Sharing RadioJOVE data with the scientists

Baptiste Cecconi (Observatoire de Paris)
Plasmas in the Solar System
Solar Wind & Magnetized Planets
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Solar Wind & Magnetized Planets

- Solar Wind
- Magnetopause
- Magnetosheath
- Shock
Plasmas in the Solar System
Solar Wind & Magnetized Planets

- Solar Wind
- Magnetopause
- Interplanetary Shock
- Coronal Mass Ejection
- Magnetosheath
- Shock
- Electron beams
- «Type II»
- «Type III»
Plasmas in the Solar System
Solar Wind & Magnetized Planets

- Solar Wind
- Magnetopause
- Shock
- Magnetosheath
- Reconnexion
- Auroral precipitation
- Auroral Radio emissions
Low Frequency Spectrum in the solar system

Planetary Radio Emissions

and solar
Radio sources at Jupiter

Radio sources are linked to electron acceleration and circulation.
Magnetosphere of Jupiter: the largest solar system object in our sky
Jovian radio emissions

- Frequency: 0-40 MHz
- Multi scale structure (a few ms to a few hr)
- Sporadic
- Very dynamic
- S-bursts [short-bursts] [=millisecond bursts]

![Voyager-2 frequency-mapping graph]

Nançay (France)

UTR-2 (Ukraine)
Science with radio emissions!

- **Frequency decrease** = Magnetic field decrease \((F = qB/m)\) = Altitude increase (magnetic field high near surface)
- **Decreasing tone** = Electron beams going away from Jupiter
- **Slope** = Electron speed \((-20\text{MHz/s} \Rightarrow ~20\ 000\ \text{km/s}!)\)
- **Change in slope** = change in speed of electrons = acceleration (or deceleration) of electrons
  - *How to accelerate electrons? (Electric field layer?)*
- **Drift of «Change in slope» frequency** = Altitude change of the «election accelerator/decelerator»
- From the data: **Drift of «Change in slope» frequency** = velocity of sound in the medium \((\sim 10\ \text{km/s})\)
  - *In a plasma, a sound wave = slow periodic movement of background electrons and protons (but 900 times more heavy \Rightarrow almost no displacement for protons)*
  => Electric field layers!!
Science with radio emissions!


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Why Sharing Jovian Radio Emissions Data?

- Occurrence can be **predicted in a statistical manner** but they are intrinsically **sporadic**.

- Enlarging the temporal coverage of the jovian radio emission is a key aspect of the understanding of this sporadicity.

- In addition to the temporal variability of the emission, a larger spatial and temporal coverage will provide informations on the temporal width of each burst (radio arc), the **short term variability** of the arc shape...

- This may provide key information on the radio source properties, as well as on the radio source environment.
Example: May 21st 2014

1 Dave Typinsky [in Florida]

2 Tom Ashcraft [in New Mexico]

Some fun maths:
Distance between observers:
~ 2700 km [~ 1700 miles]
Earth-Jupiter Distance (at that time):
~ 880 \(10^6\) km [~ 5.9 AU]
Rotation rate of jovian radio source:
~ 0.01 degree/sec [period= 9.92 hr]
Angle between two obs. seen from Jupiter:
~ 0.00017° = 0.6 ″ [=arctan(2700/880 \(10^6\))] 
Time for beam to go from one obs to the other:
~ 17.6 msec
Speed of jovian beam spot on Earth:
~150 000 km/s ⇒ ½ speed of light!
How to efficiently share data?

• Provide calibrated data, or data include enough pieces of information to calibrate the data.

• Provide data in a standard format commonly used by scientists.

• Provide data with observation «metadata» (location of observer, accurate time of observation in UT, observation target name...) using a standard set of keywords.

• Make it available to a database network (a.k.a. «virtual observatory») used by scientists.
What is a Virtual Observatory?

- A network of databases that all **speak a common language** to share their data. The user goes to a simple interface and searches for data, the portal is looking into remote databases and fetches results.

