Project Final Report

Grant Agreement number: **262 863**

Project acronym: **IMPEx**

Project title: **Integrated Medium for Planetary Exploration**

Funding Scheme: **Collaborative Project**

Period covered: *from* **1st of June 2011** *to* **31st of May 2015**

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V1.0

Content

Figures

Tables

1. Final publishable summary report

1.1. Executive summary

IMPEx was a four year collaborative project, funded under the 7th framework of the *European Union* (FP7) that started in June 2011. Its consortium is made up of four members, scientific institutions from Austria (*IWF-OeAW*, the coordinating entity), Finland (*FMI*), France (*CNRS*), and Russia (*SINP*). The projects main goal is the creation of a software environment that facilitates and supports the comparison and overlay of modelled space plasma data vis-à-vis real world observational data, obtained in the course of past and future space missions. The software environment is consisting of several well established tools (mainly *CDPP-AMDA*, *CDPP-3DView* and *CLWeb*) provided by CNRS, for the analysis and visualization of space mission data. These tools have been extended to handle various aspects of simulation data with the goal of gaining a better understanding of observed phenomena, as well as to optimize existing simulation codes and related models. IMPEx enabled tools are aimed at supporting mission planners and spacecraft designers, by providing modelled and empirical data for e.g. virtual space flights in simulated planetary (plasma) environments.

During the first project year the concepts and goals outlined in the proposal were concretized in the course of the requirements definition (supported by the creation and analysis of *scientific use cases*) and architectural design phase (see **D2.2** and **D2.3**). Several approaches were discussed and finally agreed upon and carefully documented. The main pillars of the IMPEx system were created; the *IMPEx Protocol* and the *IMPEx Data Model* basically cover all requirements from a technical and conceptual perspective, and allow for the exchange of data between various nodes of the topology as captured in the *IMPEx Configuration*. In the second and third year of the project the focus was primarily set on the finalization of all designs and of course the implementation, including the preparation of test cases for testing and system validation. In this period the project's advisory boards were an important source of feedback and orientation for the team, with the aim to provide a system that is relevant and capable of solving real life problems in the course of scientific investigations. The boards are also pivotal in capturing all relevant requirements for the *IMPEx Portal* that was developed at *IWF-OeAW* during the second half of the project. It provides a one-stop-solution for anyone who is interested in IMPEx and wants to learn about the system through a *hands-on* experience, covering all aspects of IMPEx and integrating all tools of the environment.

The final project year was dedicated to the finalization of remaining definitions, features and functionalities deemed essential by the user community, as well as an integrated test effort to assure the required stability and general quality of the system. Further the *IMPEx Data Model* became an official part of the *SPASE* data model, upon which it is based on. The *IMPEx Data Model* hence becomes the *SPASE simulation extension* that will enable all users and applications of *SPASE* to integrate simulation data into their (database) systems, being able to handle and search simulation data as it is also possible for observational data.

The IMPEx website was established very early on during the project and provides comprehensive access to all relevant information (technically and scientifically) in order to gain a detailed insight into IMPEx, its tools and capabilities. The website offers a rich selection of video tutorials, comprehensive online material as well as a dedicated project podcast, featuring team members, members of the advisory boards etc. in 16 episodes, covering a wide range of subjects about and surrounding IMPEx. All in all it can be said that IMPEx exceeded expectations by its protagonists, in particular by setting a de facto standard in the field of simulation data and by establishing a prototype system that is based on common design principles of the *Virtual Observatory* (VO) and planetary science community.

1.2. Summary description

Europe as a leading participant in international endeavours (e.g. *Rosetta*, *Mars Express*, *Venus Express*, *ESA/NASA Cassini-Huygens*) to explore our solar system and planetary objects is also at the forefront in the development of theoretical models to simulate conditions in space. Empirical data derived via actual measurements during space missions and data obtained through computational model runs are two major aspects of modern space research. While it is obvious that models can only be **further developed by comparing the results to real word measurements**, it is as important to then use these models (once sufficiently confirmed by observational data) to **interpret new measurements and to understand the physical processes** behind the data. Both processes need adequate software support that was practically not available in planetary science by the time the project idea of IMPEx was developed. Once realized, modelled data can also be easily applied to **support spacecraft designers and engineering** in general, by providing the means to simulate conditions in planetary environments to e.g. obtain accurate requirements for spacecraft hardening, and design requirements in general. The last major application is to **fill measurement gaps** in observational data using modelled data derived via validated (sic) models.

Figure 1: *The IMPEx environment with its main tools and SMDBs, connected through the* ***IMPEx Protocol*** *that is fully implemented by the* ***IMPEx Portal****. All data is stored compliant with the* ***IMPEx Data Model*** *and can be easily exchanged between the various nodes (tools and SMDBs).*

The consortium of IMPEx includes several institutions that have developed world renowned computational models in the field of **space plasma physics**, being able to simulate the (plasma) environments of the majority of planetary objects in the solar system, including moons and comets. The IMPEx modelling sector is comprised of two hybrid models provided by FMI and LATMOS

(CNRS), a magneto hydrodynamic model by FMI, as well as a unique paraboloid model provided by SINP – the models in detail are:

- The worldwide recognized ***3D hybrid modelling platform HYB*** for study of Solar System objects' plasma environments (developed and hosted at *FMI*)
- ***Global MHD modelling platform*** for 3D terrestrial magnetosphere (developed and hosted at *FMI*)
- The global ***3D Paraboloid Magnetospheric Model*** for simulation of magnetospheres of different Solar System objects (developed and hosted at *SINP*). This model also offers on-demand calculations (see *IMPEx Protocol*), i.e. responses are **more or less *real-time***.
- The ***LATMOS hybrid model*** developed and hosted at Université de Versailles Saint-Quentin.

Further, several **web based** analysis tools (*CDPP-AMDA*, *CLWeb*, the *Java* based visualization tool *CDPP-3DView*, see **Figure 2**) and user interfaces for the simulation databases (*SMDBs*) provided by *FMI*, *SINP* and *LATMOS* are part of the environment. The user interfaces of *FMI* and *SINP* also offer *WebGL* based visualization capabilities (**Figure 1**).

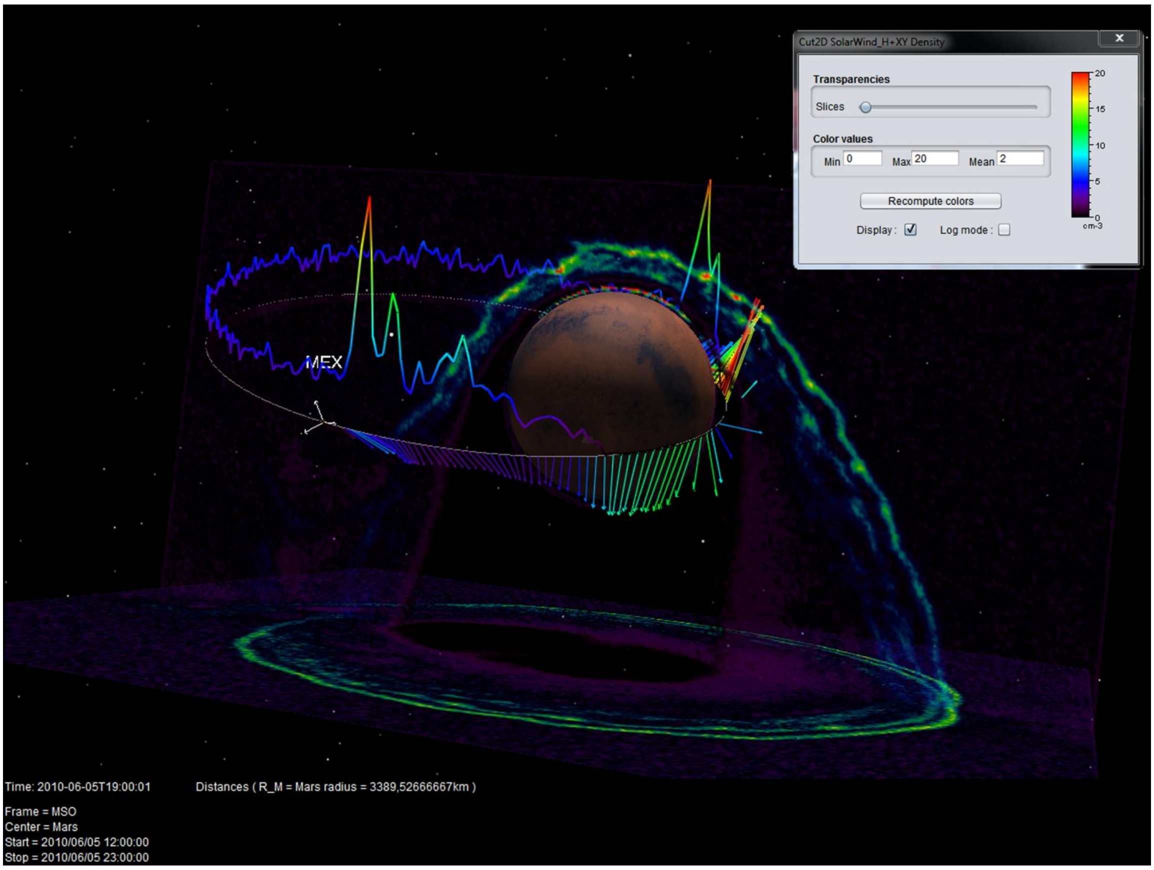

Figure 2: *Visualization of a magnetic field simulation run interpolated onto the orbit of Mars Express, visualized via the Java based 3D tool CDPP-3DView provided by CDPP. The tool has been extended with regard to visualization capabilities required for the visualization of magnetic field and plasma data and enabled to communicate with the IMPEx environment (IMPEx enabled tool).*

One of the main technical objectives of the project was to enable these tools to exchange data with all participating *SMDBs* and hence integrate data obtained through complex simulation runs with observational data that is already being processed and analysed by the aforementioned tools (the available data was also significantly increased in the course of IMPEx, see **D2.13**). Another (scientific) objective is to further develop models in particular the paraboloid models for *Mercury*, *Jupiter*, *Saturn* and *Earth* by *SINP* (also see **D4.4**, **D4.5** and **D4.6**).

Connecting tools and databases is a challenging task, in particular when complex scientific data is involved. Numerous problems must be tackled as e.g. the aspect of **generality**, i.e. the ability to scale and reuse the solutions defined and implemented in other systems, and to extend the "data network" far beyond the original set of software applications and data collections.

In this sense the approach of IMPEx is highly compatible with the vision of the *International Virtual Observatory Alliance* (*IVOA*) that calls for astronomical datasets and other resources to work as a seamless whole. The philosophy followed here is that it is unproductive to put effort in "reinventing the wheel", i.e. to implement similar functionalities over and over again in different tools. Instead the *IVOA* initiative, as does IMPEx, aims at connecting systems in order to be able to easily exchange (scientific) data and leverage functionalities of a rich set of tools. Thus, IMPEx uses several standards that originated out of the *VO* community that were defined by *IVOA*. Among them is the *VOTable* format that is heavily used in IMPEx, to exchange trajectories etc. *SAMP* is another *IVOA* standard used that allows web based tools to communicate with each other in a straight forward way, circumventing the back ends.

Besides scientific and technological aspects, there is also a strong relation to public education as well as a significant socio economic component in general. IMPEx delivered a wide range of materials that can be used in public education at the level of public schools as well as higher education including university level courses (see **D2.14**, **D2.15**, **D3.12**, **D4.7** and **D5.2**). The website, which has been a central element for public outreach as well as an essential hub for technical information, features a number of tutorials, videos and extensive documentation of tools, models and the scientific approaches that lie underneath the environment. It is the hope that these materials will help to encourage young students to seek **careers in space science** and to engage in exciting research that is conducted in Europe and all over the world. In addition to that, the *IMPEx Data Model* (see **Figure 37**) provides a pivotal prerequisite in order to foster the exchange of scientific data, derived from computational models.

The *IMPEx Data Model* is, and will be even more so in the future, helping to bring the data and models outside of mission teams and specialized modelling groups, making them accessible and useful for the broad planetary science community, and, in this way, promoting the contribution of space assets to scientific and technological knowledge and development. Existing levels of scientific data exploitation, cooperation, as well as technical capabilities for communication of researchers including access to remote databases and computing infrastructures, provide ideal conditions for the integration of a combined modelling and data environment, as IMPEx is representing today.

As already briefly mentioned in **Chapter 1.1**, the *IMPEx Data Model* became the *SPASE simulation extension* and hence an official part of *SPASE*, which is one of the leading and most widely applied data models in space plasma physics worldwide. By integrating the IMPEx definitions, *SPASE* now is capable to also reflect on plasma data that was derived by computational modelling, and hence becomes the ideal environment for a combined use of both types of data. Since the *IMPEx simulation extensions* are conceptually close to the corresponding data structure and definitions for empirical plasma data, it is now a straight forward task to match data sets from both worlds. To use a practical example, as we can see in **Figure 37**, *NumericalOutput* is related to a certain *Repository* just as is *NumericalData* used in "traditional" *SPASE*. However, in the context of the simulation extensions the ontology is adapted, and the *Instrument* element used for empirical data becomes the *SimulationModel*, to clearly specify the technical source of the data so it can be adequately assessed.

With the development of the *IMPEx Protocol* a commonly used approach in IT development has been followed, and a set of *SOAP* web services was defined, implemented and offered (via **.wsdl* files) to the worldwide community, in order to enable it to fully leverage functionalities of the IMPEx environment. The idea is that through the provision of a common mechanism to expose modelled data including functionalities (i.e. web services) that can be applied on the data, also other *SMDBs* and infrastructures worldwide are encouraged to join the community and integrate their data, ever increasing the scientific scope of IMPEx. In mid-2015 there are already advanced prototype implementations available, and data from *UCLA* has e.g. been added to the *IMPEx Configuration*. There are many other projects (besides *SPASE*) and initiatives that benefit from IMPEx developments and vice versa that are cooperating with the project as e.g. *EFTLA/Astronet*, *CCMC*, *VESPA* - see **D5.3** for further information.

New requirements coming up in the future can be addressed straight forward through further updates of the *IMPEx Protocol* by either adding new methods, extending existing methods (preserving backward compatibility) or by extending the *IMPEx Data Model* to be able to describe an even broader range of simulation data and models. This way IMPEx is to be regarded as a living definition that will grow along with its applications and future requirements.

New horizons could also be reached by integrating *cloud computing* capabilities in possible follow up projects. Already within IMPEx *FMI* has done some experimentation with cloud technologies, by deploying the *HYB* modelling code on cloud resources, in order to test integration of these technologies in possible follow-up projects. Since modelling runs are a vital part of IMPEx, the inclusion of cloud resources would also enable smaller institutions to do complex runs on-demand, tailored to specific empirical data, to be analysed. All in all it can be said, that the modular approach of IMPEx lends itself perfectly to future extensions towards cloud computing and related technologies.

1.3. Main S&T results

This chapter details the main results in science and technology for every RTD related work package of IMPEx as well as WP5 that was leading the implementation of the *IMPEx Portal*.

1.3.1. *Data and Models Environment (DaME)*

The major goal of Work Package 2 consisted in providing *a user-friendly environment where the models and their results can be compared with the data of space missions and used jointly for scientific research and technological applications.* The key objectives were:

- To design and implement an **integrated environment of tools** enabling the **visualization** of data originating from simulations, observations and models.
- To define and use standards for data and time table exchange between tools (*CDPP-AMDA*, *CDPP-3DView*, *CLWeb* and simulation databases).
- To define and use several **methods of *data discovery***, aimed at helping the user fine-tuning the observations/models/simulations comparison.
- To provide a variety of **data representations in multiple dimensions**.
- To initiate **collaborations with similar infrastructures** in order to avoid duplication of efforts.

Integrated environment of tools

The first task of WP2 was the definition of an architecture facilitating the communication between scientific software tools, computational services and databases, as depicted in the figure below.

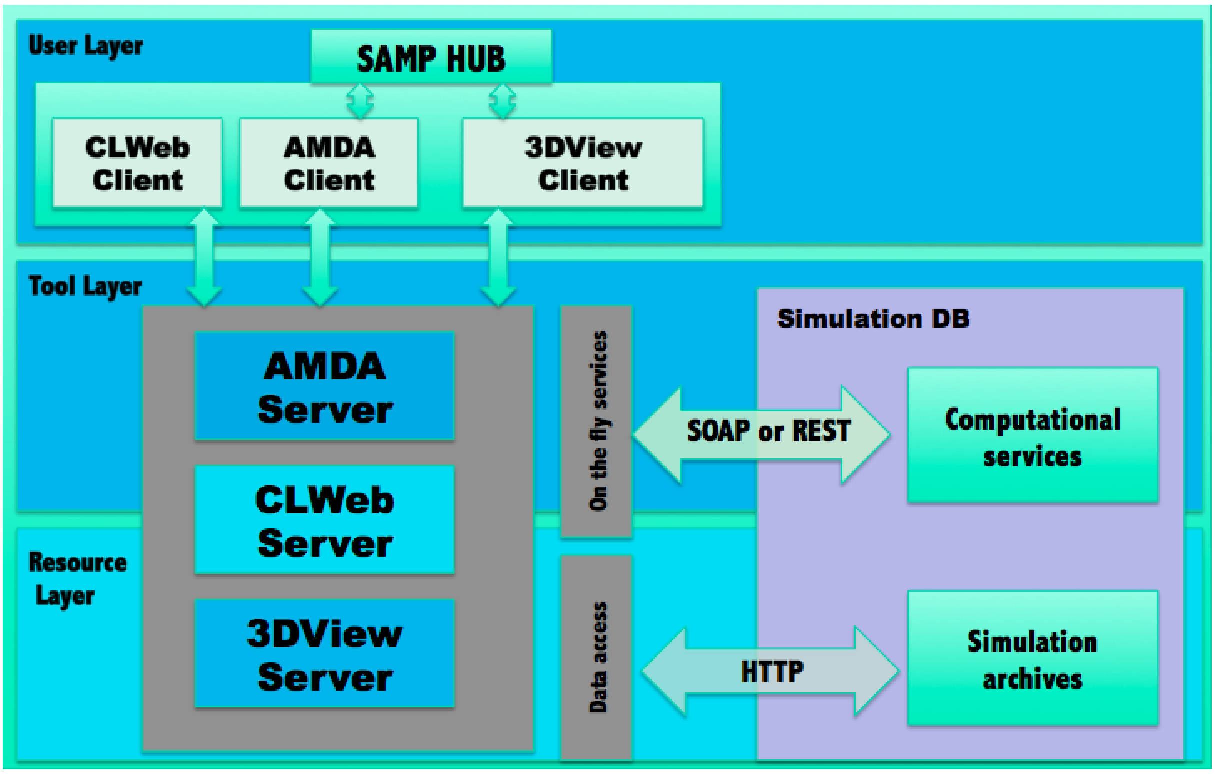

Figure 3*: Overview of the IMPEx architecture and flow of information.*

The implementation was facilitated by the adoption of widely used standards like *SOAP*, *REST* and *HTTP*, or *IVOA SAMP* and *VOTable*. In order to exchange data sets, a detailed description of their contents is necessary. This is achieved with the definition of metadata. Since a metadata model for observations already existed, it has been extended to take into account data coming from simulations. This task was conducted in collaboration with WP3.

Interfaces and protocols for data and time tables exchange

It is now possible to browse the contents of PMM and HMM catalogues in *CDPP-3DView*, *CDPP-AMDA* and *CLWeb*, using a file containing all the metadata necessary to access *HMM* or *PMM* data. A common format has been defined for this file, which is provided by all simulation databases (SMDBs). Every IMPEx tool must parse this file to display an interface for searching and getting data.

It is also possible to exchange data between *CDPP-AMDA* and *CDPP-3DView* using the *SAMP* protocol, widely used by astronomers. When *CDPP-AMDA* and *CDPP-3DView* are active on the user's desktop, *CDPP-AMDA* can send data in *VOTable* format via a *SAMP-Hub*. These data can be scalars, vectors or spectrograms. *CDPP-3DView* implements a *SAMP* listener, which is waiting on a signal from *CDPP-AMDA*. When data are available in the *SAMP-Hub*, *CDPP-3DView* creates the related graphical objects and displays them in the scene. If these data are not in the same coordinate system, a transformation of coordinate system is performed.

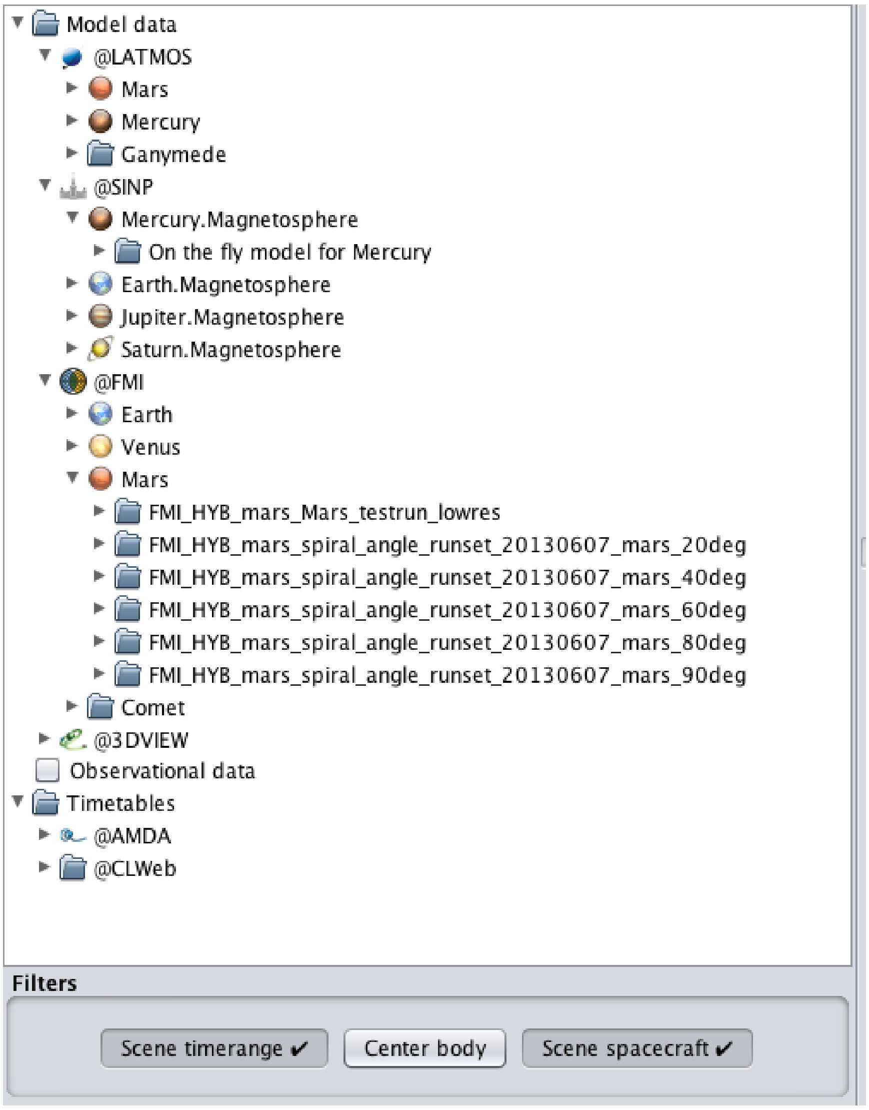

Figure 4*: Browsing IMPEx data in CDPP-3DView (with filters).*

New methods for data discovery

New methods for data discovery were investigated and implemented; the selection of a run for comparison with observations is composed of two steps:

1) The first step is via the *HMM* and/or *PMM* simulation and model databases (*SMDBs*) catalogues browsing interface, implemented in the accessing interface. The files containing the metadata are provided by the *SMDBs*; currently *FMI*, *LATMOS* and *SINP*. They are parsed and **displayed entirely as a hierarchy of data**.

