The photoelectron-driven Upper Hybrid instability as the cause of 150 km echoes

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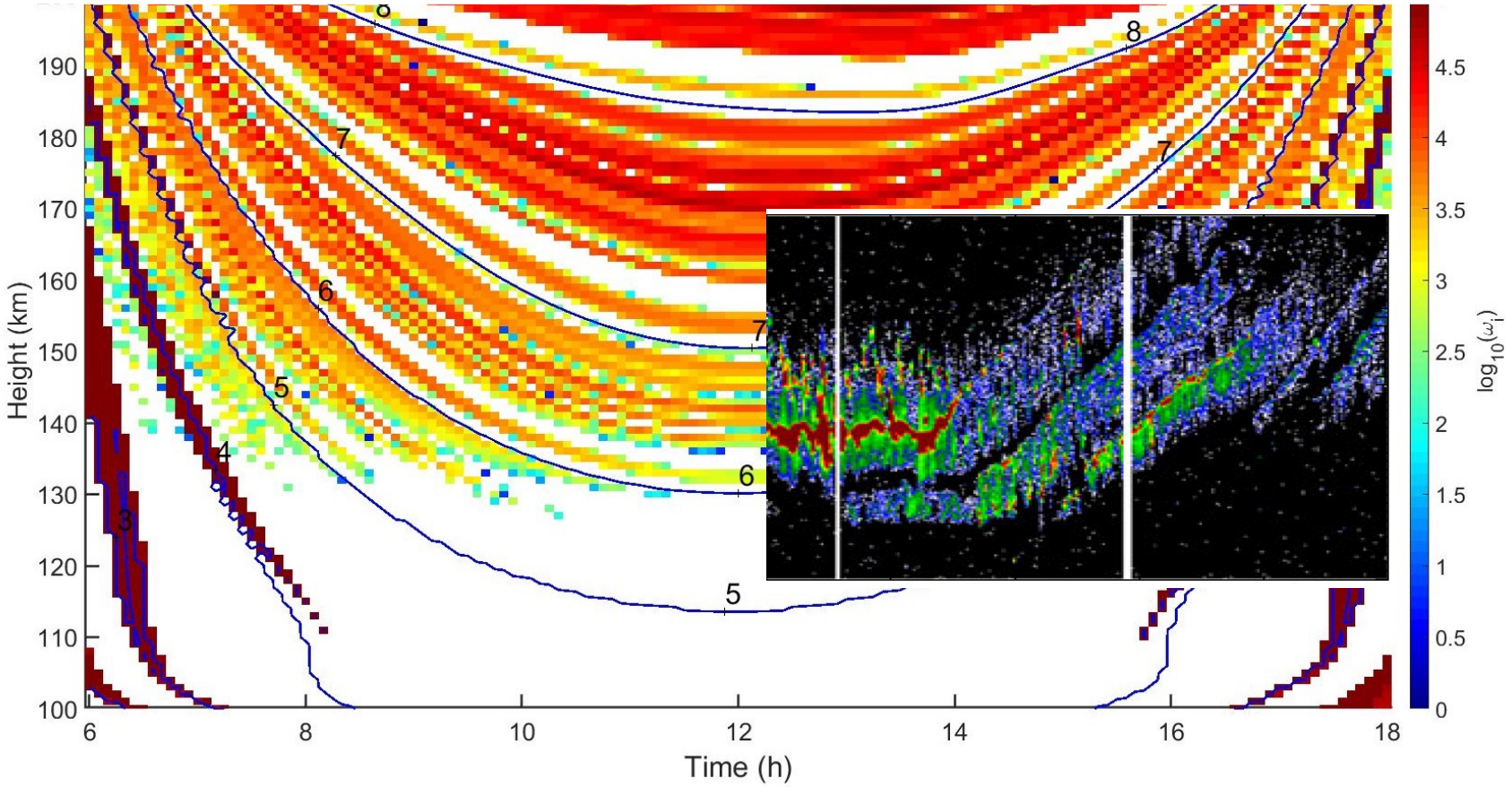

