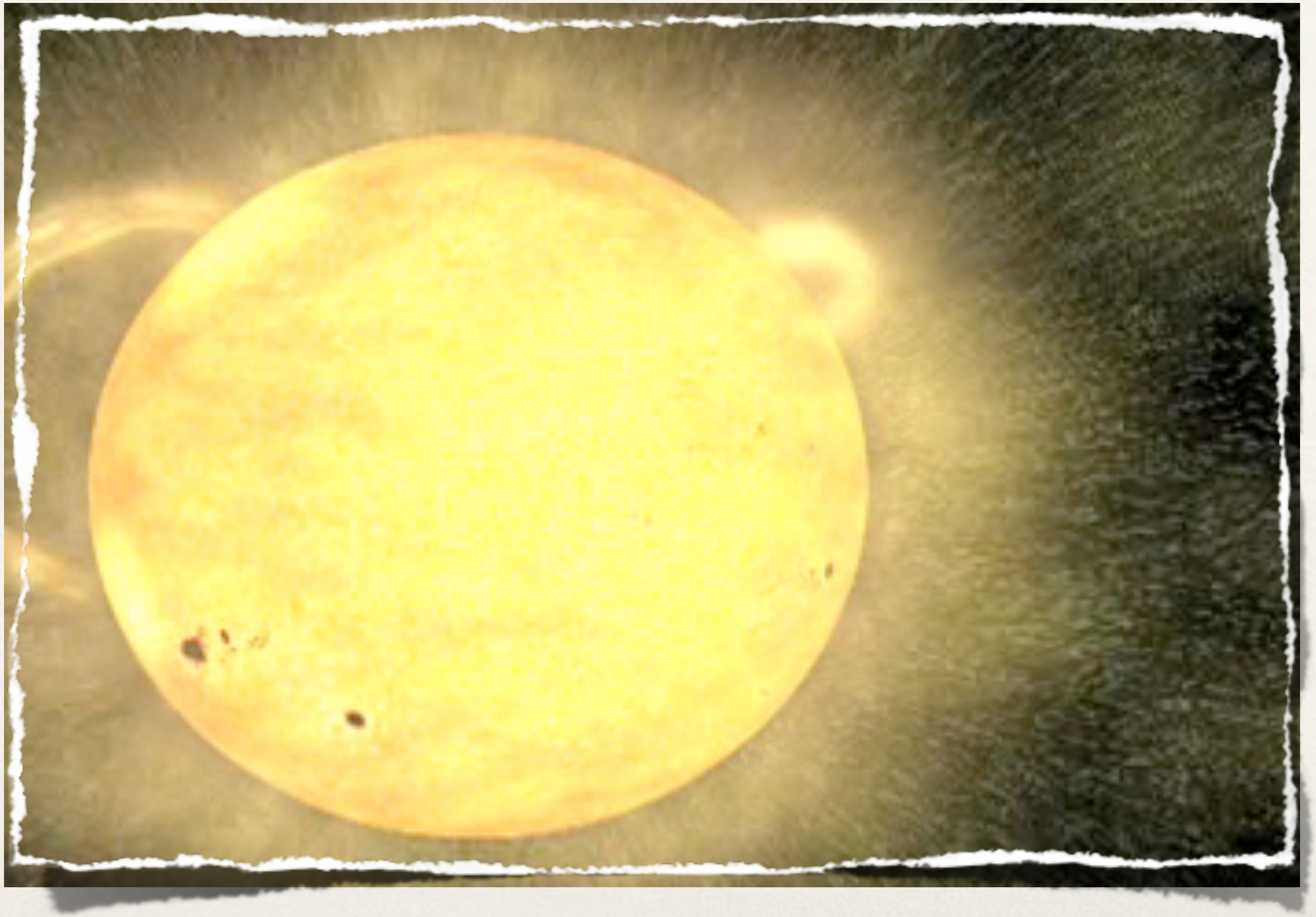
Sharing RadioJOVE data with the scientists

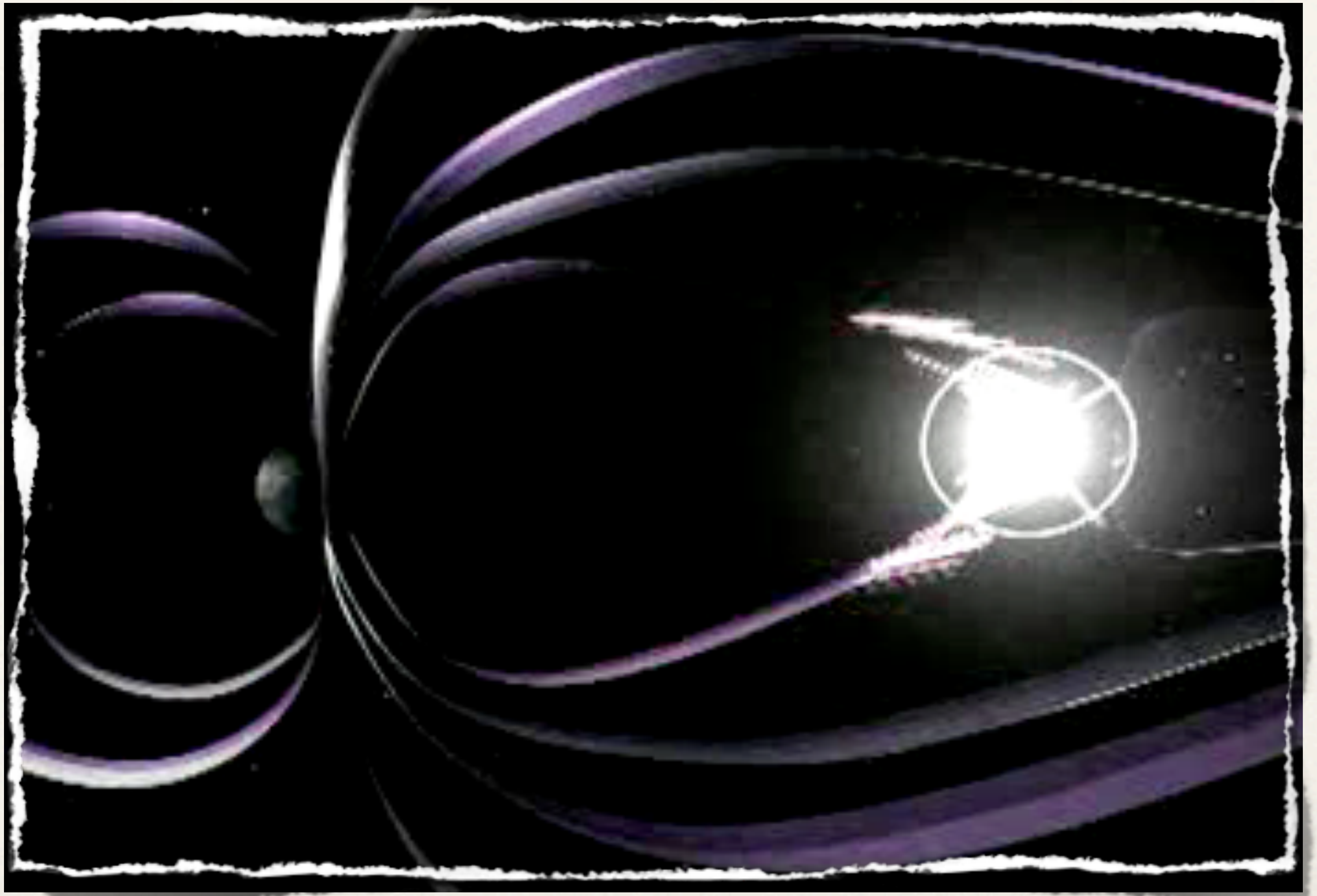
Baptiste Cecconi (Observatoire de Paris)

Thursday, July 3rd, 2014

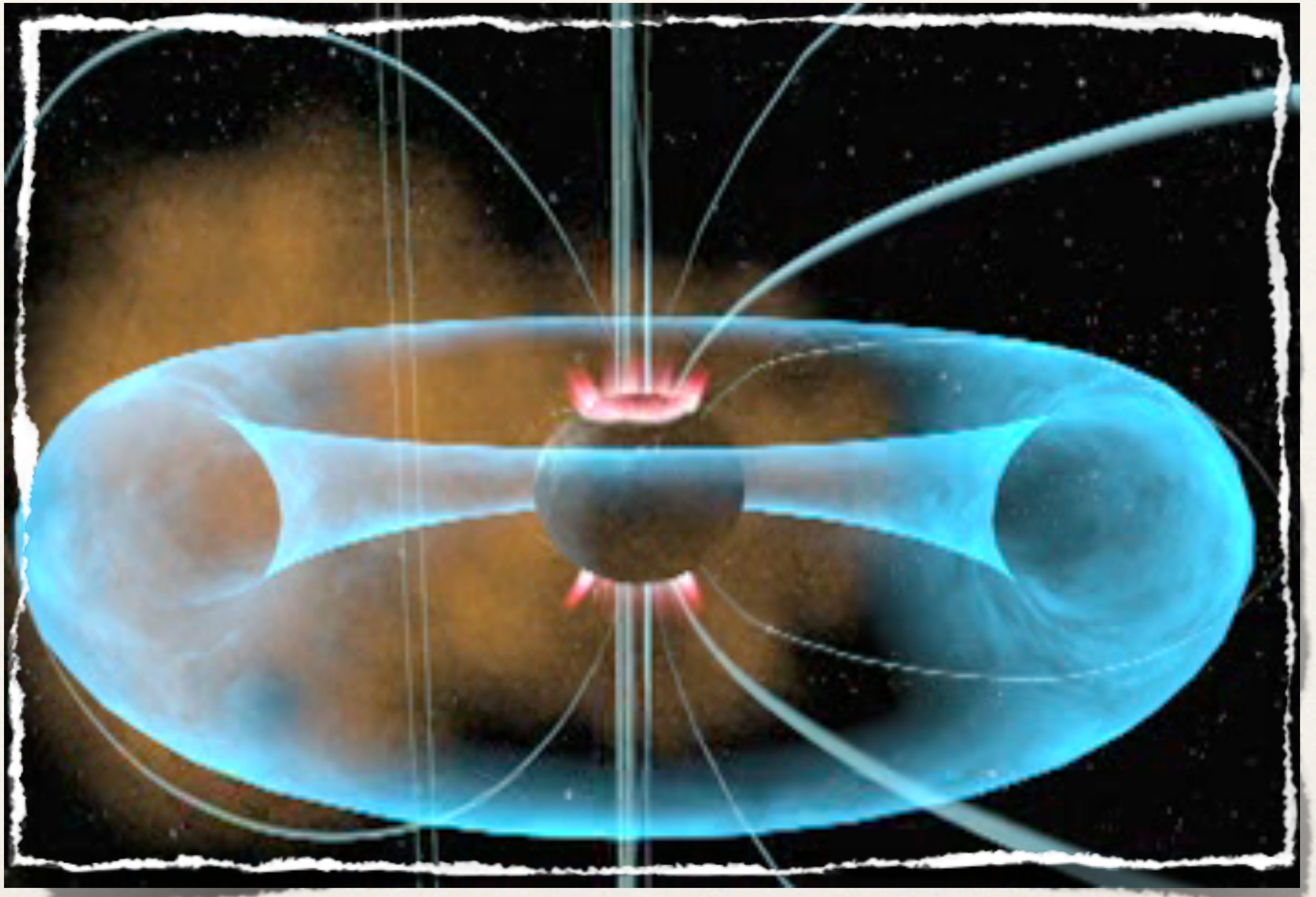
Plasmas in the Solar System
Solar Wind & Magnetized Planets



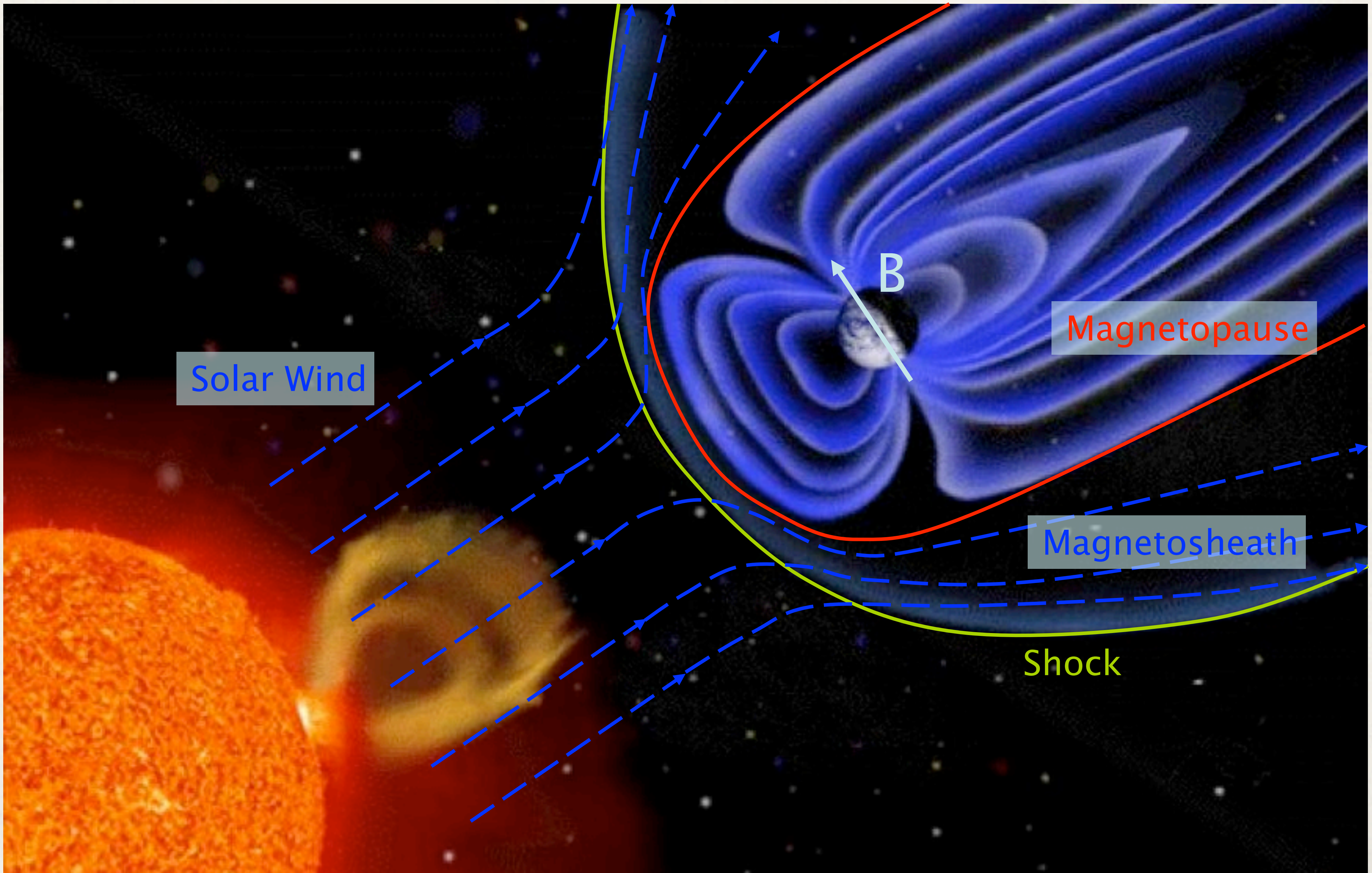
Plasmas in the Solar System
Solar Wind & Magnetized Planets



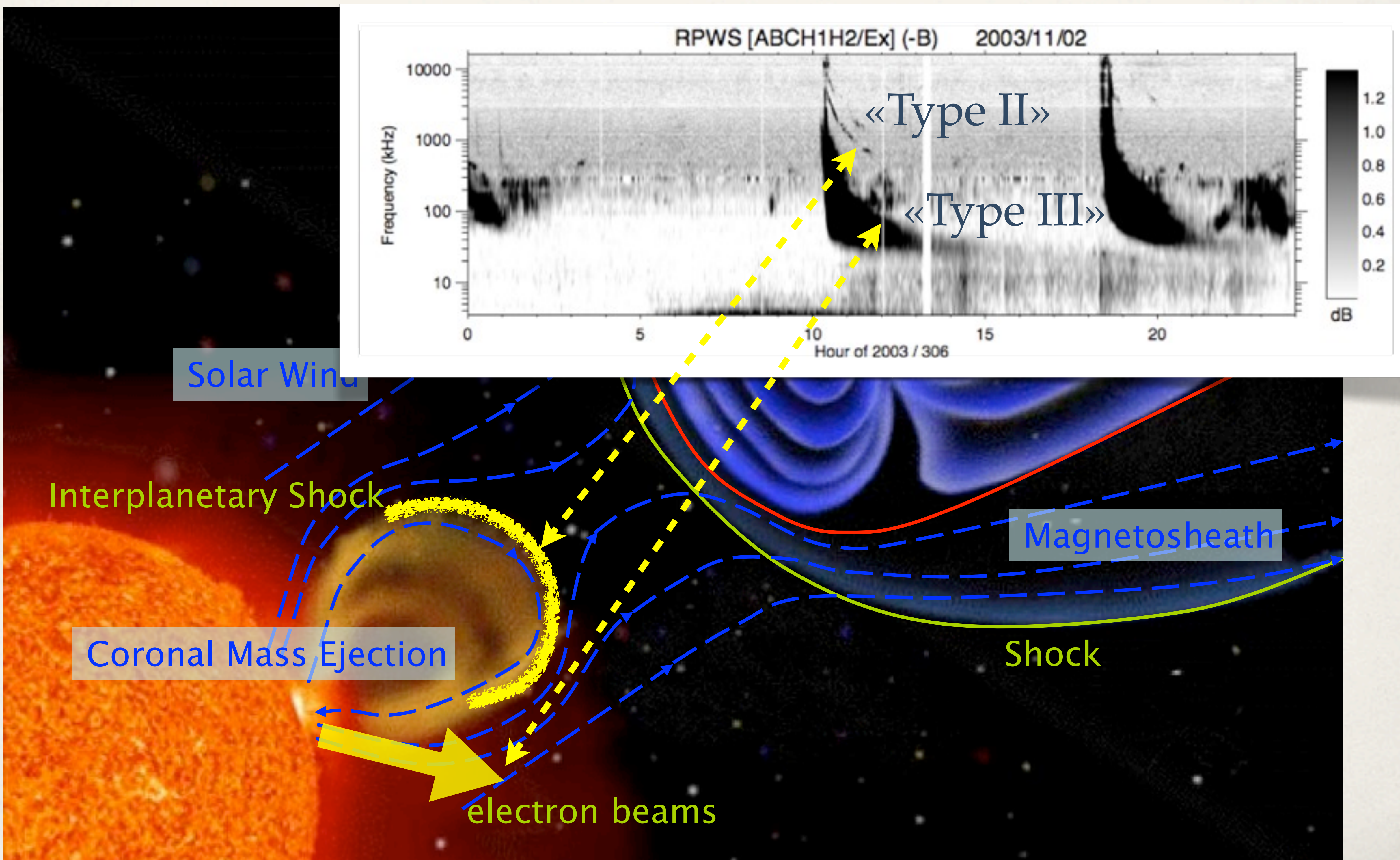
Plasmas in the Solar System
Solar Wind & Magnetized Planets



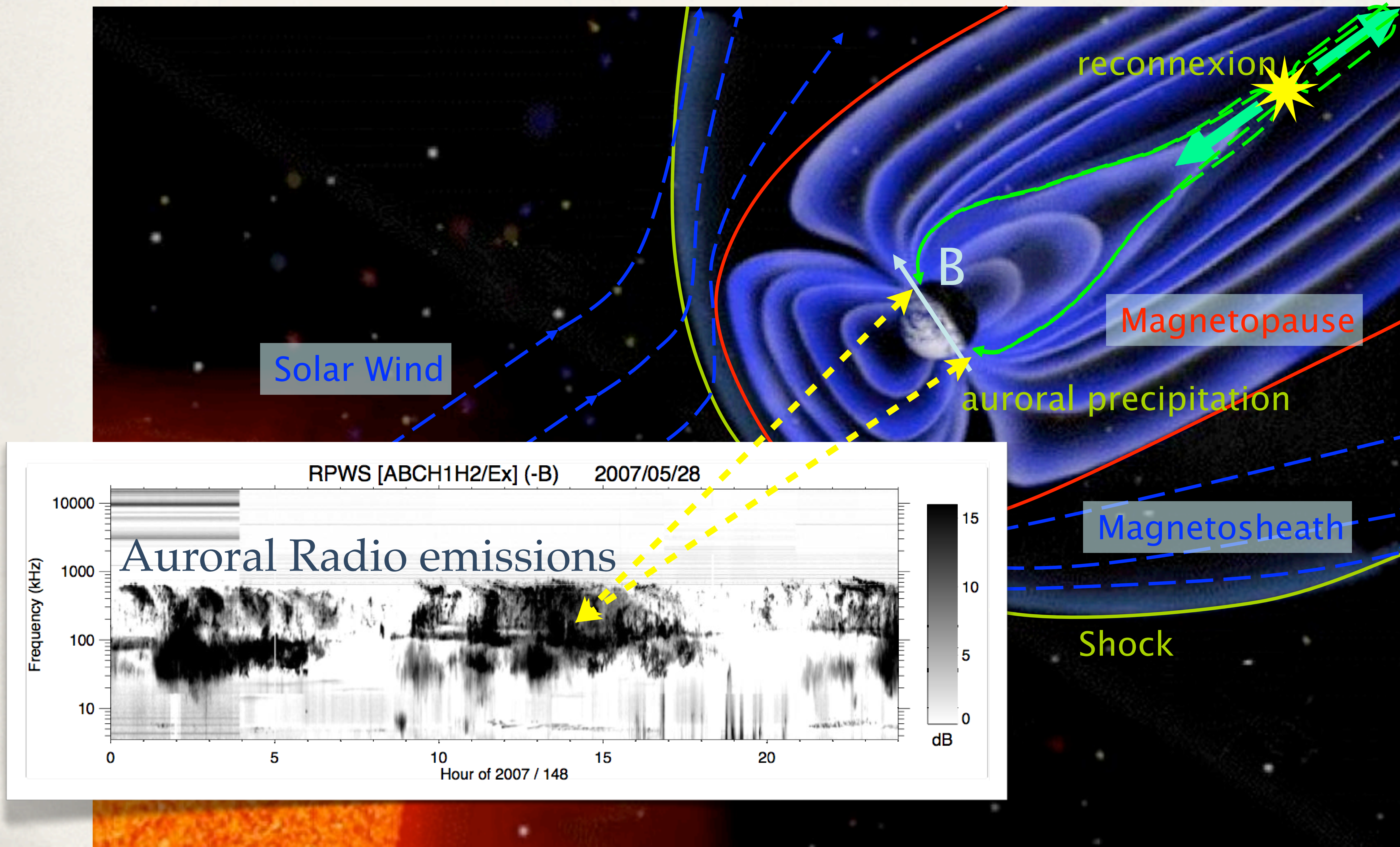
Plasmas in the Solar System
Solar Wind & Magnetized Planets



