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CONNECTING THE CDPP/AMDA SERVICE TO PLANETARY PLASMA DATA: VENUS, EARTH, MARS, SATURN (JUPITER AND COMETS)

André, N.[1], Cecconi, B.[2], Budnik, E.[3], Jacquey, C.[1], Génot, V.[1], Fedorov, A.[4], Gangloff, M.[1], Pallier, E.[4], Bouchemit, M.[1], Hitier, R.[5], Dériot, F.[6], Heulet, D.[7] and Topf, F.[8]

Abstract. 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 (magnetospheric, heliospheric, planetary plasmas) coming from either its local database or distant ones. This tool allows the user to perform on line classical manipulations such as data visualization, parameter computation or data extraction. AMDA also offers innovative functionalities such as event search on the content of the data in either visual or automated way. AMDA has been recently integrated as a service to the scientific community for the Plasma Physics thematic node of the EuroPlaNet IDIS (Integrated and Distributed Information Service) activities. We will present the service AMDA and the planetary plasma data accessible via the service. We will then illustrate some of its applications (boundary identification and planetary space weather) for the comparative analysis of the planetary ionized environments. We will finally discuss future developments under study at CDPP to integrate with AMDA new datasets (Jupiter, comets) and new (astronomical) tools.

1 Introduction

The field of planetary sciences has greatly expanded in recent years with missions orbiting around most of the planets of our Solar System. The growing amount and wealth of data available to researchers makes it clear that our understanding of the planetary objects and of their space environments 1) requires multi-disciplinary studies and 2) should greatly benefit from comparative studies. However, until now, the number of such comparative studies has been quite limited, each planets being studied to a large extent as unique objects. One of the main difficulties to do such comparative studies is that scientists have to exploit together data coming from many sources which can initially be heterogeneous in their organization, description and format. To overcome this difficulty and makes this task easier to all scientists, innovative tools taking advantage of mass storage, computer power and web technologies have to be developed and offered to the community. This is the general idea behind the Virtual Observatory paradigm.

2 The CDPP and its AMDA service

The CDPP (Centre de Données de Physique des Plasmas) is the French national centre for space physics data. Recently, the CDPP has opened a new web-based service, AMDA (Automated Multi-Dataset Analysis, http://cdpp-amda.cesr.fr/), which is a web-based facility for on line analysis of space physics data coming from either its local database or distant ones. AMDA allows the user to perform on line classical manipulations such as

[1] CDPP & CESR, CNRS/Université Paul Sabatier, 9, avenue du colonel Roche, 31028 Toulouse, France
[2] LESIA, Observatoire Paris-Meudon, 92195 Meudon, France
[3] NOVELTIS, 2 Avenue Europe, 31520 Ramonville Saint Agne, France
[4] CESR, CNRS/Université Paul Sabatier, 9, avenue du colonel Roche, 31028 Toulouse, France
[5] Co-Libri, Cremefer 11290 Montréal, France
[6] CNES, 18 avenue Edouard Belin, 31400 Toulouse, France
[7] CNES, 18 avenue Edouard Belin, 31400 Toulouse, France
[8] Space Research Institute, Austrian Academy of Sciences, Graz, Austria

data visualization, parameter computation or data extraction. AMDA also offers innovative functionalities such as event search on the content of the data in either visual or automated way. These functionalities extendable for automated recognition of specific signatures can be used for performing classification of events and for generating time-tables and catalogues (Jacquey et al., 2009; Génot et al., 2009; André et al., 2009). 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, the time tables produced and used by AMDA can be seen as one of the primary brick to be used for the interoperable exchanges in space physics. Whereas the AMDA service was primarily designed for heliospheric and magnetospheric science at Earth, where in-depth studies generally request the analysis of multi-point and multi-instruments data, it has been recently extended to planetary plasma science for the same reasons.

3 Planetary Plasma Data Accessible via AMDA

In the context of its EuroPlaNet-RI IDIS activities, the CDPP has recently included Mars and Venus Express ASPERA data in the local database of AMDA, and set up an interoperable connection between AMDA and the VEX/MAG database hosted by IWF Graz. This service will be publicly opened to the planetary community in December 2009; this will add to the already remotely connected Cassini MAPSKP (from CESR, http://mapskp.cesr.fr) and SKR (from LESIA) data at Saturn. In addition, various electromagnetic field and particle data on the Earth's magnetosphere have been obtained by numerous instruments on board a variety of spacecraft and CDPP has a long heritage in archiving many of these data sets. Widely-used data from spacecraft like THEMIS, Cluster, DoubleStar, IMP-8, Geotail, ISEE-1 and 2, ACE, WIND , as well as a variety of geomagnetic indices that diagnose the state of the terrestrial magnetosphere, have therefore been made accessible via AMDA. To register to AMDA, a user just needs to send an email to amda@cesr.fr.

