Sharing Planetary Radio Emission Dataset in the Virtual Observatory

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ASBTRACT

We are proposing a new set of tools directed to data providers as well as to users, in order to ease sharing and discovery of low frequency radio astronomy datasets. We focus on ground based planetary radio observations (thus mainly Jupiter radio emissions). The data service we are using is EPN-TAP, a planetary science data access protocol developed by VOParis and CDPP in the frame of the FP7 Europlanet/IDIS (Integrated and Distributed Information Service) project. This protocol is derived from IVOA (International Virtual Observatory Alliance) standards. The Jupiter Routine observations from the Nançay Decameter Array are already shared on the planetary science VO using this protocol. We introduce the VO tools and concepts of interest for the planetary radio astronomy community. We then present the various data formats now used for such data services, as well as their associated metadata. We finally show various prototype tools that make use of this shared datasets.

INTRODUCTION

In the double frame of the preparation of the ESA JUICE mission and the development of a planetary sciences virtual observatory (VO), we propose a framework that aims at enhancing the access to existing databases. The low frequency range (from 1 few kHz to 50 MHz) is including planetary and solar radio emissions. We concentrate here on planetary radio emissions, but the system presented here will include solar observation data as well. The main planetary radio emissions in this frequency range are those of Jupiter, mainly emitted by the

Io-Jupiter plasma interaction. The radio emissions are a remote monitoring tool of the magnetospheric activity of planets. In the case of Jupiter, one aim of this project is to enhance the temporal coverage of the Jovian Decametric (DAM) emissions by providing easy access to datasets from observatories located at various places on Earth or in space.

In order to provide this access, we use the developments that have been conducted in the frame of the EuroPlaNet-RI FP7 program[1]. We have chosen to promote the EPN-TAP[2] standard as it was designed from well-recognized IVOA[3] standards, slightly adapted to fit the needs of the planetary science community.

LOW FREQUENCY RADIO EMISSIONS

The low frequency radio emissions of the solar system are emitted by either the Sun and its

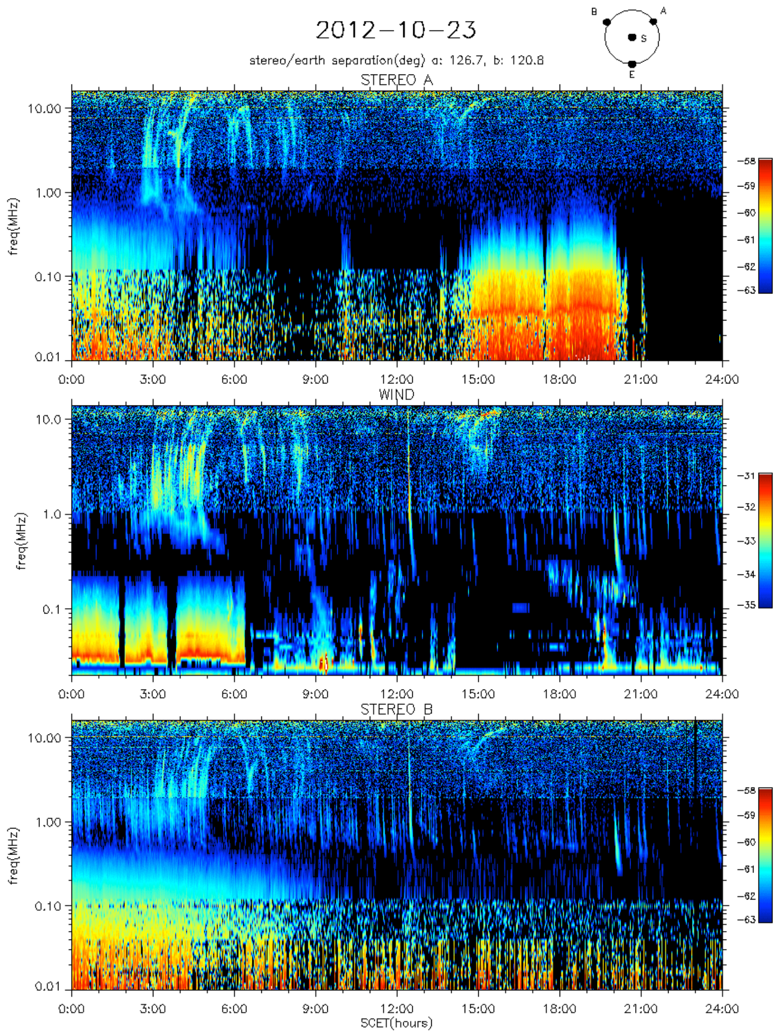

Fig. 1. Low frequency radio emissions observed simultaneously by three spacecrafts (top to bottom: STEREO-A, Wind and STEREO-B) separated by 120° along the orbit of Earth, on Oct. 23rd, 2010. The same structures are observed on each of the three dynamic spectra: arc-shaped structures (above 200 kHz) are coming from Jupiter; thin vertical line with a slight drift a below 500 kHz are Solar Type III bursts; and the low frequency structures are linked to the local environment.

