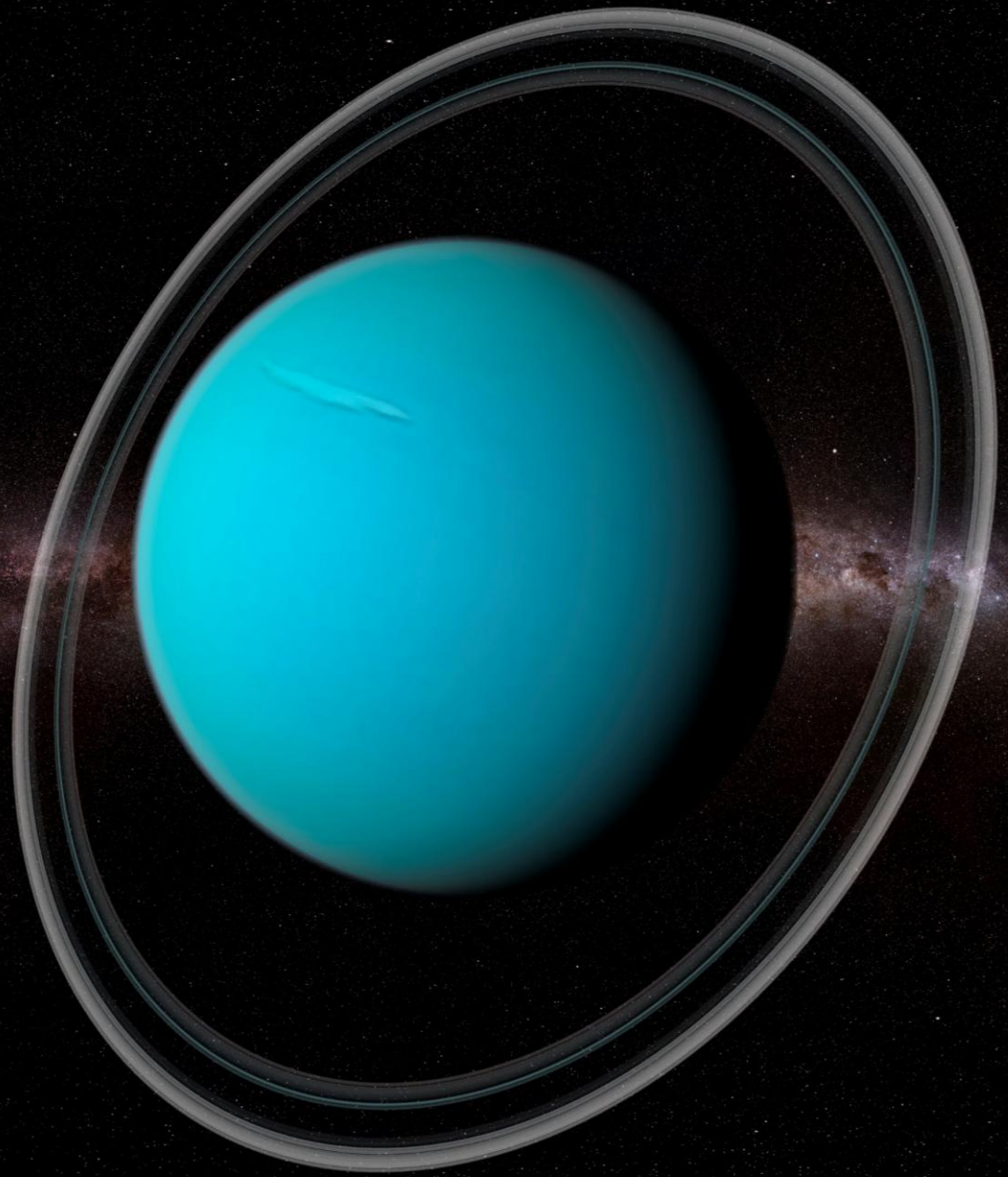

Space & Planetary Physics | Lancaster University

What Can X-Rays Tell Us About Uranus's Unusual Space Environment?

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Department of Physics
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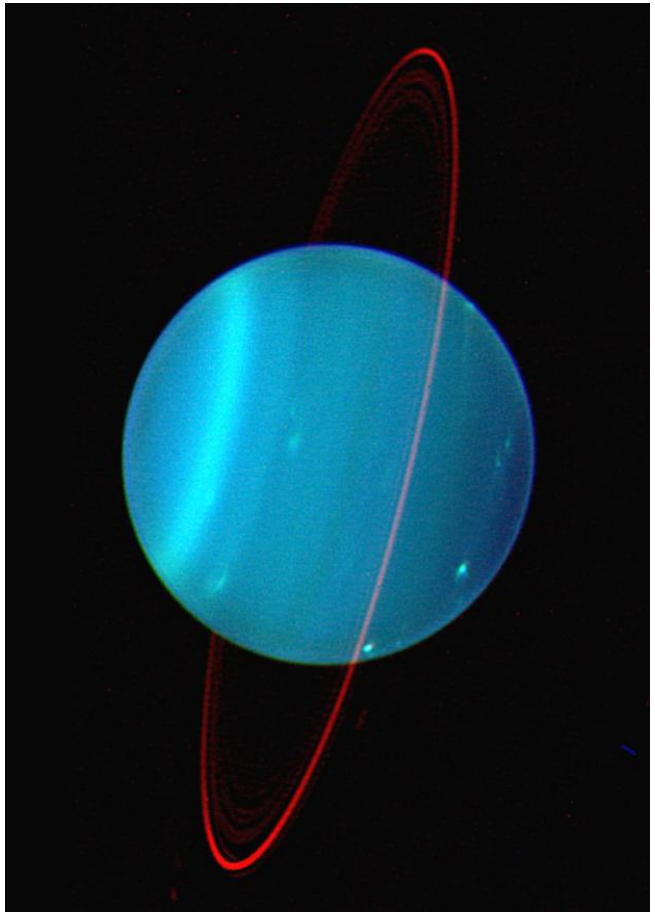
Background credit: Space.com

Uranus is a Mysterious Planet

- One of the most complex and unusual planets
- Orbits the Sun almost completely on its side
- Magnetic field tilted from the poles and offset from the centre
- Visited by Voyager 2 in 1986
- Complicated interaction with local space environment



Credit: NASA

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Uranus is a Mysterious Planet

- One of the most complex and unusual planets
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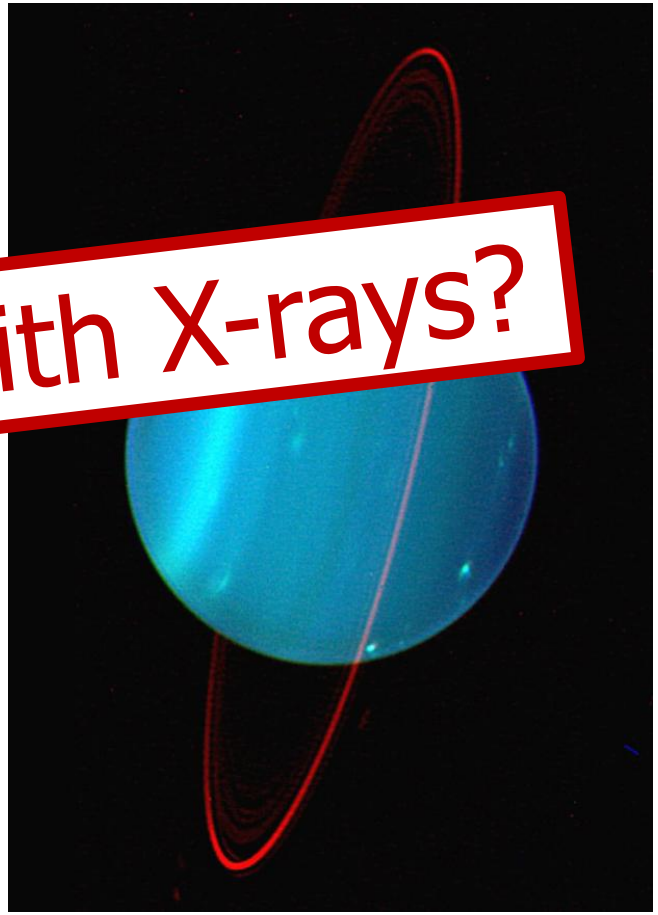
- Magnetic field tilted from the
- Voyager 2 in 1986
- Complicated interaction with local space environment

Can we image this interaction with X-rays?