2) The second step consists in "filtering" the hierarchy by applying one or several criteria to the simulation input parameters contained in the metadata files, to reduce the size of the hierarchy of data, according to these criteria, which are selected by the user. An interface enabling this feature is provided in *CDPP-3DView*. It is e.g. possible in *CDPP-3DView* to shorten the list of runs to those related to a specific body (e.g. *Mars* or *Earth*).

The other way, an analytic (minimization) method of *best fitting run* among those available in *HMM* and *GUMICS* archives, has been investigated and implemented. This ordering method is called "**N-index**". An *SMDB* that archives simulation runs, calculates this *N-index* and provides it through a web-service. This method, described below, is called *getMostRelevantRun*.

The best use of this method in the IMPEx infrastructure is to select data from *GUMICS* runs in *CDPP-AMDA* which already provides users with search and filtering capabilities in its workspace, but these capabilities are not applicable for a huge number of items, as it is the case for *FMI/GUMICS*, which provides about one hundred thousand runs.

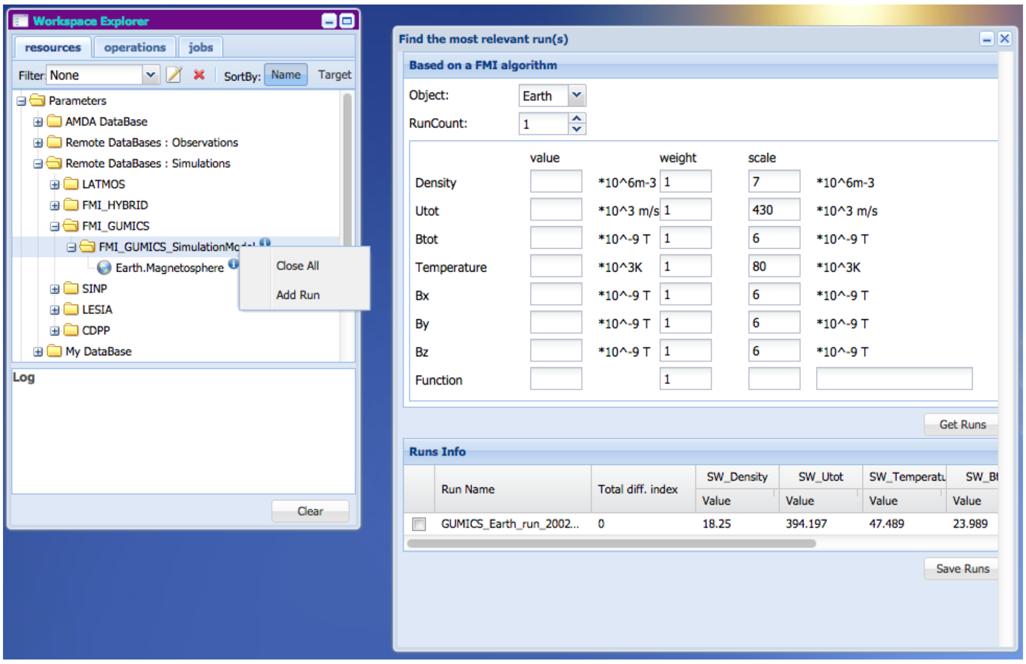

Figure 5*: Find the most relevant GUMICS Run in CDPP-AMDA.*

Data representation in multiple dimensions

One of the great achievements of IMPEx is the possibility to display new types of scientific data, coming from observations as well as simulations in *CDPP-3DView*. Users can now display *time series* along the trajectory of spacecraft, *field lines* or *flow lines*, and cuts in two dimensions. Several use cases using these new capabilities in *CDPP-3DView* are presented below, including the comparison of simulated and observed time series, the synchronization of *2D* and *3D* displays, *2D-cuts*, *magnetic field lines*, *velocity flow lines*, and *spectrograms*.

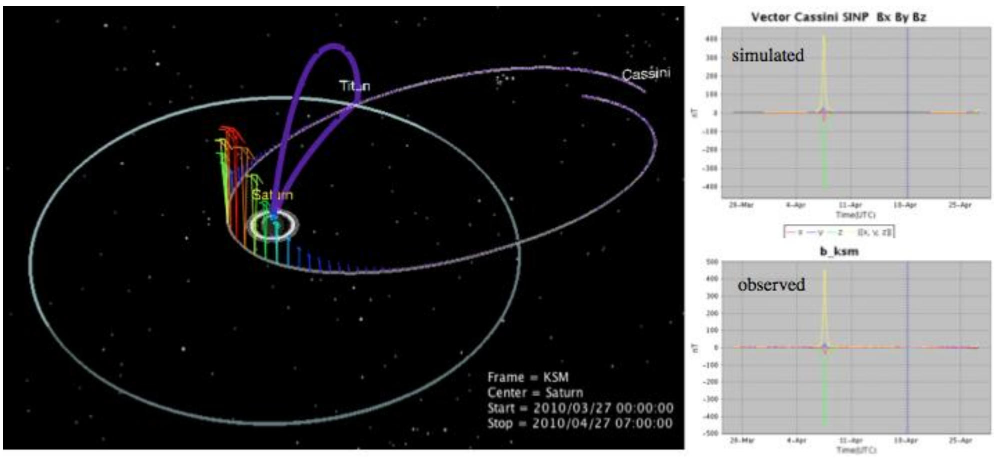

Figure 6*: CDPP-3DView - Magnetic field vector and field lines around Saturn simulated by SINP, overlaid with CASSINI/MAG data, provided by AMDA (source PDS).*

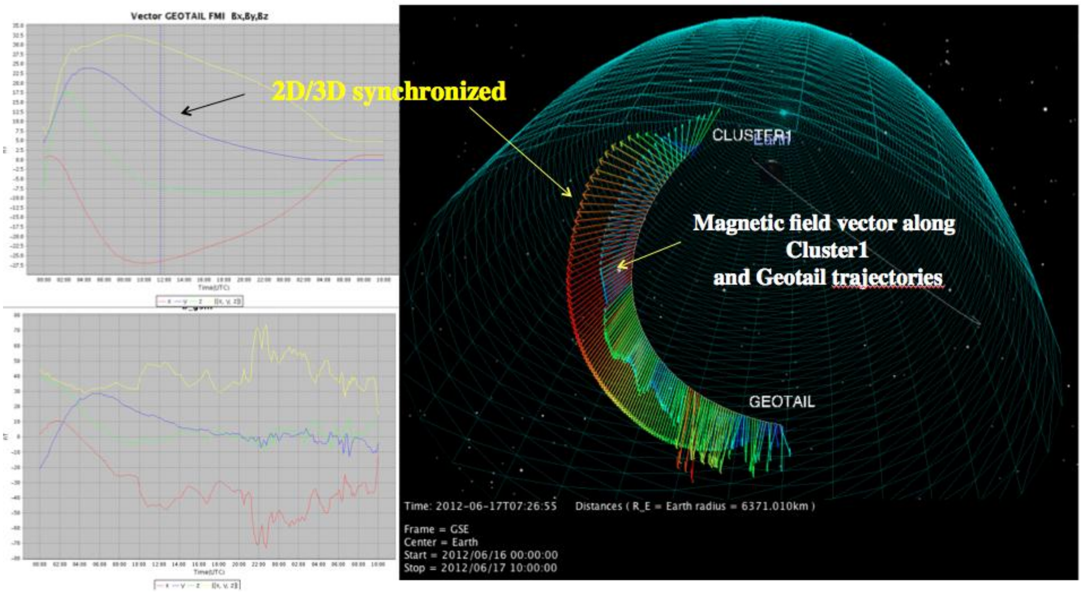

Figure 7*: Impact of a CME (2012/06/16) visualized with in-situ data in CDPP-3DView. Cluster 1 and Geotail from CDPP-AMDA, simulations from FMI-GUMICS.*

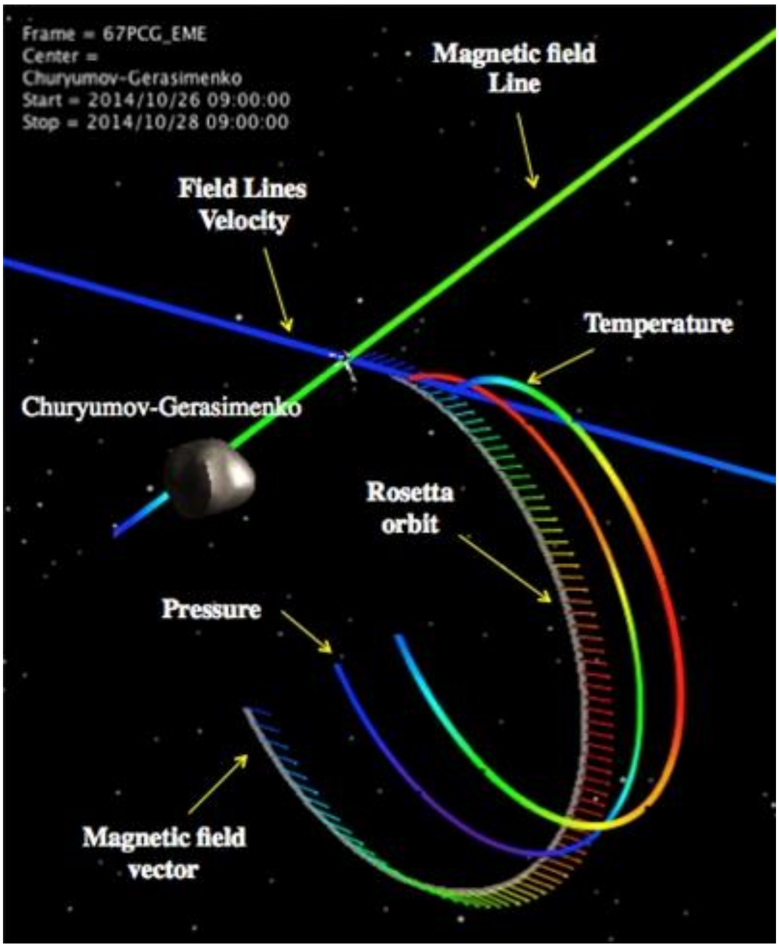

Figure 8*: Display of several types of simulation data along Rosetta orbit in CDPP-3DView (hybrid model from FMI for comets).*

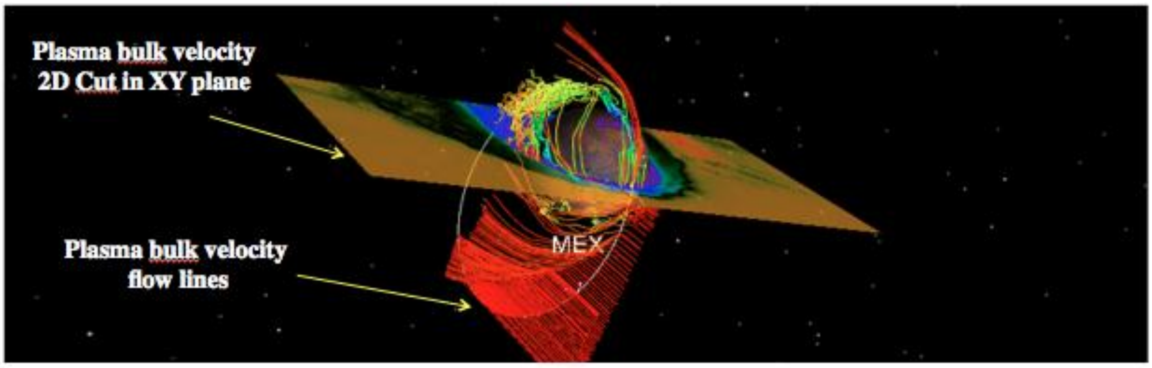

Figure 9*: Display in CDPP-3DView of several types of simulation data around Mars (MEX). Hybrid model from LATMOS.*

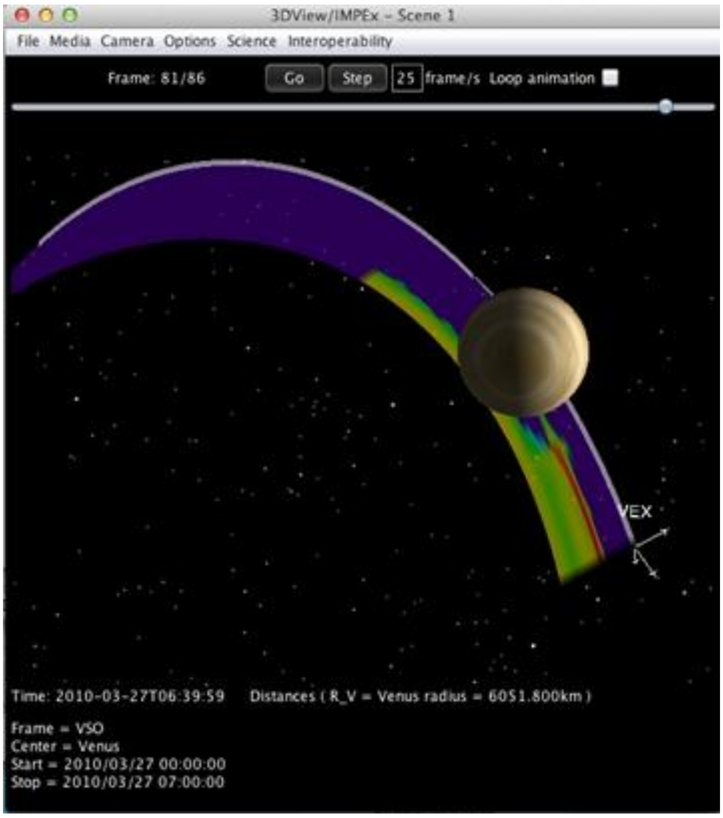

Figure 10*: Spectrogram of simulation data from FMI along Venus Express trajectory.*

In *CDPP-AMDA*, it is now possible to display on the same *2D* plot, time series of local or remote data coming from observations and remote data resulting of simulations, as depicted in the figure below:

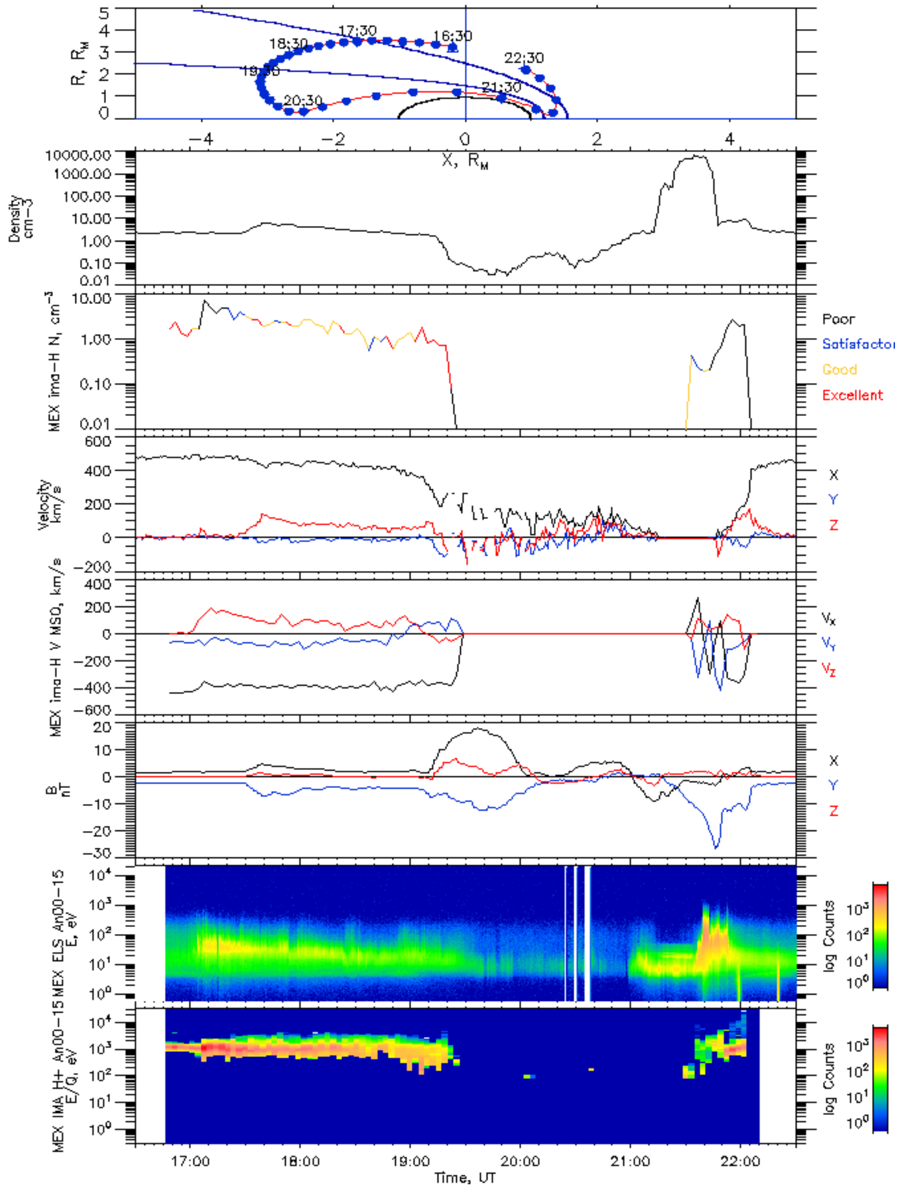

Figure 11*: CDPP-AMDA plot displaying comparison between observed data in the Martian environment (by the MEX spacecraft) and simulated ones (panels without the MEX tag). Magnetic field (6th panel from top) is absent from MEX instrumentation and can only be inferred from simulation models.*

Collaboration with similar infrastructures

IMPEx WP2 has initiated several collaborations with similar infrastructures:

CCMC: The goal of the *IMPEx-CCMC* prototype was to render *CCMC* results more easily accessible to the wider community, by providing access, visualization and analysis via *CDPP* tools (*CDPP-AMDA* and *CDPP-3DView*). Another goal was to check whether the *IMPEx Data Model*, used to describe simulations to be compared with observations, was applicable to SMDBs that did not participate in IMPEx. The prototype was limited to one type of simulation, namely *BATSRUS (MHD)*, and one run with data interpolated along the trajectory of several magnetospheric spacecraft. It focused mainly on access from *CDPP-AMDA* and *CDPP-3DView*. *CCMC* provides interpolation (in the *3D* box) of physical quantities (fields and plasma parameters) along spacecraft trajectory as time series. They can now be directly compared to in-situ observations in *CDPP-AMDA* or *CDPP-3DView*.

EuroPlaNet-RI: An interface between *IMPEx* and *EuroPlaNet-RI*, another *FP7* partner has been implemented, via a protocol defined by *EuroPlaNet-RI*, to access an *IMPEx* related database (*CDPP-AMDA*) from an external tool (*TopCat*). *EuroPlaNet-RI* has defined a common data model, *EPNCore* and a protocol, *EPNTap*. Both are used to give access to planetary science data. *IMPEx* has developed an interface between one of the participating tools, *CDPP-AMDA* and a search client designed and implemented by VO-Paris, in the framework of *EuroPlaNet-RI*. The same interface may be used between *CDPP-AMDA* and *TopCat*, a tool developed in the framework of *IVOA* (*International Virtual Observatory Alliance*) to analyze scientific data. These interfaces are based on *EPNCore* and *EPNTap*. In addition to that, IMPEx has created a translation mechanism between the IMPEx data model, which is based on *SPASE* and *EPNCore*. Every resource described within the IMPEx metadata trees can then be consumed by the *EPN* search client or by *TopCat*. Scientists familiar with *TopCat* are now able to use its numerous options to efficiently analyze and display a lot of datasets from space missions provided by *CDPP-AMDA* and simulations provided by *IMPEx*.

Extension of the CDPP-AMDA database of observations

A lot of datasets from space missions, relevant for observations/simulations comparisons, were added to the *CDPP-AMDA* database during *IMPEx*. They include data from missions to *Mercury* (*Messenger*), *Venus* (*Venus Express*, *PVO*), *Mars* (*MAVEN*, *MGS*, *Mars Express*), the *Moon* (*Artemis*) or the Giant planets (*CASSINI*, *GALILEO*, *VOYAGER 1 & 2*, *PIONEER 10 & 11*, *ULYSSES*), *Comet Churyumov-Gerasimenko* (*Rosetta*), and *Comet Halley* (*Giotto*).

Links to remote databases were also established for *Venus* (*Venus Express*) and the *Moon* (*Artemis*).

Outreach and educational products

A tutorial, demonstrating the access to data coming from observations and simulations with *CDPP-AMDA* and *CDPP-3DView* has been provided (see **D2.15** as well as the **demonstrator section** of the IMPEx website, https://sites.google.com/site/impexfp7/). With this step-by-step guide users are able to visualize data related to the *Earth* magnetosphere, coming from several origins:

- Observations from *CDPP-AMDA* database
- *SINP* paraboloid model for the magnetic field
- *FMI MHD* model (*GUMICS* code)
- *BATSRUS* (*MHD*) run at *CCMC*

1.3.2. *Hybrid and MHD Models (HMM)*

WP3 (*Hybrid and MHD Models (HMM)*) was one of the two work packages which formed the **IMPEx modelling sector**. The basic objective of **WP3** was to enable IMPEx to **access modelling codes for simulation of plasma environments** around planetary objects. Further it included the preparation of efficient interfaces for the operation of these codes and to work with their results. The modelling core of **WP3** consisted of *FMI's* hybrid (*HYB*) and *magnetohydrodynamic (GUMICS)* models and *LATMOS' hybrid model*. Hybrid models were used for the study of solar system objects environments and the *magnetohydrodynamic model* for the **terrestrial magnetosphere**. The modelling infrastructure of **WP3** builds on computational resources operated at *FMI*, as well as their related data bases and services.

The computational modelling activity in **WP3** fed directly into **WP2** in a way that the models and their data outputs were linked to the IMPEx infrastructure, which also included a large archive of space mission data (*CDPP-AMDA*) and a **3D visualization tool** (*CDPP-3DView*).

The key products obtained in WP3 are the following:

- **Defining** the content and the structure of the IMPEx methods (**.wsdl files*) and the structure of the simulation metadata (*tree.xml files*).
- **IMPEx web service interfaces**, which enable direct access to SMDB and, therefore, combining observation and simulation data.
- **Web interface *Hybrid Web Archive* (*HWA*)**, which provides a user friendly interactive web access to FMI's HYB and GUMICS model results and to its 3DHWA visualization facilities.
- **Web interface *LatHyS***, which provides a user friendly interactive web access to LATMOS' hybrid model runs results and to its visualization facilities and analysis tools.
- **Open source IMPEx method scripts**, which provide an example of how IMPEx methods have been implemented by FMI. These scripts help other model providers to build own IMPEx compatible web services.
- **Open source HYB model.** This enables users to make own runs with the FMI's HYB model and, importantly, check rationale and correctness of the used algorithms.
- **3D HWA visualization tool**, ***3DHWA***, which helps FMI's *HMM SMDB* users and users of the IMPEx methods to analyse runs in the HWA.
- **Open source MATLAB scripts**, provided by FMI, which provides MATLAB users an easy usage of the IMPEx methods
- Creating HMM modelling **demonstrators** for public education

The *IMPEx Data Model*, Interfaces, protocols and catalogues

A large effort on the definition and the implementation of the *IMPEx Data Model* has been conducted within **WP3**, together with **WP2** and **WP4**. This effort has been consolidated in a new deliverable **D3.14**, not originally planned. Most of the development work for this data model concerned the description of the simulation runs and models. For this, we created new resources: *SimulationModel*, *SimulationRun*, *SimulatedRegion*, *SimulationProduct*, *SimulationDomain*, *SimulationTime*, and *SimulationType* (also see **Figure 37**).

