# Virtual Observatory tools and Amateur Radio Observations Supporting Scientific Analysis of Jupiter Radio Emissions


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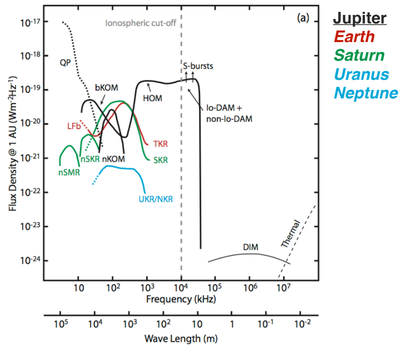
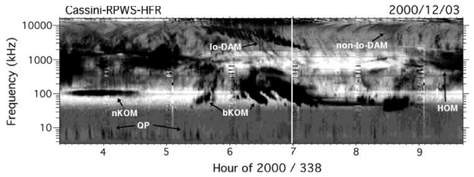
## Abstract

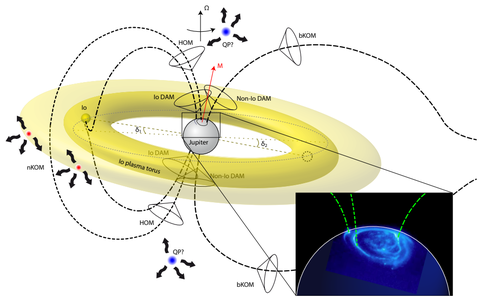

In the frame of the preparation of the NASA/JUNO and ESA/JUICE (Jupiter Icy Moon Explorer) missions, and the development of a **planetary sciences virtual observatory** (VO), we are proposing a new set of tools directed to data providers as well as users, in order to ease data sharing and discovery. We will focus on ground based planetary radio observations (thus mainly Jupiter radio emissions), trying for instance to enhance the temporal coverage of jovian decametric emission. The data service we will be using is EPN-TAP, a planetary science data access protocol developed by **Europlanet-VESPA** (Virtual European Solar and Planetary Access). This protocol is derived from IVOA (International Virtual Observatory Alliance) standards. The **Jupiter Routine Observations from the Nancay Decameter Array** are already shared on the planetary science VO using this protocol. Amateur radio data from the **RadioJOVE** project is also available. We will first introduce the VO tools and concepts of interest for the planetary radioastronomy community. We will then present the various data formats now used for such data services, as well as their associated metadata. We will finally show various prototypical tools that make use of this shared datasets.


## Jovian Radio Emissions




**Jupiter**
***Earth***
***Saturn***
***Uranus***
***Neptune***




## RadioJOVE Project

**RadioJOVE** is an educational and public outreach project developed in the USA that introduces low frequency radioastronomy concepts to students and teachers, but also the amateur radio community as well as the general public. The participants are building their own radio telescope, using a kit sold by the Radio JOVE team. This instrument can observe the sky at frequencies around 20 and 30 MHz. The users can share their observations on an archive web site, and on a mailing list. About 1000 kits have been shipped to date.

Radio-JOVE web site: http://radiojove.gsfc.nasa.gov
Radio-JOVE data Archive : http://radiojove.org/cgi-bin/calendar/calendar.cgi

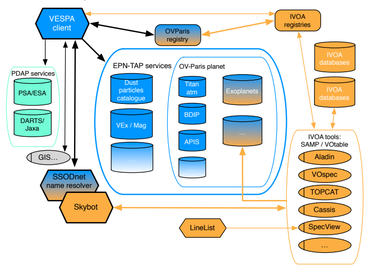
Picture of RadioJOVE antennas © Radio-JOVE/GSFC

Two types of receivers are used in the RadioJOVE project: the classical single frequency radio kit (tuned around 20 Mhz), and wide band analyzers covering a typical range of 15 to 40 MHz. There are many narrow-band analyzers and a few wide-band ones. The interest of the wide band data is scientifically obvious, as it directly compares with professional radio instruments such as the Nançay Decameter Array (France), the Iitate Radio Observatory (Japan), the LWA (USA) or LOFAR (Europe). The narrow-band data can also be used, but an assessment of the data usability should be done.

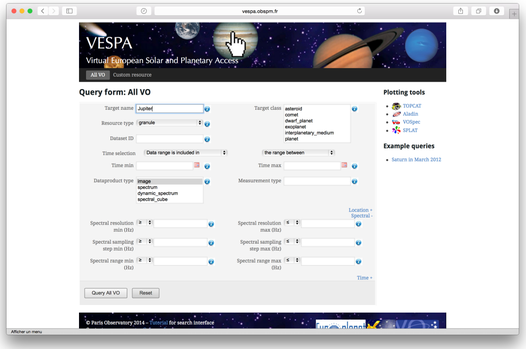
A year ago, VOParis team has approached RadioJOVE to help them distributing their data towards the scientific community. We proposed to share the RadioJOVE data using the Planetary Science Virtual Observatory developed during the EU-funded Europlanet project.

