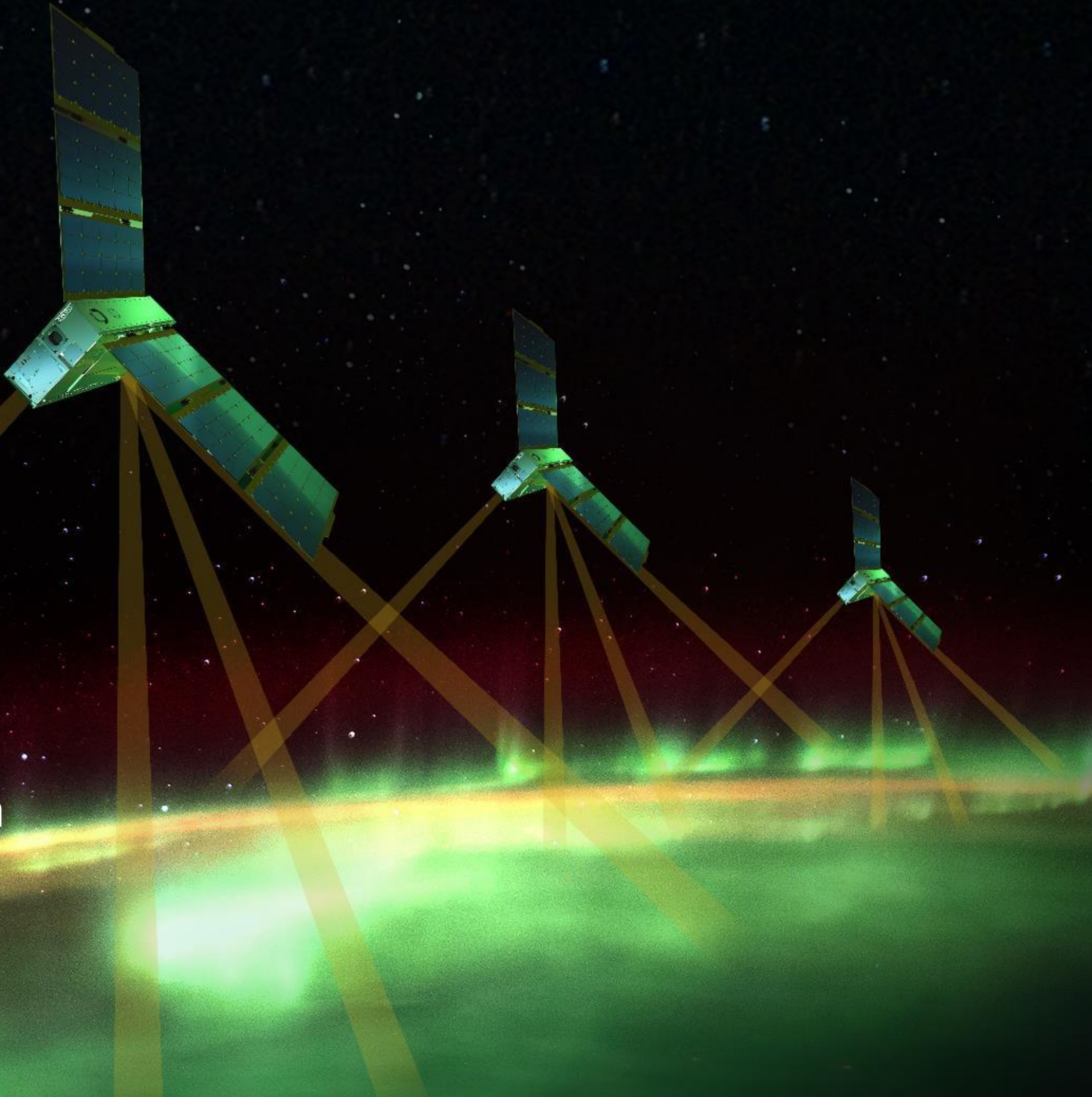
Electrojet Zeeman Imaging Explorer

The EZIE Mission

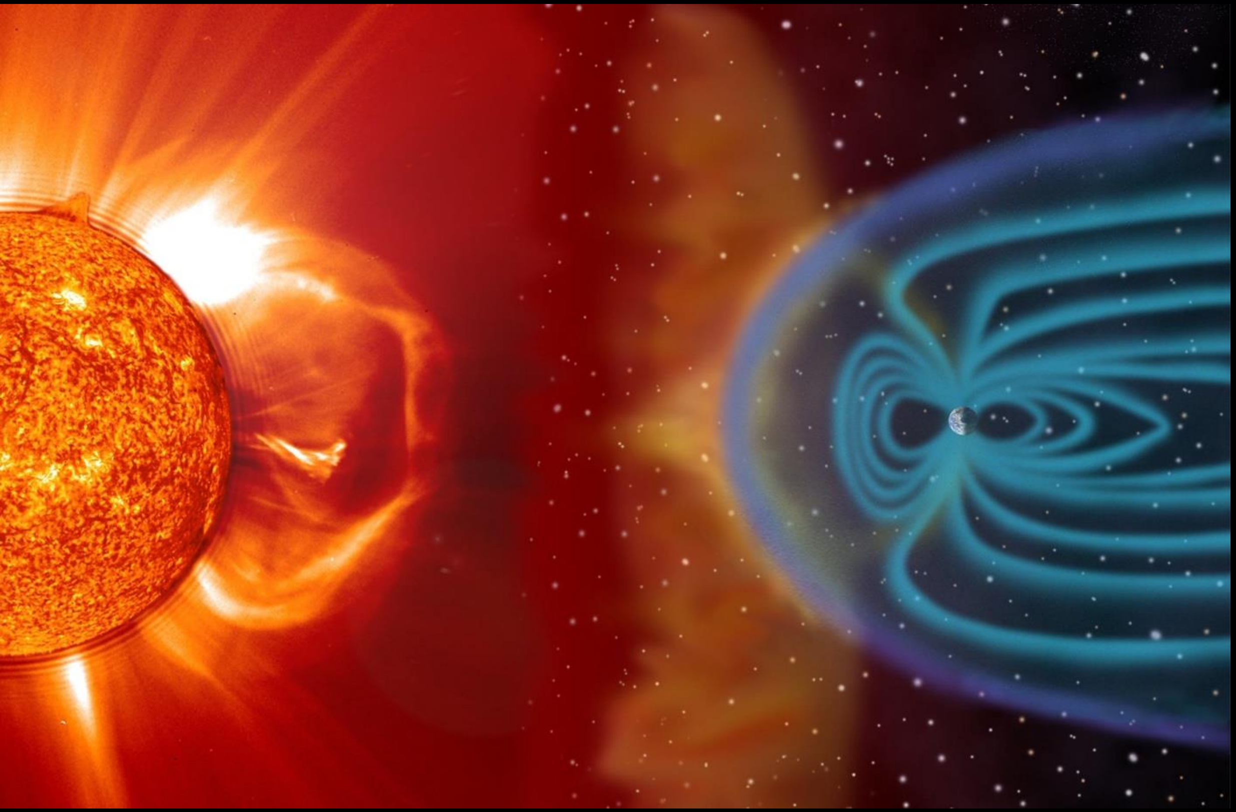
2024 CEDAR Workshop
June 14, 2024
San Diego, CA