We also made use of *xml* elements already defined in *SPASE*, to describe the simulation temporal and spatial parameters, as well as the targeted celestial body of the simulation. In all our developments we tried to limit the introduction of new terms or elements to facilitate the parsing of the metadata by automated tools (the larger the number of terms is, the more difficult it is for tools to handle them). An example of these new resources is presented in **Figure 12**.

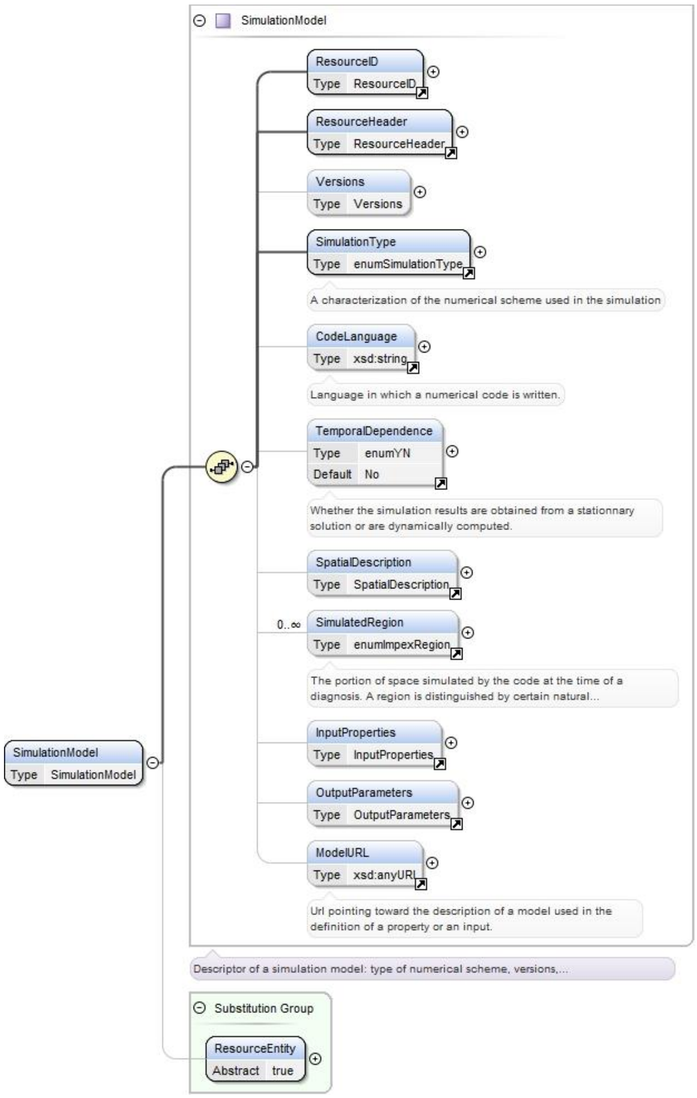

Figure 12: *Graphical representation of the SimulationModel resource*

HMM environment data for CDPP-AMDA database

This effort consisted in linkage of *HMM* models and input/output data of modelling runs to the *CDPP-AMDA* database - it was performed in coordination with **WP2**. The developed data model link provides access to various modelling tools and data products.

The work has contributed to the definition of the *tree.xml* file which describes all *HMM* simulation runs and the accessible variables thereof. The file is publicly available from IMPEx's data services.

Each simulation provider is responsible for providing the *tree.xml* on its server. A data model (standardized *xml* vocabulary and grammar) has been defined to standardize the *tree.xml* format. The *tree.xml* file describes run inputs and all simulation data, and provides links to the pre-computed data.

The **IMPEx Simulation Data Model** was designed as an extension of the existing *SPASE* Data Model, which is widely used for space physics databases. This compliance with standards ensures an integration of simulation databases in IMPEx, along with observation databases and an easier expendability of the *IMPEx framework*.

All methods have been defined for the *SMDB*. In *HMM* the methods are the following:

1. ***getDataPointValue***: Returns a physical variable or variables at given point(s) from a model database.
2. ***getDataPointValueSpacecraft***: Returns a physical variable or variables along the orbit of a spacecraft from an *SMDB*.
3. ***getDataPointSpectra****:* Returns the **energy spectra** at given point(s) from an *SMDB*.
4. ***getDataPointSpectraSpacecraft***: Returns the **energy spectra** along the orbit of a spacecraft from an SMDB.
5. ***getSurface***: Returns a physical variable or variables on a plane which normally is along the coordinate axis of an SMDB.
6. ***getFieldLine***: Makes vector field tracing as e.g. **magnetic field line tracing** or **flow line tracing**.
7. ***getParticleTrajectory***: Makes **particle tracing** *(*provided **only by FMI***).*
8. ***getMostRelevantRun***: Returns an ordered list of runs that have input values as close as possible to the provided set of values.
9. ***isAlive****:* returns the status of the database (*Alive* or *Down*).

One important task was to add ~1e5 *GUMICS Earth* magnetosphere result files into the *tree.xml* file in a way that keeps the size of the *xml*-file reasonably small and hence fast to use. The effort was successful and the method can be used efficiently on even such a large number of files. This also demonstrates that IMPEx methods and protocols are scalable and can handle in the future hundreds of thousands of missions and simulation result files. The *HYB* model was used to provide simulation results for *Venus*, *Mars* and comet *67P/Churymov-Gerashimenko*. It further supports data analysis of *ESA's Venus Express*, *Mars Express* and *Rosetta* missions, respectively.

HMM environment data for visualization

This task provided the outputs of *HYB* and *MHD* models for the *CDPP-3DView* visualization software provided by *WP2*. It is performed in **coordination with WP2**, and is connected to **WP3**.

The available data products and computational methods to access *HMM* simulation runs from *CDPP-3DView* were defined in the *tree.xml* and *methods.xml* files.

In addition to the *CDPP-3DView* visualization, a purely web based **3D visualization tool *3DHWA***, was developed to provide a *3D* tool to visualize *HYB* and *GUMICS* simulation runs in *HWA*. User picks up an interesting run from the *HWA* in a normal way. The user can then pick up plotting option "3D" (**Figure 13**) which enables interactive web based *3D* analysis of the data.

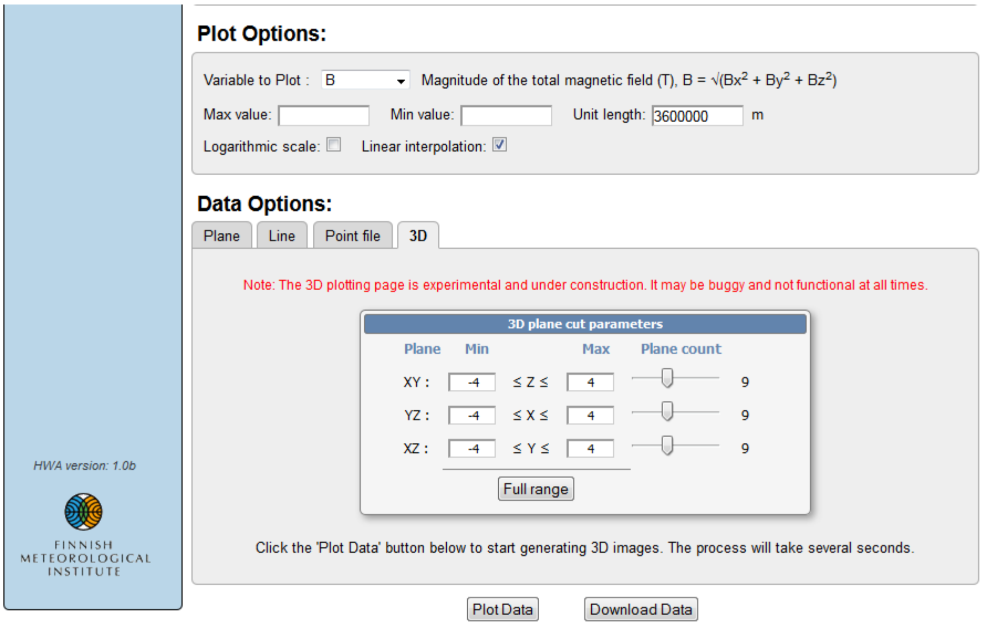

Figure 13: *An example of how 3D plots can be visualized via HWA (http://hwa.fmi.fi/) by its 3D visualization tool 3DHWA. The user can choose the "3D"page from the "Data Options". After that, a user can choose the analysed 3D region and how many planes are plotted.*

Moreover, the user can add the orbit of the spacecraft at a given time range. The orbit is obtained by a web service provided by *CDPP-AMDA* (see **Figure 14**).

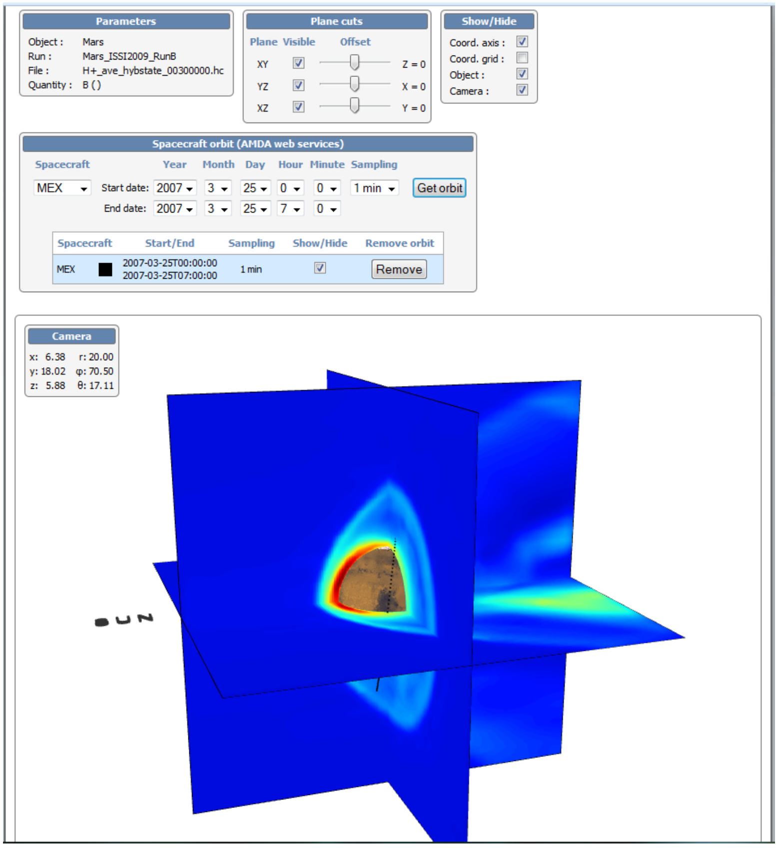

Figure 14: *An example of a 3D plot obtained at HWA (http://hwa.fmi.fi/) by its 3D visualization tool 3DHWafter the user has pressed the button "Plot Data", as shown in Fig. 13. The window makes it possible for a user to analyse data at various planes and to study how the data is related to the orbit of the spacecraft.*

HMM-WWW interface for external users and infrastructures

The goal was to provide the *HMM* modelling tools, being further developed within IMPEx, for those users who operate data sets and services that are not part of the IMPEx core infrastructure (e.g. *Europlanet-RI*, *HELIO*, *CCMC* etc.), as well as for users who may want to apply *HMM* for basic research or for technological development.

Simulation runs stored in *HWA* can be accessed and searched by users. In **Figure 15** an example is shown, where simulation runs are categorized according to the object and simulation run name - the physical and numerical parameters are also shown. Plot options and data download functionalities provide access to the simulation run results.

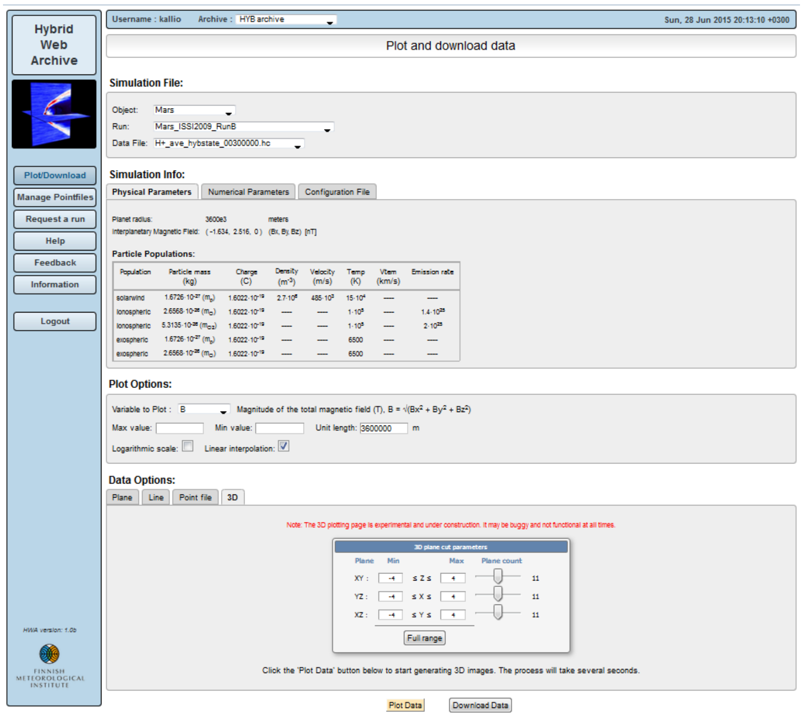

***Figure 15**: HWA (http://hwa.fmi.fi/) hybrid simulation access and search (vs. object and run name).*

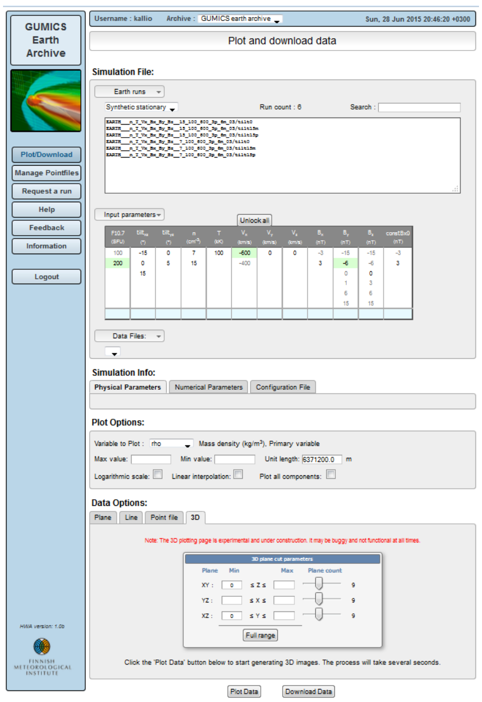

***Figure 16**: HWA (http://hwa.fmi.fi/) MHD run catalogue, run access and search via input parameters.*

Simulation runs on HWA can also be searched by their input parameters - **Figure 16** shows an example of that.

An example of access to simulation results (HWA's *2D* plotting facility) is demonstrated in **Figure 17 (left)**. The variables to select for downloading are shown in **Figure 17 (right)**. As noted before, in addition to *2D* plots the *HWA* offers also a possibility for *3D* plots.

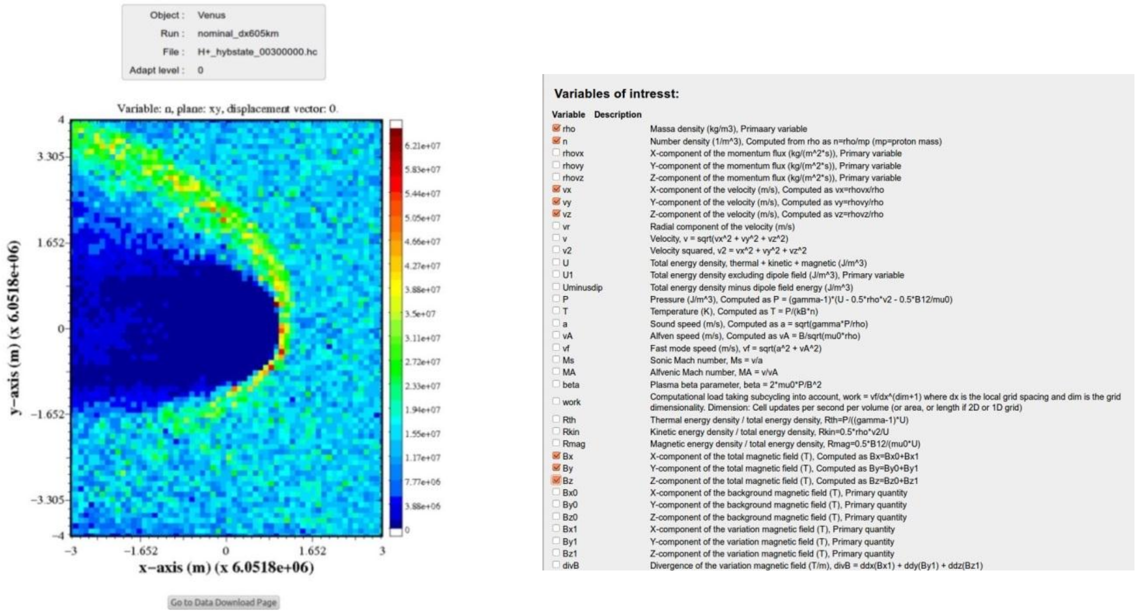

***Figure 17**: **(left)**: An example of the HWA (http://hwa.fmi.fi/) 2-D plotting **(right)**: Selection of HMM output variables in HWA.*

The *HMM-Direct Access Mechanism (HMM-DA)* is realized using **web service technology** which is a standardized method of communication between two computers/applications over the internet. The interface to the service is described in a machine-processable format called *WSDL* (*Web Services Description Language*), which is an *xml* language. The interface defines all services (methods) that the server provides along with all necessary input and output format descriptions. Other systems interact with the web service by exchanging messages using the *SOAP* protocol.

HMM modelling demonstrators for public education

This effort included activities to provide a set of *HMM* modelling demonstrators, organized in the form of interactive **web based educational services** addressed to **general public**. The modelling demonstrators provide **tutorials** and **explanations** of the computational and physical backgrounds, making them ready for use in public educational institutions (schools, universities, planetariums, etc.).

Descriptions of the *HYB* modelling platform are available as a file and via the *IMPEx Website* (see https://sites.google.com/site/impexfp7/home/hmm). Furthermore, as illustrated in **Figure 18**, the *HWA* main page (http://hwa.fmi.fi) contains several links to the webpage which has been prepared for *HMM* modelling demonstrators for public education purposes. The pages describe the *HYB* (**Figure 18 b**) and *GUMICS* (**Figure 18 c**) models, the physical basics of the models, example of results, publications etc. Moreover, several videos were made and distributed via *YouTube* which describe and demonstrate the properties of the *HWA* in English as well as Finnish language, including code and usage of *Matlab* scripts. Last but not least, the *HYB* code, *Matlab* and *FMI's*

IMPEx web service scripts **are made openly available at *GitHub*** (see https://github.com/fmihpc/impex-tools).

Figure 18*: An illustration of the access of video demonstrations and descriptions of the models. The HWA main page http://hwa.fmi.fi* ***(a)*** *contains links to the description of the HYB model* ***(b)****, GUMICS model* ***(c)*** *and YouTube demonstration videos about the HWA and open source MATLAB scripts* ***(d)****.*

Complementary catalog at LATMOS

The goal of this effort (also see **task 3.7**) was to complete the catalogue of hybrid simulation runs by creating a new *SMDB* and linking it to *CDPP-AMDA* and *CDPP-3DView* tools.

In addition to the development of the infrastructure of simulation databases and services, LATMOS has made a significant contribution to the definition of the *IMPEx Data Model* (see **D3.14**).

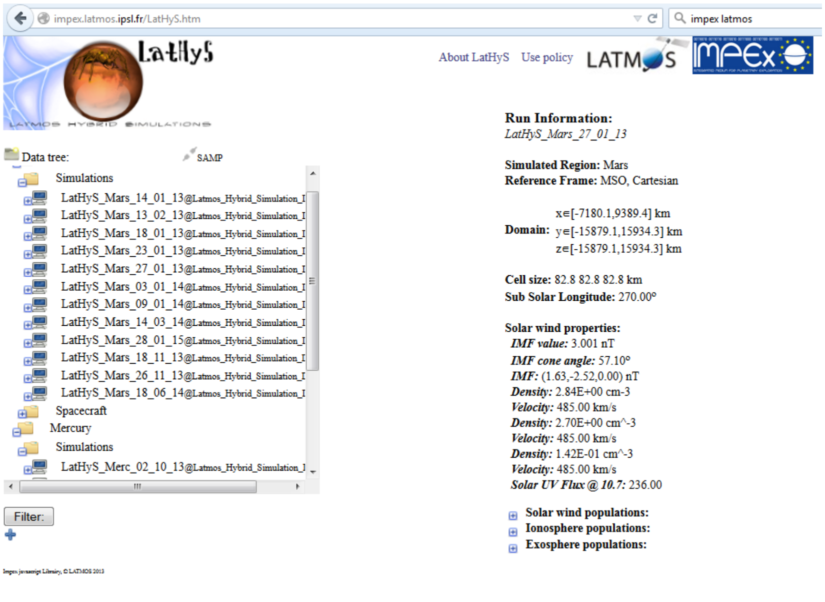

Figure 19*: Screenshot of the LATMOS SMDB web interface.*

The simulation catalogue is publically accessible and some documentation concerning the simulation model and the web services can be found on the LATMOS website (http://impex.latmos.ipsl.fr) - a screenshot showing a partial description of the simulation runs available is presented in **Figure 19**.

The catalogue includes simulation runs for various celestial bodies such as *Mars*, *Mercury* and *Ganymede*. This database is characterized by the provision (via **open access**) of 3D data cubes and the full set of data products, in a way that enables the whole community to access the various simulated quantities. The full plasma package released in the catalogue consists in electric and magnetic fields, electron number density and temperature, plasma bulk speed and all ion species information (density, velocity and temperature). A detailed description of the data-products is provided in **D3.5**. Information concerning the *URL* of these pre-calculated files is indicated in the *tree.xml* file. Tools like *CDPP-AMDA* or *CDPP-3DView* parsing the *tree.xml* have the information about the pre-calculated files (see **D3.7**).

Interoperability of the LatHyS website with VO-tools

In addition to the archive of full 3D cubes simulations results, we archive and provide pre-computed *2D* plane cuts for all data products. These pre-computed products can also be downloaded; it gives a preview of the simulation results. Moreover, LATMOS web-interface proposes connection to VO tools, like Topcat (Tool for Operation Catalogues And Tables, http://www.star.bris.ac.uk/~mbt/topcat/), using the SAMP protocol (Simple Application Messaging Protocol, developed for the IVOA community http://www.ivoa.net/documents/REC/App/SAMP-20090421.html). We can use SAMP as a hub and route all messages between clients. It allows exporting and displaying 1D and 2D data products on these tools.
A simple and interactive connection between LATMOS SMDB and Topcat has been developed on LatHyS (the LATMOS web-interface).

