LA-UR-12-23037
Approved for public release; distribution is unlimited.

Title: Lower Hybrid to Whistler Wave Conversion

Author(s): Winske, Dan

Intended for: Project review with sponsor

LA-UR-XXXXX

Lower Hybrid ↔ Whistler Wave Conversion

Dan Winske

Los Alamos National Laboratory

DTRA Technical Review
July 19, 2012

Abstract

In this presentation we discuss recent work concerning the conversion of whistler waves to lower hybrid waves (as well as the inverse process). These efforts have been motivated by the issue of attenuation of upward propagating whistler waves in the ionosphere generated by VLF transmitters on the ground, i.e., the "Starks' 20 db" problem, which affects the lifetimes of energetic electrons trapped in the geomagnetic field at low magnetic altitude (L). We discuss recent fluid and kinetic plasma simulations as well as ongoing experiments at UCLA to quantify linear and nonlinear mode conversion of lower hybrid to whistler waves.

Lifetimes of Trapped Electrons Peak at L < 2

- The effect was evident from the HANE tests (Van Allen , 1964)
- Peak at L ~ 1.6 due to long-lived STARFISH belt
- Also occurs for naturally trapped electrons (Benck et al., 2010)

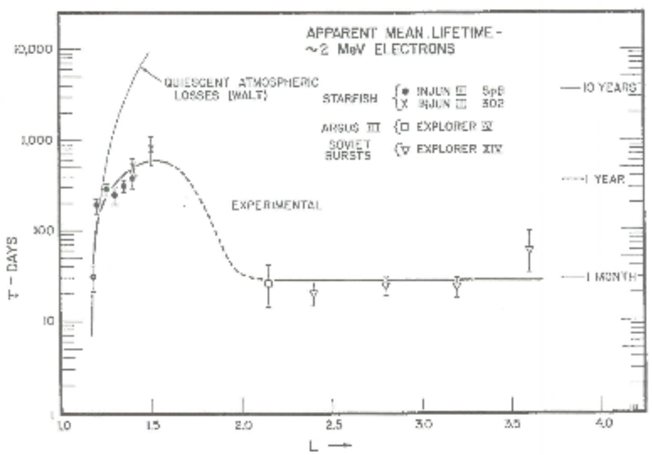
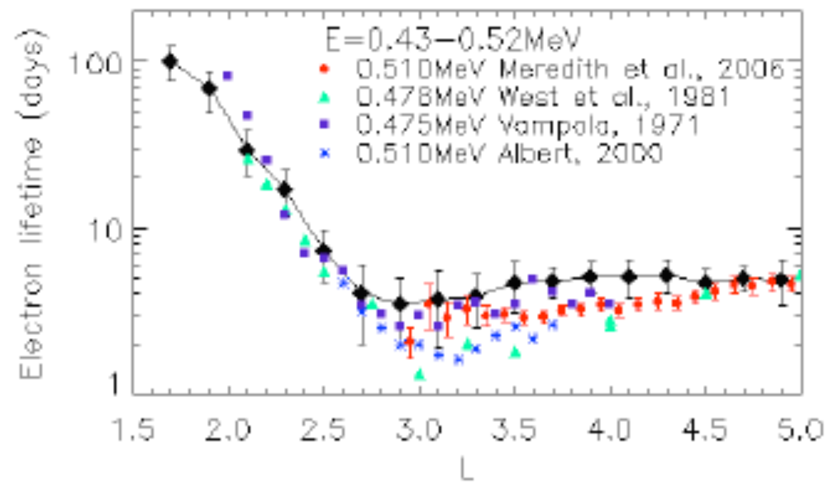
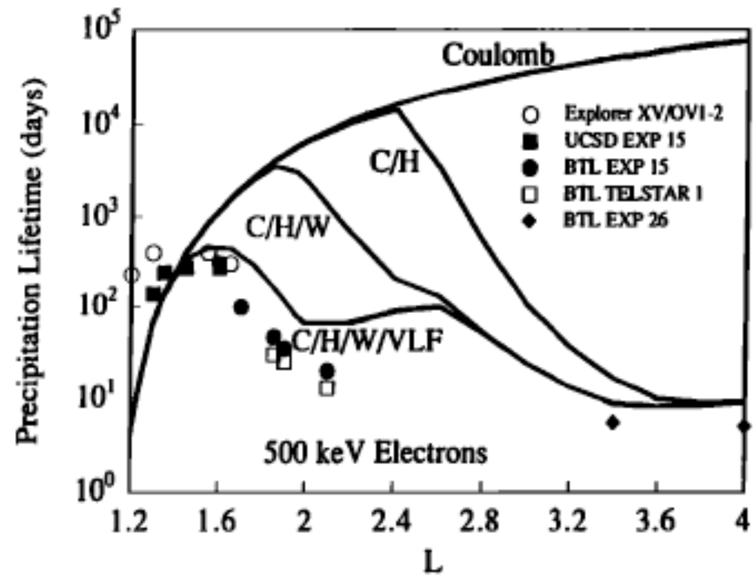


Fig. 18.



