Auroral Physics at Jupiter:
Radio and Plasma Wave Observations by Juno

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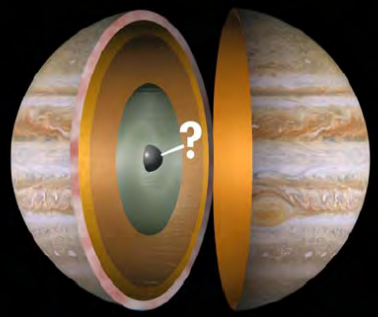
Juno Science Objectives

Origin

Determine O/H ratio (water abundance) and constrain core mass to decide among alternative theories of origin.

Interior

Understand Jupiter's interior structure and dynamical properties by mapping its gravitational and magnetic fields

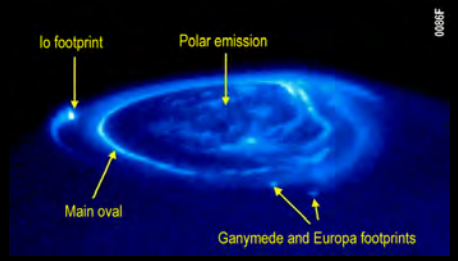


Atmosphere

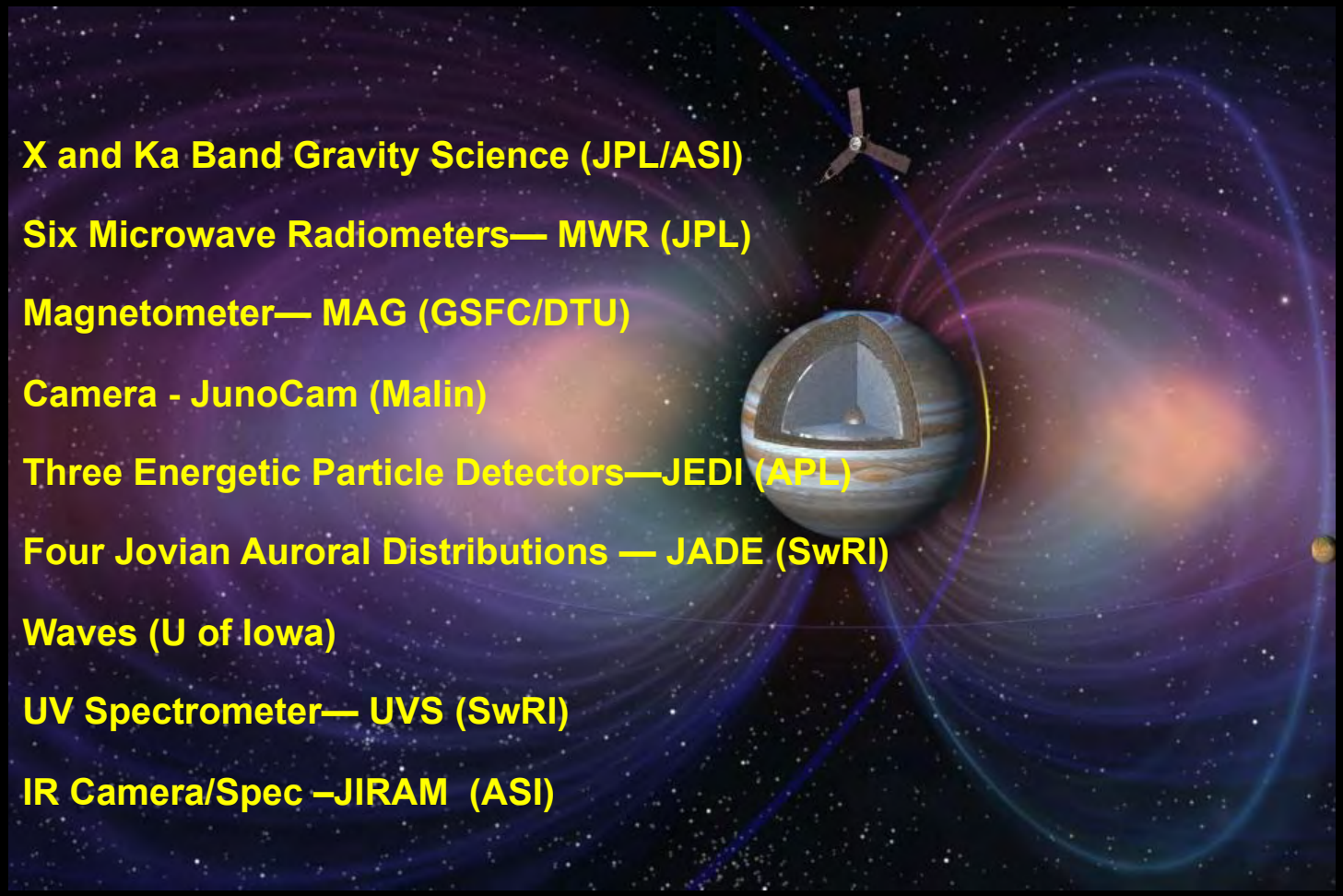
Map variations in atmospheric composition, temperature, cloud opacity and dynamics to depths greater than 100 bars at all latitudes.

Magnetosphere

Characterize and explore the three-dimensional structure of Jupiter's polar magnetosphere and auroras.



Juno Payload



X and Ka Band Gravity Science (JPL/ASI)

Six Microwave Radiometers— MWR (JPL)

Magnetometer— MAG (GSFC/DTU)

Camera - JunoCam (Malin)

Three Energetic Particle Detectors—JEDI (APL)

Four Jovian Auroral Distributions — JADE (SwRI)

Waves (U of Iowa)

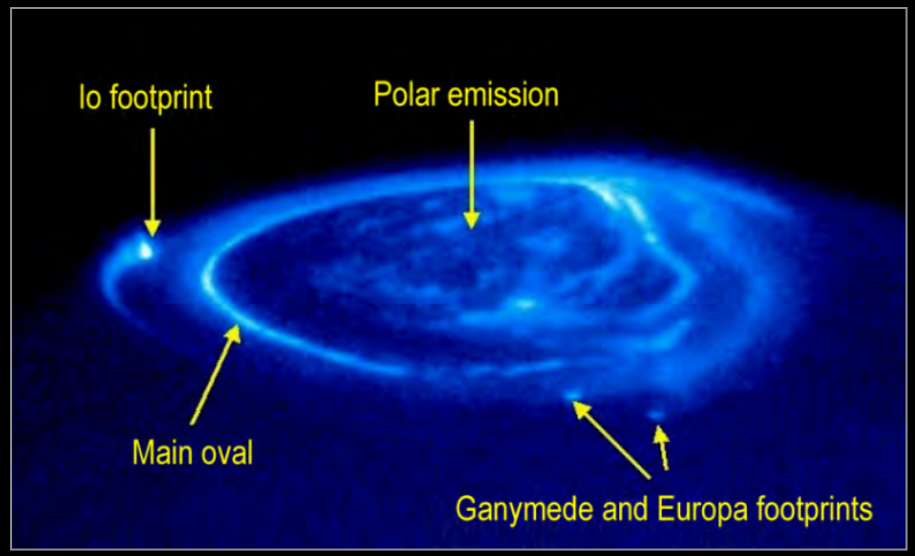
UV Spectrometer— UVS (SwRI)

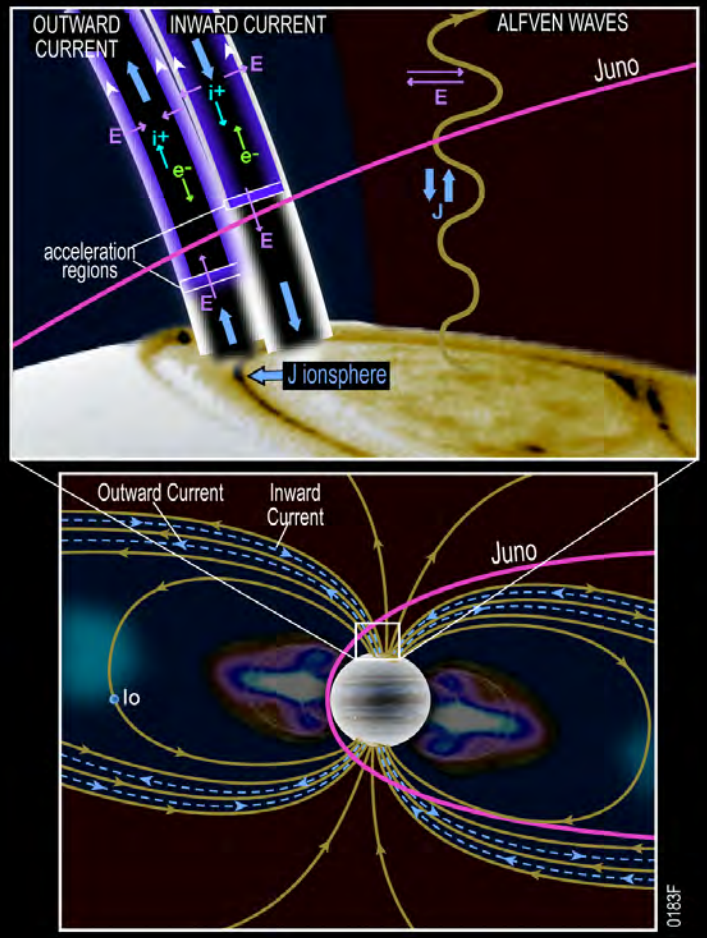
IR Camera/Spec –JIRAM (ASI)

Polar Magnetosphere Exploration

Location is Key: Juno passes directly through auroral field lines.

A suite of instruments is used to understand the physics:
JADE, JEDI, MAG, Waves, JIRAM, UVS





Outstanding Questions: Polar Magnetosphere

- What structure of the polar magnetosphere? How does it compare to Earth's?
- Where and how are auroral particles accelerated?
- Where and how are auroral radio emissions generated?
- What causes the transient polar aurora?
- What is the topology of the polar magnetic field? How much connects to the solar wind and how variable is this?
- How do internal magnetospheric dynamics and solar wind variability affect the main aurora?
- How does the polar magnetosphere couple to the distant magnetotail?

