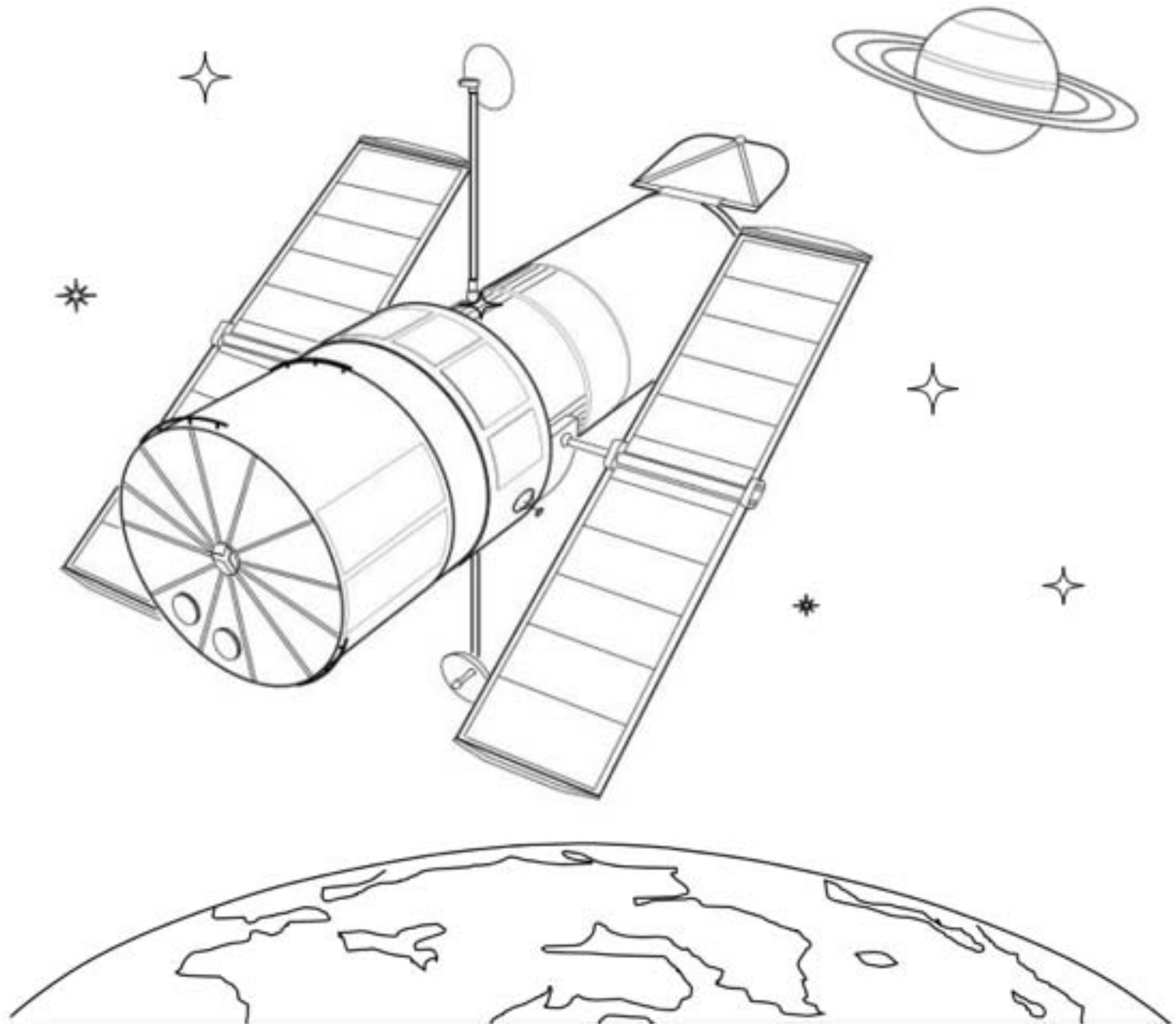
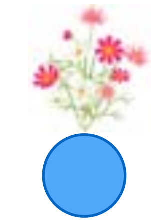
La printanière magnétosphère d’Uranus



L. Lamy, R. Prangé, L. Gosset
LESIA, Observatoire de Paris

La printanière magnétosphère d'Uranus

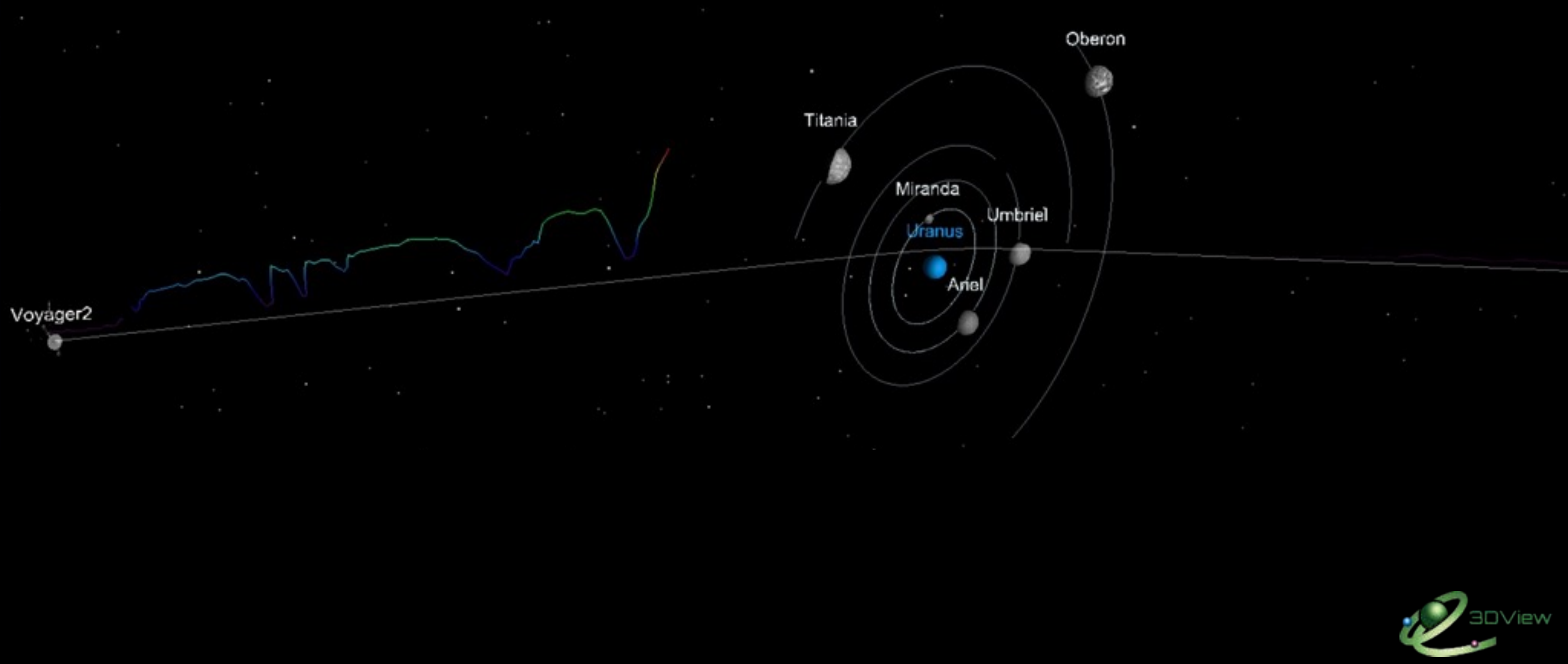


L. Lamy, R. Prangé, L. Gosset
LESIA, Observatoire de Paris

A mission to Uranus : Science case

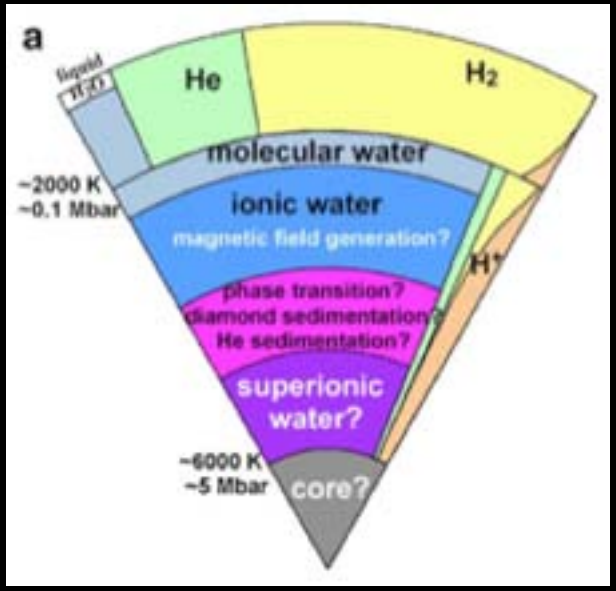
Uranus
Pathfinder

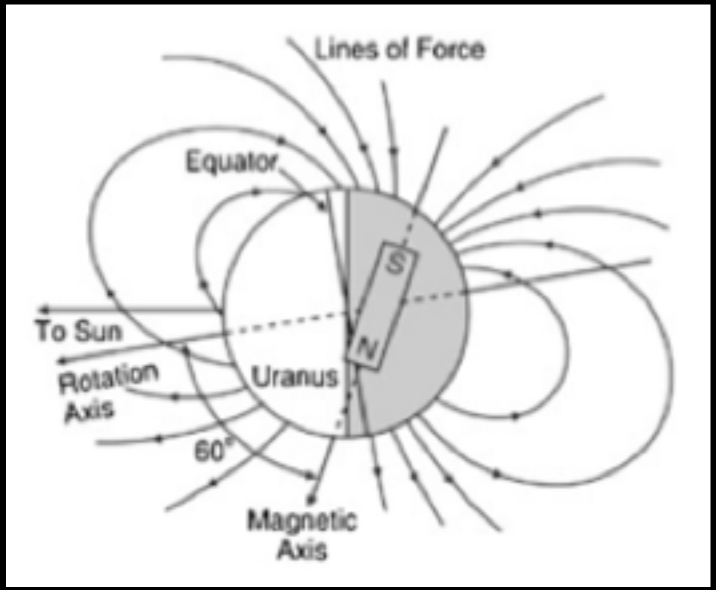
24 Jan. 1986

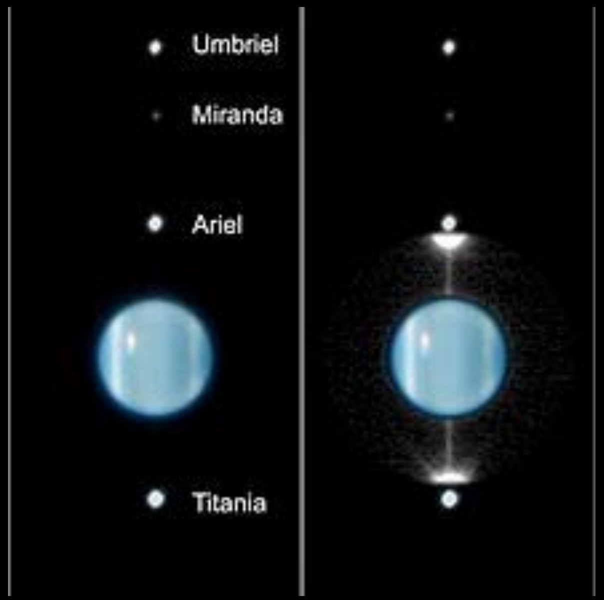


A mission to Uranus : Science case

* Système d'Uranus :
- origine
- intérieur et champ magnétique
- atmosphère
- ionosphère
- anneaux
- satellites
- **magnétosphère**



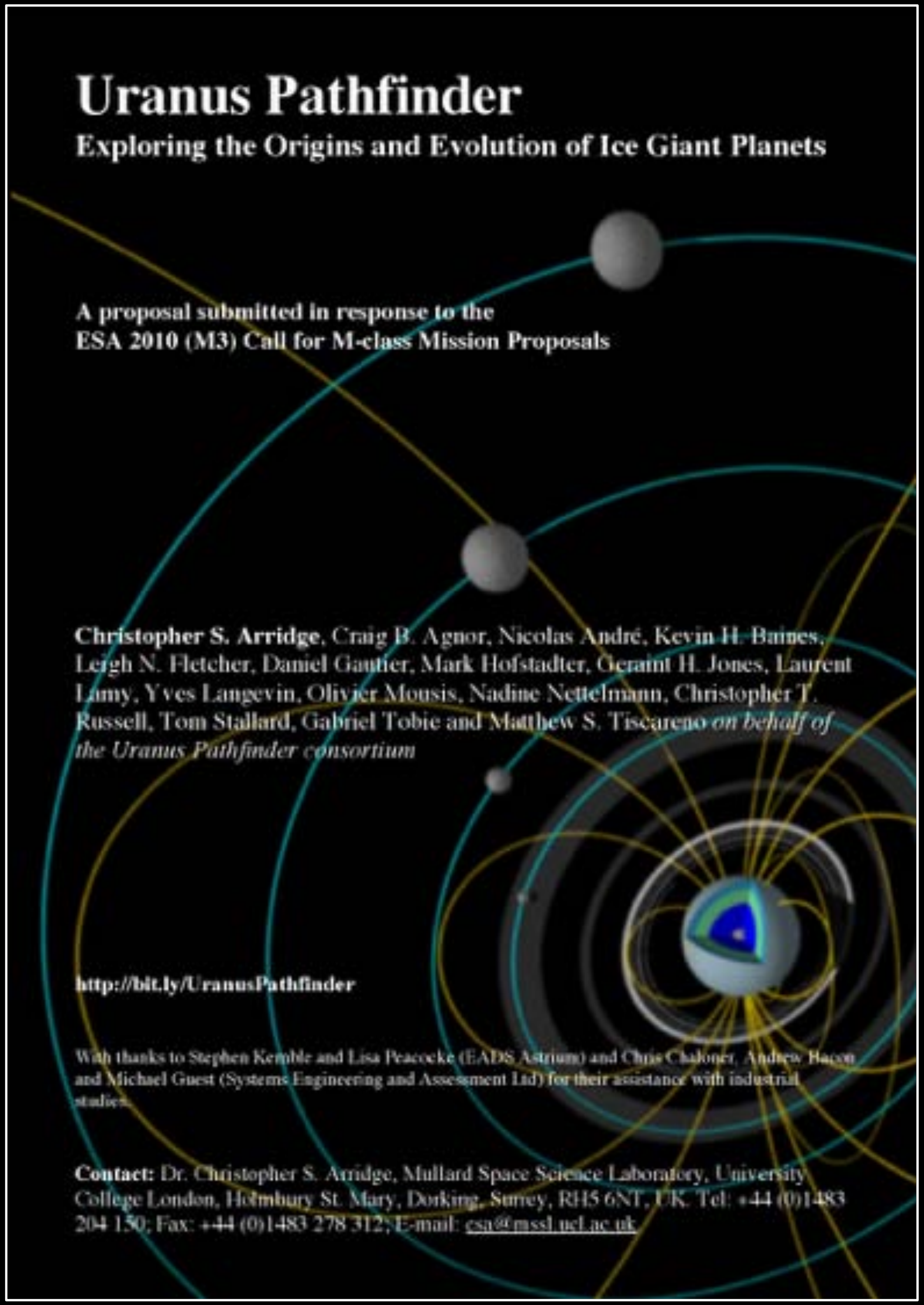




* Héliosphère externe :
- transport d'énergie et vent solaire
- ondes radio héliopause
- physique fondamentale

A mission to Uranus : context

- Substantial interest in Uranus missions in the US since Voyager 2 flyby in 1986.
- Missions to Uranus first appeared in Europe in 2010: internal **ESA CDF probe** study and **M3-M4 Uranus Pathfinder** proposals.
- **L2/L3** science theme selection process: Uranus/Neptune mentioned first in committee report.



Uranus Pathfinder

Exploring the Origins and Evolution of Ice Giant Planets

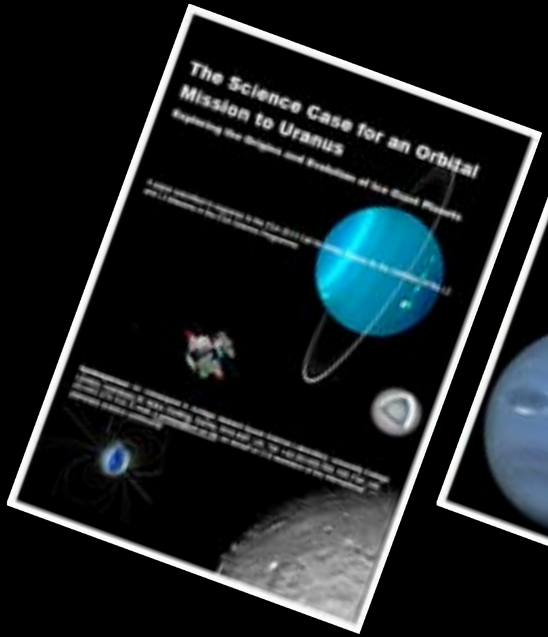
A proposal submitted in response to the ESA 2010 (M3) Call for M-class Mission Proposals

Christopher S. Arridge, Craig B. Agnor, Nicolas André, Kevin H. Baines, Leigh N. Fletcher, Daniel Gautier, Mark Hofstadter, Geraint H. Jones, Laurent Lamy, Yves Langevin, Olivier Mousis, Nadine Nettelmann, Christopher T. Russell, Tom Stallard, Gabriel Tobie and Matthew S. Tiscareno *on behalf of the Uranus Pathfinder consortium*

http://bit.ly/UranusPathfinder

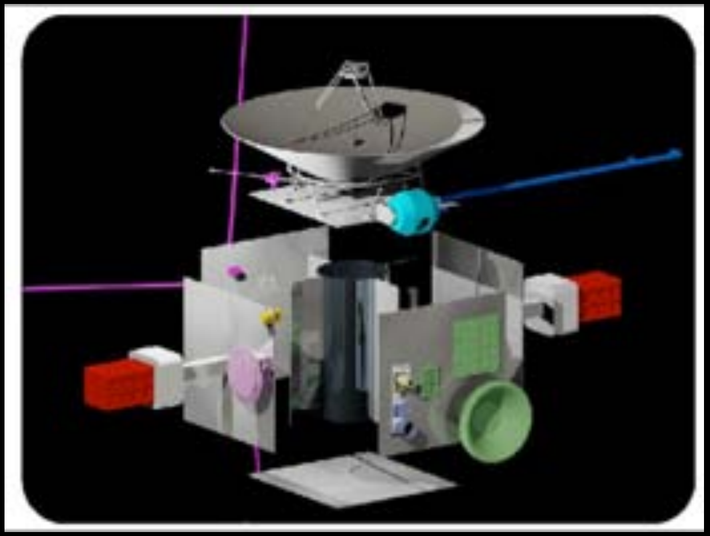
With thanks to Stephen Kemble and Lisa Peacocke (EADS Astrium) and Chris Chaloner, Andrew Bacon and Michael Guest (Systems Engineering and Assessment Ltd) for their assistance with industrial studies.

Contact: Dr. Christopher S. Arridge, Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking, Surrey, RH5 6NT, UK. Tel: +44 (0)1483 204 150; Fax: +44 (0)1483 278 312; E-mail: csa@mssl.ucl.ac.uk



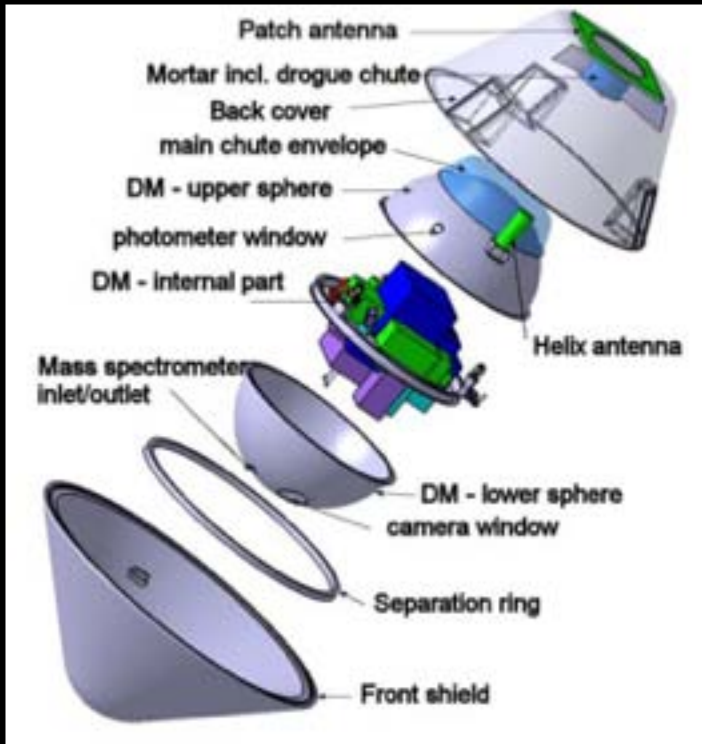
A mission to Uranus : context

Uranus Pathfinder
Exploring the Origins and Evolution of Ice Giant Planets



L. Lamy, N. André, D. Gautier, C. Briand, S. Charnoz, B. Christophe, T. Fouchet, S. Hess, Y. Langevin, J.-P. Lebreton, O. Mousis, G. Tobie, P. Zarka et al.

Lead Proposer : Chris Arridge [UK]



Community of 258 (190 in Europe, 68 in France) scientists world-wide.

A mission to Uranus : M4 Model payload

High TRL with substantial European flight heritage.

Instrument	Consortia and funding agencies	Heritage
Narrow angle camera (NAC)	JHU/APL, USA [NASA] INAF, Italy [ASI]	New Horizons/LORRI JUICE/JANUS
Visual and near-IR spectral imager (VIRTIS)	INAF, Italy [ASI] Luleå U. T., Sweden [SNSB]	Rosetta/VIRTIS DAWN/VIR
Thermal Infrared Bolometer (UTIRM)	U. Oxford, UK [UKSA]	LRO/Diviner
Magnetometer (MAG)	Imperial College, UK [UKSA]	Rosetta/MAG Cassini/MAG
Electron/ion plasma detector (PLS)	MSSL, UK [UKSA] **IRAP, France [CNES]**	Solar Orbiter/SWA Cassini/CAPS/ELS
Radio and plasma wave experiment (RPW)	**LESIA, France [CNES]** IAP, Czech Rep. [MEYS]	JUICE/RPW BepiColombo/MMO/PWI
Accelerometer (GAP)	**ONERA, France [CNES]**	CHAMP/STAR

A mission to Uranus : Collaborations

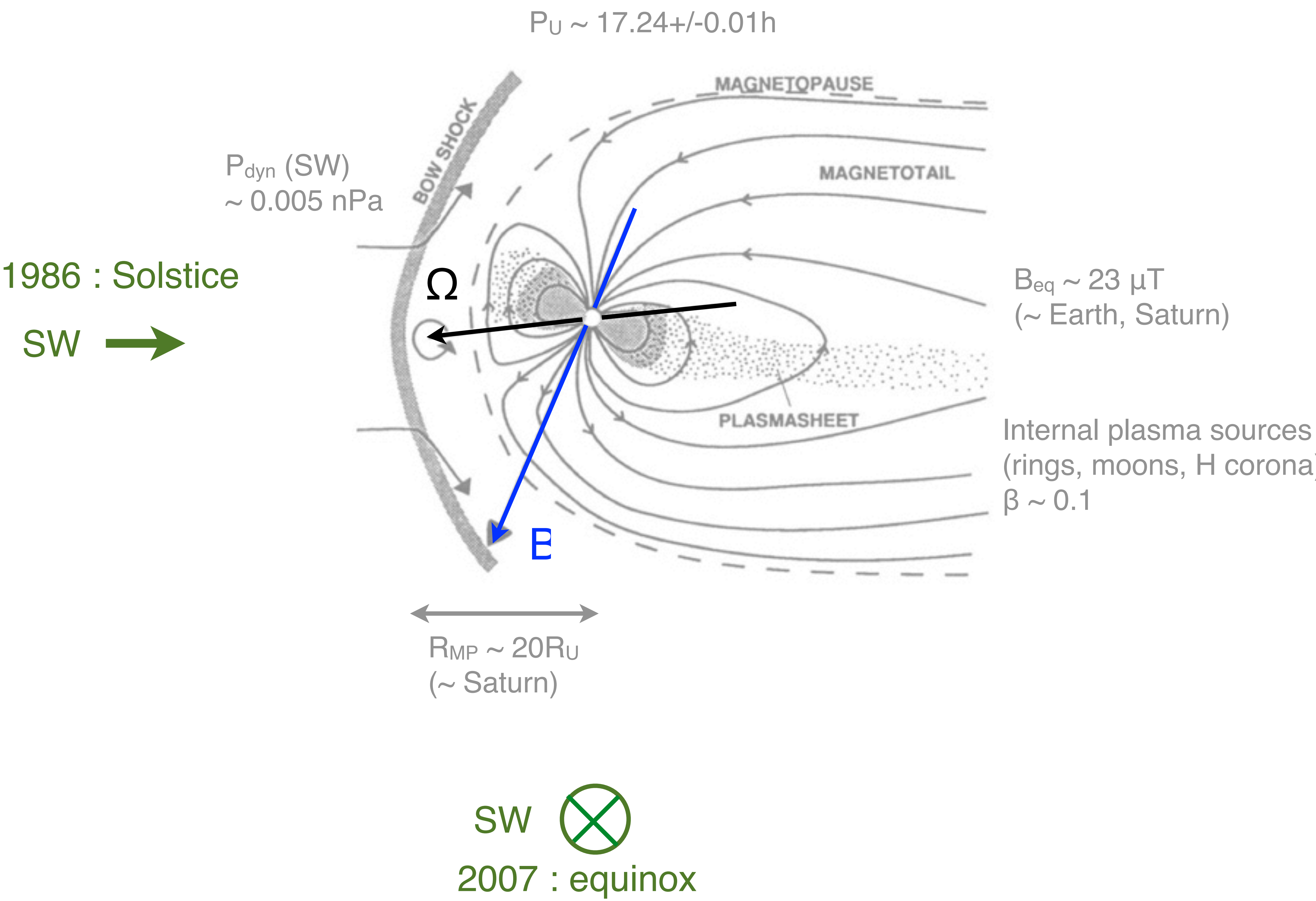
- **International collaboration in the M4 frame** : ESA spacecraft, NASA launch vehicle/ RTGs, on the example of **Ulysses**

- **Recent developments** :
  - **ESA** : larger M5 cost cap, but recent decision **not to resubmit** Uranus Pathfinder
  - **NASA** :

    + Europa Clipper will fly on solar panels : RTGs available **for next missions**

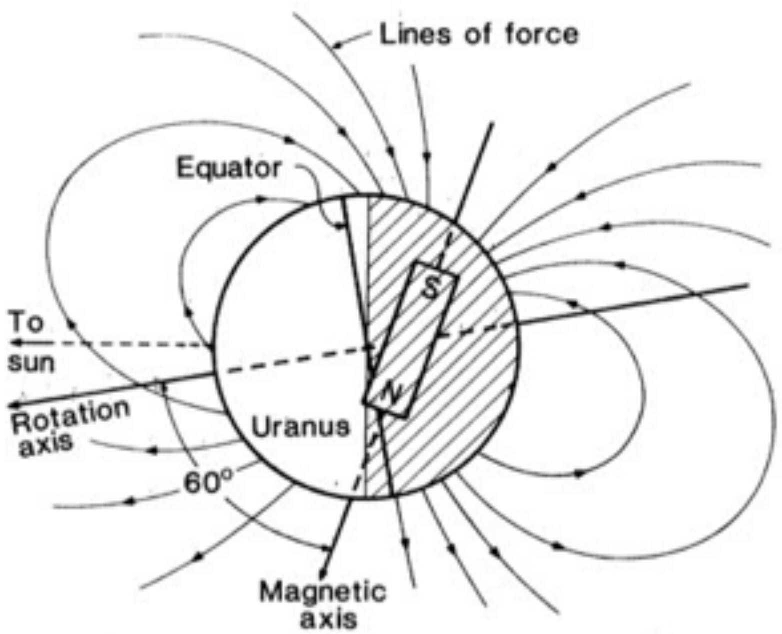
    + **NASA Ice Giant mission study** : M. Hofstadter, A. Simon-Miller, S. Atreya, D. Banfield, J. Fortney, A. Hayes, M. Hedman , G. Hospodarsky, K. Mandt, M. Showalter, K. Soderlund, E. Turtle, J. Elliott, D. Turrini, A.Masters
  - **CNES** : will (eventually !) start an exploratory **phase 0 study** by mid-2016

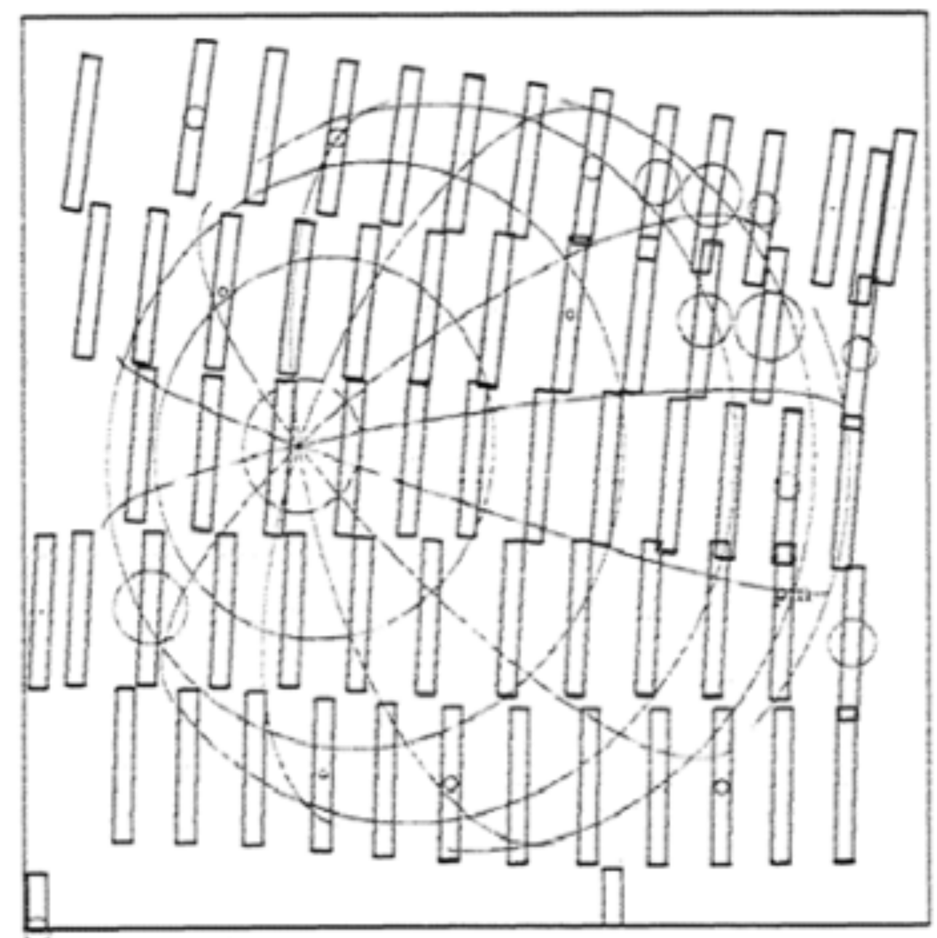
Uranus



P_U ~ 17.24+/-0.01h
MAGNETOPAUSE
BOW SHOCK
MAGNETOTAIL
P_{dyn} (SW)
~ 0.005 nPa
1986 : Solstice
Ω
SW
B_{eq} ~ 23 μT
(~ Earth, Saturn)
PLASMASHEET
Internal plasma sources
(rings, moons, H corona)
β ~ 0.1
B
R_{MP} ~ 20R_U
(~ Saturn)
SW
2007 : equinox

1986 : Voyager 2





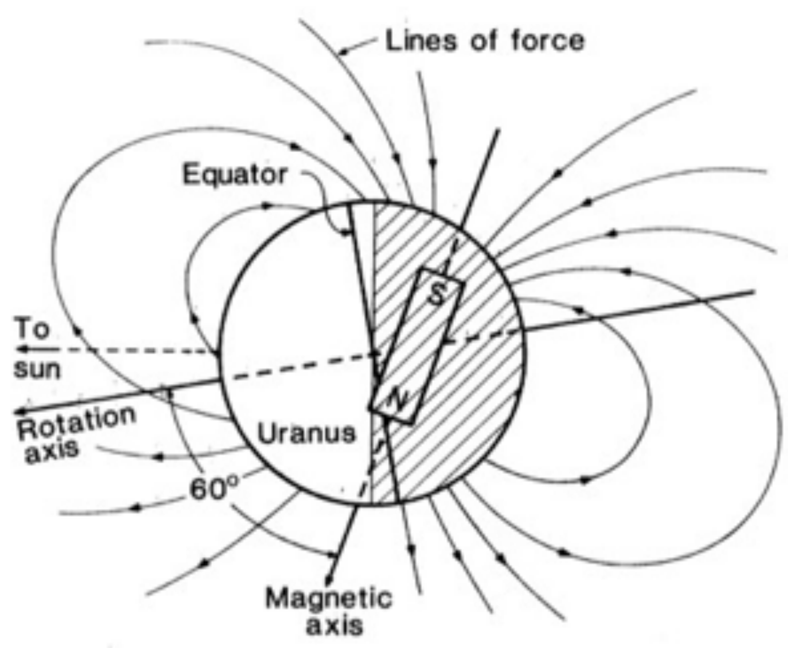
(Herbert et al., 1994)

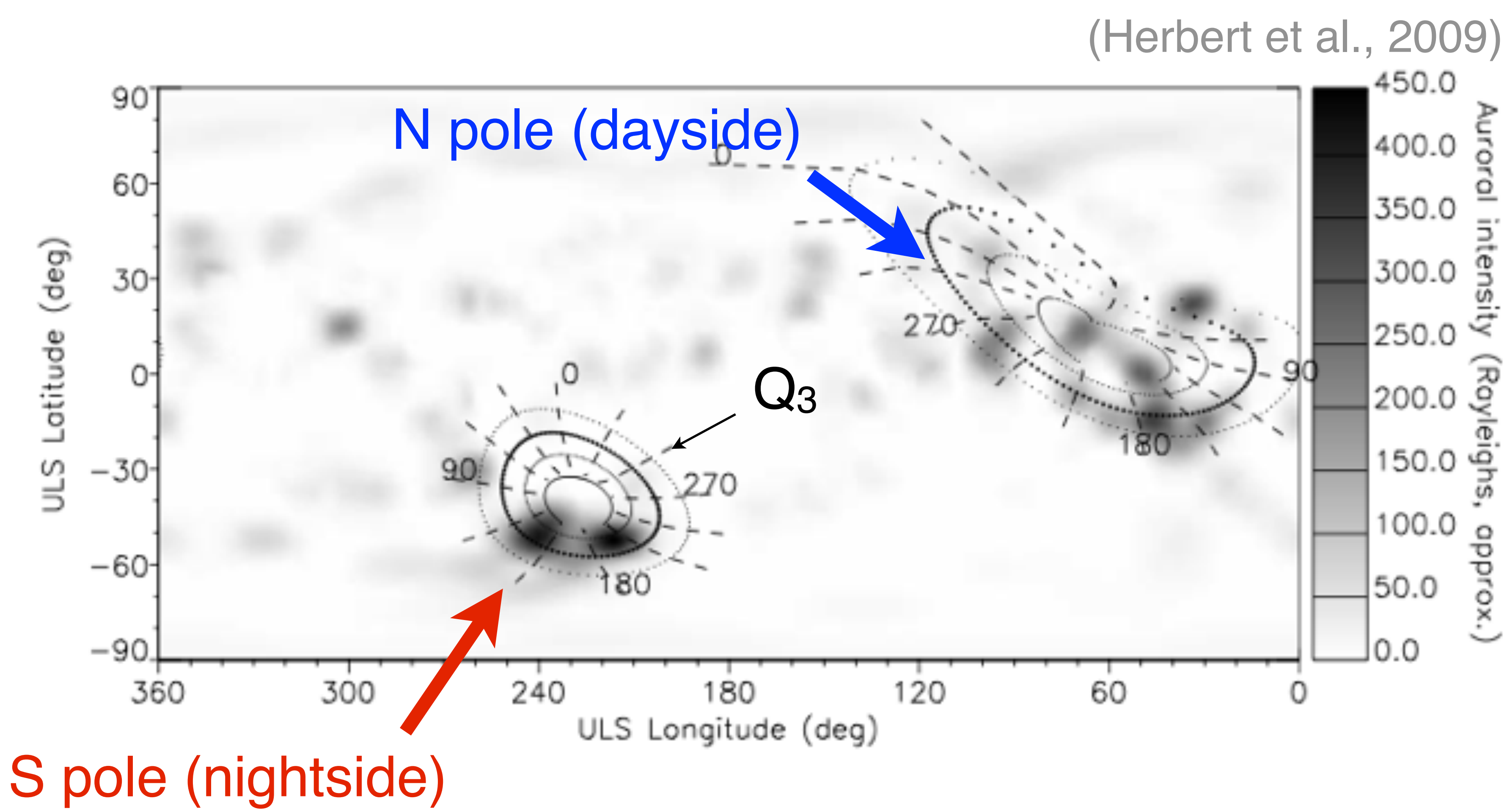
UV aurorae detected at 70-190nm by the UVS spectrometer : a few kR of H and H_2