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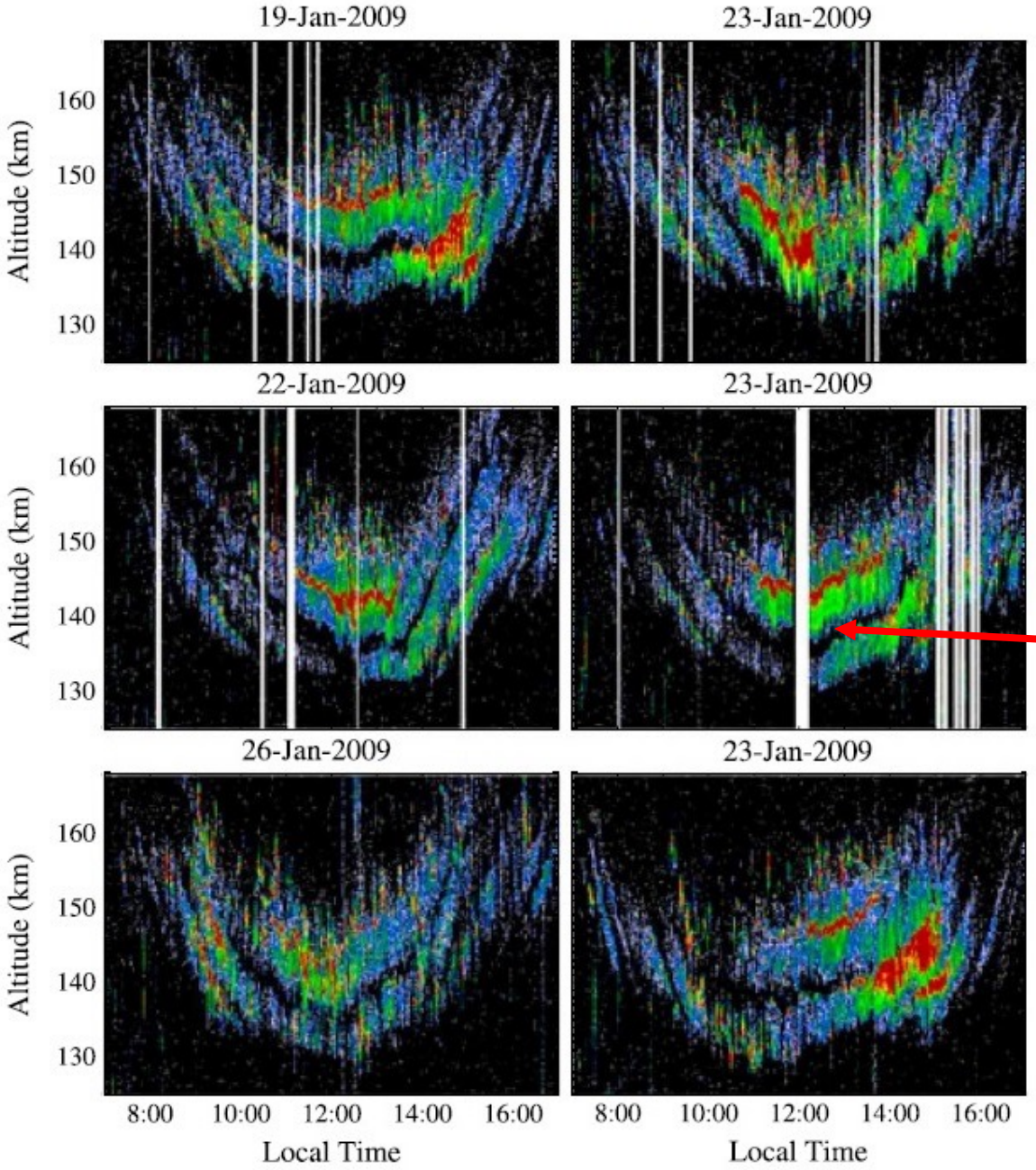