- Astronomical Virtual Observatory (VO) is the main one:
  - sharing images, spectra, catalogs, times series...
  - large data repositories and catalogs
  - searchable interfaces
  - plotting tools
Everything is **freely available on the web**.

  US portal to Astronomical VO: [http://www.usvao.org](http://www.usvao.org)
  French portal to Astronomical VO: [http://cdsweb.u-strasbg.fr](http://cdsweb.u-strasbg.fr)

- **What about low frequency radio?**
  [http://cdaweb.gsfc.nasa.gov](http://cdaweb.gsfc.nasa.gov) CDAWeb is providing free access to a lot of space borne data
  [http://vwo.gsfc.nasa.gov](http://vwo.gsfc.nasa.gov) VWO (Virtual Wave Observatory): access to many radio instrument (mostly space based)
  [http://amda.cdpp.eu](http://amda.cdpp.eu) (Automated Multi Dataset Analysis tool) plotting tool with many space physics and planetary dataset included (free, but login required to keep user settings between connections)
User's experience «classic»

Search Data (many interfaces)

Get Data (many formats)

SSODnet
GhosST
KIDA
PSA
AMDA...
EPN
PDS

Data bases

Space agency archives

many readers (to be written by user)
User's experience «enhanced»

User

Search Data (many interfaces)

Get Data (Standard formats) [FITS, CDF, VOTable...]

Data bases

Space agency archives

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a few readers (existing!)

Visualization and other tools

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Data bases

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a few readers (existing!)

Visualization and other tools
**User's experience** «ultimate» (=Virtual Observ.)

- **Search Data** (one simple interface)
- **Standard Query**
- **Standard Answer**
- **Automated Data Access**

**Catalogue / Registry**
- SSODnet
- GhoSST KIDA
- PSA
- AMDA...
- EPN
- PDS

**Data bases**

**Space agency archives**

**Visualization and other tools**

**Specialized tools, GIS**
User's experience «ultimate» (=Virtual Observ.)
Currently available data

- Nançay Decameter Array Routine Observations (France)
  - raw data file on Obs-Nancay website + quicklooks
  - available on VESPA network (Virtual Observatory access)

- Iitate Observatory (Japan)
  - FITS files + quicklooks
  - available on IUGONET network (Virtual Observatory access)

- Current RadioJove Archive website
  - quicklooks (very few data [wav files?])

- Univ. of Florida data
  - available soon (C. Higgins, next year?)
Nançay Jupiter data

- Quicklooks + Access to raw data
Nançay Jupiter data

- Virtual Observatory access
Welcome to the IPRT DATA CENTER

What is IPRT and AMATERAS?

IPRT is a ground-based radio telescope developed by Tohoku University. IPRT has been developed at the itilate observatory in Fukushima prefecture Japan since 2000. Its wideband metric radio spectro-polarimeter, AMATERAS (the Assembly of Metric-band Aperture TElescope and Real-time Analysis System), performs well enough to observe solar radio bursts in the frequency range between 150 and 500 MHz. The minimum detectable flux in this frequency range is less than 0.7 SFU with 10 ms accumulation time and 61 kHz bandwidth. Simultaneous observations for both RCP and LCP are possible.

Observation data (time and frequency resolutions are rescaled to 1 sec and 1 MHz) and quick look plot are available from links below.

Data availability & Daily FITS files
Daily quick look:[10dB range]/[22.5dB range]
High-res quick look (access restricted)
Data search (IUGONET Web page)

Data open policy

We would like to present the following two guidelines. The 1st one concerns what we would like you to do when you use the data. The 2nd concerns what you do when you make any presentations and publications using the data.

I. Contacts: Please tell us what you are working on. This is partly because to protect potential Ph.D. thesis projects. Also, if your project coincides with one that team members are working on, that can lead to a fruitful collaboration. This will also work for you to obtain better insights relating to the data.
Iitate Jupiter data

Quicklooks via IUGONET registry:
RadioJove archive

- Archive with mainly quicklooks, very few data.
RadioJove archive

- Archive with mainly quicklooks, very few data.
ExPRES: Exoplanetary and Planetary Radio Emissions Simulator

Model input parameter:
- Location of observer
- location of radio source
- energy of electrons in the radio source
- magnetic field model for Jupiter

Works also for other planets and exoplanets (not observed yet, though...)

