UCLA College | Physical Sciences
Earth, Planetary & Space Sciences

Hot Plasma Effects on Electron Resonant Scattering by Electromagnetic Ion Cyclotron Waves

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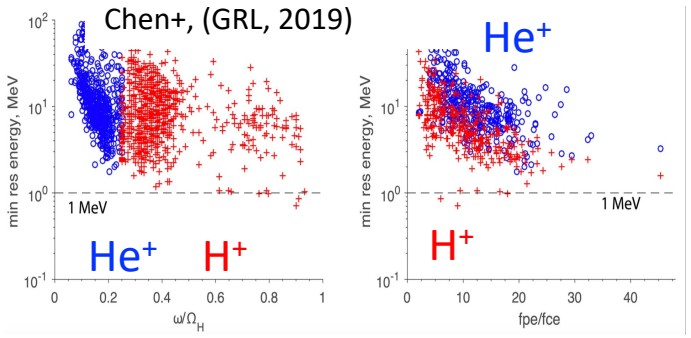
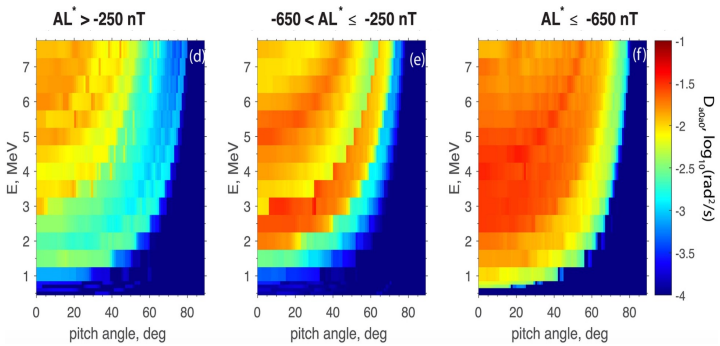
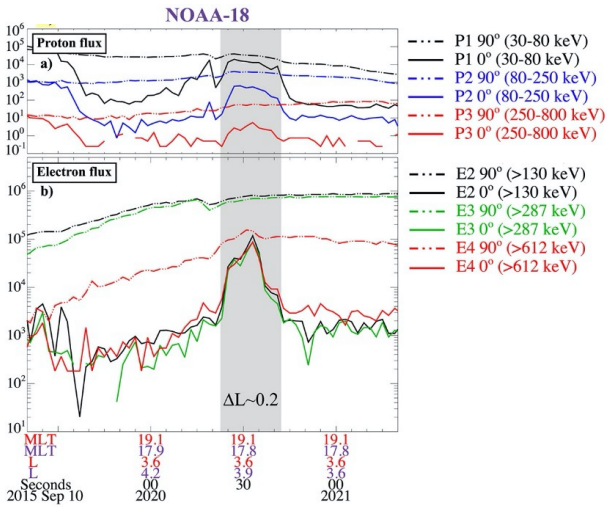
Motivation and Goals and Objectives:







Capannolo+ (JGR 2019)

$$E_{min} = \left(\sqrt{\frac{\Omega_{ce}^2}{k_\parallel^2 c^2} + 1} - 1 \right) m_0 c^2$$

Observations: MMS (Vines+ (JGR, 2021) VAPs (Chen+ (GRL, 2019))

Theory

Cold Plasma Hot Plasma

$$\frac{k_\parallel^2 c^2}{\omega^2} = 1 - \sum_{cs} \frac{\omega_{pcs}^2}{\omega\,(\omega - \Omega_{cs})} + \sum_{hs} \frac{\omega_{phs}^2}{\omega^2} \left[A_{wp} + \left\{ A_{wp} + \frac{\omega}{(\omega - \Omega_p)} \right\} \xi_{wp} Z(\xi_{wp}) \right]$$