Plasmas in the Solar System
Solar Wind & Magnetized Planets

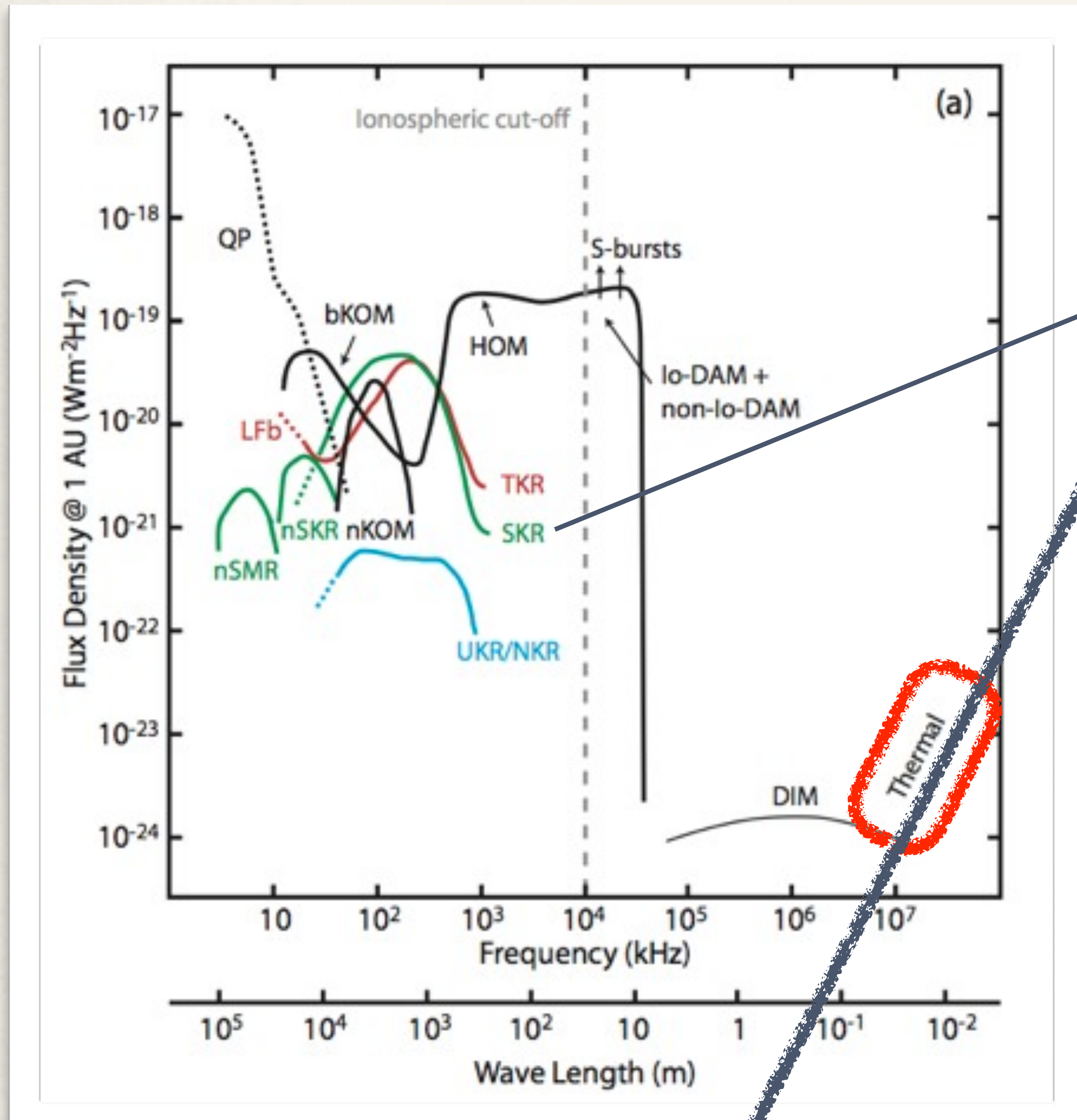


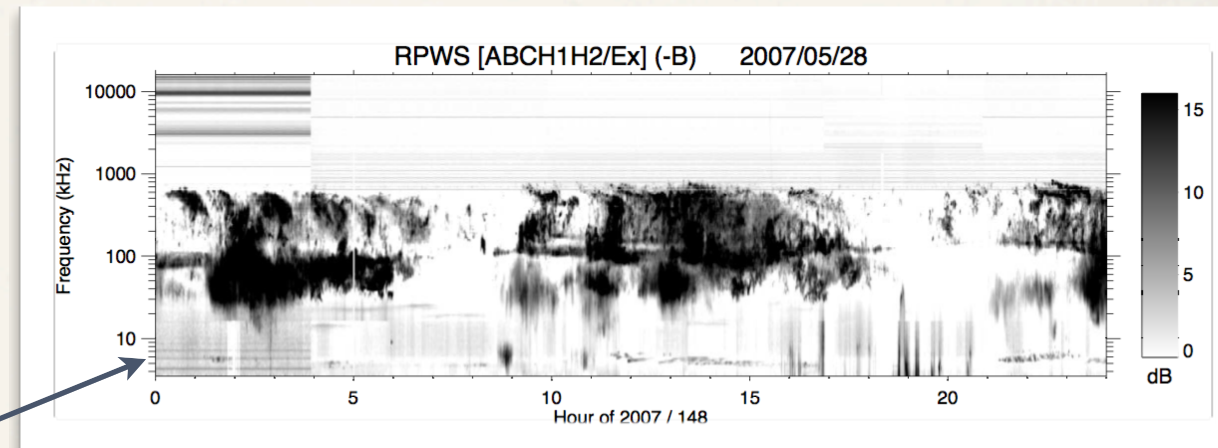
Plasmas in the Solar System
Solar Wind & Magnetized Planets



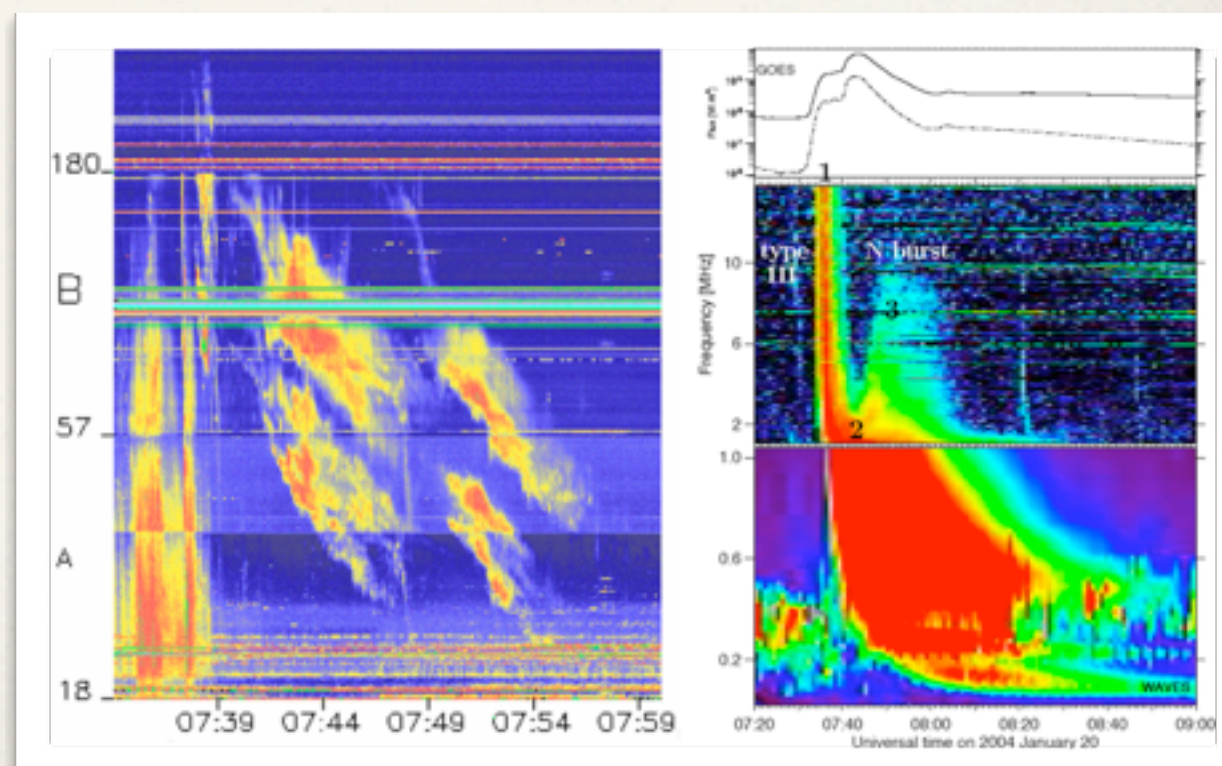
Low Frequency Spectrum in the solar system

Planetary Radio Emissions



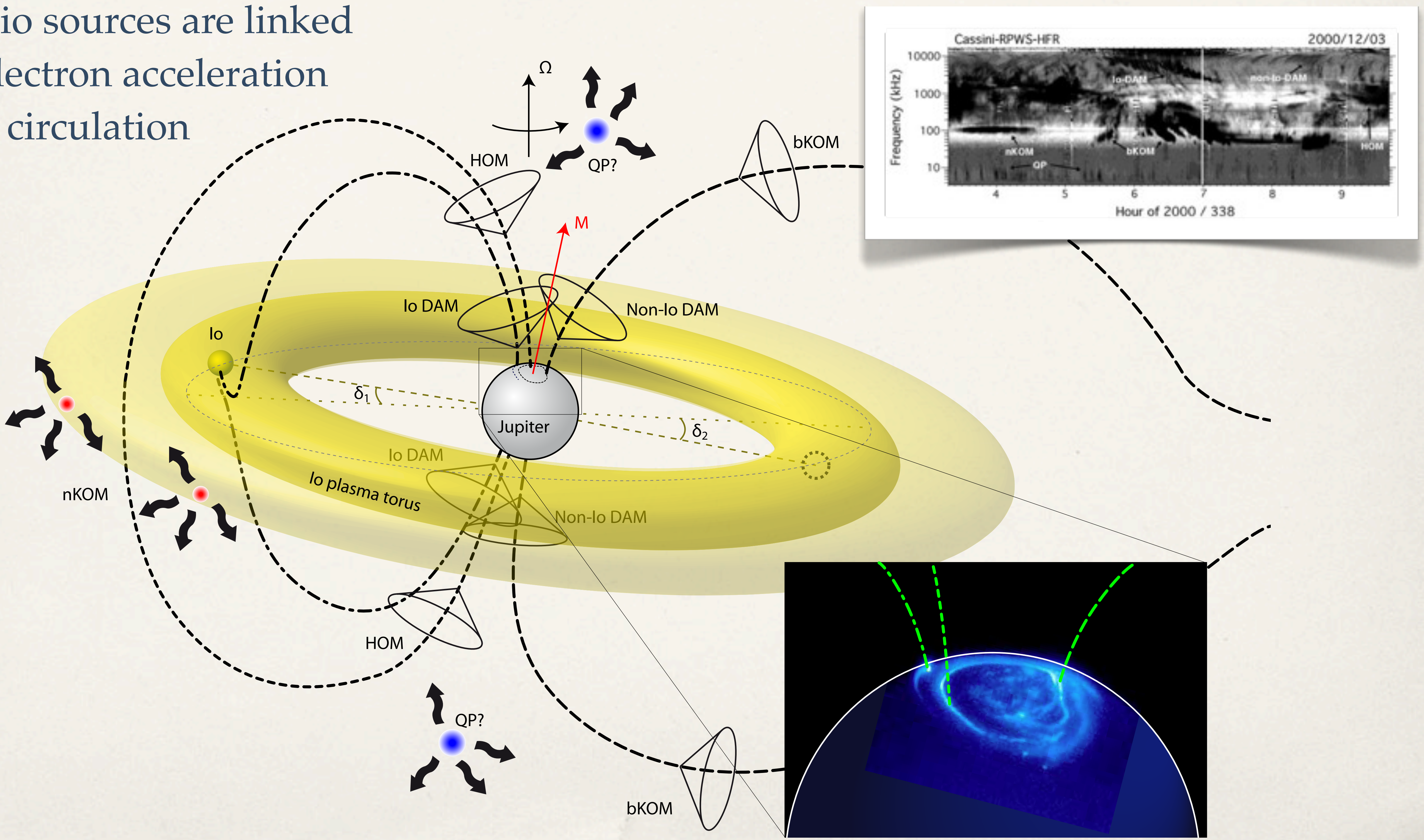


and solar

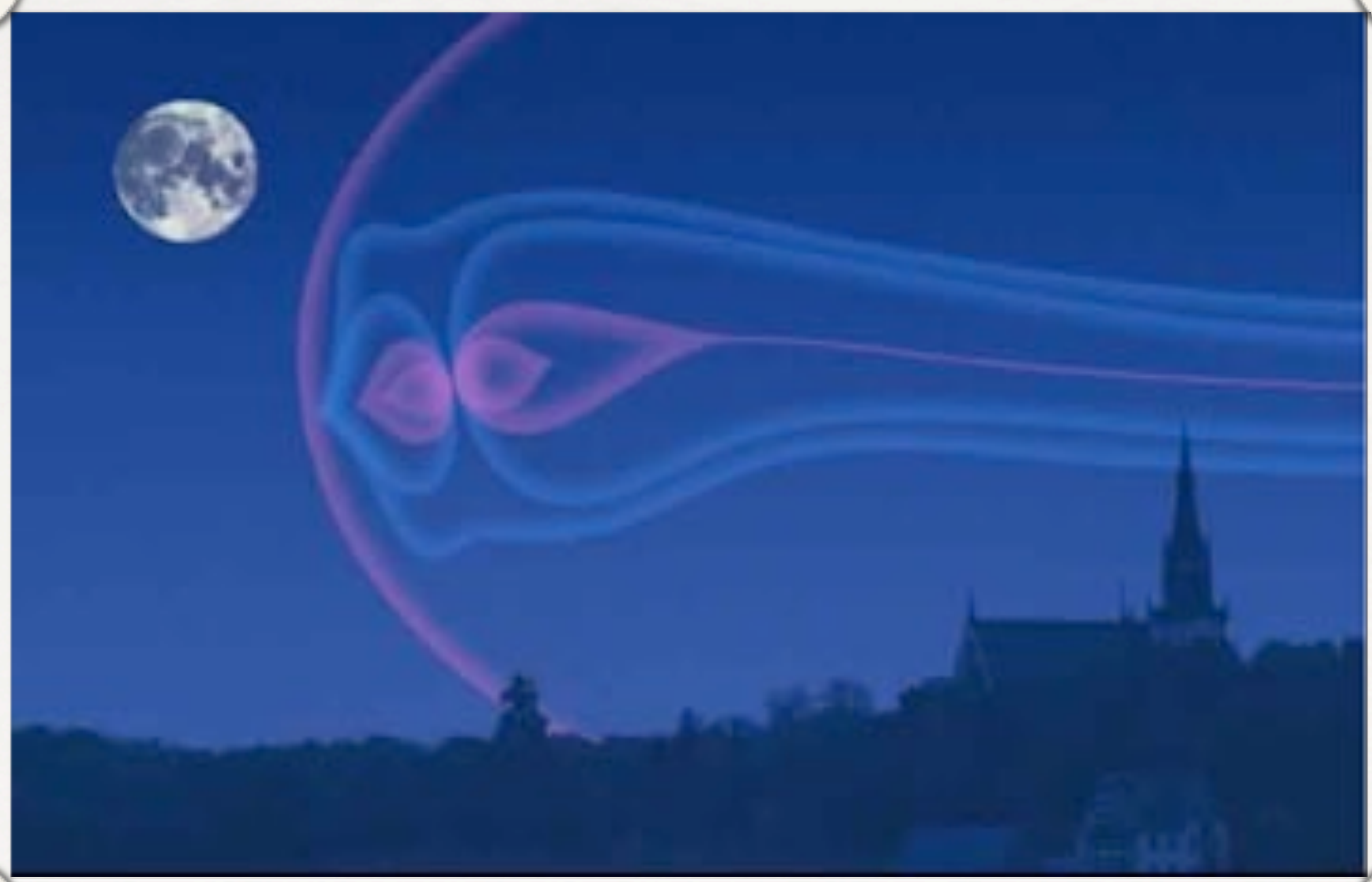


Radio sources at Jupiter

Radio sources are linked to electron acceleration and circulation

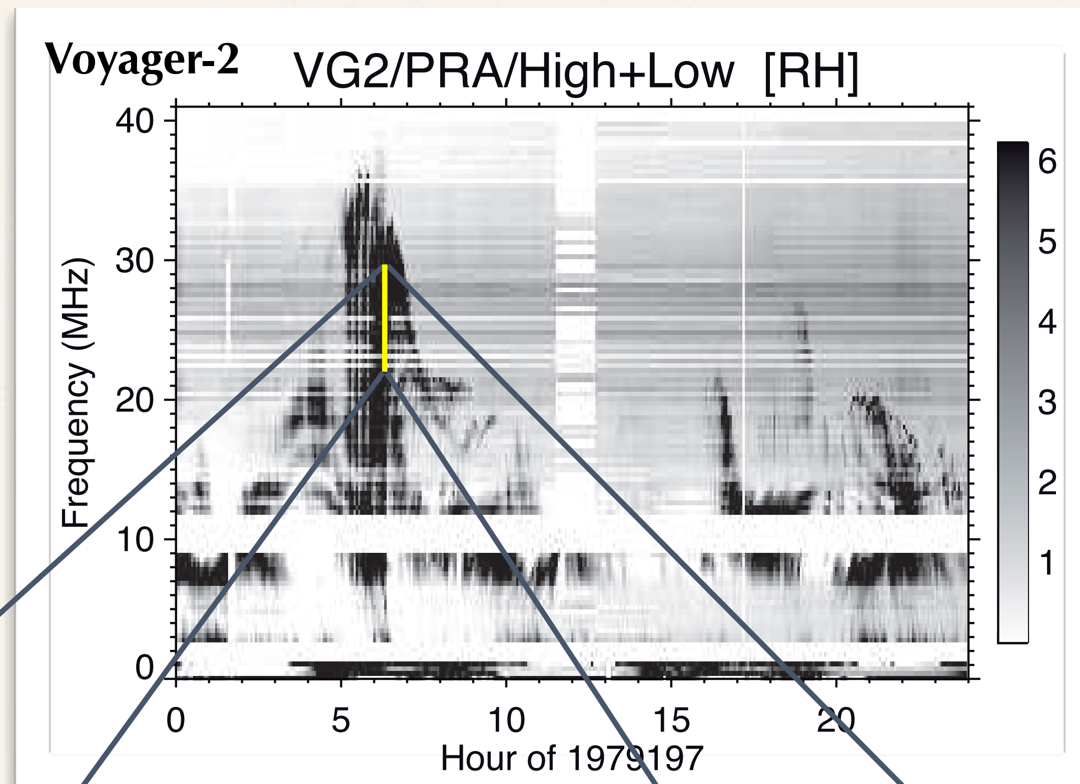


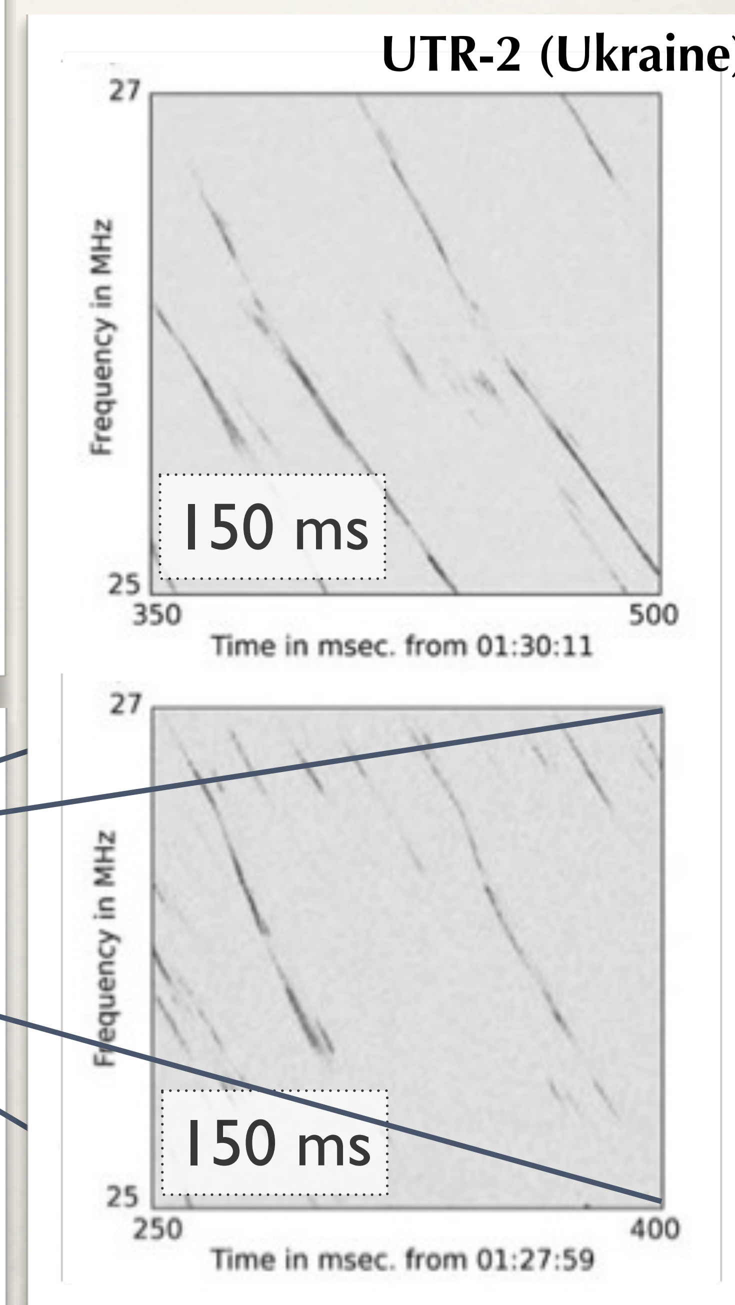
Magnetosphere of Jupiter:
the largest solar system object in our sky

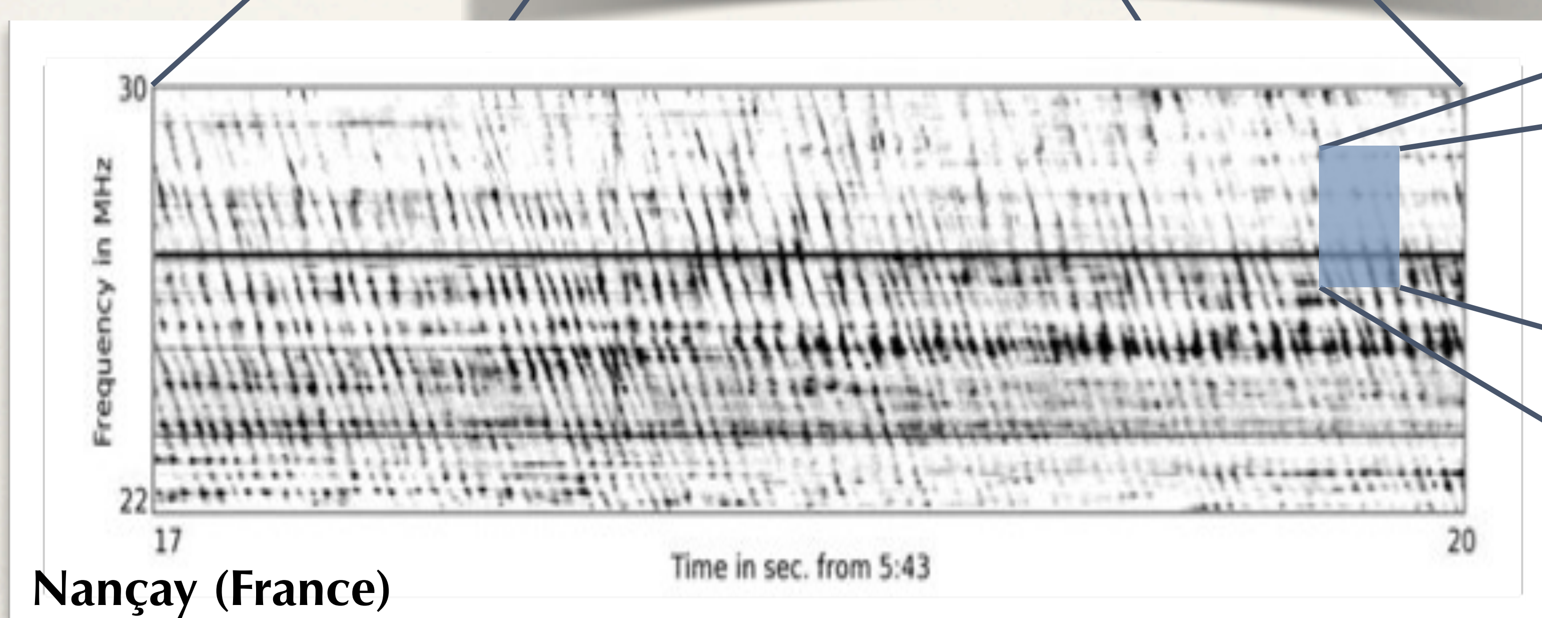


Jovian radio emissions

- Frequency: 0-40 MHz
- Multi scale structure (a few ms to a few hr)
- Sporadic
- Very dynamic
- S-bursts [short-bursts] [=millisecond bursts]



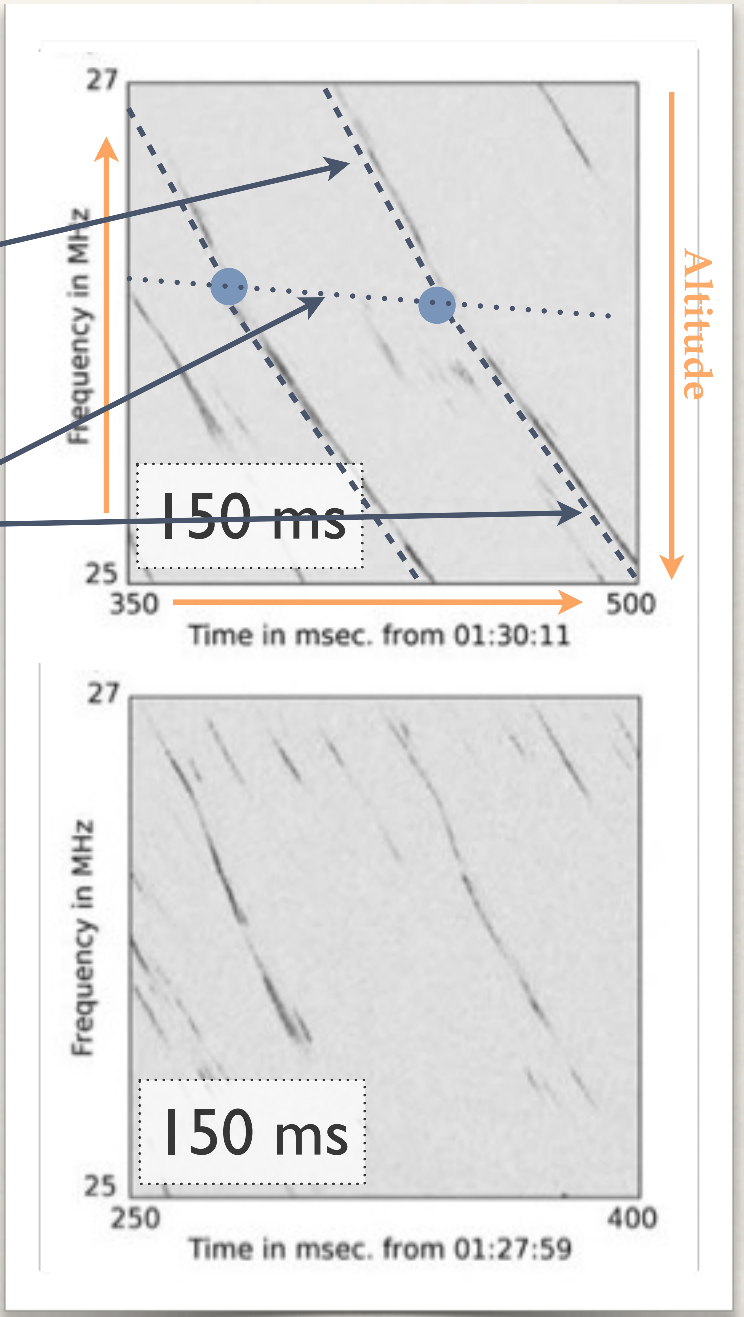




Science with radio emissions !

