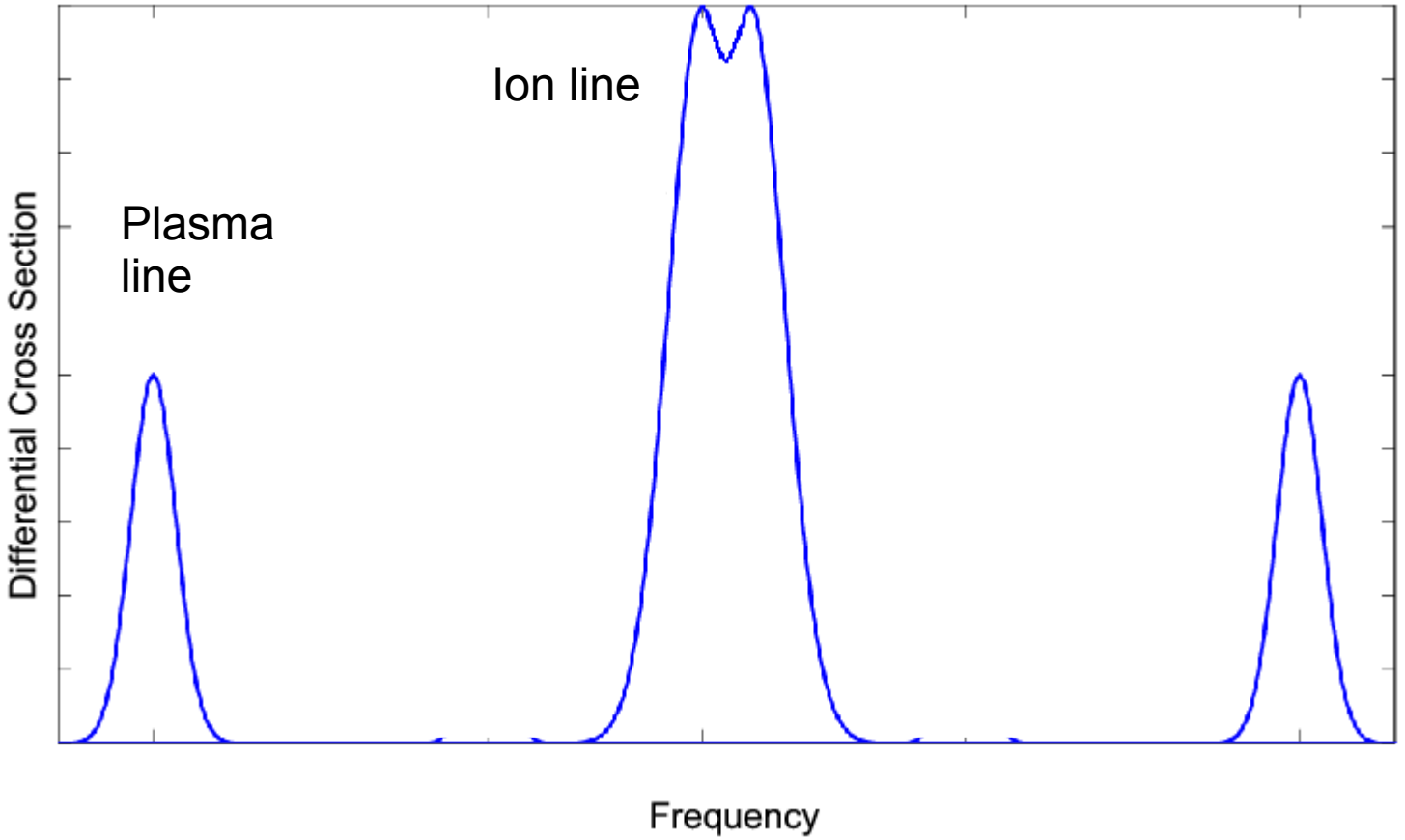
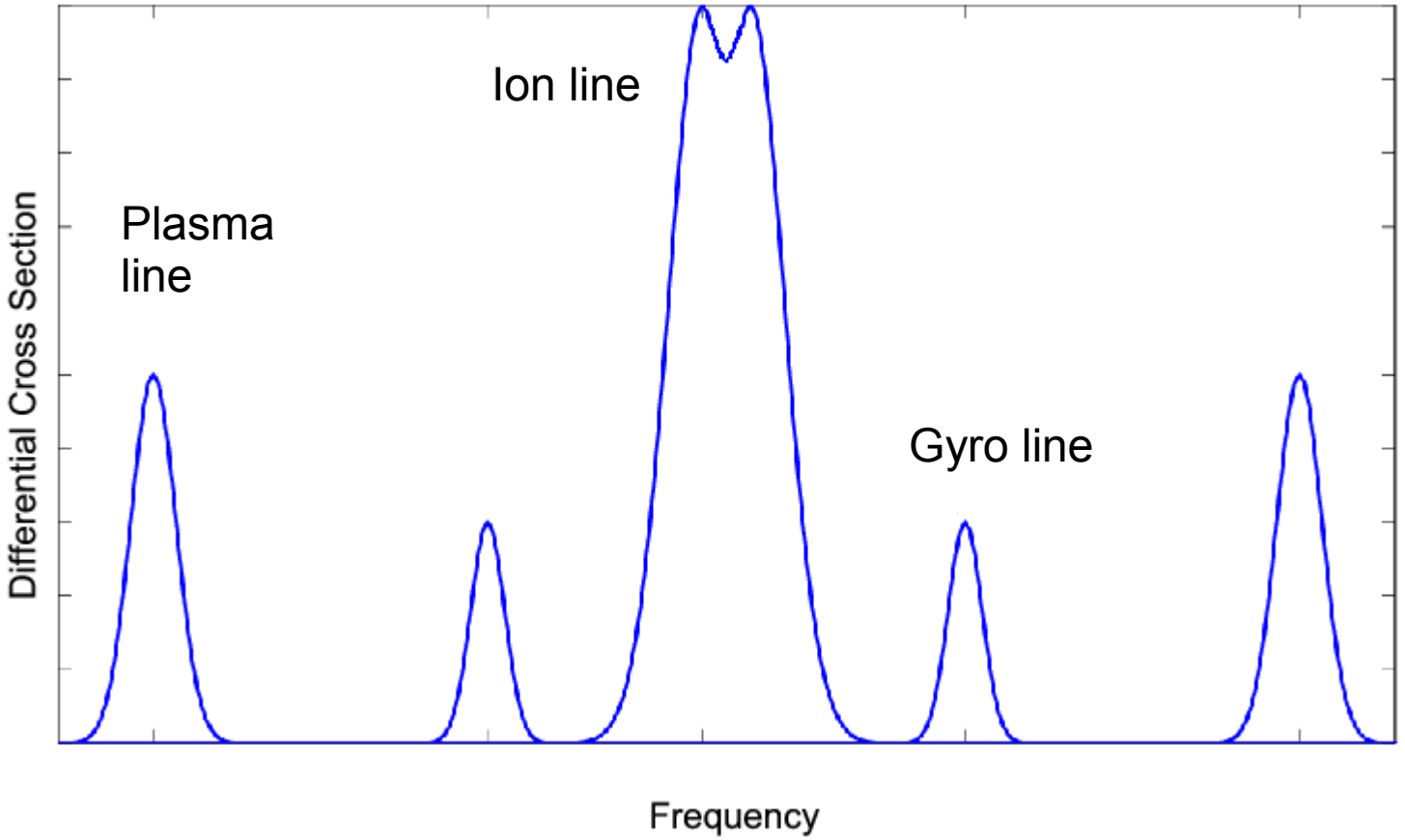
