Incoherent scatter spectra based on Monte Carlo simulations of ion velocity distributions

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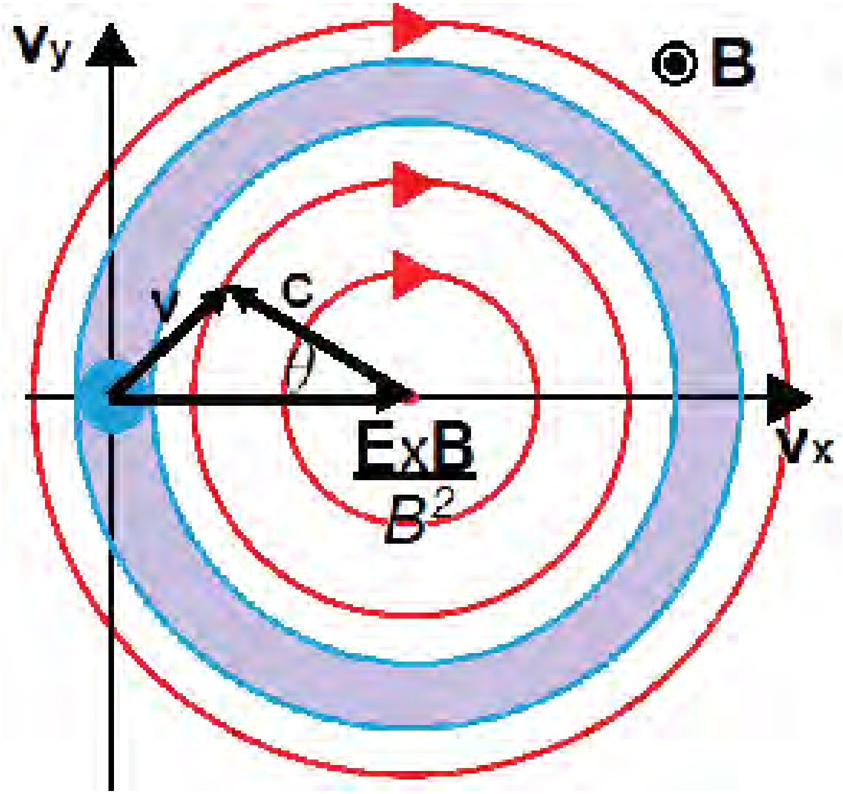
Outline

- Ion frictional heating and ion velocity distributions
- Modifications to previous work
- Anisotropic ion temperatures
- Incoherent scatter spectra
- Preliminary spectral fitting results
- Summary

