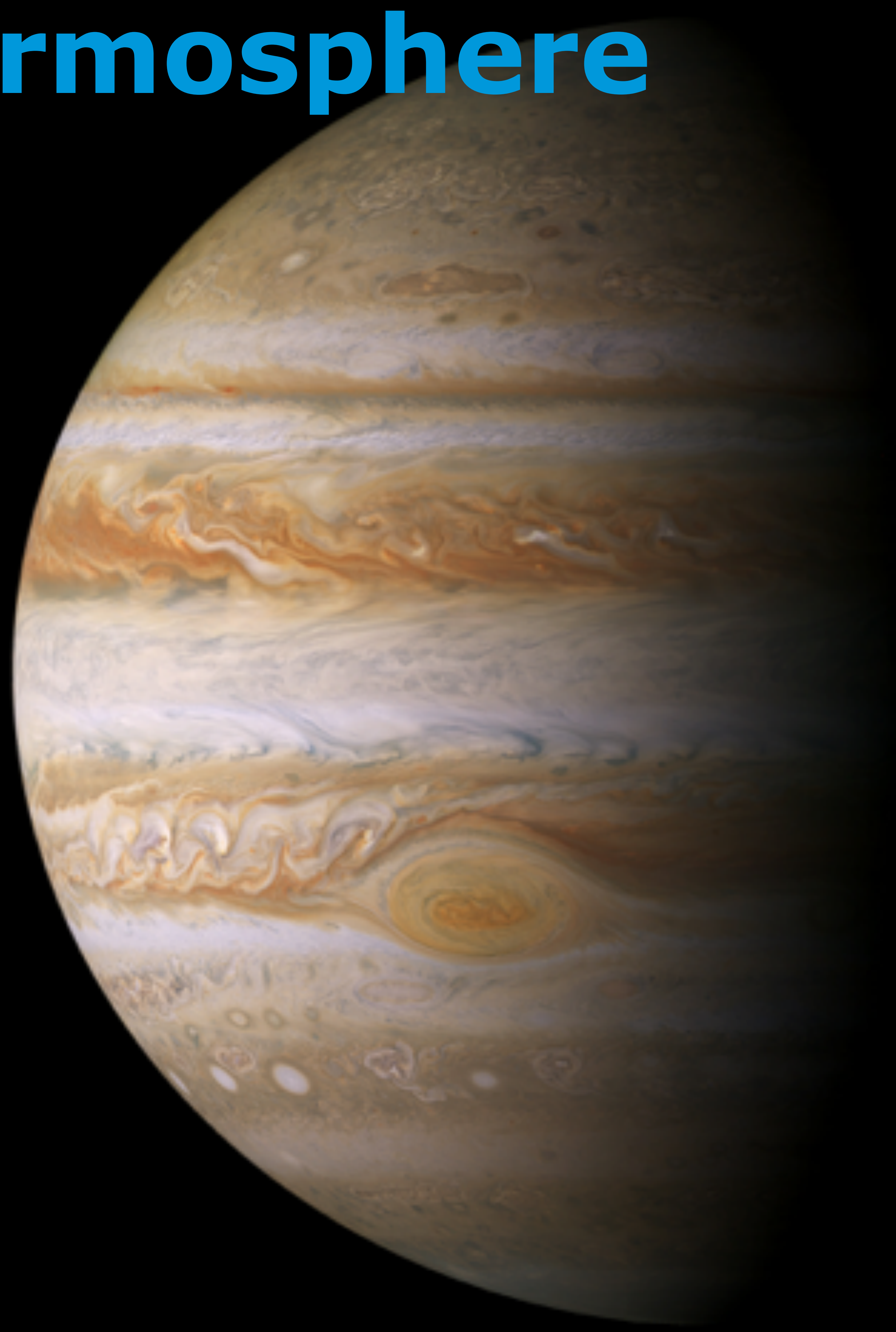
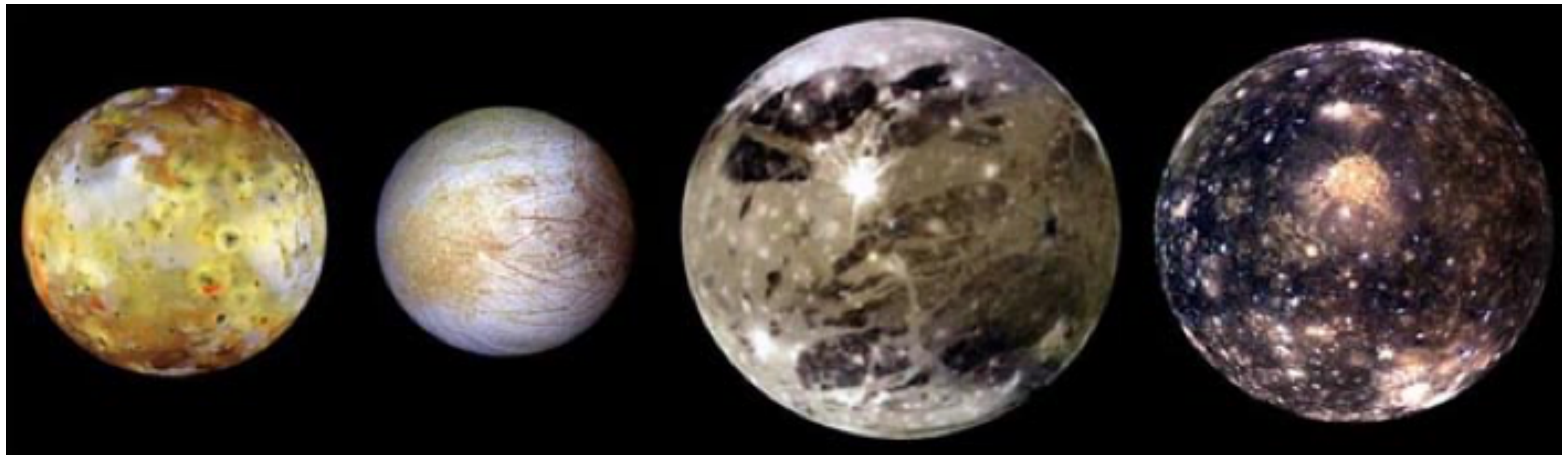
Magnetosphere – Ionosphere – Thermosphere coupling at Jupiter



