Mesures in situ des régions aurorales de Saturne, Jupiter (et la Terre)

Atelier Magnétosphères comparées, 6 février 2015, Meudon-les-bains

Contexte

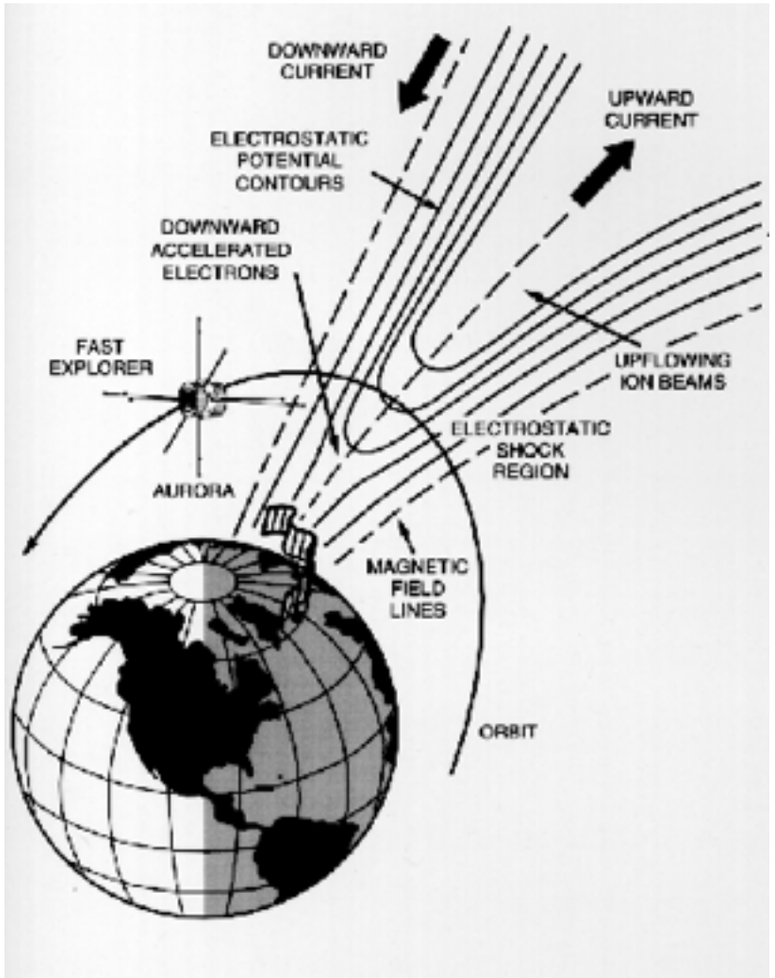
Régions aurorales :

(i) Accélération de particules, transfert d'énergie/de moment

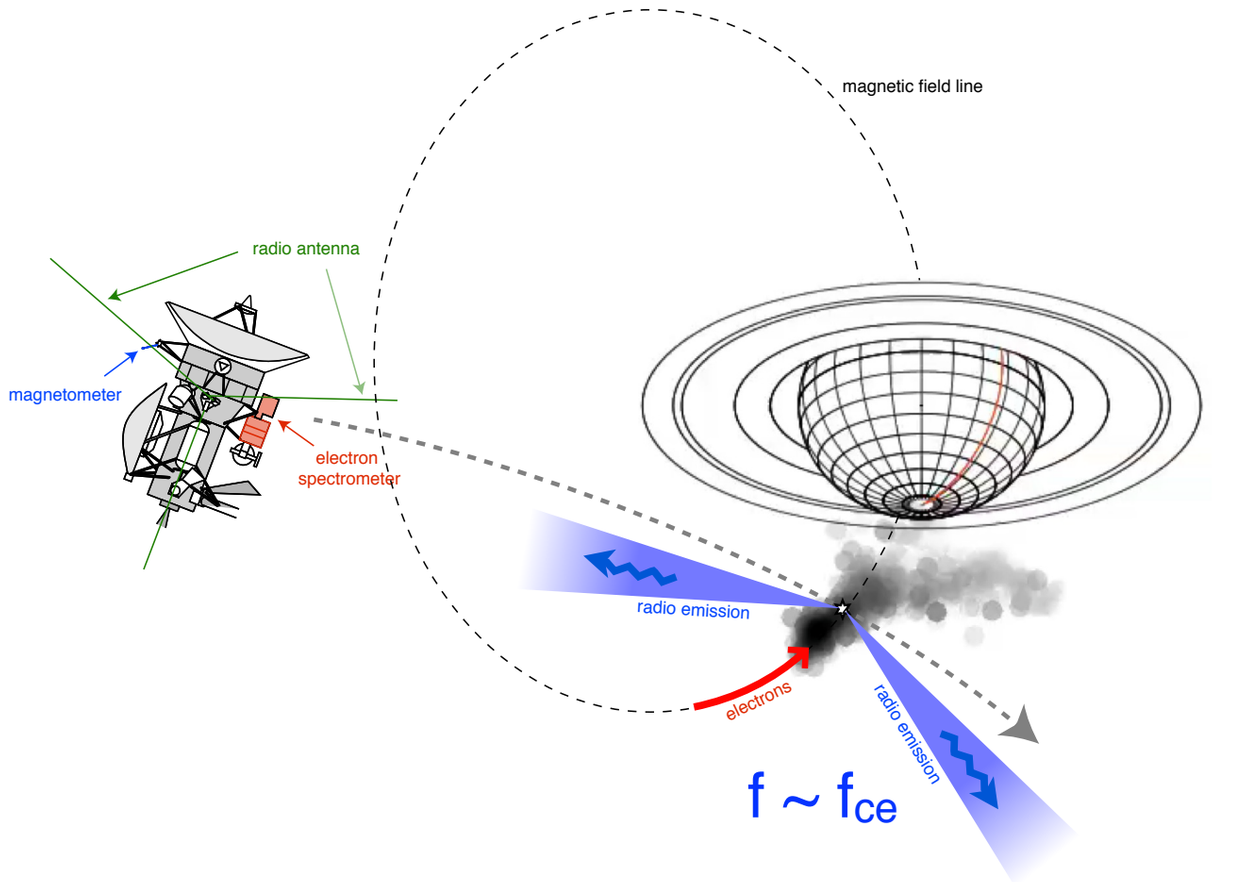
(ii) Emission et propagation radio (mesures radio, plasma)

=> Mesures *in situ* (particules, champ, radio)

+ *à distance* (radio, UV/IR/visible, ENA)



Terre (N>>1 passages)



Saturne (1 passage)

Contexte

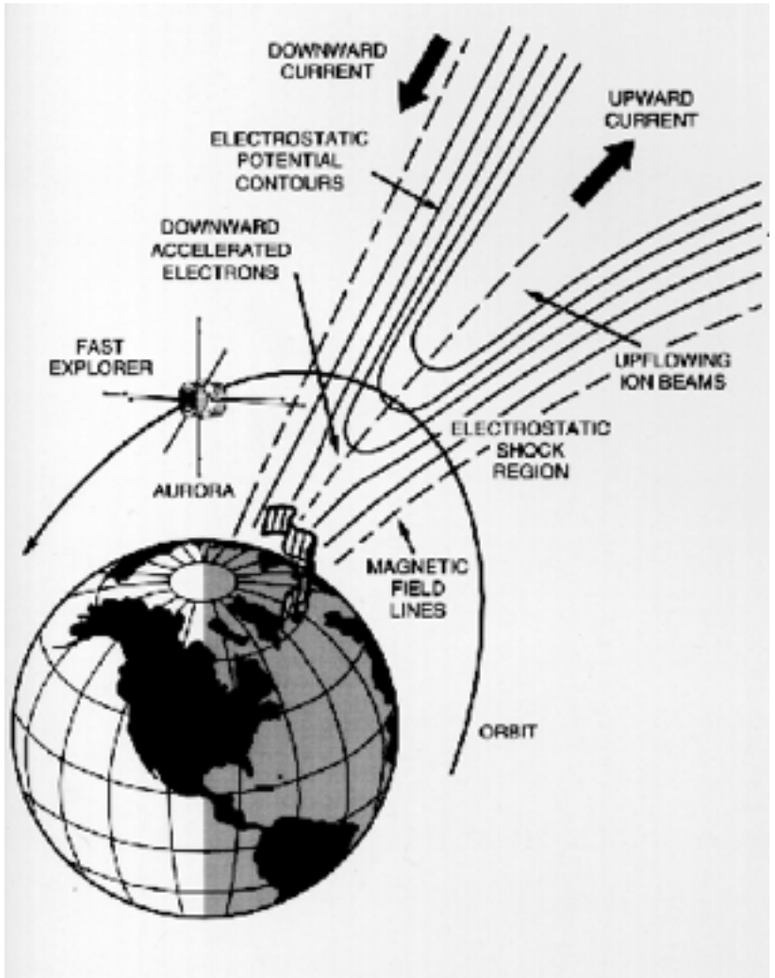
<u>Régions aurorales :</u>

(i) Accélération de particules

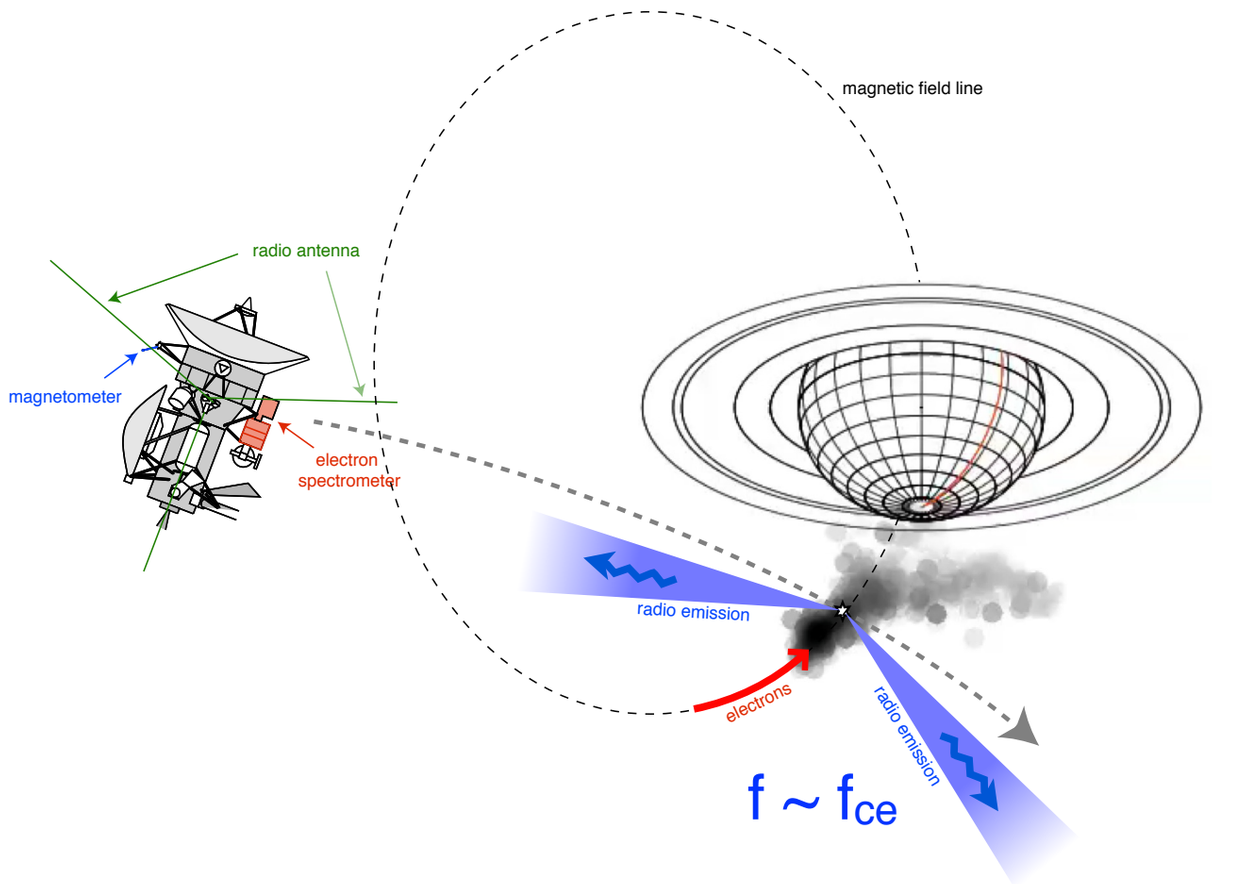
(ii) Emission et propagation radio (mesures radio, plasma)

=> Mesures *in situ* (particules, champ, radio)

+ *à distance* (radio, UV/IR/visible, ENA)



Terre (N>>1 passages)



Saturne (1 passage)

Contexte

<u>Régions aurorales :</u>

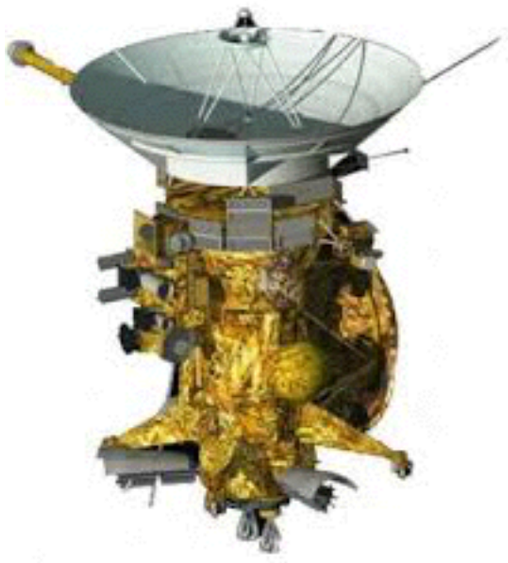
(i) Accélération de particules

(ii) Emission et propagation radio (mesures radio, plasma)

=> Mesures *in situ* (particules, champ, radio)

+ *à distance* (radio, UV/IR/visible, ENA)