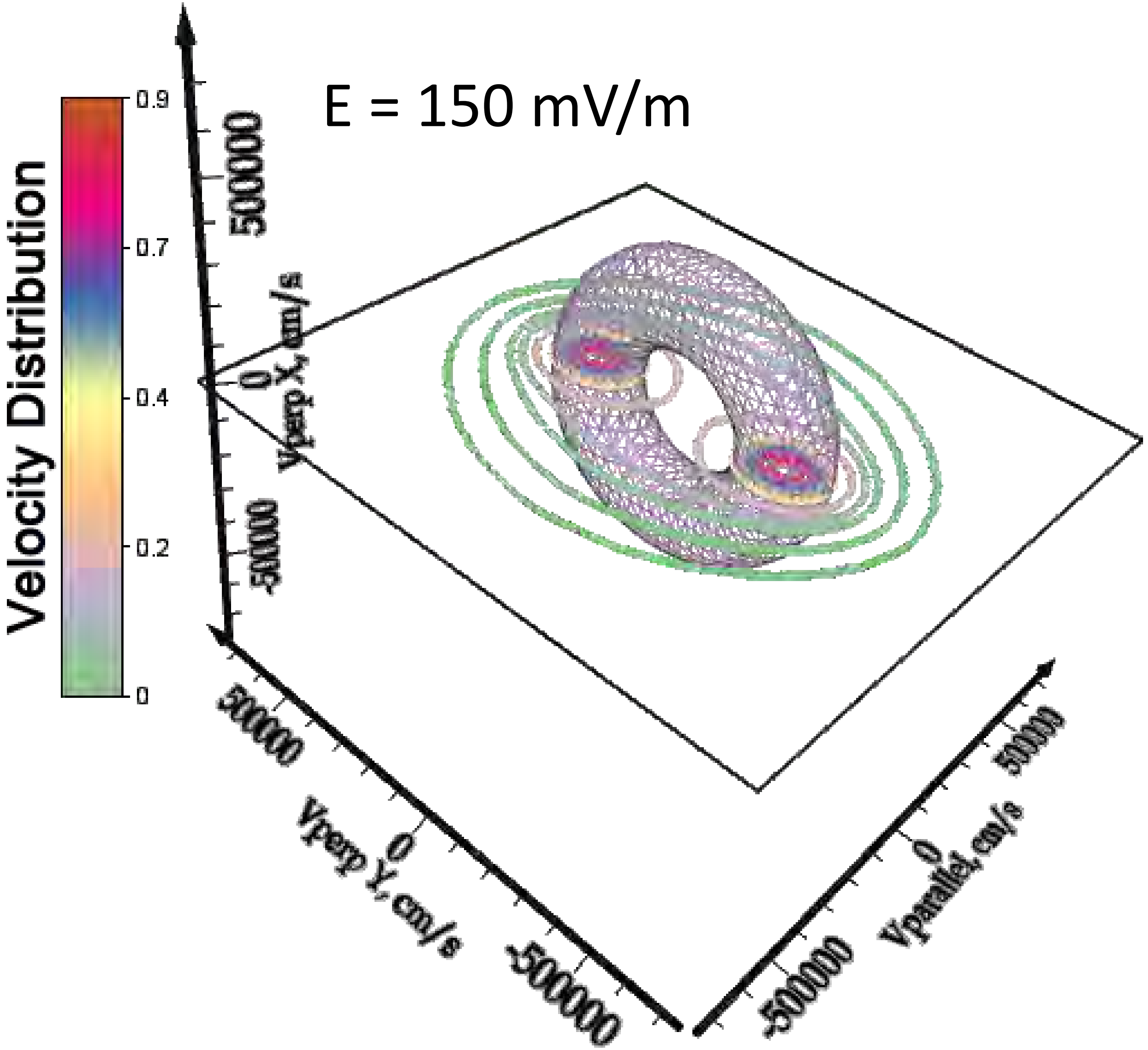
Ion frictional heating and IS spectra

- From St-Maurice and Schunk [1977] the Lorentz force can be re-written as:

$$\frac{d}{dt}\left(\mathbf{v} - \frac{\mathbf{E}\times\mathbf{B}}{\mathbf{B}^2}\right) = \left(\mathbf{v} - \frac{\mathbf{E}\times\mathbf{B}}{\mathbf{B}^2}\right) \times \vec{\Omega}$$



- The distortions introduce different temperatures parallel and perpendicular to the magnetic field.
- Monte-Carlo simulations (e.g. Winkler et. al., [1992]) are needed for a precise ion velocity distribution determination.



Modifications to Winkler et. al., [1992]

