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Interoperability of the CDPP tools and databases through the EPN-TAP protocol

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Abstract

The French Plasma Physics Data Center (CDPP, http://cdpp.eu) distributes and valorizes natural plasma data for nearly 20 years. The CDPP is involved for many years in the definition and implementation of interoperability standards like SPASE, IVOA and IPDA. In the frame of the VESPA work package of EuroPlaNet RI (H2020), the CDPP has developed an EPN-TAP compatible server, using the DaCHS software distribution, which provides observational time series from the AMDA database, illumination maps from the 67P comets, as well as simulation results from the IPIM model. These services are available through the VESPA portal (http://vespa.obspm.fr). EPN-TAP compatible interfaces were also added in AMDA (http://amda.cdpp.eu), 3DView (http://3dview.cdpp.eu) and the PropagationTool (http://propagationtool.cdpp.eu/). These interfaces, also called “EPN-TAP clients” are freely available in Java and Javascript. The Java implementation is used by 3DView, the Propagation Tool and Cassis (http://cassis.irap.omp.eu), a free interactive spectrum analyser developed by IRAP, whereas the Javascript version is used by AMDA.

Acknowledgements

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Juno-Ground-Radio Observation Support Tools

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Abstract

In the frame of the NASA/Juno mission, an international support activity with observations in the low frequency radio range has been set up. We are proposing a new set of tools directed to data providers as well as users, in order to ease data sharing and discovery. 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. Data from all major decametric radio instruments will contribute: Nançay Decameter Array (France), LOFAR (France, Sweden, Poland), URAN (Ukraine), LWA (USA), Iitate Radio Observatory (Japan), etc. 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 tools that make use of this shared datasets. This activity also supports the development of the ESA/JUICE (Jupiter Icy Moon Explorer) mission, and that of the planetary sciences virtual observatory.

1. Introduction

The Jovian radio emissions have been discovered in 1955 by Burke and Franklin (1). They are observed from ground in the decameter wavelength range (10 MHz to 40 MHz). They have been studied and monitored since the Voyager fly-bys in the 70's. Several ground observatories have dedicated operations for Jovian radio emission monitoring, e.g., the Nançay Decameter Array (NDA), at Station de Radioastronomie de Nançay (SRN), in France; the Iitate Radio Observation, in Japan; or the Ukrainian T-shaped Radiotelescope mark 2 (UTR-2), at Kharkiv in Ukraine. These intense radio emissions are also observed from space with, e.g., the Cassini/RPWS (2), Wind/Waves (3) and STEREO/Waves (4) instruments. Ground-based and space-borne observations are complementary. Ground-based observatories are more sensitive due to their larger antenna and are not limited in data volume by the space telemetry downlink rate. On the other hand, space-borne instruments can observe at all times. The exploration of the Jovian radio emissions from space was mainly conducted during the Voyager 1, Voyager 2, Ulysses and Cassini flybys around Jupiter (see, e.g., (5)), as well as during the Galileo mission. It is noticeable that the Ulysses/URAP (6) instrument was the first to observe the Jovian radio emissions out from the ecliptic plane (7).

The Jovian radio emissions result from the auroral precipitation of relativistic electrons in the Jovian auroral regions (8). The two main drivers for the Jovian radio emissions are the interaction with the Galilean moons (mainly Io (9; 10), but also Europa and Ganymede (11; 12)) and with the Solar Wind (13; 14; 15). The radio sources are located above the Jovian auroral regions, on magnetic field lines connected to the Jovian aurora or magnetic footprints of Galilean moons (8). The radio emission mechanism is the Cyclotron Maser Instability (16; 17; 18), which is predicting an anisotropic beaming pattern of the radio emission with the shape of a hollow cone. This radio source visibility can be modeled (10; 19). The radio emission shape in the time-frequency domain is interpreted in terms of radio source physical parameters (20; 21).

The Juno mission is a NASA flagship mission dedicated to the study of Jupiter. Several instruments are dedicated to the study of the Jovian internal magnetic field and its inner magnetosphere (22). The spacecraft started its prime mission phase in July 2016 after a successful insertion in Jupiter's gravitational system. The polar orbit of the spacecraft is very well adapted to study the Jovian auroral regions. The Juno/Waves instrument will observe the Jovian electromagnetic emissions from 24 Hz to 41 MHz. Juno will provide an entirely new view on the Jovian radio emission: the polar orbit provides systematic observations out of the ecliptic plane; and the low altitude perijove allows radio sources region in-situ exploration. However, since most of the Jovian radio emissions studies were conducted with observers in the ecliptic plane, an observation support within the ecliptic plane will allow to link Juno's observations to previous studies. This is the goal of the Juno-Ground-Radio observation support group.

In order to ease the discovery and sharing of low frequency radio astronomy data products from various sources, we propose to use new tools developed in the planetary science virtual observatory (VO). These tools are directed towards both data providers and scientists. The data providers are using EPN-TAP (23), a planetary science data access protocol developed by Europlanet-H2020-RI/VESPA (Virtual European Solar and Planetary Access) for data sharing (24). This protocol is derived from IVOA (International Virtual Observatory Alliance) standards. All services are using the same interface, so that users can query all services the same way (e.g., using the VESPA main query portal (25)).

2. Participating Observatories

The main low frequency radio observatories in the world are participating to the Juno-Ground-Radio observation support team:

- Nançay Decameter Array (NDA), at Station de Radioastronomie de Nançay (SRN), Nançay, France;
- Ukrainian T-shaped Radiotelescope mark 2 (UTR2), Kharkhiv, Ukraine;
- Iitate Log-periodic Radio Antenna, Iitate, Fukushima Pref., Japan;
- Long Wavelength Array 1 (LWA1), New Mexico, USA.

Teams from the Low Frequency Array (LOFAR) are also setting up plans for participation (with French, Polish and Swedish stations). The RadioJOVE citizen science project (26) is providing data from its "Spectrograph User Group" (SUG), which is composed of several semi-professional observers providing the community with high quality amateur data.

3. Juno-Ground-Radio Team

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Interoperability in the Planetary Science Archive (PSA)

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As the world becomes increasingly interconnected, there is a greater need to provide interoperability with software and applications that are commonly being used globally. For this purpose, the development of the Planetary Science Archive (PSA), by the European Space Astronomy Centre (ESAC) Science Data Centre (ESDC), has been focused on building a modern science archive that takes into account internationally recognised standards in order to provide access to the archive through tools from third parties, for example by the NASA Planetary Data System (PDS), the VESPA project from the Virtual Observatory of Paris as well as other international institutions.

The protocols and standards currently being supported by the recently released new version of the Planetary Science Archive at this time are the Planetary Data Access Protocol (PDAP), the EuroPlanet-Table Access Protocol (EPN-TAP) and Open Geospatial Consortium (OGC) standards.

We explore these protocols in more detail providing scientifically useful examples of their usage within the PSA.

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Planetary data distribution by the French Plasma Physics Data Centre (CDPP): the example of Rosetta Plasma Consortium in the perspective of Solar Orbiter, Bepi-Colombo and JUICE

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The French Plasma Physics Data Centre (CDPP, http://www.cdpp.eu/) has been addressing for almost the past 20 years all issues pertaining to natural plasma data distribution and valorization. Initially established by CNES and CNRS on the ground of a solid data archive, CDPP activities diversified with the advent of broader networks and interoperability standards, and through fruitful collaborations (e.g. with NASA/PDS). Providing access to remote data, designing and building science driven analysis tools then became at the forefront of CDPP developments. In the frame of data distribution, the CDPP has provided to the Rosetta Plasma Consortium (RPC), a suite of five different plasma sensors, with the possibility to visualize plasma data acquired by the Rosetta mission through its data analysis tool AMDA. AMDA was used during the operational phase of the Rosetta mission, facilitating data access between different Rosetta PI sensor teams, thus allowing 1/ a more efficient instruments operation planning and 2/ a better understanding of single instrument observations in the context of other sensor measurements and of more global observations. The data are now getting open to the public via the AMDA tool as they are released to the ESA/PSA. These in-situ data are complemented by model data, for instance, a solar wind propagation model (see http://heliopropa.irap.omp.eu) or illumination maps of 67P (available through http://vespa.obspm.fr). The CDPP also proposes 3D visualization tool for planetary / heliospheric environments which helps putting data in context (http://3dview.cdpp.eu); for instance all comets and asteroids in a given volume and for a given time interval can be searched and displayed. From this fruitful experience the CDPP intends to play a similar role for the forthcoming data of the Solar Orbiter, Bepi-Colombo and JUICE missions as it is officially part of several instrument consortia. Beside highlighting the current database and products, the presentation will show how these future data could be presented and valorized through a combined use of the tools and models provided by the CDPP.

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IASB-BIRA contribution to VESPA for planetary aeronomy studies

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Abstract

VESPA (Virtual European Solar and Planetary Access) [1] is a planetary science virtual observatory aiming to facilitate data access and to connect science tools from different institutions. IASB-BIRA is contributing to VESPA activities by developing all necessary facilities to make SOIR profiles and the radiative transfer code ASIMUT accessible through this new infrastructure.

