MASER
Low Frequency Science Ready tools

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and the MASER team

Observatoire de Paris-PSL

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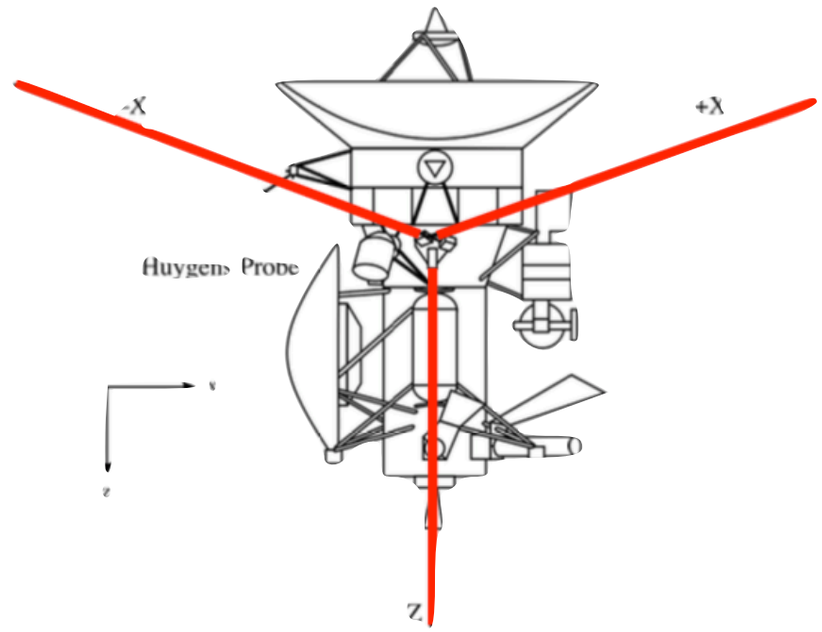
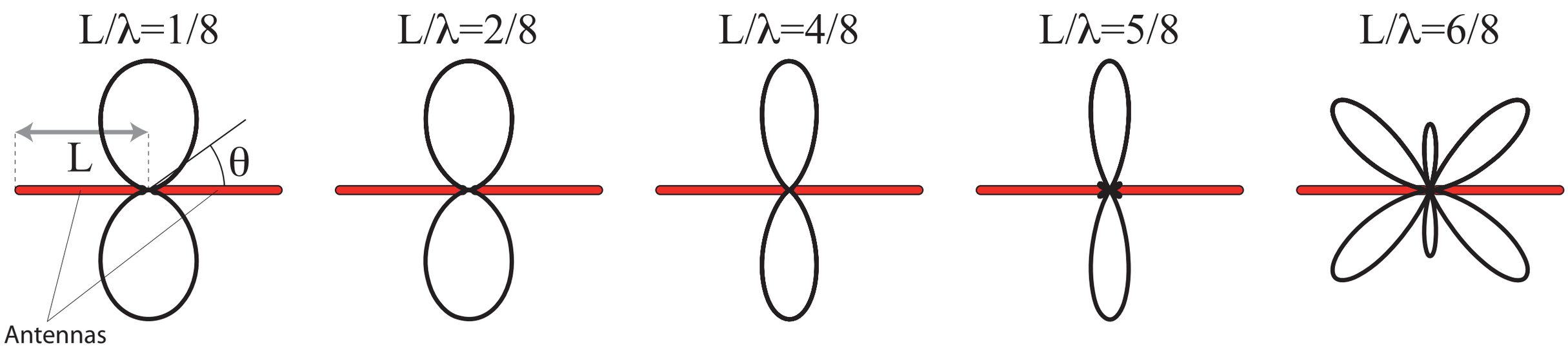
Radio Astronomy: what do we measure

- **Single antenna** (in space): no directivity,
  => spectro-temporal information.

- **Phased array**: coherent sum, beam forming.
  => spectro-temporal information within beam.

- **Interferometer**: phased correlations.
  => spectro-temporal + spatial frequencies





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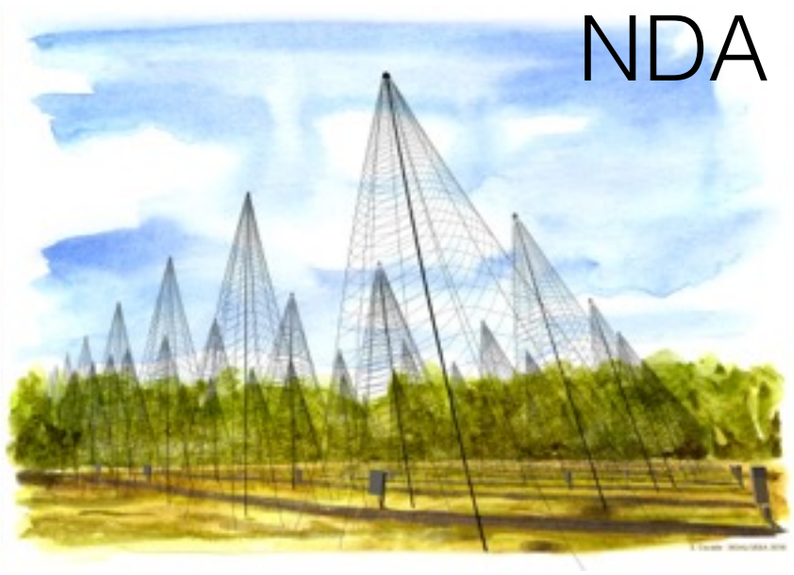

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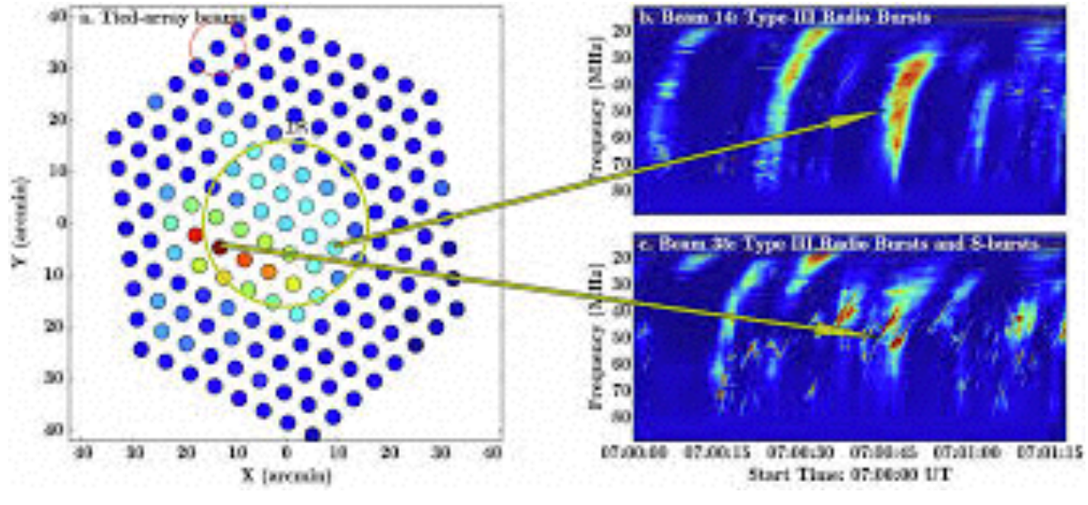

