Synergistic observations of the giant planets with HST and JWST:
Jupiter's auroral emissions

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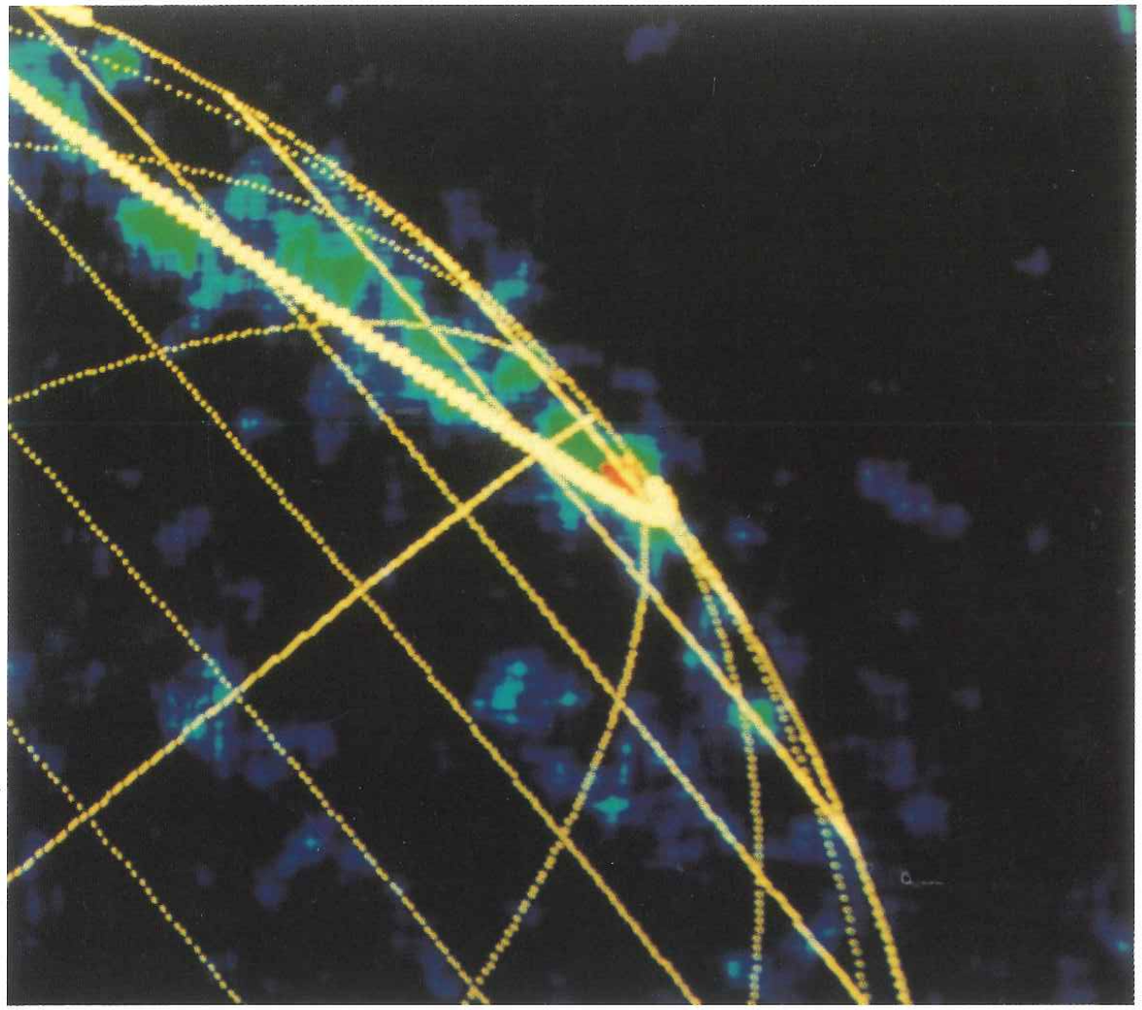
37 HST programs, giant planets aurora

- GTO-1269 (FOC) in 1991 C0
- …
- GO-14634 (STIS) Juno era 2016-2018

Geophysical
Research
Letters

First published image of Jupiter's FUV Ly-α aurora



FOC (DD time)

Dols et al., 1992
F. Paresce

SEPTEMBER 23, 1992 Volume 19 Number 18

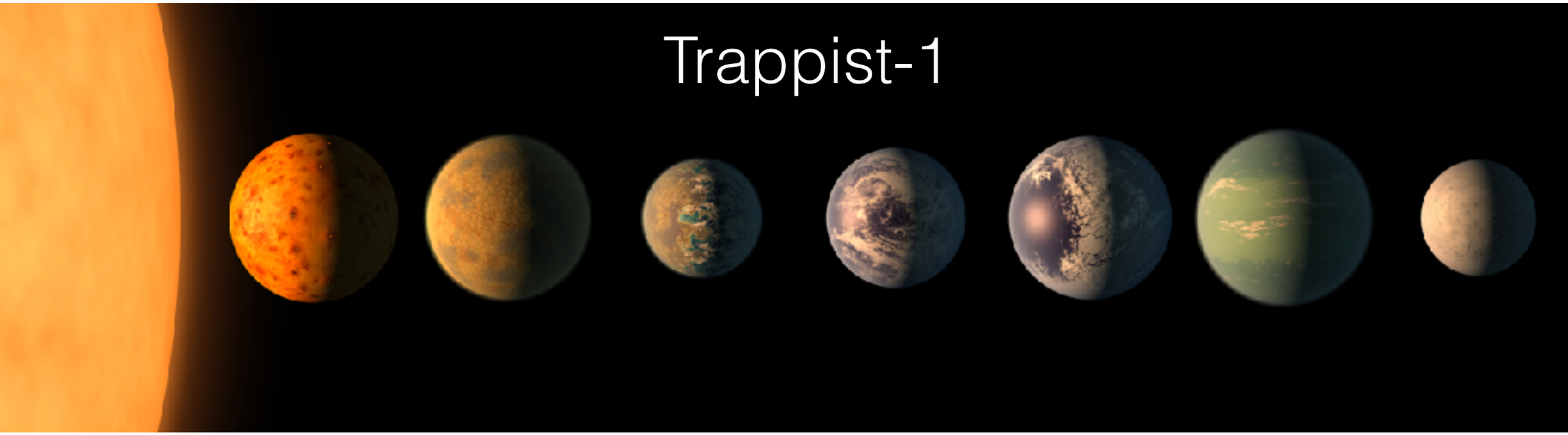
AMERICAN GEOPHYSICAL UNION

STAR Institute

star.ulg.ac.be

More than 100 researchers

- Planetology
- Stellar Physics
- Extragalactic Astrophysics & Astro-particles
- **Instrumentation**

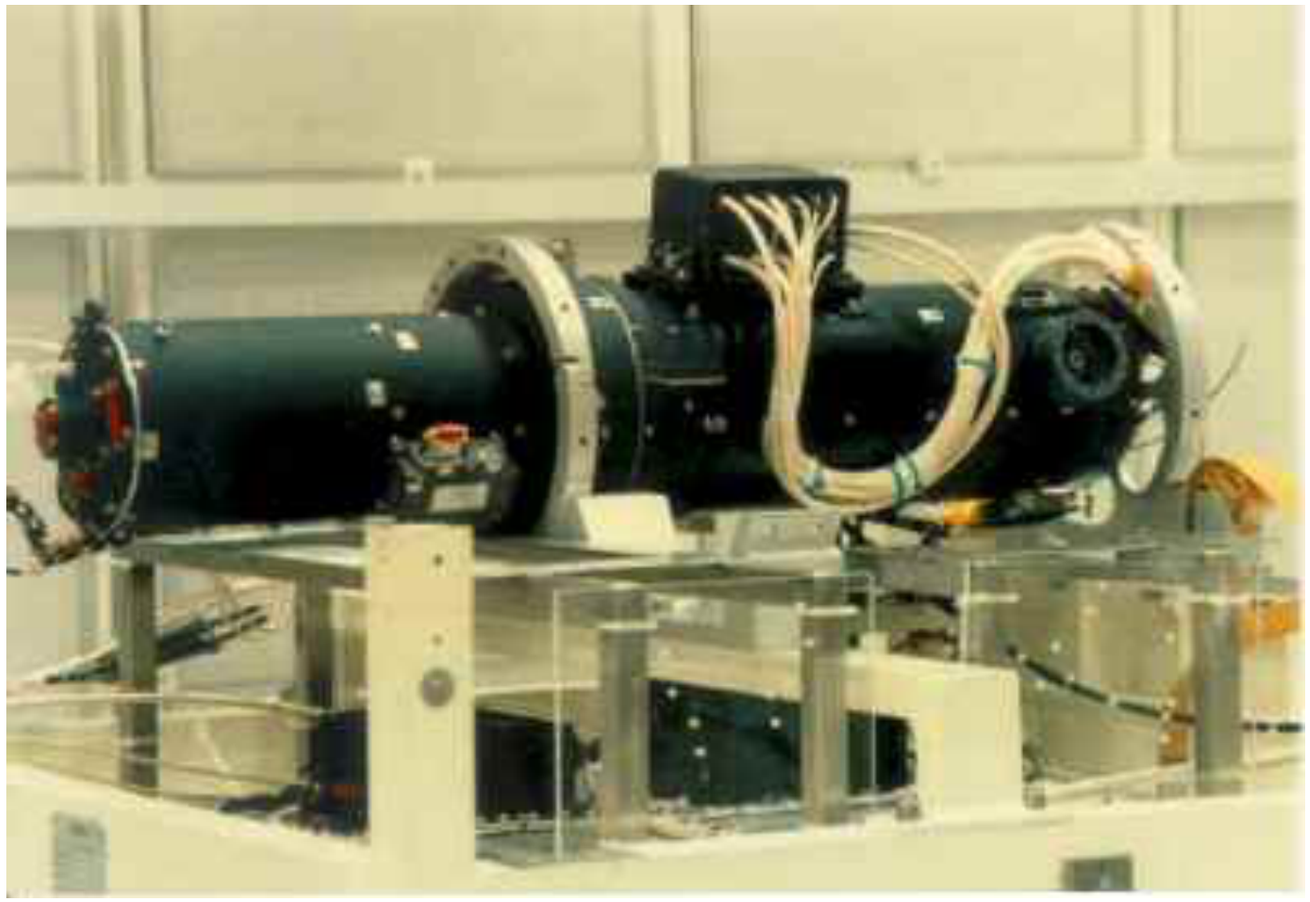


Instrumentation

Centre Spatial de Liège

HST - FOC

Development of the photon counting detector and space qualification of the FOC instrument



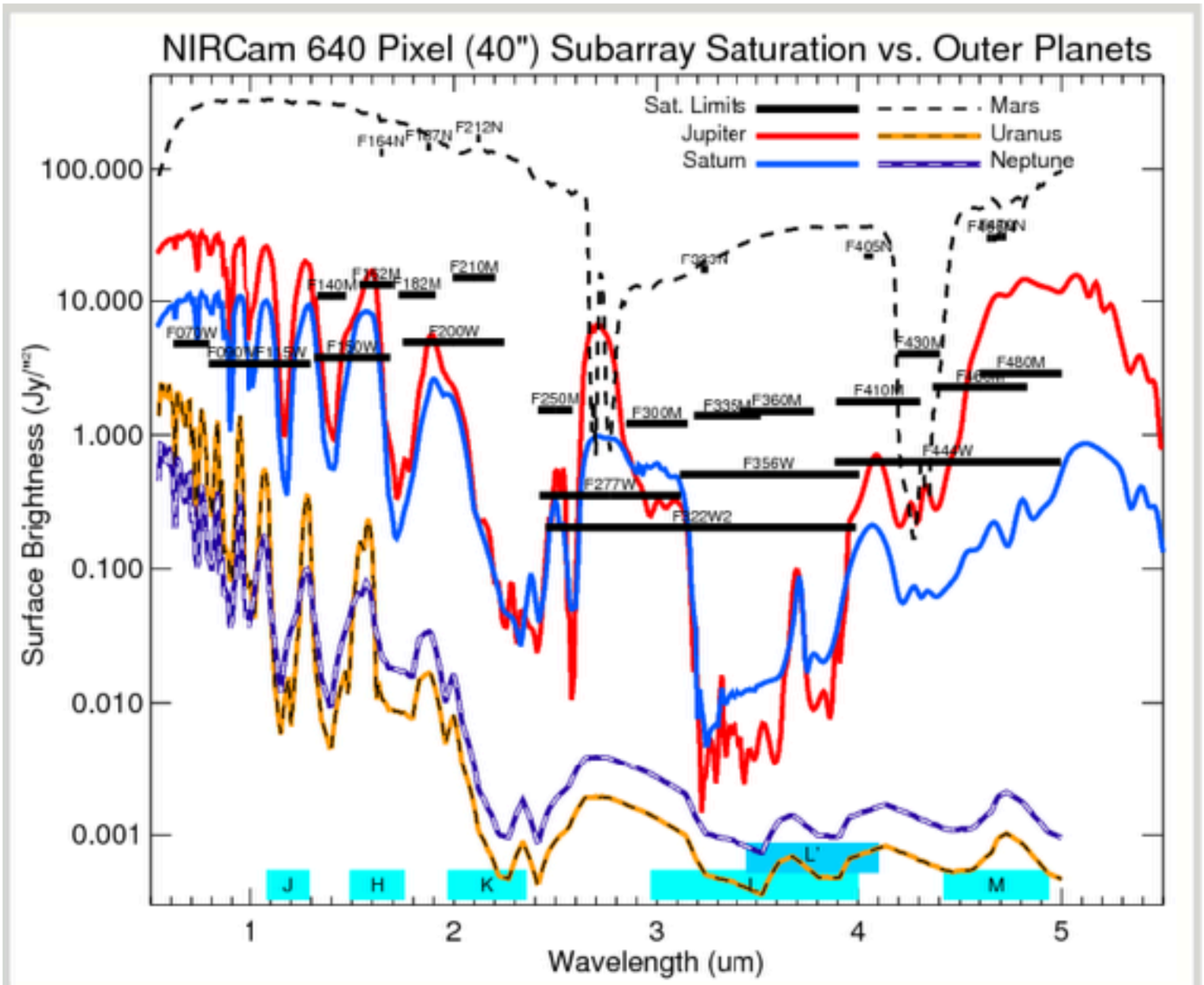
Centre Spatial de Liège

JWST - MIRI

Contribution to the Input Optics and Calibration Unit (IOC), the Instrument Control Electronics (ICE) and various optics for MIRIM