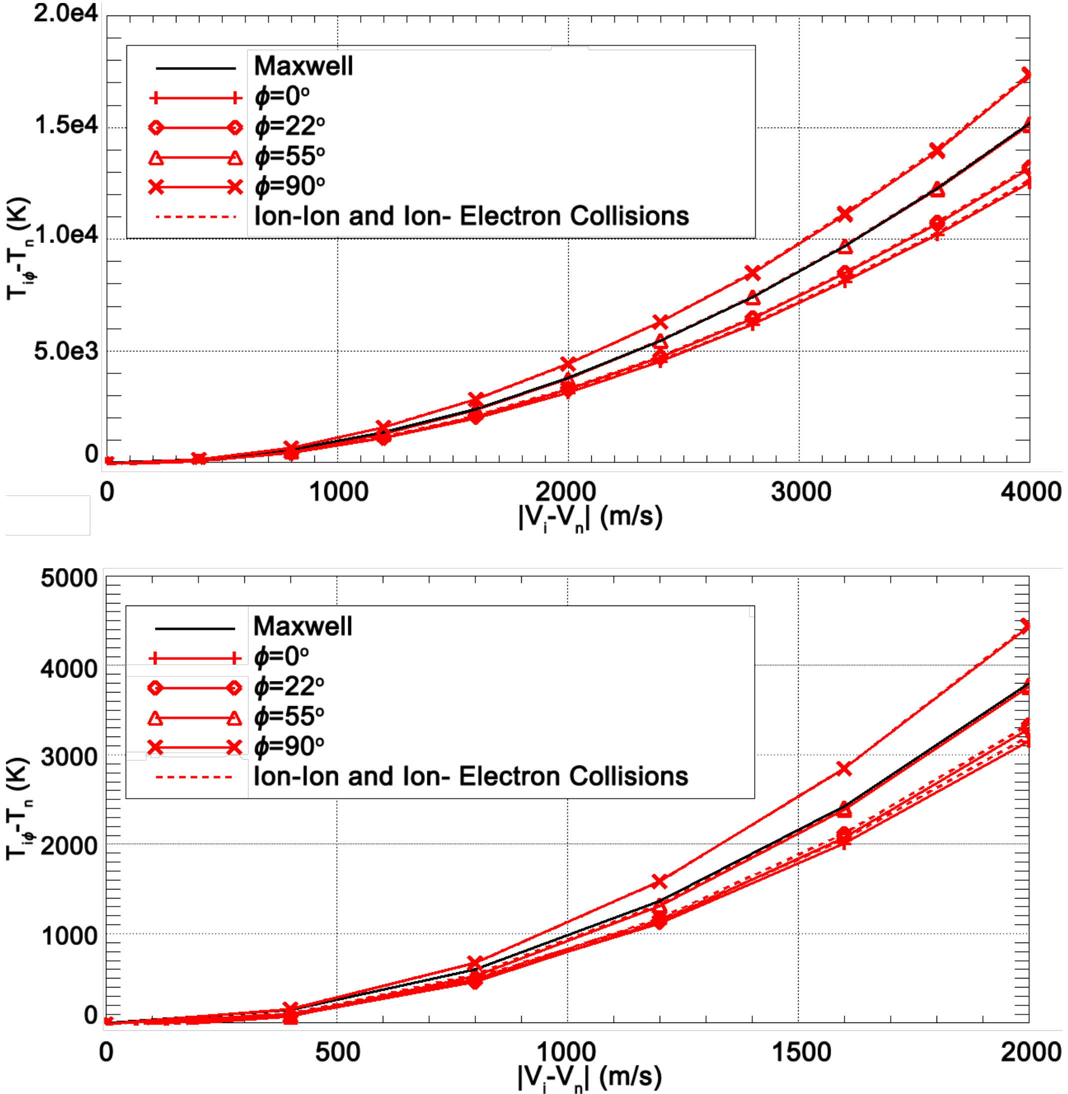
- A much higher number of collisions used to reduce statistical noise.
- Improved fitting techniques are used to smooth out the velocity distributions.
- Introduction of Nyquist diagrams to test the stability of the plasma against electrostatic fluctuations.
- Collisions with other charged particles added empirically through:

