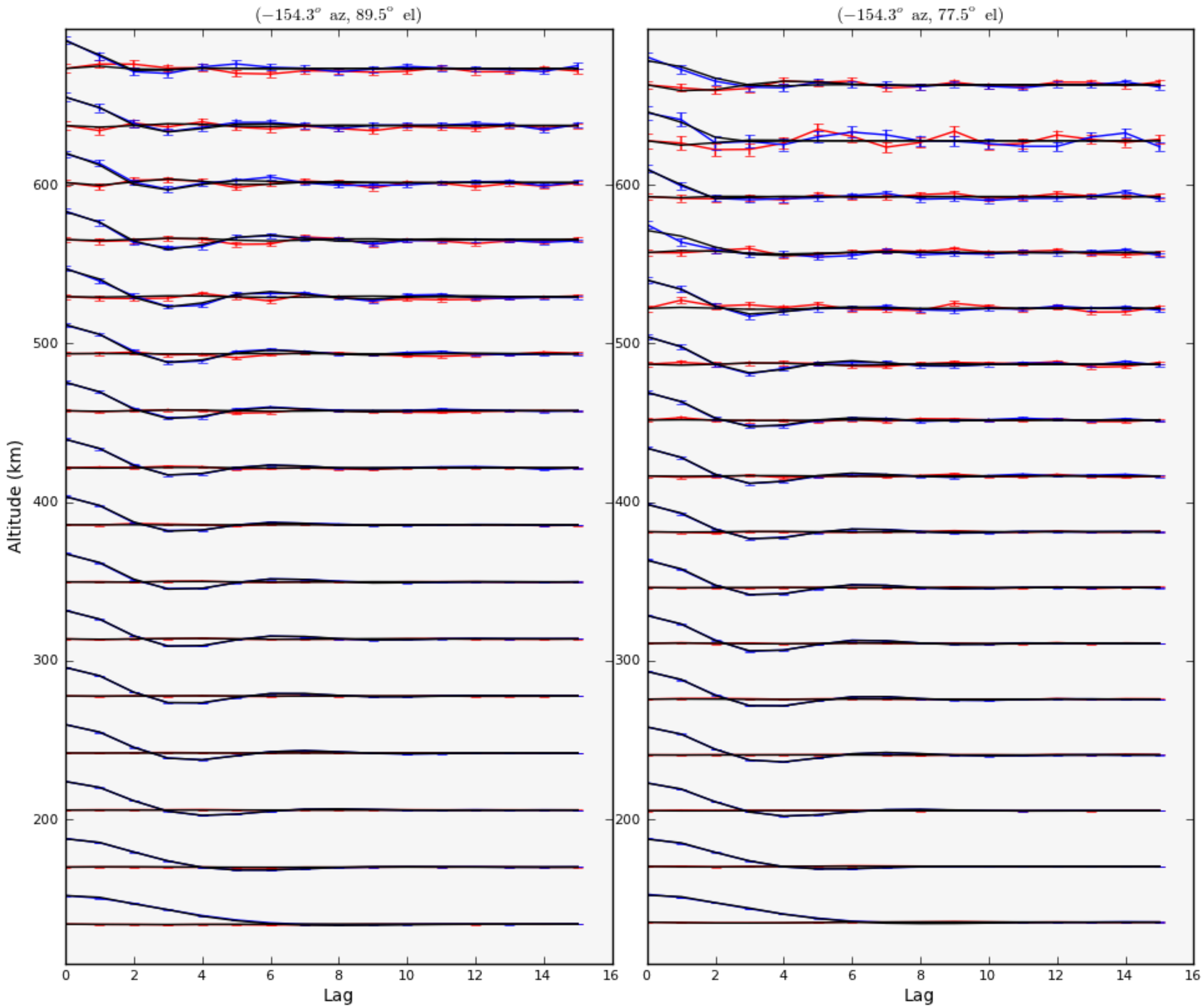
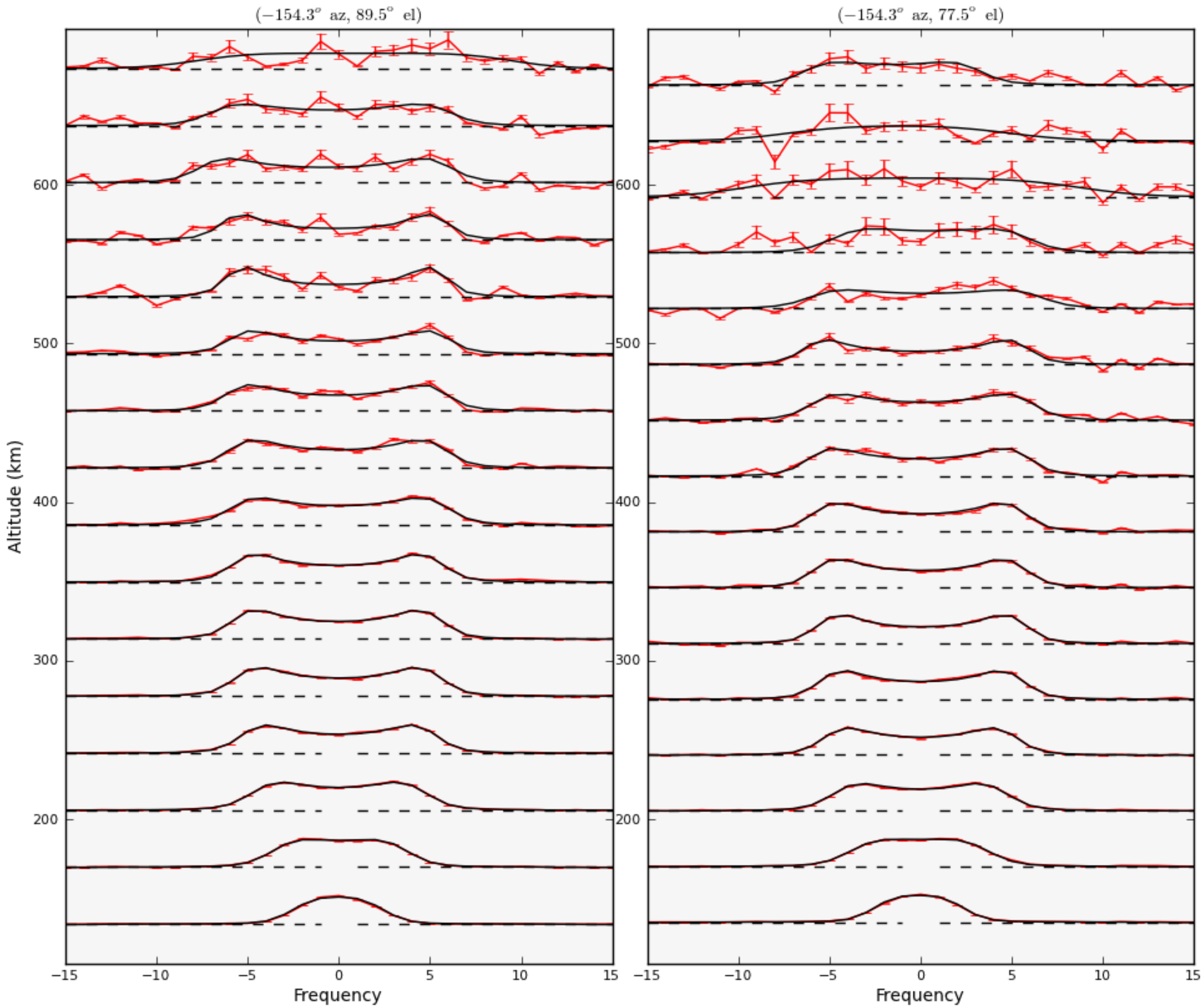
Incoherent Scatter Radar Spectra
(and other stuff)