Soft X-Ray Emission and Imaging

- Neutrals and charged particles interact
  - Produces X-ray emission
- Novel technology aims to provide global, dynamic view of systems

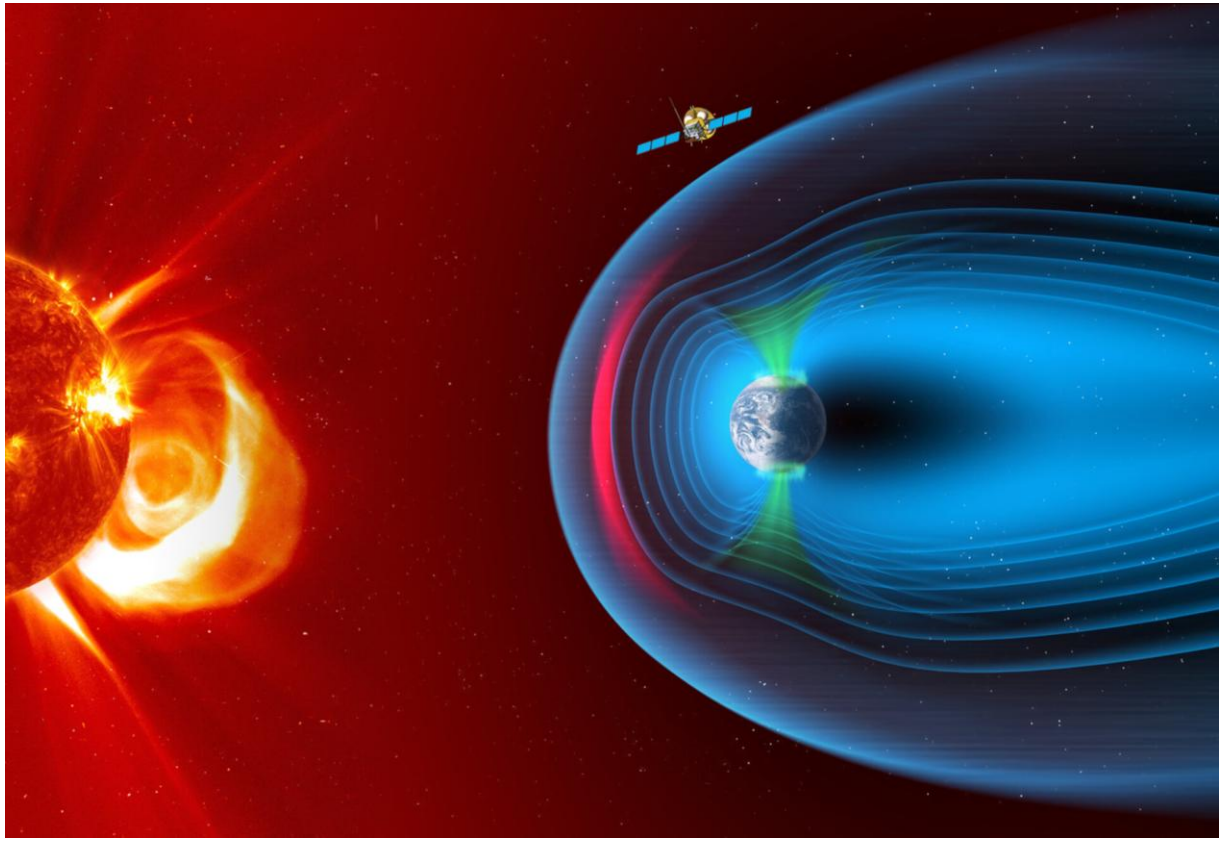
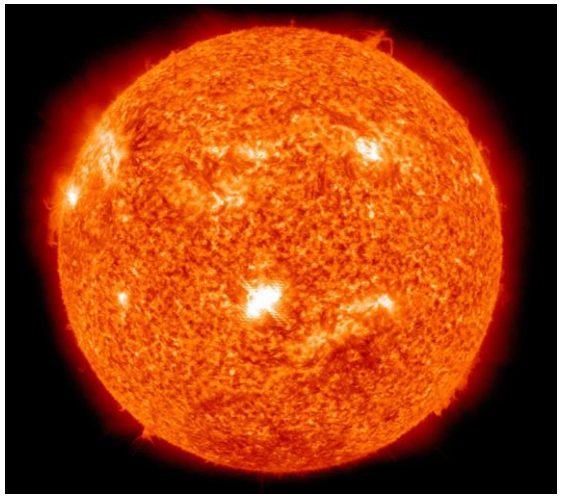


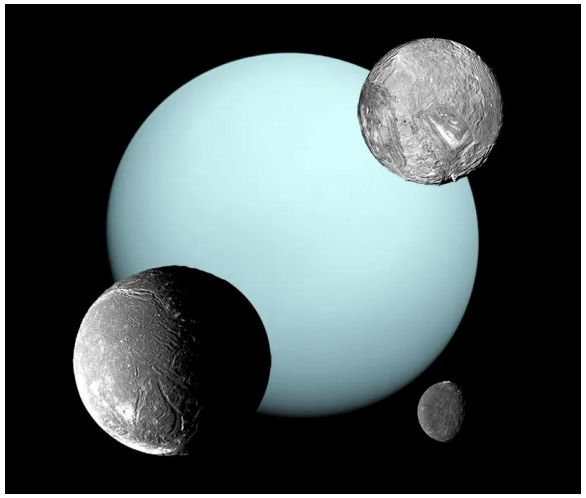
Image credit: ESA

What Dictates X-Ray Emission Rate?



Charged particle density

×



Neutral density

×

Relative speed

×

Interaction cross section

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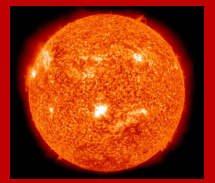
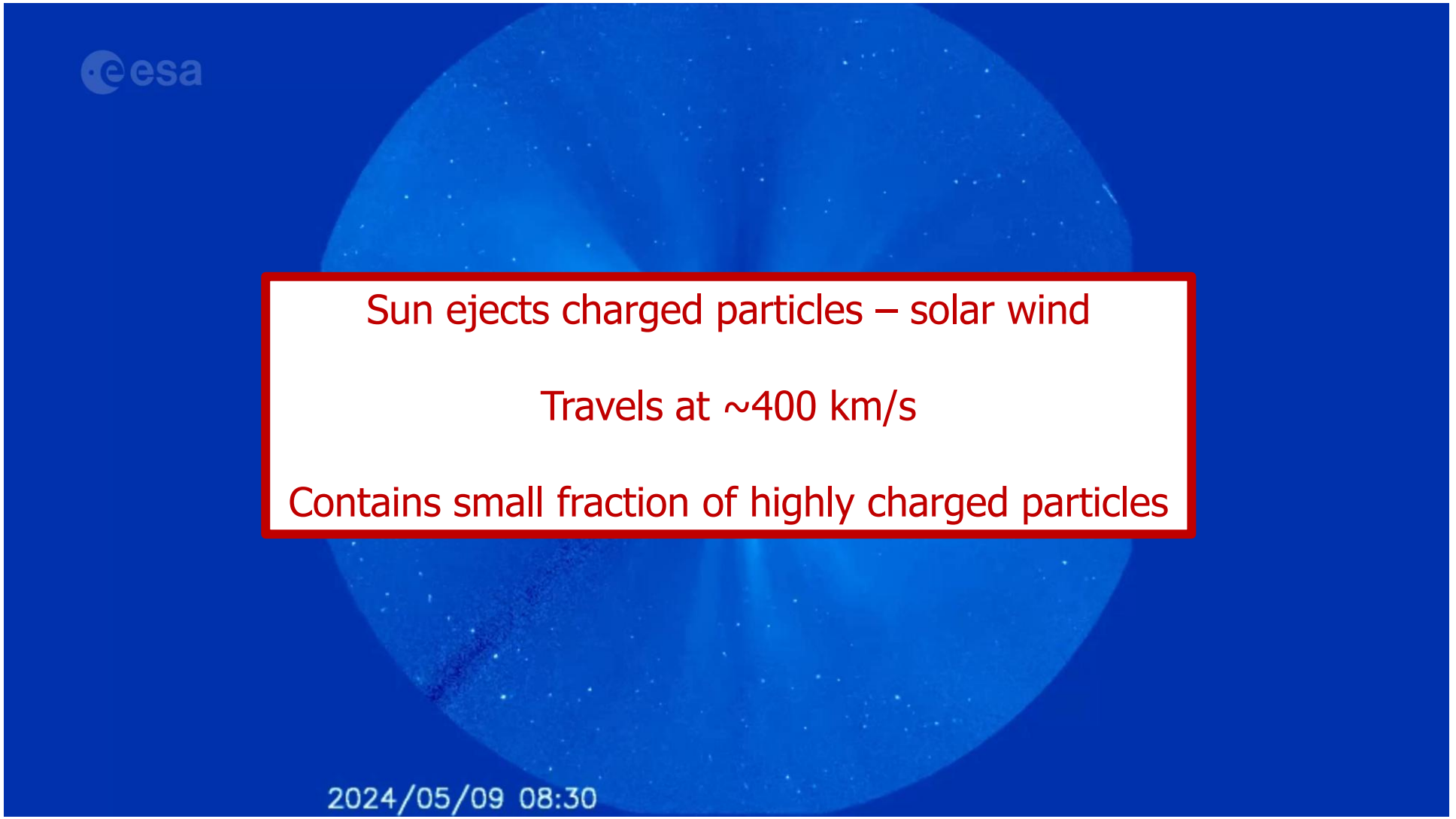
Uranus Does *Not* Exist in a Vacuum





