

# VESPA: Enlarging the Virtual Observatory to Planetary Science

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IAS, Prague

IWF, Graz

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eur  PLANET



PSIDA, St Louis

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VESPA includes 18 contributing participants (labs) in 13 beneficiary institutes:

Observatoire de Paris  
(IMCCE, LESIA)



IAPS/INAF Rome



Jacobs Univ. Bremen



CNRS  
(IRAP IPAG LATMOS  
GEOPS CDS)



IWF Graz



IASB-BIRA Brussels



UCL London



IAP Prague



+ Contributions from  
the community

UPV/EHU Bilbao



IGN/PAS Wrocław



Univ. Bern



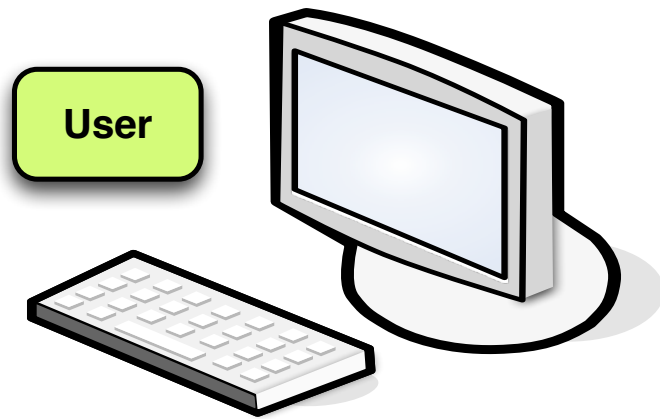
SINP/Lomonosov Univ.



GFI Toulouse



# User's experience



User

Queries

Answers

Data access

Catalogue / Registry

SSODnet

GhoSST  
KIDA

PSA

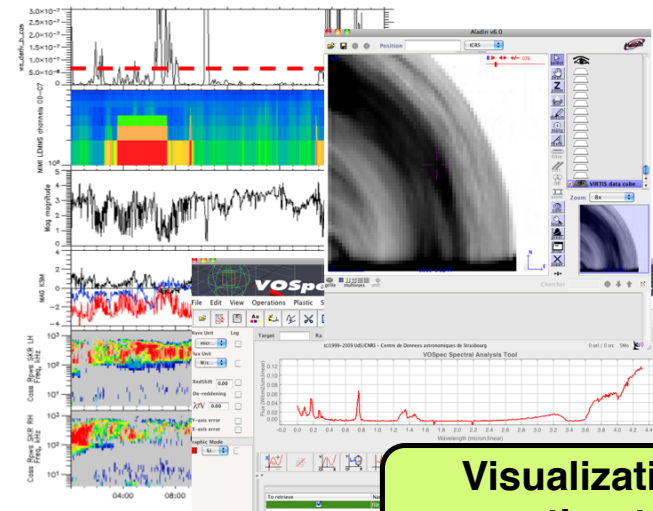
AMDA...

EPN

PDS

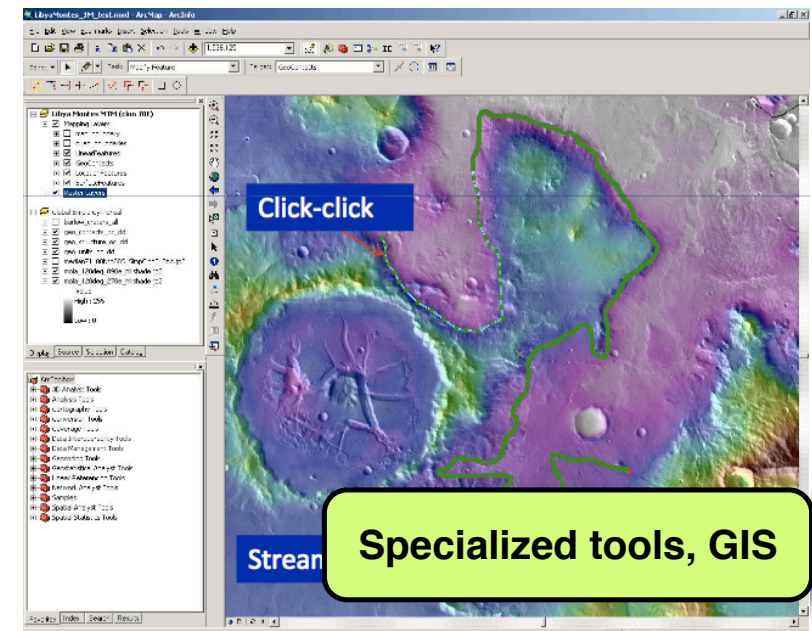
Data bases

Space agency archives



Data exchange

Visualization and other tools



Click-click

Stream

Specialized tools, GIS

## Such a system has been designed already:

=> Infrastructure adapted from the Astronomy Virtual Observatory

A set of standards to describe data contents, identify them in sparse archives, and retrieve them

+ tools able to plot, analyze, exchange, and combine the data

**VESPA uses this infrastructure to provide:**

- **An easy way to search in Planetary Science databases based on physical / observational parameters**
- **A consistent way to search many databases at once**
- **A straightforward interface to access VO tools for Planetary Science**

**=> Access to many data for researchers**

**=> Major exposition for data providers**

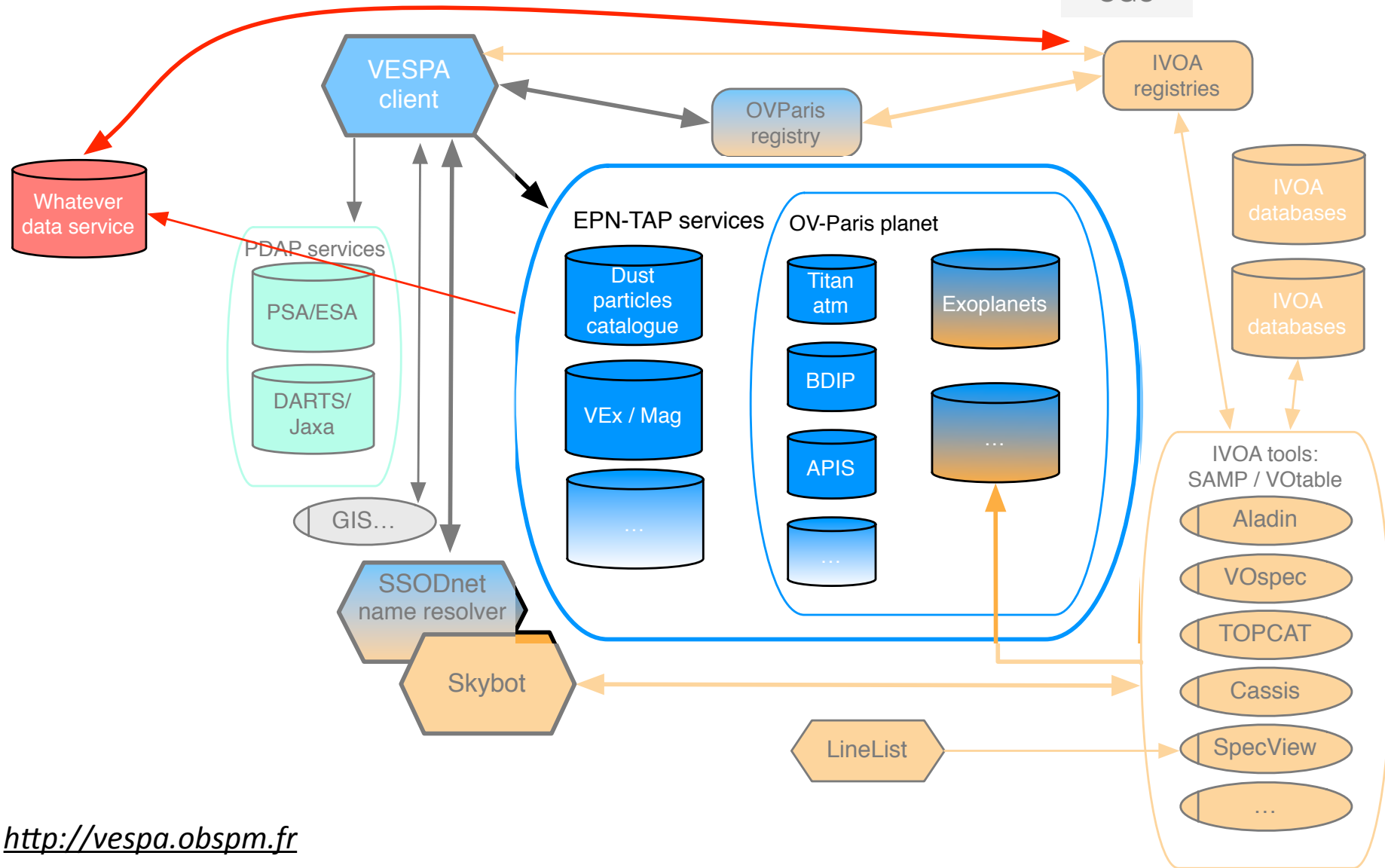
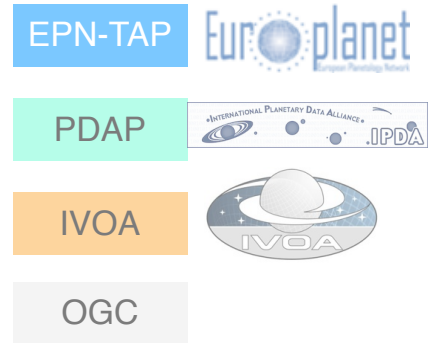


# A Virtual Observatory in Planetary Science

Built on astronomical VO developments

+ previous European programs: IMPEX, HELIO, VAMDC...

+ interfaces with: PDS, GIS/OGC, etc...



## **VESPA infrastructure:**

### **Open data / open source system:**

- **A data model: EPNCore**
- **A data access protocol: EPN-TAP**
- **An optimized search client: the VESPA portal**
  - Other search modes: through standard TAP clients & in VO tools
- **Connexion to VO tools: through the SAMP exchange protocol**
  - Connexion to other, non-VO tools: developing SAMP plug-ins
- **Relies on existing standards**
  - In particular IAU + responsive to IVOA & IPDA std
- **Data services are widespread, connected via EPN-TAP**
  - no central system - except the registry

# VESPA data access

- Global search interface for Planetary Science services
- Supports EPN-TAP + PDAP

<http://vespa.obspm.fr>

The screenshot displays the VESPA web interface. At the top, there is a navigation bar with 'All VO', 'Custom resource', 'Direct Query', and 'Advanced Query' options. Below this, a search bar shows 'apis' with 15506 results and 'bdip' with 704 results. The main content area is titled 'Results in service apis' and features a table of search results. A blue arrow points from the table to a box containing the text 'To plot / analysis tools'. On the right side, there are sections for 'Plotting tools' (listing TOPCAT, Aladin, SPLAT, and CASSIS) and 'Example queries' (showing a plot of Saturn in March 2012).

