

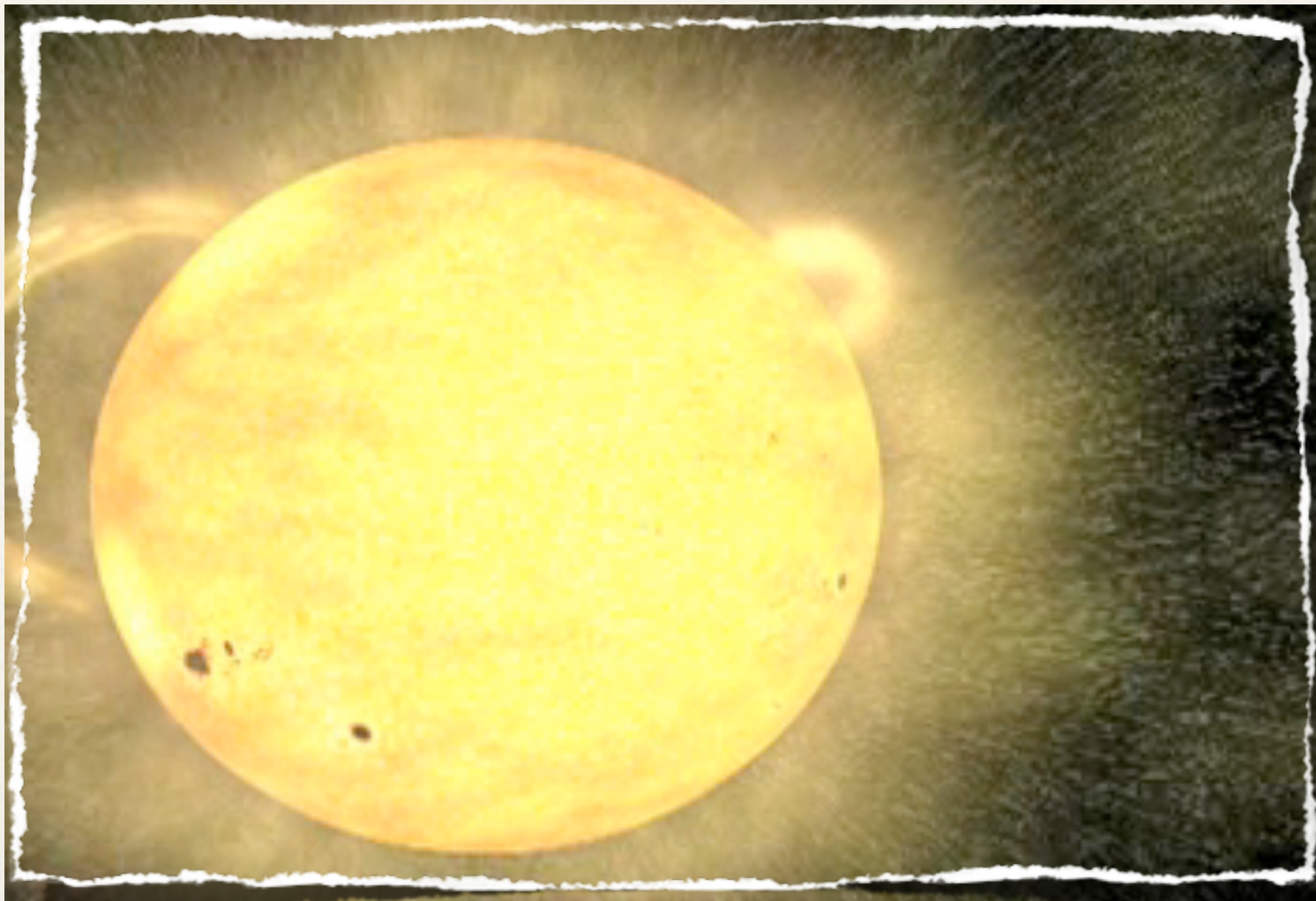
Sharing RadioJOVE data with the scientists

Baptiste Cecconi (Observatoire de Paris)