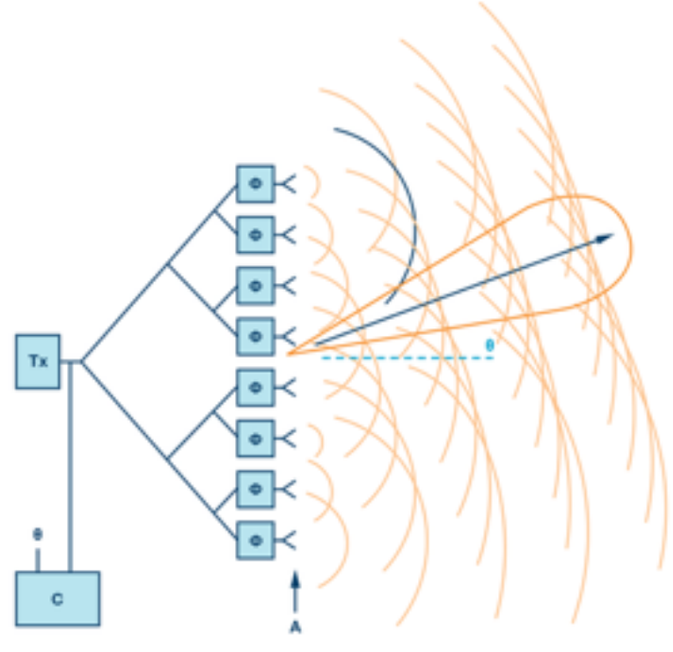

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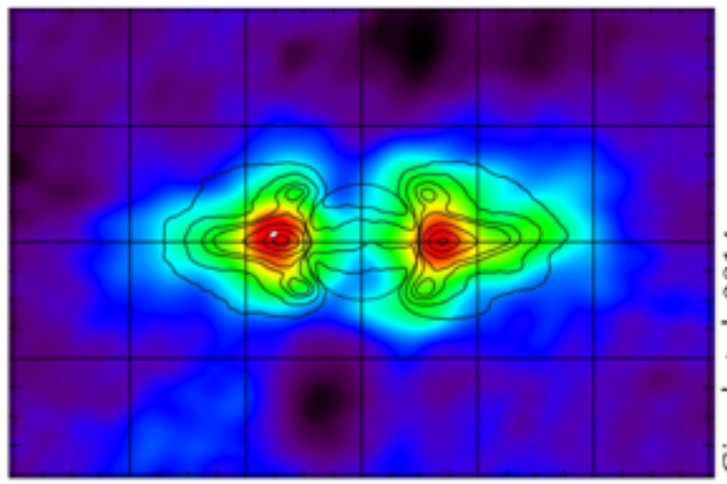

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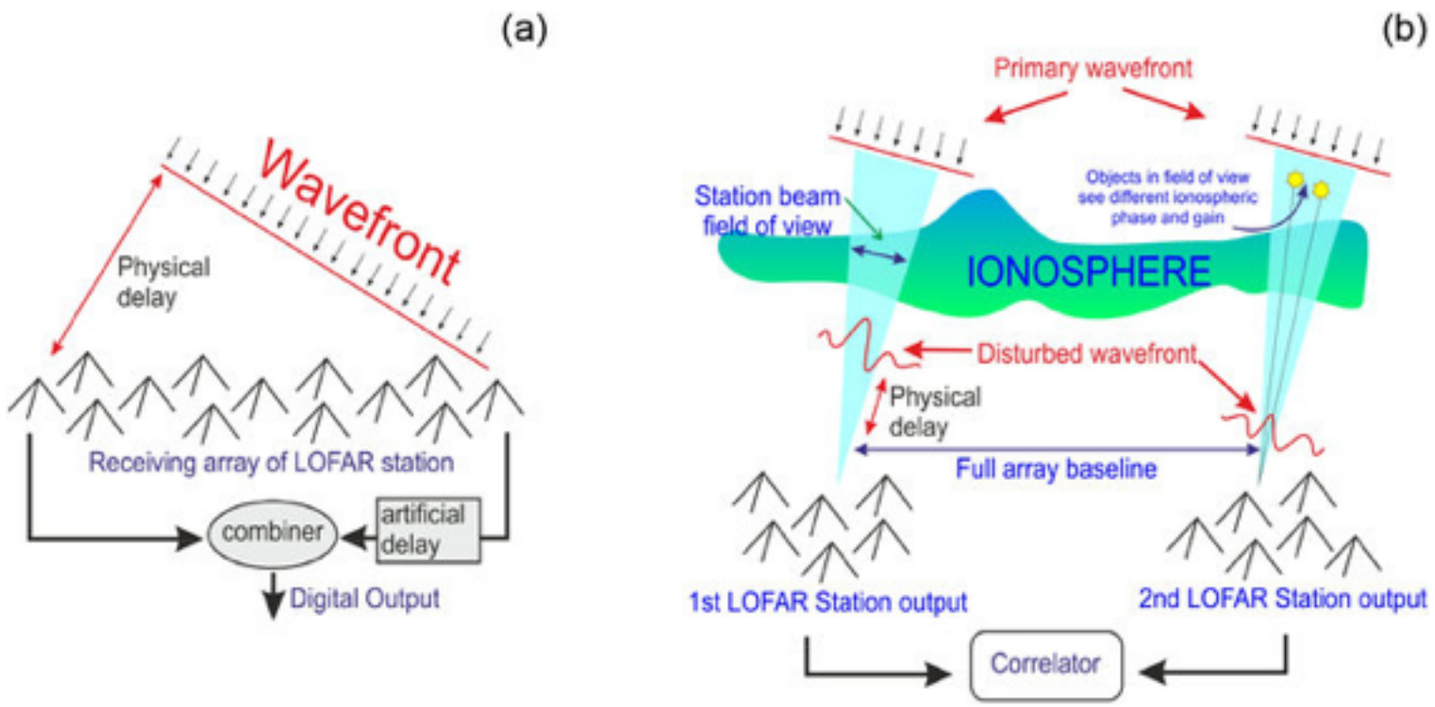
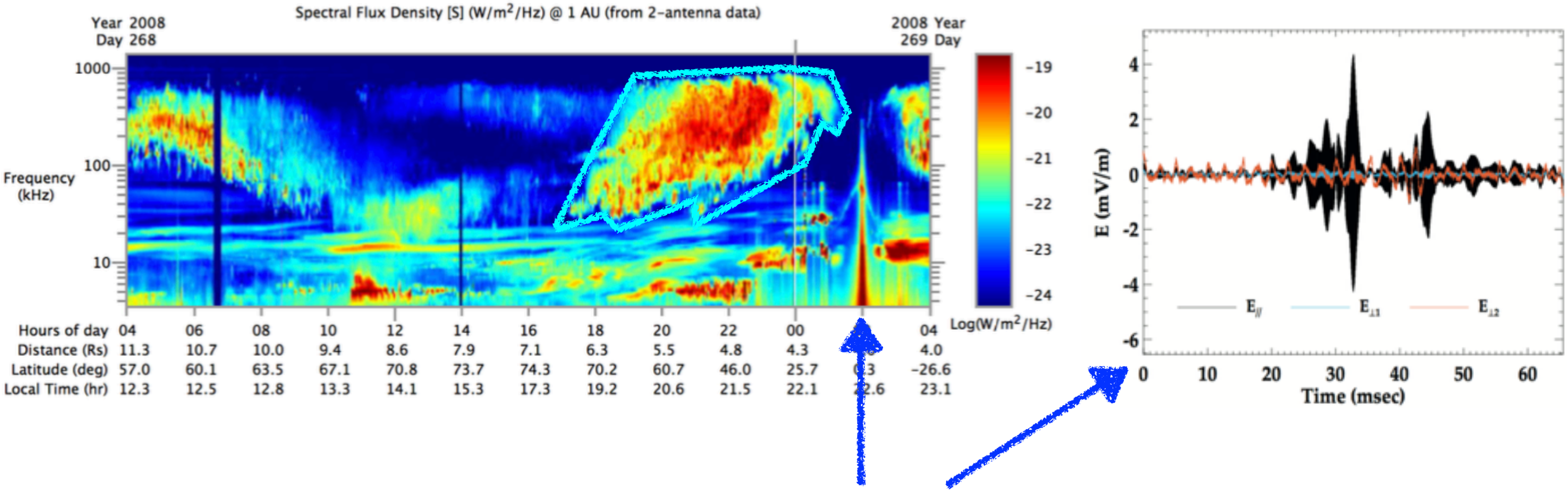


Data product types

- 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*



MASER & EPN-TAP

- MASER (Measuring, Analysing & Simulating Emissions in the Radio range) is offering access to a series of tools and databases related to low frequency radioastronomy (a few kHz to a few 10 MHz).

