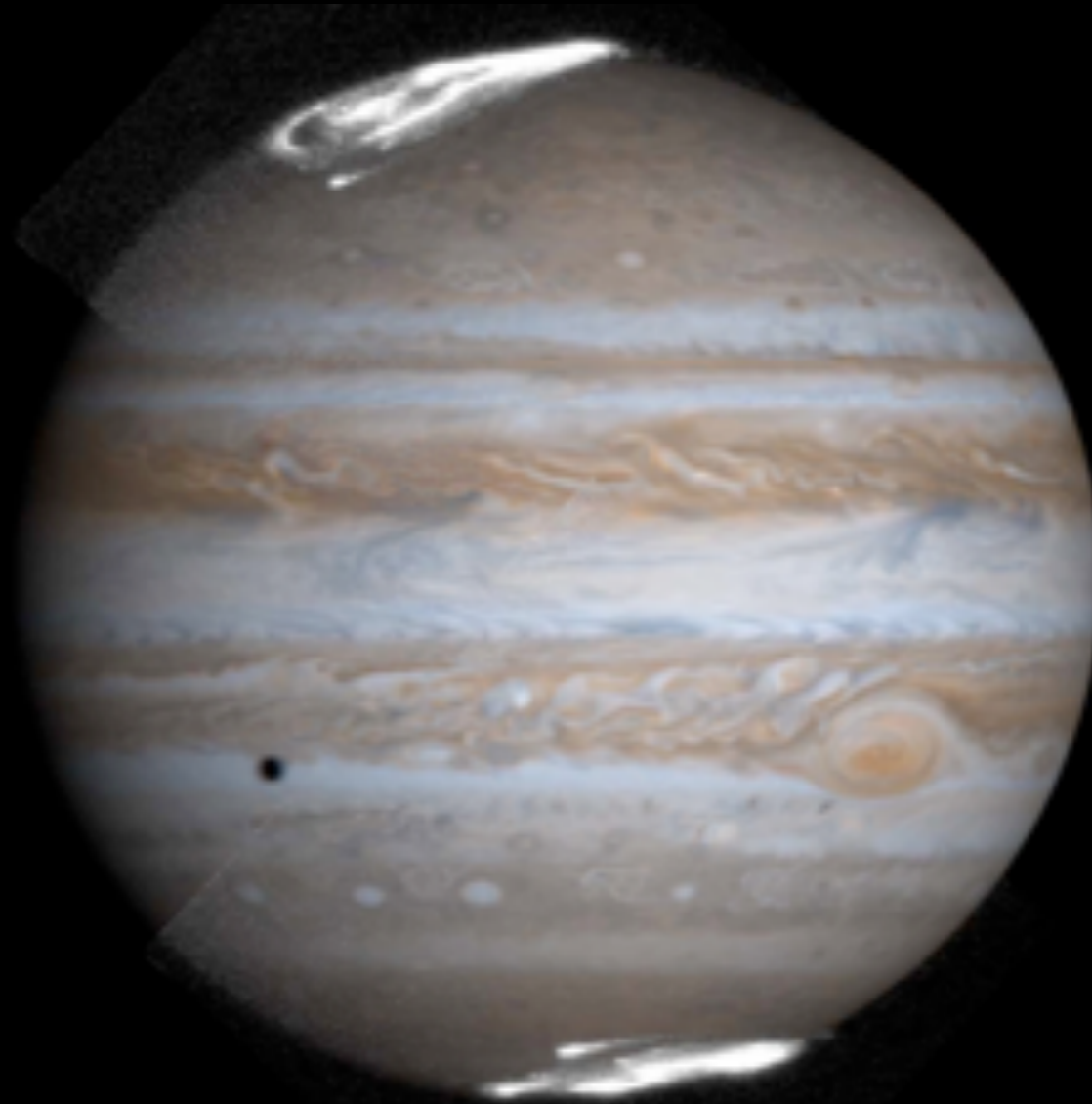


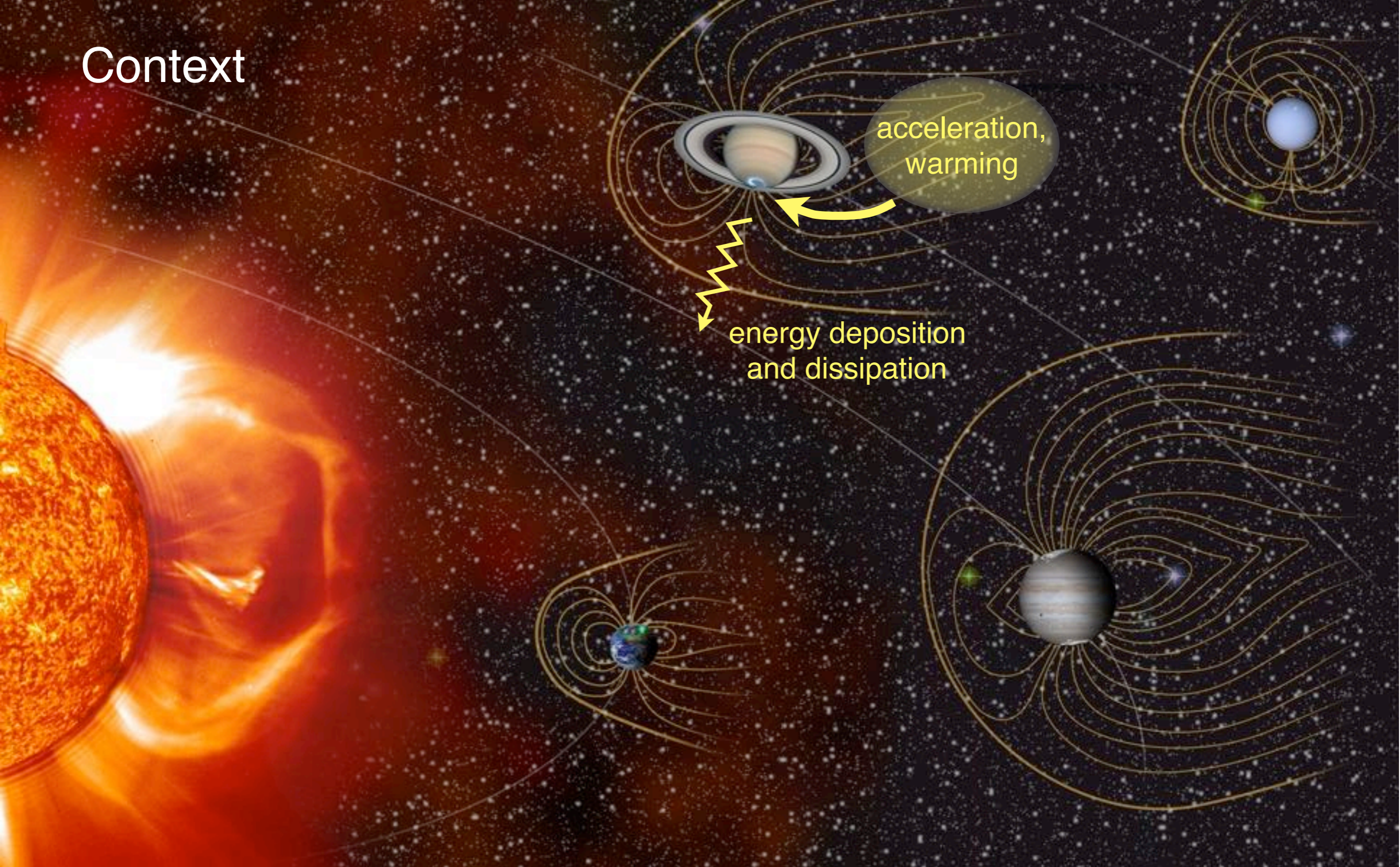
Investigating (exo)planetary aurorae in the Far-UV beyond HST