**Results in service apis**

Show 10 entries

Column visibility Show all Hide all

granule_uid	dataproduck_type	target_name	time_min	time_max	access_url	granule_gid	obs_id	ta
o4bd01ycq_cyl_pdf	image	Saturn	1997-10-11T03:53:03.524	1997-10-11T04:09:43.724	o4bd01ycq_cyl.pdf	cylindric_proj	o4bd01ycq	pli
o4bd01ycq_pol_n_pdf	image	Saturn	1997-10-11T03:53:03.524	1997-10-11T04:09:43.724	o4bd01ycq_pol_n.pdf	polar_proj_north	o4bd01ycq	pli
o4bd01ycq_pol_s_pdf	image	Saturn	1997-10-11T03:53:03.524	1997-10-11T04:09:43.724	o4bd01ycq_pol_s.pdf	polar_proj_south	o4bd01ycq	pli
o4bd01ycq_proc	image	Saturn	1997-10-11T03:53:03.524	1997-10-11T04:09:43.724	o4bd01ycq_proc.fits	processed_data	o4bd01ycq	pli
o4bd01ycq_proc_pdf	image	Saturn	1997-10-11T03:53:03.524	1997-10-11T04:09:43.724	o4bd01ycq_proc.pdf	processed_data	o4bd01ycq	pli
o4bd01ycq_x2d	image	Saturn	1997-10-11T03:53:03.524	1997-10-11T04:09:43.724	o4bd01ycq_x2d.fits	original_data	o4bd01ycq	pli
o4bd01yeq_cyl_pdf	image	Saturn	1997-10-11T04:15:43.524	1997-10-11T04:28:37.134	o4bd01yeq_cyl.pdf	cylindric_proj	o4bd01yeq	pli
o4bd01yeq_pol_n_pdf	image	Saturn	1997-10-11T04:15:43.524	1997-10-11T04:28:37.134	o4bd01yeq_pol_n.pdf	polar_proj_north	o4bd01yeq	pli
o4bd01yeq_pol_s_pdf	image	Saturn	1997-10-11T04:15:43.524	1997-10-11T04:28:37.134	o4bd01yeq_pol_s.pdf	polar_proj_south	o4bd01yeq	pli
o4bd01yeq_proc	image	Saturn	1997-10-11T04:15:43.524	1997-10-11T04:28:37.134	o4bd01yeq_proc.fits	processed_data	o4bd01yeq	pli

**Plotting tools**

- TOPCAT
- Aladin
- SPLAT
- CASSIS

**Example queries**

Saturn in March 2012

## Data services connected via EPN-TAP

### Currently:

39 interoperable data services connected, from 13 institutes (~ 15 in dev)

Encompass many aspects of Solar System studies:

- surfaces
- small bodies / satellites / rings / dynamics
- atmospheres
- magnetospheres / radio observations
- solar physics / planetary plasmas
- exoplanets
- solid spectroscopy / experimental reference data

Several high-quality amateur services preselected (PVOL, RadioJove...)

# Data services connected via EPN-TAP / field

Open  
Open in test  
In development  
Being studied

\* New in 2016-18

## 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 (via C. Wilson)

PDS3 dataset \*  
in the PSA

## 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)

PDS3 dataset  
in the PDS

## Surfaces

- \* - CRISM WMS service (MRO, Jacobs U)
- \* - Mars craters (Jacobs U, + update by GEOPS)
- \* - USGS planetary maps (Jacobs U)
- \* - M3 WMS service (Chandrayaan-1, Jacobs U)
- HRSC data (MEx, Frei Univ)
- OMEGA data (MEx, IAS, via SIttools2)
- MarsSI GIS (Lyon)

## Solid spectroscopy

- SSHADE: ices & minerals (IPAG & network)
- Minerals emission db (DLR)
- PDS spectral library (LESIA)
- \* - Berlin Reflectance Spectral Lib (DLR)

Derived from a  
PDS dataset

## 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)
- Cluster data (IAP, Prague)
- Interface with IMPEX models (IWF Graz)
- \* - Hisaki (Tohoku Univ., Jap)
- \* - Transplanets (CDPP / IRAP)

JAXA mission

## Exoplanets

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

## Solar

- 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)
- Interface with VAMDC (TBD)
- \* - PSA complete archive (ESA)
- DARTS (JAXA - currently via PDAP)
- On-going discussions with PDS & IPDA



## Favorite VESPA tools

**Only some tools are presented here**

**Favorite ones:**

**TOPCAT** (tables, mutipurpose)

**Aladin, DS9** (images/cubes) + **ImageJ, APERICubes...**

**CASSIS, SPLAT-VO** (spectra) + **VOspec, SpecView**

**3Dview, MATISSE** (3D visu, shape models) + **Cosmographia**

**Autoplot** (time series)

Ephemeris related:

**Miriade, Vision** (in Miriade), **SkyBot, name resolver** (from IMCCE)

Some services include specific tools together with the data:

**AMDA, SSHADE...** (more and more accessible from outside)

**All tools exchange data via the SAMP protocol**

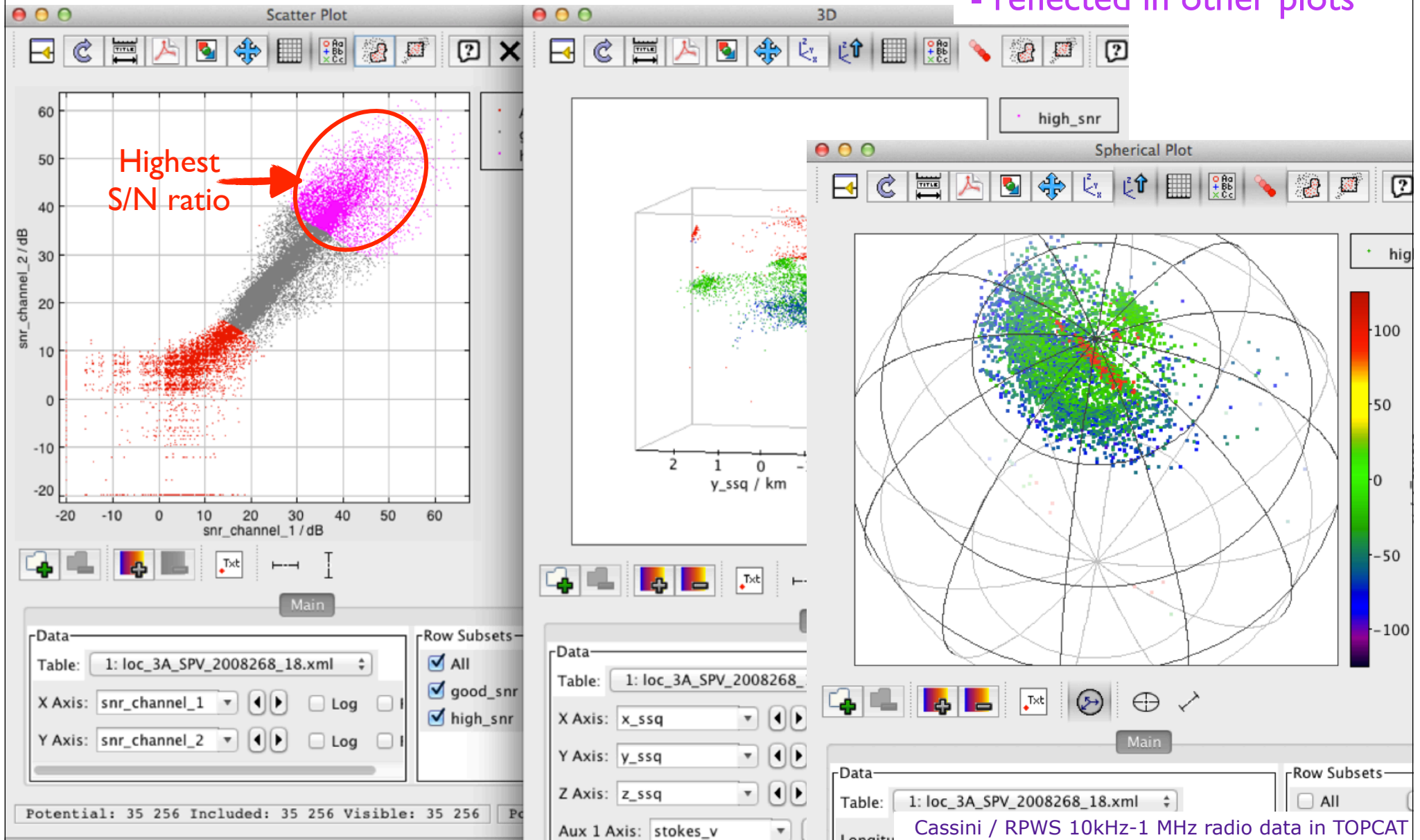


# Favorite VESPA tools

## TOPCAT (Bristol Univ):

Allows data selection

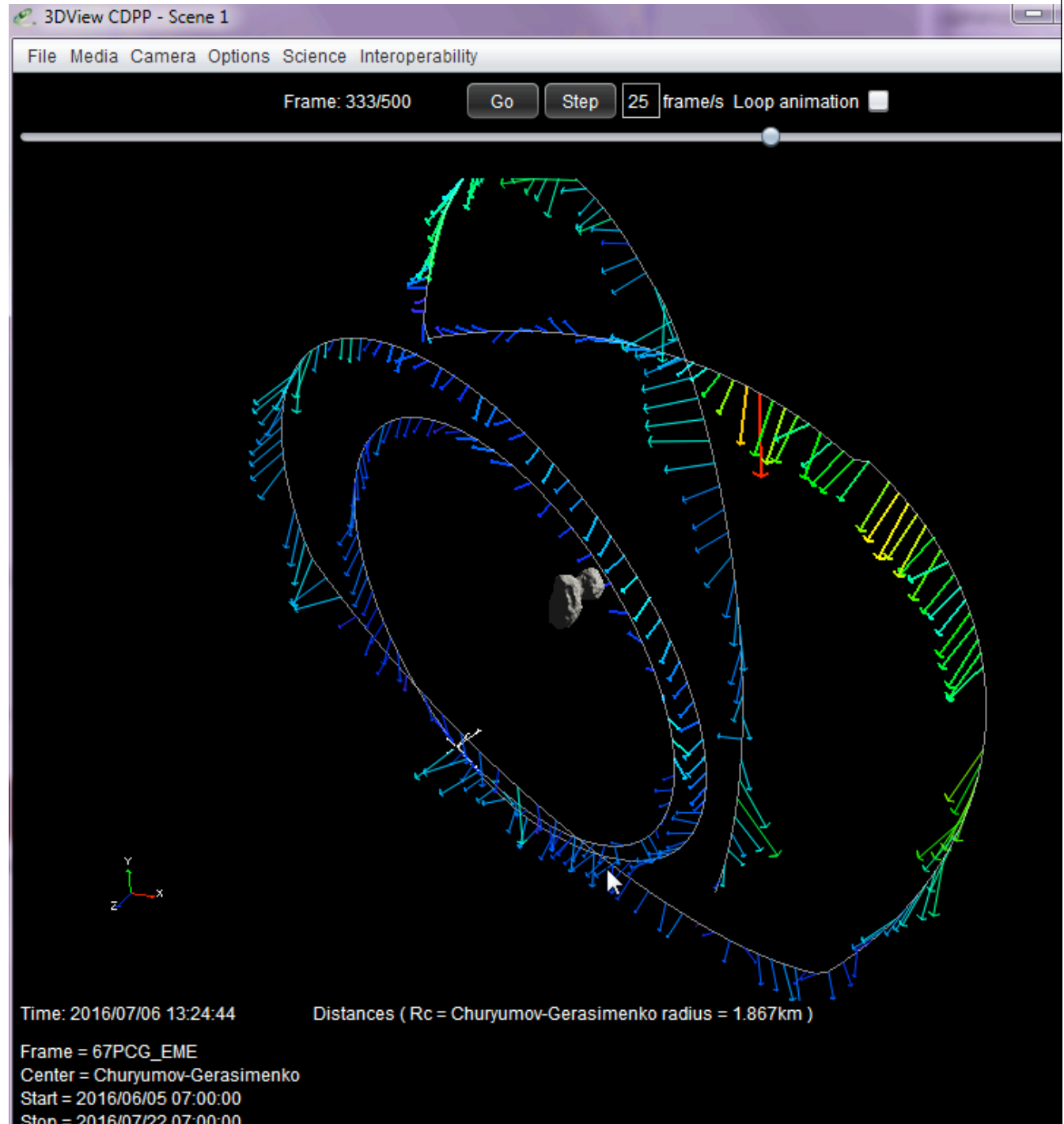
- by formula or graphically
- reflected in other plots



