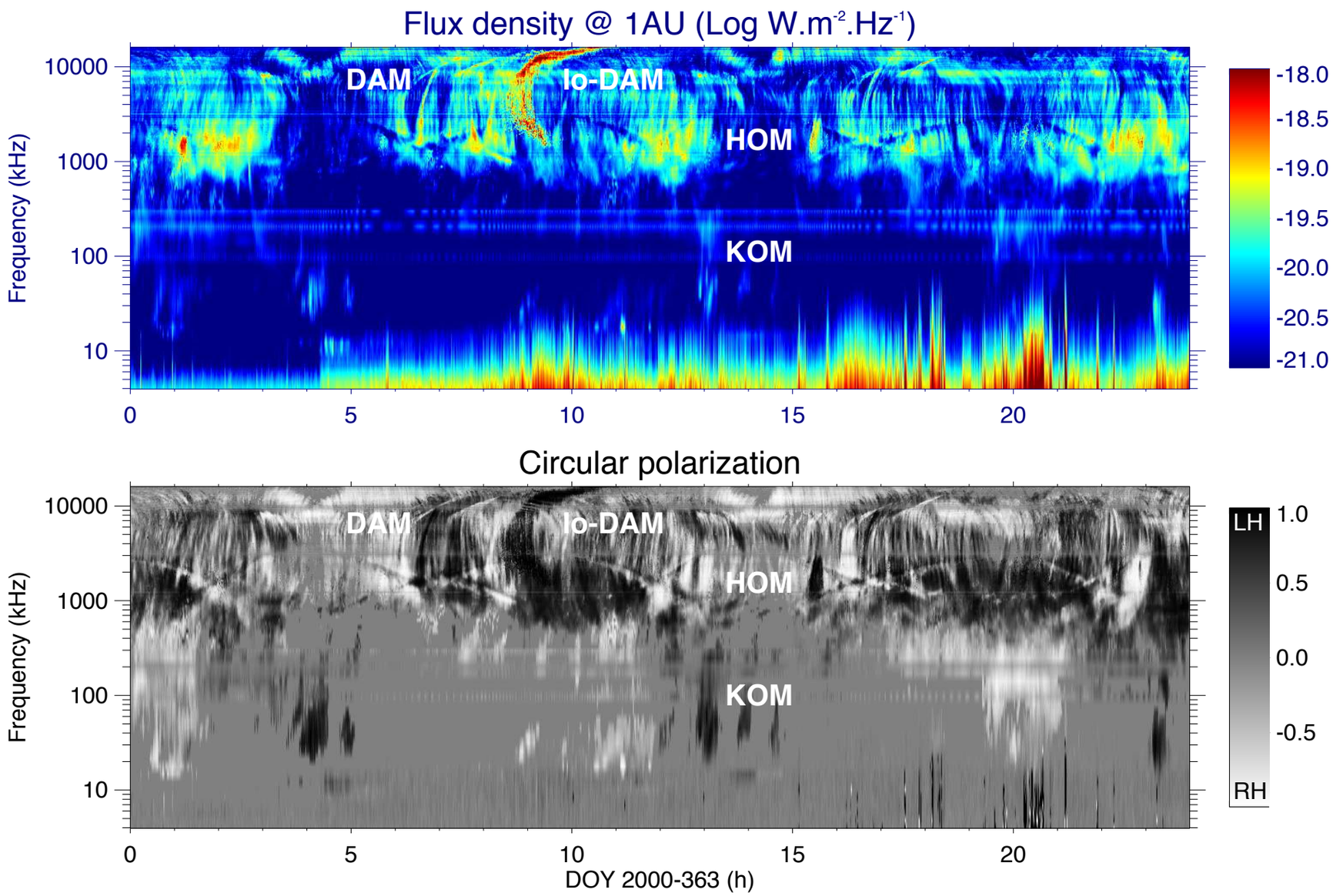
Past and future observations of Jupiter with Cassini/RPWS



L. Lamy, C. Louis, P. Zarka, B. Cecconi

LESIA, CNRS-Observatoire de Paris

Outline

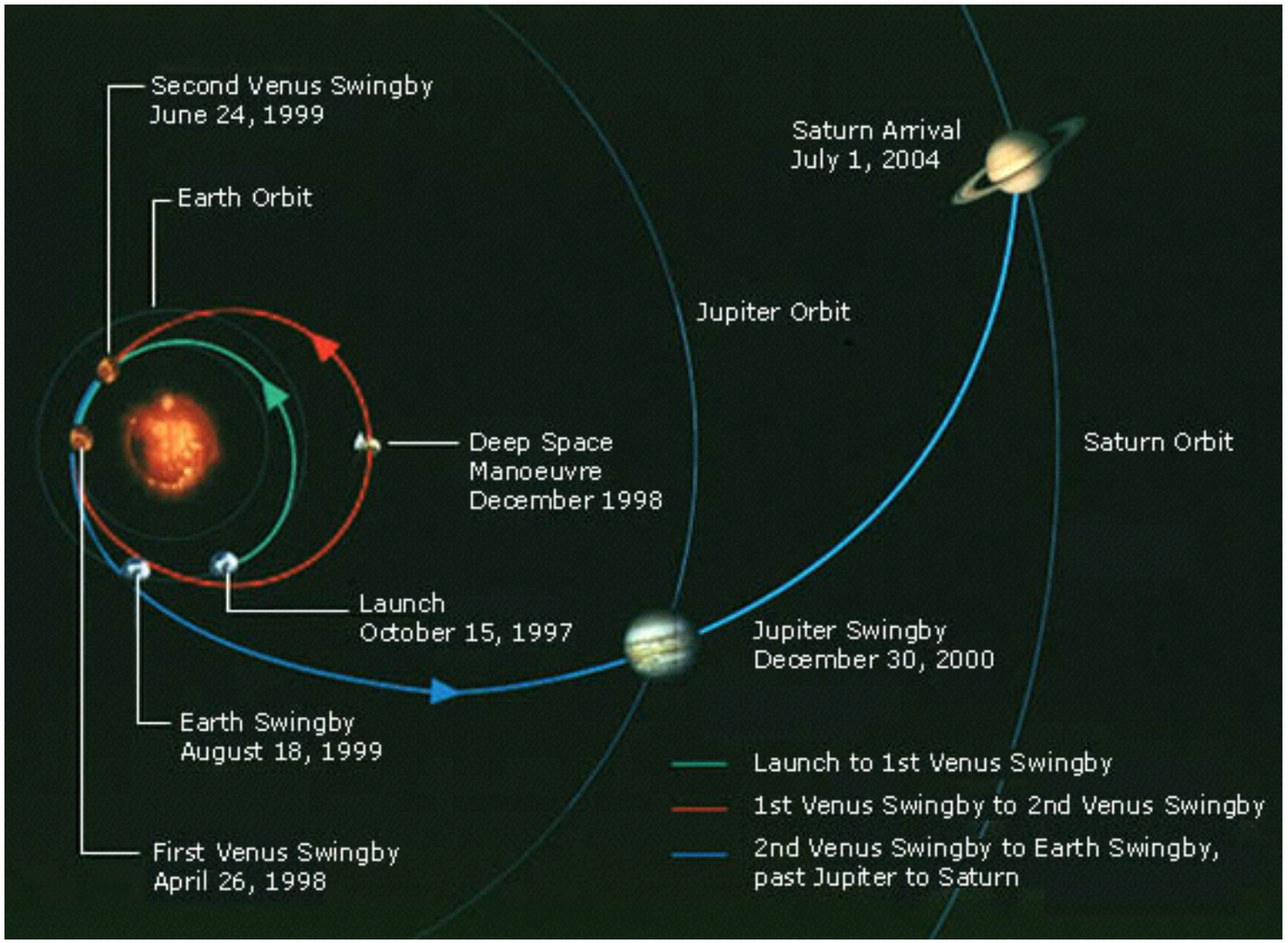
1- Catalog of Jovian emissions recorded <u>outside</u> the flyby period

2- Search for planet-satellites interactions <u>during</u> the flyby

(a) Using time series of power

(b) Using ExPRES simulations

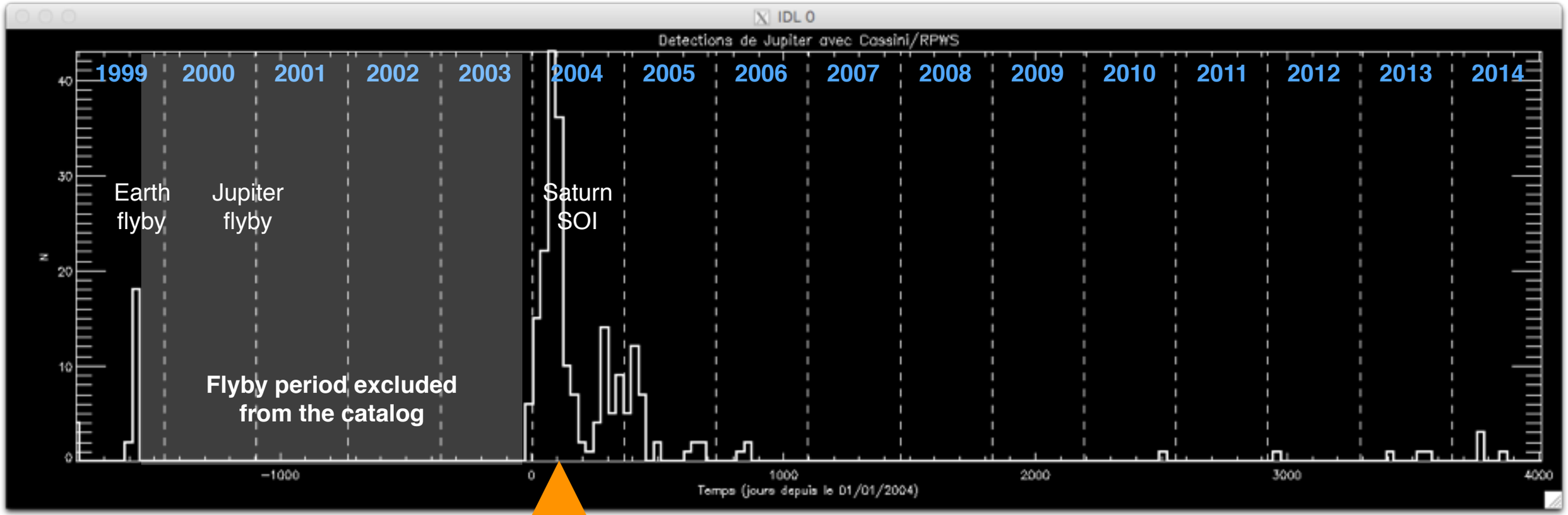
Jupiter flyby



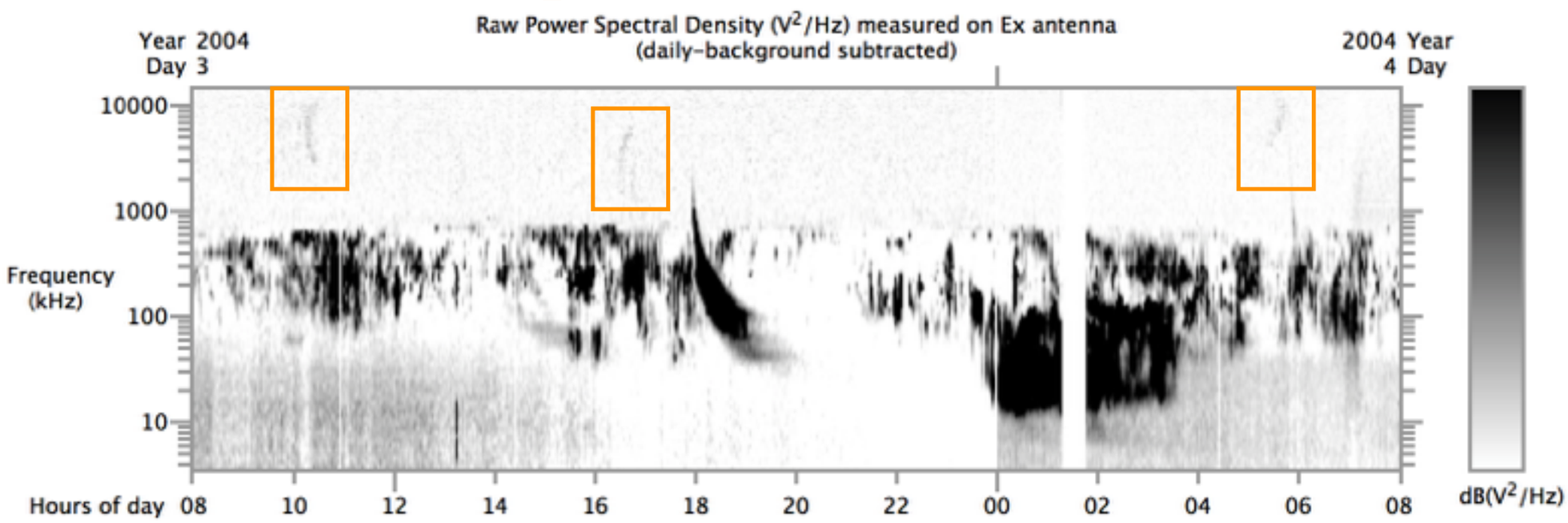
Few studies of Jupiter auroral radio emissions during the 2000-2001 flyby : e.g.

