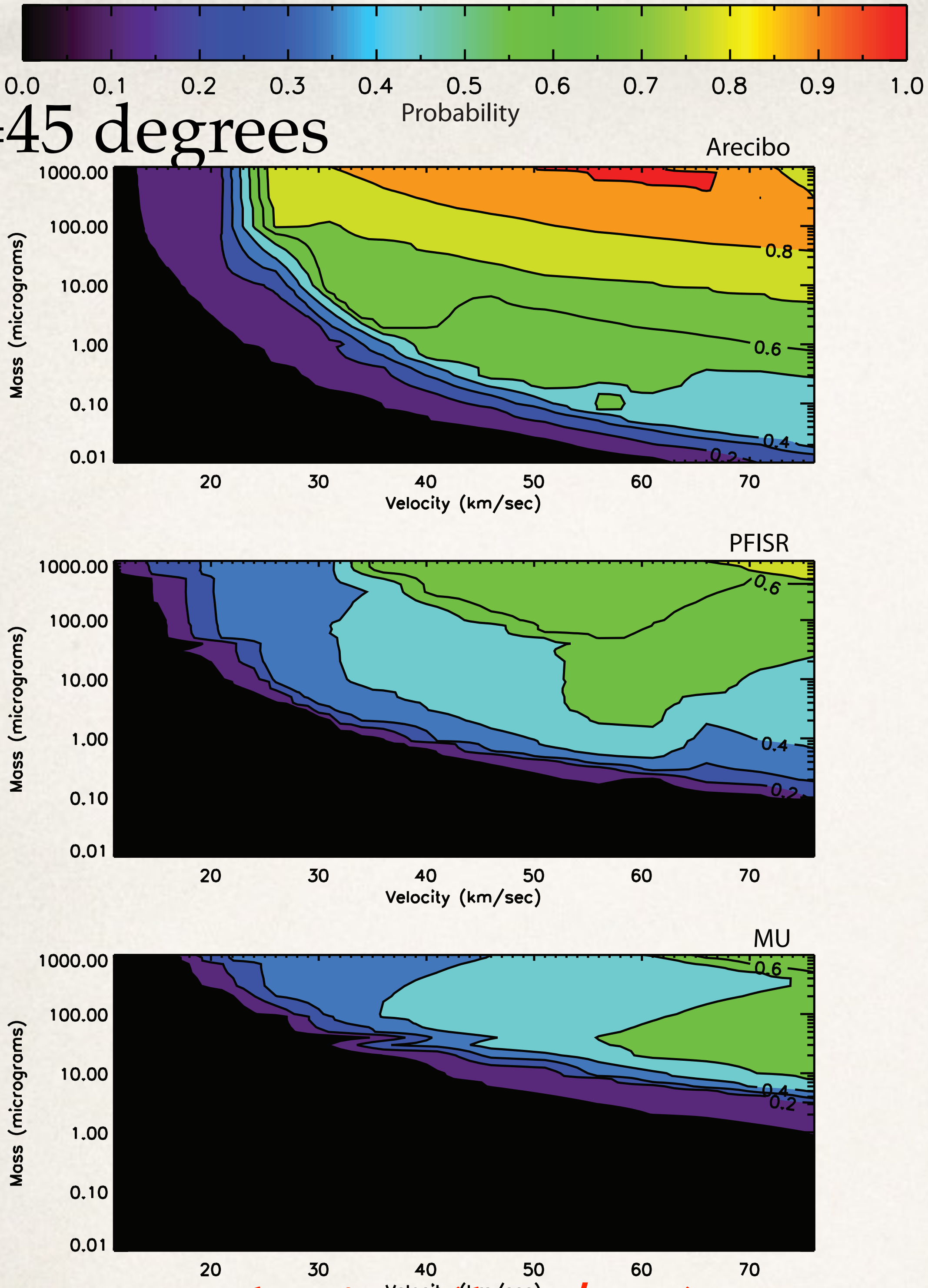


Detection Probability


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

SNR Results

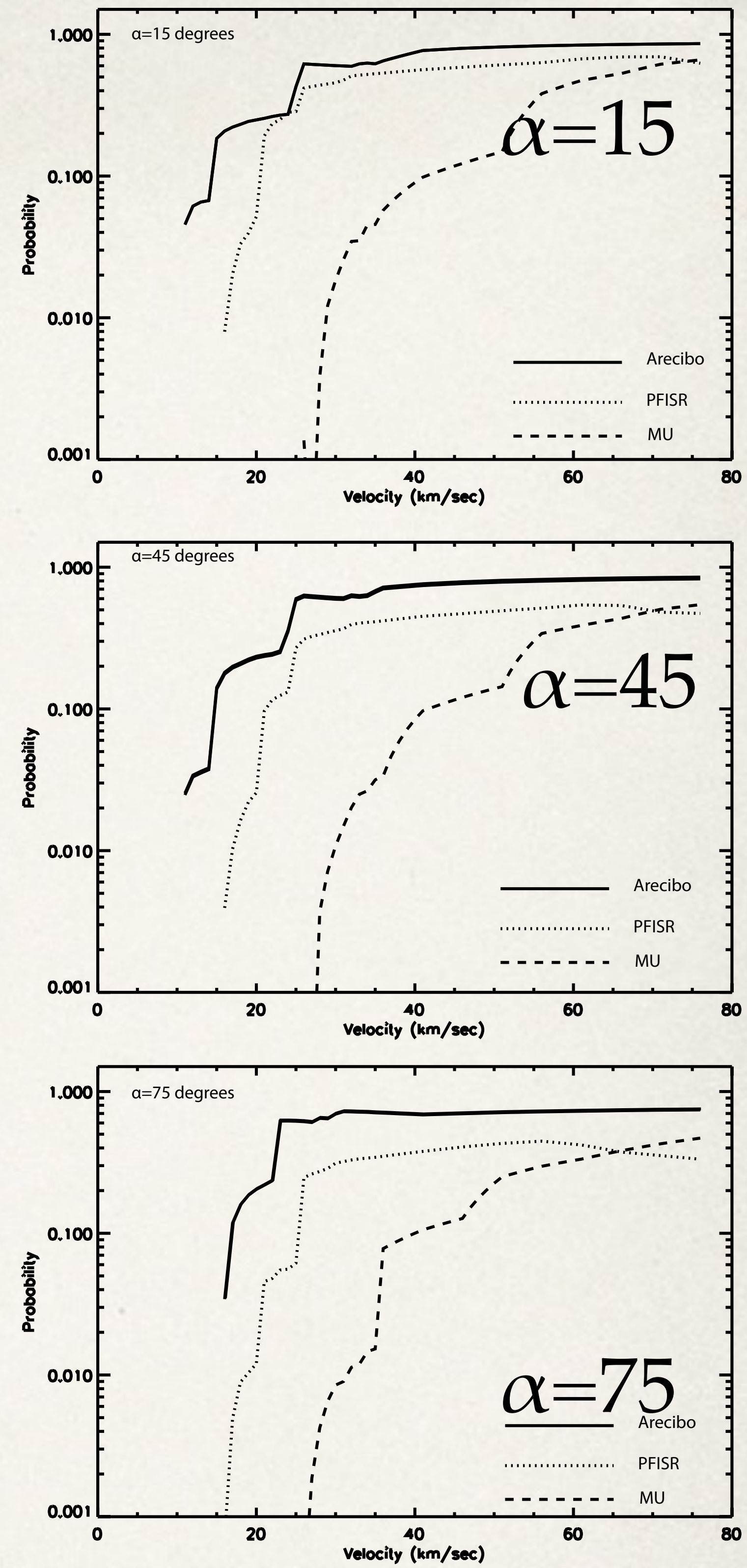
α=45 degrees



Mass (μg)

Velocity (km/sec)

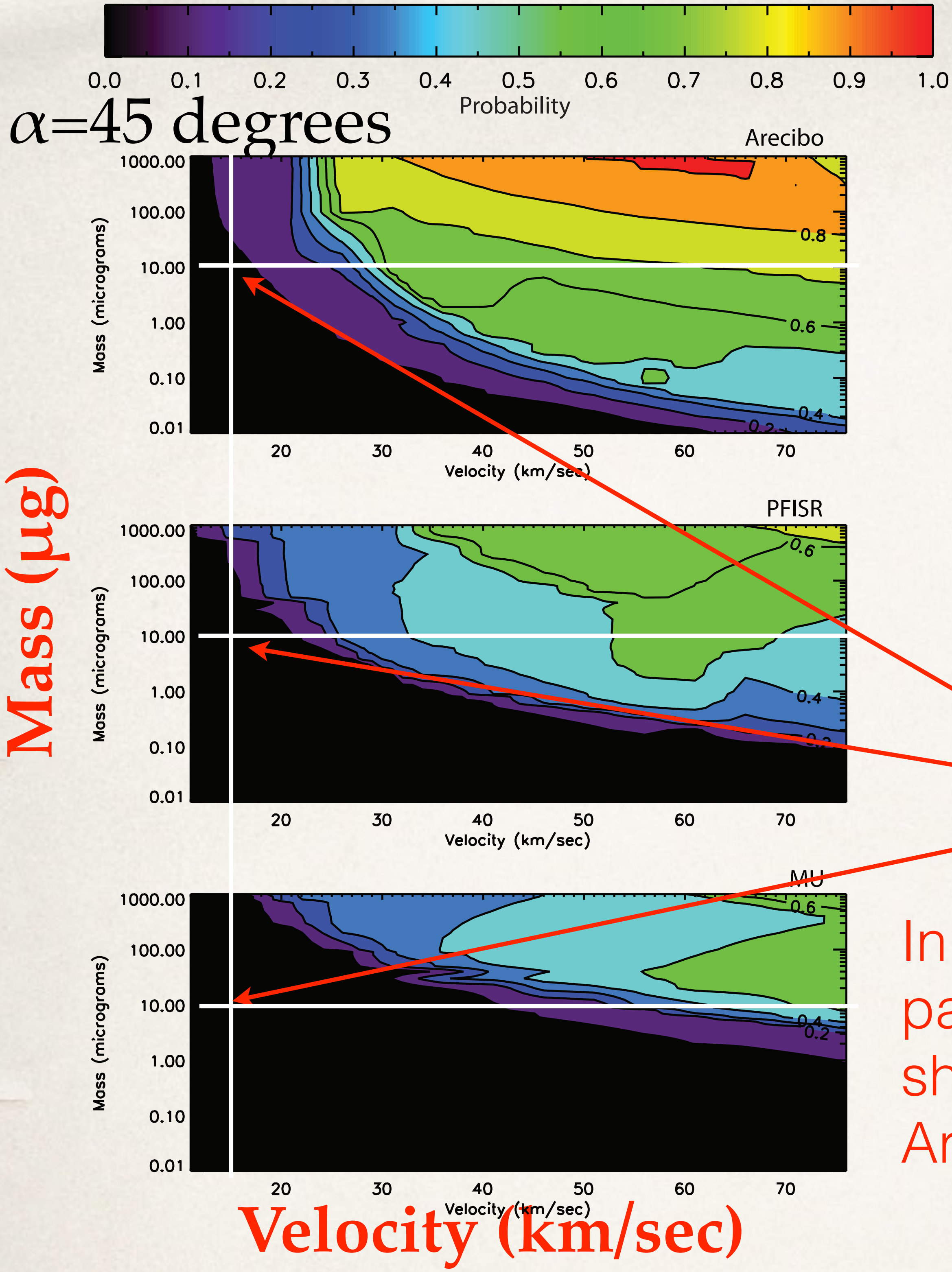
Probability



Velocity (km/sec)