Main properties :

- radiated power : N = 3.10^9 W / S = 7.10^9 W => input power ~ a few 10^{10} W
- modulated at the planetary rotation period : 17.24±0.01h
- N and S aurora magnetically conjugate at ~60-65° latitude (L=5-10) => MFL model
- enhanced along the magnetotail direction (~180° long.) => solar wind convection

1986 : Voyager 2





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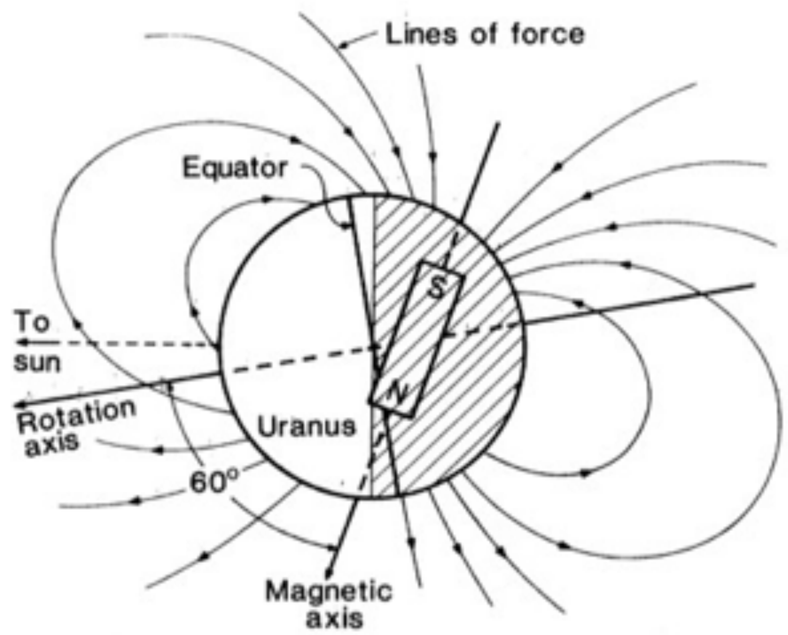

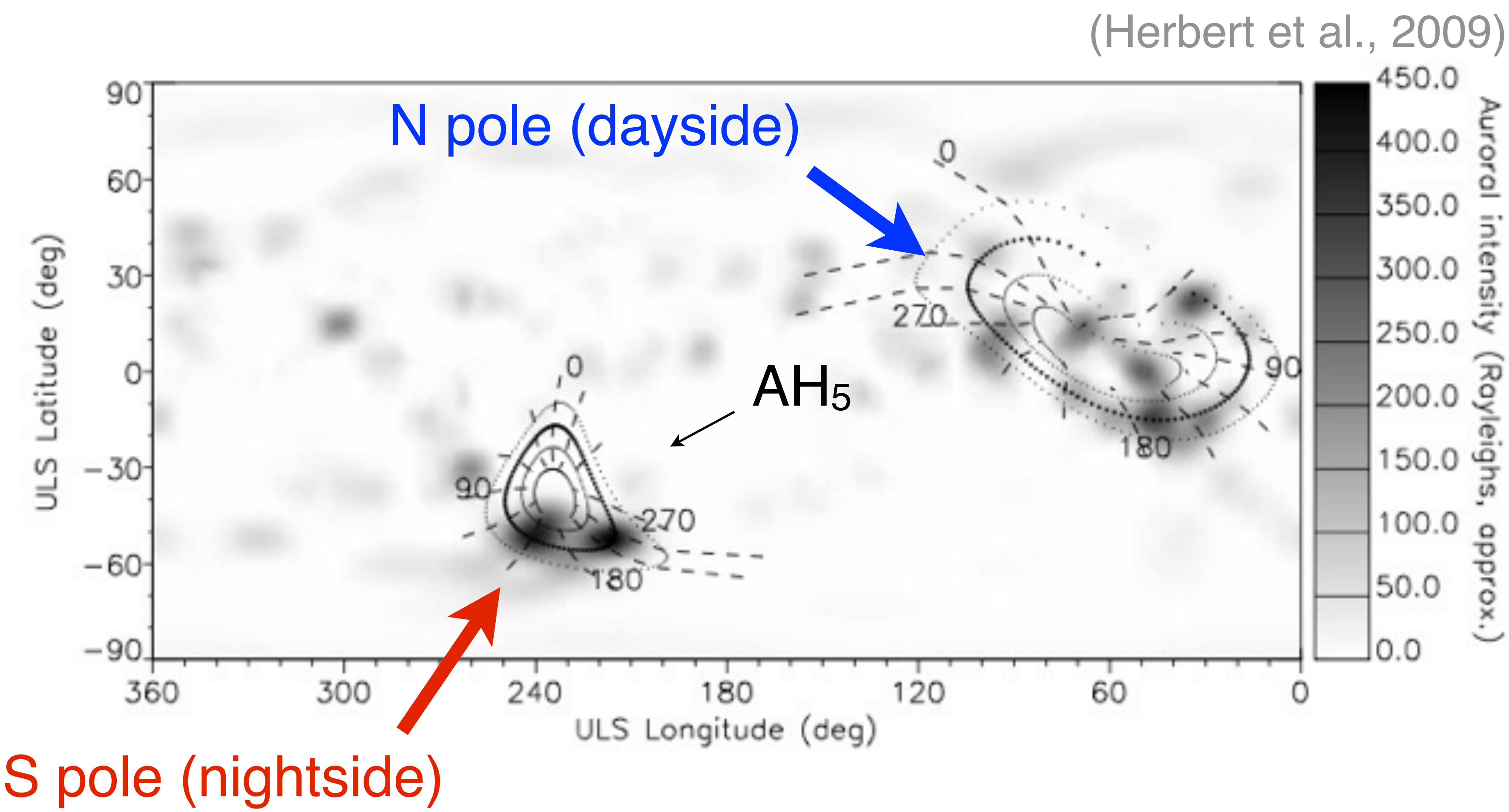

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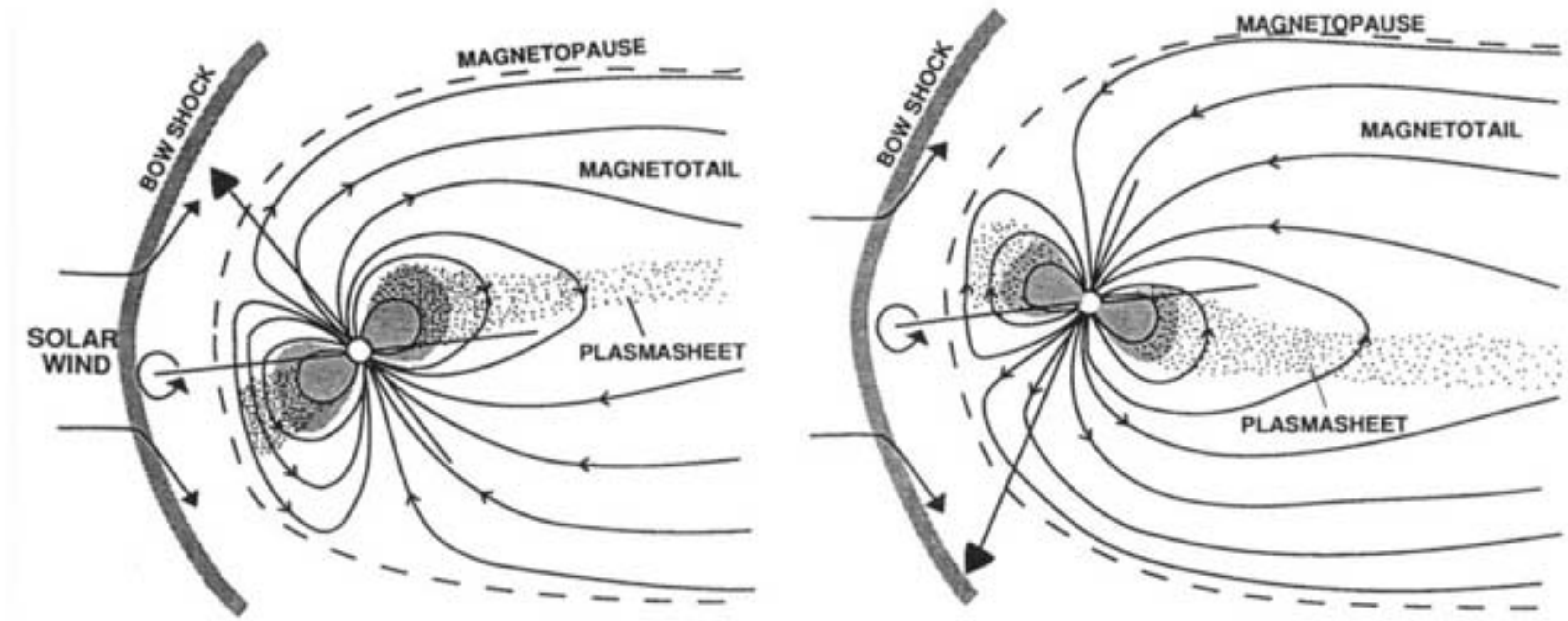
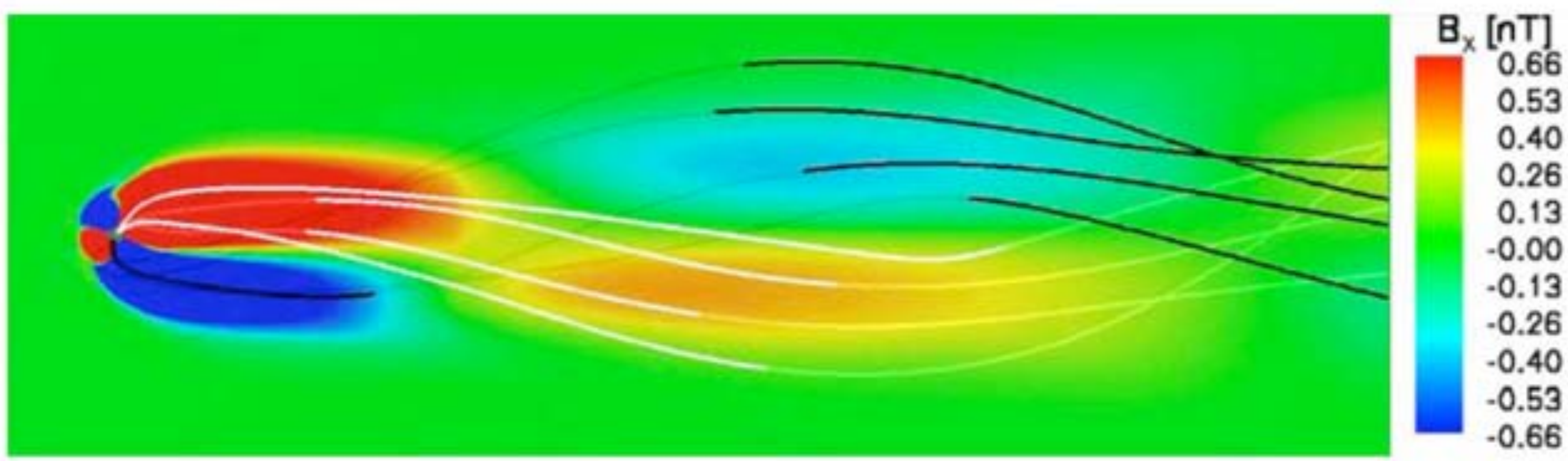


(Bagenal et al, 1992)



(Toth et al., 2004)

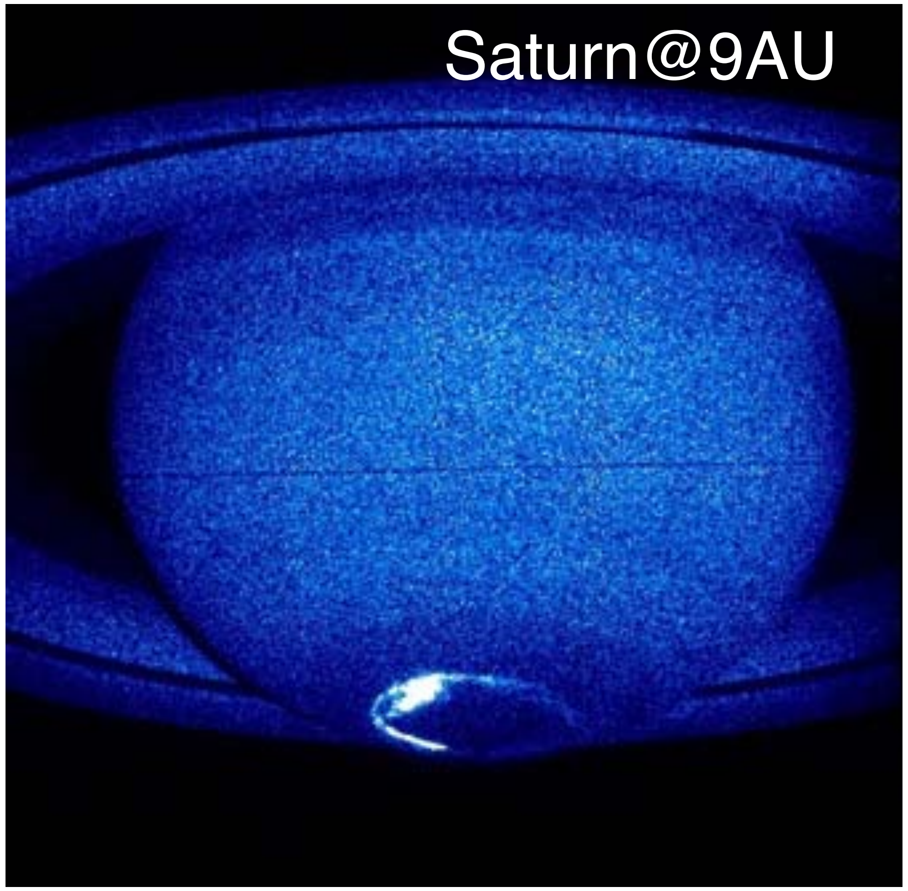
<u>Interpretation :</u>

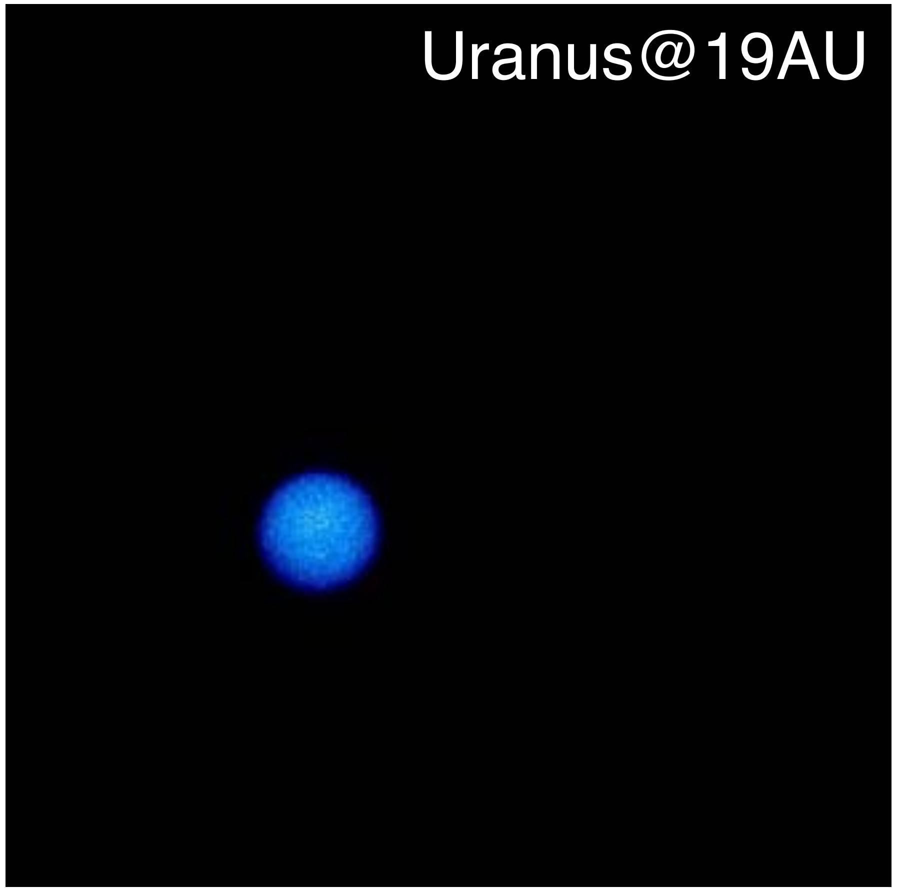
- magnetic axis permanently quasi-orthogonal to the solar wind flow
  => solar wind convection and planetary rotation act in orthogonal planes
  => stable helical plasma sheet
  => Earth-type situation (although more dynamical) = <u>nightside</u> auroral precipitations

1998 and 2005 : HST

Post-Voyager attempts for redecting Uranus aurorae with HST (sensitivity ~ 1kR) :

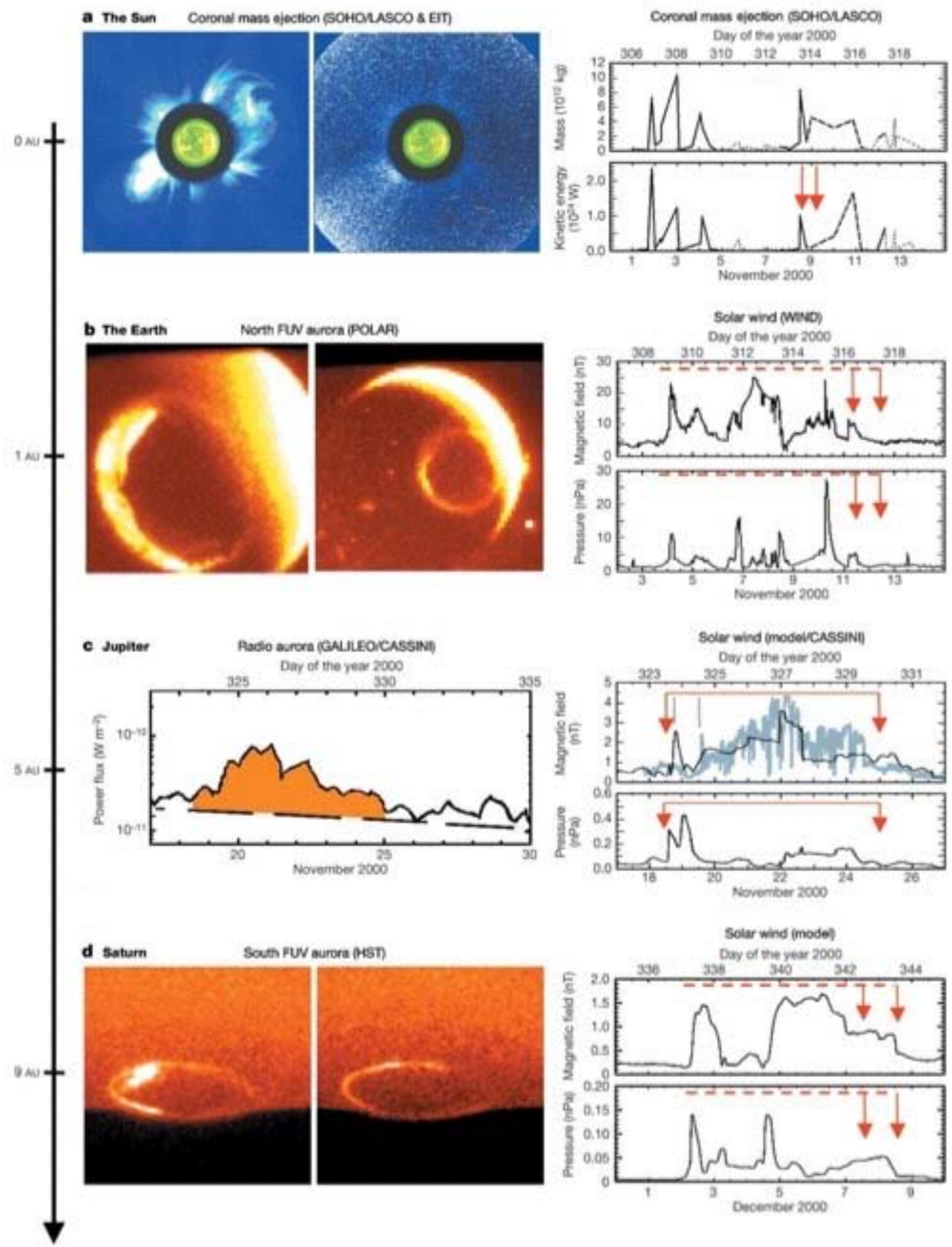
- 1998 : STIS (G. Ballester et al.) => unsuccessful
- 2005 : ACS (J. Clarke et al.) => unsuccessful





twice as far as Saturn
+ 2-3 less intense
=> attenuation by 1 order of magnitude

2011 : « A new hope »



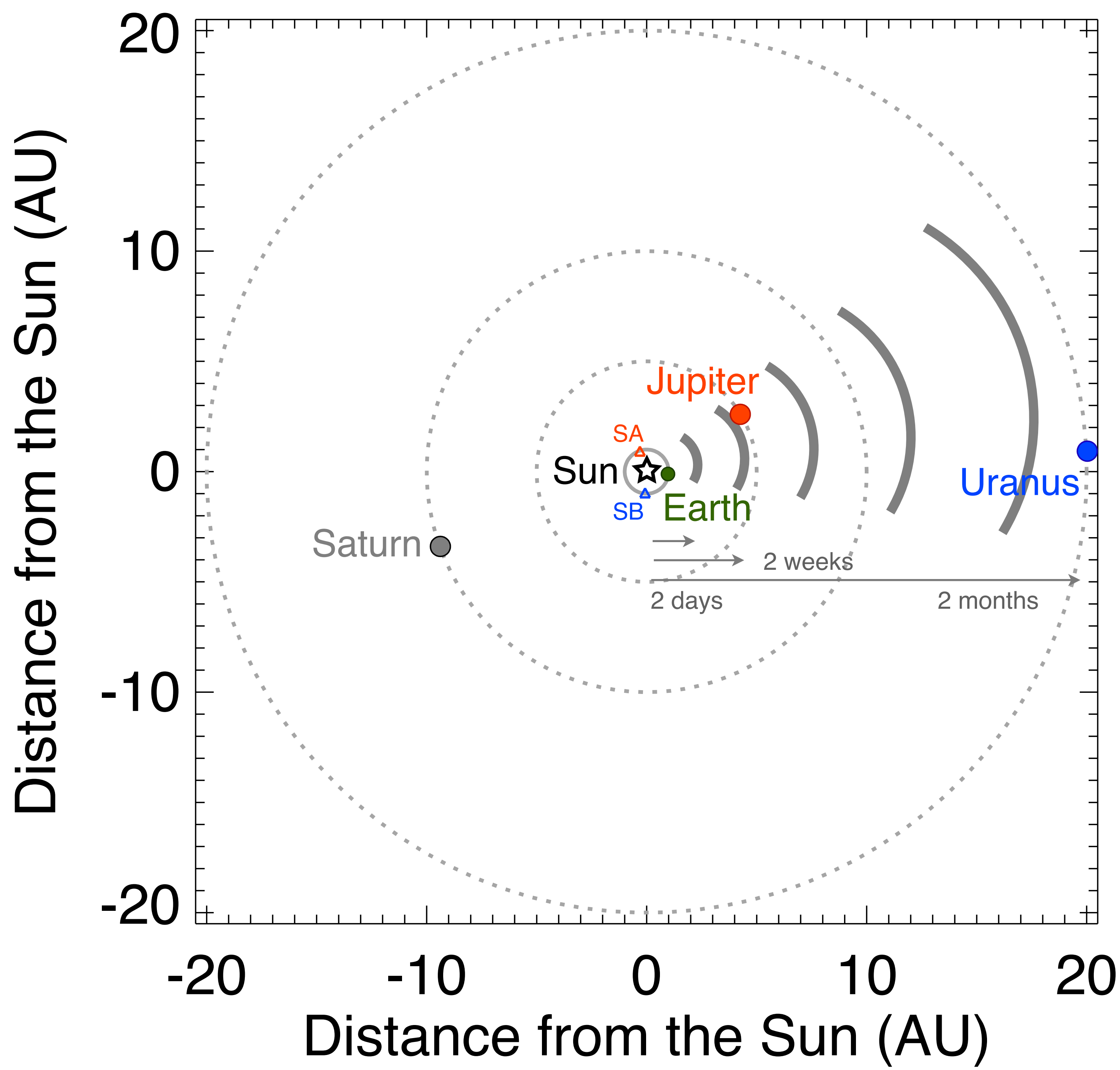
(Prangé et al., 2005)

- Interplanetary shocks known to activate planetary aurorae

- Planetary alignment in Nov. 2000 => increase of auroral power along the same CME :
  - Earth : >10 (UV)
  - Jupiter : ~3 (radio)
  - Saturn : 3-5 (UV)

=> Uranus expected to be particularly sensitive to SW

2011 : « A new hope »



<u>Aim :</u>
investigate the Uranus auroral response to <u>interplanetary shocks</u>

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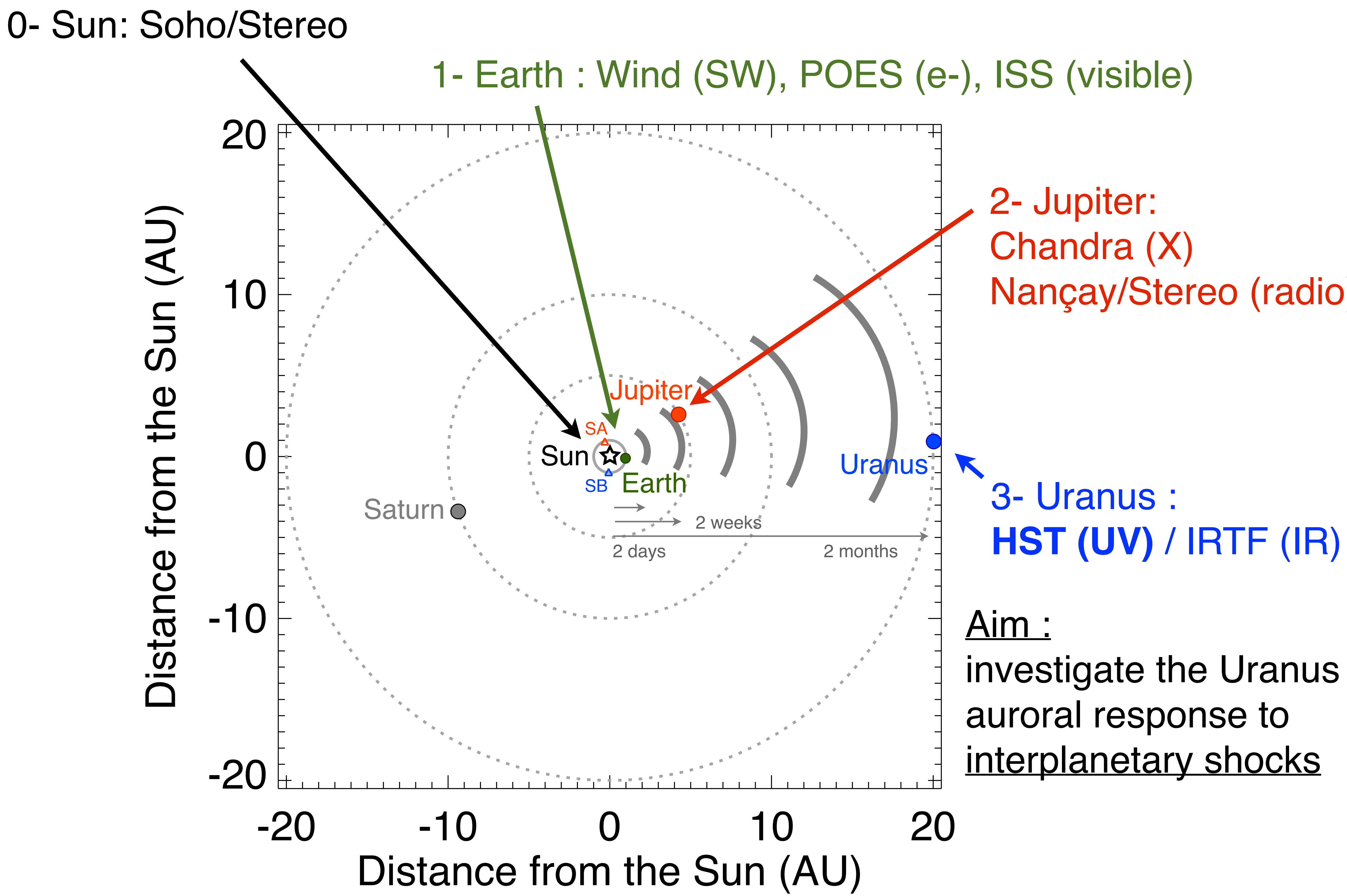

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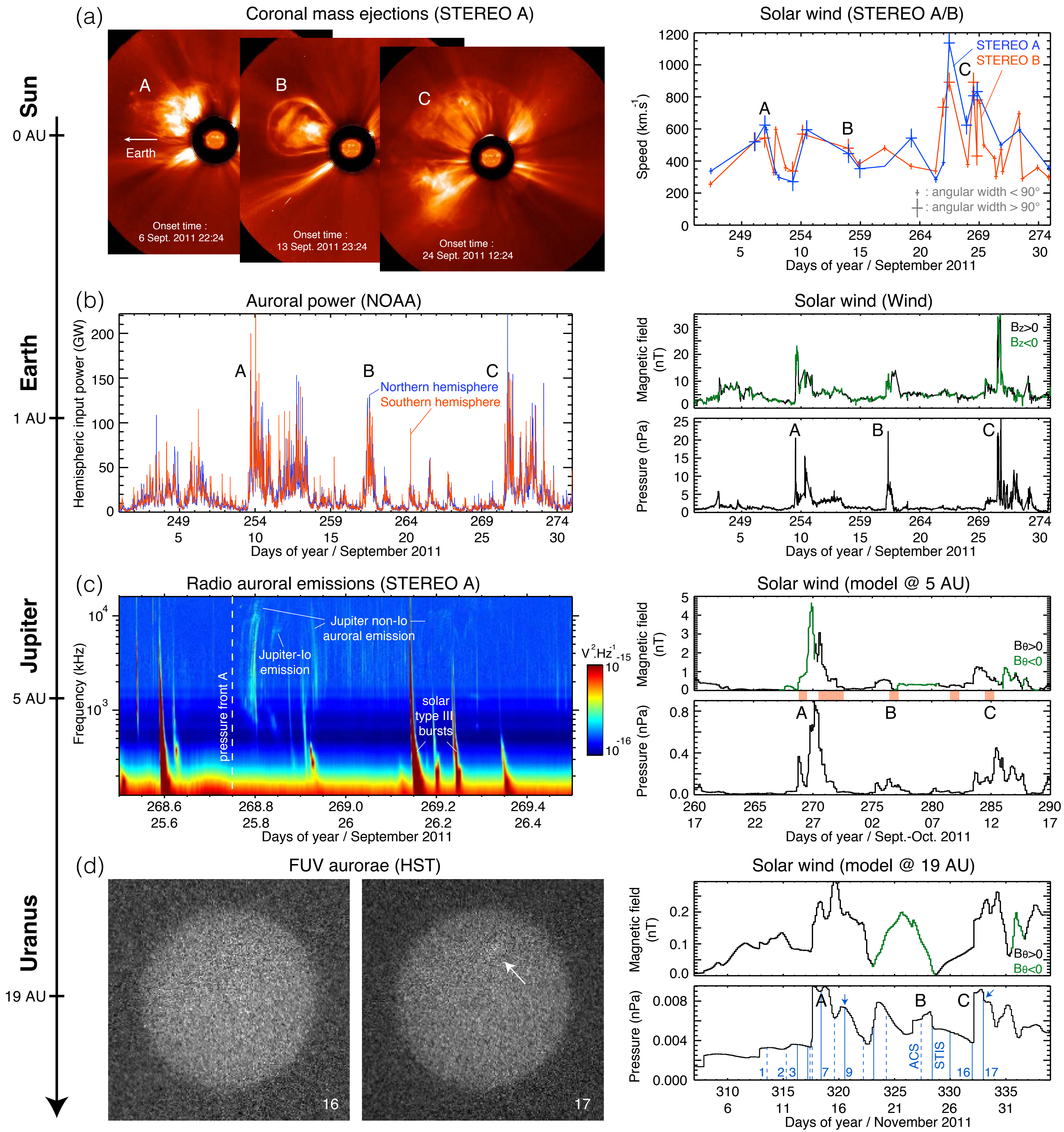
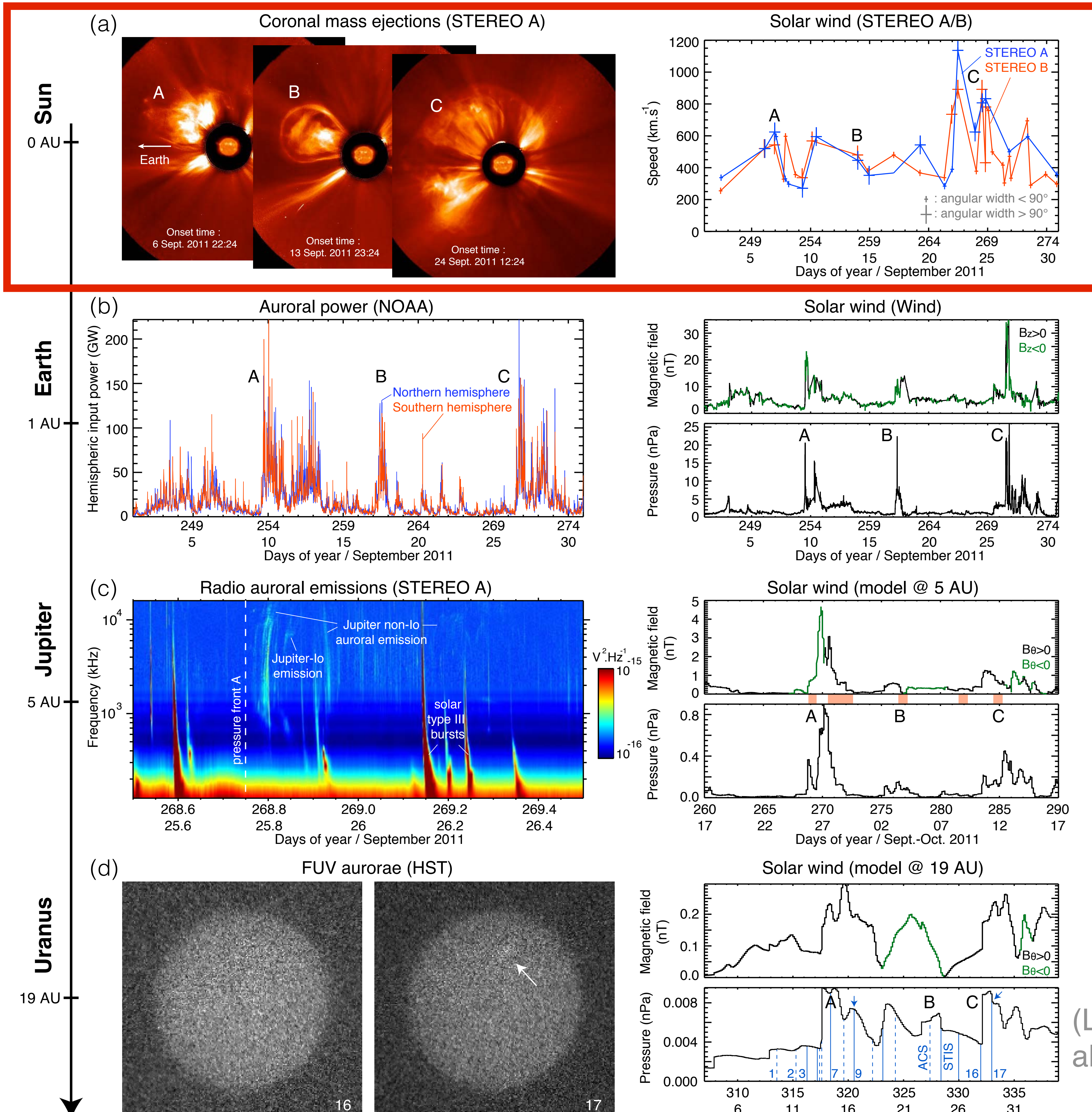