Hess, Zarka, Mottez, Ryabov. ***2009****. Planet. Space Sci.* ***57****: 23–33*

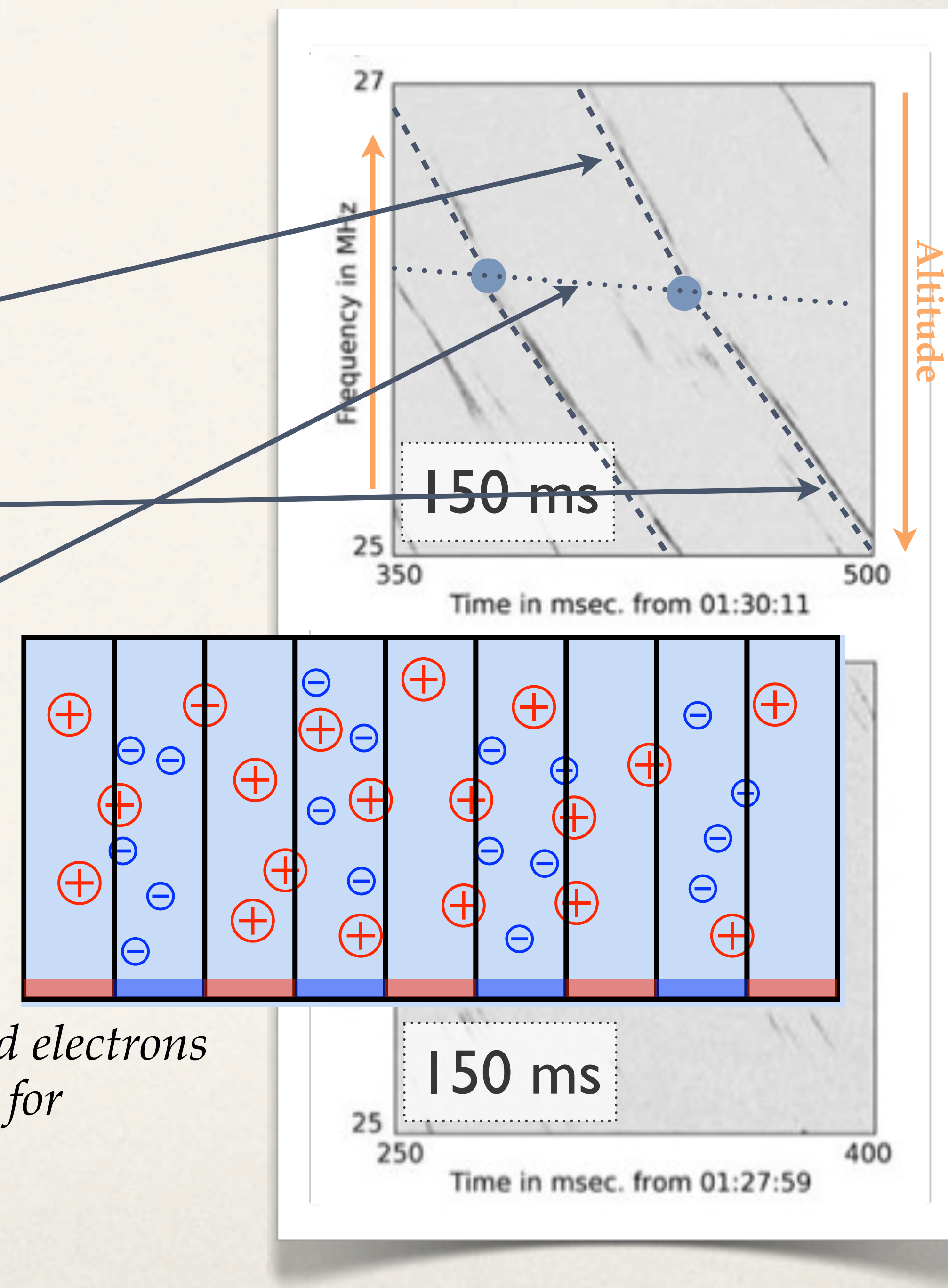
- **Frequency decrease** = Magnetic field decrease *(F = qB/m)*
  = Altitude increase (magnetic field high near surface)
- **Decreasing tone** = Electron beams going away from Jupiter
- **Slope** = Electron speed (–20MHz/s => ~20 000 km/s !)
- **Change in slope** = change in speed of electrons
  = acceleration (or deceleration) of electrons
  - *How to accelerate electrons ? (Electric field layer?)*
- **Drift of «Change in slope» frequency**
  = Altitude change of the «election accelerator/decelerator»
- From the data: **Drift of «Change in slope» frequency**
  = velocity of sound in the medium (~10 km/s)
  - *In a plasma, a sound wave = slow periodic movement of background electrons and protons (but 900 times more heavy => almost no displacement for protons)*
    => Electric field layers !!



Science with radio emissions !

Hess, Zarka, Mottez, Ryabov. ***2009****. Planet. Space Sci.* ***57****: 23–33*

- **Frequency decrease** = Magnetic field decrease *(F = qB/m)* = Altitude increase (magnetic field high near surface)
- **Decreasing tone** = Electron beams going away from Jupiter
- **Slope** = Electron speed (–20MHz/s => ~20 000 km/s !)
- **Change in slope** = change in speed of electrons = acceleration (or deceleration) of electrons
  - *How to accelerate electrons ? (Electric field layer?)*
- **Drift of «Change in slope» frequency** = Altitude change of the «election accelerator/decelerator»
- From the data: **Drift of «Change in slope» frequency = velocity of sound in the medium (~10 km/s)**
  - *In a plasma, a sound wave = slow periodic movement of background electrons and protons (but 900 times more heavy => almost no displacement for protons)*
    => Electric field layers !!

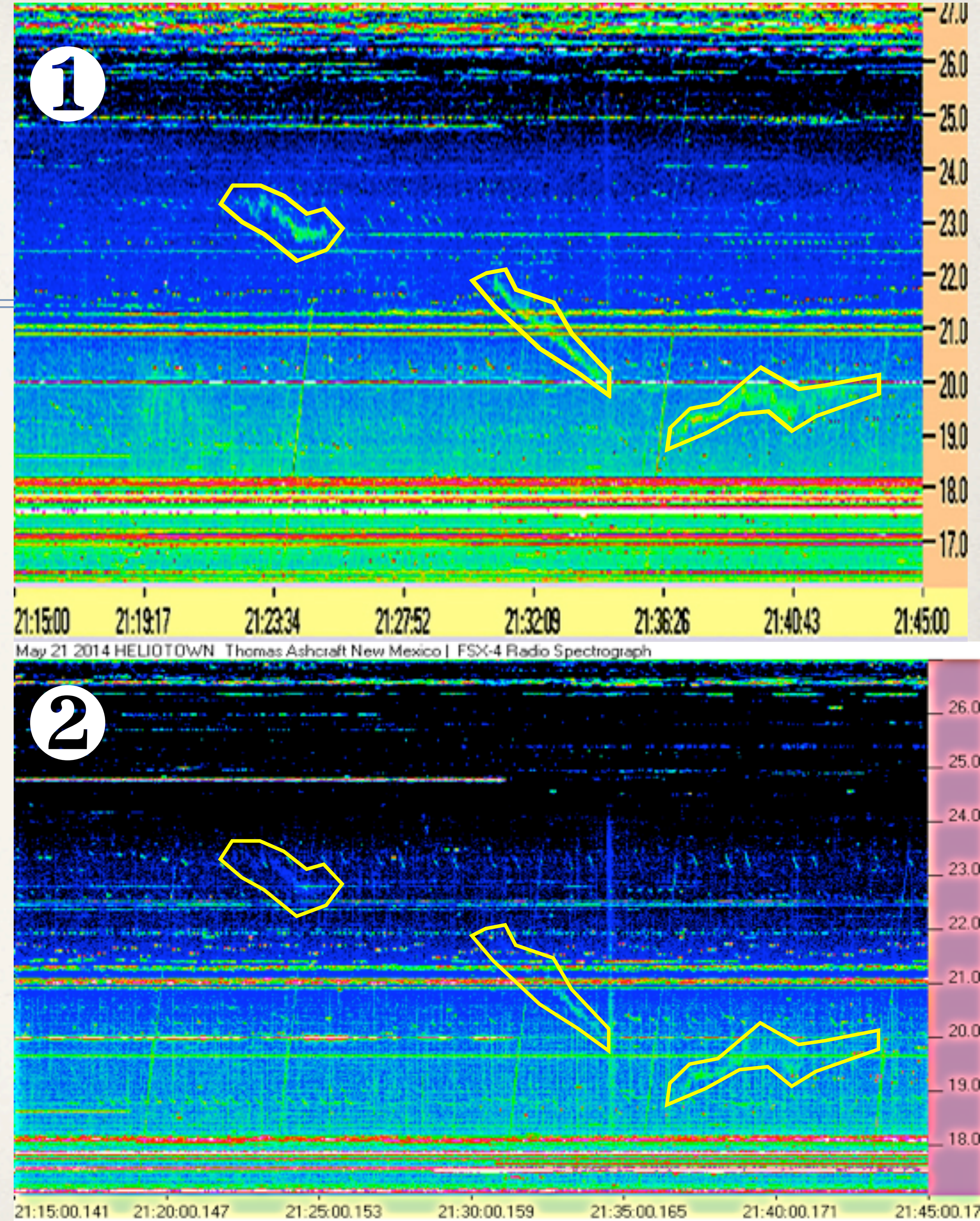


Why Sharing Jovian Radio Emissions Data ?

- Occurrence can be **predicted in a statistical manner** but they are intrinsically **sporadic**.
- Enlarging the temporal coverage of the jovian radio emission is a key aspect of the understanding of this sporadicity.
- In addition to the temporal variability of the emission, a larger spatial and temporal coverage will provide informations on the temporal width of each burst (radio arc), the **short term variability** of the arc shape...
- This may provide key information on the radio source properties, as well as on the radio source environment.

Example: May 21st 2014

- ❶ Dave Typinsky [in Florida]
- ❷ Tom Ashcraft [in New Mexico]
- **Some fun maths:**
  Distance between observers:
  ~ 2700 km [~ 1700 miles]
  Earth-Jupiter Distance (at that time):
  ~ 880 10^6 km [~ 5.9 AU]
  Rotation rate of jovian radio source:
  ~ 0.01 degree/sec [period= 9.92 hr]
  Angle between two obs. seen from Jupiter:
  ~ 0.00017° = 0.6 ʹʹ [=*arctan*(2700/880 10^6)]
  Time for beam to go from one obs to the other:
  ~ 17.6 msec
  Speed of jovian beam spot on Earth:
  ~150 000 km/s ⇒ ½ speed of light !



How to efficiently share data?

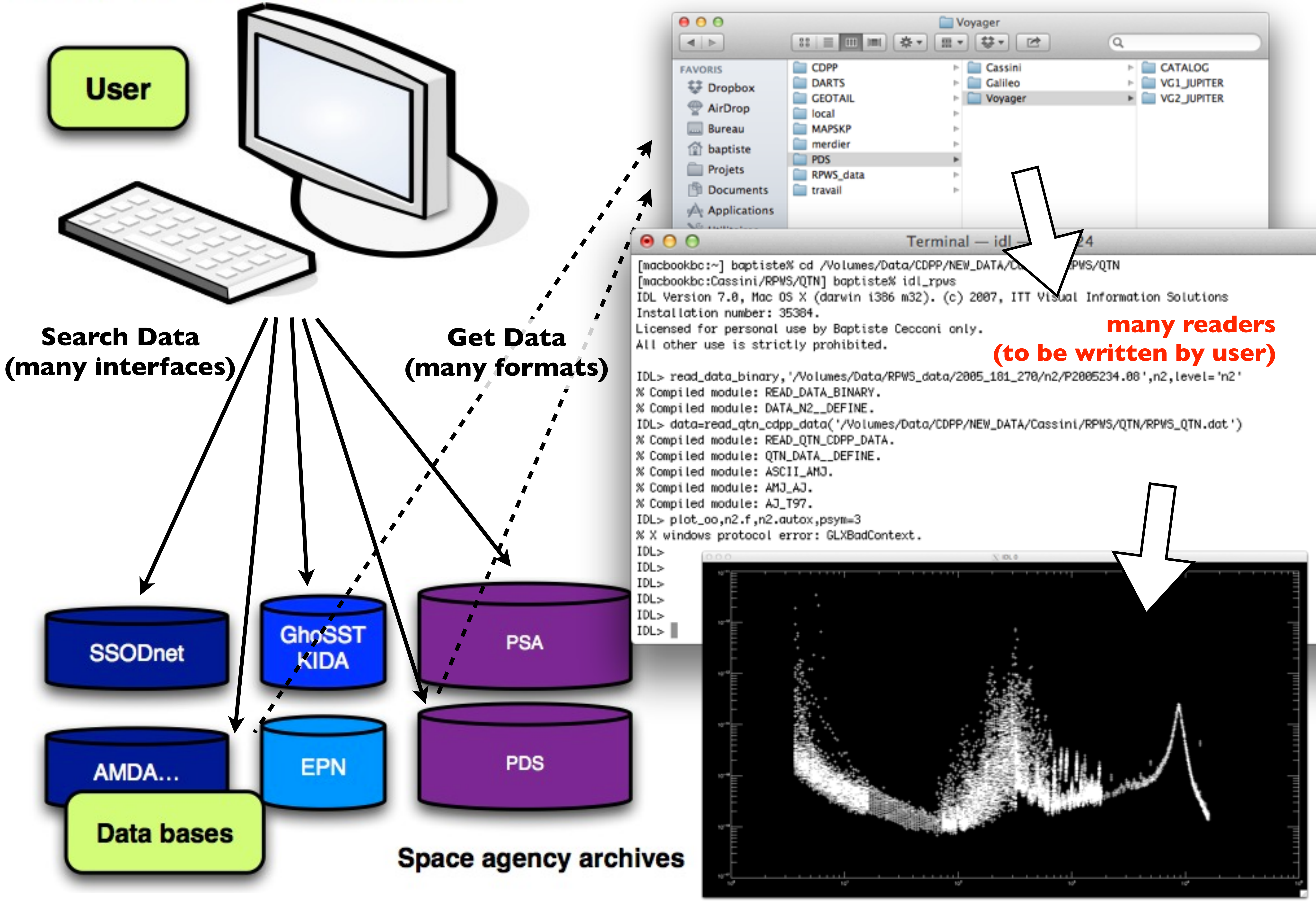
- Provide **calibrated data**, or data include enough pieces of information to calibrate the data.
- Provide data in a **standard format** commonly used by scientists.
- Provide data with observation «**metadata**» (location of observer, accurate time of observation in UT, observation target name...) using a standard set of keywords.
- Make it available to a database network (a.k.a. «**virtual observatory**») used by scientists

What is a Virtual Observatory?

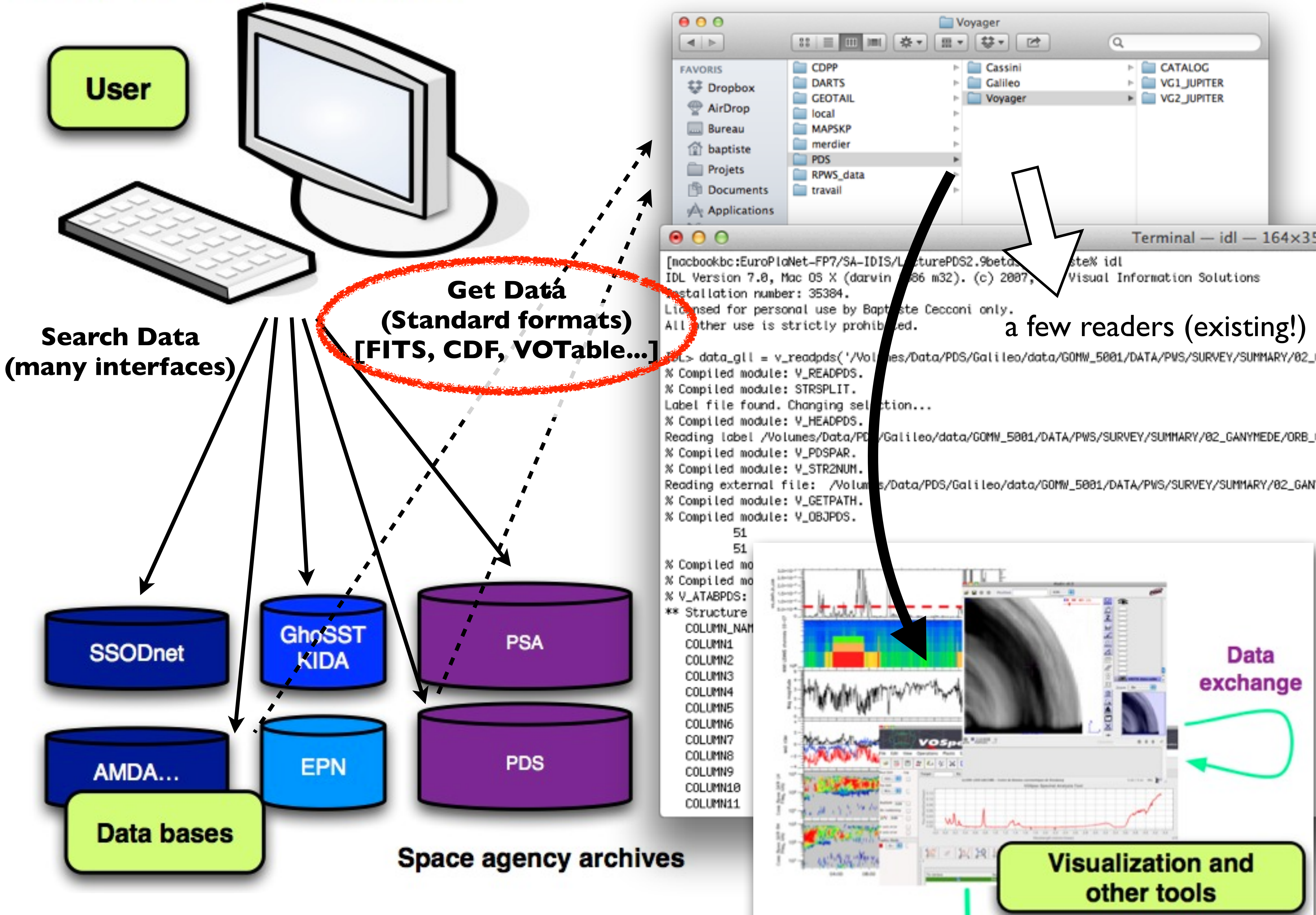
- A network of databases that all **speak a common language** to share their data. The user goes to a simple interface and searches for data, the portal is looking into remote databases and fetches results.
- Astronomical Virtual Observatory (VO) is the main one:
  - *sharing images, spectra, catalogs, times series…*
  - *large data repositories and catalogs*
  - *searchable interfaces*
  - *plotting tools*

  Everything is **freely available on the web**.
  US portal to Astronomical VO: http://www.usvao.org
  French portal to Astronomical VO: http://cdsweb.u-strasbg.fr
- **What about low frequency radio?**
  http://cdaweb.gsfc.nasa.gov *CDAWeb is providing free access to a lot of space borne data*
  http://vwo.gsfc.nasa.gov *VWO (Virtual Wave Observatory): access to many radio instrument (mostly space based)*
  http://amda.cdpp.eu *(Automated Multi Dataset Analysis tool) plotting tool with many space physics and planetary dataset included (free, but login required to keep user settings between connections)*