[1] The EuroPlaNet RI project was funded by the European Commission under the 7th Framework Program, grant 228319 "Capacities Specific Programme".

extended atmosphere (the Solar Wind) or by the magnetized planets. The main radio emissions seen from the orbit of Earth are shown on Figure 1, where Solar and Jovian radio emissions are visible. The three panels of this figure are simultaneous observation from various places in the inner solar system. Each radio emission are not visible on all panel and when they are visible, they are not exactly similar. This illustrates their temporal variability and sporadicity, as well as their anisotropic emission pattern. Furthermore, contrarily to spectral lines linked to atomic and molecular phenomena, the low frequency radio emissions have a wide spectral extent, and their shape in the time-frequency plane is linked to the emission processes and to the sources properties. Hence, these radio data are usually displayed in so-called "dynamic spectra" (or spectrograms) with the abscissa being the temporal axis, the ordinates being the spectral axis, and the displayed parameter intensity color-coded. The typical physical parameters that are used to study these radio emissions are mainly the spectral flux density and the linear and circular polarization degrees. In addition to these, when the sensing device provides such information (e.g., with goniopolarimetric system), the direction of arrival of the wave and the source spatial extension may also be displayed.

EXISTING DATABASES

There are many databases containing low frequency radio astronomy datasets, but they are usually in diverse formats and available through interfaces that can not be easily queried by a computer. Table 1 is providing a list of such databases and clearly shows that the community has not yet converged into a single data format and data access protocol. Even for the metadata, there are almost as many data models as databases. The main ones are PDS3, PDS4, SPASE and CDPP. The IVOA datamodels are not commonly used in planetary and solar physics. One of the goal of this study is to try to address these points: what data models, data formats and data access protocols could be selected, so that the community (both users and data providers) can easily adopt it. The selected data model must be easily mapped to the existing ones, when different. The selected data formats should be usable in the tools used by

Agency	**Science Objective**	**Archive (format)**	**Missions / Observatory**	**Access**
NASA	Planetary	PDS (PDS, *CDF*)	Voyager, Galileo, Cassini, JUNO	HTTP, FTP
NASA	Sun-Earth	CDAweb (CDF)	WIND, STEREO	HTTP, WSDL
ESA	Planetary	PSA (PDS, *CDF*)	Bepi-Colombo/MPO, JUICE	HTTP, FTP, PDAP
JAXA	Earth, Planets	DARTS (CDF, PDS)	Geotail, Bepi-Colombo/MMO	HTTP, PDAP
CNES	All	CDPP (CDF, native)	Interball, Cluster, Viking (Swedish), Cassini, STEREO	HTTP, WSDL, EPN-TAP
Obs. Paris	Jupiter, Sun	RDN (Native, FITS, VOTable)	Nançay Decameter Array	HTTP, EPN-TAP
Tohoku Univ.	Jupiter, Sun	Iitate (FITS)	Iitate Observatory	HTTP
ETH Zurich	Sun	e-Callisto (FITS)	Plenty of stations all over the world.	HTTP
LOFAR	All	(HDF5)	LOFAR proposals	Not defined yet

Tab. 1. List (non exhaustive) of existing databases providing low frequency radio data. Data formats in italics are for not yet approved formats in the corresponding database.

[2] EPN-TAP (EuroPlaNet-Table Access Protocol): http://voparis-europlanet.obspm.fr/docum.shtml
[3] IVOA (International Virtual Observatory Alliance): http://www.ivoa.net/

the community, and should be able to embed the required metadata. The selected access protocols should be adapted to the data objects. From Table 1, we can see that the CDF format is commonly used for space missions, the FITS format is used by the solar community; whereas the more recent instrument (LOFAR) is now using the HDF5 file format.

In addition to these observational databases, there are also modeling databases such as the ExPRES[4] service at LESIA, Observatoire de Paris, which simulates the geometrical visibility of planetary radio emissions. This database should also be accessible in the tools to be developed or selected, in order to compare data to simulations.

ARCHITECTURE AND STANDARDS

The overall architecture of the system is shown on Fig. 2. The future radio data visualization tool (draft prototype available here: http://sacred.latmos.ipsl.fr/SILFE/) will be able to access remote data repositories and simulation databases using EPN-TAP. The exchange format is not defined yet. The selected data format will have to allow the inclusion of the required metadata. We propose to use the IVOA registry for harvesting data services and to initiate the data queries.

We have selected 5 data formats for this study: VOTable[5], CDF[6], netCDF[7], FITS[8] and HDF5[9]. We will concentrate on the VOTable format in this paper show two ways of distributing solar system radio data using IVOA standards. The four other formats will also be briefly discussed.

