Interpreting IS Radar Measurements with Common Sense (and Physics)

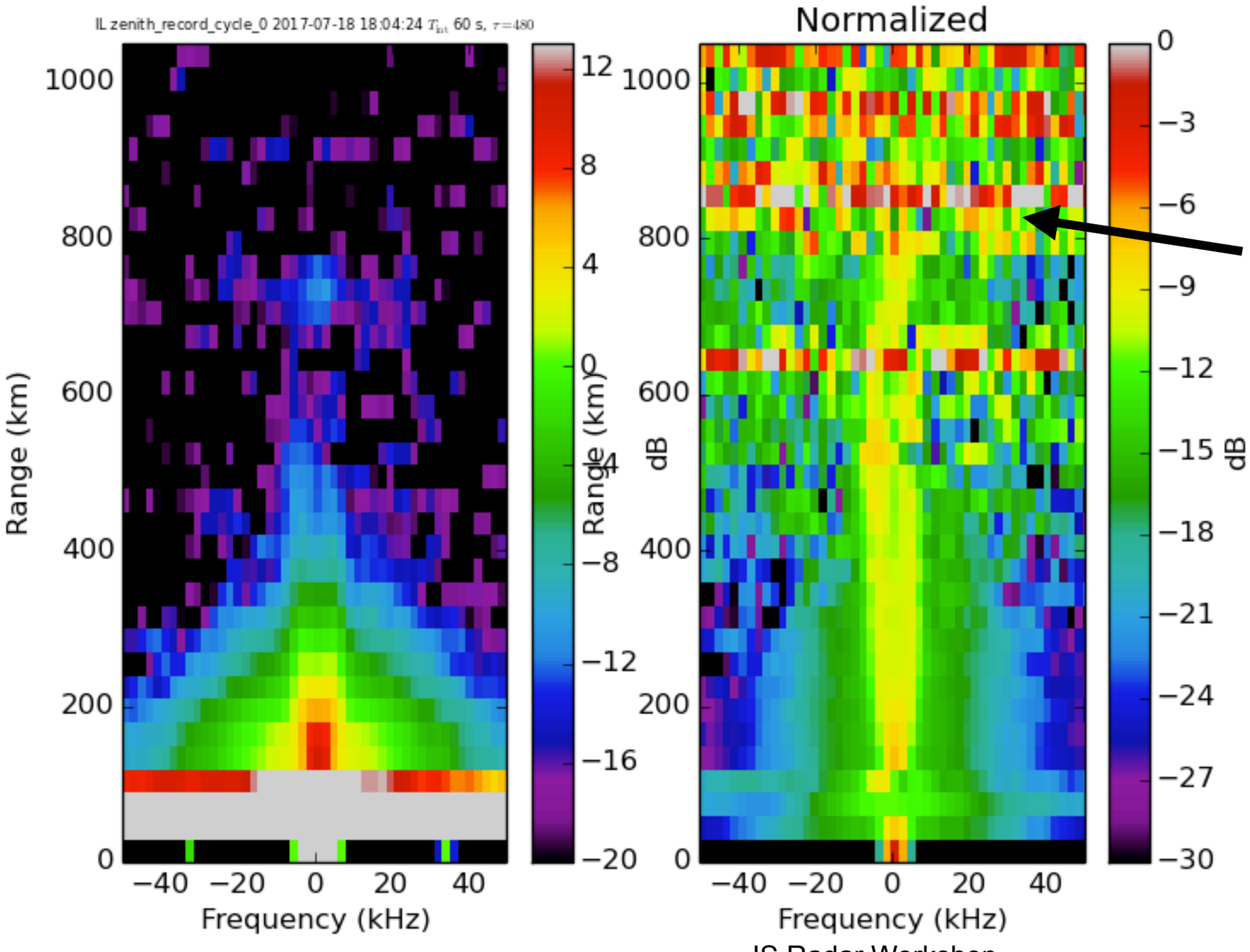
P. J. Erickson
MIT Haystack Observatory

Topics covered:

- Sensitivity Considerations
- Instrumental Effects
- Inherent IS Forward Model Ambiguities

Sensitivity Considerations

Millstone Hill Zenith Antenna 2017-07-28 60 sec integration IPP = 8.91 msec N = 2244(*)



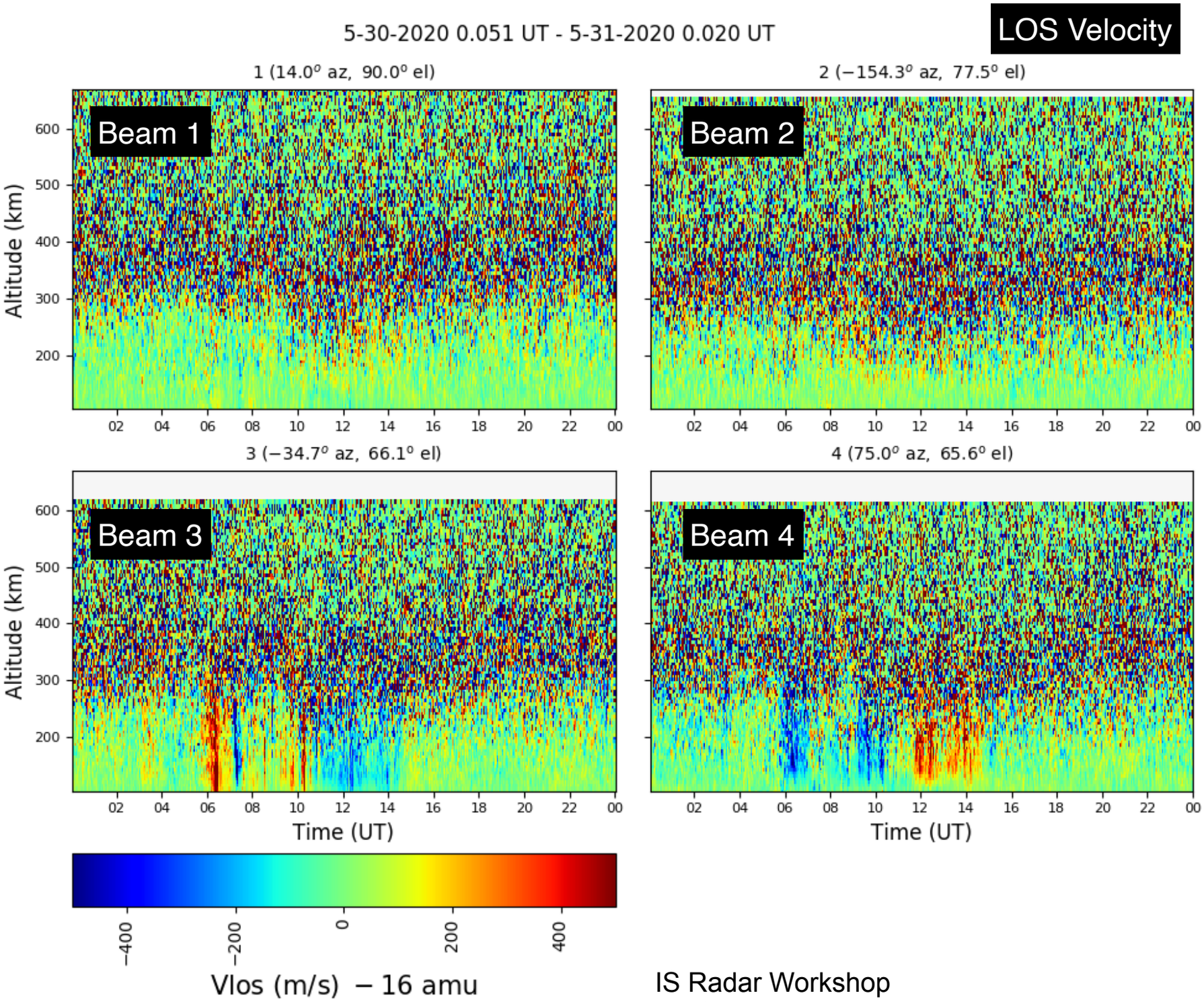
??? What is happening here?

Recall:

$$\frac{\sqrt{Var\left\{\hat{S}\right\}}}{S} = \frac{1}{\sqrt{K}}\frac{S+N}{S} = \frac{1}{\sqrt{K}}\left(1+\frac{1}{S/N}\right)$$

(*) Interleaved experiment, so N != (integration time / IPP)