L. Lamy, R. Prangé, LESIA-Observatoire de Paris
M. Barthélémy, IPAG, Grenoble

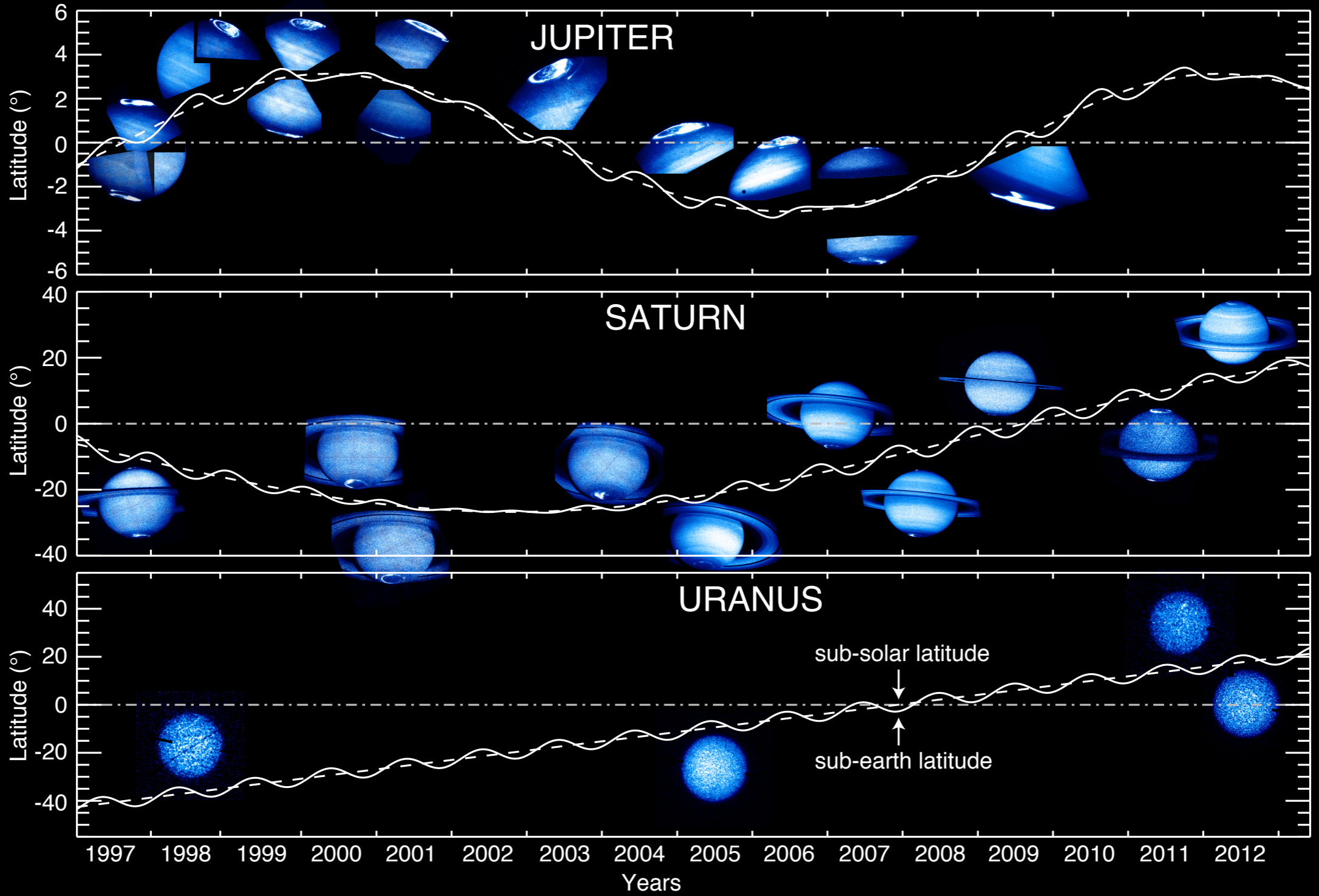
Atelier CIAS LUVOIR, Meudon, 11 Janvier 2017

Context



- Planetary magnetospheres : natural laboratories of plasma physics
- Complex interaction with the solar wind, atmosphere, satellites => plasma acceleration
- Energy deposited in polar regions of planets/satellites => aurorae = powerful diagnosis

