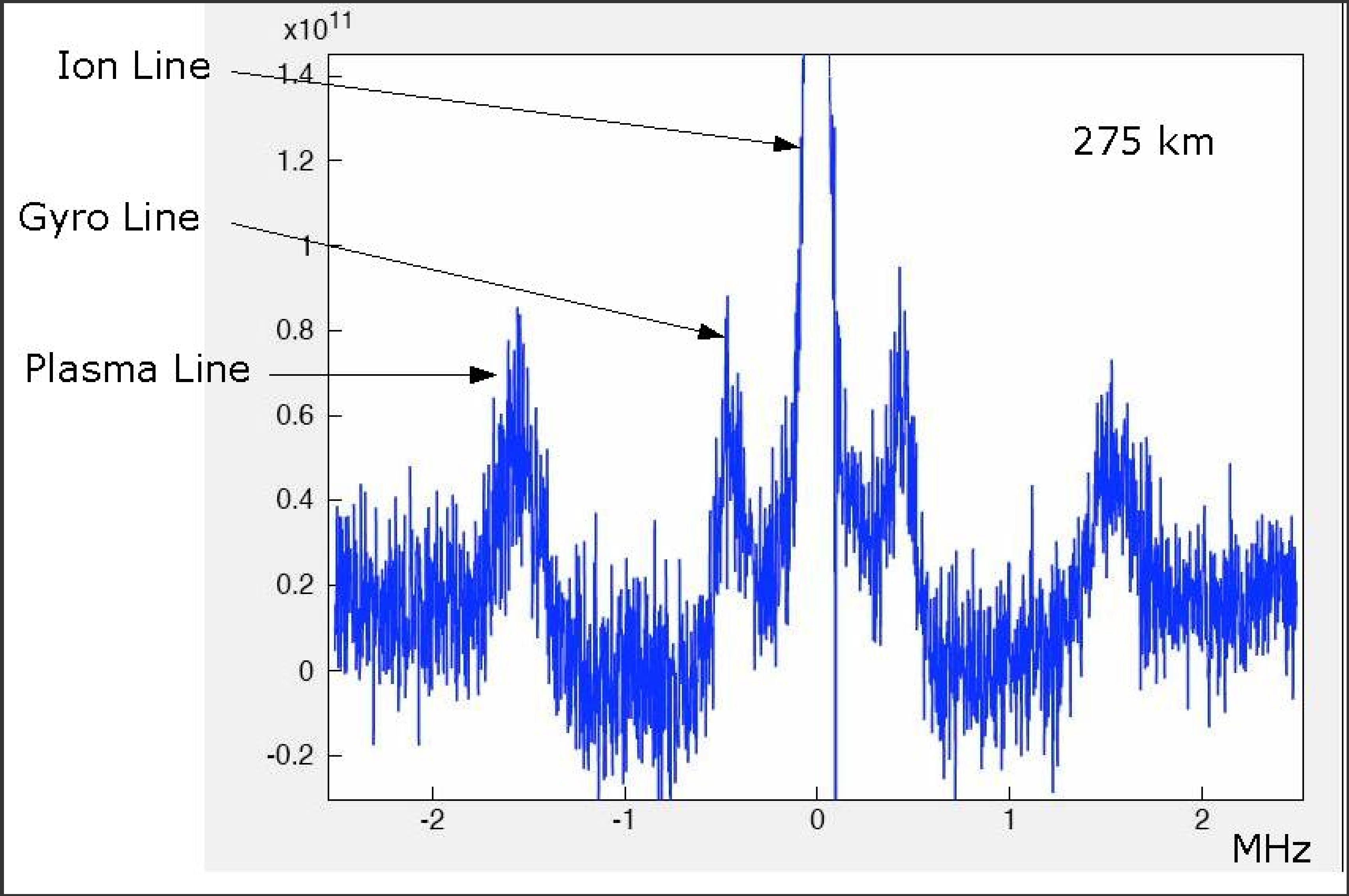
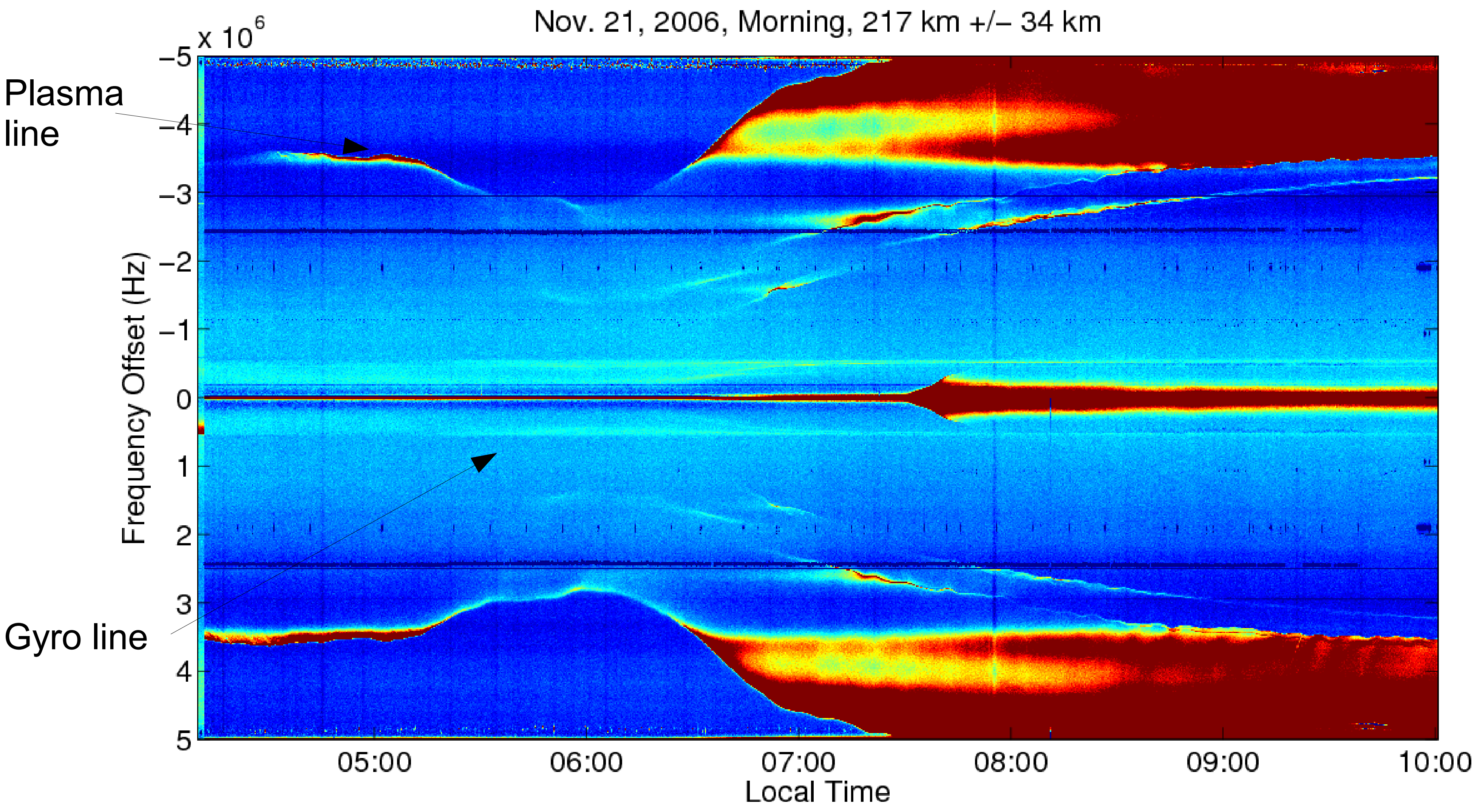
Full Incoherent Scatter Spectrum