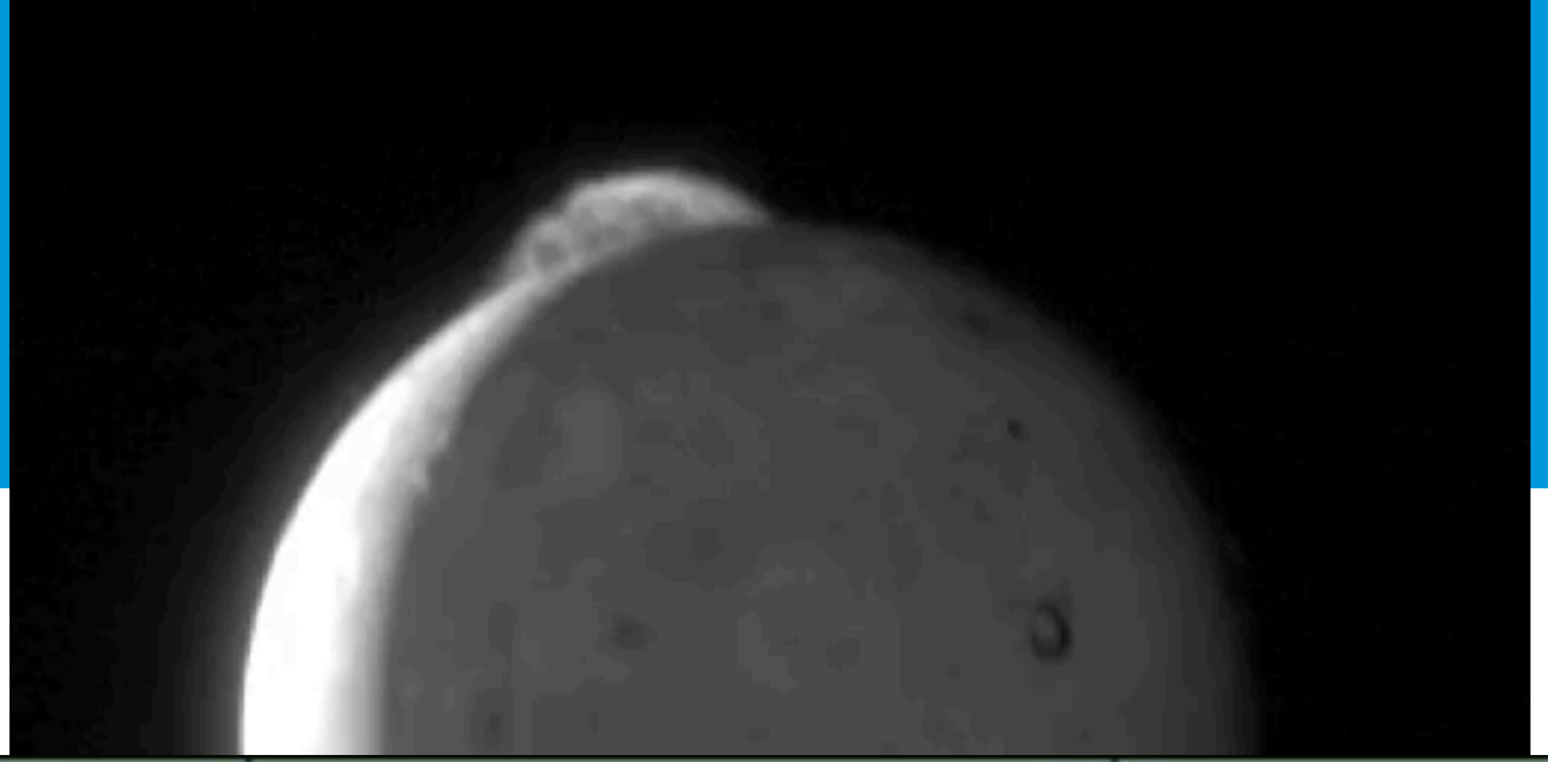
Japheth Yates
Mentor: Nicolas Altobelli

The Jovian system

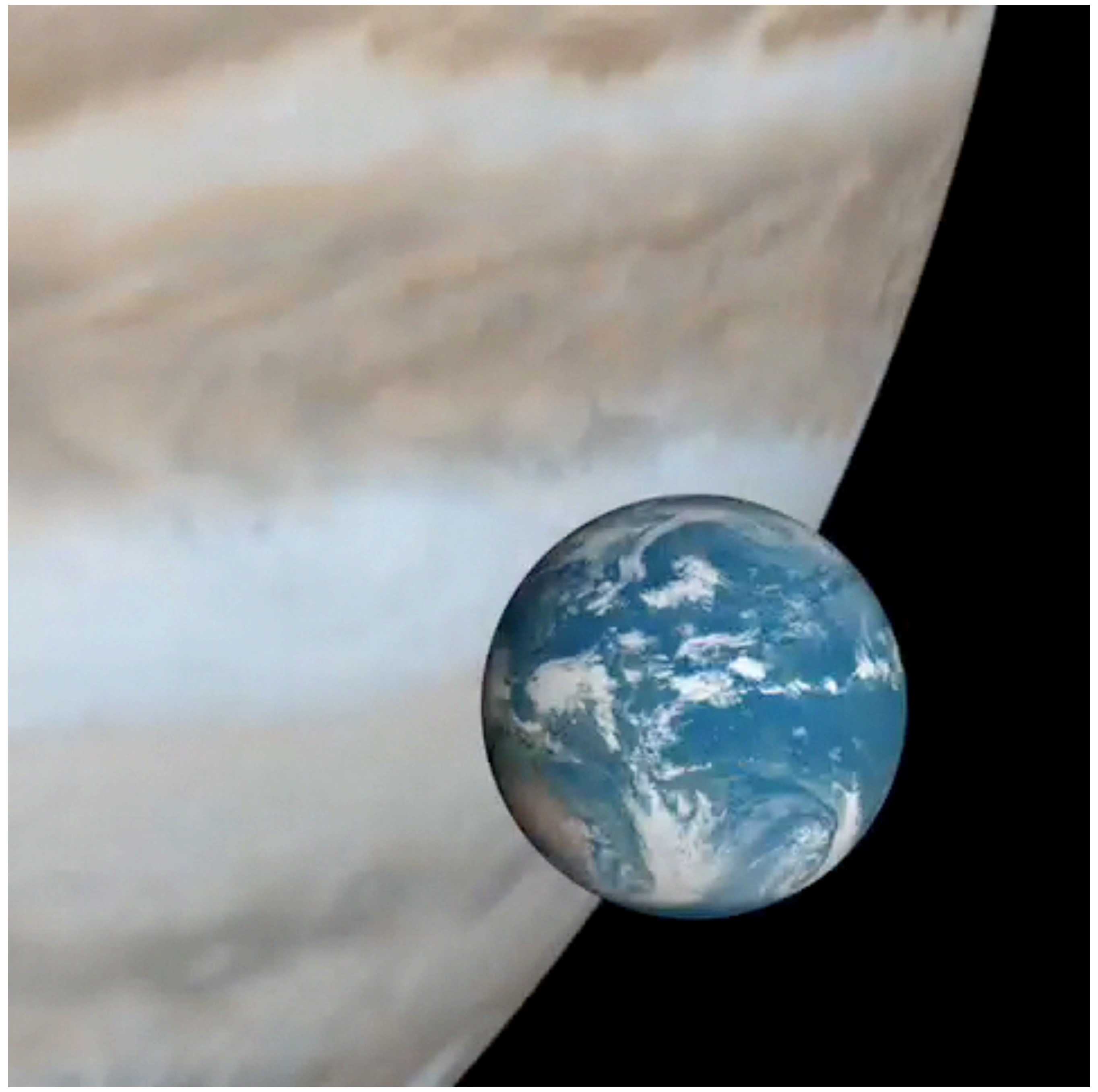
- Largest planet ($R_J \sim 11xR_E$)
- Atmosphere composed of molecular Hydrogen (~90%) and Helium (~10%)
- 4 Galilean moons: Io, Europa, Ganymede and Callisto
