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PDS Release of Phobos data from HRSC on Mars Express: Shape Model, Orthoimages and Maps

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Abstract

We are pleased to announce the delivery of geodetic data products of Phobos derived from images of the High Resolution Stereo Camera (HRSC) on Mars Express to the NASA Planetary Data System (PDS), which include a new Phobos shape model, large sets of orthoimages as well as maps. The new data will help prepare new missions to Phobos and Deimos and resolve open questions on the origins and evolutions of the two satellites [1].

1. Phobos Data

From the beginning of the Mars Express mission 2004 until November 2012, the spacecraft has engaged in 201 Phobos flybys at distances between 92 and 5578 km, during which observations have been carried out by the HRSC [2, 3]. During 49 of these flybys, the HRSC was commanded to take images in "full stereo mode" in which all five stereo channels were activated (Stereo1, Photometry1, Nadir, Photometry2, and Stereo2 channels of each orbit), allowing the production of local and global terrain models by stereo-photogrammetric techniques.

2. Shape Model

Stereo-photogrammetric methods were applied to derive a global shape model on the basis of HRSC and Viking Orbiter images [4]. This model was prepared in the form of a gridded file (Digital Terrain Model, DTM) with 100 m/pixel resolution [4, 5] (see Figure 1), a spherical harmonic function model (degree and order 45), as well as a binary "plate model", already released previously [6].

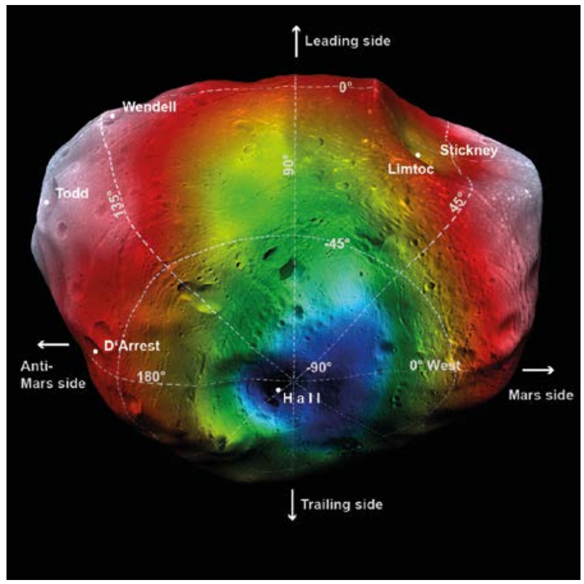

Figure 1: Perspective view of the color-coded Phobos DTM with the draped HRSC image mosaic showing the South pole.

3. Orthoimages, Mosaic and Maps

A photogrammetric adjustment was carried out for images from 18 selected HRSC orbits [4], which yields improved orientation data for a total of 90 HRSC images with varying, image resolutions from 3.7 m/pixel to 98.5 m/pixel. 10 Nadir images were finally selected for a global mosaic. These images were ortho-rectified to the shape model, resampled to a uniform resolution of 16 pixels/ degree or 12.11 m/ pixel. The overlapping images were analyzed to select only best data to be combined for a mosaic. The mosaic was the basis to produce a set of two map sheets in a scale of 1: 50,000, which comprise three maps each (see Figure 2) [7]. Sheet 1 displays contour lines derived from dynamic heights obtained from gravity field modelling [8, 9]. On sheet 2, contour lines represent geometrical heights above the sphere (R_{mean} = 11.1 km).

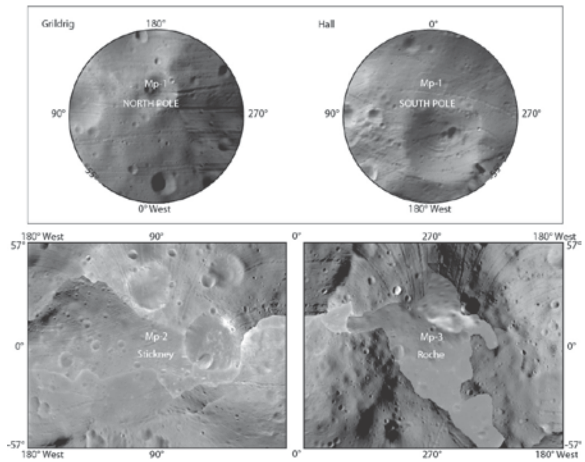

Figure 2: Quadrangle scheme of the atlas used for sheet 1 and 2, filled with the HRSC mosaic.

4. Summary and Conclusions

A Digital Terrain Model, a plate model (already available), 90 controlled ortho-images and an atlas are in preparation for PDS release. This will help the community in the scientific work and planning of future missions.

Acknowledgements

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Standardization of Observatories, Instruments and Reference Frames for Planetary Sciences

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Abstract

The recent developments on planetary science interoperability showed that a standardization of naming conventions was required for observatories (including ground based facilities and space mission), instruments (types and names) as well as reference frames used to describe planetary observations. A review of existing catalogs and naming for those entities is presented. We also report on the discussions that occurred within the IVOA (International Virtual Observatory Alliance), IPDA (International Planetary Data Alliance) and VESPA (Virtual European Solar and Planetary Access) working groups. A proposal for standard lists, possibly to be endorsed by IAU, is presented and discussed.

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Developing an Efficient Planetary Space Weather Alert Service using Virtual Observatory Standards

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Abstract

The objective of this Task is to identify user requirements, develop the way to implement event alerts, and chain those to the 1) planetary event and 2) planetary space weather predictions. The expected service of alerts will be developed with the objective to facilitate discovery or prediction announcements within the PSWD 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. OBSPARIS and UCL will study and adapt VOEvent to those purposes. CNRS-IRAP and SRC will study the way to implement VOEvent as a service for the PSWD tools.