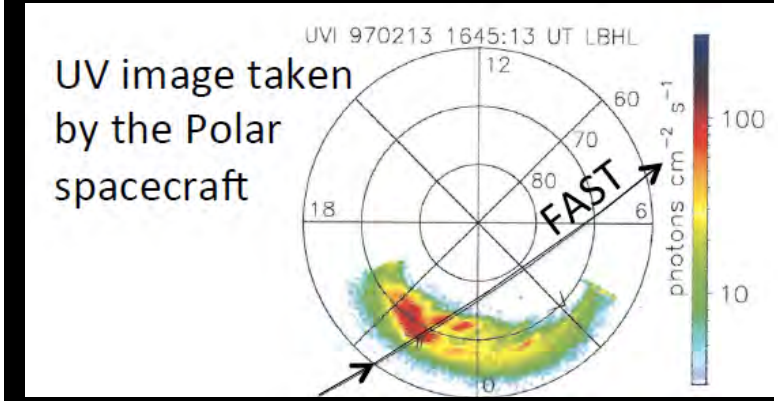
After Bagenal et al., *Space Sci. Rev.*, 2014

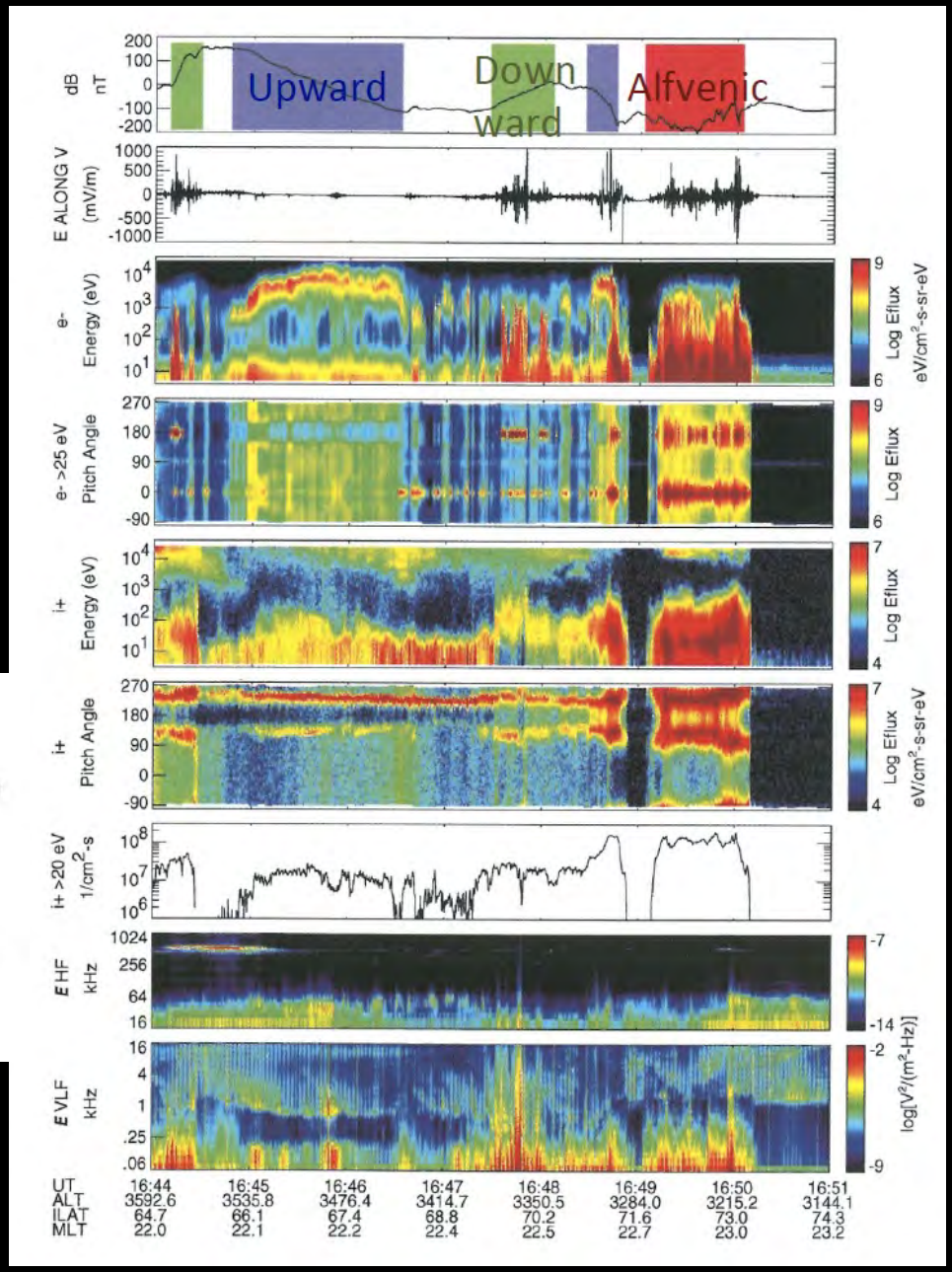
Other Outstanding Questions

- How are radiation belt particles accelerated and what processes drive the structure and dynamics of the radiation belts?
- How is the magnetosphere coupled to the solar wind? How much mass and momentum are transferred?
- What role does the solar wind play in magnetospheric dynamics and how deep does its influence penetrate?

After Bagenal et al., *Space Sci. Rev.*, 2014

Juno will enable comparisons with terrestrial auroral physics





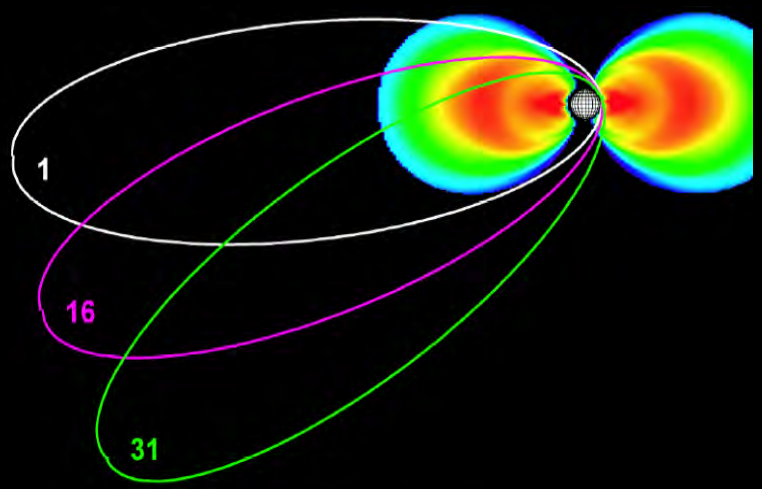
Paschmann et al. (2002)

Juno Mission Plan

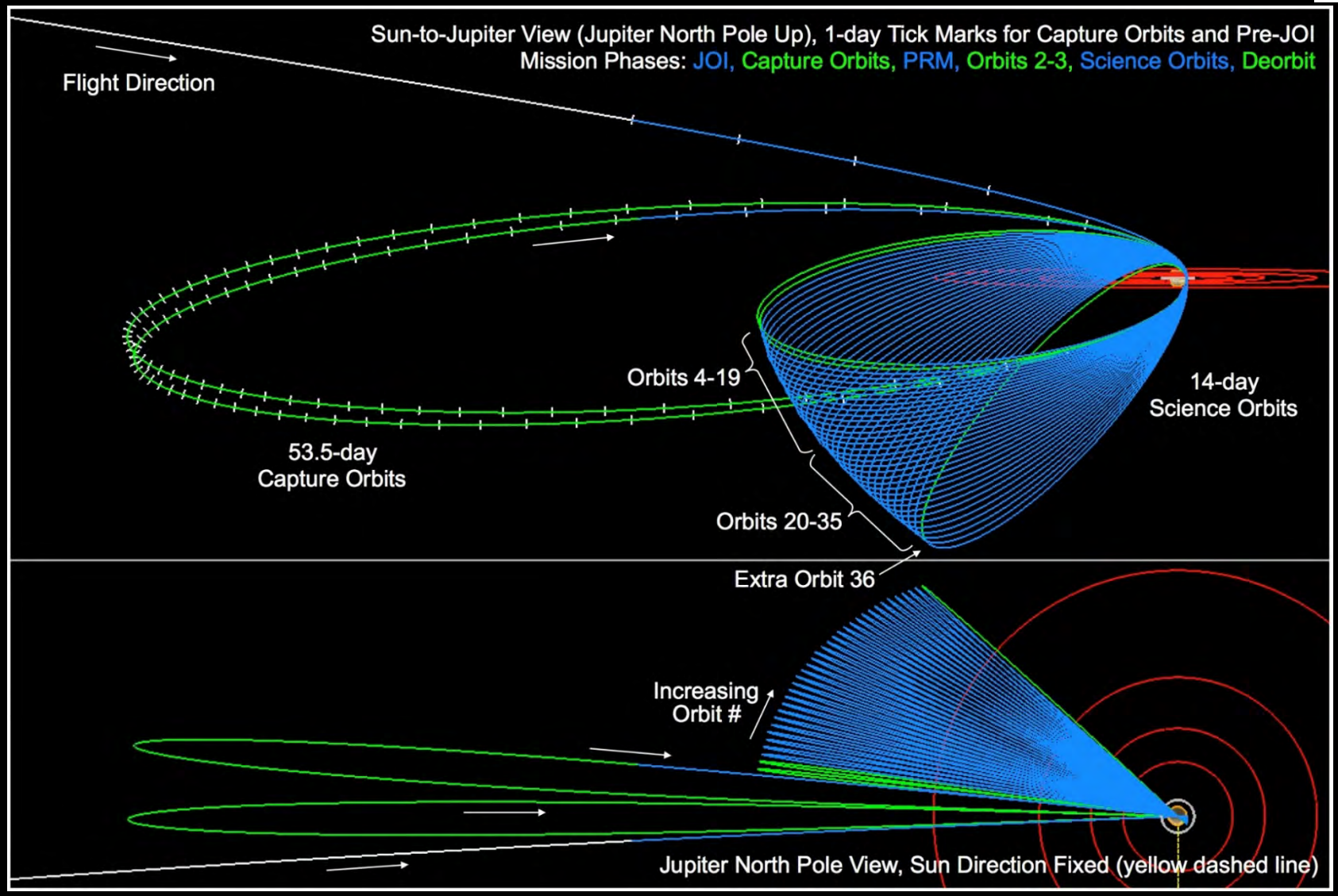
Tilted ecliptic pole view, vernal equinox up; launch at start of 8/5-26 launch period; 30-day tick marks

Baseline **mission:**

- 32 polar orbits, 12 degree net
- Perijove ~5000 km
- 14 day period
- Spinning, solar powered