The data access is proposed to be EPN-TAP, as it has been designed to convey planetary data. It is also adapted for solar data. EPN-TAP is using the IVOA TAP (Table Access Protocol), specifying a series of keywords and authorized values adapted to planetary sciences. A similar effort is currently under study within IVOA and is called Obs-TAP, but is still too focused on

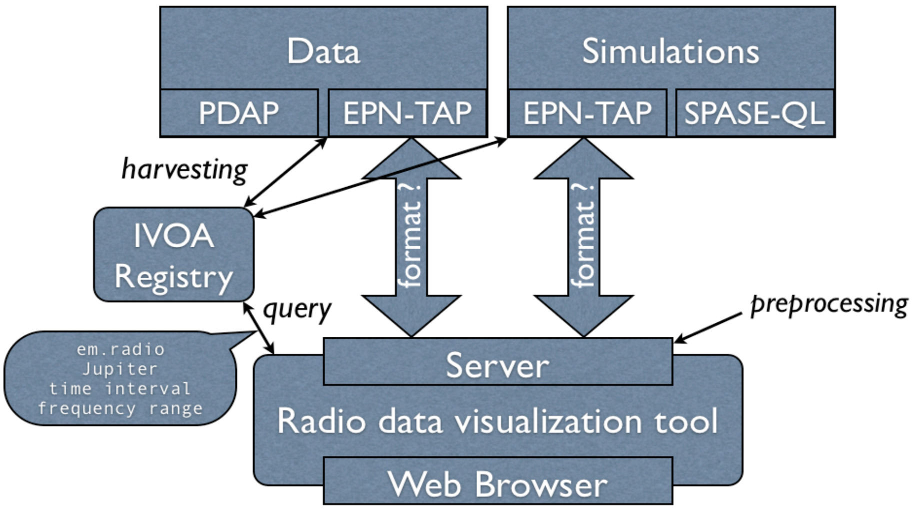

Fig. 2. Proposed architecture for the radio data visualization tool, including data and simulation repositories, the IVOA registry and the selected data access protocol EPN-TAP.

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[4] ExPRES (Exoplanetary and Planetary Radio Emission Simulator)
[5] VOTable specification: http://www.ivoa.net/documents/VOTable/
[6] CDF: http://cdf.gsfc.nasa.gov
[7] netCDF: http://www.unidata.ucar.edu/software/netcdf/
[8] FITS: http://fits.gsfc.nasa.gov/ and [Pence et al, 2010]
[9] HDF5: http://www.hdfgroup.org/HDF5/

sky coordinates and astrophysical objects to be used in the frame of planetary sciences. EPN-TAP implementation is using the DaCHS[10] framework, which provides an easy-to-install, well-documented and maintained software package including TAP. EPN-TAP has been implemented on several VOParis databases, as well as on the Nançay Decameter Array Jupiter Routine Observation. The implementation of EPN-TAP at the CDPP is ongoing, at time of writing. It is also planned to be implemented on the Cassini/Kronos[11] database at LESIA, and on the ExPRES database. An EPN-TAP client interface[12] has been set up at VOParis.

DATA DISTRIBUTION FORMATS

As discussed already discussed, several formats are used by the community to distribute radio data. We will present these formats and concentrate mainly on the VOTable format, which is XML-based and developed by IVOA. Its main advantage is to be compliant by design to IVOA standards. However we also explore the use of FITS, CDF, netCDF and HDF5 standards.

Distributing data with VOTable

The VOTable format is an XML-based format. It is well adapted to tabular data, which is the case for radio dynamic spectra. It is also well adapted to attach metadata to a data resource. We have explored two implementations of radio data in the form of VOTable, depending on the structure of the data. Radio receiver can indeed provide spectra on a fixed series of frequencies, or with various operating modes with variable spectral sampling. While the latter mode is usually used in space-borne observations (the frequency sampling is adapated to the science objectives at a given time and location of the spacecraft), the former mode is generally used for ground-based observatories. We present in the next two sections each implementation, using two examples: "fixed frequency sampling mode" is illustrated with Nançay Decameter Array data, and "variable frequency sampling mode" is illustrated with Cassini/RPWS data.

