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# The Virtual Observatory and Grid in Spain

## VO and Grid infrastructures and initiatives

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**Abstract.** The Virtual Observatory (VO) is nearing maturity, and in Spain the Spanish VO (SVO) exists since June 2004. There have also been numerous attempts at providing more or less encompassing grid initiatives at the national level, and finally Spain has an official National Grid Initiative (NGI). In this talk we will show the VO and Grid development status of nationally funded initiatives in Spain, and we will hint at potential joint VO-Grid use-cases to be developed in Spain in the near future.

**Key words.** Archives: Virtual Observatory – Computing: grid

## 1. Introduction

The Virtual Observatory, as proposed by Szalay & Gray in 2001, is today a tangible infrastructure used by thousands of astronomers (and non-astronomers) every day. It help scientists by letting them explore massive amounts of data, to derive statistical properties from thousands of objects, and even to find new kinds of objects; by providing a multi-wavelength view of particular objects or regions of the sky; and by providing time-lapsed views of any region of the sky from archived data.

As mentioned, the foundational paper of the Virtual Observatory by Szalay and Gray was written in 2001, and the first Astronomical Virtual Observatory (AVO) prototype, based on CDS's Aladin Sky Atlas[1] is from 2002 (see Padovani, 2005). By that time, our research team (the AMIGA group, Analysis of the interstellar Medium of Isolated GAlaxies, Verdes-Montenegro et al., 2005) was working on a multi-wavelength study for the 1,051 galaxies in the Catalogue of Isolated galaxies by Karachentseva in 1973 (see also her online catalogue, Karachentseva et al., 1997). The group had already compiled quite a large amount of information (revised positions, IR fluxes in different wavelengths, images with different filters), but still needed more information to be retrieved, and wanted to make our different revised data products available to the community.

Using the existing International Virtual Observatory Alliance[2] (IVOA) Proposed Recommendations, such as the VOTABLE (Ochsenbein et al., 2004) and the Simple ConeSearch (Williams et al., 2008), the AMIGA group finally provided a public web

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[1] http://aladin.u-strasbg.fr/

[2] http://ivoa.net/

site[3] delivering data in VOTABLE format, providing at the same time a Simple ConeSearch interface.

### 1.1. Radio astronomy and the VO

As astronomy started when the first humans raised their heads and reckoned that the sky was very similar from night to night, with seasonal variations that repeated from year to year, the visible part of the spectrum has always been the most used, and more familiar, to all astronomers. However, the discovery by Jansky in 1933 of a extraterrestrial and extrasolar radiation with a wavelength of 14.6 meters, opened a new spectral window that even today is just 63 years old, a small fraction of the almost 400 years of instrumental optical astronomy.

The Virtual Observatory is also developing more rapidly for data from the visible parts of the electromagnetic spectrum, but radio astronomical data is of the utmost importance for understanding the most distant and obscured objects in the universe, and the integration of these data sets in the VO infrastructure has been a goal of our group since the beginning.

### 1.2. Grid and astronomy

The computing grid was conceived by Foster & Kesselman in 1999 as *a hardware and software infrastructure that provides dependable, consistent, pervasive and inexpensive access to high-end computational capabilities*. The similarity with the power grid arises from the fact that until the power grid became common-place, electricity based facilities depended on their own power generation. Providing computing-on-demand, as easy to access as the power grid, is the aim of grid computing initiatives.

The next generation of astronomical instruments, that we might call surveying instruments, such as the Large Synoptic Survey Telescope (LSST), the Square Kilometre Array (SKA), the LOw Frequency ARray (LOFAR), or even the Atacama Large Millimetre and submillimetre Array (ALMA), will be extremely sensitive, and at the same time their schedule will be completely automated, so that the raw data rates will overwhelm any conventional computing facility. For these telescopes, parallel processing of incoming data is needed, either by extensive pre-processing at the data generation site, or by running parallel pipelines for different levels of data products, or by splitting the different levels of processing between different *tiers*. An extreme, present case, is the LOFAR which, as can be seen from Valentijn's proceeding, will need a super- computer class data reduction engine with a tiered architecture for data reanalysis.

At the same time, the storage needs for this instruments will be so demanding that for some applications no actual data access will be possible, but only streaming access to the data being provided. Again, the LOFAR is an example of this. In any case, data access has also to be distributed, and different grid techniques (grid-FTP, IBM's Grid Parallel File System...) are used.

In the following sections, we will learn about the SVO (the Spanish Virtual Observatory), grid developments in Spain, and joint grid and virtual observatory efforts in our country. We will end with a conclusions section.

