# Incoherent Scatter from Dusty Plasmas Created by the Charged Aerosol Release Experiment

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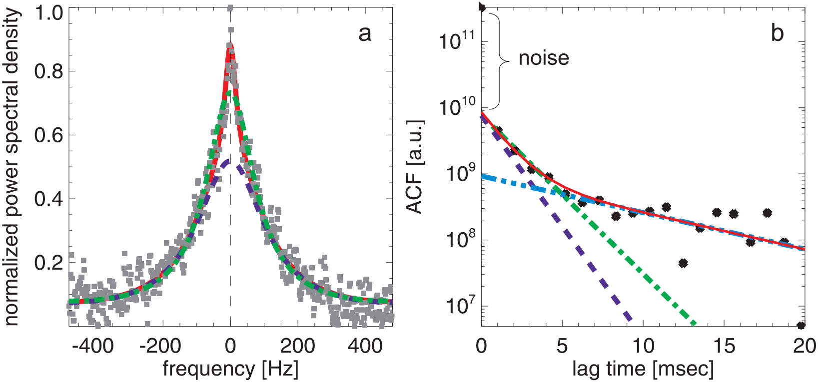
October 18, 2009

# Motivation: Arecibo Measurements of Meteoric Smoke



[Strelnikova *et al.*, *GRL*, 2007]

# Incoherent Scatter Theory

$n_d^{-1/3} < \lambda_D$:

$$\langle |n_{e1}|^2 \rangle = 2n_e \frac{|1+\chi_i+\chi_d|^2 \langle |n_e|^2 \rangle + |\chi_e|^2 \langle |n_i|^2 \rangle + Z_d^2 |\chi_e|^2 \langle |n_d|^2 \rangle}{|1+\chi_e+\chi_i+\chi_d|^2}$$

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[Hagfors, *JASTP*, 1992; La Hoz, *Phys. Scr.*, 1992]

# Incoherent Scatter Theory

Rewriting the spectrum in terms of normalized admittance:

$$2n_e \frac{\left|\frac{T_e n_i}{T_i n_e} y_i + \frac{Z_d^2 T_e n_d}{T_d n_e} y_d - ik^2\lambda_{De}^2\right|^2 \frac{\Re(y_e)}{\omega_e} + |y_e|^2 \frac{n_i \Re(y_i)}{n_e \omega_i} + |y_e|^2 \frac{Z_d^2 n_d \Re(y_d)}{n_e \omega_d}}{\left|y_e + \frac{T_e n_i}{T_i n_e} y_i + \frac{Z_d^2 T_e n_d}{T_d n_e} y_d - ik^2\lambda_{De}^2\right|^2}$$

Note:

- Ion line power is related to $n_i$ not $n_e$
- Dust line power is related to $Z_d^2 n_d$
- $\frac{T_e}{T_i} \Rightarrow \frac{T_e n_i}{T_i n_e}$

# Total Scattered Power

$n_d^{-1/3} < \lambda_D$:

$$P \propto \frac{n_i}{\left(1+k^2\lambda_{De}^2\right)\left(1+\frac{T_e n_i}{T_i n_e}+k^2\lambda_{De}^2\right)} + \frac{Z_d^2 n_d}{\left(1+\frac{T_e n_i}{T_i n_e}+k^2\lambda_{De}^2\right)\left(1+\frac{T_e n_i}{T_i n_e}+\frac{Z_d^2 T_e n_d}{T_i n_e}+k^2\lambda_{De}^2\right)}$$

