Excitation and saturation of electron loss cone by upper-hybrid wave and Z mode instabilities in the Earth's magnetosphere

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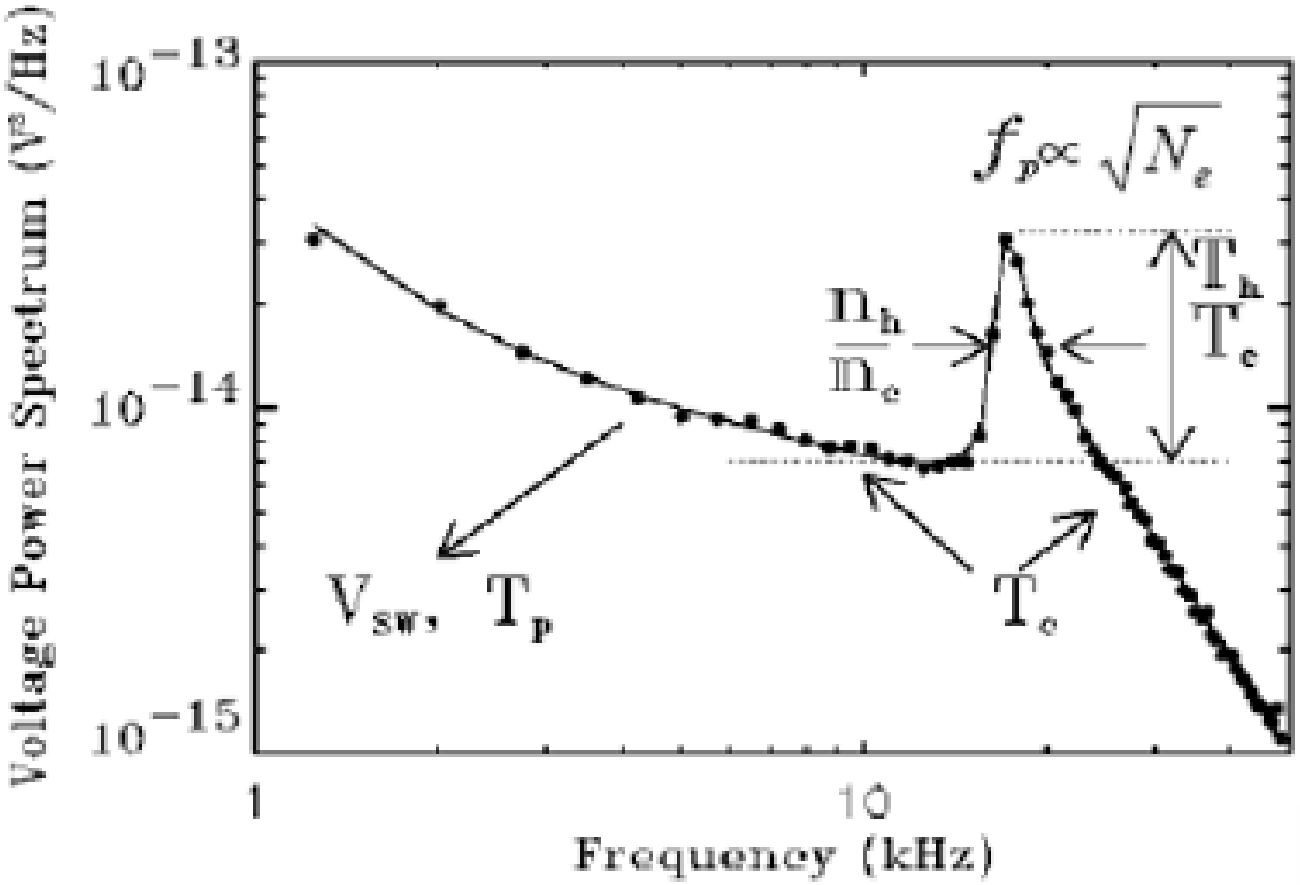
Motivation

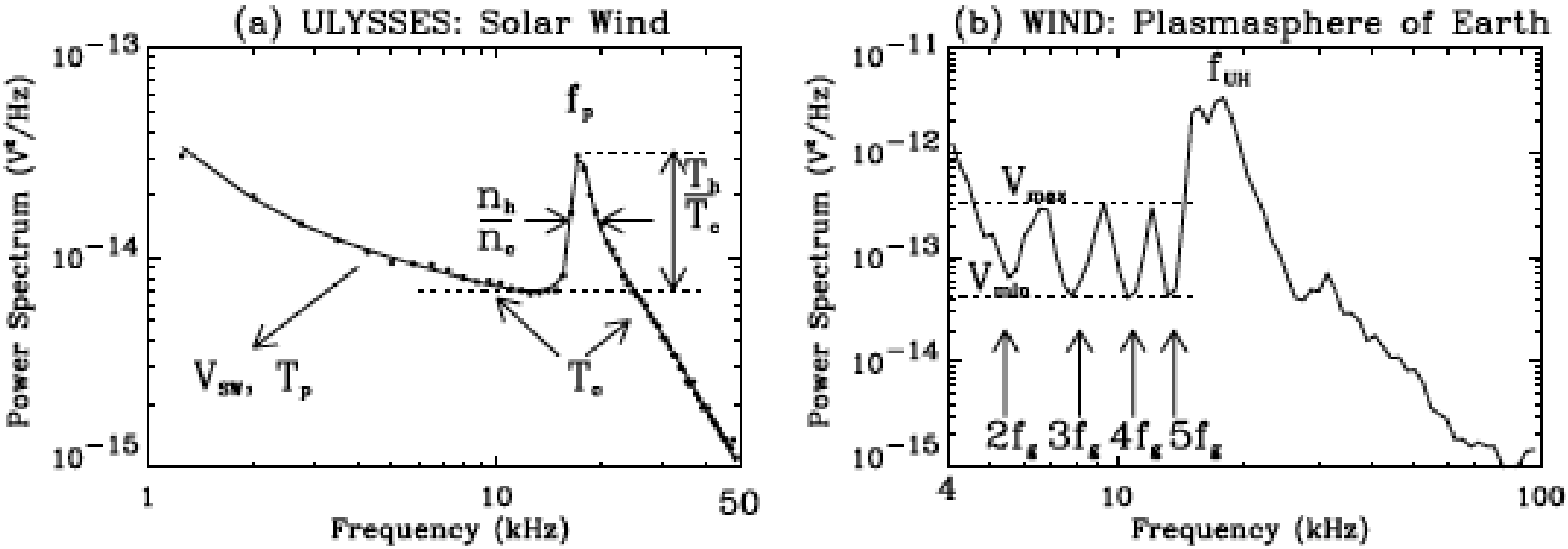
- Thermal noise spectroscopy proxy for particle detector