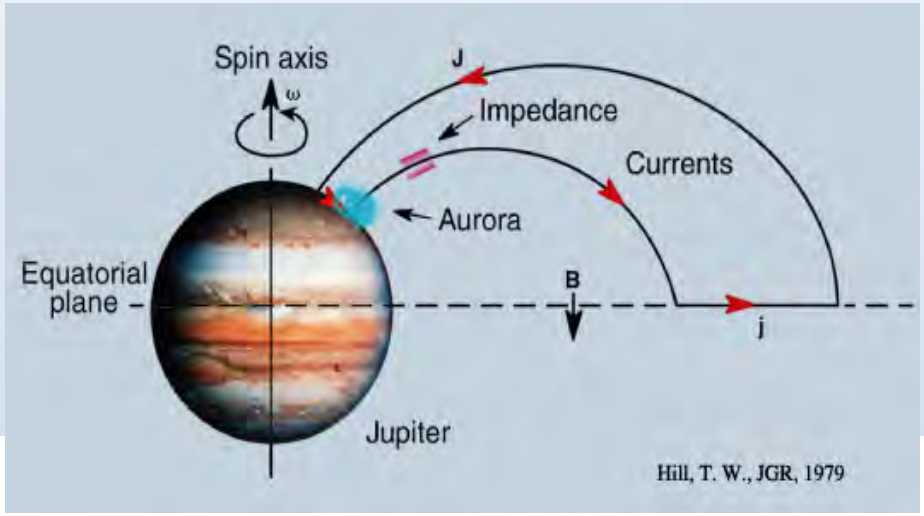


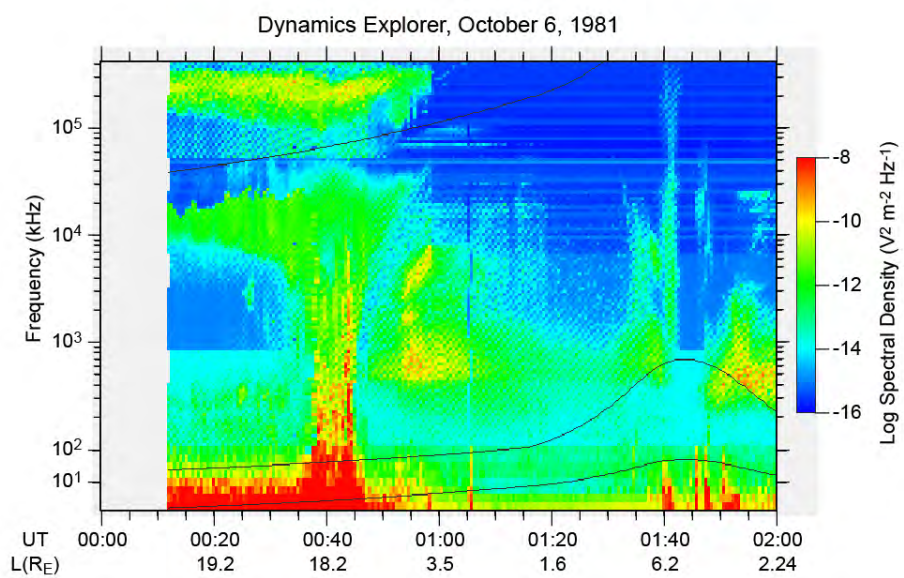
Orbital Trajectory



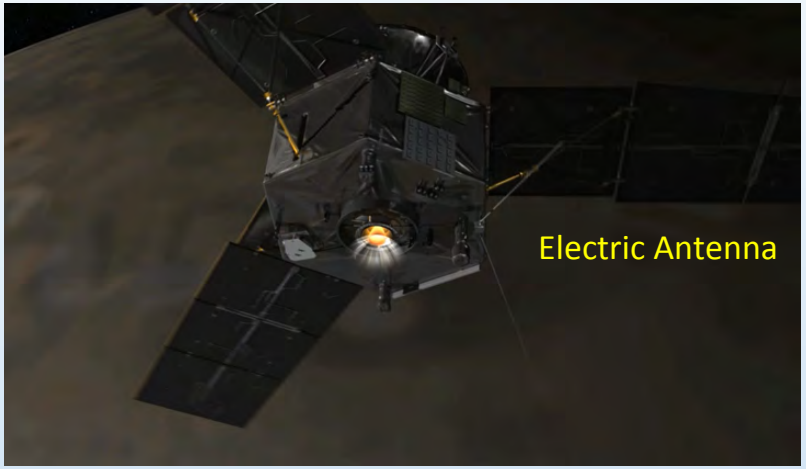
Juno Waves Science Objectives

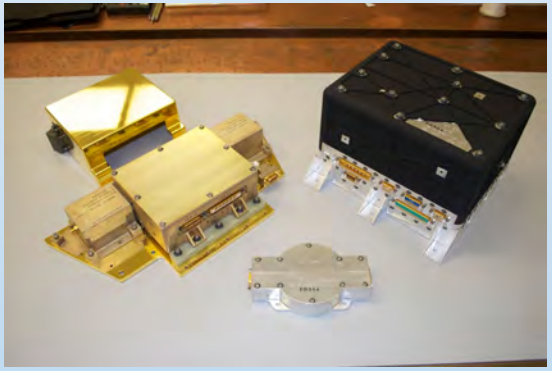
- **Waves primary objectives**:
  - Explore radio and plasma waves in Jupiter's polar magnetosphere
  - Examine the role of plasma waves in the auroral acceleration region
  - Identify source regions for Jupiter's primary radio emissions and observe these in situ
- **Additionally, Waves will**:
  - Observe the structure and dynamics of the plasmasheet
  - Monitor radio emissions as a proxy for magnetospheric dynamics
  - Measure dust impacts between the ring system and the atmosphere