LATMOS' Webservices

2D or *1D* data products which are not stored in the *LATMOS SMDB*, e.g. a *2D* cut that is not included in the set of pre-computed archived *2D* cuts, can be requested by IMPEx tools (e.g. *CDPP-AMDA*, *CDPP-3DView*, *CLWeb* or the *IMPEx Portal*) through web services, as defined in the *IMPEx Protocol*.

The eight released LATMOS web services are:

1. ***getFileURL***: this web service returns *URL*/granules for *1D* data product.
2. ***getDataPointValue***: a generic method that can be used to return parameters for *0D* (a given point), *1D* (along a curve/trajectory), *2D* (in a plane) or *3D* (inside a volume).
3. ***getDataPointValueSpacecraft***: this Method interpolates the physical simulation parameters along a given spacecraft.
4. ***getSurface***: this method is called via *CDPP-3DView*. It is used to generate a *meshgrid* and compute interpolation for one or several parameters.
5. ***getFiledLine:*** this method is called via *CDPP-3DView*. It computes field or flow lines for requested footprints or passing through the *S/C* track.
6. ***getDataPointSpectra***: This method returns ion spectra for a requested position or a list of positions.
7. ***getDataPointSpectraSpacecraft:*** this method returns ion spectra along the spacecraft track (the spacecraft is requested from the user).
8. ***isAlive:*** this method returns the status of the database (available or not).

Figure 20 shows a schematical description of one of the web services. A full documentation of LATMOS web services is provided online as *xml* documentation (see http://impex.latmos.ipsl.fr/Methods_LATMOS.html) and through the IMPEx Technical Documentation section that can alse be accessed via the *IMPEx website* (see http://impex-fp7.oeaw.ac.at/fileadmin/user_upload/pdf/ListofWebservices_for_LATMOS_v1.0.pdf).

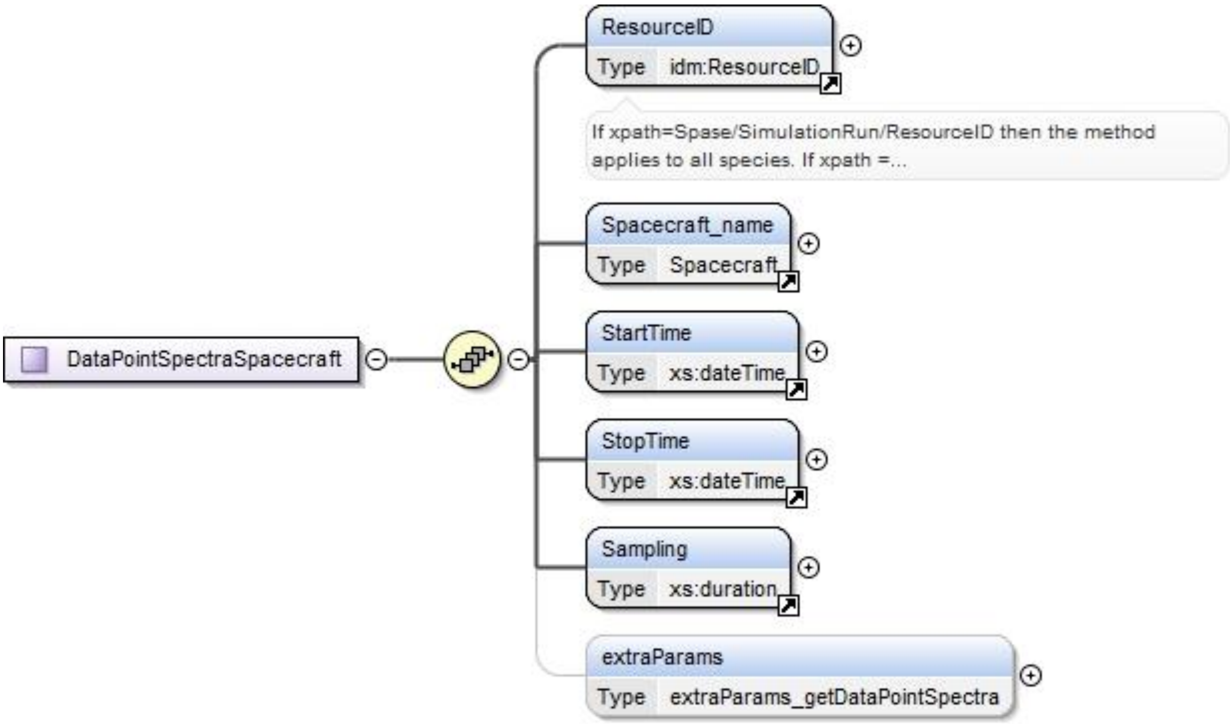

Figure 20*: Schema of input parameters required for one web service.*

Outreach and Educational resources

The description of the model, the hybrid formalism and the archive is presented in the *IMPEx Demonstrators* webpage (see https://sites.google.com/site/impexfp7/), additional documentation can be found on the *LatHyS* website (http://impex.latmos.ipsl.fr/doc/Hybrid_model_documentation.pdf), and in **D3.12**.

Two **tutorial videos** on the interoperability of *LatHyS* and *VO-Tools* (*Topcat*, *CDPP-AMDA* and *CDPP-3DView*) are posted on the *IMPEx Website* (http://impex-fp7.oeaw.ac.at/84.html) and have been created in synergy with the *Europlanet-RI* project.

1.3.3. *Paraboloid Magnetospheric Models (PMM)*

The **WG4** (*SINP*) main scientific task was to **upgrade the generalized paraboloid model of the planetary magnetosphere**, so that it could be used for the on the fly calculations in the IMPEx framework. The model is intended for description of the magnetospheric dynamics, taking into account the intrinsic planetary magnetic field, the magnetopause current magnetic field, the tail current system magnetic field, the magnetodisc magnetic field, the ring current magnetic field, and the interplanetary magnetic field, penetrated from the solar wind. Such modular structure allows us to represent the magnetic field inside the magnetospheres of *Mercury*, *Earth*, *Jupiter*, and *Saturn*.

Based on the *Earth's* magnetospheric space missions' data, and the missions to *Mercury* (*Messenger*), *Jupiter* (*Ullysses*, *Galileo*), and *Saturn* (*Cassini*) systems, the important features and dynamics of these planetary magnetospheres were discovered. The *Hubble Space Telescope* (*HST*)

images of the *Jovian* and *Kronian* aurora also brought a new finding related to the outer magnetospheres structure.
For the *Earth's* magnetosphere, the time dependent functions of the global magnetospheric parameters were found on the basis of the solar wind monitors' data and geomagnetic indices. As a result, the current state of *Earth's* environment is represented as a function of solar wind parameters and geomagnetic activity level.

The *Cassini* measurements were compared with the modeled magnetic field in *Saturn's* magnetosphere. The *Kronian* auroral *UV* images obtained by the *Hubble Space Telescope*, together with the *Cassini* solar wind magnetic field data gave us the dependence of *Saturn's* outer magnetospheric and ionospheric dynamics on the solar wind dynamic pressure and the interplanetary magnetic field.

During the *Messenger* flybys *Mercury's* dipole moment was estimated. A northward dipole offset about a half thousand km was found by minimization of differences between the model calculations and *Messenger's* magnetometer data.

The scientific studies of the *SINP* group allowed the development of the model, which can be implemented in the IMPEx framework as the basis for real-time calculations of the magnetic field in the different magnetospheres.

The key objectives and milestones in the course of the project for the IMPEx group and in particular for the team at *SINP* were:

- Development and elaboration of the **Paraboloid Magnetospheric Models** for ***Earth***, ***Mercury***, ***Saturn*** and ***Jupite***r.
- **Scientific publications** on the results of the PM Models development by *SINP*.
- Establishing a general approach to a **unified access** to the data producers (*FMI*, *LATMOS*, *SINP*, *CDPP*) by members of the IMPEx team.
- Support for *SOAP* **web service** technology as communication technique between the data producers and the *IMPEx Portal*, visualization tools etc.
- Support for *NetCDF* and *VOTable*.
- Defining **main functionalities** of data producers: value in points, along a line, on a surface, in a cube and magnetic field lines.
- Implementation of the **web services** defined for the **planets**: *Earth*, *Mercury*, and *Saturn*.
- Elaboration and improvement of the **web services**, together with web service **consumers** (*IMPEx Portal*, *CDPP-3DView*, *CDPP-AMDA*).
- Development of the SINP **visualization tool prototype** based on *WebGL* technology.
- Constant coordination with the IMPEx team during the project's lifetime.
- Preparation of documentation for models and services.

Web services

Two approaches to the model usage have been developed via SINP web services: ***get*** – i.e. access to database and interpolation of pre-calculated data and ***calculate*** – i.e. direct calculations in **real-time**. Following the list of services, implementing these two principles:
getDataPointValue, getSurface, calculateDataPointValueFixedTime, calculateDataPointValue, calculateDataPointValueSpacecraft, calculateFieldLine, calculateCube, calculateDataPointValueMercury, calculateCubeMercury, calculateFieldLineMercury,

calculateDataPointValueSaturn, calculateCubeSaturn, calculateFieldLineSaturn, calculateDataPointValueJupiter, calculateCubeJupiter, calculateFieldLineJupiter

Paraboloid Magnetospheric Model of the Earth

The magnetic field can be calculated in the solar magnetospheric coordinate system only inside *Earth's* magnetosphere, in the region -40 < x < 20 R_e; -30 < y,z < 30 R_e, which is bounded by magnetopause, represented by a paraboloid of revolution. Inside the magnetopause of the paraboloid model (PM) of the Earth's magnetosphere (*Alexeev et al*., 2003), the magnetospheric magnetic field of each large scale current system is determined by an analytical solution of the *Laplace* equation for the magnetic field scalar potential. The magnetic field component, normal to the magnetopause is assumed to be zero. The model represents the magnetic field inside the magnetosphere as a sum of the internal planetary magnetic field, given by the *IGRF2015* model and the external one (B_m), represented by a superposition of the magnetic fields of the ring current, B_r, the tail current system including the currents across a tail, and their closure currents on the magnetopause, B_t, the Region 1 field-aligned currents, B_{fac} the magnetopause currents screening the dipole field, B_{sd}, and the magnetopause currents screening the ring current magnetic field, B_{sr}:

$$B_m = B_{sd}(\psi, R_1) + B_t(\psi, R_1, R_2, \Phi_\infty) + B_r(\psi, b_r) + B_{sr}(\psi, R_1, b_r) + B_{IMF}.$$

Here B_{IMF} is the interplanetary magnetic field partially penetrated into the magnetosphere. The model input values are the key parameters of the magnetospheric current systems, which represent their location and intensity:

- the geomagnetic dipole tilt angle Ψ,
- the magnetopause stand-off distance R_1,
- the distance to the inner edge of the tail current sheet R_2,
- the magnetic flux through the tail lobes Φ_∞,
- the ring current magnetic field at the Earth's center b_r,.

The time dependent model parameters are calculated by the empirical data (*solar wind density* (*n*), *velocity* (*v*), *Dst* and *AL* indices, interplanetary magnetic field *B-components* (*IMF_B*) and by the current date/time using special submodels (*Alexeev et al., 2003*) optimizing parameter dependences on the specific sets of empirical data. Input model parameters could be specified by the user or taken fully or partially from the *OMNI* database for a given time moment (*StartTime* input parameter).

getDataPointValue

"get-" methods are based on the approach of interpolation values in the precalculated 3D-cubes in order to return values in the requested points. 3D-cubes are a set of three-dimensional arrays, which contain magnetic field vectors, calculated in points of a grid around planets. The *tree.xml* file contains a catalog of these pre-calculated 3D-cubes.

The web service *getDataPointValue* can be used to get a magnetic field vector, calculated by *PMM* in chosen points and inside a volume.

Magnetopause dimensions were determined by input model parameters of the corresponding run.

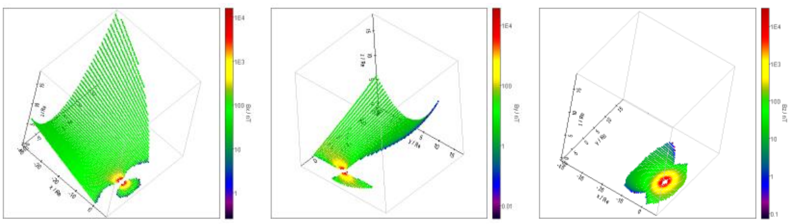

Figure 21: *Components of the magnetic field vector calculated in points with getDataPointValue (Topcat).*

calculateDataPointValueFixedTime

Calculations realized through "calculate-" services allow the **model runs in *real-time***. The web service *calculateDataPointValueFixedTime* can be used to get a magnetic field calculated by *PMM* in chosen points in one time moment (i.e. a 'static' picture).

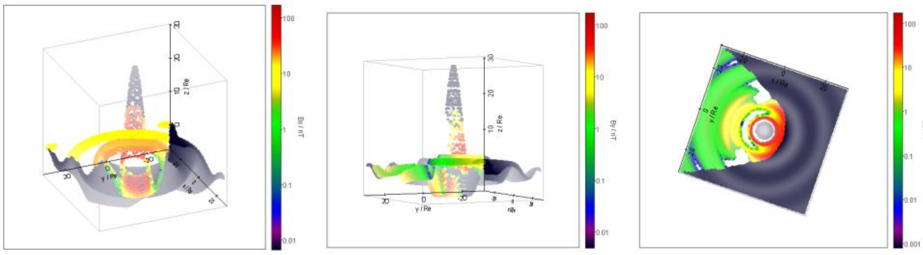

Figure 22: *Magnetic field vector magnitude calculated in points with calculateDataPointValueFixedTime (Topcat).*

calculateDataPointValue

The web service *calculateDataPointValue* can be used to get a magnetic field (calculated by *PMM*) in chosen points and in different time moments for each point (i.e. a 'dynamic' picture). Model parameters are retrieved from the database for each time moment (each point) - can be used for magnetic field calculation along a spacecraft trajectory that is provided by the user.

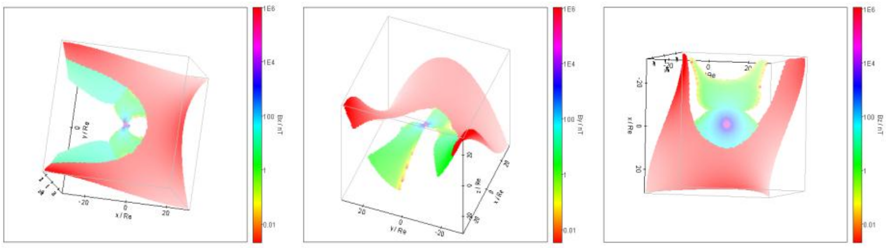

Figure 23*: Magnetic field vector magnitude calculated in points with calculateDataPointValueFixedTime (Topcat).*

calculateDataPointValueSpacecraft

The web service *calculateDataPointValueSpacecraft* can be used to get a magnetic field along the spacecraft trajectory in the chosen time period calculated by *PMM*. The spacecraft trajectory should be inside *Earth's* magnetosphere. Input model parameters are obtained from the database for each position of spacecraft and time moment within the chosen time period. Spacecraft trajectory is obtained through the *CDPP-AMDA* web service. Calculations can be made along the spacecraft's trajectories, provided by *CDPP-AMDA*.

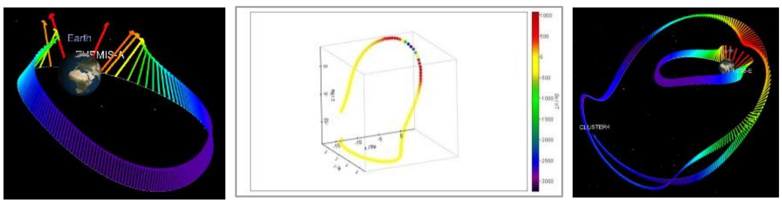

Figure 24*: l.t.r: Magnetic field calculated along Themis-A trajectory (CDPP-3DView). Example of the magnetic field visualization (Topcat). Magnetic field calculated along Themis-E and Cluster4 trajectories (CDPP-3DView).*

calculateFieldLine

The web service *calculateFieldLine* can be used to get field lines (calculated by *PMM*), starting in chosen points and in different time moments for each point, including the magnetic field along these lines. Magnetic field lines starting points should be placed inside the valid region. Input model parameters are retrieved from the database for each field line. The user determines the length of field lines and step size along them. The sign of the *step size* parameter defines which way field lines go: positive value - along the planetary magnetic field vector, negative value - against the magnetic field vector.

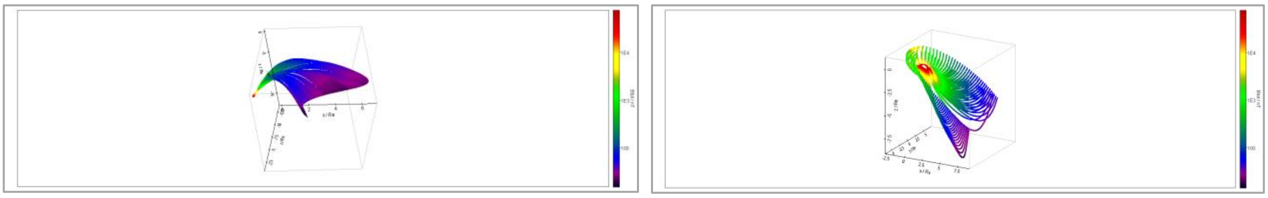

***Figure 25**: Magnetic field lines, calculated from the given starting points with calculateFieldLine (Topcat).*

calculateCube

The web service *calculateCube* returns a magnetic field, calculated by the *Paraboloid Model* in grid points of a cube. Time moment, cube boundaries and grid sampling can be set by user.

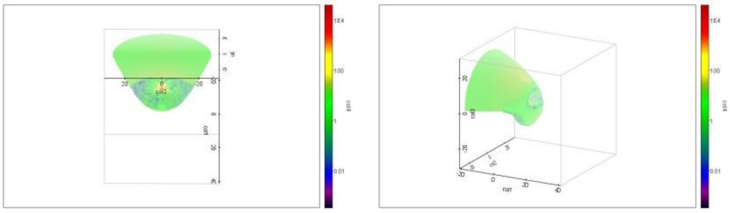

***Figure 26**: Visualization of the magnetic vector field magnitude, calculated with calculateCube, in the cube -20<x<40Re, -30<y,z,<30 Re. (Topcat)*

getSurface

The web service *getSurface* can be used to generate a meshgrid and perform a magnetic field interpolation on the grid between values from a pre-calculated *PMM* 3D-cube. Input: a point and a normal vector to the requested plane as input parameters.

Paraboloid Magnetospheric Model of Mercury

The magnetic field can be calculated only inside the *Hermean* magnetosphere that is implied to be bounded by magnetopause, represented by paraboloid of revolution in the region $-5.5 < x < 2.6\ R_m$; $-4.1 < y,z < 4.1\ R_m$ in the *Hermean* solar magnetospheric coordinates system. The paraboloid model (*Alexeev at al.*, 2010) represents the magnetic field as a sum of the *Hermean* internal magnetic field R_{INT} and magnetic fields of the tail current, R_t, the magnetopause currents, R_{sd}, and the interplanetary magnetic field partially penetrated into the magnetosphere of Mercury, R_{IMF}:

$$B = B_{INT}(BD) + B_{sd}(BD, R_{ss}) + B_t(R_{ss}, R_2, Flux) + B_{IMF}(IMF\_B)$$

Model input parameters (all are optional):

- *BD* - dipole field strength on the equator of *Mercury*,
- *Flux* - magnetic flux at the polar cap open field line region,
- R_{SS} - subsolar magnetopause distance in *Mercury* radii (2439km),
- R_2 - the distance to the inner edge of the tail current sheet,
- *DZ* - northern displacement of the dipole relative to the center of *Mercury*,
- *IMF_B* - components of the *Interplanetary Magnetic Field* penetrated into *Mercury's* magnetosphere (in the *HSM* coordinate system).

calculateDataPointValueMercury

The web service *calculateDataPointValueMercury* can be used to get a magnetic field (calculated by *PMM*) in chosen points.

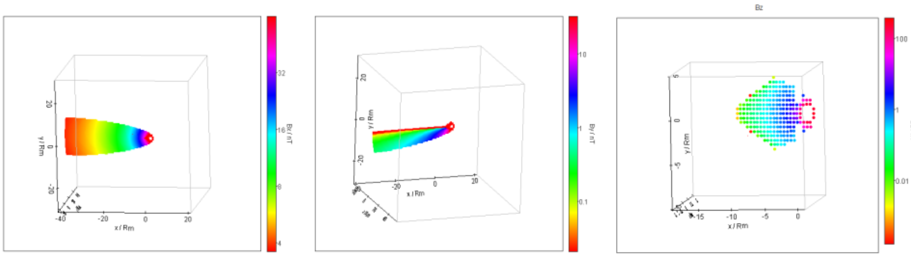

***Figure 27**: Components of the magnetic field vector calculated with calculateDataPointValueMercury (Topcat).*

calculateCubeMercury

The web service *calculateCubeMercury* returns a magnetic field, calculated by *Paraboloid Model*, in grid points of a cube with chosen boundaries and sampling.

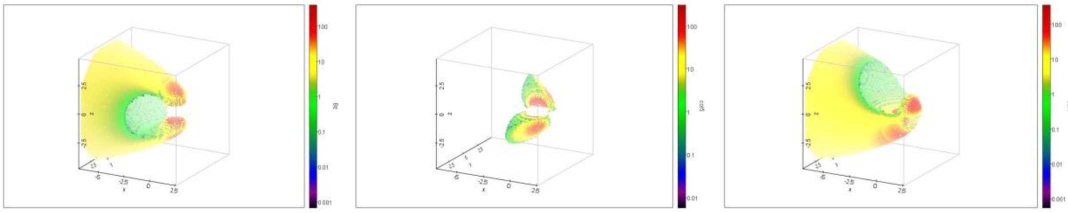

***Figure 28**: Components of the magnetic field vector calculated in the cube -7.5<x<2.5 Rm, -5<y,z<5 Rm with calculateCubeMercury (Topcat).*

CalculateFieldLineMercury

The web service *calculateFieldLineMercury* calculates magnetic field lines, which start in chosen points. The user determines the length of the field lines and step size along them. The sign of the *step size* parameter defines which way field lines go: positive value - along the planetary magnetic field vector, negative value - against the magnetic field vector.