1AU Solar Wind Quasi Thermal Noise Spectroscopy



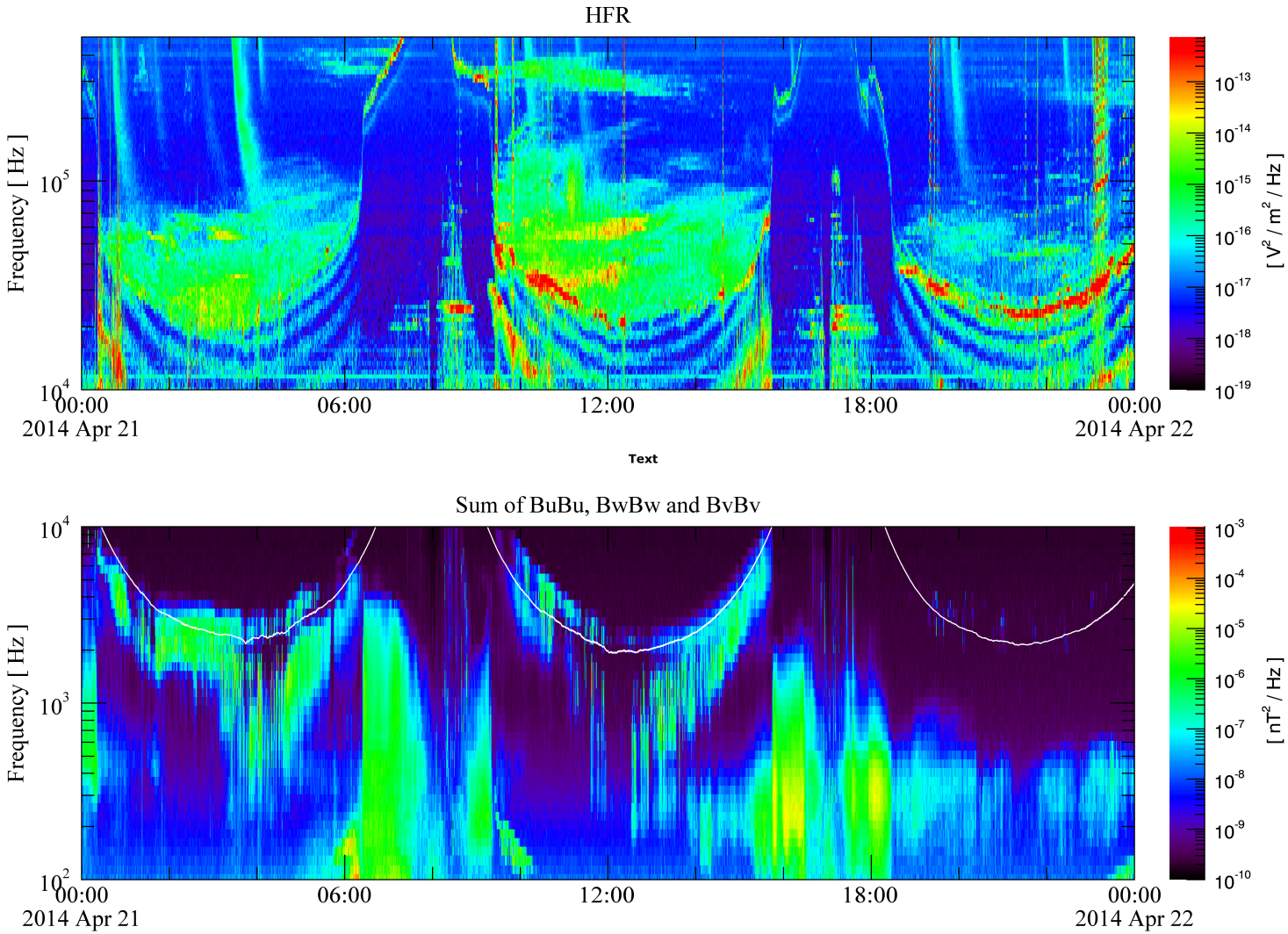
(Meyer-Vernet, Issautier, ...)

Langmuir vs Upper-Hybrid Fluctuations

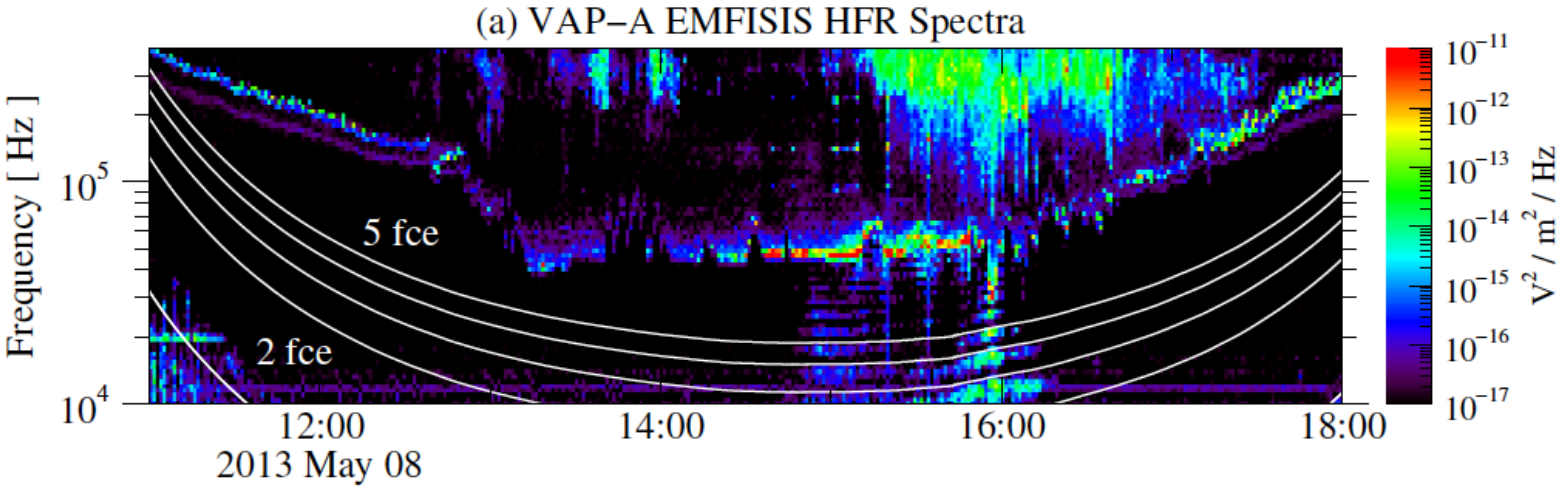


[Left] Langmuir fluctuations in the solar wind (Ulysses). [Right] Upper-hybrid fluctuations in the plasmasphere (Wind).

