**SSHADE: THE EUROPEAN SOLID SPECTROSCOPY DATABASE INFRASTRUCTURE.**

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**Introduction:** Spectroscopy and spectro-imagery are increasingly used in space missions towards planets and small bodies (e.g. OMEGA/Mars Express, CRISM/MRO, VIRTIS/Rosetta, RALPH/New Horizons, MAJIS/JUICE, …), including the Moon (NIR/Clementine, SIR/Smart-1, MI/Selene-Kaguya, SIR-2 and M3/Chandrayaan-1, IIRS/Chandrayaan-2, …), to study the solid phases at their surface (ices, minerals or organic materials). 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, the Moon, …).

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 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.

**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 is now open to the community since 5th February 2018 (http://www.sshade.eu).

The SSHADE databases cover laboratory, field, airborne as well as simulated and theoretical spectral data including various levels of products (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.

The SSHADE consortium has currently 23 partner groups in 21 laboratories from 8 different European countries (F, UK, I, D, E, HU, PL, CH), plus India and Taiwan. Information about this project can be found in the SSHADE wiki (http://wiki.sshade.eu)

**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, phases, publications, objects, …)
- A set of spectral databases: one per group/laboratory (GhoSST is one of them)

**SSHADE interface:** A user can currently search either spectral data or publications through two distinct forms using a simple 'Google-style' search tool that he can complement with a number of specialized filters to refine the search. For the spectral data he can filter his search according to a series of topics: by experiment, by instrument parameters, by environment, by extra-terrestrial object, by sample, by composition and/or by publication. Both tools can be combined.

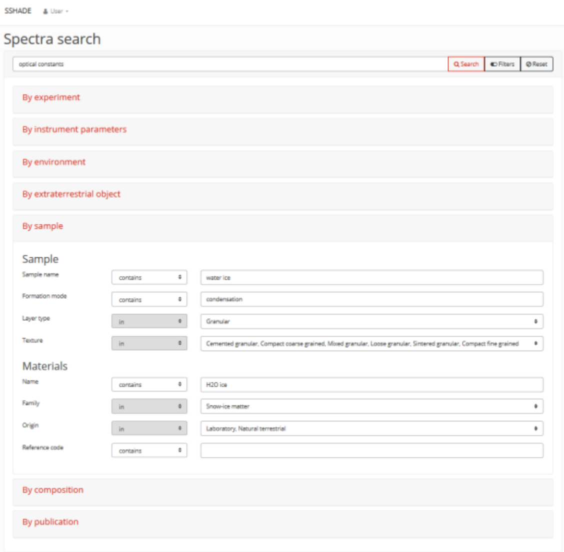


**Figure 2**. User search page for ‘Spectra’ showing the different filters for the sample search option

The user can select and visualise a spectrum, he will then get a page with the collapsible structure of the experiment/spectra, and of the sample/layer(s) /material(s)/constituent(s). The page also display a preview of the spectrum together with the main information on the spectrum and on the measured sample.

The user can then decide either to visualize the spectrum interactively together with all its associated information, or to look at the detailed information of the experiment or of any part of the sample structure.

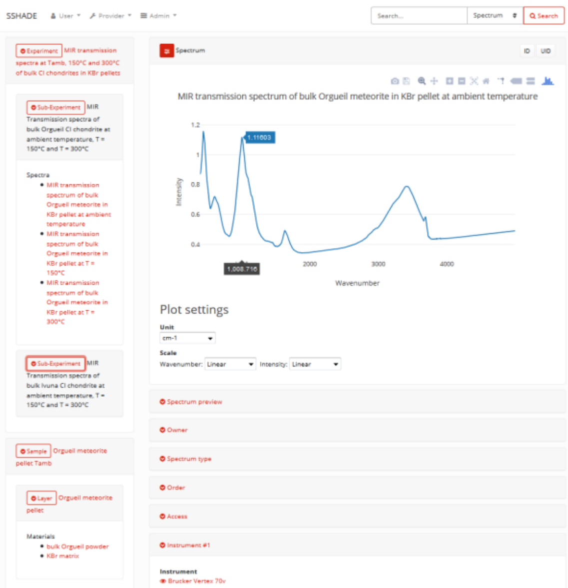


**Figure 3**. Display of a meteorite spectrum (dynamic), with the different categories of spectrum metadata below (left: experiment and sample structures).

The detailed page of each level of the experiment or sample structure contains all the relevant parameters values with different types of links either to another level of the structure, to other information stored in SSHADE (such as publications) or to external pages (such as Wikipedia, WebMineral, …).

The users can download a spectrum or an experiment from the export page for immediate and individual download. The users may also add a spectrum or an experiment in the ‘basket’ for future export.

**Databases implementation:** We are progressively implementing in the SSHADE infrastructure the databases of each of the 20 partners of the SSHADE consortium. 10 databases are already active in SSHADE (BYPASS, DAYSY, DOCCD, FAME, GhoSST, LSD, PaSSTEL, SOSYPOL, SSTONE and STOPCODA) and one is just starting (MIA), and over 1250 spectra are already online (from 182 experiments on about 830 samples), well over what we expected for the initial delivery of the SSHADE infrastructure.

The 10 already active databases already cover a wide range of samples, spectroscopic techniques and spectral ranges.

- various types of natural and synthetic samples (ices, minerals, rocks, meteorites, carbonaceous material, micrometeorites, prebiotic and bio molecules, …), including some made from 'soil simulants' such as JSC Mars 1.
- various types of spectral data from transmission spectra, reflectance spectra, to optical constants
- Various spectral ranges: X, Vis, NIR, MIR, FIR, sub-mm and mm.

The current contents of the 10 active databases is described in the SSHADE wiki. It also contains a SSHADE user guide and a Data search guide. ([https://wiki.sshade.eu](https://wiki.sshade.eu))

Tutorials on the use of the SSHADE database infrastructure will be organized during the Symposium.

**SSHADE in Virtual Observatories:** SSHADE will be soon 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].

**References:** [1] Erard et al (2014) Planetary Science Virtual Observatory architecture. *A&C* **7-8**, 71-80. [2] Erard et al (2014) The EPN-TAP protocol for the Planetary Science Virtual Observatory. *A&C* **7-8**, 52-61. [3] Erard et al (2017) Spectroscopy of planetary surfaces in a VO context (VESPA), EPSC2017

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