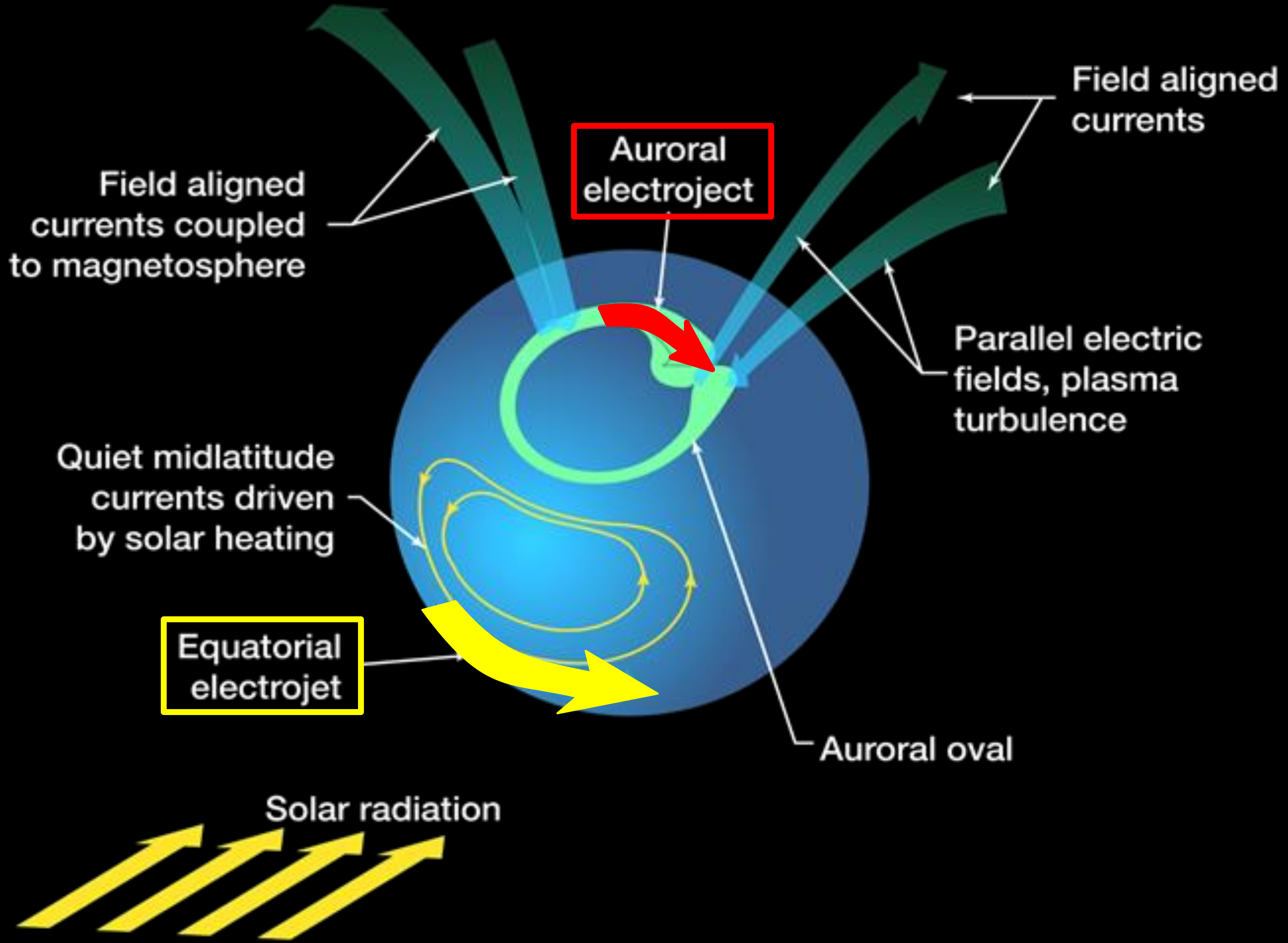
Sam Yee and the Entire EZIE Team



Acknowledgment: NASA Heliophysics Division

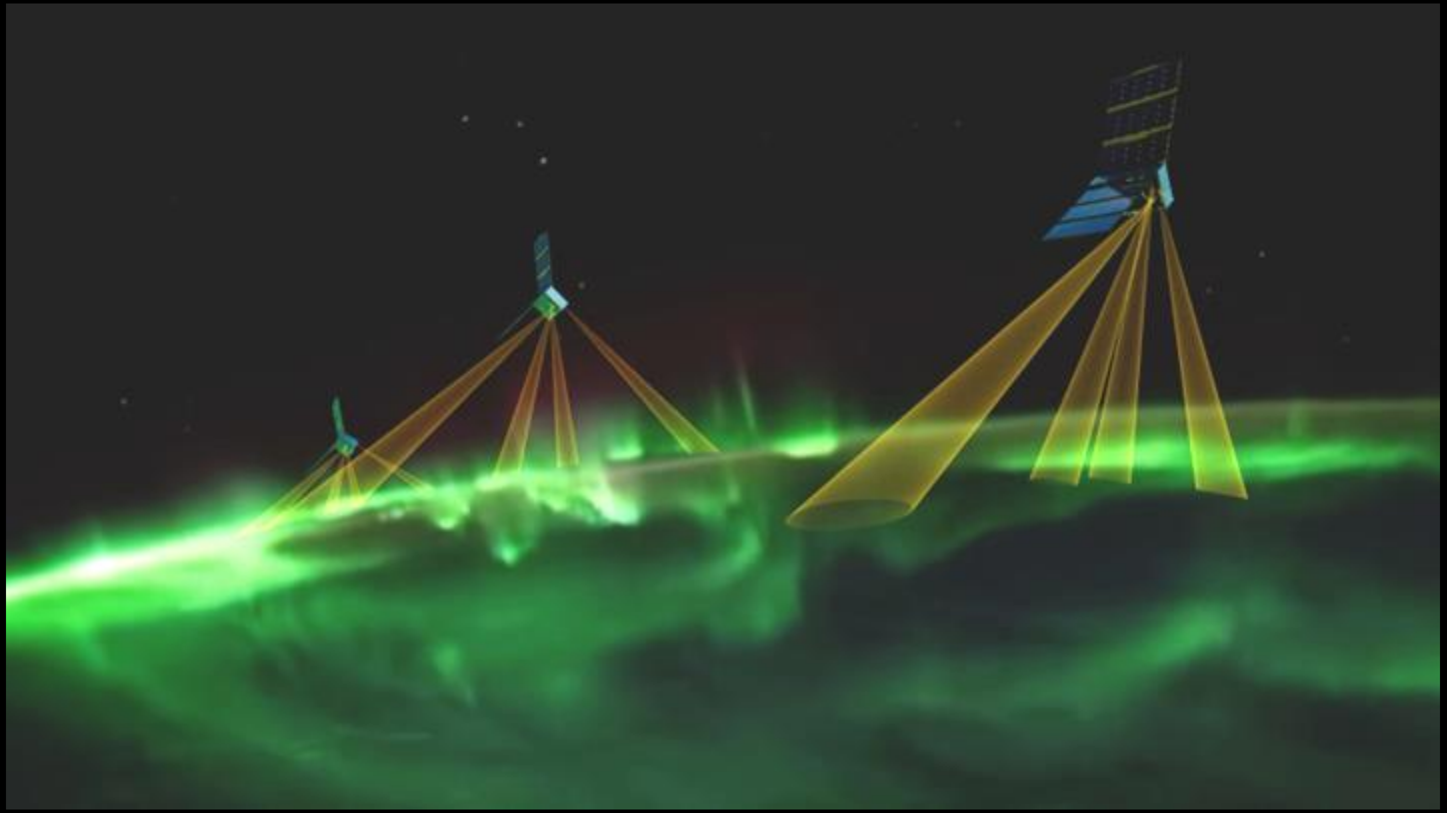
EZIE Studies the Electrical Currents in the Earth Ionosphere, Fundamental to Energy Transfer within the Sun-Earth System





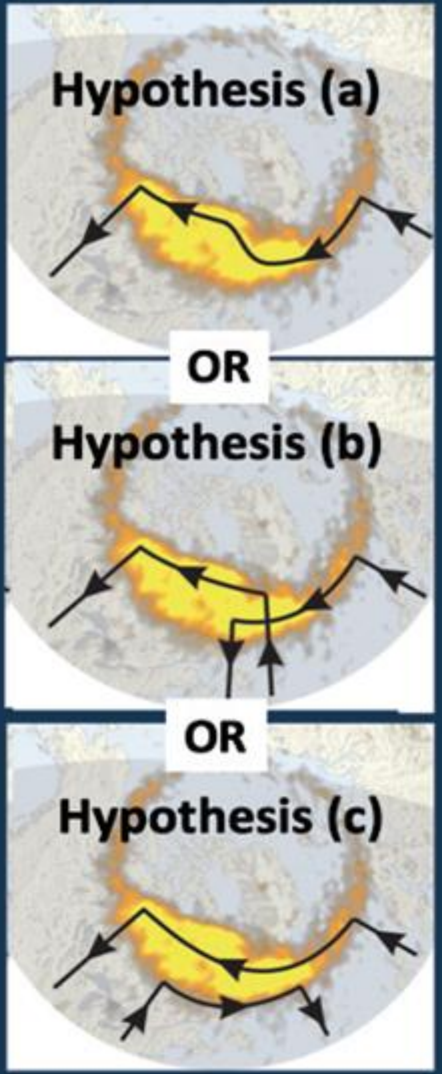
EZIE Focuses on A New Frontier of Near-Earth Magnetic Field Measurements to Study the Mesoscale Variations of Electrojets

EZIE is a 3-CubeSat mission flying in a pearls-on-a-string configuration that uses compact multi-beam instruments and Zeeman sensing technique to image the electrojets. These electrical currents flow at altitudes of ~100–130 km and are notoriously difficult to explore. EZIE will study the "mesoscale" spatial structure and its temporal evolution of these electrojets, important for our understanding of geospace coupling and energy transfer processes.

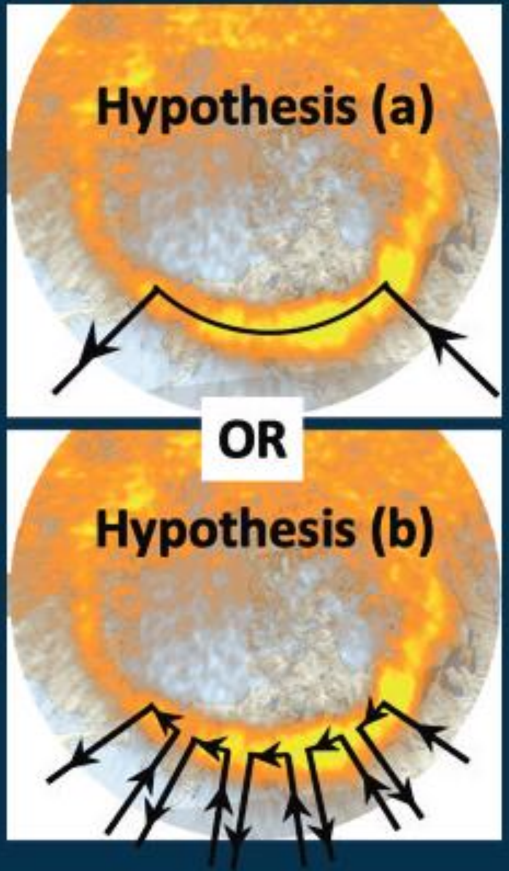


EZIE Objectives are to Resolve Fifty Year-old Debates on the Structures of the High-Latitude Current System

TSQ 1:
EZIE will resolve the decade old debate about the substorm current wedge (SCW) configuration. Figure shows three published SCW scenarios as wire models superposed onto auroral images from the NASA Polar VIS Earth Camera.



TSQ 2:
EZIE will determine to what extend the electrojet consist of small current wedgelets. Figure shows (a) the classical auroral electrojet configuration and (b) the recently much promoted wedgelet scenario.



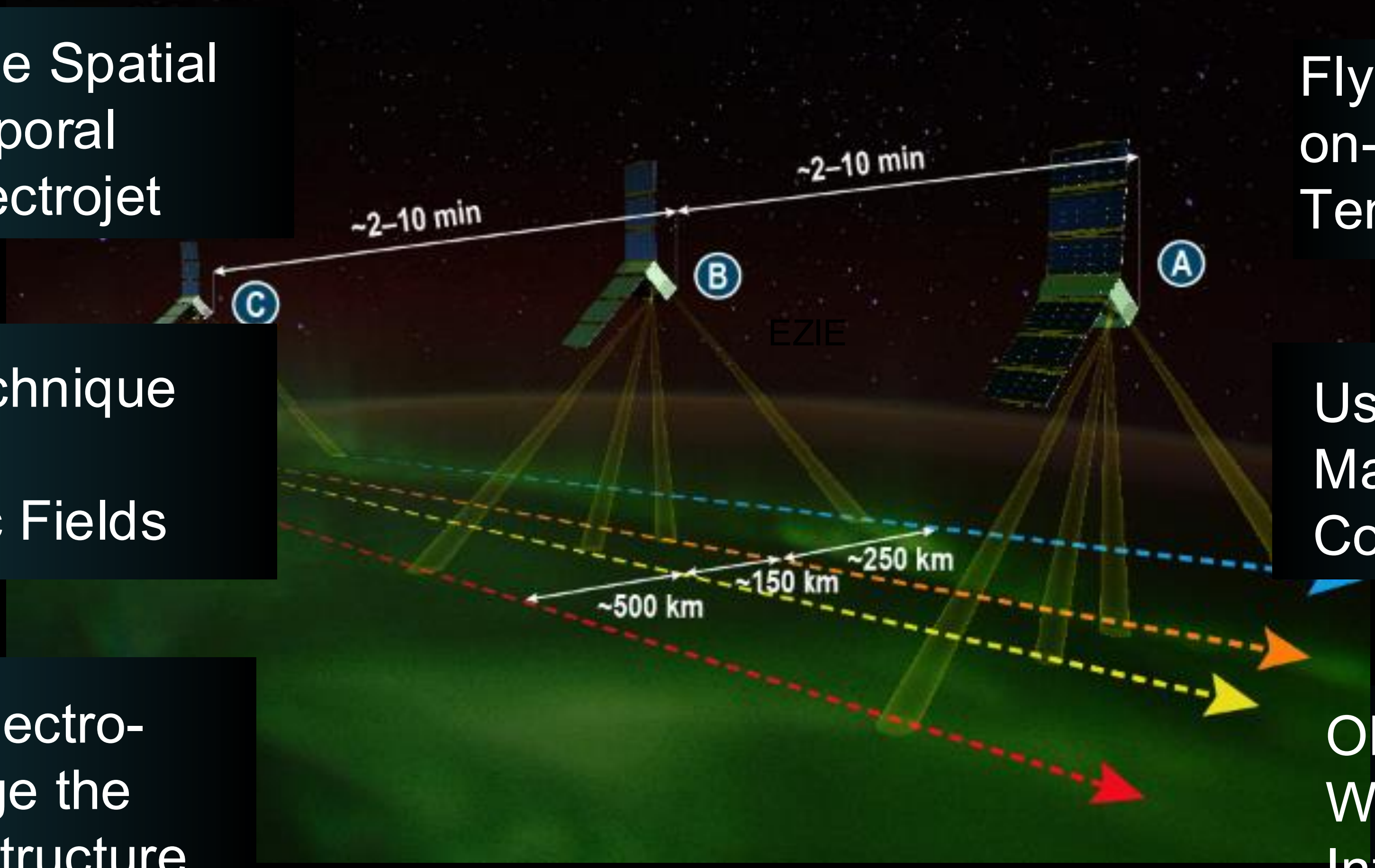
EZIE Mission Objectives and Implementation Approach

Objective: To gain insight into decade old mysteries about the magnetosphere-Ionosphere coupling processes & uncover physics required for better prediction of space weather

Map the Meso-scale Spatial Structure and Temporal Evolution of the Electrojet

Utilize Zeeman Technique to Remotely Sense Electrojet Magnetic Fields

Use of A 4-view Spectro-polarimeter to Image the Electrojet Spatial Structure.