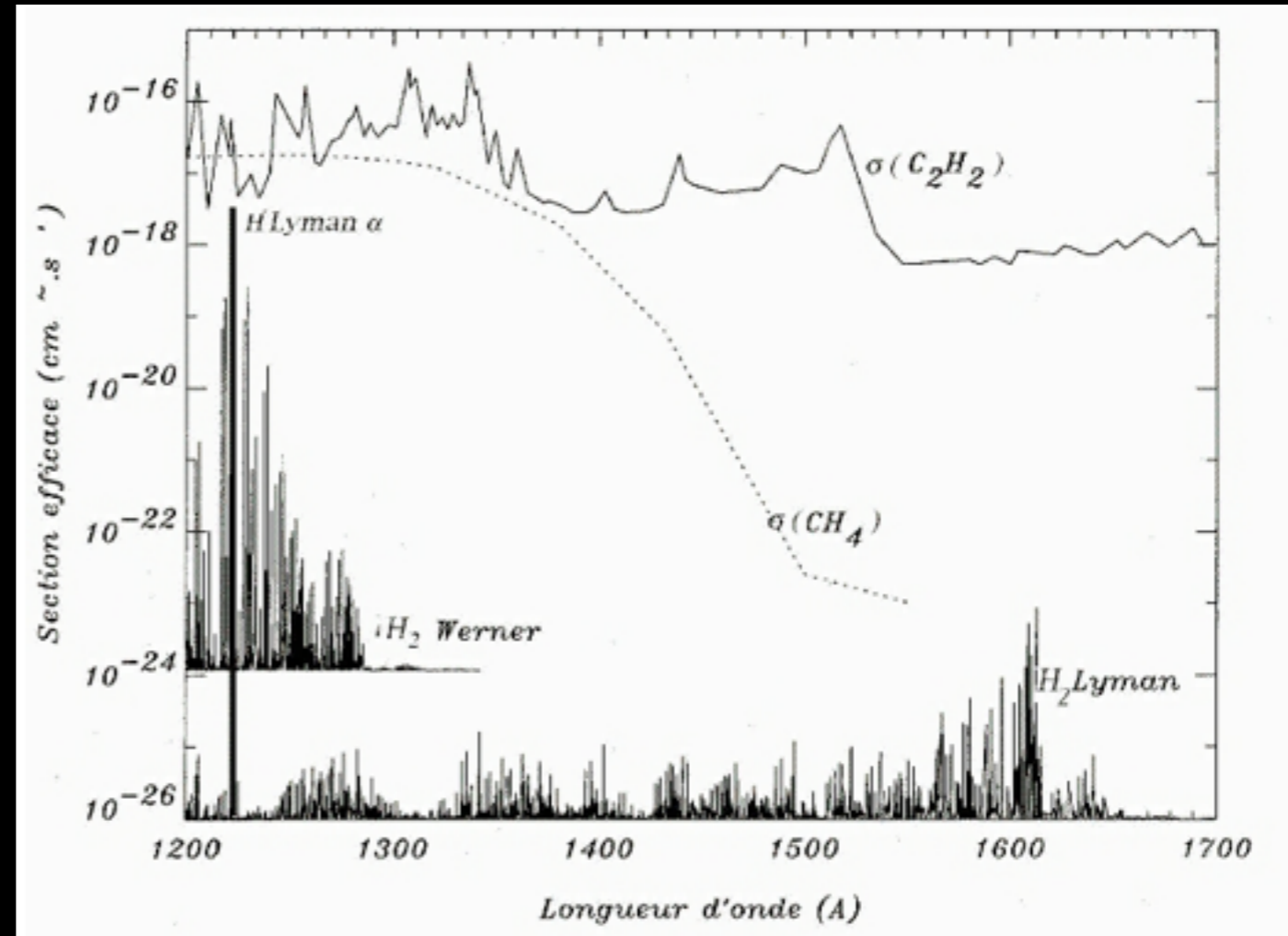
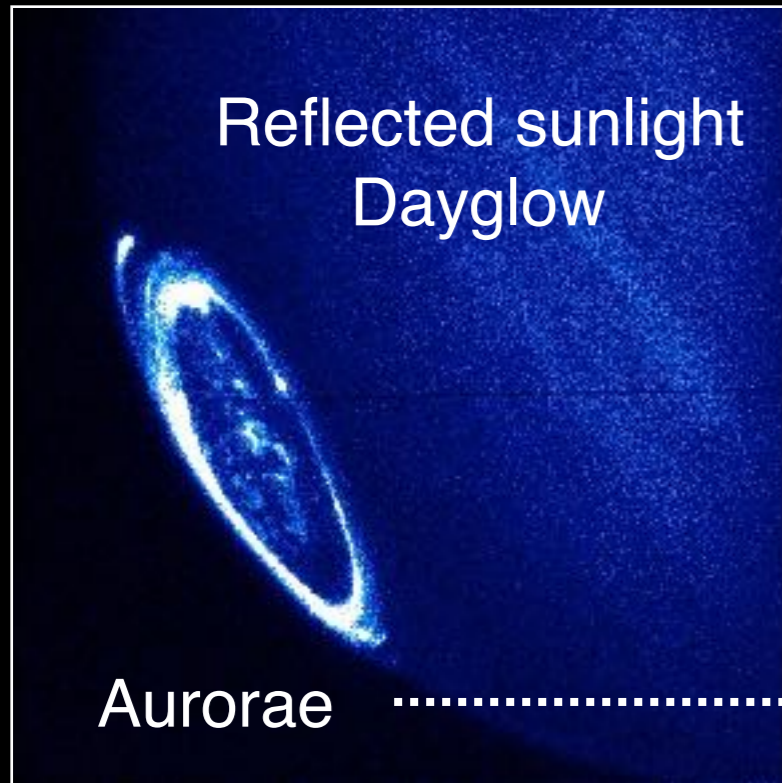
Planetary ultraviolet aurorae : the legacy of Hubble



The HST heritage : ~6300 FUV observations of Jupiter, Saturn, Uranus systems >1990

