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VObs.it, the Italian contribution to the international Virtual Observatory—History, activities, strategy

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ABSTRACT

The origins of the Italian contribution to the international Virtual Observatory (VO) were mainly tied to the definition and implementation of a Data Grid using Grid standards. From there on, by means of a step-wise evolution, activities started including the implementation of VO-aware tools and facilities, or the production of services accessing data archives in ways compliant to the international VO standards. An important activity the Italian VO community has carried out is the dissemination of the VO capabilities to professionals, students and amateurs: in particular, an important and maybe unique success has been bringing to the classrooms the VO, and using it as a powerful tool to teach astronomy at all levels, from junior high school to undergraduate courses. Lately, there has been also direct involvement of the Italian community in the definition of standards and services within the framework of the International Virtual Observatory Alliance (IVOA), and participation and leadership in the IVOA Working Groups.

Along this path, the national funding for these activities has been rather low, although essential to carry the activities on. There were no bursts of funding to allow a quick rise in activities leading to the fast realisation of tools and systems. Rather, the manpower involved in VObs.it has been always fairly low but steady. In the view of managing a national VO initiative with a low budget, strategic choices were made to exploit the available resources and to guarantee a constant background activity, mainly geared at providing services to the community, development in lower-priority VO areas, dissemination and support.

1. Introduction

In this paper, the development of the Italian VO initiative is discussed, describing first its evolution in time (Section 2), from the original focus on the Grid infrastructure to full participation in the International Virtual Observatory Alliance (IVOA); the resources available (Section 3) are described, followed by the specific activities carried out (Section 4); lessons learned and future perspectives are finally discussed (Section 5). Throughout the paper, the focus is on the reasons behind the tactical and strategic choices made to optimise the cost-to-benefit ratio within a national VO initiative working on a low budget.

2. Timeline

The Italian contribution to the international Virtual Observatory (VO) has evolved following peculiar ways. Initially, it was rather tightly linked to the specific priorities of the Italian scientific community, mainly led by the particle physicists, which was focused on the development of e-infrastructures for distributed computing (at the time, the Grid infrastructure). When the interest for the VO grew within the astronomers' user community, and consequently at the funding agencies level, it was possible to develop an autonomous VO initiative (VObs.it). This initiative has been supported since by INAF with a very limited degree of funding, which was anyhow roughly constant, and has guaranteed continuity in the activities. Funding from the European Union (EU) provided, from time to time, support to specific focused work.

A timeline ranging from 2001 to 2014 is shown in Fig. 1. On top, the main international milestones and the projects funded by the European Union are listed. Below, the Grid projects funded by the Italian Ministry of Education are compared with the Italian VO initiative, and the main milestones accomplished at the national level are listed (the ones related to the Italian participation in international initiatives are marked in bold). A comprehensive list of milestones is reported in Table 1.

2.1. The origins

The VO concept was conceived and started gaining momentum in Europe and in the world during two years, 2001 and 2002:

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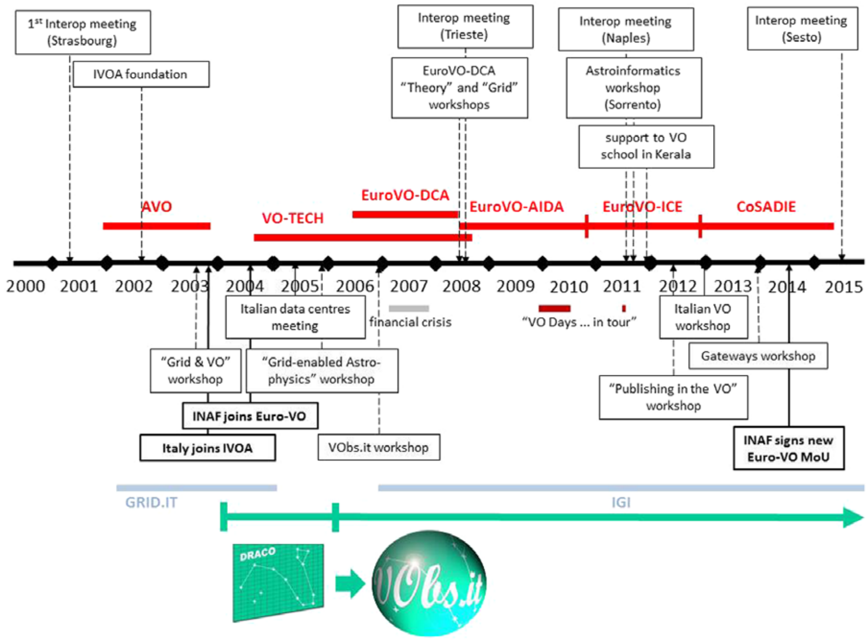

Fig. 1. Timeline representing the evolution of the Italian VO initiative, evidencing the transition between DRACO and VObs.it: explanations in the text.

the first Interoperability meeting was held in Strasbourg in January 2001; the Astronomical Virtual Observatory (AVO) project (Quinn et al., 2002) was funded by the European Union; the International Virtual Observatory (IVOA) (Hanisch and Quinn, 2003) was founded in June 2002.

Of course, the Italian astronomical community was interested in interoperability among archives, since there were (and still are) two separate data centres operating in Italy: the Italian centre for Astronomical Archives (IA2) for ground-based data and the Italian Space Agency Science Data Centre (ASDC) for space-borne facilities. Logically enough, Italian representatives attended the first Interoperability meeting in Strasbourg, January 2001. But, at the time of IVOA establishment, Italy could not join since there was no funded project dedicated to the VO within the Italian astronomical community.

Two facts allowed Italy to finally join the international VO activities:

- In 2003 a project called DRACO (DataGrid for Research in Astronomy and Coordination with the virtual Observatory), involving both Grid and the VO, was funded by the Ministry of University and Research; through DRACO the Italian astronomical community was allowed to join the IVOA.
- In 2004, the importance of the VO was appreciated by the newly appointed INAF leadership, and a Letter of Intent (LoI) was signed by the President to allow INAF participation in the European VO initiative, EuroVO (Genova et al., 2015).

2.2. DRACO

DRACO was approved as an astronomy-oriented component of the Italian national Grid project (Grid.it), focusing on distributed computing but also on data, especially if contained in archives. In this case, the focus was on enabling VO-compliant access to the data archive of the National Galileo Telescope (TNG). Towards the end of 2005, IA2 released a first IVOA-compliant alpha version of a system allowing access to TNG data, and aimed at supporting the future access to the data of the Large Binocular Telescope (LBT) acquired during the Italian time. Most efforts were however devoted to Grid-related activities.

A *key element* for the enhancement of the Italian VO initiative was the participation in projects funded by the European Union (EU). The agreement of INAF to join the EuroVO initiative allowed the Italian VO team to participate in the Virtual Observatory Technology (VO-TECH) and in the EuroVO Data Centre Alliance (EuroVO-DCA) projects, that were funded in 2004 and 2006, respectively, by the European Sixth Framework Programme (EU/FP6). The two projects allowed the Italian VO community to improve the VO accessibility to Italian archives, and to participate in development activities, in particular related to applications and to the interface with the Grid.