150 km echoes: Open Questions

- What generates ion scale irregularities detected by radars?
- What sets the upper and lower boundaries of the echoes?
- Why are there large gaps in the vertical structure?
- Why are the echoes only observed at equatorial radars?
  - But not at ALTAIR

Observations from *Chau and Kudeki* (2013)

Photoelectron Driven Upper-Hybrid Instability

- Bump-on-tail instability growth rate:

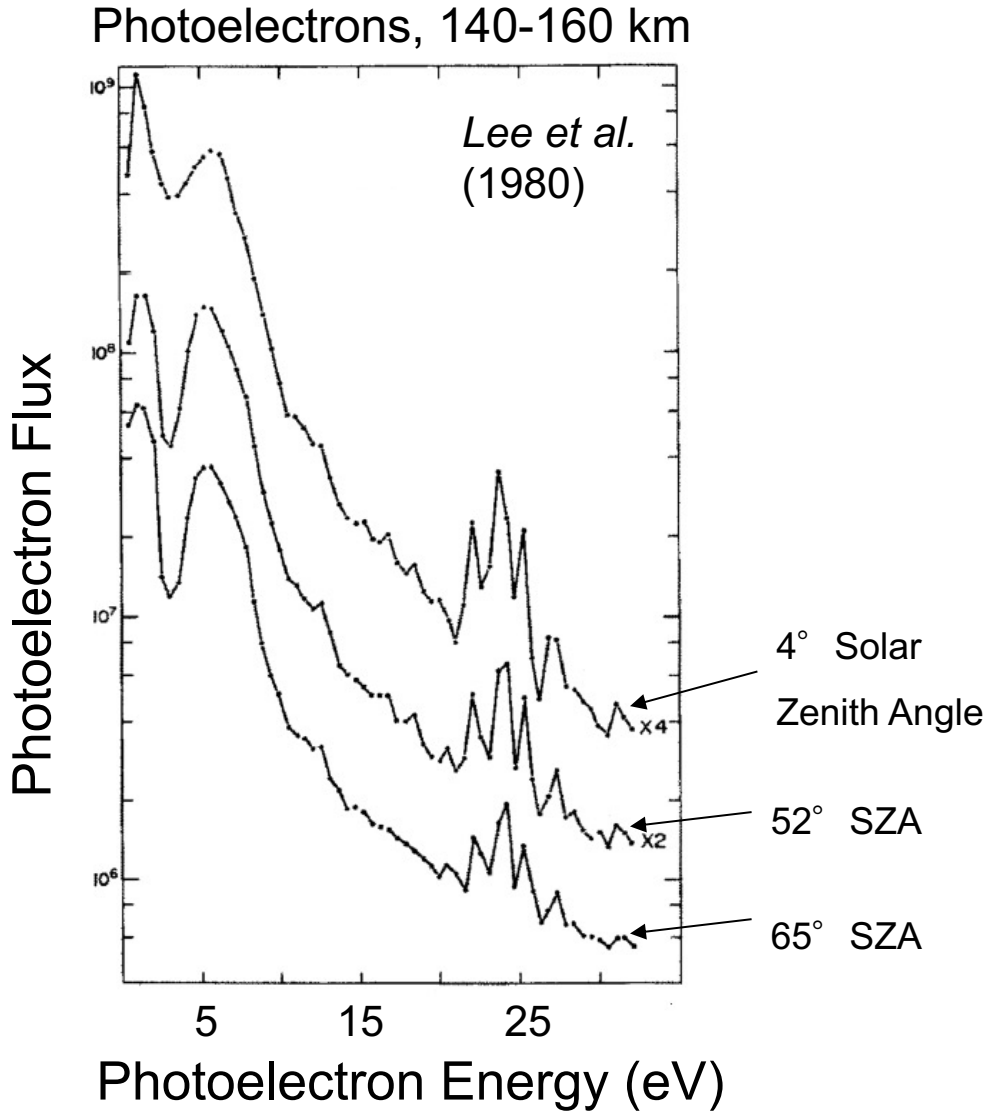
$$\gamma \propto \int_0^\infty dE\, J_n^2(E) \left[\frac{\partial F_{0h}}{\partial E}\right]_{v_\parallel = (\omega_{UH} - n\Omega)/k_\parallel}$$

