Connecting the CDPP/AMDA service and IVOA tools

A Science Case: Auroral Campaign Observations of Jupiter and Saturn

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ABSTRACT

The Integrated and Distributed Information Service (IDIS) is one of the activities in Planetary Sciences developed during the EuroPlaNet project. This service is divided into four thematic nodes and one technical top node. In the long-term (FP7, EuroPlaNet RI - and beyond), the objective is to provide the planetary science community with Virtual Observatory tools for the access of data and information from laboratory measurements, ground- and spaced-based observations as well as modeling results, allowing comparative and pluri-disciplinary studies of planetary objects and environments. The Plasma Physics thematic node of IDIS is established in close cooperation between the IWF Graz and CDPP Toulouse. These last years, CDPP has developed a new service, AMDA (Automated Multi-Dataset Analysis,), which is a web-based facility for on line analysis of space physics data (heliosphere, magnetospheres, planetary environments) coming from either its local database or distant ones, such as the Cassini/MAPSKP, VEX/MAG at IWF/Graz or the CDAWeb.
These last years, a large campaign of remote high resolution imaging of Jupiter and Saturn aurorae has been undertaken using the Hubble Space Telescope, in association with in situ measurements of local solar wind and magnetospheric plasma conditions using several different spacecraft (including Galileo, Cassini and New Horizons). The coordinated scientific exploitation of all these data is a major technical challenge, since it requires accessing heterogeneous data from diverse origins to perform an integrated study combining different software tools appropriate for the analysis of the solar wind, magnetospheric, ionospheric and atmospheric phenomena observed.
In the context of our IDIS activities, we will present our future plans to connect the CDPP/AMDA service with IVOA tools like Aladin, which is an interactive software that will enable the user to visualize digitized astronomical images of Jupiter and Saturn aurorae in combination with solar wind and magnetospheric data reachable via AMDA.

Keywords: virtual observatory, plasma, astrophysics, web-service, IVOA tools

INTRODUCTION

These last years, several campaigns of ground- and space-based high resolution multi-wavelength spectroscopy and imaging of Jupiter and Saturn auroral emissions have been undertaken (e.g., IUE, HST, Chandra, XMM, ROSAT, IRTF, CFHT, …), in association with remote auroral observations and in situ measurements of local solar wind and magnetospheric plasma conditions using several different spacecraft (e.g., Galileo, Cassini, New Horizons, …), as illustrated in Figure 1. The coordinated scientific exploitation of all these data provide unique and complementary information but is a major technical challenge, since it requires accessing heterogeneous data from diverse origins in order to perform an integrated study combining different software tools appropriate for the analysis of the coupled solar wind, magnetospheric, ionospheric, thermospheric and atmospheric (hereinafter referred to as the coupled SWMITA system) phenomena observed.