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Planetary GIS and EuroPlanet-RI H2020

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Geographic Information System (GIS) practice and applications within Planetary Science became in the last decade a major component for studying solid surfaces of Solar System bodies [e.g. 1,2,3]: from earlier mainly Mars-focused efforts limited to few datasets, the availability of high-quality spatial data grew enormously and its accessibility is also enhanced by the use of OGC web standards.

Higher-level, calibrated georeferenced datasets are the prime target for geologic and related thematic mapping [e.g. 4], although the communities potentially benefiting from a GIS-based approach are beyond and they include most closely Atmospheric science, as well as Magnetospheric and Plasma Physics, to quote only few.

In the upcoming EuroPlanet-RI H2020 project Planetary GIS efforts are embedded within the VESPA activity [5] and they allow for a tight integration of OGC and VO-based tools and interfaces [6].

Nowadays GIS-based analyses are used for carrying out research tasks and systematic mapping on planetary bodies, but also for a wide range of analyses related [e.g. 7] to landing site selection, ranging from scientific merit to safety [e.g.8]

Community building is a key part of VESPA [5], but also independently followed by other actors like ESA PSA [9]. Recently a workshop on Planetary GIS in broad sense and with particular reference to ESA data archives has been organized [10]. Such workshop has been strongly supported by ESA and the broad planetary community, both directly and through its official channel for Planetary Science archive science access and exploitation-related needs, the PSA User Group [11]. Its outcomes, also in terms of use case development, might be instrumental to VESPA GIS/VO future activities.

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iSPHERE – A New Approach to Collaborative Research and Cloud Computing

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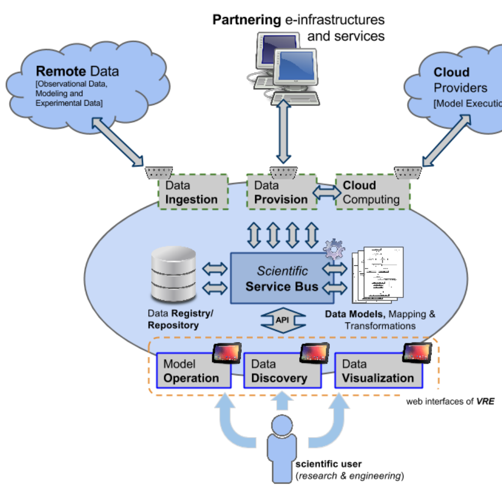
Abstract

The project ***iSPHERE*** (*integrated Scientific Platform for HEterogeneous Research and Engineering*) that has been proposed for **Horizon 2020** (*EINFRA-9-2015*, [1]) aims at creating a next generation *Virtual Research Environment* (VRE) that embraces existing and emerging technologies and standards in order to provide a versatile platform for scientific investigations and collaboration. The presentation will introduce the large project consortium, provide a comprehensive overview of *iSPHERE's* basic concepts and approaches and outline general user requirements that the VRE will strive to satisfy.



An overview of the **envisioned architecture** will be given, focusing on the adapted *Service Bus* concept, i.e. the "Scientific Service Bus" as it is called in *iSPHERE*. The bus will act as a central hub for all communication and user access, and will be implemented in the course of the project. The agile approach [2] that has been chosen for detailed elaboration and documentation of user requirements, as well as for the actual implementation of the system, will be outlined and its motivation and basic structure will be discussed. The presentation will show which user communities will benefit and which concrete problems, scientific investigations are facing today, will be tackled by the system.

Another focus of the presentation is *iSPHERE's* seamless **integration of cloud computing resources** and how these will benefit scientific modeling teams by providing a reliable and web based environment for cloud based model execution, storage of results, and comparison with measurements, including fully web based tools for data mining, analysis and visualization. Also the envisioned creation of a dedicated data model for experimental plasma physics will be discussed. It will be shown why the *Scientific Service Bus* provides an ideal basis to integrate a number of data models and communication protocols and to provide mechanisms for data exchange across multiple and even **multidisciplinary** platforms.

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VESPA: Developing the Planetary Science Virtual Observatory in H2020

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Introduction

The Europlanet H2020 programme will develop a research infrastructure in Horizon 2020. The programme includes a follow-on to the FP7 activity aimed at developing the Planetary Science Virtual Observatory (VO). This activity is called VESPA, which stands for Virtual European Solar and Planetary Access. Building on the IDIS activity of Europlanet FP7, VESPA will distribute more data, will improve the connected tools and infrastructure, and will help developing a community of both users and data providers.

One goal of the Europlanet FP7 programme was to set the basis for a European Virtual Observatory in Planetary Science. A prototype has been set up during FP7, most of the activity being dedicated to the definition of standards to handle data in this field. The aim was to facilitate searches in big archives as well as sparse databases, to make on-line data access and visualization possible, and to allow small data providers to make their data available in an interoperable environment with minimum effort. This system makes intensive use of studies and developments led in Astronomy (IVOA), Solar Science (HELIO), plasma physics (SPASE), and space archive services (IPDA). It remains consistent with extensions of IVOA standards.

1. Infrastructure

The system is based on a new access protocol, a specific client to query the available services, and intensive recycling of tools developed for the Astronomy VO [1]. The architecture consists in connecting existing data services with IVOA protocols (Cone Search, TAP…) or with the IPDA protocol (PDAP) whenever relevant (Fig. 1). However, a more general standard has been devised to handle the specific complexity of Planetary Science, e.g. in terms of measurement types and coordinate frames. This protocol, named EPN-TAP, is based on TAP and includes precise requirements to describe the contents of a data service [2]. Services are declared in standard IVOA registries and are expected to provide answers formatted as VOtables.