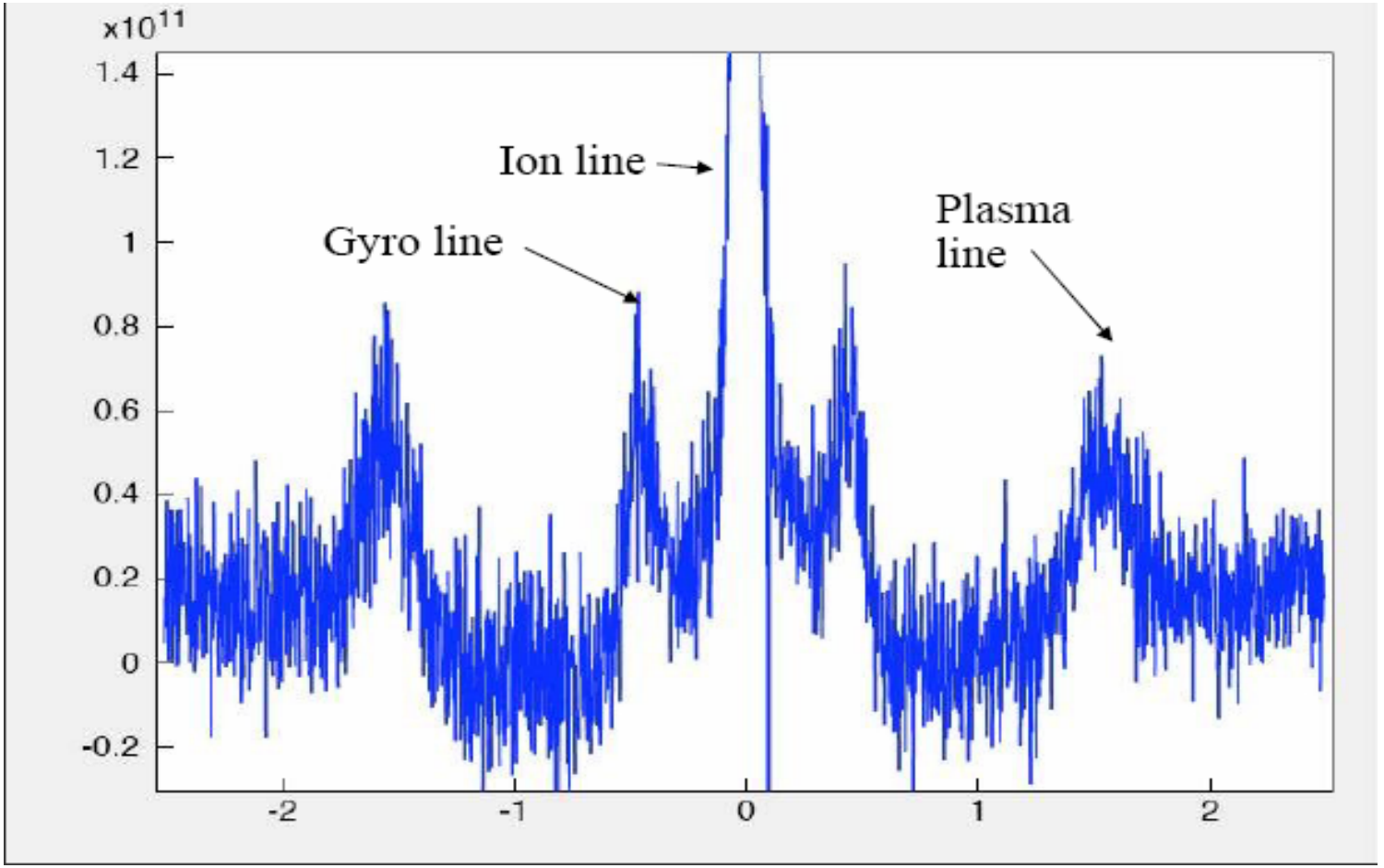
# Full Incoherent Scatter Spectrum