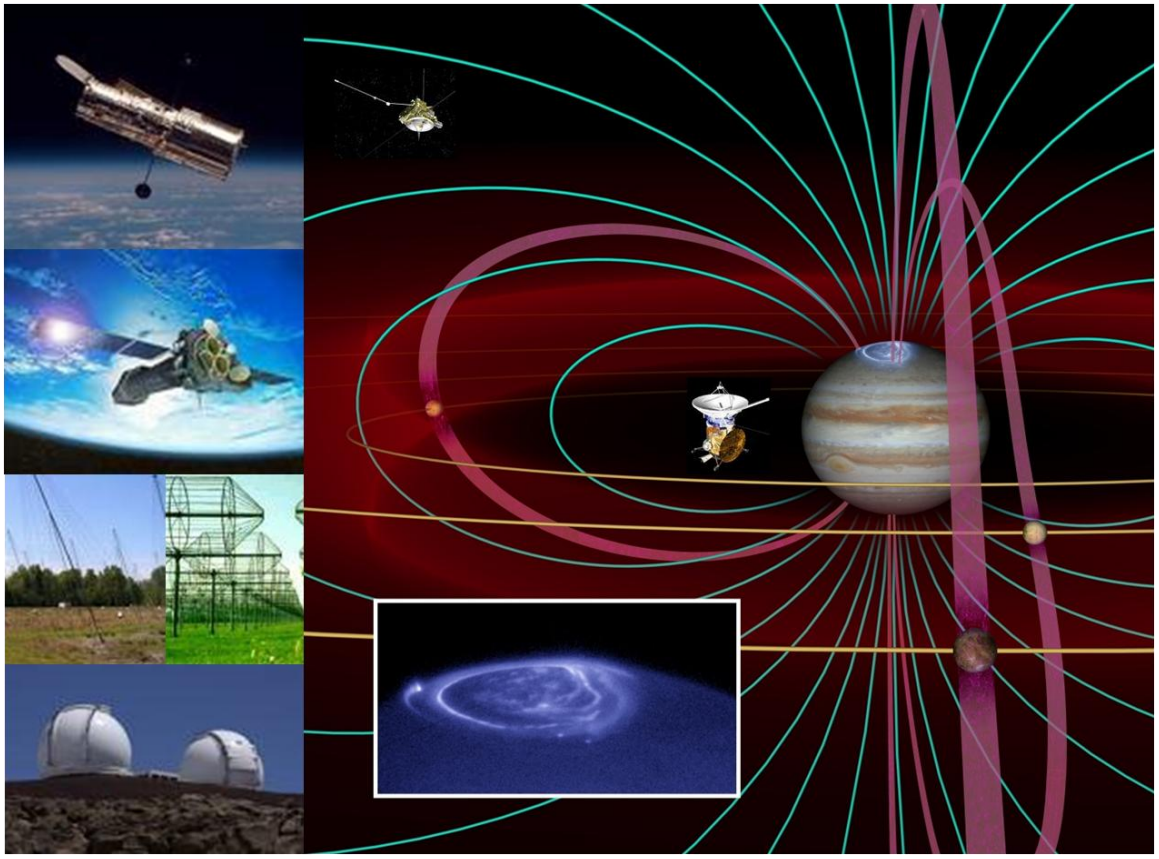

Figure 1: Schematic illustrating a coordinated network of ground- and space-based telescopes operating in various wavelengths (left panel, from top to bottom: HST (UV/VIS), XMM/Newton (X-ray), the Nançay, Kharkov (radio) and CFHT (IR) telescopes) and observing the auroral emissions of Jupiter (right panel, shown in UV from HST observations), in association with simultaneous in-situ measurements of the local solar wind and magnetospheric plasma conditions using several different spacecraft (Ulysses and Cassini/Huygens).

In the context of FP7 EuroPlaNet-RI activities [1], the Planetary Plasma thematic node of IDIS (http://www.europlanet-ri.eu/idis) established in close cooperation between IWF Graz and CDPP Toulouse aims to connect the CDPP/**AMDA** (Automated Multi-Dataset Analysis, http://cdpp-amda.cesr.fr/) SPASE-compatible web-based service for on-line analysis of space physics data (planetary, heliospheric, magnetospheric) together with VO interoperable tools like **Aladin** (http://aladin.u-strasbg.fr/, Figure 2), **VOSpec** (http://esavo.esa.int/vospec/), and **Topcat** (http://www.star.bris.ac.uk/~mbt/topcat/) used mainly by astronomical communities.

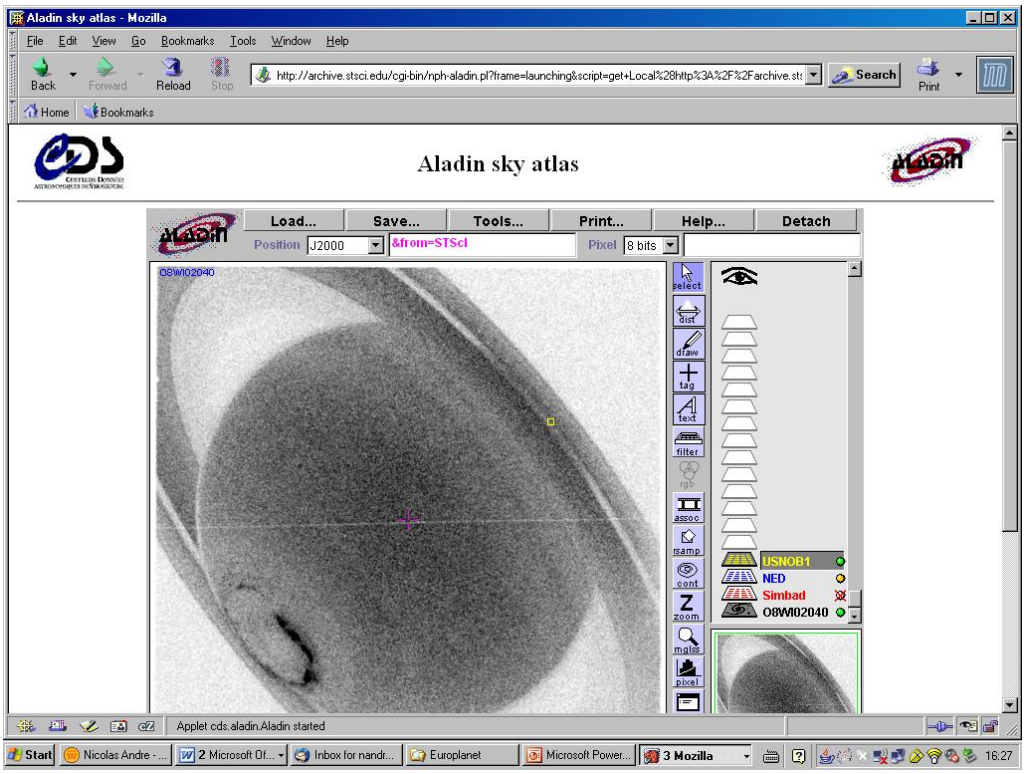

Figure 2: Saturn auroral emissions observed by HST and displayed using Aladin.