Thursday, July 3rd, 2014

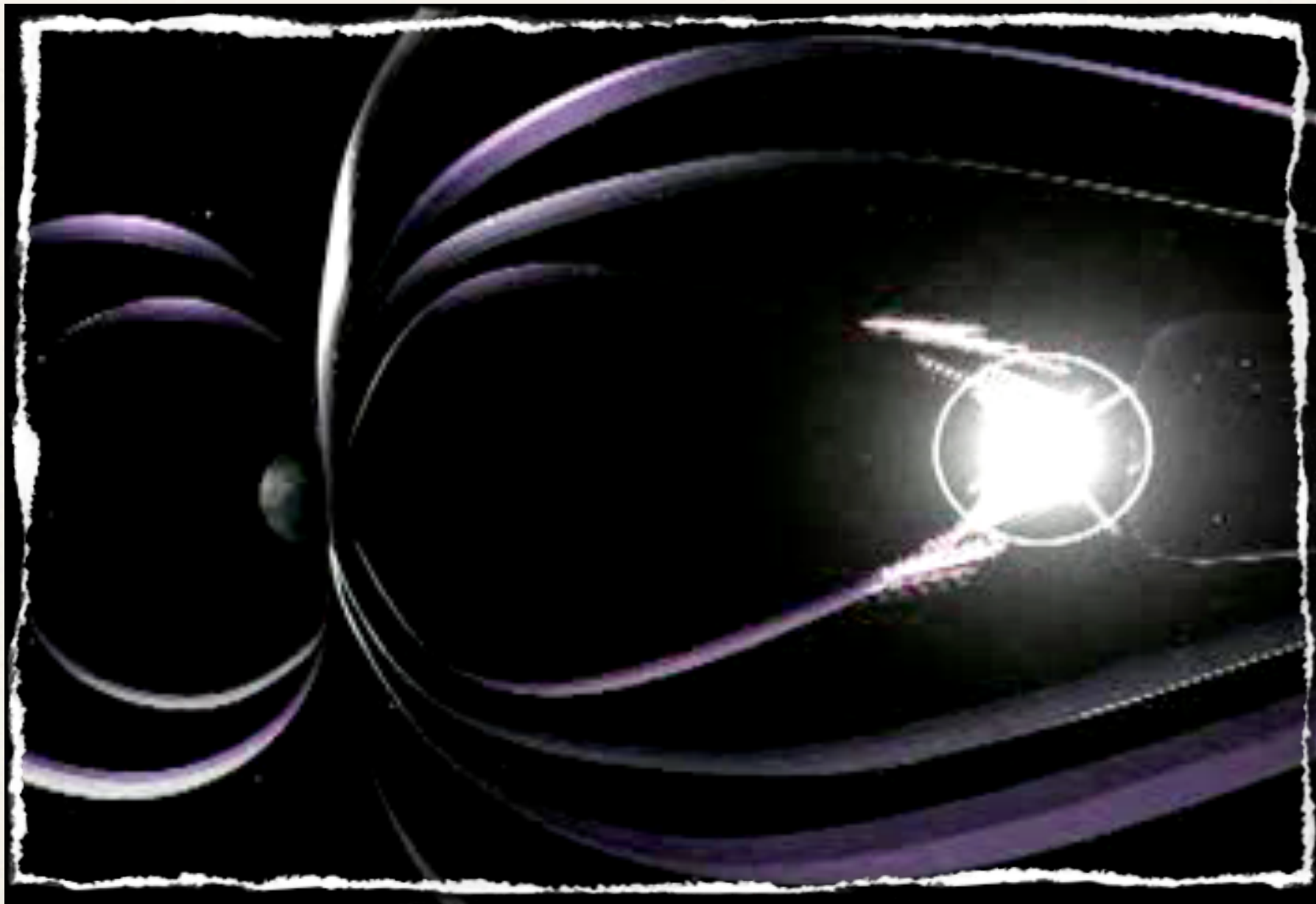
Plasmas in the Solar System

Solar Wind & Magnetized Planets



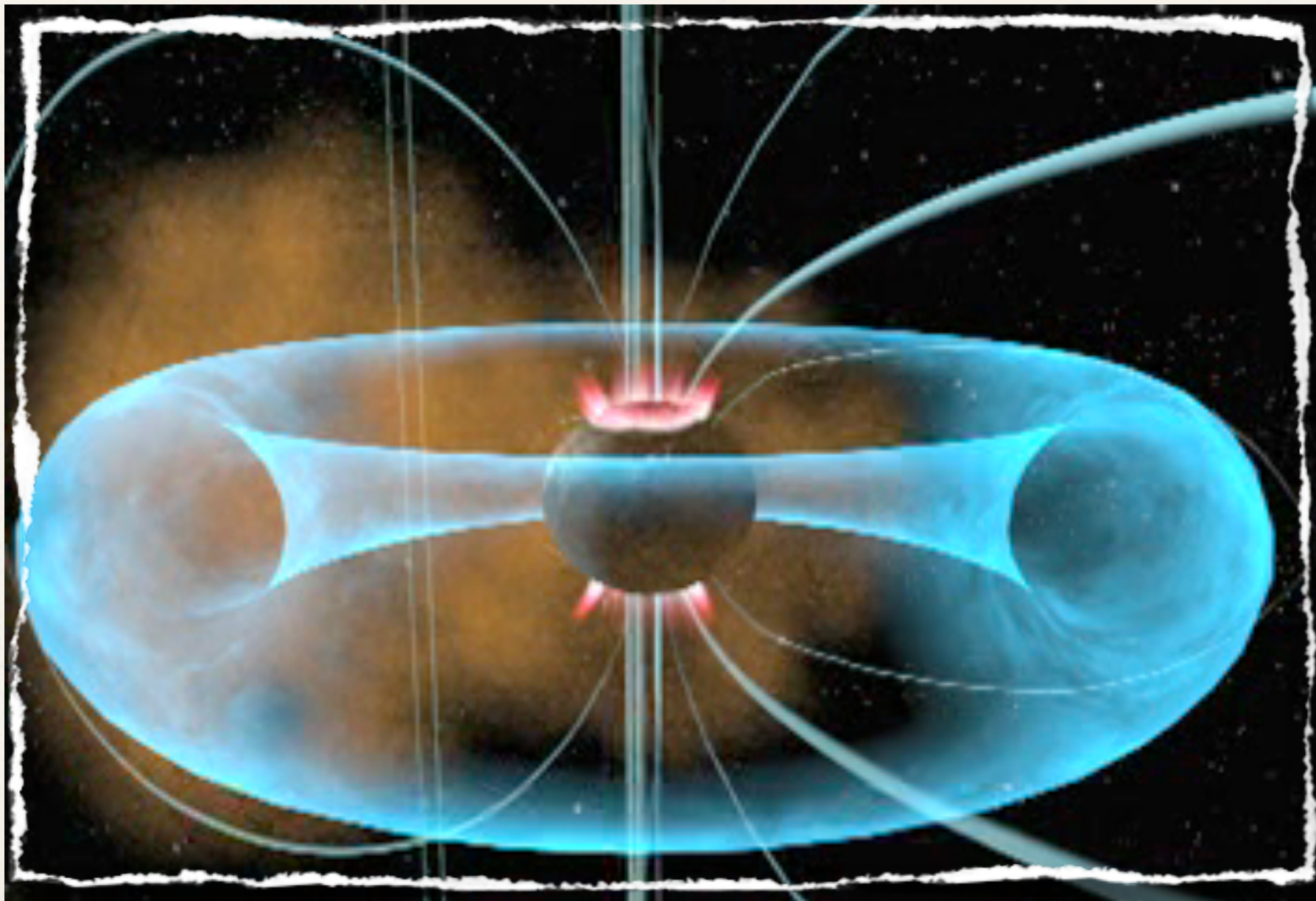
Plasmas in the Solar System

Solar Wind & Magnetized Planets



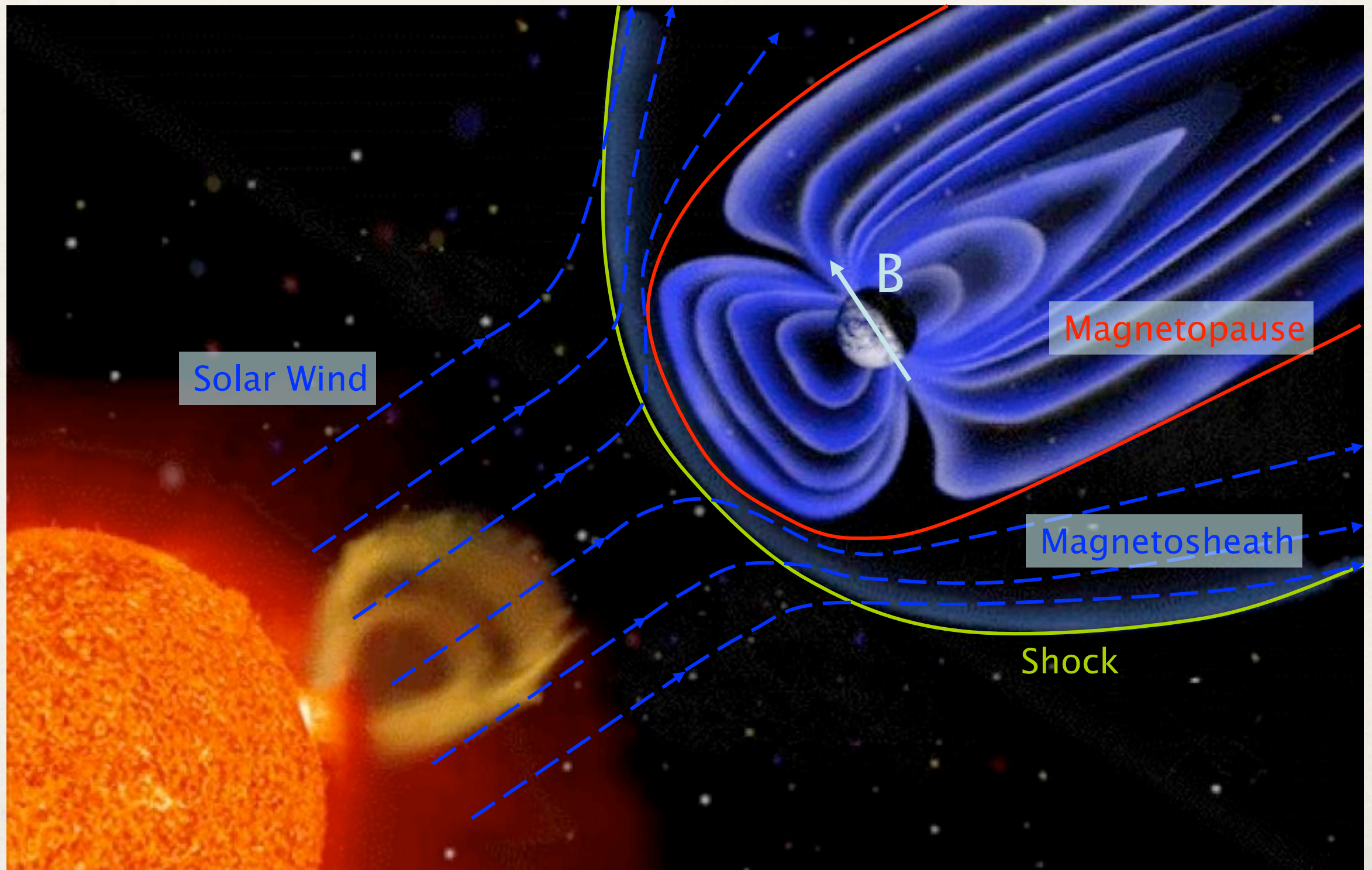
Plasmas in the Solar System

Solar Wind & Magnetized Planets



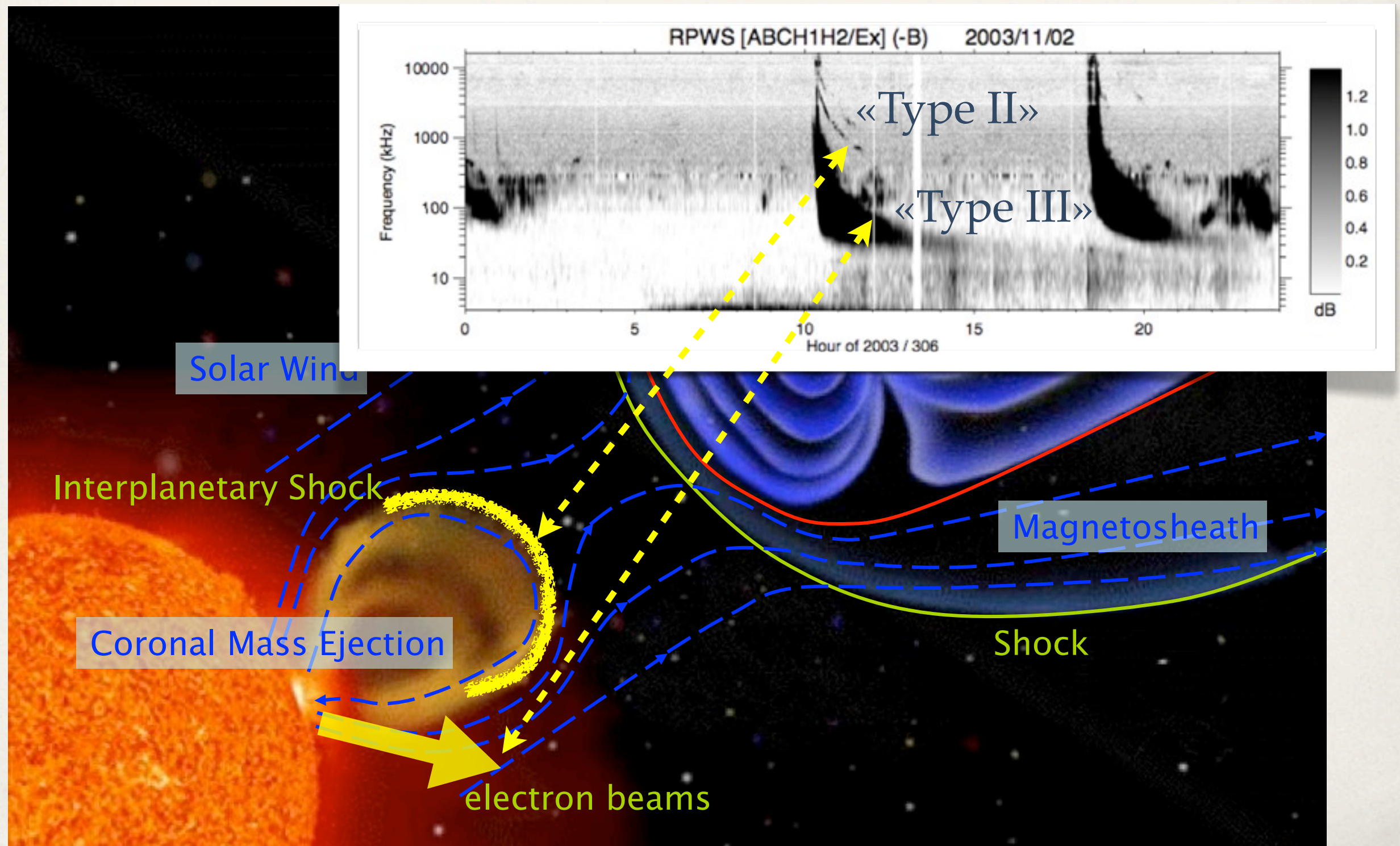
Plasmas in the Solar System

Solar Wind & Magnetized Planets



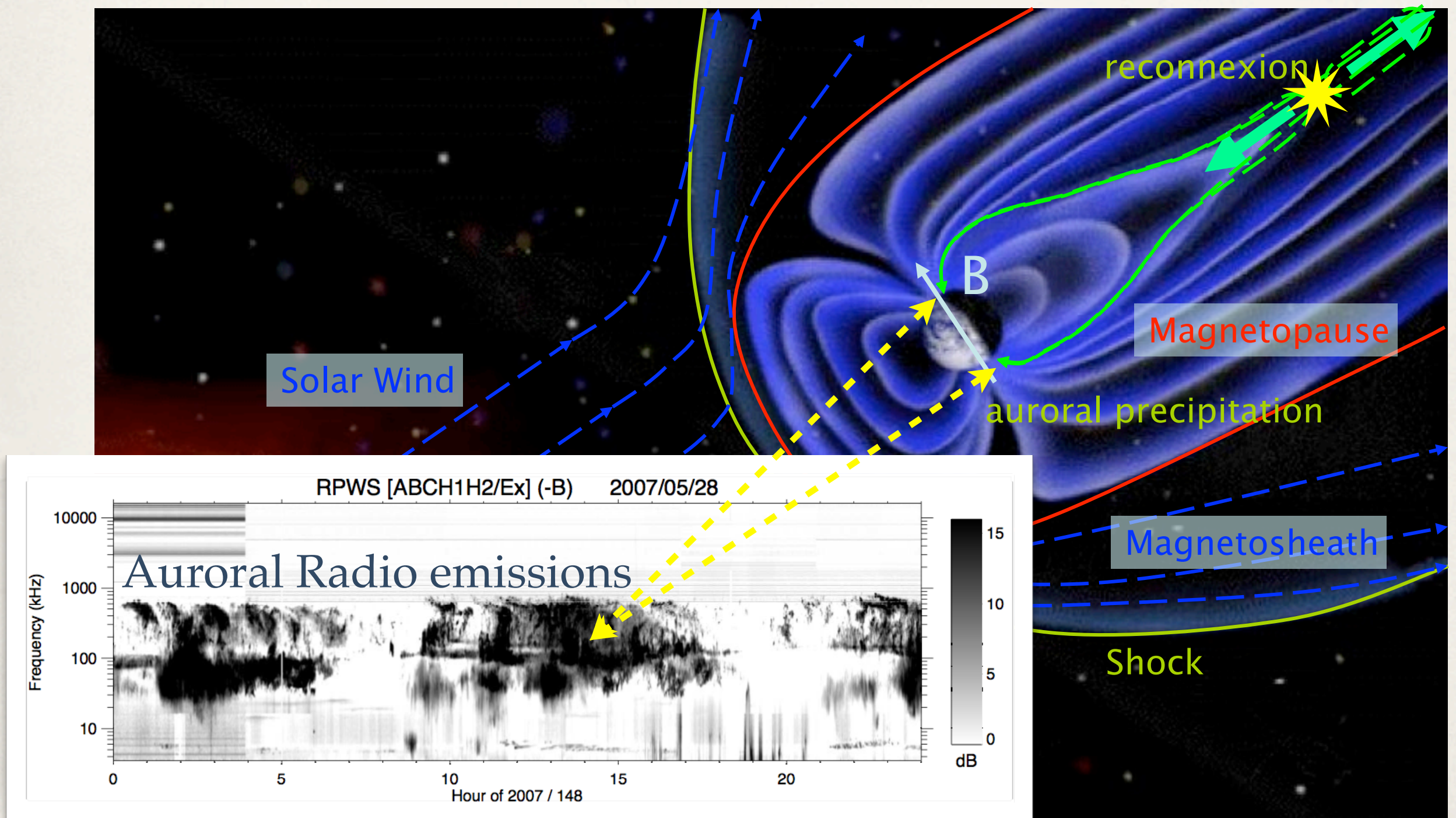
Plasmas in the Solar System

Solar Wind & Magnetized Planets



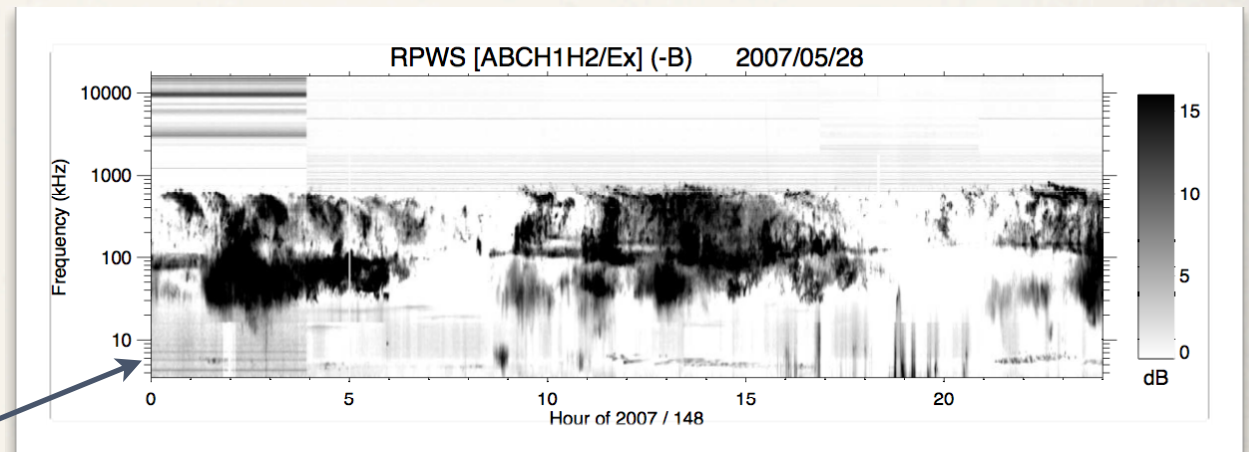
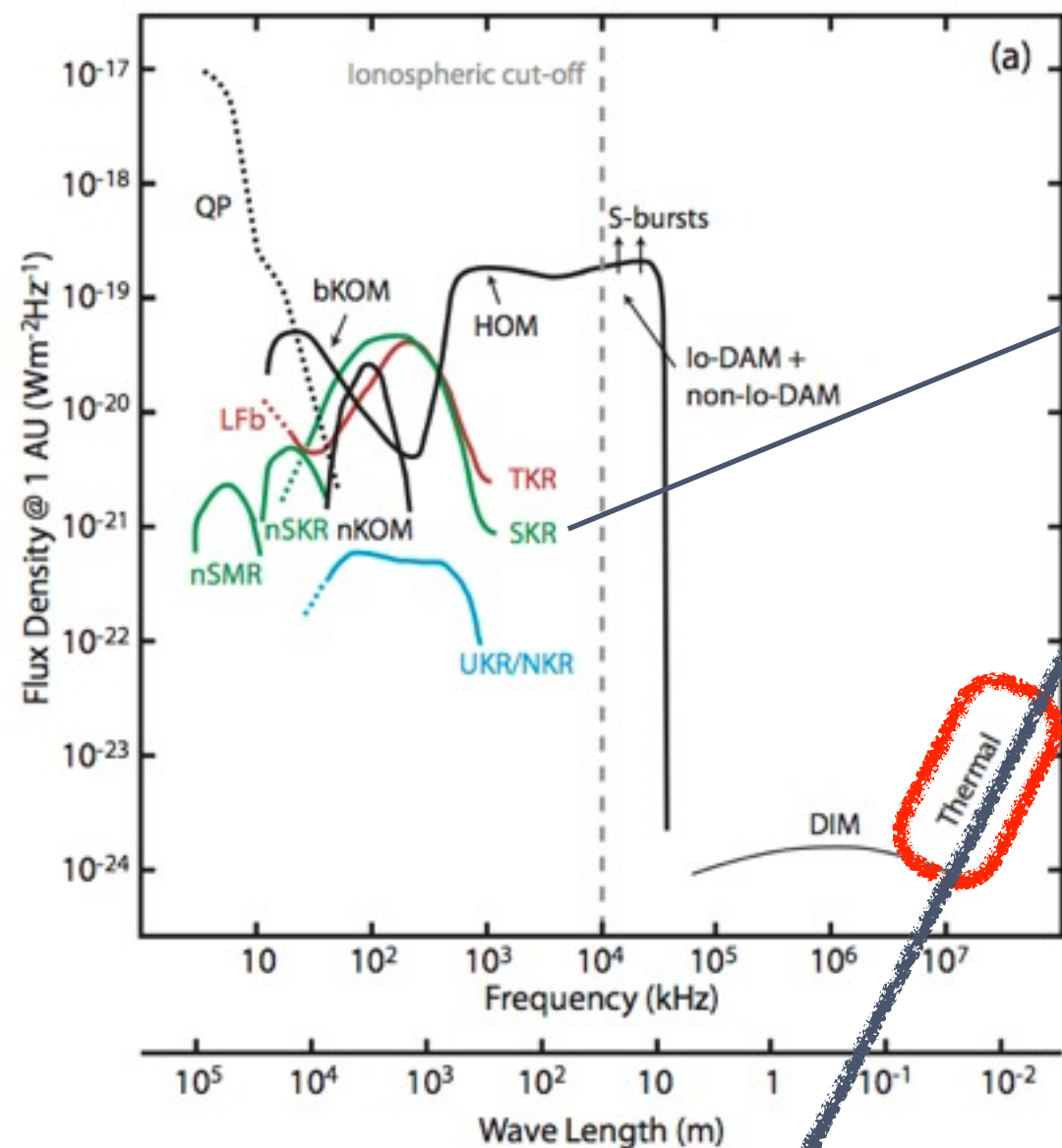
Plasmas in the Solar System

Solar Wind & Magnetized Planets

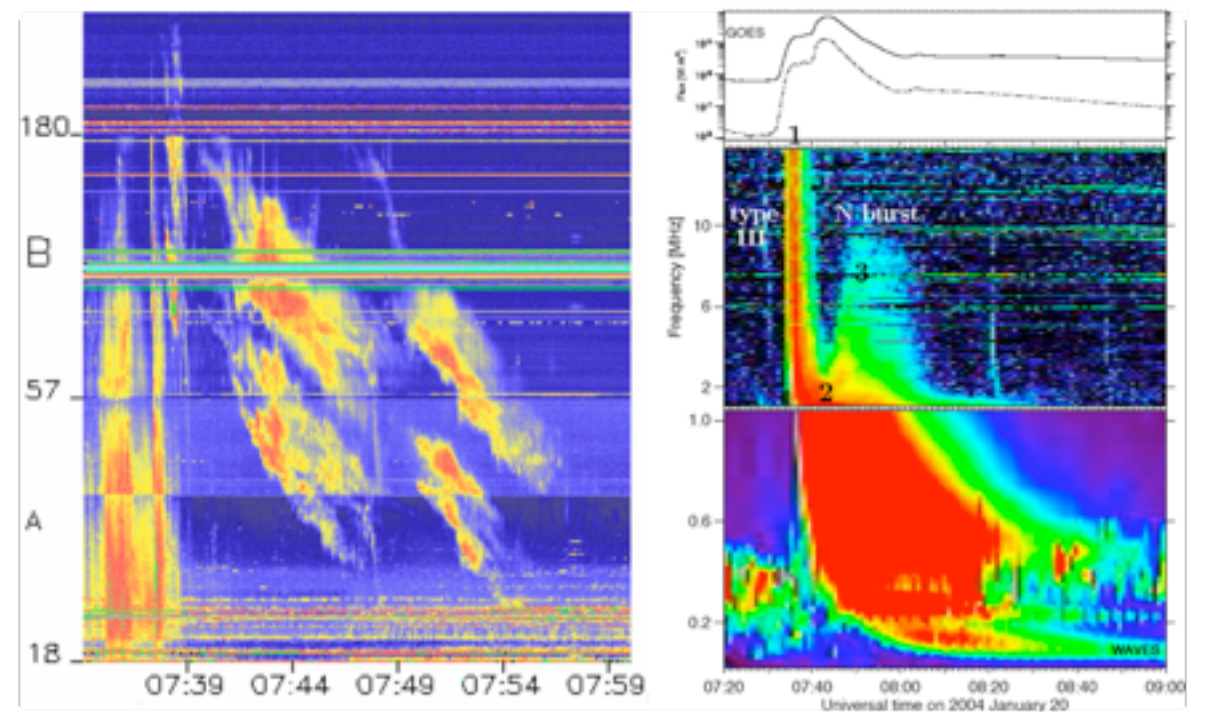


Low Frequency Spectrum in the solar system

Planetary Radio Emissions

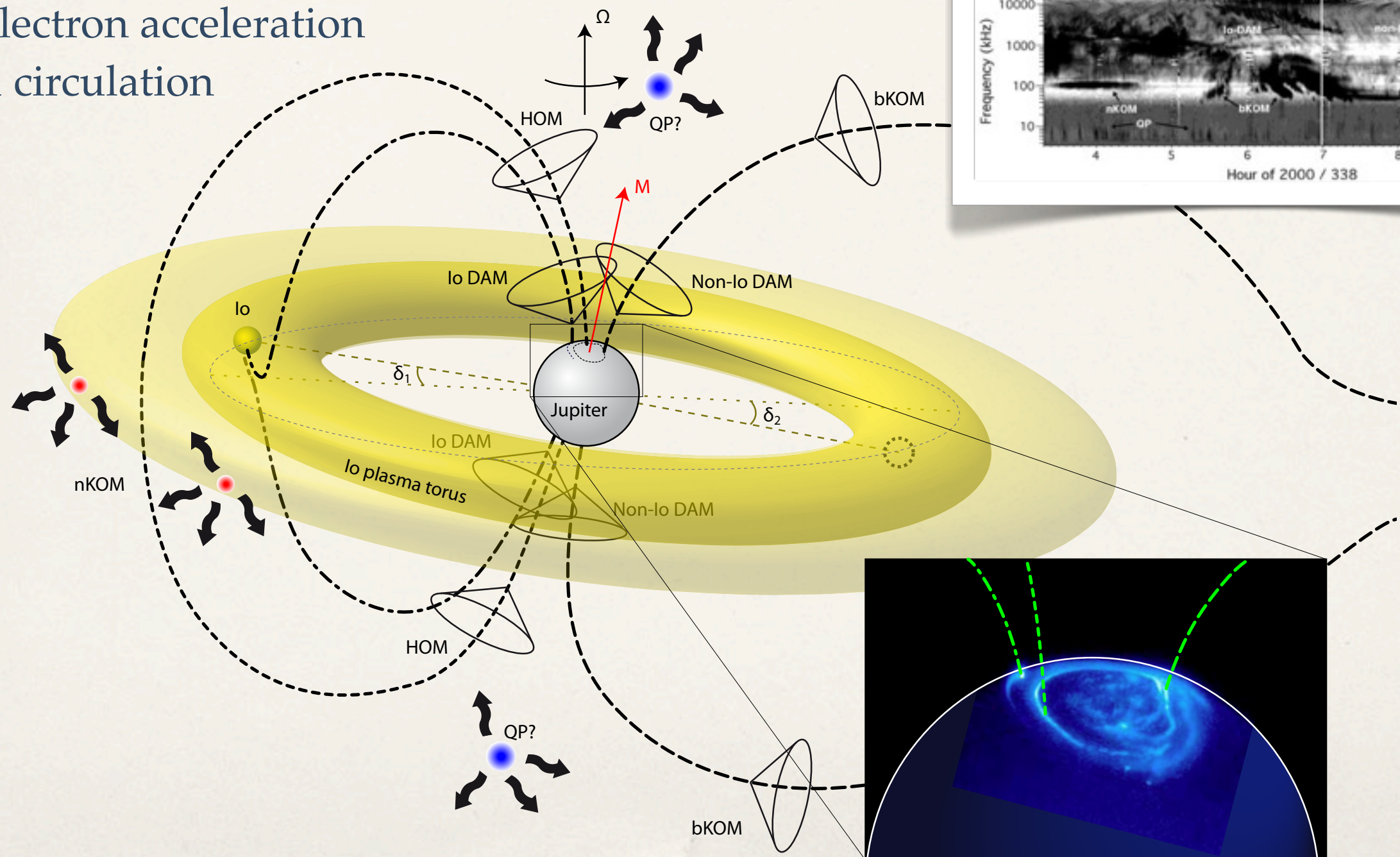


and solar



Radio sources at Jupiter

Radio sources are linked
to electron acceleration
and circulation

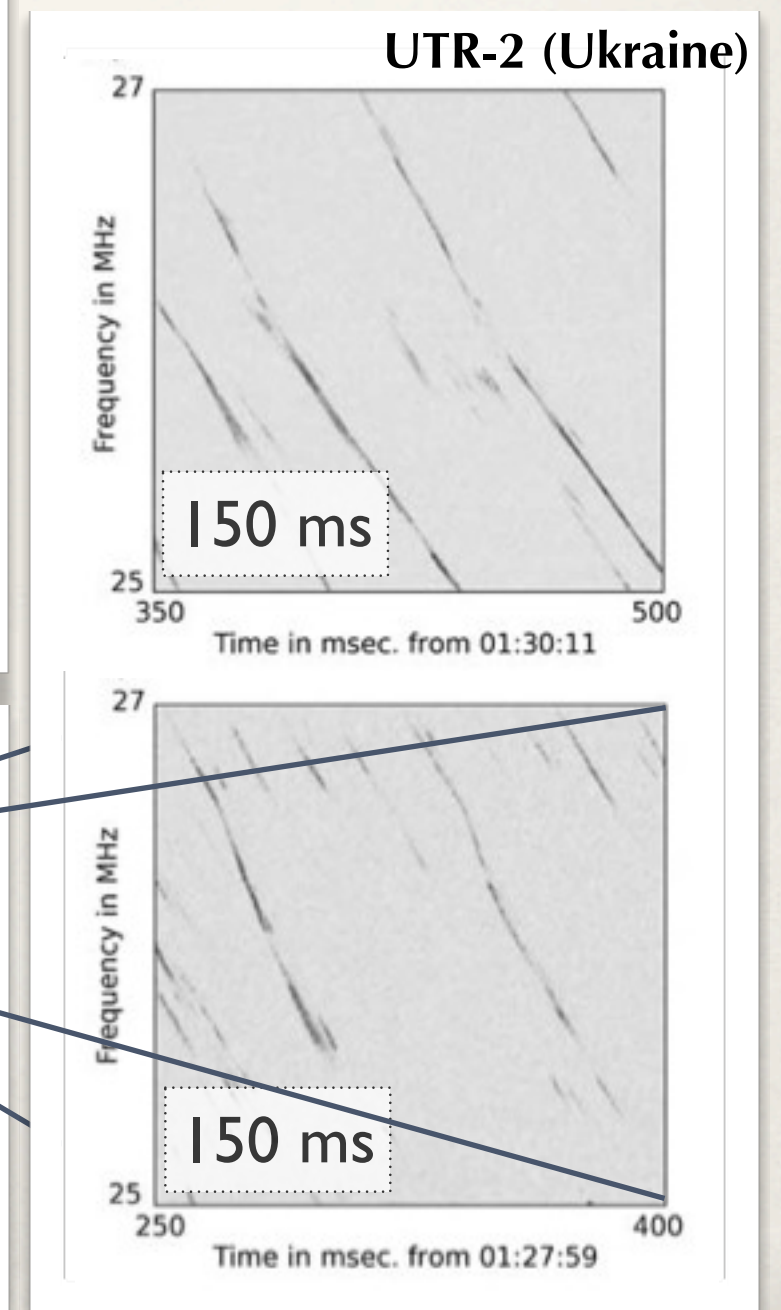
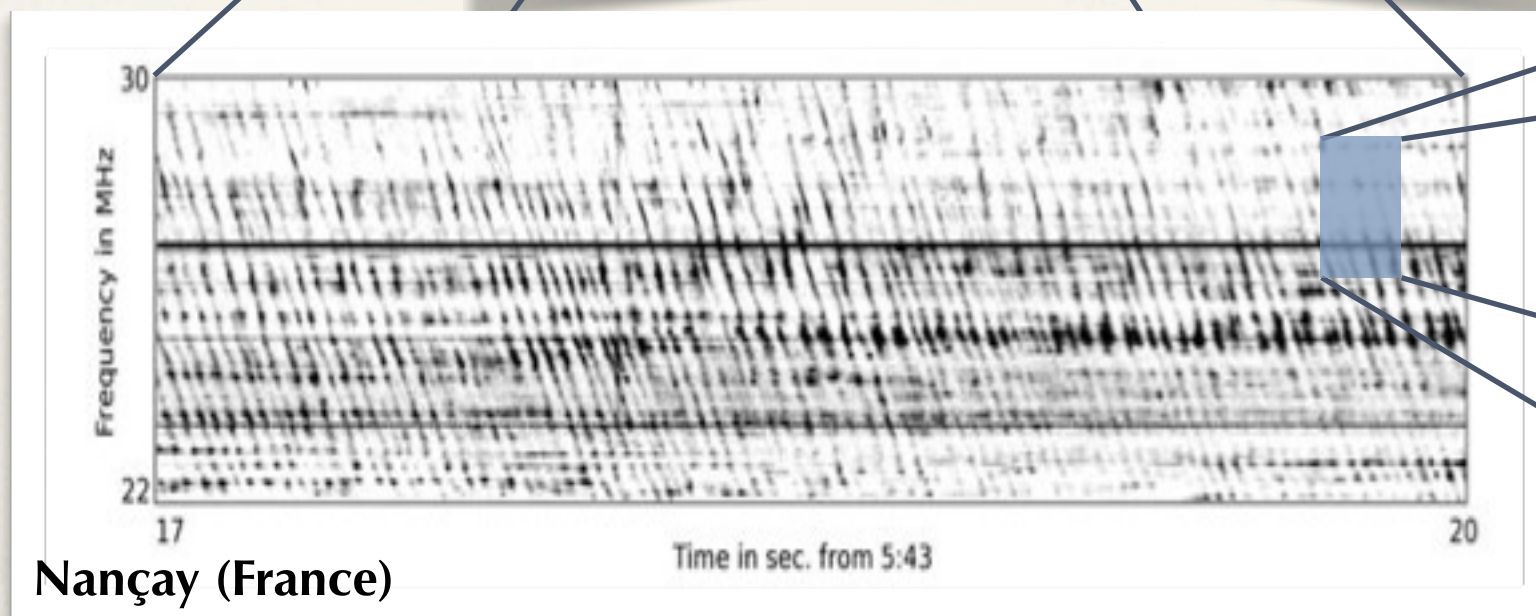
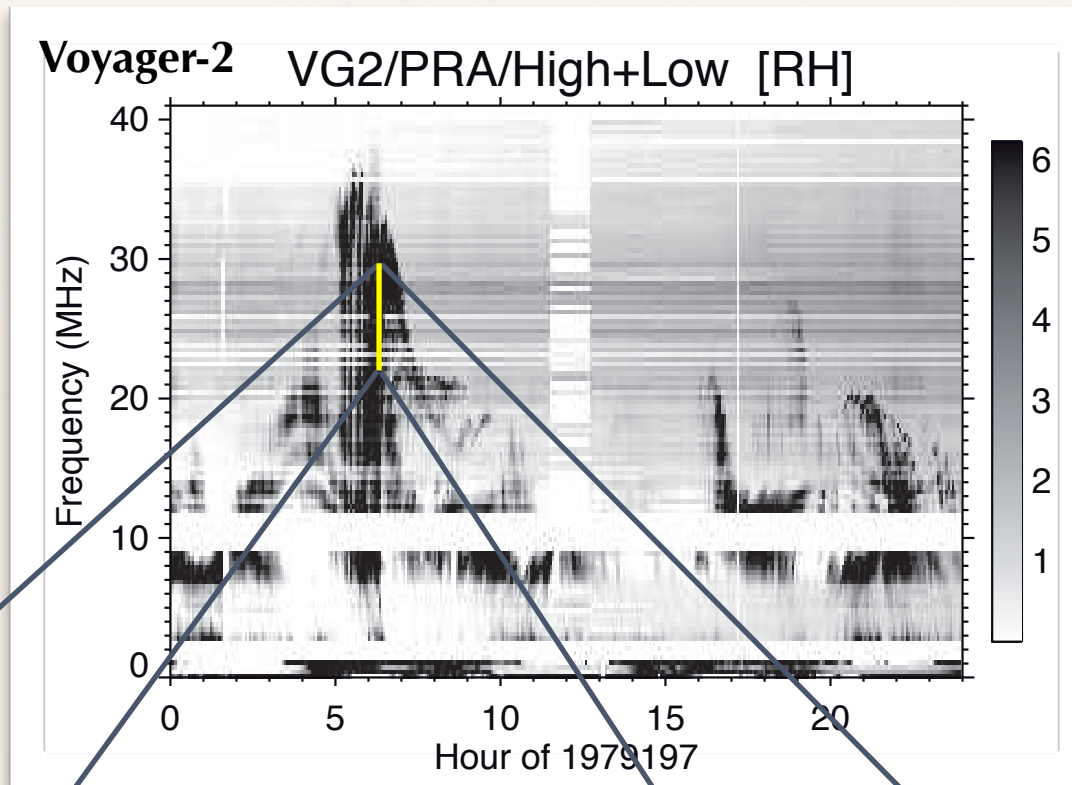