Fixed frequency sampling mode

In this case, the data is sampled on a list of frequencies, which is fixed for the whole dataset. Each spectrum has then the same length, throughout the dataset. We then provide the data in the form of a time series of spectra, each spectrum being a list of *N* values, where *N* is the number of sampled frequencies. The description of the spectral axis (number of frequencies, values of the frequencies, frequency resolution, frequency bandwidth…) is provided in the header of the VOTable. The spectral axis description is also using the SpectrumDM[13] proposed by IVOA. Fig. 3 shows an example of a spectral axis specification in a VOTable, using utype attributes to link the parameters to the SpectrumDM (with the prefix '`spec:`' that should defined in the VOTable element. We describe the spectral axis name, the number of frequencies, the minimum and maximum frequencies, the list of frequencies, the frequency sampling (distance between two frequency steps) and resolution (bandwidth of the spectral filters. For each element, we provide the unit (compliant to VOUnits[14]), a UCD[15], which

[10] DaCHS (Data Center Helper Suite): http://vo.ari.uni-heidelberg.de/soft/dachs
[11] Cassini/Kronos server: http://www.lesia.obspm.fr/kronos
[12] EPN-TAP client: http://voparis-europlanet-new.obspm.fr/
[13] SpectrumDM specification: http://www.ivoa.net/documents/SpectrumDM/
[14] VOUnits: http://www.ivoa.net/documents/VOUnits/index.html
[15] UCD: http://www.ivoa.net/documents/latest/UCDlist.html

provides information on the content of that parameter, and a utype, which links to a data model element. The <GROUP> element that contains this description should have an ID, which used in the <FIELD> descriptions of the VOTable. The <FIELD> elements are used to describe the columns of the table. In our example (see Fig. 4), we propose three columns: the date of observation in Julian Day, the date of observation in ISO-8901 format and a spectral column containing a series of 400 values per date of observation. Each <FIELD> element contains attributes that indicate how to interpret the data. The spectral column refers to the spectral axis definition with the "ref="freq_table"" attribute. Then, the data section can be either formatted as a table (identical to an HTML table) or an encoded data stream (with BASE64 encoding).

The specification of the "fixed frequency sampling mode" VOTable could be described as follows:

- A GROUP element must be declared with an ID such as <GROUP ID="freq_table">. It must contain the spectral axis information (mininum, maximum, values, resolution...) linking to the Spectrum DM using utype attributes.
- Each line of the table corresponds to an observation date
- Each column (defined with a FIELD element) containing a spectrum must have a reference to the spectral axis group (ref="freq_table"). It is possible to have as many spectral columns as available observables.
- Several frequency table groups may be defined if necessary.
- Base64 encoding is recommended but not mandatory.

The main advantages of this data formatting proposition are: the spectral structure of the data is preserved, so that it requires little work on the data provider side to implement it; the metadata is clearly exposed (readily readable). The main drawback is that the existing IVOA tools reading VOTable (such as TOPCAT[16]) can not make an efficient use of it.

```
<GROUP ID="freq_table" utype="spec:Char.SpectralAxis">
    <PARAM value="Frequency" datatype="char" arraysize="*" name="Spectral Axis Name"
        utype="spec:Char.SpectralAxis.Name"/>
    <PARAM datatype="int" name="Number of Frequencies" ucd="meta.number" value="400"
        utype="spec:Length"/>
    <PARAM value="10.0000" datatype="float" name="Minimum Frequency" unit="MHz"
        ucd="em.freq;stat.min" utype="spec:Char.SpectralAxis.Coverage.Bounds.Range.Min"/>
    <PARAM value="40.0000" datatype="float" name="Maximum Frequency" unit="MHz"
        ucd="em.freq;stat.max" utype="spec:Char.SpectralAxis.Coverage.Bounds.Range.Max"/>
    <PARAM datatype="float" name="Frequency" unit="MHz" ucd="em.freq" arraysize="400"
        utype="spec:Char.SpectralAxis.Coverage.Location.Value"
        value="10.0000 10.0750 10.1500 10.2250 10.3000 10.3750 10.4500 10.5250
        10.6000 10.6750 10.7500 10.8250 10.9000 10.9750 11.0500 11.1250 11.2000
        .......................................................................
        39.6250 39.7000 39.7750 39.8500 39.9250"/>
    <PARAM value="75.0000" datatype="float" name="Frequency Sampling Step" unit="kHz"
        ucd="em.freq" utype="spec:Char.SpectralAxis.Accuracy.BinSize"/>
    <PARAM value="30.0000" datatype="float" name="Integration Bandwdith" unit="kHz"
        ucd="em.freq" utype="spec:Char.SpectralAxis.Resolution"/>
</GROUP>
```

Fig. 3. Spectral axis description in a VOTable for fixed frequency sampling.

```
<FIELD datatype="double" name="Time (Julian Day)" ucd="time.epoch" xtype="julianDay"
    unit="d"/>
<FIELD datatype="char" arraysize="24" name="Time (ISO)" ucd="time.epoch"
    xtype="dateTime"/>
<FIELD datatype="float" arraysize="400" name="Spectral Power Density" ref="freq_table"
    unit="dB(V2/Hz)" ucd="phot.flux.density;phys.polarization.circular.LL;em.radio"/>
```

Fig. 4. Columns definition in a VOTable for fixed frequency sampling.