The extension of our CDPP/**AMDA** service to the relevant astronomical data and IVOA tools will open a new window in our understanding of comparative auroral and magnetospheric physics of giant planets and enhance the scientific return of previous, current and future (NASA/Juno) planetary missions to these environments. Our extended service will ultimately serve and benefit the European planetology community (and beyond) as well as promote and enlarge the application domain of astronomical VO tools. Also, this will consist of one of the first experiment to combine tools at the interface of the plasma (SPASE) and astronomy (IVOA) communities.

PRESENTATION OF CDPP AND ITS AMDA SERVICE

The CDPP (http://cdpp.cesr.fr/, Centre de Données de Physique des Plasmas) is the french national centre for space physics data. It was jointly created by CNES (Centre National d'Etudes Spatiales) and CNRS (Centre National de la Recherche Scientifique) in 1998. Recently, the CDPP has opened a new web-based service, **AMDA** [2].

This service offers "classical" functionalities such as data extraction, merging or visualization but also innovative ones such as user-edited automated search or computation on the content of the data as well as the creation and the use of time-tables (VOTable). **AMDA** is also evolving in the Virtual Observatory paradigm. It gives a direct access to data from distant databases and includes a data access layer compliant with the SPASE (http://www.spase-group.org/) standards. Finally, **AMDA** produces, manipulates and uses time tables. The time tables can be seen as one of the primary brick to be used for the interoperable exchanges in space physics.

MULTI-WAVELENGTH OBSERVATIONS OF GIANT PLANETS AURORAL EMISSIONS

Remote sensing of giant planet auroral emissions from x-ray to radio wavelengths has provided not only a unique tool for the global understanding of the large-scale coupling between the ionosphere, the magnetosphere and the solar wind [3,4,5,6,7] of planets, but also a wealth of information about their micro-physical generation mechanisms. These auroral emissions being triggered by magnetospheric precipitating particle beams, they mark the moon footprints, and the main auroral oval as well as polar emissions, each one bearing the signature of different triggering particles.

Each wavelength regime revealed a different aspect of planetary auroral processes. UV, IR and radio observations revealed the complex interplay of plasma sources (solar wind, satellites, ionosphere, rings...) and energy sources (solar wind, planetary rotation) in and above the ionosphere. X-ray observations indicated that precipitation of both energetic heavy ions and electrons energized in the outer magnetosphere contribute to auroral excitation, whereas IR observations additionally revealed the planetary thermal structure as well as the dynamics of the thermospheric wind system.

Whereas imaging provided the **spatial** distribution and **temporal** variability of giant planet auroral emissions, **multispectral** spectroscopy provide crucial information about the populations of magnetospheric particles responsibles of those emissions (energy range, acceleration process) and the characteristics of the interface magnetosphere/ionosphere (altitude of emission, ionospheric composition, existence of cavities depleted in plasma).