Planetary ultraviolet aurorae : the legacy of Hubble

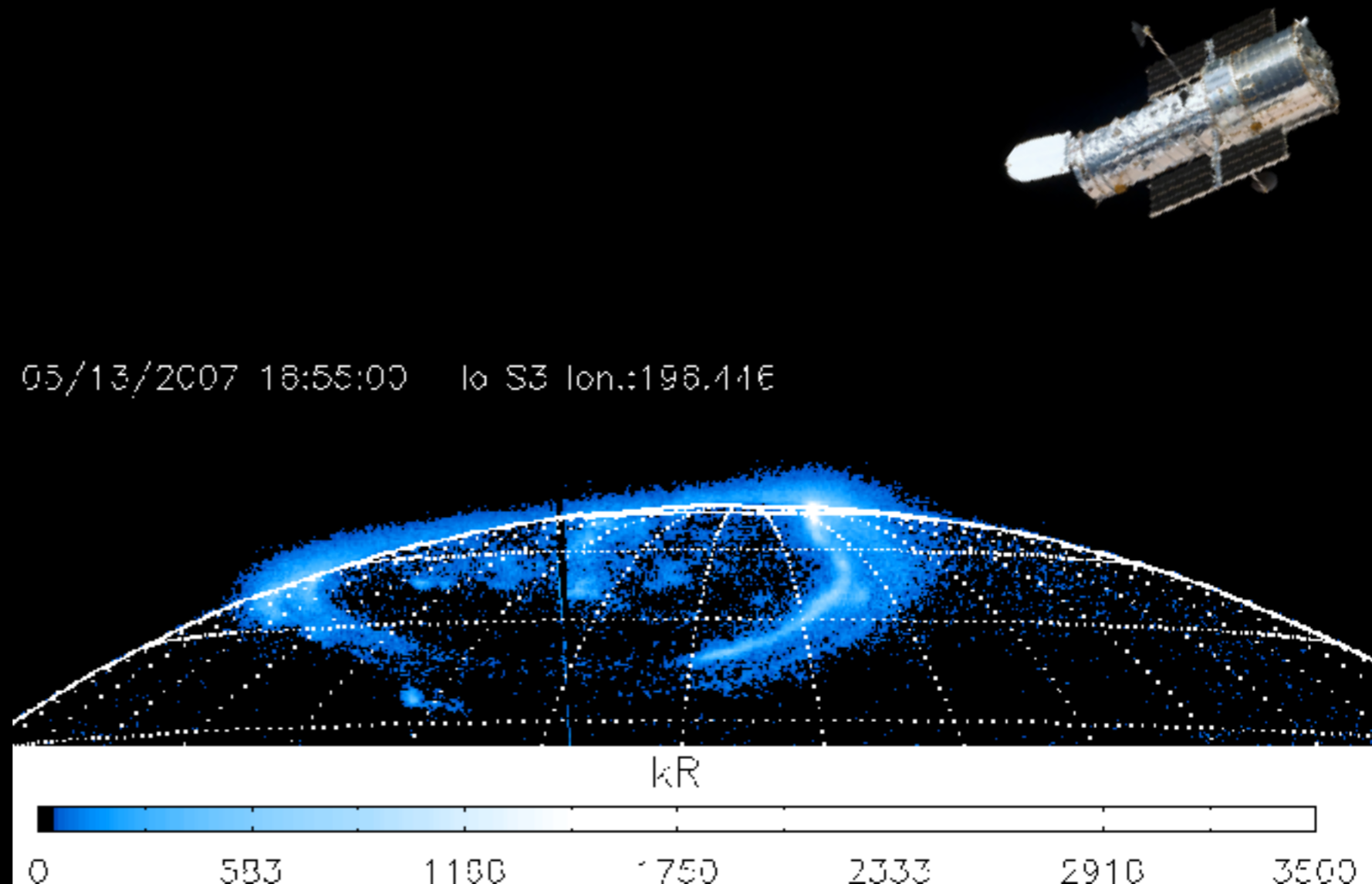
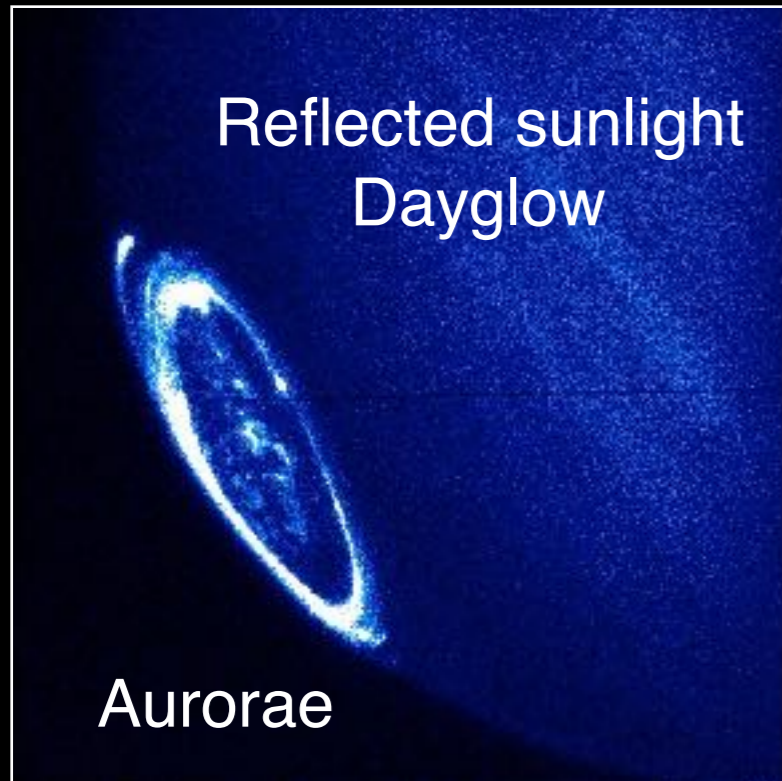
JUPITER



- Aurorae of giant planet systems : HST database => <http://apis.obspm.fr>
- + H/H₂ (80-180nm) for planets + OI (~130nm) for satellites
- + localized/extended emissions (spots, circumpolar ovals)
- + variability down to timescales of seconds (Jupiter polar spots, Uranus)

Planetary ultraviolet aurorae : the legacy of Hubble

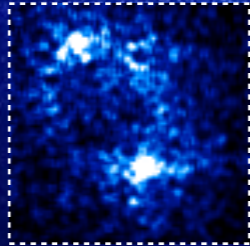
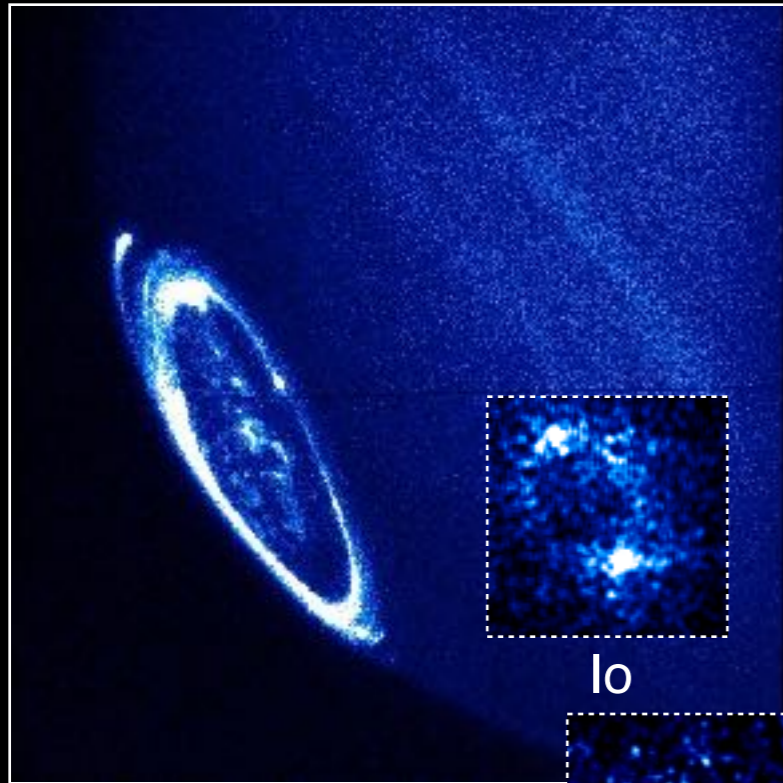
JUPITER



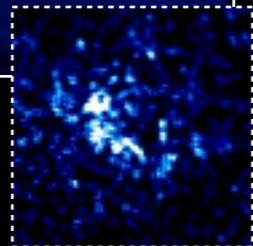
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Planetary ultraviolet aurorae : the legacy of Hubble