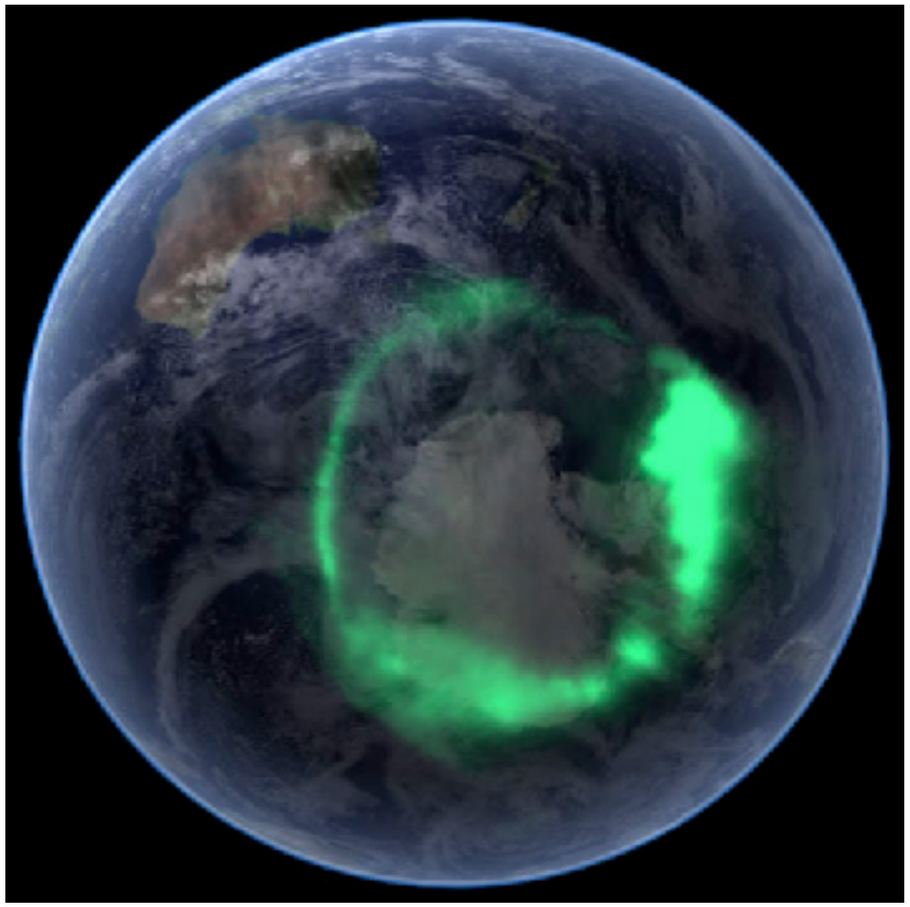
Solar System Planets

Jupiter's aurora



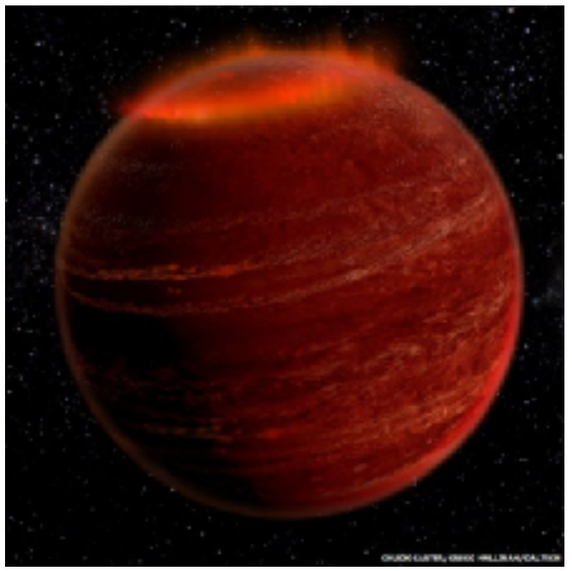
OK HST
OK JWST

« JWST will be able to observe the outer planets without saturating in at least some modes. »

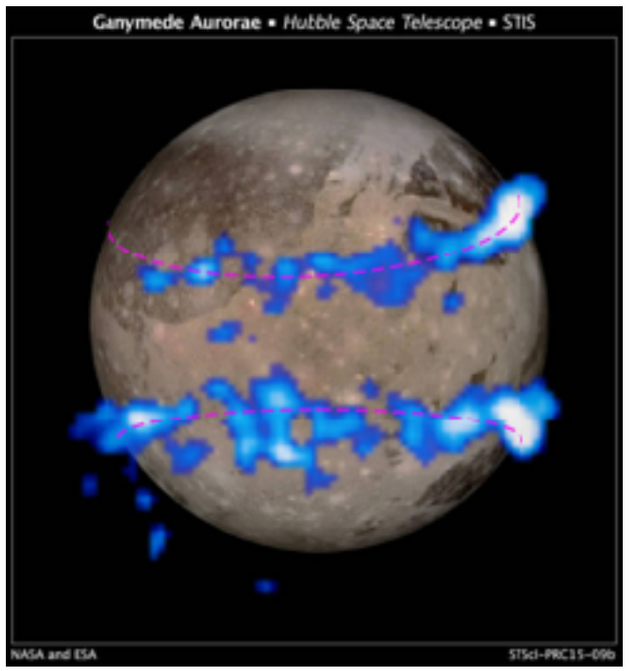


Auroral process

applies to all magnetized bodies surrounded by plasma



Brown dwarf aurora
(Hallinan et al., 2015)



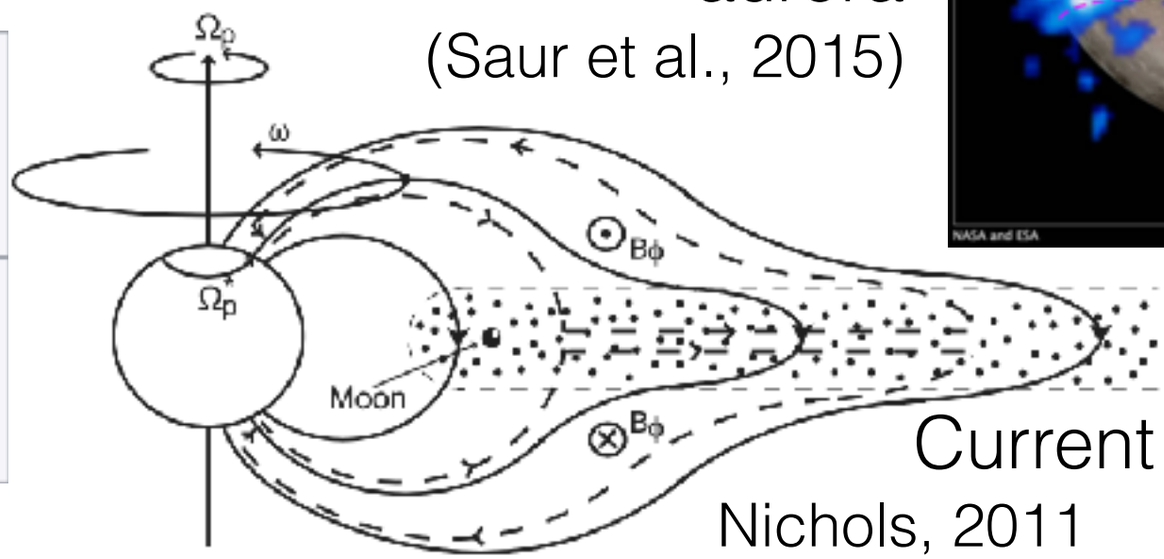
Ganymede aurora
(Saur et al., 2015)

