Fireside Chat: Polar Radio Science

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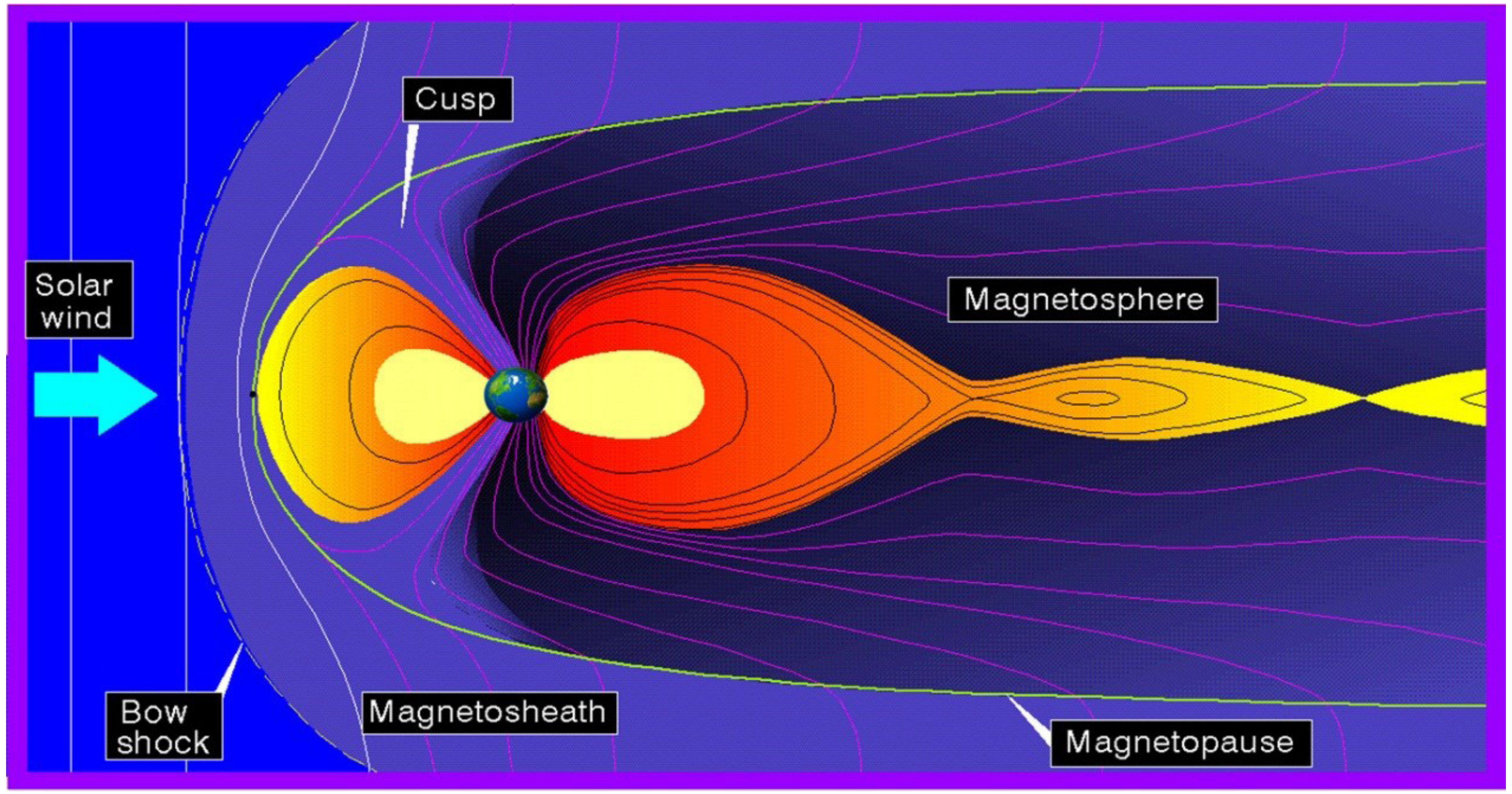
Earth’s Magnetosphere



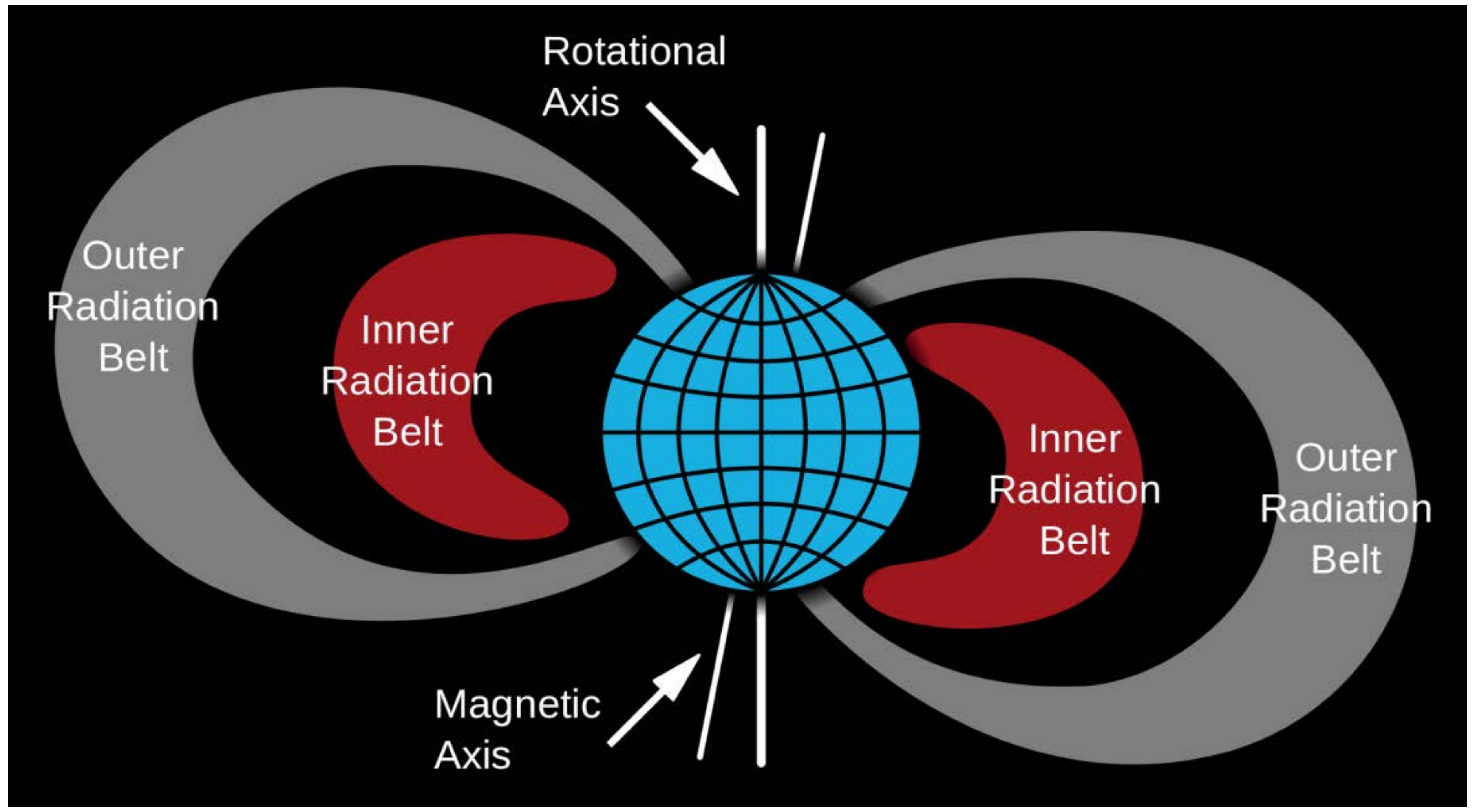
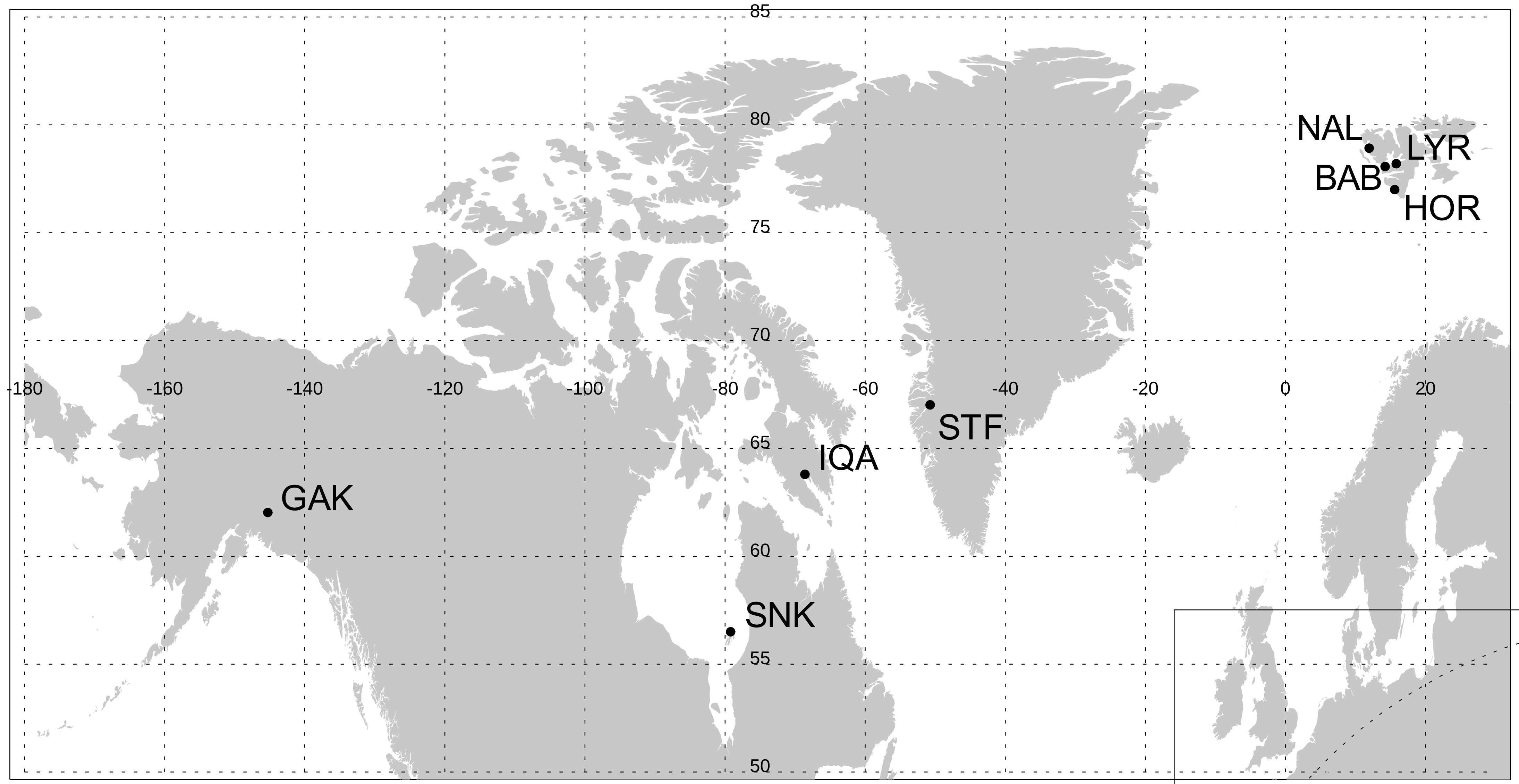