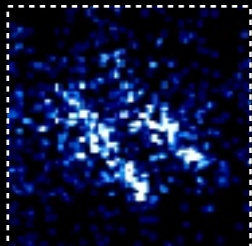
JUPITER



Io

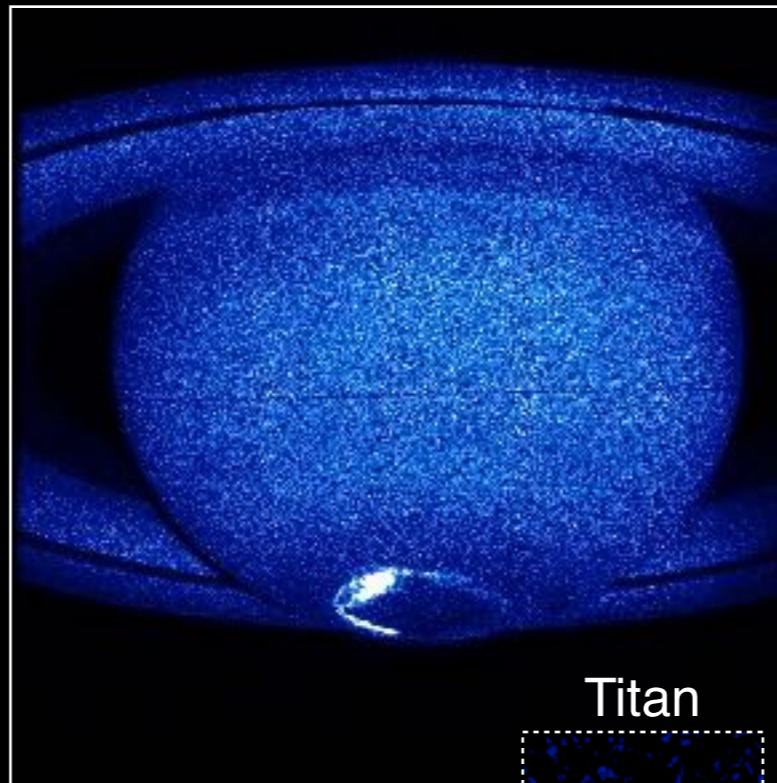


Europa

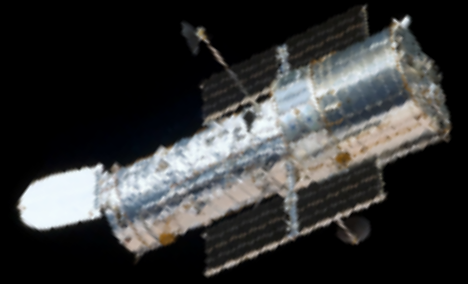
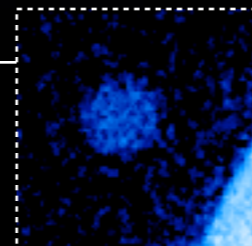


