Ten Years of CASSIOPE: A Canadian Space Science Success Story

Andrew Howarth

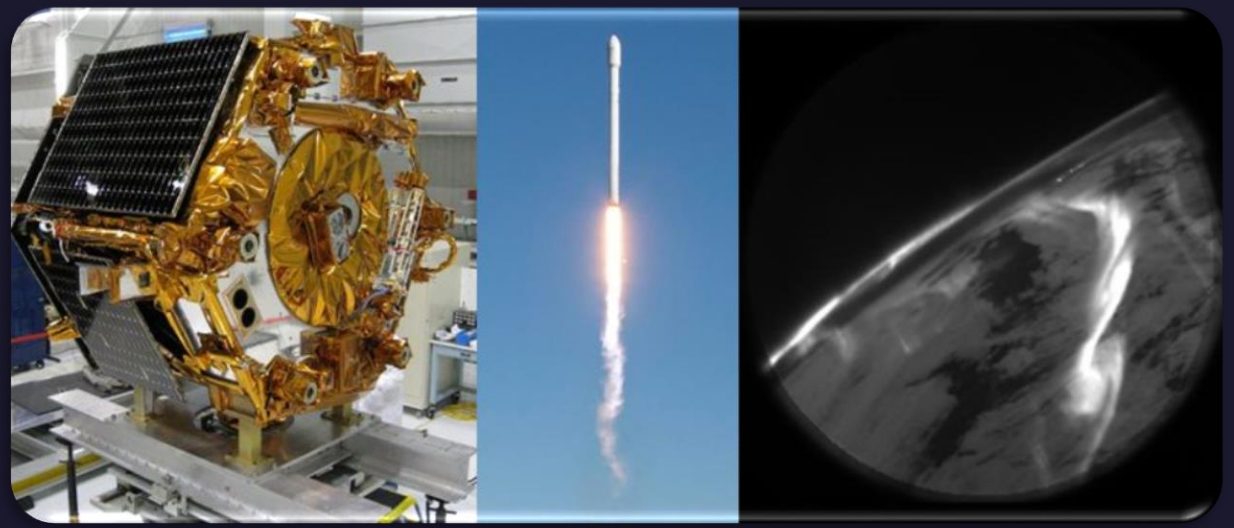
DASP 2024

February 21, 2024

Edmonton, Alberta

Mission Overview

Spacecraft	**Small satellite, 125 cm x 180 cm**
Names	**CASSIOPE/e-POP/Swarm-Echo**
Launch	**September 29, 2013**
Support	**CSA, Government of Canada, MDA, ESA, University of Alaska Fairbanks**
Orbit	**325 x 1500 km, 81° inclination, non-sun-synchronous**
Attitude	**3-axis stabilized until 2021, then spin-stabilized (6 min period)**



Science Payload

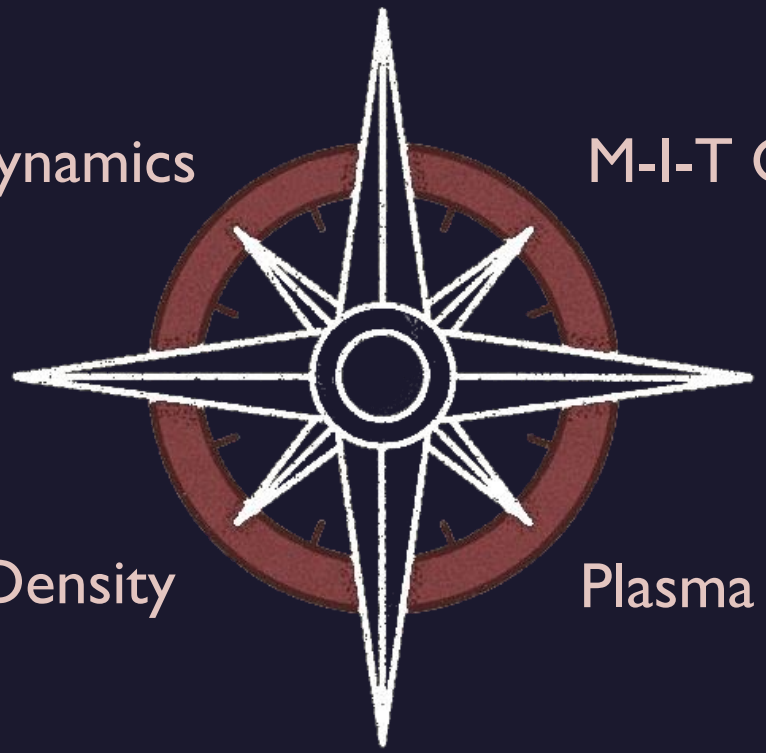
HF Beacon Transmitter	150/400/1066 MHz	CERTO
Auroral Imager	650–1000 nm; 630 nm	FAI
GPS Receivers	5 units, L1 and L2	GAP
Ion Mass Spectrometer	0.5-70 eV/q; 1-40 amu/q	IRM
Magnetometer	Dual mags, 160 samples/s	MGF
Radio Receiver	0.01-18 MHz; 31.25 kHz bandwidth	RRI
Electron Imager	0.1-350 eV ions or electrons	SEI

Highlights from the last 10 years

Radio Science – *SuperDARN*

Auroral Dynamics

M-I-T Coupling



Radio Science – *Citizen Science*

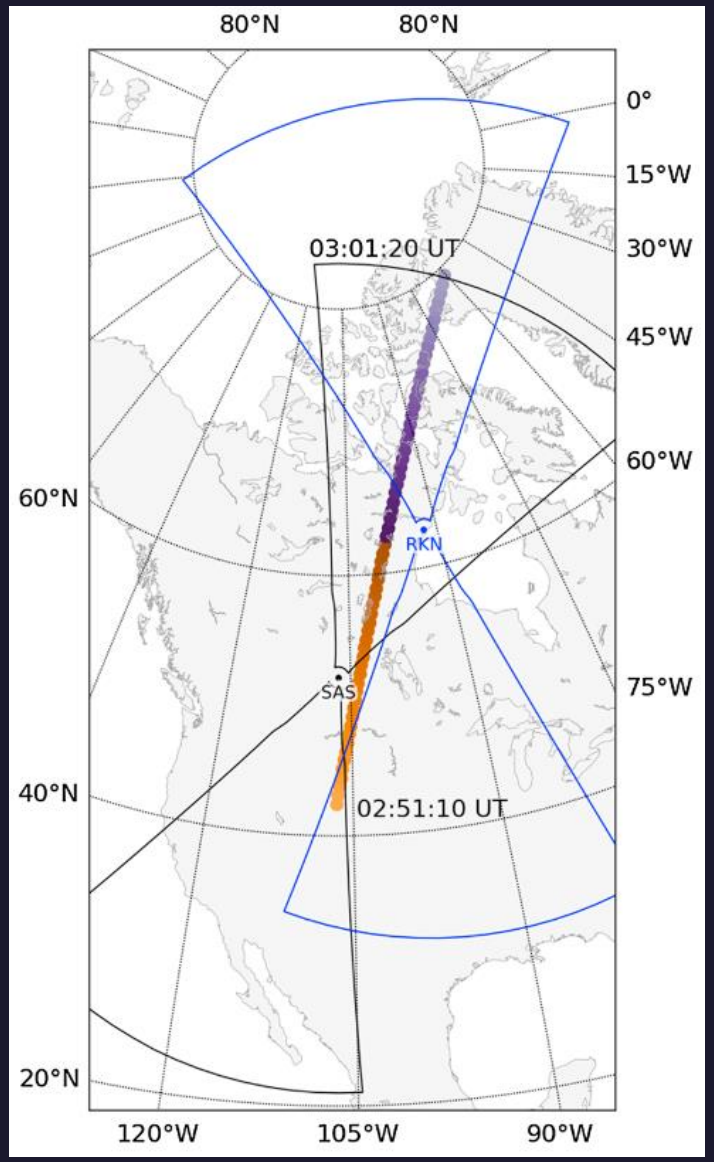
Radio Science – *HF Propagation*

Thermospheric Density

Plasma Structure

Radio Science – *VLF Wave Amplification*

Radio Science *SuperDARN*



Burrell, A. G., S. E. Milan, G. W. Perry, T. K. Yeoman, and M. Lester (2015), Automatically determining the origin direction and propagation mode of high-frequency radar backscatter, Radio Sci.,50, 1225–1245,doi:10.1002/2015RS005808

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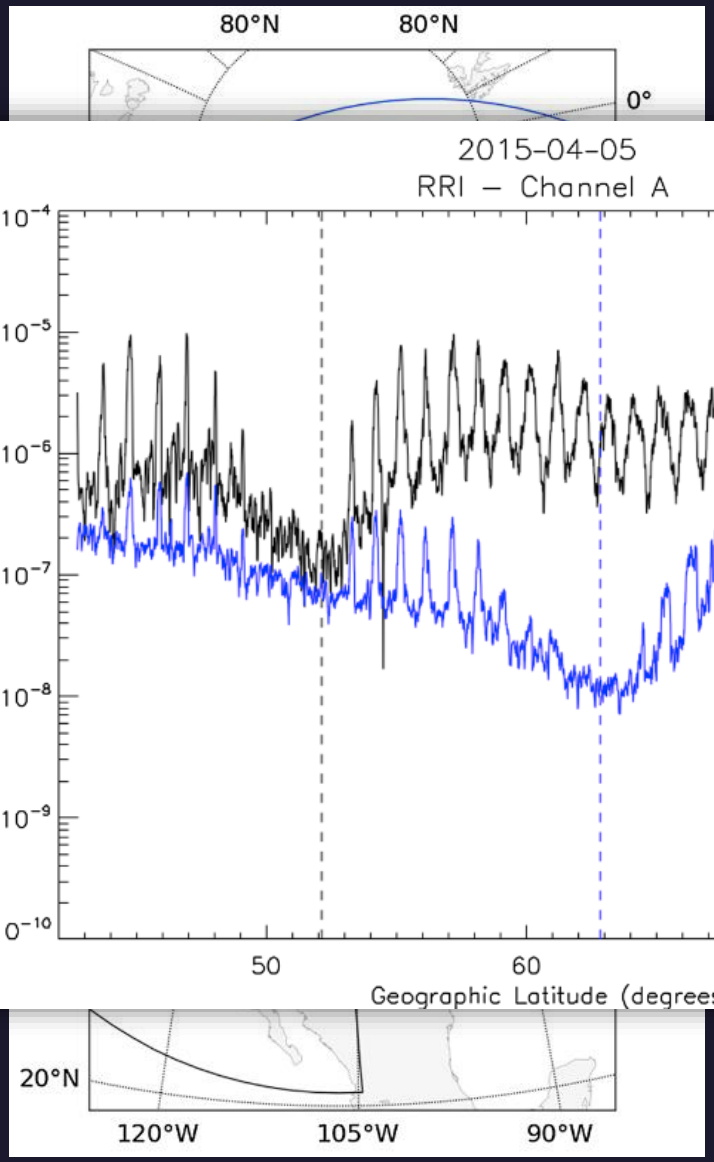

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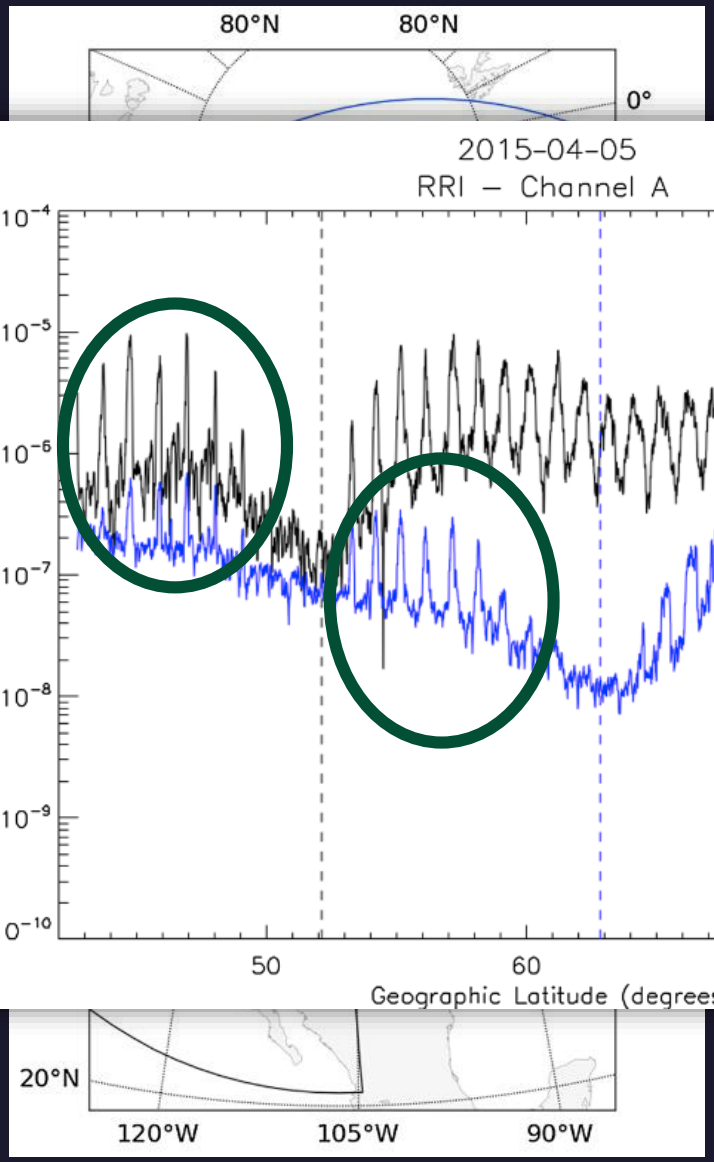