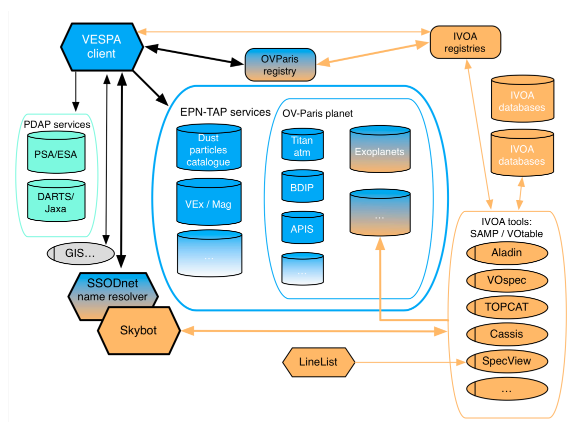

Fig 1: Data access and visualization services (in orange: IVOA, blue: Europlanet, cyan: IPDA, gray: OGC)

A full client, also called VESPA, has been developed at VO-Paris (Fig. 2). It is able to use all the mandatory parameters from EPN-TAP, plus extra parameters from individual services. The results can be sent to VO visualization tools such as TOPCAT, SpecView, or Aladin though the SAMP protocol. A resolver for target names and an ephemeris service are also available. The H2020 activity will focus on improving the user's experience, will connect extra tools such as GIS or mosaics builders, and will make it possible to read and visualize PDS3 data files on-line. Future developments include implementations of workflows to support on line data processing. A special task related to VO standards will be in charge of formalizing the Europlanet standards and have them validated by higher-level consortia (IVOA, IPDA, IAU…). This will ensure the sustainability of the Planetary Science VO after the end of the H2020 programme.

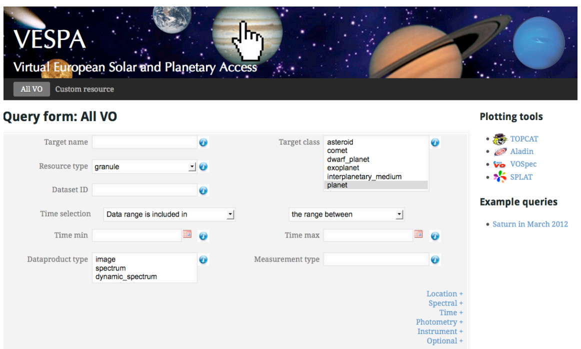

Fig 2: The VESPA user interface: http://vespa.obspm.fr

2. New services

Some new data services were produced in the Europlanet-RI framework, and some older data services were provided VO access through EPN-TAP. This system will be extended to all fields of Planetary Science in the frame of the H2020, and open to external data providers.

The activity will be organized around 5 science themes (surfaces, atmospheres, small bodies, magnetospheres, spectroscopy). The science themes will setup new, selected data services, and will work on improving interfaces between domains. Of particular importance is the study of an interoperable link between the VO and Geographic Information Systems now commonly used for planetary surfaces; SSHADE is a network of 20 European spectroscopy laboratories that will distribute their data in a consistent service accessible to observers in support of data interpretation; projection of high-resolution data on shape models of small bodies will be made possible; several large data services related to atmospheres and plasma environments will be also become interoperable [3].

An important part of the programme will consist in annual calls for new data services open to the community. The selected teams will get dedicated support to set up EPN-TAP services from their data, typically corresponding to published works. The benefit for the teams will be in terms of visibility of their science work, and VO techniques knowledge transfer. We expect to be able to implement 15 such services during the programme lifetime. In addition, a few significant amateur services will be considered for implementation in the same system, and links with major data archives (ESA, ESO…) will be studied.

3. Community building

In addition to providing support to selected providers during the program lifetime, VESPA will seek to spread the EPN-TAP system among other research teams. A light framework (DaCHS/GAVO) and a procedure have been identified to install topical data services easily, and several hands-on sessions aimed at potential data providers have been organized in the past three years. The immediate benefit will be to provide search functions to data archives.

Training of potential users is also a crucial part of the programme, and will be centred on tutorials and hands-on sessions during conferences in Europe (EGU and EPSC).

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Automatic quality assessment of planetary images

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Abstract

A significant fraction of planetary images are corrupted beyond the point that much scientific meaning can be extracted. For example, transmission errors result in missing data which is unrecoverable. The available planetary image datasets include many such "bad data", which both occupy valuable scientific storage resources and create false impressions about planetary image availability for specific planetary objects or target areas. In this work, we demonstrate a pipeline that we have developed to automatically assess the quality of planetary images. Additionally, this method discriminates between different types of image degradation, such as low-quality originating from camera flaws or low-quality triggered by atmospheric conditions, etc. Examples of quality assessment results for Viking Orbiter imagery will be also presented.

1. Introduction

The quality assessment of multimedia content began at the same time as the television broadcasting of pictures. Ever since, a large number of objective image quality measures have been introduced. Recently, research interest has shifted towards no-reference image quality assessment, in which the image quality is assessed without any a priori information about the authentic image. No-reference image quality assessment can be performed only if it is based on assumptions regarding the relationship of image quality with pixel-level image appearance. For a thorough presentation of automatic image quality assessment (IQA) domain, the reader is referred to [1].

Image quality assessment techniques that focus on planetary images should take into account the characteristics of these type of images, especially the multitude of causes that can trigger content degradation. The nine types of image degradation that are included in this work are summarized in Table 1. The low-quality types are further discriminated into those originating from system failure (internal) and those originating from imaging conditions (external). Currently, no metadata is included in any of the PDS/PSA archives for such low quality.

Table 1: Degradation mechanisms triggering low-quality planetary images.

Id	Degradation	Group
1	Burst Noise	Internal
2	DN Quantisation	Internal
3	Horisontal Stripes	Internal
4	Verticall Stripes	Internal
5	Salt & Pepper Noise	Internal
6	Low contrast	Internal
7	Dust	External
8	Clouds	External
9	Near Terminator Image	External

2. Methods

The automatic image quality assessment that has been developed combines 6 quality assessment measures, 3 selected from the (generic) image quality assessment literature and 3 novel ones, tailored to the planetary image requirements. More specifically, the literature measures included image anisotropy [2], which is a generic image quality measure based on the assumption that high-quality images have richer information content than low-quality images, power spectrum slope [3], which gauge image blur at the local level, and edge profile kurtosis [4], which is a computationally efficient measure of global image blur based on image edge appearance. In addition, we developed three more image quality measures, a novel self-similarity measure to gauge distortion types that create symmetrical image patches, such as gravity waves, a measure that aims to detect images suffering from low contrast and, finally, an impulse noise measure.