# Favorite VESPA tools

## 3Dview (CNES/IRAP):

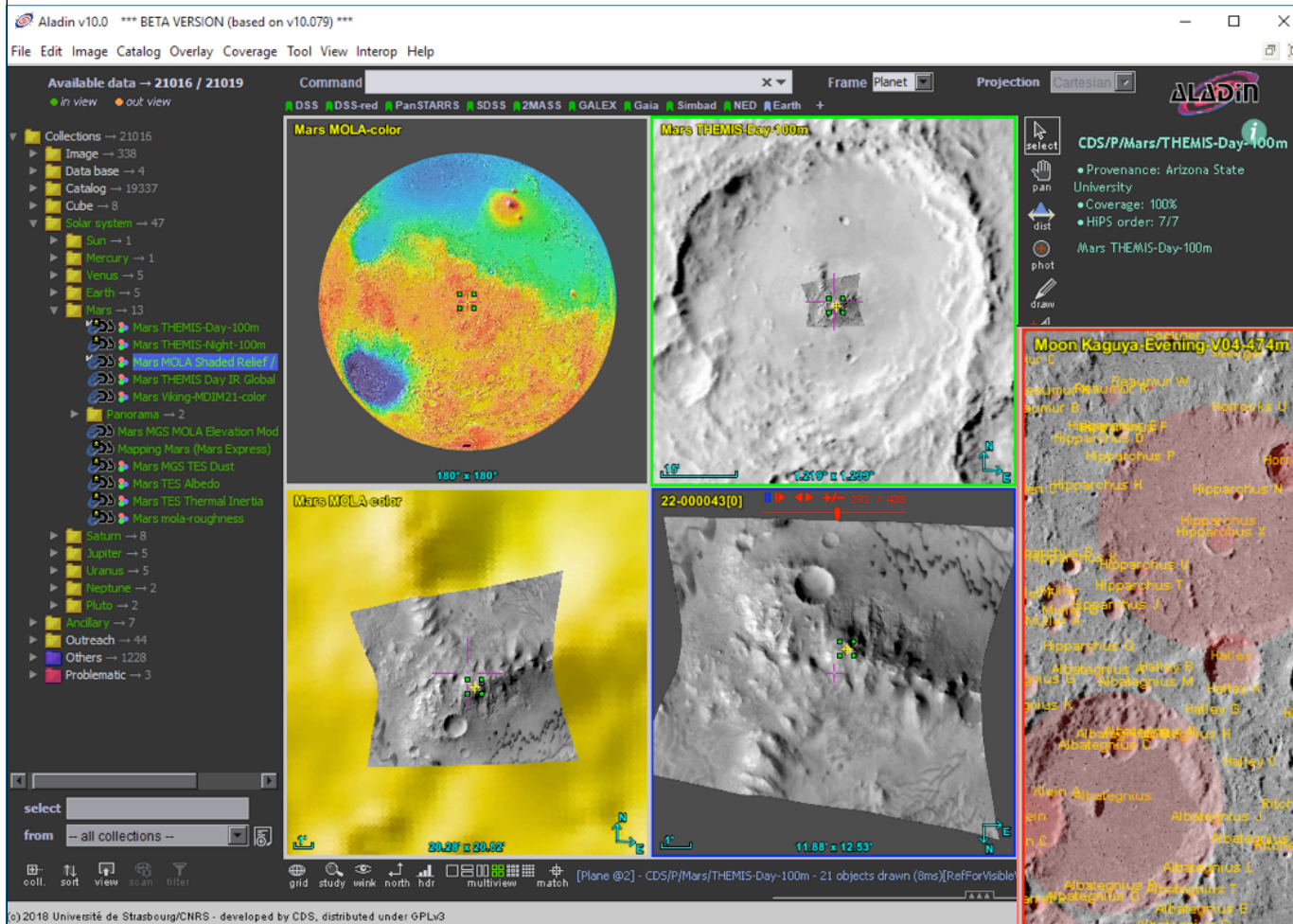
- added Spice kernels from all space missions
- Added image projection capacities



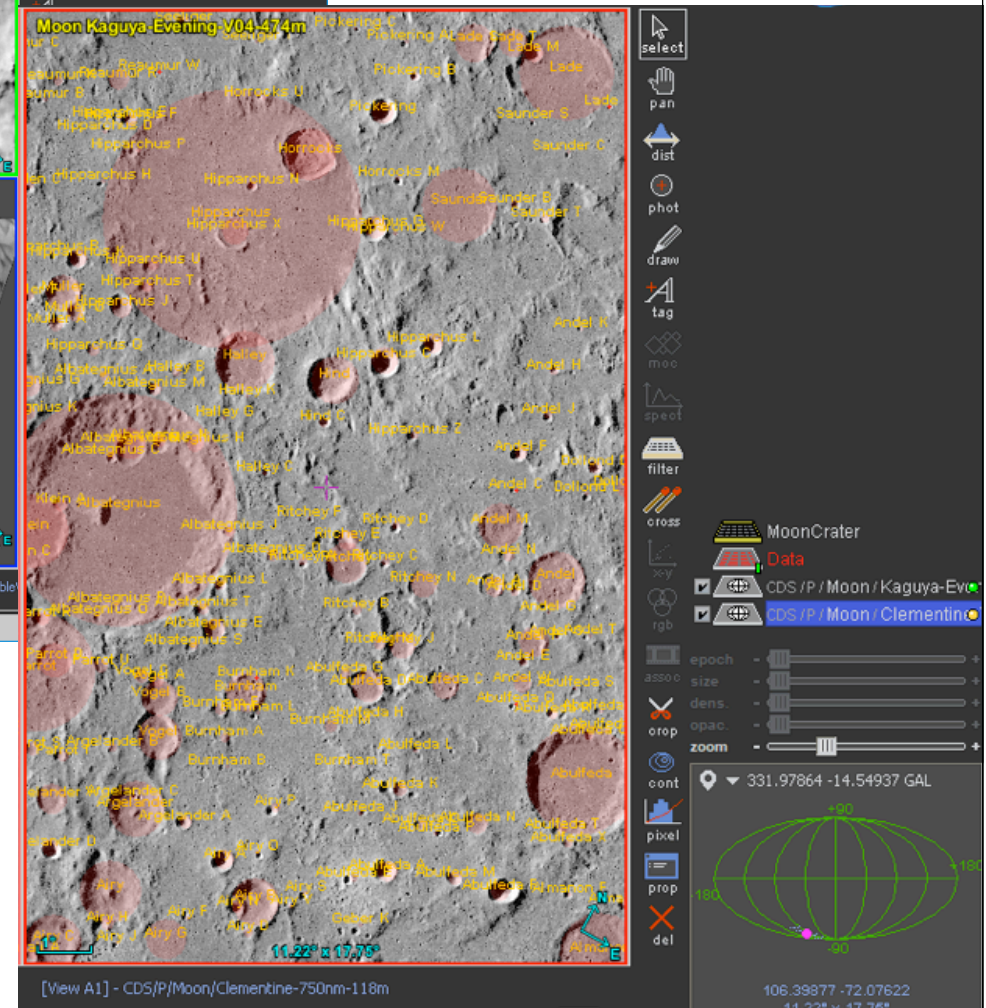
# Favorite VESPA tools

# Aladin (CDS/CNRS):

# Georeferenced images + objects superpositions



Lunar crater catalogue on Kaguya HiPS



CRISM cubes on MOLA HiPS

Relies on IAU planetary coordinate frames (fits' WCS)

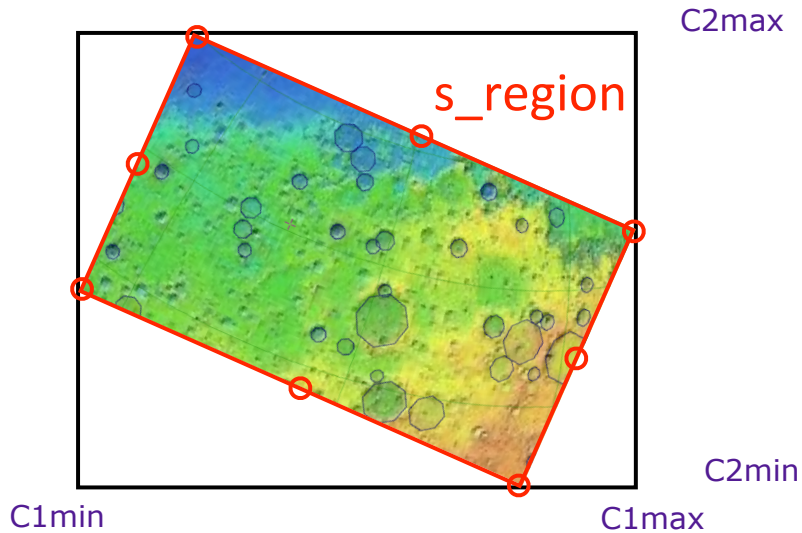


## Aladin: using clever footprints

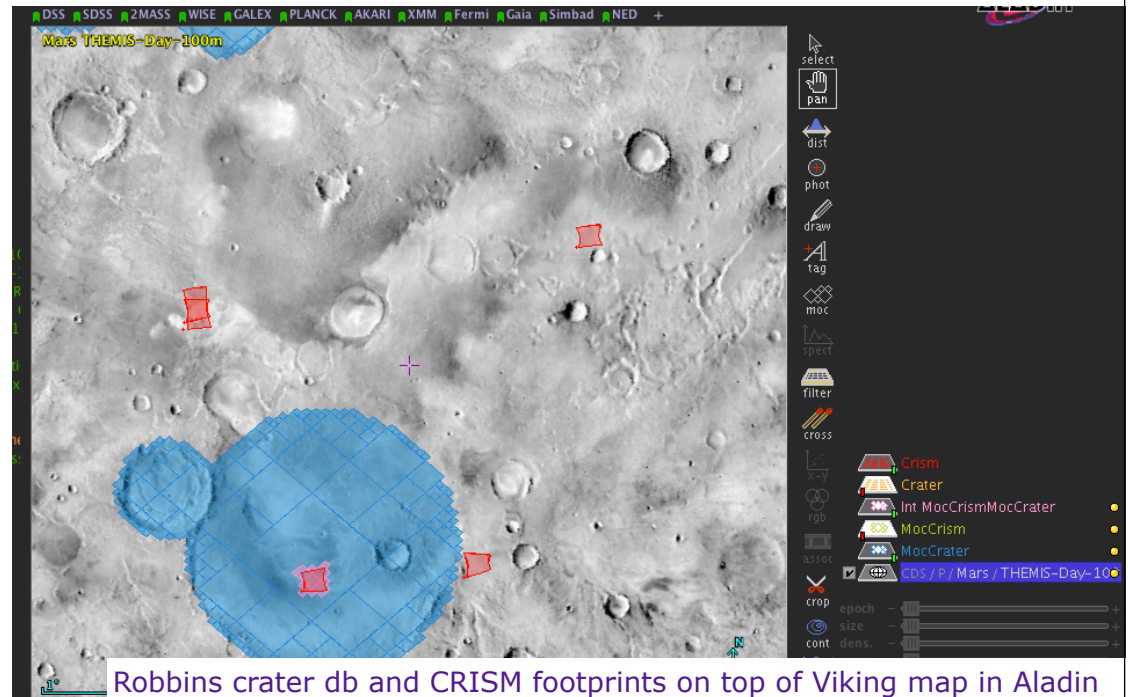
C1/C2 min/max coordinates  
in body-fixed frame