1. Introduction

SOIR (Solar Occultation in the InfraRed) is an infrared spectrometer that work in the 2.2-4.3 µm spectral range. It made solar occultation observation of the atmosphere of Venus during the complete mission of the Venus Express spacecraft from May 2006 till November 2014. Profiles of pressures, temperatures and densities of different constituents of the atmosphere of Venus have been derived from the spectra recorded by SOIR. Mahieux et al. (2015,2012,2010) [2-4] describe the algorithm used to derive these profiles. Nine species have been studied: CO_2, CO, $H^{35}Cl$, $H^{37}Cl$, HF, SO_2, H_2O, HDO and the aerosols. Vandaele et al. [5] gives an overview of these studies.

ASIMUT is a modular program for radiative transfer calculations in planetary atmospheres, particularly for Mars, Venus and the Earth, considering different geometries. This program can simulate spectra or retrieve columns and/or profiles of atmospheric constituents simultaneously from different spectra. This allows the possibility to perform combined retrievals.

Any SOIR profile file or ASIMUT calculation result should be obtained by a query through the search interface of the VESPA infrastructure at http://vespa.obspm.fr. These query will lead to different mechanisms depending if it is experimental data or calculated data that are requested.

2. Description and access to SOIR profiles

SOIR profiles of pressures, temperatures and densities are available in two formats: in HDF5 for efficient read/write operations and in VOtables. The later is required to use the VO tools for quick and convenient data plotting. Figure 1 is an example of plot generated using the TOPCAT VO tool [6] showing the latitudes and longitudes of all profiles of CO_2, CO, $H^{35}Cl$, $H^{37}Cl$, HF, SO_2. The content of the HDF5 files is separated under different groups: Science, Geometry, Observation and Reference. The Science group contains the profiles with units as attributes. The corresponding altitudes, latitudes and longitudes can be found in the Geometry group. The other groups contain useful data: the time of the observation, the attitude of the spacecraft, the coordinates of the profile, etc. The VOtables contain the same data as the Science group of the HDF5 files in addition to the altitudes. All these files are available online.

Each of these files has a unique set of EPNcore parameters (version 2). These parameters are required for compatibility with the Europlanet Table Access Protocol (EPN-TAP) developed by the International Virtual Observatory Alliance (IVOA). These EPNcore parameters are the metadata of our database called *soir*. They have to be described by a view called *epn_core* which is accessible through a TAP query to our EPN-TAP data service called *BIRA-IASB TAP*. The VESPA server can query the *soir.epn_core* view since our data service has been registered in the IVOA registry. More information can be found in Trompet et al. (2017) [7].

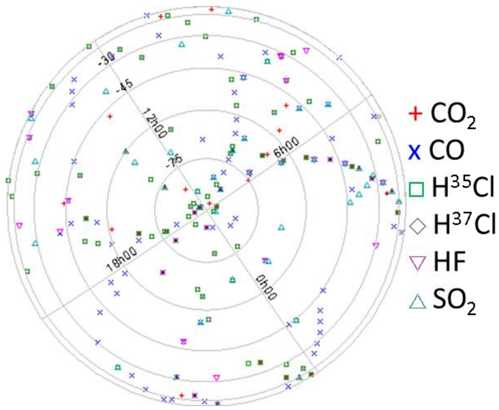

Figure 1: Position on the South hemisphere of Venus for all SOIR profiles of CO_2, CO, $H^{35}Cl$, $H^{37}Cl$, HF, SO_2.

3. ASIMUT calculations through VESPA

VESPA infrastructure will be enhanced with the ASIMUT radiative transfer code. Another VESPA research interface (than the one used to query experimental data) has to be filled. The parameters will be send by VESPA to IASB-BIRA with an HTTP query. Some parameters will be restricted to avoid too long calculations. The query with these parameters will be parsed at the IASB-BIRA side: if the set of parameters is incomplete or if the value of a parameter does not make sense or is not contained in the required limits, a VOtable will be returned with a description of the error. If the input parameters are correct, several calculations of ASIMUT can be launched in the same time using slots. Obviously, a limit of this number of slots has to be defined. Once the calculation are finished, the results will be transformed in VOtable and returned to the user.

In a first step, a simplified version of ASIMUT will be available through VESPA, with no possibility to perform retrievals and without any scattering processes included. These options will be added in the future if they do not appear to be too much time consuming. Similarly, at first, only IASB-BIRA internal atmosphere models for the different planets will be available. But in a second step, an attempt will be done to use other atmosphere models from other data services accessible through the VESPA infrastructure.

Acknowledgements

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Extant Interoperability across the Solar and Planetary Science Communities

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Abstract

1. The Planetary Data System's PDS4 Reference Information System Architecture [1, 2, 3] is comprised of two components: an information architecture and a software architecture. The information architecture enables interoperability across the diverse disciplines of the Planetary Science community and overlapping elements of the Heliophysics and Astrophysics communities. The PDS4 Information Model, the core component of the information architecture, enables interoperability by means of an integrated set of domain ontologies and common vocabularies. The software architecture defines the service and application layers that support core functions across a set of federated digital repositories, including ingest, validate, locate, search, and retrieve. Higher level software layers accommodate workflow and analytical processing. As illustrated in Figure 1 the information model is intrinsically involved in the creation and validation of data products and the configuration of the software services. The model also institutes governance over data and metadata at the common, discipline, and mission levels. Efforts are underway to look at how the PDS4 reference information system architecture can be used to define a more generalized reference architecture for science data archives.

This presentation will provide an overview of the information system architecture, and how it is being applied across digital repositories. Efforts to leverage and enhance these components will also be identified.

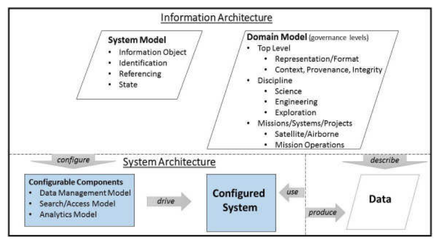

Figure 1: Information System Architecture [3].

Acknowledgements

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DynAstVO: a Europlanet database of NEA orbits

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Abstract

DynAstVO is a new orbital database developed within the Europlanet 2020 RI and the Virtual European Solar and Planetary Access (VESPA) frameworks. The database is dedicated to Near-Earth asteroids and provide parameters related to orbits: osculating elements, observational information, ephemeris through SPICE kernel, and in particular, orbit uncertainty and associated covariance matrix. DynAstVO is daily updated on a automatic process of orbit determination on the basis of the Minor Planet Electronic Circulars that reports new observations or the discover of a new asteroid. This database conforms to EPN-TAP environment [3] and is accessible through VO protocols and on the VESPA portal web access (`http://vespa.obspm.fr/`). A comparison with other classical databases such as Astorb, MPCORB, NEODyS and JPL is also presented.

1. Parameters of DynAstVO

For each NEA in the database, DynAstVO provides:

- name, number and designations;
- orbital elements and the state vector at the epoch corresponding approximatively to the middle of the observational period;
- number of observations and radar measurements, dates of first and last observations used for the orbit determination;
- magnitude parameters (H and G slope);
- covariance matrix and Sky-Plane uncertainty (uncertainty in the position at epoch);
- Earth-MOID (minimum orbital intersection distance);
- ephemeris in Spice Kernel format (bsp file) for the 1980-2030 period.

An additional table also provides the orbital elements and the state vector at a current epoch, identical for all asteroids. Dates, minimum distances (and their uncertainties) of close approaches with Mercury, Venus, Earth, Moon and Mars are presented.

2. Processing of DynAstVO

The database is daily updated on the basis of electronic circulars (MPECs) of the Minor Planet Center. The MPECs provide new discovered asteroids and new observations. Orbit determination is proceeded for NEAs in the MPECs according to the following functional scheme:

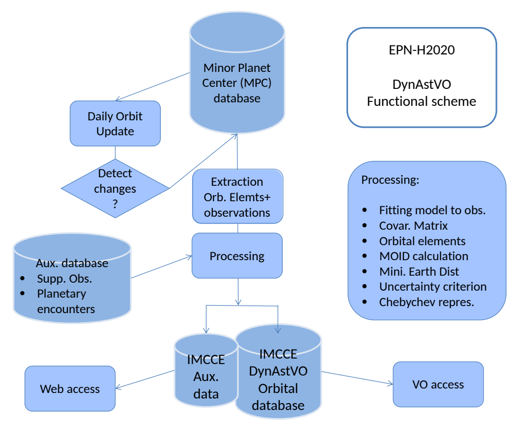

Figure 1: Functional scheme of the processing of DynAstVO.

DynAstVO is built into the EPN-TAP environment [3] and accessible through VO protocols and a web access (`http://vespa.obspm.fr/`).

3. Dynamical model and observations

The orbit determination process comes from [1] and consists in an integration of equations of motion and variational equations. Orbital elements are determined by a Levenberg- Marquadt algorithm. The dynamical model takes into account the gravitational perturbations of the Sun, the eight planets, the Moon and Pluto (positions are from INPOP13c [5], the gravitational perturbations of the four main asteroids (Ceres, Pallas, Vesta and Hygiea), the corrections of relativistic effects of the Sun, the flatness of Sun $J_{2\odot}$ and the flatness of the Earth $J_{2\oplus}$. Corrections from bias in stellar catalogues are applied and the weighting scheme presented in [4] is used. Observations and radar measurements come from the Minor Planet Center database.

