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Memorie della

The European Virtual Observatory projects

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Abstract. European teams have been actively participating in the development of the international virtual observatory (VO) since the emergence of the concept in 1999/2000, with commitment of the two European agencies, ESA and ESO, and of national VO projects. This paper describes how coordination at European level has been achieved, taking advantage of several projects funded by the European Commission at different stages of the VO development.

Key words. Virtual Observatory

1. Introduction

The concept of a Virtual Observatory (VO) emerged in 1999/2000: the objective is to provide seamless and transparent query of data centres, with new analysis and visualisation tools, and a standard structure for data centres to publish their data and services in the VO.

The astronomical virtual observatory is presently in transition towards operations. In the following Sections, the successive steps of the project will be described, with particular emphasis on European projects and on a few selected milestones. The reader is invited to refer e.g. to the Euro-VO and international VO pages, respectively at http://www.euro-vo.org/pub/ and at http://www.ivoa.net/, for a more general description of the astronomical VO and for links to the web pages of the national VO projects.

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2. The emergence of the astronomical virtual observatory

The VO was from the very beginning an international endeavour, as demonstrated by the fact that its first two milestones have been two conferences held respectively in USA and in Europe: *Virtual Observatories of the Future* (Pasadena, June 13-16, 2000), and *Mining the Sky* (Garching, July 31 - August 4, 2000).

In Europe, the first pionneering project supported by the European Commission had been *ASTROVIRTEL - Accessing Astronomical Archives as Virtual Telescopes* (2000-2003), managed by ST-ECF on behalf of ESA and ESO. Astrovirtel offered the possibility to exploit their archives as a virtual telescope, with the assistance of archive operators and personnel, through Announcement of Opportunities. Then OPTICON, the European Optical Infrared Coordination Network for Astrnonomy, created two Working Groups in 2000 to prepare European VO proposals: one, led by ESA-ECF, to consider the scientific requirements and associated financial implications, the second, led by CDS, to consider technical requirements and constraints, including interoperability. The two Working Groups effectively participated in the preparation of the first European VO proposal, AVO, which will be described later.

The *OPTICON Interoperability Working Group* also had a wider scope. It had been quickly understood that interoperability was the key for a truly global VO, and the mandate was given to promote technical collaboration with other VO projects, in particular with the US VO community. Working Group membership thus included Americans and Canadians interested in the technical aspects of the VO development, in addition to Europeans data managers from different countries. The Working Group aims, as described in November 2001, were :

- to study *cost effective tools and standards* for improving access and data exchange to/from data archives and information services (bringing minimal workload for adoption);
- to discuss the technical results of the AVO interoperability prototyping;
- to consider the optical/IR (OPTICON) and radio (RadioNet) domains;
- to promote and integrate international partnership beyond European Union: USA (NVO key actors), Canada, Australia.

3. The first VO projects: science requirements and technical assessment

The first VO projects were funded in 2001: the *Astrophysical Virtual Observatory* (AVO) project in Europe, *AstroGrid* in UK, and the *National Virtual Observatory* in USA. [1]

[1] A more focussed project, *Images Distribuées Hétérogènes pour l'Astronomie/Heterogeneous Images for Astronomy*-IDHA, which set the foundations of the *Characterisation* Data Model in close collaboration with AVO, was funded in France at the same time by an Information Technology Announcement of Opportunity (*Action Concertée Incitative GRID*).

The AVO project (2001-2004) was selected for funding by the fifth Framework Programme of the European Community for Research, Technological development and Demonstration activities (FP5), as a Research Infrastructure RTD project. It was a Phase A study with R&D on VO scientific requirements and technology. It was coordinated by ESO, with 6 partners (ESO, ESA-ECF, Astrogrid (the UK VO project), CDS, Terapix, Jodrell Bank), and organised into three Work Packages:

- Science requirements and case (ST-ECF)
- Interoperability (CDS)
- Technologies (AstroGrid)

The AVO project set up a Science Working Group, which produced the AVO Science Reference Mission, and guided the developments. The project strategy was in particular driven by three successful scientific demonstrations: “First Light” in January 2003, “First Science” in January 2004, “Towards the Euro-VO” in January 2005, just after the end of the project.

These demonstrations were used to define and prototype the VO framework, in particular interoperability standards, and as proofs of concept. For instance, the “First Science” demonstration (Padovani et al. 2004) showed a remarkable example of end-to-end usage of VO data and tools producing cutting-edge science, to identify optically faint, obscured (i.e., type 2) active galactic nuclei in the two Great Observatories Origin Deep Survey (GOODS) fields. Candidates were discovered by employing publicly available X-ray and optical data and catalogues, and qualified as QSO-2 using an empirical estimator for the X-ray luminosity. This allowed to go about 3 mag fainter than previously known type-2 AGN in the GOODS fields, and quadrupled the number of QSO-2 in the fields.