(Lamy et al., 2012)



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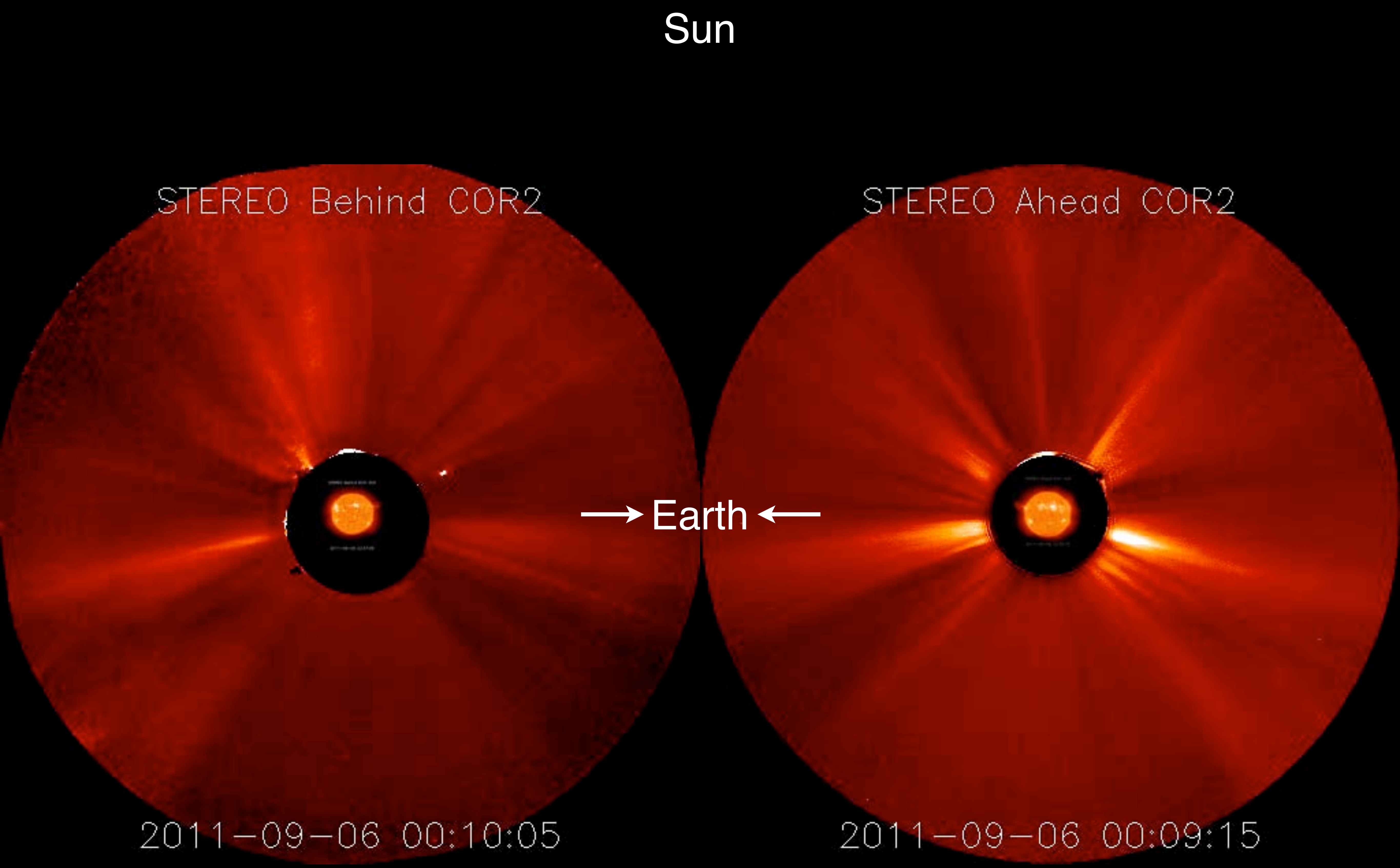
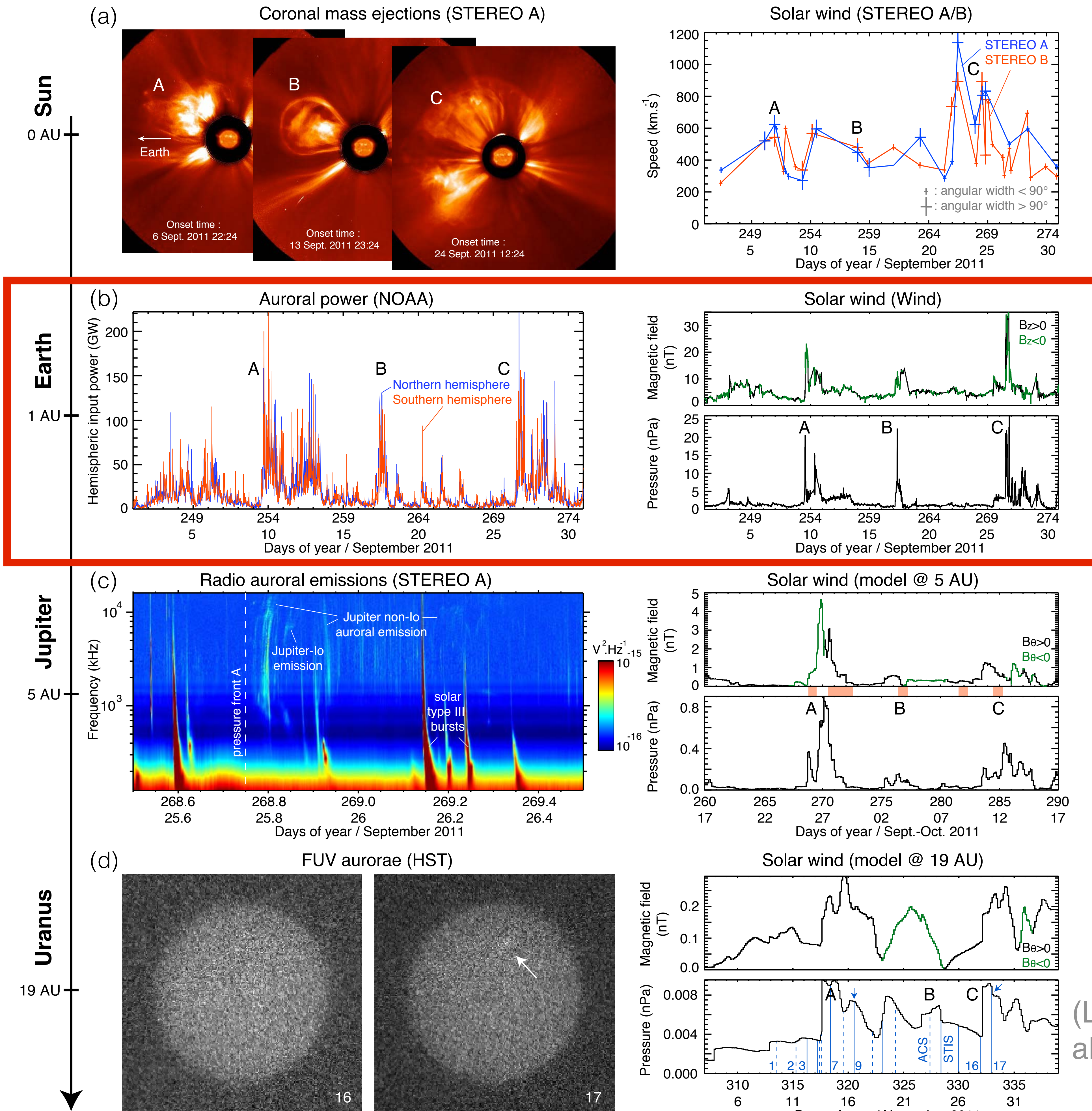

Sun
STEREO Behind COR2
STEREO Ahead COR2
Earth
2011-09-06 00:10:05
2011-09-06 00:09:15



(Lamy et al., 2012)

Earth

<u>Properties :</u>

- MS compression => large-scale tail reconnection over extended longitudes
- high correlation between auroral power and P_{dyn} (0.59), maximized for Bz<0 (0.64)
- hemispheric radiated power : 5-230GW => intensified by a factor of 30-60

Earth

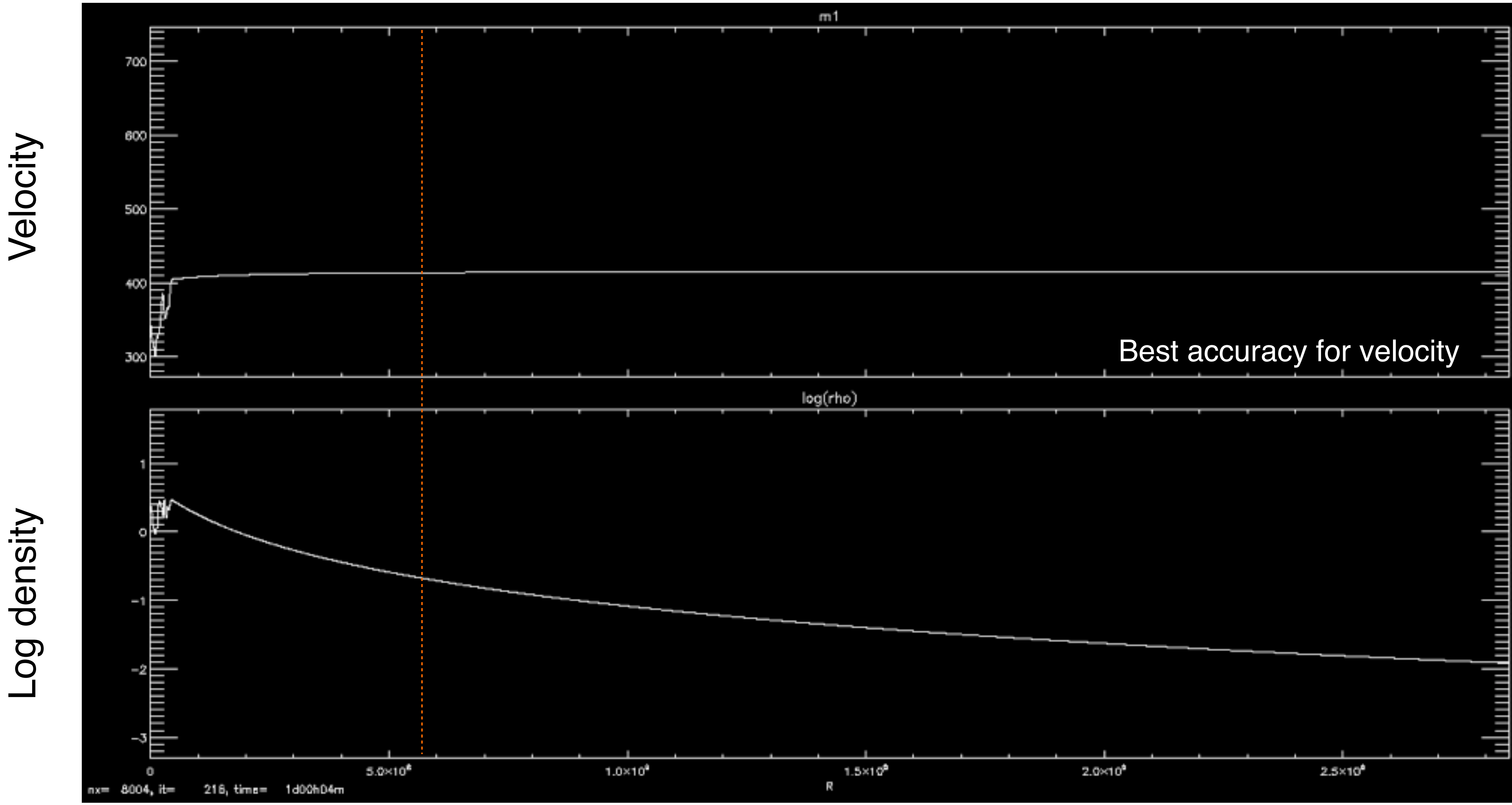
9 Sept. 2011

Washington

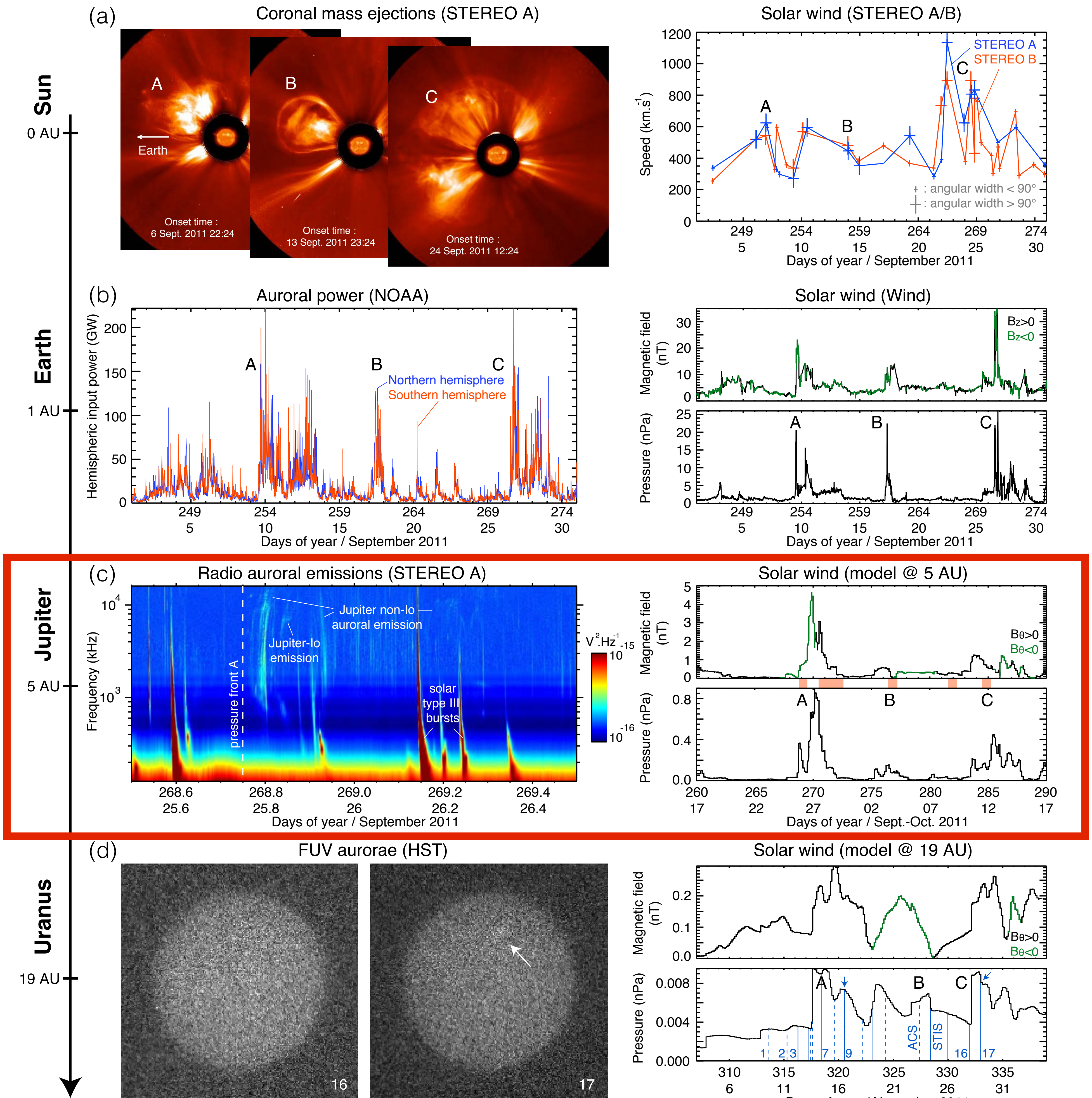
Sept : A coronal mass ejection (CME) hit Earth's magnetic field on Sept. 9th, sparking a (Kp=7) geomagnetic storm. Northern Lights were sighted in the United States as far south as Maine, Michigan, Vermont and Washington. Another CME struck on Sept. 17th, sparking a Kp=6 storm. The biggest CME strike of the month occured on Sept. 26th. A severe (Kp=8) geomagnetic storm ignited auroras over both hemispheres.

MHD simulation

(Courtesy to KC Hansen)

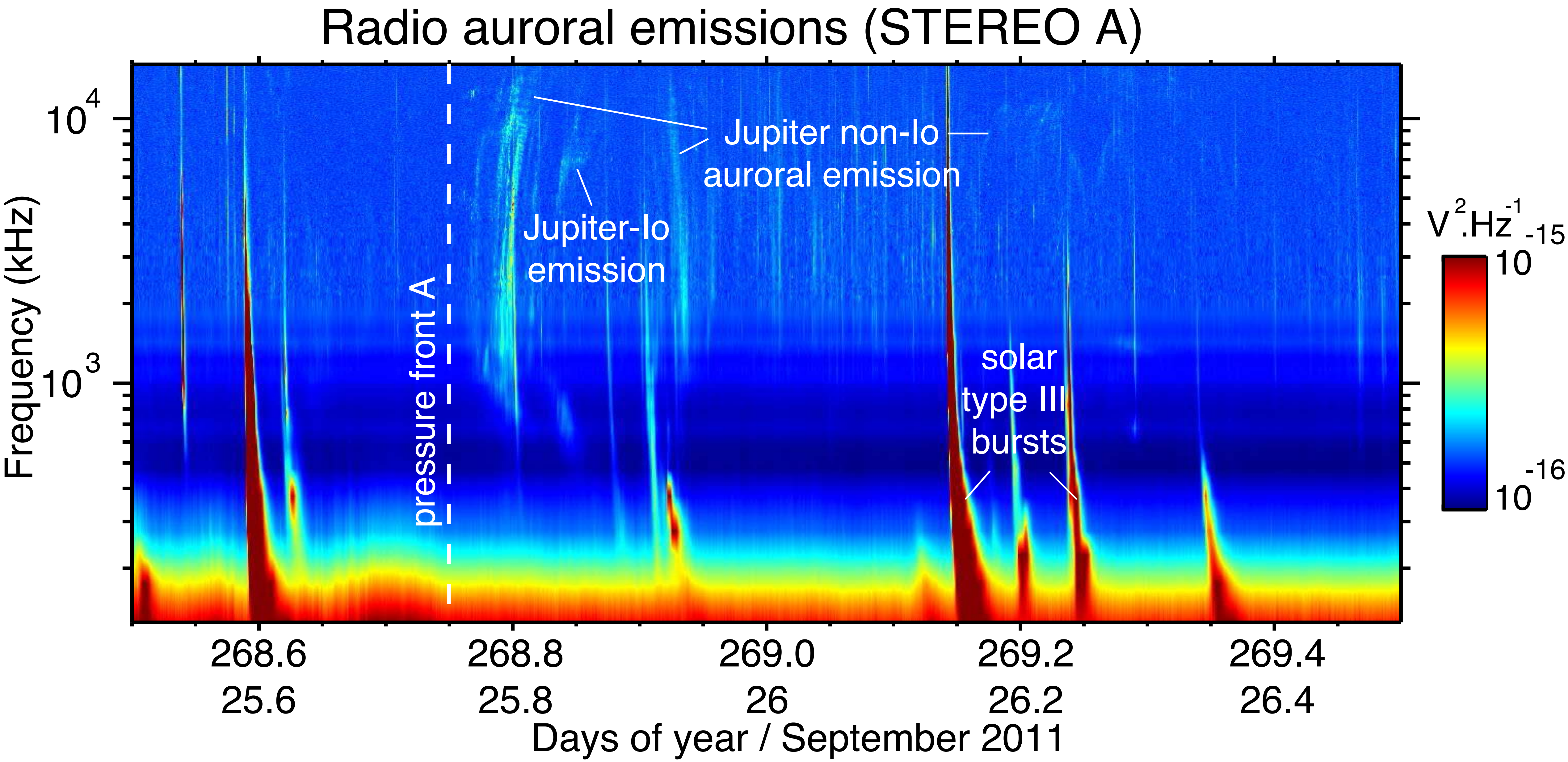


Earth Jupiter Uranus



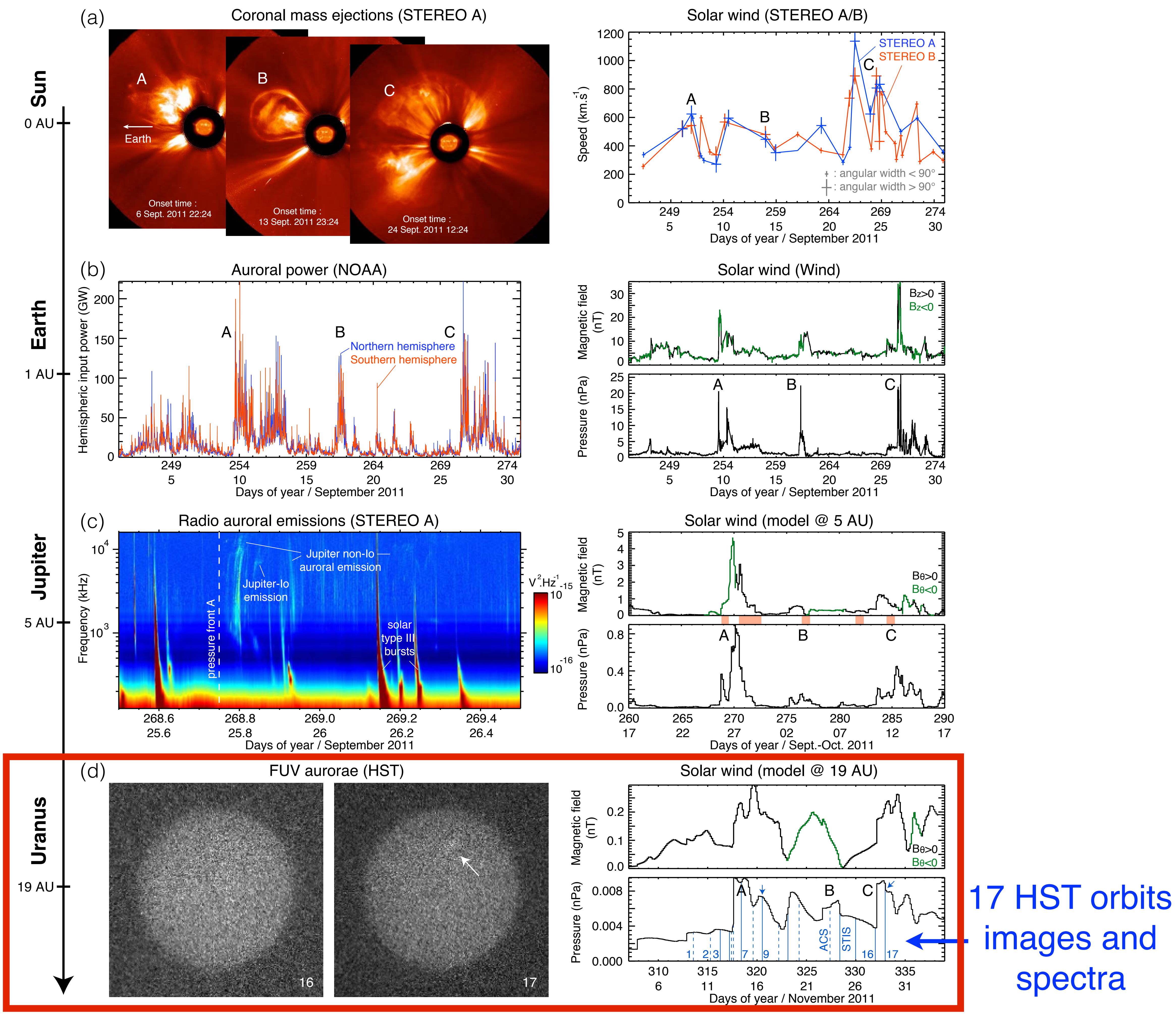
Sun
0 AU
Earth
1 AU
Jupiter
5 AU
Uranus
19 AU
(a)
Coronal mass ejections (STEREO A)
A
B
C
Earth
Onset time : 6 Sept. 2011 22:24
Onset time : 13 Sept. 2011 23:24
Onset time : 24 Sept. 2011 12:24
Solar wind (STEREO A/B)
STEREO A
STEREO B
Speed (km.s-1)
: angular width < 90°
: angular width > 90°
Days of year / September 2011
(b)
Auroral power (NOAA)
Hemispheric input power (GW)
Northern hemisphere
Southern hemisphere
Days of year / September 2011
Solar wind (Wind)
Magnetic field (nT)
Bz>0
Bz<0
Pressure (nPa)
Days of year / September 2011
(c)
Radio auroral emissions (STEREO A)
Frequency (kHz)
Jupiter non-Io auroral emission
Jupiter-Io emission
pressure front A
solar type III bursts
V².Hz⁻¹
Days of year / September 2011
Solar wind (model @ 5 AU)
Magnetic field (nT)
Bθ>0
Bθ<0
Pressure (nPa)
Days of year / Sept.-Oct. 2011
(d)
FUV aurorae (HST)
16
17
Solar wind (model @ 19 AU)
Magnetic field (nT)
Bθ>0
Bθ<0
Pressure (nPa)
ACS
STIS
Days of year / November 2011

Jupiter



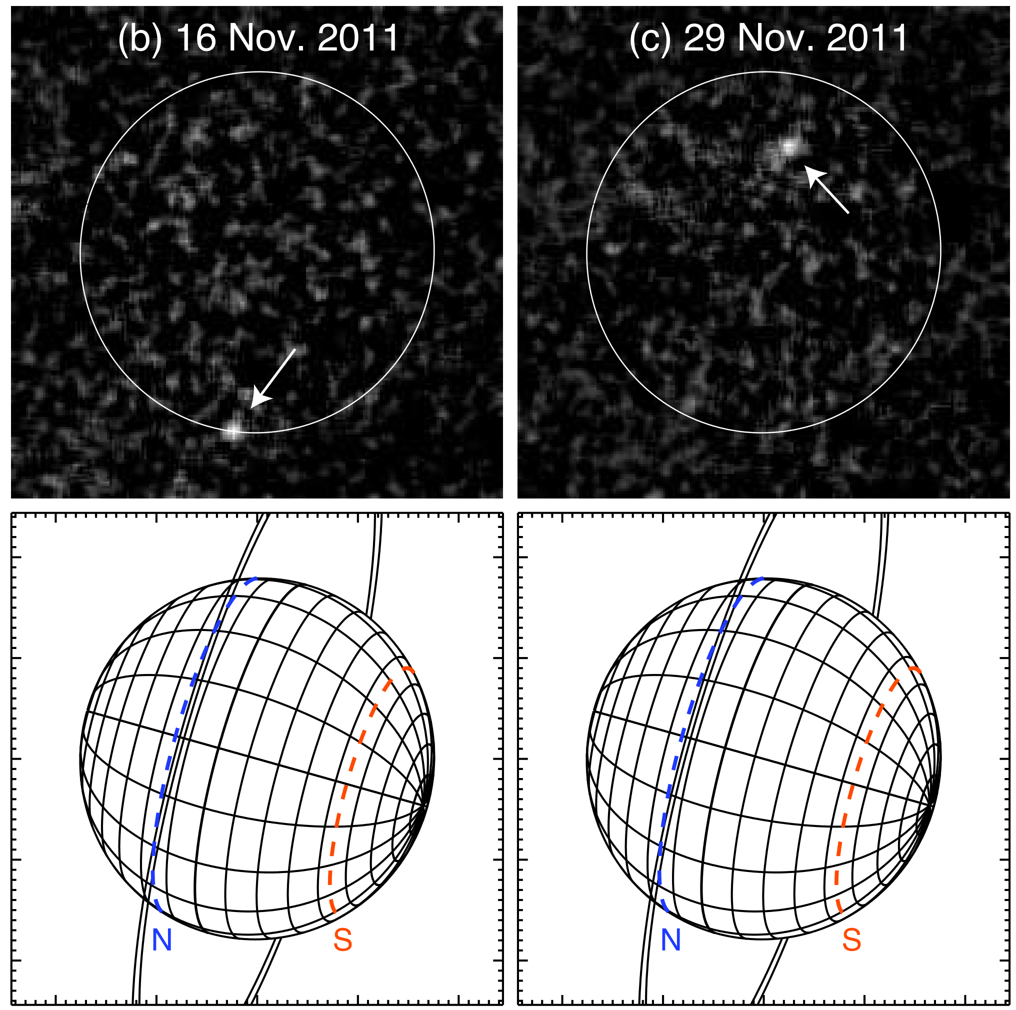
Properties :

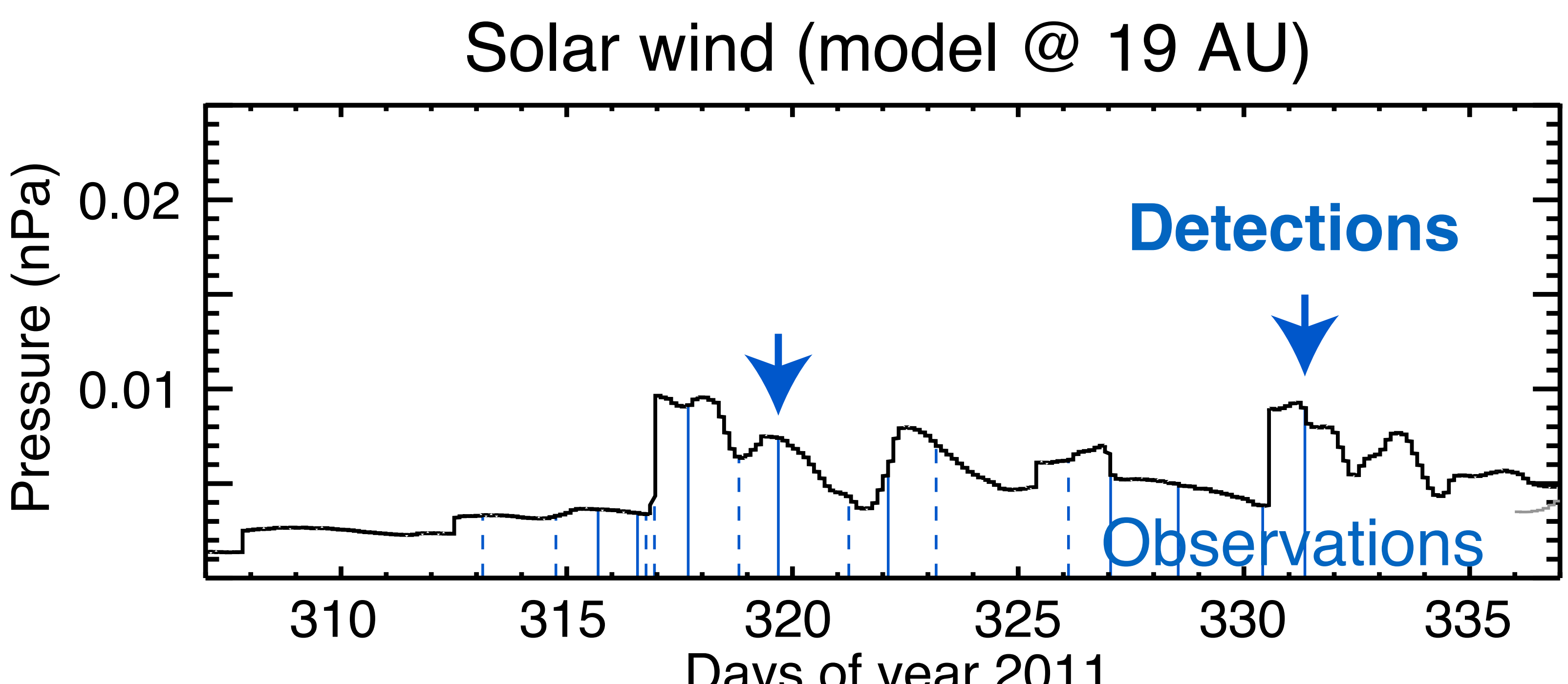
- occurrence close to each predicted arrival within 12h
- brightening from DAM to KOM : common origin
- cross-calibration with Nançay => intensity : 1% occurrence level (50GW/sr)
- intensification by a factor of >2 (<< Earth)



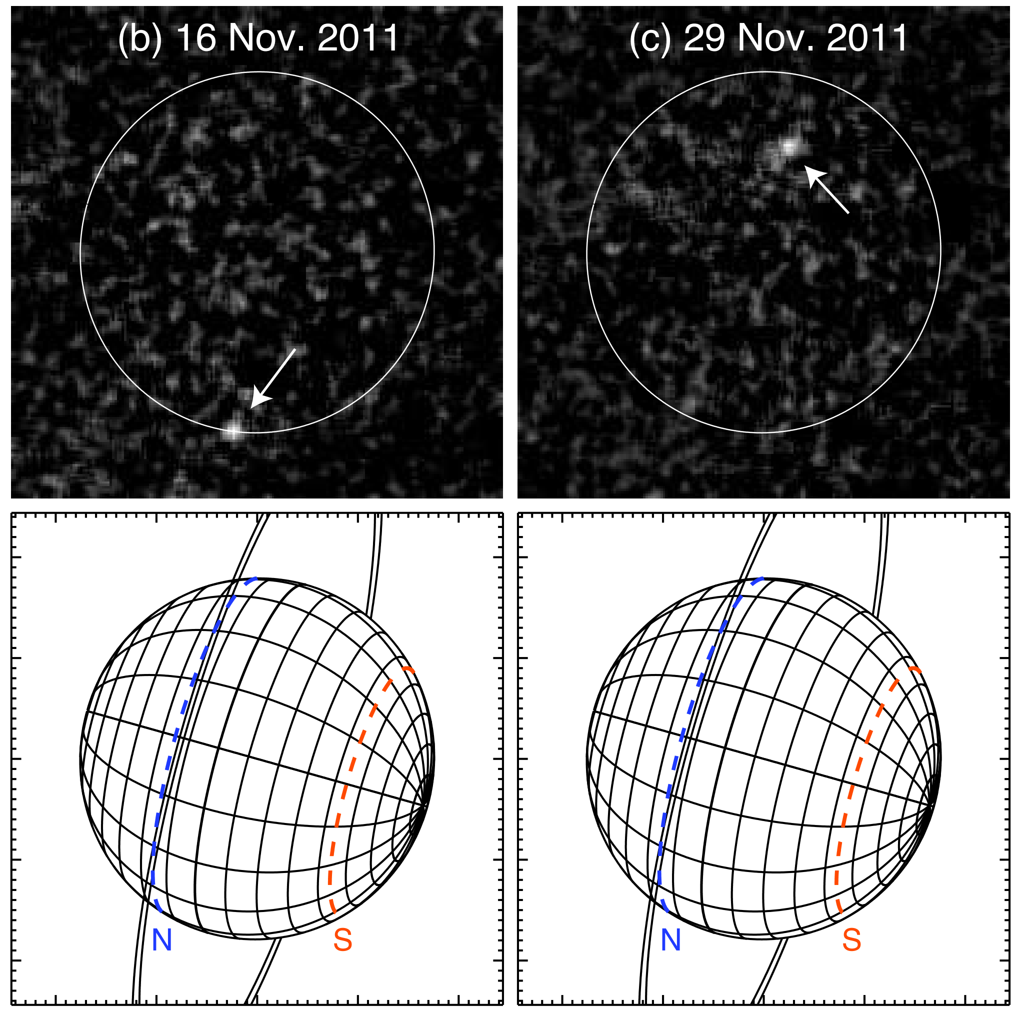
(a)
Coronal mass ejections (STEREO A)
Sun
0 AU
A
B
C
Earth
Onset time : 6 Sept. 2011 22:24
Onset time : 13 Sept. 2011 23:24
Onset time : 24 Sept. 2011 12:24
Solar wind (STEREO A/B)
STEREO A
STEREO B
Speed (km.s-1)
+ : angular width < 90°
+ : angular width > 90°
Days of year / September 2011
(b)
Auroral power (NOAA)
Earth
1 AU
Hemispheric input power (GW)
Northern hemisphere
Southern hemisphere
Days of year / September 2011
Solar wind (Wind)
Magnetic field (nT)
Bz>0
Bz<0
Pressure (nPa)
Days of year / September 2011
(c)
Radio auroral emissions (STEREO A)
Jupiter
5 AU
Frequency (kHz)
Jupiter non-Io auroral emission
Jupiter-Io emission
pressure front A
solar type III bursts
V².Hz-1
Days of year / September 2011
Solar wind (model @ 5 AU)
Magnetic field (nT)
Bθ>0
Bθ<0
Pressure (nPa)
Days of year / Sept.-Oct. 2011
(d)
FUV aurorae (HST)
Uranus
19 AU
16
17
Solar wind (model @ 19 AU)
Magnetic field (nT)
Bθ>0
Bθ<0
Pressure (nPa)
ACS
STIS
Days of year / November 2011
17 HST orbits images and spectra