VAP Electric and Magnetic Field Dynamics Spectra



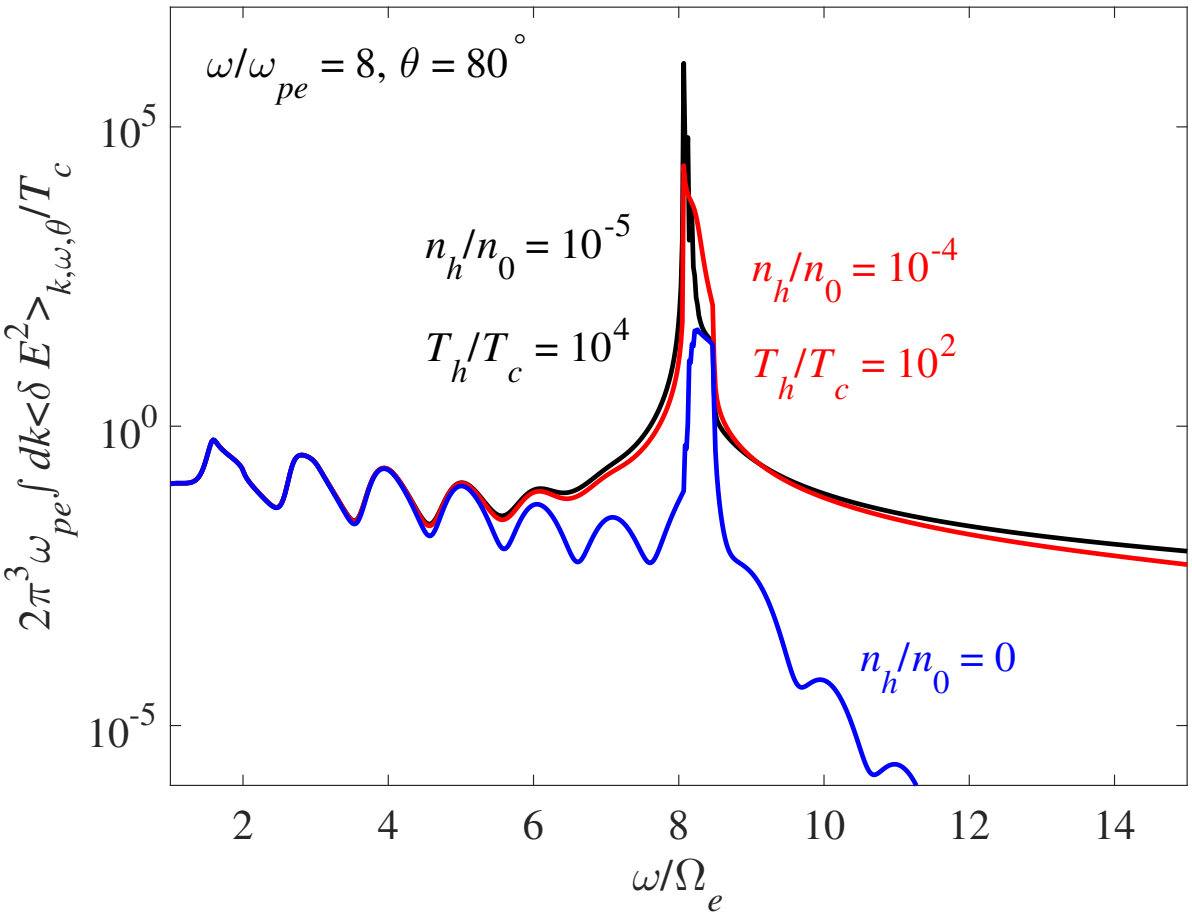
f_{uh} determines electron density



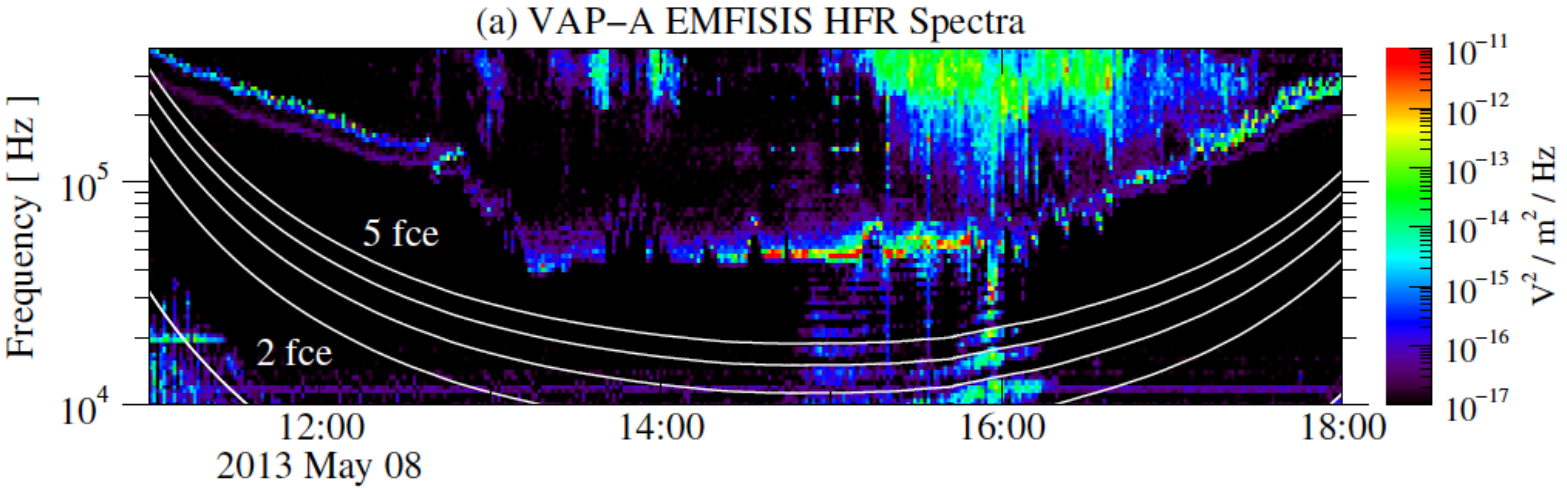
Kurth et al., JGR (2015)

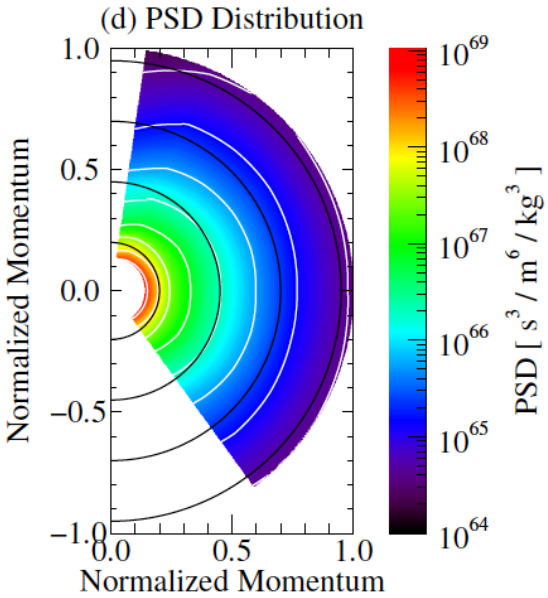
$$f_{uh}^2 = f_{pe}^2 + f_{ce}^2$$
$$f_{uh}^2 = (8.98 \times 10^3)^2 n_e + (2.80 \times 10^6)^2 B$$

