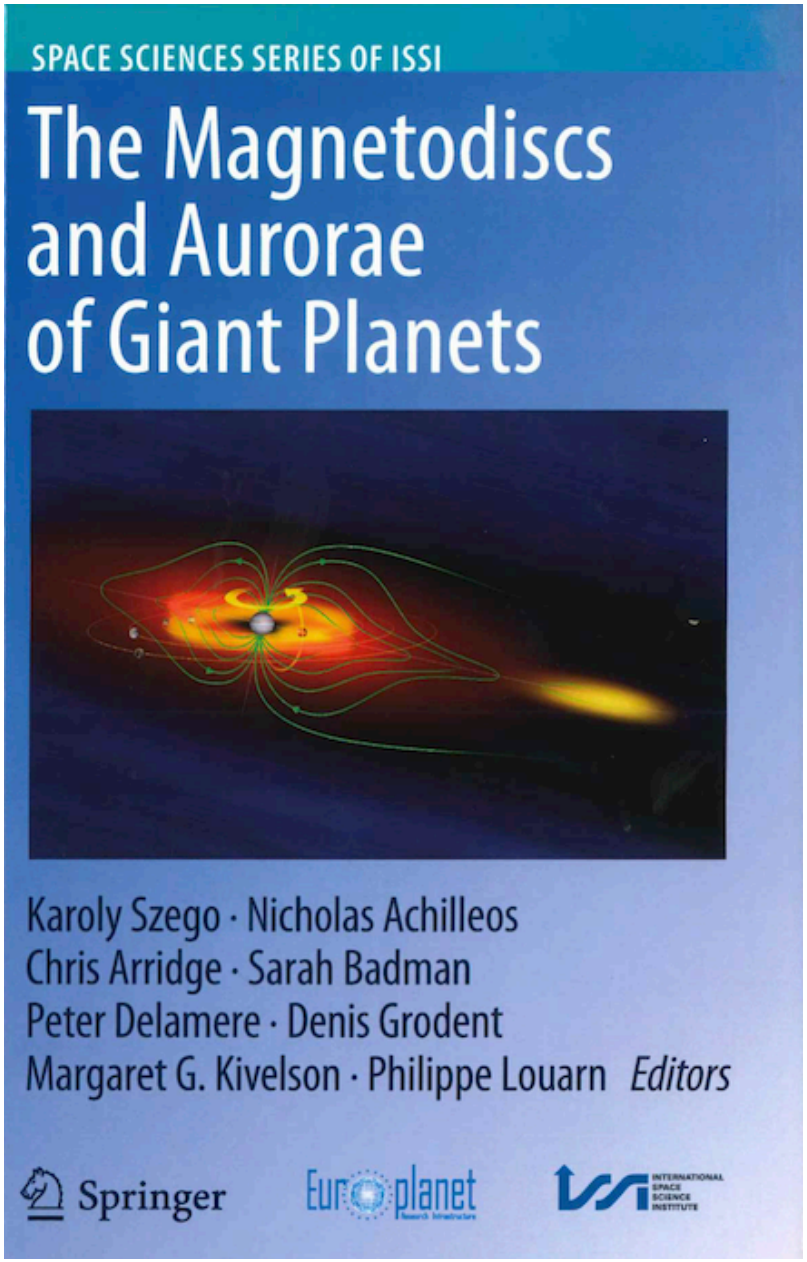
Ultraviolet auroral emissions on giant planets

Denis Grodent[1]
Bertrand Bonfond[1], *Aikaterini Radioti*[1],
Jacques Gustin[1], *Jean-Claude Gérard*[1],
Maïté Dumont[1], *Benjamin Palmaerts*[1,2]

[1] Laboratoire de Physique Atmosphérique et Planétaire, Université de Liège, Belgium
[2] Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany

ESWW12 – Oostende, 25 Nov 2015



Collection of 7 review papers previously published in *Space Science Reviews*

focus on space weather perspective:

Delamere et al. 2015
"Solar wind and internally driven dynamics"

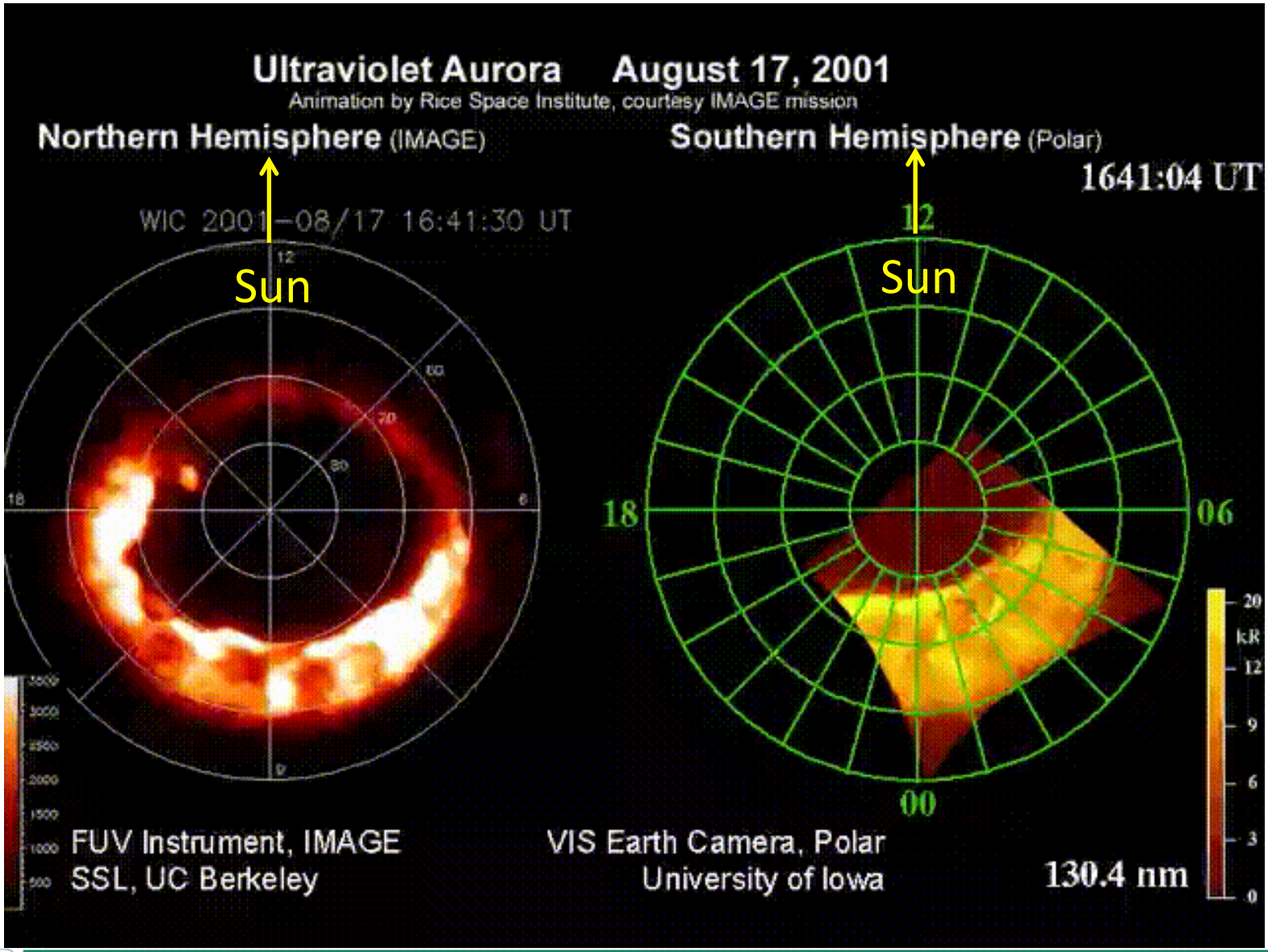
Grodent 2015
"Brief review of UV auroral emissions on giant planets"