Maxwell-Faraday induction law

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

Ampere law

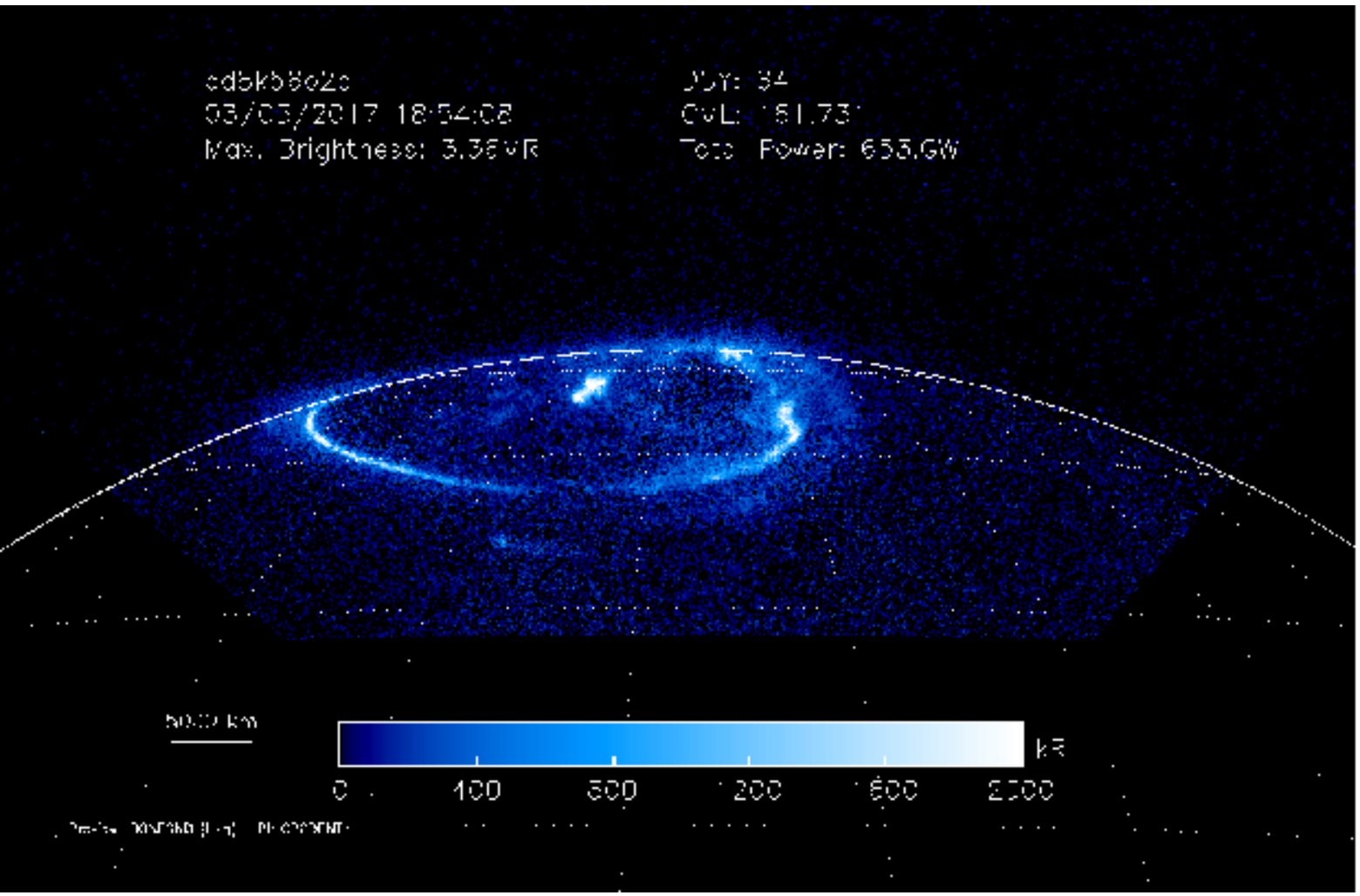


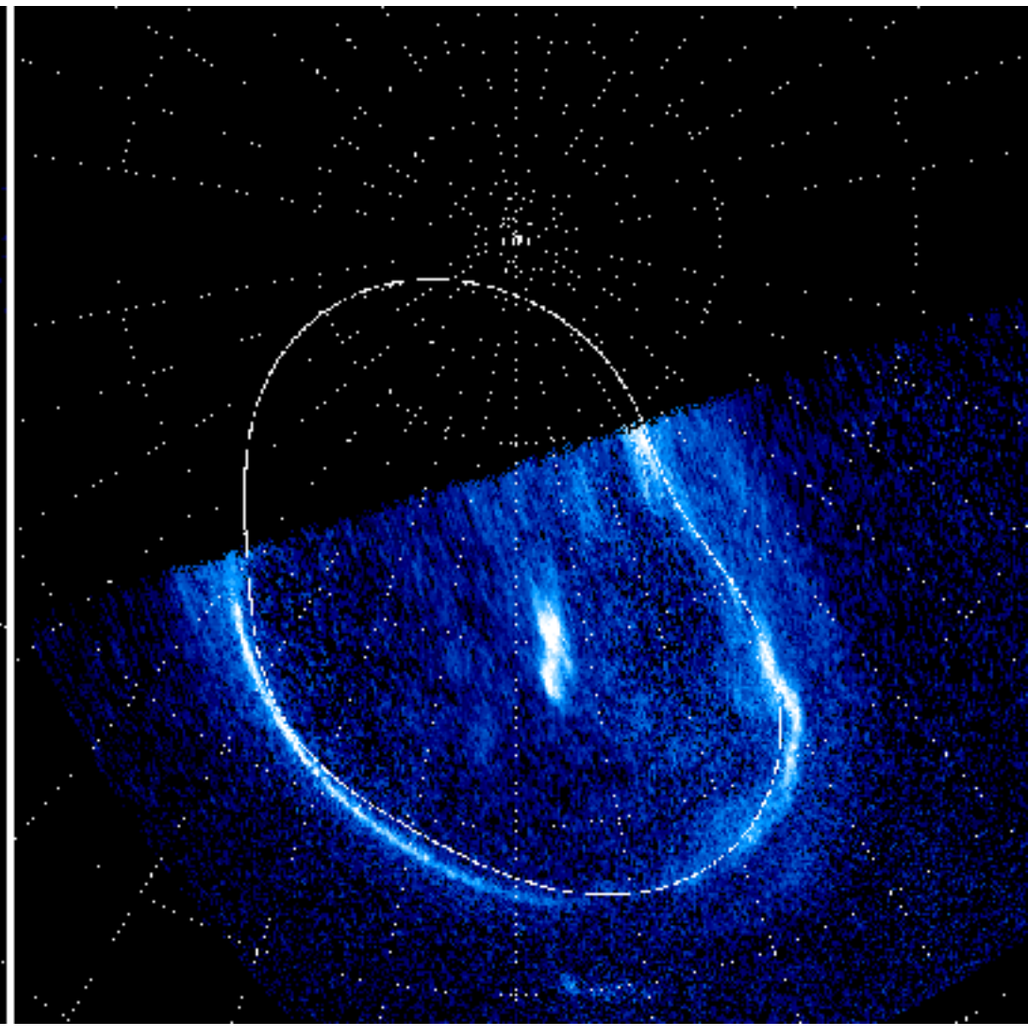
Current system
Nichols, 2011

Jupiter (North) FUV aurora

HST STIS TTAG F25SRF2 MIRFUV

GO-14634

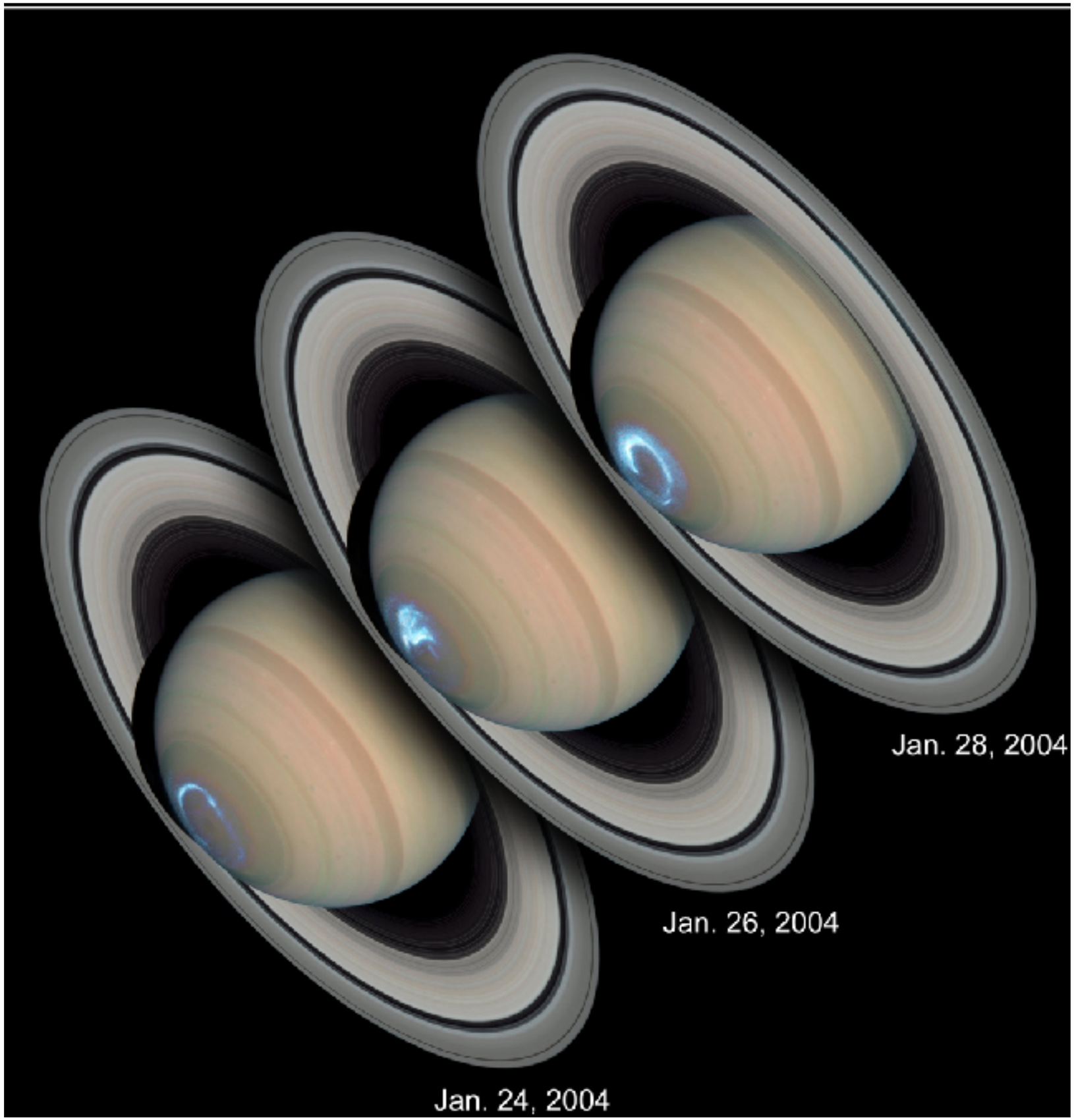




H_2 / H / He /CH_4

Total emitted UV Power ~1 TW

~200km/pix 30sec



Saturn

(South) FUV aurora

HST STIS Accum 25MAMA MIRCUV GO-10083

540 sec

~500km/pix

0.1 TW

Clarke et al., 2005