2011

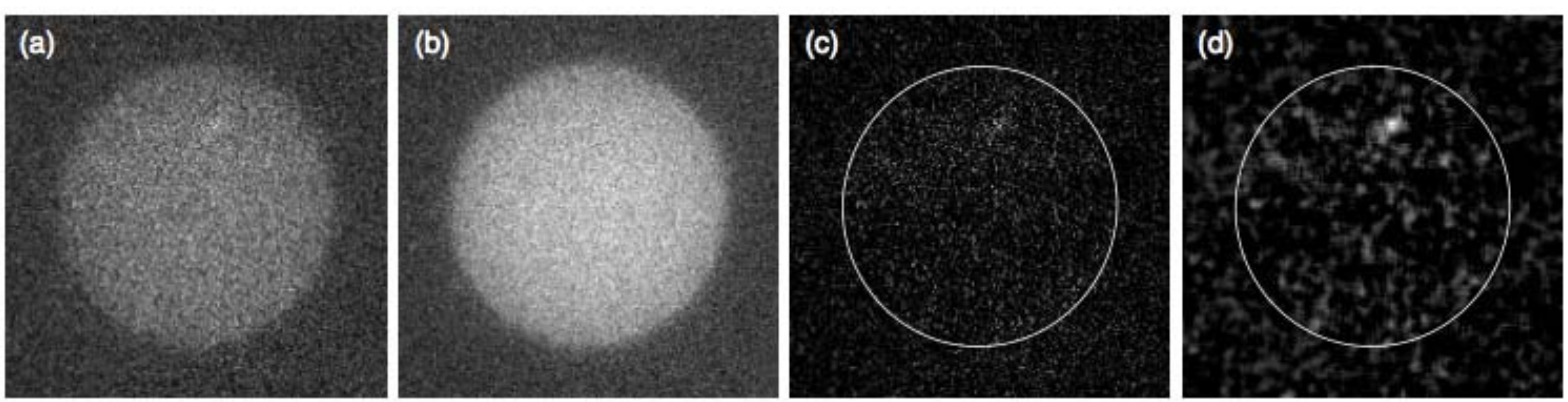

(b) 16 Nov. 2011
(c) 29 Nov. 2011
N
S
N
S


Solar wind (model @ 19 AU)
Pressure (nPa)
0.02
0.01
Detections
Observations
310
315
320
325
330
335
Days of year 2011

2011

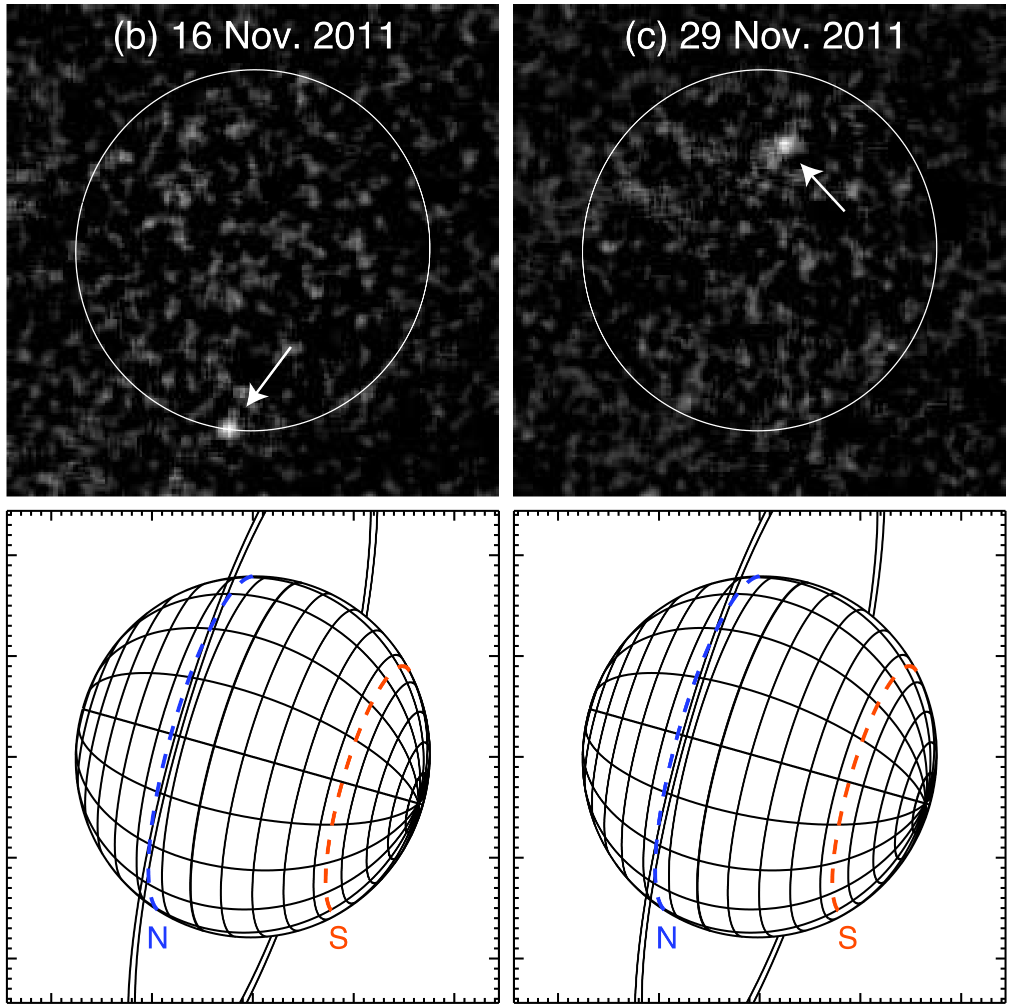


Straigthforward data processing :



spatially extended signal~ 3-5σ

2011



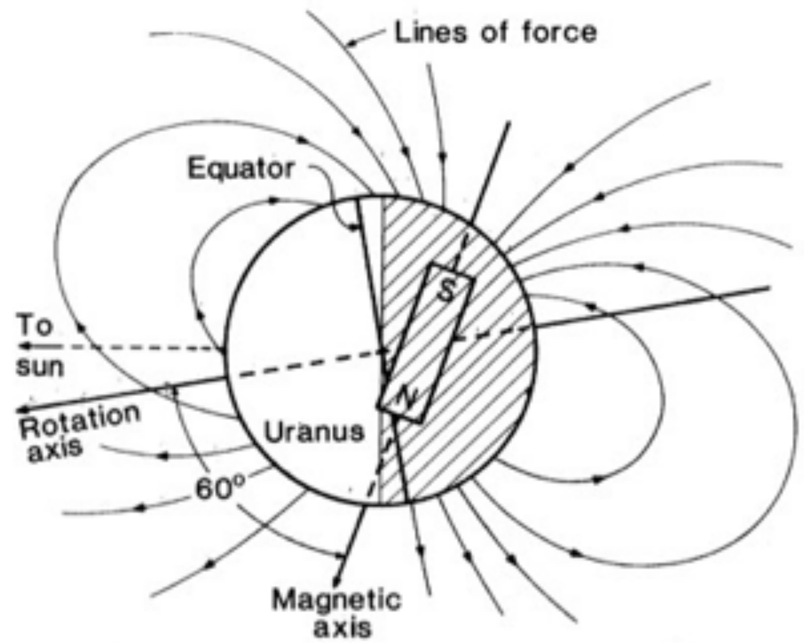
Properties :

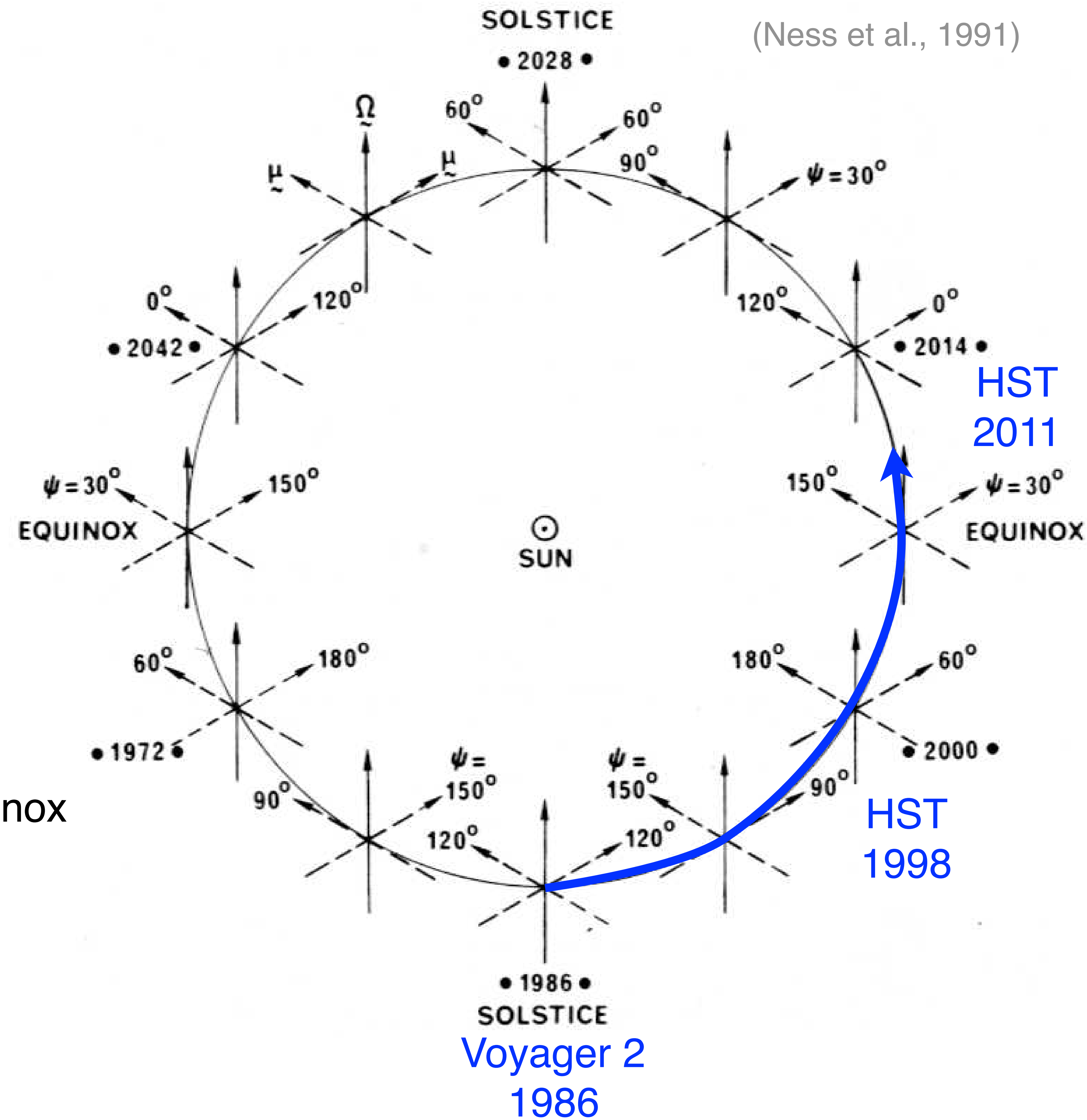
- faint N spots (~1kR)
- short-lived (a few min)
- occur close to predicted shocks
- rotationally phased !

Interpretation ?

2011

(Ness et al., 1991)

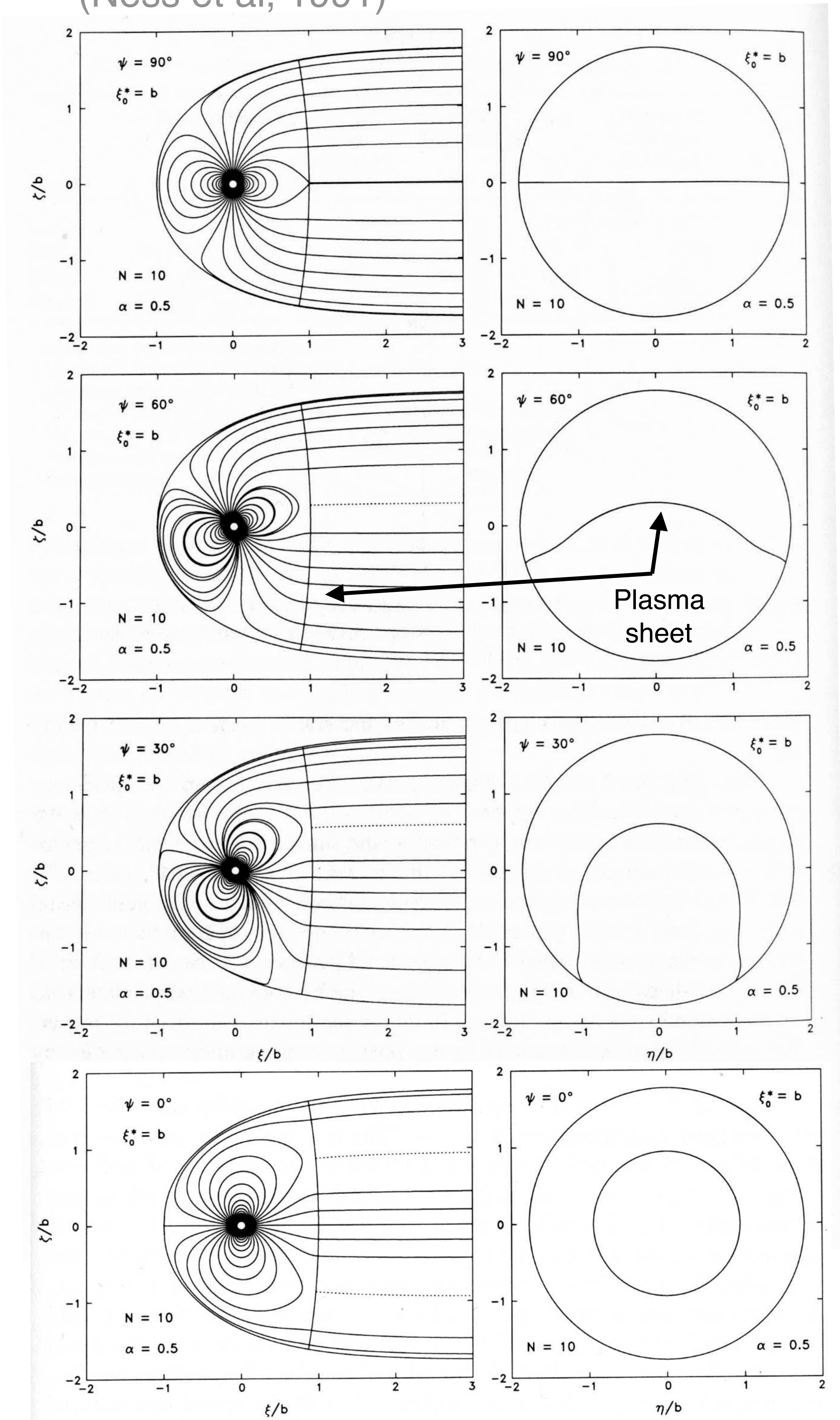




Sun ← 1986 : Solstice

Sun ⊙ 2011 : Near-equinox

(Ness et al, 1991)

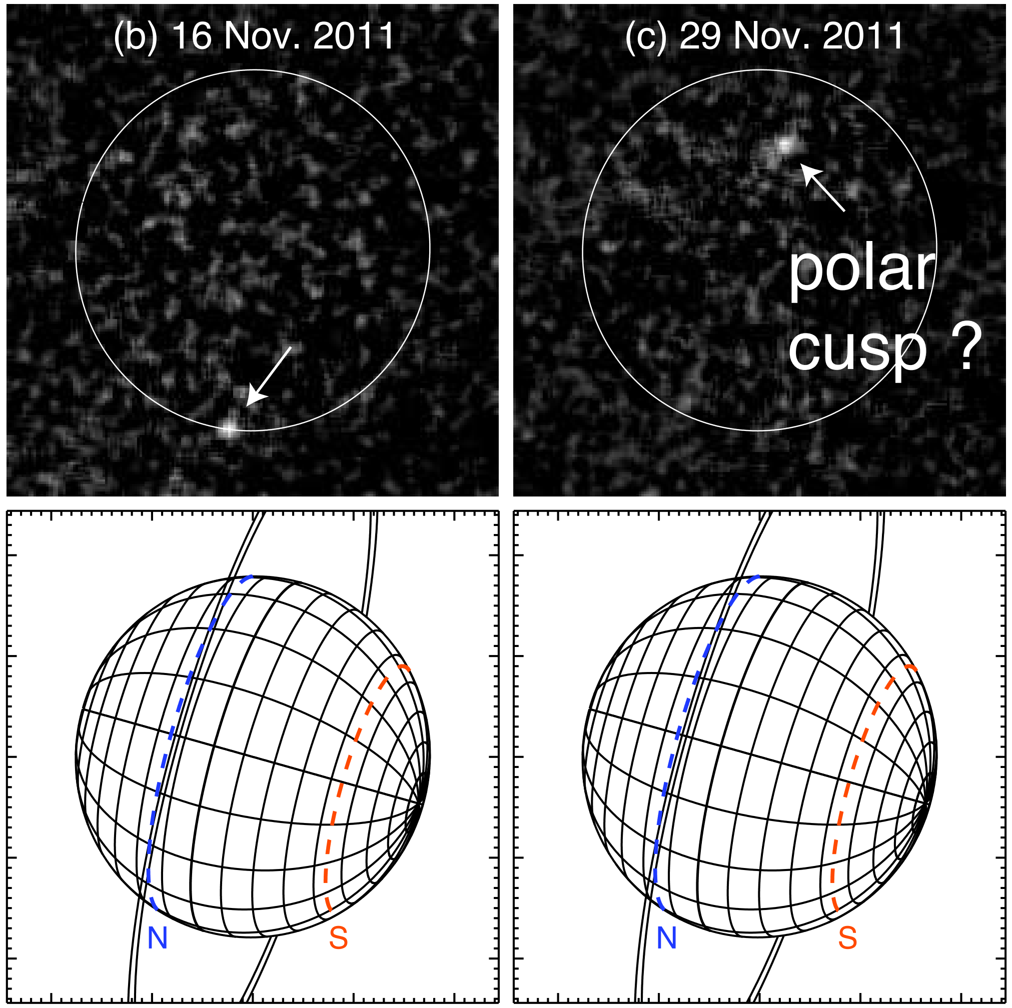


2011

Interpretation :

- extreme SW/MS configurations during each rotation from Earth-like to ‘pole-on’
  - => unlikely that a significant plasma sheet survives more than half a rotation
  - => dayside reconnection with interplanetary magnetic field favored once per rotation

2011



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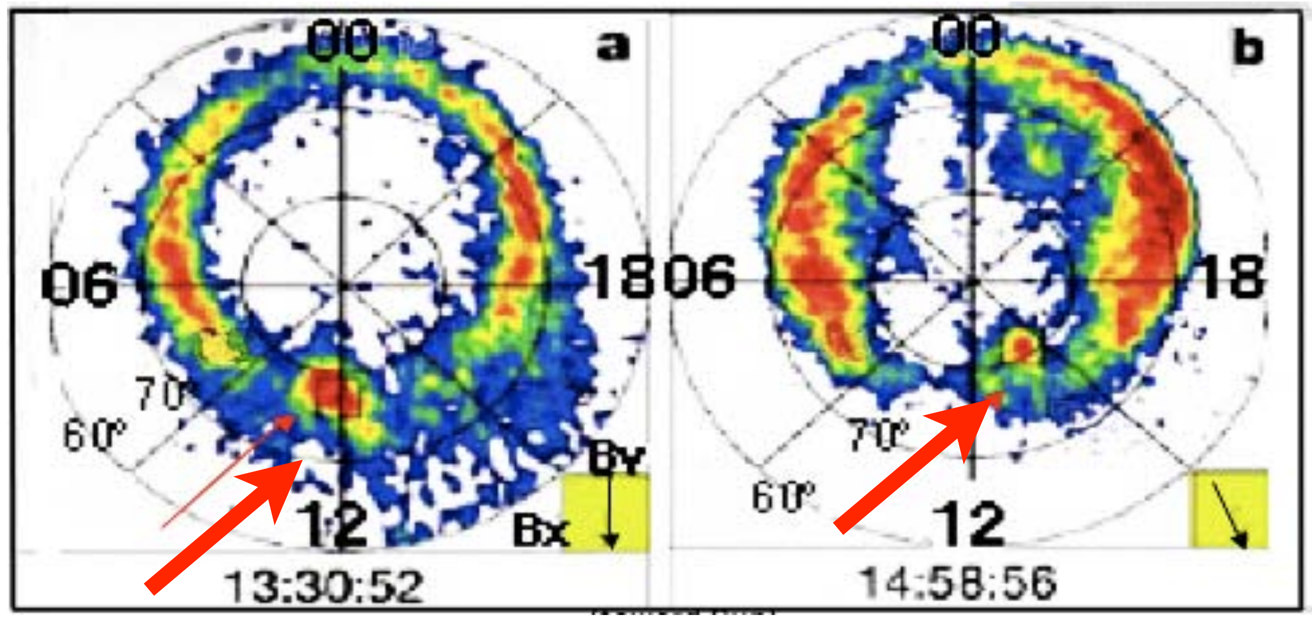
- extreme SW/MS configurations during each rotation from Earth-like to 'pole-on'

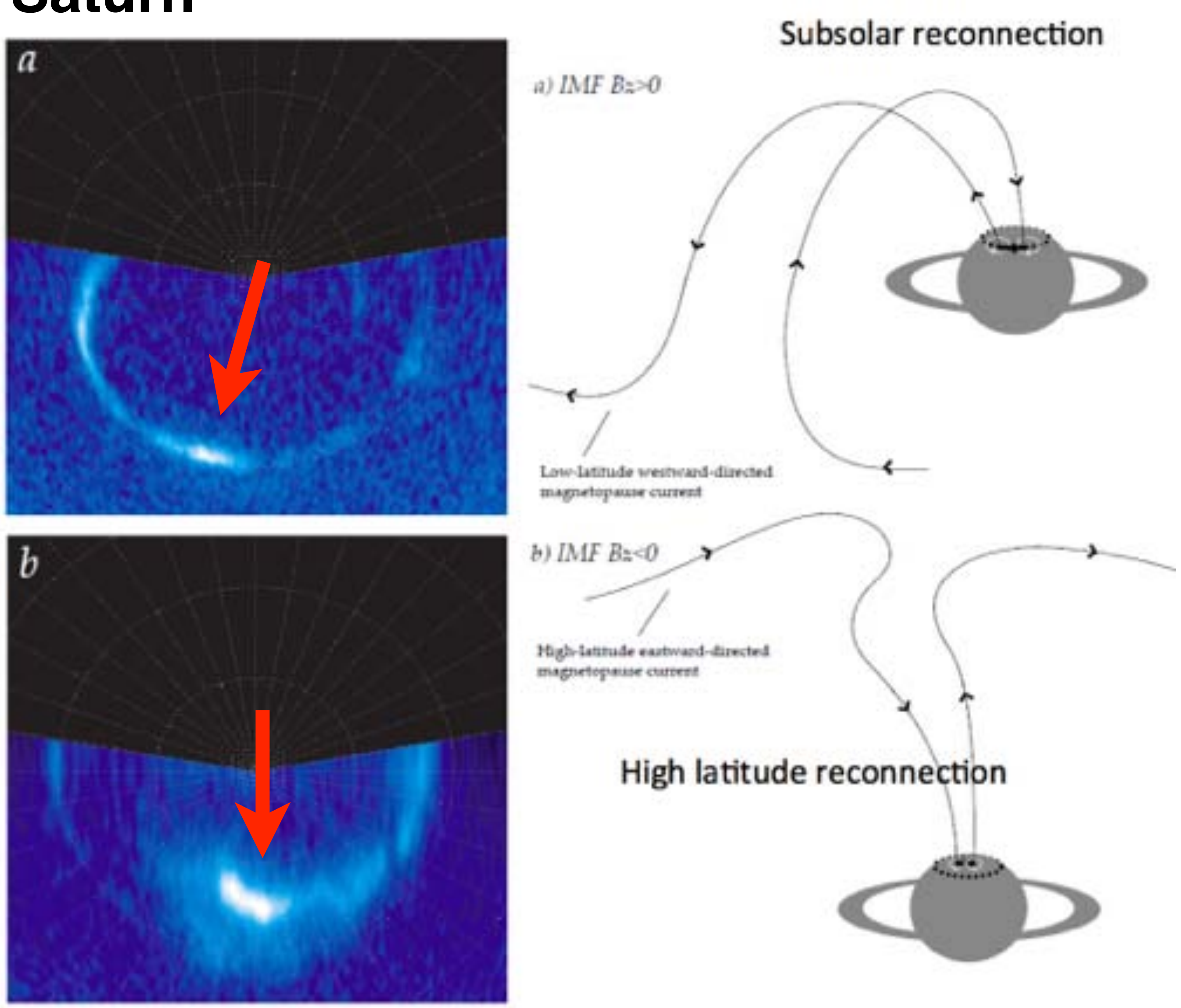
  => unlikely that a significant plasma sheet survives more than half a rotation

  => dayside reconnection with interplanetary magnetic field favored once per rotation = polar cusp ?

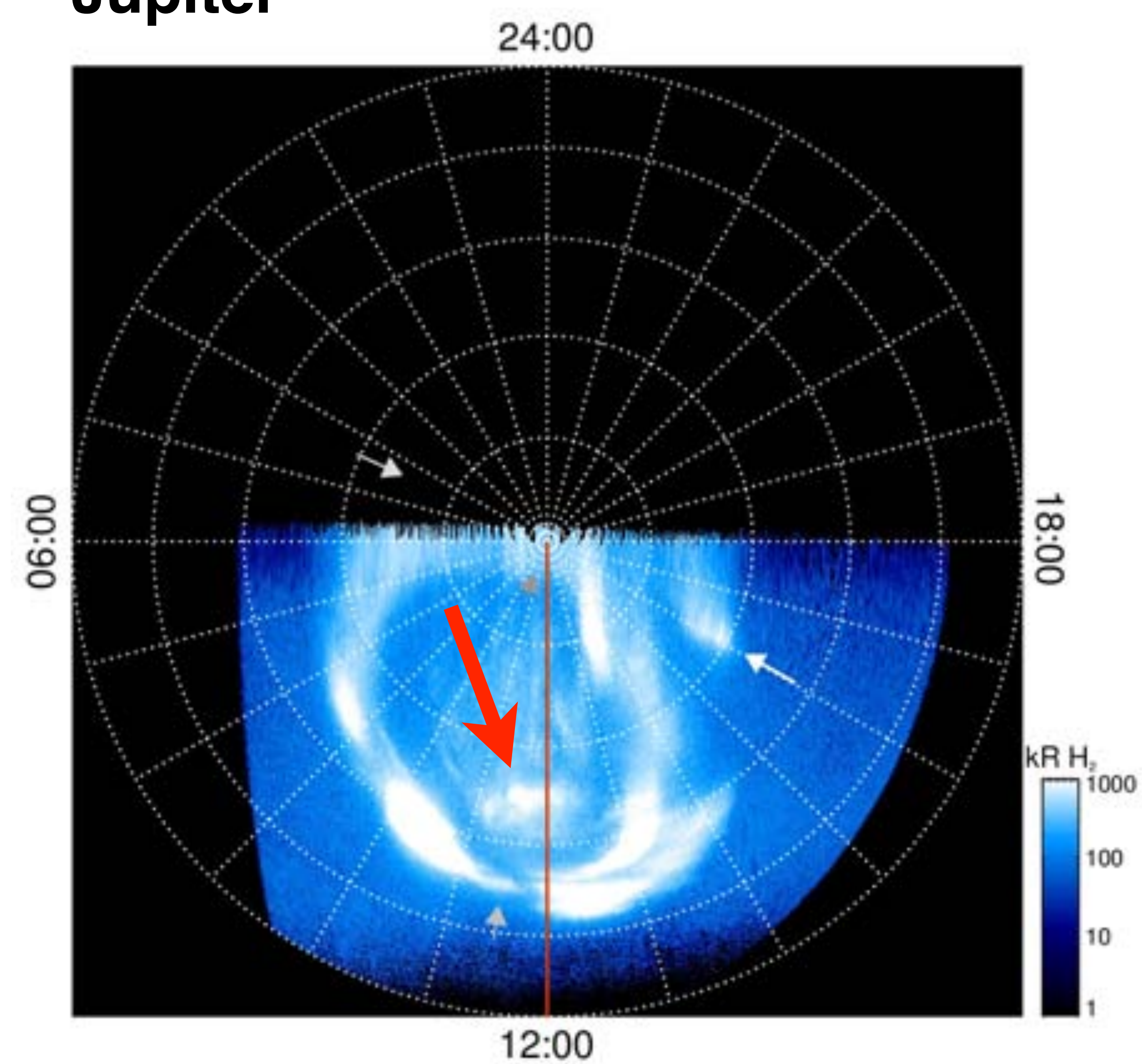
Earth



Saturn

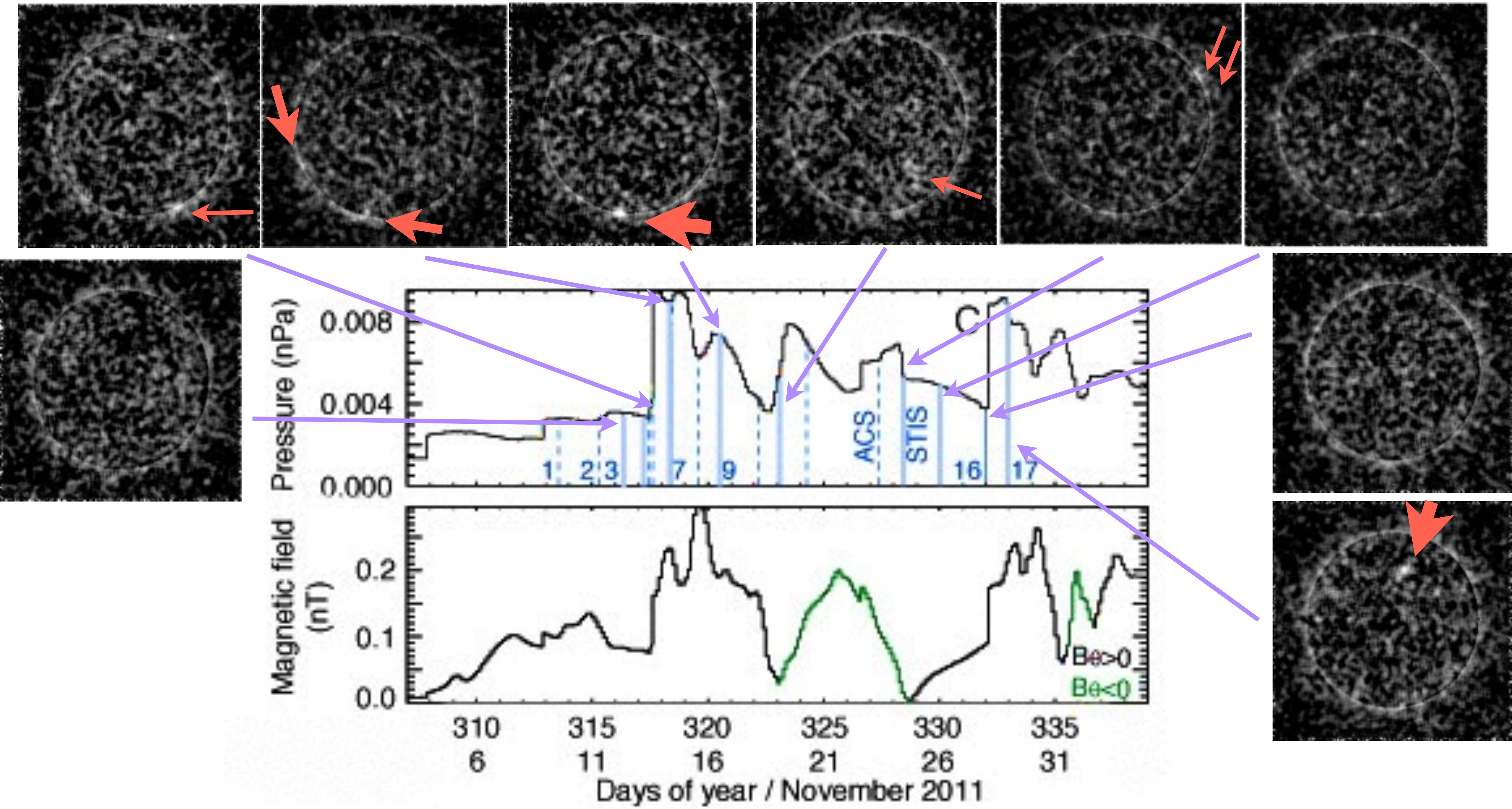


Jupiter



2011

In progress : what about *ambiguous* detections ?