During this period, VO teams around the world begun to be very active in the development of the interoperability standards. The first VO standard, VOTable, arose from a discussion between F. Ochsenbein from CDS and R. Williams, then the NVO system architect, who begun to work on the convergence

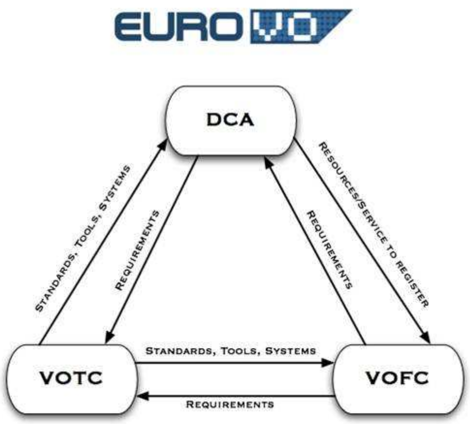

Fig. 1. The three interacting elements of Euro-VO: the Data Centre Alliance (DCA), the Technology Centre (VOTC), and the Facility Centre (VOFC).

of existing XML standards in October 2001. They produced the draft of a standard called VOTable, an XML standard for representing tabular data in the VO context. The draft was widely discussed by email and at the first face-to-face Interoperability meeting, organised in Strasbourg by the OPTICON Working Group in Strasbourg in January 2002, and adopted on April 15, 2002 (Ochsenbein et al. 2002). VOTable has been since then an essential building block of the VO, widely used as data exchange format, thus demonstrating as expected the importance of internationally agreed interoperability standards for the VO development.

The next milestone was another important conference, *Toward an International Virtual Observatory*, jointly organised by ESO, ESA, NASA and NSF, which was held in June 2002. At this conference, Euro-VO, NVO and AstroGrid announced the foundation of the *International Virtual Observatory Alliance* (IVOA), with a mission to *facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating virtual observatory*.

Other VO projects got recognition from their national authorities, and the IVOA now comprises 16 projects (Armenia, Australia, Canada, China, Europe, France, Germany, Hungary, India, Italy, Japan, Korea, Russia, Spain, the United Kingdom, and the United States).

The work of IVOA focuses on the coordination of interoperability standard development (it has succeeded in this task to the OPTICON Interoperability Working Group). The IVOA has defined a formal procedure for adoption of the standards and created Working Groups and Interest Groups to tackle the different aspects of the standard development. The work force comes from the VO projects.

4. Setting the European VO landscape

The development and implementation of the VO in Europe is based on national VO teams and on the VO teams of the two European Agencies, ESA and ESO. Coordination at European level is provided by the Euro-VO, which is a best effort alliance with 8 partners, ESA, ESO, and six national projects in France, Germany, Italy, the Netherlands, Spain, and the United Kingdom.

Building on the expertise gained from the AVO project, the Euro-VO consists in three interacting elements (Fig. 1):

- the Euro-VO Data Centre Alliance (DCA, led by CDS): a network of the European data centres, which populates the system with data, metadata and services, and provides the physical storage and computational fabrics;
- the Euro-VO Technology Centre (VOTC, led by AstroGrid), a distributed organization, coordinating a set of research and development projects on the advancement of VO technology, systems and tools;
- the Euro-VO Facility Centre (VOFC, led by ESA and ESO), which provides the Euro-VO with a persistent, centralized registry for resources, as well as community support for VO take-up and dissemination.

The VOFC provides a ”public face” to the Euro-VO.

As a follow-up from the AVO Phase A, European support was sought for these co-ordination activities. It has unfortunately not been possible to get funding for Euro-VO as a whole from the Sixth Framework Programme, but two projects tackling at least partly DCA and VOTC activities were selected in different Announcement of Opportunities.

VO-TECH (2005-2008) is a Design Study, aimed at completing the technical preparatory work necessary for the construction of the European Virtual Observatory. There are four areas of work: Architecture, Tools, Intelligent resource discovery, and Data mining and visualisation. The project is co-ordinated by the University of Edinburgh for Astrogrid (Universities of Edinburgh, Cambridge, Leicester). CDS, ESO and INAF are also partners. VO-TECH is a component of the **Euro-VO Technology Centre**, together with technical activities from the other Euro-VO parners, in particular ESA-VO. The teams have been meeting bi-yearly, which has proven to be very useful for technical exchange and cooperation. They develop tools such as Aladin (CDS), the AstroGrid Desktop (AstroGrid), VOSpec (ESA), VisIVO (INAF), and work is also devoted e.g. to the general architecture of the VO, to its semantics aspect, to data models and data access layer, to data mining tools, etc.

European teams participate very actively in the interoperability standard development coordinated by the IVOA. One important product of VO-TECH is for instance PLASTIC (Platform for Astronomy Tool InterConnection), a protocol for desktop application interoperability. PLASTIC has had an immediate success among application developers and is the basis for the Simple Application Messaging Protocol (SAMP) which is progressing towards Recommendation in the IVOA. The aim is to provide easy communication from one VO application to another, which is of tremendous importance in the VO paradigm for seamless access to services and tools.

