Investigation of the Feasibility of Meteoric Smoke Detection with Jicamarca

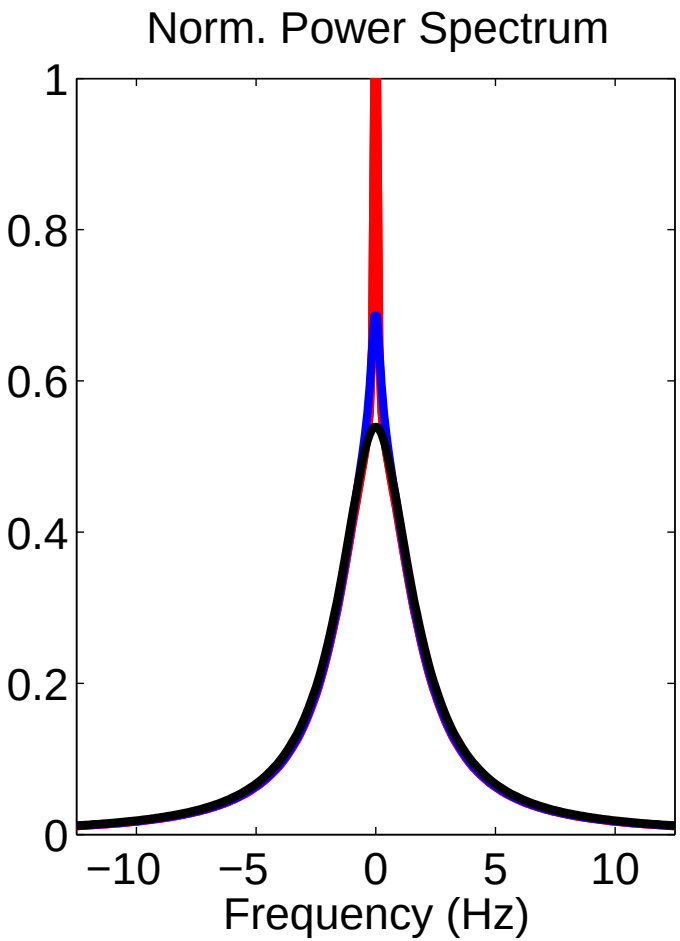
Roger H. Varney [1] Michael C. Kelley [1]
Jorge L. Chau [2]

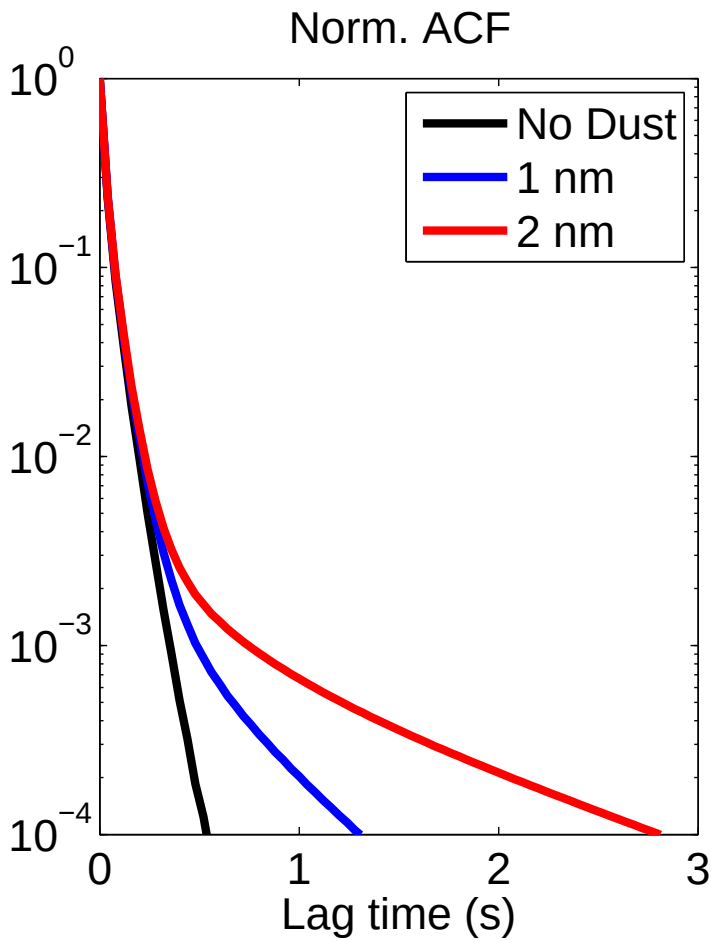
[1]Department of Electrical and Computer Engineering
Cornell University
Ithaca, NY USA