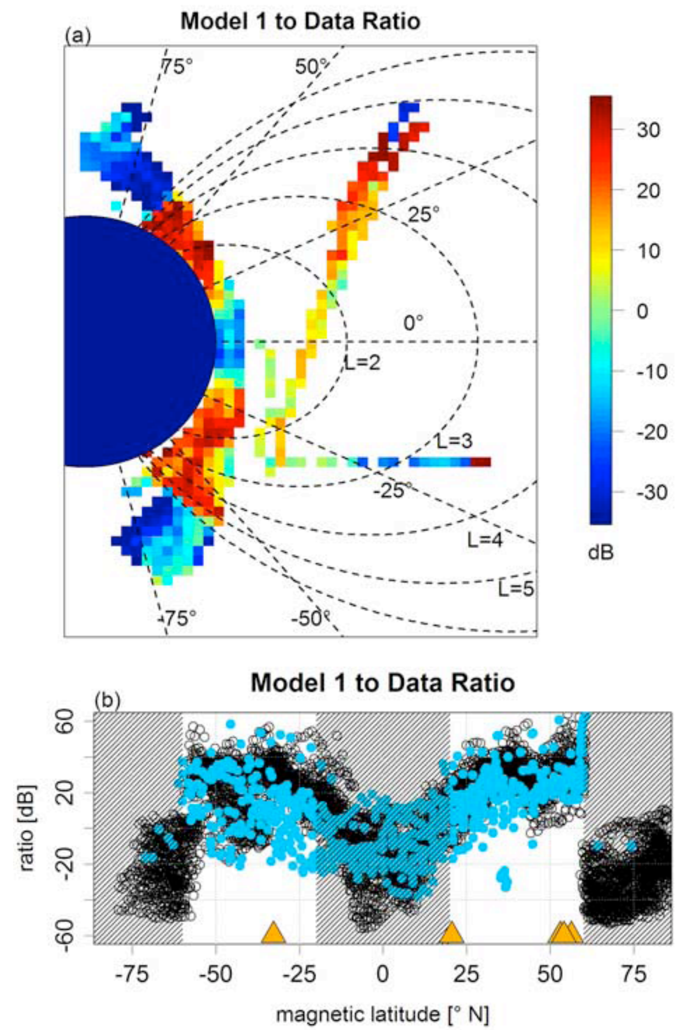
Lifetimes of Trapped HANE Electrons "Understood" by late 90's

- Abel and Thorne (1998) considered lifetimes of HANE electrons determined by:
  - Coulomb collisions (C)
  - Magnetospheric hiss (H)
  - Whistlers due to lightning (W)
  - VLF transmitters (VLF)
- Including all effects, especially transmitters, reproduced the Van Allen plot.



However, Starks et al. (2008) compared satellite data with the VLF model and found large differences

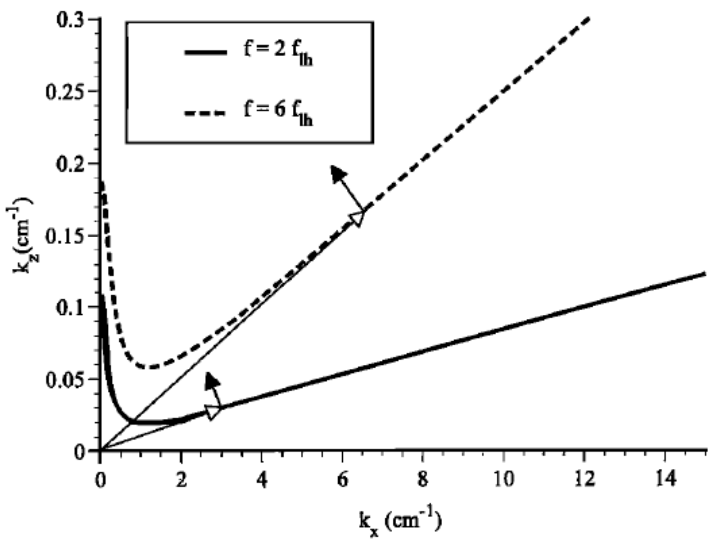
- Model calculations were as much as 100x larger than observed values. ("20 dB problem")
- Differences suggest strong attenuation of VLF signals as they propagate upward.
- Issue is important since the explanation of the peak of the long lifetimes at L ~ 1.6 is no longer valid.