## 2. VO in Spain: the SVO

Publicly-funded VO activities in Spain are organised around the Spanish Virtual Observatory (SVO[4], Gutiérrez et al., 2006). Enrique Solano is the PI of the SVO, which joined IVOA in July 2004. With the creation of a publicly funded thematic network on the Virtual Observatory, the SVO has spurred collaborations between all people with interest in the VO, from scientists who wanted to use VO applications or technologies, to data centres wishing to provide VO-compatible archives, with groups wanting to publish data in the VO in between.

[3] `http://amiga.iaa.csic.es:8080/DATABASE/`

[4] `http://svo.laeff.inta.es/`

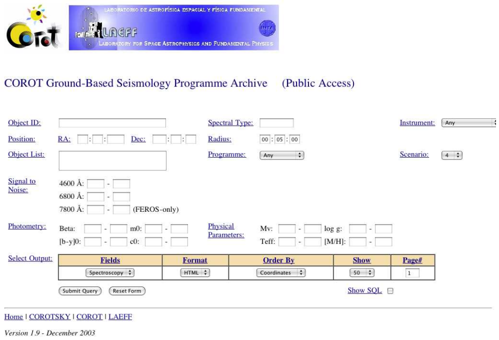


**Fig. 1.** Main entry page for the VO-compliant GAUDI archive, developed for the preparation of the CoRoT mission by the SVO-core.

Nowadays, the SVO provides 4 Full Time Employees (FTEs) from the LAEFF-INTA devoted to VO tasks, while the IAA-CSIC provides another FTE. The LAEFF-INTA group constitutes what is known as the SVO-core, and its continuity is guaranteed by recurring funding by the Instituto Nacional de Técnica Aeroespacial (INTA).

The SVO-core has developed, and maintains, several VO archives, such as the INES[5] (IUE Newly Extracted Spectra), GAUDI[6] (CoRoT Ground-based Asteroseismology Uniform Database Interface, see Solano et al., 2005), and OMC[7] (INTEGRAL mission Optical Monitoring Camera, see Gutiérrez et al., 2004), among others.

This experience will be key for the participation of the SVO-core in the CONSOLIDER consortium for the GTC, both for the VO archive of the telescope, but also for the artificial intelligence techniques for scientific exploitation.

The SVO maintains presence in different VO-related international bodies and projects: Enrique Solano is part of the IVOA Executive, and the LAEFF-INTA is member of the VOTech, EuroVO-DCA, and EuroVO-AIDA EU funded programmes.

[5] http://sdc.laeff.inta.es/ines/
[6] http://sdc.laeff.inta.es/gaudi/
[7] http://sdc.laeff.inta.es/omc/

Fostering VO-enabled science, science performed with VO tools, has always been one of the main concerns of the SVO. In that regard, two kinds of tools have been developed by the VO: ready to use web-based tools, such as the VOSED[8] (see figure 2), and artificial intelligence/data mining tools.

The VOSED provides an interface to Simple Spectral Access (SSA, see Tody & Dolensky, 2007), photometry, and synthetic spectra services, and even to user provided spectra files, so that a user can compile a multi-wavelength Spectral Energy Distribution (SED) that can later be fitted to simple blackbody emissions, or to more complex star and dust/debris disks models.

In order to access theoretical spectra, the SVO also developed the Theoretical Spectra Access Protocol (TSAP, see Rodrigo et al., 2007), an extension to the SSA with additional parameters that allow applications to find out supported models, and for spectra to be synthesised on the fly from them. The VOSED uses the TSAP to perform the theoretical spectra fitting. Additional theoretical related efforts by SVO members include the PGos3[9] theoretical model database for stellar populations, developed in coordination with the Mexican National Institute for Astrophysics, Optics and Electronics (INAOE).

Data mining is another constituent of the SVO. The VO allows access to large amounts of data, but being able to extract meaningful properties from huge sets of objects, such as classification in different kinds, or finding completely new kinds of objects, is only possible by means of data mining techniques, such as neural networks, Support Vector Machines, k-Means algorithms... One example of neural networks use at the SVO is the paper on automated classification of eclipsing binaries by Sarro et al. in 2006.

Several science papers have been published by members of the SVO, or using tools developed at the SVO. Members of the SVO take part in the VSOP project (Dall et al., 2007) for variability-type determination through data