- Beam width of HOM-DAM emissions (Kaiser et al., 2000)
- Solar wind control of HOM-DAM (Gurnett et al., 2002 ; Hess et al., 2014)
- Average spectrum over 3kHz-16MHz (Zarka, 2004)
- DAM beaming (Imai, 2008, 2011, 2015)
- …

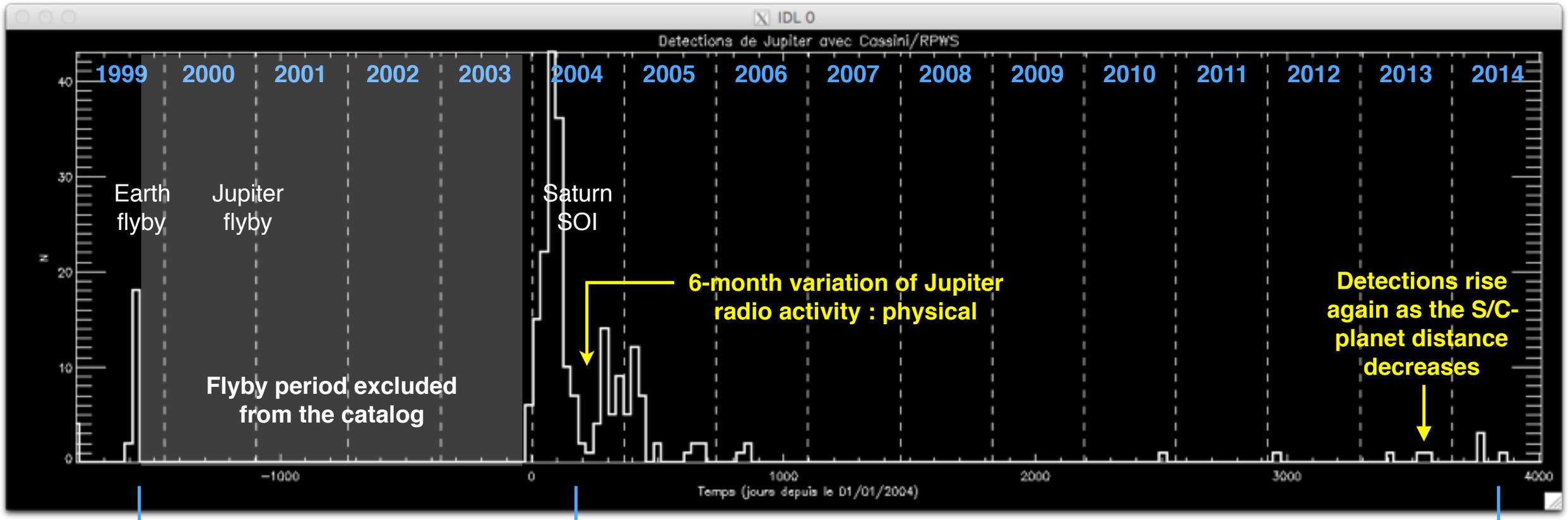
1- Catalog of Jovian emissions <u>outside</u> the flyby

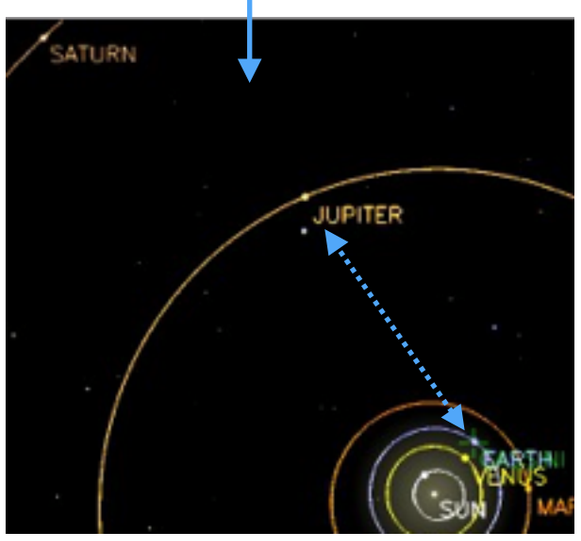


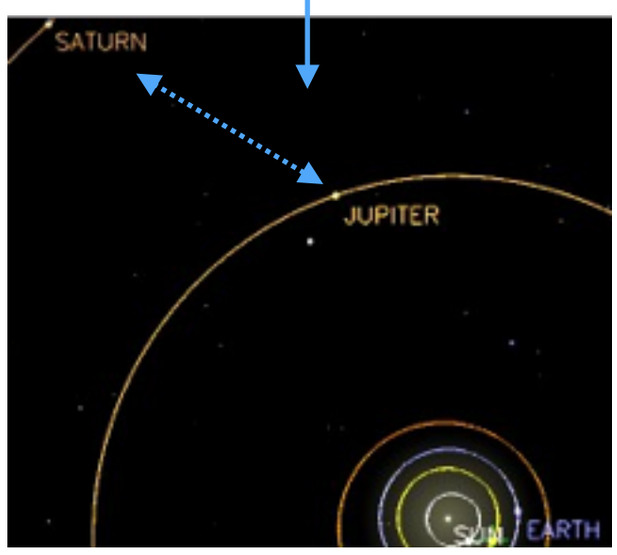
(Beaudonnet, Wurmser, internship 2015)

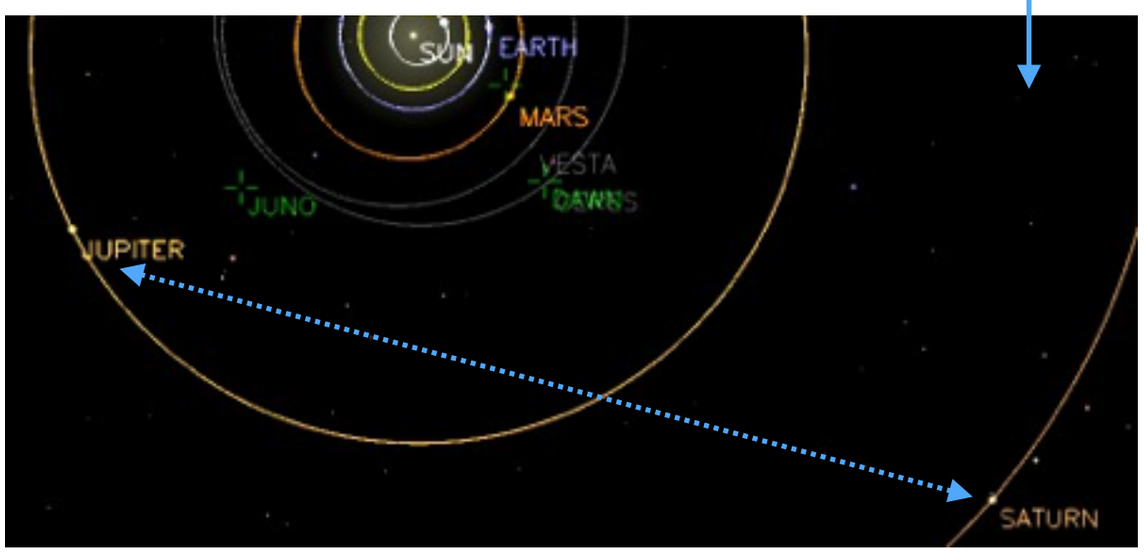


1- Catalog of Jovian emissions outside the flyby

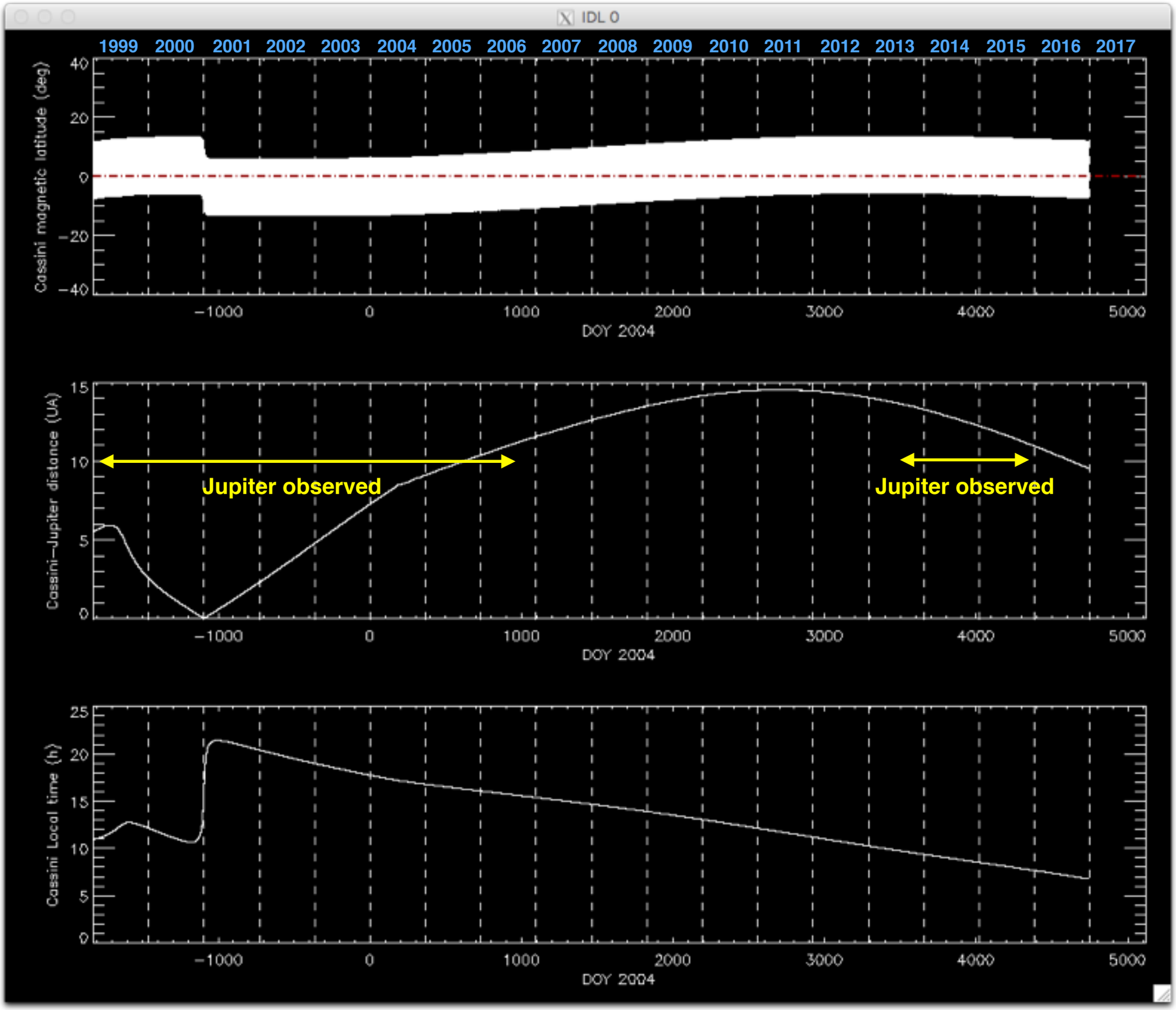




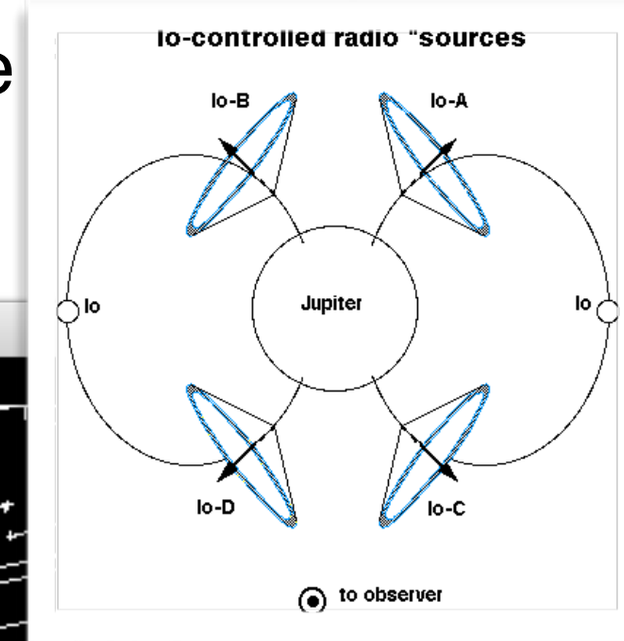




1- Catalog of Jovian emissions outside the flyby



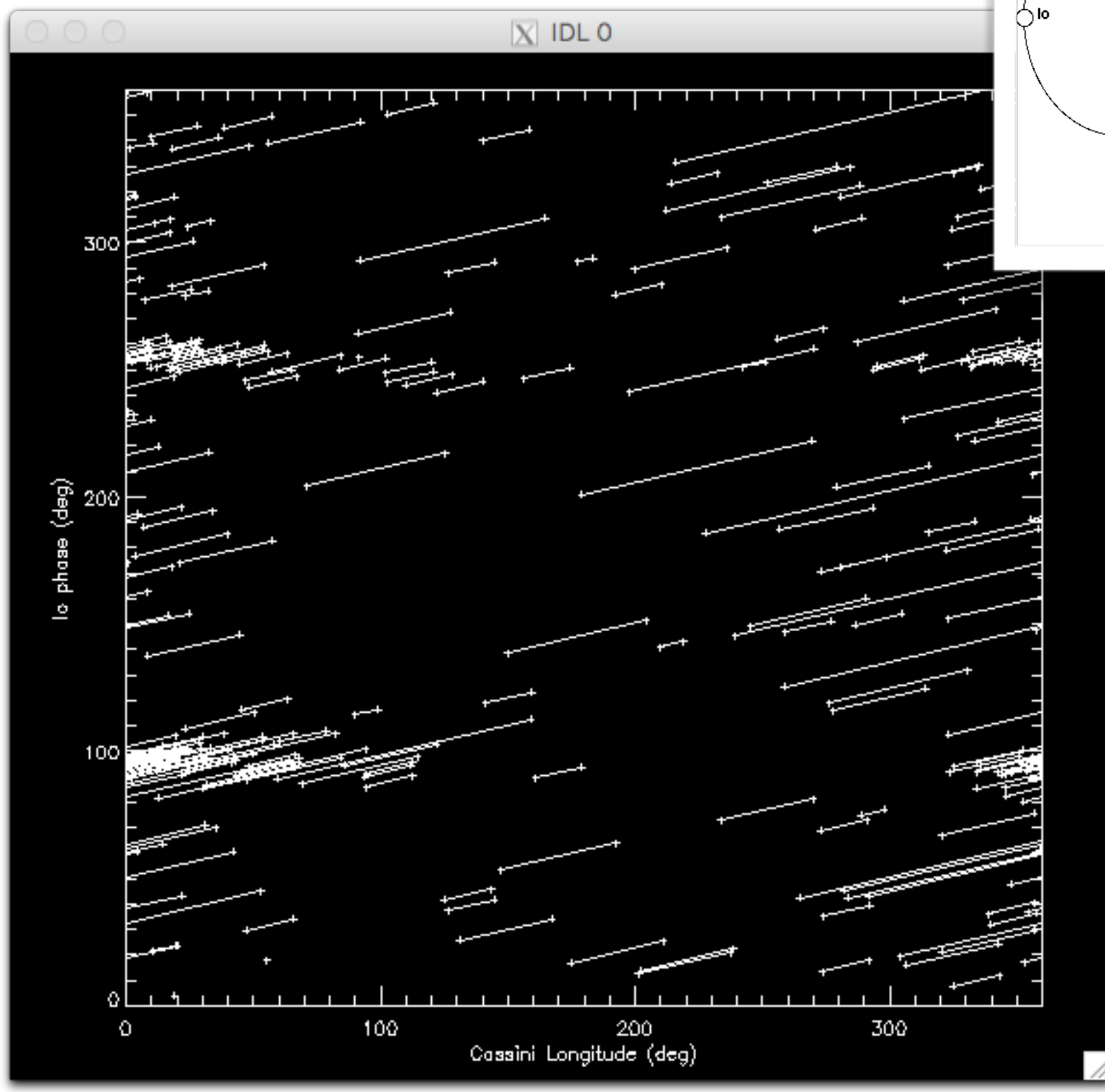
1- Catalog of Jovian emissions <u>outside</u> the



