

MASER (Measuring Analyzing & Simulating Emissions in Radio frequencies), a Toolbox for Low Frequency Radio Astronomy

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Abstract

The MASER (Measuring, Analysing and Simulating Radio Emissions) project provides a comprehensive infrastructure dedicated to low frequency radio emissions (typically < 50 to 100 MHz). The four main radio sources observed in this frequency are the Earth, the Sun, Jupiter and Saturn. They are observed either from ground (down to 10 MHz) or from space (down to a few kHz). Ground observatories are more sensitive than space observatories and capture high resolution data streams (up to a few TB per day for modern instruments). Conversely, space-borne instruments can observe below the ionospheric cut-off (10 MHz) and can be placed closer to the studied object. Several tools have been developed in the last decade for sharing space physics data. Data visualization tools developed by the CDP (http://cdp.eu, Centre de Données de la Physique des Plasmas, in Toulouse, France) and the University of Iowa (Autoplot, http://autoplot.org) are available to display and analyse space physics time series and spectrograms. A planetary radio emission simulation software is developed in LESIA (ExPRES: Exoplanetary and Planetary Radio Emission Simulator). The VESPA (Virtual European Solar and Planetary Access) provides a search interface that allows to discover data of interest for scientific users, and is based on IVOA standards (astronomical International Virtual Observatory Alliance). The University of Iowa also develops Das2server that allows to distribute data with adjustable temporal resolution. MASER is making use of all these tools and standards to distribute datasets from space and ground radio instruments available from the Observatoire de Paris, the Station de Radioastronomie de Nançay and the CDP deep archive. These datasets include Cassini/RPWS, STEREO/Waves, WIND/Waves, Ulysses/URAP, ISEE3/SBH, Voyager/PRA, Nançay Decameter Array (Routine, NewRoutine, JunoN), RadioJove archive, swedish Viking mission, Interball/POLRAD... MASER

also includes a Python software library for reading raw data. This work is supported by CDPP, CNES, PADC and Europlanet-2020-RI. The Europlanet 2020 Research Infrastructure project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208.

MASER (Measuring Analyzing & Simulating Emissions in Radio frequencies)
— a toolbox for low frequency radio astronomy —

B Cecconi^{1,3}, P Le Sidaner², **Alan Loh**¹, R Savalle², X Bonnin¹, **Q N Nguyen**¹, S Lion¹, A Shih², S Aicardi², P Zarka^{1,3}, C Louis¹, A Coffre³, L Lamy^{1,3}, L Denis³, J-M Griessmeier⁴, J-L Pinçon⁴.

A Toolbox for Data Providers

- Distribute data catalogues
- Distribute data for direct access
- Standard APIs

A Toolbox for Scientists

- Search for data of interest
- Visualize online data
- Use a library of tools and codes

An Open Toolbox

- Interoperable standards
- Virtual Observatory access
- Reuse of existing software

Interfaces

- Distribution of catalogues (events and products) : **VESPA**
- Online visualization: **Das2+Autoplots**

What Data?

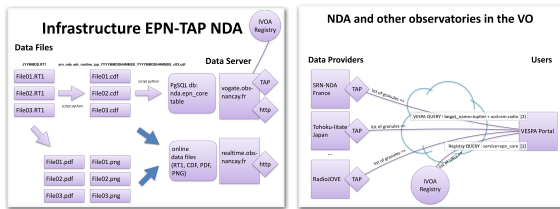
- Low Frequency radio data: up to ~100 MHz
- Mostly spectrograms (time-frequency)
- Ground observatories and Space platforms
- Catalogues of events
- Raw and derived data
- Standard formats (CDF) and metadata

Main Tools and Software

- **EXPress** (Exoplanetary & Planetary Radio Emissions Simulator) Simulation of CMI [maser cyclotron instability] emissions. Public query interface coming soon.
- **Maser4py**: Python (3.5+) software library
<https://github.com/maserlib/maser4py> (open source)
- **ARTEMIS-P** (ray tracing code for planetary radio emissions)
[available soon]
- **Das2** servers (currently under test): Meudon and Nançay.
<http://voparis-maser-das.obspm.fr/das2/server>
- **Project interfaces**: Juno-Ground-Radio, RadioJOVE