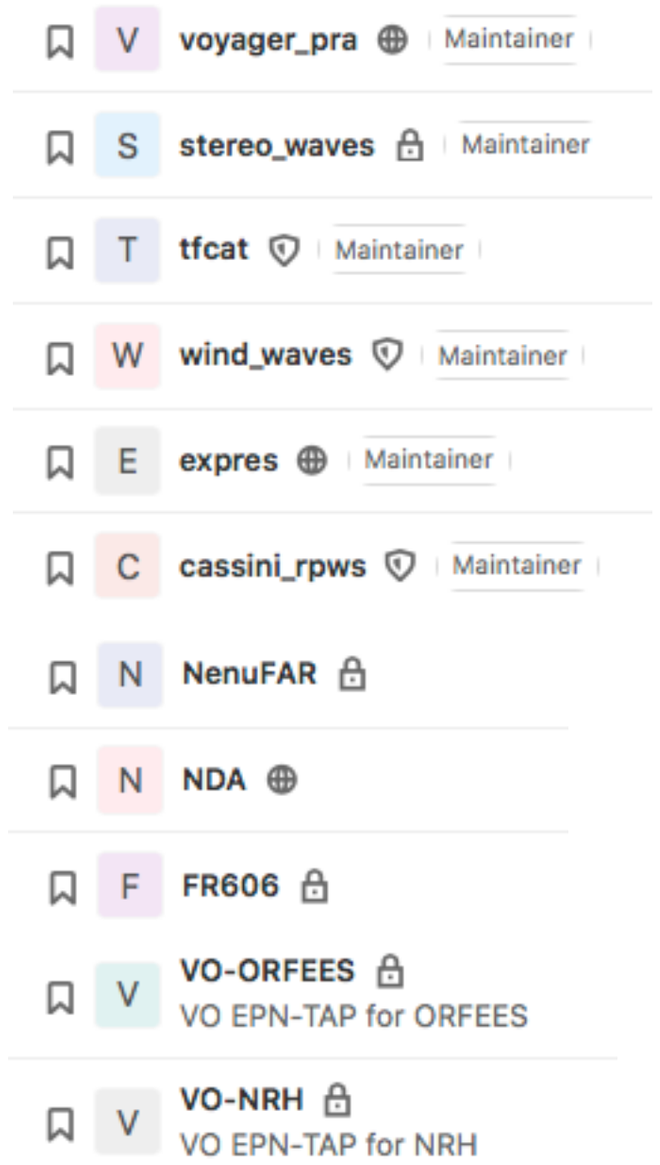
- MASER web site: https://maser.lesia.obspm.fr

- Dedicated TAP servers:
  http://voparis-tap-maser.obspm.fr
  http://vogate.obs-nancay.fr

- Gitlab repository for service description:
  https://voparis-gitlab.obspm.fr/vespa/dachs/services/padc/voparis-tap-maser

TAP services

- space borne observations (Voyager/PRA, Cassini/RPWS, Wind/Waves, STEREO, Juno…),
- ground based observations (NenuFAR, NDA, LOFAR-FR606, ORFEES, NRH, RadioJOVE…)
- catalogues (TFCat)
- simulations (ExPRES)



Not all RD public yet

Not all on VESPA portal

EPN-TAP service configuration

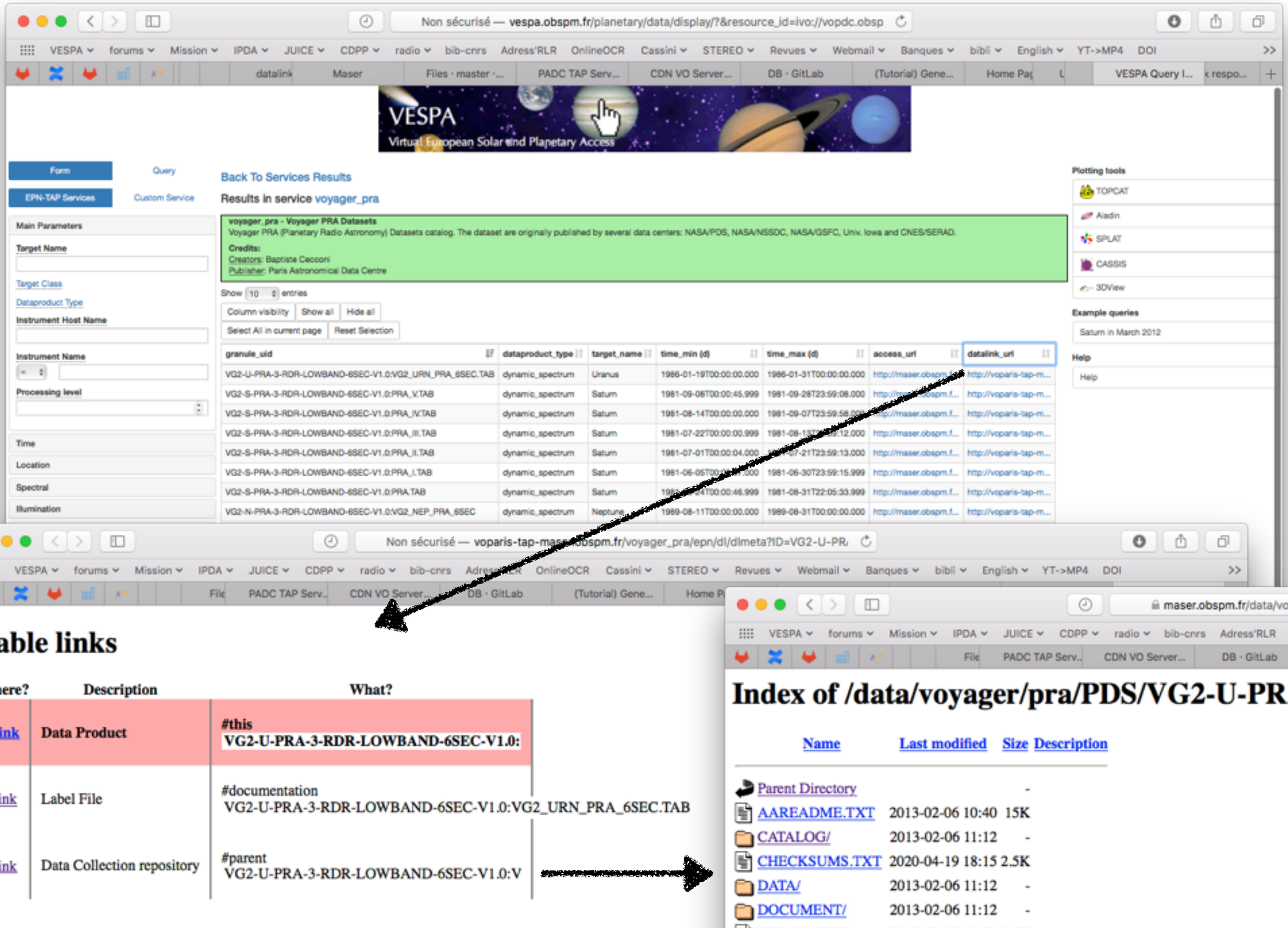
- DaCHS servers (v2.4, soon v2.5)