$$\nu_T f_i = \nu_{in} f_{in} + \nu_{ii} f_{i1} + \nu_{ie} f_{i2},$$

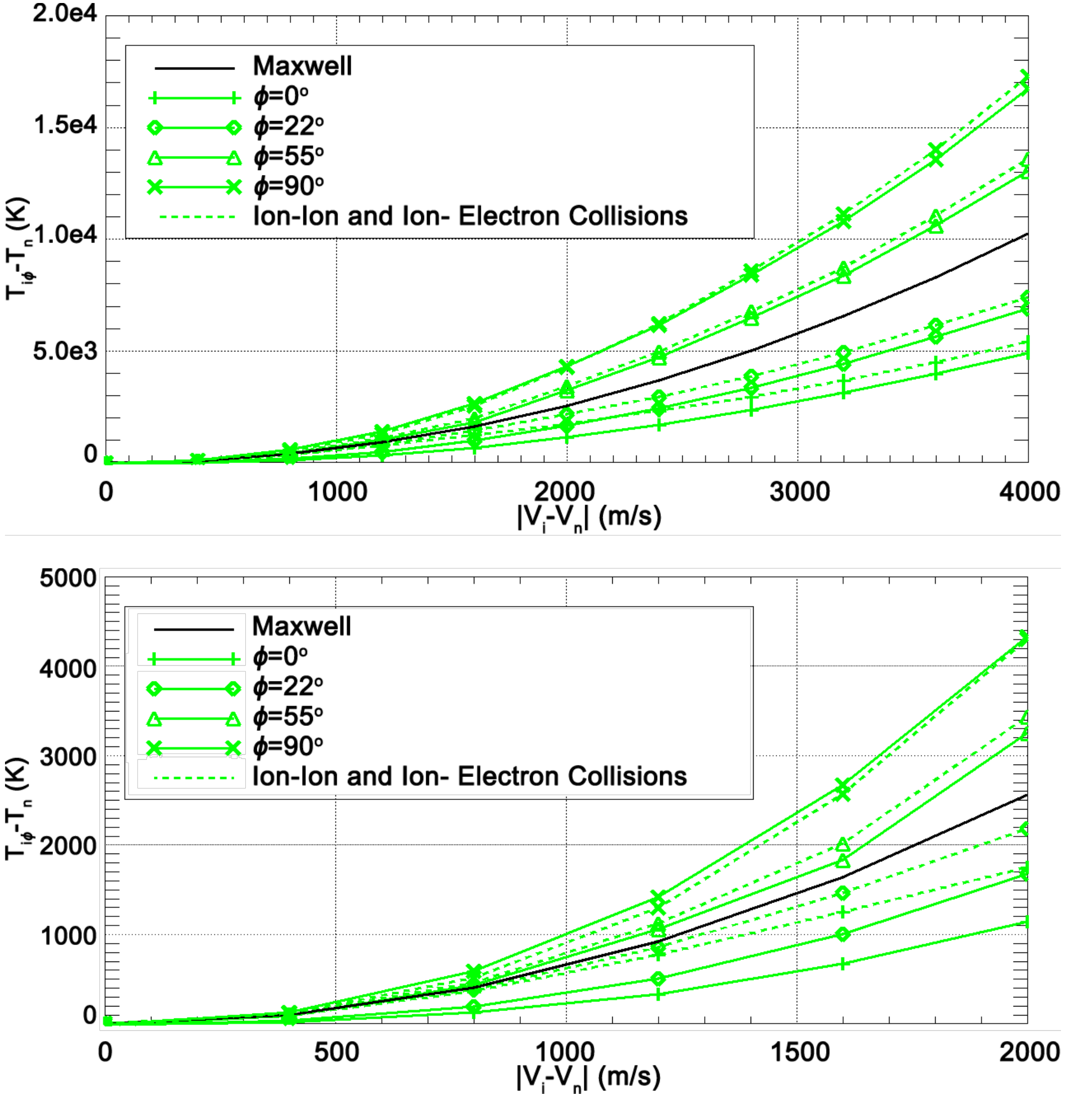
where $\nu_T = \nu_{in} + \nu_{ii} + \nu_{ie}$