The second proposal selected in the Sixth Framework Programme is the **Euro-VO Data Centre Alliance** (EuroVO-DCA, 2006-2008). This project, which is a Coordination Action of the *Communication Network Development* programme, is coordinated by CDS/CNRS and gathers all Euro-VO partners. The aim is to support European data centres in their take-up of the VO framework (the project does not fund the data centre activities themselves). There are six strands of work:

- co-ordinate the national and European Agencies VO initiatives, to implement networking of European data centres (Work Package 2, CNRS);
- disseminate knowledge and good practice about the VO technical framework (WP3, ESA/ESO);
- organise feedback from implementation of interoperability standards (WP3-2, Astrogrid/Leicester University);
- prepare the inclusion of theoretical astronomy in the VO framework (WP4, MPE);
- *seek coordination with national and international projects for computational Grids* (WP5, INAF);
- help data centres from beyond the partners' countries to participate in the VO endeavour (WP6, INTA).

The present workshop *Grid and the Virtual Observatory*, as well as its companion workshop *Theory in the Virtual Observatory*, which was held on April 9-11, 2008, have been organised under the auspices of EuroVO-DCA, by WP5 and WP4 respectively.

As a Coordination Action, networking aspects are very important for EuroVO-DCA, and workshops aimed at data centres are also organised on *how to publish data in the VO* (the first such workshop had been organised in 2005 in Garching by the Euro-VO partners). A census of European astronomy data centres which provide observational archives and data products, archives and services for theory, and/or services, tools and software, has also been performed, with more than 65 answers. This draws a rich landscape of data centres covering a wide range of scientific areas of astronomy and wavelength regimes.

European funds have of course been complemented by funds from national and European Agencies for the technological developments and the take-off of the VO framework by data centres. The Euro-VO Facility Centre did not get European fund to support VO usage by the science community, but some activities were nevertheless undertaken, on Euro-VO partners' funds, plus some support from the OPTICON and Radionet FP6 Integrated Infrastructure Initiatives. In particular a Science Advisory Committee composed of independent scientists was formed, ESO ensuring the scientific secretariship, and a prototype Call for proposal was launched in 2006.

In addition to guidance by the Science Advisory Committee, it is very important to create occasions to gather input and feedback directly from the community. A workshop was organised with this purpose in March 2007 at ESAC in Villafranca del Castilloby by the EuroVO-DCA project and the Euro-VO Facility Centre , *Astronomical Spectroscopy & the Virtual Observatory*. This workshop raised lots of interest, with an unexpectedly high number of participants (more than 130, a large fraction of them not previously involved in the VO) and very lively debates. Participants expressed high expectations, and their requirements have influenced subsequent implementation of VO standards and tools.

5. Transition to operations: EuroVO-AIDA

In 2007, the VO framework was essentially ready and progressively implemented by many data centres all over the world, and the VO projects were in transition to operations: widespread implementation by data centres and usage by the science community, gathering of additional requirements and of feedback from implementation and usage from the science community and from data centres, evolution of the interoperability standards and of tools following these requirements.

A project aiming at supporting transition of Euro-VO to operations, *Euro-VO Astronomical Infrastructure for Data Access* (EuroVO-AIDA), was successfully submitted to the first Infrastructure Announcement of Opportunity of the Seventh Framework Programme, *Scientific Digital Repositories*, in May 2007. This project is an "Integrated Infrastructure Initiative", with the usual three types of activities: *Networking*, *Service Activities*, and *Joint Research Activities* for Research & Technology developments. It is coordinated by CDS/CNRS, and has the same partners as Euro-VO.

EuroVO-AIDA includes all Euro-VO activities, and thus, for the first time, support of users. Among the activities in support of users, two workshops focussed on different topics will be organised to gather science needs and feedback from usage (the first of these meetings, dealing with multiwavelength astronomy, will be held in December 2008 at ESAC); one User "Hands-on" workshop will be organised in March 2009 by ESO, as well as two calls for proposals, in June 2008 and June 2009; plus the development of tools and on-line tutorials. Activities in support of data centres include workshops similar to the EuroVO-DCA ones, and services such as a European registry of resources, tools and tutorials.

Activities in support of technology developments include the organisation of bi-yearly "Technology Forums", to continue the very successful regular meetings initiated by VO-TECH; continuation of the development of interoperability standard and of participation in IVOA activities; and assessment of new technologies in domains such as the Web 2.0, semantics and data mining. One Work Package is devoted to a new topic for Euro-VO, outreach. Detailed information about the project can be found on the project TWiki site.

6. Conclusion

The astronomical Virtual Observatory can be viewed as a data grid, and at present the astronomical VO is a rare example of an operational, world-wide data and service grid. The VO may have to re-use Grid developments, in particular in the domain of authentication/authorization, and is aiming to be able to interact with the computational Grid.

Relationship with the computational Grid are explored in particular in the EuroVO-DCA project, hence this workshop, and through the Astro Research Group (Astro-RG) of the Open Grid Forum, which is also an Interest Group of the International Virtual Observatory Alliance. Several Euro-VO partners develop their own Grid activities, as shown in several talks of the Workshop, and concertation with Grid project is also using European channels, for instance through the OGF-Europe project, and the implementation of the Astro cluster in EGEE.

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