Saturne

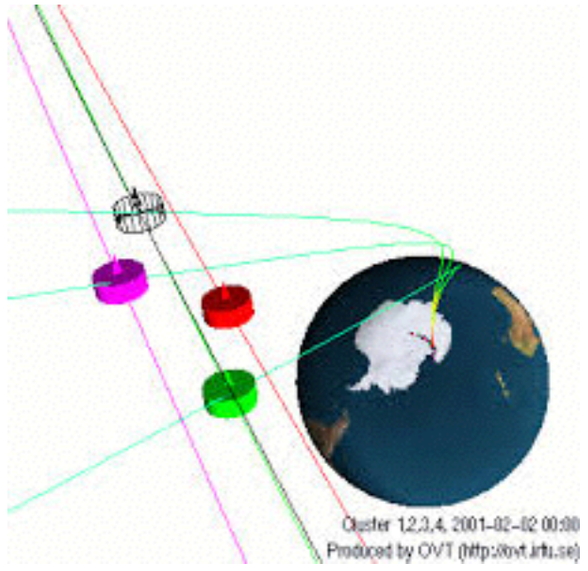


2016-2017

Jupiter

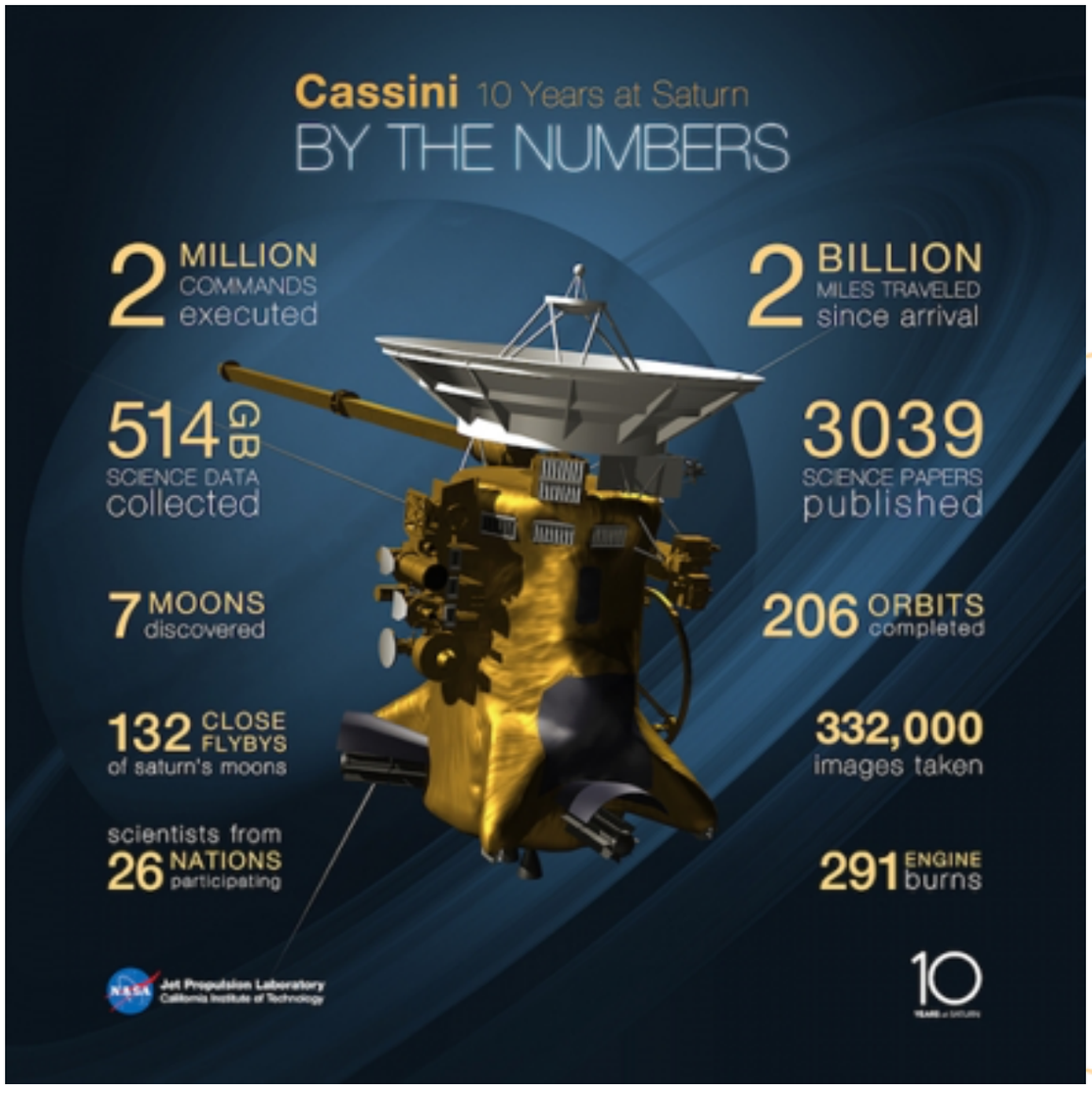
2016-2017

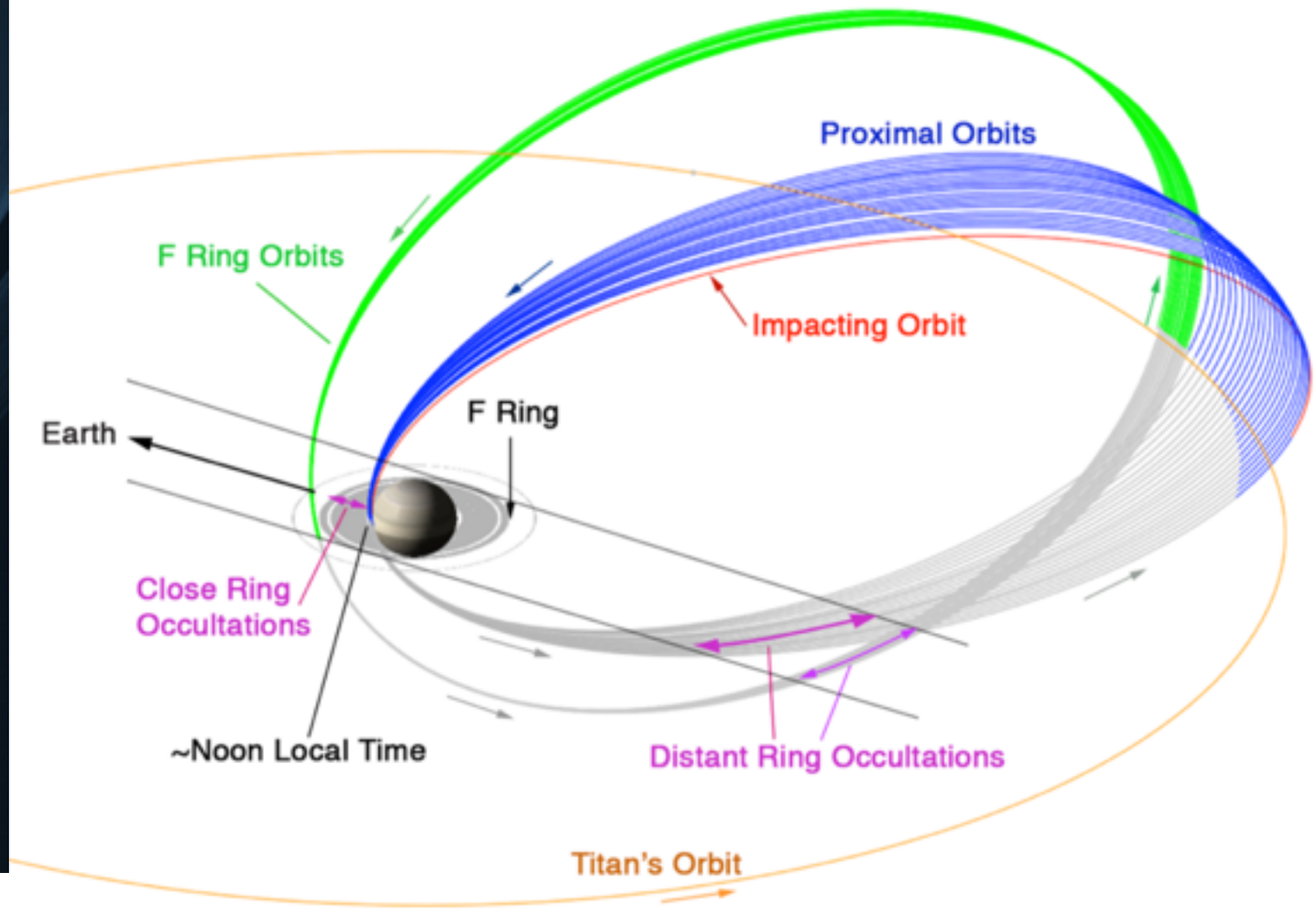
Terre



2011-2013

Cassini



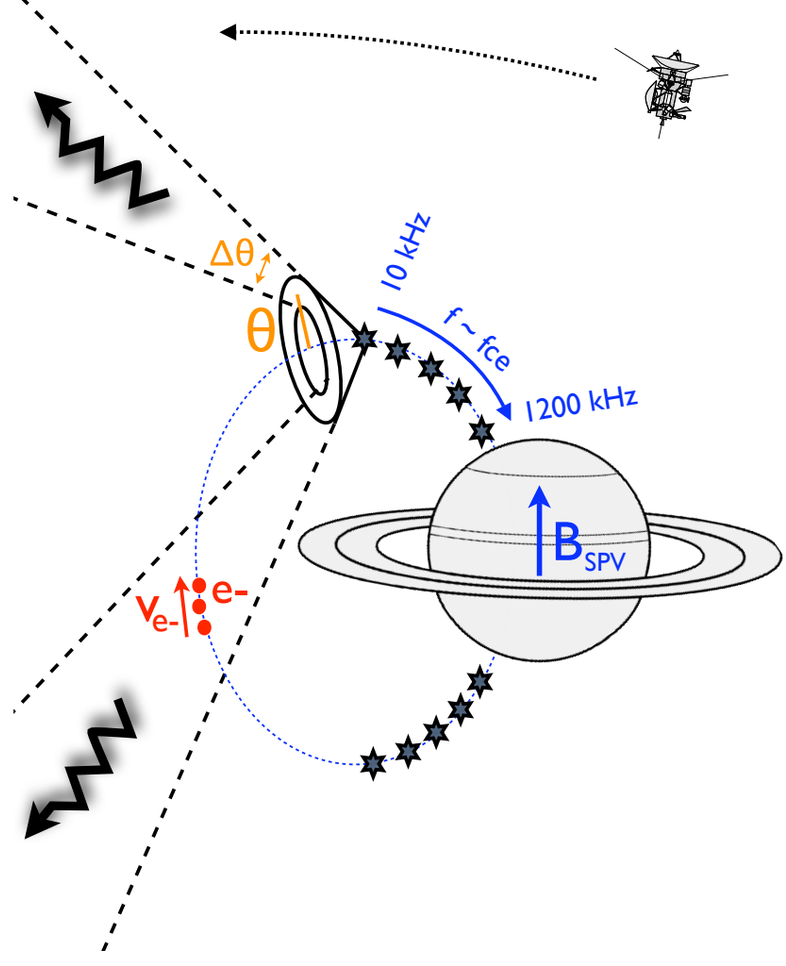


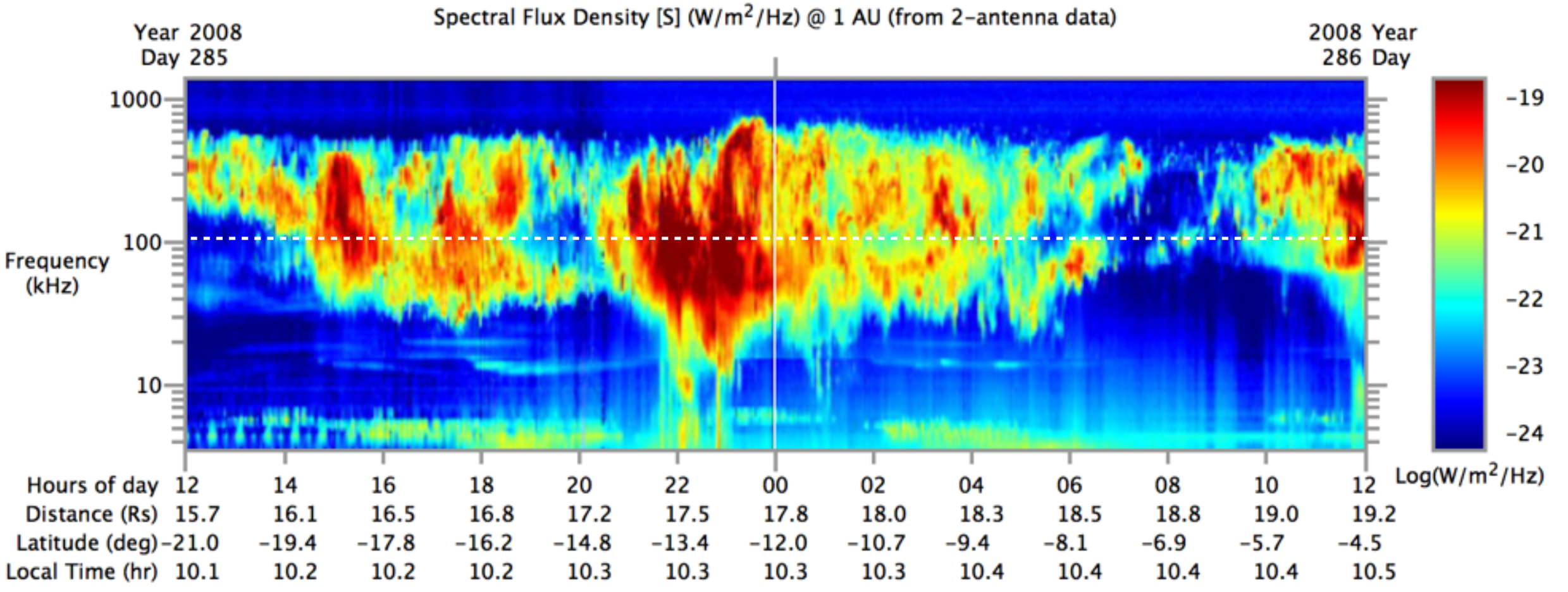
Lancement : 1997
Entrée en orbite : 30 Juin 2004
Fin de mission : 16 Septembre 2017

=> Mi-2016 à Fin 2017 : « *Grand Finale* »
Passages polaires jusqu'à impact final

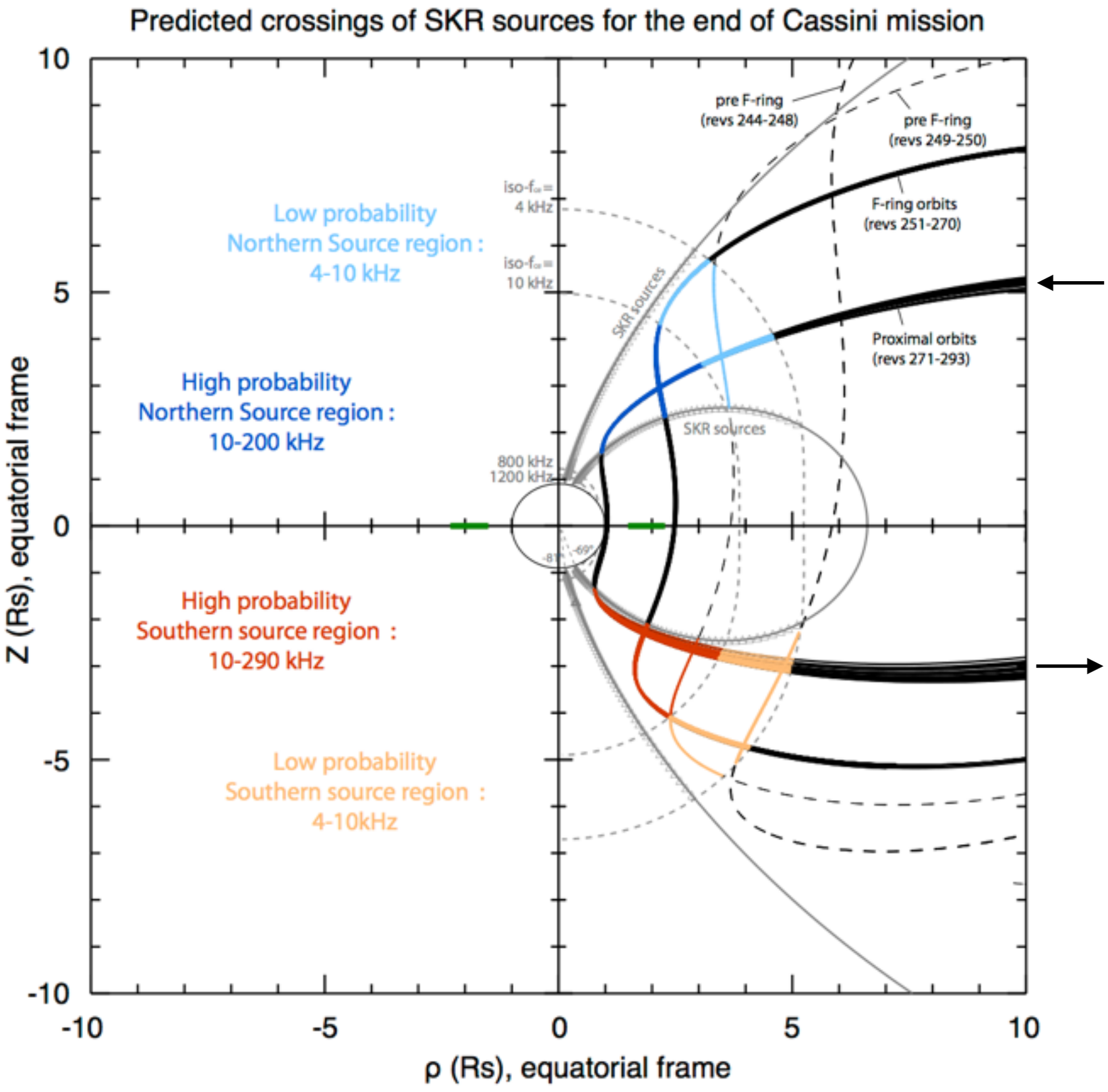
Cassini

* Simulations of SKR sources :
  - (i) Locus of active magnetic field lines (model)
  - (ii) freq. range (SKR spectrum) + assumption $f \sim f_{ce}$
  - (iii) beaming (for remote observations)
  - => to be compared with the Cassini's trajectory