# Full Incoherent Scatter Spectrum



# Full Incoherent Scatter Spectrum



# Electron component

$$\Im(y_e) + k^2\lambda_{de}^2 =$$

$$k^2\lambda_{de}^2 + \frac{\sin^2\alpha}{2(\varepsilon^2 - x^2)} + \frac{(\sin^2\alpha - 2\varepsilon^2)\cos^2\alpha}{4\varepsilon^2 x^2} = 0$$

$\alpha$ = angle between k and B

$\varepsilon = \omega_{ce}/kv_{the}$

$x = \omega/kv_{the}$

* Adding magnetic field to the IS theory affects the electron component
* Two roots of this equation are Plasma and Gyro lines
* Electron component $k^2\lambda_{de}^2$ weaker than the Ion component

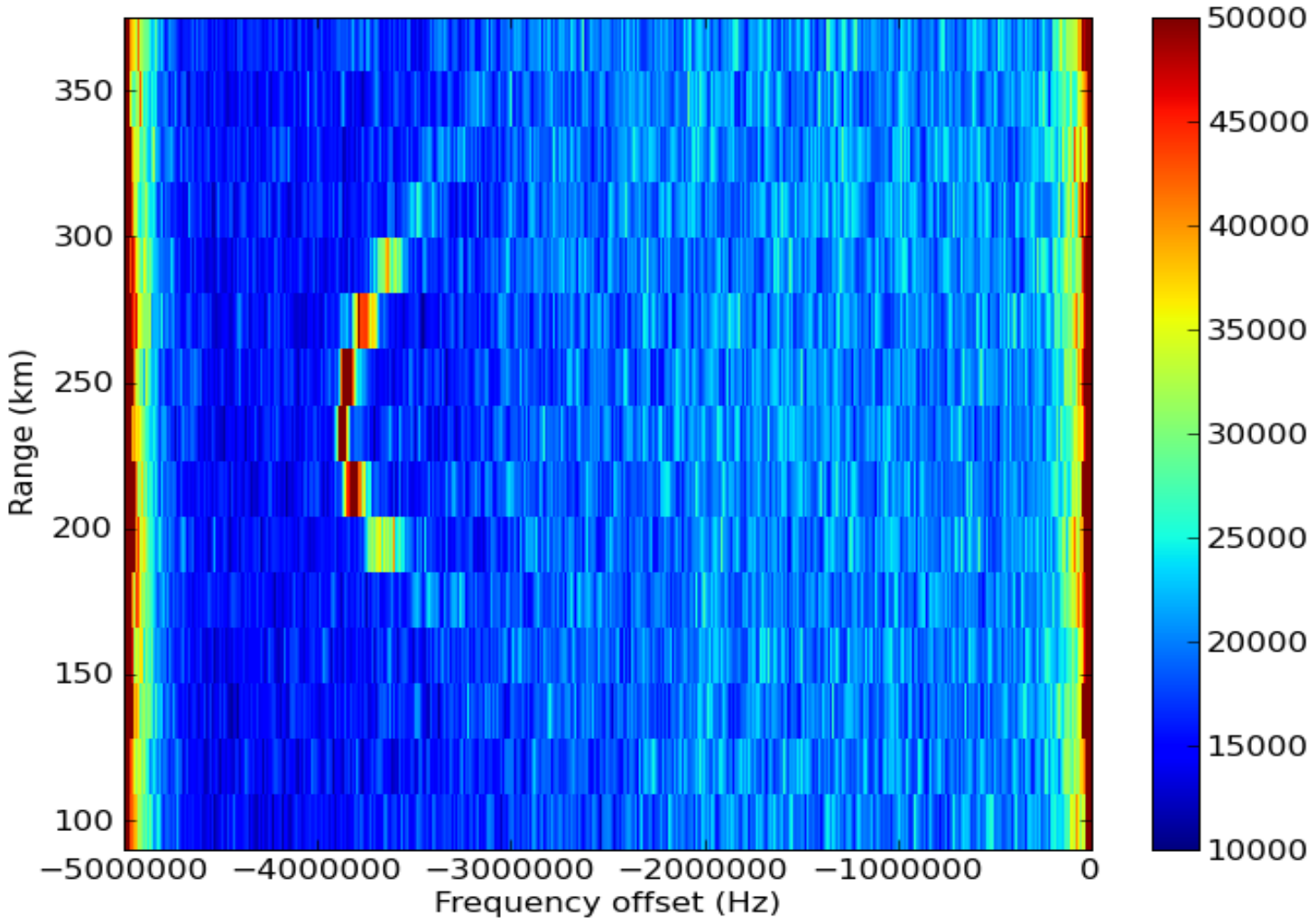
# Plasma line

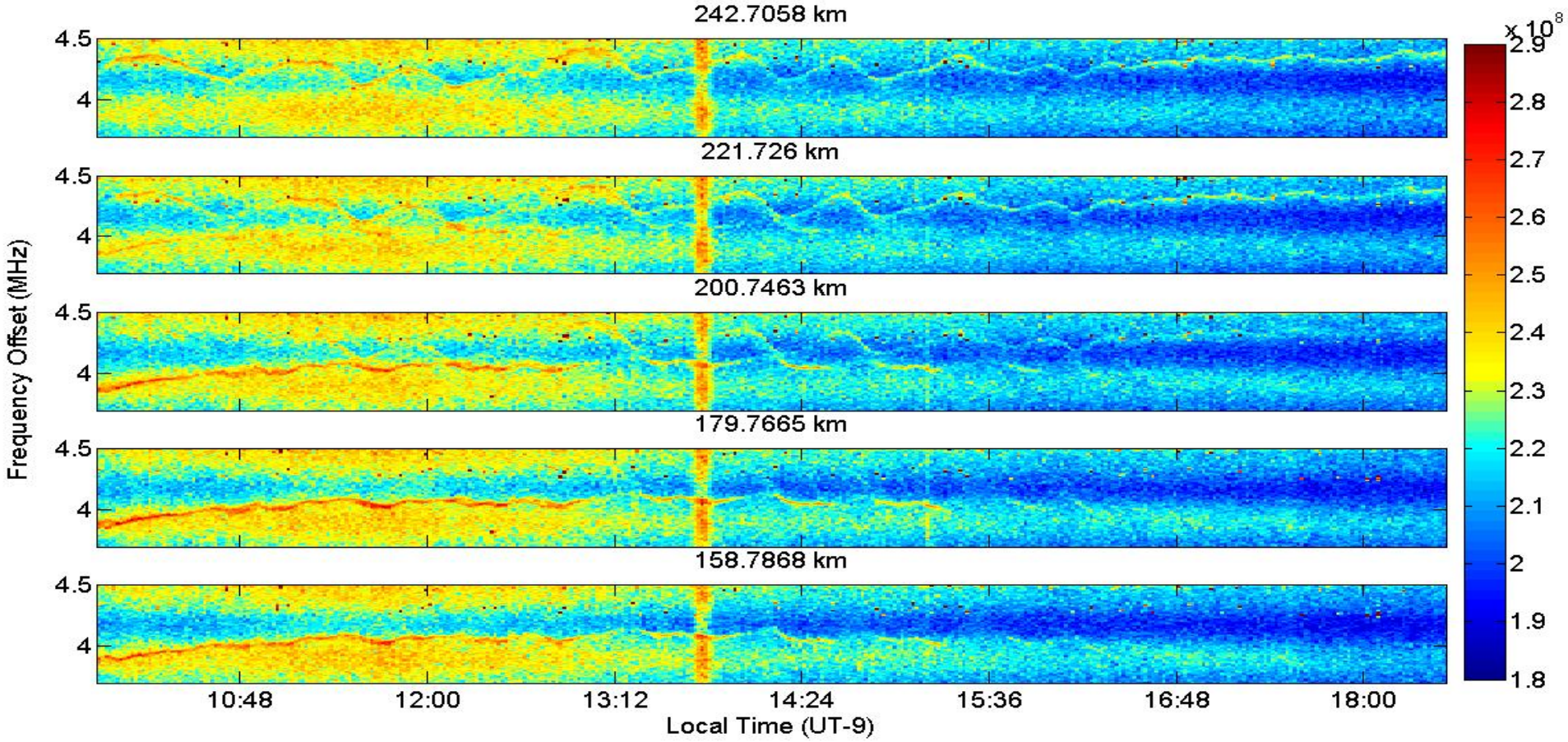
- Scatter from electron Langmuir waves in the ionosphere
- High energy electrons create a bump-in-tail of the Maxwellian velocity distribution that pumps energy into this wave
- The most precise ground-based measurement of electron density