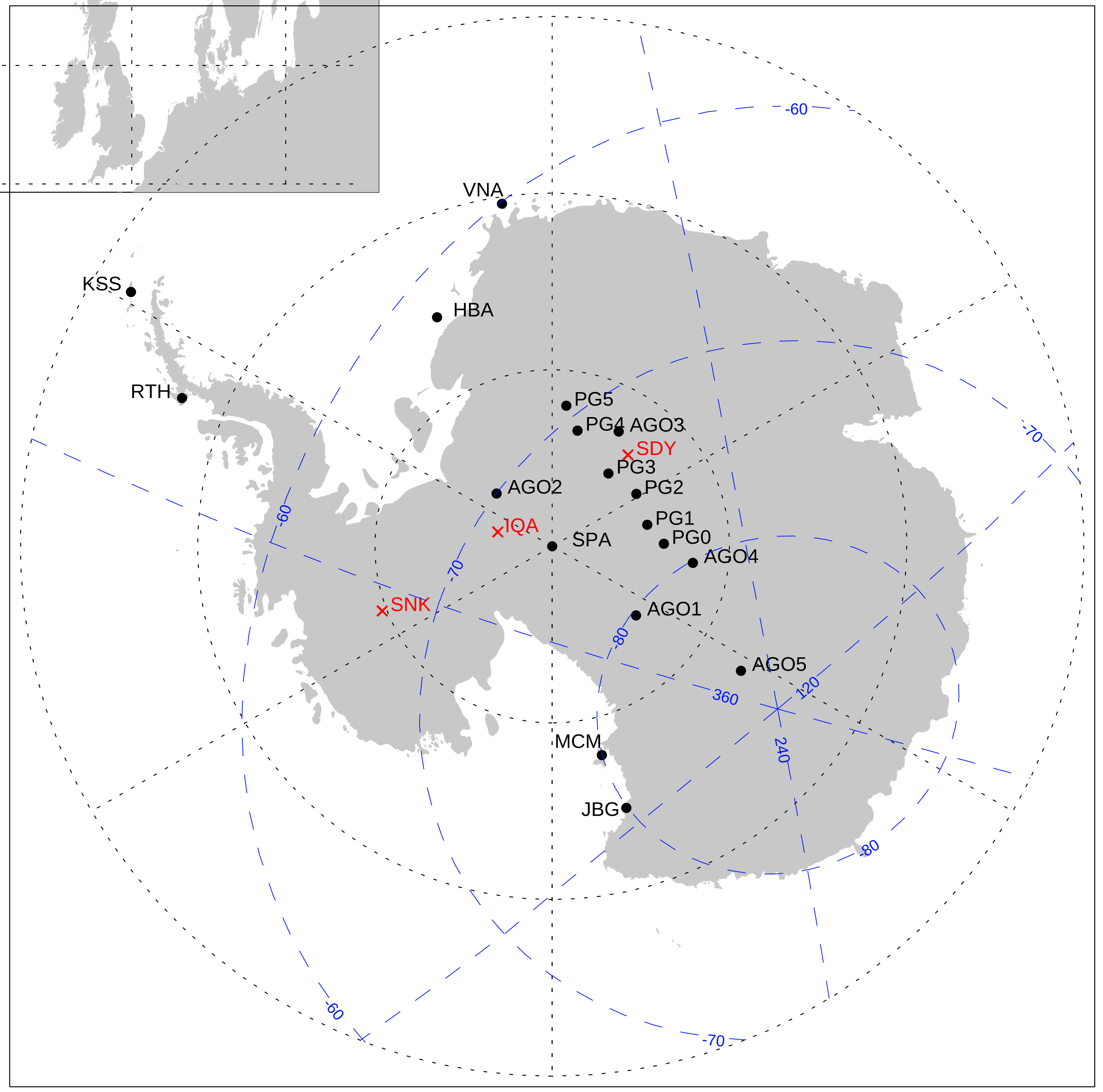
Fig 3. Schematic view of the inner and outer radiation belts

- “Open” vs “closed” magnetic field lines
- Earth’s radiation belts (closed)
- Auroral zone (mixed but near the boundary)
- Polar cap (open)