magnetospheres - aurorae

Earth ≠ Jupiter ≠ Saturn

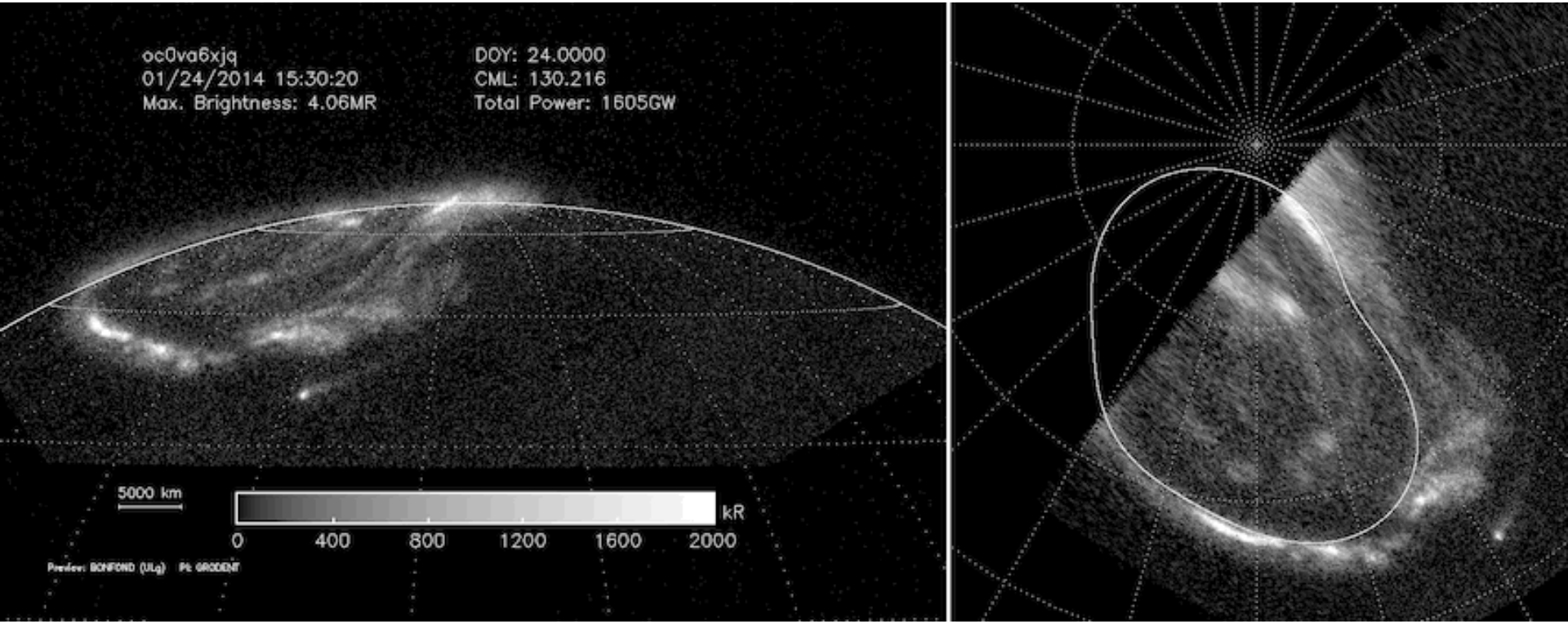
Springer 2016

Earth UV aurora N_2 LBH bands, N_I lines



Jupiter UV aurora

H_2 Lyman-Werner, Ly-α



HST – ACS FUV images

Polar S3 map
rotating with planet

Rotating magnetosphere

Saturn UV aurora

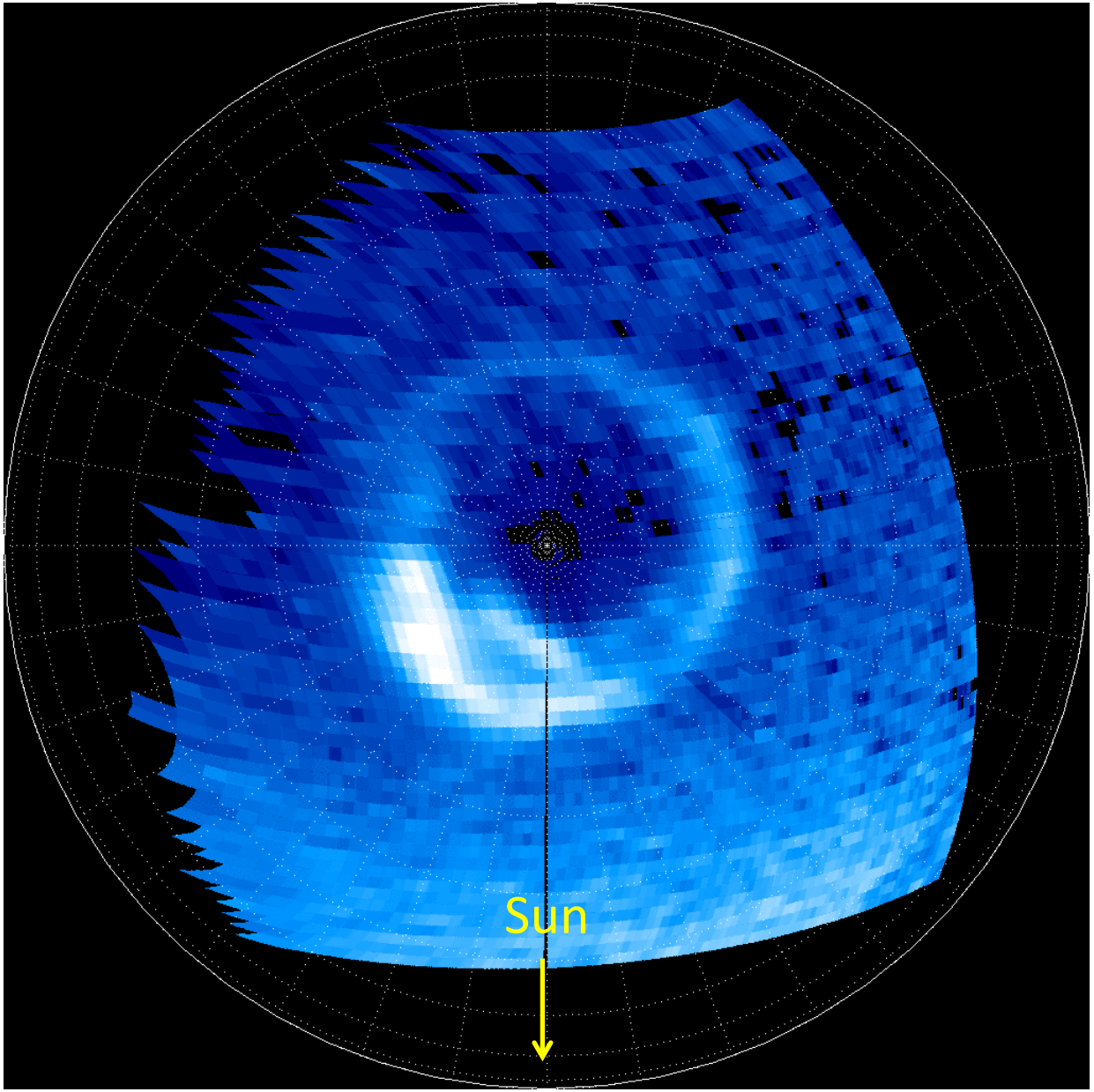
H_2 Lyman-Werner

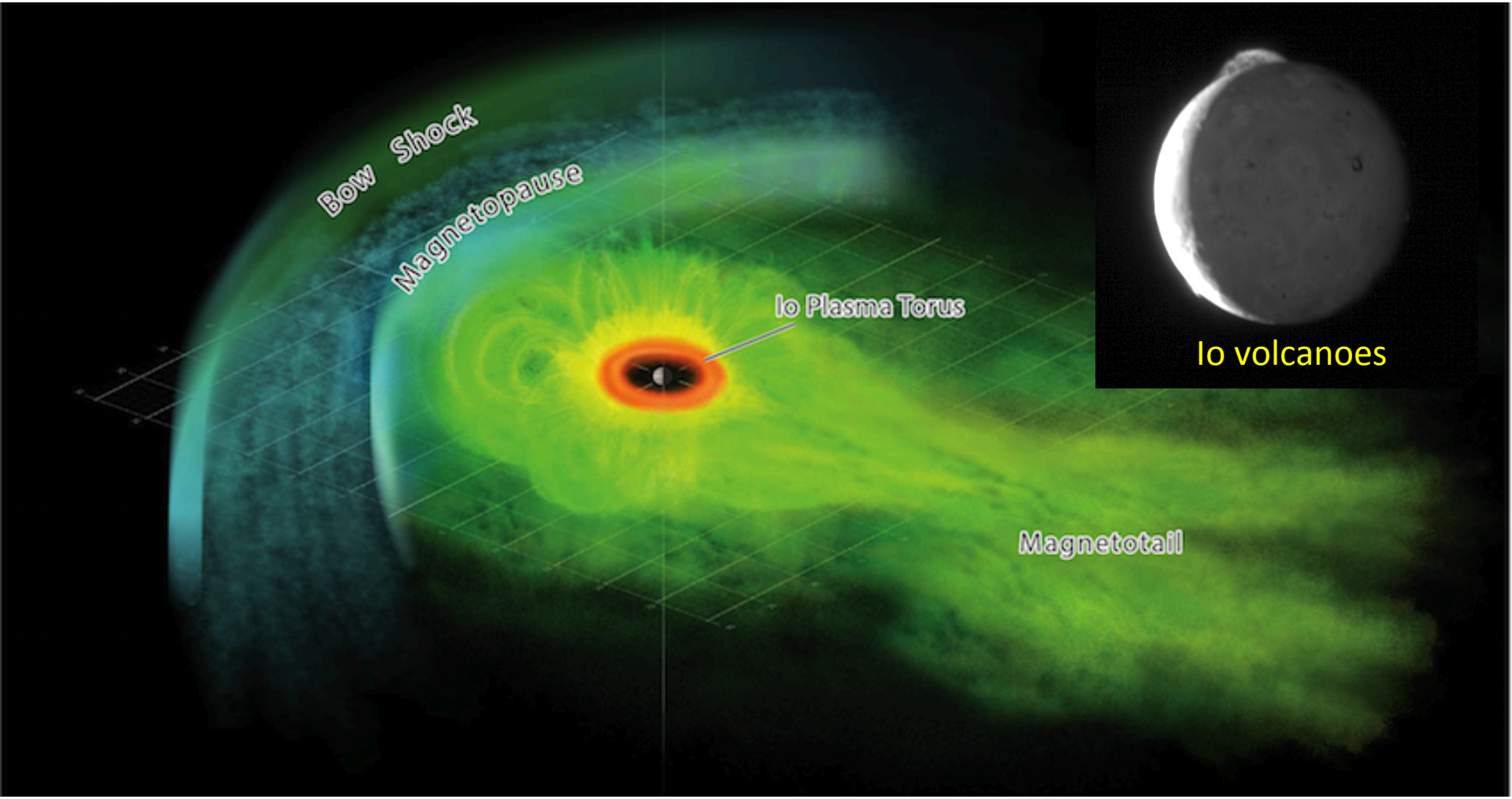
Ly-α

Cassini UVIS
FUV "images"