[2]Radio Observatorio de Jicamarca
Instituto Geofísico del Perú
Lima, Peru

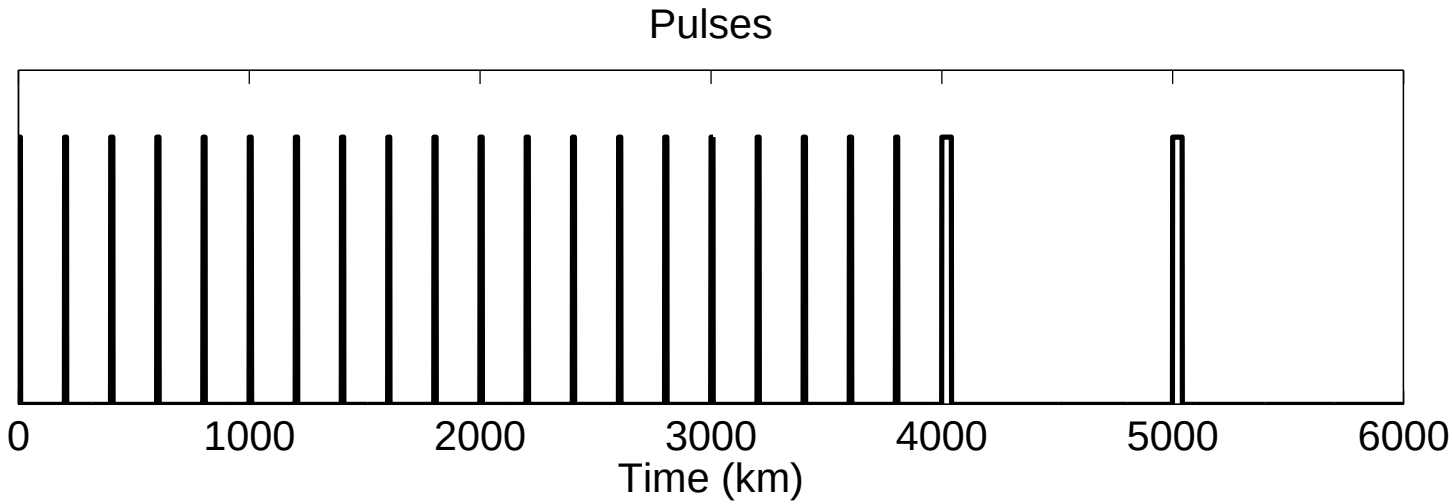
June 12, 2009

Meteoric Smoke Effects on ISR Spectra





MST-ISR Mode



- First 20 pulses for MST data
  - 64-baud complimentary codes
  - 150 m resolution
  - All 20 pulses are coherently integrated
  - Effective IPP of 6000 km (40 ms) after integration
- Last 2 pulses for Faraday rotation
  - 7-baud Barker codes
  - 6 km resolution