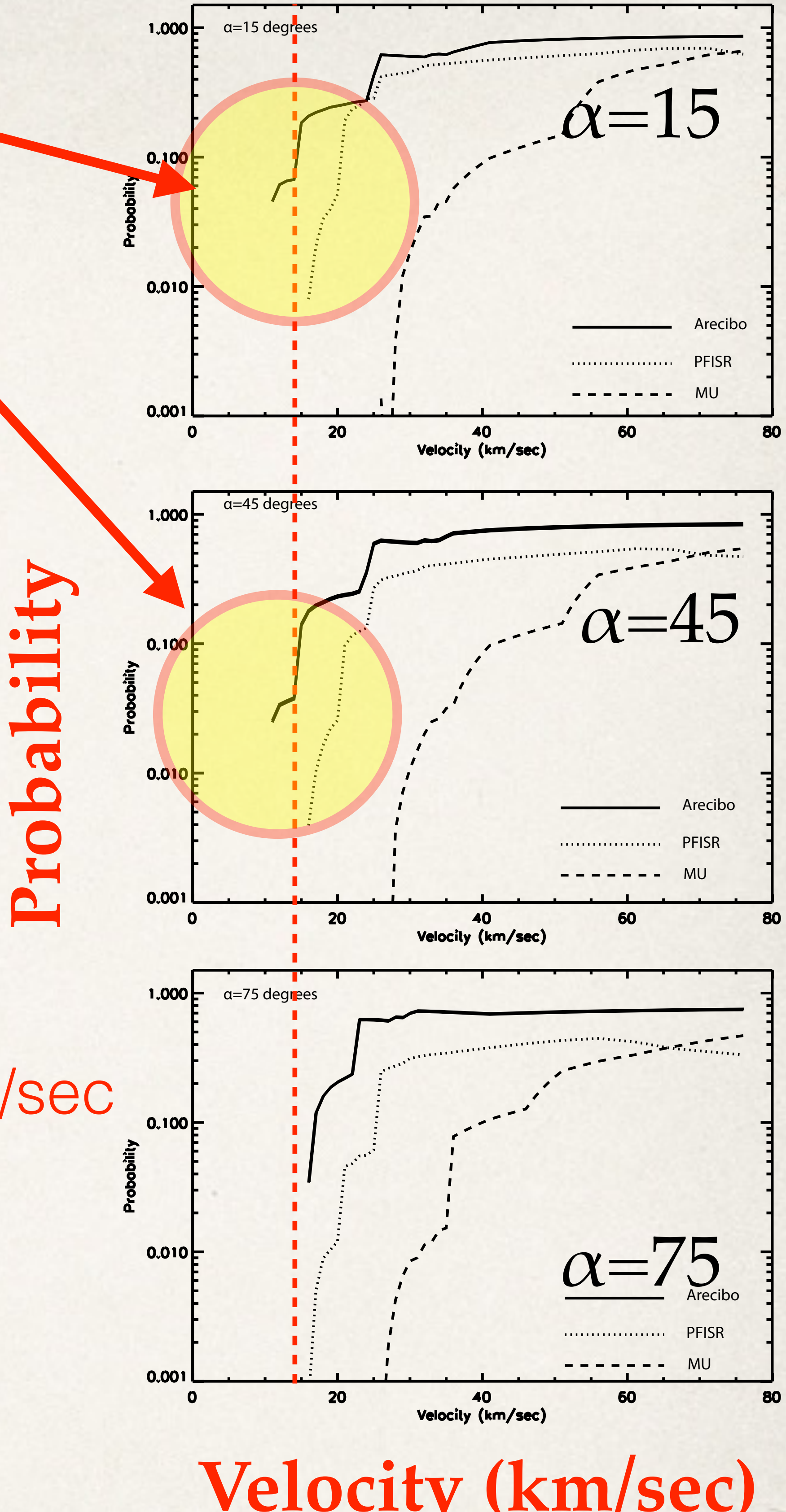
$P(\alpha, m, V)$

Janches et al., ApJ, 2015



V = 14 km/sec

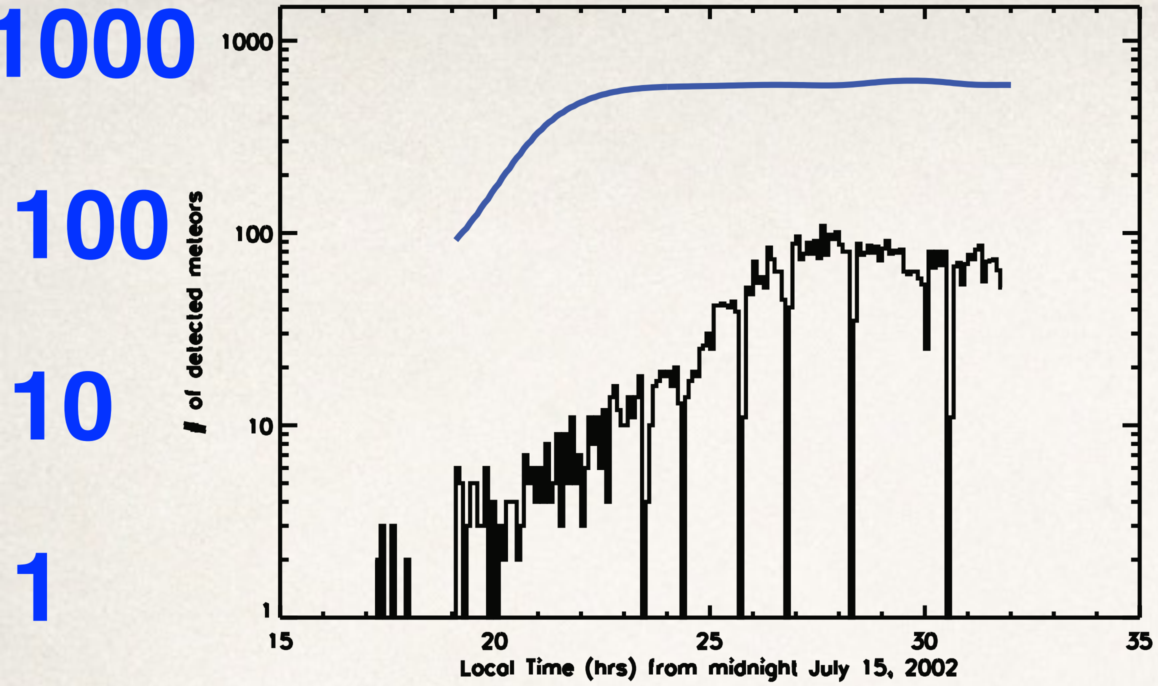
P<1%



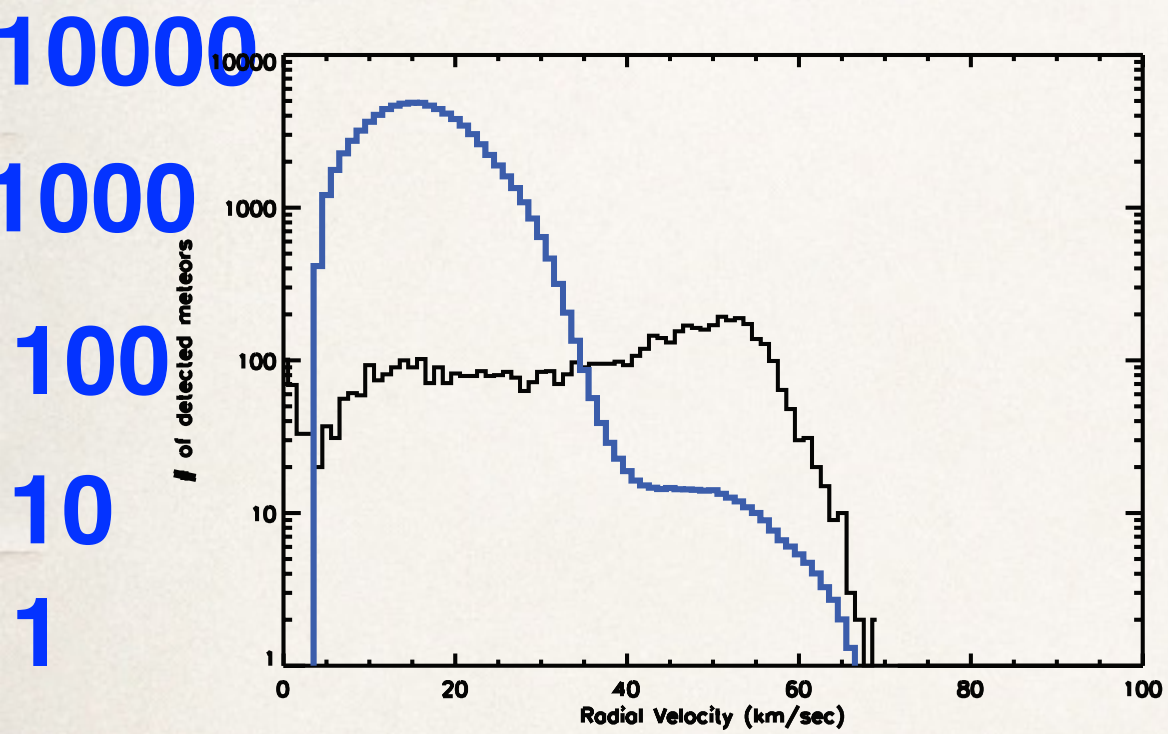
In principle a 10 μg particle with V = 14 km/sec should be detected by Arecibo