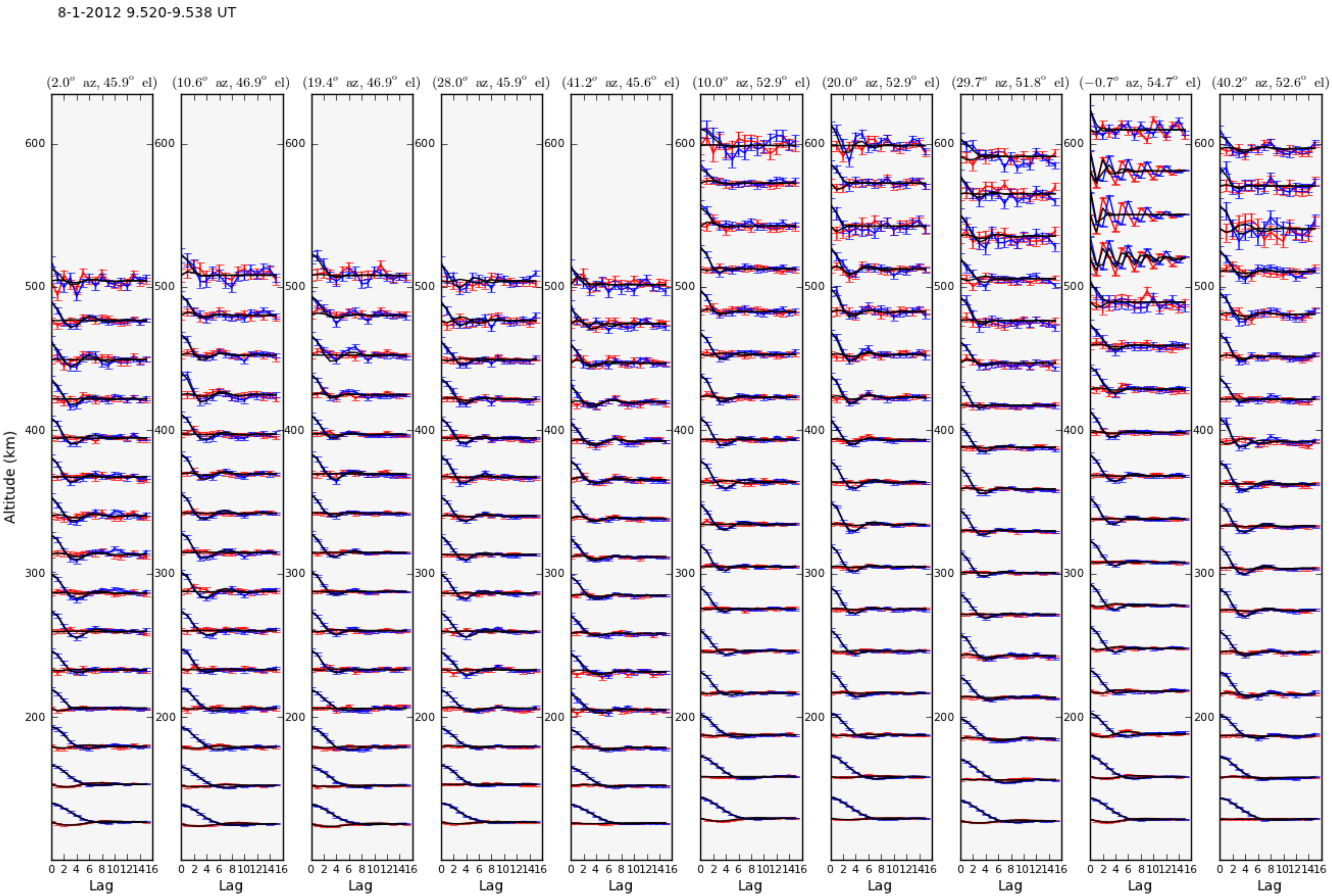
Additional Plots Available

8-1-2012 3.514-3.534

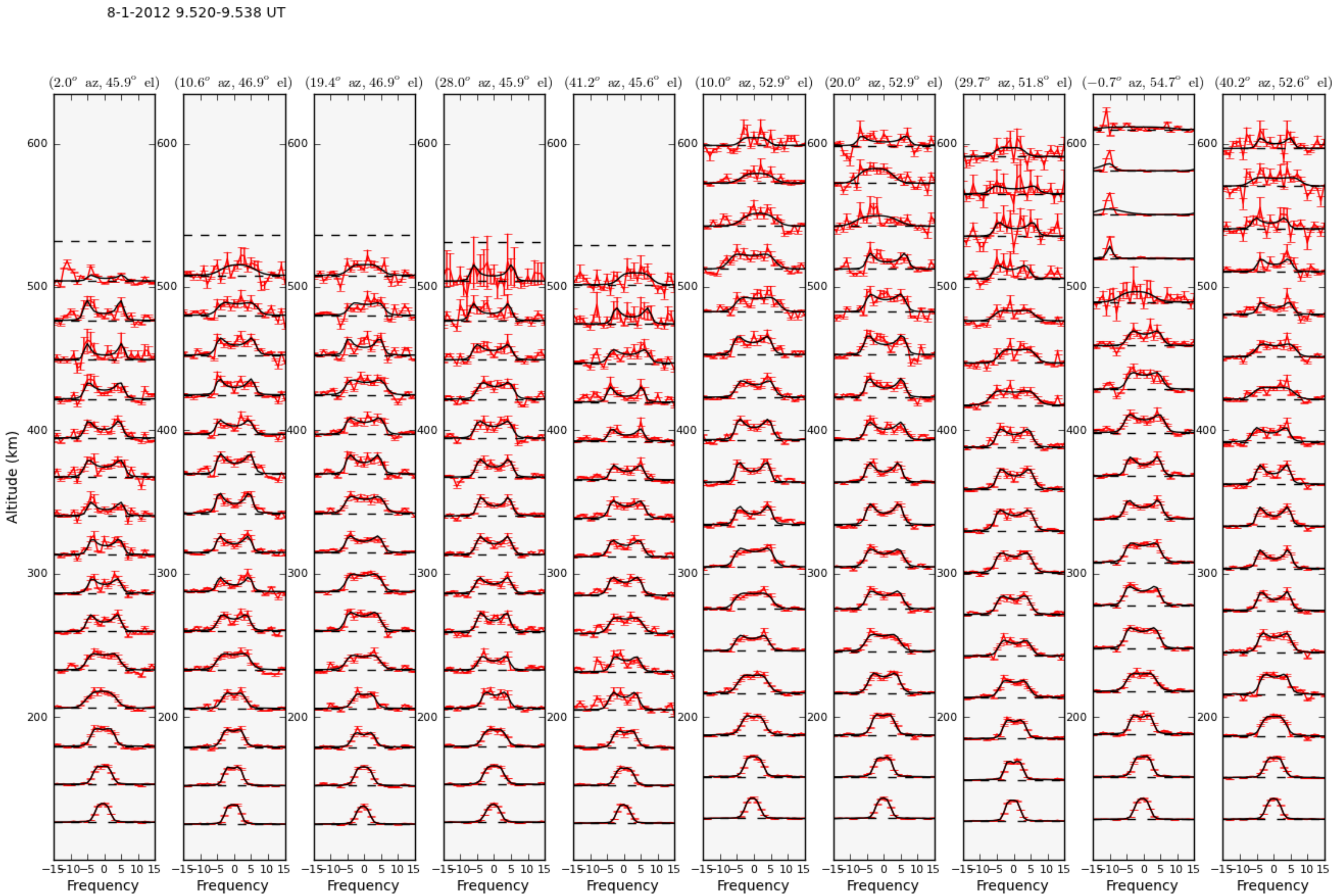


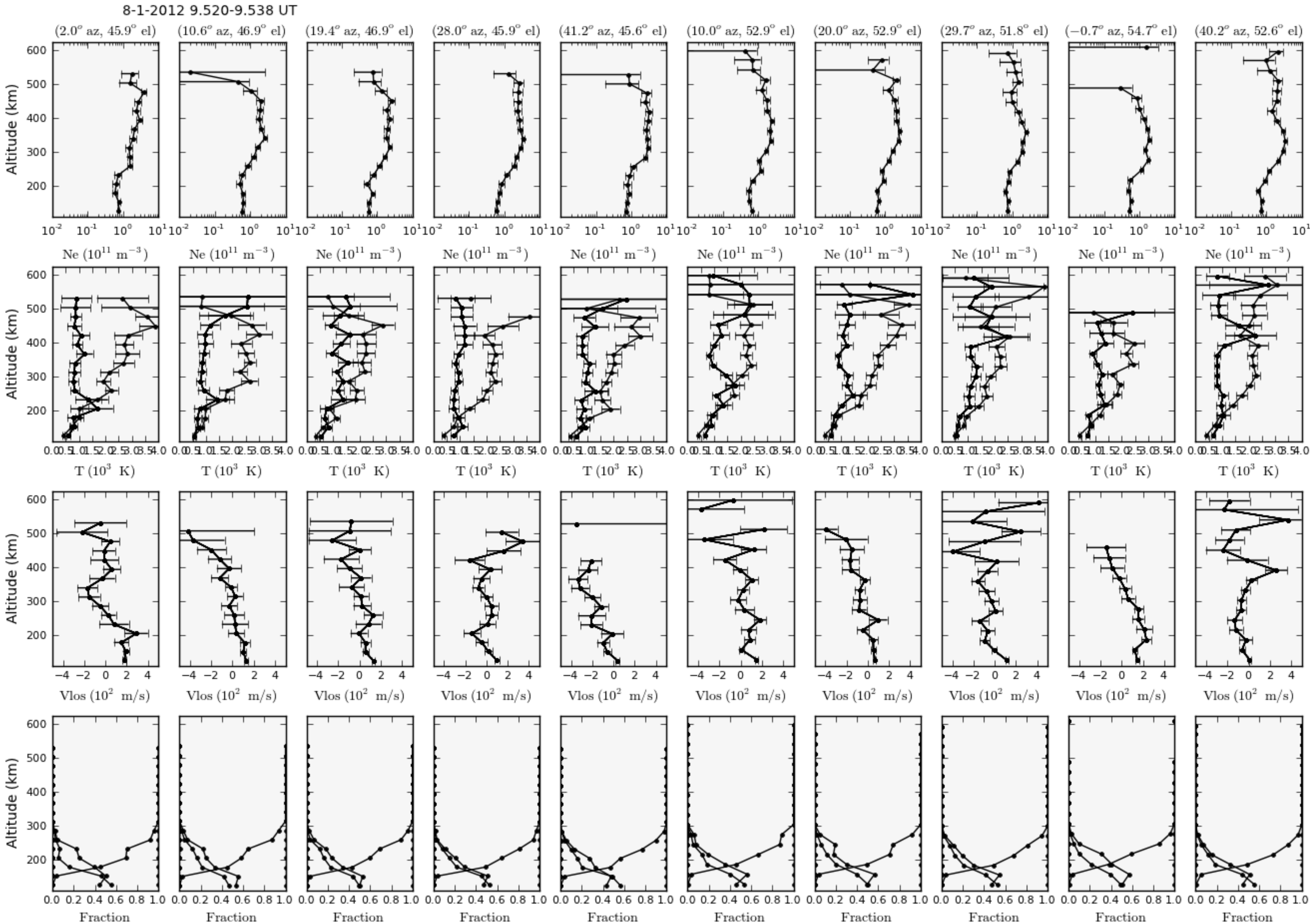
8-1-2012 3.514-3.534 UT





8-1-2012 9.520-9.538 UT
(2.0° az, 45.9° el)
(10.6° az, 46.9° el)
(19.4° az, 46.9° el)
(28.0° az, 45.9° el)
(41.2° az, 45.6° el)
(10.0° az, 52.9° el)
(20.0° az, 52.9° el)
(29.7° az, 51.8° el)
(−0.7° az, 54.7° el)
(40.2° az, 52.6° el)
Altitude (km)
600
500
400
300
200
0 2 4 6 8 10 12 14 16
Lag