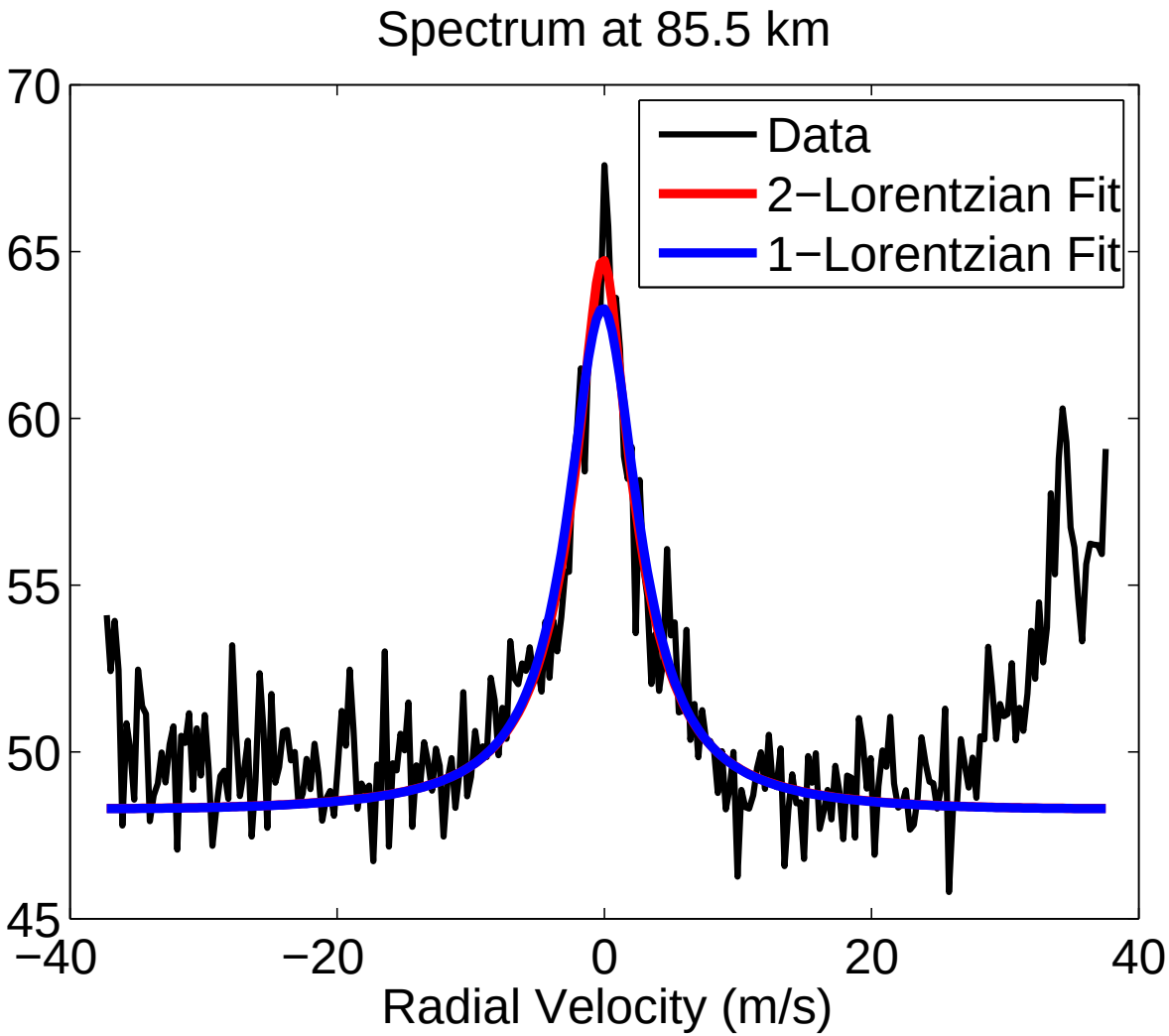
Data Processing Summary

- Model received voltages with a Rayleigh distribution
  - eliminate any return greater than 5σ
- Compute 256 / 512 point spectra
- Incoherently integrate 15 minute blocks
- Fit a single Lorentzian to each block
- Shift spectra to remove Doppler shift and average 4 blocks
- Convert power to electron density using Faraday rotation

Fitting Two Lorentzians

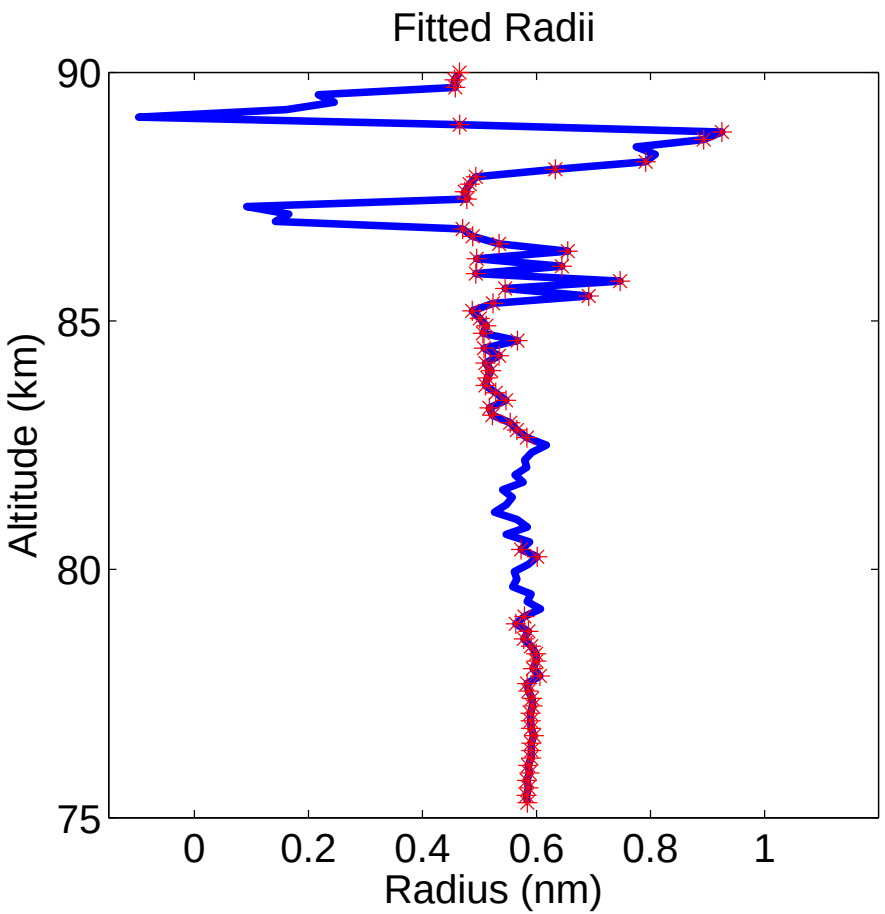
- Doppler shift set to 0
- Spectral width of ion component set by assuming m_i=31 amu, and using temperatures and densities from the MSIS model
- 3 fitted parameters:
  - Size of ion component
  - Size of dust component
  - Spectral width of dust component
- Included several extra penalty terms to encourage fitting two Lorentzians instead of one

