# VESPA, a Planetary Science Virtual Observatory cornerstone

Stéphane Erard[1], Baptiste Cecconi[2], Pierre Le Sidaner[3], Angelo Pio Rossi[4], Maria Teresa Capria[5], Bernard Schmitt[6], Vincent Genot[7], Nicolas André[8], Ann Carine Vandaele[9], Manuel Scherf[10], Ricardo Hueso[11], Anni Maattanen[12], Benoit Carry[1], Nicholas Achilleos[13], Chiara Marmo[14], Ondrej Santolik[15], Jan Soucek[16], Kevin Benson[17], and Pierre Fernique[18]

[1]Paris Observatory
[2]Paris Observatory Meudon
[3]Observatoire de Paris
[4]Jacobs University Bremen
[5]IAPS-INAF
[6]Laboratoire de Planétologie de Grenoble (LPG)
[7]IRAP / CNRS / UPS
[8]Universite Paul Sabatier
[9]Belgian Institute for Space Aeronomy
[10]IWF Institute for Space Research
[11]University of the Basque Country
[12]LATMOS Laboratoire Atmosphères, Milieux, Observations Spatiales
[13]University College London
[14]GEOPS / University of Paris-Sud 11
[15]IAP Prague
[16]Inst. of Atmospheric Physics
[17]Mullard Space Science Laboratory
[18]Observatoire de Strasbourg

November 24, 2022


### Abstract

The Europlanet H2020 program started on 1/9/2015 for 4 years. It includes an activity to adapt Virtual Observatory (VO) techniques to Planetary Science data called VESPA. The objective is to facilitate searches in big archives as well as sparse databases, to provide simple data access and on-line visualization, and to allow small data providers to make their data available in an interoperable environment with minimum effort. The VESPA system has been hugely improved during the first three years of Europlanet H2020: the infrastructure has been upgraded to describe data in many fields more accurately; the main user search interface (http://vespa.obspm.fr) has been redesigned to provide more flexibility; alternative ways to access Planetary Science data services from VO tools have been implemented; VO tools are being improved to handle specificities of Solar System data, e.g. measurements in reflected light, coordinate systems, etc. Current steps include the development of a connection between the VO world and GIS tools, and integration of Heliophysics, planetary plasmas, and mineral spectroscopy data to support of the analysis of observations. Existing data services have been updated, and new ones have been designed. The global objective is already overstepped, with 42 services open (including ESA's PSA) and ~15 more being finalized. A procedure to install data services has been documented, and hands-on sessions are organized twice a year at EGU and EPSC; this is intended to favour the installation of services by individual research teams, e.g. to distribute derived data related to a published study. In complement, regular discussions are held with big data providers, starting with space agencies (IPDA).

Common projects with PDS have been engaged, with the goal to connect PDS4 and EPN-TAP based on a local data dictionary. In parallel, a Solar System Interest Group has been established in IVOA; the goal is here to adapt existing astronomy standards to Planetary Science. The Europlanet 2020 Research Infrastructure project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208. [1] Erard et al 2014, Astronomy & Computing 7-8, 71-80. http://arxiv.org/abs/1407.4886

# VESPA (Virtual European Solar & Planetary Access): a Planetary Science Virtual Observatory cornerstone

S. Erard[1], B. Cecconi[1], P. Le Sidaner[2], A. P. Rossi[3], M. Minin[3], T. Capria[4], B. Schmitt[5], V. Génot[6], N. André[6], A.C. Vandaele[7], M. Scherf[8], R. Hueso[9], A. Määttänen[10], B. Carry[11], N. Achilleos[12], C. Marmo[13], O. Santolik[14], J. Soucek[14], K. Benson[12], P. Fernique[15]

[1] **LESIA, Observatoire de Paris/**PSL Research University/CNRS**,** France [2] **DIO-VO/Observatoire de Paris/**PSL Research University, France [3] **Jacobs Univ.**, Bremen, Germany [4] **INAF/IAPS**, Rome, Italy [5] **IPAG/CNRS**, Grenoble, France [6] **IRAP/CNRS/ Univ. Paul Sabatier**, Toulouse, France [7] **IASB/BIRA**, Brussels, Belgium [8] **OeAW**, Graz, Austria [9] **UPV/EHU**, Bilbao, Spain [10] **LATMOS/CNRS**, Guyancourt, France [11] **IMCCE**, Paris, France [12] **UCL,** London, U-K [13] **GEOPS/CNRS/Univ Paris-Sud**, Orsay, France [14] **IAP**, Prague, Cz. Rep. [15] **CDS**, Observatoire de Strasbourg, France.

europlanet

stephane.erard@obspm.fr

## Europlanet H2020 EU program

The Europlanet H2020 program is a EU founded initiative dedicated to providing a research infrastructure to Planetary Science in Europe. VESPA, a large part of the program, is related to providing easy and efficient access to observational, modeled, and experimental data in the field.
The program started on Sept 1st, 2015 for a 4-years period.