$P(\alpha,m,V)$

Janches et al., ApJ, 2015

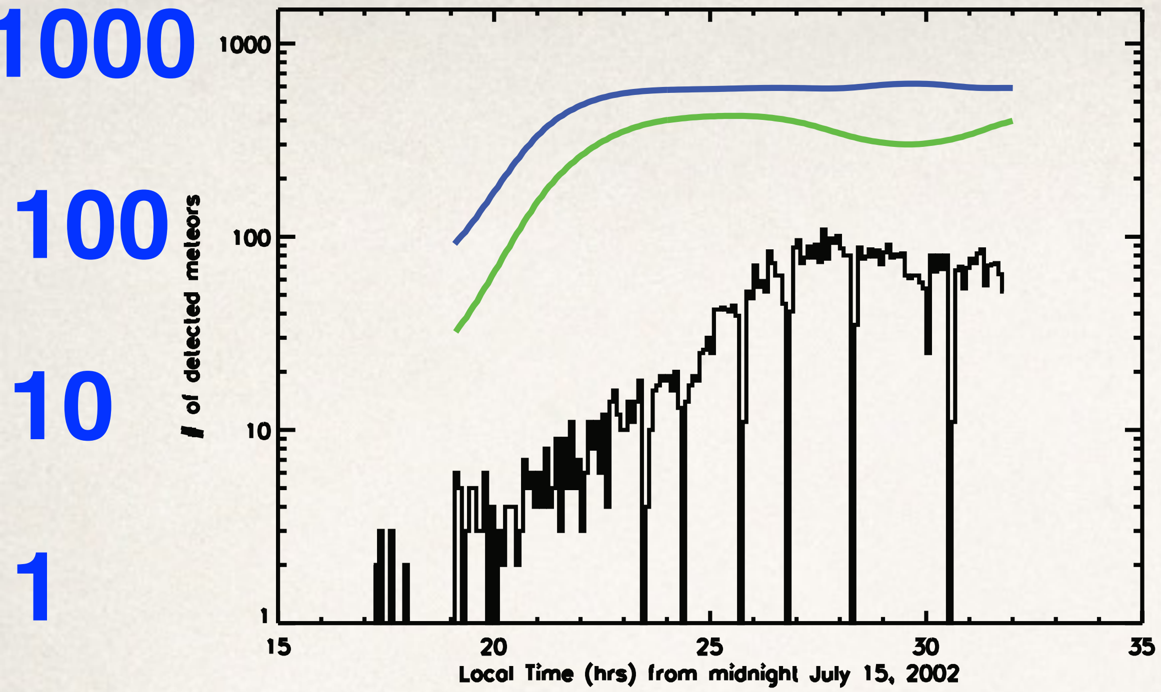


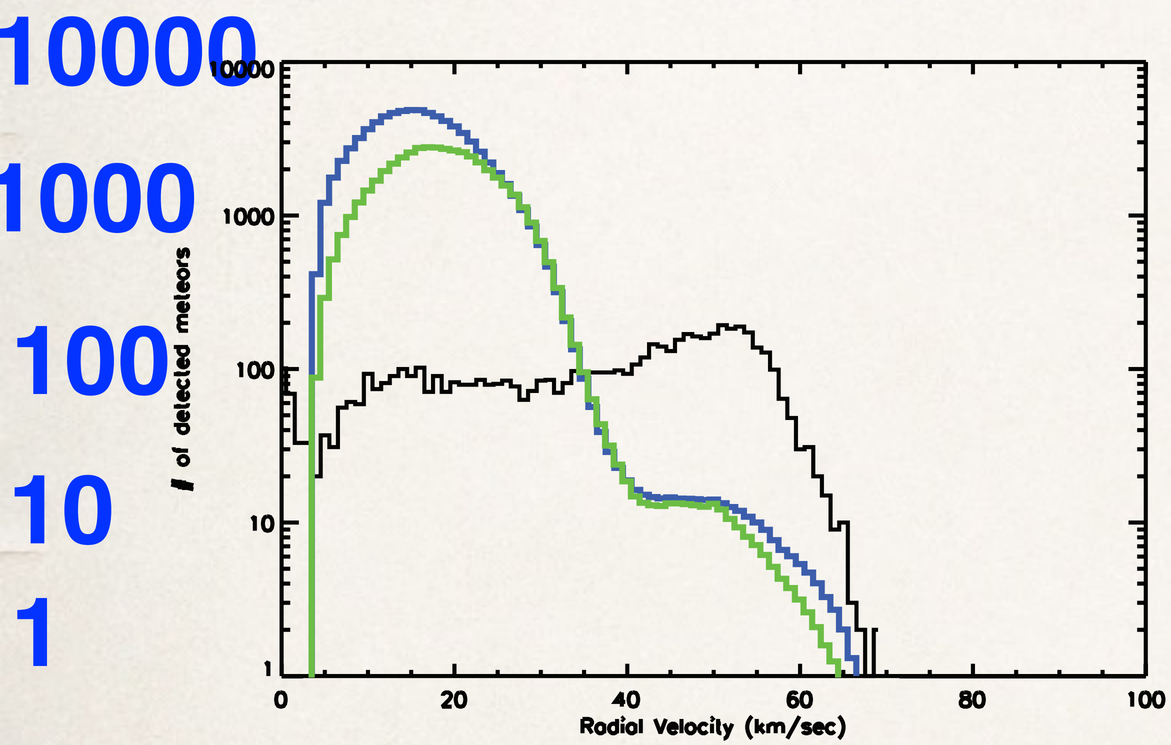
Original JFC (Nesvorny et al., 2010, Janches et al., 2014, 2015)



Results: JFC dilemma

HSD





Original JFC (Nesvorny et al., 2010, Janches et al., 2014) - mean size ~ 100 microns

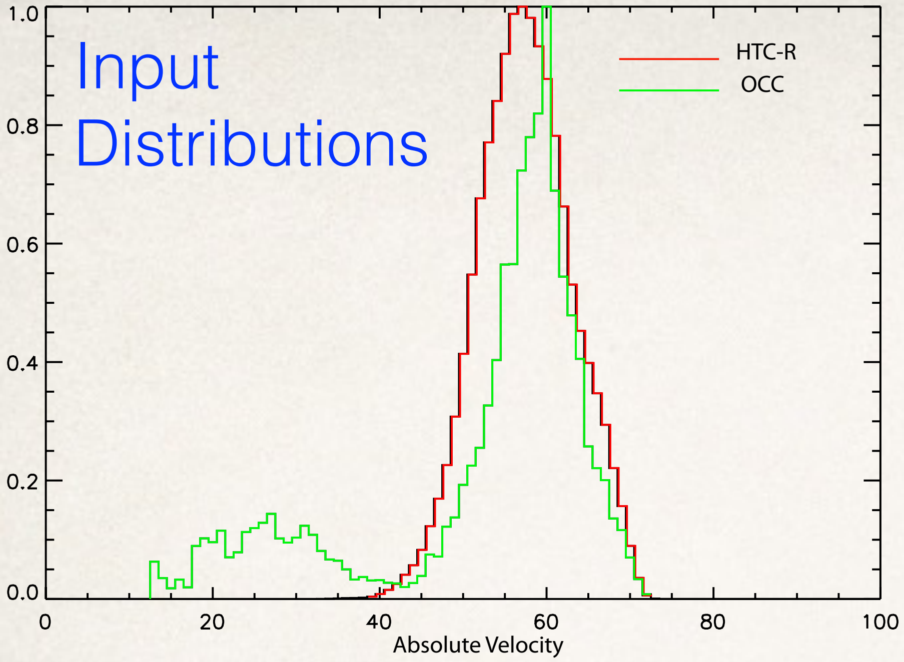
Planck JFC (Ade et al., 2014; Janches et al., 2015) mean size ~ 30 microns

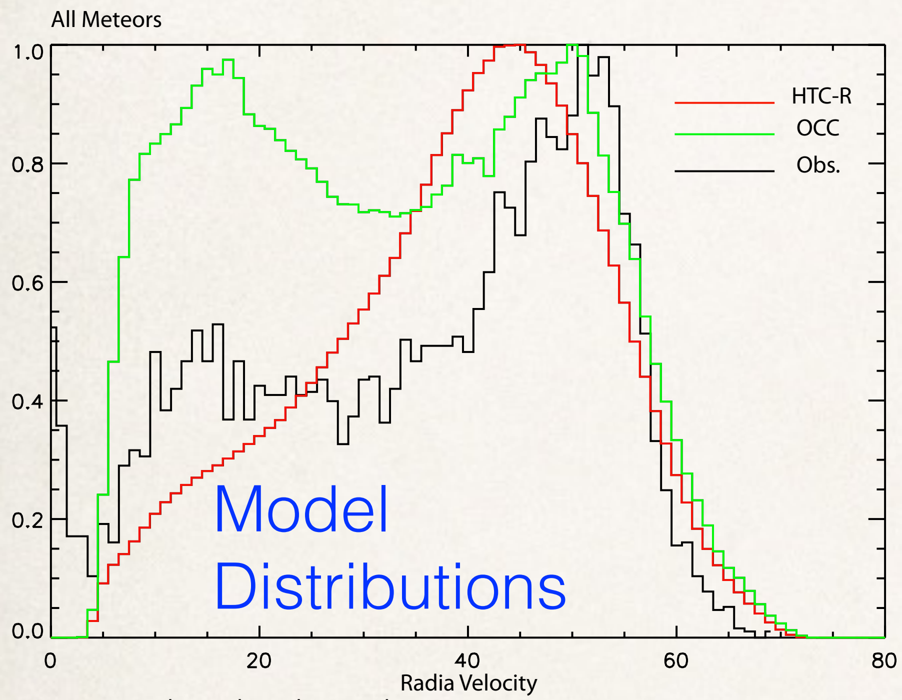
Also investigated the effect of:

1) β (Janches et al., 2014; 2015) - 1-2 order of magnitude required to make a difference - Thomas et al., (2016) shows β is close to Jones 1997 values **(see Sternovsky's talk)**

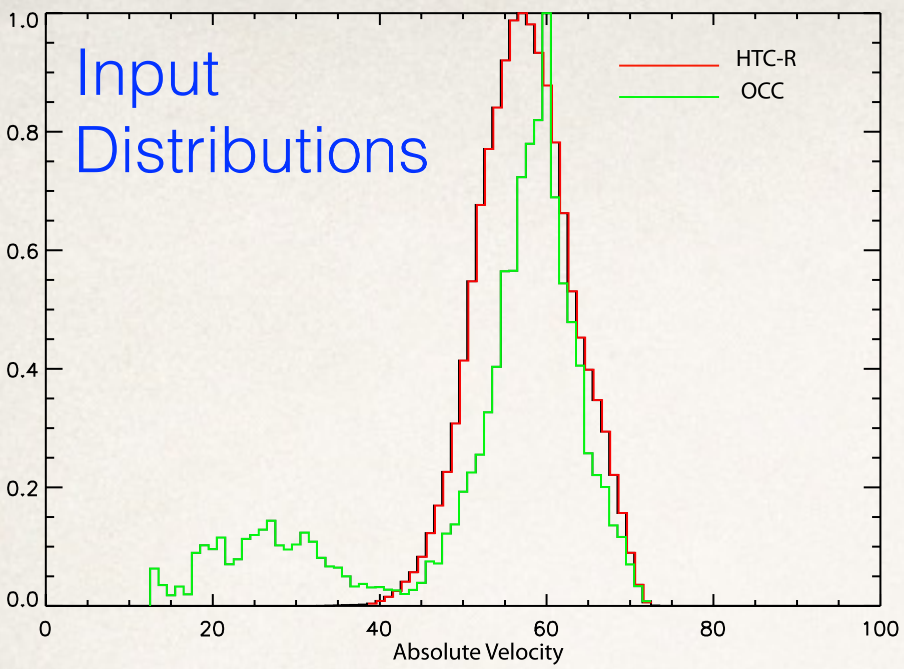
2) New laboratory measurements of differential ablation **(See Plane's talk)** showed that at slow velocity Na and K may ablate over a longer range but at a smaller intensity. However, changes on electron production and SNR are a factor of 2 (no the order of magnitude required)