Sun ejects charged particles – solar wind

Travels at ~400 km/s

Contains small fraction of highly charged particles

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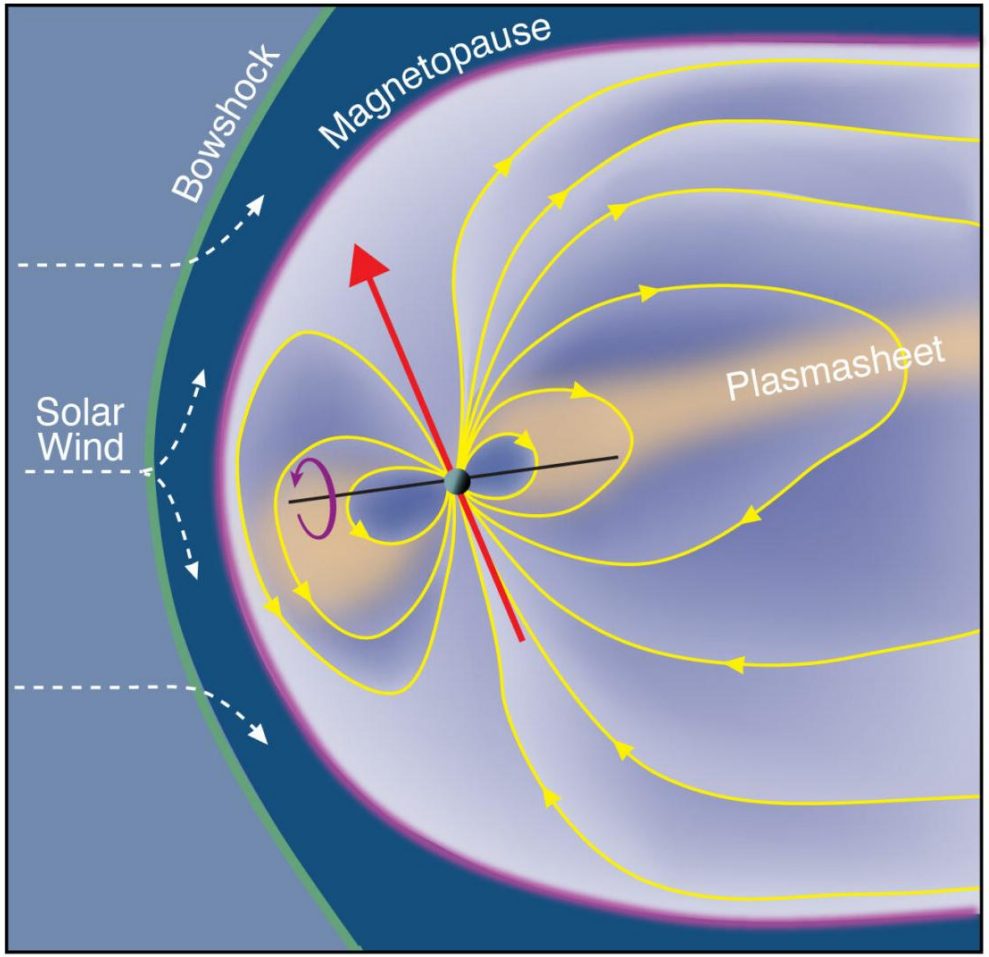
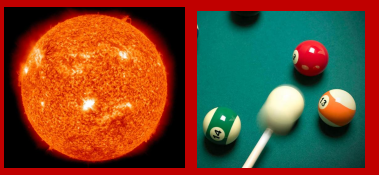
Uranus's Magnetosphere

- Magnetic field carves cavity into solar wind
- Complicated magnetosphere with seasonal and daily variations
- Regions of interest
  - Bow shock
  - Magnetosheath
  - Magnetopause