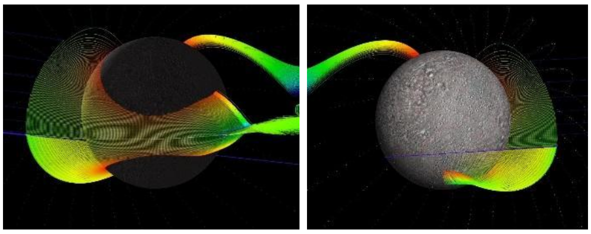

***Figure 29**: Magnetic field lines, calculated with calculateFieldLineMercury, along the spacecraft Messenger trajectory on the 2009/09/29 (CDPP-3DView).*

Paraboloid Magnetospheric Model of Saturn

The magnetic field can be calculated only inside the *Kronian* magnetosphere, which is bounded by magnetopause, represented by paraboloid of revolution (in the region -1200 < x < 40 Rs ; -500 < y, z < 500 Rs in the *Kronian Solar-Magnetospheric* coordinate system). The paraboloid model (*Alexeev at al.,* 2006) represents the magnetic field as a sum of the *Kronian* internal magnetic field B_{INT} (*Burton et al.,2010*) and magnetic field of the external sources B_m, which is a superposition of the magnetic fields of the magnetodisc, B_r, the tail current system including currents across the tail and their closure currents on the magnetopause, B_t, the magnetopause currents, B_{sd}, and the interplanetary magnetic field partially penetrated into the *Kronian* magnetosphere, B_{IMF}:

$$B_m = B_{sd}(R_{ss}) + B_t(R_{ss}, R_2, b_t) + B_r(R_{D1}, R_{D2}, B_{DC}) + B_{IMF}(IMF\_B).$$

Model input parameters (all are optional):

- B_{DC} - magnetic field at the magnetodisc (MD) outer edge
- b_t - minus Z-component of the magnetic field at the tail current sheet inner edge
- R_{D2} - distance to the inner edge of the magnetodisc,
- R_{D1} - distance to the outer edge of the magnetodisc,
- R_2 - distance to the inner edge of the tail current sheet,
- R_{ss} - magnetopause stand-off distance,
- *IMF_B* - components of the Interplanetary *Magnetic Field* penetrated into the magnetosphere in the *KSM* coordinate system.

For each input model parameter a user can set a value manually or take a value by default.

calculateDataPointValueSaturn

The web service *calculateDataPointValueSaturn* returns a magnetic field (calculated by *PMM*) in chosen points with different timestamps but one set of parameters for all the points.

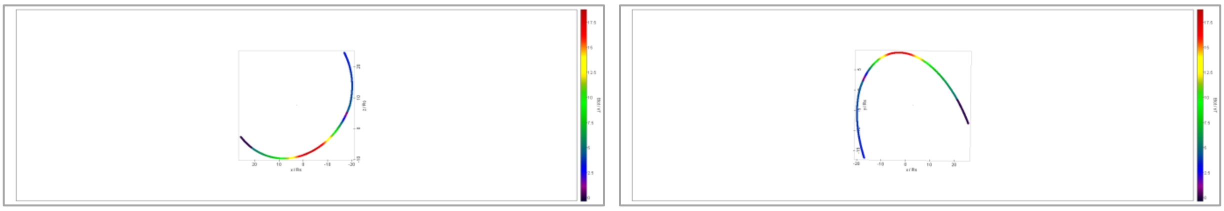

Figure 30*: Magnetic vector field magnitude calculated with calculateDataPointValueSaturn (Topcat).*

calculateCubeSaturn

The web service *calculateCubeSaturn* returns a magnetic field, calculated by the *Paraboloid Model*, in grid points of a cube. Cube boundaries and grid sampling can be set by user.

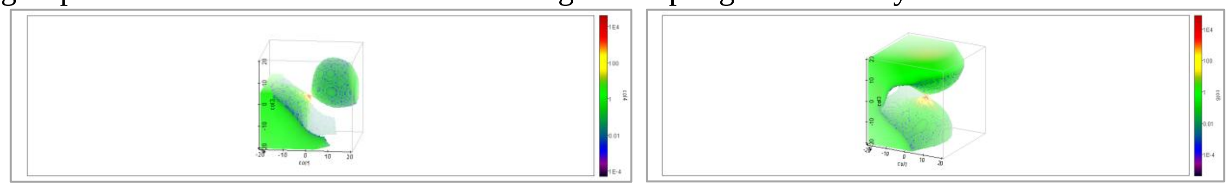

Figure 31*: Components of magnetic vector field in the cube -20<x<20 Rs with calculateCubeSaturn (Topcat).*

calculateFieldLineSaturn

The web service *calculateFieldLineSaturn* calculates magnetic field lines that start in points chosen by the user who also determines the length of field lines and step size along them. The sign of the *step size* parameter defines which way field lines go: positive value - along the planetary magnetic field vector, negative value - against the magnetic field vector.

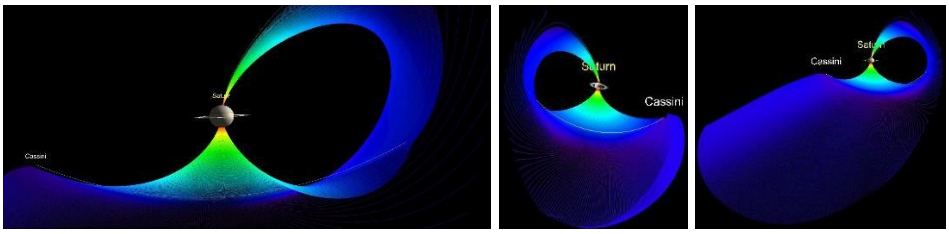

Figure 32*: Magnetic field lines by calculateFieldLineSaturn, along Cassini trajectory (CDPP-3DView).*

Paraboloid Magnetospheric Model of Jupiter

The magnetic field can be calculated only inside the *Jovian* magnetosphere, which is bounded by magnetopause, represented by paraboloid of revolution (in the region -450 < x < 150 Rj; -300 < y, z < 300 Rj in the *Jovian Solar-Magnetospheric* coordinates system). The paraboloid model (*Alexeev and Belenkaya*, 2005) represents magnetic field as a sum of the *Jovian* dipole magnetic field B_{INT} (System III model) and the magnetic field of the external sources B_m, which is a superposition of the magnetic fields of the magnetodisc B_r, the tail current system including tail currents and the closure currents on the magnetopause B_t, the magnetopause currents B_{sd}, and the interplanetary magnetic field partially penetrated into the *Jovian* magnetosphere B_{IMF}:

$$B_m = B_{sd}(R_{ss}) + B_t(R_{ss}, R_2, b_t) + B_r(R_{D1}, R_{D2}, B_{DC}) + B_{IMF}(IMF\_B)$$

Model input parameters:

- B_{DC} - magnetic field at the magnetodisc (MD) outer edge,
- b_t - minus Z-component of the magnetic field at the tail current sheet inner edge,
- R_{D2} - distance to the inner edge of the magnetodisc,
- R_{D1} - distance to the outer edge of the magnetodisc,
- R_2 - distance to the inner edge of the tail current sheet,
- R_{ss} - magnetopause stand-off distance,
- *IMF_B* - components of the *Interplanetary Magnetic Field* partially penetrated into the *Jovian* magnetosphere in the *JSM* coordinate system.

For each input model parameter a user can set a value manually or take a value by default.

calculateDataPointValueJupiter

The web service *calculateDataPointValueJupiter* returns a magnetic field (calculated by *PMM*) in chosen points with different timestamps, but one set of parameters for all the points.

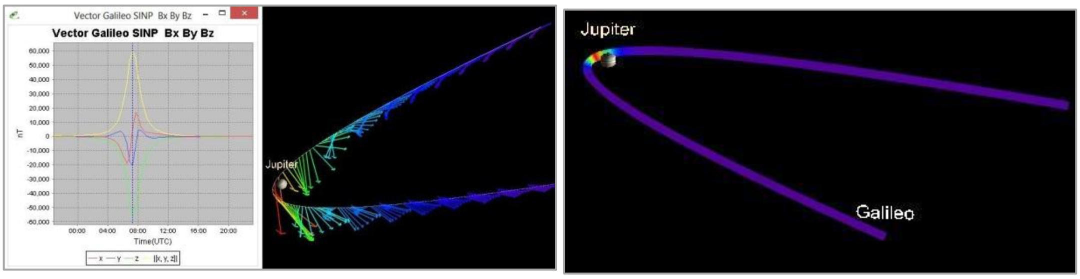

Figure 33*: Magnetic field vectors calculated in points of the Galileo spacecraft trajectory on the 2002/11/01 with calculateDataPointValueJupiter (CDPP-3DView).*

calculateCubeJupiter

The web service *calculateCubeJupiter* returns a magnetic field, calculated by the *Paraboloid Model*, in grid points of a cube. Cube boundaries and grid sampling can be set by the user.

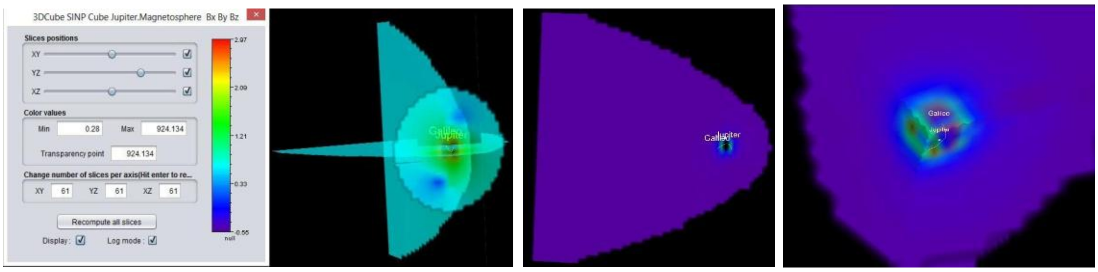

Figure 34*: Components and slices of magnetic vector field in the cube -100<x<100 Rj with calculateCubeJupiter. (Topcat and CDPP-3DView).*

calculateFieldLineJupiter

The web service *calculateFieldLineJupiter* calculates magnetic field lines that start in points chosen by the user. The user determines the length of field lines and step size along them. The sign of the *step size* parameter defines which way field lines go: positive value - along the planetary magnetic field vector, negative value - against the magnetic field vector.

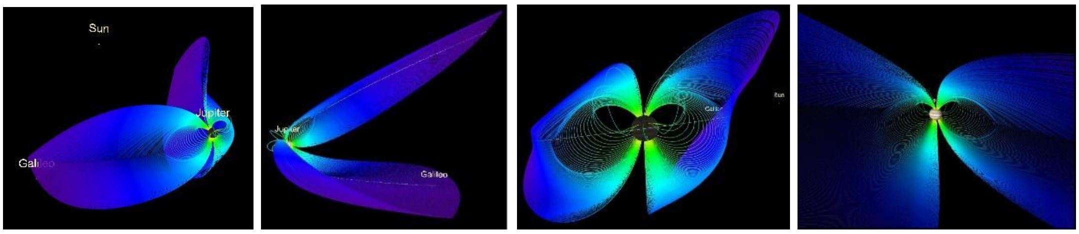

Figure 35*: Magnetic field lines, calculated with calculateFieldLineJupiter, along Galileo trajectory on the 2002/11/01 (CDPP-3DView).*

1.3.4. *The IMPEx Portal*

The IMPEx Portal has been fully developed at the *IWF* in Graz in the course of the bachelor and master thesis of **Florian Topf** (also see chapter **1.4.2).** The *IMPEx Portal* has been defined as part of **WP5** in **RP2**, in accordance with the *Project Officer* **Antonio Fernandez-Ranada Shaw**, since one of its main purposes is to attract new users to IMPEx and to introduce the capabilities and hence the potential of IMPEx in a user friendly and comprehensive way.

The development phase of the *IMPEx Portal* was concluded successfully in **RP4**. All major features derived from various requirements obtained e.g. by the advisory boards have been implemented and validated. The portal is now a central element of the IMPEx environment and a *one-stop-solution* for any interested parties and potential users. It allows obtaining a **quick, practical insight** into available tools as well as methods on a lower level of the system. The *portal map* (see **Figure 36**) connects all IMPEx enabled tools and also allows browsing, querying and transferring data from one of the attached *SMDBs* to e.g. *CDPP-AMDA* via *SAMP*. All queries are conducted in a **unified internal registry** that is updated on a daily basis, pulling in meta data from all attached *SMDBs*. It also conducts an “is alive” test at start-up and hence is an effective monitoring tool of the IMPEx environment including all attached components of the system.

Access to the *IMPEx Portal* is completely free and no user credentials must be provided for access. Nevertheless users can store selections made and results obtained via methods calls in the local browser storage for later access. This way data can be saved for later use, without the need of authentication. The portal is developed using *HTML5/CSS3* technologies and can be operated on desktop computers as well as mobile devices without restrictions. To support the latter it can adapt to the actual screen size, offering an optimal experience for on all devices

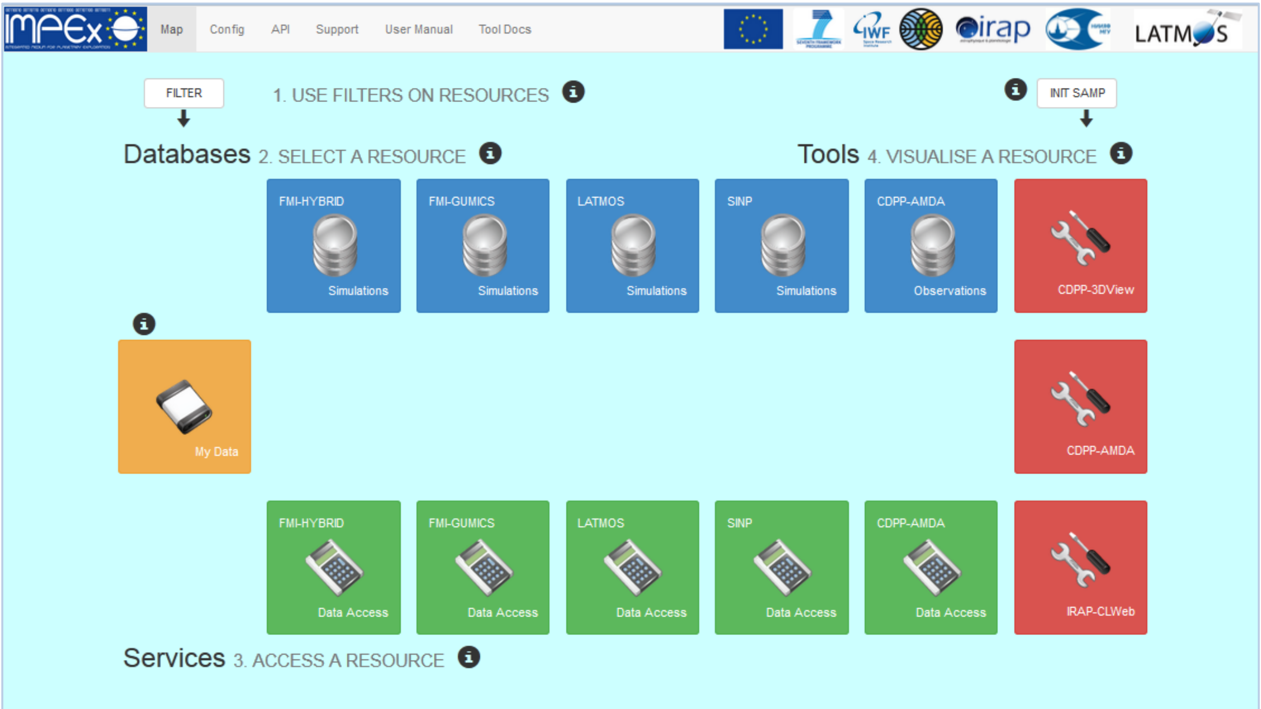

***Figure 36**: The **IMPEx Portal** showing tab of the "portal map".*

As can be seen in **Figure 36**, the portal offers several different sections via a tapped interface, these are briefly described in the following:

- **Section "Map"**: The *portal map* is the main interface shown per default, detailing all IMPEx enabled tools and SMDBs and allowing to query data, call methods, store results, transfer data etc.
- **Section "Config"**: Allows accessing the IMPEx configuration file as *xml* as well as *json*. The configuration is also parsed and displayed in a human readable form.
- **Section "API"**: This section offers a **REST based interface to the *IMPEx Protocol***. Further it offers methods to retrieve the configuration file and query the internal (meta-)data registry.
- **Section "Support"**: This section offers a simple way of **contacting the IMPEx** team with regard to specific (technical) questions. At least one expert of each team is part of the list of recipients - the form offers select boxes to specify to which tool or part of IMPEx the question is related to (consequently also indicated in the mail's subject line). All questions posed will be listed, thus building up a (searchable) FAQ in the future.
- **Section "User Manual"**: A **comprehensive manual as a *PDF*** for all types of users of the *IMPEx Portal*. The manual also features examples and step by step descriptions, including numerous screen shots of real *use cases*. The document is available at:

  https://sites.google.com/site/impexfp7/home/impex-portal-user-manual

- **Section "Tool Docs":** This section provides the ***QuickGuide to IMPEx Tools***, which was motivated by feedback obtained from the advisory boards in **RP3**. The *QuickGuide* gives a brief overview of IMPEx and its available tools, and thus directs the user to the tool that best fits his/her needs or use case. The document is available at:

  http://impex-fp7.oeaw.ac.at/fileadmin/user_upload/pdf/IMPExToolsandtheirUsability.pdf

1.4. Potential impact

This chapter details the potential **impact of the IMPEx project on planetary science** in general and *R&D* activities in this field, including the **socio-economic and the wider societal implications** of the project so far as well as the main **dissemination activities** and exploitation of results.

1.4.1. *Impact of technological developments of IMPEx*

One of the main achievements of IMPEx-FP7, the definition of a comprehensive data model applicable on numerical simulations in the area of space plasma physics and the plasma environments of planetary objects, is expected to have a significant impact on planetary science. Until the advent of the *SPASE simulation extensions* (which have been directly derived from the *IMPEx Data Model*, also see **Figure 37** and **D3.14**), numerical models mostly used proprietary data structures and metadata descriptions to store and process data, obtained via modelling runs. This of course considerably increased the complexity for modelling and research groups to exchange data and solve scientific and technological tasks in a concerted effort, involving data from multiple sources. Since data needs to be consistent and described in a homogenous way, each team more or less had to translate back and forth between the data structures used by the different group respectively – this is of course not necessary any more, as soon as all teams agree to **use one common data model**. However, this again is only feasible, once a format exists that satisfies the requirements of all parties involved and allows to describe all relevant aspects of the data in relation to the respective scientific investigation at hand.

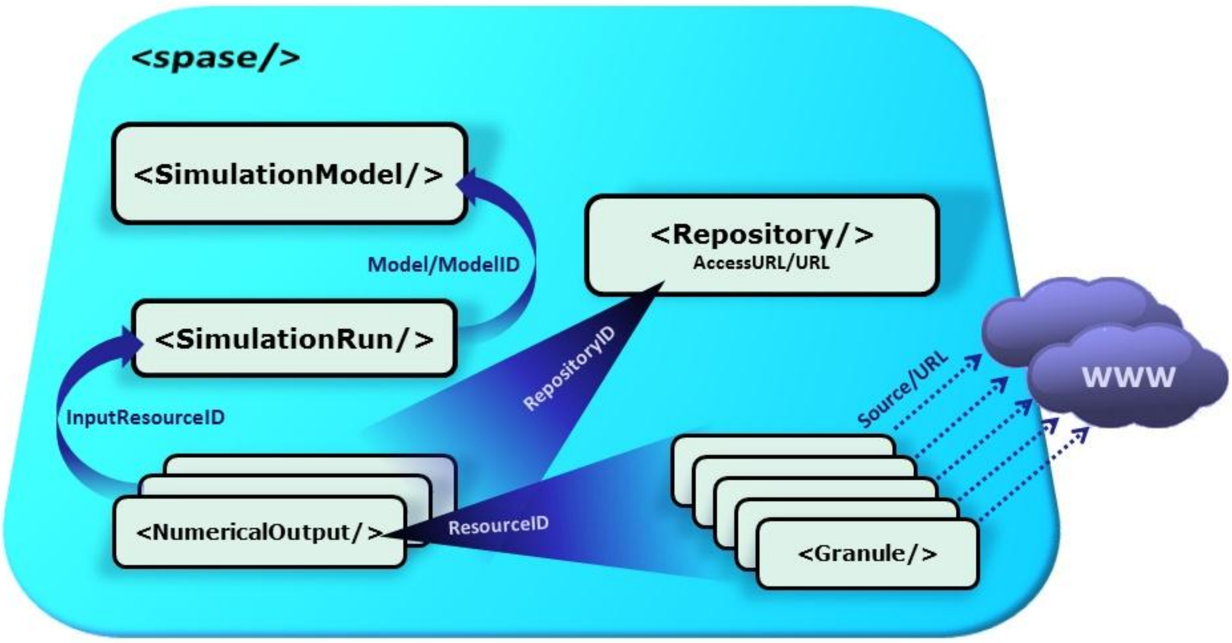

Figure 37: *A diagram of the* ***IMPEx Data Model*** *- the first complete data model of its kind that has been finalized, documented and fully released for public use, allowing to fully describe modelled space plasma data.*

The IMPEx team is convinced that the *SPASE simulation extensions* fulfil the basic requirements of a wide range of research carried out in space plasma physics. Moreover, since it is a **living definition**, the model can be extended in the future to include further elements that will enable new users to describe aspects required for their specific research. To this behalf, processes have been defined within the *SPASE* group, and this way new additions to the data model are regularly discussed in web conferences and added to the definition, once agreed by all parties and stakeholders involved. Hence, it is expected that this new data model based on *SPASE* (already widely used in the field of observational data in the field of space plasma physics) will foster the exchange of data between different modelling groups and even more so open up data archives formerly only used and even accessible within specialized mission teams to the wider scientific community.

Since communication among experts and scientists is of course crucial in research, the impact of a common data standard, once adopted by a sufficiently big number of researchers, archives and institutions cannot be underestimated. The less time is lost in administrating and distributing the data, and the easier it is to compare results obtained by different groups, the more efficient research can be carried out. This is of course achieved by enabling automated tools and applications to handle data in a consistent and transparent way, thus freeing users from having to deal with the specifics of different formats. The more tools are enabled to access and process data, the more users are reached and the bigger the impact hence is. To further facilitate the interoperability of tools, IMPEx created a common protocol that covers a broad range of requirements. In IMPEx this was achieved primarily by defining a set of web services (i.e. the *IMPEx Protocol*) that allows different tools as e.g. *CDPP-AMDA*, *CDPP-3DView* and various SMDBs to exchange data and call functionalities taking these data, stored compliant with the *IMPEx Data Model* (i.e. *SPASE simulation extensions* which is an inherent component of the protocol), as input. This way all users of this set of **IMPEx enabled tools** can access a common data pool and researchers, students, post docs and the public in general have access to all information and functionalities of the IMPEx environment.

As with the data model, the set of web services can be extended as well, to cover requirements in the future that were not thought of or even viable during the project's inception or lifetime. Moreover, the definition can also be taken as a basis for proprietary extensions by other institutions, while preserving backward compatibility, taking advantage of the fact that many problems one is faced with when designing a coherent set of web services to handle plasma data, have already been successfully solved in IMPEx. It should also be noted that the *IMPEx Protocol* is also able to handle models for real-time calculations, as well as pre-calculated cube data stored in an SMDB (see **Chapter 1.3.3** for further details on real-time methods).

