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Euro-VO—Coordination of virtual observatory activities in Europe

Françoise Genova [a,*], Mark G. Allen [a], Christophe Arviset [b], Andy Lawrence [c], Fabio Pasian [d], Enrique Solano [e,f], Joachim Wambsganss [g]

[a] Observatoire Astronomique de Strasbourg, Université de Strasbourg - CNRS UMR 7550, 11 rue de l'Université, Strasbourg, France
[b] ESA-ESAC, POBOX 78, 28691 Villanueva de la Canada, Madrid, Spain
[c] Institute for Astronomy, University of Edinburgh, Scottish Universities Physics Alliance (SUPA), Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, UK
[d] INAF - Astronomical Observatory of Trieste, Via G.B. Tiepolo 11, 3114, Trieste, Italy
[e] Centro de Astrobiología (INTA-CSIC), Departamento de Astrofísica, Campus Villafranca, P.O. Box 78, E-28691 Villanueva de la Cañada, Madrid, Spain
[f] Spanish Virtual Observatory, Spain
[g] Zentrum für Astronomie der Universität Heidelberg (ZAH), Astronomisches Rechen-Institut (ARI), Mönchhofstr. 12-14, 69120 Heidelberg, Germany

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ABSTRACT

The European Virtual Observatory Euro-VO has been coordinating European VO activities through a series of projects co-funded by the European Commission over the last 15 years. The bulk of VO work in Europe is ensured by the national VO initiatives and those of intergovernmental agencies. VO activities at the European level coordinate the work in support of the three "pillars" of the Virtual Observatory: support to the scientific community, take-up by the data providers, and technological activities. Several Euro-VO projects have also provided direct support to selected developments and prototyping. This paper explains the methodology used by Euro-VO over the years. It summarises the activities which were performed and their evolutions at different stages of the development of the VO, explains the Euro-VO role with respect to the international and national levels of VO activities, details the lessons learnt for best practices for the coordination of the VO building blocks, and the liaison with other European initiatives, documenting the added-value of European coordination. Finally, the current status and next steps of Euro-VO are briefly addressed.

1. Introduction: Why a European Virtual Observatory project?

The digital revolution is bringing a change in paradigm in the way science is done. Astronomy has long been at the forefront for widespread sharing and re-use of data, with a new step towards interoperability and data integration through the development of the astronomical Virtual Observatory (VO). The concept of a Virtual Observatory is that astronomical data worldwide should be accessible through common protocols, with interoperability standards for metadata and tools so that access and use of the data become seamless. VO is embraced as a world-wide community-based initiative that is transforming and restructuring the way astronomy research is done.

The VO has now reached a significant level of maturity and provides an operational framework for interoperable and efficient access to world-wide astronomical data and services. The construction of the VO has followed a predominantly bottom-up, incremental, pragmatic approach that has been carefully matched to the needs of the astronomical community. This has been supported by national VO initiatives and data centres, with a significant contribution from the European VO initiatives. Having reached this level of maturity, it is now timely to write its history and to describe how it was built and the lessons learnt over the years. This paper is focused on the European Virtual Observatory, Euro-VO. The main role of Euro-VO has been to coordinate European VO activities, with also for some of the European projects support to technological activities. This paper will highlight the main VO building blocks and lessons learnt on how to coordinate them.

The astronomical VO was conceived from the beginning as a global endeavour, and European participants were among the founding members together with similarly interested US-based participants. The two colloquia which set the scene in 2000,

* Corresponding author.
E-mail addresses: francoise.genova@astro.unistra.fr (F. Genova), mark.allen@astro.unistra.fr (M.G. Allen), christophe.arviset@esa.int (C. Arviset), al@roe.ac.uk (A. Lawrence), pasian@oats.inaf.it (F. Pasian), esm@cab.inta-csic.es (E. Solano), jkw@ari.uni-heidelberg.de (J. Wambsganss).

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Virtual Observatories of the Future and *Mining the Sky*, were organised respectively in Pasadena (USA) on June 13th–16th and in Garching near Munich (Germany) on July 31st–August 4th, both with an international Programme Committee. Then the International Virtual Observatory Alliance (IVOA) was founded during the Conference *Towards an International Virtual Observatory* held in 2002 in Garching, June 10th–14th.

Formal participation in the VO is based on national and international collaborations gathering development teams and data providers, as stated in the "Guidelines for participation of the International Virtual Observatory Alliance" (Hanisch et al., 2010). VO initiatives from several European countries are IVOA members, as is the European Space Agency (ESA), which is an intergovernmental organisation. The potential usefulness of the coordination of VO activities at the European level was recognised very early. A mechanism was needed to bring the relevant parties together.