Fly 3 CubeSat on pearls-on-a-string to study Temporal evolution

Use Differential Drag to Manage the Flight Configuration

Obtain Mesospheric Wind & Temperature Information

EZIE Utilizes the Zeeman Technique to Remotely Sense Electrojet Induced $\vec{B}$

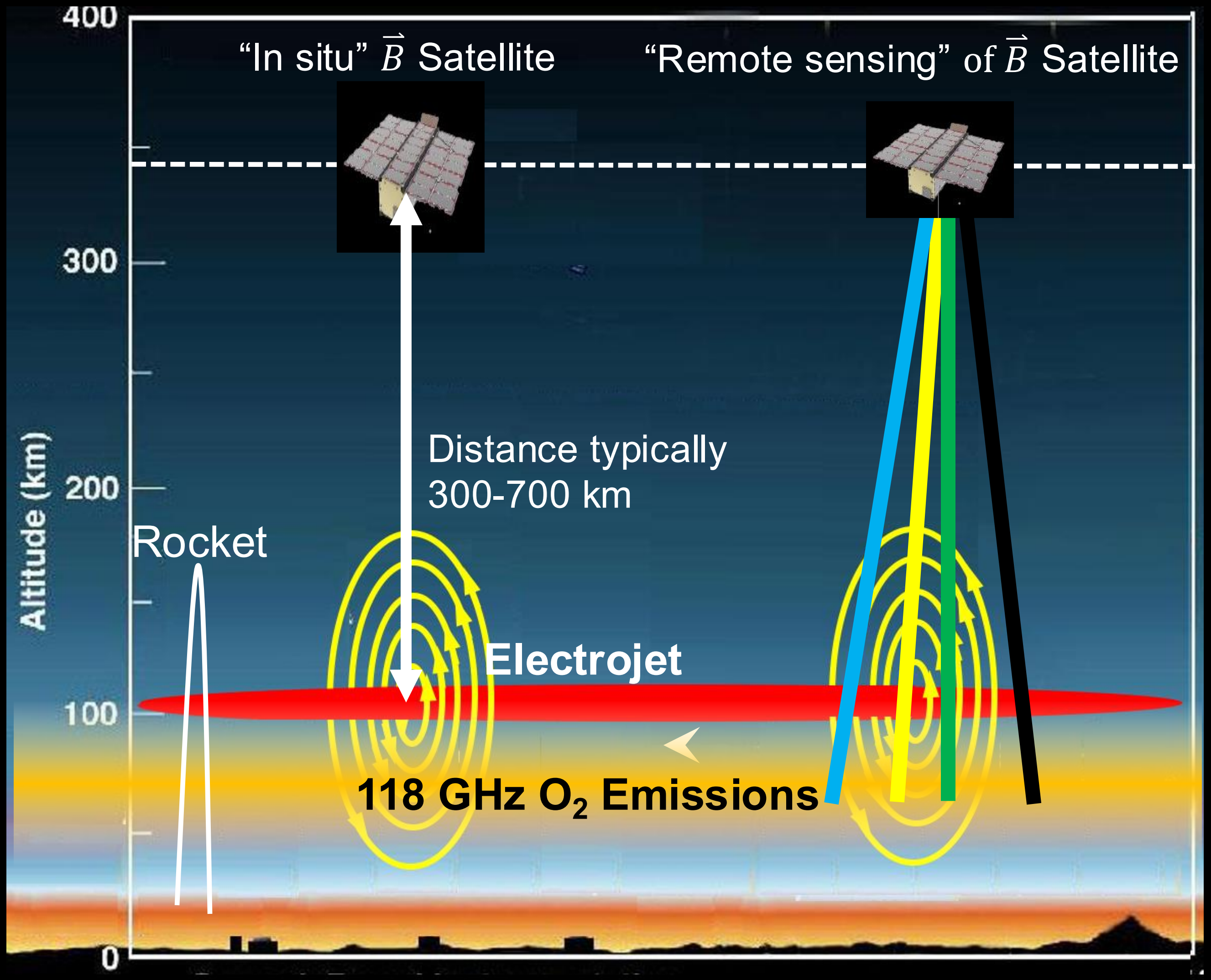
Ground based magnetometers sensing $\vec{B}$ at distances of ~100 km from electrojet

Spaceborne magnetometers sensing $\vec{B}$ at distances of ~300-700 km from electrojet

EZIE Technique:

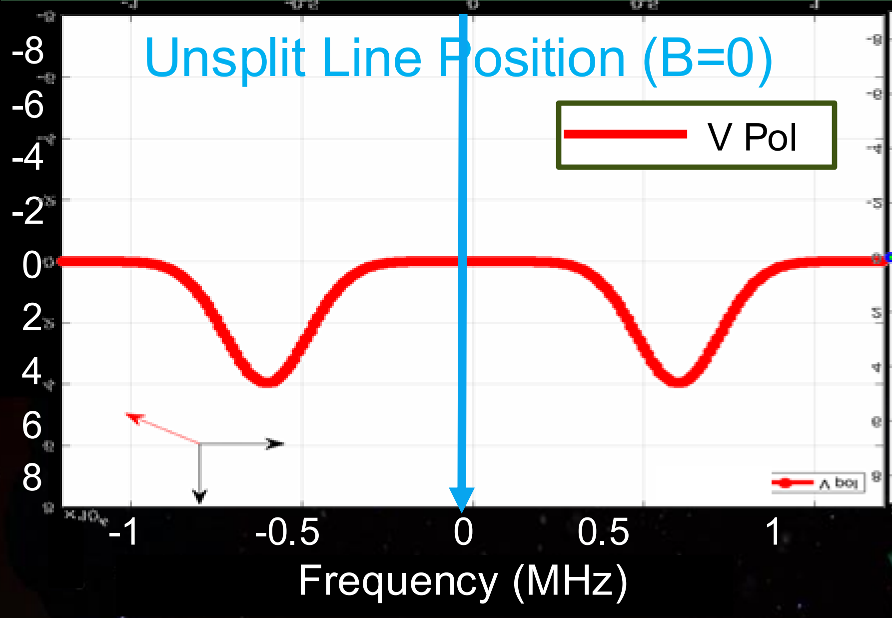
Spectrometers sensing $\vec{B}$ at distances of ~20-30 km from electrojet

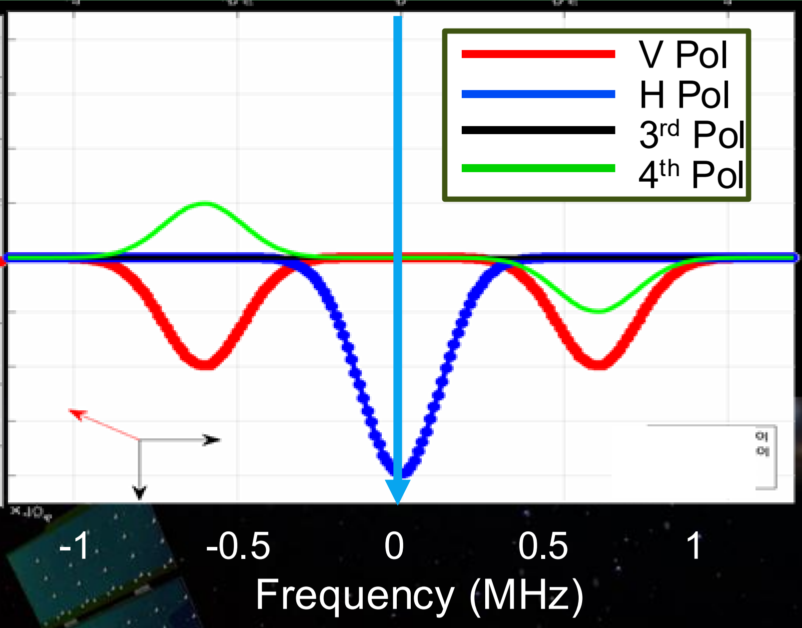
- Electrojet-induced $\vec{B}$ fields are stronger
- Smaller spatial scale fields can be detected
- $\vec{B}$ field structure can be imaged with multi-beam observations from one s/c



Magnetometers on ground, distance ~100 km

EZIE Measures the Effect of Magnetic Field on the Naturally Present O_2 118 GHz Thermal Emission Spectral Radiances



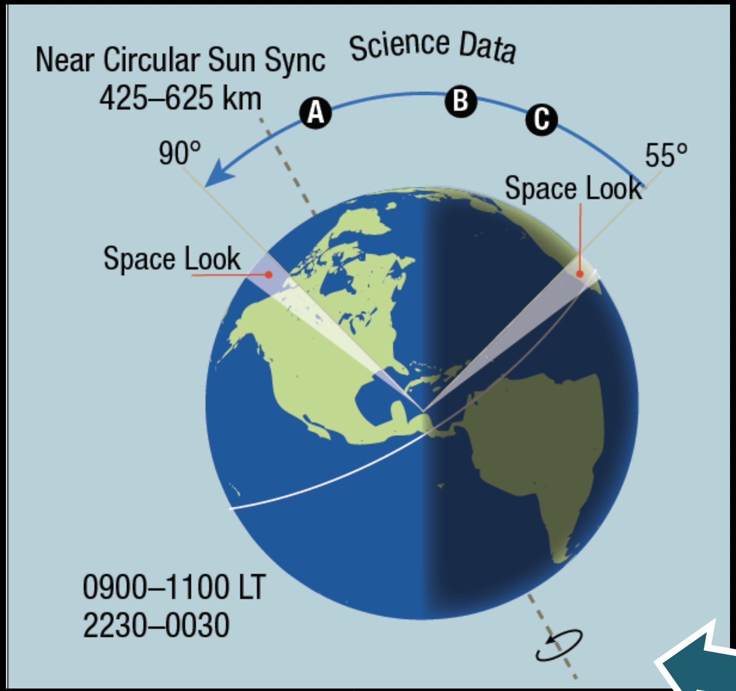


Each EZIE downward-looking O_2 118-GHz emission spectral radiance measurement

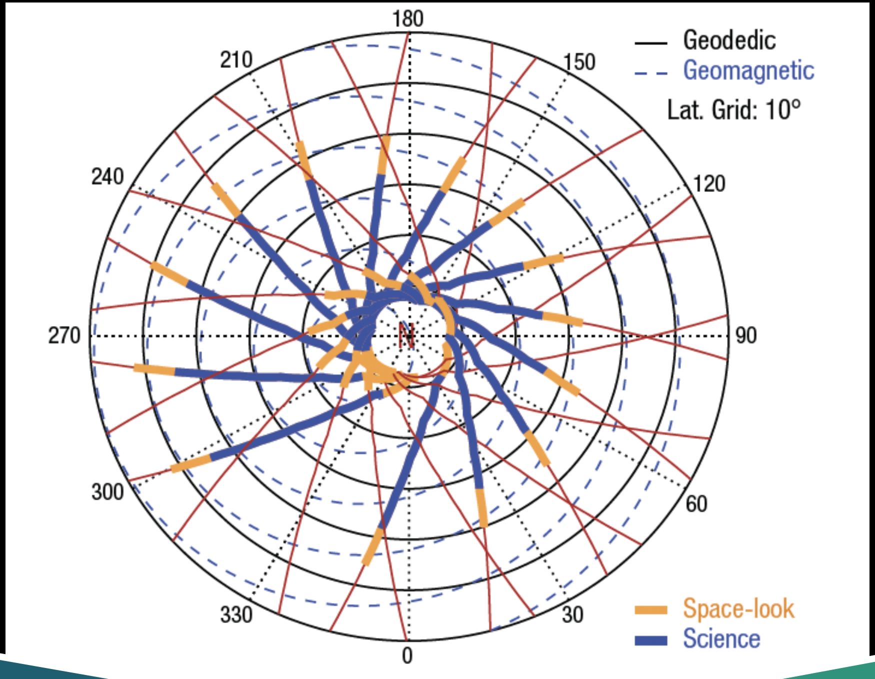
- Covers the entire Zeeman spectra and resolves the three split lines
  - Spectral split → Total magnetic field
  - Spectral shift → Line of sight wind
  - Spectral Radiances → Temperature profile
- Characterizes the full polarization state of the three Zeeman lines
  - Polarization → Vector B-field