8-1-2012 9.520-9.538 UT
(2.0° az, 45.9° el)
(10.6° az, 46.9° el)
(19.4° az, 46.9° el)
(28.0° az, 45.9° el)
(41.2° az, 45.6° el)
(10.0° az, 52.9° el)
(20.0° az, 52.9° el)
(29.7° az, 51.8° el)
(−0.7° az, 54.7° el)
(40.2° az, 52.6° el)
Altitude (km)
600
500
400
300
200
−15 −10 −5 0 5 10 15
Frequency



8-1-2012 9.520-9.538 UT
(2.0° az, 45.9° el)
(10.6° az, 46.9° el)
(19.4° az, 46.9° el)
(28.0° az, 45.9° el)
(41.2° az, 45.6° el)
(10.0° az, 52.9° el)
(20.0° az, 52.9° el)
(29.7° az, 51.8° el)
(−0.7° az, 54.7° el)
(40.2° az, 52.6° el)
Altitude (km)
Ne (10^11 m^-3)
T (10^3 K)
Vlos (10^2 m/s)
Fraction

N_e From Ion Line vs. Plasma Line

Ion Line

$$N_e(r) = (1 + k^2\lambda_D^2)(1 + k^2\lambda_D^2 + T_r)\frac{C_s}{P_T\tau_p}P_r(r)$$

$$k = {2\pi}/{\lambda_{TX}} + {2\pi}/{\lambda_{RX}}$$

$$\lambda_D = \sqrt{{\varepsilon_0 k_B T_e}/{q_e^2 N_e}}$$

So N_e is proportional to the received power from the ion line (a noise-like signal) and is affected to a very minimal extent by λ_D.

N_e From Ion Line vs. Plasma Line

Plasma Line

$$f_{pl}^2 \approx f_{pe}^2 + \frac{3k^2}{4\pi^2}\frac{k_B T_e}{m_e}$$

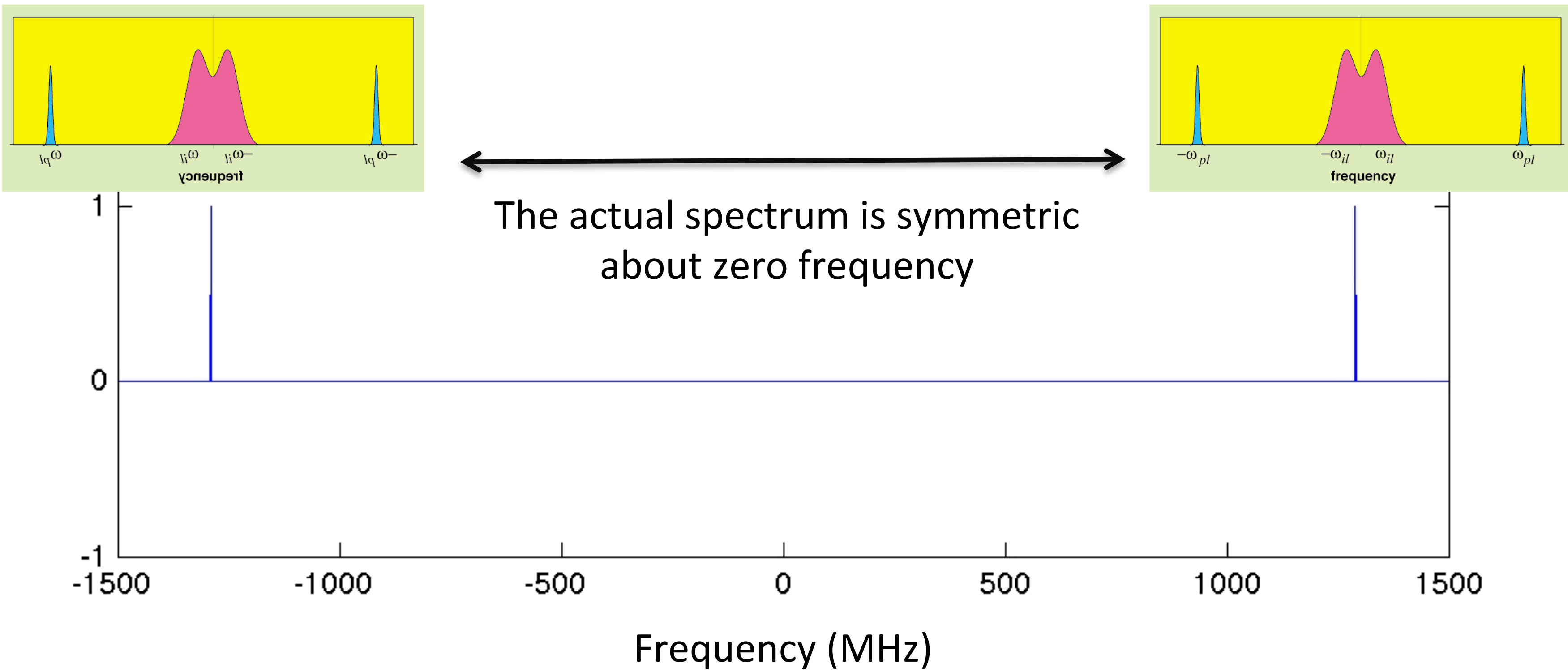
$$f_{pe} = \frac{1}{2\pi}\sqrt{N_e q_e^2 / m_e \varepsilon_0}$$