- 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



Example with NDA collection

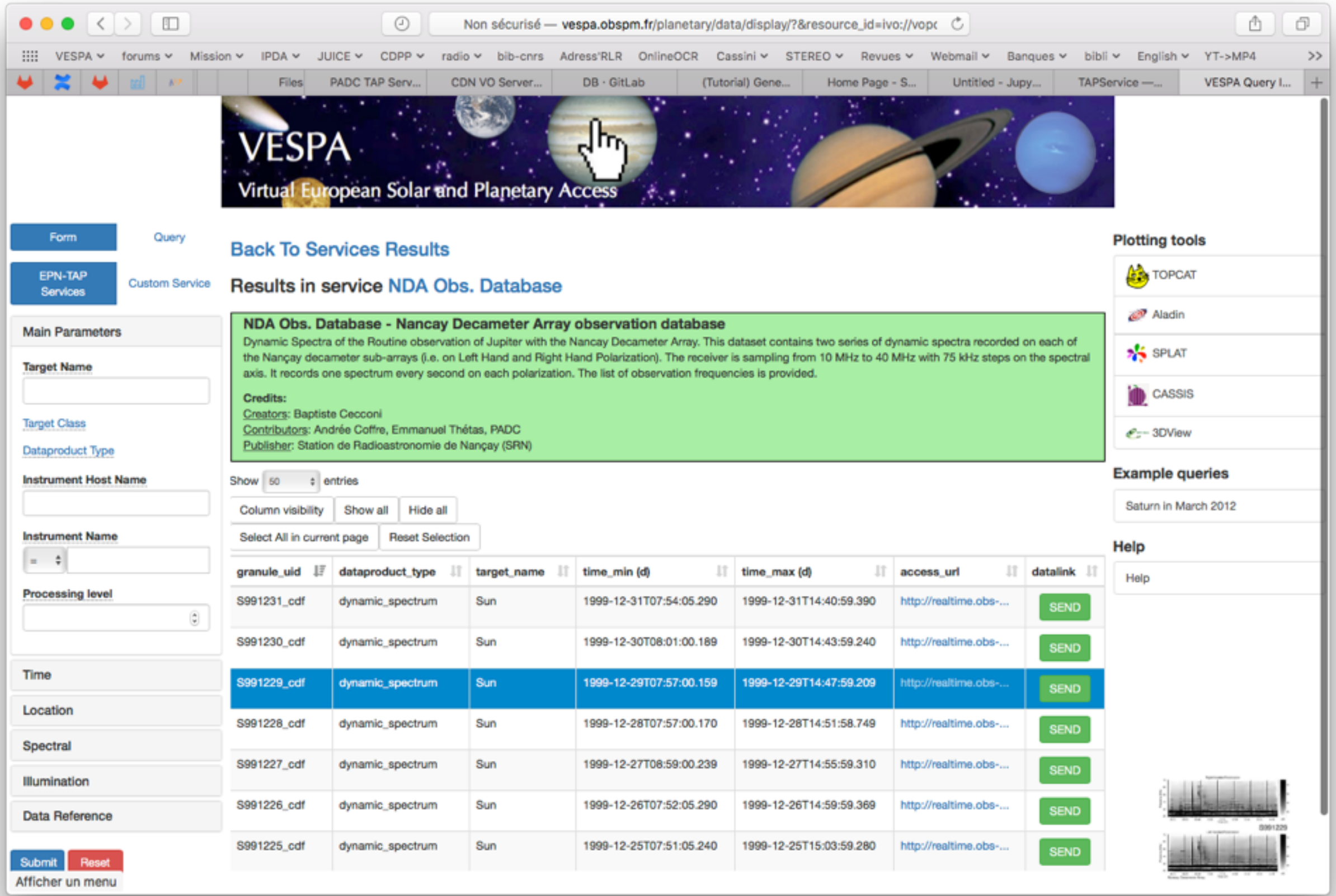
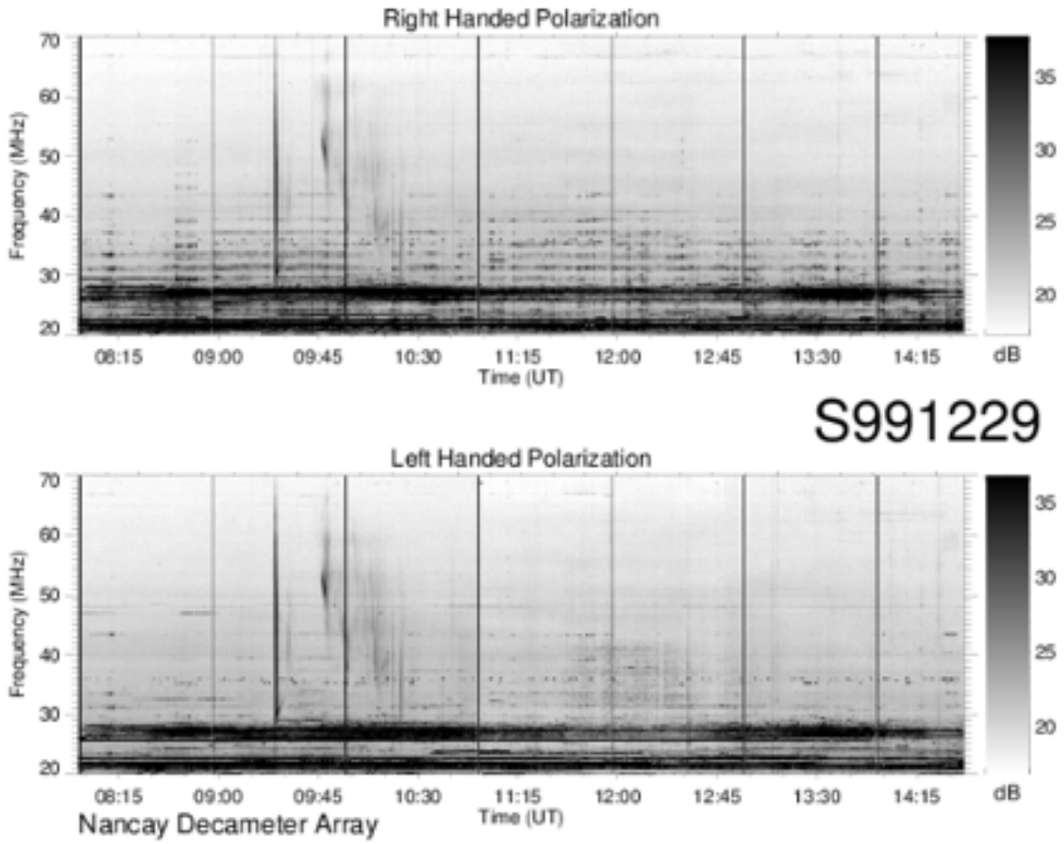