- Magnetosphere is largest object in solar system ($M_J \sim 20{,}000\ M_E$)

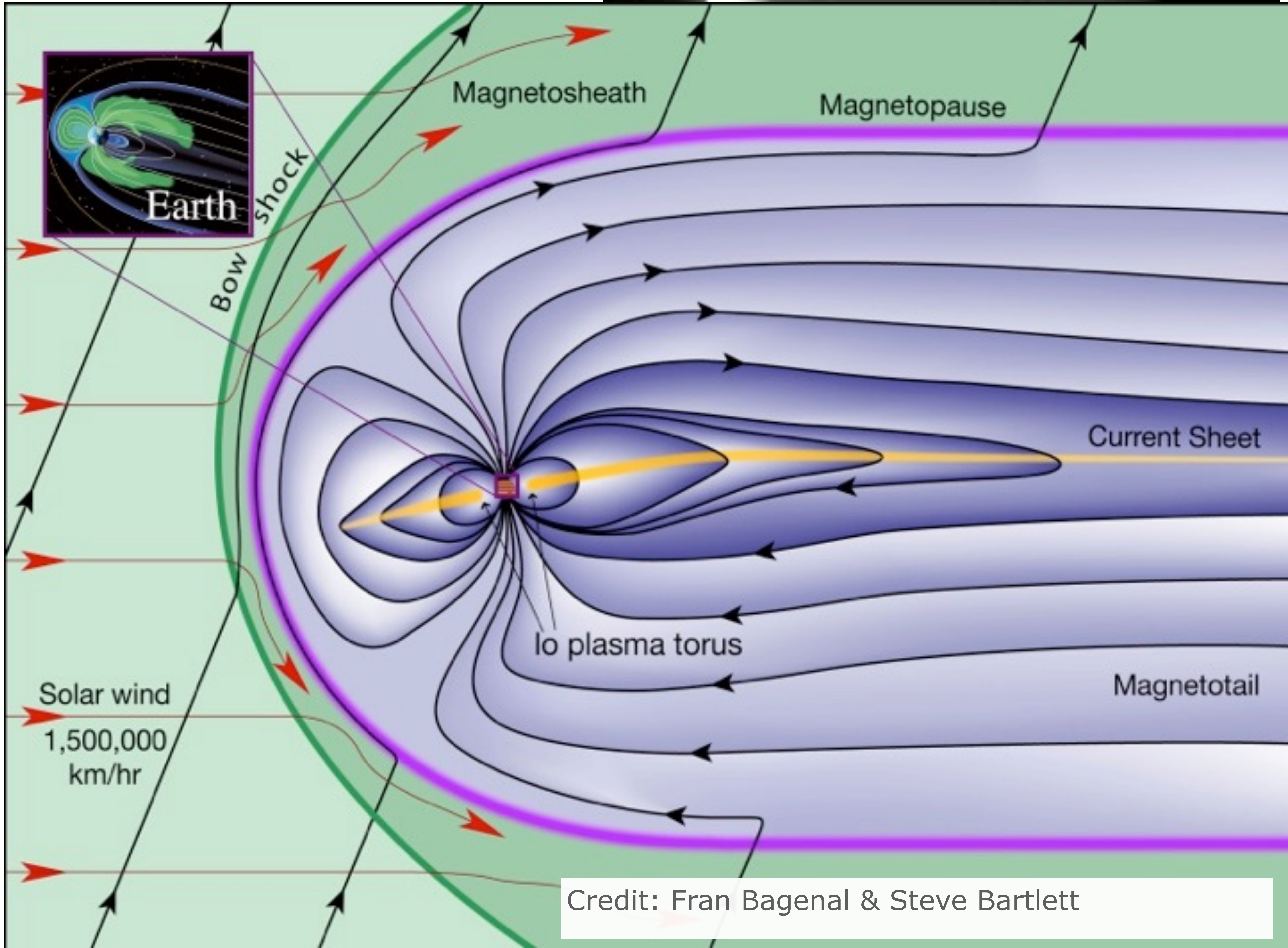


The Jovian magnetosphere



- Magnetosphere is controlled by internal sources:
  - Rapid planetary rotation rate (~10 hrs)
  - Internal plasma source… Io (~1000 kg/s)