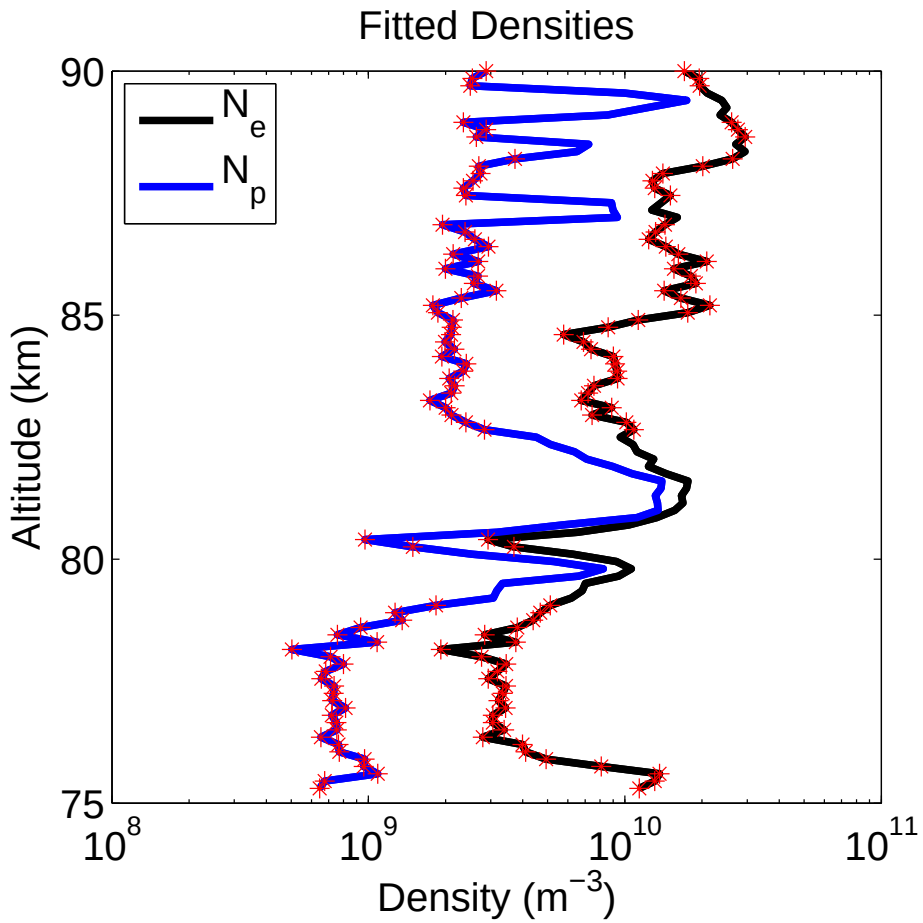
Example Spectrum



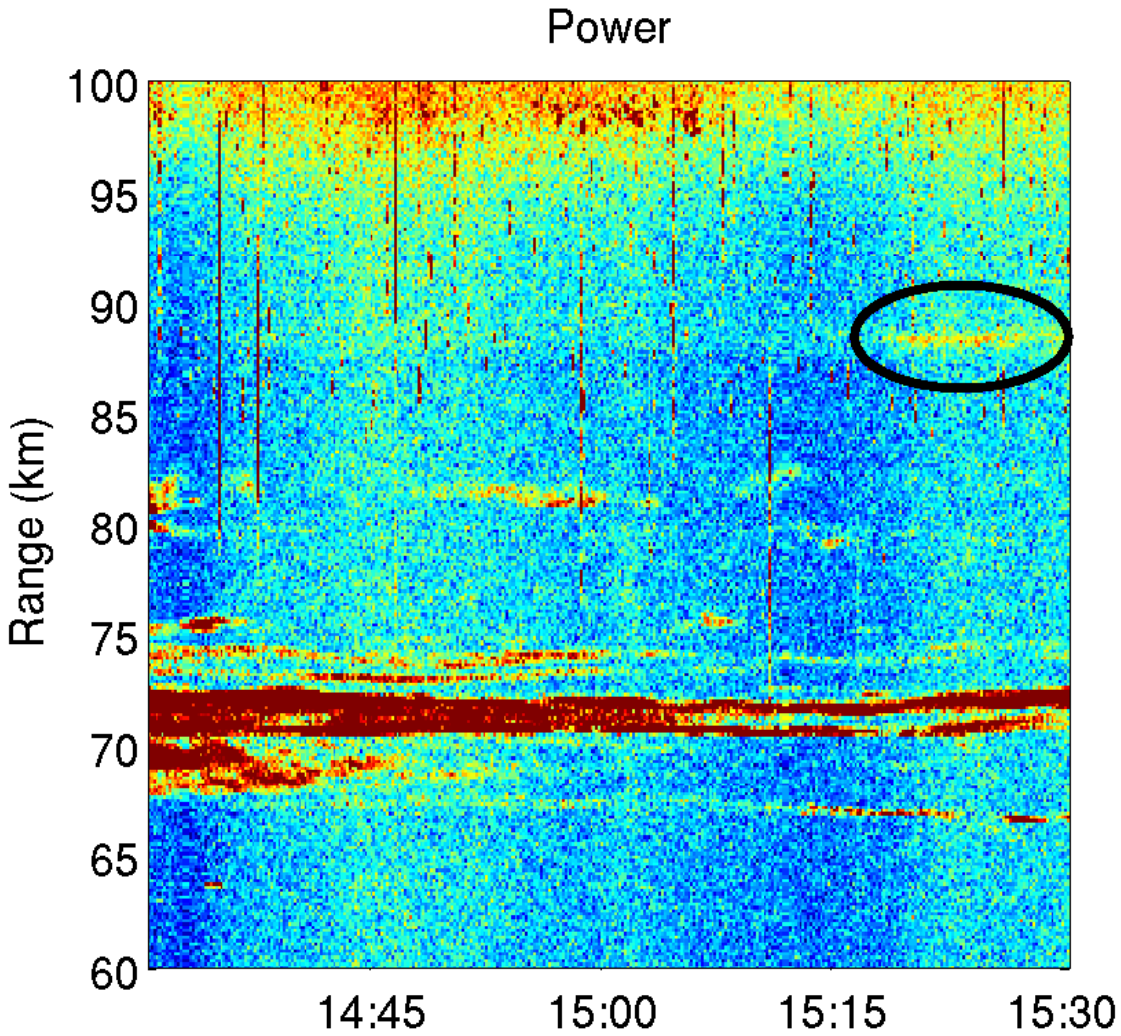
- Single and double Lorentzian fits look nearly identical.
- The interference is almost as strong as the signal itself.