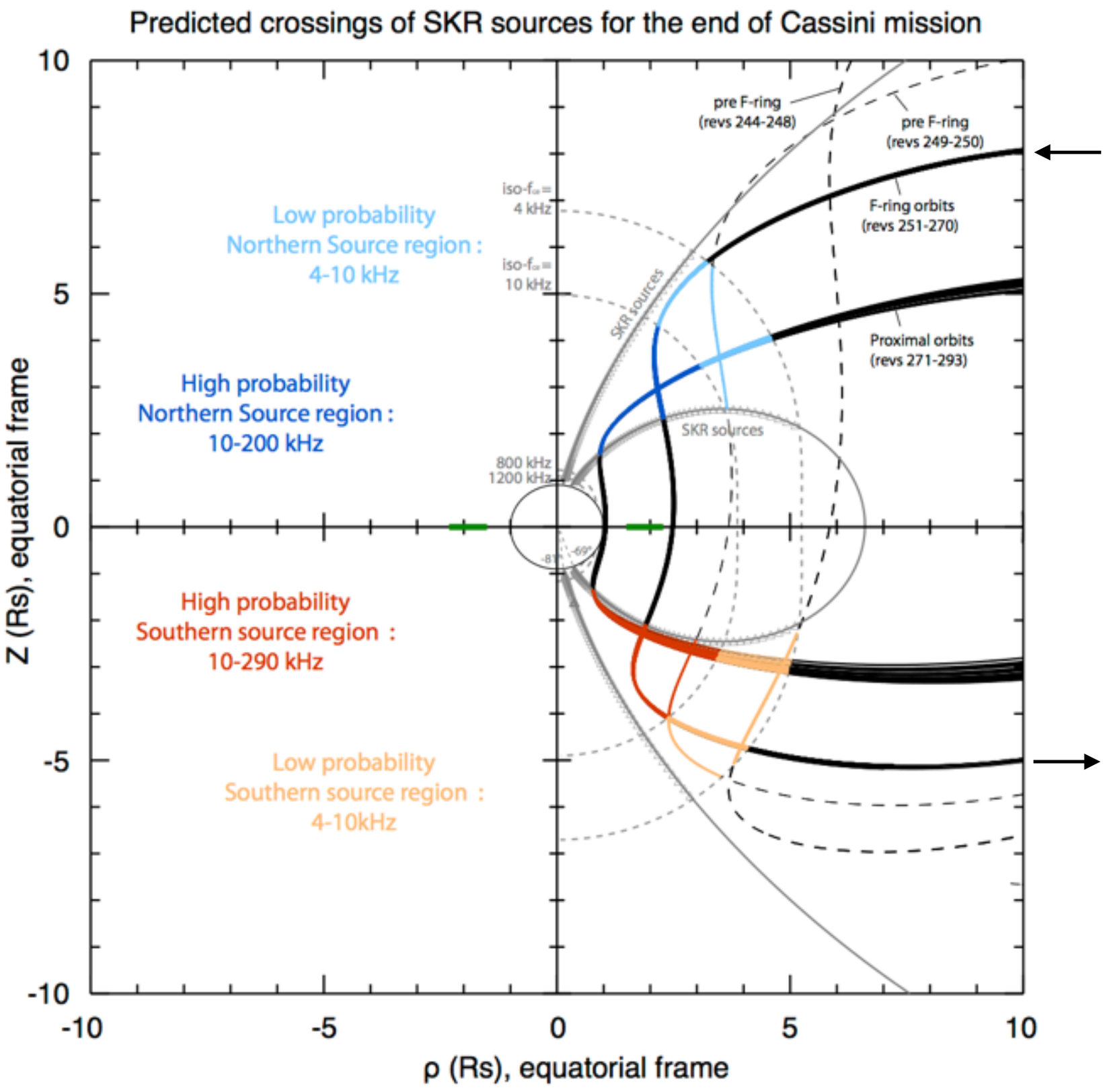


Cassini



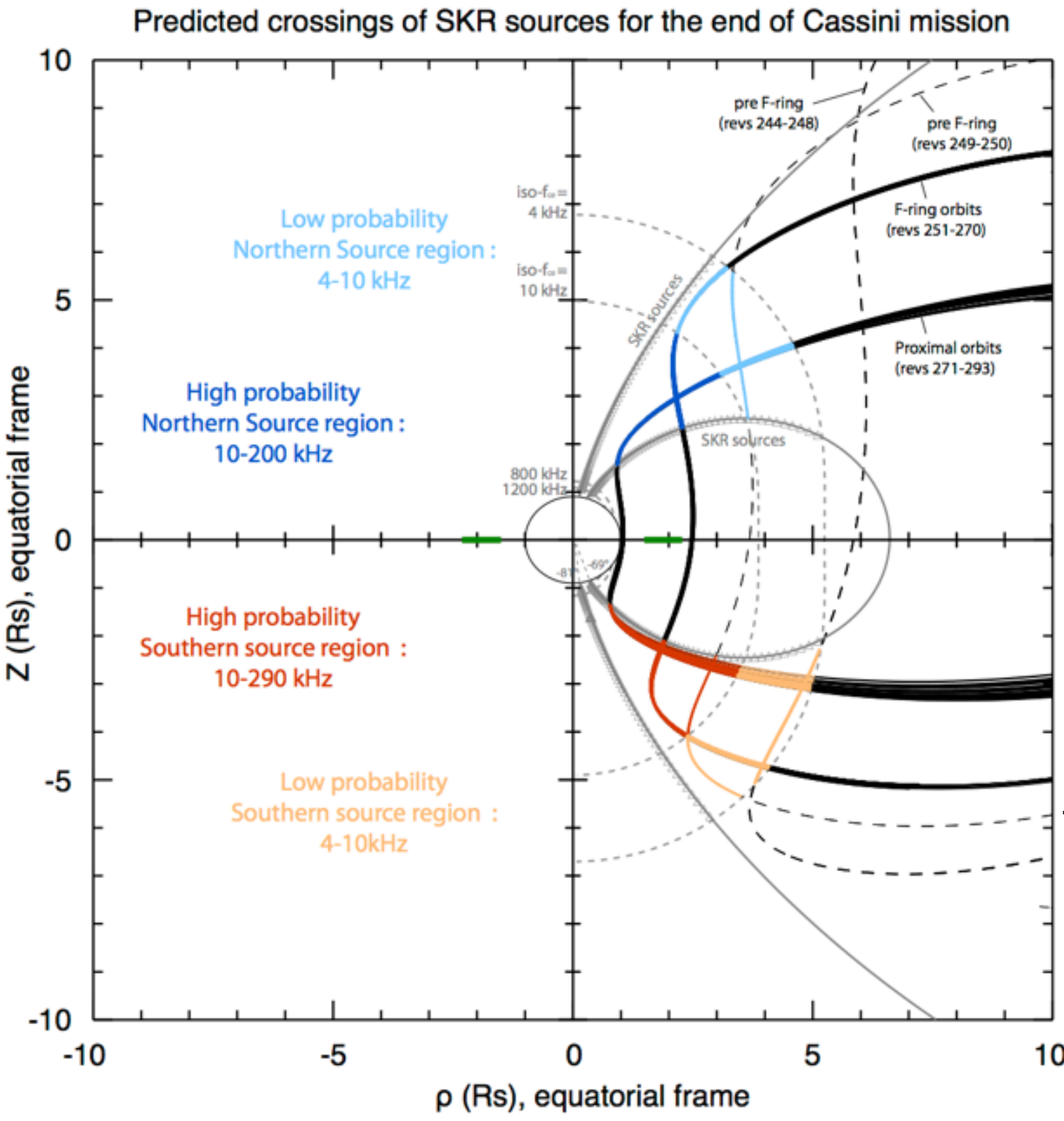
Proximal orbits :
23 high (+ 23 low) probability passes in <u>each</u> hemisphere

Cassini



F-ring orbits :
20 high (+ 20 low) probability passes in <u>each</u> hemisphere

Cassini



← **Pre F-ring orbits :** 0 high (+ 2 low) probability passes in the north

→ 2 high (+ 7 low) probability passes in the south

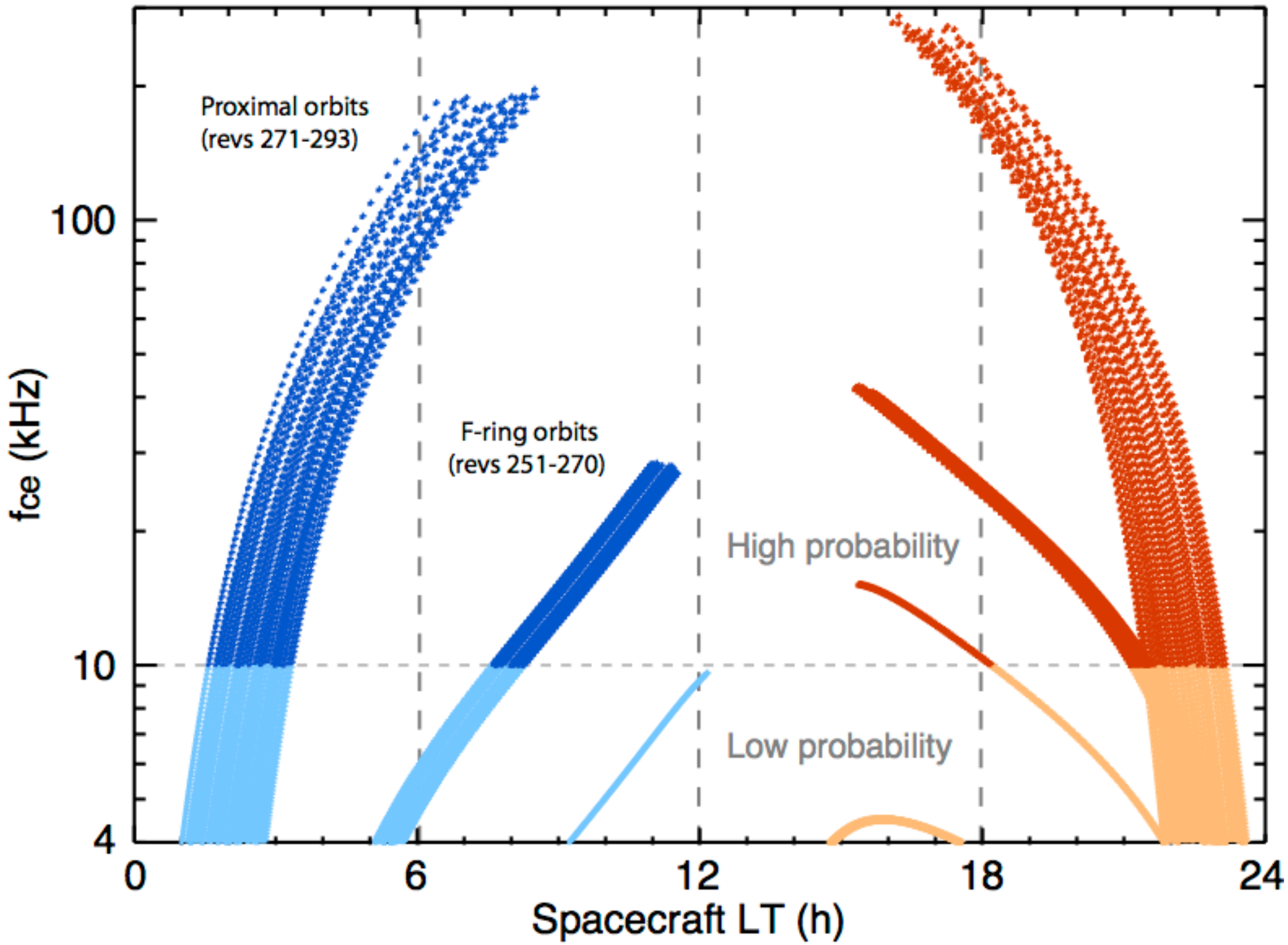
Cassini

* Simulation results : 188 possible passes within auroral regions

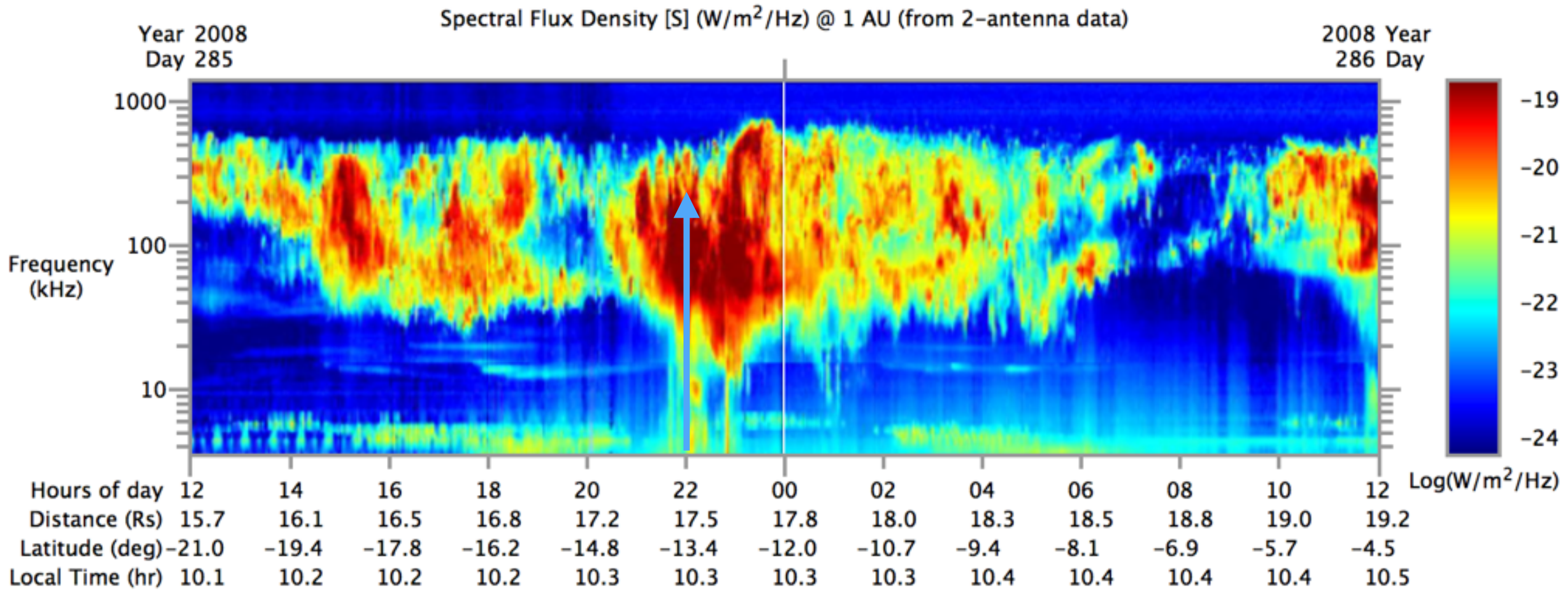
ASCII file of intervals at :
http://www.lesia.obspm.fr/kronos/skr_sources.php

