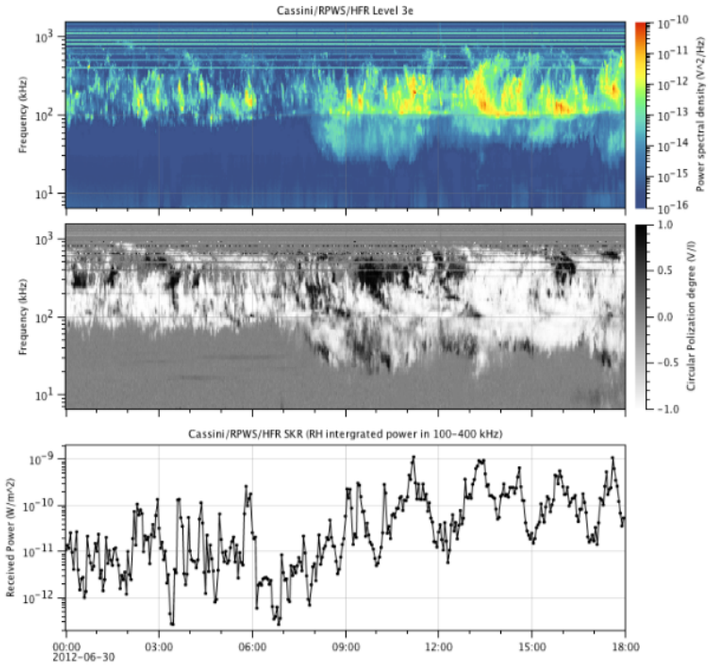
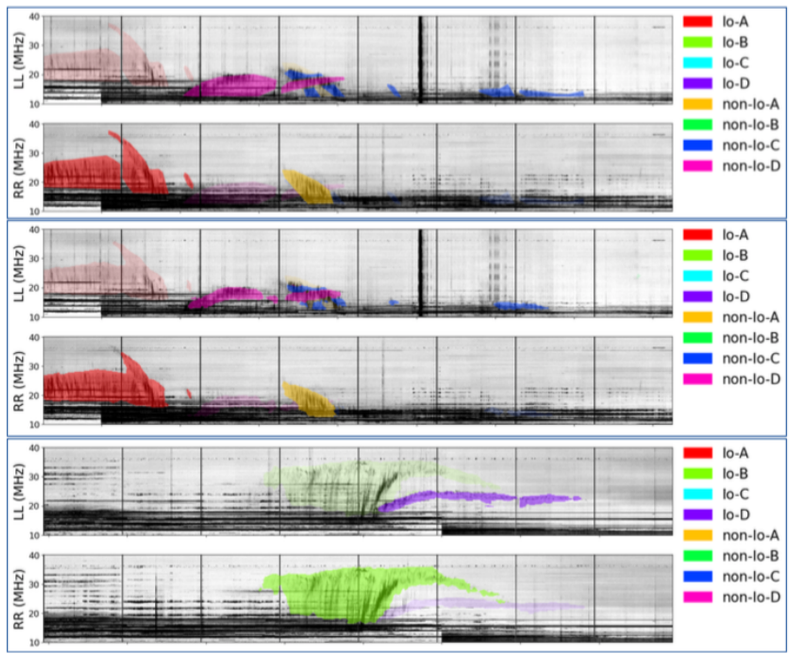
MASER

Measurement, Analyses, Simulations of Emissions in the Radio range

https://maser.lesia.obspm.fr

- **Science-ready** and **Open science** Toolbox
  for low frequency radio astronomy
  publishing, discovery, sharing, display, modeling …





Cecconi, B., Loh, A., Sidaner, P. L., Savalle, R., Bonnin, X., Nguyen, Q. N., et al. (**2020**). MASER: A Science Ready Toolbox for Low Frequency Radio Astronomy. *Data Science Journal*, *19*(18), 1062. https://doi.org/10.5334/dsj-2020-012

The Europlanet-2024 Research Infrastructure project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149.

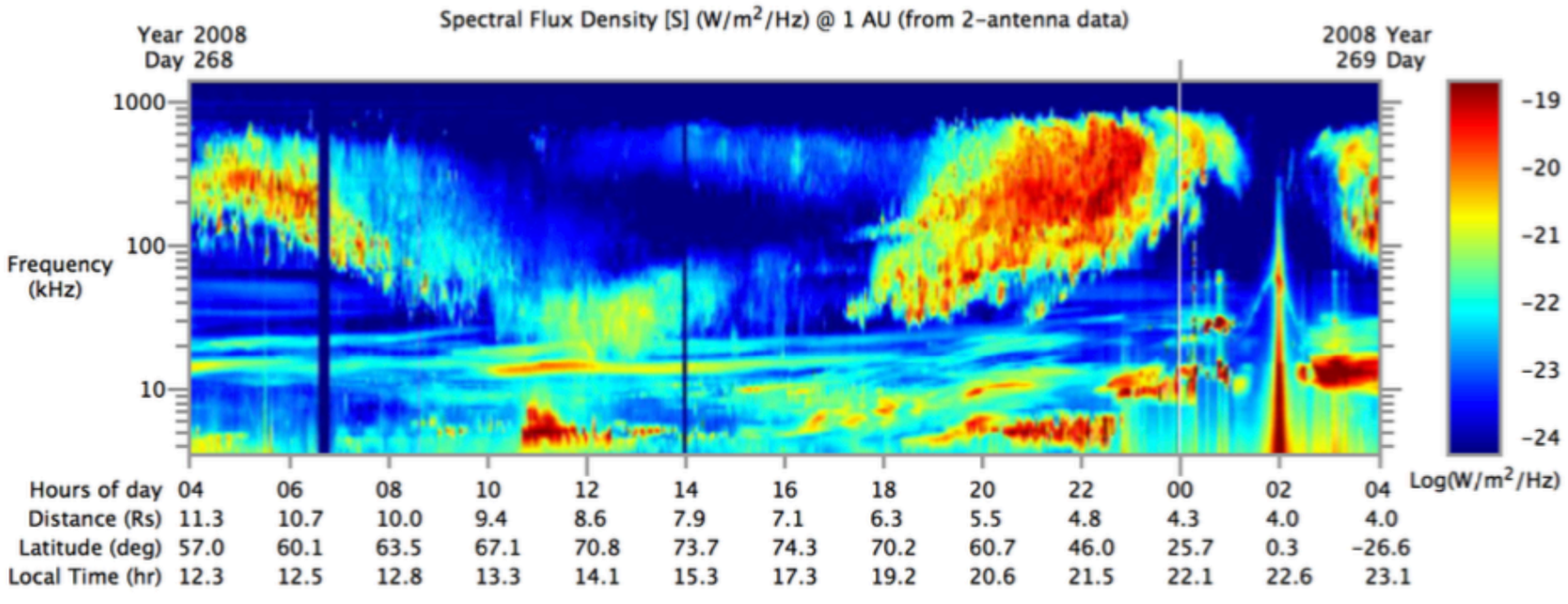
MASER
Why and for whom?

- Low frequency radioastronomy:
  - large collections (long time scales and/or high resolution…)
  - event/features not always predictibles (sporadic, intermittent…)

- Users needs:
  - **discovery** of datasets
  - online access for **visualisation**
  - python library for **programmatic access**
  - **annotation and sharing** of event/feature catalogues
  - **hosting** datasets

Data product types

- Mostly **spectrograms (aka dynamic-spectra)**. Measured parameter (flux, polarization…) depending on time and frequency.
- Sometime: "**waveform**" (direct sampling of electric signal temporal fluctuations). Much higher data rate needed.
- also, **events**. timestamp + label + parameters (coverage) + data ? waveform snapshot can be considered as an event.
- and **catalogues** of events/features
- NB: *imaging data not in the scope of MASER*



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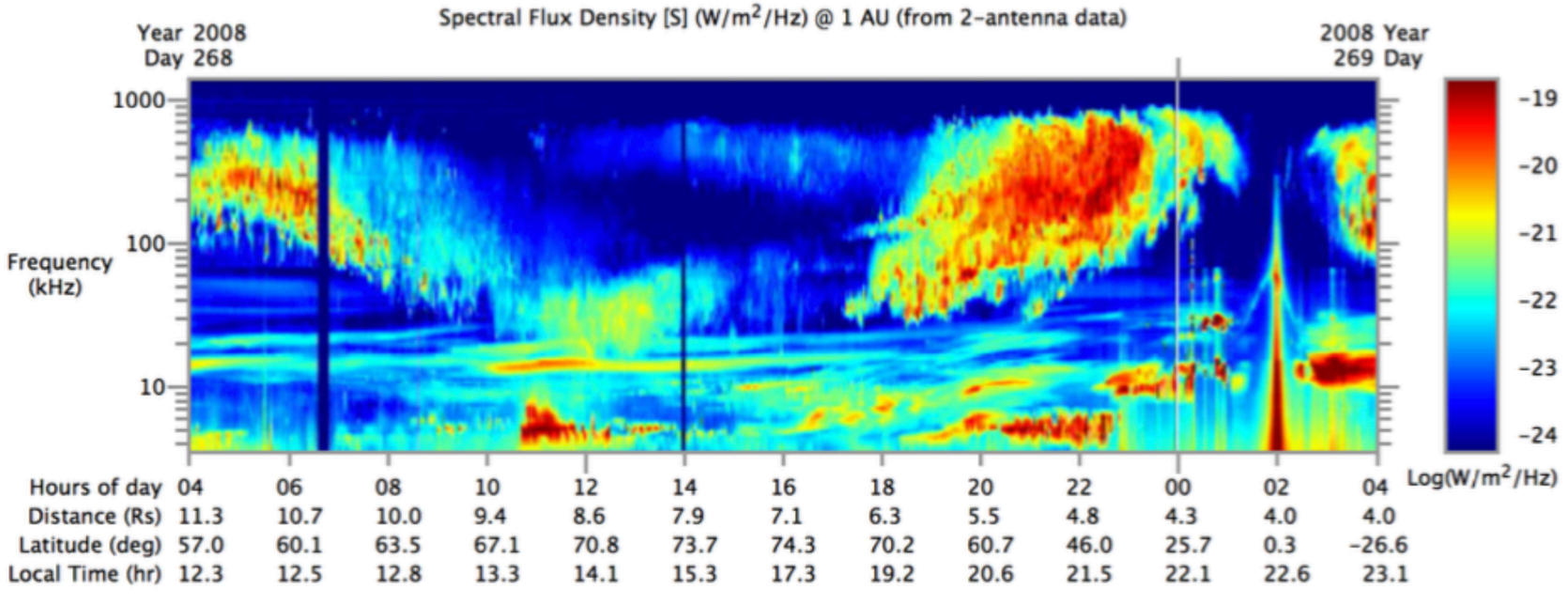