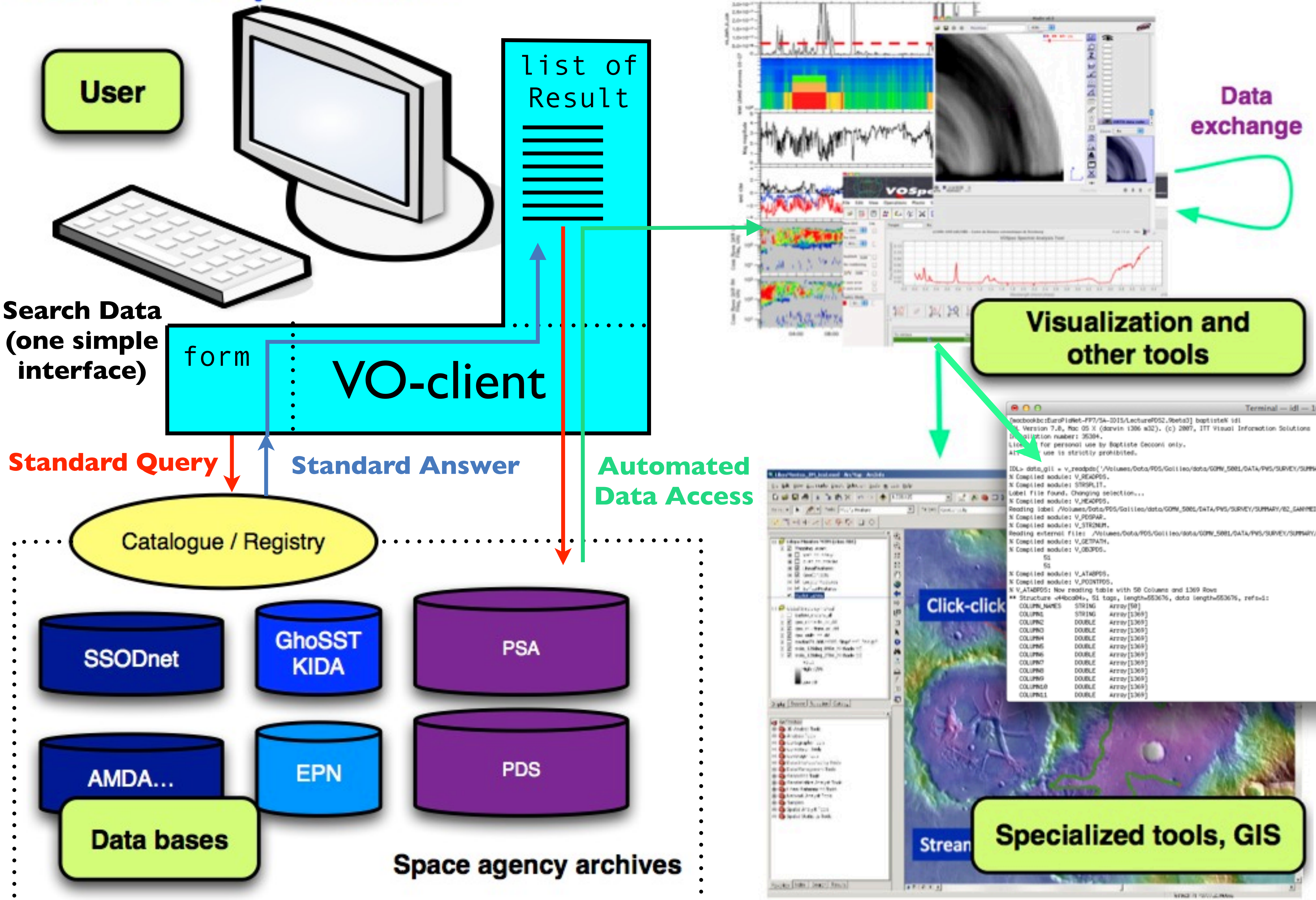
User's experience «classic»



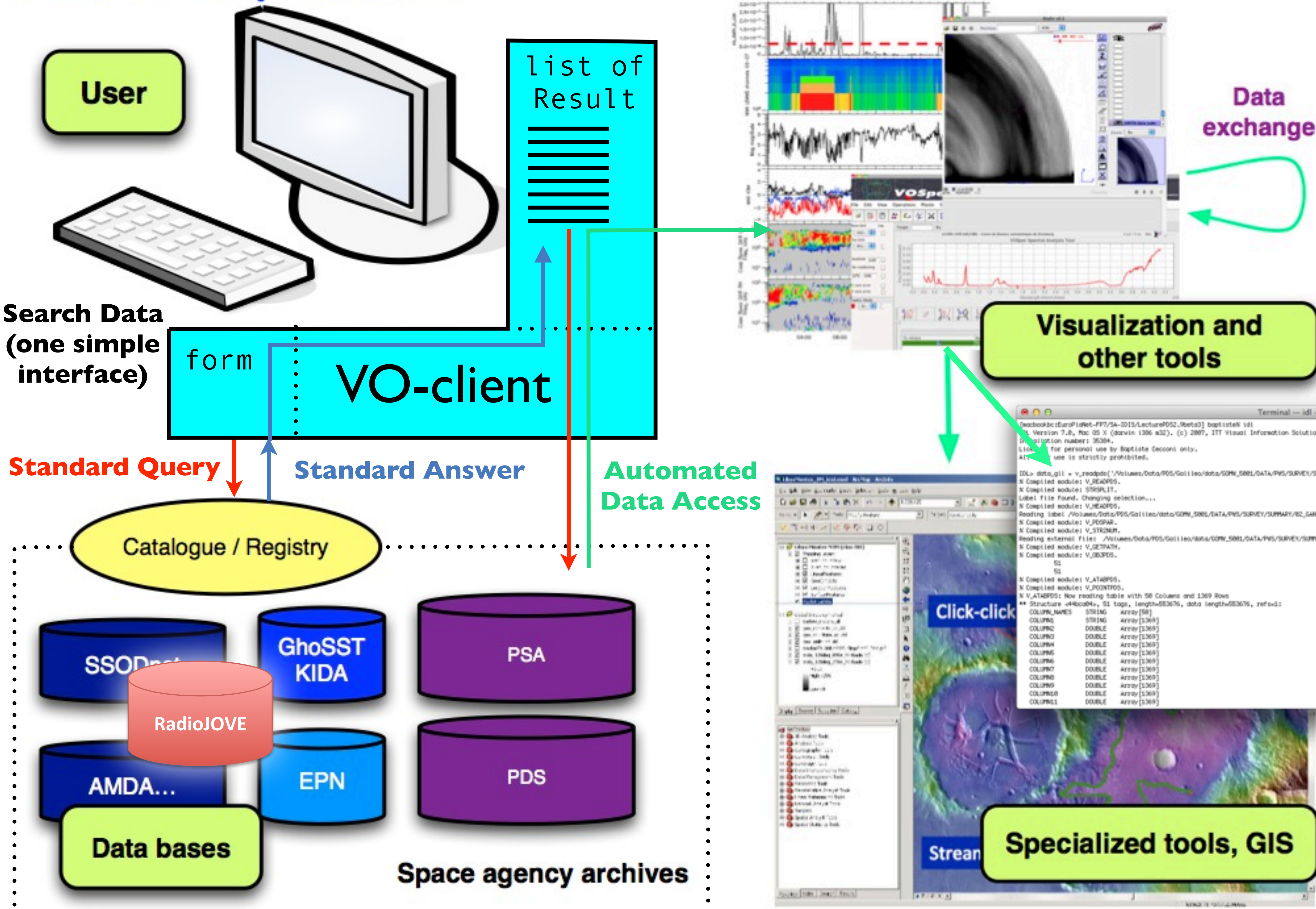
User's experience «enhanced»



User's experience «ultimate» (=Virtual Observ.)



User's experience «ultimate» (=Virtual Observ.)



Currently available data

- Nançay Decameter Array Routine Observations (France)
  - raw data file on Obs-Nancay website + quicklooks
  - available on VESPA network (Virtual Observatory access)

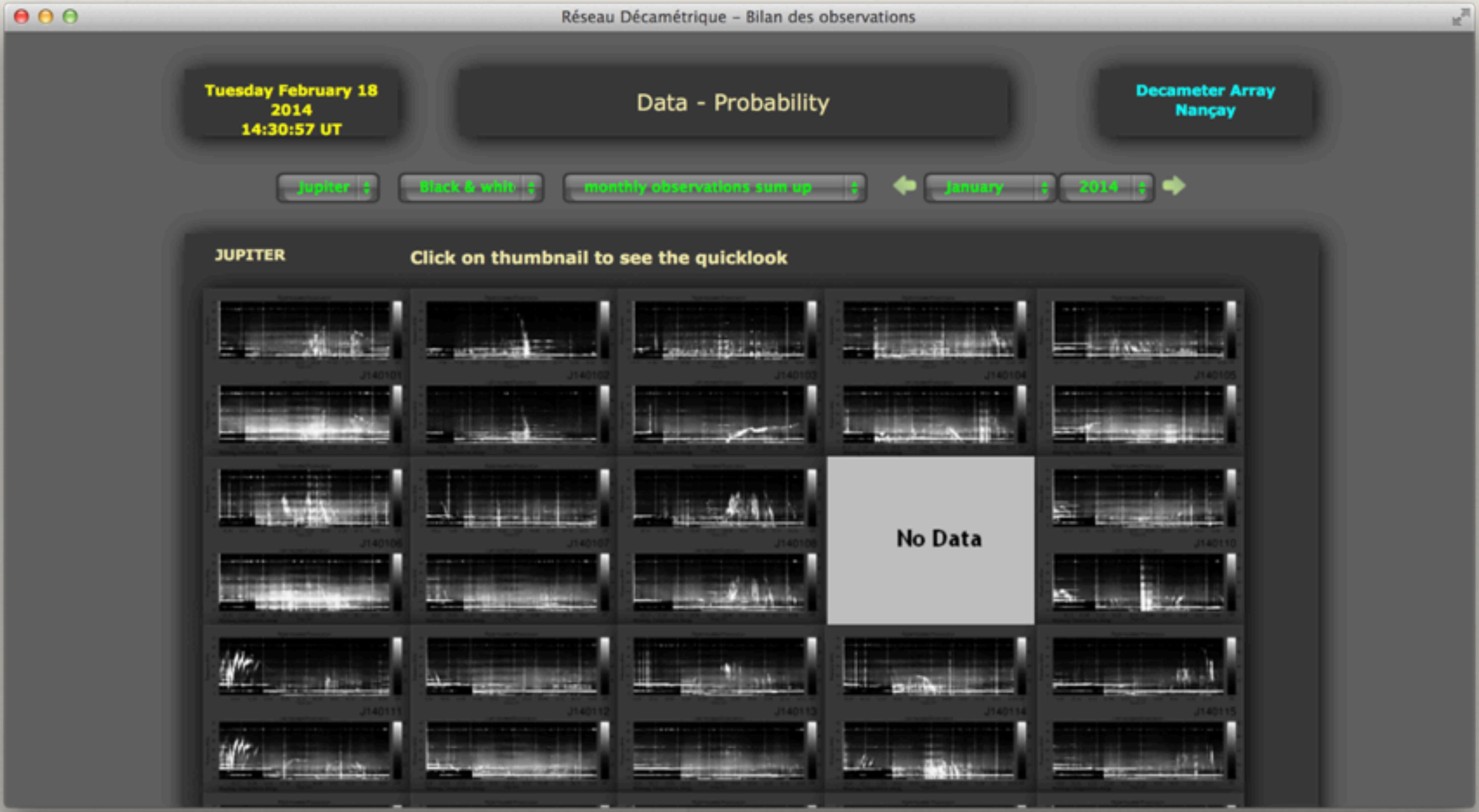
- Iitate Observatory (Japan)
  - FITS files + quicklooks
  - available on IUGONET network (Virtual Observatory access)

- Current RadioJove Archive website
  - quicklooks (very few data [wav files?])

- Univ. of Florida data
  - available soon (C. Higgins, next year?)

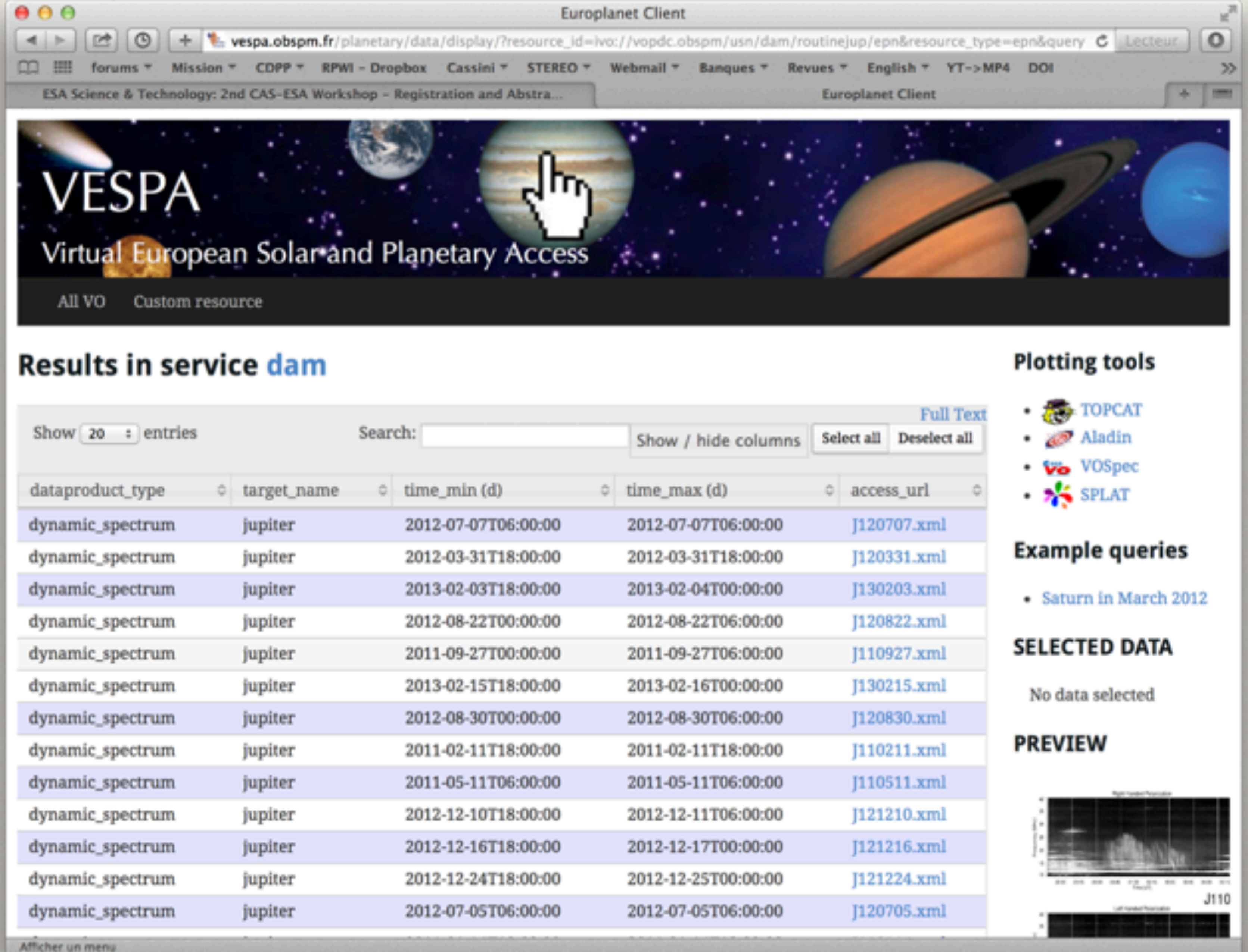
Nançay Jupiter data

- Quicklooks + Access to raw data



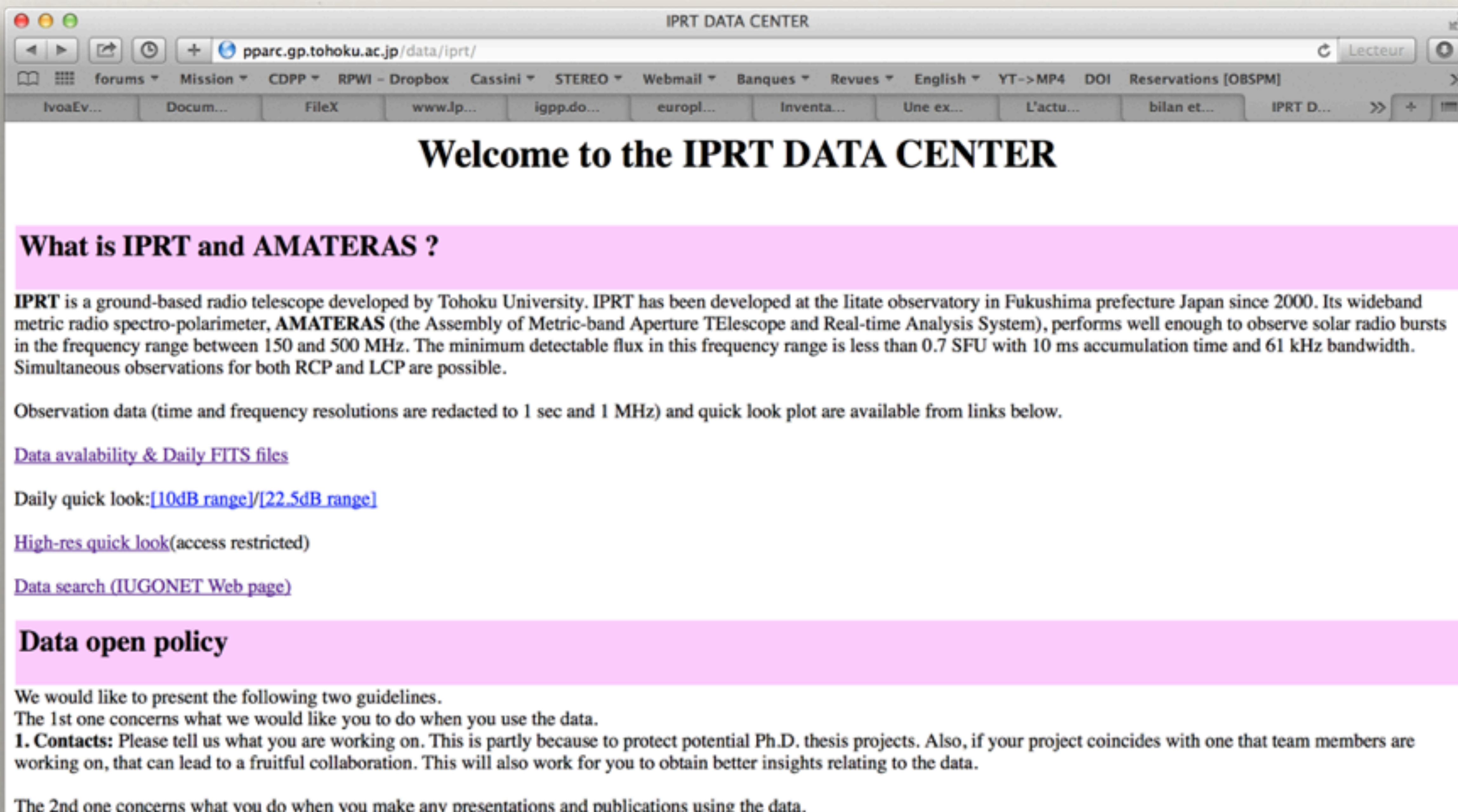
Nançay Jupiter data

- Virtual Observatory access



Iitate Jupiter data

- High Res Quicklooks (password) + Daily FITS files (free access)



Welcome to the IPRT DATA CENTER

What is IPRT and AMATERAS ?

IPRT is a ground-based radio telescope developed by Tohoku University. IPRT has been developed at the Iitate observatory in Fukushima prefecture Japan since 2000. Its wideband metric radio spectro-polarimeter, **AMATERAS** (the Assembly of Metric-band Aperture TElescope and Real-time Analysis System), performs well enough to observe solar radio bursts in the frequency range between 150 and 500 MHz. The minimum detectable flux in this frequency range is less than 0.7 SFU with 10 ms accumulation time and 61 kHz bandwidth. Simultaneous observations for both RCP and LCP are possible.

Observation data (time and frequency resolutions are redacted to 1 sec and 1 MHz) and quick look plot are available from links below.

Data avalability & Daily FITS files

Daily quick look:[10dB range]/[22.5dB range]

High-res quick look(access restricted)

Data search (IUGONET Web page)

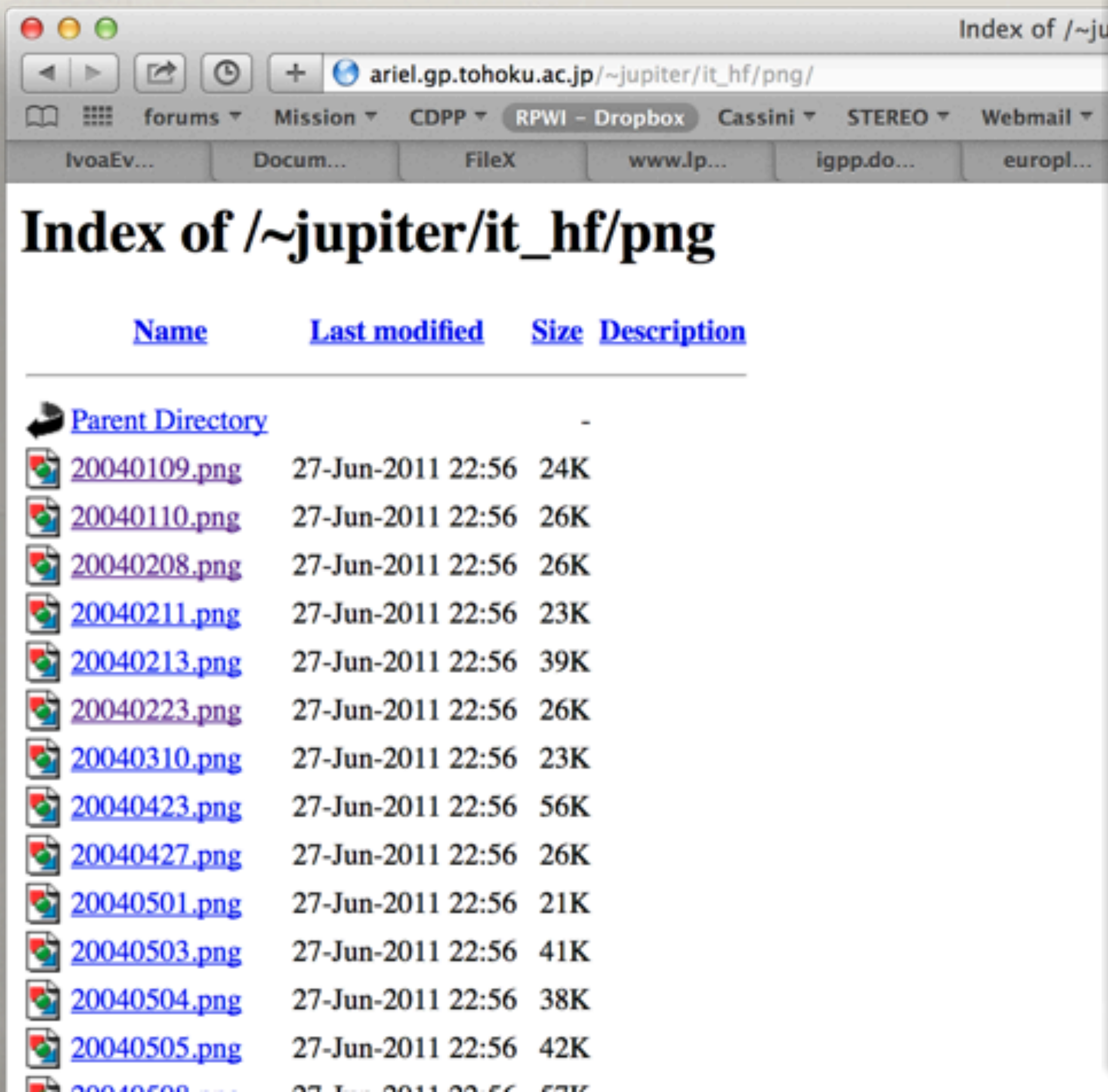
Data open policy

We would like to present the following two guidelines.
The 1st one concerns what we would like you to do when you use the data.
1. Contacts: Please tell us what you are working on. This is partly because to protect potential Ph.D. thesis projects. Also, if your project coincides with one that team members are working on, that can lead to a fruitful collaboration. This will also work for you to obtain better insights relating to the data.

The 2nd one concerns what you do when you make any presentations and publications using the data.