Baseline EZIE Observation Plan: One DCE per Orbit and Alternating AEJ and EEJ Observations By Seasons

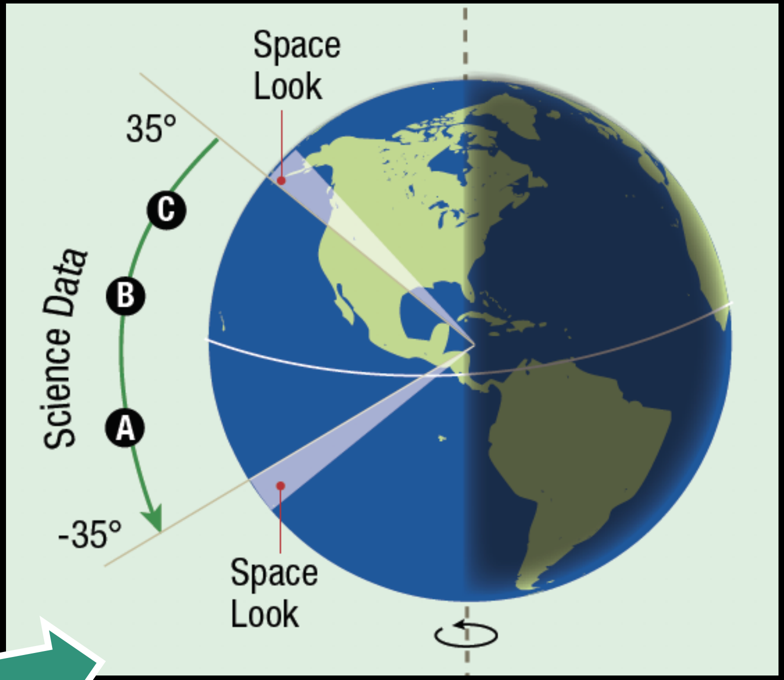
Primary Science: Auroral Electrojet



One Day of Auroral Electrojet Observations
One 9-11 min Data Collection Event (DCE) Per Orbit



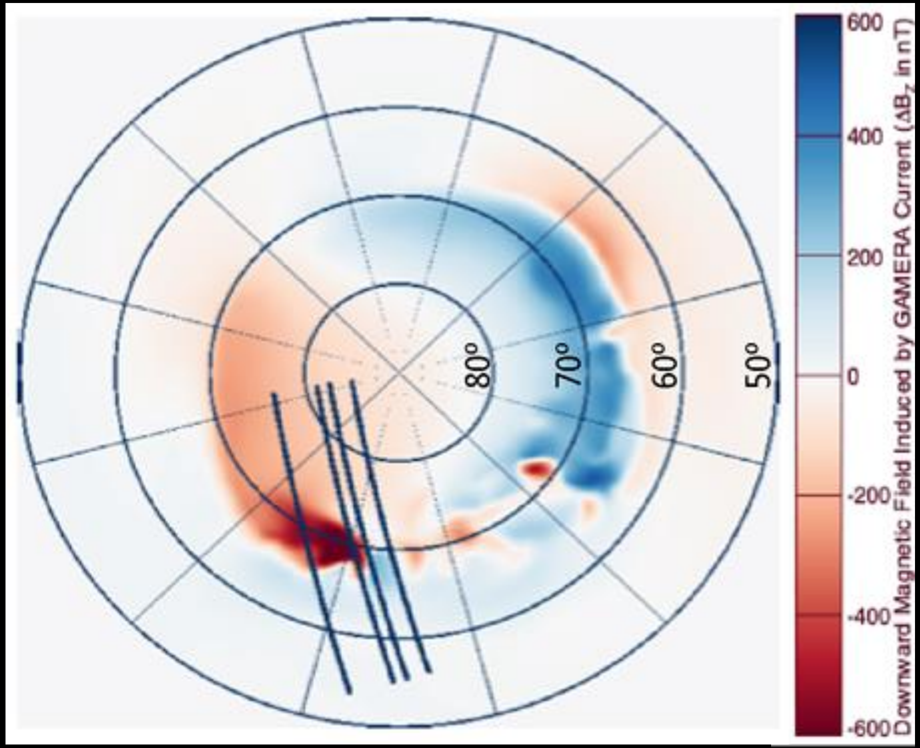
Science Augmentation Equatorial Electrojet



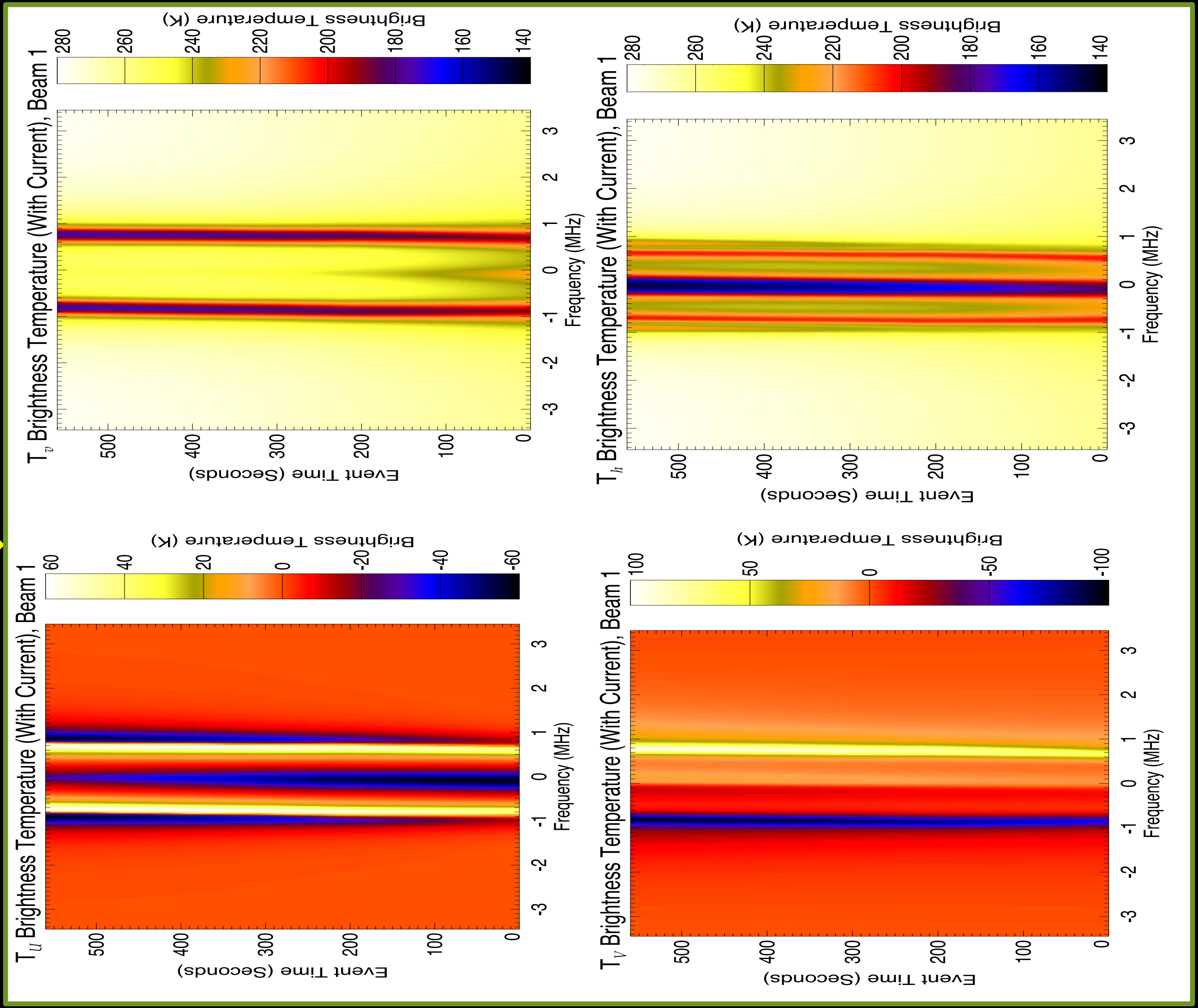
Northern Summer	Equinox	Southern Summer	Equinox

Primary EZIE Level-1 Data Product:
4 Tracks of O_2 Stokes Radiance Measurements Per DCE