The above 6 features comprise the image quality vector of a planetary image. The image quality assessment is performed through a Support Vector Machine

(SVM) classifier [5]. The SVM classifier includes a training step, which is conducted through the extraction of the image quality vectors from a set of manually annotated (regarding their quality) planetary images, and the estimation of the hyperplane that best separates the two classes of image quality vectors (i.e. vectors extracted from low-quality images and vectors extracted from high-quality images) by a Support Vector Machine (SVM). After estimating the class boundary, for each input planetary image it's quality vector is extracted and the sub-space that it belongs to determines the quality label that is assigned, i.e. high-quality or low-quality image. Finally, a group of (trained in a similar way) SVM classifiers is used to identify different types of planetary image degradations.

3. Results

We have tested our technique on planetary visual spectrum images that were acquired from Viking Orbiter missions. These missions were active between 1976 and 1980, during which approximately 47 thousand visual spectrum images were acquired. Due to relatively primitive technology, images were degraded through a number of types of data corruption, which in total can reach up to several thousand images. The preliminary tests included only a small part of the available data (Figure 1), while currently we have started the evaluation of the complete Viking Orbiter dataset. Results and statistics of this on-going work are going to be presented during EPSC.

4. Conclusions and future work

In this work we have presented a method, which we have developed to perform fully automatic planetary image quality assessment. Preliminary results have been shown that automatic quality assessment is feasible to be conducted in a systematic approach. In the future we plan to make our system both faster and more accurate, while the ultimate goal is to develop a hardware prototype, which can be used on future space missions.

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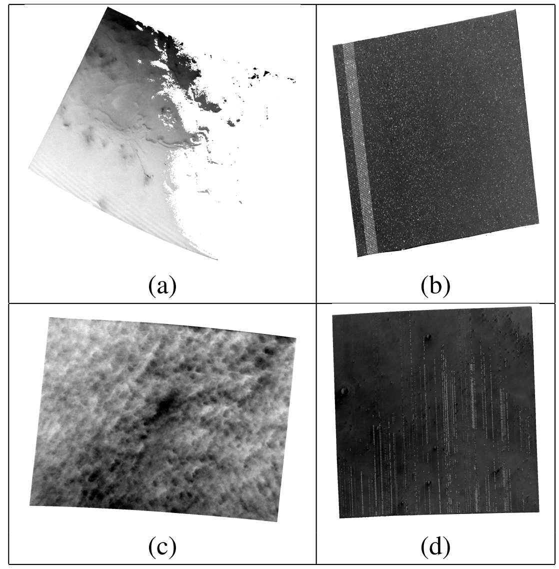
Figure 1: Examples of Viking Orbiter low-quality images, caused by (a) DN Quantisation (b) Salt and pepper noise (c) Atmospheric dust (d) Vertical stripes.



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A new data mining tool for the Cluster Science Archive

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Abstract

Heliophysics archives mainly offer to download data for a specific time period. On the other hand, scientists usually look for data measured in a specific region of space, which fulfills a number of conditions for key physical parameters (e.g. DC magnetic/electric field, electron/ion density, temperature, velocity...), no matter when. Moreover, multi-spacecraft space missions such as Cluster and Double Star have been orbiting Earth for the last 15 years with various inter-spacecraft distances for specific scientific targets; in other words data campaigns. Such information is often difficult to find out by scientists not directly related to PI teams. For these reasons, a new data mining tool for the Cluster Science Archive is being developed by the European Space Agency. Its main features will be presented. This tool is tailored to the specificities of the Cluster and the Double Star missions and high-level datasets generated in the framework of two EU FP7 projects (ECLAT and MAARBLE). While focused on these two space missions, the approach used in this tool might be of interest for other online tools and the development of future tools. Needless to say that the goal of this presentation is also to trigger interaction with the community to improve the scientific relevance of this tool.

1. Introduction

Solar-terrestrial physics, magnetospheric dynamics and space weather combined is a major field of research. It is supported by a significant number of space missions supported by all space agencies worldwide and coordinated by the International Living with a Star (ILWS) program.

The SOHO and Cluster space missions represent a major contribution of the European Space Agency (ESA) to ILWS. SOHO is a solar observatory located at Lagrangian point L1, and operated since 1995. Cluster is the first constellation of four spacecraft flying in formation around Earth [1], enabling the first in-situ 3D mapping of the terrestrial space

Since 2000, the Cluster spacecraft relay the most detailed information on how the solar wind affects our planet in three dimensions. Science output from Cluster is a leap forward in our knowledge of space plasma physics: the science behind space weather. It has been key in improving the modeling of the magnetosphere and understanding its various physical processes. Cluster data have enabled the publication of more than 2000 refereed papers and counting.

This substantial scientific return is often attributed to the online availability of the Cluster data archive, now called the Cluster Science Archive (CSA). It is being developed by the ESAC Science Data Centre (ESDC) team and maintained alongside other ESA science missions archives at ESAC (ESA's Space Astronomy Centre, Madrid, Spain).

2. The Cluster Science Archive

The Cluster Science Archive (CSA) is the successor of the Cluster Active Archive [2], which provides access to the Cluster data since 2006 (see acknowledgements section).

CSA is a unique online archiving effort which contains the entire set of Cluster high-resolution data, Double Star high resolution data, and other related products in a standard format and with a complete set of metadata. The total amount of data format now exceeds 100 TB. The data archive is publicly accessible and suitable for science use and publication by the worldwide scientific community.

The CSA aims to provide user-friendly services for accessing data (Graphical User Interface, command line, data streaming, SAMP protocol); quick data browsing (with more than 15 TB of pre-generated plots), on-demand visualization (including particle distribution) and finally detailed documentation and various ancillary products (e.g. instrument caveat files, position of the spacecraft...). Accessing CSA requires to be registered to enable user profiles.