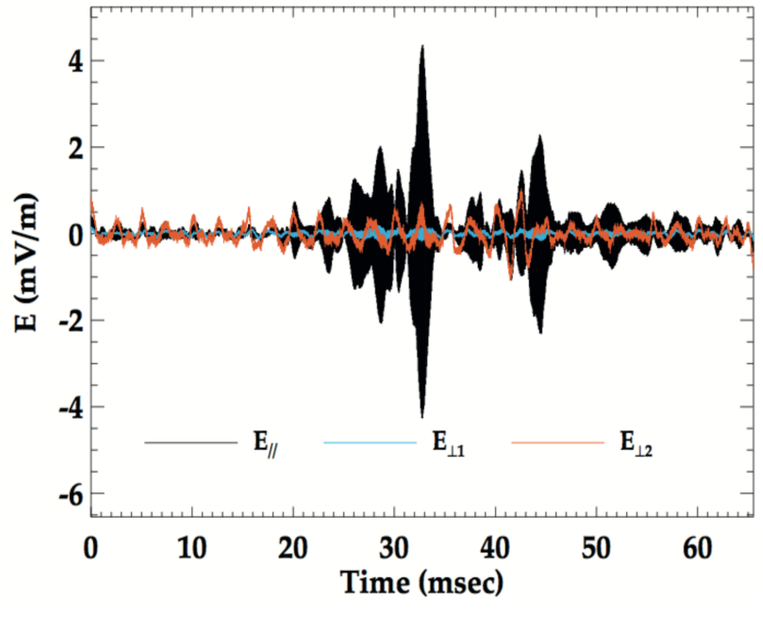

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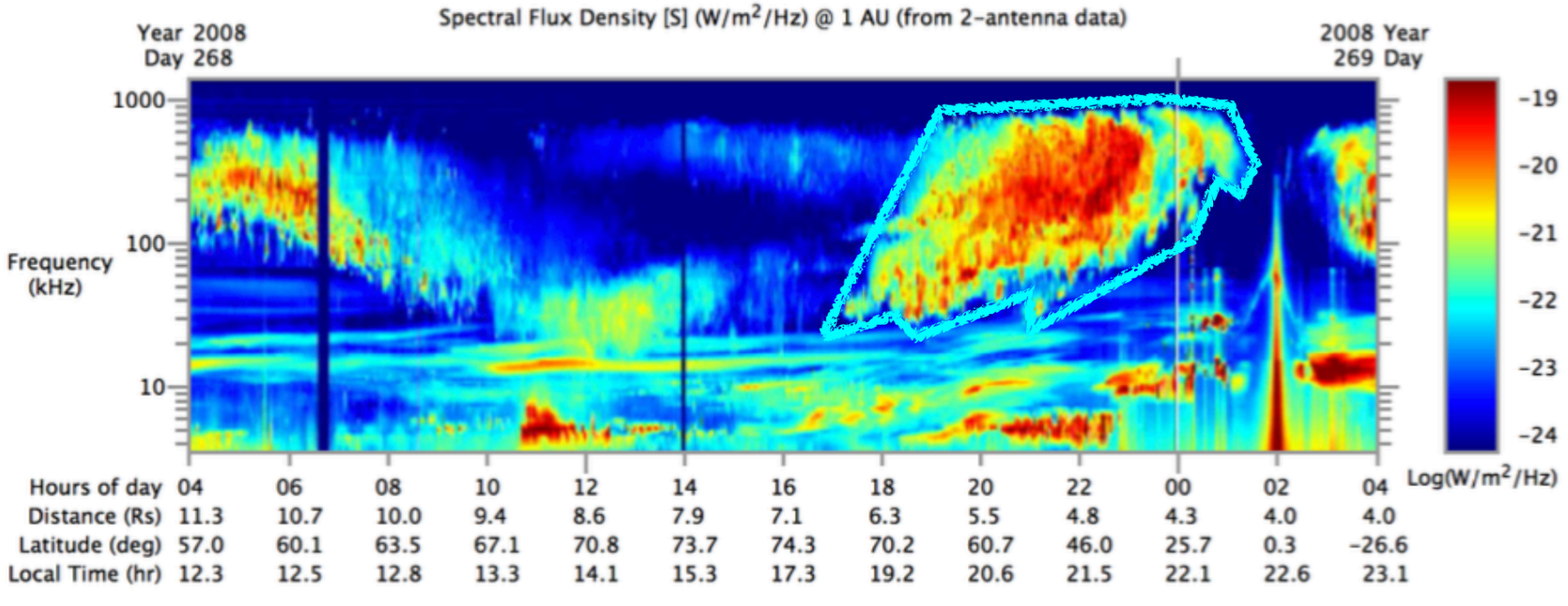

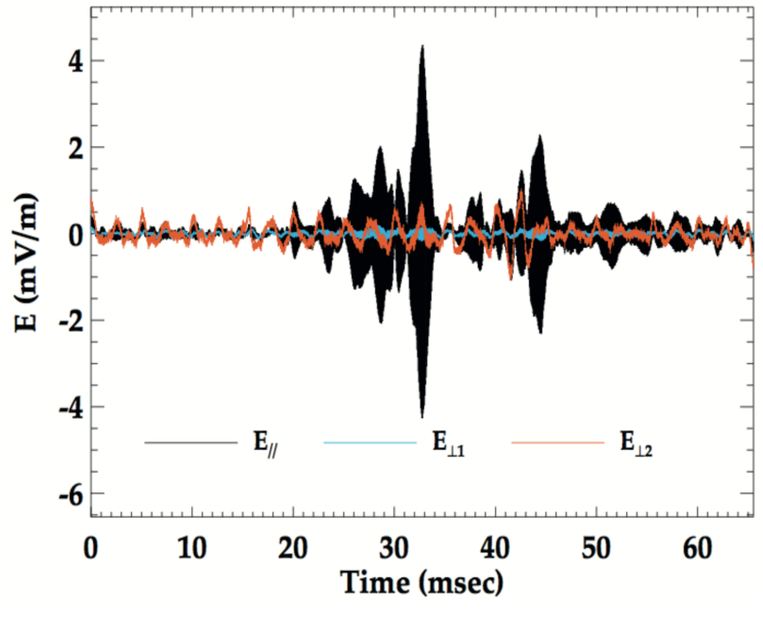

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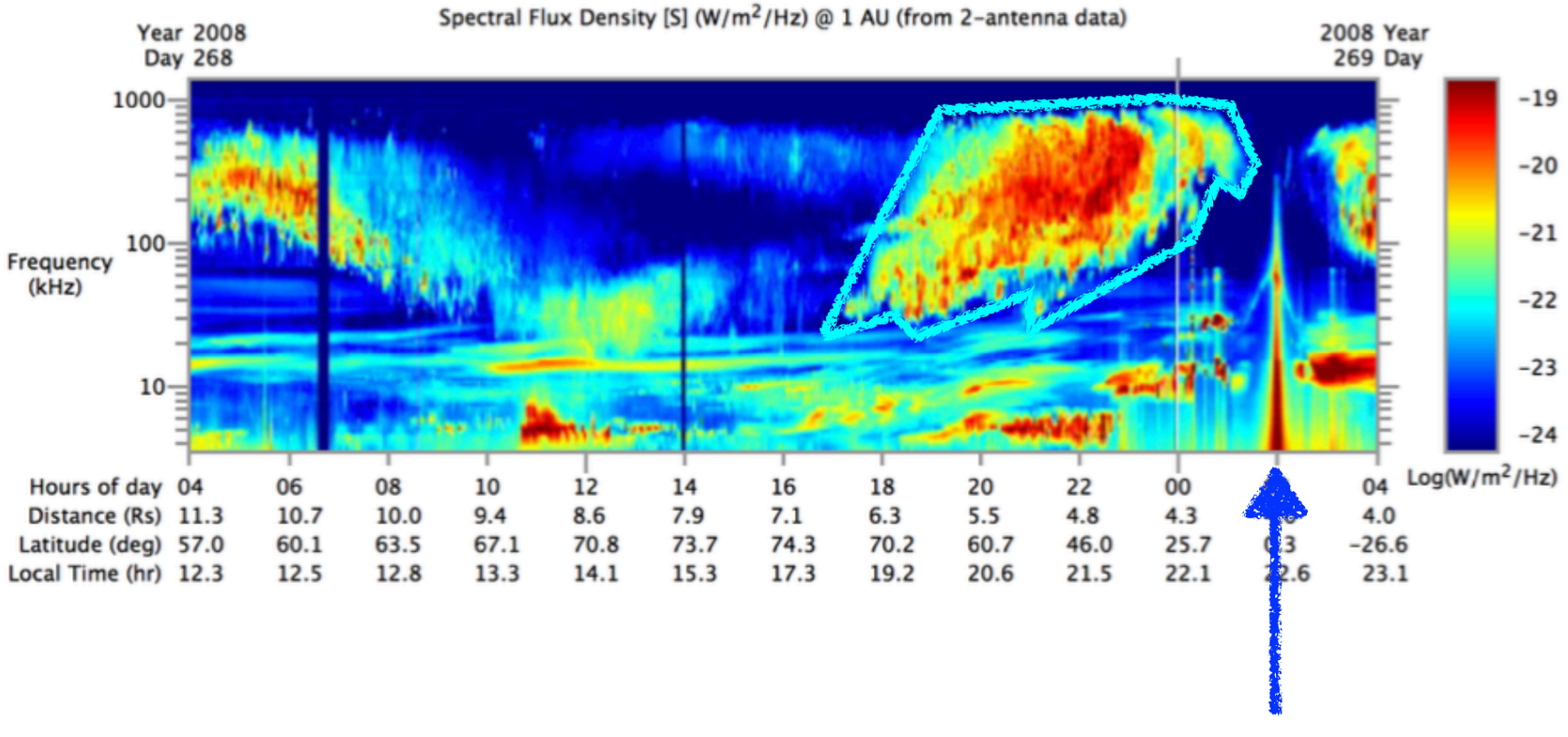