Since SOAP is used for the basic implementation, tools and web apps all over the world can harvest the available functionalities more or less automatically and bring them into their respective software landscape, hence making them accessible and workable for their specific community. This way the idea of IMPEx will also spread across the web and it can be expected that it will encourage other projects to follow a similar path or to seek cooperation with institutions that are part of the original project team - see **D5.3** for more information on projects and institutions that are already collaborating with IMPEx. If users run into access restrictions at certain tools or *SMDBs* connected to IMPEx, they can simply contact the respective institution providing the service and ask for a free account. In any case the philosophy behind IMPEx is to **offer as much data and functionalities for free as possible**, which is an approach that is highly beneficial for scientific endeavours in general. The more tools and applications in the scientific world are able to interoperate without restriction, the easier it is to distribute information and collectively tackle problems that are difficult to solve for a single entity, researcher or institution. Following this approach has been shown to be very successful in the context of IMPEx, and it is to be expected that this advantage scales up very well to the scientific community as a whole. After all, as already briefly discussed in **Chapter 1.2**, there are also other initiatives, as e.g. *IVOA* that are following this approach with great success.

Information technology naturally is an essential part of modern science, and building solutions that are designed to provide certain minimum standards with regard to usability and stability is a time consuming task that requires professional software developers to be engaged for considerable time spans. It can't be stressed enough that a lot of resources are freed up and thus made available for pursuing the actual research, when (IT related) solutions already implemented and validated at one institution can be re-used at other institutes and projects, either solving the task altogether or providing a stable basis on which further, more specialized solutions can be built upon. In a nutshell, IMPEx thrives to **provide the common language** that allows this close interaction to take place on a technical level as well.

With regard to access restrictions, it should also be stressed that all functionalities available at the *IMPEx Portal*, i.e. all methods offered by participating nodes (tools and SMDBs) are **fully accessible without any credentials required** at all, and hence **free of charge**. The same is true for most of the data that can be browsed and downloaded via the portal interface, or the respective *SMDB* providing the data in the first place. However, there are of course (observational) data sets, e.g. offered by the tool *CDPP-AMDA* that are not yet fully released by the respective PI, and thus require users to log-on to the system with specific credentials, in order to be able to access them. However, this is completely outside of the influence of the project members of course.

1.4.2. *Socio-economic and wider societal implications*

Software development is a costly endeavour since applications and software environments satisfying up-to-date standards with regard to **usability and stability** require considerable effort in terms of design, development as well as testing and validation. Thus, purely scientific institutions rarely have the time and resources available to develop customized software in a coordinated way, which leads to a scattered software landscape in the field of science tools that often cannot satisfy the true needs of its user communities. Here projects like IMPEx can make a valuable contribution, since dedicated funds are available and professional software development can be conducted via e.g. sub-contracting of development companies as e.g. *GFI* in IMPEx engaged by *CNRS* for the development of the visualization software *CDPP-3DView*. Apart from the implementation of ready to use applications, also the definition end extension of standards is a vital part of modern software development, keeping in mind that without standardization and the definition of appropriate interfaces no true interoperability of different applications can be achieved. As with writing code, the definition of sound, stable and comprehensive standards and interfaces requires a considerable coordinated effort, involving all or as many stakeholders as possible, in order to produce a meaningful definition that will actually be leveraged in future development efforts. IMPEx has not only produced ready to use software, but also put a lot of thinking, time and effort into the framework itself, i.e. the *IMPEx Data Model* and the *IMPEx Protocol* (including further definitions as e.g. the *IMPEx Configuration* etc.).

This broadens the base of stable implementations and definitions available in order to build specialized, heavy tailored solutions on top. The latter can then be again performed much more easily by institutions that have a strict scientific focus. Here of course the flexible architecture of IMPEx, relying on a standard data model and a set of web services that have been designed with the principle of generality in mind, provides a valuable contribution to the (planetary) science community. More efficient software tools naturally lead to better scientific results and more productiveness by minimizing administrative and purely technical tasks, allowing scientists to focus on the actual investigation and scientific questions at hand.

Another important aspect are the numerous tutorials (video, speech and textual), and the technical documentation produced during the project. The videos can be used as a quick and comfortable way of getting an overview of the possibilities offered by IMPEx, while the documents (as e.g. the *Hybrid Model Demonstrators* or the *IMPEx Tutorial for CDPP-AMDA & CDPP-3DView*) provide all required information and resources to then deepen the knowledge in specific (scientific and technical) areas, or with regard to concrete tool support needed. The *IMPEx Portal* which is designed to be a *one-stop-solution* for newcomers to IMPEx is also covered by a dedicated and comprehensive tutorial that allows potential users to quickly get started. These materials can also be used by students and senior classes as well as teachers and at university level in general, in order to prepare classes and gather material for talks and presentations. It is the hope that the educational materials and tools provided will help to encourage pupils and students to pursue a career in space physics. The visual tools as e.g. *CDPP-3DView* are particularly suitable in order to attract attention and generate interest through presentations etc. All tutorials can be accessed on the IMPEx website at the *IMPEx Demonstrator*s section at https://sites.google.com/site/impexfp7/ - IMPEx tutorial videos can be viewed directly at the *IMPEx Videos* section, as well as from the *HYB Code* channel available on *YouTube* – the latter featuring videos for FMI's hybrid and MHD codes, explaining their theoretical background as well as their usage via IMPEx and the *SMDB* interface provided by FMI.

An important **socio economic impact** of IMPEx is the fact that many positions at the participating scientific institutions were created, and in particular *post-docs* and students were able to work for the project and gain valuable (first) experiences and insights into new technologies and *IT* related approaches.

Figure 38*: The IMPEx Team at PMC 36 in Moscow (May 2014).* ***Natasha Bourrel*** *(3rd from left, top row),* ***Tarek Al-Ubaidi*** *(first from right, top row),* ***Manuel Scherf*** *(3rd from right, middle row) and* ***Florian Topf*** *(2nd from right, bottom row).*

At IWF also a project management position was supported during project execution, held by **Tarek Al-Ubaidi**, who brought many years of experience in the field of professional software development, web development and knowledge management into the project. Also at IWF, **Florian Topf** was engaged for development work – in the course of his employment **Florian Topf** (supported by

Tarek Al-Ubaidi) worked out a comprehensive concept for the *IMPEx Portal*, and successfully finished his bachelors and then also his master thesis focusing on the IMPEx portal, scientific tools in general, and the benefits of functional programming in this field. **Tarek Al-Ubaidi** also served as a supervisor for the master thesis of **Florian Topf**. Finally **Florian Topf** also implemented the portal according to the design agreed by the team at a face-to-face meeting at the end of **RP3** (in the course of **PMC #36** in Moscow), using *scala*, an innovative run time environment and development platform, based on the functional programming paradigm. Also at IWF **Manuel Scherf** was engaged as a research assistant, supporting the team in the creation of tutorials and the editing of scientific material from a didactic point of view. Further **Manuel Scherf** was pivotal in **validating software products** that were created or extended in the course of the project, as e.g. the visualization software *CDPP-3DView* or the *IMPEx Portal* in general.

At *SINP* (*Moscow State University*) **Lucy Mukhametdinova** was engaged, starting at the beginning of **RP3**. She was responsible for supporting **Vladimir Kalegaev** in implementing, testing, bug fixing and last but not least documenting the extensive web service interface provided for the paraboloid model and the *SMDB* at *SINP*.

At *FMI* **David Perez-Suarez** did extensive experimentation with regard to workflow integration of the IMPEx toolset, in particular in connection with the scientific workflow system *Taverna* (also see periodic reports for **RP2** and **RP3**) that was used to build prototype workflow support for IMPEx on the basis of the *IMPEx Protocol*.

AT *CNRS/LATMOS* **Sébastien Hess** was engaged as a post-doc in **RP2** and **RP3**, in order to support the definition process of the *IMPEx Data Model*. **Sébastien Hess** subsequently took the lead in this process and made a decisive contribution to this effort that resulted in the successful finalization of the prototype version of the data model in **RP3**.

At *CNRS/IRAP* **Natasha Bourrel** was engaged as an *IT* engineer to develop most of the *CDPP-AMDA* extensions, i.e. to implement the *IMPEx Protocol* in this tool. Her experience in the former *FP7-Helio* project was instrumental for this task.

As already discussed in the course of technical impacts, IMPEx, through its very nature of being a software environment, providing the means for tools and services to communicate and exchange data, very well supports and even fosters the cooperation of different institutes, not only on a purely technical, but a scientific and educational level as well. Hence many new cooperative links have been either newly established in the course of the project, or deepened due to a now available (technical) infrastructure that allows to do things that were either impossible or of a too high effort prior to IMPEx. At the end of **RP4** IMPEx has active links to the following projects and infrastructures (also see **D5.3** for further details):

- *SPASE* (http://www.spase-group.org/)
- *Europlanet/IDIS* (http://www.europlanet-idis.fi/)
- *HELIO* (http://www.helio-vo.eu/)
- *CCMC* (http://ccmc.gsfc.nasa.gov/)
- *ETFLA/Astronet* (http://www.astronet-eu.org/)
- *ASTRONET* (http://www.astronet-eu.org/)
- *VESPA* (http://vespa.obspm.fr/)

The level and nature of cooperation is of course dependant on available funding, as well as the focus of the respective institution involved. While e.g. cooperation with *ASTRONET* is primarily of a scientific nature, the ties to the *SPASE* community are more or less purely technical. Links to *CCMC* and *Europlanet* were primarily driven by **WP2**, see **chapter 1.3.1** for further details.

Further cooperative ties are built, as this report is being written. One of them concerns a technical as well as scientific link to *UCLA*; here the integration of simulation results is being prototyped and the respective data is already part of the *IMPEx Configuration*. Another link is being established to *LESIA* (http://www.lesia.obspm.fr).

The impact of these scientific and technological ties is often considerable, given that developments at one institution often **drive or spin-off further developments at other institutions** that would not have been possible or feasible otherwise without the groundwork being laid. By taking advantage of synergies, it is often possible to minimize the effort involved in following a certain research topic, or develop a solution for a highly specialized problem, specific to a given scientific use case.

1.4.3. *Dissemination activities and exploitation of results*

IMPEx has been presented at numerous scientific conventions and congresses, including the annual *EPSC* (*European Planetary Science Congress*, organized by the *Europlanet* community), the *EGU* (*European Geosciences Union*) and other important events, covering the field of planetary science. These events included poster presentations as well as oral presentations, hands on sessions and talks on various subjects of the IMPEx projects, ranging from technological to purely scientific topics.

In June 2012 **Tarek Al-Ubaidi** e.g. joined the *Planetary Data Workshop for Users and Developers* that took place in Flagstaff Arizona. The oral presentation that was received with great interest also resulted in a closer exchange with **Dan Crichton** (*PDS* Engineering Node Manager at *NASA/JPL*), with regard to efforts related to the (then on-going) definition process of the *xml* based *PDS4* data model, to integrate modelled plasma data into *PDS4*, as the *IMPEx simulation extensions* are doing in the context of *SPASE*. Dan Crichton consequently also joined the *IMPEx User Support Board* in 2012 – please refer to **Table 2** for a complete list of dissemination activities for the entire project duration (until June 2015). It is expected that IMPEx and its technological as well as scientific results will continue to be referenced extensively in publications and talks, in particular those held by members of the IMPEx core team (*IWF*, *FMI*, *CNRS*, and *SINP*). As an example this year's *EPSC* taking place in October in Nantes, France, will include a **poster presentation on possible follow up actions** and projects, talking the ideas of IMPEx to the next level, also integrating cloud resources and advanced data discovery technologies.

Starting in **RP2**, also annual briefing sessions were held to inform the board members (*USB* and *SSB* boards, see **D1.3** for details) of all the latest developments, and to gather valuable feedback that was consequently processed and henceforth strongly influenced further developments as well as the planning process. The live events held as *face-to-face* meetings at *EGU* in Vienna in **RP2** (2013) and **RP4** (2015), were public in the sense that any participant of *EGU* could take part.

Several **press releases** detailing the project goals and current status were written and subsequently published throughout the project. As captured in **D5.2** of **WP5**, two articles were written by the IMPEx team (under the lead of *IWF-OeAW*) and published in the *Parliament Magazine* in **RP1** and **RP2** respectively. In the latter half of the project, the Vienna based PR company *PR&D*, specialized on the publication of scientific content, wrote an article in close cooperation with *IWF-OeAW* and with input and feedback from the entire IMPEx team. The publishing effort by *PR&D* turned out to be very effective; the first article in **RP3** (titled *Ready For Take-Off - Launch of New Data Model Boosts Space Science*) reached over 60 confirmed coverages. The second article by *PR&D* published in **RP4** (*European Team Creates Universal "Language" for Space Science*) reached **74 confirmed coverages** (May 2015). The media outlets also included local newspapers (e.g. *Kleine Zeitung*) technical journals (e.g. *Computerwelt* or *Deutsches Ingenieurblatt*) and scientific publications (e.g. *science 2.0*). The articles by *PR&D* were available (and published) in German as well as English language. In **RP4** also Finnish and Russian versions were prepared and published locally. The team at *IWF-OeAW* also prepared a publicly accessible directory that included several images that could be published along with the text provided. Since **RP3** there is also an *IMPEx Press Kit* available from the website that can be used by journalists and other interested parties to gain further background knowledge on the project, its content and goals.

The *IMPEx Website* (also see **chapter 1.5**) also includes a **video section** that currently features **six video tutorials** on the following subject:

- **IMPEx Tutorial Video** - Tutorial demonstrating the combined use of the *IMPEx Portal* and several IMPEx enabled tools (*IWF-OeAW*, ~10 min.).
- **Tutorial on interoperability** of *CDPP-AMDA*, *LatHyS* and *Topcat* - this video was created by *Europlanet* in cooperation with *IMPEx* using funding from *FP7/REA*, and presented at *EPSC 2013* (~7:30 min.).
- **Tutorial on *CDPP-AMDA*, *CDPP-3DView* and *Simulation Databases* (*SMDBs*)** - this video was created by *Europlanet* in cooperation with *IMPEx* using funding from *FP7/REA*, and presented at *EPSC 2013* (~10:30 min.).
- **Auroral Processes of Saturn** - This video was created by *Europlanet* with funding from *FP7/REA* and presented at *EPSC 2013* (~9:00 min.).
- **Tutorial on IMPEx Matlab Tools** (~9:40 min.)
- **Tutorial on *Hybrid Web Archive*** (~06:40 min.).

Further there are **nine videos** (mostly in Finnish language) available from the following *HYB video channel*, provided and maintained by FMI: https://www.youtube.com/channel/UC-auXDoJSbYBVrSsI2-NpPg/. The channel deals on various subjects surrounding the *hybrid code* (*HYB*) as provided by FMI, see **Table 2** for further details.

The *IMPEx Podcast* has been part of the project from the start and issued **16 episodes in total** over the whole project duration of four years. Each episode featured a guest from the wider (planetary) science community covering a topic that is related to the project. Many of the episodes featured members of the IMPEx core team, including the coordinator, deputy coordinator, scientific representative, work package and task leaders as well as members of the advisory boards. The podcast is an ideal way of becoming acquainted with the project, its goals and main achievements. All episodes are hosted and produced by **Tarek Al-Ubaidi** and can be listened to via the IMPEx website: http://impex-fp7.oeaw.ac.at/podcast.html. Also see **Table 2** for a complete list of episodes including titles and featured guests.

The *IMPEx Portal* that has been implemented in the course of **WP5** (dedicated to outreach and dissemination) is also an important instrument for attracting new users to the system. The portal can be accessed with any desktop or mobile device, capable of displaying and executing *HTML5/JavaScript* based web apps, and collects **all relevant information at one spot**. Users can enter the portal without having to provide any credentials and are free to browse data provided by *SMDBs* or to call methods of the *IMPEx Protocol*, supported by a graphical and easy to use interface. It is an attractive way of making oneself familiar with all relevant IMPEx capabilities (including the *IMPEx Configuration*, the *REST* based web service interface etc.) and hence become involved on a very practical level. This way the sometimes rather abstract definitions and concepts of IMPEx (in particular for non-IT savvy users) become much clearer, easy to grasp and fully leverage. Please refer to **Chapter 1.3.4** for further (technical) details on the IMPEx Portal**.**

1.5. Project Website

The **IMPEx website** (also see **Figure 39**) is the central access point for all IMPEx relevant information. It provides access to comprehensive **technical documentation**, **tutorials**, **videos** and the *IMPEx Podcast*. Further there is general information about the team, links to **publications & talks**, **articles** and **news on latest developments** of the project.

The IMPEx website can be reached via: http://impex-fp7.oeaw.ac.at/

The website is administrated and moderated by **Tarek Al-Ubaidi** (tarek.al-ubaidi@oeaw.ac.at, +43 316 4120 673) and **Manuel Scherf** (manuel.scherf@oeaw.ac.at, +43 (316) 4120-672). For technical problems please contact Manfred Stachel (Manfred.stachel@oeaw.ac.at, +43 (316) 4120-412).

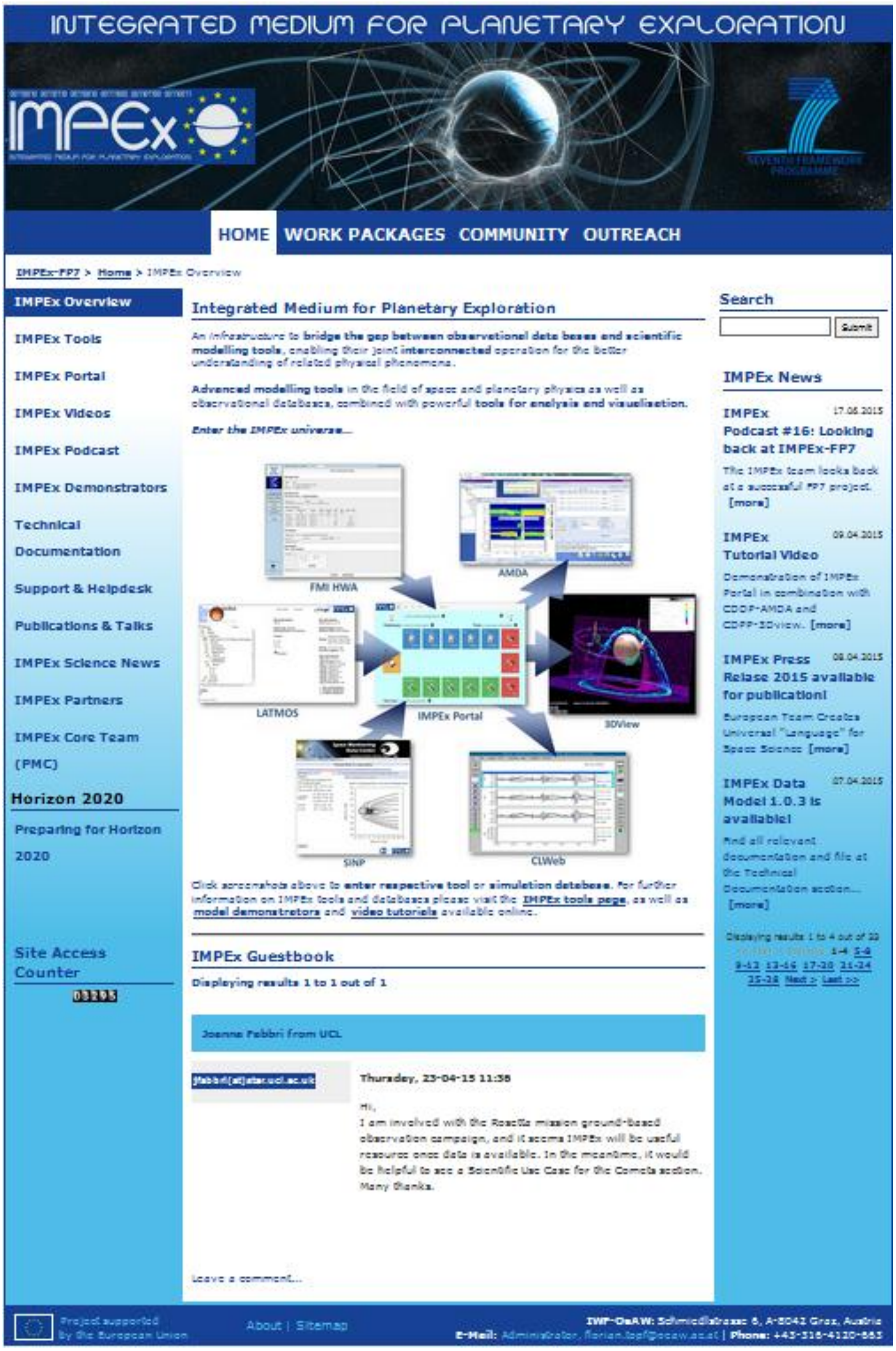

Figure 39*: Front-page of the IMPEx website at the end of RP4, http://impex-fp7.oeaw.ac.at/*

2. Use and dissemination of foreground

2.1. Section A (public)

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
1	*Probing the blow-off criteria of hydrogen-rich `super-Earths'*	*Lammer, H.*	*Monthly Notices of the Royal Astronomical Society*	*Vol. 430*	*Oxford Journals*	*online*	*2012*	*p. 1247*	*http://mnras.oxfordjournals.org/content/430/2/1247*	*yes*
2	*XUV-Exposed, Non-Hydrostatic Hydrogen-Rich Upper Atmospheres of Terrestrial Planets. Part II: Hydrogen Coronae and Ion Escape*	*Kislyakova, K.G.*	*Astrobiology*	*Vol. 13*	*Mary Ann Liebert, Inc. publishers*	*online*	*2013*	*p. 1030*	*http://online.liebertpub.com/doi/abs/10.1089/ast.2012.0958*	*no*
3	*Magnetospheres of 'Hot Jupiters': The importance of magnetodisks for shaping of magnetospheric obstacle*	*Khodachenko, M.L.*	*Astrophys. Journal*	*Vol. 744*	*IOP Science*	*online*	*2012*	*Article id. 70*	*http://iopscience.iop.org/0004-637X/744/1/70/*	*yes*
4	*XUV-Exposed, Non-Hydrostatic Hydrogen-Rich Upper Atmospheres of Terrestrial Planets. Part I:*	*Erkaev, N.V.*	*Astrobiology*	*Vol. 13*	*Mary Ann Liebert, Inc. publishers*	*online*	*2013*	*p. 1011*	*http://online.liebertpub.com/doi/abs/10.1089/ast.2012.0957*	*no*