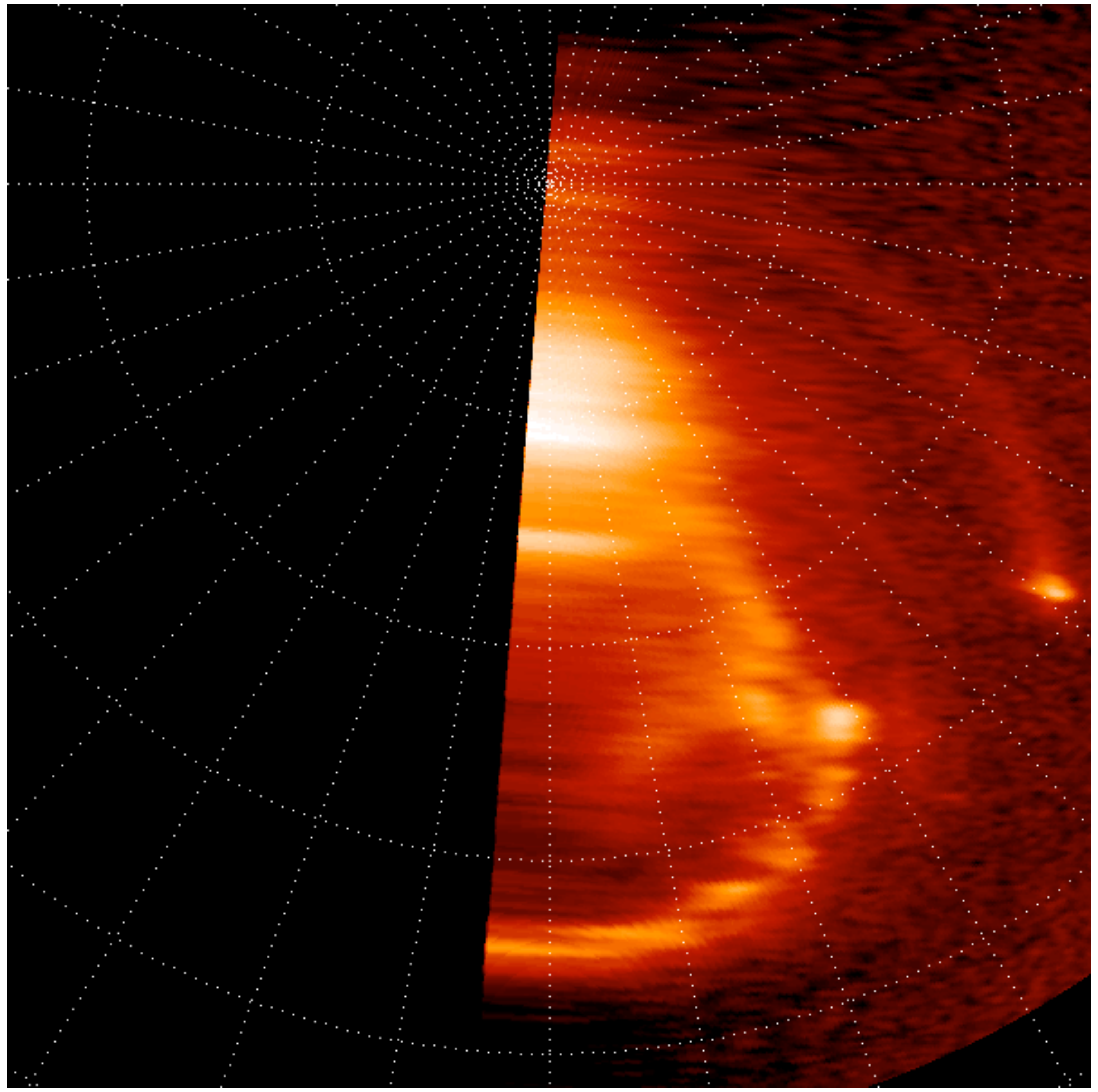


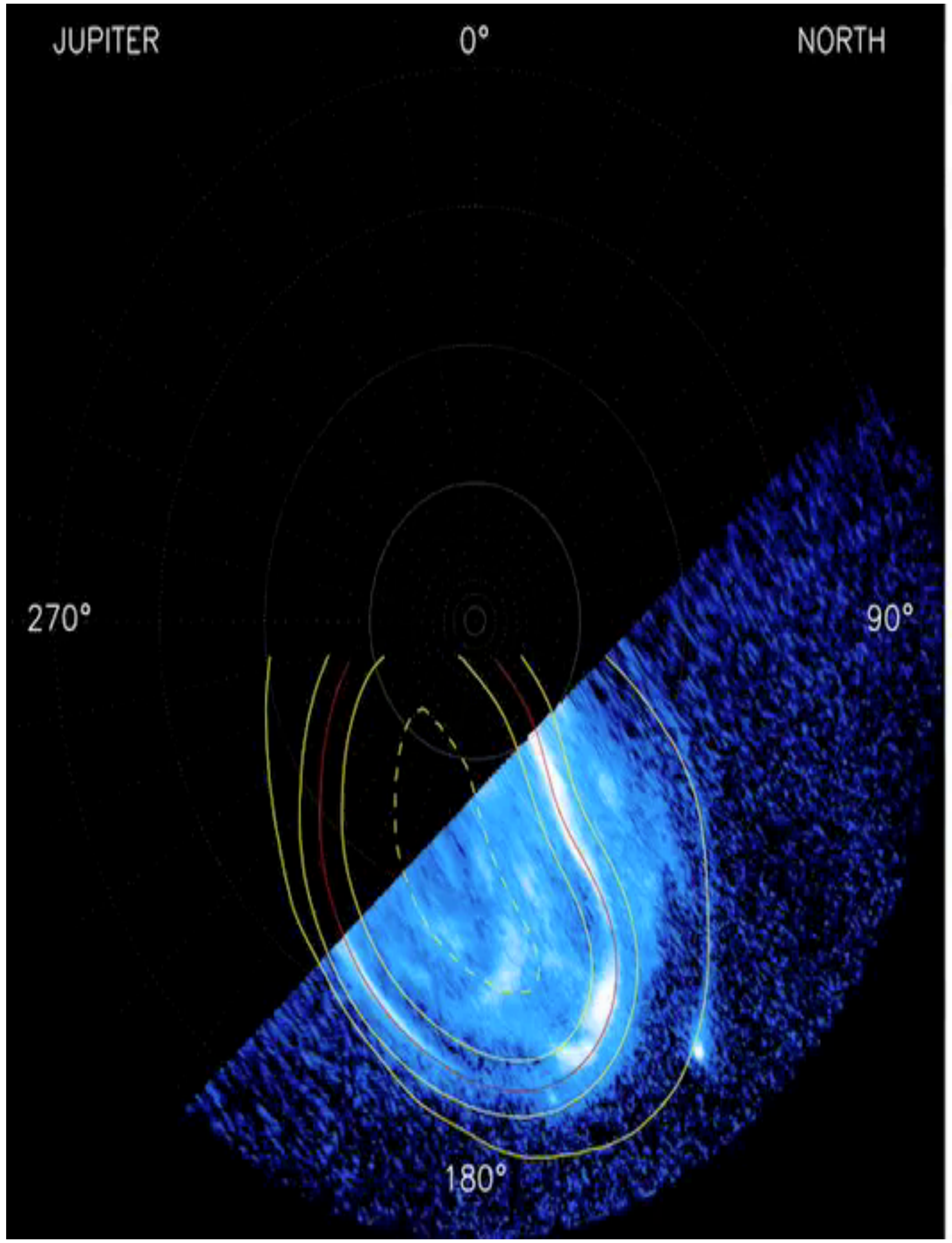
Credit: Fran Bagenal & Steve Bartlett

Why study the Jovian system?

Aurora:

- Main auroral emission at Jupiter is purely driven by internal processes - corotation enforcement currents
- Aurora due to electromagnetic interaction with Galilean moons