[16] TOPCAT: http://www.star.bris.ac.uk/~mbt/topcat/

```xml
<FIELD arraysize="*" datatype="char" name="time" ucd="time.epoch" xtype="dateTime">
    <DESCRIPTION>Cassini SCET</DESCRIPTION>
    <VALUES null="0000-00-00T00:00:00.000Z"/>
</FIELD>
<FIELD datatype="float" name="frequency" ucd="em.freq" unit="kHz" utype="">
    <DESCRIPTION>Frequency of Observation</DESCRIPTION>
    <VALUES null="0.0"/>
</FIELD>
<FIELD datatype="int" name="antenna_code" ucd="meta.id" unit="none" utype="">
    <DESCRIPTION>Antenna combination code</DESCRIPTION>
    <VALUES null="-1"/>
</FIELD>
<FIELD datatype="float" name="snr_channel_1" ucd="stat.snr" unit="dB" utype="">
    <DESCRIPTION>SNR on Channel 1</DESCRIPTION>
    <VALUES null="NaN"/>
</FIELD>
<FIELD datatype="float" name="snr_channel_2" ucd="stat.snr" unit="dB" utype="">
    <DESCRIPTION>SNR on channel 2</DESCRIPTION>
    <VALUES null="NaN"/>
</FIELD>
<FIELD datatype="float" name="stokes_s" ucd="em.radio;phot.flux.density" unit="V^2/Hz"
    utype="">
    <DESCRIPTION>Stokes parameter S (Flux Density)</DESCRIPTION>
    <VALUES null="NaN"/>
</FIELD>
<FIELD datatype="float" name="stokes_q"
    ucd="phys.polarization.stokes;phys.polarization.linear" unit="%" utype="">
    <DESCRIPTION>Stokes Parameter Q (Linear polarization degree)</DESCRIPTION>
    <VALUES null="NaN"/>
</FIELD>
<FIELD datatype="float" name="stokes_u"
    ucd="phys.polarization.stokes;phys.polarization.linear" unit="%" utype="">
    <DESCRIPTION>Stokes Parameter U (Linear polarization degree)</DESCRIPTION>
    <VALUES null="NaN"/>
</FIELD>
<FIELD datatype="float" name="stokes_v"
    ucd="phys.polarization.stokes;phys.polarization.circular" unit="%" utype="">
    <DESCRIPTION>Stokes Parameter V (Circular polarization degree)</DESCRIPTION>
    <VALUES null="NaN"/>
</FIELD>
<FIELD datatype="float" name="x_ssq" ucd="pos.cartesian.x" unit="km" utype="">
    <DESCRIPTION>Source location in Saturn Solar Equatorial (SSQ) coordinates (X
    component)</DESCRIPTION>
    <VALUES null="NaN"/>
</FIELD>
<FIELD datatype="float" name="y_ssq" ucd="pos.cartesian.y" unit="km" utype="">
    <DESCRIPTION>Source location in Saturn Solar Equatorial (SSQ) coordinates (Y
    component)</DESCRIPTION>
    <VALUES null="NaN"/>
</FIELD>
<FIELD datatype="float" name="z_ssq" ucd="pos.cartesian.z" unit="km" utype="">
    <DESCRIPTION>Source location in Saturn Solar Equatorial (SSQ) coordinates (Z
    component)</DESCRIPTION>
<VALUES null="NaN"/>
</FIELD>
```

Fig. 5. Column descriptions in a VOTable for variable frequency sampling.

Variable frequency sampling mode

In many cases (especially on space mission), the frequency sampling is changing depending on the observation targets. Although a finite number of operating modes are used for a given instrument, spitting them into as many datasets with fixed frequency sampling is of little interest. Hence, data providers has decided to either provide data with "variable record length", which is never easy to use, or to define the record as a single time-frequency measurement, removing the spectral structure of the data. The latter solution is proposed here.

Each line of the table contains the information of a time-frequency record. Hence, there should be at least two columns describing time and frequency information for each record. On Figure 6, we show an example of such a column description. This example is derived from Cassini/RPWS data and contains various parameters (operating mode, calibrated measurement, derived parameters...).

The specification of the "variable frequency sampling mode" VOTable could be described as follows:

- Each line is a single time-frequency record.
- There must be a time and a frequency column.

The advantages are: the data is "flattened" and thus very easy to describe; it can be efficiently used in IVOA tools reading VOTable, such as TOPCAT. The two main drawbacks are: the original structure of the data (output of the receiver in form of spectra) is lost; the size of the data is increased as spectral information is repeated in each record. Figures 7 and 8 show the Cassini/RPWS dataset displayed in TOPCAT.