- Member of the **Helio-Python** working group
- Interoperability:
 - IHDEA: <https://ihdea.net>
 - IPDA: <https://planetaryrdata.org>
 - IVOA: <http://www.ivoa.net>
- Link with SPASE under study
 - Reorganization of Observatories and instruments
 - NumericalData and Display Data
- Distributing CDDP radio datasets through authenticated webervices

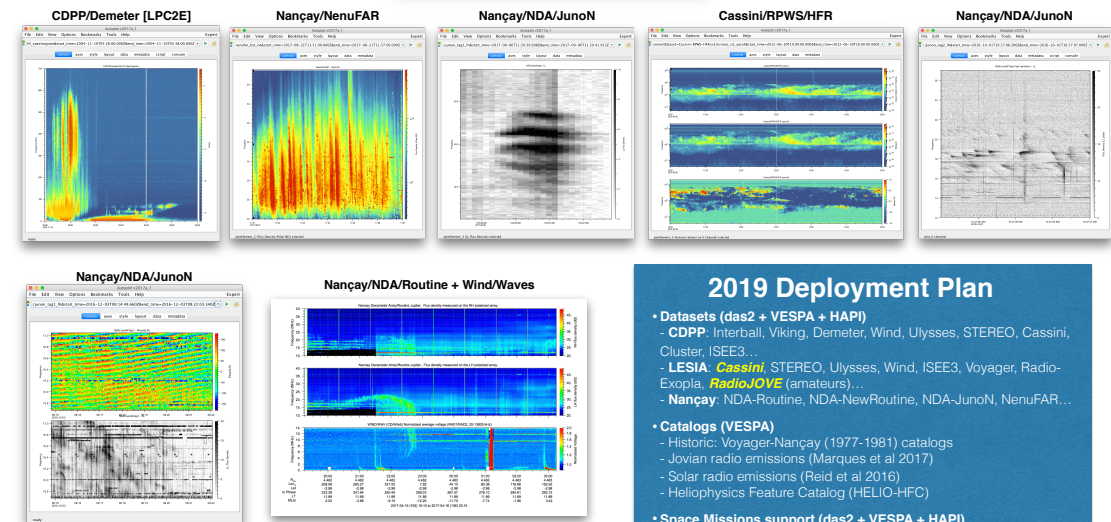
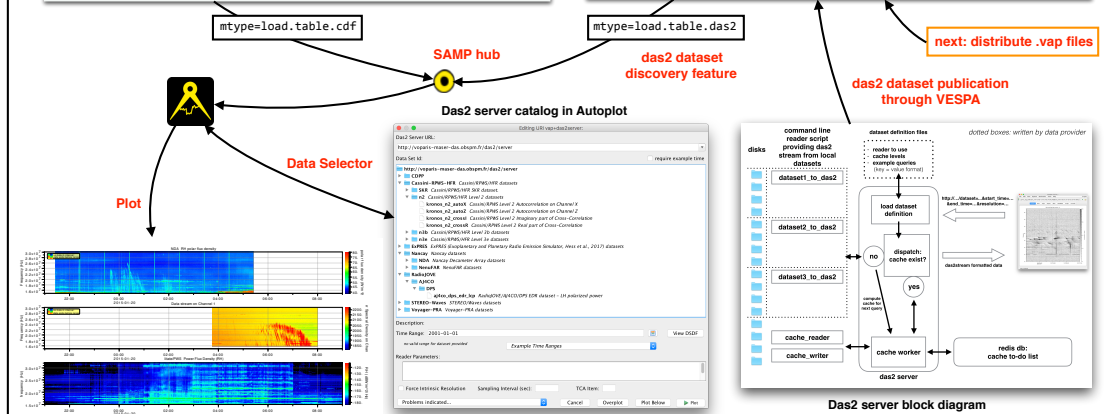
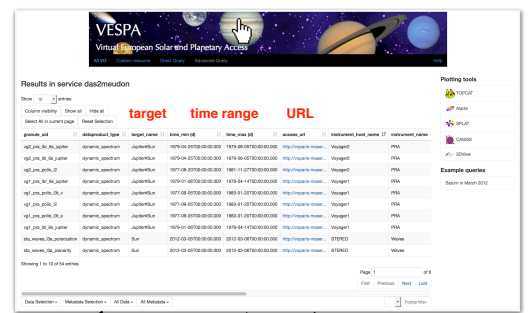
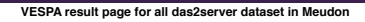
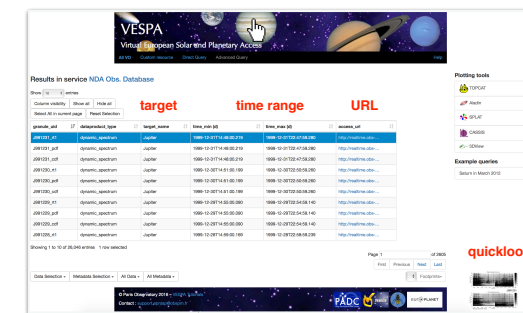
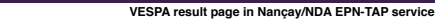
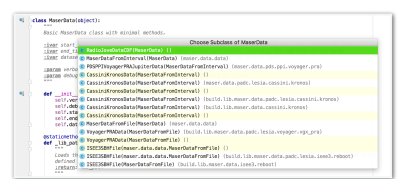
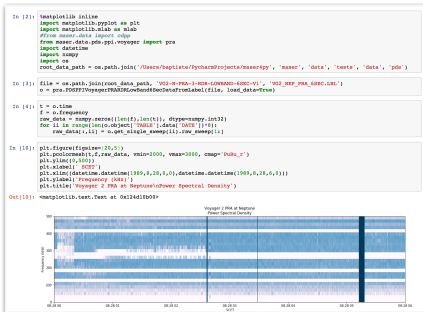