$$\omega^2 = \omega_{pe}^2 + \frac{3}{2}k^2 v_{the}^2 + \Omega_e^2 \sin^2 \alpha$$

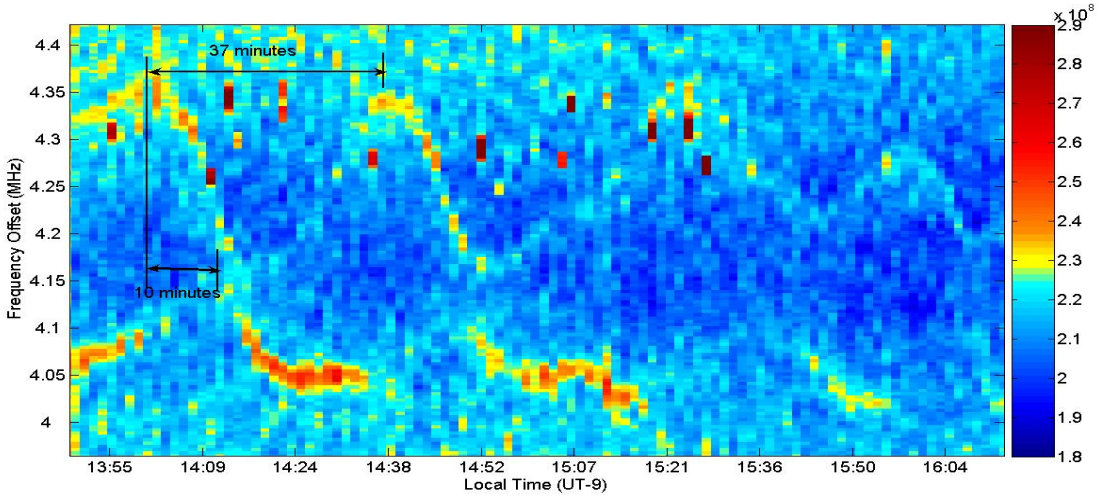
- Width corresponding to electron temperature