In the meantime, the DRACO project reached its end in December 2005, successfully achieving the main purpose of its activity, i.e. porting on the Grid a number of applications of astrophysical interest. A workshop was organised at the end of the project (Benacchio and Pasian, 2007): while waiting for the availability of a coherent set of standards established by the IVOA, a number of Italian scientists were put in the position of using Grid facilities.

2.3. VObs.it

In order to fulfil the obligations of the EuroVO LoI the INAF Board decided, starting with the 2006 fiscal year, to fund separately Grid and VO activities through its Information Systems Unit (INAF-SI). The VO-related project was called VObs.it and has been since the official representative of the Italian community within IVOA.

There was a slow start of national activities but a steady increase of interest for the use of the VO, and for allowing public access through IVOA standards to private or institution archives. Several INAF sites (Catania, Milano, Teramo, Torino, Trieste) and the Italian supercomputing centre (CINECA) were involved in the initial activities of VObs.it. The participation of CINECA was supported by the INAF–CINECA collaboration agreements (2005–2007 and 2007–2010). The initial inclusion of ASDC was planned but did not materialise due to the lack of a formal ASI–INAF agreement on the topic: hence, the direct participation of ASDC in VObs.it was never implemented, but collaboration has always been fostered.

The first VObs.it workshop was held at INAF-OARoma on November 2006 with the participation of over 40 scientists. In the presentations made, many proposals were received to include

Table 1
Milestones of the Italian VO initiative.

Time	Milestone
Jan 99	INAF formed merging Italian observatories
Jan 01	INAF participates in Grid.it
Jan 01	First Interoperability meeting (Strasbourg)
Nov 01–Oct 04	First European VO project funded by EU/FP5: AVO
Jun 02	Foundation of IVOA
Jul 03	"Grid in astrophysics and the virtual observatory" workshop (Rome, INAF HQ)
Oct 03	DRACO approved by Italian Ministry of Education
Nov 03	Italy joins IVOA through DRACO
Jan 04–Dec 05	DRACO project
Jan 04	INAF reform: CNR institutes join INAF, creation of INAF-SI
Jun 04	INAF signs Letter of Interest for EuroVO
Jul 04–Jun 08	European VO project funded by EU/FP6: VO-TECH
Oct 05–Sep 10	Two INAF–CINECA agreements including VO activities
Mar 05	Meeting of INAF centres interested in VO (Trieste)
Nov 05	"Grid-enabled Astrophysics" workshop (Rome, INAF HQ)
Nov 05	IA2 releases α version of IVOA compliant access to TNG, LBT
Jan 06	Start of VObs.it as independent initiative under INAF-SI
Apr 06–Mar 08	European VO project funded by EU/FP6: EuroVO-DCA
May 06	Joint IVOA-GGF workshop at GGF17 (Tokyo)
Jun 06	ASI–INAF Steering Committee approves ASDC in VObs.it
Nov 06	VObs.it workshop (Monte Porzio)
Jan 07	INAF participates in Italian Grid Initiative (IGI)
Jan–Oct 07	Financial crisis
Feb 07	"Porting applications on the Grid" workshop (Trieste)
Oct 07	EuroVO-DCA Board meeting (Trieste)
Feb 08–Jul 10	European VO project funded by EU/FP7: EuroVO-AIDA
Apr 08	"Theory in the VO", "Grid and the VO" workshops (Garching)
May 08	IVOA Interoperability workshop hosted in Trieste
Sep 09	EuroVO Technology Forum (Trieste)
Dec 09–Mar 10	"VO Days … in Tour" (all INAF sites)
Sep 10–Aug 12	European VO project funded by EU/FP7: EuroVO-ICE
Apr 11	EuroVO Technology Forum (Trieste)
May 11	VO Days wrap-up meeting (Rome, INAF HQ)
May 11	IVOA Interoperability workshop hosted in Naples
Sep 11	"Astroinformatics 2011" hosted in Sorrento
Oct 11	VObs.it supports VO School in Kerala, India
Jan 12	INAF reform—end of INAF-SI
Feb 12	"Publishing in the VO" workshop (Trieste)
Sep 12–Feb 15	European VO project funded by EU/FP7: CoSADIE
Dec 12	Italian VO workshop (Rome, INAF HQ) with hands-on session
May 13	Creation of INAF ICT Unit, coordinating VObs.it
Dec 13	"Science Gateways and the VO" workshop (Catania)
Mar 14	EuroVO/CoSADIE Technology Forum (Trieste)
May 14	INAF signs new EuroVO MoU
Jun 15	IVOA Interoperability workshop hosted in Sesto/Sexten
Oct 16	ADASS XXVI and IVOA Interoperability workshop in Trieste

private or observatory archives and databases into the VO. Some of the VObs.it resources were assigned, following well-defined priorities, to allow a number of data providers to become VO-compatible: but financial problems in 2007 hampered this possibility. It was therefore decided to rather import these datasets into the IA2 data centre to allow their VO-awareness.

The EuroVO-AIDA (Astronomical Infrastructure for Data Access) project, funded by the European Seventh Framework Programme (EU/FP7), started in February 2008 and ended in July 2010. INAF was active in the project preparing prototype software implementing the draft standards under development, defining semantics, ontologies and an astronomical vocabulary. The task where the INAF effort was stronger, as institution leading the relevant work-package, was on services for *higher education and outreach*: EuroVO-AIDA allowed to initialise an activity in which the Italian VO community has been leader since. Cooperation at the European and international level has been maintained through two small "bridging" projects, funded by EU/FP7: EuroVO-ICE (International Cooperation Empowerment) and CoSADIE (Collaborative and Sustainable Astronomical Data Infrastructure for Europe) expected to end in February 2015.

In the 2011–2012 timeframe INAF offices and units were reorganised and a new ICT Unit, directly under the INAF Scientific Directorate and replacing the former Information Systems Unit, has been formally created in 2013. The ICT Unit coordinates a number of e-infrastructure projects, including VObs.it.

In December 2012, a VO workshop (INAF headquarters, Rome) was attended by about 40 people. Lots of interest for the VO was shown by neighbouring communities, especially planetology, radio astronomy, high-energy astrophysics (through ASDC). In parallel, contacts are continuously pursued by INAF and VObs.it with the other research institutions and initiatives active in other domains, in Italy and in Europe, that are involved in Big Data projects both for the management and preservation of data.

The INAF commitment to participate in international VO activities was reinforced by the agreement on the *new EuroVO Memorandum of Understanding (MoU)*, which was signed in spring 2014. This is coherent with the recommendations by the INAF Science Committee, which stressed the importance of the Italian participation in international activities, and in particular in the EuroVO, as the main focus of the Italian VO work.

3. Resources

The global effort during the eleven years of VO-related work in Italy has been non-negligible overall, and is shown in Fig. 2.