Io phase-CML diagram

Mainly Io-C →

Mainly Io-D →



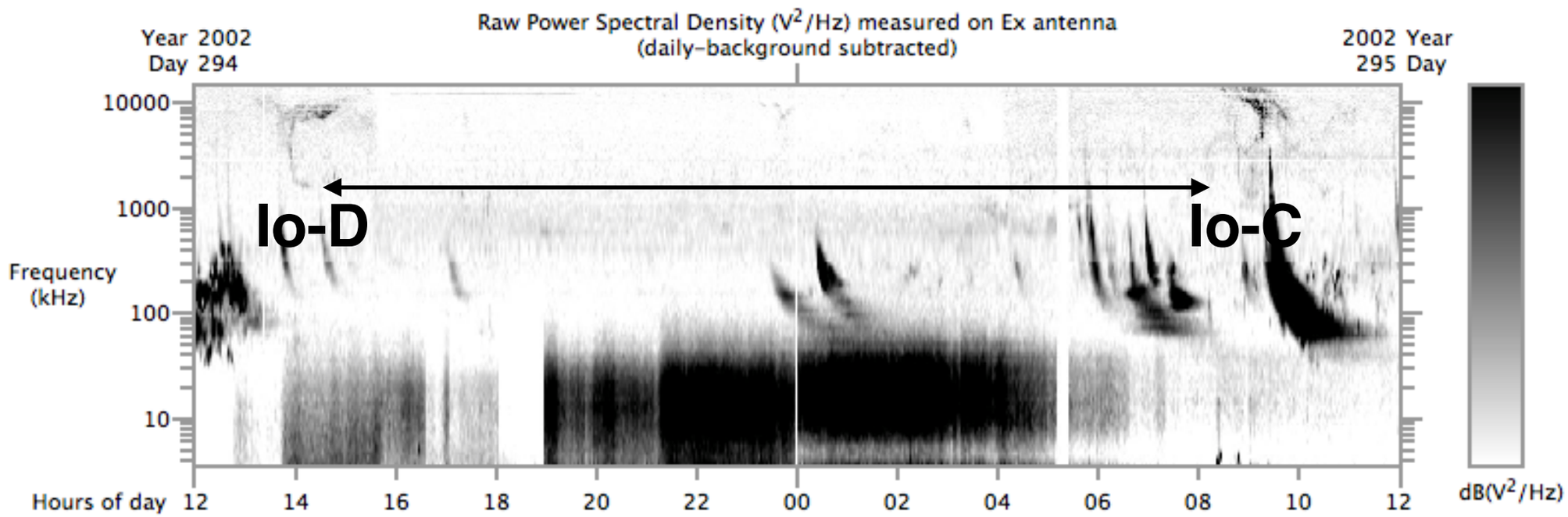
1- Catalog of Jovian emissions <u>outside</u> the flyby

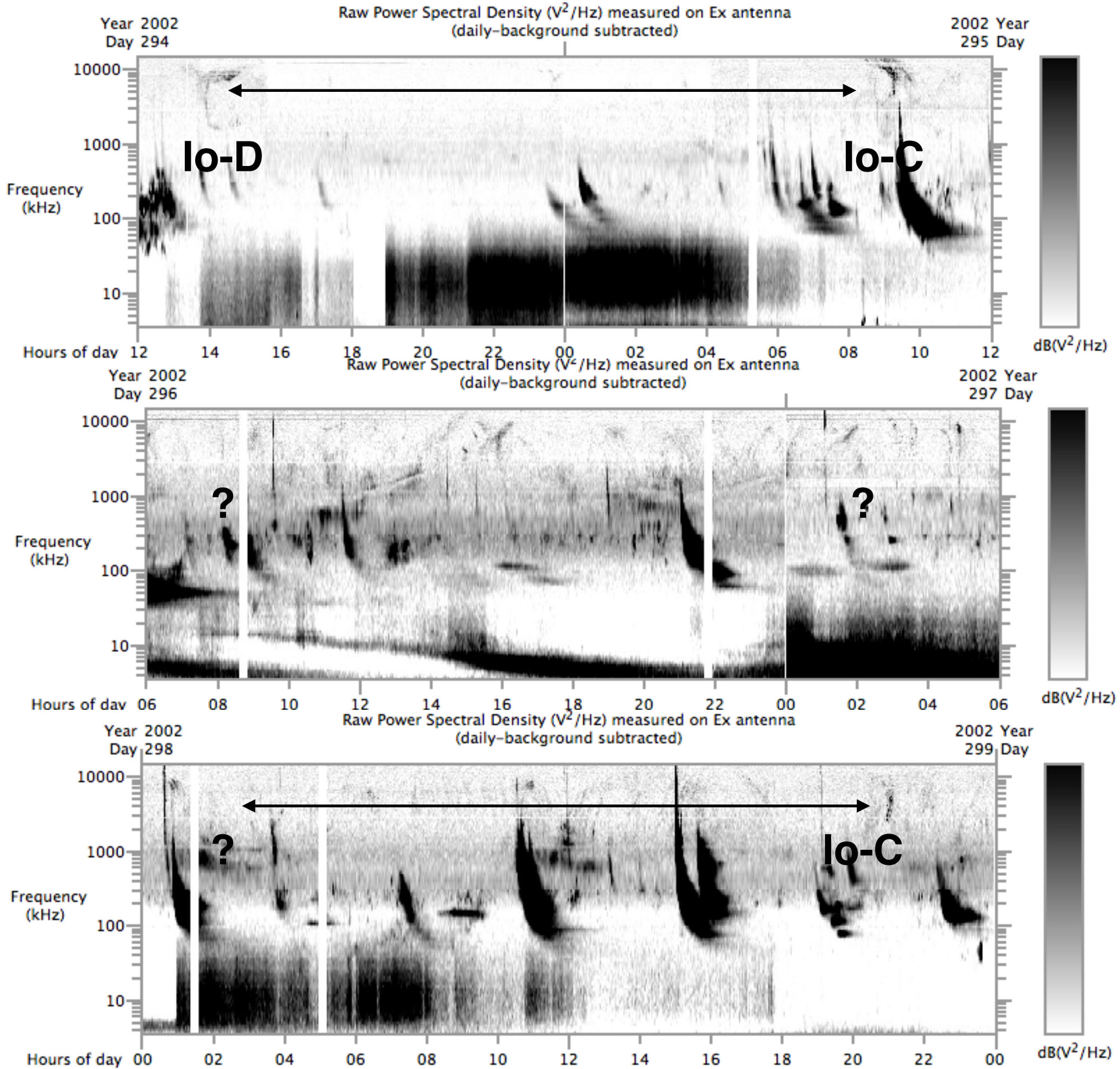
Continuous RPWS observations make it an excellent tracker of Io emissions :

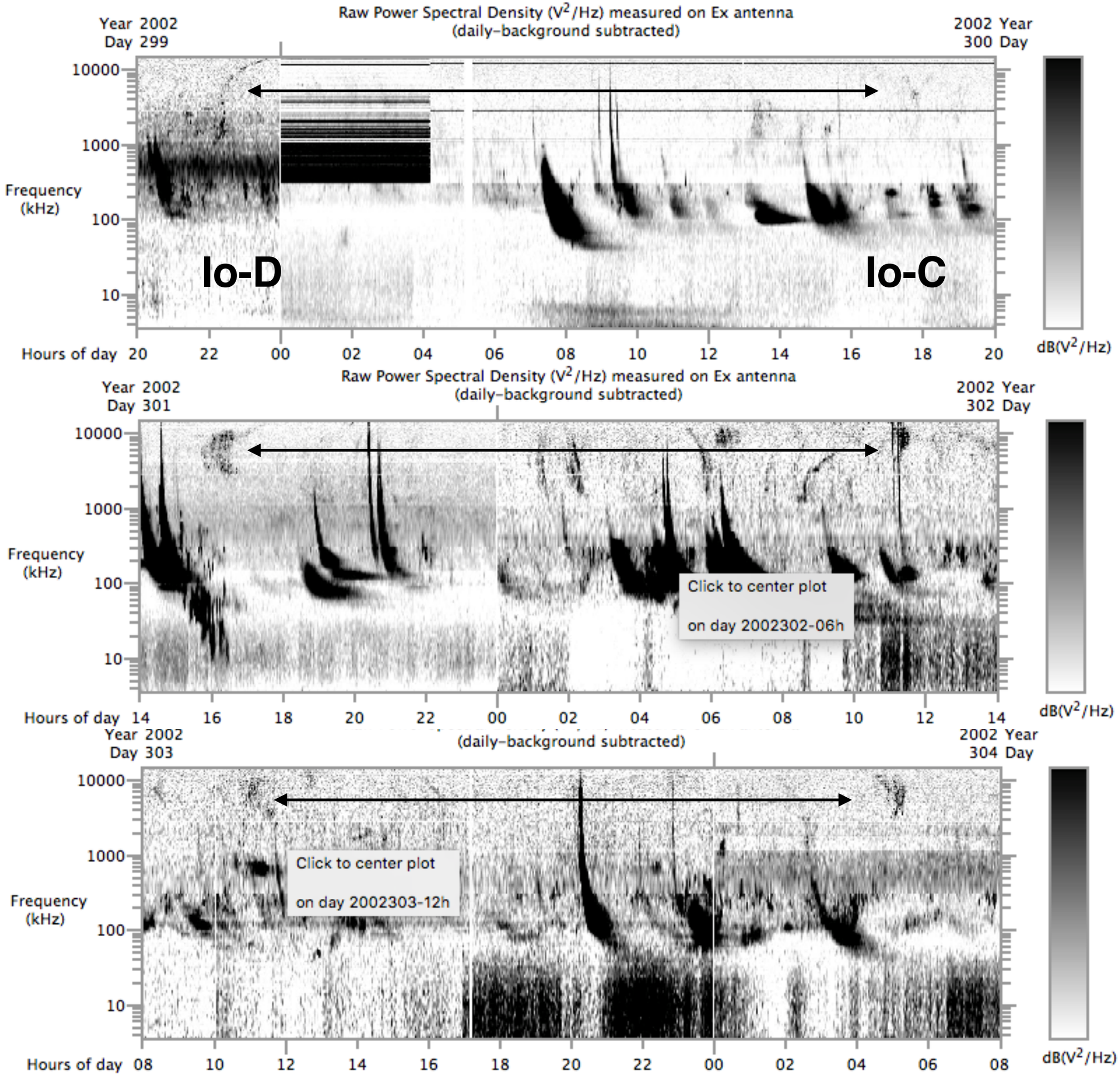
=> (very) long-term monitoring of the Io-Jupiter interaction

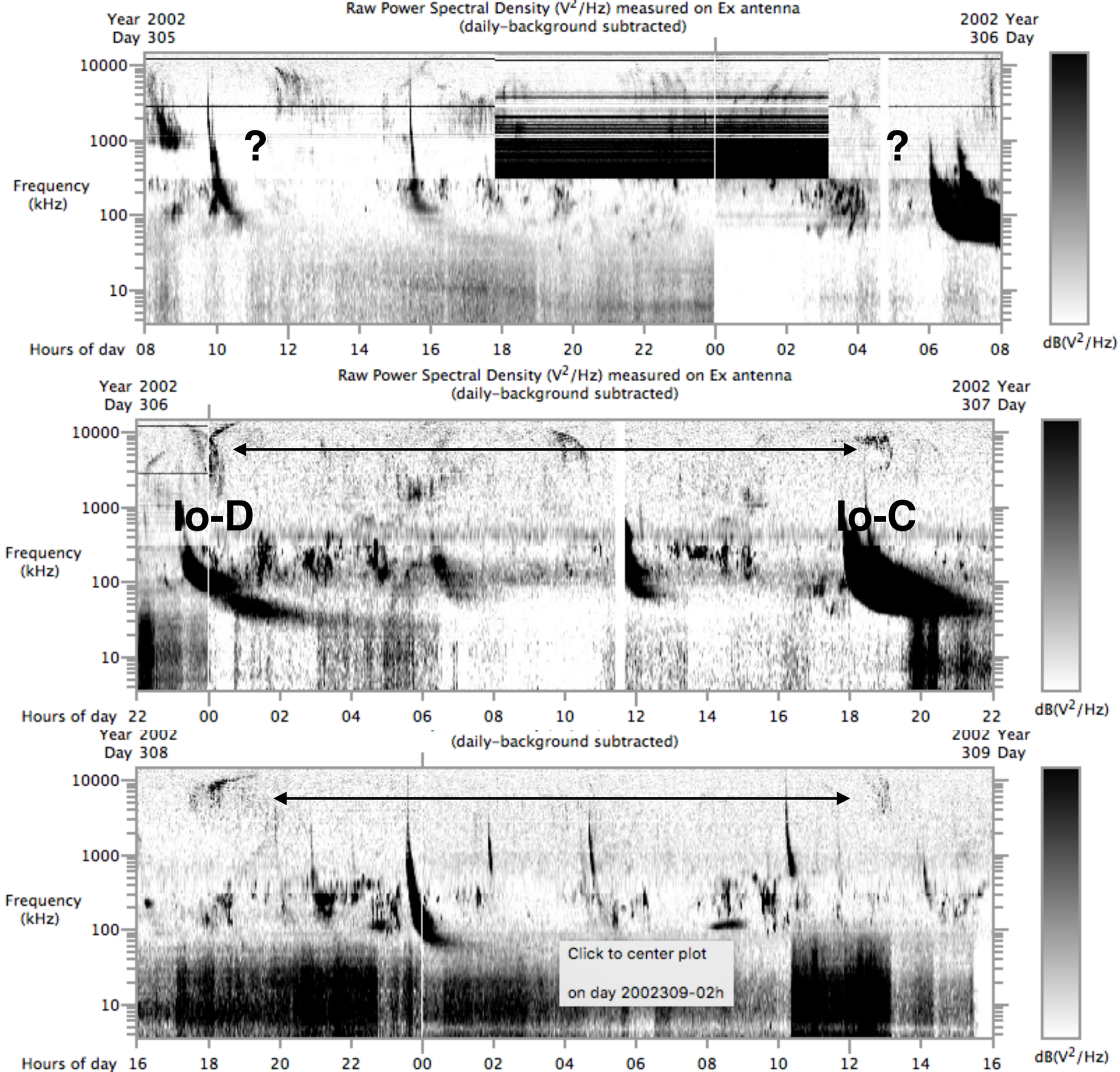
=> short-term monitoring as well (< 1 rot.)