- Polar auroral emission is poorly understood
  - magnetospheric dynamics e.g. plasma release
  - Solar wind driven
- A lot of variability over different timescales



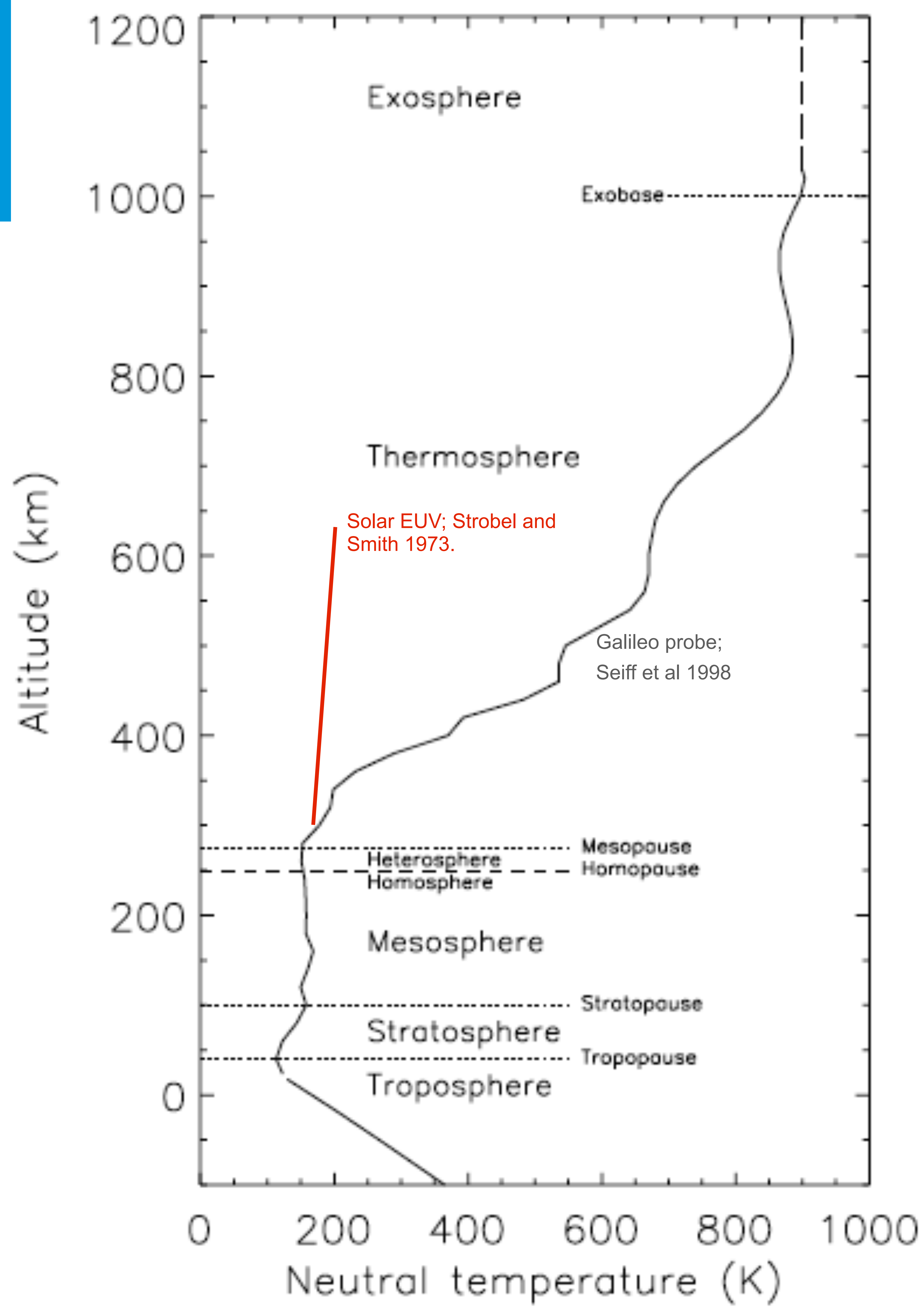


Credits: J. Clarke, J. Nichols and D. Grodent

Why study the Jovian system?