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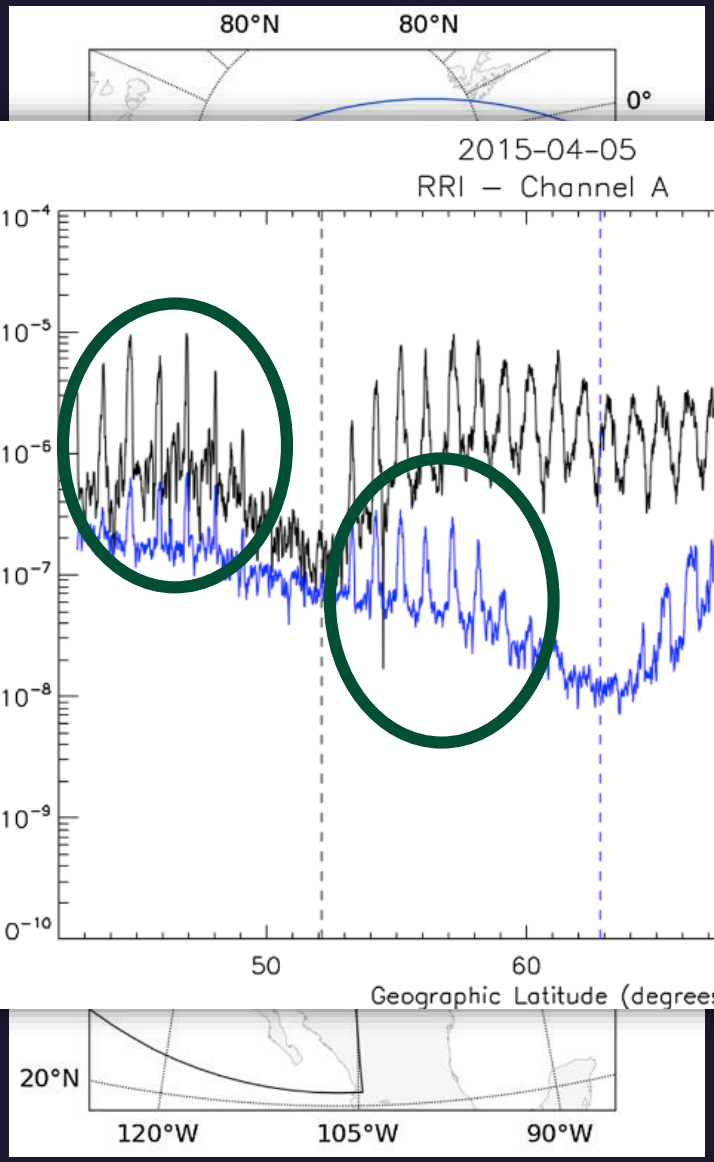

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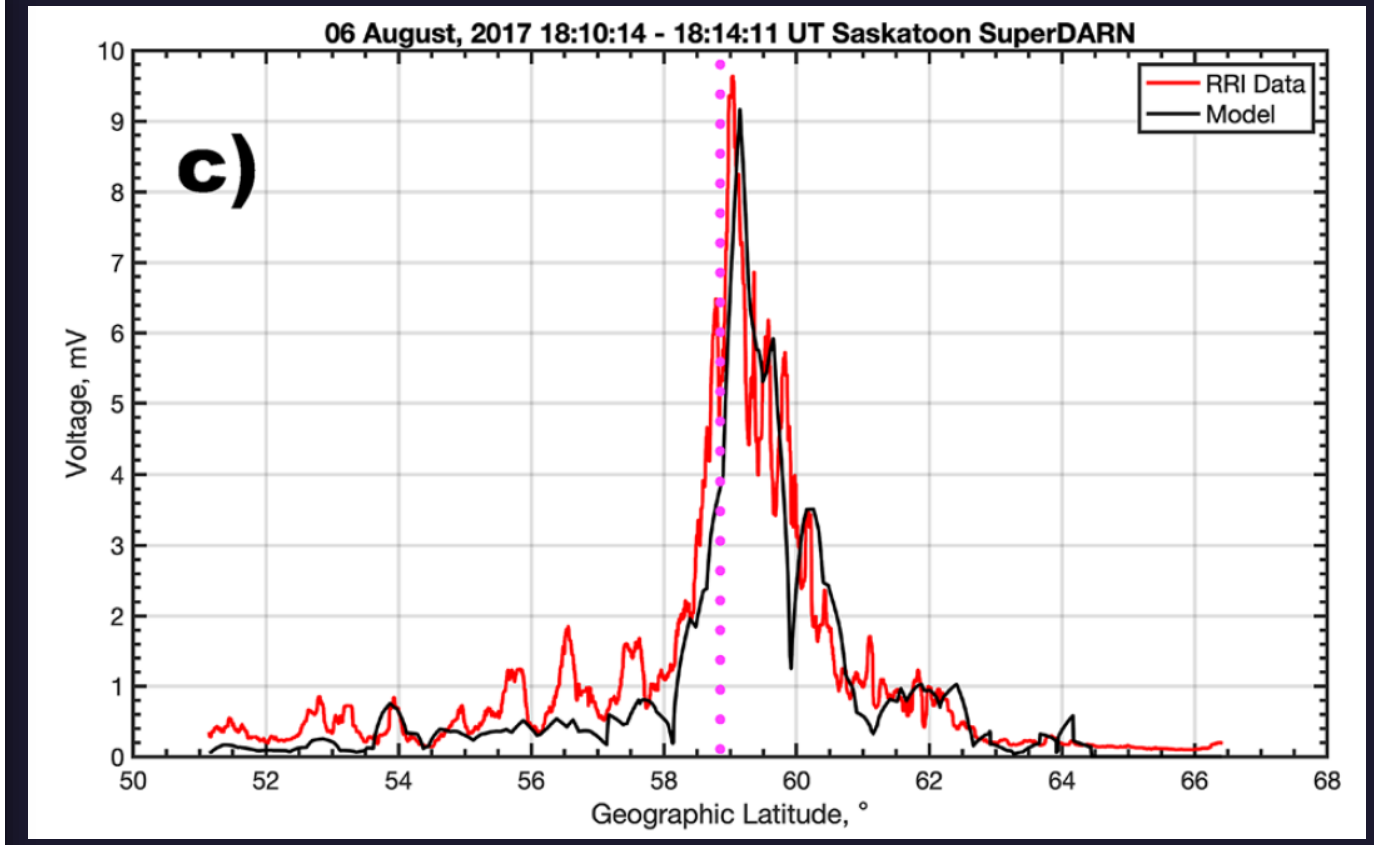
Modeling SuperDARN signals



Perry, G. W., Ruzic, K. D., Sterne, K., Howarth, A. D., & Yau, A. W. (2022). Modeling and validating a SuperDARN radar's Poynting flux profile. *Radio Science*, *57*, e2021RS007323. https://doi.org/10.1029/2021RS007323

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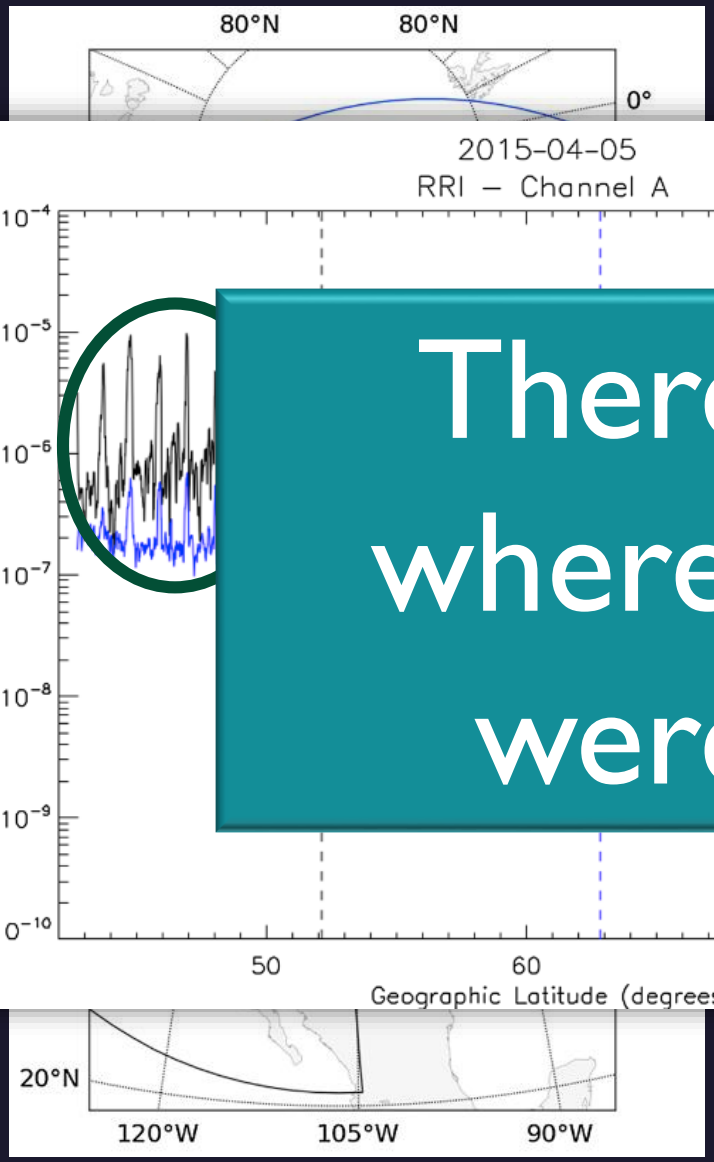

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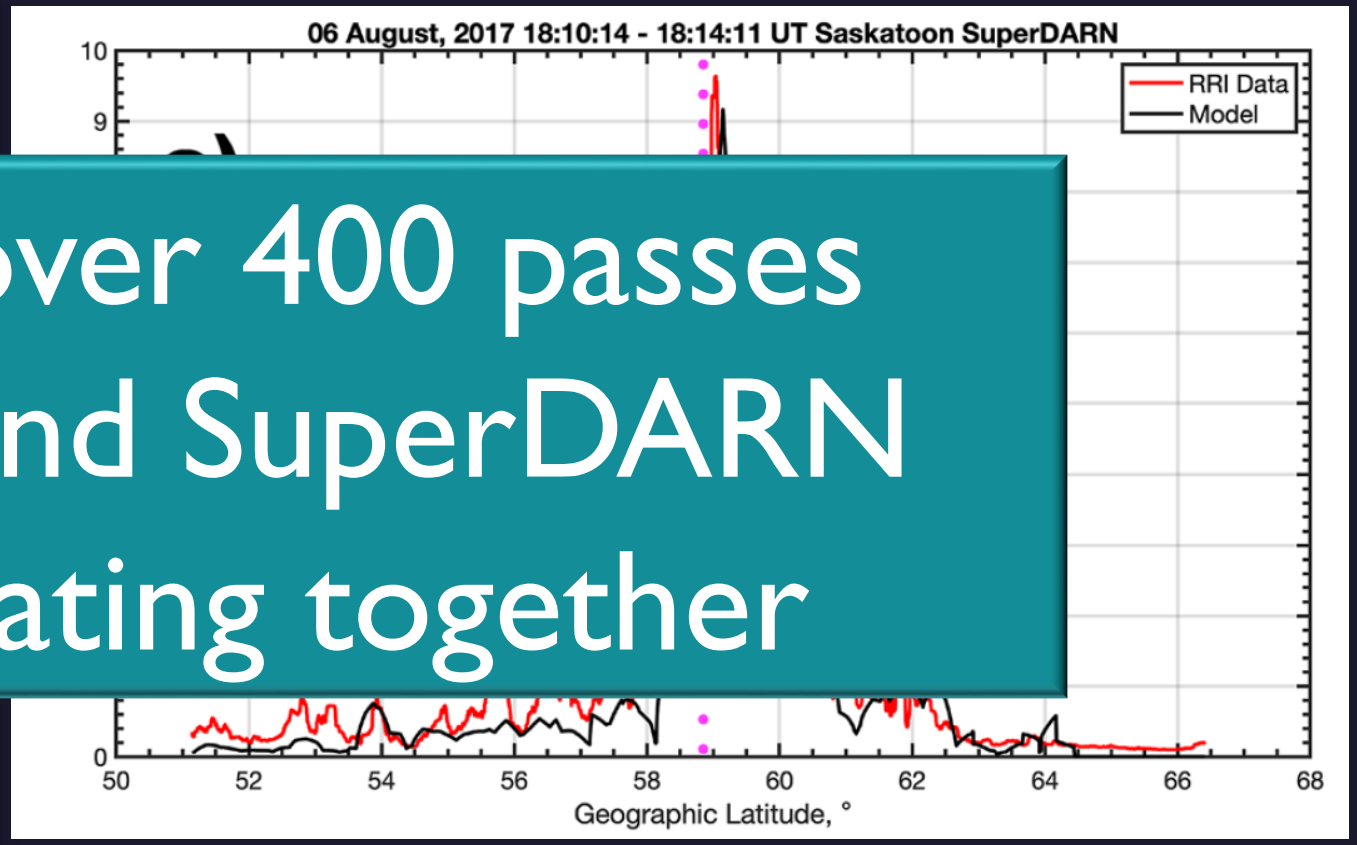