Polar LT map

Rotating magnetosphere





Fran Bagenal

Table 1 Radii, Sidereal Rotation Periods, and Dominant Magnetospheric Ions of Selected Planets*

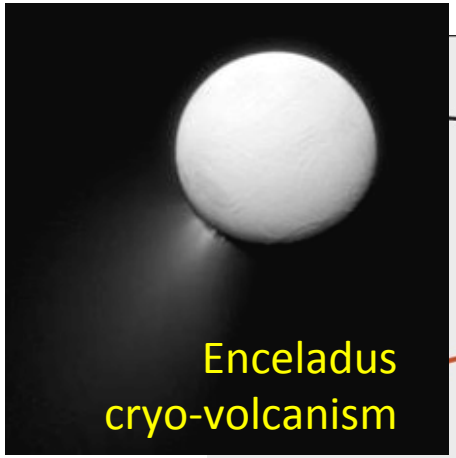
Planet/Property	Equatorial radius (km)	Rotation period (h)	Dominant ions
Earth	6,378	23.934	H^+ SW
Jupiter	71,492	9.925 Io	$O^+, O^{++}, S^+, S^{++}, S^{+++}$
Saturn	60,268	10.543**	Water group ions

Kivelson, 2015

Enceladus, rings

Important centrifugal effects at Jupiter and Saturn

Formation of a complete magnetodisc



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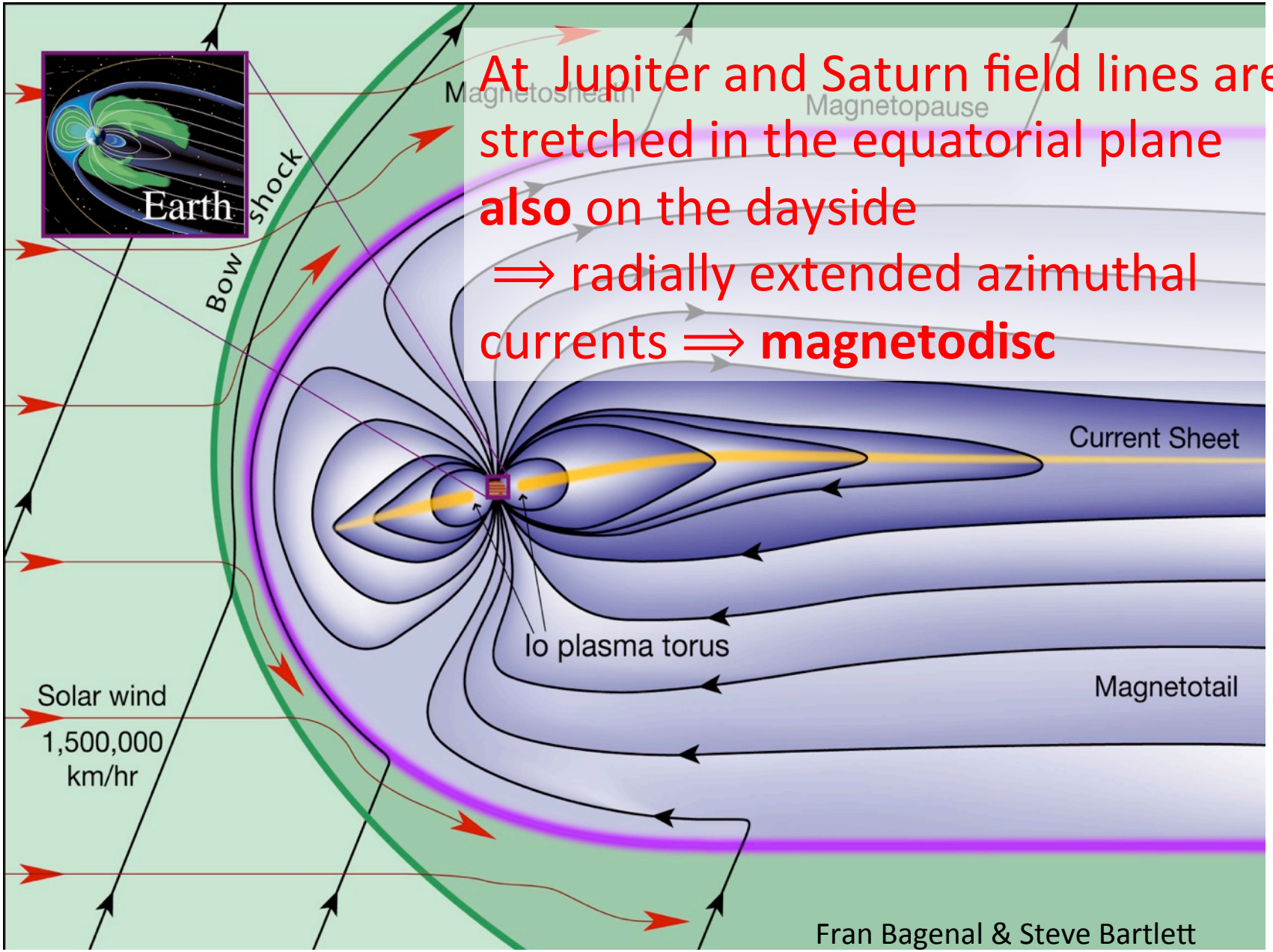
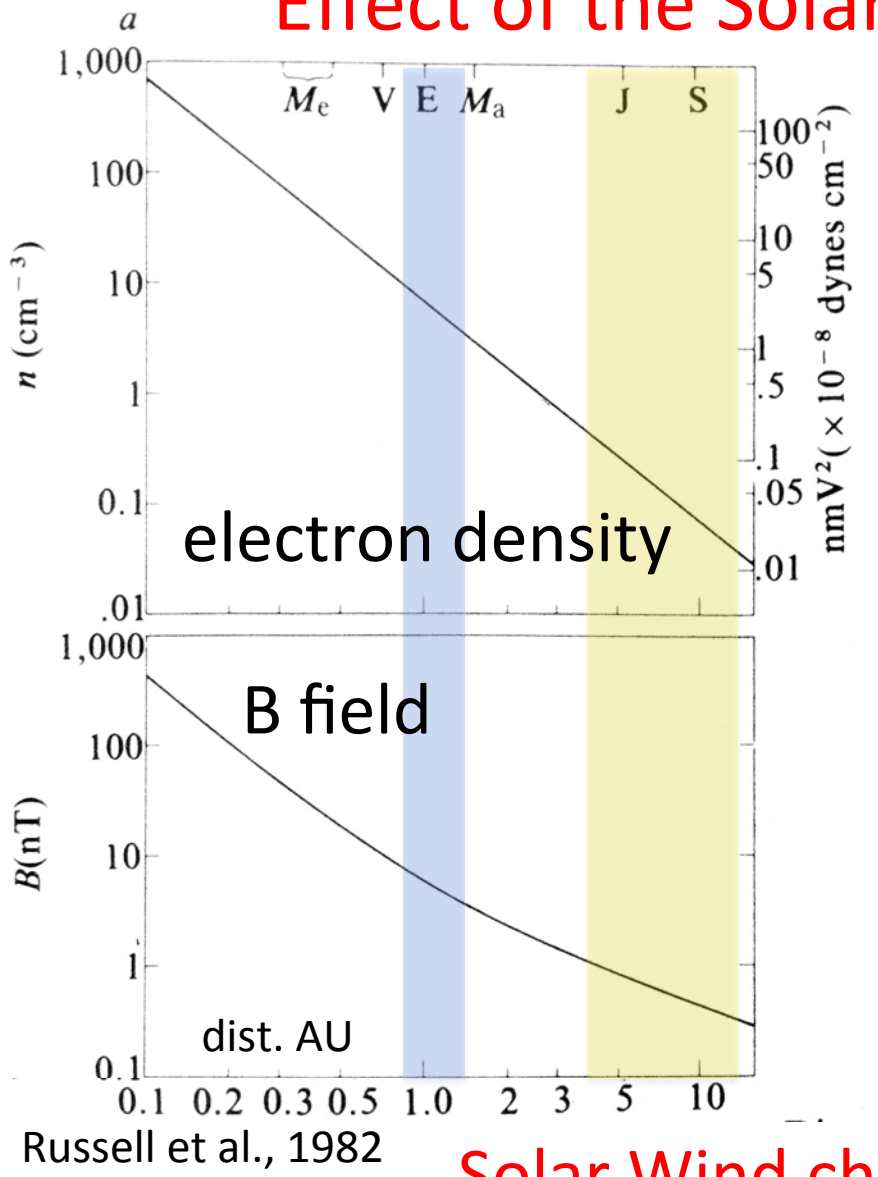
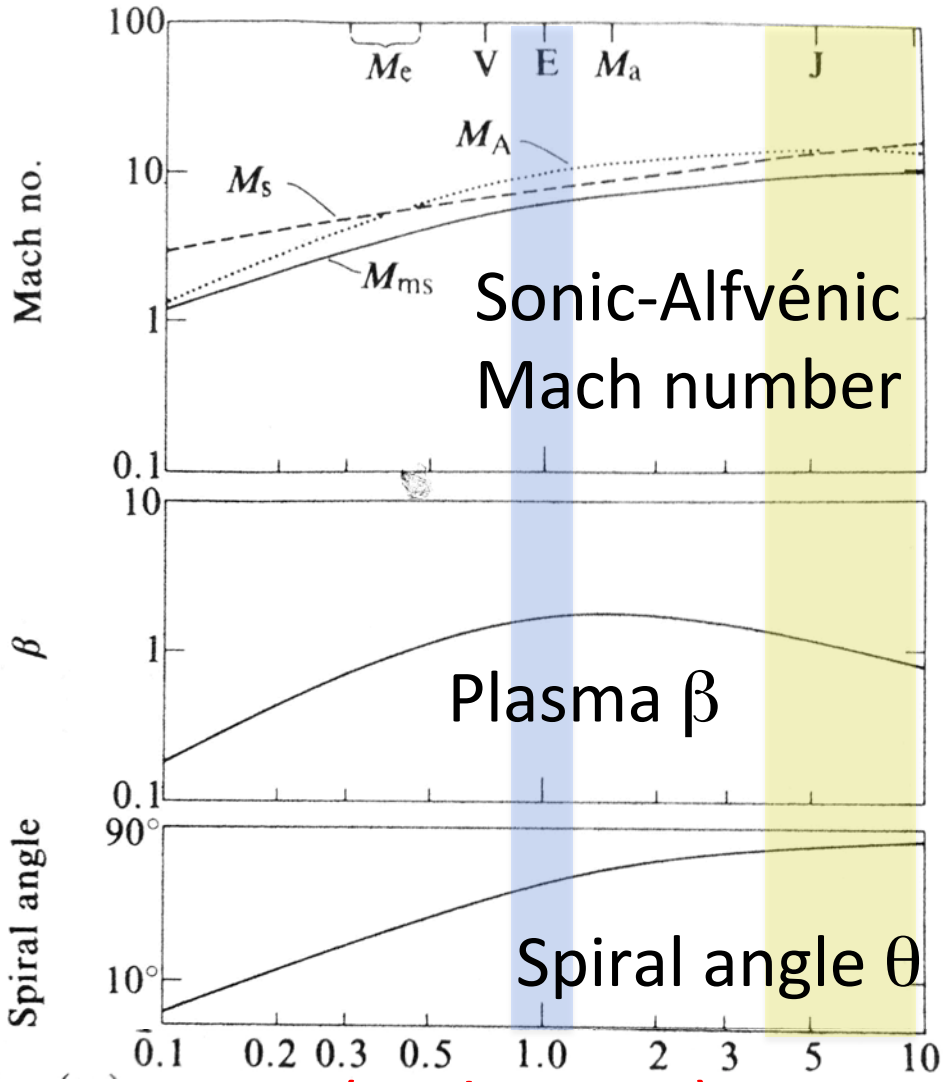