CSA accounts more than 1,800 users and is accessible at the following address

http://cosmos.esa.int/csa

3. A new data mining tool

The CSA data mining tool is a web tool composed of three main parts:

- Key physical parameters conditions (e.g. |B|<10 nT)

- Constellation configuration&locator

- Cluster data campaigns

Once the conditions are specified, the tool will look for all time periods fulfilling these conditions. The output are eventually sent to the user by email and logged on her/his CSA user profile as a list of time periods. This list can then be used by the user to download all the relevant Cluster and Double Star datasets in one go.

4. Summary and Conclusions

The main workload for any heliophysics space mission archive is to provide the best calibrated data, with the highest time resolution measured to the scientific community. Once the data quality reaches a satisfactory level (i.e. including detailed instrument documentation, caveats, etc...), higher level services can be provided such as fast data browsing, on-demand data visualization and user profiles. The CSA data mining tool is the next step to provide further high-level data service to the community. The goal is simple: increase the scientific return of the Cluster and the Double Star missions

Acknowledgements

The Cluster Science Archive (CSA) supersedes the Cluster Active Archive (CAA) as the public interface to the Cluster mission archive since November 2014. The design is based on the CAA interface so the look, feel and capabilities are meant to be familiar to users of its predecessor. The CSA services can be accessed either via its Java based Graphical User Interface or by using its Archive Inter-Operability interface (command line, data streaming).

The Cluster Active Archive opened its services to the community in February 2006. Until one year post-mission the CAA will continue to be solely responsible for data validation & ingestion and interaction with the instrument teams including product specification and coordination of cross-calibration activities. The CAA will also retain responsibility for development of value added products, maintaining the Cluster data & metadata standards and provision of some mission operations services.

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SSHADE in H2020: Development of 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 to the community with a large number of spectra of solids (ices, minerals, organics, cosmomaterials, …) of astrophysical and terrestrial interests in the X-ray to sub-mm range. The first of these databases is *GhoSST* (http://ghosst.osug.fr). The SSHADE consortium has currently 20 partner groups in 18 laboratories from 8 different European countries. This project will be developed as part of the VESPA activity within the Europlanet-RI Horizon 2020 program (09/2015-08/2019).

1. Introduction

Spectroscopy and spectro-imagery are increasingly used in space missions, in orbit or *in situ*, to study the solid phase of the objects of the solar system (e.g. VIMS/Cassini, DISR/Huygens, VIRTIS/Rosetta, RALPH/New Horizons, …): icy, mineral or organic surfaces and grains, dust particles, aerosols, etc. Infrared, Raman, fluorescence and X-rays micro-spectroscopies are used to study meteorites and cometary dusts in the laboratory and onboard some space missions for *in situ* measurements. A major contribution to the analysis of these observations is the measurement in the laboratory of UV, Visible, IR, 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. The amount of data collected is huge and several of these laboratories boast leading-edge expertise in some solid spectroscopy fields. However most of these data, although published, are very difficult to access in an usable form (i.e. electronic) to compare with observation or to use in radiative transfer codes.

We thus decided to extend our datamodel (SSDM) and expand the GHOSST database structure in order to build a database infrastructure able to gather and distribute the spectroscopic data of most of the European laboratories working on solids of any type 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 will start its development in September 2015.

The SSHADE databases will cover laboratory, field, airborne as well as simulated and theoretical spectral data with their corresponding spectra and their various types 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 and other cosmomaterials, … with a wide range of measurement technics: transmission, bidirectional reflection, Raman, fluorescence, … and over a wide range of wavelengths: from X-rays to millimeter wavelengths (can be extended up/down).

It is based on the GhoSST database developments (Europlanet + VAMDC 2009-2012). The SSHADE database infrastructure will be hosted at the OSUG Data Center (University of Grenoble Alpes). The SSHADE project was initially boosted by INSU/CNRS who asked us to develop a "thematic pole on planetary solids" within the new framework of observation services of INSU. The SSHADE development is part of the VESPA activity within the European e-infrastructure Europlanet-RI 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 will have:

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

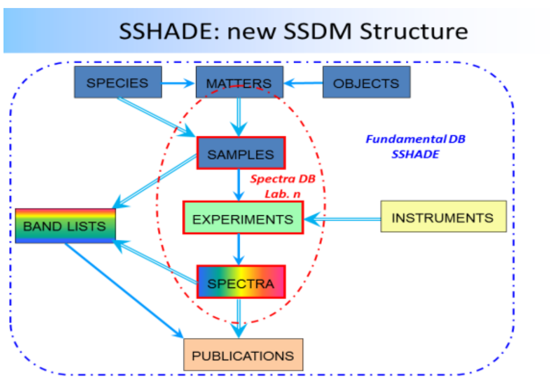

Figure 1: Schematic structure of SSDM for the SSHADE infrastructure

It will be possible either to search all databases at the same time with various filters (spectrum type, species or material type or name, …), and from different points of view (spectra, band lists, publications, objects, …), or to select the target database(s).

SSHADE will be also a service for Virtual Observatories (VESPA, VAMDC, ...).

The transformation of the GhoSST database structure into the SSHADE infrastructure will need a number of modifications such as the separation of the fundamental databases (species, publications, objects, …) from the individual spectroscopic databases (one per laboratory) and the rewriting of the data queries (mono to multi DB). Each database will be also customized to its effective content (types of solids, of spectra, …) for easier search. This work will be mostly devoted to Coriolys SCOP.