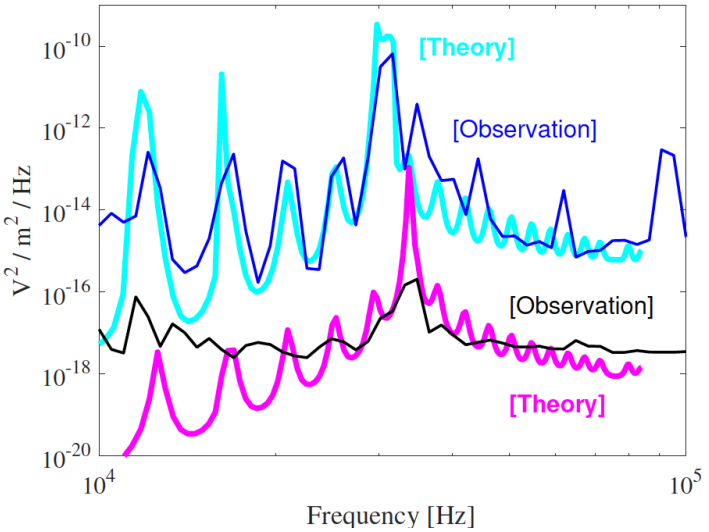
f_{uh} also determines hot electron density & temperature



Hwang et al., POP (2017), Yoon et al., JGR (2017)



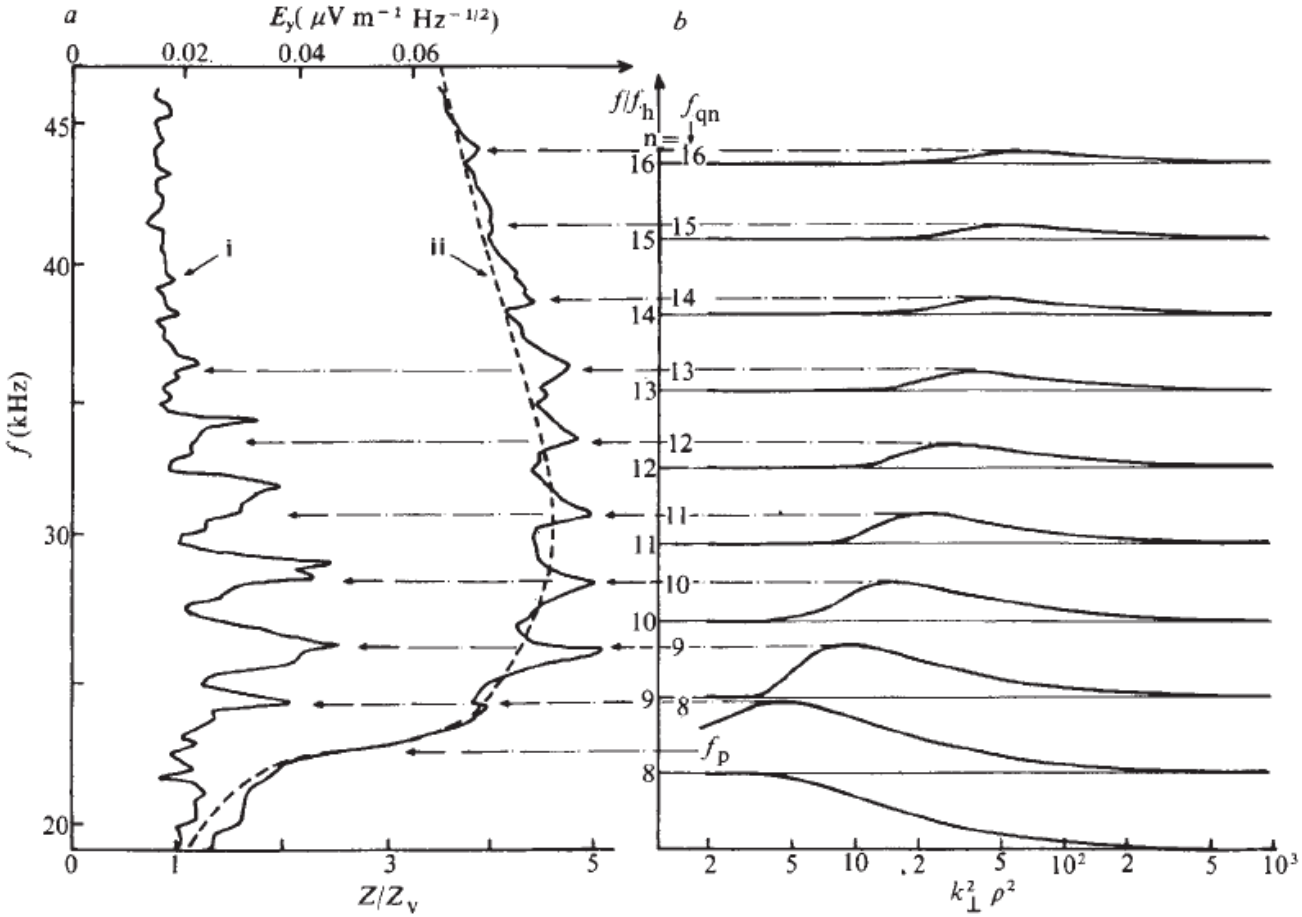




Hwang et al., POP (2017), Yoon et al., JGR (2017)

What this talk is about?

- Are upper-hybrid and nf_{ce} emissions waves or fluctuations?



Christiansen et al. 1977 (Wave interpretation)

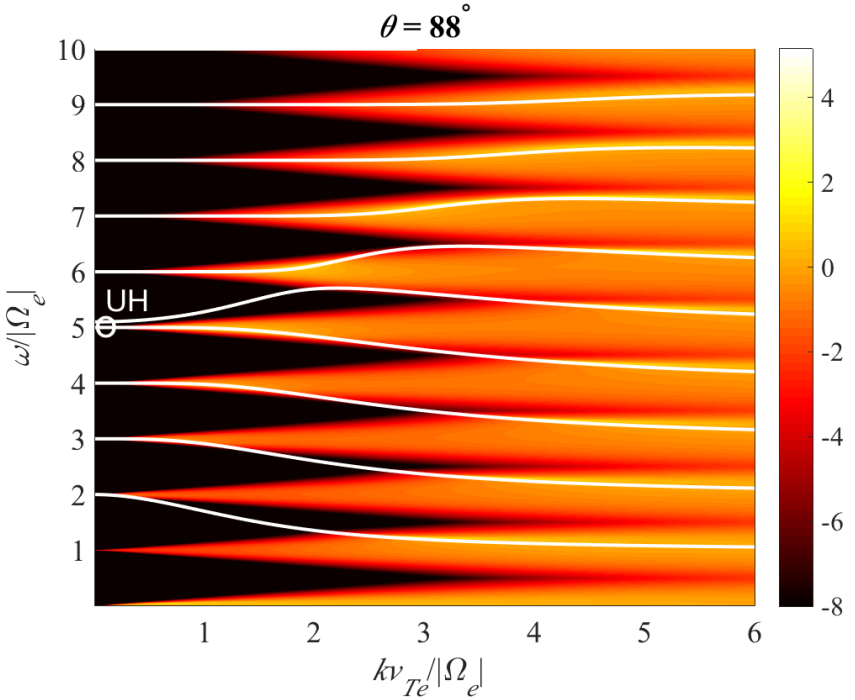
Upper-Hybrid and nf_{ce} Emissions: Waves or Fluctuations?