[8] http://sdc.laeff.inta.es/vosed/
[9] http://ov.inaoep.mx/pgos3/index.php

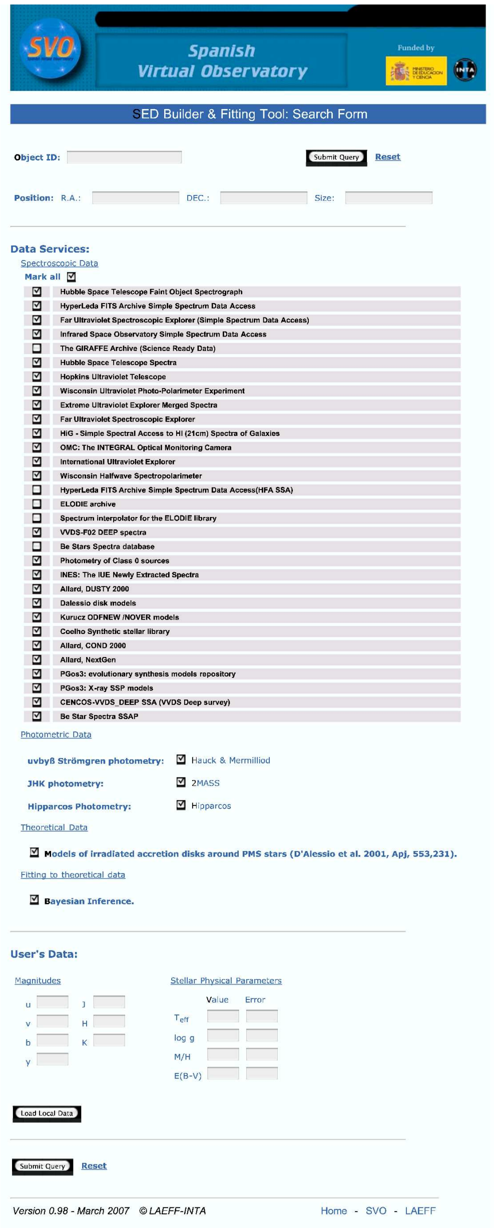


**Fig. 2.** Web page of the VOSED search form. The user enters an object name, or coordinates, and selects the different SSA services that can provide spectra for that particular position. Photometry data can also be retrieved to complete and create a synthetic SED, that the user can fit with VOSED to different models.

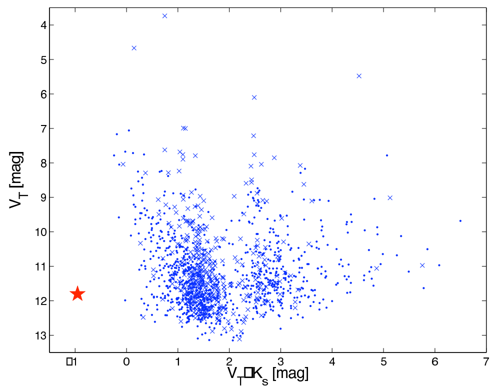


**Fig. 3.** $V_T$ versus $V_T - K_s$ color-magnitude diagram from the data in Caballero & Solano (2008). Tycho-2/2MASS sources with proper motions larger and smaller than 15 mas $yr^{-1}$ are shown with crosses and dots, respectively. Albus 1 is highlighted with a big filled (red) star.

mining techniques for not yet characterised objects, and several serendipitous discoveries have been performed, such as that of Albus 1, a very bright white dwarf candidate discovered by Solano & Caballero in 2007. In figure 3 we can see Albus 1 is clearly an outlier in the Tycho-2/2MASS color distribution.

## 3. Grid in Spain

Foster's definition of a grid can be posed as *computing power as easy to use as electricity*. Of course, that means that grid computing is a subset of networked computing, and any grid computing initiative is only meaningful when there is a powerful enough network linking available computers.

In Spain, all universities and research institutes are connected via a high-bandwidth network infrastructure that was known as RedIRIS (see figure 4), and now is known as Red.Es[10], a Spanish initiative for a networked society. RedIRIS was connected to the European research network Géant2 in March 2006, thus providing more bandwidth for research interoperation in the EU.

[10] http://www.red.es/

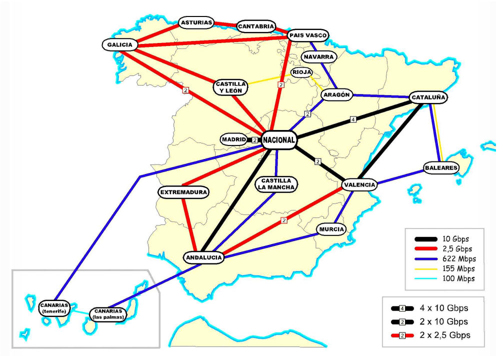


**Fig. 4.** RedIRIS high-level topology. Each region has its own networking centre that provides service to capital cities, with county access relayed from them. RedIRIS is connected in Madrid to the Géant2 network, to the global internet, and to Spanish internet through the ESPANIX internet exchange point. Regional topology not shown.


**Fig. 5.** Map of the different research groups/institutes initially forming the IRISgrid initiative. Groups with an asterisk (*) provided computing nodes for the IRISgrid computing demonstration on December 2004.

From the networking research aspect of RedIRIS, research groups started to promote the need for a grid initiative, and thus IRISgrid was born in 2003. Several research groups had also gained experience by participating in the Enabling Grids for E-sciencE (EGEE), CrossGrid, EU-DataGrid, Interactive European Grid (Int.eu.grid, also known as I2G) and other European-level grid projects. The teams involved in IRISgrid are shown in figure 5.