Uranus (?) FUV aurora

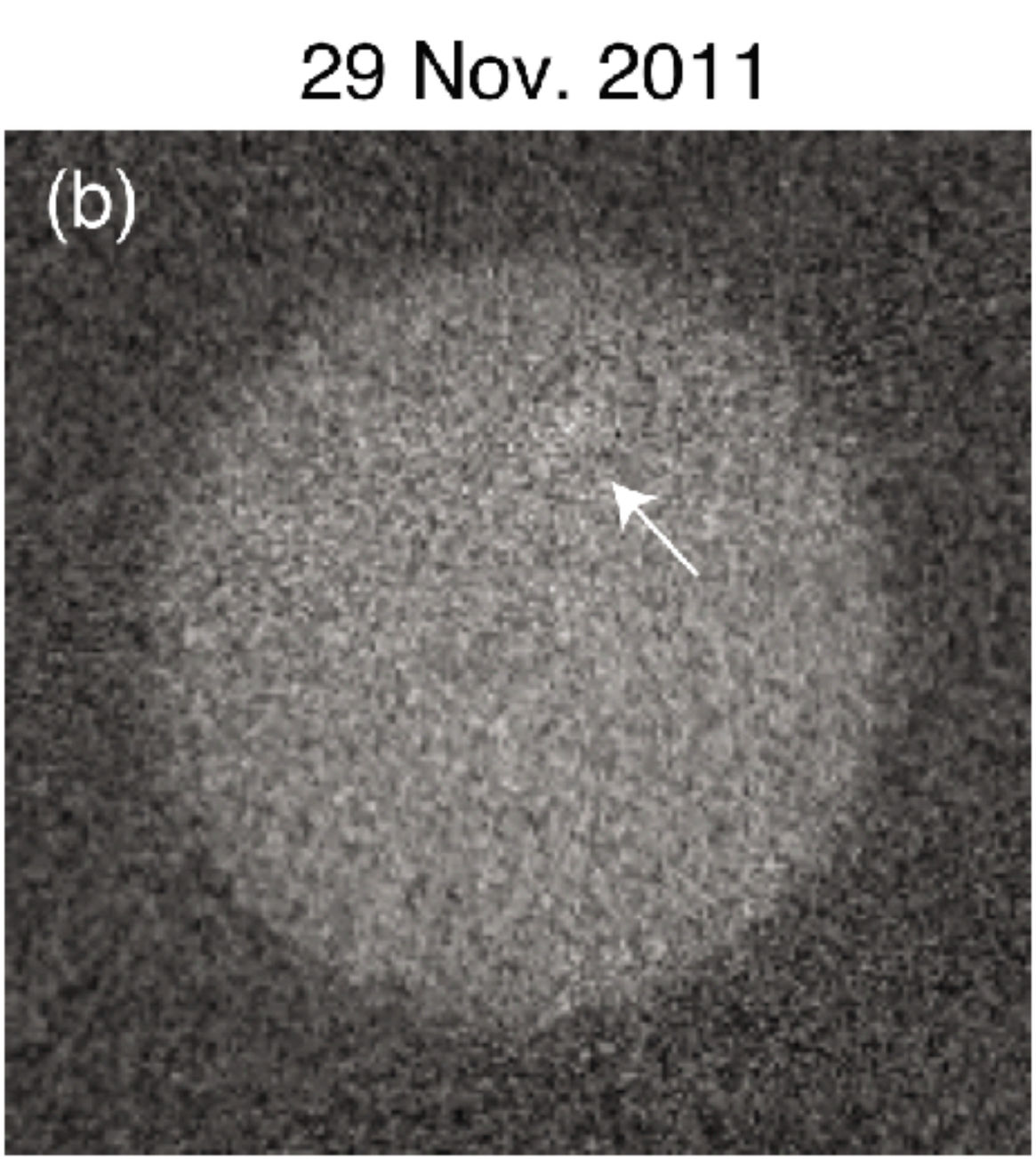
HST STIS Accum F25MAMA MIRCUV

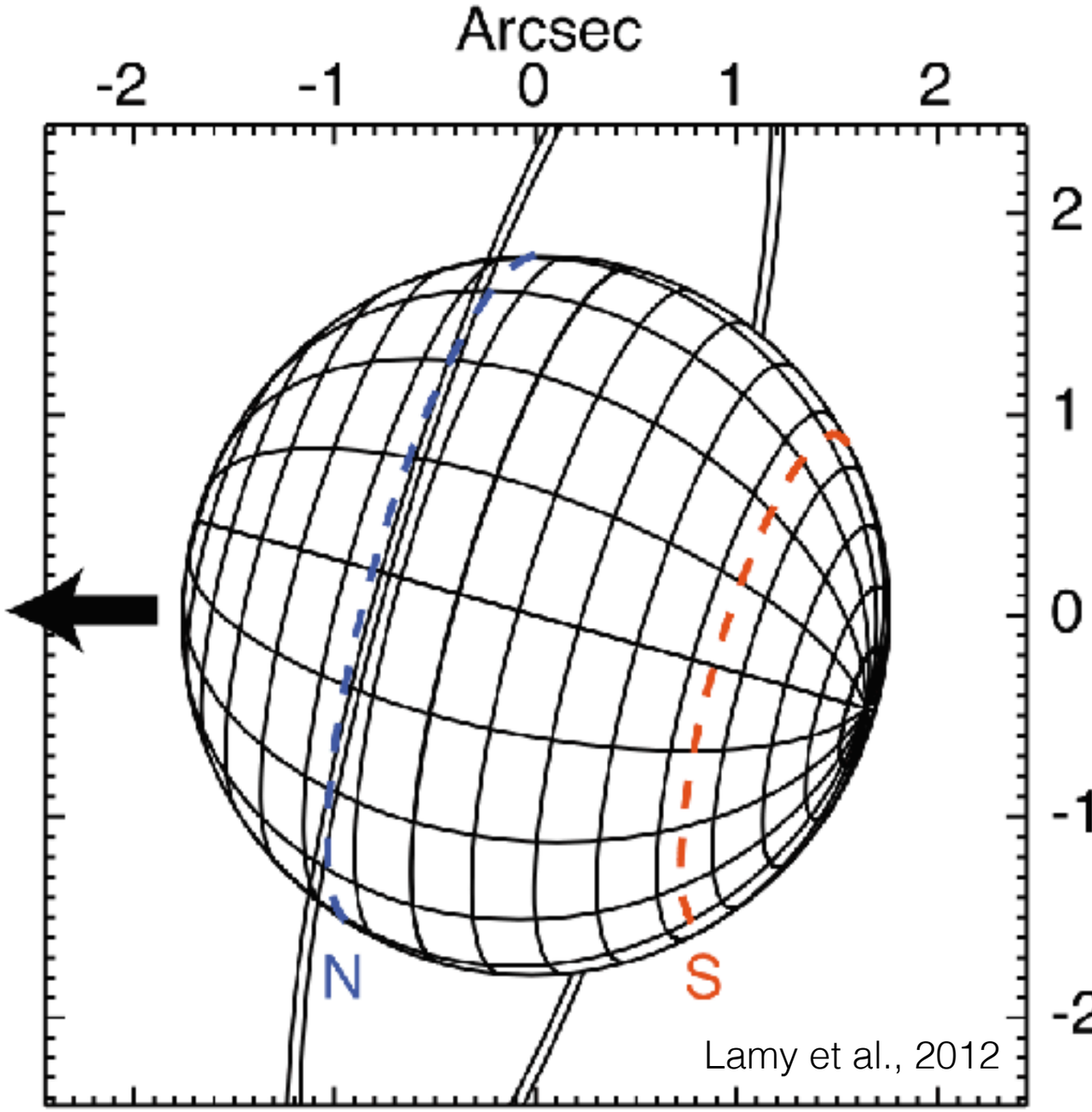
GO-12601

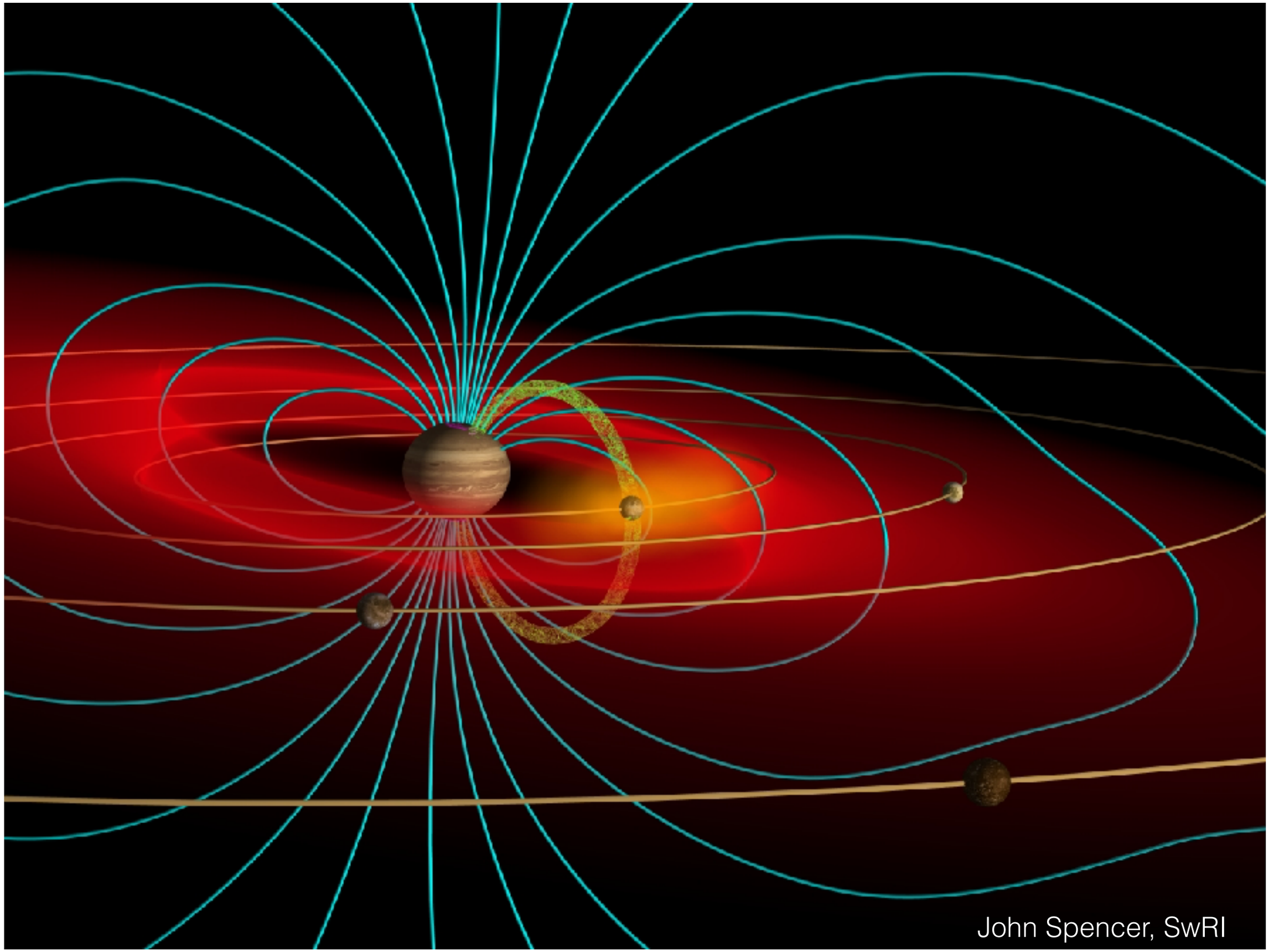
1000 sec

~1000km/pix

0.001 TW

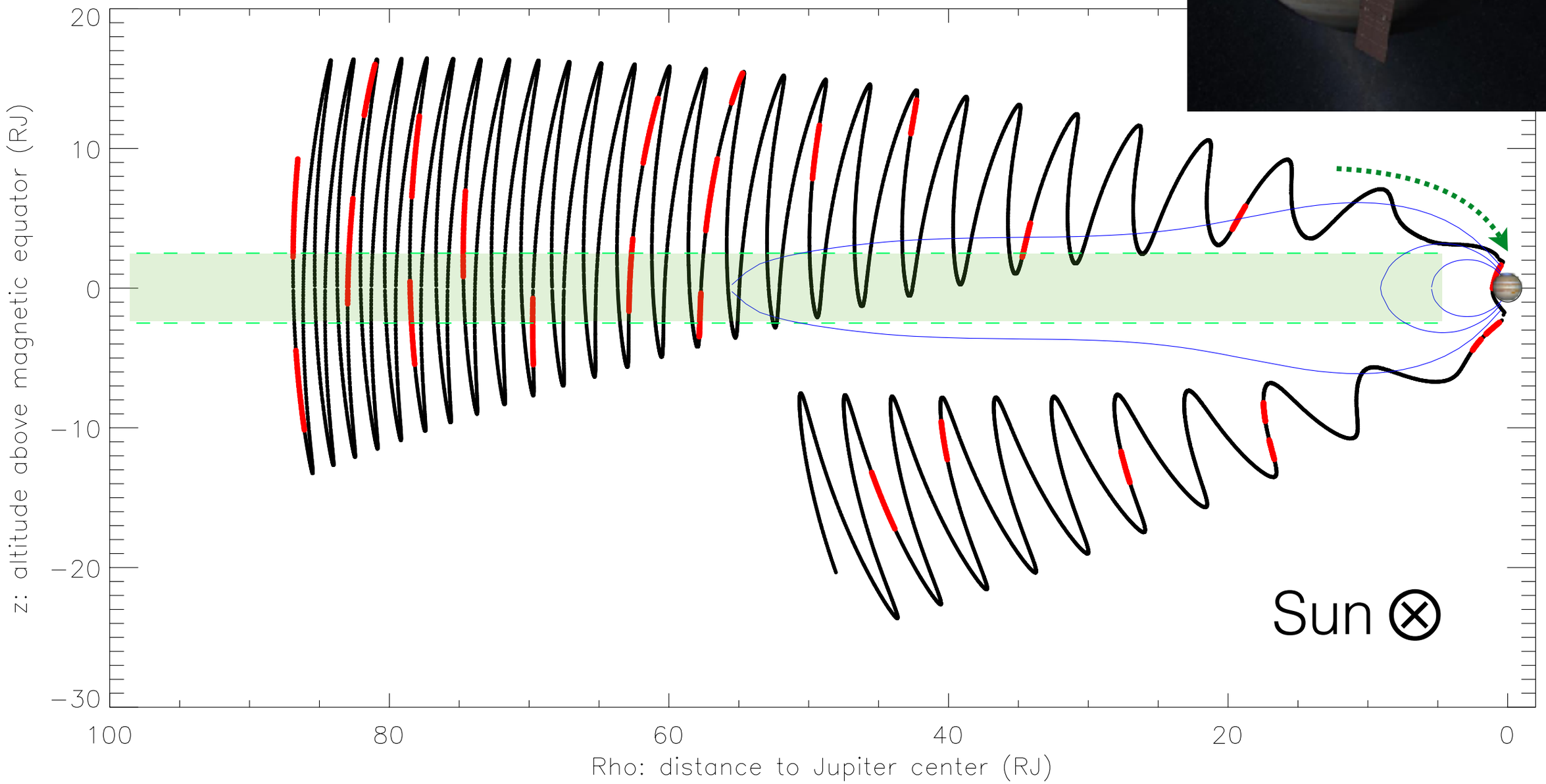





John Spencer, SwRI

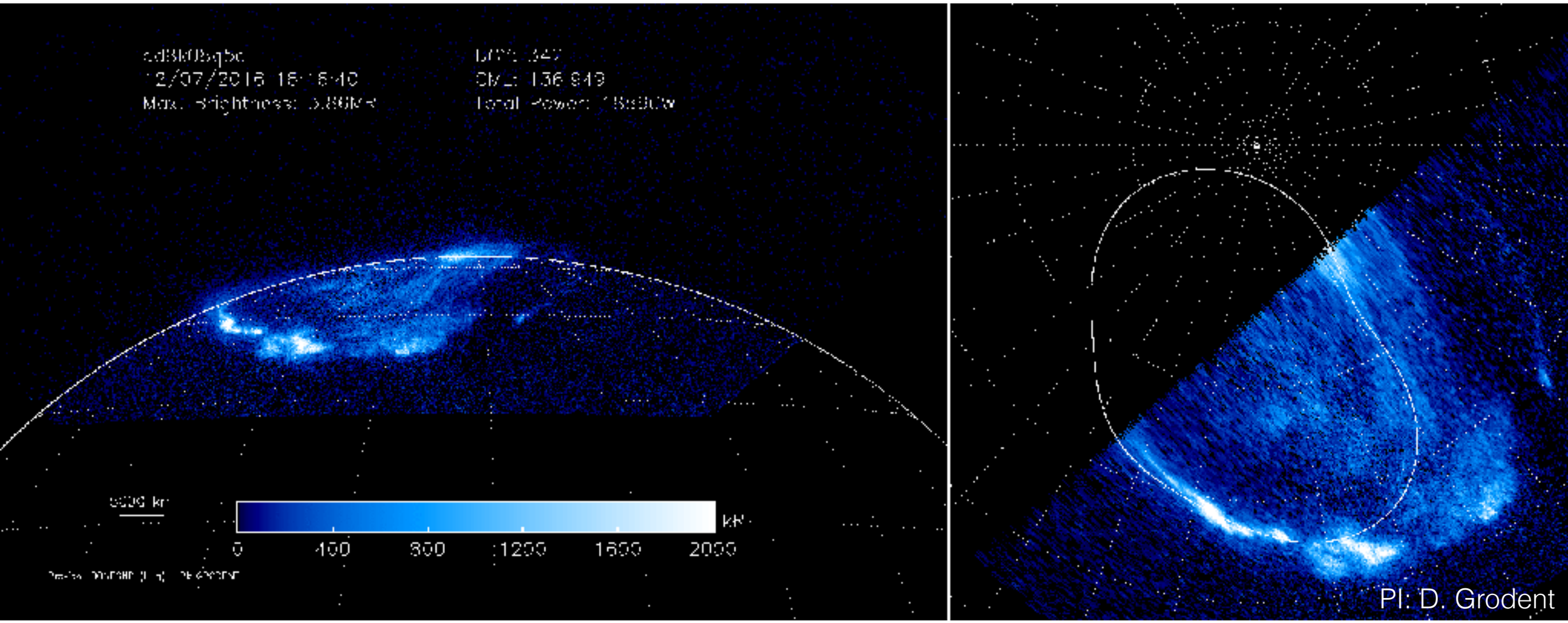
NASA Juno mission 53.5d orbit PJ03

Magnetic coordinates (tilted)



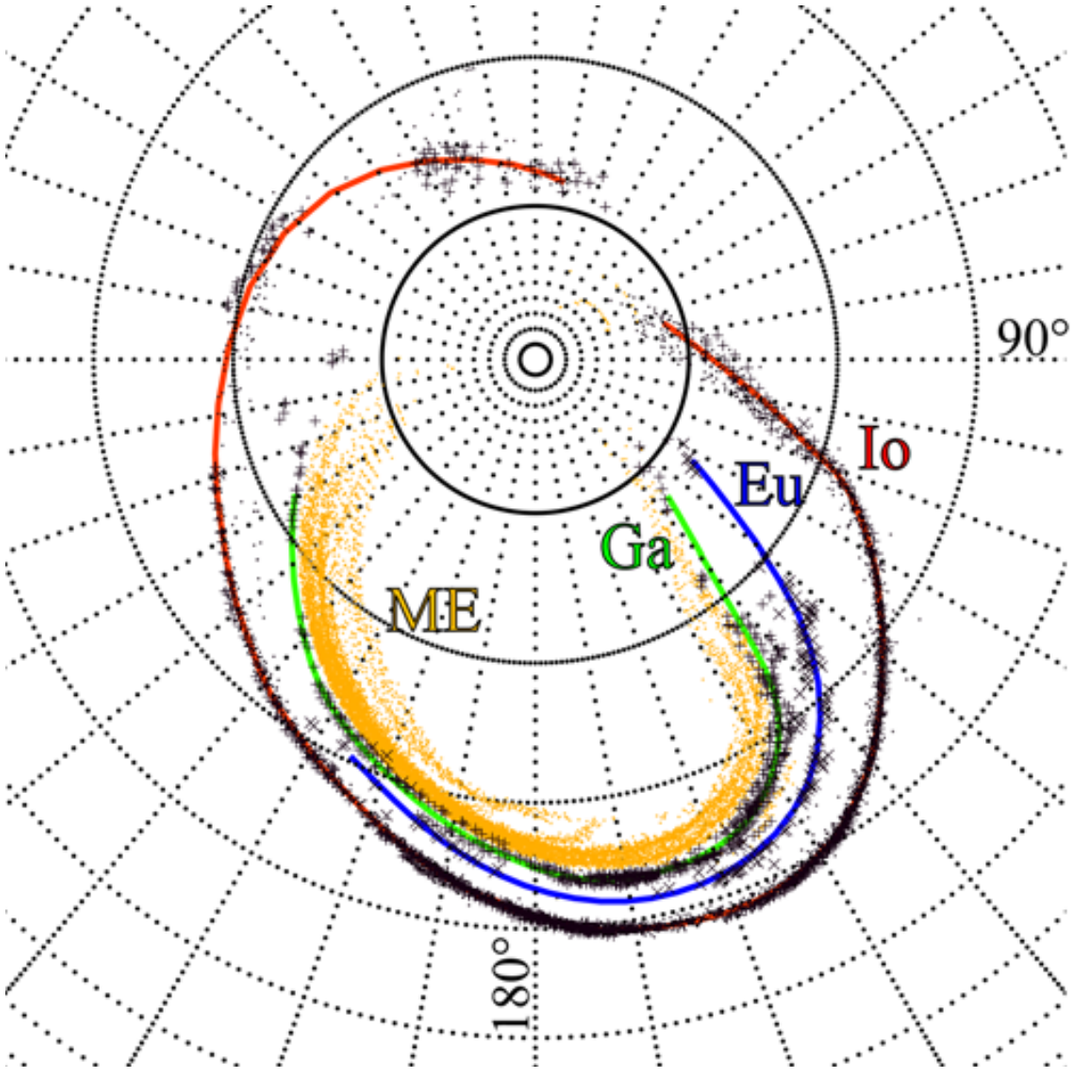
Jupiter (North) FUV aurora
HST STIS TTAG F25SRF2 MIRFUV
GO-14634