(Waves? involves instabilities)

$$\epsilon(\mathbf{k},\omega) = 1 + \sum_a \frac{2\omega_{pa}^2}{k^2\alpha_a^2}\Bigg[1 + \sum_n I_n(\lambda)\, e^{-\lambda}\, \xi_a\, Z(\zeta_n^a)\Bigg],$$

$$\lambda = \frac{k_\perp^2 \alpha_a^2}{2\Omega_a^2}, \qquad \zeta_n^a = \frac{\omega - n\Omega_a}{k_\parallel \alpha_a},$$

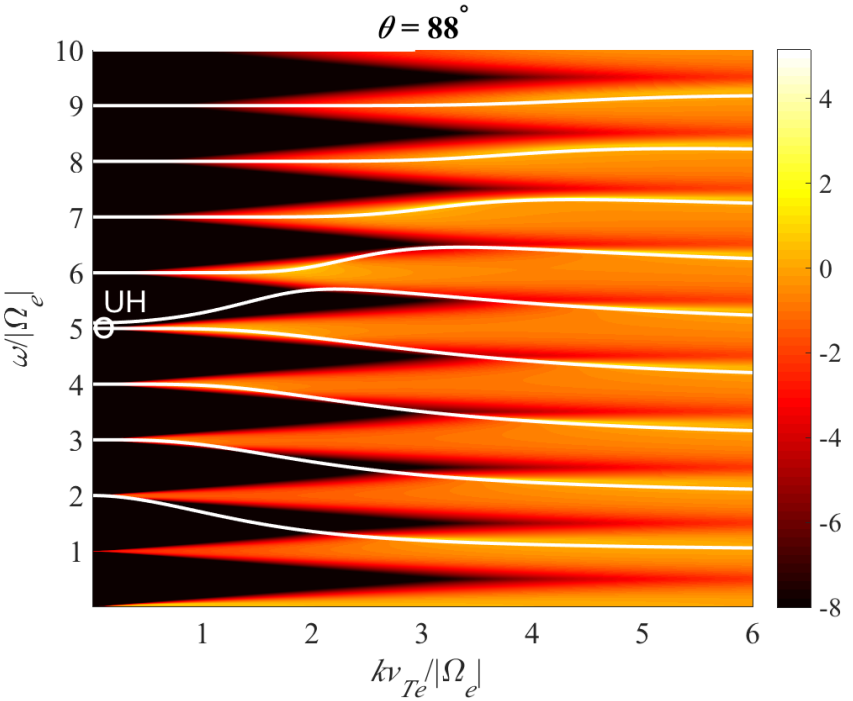
$$\xi_a = \frac{\omega}{k_\parallel \alpha_a}.$$



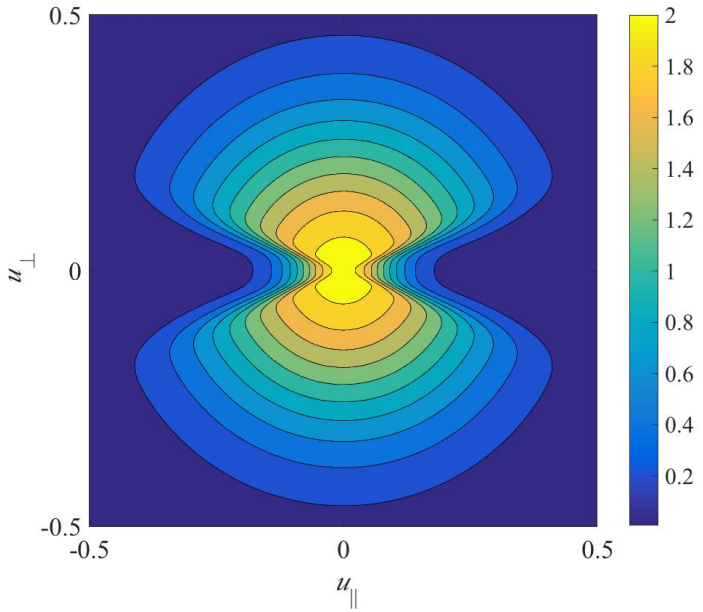
Upper-Hybrid and nf_{ce} Emissions: Waves or Fluctuations?

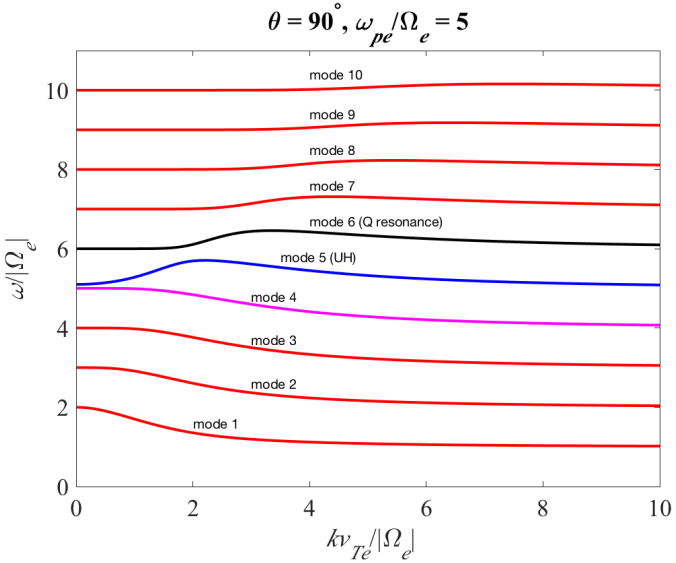
(Fluctuations? Requires quasi-equilibrium)

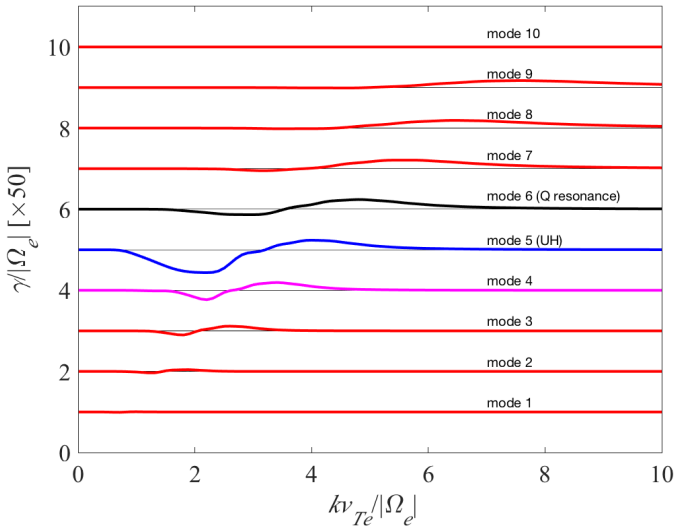
$$(2\pi)^4 < \delta E^2 >_{\mathbf{k},\omega} = \frac{8\pi T}{\omega} \frac{\mathrm{Im}\,\epsilon(\mathbf{k},\omega)}{|\epsilon(\mathbf{k},\omega)|^2}.$$