TOPCAT(3): Table Browser

Table Browser for 3: loc_3A_SPV_2008268_18.xml

	time	frequency	antenn...	snr_channel_1	snr_channel_2	stokes_s	stokes_q	stokes_u	stokes_v
1	2008-09-24T18:00:11.140Z	3,6856	11	19,4803	21,6288	2,32804E-14	-20,8362	12,5162	32,7757
2	2008-09-24T18:00:11.140Z	3,863	11	23,1336	22,114	2,17606E-14	-7,5608	5,81703	35,0649
3	2008-09-24T18:00:11.140Z	4,0489	11	21,4208	20,1434	1,97171E-14	-40,467	5,13158	29,9641
4	2008-09-24T18:00:11.140Z	4,2437	11	21,6425	20,1894	1,32410E-14	-13,3638	-9,30969	44,6195
5	2008-09-24T18:00:11.140Z	4,448	11	22,4733	19,3944	1,95923E-14	-25,483	-22,7301	15,6127
6	2008-09-24T18:00:11.140Z	4,662	11	21,8477	18,5011	7,50072E-14	-61,7941	-59,8002	4,07813
7	2008-09-24T18:00:11.140Z	4,8864	11	19,2786	18,2874	3,25546E-12	-55,5136	82,445	-0,318288
8	2008-09-24T18:00:11.140Z	5,1215	11	22,6399	18,2237	3,75315E-14	-35,7587	33,9226	-27,6082
9	2008-09-24T18:00:11.140Z	5,368	11	16,1082	17,0273	1,76410E-14	-42,6776	33,168	29,8941
10	2008-09-24T18:00:11.140Z	5,6263	11	17,9749	17,5672	8,74972E-15	8,74416	3,66727	60,2717
11	2008-09-24T18:00:11.140Z	5,8971	11	17,6009	18,8241	3,38019E-14	-54,4925	57,7426	18,8166
12	2008-09-24T18:00:11.140Z	6,1809	11	17,8089	20,4036	1,02353E-14	-9,9243	-6,2292	62,1416
13	2008-09-24T18:00:11.140Z	6,4783	11	17,2639	18,0282	8,03935E-15	-31,7401	17,6438	49,0284
14	2008-09-24T18:00:11.140Z	6,7901	11	16,3899	17,964	4,90819E-15	-0,060158	-5,44899	80,3059
15	2008-09-24T18:00:11.140Z	7,1169	11	20,8071	23,3554	1,87782E-14	-17,8812	6,06113	73,0859

Fig. 6. Variable frequency sampling data (Nançay Decameter Array data) displayed in TOPCAT.

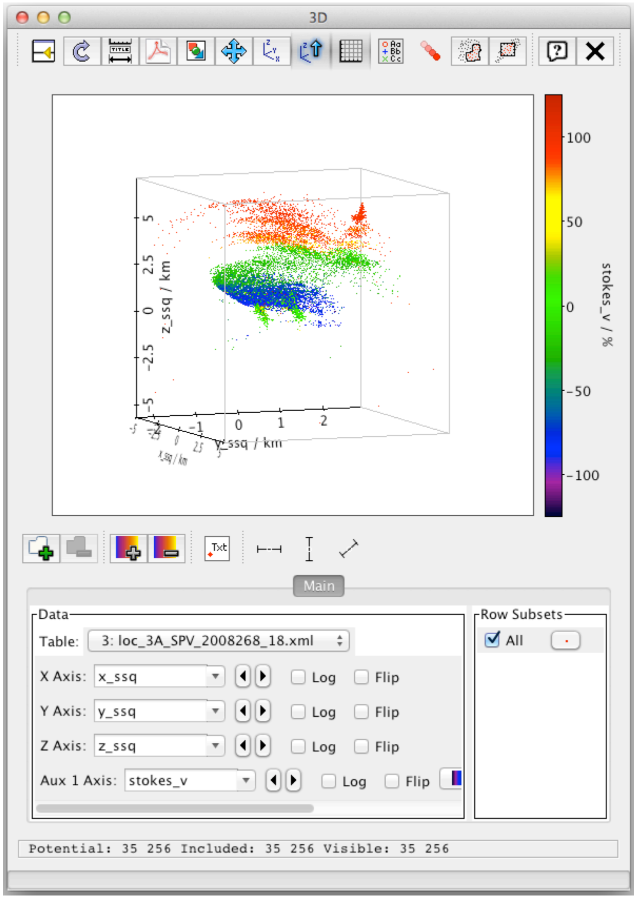
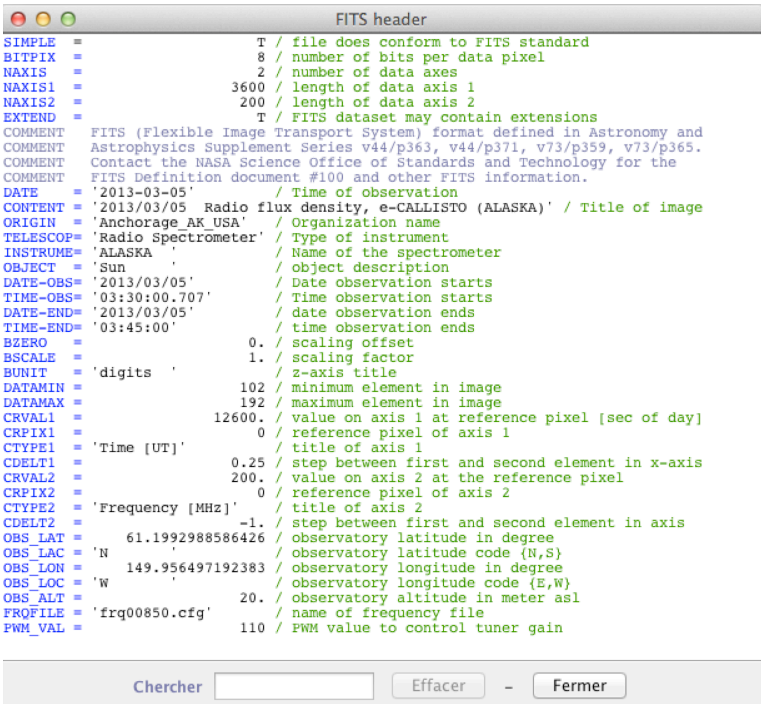