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

	Atmospheric Expansion and Thermal Escape									
5	*Pathways to Earth-Like Atmospheres. Extreme Ultraviolet (EUV)-Powered Escape of Hydrogen-Rich Protoatmospheres*	*Lammer, H.*	*Origins of Life and Evolution of Biospheres*	*Vol.51*	*Springer*	*online*	*2012*	*p. 503*	*http://link.springer.com/article/10.1007%2Fs11084-012-9264-7*	*no*
6	*MESSENGER observations of Mercury's magnetic field structure*	*Johnson, C.*	*J. Geophys. Res.*	*Vol. 117*	*Wiley Online Library*	*online*	*2012*	*CiteID E00L14*	*http://onlinelibrary.wiley.com/doi/10.1029/2012JE004217/abstract*	*yes*
7	*Stellar wind interaction and pick-up ion escape of the Kepler-11 "super-Earths"*	*Kislyakova, K.G.*	*Astron. Astrophys.*	*Vol. 562*	*EDP Sciences*	*online*	*2014*	*id. A116*	*http://www.aanda.org/articles/aa/abs/2014/02/aa22933-13/aa22933-13.html*	*yes*
8	*Magnetic moment and plasma environment of HD 209458b as determined from Lyα observations*	*Kislyakova, K.G.*	*Science*	*Vol. 346*	*AAAS*	*online*	*2014*	*p.981*	*http://www.sciencemag.org/content/346/6212/981*	*no*
9	*Saturn's dayside ultraviolet auroras: Evidence for morphological dependence on the direction of the upstream interplanetary magnetic field*	*Meredith, C.J.*	*J. Geophys. Res.*	*Vol. 119*	*Wiley Online Library*	*online*	*2014*	*p. 1994*	*http://onlinelibrary.wiley.com/doi/10.1002/2013JA019598/abstract*	*yes*
10	*Planetary Science Virtual Observatory architecture*	*Erard, S.*	*Astronomy and Computing*	*Vol. 7*	*Elsevier*	*online*	*2014*	*p. 71*	*http://www.sciencedirect.com/science/article/pii/S221313371400033X*	*no*
11	*Joining the yellow hub: Uses of the Simple Application Messaging Protocol in Space Physics analysis tools*	*Génot, V.*	*Astronomy and Computing*	*Vol. 7*	*Elsevier*	*online*	*2014*	*p. 62*	*http://www.sciencedirect.com/science/article/pii/S2213133714000353*	*no*
12	*Inflation of a Dipole Field in Laboratory Experiments: Toward an Understanding of Magnetodisk Formation in the Magnetosphere of a Hot Jupiter*	*Antonov, V.M.*	*Astrophys. J.*	*Vol. 769*	*IOP Science*	*online*	*2013*	*Article id. 28*	*http://iopscience.iop.org/0004-637X/769/1/28*	*yes*
13	*Accretion and Current Discs Controlled by Strong Magnetic Field*	*Belenkaya, E.S.*	*International Journal of Astronomy and Astrophysics*	*Vol. 2*	*Scientific Research*	*online*	*2012*	*p. 81*	*http://www.scirp.org/journal/PaperInformation.aspx?PaperID=19742#.Va0Dgvntmko*	*yes*

14	*Birth of a comet magnetosphere: A spring of water ions*	*Nilsson, H.*	*Science*	*Vol. 347*	*AAAS*	*online*	*2015*	*article id. aaa0571*	*http://www.sciencemag.org/content/347/6220/aaa0571*	*no*
15	*The response of the high-latitude ionosphere to the solar-wind pressure jump with a southward IMF on January 10, 1997*	*Belenkaya, E.S.*	*Geomagnetism and Aeronomy*	*Vol. 54*	*Springer*	*online*	*2014*	*p. 203*	*http://link.springer.com/article/10.1134%2FS0016793214020042*	*no*
16	*Magnetospheric magnetic field modelling for the 2011 and 2012 HST Saturn aurora campaigns - implications for auroral source regions*	*Belenkaya E.S.*	*Ann. Geophys.*	*Vol. 32*	*Copernicus Publications*	*online*	*2014*	*p.689*	*http://www.ann-geophys.net/32/689/2014/angeo-32-689-2014.html*	*yes*
17	*Signs of deep mixing in starspot variability*	*Arkhypov, O.V.*	*Astron. Astrophys.*	*Vol. 576*	*EDP Sciences*	*online*	*2015*	*id. A67*	*http://www.aanda.org/articles/aa/abs/2015/04/aa25307-14/aa25307-14.html*	*yes*
18	*Influence of the solar wind magnetic field on the Earth and Mercury magnetospheres in the paraboloidal model*	*Belenkaya, E.S.*	*Planetary and Space Science*	*Vol. 75*	*Elsevier*	*online*	*2013*	*p. 46*	*http://www.sciencedirect.com/science/article/pii/S0032063312003042*	*no*
19	*Location of the Inner Edges of Astrophysical Discs Related to the Central Object*	*Belenkaya, E.S.*	*Astrophysics and Space Science Proceedings*	*Vol. 33*	*Springer*	*online*	*2012*	*p. 217*	*http://link.springer.com/chapter/10.1007%2F978-3-642-30442-2_24*	*no*
20	*Exoplanet Upper Atmosphere Environment Characterization*	*Lammer, H.*	*From Interacting Binaries to Exoplanets: Essential Modeling Tools*	*IAU Symp. No. 282*	*Cambridge University Press*	*online*	*2012*	*p. 525*	*http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=8544281&fileId= S1743921311028316*	*yes*
21	*Energetic particle dynamics in Mercury's magnetosphere*	*Walsh, B.M.*	*J. Geophys. Res.*	*Vol. 118*	*Wiley Online Library*	*online*	*2013*	*p. 1992*	*http://onlinelibrary.wiley.com/doi/10.1002/jgra.50266/abstract*	*yes*
22	*The Earth’s magnetosphere response to interplanetary medium conditions on January 21-22, 2005 and on December 14-15, 2006*	*Kalegaev, V.V.*	*Adv. Space Res.*	*Vol. 54*	*Elsevier*	*online*	*2014*	*p. 517*	*http://www.sciencedirect.com/science/article/pii/S0273117713006996*	*no*
23	*Magnetic interconnection of Saturn's polar regions: comparison of modelling*	*Belenkaya, E.S.*	*Ann. Geophys.*	*Vol. 31*	*Copernicus Publications*	*online*	*2013*	*p. 1447*	*http://www.ann-geophys.net/31/1447/2013/angeo-31-1447-2013.html*	*yes*

	results with Hubble Space Telescope UV auroral images									
24	*Stellar CME activity and its possible influence on exoplanets' environments: Importance of magnetospheric protection*	*Khodachenko, M.L.*	*Nature of Prominences and their role in Space Weather*	*IAU Symp. No. 300*	*Cambridge University Press*	*online*	*2014*	*p.335*	*http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=9138035&fileId=S1743921313011174*	*yes*
25	*Magnetospheres of the Mercury, Earth, Jupiter, and Saturn*	*Alexxev, I.I.*	*Astrophysics and Space Science Proceedings*	*Vol. 33*	*Springer*	*online*	*2012*	*p. 209*	*http://link.springer.com/chapter/10.1007%2F978-3-642-30442-2_23*	*no*
26	*Atmosphere Expansion and Mass Loss of Close-orbit Giant Exoplanets Heated by Stellar XUV. I. Modeling of Hydrodynamic Escape of Upper Atmospheric Material*	*Shaikhislamov, I.F.*	*Astrophys. J.*	*Vol. 795*	*IOP Science*	*online*	*2014*	*article id. 132*	*http://iopscience.iop.org/0004-637X/795/2/132/*	*yes*
27	*Forcing continuous reconnection in hybrid simulations*	*Laitinen, T.*	*Physics of Plasmas*	*Vol. 21*	*AIP Publishing*	*online*	*2014*	*id. 072906*	*http://scitation.aip.org/content/aip/journal/pop/21/7/10.1063/1.4890854*	*no*
28	*Magnetodisk-dominated magnetospheres of close orbit giant exoplanets*	*Khodachenko, M.L.*	*EAS Publications Series*	*Vol. 58*	*EDP Sciences*	*online*	*2012*	*p. 233*	*http://www.eas-journal.org/articles/eas/abs/2012/06/eas1258037/eas1258037.html*	*yes*
29	*Response of currents in Earth's and Saturn's dayside magnetopause to a sudden change in the solar wind density*	*Belenkaya, E.S.*	*Geomagnetism and Aeronomy*	*Vol. 54*	*Springer*	*online*	*2014*	*p. 287*	*http://link.springer.com/article/10.1134%2FS0016793214030037*	*no*
30	*Low-latitude variations in the geomagnetic field caused by solar wind disturbances*	*Belenkaya, E.S.*	*Geomagnetism and Aeronomy*	*Vol. 54*	*Springer*	*online*	*2014*	*p. 445*	*http://link.springer.com/article/10.1134%2FS0016793214040070*	*no*
31	*Polar cap response to the solar wind density jump under constant southward IMF*	*Belenkaya, E.S.*	*Geomagnetism and Aeronomy*	*Vol. 54*	*Springer*	*online*	*2014*	*p. 702*	*http://link.springer.com/article/10.1134%2FS0016793214060085*	*no*
32	*Dynamics of the magnetosphere during geomagnetic storms on January 21-22, 2005 and December 14-15, 2006*	*Kalegaev, V.V.*	*Cosmic Research*	*Vol. 53*	*Springer*	*online*	*2015*	*p. 98*	*http://link.springer.com/article/10.1134%2FS0010952515020033*	*no*

33	*Field-aligned currents in Saturn's southern nightside magnetosphere: Subcorotation and planetary period oscillation components*	*Hunt, G.J.*	*J. Geophys. Res.*	*Vol. 119*	*Wiley Online Library*	*online*	*2015*	*p. 9847*	*http://onlinelibrary.wiley.com/doi/10.1002/2014JA020506/abstract*	*yes*
34	*Investigation of scaling properties of a thin current sheet by means of particle trajectories study*	*Sasunov, Yu.L.*	*J. Geophys. Res.*	*Vol. 120*	*Wiley Online Library*	*online*	*2015*	*p. 1633*	*http://onlinelibrary.wiley.com/doi/10.1002/2014JA020486/abstract*	*no*
35	*Magnetosphere Environment from Solar System Planets/Moons to Exoplanets*	*Alexeev, I.I.*	*Astrophysics and Space Science Library*	*Vol. 411*	*Springer*	*online*	*2015*	*p. 189*	*http://link.springer.com/chapter/10.1007%2F978-3-319-09749-7_10*	*no*
36	*Alfven Radius: A Key Parameter for Astrophysical Magnetospheres*	*Belenkaya, E.S.*	*Astrophysics and Space Science Library*	*Vol. 411*	*Springer*	*online*	*2015*	*p. 239*	*http://link.springer.com/chapter/10.1007%2F978-3-319-09749-7_12*	*no*
37	*On the large-scale structure of the tail current as measured by THEMIS*	*Kalegaev, V.V.*	*Adv. Space. Res.*	*Vol. 54*	*Elsevier*	*online*	*2014*	*p. 1773*	*http://www.sciencedirect.com/science/article/pii/S027311771400475X*	*no*
38	*Analysis of long-periodic fluctuations of solar microwave radiation, as a way for diagnostics of coronal magnetic loops dynamics*	*Khodachenko, M.L.*	*Fourier Transform Applications*	*April 25, 2012*	*InTech - Open Access Publisher*	*online*	*2012*	*p. 143*	*http://www.intechopen.com/books/fourier-transform-applications*	*yes*
39	*Properties of plasma near the moon in the magnetotail*	*Kallio, E.*	*Planetary and Space Science*	*in press*	*Elsevier*	*online*	*2015*	-	*http://www.sciencedirect.com/science/article/pii/S0032063314003432*	*no*
40	*One year in the Earth's magnetosphere: A global MHD simulation and spacecraft measurements*	*Facsko, G.*	*J. Geophys. Res.*	*submitted*	*Wiley Online Library*	*online*	*2015*	-	-	*no*
41	*Dynamo in the Outer Heliosheath: Necessary Conditions*	*Belenkaya, E.S.*	*Solar Physics*	*accepted*	*Springer*	*online*	*2015*	-	*http://link.springer.com/article/10.1007%2Fs11207-015-0741-9*	*no*
42	*Origin and solar activity driven evolution of Mars` atmosphere*	*Lammer, H.*	*ISPS2011 Proceedings*		*Terra Scientific Publishing Company*	*Tokyo*	*2014*	-	-	*no*

Table 1: *List of scientific (peer reviewed) publications*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
1	*press release*	*IMPEx team*	*IMPEx. Integrated Medium for Planetary Exploration*	*2011*	*Space Research Vol. 4 – A European Journey*	*public*	*-*	*international audience*
2	*web*	*Al-Ubaidi, T.*	*IMPEx project website*	*since June 2011*	*online at impex-fp7.oeaw.ac.at*	*all*	*-*	*international audience*
3	*presentation*	*Belenkaya, E.S.*	*Magnetic field topology of the Saturn's magnetosphere calculated for the IMF Cassini data, and mapping of the corresponding aurora HST images*	*June 2011*	*International Astrophysics Forum Alpbach, Frontiers in Space Environment Research, Alpbach, Austria*	*scientific community*	*~25*	*international audience*
4	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 1: Introduction of the IMPEx project (with Khodachenko, M.L.)*	*July 2011*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
5	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 2: Walter Schmidt on IMPEx and Hybrid Modelling*	*August 2011*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
6	*publication*	*Alexeev, I.I.*	*Determination of intrinsic magnetic dipole parameters of Mercury and diagnostics of magnetospheric current system with Paraboloid Model (PMM)*	*August 2011*	*online at impex-fp7.oeaw.ac.at*	*scientific community*	*-*	*international audience*
7	*presentation*	*Khodachenko, M.L.*	*Magnetospheres of close orbit giant exoplanets: Importance of magnetodisks*	*September 2011*	*European Conference on Laboratory Astrophysics, Paris, France*	*scientific community*	*~25*	*international audience*
8	*presentation*	*Alexeev, I.I.*	*Application of paraboloid model to the Mercury, Earth, Jupiter, and Saturn*	*October 2011*	*EPSC-DPS Joint Meeting, Nantes, France*	*scientific community*	*~25*	*international audience*

[3] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[4] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

			magnetospheres					
9	*presentation*	*Belenkaya, E.S.*	*Exoplanetary magnetodisc in a context of other types of astrophysical discs*	*October 2011*	*EPSC-DPS Joint Meeting, Nantes, France*	*scientific community*	*~25*	*international audience*
10	*presentation*	*Khodachenko, M.L.*	*Integrated Medium for Planetary Exploration (IMPEx): A new EU FP7-SPACE project*	*October 2011*	*EPSC-DPS Joint Meeting, Nantes, France*	*scientific community*	*~25*	*international audience*
11	*workshop*	*Khodachenko, M.L.*	*Interactive use of computational models and experimental data in planetary science*	*October 2011*	*EPSC-DPS Joint Meeting, Nantes, France*	*scientific community*	*~15*	*international audience*
12	*presentation*	*Topf, F.*	*SOAP based web services and their future role in VO projects*	*October 2011*	*EPSC-DPS Joint Meeting, Nantes, France*	*scientific community*	*~25*	*international audience*
13	*poster*	*Gangloff, M.*	*An assessment of the IPDA/PDAP protocol to access planetary data*	*October 2011*	*EPSC-DPS Joint Meeting, Nantes, France*	*scientific community*	*-*	*international audience*
14	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 3: Vincent Génot on the Challenge of Integration*	*October 2011*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
15	*poster*	*Belenkaya, E.S.*	*Possible mechanisms of Saturn's aurora generation*	*October 2011*	*The second Moscow Solar System Symposium: Moons of Planets, Moscow, Russia*	*scientific community*		*international audience*
16	*press release*	*IMPEx team*	*Integrated Medium for Planetary Exploration: bridging spacecraft measurements to computational models*	*November 2011*	*The Parliament, Issue 337*	*public*	*-*	*international audience*
17	*poster*	*Khodachenko, M.L.*	*Integrated Medium for Planetary Exploration*	*December 2011*	*AGU Fall Meeting, San Francisco, USA*	*scientific community*		*international audience*
18	*publication*	*Leubner, M.*	*Multi-scale Dynamical Processes in Space and Astrophysical Plasmas*	*2012*	*Springer, see http://www.springer.com/de/ Zbook/9783642304415*	*scientific community*	*-*	*international audience*
19	*presentation*	*Génot, V.*	*IMPEx : access to simulations for solar wind / planets interaction*	*January 2012*	*CCMC workshop*	*scientific community*	*~20*	*international audience*
20	*presentation*	*Khodachenko, M.L.*	*IMPEx – Integrated Medium for Planetary exploration*	*January 2012*	*Europlanet-IDIS General Meeting, Graz, Austria*	*scientific community*	*~15*	*international audience*
21	*presentation*	*Khodachenko, M.L:*	*Lessons from JRA3-EMDAF and sustainability foresights*	*January 2012*	*Europlanet-RI Sustainability Workshop, Vienna, Austria*	*scientific community*	*~25*	*international audience*
22	*presentation*	*Belenkaya, E.S.*	*Inner edges of astrophysical discs: the mutual property caused by magnetic field*	*February 2012*	*seminar at Institute of Applied Physics Russian Academy of Sciences, Nizni Novgorod, Russia*	*scientific community*	*~20*	*Russia*
23	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 4: Ronan Modolo onLATMOS hybrid codes*	*February 2012*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*

24	*presentation*	*Génot, V.*	*Le projet IMPEx*	*March 2012*	*Colloque du PNST, La Londe Les Maure, France*	*scientific community*	*~15*	*France*
25	*presentation*	*Khodachenko, M.L.*	*Integrated Medium for Planetary Exploration (IMPEx): an infrastructure to bridge space missions data and computational models in planetary science*	*April 2012*	*EGU GA, Vienna, Austria*	*scientific community*	*~25*	*international audience*
26	*poster*	*Belenkaya, E.S.*	*Discs around magnetized giant exoplanets and other astrophysical objects*	*April 2012*	*EGU GA, Vienna, Austria*	*scientific community*		*international audience*
27	*presentation*	*Al-Ubaidi, T.*	*IMPEx -An infrastructure to bridge the gap between space mission data and computational models in planetary science*	*June 2012*	*Planetary Data Workshop, Flagstaff, USA*	*scientific community*	*~20*	*international audience*
28	*presentation*	*Gangloff, M.*	*IMPEx - An Infrastructure For Joint Analysis Of Space Missions And Computational Modeling Data In Planetary Science*	*July 2012*	*COSPAR, Mysore, India*	*scientific community*	*~25*	*international audience*
29	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 5: Dan Chrichton on PDS4*	*August 2012*	*online at impex-fp7.oeaw.ac.at*	*public*	-	*international audience*
30	*presentation*	*Al-Ubaidi, T.*	*Planetary Science Research with the IMPEx Infrastructure*	*September 2012*	*EPSC, Madrid, Spain*	*scientific community*	*~25*	*international audience*
31	*presentation*	*Blokhina, M.*	*Saturn and Earth polar oval position forecast by IMPEx infrastructure Web services based on the paraboloid magnetospheric model*	*September 2012*	*EPSC, Madrid, Spain*	*scientific community*	*~25*	*international audience*
32	*poster*	*Génot, V.*	*Capabilities of the analysis tools of the IMPEx infrastructure*	*September 2012*	*EPSC, Madrid, Spain*	*scientific community*	-	*international audience*
33	*poster*	*Hess, S.*	*IMPEx Data Model: a simulation extension to the Spase data model*	*September 2012*	*EPSC, Madrid, Spain*	*scientific community*	-	*international audience*
34	*poster*	*Kallio, E.*	*Numeric Simulation Tools of the IMPEx Infrastructure*	*September 2012*	*EPSC, Madrid, Spain*	*scientific community*	-	*international audience*
35	*poster*	*Lavrukhin, A.S.*	*Cosmic rays cut-off in approach of dipole and homogeneous field for Jupiter system*	*September 2012*	*EPSC, Madrid, Spain*	*scientific community*	-	*international audience*
36	*splinter meeting*	*Khodachenko, M.*	*Integrated Medium for Planetary Exploration (IMPEx) and United Solutions for Scientific Research (USSR)*	*September 2012*	*EPSC, Madrid, Spain*	*scientific community*	*~15*	*international audience*

37	*presentation*	*Scherf, M.*	*Moderne Informationstechnologien in Planetologie und Weltraumwissenschaften*	*September 2012*	*Graz in Space Summer University, Graz, Austria*	*public*	*~50*	*Austria*
38	*press release*	*IMPEx team*	*Integrated Medium for Planetary Exploration (IMPEx) – a new research infrastructure for the European space exploration*	*October 2012*	*The Parliament, Issue 357*	*public*	*-*	*international audience*
39	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 6: Steve Miller on the future of Europlanet*	*October 2012*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
40	*presentation*	*Gangloff, M.*	*IMPEx, Analysis of Planetary Data with CDPP-AMDA and 3DView communicating with SAMP*	*October 2012*	*IVOA Interop Meeting, Sao Paolo, Brazil*	*scientific community*	*~20*	*international audience*
41	*presentation*	*Belenkaya, E.S.*	*Astrophysical disks in strong magnetic fields, all Russia conference*	*December 2012*	*all Russia conference "Astrophysics of high energies today and tomorrow", Moscow Russia*	*scientific community*	*~20*	*Russia*
42	*poster*	*Boardsen, S.A.*	*An Explanation for the Observed Frequency Drift of Coherent*	*December 2012*	*AGU Fall Meeting, San Francisco, USA*	*scientific community*	*-*	*international audience*
43	*presentation*	*Hess, S.*	*IMPEx Simulation Data Model: an extension to SPASE for the description of simulation runs*	*December 2012*	*AGU Fall Meeting, San Francisco, USA*	*scientific community*	*~25*	*international audience*
44	*poster*	*Nicholas, J.B.*	*Mercury: New Insights From MESSENGER's Extended Mission III Posters*	*December 2012*	*AGU Fall Meeting, San Francisco, USA*	*scientific community*	*-*	*international audience*
45	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 7: Esa Kallio on FMI and the latest developments in IMPEx*	*February 2013*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
46	*presentation*	*Pérez-Suarez, D.*	*IMPEx: Bridging between space data and planetary models*	*March 2013*	*Application porting Workshop, London, UK*	*scientific community*	*~20*	*international audience*
47	*presentation*	*Kalegaev, V.V.*	*Geomagnetic tail large scale structure and dynamics in quiet magnetosphere*	*March 2013*	*Chapman Conference on Fundamental Properties and Processes of Magnetotails*	*scientific community*	*~20*	*international audience*
48	*presentation*	*Al-Ubaidi, T.*	*Preparing for joint operation of numerical modelling and observational data in IMPEx*	*April 2013*	*EGU GA, Vienna, Austria*	*scientific community*	*~25*	*international audience*
49	*presentation*	*Parunakian, D.*	*Approximating planetary magnetic fields by simplified models using linear regression*	*April 2013*	*EGU GA, Vienna, Austria*	*scientific community*	*~25*	*international audience*
50	*poster*	*Génot*	*Interoperability of the analysis tools within the IMPEx project*	*April 2013*	*EGU GA, Vienna, Austria*	*scientific community*	*-*	*international audience*