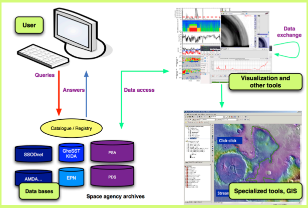
## VESPA

The goal of VESPA (Virtual European Solar and Planetary Access) is to build a Virtual Observatory (VO) for Solar System Sciences, based on the infrastructure developed in a previous program Europlanet-RI, and reusing mechanisms which have been developed for the Astronomy VO [1, 2].
Currently, 44 data services are connected to VESPA, installed and maintained in 15 different institutes.

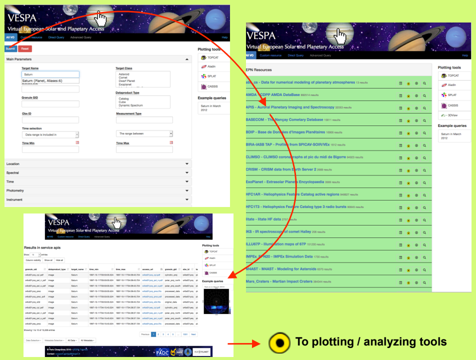
The user interface is available at: ***http://vespa.obspm.fr***

## VESPA functionalities

VESPA provides:
1) an integrated search interface to identify data of interest in many databases simultaneously, based on science-related parameters.
2) A connection to generic visualization and analysis tools, based on standards from the Astronomy VO (IVOA).




The VESPA interface queries the connected services using science-related parameters. The result is a list of services containing answers; when browsed, individual files are listed.



**To plotting / analyzing tools**

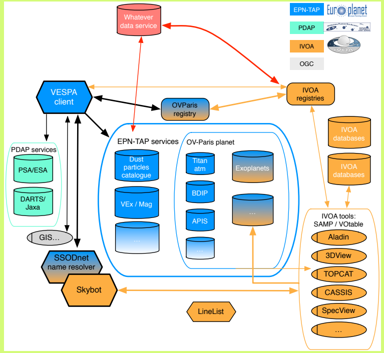
## Architecture

VESPA makes intense use of preexisting mechanisms, which are adapted to the specific needs of Planetary Science.
The original ingredients consist in a Data Model (EPNcore) to describe planetary data content, associated to the standard TAP protocol, ADQL language, and the IVOA registry of services.
EPNcore makes use of predefined lists, e.g., to identify targets, spacecraft, observatories, coordinate systems [3], etc. In most cases those are based on IAU standards.

**Any data provider can benefit from VESPA's infrastructure by providing an EPN-TAP interface to their database and declaring their service in the registry - contact our team!**

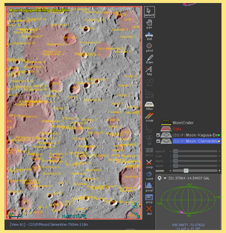
Native VO formats include fits and VOtable. A specific tool has been set up to support the PDS3 format (space data archives) and spectral cubes.

Specialized environments are also developed and connected in VESPA, including magnetosphere modeling, ephemeris computation, solid spectroscopy databases [4], and a two-way connections with planetary GIS. Simulation services are also being connected to VESPA.

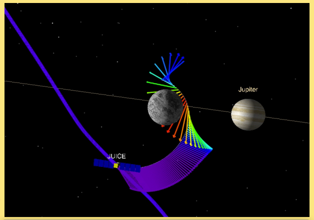



## Tools available in VESPA

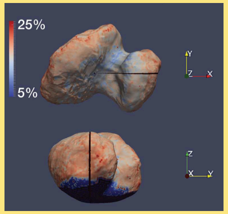
Existing tools are being adapted to Planetary Science needs for visualization and processing. They all exchange data through the SAMP protocol (see also [5])



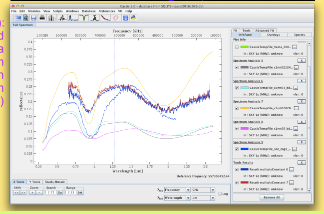
**Aladin (CDS/CNRS)**:
Added planetary HiPS (multiresolution maps), planetary coordinate frames, TAP client querying VESPA services
(Lunar crater catalogue on on Kaguya HiPS)



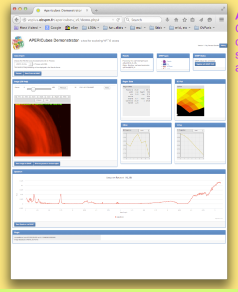

**3Dview (CNES)**:
Added all mission SPICE kernels,
Projects images on planets
(JUICE orbit study)



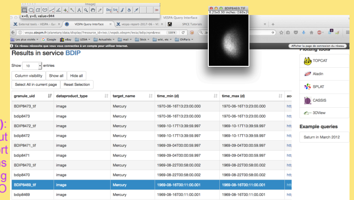

**CASSIS (IRAP/CNRS)**:
Added radiance and reflectance spectra
(spectra of Vesta from M4ast compared with SNC meteorites from PDS speclib)




