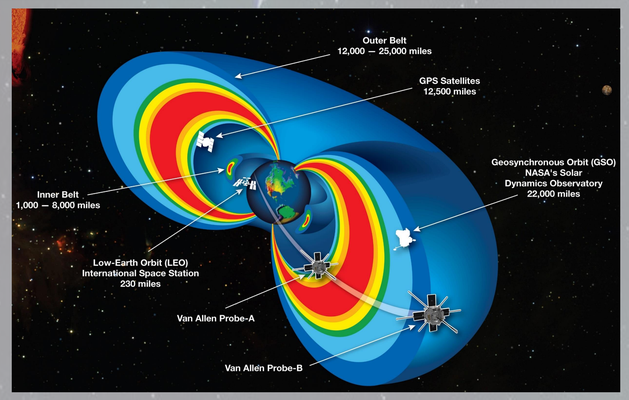
# OBSERVATIONS AND SIMULATIONS OF ELECTROMAGNETIC WAVES IN THE VAN ALLEN RADIATION BELTS

MILES BENGTSON, MORGAN MATHENY, SARA ROSBOROUGH, ANATOLY STRELTSOV
EMBRY-RIDDLE AERONAUTICAL UNIVERSITY, PHYSICAL SCIENCES DEPARTMENT




## Van Allen Radiation Belts

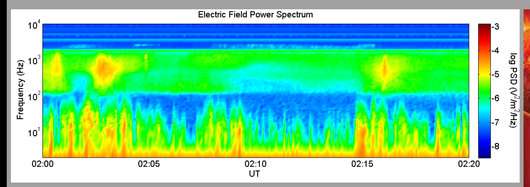
- The Van Allen Radiation Belts are a region in space containing energetic particles trapped in the geomagnetic field.
- Spacecraft flying in the Radiation Belts experience many adverse effects. The energetic particles can degrade electronics, cause circuit logic errors, and charge the spacecraft surface. There is also a major health risk for astronauts due to radiation exposure.
- Solar coronal mass ejections and high-altitude nuclear explosions can cause the Radiation Belts to become enhanced.
- A prolonged enhanced of the Radiation Belts would be detrimental to our satellite fleet and the infrastructure which it supports.

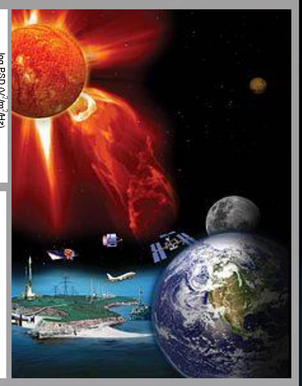
## Whistler Waves

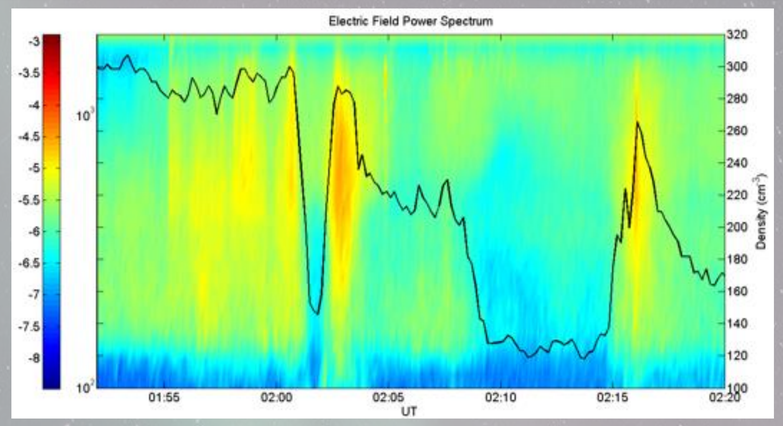
- Whistler waves are very low frequency (1-30 kHz) electromagnetic radio waves which propagate into the magnetosphere.
- Low frequency electromagnetic waves can be used to remove the energetic particles from the radiation belts.
- Whistler waves can be guided by regions of inhomogeneous plasma densities, commonly called ducts. This process, however, is not well understood.

## Purpose and Methodology

- Achieve physical understanding of how whistler waves propagate in density ducts.
- Analyze data for interesting events observed by NASA's Van Allen Probes spacecraft.
- Perform simulations to model observation conditions.
- Compare simulations and observations.