Gas giant energy crisis:

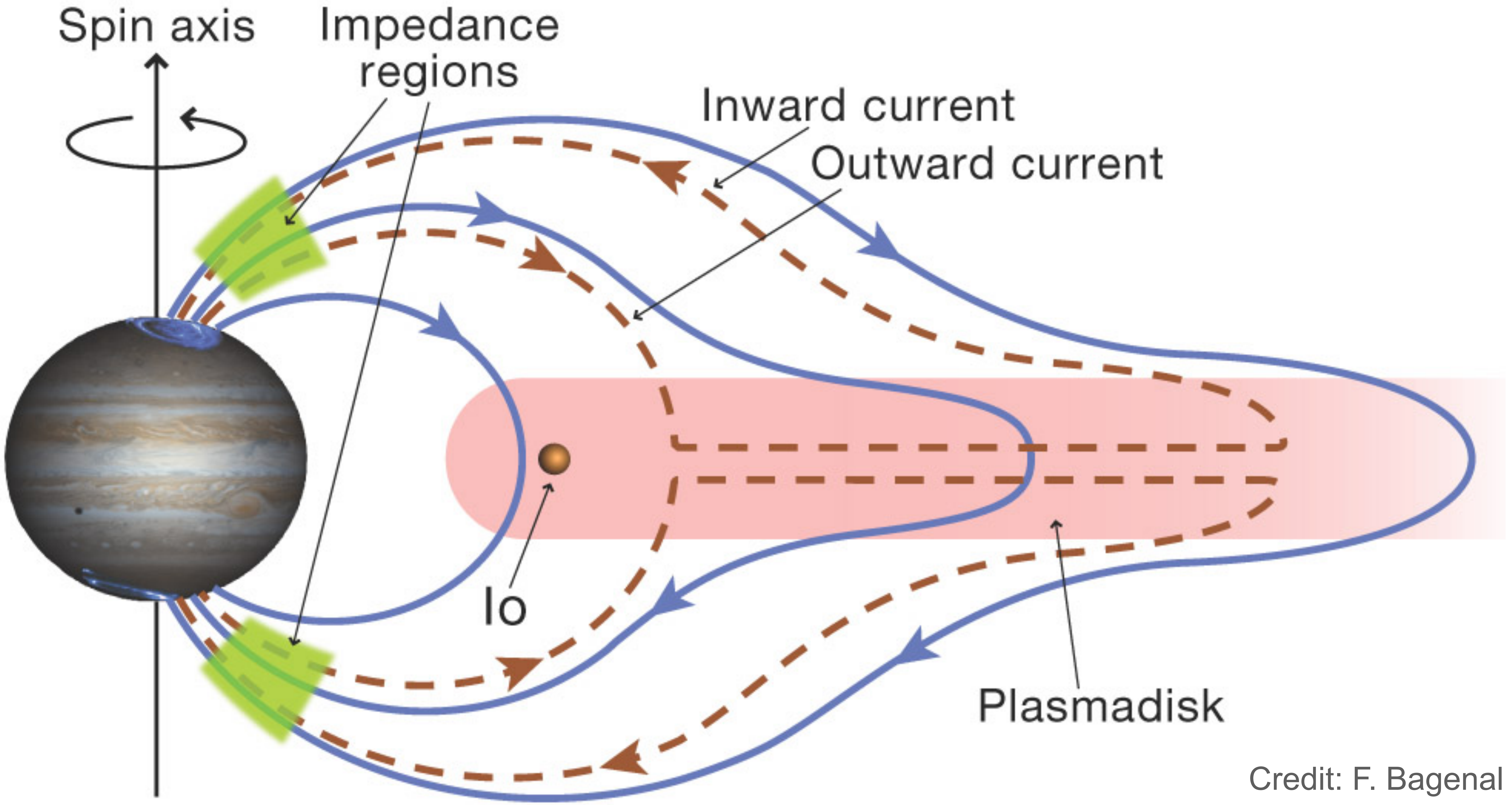
- ➢ Upper atmosphere is ~700 K hotter than expected
- ➢ Interaction with magnetosphere likely source:
  - Joule heating
  - Ion drag
  - Precipitation heating
- ➢ Current steady state modelling efforts can't solve the problem
  - Many simplifying assumptions in models e.g. 1D/2D atmosphere
  - Time dependence not included
  - Some physics not included



Smith PhD thesis 2006

What is magnetosphere-ionosphere coupling?

Describes how angular momentum and energy are transferred between a planet and its magnetosphere.



Credit: F. Bagenal

How do I study the Jovian system?

Simulate how Jupiter's magnetosphere couples to its upper atmosphere (ionosphere + thermosphere) and how this coupling influences Jupiter's

- coupling currents,
- aurora,
- thermosphere flows,
- thermosphere energy balance,

on both long and short time scales.

JASMIN 3D: 3D GCM coupled to a 1D magnetosphere

Magnetosphere

- 1-D
- 0.01 R_J resolution
- Torque balance: *ionospheric and magnetospheric currents, electric fields*

Optional Modules

Variable Pedersen conductance		✔
Inclusion of field-aligned potentials		
Local time selection (defaults to post-midnight)		
Temporal Treatment	Steady state	✔
	Transient: single pulse	✔
	Transient: multi-pulse	✔