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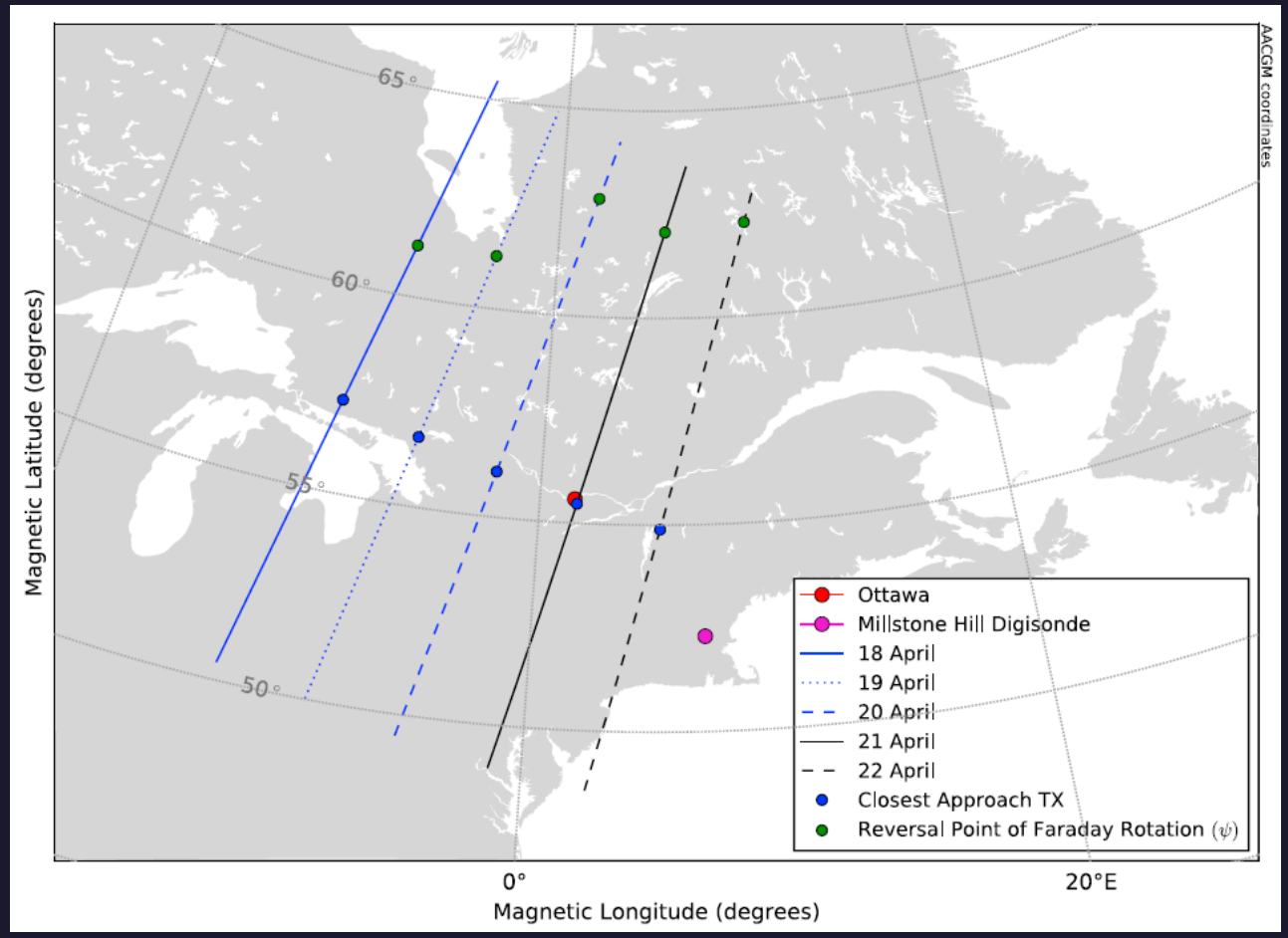
There are over 400 passes where RRI and SuperDARN were operating together

Radio Science *HF Propagation*

- NRCan HF transmitter at Ottawa
  - CW and BPSK Modulation
- Over 50 coordinated passes
- Characteristics of wave propagation
  - Faraday rotation
  - Polarization
  - O-mode vs X-mode propagation



Danskin, D. W., Hussey, G. C., Gillies, R. G., James, H. G., Fairbairn, D. T., & Yau, A. W. (2018). Polarization characteristics inferred from the Radio Receiver Instrument on the enhanced Polar Outflow Probe. Journal of Geophysical Research: Space Physics, 123, 1648–1662. https://doi.org/10.1002/2017JA024731

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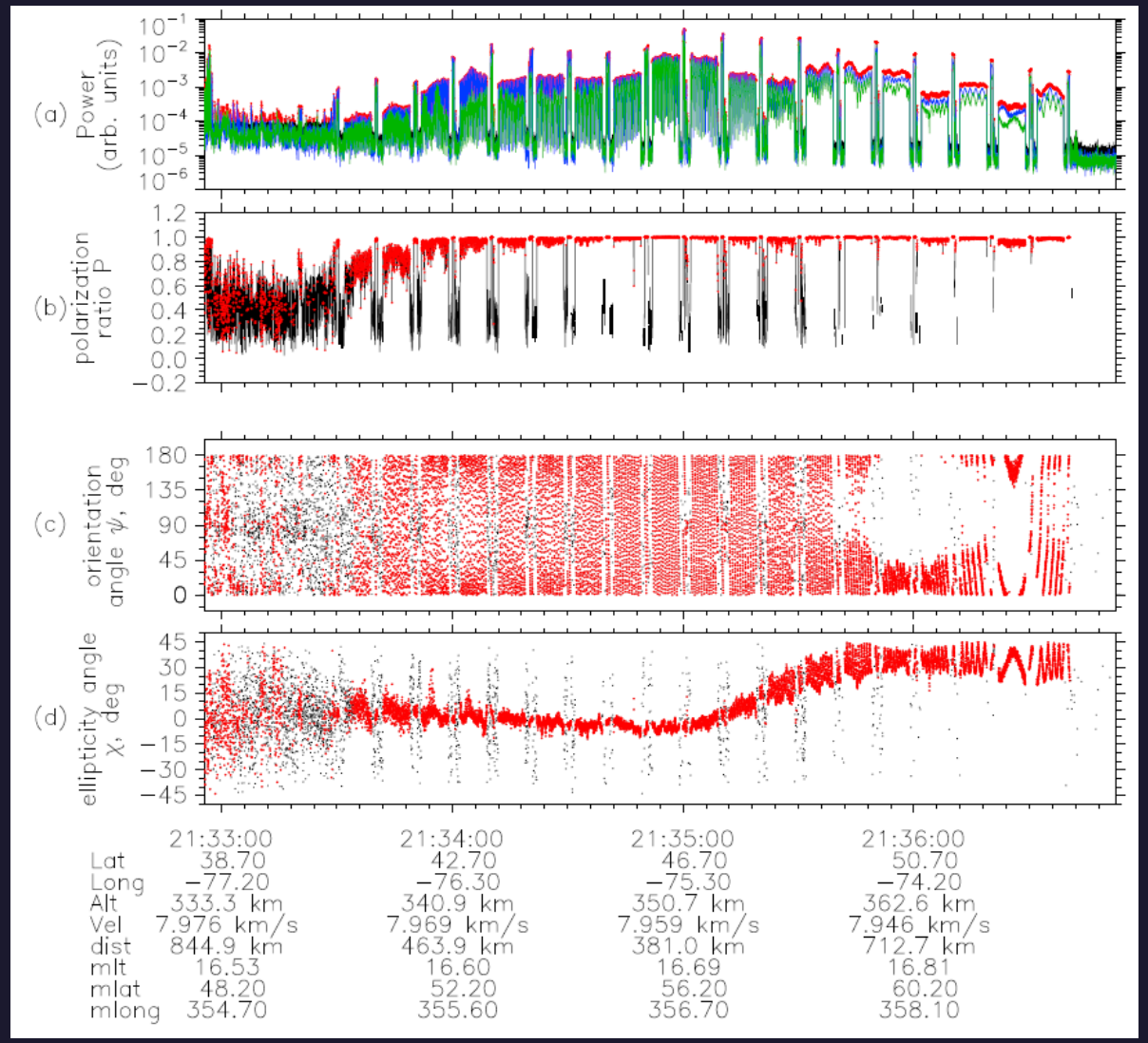

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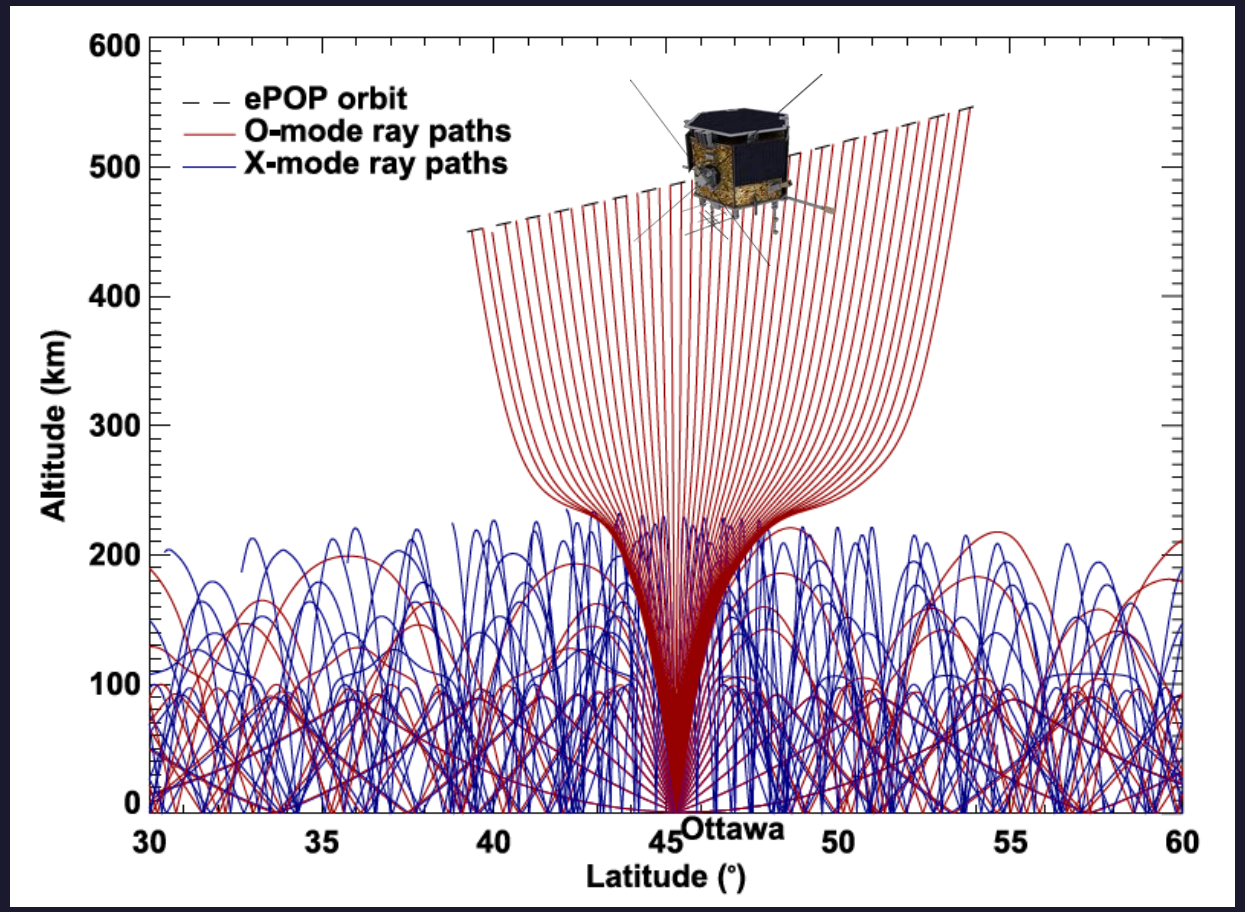
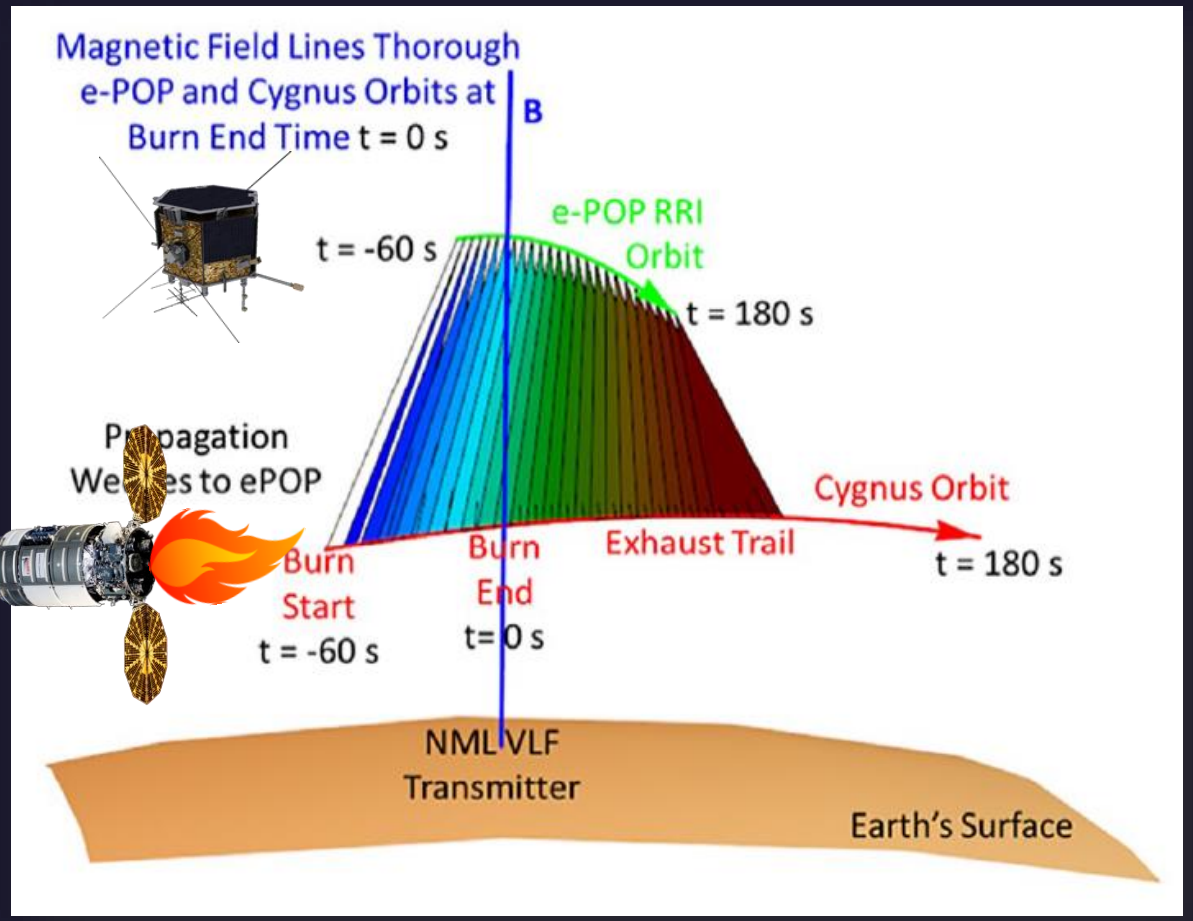