# Plasma lines with Arecibo



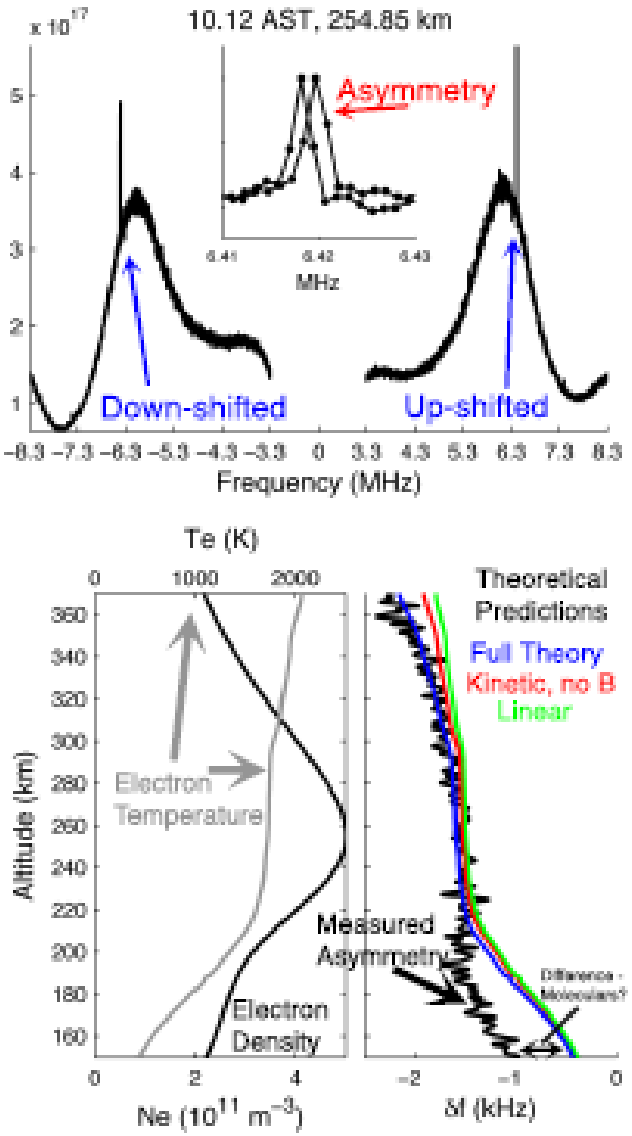



Gravity wave fluctuations in Plasma line measurements using PFISR

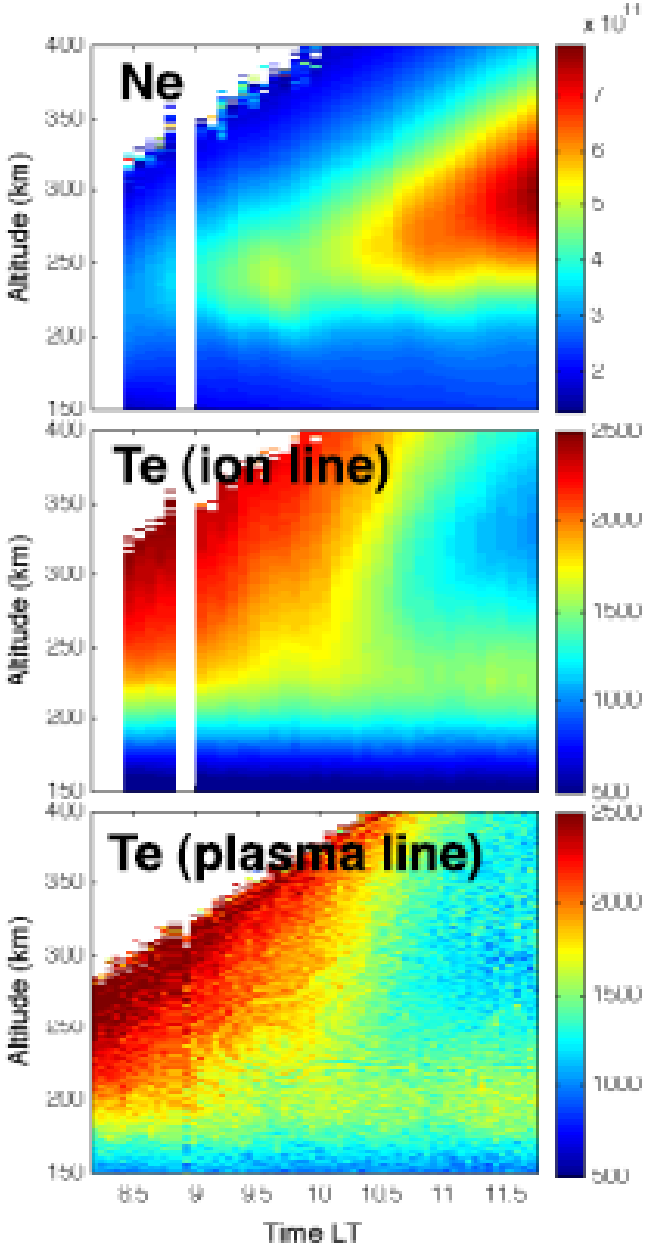


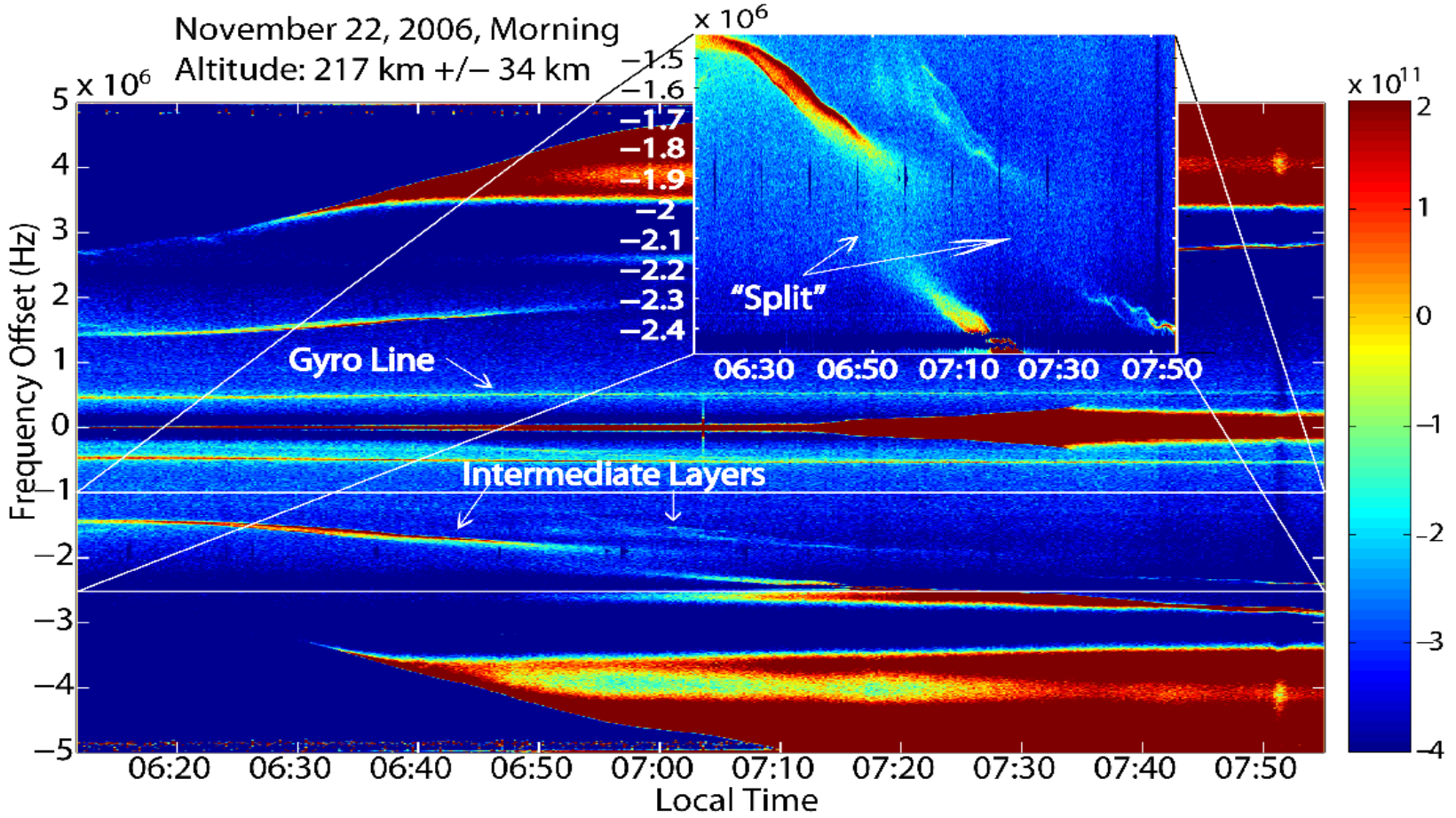
# High Resolution Plasma Line and Asymmetry