- **PDS3-like limits** (lon/lat bounding box)  
=> provide very rough estimate of footprint and many false alarms

- **pgsphere s\_region** (sampling the contour)  
=> provides much more accurate footprints with tunable resolution  
+ allows very powerful searches on intersections, etc



- **MOC - Multi Order Coverages** (healpix-based)  
=> Even quicker to compute and use. Can apply to entire datasets or individual files



## New VESPA functions - multiscale images

### Experimenting with:

1) Healpix in TOPCAT

2) HiPS in Aladin: multiresolution maps

Applications to HiRes mapping of planets

(very demanding) => Computed in advance, available on line

Currently includes 45 HiPS from a selection of USGS maps

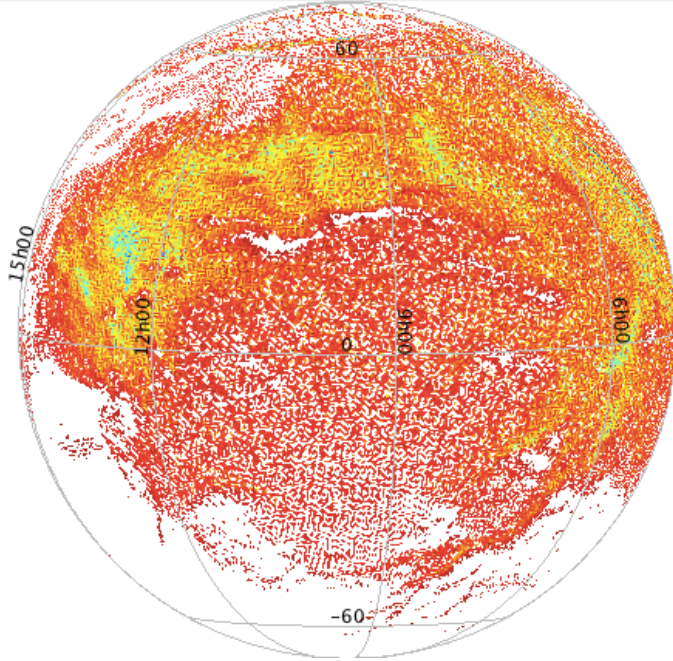
+ usage with panoramic images, TBC

3) MOC in Aladin: still another footprint format, quick and handy

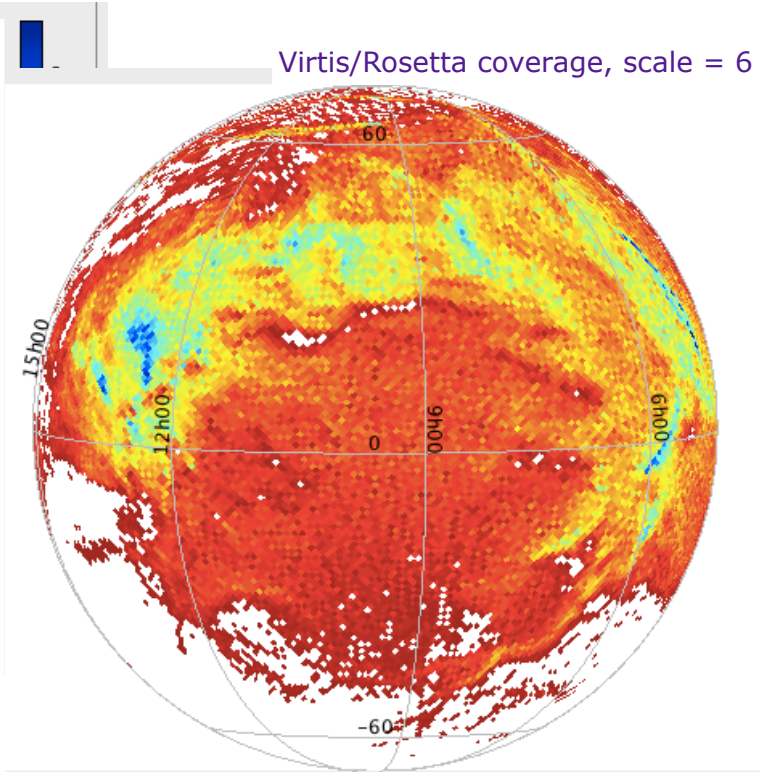
Applications to filter object catalogues, search intercepts, ROI definition, etc