Open Source Library

- **Maser4py** library:
 - Data reader classes for LF radio data collections, Unit tests built-in <https://github.com/masertlib/maser4py/tree/develop>
 - Generic tools and software for LF radio astronomy
 - Ground segment software for Solar-Orbiter/RPW, CDF file building helper tools
- **Maser4idl** library:
 - some software for STEREO and Wind, as well as HELIO. Cassini/RPWS/HFR to come soon
 - CDF building tools

Maser4py data classes

naser.data.cdpp	develop	tested
naser.data.cdpp.demeter.ice	develop	tested
naser.data.cdpp.intercal.polrad	develop	tested
naser.data.cdpp.isaac.abb	develop	tested
naser.data.cdpp.demeter.ice	develop	tested
naser.data.cdpp.ulysses.urup	develop	coming soon
naser.data.cdpp.viking.v4n	develop	tested
naser.data.cdpp.wind.waves	develop	tested
naser.data.nancy	feature/data	tested
naser.data.nancy.nda	feature/data	tested
naser.data.nancy.nda.junon	feature/data	tested
naser.data.nancy.nda.newroutein	feature/data	tested
naser.data.nancy.nda.routine	feature/data	tested
naser.data.nancy.nemusa	feature/data	tested
naser.data.pdc.lesia.cassini.kronos	develop	tested
naser.data.pdc.lesia.cassini.rwps	develop	tested
naser.data.pdc.lesia.voyager.vgpr	feature/data	tested
naser.data.pdc.radiojove.radiojove_spx	feature/data	tested
naser.data.pdc.ppi.pds	feature/data	tested
naser.data.pdc.ppi.cassini.rwps	feature/data	tested
naser.data.pdc.ppi.cassini.rwps.hfr	feature/data	tested
naser.data.pdc.ppi.cassini.rwps.vbr	feature/data	tested
naser.data.pdc.ppi.cassini.voyager.pra	feature/data	on the move
naser.data.solo	develop	on the move
naser.data.wind	develop	on the move



2019 Deployment Plan

- **Datasets (das2 + VESPA + HAPI)**
 - **CDPP**: Interball, Viking, Demeter, Wind, Ulysses, STEREO, Cassini, Cluster, ISEE3...
 - **LESIA**: *Cassini*, STEREO, Ulysses, Wind, ISEE3, Voyager, Radio-Exopla, *RadioJOVE* (amateurs)...
 - **Nancay**: NDA-Routine, NDA-NewRoutine, NDA-JunoN, NenuFAR...
- **Catalogs (VESPA)**
 - Historic: Voyager-Nancay (1977-1981) catalogs
 - Jovian radio emissions (Marques et al 2017)
 - Solar radio emissions (Reid et al 2016)
 - Heliophysics Feature Catalog (HELIO-HFC)
- **Space Missions support (das2 + VESPA + HAPI)**
 - Solar Orbiter/Parker Solar Probe
 - Juno-Ground Radio
- **Codes**
 - **EXPRES** run-on-demand interface (advanced prototype ready).
 - Implementation of Helio-Python guidelines