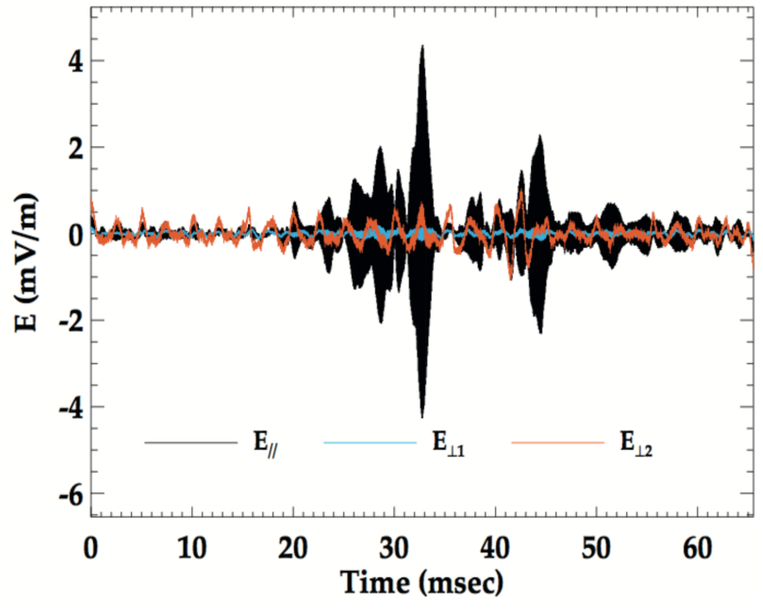

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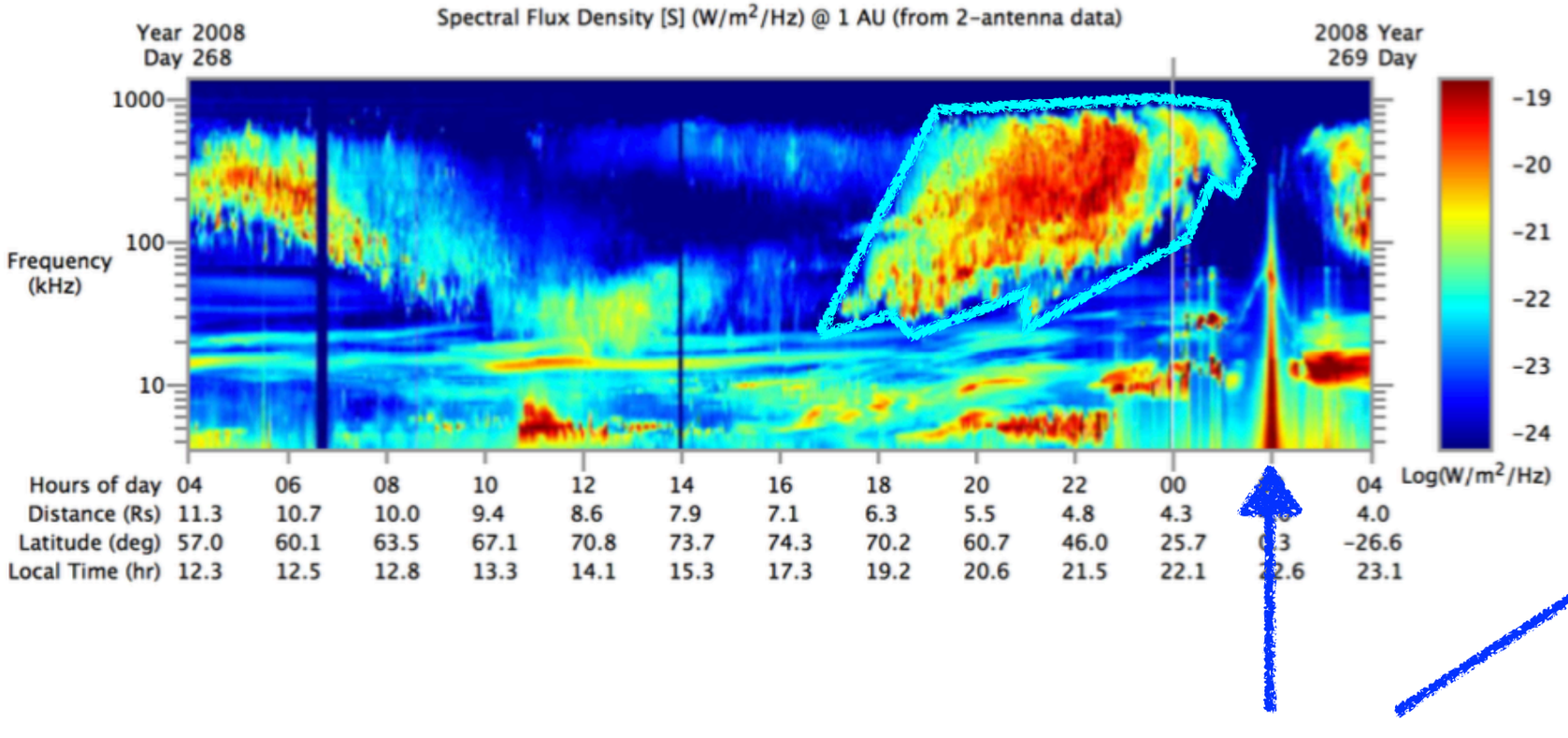
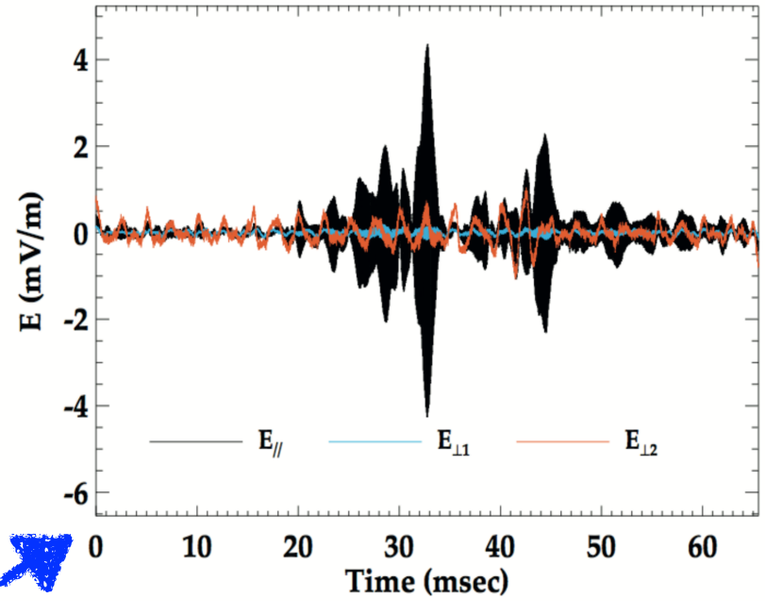
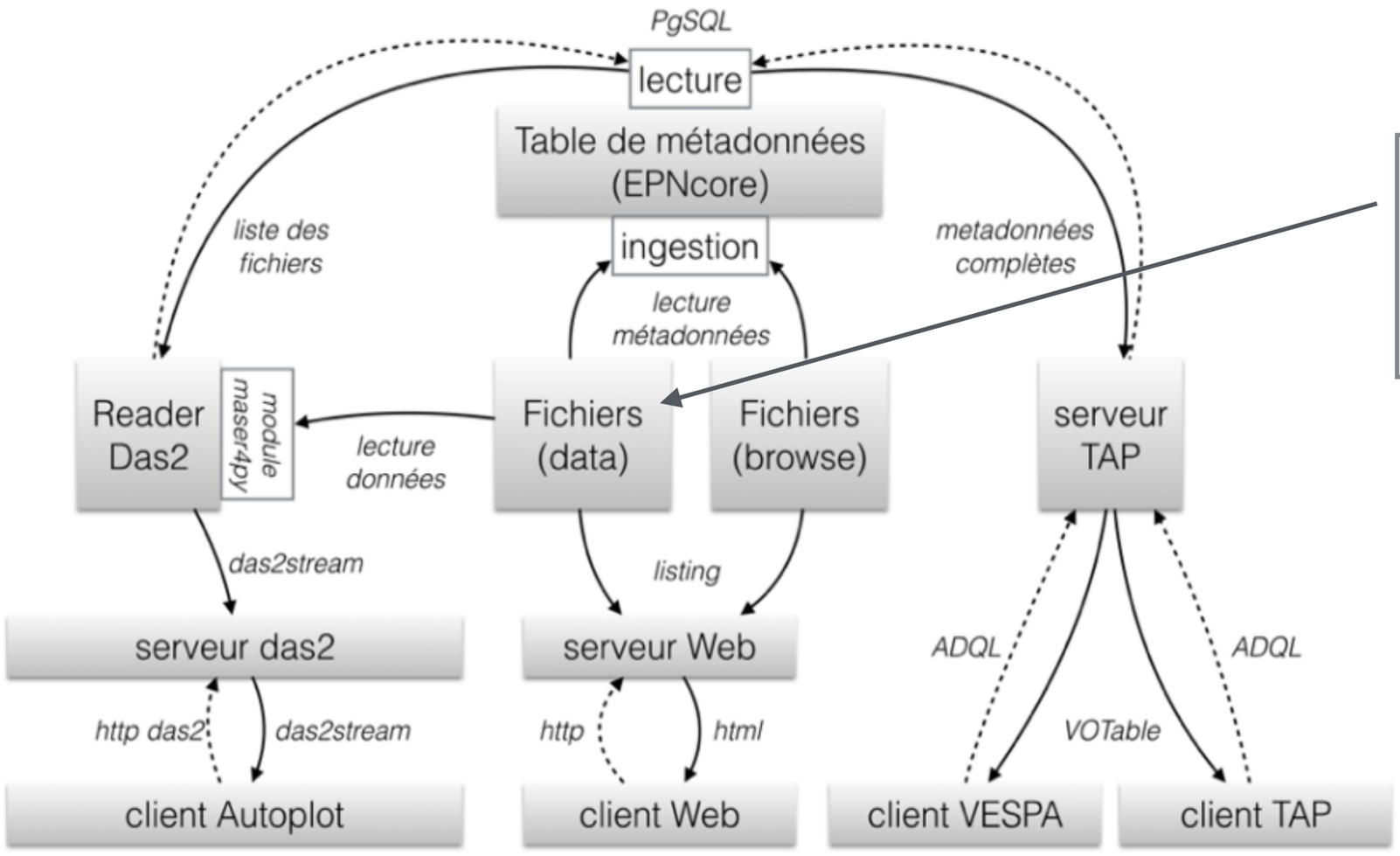




MASER Architecture



- Data file in FITS, CDF…
- TFCat Catalogues
- Paper supplement material…

Figure 5. Ecosystème MASER : relation entre les différentes interfaces mises en place.

Access (stream) **Access (web)** **Discovery**

DMP + DOI (+landing page) per collection

raw data
N1, (N2, N3…)

standard format
(N1,) N2, N3…

quicklooks
(N1,) N2, N3…

PDS4 labels

SPASE descriptors

documentation

archive delivery
PDS, CDPP…

software (git, svn)

DOI(s)

EPNcore
table

TAP

das2
reader+dsdf

das2

SPASE repo.
(PADC?)

XML

Interfaces

- **IVOA**:
  - EPN-TAP (solar system data discovery)
  - TAP (tabular data access): 2 servers (PADC: http://voparis-tap-maser.obspm.fr, CDN: http://vogate.obs-nancay.fr)
  - Datalink (linking between data, quicklook, access)
  - UWS (run on demand): 1 server, https://voparis-uws-maser.obspm.fr/client/
  - IVOA registry

- **IHDEA**:
  - das2: data streaming, 2 servers (PADC: http://voparis-das-maser.obspm.fr/das2/server, CDN: https://das2server.obs-nancay.fr/das2/server)
  - CDF-ISTP (format)
  - SPASE registry

- **DOI**:
  - publishing collections (https://maser.lesia.obspm.fr/publications/doi/)
  - landing page with schema.org

- **Other**:
  - TFCat (Time-Frequency Catalogue) https://gitlab.obspm.fr/maser/catalogues/tfcat
  - WebGeoCalc (local instance of WGC/SPICE server developed by NASA/JPL)

EPN-TAP service configuration

- DaCHS servers (v2.6)

- Resource configuration using CustomGrammar (external python script parsing data files), CDFGrammar or ODBCGrammar

- Subjects in IVOA/UAT keywords (not updated in Registry yet)

- Datalink implemented on some services to relate with previews, data streaming interfaces, documentation…

Example with Voyager/PRA collection

Non sécurisé — vespa.obspm.fr/planetary/data/display/?&resource_id=ivo://vopdc.obsp

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datalink Maser Files · master ·... PADC TAP Serv... CDN VO Server... DB · GitLab (Tutorial) Gene... Home Pag VESPA Query I... respo...

Form | Query

EPN-TAP Services | Custom Service

Main Parameters

Target Name

Target Class

Dataproduct Type

Instrument Host Name

Instrument Name

=

Processing level

Time

Location

Spectral

Illumination

Back To Services Results

Results in service voyager_pra

voyager_pra - Voyager PRA Datasets
Voyager PRA (Planetary Radio Astronomy) Datasets catalog. The dataset are originally published by several data centers: NASA/PDS, NASA/NSSDC, NASA/GSFC, Univ. Iowa and CNES/SERAD.

Credits:
Creators: Baptiste Cecconi
Publisher: Paris Astronomical Data Centre

Show 10 entries

Column visibility | Show all | Hide all

Select All in current page | Reset Selection

granule_uid	dataproduct_type	target_name	time_min (d)	time_max (d)	access_url	datalink_url
VG2-U-PRA-3-RDR-LOWBAND-6SEC-V1.0:VG2_URN_PRA_6SEC.TAB	dynamic_spectrum	Uranus	1986-01-19T00:00:00.000	1986-01-31T00:00:00.000	http://maser.obspm.f...	http://voparis-tap-m...
VG2-S-PRA-3-RDR-LOWBAND-6SEC-V1.0:PRA_V.TAB	dynamic_spectrum	Saturn	1981-09-08T00:00:45.999	1981-09-28T23:59:08.000	http://maser.obspm.f...	http://voparis-tap-m...
VG2-S-PRA-3-RDR-LOWBAND-6SEC-V1.0:PRA_IV.TAB	dynamic_spectrum	Saturn	1981-08-14T00:00:00.000	1981-09-07T23:59:58.000	http://maser.obspm.f...	http://voparis-tap-m...
VG2-S-PRA-3-RDR-LOWBAND-6SEC-V1.0:PRA_III.TAB	dynamic_spectrum	Saturn	1981-07-22T00:00:00.999	1981-08-13T23:59:12.000	http://maser.obspm.f...	http://voparis-tap-m...
VG2-S-PRA-3-RDR-LOWBAND-6SEC-V1.0:PRA_II.TAB	dynamic_spectrum	Saturn	1981-07-01T00:00:04.000	1981-07-21T23:59:13.000	http://maser.obspm.f...	http://voparis-tap-m...
VG2-S-PRA-3-RDR-LOWBAND-6SEC-V1.0:PRA_I.TAB	dynamic_spectrum	Saturn	1981-06-05T00:00:01.000	1981-06-30T23:59:15.999	http://maser.obspm.f...	http://voparis-tap-m...
VG2-S-PRA-3-RDR-LOWBAND-6SEC-V1.0:PRA.TAB	dynamic_spectrum	Saturn	1981-08-24T00:00:46.999	1981-08-31T22:05:33.999	http://maser.obspm.f...	http://voparis-tap-m...
VG2-N-PRA-3-RDR-LOWBAND-6SEC-V1.0:VG2_NEP_PRA_6SEC	dynamic_spectrum	Neptune	1989-08-11T00:00:00.000	1989-08-31T00:00:00.000	http://maser.obspm.f...	http://voparis-tap-m...

