Planetary Data in the Virtual Observatory: VESPA (Virtual European Solar and Planetary Access)

Stéphane Erard, Baptiste Cecconi, Pierre Le Sidaner, A. Rossi, L. Tomasik, S. Ivanovski, B Schmitt, Nicolas André, Loic Trompet, M. Scherf, et al.

PLANETARY DATA IN THE VIRTUAL OBSERVATORY: VESPA (VIRTUAL EUROPEAN SOLAR & PLANETARY ACCESS). **S. Erard** (1), B. Cecconi (1), P. Le Sidaner (2), A. P. Rossi (3), L. Tomasik, (4), S. Ivanovski (5), B. Schmitt (6), N. André (7), L. Trompet (8), M. Scherf (9), R. Hueso (10) M. Demleitner (17), N. Manaud (18), M. Taylor (19), I. Alexeev (20), A. Määttänen (11), E. Millour (12), F. Schmidt, (13), I. Waldmann (14), P. Fernique (15), M. D'Amore (16), C. Brandt (3), H. Rothkaehl (4), M. Molinaro (5), V. Génot (7), A. C. Vandaele (8)

(1) LESIA, Obs. Paris/PSL/CNRS/Sorbonne Univ/Univ. Paris, Fr (stephane.erard@obspm.fr) (2) DIO-VO, Obs. Paris/CNRS, Fr (3) Jacobs University, Bremen, Ge (4) CBK-PAN, Warsaw, Po (5) INAF/OATS, Trieste, It (6) IPAG UGA/CNRS, Grenoble, Fr (7) IRAP/CNRS/UPS/CNES, Toulouse, Fr (8) BIRA/IASB, Brussels, Be (9) OeAW, Graz, Aust (10) UPV/EHU, Bilbao, Spain (11) LATMOS/IPSL, Sorbonne Université, UVSQ, U. Paris-Saclay, CNRS, Guyancourt, Fr (12) LMD/IPSL/CNRS, Paris, Fr (13) GEOPS/IPSL/CNRS/UPS, Orsay, Fr (14) University College London, UK (15) Observatoire de Strasbourg/UMR 7550, Fr (16) PLL, DLR, Berlin, Ge (17) Heidelberg Univ, Ge (18) Spacefrog, Toulouse, Fr (19) Univ of Bristol, UK (20) LMSU, Moscow, Ru

Introduction: VESPA (Virtual European Solar and Planetary Access) has been focusing for nearly 10 years on adapting Virtual Observatory (VO) techniques to handle Planetary Science data [1] [2]. The objective of this activity is to build a contributive data distribution system where data services are located and maintained in research institutes, as well as in space agencies and observatories. VESPA is part of Europlanet, a series of programs funded by the European Union and dedicated to enforcing collaborative activities in Planetary Science both within and outside Europe. A new program called Europlanet-2024 has started in 2020 for a 4-year period.

During the previous Europlanet-2020 program, VESPA has defined an architecture adapted from the astronomy VO, and incorporating concepts and standards from other areas (Earth observation, Heliophysics, etc). The basic system uses the VO infrastructure: data services are installed in any location but are declared in a system of harvested registries with identifiers, end-point (URL), mention of supported access protocols, and rough description of content. Such services are interoperable via clients and tools, which also provide visualization and analysis functions.

Data description: VESPA has adopted the Table Access Protocol (TAP) from the International Virtual Observatory Alliance (IVOA) to query data services. In addition to this general mechanism, the EPNCore vocabulary has been designed to provide a uniform metadata system describing observational, instrumental, and physical parameters with fixed names, scales, and units. EPNCore encompasses all fields of Solar System studies and supports simulations and experimental data as well as observational ones. It can be extended to new parameters whenever required. Beyond TAP, EPNCore provides a handy parameter description system that can be used in various contexts, including with personal databases in the course of a research program.

A PDS4 dictionary has been provided for future conversion schemes with modern space agency archives. ENPCore is both a project study of the International Planetary Data Alliance (IPDA), and an emerging standard of the IVOA (currently under review to become a proposed recommendation [3]).

Data access and tools: Since VESPA data services are responsive to TAP, they can be queried by all TAP clients – either web interfaces, java tools, python libraries, Jupyter notebooks, etc. Some VO tools include specific support for EPN-TAP (i.e., using EPNCore with TAP).

The VESPA portal (http://vespa.obspm.fr) is a dedicated web interface oriented towards data discovery, that can query all public EPN-TAP services simultaneously; it also converts EPN-TAP queries to NASA keyword-search queries and the older PDAP protocol. The portal also uses VO-compliant web services as support applications, e.g. Miriade (ephemeris system), quaero (name resolver for solar system objects) and WebGeoCalc (SPICE computation).

All tools and search interfaces in the VO can exchange data via a specific protocol called SAMP. Hence, data selected from the VESPA portal are readily sent to TOPCAT, Aladin, CASSIS, SPLAT-VO, etc (respectively for tables, images and spectra), for visualization and analysis — when data format permits. Aladin now provides access to planetary HiPS, which are multiscale versions of the most recent planetary maps distributed by USGS and other institutes. Non-VO tools can be connected by installing available SAMP libraries. Such integrations have been performed with 3Dview (spacecraft measurements), Autoplot (time series) and QGIS (georeferenced surface data).

Data services: 55 public data services currently have an EPN-TAP interface, including the complete ESA Planetary Science Archive, and the outcome of

several EU funded projects and space experiments in various fields: SSHADE for experimental spectroscopy of solids, PVOL for amateurs images, AMDA for plasma-related data, several archives of radio observations and solar data, planetary observations by HST, several services providing access to georeferenced data according to the WMS or WCS protocols, etc.

About 20 more projects are currently under development in the frame of Europlanet-2024. Of particular interest is the VizieR database of astronomical catalogues at CDS, which includes many planetary data tables published in science journals but not easily accessible due to limited description. Beyond such catalogue archives, VESPA potentially provides research institutes with a simple and economical solution to distribute data associated to publications, according to FAIR principles.

Prospects: In the framework of the Europlanet-2024 program, VESPA will develop this infrastructure even further (Fig. 1): 30-50 new data services will be installed, focusing on derived data, and experimental data produced in other Work Packages of Europlanet-2024.

EPNCore will be developed by integrating future community standards in critical areas, e.g. universal identifiers for planetary coordinate systems or spacecraft and observatories. Interoperability with other data distribution systems will be enhanced.

A run-on-demand platform (OPUS, adapted from the ESCAPE astronomy program) is under assessment to provide simulations and data analysis capacities. Machine Learning capacities are developed to process the available content of data services in several fields.

Long-term sustainability is also being improved: definition files from all public services are gathered in a unique gitlab platform to assist data providers in maintaining their services. Authentication is provided by GÉANT/eduTEAMS, and services stored in the gitlab can be deployed on the new EU-funded European Open Science Cloud (EOSC), with support from the EGI consortium. In addition to favoring data exploitation, VESPA will provide a handy and economical solution to Open Science challenges in the field.

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References: [1] Erard et al (2018) PSS 150, 65 [2] Erard et al (2020) Data Science Journal 19, 22 [3] https://ivoa.net/documents/EPNTAP/20201027/index.html

Figure 1 : global infrastructure of VESPA