Initially, there was about 1.5 FTE/year of contracted DRACO staff dedicated to VO, but to this low value, INAF personnel having

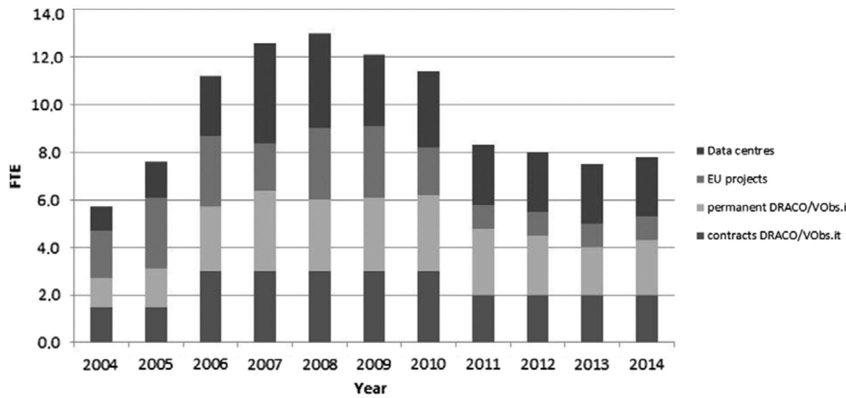

Fig. 2. Resources available for VO activities in Italy from 2004 to 2014: to build up the total, the contracted and permanent staff dedicated to the DRACO (2004–2005) and VObs.it (2006–2014) initiatives are considered, plus the staff funded by the EU projects; the personnel of Data Centres devoted to VO activities is also considered. These different contributions are marked in the graph with different shades of grey.

permanent positions was added. From 2006 on, when VObs.it started, the number of contracted staff increased and was synchronised with the peak of activities in EU-funded projects (VO-TECH and EuroVO-DCA first, then EuroVO-AIDA). As previously, contracted staff was complemented by personnel from INAF and Universities holding permanent positions, and who were considered as co-funding to the EU-supported activities. Furthermore, there is continuous support from Italian data providers to build VO-compliant access to their holdings. The sum of these four contributions (contracts and permanent staff dedicated to the VO initiatives, EU-supported projects, staff from Data Centres) provides the total VO-related effort In Italy in the period. This is well evidenced in Fig. 2, by the different shades of grey of the histogram bars.

It is however to be noted that VObs.it does not control all of the staff shown, since personnel from the Data Centres follow their own plans and have their own priorities. On the other hand, being VObs.it committed to support international activities, the work of VObs.it is in total coordination with EuroVO.

Almost all of the funding (both VObs.it and from the EuroVO projects) was used in personnel. A fraction was used to provide support for the IVOA and EuroVO events held in Italy, while hardware and general infrastructure costs were taken care of by the partner data centres. The totality of the development was made in-house, and no software products nor services were provided by third-parties.

The composition of the team in terms of professional profiles did not change much in time, and depends on the different classes of staff evidenced in Fig. 2. Personnel in data centres are evenly distributed between technicians (computer support) and scientists (scientific support); permanent staff is all composed of scientists; computer engineers were hired with contracts (both for DRACO/VObs.it and the EU projects) during the years of major development (2005–2010). It is to be noted that here the term "scientists" means either computer-aware astronomers or astronomy-aware computer scientists/engineers.

4. Activities

4.1. Distributed computing and distributed data

The interconnection of the Virtual Observatory and the computational grid infrastructures appeared to be an important goal to achieve, through the harmonisation of the Virtual Observatory infrastructure and user tools with the developments that were carried out within the various national and European Grid projects. The objective of the DRACO, and then VObs.it (see Fig. 1), work in this field has been to allow the compute-intensive VO applications to run on the Grid, and vice versa Grid applications to access VO resources, so to allow a smooth two-ways integration of the two standards (Pasian et al., 2007a). The activities carried out are listed in the following.

The **Grid Data Source Engine (G-DSE)** was conceived and developed as a system to integrate databases with the Grid in "native" mode: G-DSE (Taffoni et al., 2006) was capable of accessing generic databases using both Grid and IVOA standards (e.g. prototype ADQL calls). As an extension to the Grid middleware, a specialised "query element" was designed, in addition to the Grid concept of "computing element", to work as a Virtual Observatory resource in the Grid so that an astronomer could access data using the IVOA standards from an existing Grid production environment. For some time, G-DSE was included in the official distribution of the Italian Grid Initiative (IGI).

FITS on the Grid: one of the main issues in Grid computing was data sharing and distribution, which in the case of astronomical applications is a crucial point. To overcome this problem, a set of drivers was designed and implemented for the CFITSIO libraries that interact directly with the Grid file system through its different layers, from the GridFTP up to the file catalogue. These drivers allow a direct access to astronomical data stored on the Grid, as the GridFTP transfer protocol is common to every Grid infrastructure (Taffoni et al., 2007).

Grid-VO coordination: when the EuroVO-DCA project was kicked-off, the VObs.it team led a work-package investigating the use of Grid standards within the VO, and in particular the possible interactions between EuroVO and EGEE, the European Grid project (Taffoni et al., 2008). Information on the different mechanisms for users to access the individual computational Grid infrastructures (middleware, authentication procedures, user interfaces, etc.) was gathered through contacts with various computational Grid projects. Preparatory studies were performed on how to interface VO computing tasks with the different computational Grids, through contacts with user communities and technical groups. Access by data centres to their own national Grids was encouraged, and contacts with computational Grid projects and the Global Grid Forum (GGF) were initialised, to verify that the requirements from the VObs community were taken in the appropriate consideration by the individual computational Grid projects. VObs.it staff has been coordinating the A&A "cluster" within the EU-funded EGEE-III project and the European Grid Initiative (EGI), with the purpose of supporting the porting of application software of astrophysical interest on the Grid, VO-enabled codes being high in the priorities. Given the experience that the VObs.it team gathered in this kind of activities, the first noticeable participation of INAF within IVOA was in the Astro-RG Interest Group, established during the summer of 2003 as a link to the GGF. In 2006, the joint IVOA-GGF workshop at GGF17 in Tokyo was attended and actively supported by VObs.it. However, due to substantial lack of interest within IVOA, the Astro-RG group was disbanded in 2008. The IVOA liaison to Grid activities, and specifically to the successor of GGF, the Open Grid Forum (OGF), was resumed in 2011 by means of a Liaison Group. On the OGF side, this has the form of an Astro OGF User Group dedicated to data and processing in astronomy and astrophysics; the responsibility of its leadership was taken by VObs.it. The task of the group is identifying and facilitating interactions between IVOA and OGF on all aspects concerning Distributed Computing Infrastructures (DCIs), porting of workflows and applications, and their interaction with data.

A **web portal for BaSTI** was created implementing a Grid and Virtual Observatory integrated facility that allows to exploit the computational and storage capabilities of the Grid environment from a Virtual Observatory compliant web portal (Pasian et al., 2008). This facility provides data access to large sets of stellar evolution models; it is also able to create on-the-fly models by submitting a large number of jobs on the Grid and collecting the results. This portal was a first example of a service that is able to bridge two different environments: the Virtual Observatory and the computational and data Grid (Taffoni et al., 2010).

Workflows: A number of experiences have been also gathered in the field of workflows for data processing over distributed computing infrastructures, e.g. SHIWA (http://www.shiwa-workflow.eu/), SCI-BUS (http://www.sci-bus.eu/), and ER-flow (http://www.erflow.eu/), with special reference to the evolution of distributed computing and data in the direction of cloud services. Contacts have been carried out within EuroVO, especially with VO-France, to harmonise the development of workflows between the Grid and Web Services (GWS) Working Group of IVOA and the multidisciplinary EU-funded projects. Moreover, a project was prepared to allow interoperability between EGI and CANFAR, the Canadian computing infrastructure for astrophysics, to implement a federated cloud service using VO standards. A collaboration between VObs.it and the Canadian VO (CVO) has been defined to have this project implemented within summer 2016.