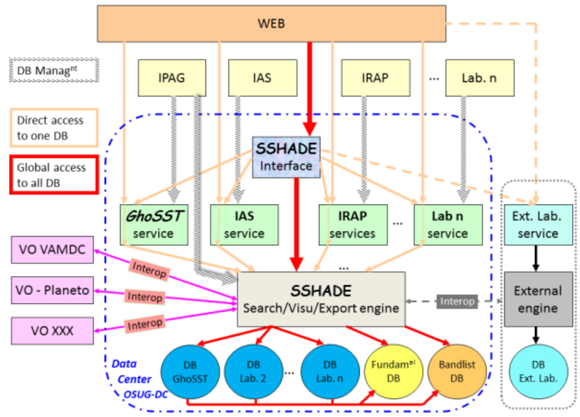

Figure 2: Schematic structure of SSHADE infrastructure

4. Databases implementation

The databases of each of the 20 partners of the SSHADE consortium will be progressively implemented in the SSHADE infrastructure all along the 4 years of the program. Each of the groups have a Scientific manager (responsible of the scientific content of the database and it quality) and a database manager (responsible of the ingestion of the data in the database), as well as contributors (experimentalists who produce data) to develop the content of their database. They will also contribute to the common 'band list' database of molecular solids by providing band parameters data or critical reviews of published data. They will be trained to the tools developed for data preparation, validation, ingestion and management. Tutorials for the database users will be also organized mostly during major planetary sciences and astrophysics conferences. The SSHADE web site will contain all documentation on the SSDM data model, the use of the SSHADE database, tutorials, as well on the experimental systems and cells used to record the spectra.

Acknowledgements

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Planetary Sciences Interoperability at VO Paris Data Centre

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1. Introduction

The Astronomy community has been developing interoperability since more than 10 years, by standardizing data access, data formats, and metadata. This international action is led by the International Virtual Observatory Alliance (IVOA). Observatoire de Paris is an active participant in this project. All actions on interoperability, data and service provision are centralized in and managed by VOParis Data Centre (VOPDC).

VOPDC is a coordinated project from all scientific departments of Observatoire de Paris..

2. Interoperability model

Our interoperability model [1] is directly derived from the IVOA one. To face challenges such as a large community and many distributed database around the world, making data interoperable can not rely on a central point managing all the data. The user interface must provide a layer of interoperability over all databases and data centres. It must include a distributed catalogue of available services. Finally, such a model is the only scalable and sustainable way to reliably distribute data to our clients.

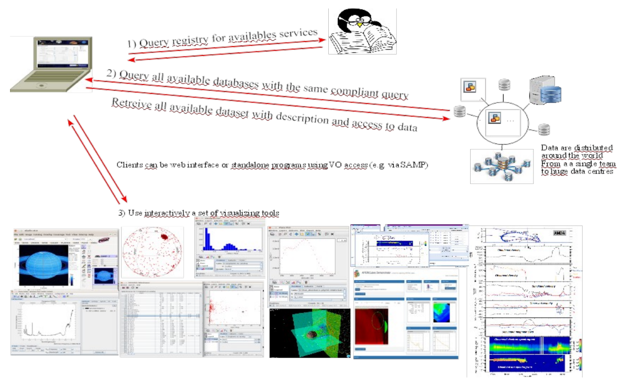

Figure 1: The user in front of the VO infrastructure

Users may request different levels of queries, from a very general one, e.g. “Show me what you have about Jupiter” to more specific, e.g. “Give me the spectra of Saturn from 0.4 to 1.3 microns with a resolution smaller than 0.1 micron, taken after 2010”.

In our case, the web client first accesses one IVOA registry where all the services are described and registered, by querying for URL and description of all the Table Access Protocol (TAP) services that can answer a EPN-TAP query. Then the web client queries each of these services in parallel, using the filter defined by the user. The first view displayed is therefore a count of the number of replies per service. From that information the user can look at meta-data for all replies or reformulate his query using a more accurate filter (like limitation on the processing level, mission name, instrument, etc.) From the final list of results, the user can visualize directly a preview of the data, download the result to his computer or display it in one of his favorite VO visualization client.

3. Registry

The services registry is the heart of our Information System. It consists of a database which stores the description of all the services using mainly the Dublin Core meta-data. The registry database is replicated to ensure its availability and sustainability (in particular to avoid a single point of failure). The replication system is based on OAI-PMH from the library world. The interface to the registry in the VO is going to change to a TAP interface which will allow a full text search. VO-Planetary science takes advantage of the IVOA infrastructure to declare (and retrieve) all EPN-TAP services in the registry.

4. Data Access

Data access is made using TAP, (Table Access Protocol) a standard protocol for querying database tables. The query language for TAP is ADQL (Astronomical Data Query Language), designed from SQL 92 and extended to provide polygon delimitations on the celestial sphere. The TAP protocol supports synchronous and asynchronous ADQL queries to perform complex requests on large databases hosted in big data centres.The Planetary data model constrains a set of parameters that are present in all EPN-TAP services, thus the same query can be sent to all services. Several frameworks and libraries allow data providers to install a VO layer on top of their existing database, or create a new database to be compliant with EPN-TAP. Tutorials are available using the GAVO (German VO)– DaCHs framework for publishing planetary data.

5. Data Model

.As Data Access is a general mechanism to query databases, the specificity of planetary science is expressed in a "Data Model" (DM) that describes contents, origin, and context of the data. During this project, initiated during the Europlanet FP7 program, we have designed a list of query-able parameters as the core of the planetary DM. A specific IVOA Working Group is in charge of data model definition and the planetary DM takes advantage of its work. Hence our model references as much as possible the existing IVOA DM.

6. Data Exchange

As Interoperability exists between programs, all information for data exchange must be fully described in a standard way [2] . The file format for exchanging data is the VOTable xml format with some extensions to allow data in binary format for large set of data.The VOTable format is used in exchange between services and client, but can also be a final user data format.

After querying the service, the response contains the list of files matching the query together with information on the contents of the result. The IVOA have developed a machine readable way to describe the physical quantities called Unified Content Descriptor (UCD) based on a list of word and adjustment possibilities. VO-Planetary science has extended this dictionary in coordination with the IVOA.