Fitted Parameters



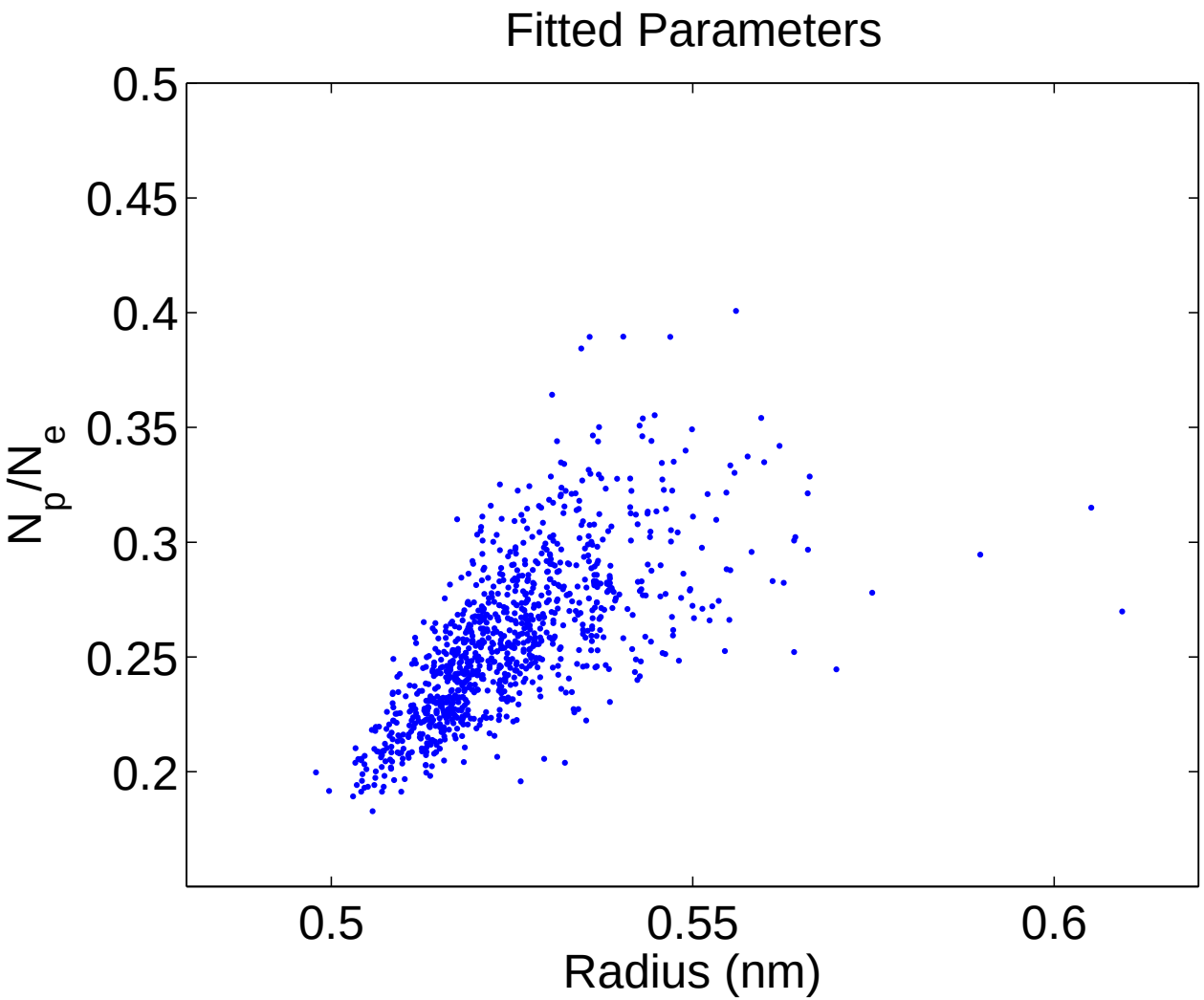


Troublesome Turbulence