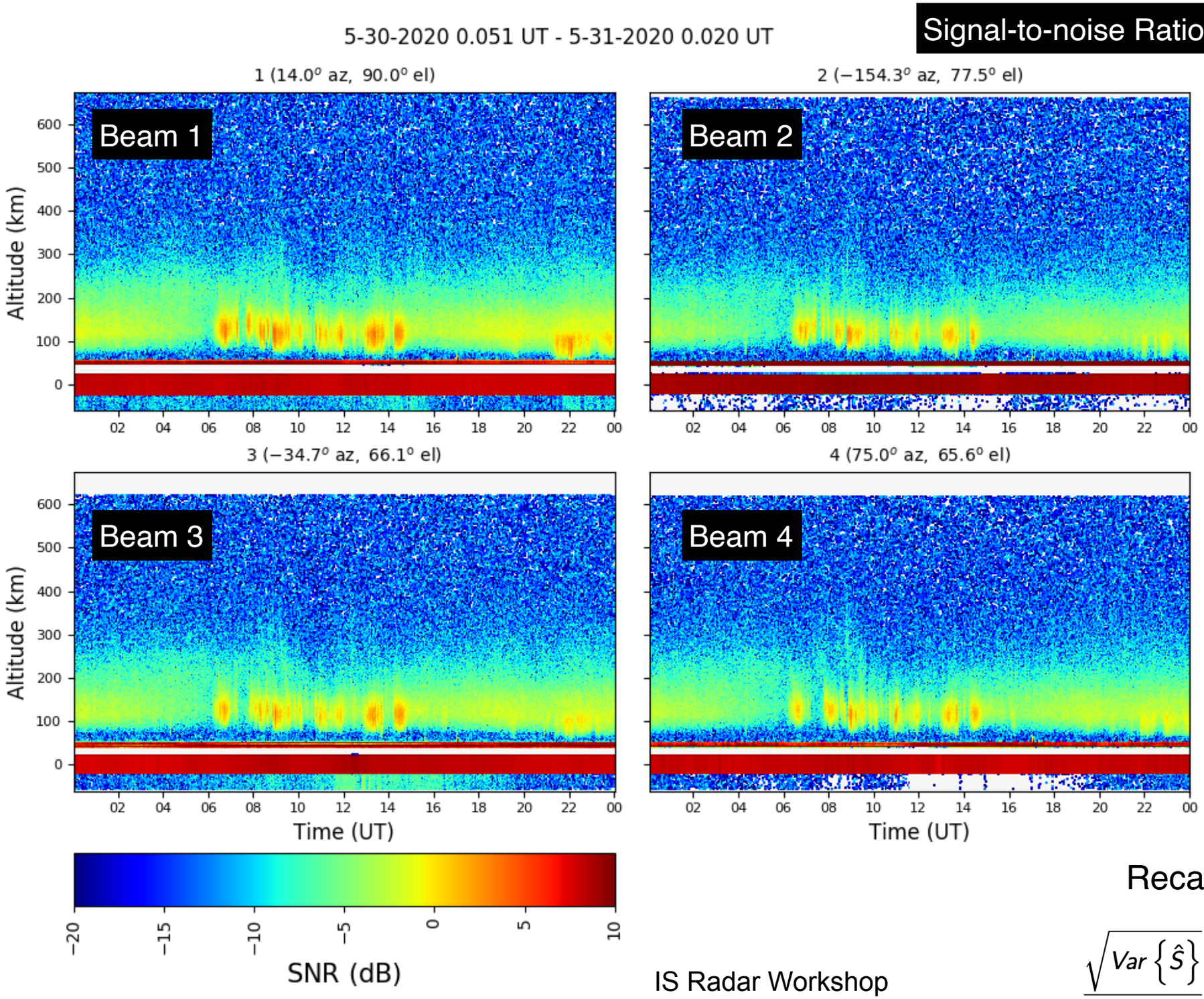
Sensitivity Considerations



PFISR
IPY “Screen saver” mode
4 Beams

2020-05-30
Solar minimum conditions

Sensitivity Considerations



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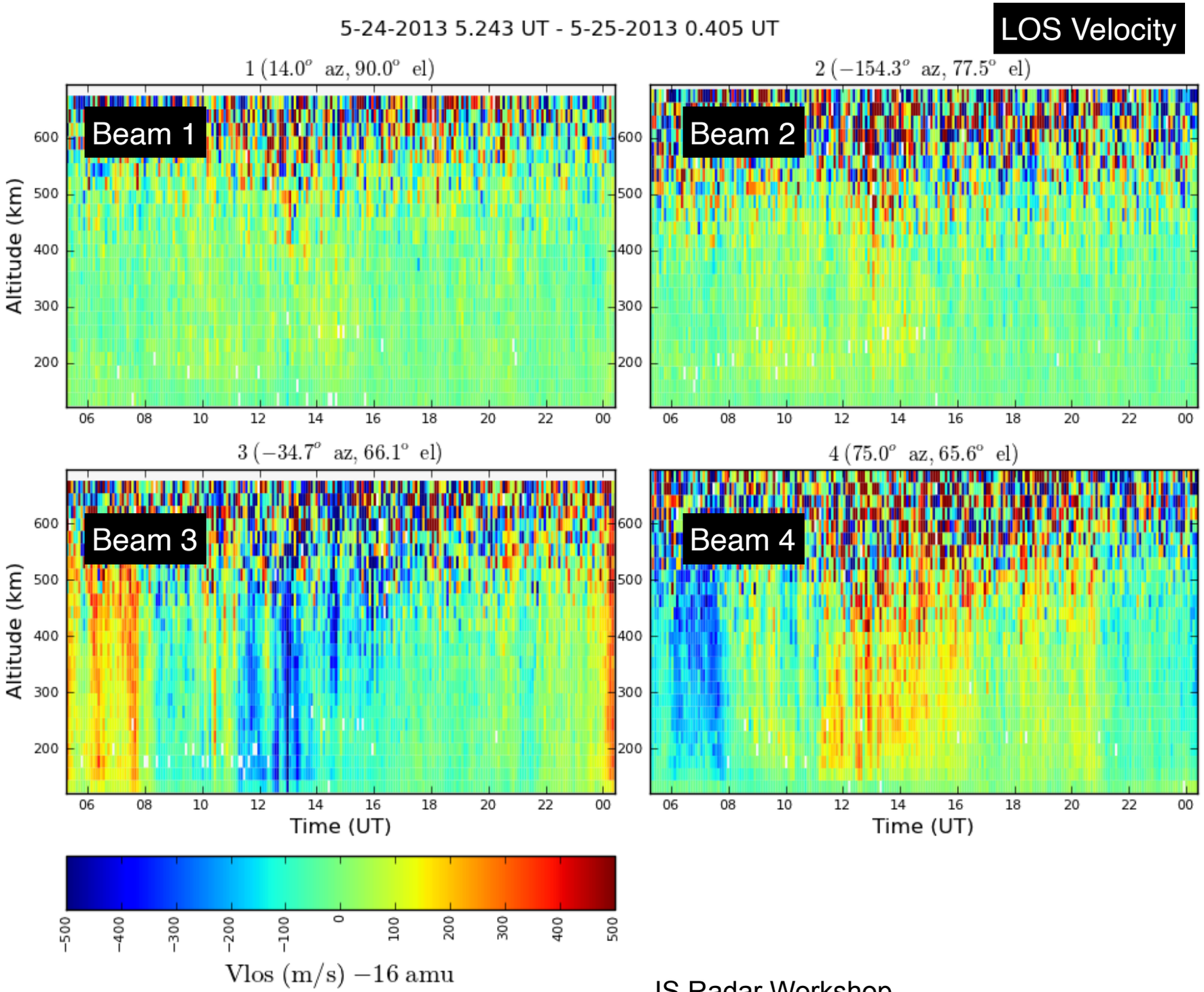
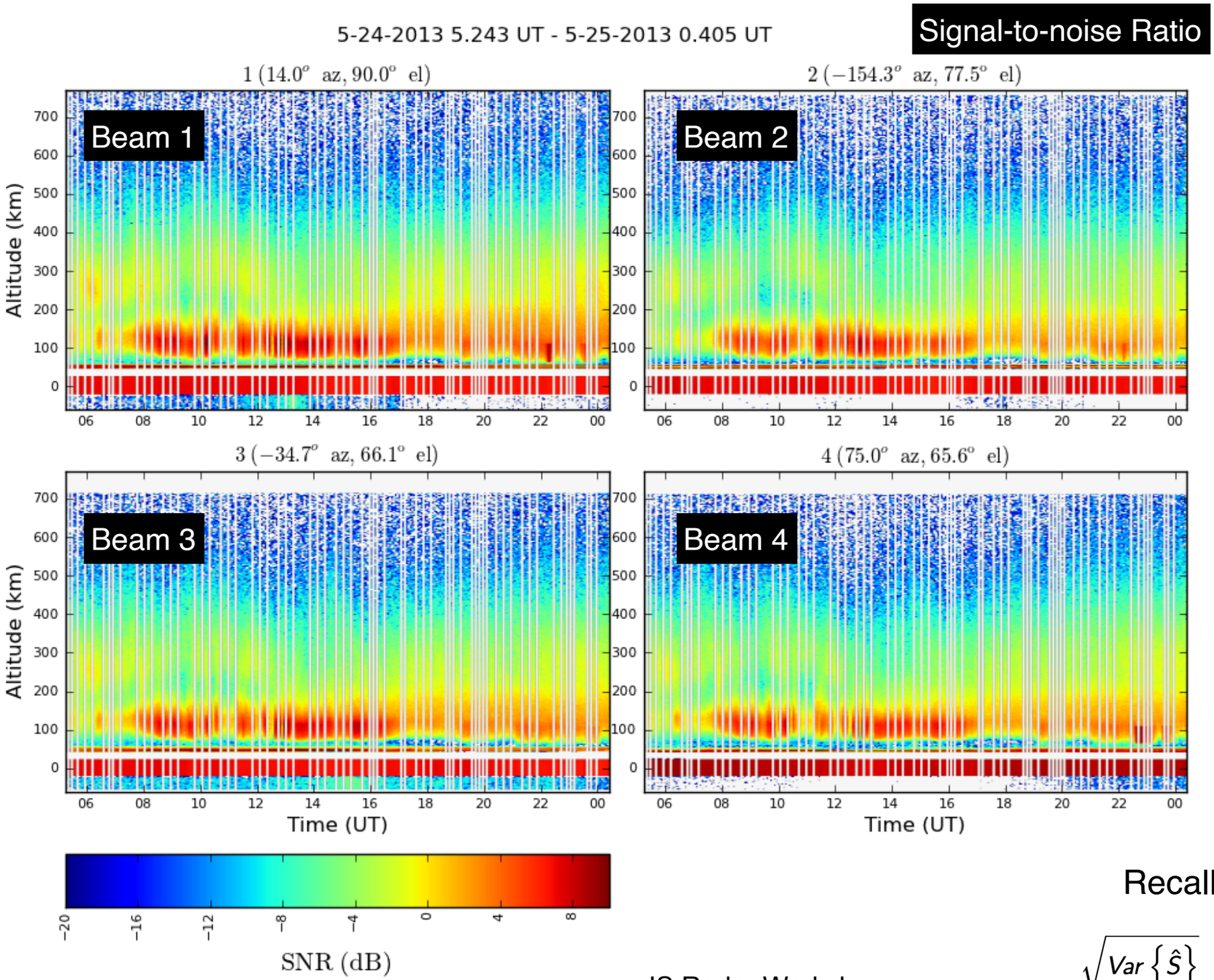