Ganymede

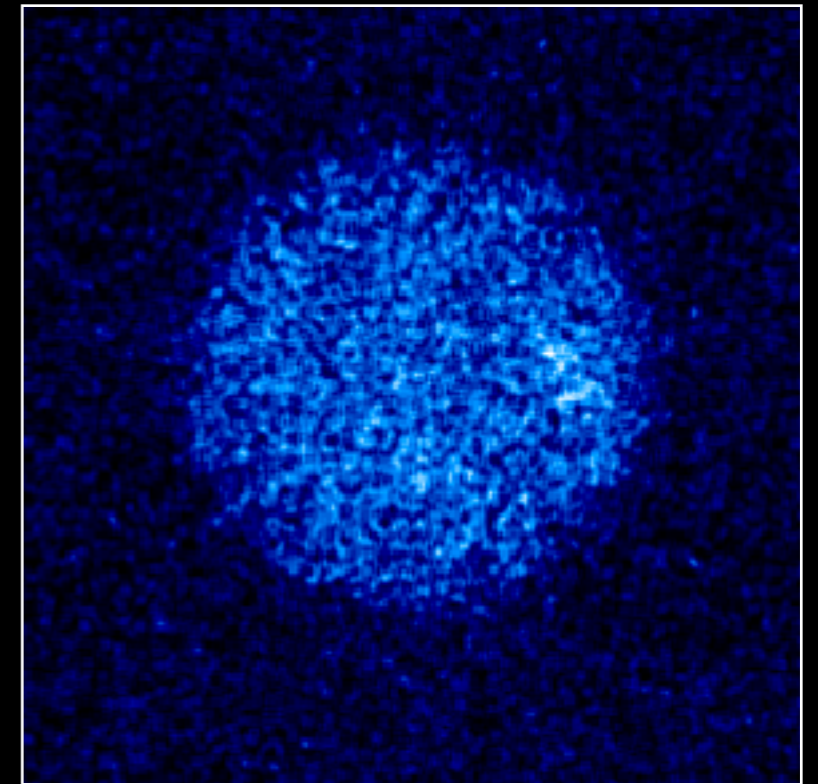
SATURN



Titan



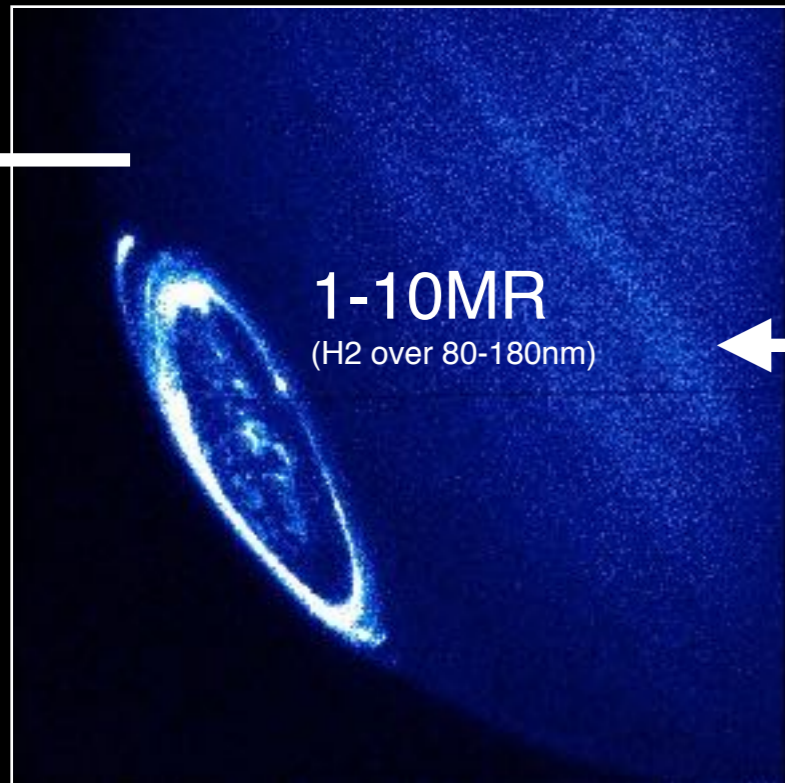
URANUS



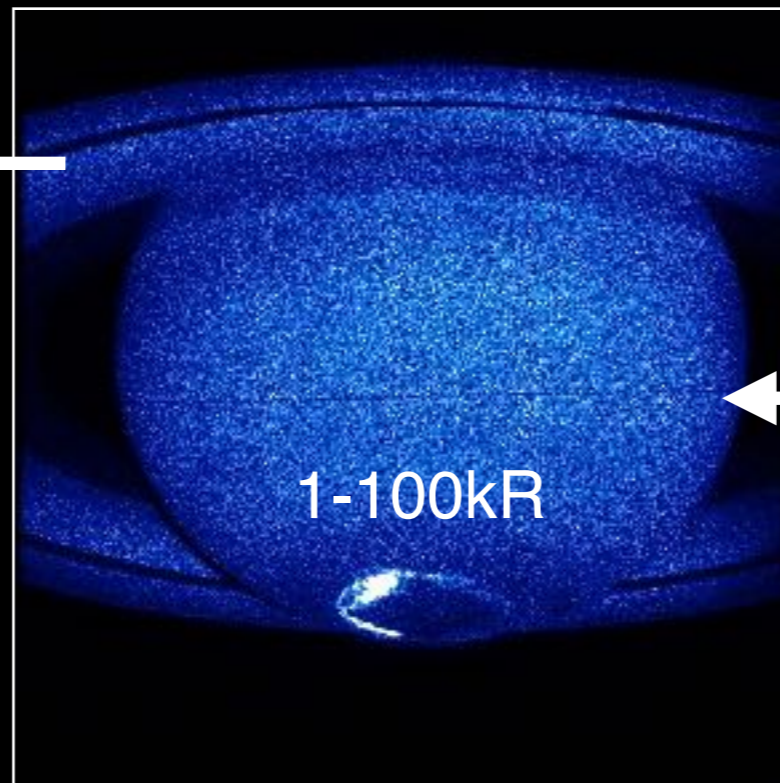
- Aurorae of giant planet systems : HST database => <http://apis.obspm.fr>
- Series of Far-UV spectro-imagers : FOC, WFCP2, STIS, ACS, COS
=> above examples : STIS images (24"x24", 120-180nm)

Planetary ultraviolet aurorae : through the LUVOIR

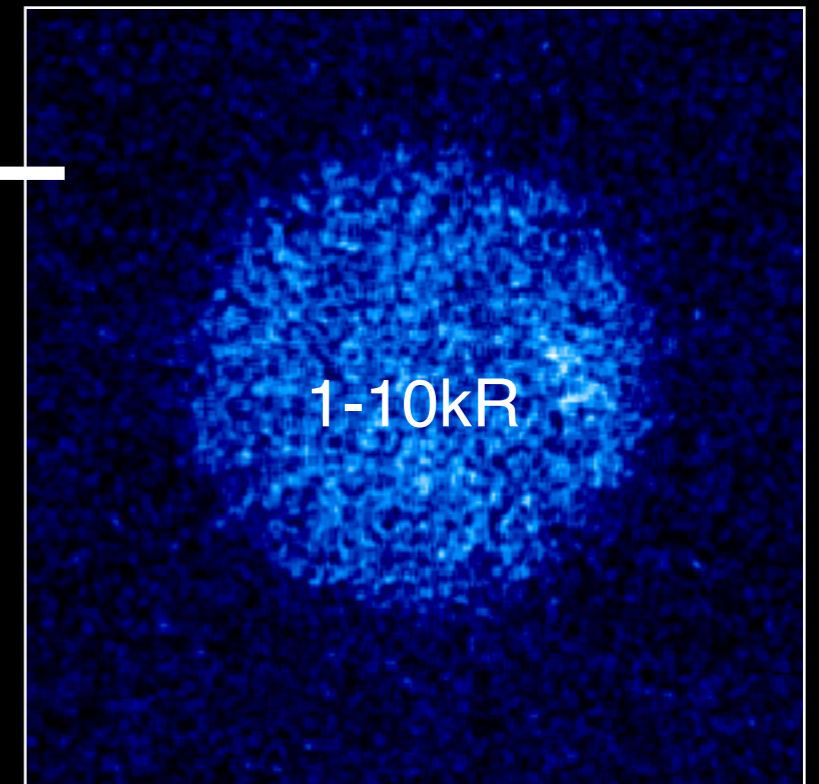
JUPITER



SATURN



URANUS



- From HST to LUVOIR (6-12m) :

Theoretical gain in angular resolution ~ 3 to 5

=> Uranus ~ seen as Saturn, Saturn ~ as Jupiter etc.

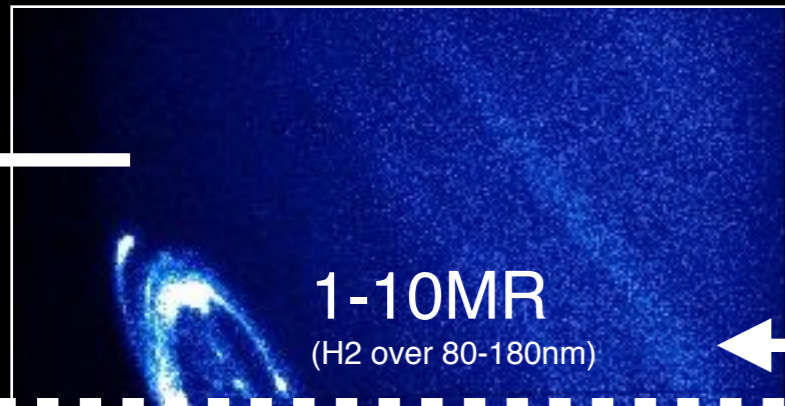
Theoretical gain in sensitivity ~ 11 to 25

=> Uranus emissions of a few kR easily detectable (harsh today)

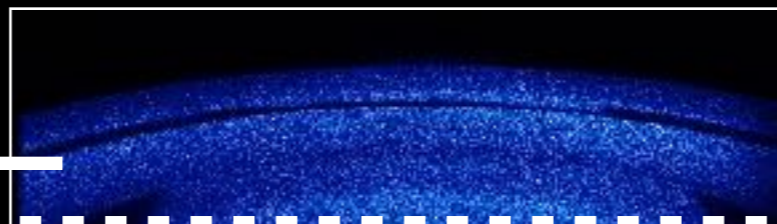
=> Confirmation of Neptune's aurorae (ambiguous detection by Voyager2/UVS) ?