Table links



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

Afficher un menu

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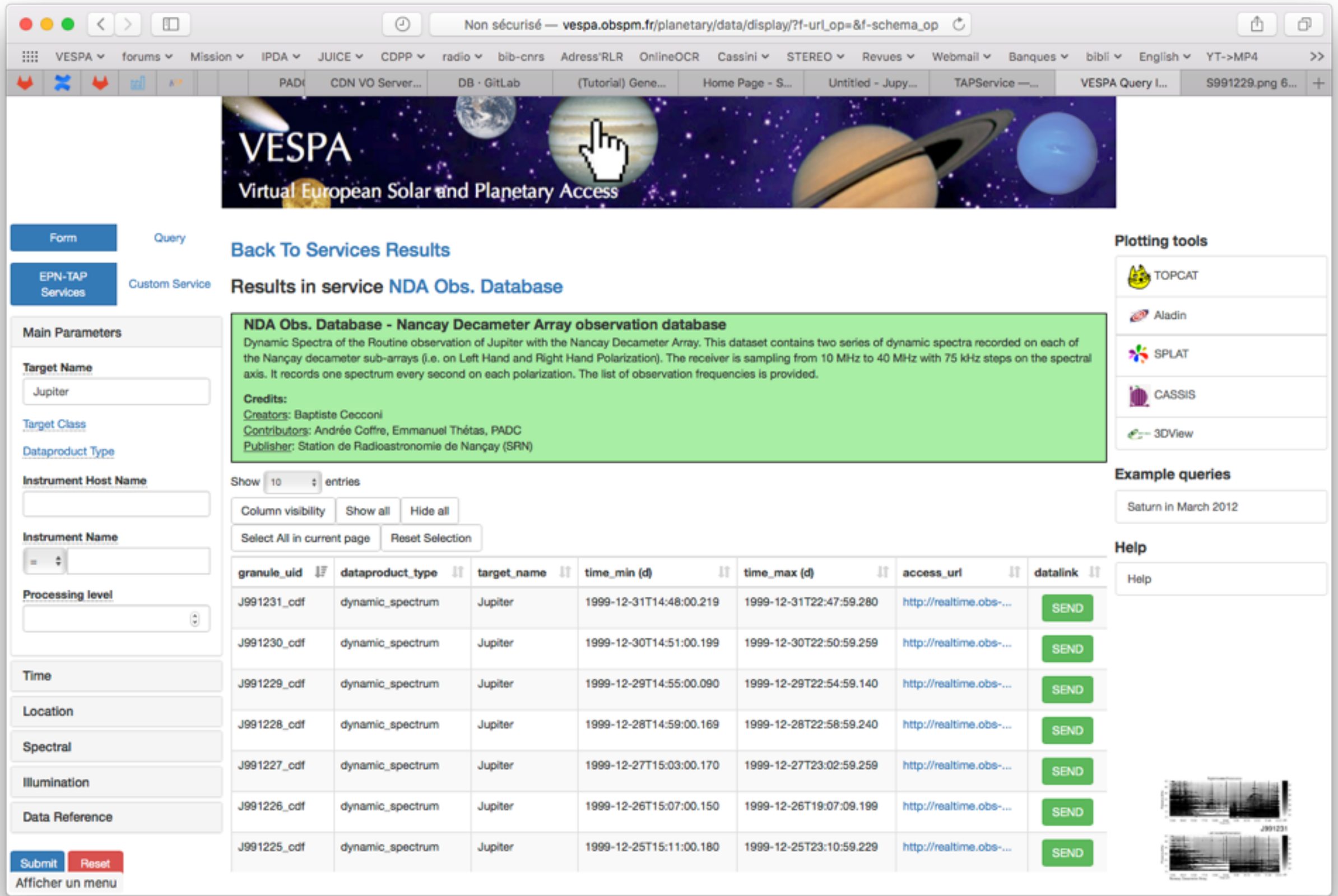
Link	Das2 access (differential polarization)	#cutout ivo://vopdc.obspm/~?nda/S991229_cdf
Link	PDF Preview (Greyscale)	#preview ivo://vopdc.obspm/~?nda/S991229_cdf
Link	PDF Preview (Color)	#previ ivo://v
Link	PNG Preview (Greyscale)	#previ ivo://v
Link	PNG Preview (Color)	#previ ivo://v
Link	PNG Thumbnail (Greyscale)	#previ ivo://v
Link	PNG Thumbnail (Color)	#previ ivo://v
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

Afficher un menu

Example with NDA collection (target_name=Jupiter)

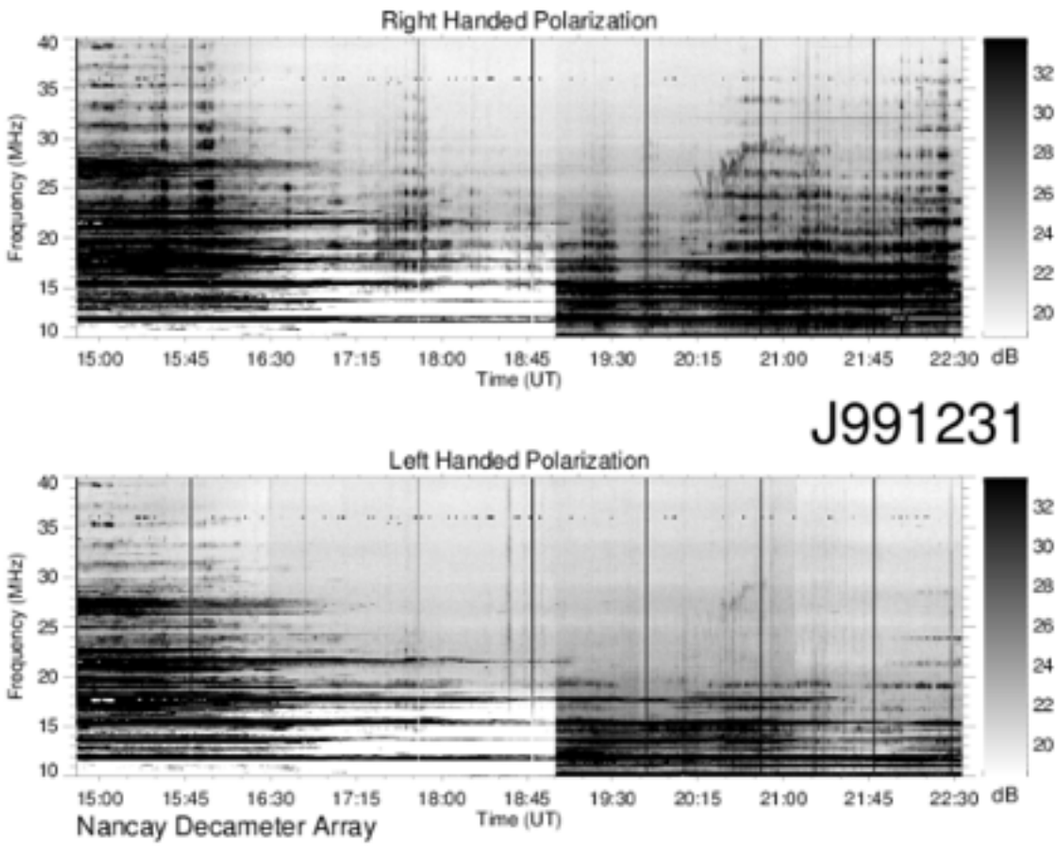


Non sécurisé — vogate.obs-nancay.fr/nda/q/dl/dlmeta?ID=ivo%3A//vopdc.obspr

VESPA forums Mission IPDA JUICE CDPP radio bib-cnrs Adress'RLR OnlineOCR Cassini STEREO Revues Webmail Banques bibli English YT->MP4

PAD(CDN VO Server... DB · GitLab (Tutorial) Gene... Home Page - S... Untitled - Jupy... TAPService —... VESPA Query l... Datalink respo...