4.2. Theory data in the VO

VObs.it work on theory data was evenly divided between data model activities and test-bed implementations.

When the aim of the Virtual Observatory was expanded from seeking interoperability among astronomical catalogues and archive systems to including access to numerical simulations as well, the Italian community and the VObs.it staff started participating in the design of a **data model for theoretical data** and of an interim Simple Numerical Access Protocol (SNAP), devised to become part of the Data Access Layer. VObs.it provided the first integration within the Virtual Observatory of a set of theoretical data structured with a prototype of the SNAP data access protocol. The resource provided not only access to simulation data stored in a dedicated archive but also, through interfacing web services, a visualisation service and the possibility to extract a number of astronomical observables. The work was focused on a set of numerical simulations of galaxy clusters identified at redshift 0 and produced with the Gadget-2 code: the possibility was demonstrated of computing the temperature and density profiles, of visualising theoretical results with VO-enabled astronomical tools, of comparing the results with astronomical observations (Pasian et al., 2007b).

Eventually, the data model for Theory (Simulation Data Model), describing numerical computer simulations of astrophysical systems, was issued (Lemson et al., 2014). The primary goal of this standard is to support discovery of simulations by describing those aspects of them that scientists might wish to query on: i.e. it is a model for meta-data describing simulations. The SimDM has been developed in the IVOA Theory Interest Group with assistance of representatives of relevant IVOA working groups, in particular Data Model and Semantics.

A full-fledged project, the **Italian Theoretical Virtual Observatory (ITVO)**, was created as a test-bed project for the inclusion of theoretical data and related tools inside the VO, and involving INAF (Trieste, Catania and Teramo), CINECA and the University of Trieste. ITVO was partially supported by the VO-TECH EU project. Standards and tools applicable to the theoretical data obtained from cosmological simulations were studied. The database structure was created with the main purpose of defining a structure for the cosmological simulations, generic enough to be able to ingest metadata from many types of simulations (N-body, N-body + SPH, Mesh, N-Body + AMR, etc.) (Manzato et al., 2008a). The system allowed to provide searching criteria through which a single query could get data from different kinds of simulations archives; to develop appropriate IVOA tools to visualise and analyse the data; and finally to make possible an easy comparison between theoretical and observational data. VisIVO was used to find and visualise N-D boxes data, whereas Aladin was modified to study the 2-D maps and permit the search for simulated galaxy clusters. A code was also generated that creates on-the-fly the profiles of ten quantities of the simulated galaxy clusters produced by the Gadget-2 code which can be easily visualised by TOPCAT. All of these tools were connected to each other using the PLASTIC hub, a software specifically designed to provide interoperability among astronomical VO applications (Manzato et al., 2008b). Besides providing theory data, ITVO was also used as a sandbox where the IVOA theory standards were tested and checked. The verification of the Theory Data Model was carried out by a database implementation built by the ITVO/VObs.it Trieste group.

The **BaSTI** facility providing stellar evolution models has been converted to a database structure and was ported to the VO (Pietrinferni et al., 2014); the page at INAF-OATeramo is mirrored at the IA2 Web site.[1] As an example of interoperability between VO and Distributed Computing for BaSTI, the code building the models has been ported onto the DCI infrastructure and is now populating the database with improved physics (Taffoni et al., 2015).

4.3. Dissemination to astronomy professionals

Dissemination of information to professionals in astronomy is a critically important activity for the take-up of the VO within the scientific community. VObs.it has always supported these activities in the framework of the EU-funded EuroVO projects, providing staff who acted as teachers at VO schools. But specific dissemination activities have been carried out also for the Italian community alone, starting from a school on the porting of applications on the Grid that was organised in Trieste for INAF, Planck and EuroVO-DCA staff (26 Feb–2 Mar 2007).

To foster a complete involvement of Italian community in the use of the VO, a cycle of two-days-long seminars and hands-on laboratories, called "**VO-days … in Tour**" was successfully organised between December 2009 and March 2010. The initiative was carried out in the framework of the EuroVO-AIDA project, with the support of INAF, CINECA and the Universities of Padua and Naples "Federico II". The "VO-days … in Tour" included demos and hands-on sessions applied to four use cases, plus contacts with students, teachers and amateurs to demonstrate the educational/outreach

[1] BaSTI is hosted at the Italian Astronomical Archives Centre at the URL http://ia2.oats.inaf.it/archives/basti-a-bag-for-stellar-tracks-and-isochrones.

system ("AIDA-WP5"), built by VObs.it within the EuroVO-AIDA project. Twelve sites were visited (plus a video conference with the TNG Centre in La Palma, Canary Islands). The number of registered attendees was 272 (more than one fourth of the INAF research staff); 244 persons actually attended, and 176 filled the final Evaluation Form. From the completed forms, it was evidenced that about 70% had already heard about VO and its tools, and that over 80% were satisfied of the demo and hands-on session (see below), while many requested more specific tutorials on tools and information on how to publish their own data in VO. As for the four use cases:

- Use Case 1: Confirmation of a Supernova candidate (89% found it interesting or very interesting);
- Use Case 2: Searching for data available for M51 (88%);
- Use Case 3: Photometric redshifts with DAME (84%);
- Use Case 4: Data extraction from a multidimensional dataset with VisIVO (82%).

The final meeting of the "VO-days … in Tour" cycle of seminars was held in May 2011 at INAF headquarters: it was a wrap up, complemented by a hands-on session, with participants bringing their own scientific case to be solved. And, following the suggestions contained in the Evaluation Forms, a "VO publishing workshop" (Trieste, February 2012), mostly hands-on, was organised and was attended by about 30 people. Furthermore, a national hands-on workshop on VO, with attached a session on Science Gateways, took place in Catania in December 2013.

4.4. Outreach and education for the general public and schools

The purpose of the VO is to collect astronomical data (images, spectra, simulations, mission-logs, etc.), organise them and develop tools that allow astronomers to access this huge amount of information. It is has always been stated that the VO not only simplifies the work of professional astronomers, but it is also a valuable tool for education and public outreach. For teachers and amateurs who actively promote astronomy to the public, the VO is a great opportunity to access and use real astronomical data, and have a taste of the daily life of astronomers. When the international VO standards defined by IVOA became stable, and the VO thus became a stable infrastructure accessible to the general users, VO access by students and general public became an important item to be tackled.

VObs.it has always been at the forefront of **designing and implementing services for higher education and outreach** since the EuroVO-AIDA project, where it led the relevant work-package (Iafrate et al., 2009). In this project, the activities were to identify VO tools of interest, adapt them for a simplified use (in particular the production of a light version of Aladin), identify the required adjustments of the IVOA standards and suggest them, identify and list all the existing outreach material and encourage the translation of the most interesting ones, preparing tools tailored to the VO access for educational/outreach purposes. A version of some VO tools is available for the educational/outreach system ("AIDA-WP5" initiative), made available by VObs.it within the EuroVO-AIDA project funded by the EU. The purpose is to allow students, teachers and amateurs to access the VO via guided use cases and simplified tools.