ionospheric electric field, Pedersen conductance →

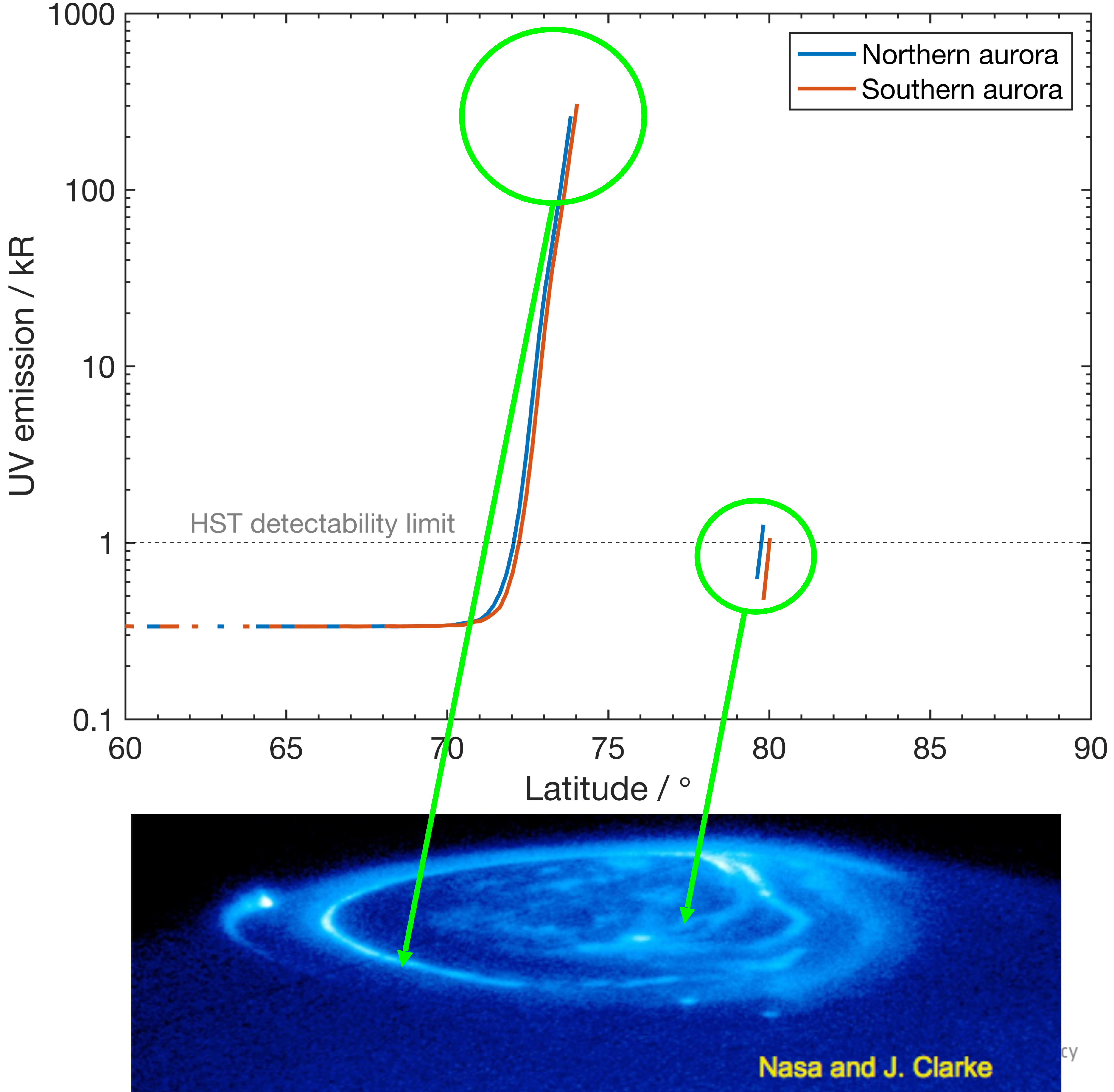
← **thermospheric angular velocity**

Atmosphere:

- 3-D
- 0.4° x 10° lat x long resolution
- 0.4 pressure scale height resolution
- H_2 , H and He atmosphere
- Continuity, momentum, and energy equations: *Joule heating, thermospheric temperatures & thermal winds, ion drag*