Asti Bhatt, MIT Haystack Observatory, AMISR Summer School 2009



Nov. 21, 2006, Morning, 217 km +/– 34 km
x 10^6
Plasma line
Gyro line
Frequency Offset (Hz)
–5
–4
–3
–2
–1
0
1
2
3
4
5
05:00
06:00
07:00
08:00
09:00
10:00
Local Time

Electron density fluctuations in plasma in thermal equilibrium with Maxwellian velocity distribution can be given as,

$$\frac{\langle |n_e(\mathbf{k},\omega)^2| \rangle}{N_e} = \left(|y_e|^2 \frac{\sum_j \eta_j \Re(y_j)}{\omega - \mathrm{k}\dot{\mathrm{v}}_{\mathrm{dj}}} + \left| \sum_j \mu_j y_j + i\lambda_e^2 k^2 \right|^2 \frac{\Re(y_e)}{\omega - \mathrm{k}\dot{\mathrm{v}}_{\mathbf{de}}} \right)$$

$$\times \left(\left| y_e + \sum_j \mu_j y_j + i\lambda_e^2 k^2 \right|^2 \right)^{-1},$$

v_{dj} = bulk motions of particles

λ_e = Debye length

k = Bragg scattering wave number

η_j = Nj/Ne = ion fraction

μ_j = njTe/Ti = weighted temperature ratio

y_j = admittance function

If we neglect the effect of the bulk motion and ignore ions

$$\frac{\langle |n_e(\mathbf{k},\omega)|^2\rangle}{N_e} = \frac{\lambda_e^4 k^4}{\omega} \frac{\mathrm{Re}(y_e)}{\mathrm{Re}(y_e)^2 + [\mathrm{Im}(y_e) + \lambda_e^2 k^2]^2}$$

Equate denominator to 0 to get resonances

$$\mathrm{Im}(y_e) + \lambda_e^2 k^2 = \lambda_e^2 k^2 + \frac{\sin^2\alpha}{2(\phi_e^2 - \theta_e^2)} + \frac{(\sin^2\alpha - 2\phi_e^2)\cos^2\alpha}{4\phi_e^2\theta_e^2} = 0.$$

Two solutions of this dispersion relation are the gyro and the plasma lines

Gyro line

The gyro line frequency can be given approximately -

$$\omega^2 = \Omega_{ce}^{2}\omega_{pe}^{2}\cos^2\alpha/(\Omega_{ce}^{2} + \omega_{pe}^{2})$$