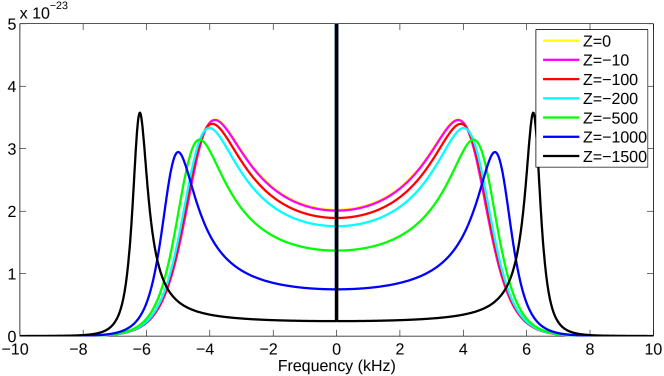
$n_d^{-1/3} < \lambda_D$:

$$P \propto \frac{n_i}{\left(1+k^2\lambda_{De}^2\right)\left(1+\frac{T_e n_i}{T_i n_e}+k^2\lambda_{De}^2\right)} + \frac{Z_d^2 n_d}{\left(1+\frac{T_e n_i}{T_i n_e}+k^2\lambda_{De}^2\right)^2}$$

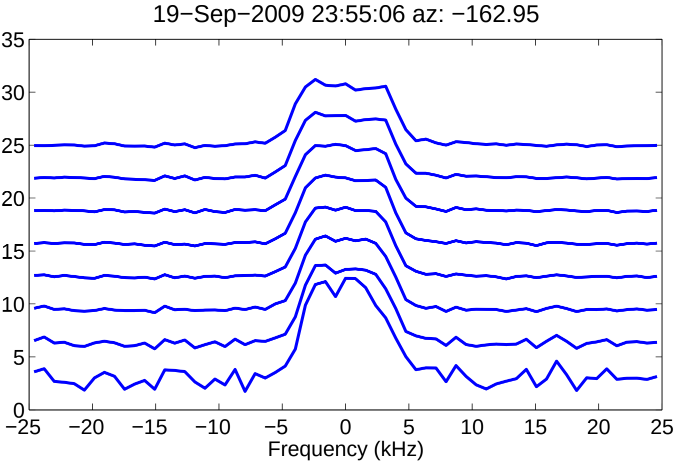
# Dust Effects on Ion Line

Dust ion acoustic wave velocity:

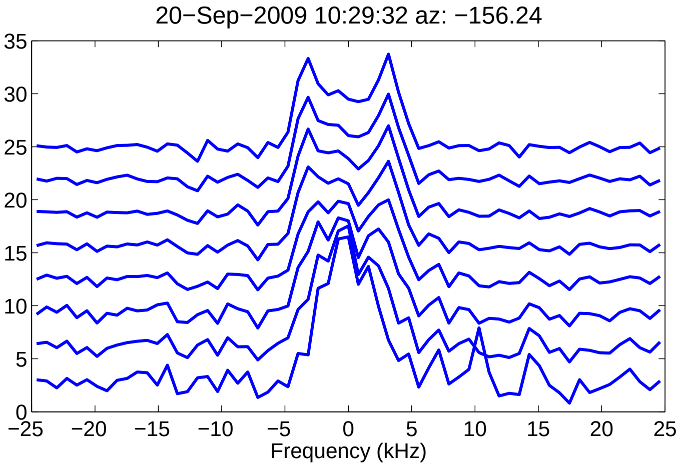
$$c_{DIAW}^2 = \frac{n_i}{n_e} \frac{k_B T_e + \gamma k_B T_i}{m_i}$$



# Spectra after CARE launch



# Spectra After Dawn



# Qualitative Spectral Characteristics

| Characteristic | Controlling Parameters |
|---|---|
| Power in ion line | $n_i$ |
| Power in dust line | $Z_d^2 n_d$ |
| Location of ion acoustic peaks | $T_i$, $m_i$ |
| Sharpness of ion acoustic peaks | $\frac{T_e n_i}{T_i n_e}$ |