Bernstein mode instability by loss-cone distribution





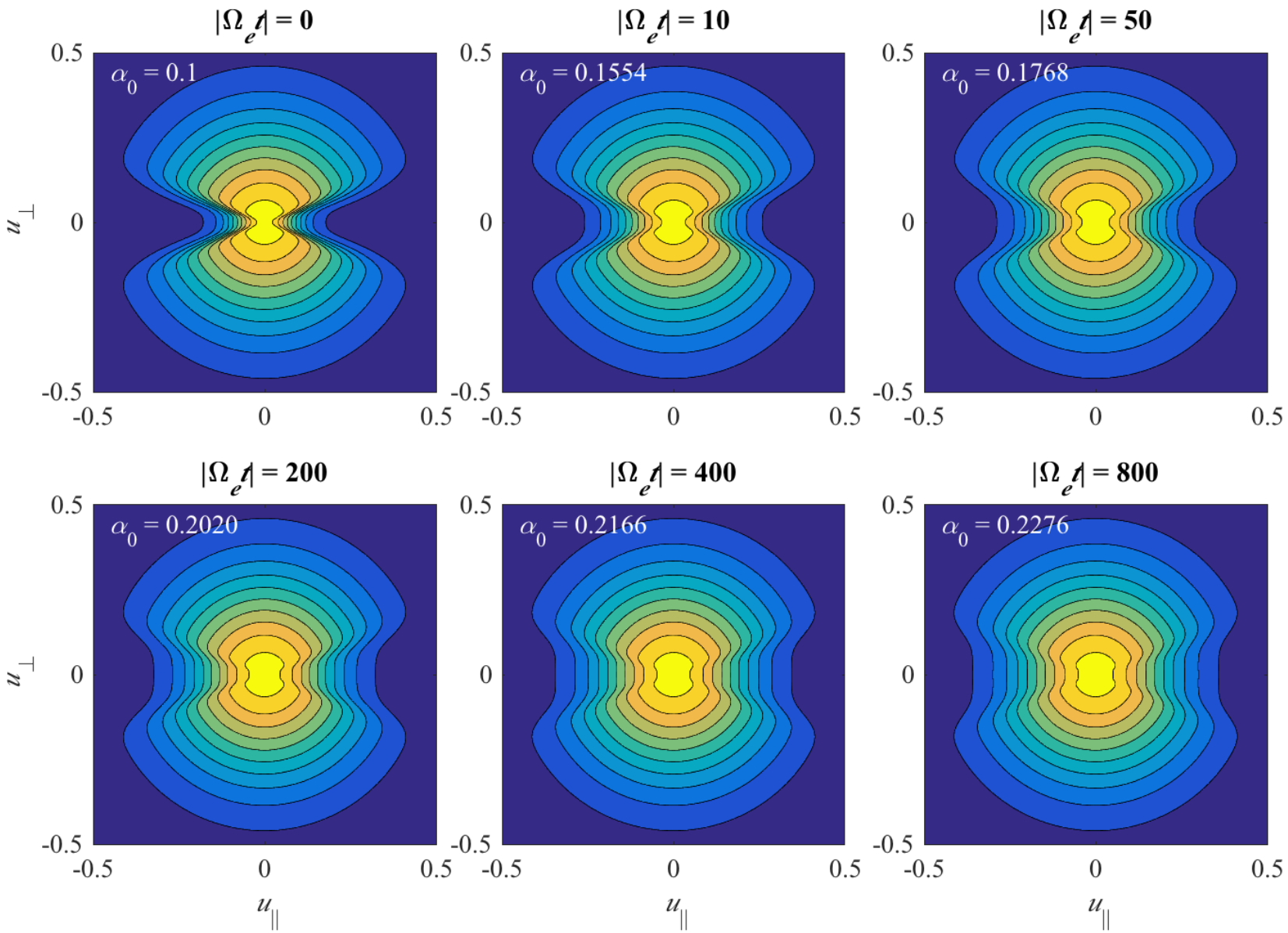


Upper-Hybrid and nf_{ce} Emissions: Quasilinear Theory

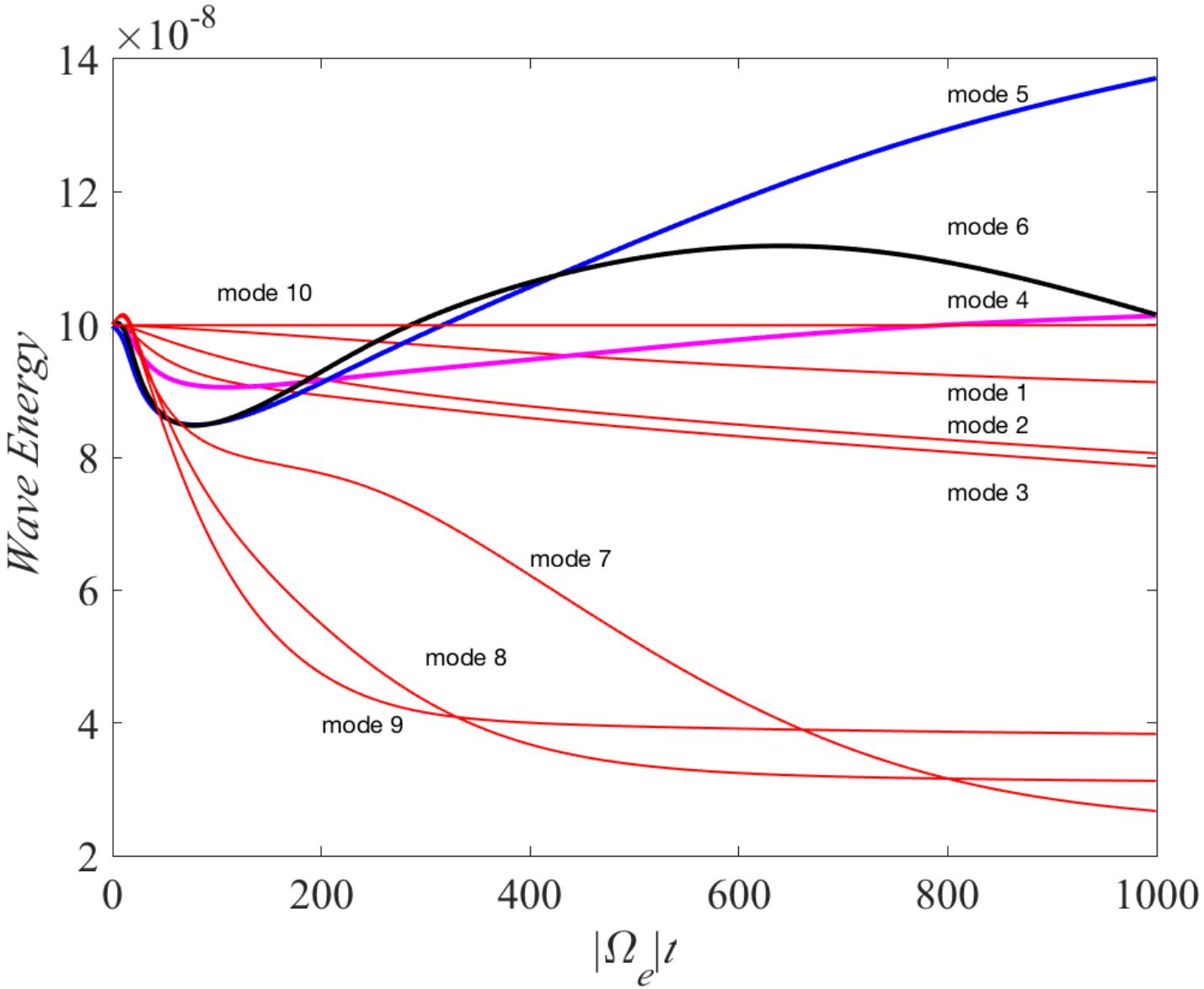
$$\frac{\partial F_a}{\partial t} = \pi e_a^2 \sum_n \int d\mathbf{k} \left(\frac{n m_a \Omega_a}{p_\perp} \frac{\partial}{\partial p_\perp} + k_\parallel \frac{\partial}{\partial p_\parallel} \right) \times J_n^2 \left(\frac{k_\perp p_\perp}{m_a \Omega_a} \right) \left\langle \delta\phi_{\mathbf{k}}^2 \right\rangle \delta \left(\omega_{\mathbf{k}} - n\Omega_a - \frac{k_\parallel p_\parallel}{m_a} \right) \times \left(\frac{n m_a \Omega_a}{p_\perp} \frac{\partial F_a}{\partial p_\perp} + k_\parallel \frac{\partial F_a}{\partial p_\parallel} \right),$$