Planetary ultraviolet aurorae : through the LUVOIR

JUPITER



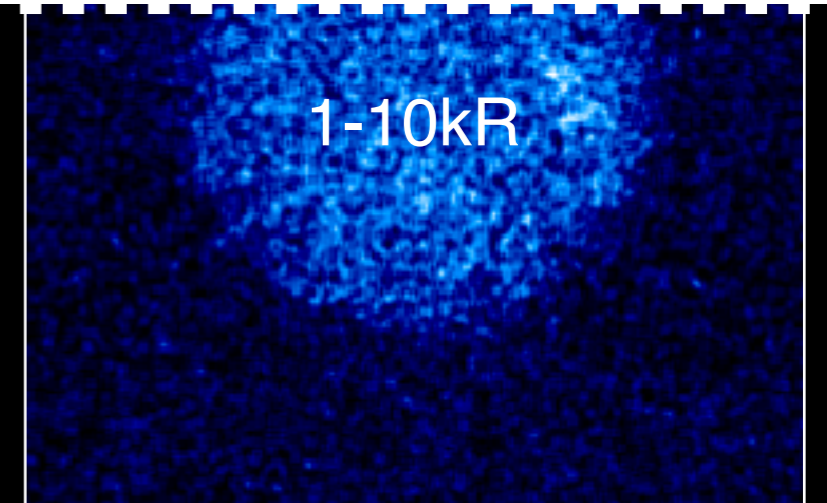
SATURN



URANUS

LUVOIR contribution to the study of the solar system :

- (1) ONLY TOOL to study the Uranus/Neptune magnetospheres (no planned probe yet)
- (2) complete the investigation of Jupiter/Saturn/Satellites at high spatial/spectral res.



- From HST to LUVOIR (6-12m) :

Theoretical gain in angular resolution ~ 3 to 5

=> Uranus seen as Saturn etc.

Theoretical gain in sensitivity ~ 11 to 25

=> Uranus easily detectable (harsh today)

=> Confirmation of Neptune's aurorae (barely detected by Voyager2/UVS) ?

Planetary ultraviolet aurorae : through the LUVOIR

Currently planned instruments :

- High Definition Imager (HDI) $>200\text{nm}$ \Rightarrow beyond auroral bandpass
- O/NIR spectrograph $>300\text{nm}$ \Rightarrow beyond auroral bandpass
- LUMOS : ok !

LUMOS planned modes : (K. France et al.)

(1) Point-echelle spectrograph : high resolving power

(2) Multi-object imaging spectrograph :

- Spectral window : 100-400 nm
- Temporal resolution : 1 msec
- Multi-Object FoV : $2'' \times 2''$ and resolution = $0.05''$
NB : Uranus at opposition $\sim 3.7''$ wide

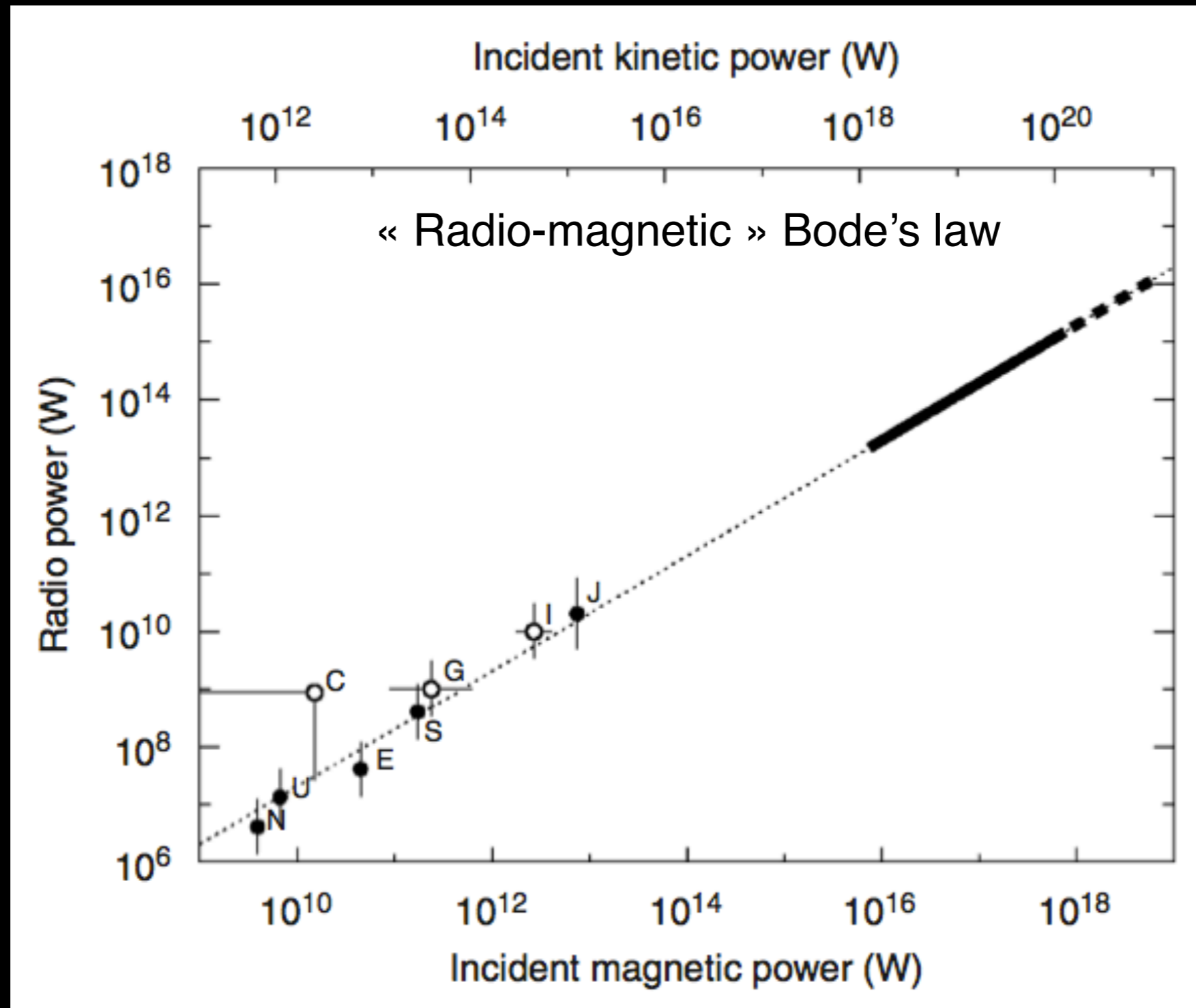
(3) FUV imaging mode (under discussion) : ?

Needs for auroral physics :

\Rightarrow modes (1) and (2) : spectroscopic studies (radiative species, line profiles, absorption by CH_4 , $\text{H}_2 \Rightarrow$ energy of precipitating e^- , radiated power) with limited/discrete imaging capability ? (= question to Kevin et al.)