# New VESPA functions

# Multiresolution maps in TOPCAT



Virtis/Rosetta coverage of 67P for a selected mission phase, scale = 7



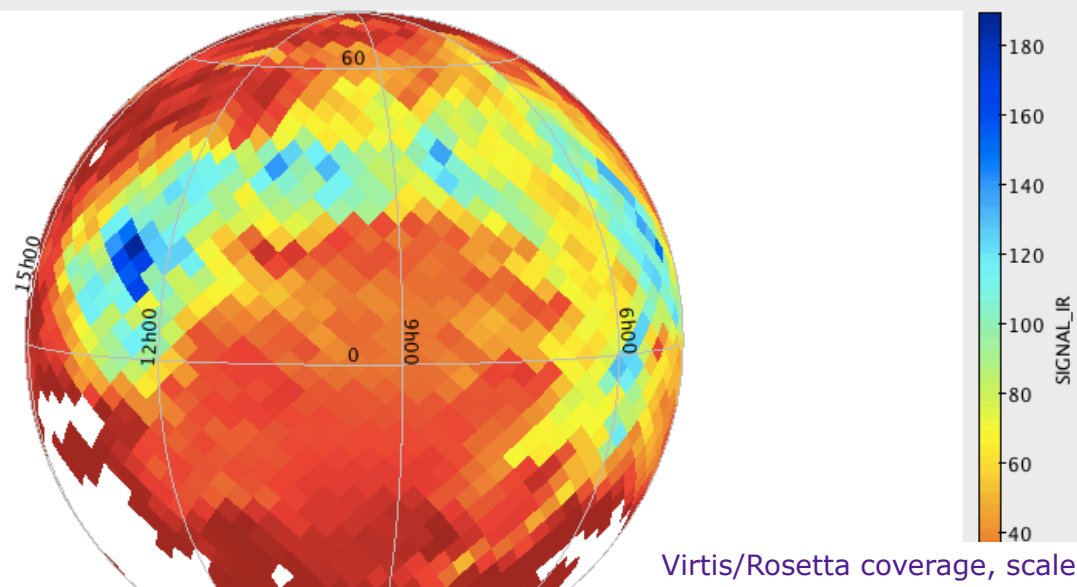
Virtis/Rosetta coverage, scale = 6

**Start from a table of sparse observations (lon/lat)**

VIRTIS/Rosetta on 67P

**Integrate / average on healpix cells**

**Modify resolution / scale on the fly**

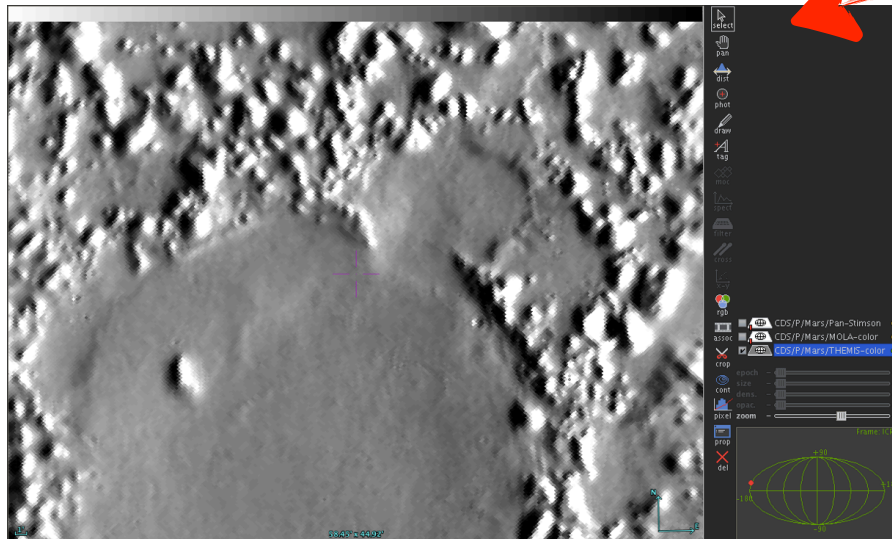
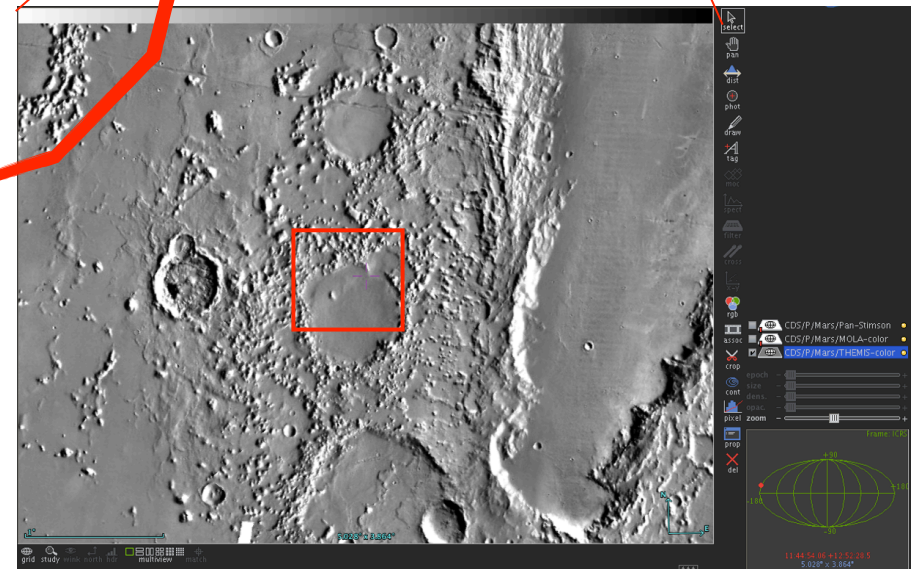
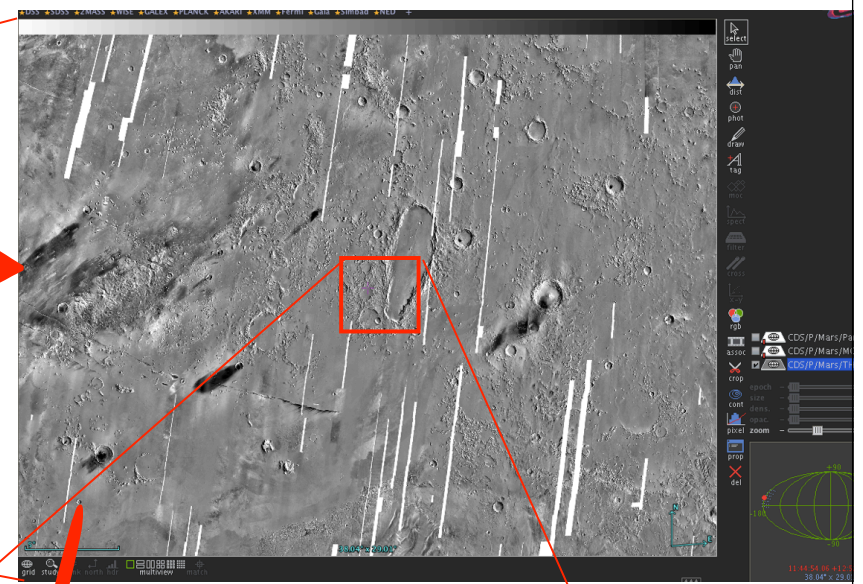
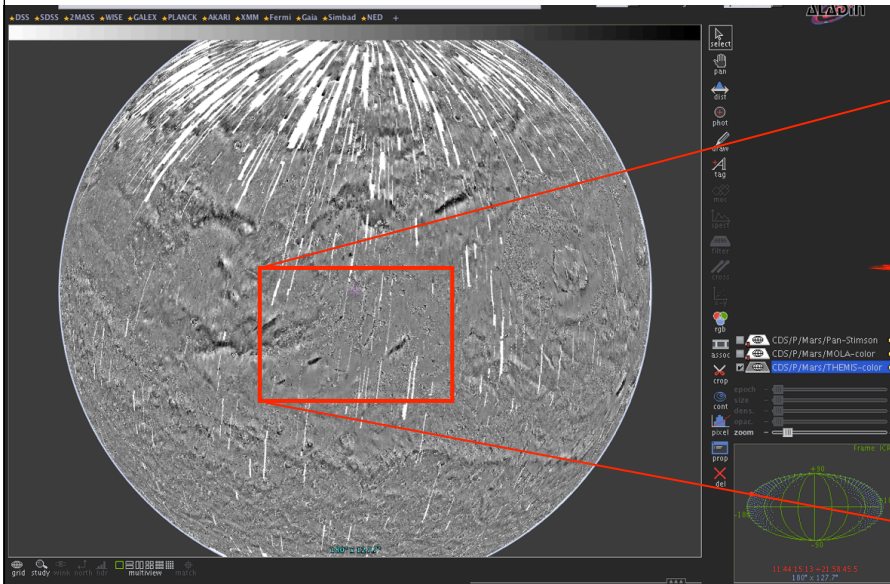


Virtis/Rosetta coverage, scale = 5



# New VESPA functions

# Multiresolution maps (HiPS) in Aladin

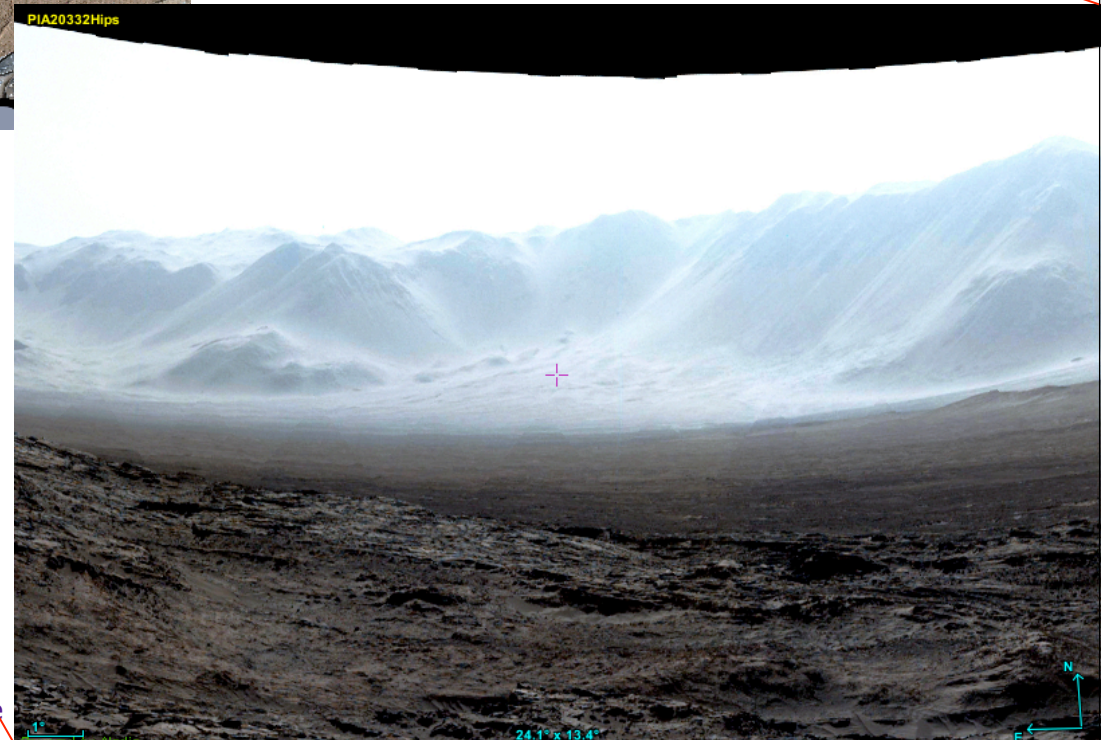
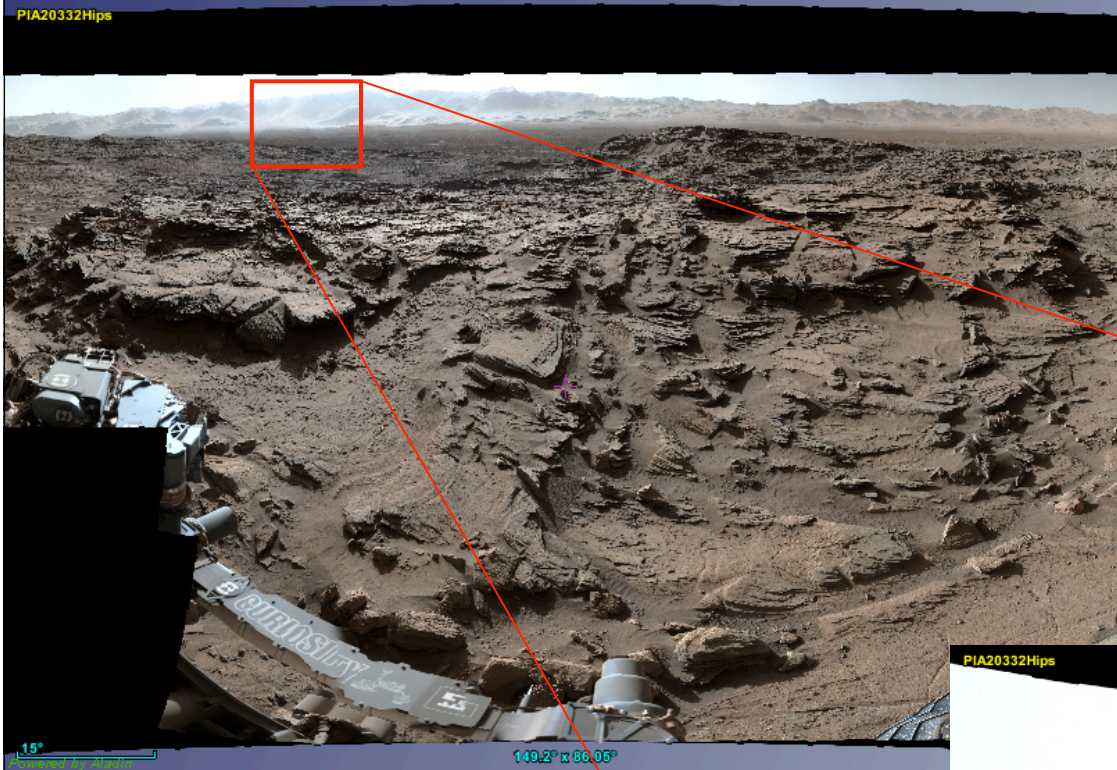


Currently 45 planetary HiPS available  
(from USGS maps)



# New VESPA functions

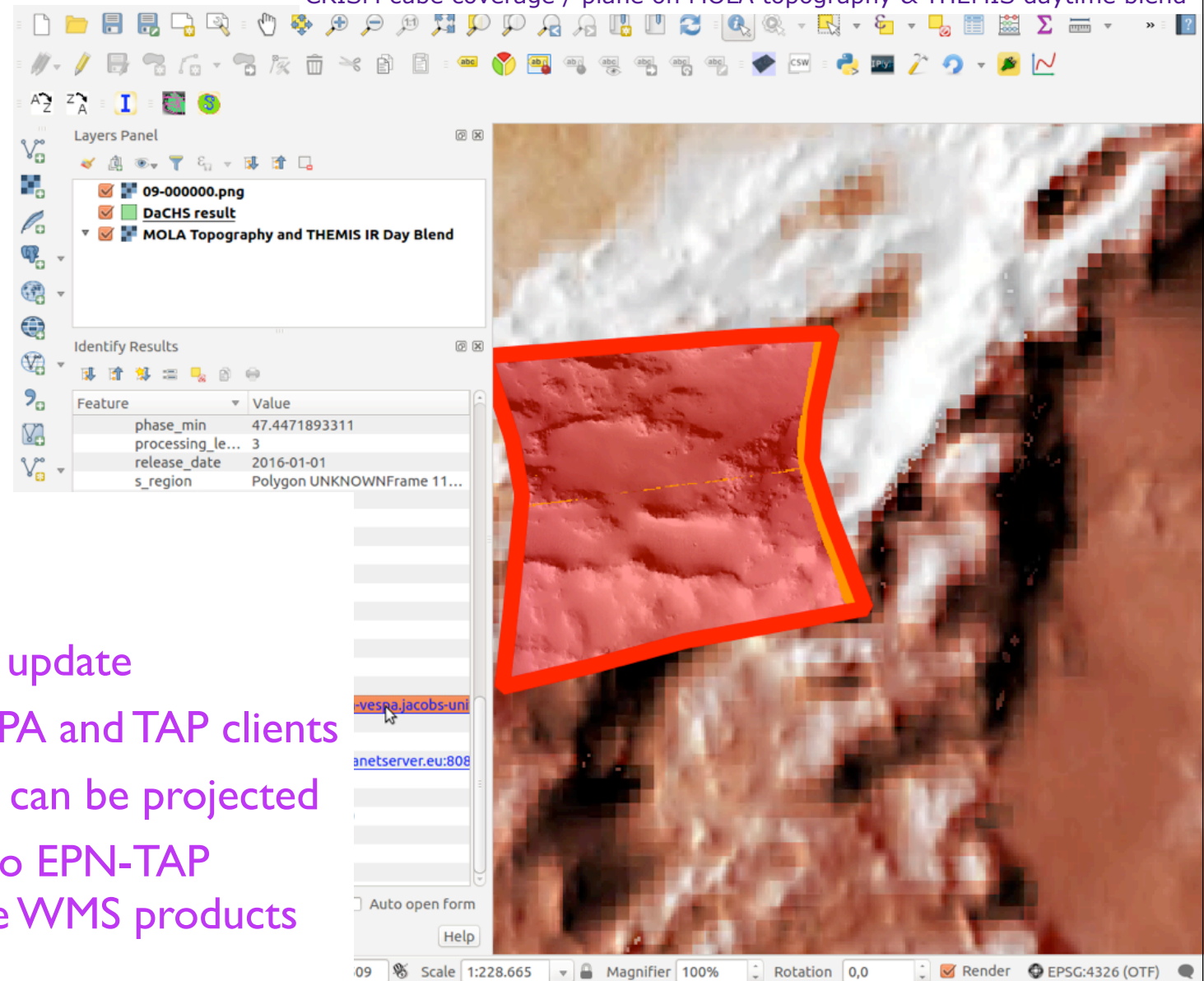
# Multiresolution in Aladin: panoramic images