Magnetosphere of Jupiter: *the largest solar system object in our sky*



Jovian radio emissions

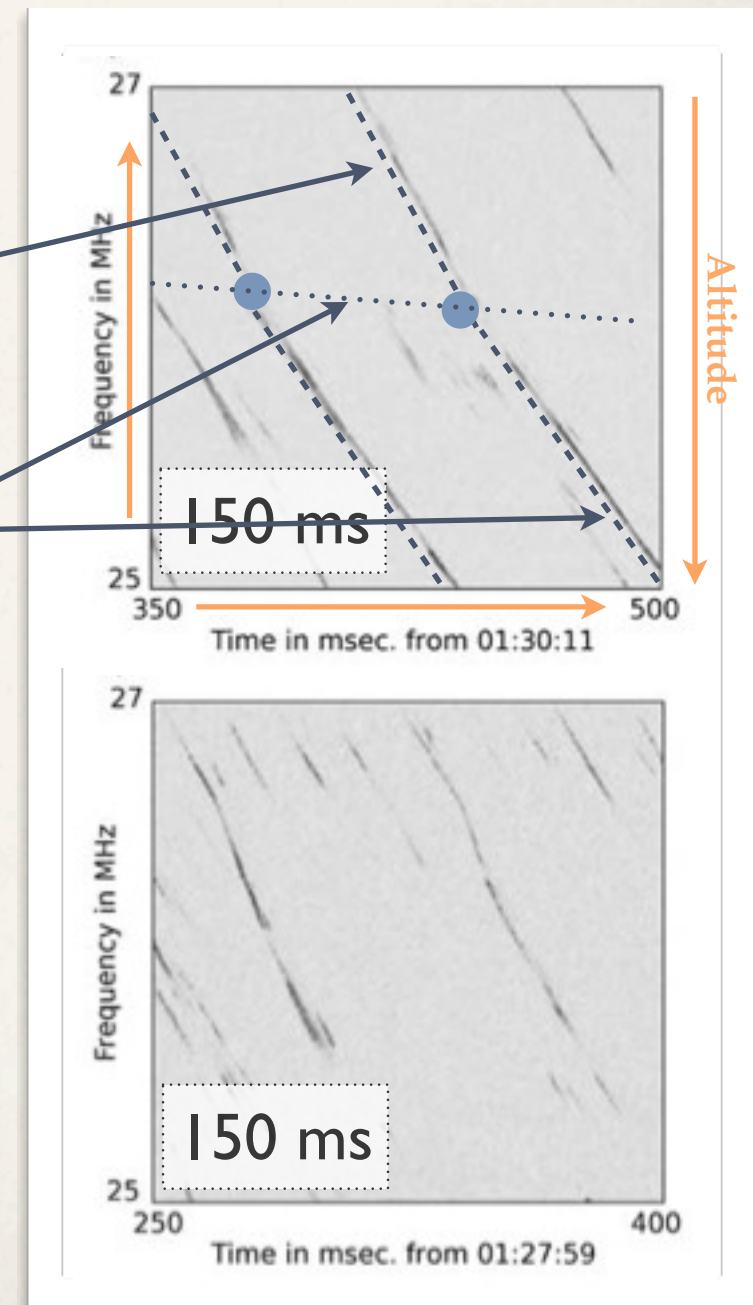
- Frequency: 0-40 MHz
- Multi scale structure (a few ms to a few hr)
- Sporadic
- Very dynamic
- S-bursts [short-bursts] [=millisecond bursts]



Science with radio emissions !

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

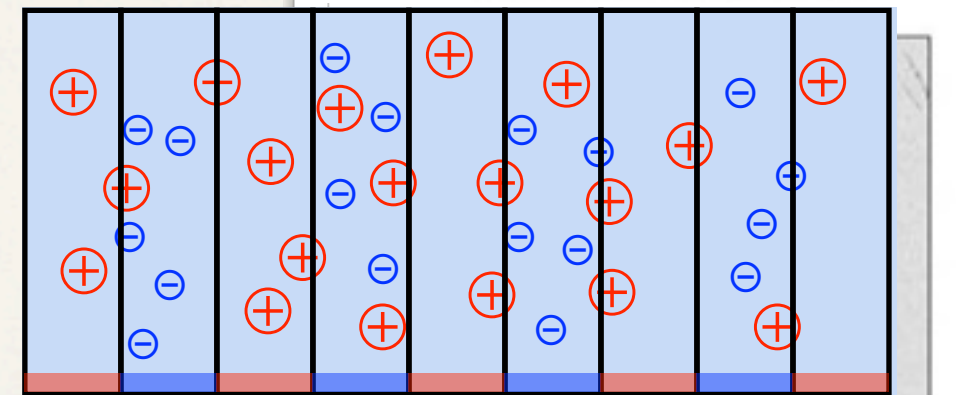
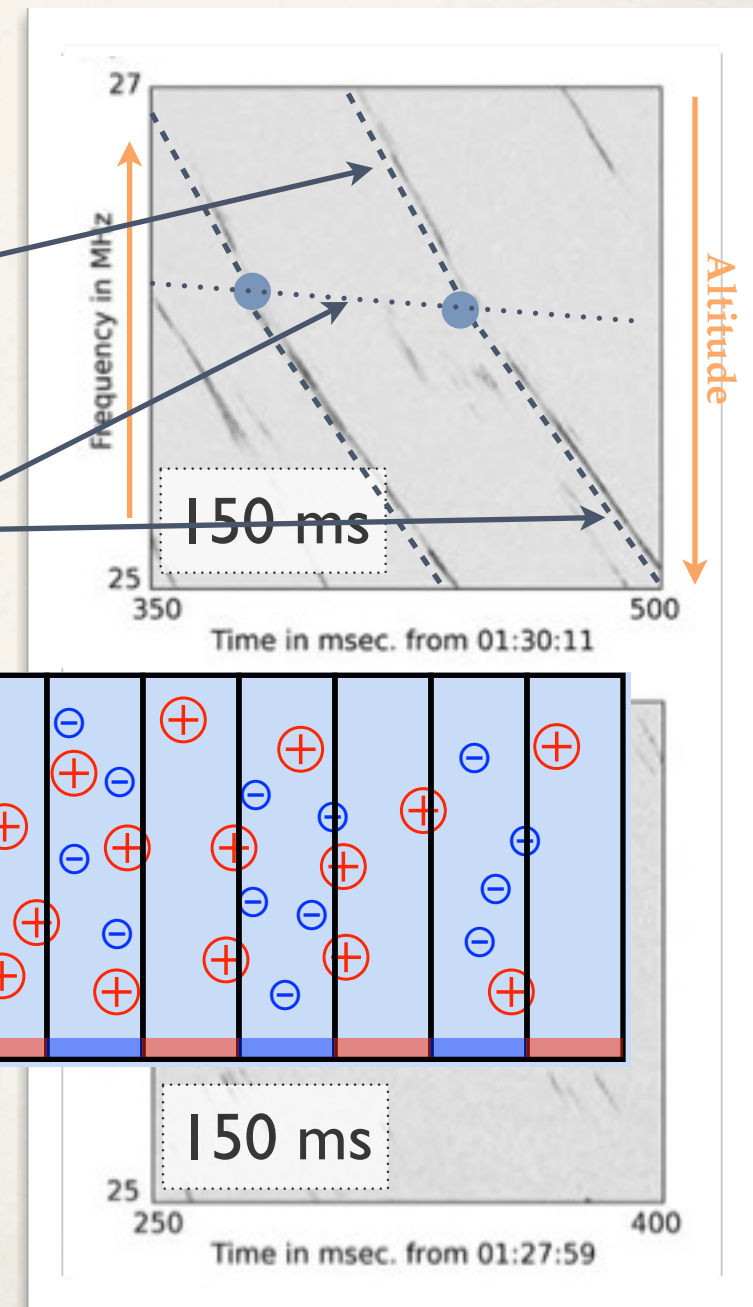
- * **Frequency decrease** = Magnetic field decrease ($F = qB/m$)
= Altitude increase (magnetic field high near surface)
- * **Decreasing tone** = Electron beams going away from Jupiter
- * **Slope** = Electron speed ($-20\text{MHz/s} \Rightarrow \sim 20\,000\text{ km/s} !$)
- * **Change in slope** = 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 «electron accelerator/ decelerator»
- * From the data: **Drift of «Change in slope» frequency**
= **velocity of sound in the medium ($\sim 10\text{ km/s}$)**
 - * *In a plasma, a sound wave = slow periodic movement of background electrons and protons (but 900 times more heavy $\Rightarrow$ almost no displacement for protons)
 $\Rightarrow$ 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 ($-20\text{MHz/s} \Rightarrow \sim 20\,000\text{ km/s} !$)
- * **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 «electron accelerator / decelerator»
- * From the data: **Drift of «Change in slope» frequency**
= **velocity of sound in the medium** ($\sim 10\text{ km/s}$)
 - * *In a plasma, a sound wave = slow periodic movement of background electrons and protons (but 900 times more heavy $\Rightarrow$ almost no displacement for protons)
 $\Rightarrow$ 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:

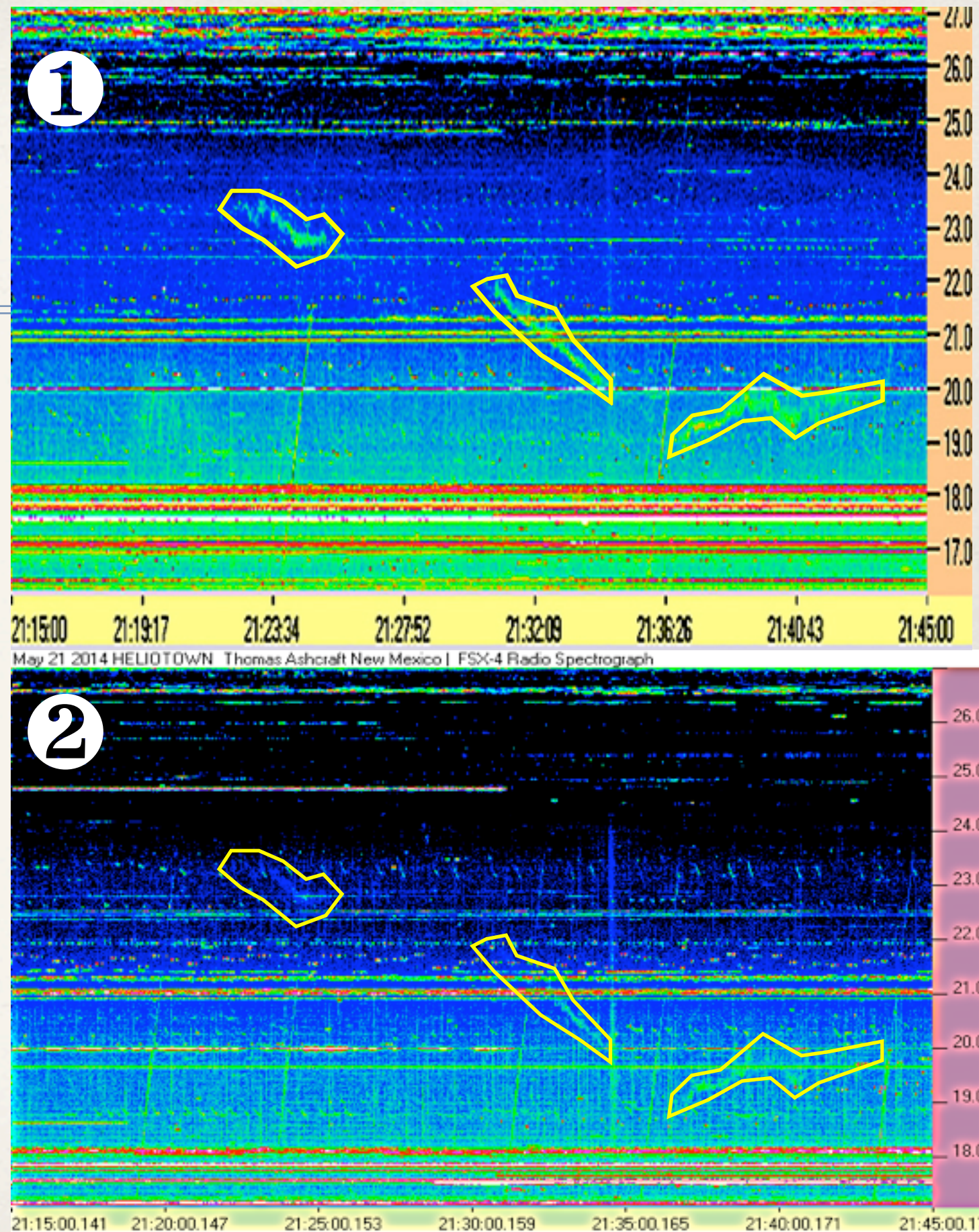
~ $0.00017^\circ = 0.6''$ [=arctan($2700 / 880 \times 10^6$)]

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 $\Rightarrow$ $\frac{1}{2}$ 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>

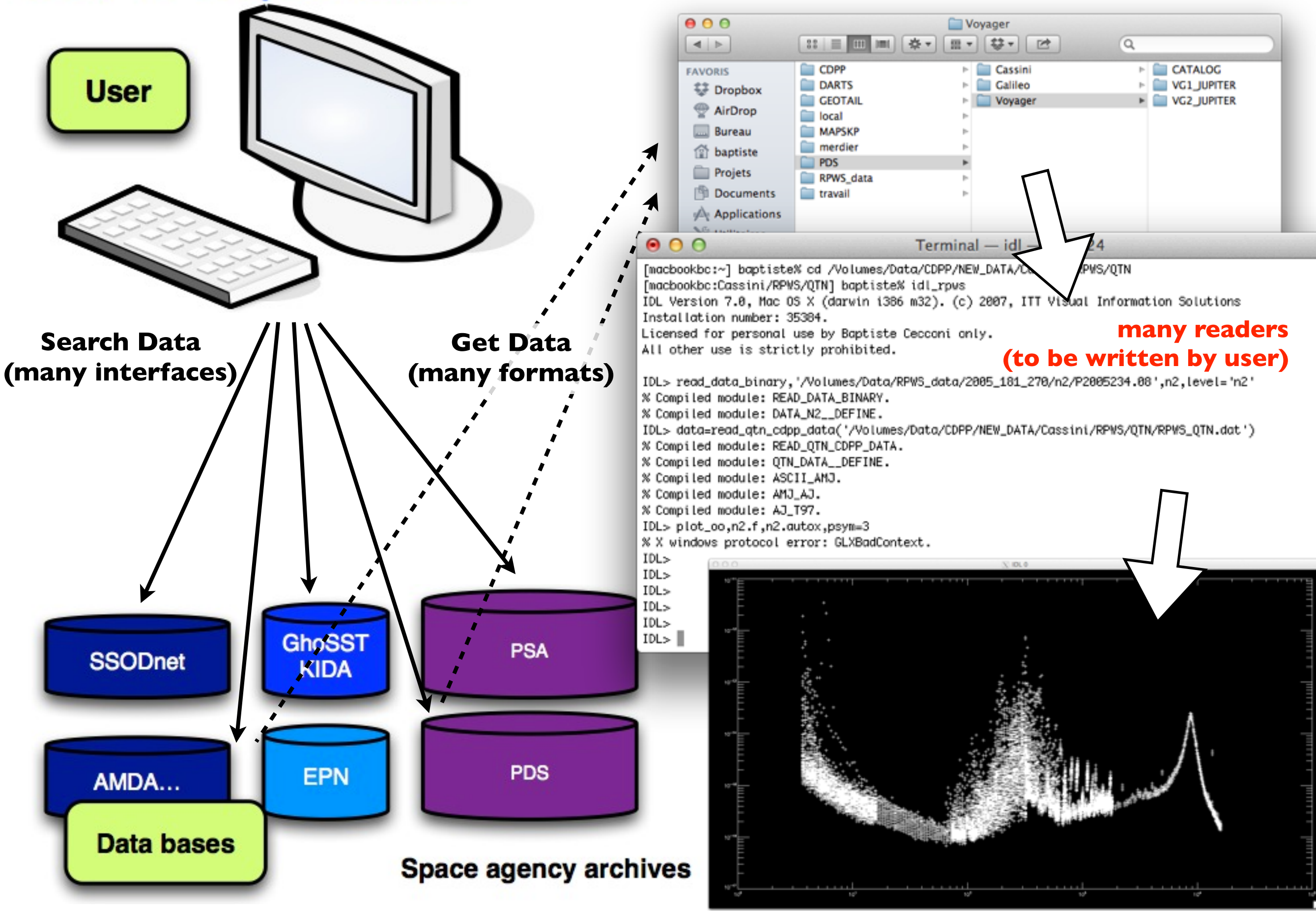
- ❖ **What about low frequency radio?**

<http://cdaweb.gsfc.nasa.gov> CDAWeb is providing free access to a lot of space borne data