- Collisional damping rate:

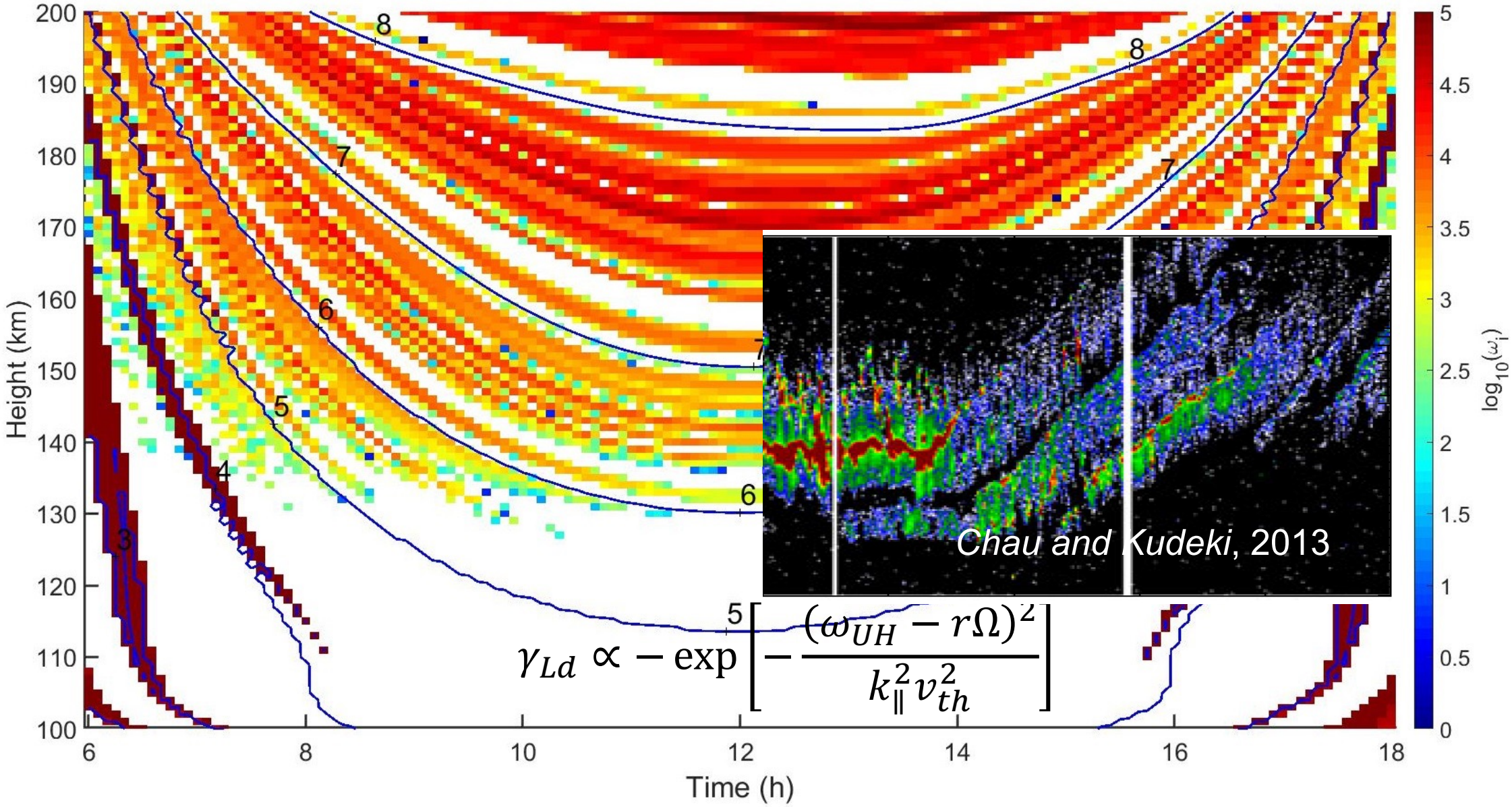
$$\gamma_\nu \propto -\nu_{en}$$

- Thermal Landau (and cyclotron) damping:

$$\gamma_{Ld} \propto -\frac{\omega_p}{k^3 \lambda_D^3} \exp\left[-\frac{(\omega_{UH} - n\Omega)^2}{k_\parallel^2 v_{th}^2}\right]$$