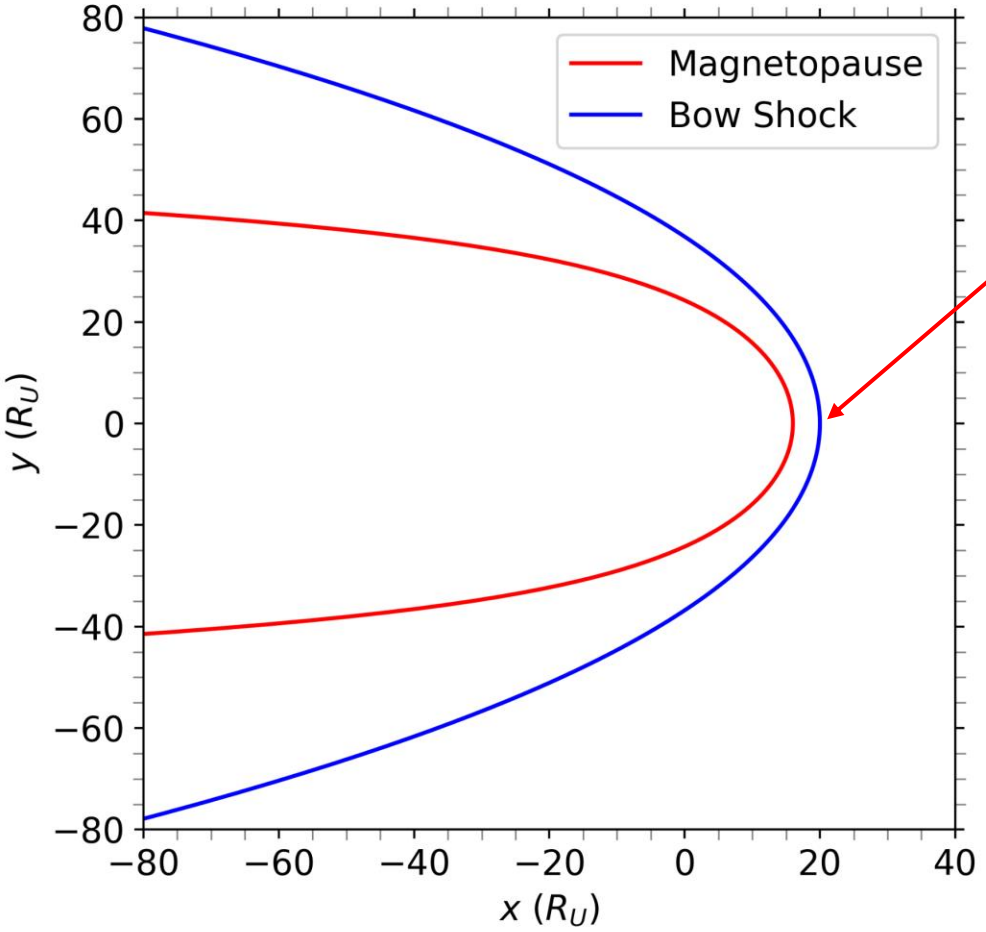


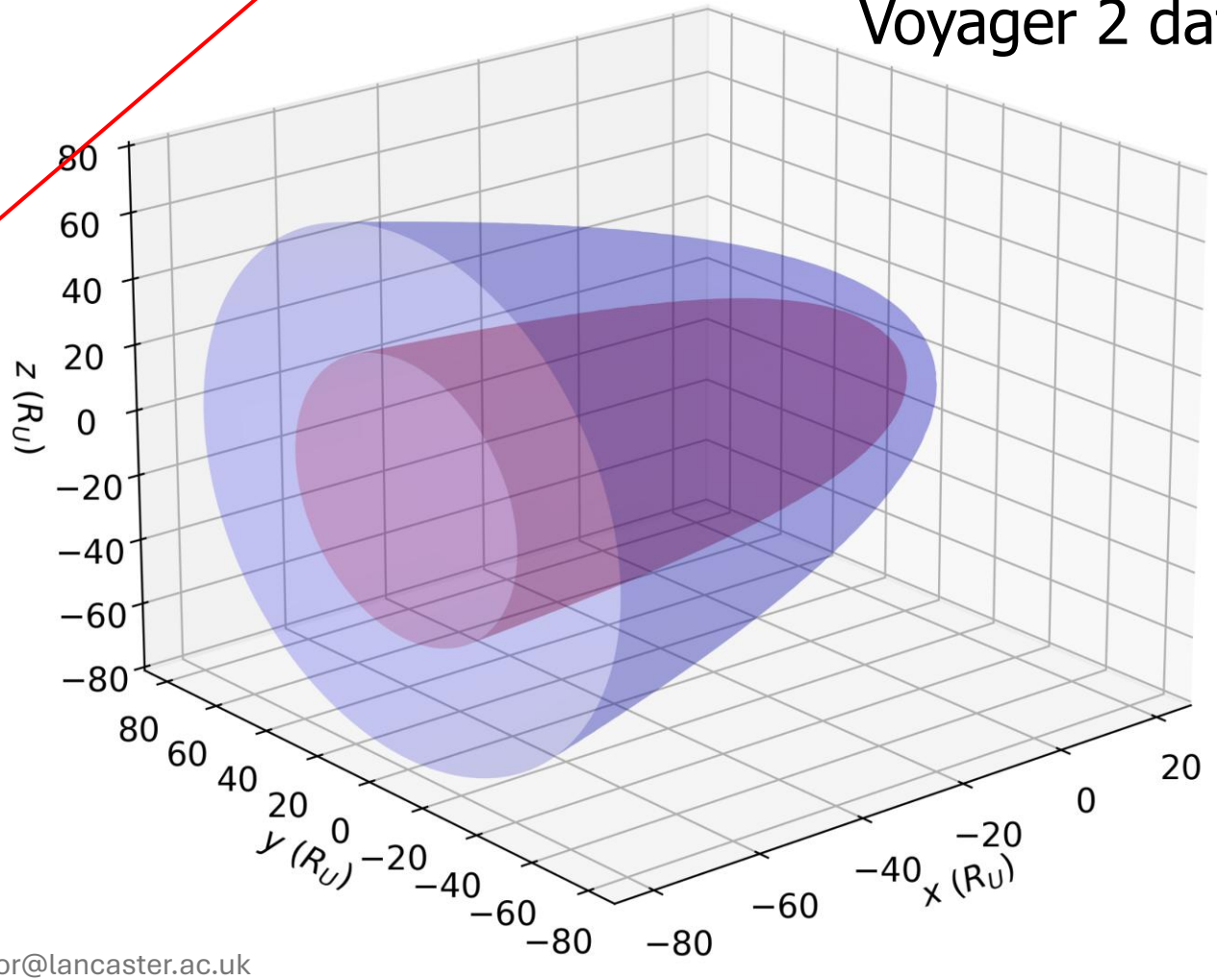
Credit: Bagenal & Bartlett

Magnetopause and Bow Shock Surfaces



‘Standoff distances’ estimated from Voyager 2 data





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The Icy Moons of Uranus

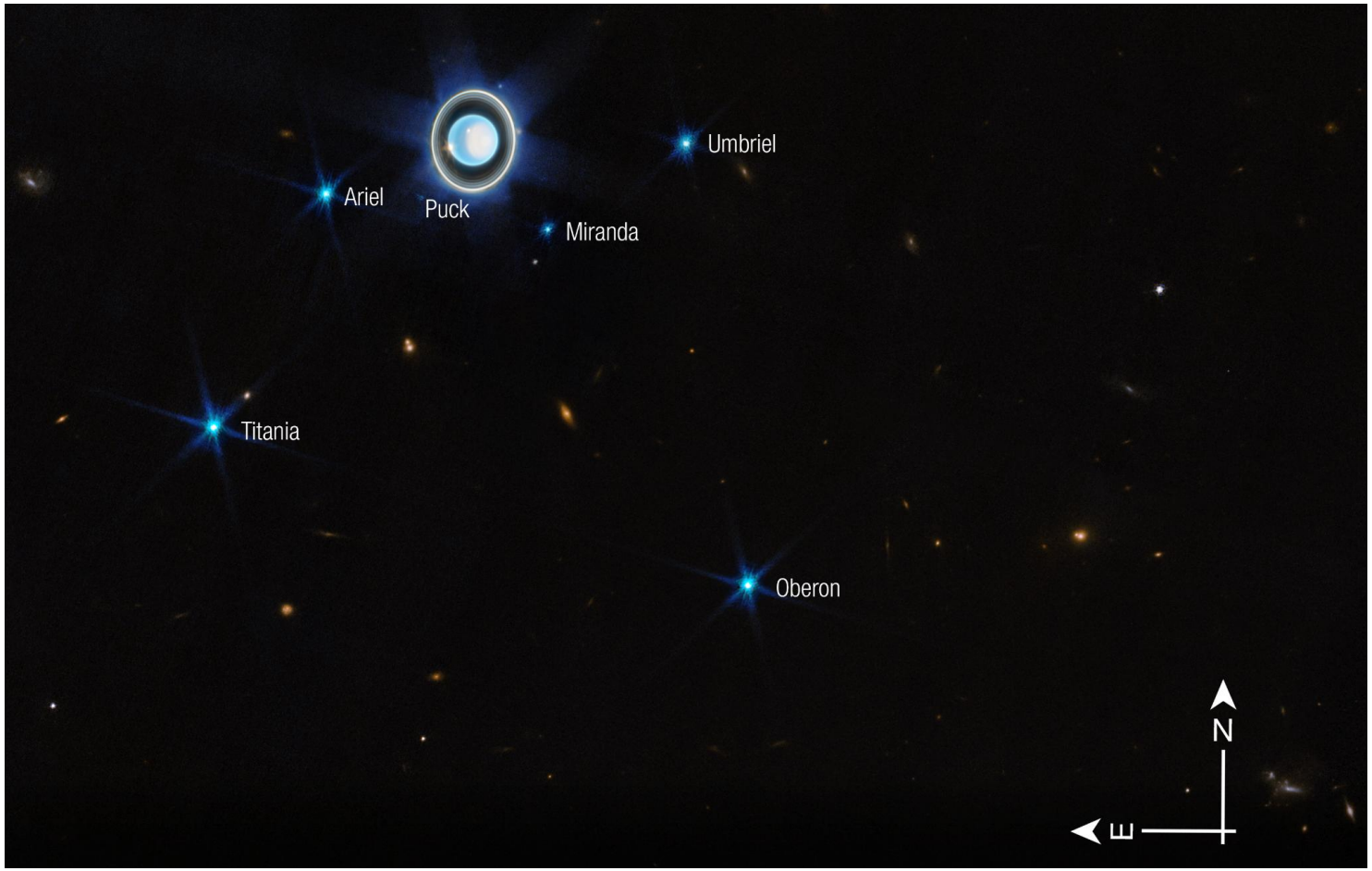

Image credit: JWST, NASA

- Moons may provide water-based particles to system
- Source rates not well constrained

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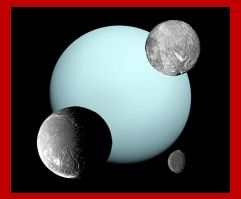
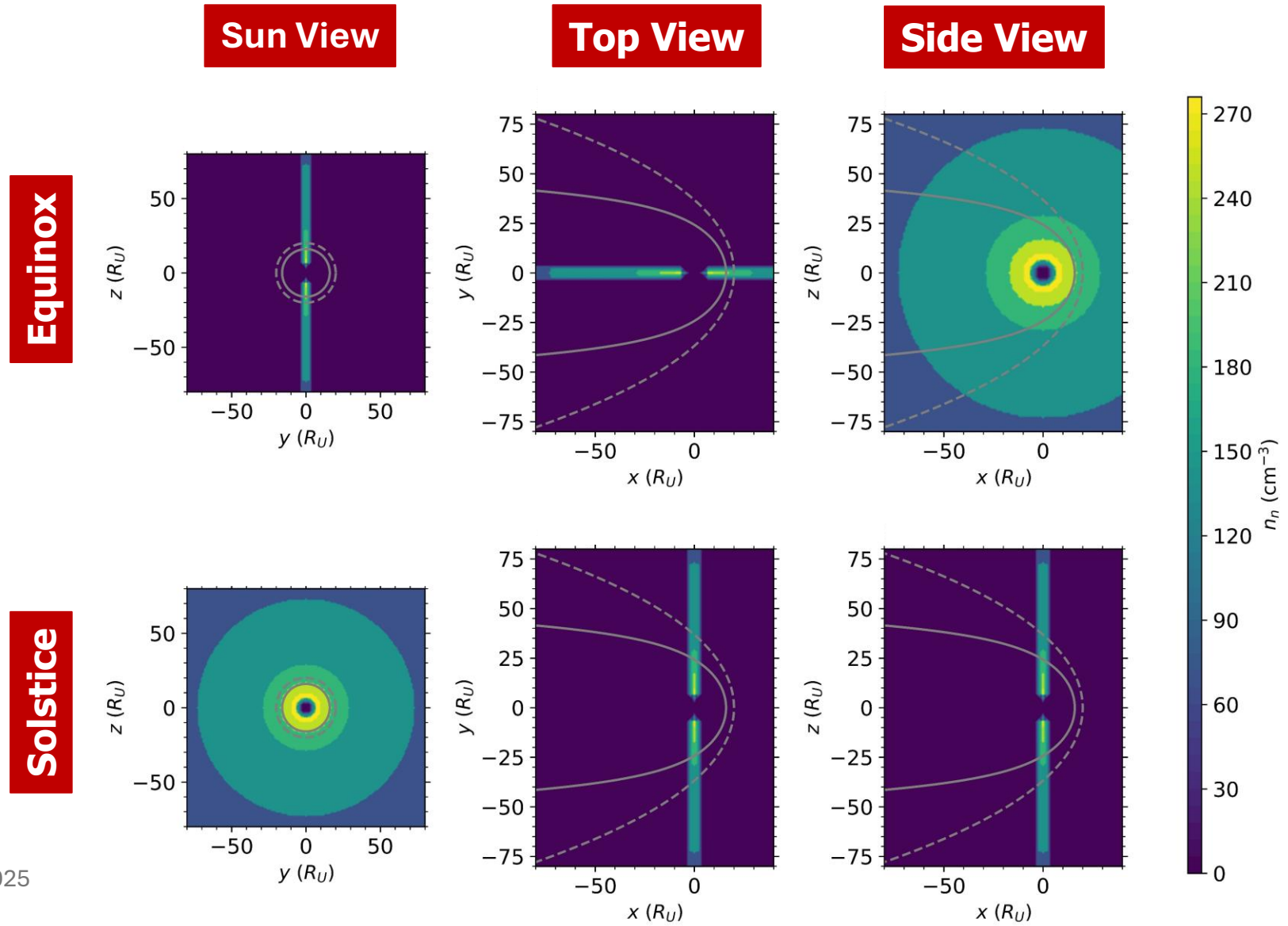
Where are the Neutrals?