7. Visualization

The Astronomy and plasma community has developed a set of visualization clients usually dedicated to a data product, for example Aladin and ds9 for images, Topcat for catalogues, VOSpec, Cassis and Specview for spectra, amda for time series, 3D View for orbital and surface representation.

They are all integrated into the VO environment so that they can directly query registries and databases to retrieve the data products they can handle. In order to gather such applications into a self consistent toolbox, the Simple Application Messaging Protocol (SAMP) has been developed to allow them to communicate and exchange data between each other, and even from web

pages. This allows the user to send data to the SAMP-enabled clients from a web portal by simply clicking on a button. However a specificity of Planetary science is the heterogeneity of data format, from PDS to FITS, ASCII, NetCDF. Data transformation engines have been developed to transform specific data products on a fly into a format readable by visualization clients.

8. VO Client

Access can be performed via programming libraries (for Python and Java), or thanks to a web portal vespa designed to query data products using EPN-TAP http://vespa.obspm.fr

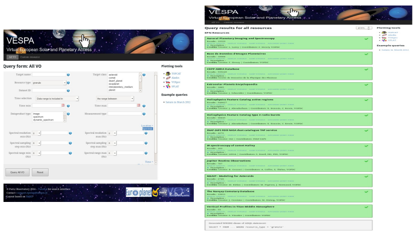

figure 2 : Views of the vespa web client

9. Available Data Services

A first set of services are reachable via EPN-TAP to demonstrate the capability and efficiency of our concept. This set spans a sample of different data products and different scientific disciplines :

Auroral Planetary Imaging and Spectroscopy APIS (images + spectra)
Planetary images databases BDIP (images)
CDPP AMDA DataBase (temporal series)
Extrasolar Planets Encyclopaedia (table-catalog)
Heliophysics Feature Catalog active regions (table)
Heliophysics Feature Catalog type 3 radio bursts (table)
INAF-IAPS RDB NASA dust catalogue TAP service (table)
IR spectroscopy of comet Halley (table)
Jupiter Routine Observations (dynamic spectra)
M4AST - Modeling for Asteroids (spectra)
The Nançay Cometary Database (radio spectra + tables)
Vertical Profiles in Titan Middle Atmosphere (vertical profile).

10. Computational services

Some computational services can not be run on the fly and need an asynchronous interface. We have adopted the Universal Worker Service (UWS) IVOA standard, which uses a REST protocol to define communication between clients and server. Implementation of such services has been done at Observatoire de Paris, using: on the server side an interface with our cluster using the SLURM batch scheduler. on the client side a UWS 1.0 compliant javascript library developed locally.

11. Conclusion

VO Planetary science is a good example of interoperability process built quickly because 1) it focused on the specificities and the needs of planetary science community and 2) it takes advantage of an existing VO infrastructure with a global sustainability. Many standards which have already been designed are ready to be re-used by the community. The success of this project during FP7 has allowed it to be a major part of Europlanet in H2020 program.

Acknowledgements

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The data distribution of the ESPaCE project

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Abstract

In the framework of the European Union project entitled ESPaCE (European Satellite Partnership for Computing Ephemerides, 2011-2015) we have carried out research by collecting unexploited space data and ground-based data for providing new dynamical orbit models and ephemeris of natural satellites and spacecraft orbits. Besides new digitization of old astrometric plate data, Radio Science, VLBI tracking, Laser Ranging methods are applied to these goals. Furthermore shape and gravity field data, reference systems are provided for several natural satellites. This project intends to put all this material online for free access by the scientific community. We will describe the data acquisition and distribution performed and in particular the set-up of the ESPaCE-NSDB astrometric database.

1. Introduction

The ESPaCE project aims at strengthening the collaboration and at developing new knowledge, new technology, and products for the scientific community in the domains of the development of ephemerides and reference systems for natural satellites and spacecraft by combining expertise of seven main European research centers involved in space sciences and dynamics: Royal Observatory of Belgium, Technical University of Berlin, Joint Institute for VLBI in Europe, Delft University of Technology, CNES-Centre National d'Etudes Spatiales, DLR-Berlin and IMCCE- Paris Observatory.

1.1 The workpackages and the data provided.

The core of the activity concerns the extraction and analysis of astrometric data from spacecraft measurements that have not yet been used in the orbit dynamic reconstruction, their combination with ground-based astrometric data digitized from old plates and the development of new dynamical models. The project intends also to advance the European expertise in ultra-precise tracking of planetary probes and other deep space science missions. By these means, we intend to provide new ephemerides of several natural satellites, a characterization of their rotation properties, and to improve spacecraft orbit determination methods for space science. This 4 year project is organized in work-packages with the goal to deliver to the scientific communities and communities at large the best scientific products adequate to the present day cutting edge space science and technology. In this context the setup of databases, the performing of data access and the distribution methods are important activities.

Radio Science: Tracking data of probes which flew by natural satellites are collected and analyzed thanks to a priori ephemerides of the objects. Several considerations upon the acting forces, gravitational and non-gravitational forces, are made in order to get the best results. These forces are estimated and precise orbit of the probes can be computed. SPICE Kernels are provided.

Laser ranging. In this WP the near-future potential of interplanetary laser ranging is assessed, by means of both numerical simulation and analysis of one-way laser ranging data to LRO. Simulations of a laser-equipped Phobos lander show orders of magnitude improvement in geodetic parameter estimation accuracy for Phobos and Mars, indicating the added value of such a system for planetary science missions. Comparison of one- and two-way concepts is underway. Using only one-way laser ranging data, we have estimated orbits of LRO which show a difference of only 10 m with operational SPICE kernels.

VLBI. Applications of VLBI technologies VLBI tracking data are analyzed in view of their use for various planetary science objectives. A special software is developed and applied to planetary science spacecraft VLBI observations. VLBI campaigns observing radio science signal from different spacecraft have been performed and first results are analyzed.