**MATISSE (ASI)**:
3D mapping on shape models. Added VO interface on input.
(VIRTIS/Rosetta observations of 67P on OSIRIS 3D shape model)

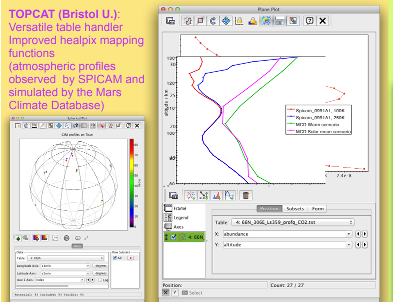


**APERICubes (Obs Paris)**:
Open and browse PDS3 spectral cubes, extract spectra and images, send them via SAMP hub to imaging and spectral tools (VIRTIS/VEx cube)



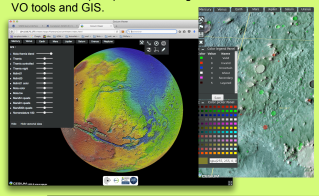
**ImageJ (NIH, open source)**:
Added VO interface on input
Improved fits support
Provides format conversions and image processing functions to the VO

**TOPCAT (Bristol U.)**:
Versatile table handler
Improved healpix mapping functions
(atmospheric profiles observed by SPICAM and simulated by the Mars Climate Database)



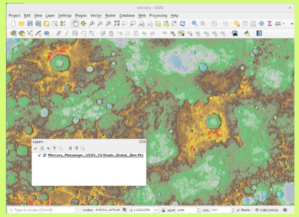

## Bridging the VO and GIS

Several techniques permit handling of surface related data in VO tools and GIS.



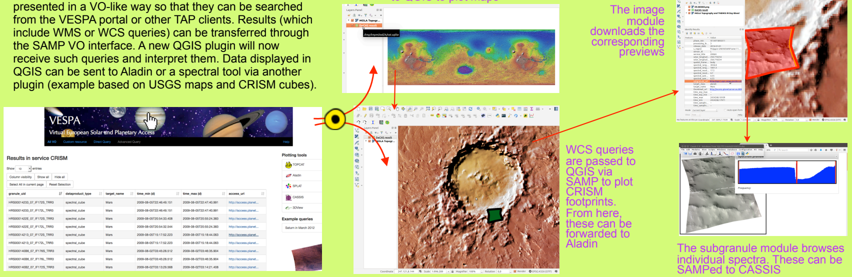
• Planetary Cesium Viewer is a new 3D displayer with SAMP interface, supporting elliptic shapes, annotations. It is used here to check and improve Robbins' Mars craters database.

• Supporting the full WCS standard in planetary images allows ds9 to project properly oriented images on planets. The new geofits extension [6] further improves handling of planetary images, and GDAL support makes it possible to handle them in QGIS (here a MESSENGER qube in fits format).




• Web services using GIS protocols such as WMS can be presented in a VO-like way so that they can be searched from the VESPA portal or other TAP clients. Results (which include WMS or WCS queries) can be transferred through the SAMP VO interface. A new QGIS plugin will now receive such queries and interpret them. Data displayed in QGIS can be sent to Aladin or a spectral tool via another plugin (example based on USGS maps and CRISM cubes).

WMS queries are passed to QGIS to plot maps




The image module downloads the corresponding previews

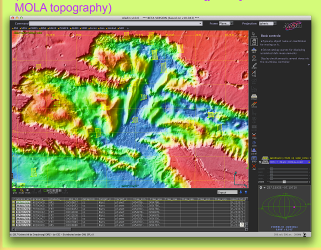
WCS queries are passed to QGIS via SAMP to plot CRISM footprints. From here, these can be forwarded to Aladin

The subgranule module browses individual spectra. These can be SAMPed to CASSIS

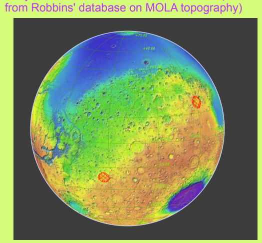
## Footprints and spatial searches

Footprints can be plotted to visualize data on planetary surfaces or in the sky.
Powerful spatial searches based on intersections between footprints are available.