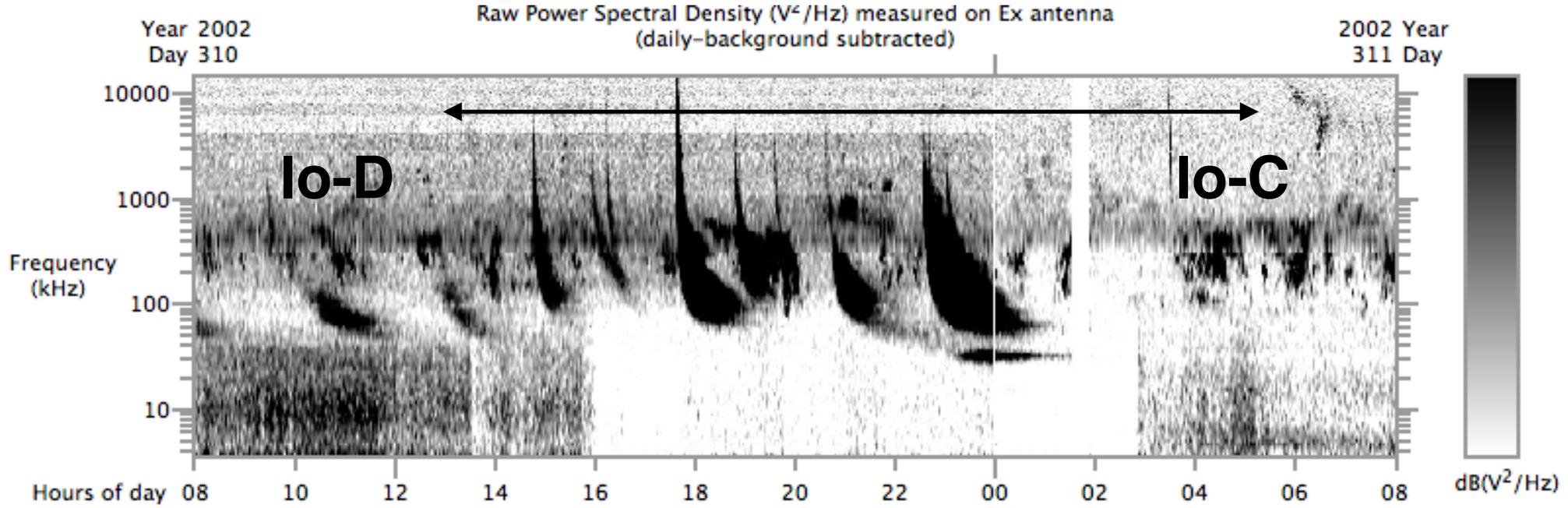
Example :

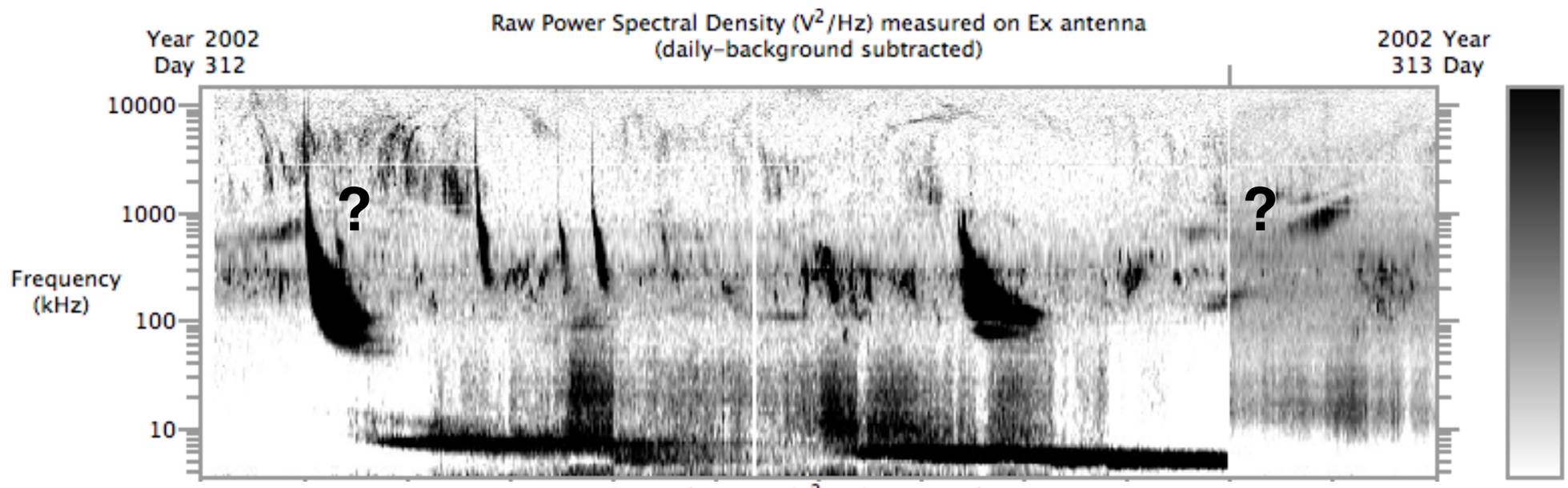


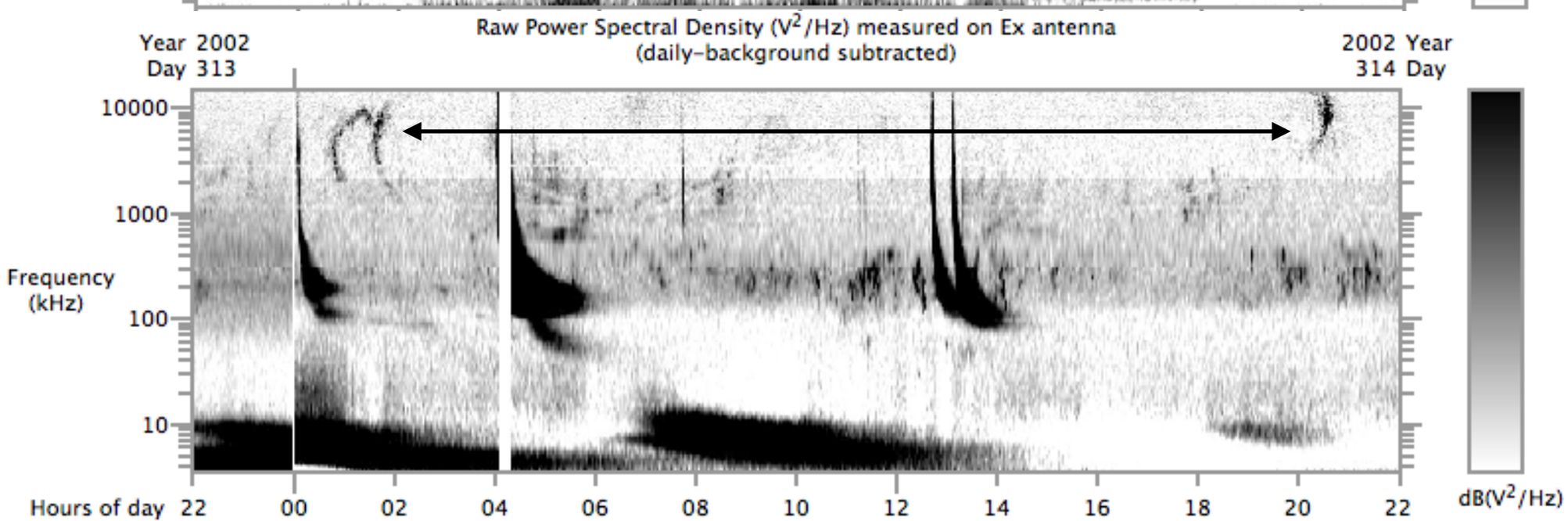

Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 294
2002 Year
295 Day
Io-D
Io-C
Frequency
(kHz)
10000
1000
100
10
Hours of day 12 14 16 18 20 22 00 02 04 06 08 10 12
dB(V²/Hz)
Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 296
2002 Year
297 Day
?
?
Frequency
(kHz)
10000
1000
100
10
Hours of day 06 08 10 12 14 16 18 20 22 00 02 04 06
dB(V²/Hz)
Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 298
2002 Year
299 Day
?
Io-C
Frequency
(kHz)
10000
1000
100
10
Hours of day 00 02 04 06 08 10 12 14 16 18 20 22 00
dB(V²/Hz)


Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 299
2002 Year
300 Day
Frequency
(kHz)
10000
1000
100
10
Io-D
Io-C
Hours of day 20 22 00 02 04 06 08 10 12 14 16 18 20
dB(V²/Hz)
Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 301
2002 Year
302 Day
Frequency
(kHz)
10000
1000
100
10
Click to center plot
on day 2002302-06h
Hours of day 14 16 18 20 22 00 02 04 06 08 10 12 14
dB(V²/Hz)
Year 2002
Day 303
(daily-background subtracted)
2002 Year
304 Day
Frequency
(kHz)
10000
1000
100
10
Click to center plot
on day 2002303-12h
Hours of day 08 10 12 14 16 18 20 22 00 02 04 06 08
dB(V²/Hz)

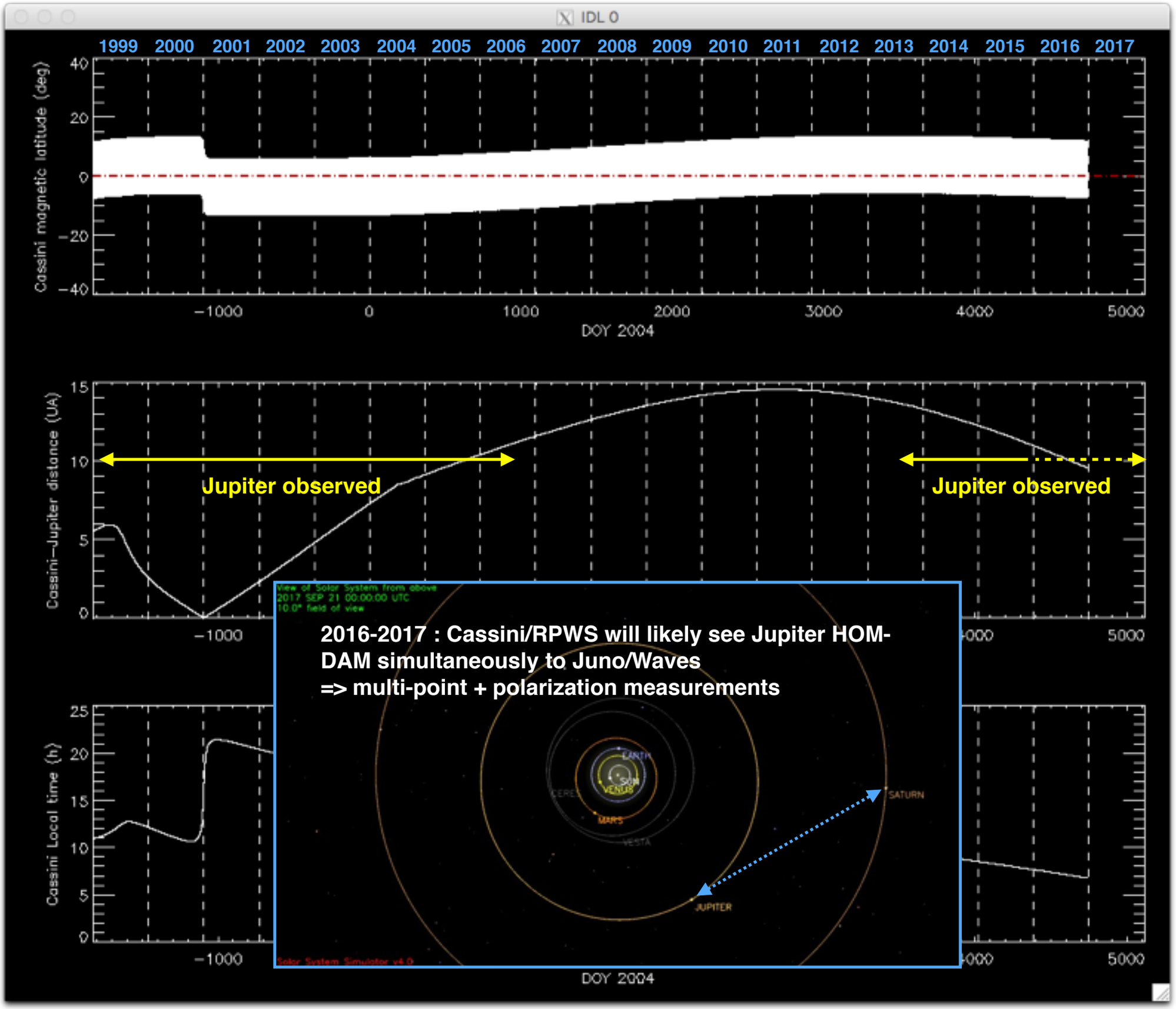

Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 305
2002 Year
306 Day
Frequency
(kHz)
10000
1000
100
10
?
?
Hours of day 08 10 12 14 16 18 20 22 00 02 04 06 08
dB(V²/Hz)
Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 306
2002 Year
307 Day
Io-D
Io-C
Hours of day 22 00 02 04 06 08 10 12 14 16 18 20 22
dB(V²/Hz)
Year 2002
Day 308
(daily-background subtracted)
2002 Year
309 Day
Click to center plot
on day 2002309-02h
Hours of day 16 18 20 22 00 02 04 06 08 10 12 14 16
dB(V²/Hz)


Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 310
2002 Year
311 Day
Io-D
Io-C
Frequency
(kHz)
10000
1000
100
10
Hours of day 08 10 12 14 16 18 20 22 00 02 04 06 08
dB(V²/Hz)