Angle between ***k*** and **B**

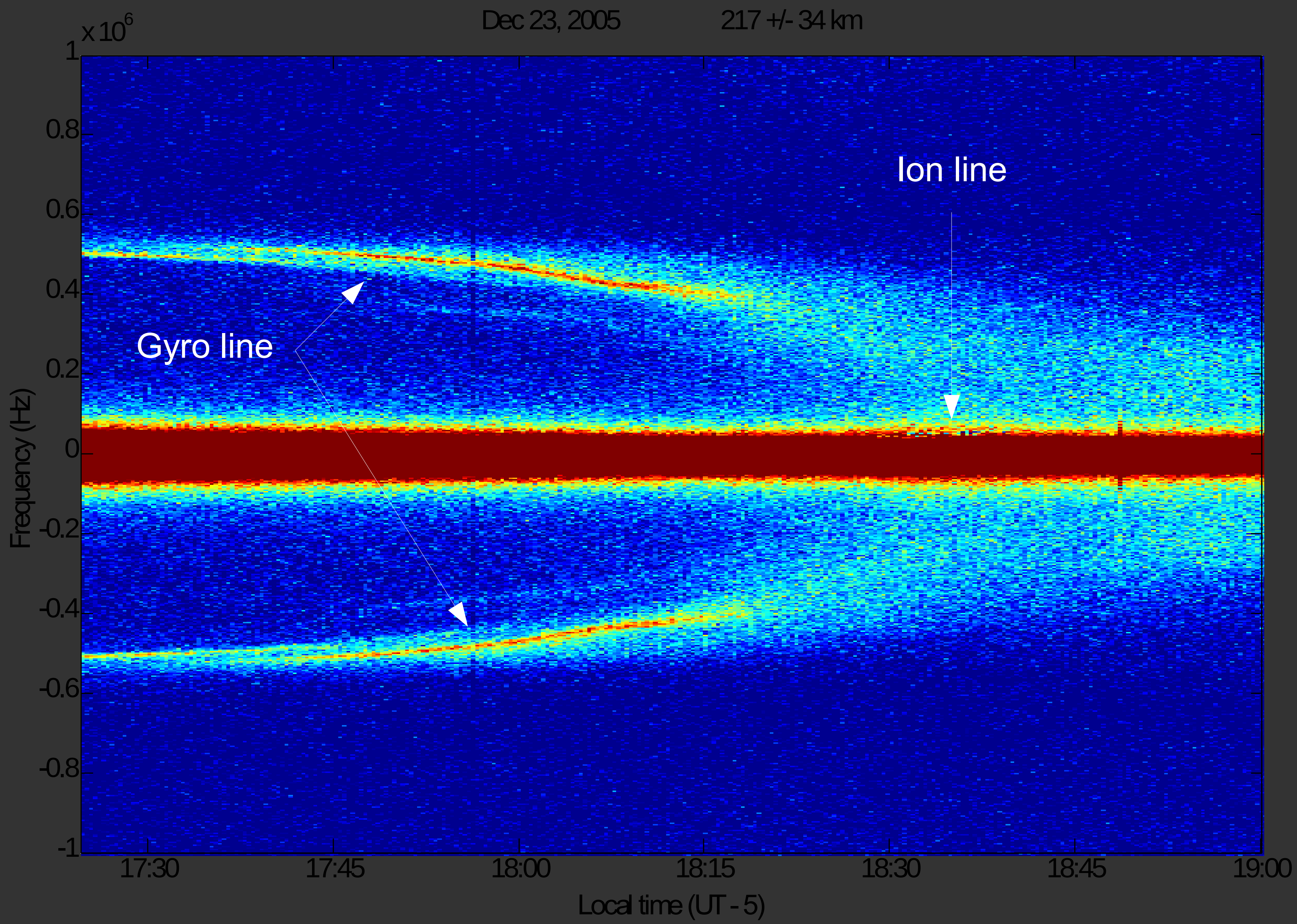
Electron plasma frequency

Electron gyro frequency

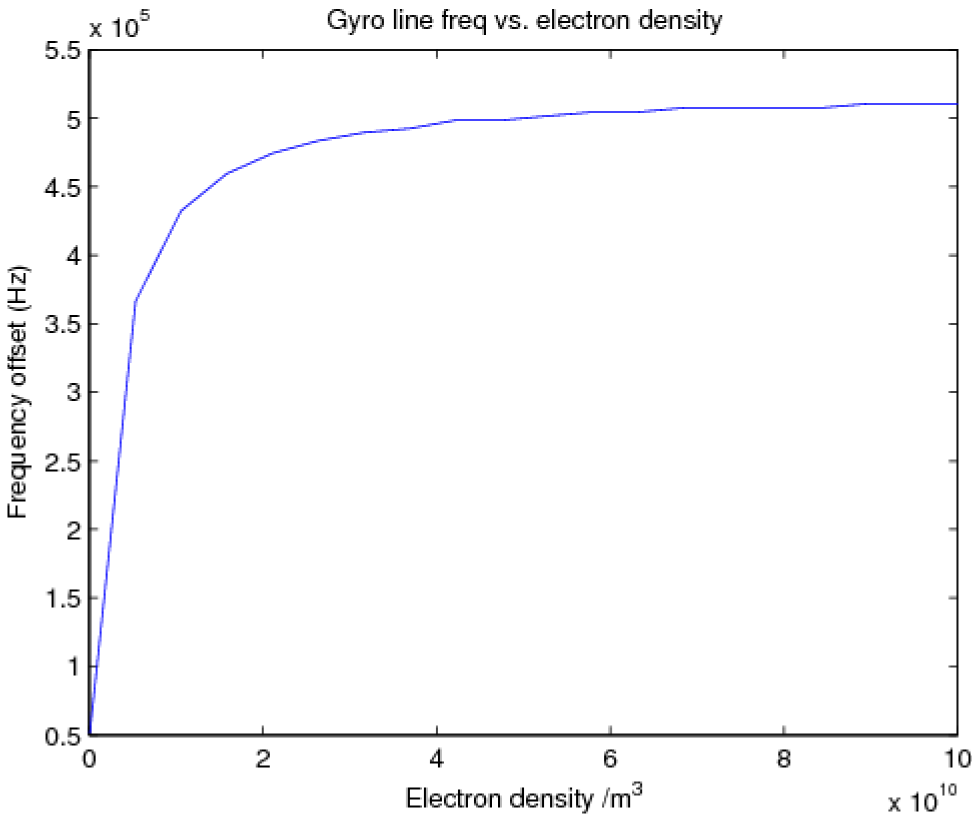
It is highly sensitive to the magnetic field and α