Cross-Track Orientation

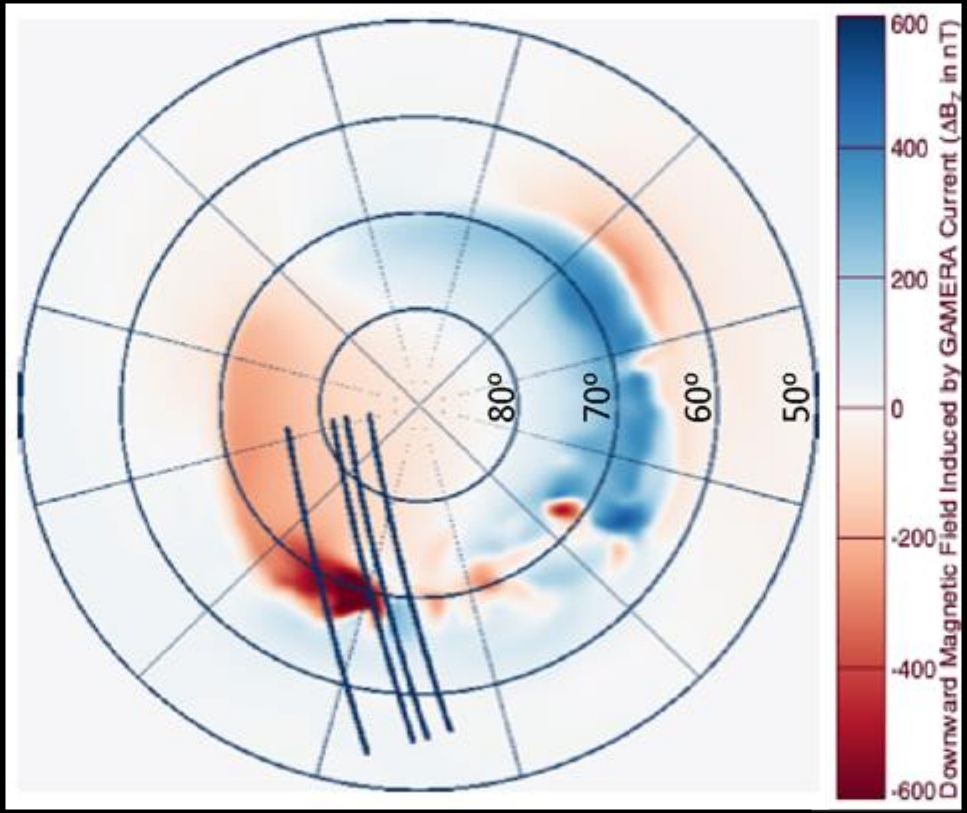


4 Stokes every 2 seconds per track in one orbit



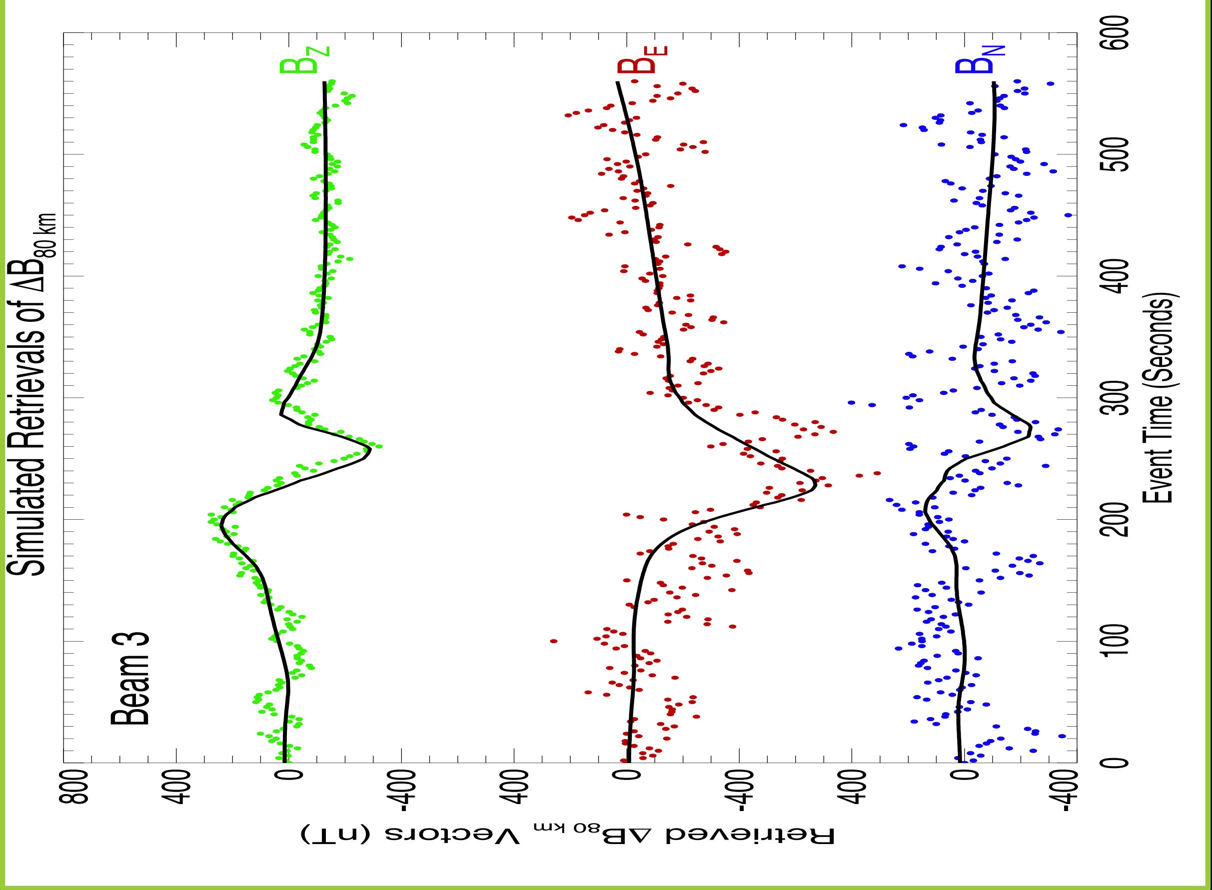
Primary EZIE Level-2 Data Products:
4 Tracks of $\vec{B}$ measurements per DCE per S/C

Cross-Track Orientation



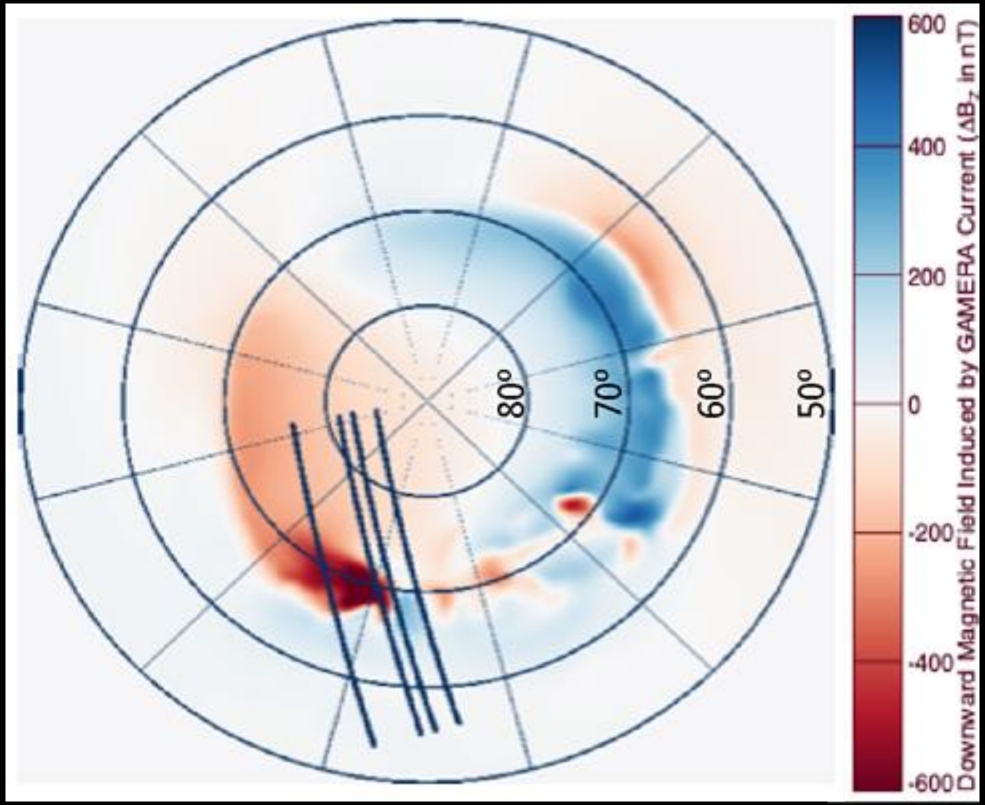
$\vec{B}$ fields every 2 seconds per track

Simulated Retrievals of Vector B

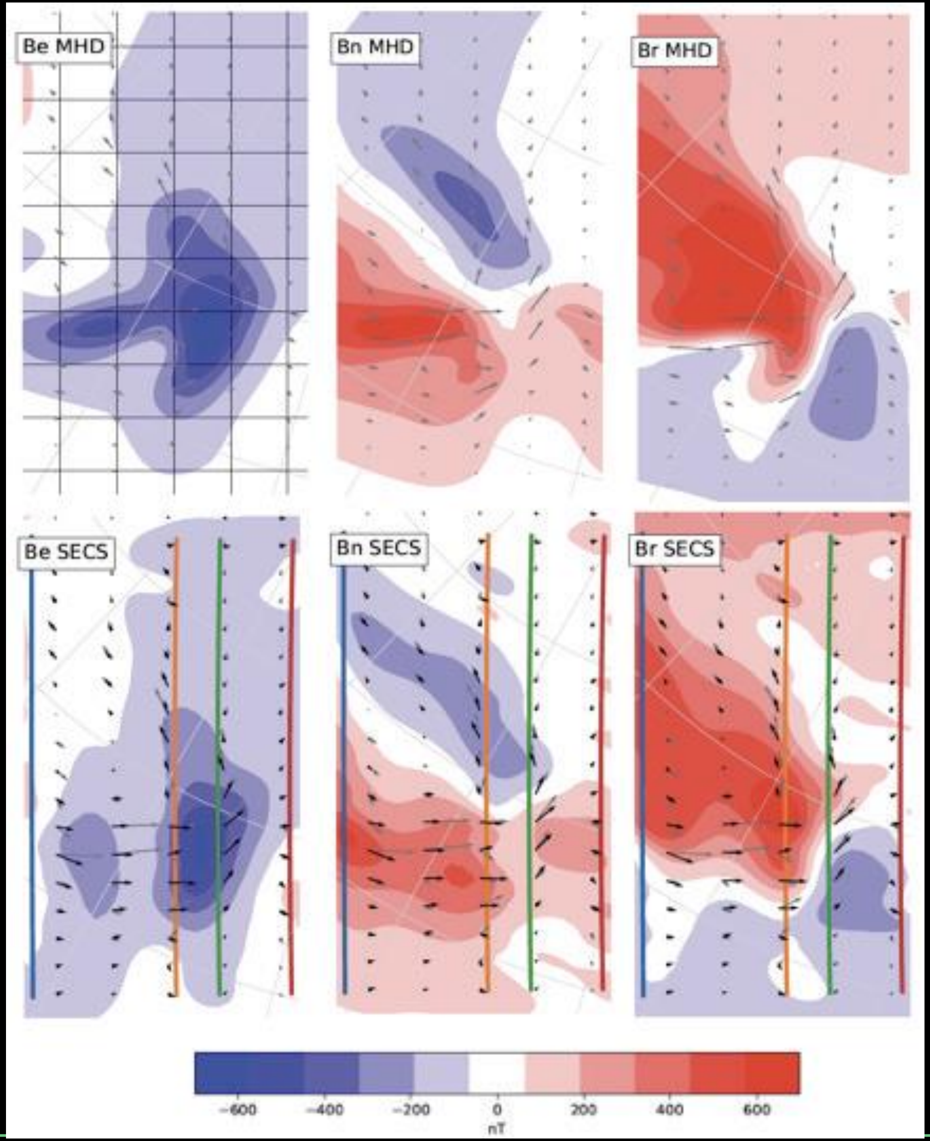


Primary EZIE Level-3 Data Product:
One 2D Equivalent Current Map Per Orbit Per S/C