Table links



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

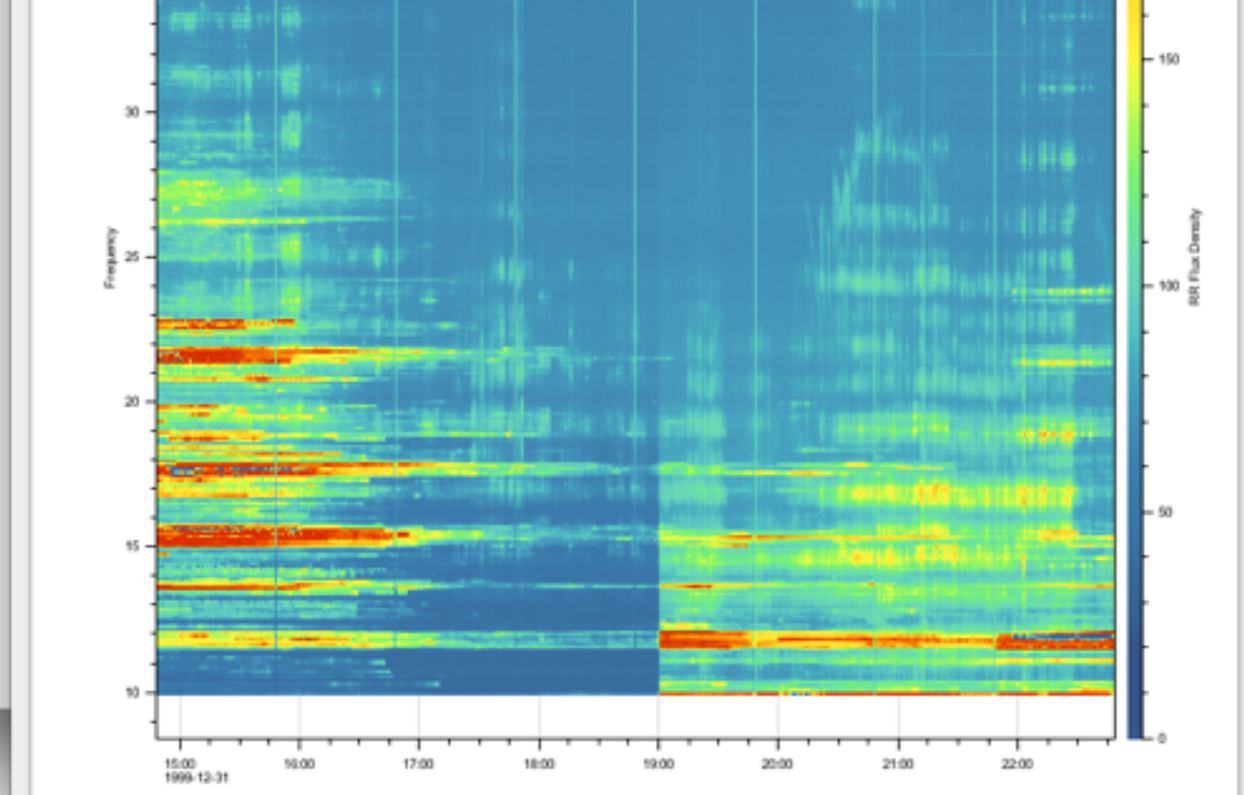
Afficher un menu

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.

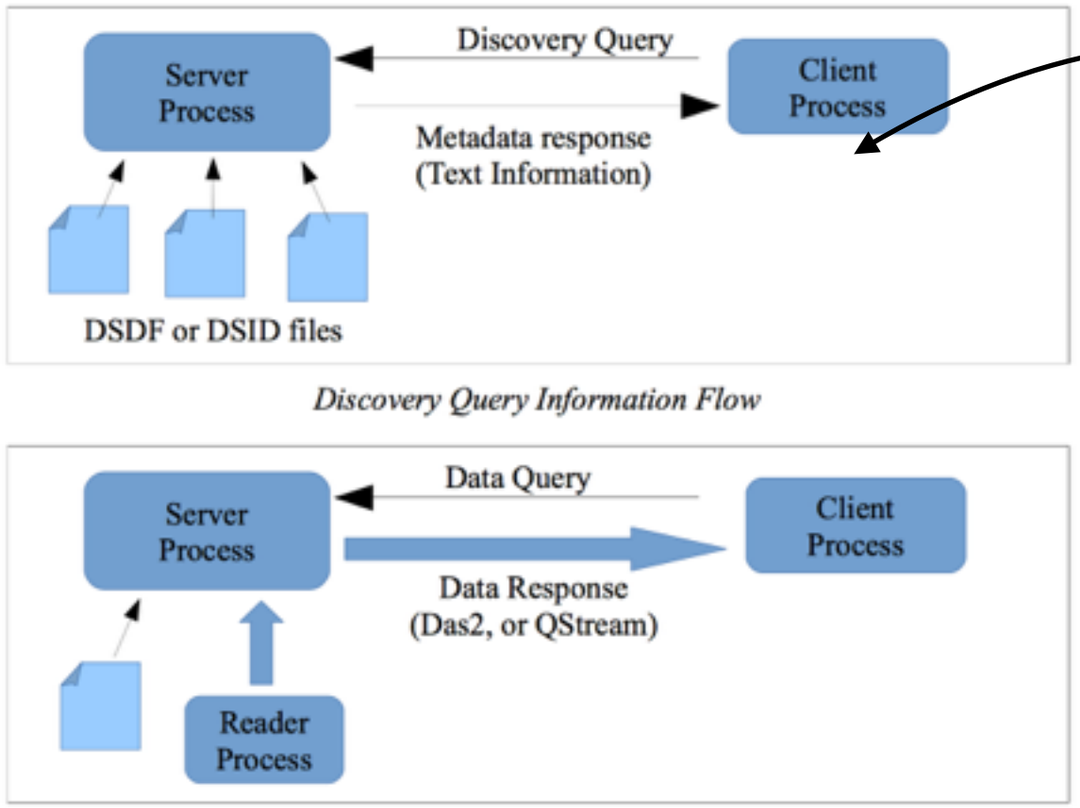
- Existing solution developed by University of Iowa (USA):
  server=**Das2** (http://das2.org) and client=**Autoplot** (http://autoplot.org)

- **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.

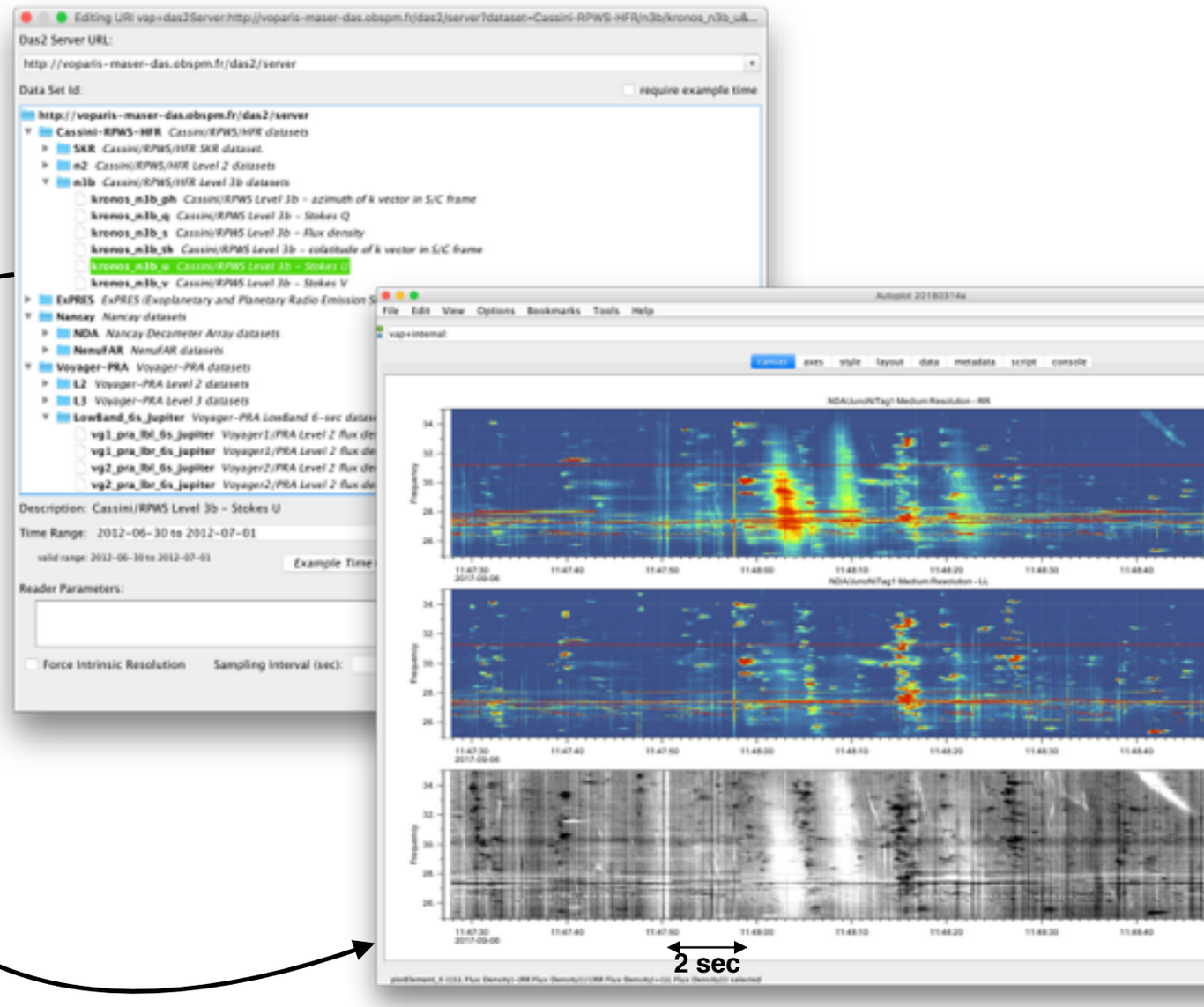
- Implemented on LESIA, CDPP, and Nançay data collections (using the Maser4py modules):
  - LESIA: http://voparis-maser-das.obspm.fr/das2/server
  - Nançay: https://das2server.obs-nancay.fr/das2/server