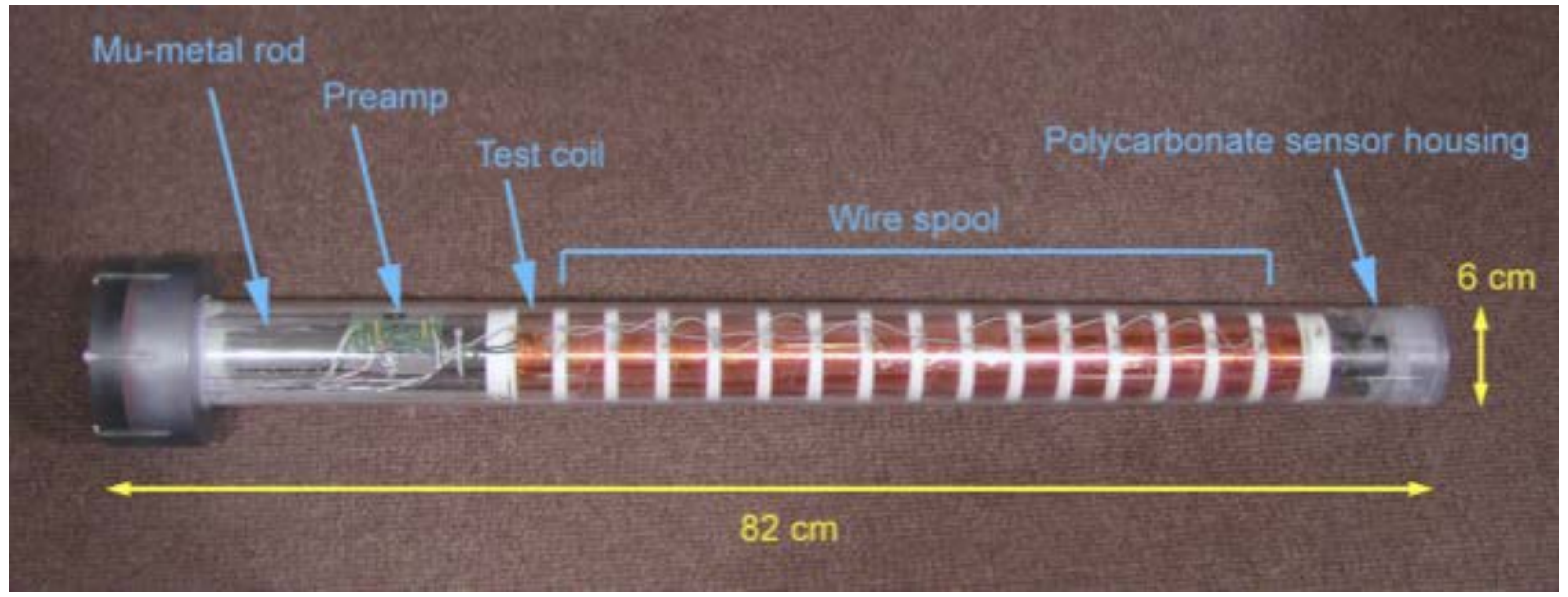
Credit: International Space Science Institute in Beijing

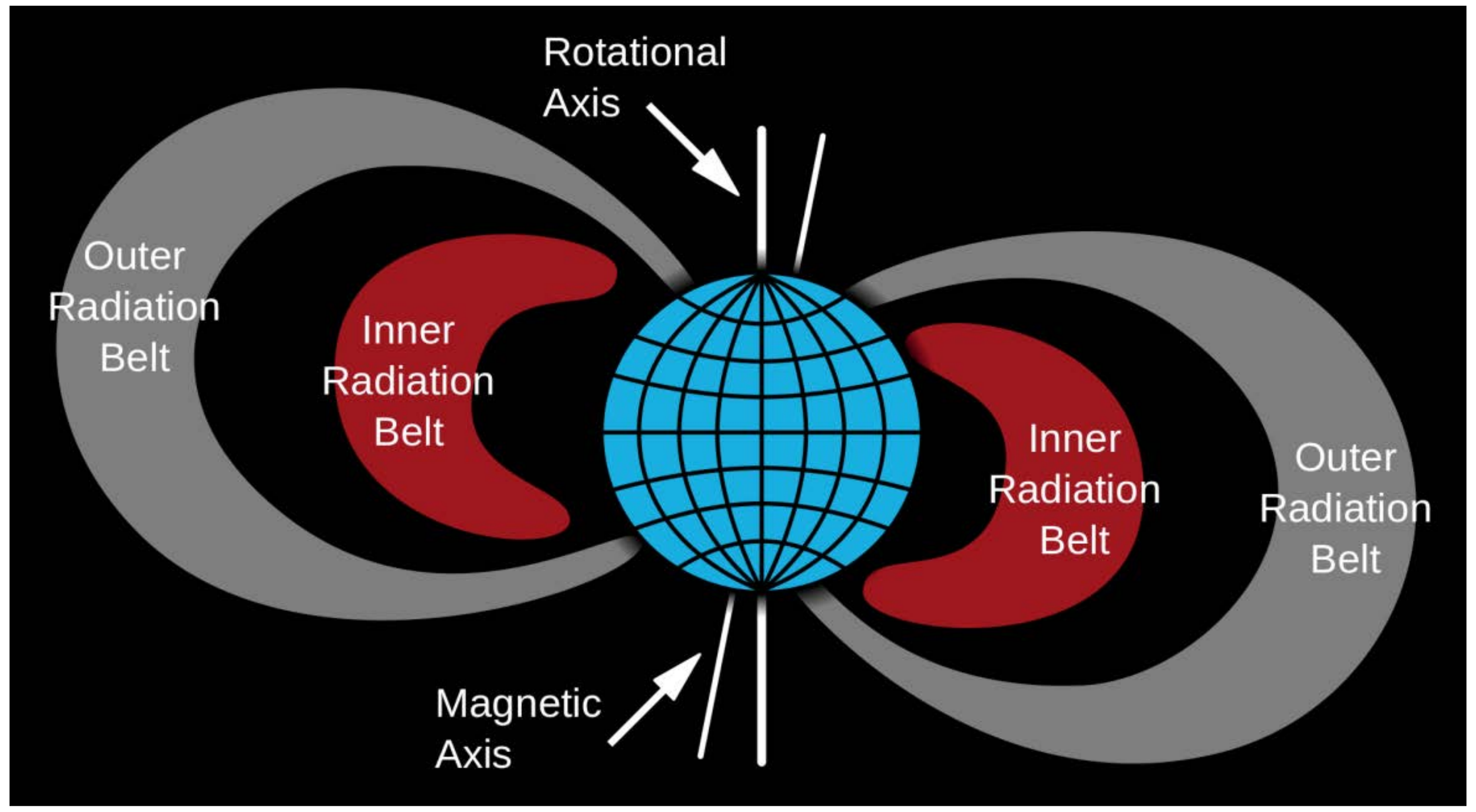
Observing waves from space at high-latitudes: Magnetic Induction Coil Array (MICA)





Locations of MICA-N/S





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Electromagnetic Ion Cyclotron (EMIC) waves
Observed in space and on the ground

2012-09-10 — Ground activity lasts 10+ hrs.