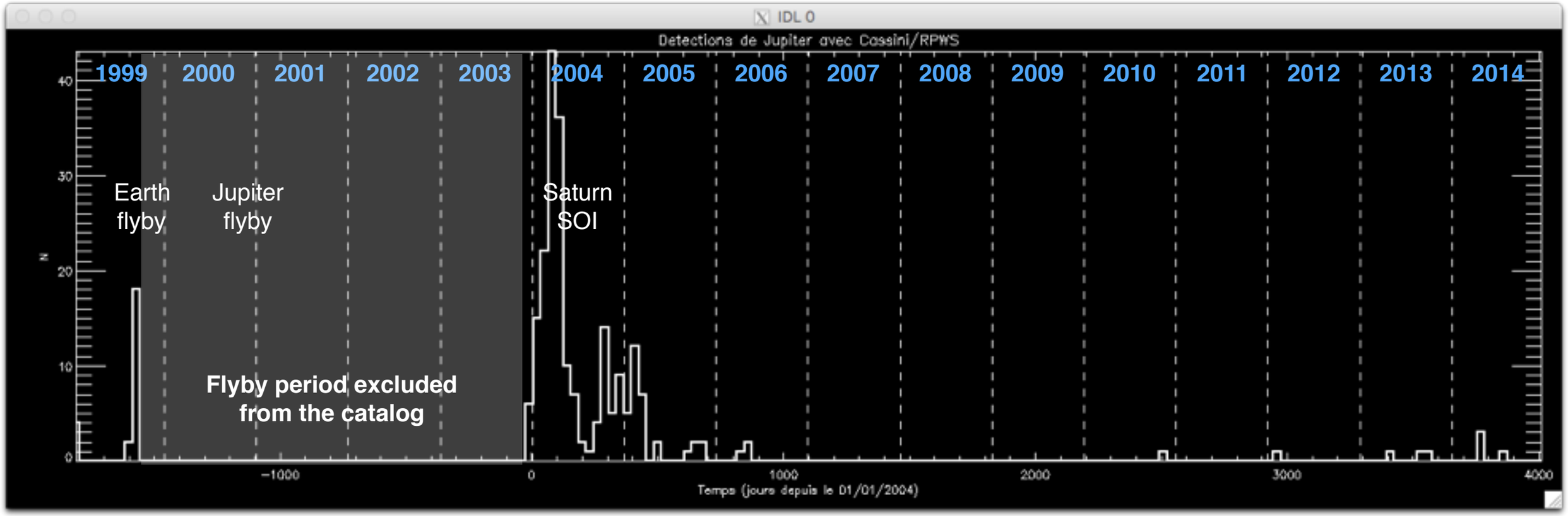

Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 312
2002 Year
313 Day
?
?
Frequency
(kHz)
10000
1000
100
10


Raw Power Spectral Density (V²/Hz) measured on Ex antenna
(daily-background subtracted)
Year 2002
Day 313
2002 Year
314 Day
Frequency
(kHz)
10000
1000
100
10
Hours of day 22 00 02 04 06 08 10 12 14 16 18 20 22
dB(V²/Hz)

1- Catalog of Jovian emissions <u>outside</u> the flyby



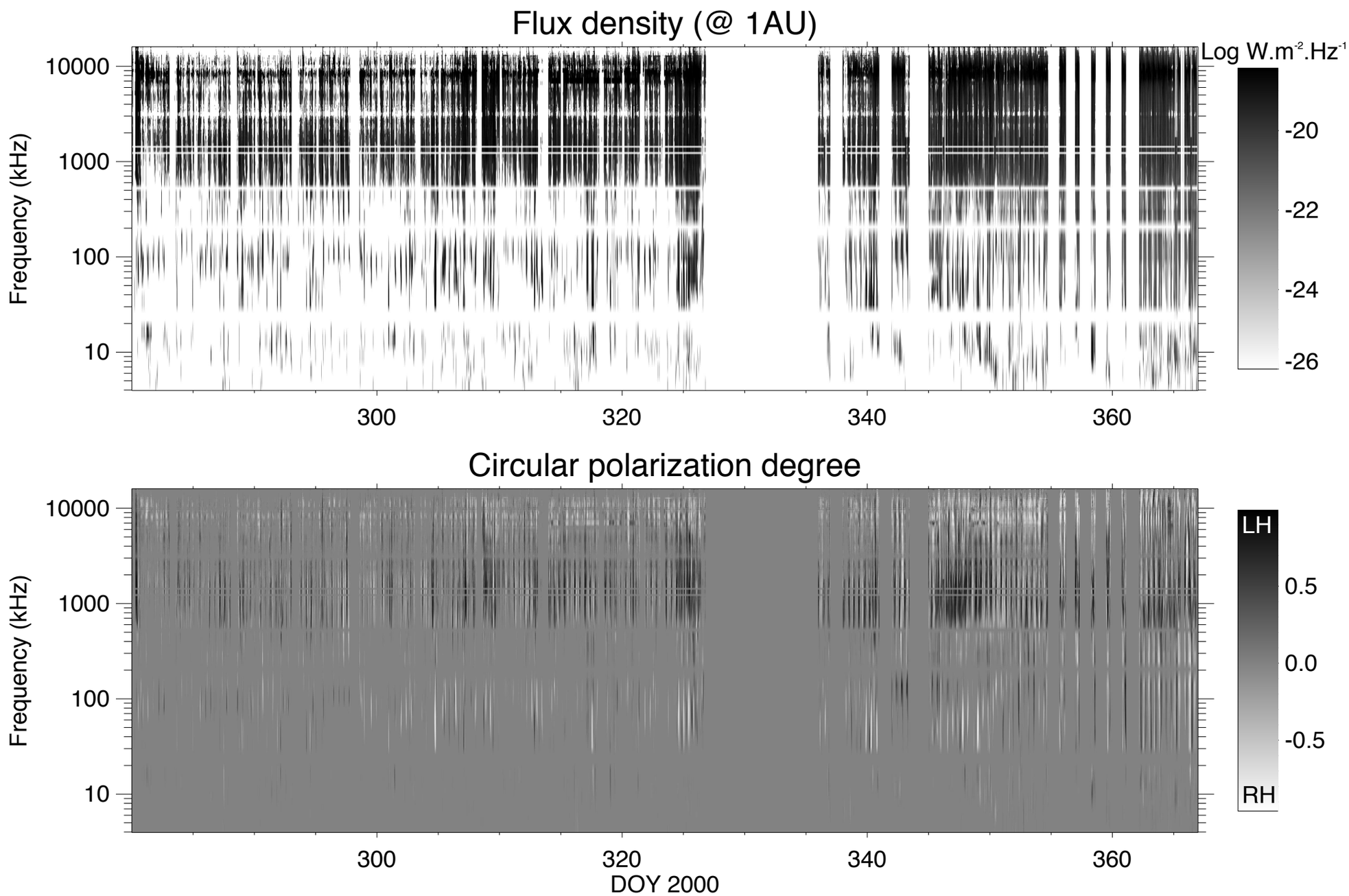
2- Search for planet-satellites interactions during the flyby



High sensitivity
+ continuous
observations

2- Search for planet-satellites interactions during the flyby

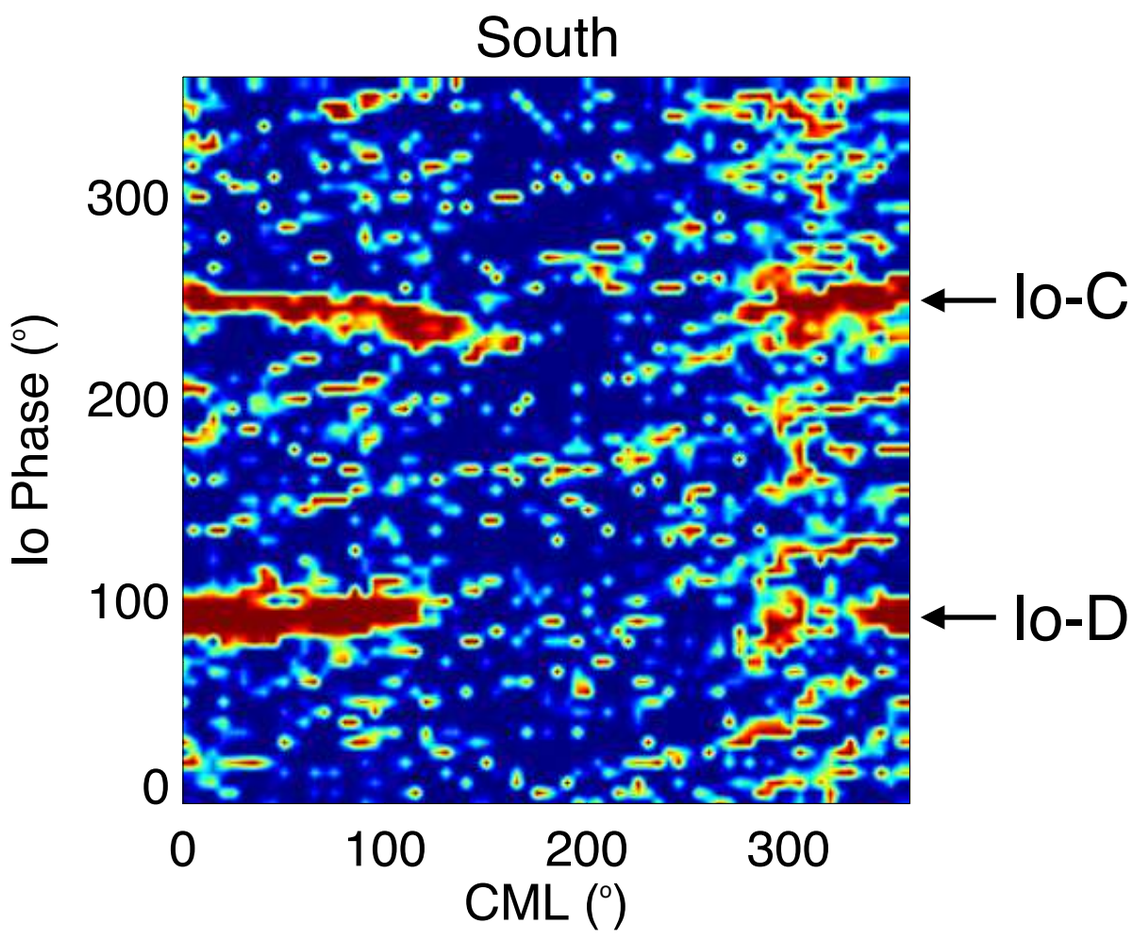
Method (a) : power time series

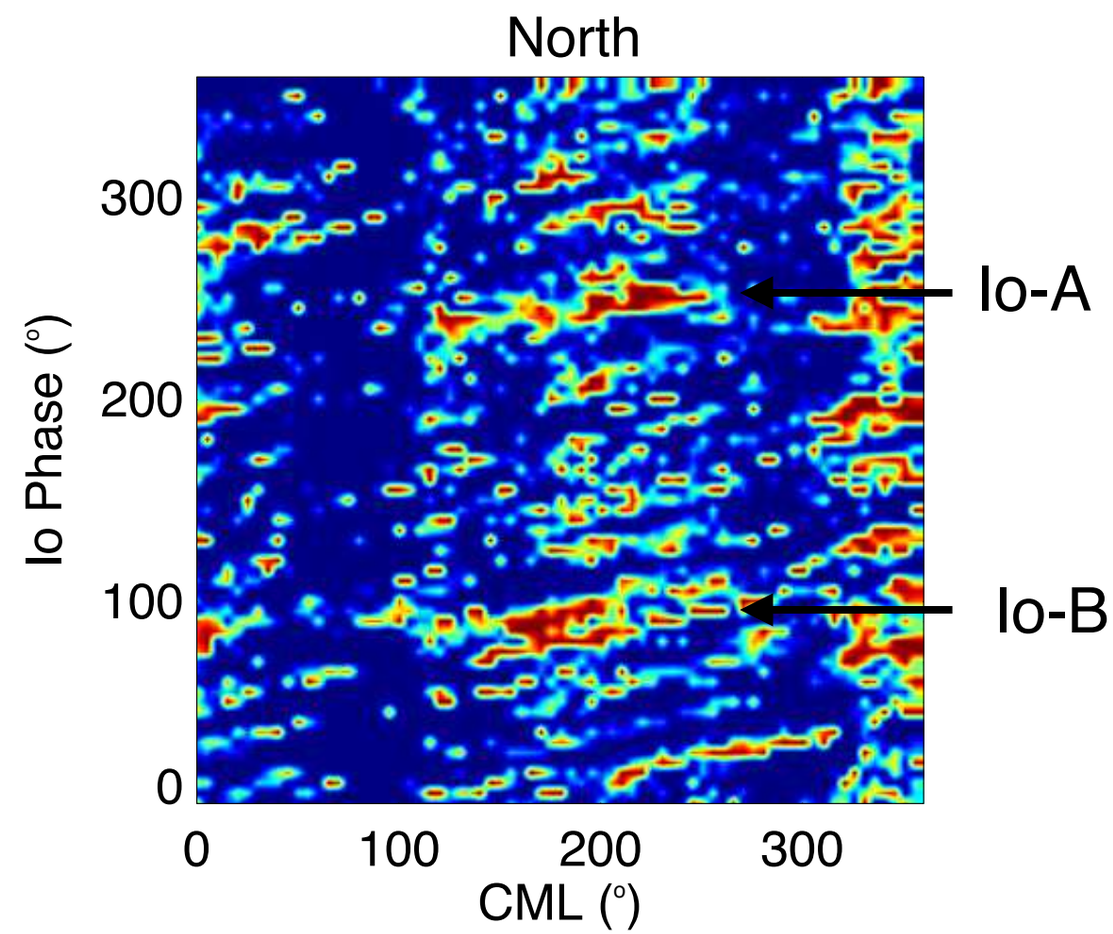


- Time interval : 2000-2001
- Southern and Northern power time series (separated by circular polarization)
- Normalized to 1 AU