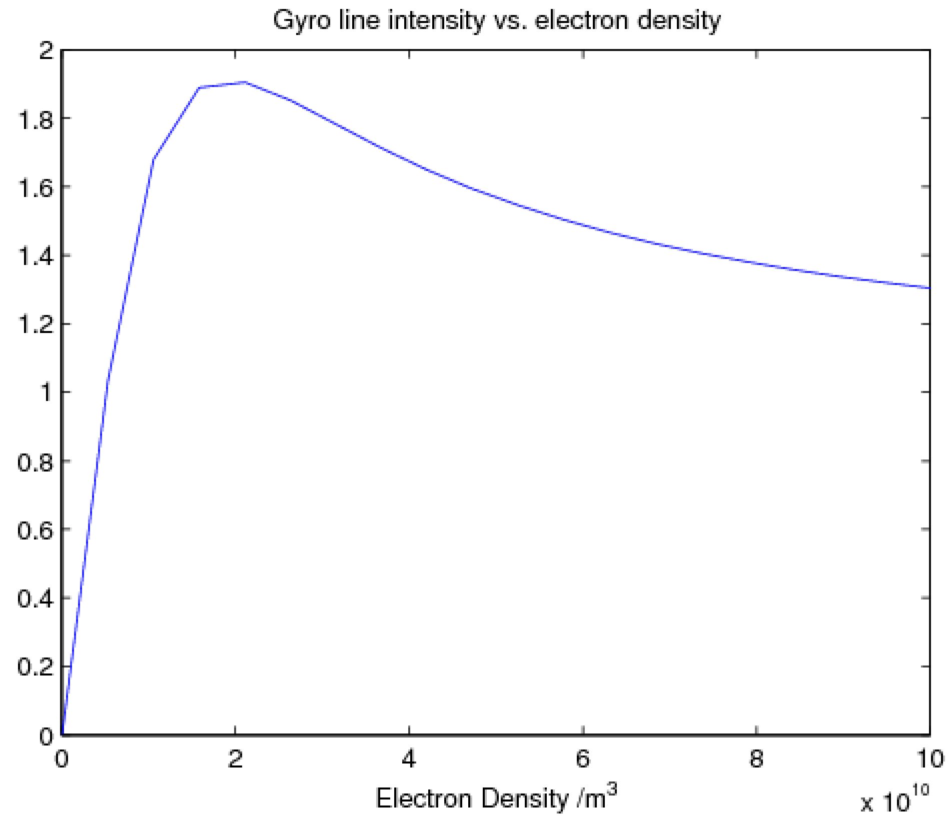
Salpeter [Phys. Rev., 1961]

Low electron density



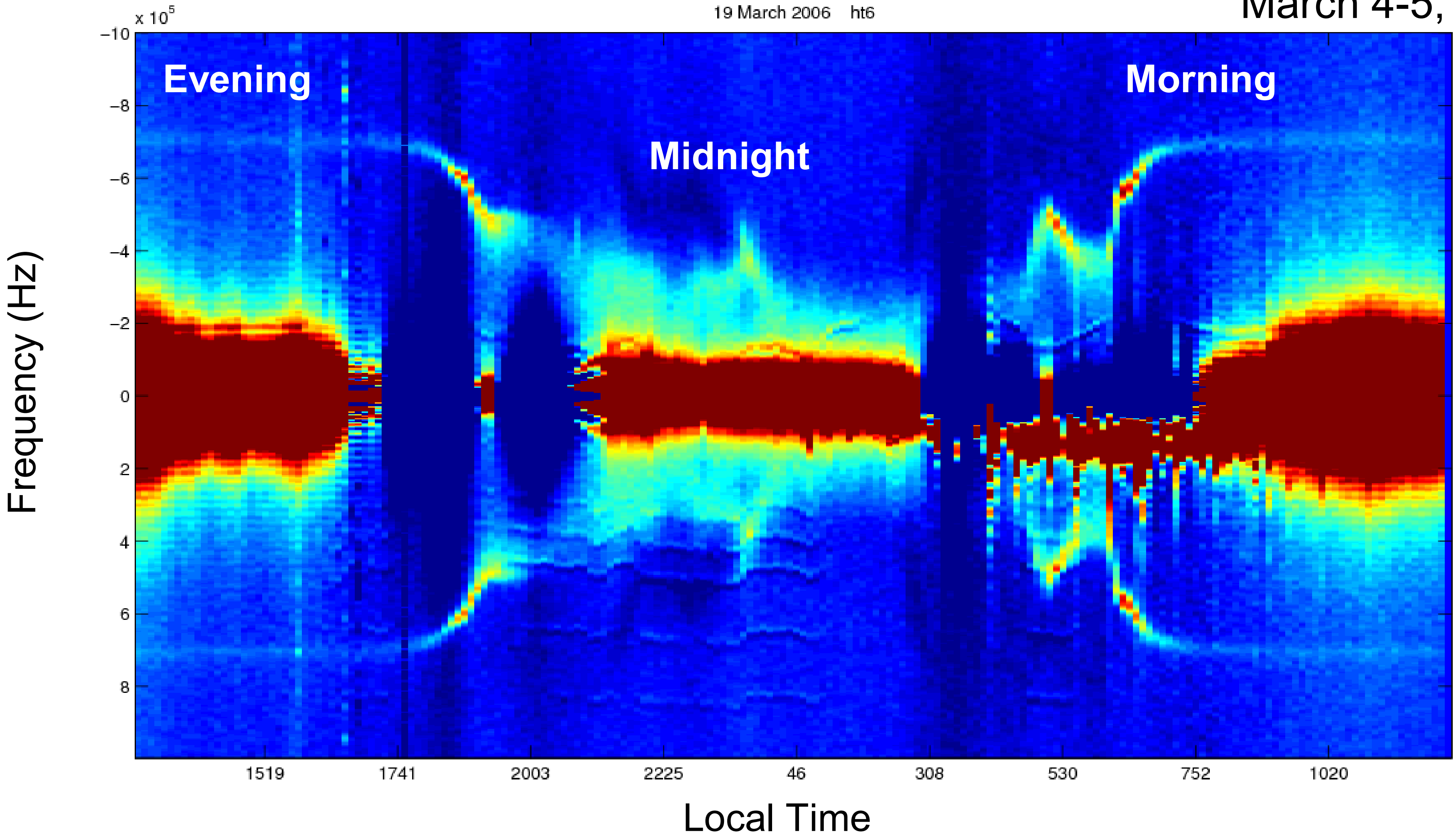
Prediction from theory





Varying with time

March 4-5, 2006



Janches and Nicolls [GRL, 2007]