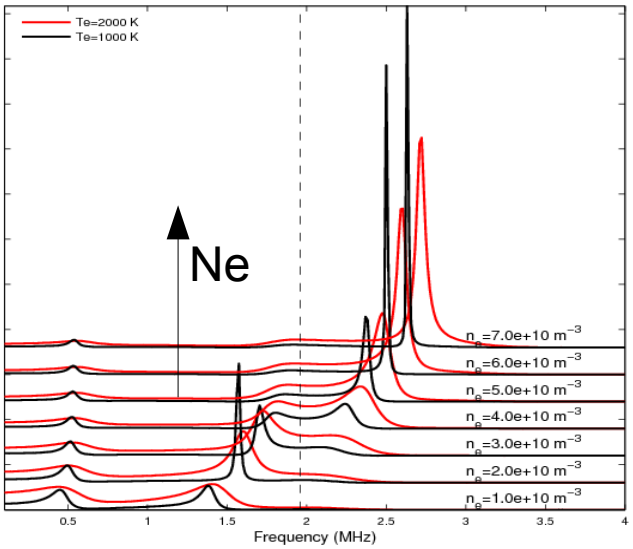
Using the asymmetry of the up- and down-shifted plasma lines, we can obtain an independent, high resolution measurement of $T_e$



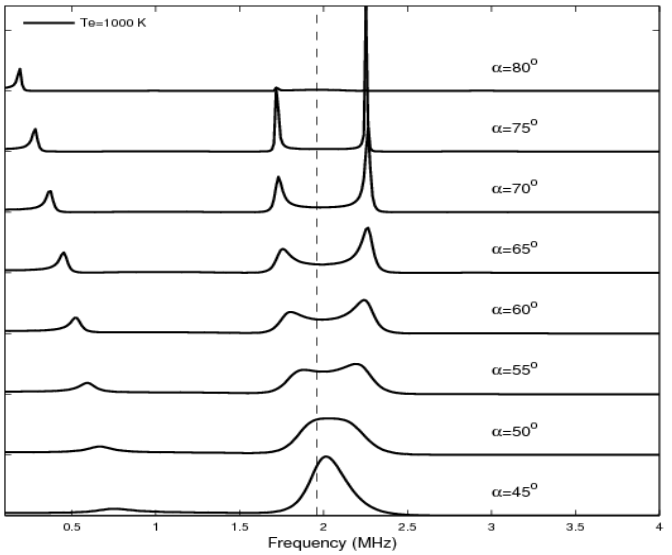

*Nicolls et al., GRL, 2006*





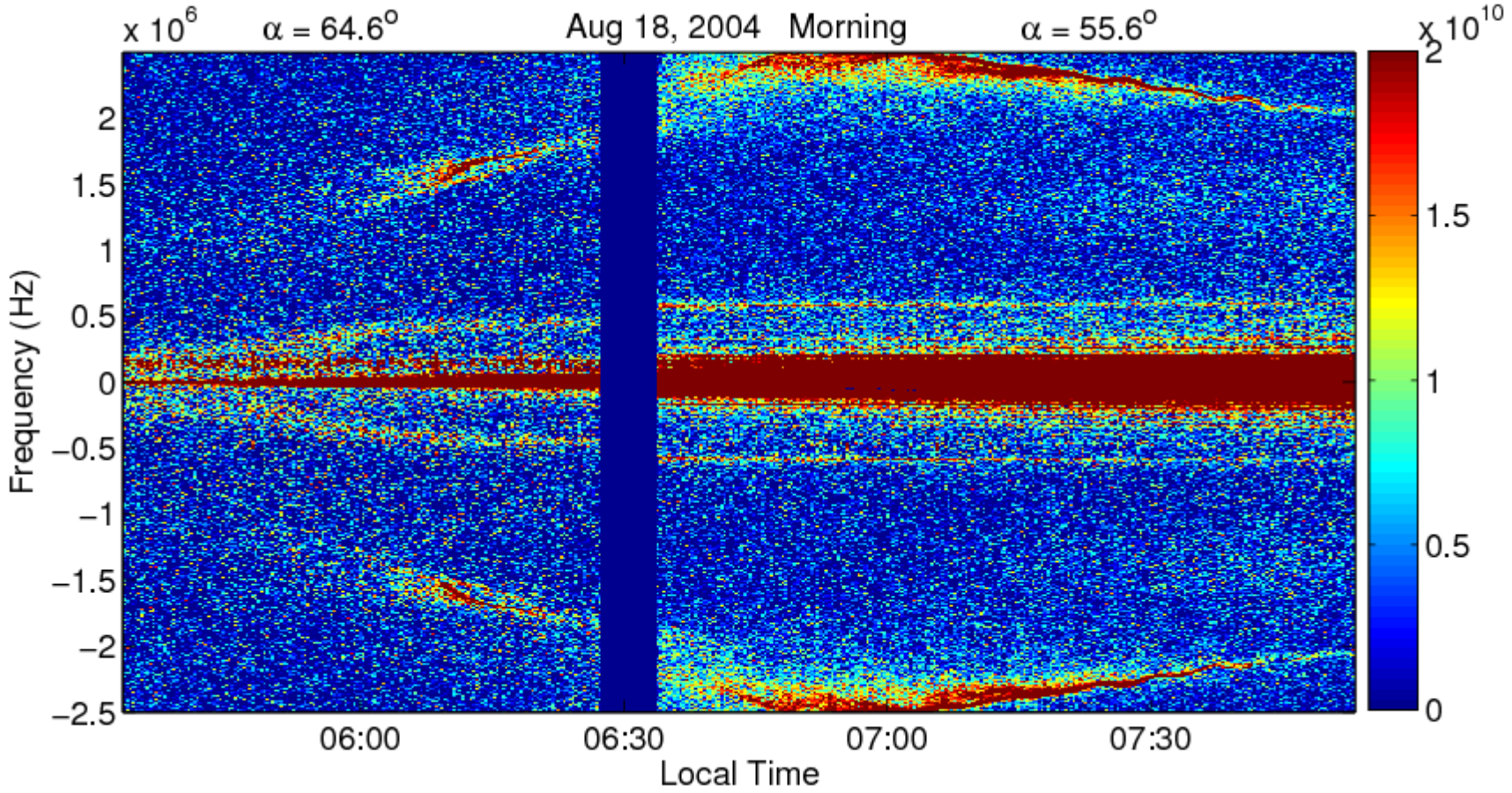




Plasma line "splits" where plasma frequency matches the second electro gyroharmonic