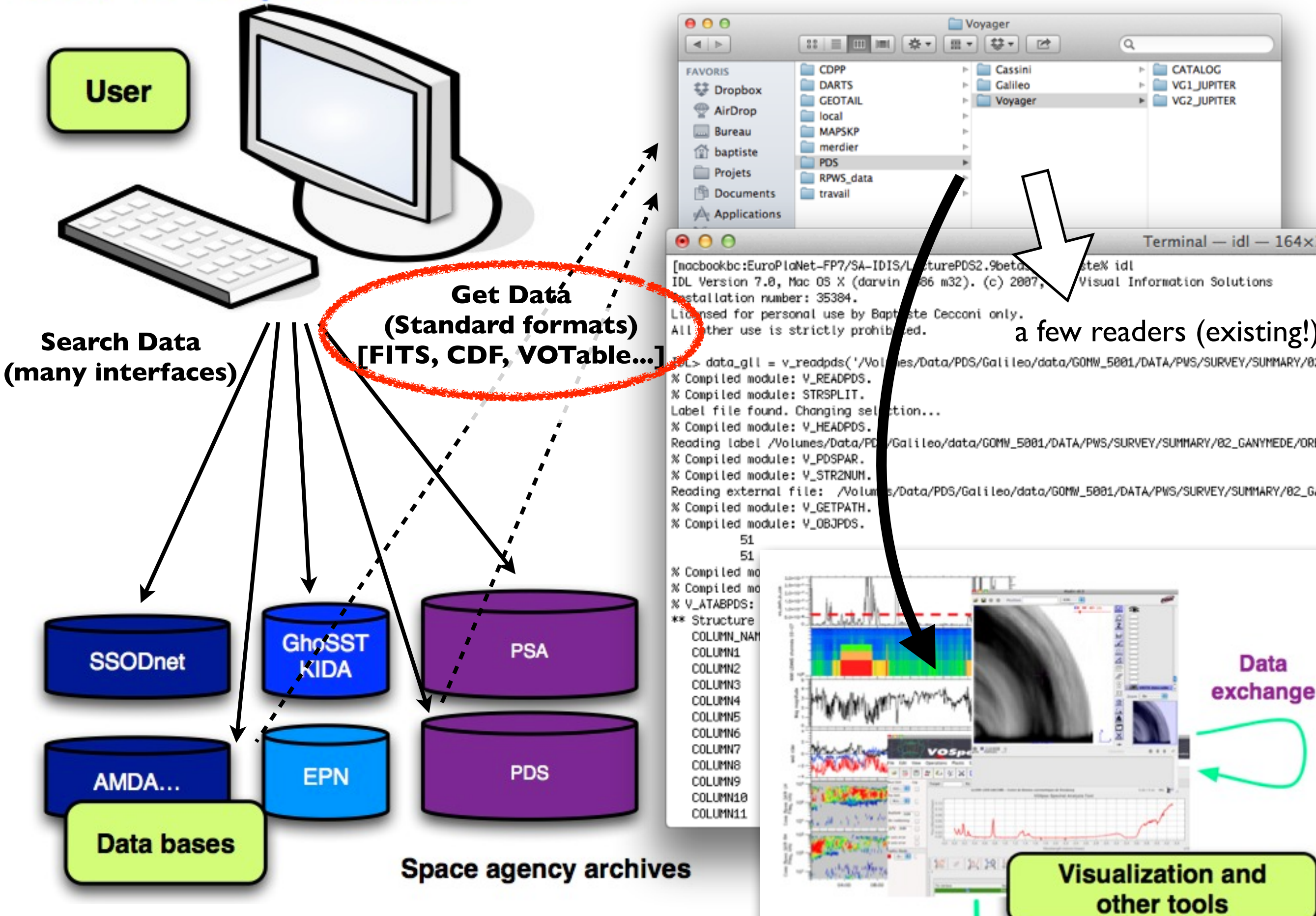
<http://vwo.gsfc.nasa.gov> VWO (Virtual Wave Observatory): access to many radio instrument (mostly space based)

<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)

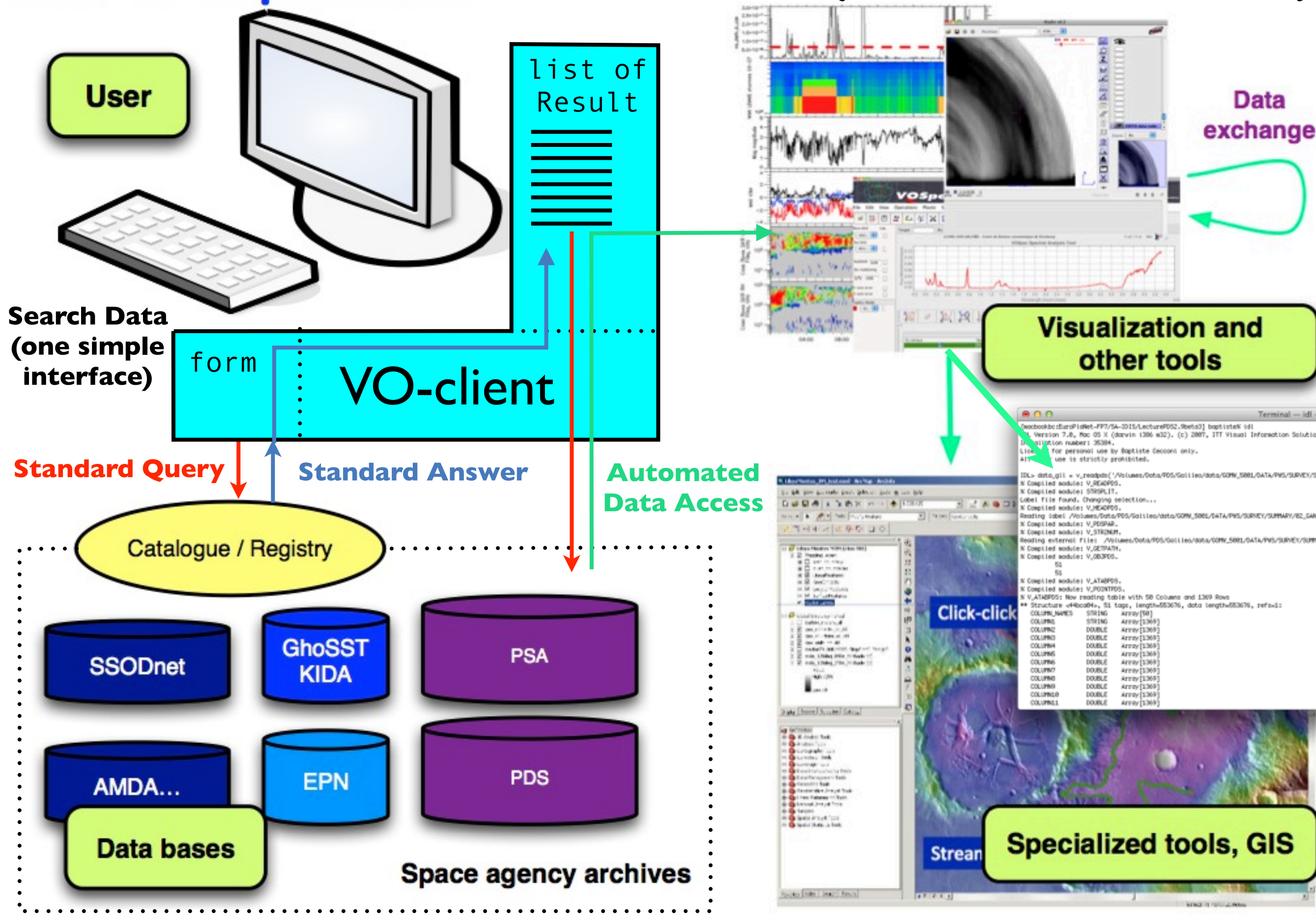
User's experience «classic»



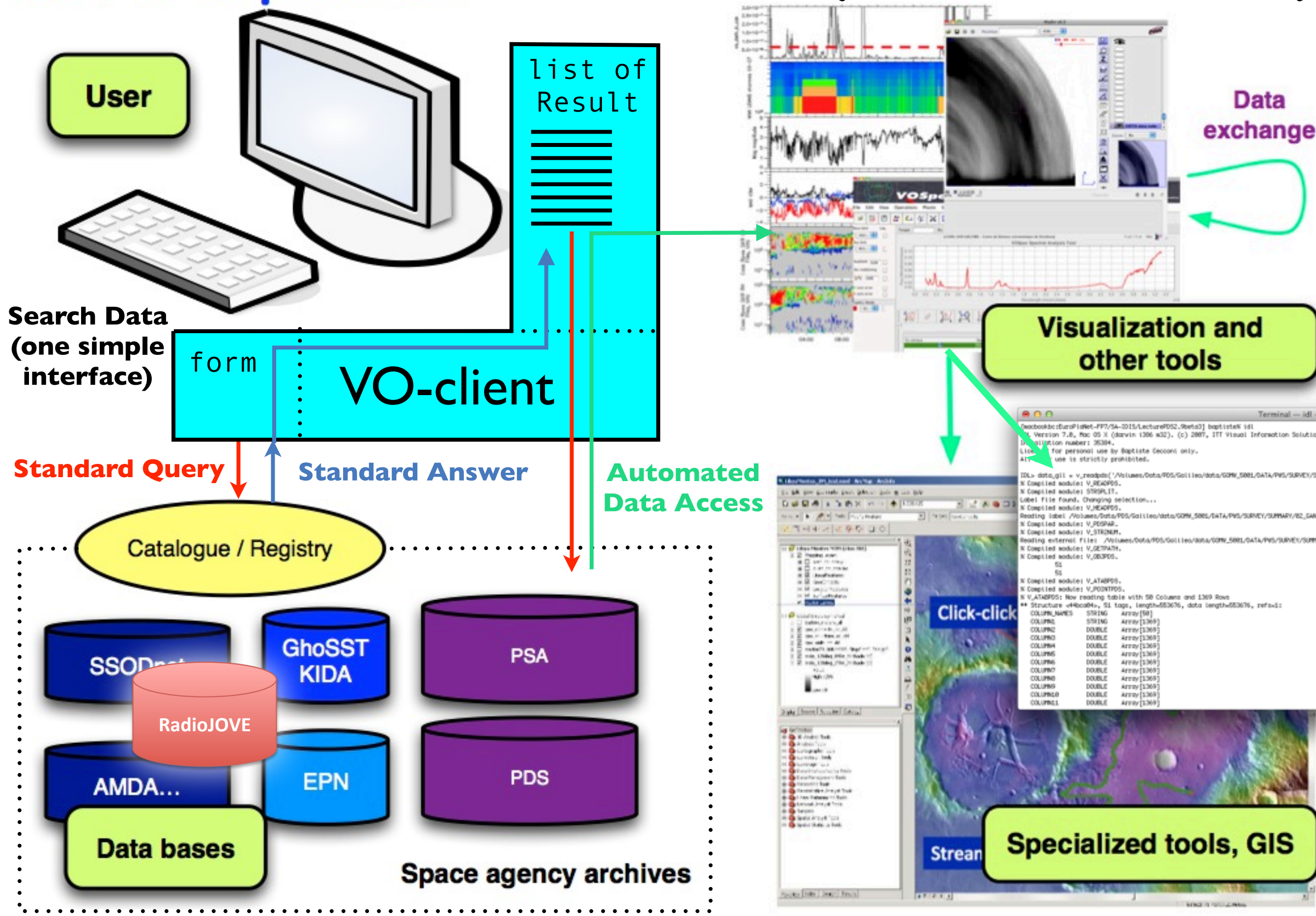
User's experience «enhanced»



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



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

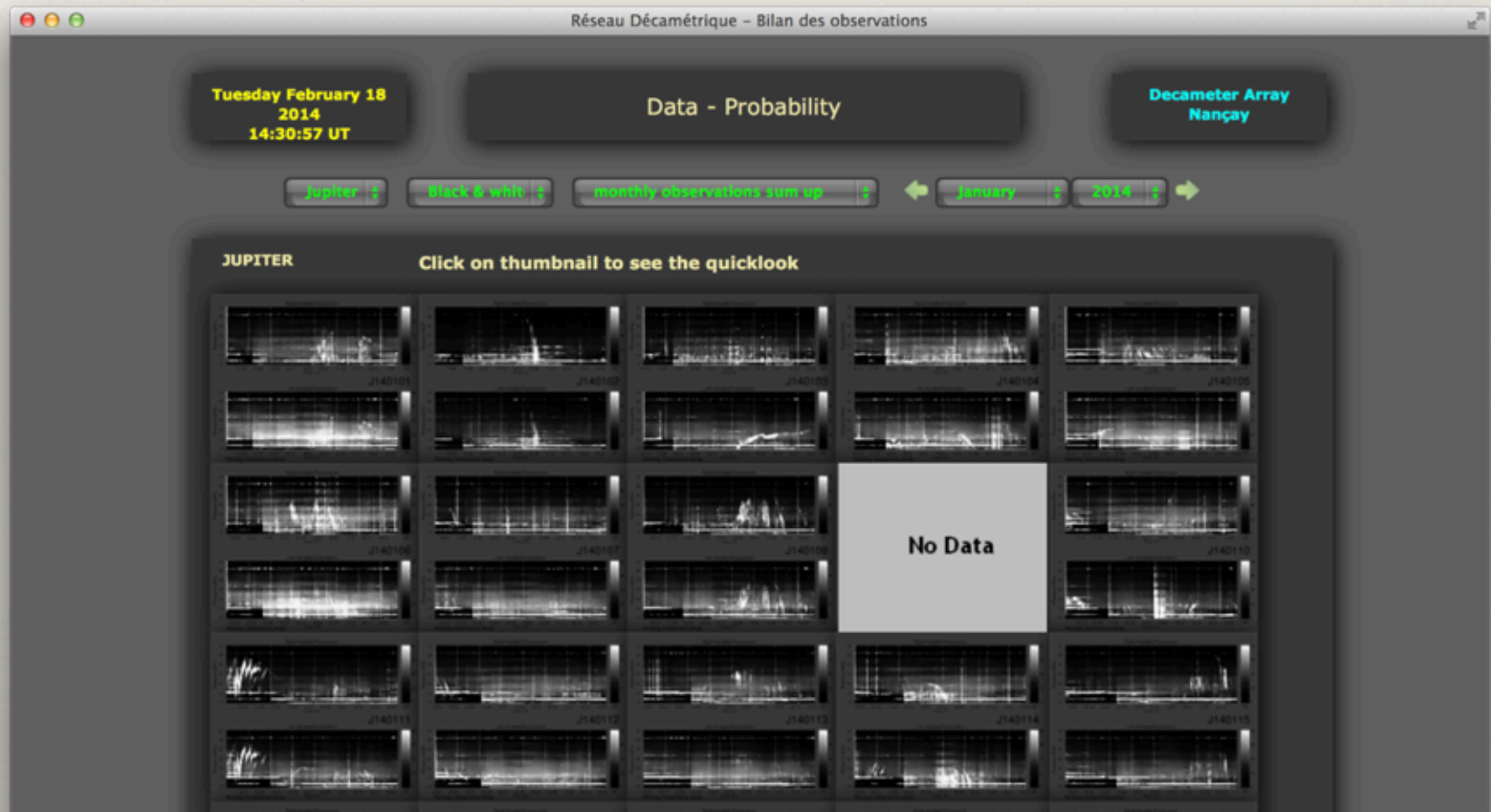


Currently available data

- ❖ 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

The screenshot displays the VESPA (Virtual European Solar and Planetary Access) interface within a web browser. The browser's address bar shows the URL: `vespa.obspm.fr/planetary/data/display/?resource_id=ivo://vopdc.obspm.usn/dam/routinejup/epn&resource_type=epn&query`. The page features a header with the VESPA logo and a navigation menu. Below the header, a banner image shows various celestial bodies, with a hand cursor pointing at Jupiter. The main content area is titled "Results in service dam" and contains a table of Jupiter data. The table has columns for `dataprodukt_type`, `target_name`, `time_min (d)`, `time_max (d)`, and `access_url`. The data rows show dynamic spectrum observations of Jupiter from 2011 to 2013. To the right of the table, there are sections for "Plotting tools" (listing TOPCAT, Aladin, VOSpec, and SPLAT), "Example queries" (listing "Saturn in March 2012"), "SELECTED DATA" (showing "No data selected"), and "PREVIEW" (showing a spectral plot labeled J110).

VESPA
Virtual European Solar and Planetary Access

All VO Custom resource

Results in service dam

Show 20 entries Search: Show / hide columns Select all Deselect all Full Text

dataprodukt_type	target_name	time_min (d)	time_max (d)	access_url
dynamic_spectrum	jupiter	2012-07-07T06:00:00	2012-07-07T06:00:00	J120707.xml
dynamic_spectrum	jupiter	2012-03-31T18:00:00	2012-03-31T18:00:00	J120331.xml
dynamic_spectrum	jupiter	2013-02-03T18:00:00	2013-02-04T00:00:00	J130203.xml
dynamic_spectrum	jupiter	2012-08-22T00:00:00	2012-08-22T06:00:00	J120822.xml
dynamic_spectrum	jupiter	2011-09-27T00:00:00	2011-09-27T06:00:00	J110927.xml
dynamic_spectrum	jupiter	2013-02-15T18:00:00	2013-02-16T00:00:00	J130215.xml
dynamic_spectrum	jupiter	2012-08-30T00:00:00	2012-08-30T06:00:00	J120830.xml
dynamic_spectrum	jupiter	2011-02-11T18:00:00	2011-02-11T18:00:00	J110211.xml
dynamic_spectrum	jupiter	2011-05-11T06:00:00	2011-05-11T06:00:00	J110511.xml
dynamic_spectrum	jupiter	2012-12-10T18:00:00	2012-12-11T06:00:00	J121210.xml
dynamic_spectrum	jupiter	2012-12-16T18:00:00	2012-12-17T00:00:00	J121216.xml
dynamic_spectrum	jupiter	2012-12-24T18:00:00	2012-12-25T00:00:00	J121224.xml
dynamic_spectrum	jupiter	2012-07-05T06:00:00	2012-07-05T06:00:00	J120705.xml

Afficher un menu

Plotting tools

- TOPCAT
- Aladin
- VOSpec
- SPLAT

Example queries

- Saturn in March 2012

SELECTED DATA

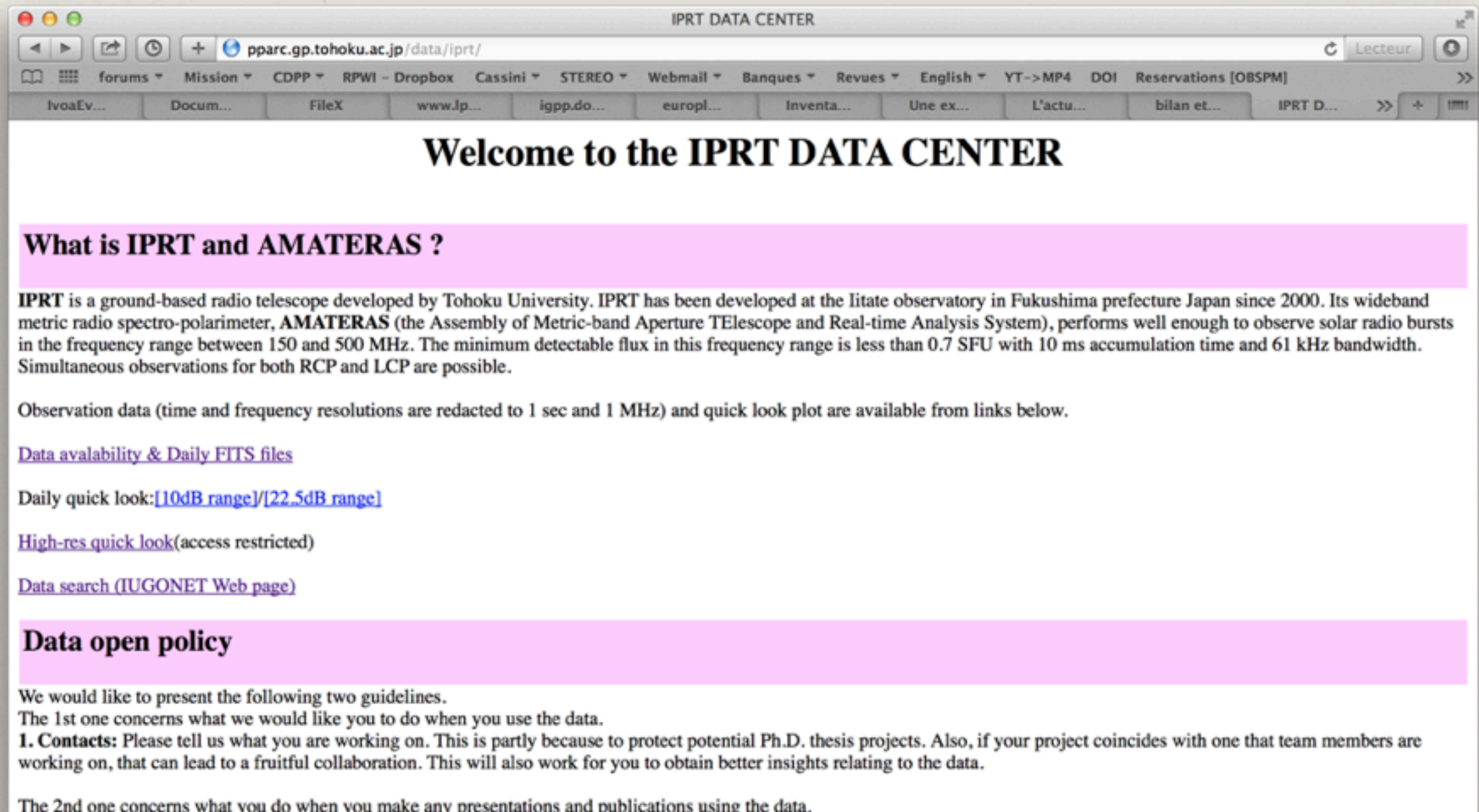
No data selected

PREVIEW

J110

Litate Jupiter data

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



The screenshot shows a web browser window titled "IPRT DATA CENTER". The address bar displays "pparc.gp.tohoku.ac.jp/data/iprt/". The browser's menu bar includes "forums", "Mission", "CDPP", "RPWI - Dropbox", "Cassini", "STEREO", "Webmail", "Banques", "Revues", "English", "YT->MP4", "DOI", and "Reservations [OBSPM]". The page content begins with a large heading "Welcome to the IPRT DATA CENTER". Below this, a pink-shaded section titled "What is IPRT and AMATERAS ?" contains text describing the telescope and its capabilities. Further down, there are links for "Data availability & Daily FITS files", "Daily quick look" (with sub-links for "[10dB range]" and "[22.5dB range]"), "High-res quick look (access restricted)", and "Data search (IUGONET Web page)". Another pink-shaded section titled "Data open policy" follows, containing guidelines for data use, including a section on "1. Contacts".