$$\frac{\partial \left\langle \delta\phi_{\mathbf{k}}^2 \right\rangle}{\partial t} = 2\gamma_{\mathbf{k}} \left\langle \delta\phi_{\mathbf{k}}^2 \right\rangle .$$

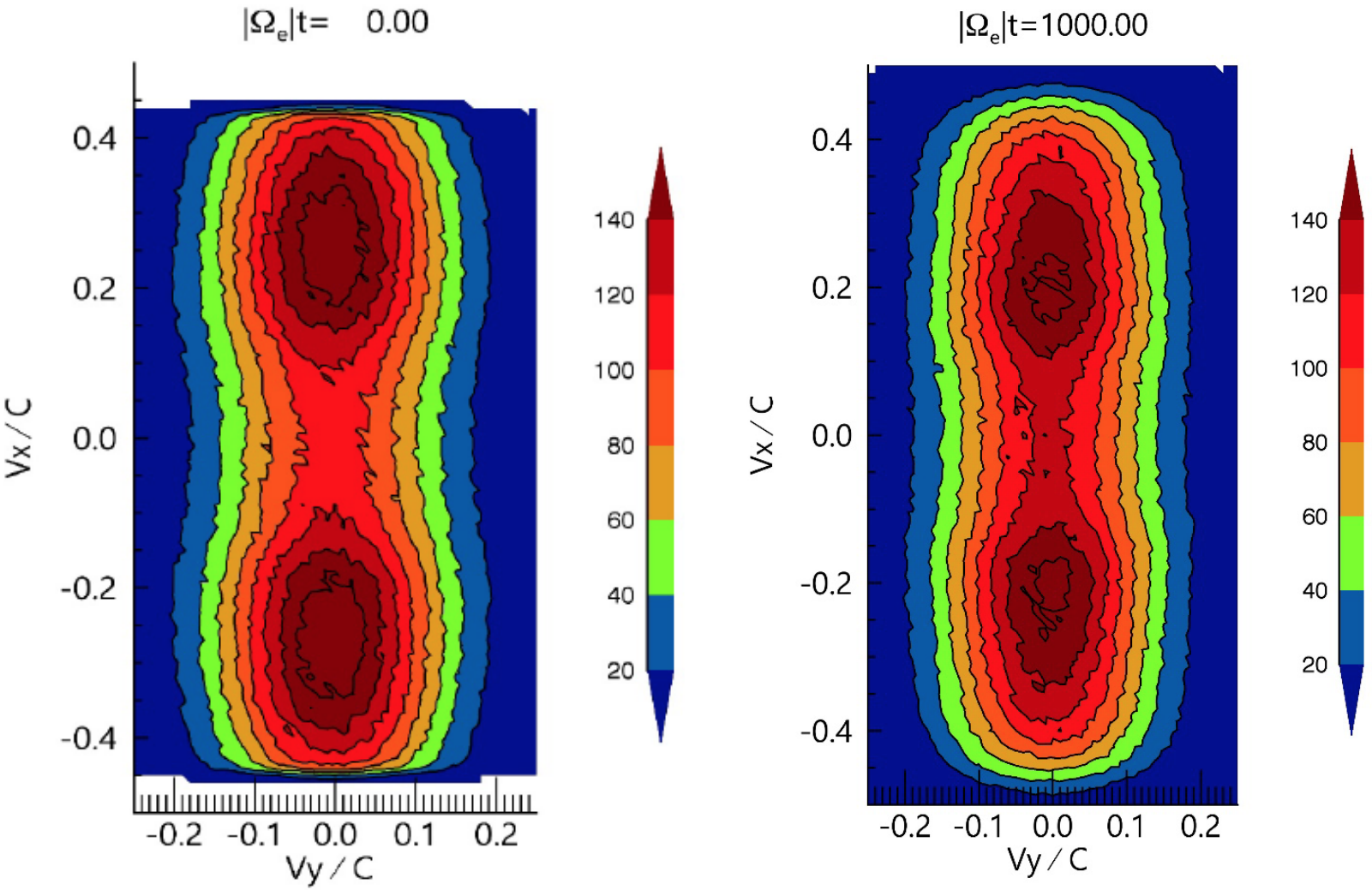
Upper-Hybrid and nf_{ce} Emissions: Quasilinear Theory