HiPS computed from a Curiosity MASTCAM panorama from JPL web site

# New VESPA tools: VO-GIS connection

CRISM cube coverage / plane on MOLA topography & THEMIS daytime blend



**QGIS** (open source):

SAMP plug-in installed

GEOfits format / GDAL update

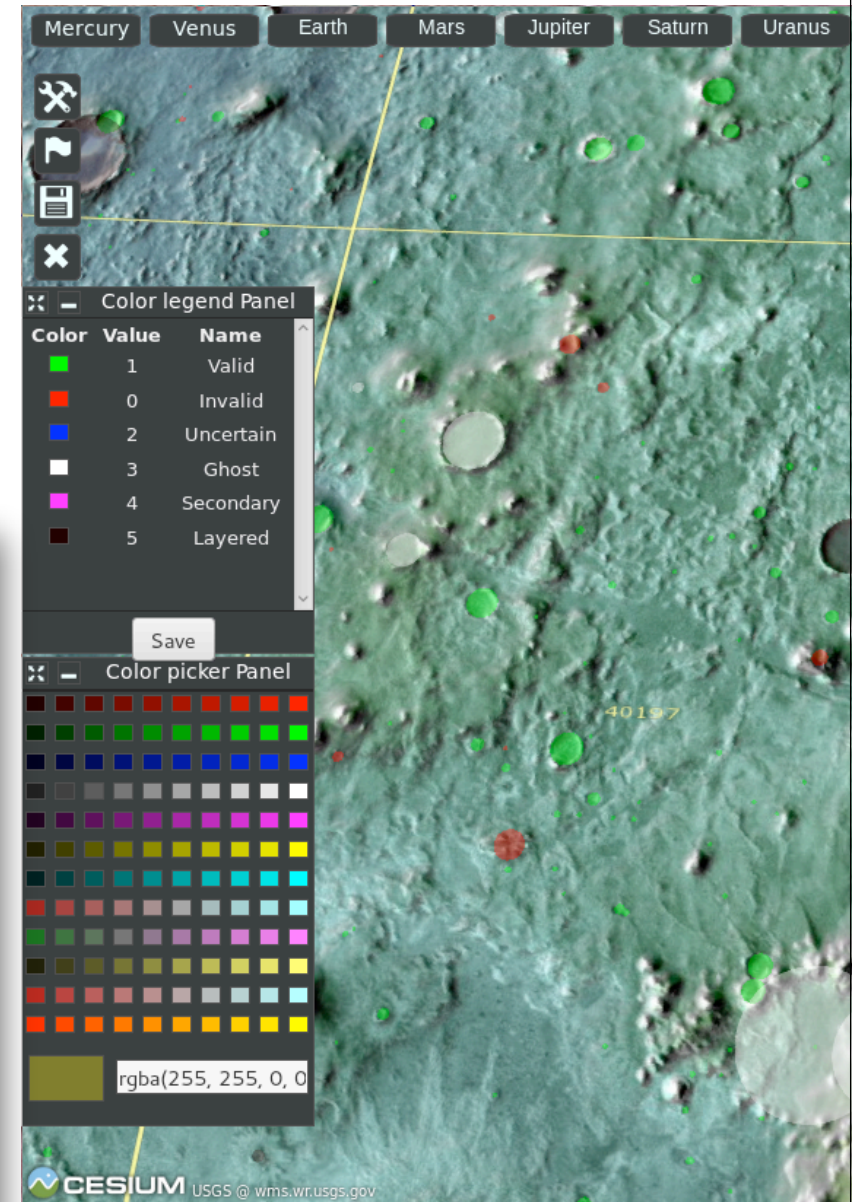
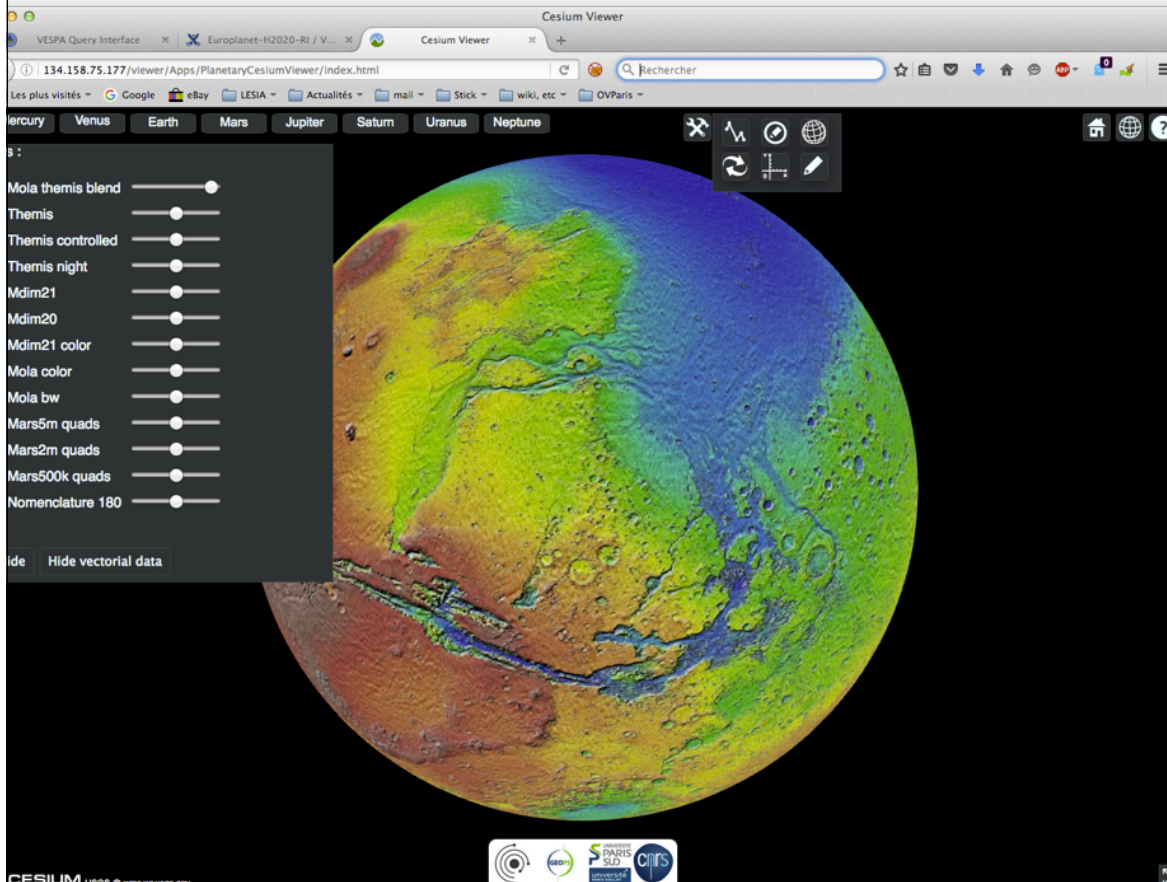
- receives data from VESPA and TAP clients
- georeferenced fits files can be projected
- Provides visualization to EPN-TAP services which distribute WMS products



# New VESPA tool

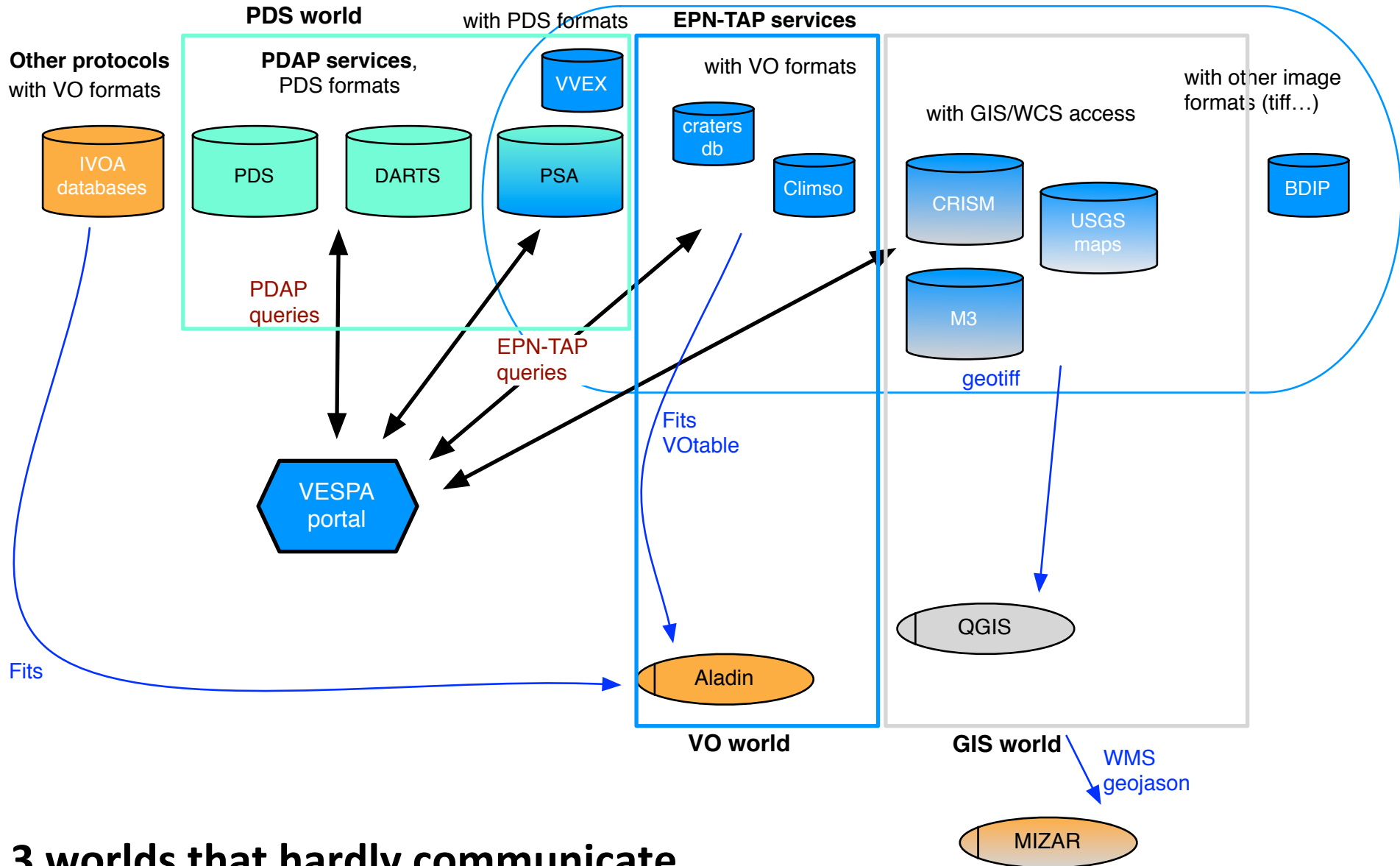
## Planetary Cesium Viewer (GEOPS/CNRS)