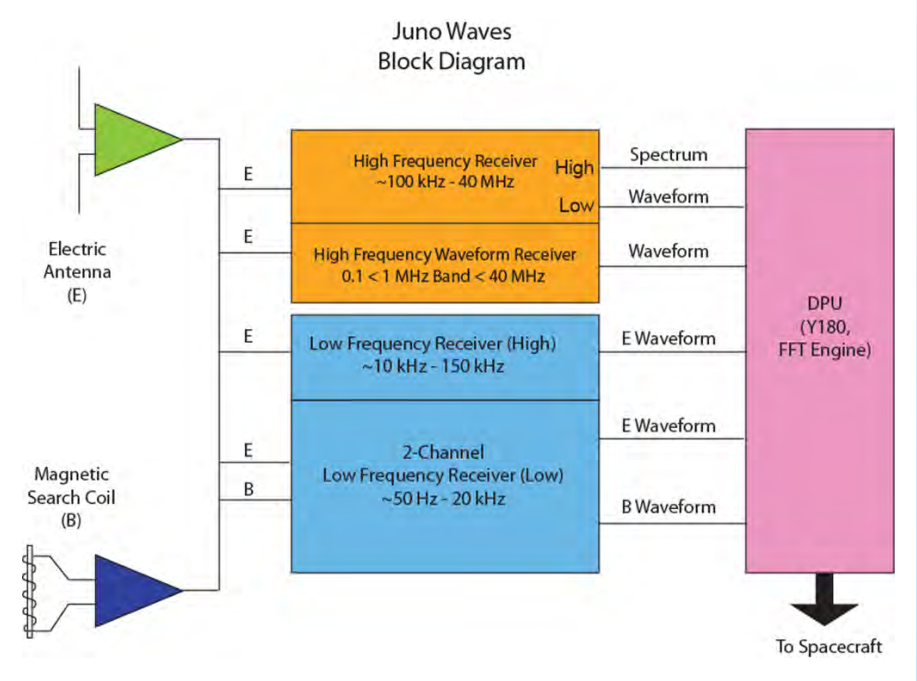
Juno Waves Overview





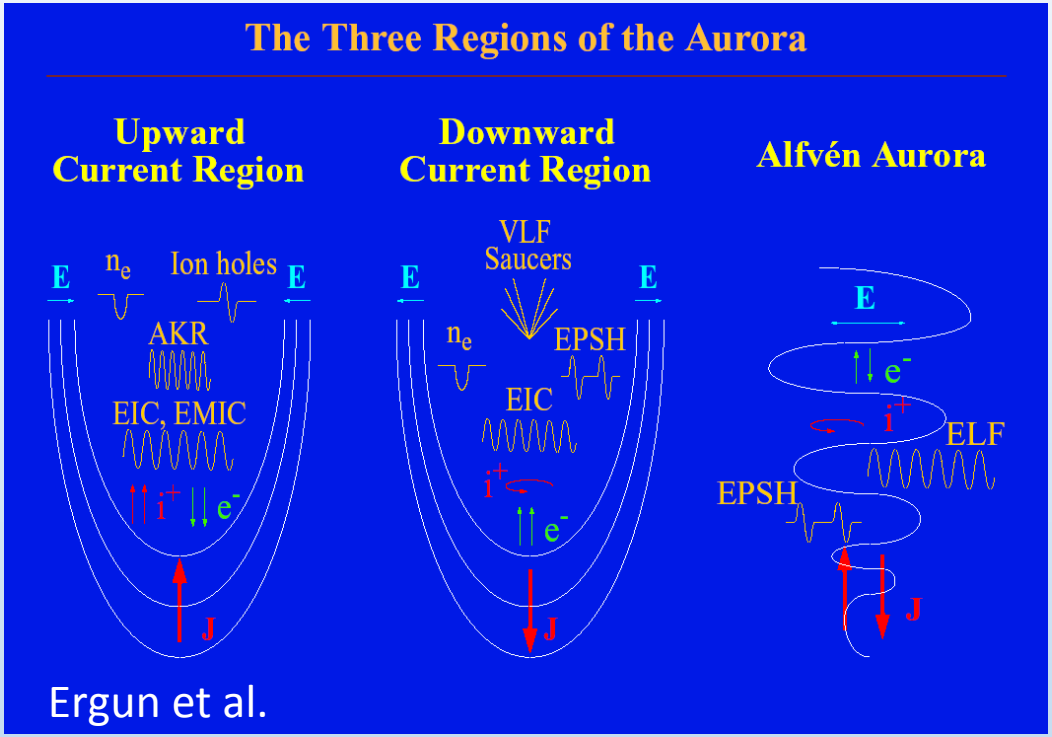
Preamps & Electronics

Search Coil

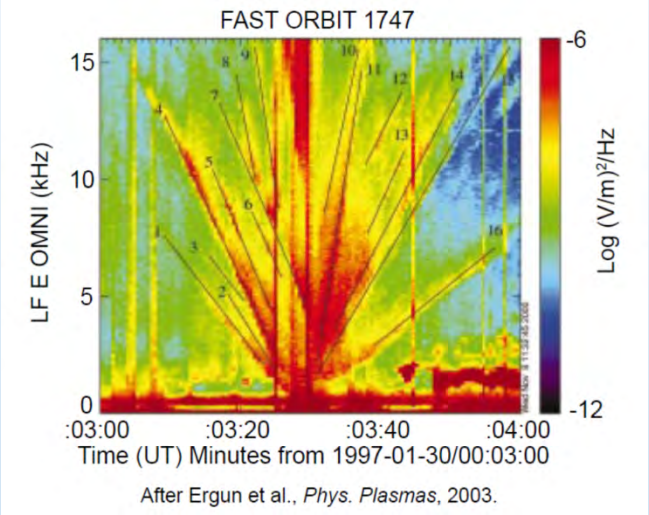


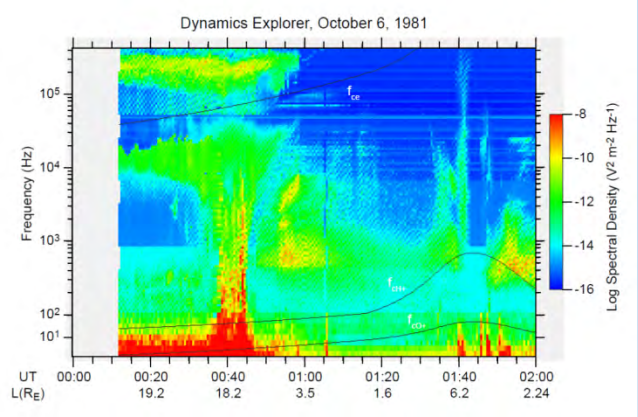
Instrument Characteristics	
Spectral Coverage	50 Hz – 20 kHz Magnetic
Spectral Coverage	50 Hz – 40 MHz Electric
Spectral Resolution	~20 Channels/decade
Periapsis Mode Cadence	1 spectrum/s
LF and MF Burst Modes	Waveform Captures in all bands to 150 kHz triggered onboard
HF Burst Modes	Ability to select a 1-MHz band including f_{ce}

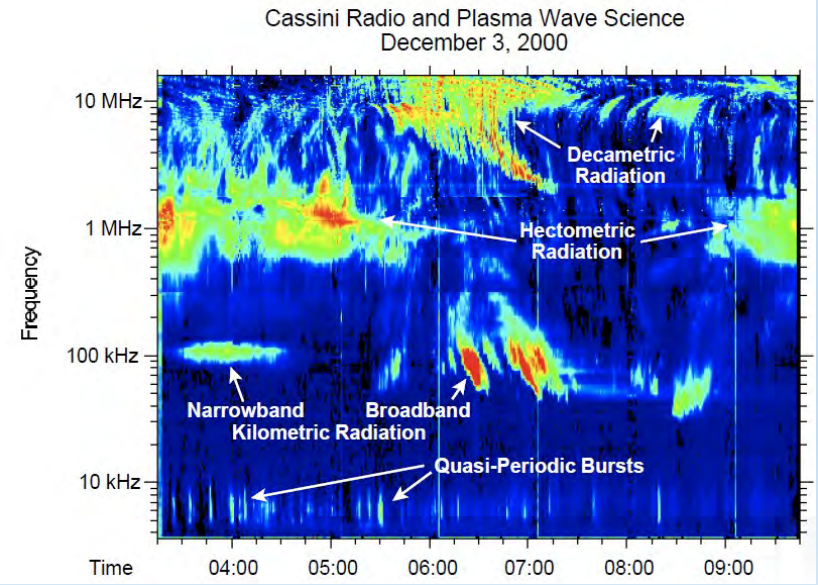
Prime Waves Targets



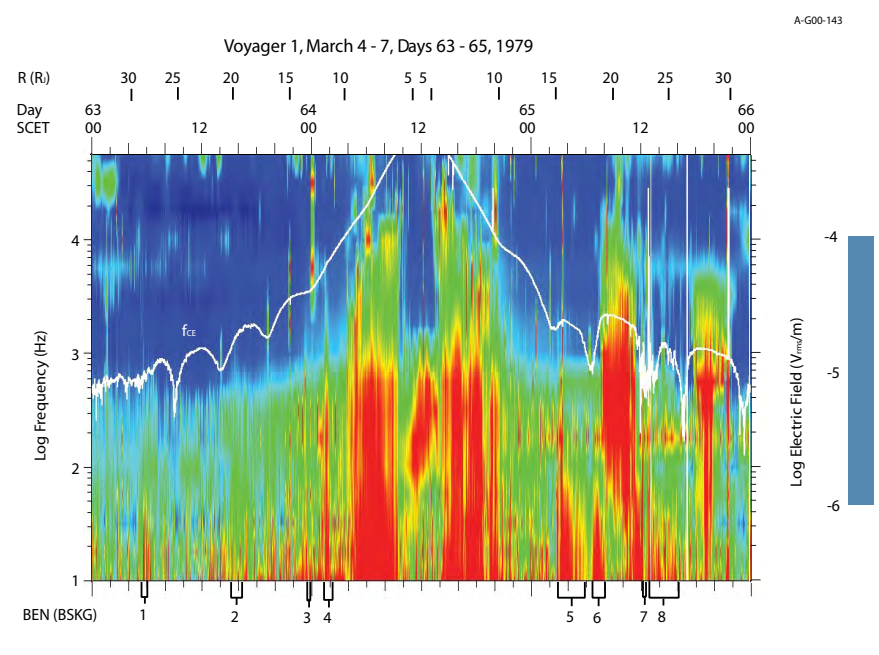
Ergun et al.