Plasma line

The plasma line dispersion relation in the presence of a magnetic field is -

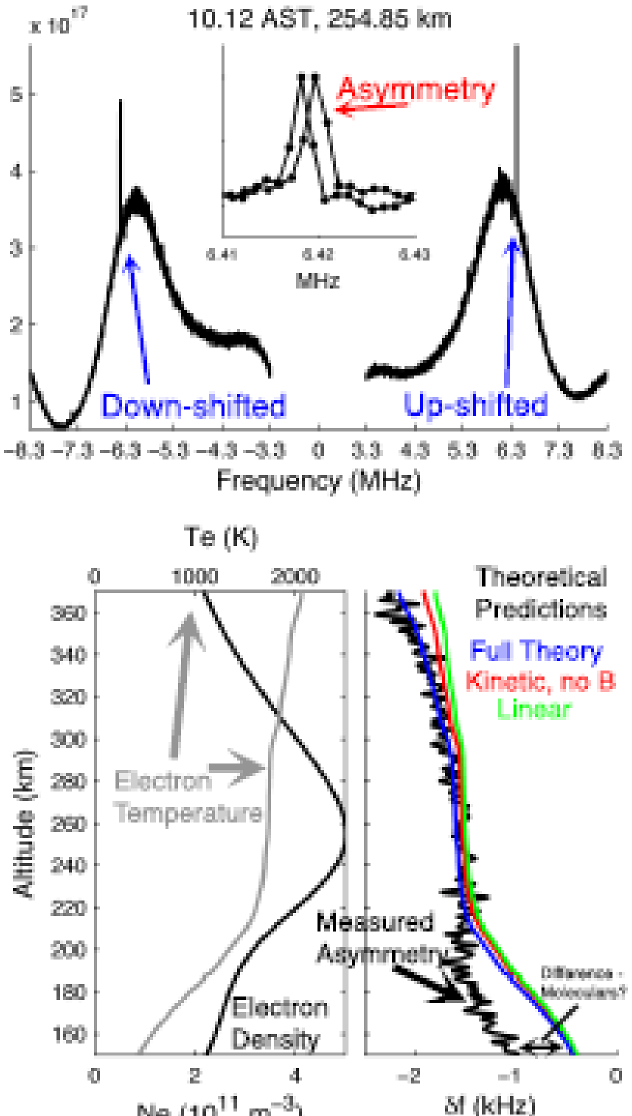
$$\omega^2 = \omega_{pe}{}^2 + (3/2)k^2 v_{th}{}^2 + \Omega_{ce}{}^2 \sin^2\alpha$$

which makes the plasma line frequency a very precise measure for the electron density.

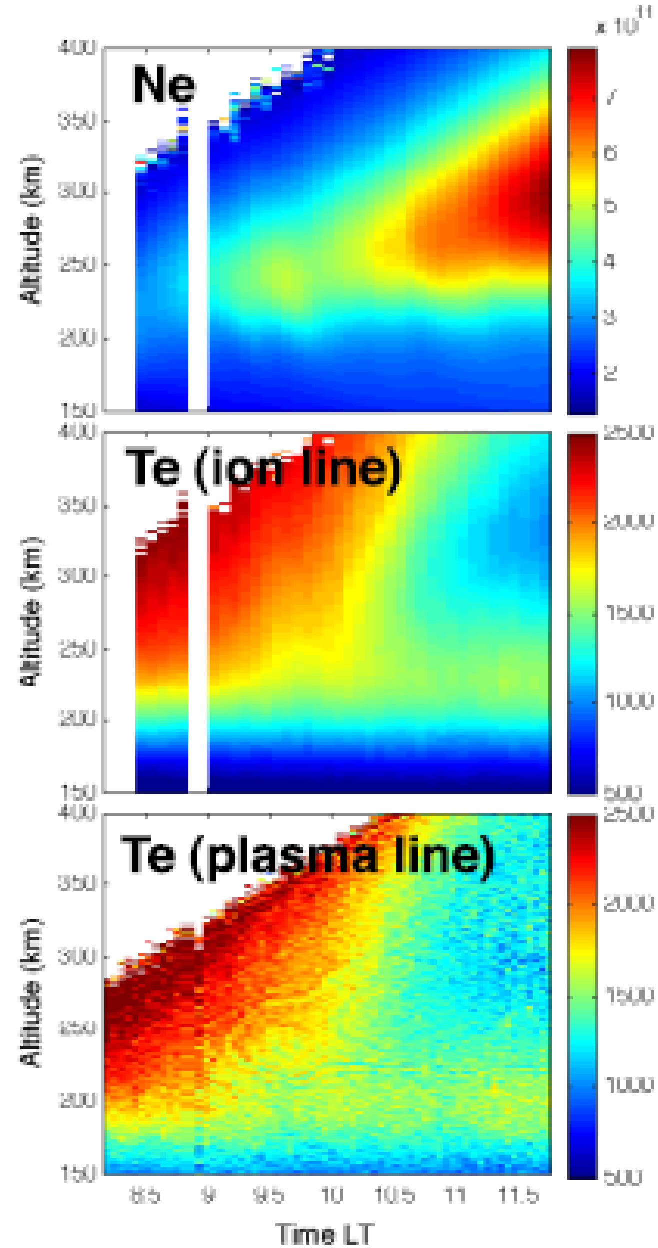
The width of both the plasma and the gyro line are sensitive to the electron temperature.