Pandey, K., Eyiguler, E. C. K., Gillies, R. G., Hussey, G. C., Danskin, D. W., & Yau, A. W. (2022). Polarization characteristics of a single mode radio wave traversing through the ionosphere: A unique observation from the RRI on ePOP/SWARM-E. Journal of Geophysical Research: Space Physics, 127, e2022JA030684. https://doi.org/10.1029/2022JA030684

Radio Science *VLF Wave Amplification*



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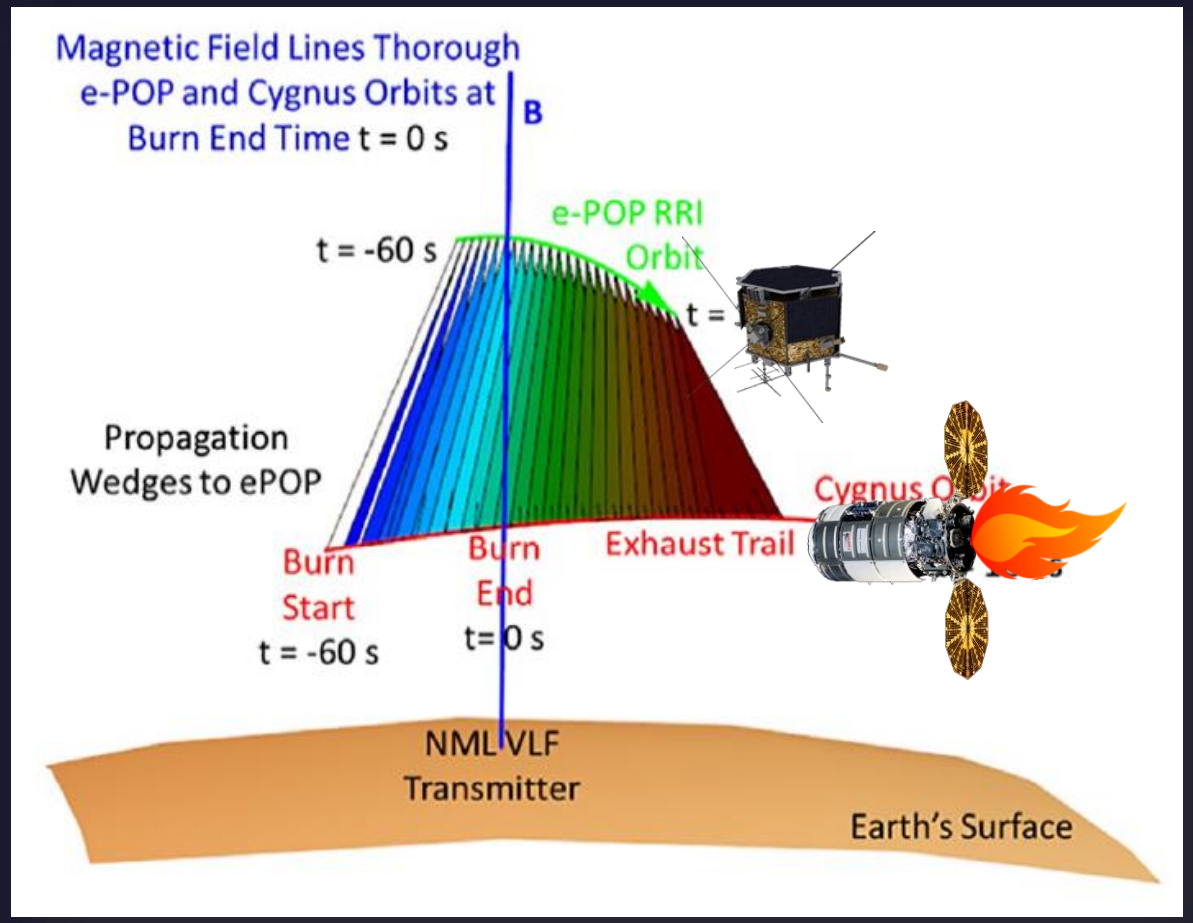

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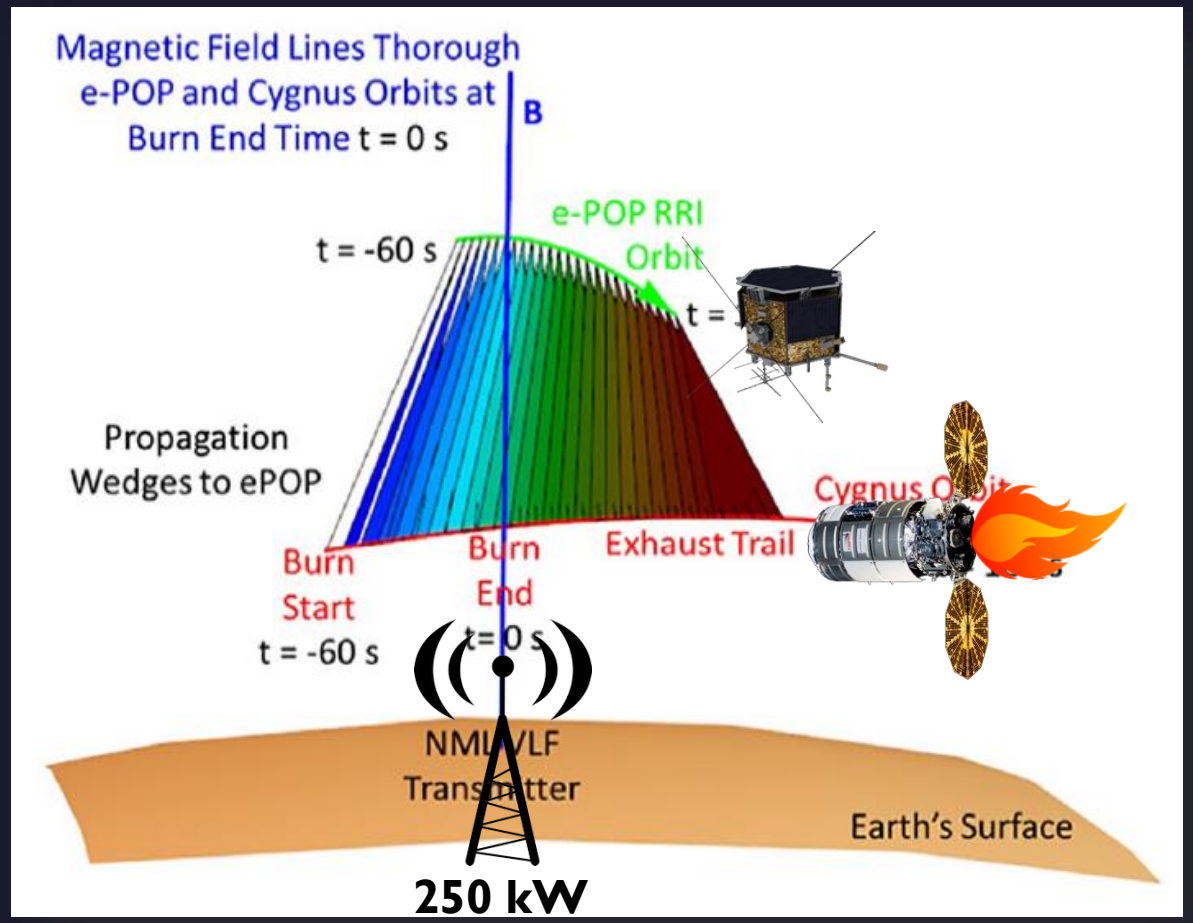

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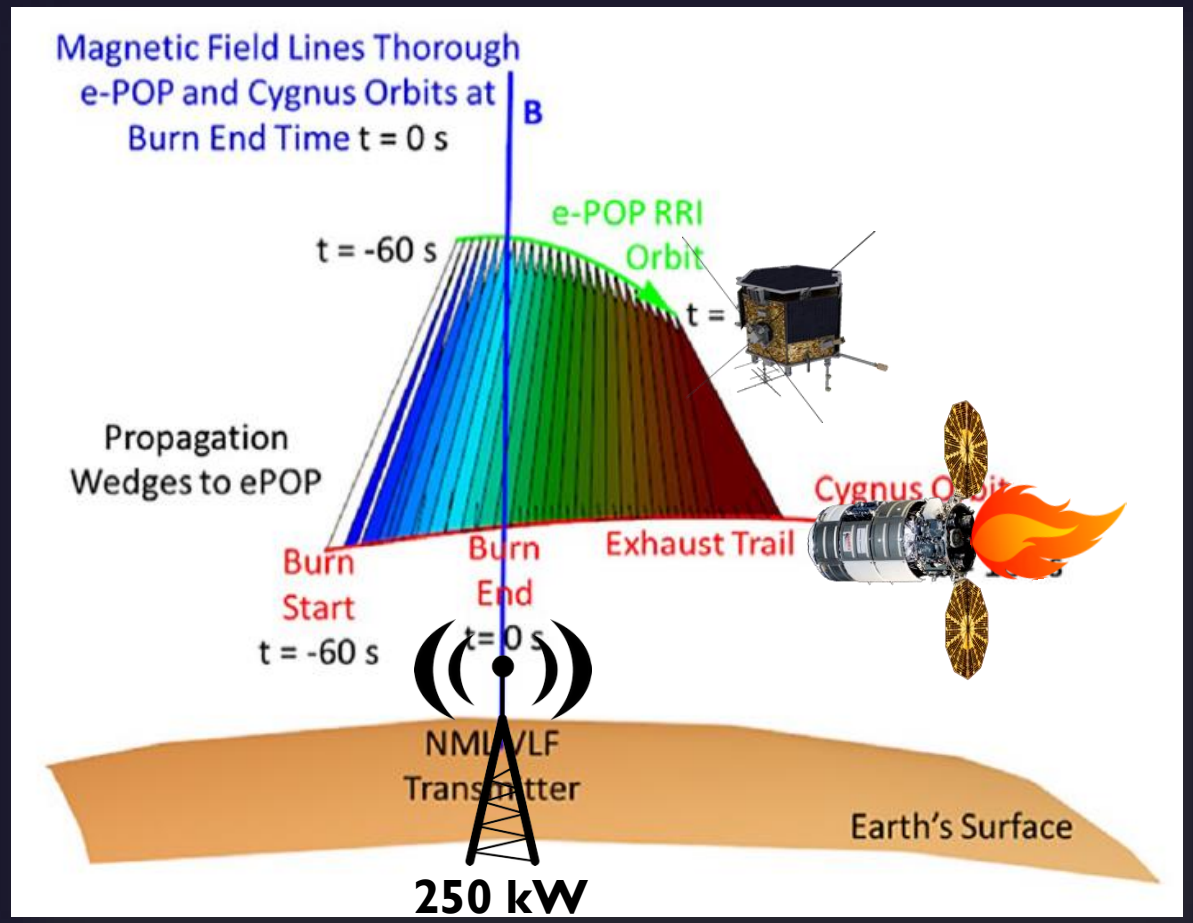