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 availability & 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.

Litate Jupiter data

- ❖ Quicklooks via IUGONET registry:

Index of /~ju

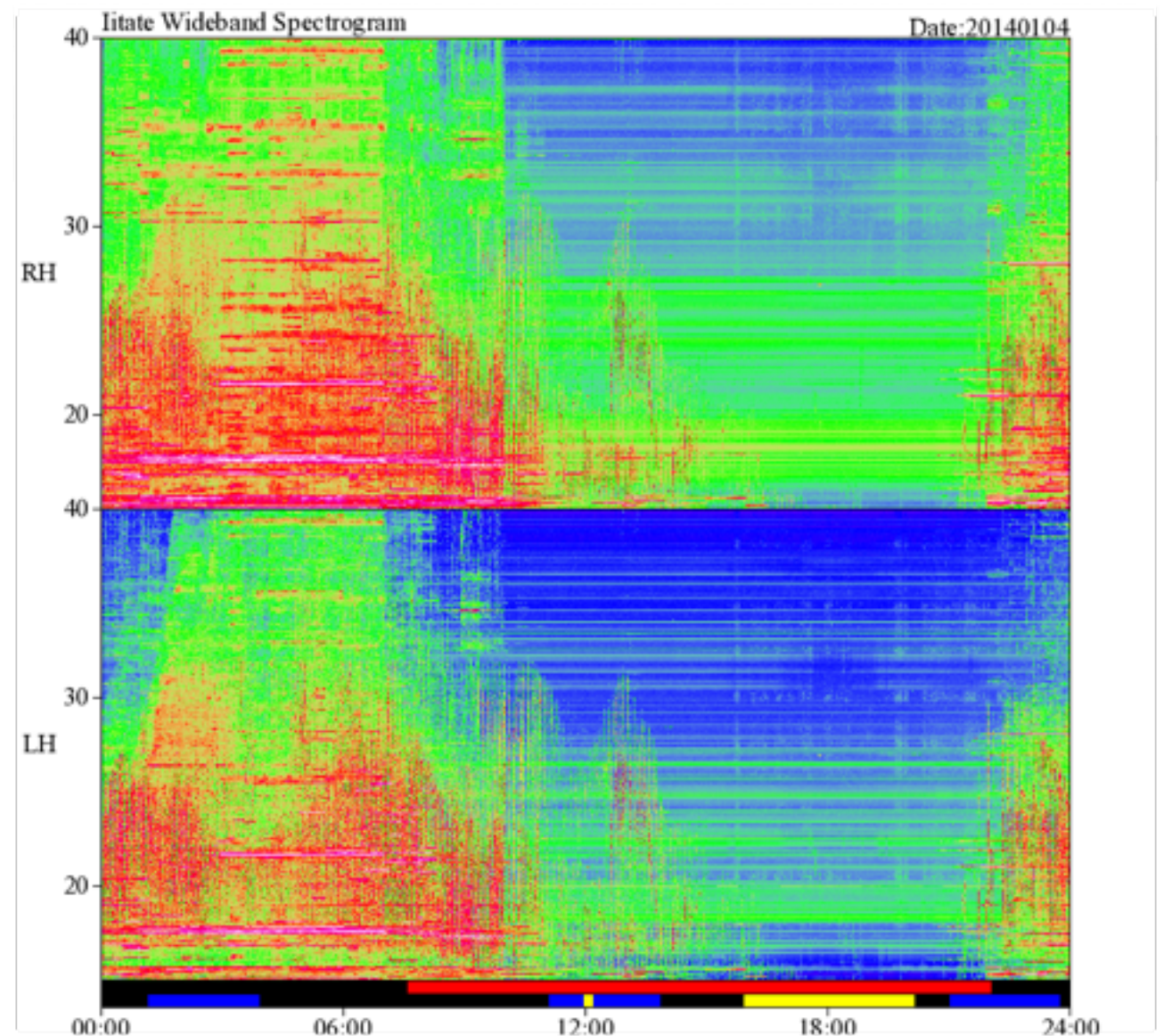
ariel.gp.tohoku.ac.jp/~jupiter/it_hf/png/

forums Mission CDPP RPWI - Dropbox Cassini STEREO Webmail

IvoaEv... Docum... FileX www.lp... igpp.do... euopl...

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	
20040508.png	27-Jun-2011 22:56	57K	



RadioJove archive

- ❖ Archive with mainly quicklooks, very few data.

Radio JOVE Archive Calendar

radiojove.org/cgi-bin/calendar/calendar.cgi?month=1&year=2014

forums Mission CDPP RPWI - Dropbox Cassini STEREO Webmail Banques Revues English YT->MP4 DOI Reservations [OBSPM]

IvoaEv... Docum... FileX www.lp... igpp.do... europa... Invent... Une ex... L'actu... bilan et... Radio J...

Radio JOVE Archive Calendar

[Radio JOVE Homepage](#) [Return to Welcome Page](#)

[Return to Current Year & Month](#)

☐ [--Month--](#) [--Year--](#) [show](#) [next month -->](#)

[<-- previous month](#)

January 2014

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1 Sun Jupiter	2	3 Jupiter	4 Jupiter
5 Jupiter	6 Jupiter	7 Jupiter Sun	8 Jupiter	9 Jupiter	10 Jupiter	11 Jupiter
12 Jupiter	13 Jupiter	14	15 Jupiter	16 Jupiter	17 Jupiter	18 Jupiter
19	20 Jupiter	21 Jupiter	22	23 Jupiter Sun	24 Jupiter	25 Jupiter
26	27	28	29	30	31	

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

forums Mission CDPP RPWI - Dropbox Cassini STEREO Webmail Banques Revues English YT->MP4 DOI Reservations [OBSPM]

IvoaEv... Docum... FileX www.lp... igpp.do... europa... Inventa... Une ex... L'actu... bilan et... Radio J... >> +

 **Radio JOVE Data Archive Display**

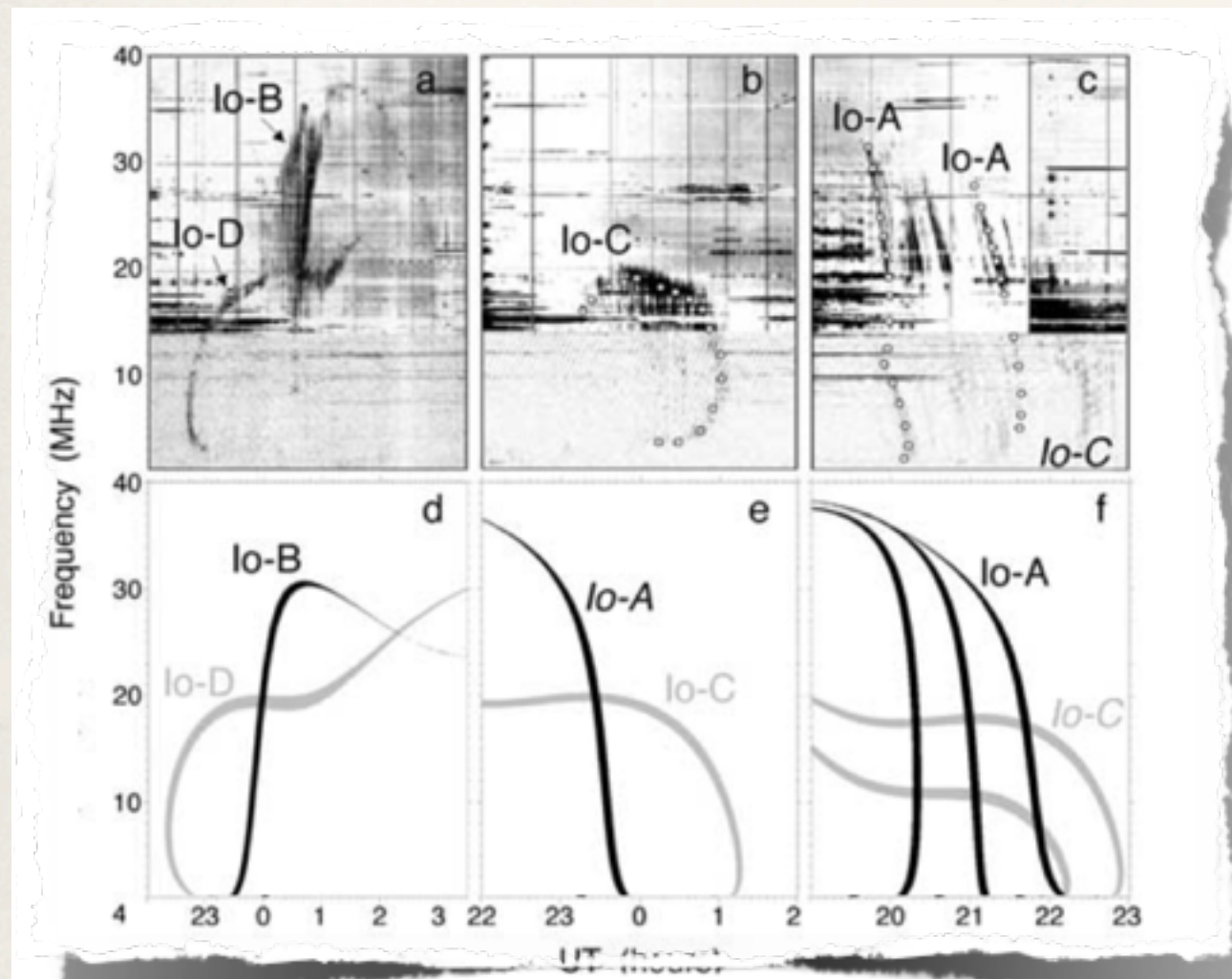
[Radio JOVE homepage](#) [Return to Welcome Page](#) [Return to Calendar Page](#)

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*



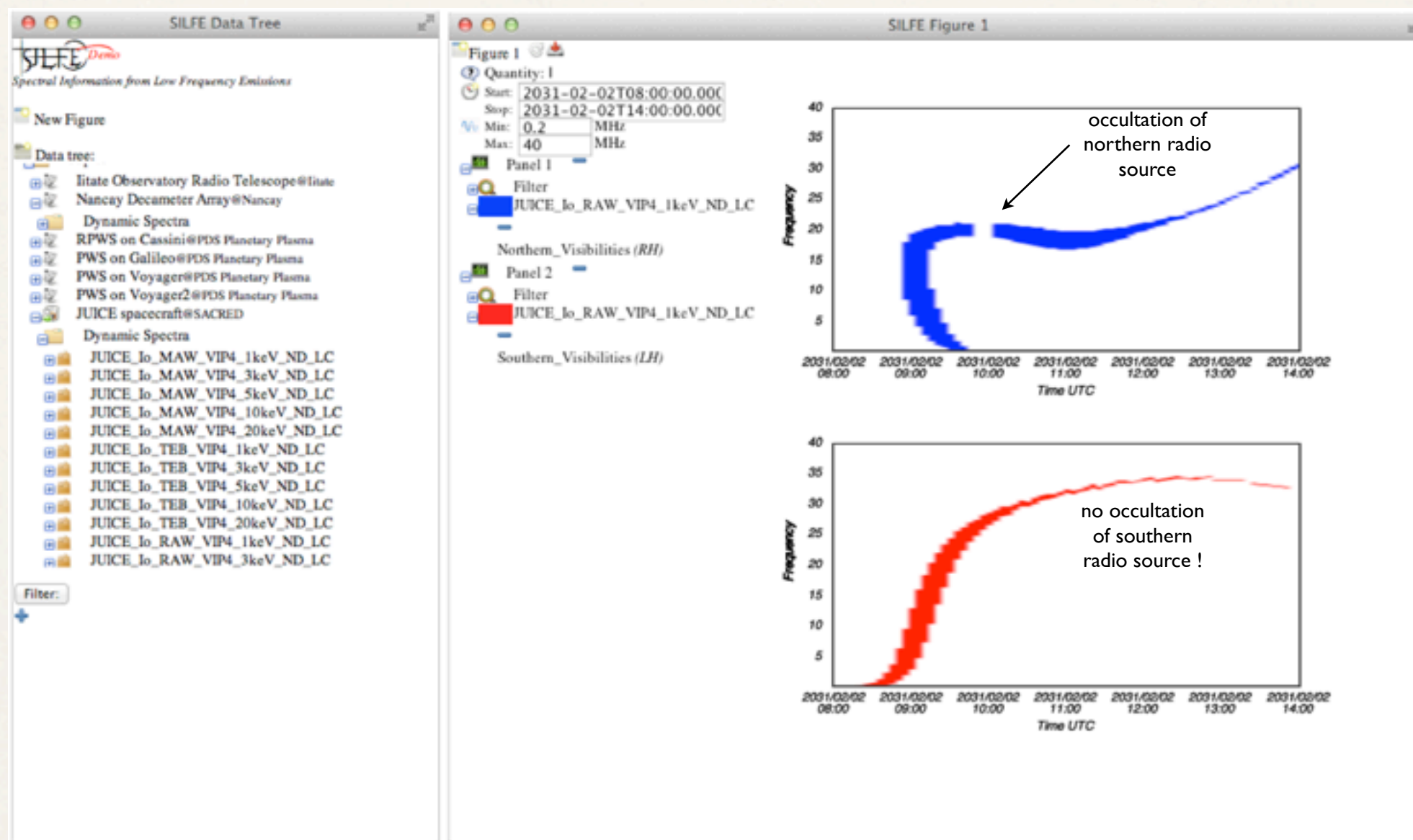
Model input parameter:

- *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*



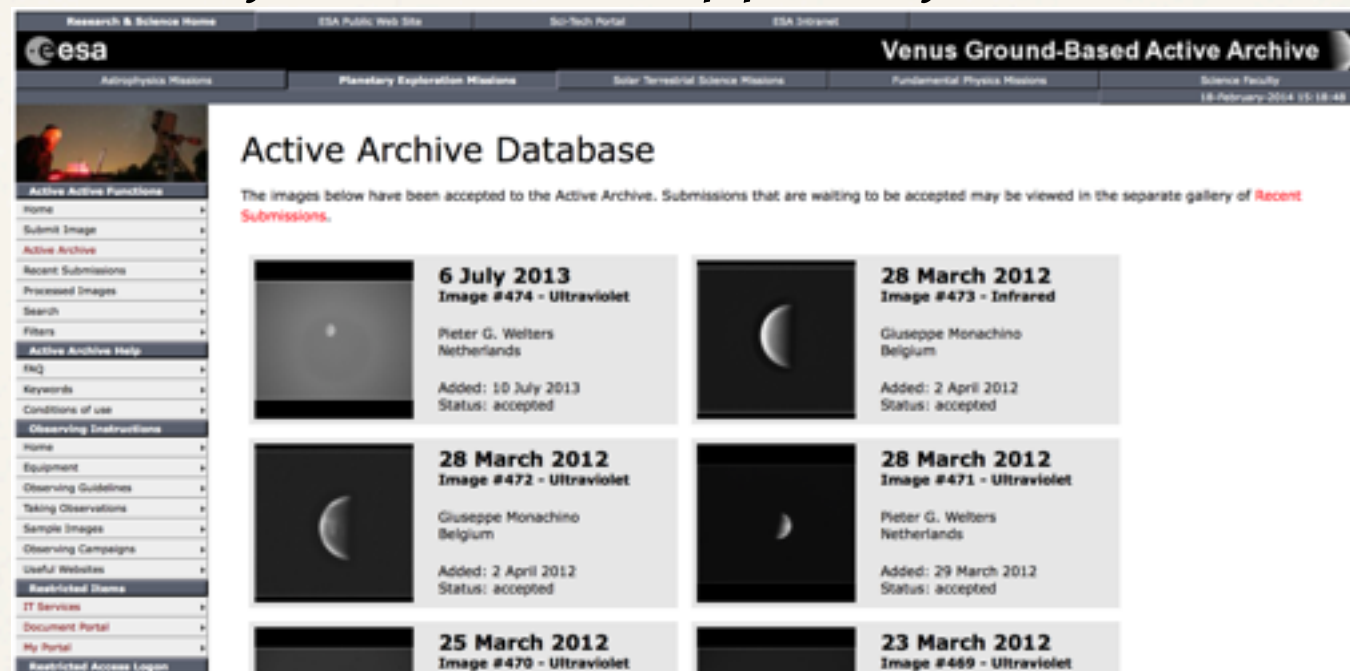
- ❖ <http://typhon.obspm.fr/maser/serpe>
(still a prototype, login required, needs a cookbook and a user manual!)

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 ± 3 h 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?)