## Europlanet/VESPA

VESPA (Virtual European Solar and Planetary Access) is an planetary science virtual observatory infrastructure based on IVOA (International Virtual Observatory Alliance) and IPDA (International Planetary Data Alliance) standards.




The data shared via VESPA can be accessed by standard TAP clients (e.g. TOPCAT), but also using the generic VESPA query interface available at: http://vespa.obspm.fr

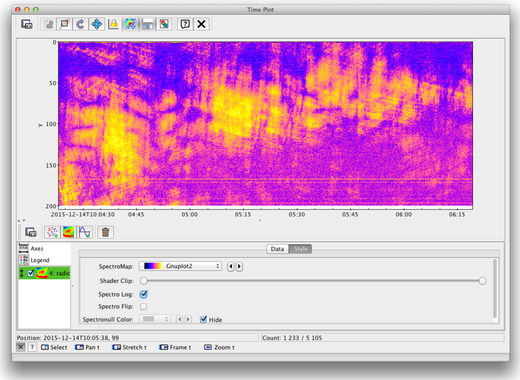



This web-based form is proposing to search for data using physical parameters such as: time range, spectral range, data type, target name… Currently 14 data repositories are connected in VESPA, while 6 are under development. During the upcoming EPN2020-RI project we plan to include about 40 other repositories. ESA has also committed to implement a VESPA interface on top of the planetary science archive (PSA).

## RadioJOVE in VESPA

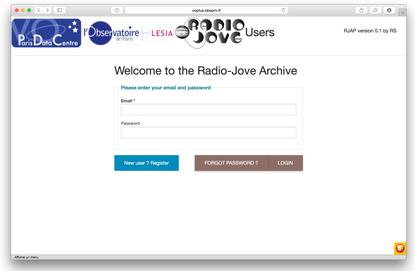
The RadioJOVE data is currently provided in various formats that are not directly usable by the scientific community. Most of the shared data is distributed as screen shots. The narrow-band data providers are usually sharing data files in WAV or MP3 formats. These data format don't include any metadata, which makes it very difficult to define the provenance and relevance of the data. The wide-band data providers are using the direct output binary format from the RadioSkyPipe software.

The VOParis team has built a data format translator that produces CDF files, including additional metadata. Those CDF files are ISTP compliant (required for HPDE and SPDF interoperability), PDS4 compliant (required for PDS archiving) and VESPA compliant. These CDF files can be loaded into plotting software for rapid data display. Here an example of data loaded in TOPCAT (an IVOA tool):

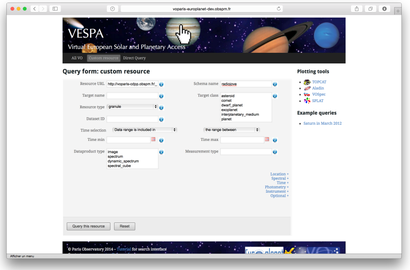



The VOParis and RadioJOVE teams are now working on a RadioJOVE archive service, with an online submission form for data providers. The submitted data will be review by a panel of scientific validators. This step this required for ensuring the data is scientifically valuable. After this validation step, the data files are automatically ingested into a PostgreSQL database used to share date in VESPA. During the ingestion pipeline, data previews are computed using a scriptable version of TOPCAT (the STILTS library). The screenshots below are illustrating the data submission, validation and search.

RadioJOVE Archive Login Page

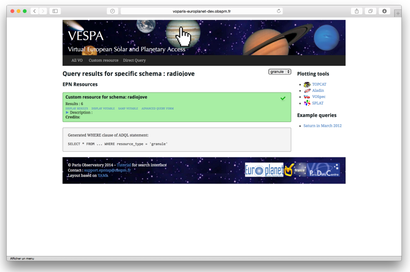



Search RadioJOVE in VESPA



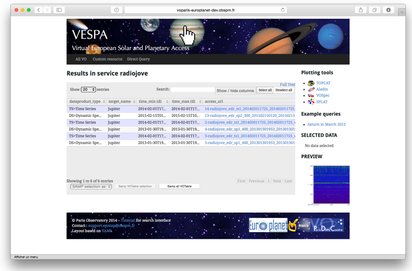

Logged-in as a data validator


RadioJOVE data archive in VESPA: overview




Logged-in as a data provider


RadioJOVE data archive in VESPA: detailed view




## Summary

The VOParis and RadioJOVE teams are preparing a new archive to share the RadioJOVE data to the community. A proposal is also being prepared to archive the RadioJOVE validated data at PDS/PPI node. The current implementation of CDF data files are compliant with the PDS4 archiving standard. Sharing data using VESPA will ease data search and access.
In the future, links with the VWO (USA based Virtual Waves Observatory) will be studied.