Anisotropic Ion Temperatures

NO^+ with 50% N_2 and 50% O

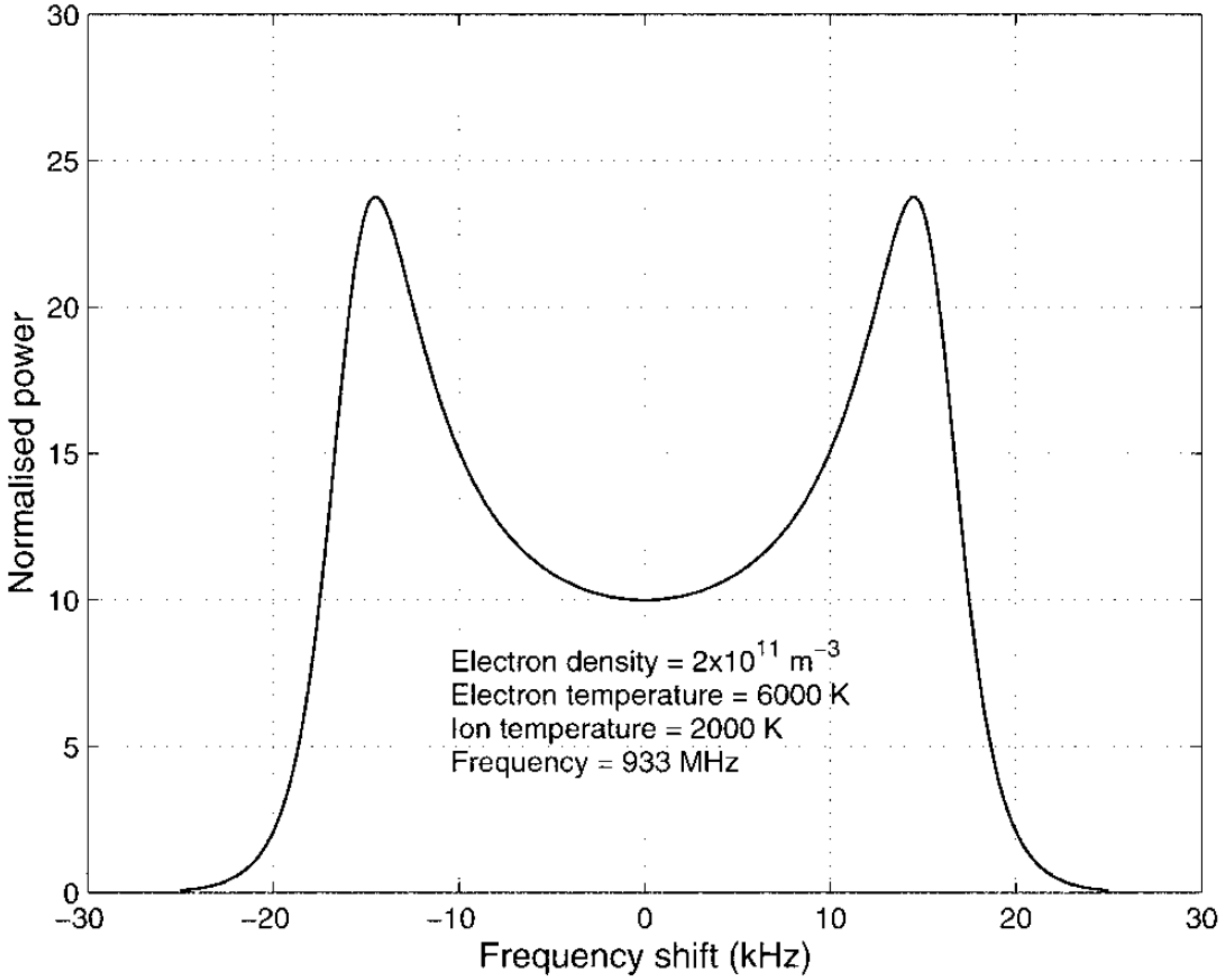


O^+ with O using Pesnell et al., [1993]