Plotting tools

TOPCAT | Aladin | SPLAT | CASSIS | 3DView

Example queries

Saturn in March 2012

Help

Help

Non sécurisé — voparis-tap-maser.obspm.fr/voyager_pra/epn/dl/dlmeta?ID=VG2-U-PR

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File PADC TAP Serv... CDN VO Server... DB · GitLab (Tutorial) Gene... Home P

Table links

Where?	Description	What?
Link	**Data Product**	**#this VG2-U-PRA-3-RDR-LOWBAND-6SEC-V1.0:**
Link	Label File	#documentation VG2-U-PRA-3-RDR-LOWBAND-6SEC-V1.0:VG2_URN_PRA_6SEC.TAB
Link	Data Collection repository	#parent VG2-U-PRA-3-RDR-LOWBAND-6SEC-V1.0:V

maser.obspm.fr/data/voyager/pra

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File PADC TAP Serv... CDN VO Server... DB · GitLab

Index of /data/voyager/pra/PDS/VG2-U-PRA-3

Name	Last modified	Size	Description
Parent Directory		-	
AAREADME.TXT	2013-02-06 10:40	15K	
CATALOG/	2013-02-06 11:12	-	
CHECKSUMS.TXT	2020-04-19 18:15	2.5K	
DATA/	2013-02-06 11:12	-	
DOCUMENT/	2013-02-06 11:12	-	
ERRATA.TXT	2012-02-03 09:51	6.0K	

Example with NDA collection

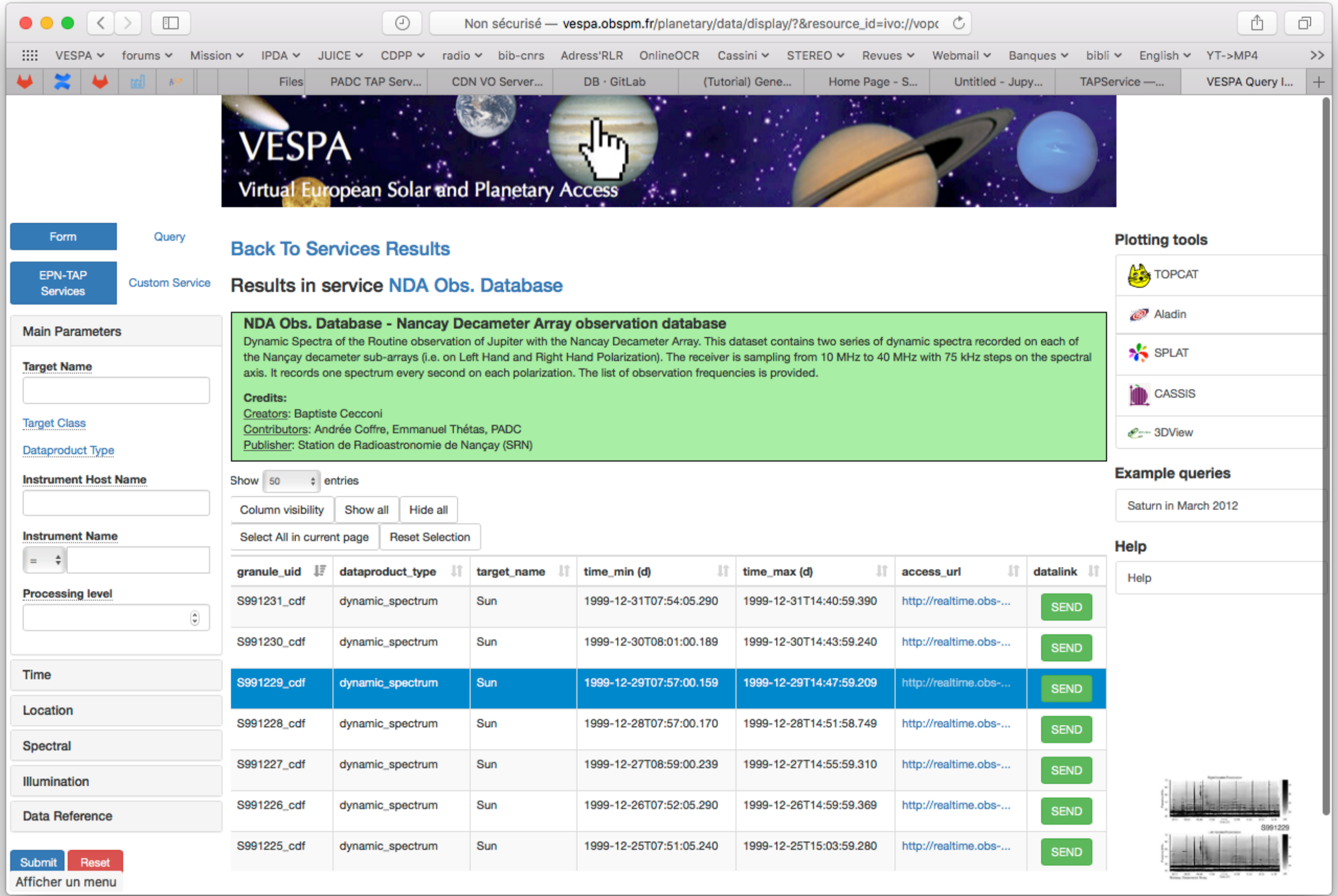
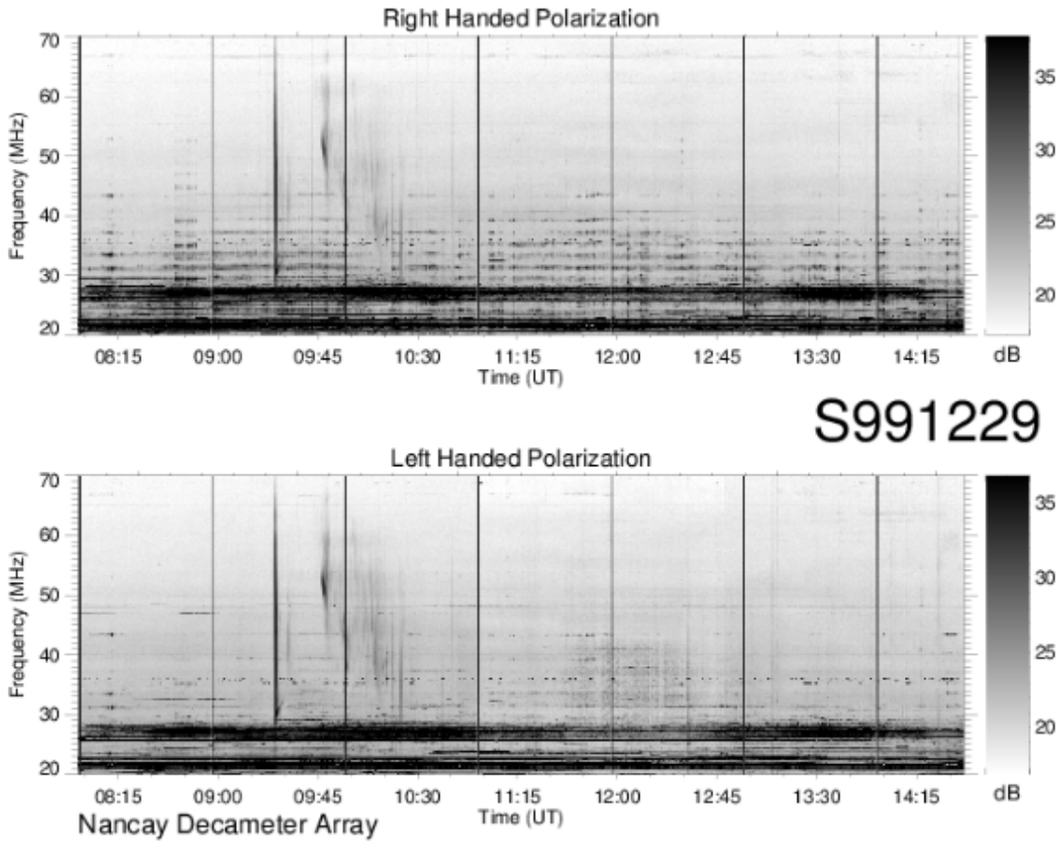
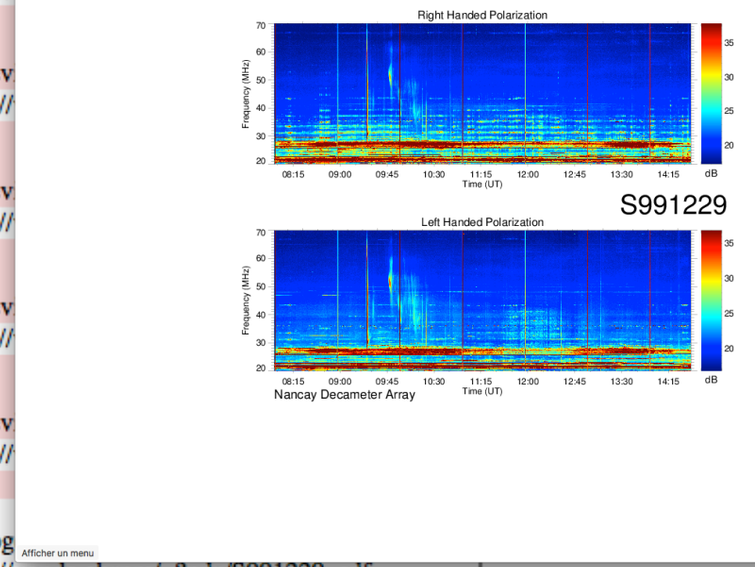