At Jupiter and Saturn field lines are stretched in the equatorial plane
also on the dayside
⟹ radially extended azimuthal currents ⟹ **magnetodisc**
Earth
Bow shock
Magnetosheath
Magnetopause
Current Sheet
Io plasma torus
Magnetotail
Solar wind
1,500,000 km/hr
Fran Bagenal & Steve Bartlett

Effect of the Solar Wind (Space Weather)



Russell et al., 1982

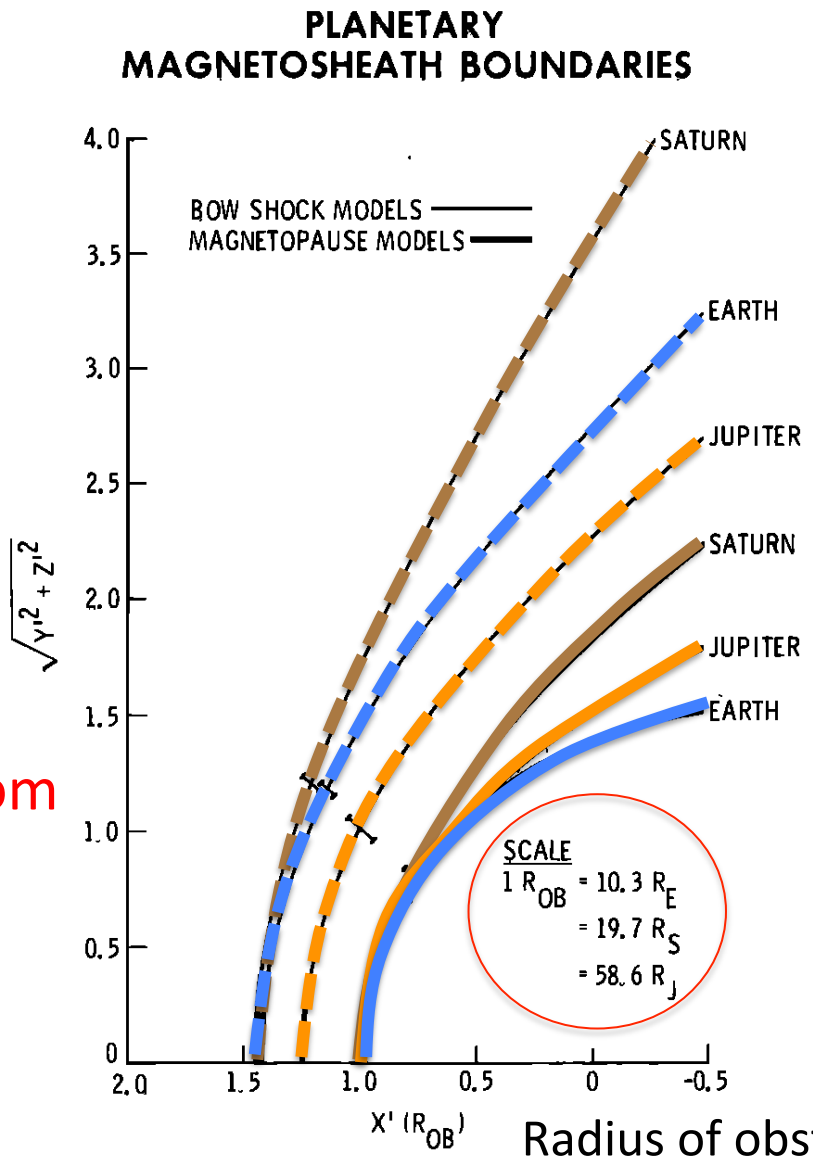


Solar Wind characteristics (vs distance)

Shapes of bow shock and magnetopause depend on:

- ram pressure (ρv^2)
- M_S, M_A
- θ

Solar wind is very different from planet to planet ⟹ analogies with Earth are misleading

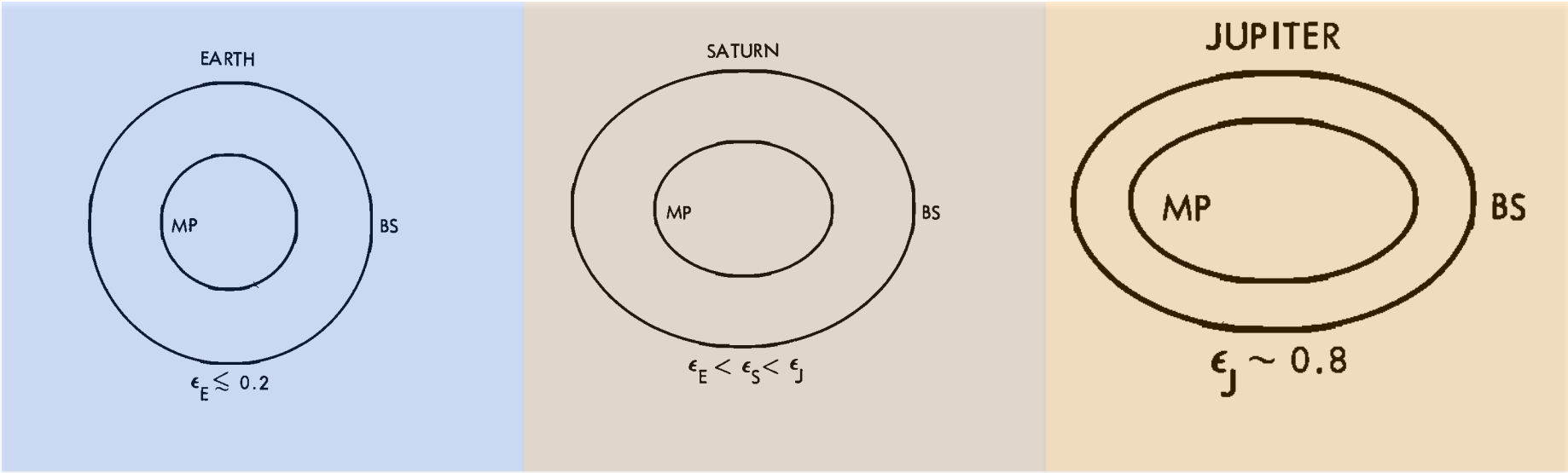


Slavin et al., 1985

Radius of obstacle

Presence of **magnetodisc** is significantly affecting the shape of the magnetospheres of Jupiter and Saturn

$\Longrightarrow$ **Polar flattening** $\Longrightarrow$ impacts reconnection (Dungey cycle)



magnetospheric cross sections

Two processes prevent Dungey-like (Earth-like) reconnection at Jupiter and Saturn

Diamagnetic suppression

Large plasma β gradient across a current sheet (magnetopause) prevents establishment of flow patterns and B_{field} bending required for reconnection (Swisdak et al., 2010)

Flow shear suppression

Super-Alfvénic flow shear in the direction of the reconnecting field can suppress reconnection (Cassak and Otto, 2011)