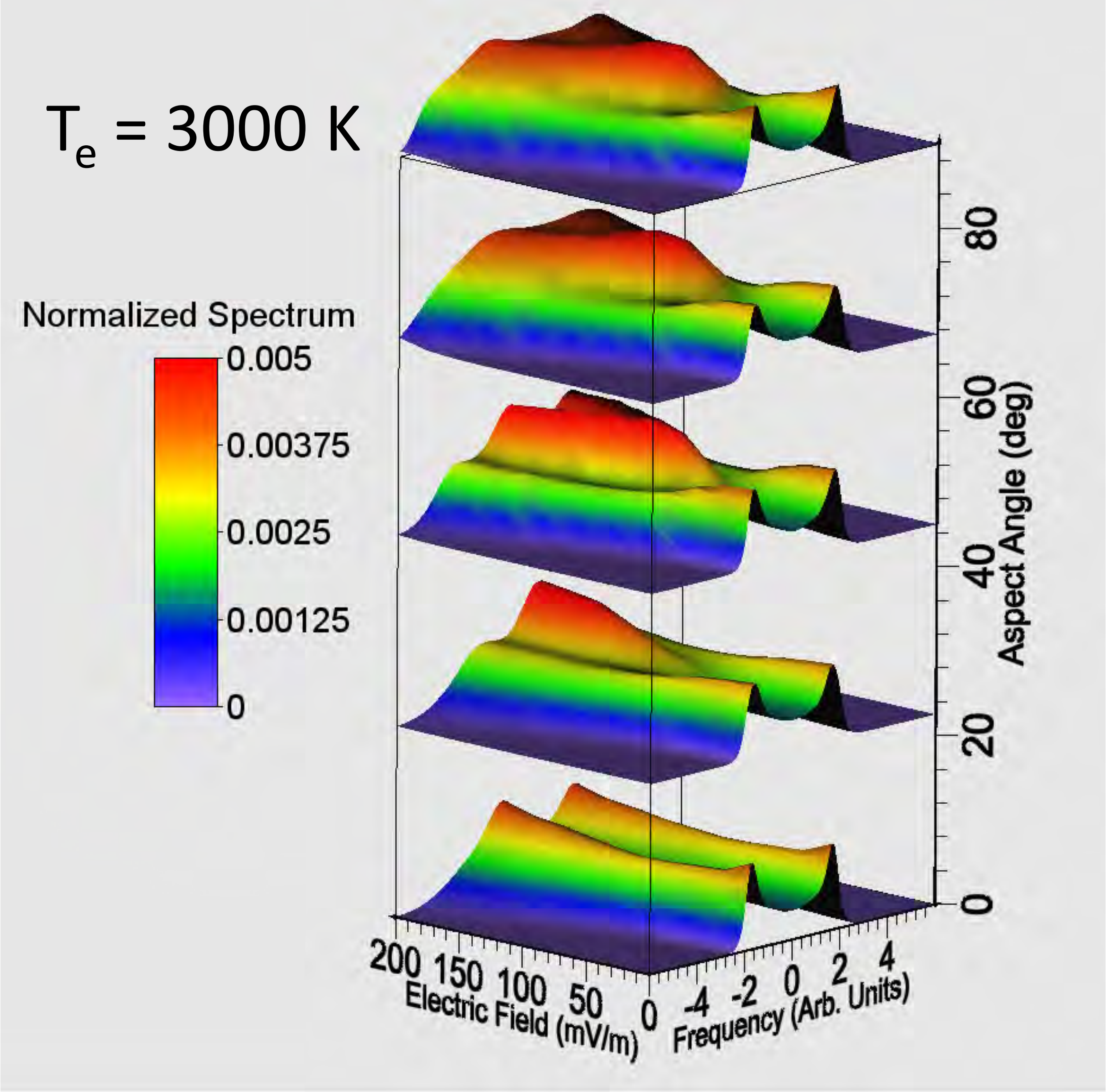
Incoherent Scatter Spectra

- Current ISR spectral fitting techniques assume that the ion velocity distribution to be Maxwellian:
  - The tip of the peak to the bottom of the trough relates to T_e/T_i.
  - The frequency shift indicates the Doppler shift and V_i.
  - The integrated spectral power is approximately
    $n_e/(1 + T_e/T_i)$.