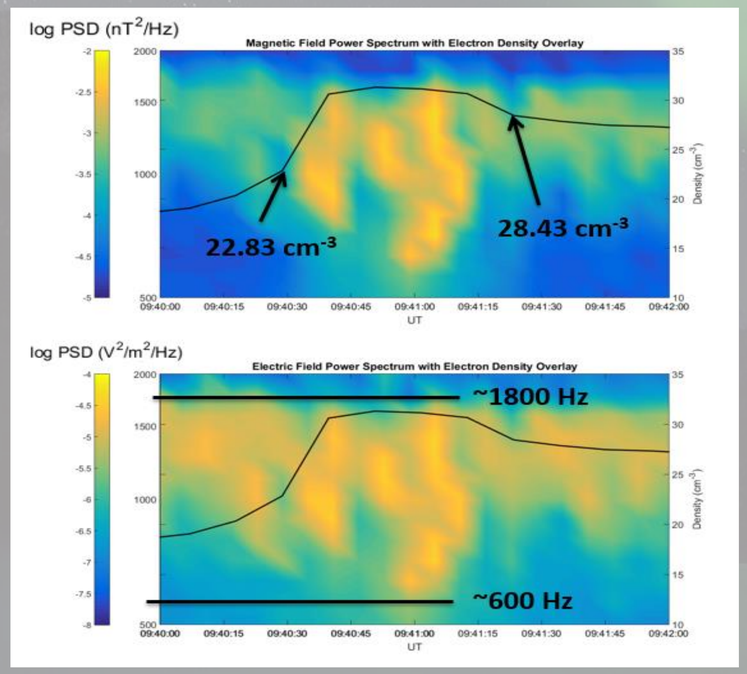


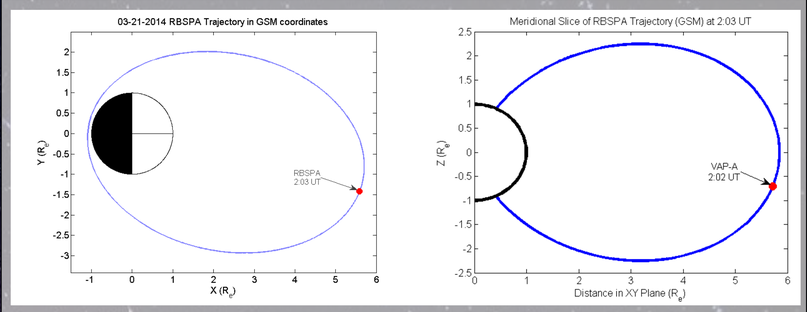






## Spacecraft Observations

- We have analyzed several interesting whistler waves events using observations from the Van Allen Probes satellites.
- As seen in the figures on this panel, the observations show that the whistler waves were localized within the regions of plasma density inhomogeneity.
- In agreement with theoretical predictions, we have observed waves confined within enhancements, depletions, and along gradients of the plasma density called density ducts.
- Given the wave and particle data, along with spacecraft trajectory data (shown on the next panel), we can extract the important parameters related to the event. This includes the wave amplitudes, frequencies, wavenumbers, and propagation angle.
- We then use these parameters as inputs to numerical simulations developed by Dr. Anatoly Streltsov to model the observed events in maximum detail.



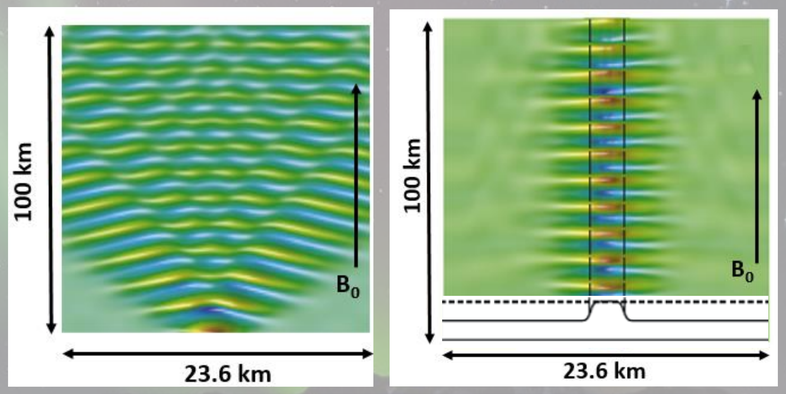



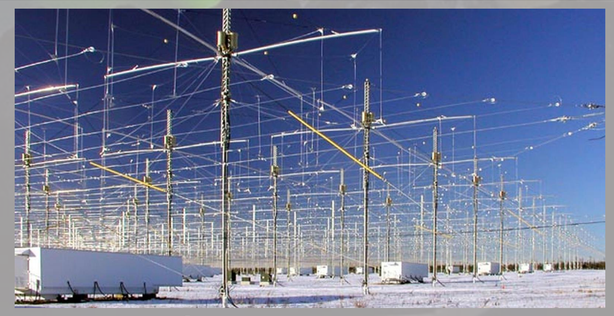

## Numerical Simulations

- We use a magnetohydrodynamics code to simulate the propagation of the whistler waves within density ducts.
- Simulations of the exact event conditions are ongoing, but preliminary results (seen below) show that the whistlers can become trapped in the density ducts with minimal leakage.

## Future Work

- As the Van Allen Probes continue collecting data, we will look for other interesting events showing whistler wave ducting. We will analyze the events and model them to achieve physical understanding of the ducting process.
- The results of this research will be important for proposed studies of launching whistler waves into the Radiation Belts to remove harmful energetic particles. This could be done with ground transmitters (shown below) or with spacecraft.



## Acknowledgements

We would like to thank the Embry-Riddle Office of Undergraduate Research for their support. In addition, we thank the Van Allen Probes EMFISIS and EFW instrument teams for providing the data.