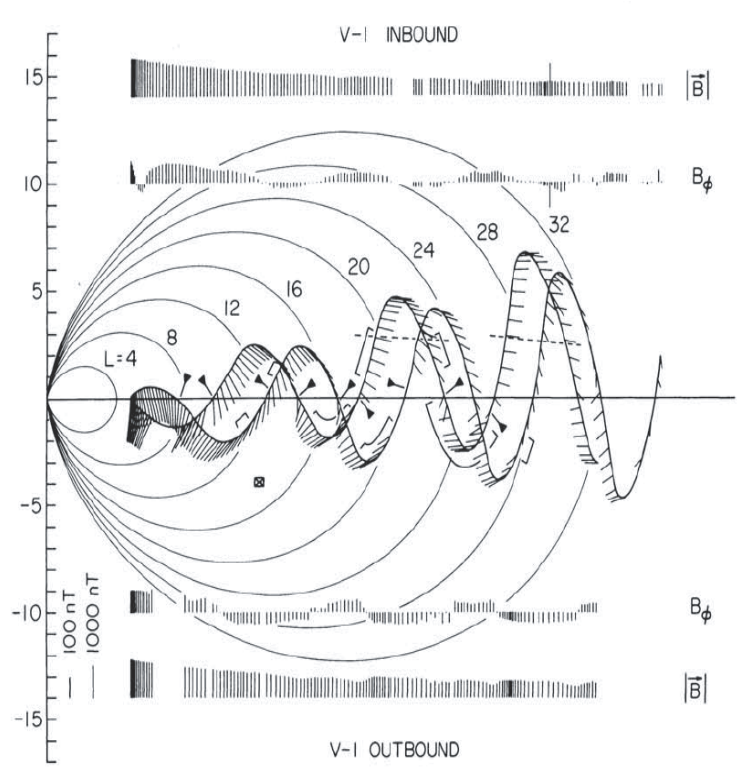


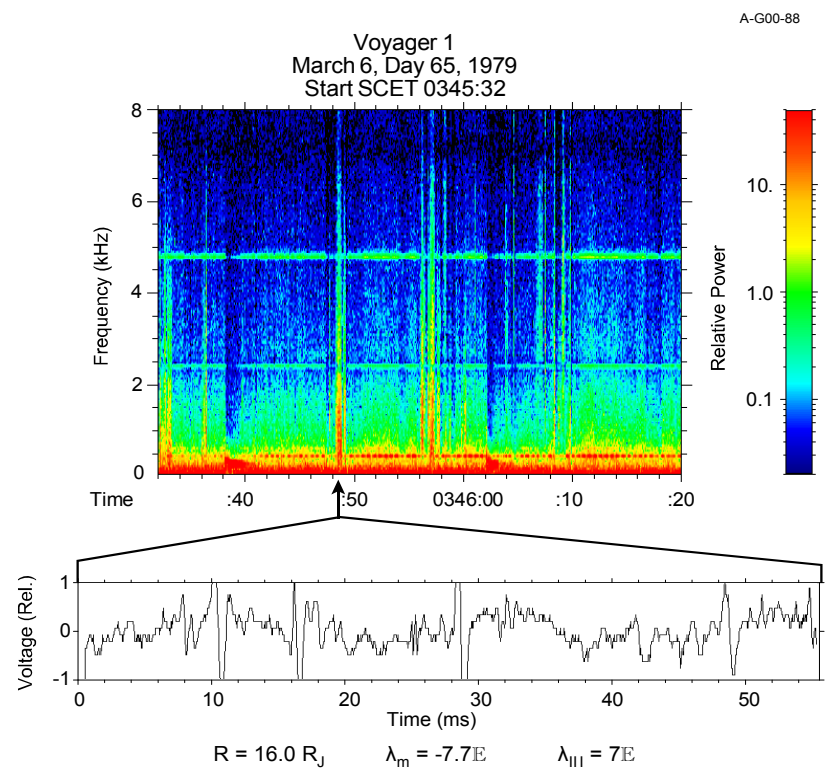




Coupling the Middle Magnetosphere to the Aurora

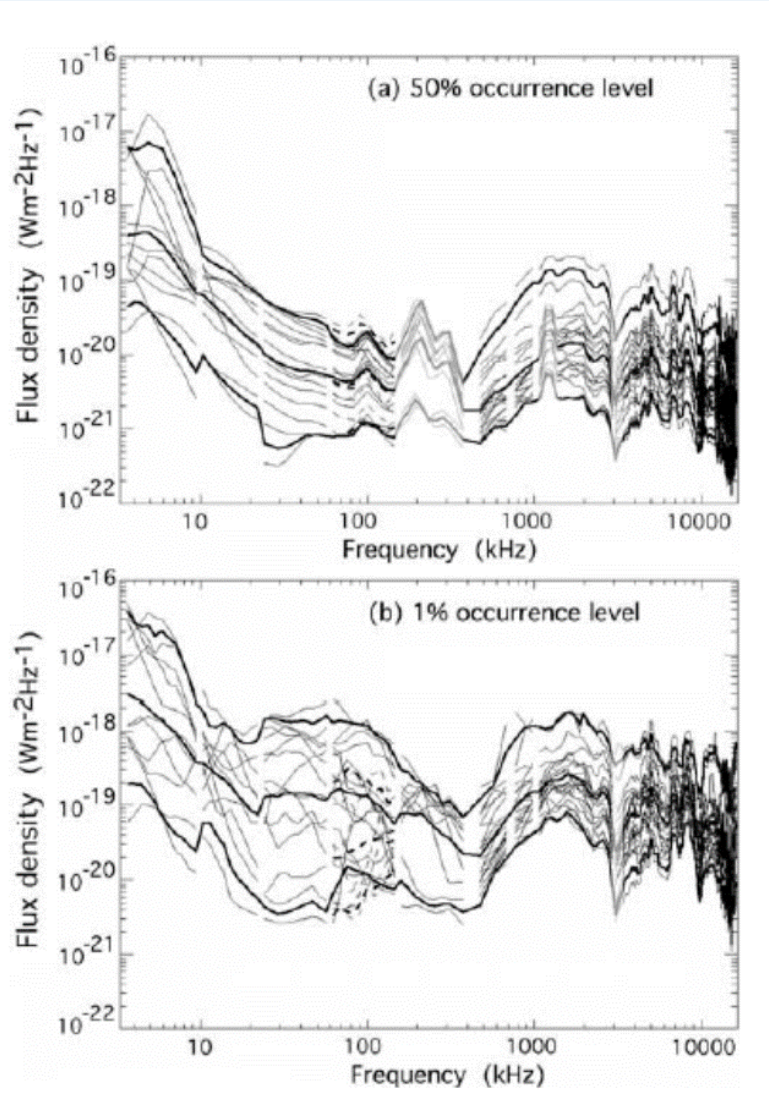


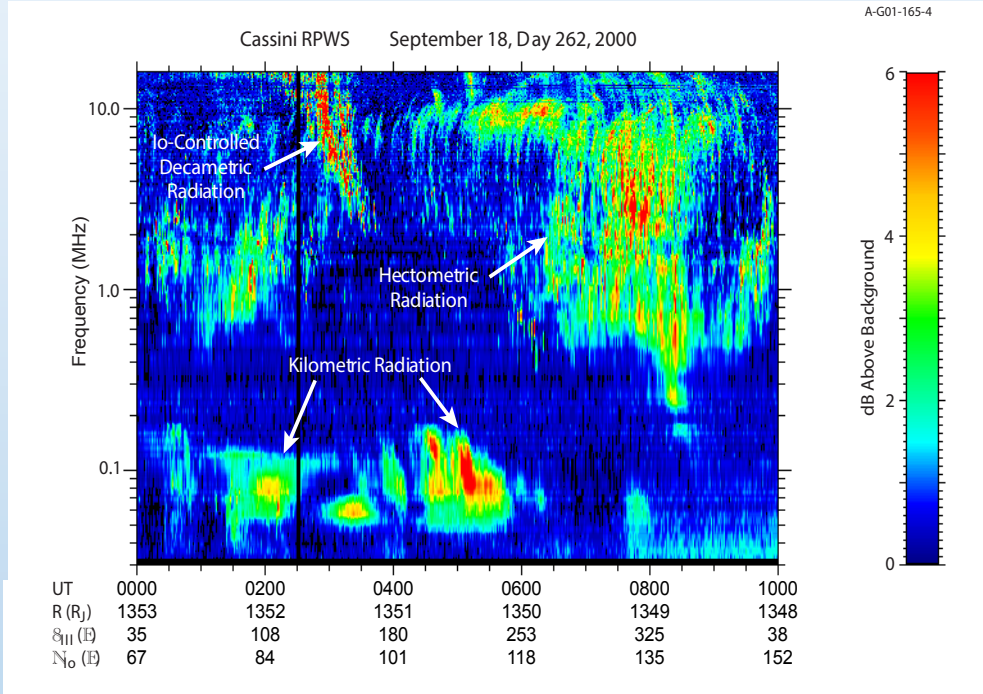




Barbosa et al., 1981

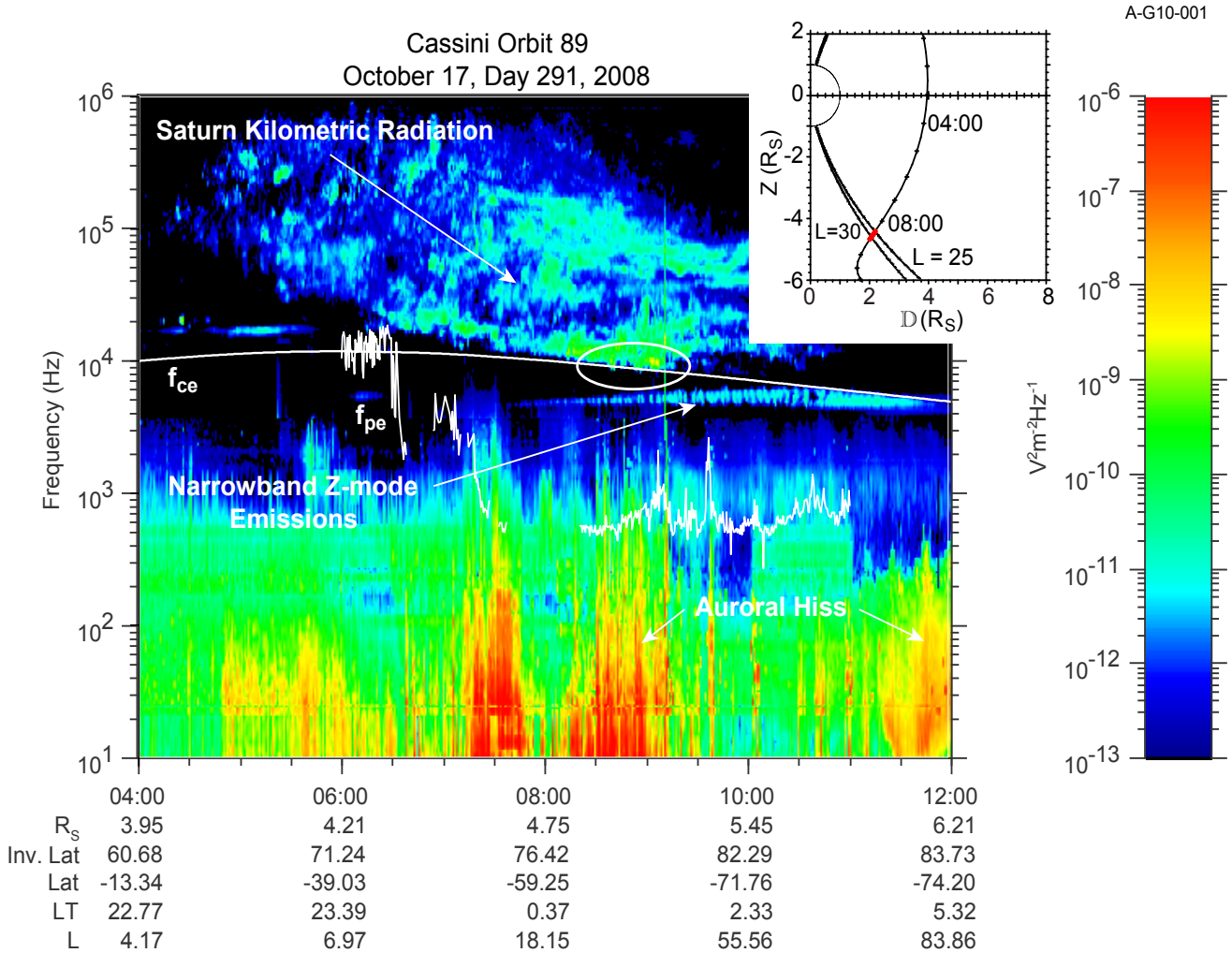
Auroral Radio Emissions



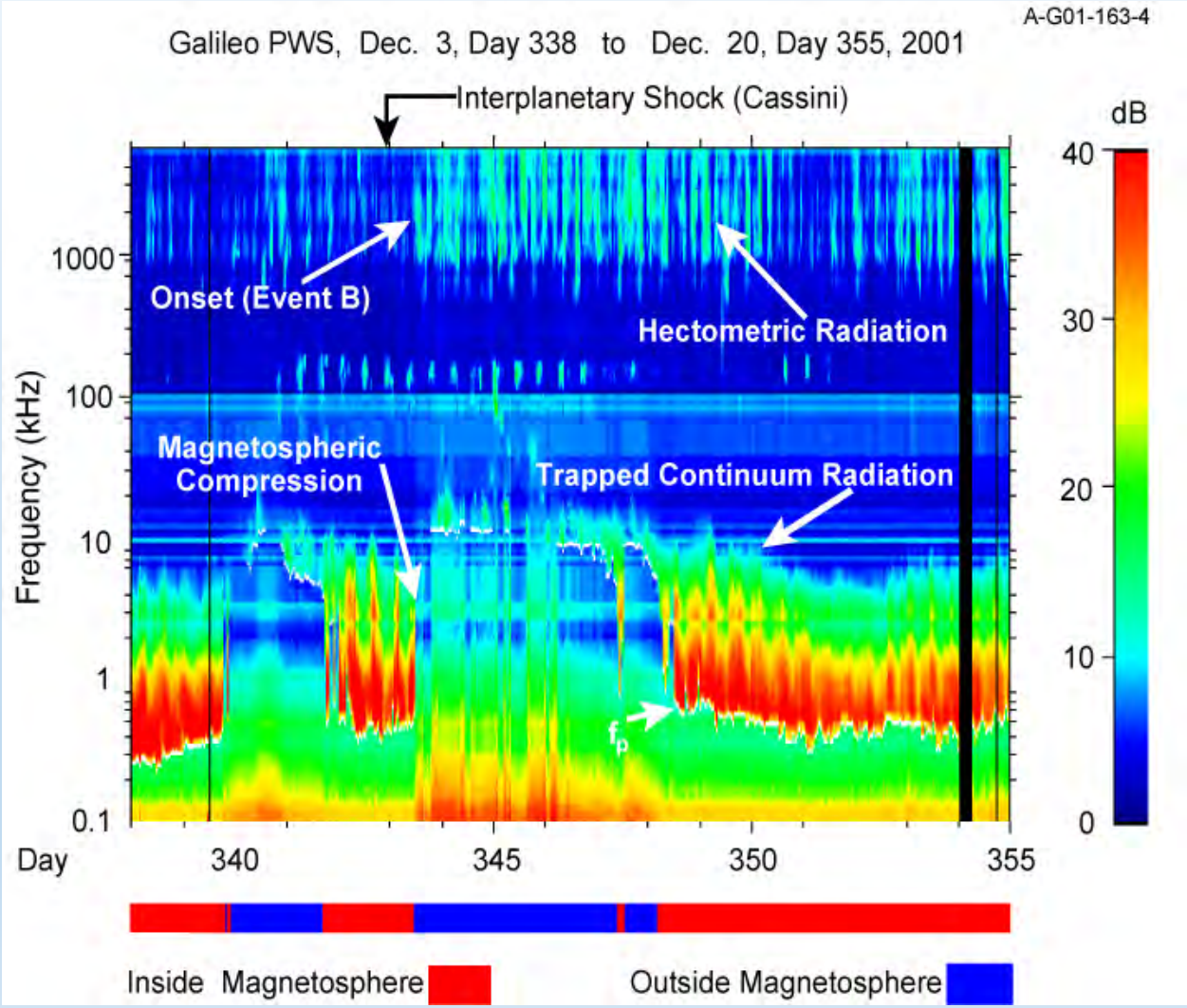


Zarka et al., 2004.