Our analytical Model

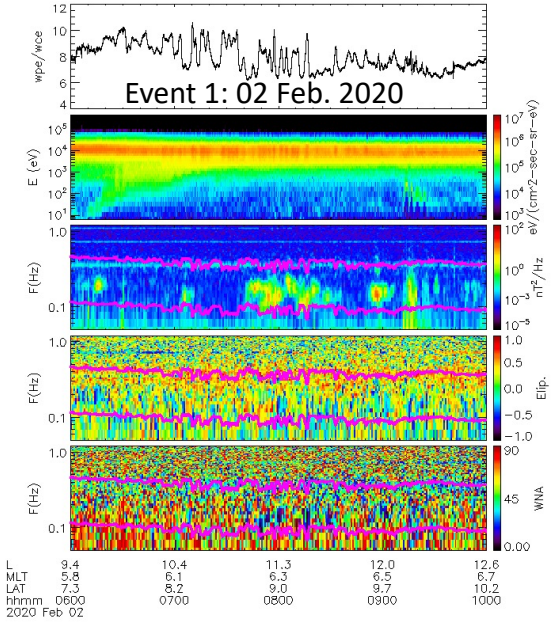
$$\frac{k_{hot}}{k_{cold}} = \frac{1}{\sqrt{1 + \sum_{hs} \left(A_{hs} - \frac{x}{1 - \epsilon_{hs} x} \right) \frac{\beta_{\parallel hs}}{2(x-1)^2}}}$$

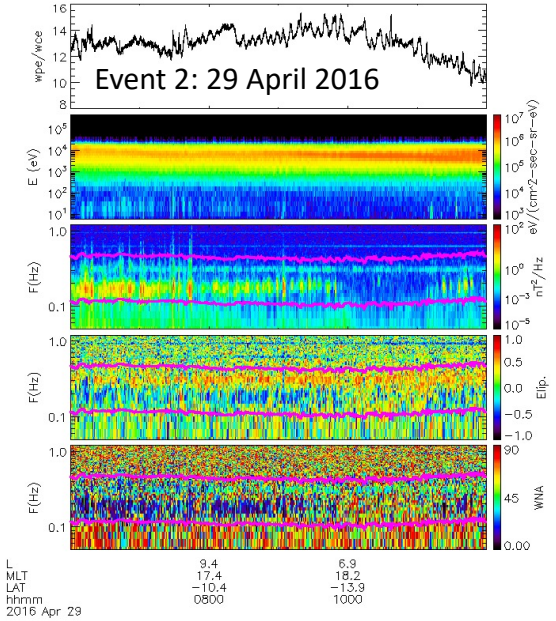
Questions:

- What are the typical hot ion spectral characteristics during EMIC wave observations?
- How can we quantify the hot plasma effects on the electron resonant losses driven by EMIC waves?
- What are the typical electron resonant energies for observed EMIC waves with cold and hot plasma dispersions?

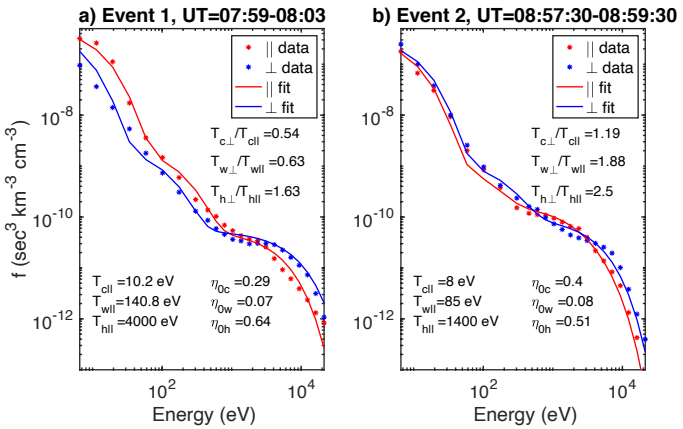
EMIC Observations by THEMIS and related properties