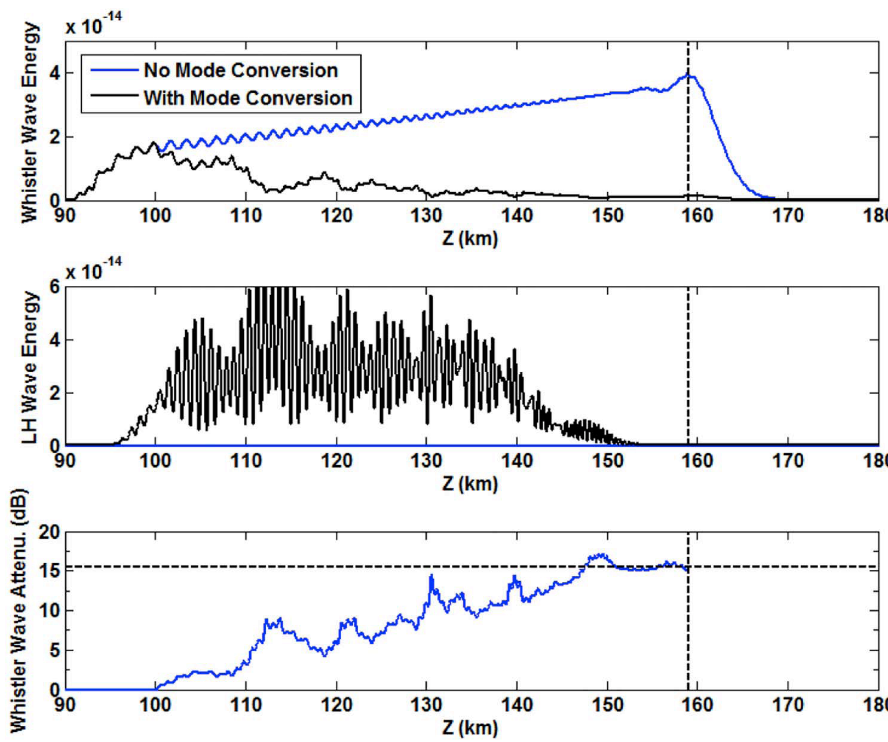


R (db) ~ 20 $\log_{10} (W_{model}/W_{obs})$

A Number of Explanations for the Differences Have Been Proposed

- A possible explanation is that upward propagating whistler waves are mode converted to lower hybrid waves that are dissipated through plasma heating.
- Shao et al. (2012) have done fluid calculations to show that linear mode conversion at density gradients is a very efficient process.

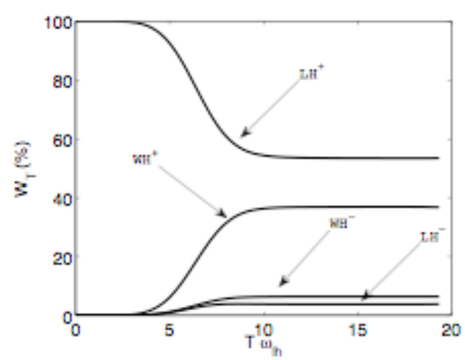


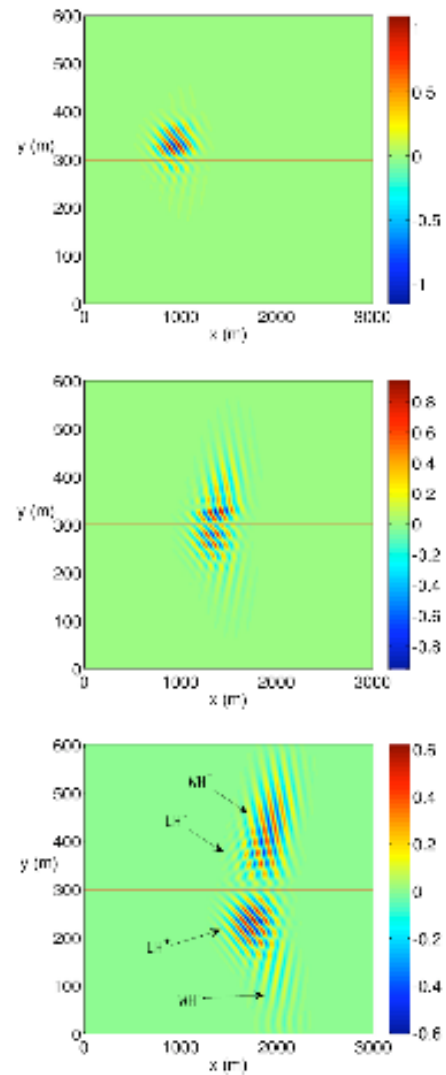


At LANL We Have Used a More General Formulation to Study LH → Whistler Conversion

- Camporeale et al. (2012) have developed a more general fluid model to study linear mode conversion from lower hybrid to whistler at a density gradient

- Generally, an incoming LH wave produces a transmitted and reflected LH wave as well as whistler waves
- Conversion efficiency can be large ~ 40%