Source region appears radially narrow and azimuthally large

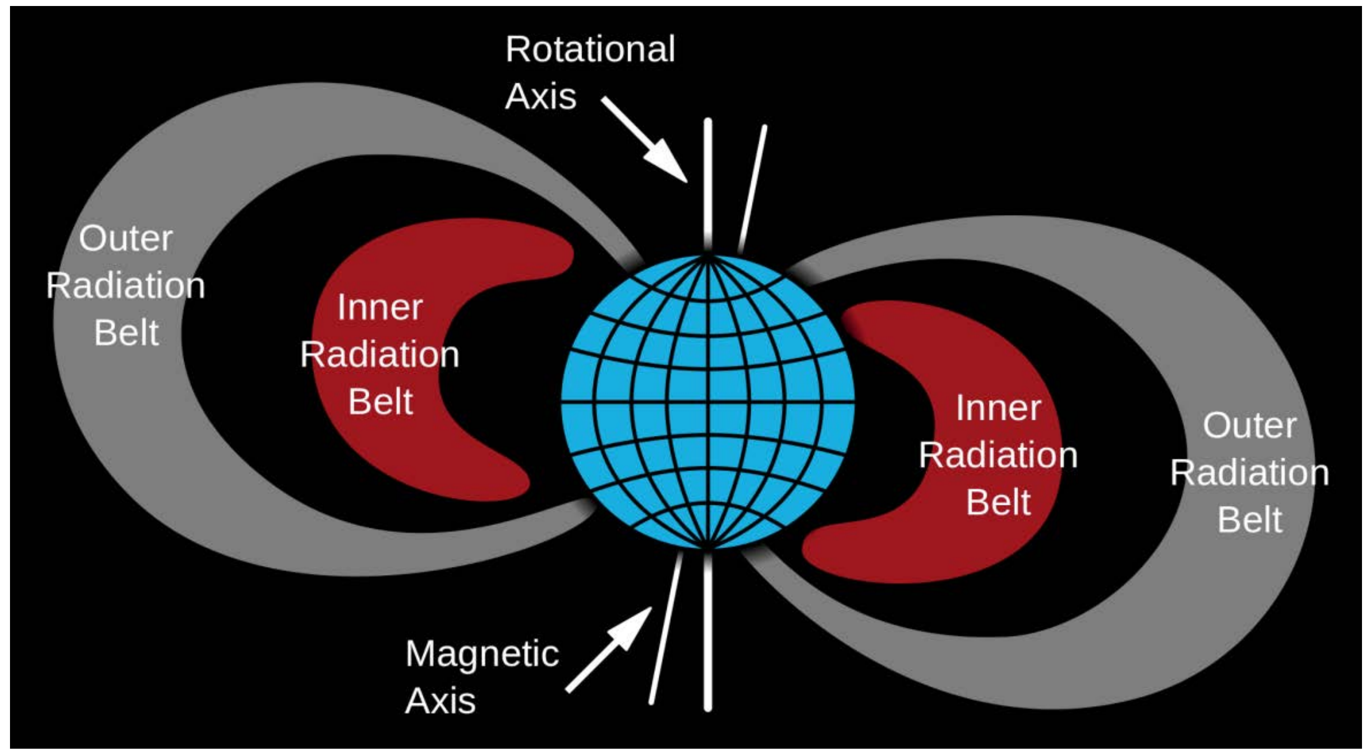
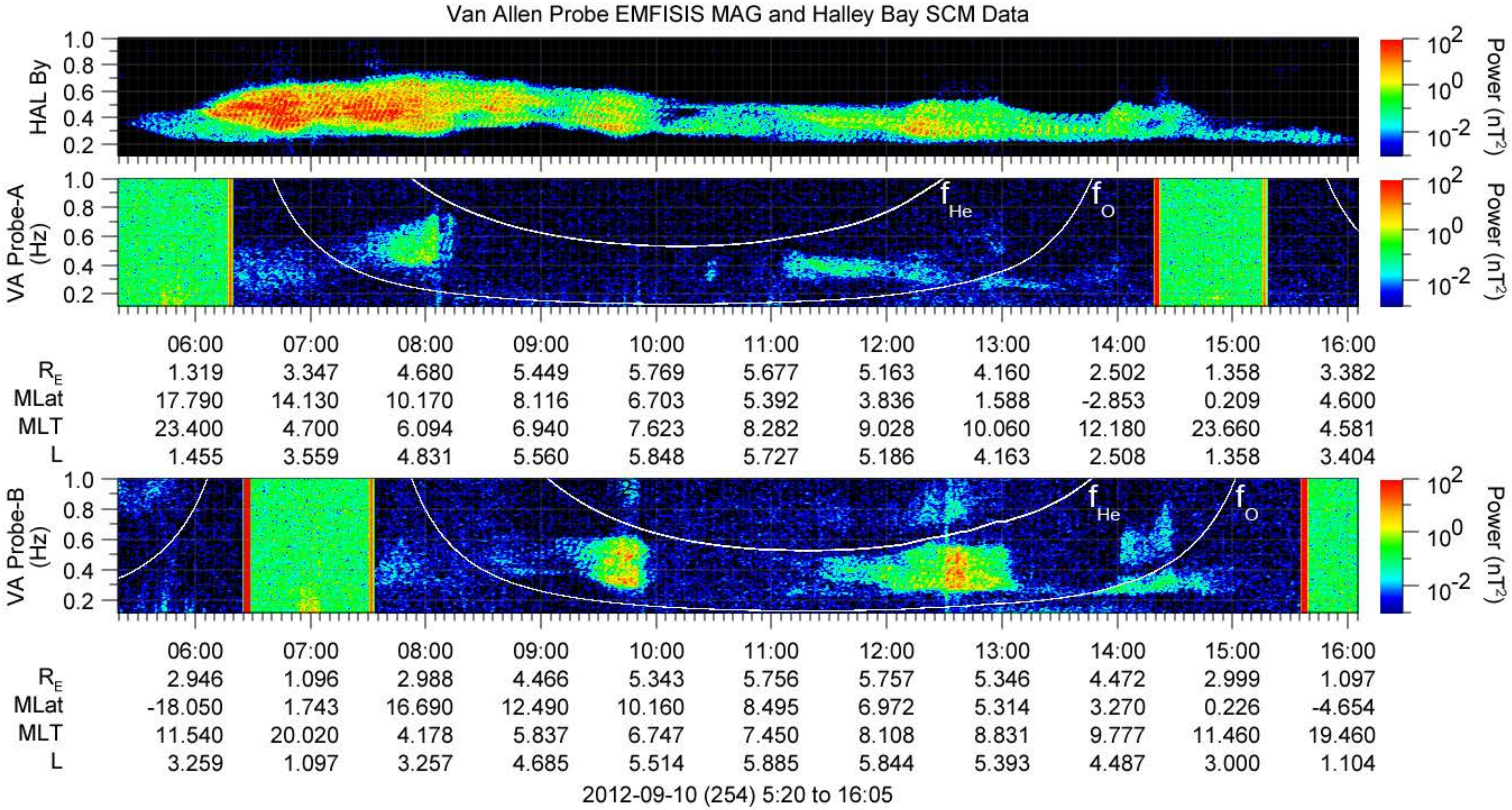
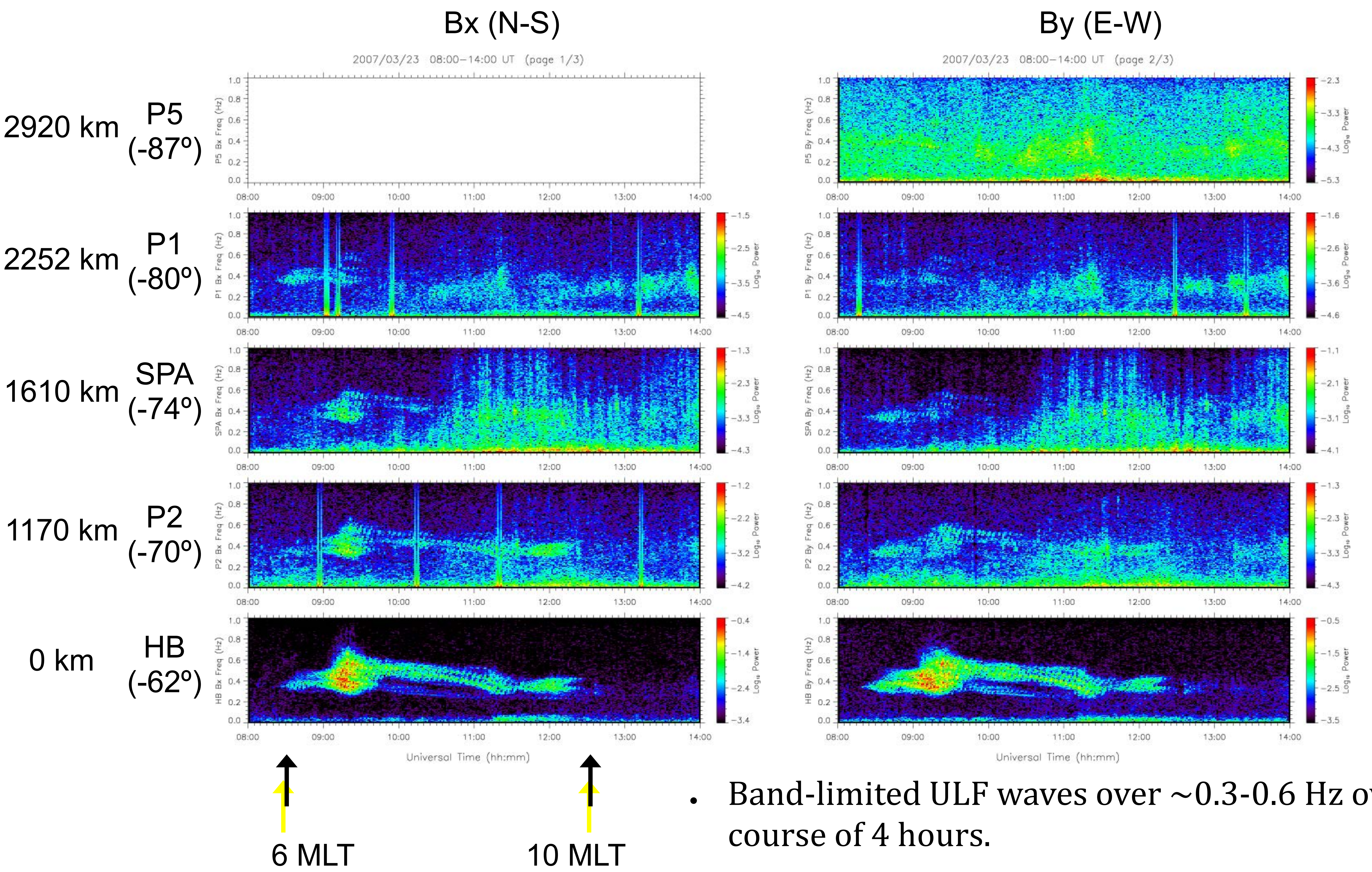