Examples

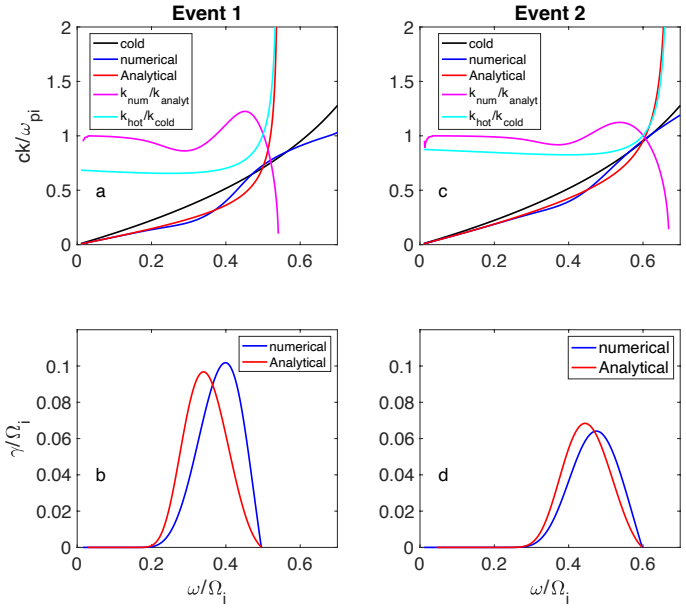




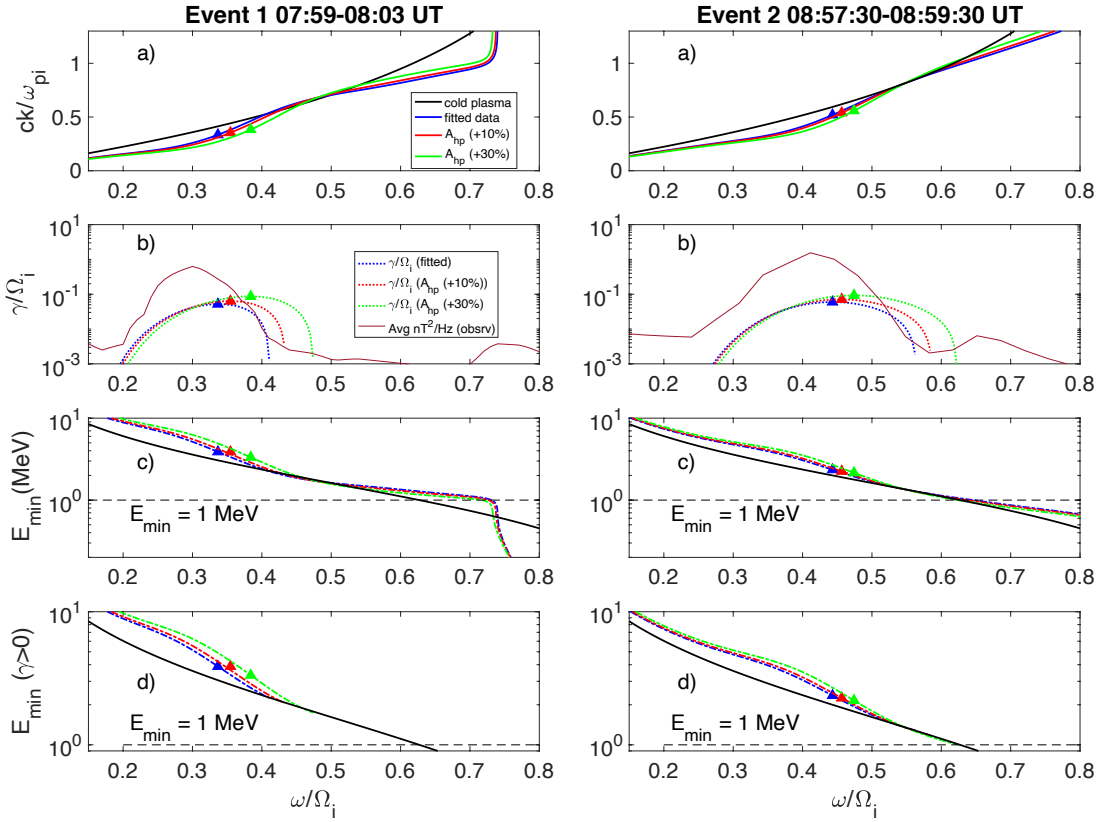
Ion Distribution



Model Comparison (~90% accuracy)



Hot plasma Effects on Resonant Energies



- The **hot plasma** (ion) effects significantly
- **A proper** evaluation of the minimum energy for electron resonant scattering by EMIC waves with a hot plasma dispersion requires consideration of the **entire unstable wave frequency range.**
- Our **analytical model** is in a very good agreement (**~90% accuracy)** with numerical results.