PFISR
IPY “Screen saver” mode
4 Beams

2013-05-24
~Solar Max conditions

Sensitivity Considerations



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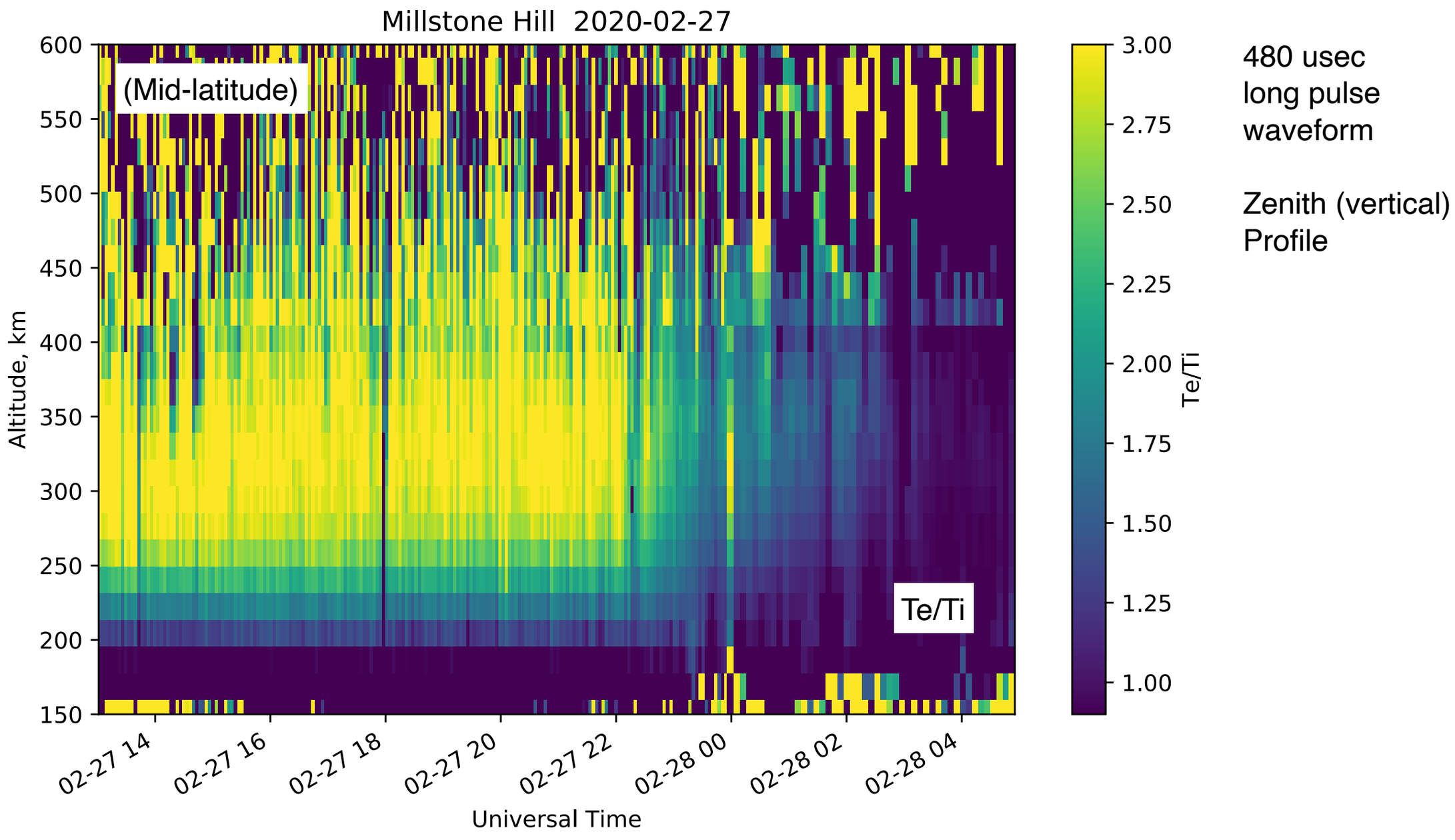
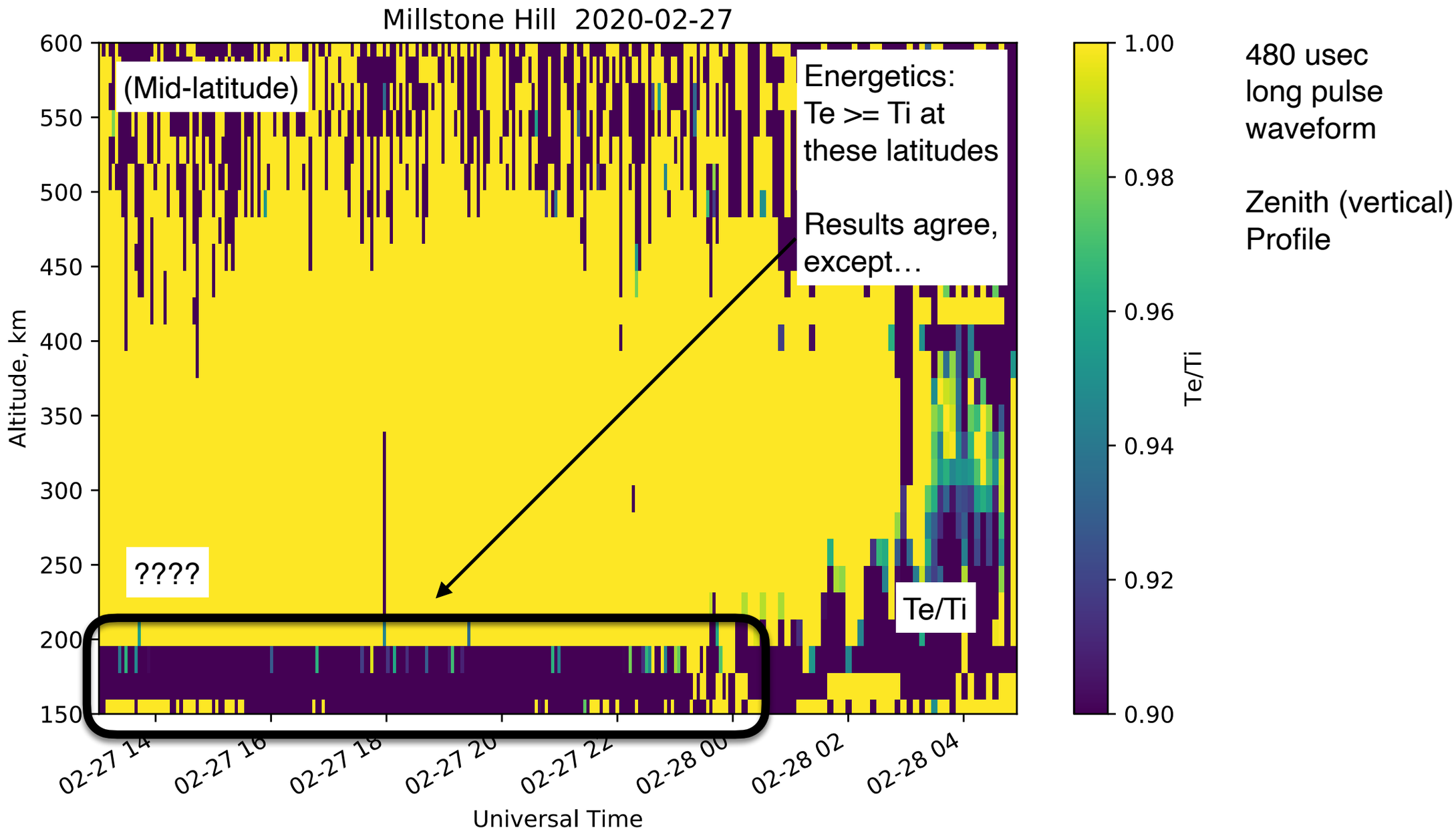
Common Sense Physics: Spotting Problems



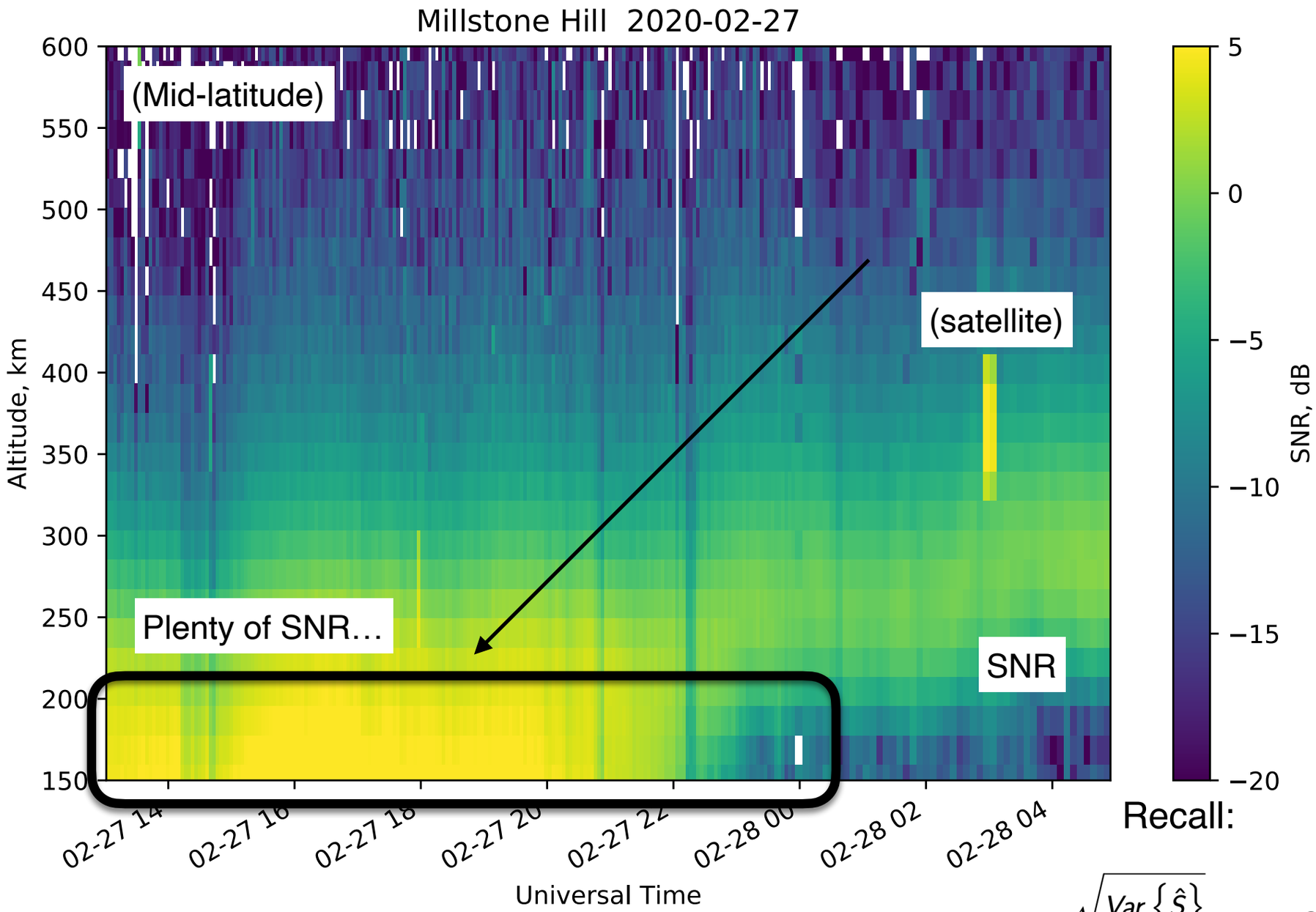
480 usec long pulse waveform

Zenith (vertical) Profile

Common Sense Physics: Spotting Problems



Common Sense Physics: Spotting Problems



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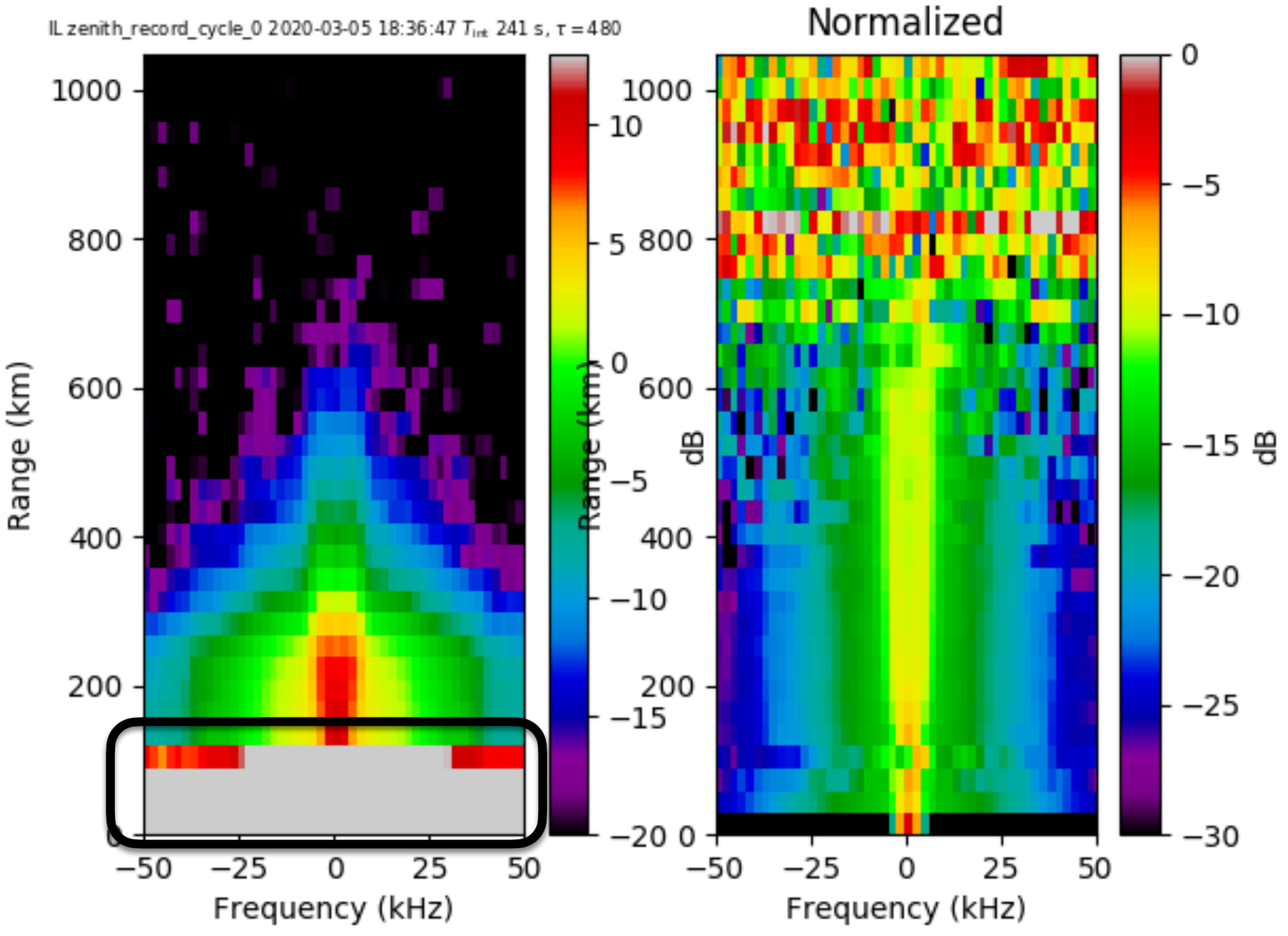
Problem Revealed: Radar Clutter Effects