4 Example science cases: Planetary boundary identification and planetary space weather

Planetary environments contain plasma of various origins, hence, with various composition and energy. These different plasma populations structure the environment and their identification can be used to define magnetospheric regions and boundaries, where exchanges of mass, momentum and energy take place. The magnetospheres of Mars, the Earth and Venus share common features such as a bow shock, magnetopause (Earth, Saturn and other magnetized planets) or ion composition boundary (Mars, Venus), and magnetotails. From the definitions of these boundaries, it may be possible to identify automatically a bow shock by looking at the flow deceleration and/or plasma heating, a magnetopause or ion composition boundary layer by looking at magnetic field increases and/or changing plasma composition, and a current sheet crossings in planetary magnetotails by searching for changes of the polarity of the Sun-planet magnetic field component which occur when the spacecraft effectively crosses the neutral sheet. Figure 1 illustrates the AMDA-based identification of 1) a current sheet in the magnetotail of Venus and of 2) multiple magnetopause crossings at Saturn.

These years, the Solar System plasma environment is currently explored by an exceptional set of observatories providing continuous observations of the Sun and its corona, in situ plasma and field measurements obtained in the vicinity of various planets, and inside the heliosphere. This wealth of data will offer previously unequalled opportunities to study global and multi-scale phenomena of the inner heliosphere, the propagation of the solar perturbations and space meteorology, local interplanetary conditions around planets and the comparison of the ionised environments of various planets. We consider the case of a user who is interested to study the response of the Martian, Terrestrial and Venusian magnetospheres during the passage of solar wind disturbances. Whereas the lack of solar wind monitor in the vicinity of Mars and Venus makes this kind of study more challenging, the solar wind properties at Earth are continuously and routinely monitored by various spacecraft (SOHO, ACE, WIND). We take advantage of a particularly favorable configuration of the planets and satellites in the inner heliosphere in November 2007 when Venus, ACE (orbiting the Earth) and Mars were more or less radially aligned. We focus our attention on the last ICME reported during the year 2007, and we used AMDA to time-shift ACE solar wind observations at Earth by the appropriate time delay to reach Mars and superpose the time-shifted ACE observations on top of MEX ASPERA ELS observations, in order to look if and how this ICME may have impacted the Martian environment (André et al., 2009). Figure 2 displays the end results. Modifications of the response of the Martian environment appear clearly in the MEX/ASPERA ELS observations, with enhanced electron fluxes at all energies (especially for low-energy and suprathermal electrons) observed at the time of the

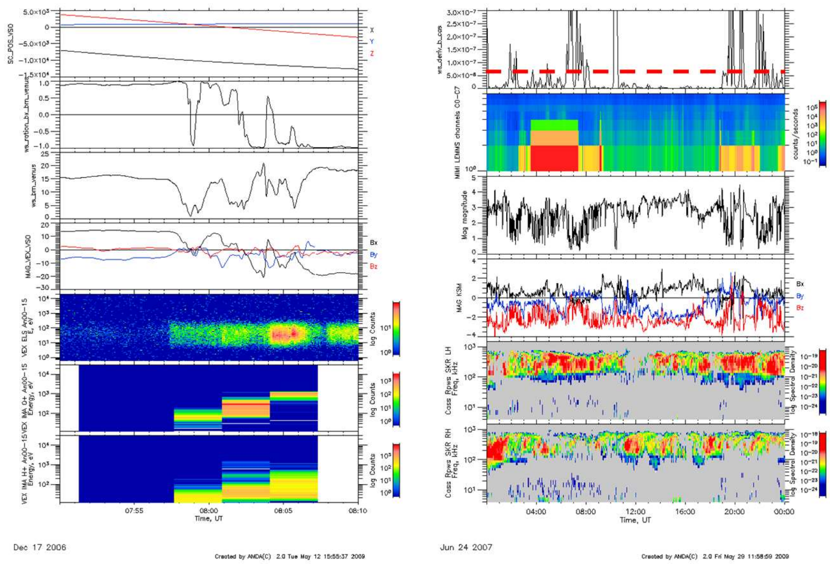

Fig. 1. Let: Crossing of a magnetotail current sheet at Venus. From top to bottom: Time series of VEX trajectory, ratio B_x/B_m, VEX/MAG magnetic field intensity B_m, (VSO) magnetic field components, VEX/ASPERA electron, oxygen and proton counts. Right: Magnetopause crossings at Saturn. From top to bottom: Time series of (squared and normalized) time-derivative of Cassini MAG magnetic field intensity, MIMI-LEMMS electron counts, MAG (KSM) magnetic field intensity and components, RPWS left- and right-handed polarized Saturn Kilometric Radiation emissions.

arrival of the solar wind perturbation.