Cross-Track Orientation



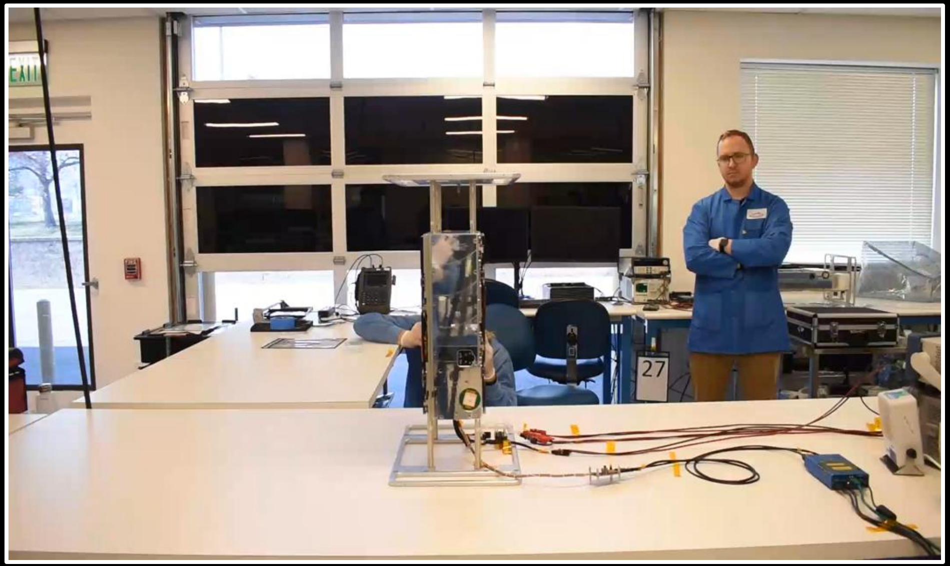
One 2D equivalent current map per one 9-min DCE

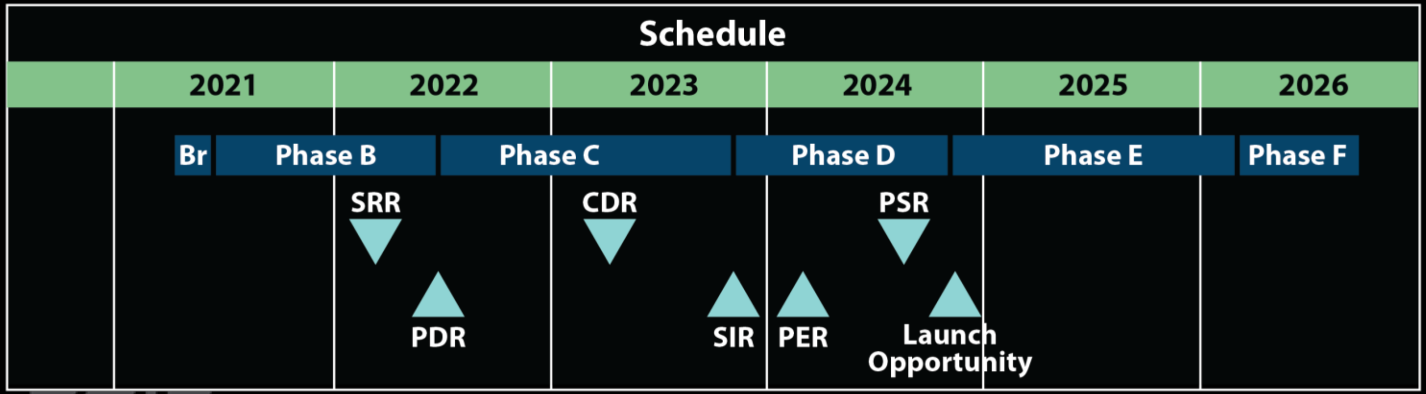


EZIE Development Status and Readiness to Launch

MEM instrument cold calibration test

EZIE SV-B Solar Array Deployment

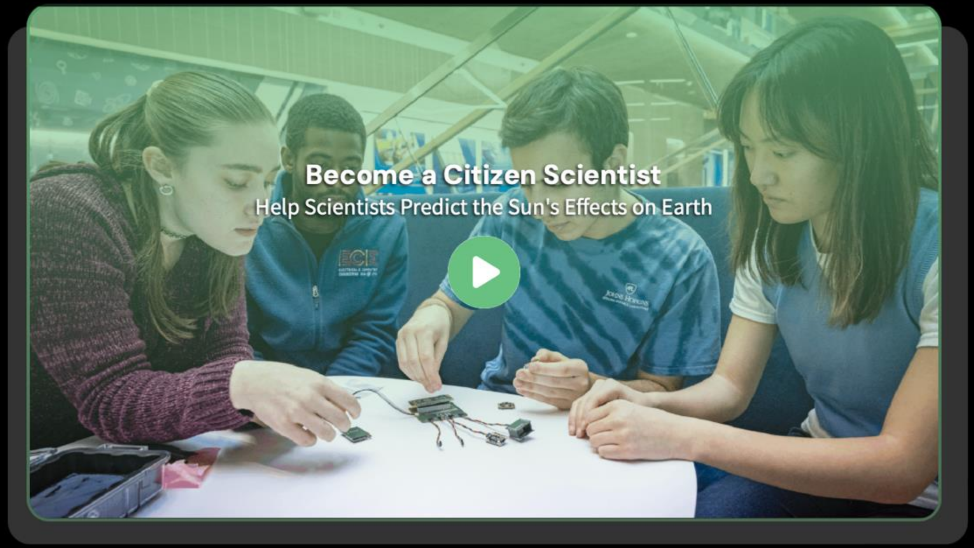




- All 3 MEM instruments tested, calibrated, and delivered to BCT for S/C I&T
- All 3 S/C are integrated, vibration tested, and currently under environmental TV testing
- Getting ready to ship to MSS after PSR
- Scheduled to launch on Falcon-9 as ride-shares on 10/1 to 11/30.

EZIE Outreach and Citizen Science Program: EZIE-Mag

EZIE Mission Team News & Resources Media Gallery Contact Outreach Science Workshop



What is EZIE-Mag?

Want to experience the aurora from your hometown? You can with EZIE-Mag.

EZIE-Mag is a citizen science magnetometer program that will enable learners to capture science data similar to that obtained by the EZIE mission.

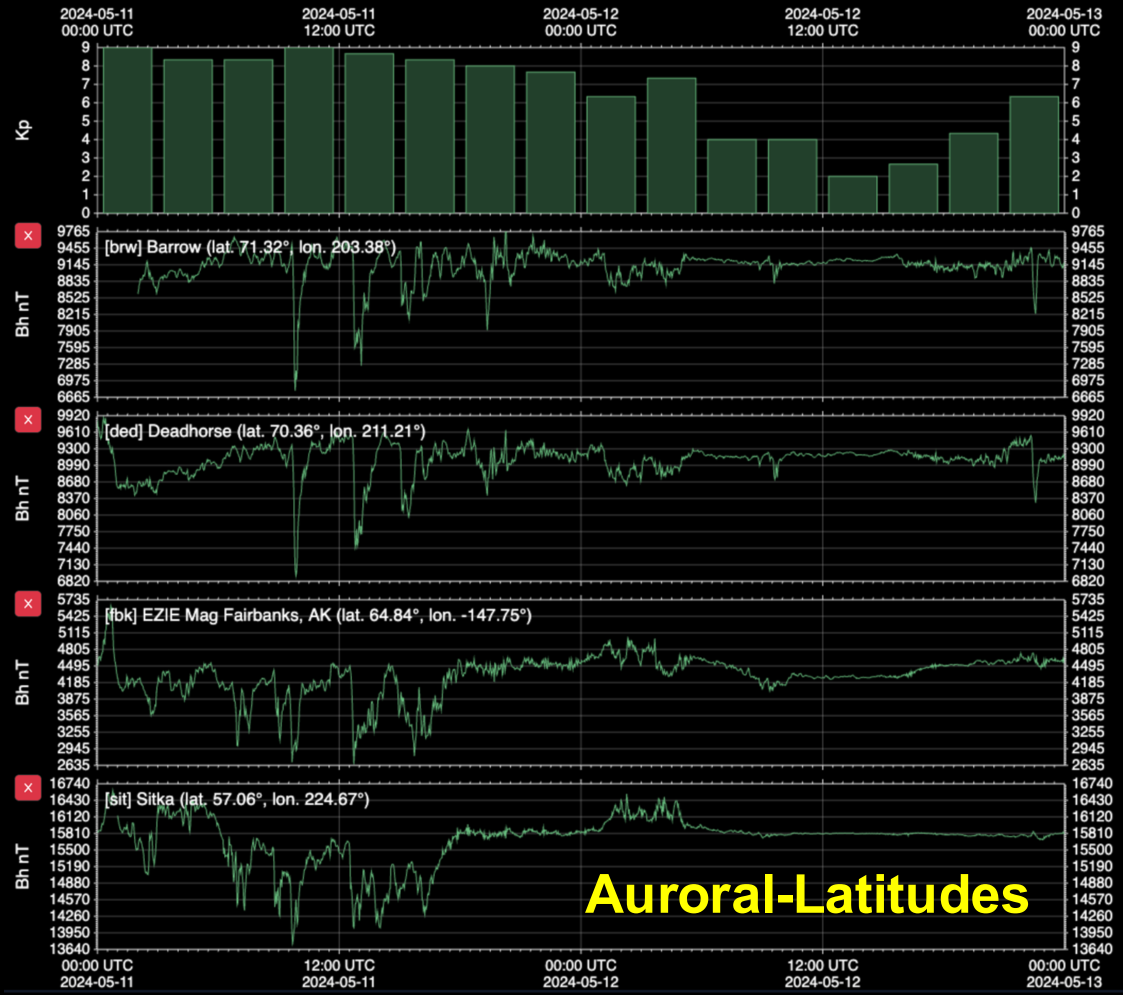
The program will distribute kits around the time of EZIE's launch in September 2024 that will enable diverse communities to collect data about the connections between Earth and space.

But the program is much more than just a kit! EZIE-Mag is also a learning program that includes activities and challenges that focus on science, engineering, art, literacy and leadership, as well as social and emotional skill-building. There are many options to customize and enhance learners' experiences.

Apply to receive an EZIE-Mag kit!

EZIE-Mag

2024 Super Storm



EZIE

Thank You and Collaborations are Welcome!