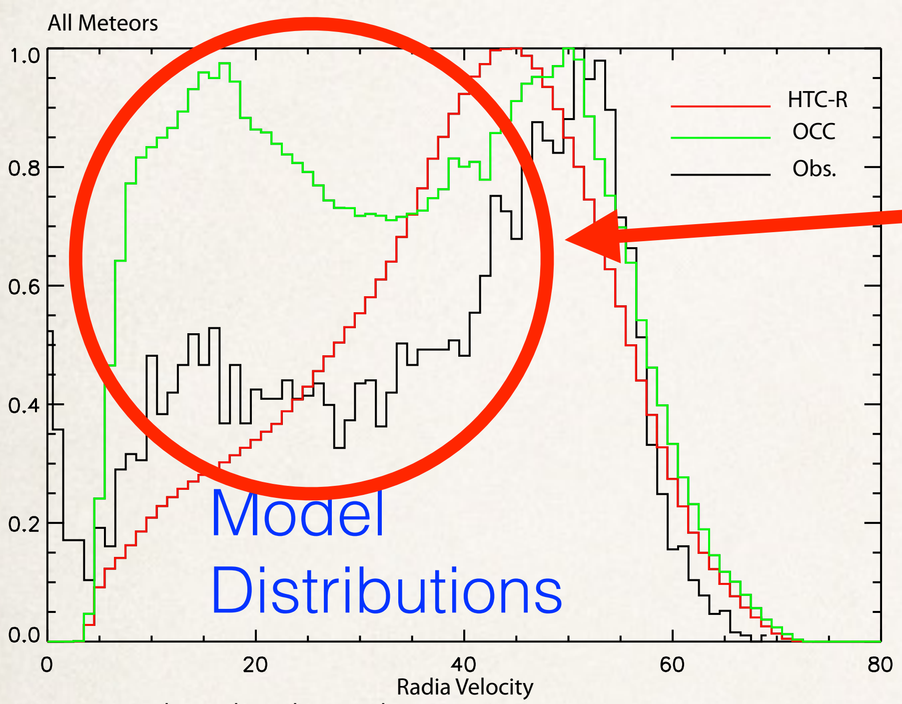
Results: JFC dilemma





Results: HTC & OCC

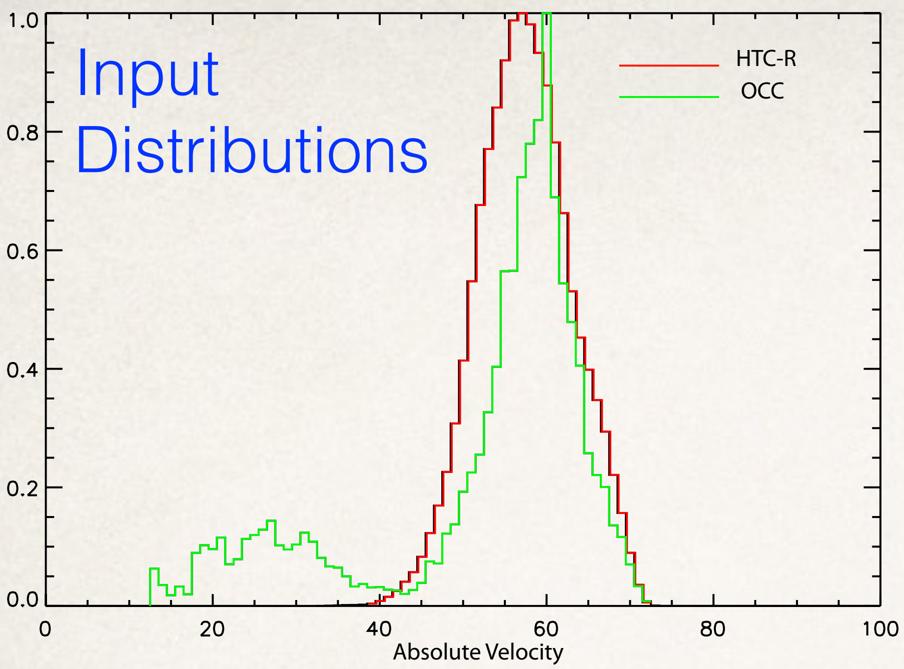


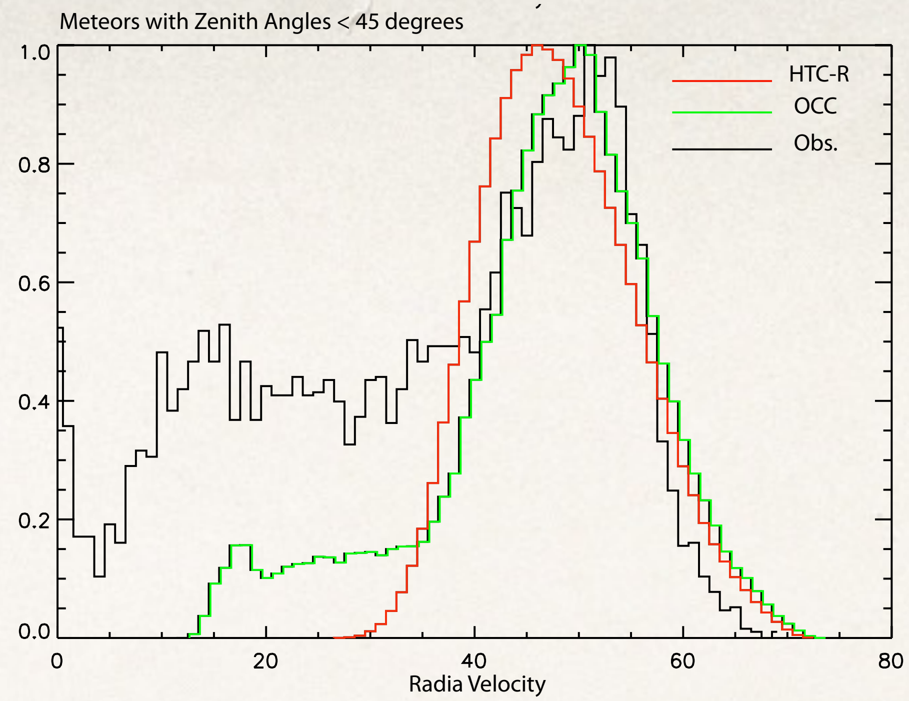


Over prediction of the detection of meteor entering at shallow angles

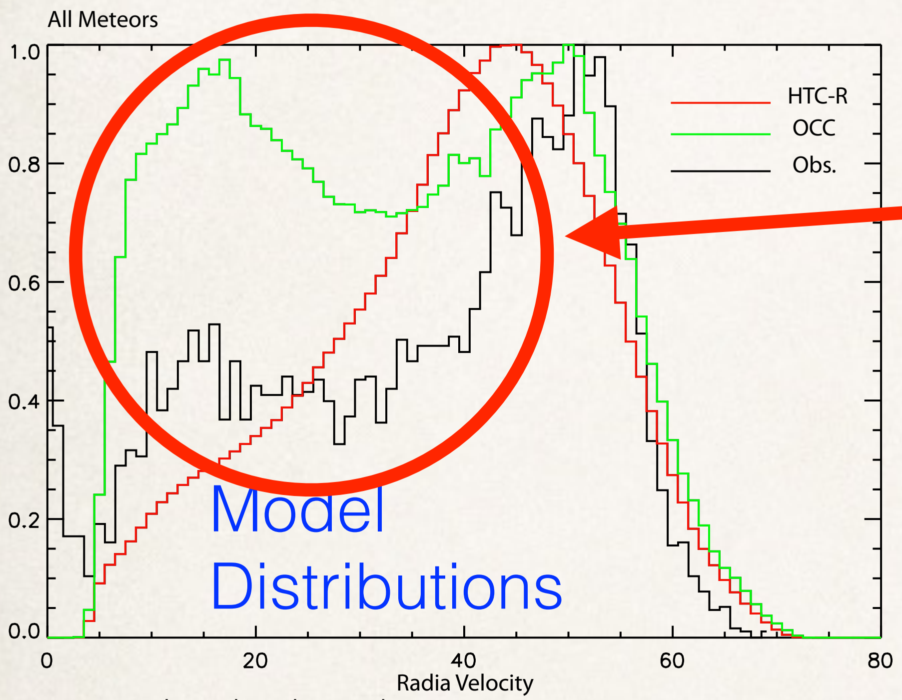
Results: HTC & OCC

Results: HTC & OCC



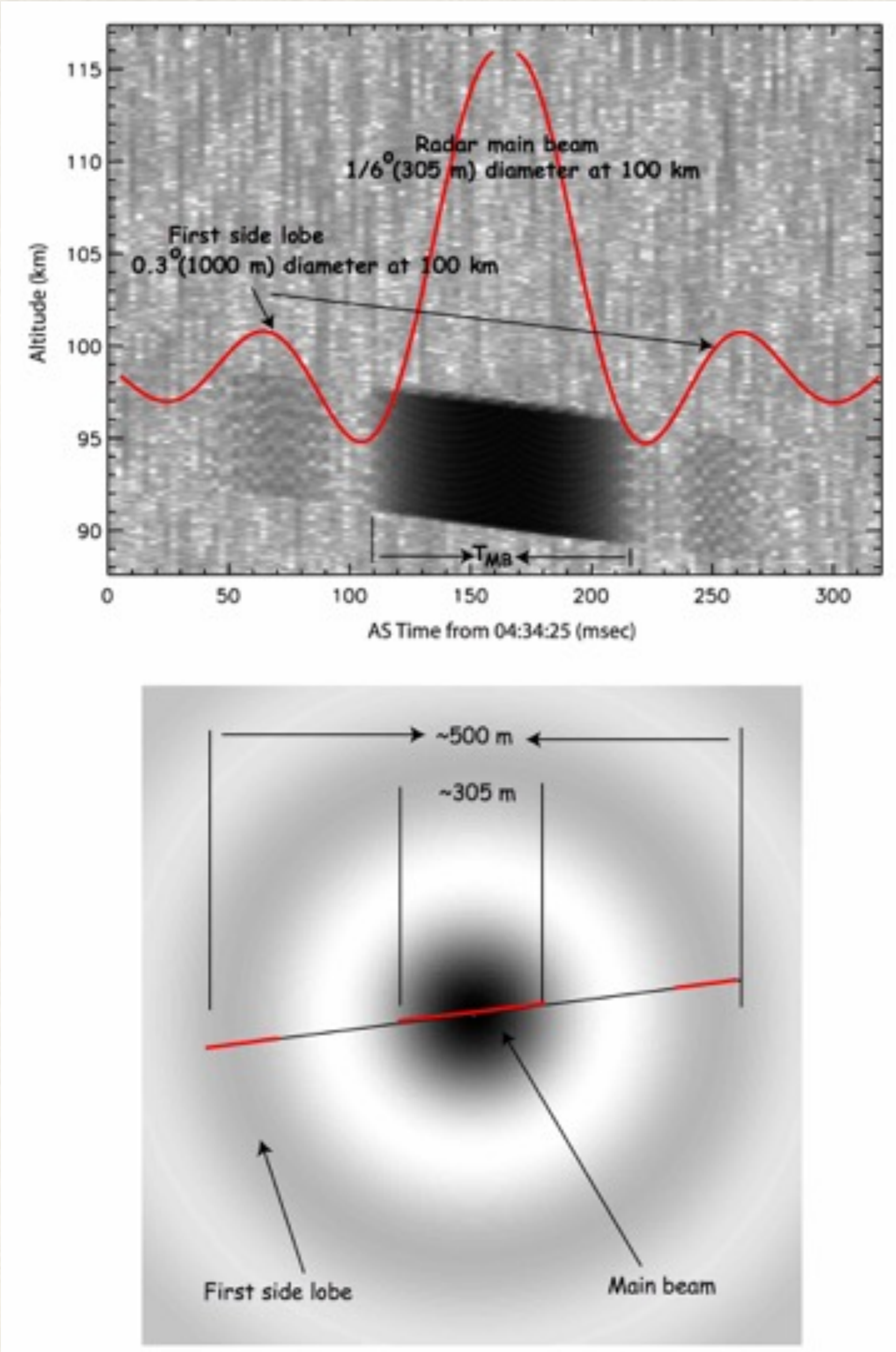


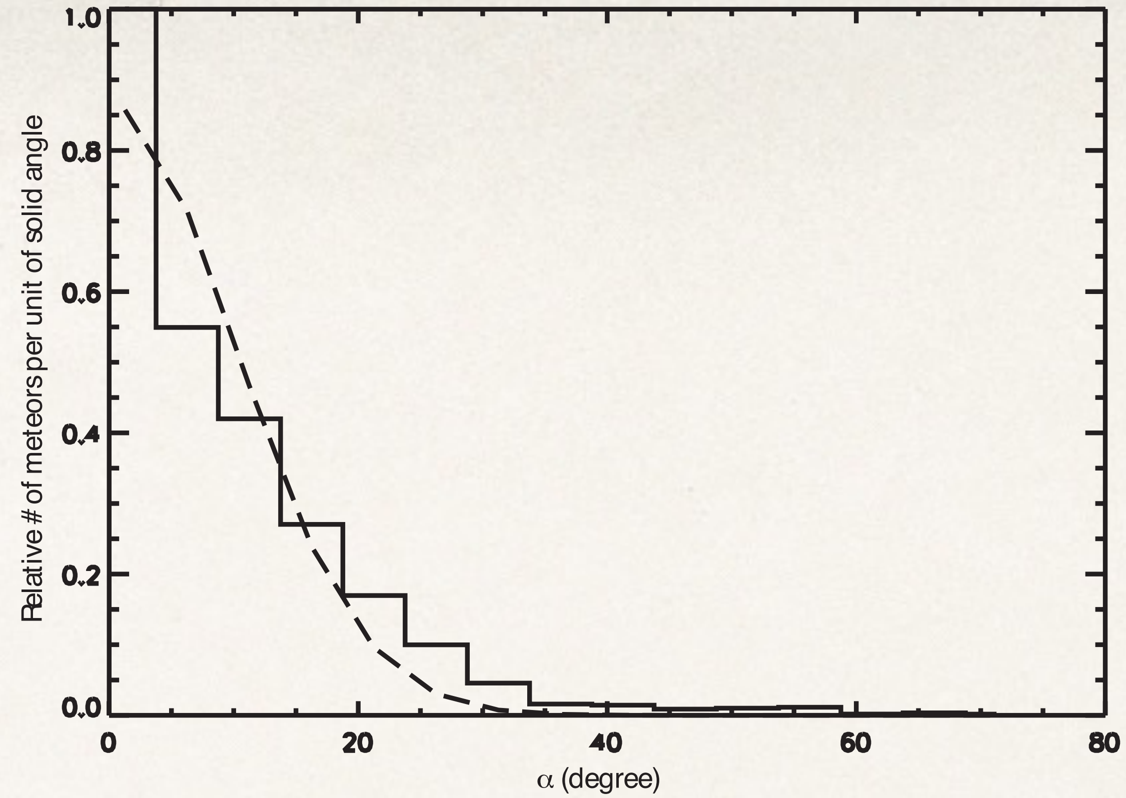
Model Distributions removing meteors with entry angles greater than 45 degrees