4. Comparison with other databases

We compare DynAstVO with MPCORB, ASTORB, and NEODyS by computing the apparent position from geocentre at reference epoch. Figures 2 show the difference in position for 2238 numbered NEAs in right ascension and declination.

The orbital elements from DynAstVO are in a good agreement with those in ASTORB and MPCORB (about 0.1 arcsec of difference in right ascension and declination). Compared to NEODyS, the differences are even smaller.

Small differences can be explained by different processes of propagation (as epoch is 2016.11.08 for ASTORB and 2016.07.31 for MPCORB and NEODyS).

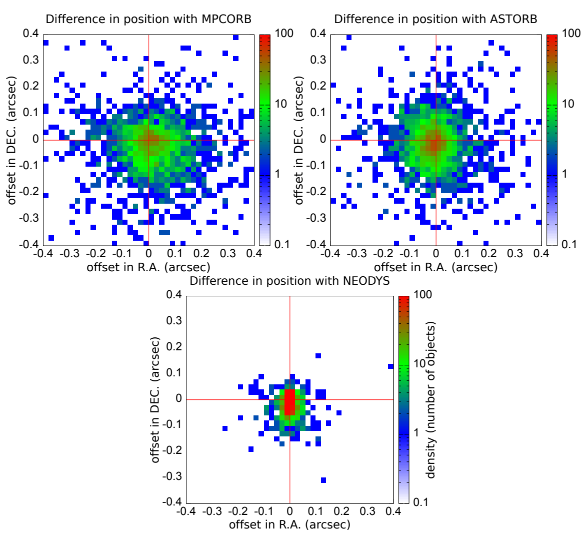

Figure 2: Difference in apparent position for 2238 numbered NEAs in right ascension and declination between Astorb, MPCORB, NEODyS compared to DynAstVO.

5. Conclusion and prospectives

DynAstVO provides the orbits, ephemerides, close approaches of NEAs (15 848 objects on 7 April 2017). In the future, we plan to develop the database by including MOID data, impact probabilities, and post-mitigation tools [2] and to extend the database to all minor planets. Data from Gaia as well as data from NAROO project [6] will be used for the database.

Acknowledgements

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GIS Technologies for the Planetary Science Archive (PSA)

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Abstract

Geographical information systems (GIS) is becoming increasingly used for planetary science. GIS are computerised systems for the storage, retrieval, manipulation, analysis, and display of geographically referenced data.

Some data stored in the PSA have spatial metadata associated to them. To facilitate users in handling and visualising spatial data in GIS applications, the PSA should support interoperability with interfaces implementing the standards approved by the Open Geospatial Consortium (OGC).

These standards are followed in order to develop open interfaces and encoding that allow data to be exchanged with GIS Client Applications, well-known examples of which are Google Earth and NASA World Wind, as well as open source tools such as Openlayers (2D) and Cesium (3D). Access to this data for use in World Wide Web applications can be provided through OGC Web Service (OWS) implementations.

An existing open source server is GeoServer, an instance of which has been deployed for the PSA, that uses the OGC standards to allow the sharing, processing and editing of data and spatial data through the Web Feature Service (WFS) standard.

Our final goal is to convert the recently released PSA (accessible through http://psa.esa.int) into an archive which enables science exploitation of ESA's planetary missions datasets. This can be facilitated through the GIS framework, offering interfaces (both web GUI and scriptable APIs) that can be used more easily and scientifically by the community, and that will also enable the community to build added value services on top of the PSA.

1. Introduction

Within the ESA planetary missions (where they can be seen in the Table 1), there is a well-defined way of visualize their main targets depending on their nature and shape. For instance, for planets and satellites, which are almost spherical, a GIS tool can be used to represent the geographical information as they can be contained within a ellipsoid. For comets (such as Halley and 67P), they are often irregular bodies, whose 2D mapping can become tedious or almost impossible. Consequently, a 3D tool can be considered a more suitable way to visualize irregular bodies such as asteroids, comets…etc

Mission	Main Target	Visual Tool
Giotto	Comet	3D tool
Huygens	Satellite	GIS tool
SMART1	Satellite	GIS tool
Venus Express	Planet	GIS tool
Mars Express	Planet	GIS tool
Rosetta	Comet	3D tool
ExoMars 2016	Planet	GIS tool

Table 1: ESA Planetary missions, with their main targets types and ways of visualizing them

2. GIS Architecture in the PSA

The new PSA will rely on 3-tiered system for the GIS architecture. The database layer will be composed by a PostgreSQL database with the PostGIS extension to store the spatial info. The server layer will have a Geoserver as a map server which will offer the web application (implemented with Vaadin) the WMS and WFS answers in some formats such as Geojson, xml…etc. Finally, the client layer will be defined by a browser which will executes some GIS jasvascript tools such as Openlayers or Cesium (for planets and satellites) and some 3D javascripts libraries such as ThreeJS (based on WebGL) to visualize the irregular bodies.

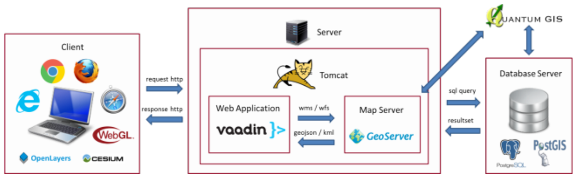

Figure 1: GIS architecture diagram for the PSA

3. GIS tools for the PSA

For regular bodies such as planets or satellites, there are good tools based on Javascript and WebGL to visualize the spatial info like Openlayers and Cesium which offer the typical features like panning, zooming, layers control…etc, even a 3D environment (Cesium). Both are open source. As the PSA is a multi-mission website, some cross-mission queries will be able to do (e.g. retrieving all the footprints from Mars Express and Exomars 2016 and visualize them in 2D or 3D environments. See Figure 2 and 3 respectively)

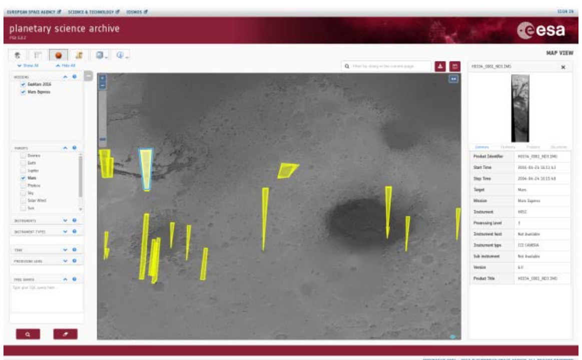

Figure 2: GIS 2D example in the PSA

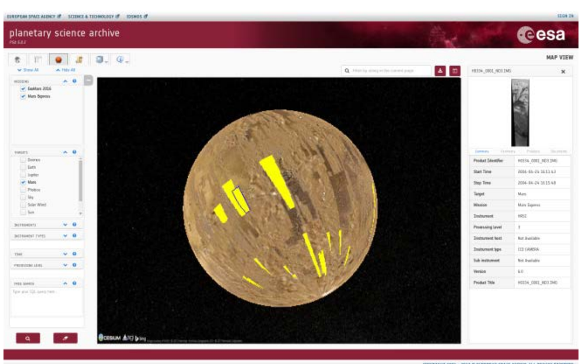

Figure 3: GIS 3D example in the PSA

4. 3D tools for the PSA

For irregular bodies such as comets, asteroids…etc, a GIS tool is not a good approach as long as the body has irregular shapes which cannot be contained in an ellipsoid to be able to generate a consistent datum which can be handled by a GIS. For the 67P/Churyumov-Gerasimenko and its "peanut" shape, a 3D visualization tool is a better candidate to handle this situation. There are some Javascript libraries based on WebGL which can be used to deal with it like ThreeJS. A mockup to visualize this comet within the Rosetta mission can be seen in the figure 4.

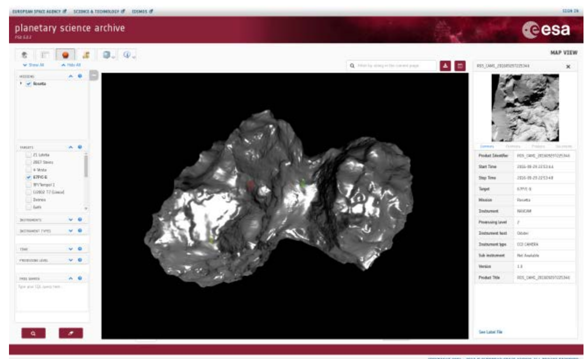

Figure 4: 3D visualization tool example in the PSA

5. Summary and Conclusions

As mentioned before, the new PSA will rely on some different tools to visualize and handle the spatial information depending on the nature of the target for each particular ESA mission.

Regarding interoperability, PSA aims to have ideally a GIS which is able to handle all the visualization geometry layers for the planets, satellites and comets, regardless where they come from (PDS3, PDS4, SPICE…)

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Implementation of the interface for sPECtral Matrix ANalyzer (iPECMAN)

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Abstract

Interface for a sPECtral Matrix ANalyzer (iPECMAN) is an online data analysis tool aimed at multi-dimensional measurements of planetary electromagnetic fields. It calculates characteristics of electromagnetic waves from in-situ spacecraft measurements. These characteristics are the key signatures of fundamental processes in the solar wind and planetary magnetospheres. The interface is developed as a part of VESPA (Virtual European Solar and Planetary Access) work packages in the frame of Europlanet-H2020-RI.