High Resolution Plasma Line and Asymmetry

Using the asymmetry of the up- and down-shifted plasma lines, we can obtain an independent, high resolution measurement of T_e

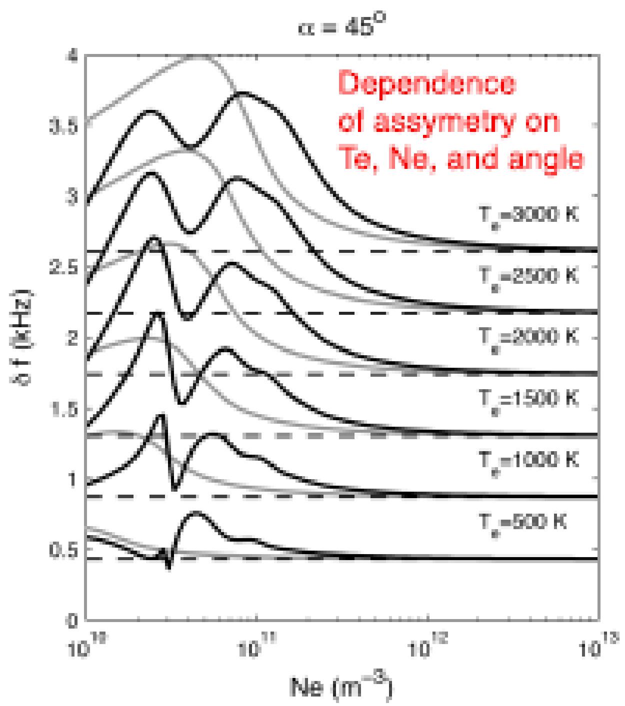


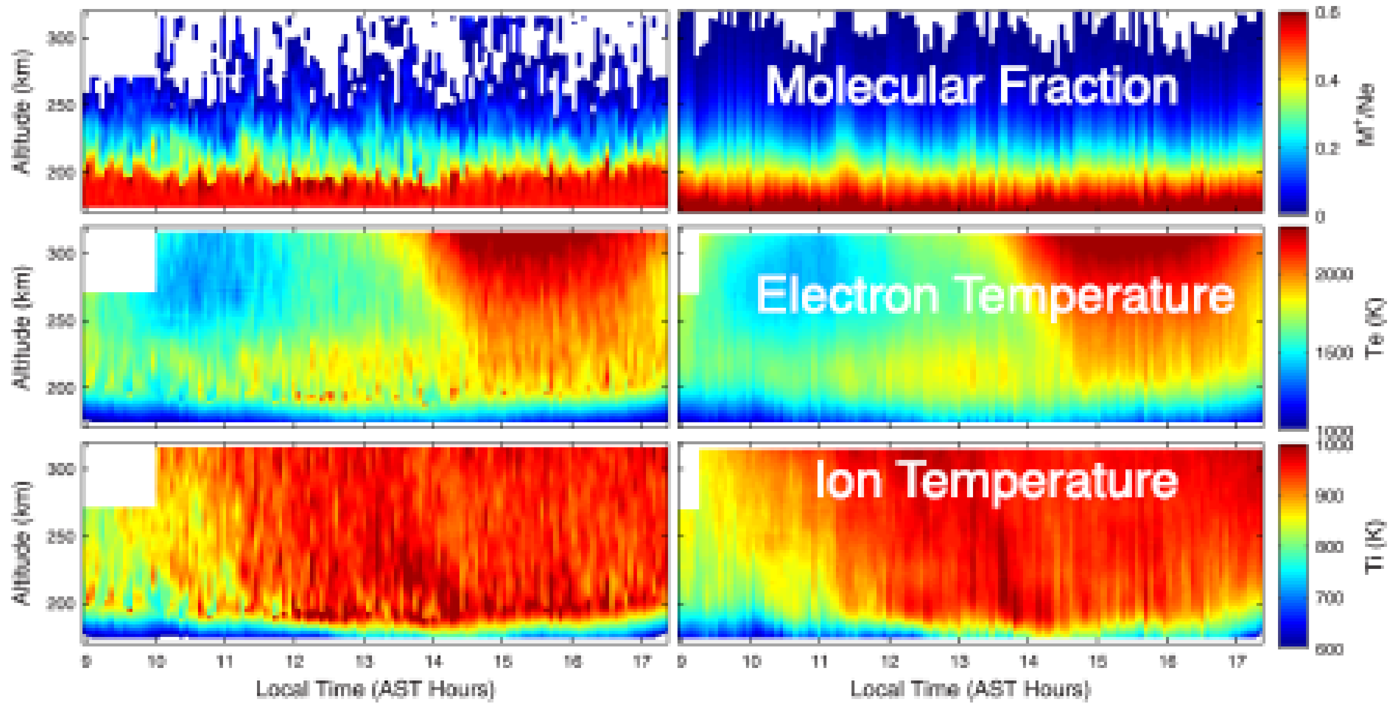
Nicolls et al., GRL, 2006



Some Applications of HR Plasma Line and Asymmetry

Independent measures of N_e, T_e allow for derivation of other unknowns, e.g., M^+ fractions