# Year-Day	hh:mm:ss	fce_1	lat_1	lt_1	rp_1	fplat1	Year-Day	hh:mm:ss	fce_2	lat_2	lt_2	rp_2	fplat2	Dt	Probability
2016-278	00:42:00	4.0	-24.21	14.88	5.63	-69.50	2016-278	06:18:00	4.0	-53.14	17.57	6.33	-77.64	5.60	LOW
2016-287	14:27:00	4.0	-24.60	14.87	5.64	-69.60	2016-287	19:54:00	4.0	-52.81	17.48	6.32	-77.53	5.45	LOW
2016-297	04:03:00	4.0	-24.22	14.82	5.63	-69.49	2016-297	09:39:00	4.0	-53.18	17.52	6.33	-77.65	5.60	LOW
2016-306	17:30:00	4.0	-23.98	14.79	5.63	-69.46	2016-306	23:09:00	4.0	-53.19	17.51	6.33	-77.66	5.65	LOW
2016-316	07:06:00	4.0	-24.05	14.76	5.62	-69.46	2016-316	12:45:00	4.0	-53.28	17.49	6.33	-77.68	5.65	LOW
2016-323	23:45:00	4.0	59.10	9.27	6.48	80.42	2016-324	04:42:00	9.6	34.81	12.16	4.44	71.04	4.95	LOW
2016-324	10:36:00	15.2	-39.11	15.41	3.84	-69.04	2016-324	13:21:00	10.1	-59.47	18.18	4.72	-77.96	2.75	HIGH
2016-324	13:24:00	10.0	-59.62	18.24	4.74	-78.04	2016-324	17:21:00	4.0	-56.74	21.87	6.39	-78.79	3.95	LOW
2016-331	22:60:00	4.0	58.99	9.25	6.48	80.39	2016-332	03:54:00	9.5	35.09	12.11	4.46	71.17	4.90	LOW
2016-332	09:51:00	15.2	-39.17	15.37	3.85	-69.08	2016-332	12:36:00	10.1	-59.53	18.15	4.72	-77.98	2.75	HIGH
2016-332	12:39:00	10.0	-59.69	18.21	4.73	-78.06	2016-332	16:36:00	4.0	-56.77	21.85	6.39	-78.80	3.95	LOW
2016-339	04:57:00	4.0	60.80	5.74	6.51	80.93	2016-339	08:03:00	10.0	63.32	8.28	4.83	80.30	3.10	LOW
2016-339	08:06:00	10.1	63.25	8.34	4.81	80.25	2016-339	10:51:00	26.9	46.02	11.53	3.30	71.33	2.75	HIGH
2016-339	15:15:00	39.7	-48.21	15.83	2.88	-69.29	2016-339	18:45:00	10.1	-60.25	21.55	4.72	-78.25	3.50	HIGH
2016-339	18:48:00	9.9	-60.08	21.60	4.74	-78.22	2016-339	21:36:00	4.0	-49.68	23.19	6.26	-76.56	2.80	LOW
2016-346	09:15:00	4.0	60.77	5.72	6.50	80.92	2016-346	12:18:00	9.8	63.25	8.22	4.85	80.30	3.05	LOW
2016-346	12:21:00	10.0	63.19	8.27	4.83	80.25	2016-346	15:09:00	27.0	45.66	11.51	3.29	71.18	2.80	HIGH
2016-346	19:30:00	40.1	-47.84	15.75	2.87	-69.07	2016-346	23:03:00	10.1	-60.25	21.55	4.72	-78.25	3.55	HIGH
2016-346	23:06:00	9.9	-60.07	21.60	4.75	-78.23	2016-347	01:51:00	4.0	-49.81	23.16	6.25	-76.58	2.75	LOW
2016-353	13:18:00	4.0	60.69	5.64	6.50	80.90	2016-353	16:21:00	9.9	63.42	8.12	4.85	80.36	3.05	LOW
2016-353	16:24:00	10.0	63.35	8.18	4.83	80.31	2016-353	19:12:00	27.4	46.13	11.46	3.28	71.31	2.80	HIGH
2016-353	23:33:00	40.6	-48.01	15.75	2.86	-69.10	2016-354	03:06:00	10.0	-59.98	21.57	4.73	-78.16	3.55	HIGH
2016-354	03:09:00	9.9	-59.80	21.61	4.76	-78.13	2016-354	05:54:00	4.0	-49.50	23.14	6.25	-76.49	2.75	LOW
2016-360	17:21:00	4.0	60.65	5.62	6.50	80.88	2016-360	20:24:00	9.9	63.34	8.10	4.85	80.32	3.05	LOW
2016-360	20:27:00	10.1	63.28	8.16	4.82	80.27	2016-360	23:15:00	27.6	45.90	11.44	3.27	71.20	2.80	HIGH
2016-361	03:36:00	40.8	-48.52	15.75	2.86	-69.34	2016-361	07:06:00	10.2	-60.14	21.53	4.71	-78.20	3.50	HIGH
2016-361	07:09:00	10.0	-59.95	21.57	4.74	-78.16	2016-361	09:54:00	4.1	-49.60	23.12	6.24	-76.50	2.75	LOW
2017-001	21:15:00	4.0	60.64	5.57	6.51	80.88	2017-002	00:21:00	10.0	63.38	8.10	4.83	80.32	3.10	LOW

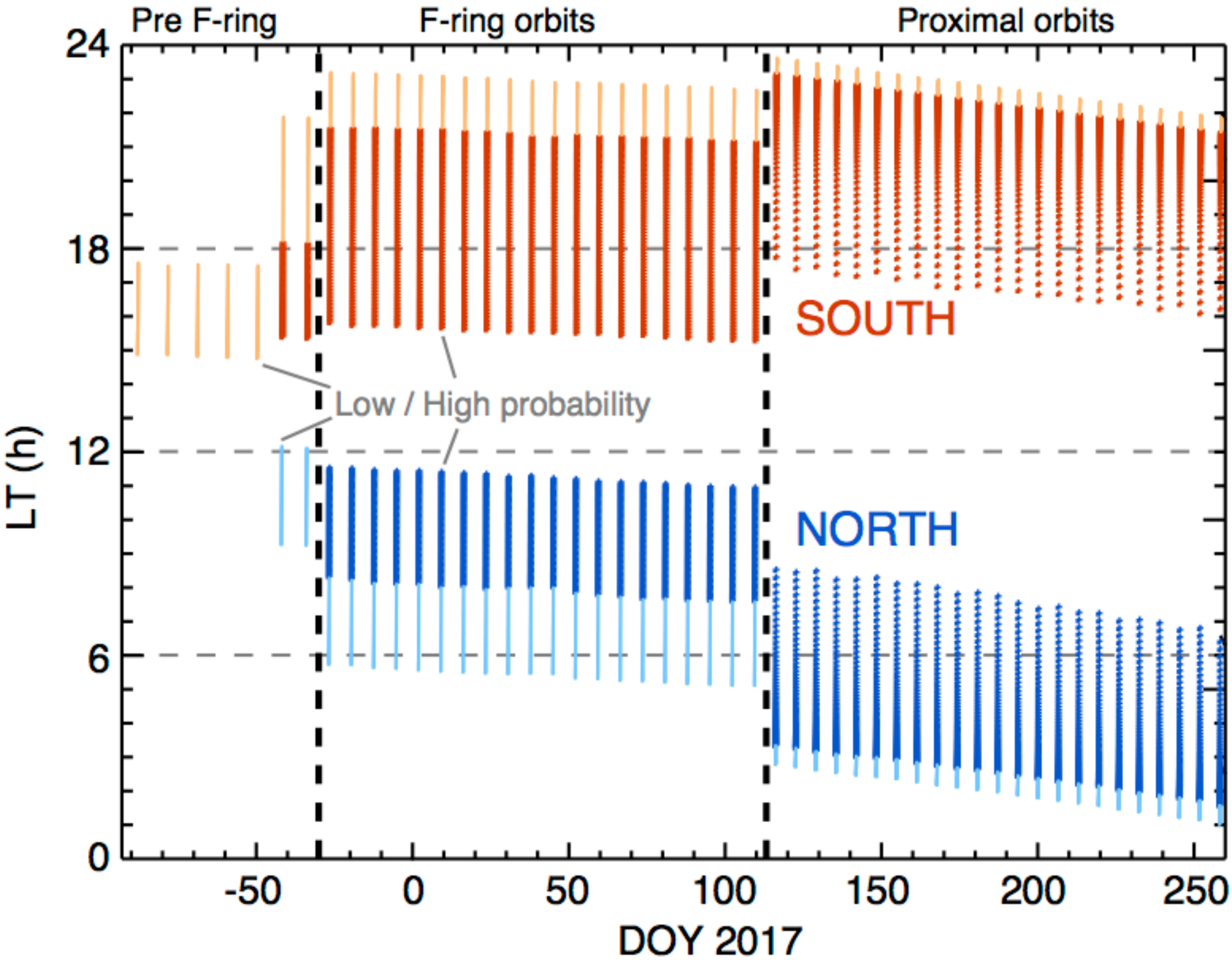
Cassini


Proximal orbits
(revs 271-293)
F-ring orbits
(revs 251-270)
High probability
Low probability
100
10
4
fce (kHz)
0
6
12
18
24
Spacecraft LT (h)

Cassini


Spectral Flux Density [S] (W/m²/Hz) @ 1 AU (from 2-antenna data)
Year 2008
Day 285
2008 Year
286 Day
1000
100
10
Frequency
(kHz)
-19
-20
-21
-22
-23
-24
Log(W/m²/Hz)
Hours of day 12 14 16 18 20 22 00 02 04 06 08 10 12
Distance (Rs) 15.7 16.1 16.5 16.8 17.2 17.5 17.8 18.0 18.3 18.5 18.8 19.0 19.2
Latitude (deg) -21.0 -19.4 -17.8 -16.2 -14.8 -13.4 -12.0 -10.7 -9.4 -8.1 -6.9 -5.7 -4.5
Local Time (hr) 10.1 10.2 10.2 10.2 10.3 10.3 10.3 10.3 10.4 10.4 10.4 10.4 10.5

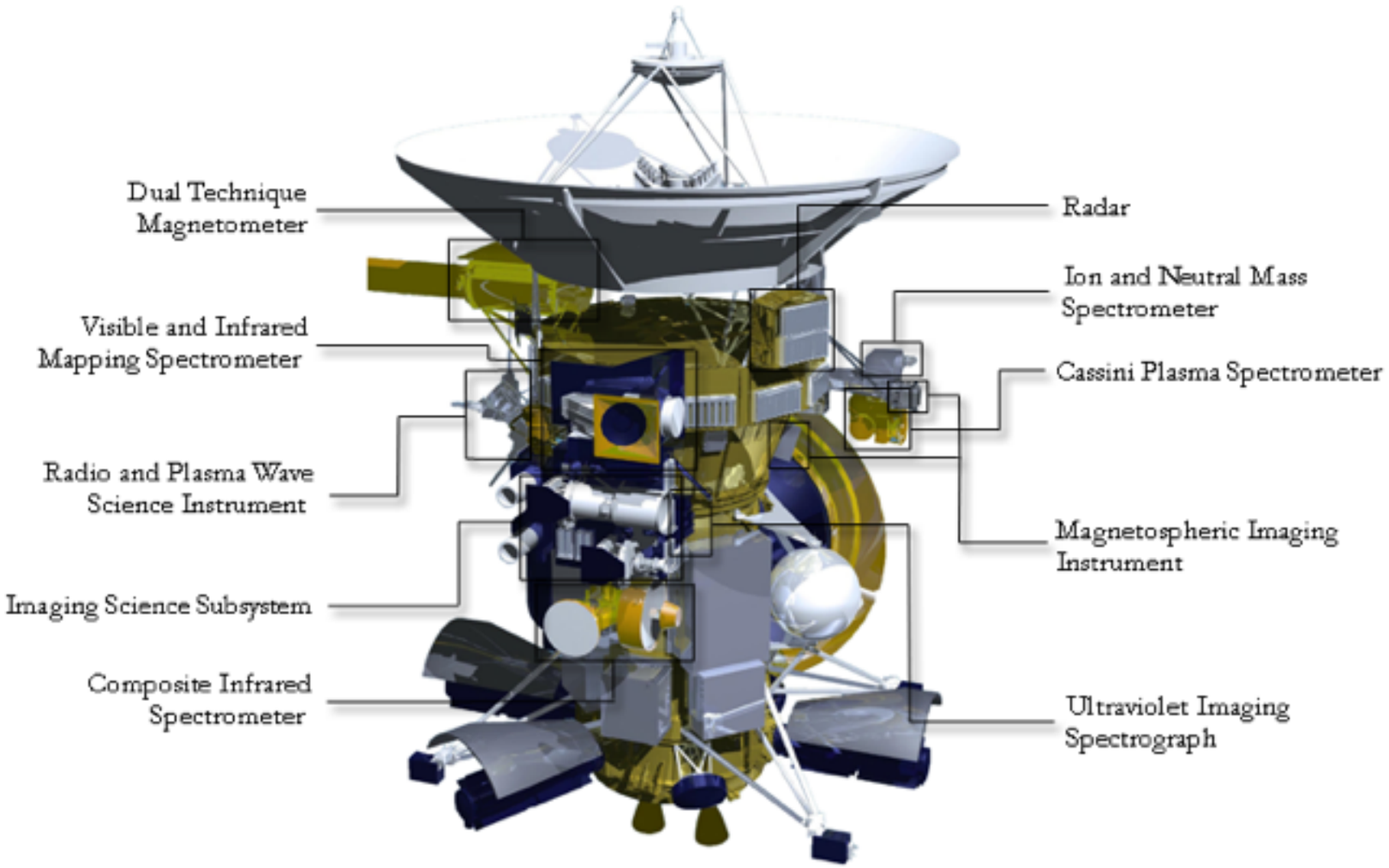
Cassini


Pre F-ring
F-ring orbits
Proximal orbits
SOUTH
NORTH
Low / High probability
LT (h)
24
18
12
6
0
-50
0
50
100
150
200
250
DOY 2017

Cassini

(1) Cassini coordinated observations within SKR sources :

* RPWS : high temporal/spectral resolution + 3A direction-finding + 80kHz waveform around ~ f_{ce}
* MAG : high temporal resolution
* CAPS/MIMI : high temporal and energy resolution
* UVIS/VIMS/ISS : pre-selection of <u>6 revs in MAPS PIEs</u>