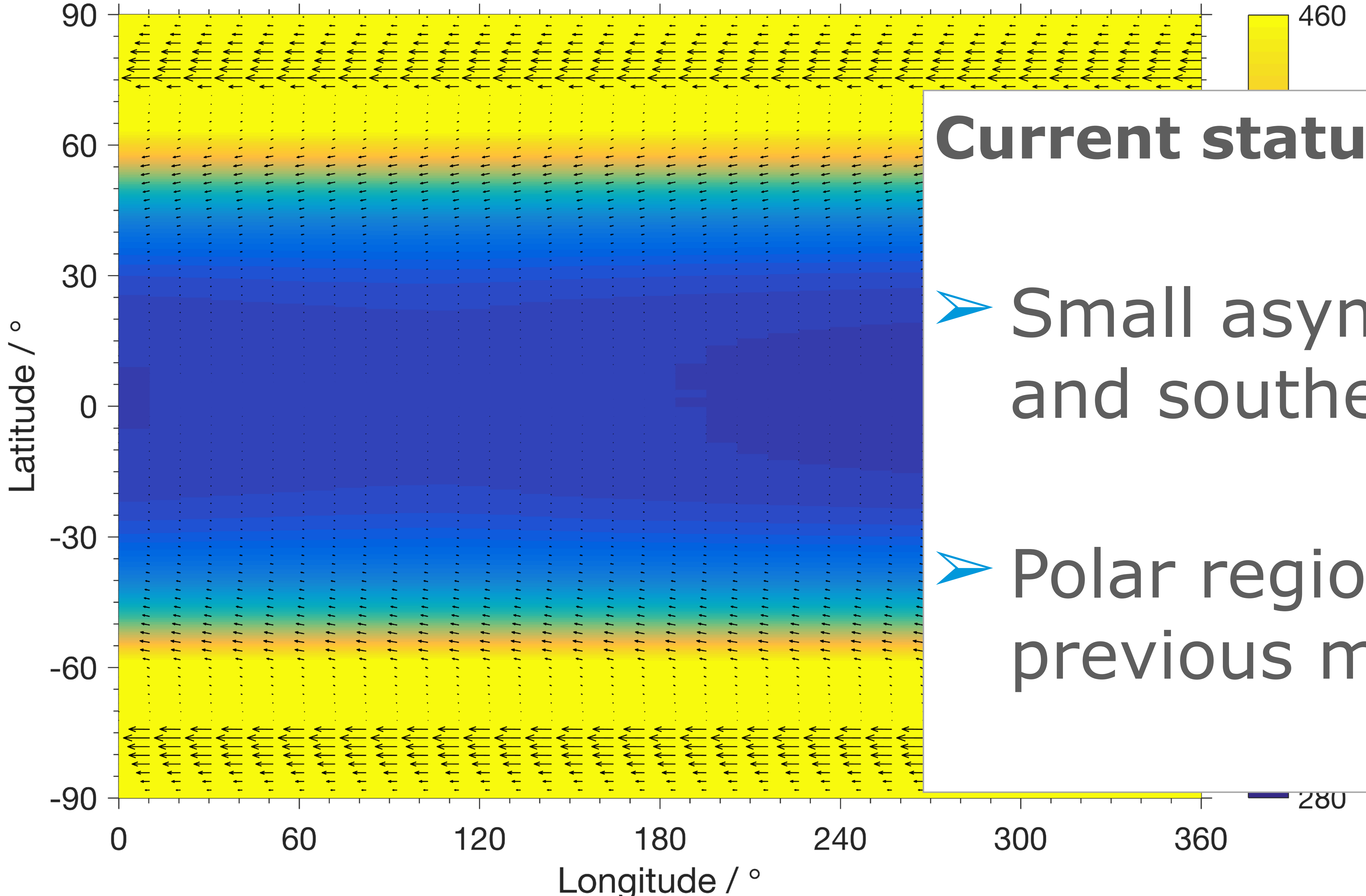
3D work: Main auroral emission

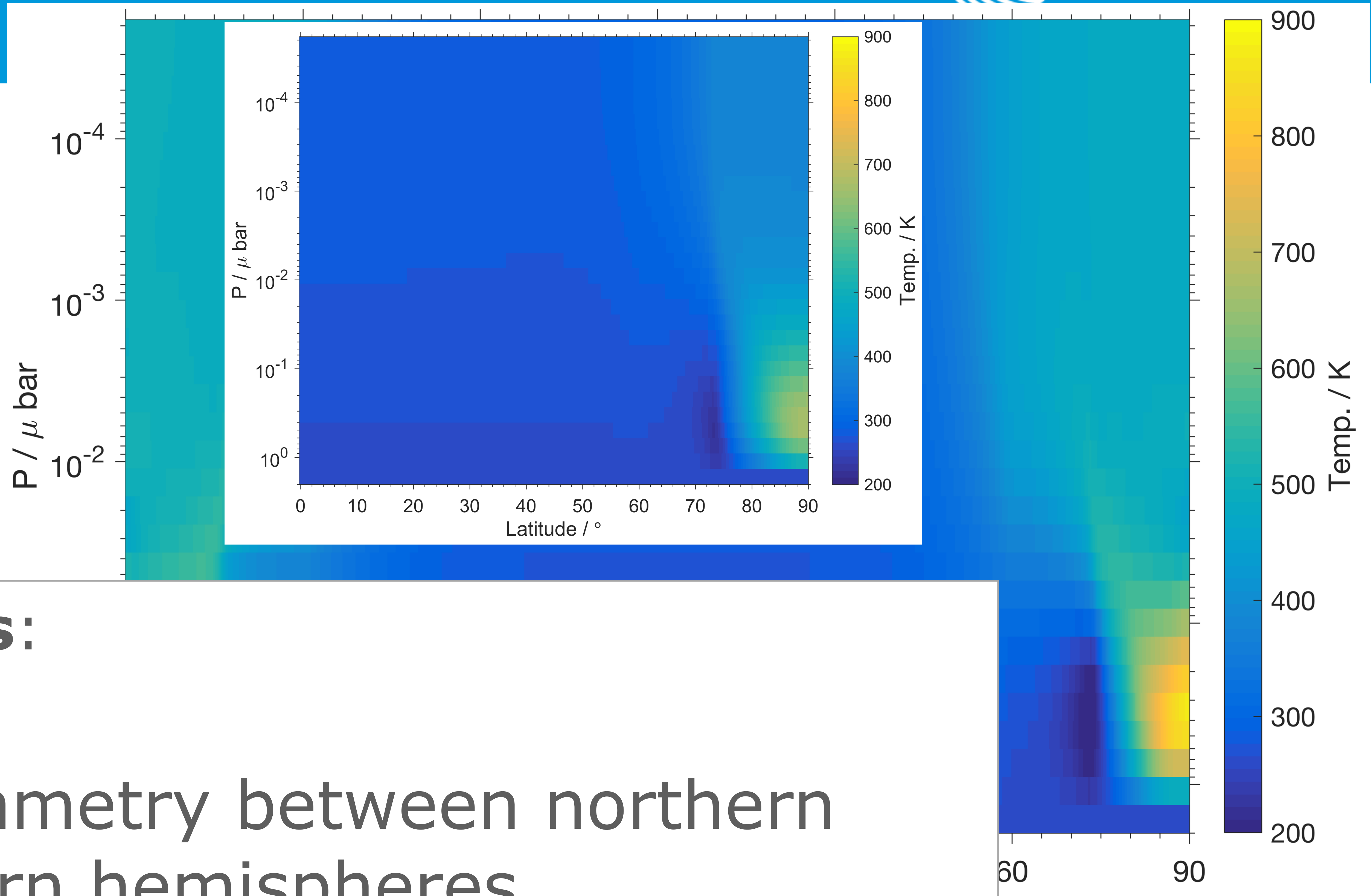
- ➢ Peak auroral emission ~74°
- ➢ Few 100 kR emission which is typically observed
- ➢ Slight poleward emission but magnetosphere is prescribed here
- ➢ Southern emission seems to be slightly greater than northern



3D work: Temperature distributions

- Atmosphere is warmer in 3D coupled case compared to 2D
- Mid-latitude sub-corotational jet is stronger in 3D





Current status:

- Small asymmetry between northern and southern hemispheres
- Polar regions are consistent with previous modelling and observations

Final thoughts

Conclusions:

- ➢ Still in model development phase
- ➢ Polar region currents, aurora and neutral temperatures and winds are consistent with simpler models and observations

Future work:

- ➢ Locate and fix source of hemispheric asymmetry
- ➢ Begin inclusion of a realistic tilted magnetosphere model