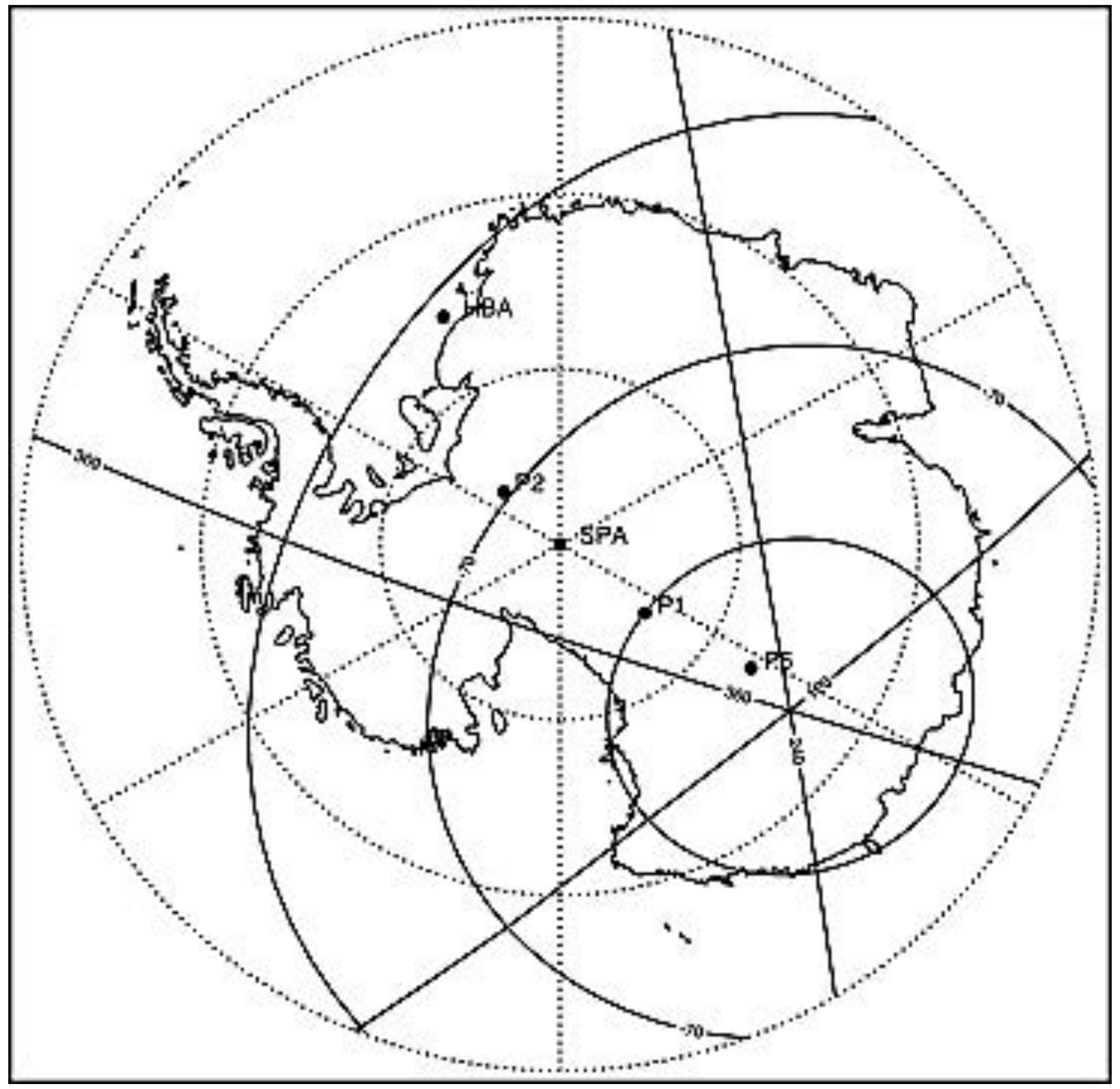
Fig 3. Schematic view of the inner and outer radiation belts



Paulson, K. W., C. W. Smith, M. R. Lessard, R. B. Torbert, C. A. Kletzing and J. Wygant, In Situ Statistical Observations of Pc1 Pearl Pulsations and Unstructured EMIC Waves by the Van Allen Probes, J. Geophys. Res, 122, 1, 105-119, 2016.

EMIC waves: Ducting in Earth's ionosphere





- Band-limited ULF waves over ~0.3-0.6 Hz over the course of 4 hours.
- Spectral features fall into a ULF subclass, "pearl waves".

Kim, H., M. Lessard, H. Lühr and M. Engebretson, Ducting Characteristics of Pc 1-2 Waves at High Latitudes on the Ground and in Space, J. Geophys. Res., 115, A09310, doi: 10.1029/2010JA015323, 2010.