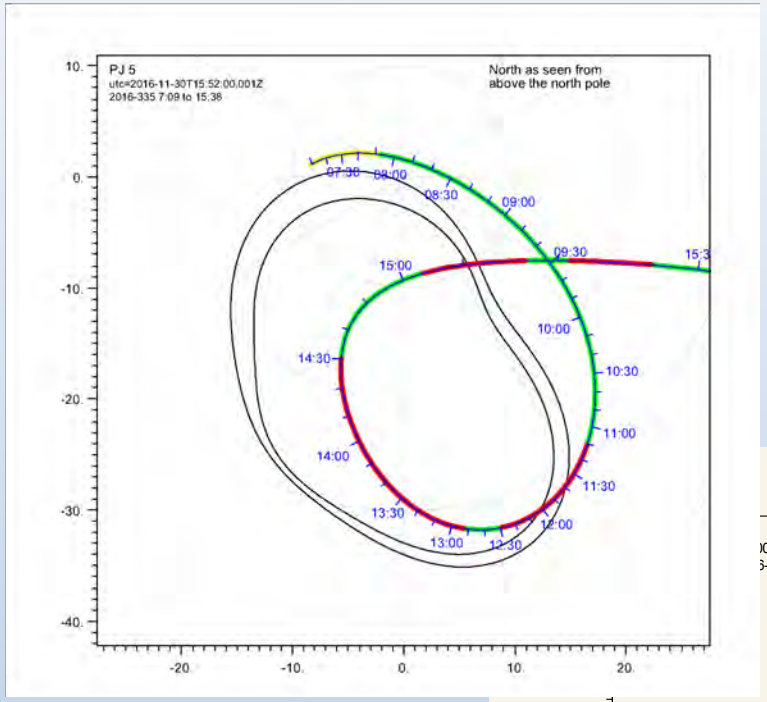
Auroral Radio Emission Source

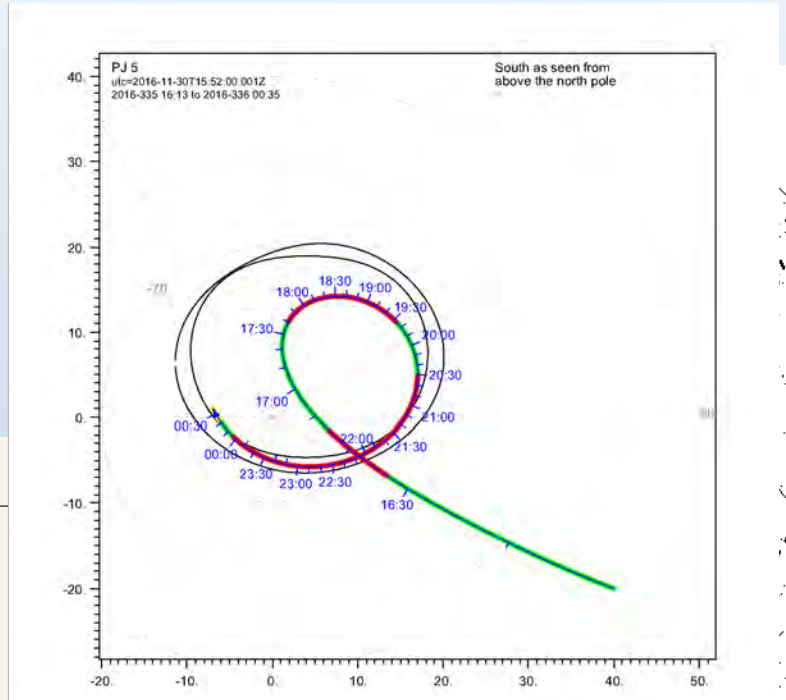


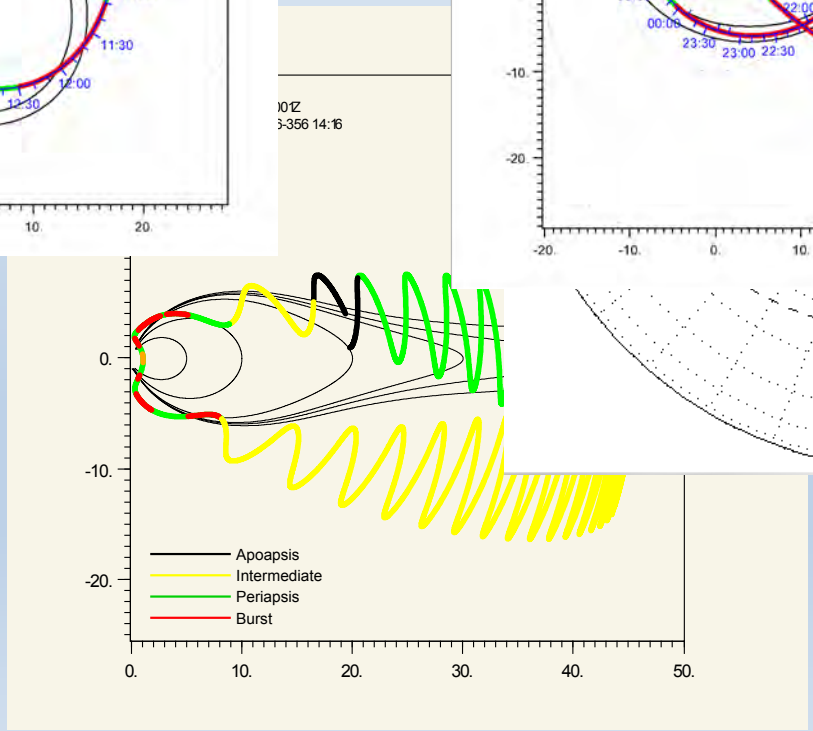
Solar Wind/Magnetospheric Interactions



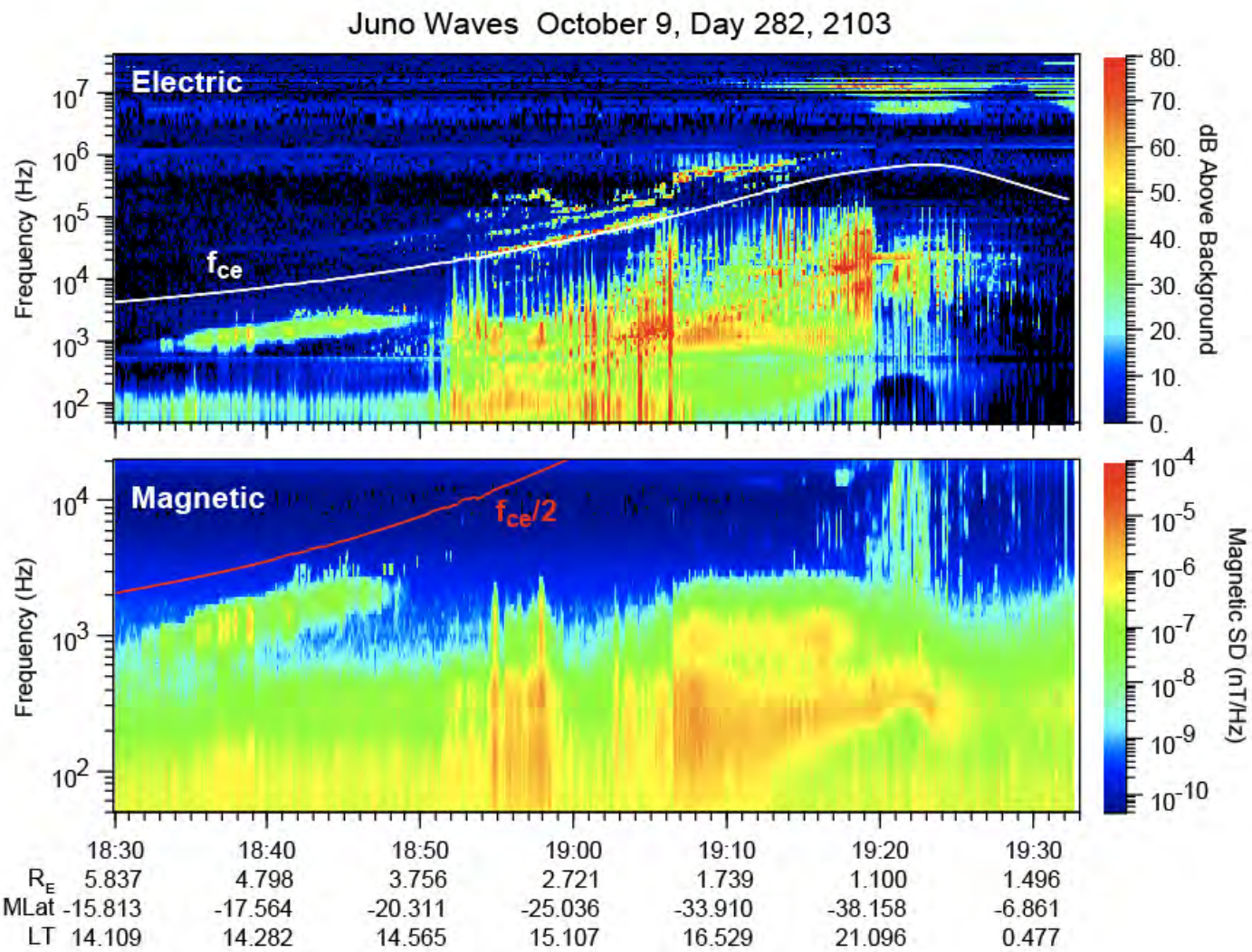
Observation Planning



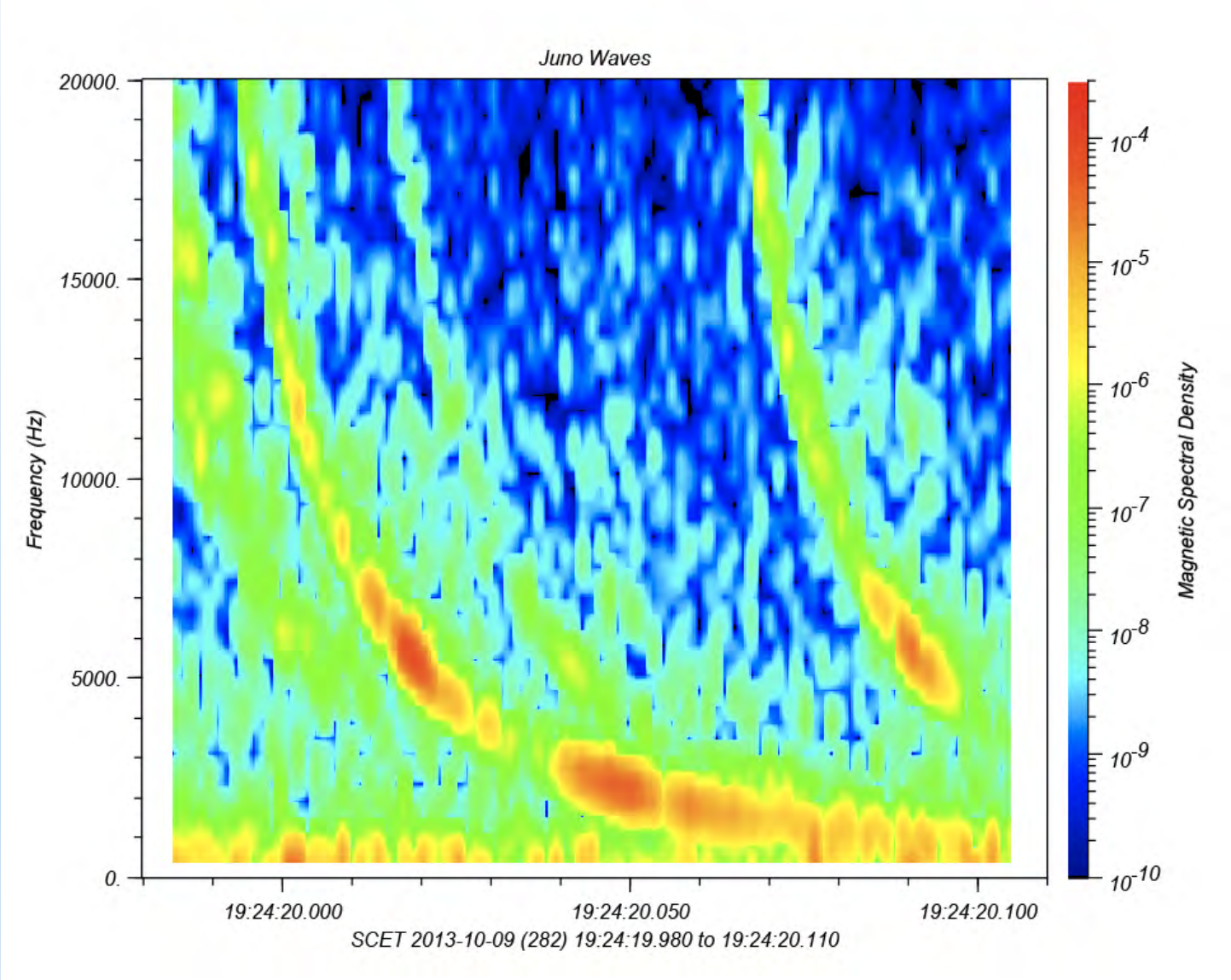




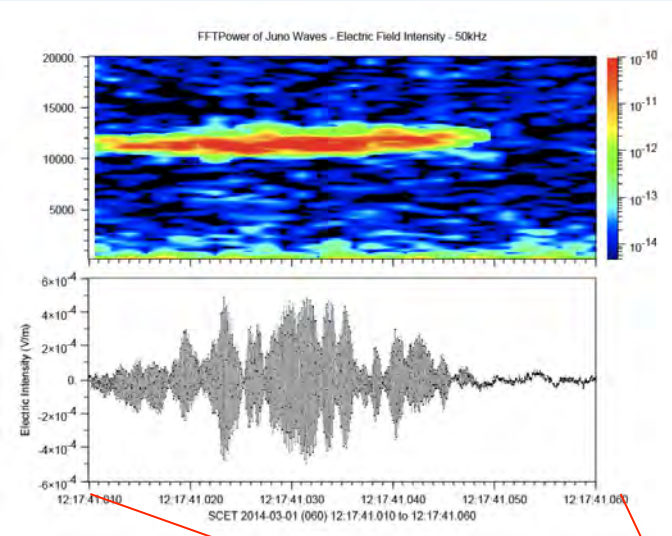
Plasma Waves in Earth's Radiation Belts



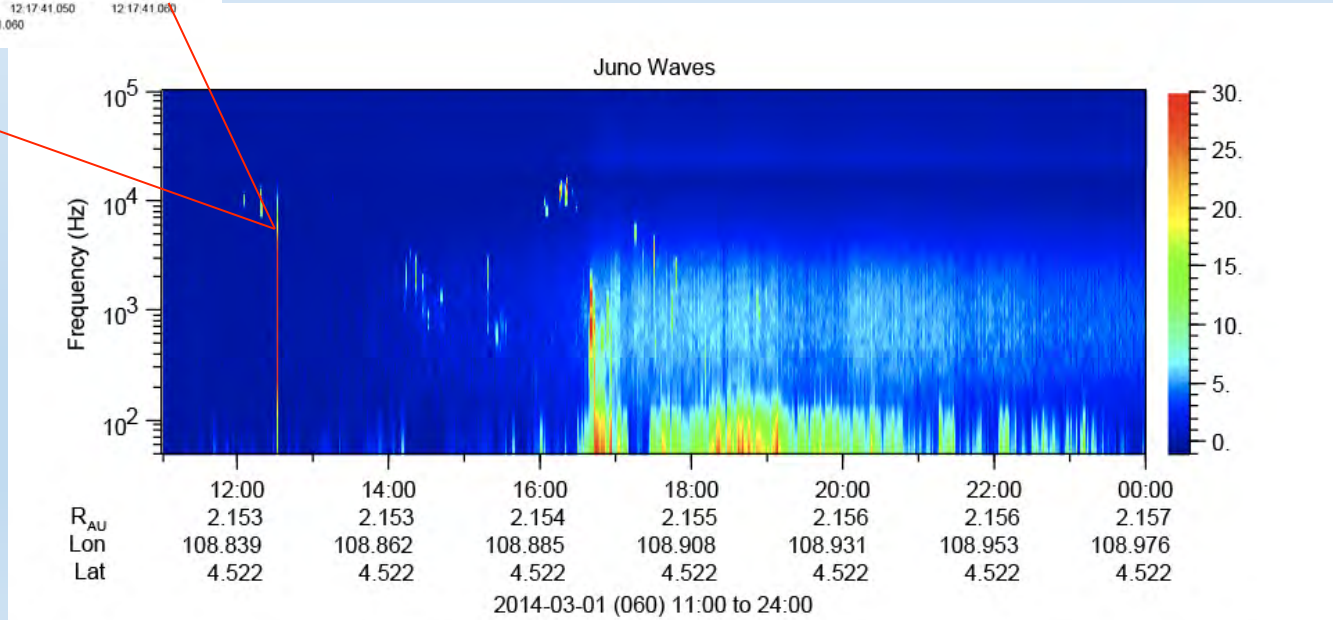