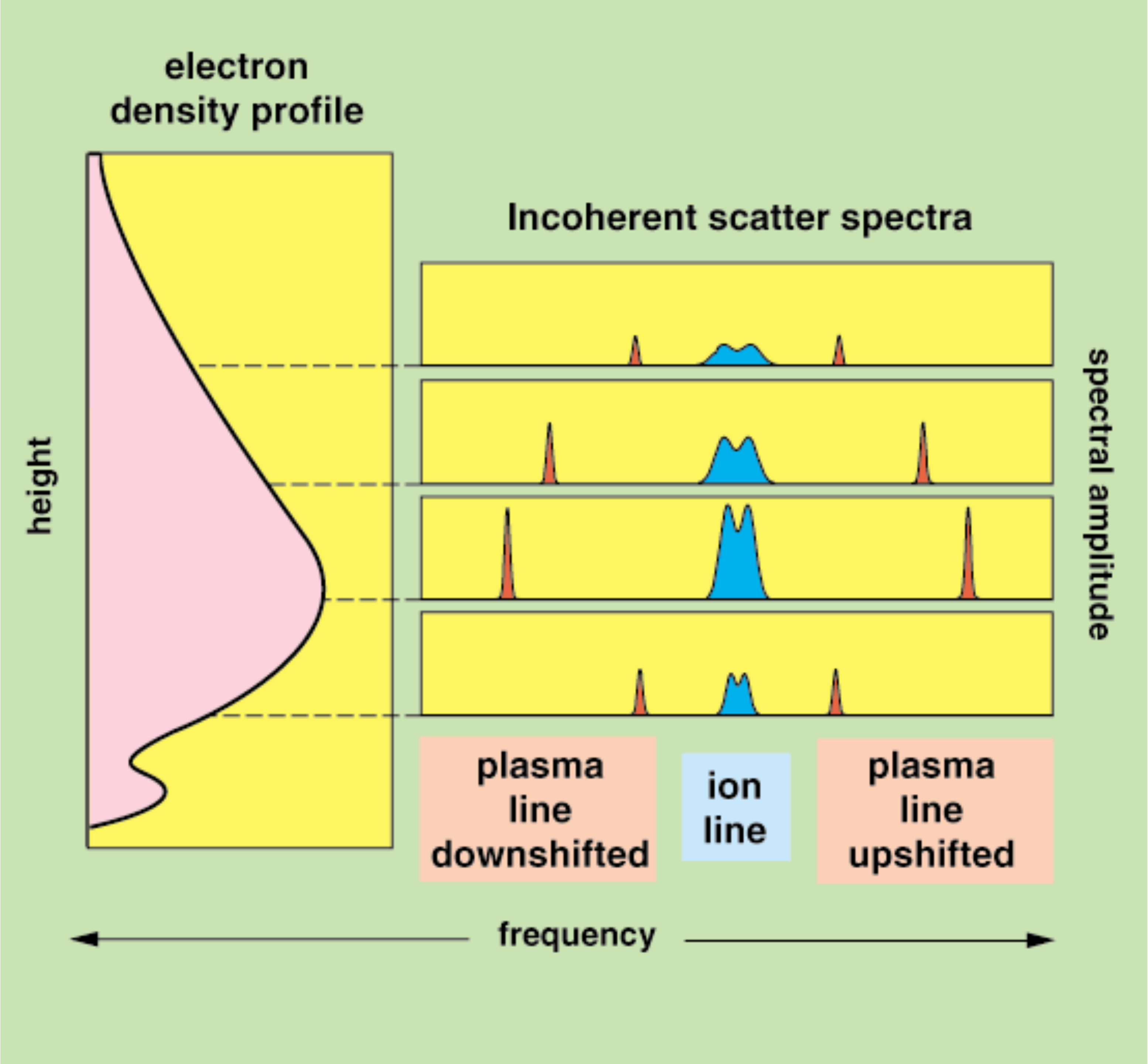
$$k = 2\pi / \lambda_{TX} + 2\pi / \lambda_{RX}$$

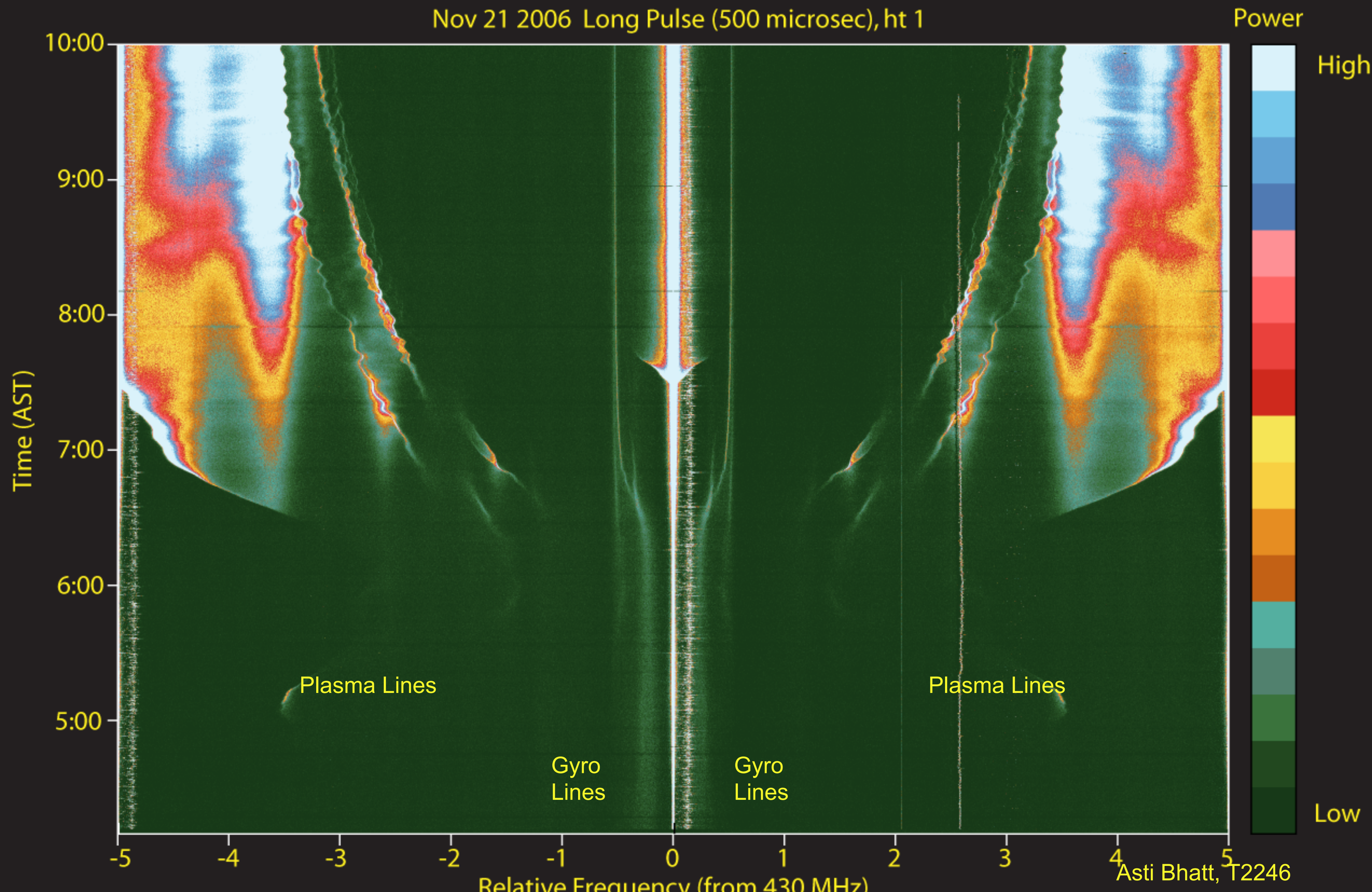
So N_e is determined by T_e and the frequency of the plasma line. Note that here λ_{RX} and λ_{TX} are significantly different for up-shifted vs. down-shifted plasma lines!