Table links

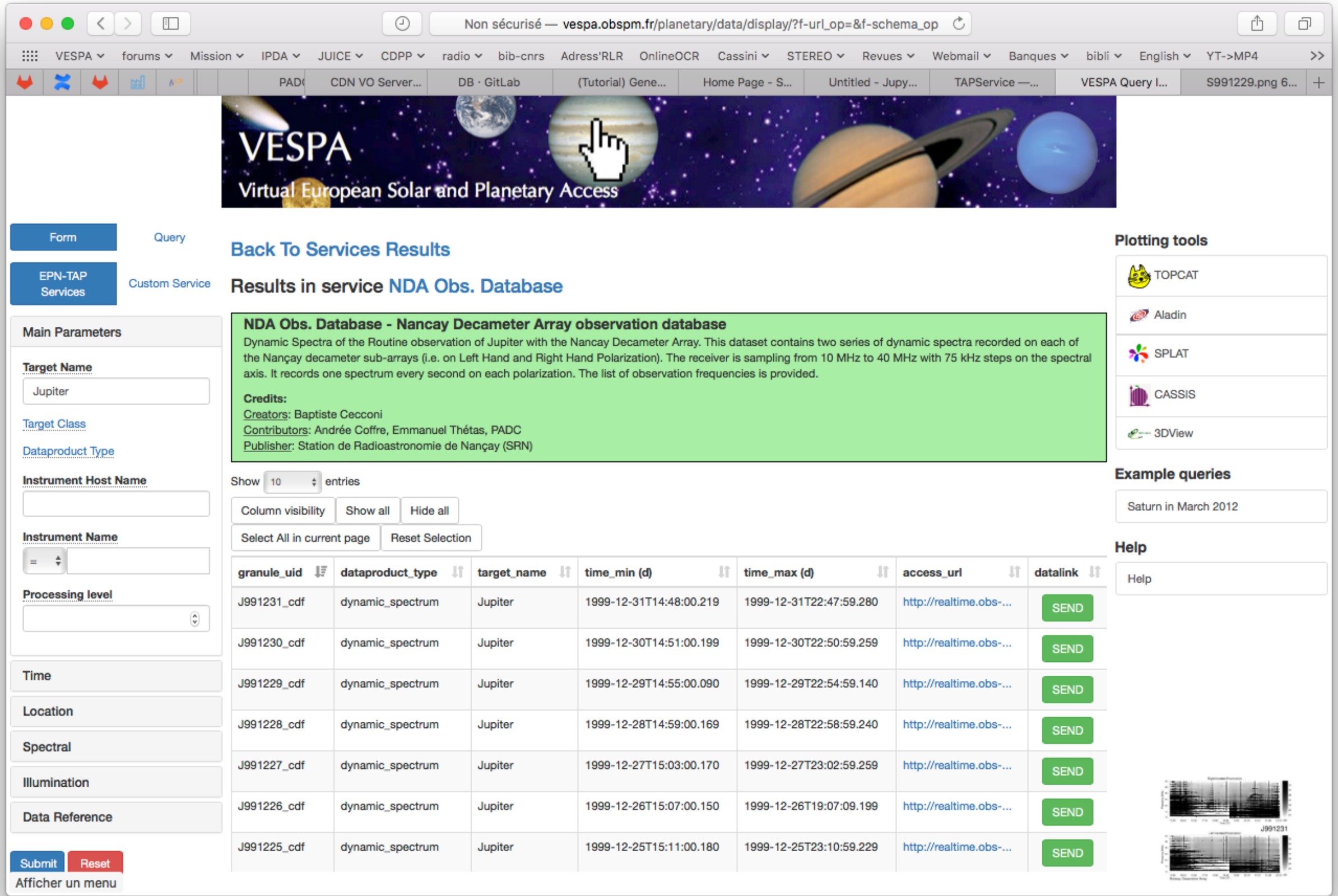


Where?	Description	What?
Link	Das2 access (Left-Hand polarization)	#cutout ivo://vopdc.obspm/~?nda/S991229_cdf
Link	Das2 access (Right-Hand polarization)	#cutout ivo://vopdc.obspm/~?nda/S991229_cdf
Link	Das2 access (differential polarization)	#cutout ivo://vopdc.obspm/~?nda/S991229_cdf

Where?	Description	What?
Link	Das2 access (Left-Hand polarization)	#cutout ivo://vopdc.obspm/~?nda/S991229_cdf
Link	Das2 access (Right-Hand polarization)	#cutout ivo://vopdc.obspm/~?nda/S991229_cdf
Link	Das2 access (differential polarization)	#cutout ivo://vopdc.obspm/~?nda/S991229_cdf
Link	PDF Preview (Greyscale)	#preview ivo://vopdc.obspm/~?nda/S991229_cdf
Link	PDF Preview (Color)	#prev ivo://
Link	PNG Preview (Greyscale)	#prev ivo://
Link	PNG Preview (Color)	#prev ivo://
Link	PNG Thumbnail (Greyscale)	#prev ivo://
Link	PNG Thumbnail (Color)	#prev ivo://
Link	RT1 raw data file	#prog ivo://vopdc.obspm/~?nda/S991229_cdf
Link	**The full dataset.**	**#this ivo://vopdc.obspm/~?nda/S991229_cdf**
Link	A preview for the dataset.	#preview ivo://vopdc.obspm/~?nda/S991229_cdf



Example with NDA collection (target_name=Jupiter)



Non sécurisé — vogate.obs-nancay.fr/nda/q/dl/dlmeta?ID=ivo%3A//vopdc.obspr

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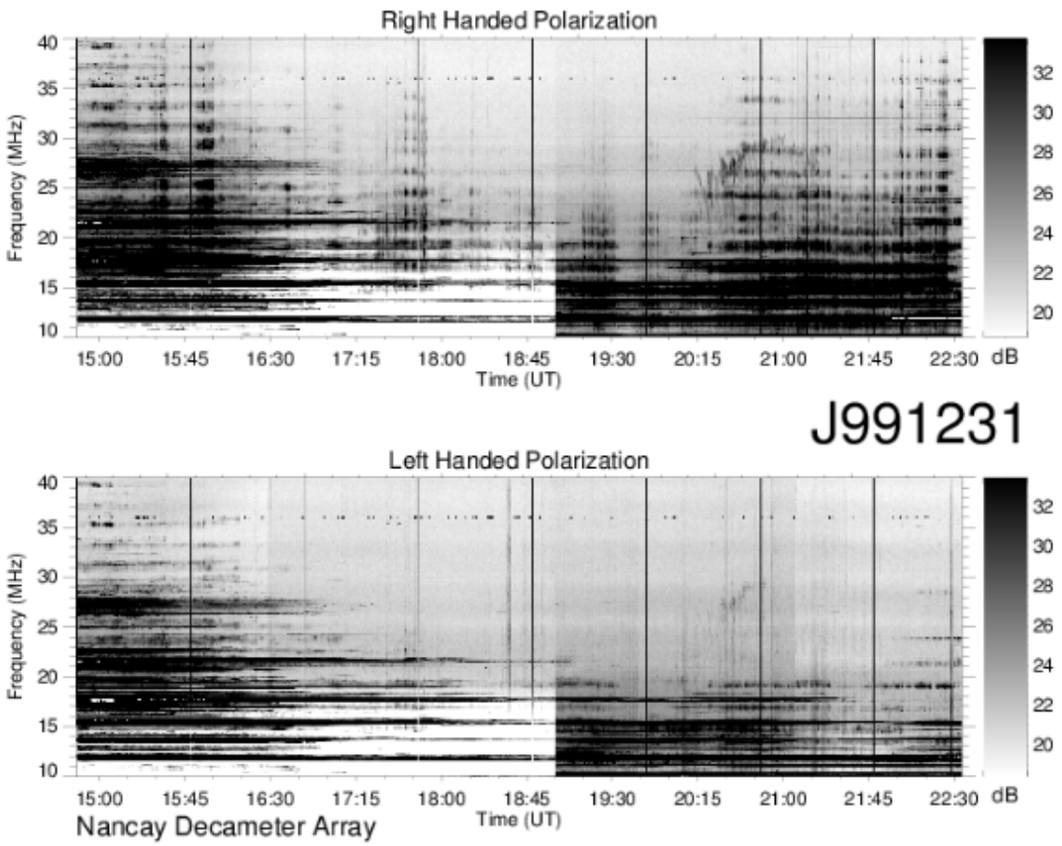
Table links



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Link	Das2 access (Right-Hand polarization)	#cutout ivo://vopdc.obspm/~?nda/J991231_cdf
Link	Das2 access (differential polarization)	#cutout ivo://vopdc.obspm/~?nda/J991231_cdf

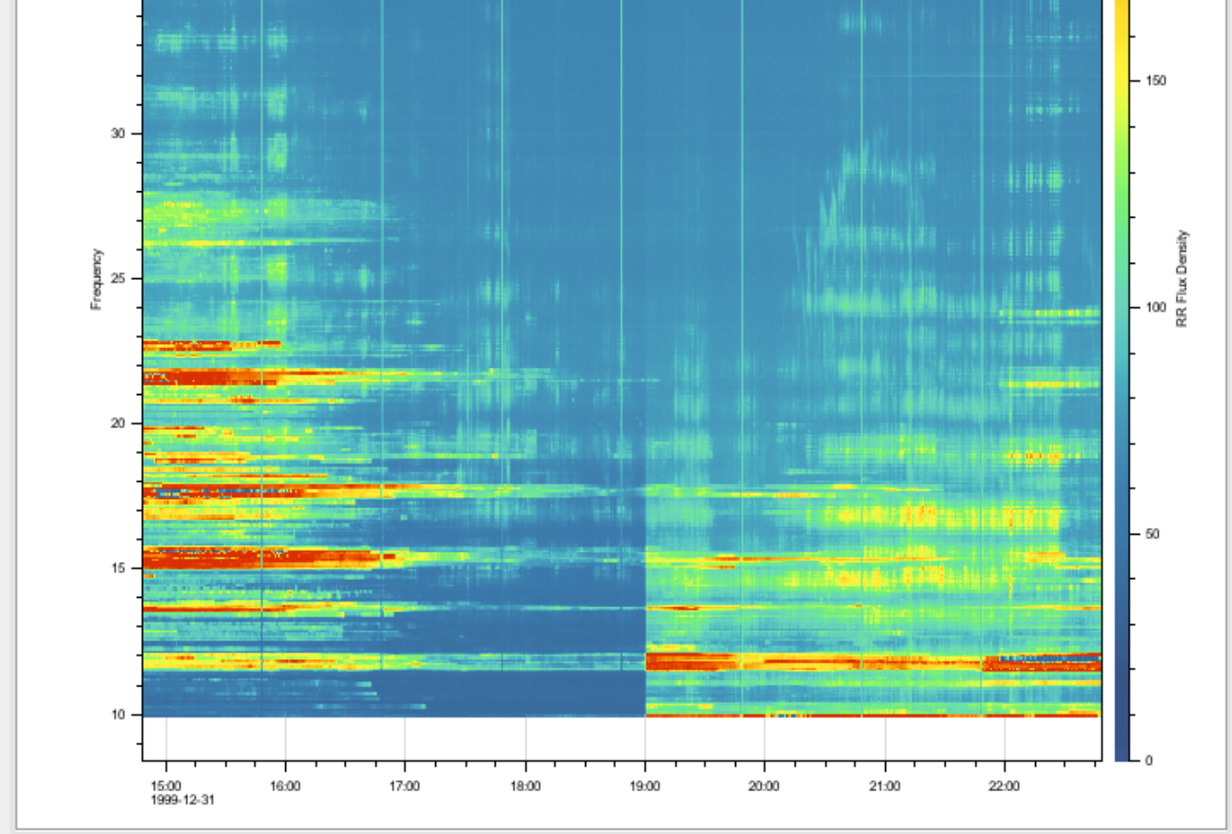
Afficher un menu

Autoplot v2021a_5

File Edit View Options Bookmarks Tools Help Expert

&server=dataset&start_time=1999-12-31T14:48:00.220Z&end_time=1999-12-31T22:47:59.280Z

canvas axes style layout data metadata script console



shift has no effect, press control to pan

Autoplot

Data on demand

- **Large data rate or long times intervals**
  => need for optimized client/server distribution system.