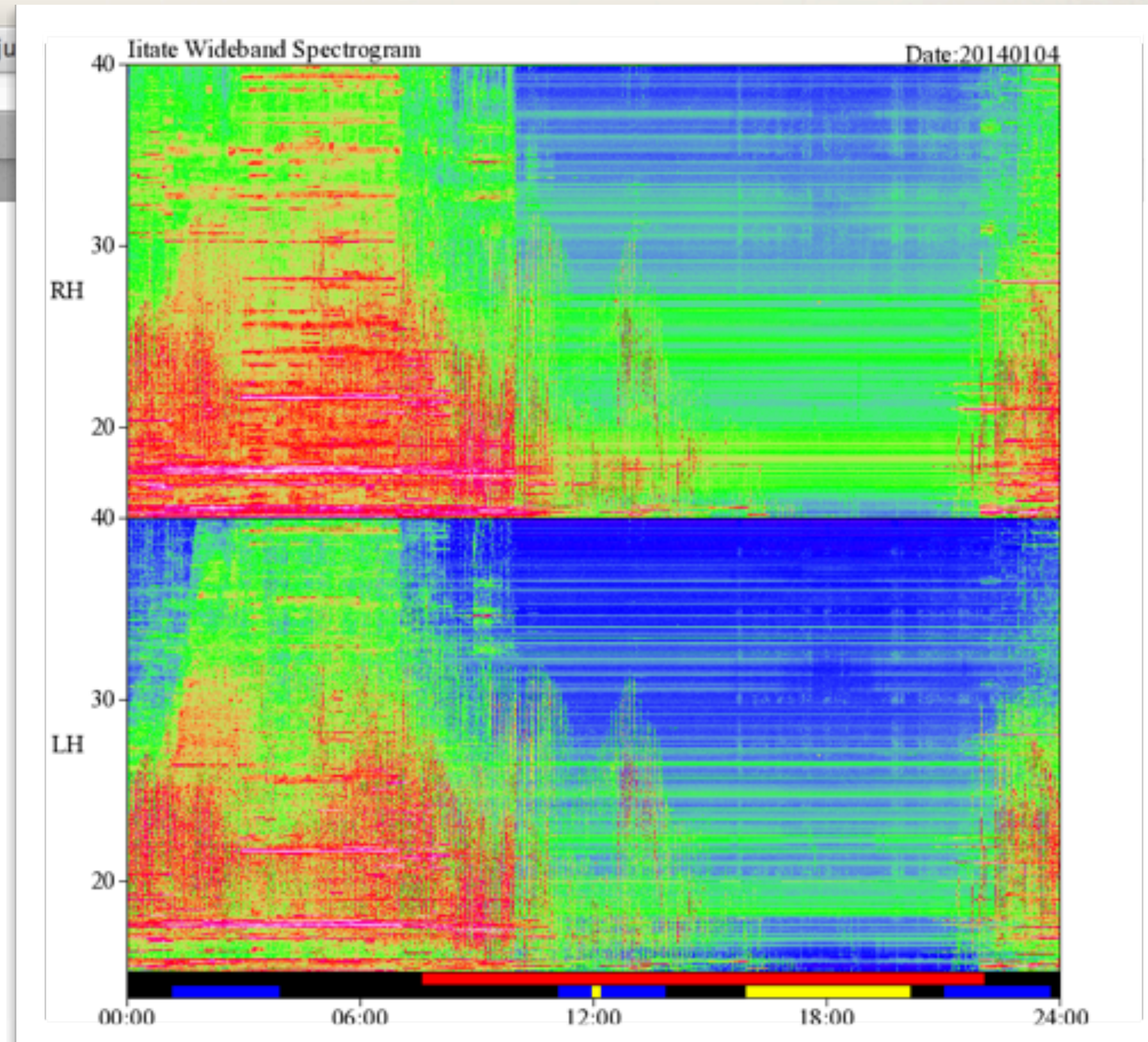
Iitate Jupiter data

- Quicklooks via IUGONET registry:



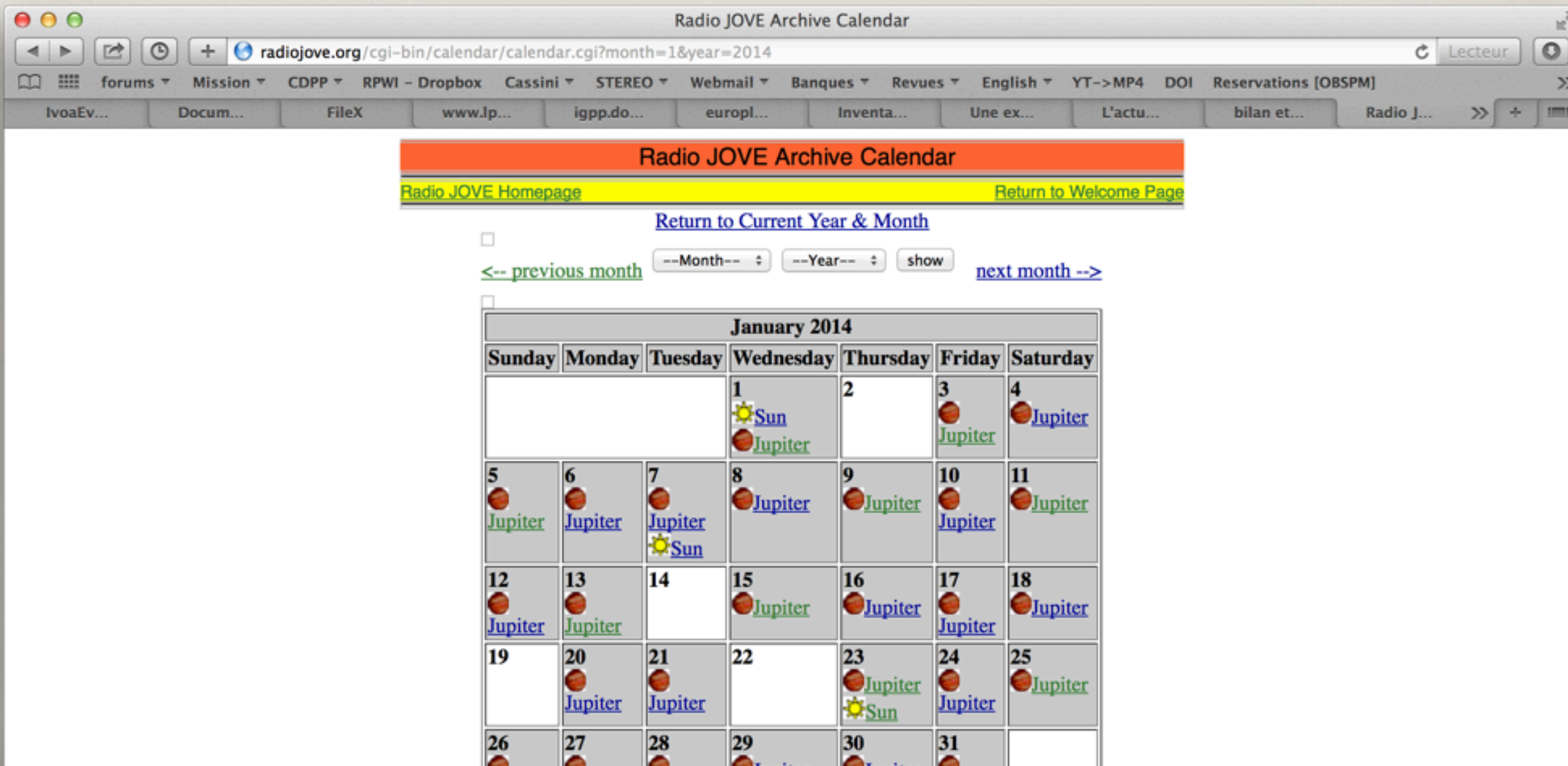
Index of /~jupiter/it_hf/png

Name	Last modified	Size	Description
Parent Directory		-	
20040109.png	27-Jun-2011 22:56	24K	
20040110.png	27-Jun-2011 22:56	26K	
20040208.png	27-Jun-2011 22:56	26K	
20040211.png	27-Jun-2011 22:56	23K	
20040213.png	27-Jun-2011 22:56	39K	
20040223.png	27-Jun-2011 22:56	26K	
20040310.png	27-Jun-2011 22:56	23K	
20040423.png	27-Jun-2011 22:56	56K	
20040427.png	27-Jun-2011 22:56	26K	
20040501.png	27-Jun-2011 22:56	21K	
20040503.png	27-Jun-2011 22:56	41K	
20040504.png	27-Jun-2011 22:56	38K	
20040505.png	27-Jun-2011 22:56	42K	



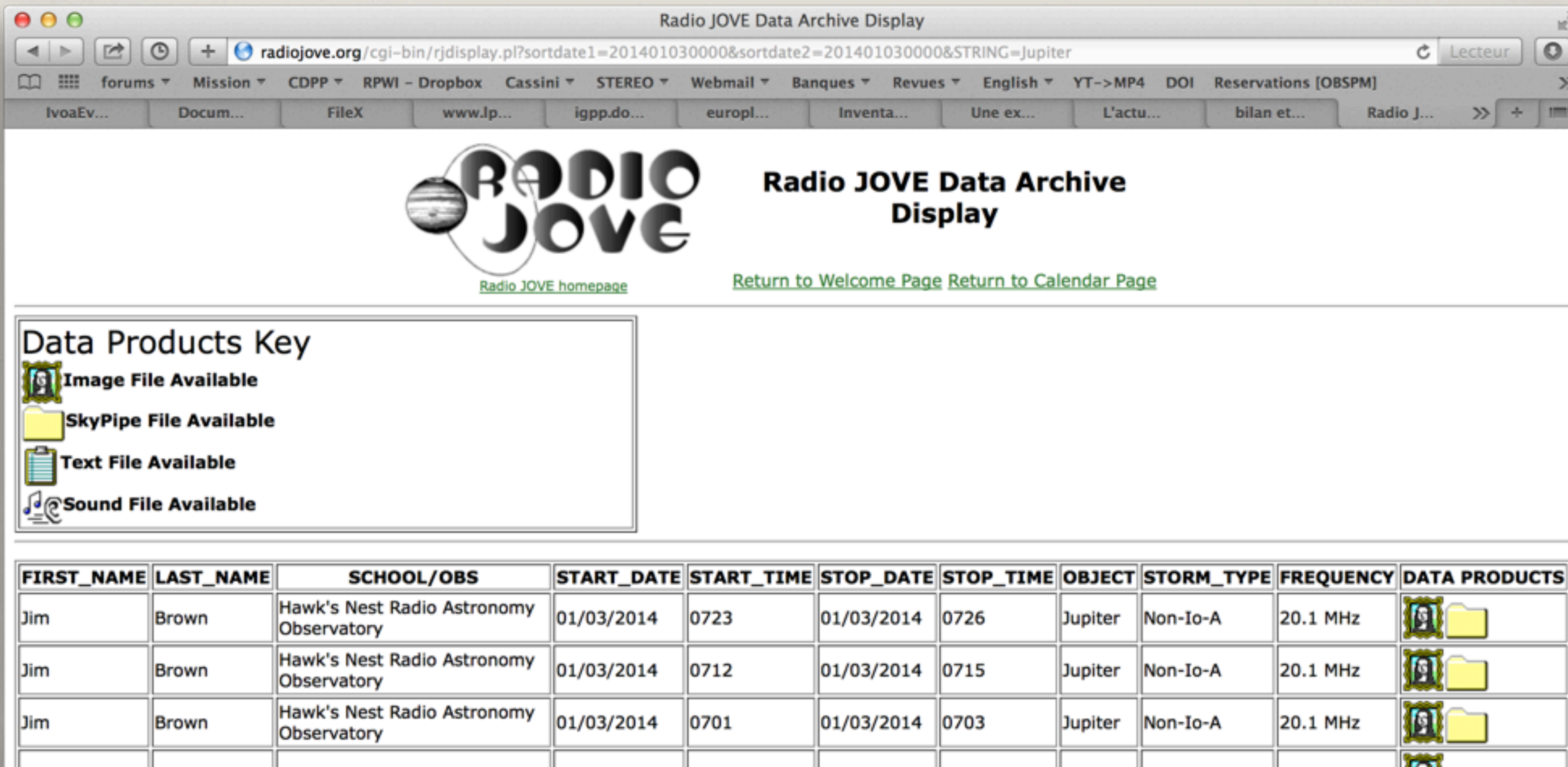
RadioJove archive

- Archive with mainly quicklooks, very few data.



RadioJove archive

- Archive with mainly quicklooks, very few data.


Radio JOVE Data Archive Display

radiojove.org/cgi-bin/rjdisplay.pl?sortdate1=201401030000&sortdate2=201401030000&STRING=Jupiter

Radio JOVE homepage

Radio JOVE Data Archive Display

Return to Welcome Page Return to Calendar Page

Data Products Key

Image File Available

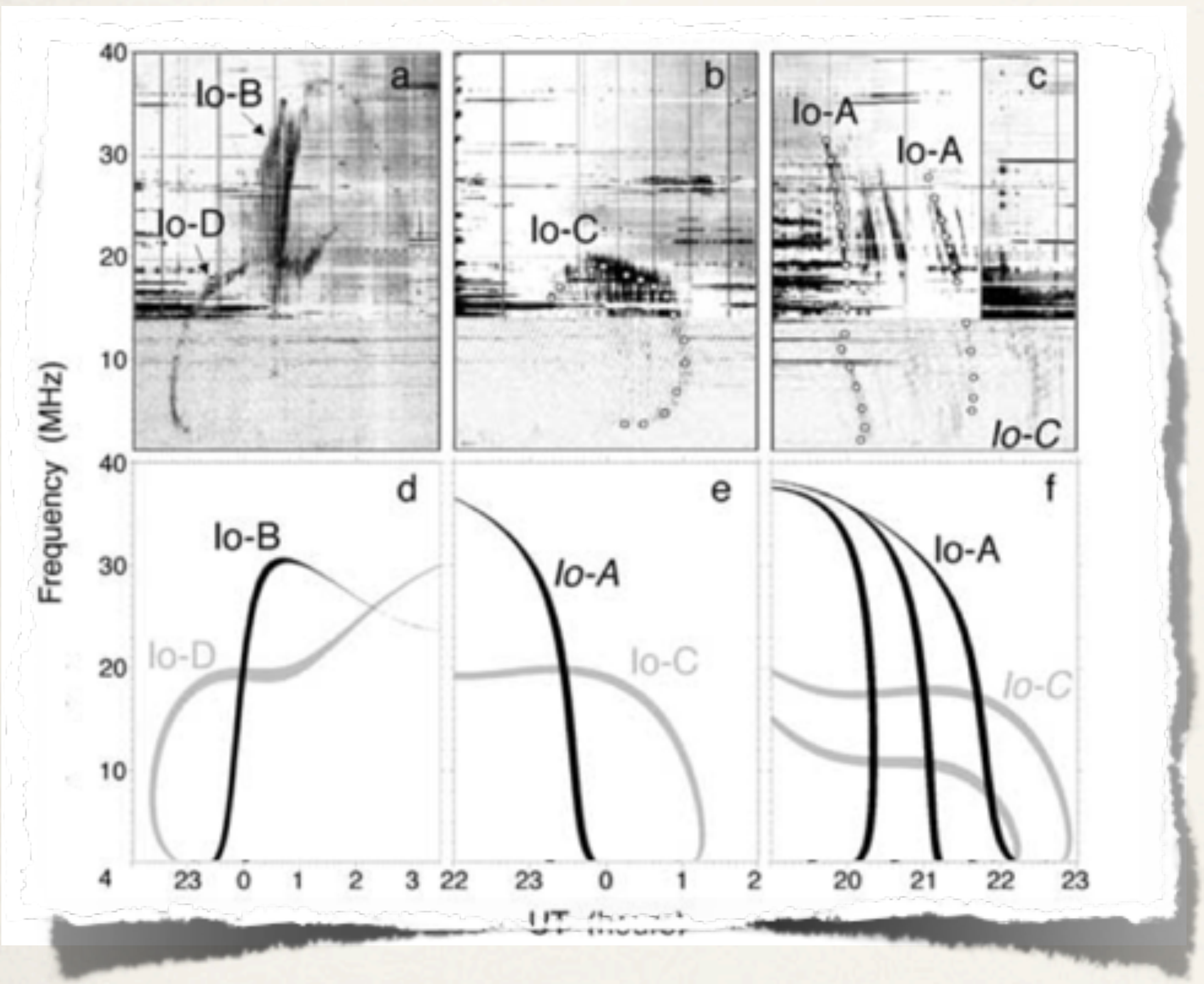
SkyPipe File Available

Text File Available

Sound File Available

FIRST_NAME	LAST_NAME	SCHOOL/OBS	START_DATE	START_TIME	STOP_DATE	STOP_TIME	OBJECT	STORM_TYPE	FREQUENCY	DATA PRODUCTS
Jim	Brown	Hawk's Nest Radio Astronomy Observatory	01/03/2014	0723	01/03/2014	0726	Jupiter	Non-Io-A	20.1 MHz	
Jim	Brown	Hawk's Nest Radio Astronomy Observatory	01/03/2014	0712	01/03/2014	0715	Jupiter	Non-Io-A	20.1 MHz	
Jim	Brown	Hawk's Nest Radio Astronomy Observatory	01/03/2014	0701	01/03/2014	0703	Jupiter	Non-Io-A	20.1 MHz	

ExPRES: *Exoplanetary and Planetary Radio Emissions Simulator*

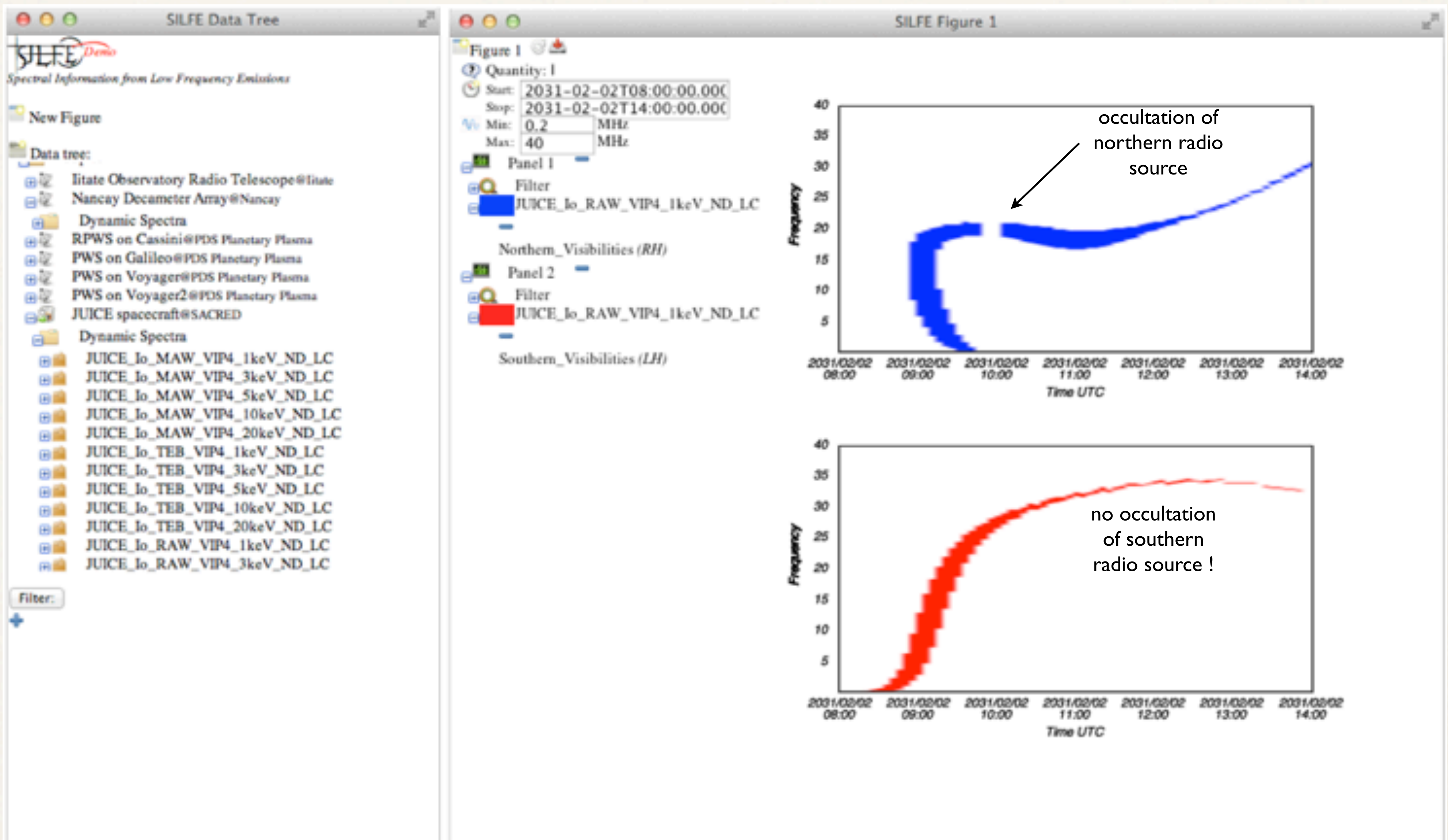


Model input parameter:
- *Location of observer*
- *location of radio source*
- *energy of electrons in the radio source*
- *magnetic field model for Jupiter*

Works also for other planets and exoplanets (not observed yet, though...)

- http://typhon.obspm.fr/maser/serpe
  (still a prototype, login required, needs a cookbook and a user manual!)

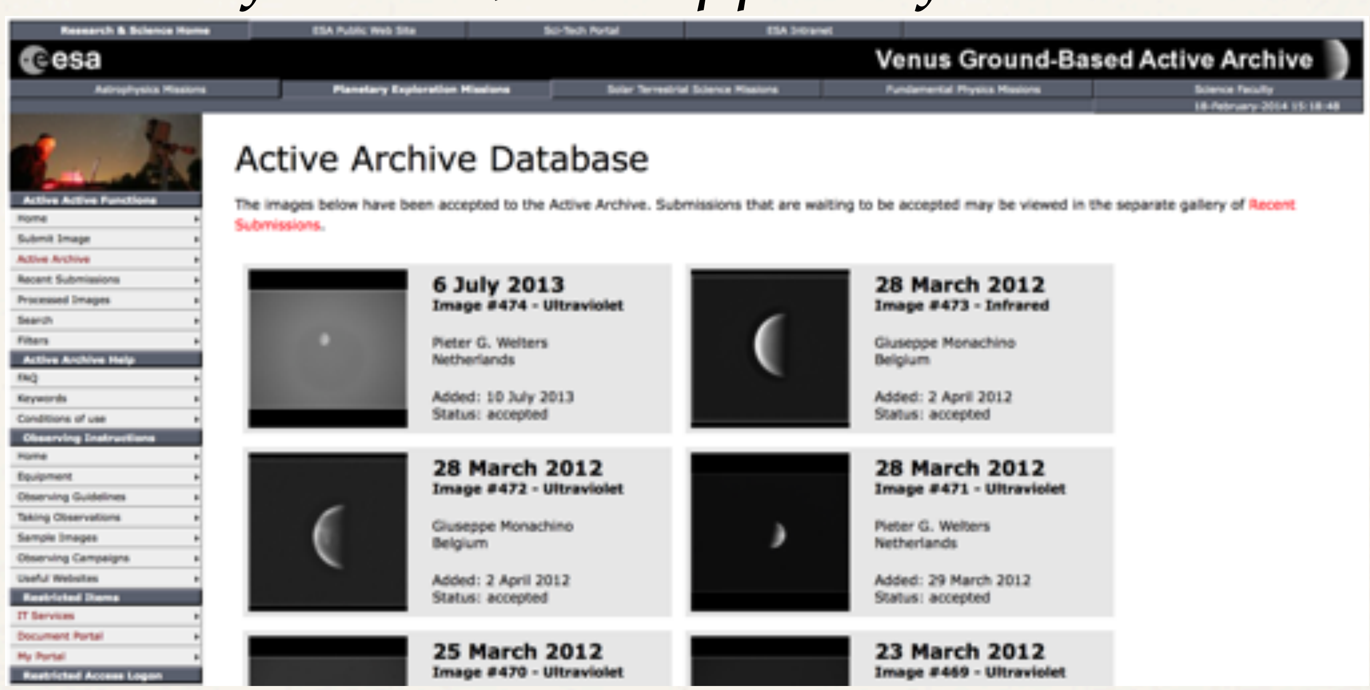
ExPRES: *Exoplanetary and Planetary Radio Emissions Simulator*



- http://typhon.obspm.fr/maser/serpe
  (still a prototype, login required, needs a cookbook and a user manual!)