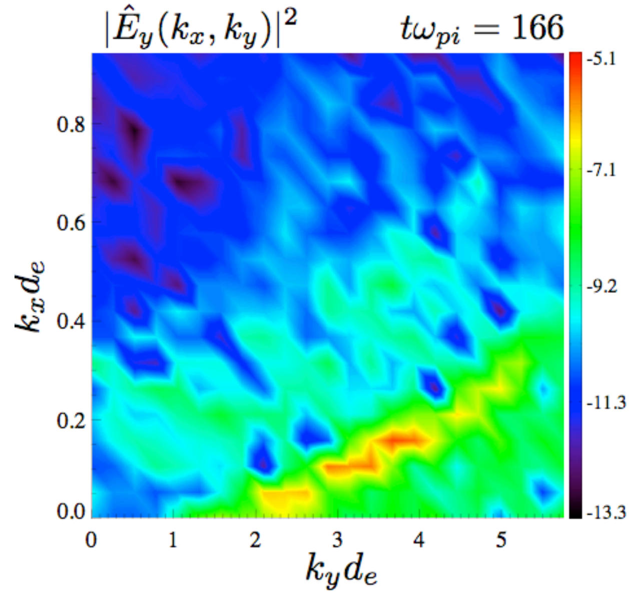


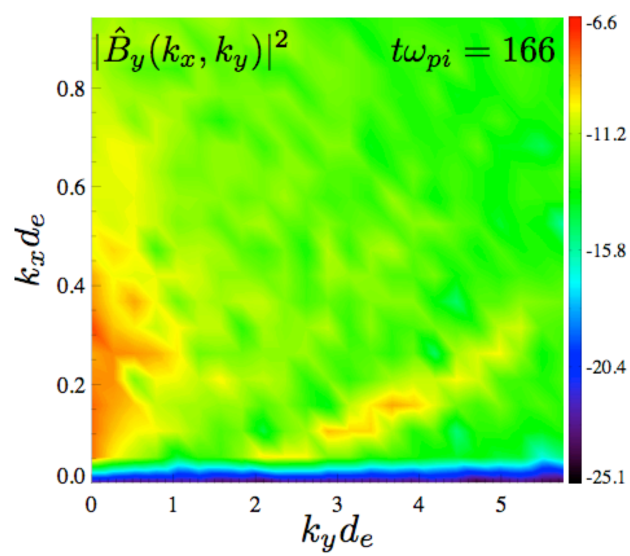
Experimentally, LH←→Whistler wave conversion is not easy

- Linear mode conversion: use antenna to generate LH waves (perp. to B) and measure whistlers along B (Rosenberg and Gekelman, 2001; Amatucci et al. (unpub. ?); Colestock and Gekelman, ongoing) – problem is that the antenna also generates whistlers.
- In principle, it also also possible to generate whistlers with the antenna that can mode convert to LH waves – but whistlers are long wavelength (not a localized source) and LH waves dissipate rapidly by heating the plasma
- Nonlinear mode conversion: Use an ion beam beam to make an ion ring distribution –but hard to make a cold ring (Seiler et al., 1976; Ganguli et al., 2010; Colestock and Gekelman, unpublished).

We Have Done 3-D Simulations of LH Ion Ring Instability and LH→Whistler Conversion

- Simulations show rapid growth of LH waves.
- Nonlinear conversion of LH waves to parallel-propagating whistlers.
- Conversion efficiency is modest, ~ 15 %.
- But level of LH waves is very small →only a small amount of whistlers is produced.





Ongoing work is Shedding New Light on Lower Hybrid←→Whistler Conversion

- Linear mode conversion is an efficient process for both LH→Wh and Wh→LH waves.
- NL conversion of LH→Wh can occur, but less efficiently, to <u>parallel-propagating</u> whistlers. Process is limited by levels of LH waves.
- Experiments at LAPD are addressing conversion processes and efficiencies.
- The "Starks 20 dB" problem is real and is most likely due to Wh→LH wave conversion in the ionosphere.

References

- Abel and Thorne, J. Geophys. Res., 103, 2385 (1998)
- Benck, S, et al., Ann. Geophys., 28, 849 (2010).
- Camporeale, E., G. L. Delzanno and P. Colestock, J. Geophys. Res., 117, in press (2012)
- Ganguli, G., et al., Phys. Plasmas, 17, 052310 (2010).
- Rosenberg, S. and W. Gekelman, J. Geophys. Res., 106, 28867 (2001).
- Seiler, S., et al., Phys. Rev. Lett., 37, 11 (1976).
- Shao, X., et al., J. Geophys. Res., 117, A04311 (2012).
- Starks, M. J., et al., J. Geophys. Res., 114, A09320 (2008).
- Van Allen, J. A., Nature, 203, 1006 (1964).
- Winske, D and W. Daughton, Phys. Plasmas, 19, in press (2012).