1. Introduction

The iPECMAN is based on the PRASSADCO (PRopagation Analysis of STAFF-SA Data with COherency tests) analysis tool [1], developed originally in the frame of the ESA Cluster Project. PRASSADCO implements a number of methods used to estimate polarization and propagation parameters, such as the degree of wave polarization, sense of elliptic polarization and axes of polarization ellipse, the wave vector direction, the Poynting vector or the refractive index.

The above methods have been previously used for data analysis and validation from the STAFF-SA instruments onboard the four Cluster spacecraft (e.g. [2]), the STAFF/DWP instrument onboard the Double Star TC-1 spacecraft, the LFEW instrument onboard the Double Star polar TC-2 spacecraft, the Cassini RPWS data, the IMSC and ICE instruments on the DEMETER spacecraft (e.g. [3]), the Polar PWI-HFWR data, and data from the EMFISIS Waves instruments onboard the NASA Van Allen Probes Spacecraft (Fig. 1).

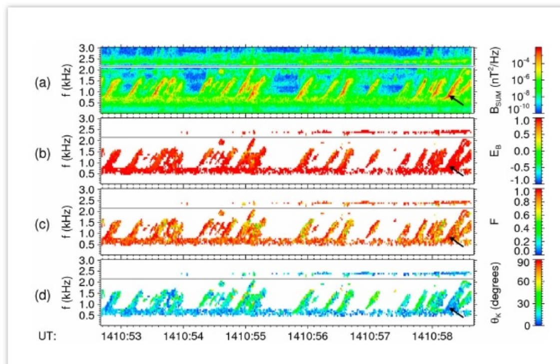

Figure 1: Example of the PRASSADCO output as presented in [4]. Analysis of one snapshot of magnetic field waveforms recorded by the EMFISIS Waves instruments onboard Van Allen Probe A on 14 November 2012.

2 iPECMAN

IPECMAN is a tool designed to provide different visual formats of the electromagnetic wave characteristics observed in the solar wind and planetary magnetospheres. It interfaces the VESPA data services or user provided data with the PRASSADCO analysis tool. The interface is written in PHP and requires Apache 2 web server and PostgreSQL database. This gives sufficient performance and painless portability.

The input data are in CDF (Common Data Format) [5]. The interface implements the existing Cluster STAFF-SA Spectral Matrix data [6] or generic CDF files [7]. The input CDF file must be structured with a header section containing the global attributes, and a data section containing the variables and the associated variable attributes. Metadata compliant with the EPNcore data model, used by the VESPA project for its data distribution protocol EPN-TAP [8], can also be included. The input data can be directly uploaded to the interface through a form or url query. Another way to provide data is to use SAMP [9]. SAMP is a messaging protocol that enables various software tools (e.g. TOPCAT) to interoperate and supports communication between applications on the desktop and in web browsers.

An uploaded CDF file is converted to the PRASSADCO input format. Then a two-step configuration of an output file format is done. In the first step, common definitions and output formats are set (Fig. 2). Consequently, an output panel setting is made. A user fills a simple form or selects output from several predefined options. Finally, input data are processed by PRASSADCO using an user-defined configuration and visual files are returned. A user is allowed to edit his options in every step of configuration.

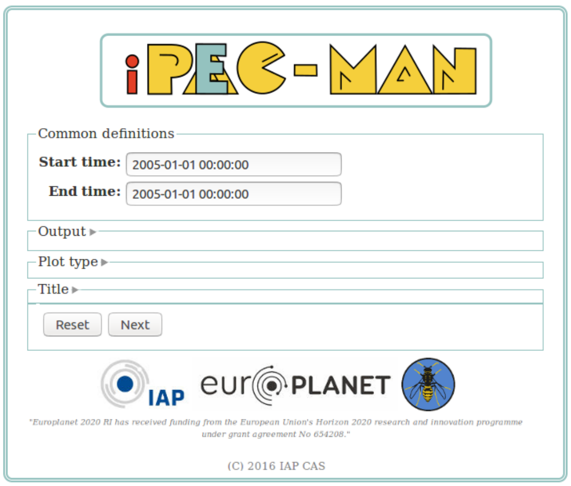

Figure 2: A screenshot of common definition form for the iPECMAN output configuration.

3 Summary

We developed the web interface (iPECMAN) dedicated to calculation and visualization of multi-dimensional electromagnetic wave analysis. It can be used to analyze characteristics of electromagnetic waves from in-situ spacecraft measurements that are the key signatures of fundamental processes in the wide range of space plasma environments. The interface implements the existing data or allows to upload user-defined data using a generic CDF data format.

Acknowledgements

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THE PLANETARY SCIENCE ARCHIVE (PSA): EXPLORATION AND DISCOVERY OF SCIENTIFIC DATASETS FROM ESA'S PLANETARY MISSIONS.

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Abstract

The Planetary Science Archive (PSA) is the European Space Agency's (ESA) repository of science data from all planetary science and exploration missions. The PSA provides access to scientific datasets through various interfaces at http://psa.esa.int. All datasets are scientifically peer-reviewed by independent scientists, and are compliant with the Planetary Data System (PDS) standards. The PSA has started to implement a number of significant improvements, mostly driven by the evolution of the PDS standards, and the growing need for better interfaces and advanced applications to support science exploitation.

1. Introduction

The PSA is hosting data from all of ESA's missions that explored the Solar System, apart from the Sun and the Sun-Earth interactions addressed by the Heliospheric archive of ESA. This includes ESA's first planetary mission Giotto, which explored the nucleus of comet 1P/Halley. Science data from the Venus Express spacecraft that orbited Venus for several years, the Mars Express mission that is still orbiting Mars and observing its moons Phobos and Deimos, and the SMART-1 mission that explored the Moon are available at the PSA. Data products from the descent module Huygens that explored the surface of Titan for the first time are accessible through the PSA as well. The PSA also contains all science data from Rosetta, the ambitious mission of ESA's Solar System exploration programme that accompanied comet 67P/Churyumov-Gerasimenko and flew by asteroids Steins and Lutetia on its way. Last year has seen the arrival of a new ESA mission with the ExoMars 2016 data being ingested into the PSA. In the upcoming years, at least three new projects are foreseen to be fully archived at the PSA. The first datasets from the BepiColombo mission to Mercury will be ingested after the launch scheduled in 2018. Following BepiColombo will be the ExoMars Rover Surface Platform (RSP) that is expected to navigate on the surface of Mars in 2020. The upcoming JUpiter ICy moon Explorer (JUICE), scheduled to launch in 2022, will also archive its observations of Jupiter, the Galilean satellites and the numerous objects of the Jupiter system in the PSA.

The PSA is also open to add to its database scientific observations of various ground-based observatories (i.e., professional or amateur), and space-based observatories; a few ground-based support programmes (for Venus Express and Rosetta), as well as data from the Hubble Space Telescope are already available in the PSA.

2. Development

The PSA released its new interface in January 2017. The newly designed PSA enhances the user experience and significantly reduces the complexity for users to find their data by promoting one-click access to the scientific datasets with more specialized views when needed. It is also up-to-date with versions 3 and 4 of the PDS standards, as PDS4 is used for ESA's ExoMars and upcoming BepiColombo missions.

The PSA home page (Figure 1) provides a direct and simple access to the scientific data, aiming to help scientists to discover and explore their content while facilitating cross-mission and cross-instrument data searches. The archive can be explored through a set of parameters that allow the selection of products through space and time (Figure 2). Quick views provide information needed for the selection of appropriate scientific products.

To support larger data search and retrieval, planetary interoperability services have been implemented; e.g. this supports the PDAP (Planetary Data Access Protocol) and the EPN-TAP (EuroPlanet-Table Access Protocol) protocols.

Users also have direct access to documentation, information and tools that are relevant to the scientific use of the dataset, including ancillary datasets, Experiment-to-Archive ICD (EAICD) or Software Interface Specification (SIS) documents, and any tools/help that the PSA team can provide.

3. Roadmap

The PSA team is now focusing on developing a map search interface using GIS (Geographic Information System) technologies to display ESA planetary datasets. This will include 2D (e.g. for Mars) and 3D (for small bodies, e.g. 67P/Churyumov-Gerasimenko) functionalities.

An image gallery will also provide navigation through images to explore the datasets (Figure 3), while search of products by metadata will be expanded, allowing product selection by wavelength, instrument types or geometrical parameters.

A login mechanism will also provide additional functionalities to the users to help their searches (e.g. saving queries, managing default views, etc).

4. Figures

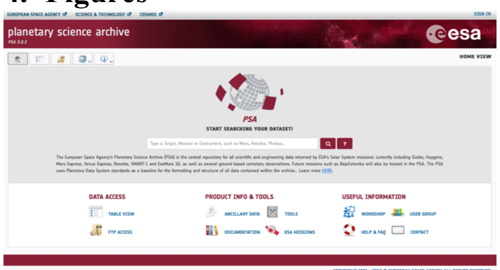

Figure 1. Home page of the Planetary Science Archive. Icons at the bottom link to various services that the PSA offers such as access to important documentation, contact form, etc. At the center, the search bar provides rapid access to data products from a mission, a target, or a specific instrument.