Funding by the European Commission through its successive Framework Programmes (FP) has a strong structuring role for astronomy in the European countries, as well as the two intergovernmental organisations ESA and ESO which pool resources from their member countries to realise large space- and ground based programmes. It thus appeared natural to set up a coordination of the VO activities at that level, which soon became the European Virtual Observatory Euro-VO. Inclusive federation of complementary expertise with a light organisational structure and an evolving partnership has been the foundation of the Euro-VO. As a starting point, the two intergovernmental organisations ESA and ESO brought in experience on how to deal with observational data from large ground and space-based telescopes, Strasbourg astronomical data centre CDS had anticipated several aspects of the Virtual Observatory (for instance Aladin already provided access to distant observatory archives, and employed a registry of resources Fernique et al., 1998), and the UK VO project AstroGrid had just started. These were the main partners of the first European project. Other VO initiatives progressively started in other countries, and Italy, Spain and Germany (respectively the Italian Virtual Observatory VObs.it, the Spanish Virtual Observatory SVO and the German Astrophysical Observatory GAVO) joined Euro-VO.

The *Astrophysical Virtual Observatory* (AVO) project was successfully submitted for funding to the European Commission in 2001 (Quinn et al., 2002). This allowed a close collaboration between the national initiatives, ESA, and ESO. As expected, the European initiatives brought their complementary expertise, and coordination and collaboration allowed them to reach a critical mass for the different aspects of the activities. We found that activities developed in collaboration at the European level worked well as templates for activities at national level, and technical collaborations between teams from different countries strengthened the impact of the work of the individual teams.

It was soon realised that the VO aim of providing seamless access to the wealth of astronomical resources, was well aligned with key objectives of the European Union. One of the main impacts of the VO is to offer an equal opportunity to access the best data and tools to scientists from all countries, and in particular to astronomers of all European countries, including peripheral and outermost regions. All data and service providers, large agencies, and small teams willing to share their knowledge, can contribute. The VO is thus a powerful vehicle for the integration of the national European astronomical communities into a single community, which is actually world-wide.

The European project also gave good visibility to VO development across Europe. This has been very important to get the VO taken into account in the European strategy for Astronomy (Bode et al., 2008) established in 2008 by the Astronet ERA-NET,[1] which gathers the astronomy funding agencies.

The paper is organised as follows: Section 2 briefly describes the suite of European projects which supported the development of Euro-VO over the years, and the evolution of the activities while the project was maturing; Section 3 explains the specific role of Euro-VO in the global VO landscape, and its positioning with respect to the IVOA and the national initiatives; Section 4 details the lessons learnt from the building of Euro-VO, and identify best practices for coordinating VO activities; Section 5 explains the Euro-VO role in a wider European context, its liaison with "nearby" disciplines and projects which work on generic building blocks of the data infrastructure. Section 6 concludes by discussing the current status of Euro-VO and the next steps.

2. The European VO projects: building the European contribution to the Virtual Observatory

The VO is one of the research infrastructures of astronomy, but it was a novel concept when it emerged and there was no pre-existing model to follow to develop it. The European projects progressively went through different phases, from R&D and proof of concept to operations, and defined the activities required to develop and maintain the European VO. The projects concerned are briefly described in this section, to show how the current Euro-VO strands of work progressively took shape. More details on how the activities were performed will be given in Section 4 which explains the lessons learnt.

2.1. The early stages of interoperability

The first key contribution of European funded projects to the construction of the VO was through the *Interoperability Working Group* set up by the OPTICON Thematic Network[2] in 2001, that was led by CDS. The global nature of the VO was understood from the start, and this Working Group included participants from the USA and Canada. It was the first international forum to discuss astronomical interoperability standards in the VO context.

A meeting held in Strasbourg in 2002, January 28th–29th, was the first exchange of views between the emerging VO projects which were just beginning to be funded (Europe, UK and USA). The meeting was a starting point for Europe-wide collaboration in the development of the VO, with representatives from France, Germany, Italy, the Netherlands, Spain, UK, ESA and ESO, going beyond the initial European VO partnership set up a few months before in the first VO project AVO, which will be described below. Several of the participants of this initial meeting have since played a key role in VO initiatives that were set up later in their country or Agency.

The Strasbourg meeting allowed a detailed discussion of a standard format for tabular data that was initially proposed in collaboration between the CDS and US-NVO. This was the starting point for VOTable (Ochsenbein et al., 2004), an XML-based standard for the exchange of tabular data, which became the first VO standard in March 2002. VOTable was derived from the *astrores* XML format (Ochsenbein et al., 2000), itself modelled on the FITS table format (Cotton et al., 1995).[3] VOTable was taken up by the IVOA after it

[1] ASTRONET was created in 2005 by a group of European funding agencies in order to establish a strategic planning mechanism for all of European astronomy. As of 2014, the ASTRONET consortium has eleven participants, twenty-one Associates and two Forum members.

[2] Fifth Framework Programme, HPRI-CT-1999-4002.

[3] VOTable overcomes limitations of FITS binary table usage in a distributed-computing environment, in particular the dataset size is not required in the header, which is an issue for remote data streams. It also allows expression of passwords or other identity information. VOTable can be used either to encapsulate FITS binary tables or to re-encode the metadata.