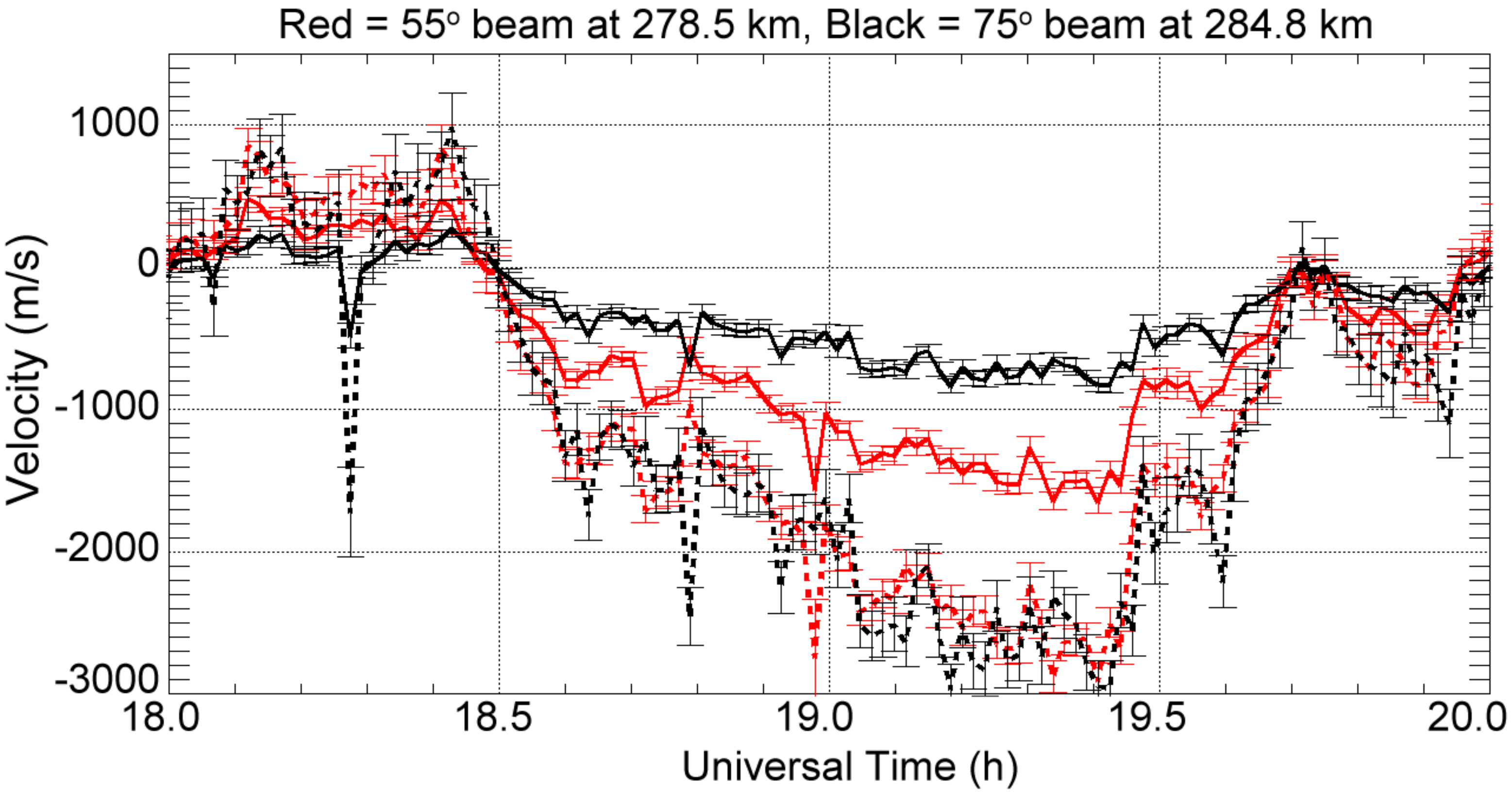
Evolution of O^+ IS spectra

- The results of this work are published in Goodwin [2018]



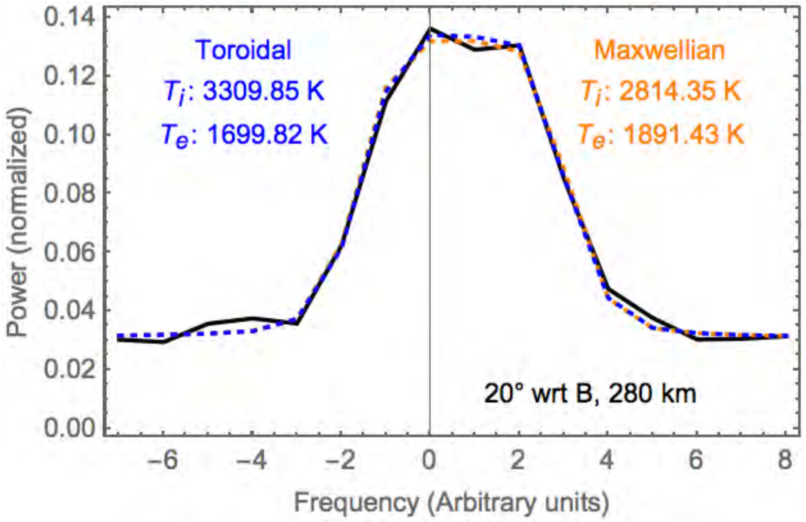
Preliminary Spectral Fitting Results – 2014-09-12

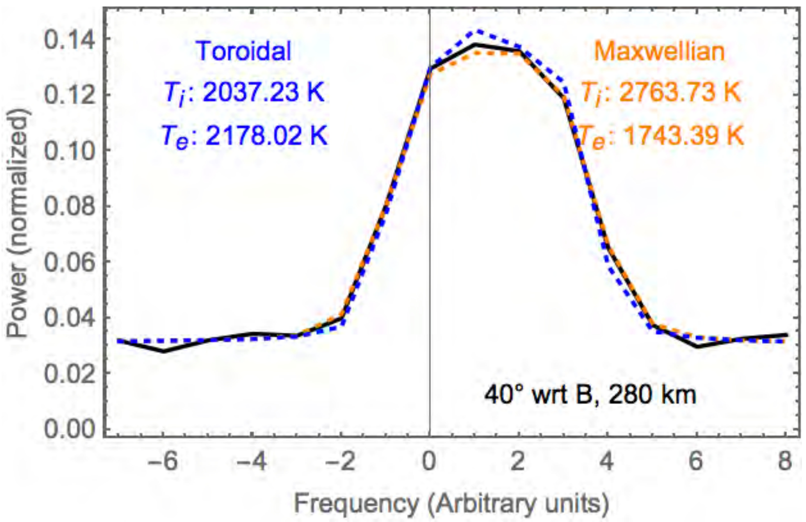
- Tests are performed using a high electric field event detailed in Clauer, et al. (2016).
- To keep things simple, we are currently examining F-region spectra taken at high elevation.
  - O^+-O collisions
  - Less noise