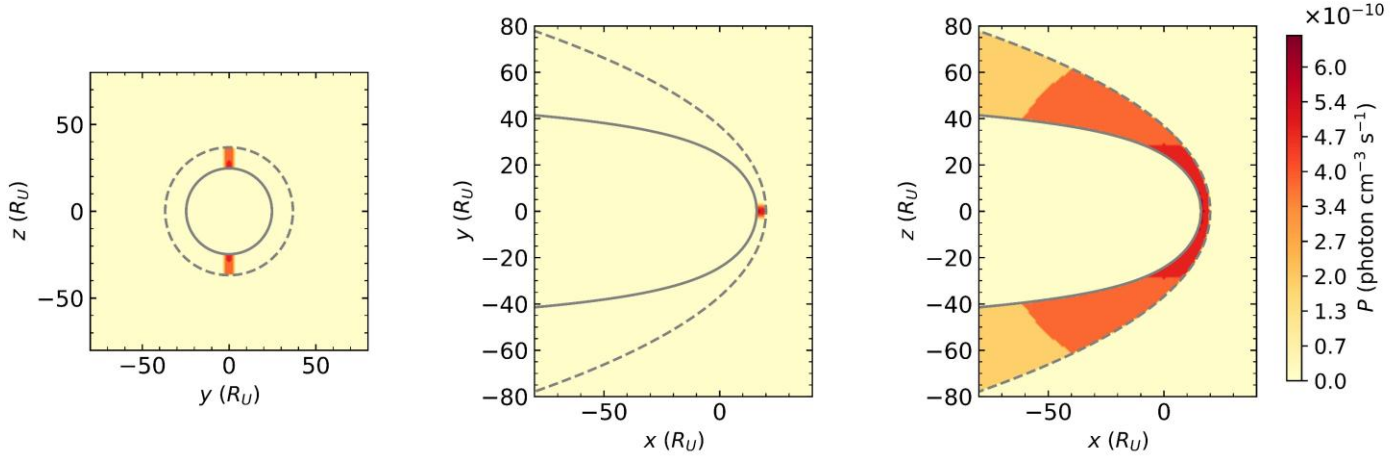


- Two models:
  1. Pre-Voyager 2, estimates from Saturn
  2. Post-Voyager 2, plasma measurements
- System potentially plasma-depleted (Jasinski et al., 2024)

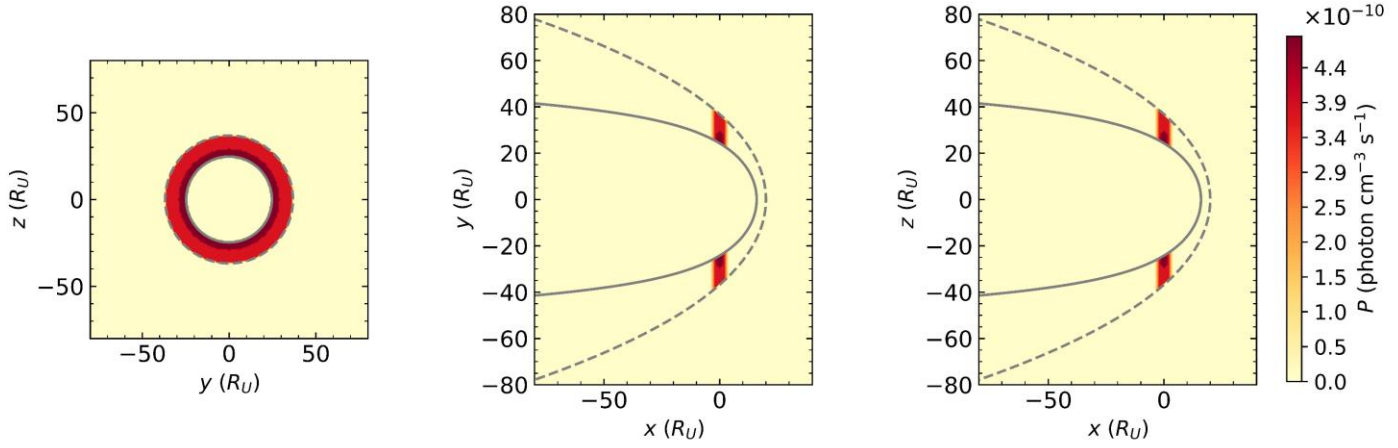
Emission Rate

Sun View | **Top View** | **Side View**

Equinox

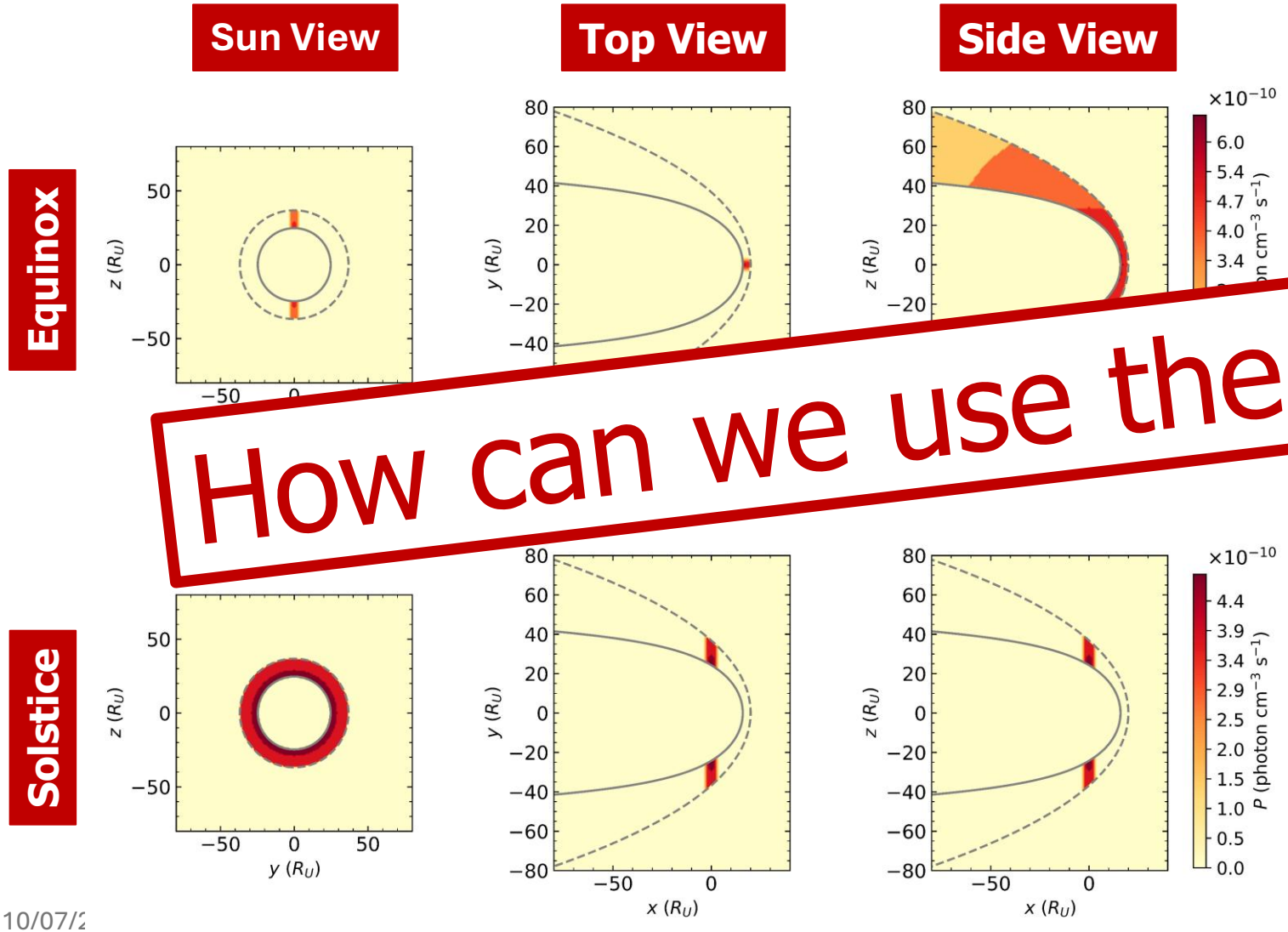


Solstice



- Intersection between neutrals and magnetosheath
- Higher at equinox than solstice