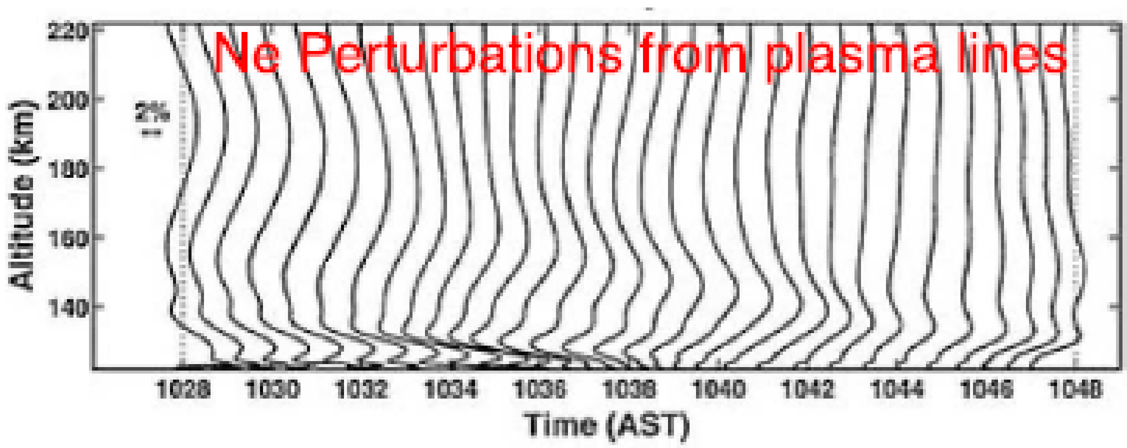




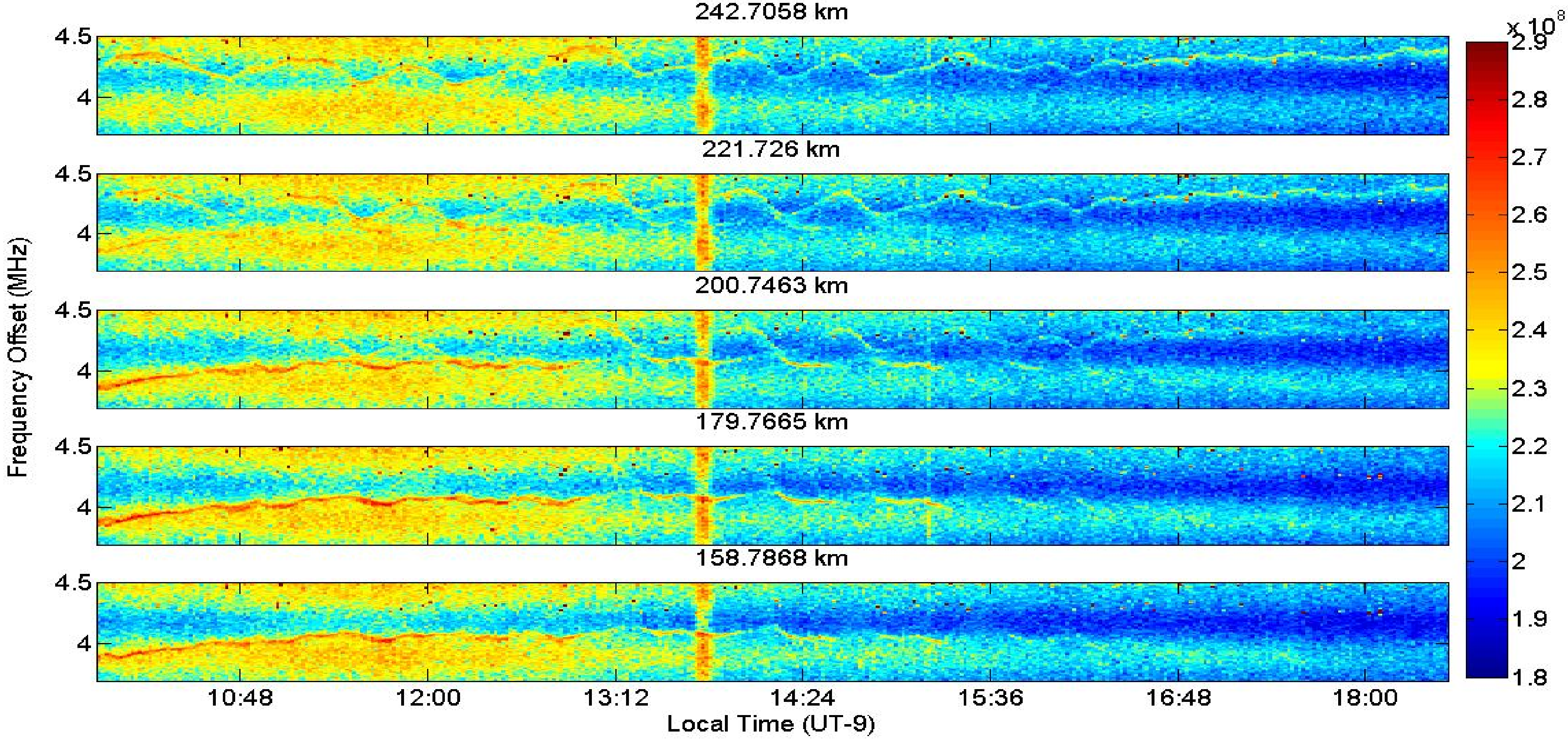
Nicolls et al., *GRL*, 2006

Aponte et al., *JGR*, 2007

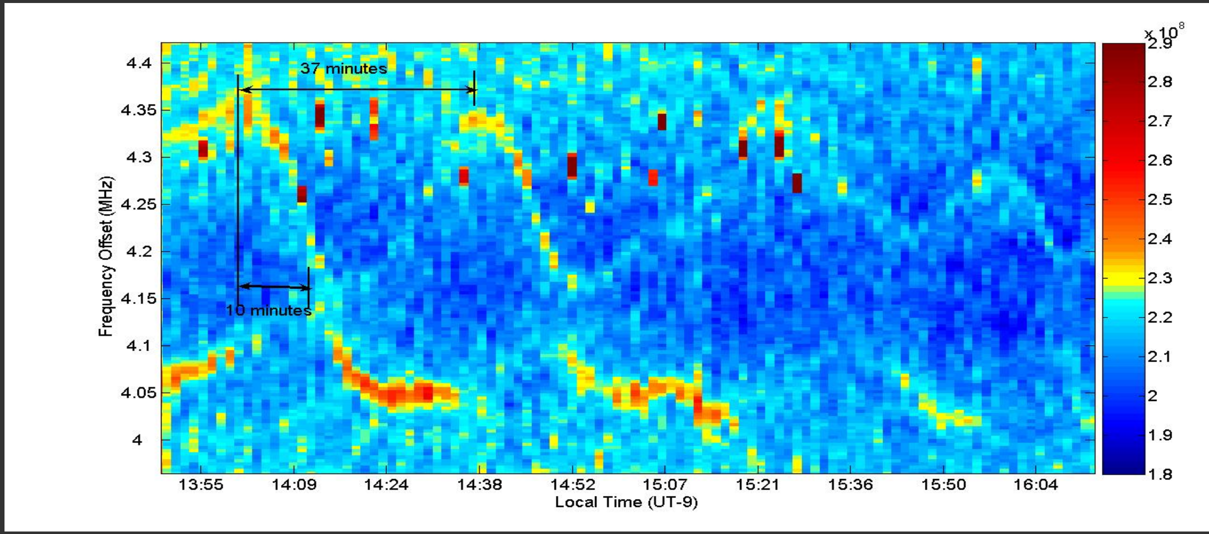
Very applicable beyond Arecibo - nail down T_i, T_e and M^+ in $F1$ region