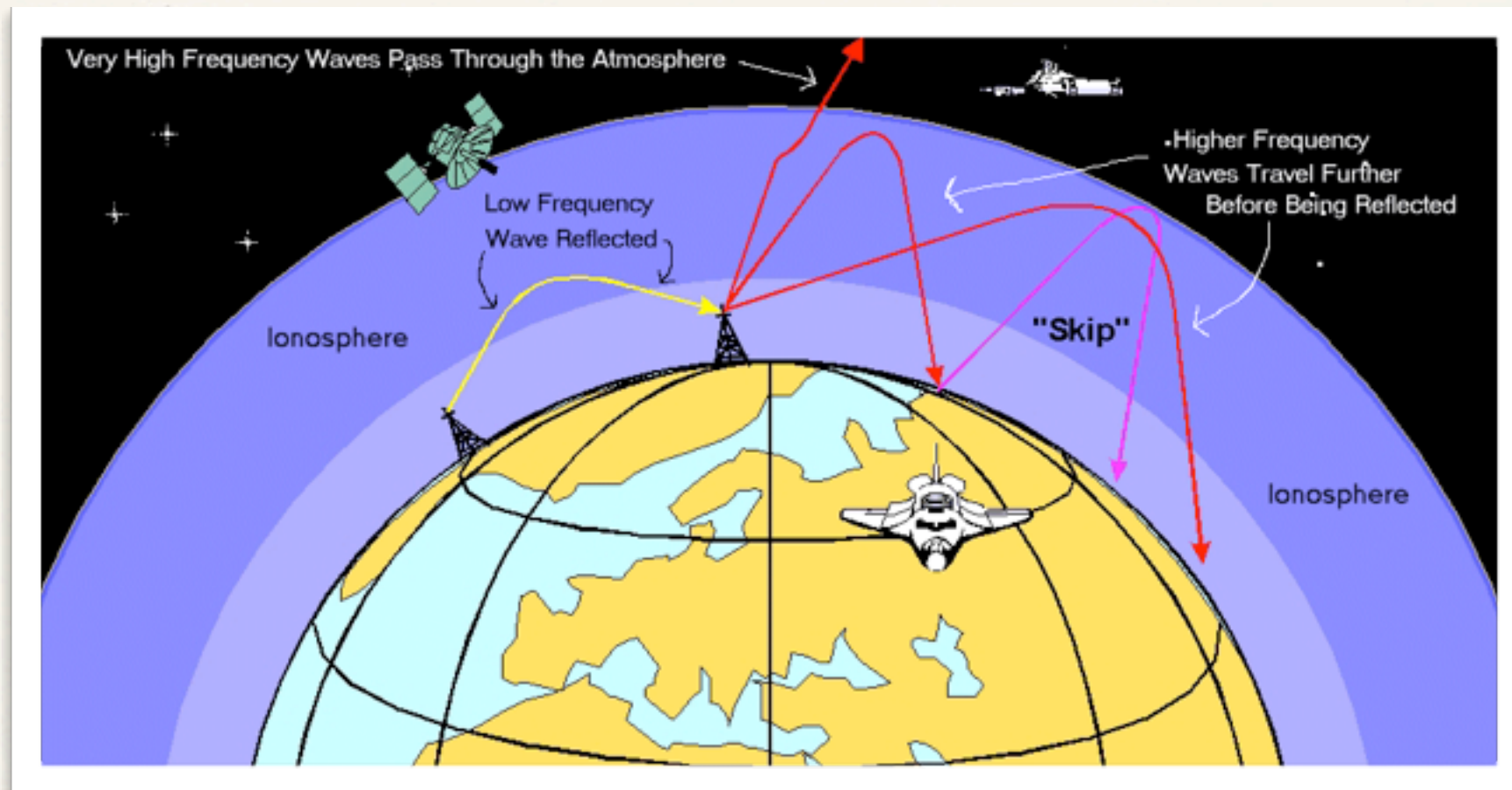
Summary

- ❖ 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*

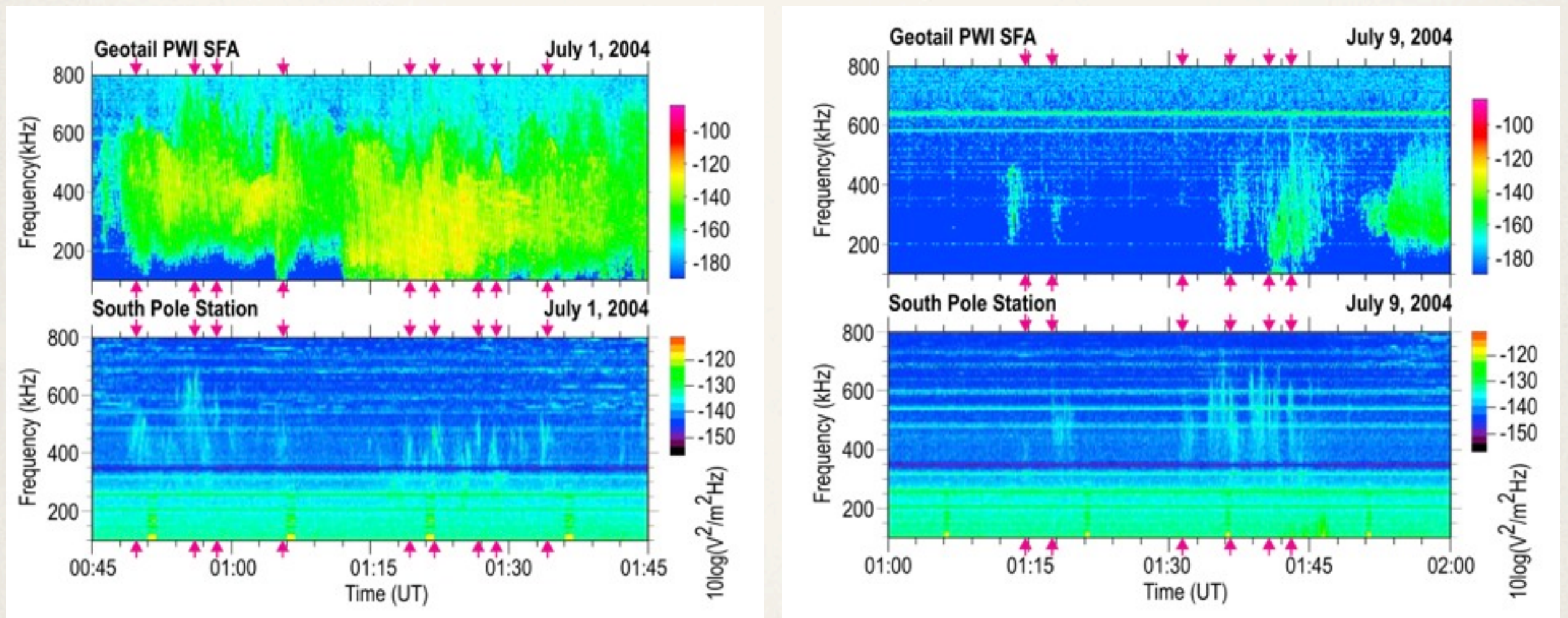
- ❖ Earth ionosphere = high-pass filter at ~ 10 MHz



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

Earth Radio emissions from ground ?

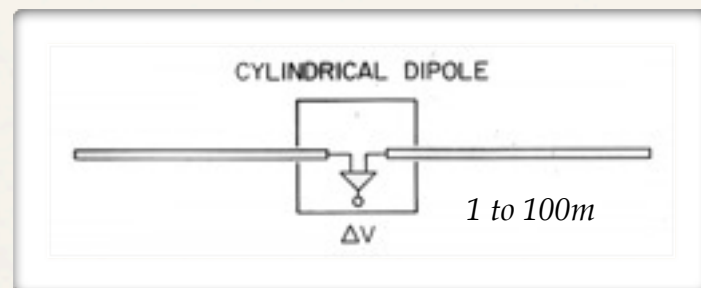
- ❖ Observation by Jim Labelle (South pole radio station)



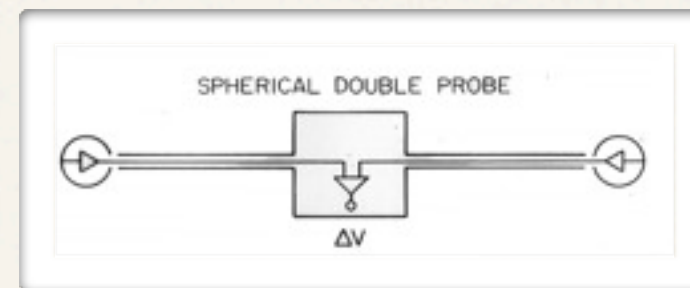
- ❖ What about trying to observe from Alaska ?

Sensors for space based radioastronomy

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

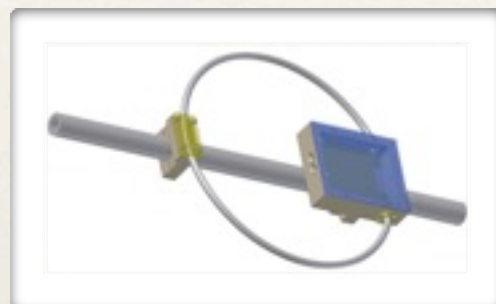


© UCLA

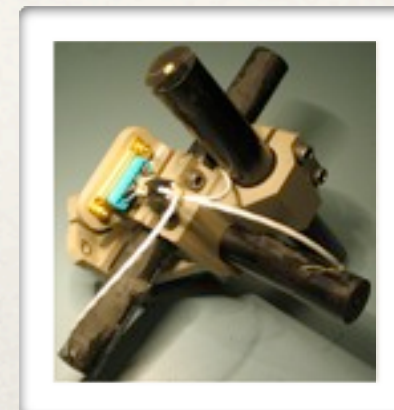


© UCLA

- ❖ magnetic loops or search-coils :



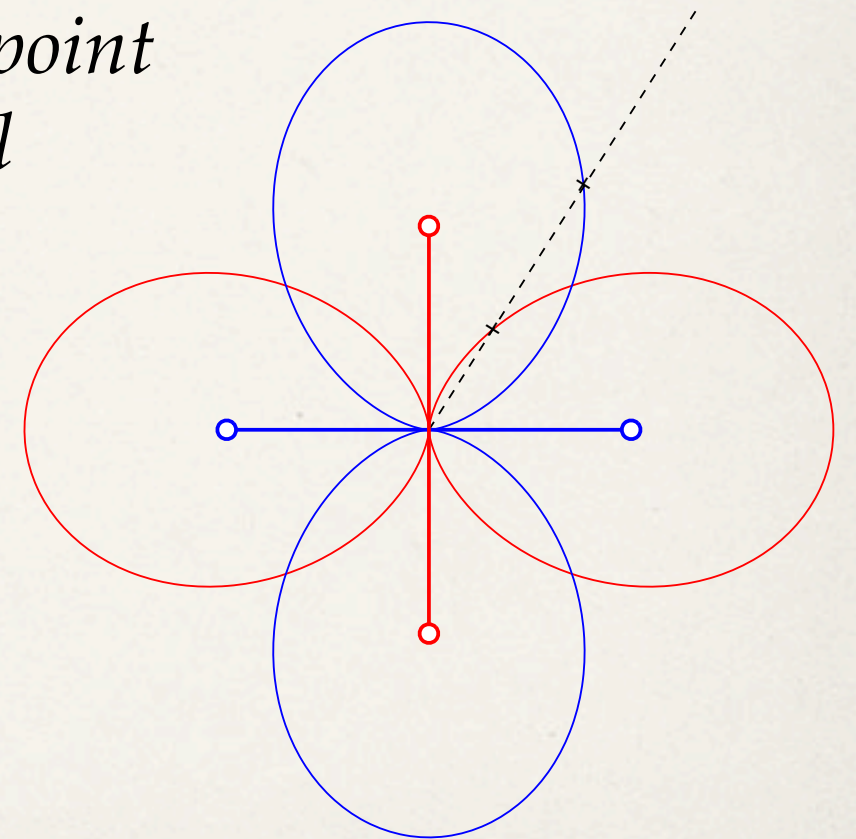
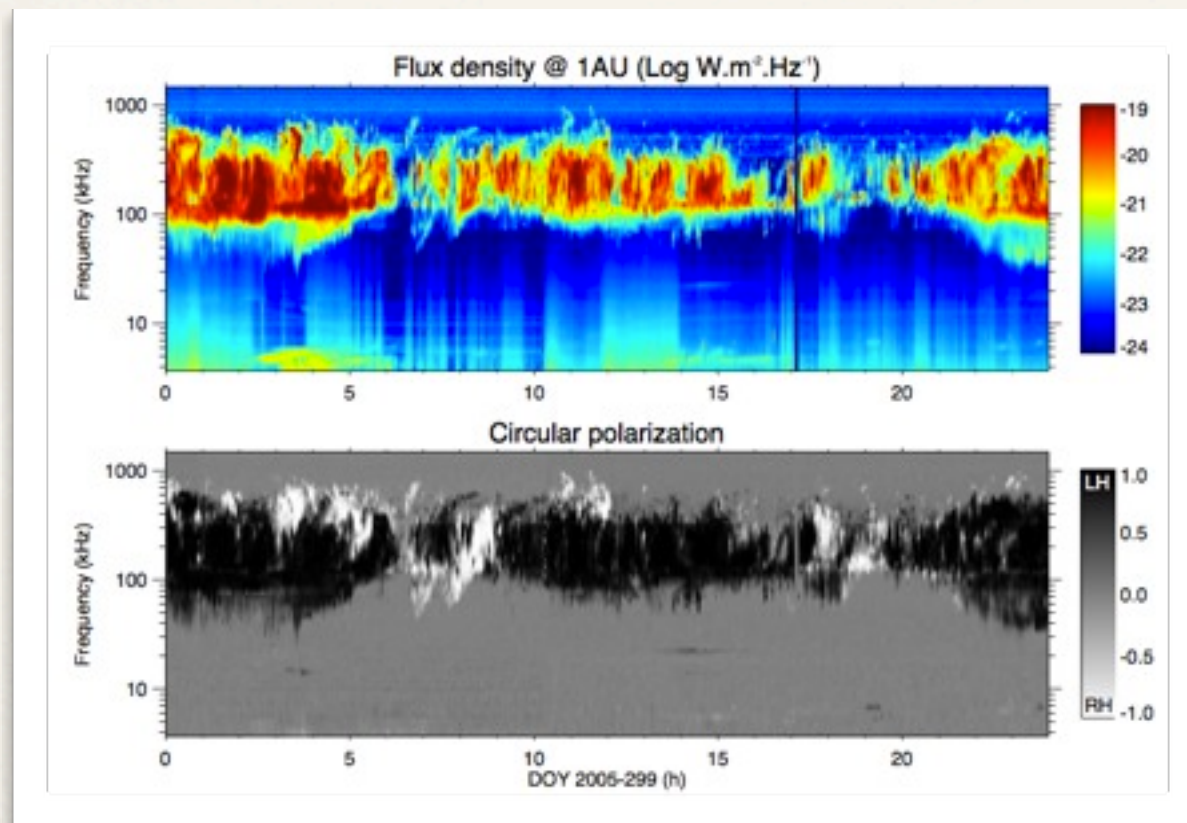
© LPC2E



© LPP

Radioastronomy observations from space

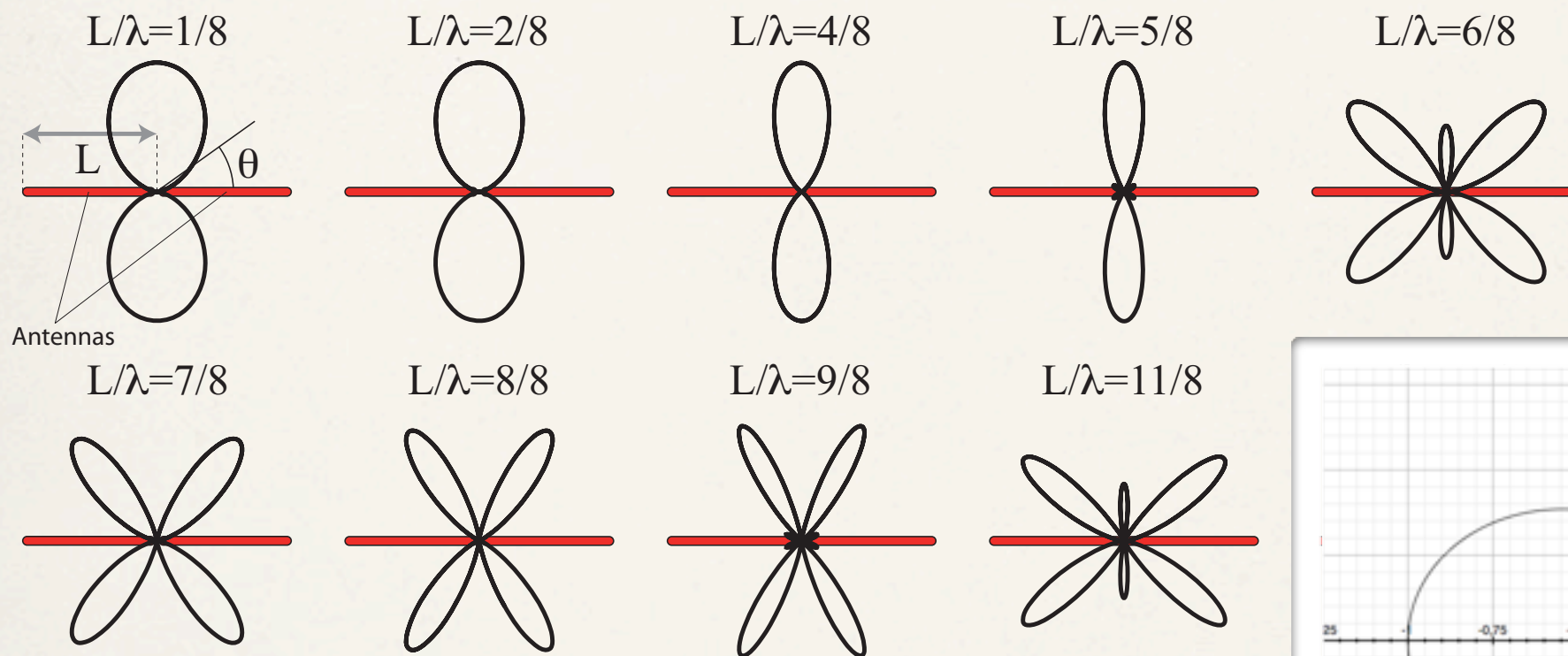
- ❖ Radio instrumentation: Goniopolarimetry (*a.k.a. Direction-Finding*)
=> yields polarization + direction of arrival (not independently !)
- ❖ On Cassini: 3 electrical antennas. Assuming a point source, we get polarization and direction of arrival



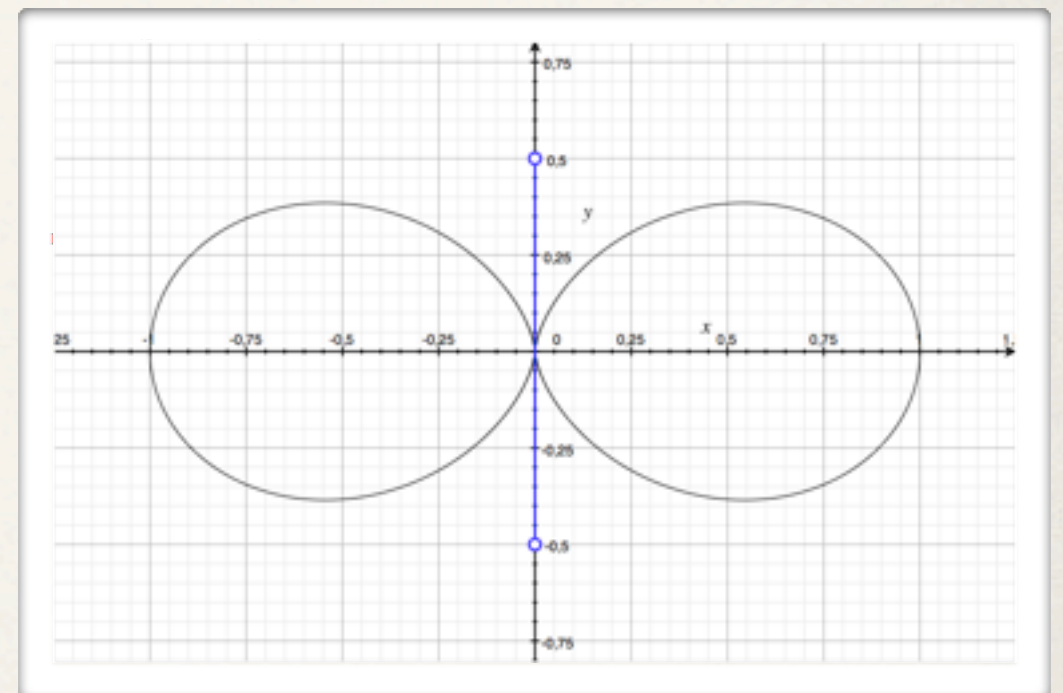
GP basics with 2 antennas

Electrical dipole, quasi-static range

- ❖ Antenna diagram for a dipole antenna

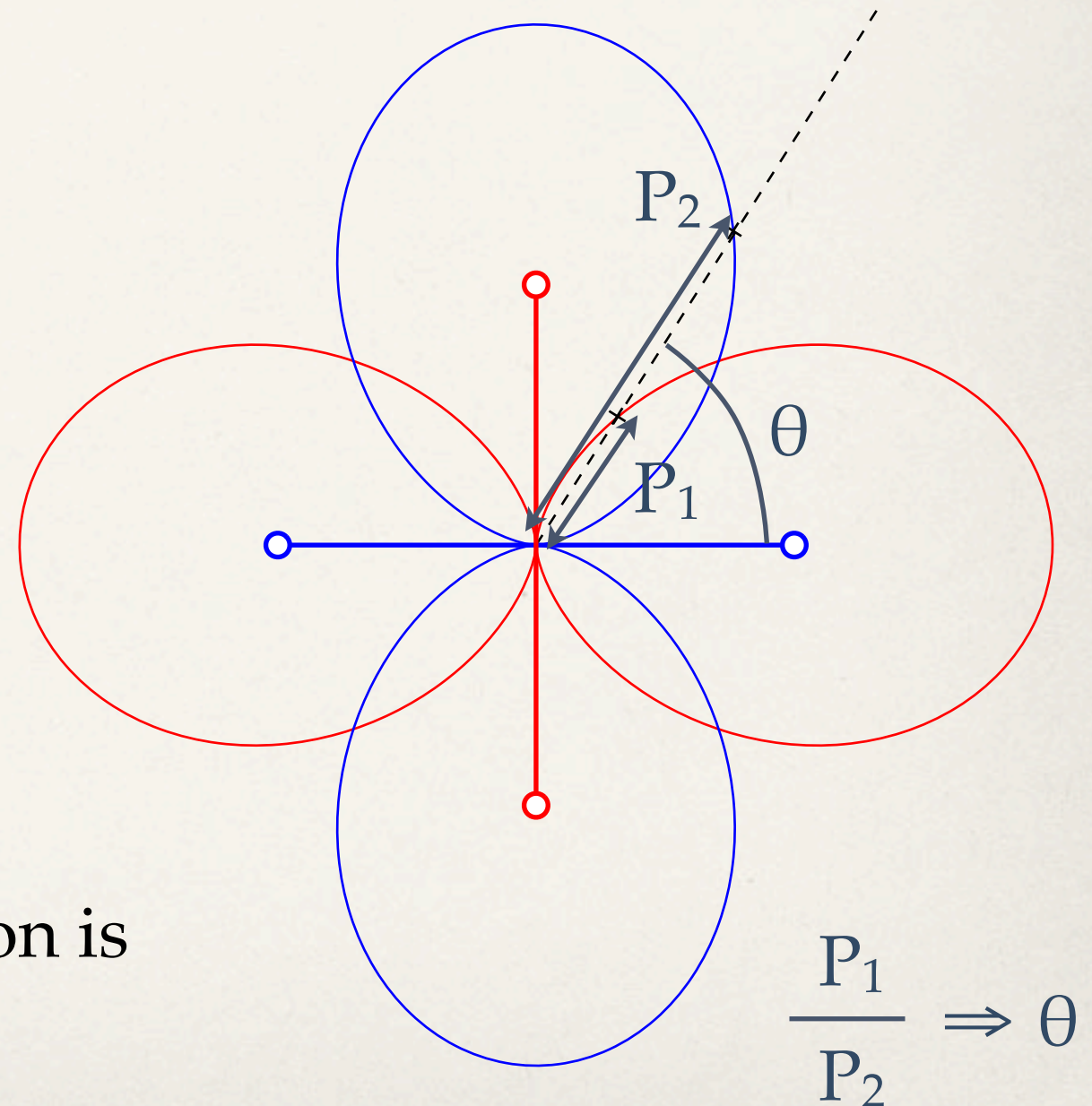


- ❖ In the quasi-static (or short antenna) range: $L \ll \lambda$
The antenna is then a perfect dipole.
Its gain varies in $\cos^2(\theta)$.