Das2 / Autoplot process



Discovery Query Information Flow

Data Query Information Flow



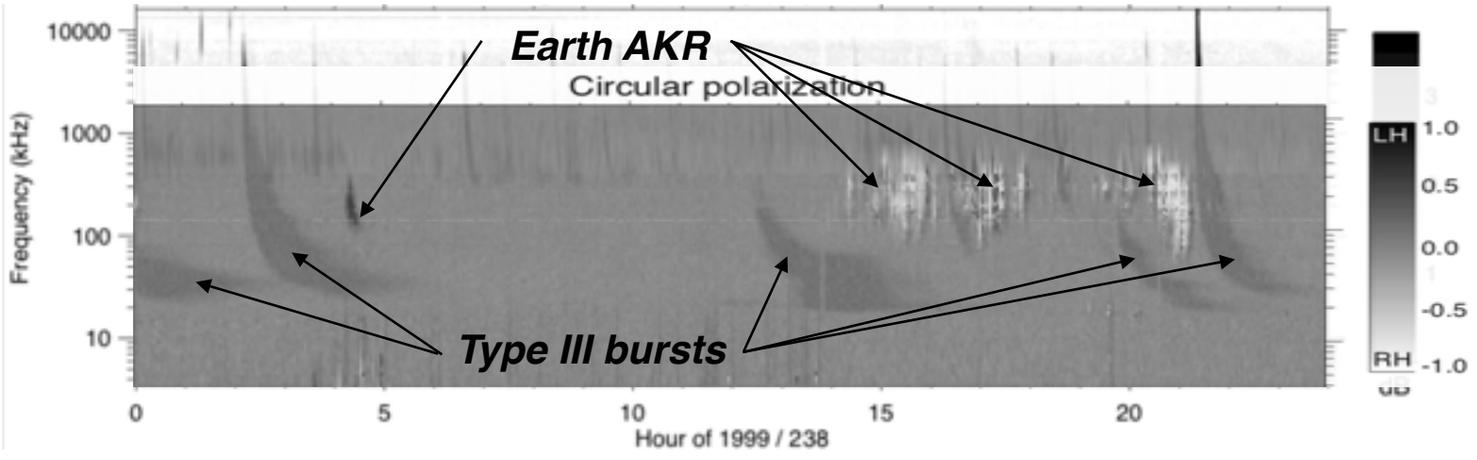
NDA/JunoN dataset (3TB/day)

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

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)

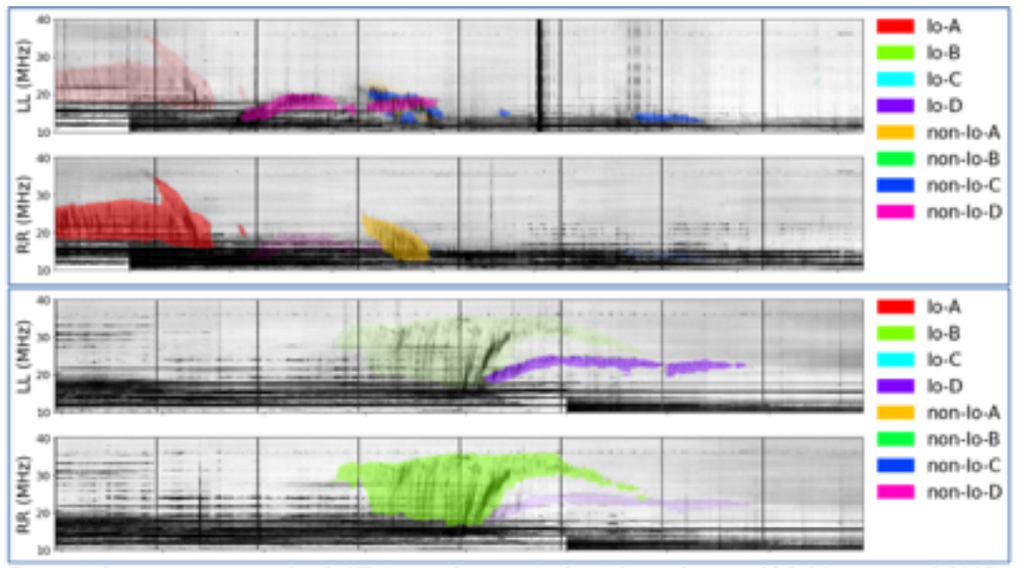


Figure 4. Spectrogrammes radio du NDA annotés, avec (en haut) le catalogue publié (Marques et al. 2017), (au milieu) les événements reconstruits pour la même observation, et (en bas), de nouveaux événements sur une observation récente (hors du catalogue d'entrainement).

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.

TFCat current implementation

- **Based on GeoJSON**, a catalogue model & format for geo-referenced shapes (on Earth, with lat-long coordinates).

- **Specification:** https://gitlab.obspm.fr/maser/catalogues/catalogue-format/-/blob/master/json/spec.md

- JSON Schema coming soon (and validator in STILTS?)

- Implementation in Python reusing GeoJSON python library

- **With astronomy standards** when applicable:
  - Using IVOA vocabularies (UCD, VOUnits…) as much as possible
  - *STC1*: no support for *complex spectro-temporal geometries** / STC2: the same
  - *VOTable*: no support for *complex spectro-temporal geometries**
  - Use of TAP for distributing and searching?
  - Geometry in TAP and ADQL?
  - *Datalink* to link catalogue of feature to catalogue of observation?
  - Export to *Astropy* table: ok, possible for complex geometries (as objects)

NB: *complex spectro-temporal geometries = something else than a point or a bounding box*