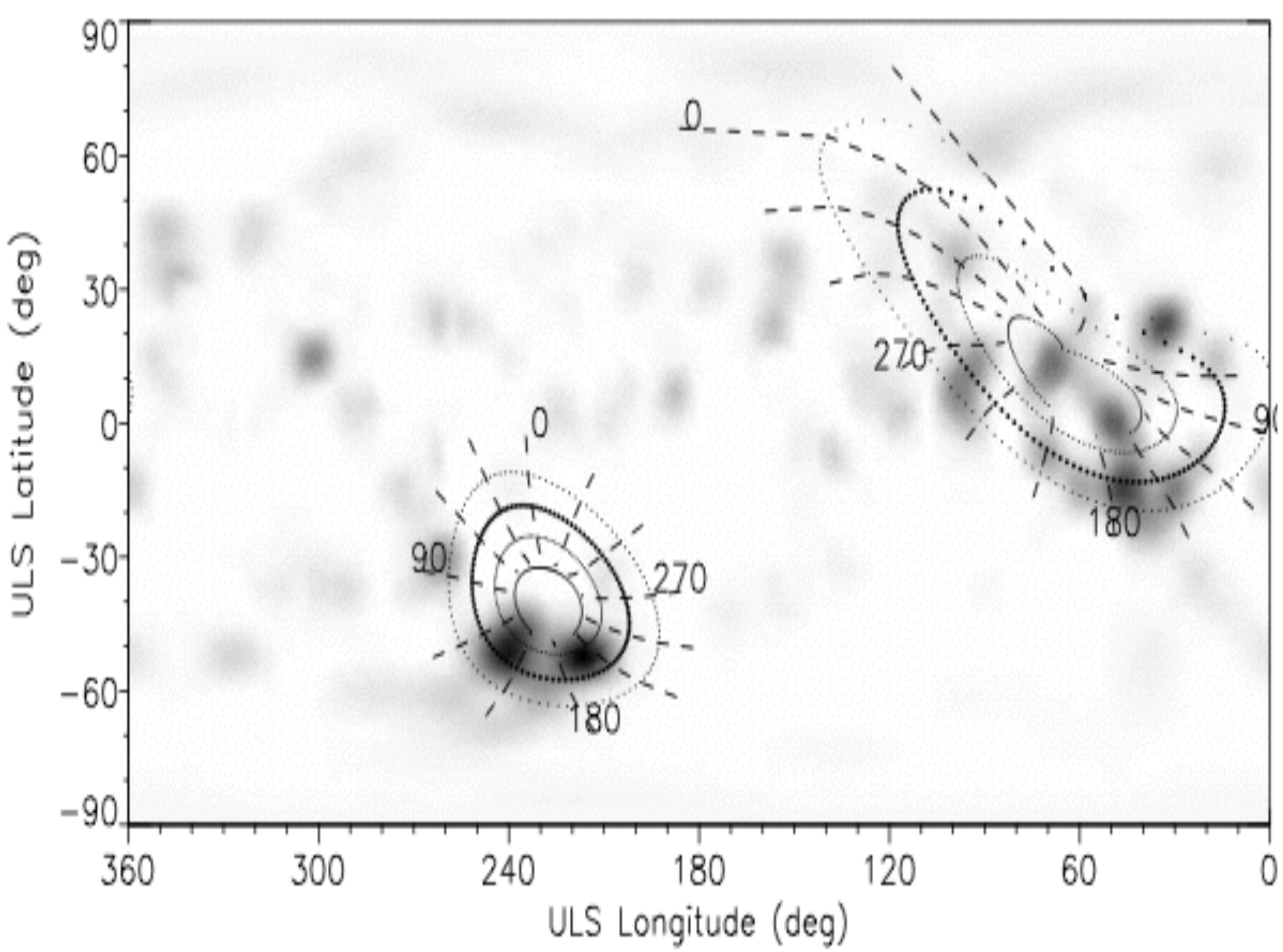


Propagated solar wind (@19 UA)

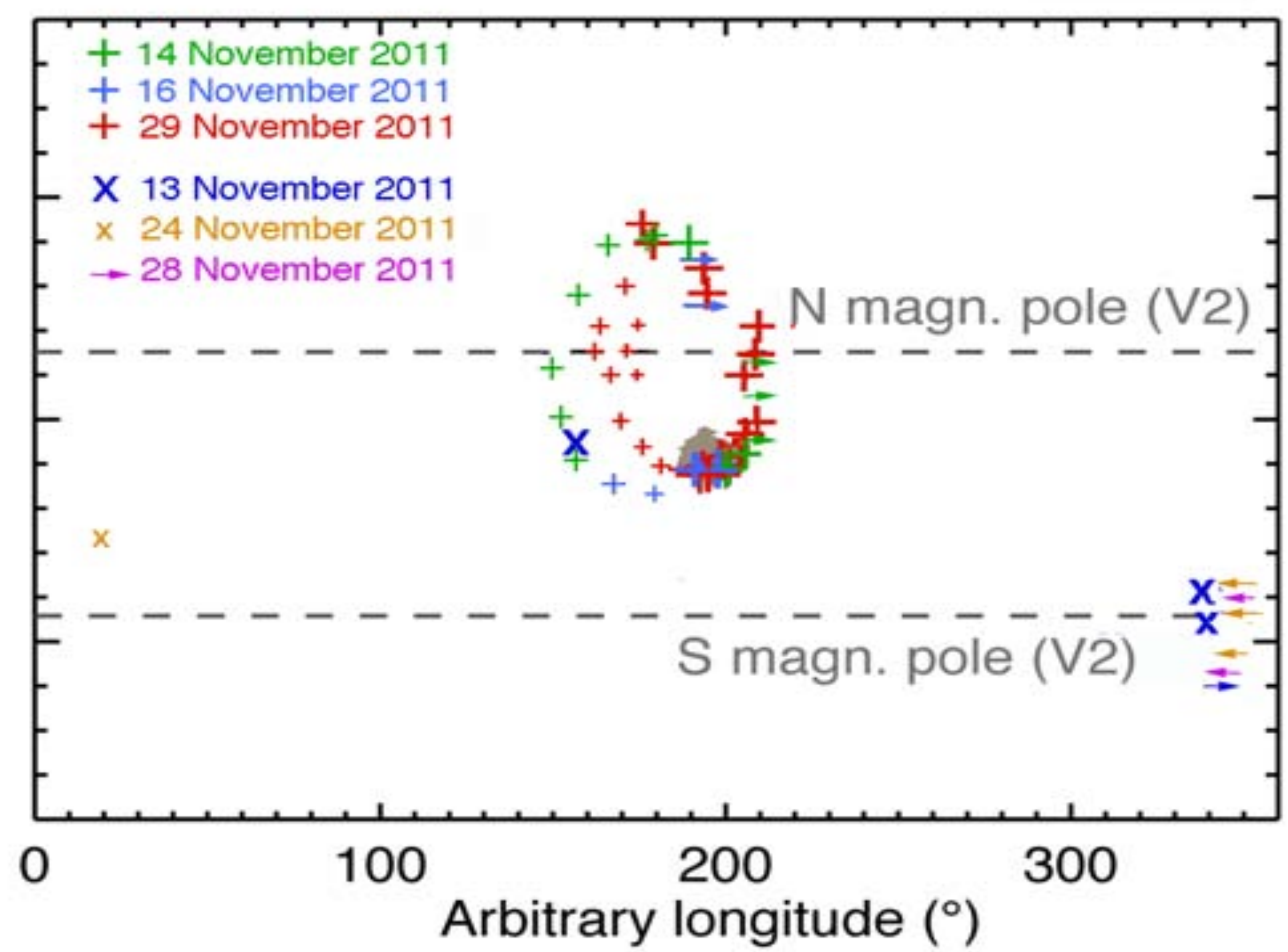
2011

In progress : what about *ambiguous* detections ?

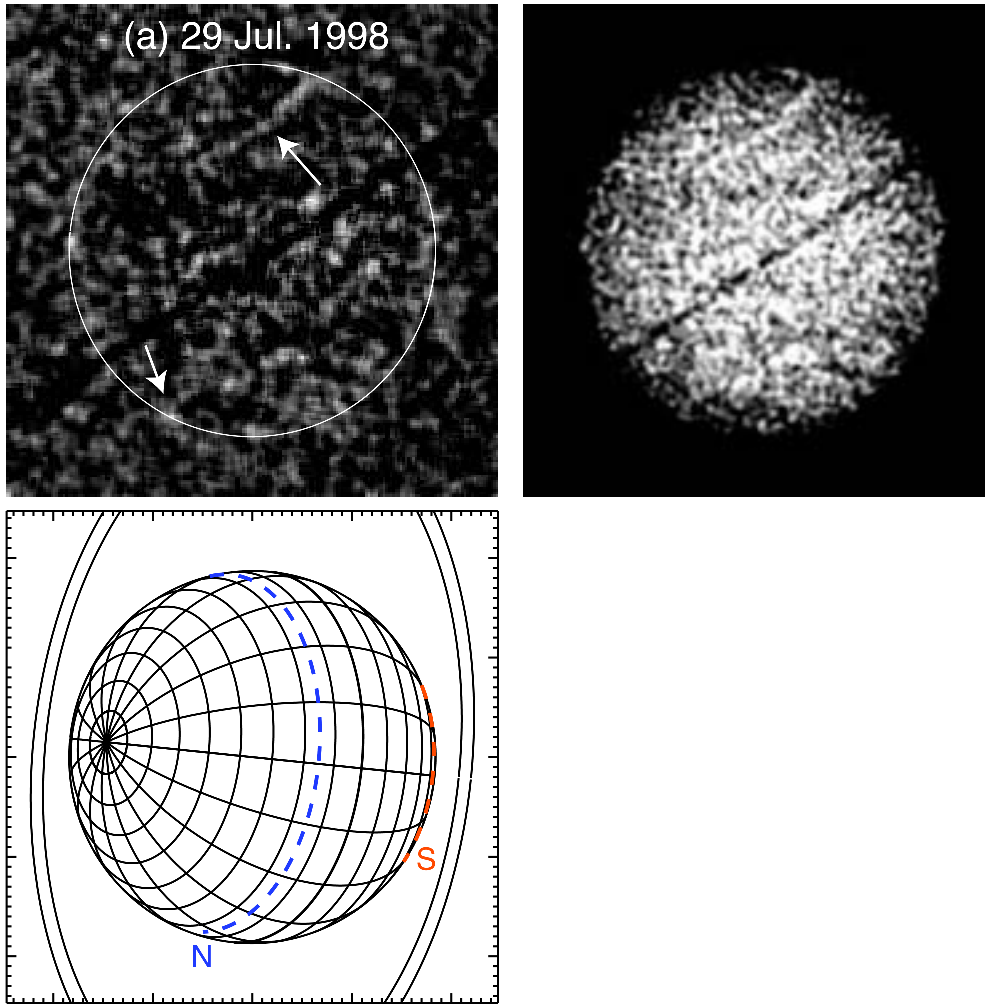
1986



2011

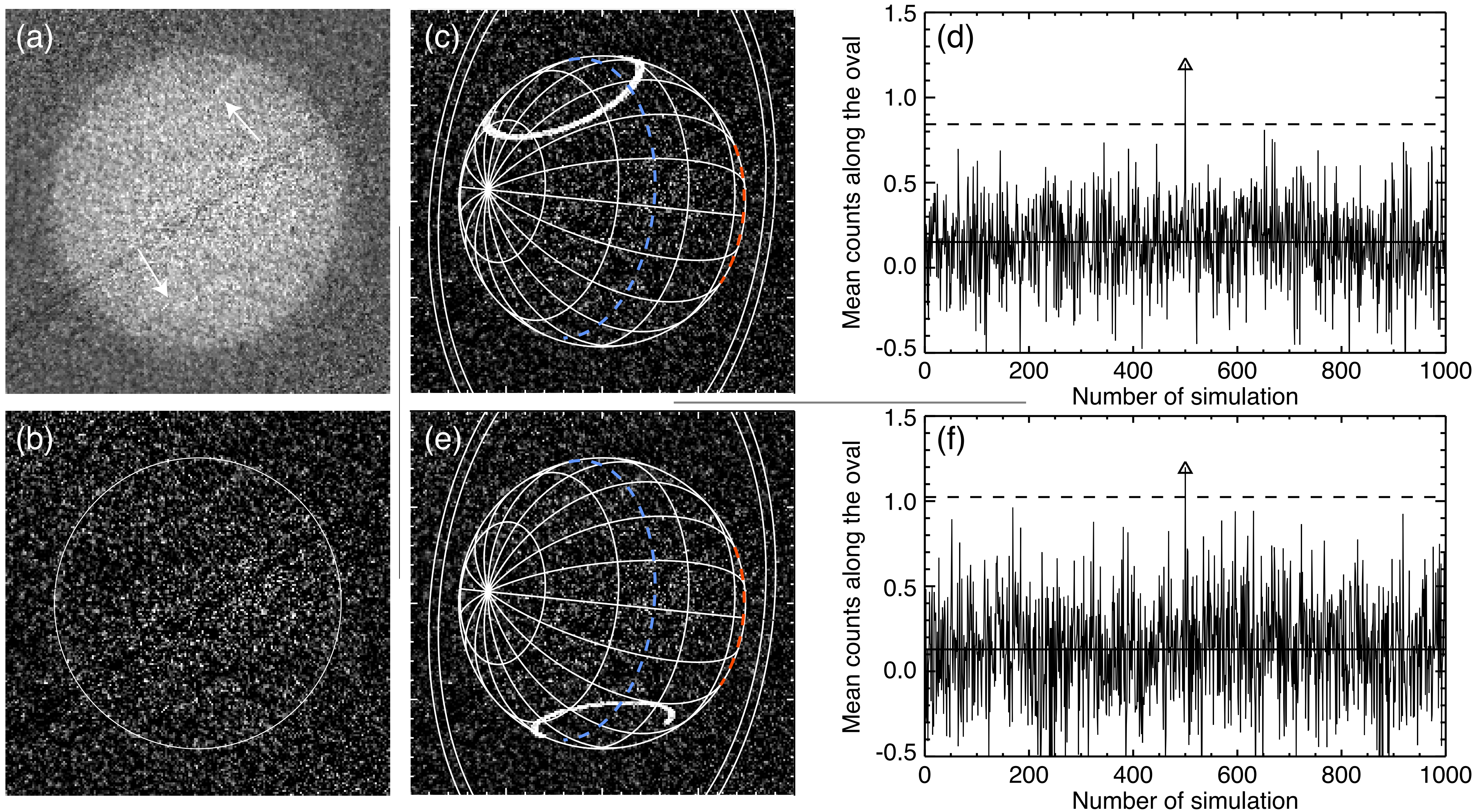


1998 : « The SNR strikes back »



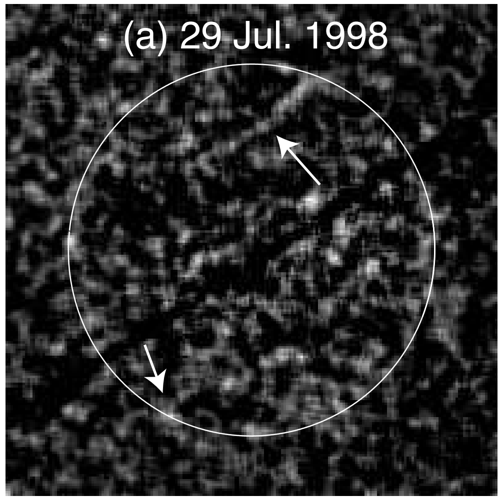
Auroral signal as well,
previously unseen !

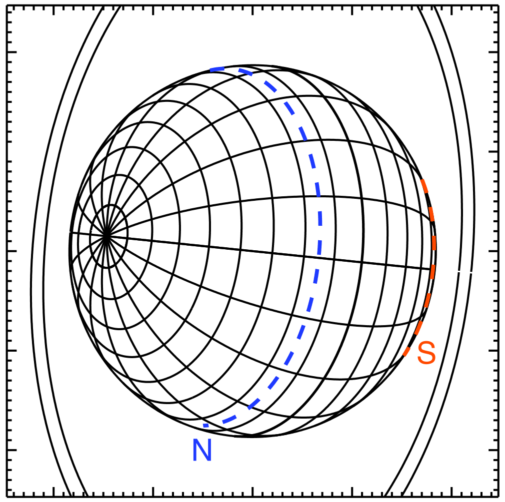
1998



ovals (assumption = circular) fitted by two partial ellipses
=> integrated signal along the oval ~ 4-5σ

1998





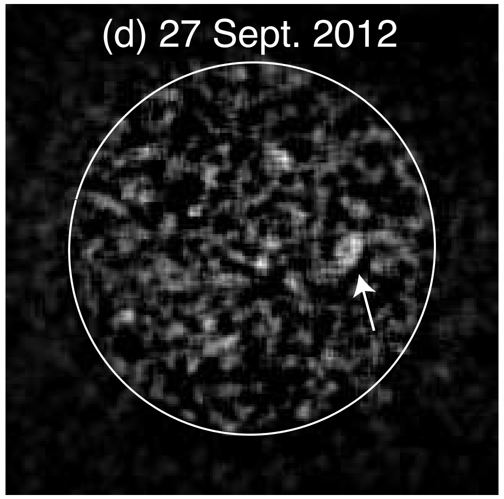
Properties :

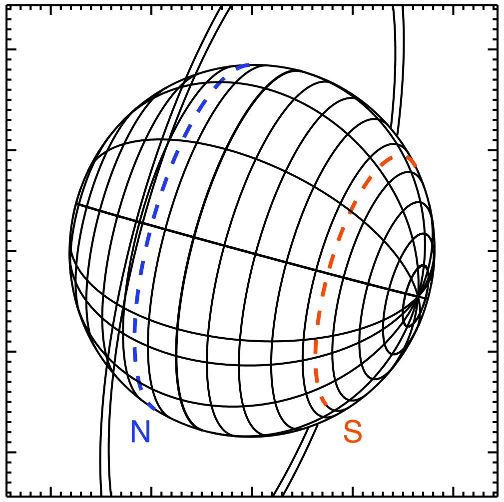
- portions of ovals
- centers do not match the latitude of magnetic poles
- quiet solar wind

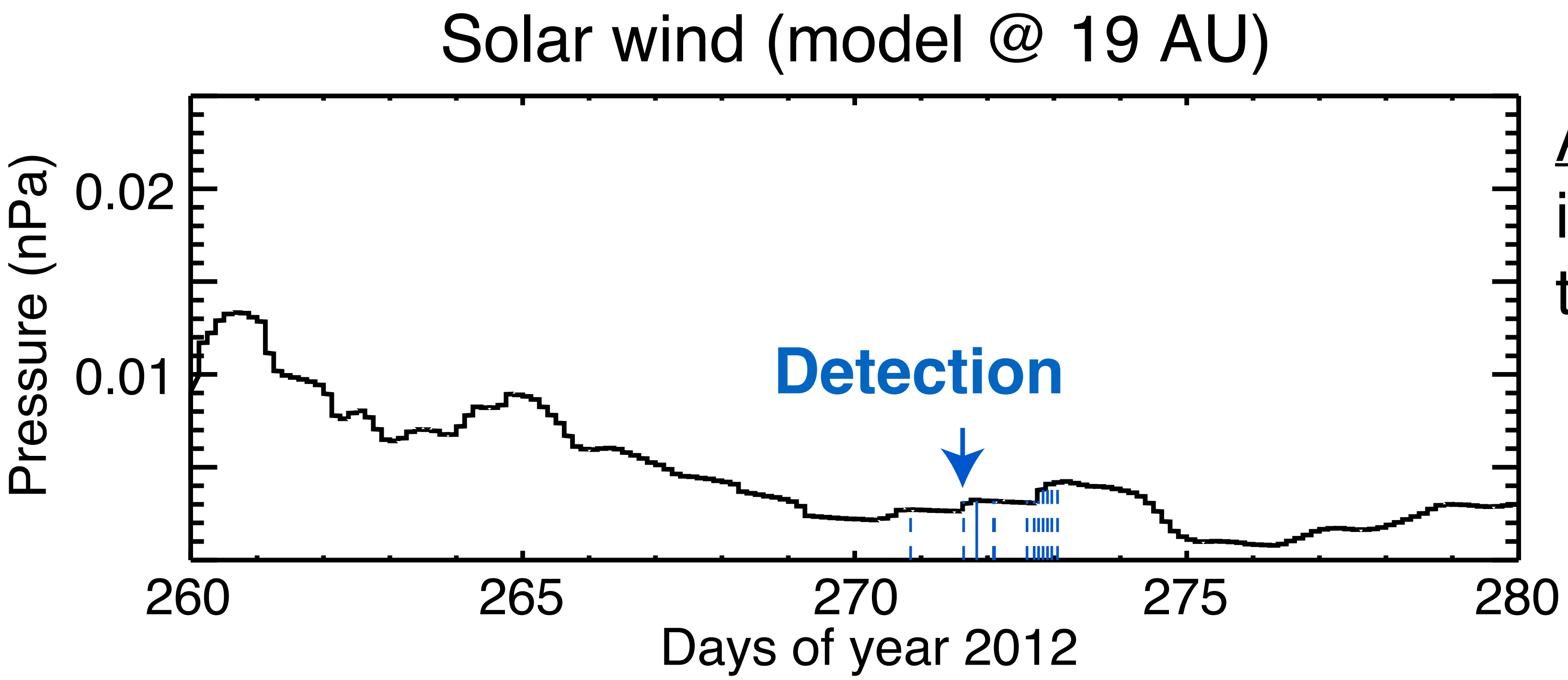
Interpretation :

- mechanism able to drive acceleration over extended longitudes (open-closed field line boundary ?) : to be determined
- intermediate solstice-to-equinox situation
  => possible short-lived twisted magnetotail

2012 : « Return of the polar spot »

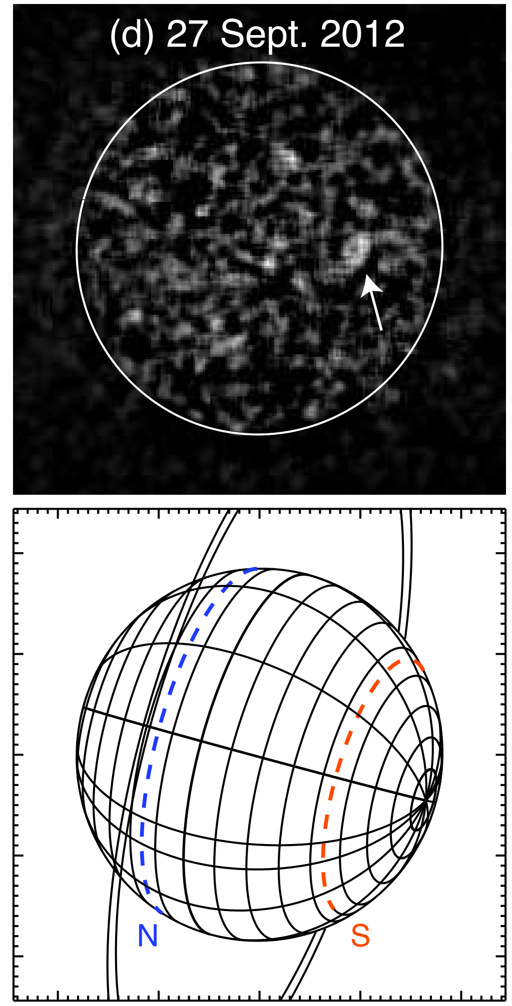






<u>Aim :</u>
investigate the auroral response to <u>planetary rotation</u>

2012 : « Return of the polar spot »



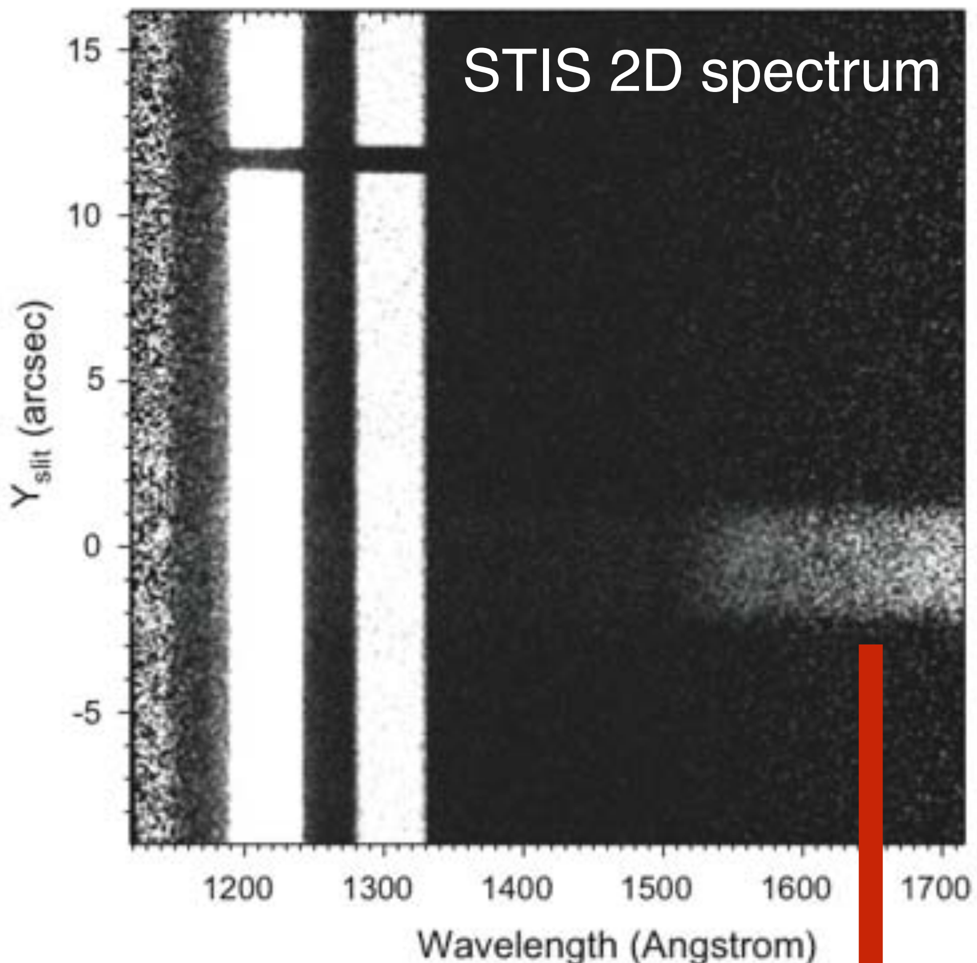
Properties :

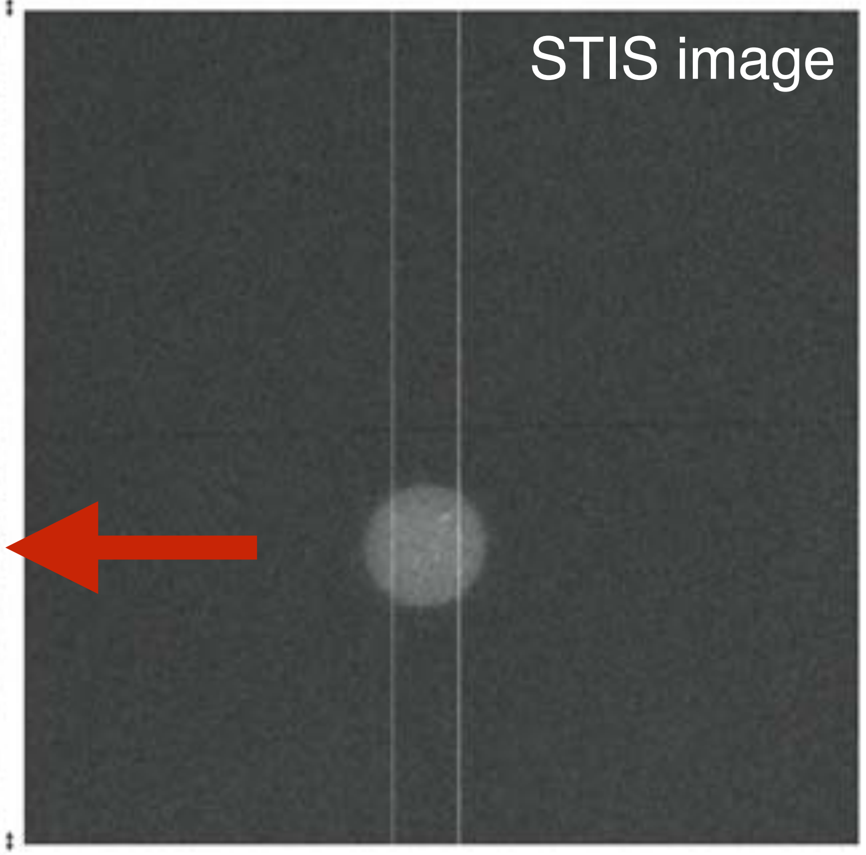
~ idem 2011 but south

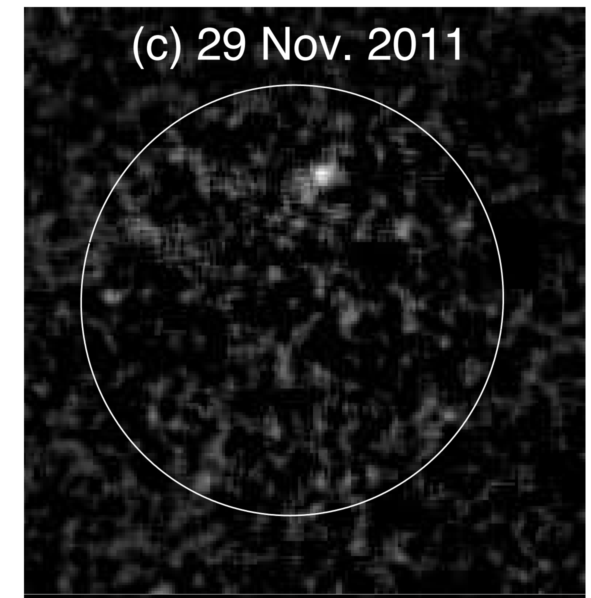
- quiet SW
- H_2 emission !

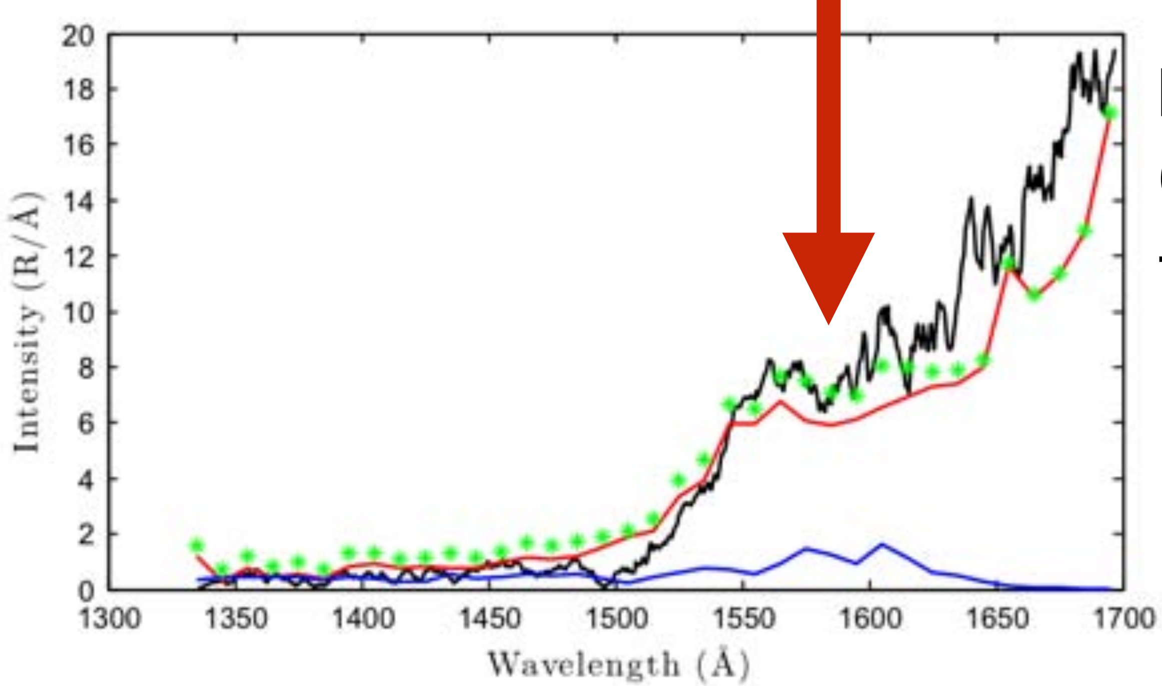
Uranus aeronomy

(Barthélémy et al., 2014)





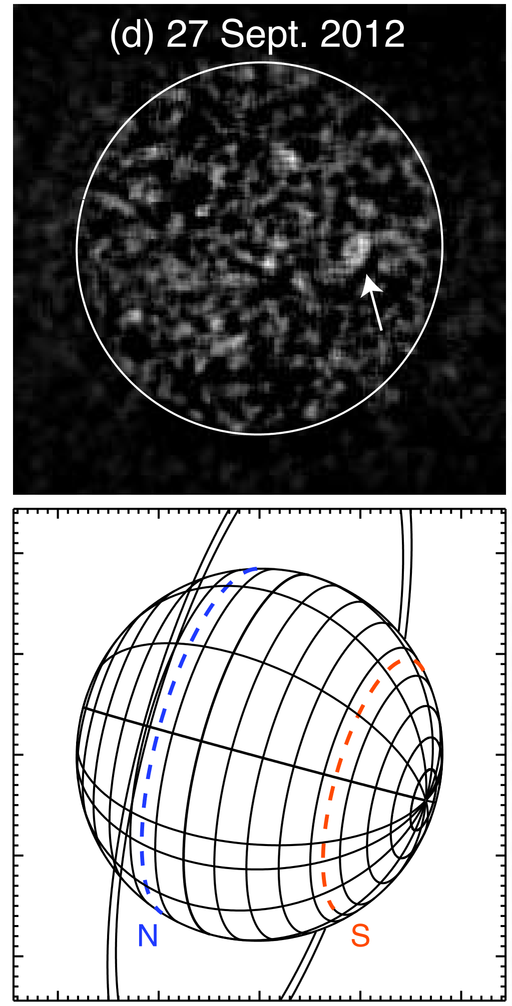




Model => precipitating flux ~ 0.05 erg.cm^{-2}.s^{-1} (3 keV e-)

+ updated contraints on the FUV albedo

2012



Properties :

~ idem 2011 but south

- quiet SW
- H_2 emission !

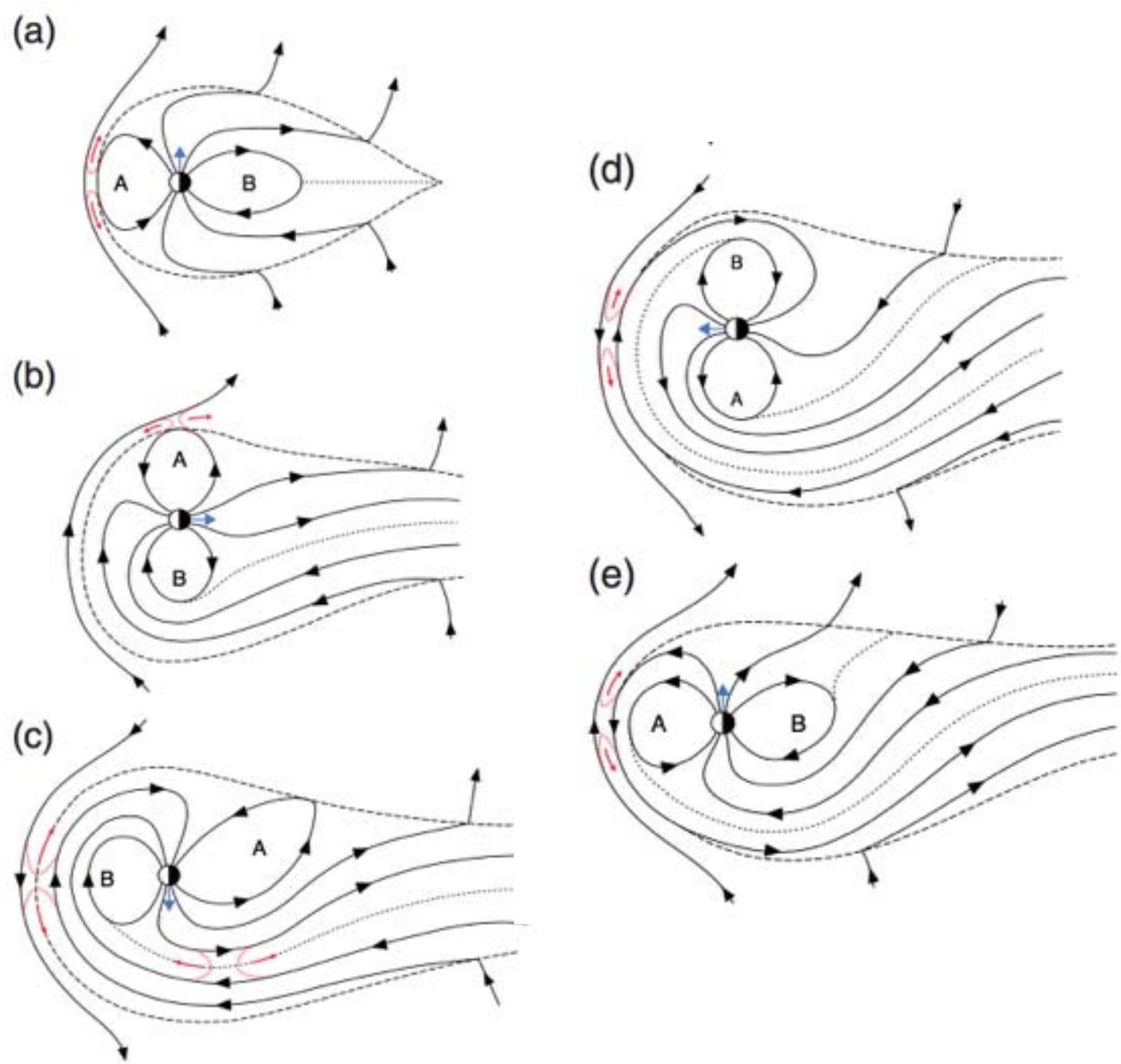
Interpretation :

- unchanged => dayside reconnection

Magnetic reconnection ?