2- Search for planet-satellites interactions during the flyby

Method (a) : power time series



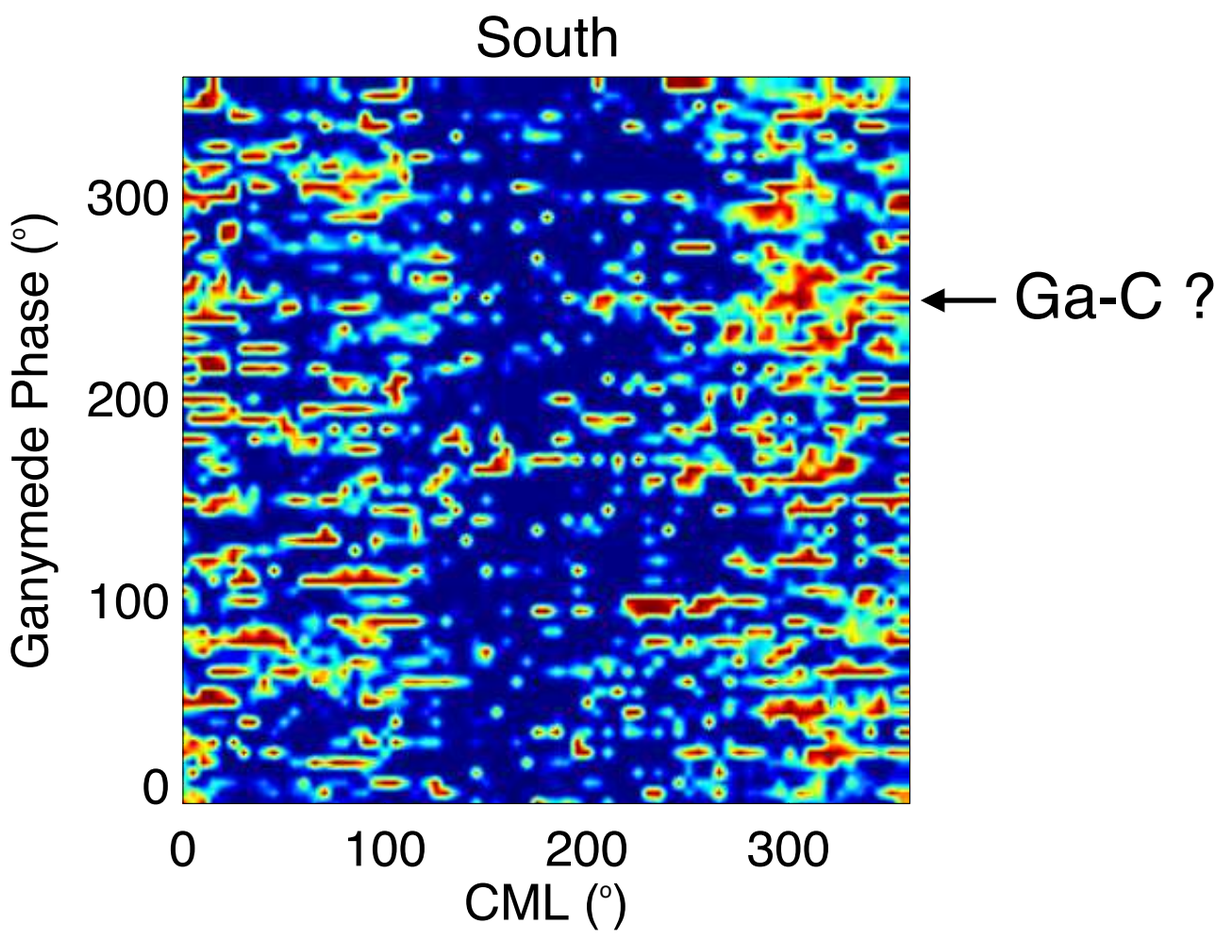


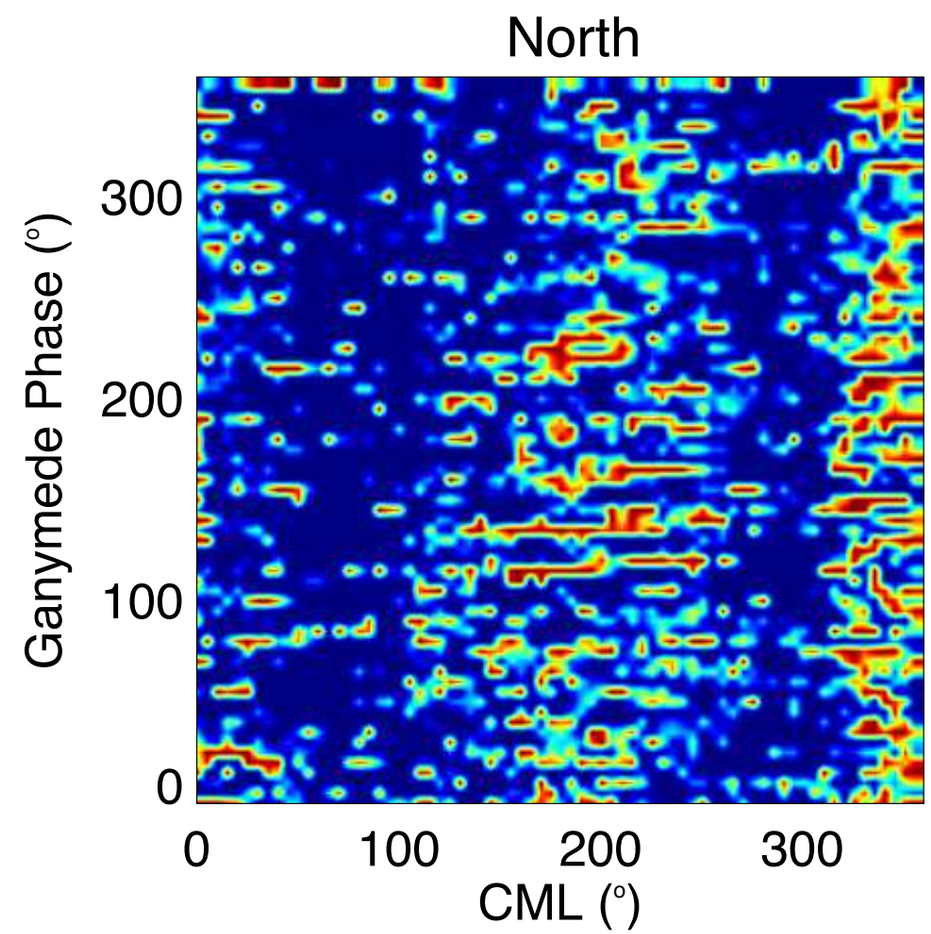
Io :

- f = [5-16MHz]
- A, B, C and D components all seen
- intensity (instead of occurrence) plot => intensity reference

2- Search for planet-satellites interactions during the flyby

Method (a) : power time series



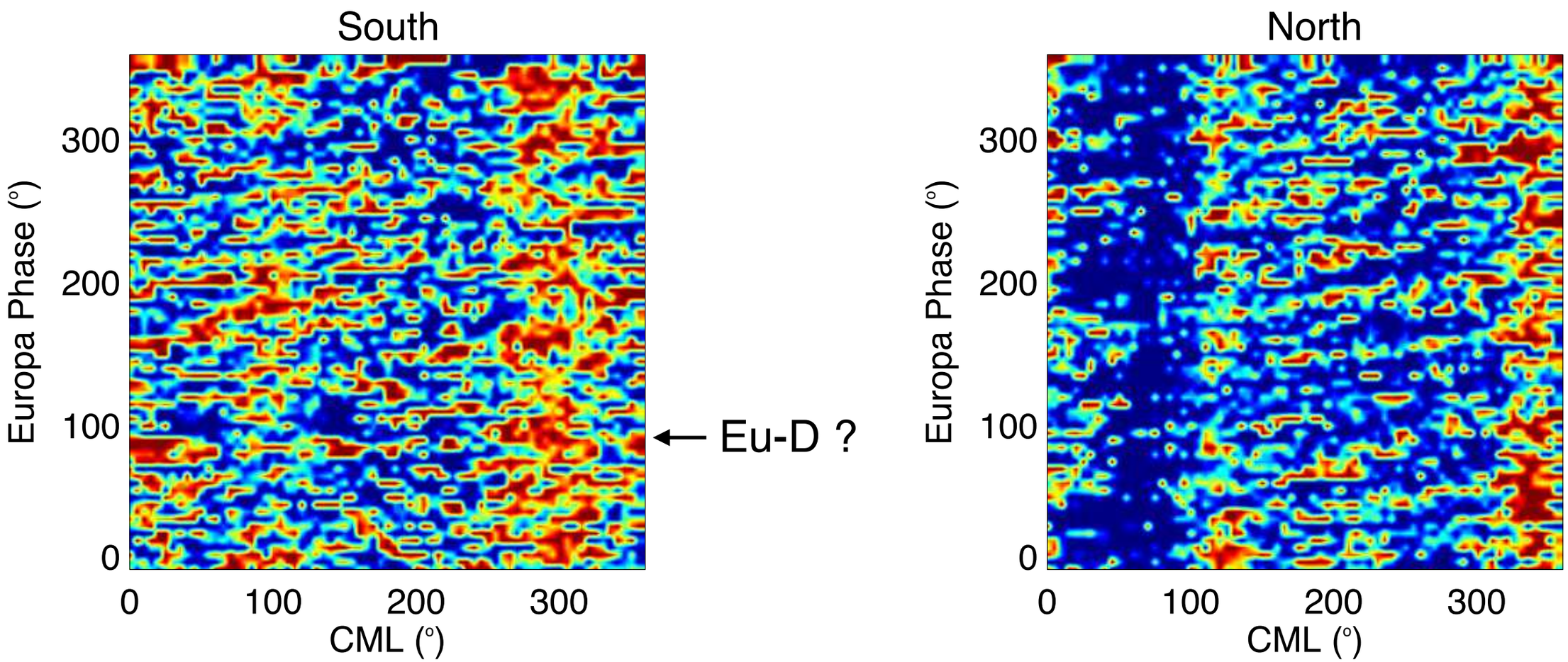


Ganymede :

- f = [5-16MHz]
- Ganymede C emission ?

2- Search for planet-satellites interactions during the flyby

Method (a) : power time series

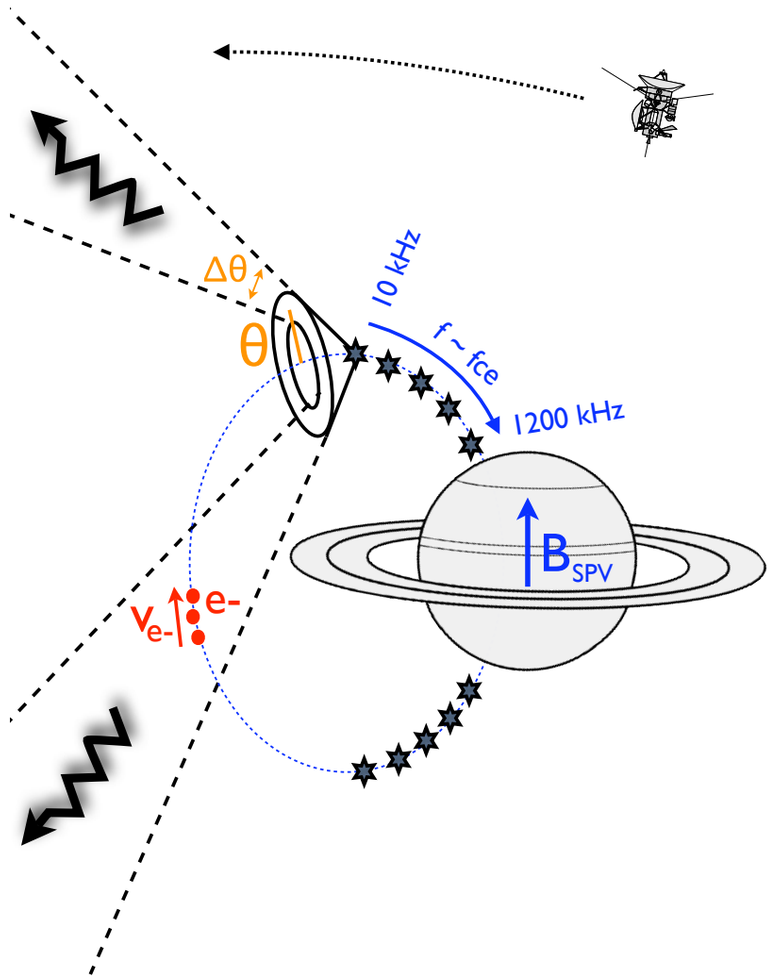


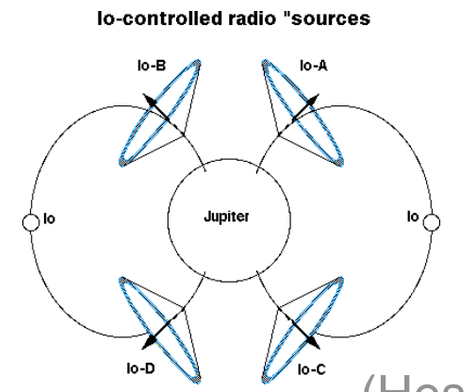
Europa :

- f = [1-16MHz]
- Europa D emission ?

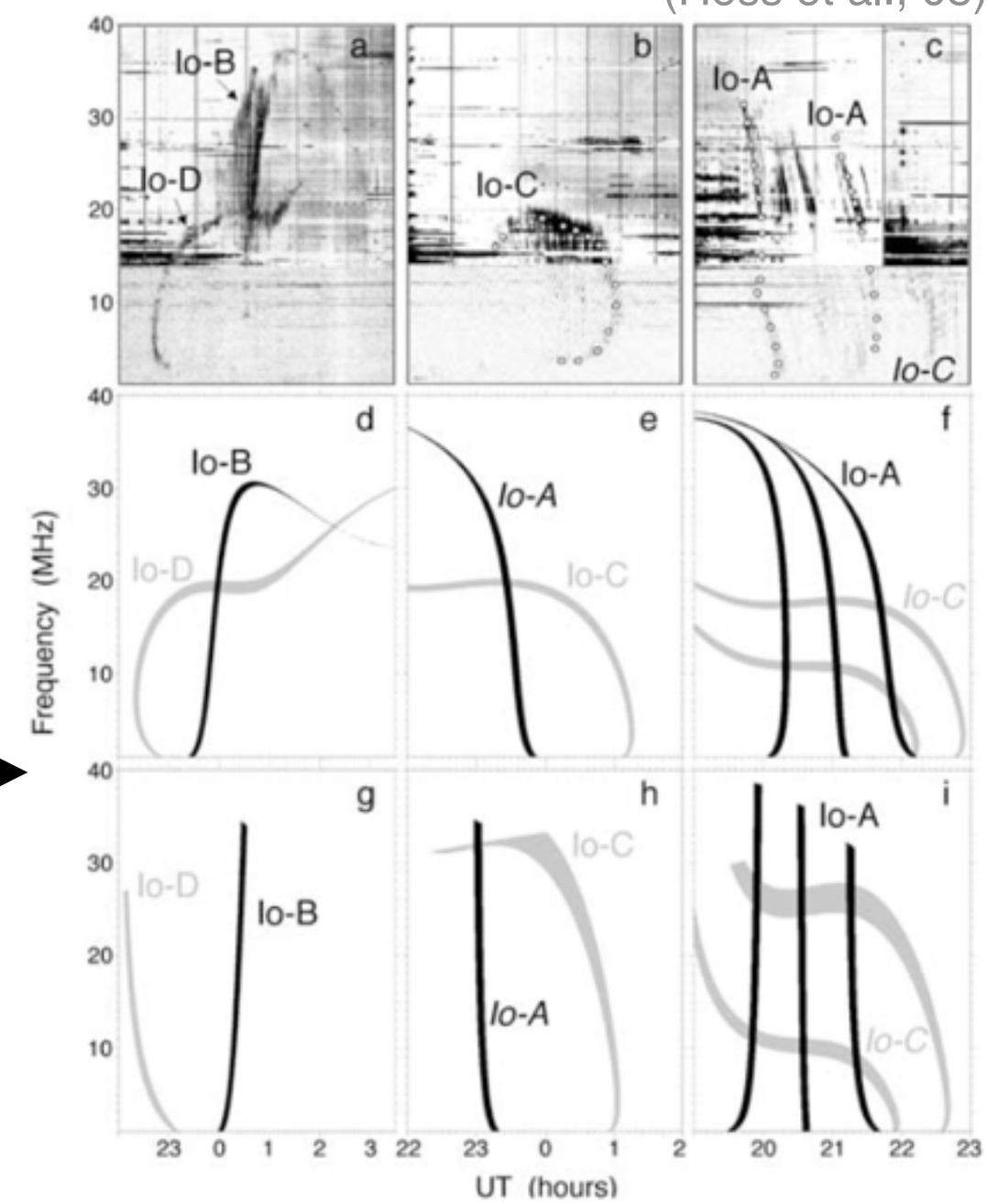
2- Search for planet-satellites interactions during the flyby