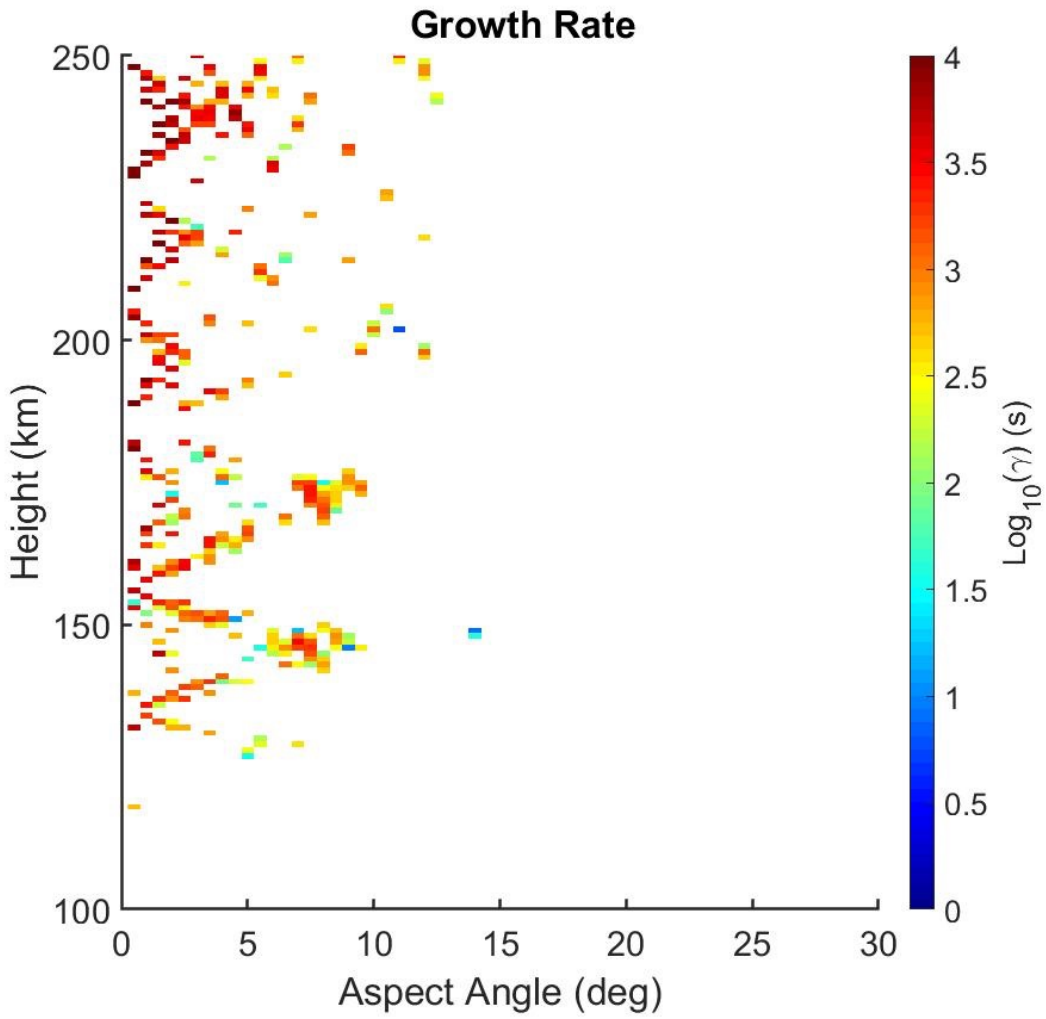


Growth Rate with ω_{UH}/Ω contours



Aspect Angle vs Latitude Dependence

- UH Instability restricted to within ~10° off perp to *B*
- Jicamarca limited to within ~6° off perp to *B*
- All VLF, perp to B radars are at low latitudes