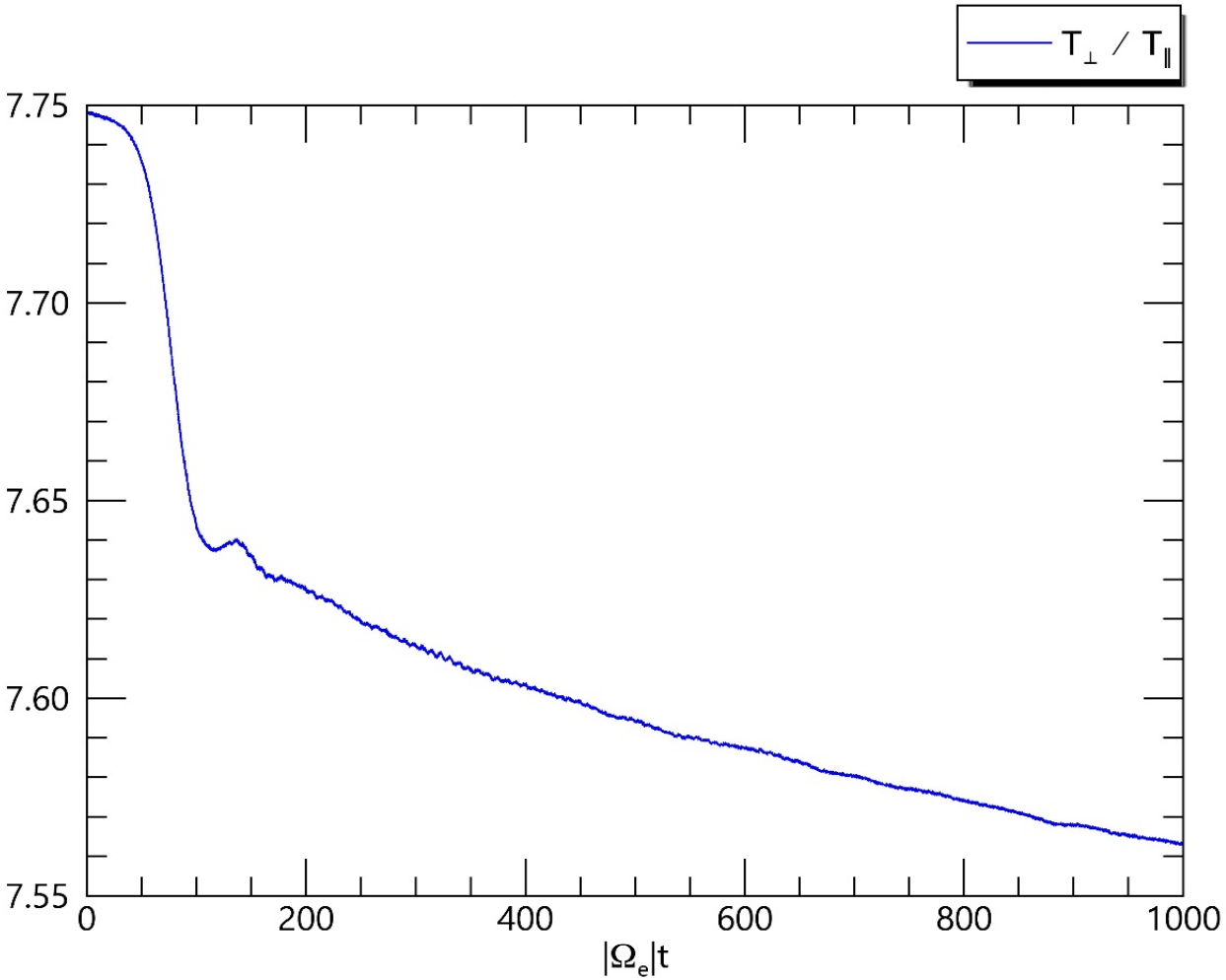
Upper-Hybrid and nf_{ce} Emissions: Quasilinear Theory



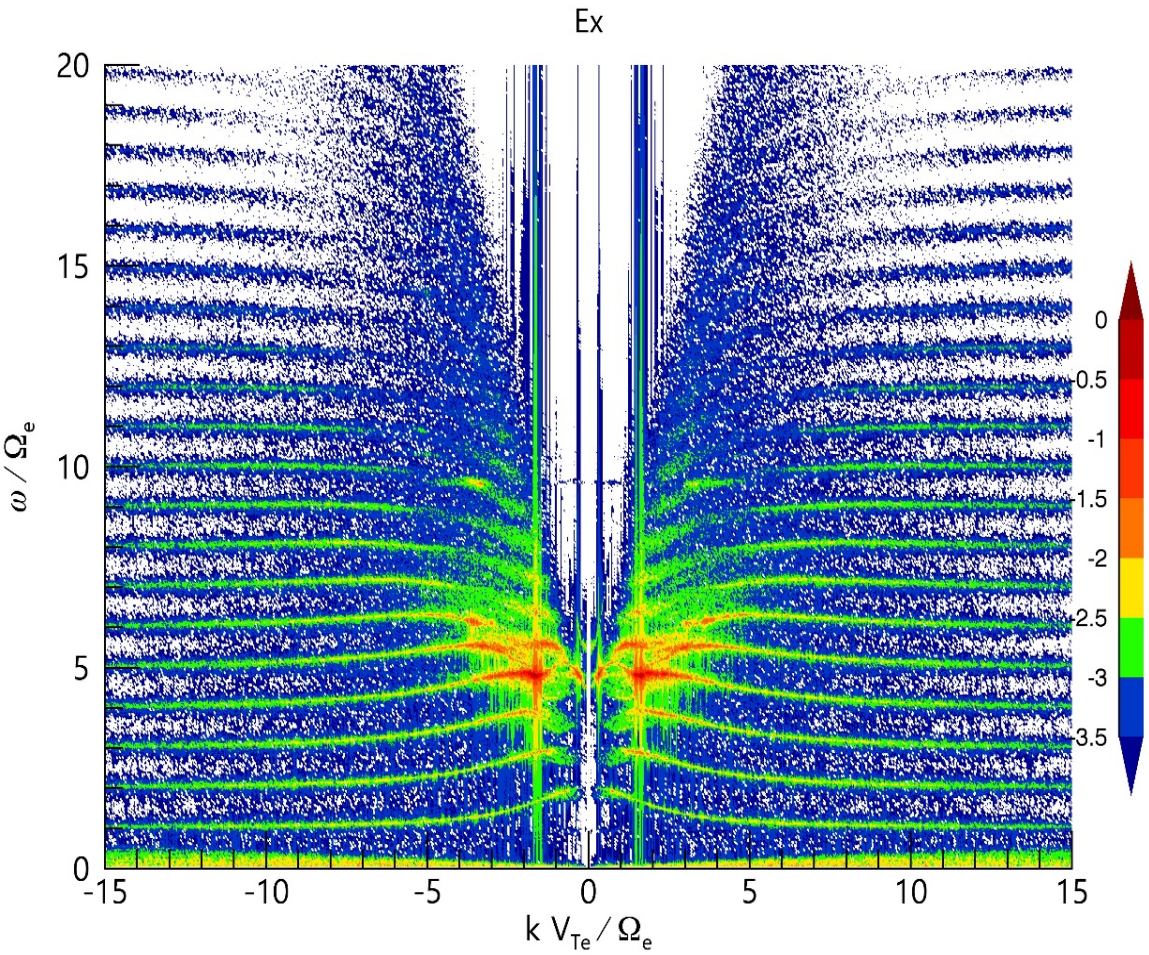
Upper-Hybrid and nf_{ce} Emissions: PIC Simulation



Upper-Hybrid and nf_{ce} Emissions: PIC Simulation



Upper-Hybrid and nf_{ce} Emissions: Loss-Cone PIC Simulation



Conclusion and Discussion

- Upper-hybrid thermal noise may be a proxy for particle detector.
- Solar Orbiter RPW and Parker Solar Probe FIELDS instruments may be able to detect EM upper-hybrid thermal noise.