* http://typhon.obspm.fr/maser/serpe
  (still a prototype, login required, needs a cookbook and a user manual!)
ExPRES: Exoplanetary and Planetary Radio Emissions Simulator

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Similar projects where Amateurs help Science

- **Venus Active Archive**
  http://www.rssd.esa.int/index.php?project=VENUS&page=Archive
  Amateur observations of Venus, in support of the Venus-Express mission

- **Virtual Meteor Observatory**
  http://www.rssd.esa.int/index.php?project=METEOR&page=vmo
  Amateur observations of meteor showers, with science tools
Project Description
Metadata («file header»)

* Additional metadata (not much) attached to archived records

- Location of observer (GPS location ?)
- UTC of observation start (synchronized with GPS or NTP if possible)
- Spectral range: min and max frequency
- Data file format: cdf/FITS / votable / netcdf…
- Data : Recorded file
- Quicklook: in png format preferred
- Target (Jupiter)
- Annotation: type of emissions if known, description of hardware (radiojove kit/other)
- Observer’s name / id / nickname

* Metadata format: SPASE or IVOA (or both = simultaneous registration!)
- SPASE: Space physics communities (Sun + Earth)
- IVOA: Astronomy and Planetary sciences
=> 2 interfaces to the same database.
Project Description
File Format

- Possible file formats: CDF, FITS, VOTable, NetCDF, HDF5, wav...

- Preferred data format: CDF (maintained by NASA/GSFC)
  CDF contains «Attributes» (= header keywords = metadata)

- What can be done with the RadioJove software?
  Jim Sky will study that with me

- Remarks:
  - «wav» file: common file format for amateurs, but not for scientists
  - other than «wav»: metadata-rich formats
Project Description

Infrastructure

- **SPASE or IVOA**, based on Europlanet developments, see here: http://voparis-europlanet.obspm.fr/docum.shtml
  
  *Linking between the two worlds is possible* (under study within the european IMPEx project).

- VO-RadioJove server would includes (may not be at the same place):
  - SQL database with all observation records
  - Access Protocols (e.g.: EPN-TAP, SPASE...)
  - Webservice (REST or SOAP) or just an upload form for data ingestion (with login?)

- VO-RadioJove **prototype server and database will be located in Paris** (VO Paris Data Center) The final server and database could be in Paris or Nançay (Radioastronomy facility in France).
  
  It could also be linked to the RadioJOVE current archive.

- Web-based interface for RadioJove participants to easily fill in events *(could be just a file upload* if file contains all information).

- Link with existing RadioJove software, which could produce a file with all information included that could be submitted directly to a webservice.

- Support staff available in Paris and/or Nançay if project is accepted.
Project Description
Next steps

* Near future
  * July 2014 - January 2015:
    - decision on the data format and header content
    - setting up a test server in Paris for data upload, data validation, data distribution
  * Need for beta-testers: volunteers? (end of 2014)
    - size of data? [24h or ±3h of meridian crossing]
    - testing upload of spectrograms and single frequency
  * Discussion with Jim Sky to include CDF output in his software.

* Further plans
  * Presentation of project at next «Magnetosphere of Outer Planets» conference, in Atlanta next year (June 1-5, 2015).
  * Opening of the service to science community when everything is ready (end of 2015 or 2016?)
Summary

- Scientists can use your data!
- Standardized distribution of RadioJove observations
- Data format usable by scientist
- Take advantage of VO infrastructure
- Possible support from France for servers and databases (at least prototypes, then to be discussed).
Spare slides...
Low Frequency Radioastronomy

Observatory location

- Earth ionosphere = high-pass filter at ~10 MHz

- Space based measurement required to observe below 10 MHz as well as for *in situ* measurement
Earth Radio emissions from ground?