Similar projects where Amateurs help Science

- Venus Active Archive
  http://www.rssd.esa.int/index.php?project=VENUS&page=Archive
  Amateur observations of Venus, in support of the Venus-Express mission



- Virtual Meteor Observatory
  http://www.rssd.esa.int/index.php?project=METEOR&page=vmo
  Amateur observations of meteor showers, with science tools

Project Description
Metadata («file header»)

- ***Additional metadata (not much) attached to archived records***

  - Location of observer (**GPS location** ?)
  - **UTC of observation** start (synchronized with GPS or NTP if possible)
  - **Spectral range**: min and max frequency
  - Data file format: cdf/FITS /votable/netcdf…
  - **Data** : Recorded file
  - **Quicklook**: in png format preferred
  - **Target** (Jupiter)
  - **Annotation**: type of emissions if known, description of hardware (radiojove kit/other)
  - **Observer's name / id / nickname**

- Metadata format: SPASE or IVOA (or both = simultaneous registration!)
  - SPASE: Space physics communities (Sun + Earth)
  - IVOA: Astronomy and Planetary sciences

  => *2 interfaces to the same database.*

Project Description
File Format

- Possible file formats: **CDF**, FITS, VOTable, *NetCDF, HDF5, wav...*

- Preferred data format: CDF (maintained by NASA/GSFC)
  CDF contains «Attributes» (= header keywords = metadata)

- What can be done with the RadioJove software?
  Jim Sky will study that with me

- Remarks:
  - «wav» file: *common file format for amateurs, but not for scientists*
  - other than «wav»: *metadata-rich formats*

Project Description
Infrastructure

- **SPASE or IVOA**, based on Europlanet developments, see here:
  http://voparis-europlanet.obspm.fr/docum.shtml
  Linking between the two worlds is possible *(under study within the european IMPEx project).*
- VO-RadioJove server would includes (may not be at the same place):
  - SQL database with all observation records
  - Access Protocols (e.g.: EPN-TAP, SPASE...)
  - Webservice (REST or SOAP) or just an upload form for data ingestion (with login?)
- VO-RadioJove **prototype server and database will be located in Paris** (VO Paris Data Center) The final server and database could be in Paris or Nançay (Radioastronomy facility in France).
  It could also be linked to the RadioJOVE current archive.
- Web-based interface for RadioJove participants to easily fill in events (**could be just a file upload** if file contains all information).
- Link with existing RadioJove software, which could produce a file with all information included that could be submitted directly to a webservice.
- Support staff available in Paris and/or Nançay if project is accepted.

Project Description
Next steps

- **Near future**
  - July 2014 - January 2015:
    - decision on the data format and header content
    - setting up a test server in Paris for data upload, data validation, data distribution
  - Need for beta-testers: **volunteers** ? (end of 2014)
    - size of data ? [24h or ±3h of meridian crossing]
    - testing upload of **spectrograms** and **single frequency**
  - Discussion with Jim Sky to **include CDF output** in his software.
- **Further plans**
  - Presentation of project at next «**Magnetosphere of Outer Planets**» conference, in Atlanta next year (June 1-5, 2015).
  - Opening of the service to science community when everything is ready (end of 2015 or 2016?)

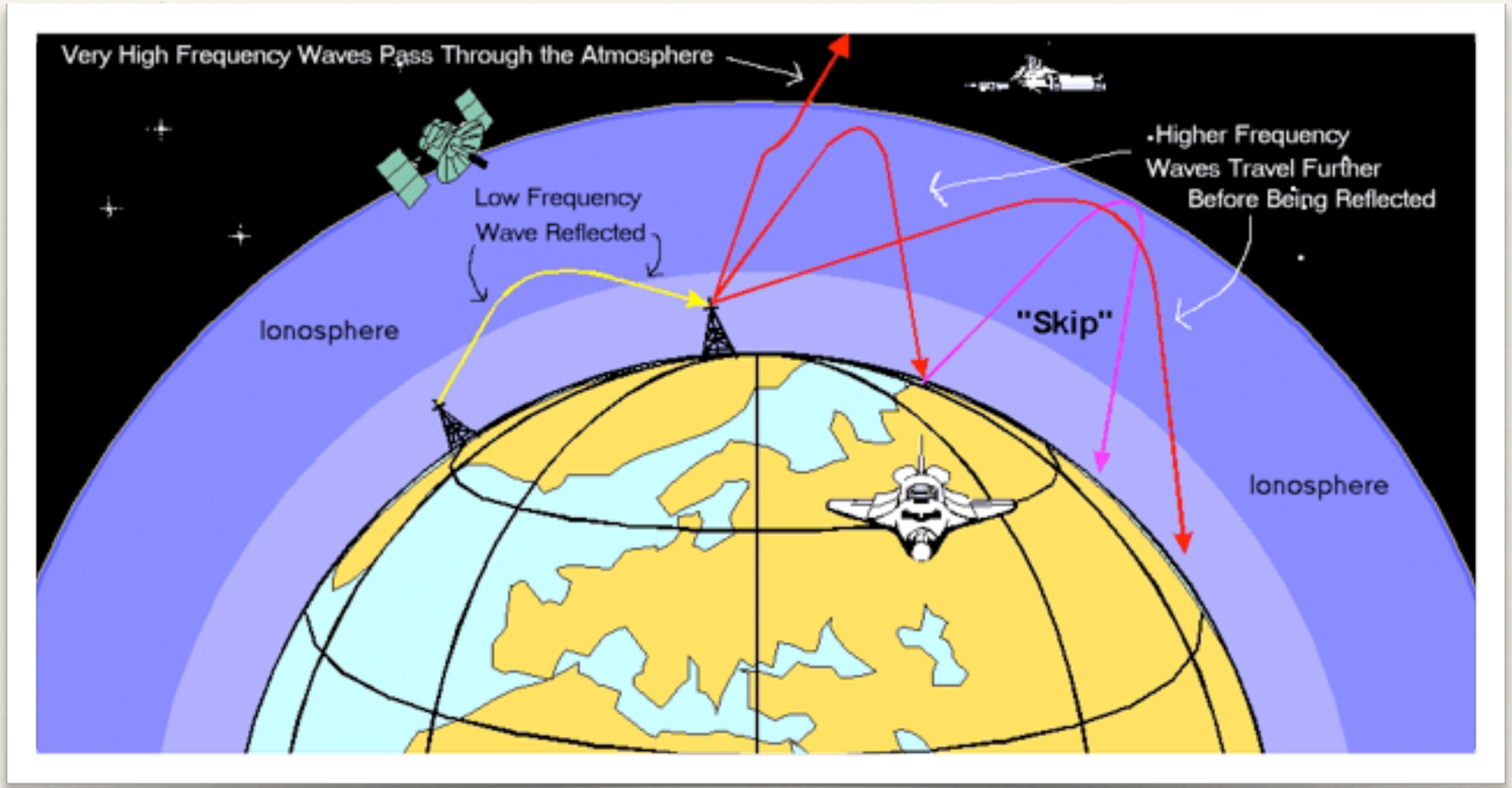
Summary

- Scientists can use your data !
- Standardized distribution of RadioJove observations
- Data format usable by scientist
- Take advantage of VO infrastructure
- Possible support from France for servers and databases (at least prototypes, then to be discussed).

Spare slides...

Low Frequency Radioastronomy
Observatory location

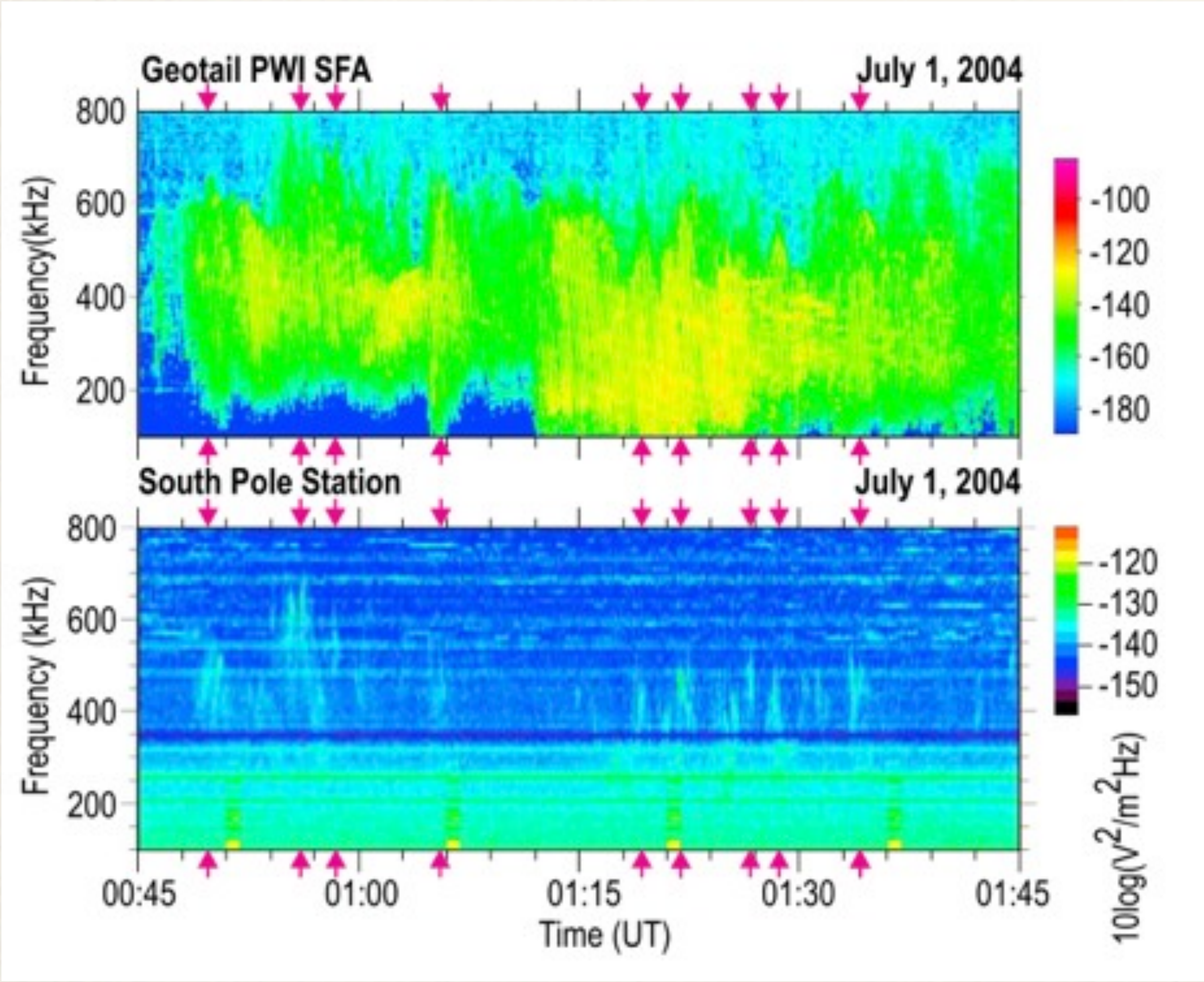
- Earth ionosphere = high-pass filter at ~10 MHz

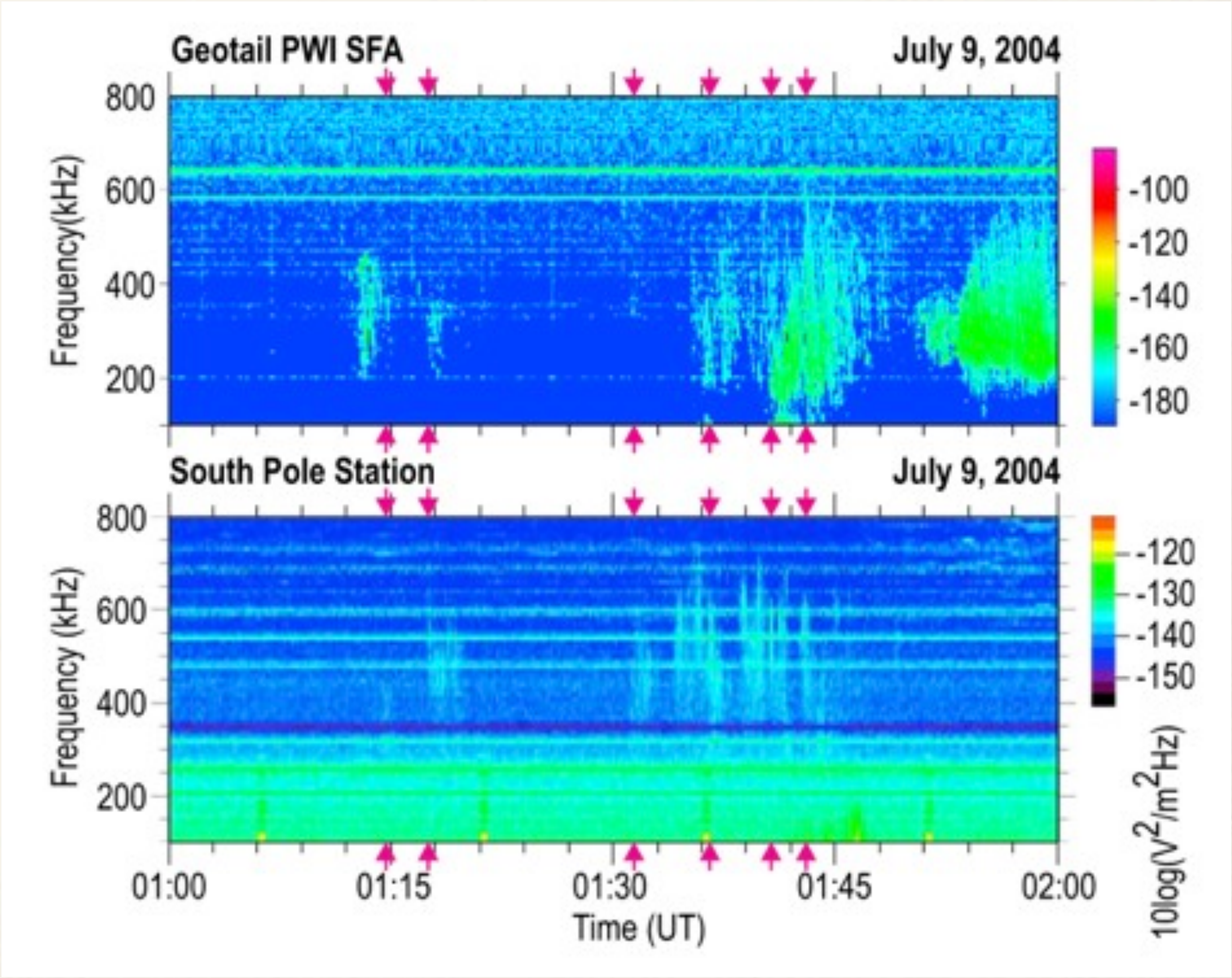


- Space based measurement required to observe below 10 MHz as well as for *in situ* measurement

Earth Radio emissions from ground ?

- Observation by Jim Labelle (South pole radio station)

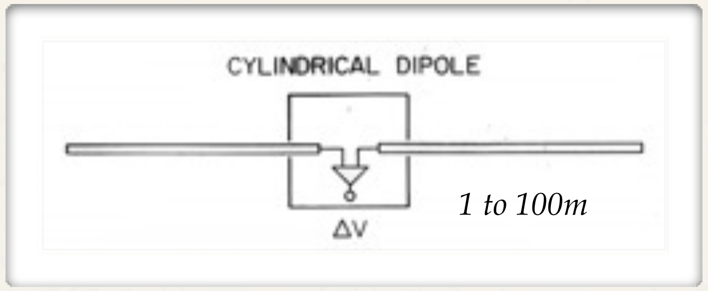




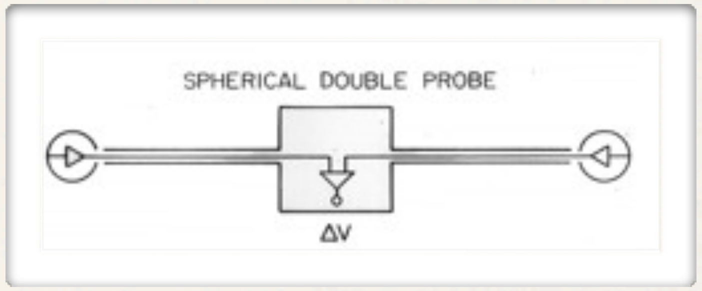
- What about trying to observe from Alaska ?

Sensors for space based radioastronomy

- With an imaging telescope, the angular resolution is ~ λ/D
  For λ ~ 10m to 100km, $\lambda/D \ll 1$ requires D $\gtrsim$ 10000 km !
  Physically impossible to build $\Rightarrow$ We have to be creative!
- Space based radioastronomy sensors:
  - electrical monopoles or dipoles:

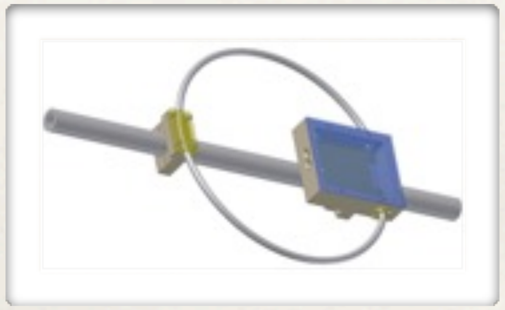


© UCLA



© UCLA

  - magnetic loops or search-coils :

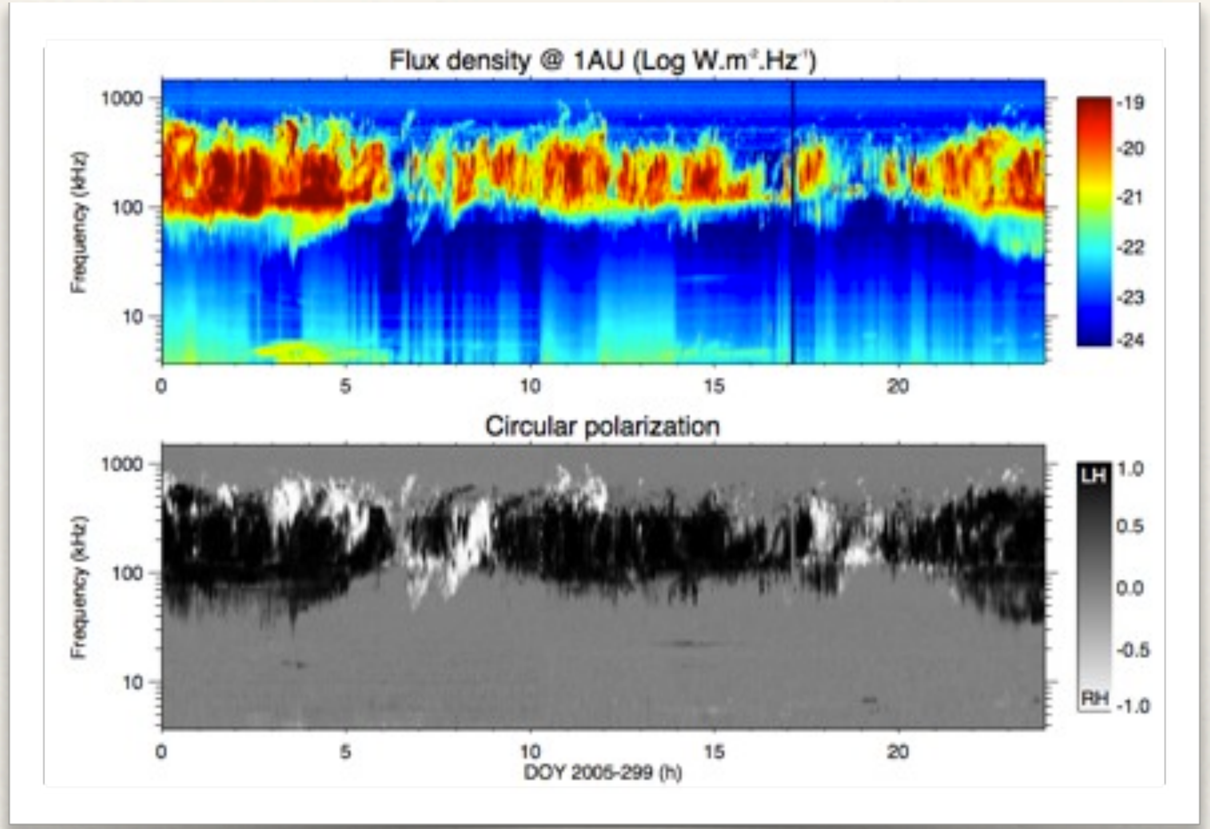


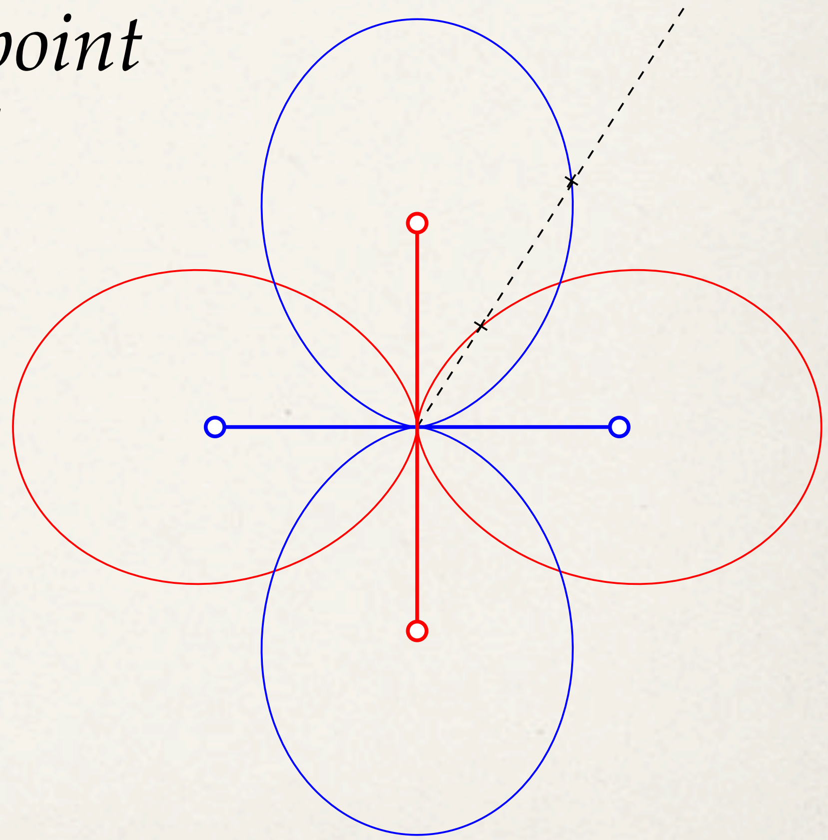
© LPC2E

© LPP

Radioastronomy observations from space

- Radio instrumentation: Goniopolarimetry (*a.k.a. Direction-Finding*) => yields polarization + direction of arrival (not independently !)
- On Cassini: 3 electrical antennas. *Assuming a point source, we get polarization and direction of arrival*