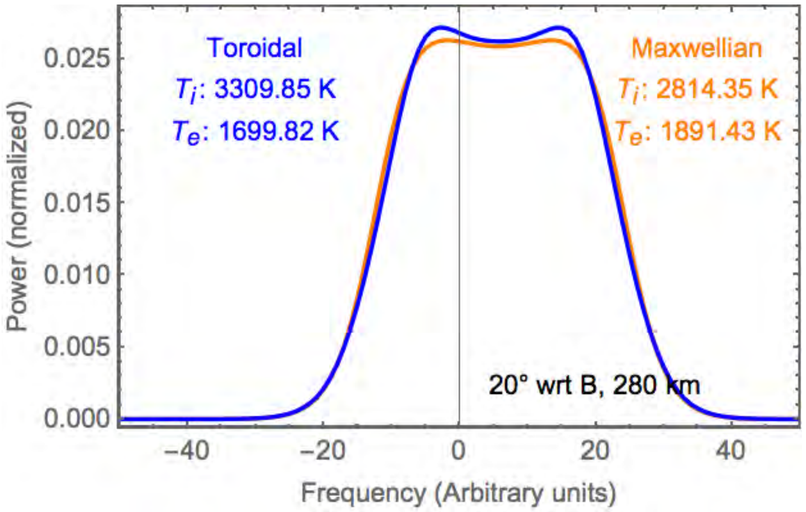


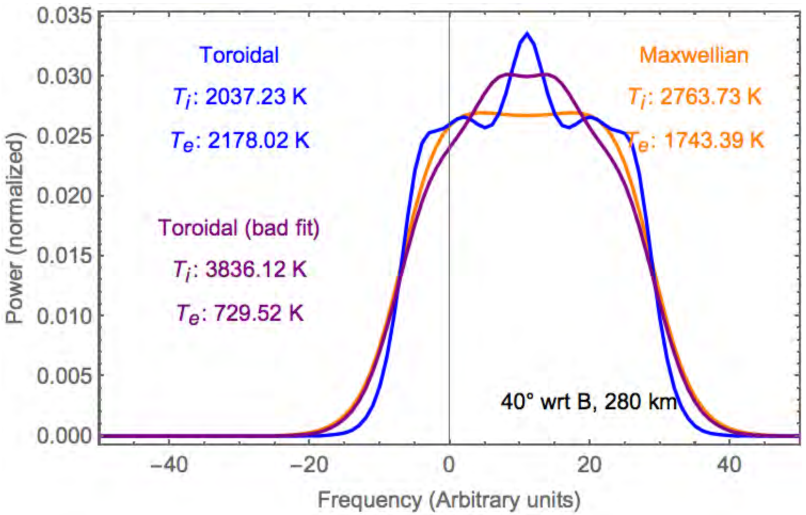
Preliminary Spectral Fitting Results

- The differences between toroidal and Maxwellian spectra are not apparent when viewed at the low resolution that ACF are fit at.
- At 20˚ (with respect to **B**) the toroidal spectra look pretty Maxwellian.
- At 40˚ they look very different than Maxwellian and there is a false best-fit minima.









Summary

- The anisotropy of the ion velocity distribution is now fully characterized for all possible interactions between atomic and molecular ions and neutrals throughout the F-region.
- This research presents the first comprehensive calculation of IS spectra from Monte-Carlo based, toroidal ion velocity distributions.
- It is critical to incorporate complete description of the ion velocity distribution for a variety of electric fields and aspect angles into ISR spectral fitting routines that currently assume ion velocity distributions to be Maxwellian.
- A better frequency resolution is needed to unambiguously fit toroidal spectra.
  - New experiment runs required

Thank you

Back-up Slides

The impact of a different O^+-O collisional cross-sections