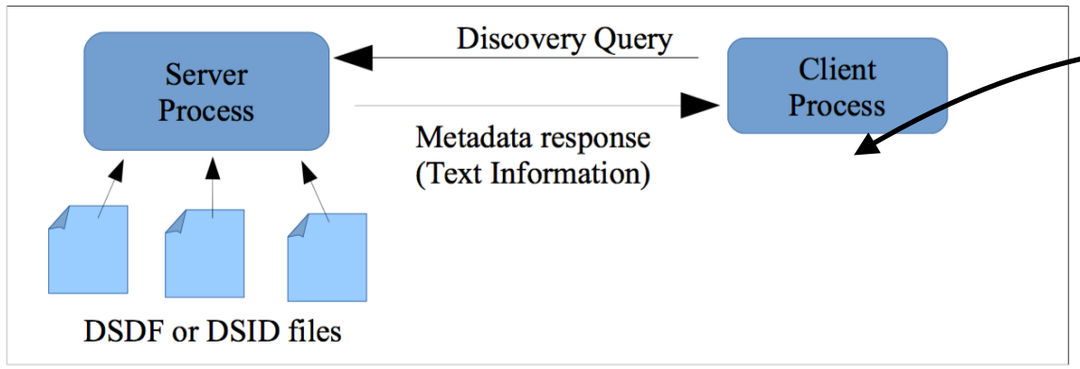
- Existing solution developed by University of Iowa (USA):
  server=**Das2** (http://das2.org) and client=**Autoplot** (http://autoplot.org)

- **Built for space data** (low data rate), but capable of serving long **resampled** times series.
  Tested with success on ground Nançay datasets: adapted also for ground based high data rate collections.

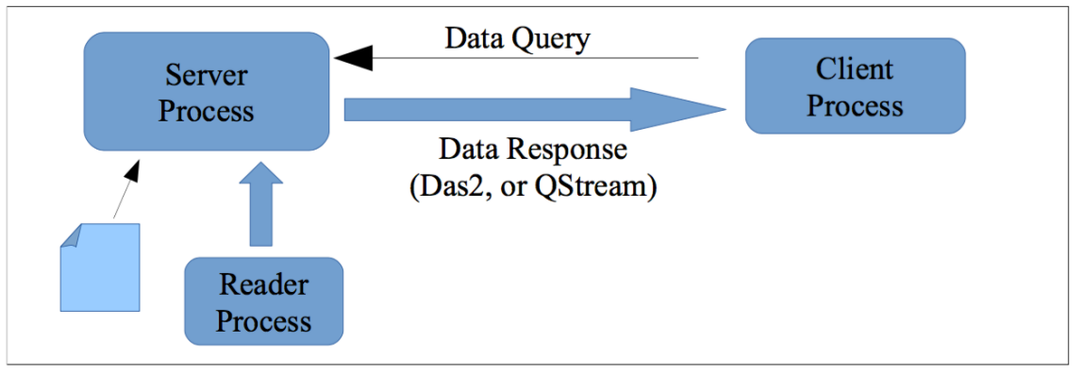
- Very simple configuration:
  data collection description files + data reader that produces “das2stream” formatted data.

- Implemented on LESIA, CDPP, and Nançay data collections (using the Maser4py modules):
  - LESIA: http://voparis-maser-das.obspm.fr/das2/server
  - Nançay: https://das2server.obs-nancay.fr/das2/server

Das2 / Autoplot process



Discovery Query Information Flow



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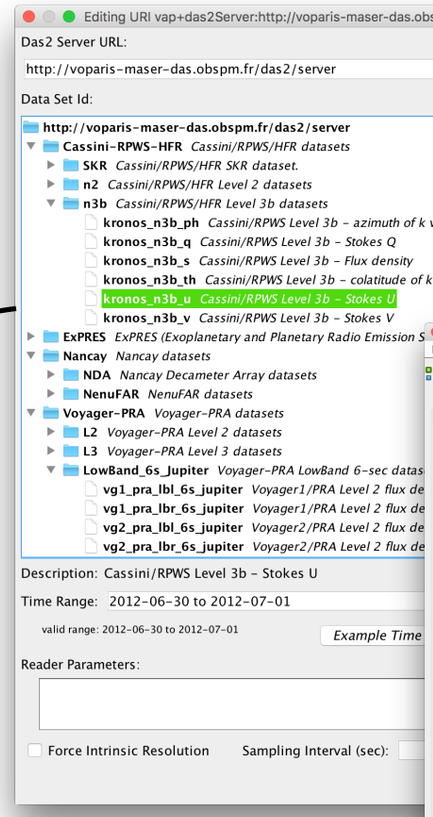
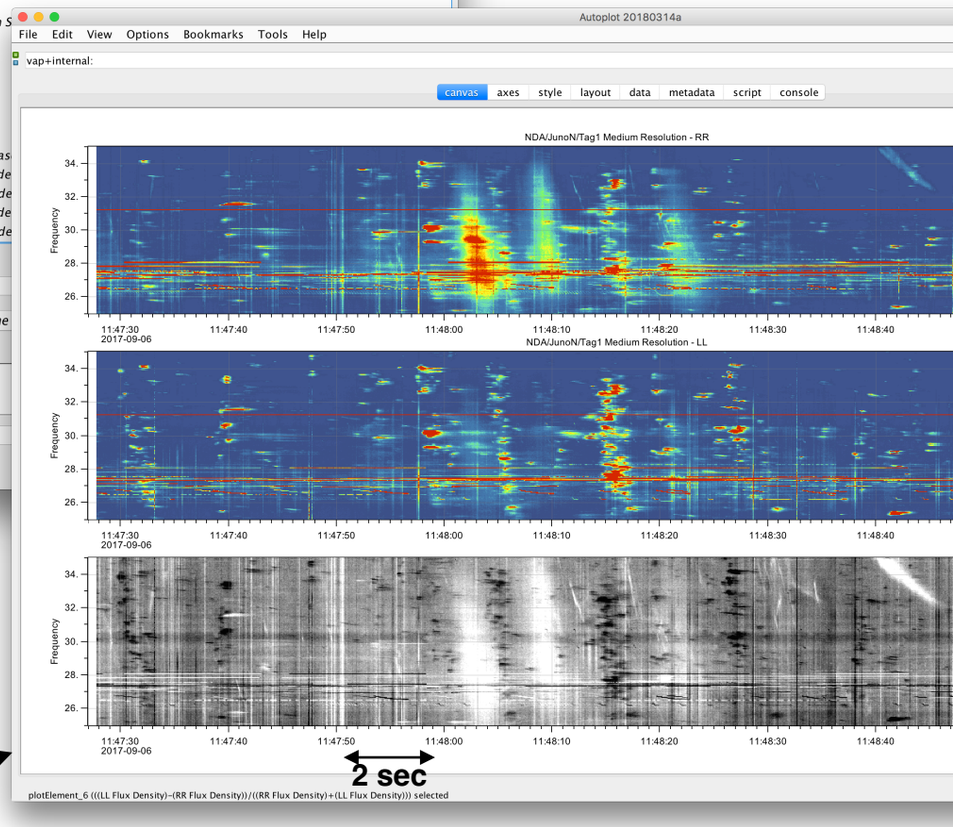




NDA/JunoN dataset (3TB/day)

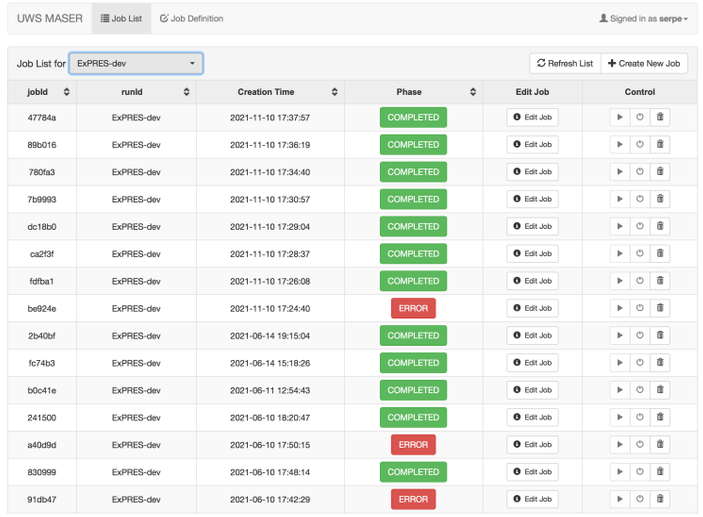
- Das2 = **data distribution** system for time series + **on demand resampling** (averaging on the fly).
  HTTP REST Query: data collection + time interval + temporal resolution

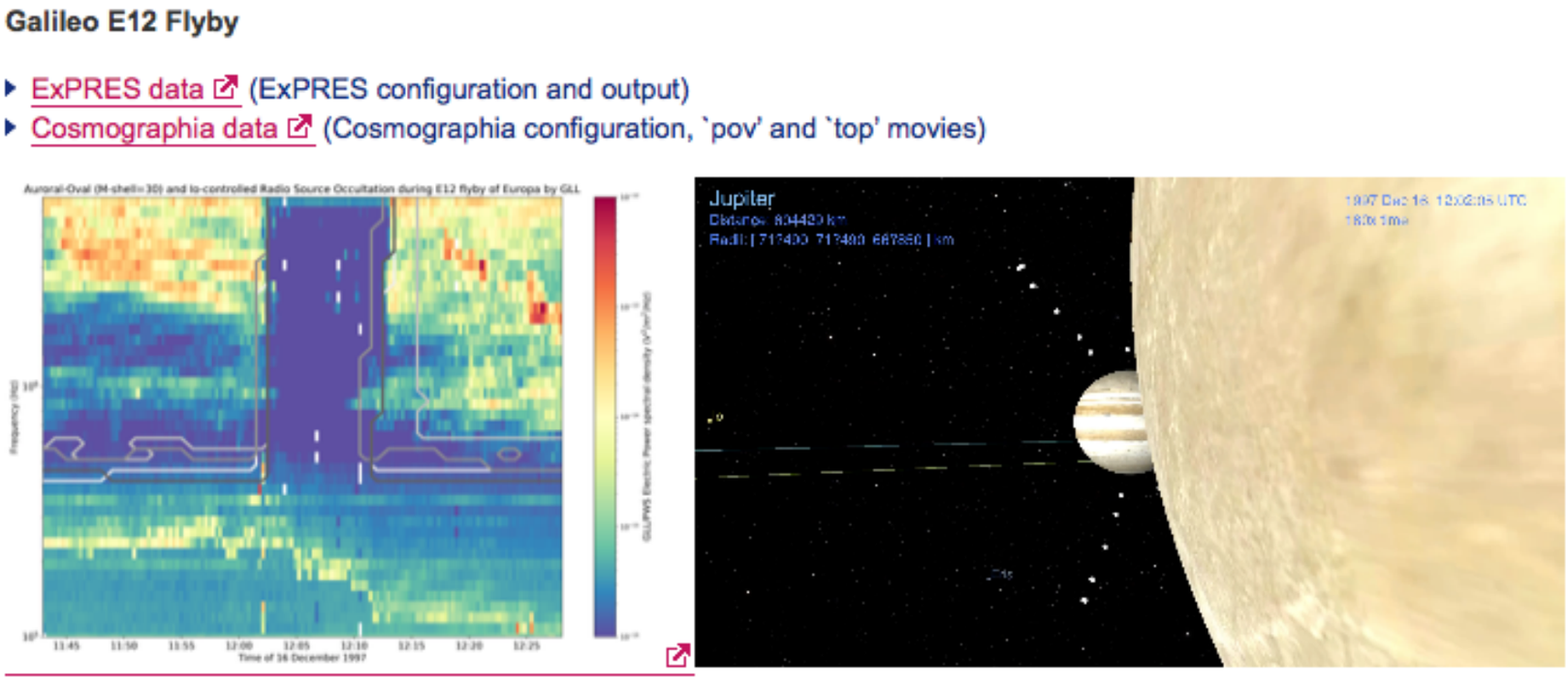
UWS for run on demand

- ExPRES code (Exoplanetary and Planetary Radio Emission Simulator)
  https://github.com/maserlib/ExPRES
  https://voparis-uws-maser.obspm.fr/client/jobs/ExPRES (using OPUS)

- Modelling of the spectro-temporal shape of radio emissions.