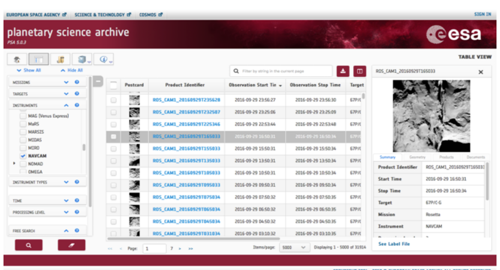

Figure 2. Display of the results after an initial query on the instrument NAVCAM. On the left side, the filter menu offers parameters to refine the query (Time, Targets, etc.). On the right side, the detail panel displays additional information as well as a visualisation of the browse products if available.

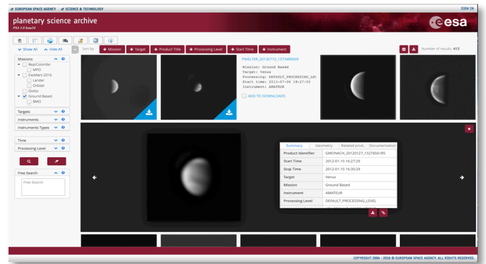

Figure 3. Example of image gallery display of the results after an initial query on the ground based observations for Venus.

5. Summary and Conclusions

The PSA new interface was released in January 2017. The home page provides a direct and simple access to the scientific data, aiming to help scientists to discover and explore its content. The archive can be explored through a set of parameters that allow the selection of products through space and time. Quick views provide information needed for the selection of appropriate scientific products. The PSA team is now focusing on developing a map search interface using GIS technologies to display ESA planetary datasets, and interoperability with international partners. This will be done in parallel with additional metadata searchable through the interface (i.e., geometrical parameters), and with a dedication to improve the content of 20 years of space exploration.

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Implementation of an EPN-TAP Service to Improve Accessibility to the Planetary Science Archive

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Abstract

To increase the accessibility of the scientific data from the European Space Agency's (ESA) planetary science and exploration missions, the Planetary Science Archive (PSA) has been redesigned and access to the new web search interface was made available to public during the beginning of 2017. [1]

To complement the web access, a focus has been made to improve the interoperability of the archive in order to provide the scientific community with a means to utilise the wide variety of existing tools and protocols and enhance the exploitability of the planetary data holdings. To this end, an EPN-TAP service has been under development for the PSA, currently in a beta-testing phase. We will present the challenges faced, and possible solutions, in implementing an EPN-TAP service for an archive hosting a significantly large amount of data as well as our experience providing this service for data following the Planetary Data System (PDS) standards.

1. Introduction

The Planetary Science Archive (PSA) is the European Space Agency's (ESA) repository of science data from all planetary science and exploration missions. The PSA provides access to scientific datasets through various interfaces at http://psa.esa.int/. All datasets are scientifically peer-reviewed by independent scientists, and are compliant with the Planetary Data System (PDS) standards [7].

In order to maximise the scientific exploitation of ESA's planetary data holdings, significant improvements have been made by utilising the latest technologies and implementing widely recognised open standards. The new PSA, released during the beginning of 2017 [1], supports Geographical Information Systems (GIS) by implementing the standards approved by the Open Geospatial Consortium (OGC) as well as increasing interoperability with the international community [5] by implementing recognised planetary science protocols such as the PDAP (Planetary Data Access Protocol) [6] and EPN-TAP (EuroPlanet-Table Access Protocol) [2].

2. Multi-mission, multi-format archive

The PSA hosts scientific data from each of the ESA planetary missions, some of which are already in the legacy phase whereas others are actively generating new data sets. The most recent mission to launch, ExoMars2016 [4], is the first of these to provide data following the latest PDS4 standards. When re-engineering the PSA to handle the new standards, challenges have been faced combining the standards into a single consistent model and due to the large quantity of data hosted. Table 1 lists the details of the current science data holdings of the PSA.

Table 1: Details of the current PSA science data holdings as of 28th April 2017.

Mission	Status	PDS Version	No. Scientific Products
Giotto	Legacy	PDS3	2054
Huygens	Legacy	PDS3	7695
SMART1	Legacy	PDS3	604527
Venus Express	Legacy	PDS3	1130780
Rosetta	Post-Operations	PDS3	57835657
Mars Express	Operational	PDS3	797809
ExoMars2016	Operational	PDS4	189162

3. EPN-TAP implementation

Efforts to adapt the VO (Virtual Observatory) protocols to planetary data have resulted in the EPN-TAP designed by Europlanet-H2020-RI/VESPA. [2] As EPN-TAP is an extension of the IVOA TAP [3], it is therefore compatible with all the relevant VO tools.

The EPN-TAP service is implemented as a web application and accessed via REST-based HTTP requests. Access to the PSA metadata is provided by an implementation of the EPNCore parameters as a table in a PostgreSQL relational database. This table is then exposed to the TAP service. One of the main challenges faced has been to provide a service that performs quickly enough given the large number of results that must be queried and returned (potentially several million depending on the query). This may be addressed through the chosen data model implementation and database strategy. The other main challenge has been how to provide the service based on PDS products and retrieve the necessary search parameters from the data.

4. Summary and Conclusions

The re-engineered PSA has a focus on improved access and search-ability to ESA's planetary science data. In addition to the new web interface released in January 2017, the new PSA supports several common planetary protocols in order to increase the visibility and ways in which the data may be queried and retrieved.

Work is on-going to provide an EPN-TAP service covering as wide a range of parameters as possible to facilitate the discovery of scientific data and interoperability of the archive.

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SSHADE: an European Database Infrastructure in Solid Spectroscopy

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Abstract

SSHADE (http://blog.sshade.eu) is an European project of a set of databases to provide the community with a large number of reference spectra of solids (ices, minerals, organics, cosmo-materials, …) of astrophysical and terrestrial interests in the X-ray, UV, visible, infrared and mm ranges. The SSHADE consortium has currently 20 partner groups in 18 laboratories from 8 different European countries. This project is developed as part of the VESPA activity within the Europlanet 2020-RI project of the Horizon 2020 program.

1. Introduction

Spectroscopy and spectro-imagery are increasingly used in space missions (e.g. VIMS/Cassini, OMEGA/Mars Express, CRISM/MRO, VIRTIS/Rosetta, RALPH/New Horizons, MAJIS/JUICE, …) to study the solid phases (icy, mineral or organic surfaces and grains, dust particles, aerosols…) of the objects of the solar system. Infrared, Raman, fluorescence and X-rays micro-spectroscopies are also used to study meteorites and cometary dusts in the laboratory and onboard some space missions (landers, rovers) for *in situ* measurements. A major contribution to the analysis of these observations is the measurement in the laboratory of UV, Visible, IR, sub-mm, Raman and XANES spectra of a variety of materials (ices, minerals, organics, …) expected to be present at the surface of the bodies of the solar system or in their ejected grains (e.g. comets, asteroids, TNO, icy satellites, Pluto, Mars, …).

A large number of laboratories in Europe have developed experiments to measure and study the spectroscopic properties of a variety of solid materials of astrophysical interest, either natural (terrestrial or extra-terrestrial) or synthetics, as a function of various compositional, structural, textural or environmental (T, P, irradiations…) parameters. The amount of data collected is huge (several tens of thousands) and many of these laboratories boast leading-edge expertise in some solid spectroscopy fields. However most of the published data (but not all by far) are very difficult to access in a usable form (i.e. electronic) to compare with observations or to use in radiative transfer codes.

We thus decided in the frame of the Europlanet 2020-RI project (09/2015-08/2019) to extend our Solid Spectroscopy Data Model (SSDM) to the needs of all spectroscopy laboratories and to convert and expand the GhoSST database structure in a database infrastructure, called SSHADE, able to gather and distribute the spectroscopic data of most of the European laboratories working on solids of any types, with astrophysical and terrestrial applications.

2. What is SSHADE?

SSHADE ("Solid Spectroscopy Hosting Architecture of Databases and Expertise") is a project of a set of databases on solid spectroscopy that started its development in September 2015 and should be publicly available early in 2018, with hopefully a public demonstrator in September 2017.

The SSHADE databases cover laboratory, field, airborne as well as simulated and theoretical spectral data including various levels of products (ex: transmission, absorbance, absorption coefficient, optical constants, band list) for many different types of solids: ices, snows and molecular solids, minerals, rocks, inorganic solids, natural and synthetics organic and carbonaceous matters, meteorites, IDPs and other cosmo-materials,… They come from a wide range of measurement technics: transmission, bidirectional reflection, Raman, fluorescence, … and over a wide range of wavelengths: from X-rays, through UV, visible, infrared to millimeter wavelengths

It is based on the GhoSST database developments (Europlanet + VAMDC 2009-2012). The SSHADE database infrastructure is hosted at the OSUG Data Center (Université Grenoble Alpes, France). The SSHADE development is part of the VESPA activity [1] within the European Europlanet-RI project of the Horizon 2020 program (09/2015-08/2019).

The SSHADE consortium has currently 20 partner groups in 18 laboratories from 8 different European countries (F, UK, I, D, E, HU, PL, CH). News about this project can be followed on the SSHADE blog (http://blog.sshade.eu).