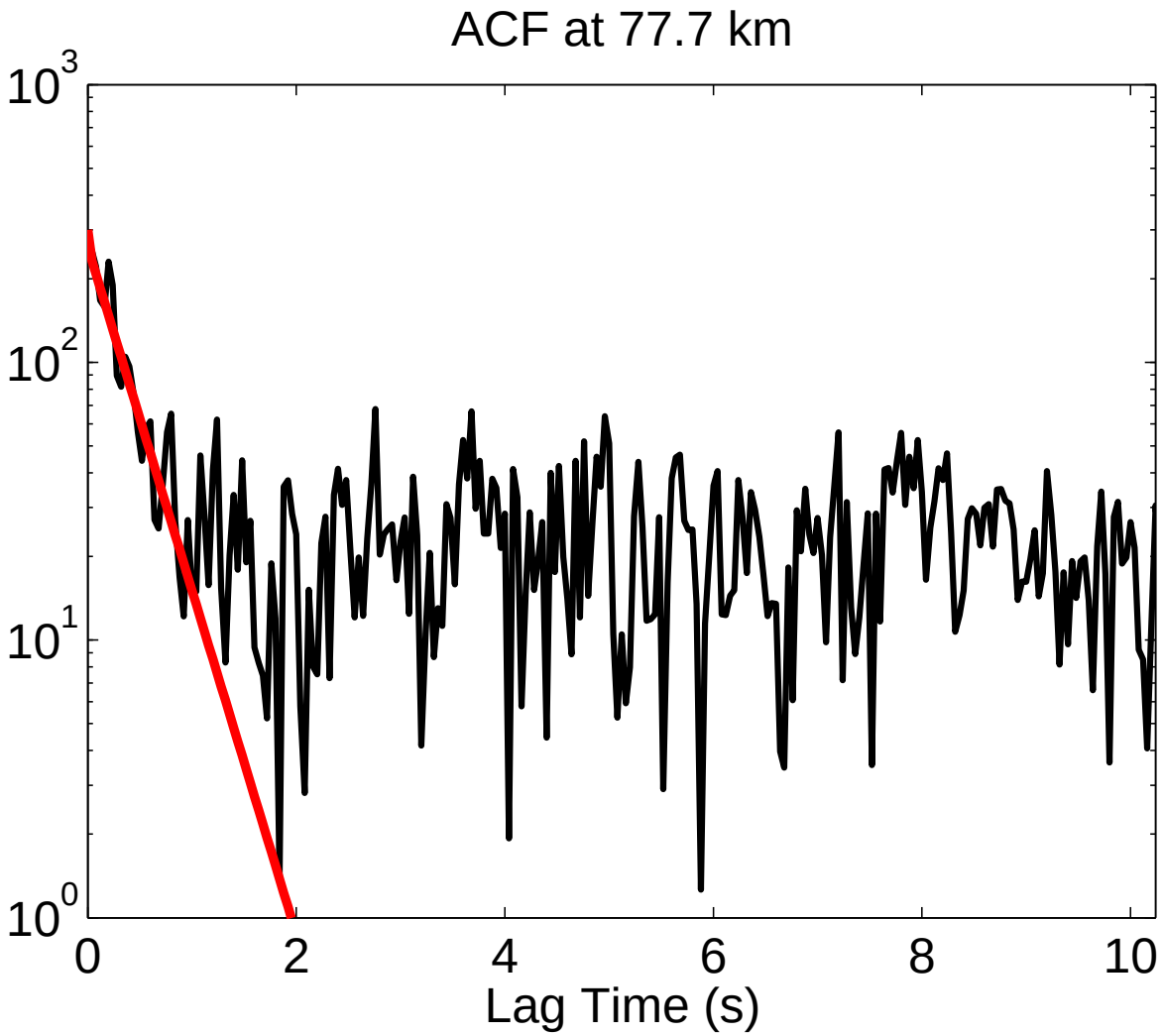
A short patch a turbulence at the end of the integration period will appear like dust.