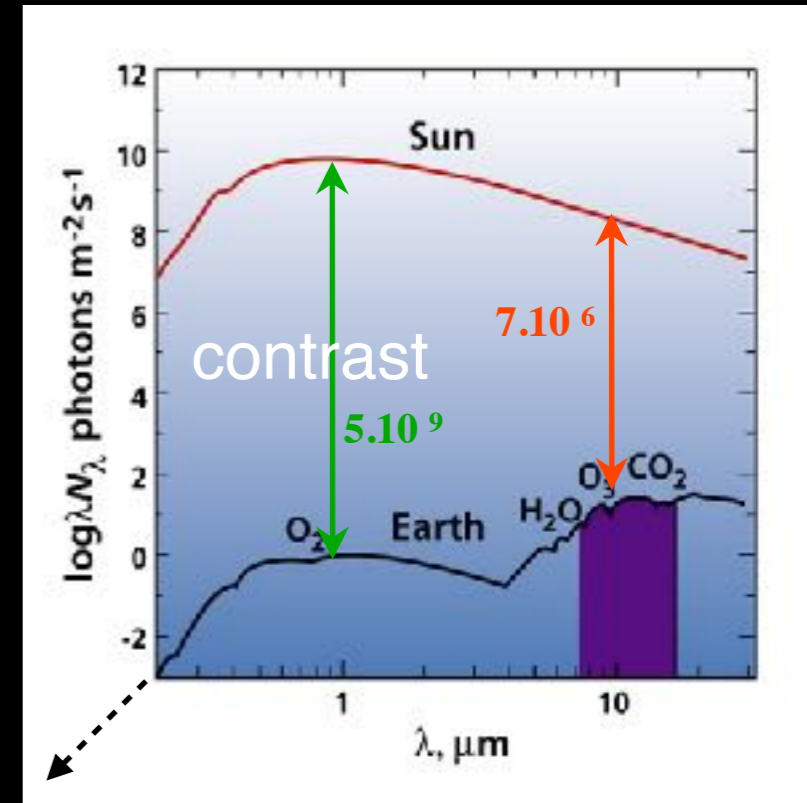
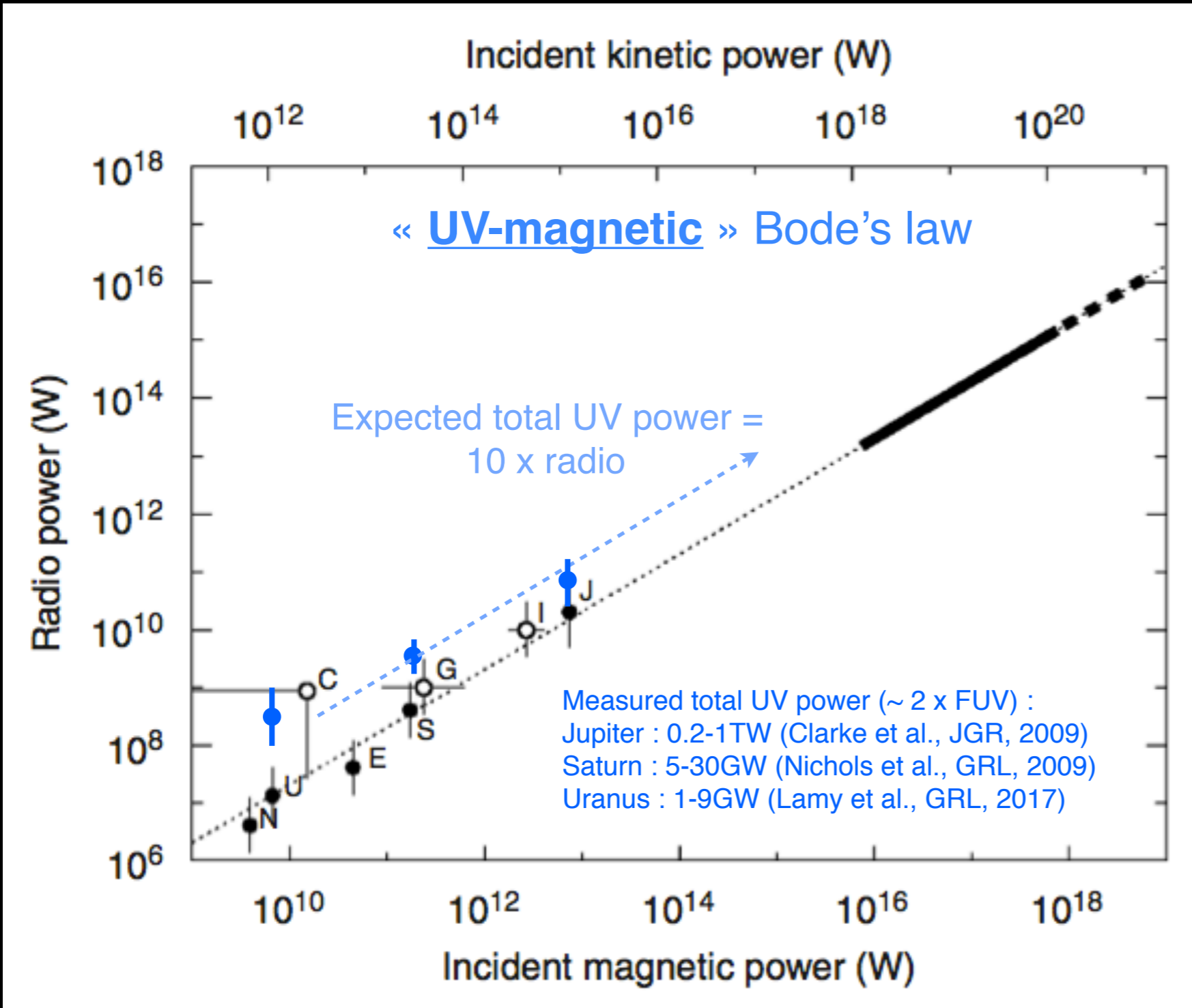
\Rightarrow mode (3) : highly valuable to track magnetospheric active regions !

Tracking exoplanetary aurorae with the LUVOIR ?



All planetary magnetized planets emit auroral emissions :
=> active search in radio (contrast ~ 1) with predictions through scaling laws

Tracking exoplanetary aurorae with the LUVOIR ?



All planetary magnetized planets emit auroral emissions :
 => applicable to H₂ aurorae : bad contrast improved by bright enough emissions ?

Some references

Planets :

- Jupiter/Saturn : huge literature
 - + see the reviews of (Badman et al., SSR, 2014) or (Grodent, SSR, 2014)
 - + main emission and SW control : (Clarke et al., 2009, Nichols et al., 2009)
 - + satellite footprints : (Clarke et al., 2002, Grodent et al., 2009, Bonfond et al., >2007)
- Uranus : (Herbet & Sandel, 1994, Lamy et al., 2012, 2017 ; Barthélémy et al., 2014)
- Neptune : (Sandel et al., 1990)

Satellites :

- Io : (Saur et al., 2000, Retherford et al., 2002)
- Europa : (Roth et al., 2014, 2016)
- Ganymede : (McGrath et al., 2016, Saur et al., 2015)

Data :

- APIS database : (Lamy et al., 2015)

Exoplanets & scaling laws :

- Radio : (Zarka et al., 2007)
- UV : (Lamy et al., PNST, 2013)