(NB: not exactly same time but similar effects)



480 usec long pulse waveform

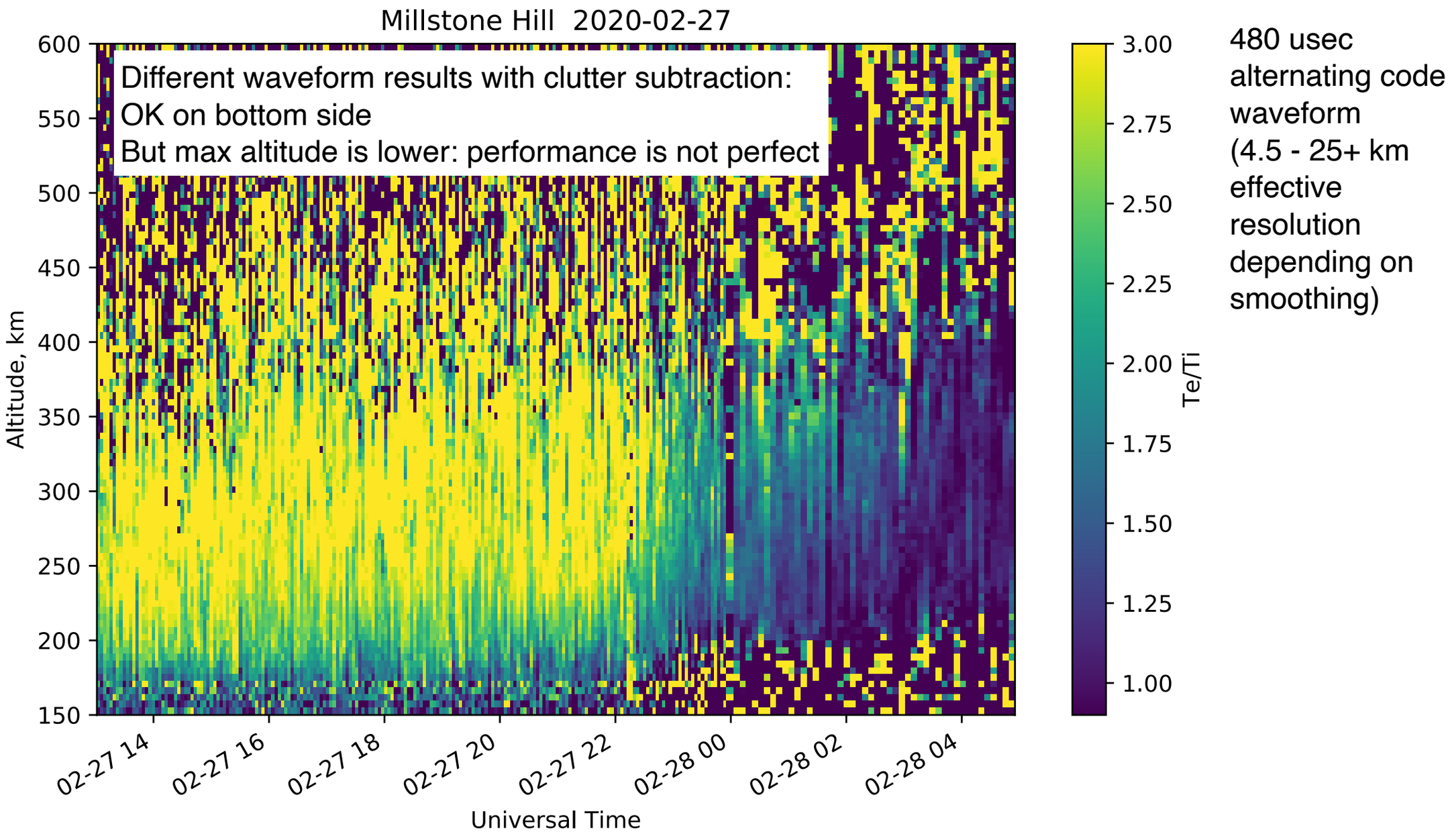
White Mountains (NH) = 150-200 km away

Convolution of long pulse with horizontal mountain echo = very bright scatter with non-IS form spectral characteristics

Unstable return due to water vapor effects

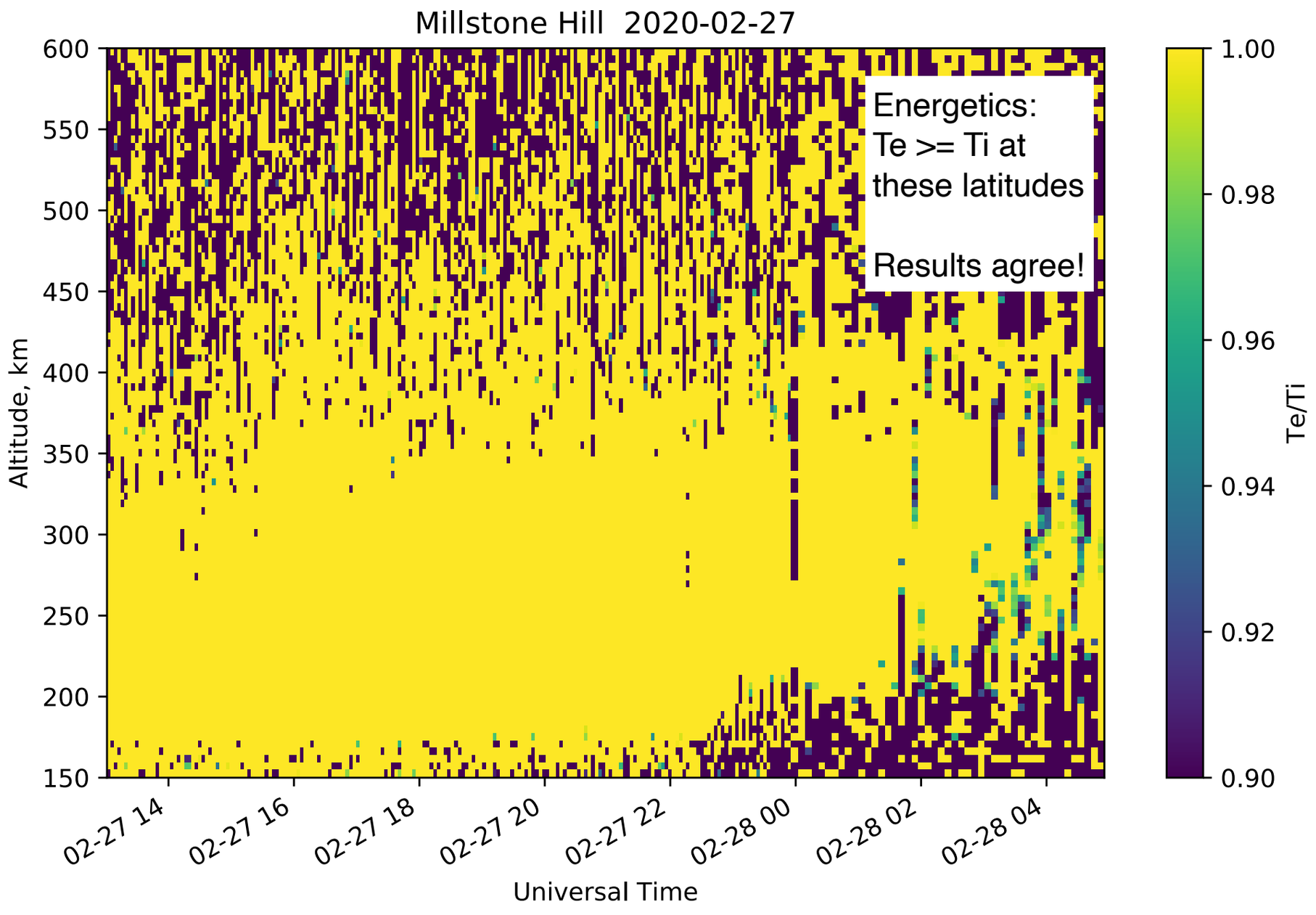
IS analysis misinterprets correlation shape

Picking the Right Experimental Waveform

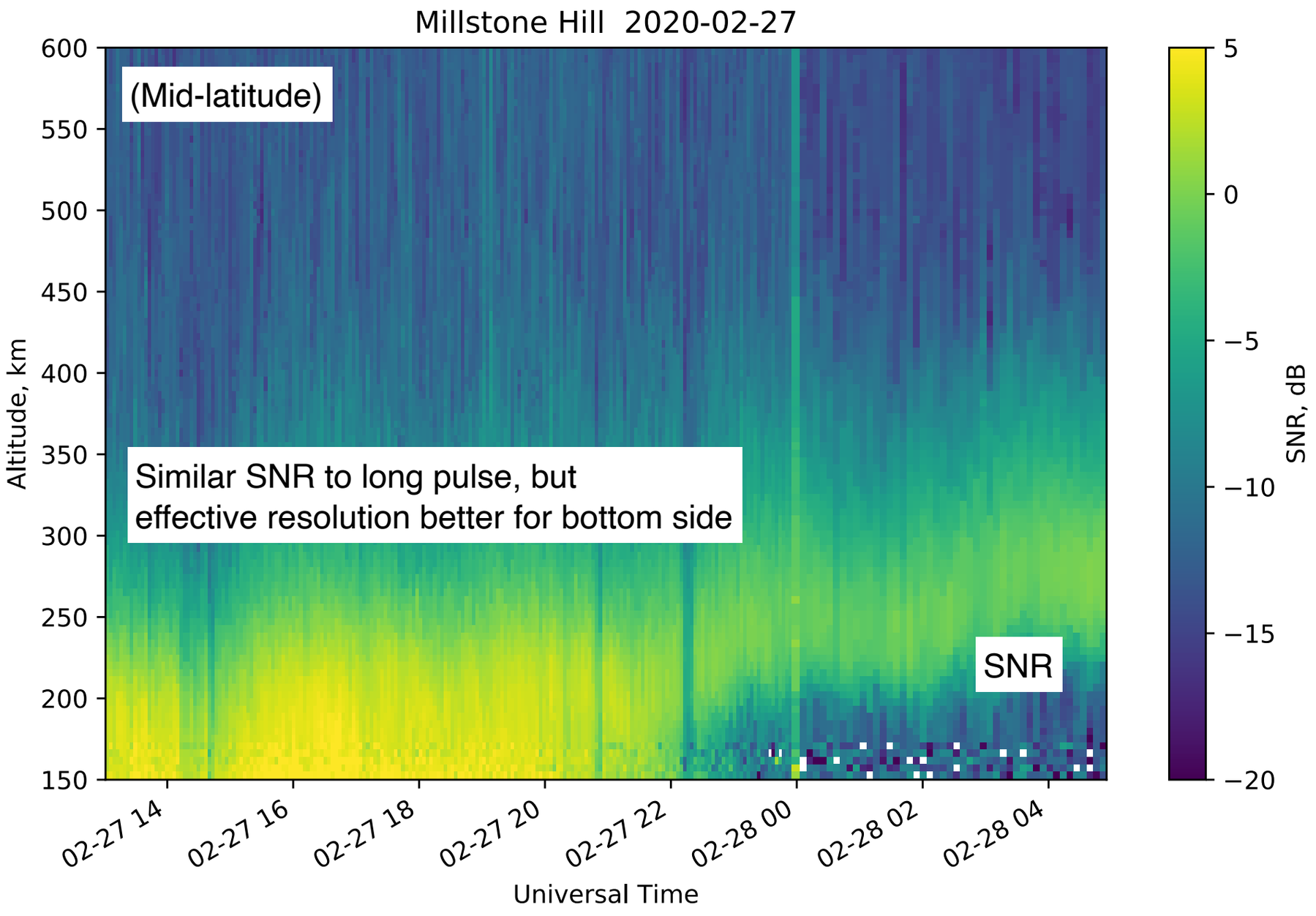


480 usec alternating code waveform (4.5 - 25+ km effective resolution depending on smoothing)