Method (b) : simulations of dynamic spectra





(Hess et al., 08)



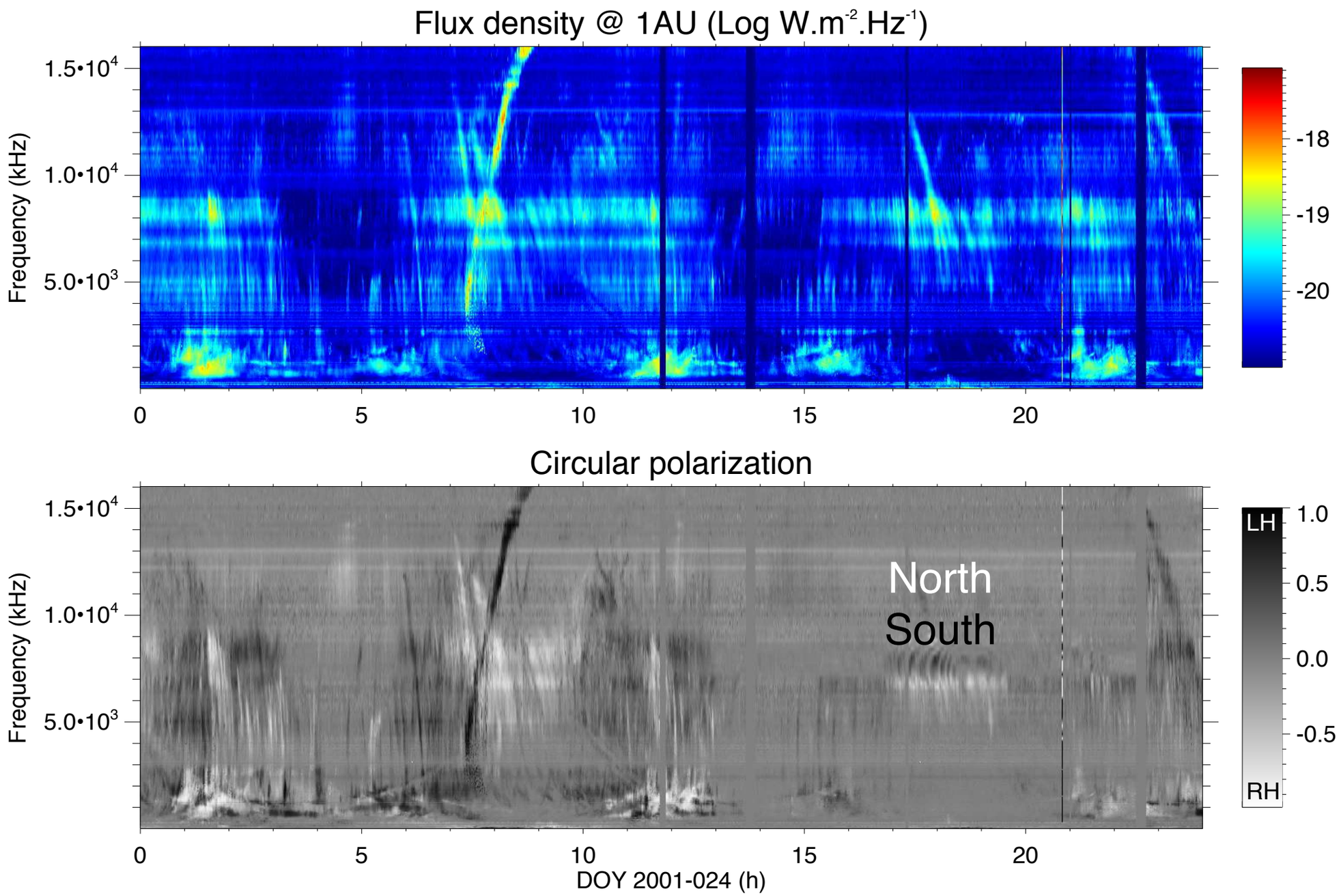
- CMI-based visibility modeling with the ExPRES code (Hess et al., 08,11,16; Lamy et al.,08b,13)

- updated magnetic field model : ISAaC (>VIPAL) constrained by the locus of both Io and Ganymede UV footprints (Hess, pers. com.)

=> long-term simulations of Io, Europa & Ganymede

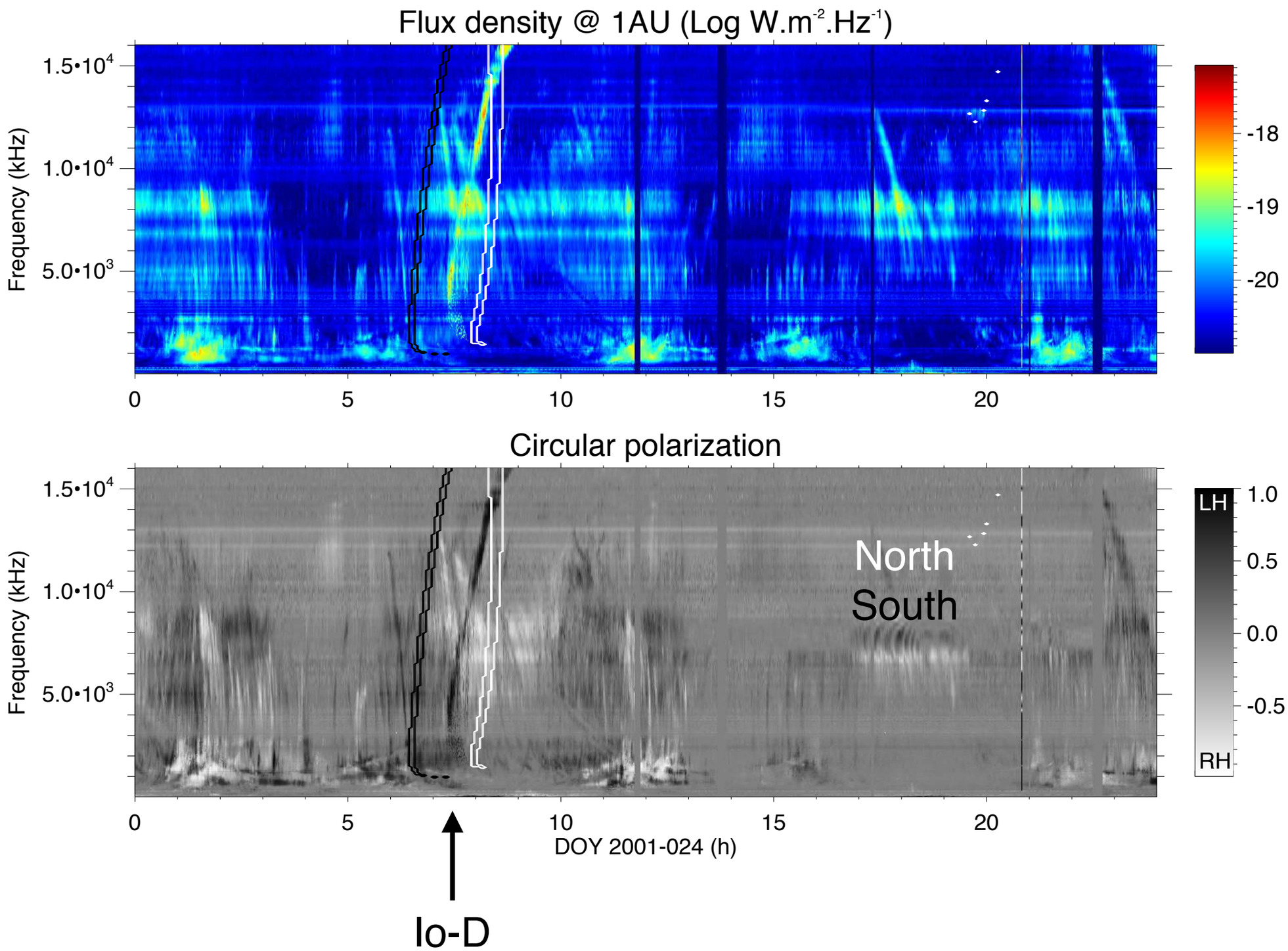
2- Search for planet-satellites interactions during the flyby

Method (b) : simulations of dynamic spectra



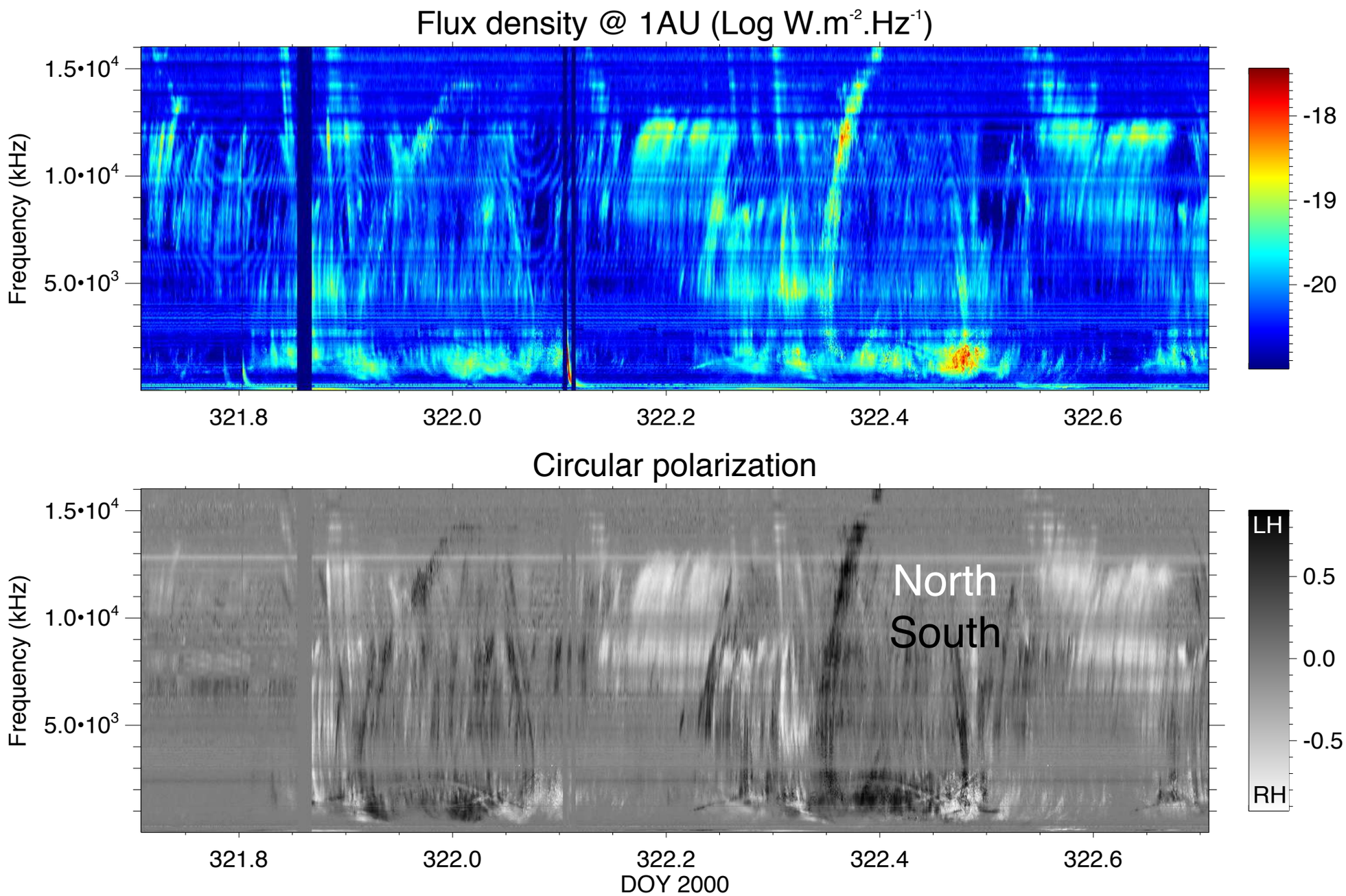
2- Search for planet-satellites interactions during the flyby

Method (b) : simulations of dynamic spectra



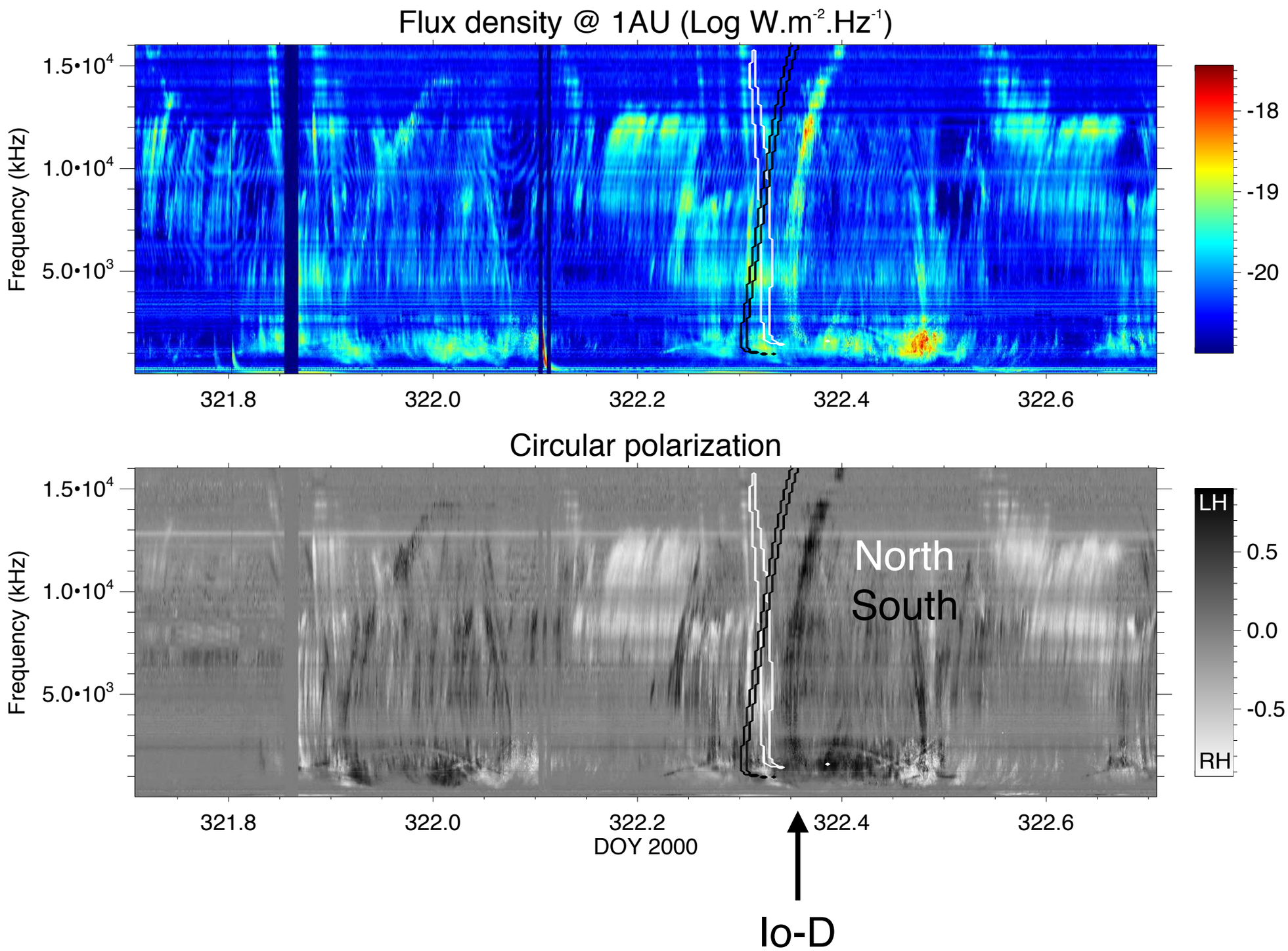
2- Search for planet-satellites interactions during the flyby