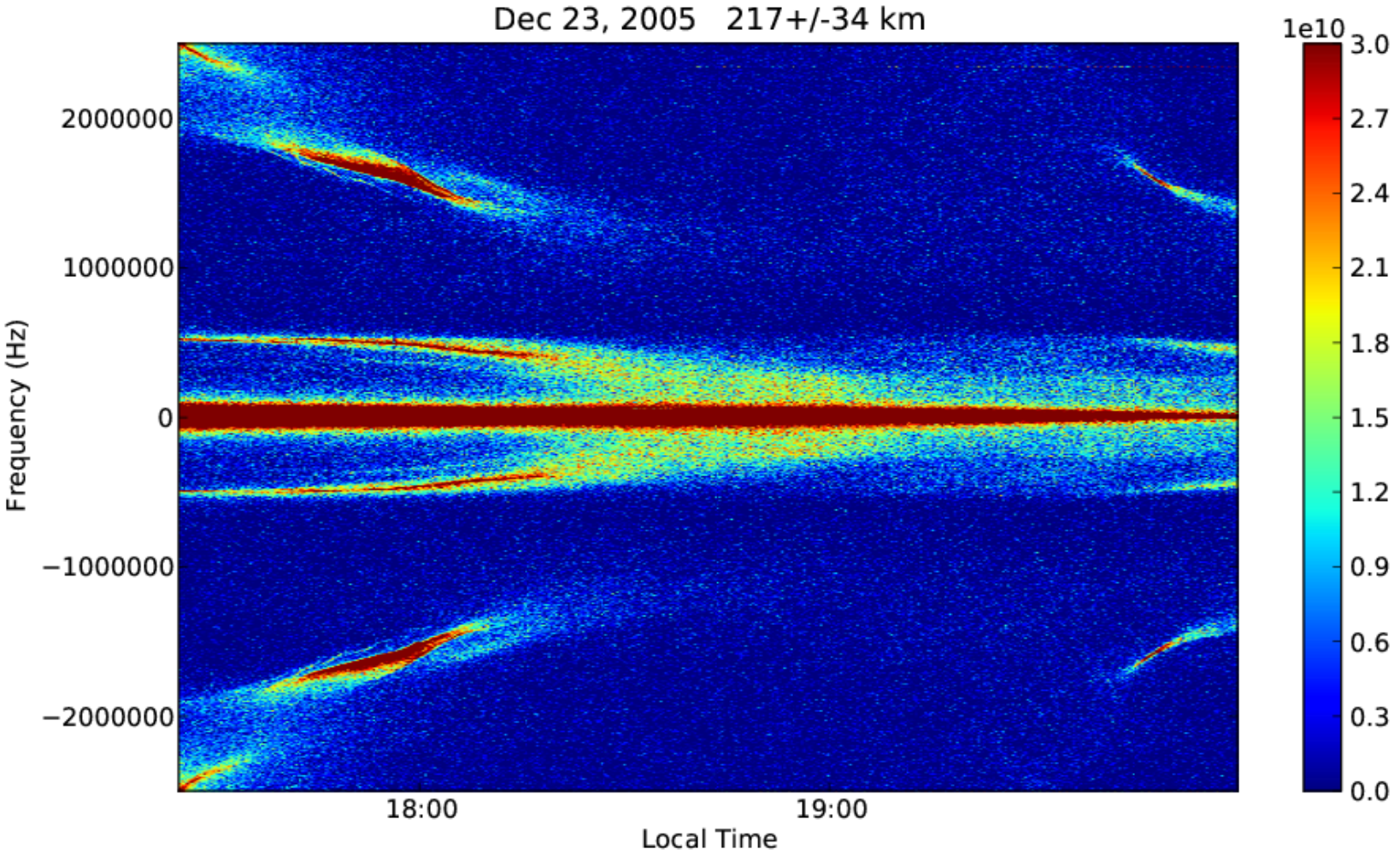


# Gyro line

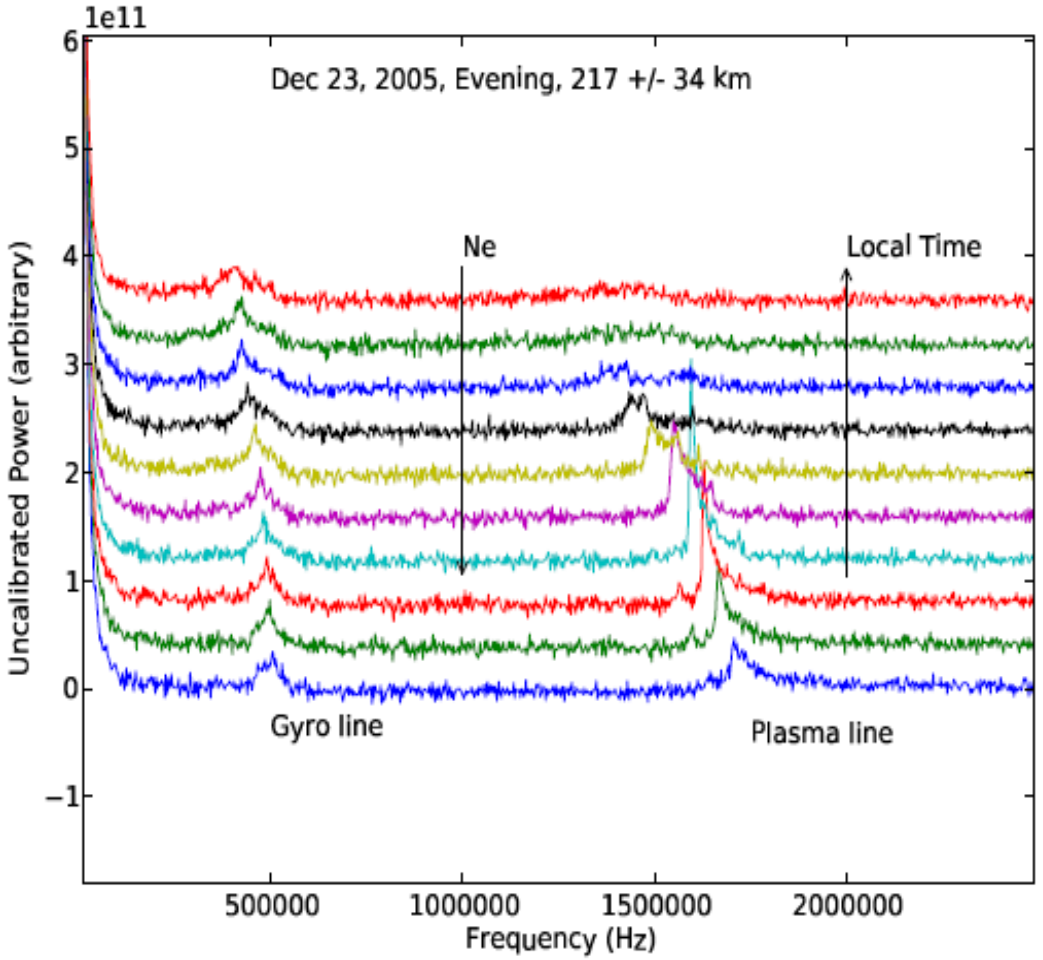
Scatter from electrostatic electron cyclotron wave – sensitive to the magnetic field and angle between k and B



# Gyro line


Dec 23, 2005 217+/-34 km
Frequency (Hz)
2000000
1000000
0
−1000000
−2000000
18:00
19:00
Local Time
1e10
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0