Picking the Right Experimental Waveform

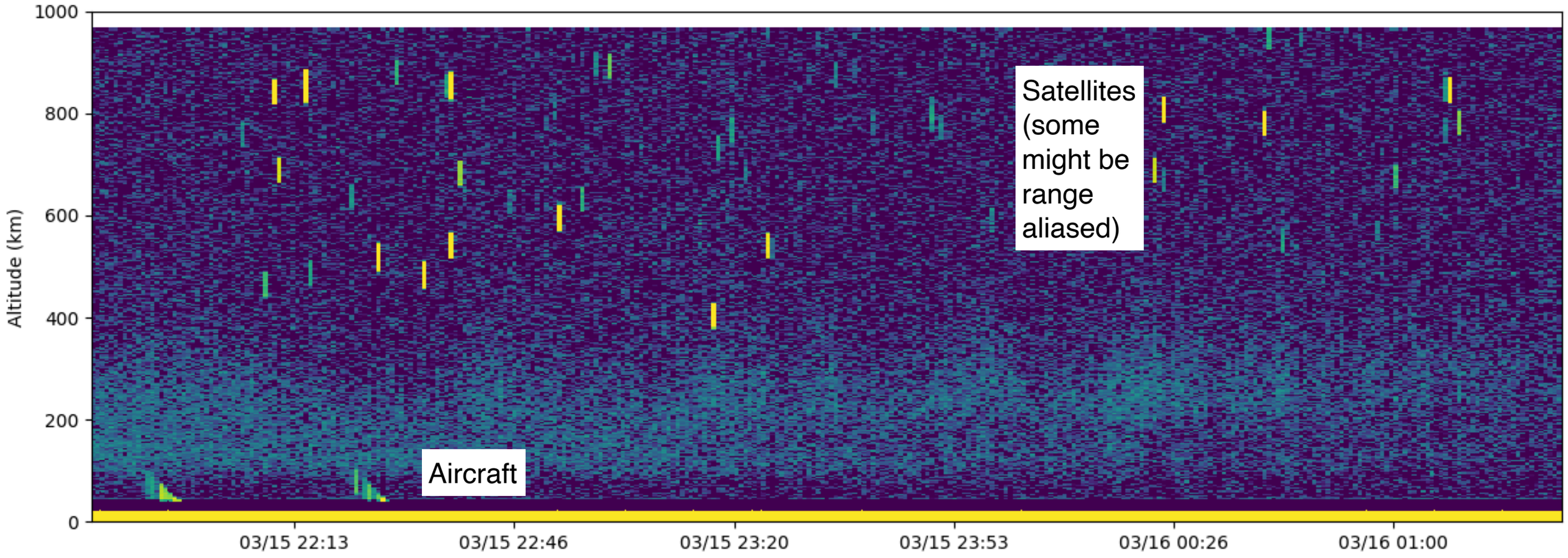


Picking the Right Experimental Waveform

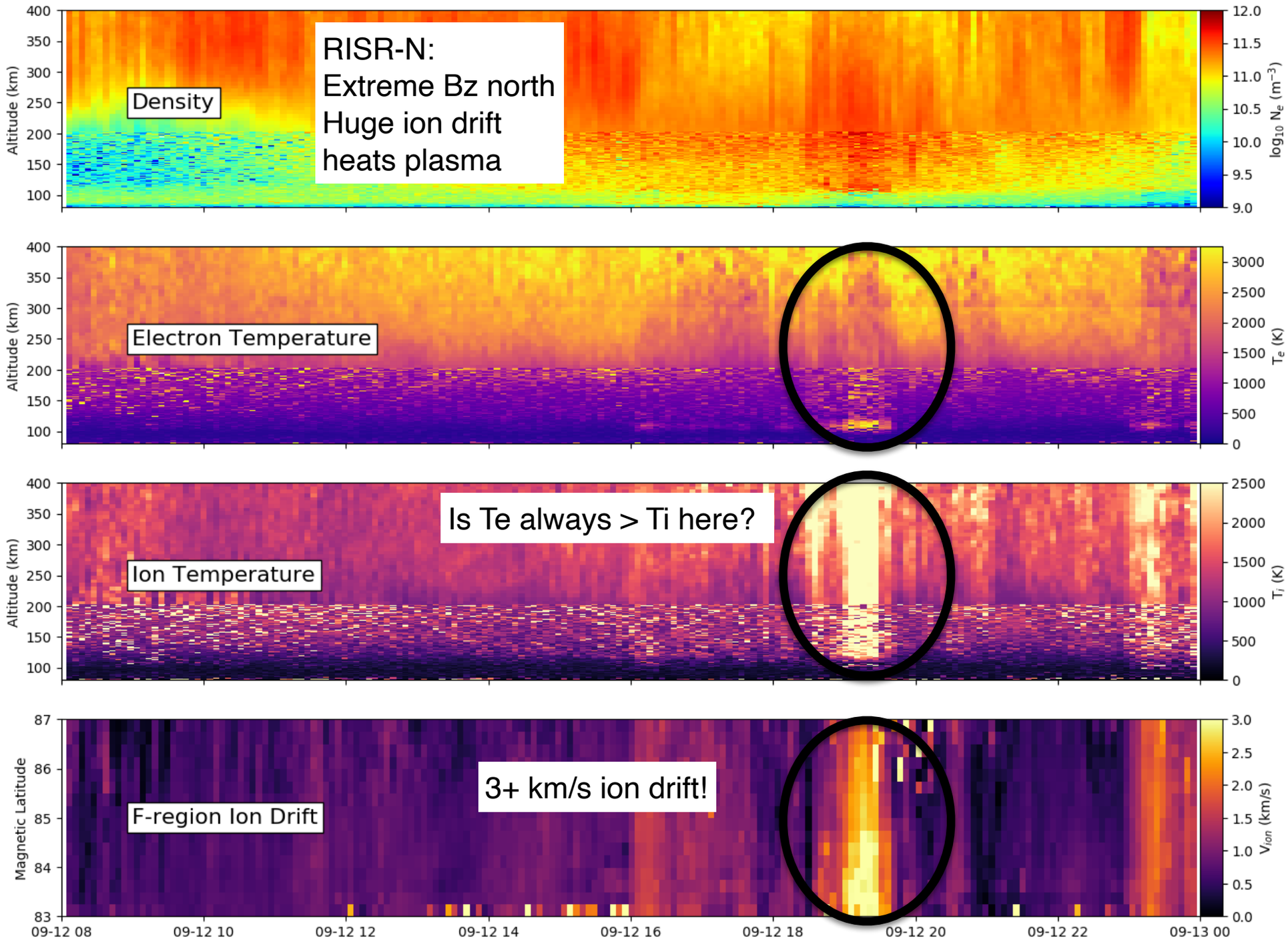


Another Non-IS Example

RISR-N Backscattered Power



Be Aware of the Geophysical Context



cf.
Clauer et al. JGR 2016
doi:10.1002/2016JA022557

IS Forward Model Behaviors

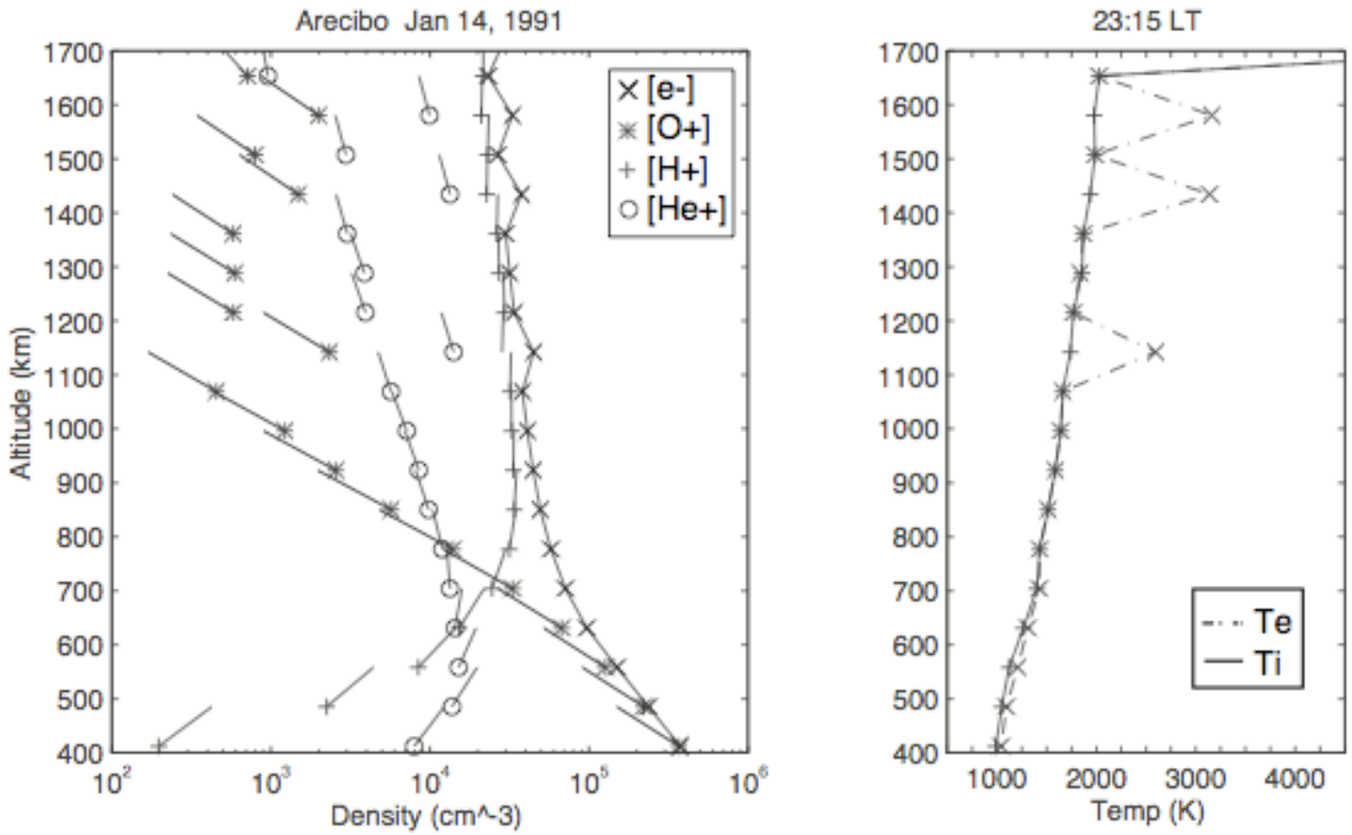
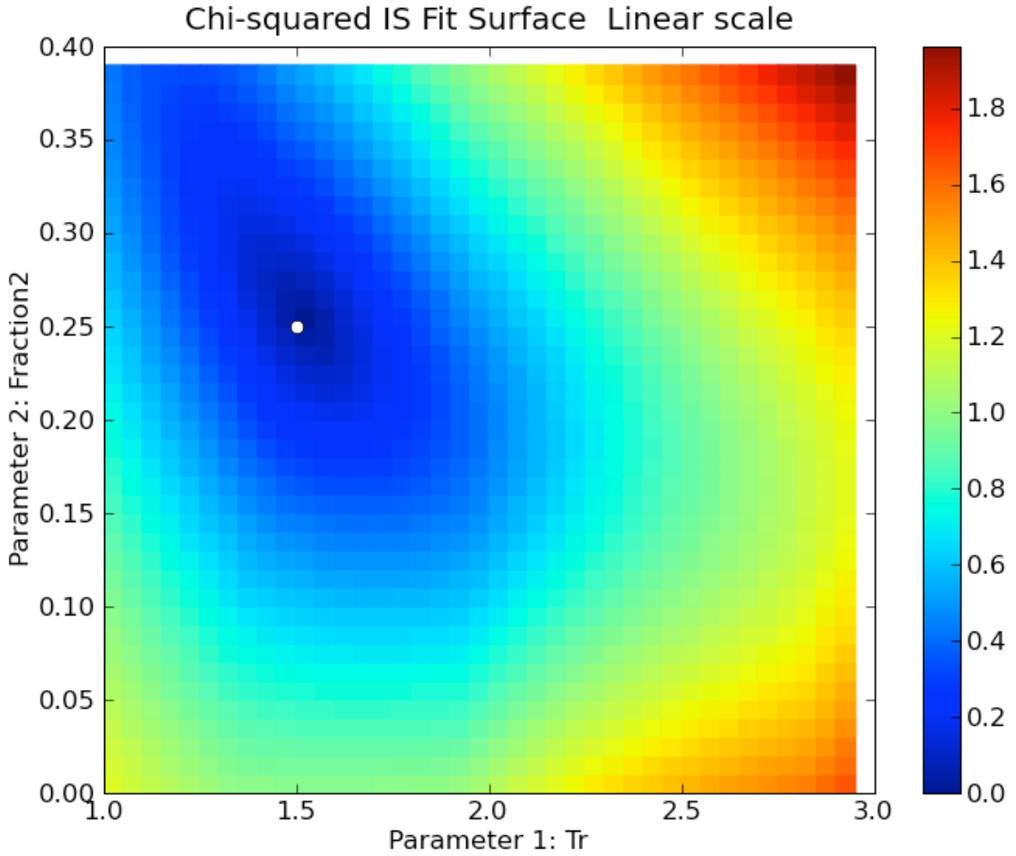
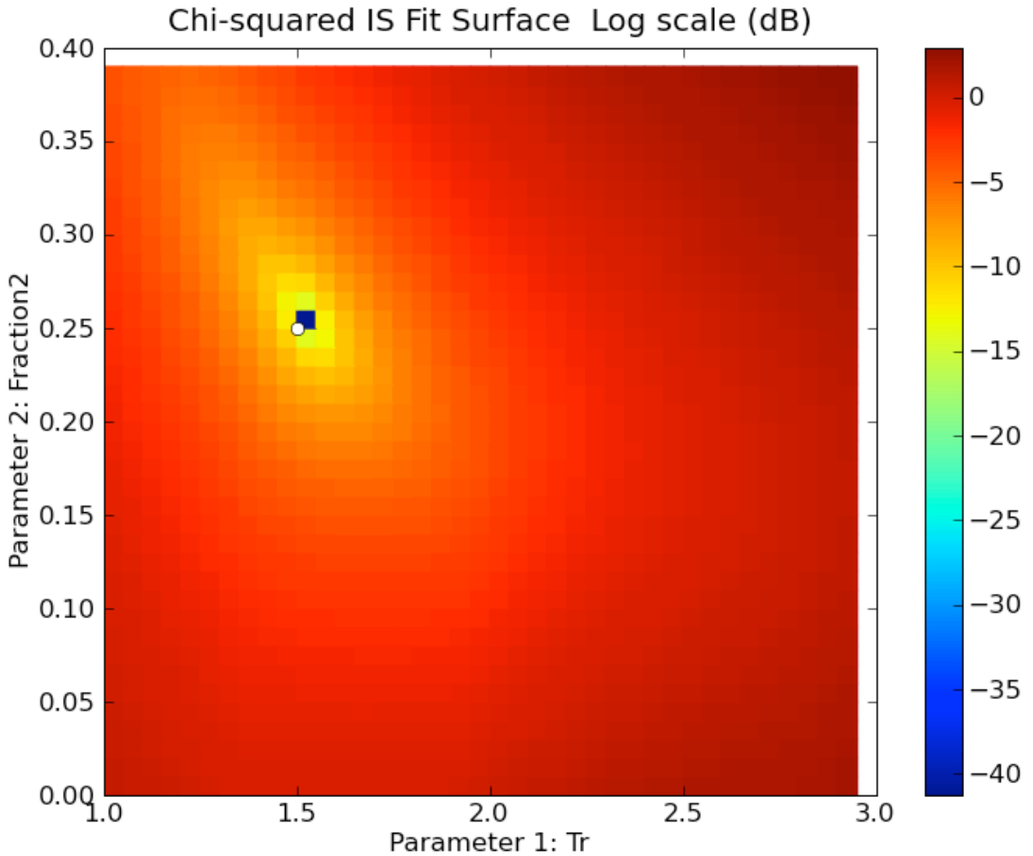