Method (b) : simulations of dynamic spectra



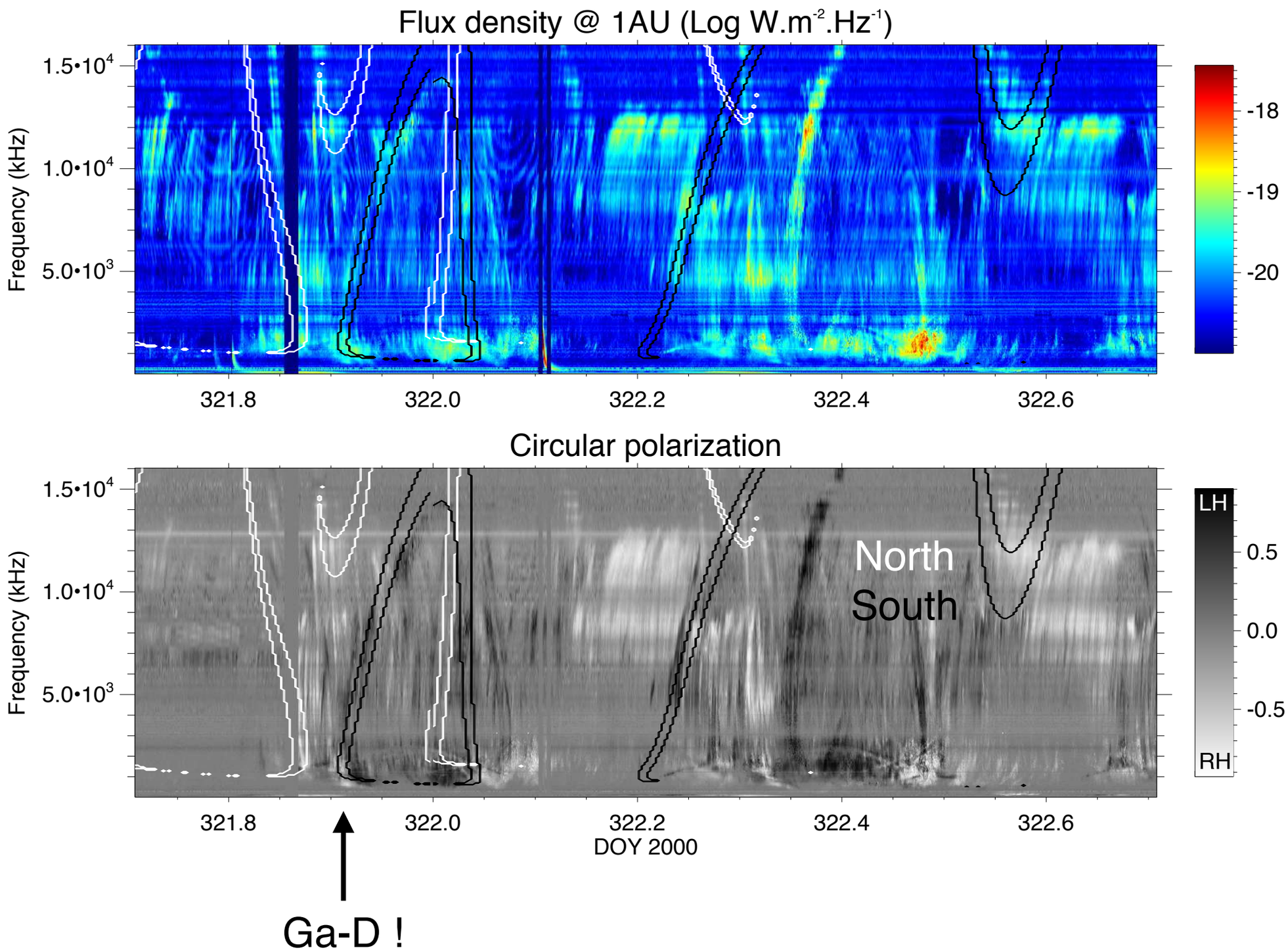
2- Search for planet-satellites interactions during the flyby

Method (b) : simulations of dynamic spectra



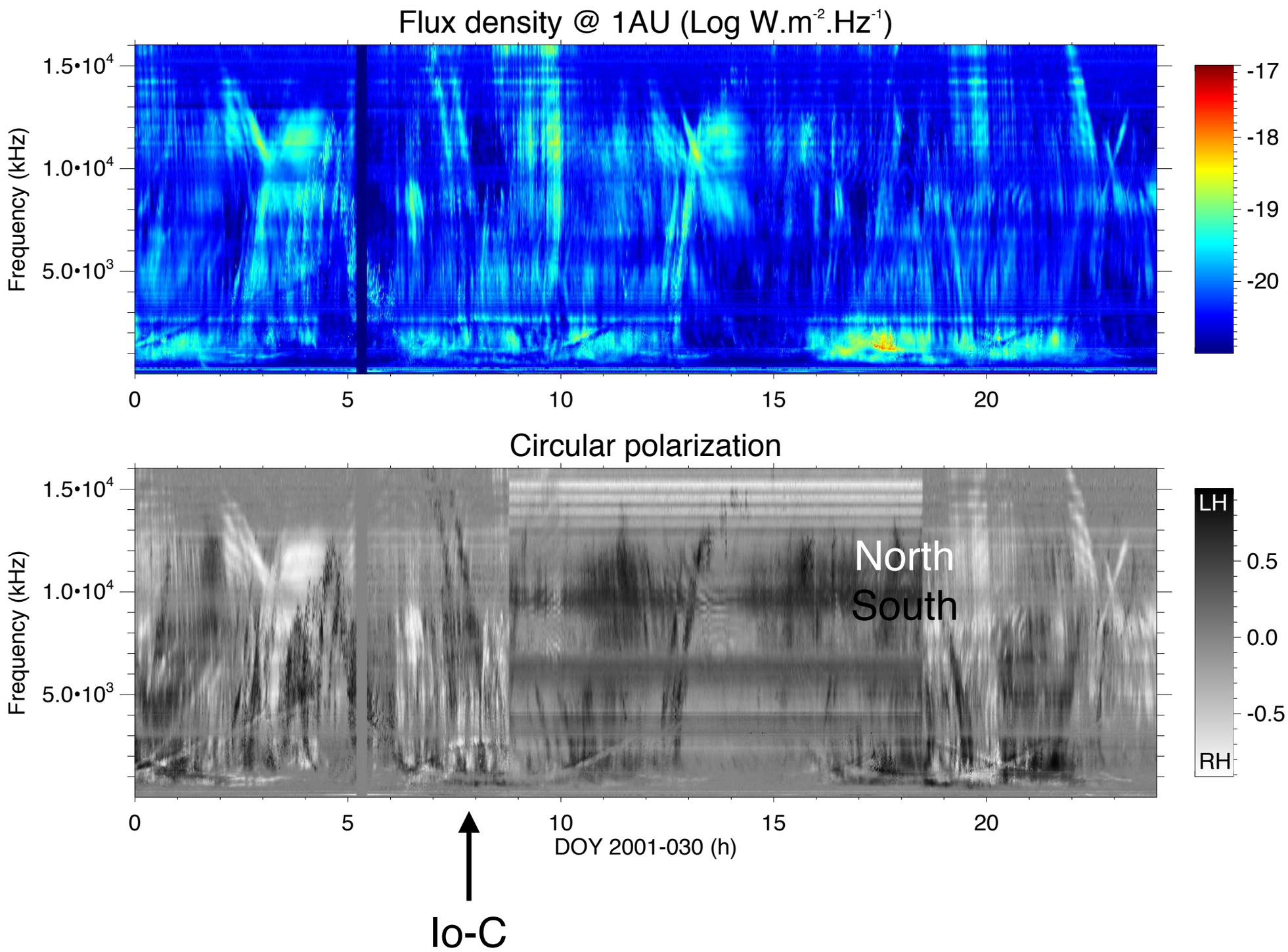
2- Search for planet-satellites interactions during the flyby

Method (b) : simulations of dynamic spectra



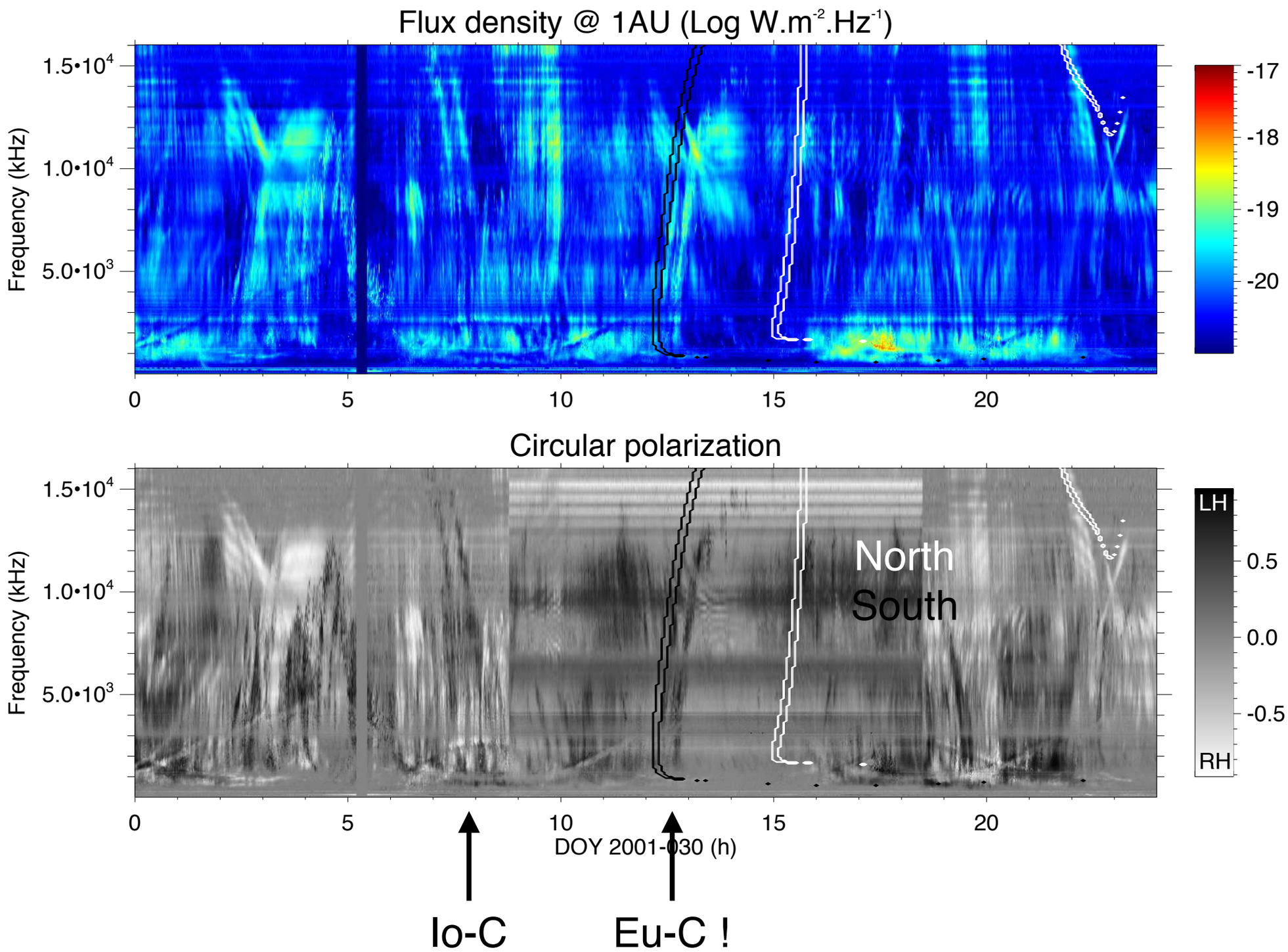
2- Search for planet-satellites interactions during the flyby

Method (b) : simulations of dynamic spectra



2- Search for planet-satellites interactions during the flyby

Method (b) : simulations of dynamic spectra



2- Search for planet-satellites interactions during the flyby

Method (b) : simulations of dynamic spectra

(Louis et al., in prep.) :

- Catalog of Europa and Ganymede detections

  + Cassini/RPWS : 2000-2003
    177 candidates total : 105 Europa + 69 Ganymede + 3 Europa or Ganymede

  + Voyager/PRA : 1979
    Voyager 1 => **15 candidates** total : 10 Europa + 5 Ganymede
    Voyager 2 => **24 candidates** total : 12 Europa + 12 Ganymede
    NB : One case where Europa was observed by both spacecraft

- Search for multi-point measurements (Nançay decameter array).

- Characterization of average properties in progress : ocurrence, spectrum, arc shape, multiplicity, intensity, variability etc.

Conclusions

* Cassini/RPWS regularly tracked Jupiter emissions over 1999-2005 and >2013
  => unexpected support to Juno ?

* Outside the flyby period : mainly Io
  => Io activity can be tracked on long (years) and short (half a revolution) timescales

* During the flyby :

  (a) Satellite phase-CML diagrams of intensity :
  => all components of Io
  => possible detection of Europa and Ganymede

  (b) Simulations of Europa and Ganymede induced emissions :
  => identification of Europa arcs !
  => identification of Ganymede arcs !
  => statistical study in progress.