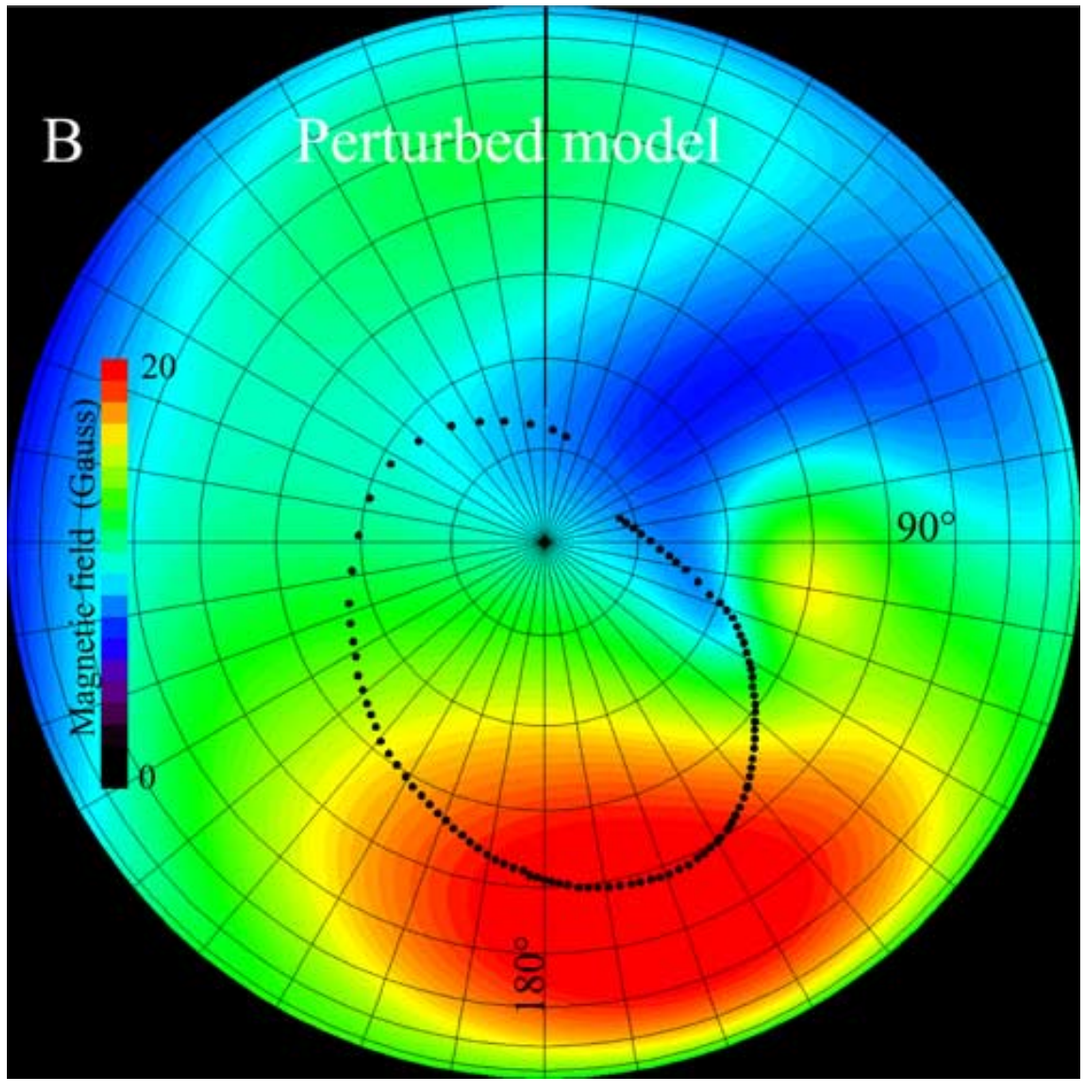
151 HST orbits
Coordinated with Juno



PI: D. Grodent

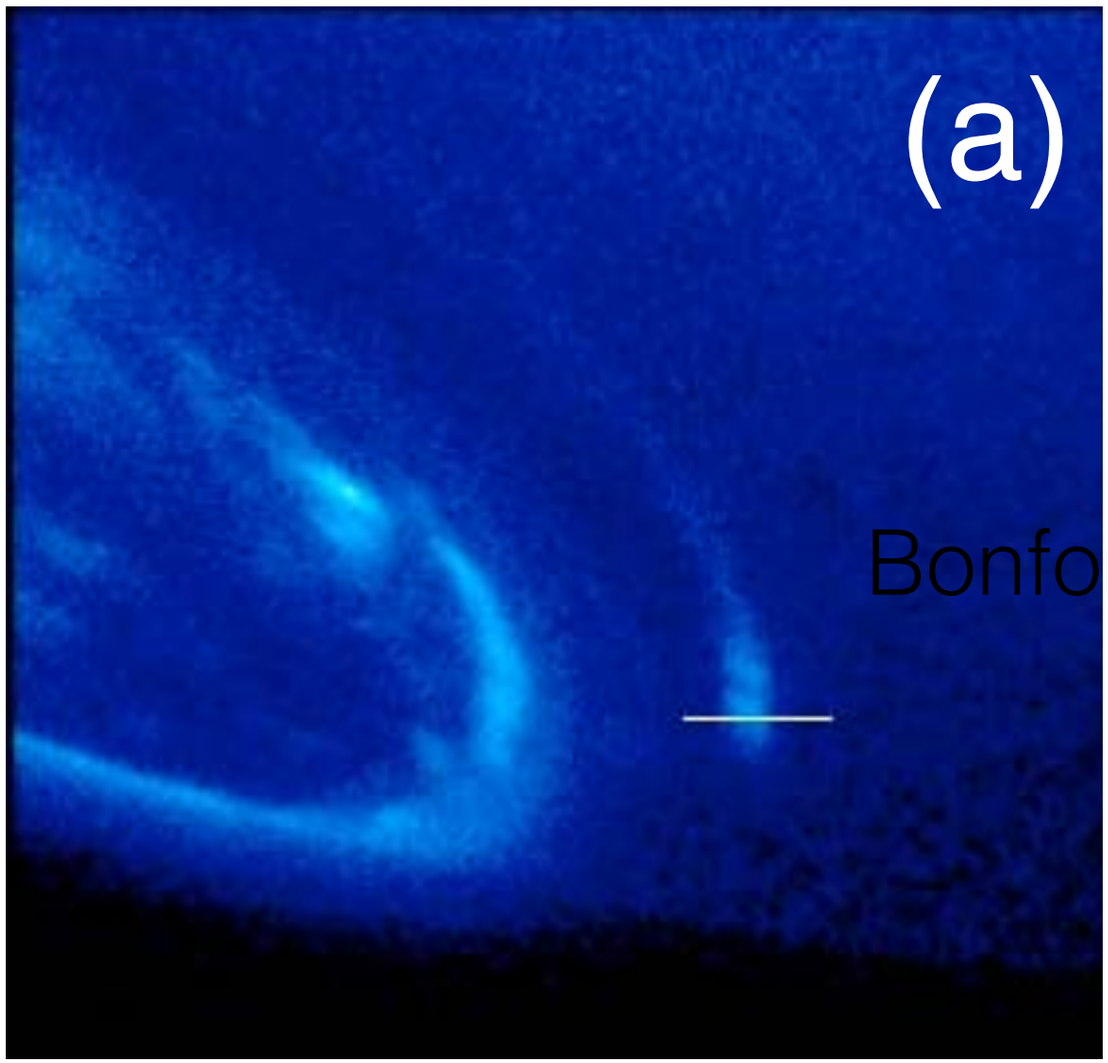
Magnetic Anomaly near the surface of Jupiter



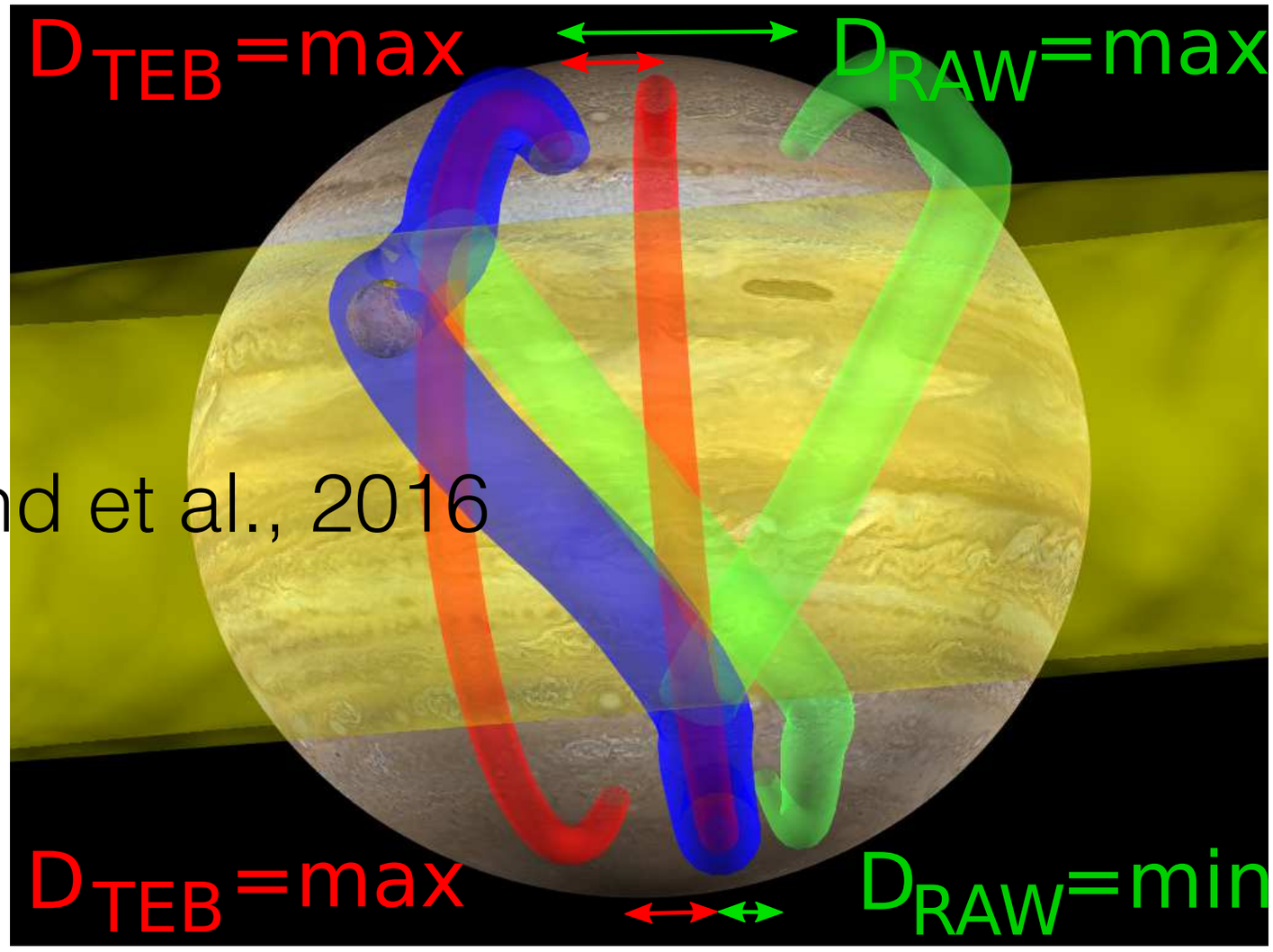


Grodent et al., 2008

Multiple satellite footprints



Bonfond et al., 2016

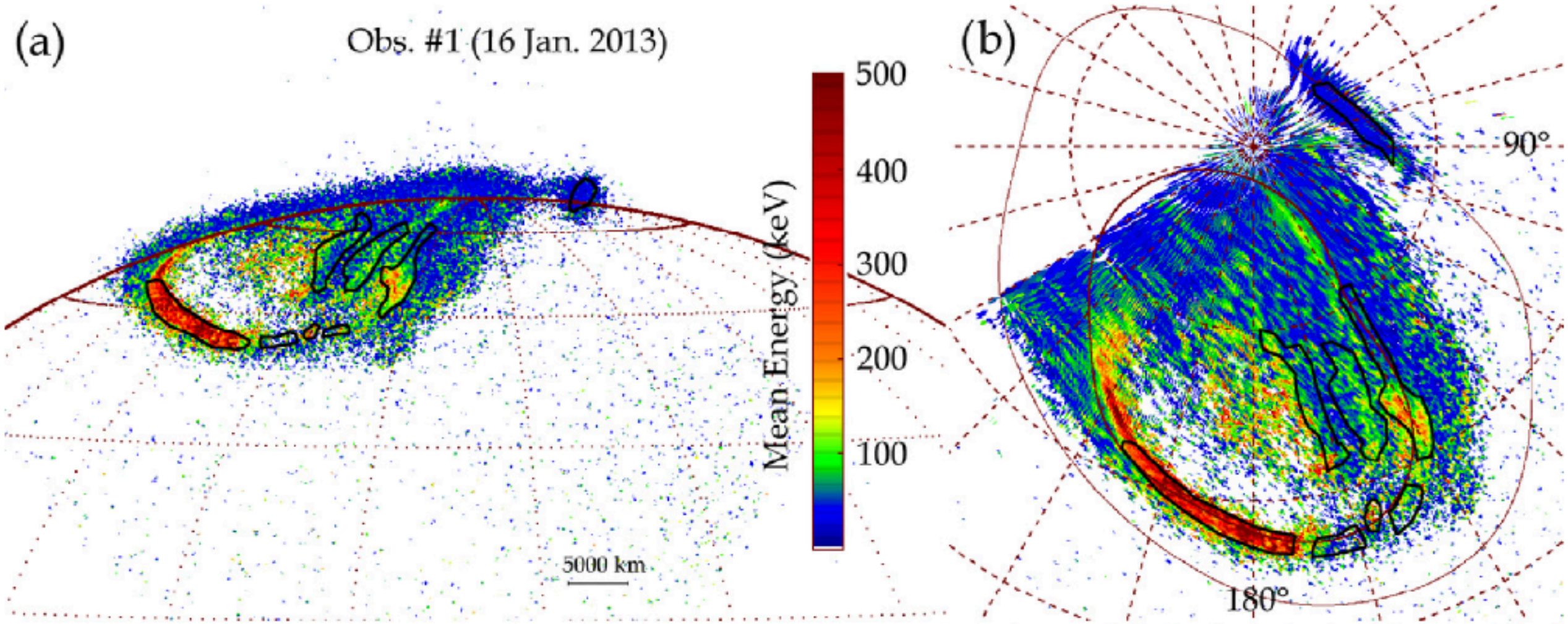


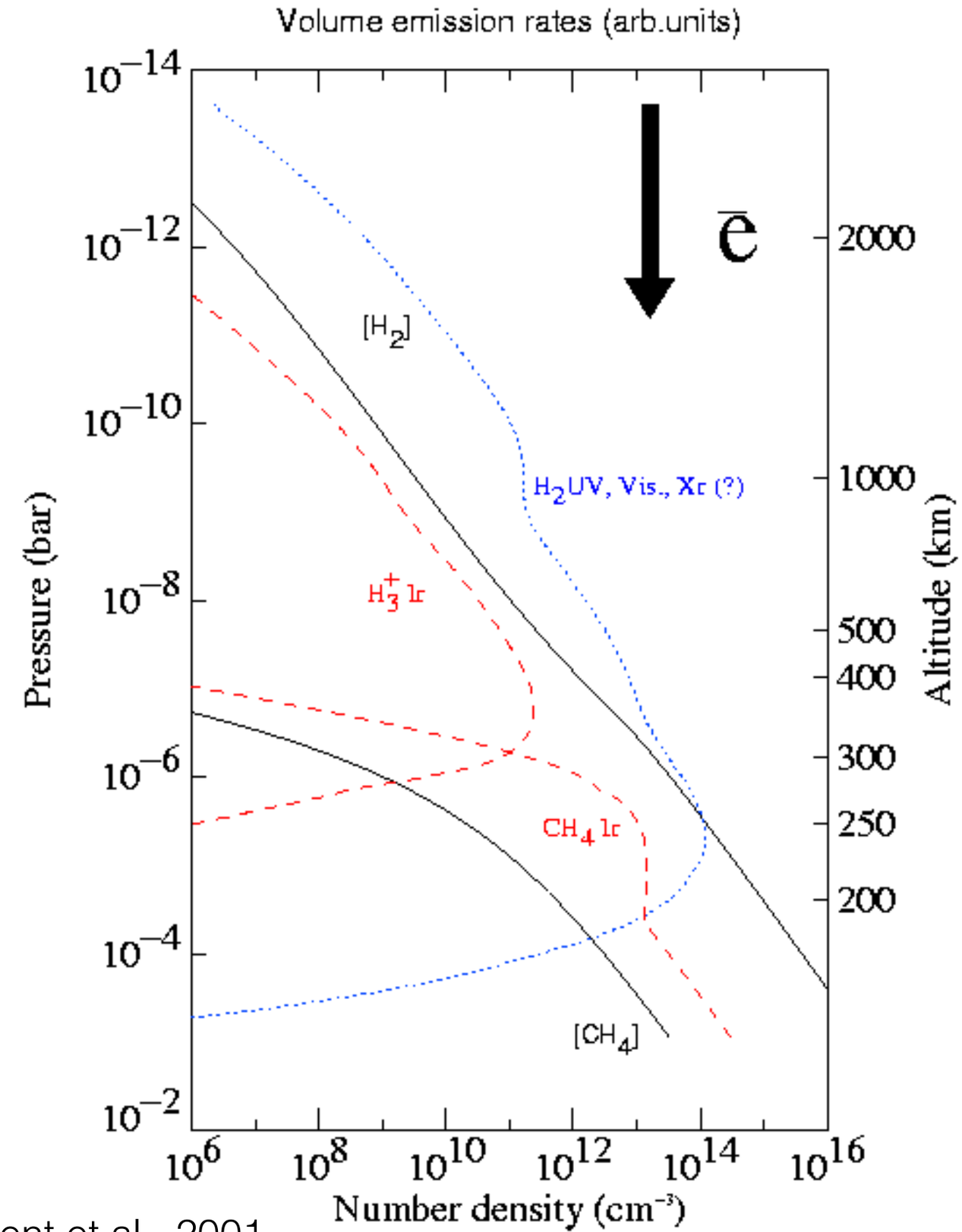
Bonfond et al., 2016

Spectral auroral scan (unsupported mode)