3. SSHADE infrastructure

The SSHADE infrastructure has:

- A common data model: SSDM
- A common 'solid spectroscopy' interface
- A common data Import / Search / Visualization / Export engine
- A common fundamental database (species, publications, objects, …)
- A set of spectral databases: one per group/laboratory (GhoSST is one of them)

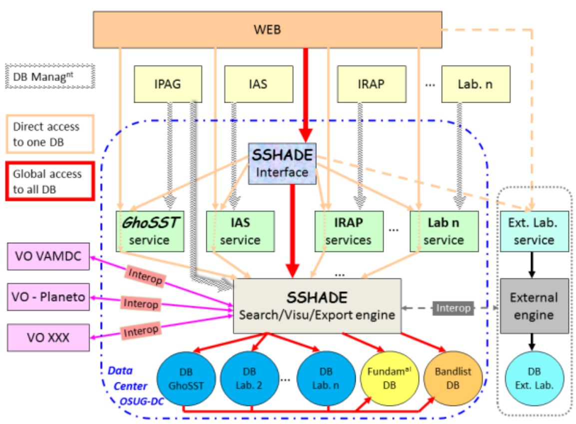

Figure 1: Schematic structure of SSHADE infrastructure

It is possible to search spectral data either with an 'Elastic Search' tool (à la Google) based on the content of a selected set of key words, or with various filters (spectrum type, species or material type or name, database, …), or from different points of view (spectra, band lists, publications, objects, …).

SSHADE will be also a service for Virtual Observatories (VESPA, VAMDC, ...). In particular part of the SSHADE databases will be accessible via the EPN-TAP protocol [2], which will allow comparison with observational data and mass processing in the VESPA environment through a series of dedicated spectroscopy plotting and analysing tools [3].

4. Databases implementation

We are progressively implementing in the SSHADE infrastructure the databases of each of the 20 partners of the SSHADE consortium. For each database the 'scientific manager' (responsible of the scientific content of its database and its quality) and the 'database manager' (responsible of the ingestion of the data in its database) are trained to the tools developed for data preparation, validation, import and management. They are in charge, with the help of contributors (experimentalists who produce data) to progressively develop the content of their database. They will also contribute to the future common 'band list' database of molecular solids by providing band parameters data or critical reviews of published data.

Tutorials on the use of the database infrastructure will be organized mostly during major planetary sciences and astrophysics conferences. The SSHADE web site will contain all documentation on the SSDM data model, tutorials and user case on the use of the SSHADE database, as well as on the experimental systems and cells used to record the spectra contained in SSHADE.

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User-defined Statistical Estimators as Virtual Observatory Search Parameters

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Abstract

Finding and retrieving space physics data is often a complicated task even for publicly available data sets: Thousands of relatively small and many large data sets are stored in various formats and, in the better case, accompanied by at least some documentation. Virtual Heliospheric and Magnetospheric Observatories (VHO and VMO) help researches by creating a single point of uniform discovery, access, and use of heliospheric (VHO) and magnetospheric (VMO) data.

The VMO and VHO functionality relies on metadata expressed using the SPASE data model. This data model is developed by the SPASE Working Group which is currently the only international group supporting global data management for Solar and Space Physics. The two Virtual Observatories (VxOs) have initiated and lead a development of a SPASE-related standard named SPASE Query Language for provided a standard way of submitting queries and receiving results.

The VMO and VHO use SPASE and SPASEQL for searches based on various criteria such as, for example, spatial location, time of observation, measurement type, parameter values, etc. The parameter values are represented by their statistical estimators calculated typically over 10-minute intervals: mean, median, standard deviation, minimum, and maximum. The use of statistical estimators enables science driven data queries that simplify and shorten the effort to find where and/or how often the sought phenomenon is observed.

We have recently developed an interface that allows users to define new parameters, which are then used as statistical estimators in data searches. The interface offers a selection of existing parameters and mathematical functions to chose from. After a new parameter request is submitted, the VxO then calculates the statistical estimators and when completed, the user can use them for data queries.

The user-defined parameters provide a customized search tool that allows for more specific science-driven queries.

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3D visualization of planetary data: the MATISSE tool in the framework of VESPA-Europlanet 2020 activity

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Abstract

MATISSE is a web tool allowing 3D visualization of planetary data. Here we discuss the new functions implemented on MATISSE to allow visualization of derived and high-level data, as well as the implementation of protocols to make it compatible with the planetary Virtual Observatory, developed under the VESPA-Europlanet2020 activity.

1. Introduction

The goal of the VESPA (Virtual European Solar and Planetary Access) activity, developed in the framework of the Horizon2020 Europlanet project, is the development of a Virtual Observatory for planetary data, in order to make them interoperable and facilitate its access, visualization and correlation [1]. A VESPA user interface (http://vespa.obspm.fr) is available to select planetary data from main databases (by means of specifically developed protocols, i.e. EPN-TAP) and includes many tools for analyze them.
The MATISSE (Multi-purpose Advanced Tool for Instruments for the Solar System Exploration) web-tool [2], developed by ASI-ASDC, allows the visualization of basic and derived data on shape models of planetary bodies. This operation is fundamental especially for minor bodies with irregular shape, since a cylindrical projection could be not sufficient for a straightforward data analysis. Here we discuss the functions implemented on MATISSE to analyze spectroscopic data and to derive high-level products, and present the activities in progress to integrate MATISSE with the VESPA interface.

2. New MATISSE functions

2.1 Radiance to reflectance conversion

Most of spectral and hyperspectral data are provided in radiance (level 1A), but especially in the visible and near-infrared spectral range reflectance spectra are more suitable to retrieve absorption features and infer the corresponding carrier.
This function converts spectral radiance in radiance factor (I/F), basing on the procedure explained in [3]: radiance is divided by a solar spectrum irradiance [4], convoluted with the spectral resolution of the VIR spectrometer [3] (only minor changes would be required to make the function suitable for other instruments), and multiplied for πd^2, being d the spacecraft solar distance expressed in Astronomical Unit. A reflectance image obtained by applying this function is shown in Figure 1.

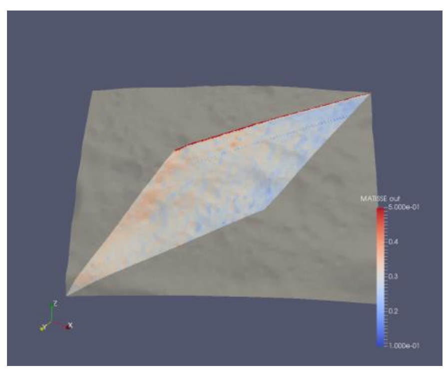

Figure 1. Reflectance image at 1.2 µm, obtained by converting a VIR radiance hyperspectral image of Vesta, and projected into MATISSE on the Vesta shape model.

2.2 Retrieval of band depths

Descriptors of band depths are fundamental to infer composition of a planetary surface or atmosphere. We implemented on MATISSE a function for retrieval of spectral descriptors of pyroxene's bands, centered at 1 and 2 μm and commonly found e.g. on many asteroids visited by space missions (Eros, Vesta).

The procedure is based on the approach by [5]. The two shoulders of each band are fitted by polynomial curves, whose local maxima represent the band boundaries. Continua are straight lines connecting the two band boundaries. Band center is calculated as the reflectance minimum after continuum removal; band depth as the complement to 1 of the ratio between measured reflectance and calculated continuum reflectance at the band center; band area as sum of differences between continuum and reflectance at each wavelength inside the band; band slope as ratio between the differences of shoulders' reflectances and shoulder's wavelengths, respectively; band width as difference between the two wavelengths corresponding to a half band depth.

2.3 Photometric correction

Photometric correction is necessary to remove influence of illumination and viewing angles from reflectance. We implemented on MATISSE a two-steps process of photometric correction, based on the approach described by [5-6]. The first step is the application of the Akimov disk function [7] to remove the influence of topography. The second step is the application of a phase function obtained by means of a statistical analysis, in order to retrieve the albedo at a defined phase angle (0° or 30°). Currently, phase functions retrieved for photometric correction of VIR [3] data of Vesta and VIRTIS-M [8] data of the Churyumov-Gerasimenko comet (Figure 2) are available on MATISSE.

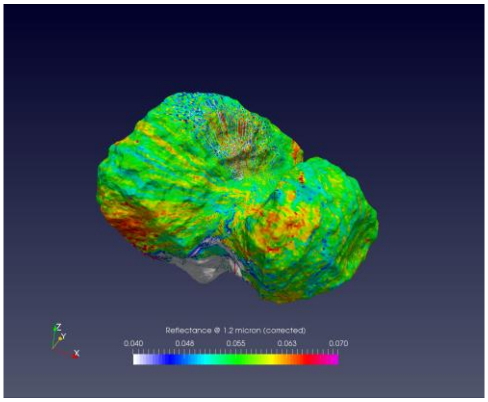

Figure 2: Photometrically corrected reflectance at 1.2 μm of Churyumov-Gerasimenko projected into MATISSE on its shape model.

3. MATISSE vs VESPA

We plan to interconnect MATISSE with VESPA VO tools and data services, which require the implementation of SAMP (Simple Application Messaging Protocol) protocol. We could implement the following possibilities:

1. MATISSE linked to the VESPA user interface, in order to visualize with MATISSE the data searched and selected from VESPA;
2. MATISSE linked with the APERICubes demonstrator (which is the tool currently used on VESPA for PDS file), together with the other VO tools currently present on VESPA;
3. MATISSE used to visualize the outputs from VO tools, in order to allow different visualizations of planetary data.