IS Received Spectrum

The individual sides are **not** symmetric about their center frequencies!

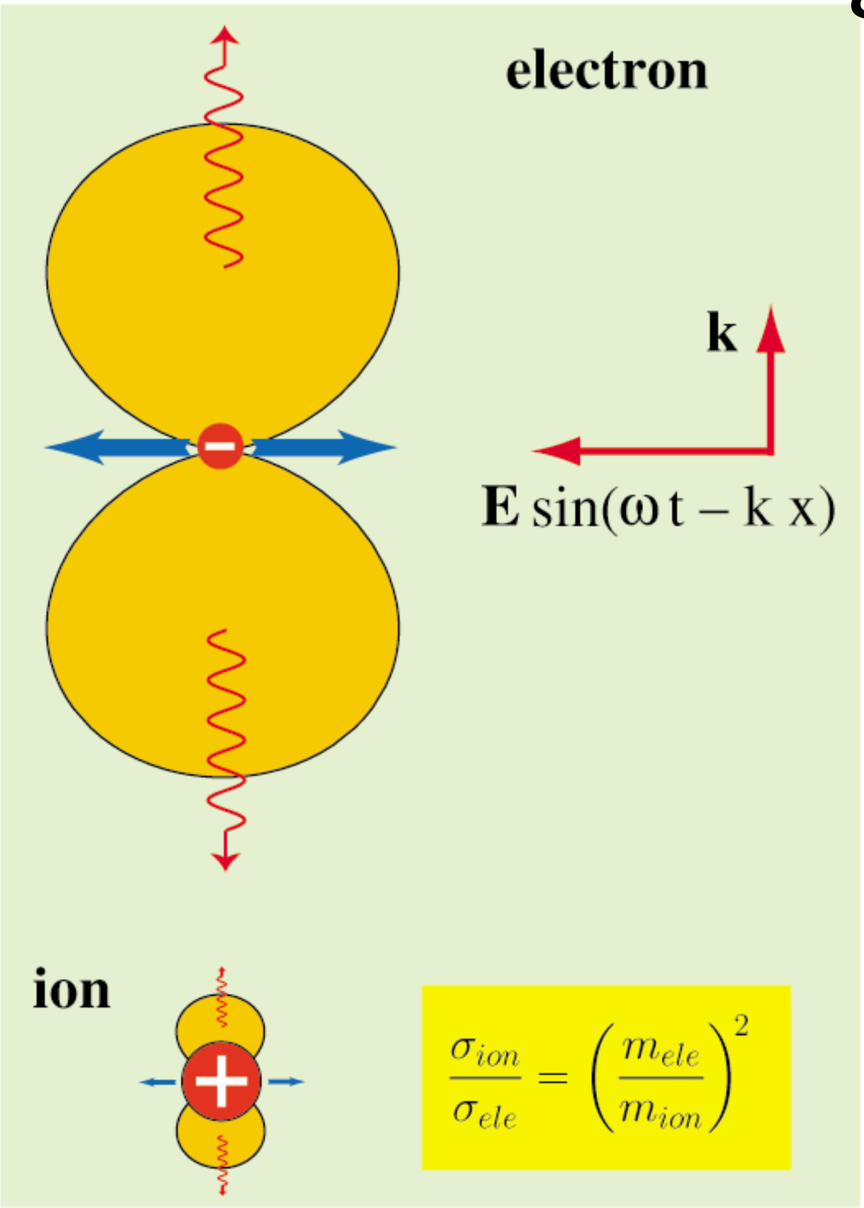



electron
density profile
height
Incoherent scatter spectra
spectral amplitude
plasma
line
downshifted
ion
line
plasma
line
upshifted
frequency



Arecibo Sensitivity: The 305 m dish, 2.5 MW of power, and Tsys of about 80 K (condition dependent) provide high time resolution on even weak features such as the gyro line. The data above are centered on the E region. The strong plasma line after sunrise is "leakage" from the low F region. The complicated behavior of the gyro line is probably due to multiple layers, but is not completely understood.

Thomson Scattering



Thomson Scattering

$$E_x = E_0 e^{j(\omega t - kx)}$$

$$\vec{F} = q\left(\vec{E} + \vec{v} \times \vec{B}\right)$$

$$v_x = -j \frac{q_e E_0}{m_e \omega} e^{j\omega t}$$

$$E_\phi = \frac{\mu_0 q_e^2}{4\pi m_e} \frac{\sin\phi}{r} e^{-jkr} E_0$$

$$\sigma_e = 4\pi \left(\frac{\mu_0 q_e^2}{4\pi m_e} \right)^2 \sin^2\phi = 4\pi r_e^2 \sin^2\phi$$

$$\approx 10^{-28} \sin^2\phi \quad (\mathrm{m}^2)$$

Plasma Response to a Stationary Test Charge

For a neutral Maxwellian plasma ($q\phi << k_B T$), with a static potential ϕ, the density fluctuations will look like

$$n_{e,i} = n_0 \exp\left(-\frac{q_{e,i}\phi}{k_B T_{e,i}}\right) \approx n_0 \left(1 - \frac{q_{e,i}\phi}{k_B T_{e,i}}\right)$$

Solving Poisson's equation for a test charge at the origin, we obtain

$$\Delta n_e = n_e - n_0 \approx n_0 \frac{q_e^2}{4\pi\varepsilon_0 r} \exp\left(-\frac{r}{\lambda}\right)$$

$$\frac{1}{\lambda^2} = \frac{1}{\lambda_{Di}^2} + \frac{1}{\lambda_{De}^2} = -n_0 \frac{q_e^2}{\varepsilon_0 k_B}\left(\frac{1}{T_i} + \frac{1}{T_e}\right)$$

where λ_D is the Debye length of the plasma.