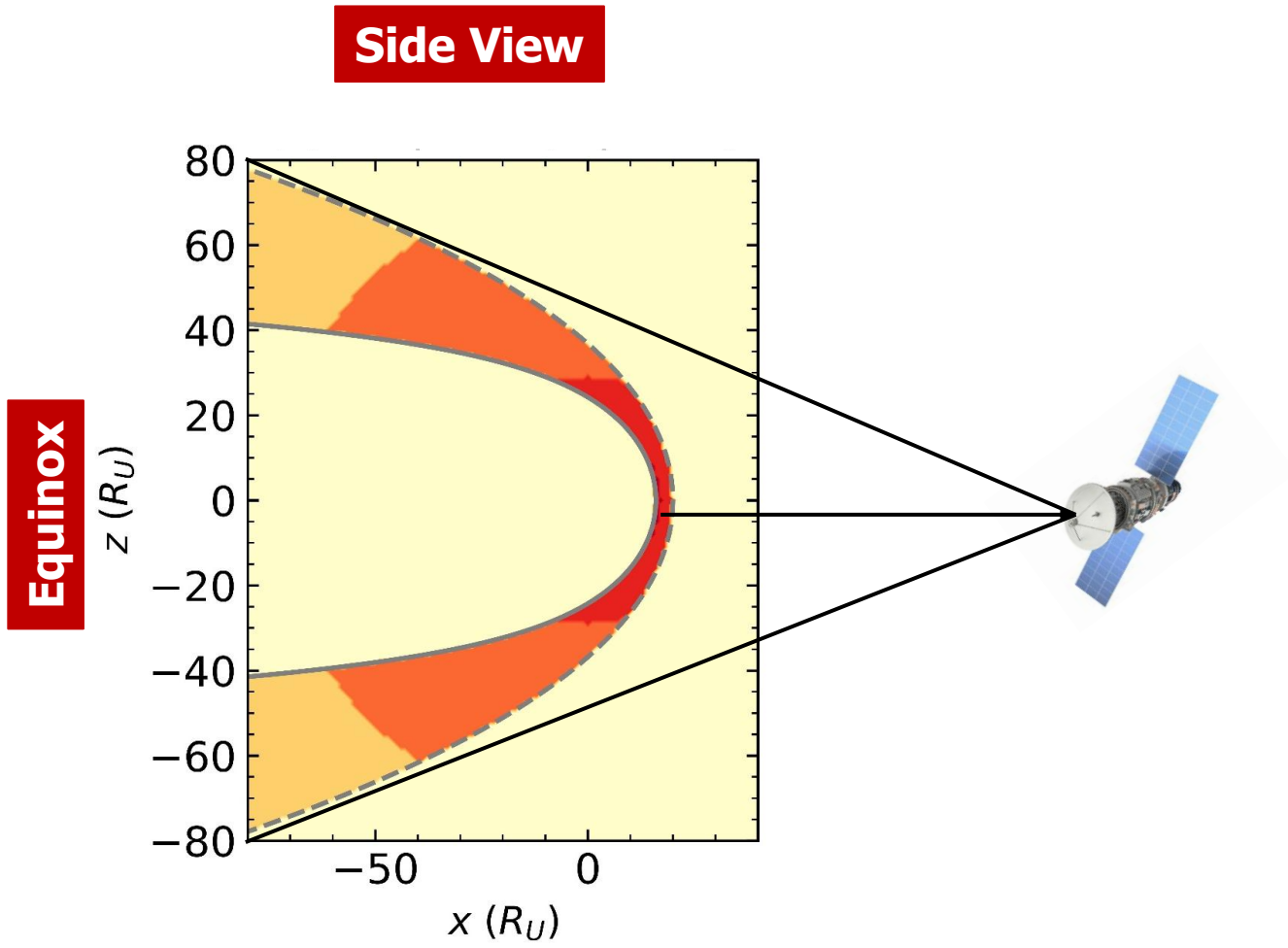
Emission Rate



How can we use the emission?

- Intersection
  magnetosheath
- Higher at equinox than solstice

How Do We Detect Emission?



- We want to detect the emission
- Sum along a line of sight for flux
- SMILE-like soft X-ray imager (SXI)

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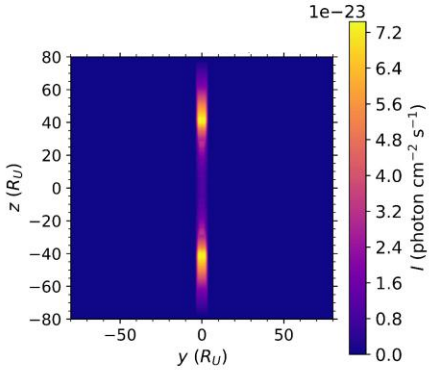
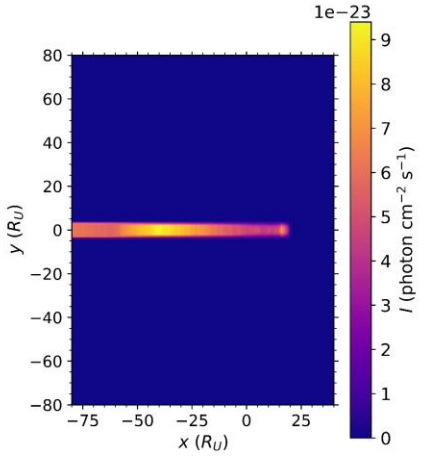
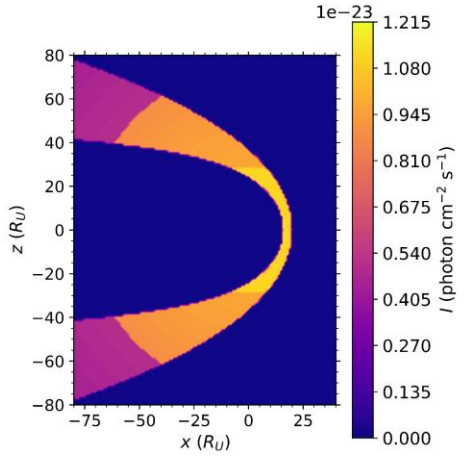
Viewing Geometries

Sun View | **Top view** | **Side view**

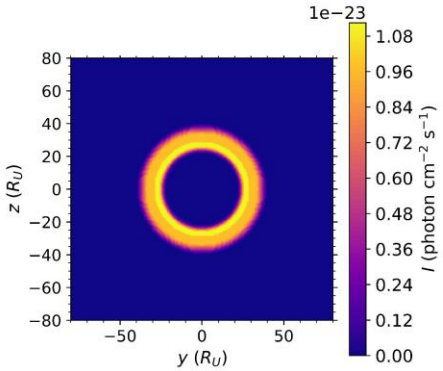
Equinox

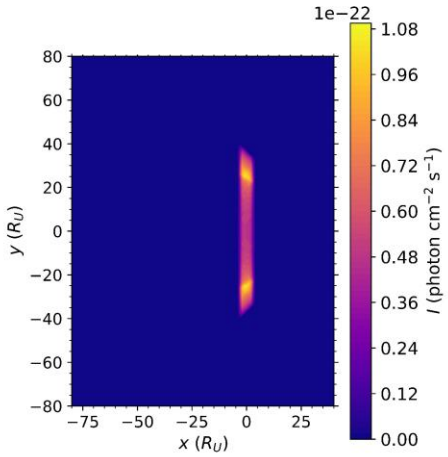


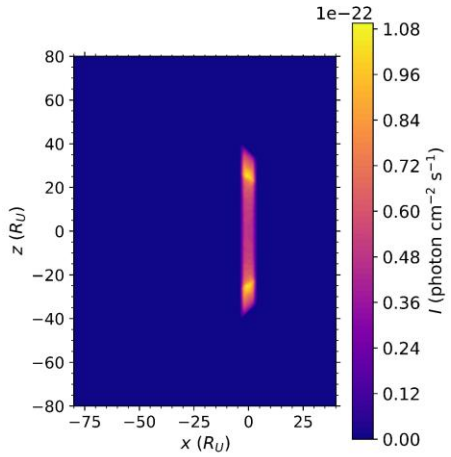




Solstice







- SXI position affects flux detection
- Top-down view is preferable
  - ✓ Avoids planetary disk reflection
  - ✓ Allows for equatorial orbit