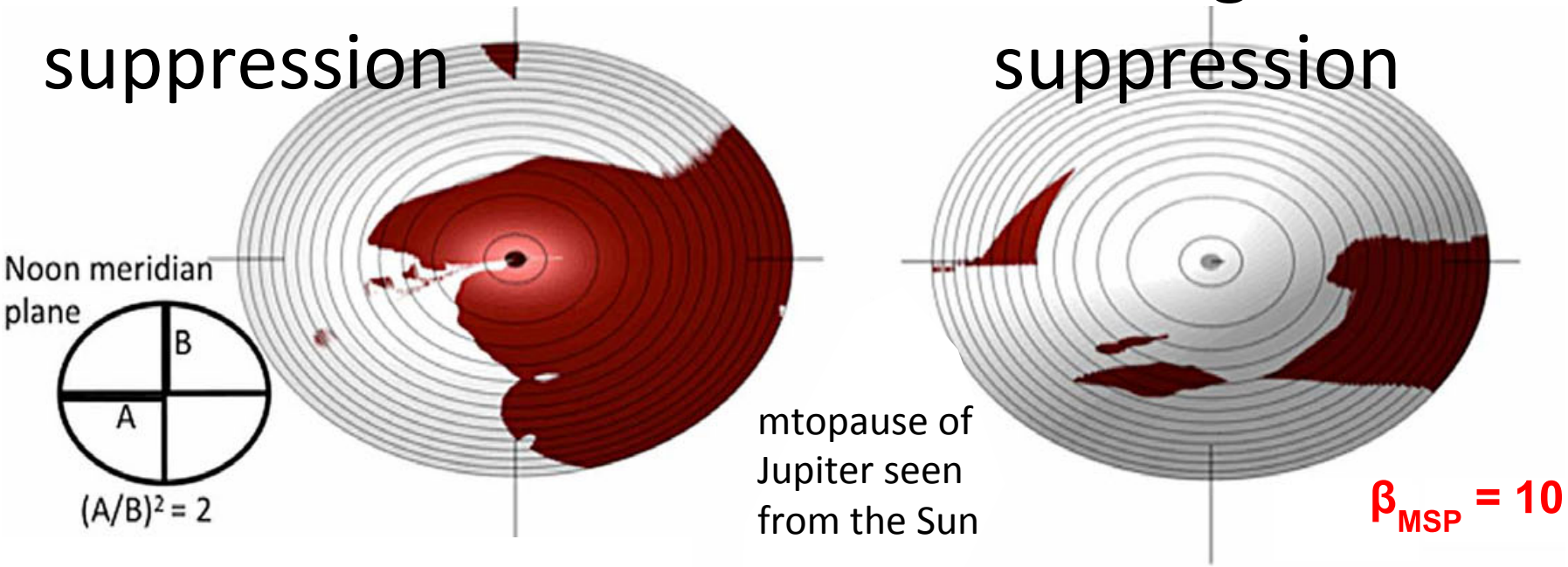
Jupiter (similar for Saturn)

Delamere et al., 2013

Masters et al., 2012

Flow shear suppression

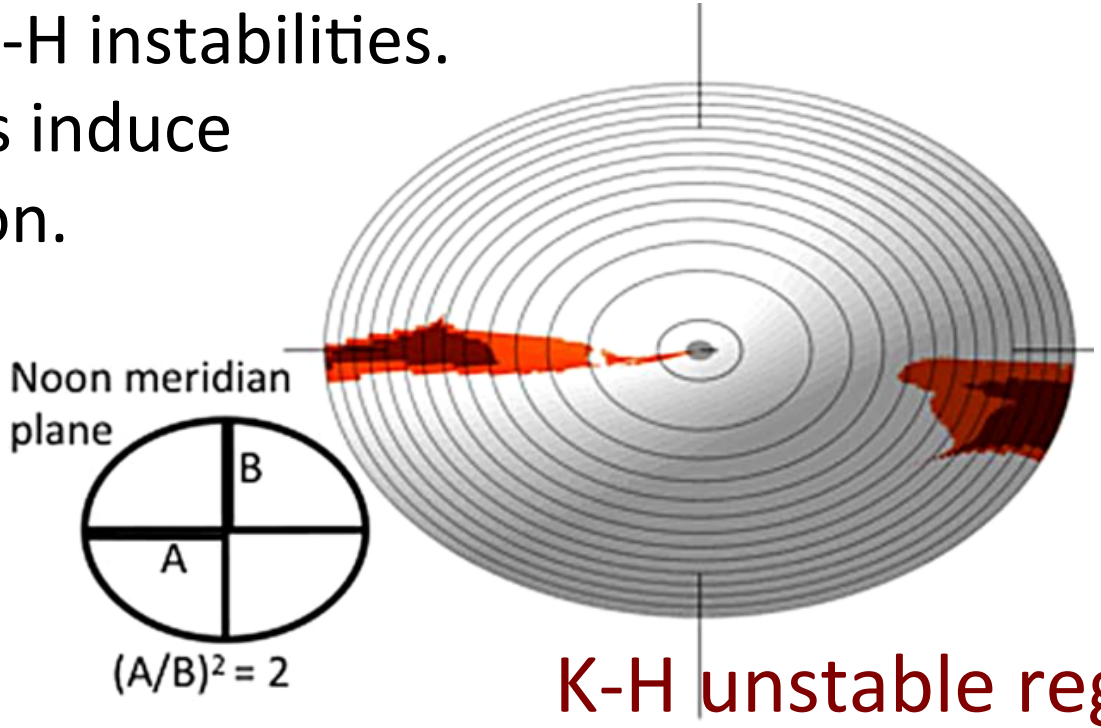
Diamagnetic suppression



Reconnection is only possible in the red regions

Desroche et al., 2012

Interaction of Solar Wind with Jupiter (Saturn) is mainly through viscous processes at magnetopause such as the growth of K-H instabilities.
K-H vortices induce reconnection.



Delamere and Bagenal (2010): at Jupiter, flux is predominantly opened and closed intermittently in small-scale structures in turbulent interaction regions (K-H vortices) on the flanks of the magnetosphere.

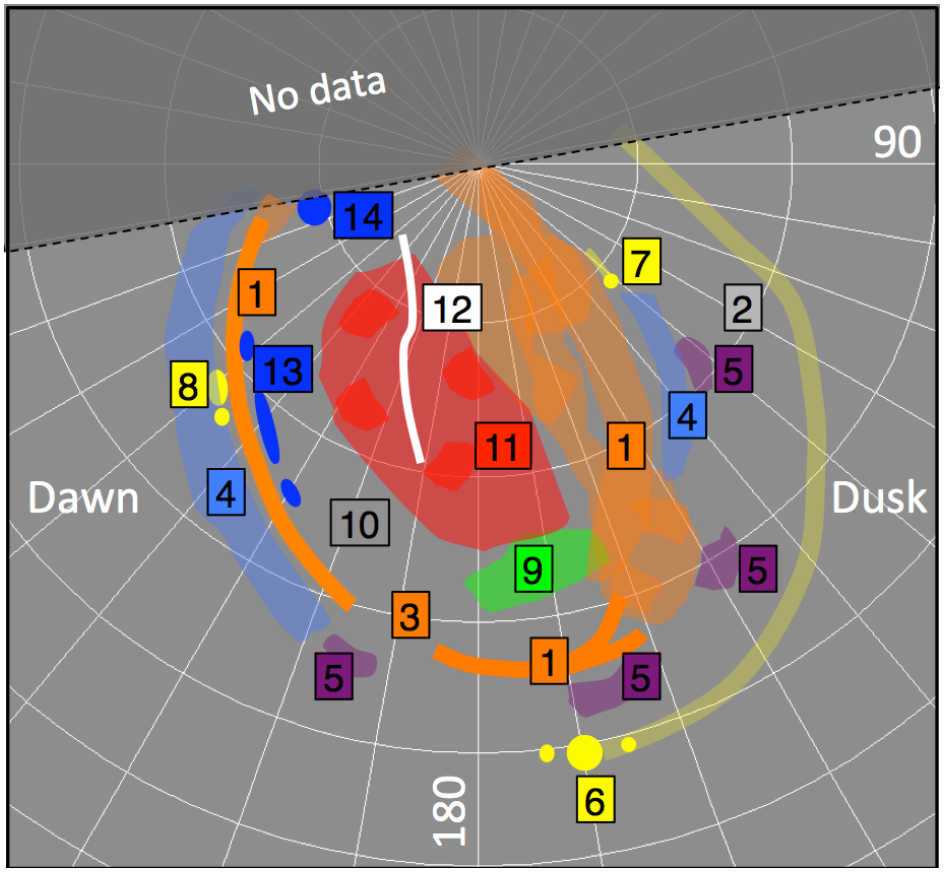
Does that mean that at Jupiter and Saturn there are no SW signatures in the aurora?