Monte Carlo Results with No Input Dust



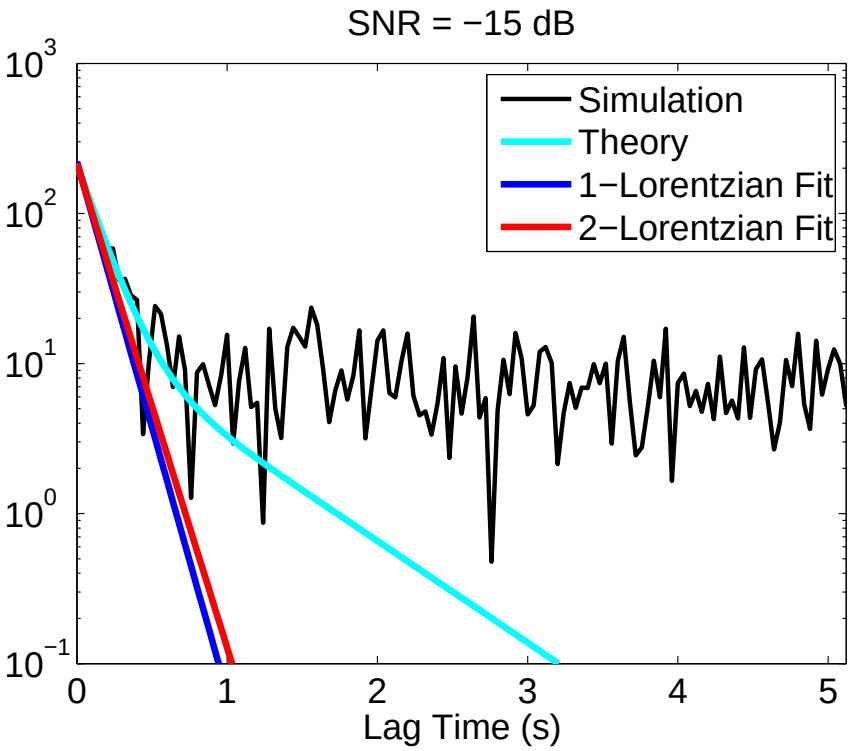
- Fitted parameters cluster around $r_p = 0.52$ nm and $N_p = 0.25 N_e$
- The extra regularization which encouraged fitting two Lorentzians is creating false and misleading results

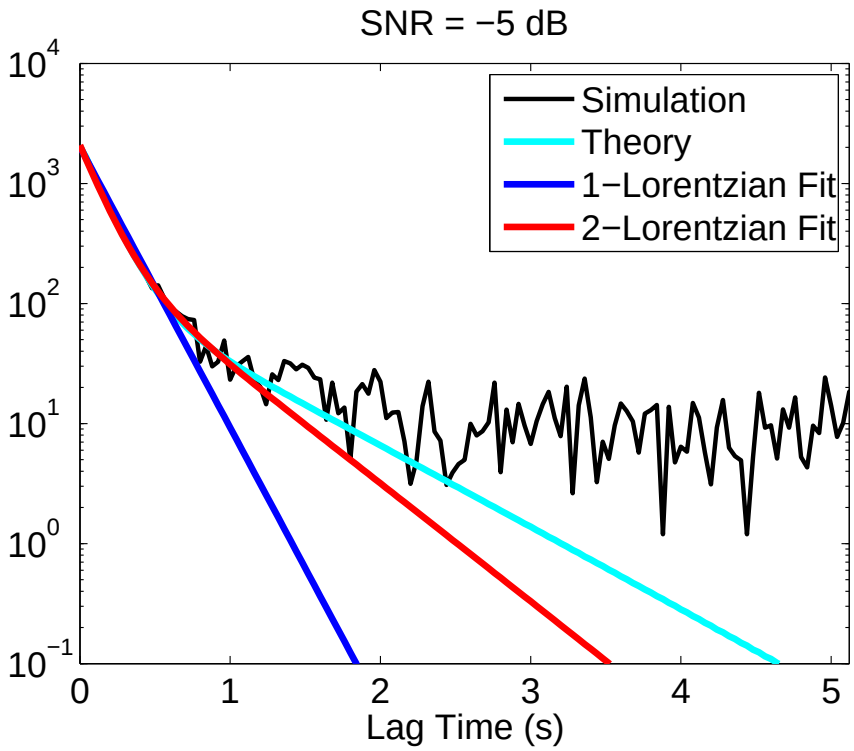
Example Autocorrelation Functions



- Voltages passed through FIR filter to remove interference
- Colored noise subtracted off
- No evidence of two slopes is visible

