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VO for education and outreach

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Abstract. The Virtual Observatory (VO) is an international astronomical community-based initiative. VO aims to allow global electronic access to the available astronomical data archives of space and ground-based observatories and other sky survey databases. *VO for education* is a project developed within the framework of the European Virtual Observatory (EuroVO) with the aim of diffusing VO data and software to the public, in particular students, teachers and astronomy enthusiasts. *VO for education* offers use cases, pedagogical units, and simplified professional software that will allow a taste of the emotion of scientific research even to those approaching astronomy for the first time or simply wishing to wander between stars.

Keywords. miscellaneous, astronomical data bases: miscellaneous, atlases, catalogs, surveys

1. Introduction

Billions of Bytes are written every night in the computers of astronomical observatories. Such a wealth of information is often underused because data are not distributed widely enough, or because formats are very different from place to place, or because it is difficult to retrieve data once found. In order to improve on this situation several teams of astronomers have created the Virtual Observatory (VO). The goal is to have a virtual instrument that to an astronomer is, or is going to be, just another telescope. There are familiar interfaces and tools and, in principle, nothing set the astronomer know that his/her observations are retrieved from digital archives rather than collected directly at a telescope. Of course, only data of observatories that join the project are available, but almost all major data centers have already adhered to the VO and most new telescopes and instruments will be VO compliant.

The International Virtual Obervatory Alliance (IVOA - Hanisch R. J. *et al.* 2010) now coordinates 21 national or super-national VO projects. Among these projects there is the European VO (EuroVO). EURO-VO aims at deploying an operational VO in Europe. It supports the utilization of VO tools and services by the scientific community, technology take-up and VO compliant resource provision, and building of the technical infrastructure. The specific project ASTERICS† (Astronomy ESFRI & Research Infrastructure Cluster), is leading VO into operations.

Among the many tasks of the EuroVO, an important part deals with service activities for higher education and outreach (Demleitner, M. *et al.* 2018). It is certainly important that some of the benefits that VO offers to professional astronomers, also become resources for teachers, students and people who are simply curious about celestial objects. Researchers of many European countries contribute to the development of software tools, documentation and use cases that constitute the main product of VO for education.

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In the present contribution we outline the VO for education project, we briefly describe its development, then we give information on products and on how to retrieve them. Finally we present the educational activities we perform in Trieste combining real, remote and virtual observations and we describe the IVOA *education interest group* activities.

It is worth pointing out that all our products can be freely downloaded and used. If you will use them, we will be glad to hear from you: our possibility to keep developing our educational material also depends on its documented use by as many people as possible. Of course, also bug reports, suggestions, and complaints are most welcome.

2. *VO for education* products

In the framework of *VO for education* we want, through the VO resources, to bring science to students, get them engaged and give students an involving glimpse of the professional world of astronomy, including a perception of the infrastructure. We want also to make them realize they could become scientists and teach some elements of astronomy also.

In order to reach our purposes we adapted and simplified key tools (with users help), we provide a library of use cases and propose activities that mix "serious work" with "fun". We organize workshop for teachers training also.

VO for education offers a software to visualize the sky (Stellarium) and a software to access VO data (Aladin). Both software come from a professional version and have been modified to be used by everybody. Several use cases and pedagogical units are available, each one focused on a specific astrophysical problem. These examples include user guides on how to use the software and have been developed with the help of teachers and students (Freistetter, F. *et al.* 2010).

VO for education software tools and use cases have been revised in the last school year during an intense program with high school students, in the framework of the H2020 ASTERICS project. They are available in several languages and can be free downloaded from the web site http://vo-for-education.oats.inaf.it/.

2.1. *Software tools*

We identified existing professional software tools for the retrieval, visualization and analysis of VO data that could be efficiently and successfully adapted for educational and/or outreach purposes. We selected Aladin (Bonnarel, F. *et al.* 2010), a tool to retrieve and display VO images, and Stellarium (http://stellarium.org/), a sky browser. These tools were already stable and in use among professional astronomers, their developers working in Institutions of the EuroVO collaboration.

Aladin is an interactive celestial atlas for the visualization of digital images available in VO format, together with a selection of large area sky surveys. It also displays the nicest images taken with the NASA Hubble Space Telescope. Aladin allows to mark on images the positions of the celestial objects contained in the astronomical catalogs available in international archives like Simbad and VizieR at the Centre de Donnes astronomiques de Strasbourg (CDS). Aladin has several built-in functions that allow image handling and a quick analysis. All professional applications developed for VO are available to Aladin.

Stellarium simulates a realistic sky on the screen of the PC, like it could be seen by naked eye or with a telescope from anywhere on the earth and at any time. Stellarium may be used by anybody, but in particular it may be useful to teachers for exploring the night sky and the basics of the celestial sphere. It is also a useful tool for amateur astronomers who wish to plan an observing session.