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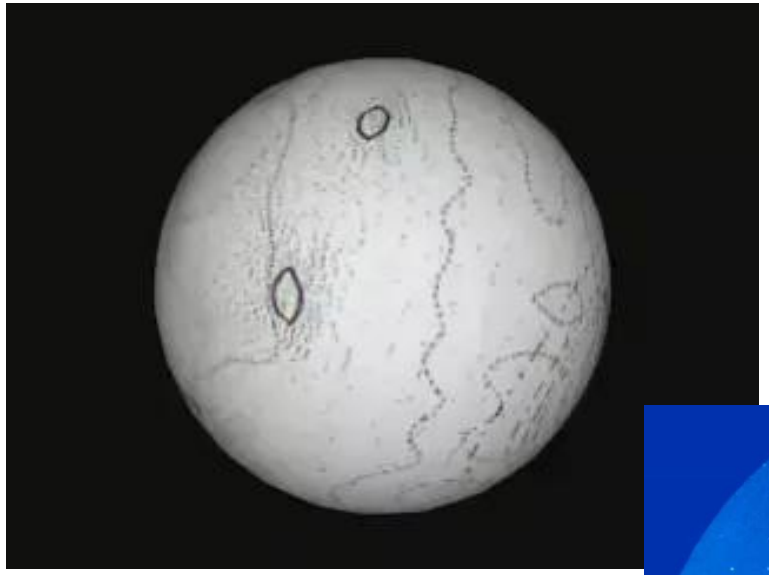
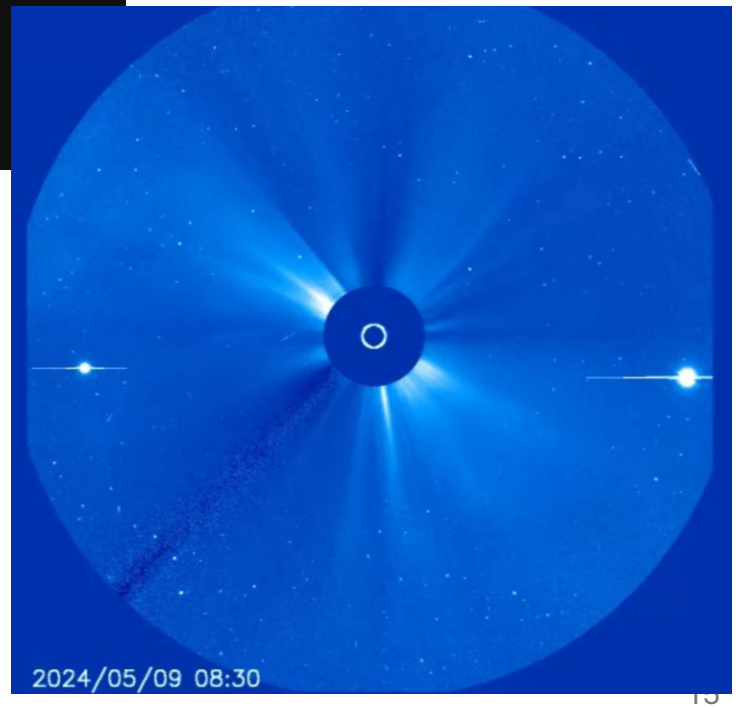
Would SMILE Perform Well?

- System timescales:
  - Planetary rotation ~17.2 hours
  - Variable solar wind

- SMILE detects ~100 X-rays in ¼ of planetary rotation



Note: rotation vs solar wind time not to scale!



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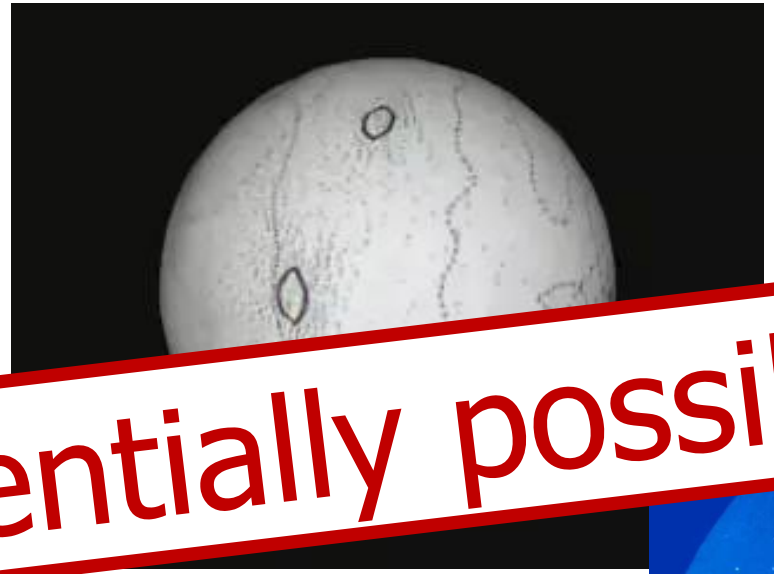
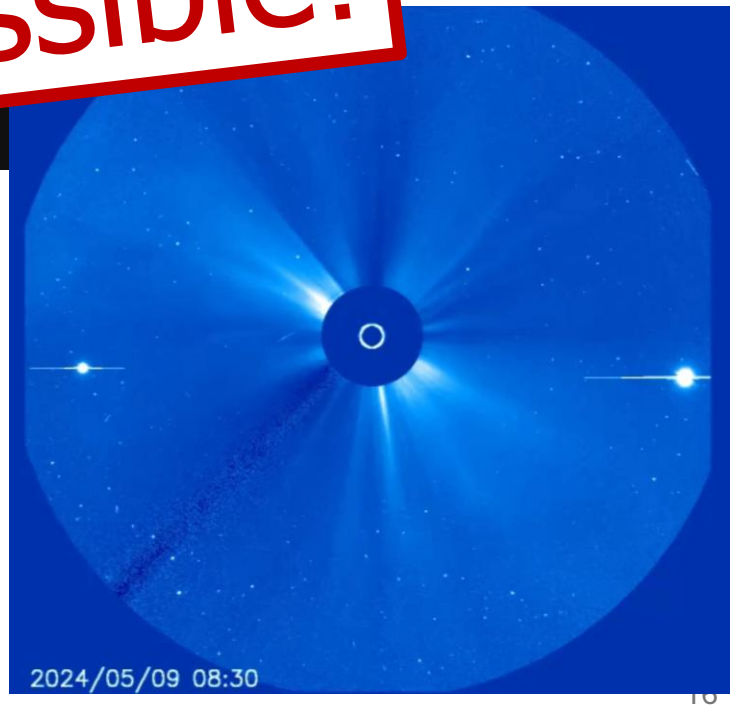


Note: rotation vs solar wind time not to scale!

Imaging potentially possible!



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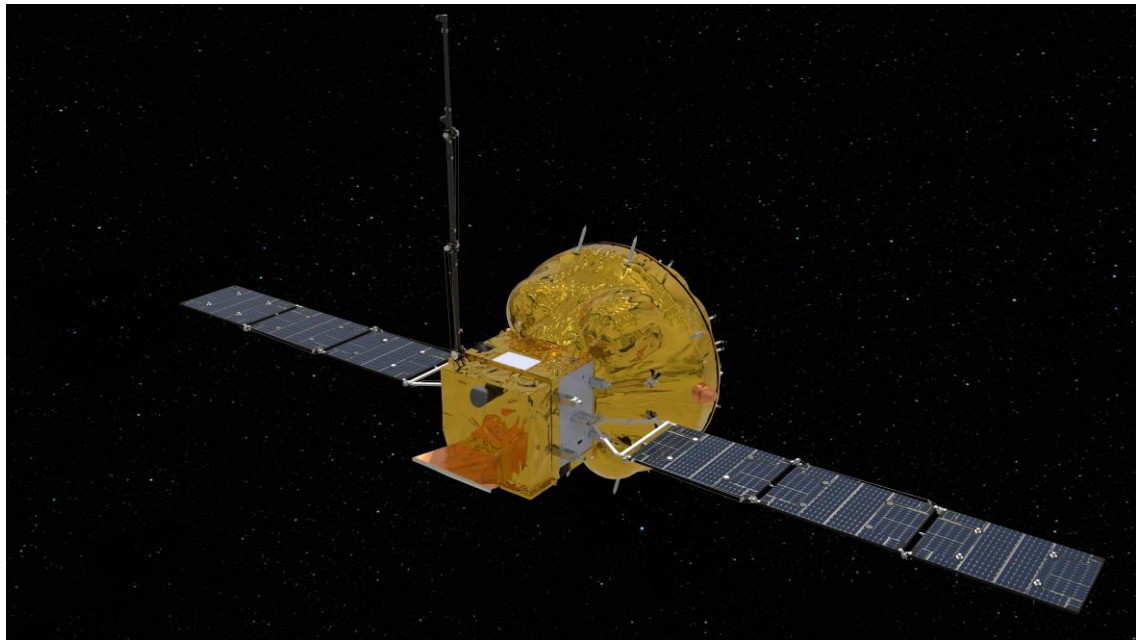
What Might a Future Imager Look Like?