- Quick multiresolution 3D visu
- Supports elliptic shapes
- Annotation/validation tool
- SAMP implementation



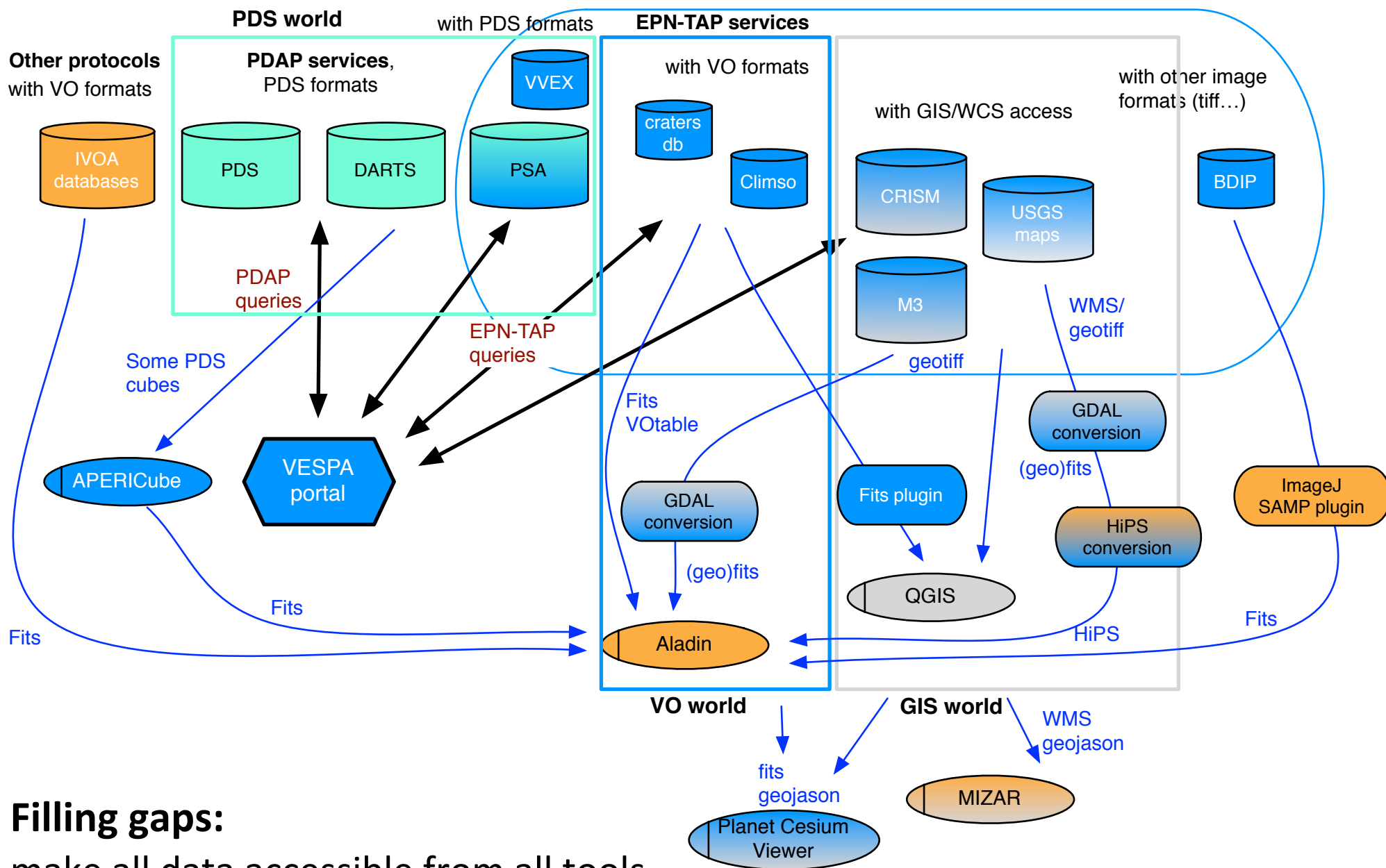
Robbins Mars craters database in PCV

# Planetary images: data and tools



**3 worlds that hardly communicate**  
but EPN-TAP allows for searches in data services

# Planetary images: data and tools



## Filling gaps:

make all data accessible from all tools

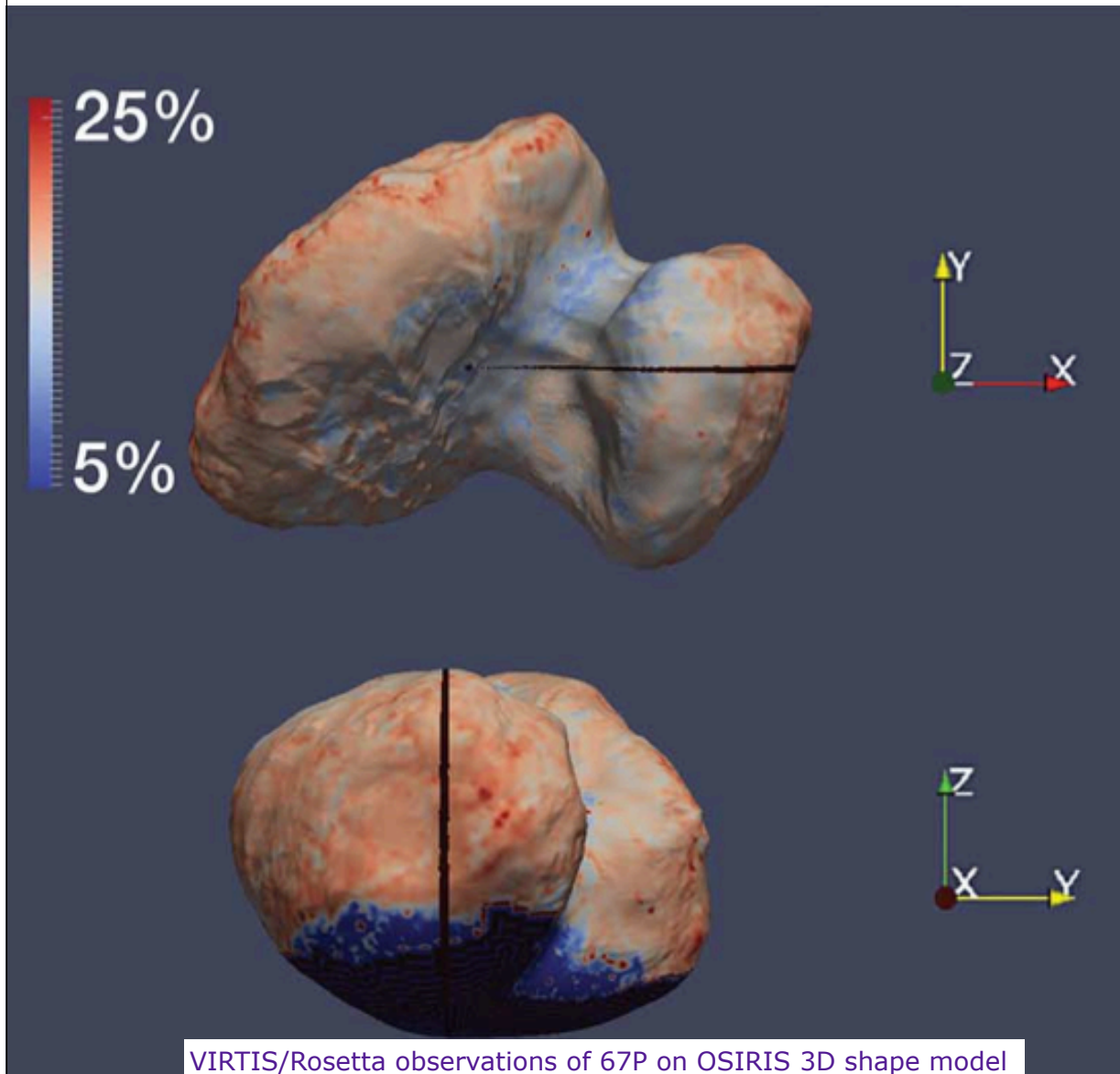


## Updated VESPA tools

## MATISSE (ASI):

mapping on 3D shape models

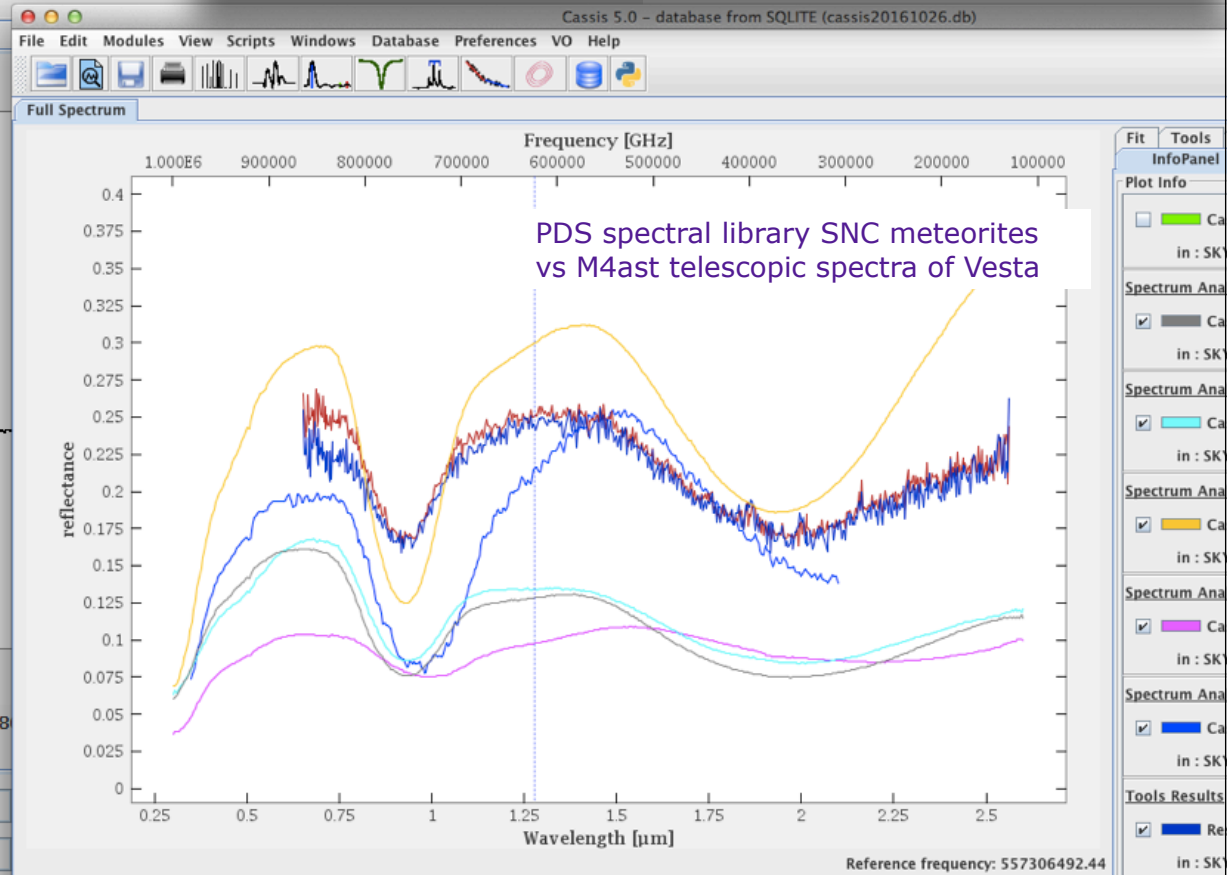
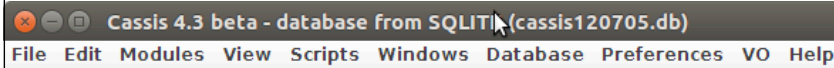
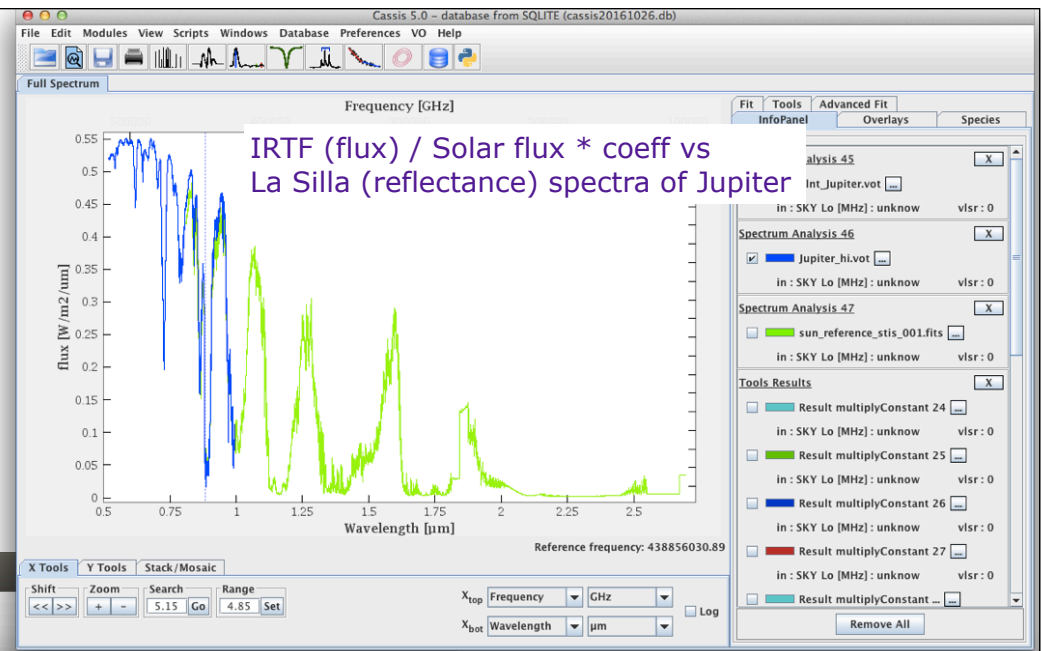
SAMP connection added



# Updated VESPA tool

## CASSIS v5 (IRAP/CNRS)

- Auto converts spectral axis & flux
- Support data in flux & various types of reflectance (scaling)
- Now supports multi-order spectra

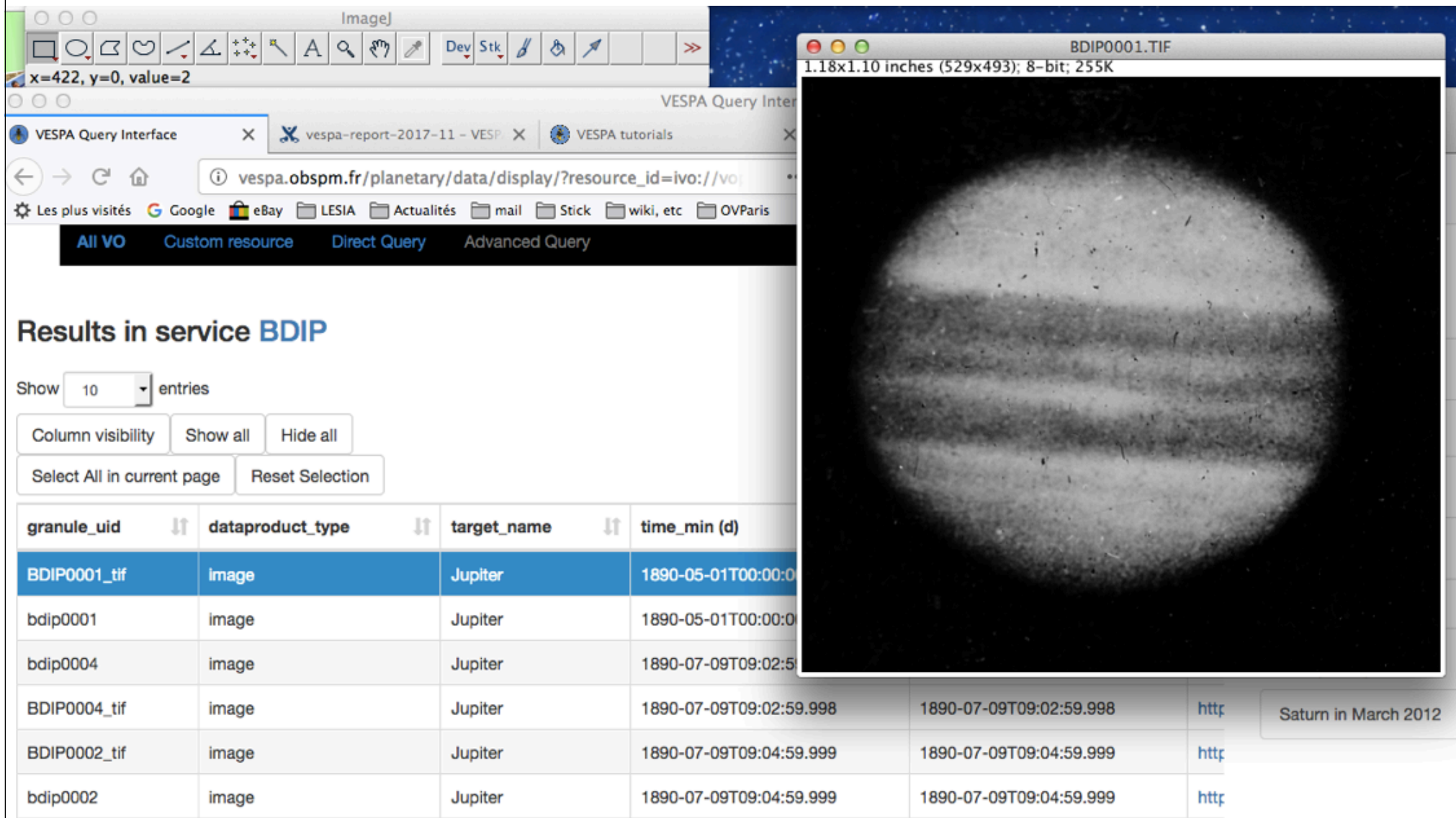


# New tools in VESPA

## ImageJ (open source):

- SAMP connection installed
- Provides support for unusual data types (TIFF...), format conversion, and image processing functions in the VO

Historical image of Jupiter from BDIP (tiff format) in ImageJ



The screenshot shows a web browser window displaying the VESPA Query Interface. The browser tabs include 'VESPA Query Interface', 'vespa-report-2017-11 - VESP', and 'VESPA tutorials'. The address bar shows the URL 'vespa.obspm.fr/planetary/data/display/?resource\_id=ivo://vo...'. The page content includes a navigation bar with 'All VO', 'Custom resource', 'Direct Query', and 'Advanced Query'. Below this, the heading 'Results in service BDIP' is followed by a 'Show 10 entries' dropdown and buttons for 'Column visibility', 'Show all', 'Hide all', 'Select All in current page', and 'Reset Selection'. A table of search results is displayed, with columns for 'granule\_uid', 'dataproduct\_type', 'target\_name', and 'time\_min (d)'. The first row is highlighted in blue and corresponds to the image shown in the ImageJ window.