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Both Aladin and Stellarium have been modified and simplified according to students' and teachers' feedback, new features have been added also (e.g. search objects by class in Aladin and information about star spectral type in Stellarium).

2.2. *Use cases*

Usage examples aim at familiarizing the users with Aladin and Stellarium and at stimulating further interest and activities in astronomy. Usage examples are in the form of pedagogic modules consisting of two main parts. The first part presents a typical astronomical problem with a short introduction and a description of the solution found by astronomers, or, in some cases, an expanded treatment of the problem. The second part is a step-by-step guide to the commands needed to reach the solution of the problem with Aladin or Stellarium. Some of our usage examples include exercises that are proposed for teachers' activities in the classroom. Solutions are provided separately.

Use cases have been developed with the support of teachers, are dedicated to middle and high school students and are divided into three difficult levels: *basic* - requires no astronomical knowledge or ability to solve math computations, age group 12-15; *intermediate* - requires basic astronomy and math knowledge and the capability to understand a plot, age group 15-18; *advanced* - requires good astronomy and math knowledge and the capability to build and understand a plot - age group 18+.

- ***Basic***
  - **Introduction to Aladin**: Aladin's main features, each presented with examples taken from its most common use.
  - **Stellarium for beginners**: Stellarium's main features, each presented with examples taken from its most common use.
  - **The sky**: celestial coordinates, Earth's rotation and revolution, constellations, light pollution.
  - **The shape of galaxies**: galaxy morphology and classification according to the Hubble diagram.
  - **Planetary conjunctions**: motion of planets both around the Sun and in the sky, planetary conjunctions and the Star of Bethlehem.
  - **Introduction to Stellarium for preschoolers**: easiest and most appealing functions of Stellarium for a presentation to preschoolers, as the constellations and their variation between different cultures, light pollution.
  - **The constellations of the Zodiac**: the orbital motion of the Earth, history of astronomy and the precession of the equinoxes.
  - **The Messier catalog**: examples of the most interesting categories of celestial objects, from stellar clusters to galaxies, belonging to the Messier catalog that includes some of the most viewed objects of the deep sky.

- ***Intermediate***
  - **The stars**: basic observational parameters of stars, color, magnitude, temperature, Herzsprung-Russell diagram and how stars work and evolve.
  - **Proper motion of the Barnard's star**: motion on the celestial sphere of stars that seem "fixed" on the sky, estimation of displacement on the sky of the Barnard's star.
  - **Confirmation of an apparent supernova**: supernova search and discovery, astrometrical solution of images.
  - **Distance of the Crab nebula**: supernovae, exploding or exploded stars, the Crab Nebula (the 1054 AD supernova registered by Chinese astronomers) and its distance.

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- **Asteroids in the Solar System**: main characteristics of asteroid orbits and their distribution within the Solar System.
- **The Moon**: geometry of the orbit of the Moon and the nature of its phases, eclipses of Moon and Sun.
- **The mass of Jupiter**: determination of the mass of Jupiter by observing the orbits of the Galileian moons and by inserting these data into Kepler's laws.
- **Star clusters**: intrinsic linear size and apparent angular size, basic facts about star clusters.
- **The disk of the Milky Way**: shape and thickness of the disc of our own Galaxy by counting stars within and around the Milky Way.

• ***Advanced***

- **The Pleiades open cluster**: distance of Pleiades open cluster derived from parallax, Herzsprung-Russell diagram of stellar clusters.
- **Distance of the Andromeda galaxy**; distance of the Andromeda Galaxy by identification of variable stars of the Cepheid class and the determination of the relation between their period and their intrinsic luminosity.
- **Planetary motion**: Kepler's laws, a cornerstone of astronomy and a fundamental brick of both Newton's and Einstein's theories of gravitation.

3. Combining real, virtual and remote observations for kids

At the astronomical observatory of Trieste (part of the Italian National Institute for Astrophysics) we developed a completely remoted educational telescope, called "Stars go to school" (SVAS - Baldini *et al.* 2010), and set up a interactive laboratory (Esploracosmo) where students can deal with real, virtual and remote observations.

SVAS offers to schools and teachers a remote laboratory with which carry out real observation sessions, managed in real time by the students under the supervision of the teacher, in the classroom, and of an astronomer, at the Astronomical Observatory of Trieste, "Osservatorio Astronomico di Trieste (OATs)" in Italian, thanks to the telematic link between the school and the observatory. Students and teachers experience real astronomical observations, through the interactive participation to the different steps of planning, observing and acquiring the data.

The project is addressed to 13-18 yr students. Every observation is previously planned together with the teachers, according to age and curriculum of the students, with the aim to maximize the results. The observing activity, lasting about 90 minutes and led by an astronomer of the OATs, can be done during the morning (observation of the Sun) or in the evening (observation of stars, nebulae, clusters and galaxies). SVAS is a member of the Italian Remote Network of Educational Telescopes (IRNET).