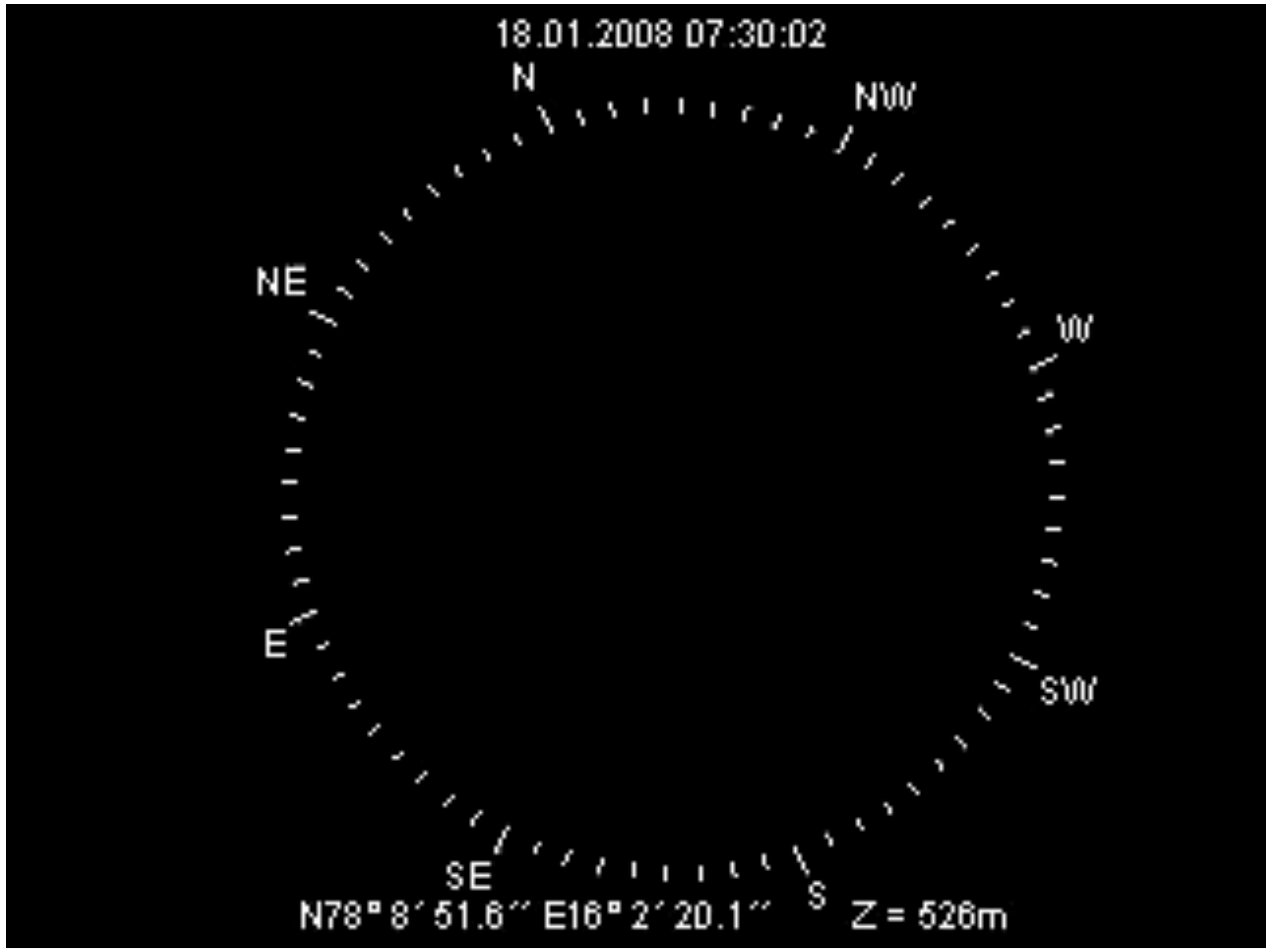
At higher latitudes: Aurora

Types of aurora:

Discrete ("curtains"):
- Inverted-V arcs: 5-20 keV electrons; north-south extent of ~10 km, elongated east-west.
- Alfvenic (wave) aurora: 100-200 eV tall, thin arcs at higher altitudes (see movie).
- Occurs at altitudes of ~250 km

Diffuse:
- Broad regions of dim aurora with little or no structure
- Source of electrons is near magnetic equator

Pulsating aurora:
- 10s to several 10s of keV electrons
- Occurs in pulsating patches, maybe 50+ km in extent, with periods of 8-20 seconds.
- Patches are often only a few km thick, but at lower altitudes (~95 km).



Alfvenic aurora above Longyearbyen, Svalbard, during RENU2 rocket launch. This aurora transfers energy to Earth's thermosphere (our atmosphere at hundreds of km altitude).

Pulsating aurora

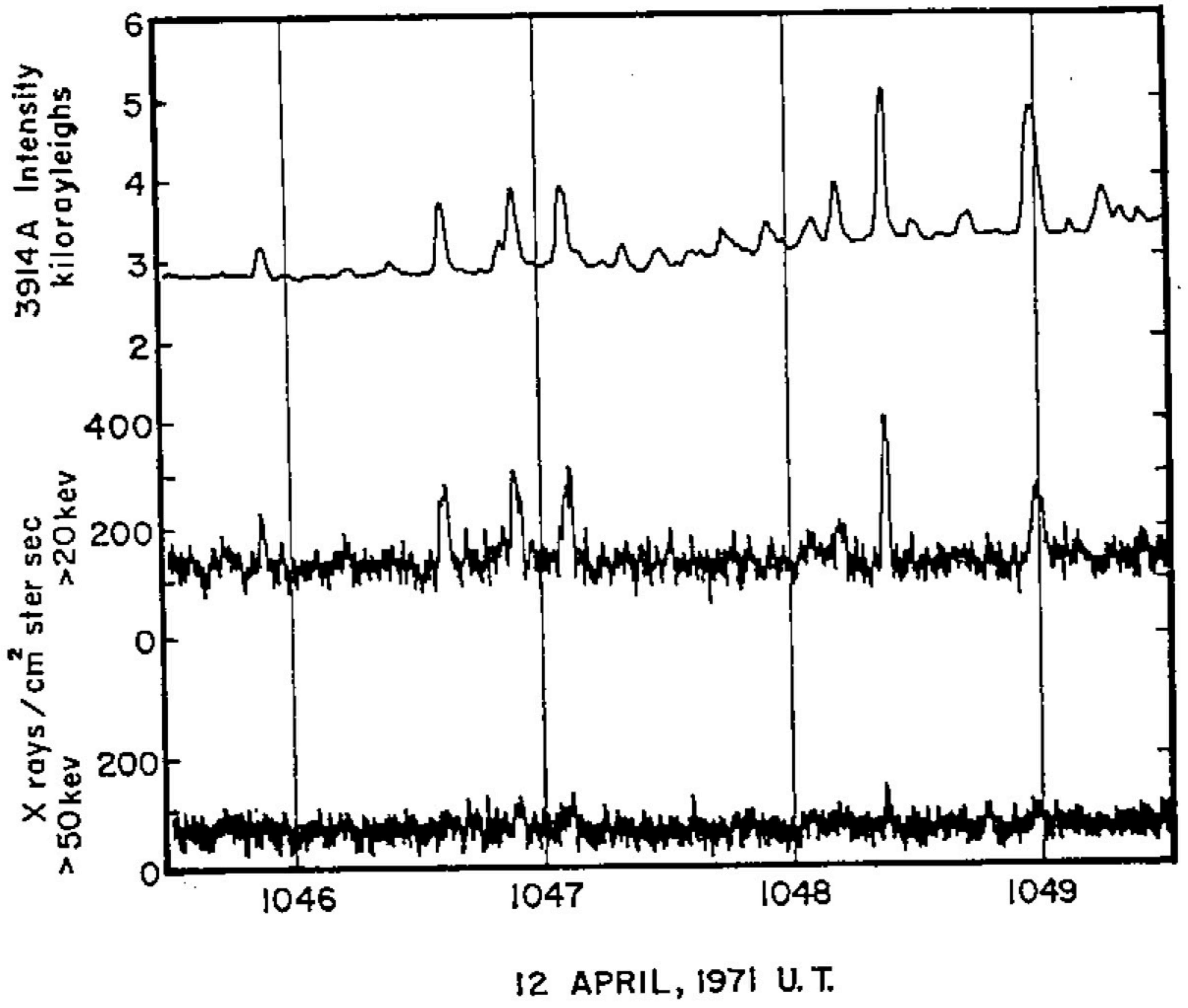
Dim, but very common, persistent and widespread; high electron energies

Jones, S. L., M. R. Lessard, K. Rychert, E. Spanswick, E. Donovan, and A. N. Jaynes, Persistent, widespread pulsating aurora: A case study, Journal of Geophysical Research (Space Physics), 118, 2998–3006, doi:10.1002/jgra.50301, 2013