EZIE Web Site: https://ezie.jhuapl.edu

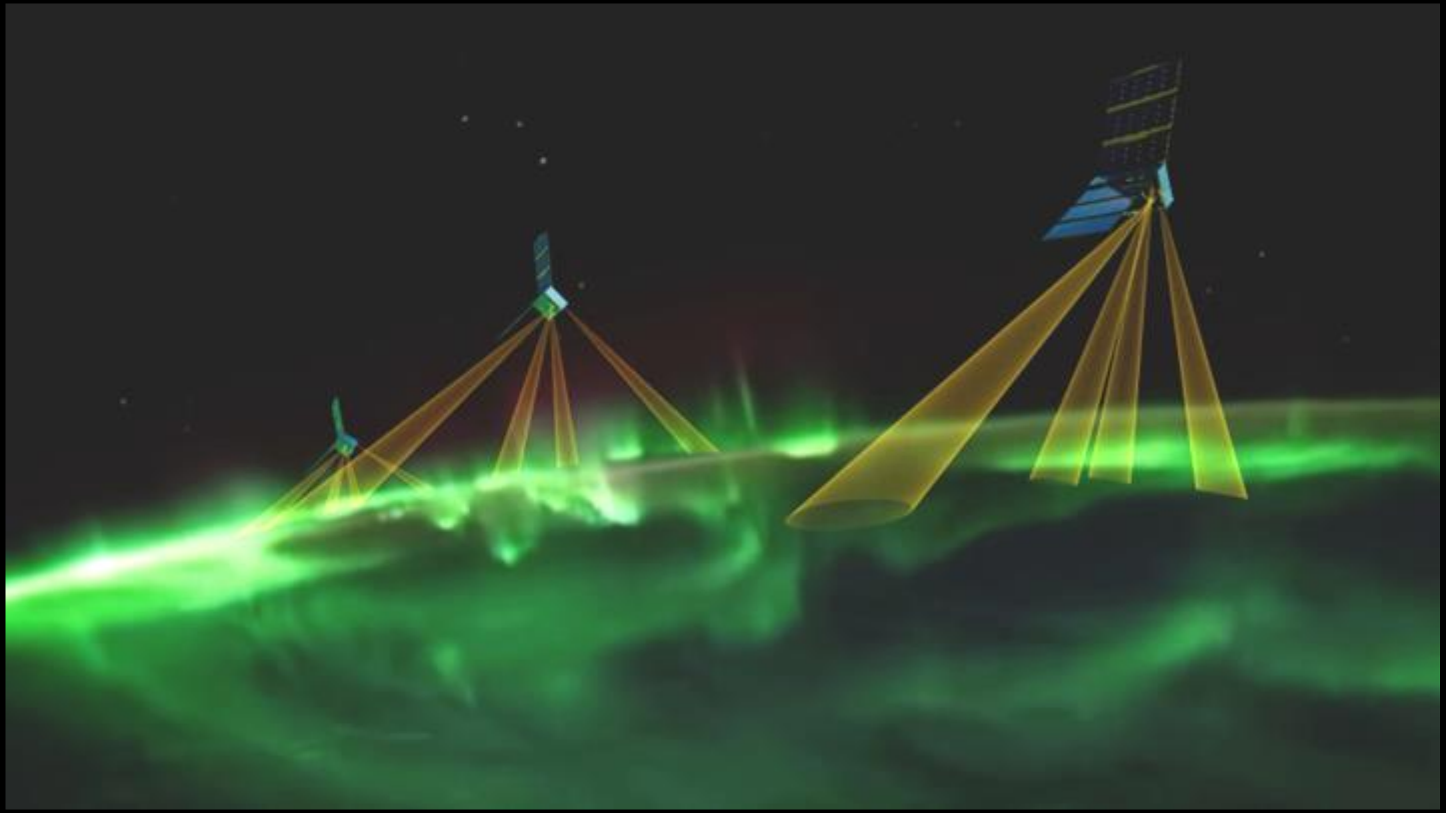
Open Science Workshop :

When: 9/25-9/27 2024

Format: Virtual and On-site at APL

Registration: Open

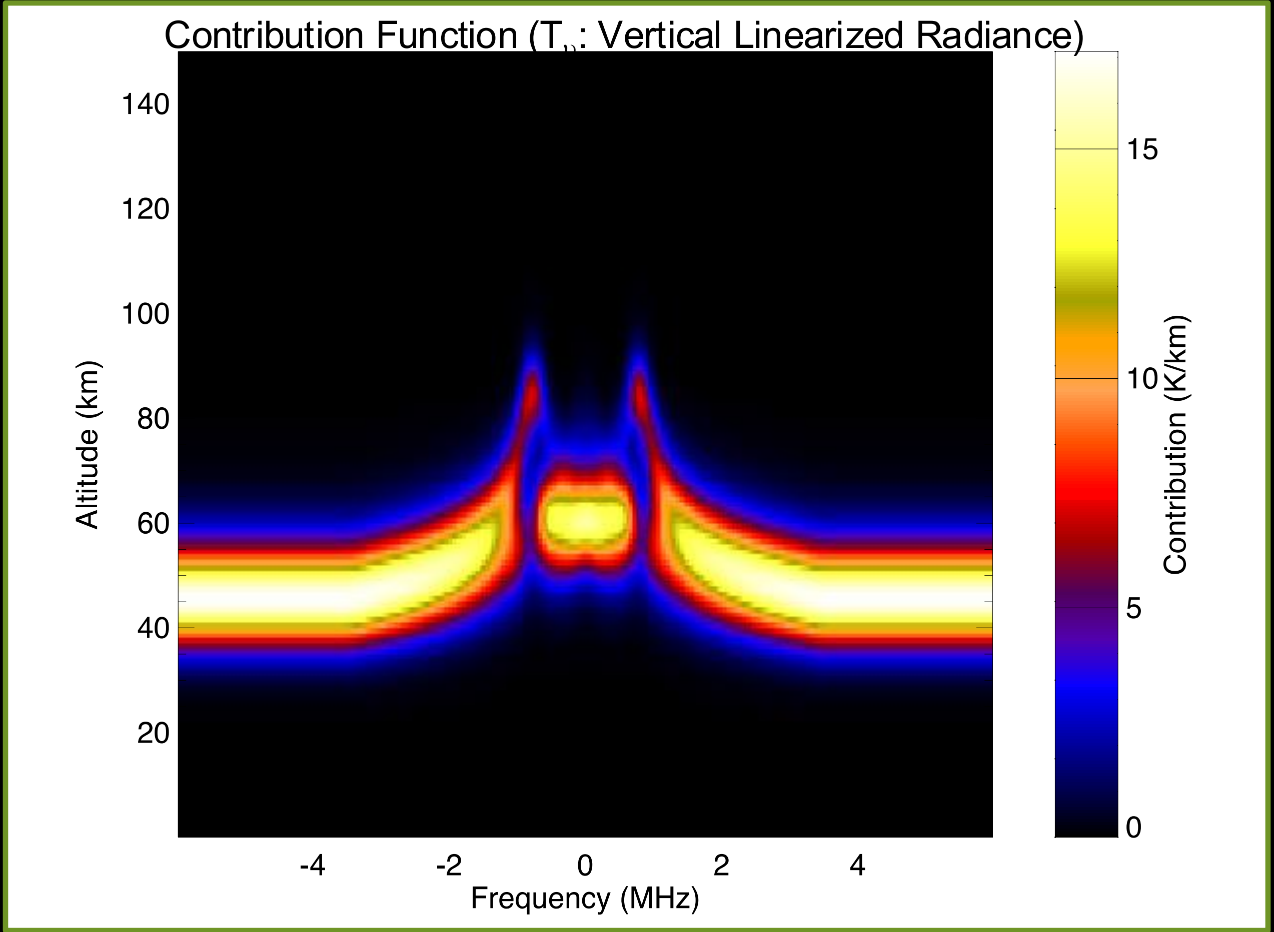
EZIE Mission Summary

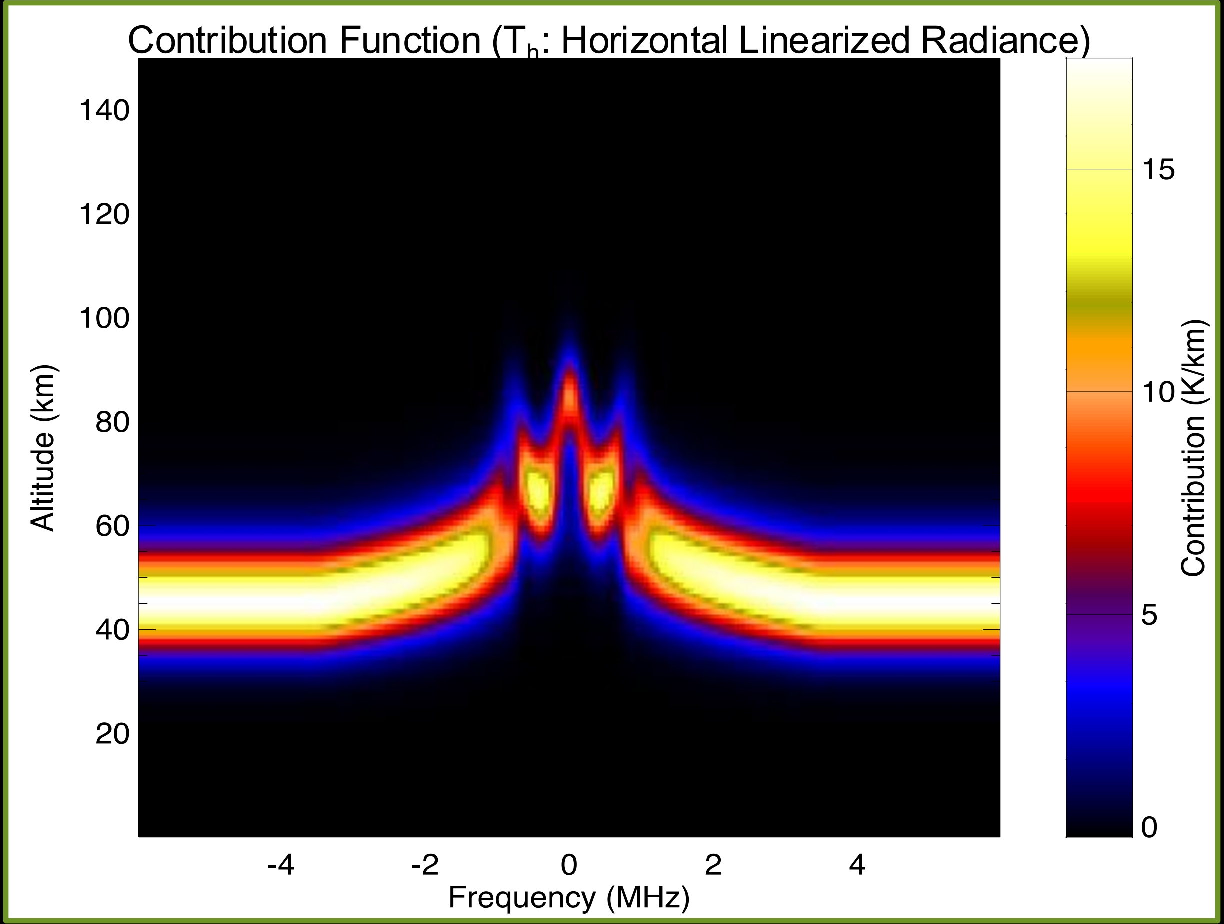


- <u>Measurement Products:</u>
  - O_2 118 GHz 4-Stokes spectral radiances
  - Current-induced magnetic field vectors near ~80 km
  - 2-D equivalent current maps
  - Line-of-sight Winds
  - Temperature profiles ~45 km to 90 km
- <u>Measurement Properties:</u>
  - Collection Duration: ~9 to 11 min
  - Integration time: 2 seconds
  - Instantaneous FOV: ~30-50 km
- <u>Deployment Orbit:</u>
  - Circular, 425- to 650-km altitude
  - Near Sun-Sync, 10:00–12:30 or 22:00–02:00 LTAN
  - Launch Date: Late 2024 or early 2025

Secondary EZIE Level-2 Science Product: Temperature Profiles Between ~45 km and 90 km