Uranus equinox

(Cowley, 2013)



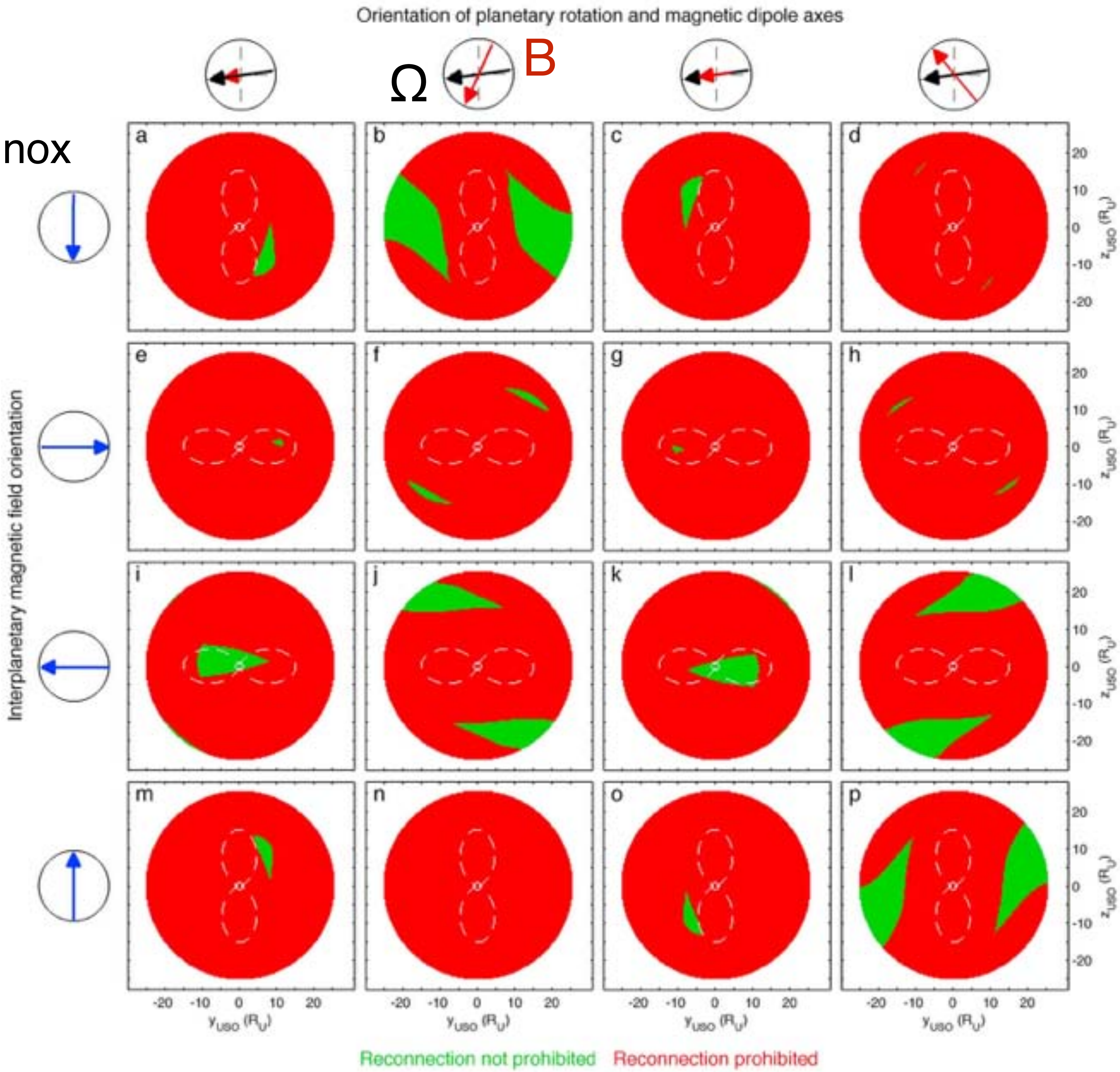
- open flux production - and therefore tail formation - is inhibited
- north or south compression of flux tubes => tail reconnection and open flux closure

=> no major auroral enhancements induced by magnetospheric compressions

Magnetic reconnection ?

Uranus equinox

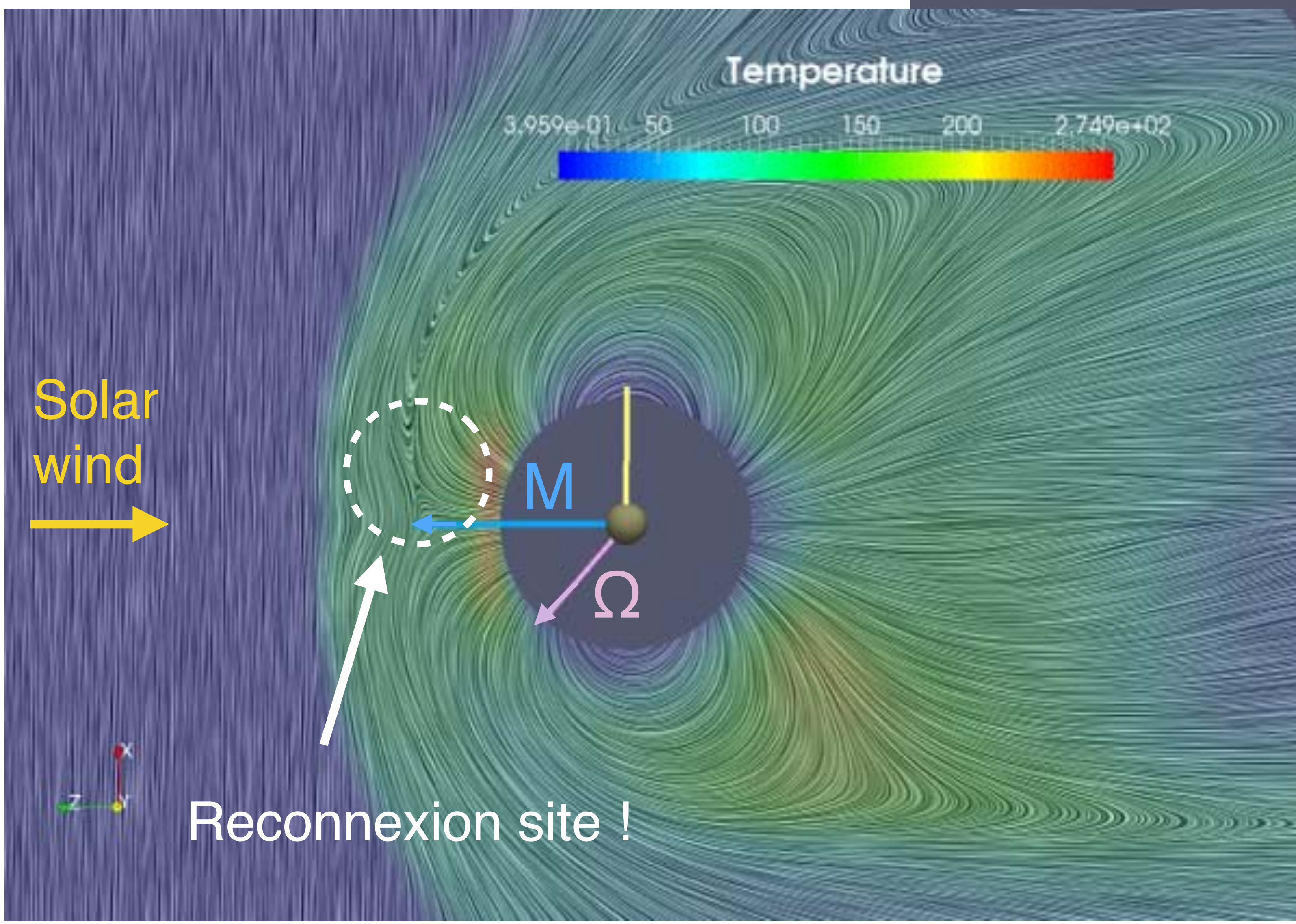
(Masters, 2014)

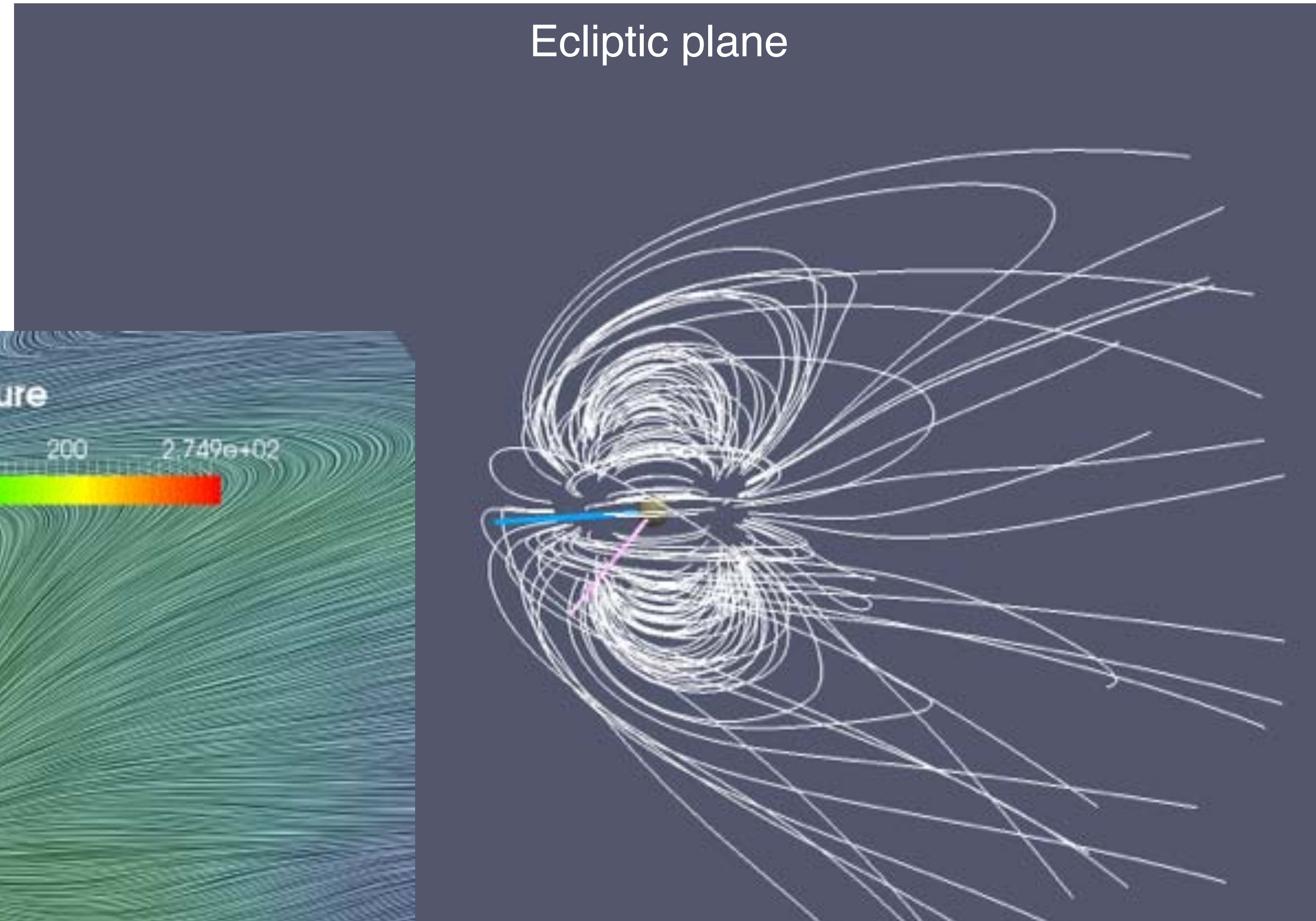


=> reconnection mostly prohibited + reconnection sites highly dynamical

Magnetic reconnection ?

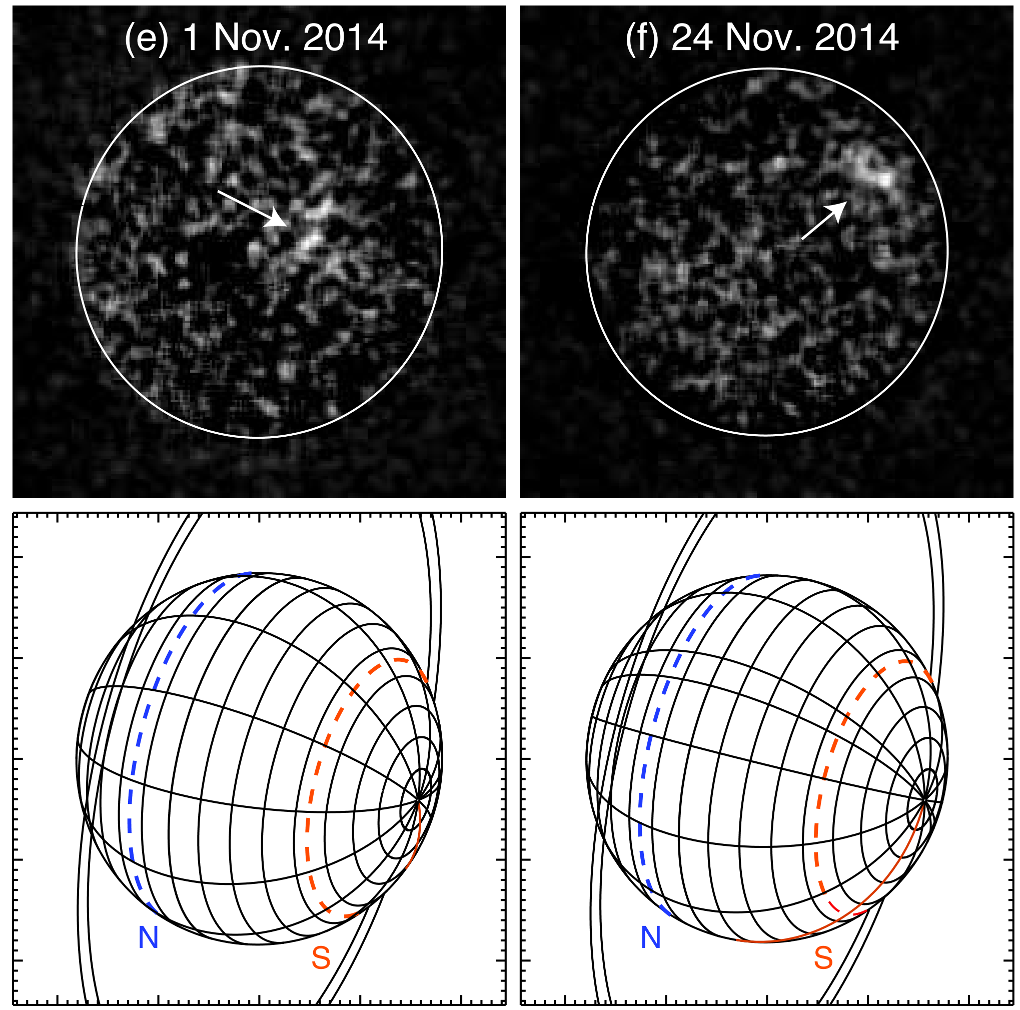
3D MHD simulation : MRVRAC
(V. Montagud, F. Pantellini)

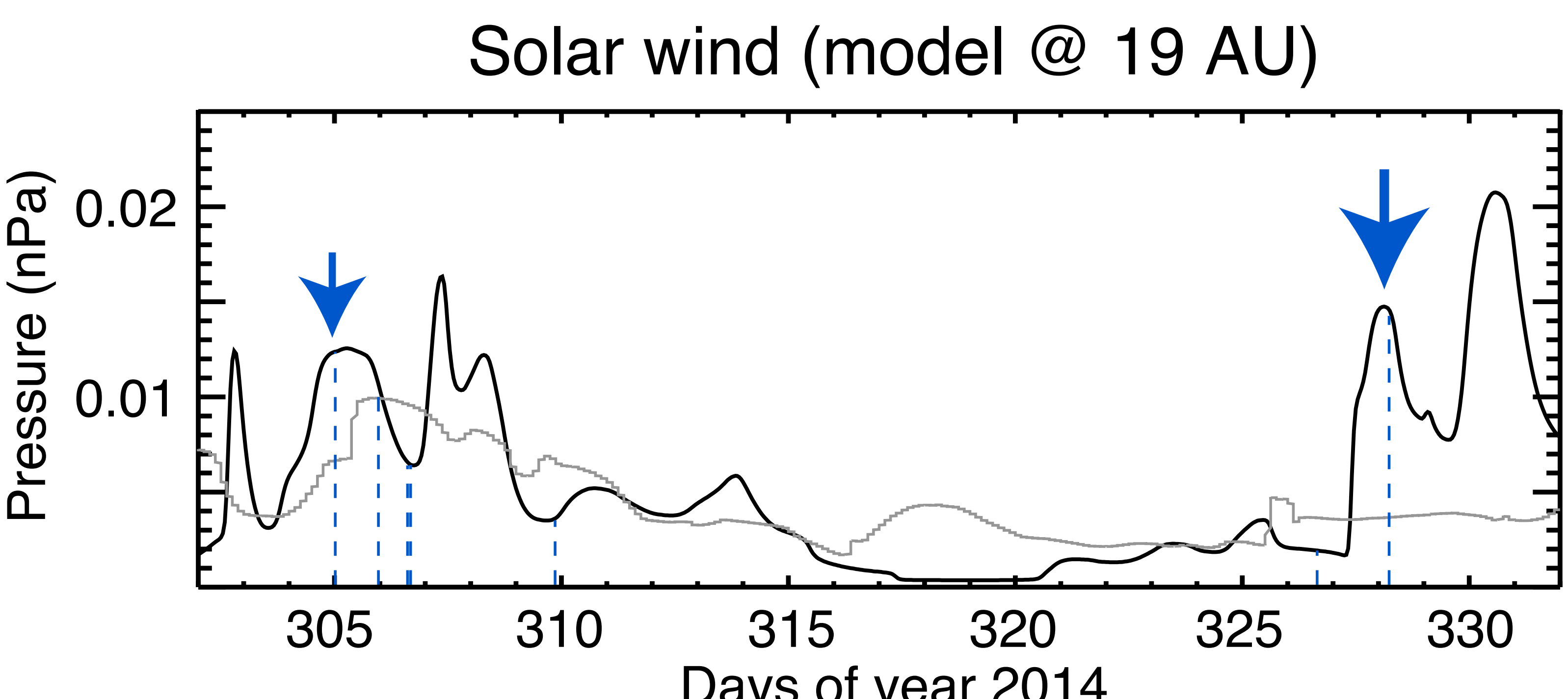




to be pursued with realistic geometry and SW time-variable parameters
(L. Griton, F. Pantellini)

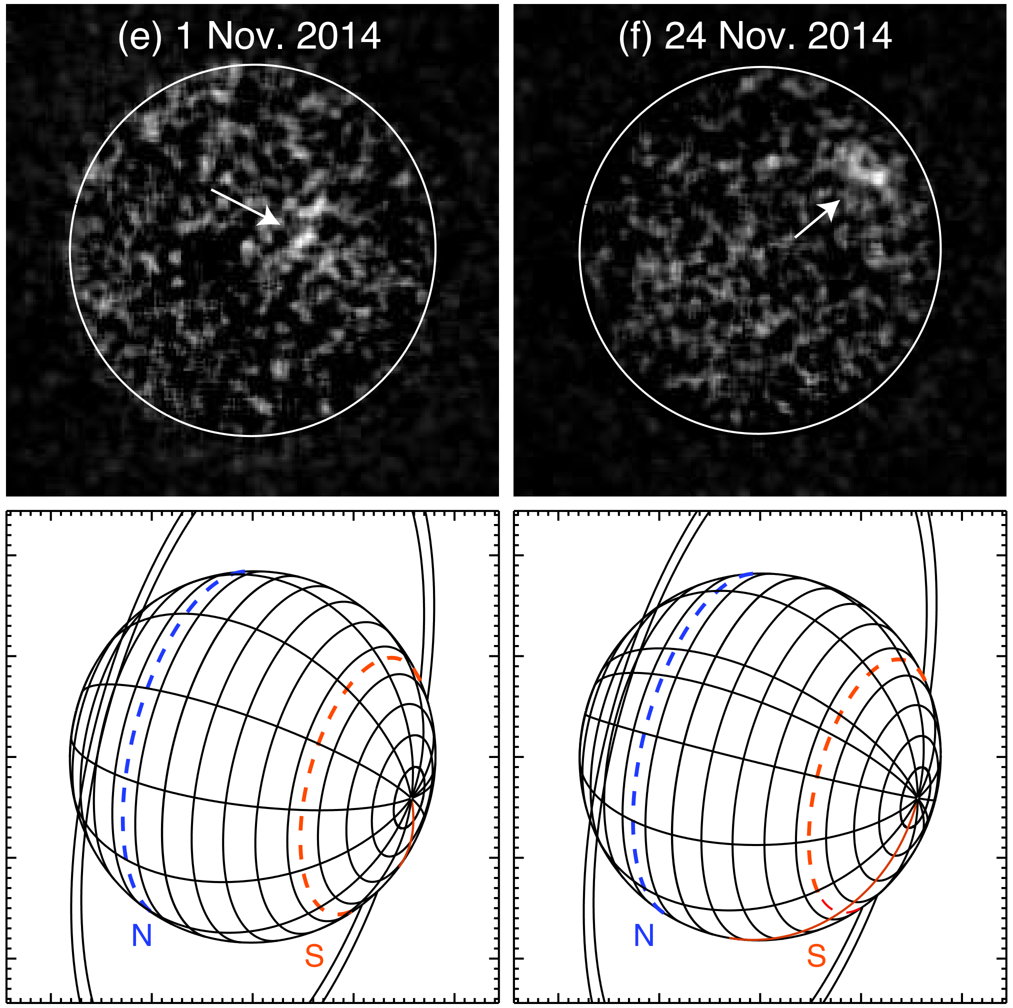
2014 : « The cusp awakens ? »





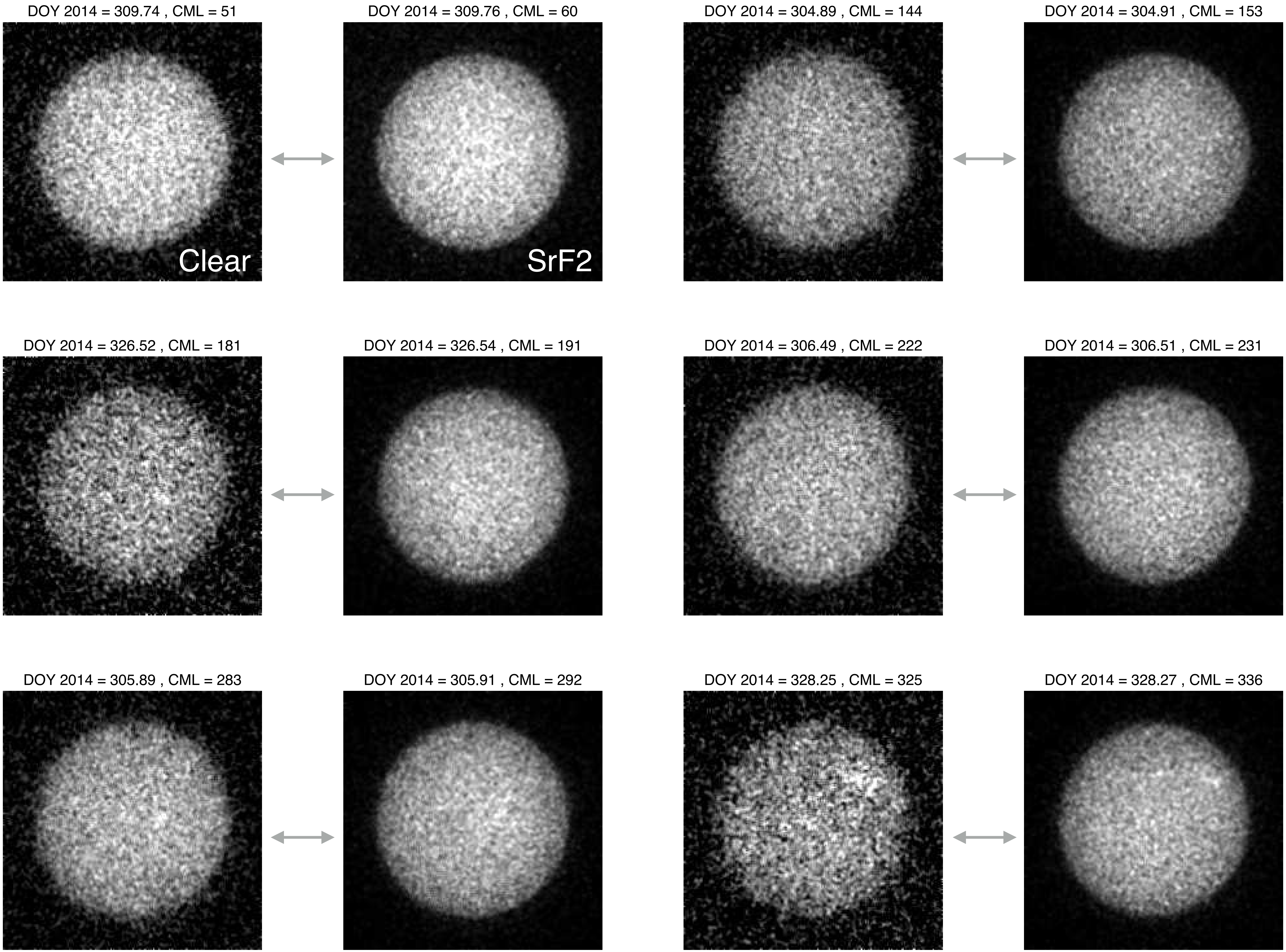
<u>Aim :</u>
investigate the auroral response
to <u>powerful interplanetary shocks</u>

2014 : « The cusp awakens ? »



Properties :
- several bright detections
- longer-lived, larger regions (A = 1400x1400km)
- southern hemisphere

2014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DOY 2014 = 304.91 , CML = 153
Clear
SrF2
DOY 2014 = 326.52 , CML = 181
DOY 2014 = 326.54 , CML = 191
DOY 2014 = 306.49 , CML = 222
DOY 2014 = 306.51 , CML = 231
DOY 2014 = 305.89 , CML = 283
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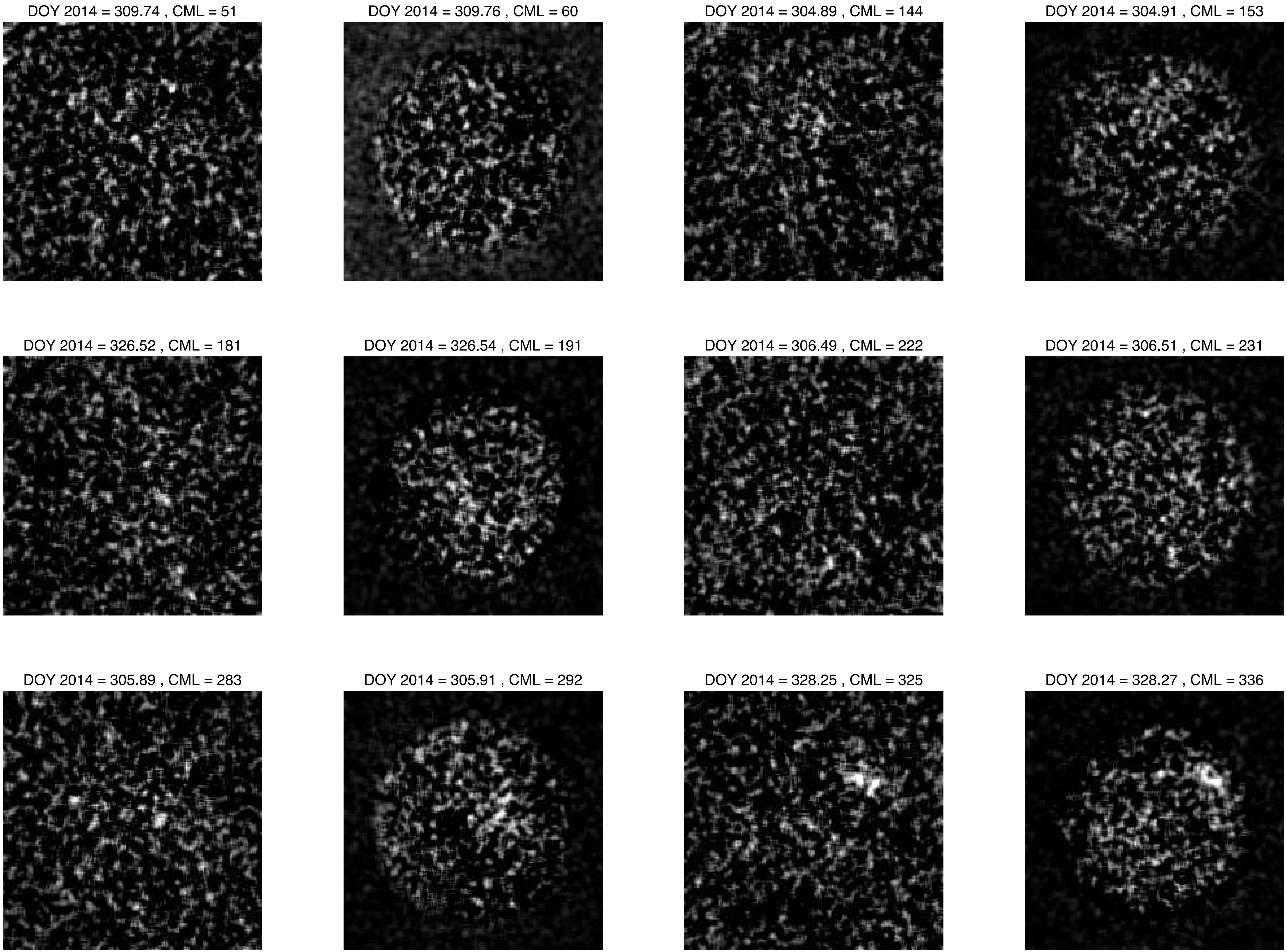
DOY 2014 = 328.25 , CML = 325
DOY 2014 = 328.27 , CML = 336

2014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DOY 2014 = 326.54 , CML = 191
DOY 2014 = 306.49 , CML = 222
DOY 2014 = 306.51 , CML = 231
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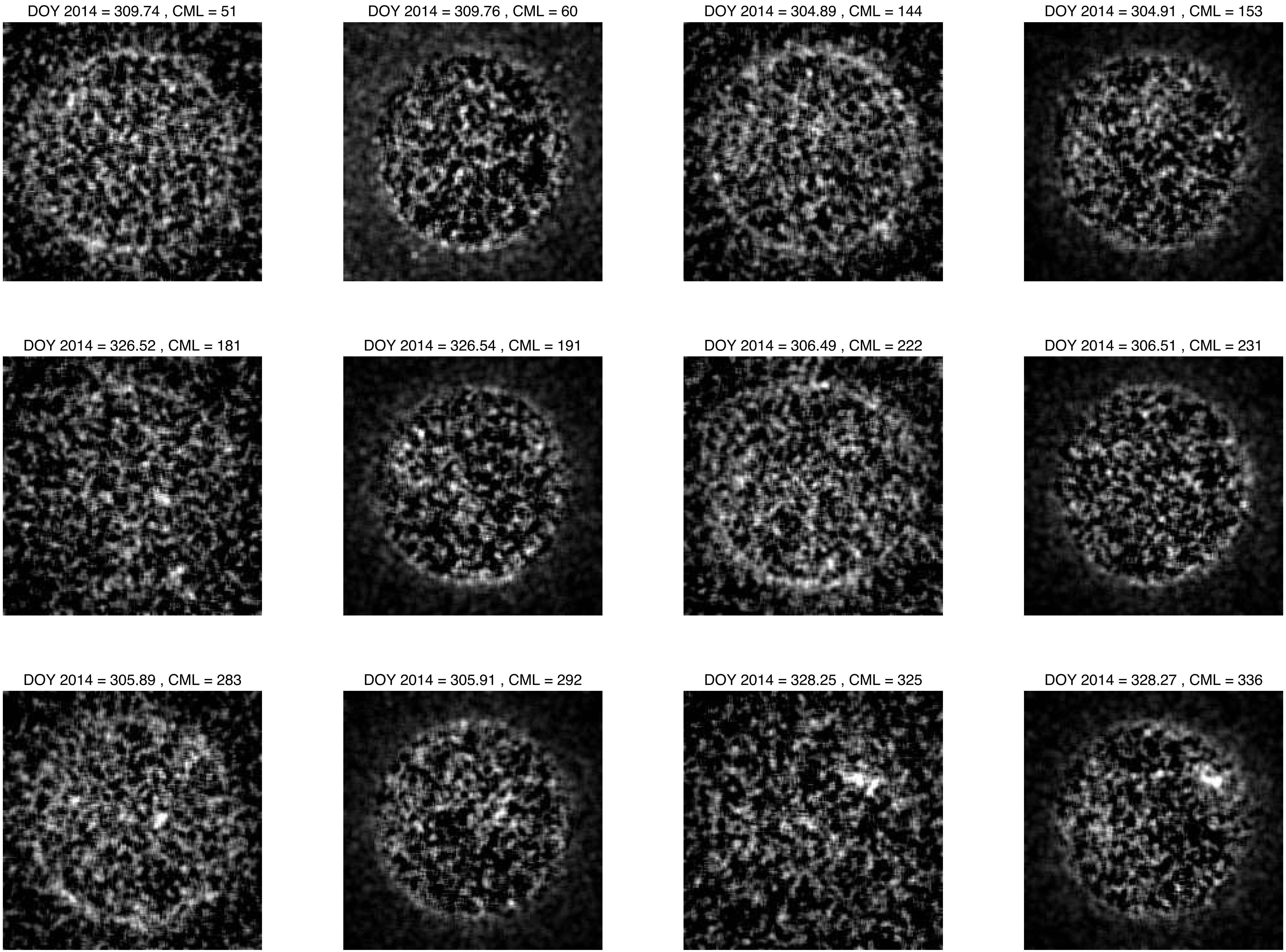
DOY 2014 = 305.91 , CML = 292
DOY 2014 = 328.25 , CML = 325
DOY 2014 = 328.27 , CML = 336