The professional tools adapted to the requirements of outreach and education activities are Aladin (CDS), Stellarium/VirGO (ESO) and VOSpec (ESA VO). Some initial requirements have been set a priori in order to produce a first version of the simplified interfaces; the initial simplified versions were tested with a sample of target users in order to take their feed-back into account for the development of the final outreach interface. The core of the work consisted in the preparation of a set of **use cases** designed and complemented with proper multilingual documentation covering both the astrophysical context and the use of the software. In the special case of students in the age group 14–18 and their teachers, use cases are brought to schools. The tests are routinely carried out in classrooms supporting students working on personal computers connected to the Internet (Freistetter et al., 2010). The educational/outreach system is being kept up-to-date and has been upgraded to include also Sun and Solar System use cases.[2]

The definition of technical mechanisms to allow education/outreach data to be archived and retrieved following IVOA standards is an extension of this activity (Ramella et al., 2014). The number of remote control telescopes dedicated to education is increasing in many countries, leading to correspondingly larger and larger amount of stored educational data that are usually available only to local observers. A project was proposed by VObs.it for a new infrastructure that will allow teachers to use **educational telescopes**, to archive their data and easily publish them within the VO avoiding the complexity of professional tools. Students and teachers anywhere are expected to be able to access such data, with obvious benefits for the realisation of wide-scale collaborative projects. Educational VO data are also an important resource for teachers not having direct access to any educational telescopes. The educational telescope at INAF-OATrieste has been used as a prototype of a VO educational data archive resource. The whole system is expected to be very flexible, scalable and with the objective of leaving the minimal amount of work for humans. A note was prepared within the IVOA Interest Group in Education (Edu IG),[3] concerning the creation and deployment of astrophysical resources dedicated to education within the standard VO framework.

It is to be noted that the VObs.it staff dedicated to outreach and education participated in the "VO-days … in tour" initiative (see previous section) and supported dedicated sessions on the use of VO resources to teach astronomy at different levels, from junior high school to undergraduate courses. Support was also provided by VObs.it to the VO School in Kerala, India, in October 2011.

4.5. VO applications

VObs.it work on the core of the VO started from applications, to concentrate subsequently on standards and services. Here the VO applications developed by VObs.it are listed, in rough order of availability in time.

VisIVO is a package for supporting the visualisation and analysis of astrophysical three-dimensional data and has several built-in tools which allow an efficient manipulation and analysis of data. The VisIVO code evolved from the EU-funded project AstroMD (Becciani et al., 2010), in order to be integrated with the VO. The focus was on connection to VO web services, retrieval and management of data in the VOTable format, interoperability with other popular VO tools (in particular with Aladin and Topcat) initially using PLASTIC (Becciani et al., 2006). The integration with other VO applications through PLASTIC was successfully demonstrated at the IAU SPS3 meeting in Prague (August 2006). VisIVO ran on GNU/Linux platforms and was made compliant with VO and Grid standards while supporting the most important astronomical data formats such as FITS, HDF5 and VOTables (Becciani et al., 2007). VisIVO was subsequently ported to different platforms (Windows, Mac) and implemented in "server" mode. A web-based and workflow-enabled framework called VisIVO Gateway was furthermore implemented, that allows integration of large-scale multidimensional datasets together with applications for visualisation

[2] The download page for the"AIDA-WP5" outreach/educational material is http://wwwas.oats.inaf.it/aidawp5/eng_download.html.

[3] http://wiki.ivoa.net/twiki/bin/view/IVOA/IvoaEducation.

and exploration on Distributed Computing Infrastructures (DCIs). The framework was implemented through a workflow-enabled portal wrapped around WS-PGRADE which is the grid User Support Environment (gUSE) portal. Customised interfaces for creating, invoking, monitoring and also modifying scientific workflows are provided. All technical complexities, e.g. related to visualisation algorithms and DCI configurations, are conveniently hidden from the user (Costa et al., 2013). This version is not yet SAMP-enabled, and plans are to refurbish VisIVO within the VO framework. The code is available in the download area of the VisIVO Web page.[4]

VO-Neural/DAME is a set of VO-aware data mining tools built in collaboration between the University of Naples "Federico II" and CalTech within the framework of VObs.it and of the VO-TECH project. VO-Neural is the natural evolution of the Astroneural project which started in 1994 with the aim of implementing a suite of neural tools for data mining in massive astronomical datasets. As a difference with its ancestor, which was implemented under Matlab, VO-Neural is written in C++, object oriented, and is specifically tailored to work in distributed computing architectures (Brescia et al., 2009). The aim is to provide a service for the community, thus the possibility is provided to use it within complex workflows which each user can fine-tune in order to match the specific demands of his/her scientific goal. These workflows need often to access different resources (data, providers, computing facilities and packages) and require a strict interoperability on (at least) the client side. The DAME (DAta Mining & Exploration) project arises from these requirements by providing a distributed Web-based data mining infrastructure specialised on massive datasets exploration with soft computing methods. Originally designed to deal with astrophysical use cases, the DAME Suite has become a multi-disciplinary platform-independent tool perfectly compliant with modern KDD (Knowledge Discovery in Databases) requirements and ICT (Information and Communication Technology) trends (Brescia et al., 2011). The system was more recently upgraded using Clustering-Labels-Score Patterns Spotter (CLaSPS), a methodology for the determination of correlations among astronomical observables in complex datasets, based on the application of distinct unsupervised clustering techniques (D'Abrusco et al., 2012).[5]

VO-Dance is a tool designed to allow users and data centres to easily create services compliant with the VO Data Access Layer standards (Cone Search, SIAP, SSAP), on the fly and starting only with a database table or view, without the need of writing any code and in a matter of minutes. Users who want to publish their datasets to the Virtual Observatory can achieve this goal without having to deal with the technical details of standard services development and without having to move their data. With VO-Dance, users just have to provide a database connection that points to their available data and to fill out a metadata description form without having to export their data. Data Access Layer services are created on the fly and published, as a hosted service of IA2, to the Virtual Observatory. VO-Dance has been successfully used to publish Cone Search and Simple Image Access Protocol services out of the MySQL and Oracle database management systems (Smareglia et al., 2011). VO-Dance is written in Java and, in turn, relies on a database (potentially DBMS independent) to store the translation layer information of each resource and auxiliary content (UCDs, field names, authorisations, policies, etc.). The last token is an administrative interface (currently developed using the Django python framework) to allow the data centre administrators to set up and maintain resources. This deployment, platform independent, with database and administrative interface highly customisable, means that the package can be also used by single astronomers or groups to set up their own resources from their public datasets (Molinaro et al., 2012). The extension of VO-Dance to planetology is under study (Smareglia et al., 2012).

VOdka (VO Data Keeping-up Agent) is an agent which monitors the state of the VO seeking for changes in services and datasets and notifying users for those changes and updates. Currently, Virtual Observatory (VO) users interact with the VO infrastructure as the main actors: in particular, each time they want to fetch data from the VO they have to choose an application and trigger it. VOdka seeks for changes in services and datasets on their behalf and provides notification. These snapshots are persistent so that users can manage them and, when new interesting data are found, download them (Laurino and Smareglia, 2011).