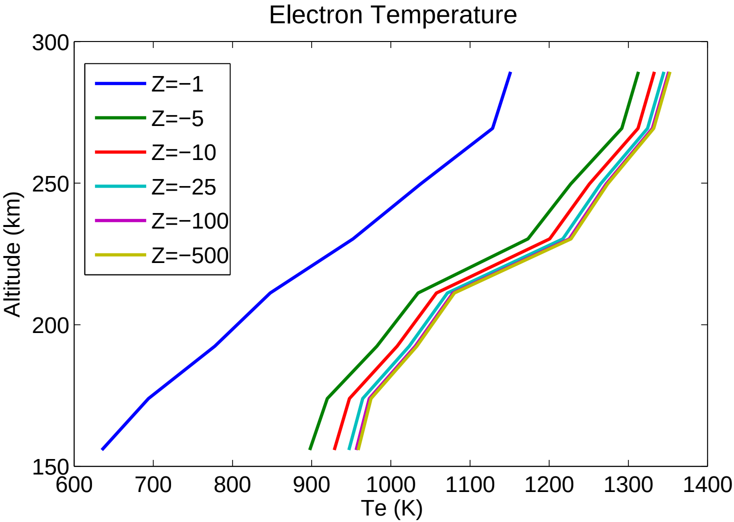
Note that $T_e$ and $n_e$ are not well specified.

# Simplified Model for Fitting

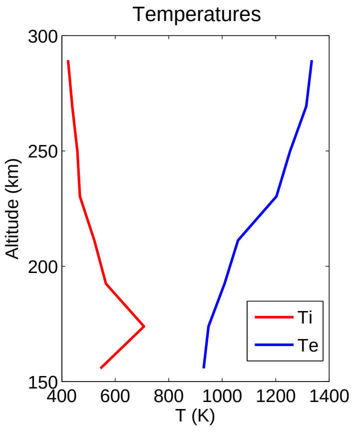
- Treat the dust line as a $\delta$-function
- Fit for $T_i$, $\frac{T_e}{T_i}$, $Z_d^2 n_d, V_i, V_d$
- Fix $Z_d$, $m_i$, and ion composition
- Solve for $n_e$ and $n_i$ such that the total scattered power is consistent with the calibrated SNR and

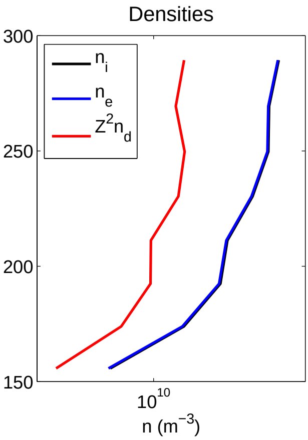
$$n_e = n_i - |Z_d| n_d$$

# Bias Associated with Fixing Z

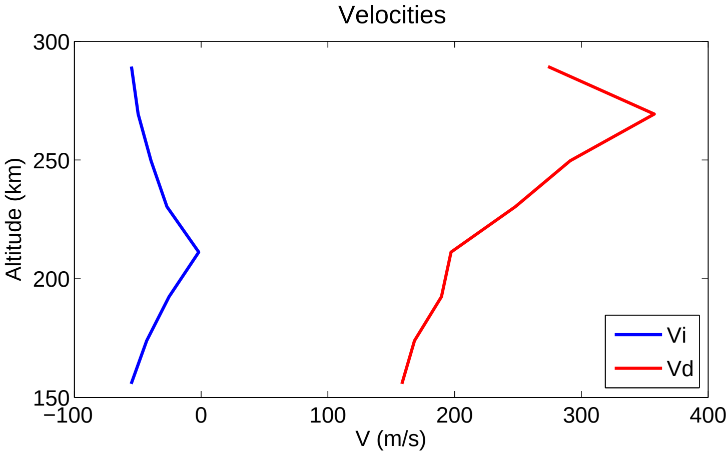


# Results for $Z = -10$





# Fitted Velocities



# Remaining Questions

- Are the dust velocities reasonable?
- What is the ion composition?
- What are bound on $Z_d$ or $n_d$?
- Are there additional measurements of $n_e$ or $T_e$ which I could incorporate?