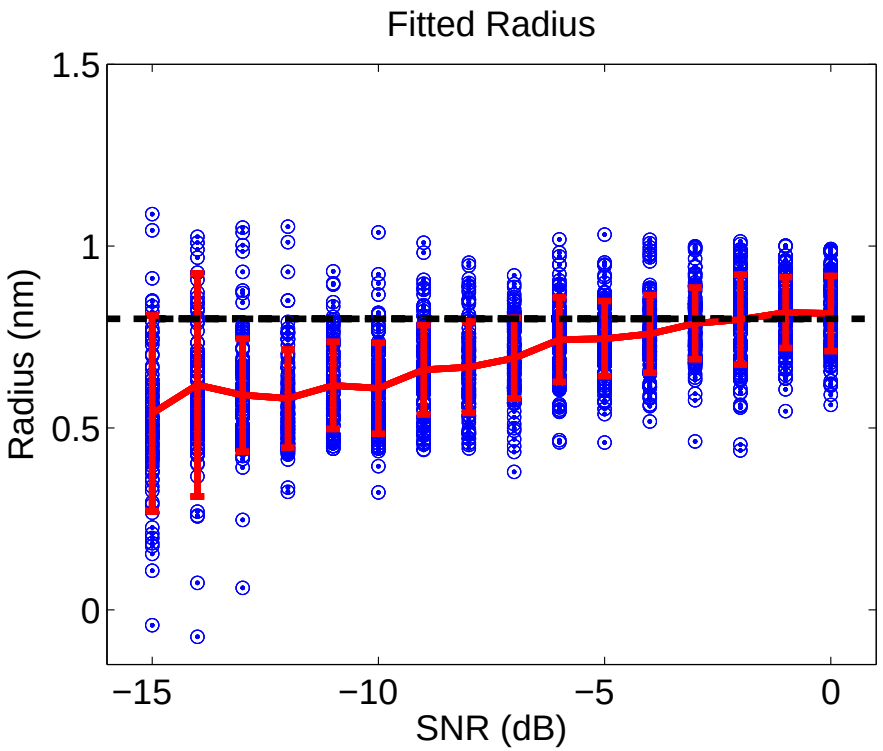
Simulated Autocorrelation Functions

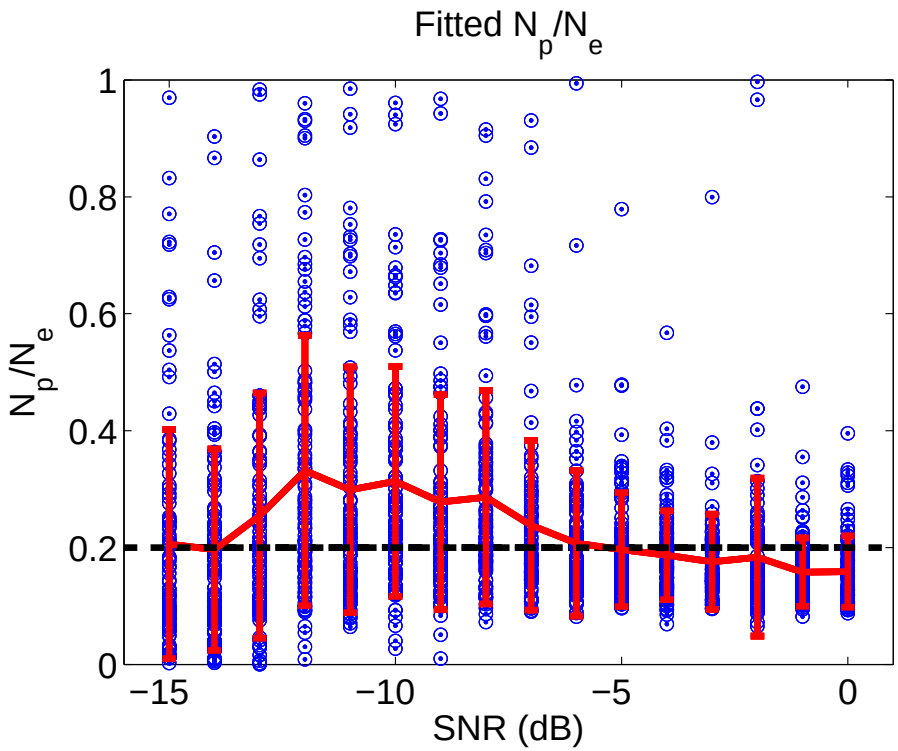




Monte Carlo Simulation of Autocorrelation Function Fits

Fixed parameters: $r_p = 0.8$ nm, $\frac{N_p}{N_e} = 0.2$, 1400 integrations





Results appear reliable above −6 dB

Why can Arecibo Detect Dust?

Arecibo

- $SNR = -15\mathrm{dB}$
- IPP $= 1.04$ ms
- 256 point spectra
- 0.266 s per spectrum
- 13521 spectra per hour of integration

Why can Arecibo Detect Dust?

Arecibo

- $SNR = -15\mathrm{dB}$
- IPP = 1.04 ms
- 256 point spectra
- 0.266 s per spectrum
- 13521 spectra per hour of integration

Jicamarca

- $SNR = -15$ to $-10\mathrm{dB}$
- IPP = 40 ms
- 256 point spectra
- 10.24 s per spectrum
- 4 channels
- 1406 spectra per hour of integration

Why can Arecibo Detect Dust?

Arecibo

- $SNR = -15\mathrm{dB}$
- IPP = 1.04 ms
- 256 point spectra
- 0.266 s per spectrum
- 13521 spectra per hour of integration

Jicamarca

- $SNR = -15$ to $-10\mathrm{dB}$
- IPP = 40 ms
- 256 point spectra
- 10.24 s per spectrum
- 4 channels
- 1406 spectra per hour of integration

To match the statistical accuracy which Strelnikova et al. (2007) achieves with 1 h 40 min of integration at Arecibo, we would need to integrate for 16 hours!!

Summary and Recommendations

- The needed statistical accuracy for smoke detection cannot be reasonably achieved with the current MST-ISR mode.
- The amount of incoherent integration needed could be made more reasonable it the SNR were increased by $\sim$ 5dB.
- SNR can be increased by
  - Omitting Faraday rotation pulses and coherently integrating 30 times instead of 20
  - Using the entire array to transmit
  - Combining both transmitters into a single polarization, and receive on that polarization