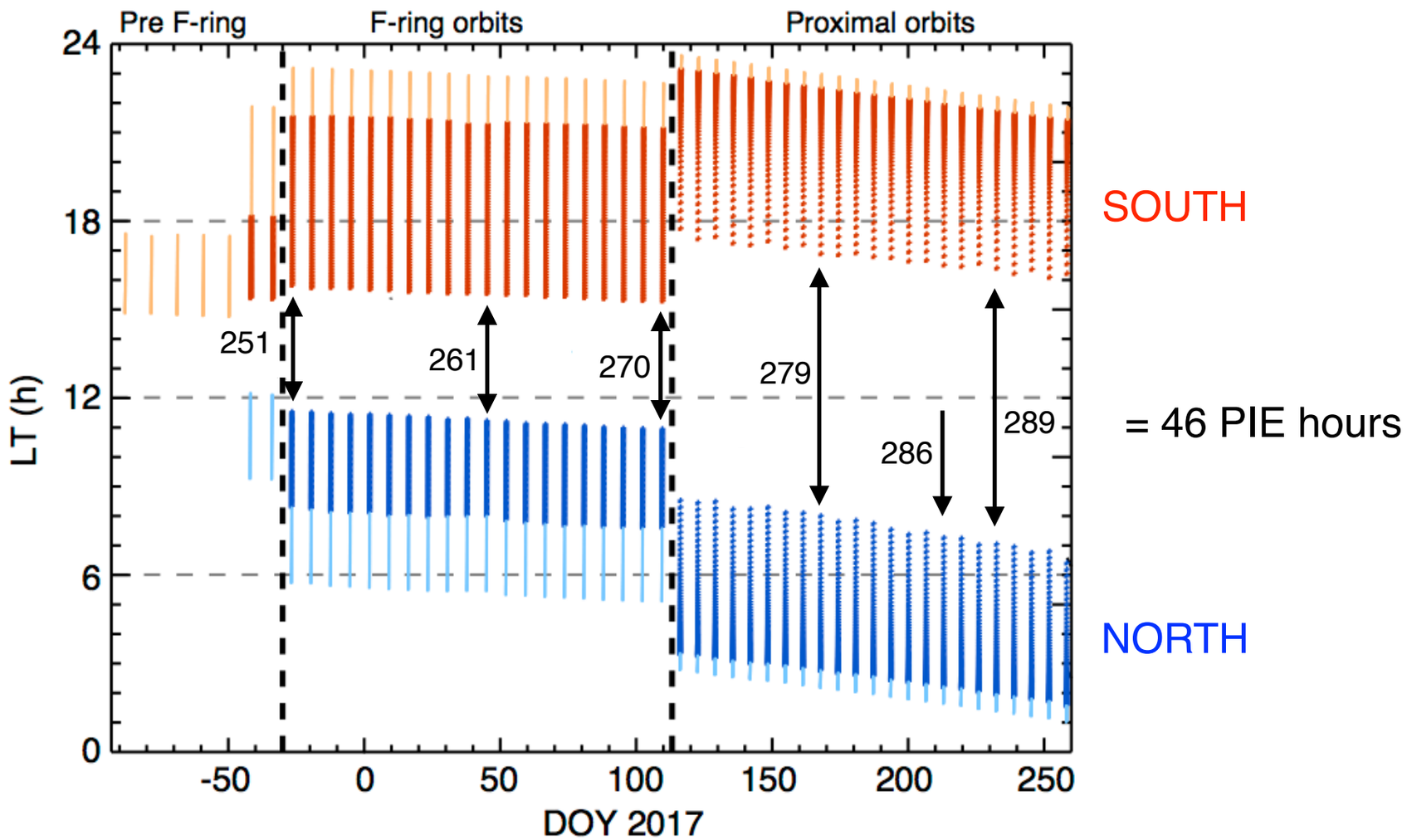


<u>NB :</u> CAPS/ ELS arrêté => plus de mesures d'e-

Cassini

(1) Cassini coordinated observations within SKR sources :

* RPWS : high temporal/spectral resolution + 3A direction-finding + 80kHz waveform around ~ f_{ce}
* MAG : high temporal resolution
* CAPS/MIMI : high temporal and energy resolution
* UVIS/VIMS/ISS : pre-selection of <u>6 revs in MAPS PIEs</u>



= 46 PIE hours

Cassini

(1) Cassini coordinated observations within SKR sources :

* RPWS : high temporal/spectral resolution + 3A direction-finding + 80kHz waveform around ~ f_{ce}
* MAG : high temporal resolution
* CAPS/MIMI : high temporal and energy resolution
* UVIS/VIMS/ISS : pre-selection of 6 revs in MAPS PIEs

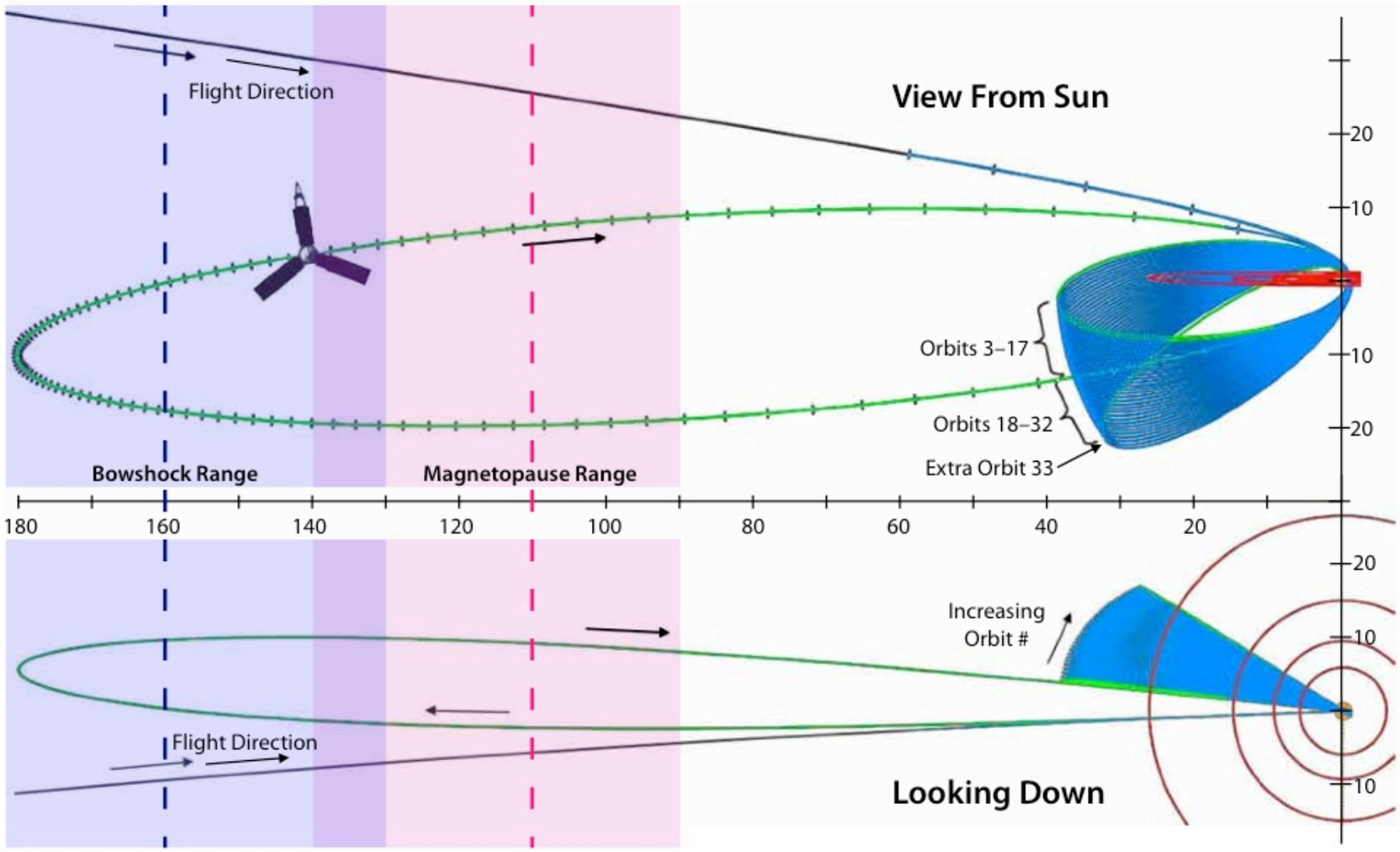
(2) HST coordinated observations in prep.

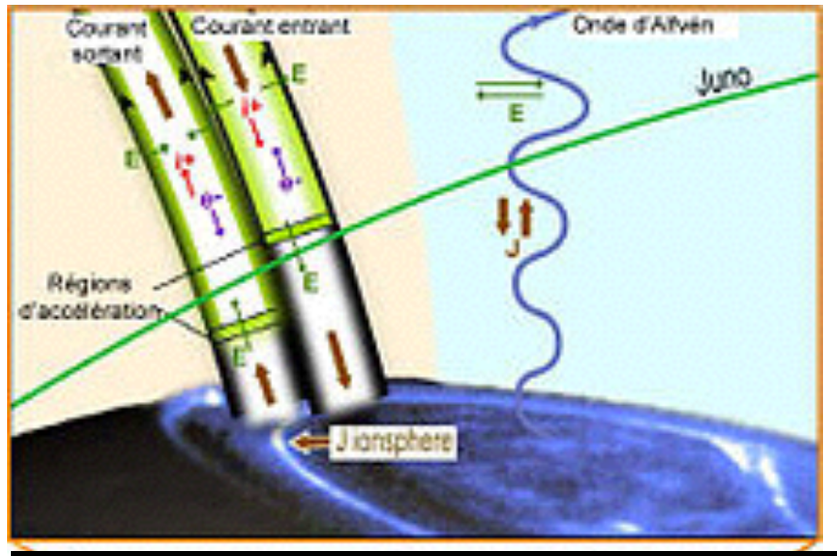
(3) Other coordinated auroral observations : in progress