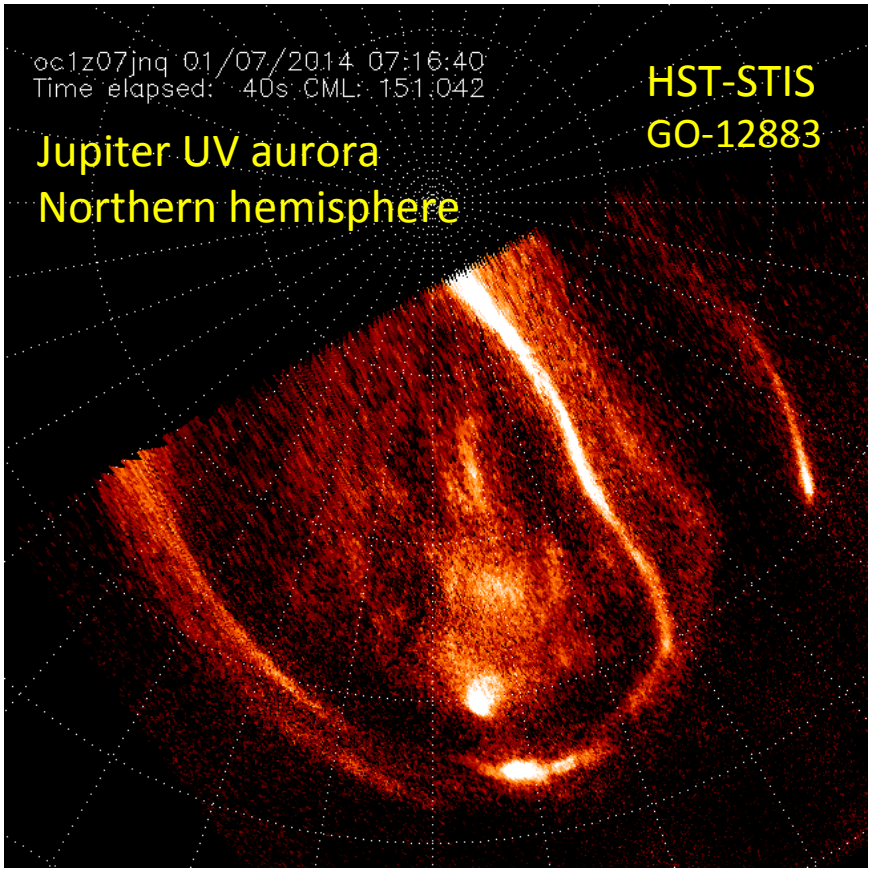
Yes and no.

Situation is far more complex than at the Earth because of an additional ingredient: the subcorotating magnetodisc.

Auroral components of giant planets

Jupiter (North)

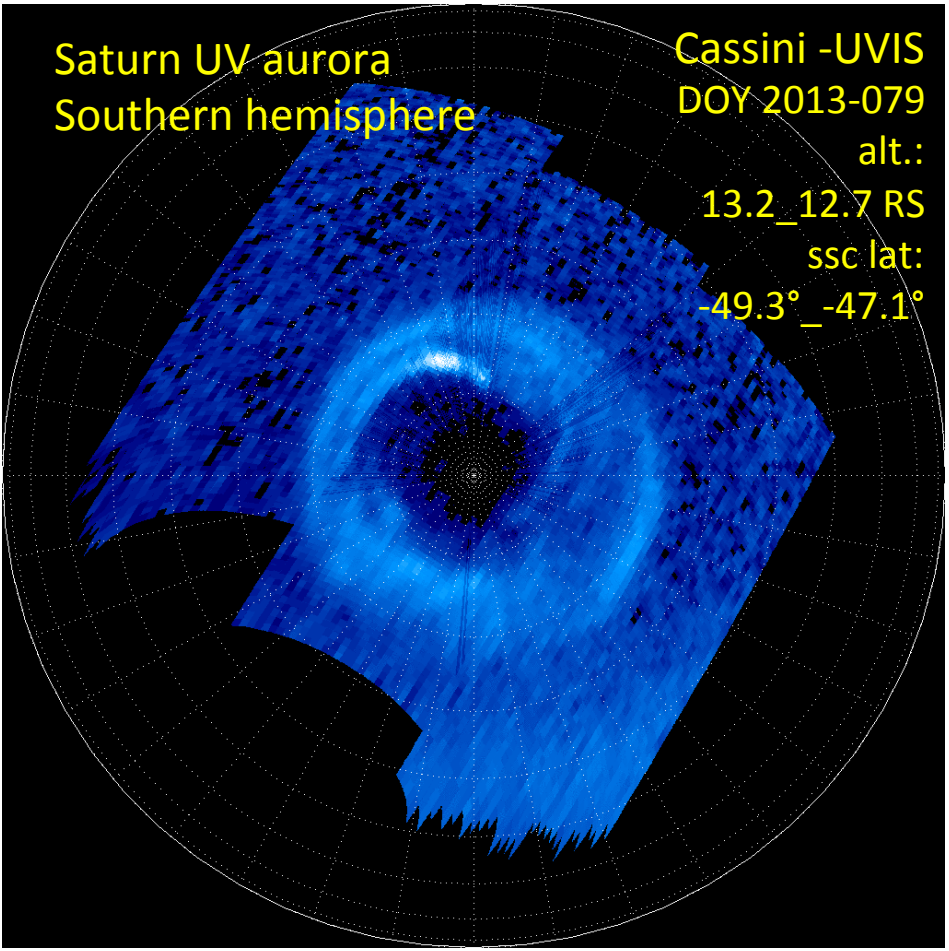




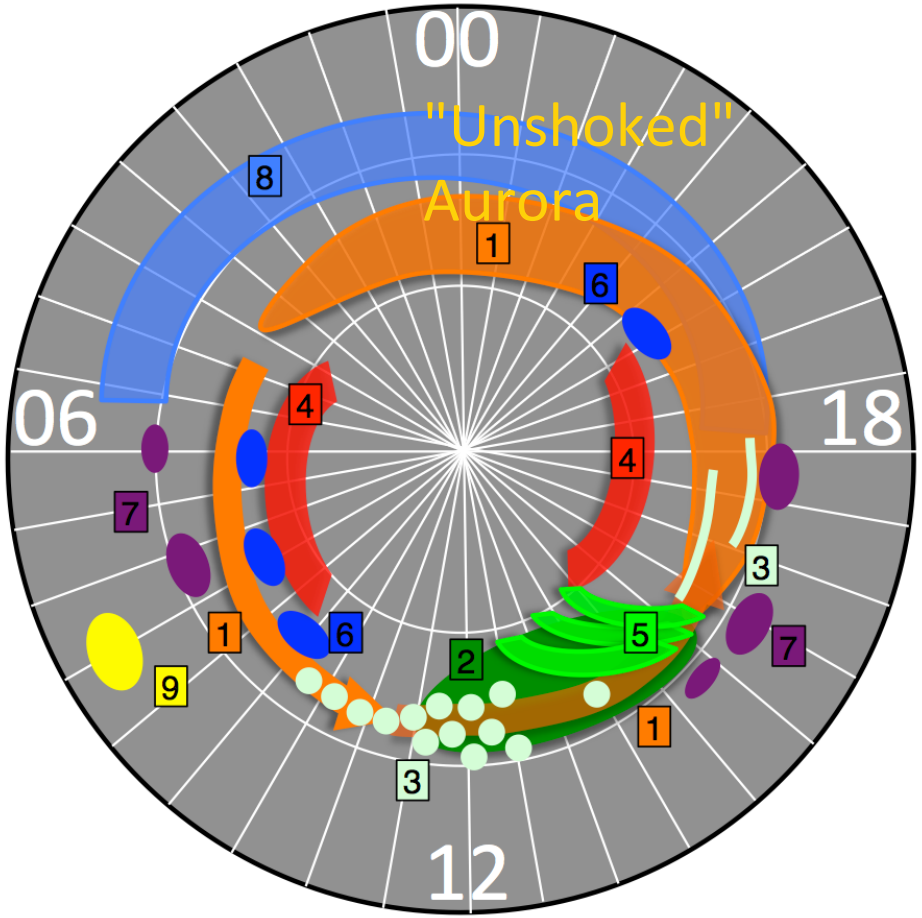
S3 frame (equiv. to LT if CML=180°)