Terrestrial Lightning Whistlers



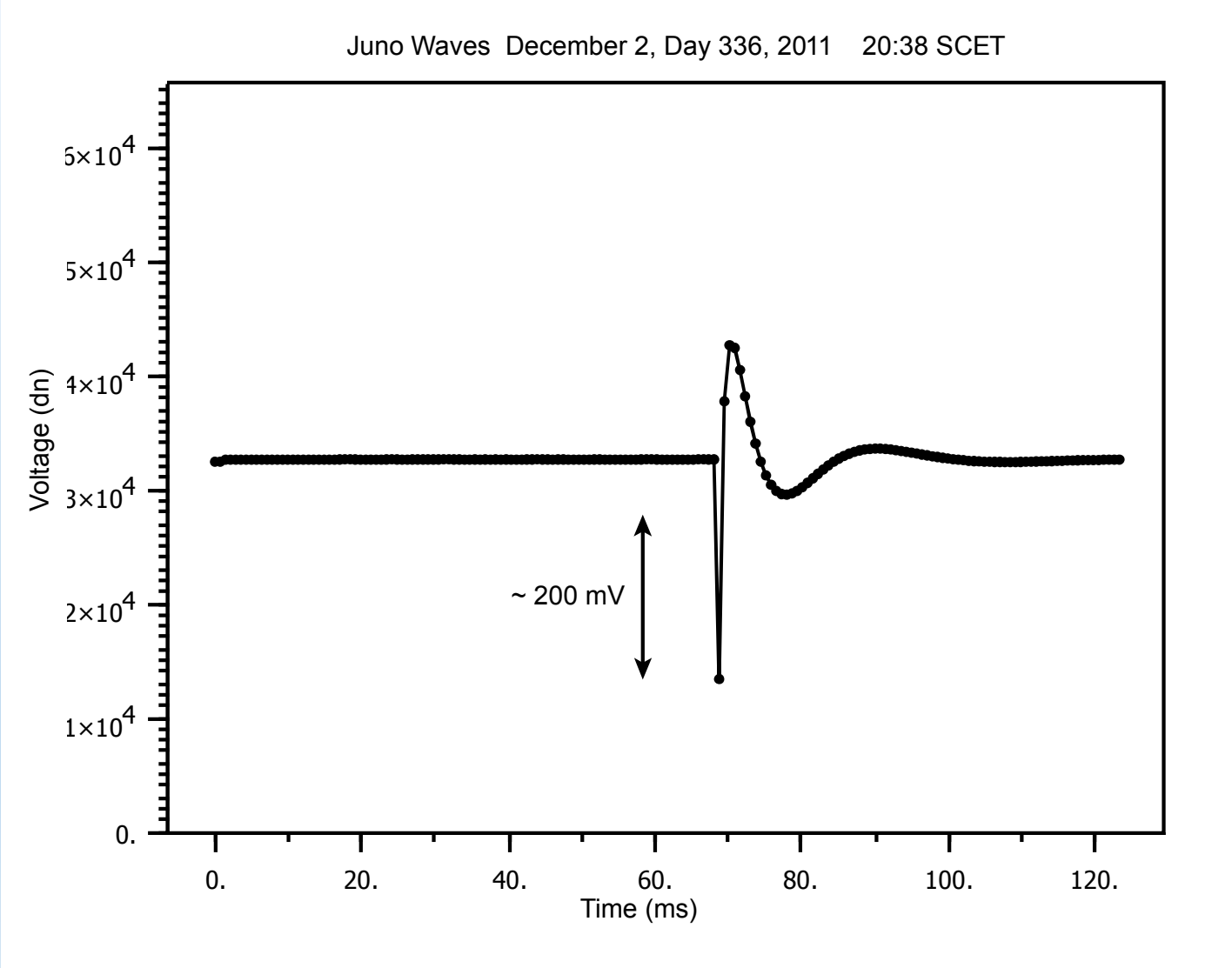
Interplanetary Shock Associated with X4.9 flare on 2/25/2014



- Class X4.9 flare occurred early on 25 February
- Associated with coronal mass ejection
- Juno/Waves observed type III solar radio emission
- Disturbance propagated to Juno as an interplanetary shock shown here
- Upstream plasma oscillations caught in Waves burst mode.