- Used in *Cecconi et al., Planet. Space Sci (2021)*
  mission planning of JUICE
  supplementary material: https://doi.org/10.25935/8ZFF-NX36

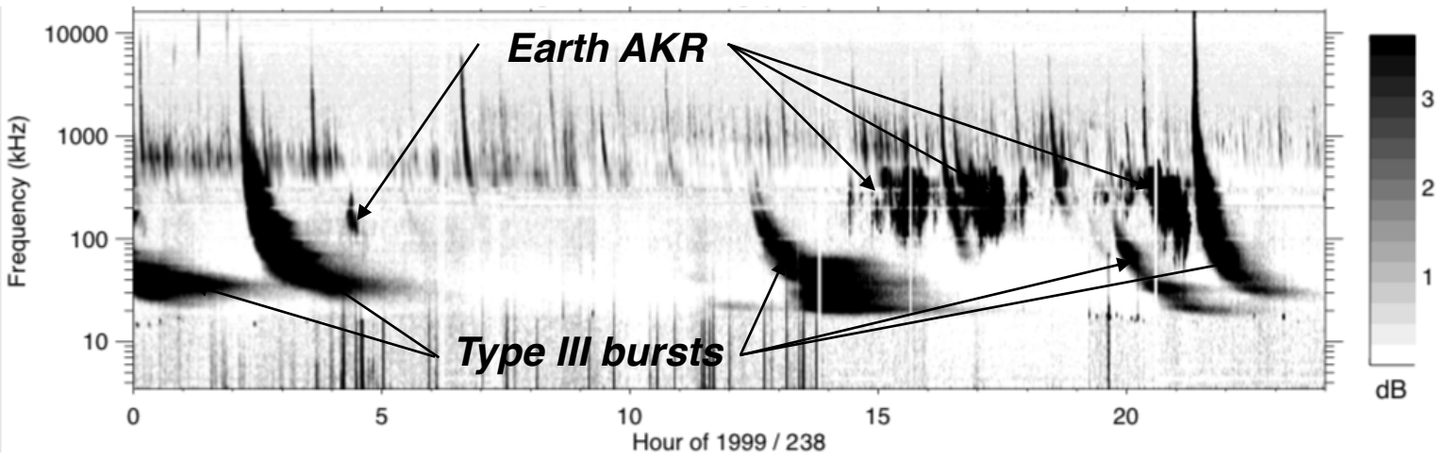




Time-Frequency Catalogue Model & Format

- **Why?**
  In low frequency radio astronomy, *spectro-temporal* (aka *time-frequency*) features are key for science analysis.
- **Features:**
  - planetary emissions (auroral, lightnings…)
  - solar emissions
- **Geometries:**
  - contour of feature (polygon, points…)
  - skeleton line / shape of feature (line, points)

Solar bursts + Earth AKR emissions (Cassini/RPWS)



Jupiter DAM emissions (Nançay/NDA)

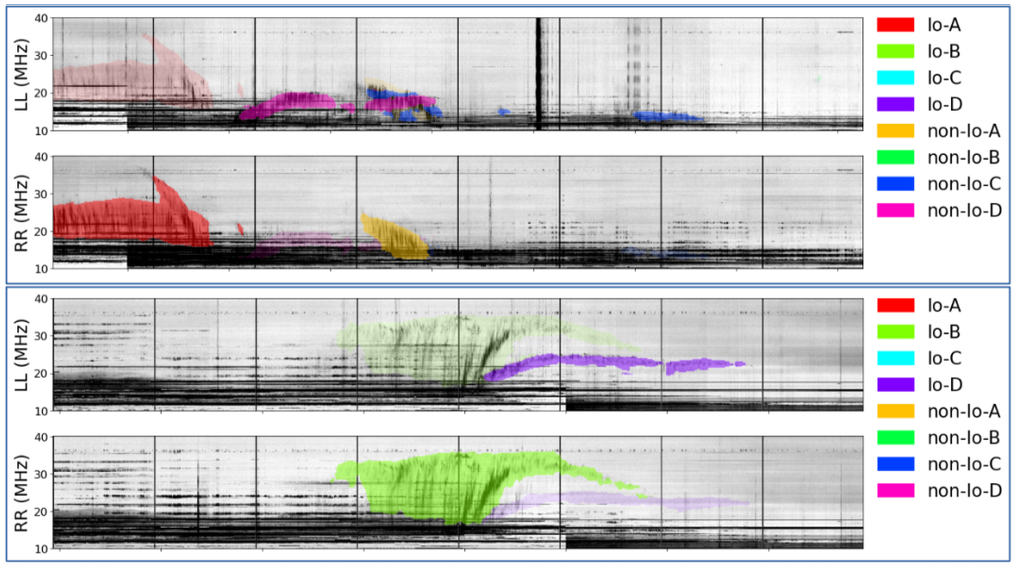


Figure 4. Spectrogrammes radio du NDA annotés, avec (en haut) le catalogue publié (Marques et al. 2017), (au milieu) les événements reconstruits pour la même observation, et (en bas), de nouveaux événements sur une observation récente (hors du catalogue d'entrainement).

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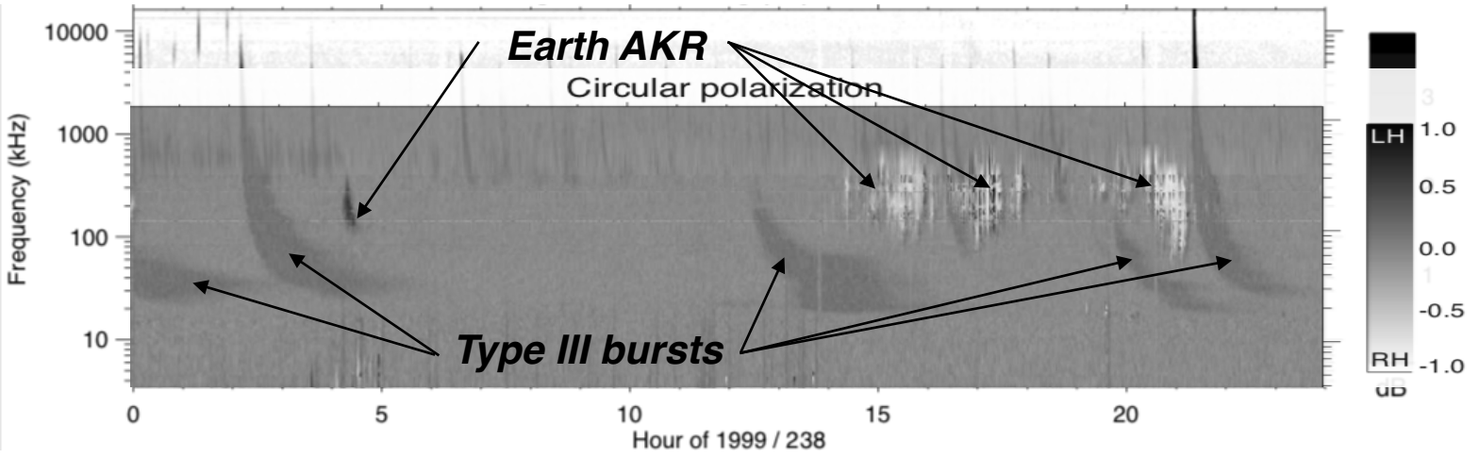
  - contour of feature (polygon, points…)
  - skeleton line / shape of feature (line, points)

Solar bursts + Earth AKR emissions (Cassini/RPWS)



Jupiter DAM emissions (Nançay/NDA)

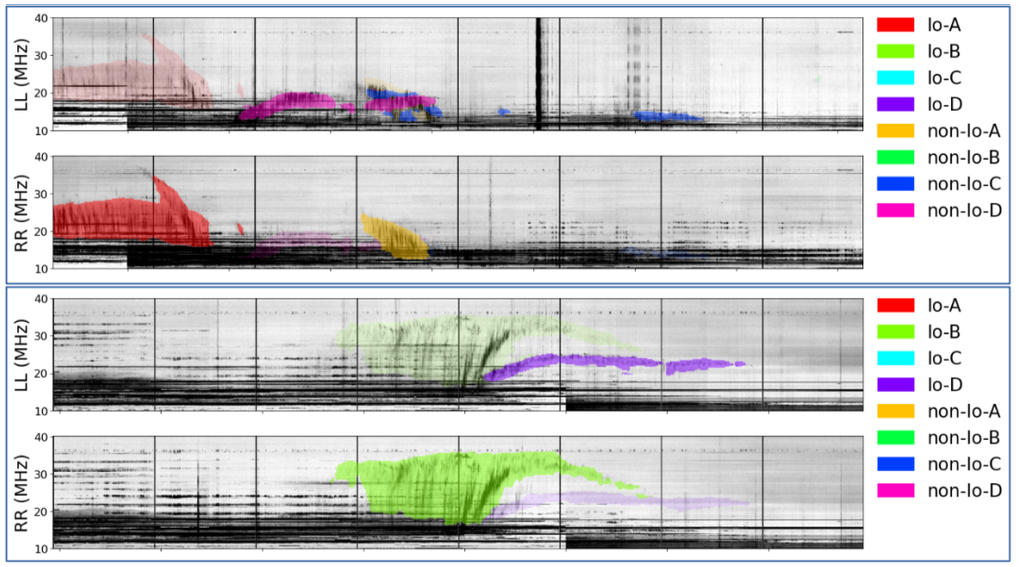
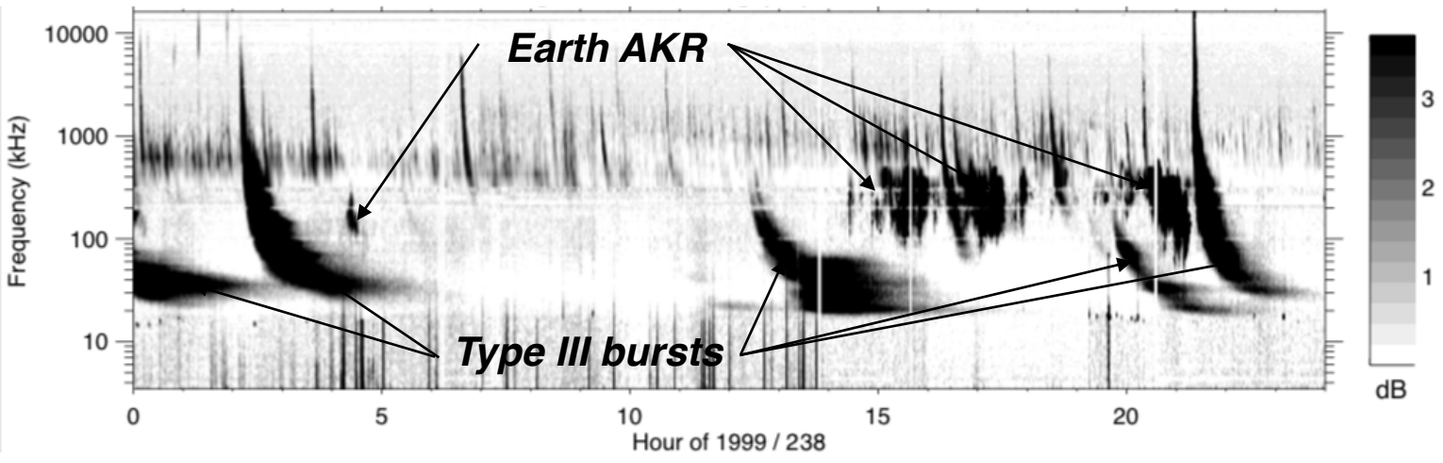


Figure 4. Spectrogrammes radio du NDA annotés, avec (en haut) le catalogue publié (Marques et al. 2017), (au milieu) les événements reconstruits pour la même observation, et (en bas), de nouveaux événements sur une observation récente (hors du catalogue d'entrainement).