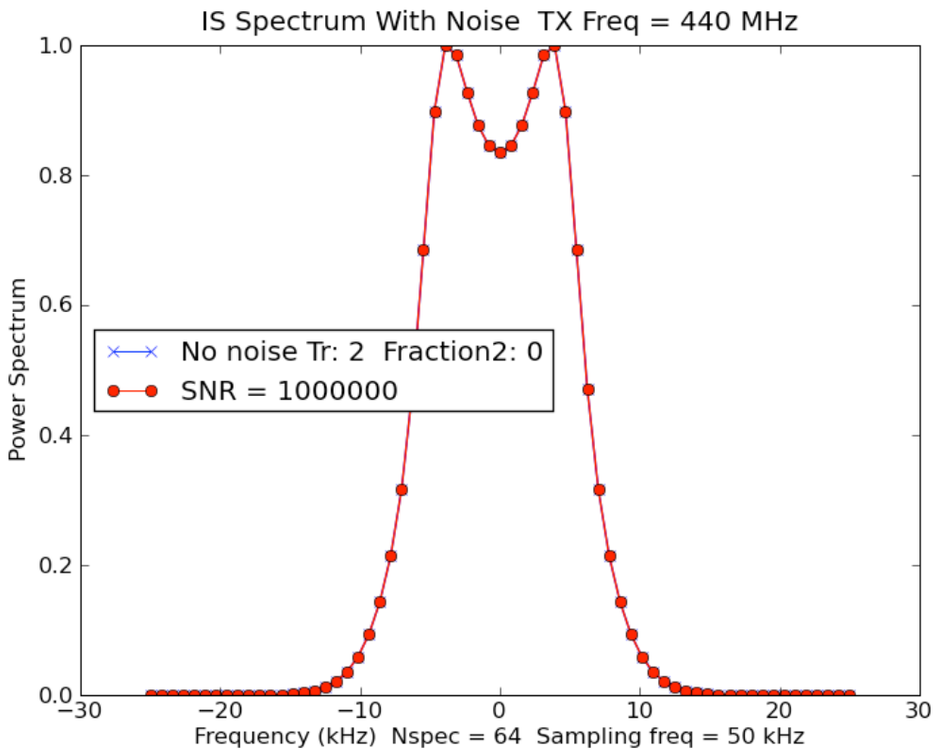
Figure 5.3: Density and temperature values as a function of altitude over Arecibo at 23:15 LT on January 14, 1991, using a 15 minute integration period. The lines emanating from each density value plotted in the left hand panel are predictions of density variation based on multicomponent diffusive equilibrium. There are clear inconsistencies in parameter values at several altitudes.

Physical topside Te behavior?