TFCat + TAP exploration

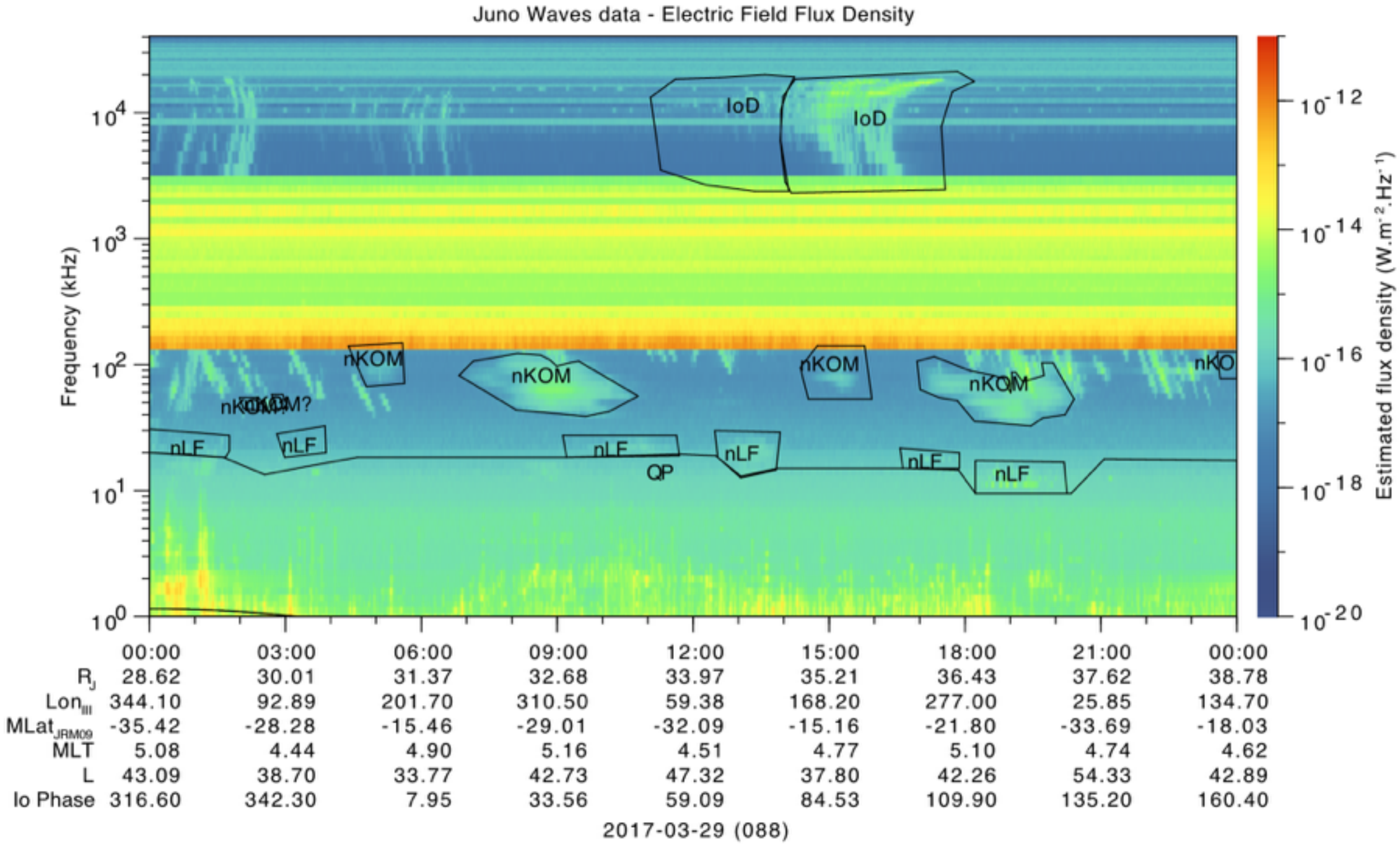
- 1 Feature per row, Geometry as JSON string, Feature mapped properties into columns
- JSON-string allows to keep all information (geometry type, CRS, coordinates) of Feature for future use.

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],

TFCat in Autoplot

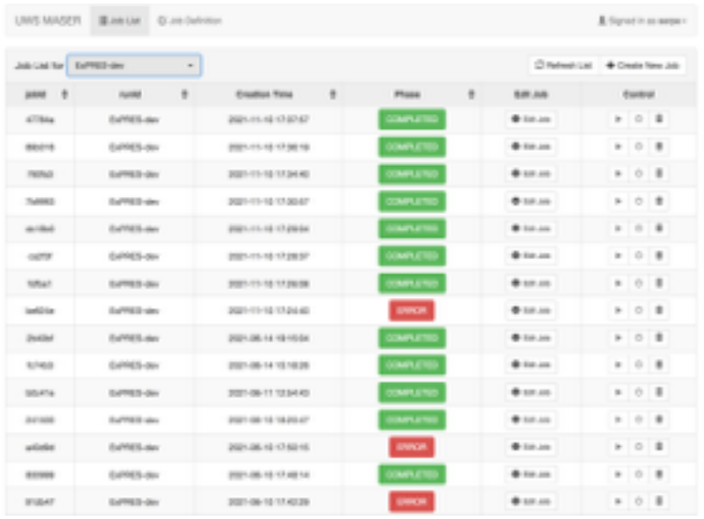


UWS for run on demand

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

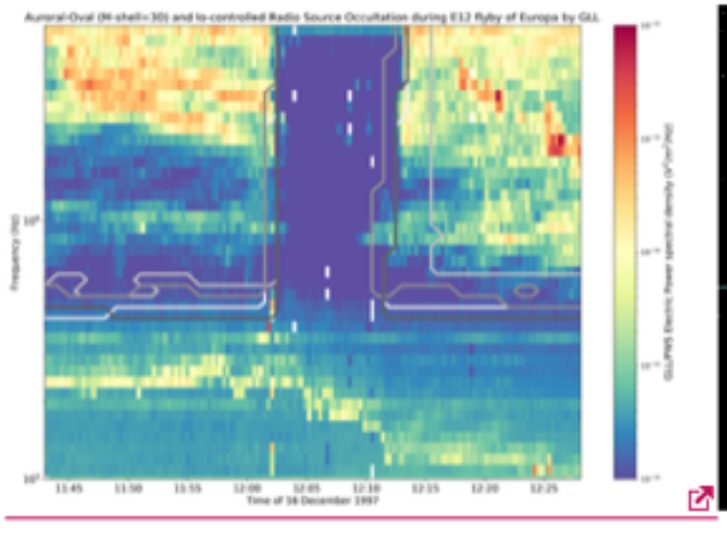
- Modelling of the spectro-temporal shape of radio emissions.

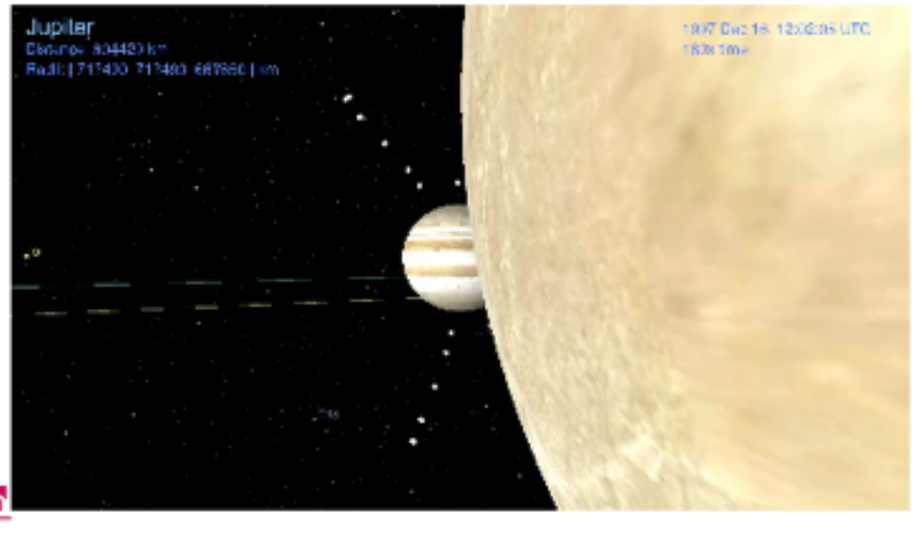
- Used in *Cecconi et al., Planet. Space Sci (2021)*
  mission planning of JUICE
  supplementary material: https://doi.org/10.25935/8ZFF-NX36



Galileo E12 Flyby

- ExPRES data (ExPRES configuration and output)
- Cosmographia data (Cosmographia configuration, `pov' and `top' movies)





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