Esploracosmo is the interactive computer laboratory in operation at the Observational Branch of Basovizza of the Astronomical Observatory of Trieste. It proposes a modern tool to support teaching of astronomy, through the study and experimentation of its observation methods. Esploracosmo can host 25 students and has an educational network that connects the PCs equipped with software expressly developed for schools. Projection systems and TV monitors complete its equipment. Thanks to the data access, coming from both the OATs archives and the archives of the major professional telescopes of the world through the VO, and the possibility to perform remote observations with educational telescopes available in the world, Espploracosmo allows the exploration of the Solar System, stars, nebulae and galaxies, as well as the study of the gravitational laws, one of the building blocks of the structure and evolution of the Universe. Esploracosmo allows to perform the observations with the telescopes of the SVAS project and the activities of the *VO for education*. The activity proposed in Esploracosmo is managed by

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an astronomer and lasts about 90 minutes. To whom who desire to match astronomy with a tour in a research institute, Esploracosmo offers the emotion of the scientific research in contact to the instruments and, thanks to the joint between real and virtual observations, assures educational activities also under a cloudy sky.

4. IVOA education interest group

The *education interest group* (eduIG) of the IVOA has been founded in 2012 with the assignment to coordinate the widest global distribution of VO tools, data and practices in support of astronomy teaching in schools and universities.

The eduIG is a a two-way communication channel between the public and VO. The main activities developed by the eduIG are:

- identify scientists/educators interested in working within eduIG;
- collect information on educational activities that would immediately benefit from VO resources or that are already using them;
- compile lists of general educational resources in astronomy that may be useful in the VO environment (either as they are, or as a starting point for possible VO developments);
- open communication channels with projects active in astronomy and education worldwide;
- evaluate and discuss educational requirements on tools, data, and guides to be submitted to IVOA, providing information for possible actions (e.g. simplification of tools or publication of data). Feedback to the relevant IVOA WG;
- provide IVOA endorsement in support of national VO actions aimed at obtaining recognition and funding from high level national government education structures and/or from nation-wide organizations of teachers;
- create and maintain an online repository where to store documentation, lists of available resources and projects for educators as well as VO developers and astronomers.

If you are interested in joining the eduIG and subscribing to the IVOA education mailing list visit: http://www.ivoa.net/members.

4.1. *VO doc registry*

As argued above, disseminating text-like material like tutorials, worked-out use cases, or larger introductions, is an important task in facilitating VO exploitation. Within the VO community, there is a large body of educational material for a wide variety of audiences ranging from pre-school to researchers.

To date, such material has been collected informally by the various projects on plain web pages as the *VO for education* web site. The VO already has a registry extension for standards, which of course are also text-like. This extension, however, focuses on metadata important for standards e.g., vocabularies and status that is not pertinent for educational material. Conversely, it is not concerned with document language (which can safely be assumed to be English for standards), or education levels, and it disregards the issue of locating formatted and source versions, which for educational material is important.

In order to improve upon this situation a dedicated VO registry to keep record of educational material has been created.

4.2. *SVN repository for edu resources and Virtual Observatory Text Treasures*

Registering text documents as VO resources allows searching for tutorials and similar material through standard registry interfaces. But keeping tutorials up to date, in their master form and also in their translated versions, is an obviously important management

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issue not really addressed by the registry. For tracking changes and versions, the standard tool is a version control system. Therefore, a versioned repository (SVN) has been set up at GAVO (German Astrophysical Virtual Observatory). It collects part of the already existing VO tutorials with the goal of preserving them and letting users update and translate them.

The Virtual Observatory Text Treasures VOTT is a formatted list of VO educational and outreach texts: use cases, tutorials, courses, etc. VOTT contains material for all settings, from pre-school to graduate. It is generated from the documents known to the VO registry and available at the url http://dc.zah.uni-heidelberg.de/VOTT.

4.3. *VAPE web application*

VAPE (http://ia2-edu.oats.inaf.it:8080/vape) is an application for the publication of educational data in the VO, developed by IA2 (Italian center for Astronomical Archive). Thanks to VAPE, institutes managing educational telescopes can publish their data in the VO without facing the complexity of (more complete) professional tools. The creation of an educational data archive a) provides teachers performing observations with an educational telescope to easily store and access their observations, b) makes observations available to teachers that have otherwise no access to a telescope. An added advantage of the publication in VO is the availability of many free tools for displaying and/or analyzing data.

5. Conclusions

Many remote educational telescopes are now available around the world and the VO is growing also. We think VO and remote observing, together with dedicated examples and use cases, is the winning combination for astronomy education and teachers' and students' feedback confirm it. So we aim to a wide diffusion of *VO for education* software tools and use cases along with an increasing number of educational remote telescopes.

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