Plausibility of UH instability causing 150 km echoes

Theory explains:

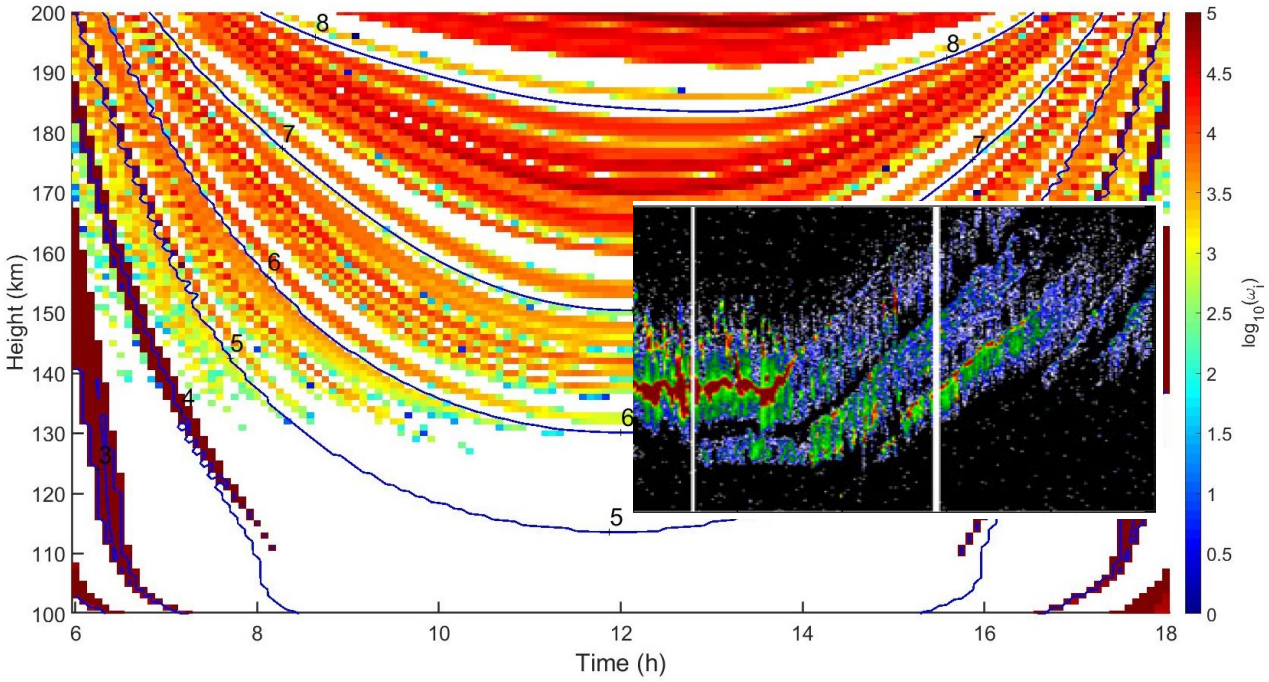
- Diurnal variation
- Altitude gaps where $\omega_{UH} = n\Omega$
- 130 km lower boundary
- Latitude dependence, need $k_{\perp} \gg k_{\parallel}$
- Solar flare observations: growth rate varies as $\gamma \propto n_{photo}$

Theory does not explain:

- Conversion of electron scale waves to ion scale observations
  - Shown to occur in PIC simulations
- Lack of observations at ALTAIR
- Seasonal dependence, FAI echoes, small scale structure

Regions of photoelectron driven instability follow 150 km echo morphology:

- Diurnal variation
- Lower boundary due to collisional damping
- Gaps in the echoes where $\omega_{UH} = n\Omega_{ce}$
- Perpendicular to *B* dependence



References

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Acknowledgements

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