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A brief survey on the Virtual Observatory

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HIGHLIGHTS

- We present a brief survey on the Virtual Observatory status.
- We describe the main IVOA members, standards and tools.
- We explore the capabilities of the IVOA registry.
- We conclude with the immediate challenges for the VO.

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ABSTRACT

This paper presents a short survey on the astronomical Virtual Observatories (VOs) that are part of the International Virtual Observatory Alliance (IVOA). From how they are distributed worldwide to their specialization range on the electromagnetic spectrum, we summarize key aspects of the current 21 VO members. Through the registry service, we explore the resources that the VO offer as a whole, and identify that even though the VO is already a mature initiative, there are important challenges to address in the near future.

1. Introduction

The Virtual Observatory (VO) (Borne, 2013; Hanisch and Quinn, 2003) is an international initiative that allows accessing the astronomical files hosted in several data centers around the world. The standardization of methods and information enables astronomers, and in general any person on the Internet, to study the astronomical data without the need of physical displacement of the researchers or their tools. Beside the obvious advantages in terms of time and budget of using a virtual service, the VO provides a broad access to previous observations and related data, helping astronomers to produce better and updated science. Furthermore, VO members provide in some cases on-line processing and data analysis tools, which enrich even more the research possibilities of astronomers. This standardization goes beyond interoperable services: common semantics and generic data models also serve as patterns for VO software development.

In June 2002, the International Virtual Observatory Alliance (IVOA)[1] was created, with the main objective of defining standards to produce synergy and interoperability between the VO members. The members of the alliance are local organizations that represent a whole country VO, and propose and defend their interest in IVOA. Since it inception, IVOA had grown up to 21 members in the 5 continents, reaching reasonable maturity and consensus on how VO data should be modeled and accessed.[2] Nevertheless, most of the VOs aim beyond data access, where grid and cloud computing are probably the most interesting challenges for the near future.

A rather uncommon property, compared to other virtual centers, that virtual observatories hold, is the will of collaboration and openness of IVOA members, motivated by the scientific culture of astronomers towards public access. This allows not only good interoperability, but the natural specialization of the VOs with respect to the instruments, data and science that each country possesses. Unfortunately, IVOA only keep track of the standards

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[1] http://www.ivoa.net/.
[2] Despite this, the arrival of new observatories and instruments require a continuous revision of the standards and protocols to support new data.

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and technical discussions of interoperability, so there is no broad perspective nor unifying view of what the VO offer as a whole.

This paper provides this broad view of the VO, including its basic architecture and popular services in Section 2. Then, in Section 3 we present the projects, services and specializations that each IVOA member have developed (or plan to develop). In Section 4, we present examples of the benefits of IVOA standardization in practice, which allows us to discover resources through the whole VO around the world.

2. IVOA virtual observatories

Astronomy has always been a data-driven science, and therefore, the digital revolution have completely change the astronomical practice. In fact, the actual presence of the astronomer on site is every day less required for performing observations, and data reduction process is migrating out of the observatories, and international data sharing and collaboration are becoming common practices in the community.

However, the paradigm change does not stop here, because astronomers have to front the main challenge of 21st century science: the data deluge. It is a fact that astronomical data will strongly increase both in size and in quantity on the next decade due to various reasons, including the building of large projects like ALMA and E-ELT, the improvement and deployment of new instruments, and the execution of large astronomical surveys like the LSST project. The effort needed to process all this data will be enormous both scientifically and in terms of computational capacity. For instance, simple search and access procedures could become highly expensive when too many files are available in the database.

Consequently, is desirable to distribute the scientific and the computational load in several centers, each one specialized on certain data and instruments to avoid redundancy of observations and work. However, this distributed work should be organized to be able to interoperate between centers. In this context, organizing the inherent diversity of several countries working together, with different goals, working-style and budgets is the central objective of the IVOA.