- Observation by Jim Labelle (South pole radio station)

- What about trying to observe from Alaska?
With an imaging telescope, the angular resolution is $\sim \frac{\lambda}{D}$
For $\lambda \sim 10\text{m}$ to $100\text{km}$, $\frac{\lambda}{D} \ll 1$ requires $D \approx 10000 \text{ km}$ !
Physically impossible to build $\Rightarrow$ We have to be creative!

- Space based radioastronomy sensors:
  - electrical monopoles or dipoles:
  - magnetic loops or search-coils:
Radioastronomy observations from space

- Radio instrumentation: Goniopolarimetry (a.k.a. Direction-Finding) => yields polarization + direction of arrival (not independently!)

- On Cassini: 3 electrical antennas. Assuming a point source, we get polarization and direction of arrival

GP basics with 2 antennas
Electrical dipole, quasi-static range

- Antenna diagram for a dipole antenna
- In the quasi-static (or short antenna) range: \( L \ll \lambda \)
  The antenna is then a perfect dipole. Its gain varies in \( \cos^2(\theta) \).
(Very) Simple case: 2 antennas in a plane

* Two perpendicular antennas (red and blue).
* A non polarized wave is propagating along the dashed-line direction.
* The ratio between the power sensed on each antenna provides the direction of propagation.
* Unfortunately, in this case, the solution is not unique.
Real case: 3D geometry & polarized wave

* Electrical signal induced by the wave on an antenna: \[ V_a = \vec{h}_a \cdot \vec{E}_w(t) \]

* We measure the power on each sensor, as well as the cross-correlation of the signals sensed on two antennas. We then get the full spectral matrix of the wave.

* Wave parameters (for a polarized transverse plane wave)
  - Direction of propagation: two angles \( \theta, \phi \).
  - Flux and polarization: 4 Stokes parameters \( S, Q, U, V \)

\[
P_{ij} = \frac{Z_0 G h_i h_j S}{2} \left[ (1 + Q)A_i A_j + (U - iV)A_i B_j + (U + iV)A_j B_i + (1 - Q)B_i B_j \right]
\]

\[
A_i = -\sin \theta_i \cos \theta \cos(\phi - \phi_i) + \cos \theta_i \cos \theta \\
B_i = -\sin \theta_i \sin(\phi - \phi_i)
\]

* Antenna parameters: length \( h_i \) and direction \( \theta_i, \phi_i \)
Goniopolarimetry

*How to «see» the radio*

Dynamic spectrum of SKR (Saturn Kilometric Radiation) observed with Cassini/RPWS/HFR.
Example: 
**Saturn auroral radio and UV sources**

* Aurore UV et Radio:

[Image of Cassini field of view, UV images, and radio maps.]

[Lamy et al. 2009]
Remote Localization of Radio Auroras (and comparison with atmospheric auroras)

- Earth: DE-1
- Saturn: Cassini
Planetary Radio Emissions - Observation Techniques

SKR Source Localization (from Cassini/RPWS/HFR)

Ephemeris
2006268−10:00
2006268−10:05
LT = 05:29
Lat = −29.7 deg
Dist = 7.2 Rs

Color Code
100−200 kHz
200−400 kHz
400−800 kHz
800−1000 kHz

Symbol Code
• out of iso−fc
△ within iso−fc (2° error contour)

Active Magnetic Field Line Footprints
(SPV magnetic field model with current sheet)

[Ceccconi et al. 2009]
Cassini crossing the auroral radio sources

Radio Flux

Polarization

[Lamy et al. 2010]
Example: Radio view of Saturn by Cassini

Ephemeris
2006268 - 17:20
2006268 - 17:25
LT = 10:06
Lat = -34.5°
Dist = 4.3 Rs

Color Code
100 - 200 kHz
200 - 400 kHz
400 - 800 kHz
800 - 1000 kHz

Symbol Code
* out of iso-fc
within iso-fc (2° error contour)

Active Magnetic Field Line Footprints
Solar Wind Control of Auroral Sources

- Earth: Sub-storms onset controlled by solar wind conditions
- Jupiter: QP & HOM controlled by SW
- Saturn: SKR intensity correlated to SW ram pressure