Plasma Response to a Stationary Test Charge (cont'd)

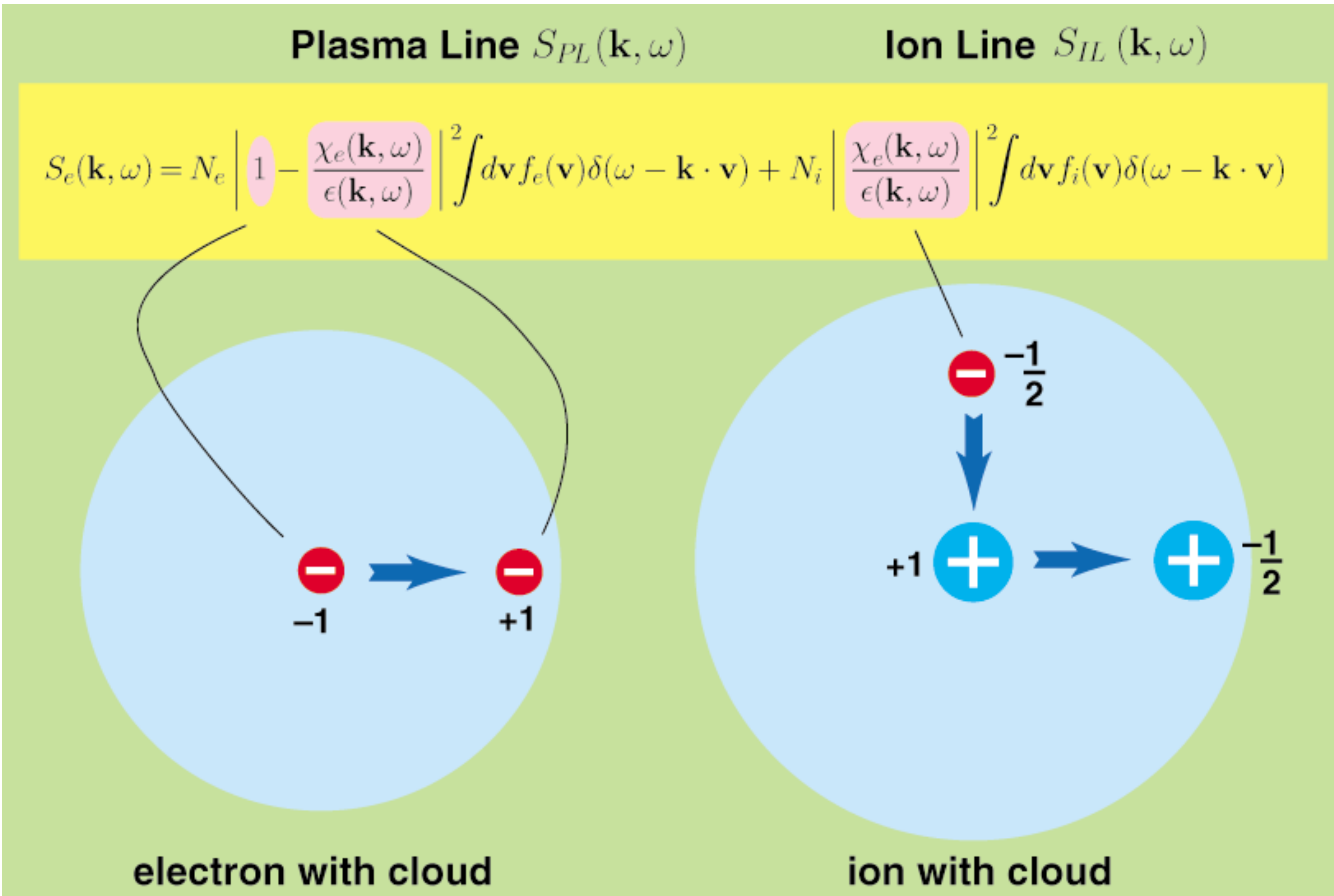
Integrating over all space, we can calculate the total number of additional electrons and ions due to this test charge

$$\iiint \Delta n_e dV = \frac{T_i}{T_e + T_i} = \frac{1}{1 + T_r}$$

$$\iiint \Delta n_i dV = -\frac{T_i}{T_e + T_i} = -\frac{1}{1 + T_r}$$

So the test ion is neutralized by attracting half of an electron and repelling half of an ion when the ion and electron temperatures are equal.

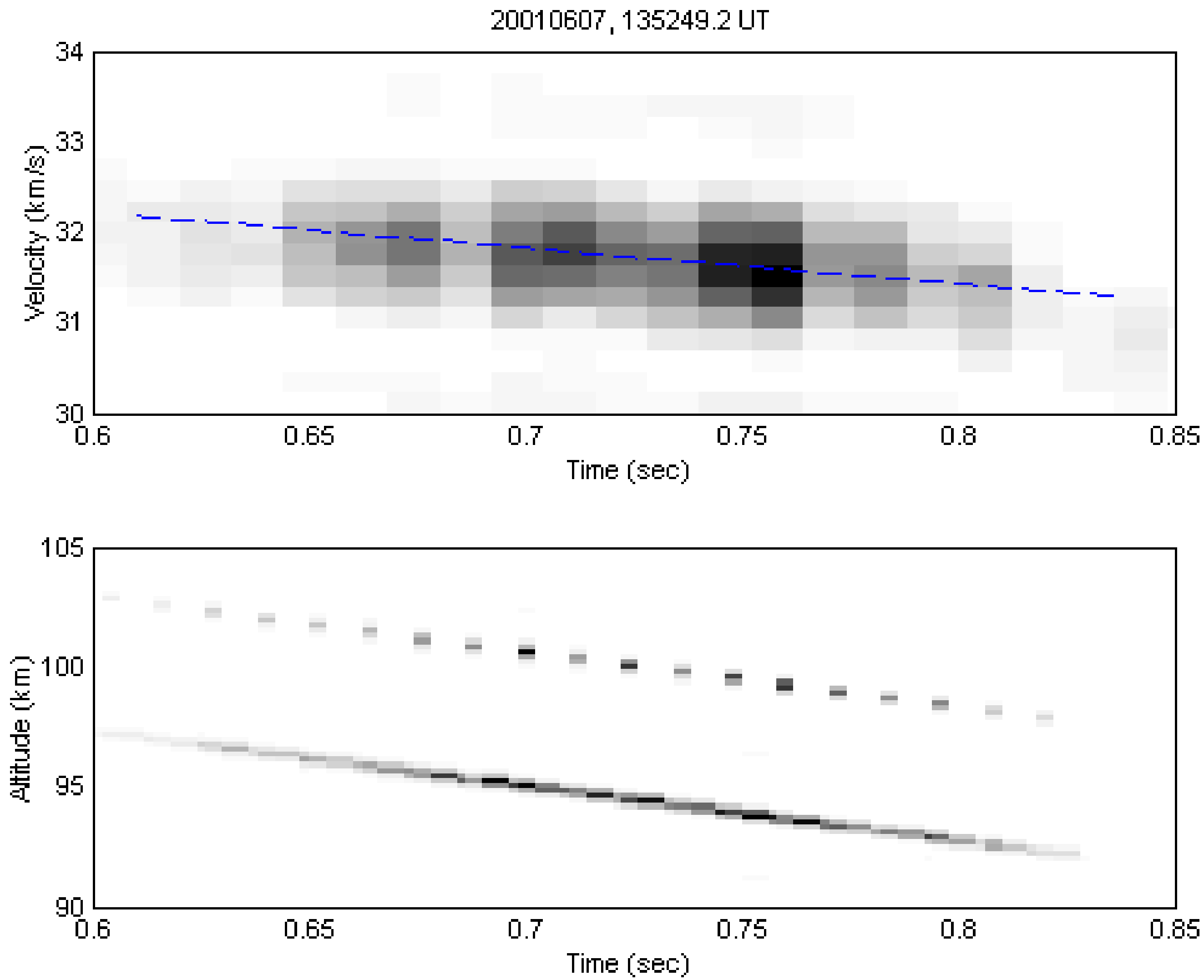
Plasma Response to a Stationary Test Charge (cont'd)