51	*poster*	*Kallio, E.*	*HWA modelling web services for the IMPEx infrastructure*	*April 2013*	*EGU GA, Vienna, Austria*	*scientific community*	*-*	*international audience*
52	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 8: The IMPEx Support Meeting 2013*	*May 2013*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
53	*presentation*	*Kalegaev, V.V.*	*Russian radiation monitoring missions and space weather forecast*	*June 2013*	*International Living With A Star Workshop 2013, Irkutsk, Russia*	*scientific community*	*~20*	*international audience*
54	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 9: Serene Universe (interview with Maarten Roos & William Zeitler)*	*September 2013*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
55	*poster*	*Kalegaev, V.V.*	*Representation of planetary magnetospheric environment with the paraboloid model*	*September 2013*	*EPSC, London UK*	*scientific community*	*-*	*international audience*
56	*presentation*	*Hess, S.*	*Theoretical VO: description of models and simulations in IMPEx*	*September 2013*	*EPSC, London UK*	*scientific community*	*~25*	*international audience*
57	*presentation*	*Alexeev, I.I.*	*Auroral ionosphere Joule heating by the magnetosphere-ionosphere slippage in the Jupiter and Saturn systems*	*September 2013*	*EPSC, London UK*	*scientific community*	*~25*	*international audience*
58	*poster*	*Génot, V.*	*IMPEx: enabling model/observational data comparison in planetary plasma sciences*	*September 2013*	*EPSC, London UK*	*scientific community*	*-*	*international audience*
59	*poster*	*Belenkaya, E.S.*	*Interconnection between Saturn's polar caps*	*September 2013*	*EPSC, London UK*	*scientific community*	*-*	*international audience*
60	*publication*	*Hess, S.*	*IMPEx Simulation Data Model, a SPASE extension to manage simulations and models*	*October 2013*	*online at impex-fp7.oeaw.ac.at*	*scientific community*	*-*	*international audience*
61	*video*	*Cecconi, B.*	*IMPEx demonstration: Interoperability of AMDA, LatHyS and Topcat (in cooperation with Europlanet*	*online at IMPEx website since November 2013*	*online at impex-fp7.oeaw.ac.at*	*all*	*-*	*international audience*
62	*video*	*Modolo, R.*	*IMPEx demonstration: AMDA, 3DView and Simulation Databases (in cooperation with Europlanet)*	*online at IMPEx website since November 2013*	*online at impex-fp7.oeaw.ac.at*	*all*	*-*	*international audience*
63	*presentation*	*Khodachenko, M.*	*Planetary Science Research with the IMPEx Infrastructure*	*November 2013*	*Seminar at IWF-OeAW, Graz, Austria*	*scientific community*	*~20*	*Austria*
64	*presentation*	*Génot, V.*	*IMPEx, a FP7 infrastructure for joint analysis of planetary plasma data following the Virtual Observatory paradigm*	*November 2013*	*PV2013 conference, Frascati, Italy*	*scientific community*	*~20*	*international audience*
65	*presentation*	*Hess, S.*	*IMPEx Simulation Data Model, an extension to SPASE*	*November 2013*	*PV2013 conference, Frascati, Italy*	*scientific community*	*~20*	*international audience*

66	*presentation*	*Cecconi, B.*	*Applicability of the IMPEx DM to external SMDB*	*November 2013*	*Seminar at UCL, London, UK*	*scientific community*	*~20*	*UK*
67	*presentation*	*Kalegaev, V.V.*	*Space Weather Monitoring and Analysis System Developed at Moscow State University*	*November 2013*	*Tenth European Space Weather Week, Antwerp, Belgium*	*scientific community*	*~20*	*international audience*
68	*presentation*	*Belenkaya, E.S.*	*Exomagnetospheres controlled by the stellar wind*	*December 2013*	*ISSI team meeting "Characterizing Stellar and Exoplanetary Environments via Observations and Advanced Modelling Techniques", Bern, Switzerland*	*scientific community*	*~20*	*international audience*
69	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 10: Igor Alexeev on Russian Space Exploration and IMPEx*	*December 2013*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
70	*poster*	*Génot, V.*	*Model/observational data cross analysis in planetary plasma sciences with IMPEx*	*December 2013*	*AGU Fall Meeting, San Francisco, USA*	*scientific community*	*~25*	*international audience*
71	*press release*	*IMPEx team*	*Ready For Take-Off: Launch of New Data Model Boosts Space Science*	*March 2014*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
72	*press release*	*IMPEx team*	*Ready For Take-Off: Neues Datenmodell fördert Weltraumforschung*	*March 2014*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*Austria*
73	*interview*	*Ljudvigovna, V.A.*	*SINP scientists take part in the development of IMPEx database for planetary research (interview with Igor Alexeev)*	*March 2014*	*online at http://sinp.msu.ru/en/post/17506*	*public*	*-*	*Russia*
74	*presentation*	*Modolo, R.*	*Seminar on LATMOS Ganymede modeling (including presentation of some IMPEx capabilities (LatHyS and 3Dview interoperability),*	*March 2014*	*Seminar at IRF-Uppsala, Uppsala, Sweden*	*scientific community*	*~20*	*Sweden*
75	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 11: Günter Kargl on the Rosetta Mission*	*April 2014*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
76	*poster*	*Gangloff, M.*	*CDPP Tools in the IMPEx infrastructure*	*April 2014*	*EGU GA, Vienna, Austria*	*scientific community*	*-*	*international audience*
77	*poster*	*Topf, F.*	*IMPEx – a web-based distributed research environment for planetary plasma science*	*April 2014*	*EGU GA, Vienna, Austria*	*scientific community*	*-*	*international audience*
78	*workshop*	*Cecconi, B.*	*Solar System Virtual Observatory Hands-on Session*	*April 2014*	*EGU GA, Vienna, Austria*	*scientific community*	*~20*	*international audience*
79	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 12: Lasse Häkkinen on IMPEx development*	*May 2014*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*

80	*presentation*	*Khodachenko, M.*	*Planetary Science Research with the IMPEx Infrastructure*	*May 2014*	*Seminar at Moscow State University, Moscow, Russia*	*scientific community*	*~20*	*Russia*
81	*presentation*	*Scherf, M.*	*Interaktive Datenanalyse-Tools in Planetologie und Weltraumforschung*	*May 2014*	*Seminar at Karl-Franzens University, Graz, Austria*	*scientific community*	*~10*	*Austria*
82	*web*	*Scherf, M.*	*IMPEx Demonstrators & Tutorials*	*since May 2014*	*online at https://sites.google.com/site/ impexfp7/*	*all*	*-*	*international audience*
83	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 13: Michel Gangloff on the IMPEx Data Model*	*July 2014*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
84	*presentation*	*Al-Ubaidi, T.*	*The IMPEx data model – a common metadata standard for the analysis of simulated and observational space plasma physics*	*August 2014*	*COSPAR Scientific Assembly, Moscow, Russia*	*scientific community*	*~25*	*international audience*
85	*presentation*	*Kalegaev, V.*	*Solar wind pressure as a source of ring current development*	*August 2014*	*COSPAR Scientific Assembly, Moscow, Russia*	*scientific community*	*~25*	*international audience*
86	*presentation*	*Parunakian, D.*	*On minute variations of solar wind bulk velocity, density and other parameters*	*August 2014*	*COSPAR Scientific Assembly, Moscow, Russia*	*scientific community*	*~25*	*international audience*
87	*presentation*	*Kalegaev.V.*	*The IMPEx data model - representation of planetary magnetospheric environment with the paraboloid model*	*August 2014*	*COSPAR Scientific Assembly, Moscow, Russia*	*scientific community*	*~25*	*international audience*
88	*poster*	*Belenkaya, E.S.*	*Auroras at the Earth, Jupiter, and Saturn*	*August 2014*	*COSPAR Scientific Assembly, Moscow, Russia*	*scientific community*	*-*	*international audience*
89	*presentation*	*Scherf, M.*	*The IMPEx Protocol - building bridges between scientific databases and online tools*	*September 2014*	*EPSC, Lisbon, Portugal*	*scientific community*	*~25*	*international audience*
90	*workshop*	*Cecconi, B.*	*Solar System Virtual Observatory Hands-on Session*	*September 2014*	*EPSC, Lisbon, Portugal*	*scientific community*	*~15*	*international audience*
91	*poster*	*Gangloff, M.*	*IMPEx SimDM, a metadata model to search and exchange simulation data in the field of space plasma and planetary physics*	*September 2014*	*EPSC, Lisbon, Portugal*	*scientific community*		*international audience*
92	*presentation*	*Scherf, M.*	*Virtuelle Observatorien am Beispiel des EU-Projektes IMPEx*	*September 2014*	*Graz in Space Summer University, Graz, Austria*	*public*	*~50*	*international audience*
93	*presentation*	*Belenkaya, E.S.*	*FTEs in the Mercury magnetosphere: Dependence on IMF*	*October 2014*	*5M-S3 / Annual Moscow Solar System Symposium*	*scientific community*	*~20*	*international audience*
94	*presentation*	*Mukhametdinova, L.*	*The Earth's magnetosphere model in the framework of the IMPEx data model: on-line web services and*	*November 2014*	*11th European Space Weather Week, Liége, Belgium*	*scientific community*	*~20*	*international audience*

			visualization tool					
95	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 14: The IMPEx Portal (interview with Manuel Scherf & Florian Topf)*	*December 2014*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
96	*publication*	*Lammer, H.*	*Characterizing Stellar and Exoplanetary Environments*	*2015*	*Springer, see http://www.springer.com/de/ book/9783319097480*	*scientific community*	*-*	*international audience*
97	*publication*	*Kallio, E.*	*The birth of a comet's magnetosphere: a spring of water ions*	*January 2015*	*online at space.aalto.fi*	*public*	*-*	*international audience*
98	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 15: A first résumé by Maxim Khodachenko*	*March 2015*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
99	*interview*	*Al-Ubaidi, T.*	*IMPEx Audio-Podcast, Episode 16: Looking back on IMPEx-FP7*	*March 2015*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
100	*presentation*	*Scherf, M.*	*Interaktive Datenanalyse-Tools in Planetologie und Weltraumforschung*	*March 2015*	*Seminar at Karl-Franzens University, Graz, Austria*	*scientific community*	*~10*	*Austria*
101	*press release*	*IMPEx team*	*Impact with IMPEx: European Team Creates Universal "Language" for Space Science*	*April 2015*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*international audience*
102	*press release*	*IMPEx team*	*FP7 Projekt IMPEx: Europäisches Team entwickelt universelle "Sprache" für Weltraumforschung*	*April 2015*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*Austria*
103	*press release*	*IMPEx team*	*Результаты проекта IMPEx: Европейская команда создала универсальный "язык" для космической науки*	*April 2015*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*Russia*
104	*press release*	*IMPEx team*	*IMPEx ratkoo aurinkokunnan arvoituksia: eurooppalainen ryhmä kehittää yhteistä "kieltä" avaruustutkimukseen*	*April 2015*	*online at impex-fp7.oeaw.ac.at*	*public*	*-*	*Finland*
105	*poster*	*Gangloff, M.*	*Planetary plasma data analysis and 3D visualisation tools of the CDPP in the IMPEx infrastructure*	*April 2015*	*EGU GA, Vienna, Austria*	*scientific community*		*international community*
106	*workshop*	*Al-Ubiaidi, T.*	*IMPEx Tools and Capabilities*	*April 2015*	*EGU GA, Vienna, Austria*	*scientific community*	*~15*	*international community*
107	*workshop*	*Cecconi, B.*	*Solar System Virtual Observatory Hands-on*	*April 2015*	*EGU GA, Vienna, Austria*	*scientific community*	*~20*	*international community*
108	*presentation*	*Kalegaev, V.V.*	*Space Radiation Monitoring Center at SINP MSU*	*April 2015*	*EGU GA, Vienna, Austria*	*scientific community*	*~25*	*international community*
109	*video*	*Cecconi, B.*	*Auroral Processes of Saturn*	*online at IMPEx*	*online at*	*all*	*-*	*international audience*

				website since April 2015	impex-fp7.oeaw.ac.at			
110	*video*	*Scherf, M.*	*Impex Tutorial Video*	*April 2015*	*online at impex-fp7.oeaw.ac.at*	*all*	-	*international audience*
111	*presentation*	*Génot, V.*	*Mapping functionalities of CDPP/3DView*	*May 2015*	*ESAC Planetary GIS Workshop*	*scientific community*	*~20*	*international audience*
112	*presentation*	*Al-Ubaidi, T.*	*The IMPEx Protocol – building bridges between scientific databases and online tools*	*May 2015*	*EGI conference, Lisbon, Portugal*	*scientific community*	*~25*	*international audience*
113	*video*	*FMI team*	*Tutorial: IMPEx Matlab Tools*	*June 2015*	*online at impex-fp7.oeaw.ac.at*	*all*	-	*international audience*
114	*video*	*FMI team*	*Tutorial: Hybrid Web Archive*	*June 2015*	*online at impex-fp7.oeaw.ac.at*	*all*	-	*international audience*
115	*video*	*FMI team*	*Magnetic environment of Titan in the HYB simulation*	*June 2015*	*online at HYB Code Youtube-Channel*	*all*	-	*international audience*
116	*video*	*FMI team*	*Atmospheric erosion at Venus in the HYB simulation*	*June 2015*	*online at HYB Code Youtube-Channel*	*all*	-	*international audience*
117	*video*	*FMI team*	*Solar storm at Venus in the HYB simulation*	*June 2015*	*online at HYB Code Youtube-Channel*	*all*	-	*international audience*
118	*video*	*FMI team*	*Formation of Venus induced magnetosphere in the HYB simulation*	*June 2015*	*online at HYB Code Youtube-Channel*	*all*	-	*international audience*
119	*video*	*FMI team*	*Flying along Venus Express orbit in the HYB simulation*	*June 2015*	*online at HYB Code Youtube-Channel*	*all*	-	*international audience*
120	*video*	*FMI team*	*Esittely: IMPEx Matlab-työkalut*	*June 2015*	*online at HYB Code Youtube-Channel*	*all*	-	*Finland*
121	*video*	*FMI team*	*Esittely: Hybrid Web Archive*	*June 2015*	*online at HYB Code Youtube-Channel impex-fp7.oeaw.ac.at*	*all*	-	*Finland*
122	*web*	*Gangloff, M.*	*3DVIEW IMPEx Tutorial*	*online since July 2015*	*online at http://3dview.cdpp.eu/other/3DVIEW-IMPEx_Tutorial.pdf*	*all*	-	*international audience*

Table 2: *List of dissemination activities*

2.2. Section B

2.2.1. Part B1

Since all definitions and designs (e.g. *IMPEx Protocol*, *IMPEx Data Model*) elaborated in the course of the project are openly accessible and implementations thereof mostly are *open source* (e.g. *GPL* v3 for *CNRS* and *FMI*) and also open to the interested public, no patent applications could be filed.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[5]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
-	-	-	-	-	-

Table 3: *List of applications for patents, trademarks, registered designs etc.*

[5] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

2.2.2. Part B2

Type of Exploitable Foreground	Description of exploitable foreground	Confidential	Foreseen embargo date	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	***IMPEx Portal**: Web portal allowing to access all IMPEx functionalities and data*	*No*	-	*Web application*	***J63.1.2** - Web portals*	*Publicly available since 2015*	*GPL v2*	*IWF-OeAW (owner) CNRS, FMI, SINP*
Exploitation of R&D results via standards	***IMPEx Data Model** (SPASE): Comprehensive data model for plasma simulation results*	*No*	-	*Re-usable software standard*	*n/a*	*Publicly available since 2014*	*n/a*	*All*
Exploitation of R&D results via standards	***IMPEx Protocol** Implementations*	*No*	-	*Re-usable software standard*	*n/a*	*Publicly available since 2013*	*n/a*	*All*
General advancement of knowledge	***CDPP-AMDA**: web tool allowing browse, display and analyse planetary plasma data from observations and models (IMPEx extensions)*	*No*	-	*Web application*	***J63.1.1** - Data processing, hosting and related activities*	*Publicly available since 2006*	*GPL v3*	*CNRS (owner), IWF-OeAW, FMI, SINP*
General advancement of knowledge	***CDPP-3DView**: web tool allowing joint display of science data and spacecraft orbit and ephemerides (IMPEx extensions)*	*No*	-	*Web application*	***J63.1.1** - Data processing, hosting and related activities*	*Publicly available since 2005*	*GPL v3*	*CNRS (owner), IWF-OeAW, FMI, SINP*

Table 4: *List of exploitable foregrounds*

IMPEx Portal

The *IMPEx Portal* is designed to be a *one-stop-solution* for anyone interested in the capabilities and services provided by IMPEx. It allows browsing data, calling methods on the data provided and transferring data to other **IMPEx enabled tools** as e.g. *CDPP-AMDA* via *SAMP*.

The portal is publicly accessible to anyone interested from science, education and the general public. No credentials have to be provided, all that is needed to access the portal is an *HTML5* capable web browser on a desktop computer or mobile device.
Currently there are no measures planned with regard to *IPR*.
The portal as it stands by mid-2015 is implemented according to requirements gathered during the project also involving the IMPEx Advisory Boards, no further development or research is needed at this point in time.
The impact to be expected is that more people become interested in IMPEx and its technological as well as scientific achievements, providing the means to have an ad-hoc practical experience. This is expected to encourage other projects and institutions to use the resources provided by IMPEx and help to further develop the data model as well as the web service interface (*IMPEx Protocol*).

IMPEx Data Model

The *IMPEx Data Model* is the first comprehensive *xml* definition that allows to **completely describe simulation results in the field of numerical plasma physics**. It is part of the *SPASE* definition and hence ideally complements this data model that is now capable of describing observational and modelled plasma data in one data structure.
The *IMPEx Data Model* i.e. *SPASE simulation extensions* is required by any plasma physicist attempting to make public his/her simulated plasma data and/or exchange data with other groups and institutions.
The *IMPEx Data Model* is completely open to the public and can be freely used by any scientific or otherwise interested party. Extension can be suggested to the *SPASE* group. Currently there are no measures planned with regard to *IPR*.
The *IMPEx Data Model* is a living definition that can be extended as needed in order to cover future applications and technologies. The definition as it stands now however can be used as is, without further development needed.
The *IMPEx Data Model* will vastly facilitate the exchange of data and hence **foster cooperation and joint scientific investigations** in the field of numerical plasma physics and planetary science.

IMPEx Protocol

The *IMPEx Protocol* is the “common language” of the system that every node (*SMDB*, tool …) uses in order to **communicate with other nodes, expose data and call methods** and functionalities of other nodes.
It is currently **used by *FMI* (*HWA*), *CNRS* (*CDPP-AMDA*, *CDPP-3DView*, *CLWeb*, *LatHys*), *IWF-OeAW* (*IMPEx Portal*) and *SINP* (*SMDB tools*)** to integrate their services. It can be implemented as is by any other project, initiative or individual and extended if needed in order to integrate a new *SMDB* or tool into IMPEx, being able to then also leverage all data and methods, available in the environment.
The definition is freely available, prototype implementations are available e.g. by *FMI* on *GitHub* under *GNU General Public License version 3*; no IPR exploitable measures have been taken or planned.
The set of web services should cover most use cases without further research necessary. It can however be extended anytime, preserving backward compatibility.

The *IMPEx Protocol* provides a **harmonized set of web services** to exchange and process numerical plasma data. The expectation is that it will foster the growth of the IMPEx environment and encourage other tools to follow the *IVOA* philosophy of reusing existing solutions, rather than "reinventing the wheel".

CDPP-AMDA

AMDA is developed by *CDPP* since 2006 with the aim to **distribute observational data and help in their analysis**, in the frame of *planetary plasma physics*.
Extensions have been developed to implement the *IMPEx Protocol*, especially to make *SMDBs* accessible via *CDPP-AMDA*; already developed visualization and analysis functionalities could then be applied to these newly accessed data from numerical simulations and models. The ingestion of new planetary data was fostered in order to keep the database up to date regarding data from recent science missions.
CDPP-AMDA is freely accessible upon registration. Development of *CDPP-AMDA* (in open source) continues by CDPP in the frame of its "data distribution" mission. Suggestions by interested users are always welcome.
CDPP-AMDA is used by scientists, referenced and acknowledged in papers; the IMPEx extensions are expected to **encourage new communities (simulators/modellers) to use the tool** but also to facilitate model/observations cross-comparisons in the field of *planetary plasma physics*.

CDPP-3DView

CDPP-3DView was first designed in 2005 by *CNES* and *GFI* to **visualize time interpolated orbit and attitude data of spacecraft and planetary ephemerides** for the *Rosetta* mission. Subsequently, many other interplanetary missions were taken into account.
IMPEx extensions implement the *IMPEx Protocol* to access and display simulations as well as observations from remote databases. This includes the visualization of time series or event tables along the trajectory of spacecraft, 2D cuts, magnetic field and flow lines or spectrograms. *SAMP*, a communication protocol designed by the *IVOA*, is used to access data from *CDPP-AMDA* and other tools. Several models of planetary environments have been implemented: *Cain* model for *Mars*, *Tsyganenko* model for the *Earth*.
CDPP-3DView is freely accessible, and **will continuously be improved as open source** after the IMPEx project. It has been used since several years by scientists as well as new planetary missions designers, and like *CDPP-AMDA*, it is anticipated that the *IMPEx Extensions* will **facilitate the comparison of observations and simulations** in the field of *planetary plasma physics*, **testing/validation of numerical models**, and the **preparation of new missions**.

3. Report on societal implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	262863
Title of Project:	Integrated Medium for Planetary Exploration
Name and Title of Coordinator:	Dr. Maxim Khodachenko

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***No***
2. Please indicate whether your project involved any of the following issues (tick box):	
RESEARCH ON HUMANS	
• Did the project involve children?	***No***
• Did the project involve patients?	***No***
• Did the project involve persons not able to give consent?	***No***
• Did the project involve adult healthy volunteers?	***No***
• Did the project involve Human genetic material?	***No***
• Did the project involve Human biological samples?	***No***
• Did the project involve Human data collection?	***No***
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	***No***
• Did the project involve Human Foetal Tissue / Cells?	***No***
• Did the project involve Human Embryonic Stem Cells (hESCs)?	***No***
• Did the project on human Embryonic Stem Cells involve cells in culture?	***No***
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	***No***
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	***No***
• Did the project involve tracking the location or observation of people?	***No***
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	***No***
• Were those animals transgenic small laboratory animals?	***No***
• Were those animals transgenic farm animals?	***No***
• Were those animals cloned farm animals?	***No***
• Were those animals non-human primates?	***No***
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	***No***
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	***No***
DUAL USE	
• Research having direct military use	***No***
• Research having the potential for terrorist abuse	***No***

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	-	1
Work package leaders	-	5
Experienced researchers (i.e. PhD holders)	6	16
PhD Students	2	3
Other	4	2

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**3**
Of which, indicate the number of men:	3

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	○ ⦿	Yes No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
❑	Design and implement an equal opportunity policy	○	○	○	○	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
❑	Actions to improve work-life balance	○	○	○	○	○

○ Other:

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

⦿ No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

⦿ Yes- please specify: Talks and presentations held at universities.

○ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

⦿ Yes- please specify: Videos, online tutorials, podcasts (on webpage).

○ No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

⦿ Main discipline[6]: **1.2 Physical sciences**

⦿ Associated discipline[6]: **1.1 Mathematics and computer sciences**

⦿ Associated discipline[6]: **1.4 Earth and related Environmental sciences**

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	⦿ ○	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

⦿ No

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

○ Yes, in communicating /disseminating / using the results of the project

[6] Insert number from list below (Frascati Manual).

11c	**In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?**	○ ⊙	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ⊙ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ○ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ⊙ No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- ○ European level
- ○ International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**42**
To how many of these is open access[7] provided?	**20**
How many of these are published in open access journals?	**17**
How many of these are published in open repositories?	**8**
To how many of these is open access not provided?	**22**
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ■ no suitable open access journal available ■ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[8]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**0**

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**

17. How many spin-off companies were created / are planned as a direct result of the project?	**1**
Indicate the approximate number of additional jobs in these companies:	***1***

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

■	Increase in employment, or	■	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure: **32***

[7] Open Access is defined as free of charge access for anyone via Internet.
[8] For instance: classification for security project.

Difficult to estimate / not possible to quantify	❑

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ⦿ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ⦿ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

■	Press Release	■	Coverage in specialist press
❑	Media briefing	■	Coverage in general (non-specialist) press
❑	TV coverage / report	■	Coverage in national press
❑	Radio coverage / report	■	Coverage in international press
■	Brochures /posters / flyers	■	Website for the general public / internet
■	DVD /Film /Multimedia	■	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

■	Language of the coordinator	■	English
■	Other language(s)		

Table 5: *Report on societal implications*

Question F-10**:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES
1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]
1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)
1.3 Chemical sciences (chemistry, other allied subjects)
1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)
1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY
2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)
2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]
2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial

chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]