Resonant Interaction of EMIC with Energetic electron (Diffusion Coefficient)

Diffusion coefficient

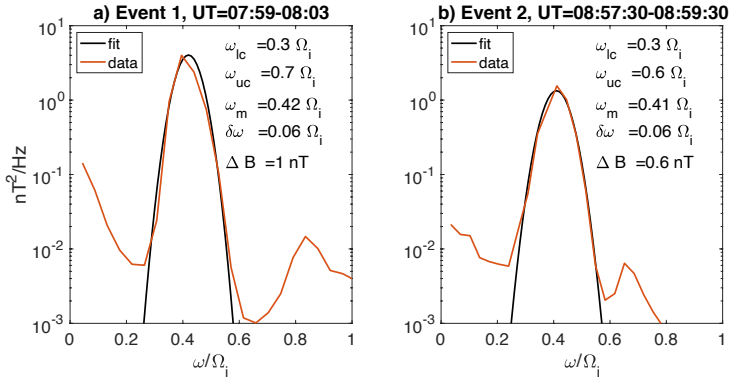
Summers (JGR, 2005)

$$D_{\alpha\alpha} = \frac{\pi}{2}\frac{\Omega_e^2}{W_0}\frac{1}{(E+1)^2}\left(1-\frac{\omega\mu}{kv}\right)^2\frac{W(k)}{|v\mu - d\omega/dk|}$$

with

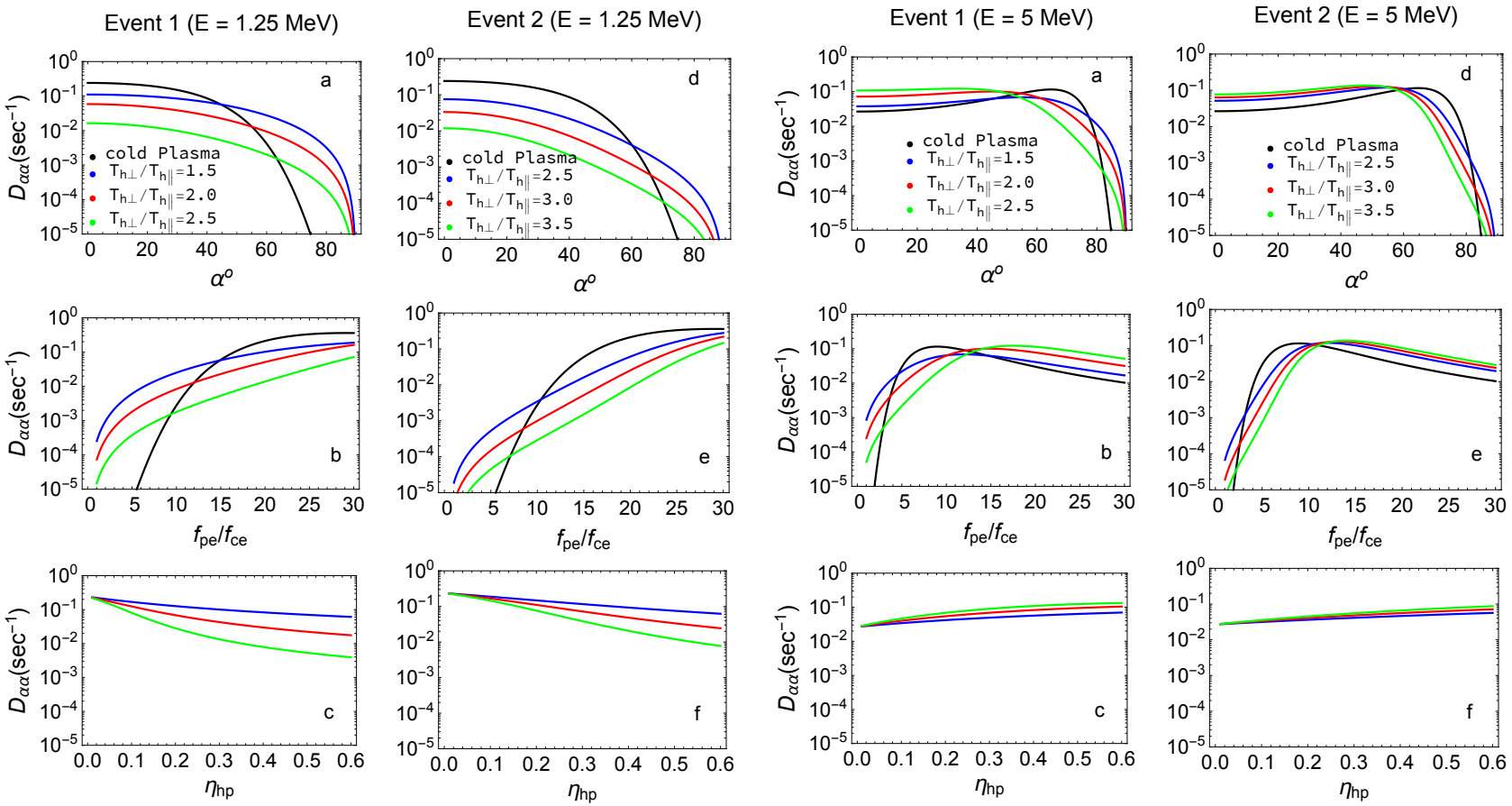
$$W(k_\parallel) = \frac{|\Delta B|^2}{8\pi}\frac{1}{\nu}\frac{1}{\delta\omega}\left|\frac{d\omega}{dk}\right|\exp\left(-\frac{(\omega-\omega_m)^2}{\delta\omega}\right)$$