In all the three cases, the implementation of SAMP protocols on MATISSE is needed and is an operation in progress.

Acknowledgements

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Spectroscopy of planetary surfaces in a VO context (VESPA)

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Introduction

The VESPA data access system developed in the Europlanet-2020 program focuses on applying Virtual Observatory (VO) techniques and tools to Planetary Science [1]. A specific theme in this activity is related to spectroscopy in solid phase, with applications to the observation of the surfaces of planets, satellites, and small bodies, and is now being implemented. A first aspect consists in providing observational databases in an interoperable form; this currently includes observations of terrestrial planets and asteroids, and will develop in the next two years. A second aspect is to make experimental databases available and searchable in this context. A third aspect is to adapt existing VO tools to handle spectra of solid phases and make comparisons with observations possible. All data and tools will be available from the VESPA search interface (http://vespa.obspm.fr).

1. Solid spectroscopy in VESPA

VESPA actions related to experimental data include on one hand the evolution of the GhoSST database into a much larger infrastructure called SSHADE; on the other hand a unified access to several existing databases of mineral spectra.

SSHADE (Solid Spectroscopy Hosting Architecture of Databases and Expertise) is a sub-network of 20 European contributors from 8 different countries [2]. It will extend the existing GhoSST (Grenoble astropHysics and planetOlogy Solid Spectroscopy and Thermodynamics) database [3] to a large set of contributor databases in the field of solid spectroscopy, including major ones. The on-going implementation phase will be followed by a phase of data documentation and validation, to ensure consistency and data quality. The resulting service will not only help extend the spectral databases of ices, minerals and organic materials, but will also make the state-of-the-art laboratory data readily available as references to interpret observations of planets and small bodies, in particular from spacecraft. SSHADE includes a dedicated environment with visualization and processing tools for specialists; the databases will include measured spectra as well as derived data such as band lists and optical constants, relying on the very complete Solid Spectroscopy Data Model defined for this service. A first public interface will be available early in 2018. The databases will also be accessible via the simpler EPN-TAP protocol [4], which is intended to speed up comparison with observational data and to allow for mass processing in the VESPA environment (Fig. 1).

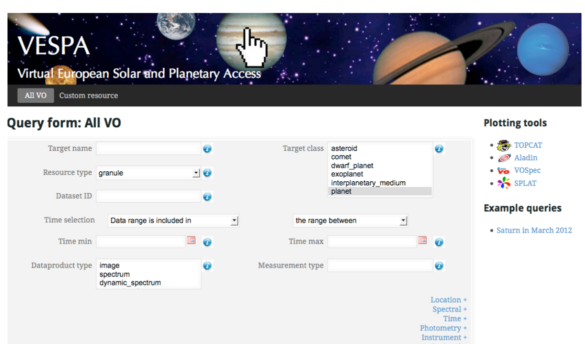

Fig 1: The VESPA user interface: http://vespa.obspm.fr

Other databases of mineral reflectance spectra have been regularly populated in the past 20 years and are routinely used to interpret observations of planetary surfaces, e. g., on Mars, the Moon, or small bodies. An important project is therefore to extend EPN-TAP to define parameters describing samples of interest in terms of mineralogical composition, origin, grains size, mixing, possible processing, etc, as well as measurement technique and physical quantity. The current design phase is based on several spectral libraries, in particular the Berlin Rosetta Spectral library (minerals and meteorites in reflectance) and the CRISM spectral library [5] that is currently searchable from a web form at the PDS Geosciences Node (http://speclib.rsl.wustl.edu/). The Berlin Emissivity Database at DLR, which is supported in other Europlanet activities, is another possible candidate to make an EPN-TAP data service. With such descriptions available, the spectral libraries will be readily accessible by spectral fitting tools, but also by planetary GIS environments connected to VESPA.

2. Plotting and analyzing tools

A more technical but important action in this science theme is to adapt astronomical standards and tools to Planetary Science needs, where many spectral observations are acquired in reflected light and on extended objects. Current VO data models do not include the descriptors (*UCD*s and *UTypes*) identifying the corresponding physical quantities (radiance, I/F ratio, many sorts of reflectance, albedos and emissivities, etc), nor the usual physical units in the field. More generally, the various existing VO tools do not seem to handle our spectral data similarly at present, probably because of incomplete requirements provided by the standards. CASSIS [6] is the tool of choice to assess the consistency of standards extension, since it is partly supported by VESPA (Fig. 2).

3. Use case

A simple use case consists in searching spectra of asteroid Vesta in M4ast and comparing them with basaltic meteorites measured in reflectance from spectral libraries. The main issue is to search for samples in the experimental databases, and to retrieve spectra that are sufficiently documented for later processing. The availability of spectral thumbnails in the VESPA search interface appears important to quickly identify data of interest.

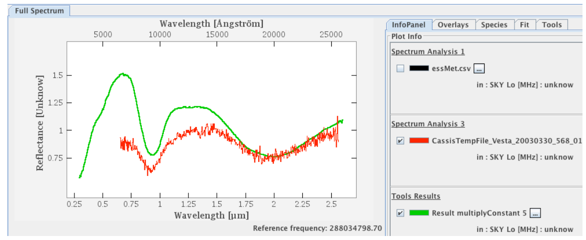

Figure 2: Comparison between spectra of asteroid Vesta from the M4ast service and the ALH84001 SNC meteorite extracted from the PDS spectral library, in CASSIS.

The PDS spectral library uses a description with 8 different levels (global type, class, subclass, group, species…), while the Berlin one uses only 4 such levels, some with multiple values. In practice, it is difficult for the user to identify what keyword is expected to contain what descriptor, and it appears that existing databases do not always use fully consistent descriptions. The simple solution currently under assessment in EPN-TAP is to concatenate all available descriptors in a single list where substrings related to composition will be searched, e. g. "phyllosilicate" or "meteorite" as well as "kaolinite" or "CV3". Many tests are on going to converge towards a satisfying description common to all data services, but fully efficient implementations will require some level of reprocessing of the compositional information. In addition, a dedicated form may be required to address this level of complexity in the main search interface.

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VOEvent for Solar and Planetary Sciences

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Abstract

With its Planetary Space Weather Service (PSWS), the Europlanet-H2020 Research Insfrastructure (EPN2020RI) project is proposing a compelling set of databases and tools to that provides Space Weather forecasting throughout the Solar System. We present here the selected event transfer system (VOEvent). We describe the user requirements, develop the way to implement event alerts, and chain those to the 1) planetary event and 2) planetary space weather predictions. The service of alerts is developed with the objective to facilitate discovery or prediction announcements within the PSWS user community in order to watch or warn against specific events. The ultimate objective is to set up dedicated amateur and/or professional observation campaigns, diffuse contextual information for science data analysis, and enable safety operations of planet-orbiting spacecraft against the risks of impacts from meteors or solar wind disturbances.

1. Introduction

The PSWS (Planetary Space Weather Service) Joint Research Activities (JRA) will set up the infrastructure necessary to transition to a full planetary space weather service within the lifetime of the project. A variety of tools (in the form of web applications, standalone software, or numerical models in various degrees of implementation) are available for tracing propagation of planetary or solar events through the Solar System and modeling the response of the planetary environment (surfaces, atmospheres, ionospheres, and magnetospheres) to those events. As these tools were usually not originally designed for planetary event prediction or space weather applications, additional development is required for these purposes. The overall objectives of PSWS will be to review, test, improve and adapt methods and tools available within the partner institutes in order to make prototype planetary event/ diary and space weather services operational through PSWS Virtual Access (VA) at the end of the program. One of the goals is: *To identify user requirements, develop a methodology for issuing event alerts, and link those to the planetary event and space weather predictions.* This is the scope of this paper. We first present selected science cases that demonstrate the need for the proposed system. The VOEvent infrastructure is then described, followed with the way we implement it for solar system wide space weather.

2. Science Cases

The forecasting planetary and space weather events is initiated by observations. The observational events can be used as such, or used as inputs for prediction or modeling tools to predict potential subsequent effects.

Planetary meteor impacts have been reported by several teams (including amateurs) in the last decade: First shooting star seen from Mars [1]; amateur astronomer see Perseid hits on the Moon [2]; Fiercest meteor shower on record to hit Mars via comet [3]; Explosion on Jupiter spotted by amateur astronomers [4]. The events are often reported in the news or on amateur online forums. Those transient events are useful for studying the properties of the impacted region. Quick and efficient transmission of them is thus a key step. This methodology is used in astronomy with the Gamma-Ray Bursts alert system [5].

Several studies have been published [6, 7] presenting the observed effects of interplanetary shocks while the hit various planets throughout the solar system, from the Sun to Jupiter, Saturn or even Uranus. Figure 1 shows an interplanetary shock triggered by three coronal mass ejections (CME) in September 2011. The shock has been observed at Earth a few days later (with *in situ* measurement on the WIND spacecraft, as well as in the auroral power monitored by NOAA). It also triggered intense decametric radio emissions at Jupiter three weeks later, that were observed by the STEREO-A/Waves instrument. It finally hit Uranus after a two months journey in the interplanetary medium, with the activation of Uranus atmospheric aurora. The planning of Uranus' aurorae has been prepared using the 1D MHD mSWiM model [8] developed at University of Michigan. This code also confirmed the Jovian radio detection link with the studied event. The major outcome of this study is the first observation of the faint Uranus' aurorae from Earth orbit, and this was only possible thanks to the propagation model.