The **ASDC SED Builder** (Stratta et al., 2011), a tool developed to run at the ASDC, was upgraded to comply to the IVOA standards; in collaboration with the VAO/CfA team an ASDC Plug-in was included in the Iris SED Builder tool (Laurino et al., 2014). The plugin allows to connect to the ASDC SED Builder and to obtain the data to visualise and analyse a SED within Iris, implementing interoperability between the two tools in the VO environment. Version 1.1.3 was documented and fully integrated within the Iris package.

VESPA (VO Educational Service Publisher and Archive) is a Web application for easily preparing VO services, targeted at people involved in education. Service publishing is done through the VO-Dance IA2 application; everything is transparent to the user, while data ingestion is handled automatically by NADIR (an internal IA2 infrastructure development project). VESPA is already deployed and publicly accessible (in its beta test version).[6] At the moment only the SIAP protocol is supported and was successfully used for publishing the data of the INAF-Trieste SVAS educational telescope. The SVAS service has been registered (on the EuroVO registry) and is accessible through the standard VO tools (Cepparo, 2014).

4.6. VO standards

Participation from VObs.it staff in the IVOA Working Groups defining standards has started slowly, due to the pretty steep learning curve the Italian community had to face after its inclusion in the VO community. However, with increasing involvement, and training from the more experienced foreign IVOA and EuroVO colleagues, VObs.it has provided a significant amount of work to the various IVOA Working Groups contributing to the definition of relevant standards.

In **Grid and Web Services**, staff from VObs.it participated in the IVOA Tiger Team on Authentication Procedures (single-sign-on); a Web application handling the release of certificates was implemented, in coordination with IVOA and AstroGrid. There was participation in the definition of the IVOA Credential Delegation Protocol Version 1.0 Recommendation (Graham et al., 2011) as well. The credential delegation protocol allows a client program to delegate the user's credentials to a service which may make requests to other services in the name of that user; the protocol defines a REST service that works alongside other VO services to enable such a delegation in a secure manner.

In **Applications**, work on the Simple Applications Messaging Protocol (SAMP) was performed. SAMP is a VO specification, built on the success of its predecessor, PLASTIC. SAMP is a messaging protocol that enables astronomy software tools to exchange control information and data, allowing desktop applications to

4 The code is available on http://visivo.cineca.it/.

5 The code is available on http://voneural.na.infn.it/.

6 http://ia2-edu.oats.inaf.it:8080/vespa.

work as an integrated suite of tools rather than requiring complex functionality to be built into the individual tools (Taylor et al., 2011). In addition, SAMP reduces the time needed to switch between applications and tasks, allowing efficient workflows to be created (Fitzpatrick et al., 2013).

Within **Semantics**, work has been done on UCDs (Unified Content Descriptors), metadata that have been used in the CDS VizieR catalogue service since they were first developed in the ESO/CDS data mining project. Because the catalogues currently described by UCDs cover many different domains, UCDs can be used to describe a large fraction of astronomical concepts: therefore VO supports UCDs, and collaborates to define a new set of standard metadata (Derriere et al., 2004). A close collaboration between VObs.it and CDS allowed the Italian team to provide support to the definition of the standard, and its update, UCD1+ (Preite Martinez et al., 2011). Furthermore, there was participation in the definition of the Vocabularies in the VO, a standard format for vocabularies based on the W3C's Resource Description Framework (RDF) and Simple Knowledge Organization System (SKOS): by adopting a standard and simple format, the IVOA allows different groups to create and maintain their own specialised vocabularies while letting the rest of the astronomical community access, use, and combine them (Derriere et al., 2011).

Work for **Theory** has materialised in the definition of SimDM (Lemson et al., 2014), the IVOA Simulation Data Model for Theory, which describes numerical computer simulations of astrophysical systems; the aim is supporting discovery of simulations by describing those aspects of them that scientists might wish to query on. In other words, it is a model for meta-data describing simulations.

In **Data Model** there is an on-going effort to extend the High Energy Spectral Data Model (Gendre et al., 2013), and there are discussions with the radio astronomy community and CDS for feedback on the access to radio and multidimensional data following IVOA standards.

In **Data Access Layer** some work was devoted to adapt the data access protocols to correctly identify educational/outreach data. Furthermore, collaboration with the EU-funded EuroPlanet project allowed to support EPN-TAP services, using a standard that extends the IVOA TAP for planetary science, offering a specific tool to realise access services for planetary datasets.

Finally, for **Registry**, VObs.it is involved in the implementation of the Relational Registry Schema Working Draft currently being proposed.

4.7. VO-compliant implementations

Efforts have been carried out along the years to provide Italian VO-compliant services to the International VO users. As of the 31 October 2014, there are 50 registered services identified using RegTAP. The main provider of services in Italy is the IA2 data centre, which provides VO-compliant access to the data of the major Italian ground-based telescopes (LBT, TNG), but also support for the WINGS survey, WGE/SDSS data, the ERCSC catalogues of the Planck CMB mission, plus the first educational archive (SVAS); hosted archives, including TIRGO/AMICA and the BaSTI simulation data, are also featured. Plans are to pursue VO compliance within major projects (Euclid, SKA, CTA) and, through inclusion of data within the IA2 facilities, also for minor projects (REM) and local observatory archives (e.g. OAPD-Ekar). INAF-IASF in Milan supports VO-compliant access to the VIMOS data. INAF-OACatania supports access to Byurakan data; access to planetary datasets through EPN-TAP is provided at INAF-IAPS in Rome. INAF-OACapodimonte and the University of Naples provide access to the catalogues built out of data mining services.

The ASI Science Data Centre integrated within the VO sets of ASDC data, mostly acquired by high-energy space missions. Two TAP-based services are provided to allow access to the ASDC multi-frequency catalogue; all the mandatory functionalities of a TAP service have been implemented, and have been tested with the taplint tool of the STILTS package, and with the TOPCAT client.

4.8. Documentation

VObs.it is acting as one of the documentation sites for IVOA: VObs.it (and specifically the IA2 data centre located at INAF-OATrieste) hosts the IVOA Internet domain, the mailing lists and the wiki, while the Document Repository is hosted by VO-India (at IUCAA). The technical handover from VAO (previously responsible for the whole IVOA documentation) to VObs.it was completed in September 2014 (Berriman et al., 2014). At the same time, VObs.it has also taken responsibility for providing the IVOA Document Coordinator.

4.9. Responsibilities

While the VO activity progressed within Italy, VObs.it staff increasingly took up responsibilities within an international framework, both in EuroVO and IVOA. The IVOA responsibilities are listed in Table 2. As for responsibilities within EuroVO, Fabio Pasian and Riccardo Smareglia of INAF-OATrieste were alternatively the INAF/VObs.it representatives in the EuroVO Board; Paolo Giommi of ASI-ASDC and Santi Cassisi of INAF-OATeramo were, at different times, members of the EuroVO Science Advisory Committee; finally Andrea Preite-Martinez of INAF-IASF Rome, Giuliano Taffoni and Massimo Ramella of INAF-OATrieste led, at different times, work-packages within the various EuroVO projects funded by the EU.