Grodent, 2015

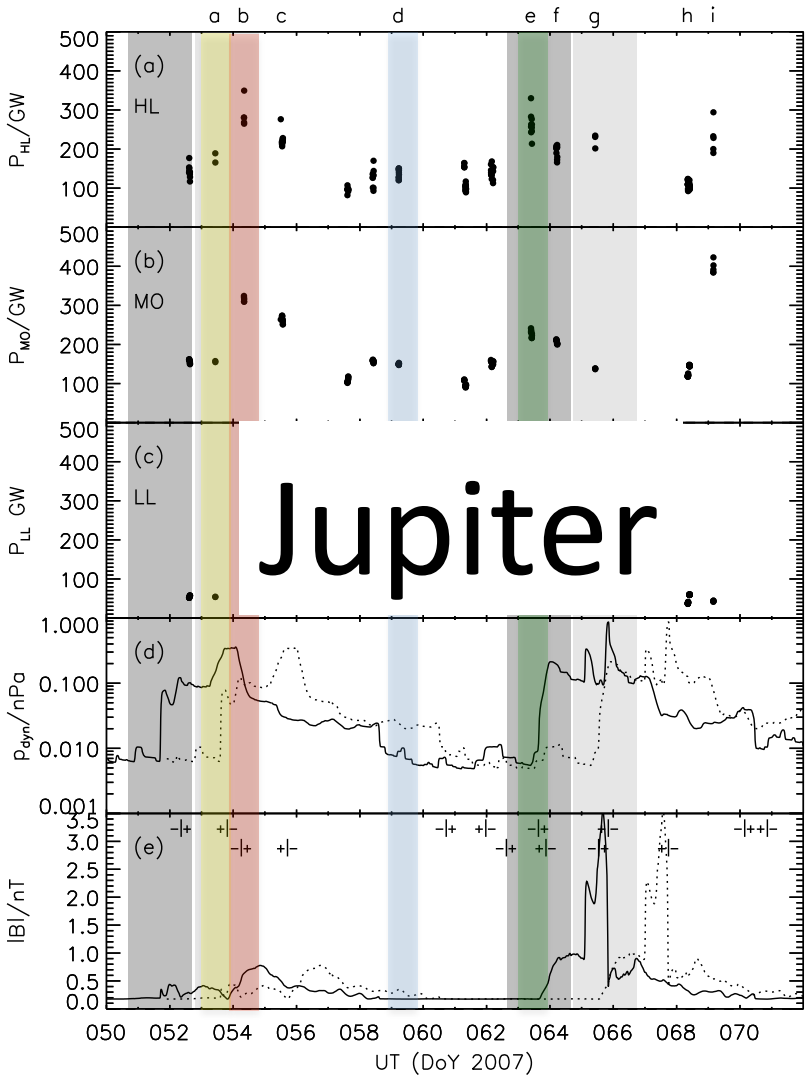
Auroral components of giant planets



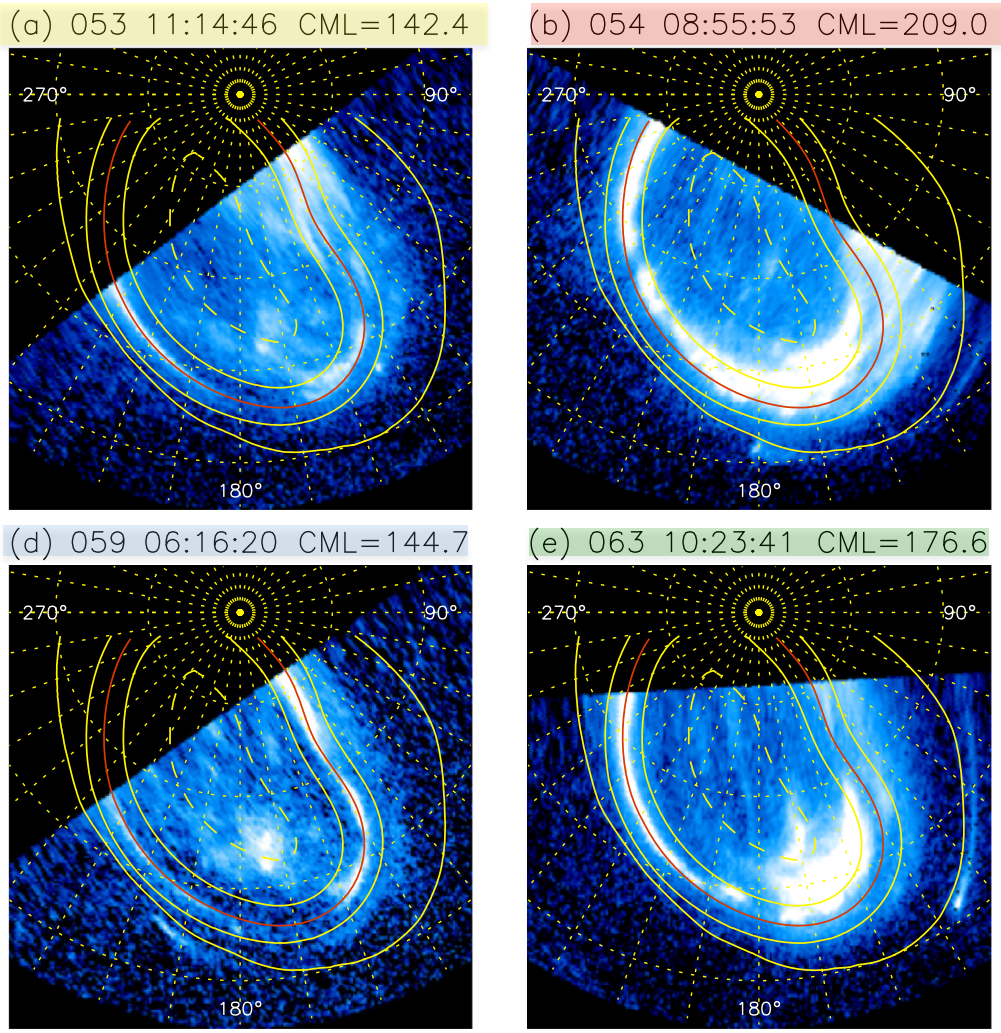
Saturn (both)