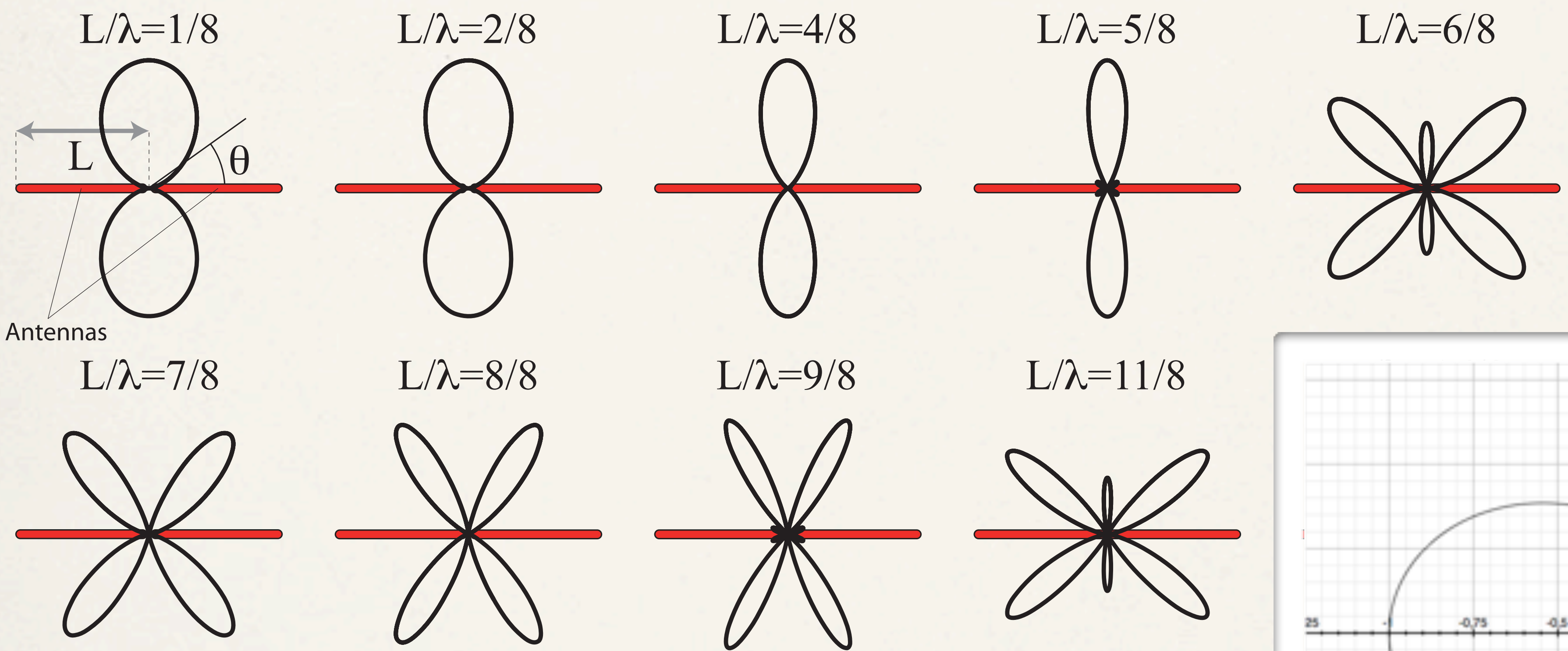


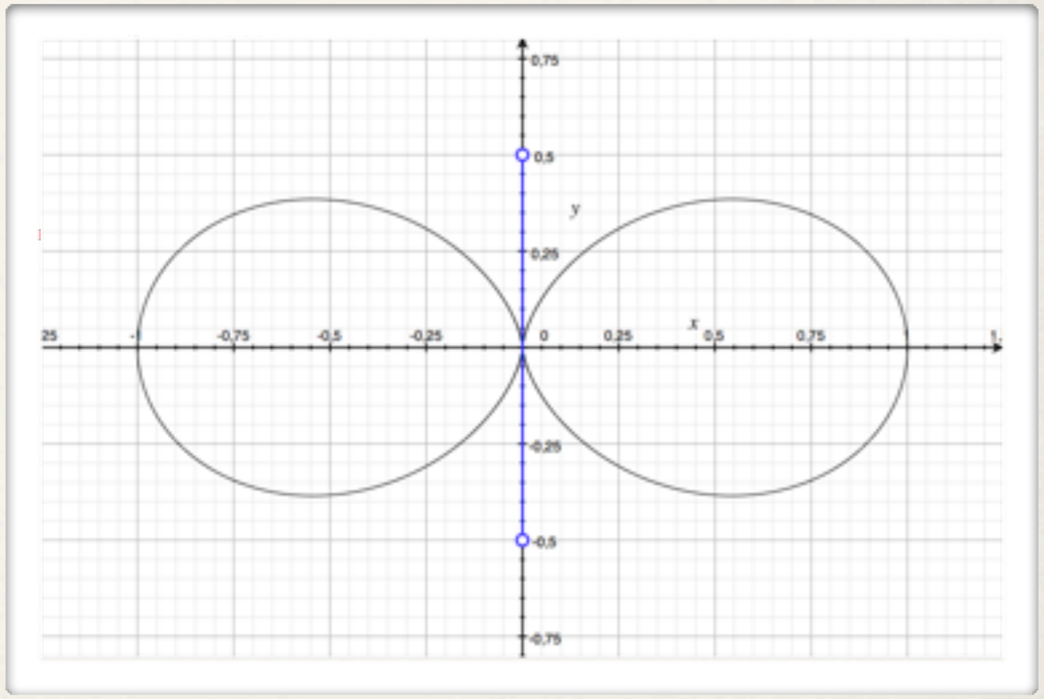


GP basics with 2 antennas

Electrical dipole, quasi-static range

- Antenna diagram for a dipole antenna

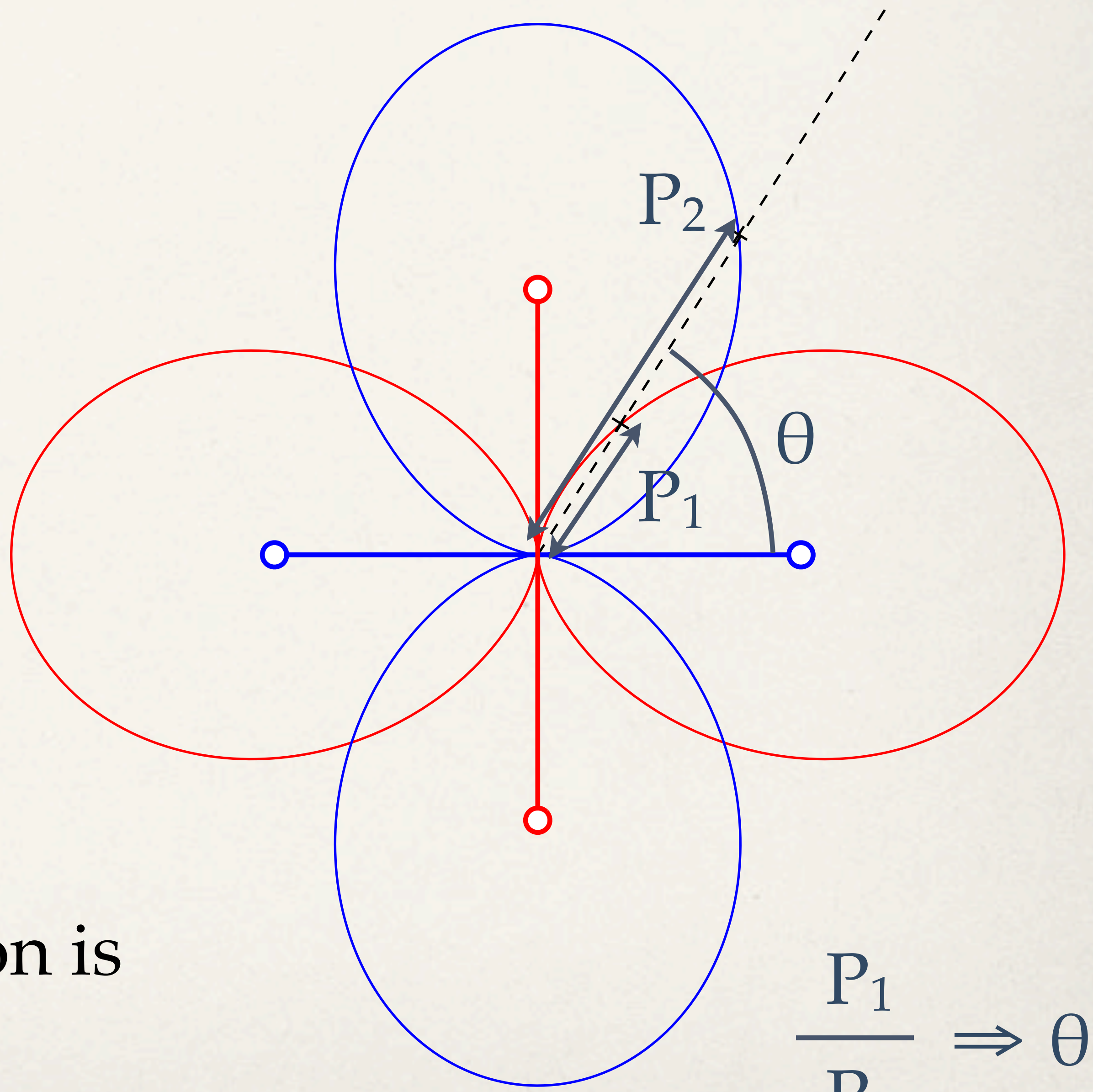




- In the quasi-static (or short antenna) range: $L \ll \lambda$
  The antenna is then a perfect dipole.
  Its gain varies in $\cos^2(\theta)$.

(Very) Simple case: 2 antennas in a plane

- Two perpendicular antennas (red and blue).
- A non polarized wave is propagating along the dashed-line direction
- The ratio between the power sensed on each antenna provides the direction of propagation
- Unfortunately, in this case, the solution is not unique



$$\frac{P_1}{P_2} \Rightarrow \theta$$

Real case: 3D geometry & polarized wave

- Electrical signal induced by the wave on an antenna: $V_a = \vec{h}_a.\vec{E}_w(t)$

- We measure the power on each sensor, as well as the cross-correlation of the signals sensed on two antennas. We then get the full spectral matrix of the wave.

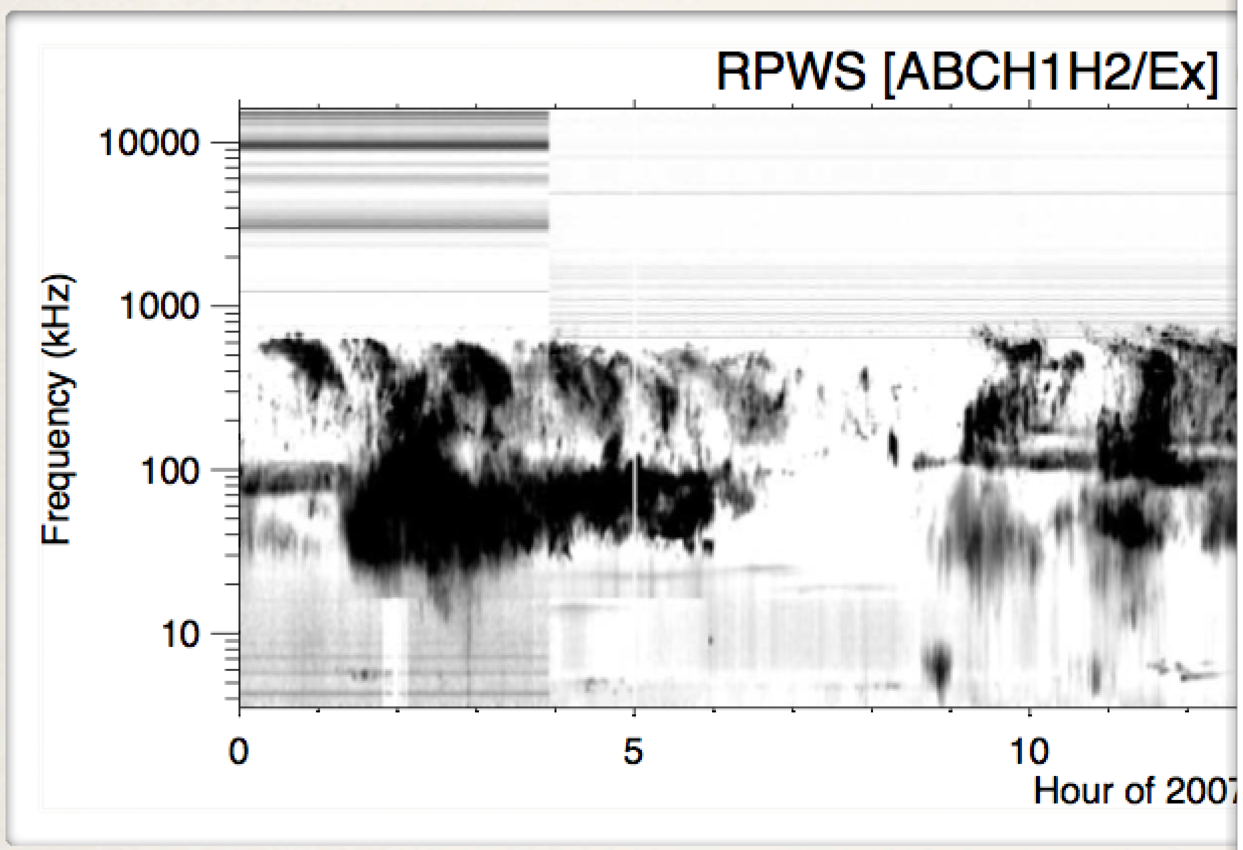
- Wave parameters (for a polarized transverse plane wave)
  - Direction of propagation: two angles (θ, ϕ).
  - Flux and polarization: 4 Stokes parameters (S, Q, U, V)

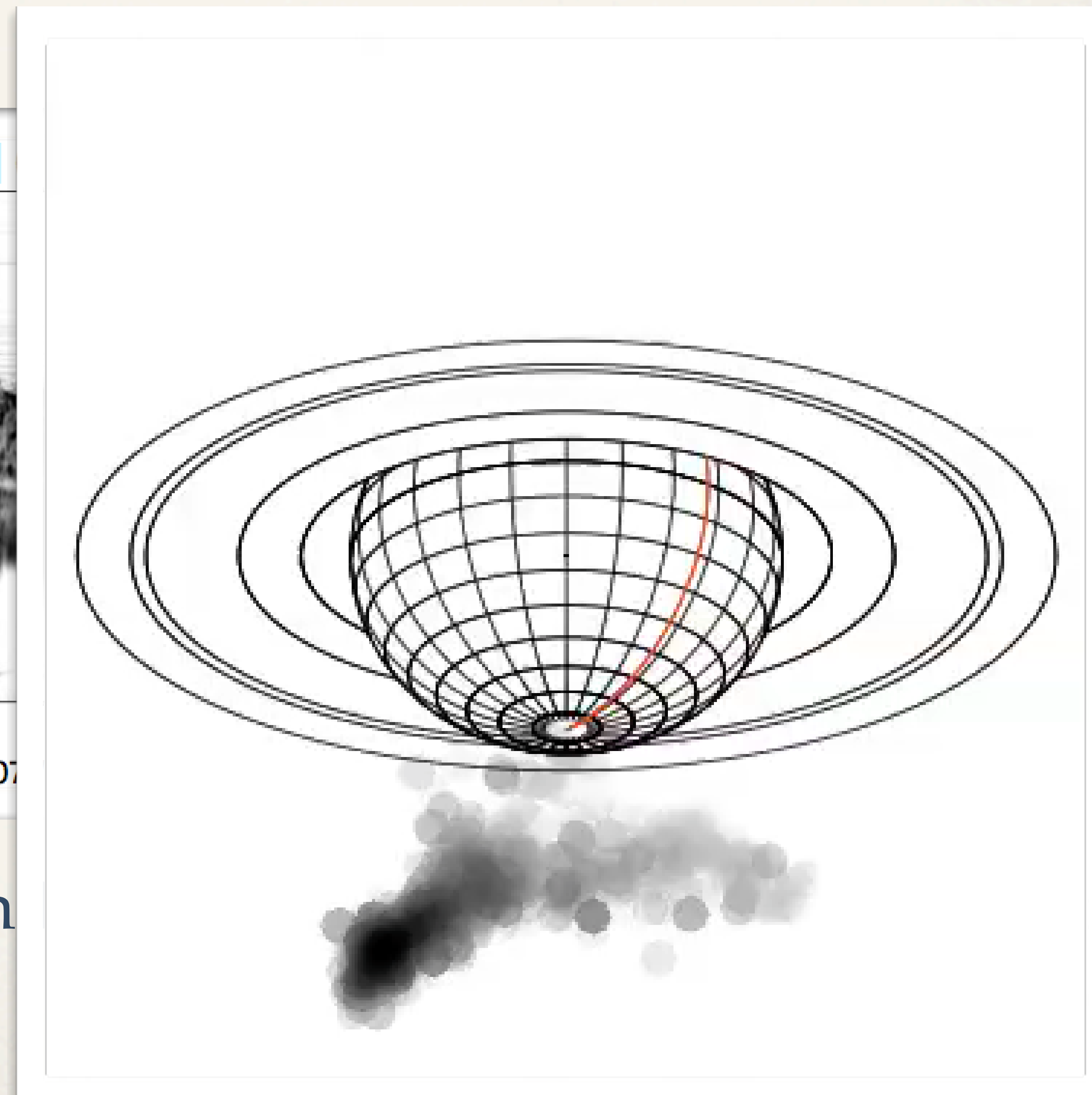
$$P_{ij} = \frac{Z_0 G h_i h_j S}{2}\Big[(1+Q)A_iA_j + (U-iV)A_iB_j + (U+iV)A_jB_i + (1-Q)B_iB_j\Big]$$

$$A_i = -\sin\theta_i\cos\theta\cos(\phi-\phi_i) + \cos\theta_i\cos\theta$$
$$B_i = -\sin\theta_i\sin(\phi-\phi_i)$$

- Antenna parameters: length (h_i) and direction (θ_i, ϕ_i)

Goniopolarimetry
How to «see» the radio





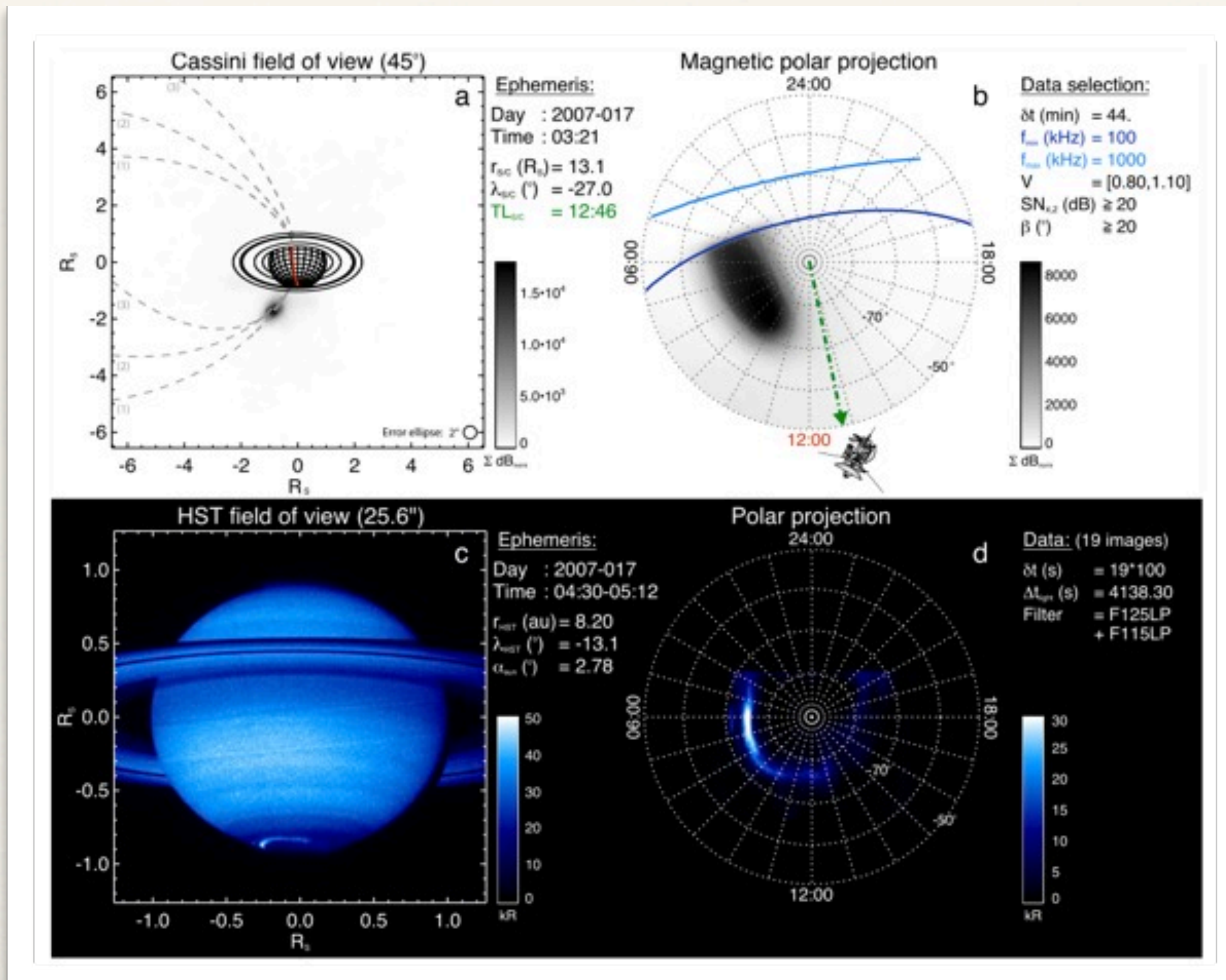
Dynamic spectrum of SKR (Saturn n
Cassini / RPWS / HFR.