Over prediction of the detection of meteor entering at shallow angles

Conclusion: The results strongly suggest that there MUST be a 'preferred' directionality on the detection of meteor HE by HPLA radars





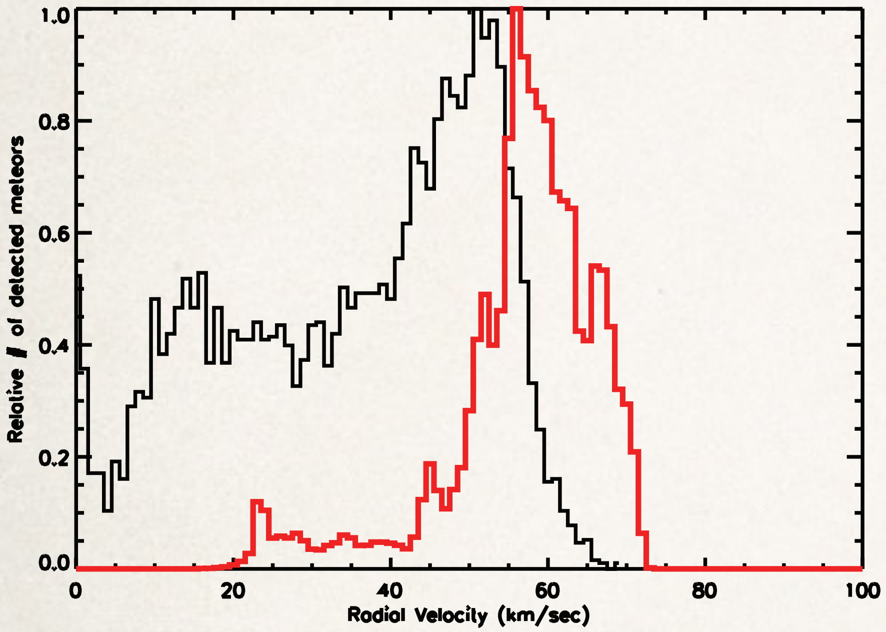
Janches et al., 2004 used a sub-sample of Arecibo detected meteor head echoes. The results suggested a 'down-the-beam' preferential directionality not he detections.

In other words: The HE is aspect sensitive with a Gaussian function describing the angular dependance.