4.10. Events

Quite a number of VO international workshops or technical meetings were organised, hosted and/or supported by VObs.it and/or hosted in Italy. Among these: two IVOA Interoperability meetings and one to come, two back-to-back workshops on Theory and Grid and the VO co-organised by INAF/VObs.it and MPE/GAVO in the framework of the EuroVO-DCA project, and several EuroVO Technical Coordination meetings. Dates and details can be found in Section 2, within Table 1.

5. Discussion: lessons learned and road ahead

5.1. How to achieve in a relatively low funding situation

Due to the slow start of the Italian participation in VO activities, and the subsequent low-but-steady level of funding, specific strategies and both long- and short-term choices were needed to invest such resources for activities useful both in the international VO framework and for the Italian astronomical community. It is clear that the slow start hampered the capability of acquiring the know-how needed to participate in the development of the core components of the VO: adding still-to-be-trained staff to the running development activities would have been a burden rather than a benefit for the international projects and initiatives VObs.it was participating in. Rather, compatibly with the available resources, the manpower was invested in preparing interim implementations to verify the soundness of the standards being discussed, and the correctness of the assumptions and/or solutions. This was applied especially to the development of standards for Theory. As a matter of fact, another strategical decision was to try to fill the voids in the development, where the focus on the core VO

Table 2
VObs.it staff responsibilities within the IVOA.

Name	Institute	Task	Period
A. Preite-Martinez	IASF Rome	Semantics Chair	Jan 05–Jan 08
F. Pasian	OATrieste	IVOA Vice-Chair	Aug 07–Oct 08
C. Gheller	CINECA	Theory Vice-Chair	May 08–May 11
F. Pasian	OATrieste	IVOA Chair	Nov 08–May 10
G. Longo	U. Naples	KDD Chair	Sep 10–Oct 12
F. Pasian	OATrieste	IVOA-OGF contact	since Sep 11
M. Ramella	OATrieste	Education Chair	since Dec 12
M. Molinaro	OATrieste	DAL Vice-Chair	since May 14
G. Iafrate	OATrieste	IVOA Doc. Coord.	since Sep 14

achievements left room for contributions of newcomers or experts in complementary fields. Therefore VObs.it concentrated (and still is concentrating) in theory, distributed computing technology, KDD and data mining, education and outreach, dissemination of knowledge on VO tools and capabilities.

It is also to be noted that, through the past couple of years, VObs.it has increased its activities within the IVOA. This is certainly due to an increased knowledge by the Italian community of the VO ''internals'' and thus to the capability of being useful, but it is also caused by a decreasing activity of other national initiatives that have seen their funding reduced. This is a situation in which constant funding, although at a low level, is an advantage. This is where VObs.it can play a useful role, and plans to continue on this path.

Getting to know the ''internals'' of the VO standards is not an easy task, since the system needs to be complex to cope with the needs of the astronomical community. To face this apparently steep learning curve, the VObs.it strategy was to take advantage of the training provided in EuroVO schools and technical meetings from the more experienced foreign colleagues. Constant participation in IVOA Interoperability meetings also played, and still plays, an essential role in the learning and updating process.

One of the keys that allowed optimisation of human resources within the VObs.it activities was the existence in the staff of scientists knowledgeable in both astronomy and computer science/engineering. This new breed of scientists, ''astro-informaticians'' we could call them, act as a linking point between the needs of the users (the ''true'' astronomers) and the computer engineering ''nuts-and-bolts''. In Italy the University of Naples ''Federico II'' provides this sort of background as part of its Master courses. And within some of the INAF institutes (Trieste, Catania, Milan, Naples) there are groups where this knowledge can be developed and exploited.

5.2. National tensions and differing interests

For several years, there has been an attempt to prepare a MoU to formalise the on-going collaboration across Italy regarding VO activities within VObs.it and involving INAF, ASI, CINECA and the Universities of Padua and Naples (''Federico II''). The document, although positively received at the technical level, was never officially signed by the respective partners. On the other hand, requests for a higher national funding, at the level of the Ministry of Education and Research, was always turned down. Maybe the lesson to be learned is that the importance of VO is still underestimated by upper management. If this was the case, it would evidence an interesting but dangerous discrepancy with the requests coming from scientists in the community who, in contrast, ask for a higher level of VO support.

Certainly, the lack of an overall formal agreement to coordinate VO work within the Italian community has brought to non-negligible issues.

- On one hand, the collaboration with CINECA on the VO has ceased with the expiration of the INAF–CINECA collaboration agreements; the new CINECA policy does not foresee separate agreements with the various science disciplines, and this hampers the feasibility of working jointly on domain-specific activities.
- On the other hand, the coordination with ASDC has been at a level much lower than originally expected. The bi-lateral committees superseding the global ASI–INAF collaboration agreements have recommended ASDC-VObs.it collaboration, and the User Committee of ASDC has issued a set of recommendations for a better integration of the centre (mainly holding data from high-energy space missions) within the international VO, and for ASDC participation in VObs.it. A letter of agreement between the main Italian data centres for astrophysics (ASDC and IA2) for joint activities to be carried out within the VObs.it framework has been agreed upon and was endorsed by the INAF–ASI coordination committee. But the limited ASI funding for ASDC VO work, and the currently unsatisfactory IVOA data model for high-energy data, both do not allow the ASDC to perform the wealth of activities that could be done, considering their know-how.
- Finally, it is noted that the University teams (Naples and Padua) participating in VO work are too small, compared to the size of the Universities themselves, to receive proper recognition (and funding), not to mention the signature of a formal MoU.

5.3. The future

The future of VObs.it is therefore tied to INAF funding, which has been, and is, crucial for development of work and for the maintenance of the services. The funding is approved year-by-year, therefore performing long-term planning is not an easy task. The issue of who would actually do the work of maintaining the VO infrastructure in the lack of appropriate funding was discussed at IVOA Executive Committee level. In Italy, the IA2 and ASDC data centres would continue to provide service because it is in their interest to do so, but it is to be noted that the benefit of having a running VO technical development effort is crucial to allow adapting standards and tools to the raising new needs. The IVOA Executive Committee discussed some ideas for different styles of participation in IVOA, such as having data centres as partners in IVOA. This is not acceptable, nor accepted, because there is the concrete risk that it would break the IVOA into a set of contradicting flows of work. National coordination is felt as absolutely necessary, and this is a constraint everybody should accept. The strength of IVOA is that it is a worldwide collaborative effort, and collaboration shall begin at the national level.

In planning the future, it is to be noted that with the current Italian legislation it is difficult to keep skilled staff holding certain specific types of contracts for more than a limited amount of time (four to five years), even in presence of appropriate funding. This is a constraint to be seriously taken in consideration, because it is likely that skilled persons are obliged to leave the projects due to bureaucratic limitations, creating problems in the continuity of VO know-how. Managing these types of risks within VObs.it may become quite challenging.

