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EVOLUTIONS OF THE VIRTUAL OBSERVATORY

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Abstract. The paper describes the status of the astronomical Virtual Observatory, and introduces the new European projects of the Seventh Framework Programme, EuroVO-AIDA (Astronomical Infrastructure for Data Access) and EuroPlaNet Research Infrastructure. The role of the *Action Spécifique Observatoires Virtuels France* is also discussed.

1 Introduction

The objective of the Virtual Observatory (VO) is to provide seamless and transparent query of on-line data and services, with tools, in particular for data visualisation, processing and analysis. The VO also offers data centers a framework of standards and tools to "publish" their data and services in the VO.

The VO concept has emerged in 1999/2000, and the first projects have been funded in 2001, among which the European Phase A project, *Astrophysical Virtual Observatory* (AVO) . The VO is now in transition to operations, and it appears in the AstroNet European Roadmap as one essential infrastructure of astronomy.

At European level, the VO development is coordinated by the Euro-VO project, a best effort alliance of 8 partners (France, Germany, Italy, the Netherlands, Spain, the United Kingdom, and the two European Agencies, ESA and ESO). Building on the expertise gained during Phase A, Euro-VO is organised in three interacting parts: the *Euro-VO Data Centre Alliance* (DCA), led by the *Centre de Données astronomiques de Strasbourg* (CDS), a network of data centres which populate the system with data, metadata and services; the *Euro-VO Technology Centre* (VOTC), led by AstroGrid (the UK VO project), a distributed organisation which coordinates a set of research and development projects on the advancement of VO technology, systems and tools; and the *Euro-VO Facility Centre* (VOFC), led by ESA and ESO, which provides a registry of resources as well as community support for VO take-up and dissemination.

The following sections follow the Euro-VO structure: Section 2 describes the status of the construction of VO technical infrastructure, Section 3 deals with data centres in the VO and with the Euro-VO DCA Coordination Action, and Section 4 with interaction with users. Finally, Section 5 describes the new European VO project in astronomy (Euro-VO Astronomical Infrastructure for Data Access - EuroVO-AIDA) and the emergence of an international coordination in the field of planetary studies (the International Planetary Data Alliance and the EuroPlaNet projects of the Sixth and Seventh Framework Programmes). The conclusion summarizes open questions on the evolution of the *Action Spcifique Observatoires Virtuels France*.

2 Building the VO technical infrastructure

National VO projects are all different. For instance, in France, the *Action Spécifique Observatoires Virtuels France* (ASOV) coordinates French participation in the VO development, with a small amount of "triggering" money from INSU and CNES. The work force is coming from the commitment of research laboratories. In other countries VO projects also pay for human resources engaged in the VO development.

The astronomical VO aims at building *a single VO* to access all astronomical data available world-wide, and it was realized early that internationally agreed interoperability standards were the key, which would allow VO tools to communicate with all VO-enabled data and services for data discovery, retrieval and analysis. The first structure which tackled the development of interoperability standards was a Working Group formed by the

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OPTICON European network in 2000, led by CDS, which included from the beginning membership from USA and Canada. It was shortly superseded by the *International Virtual Observatory Alliance* (IVOA), founded in 2002 by the three projects which had then started (AVO for Europe, the USA *National Virtual Observatory* and AstroGrid). The IVOA is an alliance of the national and continental VO projects, with presently (mid-2008) 16 members including France and Euro-VO. It coordinates the definition of the VO interoperability standards, and has created Working Groups and Interest Groups to tackle the different aspects (Fig. 1).

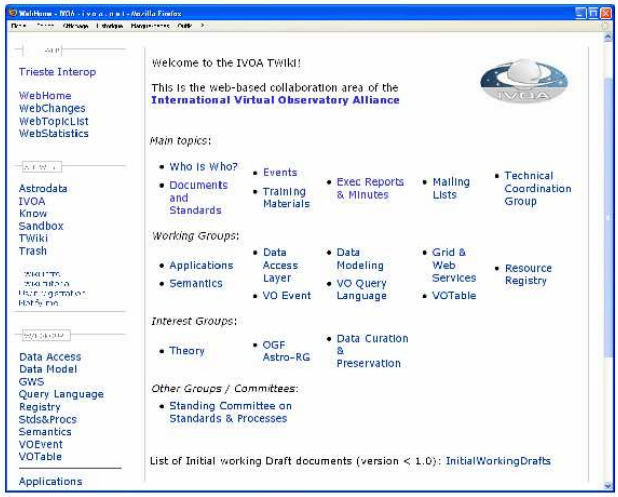

Fig. 1. Summary of IVOA activities, showing in particular the list of IVOA Working Groups and Interest Groups (copy of a web page from the IVOA web site).