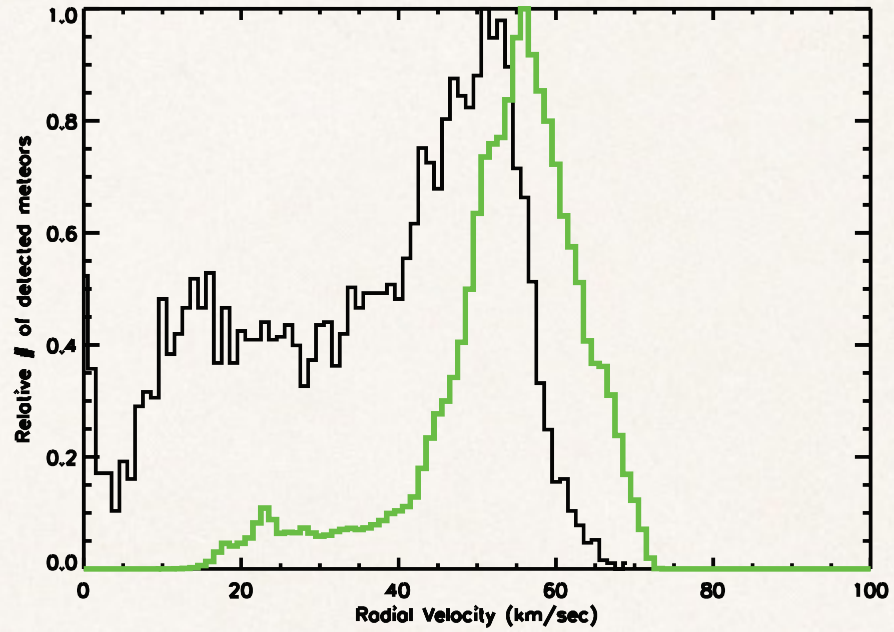
Results: HE Shape

Color curves = Modeled OCCs
Black Curves = Observations

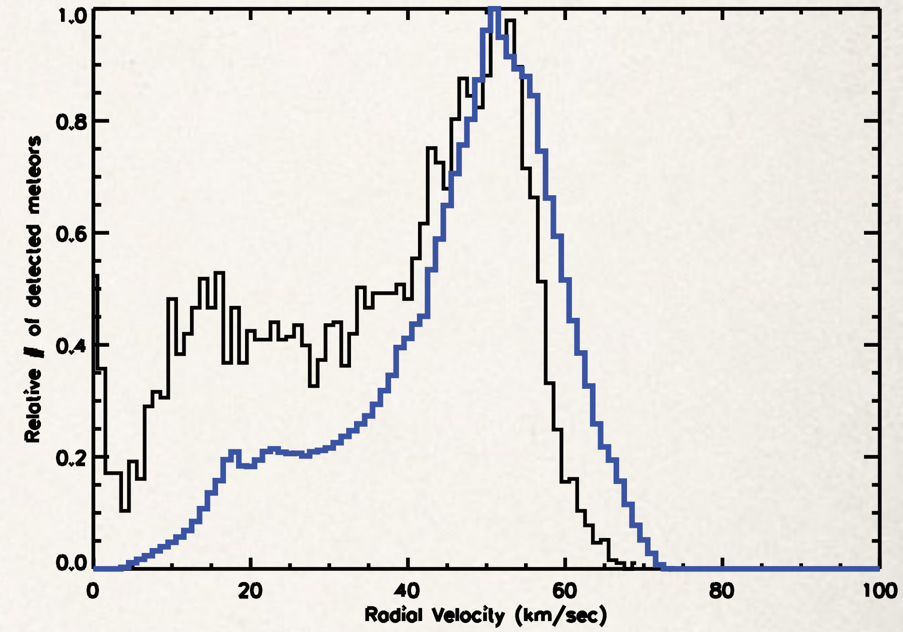
σ = 10 degrees



σ = 20 degrees



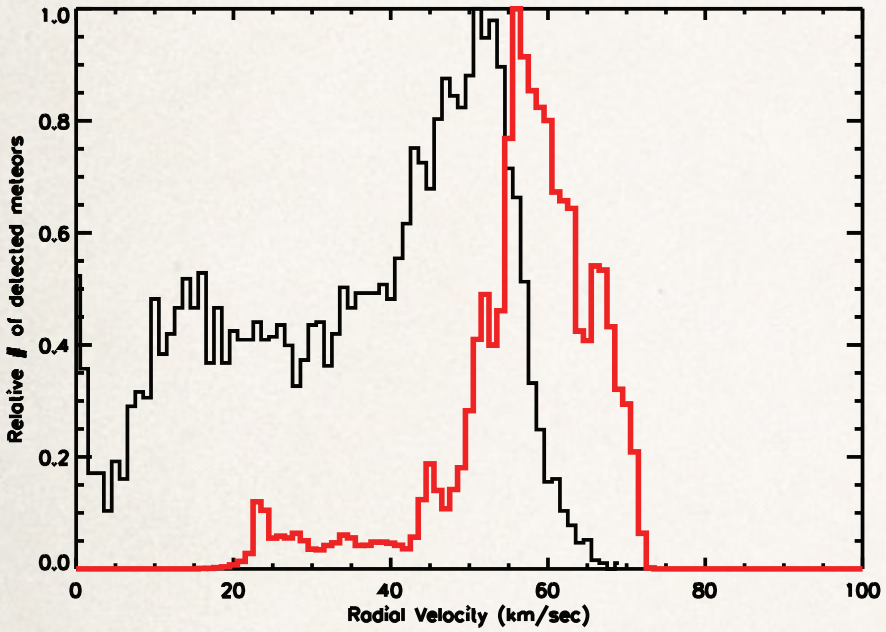
σ = 40 degrees



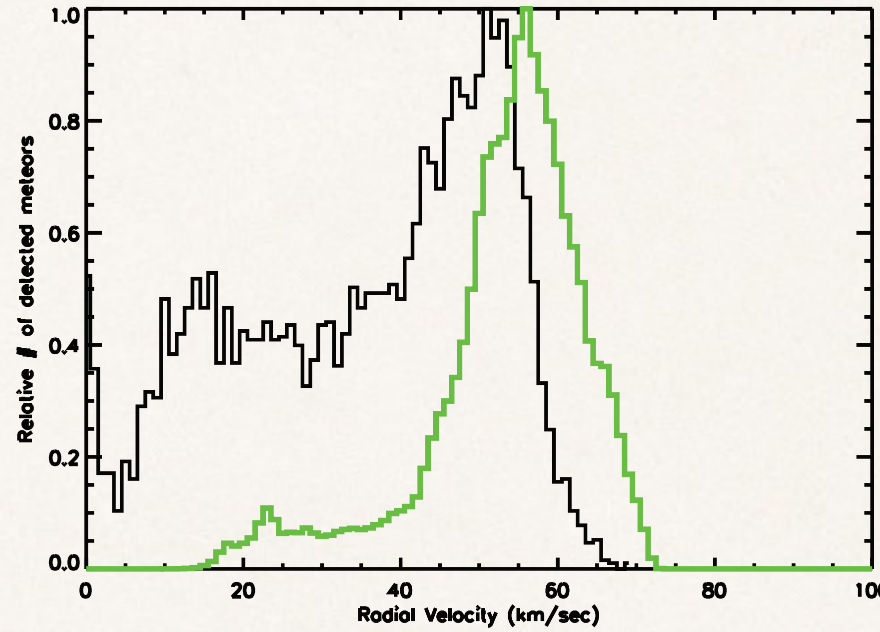
Results: HTC & OCC

Color curves = Modeled OCCs
Black Curves = Observations

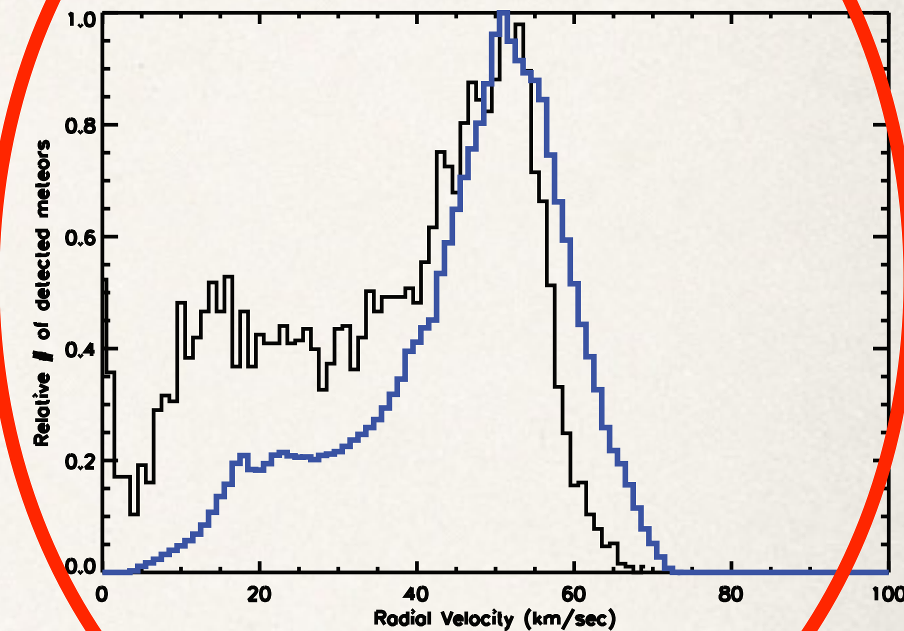
σ = 10 degrees



σ = 20 degrees



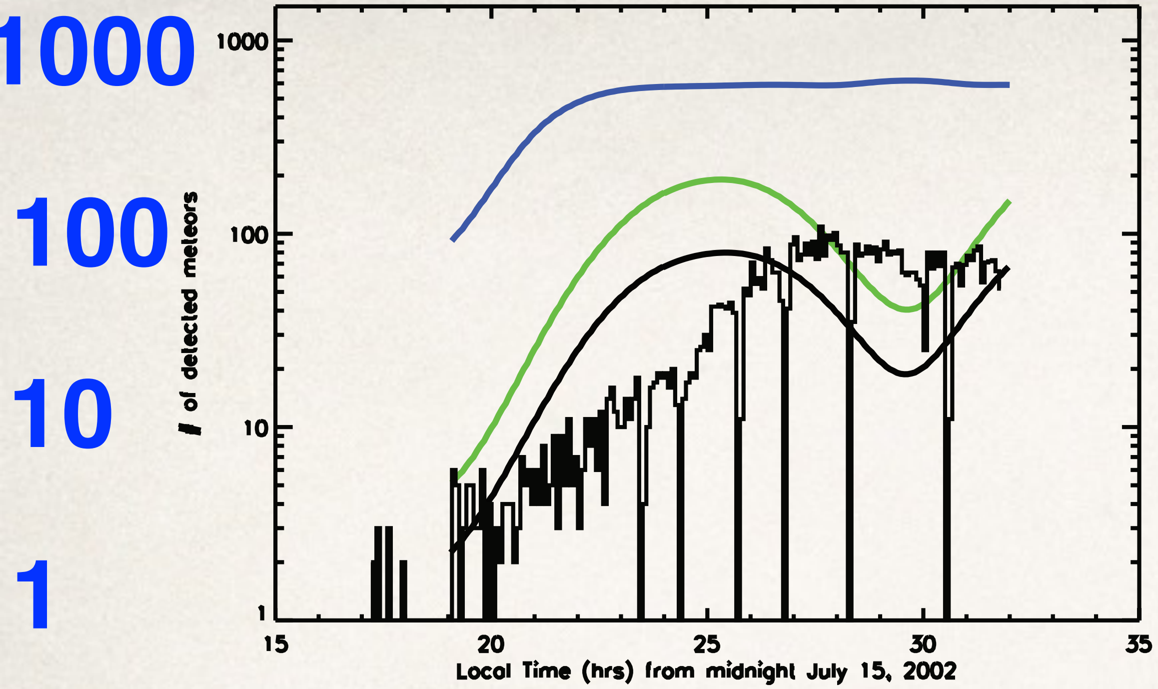
σ = 40 degrees



A HE described by a Gaussian distribution with σ = 40 degrees fit best the HTC-Retrograde and OCC to the Arecibo high velocity portion of the speed distributions

Results: HTC & OCC

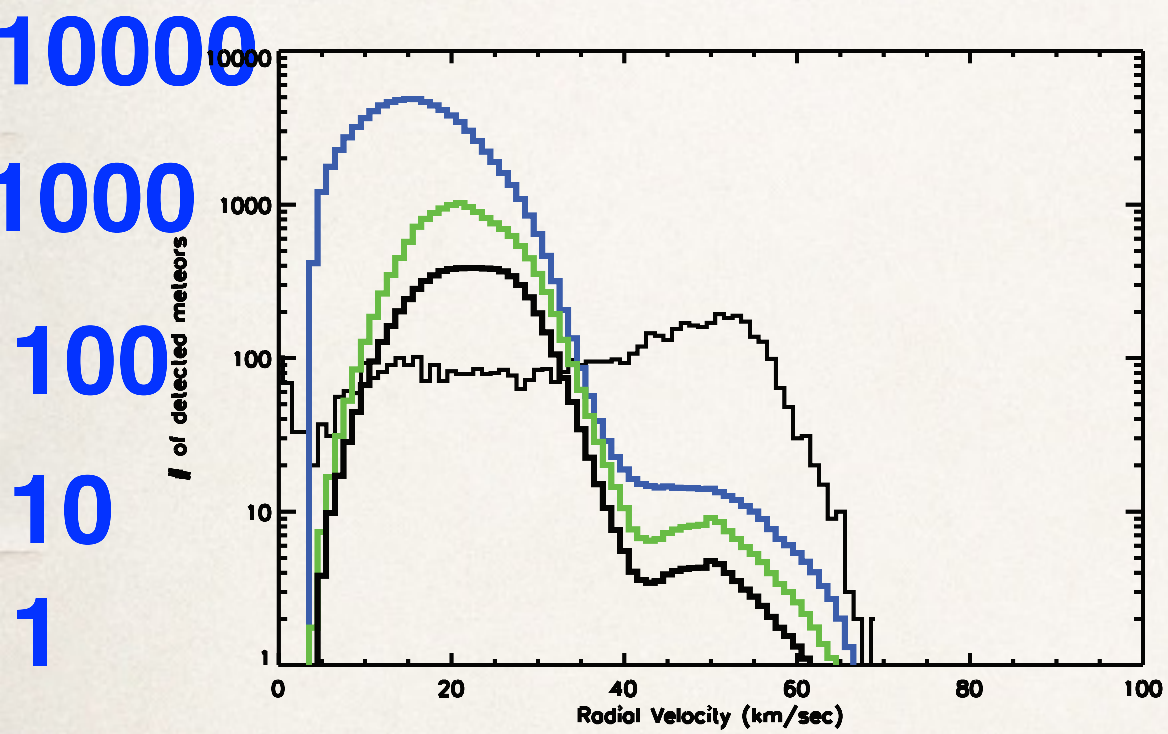
Results: HE Shape



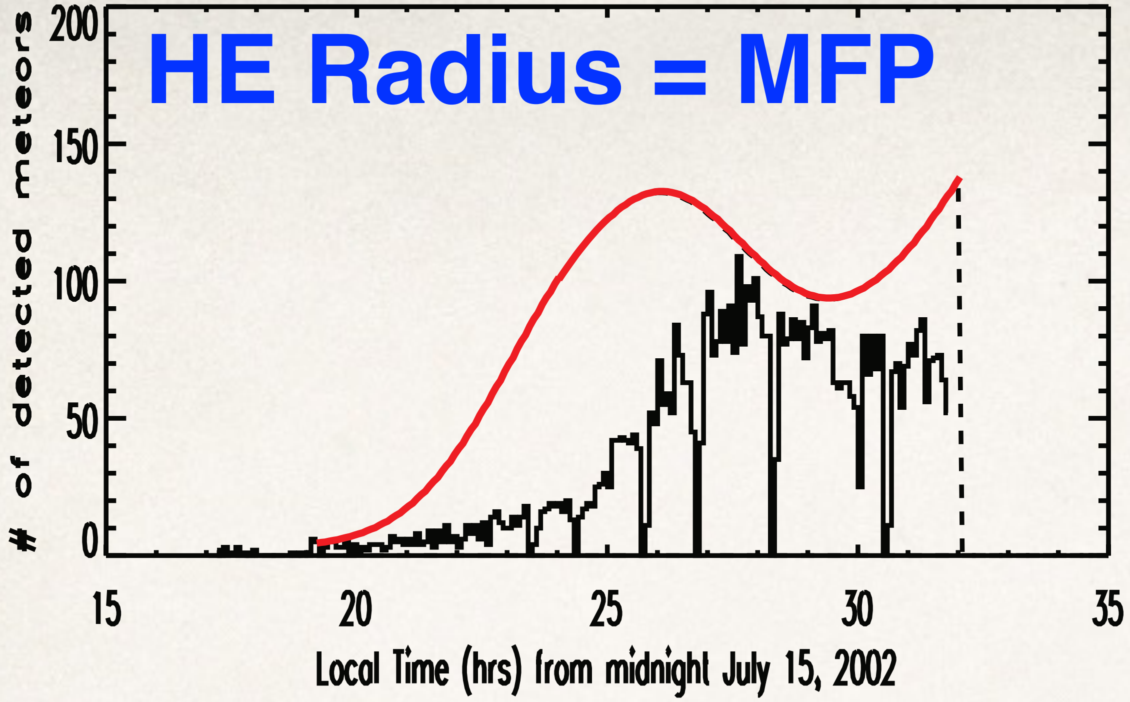
Original JFC (Nesvorny et al., 2010, Janches et al., 2014) - mean size ~ 100 microns

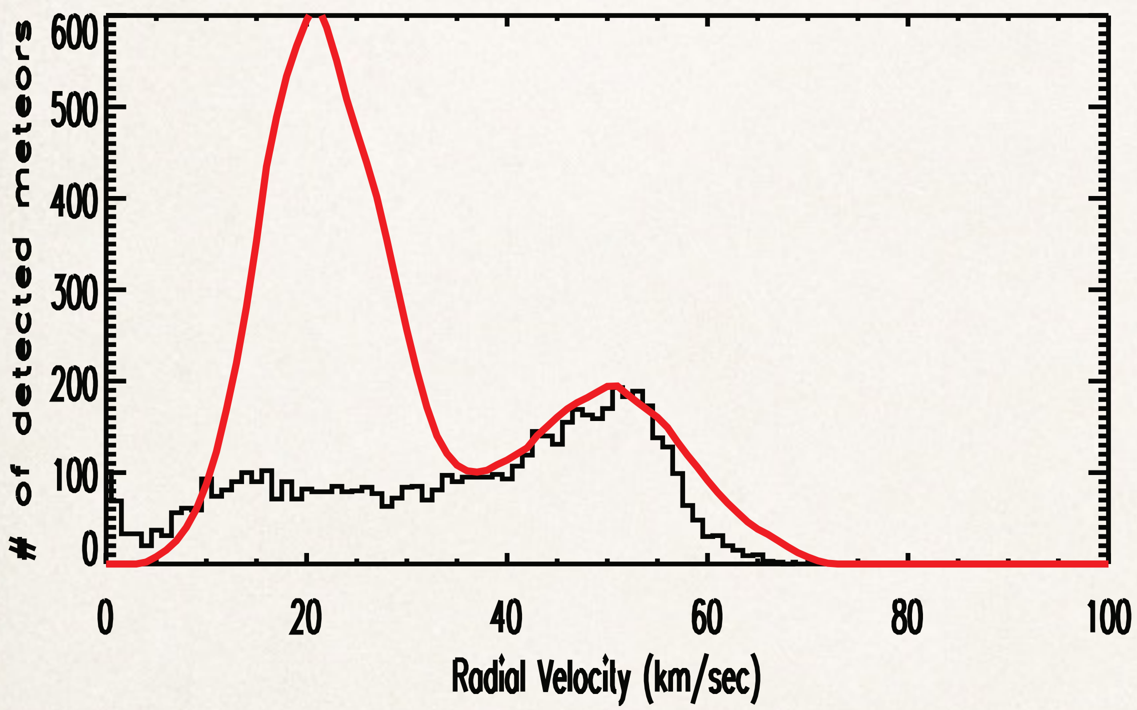
Planck JFC (Ade et al., 2014; Janches et al., 2015) mean size ~ 30 microns - Assuming the HE is aspect sensitive following a Gaussian distribution with a σ = 40 degrees