Juno Dust Impact



Earth-based Supporting Observations

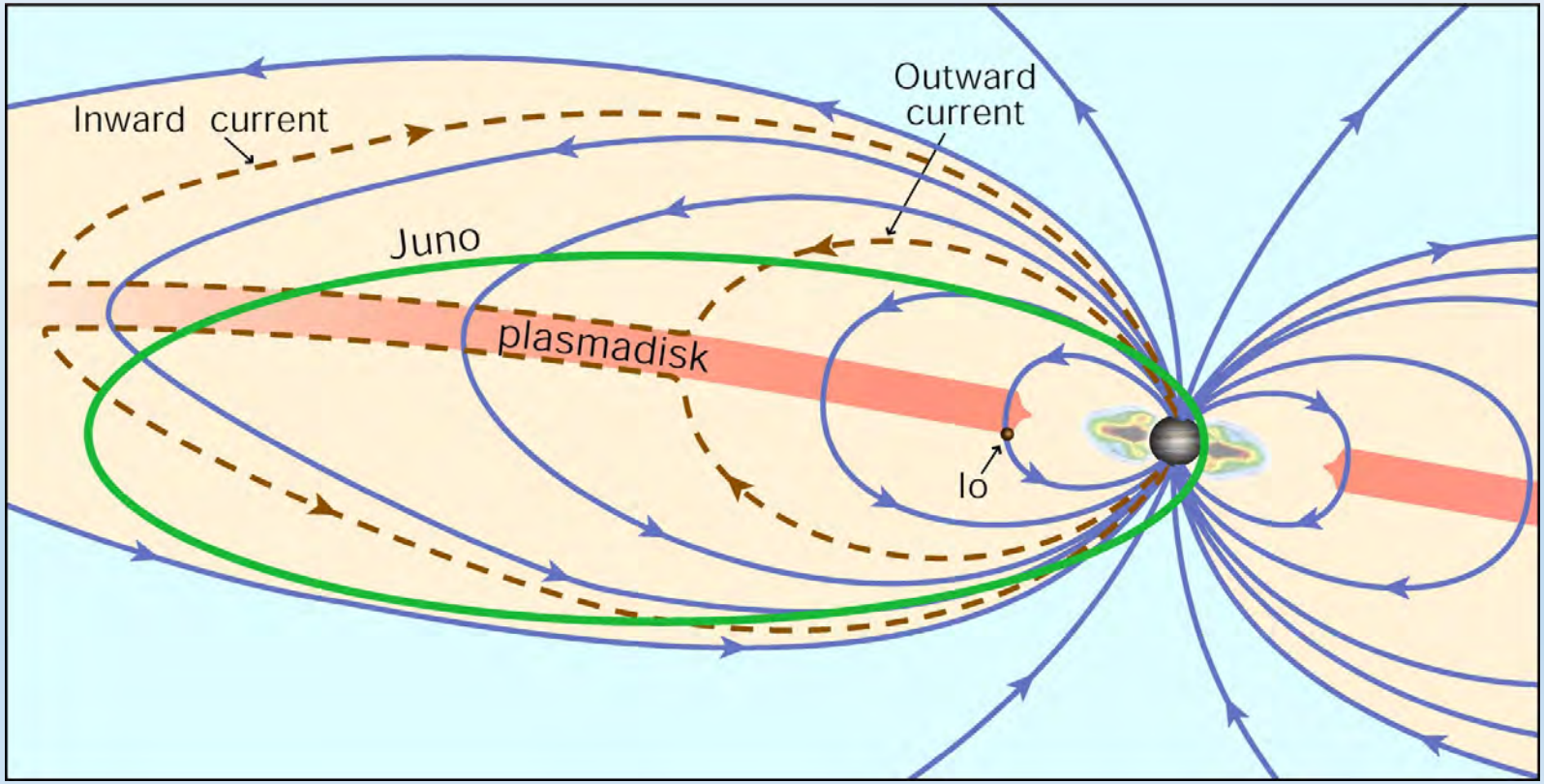
- Glenn Orton is responsible for organizing Earth-based observations in support of the Juno mission
  - Amateurs
  - Professionals
- Specifically for auroral physics, professional support is expected from:
  - HST UV (e.g. Nichols Cycle 23 coinciding with Juno's orbit insertion)
  - IRTF H_3^+
  - Giant Telescopes: COMICS, VISIR, CanariCam (Mid-IR)
- Philip Zarka was asked to coordinate ground-based decametric radio observations under an ad-hoc group named "Juno Ground Radio":
  - Nançay Decameter Array (France)
  - LOFAR (various European locations)
  - UTR-2, URAN 1-4 (Ukraine)
  - LWA, LWA1 (USA)
  - Tohoku U., Fukui Inst. Tech., U. Elect. & Comm., Kochi U. (Japan)
  - Others

Summary

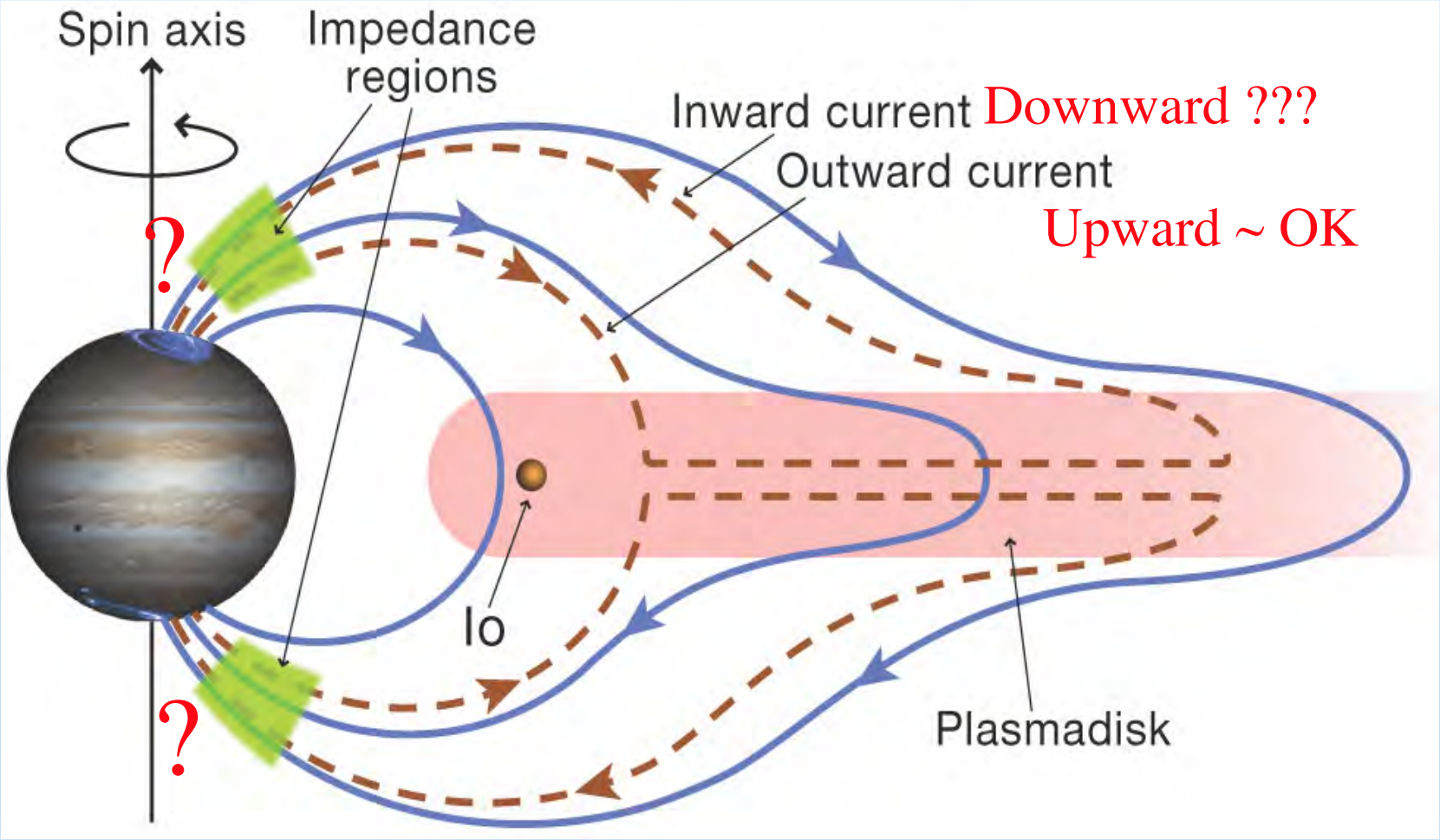
- The exploration of the polar magnetosphere is a basic objective of Juno.
- The polar orbit with very low periapsis is ideal to survey the expected auroral acceleration region.
- Juno has a well-balanced payload allowing a comprehensive examination of auroral processes at Jupiter
- Juno Waves investigation should allow comparisons with the terrestrial auroral situation, thereby advancing our understanding of Jupiter's polar magnetosphere.
- Arrival on July 4, 2016!

UVS and JIRAM observe auroral emissions on approach & departure

In situ instruments measure particles & fields over poles and in plasma disk



The aurora is the signature of Jupiter's attempt to spin up its magnetosphere



Hill; Cowley et al.,