HST STIS FUV MAMA G140L slit 52x0.5 1425A

J. Gustin et al. / Icarus 268 (2016) 215–241



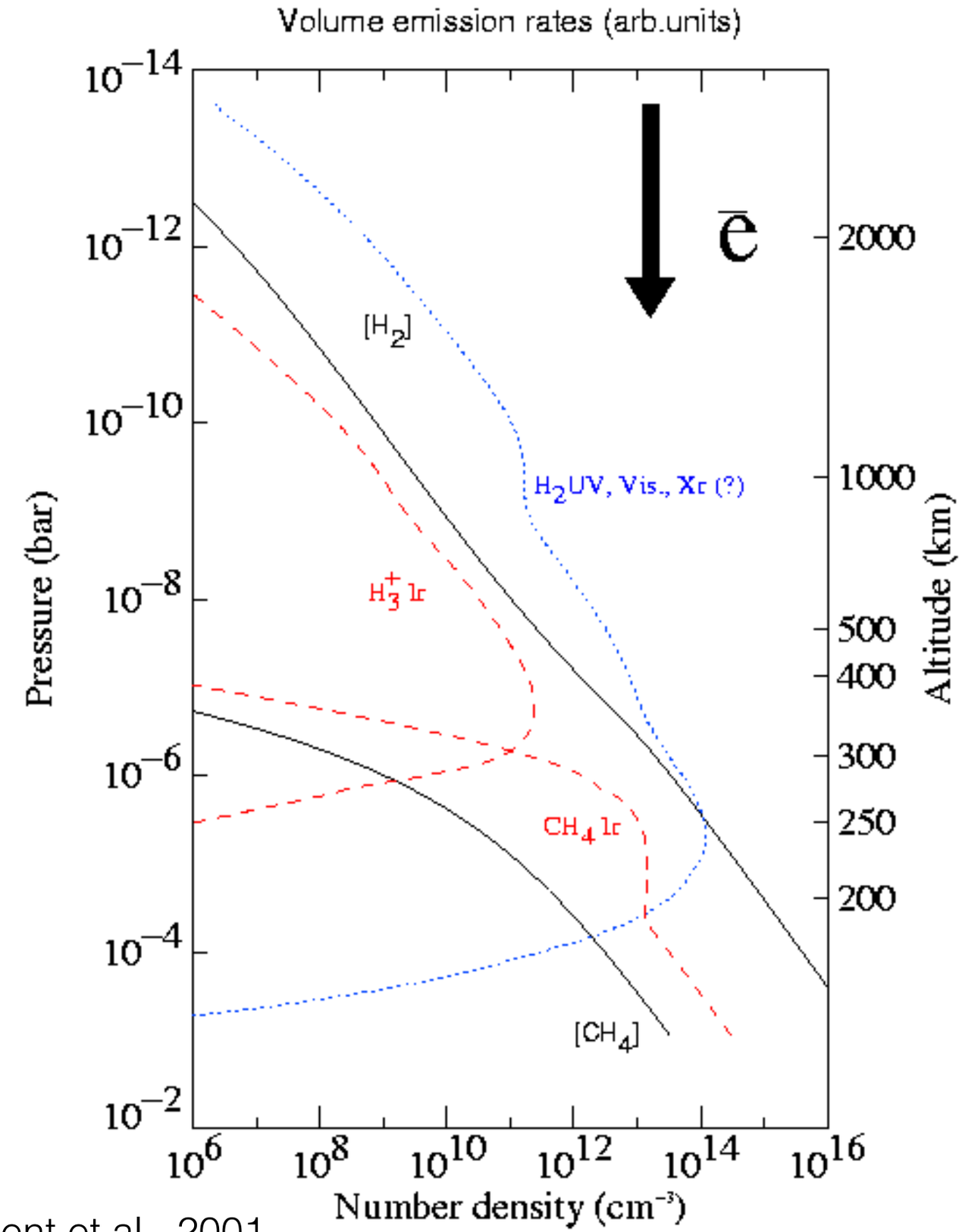


Grodent et al., 2001

EUV - FUV aurora

$H_2 + e \rightarrow$
$H_2^* + e \rightarrow H_2 + h\nu$

$H_2 + e \rightarrow$
$H + H^* + e \rightarrow 2H + h\nu$



Grodent et al., 2001

IR aurora

$H_2 + e \rightarrow H_2^+ + 2e$

$H_2^+ + H_2 \rightarrow \mathbf{H_3^{+*}} + H$

$H_3^{+*} \rightarrow H_3^+ + h\nu$

τ ~1000 sec

$H_3^+ + CH_4 \rightarrow CH_5^+ + H_2$

$H_3^+ + e \rightarrow H_2 + H$

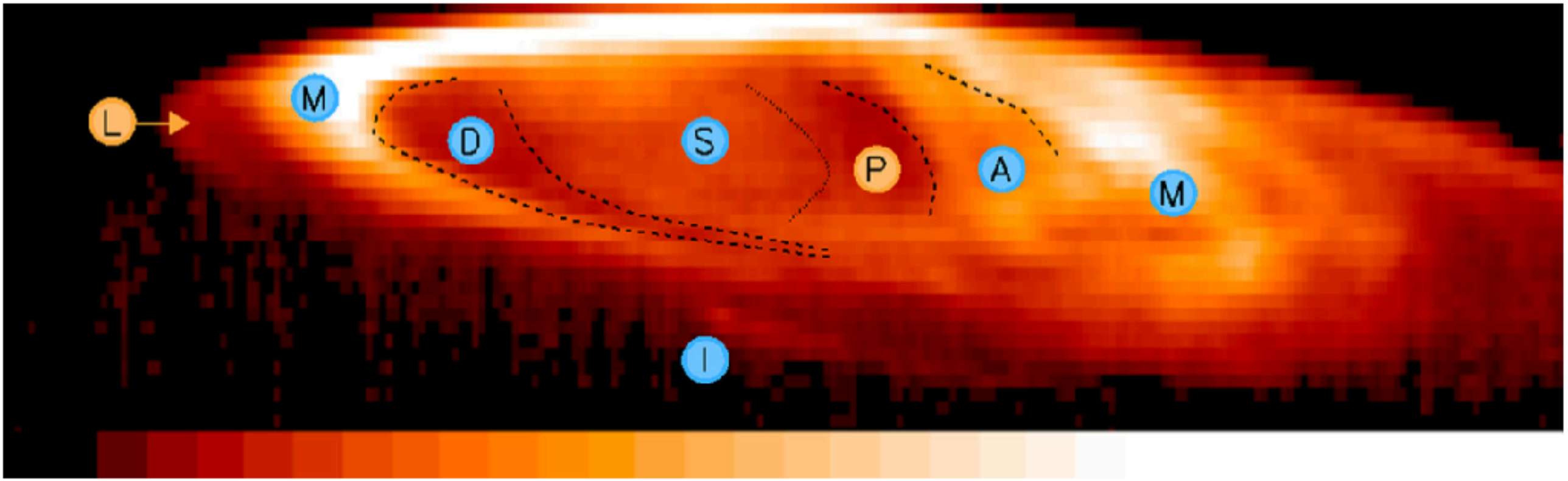
$H_3^{+*} + H_2 \rightarrow H_3^+ + H_2^*$

$H_2^* \rightarrow H_2 + h\nu$

H_2 quadrupolar

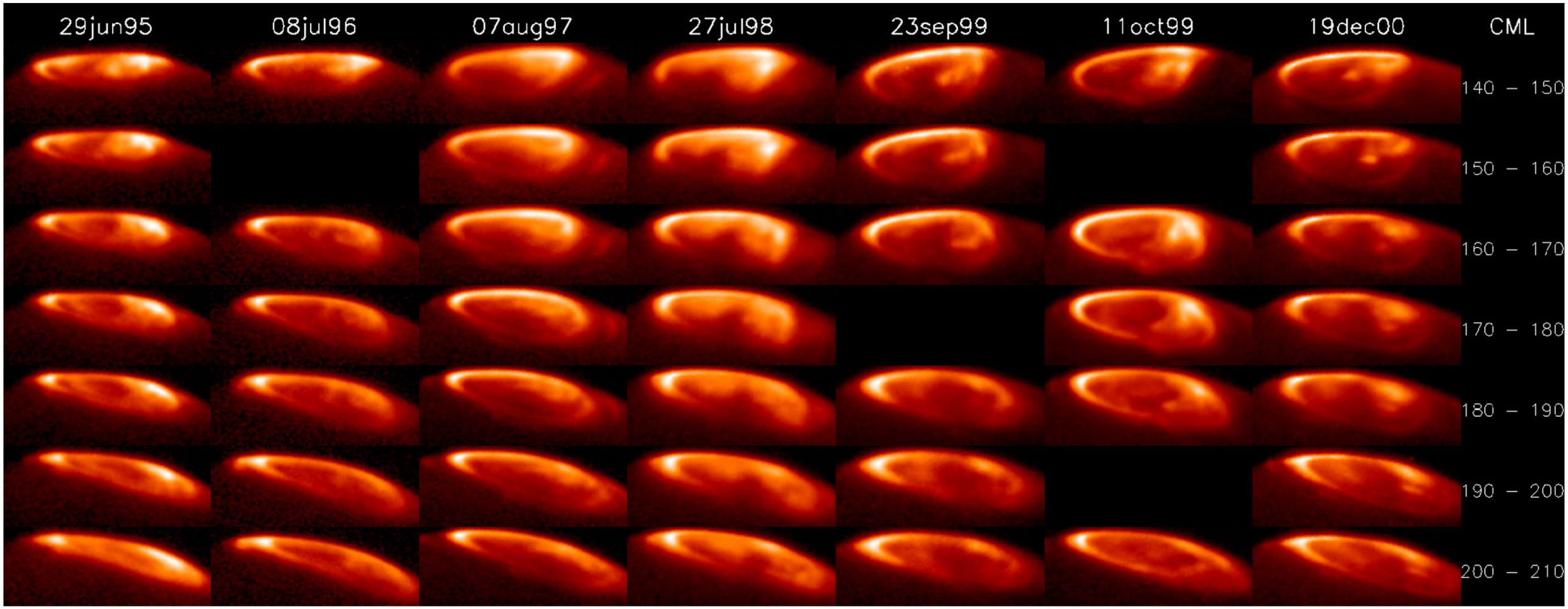
Jupiter IR aurora
ESO VLT CRIRES (AO, 8m)
Spectral scan (similar to UV)
pixel scale ~0.1” (0.2”, STISx8)
L-band 3-4 μm

long-slit 10 sec for 15 min

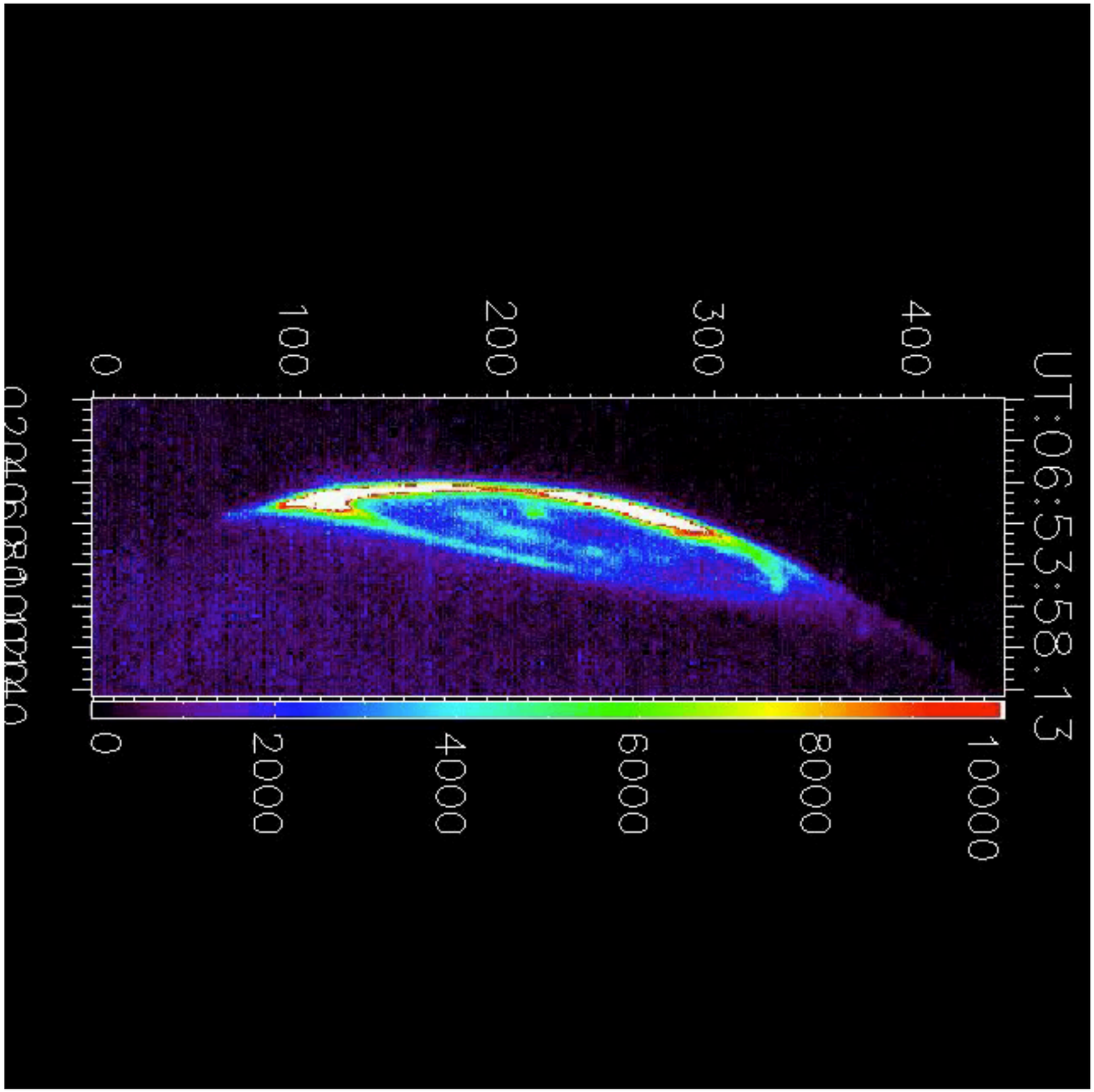


Stallard et al., 2016

Jupiter IR aurora
NASA IRTF NSFCam (3m)
120 sec Images
Pixel scale ~0.15” (0.2” STISx8)
narrow band 3.45 μm



Stallard et al., 2016



Subaru Telescope

0.2'' resolution with AO.
10 x 2 sec exposures.