granule_uid	dataproduct_type	target_name	time_min (d)
BDIP0001_tif	image	Jupiter	1890-05-01T00:00:00
bdip0001	image	Jupiter	1890-05-01T00:00:00
bdip0004	image	Jupiter	1890-07-09T09:02:59
BDIP0004_tif	image	Jupiter	1890-07-09T09:02:59.998
BDIP0002_tif	image	Jupiter	1890-07-09T09:04:59.999
bdip0002	image	Jupiter	1890-07-09T09:04:59.999

The ImageJ window, titled 'BDIP0001.TIF', shows a grayscale image of Jupiter with a diameter of 1.18x1.10 inches (529x493 pixels), 8-bit, and 255K. The image shows the characteristic bands of Jupiter's atmosphere.

Saturn in March 2012

## Next steps

- **More data services!** - including from external contributors
- **Process answers from multiple services**
- **Finalize VO-GIS interface** - including geofits
- **Develop interface with lab spectroscopy services**  
(minerals and ices spectra, band lists, etc) - now 4 services implemented
- **Bridge EPNCore and PDS4**
- **Connect simulation services, use with related data services**  
requires different protocols
- **Formalize docs / standards => submit to IPDA & IVOA**  
and refine/complete tutorials
- **Longer term (> 2019) => extract knowledge from data:**  
data processing, feature extraction, machine learning...

<http://vespa.obspm.fr>

<http://www.europlanet-vespa.eu/>

Next VESPA call to be open in December 2018 (last one in the current program)

**Related posters this week:**

- Cecconi B. et al. MASER: A Tool Box for Solar System Low Frequency Radio Astronomy [#6029]
- Marmo C. et al. FITS and PDS4: Planetary Surface Data Interoperability Made Easier [#6024]
- Trompet L. et al. Tools to manage and access the NOMAD data [#6007]
- Giardino M. et al. A Virtual Observatory Approach to Planetary Data for Vesta and Ceres [#6011]
- Zinzi A. et al. MATISSE 2.0: New Ideas to Support Planetary Sciences [#6002]