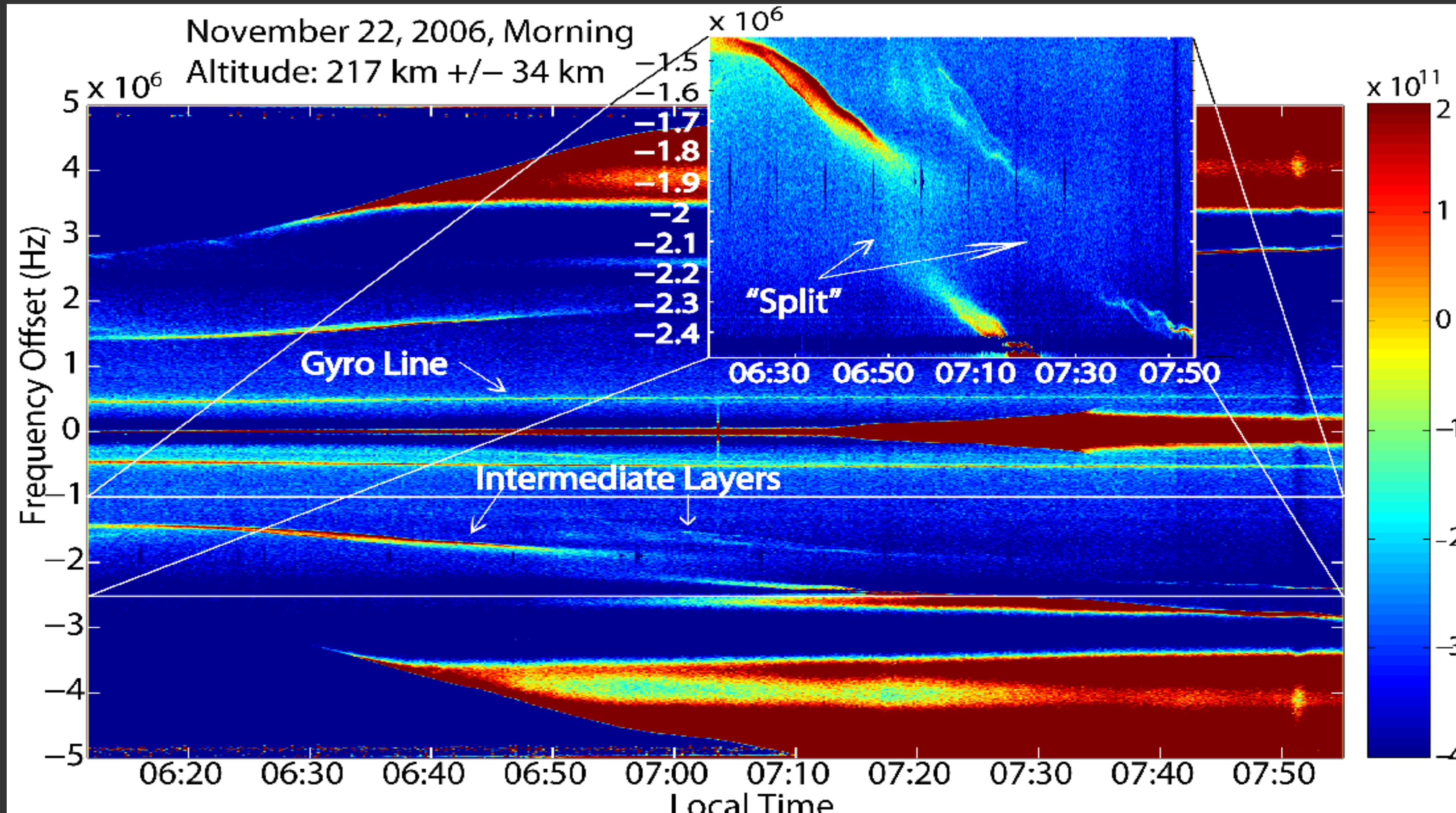


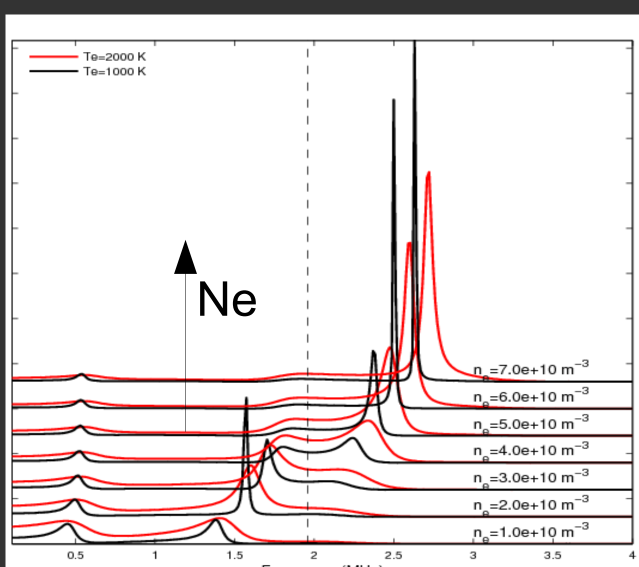
Gravity wave studies are another exciting new application of high resolution plasma line measurements (*Djuth et al.*, 1997,2004)



Gravity wave fluctuations in Plasma line measurements using PFISR







Plasma line "splits" where plasma frequency matches the second electro gyroharmonic