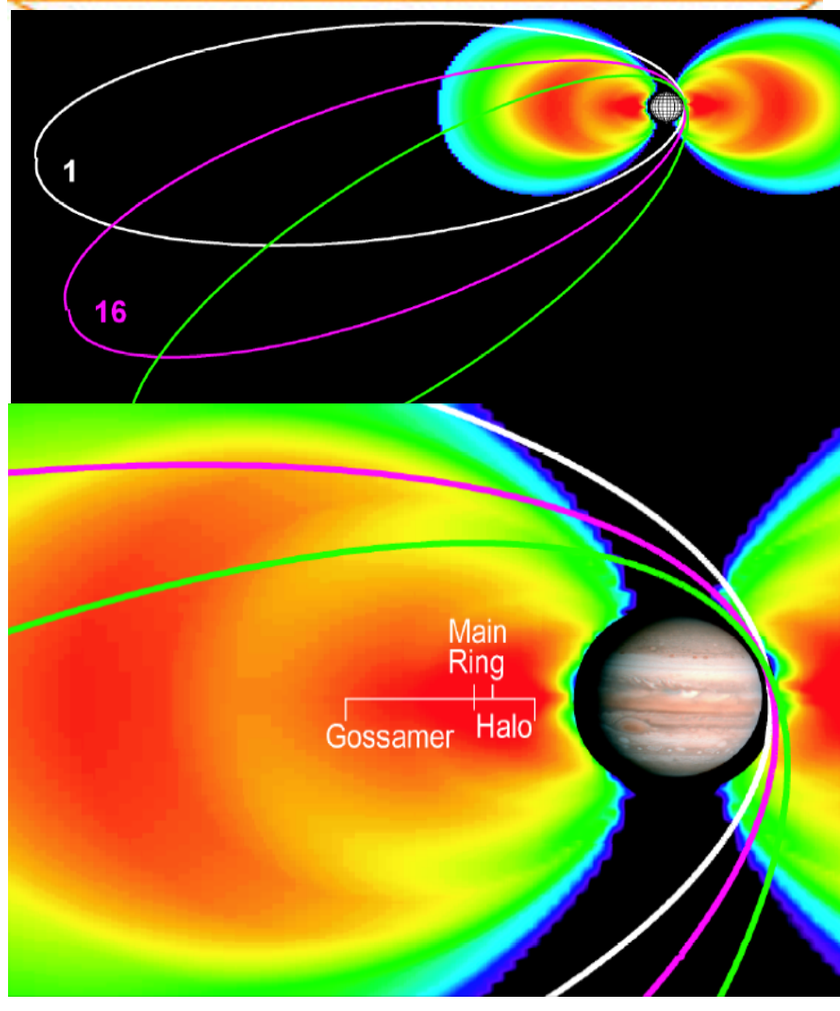
JUNO

- **Origin**
- **Interior**
- **Atmosphere**
- **Magnetosphere**

JUNO

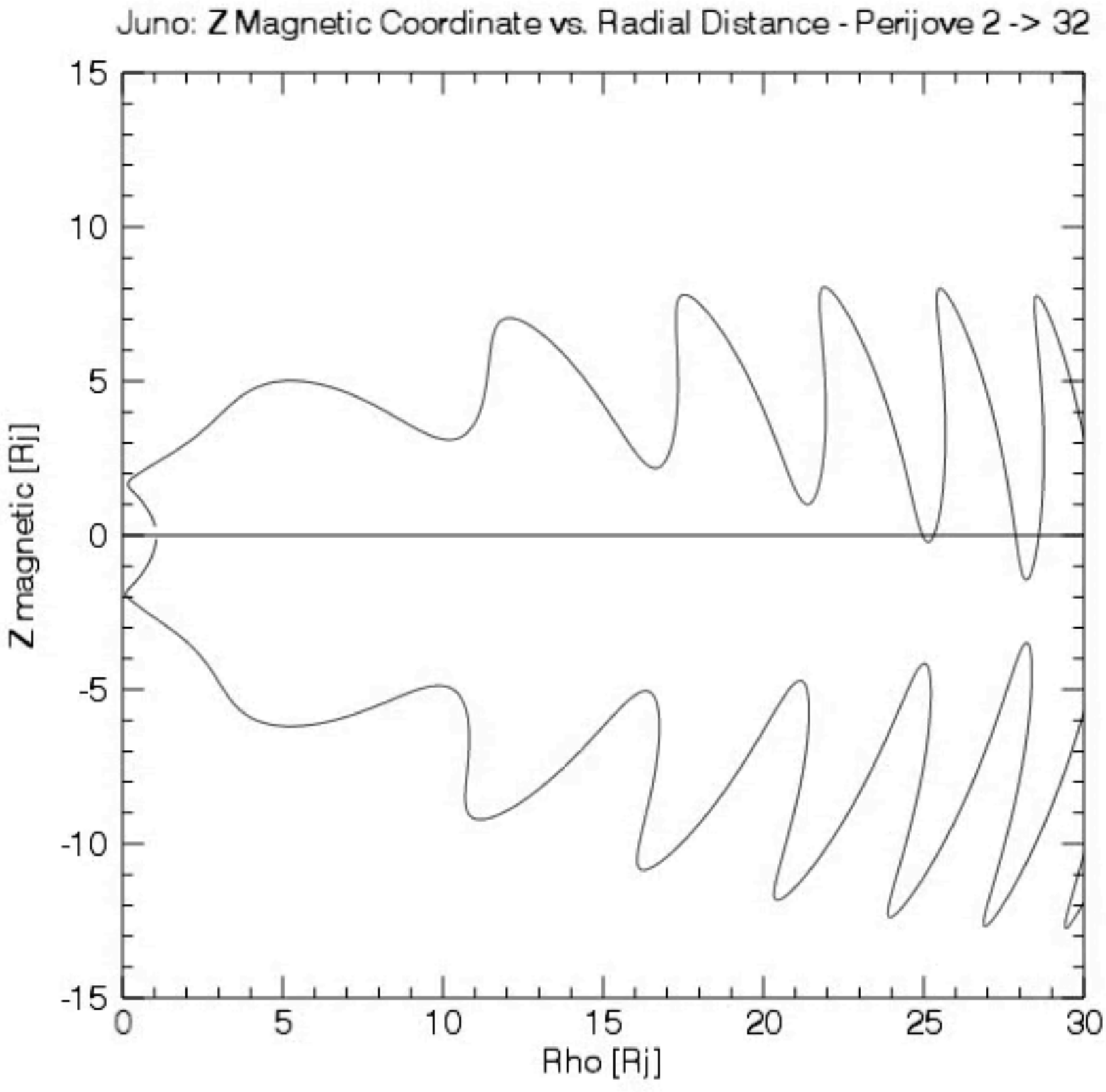




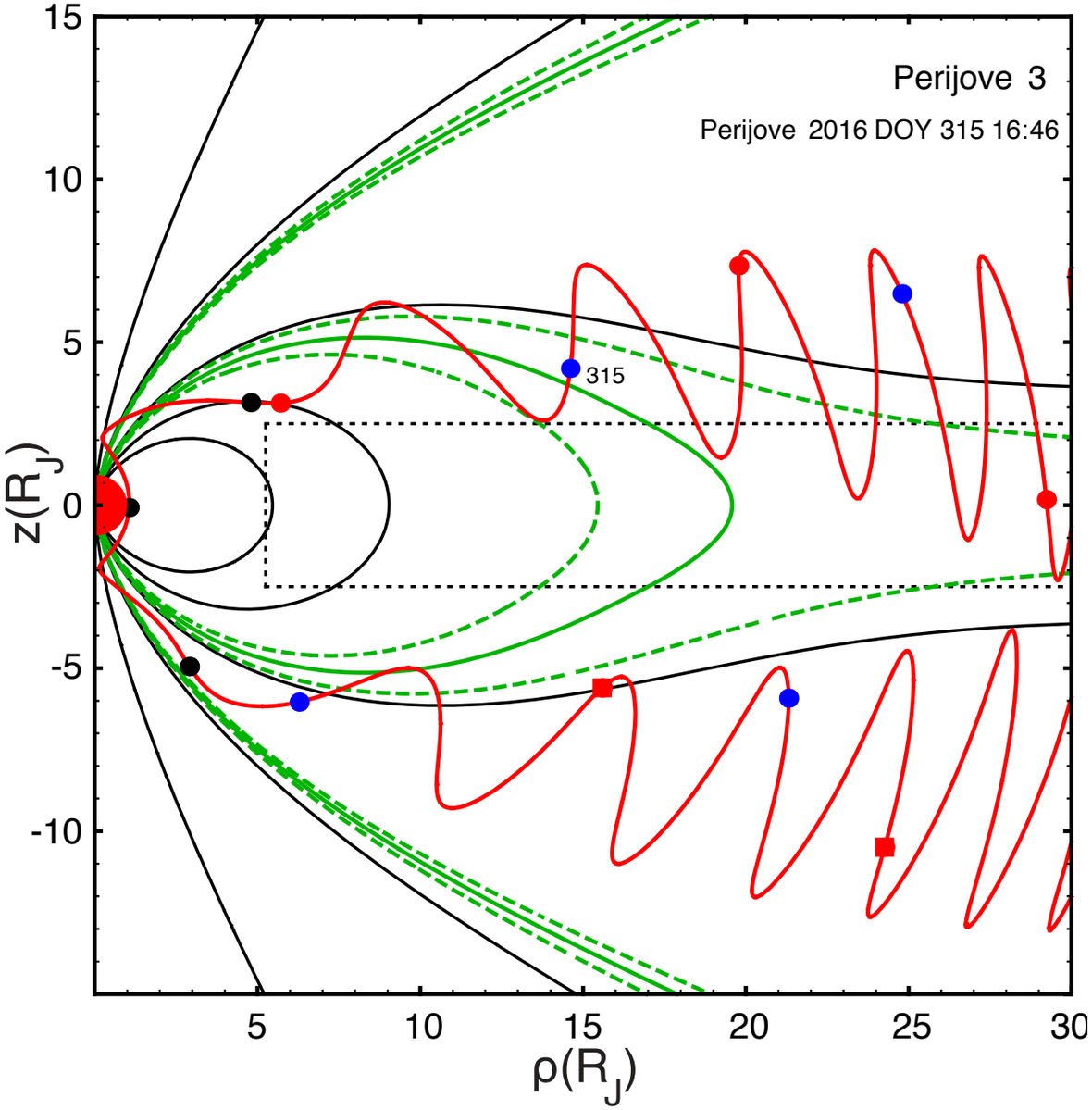


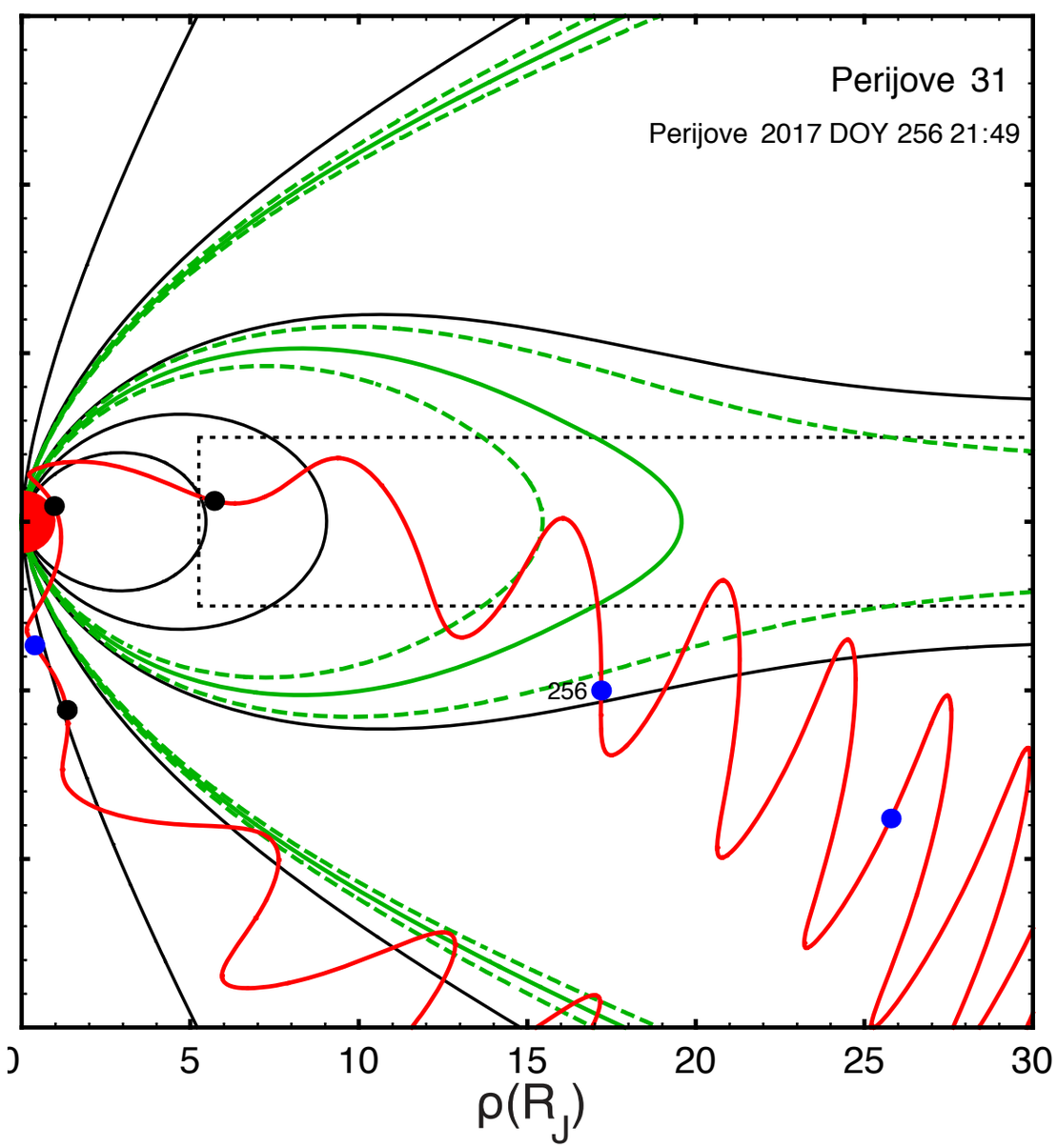
Lancement : 2011
Entrée en orbite : 1er Juillet 2016
Fin de mission : 16 Octobre 2017
32 orbites, périjove ~5000km, P ~ 11 jours

JUNO

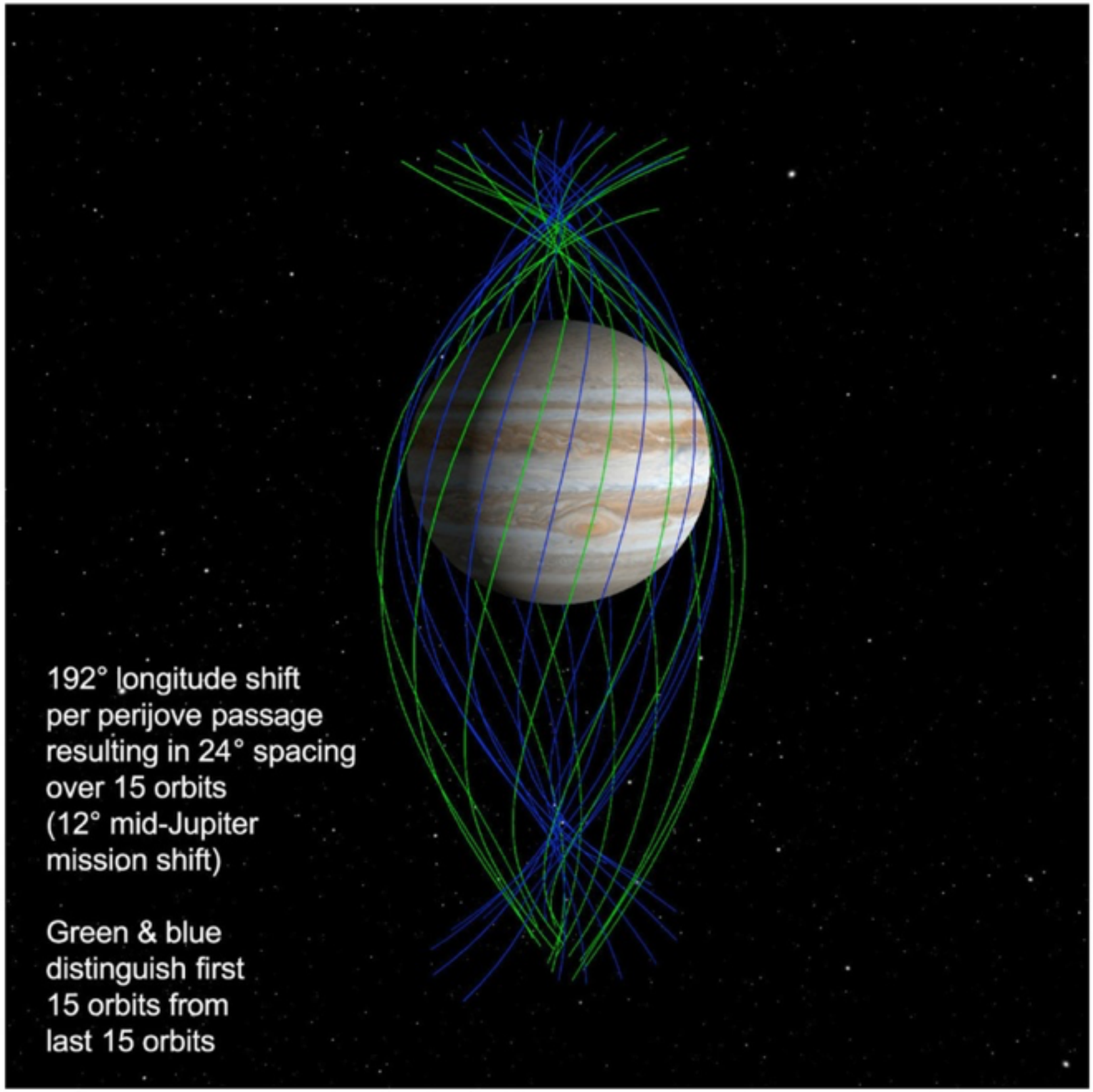

Juno: Z Magnetic Coordinate vs. Radial Distance - Perijove 2 -> 32
Z magnetic [Rj]
Rho [Rj]
15
10
5
0
-5
-10
-15
0
5
10
15
20
25
30

JUNO


Perijove 3
Perijove 2016 DOY 315 16:46
315
15
10
5
0
-5
-10
z(R_J)
5
10
15
20
25
30
ρ(R_J)

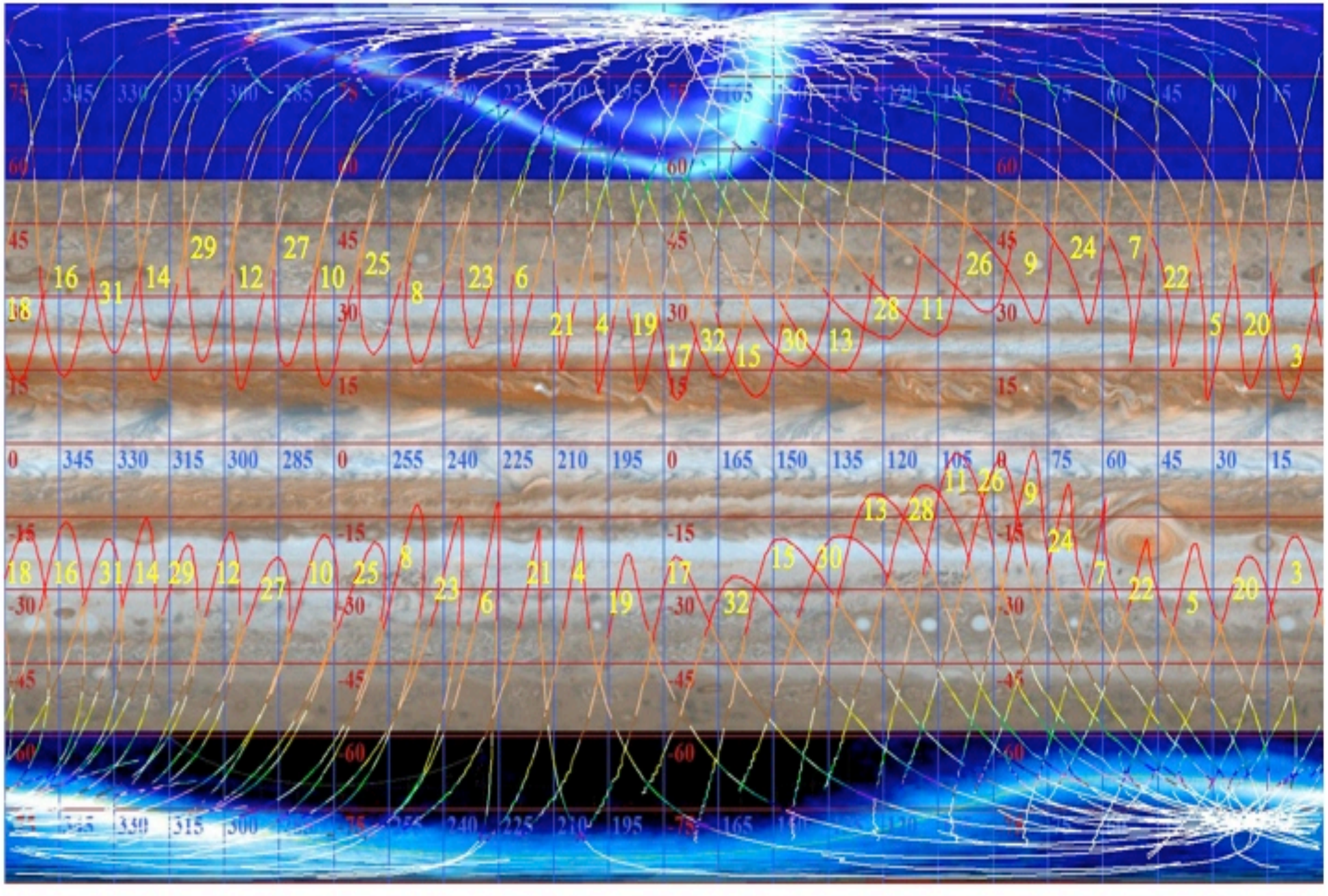

Perijove 31
Perijove 2017 DOY 256 21:49
256
5
10
15
20
25
30
ρ(R_J)