Grodent, 2015 LT frame



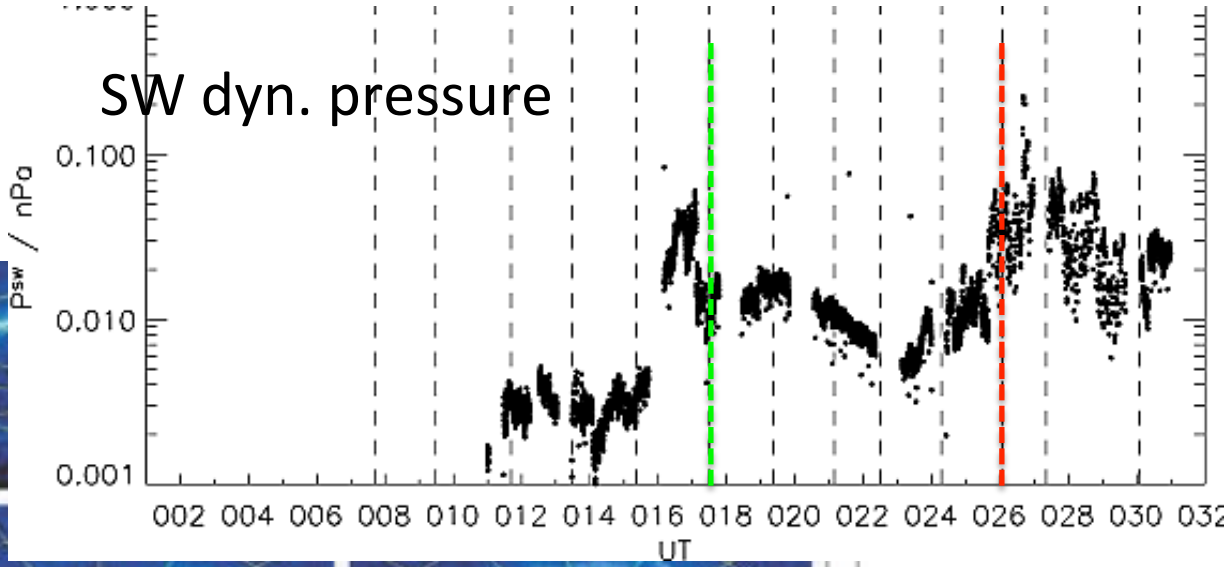
Propagated SW data

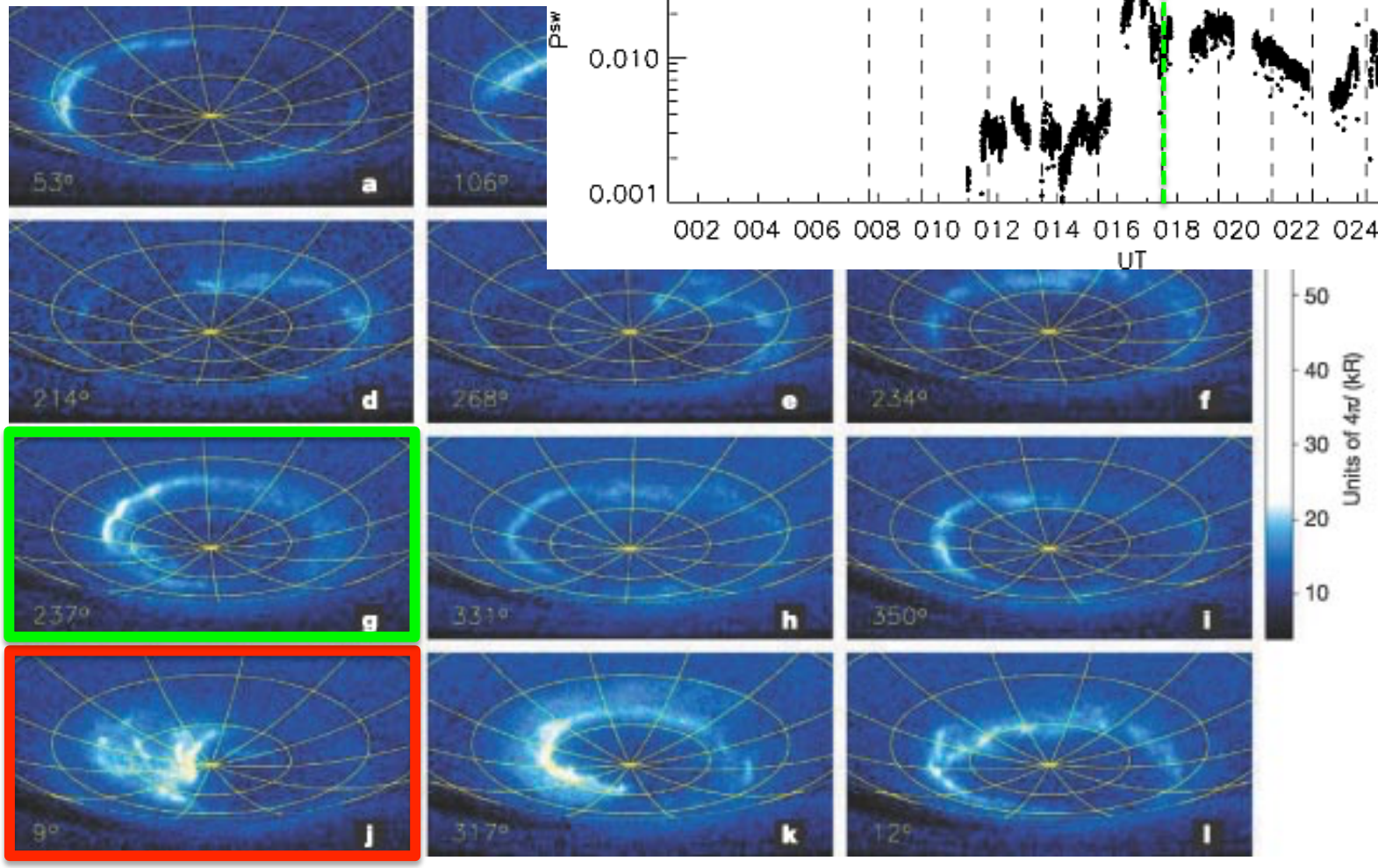


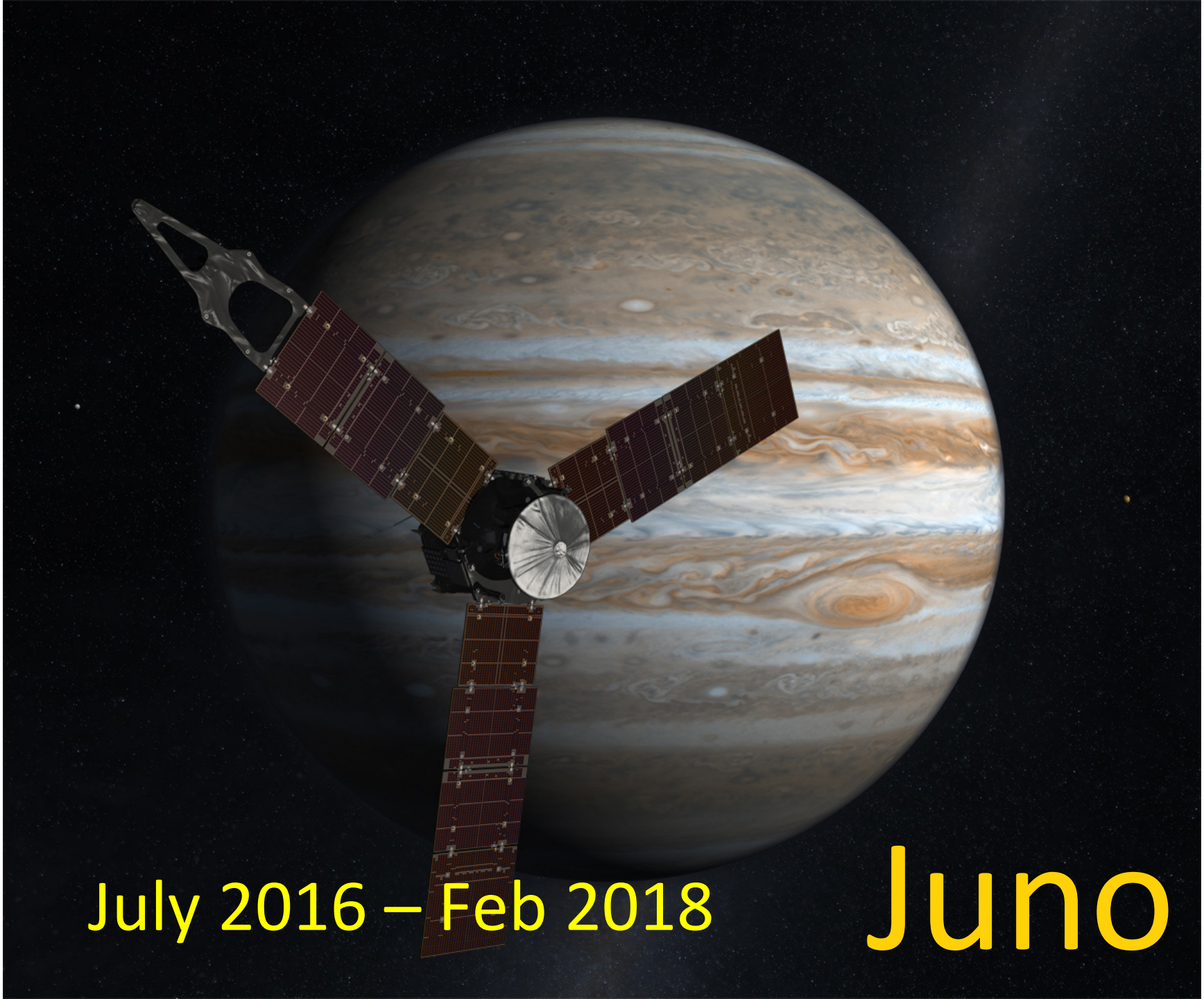
Brightenings are observed during periods of increased $\mathbf{p_{dyn}}$. No B_z effect

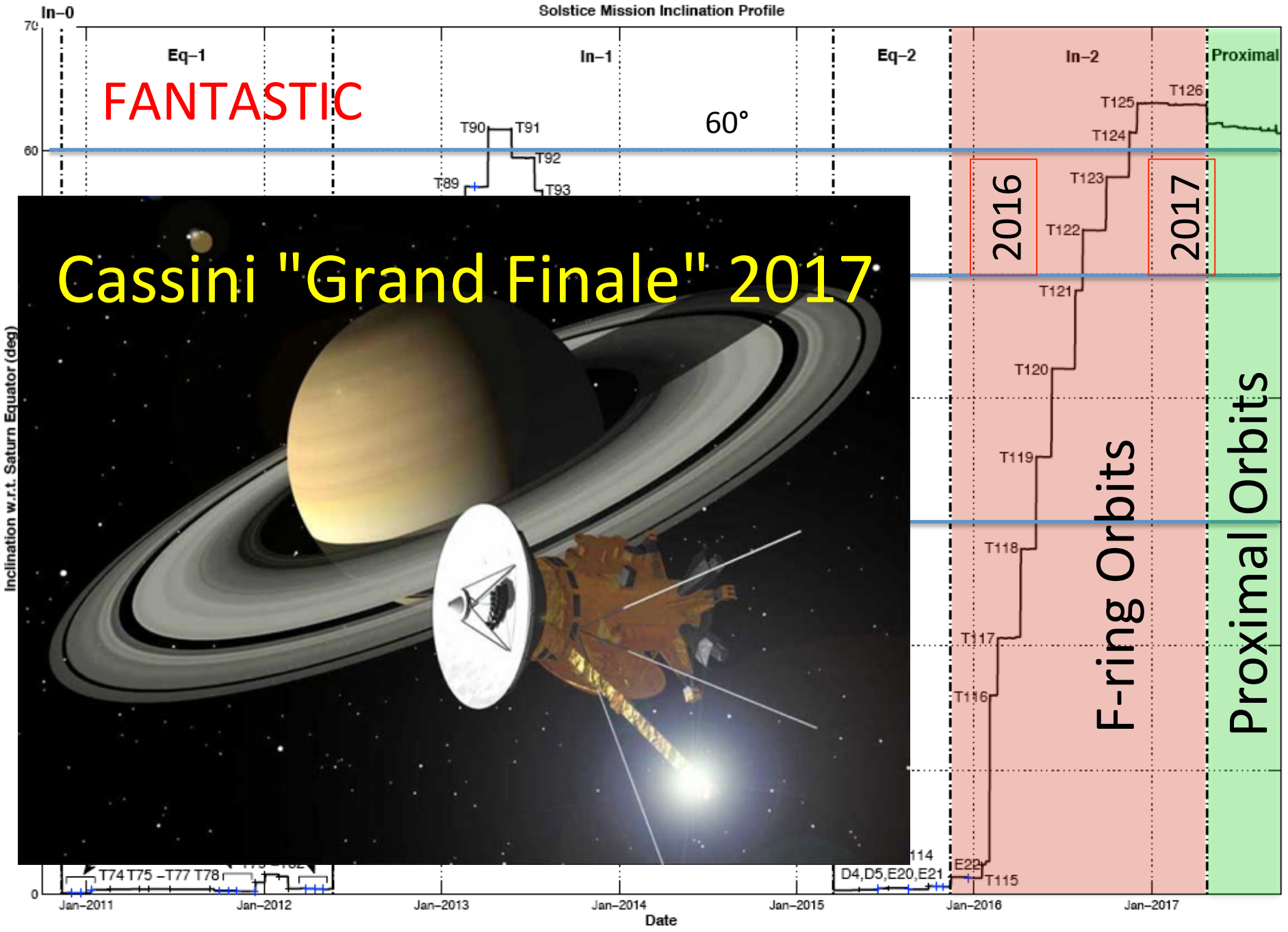
Nichols et al., 2009

Saturn


SW dyn. pressure
Psw / nPa
0.100
0.010
0.001
002 004 006 008 010 012 014 016 018 020 022 024 026 028 030 032
UT


53°
a
106°
214°
d
268°
e
234°
f
237°
g
331°
h
350°
i
9°
j
317°
k
12°
l
50
40
30
20
10
Units of 4πI (kR)


July 2016 – Feb 2018
Juno


Solstice Mission Inclination Profile
In–0
Eq–1
In–1
Eq–2
In–2
Proximal
FANTASTIC
60°
T89
T90
T91
T92
T93
T74 T75 –T77 T78
D4,D5,E20,E21
T114
T115
E22
T116
T117
T118
T119
T120
T121
T122
T123
T124
T125
T126
2016
2017
F-ring Orbits
Proximal Orbits
Cassini "Grand Finale" 2017
Inclination w.r.t. Saturn Equator (deg)
70
60
0
Jan–2011
Jan–2012
Jan–2013
Jan–2014
Jan–2015
Jan–2016
Jan–2017
Date

Thank you