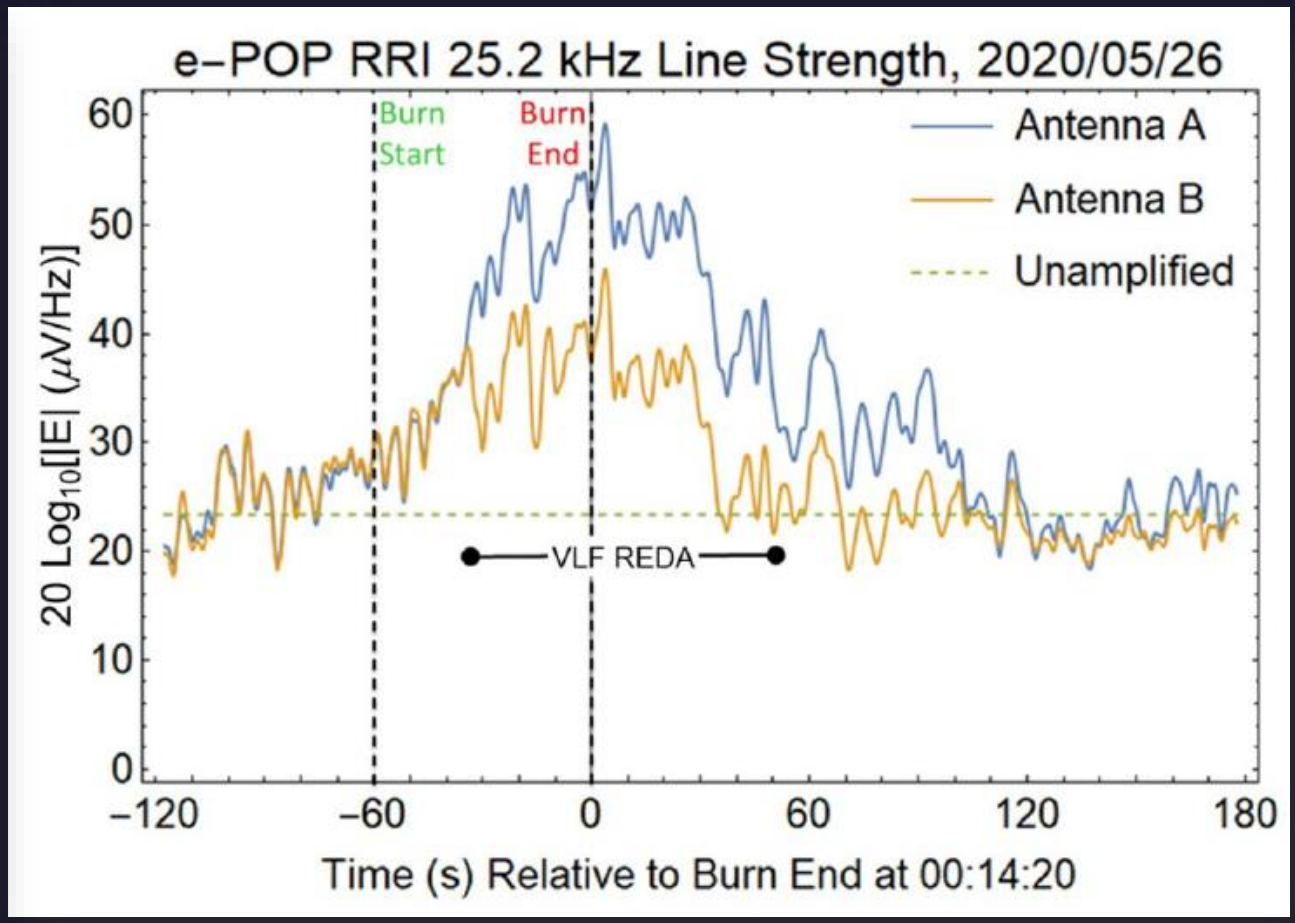

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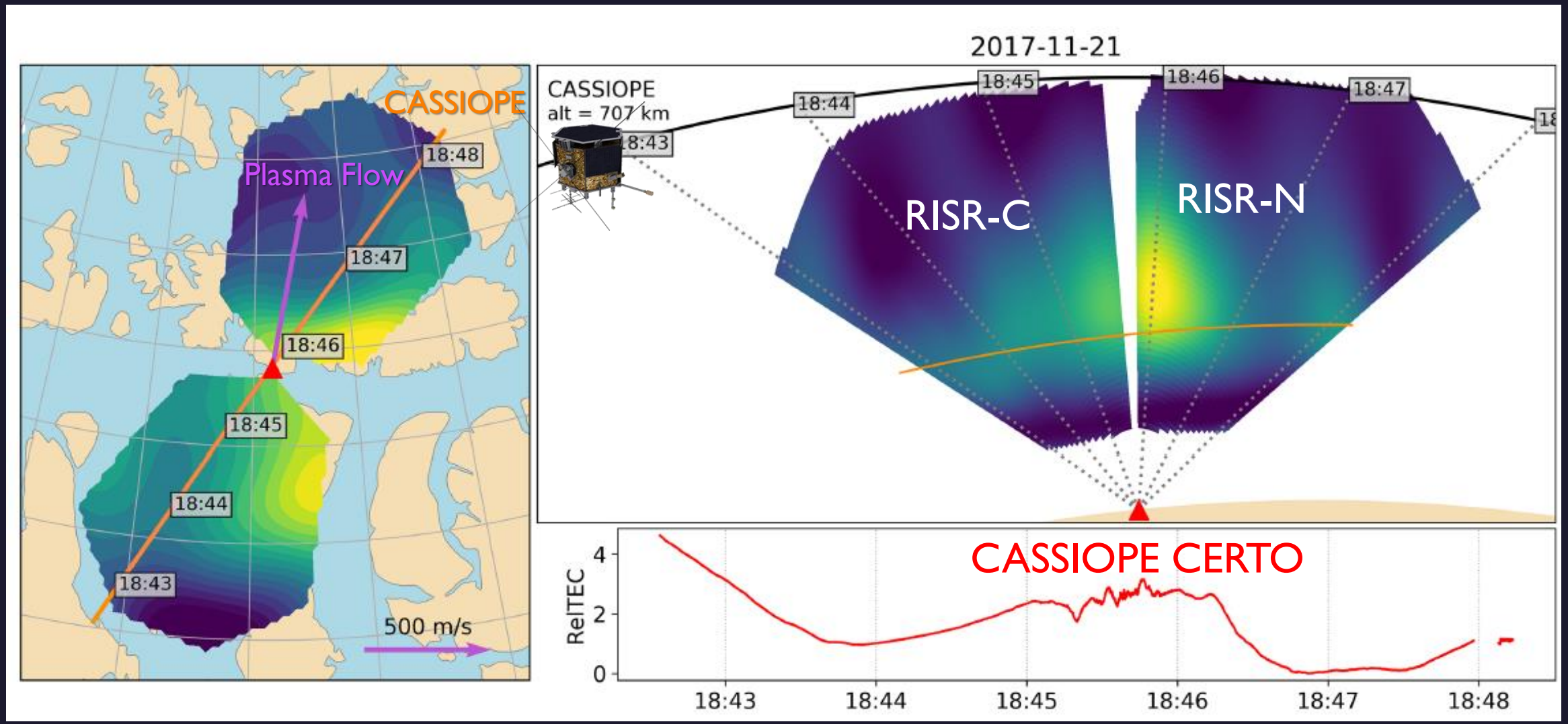
Plasma *Structure*



Lamarche L. J., Varney, R. H., & Siefring, C. L. (2020). Analysis of plasma irregularities on a range of scintillation-scales using the Resolute Bay Incoherent Scatter Radars. Journal of Geophysical Research: Space Physics, 125, e2019JA027112. https://doi.org/10.1029/2019JA027112

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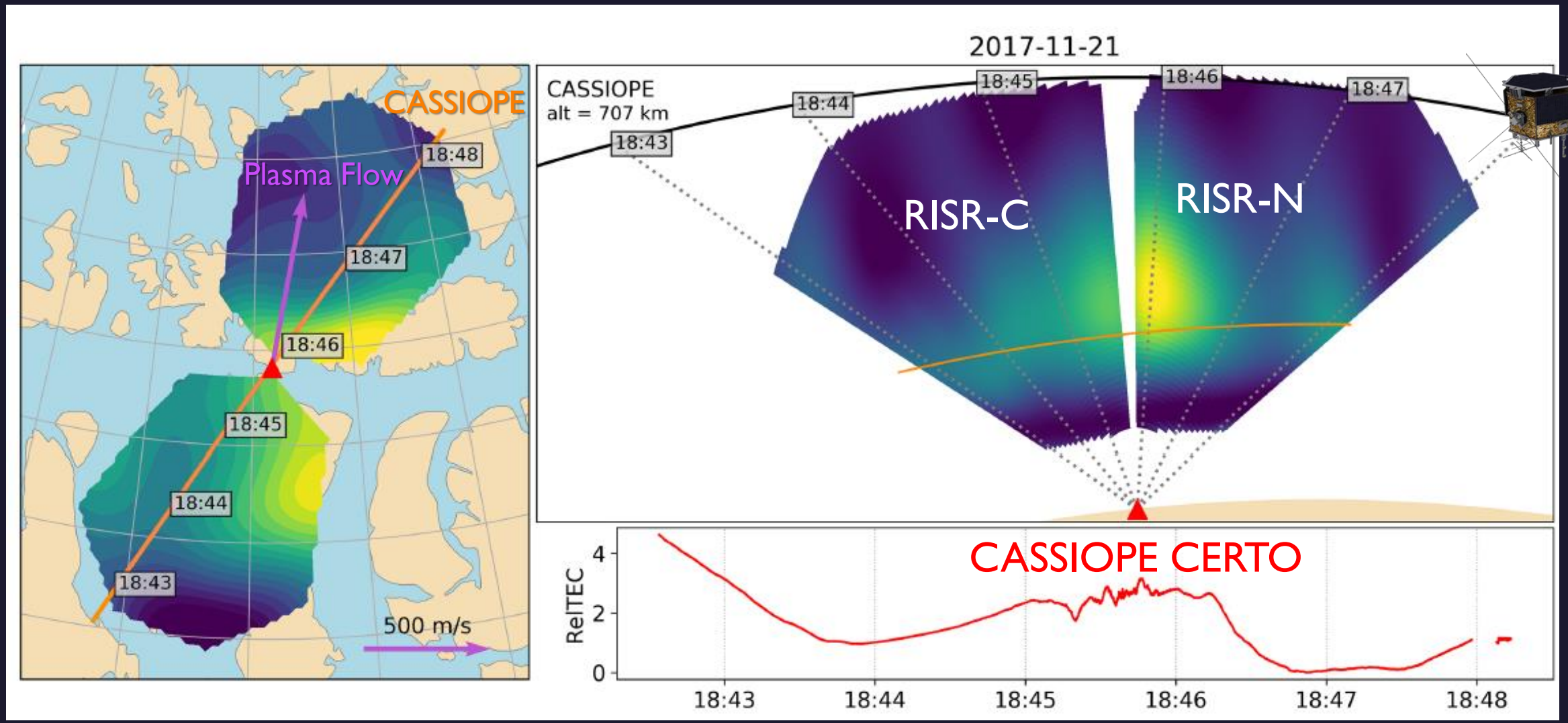

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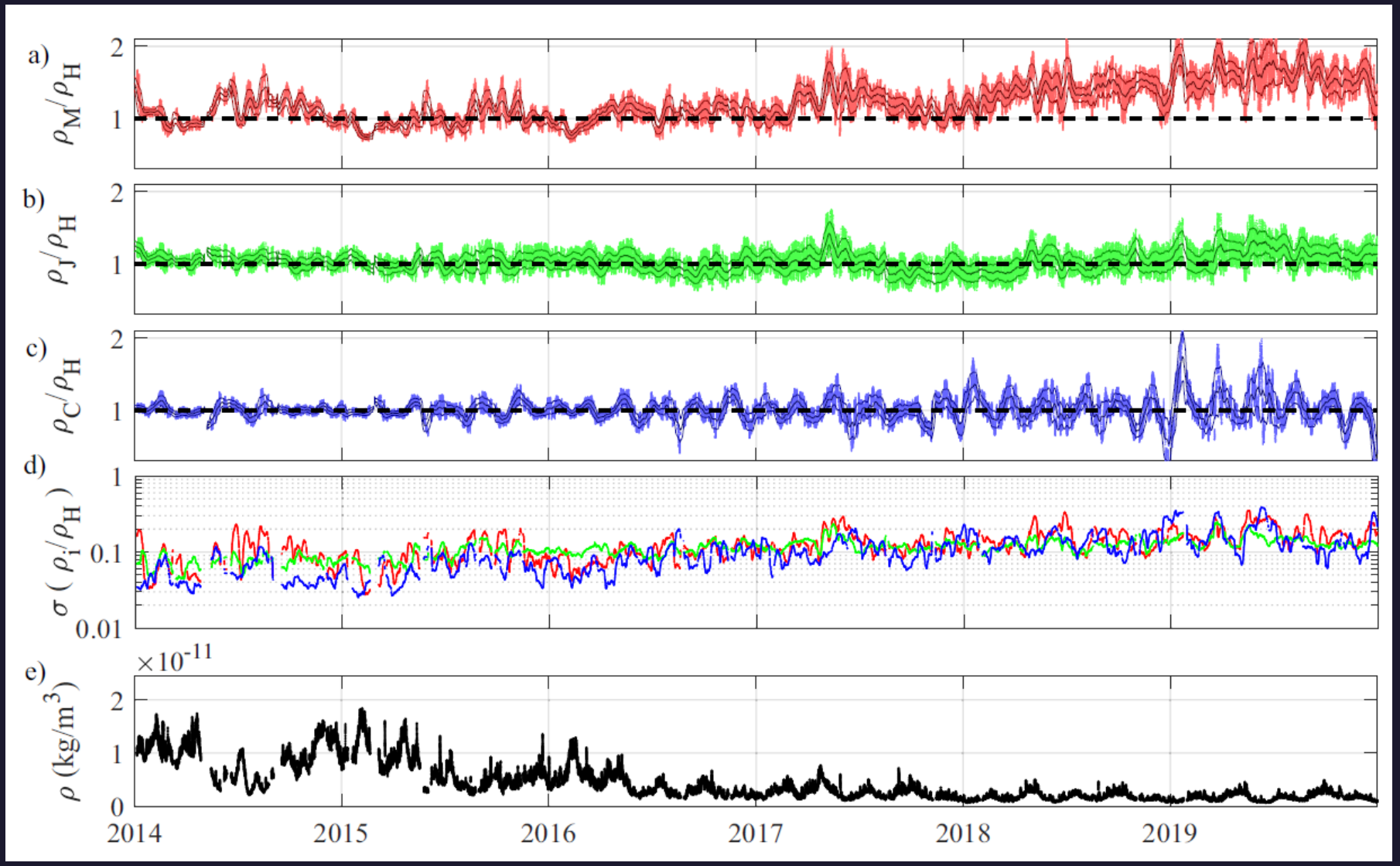
Thermosphere *Density from GNSS*



350 km Altitude

NRLMSISE-00/HASDM

JB2008/HASDM

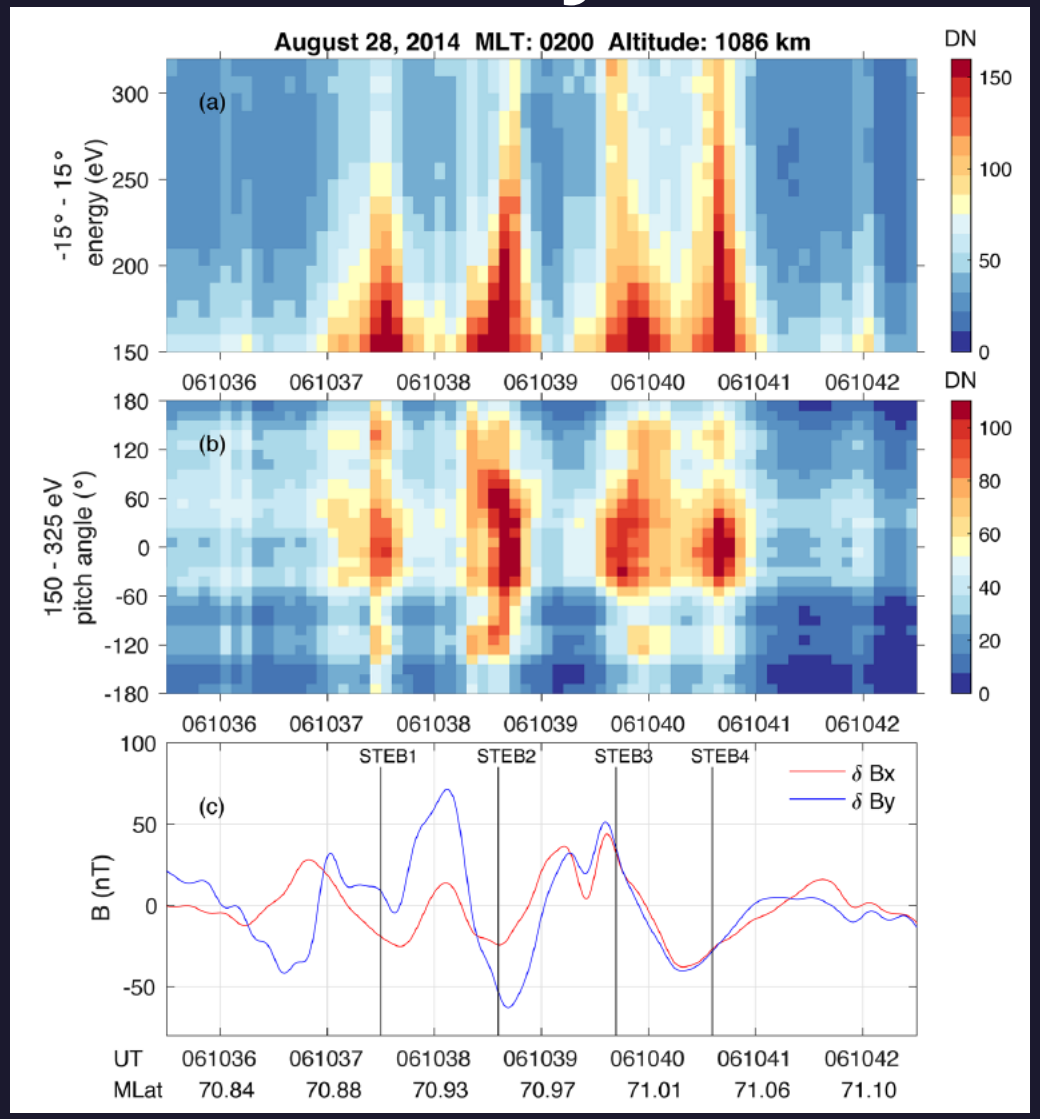
CASSIOPE/HASDM

Standard Deviations

Background Density

Calabia, A., & Jin, S. (2021). Thermospheric mass density disturbances due to magnetospheric forcing from 2014–2020 CASSIOPE precise orbits. Journal of Geophysical Research: Space Physics, 126, e2021JA029540. https://doi.org/10.1029/2021JA029540