- Consider future SXI:
  - Double field-of-view (FOV)
  - Much higher effective area
- Much improved detection times – every 3 seconds!
- Trade off between improvements

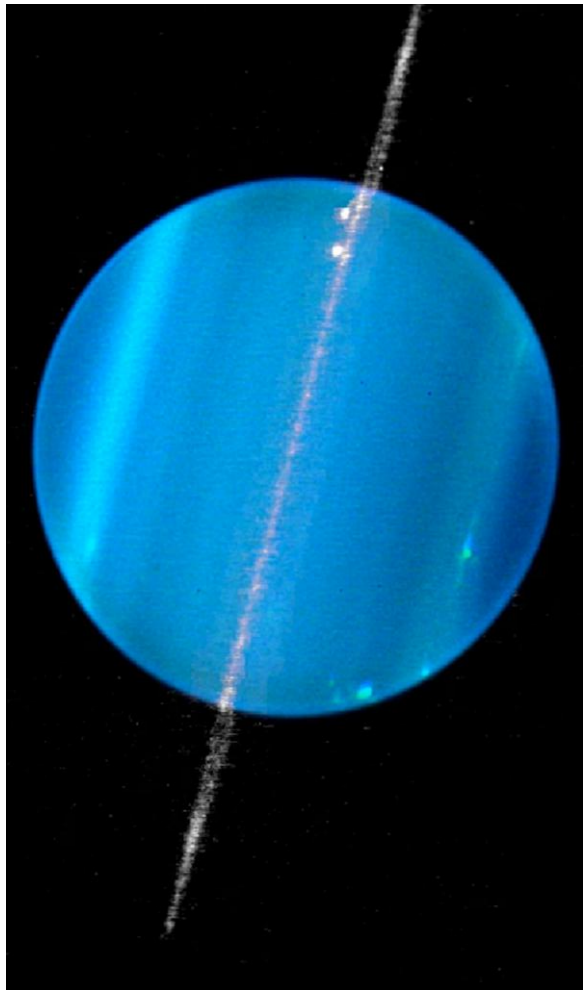


Credit: ESA

Conclusions

- Neutral density largest driver of emission
- Seasonal dependence of emission
- Current technology is viable
- Technology improvements always welcome

Proof of concept model justifies further development!



Credit: NASA

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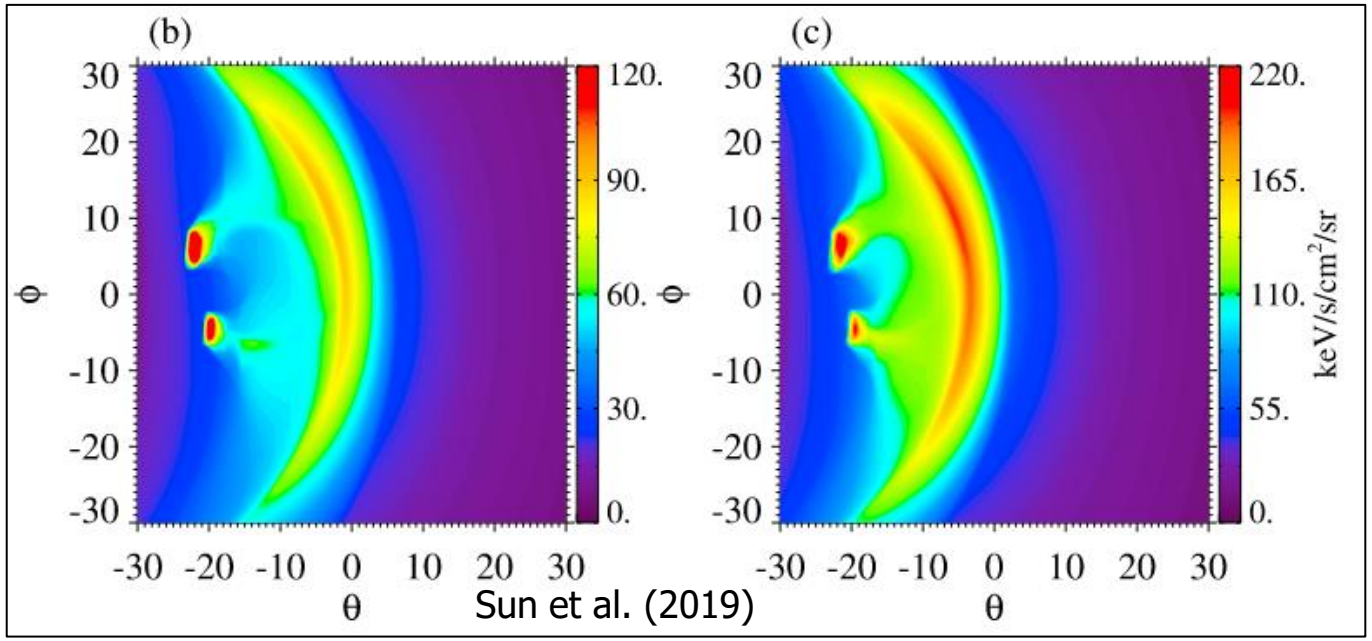
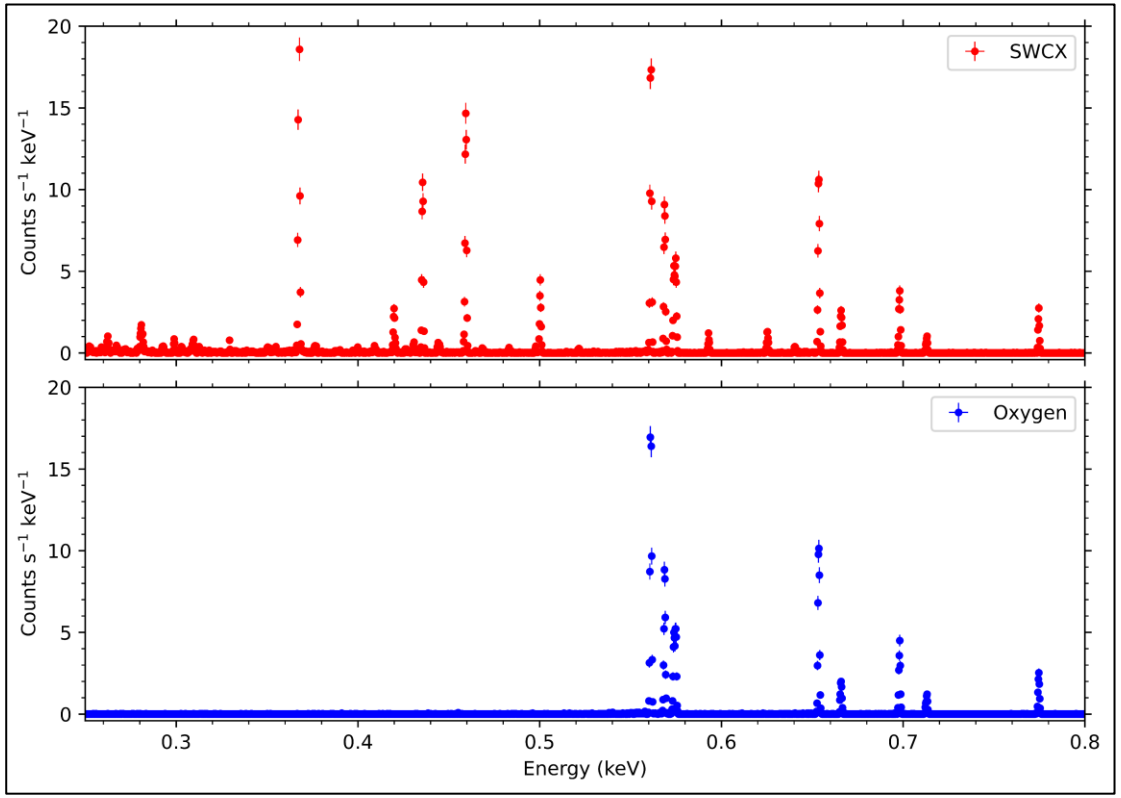
Next Steps

- Cusp inclusion
- Full range of solar wind ions
- Full charge exchange physics



Sun et al. (2019)



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