5 Perspectives: Giant planet auroral emissions and Jupiter Science Archive

AMDA is in continuous development and user feedback is welcome (amda@cesr.fr). Future developments under study at CDPP to exploit planetary plasma data concern 1) the connection to other generic (analysis and simulation) tools in space physics or in astronomy, as well as 2) the accessibility of new datasets in AMDA (Jupiter and comets) thanks to a potential collaboration with other data centers (e.g., ESA PSA and NASA PDS). Multi-wavelength remote sensing of giant planet auroral emissions provide a unique tool for the global understanding of the large-scale coupling between the planetary ionosphere, the magnetosphere and the solar wind. In the context of our EuroPlaNet-RI activities, the CDPP aims to connect its AMDA service together with VO interoperable tools like Aladin. The extension of our AMDA service to the relevant astronomical data (e.g., HST) and IVOA tools will open a new window in our understanding of comparative auroral and magnetospheric physics of giant planets. This will consist of one of the first experiment to combine tools at the interface of the plasma (SPASE) and astronomy (IVOA) communities. Support from Euro-VO has been requested to follow this development. Finally, in the context of the preparation of the NASA/ESA Europa Jupiter System Mission (EJSM), the CDPP aims to develop a service to connect AMDA with magnetospheric and plasma observations obtained by previous missions having flown by or orbited Jupiter. Indeed, the preparation of EJSM will stimulate new scientific, instrumental, and engineering studies that will rely on a deep re-analysis of the existing datasets. Support from CNES has been requested to integrate locally plasma observations (not raw data but physical parameters) at CDPP, for the benefit of a broad science community.

References

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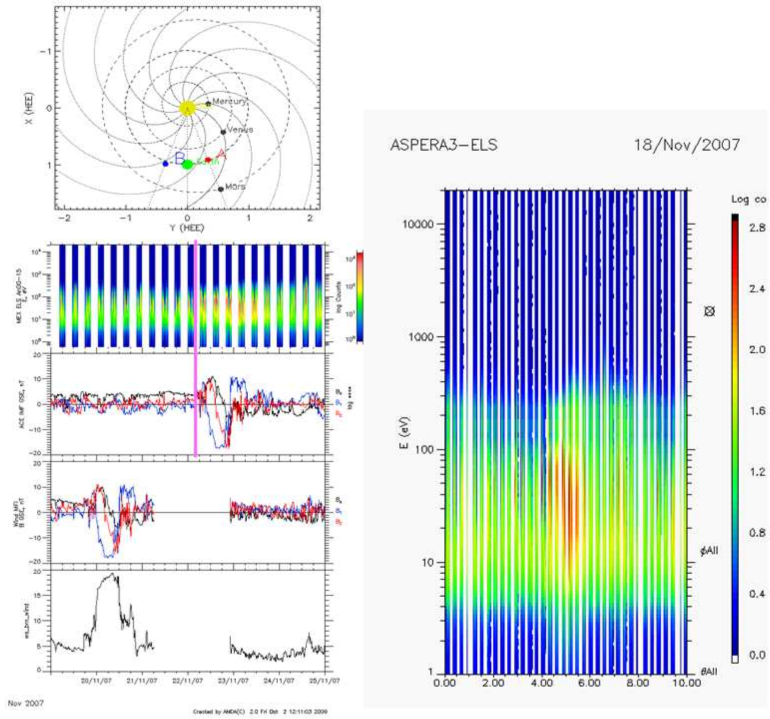

Fig. 2. Top left: position of the planets in the heliosphere on 14/11/2007. Bottom left: AMDA plot showing (from top to bottom): Time series of MEX ASPERA/ELS electron counts, time-shifted ACE/MAG (GSE) magnetic field components, WIND (GSE) magnetic field components and intensity (without time-shift), from 19/11 to 25/11/2007. Right: Zoom in on MEX/ASPERA ELS counts.

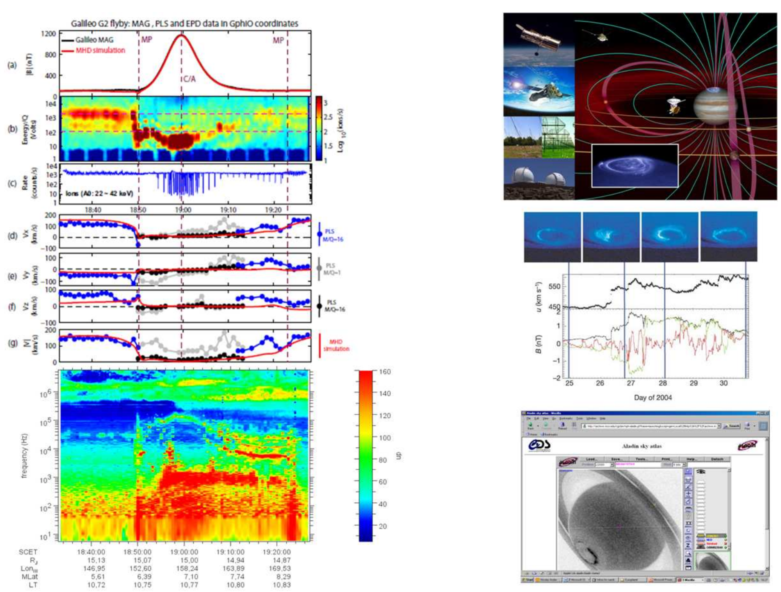

Fig. 3. Left: Multi-instrumental view of the G2 Gallileo Ganymede flyby. From top to bottom: Time series of magnetic field, low-energy ion plasma, energetic particle, plasma bulk velocity and frequency-time spectrogram of radio emissions (data obtained from NASA PDS). Right: Schematic illustrating potential applications of VO tools to couple in situ plasma (Cassini data) and remote multi-wavelength auroral observations (HST data at Saturn previewed with Aladin).