2.1. The IVOA

Since June 2002, different Virtual Observatory projects have come to integrate the International Virtual Observatory Alliance (IVOA) under the **Guidelines for Participation**.[3] These projects are funded through national and international programs, both governmental and private, in collaboration with various centers of scientific studies, universities and others institutions. The members of the Virtual Observatory share knowledge between them and the community in a standardized manner. They themselves are who develop these standards for data exchange and interoperability. Table 1 shows the partners of IVOA up to November 2014 that represents a nation. Also, two international organizations are part of the VO, including the European Space Agency VO (ESA-VO[4]) and the EURO-VO,[5] which is a federation of several VOs in Europe.

Table 1
IVOA's country partners by year of affiliation with their websites.

Project	Since	URL
Aus-VO (Australia)	2002	http://aus-vo.org.au/
CVO (Canada)	2002	http://cadc-ccda.hia-iha.nrc-cnrc.gc.ca
GAVO (German)	2002	http://www.g-vo.org/
VO-France (France)	2002	http://www.france-vo.org/
RVO (Russia)	2002	http://www.inasan.rssi.ru/eng/rvo/
US-VAO (USA)	2002	http://www.usvao.org/
VOI (India)	2002	http://vo.iucaa.ernet.in/∼voi/
AstroGrid (UK)	2002	http://www.astrogrid.org/
China-VO (China)	2003	http://www.china-vo.org/
JVO (Japan)	2003	http://jvo.nao.ac.jp/
VObs.it (Italy)	2003	http://vobs.astro.it/
HVO (Hungary)	2003	http://hvo.elte.hu/en/
SVO (Spain)	2005	http://svo.cab.inta-csic.es/
ARVO (Armenia)	2006	http://www.aras.am/Arvo/arvo.htm
BRAVO (Brazil)	2009	http://www.lna.br/bravo/
UkrVO (Ukraine)	2011	http://www.ukr-vo.org/
NOVA (Argentina)	2011	http://nova.conicet.gov.ar/
SA^3 (South Africa)	2013	http://www.sa3.ac.za/
ChiVO (Chile)	2013	http://www.chivo.cl/

2.2. IVOA architecture

A Virtual Observatory (VO) is a framework that helps to solve several problems faced by the world wide astronomical community. One of this problems is related to have access to generated data by different instruments. Therefore, an architecture[6] was designed by the IVOA, which is composed by standards and protocols, that allow the transparent and unified access to astronomical data servers. The IVOA architecture defines 3 layers:

- the **Resource Layer** consists in a server collection with data from different instruments,
- the **User Layer** where astronomers and researchers can search for data through different mechanisms,
- and the **Middle Layer** which allows the connection between the previous two layer, hiding all the complexity for the users. Thus, they can find data through the *Registry*, or get the data through *Data Access* protocols.

2.3. Working groups

For the creation and update of standards and protocols, IVOA is organized by working groups. The description of each standard can be found in IVOA website.[7] Currently, IVOA is organized in the following **Working Groups**:

- **Applications**: it is concerned primarily with the software tools that astronomers use to access VO data an services.
- **Data Access Layer**: define and formulate VO standards for remote access, oriented to publishers and clients functionalities.
- **Data Modeling**: provide a framework for the description of metadata attached to observed or simulated data.
- **Grid and Webservices**: define the use of grid technologies and web services within the VO context.
- **Resource Registry**: allow an astronomer to be able to locate, get details, and use, any resource located anywhere in the VO.
- **Semantics**: explore the word and sentences meaning or interpretation, or another language forms in the astronomical context.
- **VO Event**: define the content and meaning of a standard information packet for representing, transmitting, publishing and archiving information about a transient celestial event.
- **VOTable**: maintenance of an XML format, defined for the exchange of tabular data in the context of the VO.

2.4. Popular standard and services

The working groups described above, have defined several standards and recommendations that each VO node should implement.

[3] http://www.ivoa.net/documents/latest/IVOAParticipation.html.
[4] http://www.sciops.esa.int/index.php?project=SAT&page=ESAVOIntro.
[5] http://www.euro-vo.org/.
[6] http://www.ivoa.net/documents/Notes/IVOAArchitecture/.
[7] http://www.ivoa.net/members/.