At the European level, the VOTC is as explained earlier a distributed entity. One component of VOTC is the VO-TECH Design Study (2005-2008), led by AstroGrid, with three British Universities (Edinburgh, Cambridge, Leicester), CDS, ESO and INAF as partners. The ESA-VO project is also an important contributor.

In France, the CDS has been involved in the development of VO interoperability standards from the beginning (e.g. VOTable, Ochsenbein et al. 2002), and at present many French groups participate actively in IVOA activities. Mid-2008, several Working Groups and Interest Groups (Applications, Data Model, Semantics, Theory, VOTable) have French leadership, and French teams are significantly contributing to many standards.

The development of standards for Theory is one interesting recent evolution of IVOA. The main objectives are to give access to simulation services or to simulation results, and to be able to compare simulation results with observations. French teams have been among the pioneers in this domain (Wozniak 2004), and Theory was one of the first Working Groups created by ASOV in 2004. The IVOA also formed a Theory Interest Group in 2004, with the goal of ensuring that theoretical data and services are taken into account in the IVOA standards process. A significant effort has been devoted to the assessment and definition of standards for the theoretical VO, with support in particular of the *Euro-VO Data Center Alliance* project, which is described in the next section. EuroVO-DCA has a specific work package led by the *Max Planck Institut fur extraterrestrische Physik*, with a strong French and Italian participation. In France teams from the LUTH, the CRAL and the OSUB are actively involved, respectively in Paris, Lyon and Besançon Observatories. They assess the standards on very different types of services: the HORIZON project, microphysics code (e.g. photoionized or photodissociation regions), and the Besançon model of stellar population synthesis of the Galaxy. Several services are available on-line, for instance, the GalMer simulations of the Horizon project (di Matteo et al. 2007), which implement several of the IVOA standards, or the Besançon model (Debray et al. 2006).

3 Data centres in the VO

Data centres are the essential building blocks of the VO. They provide different types of services, such as data archives, added-value services, tools, software suites, theory results and services. They are very different in size, and work in different contexts, from observation archives maintained by large Agencies to small teams in scientific laboratories. They however all share the same keywords: providing a service to users, caring for quality, and having at least some kind of medium term sustainability. The ASOV has performed a first census of French data centres in the VO context in 2005 (more than 40 answers), which has been updated in 2006, and effectively shows a wide diversity.

At European level, actions towards data centres are currently tackled by the *Euro-VO Data Centre Alliance* project. EuroVO-DCA is a Coordination Action of the *e*Infrastructure *Communication Network Development* programme, which started in September 2006 for 28 months, and is supported at the level of 1.5 MEuro by the European Commission. It is led by CNRS and gathers the 8 Euro-VO partners. The main objective is to help European data centres to publish their data and services in the VO. It also has work packages dealing more specifically with Theory, as explained above, and with connections with the computational Grid, plus one devoted to support to data centres from other European countries. Detailed information about the project activities is available from the project TWiki page at http://cds.u-strasbg.fr/twikiDCA/bin/view/EuroVODCA/WebHome. The project does not fund the data centres themselves, but organises support actions.

Among the actions organised by the EuroVO-DCA project:

- a census of the European data centres, which has produced more than 65 answers showing as expected a wide diversity;
- two workshops on *how to publish data in the VO*, organised respectively by ESAC in Villafranca in June 2007 and by ESO in Garching in June 2008, aimed at data providers;
- several workshops aiming at improving liaison and information exchange between the VO teams and the community. The first one, *Astronomical Spectroscopy & the Virtual Observatory* (Villafranca, March 2007), dealt with a domain of interest for several of the Euro-VO partners. Two other Workshops were organised back-to-back in Garching in April 2008, in domains of specific interest to EuroVO-DCA: *Theory in the Virtual Observatory* and *Grid and the Virtual Observatory*. Some more details about these workshops will be given in the next section.

4 Liaison with the science community

The 2007 *Astronomical Spectroscopy & the Virtual Observatory* Workshop has been a remarkable success, with more than 130 participants, a significant fraction of them not previously involved in the VO. ASOV has a Working Group in the domain and has been in contact for a long time with the national community on this topic. There has been an active French participation in the Organising Committee, review papers, and discussions during the workshop.

The workshop showed a high level of community expectations. One major requirement is that the "VO layer" must be transparent when seen from the users, which reinforces one of the main VO objectives. The community understands that there is a need for underlying technical work on standards and was ready to give its requirements, but insisted on the fact that standards were needed NOW. It was confirmed that some data producers do not wish to share their data, often by fear of not being cited, or that the data be misused. The only action that the VO can take in these matters is to provide detailed information on data characterisation and provenance, and hope that widespread VO take-up will ease these concerns.