**Aladin** can now retrieve and plot arbitrary footprints, and perform searches on spatial intersections (CRISM sessions in Valles Marineris [yellow], on MOLA topography)



**Aladin** also computes Multi Order Coverages (MOC) representing a footprint with a list of healpix cells. They can be used to filter another dataset (craters from Robbins' database on MOLA topography)



## Roadmap for data services

**Open**
*In development*
*Being studied*

**Atmospheres**
- **Titan profiles** - CIRS (Cassini, LESIA)
- **Venus spectroscopy** - VIRTIS (VEx, LESIA)
- **Mars Climate Database** (modeling, LMD-LESIA)
- **Venus profiles - SPICAV/SOIR** (VEx, IASB-BIRA)
- **Mars profiles - SPICAM** (MEx, LATMOS)
- All MEx derived atmospheric products (via MEx IDS)
- EuroVenus derived products

**Small bodies**
- **M4ast** (ground based spectroscopy, **IMCCE)**
- **1P/Halley spectroscopy (IKS / Vega-1, LESIA)**
- **BaseCom (Nançay obs, LESIA)**
- **TNOs are cool** (Herchel & Spitzer + compilation, **LESIA & LAM & Utinam)**
- ***Cometary lines catalogue (IAPS)***
- ***Vesta & Ceres spectroscopy*** *- VIR/DAWN (IAPS)*
- **DynAstVO**: NEO refined parameters **(IMCCE)**
- **MPCorb**: Small bodies orbital cat (MPC/Heidelberg)
- *Rosetta ground-based support (via C. Snodgrass)*
- **67P illumination config (IRAP)**

**Surfaces**
- **CRISM** WMS service **(MRO, Jacobs U)**
- **M3** *WMS service* ***(Chandrayaan-1, Jacobs U)***
- **Mars craters (Jacobs U, *+ update by GEOPS*)**
- **USGS planetary maps (Jacobs U)**
- ***HRSC data*** *(MEx, Frei Univ)*
- **OMEGA cubes and maps (IAS)**

**Solid spectroscopy**
- **PDS spectral library** (LESIA)
- ***SSHADE: ices & minerals (IPAG & network)***
- ***Planetary Spectral Library (DLR)***
- ***Berlin Reflectance Spectral Lib (DLR)***

**Magnetospheres / radio**
- **APIS (HST, LESIA)**
- **NDA (Jupiter radio Nançay, LESIA)**
- **AMDA (CDPP / IRAP)**
- **MAG data (VEx, IWF Graz)**
- ***MASER & Juno support (LESIA)***
- **RadioJove (LESIA & US amateur network)**
- **IItate HF data of Jupiter (Tohoku Univ, Jap)**
- ***UTR-2 Juno ground support (Kharkiv, Ukr.)***
- **MDISC** (modeling, UCL)
- *Generic wave polar. & propag. (modeling, IAP Prague)*
- **Interface with IMPEx models (IWF Graz)**
- **Hisaki *(Tohoku Univ., Jap)***
- **Transplanets (CDPP / IRAP)**

**Exoplanets**
- **Encyclopedia of exoplanets (LUTH/LESIA)**
- *Transit observations (Bern)*
- *Interface with DACE (Geneva)*

**Heliophysics**
- **HELIO AR & 1T3 solar features catalogues (LESIA)**
- **Bass2000 *(LESIA)***
- ***Radio Solar db (Nançay, LESIA)***
- **CLIMSO (Pic du Midi, IRAP)**
- **IItate AMATERAS (Tohoku Univ, Jap)**

**Generic / interdisciplinary**
- **BDIP (LESIA)**
- **Planets** *then satellites characteristics* (LESIA/IMCCE)
- **PVOL (UPV/EHU & amateur network)**
- **Gas absorption cross-sections (Granada)**
- **Nasa dust catalogue (IAPS)**
- *Stellar spectra, support for observations & exopl. (LESIA)*
- **Telescopic planetary spectra collection (LESIA)**
- **PSA complete archive *(ESA)***
- **HST planetary data (CADC / PADC)**
- *DARTS (JAXA - currently via PDAP)*

## References

[1] Erard S. et al (2014) The EPN-TAP protocol for the Planetary Science Virtual Observatory. Astronomy & Computing, 7-8, 52-61. *http://arxiv.org/abs/1407.5738*
[2] Erard et al (2018) VESPA: A community-driven Virtual Observatory in Planetary Science. Planet. Space Sci. 150, 65-85. *https://arxiv.org/abs/1705.09727*
[3] Joy et al, this conference, poster IN11D-0660
[4] Schmitt et al (2018) SSHADE: the European solid spectroscopy database infrastructure.EPSC2018-529
[5] Cecconi et al, this conference, poster IN11D-0648
[6] Marmo et al (2018) FITS format for planetary surfaces: definitions, applications and best practices. Earth and Space Science 5 *(Special Issue Planetary mapping). https://doi.org:10.1029/2018EA000388*
- see also: https://github.com/epn-vespa/gdal

***http://www.europlanet-vespa.eu/***

*The Europlanet 2020 Research Infrastructure project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208.*