cf.
Erickson and Swartz 1994
doi:10.1029/94GL01585







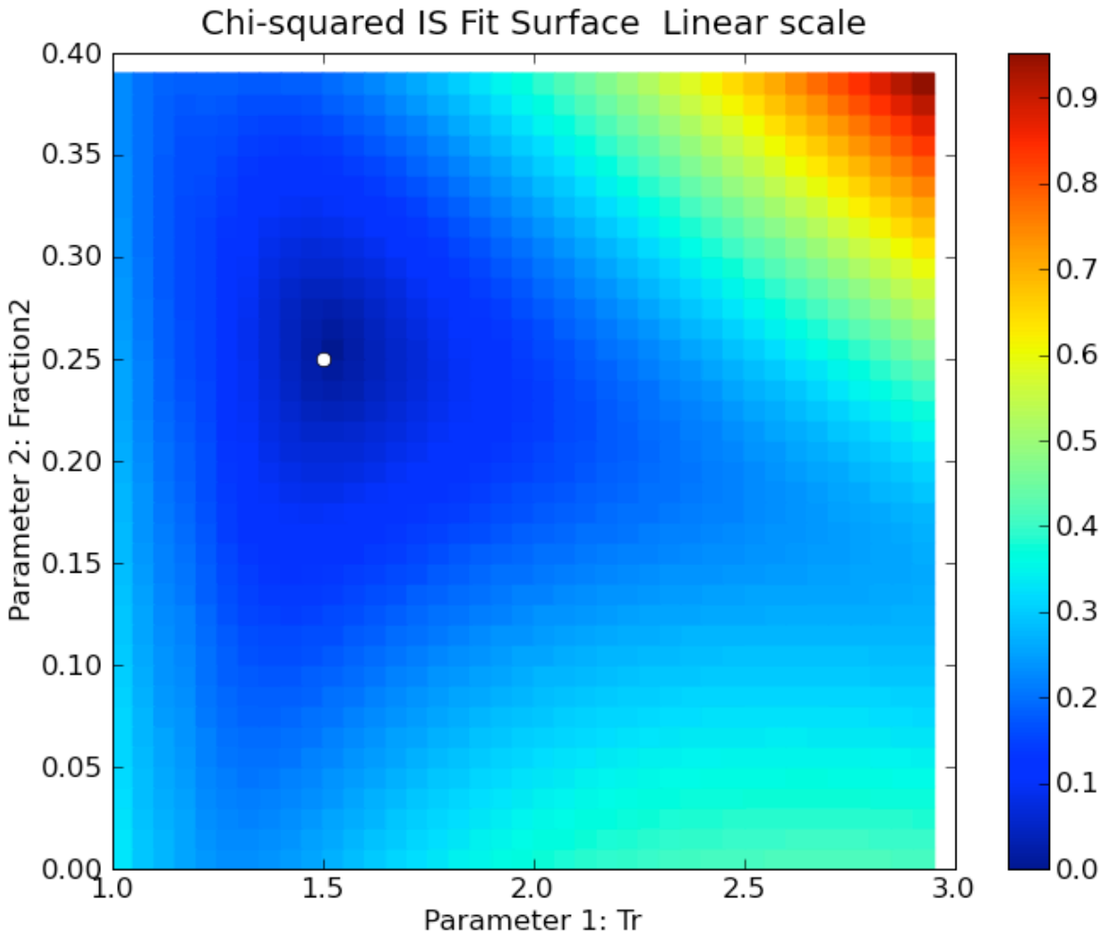
440 MHz IS Spectrum

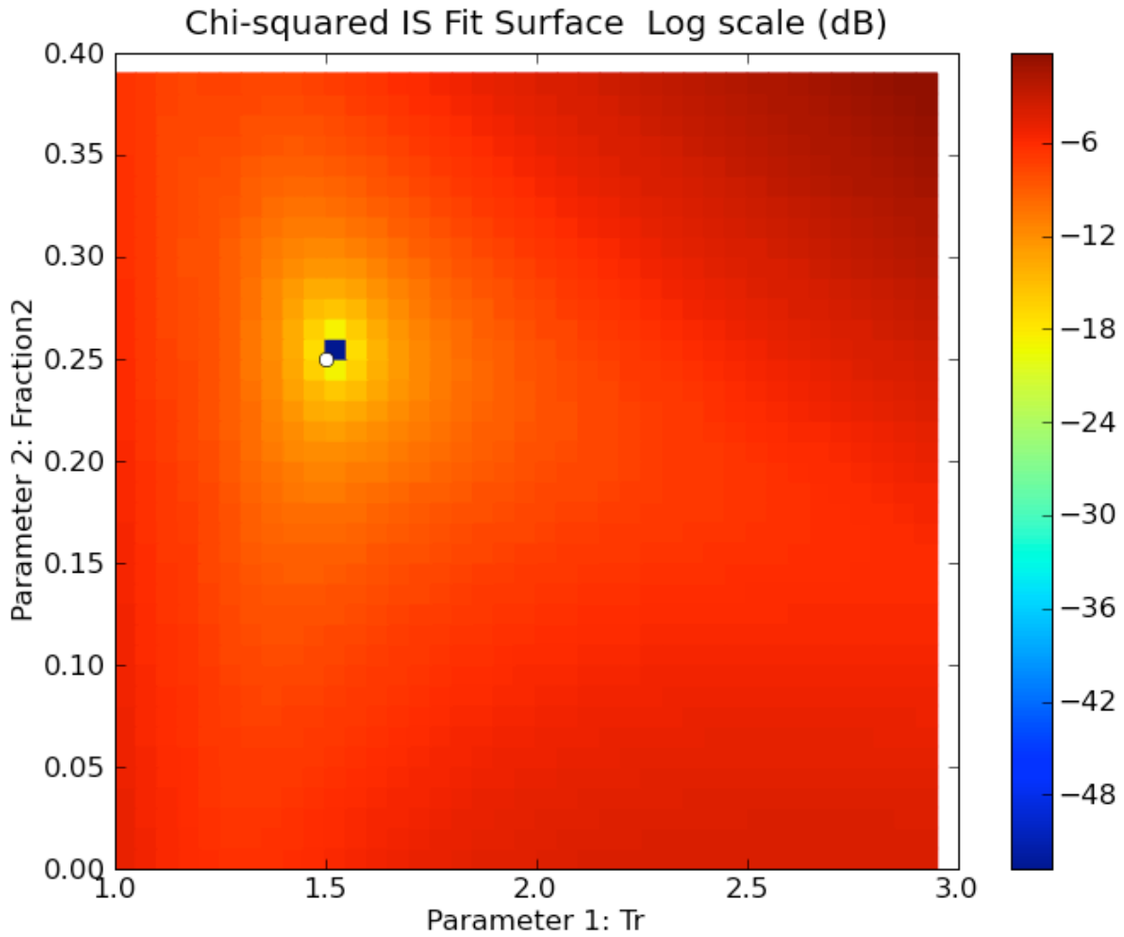
Tr / frac [He+] space

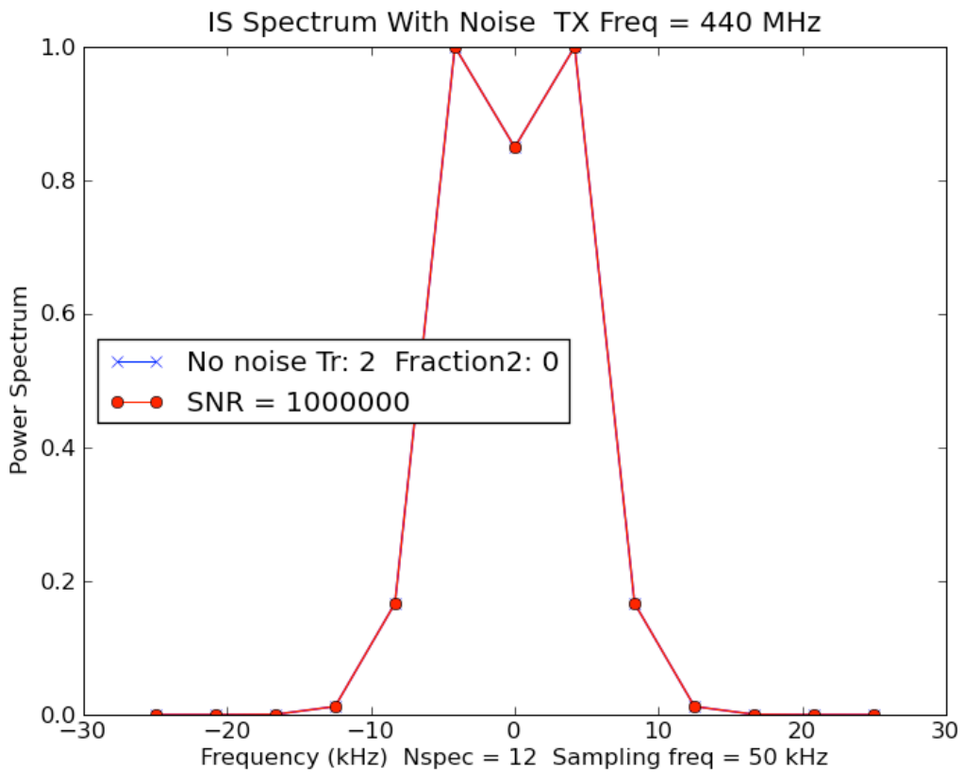
Tr = 1.5 Ti = 1000 O+/He+ mix

frac[He+]=0.25

No noise







440 MHz IS Spectrum
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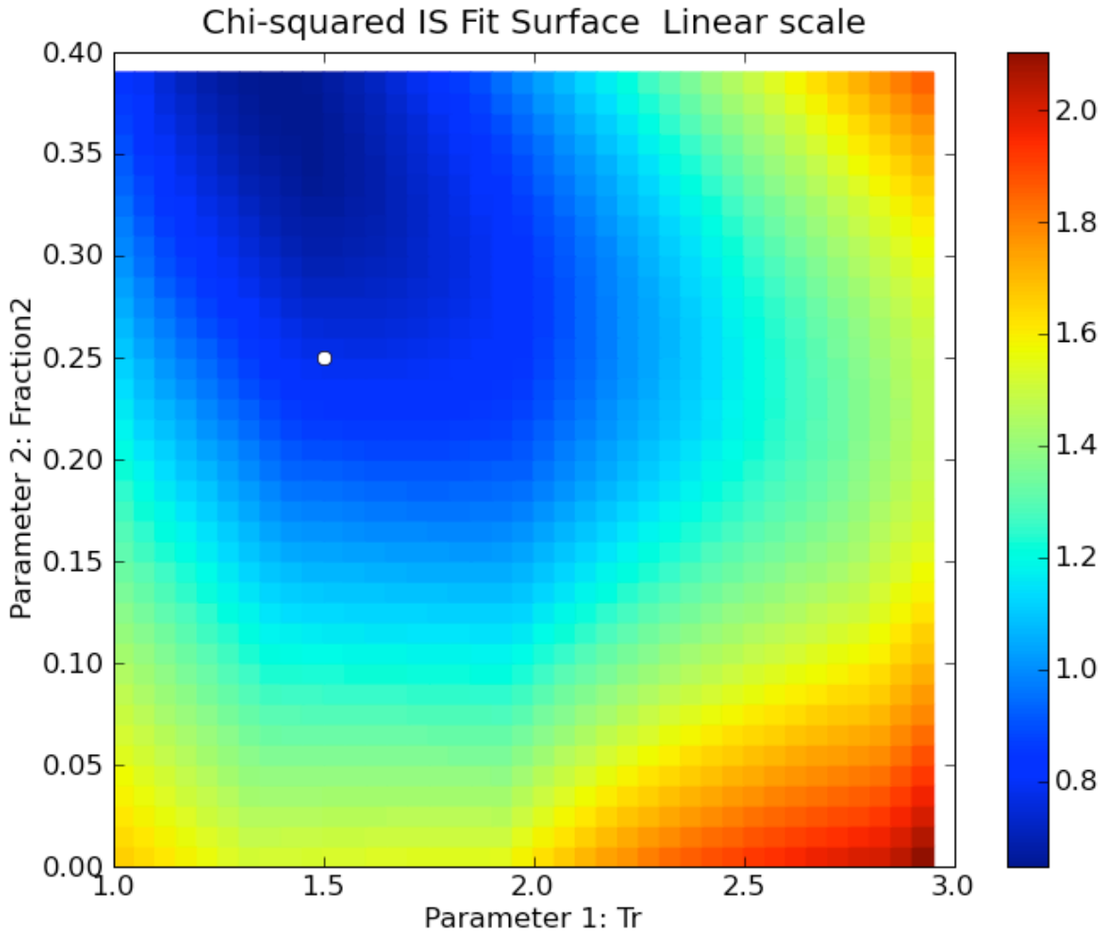
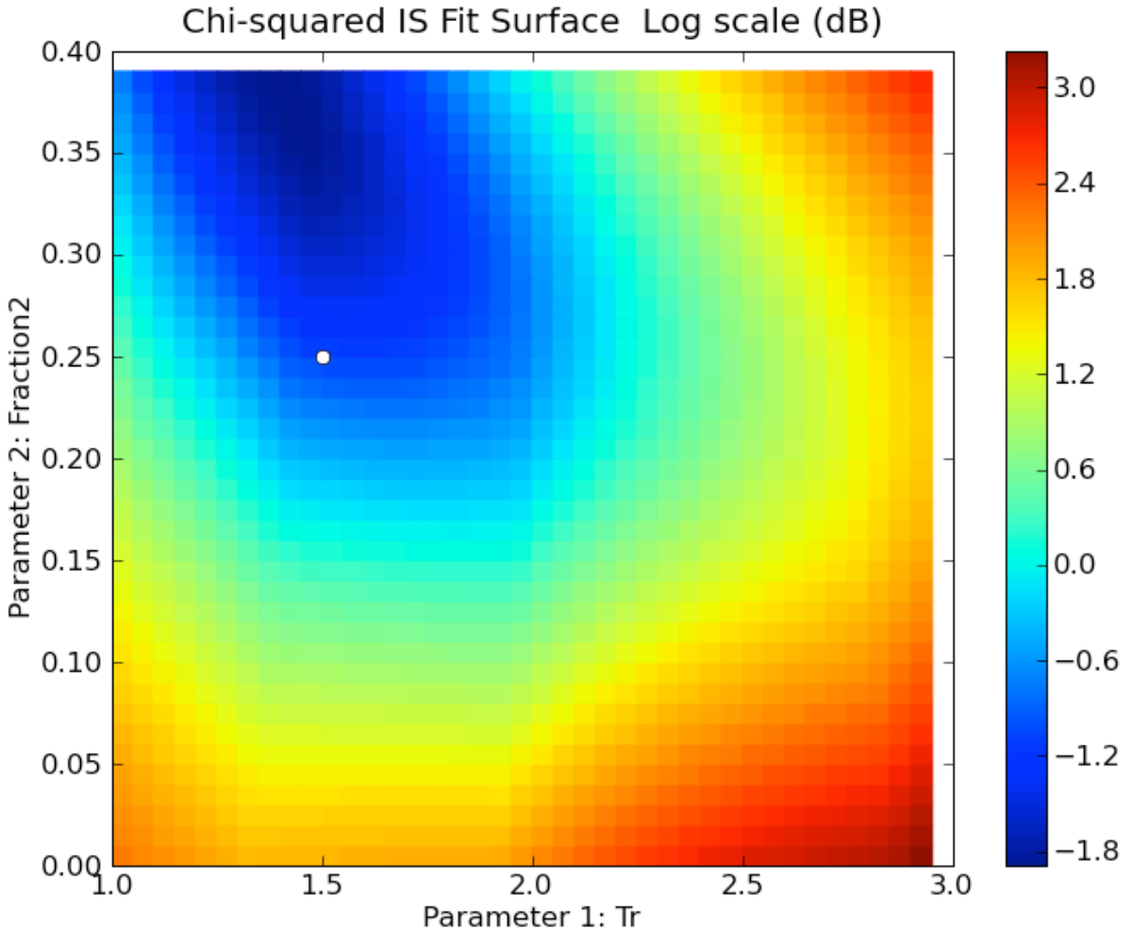
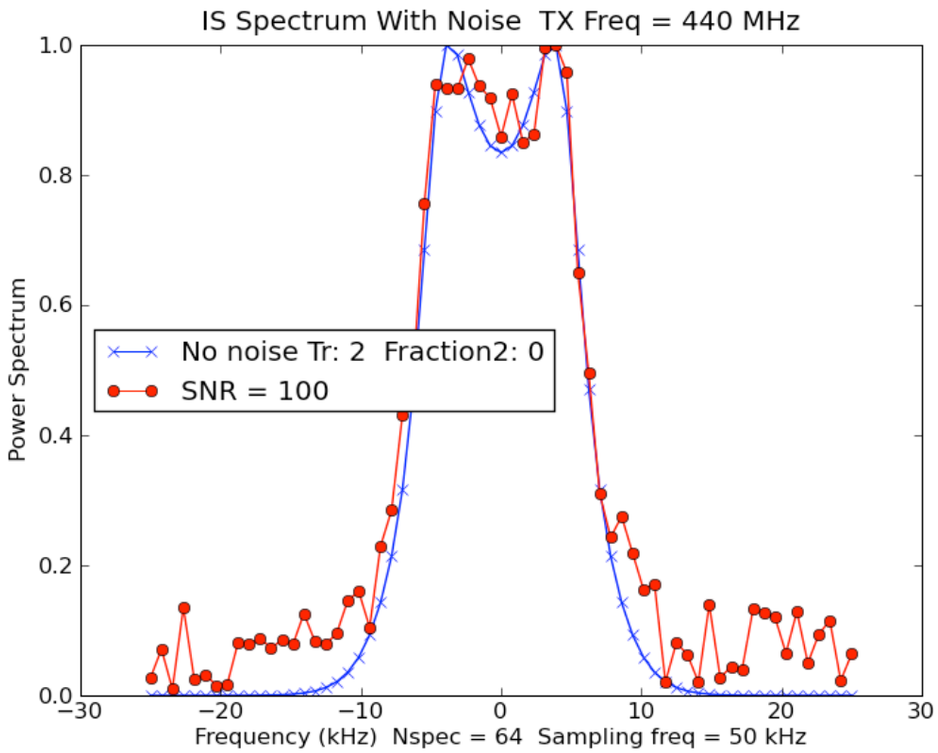
Poor sampling