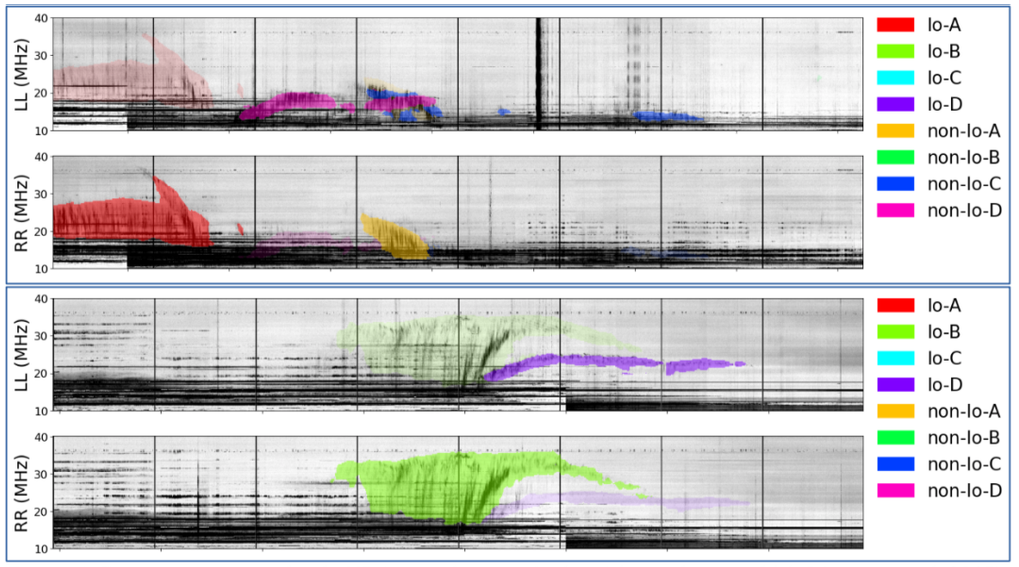
Time-Frequency Catalogue Model & Format

- **Why?**
  In low frequency radio astronomy, *spectro-temporal* (aka *time-frequency*) features are key for science analysis.
- **Features:**
  - planetary emissions (auroral, lightnings…)
  - solar emissions
- **Geometries:**
  - contour of feature (polygon, points…)
  - skeleton line / shape of feature (line, points)

Solar bursts + Earth AKR emissions (Cassini/RPWS)



Jupiter DAM emissions (Nançay/NDA)



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TFCat

- TFcat Model
    - A **TF-geometry** is a geometry (point, line-string, polygon, multi-points, multi-line-strings, multi-polygon), with coordinates in time and frequency (or wavelength, or wavenumber, or energy).
    - The **catalogue contains a list of features**, with a TF-geometry (or a set of geometries), and parameters.
    - The **catalogue contains a definition of the features additional properties**, with data type, description, unit, UCD, etc.
    - The **catalogue contains a set of global properties**, at catalogue level, with data type, description, unit, UCD, etc.
    - The **catalogue contains a description of the CRS** (coordinate reference system) defining the temporal and spectral axes, as well as the frame reference position.
- **Specification**: Cecconi, B., M. B. Taylor, X. Bonnin, A. Loh. (2022), JSON Implementation of Time-Frequency Radio Catalogues: TFCat (Version 1.0). PADC. https://doi.org/10.25935/6068-8528
  Publication: Cecconi, B., Louis, C. K., Bonnin, X., Loh, A., & Taylor, M. B. (2023). Time-frequency catalogue: JSON implementation and python library. Frontiers in Astronomy and Space Sciences, 9, 1049677. https://doi.org/10.3389/fspas.2022.1049677
  Validator: in STILTS ! (thanks to Mark Taylor)

TFCat + TAP exploration

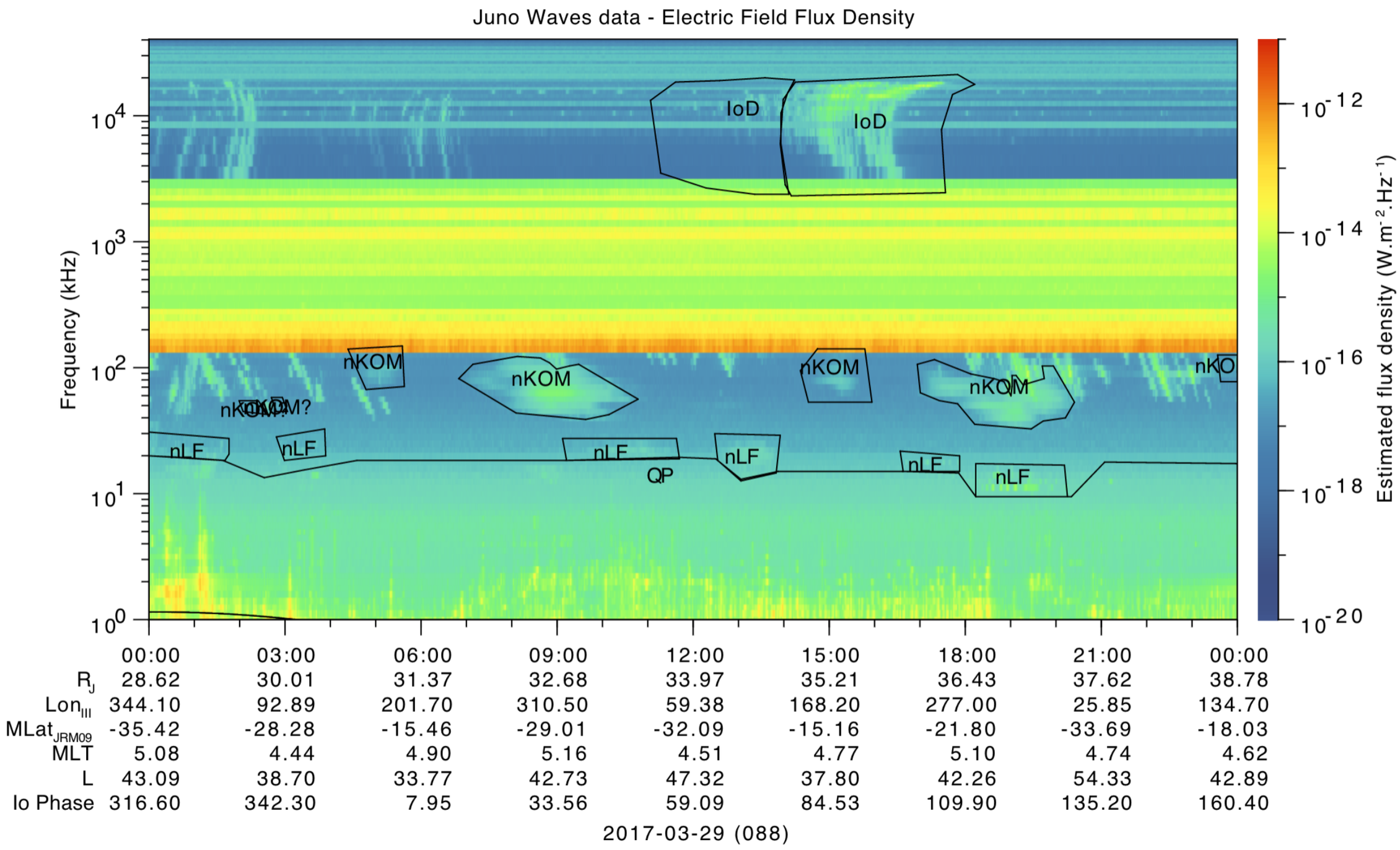
- 1 Feature per row, Geometry as JSON string, Feature mapped properties into columns
- JSON-string allows to keep all information (geometry type, CRS, coordinates) of Feature for future use.

Id	Time_start	Time_end	Freq_min [Hz]	Freq_max [Hz]	Geometry_type	Geometry	Quality	Area [s.Hz]	Nop
cassini_faraday_patches_2006-emi-0	2006-09-12T09:02:26.750000	2006-09-12T09:19:14.740000	24730.0	43469.0	MultiPoint	{"type": "Feature", "crs": {"name": "Time-Frequency", "properties": {"time_coords": {"id": "unix", "name": "Timestamp (Unix Time)", "unit": "s", "time_origin": "1970-01-01T00:00:00.000Z", "time_scale": "TT"}, "spectral_coords": {"name": "Frequency", "unit": "Hz"}, "ref_position": {"id": "Cassini"}}}, "geometry": {"type": "MultiPoint", "coordinates": [[1158051858.75, 24730.0], [1158051874.75, 24730.0], [1158051890.75, 24730.0], [1158051890.75, 25318.0], [1158051906.75, 25318.0], [1158051922.75, 25318.0], [1158051938.75, 25318.0], [1158051922.75, 25920.0], [1158051954.75, 25920.0], [1158051970.75, 25920.0], [1158051858.75, 26536.0], [1158051906.75, 26536.0], [1158052050.75, 26536.0], [1158051842.75, 27167.0], [1158052210.75, 27167.0], [1158052258.75, 27167.0], [1158052130.75, 27813.0], [1158052178.75, 27813.0], [1158052290.74, 27813.0], [1158051810.75, 29152.0], [1158052370.74, 29152.0], [1158051762.75, 29845.0], [1158052402.74, 29845.0], [1158052466.74, 29845.0], [1158052514.74, 29845.0], [1158052530.74, 29845.0], [1158051746.75, 30555.0], [1158052434.74, 30555.0], [1158052546.74, 30555.0], [1158052562.74, 30555.0], [1158052578.74, 30555.0], [1158052594.74, 30555.0], [1158052610.74, 30555.0], [1158052626.74, 30555.0], [1158052642.74, 30555.0], [1158051746.75, 31282.0], [1158052626.74, 31282.0], [1158051746.75, 32025.0], [1158052642.74, 32025.0], [1158052658.74, 32025.0], [1158052674.74, 32025.0], [1158052690.74, 32025.0], [1158052706.74, 32025.0], [1158051746.75, 32787.0], [1158052706.74, 32787.0], [1158051746.75, 33567.0], [1158052706.74, 33567.0], [1158051746.75, 35182.0], [1158052722.74, 35182.0], [1158052738.74, 35182.0], [1158052754.74, 35182.0], [1158051746.75, 36019.0], [1158051762.75, 36019.0], [1158051778.75, 36019.0], [1158051794.75, 36019.0], [1158052754.74, 36019.0], [1158051810.75, 36875.0], [1158052738.74, 36875.0], [1158052754.74, 36875.0], [1158051810.75, 37752.0], [1158051826.75, 37752.0], [1158051842.75, 37752.0], [1158051890.75, 37752.0], [1158051906.75, 37752.0], [1158052722.74, 37752.0], [1158052754.74, 37752.0], [1158051858.75, 38650.0], [1158051874.75, 38650.0], [1158051922.75, 38650.0], [1158051938.75, 38650.0], [1158051954.75, 38650.0], [1158052658.74, 38650.0], [1158052674.74, 38650.0],	2	12025431.0	880

Geometry

{"type": "Feature", "crs": {"name": "Time-Frequency", "properties": {"time_coords": {"id": "unix", "name": "Timestamp (Unix Time)", "unit": "s", "time_origin": "1970-01-01T00:00:00.000Z", "time_scale": "TT"}, "spectral_coords": {"name": "Frequency", "unit": "Hz"}, "ref_position": {"id": "Cassini"}}}, "geometry": {"type": "MultiPoint", "coordinates": [[1158051858.75, 24730.0], [1158051874.75, 24730.0], [1158051890.75, 24730.0], [1158051890.75, 25318.0], [1158051906.75, 25318.0], [1158051922.75, 25318.0], [1158051938.75, 25318.0], [1158051922.75, 25920.0], [1158051954.75, 25920.0], [1158051970.75, 25920.0],

TFCat in Autoplot



Summary

- MASER: solar system radioastronomy
  - possible extension to transient low frequency radio astronomy (starting of official operation in Jan 2022)

- IVOA integration:
  - EPN-TAP + Datalink 👍
    - search engine for local data management tools
    - data discovery
  - UWS works very well for job on demand

- Community Specific:
  - Das2: data streaming interface for dynamic spectra
  - TFCat for event/feature catalogues (next => FT-MOC !)