Digitizing. This WP is dedicated to the scan of many photographic plates of planetary systems of satellites. We have identified in particular plates of Martian, Jovian and Saturnian satellites to be scanned. This work is made possible thanks to the recent setting up of a new digitizing machine in ROB. Digitization of Mars plates, Saturn plates, of relevant plates, and the Identification of new plates have been carried out. These data allowed an accurate astrometric analysis.

Astrometry. The data scanned are analyzed in terms of astrometry in order to obtain orbit models. A special task is devoted to the astrometry of Phobos and Deimos which have been the goal of several space missions. The positions of the natural satellites, the planet and the reference stars were extracted from the digitized plates and corrected for distortion. Astrometric data related to the Martian Jovian, Saturnian and Uranian satellites have been ingested in a new database: ESPaCE-NSDB (Fig. 1).

Coordinates and reference systems. On the basis of space observations, the shape and gravity model of the natural satellites can be obtained. This WP is devoted to these tasks for the Martian satellites, the Moon, and the icy satellites. Coordinate system for these objects, reference shape, gravity model and reference system for Phobos, the Lunar coordinate system, reference shapes and coordinate systems of icy satellites are provided. Rotational data of natural satellites are provided in SPICE kernels.

Spacecraft and satellite ephemerides. New dynamical models of the natural satellites and improved orbit models of spacecraft are obtained by using the digitized astrometric data as well as spacecraft data. The dynamical models of the Martian satellites Phobos and Deimos can be improved in particular on the basis of the new analysis of the recent MEX data and the past Viking data. Other data from the Galileo and Voyager missions and from CASSINI permit also to provide new ephemerides of the Galilean, the Uranian and the Saturnian satellites. SPICE kernels have been provided and are being implemented in the IMCCE ephemeride server (MIRIAD and MultiSat interfaces).

Figure 1: ESPaCE-NSDB, astrometric database of natural satellites soon publicly accessible at http://nsdb.imcce.fr

2. The astrometric database

The astrometric database is the main tool for allowing users to access astrometric positions of satellites of Mars, Jupiter, Saturn, and Uranus. All the astrometric data obtained in ESPaCE will be soon accessible through this system. But the goal is also to have a sustainable tool for feeding the repository through a provider access. The database involves a MySQL database with interfaces through an Apache web server (Fig.2). Different format of outputs (VOTable, html, ascii) are provided.

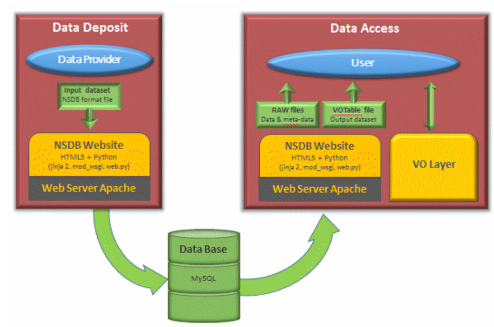

Figure 2: ESPaCE-NSDB structure

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Multidimensional analysis of electromagnetic fields

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Abstract

Multidimensional measurements of electromagnetic fields in space plasmas can be processed by various methods to obtain information about the polarization and propagation properties of the corresponding wave modes. New developments are planned in the frame of EPN-2020-RI.

1. Introduction

New developments will be based on a set of multidimensional methods for electromagnetic fields which have been previously used for analysis of data from

- STAFF-SA instrument onboard the Cluster spacecraft
- STAFF/DWP instrument onboard the Double Star TC-1 spacecraft
- LFEW instrument onboard the Double Star polar TC-2 spacecraft
- Cassini RPWS data
- IMSC and ICE instruments on the DEMETER spacecraft
- Polar PWI-HFWR data
- Van Allen Probes EMFISIS data

A demonstrator for multi-dimensional spectral analysis of electromagnetic fields has been developed in the frame of the demonstrator for on-line data analysis and related visualization tools of the EuroPlaNet-RI project.

2. Spectral matrix analyser

The Spectral matrix (SM) analyzer will be a tool designed to analyze multi-component measurements of electromagnetic waves. It will implement a number of methods used to estimate polarization and propagation parameters, such as

- the degree of polarization,
- sense of elliptic polarization and
- axes of polarization ellipse,
- the wave vector direction,
- the Poynting vector,

The results will be represented in different visual and numerical formats.

3. Summary

Dedicated set of methods for multi-dimensional analysis will be used to calculate characteristics of electromagnetic waves from in-situ spacecraft measurements that are the key signatures of fundamental process in the solar wind and planetary magnetospheres. These methods will be developed into a part of coordinated data analysis service.

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Planetary Space Weather Services for the Europlanet 2020 Research Infrastructure

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Abstract

Under Horizon 2020, the Europlanet 2020 Research Infrastructure (EPN2020-RI) will include an entirely new Virtual Access Service, **WP5 VA1 "Planetary Space Weather Services"** (PSWS) that will extend the concepts of space weather and space situational awareness to other planets in our Solar System and in particular to spacecraft that voyage through it. VA1 will make five entirely new 'toolkits' accessible to the research community and to industrial partners planning for space missions: a general planetary space weather toolkit, as well as three toolkits dedicated to the following key planetary environments: *Mars* (in support ExoMars), *comets* (building on the expected success of the ESA Rosetta mission), and *outer planets* (in preparation for the ESA JUICE mission to be launched in 2022). This will give the European planetary science community new methods, interfaces, functionalities and/or plug-ins dedicated to planetary space weather in the tools and models available within the partner institutes. It will also create a novel *event-diary* toolkit aiming at predicting and detecting planetary events like meteor showers and impacts. 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 and/or solar events through the Solar System and modelling the response of the planetary environment (surfaces, atmospheres, ionospheres, and magnetospheres) to those events. But these tools were not originally designed for planetary event prediction and space weather applications. So **WP10 JRA4 "Planetary Space Weather Services"** (PSWS) will provide the additional research and tailoring required to apply them for these purposes. The overall objectives of this JRA will be to review, test, improve and adapt methods and tools available within the partner institutes in order to make prototype planetary event and space weather services operational in Europe at the end of the programme.