# Gyro line



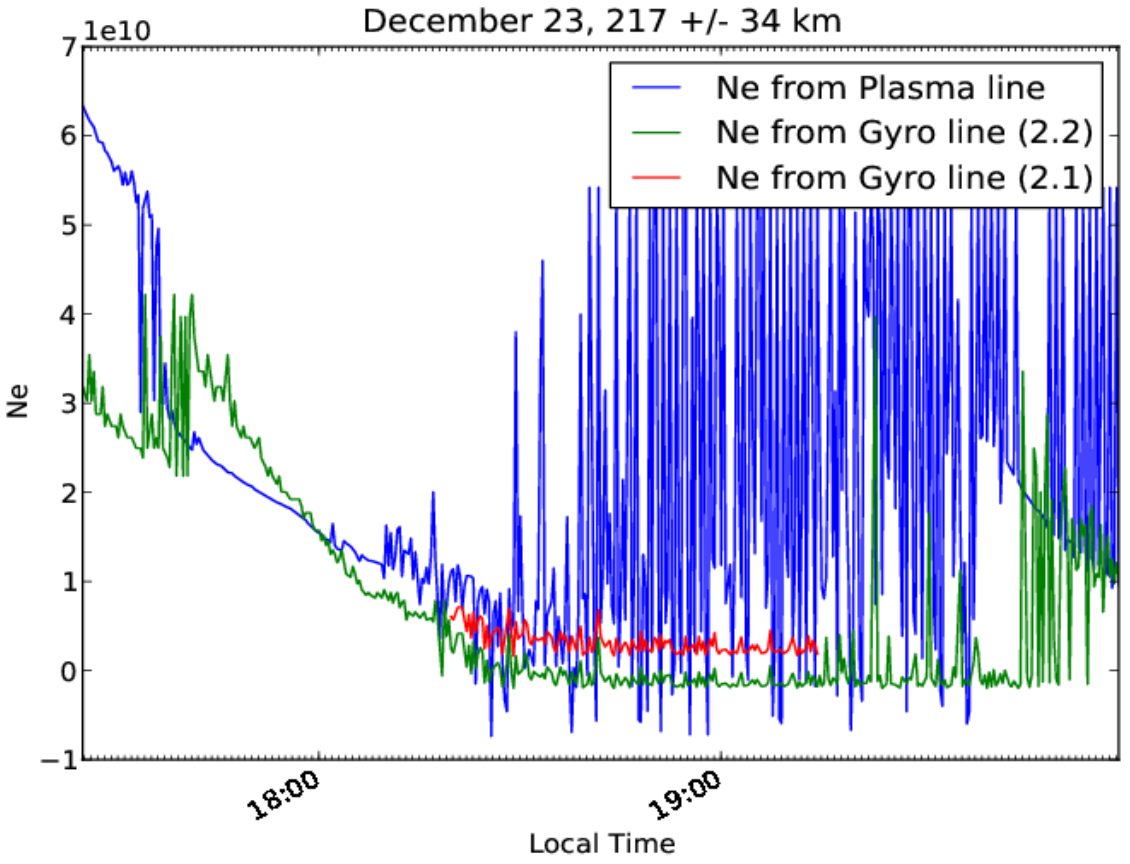

For $\omega_p < \Omega_e$

$$\omega_{GL}^2 = \omega_p^2 \sin^2 \phi$$

For $\omega_p \geq \Omega_e$

$$\omega_{GL}^2 = \Omega_e^2 \left[ \frac{\omega_p^2}{(\Omega_e^2 + \omega_p^2)} + \frac{3}{2} \frac{k^2 v_{the}^2}{\Omega_e^2} \right] \sin^2 \phi$$

# Sensitivity to electron density




Observed

From theory