Auroral Dynamics *Alfvèn Resonator*



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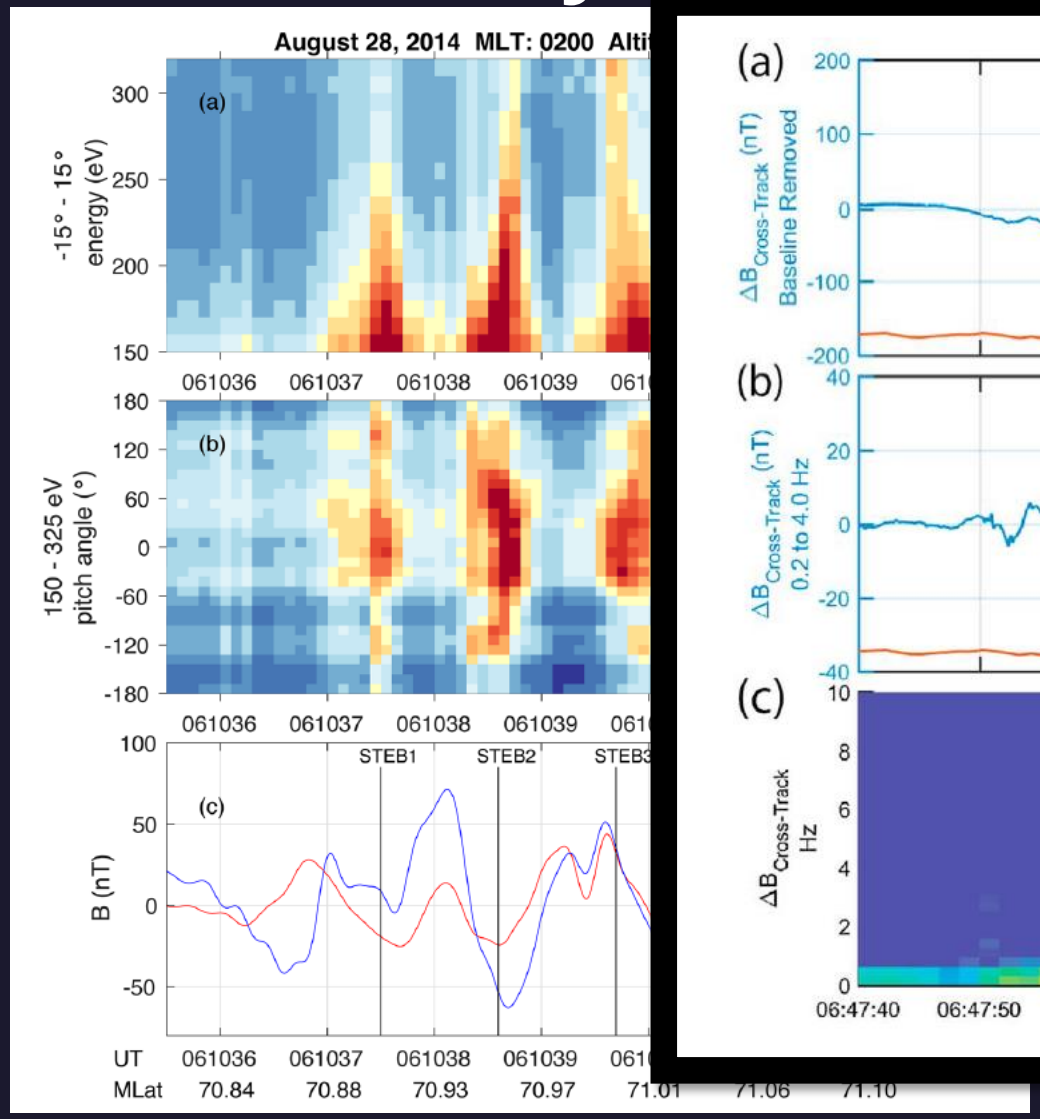

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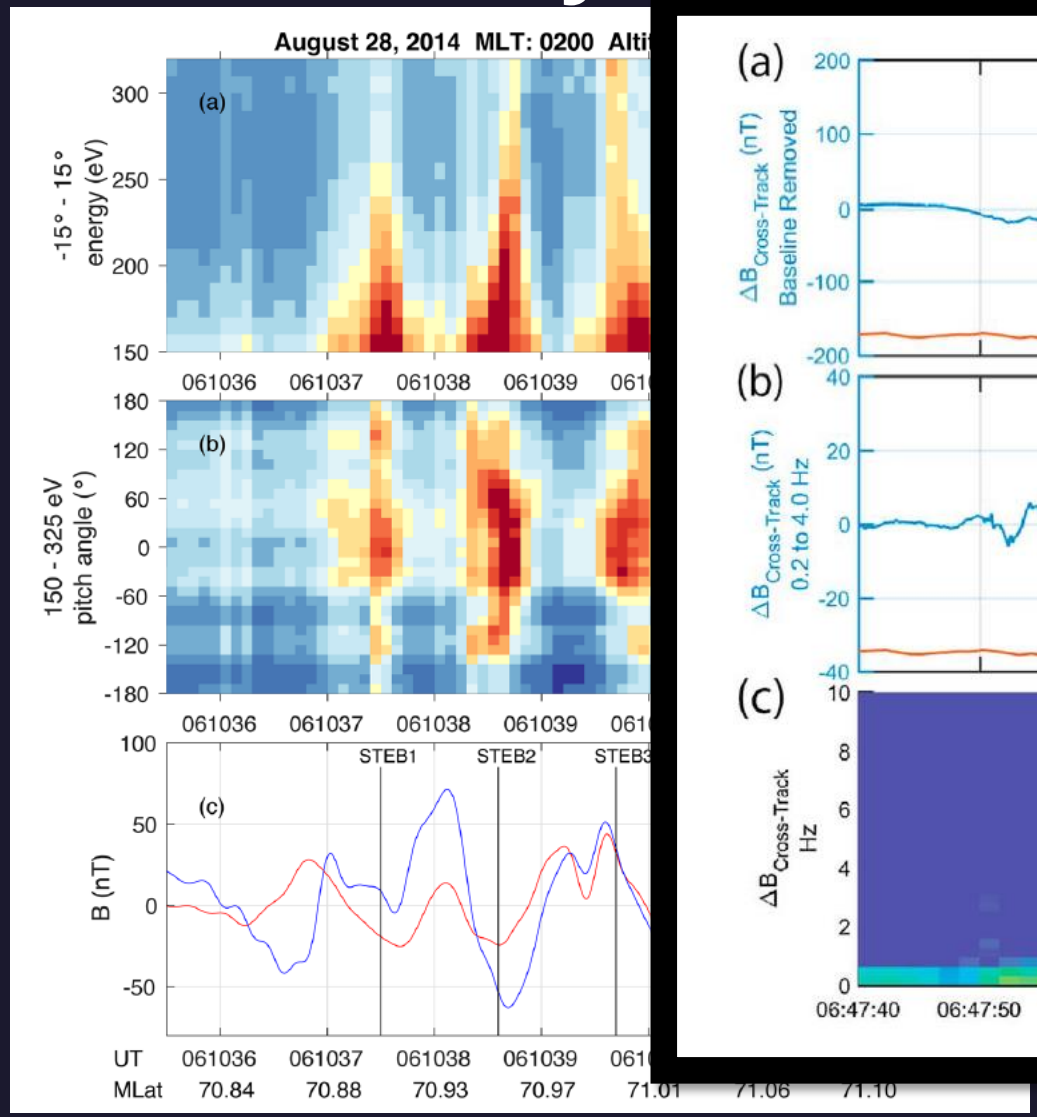

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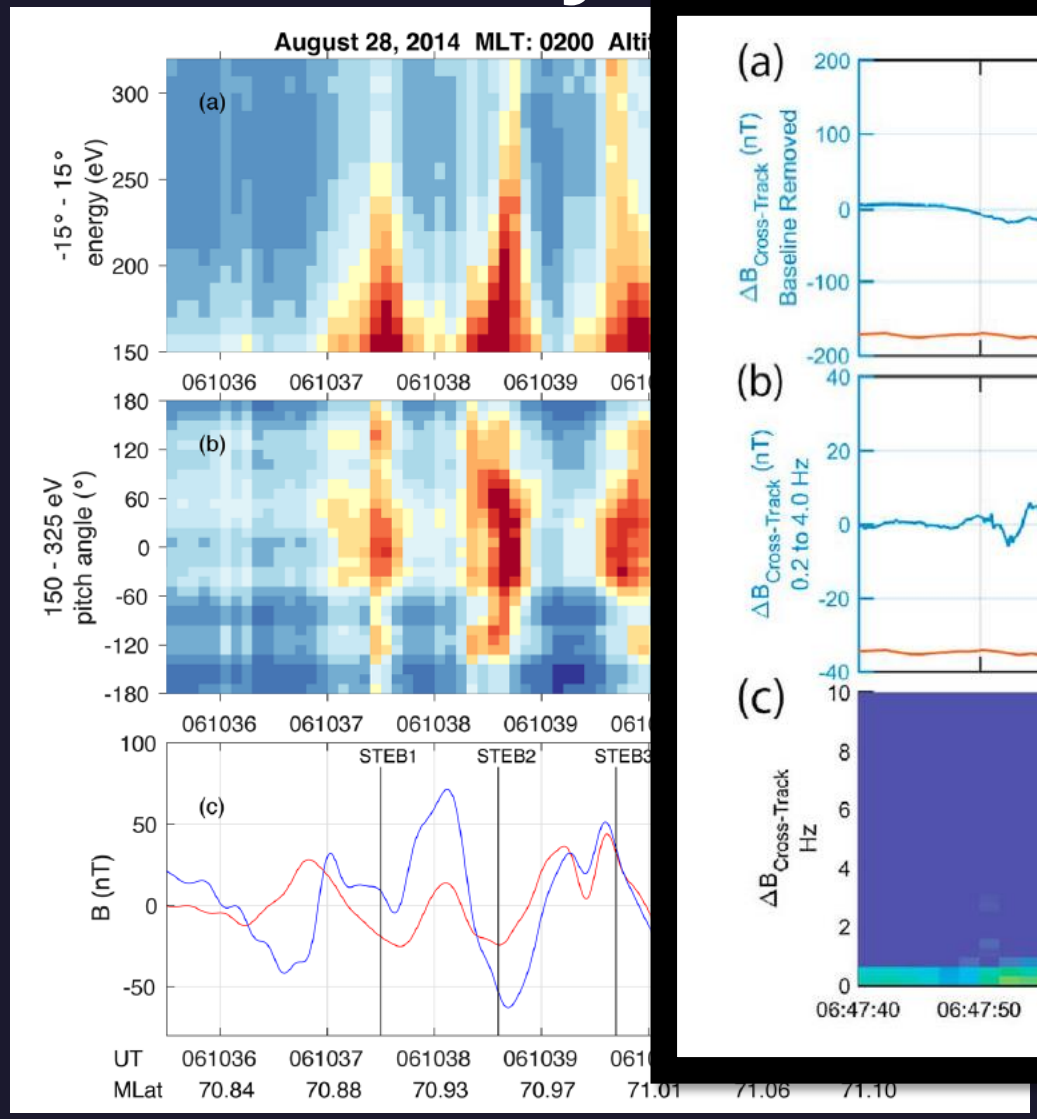