Unpublished material, courtesy Hadjime KITA, Haruna WATANABE (Tohoku Univ.)

8.2 m. National Astronomical Observatory of Japan, Mauna Kea

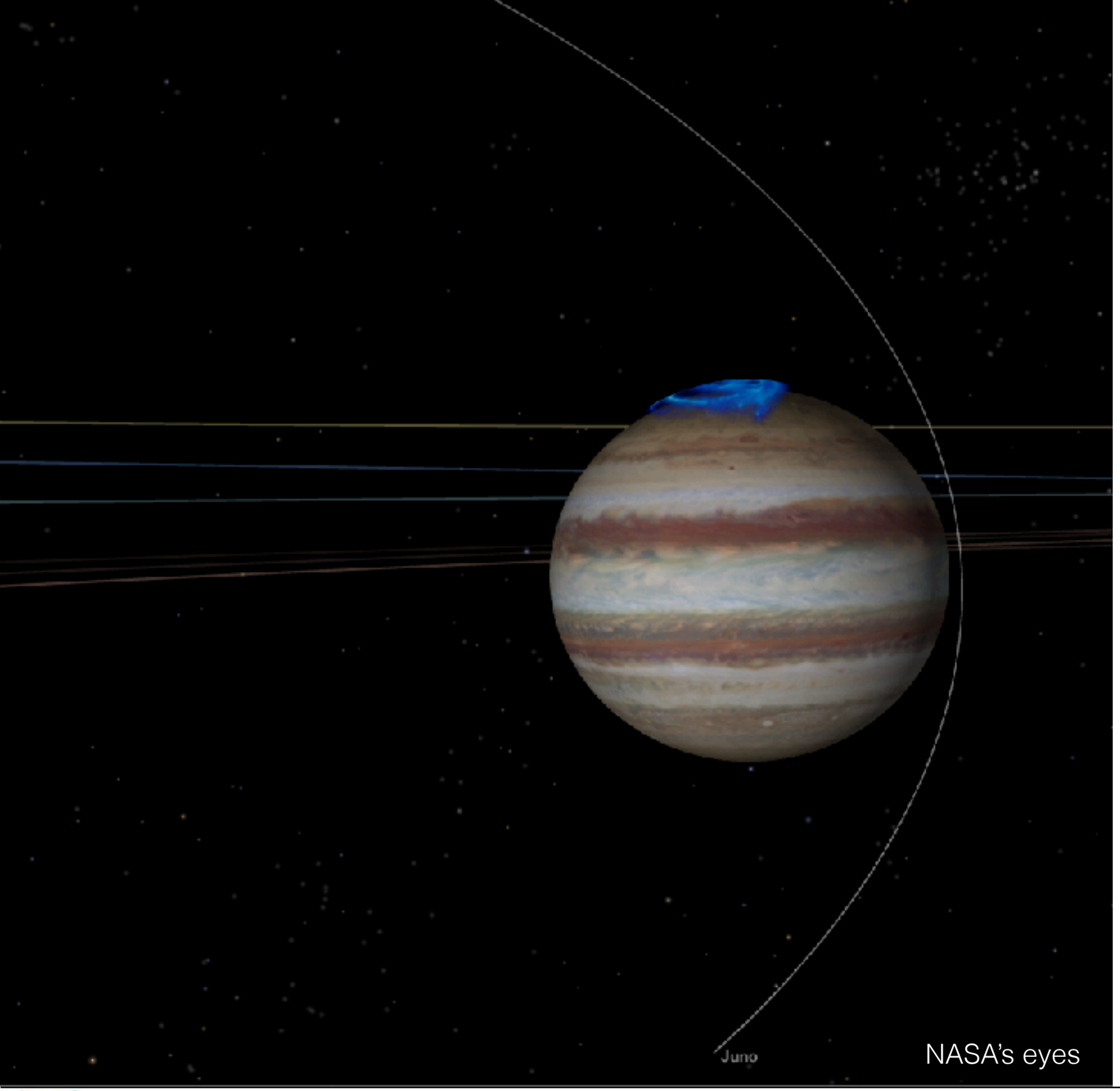
Spatial resolution appears to be limited by H_3^+ lifetime (several minutes)

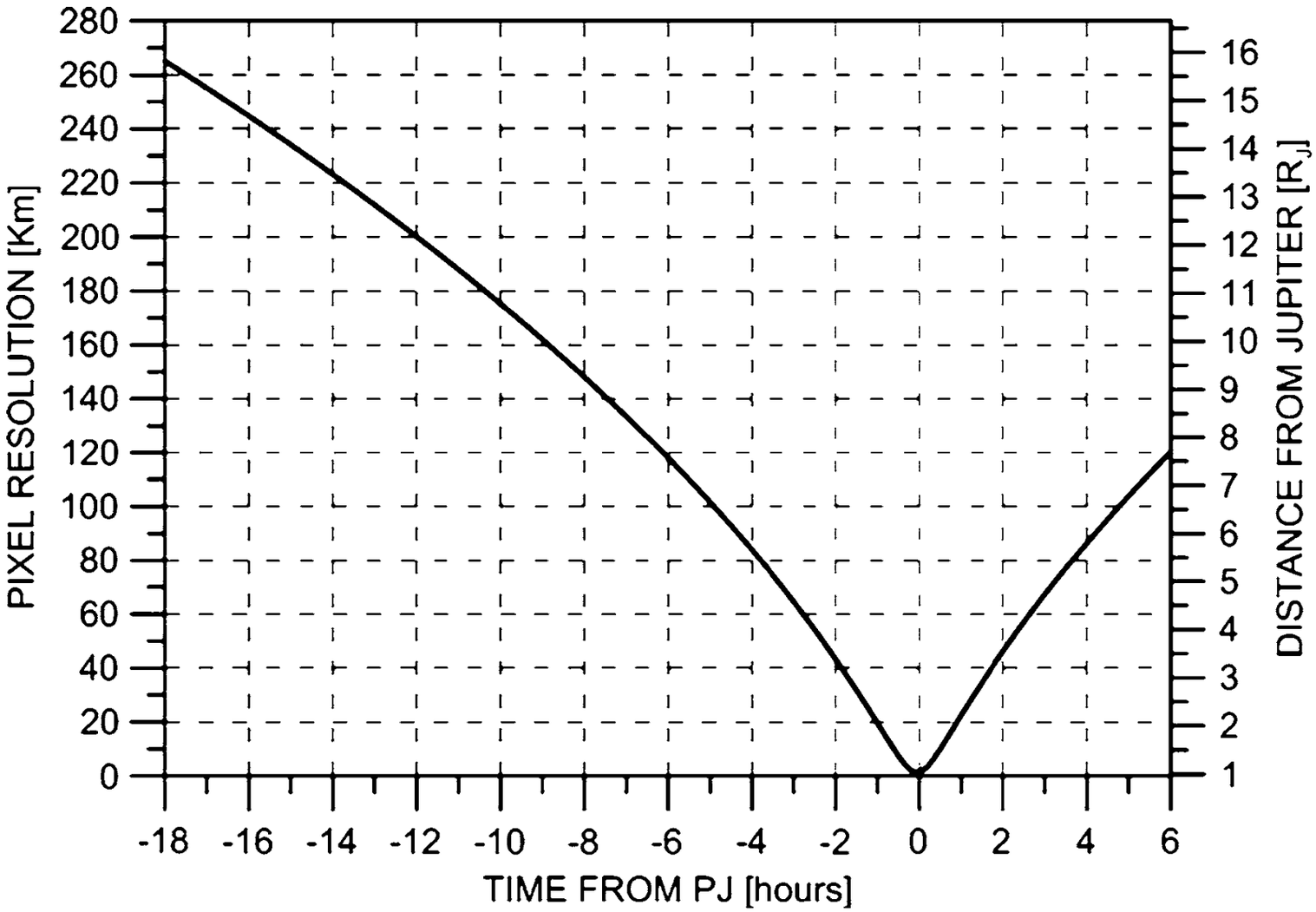
Juno - Jupiter flyby

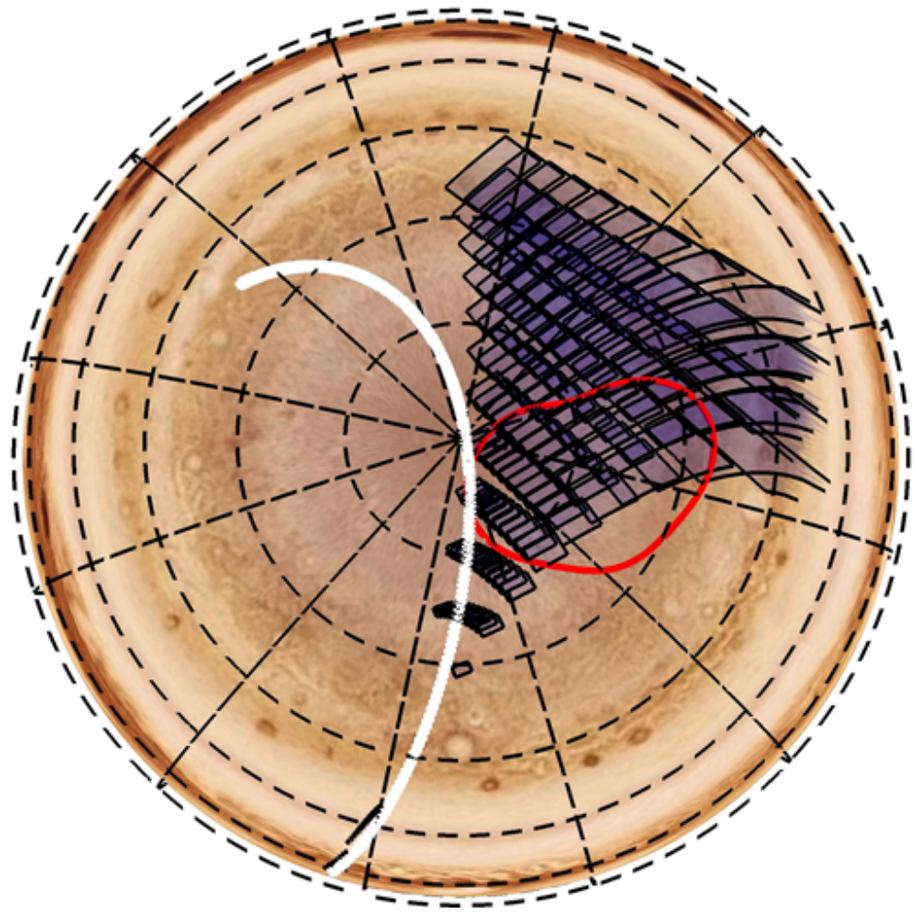
(next PJ05 on March, 27)