Fig. 7. Cassini/RPWS data loaded in TOPCAT using the variable frequency sampling mode VOTable formatting. The figure is showing the location of the radio-sources derived from the goniopolarimetric data recorded onboard Cassini, with a color code representing the measured circular degree of polarization.

Distributing data with FITS

The FITS format is used in astrophysics and solar physics to distribute images, spectra and spectrograms. A dynamic spectrum can be considered as a “Time-Frequency” image, when the data is recorded in a fixed frequency sampling mode. As the temporal and spectral axes are usually not regularly sampled (contrarily to images recorded on a CCD), each of the axis must be defined as an extension to the FITS file. This what is done for the files distributed by the e-Callisto project [Benz et al. 2009] (see Fig. 9). The FITS metadata are standardized in the FITS standard, and a mapping with IVOA Spectrum DM is given that latter documentation.



```
FITS header
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                    8 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 3600 / length of data axis 1
NAXIS2  =                  200 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format defined in Astronomy and
COMMENT   Astrophysics Supplement Series v44/p363, v44/p371, v73/p359, v73/p365.
COMMENT   Contact the NASA Science Office of Standards and Technology for the
COMMENT   FITS Definition document #100 and other FITS information.
DATE    = '2013-03-05'         / Time of observation
CONTENT = '2013/03/05  Radio flux density, e-CALLISTO (ALASKA)' / Title of image
ORIGIN  = 'Anchorage_AK_USA'   / Organization name
TELESCOP= 'Radio Spectrometer' / Type of instrument
INSTRUME= 'ALASKA  '           / Name of the spectrometer
OBJECT  = 'Sun     '           / object description
DATE-OBS= '2013/03/05'         / Date observation starts
TIME-OBS= '03:30:00.707'       / Time observation starts
DATE-END= '2013/03/05'         / date observation ends
TIME-END= '03:45:00'           / time observation ends
BZERO   =                   0. / scaling offset
BSCALE  =                   1. / scaling factor
BUNIT   = 'digits  '           / z-axis title
DATAMIN =                  102 / minimum element in image
DATAMAX =                  192 / maximum element in image
CRVAL1  =               12600. / value on axis 1 at reference pixel [sec of day]
CRPIX1  =                    0 / reference pixel of axis 1
CTYPE1  = 'Time [UT]'          / title of axis 1
CDELT1  =                 0.25 / step between first and second element in x-axis
CRVAL2  =                 200. / value on axis 2 at the reference pixel
CRPIX2  =                    0 / reference pixel of axis 2
CTYPE2  = 'Frequency [MHz]'    / title of axis 2
CDELT2  =                  -1. / step between first and second element in axis
OBS_LAT =     61.1992988586426 / observatory latitude in degree
OBS_LAC = 'N       '           / observatory latitude code {N,S}
OBS_LON =     149.956497192383 / observatory longitude in degree
OBS_LOC = 'W       '           / observatory longitude code {E,W}
OBS_ALT =                  20. / observatory altitude in meter asl
FRQFILE = 'frq00850.cfg'       / name of frequency file
PWM_VAL =                  110 / PWM value to control tuner gain

Chercher  [          ]  Effacer  -  Fermer
```

Fig. 9. FITS header attached to a file distributed bin the frame of the e-Callisto solar radio observation project.