2014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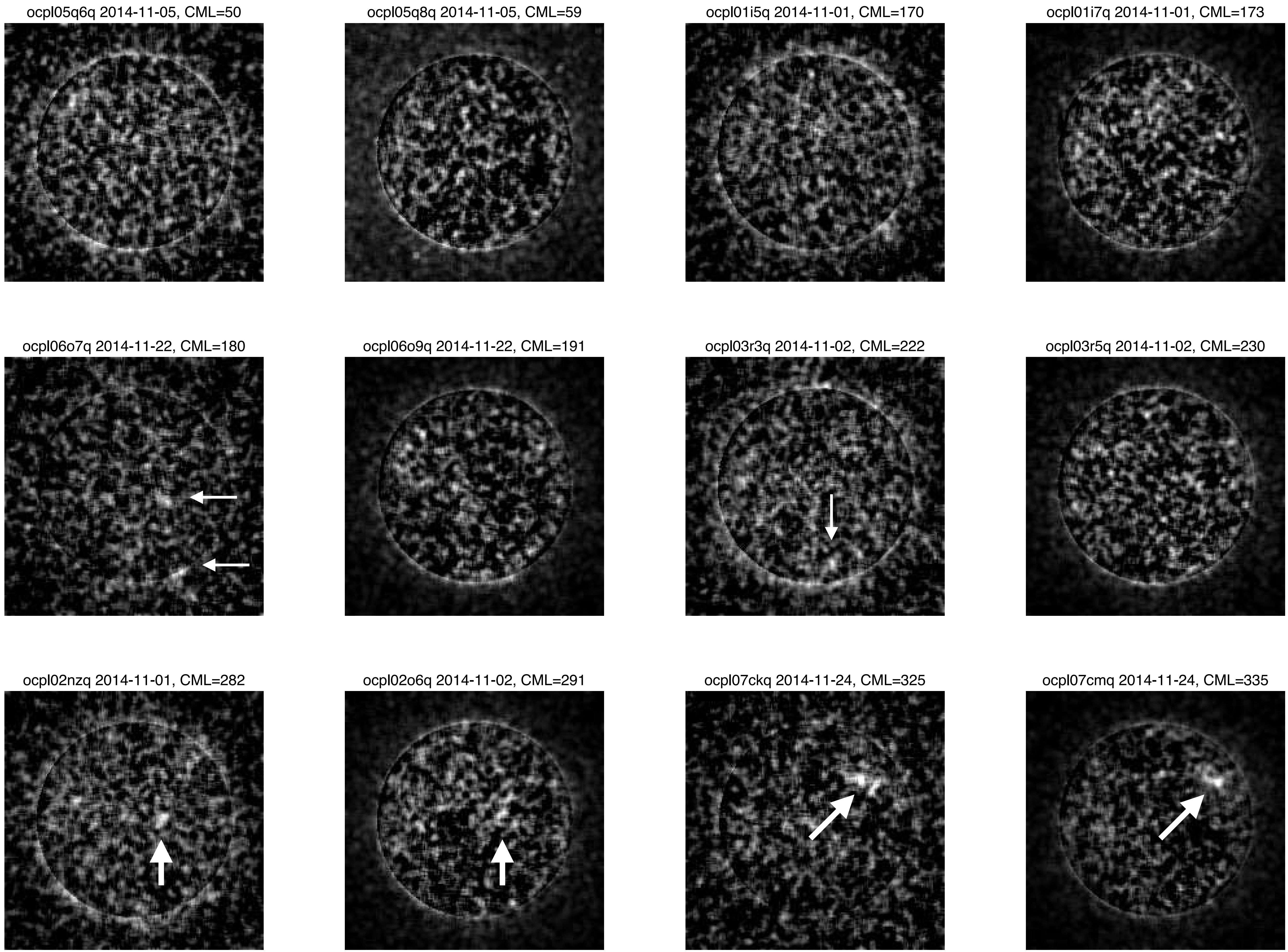
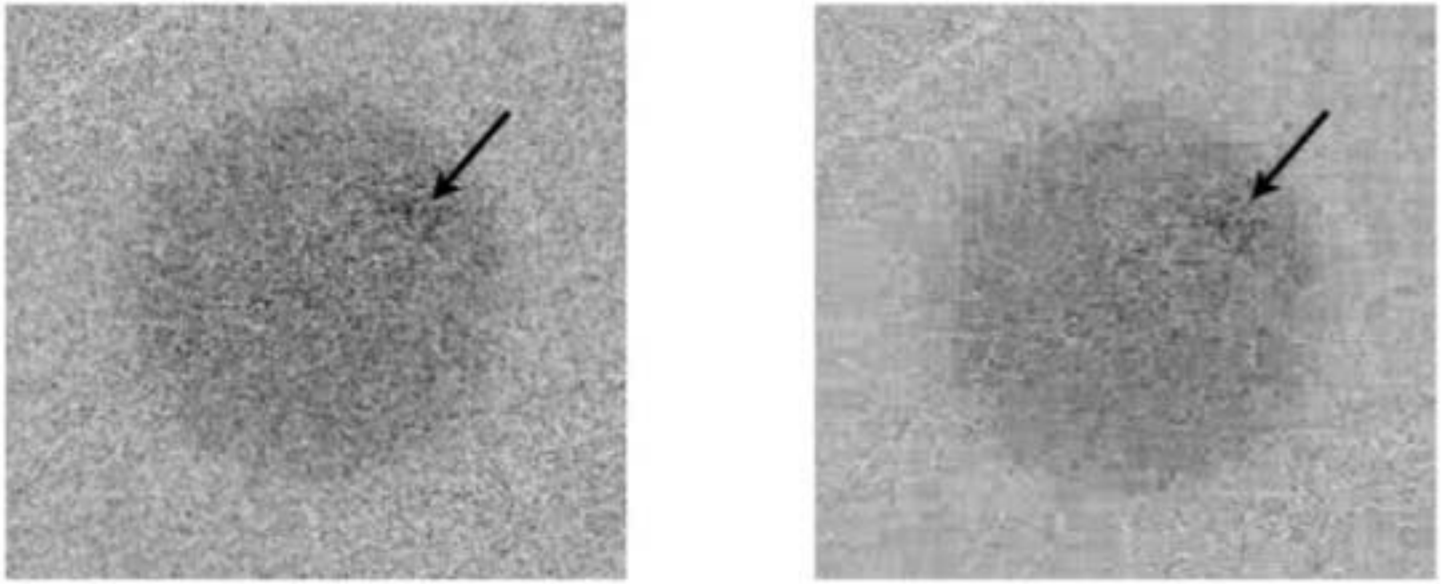
2014


ocpl05q6q 2014-11-05, CML=50
ocpl05q8q 2014-11-05, CML=59
ocpl01i5q 2014-11-01, CML=170
ocpl01i7q 2014-11-01, CML=173
ocpl06o7q 2014-11-22, CML=180
ocpl06o9q 2014-11-22, CML=191
ocpl03r3q 2014-11-02, CML=222
ocpl03r5q 2014-11-02, CML=230
ocpl02nzq 2014-11-01, CML=282
ocpl02o6q 2014-11-02, CML=291
ocpl07ckq 2014-11-24, CML=325
ocpl07cmq 2014-11-24, CML=335

2014

NB : Simple data processing <u>not improved</u> by more sophisticated techniques

Wavelets : Daubenchies, 1st order

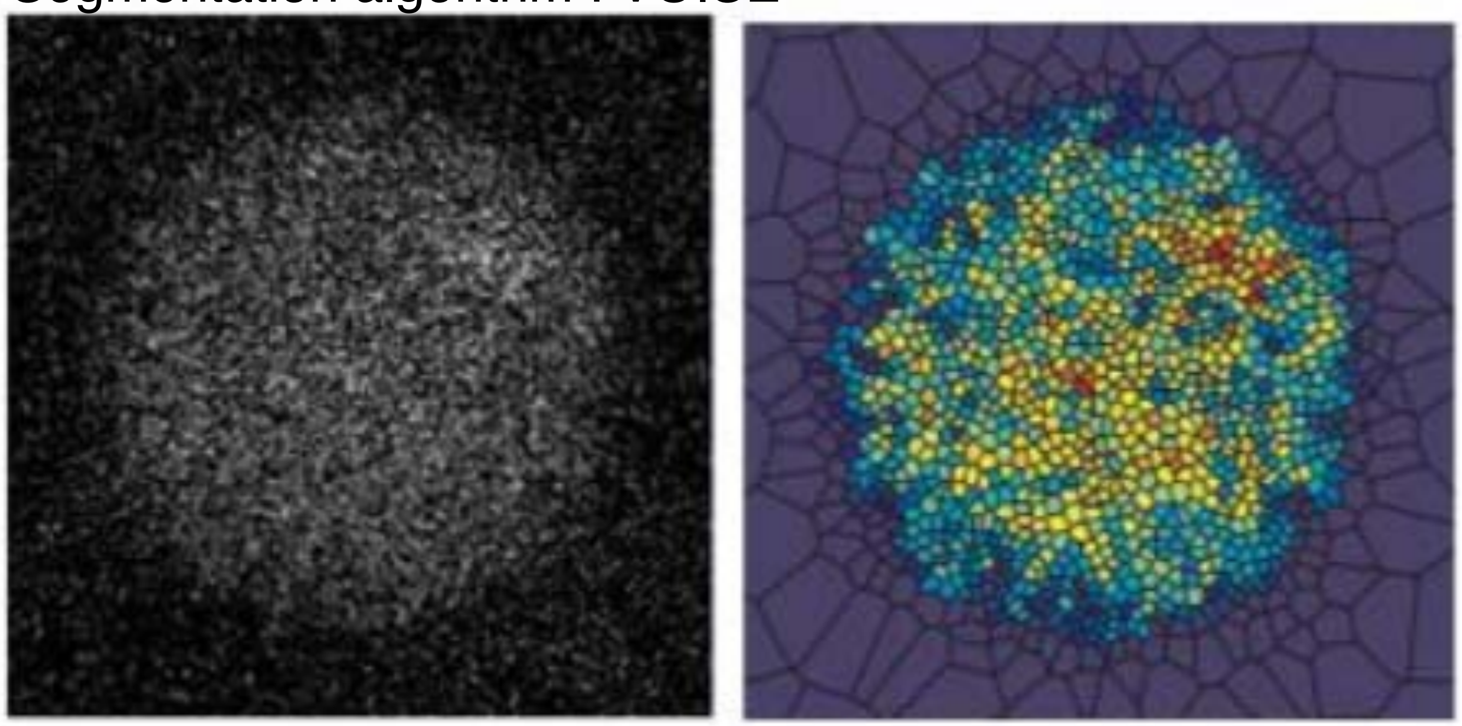


(Gosset, M2 internship 2015)

	Image	SNR moyen	SNR moyen > 3sigmas	SNR max
Ondelette Daubechies ordre 1	Image initiale	0.57	3.80	5.71
	Image débruitée seuil doux	1.34	5.15	12.58
	Image débruitée seuil dur	0.70	4.02	7.08

	Image	SNR moyen	SNR moyen > 3sigmas	SNR max
Ondelette Daubechies ordre 1	Image initiale	0.57	3.80	5.71
	Image débruitée 2 fois seuil dur	0.87	4.50	8.78

Segmentation algorithm : VOISE



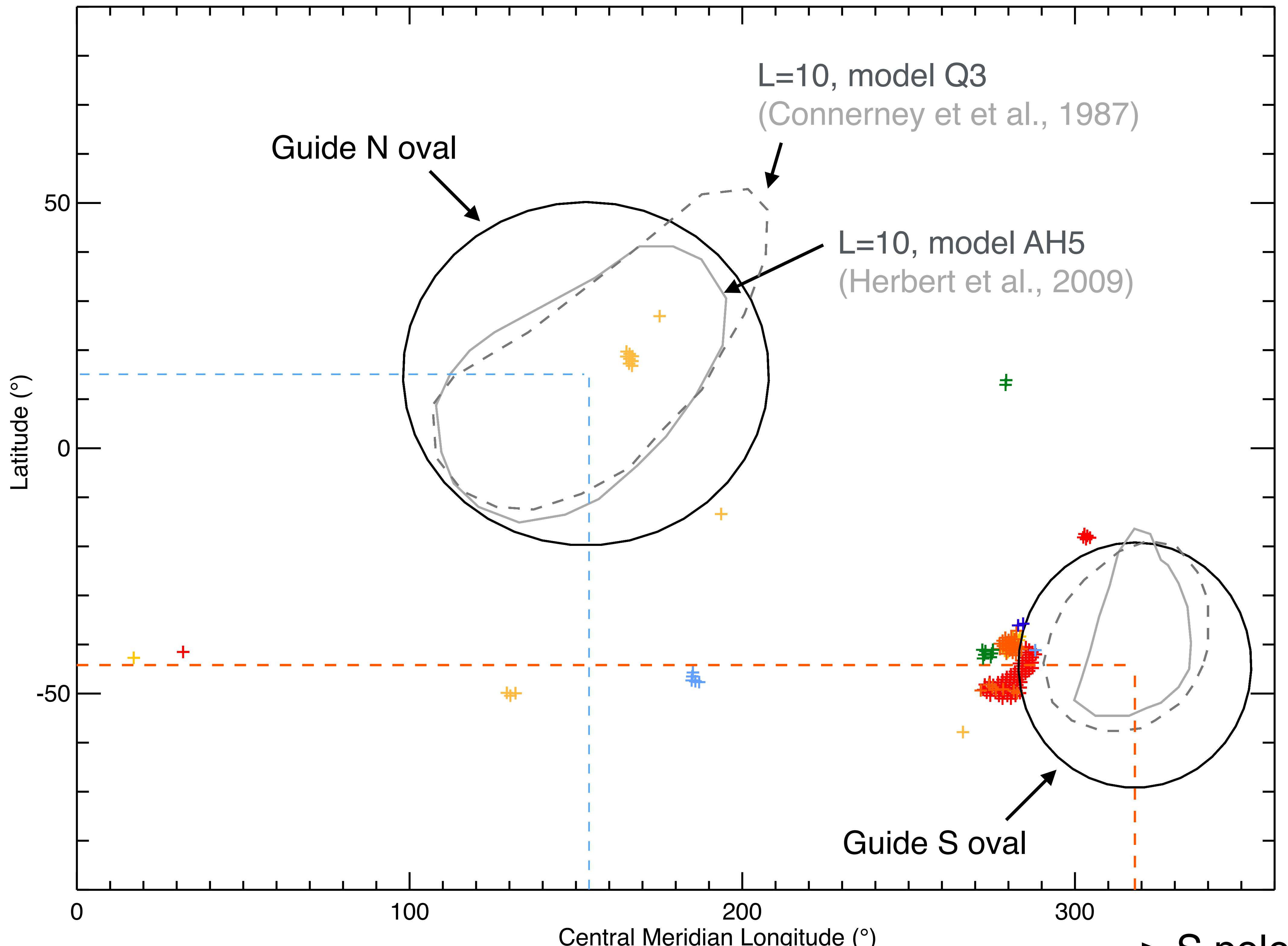
Other methods :

- PSF deconvolution
- non-linear filtering (FFT, Lucy-Richards
Non-linear means, AIDA)

In progress : A. Vecchio

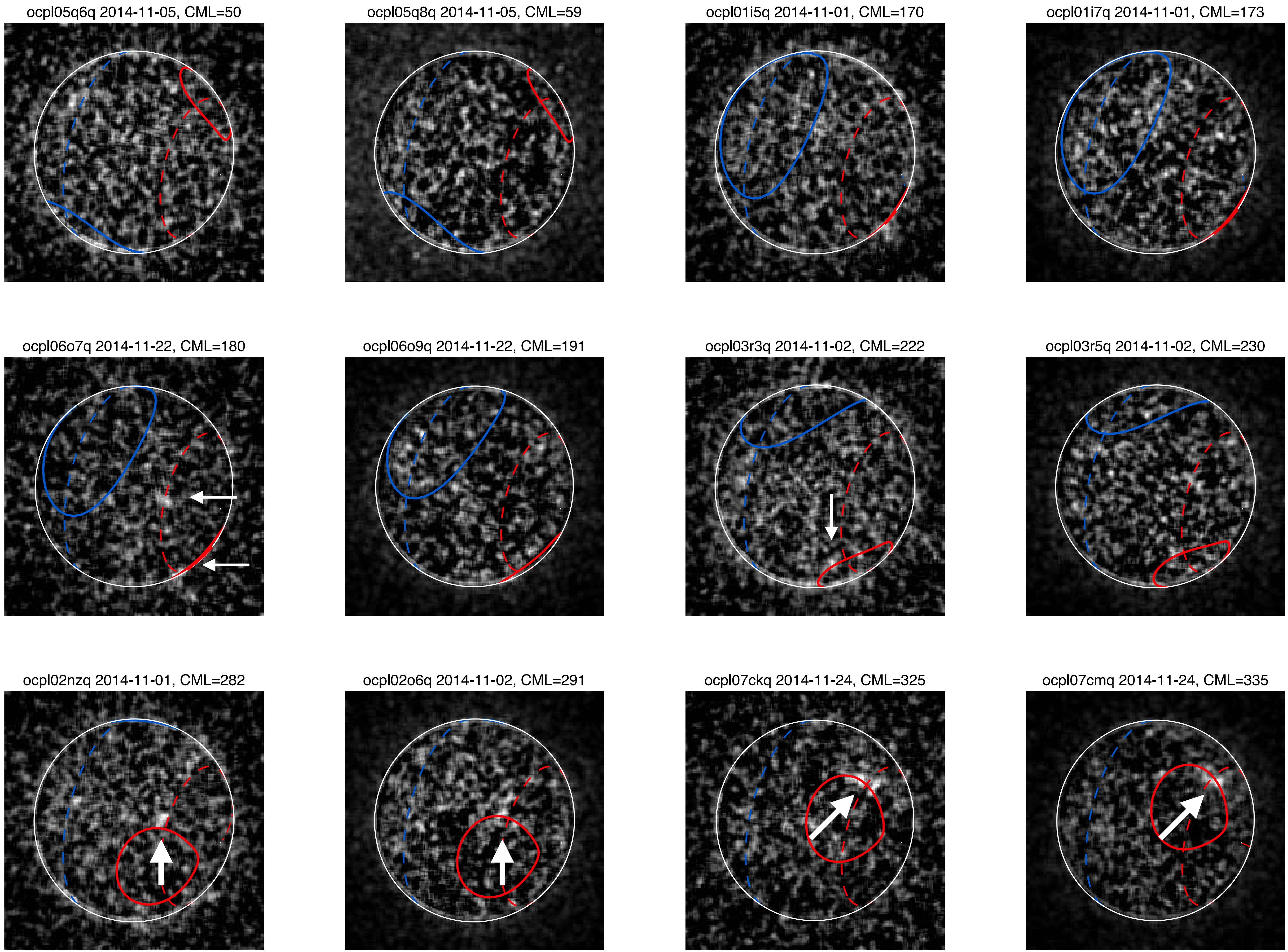
- Proper Orthogonal Decomposition (x,t)

2014



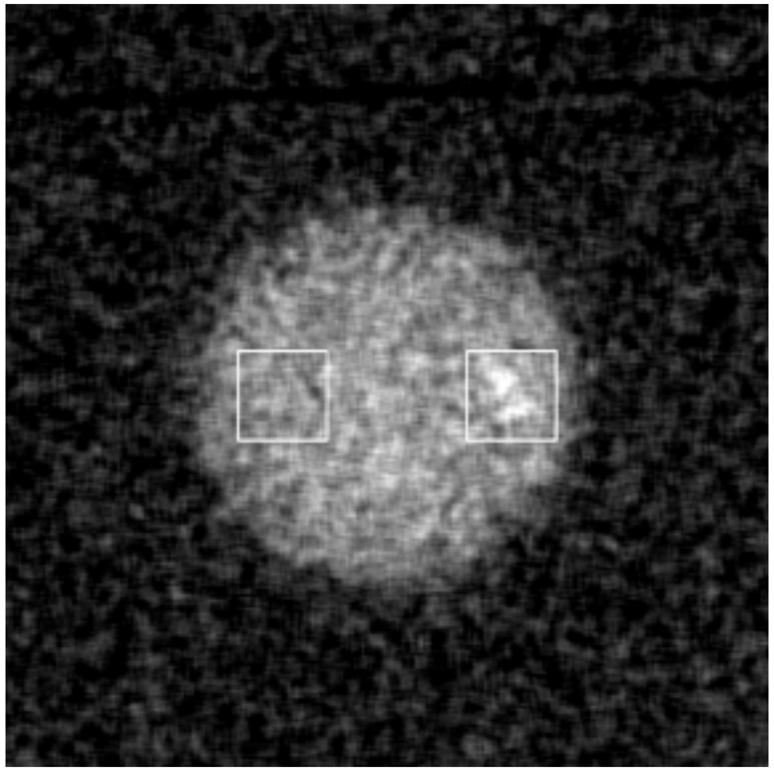
=> S pole :
CML = 320+/-20°

2014


ocpl05q6q 2014-11-05, CML=50
ocpl05q8q 2014-11-05, CML=59
ocpl01i5q 2014-11-01, CML=170
ocpl01i7q 2014-11-01, CML=173
ocpl06o7q 2014-11-22, CML=180
ocpl06o9q 2014-11-22, CML=191
ocpl03r3q 2014-11-02, CML=222
ocpl03r5q 2014-11-02, CML=230
ocpl02nzq 2014-11-01, CML=282
ocpl02o6q 2014-11-02, CML=291
ocpl07ckq 2014-11-24, CML=325
ocpl07cmq 2014-11-24, CML=335

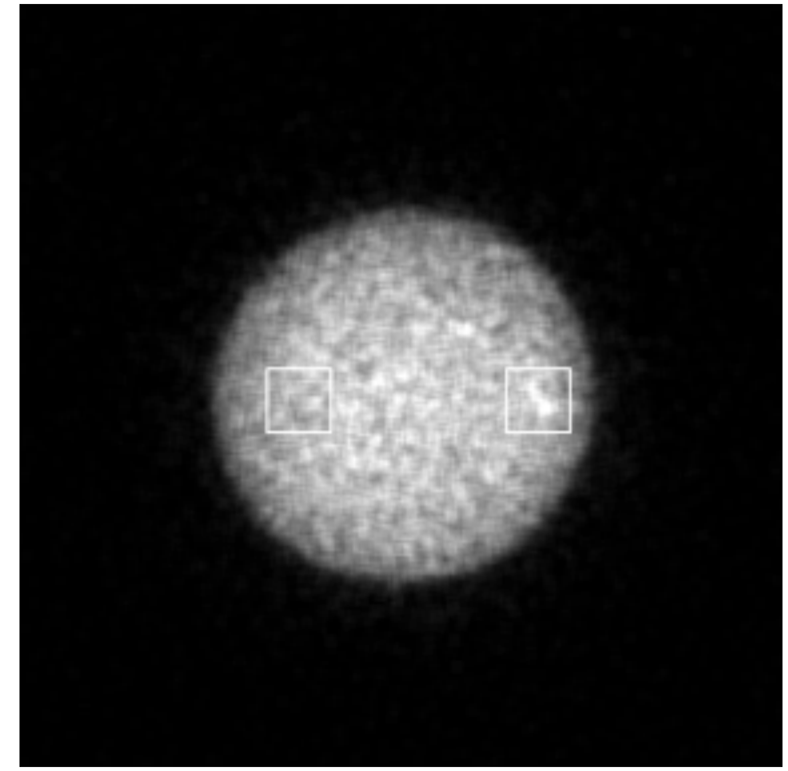
2014

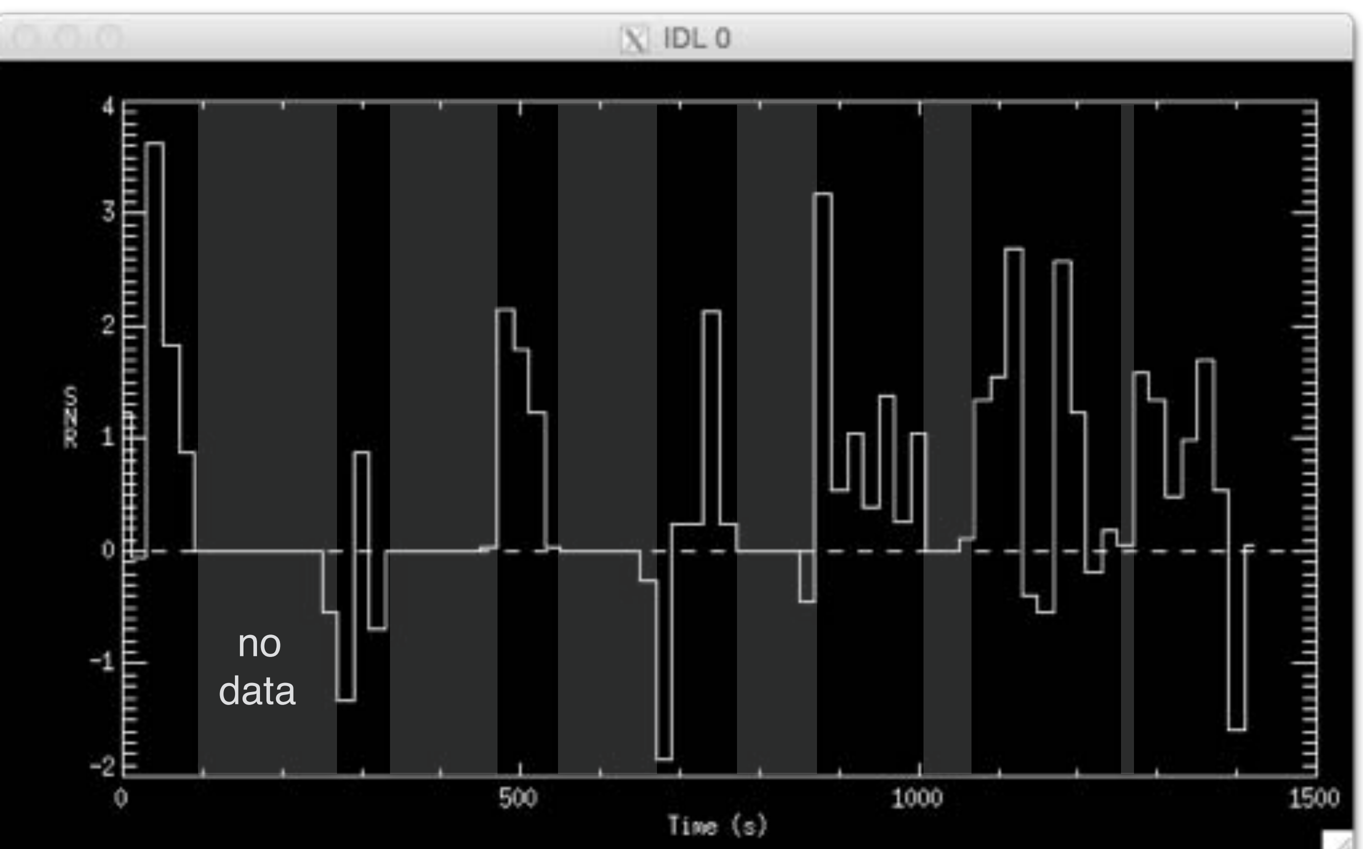
unfiltered image (H+H_2)

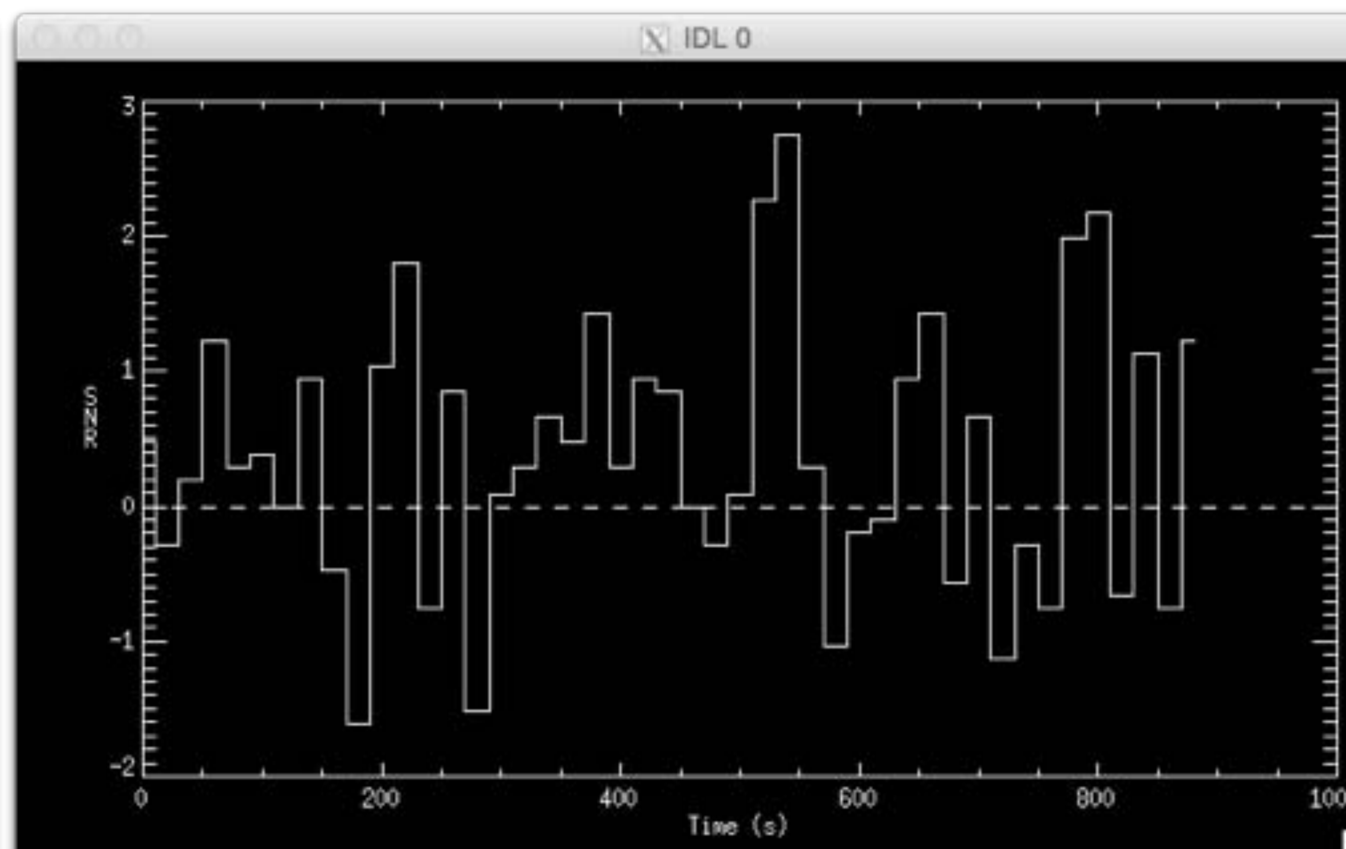


STIS time-tagged images

SrF2 image (H_2)

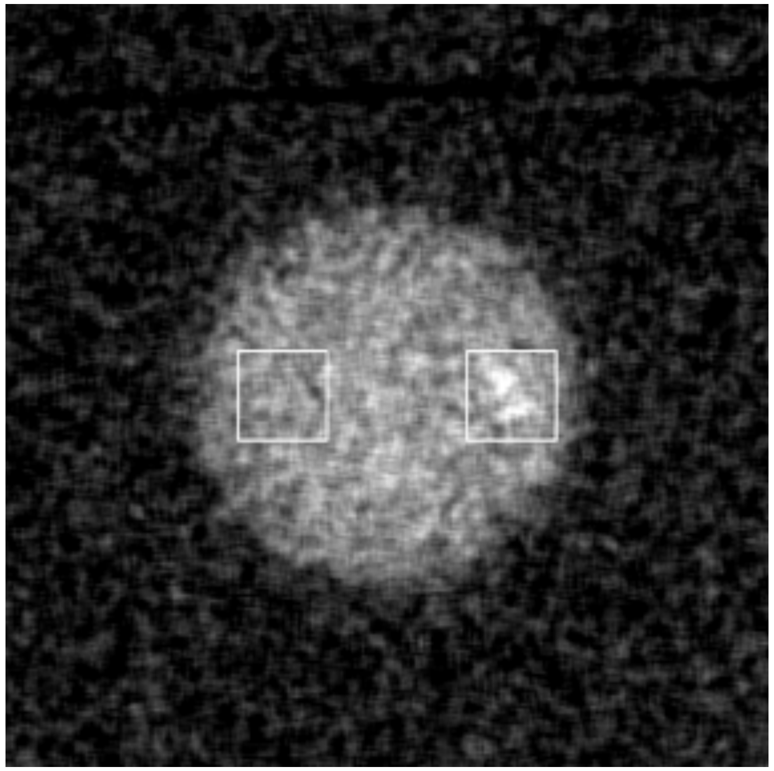






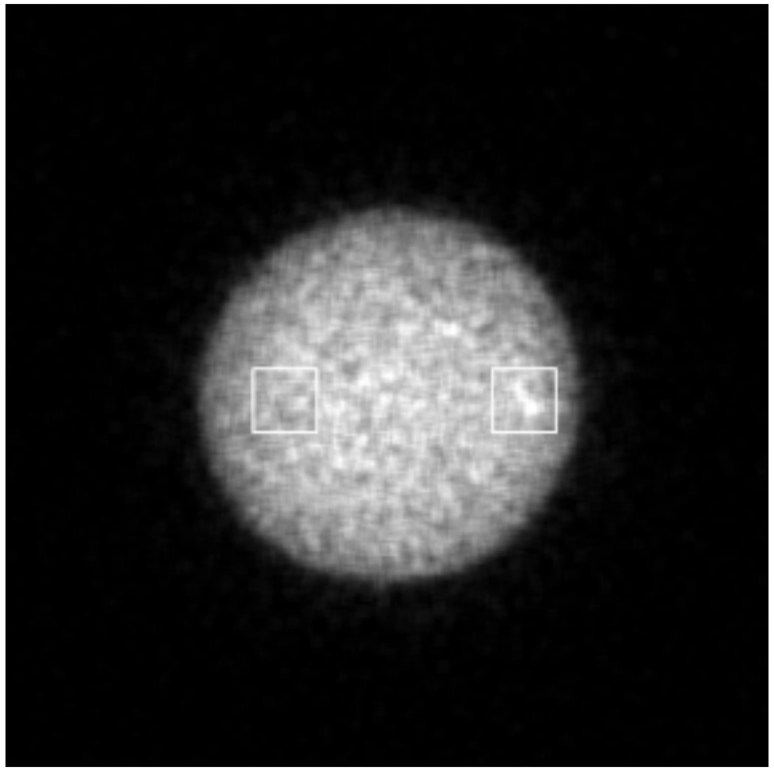
2014

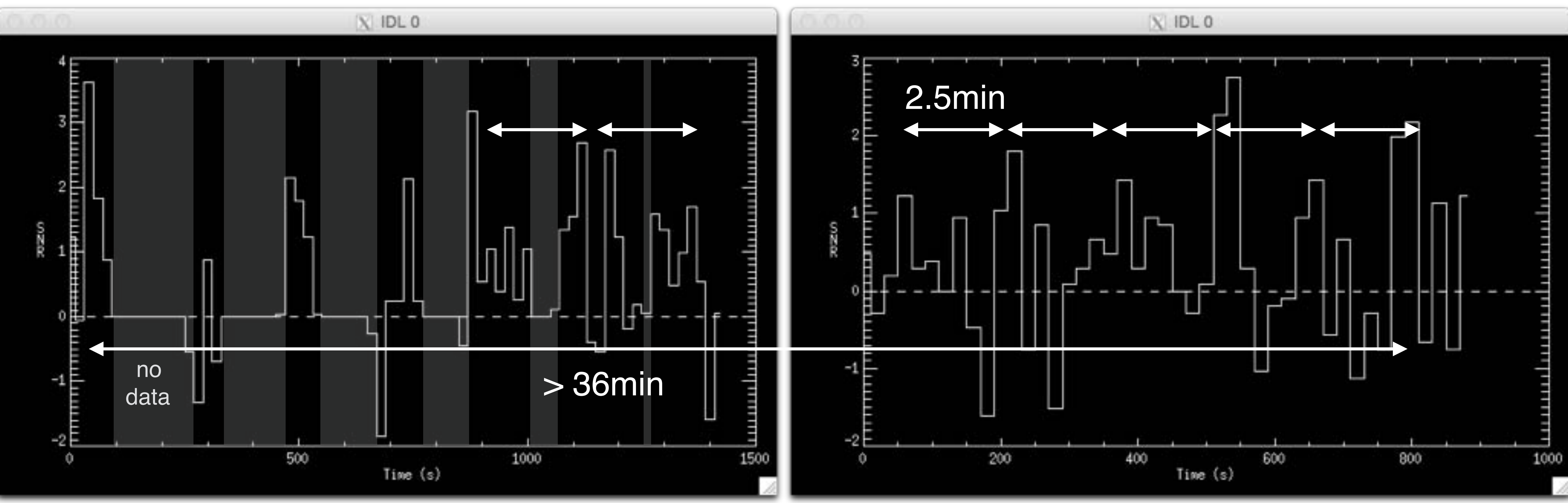
unfiltered image ($H+H_2$)



STIS time-tagged images

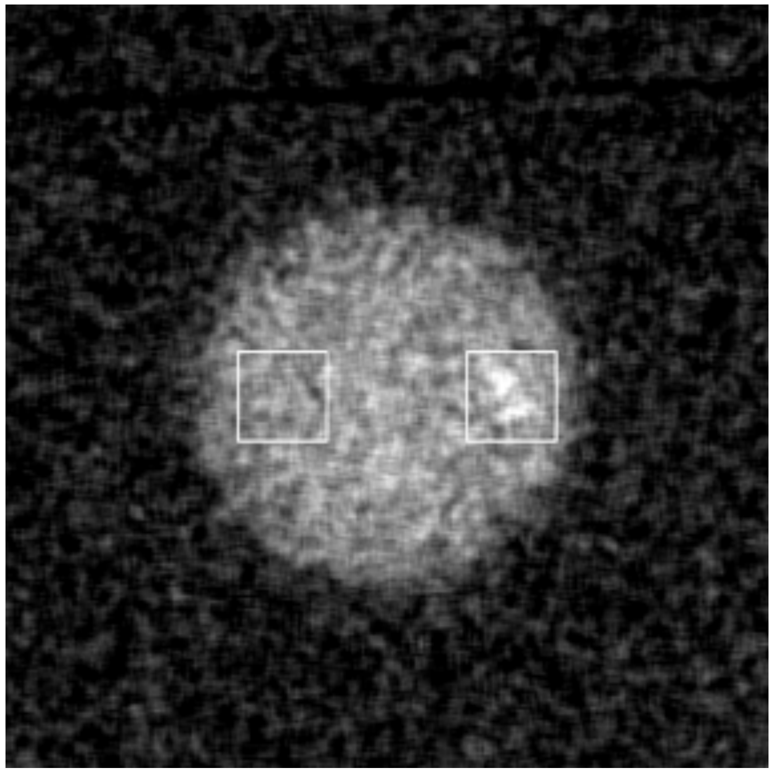
SrF2 image (H_2)