(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



Real case: 3D geometry & polarized wave

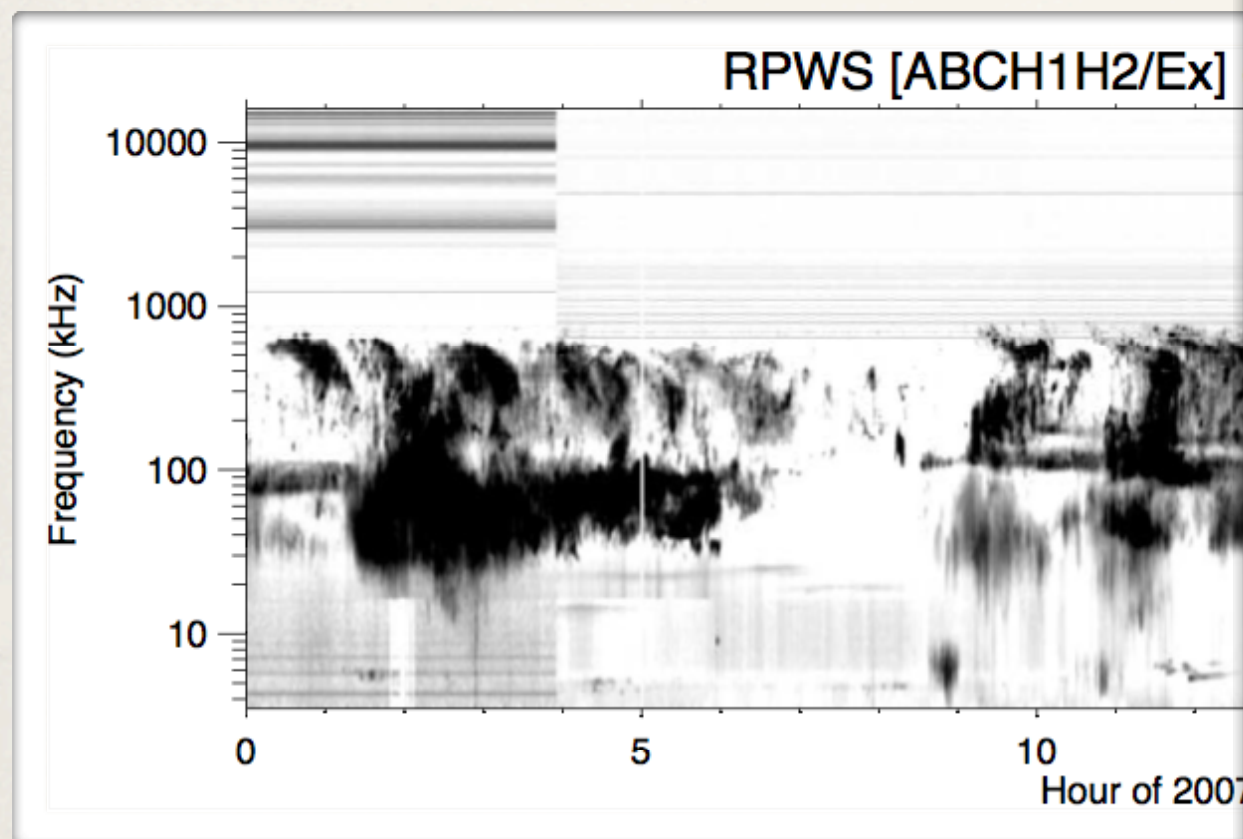
- ❖ Electrical signal induced by the wave on an antenna: $V_a = \vec{h}_a \cdot \vec{E}_w(t)$
- ❖ We measure the power on each sensor, as well as the cross-correlation of the signals sensed on two antennas. We then get the full spectral matrix of the wave.
- ❖ Wave parameters (for a polarized transverse plane wave)
 - Direction of propagation: two angles (θ, ϕ) .
 - Flux and polarization: 4 Stokes parameters (S, Q, U, V)

$$P_{ij} = \frac{Z_0 G h_i h_j S}{2} \left[(1 + Q) A_i A_j + (U - iV) A_i B_j + (U + iV) A_j B_i + (1 - Q) B_i B_j \right]$$
$$\begin{aligned} A_i &= -\sin \theta_i \cos \theta \cos(\phi - \phi_i) + \cos \theta_i \cos \theta \\ B_i &= -\sin \theta_i \sin(\phi - \phi_i) \end{aligned}$$

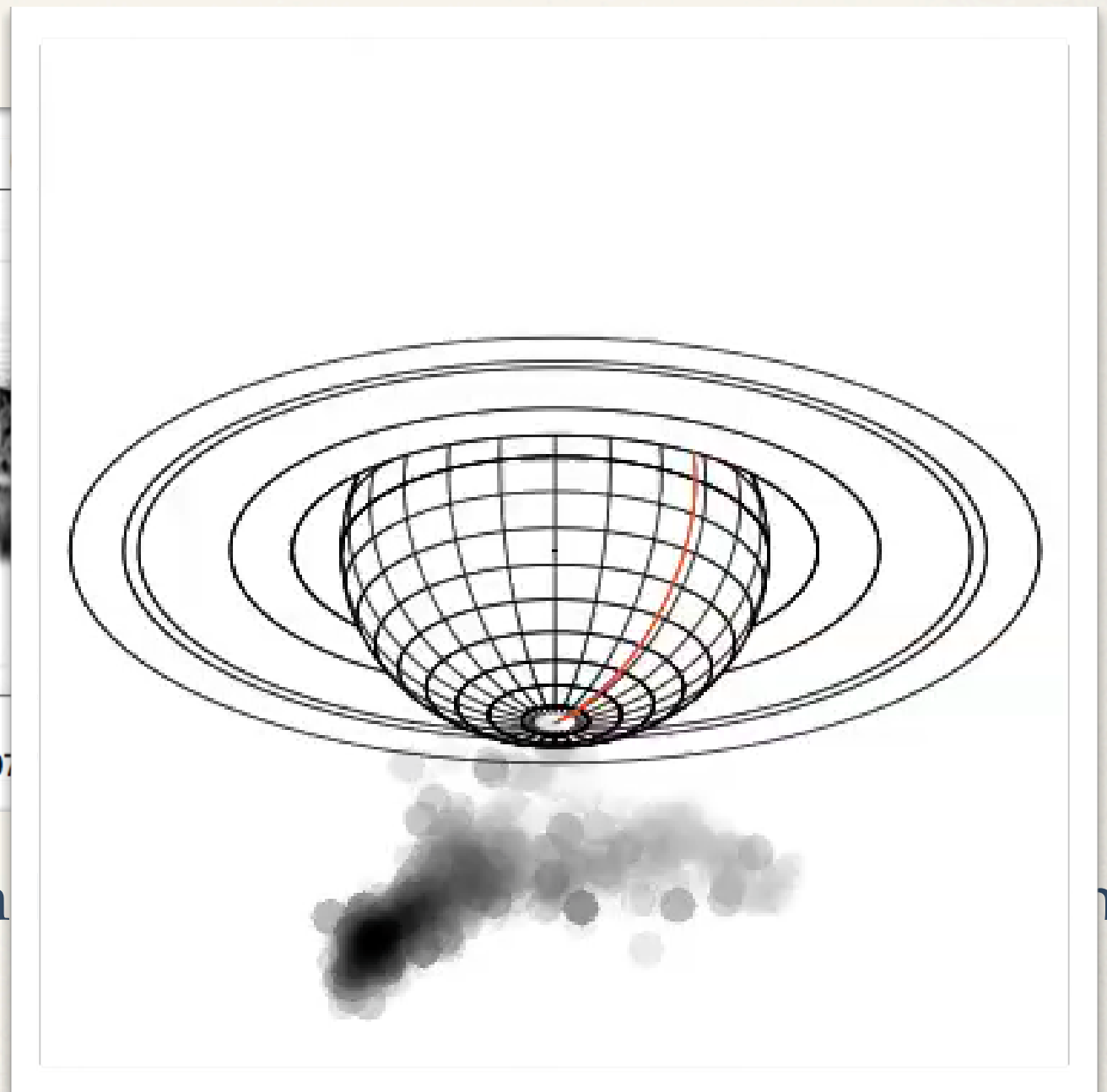
- ❖ Antenna parameters: length (h_i) and direction (θ_i, ϕ_i)

Goniopolarimetry

How to «see» the radio



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



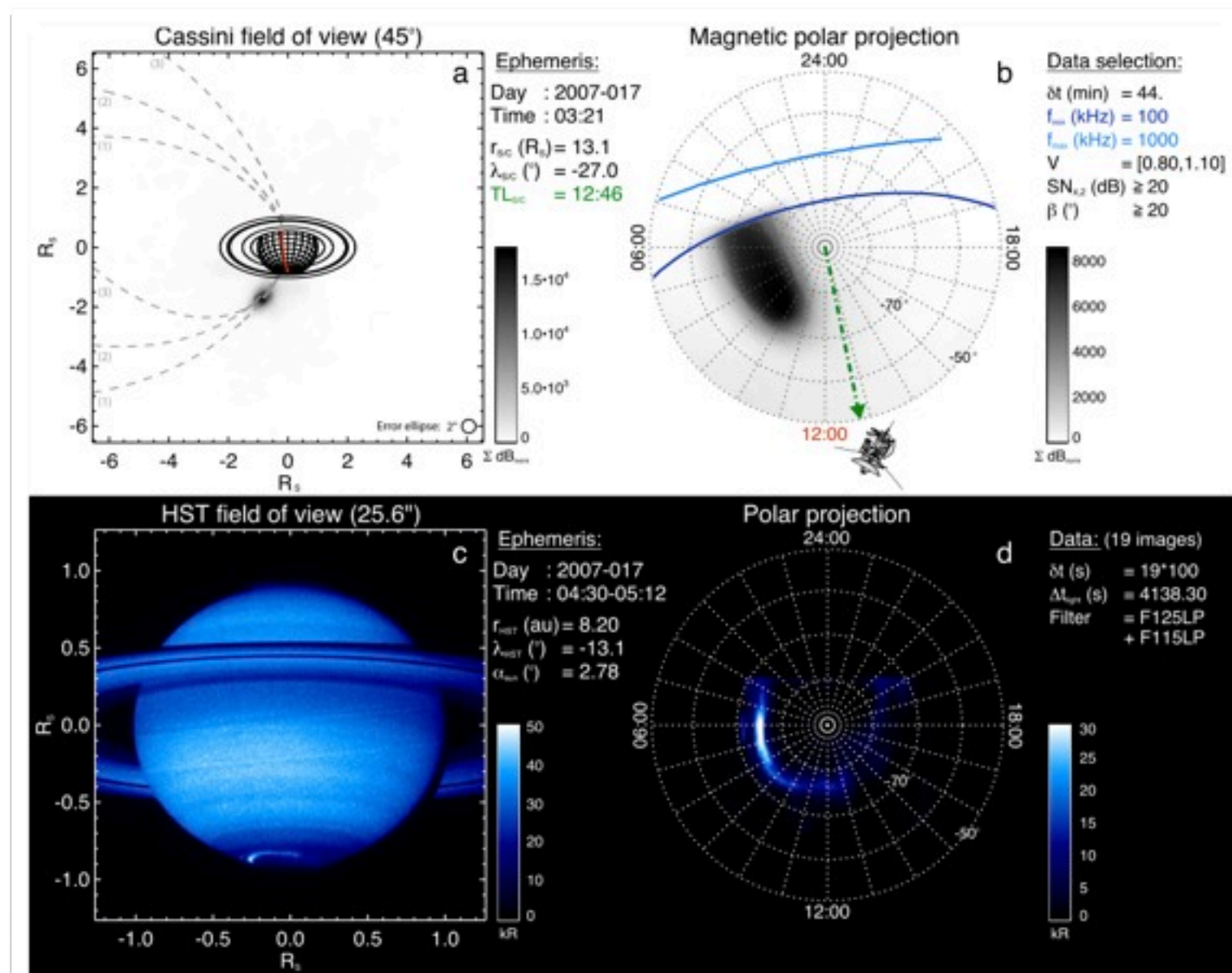
Example:

Saturn auroral radio and UV sources

- ❖ Aurore UV et Radio:

Radio Maps

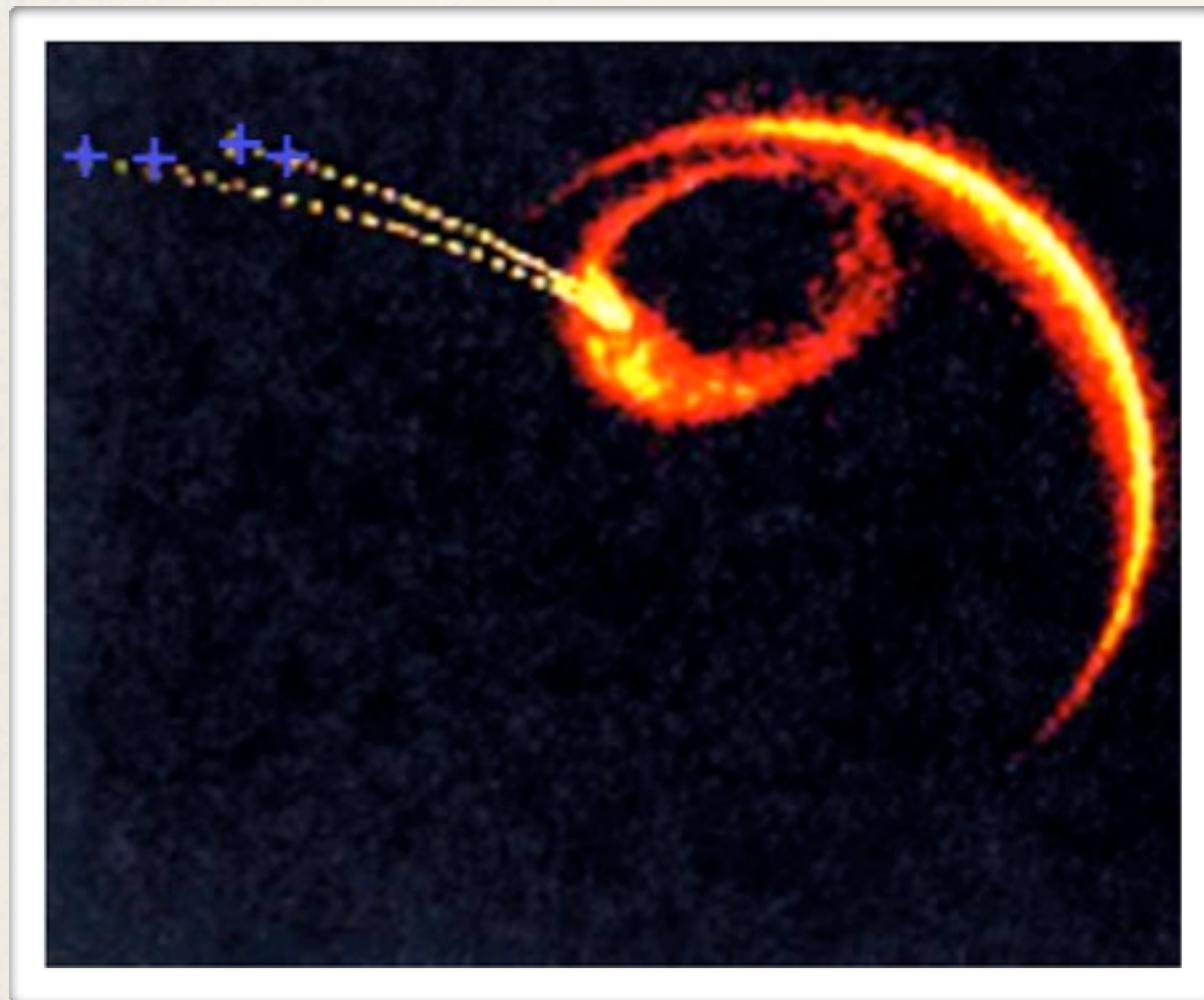
UV Images



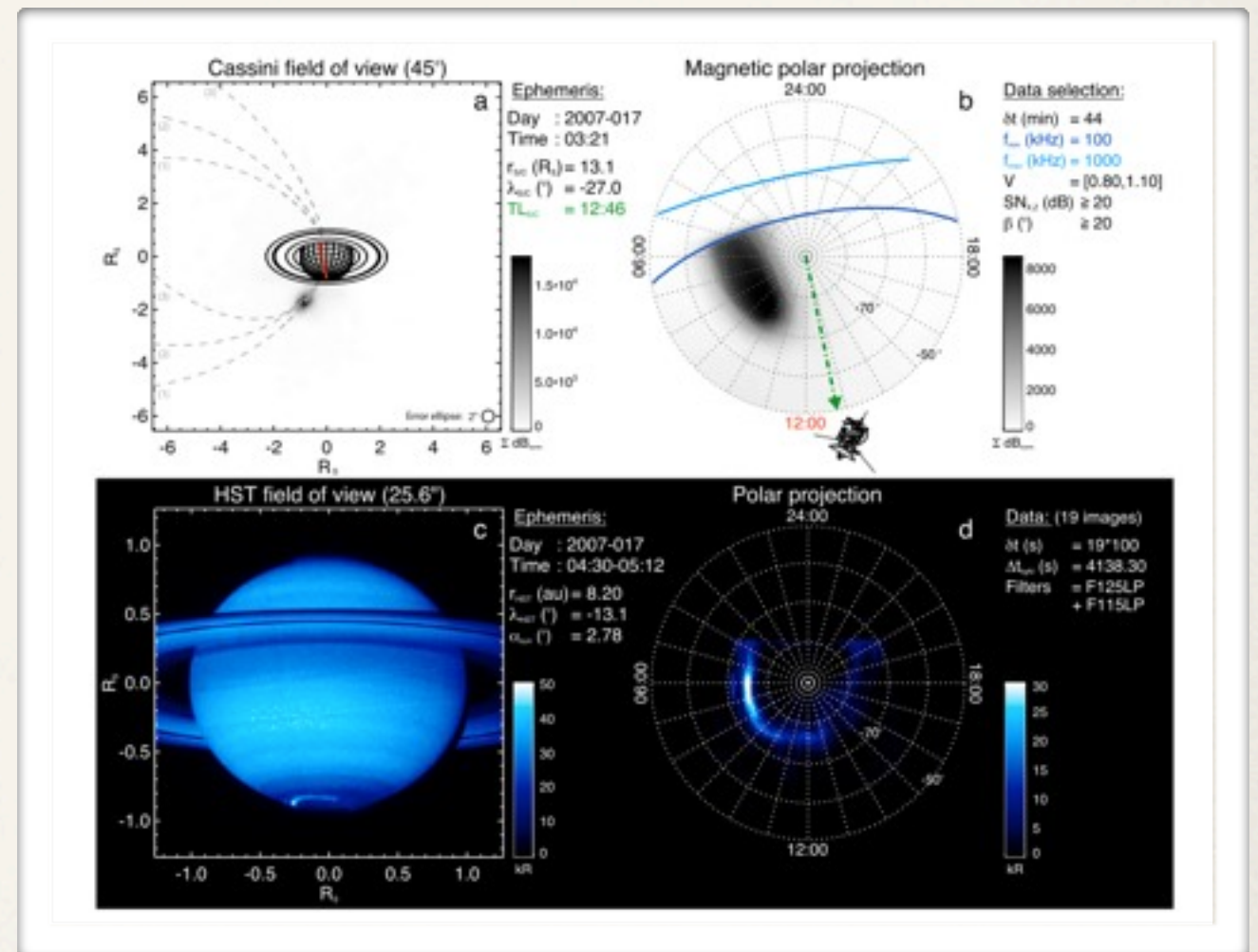
Cassini

HST

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



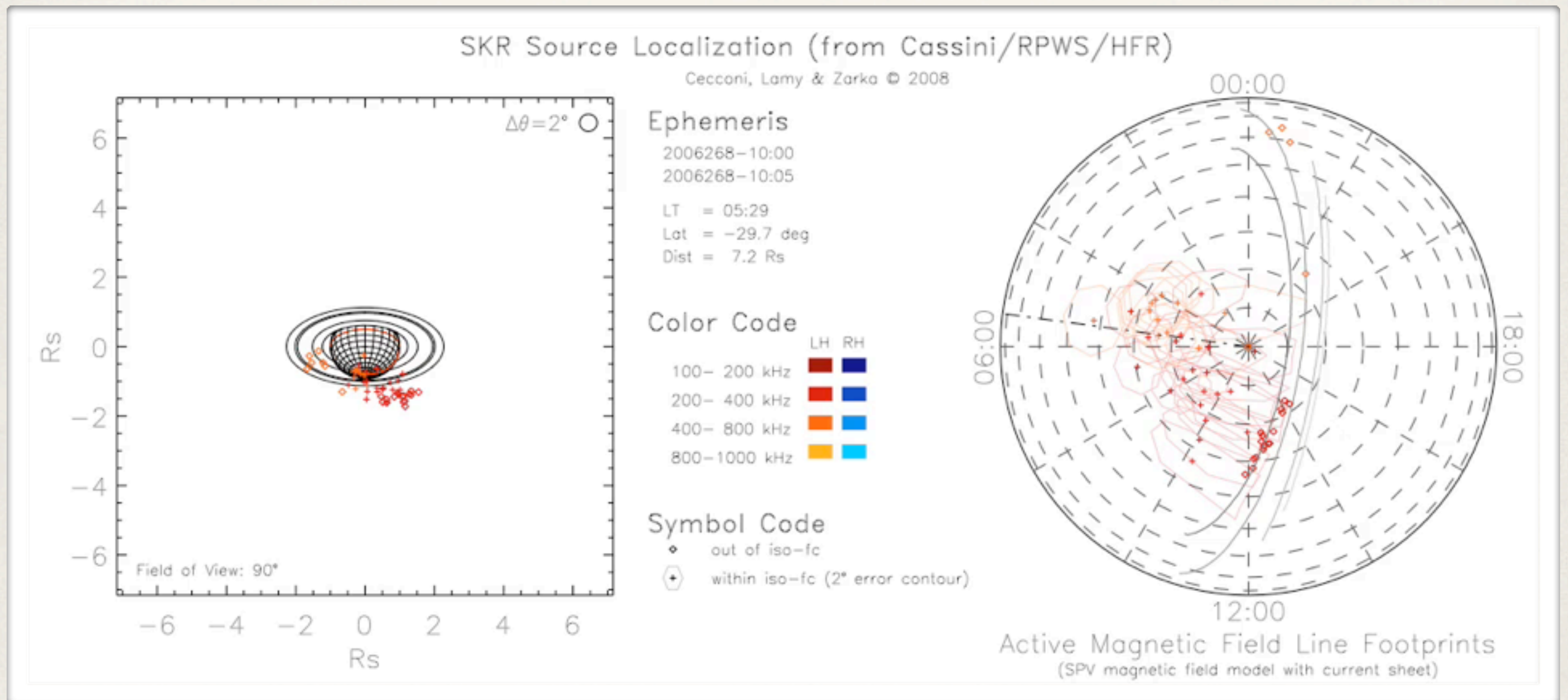
❖ Earth: DE-1



❖ Saturn: Cassini

Planetary Radio Emissions

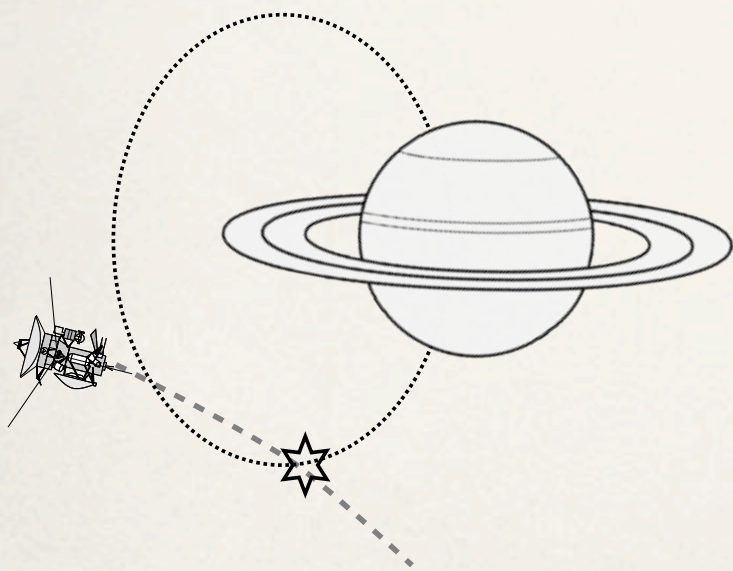
- Observation Techniques



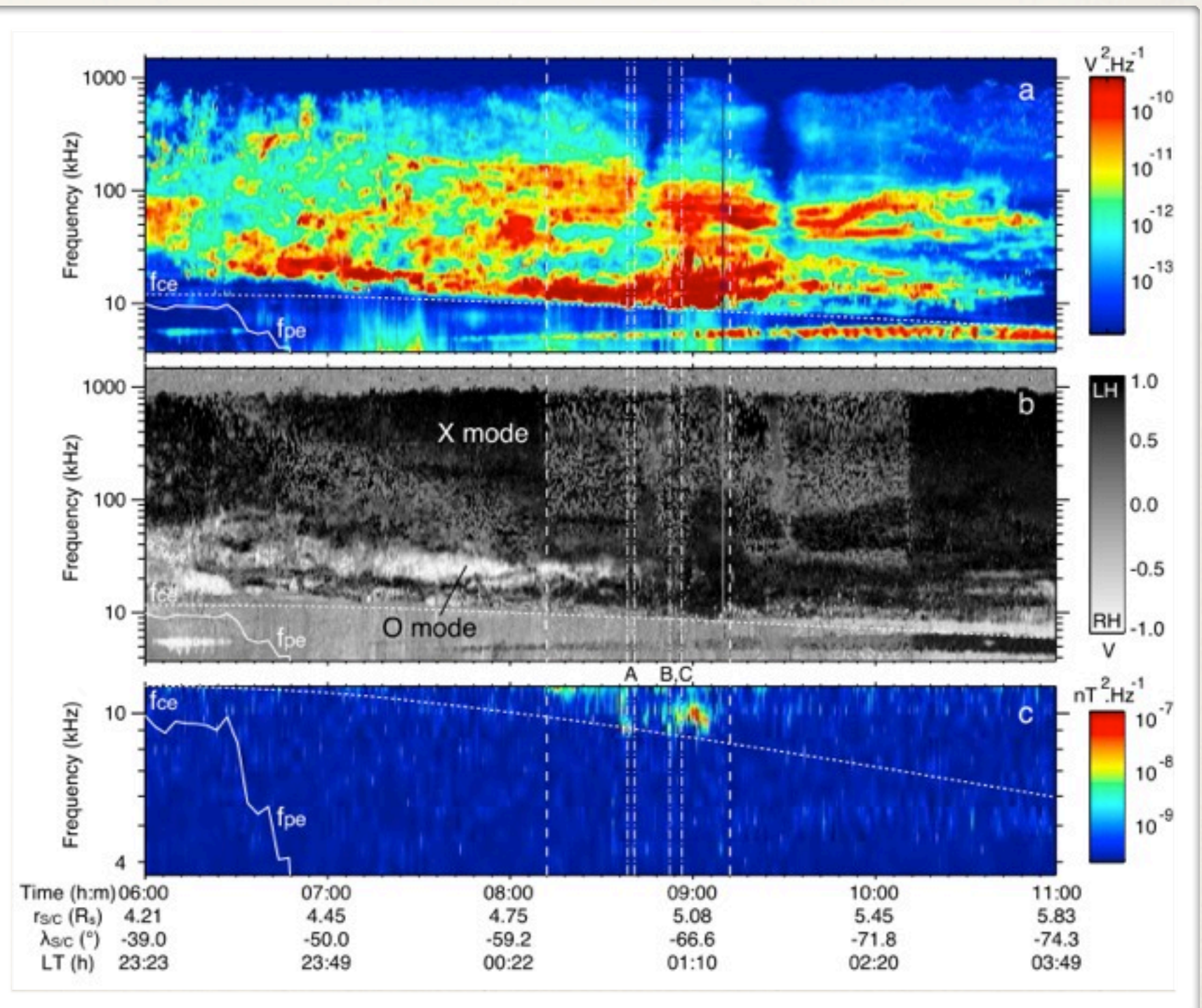
Cassini crossing the auroral radio sources

Radio Flux

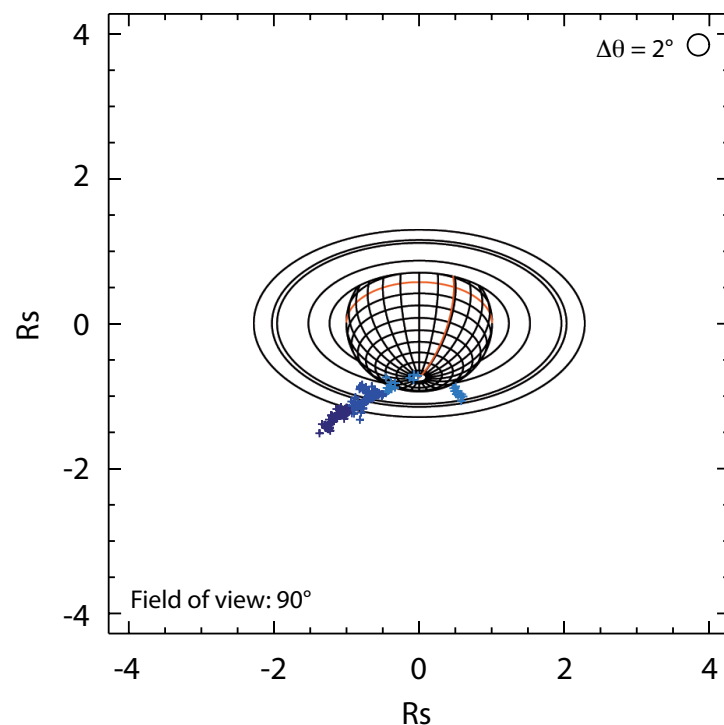
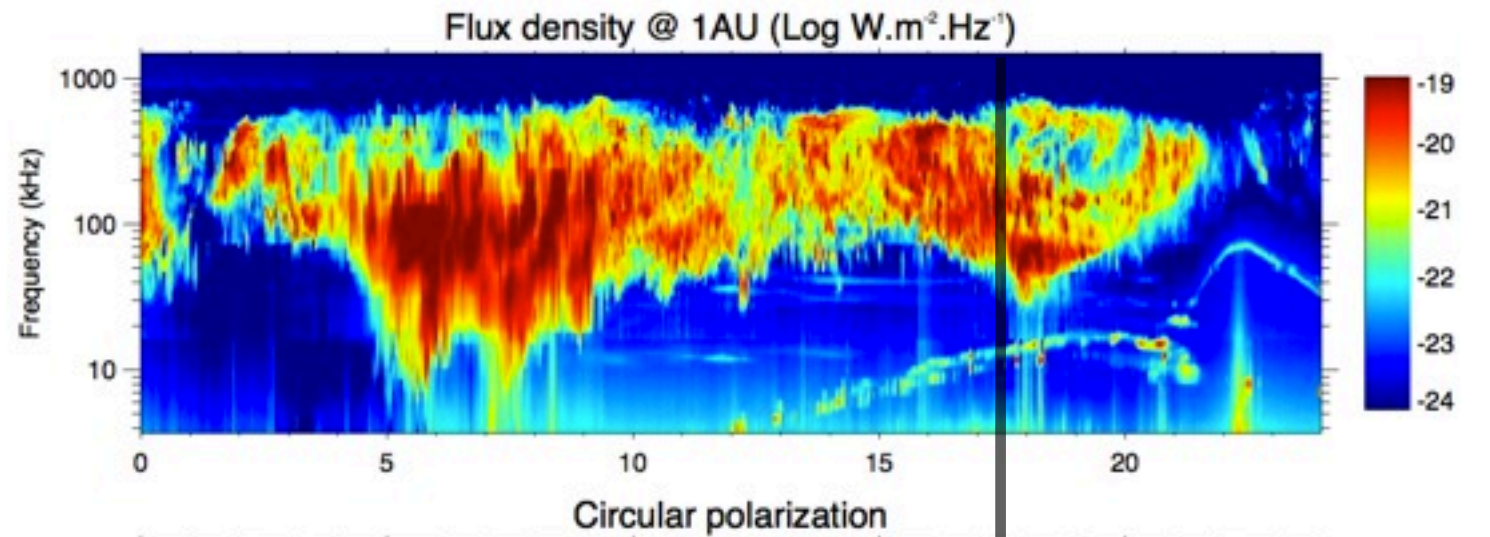
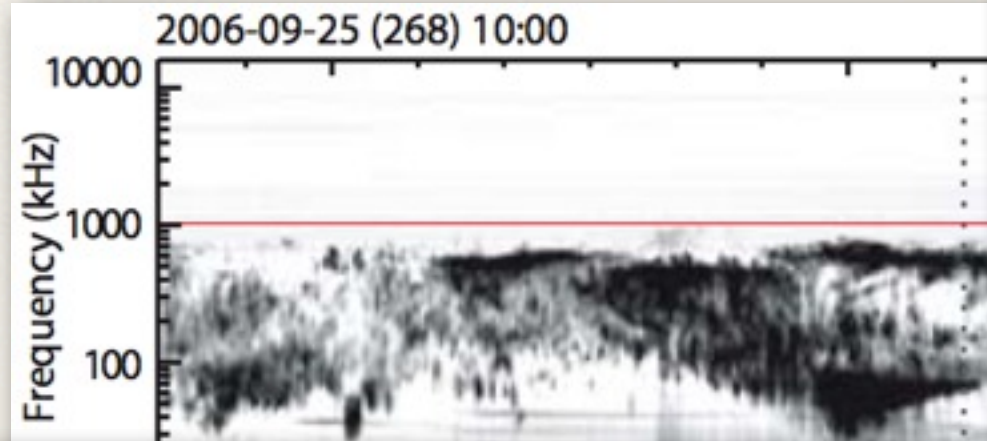
Polarization



[Lamy et al. 2010]



Example: Radio view of Saturn by Cassini



Ephemeris

2006268 - 17:20
2006268 - 17:25

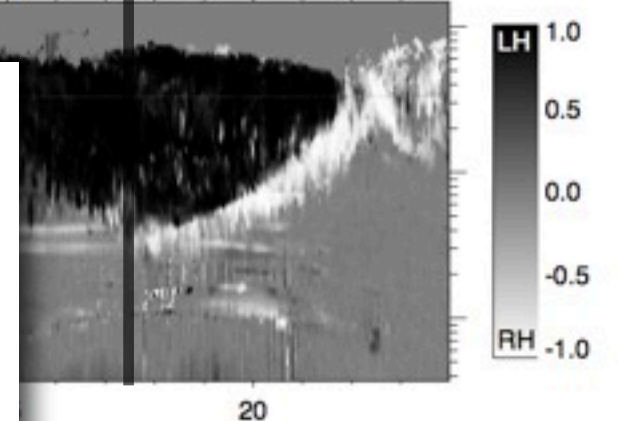
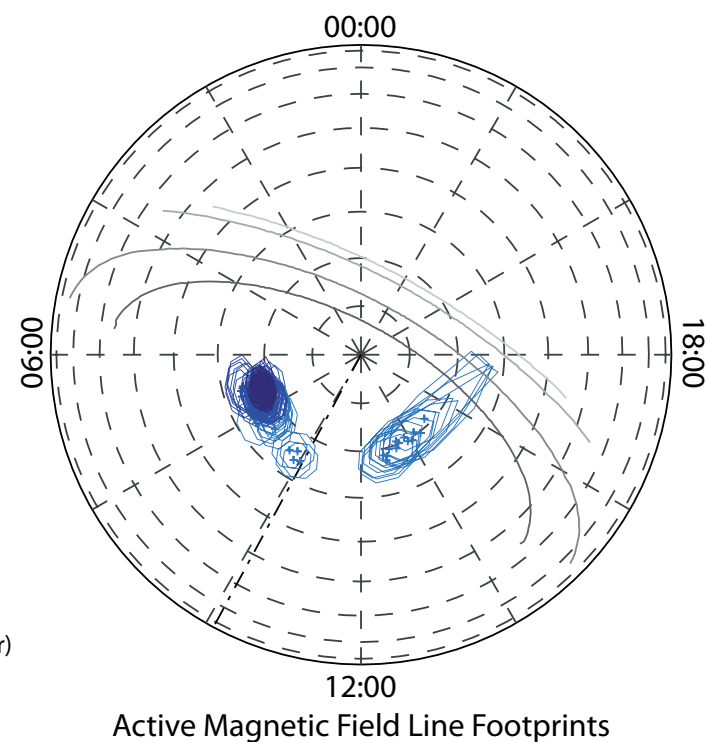
LT = 10:06
Lat = -34.5°
Dist = 4.3 Rs

Color Code

	LH	RH
100 - 200 kHz	Dark Blue	Dark Red
200 - 400 kHz	Blue	Red
400 - 800 kHz	Light Blue	Orange
800 - 1000 kHz	Very Light Blue	Light Orange

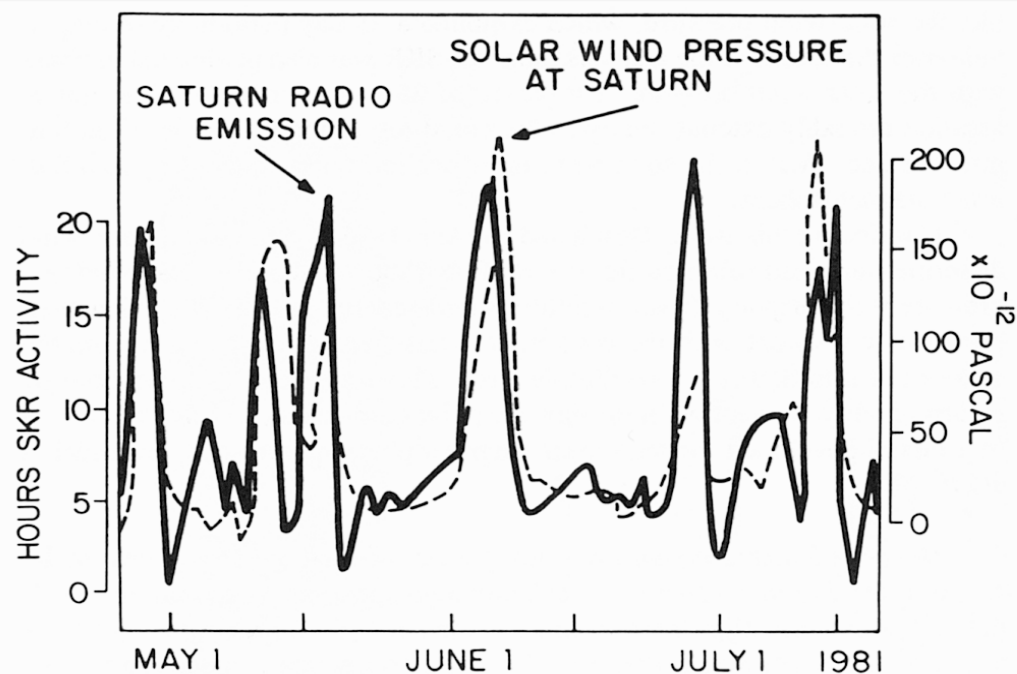
Symbol Code

- $\diamond$ out of iso-fc
- $\oplus$ within iso-fc (2° error contour)



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