Wave Spectrum



1.25 MeV case

5 MeV case



- The hot plasma effects significantly change the pitch angle scattering rate

Conclusion

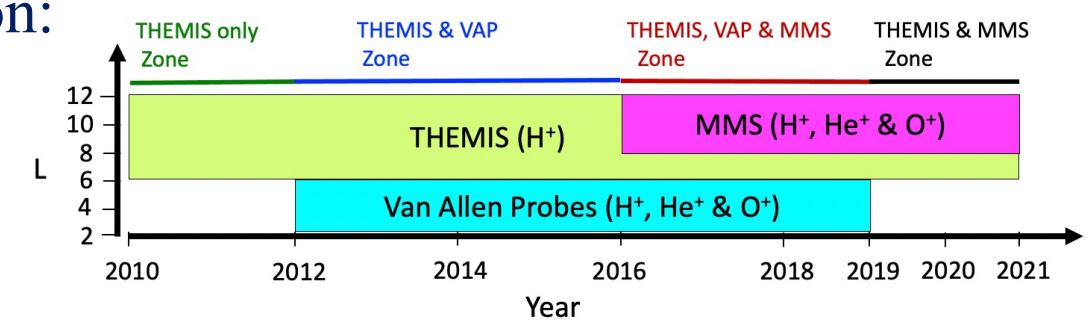
- The **hot plasma** (ion) effects significantly alter the dispersion properties of EMIC waves **especially wavenumber** and **pitch angle scattering rates.**

- **A proper** evaluation of the **minimum energy for electron resonant scattering** by EMIC waves with a hot plasma dispersion requires consideration of the **entire unstable wave frequency range.**

- Our analytically derived **k_{hot}/k_{cold} ratio is applicable to wide range of plasma parameters** and showing **a good agreement** within **10-15%** of numerical k_{hot}/k_{cold} ratio can be applied to **quasi-linear diffusion regime** and to **nonlinear regime of electron interaction** with **EMIC waves to** advancing our understanding of the energetic electron precipitation mechanism in regulating the near-Earth dynamics.

Future Direction:

$$\frac{k_{hot}}{k_{cold}} = \frac{1}{\sqrt{1 + \sum_{hs} \eta_{hs} \left(A_{hs} - \frac{x}{1 - \epsilon_{hs} x} \right) \frac{\beta_{\parallel hs}}{2(x-1)^2}}}$$



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Thank You