JUNO

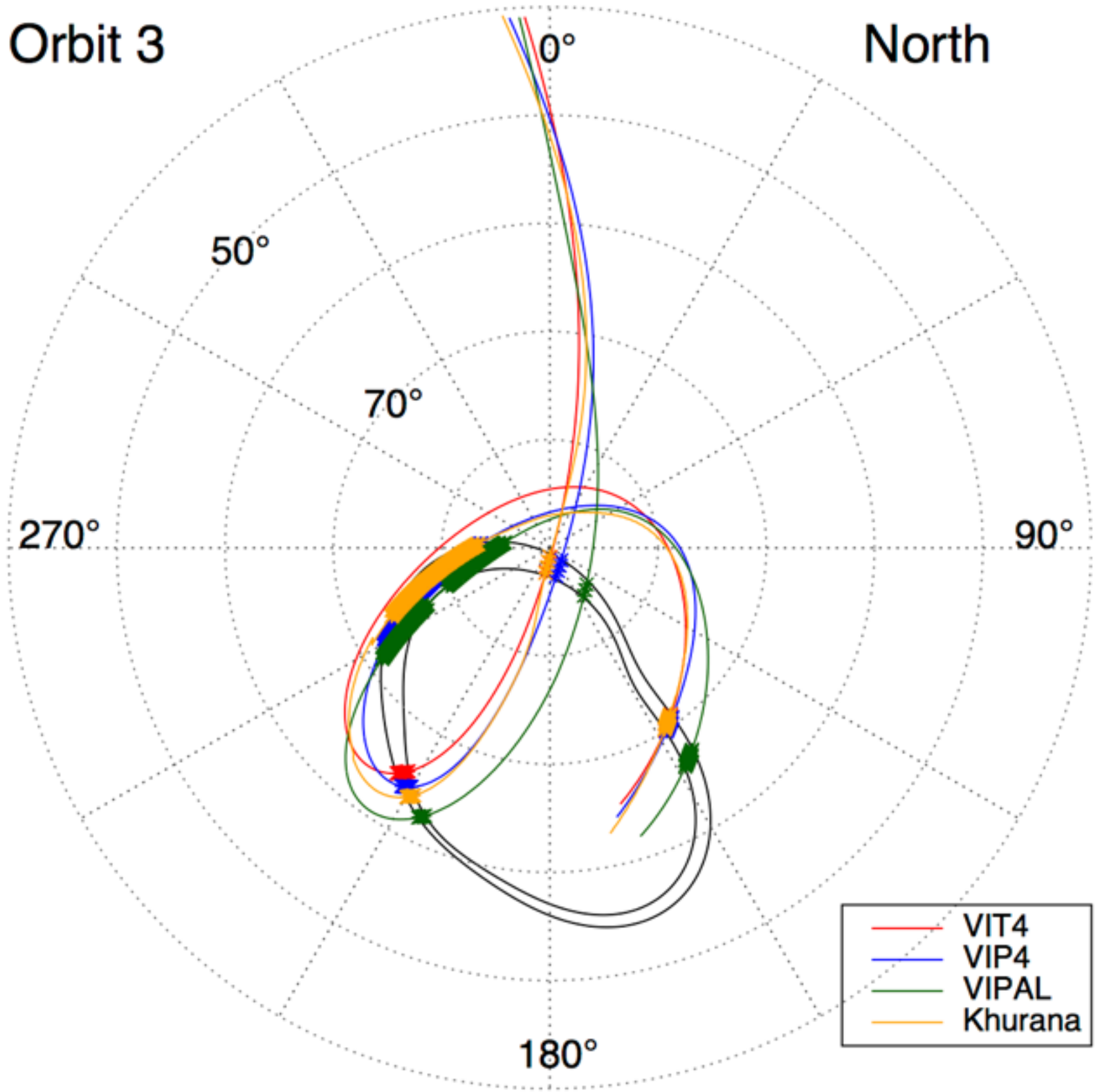

192° longitude shift
per perijove passage
resulting in 24° spacing
over 15 orbits
(12° mid-Jupiter
mission shift)
Green & blue
distinguish first
15 orbits from
last 15 orbits

JUNO

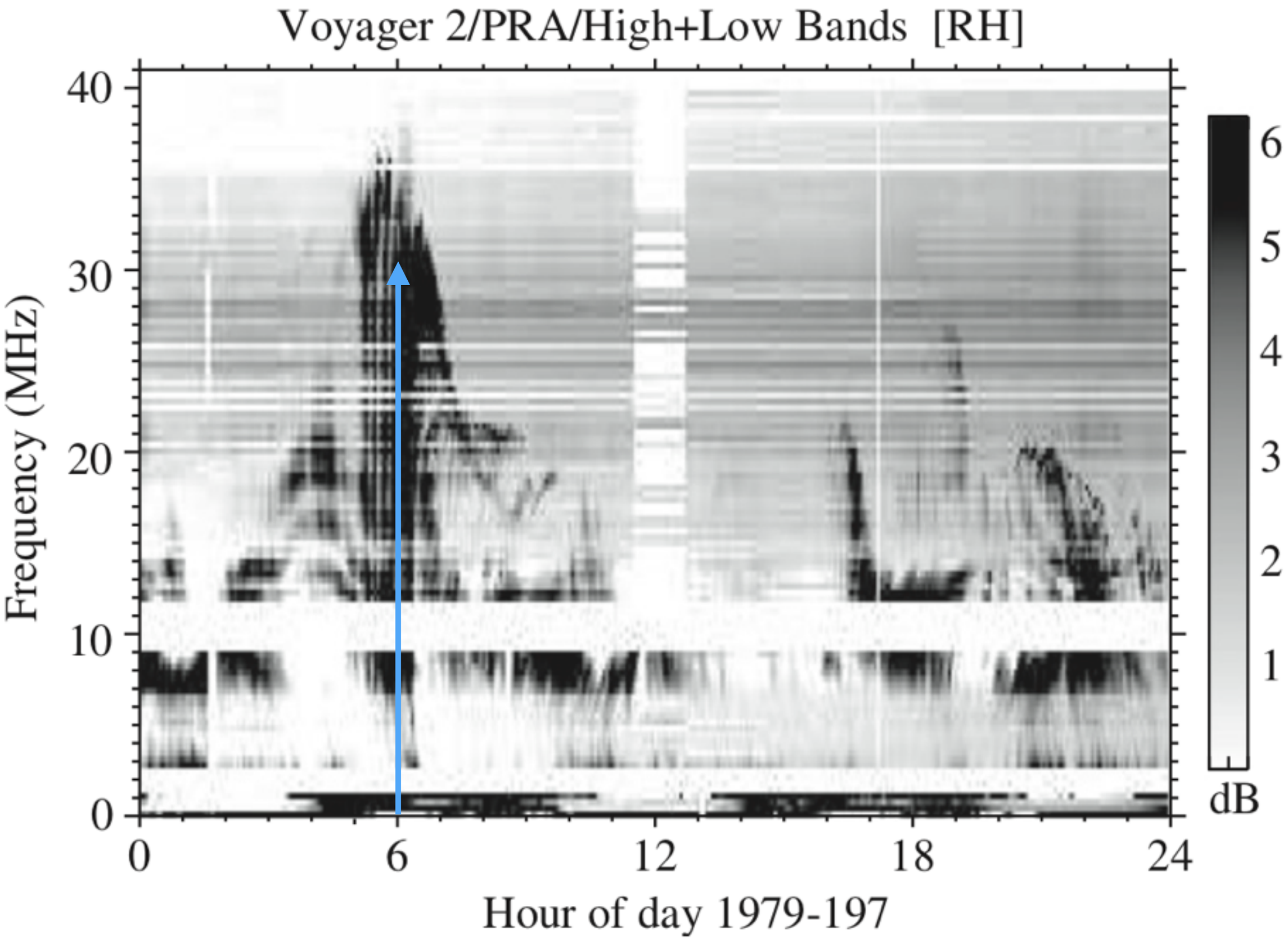
Magnetic Field Line Tracks (3-32)



JUNO



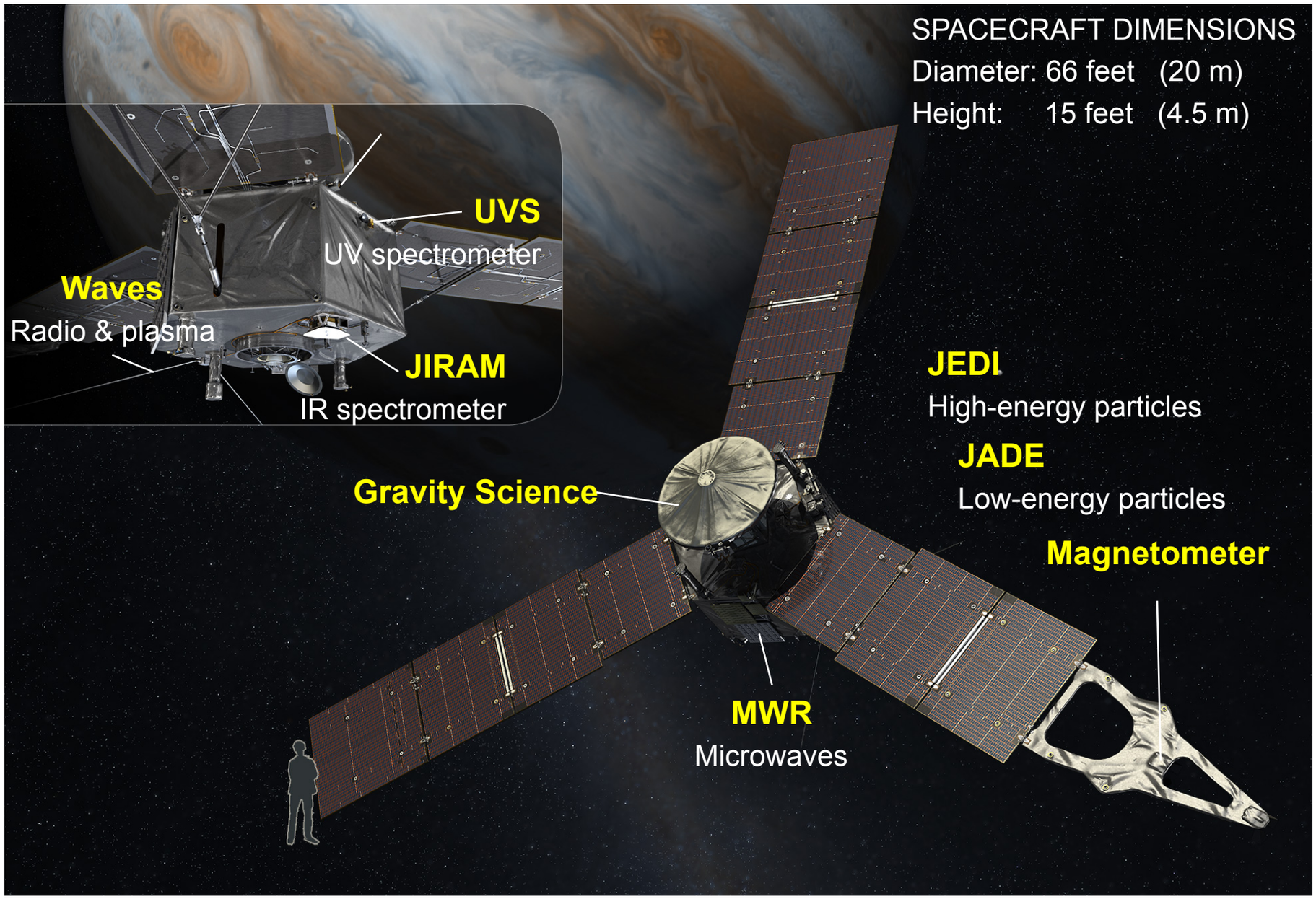
JUNO


Voyager 2/PRA/High+Low Bands [RH]
Frequency (MHz)
40
30
20
10
0
0
6
12
18
24
Hour of day 1979-197
6
5
4
3
2
1
dB

JUNO

(1) Observations magnétosphériques :

* WAVES : instrument radio
* MAG : magnétomètre
* JADE/JEDI : analyseurs de particules e-/ions
* JIRAM : sp-im IR
* UVS : sp-im UV



JUNO

(1) Observations magnétosphériques :

* WAVES : instrument radio
* MAG : magnétomètre
* JADE/JEDI : analyseurs de particules e-/ions
* JIRAM : sp-im IR
* UVS : sp-im UV

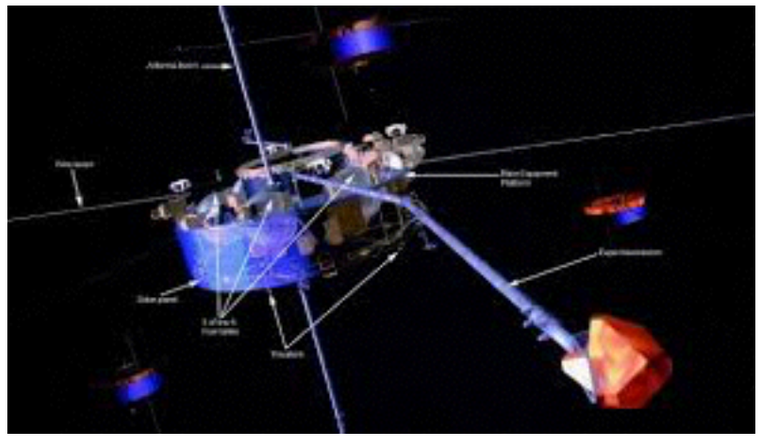
(2) HST coordinated observations in prep.