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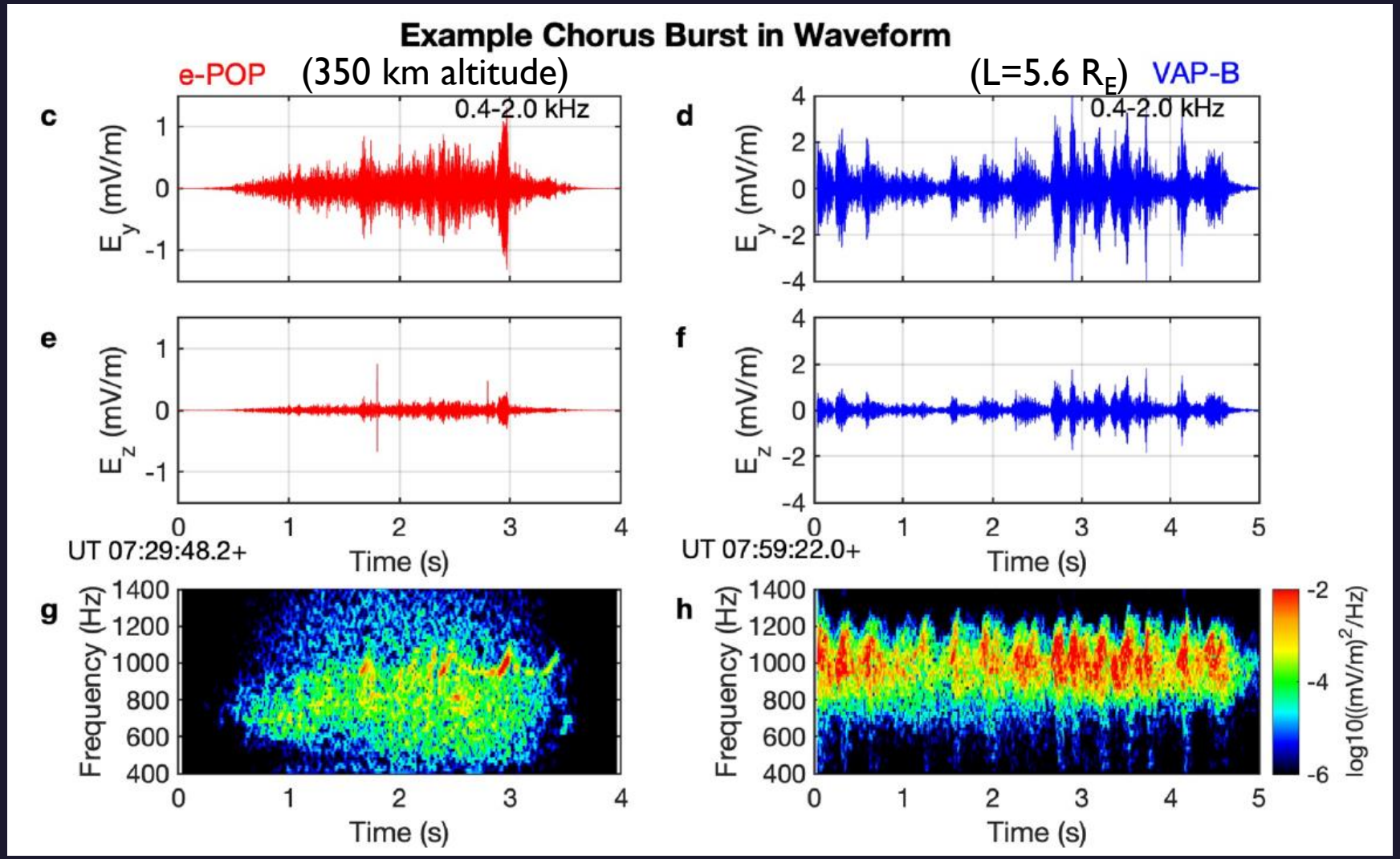
M-I-T Coupling *Ducted Chorus Waves*

- Chorus wave propagation from the magnetosphere to the ionosphere to the ground
- Waves guided by density crests
- Important for relativistic electron precipitation from the radiation belts



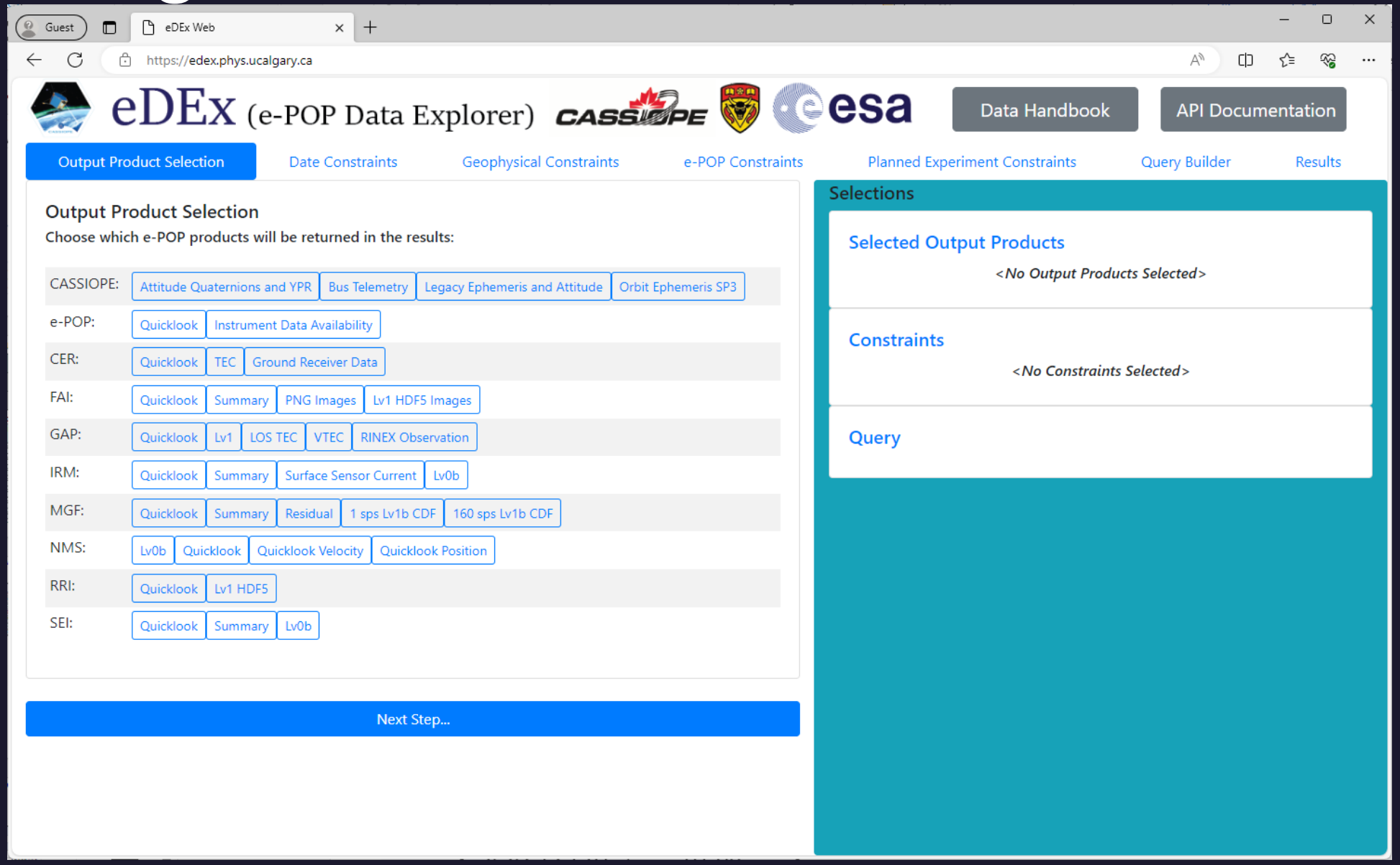
Shen, Y., Chen, L., Zhang, X.-J., Artemyev, A., Angelopoulos, V., Cully, C. M., et al. (2021). Conjugate observation of magnetospheric chorus propagating to the ionosphere by ducting. Geophysical Research Letters, 48, e2021GL095933. https://doi.org/10.1029/2021GL095933

Data Filtering

https://edex.phys.ucalgary.ca

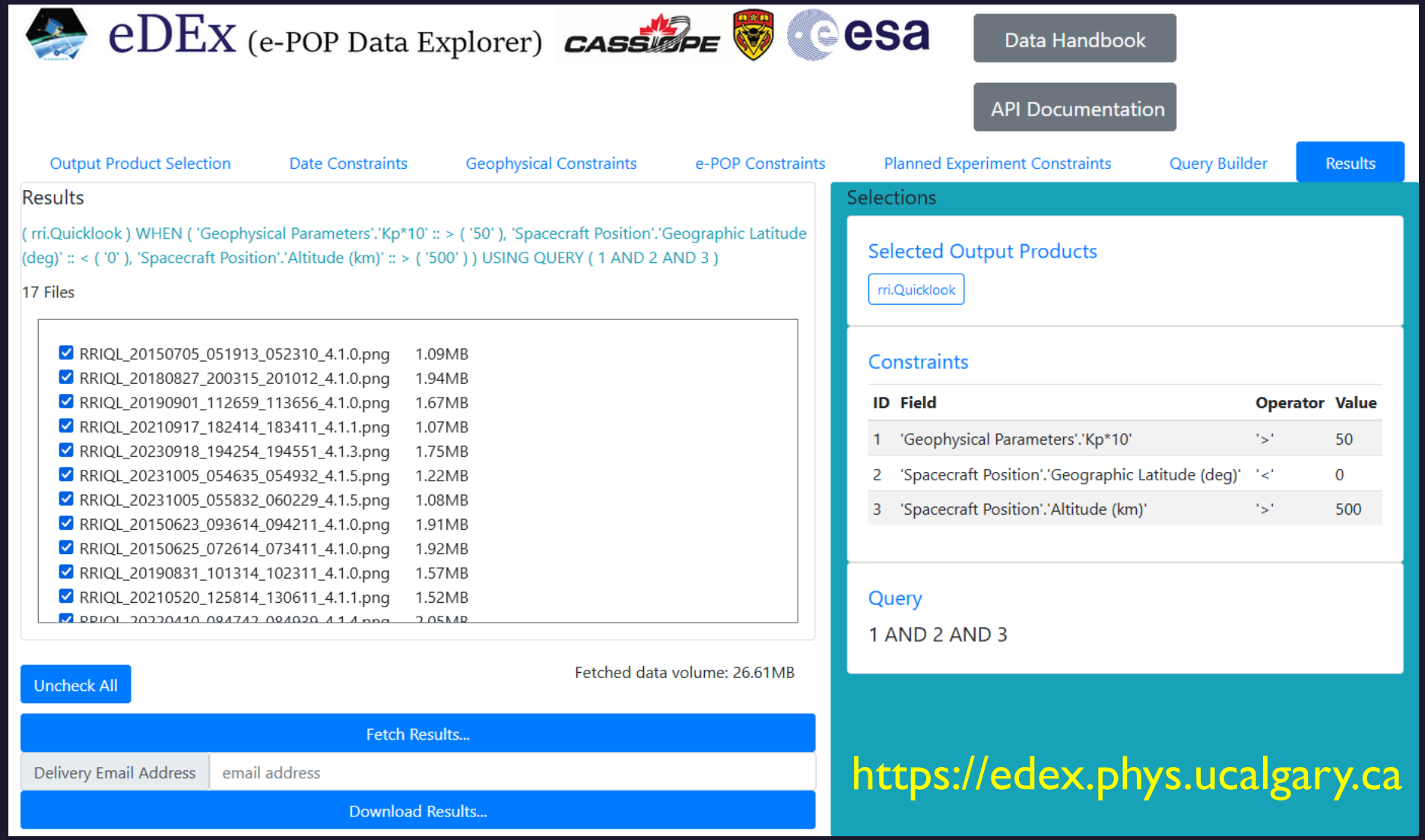
Filter e-POP data by:

- Date/Time
- Geophysical parameters
  - Kp
  - F10.7
  - Etc.
- Spacecraft constraints
  - Position
  - Attitude
  - Instruments on
  - Etc.
- Planned experiments
  - SuperDARN
  - Swarm Conjunctions
  - Etc.



Data Filtering

Example: RRI quicklook plots when Kp > 5, southern hemisphere, altitude > 500 km



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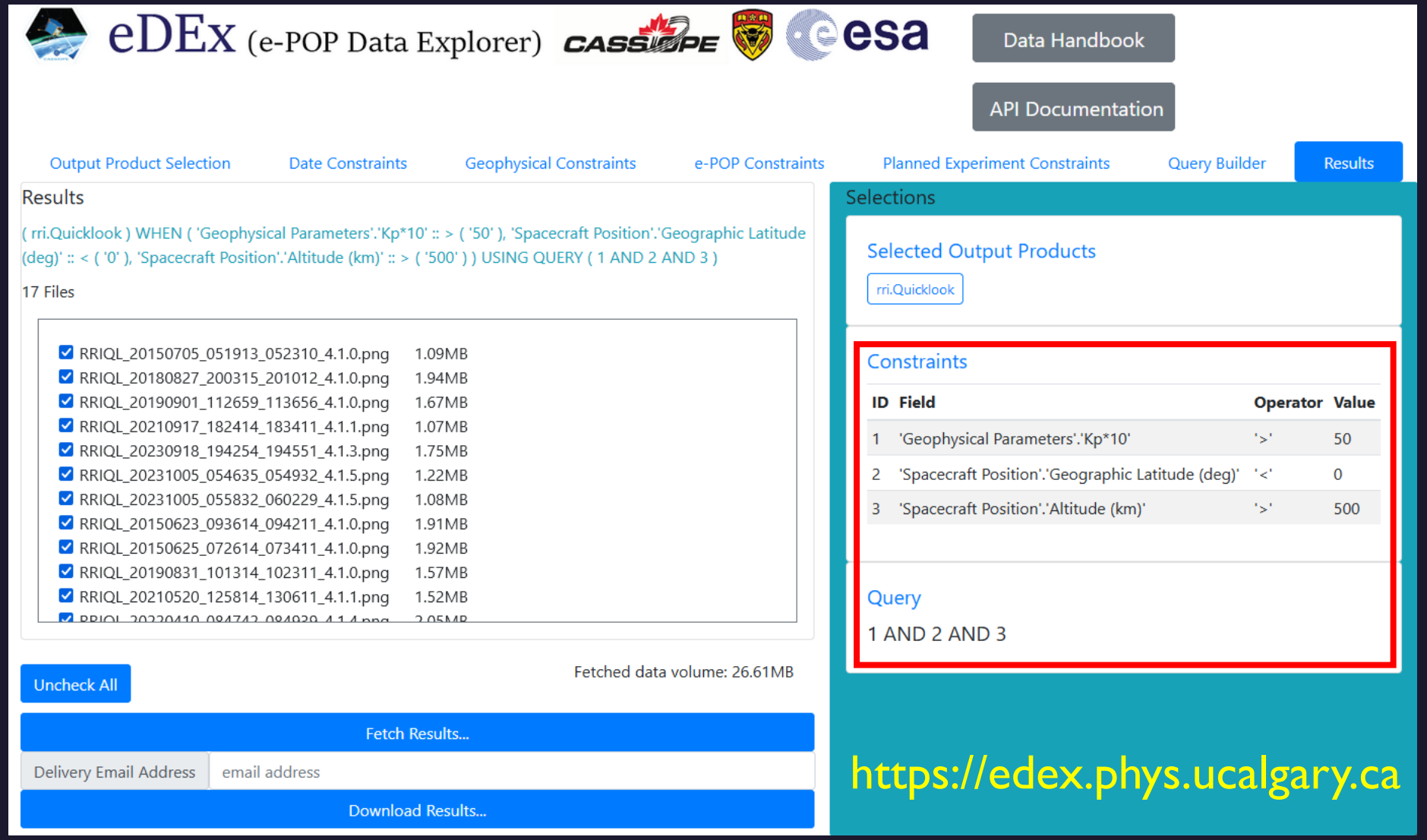


e-POP Data *Custom Quicklook*

UNIVERSITY OF CALGARY

e-POP Payload Quicklook

esa

CANADIAN SPACE AGENCY / AGENCE SPATIALE CANADIENNE

Output Plot Selection

Choose which plots to display in your quicklook:

Order of selection will display top to bottom*

EPHEMERIS:	Latitude, Longitude, Altitude, Magnetic Latitude, Magnetic Local Time, Edipse, Attitude
TELEMETRY:	ADCS Mode, Torque Rods, MGF Temperature, Wheel Temperature, Wheel Speed
IRM:	Hit Detection, Surface Sensor Current Average
FAI:	Camera - Near Infrared, Camera - Visible
MGF:	Outboard Sensor NEC, CHAOS DELTA, Outboard Sensor CRF, Inboard Sensor CRF, Sensor Deltas, CHAOS
RRI:	Sonogram A, Sonogram B

*eclipse always displayed at the bottom

Date Range (UTC)

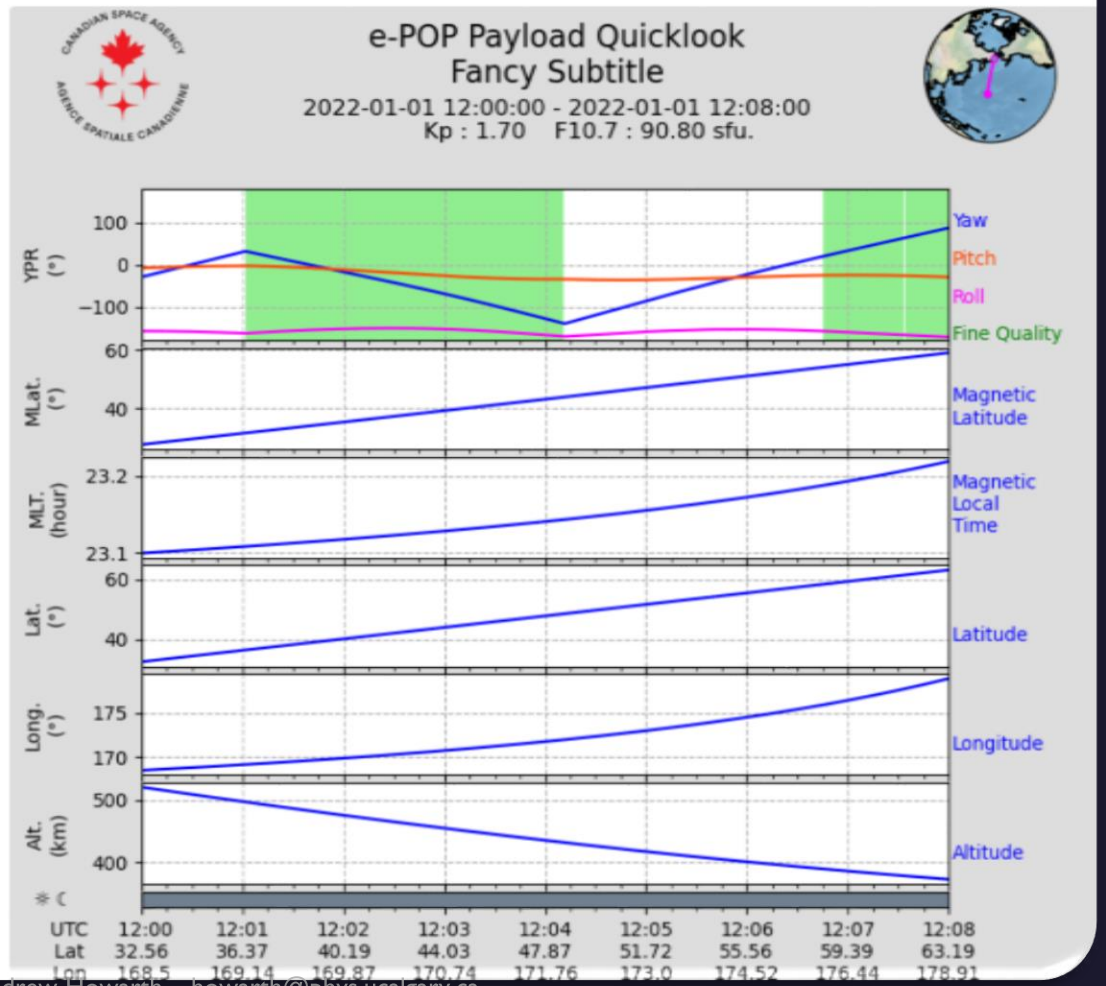
A time range of 10 minutes is typical.

Start Date: 2022-01-01 12:00:00

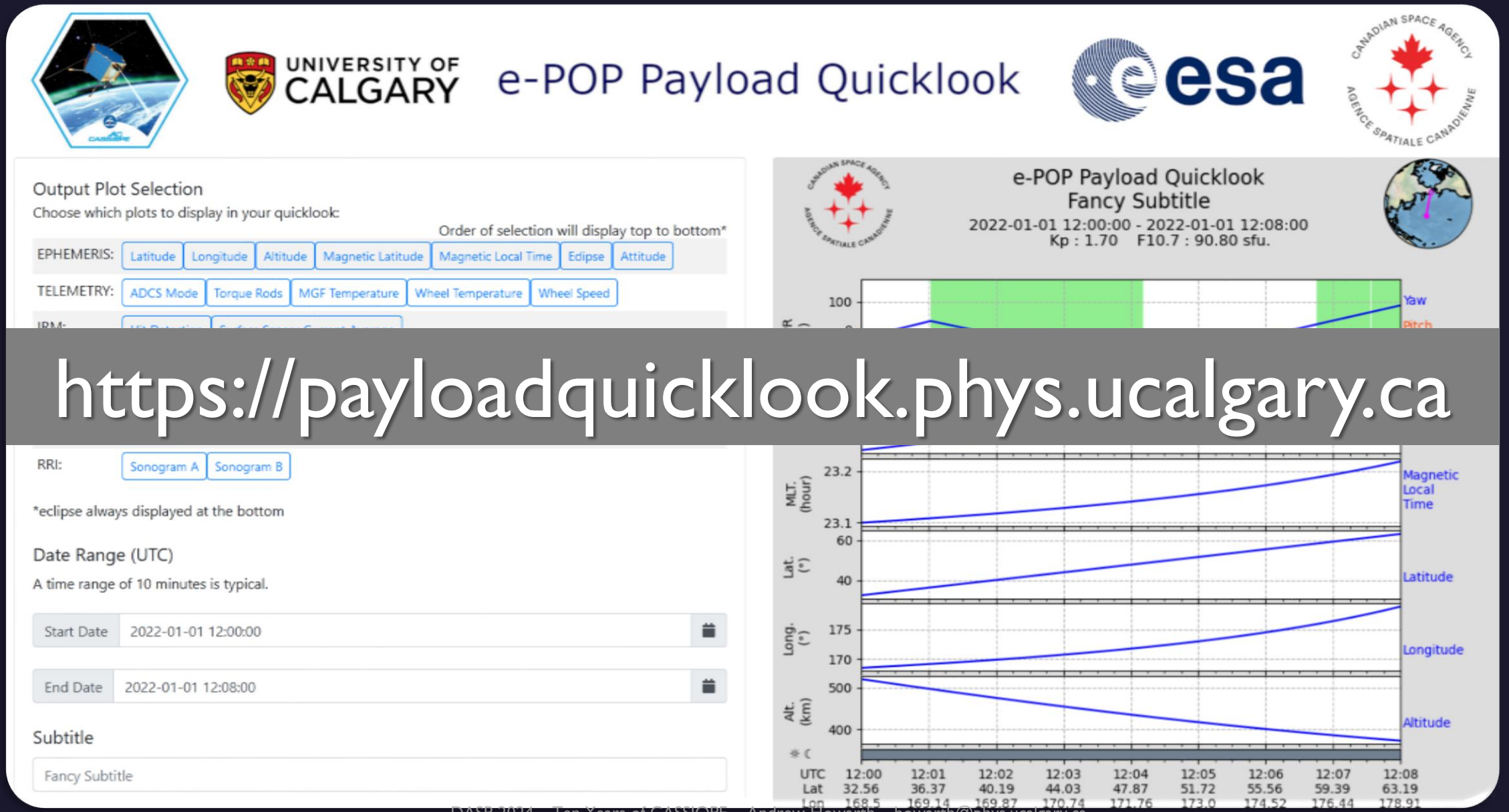
End Date: 2022-01-01 12:08:00

Subtitle

Fancy Subtitle



e-POP Data *Custom Quicklook*



https://payloadquicklook.phys.ucalgary.ca

e-POP Data *Resources*

Direct data download

https://epop-data.phys.ucalgary.ca

Filtering with multiple data sets

https://edex.phys.ucalgary.ca

More about CASSIOPE/e-POP/Swarm-E

https://epop.phys.ucalgary.ca

Canadian Space Agency | Agence spatiale canadienne

Canada | MDA | esa

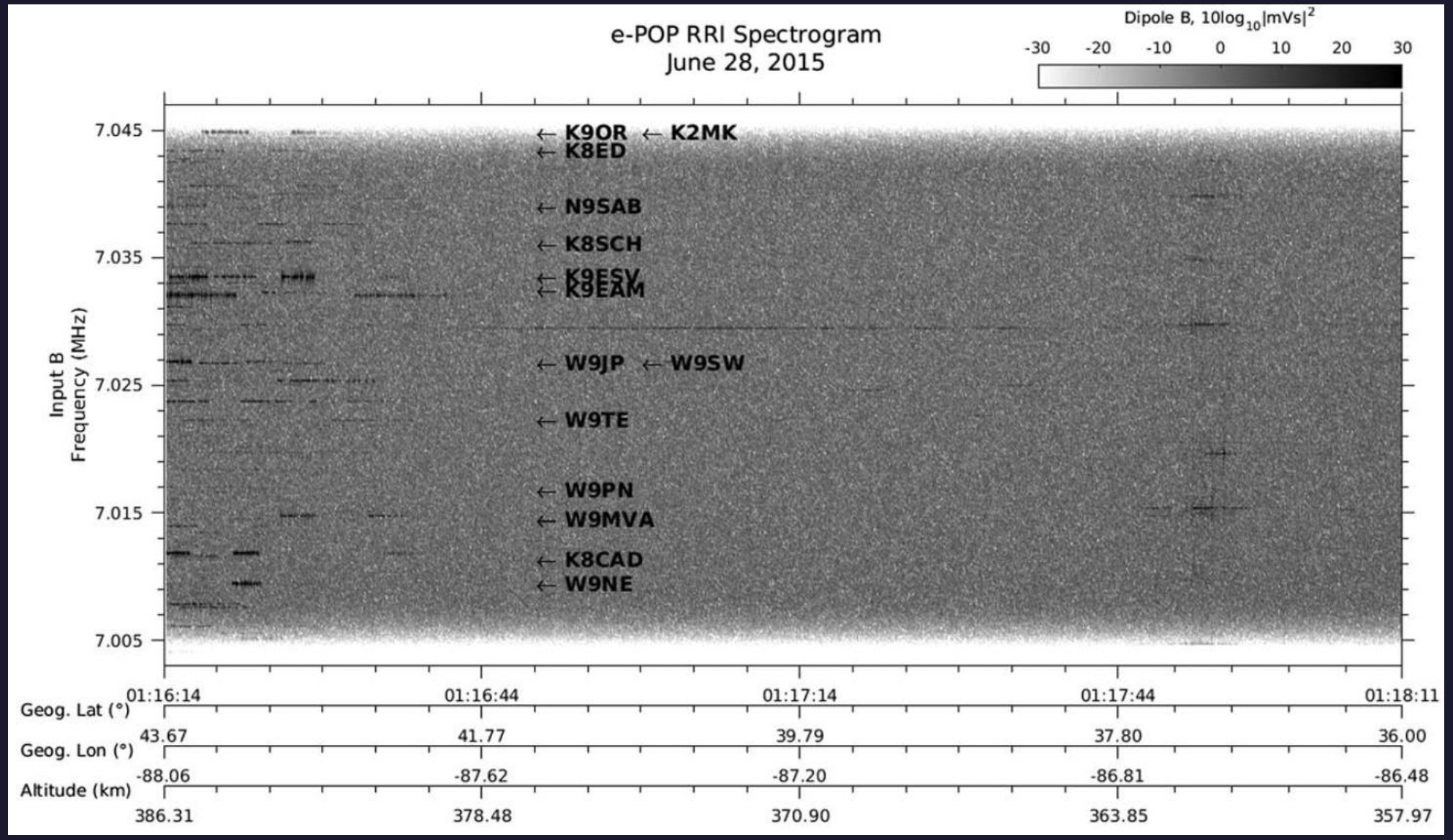
Thank You!

Andrew Howarth

howarth@phys.ucalgary.ca

http://epop.phys.ucalgary.ca

Radio Science *Citizen Science*



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