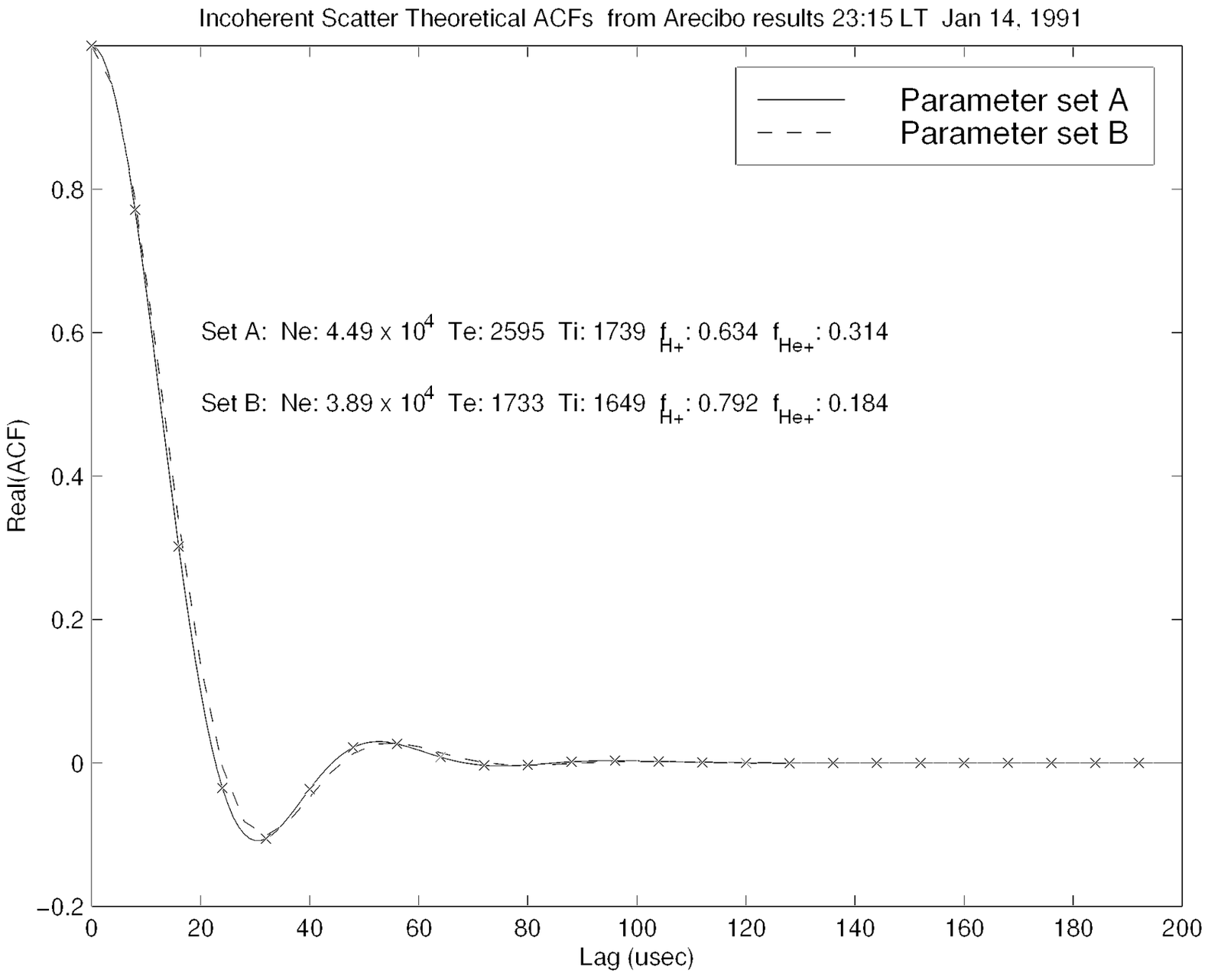






440 MHz IS Spectrum
Tr / frac [He+] space
Tr = 1.5 Ti = 1000 O+/He+ mix
frac[He+]=0.25
Noisy

Arecibo Topside: O+/H+/He+/Te/Ti ambiguity



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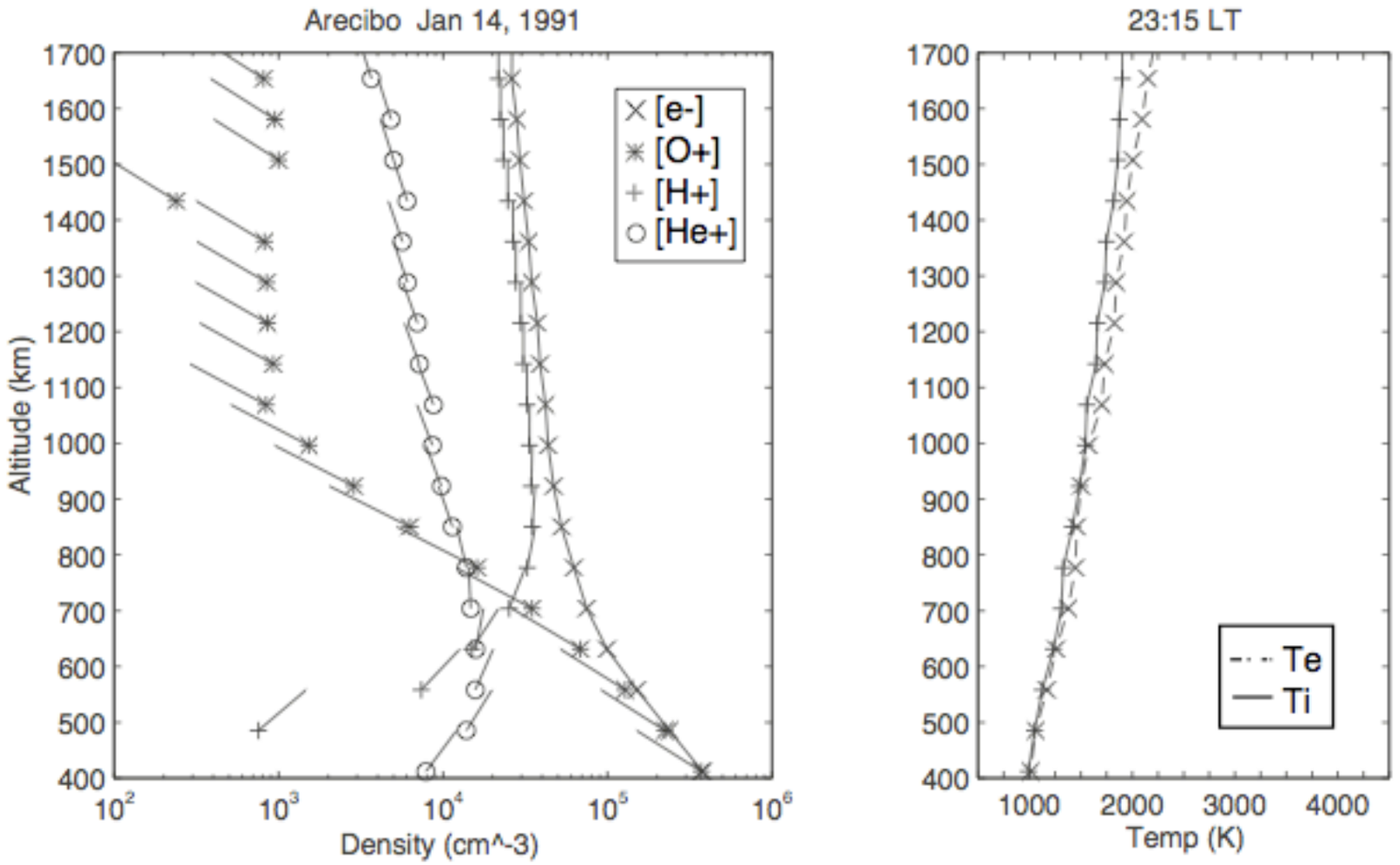

Constraints restore physicality

Figure 5.5: Density and temperature values as a function of altitude over Arecibo at 23:15 LT on January 14, 1991, using a 15 minute integration period. The lines emanating from each density value plotted in the left hand panel are predictions of density variation based on multicomponent diffusive equilibrium. The smooth temperature constraint results in a consistent set of fitted parameters.

cf.
Erickson and Swartz 1994
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Erickson 1998

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Summary:

- Common sense physics should always be applied when interpreting IS experimental measurements
- Be aware of the geophysical context
- Each facility has different location, and data qualities
- Consult staff at your friendly Geospace Facility for advice