50 % of



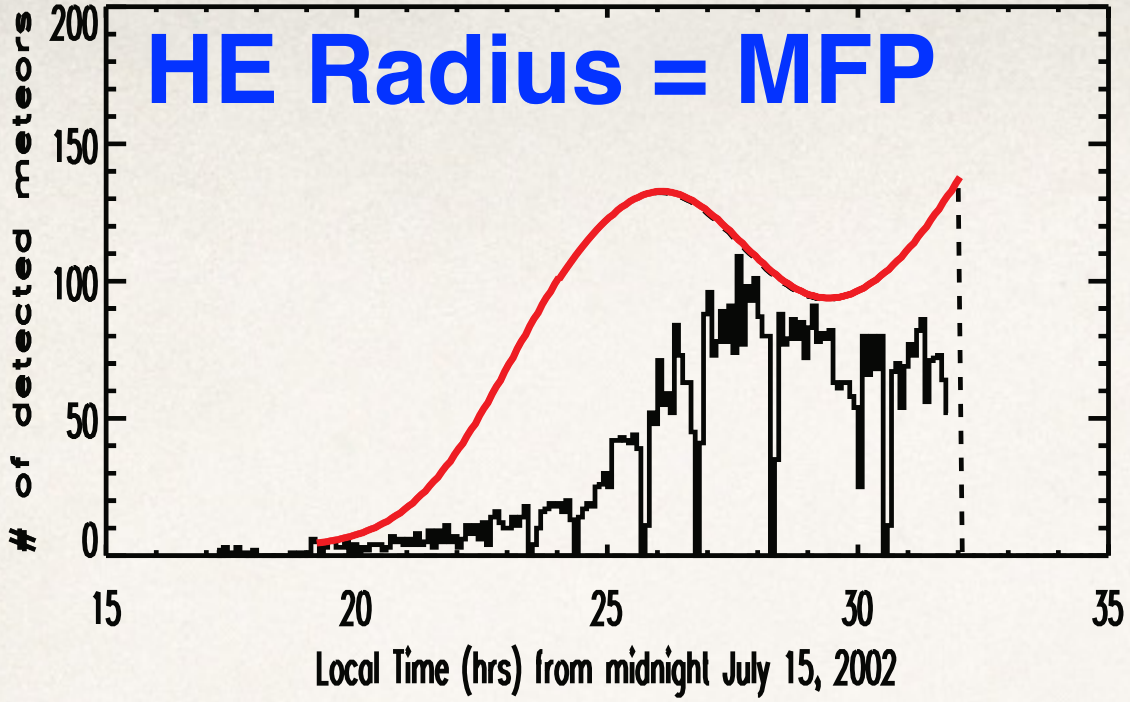
The consideration of aspect sensitivity int he HE detection treatment reduces the number of JFCs detection to the 'ball park' of the observed rates.

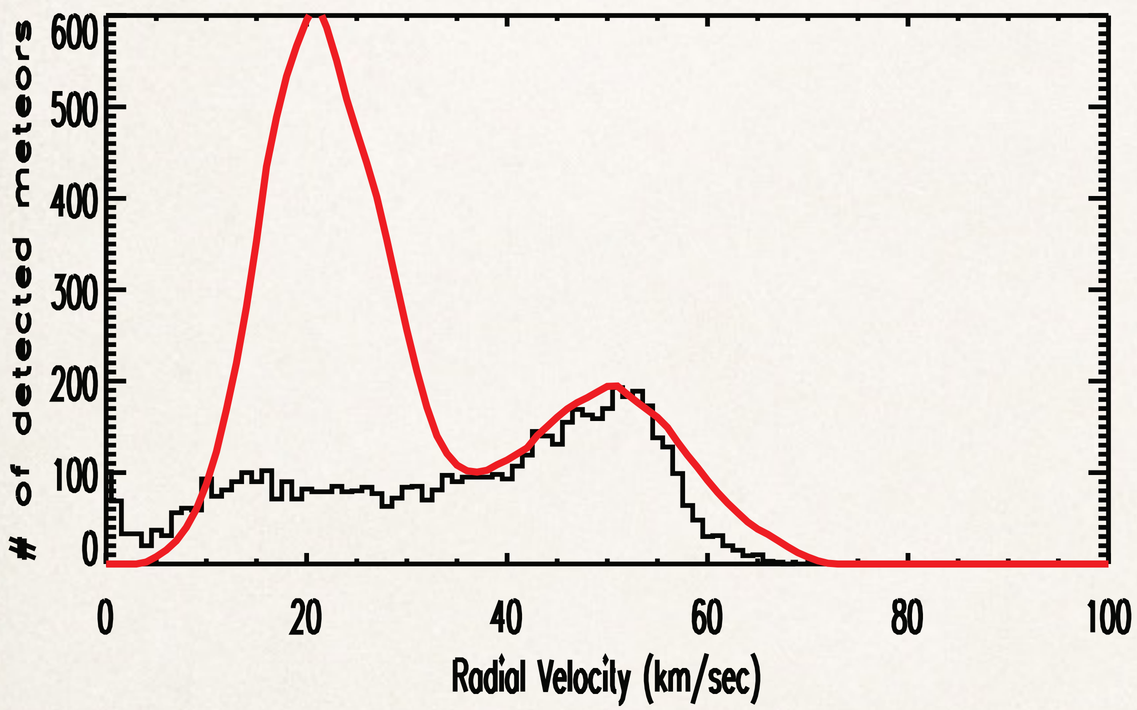




	Mass Flux (t/d)
Population	MFP
JFC (Planck)	15
HTC P	0.9
HTC R	0.2
OCC	0.3

Results: HE Shape





	Mass Flux (t/d)
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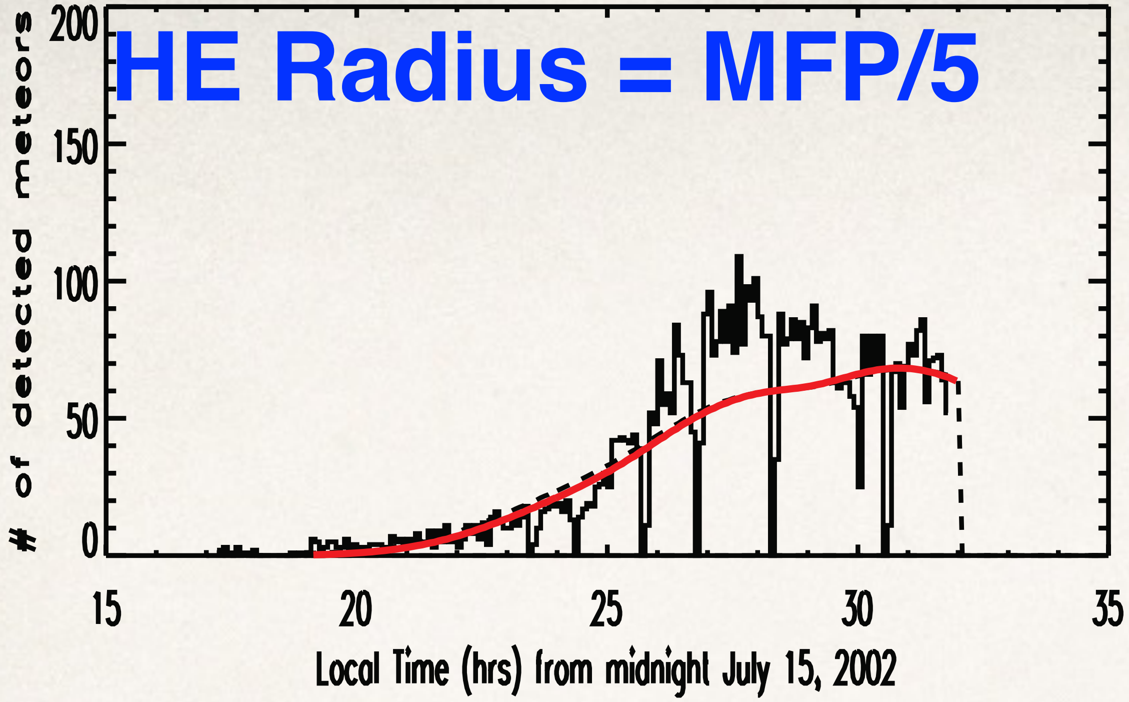
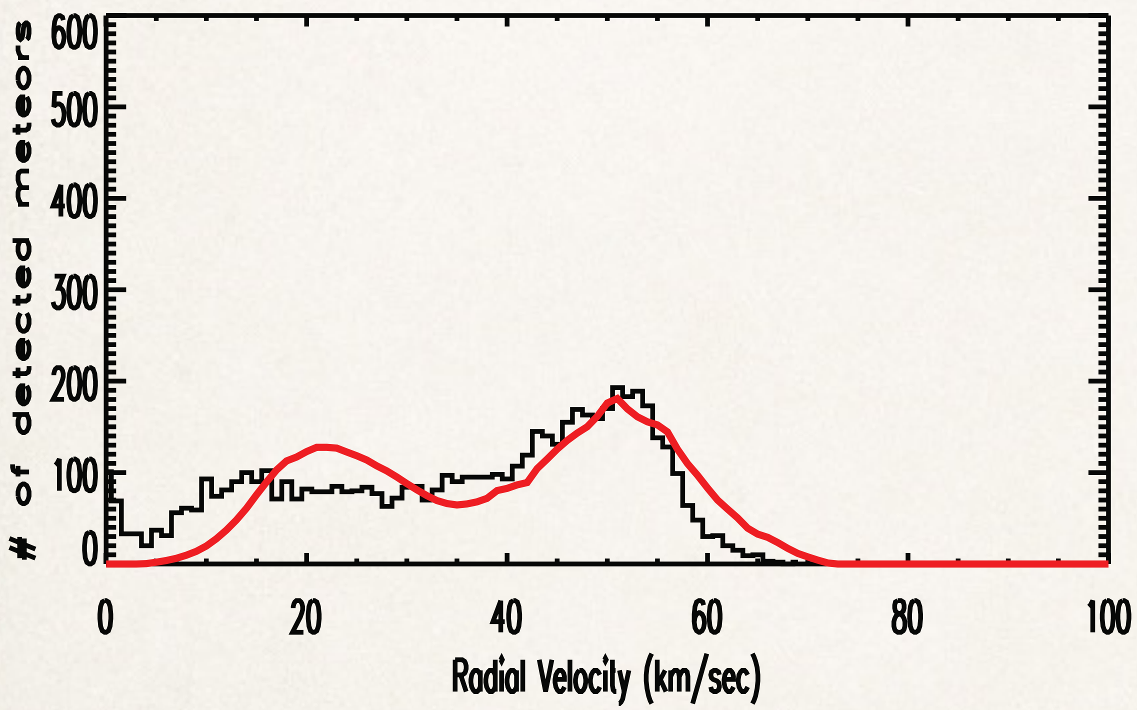
Results: HE Shape

What about HE Size?