Several heliospheric propagation models (e.g., [9, 8] have been recently developed and provide the space physics community with time of arrivals of interplanetary shocks, or high energy particle beam at planets or spacecraft in the solar system. Online tools and repositories are providing access to heliospheric simulation runs. The Coordinated Community Modeling Center (CCMC [10]) is a run on demand service center with several propagation models available. Users can also use simulation runs that were previously computed. The French Plasma Physics Data Centre (CDPP [11]) is providing precomputed simulation runs in his AMDA (Automated Multi Dataset Analysis) tool [12] as time series of predicted Solar Wind parameters at the place of the various spacecraft and planets. It also proposes a Propagation Tool [13] that uses both simulation and observational products to derive time of arrivals of Solar Wind events events at the place of the various spacecraft and planets (see Figure 2).

Many science teams and space missions could take advantage of such predictions in the recent years (Smart 1, Rosetta, MEx, MAVEN, VEx, HST, MSL, Dawn), within the next five years (Exomars, Juno, HST/JWST, Solar Orbiter) and ona longer term (Bepi-Colombo, JUICE). This list of missions will be used to prioritize the event catalogs, tools or models that will be implemented in the PSWS alert system.

3 Fripon

Meteorite composition have not change since the formation of the solar system, Fripon project propose to use a network of 100 cameras and 25 radio detectors to cover the French territory and detect the meteor orbit and the area of impact. Fripon will calculate impact position and gives area of impact in a private network that will be broadcasted by the Observatoire de Paris VOEvent Broker.

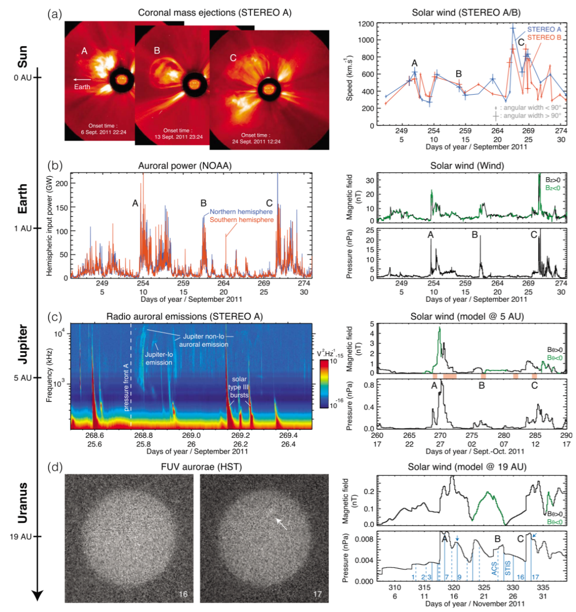

Figure 1: Following an interplanetary shock throughout the solar system, from the Sun to Uranus. Figure extracted from [7]

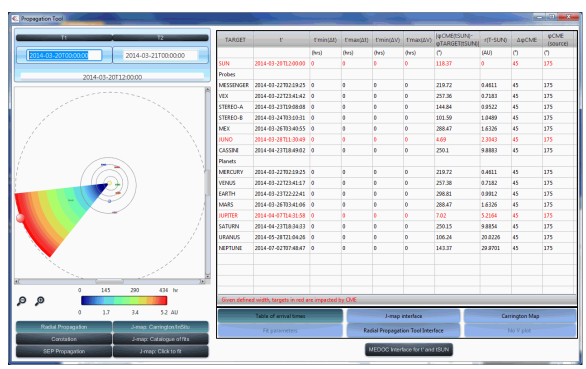

Figure 2: CDPP Propagation Tool

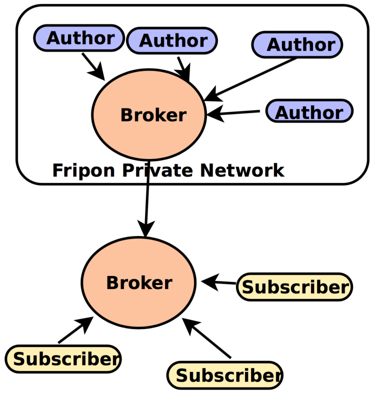

Figure 3: fripon network

4 VOEvent

VOEvent [14] is a standardized language used to report observations of astronomical events; it was officially adopted in 2006 by the International Virtual Observatory Alliance (IVOA). Though most VOEvent messages currently issued are related to supernovae, gravitational microlensing, and gamma-ray bursts, they are intended to be general enough to describe all types of observations of astronomical events, including gravitational wave events.

The VOEvent system is already used by several large-scale projects: the Gamma-Ray Coordinate System (GCN) [5]; the Large Synoptic Survey Telescope (LSST) []; the European Low Frequency Array (LOFAR); or the Solar Dynamic Observatory (SDO). That last project has scopes included in PSWS goal. In each of those projects, VOEvent is used for fast transmission of transient observations. In PSWS, we plan to use VOEvent for both observations and predictions.

Messages are written in XML, providing a structured metadata description of both the observations and the inferences derived from those observations. VOEvent messages are designed to be compact and quickly transmittable over the internet. The version of the VOEvent standard is 2.0, at the time of writing.

As shown on Figure 4, there are three types of nodes: Author, Broker and Subscriber. The Authors are issuing VOEvent. The Brokers are dispatching the VOEvents received from Authors to Subscribers. Subscribers are receiving VOEvents from Brokers. The large scale network is composed of a series of Brokers that are also Subscribers of other Brokers. The Authors must assign a unique IVOA identifier [15] to each issued VOEvent. The Subscribers will only take into account VOEvents with new identifiers. In order to update an event (e.g., update the predicted time of an event, after improved processing), a new VOEvent must be issued as an update of a previous VOEvent with reference to the previous VOEvent identifier. This system ensures consistency and avoids conflicting messages. In the PSWS project, each event will be referred to as with its identifier in catalogs shared with VESPA (Virtual European Solar and Planetary Access), the data distribution infrastructure of EPN2020RI [16].

A VOEvent message contains the following tags:

`<who>` Describing who is responsible (the author and the publisher) for the information contained in the message;

`<how>` a description of the instrumental setup on where the data were obtained;

`<what>` the data (such as source flux) associated with the observations of the event;

`<why>` inferences about the nature of the event;

`<wherewhen>` description of the time and place where the event was recorded. This draws from the Space-time Coordinate (STC) recommendation to the IVOA.

A well-formed VOEvent message must validate against the VOEvent XML schema. A valid message may omit most of the informational tags listed above, but since the creation of VOEvent messages is done automatically, most opt to transmit the fullest content available.

5 Test implementation

We use a tool developed in the frame of LOFAR (Low Frequency Array), for dispatching transient alerts: Comet. It is a freely available, open source implementation of VTP (VOEvent Transfer Protocol).

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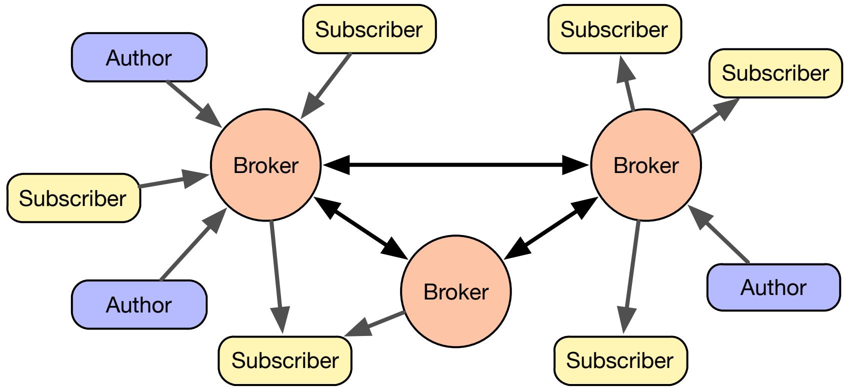

Figure 4: Architecture of VOEvent network.

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Cassini VESPA

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Abstract

NASA's Cassini Mission has gathered thirteen years of data exploring Saturn and its moons, rings, magnetosphere, and atmosphere. As the mission comes to a close, scientists need to ensure that the information they have assembled during this extraordinary mission is easily accessible to new researchers. Each of Cassini's twelve instruments can take observations in different modes and with different sensors. The instrument teams store their data in disparate systems and formats, and process them to different levels. Creating a single, intuitive interface for new scientists to search across all of this data is a daunting task. The VESPA (Virtual European Solar and Planetary Access) framework offers a potential solution for this challenge. VESPA provides a standard data model, access protocol, and registration service so that any team can turn their dataset into a service provider. The Cassini archive team has created a prototype with VESPA to evaluate whether the framework is a solution for this flagship mission. The resulting system allows users to query data from any Cassini instrument in one place, along with data from other missions, other agencies, ground-based observations, and laboratory results. This poster will describe the Cassini experience setting up the VESPA server, importing various types of Cassini data, and gathering feedback from the science community.