JIRAM

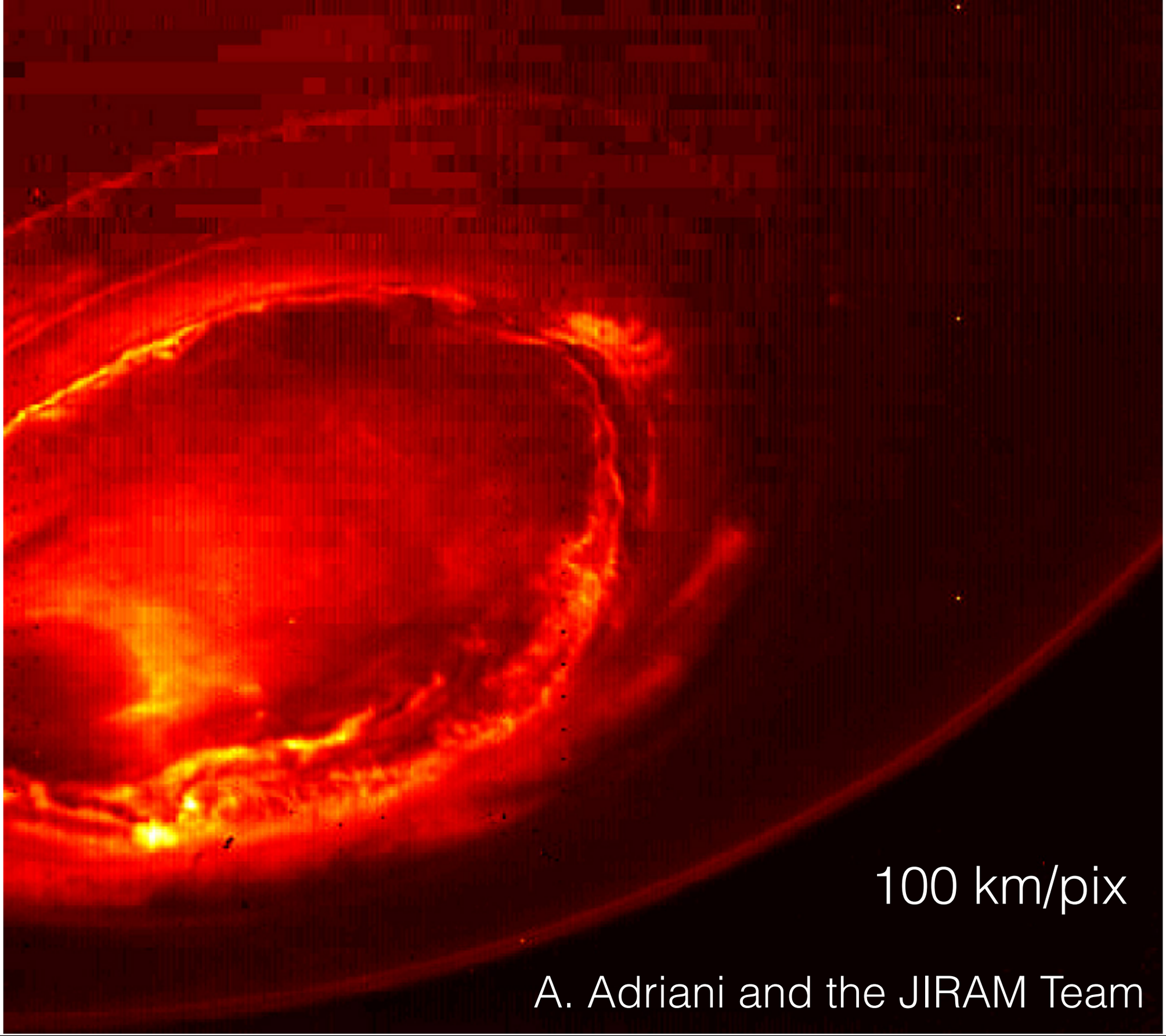
high-res images of the IR aurora







Adriani et al., 2014


100 km/pix
A. Adriani and the JIRAM Team

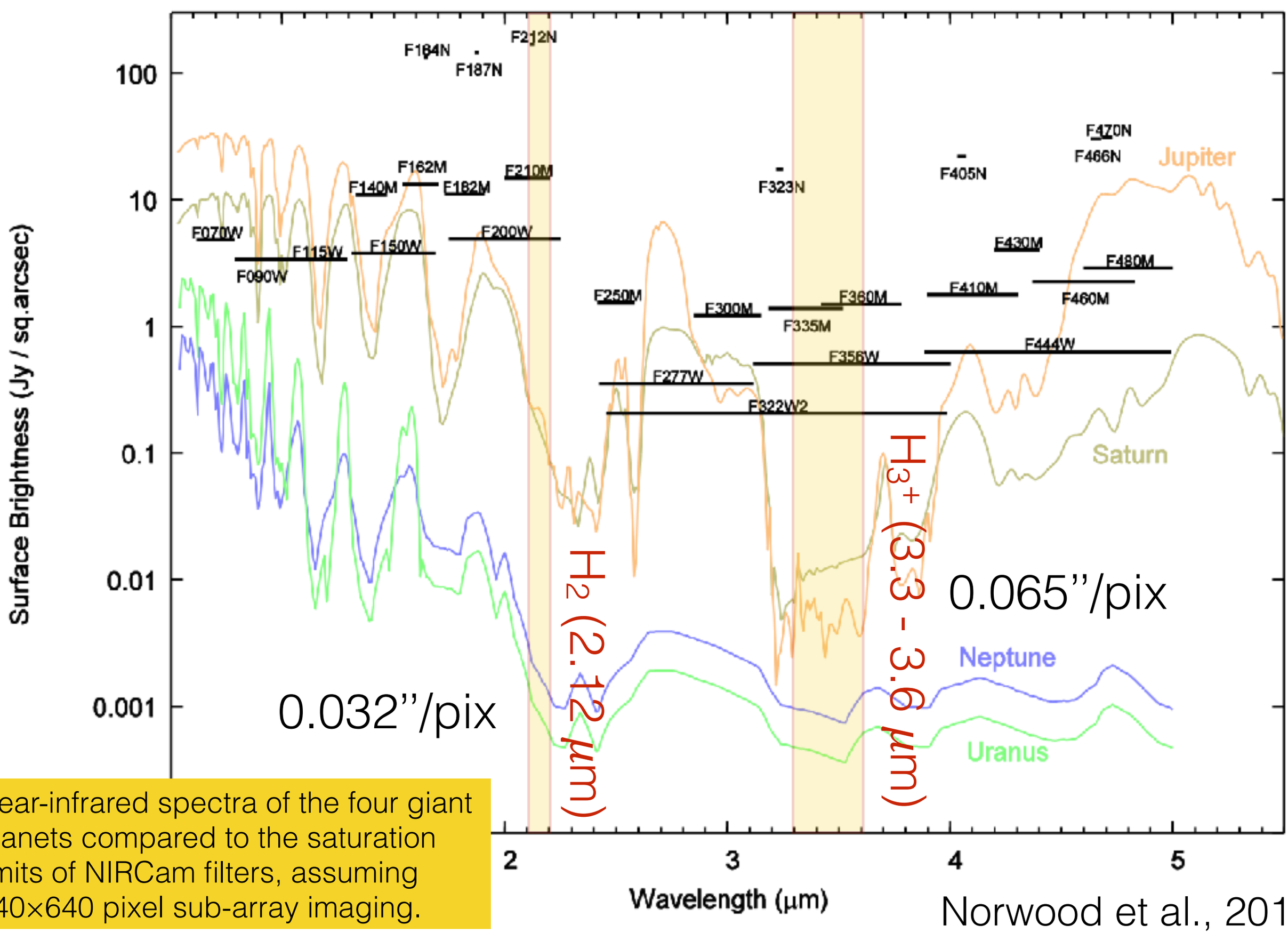
With appropriate IR instrument, it is possible to achieve the same image quality as that offered by HST-STIS in the UV.

However, UV and IR do not show exactly the same features (ionospheric convection motion, Joule heating, atmospheric Temperature, …).

⇒ Use JWST!

Possible to use JWST for Jupiter's aurora?

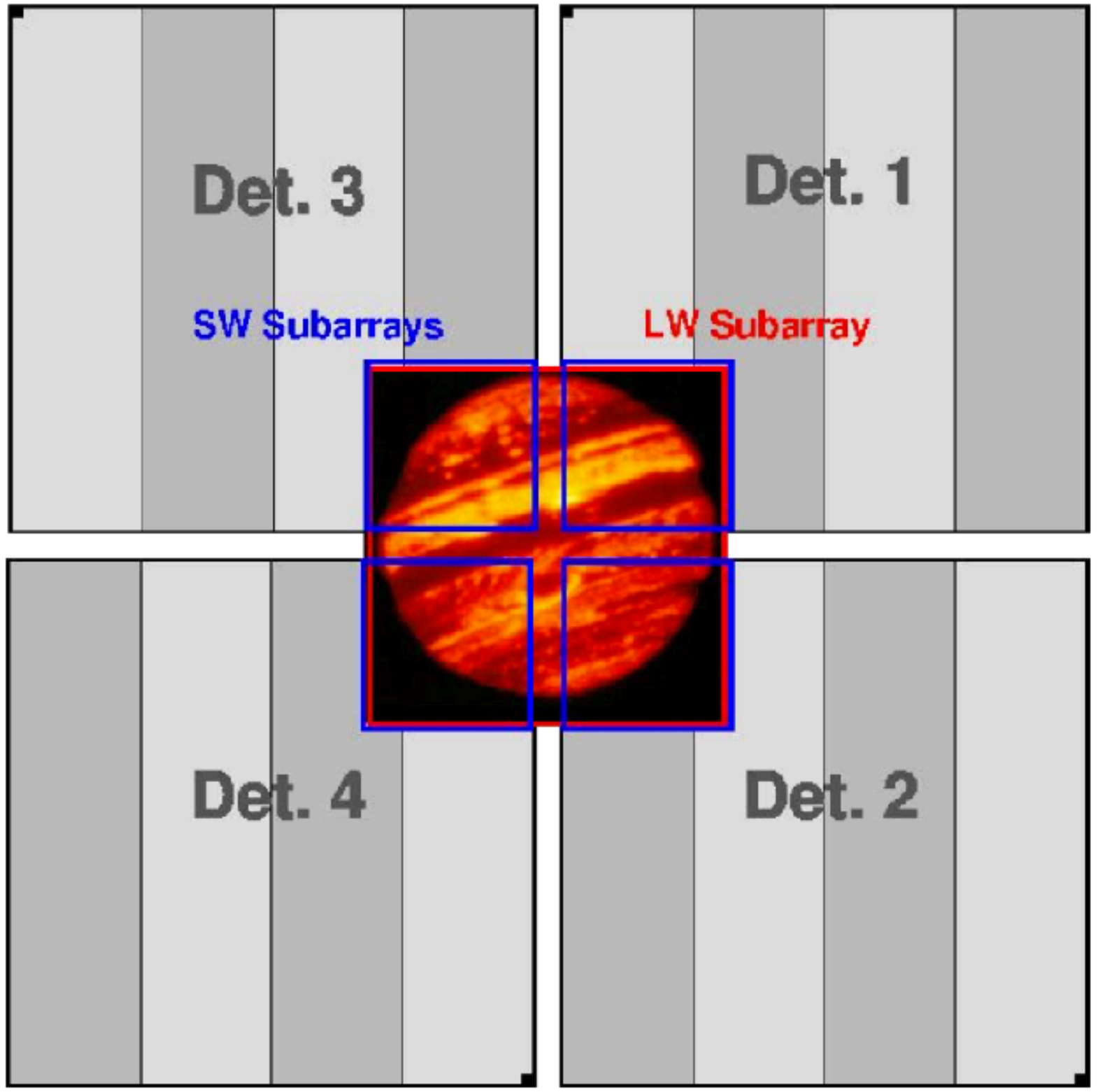
Yes, NIRCam (NIRSpec) is perfectly suited



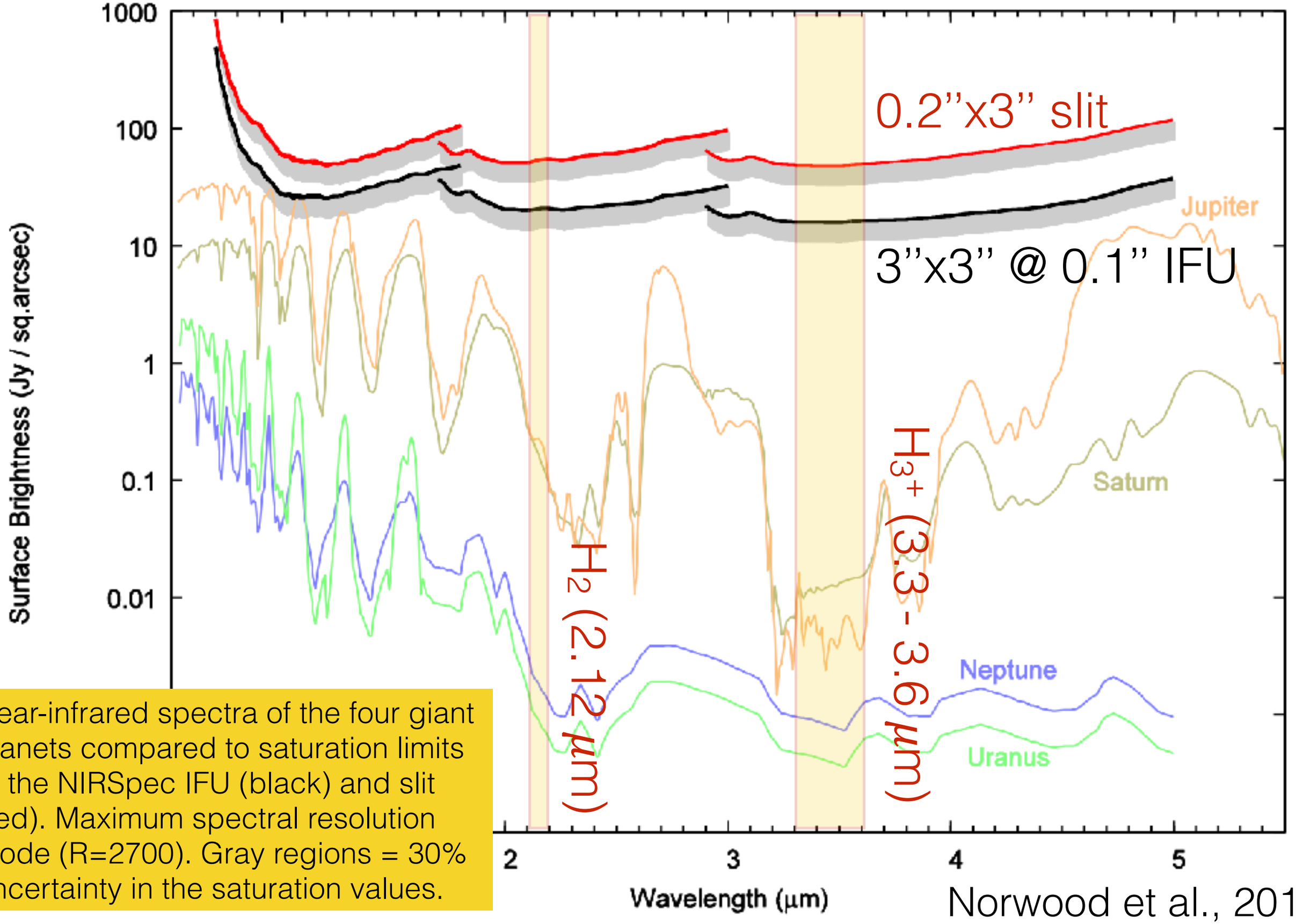
Near-infrared spectra of the four giant planets compared to the saturation limits of NIRCam filters, assuming 640×640 pixel sub-array imaging.

Norwood et al., 2015

Possible configuration for observing Jupiter using the 640x640 sub-arrays on NIRCam



Norwood et al., 2015



Near-infrared spectra of the four giant planets compared to saturation limits of the NIRSpec IFU (black) and slit (red). Maximum spectral resolution mode (R=2700). Gray regions = 30% uncertainty in the saturation values.

Norwood et al., 2015

Thank You!