Distributing data with CDF, netCDF and HDF5

The CDF format is used in the space physics and is the archive format for NASA space missions exploring the inner heliosphere (including the Earth’s magnetosphere). There are now ongoing discussions in order to validate it as an archive format foe the NASA Planetary Data System. This format will be used for fields and particle instruments in the future Bepi-Colombo, Maven and Solar Orbiter missions. This standard is comparable to XML. It defines the structure of the file, but not its content. A serialization of the metadata with IVOA standards is planned.

The netCDF format branched from the CDF format is not compatible with that format anymore. It also a file structure format, in which IVOA metadata can be placed, following a serialization which remains to be done.

Finally, the HDF5 format has been selected by the LOFAR data user group and is the most up-to-date data format. It is used in the Earth observation community to distribute data. It is very flexible and can also contain metadata. The existing standards (such as the LOFAR implementation) must be mapped with the IVOA standards.

PROJECTS AND PROTOTYPES

The CDPP has been long willing to build a tool to display and study radio datasets (especially those archived at CDPP). A «radio» tool, comparable to the AMDA/CDPP tool, is planned. We are currently in an ongoing definition phase, with possible funding available within 1-3 years. This tool should be interoperable, multi-instrument, multi-point; it should contain selection tools adapted to the various radio observables (flux, polarization, location...); it should allow light travel time correction. Two prototypes have been recently drafted:

- The SACRED portal (Simulated Auroral Cyclotron Radio Emission Database).
- The SILFE tool (Spectral Information from Low Frequency Emissions).

The studied use cases are: the comparison of simulations and observations and the preparation of future missions (JUNO and JUICE, in particular). A screen shot of the SILFE tool is presented in Fig. 10.

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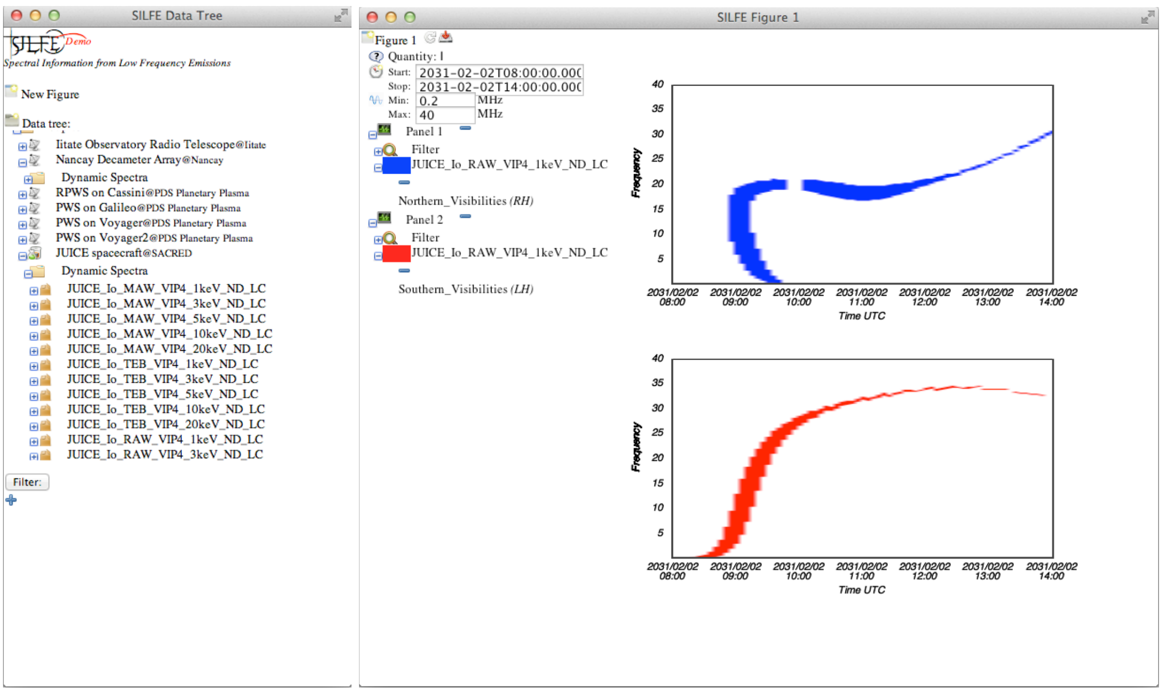

Fig. 10. SILFE Prototype. On the left-hand side, the data tree window is displayed, where all available datasets are presented. On the right-hand side, two simulations are displayed during a planned Callisto flyby of the JUICE mission. The upper/lower (blue/red) plots are the Io-controlled DAM emissions emanating from the Northern/Southern polar regions of Jupiter. The signal drop (around 10:00 on the northern curve) is the geometrical occultation of the northern source by Callisto. The Southern source is not occulted during this flyby. This information is crucial for the observation planning of the subsurface radar of the JUICE mission, as they are operating at 10 MHz and the natural Jovian radio emissions are orders of magnitude stronger than there expected echoes.