The two 2008 Garching Workshops on Theory and the Grid have also been been excellent occasions for information dissemination and debate. The *Theory in the Virtual Observatory* Workshop has permitted presentation and discussion of different types of models, and nurtured the preparation of IVOA standards. The *Grid and the Virtual Observatory* workshop has allowed a good contact between VO and European and national grid projects.

5 VO projects in FP7

5.1 Euro-VO Astronomical Infrastructure for Data Access

The *Euro-VO Astronomical Infrastructure for Data Access* project has been selected in 2007 in the first Infrastructure Call of the Seventh Framework Programme, in the *Scientific Digital Repositories* framework. Like EuroVO-DCA, EuroVO-AIDA is coordinated by CNRS and gathers the 8 Euro-VO partners. The project will get a support of 2.7 Meuros from the European Commission for 30 months, beginning in February 2008. Its aim is to lead the transition of Euro-VO into an operational phase, and it covers all aspects of Euro-VO (DCA, VOFC and VOTC).

EuroVO-AIDA is an *Integrated Infrastructure Initiative* (I3) with Networking, Service and Joint Research Activities. In terms of the different parts of Euro-VO:

- Support to users (VOFC): Several Workshops will be organised, two "Community Workshops" on specific topics (the first one at ESAC in December 2008 on *Multiwavelength astronomy*), and one "Hands-on" Workshop in March 2008; two Announcement of Opportunities for allowing science teams to get support from VO teams to perform science programmes will also be organised (in June 2008 - this one is closed - and June 2009); on-line tutorials will be provided, as well as tools for science usage of the VO.
- Support to data centres (DCA): an additional workshop on *how to publish data in the VO* will be organised at ESAC in June 2009; "service activities" will provide a registry of resources, tools for data and service providers, and on-line tutorials.
- Technological activities (VOTC) will cover continuous development and adjustments of interoperability standards and assessment of the usage of new technologies (such as the Web 2.0) in the VO context.

An additional, new topic for Euro-VO is outreach, which is tackled by a specific work package of EuroVO-AIDA.

5.2 EuroPlaNet: From IDIS towards a European Planetary VO

The planetary science community has recently launched the International Planetary Data Alliance (IPDA), an international structure focused on the development of standards for data archiving and promotion of interoperability among planetary science data archive systems, with the aim to share scientific results returned from exploration of the solar system. IPDA was invited to the last IVOA Interoperability meeting (Trieste, May 2008). This activity has been actively prepared at the national level for several years by the ASOV *Planetology* Working Group.

The FP6 EuroPlaNet Coordination Action (2005-2008), coordinated by CNRS, included a network devoted to *Integrated & Distributed Information Service* (N7 - IDIS). IDIS provides two general services (a directory of scientists and an inventory of resources). It has focussed its activities on documenting science cases produced by EuroPlaNet Discipline Working Groups in different sub-topics of planetary sciences. It is organised into four thematic nodes, with a significant participation of French laboratories:

- Planetary surfaces and interiors (DLR/IPR Berlin)
- Planetary atmospheres (CNRS/IPSL Paris)
- Space plasmas (CNRS/CESR Toulouse and IWF Graz)
- Small bodies and dust (INAF/IFSI Frascati)

with also a technical node located at FMI (Helsinki).

A new project, *EuroPlaNet Research Infrastructure* (EuroPlaNet RI), also coordinated by CNRS, has been proposed as an I3 in the first 2008 Infrastructure Call. It has been selected for the negociation phase with the European Commission for a total budget of 6 Meuros, and is expected to start its four year term in January 2009. The French participation in EuroPlaNet RI is enlarged with the contribution of Paris Observatory, especially the VO Data Centre. EuroPlaNet RI contains among others an IDIS Service Activity, which will provide web access to a host of data sources from space, ground-based, laboratory work and numerical simulations, and

to modeling and advanced data analysis tools. A companion Joint Research Activity aims at expanding and integrating web services offered by IDIS to prepare a future planetary VO. The share of IDIS JRA and SA, amounts to 1.14 Meuros within the total budget of EuroPlaNet RI.

6 Conclusion

The future of the VO is to be a seamless but important part of the research infrastructure of astronomy, as well stated in the AstroNet Roadmap. The AstroNet census of future infrastructures shows that future large projects actually plan to provide their data in the VO.

In France, the present activities of the VO teams are well described in the Web site of the 2007 ASOV annual meeting. Services and tools are incrementally made available. ASOV has been created to coordinate French participation in the VO development, and with the advent of the VO operational phase one important issue is to find if and how it is possible to help the French community to use the VO capacities at best. The community is encouraged to participate in all European activities, and gets financial support to attend the Workshops. Are there complementary actions to be taken at the national level? Suggestions are welcome, in particular from the National Programmes.

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