Relating pulsating aurora to Earth’s radiation belts

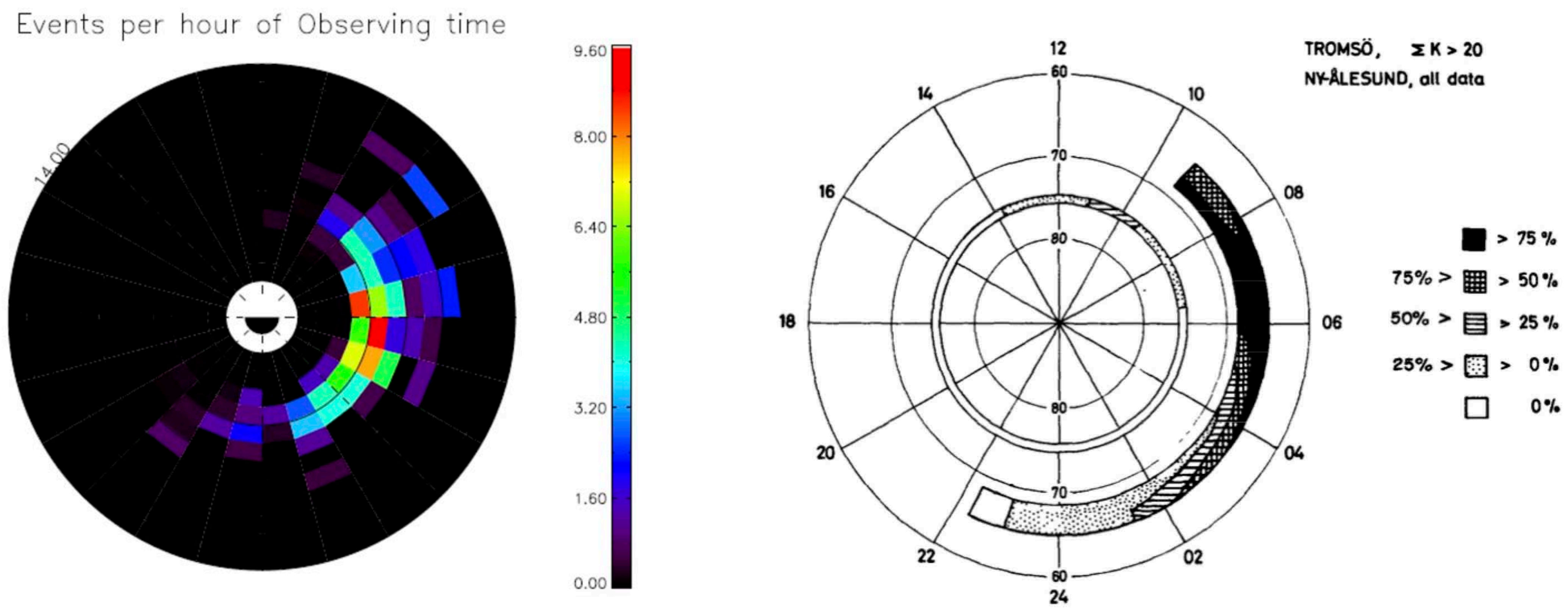
The connection between microbursts and aurora

- A term was coined by K. Anderson [Anderson and Milton, 1964], used to describe X-ray observations associated with auroral forms. Typically written as “auroral microburst”.
- Further work focused on measuring the precipitating electrons that caused the X-ray emissions.
- In 1992, Imhof et al. (1992) related microbursts to radiation belt dynamics and by the year 2000, virtually all research on microbursts addressed thei connection to the radiation belts.
- The Loss through Auroral Microburst Pulsations (LAMP) rocket, Sarah Jones, PI, will explore the connection of microbursts to pulsating aurora. Launch will occur in Jan, 2021, from Poker flat, Alaska.