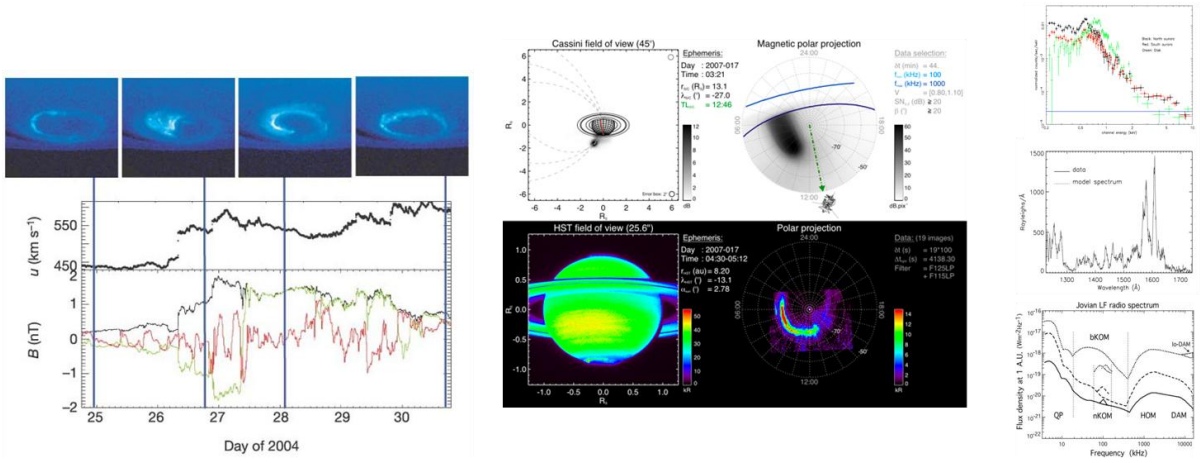

Figure 3: Schematic illustrating potential applications of VO tools to provide temporal, spatial and multispectral information on the coupled SWMITA system. Left panel: Time series of Cassini magnetometer in-situ observations (data reachable via **AMDA**) together with simultaneous HST observations of Saturn auroral UV emissions (preview possible via **Aladin**). Middle panel: Spatial localization/projection of Saturn radio (top, Cassini RPWS observations, data reachable via **AMDA**) and UV (bottom, HST STIS observations, data preview via **Aladin** and plot editor via **Topcat**) auroral emissions [5]. Right panel: Multi-spectral (X, UV, Radio) observations of Jupiter auroral emissions (combined visualization possible via **VOSpec**).

TARGETED VO TOOLS

All the observations mentioned previously remain however to be fully integrated into a coherent picture, which requires acces to large data archives from diverse origins, and use of different software tools appropriate for the visualization and scientific analysis of the observed phenomena. We have already identified several available VO-tools that will help us to reach our objectives, e.g. :

- **Data discovery: Aladin** is an interactive software that will enable our users to access and visualize/preview digitized astronomical images of Jupiter and Saturn auroral emissions in combination with solar wind and magnetospheric data reachable via **AMDA**, hence providing temporal and (limited) spatial information on the SWMITA system as illustrated in Figure 3 (left and middle panels).

- **Spectral Analysis: VOSPec** will provide our users with analysis capabilities and easy integration of spectra coming from different astronomical data providers, hence providing multispectral information on the SWMITA system as illustrated in Figure 3 (right panel).

- **Data visualization: Topcat** is an interactive graphical viewer and editor that could enable our users to manipulate astronomical data (including FITS and VOTable) and display 3-d spherical polar plots of observations, hence providing spatial information on the SWMITA system as illustrated in Figure 3 (middle panel).

OUR PROPOSED APPROACH

On a practical side, our proposed approach consists of a step by step approach, following the analysis of our fully developed use case requirements [1]:

- **Data Finder:** learn how to find all existing astronomical giant planet auroral observations 1) in UV (e.g., from the HST Science Data Archive), 2) in X-ray (e.g., from the XMM-Newton Science Archive), 3) in IR and 4) in Radio, using available astronomical catalogues, VO and associated search engines;

- **Data Access:** learn how to understand and read the corresponding data and metadata, together with their calibration files (standard(s), protocol(s), ...);

- **Use of Existing Tools:** learn how to use the VO tools mentioned previously with the corresponding astronomical data 1) as they stand, 2) but also with existing planetary data on giant planet auroral emissions obtained from planetary spacecraft (e.g., from the Cassini UVIS, Cassini VIMS, Galileo UVS instruments), and 3) identify the technical and scientific limitations (if any) of these VO tools in order to satisfy our requirements;

- **Adaptation of Existing Tools to our Needs:** learn how to extend the existing tools and develop relevant and associated Added Value Services in order to fully satisfy our requirements;

- **Connection between AMDA and VO tools:** learn how to connect our AMDA service with corresponding data and tools in an interoperable or integrated way;

- **Preparing future perspectives:** learn how to apply the experience gained to solar observations for the participation of CDPP to Heliophysics VO (e.g., Helio FP7 project).

Our project has recently been submitted for technical support to EURO-VO.

REFERENCES

[1] - André et al. (2009), A science case for IDIS: Giant planet auroral and radio emissions; Connecting the CDPP/AMDA service and IVOA tools in the future, session MT8 on Management and Exploitation of Planetary Data through Planetary VO tools and services, European Planetary Science Congress, 13-18 September 2009, Potsdam, Germany

[2] - Jacquey et al. (2008), AMDA, Automated Multi-Dataset Analysis: A web-based service provided by the CDPP, in press in the proceedings of the 15th Cluster Workshop

[3] - Prangé et al. (2004), An interplanetary shock traced by planetary auroral storms from the Sun to Saturn, Nature, 432

[4] - Bhardwaj, A. and G.R. Gladstone (2000), Auroral emissions of the giant planets, Reviews of Geophysics, 38(3)

[5] - Lamy, L. (2008), Etude des émissions radio aurorales de Saturne, modélisation et aurores UV. Thèse de Doctorat, Plasmas, Université Pierre et Marie Curie (P6)

[6] - Clarke et al. (2006), Response of Jupiter's and Saturn's auroral activity to the solar wind, Journal of Geophysical Research, 114(5)

[7] - Cravens et al. (2003), Implications of Jovian X-ray emission for magnetosphere-ionosphere coupling, Journal of Geophysical Research, 108(12), SMP 25-1, 1465