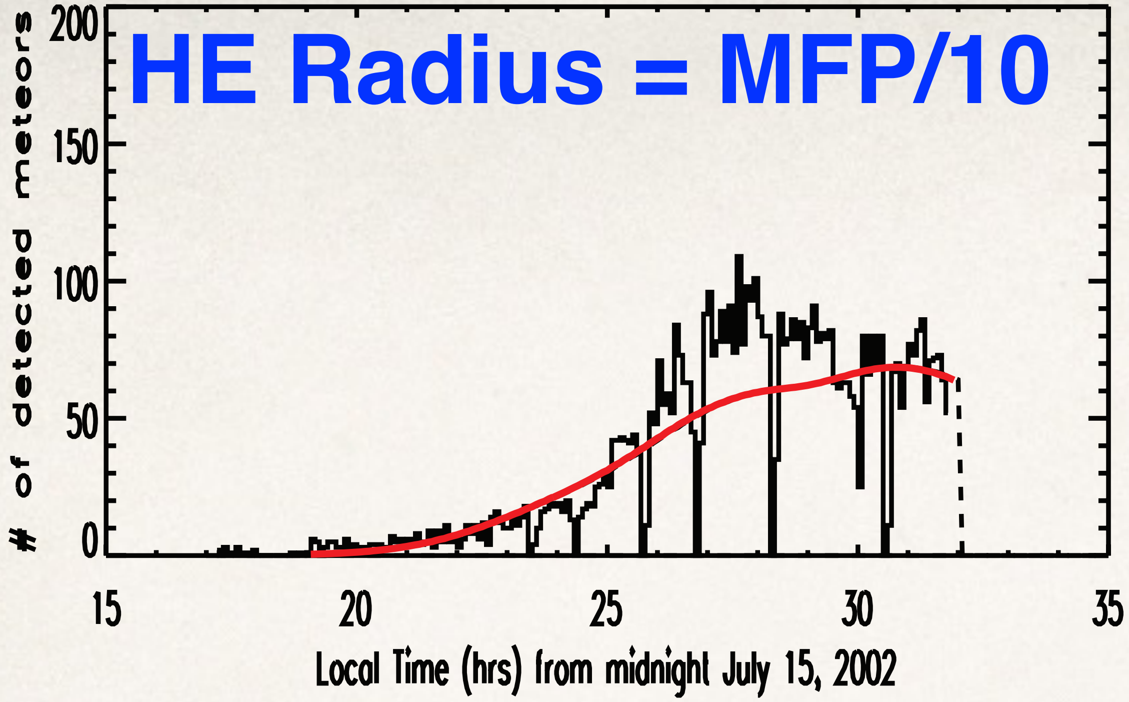


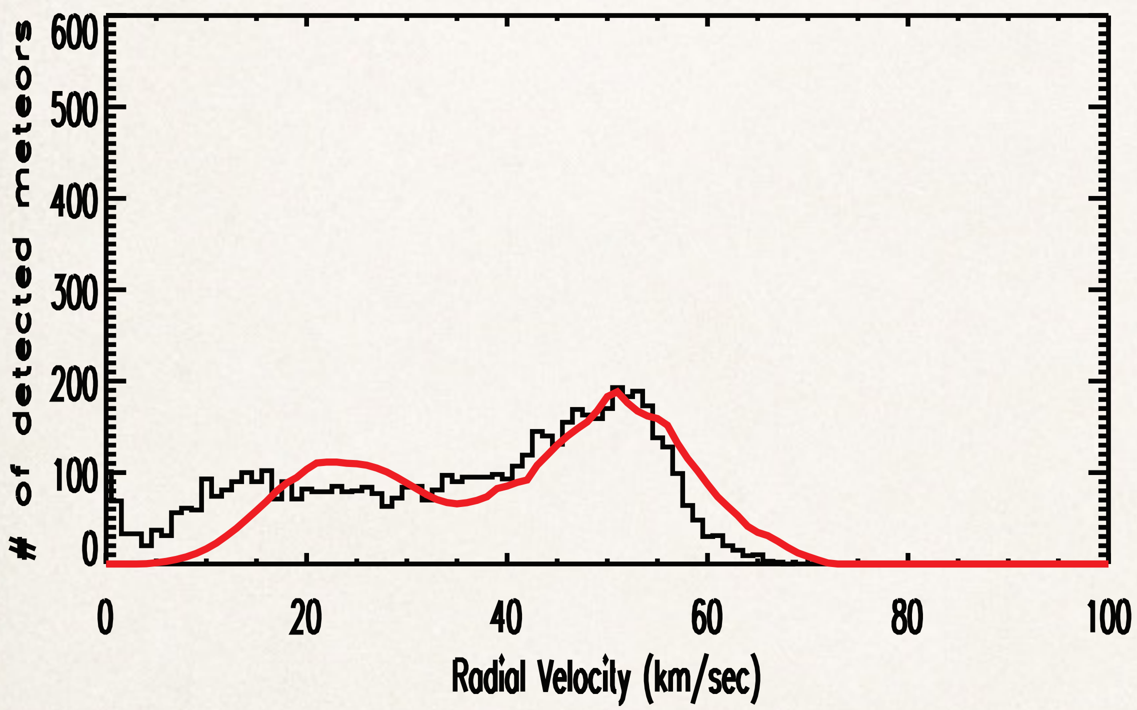


	Mass Flux (t/d)	
Population	MFP	MFP/5
JFC (Planck)	15	15
HTC P	0.9	0.4
HTC R	0.2	0.05
OCC	0.3	1

In agreement with Close et al., 2004

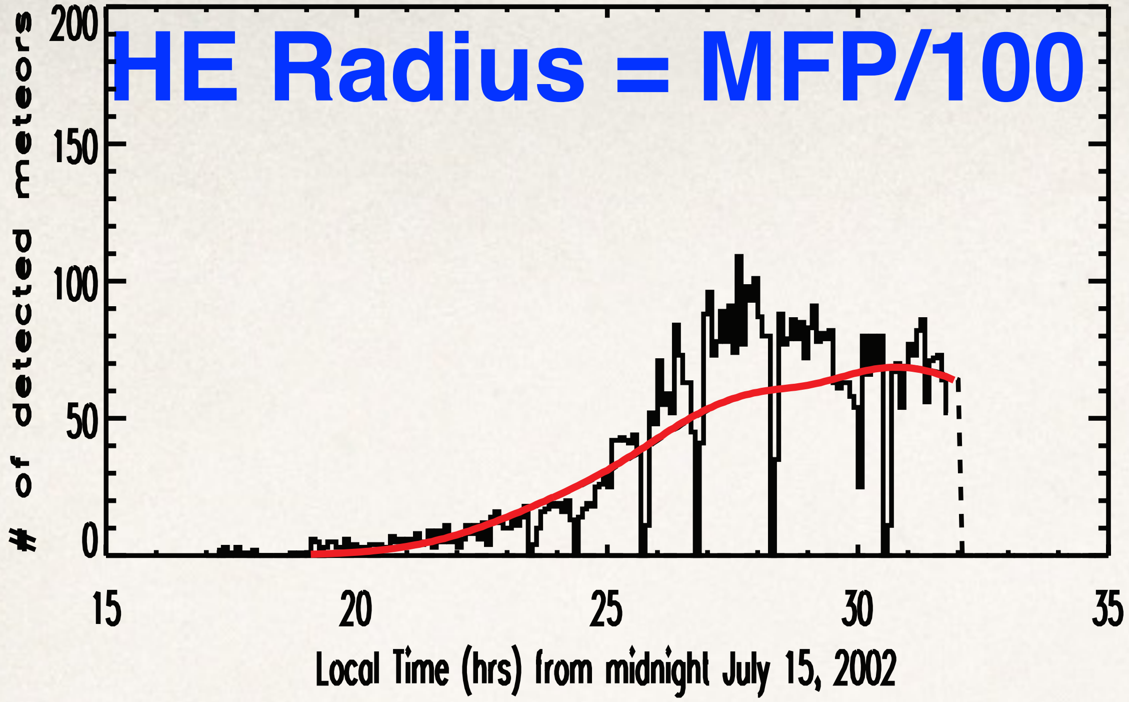
Results: HE Size

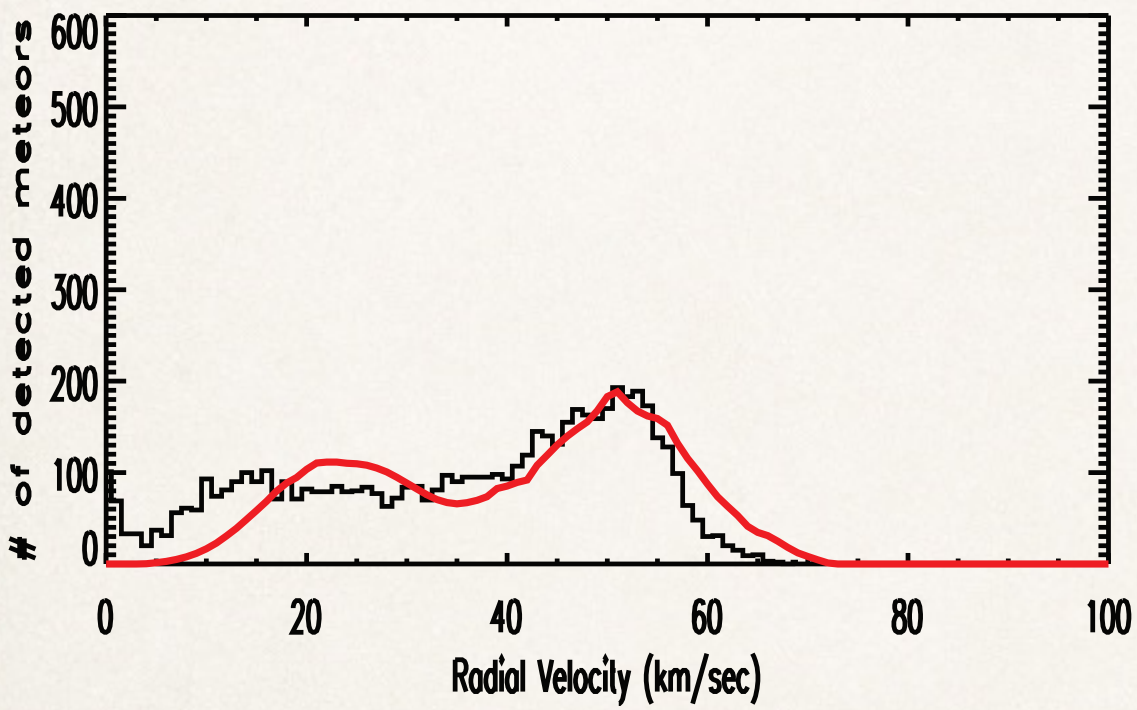




	Mass Flux (t/d)		
Population	MFP	MFP/5	MFP/10
JFC (Planck)	15	15	30
HTC P	0.9	0.4	0.4
HTC R	0.2	0.05	0.06
OCC	0.3	1	1.2

Results: HE Size





	Mass Flux (t/d)			
Population	MFP	MFP/5	MFP/10	MFP/100
JFC (Planck)	17	17	33	337
HTC P	0.9	0.4	0.4	9
HTC R	0.2	0.05	0.06	1.2
OCC	0.3	1	1.2	6

Results: HE Size

Using orbital models of different dust populations and HPLA HE observations we have found that:

1) HE must be aspect sensitive and likely a factor of 5 to 10 smaller than the MFP to:
   a) a flux where most of the contribution comes from slow JFCs
   b) make the majority of slow JFC undetected
   c) fit the high velocity populations to the observations.

Conclusions

Using orbital models of different dust populations and HPLA HE observations we have found that:

1) HE must be aspect sensitive and likely a factor of 5 to 10 smaller than the MFP to:
   a) a flux where most of the contribution comes from slow JFCs
   b) make the majority of slow JFC undetected
   c) fit the high velocity populations to the observations.

However:

2) These results are not prove that Nesvorny's JFC model is correct, only that **if** it is correct we have a way to make it undetectable. **There are still conflicting issues that must be addressed**:

Conclusions

HSD

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   a) a flux where most of the contribution comes from slow JFCs
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   c) fit the high velocity populations to the observations.

However:

2) These results are not prove that Nesvorny's JFC model is correct, only that **if** it is correct we have a way to make it undetectable. **There are still conflicting issues that must be addressed**:
   a) lack of observations of gravitational focusing effects due to slow velocity flux (Love & Allton, 2006)
   b) Miao & Stark (2001) required a faster distribution to explain the LDEF detection ratio between different surfaces of the spacecraft
   c) Lack of observational evidence that slow particles come from only the helion and anti-helion directions (Campbell-Brown, 2015, radars, etc)

Conclusions

Using orbital models of different dust populations and HPLA HE observations we have found that:

3) About 10% of the flux has to come from a combination of HTC and OCC particles
4) In particular OCCs are important because without their contribution, more than half of the HTC population would required to be retrograde in order to fit the HPLA observations. Currently only 11% HTC are retrograde in the HTC model (Levinson et al., 2006; Pokorny et al., 2014)
5) If the radius of the HE ~ MFP then flux from OCCs ~ 50% of HTCs, for smaller radius OCCs ~ 2 times the HTCs

Conclusions

Using orbital models of different dust populations and HPLA HE observations we have found that:

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4) In particular OCCs are important because without their contribution, more than half of the HTC population would required to be retrograde in order to fit the HPLA observations. Currently only 11% HTC are retrograde in the HTC model (Levinson et al., 2006; Pokorny et al., 2014)
5) If the radius of the HE ~ MFP then flux from OCCs ~ 50% of HTCs, for smaller radius OCCs ~ 2 times the HTCs

dank je!

Conclusions