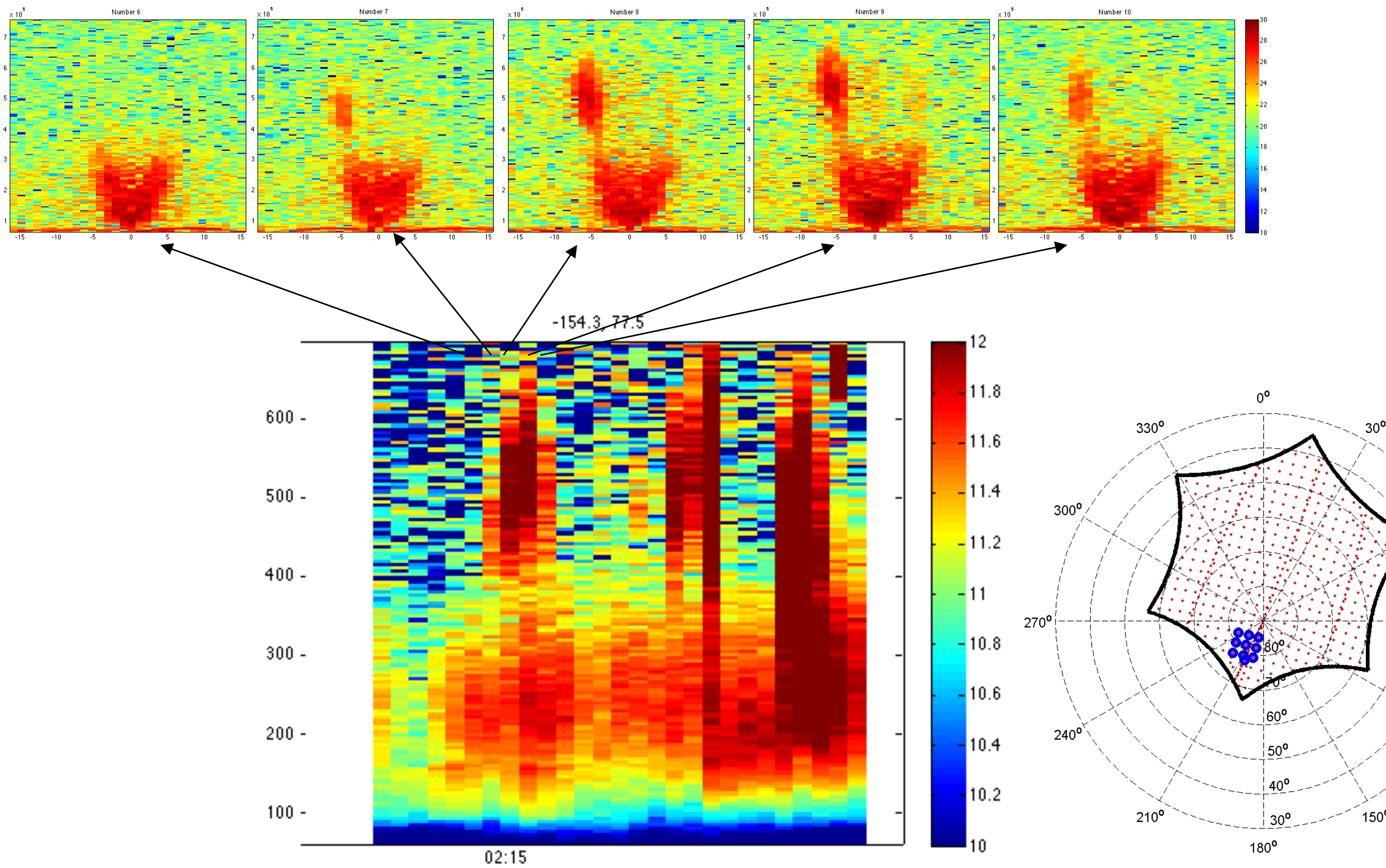
What ong?

Tao Berman, 19

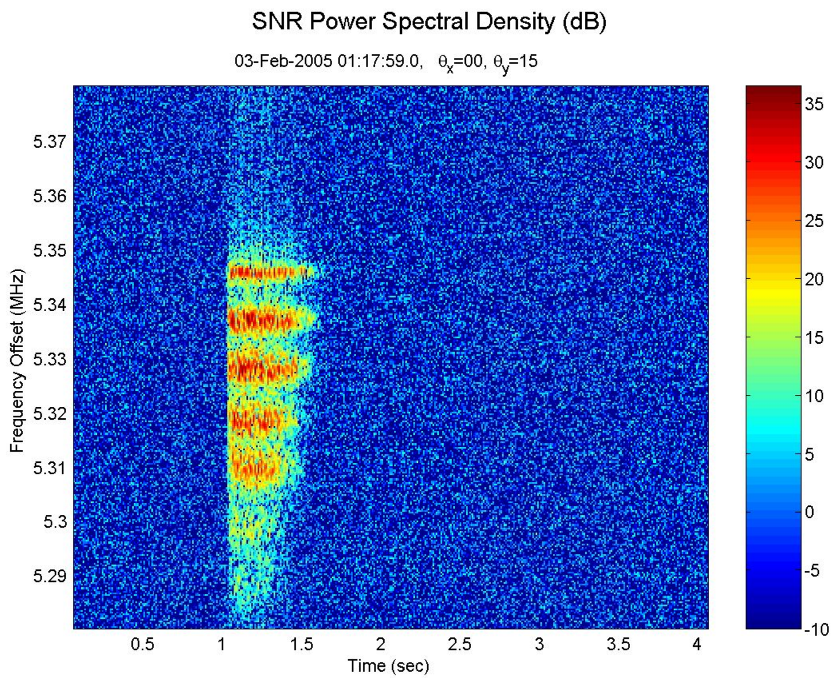
Echoes from Meteors



Naturally Enhanced Ion Acoustic Lines



Ionospheric Heating, HAARP, Feb 2005



Enhanced Plasma Line

F_{heater}=5.35 MHz, O-mode, CW, on at t=1 sec

Enhanced Ion Line

F_{heater}=4.25 MHz, O-mode, CW, on at t=1 sec