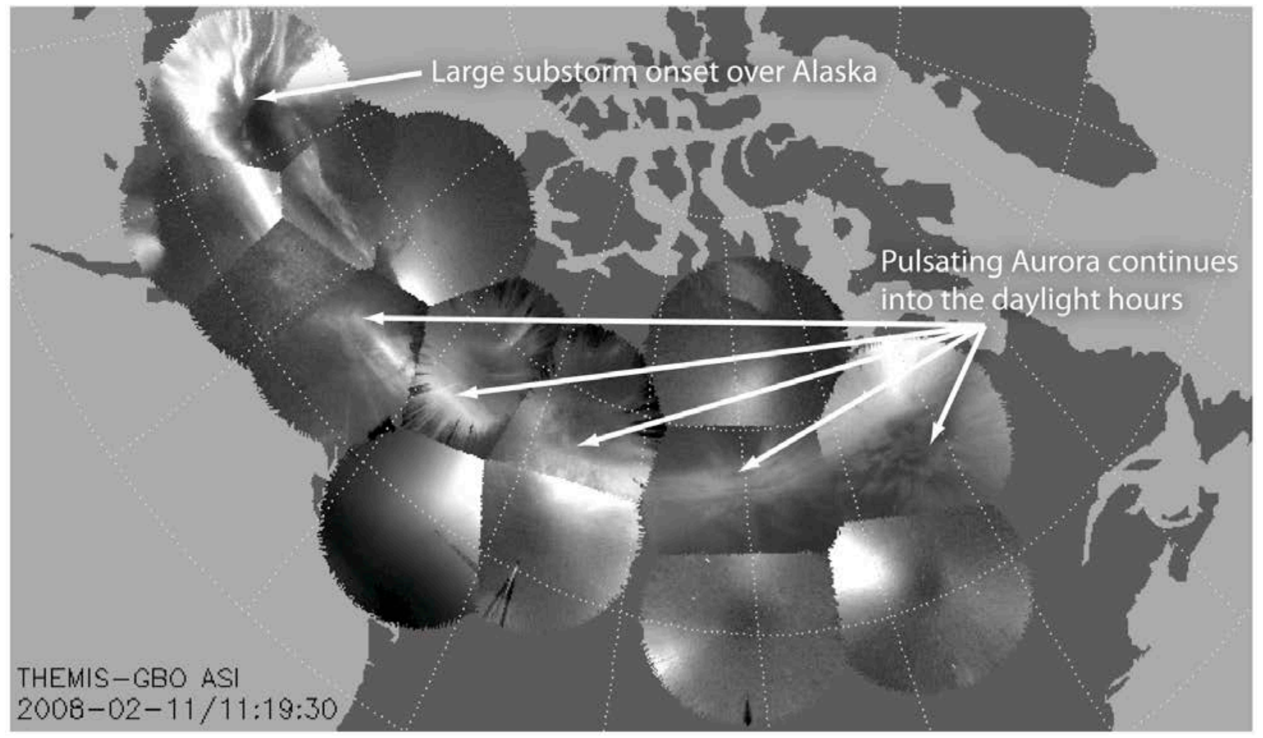


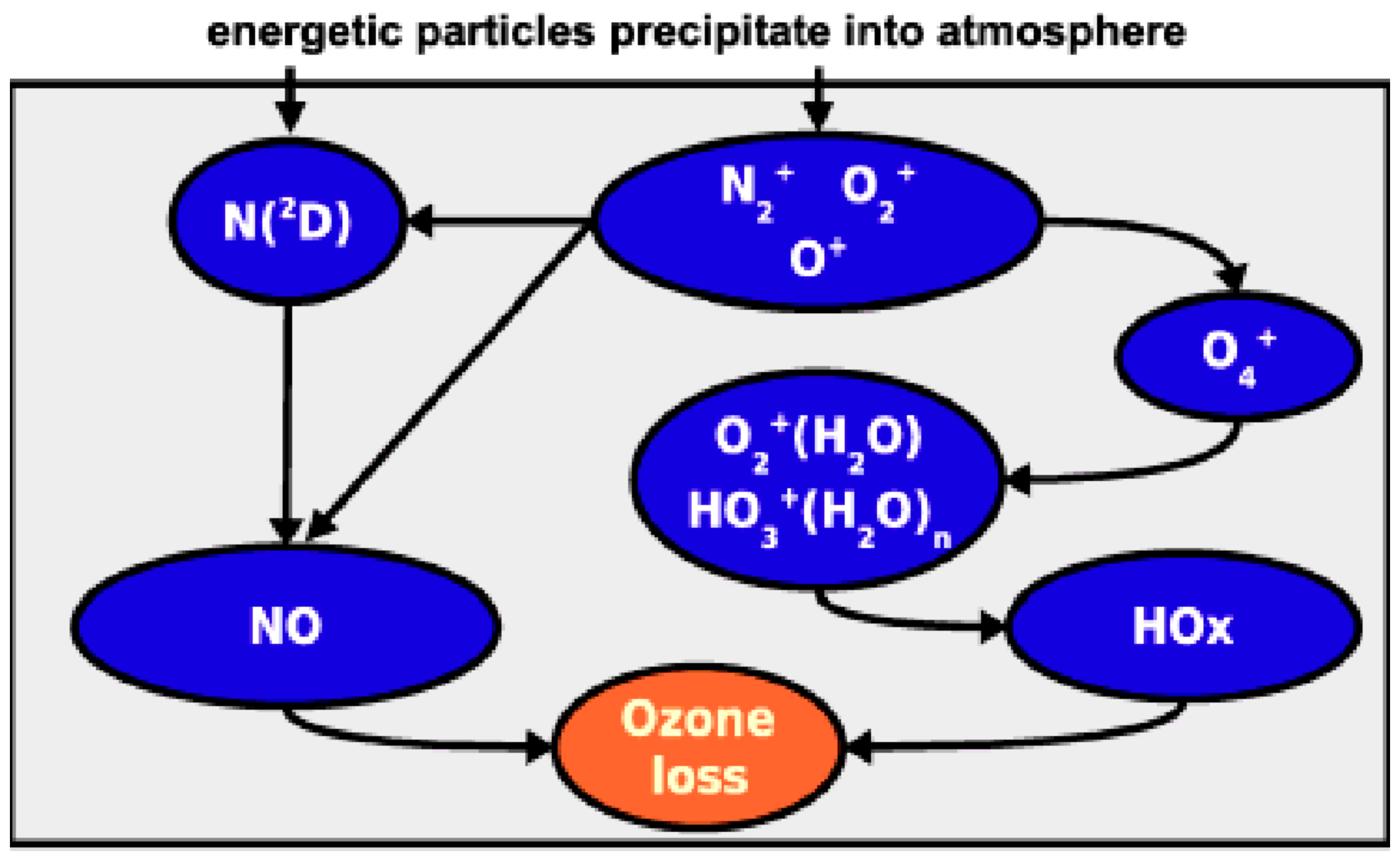
Hofmann and Greene [1972] showed correlations between balloon-borne X-ray microbursts and 391.4 nm photometer data. Figure 1, from that paper, shows the excellent correlations they obtained. FOV covered 34 km at 100 km altitude for both instruments.

Relating pulsating aurora to ozone depletion



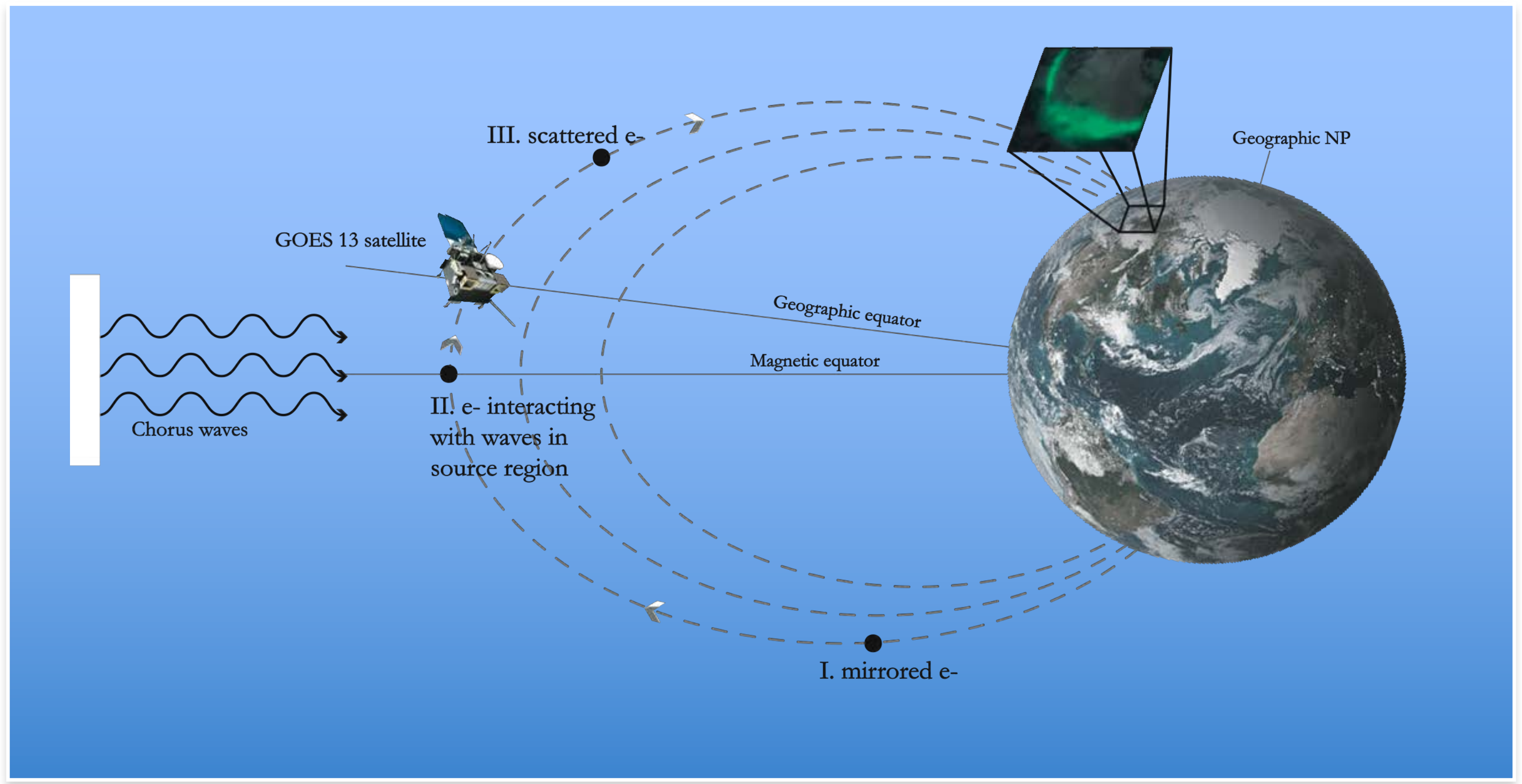
LEFT: the distribution of microburst events measured by the Freja satellite.
RIGHT: the distribution of pulsating aurora in terms of invariant magnetic latitude vs. MLT (from Kvifte and Pettersen [1969]).





Proposed mechanism — several steps:

- Pulsating aurora is excited via energetic electron precipitation.
- Energetic precipitation produces NOX at 90 km altitude.
- Over several days, NOX is transported to lower altitudes via Polar Vortex
- NOx reacts with Stratospheric ozone and depletes ozone.



Summary

These are exciting times in the field of space science, with new research ranging from studies of the microphysics of plasma processes to their impacts on global-scale dynamics. These include:

- Coupling from one region to another, both in latitude/longitude as well as altitude, eg., thermospheric upwelling in the cusp, radiation belt precipitation effects on the ionosphere.

- Coupling across a huge range of spatial scales (eg., 100 m arcs that heat the thermosphere across a few hundred km; electron microbursts (of ms time scales) that drive pulsating aurora (time scales of several seconds.

- Coupling from one process to another - eg., radiation belt precipitation -> pulsating aurora -> ozone depletion.

- Ionosphere-thermosphere-magnetosphere coupling in opposite hemispheres!

Challenges:
From my point of view, the biggest challenge is to be able to observe these processes that change over an incredible range of spatial and temporal scales.