Cluster

En 2009 et 2013, Cluster dans les régions d'accélération aurorales

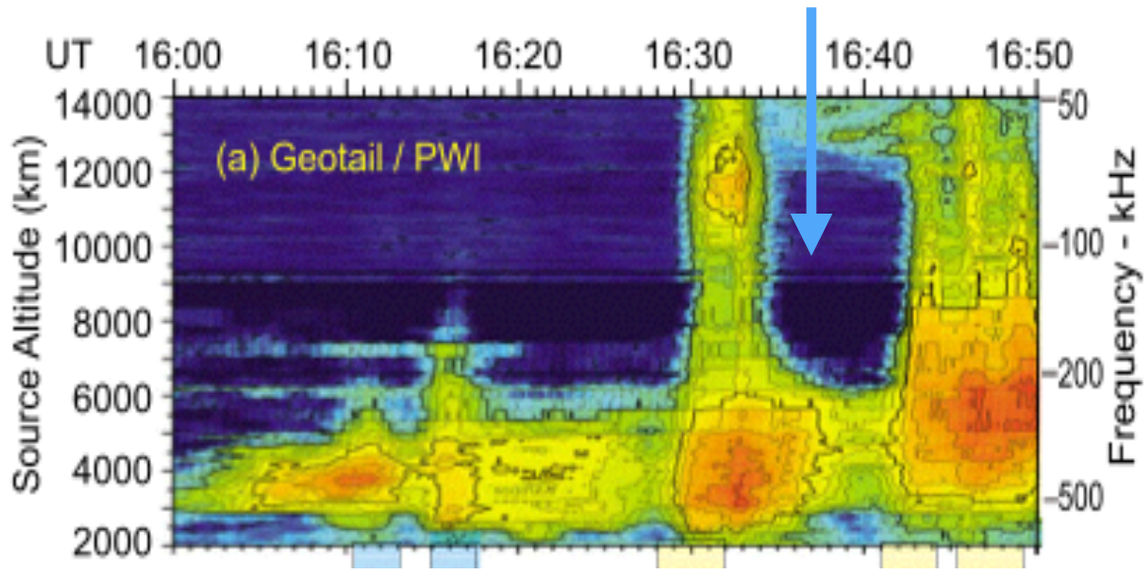
En 2013, dates remarquables :

29 Mars
7 Avril
25 Avril
2 Mai
11 Mai
27 Mai
14 Juin



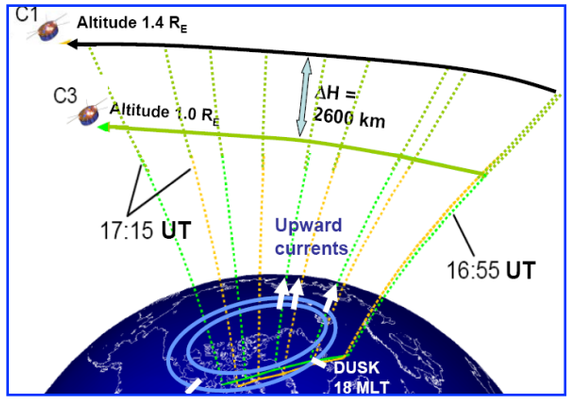
Thèmes en cours d'étude :

- Evolution spatio-temporelle des régions d'accélération
- Caractérisation de la turbulence forte associée aux structures d'accélération
- Caractérisation des rayonnements auroraux



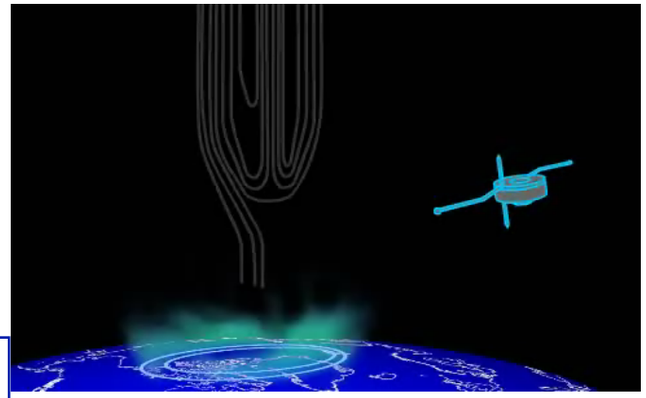
Cluster

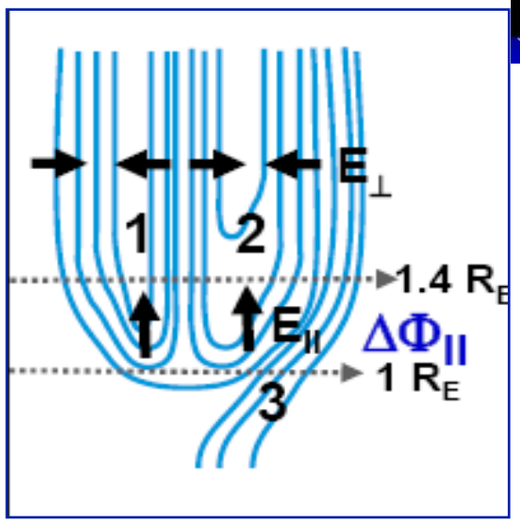
(i) Evolution temporelle de l'accélération



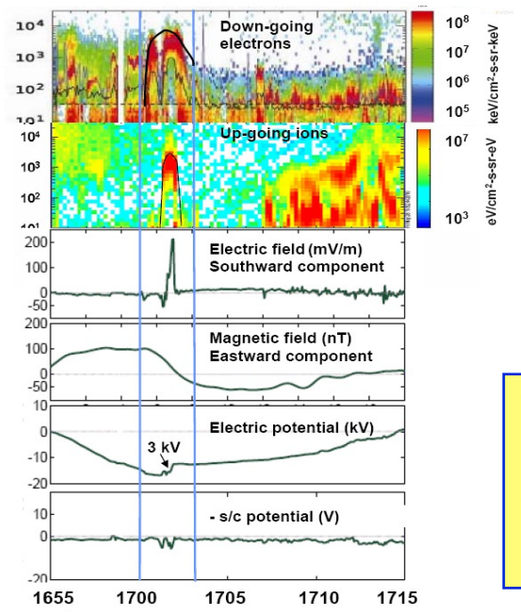
2009-06-05
18 MLT, 17 UT

Marklund et al., PRL, 2011



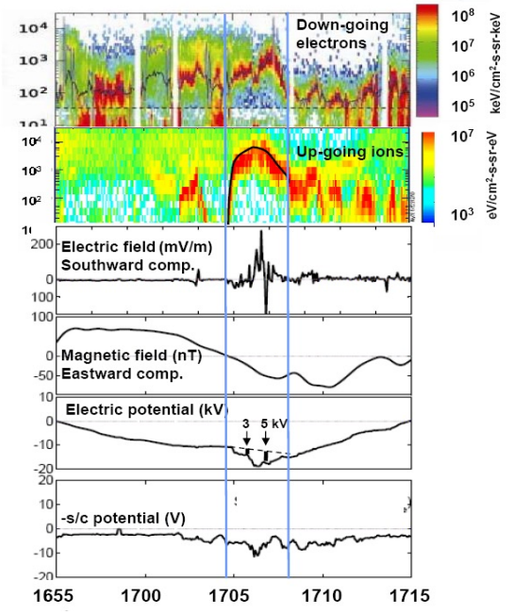


Cluster 3 data from H = 1 R_E



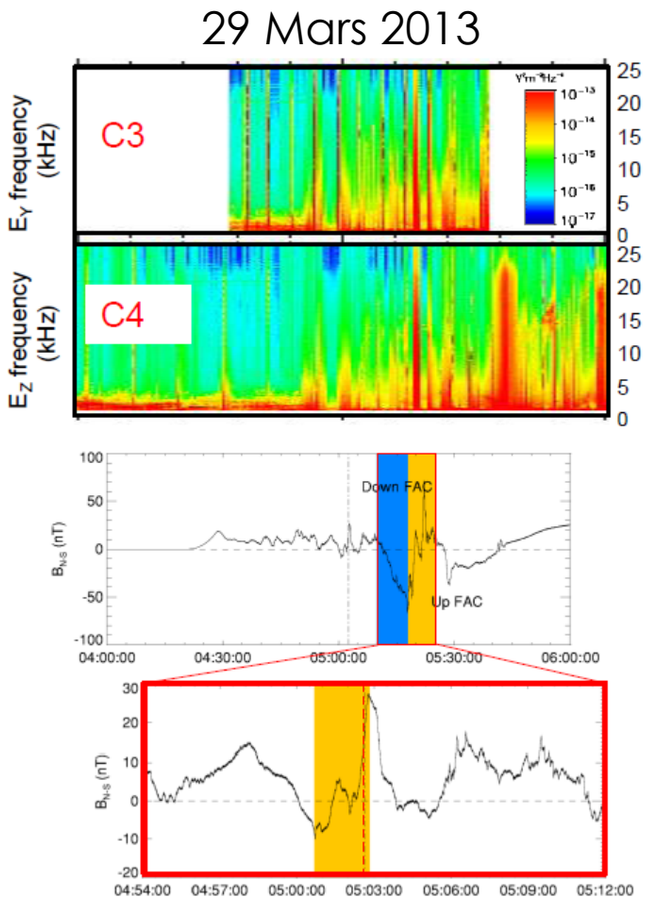
Two U-shaped + one S-shaped potential combined, consistent with C3 and C1 data, and stable on a time scale of 5 minutes

Cluster 1 data from H = 1.4 R_E

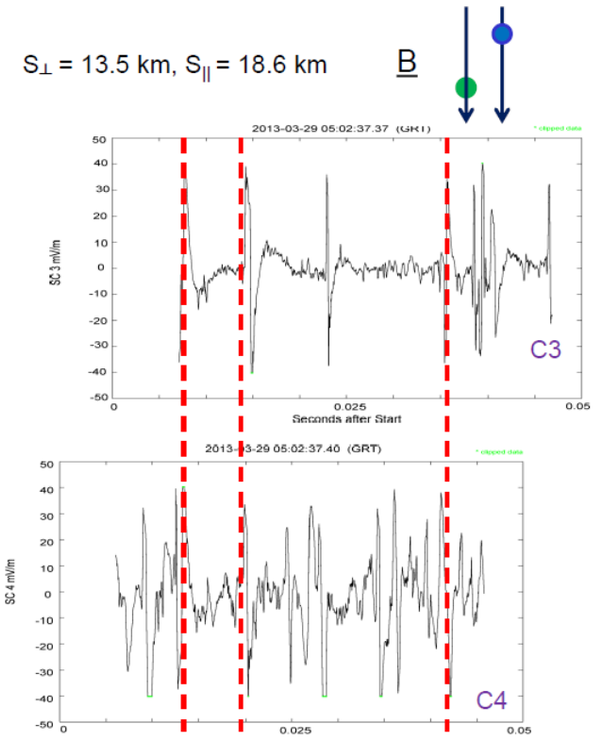


Cluster

(ii) Turbulence forte vue en 2013



Fazakerley, private com

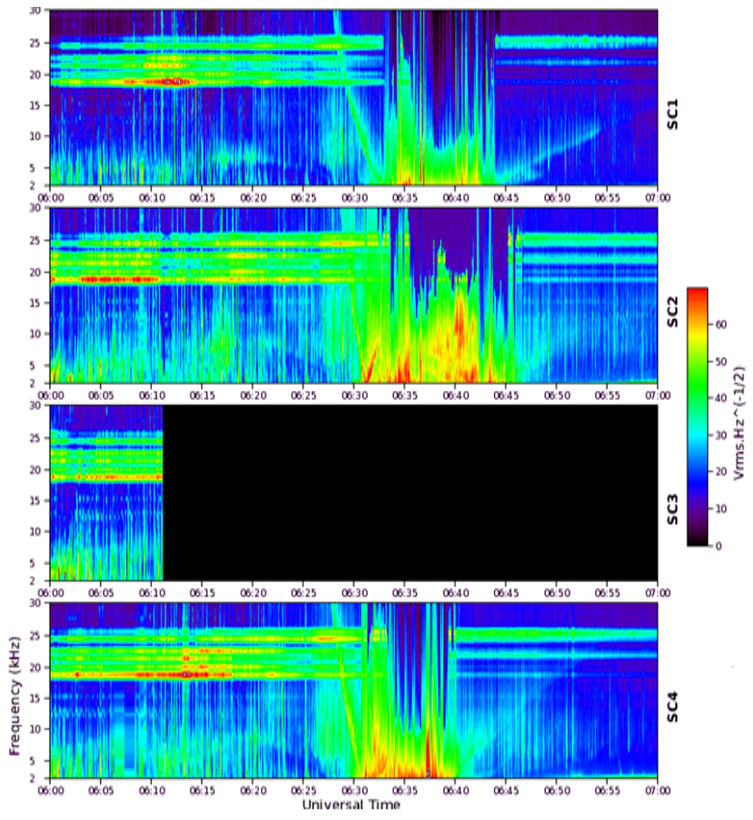


- Estimation de la vitesse ~500 km/s et de la taille (~km) des structures non-linéaires
- Influence sur le rayonnement kilométrique ?

Cluster

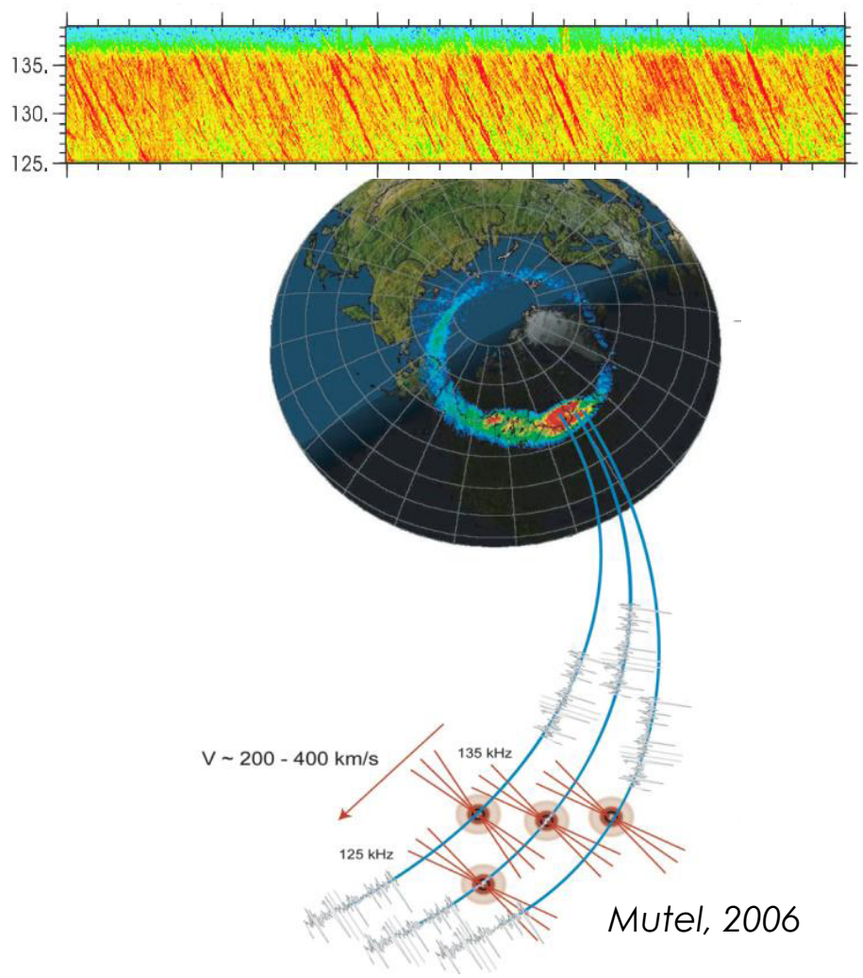
(iii) Rayonnements vus par Cluster

Stabilité des sources de VLF saucers



Masson, private com

Lien entre turbulence forte et AKR



Mutel, 2006