Given the limited amount of funding INAF, ASI and Universities can provide to VO activities, what can reasonably be done is basically to continue maintenance of the VO services and tools with some patching/upgrading. The resources for development must be seeked elsewhere, and in Europe they need to rely on EU funding. The EU policy for e-infrastructure development within the Horizon2020 programme calls for multi-disciplinary efforts and this is a path to be followed. In such a way specific tokens can be built for the VO infrastructure, that can be of general use in other communities as well (e.g. authorisation & authentication, workflows, etc.). The VO must instead remain an integral component of the big observing infrastructures endorsed by the EU ESFRI roadmap (SKA, CTA, E-ELT) and foreseen in the ESA Cosmic View 2025 program (e.g. Euclid, Plato, Athina, but also Solar Orbiter). This kind of approach would ease neighbouring communities (planetology, radio astronomy, high-energy astrophysics) to join the VO efforts.

"We need finishers rather than brainstormers". This is a phase of the VO evolution where the core set of standards and tools are stable enough to be used by the community at large. Whatever else is added to this VO core needs to be carefully studied on the basis of use cases provided by the interested astronomers and needs to be *completed timely*, for the scientists cannot wait forever for an appropriate VO solution to fulfil their needs. And this is also a phase in which large projects (SKA, CTA, E-ELT) are preparing their plans, and they need to be drivers for the VO development, since the enormous wealth of their data is a treasure the scientists of tomorrow will need to have an efficient access to. In this phase, VObs.it can provide its help and its knowledge, and the practical approach always followed by VObs.it in its life allows to identify its staff in the class of "finishers".

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Acronyms and URL	
ADQL	Astronomical Data Query Language
AMICA	Antarctic Multiband Infrared CAmera
AMR	Adaptive Mesh Refinement (cosmology simulation algorithm)
ASDC	ASI Science Data Centre (http://www.asdc.asi.it/)
ASI	Italian Space Agency
AVO	Astronomical Virtual Observatory (EU-funded project)
BaSTI	A Bag of Stellar Tracks and Isochrones (http://basti.oa-teramo.inaf.it/index.html)
CANFAR	Canadian Advanced Network For Astronomical Research (http://www.canfar.phys.uvic.ca/canfar/)
CDS	Centre Donnes Strasbourg (http://cdsweb.u-strasbg.fr/)
CINECA	Italian supercomputing centre (http://www.cineca.it/en)
CMB	Cosmic Microwave Background
CoSADIE	EuroVO Collaborative and Sustainable Astronomical Data Infrastructure for Europe (EU-funded project)
CTA	Cerenkov Telescope Array
CVO	Canadian VO initiative (http://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/cvo/)
DAME	DAta Mining & Exploration (http://dame.dsf.unina.it/ http://voneural.na.infn.it/)
DBMS	database management system
DCI	Distributed Computing Infrastructure
DRACO	DataGrid for Research in Astronomy and Coordination with the virtual Observatory
E-ELT	European Extremely Large Telescope
EGEE	Enabling Grids for E-Science in Europe (EU-funded projects)
ERCSC	Early-Release Compact Sources Catalogue (of the Planck mission)
EPN	
ER-flow	Building a European Research Community through Interoperable Workflows and Data (EU-funded project) (http://www.erflow.eu/)
ESA	European Space Agency
ESO	European Southern Observatory
ESFRI	European Strategy Forum on Research Infrastructures
EU	European Union
Euclid	mission of the European Space Agency
EU/FP6	European Sixth Framework Programme
EU/FP7	European Seventh Framework Programme
EuroVO	European VO initiative (http://www.euro-vo.org/)
EuroVO-AIDA	EuroVO Astronomical Infrastructure for Data Access (EU-funded project)
EuroVO-DCA	EuroVO Data Centre Alliance (EU-funded project)
EuroVO-ICE	EuroVO International Cooperation Empowerment (EU-funded project)
FITS	Flexible Image Transport System
Gadget-2	cosmology simulation code (http://www.mpa-garching.mpg.de/gadget/)

(*continued on next page*)

GAVO	German Astronomical VO initiative (http://www.g-vo.org/)
G-DSE	Grid Data Source Engine
GGF	Global Grid Forum
gUSE	grid User Support Environment (http://www.guse.hu/; http://sourceforge.net/projects/guse/)
GWS	Grid and Web Services (IVOA WG)
IA2	Italian centre for Astronomical Archives (http://ia2.oats.inaf.it/)
IAU	International Astronomical Union
ICT	Information and Communications Technology
IG	Interest Group
IGI	Italian Grid Initiative (http://www.italiangrid.it/)
INAF	Italian National Institute for Astrophysics
INAF-SI	INAF Information Systems Unit
INFN	Italian National Institute for Nuclear Physics
ITVO	Italian Theoretical Virtual Observatory
IUCAA	Inter-University Centre for Astronomy and Astrophysics
IVOA	International Virtual Observatory Alliance (http://www.ivoa.net/)
KDD	Knowledge Discovery in Databases (also an IVOA WG)
LBT	Large Binocular Telescope
LoI	Letter of Intent
MoU	Memorandum of Understanding
MPE	Max-Planck-Institut für Extraterrestrische Physik
OGF	Open Grid Forum
Planck	mission of the European Space Agency
PLASTIC	Platform for Astronomy Tool InterConnection (IVOA standard)
RDF	Resource Description Framework
REM	Rapid Eye Mount (robotic telescope)
REST	REpresentational State Transfer protocol
SAMP	Simple Applications Messaging Protocol (IVOA standard)
SCI-BUS	SCIentific gateway Based User Support (EU-funded project) (http://www.sci-bus.eu/)
SDSS	Sloan Digital Sky Survey (http://www.sdss.org/)
SED	Spectral Energy Distribution
SHIWA	Sharing Interoperable Workflows (EU-funded project) (http://www.shiwa-workflow.eu/)
SIAP	Simple Image Access Protocol (IVOA standard)
SimDB	Simulation Data Model (IVOA standard)
SKA	Square Kilometre Array
SKOS	Simple Knowledge Organization System
SMP	Smooth Particle Hydrodynamics (cosmology simulation algorithm)
SNAP	Simple Numerical Access Protocol (IVOA standard)
SSAP	Simple Spectra Access Protocol (IVOA standard)
STILTS	Starlink Tables Infrastructure Library Tool Set (http://www.star.bris.ac.uk/~mbt/stilts/)
TAP	Table Access Protocol (IVOA standard)
TIRGO	Telescopio Infra-Rosso al GOrnegrat
TNG	National Galileo Telescope
TOPCAT	Tool for OPerations on Catalogues And Tables (http://www.star.bris.ac.uk/~mbt/topcat/)
UCD	Unified Content Descriptor (IVOA standard)
URL	Uniform Resource Locator
VAO	Virtual Astronomical Observatory (US VO project) (http://www.usvao.org/)
VIMOS	Visible wide field Imager and Multi-Object Spectrograph
VisIVO	Visualisation Interface to the Virtual Observatory (http://visivo.oact.inaf.it:8080/)
VO	Virtual Observatory
VObs.it	Italian VO initiative (http://vobs.astro.it/)
VOQL	Virtual Observatory Query Language
VO-TECH	EuroVO Virtual Observatory Technology project (EU-funded)
W3C	World Wide Web Consortium (http://www.w3.org/)
WG	Working Group
WGE	Weak Gated Experts method
WINGS	WIde-field Nearby Galaxy-cluster Survey (http://web.oapd.inaf.it/wings/)
WP	Work-Package

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