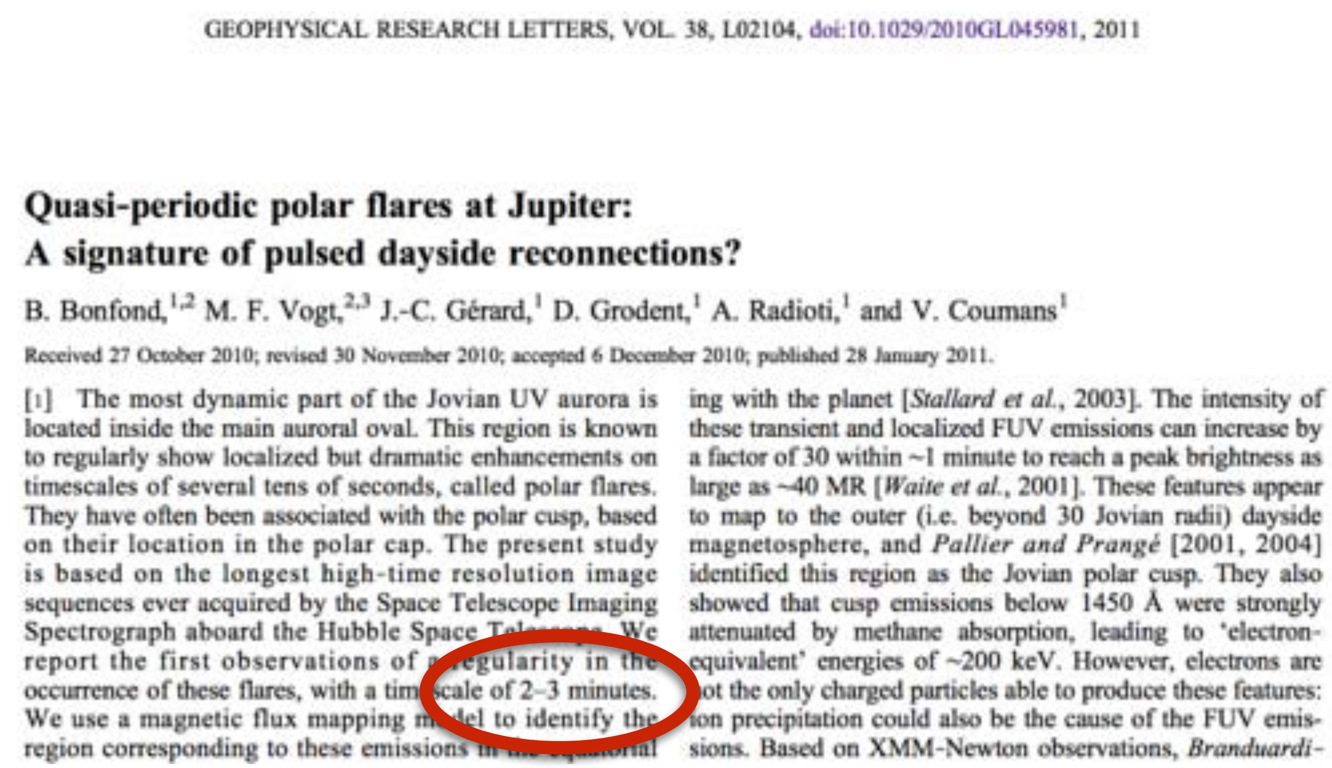




2014

unfiltered image ($H+H_2$)





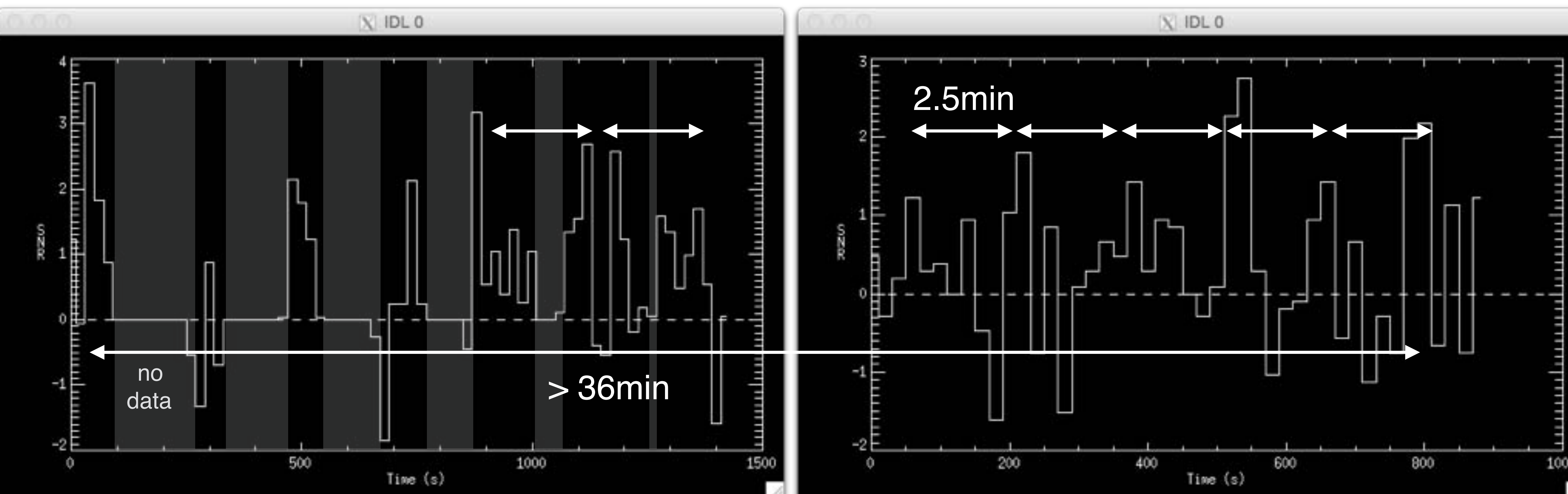
GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L02104, doi:10.1029/2010GL045981, 2011

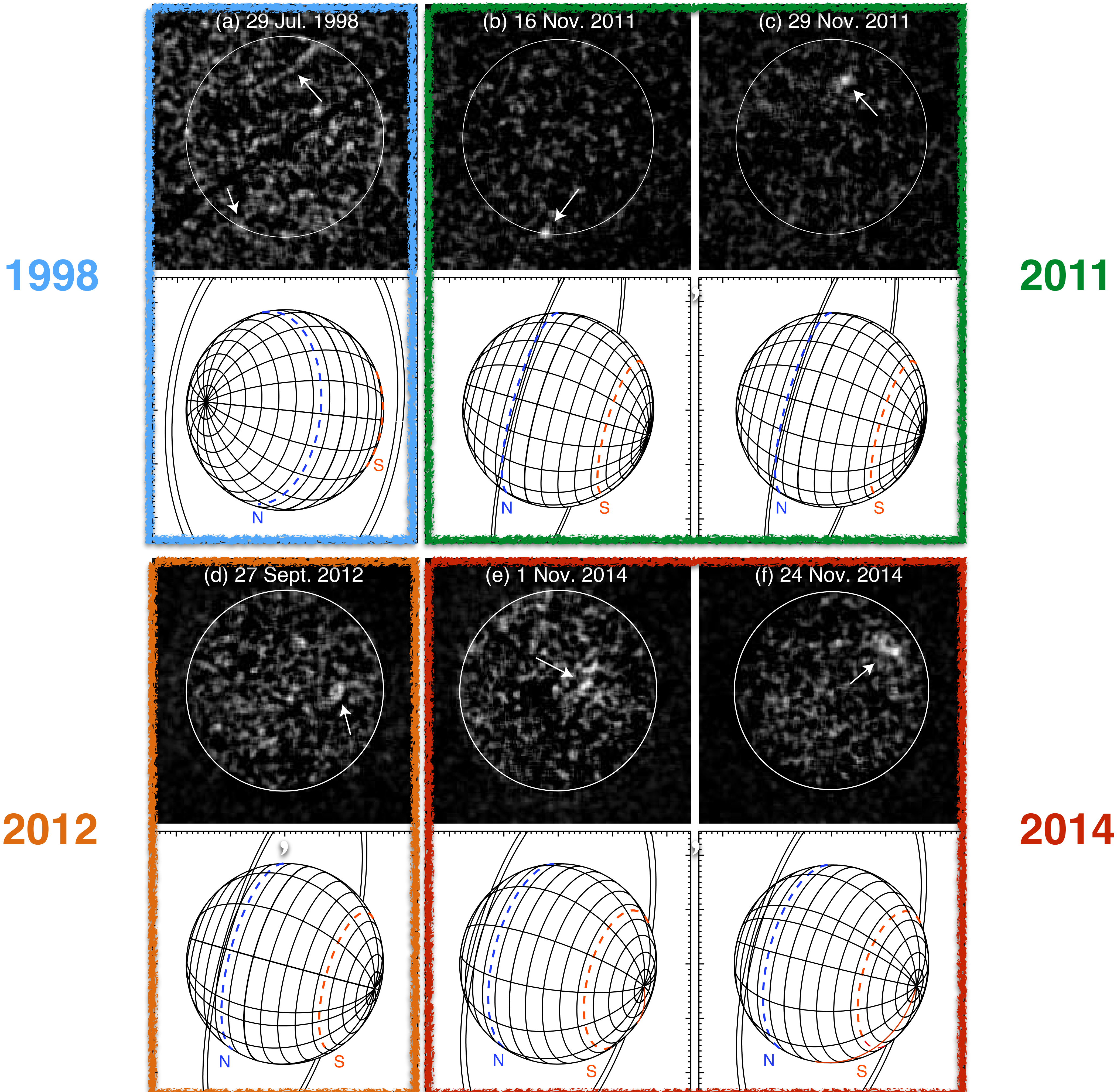
Quasi-periodic polar flares at Jupiter: A signature of pulsed dayside reconnections?

B. Bonfond,[1,2] M. F. Vogt,[2,3] J.-C. Gérard,[1] D. Grodent,[1] A. Radioti,[1] and V. Coumans[1]

Received 27 October 2010; revised 30 November 2010; accepted 6 December 2010; published 28 January 2011.

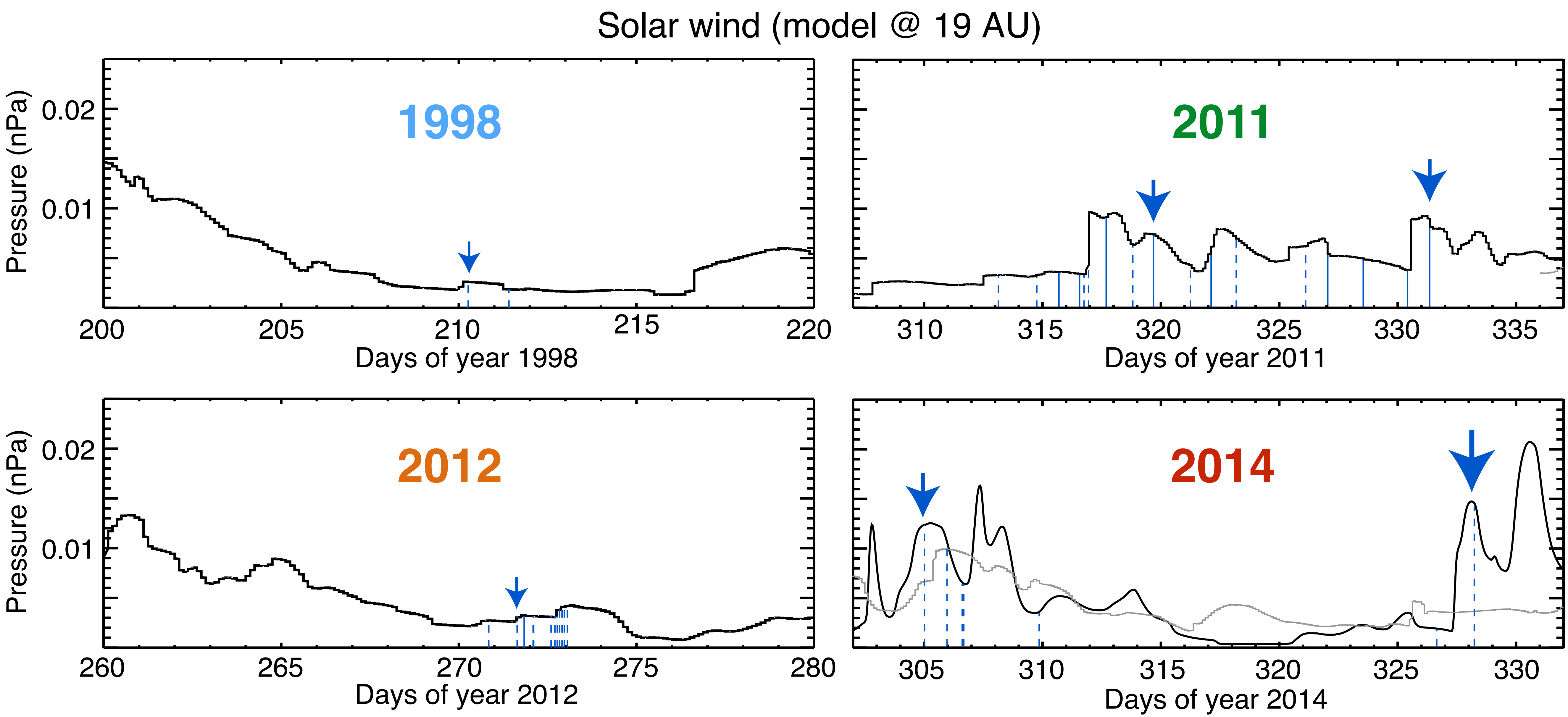
[1] The most dynamic part of the Jovian UV aurora is located inside the main auroral oval. This region is known to regularly show localized but dramatic enhancements on timescales of several tens of seconds, called polar flares. They have often been associated with the polar cusp, based on their location in the polar cap. The present study is based on the longest high-time resolution image sequences ever acquired by the Space Telescope Imaging Spectrograph aboard the Hubble Space Telescope. We report the first observations of a regularity in the occurrence of these flares, with a timescale of 2–3 minutes. We use a magnetic flux mapping model to identify the region corresponding to these emissions in the equatorial ... ing with the planet [*Stallard et al.*, 2003]. The intensity of these transient and localized FUV emissions can increase by a factor of 30 within ~1 minute to reach a peak brightness as large as ~40 MR [*Waite et al.*, 2001]. These features appear to map to the outer (i.e. beyond 30 Jovian radii) dayside magnetosphere, and *Pallier and Prangé* [2001, 2004] identified this region as the Jovian polar cusp. They also showed that cusp emissions below 1450 Å were strongly attenuated by methane absorption, leading to 'electron-equivalent' energies of ~200 keV. However, electrons are not the only charged particles able to produce these features: ion precipitation could also be the cause of the FUV emissions. Based on XMM-Newton observations, *Branduardi-*





1998
2011
2012
2014
(a) 29 Jul. 1998
(b) 16 Nov. 2011
(c) 29 Nov. 2011
(d) 27 Sept. 2012
(e) 1 Nov. 2014
(f) 24 Nov. 2014
N
S

Solar Wind role ?



- brightest signatures occur « close » to SW shocks
  => suggests a prominent role of SW dynamic pressure
  => compression-induced reconnection ?

Conclusions

- Uranus aurorae regularly detected by HST (1998, 2011, 2012 and 2014)

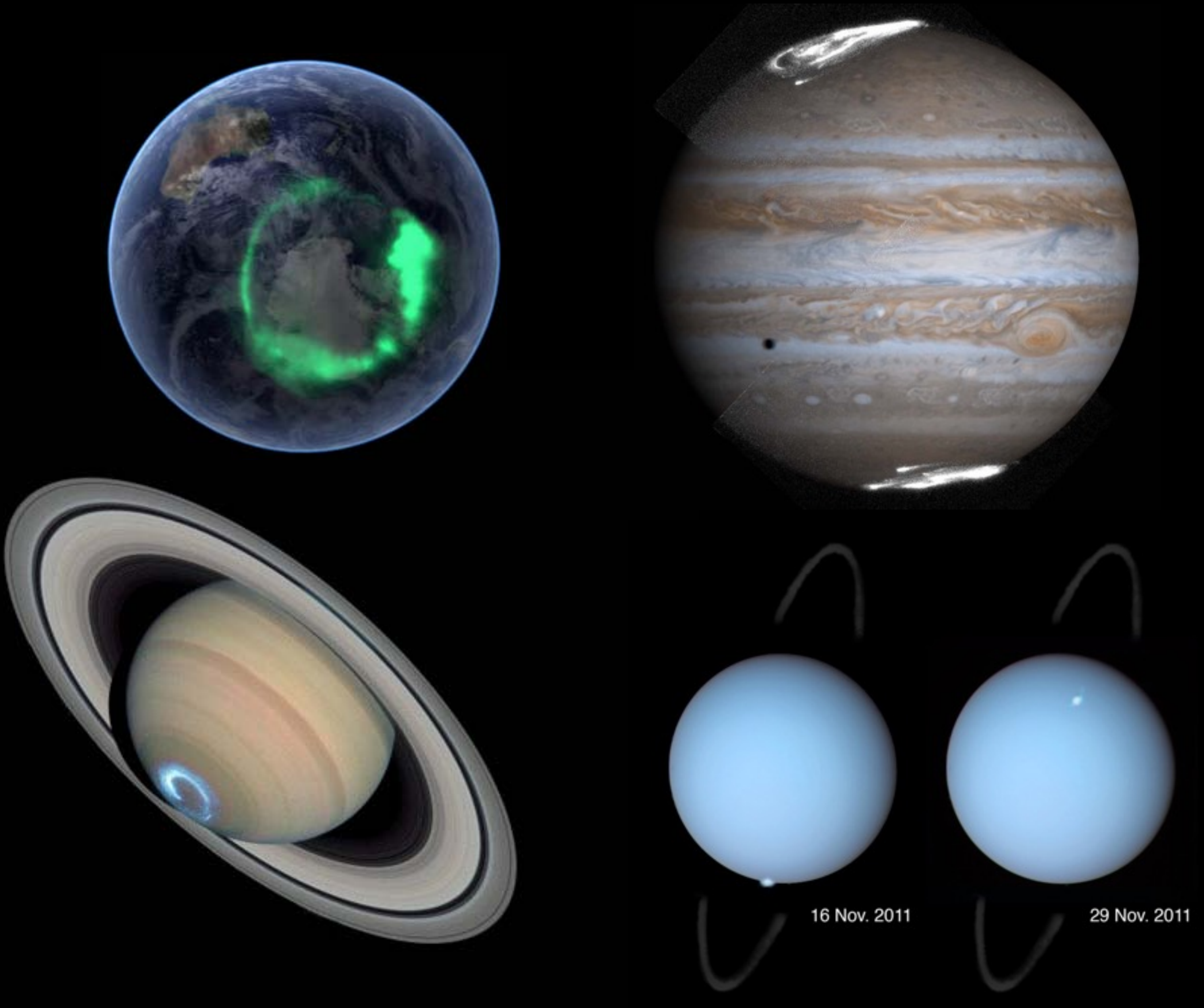
- Renewed interest of the community for Uranus but no orbital probe selected yet
=> Remote UV observations are a <u>unique mean</u> to study Uranus MS

- Most intense signatures observed in 2014 : colocated emissions in the southern hemisphere : S pole at CML = 320+/-20°

- Near-equinox emissions display similar properties : dayside transient spots
  => plausible cause : (pulsed) dayside reconnection
  => driving role of SW pressure fronts ?

- Modeling studies of reconnection and/or MHD simulations shall help to test this hypothesis, at the expense of using the (variable) solar wind parameters prevailing during these observations

- Unadressed questions yet :
  => characterization of the H corona
  => analysis of high spectra to search for atmospheric species


16 Nov. 2011
29 Nov. 2011

The Auroral Planetary Imaging and Spectroscopy (APIS) service

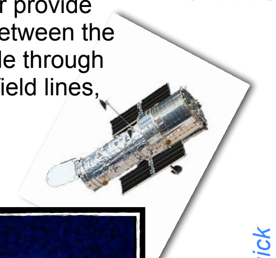
L. Lamy, R. Prangé, F. Henry and P. Le Sidaner

LESIA, VO-Paris Data Centre, Observatoire de Paris, CNRS, UPMC, Univ. Paris Diderot, Meudon, France

http://apis.obspm.fr/

ABSTRACT

Remote Ultraviolet (UV) measurement of the outer planets are a wealth of informations on planetary rings, moons, atmospheres and magnetospheres (Figure 1). Auroral emissions in particular provide highly valuable constraints on the auroral processes at work and the underlying coupling between the solar wind, the magnetosphere, the ionosphere and the moons. Key observables accessible through Far-UV spectro-imaging include the spatial topology and the dynamics of active magnetic field lines, the identification of radiative species and the radiated and precipitated energies.



THE APIS DATABASE

The STIS and ACS Far-UV instruments of the Hubble Space Telescope[1] (HST) acquired ~6000 individual spectra and images of the aurorae of Jupiter, Saturn and Uranus and their satellites over 1997-2014 (Figure 2, Table 1). But their use remains generally limited, owing to the difficulty to access and use them.

FIGURE 1

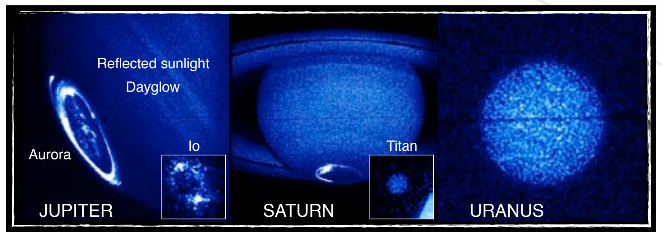


Figure 1 : Remote UV measurements of the outer planets.

APIS, the egyptian god of fertilization, is also the acronym of the new database *Auroral Planetary Imaging and Spectroscopy*, aimed at facilitating the use of HST planetary auroral observations[2]. APIS is hosted by the Virtual Observatory (VO) of Paris and provides a free and interactive access to a variety of high level data through a dedicated search interface (Figure 3) and standard VO tools (Figure 4), presented hereafter.

FIGURE 2

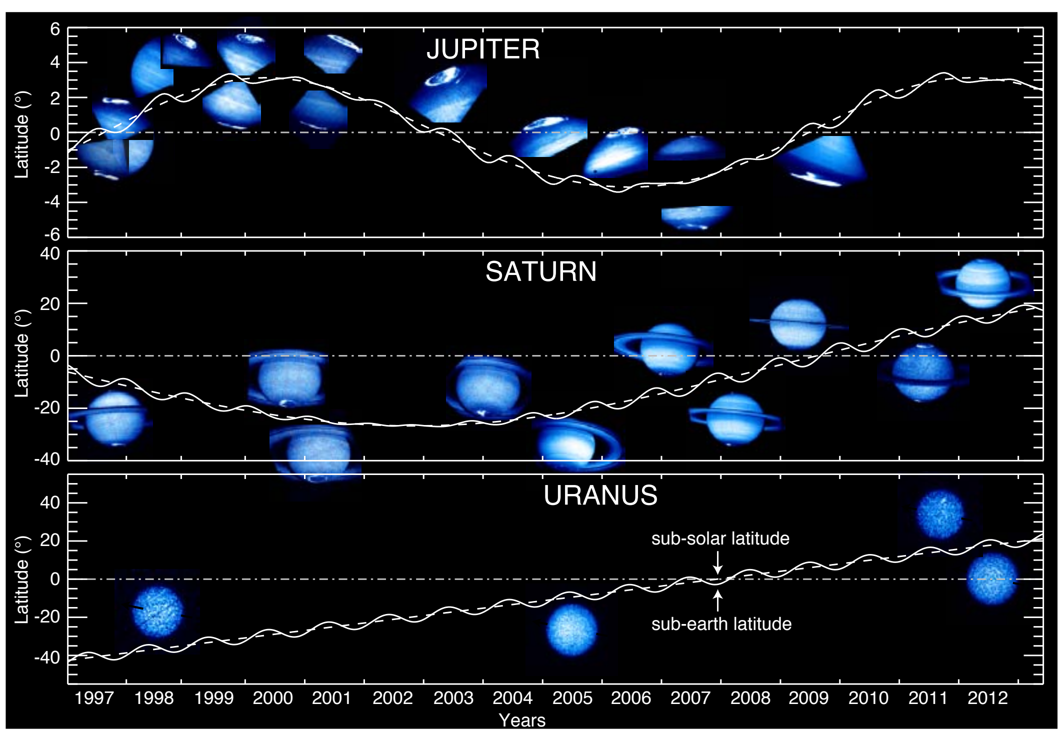


Figure 2 : HST-FUV observations over 1997-2013.

SEARCH INTERFACE

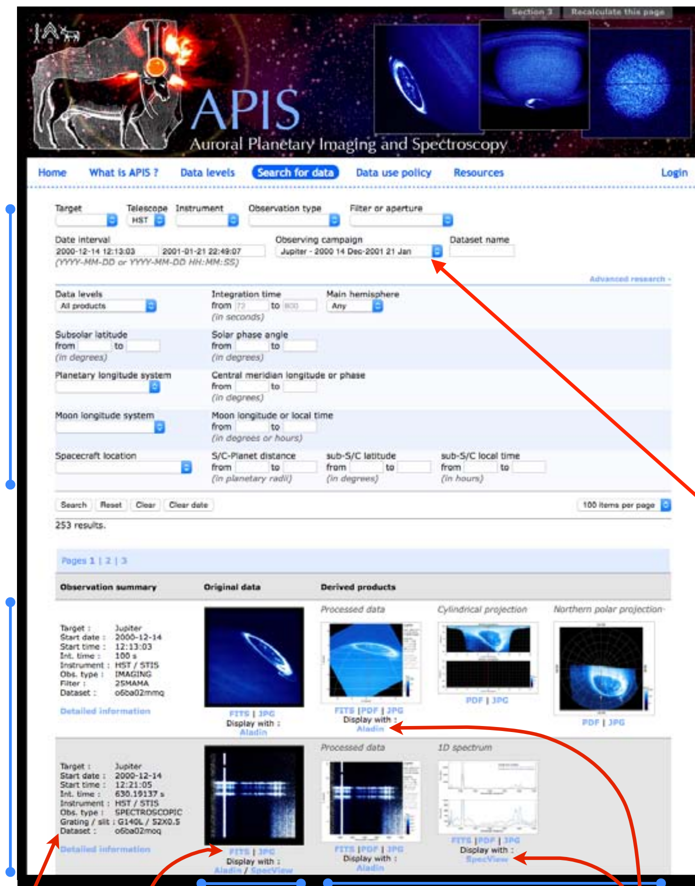


FIGURE 3

Figure 3 : Example of data request.

TABLE 1

Table 1 : Core database.

Saturn system :
Saturn, Oct.-Dec. 1997 (STIS, 9 images, 1 spectrum)
Saturn, Dec. 2000 (STIS, 2 images, 4 spectra)
Saturn, Jan. 2001 (STIS, 4 images, 8 spectra)
Saturn, Jan. 2004 (STIS, 51 images)
Saturn, Oct.-Nov. 2005 (ACS, 72 images)
Saturn, Jan. 2007-Feb. 2008 (ACS, 1008 images)
Saturn, Jan.-Feb. 2009 (ACS, 1017 images)
Saturn, Feb.-Mar. 2009 (ACS, 400 images)
Saturn, Apr. 2011 (ACS, 115 images)
Saturn, Jan.-May. 2011 (STIS, 8 images, 8 spectra)
Saturn, Mar.-Jun. 2012 (ACS, 230 images)
Saturn, Apr.-May 2013 (ACS, 345 images)
Saturn, Feb.-Jun. 2014 (STIS, 45 images)
Titan/Saturn, Jan.-Feb. 2009 (ACS, 117 images)

Polar/cylindrical projections

Saturn :
+ S/N SKR phase markers
+ Enceladus footprint (SPV model)

Jupiter system : (most recent updates)
Jupiter, Mar. 1997-Jan. 2001 (STIS, 30 images, 13 spectra)
Jupiter, Jan. 1999 (STIS, 3 images, 6 spectra)
Jupiter, Aug. 1999 (STIS, 31 images, 5 spectra)
Jupiter, Aug. 1999-Nov. 2000 (STIS, 28 images, 35 spectra)
Jupiter, Dec. 2000-Jan. 2001 (STIS, 88 images, 29 spectra)
Jupiter, Feb. 2003 (STIS, 13 images)
Jupiter, Jan.-May 2005 (ACS, 106 images)
Jupiter, Feb.-Apr. 2006 (ACS, 75 images)
Jupiter, Feb.-Jun. 2007 (ACS, 1845 images)
Jupiter, Aug.-Sept. 2009 (STIS, 3 images)
Jupiter, Nov. 2012-Jan. 2014 (STIS, 19 images, 2 spectra)
Jupiter, Jan. 2014 (STIS, 27 images, 14 spectra)
Jupiter, Jan.-Mar. 2014 (STIS, 4 long exposure spectra)
Io, Sept.-Oct. 1997 (STIS, 8 spectra)
Io, Aug. 1998 (STIS, 2 images, 18 spectra)
Io, Sept. 1999-Feb. 2000 (STIS, 2 images, 92 spectra)
Io, Dec. 2001 (STIS, 4 spectra)
Io/Ganymede/Europa, Feb. 2007 (ACS, 20 images)
Ganymede, Oct. 1998 (STIS, 8 spectra)
Ganymede/Europa, Oct. 1999-Dec. 2000 (STIS, 13 spectra)
Ganymede, Nov.-Dec. 2003 (ACS/STIS, 4 images, 4 spectra)
Ganymede, Sep. 2010-Oct. 2011 (STIS, 20 spectra)
Ganymede, Jan.-Feb. 2014 (STIS, 8 spectra)
Europa, Nov.-Dec. 2012 (STIS, 19 spectra)

Jupiter :
+ markers of satellites footprints (ISaAC model, Hess, pers. com.)

Uranus :
Uranus, Jul.-Sept. 1998 (STIS, 4 images, 8 spectra)
Uranus, Aug. 2005 (ACS, 64 images)
Uranus, Aug.-Sept. 2011 (STIS, 4 spectra)
Uranus, Nov. 2011 (ACS/STIS, 73 images, 9 spectra)
Uranus, Sept.-Oct. 2012 (ACS/STIS, 23 images, 3 spectra)

VO COMPATIBILITY

APIS is fully compliant with VO standards :

- the core table of metadata is built along the standard Europlanet-TAP (EPN-TAP) protocol[3] ;

- fits data (either raw or processed) can be interactively read online with Aladin (Fig. 4 left) and/or Specview (Fig. 4 right), which are VO softwares enabling simple operations (histogram, profiles, line list etc).

FIGURE 4

Aladin (CDS)

Specview (STSci)

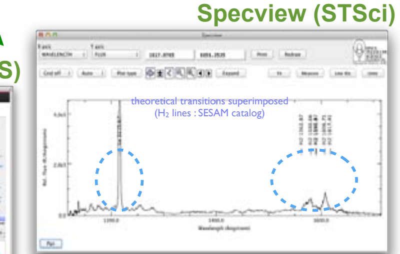
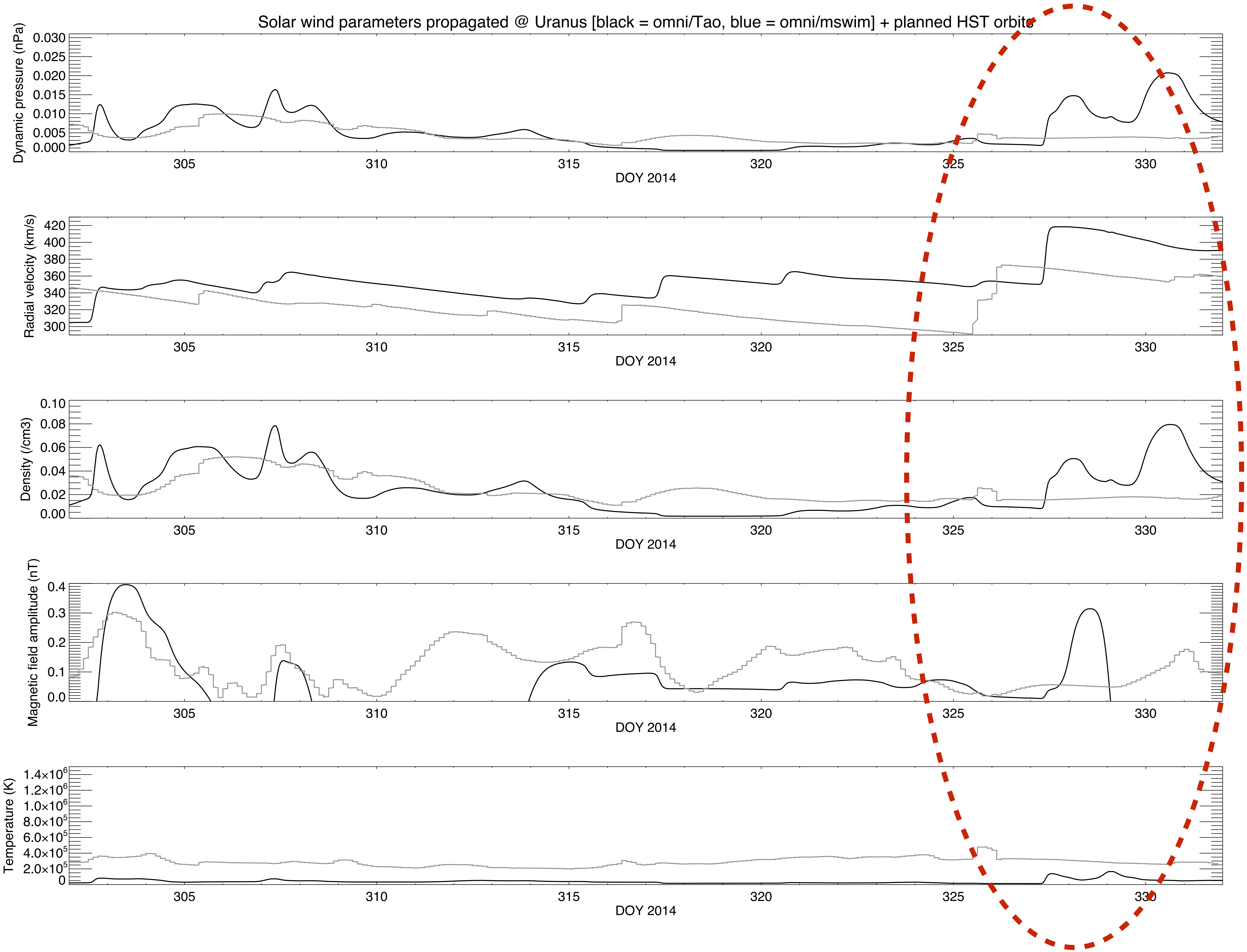


Figure 4 : Jupiter image and Saturn spectrum read with VO tools.

REFERENCES

[1] http://www.stsci.edu/hst/HST_overview/instruments
[2] L. Lamy, R. Prangé, F. Henry and P. Le Sidaner, The APIS service, *Astronomy and Computing*, 2015, ArXiv:1501.03920.
[3] S. Erard et al., The EPN-TAP protocol for the Planetary Science Virtual Observatory, *Astronomy and Computing*, 2014.



Solar wind parameters propagated @ Uranus [black = omni/Tao, blue = omni/mswim] + planned HST orbits
Dynamic pressure (nPa)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
305
310
315
320
325
330
DOY 2014
Radial velocity (km/s)
420
400
380
360
340
320
300
Density (/cm3)
0.10
0.08
0.06
0.04
0.02
0.00
Magnetic field amplitude (nT)
0.4
0.3
0.2
0.1
0.0
Temperature (K)
1.4×10^6
1.2×10^6
1.0×10^6
8.0×10^5
6.0×10^5
4.0×10^5
2.0×10^5
0