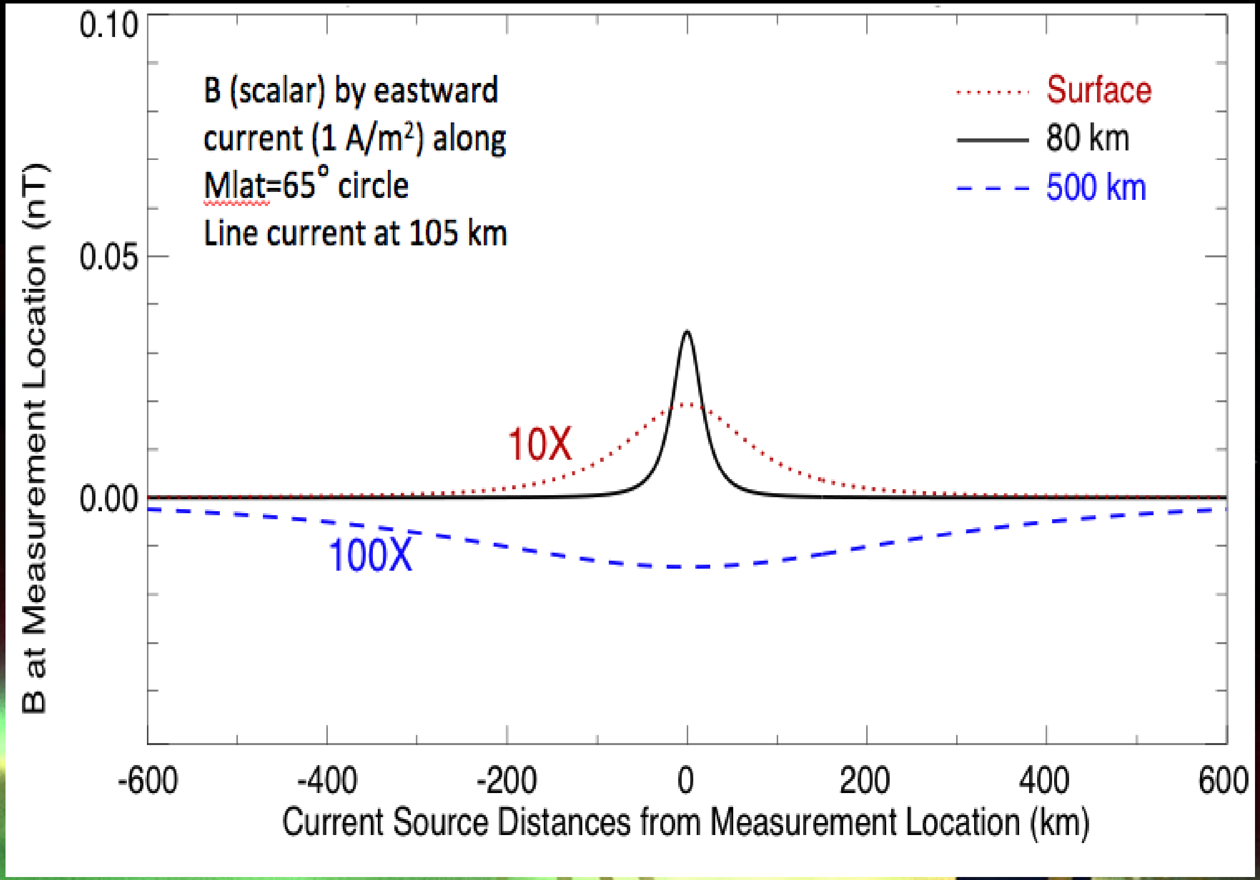
EZIE also can apply the temperature sounding technique to obtain temperature profiles every 2 seconds from the measured brightness temperature of the O_2 spectral radiances



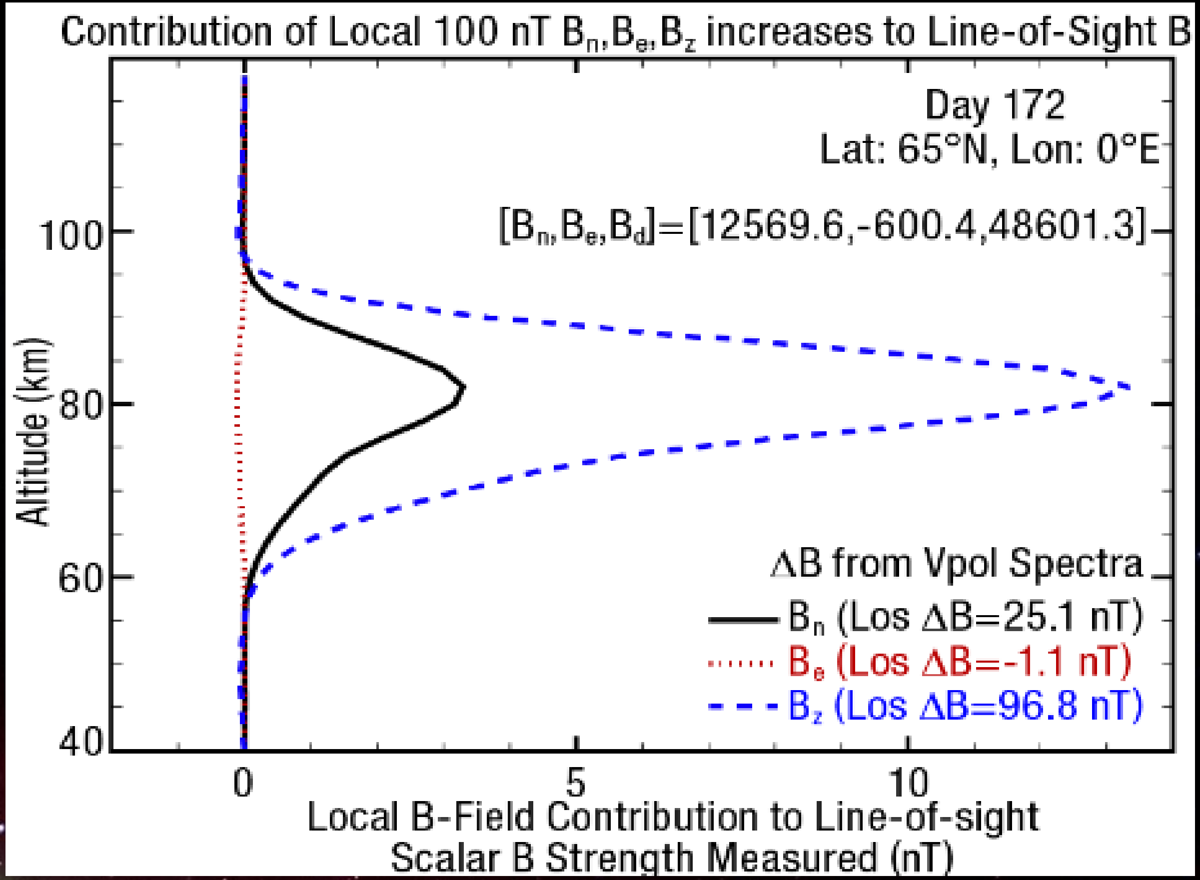


Advantages of EZIE B-Fields Measurements by Viewing Nadir

Higher Spatial Resolution



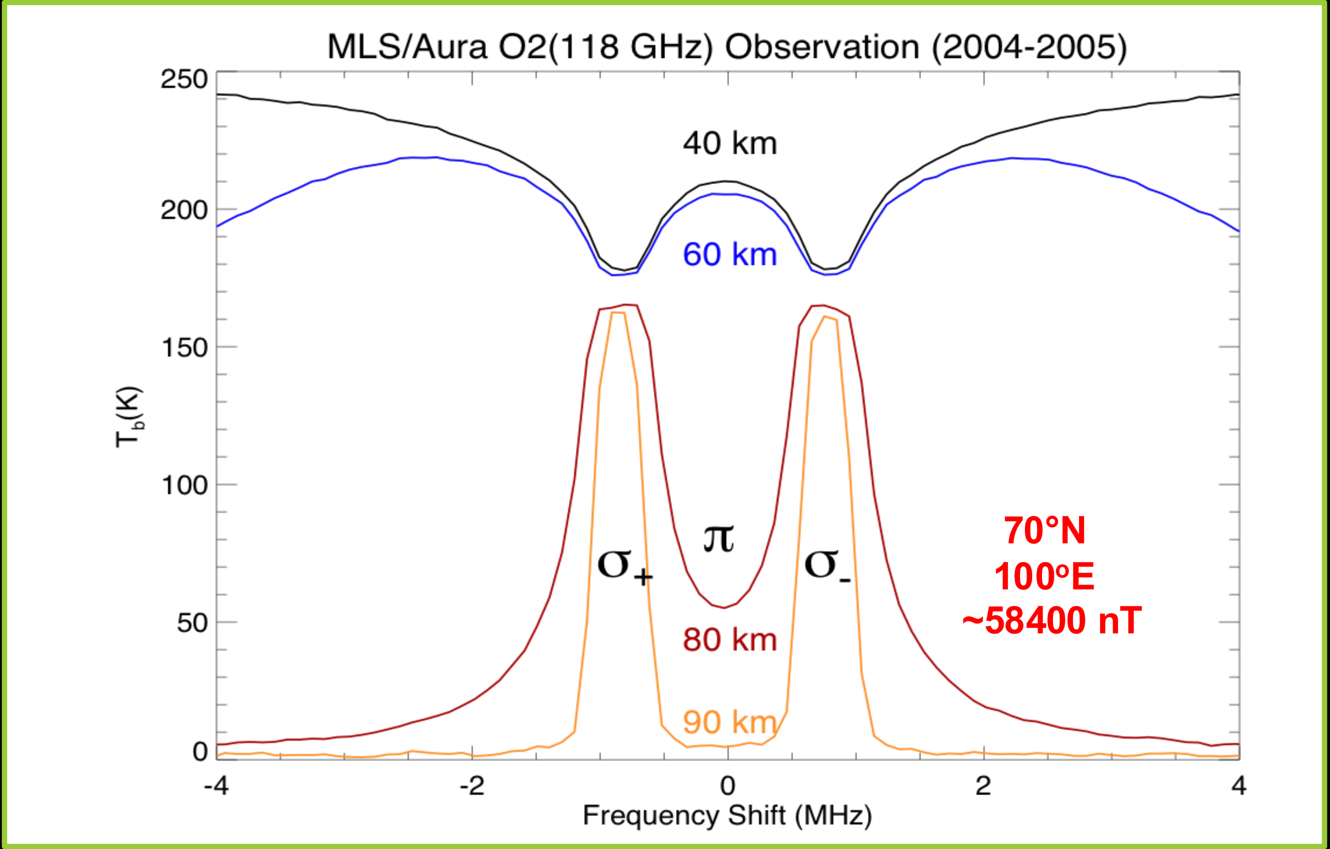
Close to the Electrojet



EZIE Uses Zeeman Effects on the O_2 118 GHz Thermal line to Obtain Magnetic Field Strengths Near the Current Altitudes of ~105 km

The O_2 (J=1 to J=0) transition at ~118.751 GHz. It has three Zeeman components (Δm=+1, 0, -1), while the splitting in typical geomagnetic fields (30000-60000 nT) is of order 1 MHz.

MLS/Aura Vertical Polarized Measurements



$\Delta\nu$ (MHz) =1.4012x10^{-5}*B (nT)

The Zeeman effects of the O_2 118 GHz lines

- the splits can be seen in both emission (high altitudes) and absorption (low altitudes) lines;
- the splits can be spectrally resolved. The splitting is larger than the width of the lines.
- the polarization states can be measured and used to obtain the information about the angles between the B-vector and viewing line-of-sight.