Example:
Saturn auroral radio and UV sources

- Aurore UV et Radio:

Radio Maps

UV Images

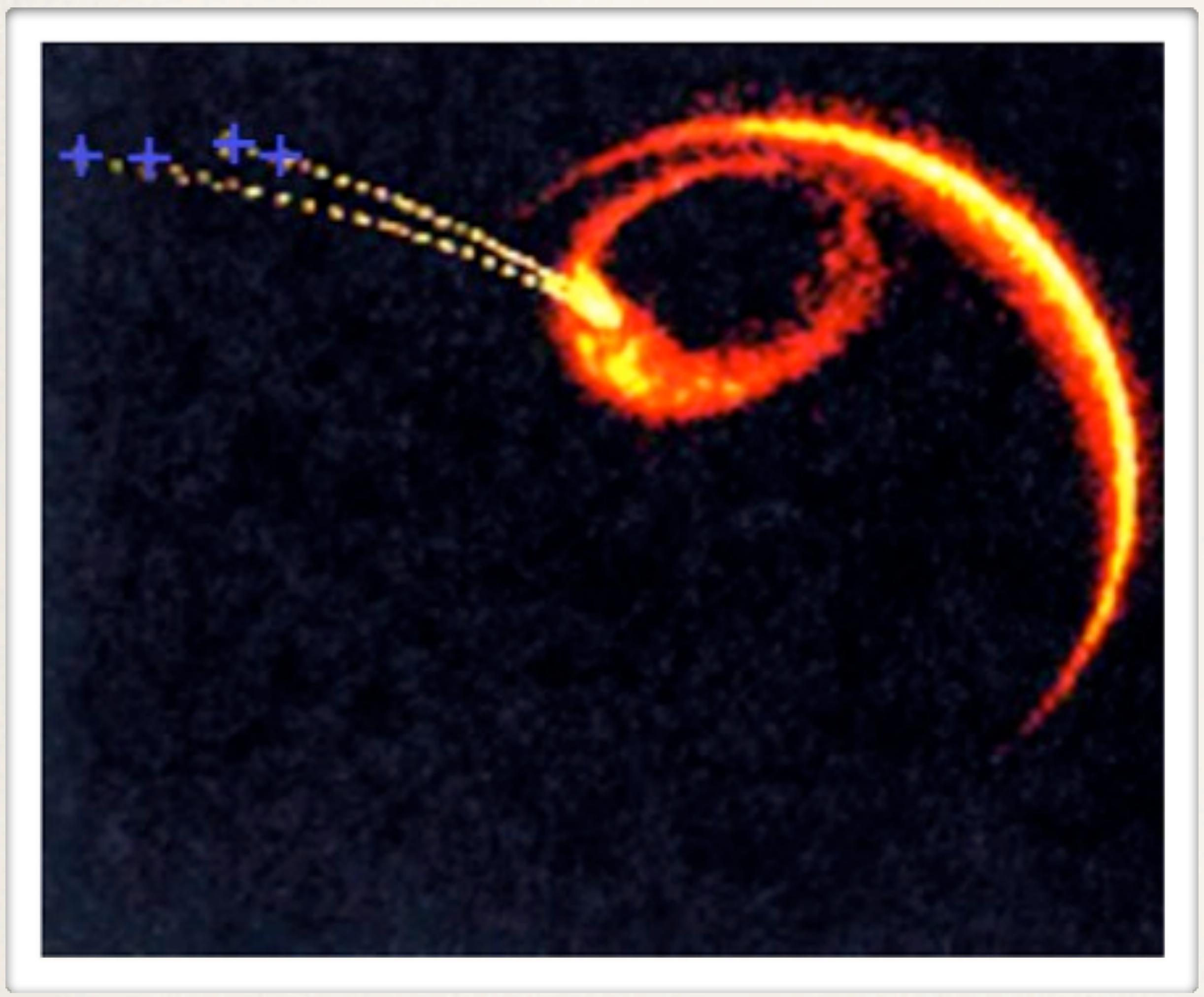


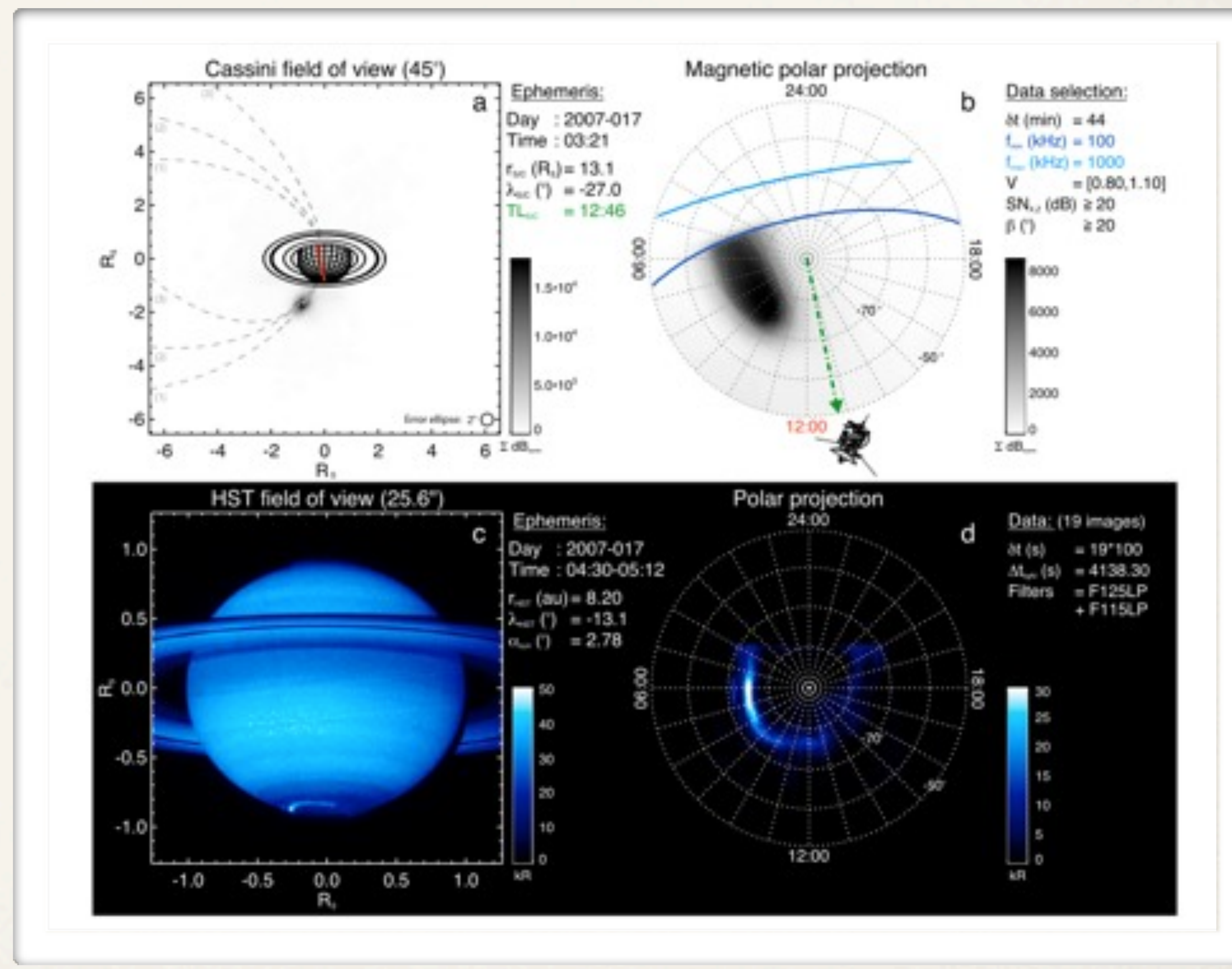
Cassini

HST

[Lamy et al. 2009]

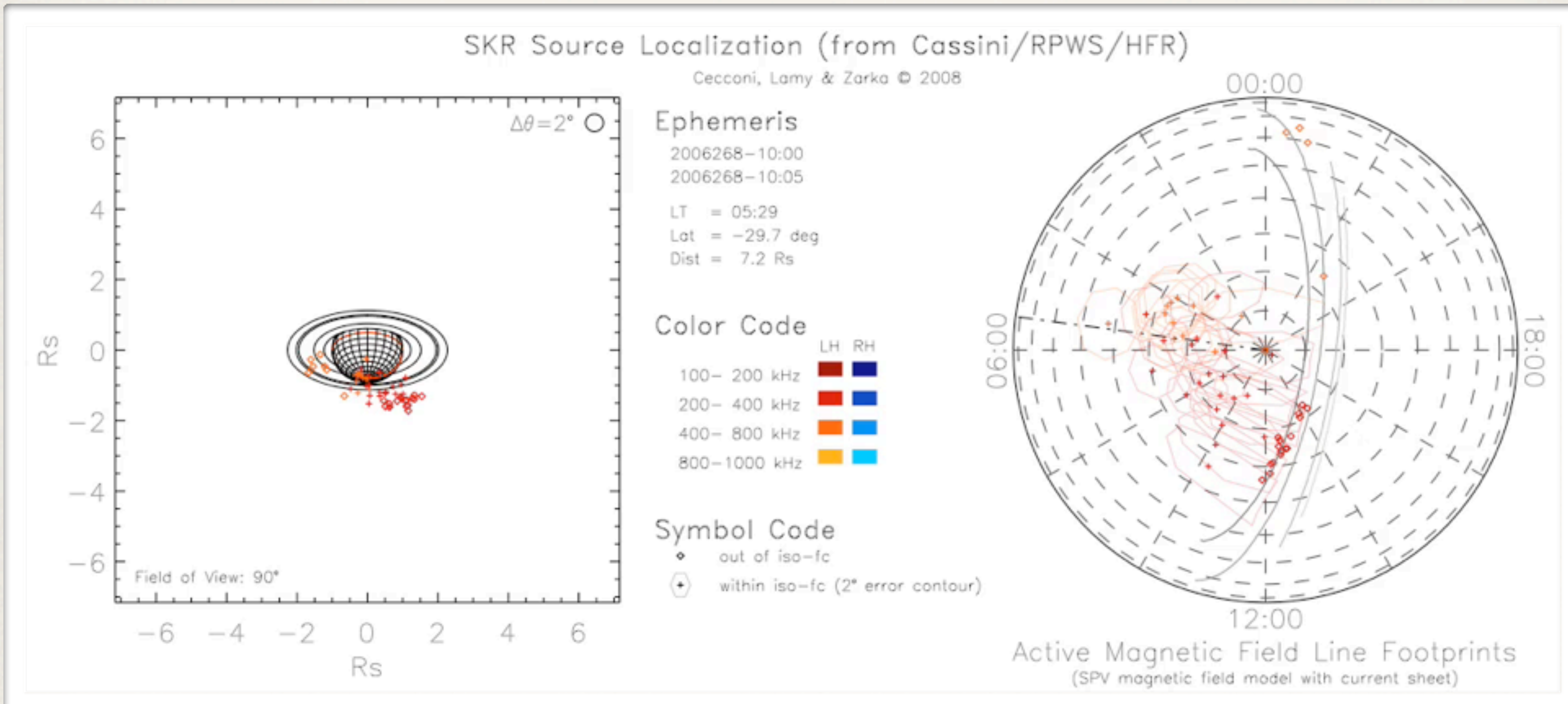
Remote Localization of Radio Auroras
(*and comparison with atmospheric auroras*)





- Earth: DE-1
- Saturn: Cassini

Planetary Radio Emissions - Observation Techniques

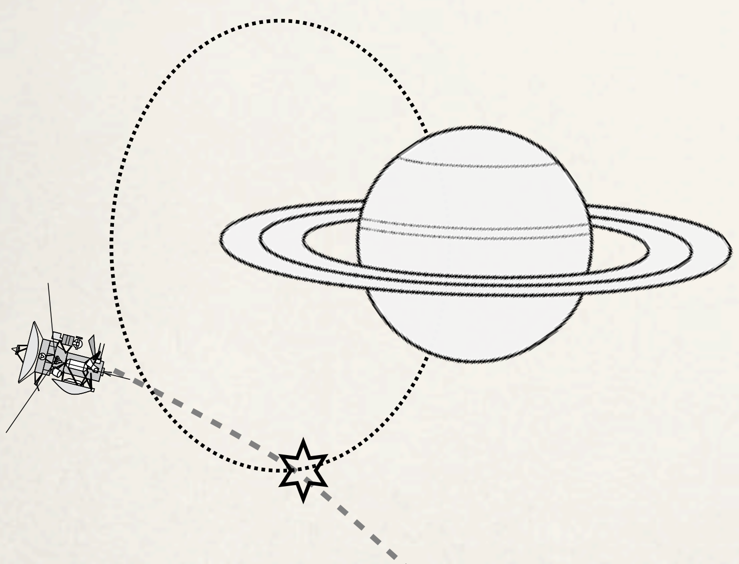


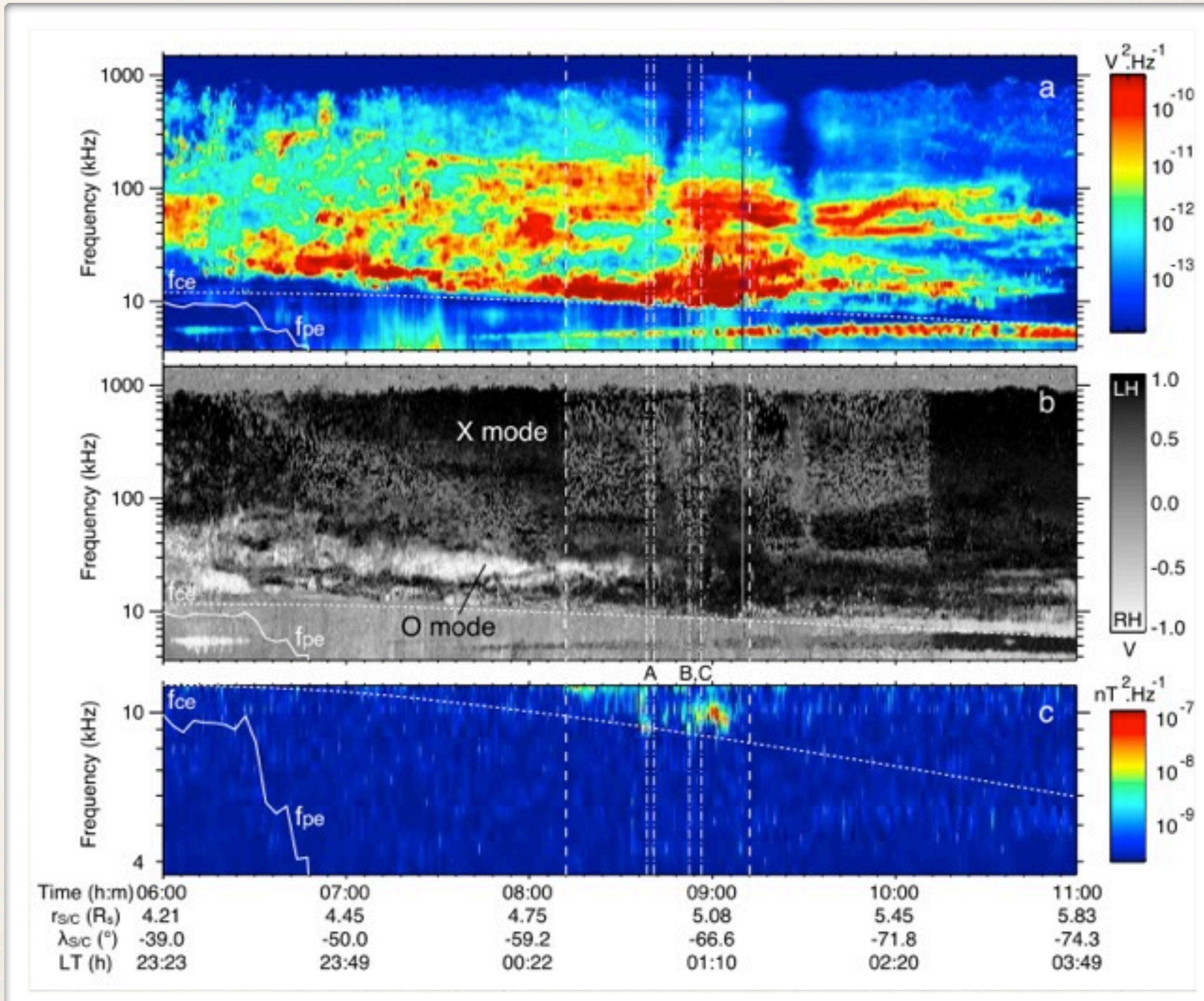
[Cecconi et al. 2009]

Cassini crossing the auroral radio sources

Radio Flux

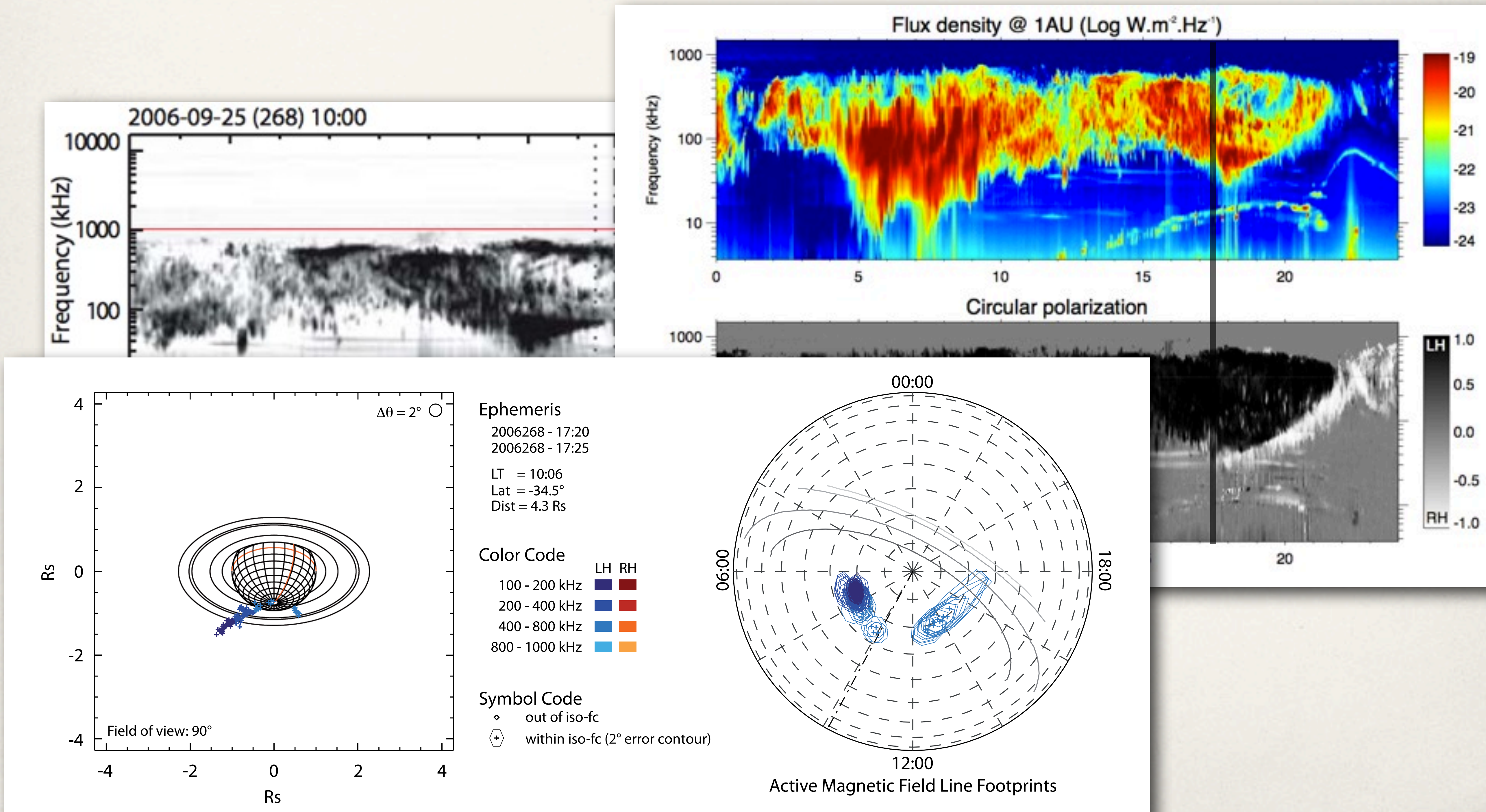
Polarization





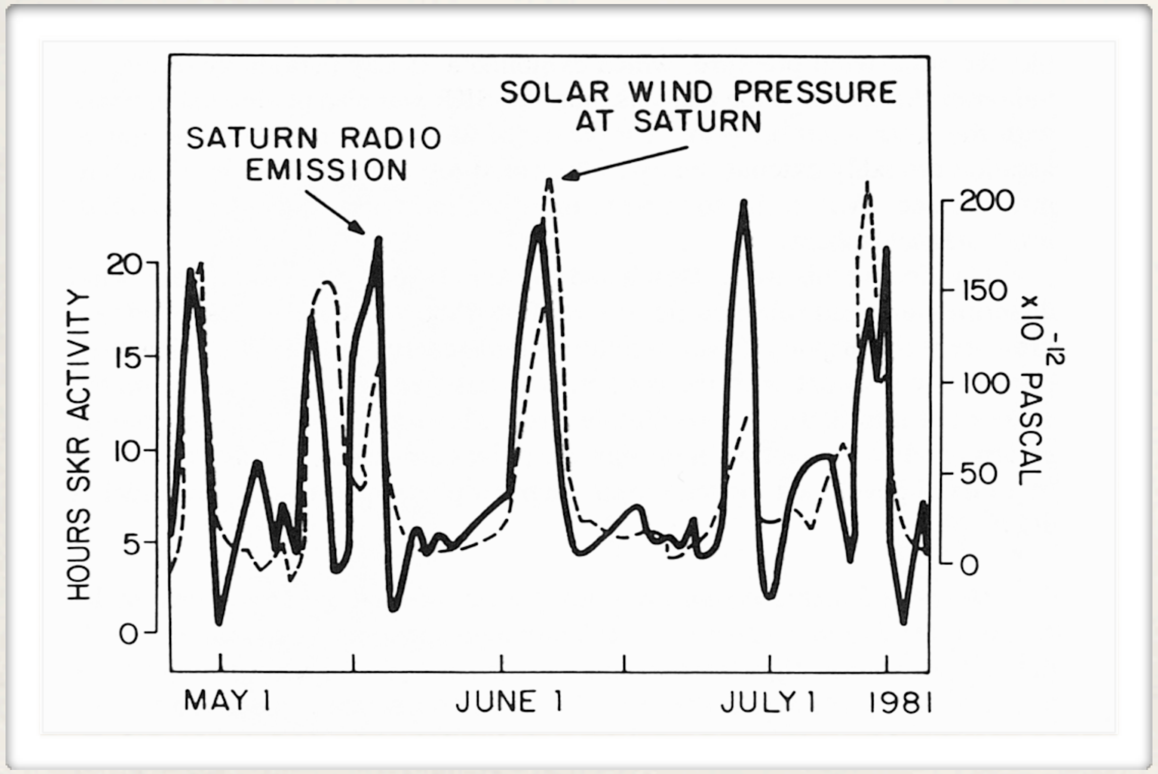
[Lamy et al. 2010]

Example:
Radio view of Saturn by Cassini

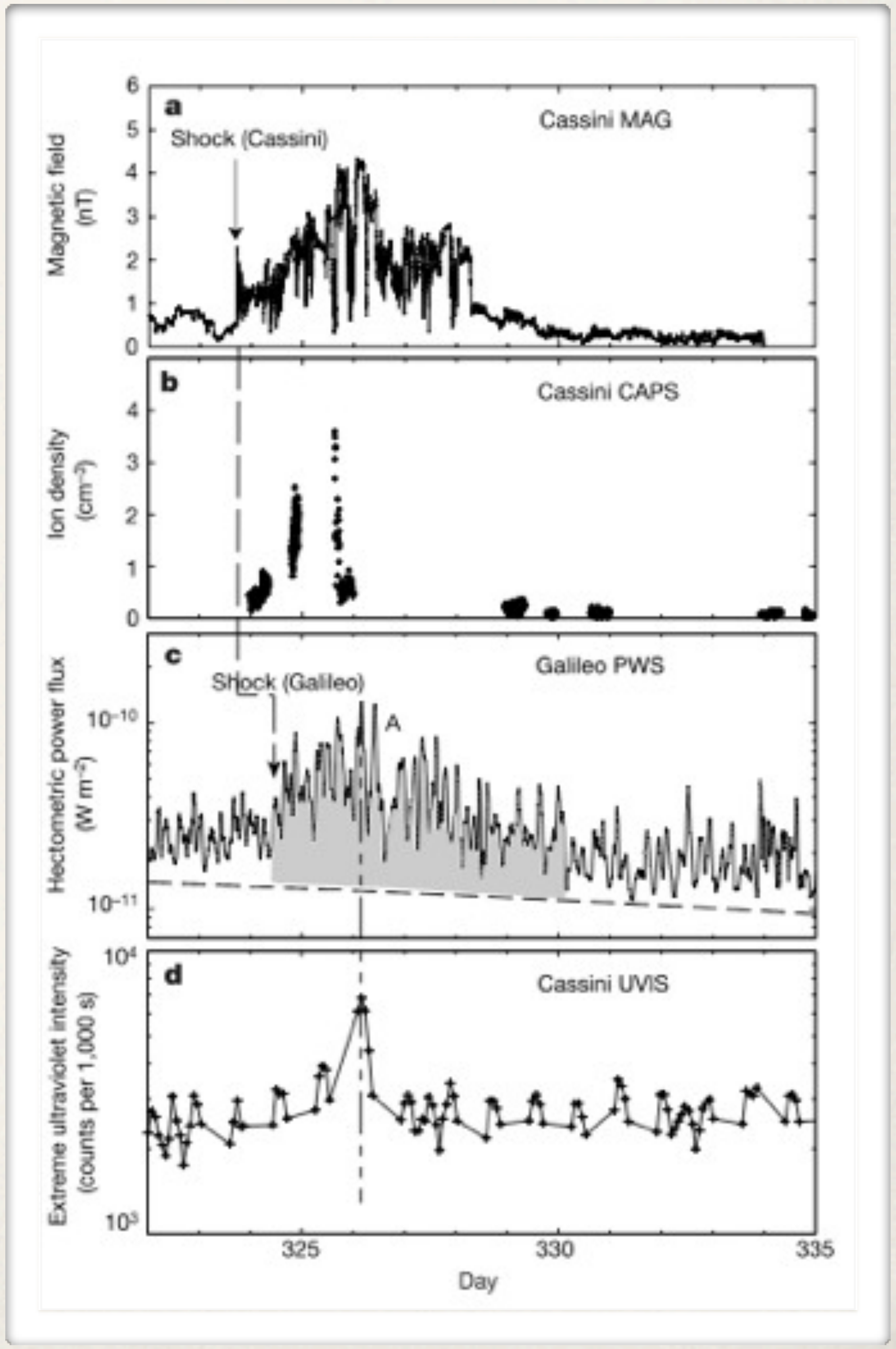


Solar Wind Control of Auroral Sources

- Earth: Sub-storms onset controlled by solar wind conditions
- Jupiter: QP & HOM controlled by SW
- Saturn: SKR intensity correlated to SW ram pressure



Saturn



Jupiter