Not surprisingly, most of the centres participating in IRISgrid come from the High Energy Physics/Particle Physics centres. Spanish experience also includes grid middleware development: the Department of Computer Architecture and Automation (DACYA[11]) at the Universidad Complutense de Madrid, has developed the GridWay[12] meta-scheduler, now part of EGEE's gLite[13] middleware distribution.

However, funding for the IRISgrid initiative ended in the beginning of 2007. Moreover, IRISgrid was never officially recognised by the Spanish ministry of Science and Education as THE national grid initiative. When the European Grid Initiative[14] started to take shape in 2007, prompting possible members to register with their own initiatives, finally an officially recognised grid initiative was launched: the Spanish Network for e-Science[15].

Still, the Spanish Network for e-Science consists mostly of the centres participating in the IRISgrid initiative, plus centres who wish to learn and start using grid techniques, but no hardware or budget (aside from continued funding for the academic inter-networking through Red.es) has been provided.

In this context, and taking into account that many of the research centres with extensive grid experience belong to the CSIC Spanish Research Agency (Consejo Superior de Investigaciones Cientficas), the GRID-CSIC initiative has been born this year (Marco, 2008) with the aim to provide CSIC centres with high-end computing facilities that will be networked and provided with EGEE- and I2G-compatible middleware so that they can be seamlessly integrated in the Spanish NGI.

This infrastructure must be compatible, and eventually shared with the joint Spain-Portugal IberGrid initiative, and with the France CNRS Institut des Grilles (Grids

[11] `http://www.ucm.es/info/dacya/`
[12] `http://www.gridway.org/`
[13] `http://glite.web.cern.ch/glite/`
[14] `http://web.eu-egi.org/`
[15] `http://www.e-ciencia.es/`


**Fig. 6.** Centres participating in the two initial phases of GRID-CSIC. The IFCA and IFIC belong to the high-energy physics community, and IAA is the Institute for Astrophysics of Andalusia, and uses grid and super computing for planetary atmospheres, stellar structure modelling, and N-body simulations, among others. The second phase will include additional, yet to be defined, nodes at Madrid and Catalonia.

Institute). It will be started in 2008-2009 with a test phase with initial deployment of just three nodes at centres with grid experience (IFCA, IFIC, IAA), with three yet to be defined additional nodes in Madrid and Catalonia for 2009-2010, and the rest of the nodes operational in 2010 (see figure 6). Total estimated computing power at the end of the project will be in the order of 8000 cores (either AMD Barcelona or Intel Xeon x86_64 architecture processors), with on-line storage of up to 1 PB (1000 TB).

Apart from project coordination and infrastructure management, an additional application development and grid porting support area has been defined, so that users can make real use of the GRID-CSIC equipment. One of the most relevant evaluation criteria of the project success will be the percentage of users making active use of the grid for their research.

IAA experience in IrisGRID comes from high-performance computing users in the area of astrophysics, and was assigned with the task of providing the use cases and background for IrisGRID in the topic of astrophysics, while the IFCA and IFIC are Tier-2 centres for the processing of LHC data. The IAA plays also a key role in the e-Science for Andalusia regional e-science initiative, e-CA[16].

## 4. The intersection of VO and grid in Spain

The VO provides an infrastructure analogous to the Data Grid envisioned by Chervenak et al., and thus allows for parallel access from different nodes at the same time. Grid computing within the VO needs to exploit the parallelism in different use cases:

**Parameter space exploration:** several astrophysical simulations, such as stellar structure, evolutionary tracks, et cetera, start running with a particular set of initial parameters, but many runs are required to sample a particular parameter space. In this case, the `gridway` meta-scheduler can be used to easily gridify this kind of applications, running instances of the same program that only differ in the input files/parameters. Many Monte Carlo simulations fall also in this category.

**Exploration of partitioned data sets:** this case is very similar to the one above, but the parameter space is partitioned instead of sampled, allowing instances to run independently of each other on each partition. Examples of this are massive object searches for particular kinds of objects, which might need querying large data sets, even from many different archives, but the search for properties of those objects can be made independently of each region of the sky. This partition is not necessarily spatial: data reduction pipeline tasks partition data based on observation blocks.

**Loosely coupled simulations:** the above mentioned cases work better because each node in the grid does not have to communicate with others, or communication is restricted at the end and the beginning of the process. N-body simulations tend to be just in the opposite corner: tracking all bodies tends to be more communications-bound than processing time bound.

[16] `http://e-ca.iaa.es/`

However, techniques such as Smoothed Particle Hydrodynamics, and hierarchical N-body simulations are more grid friendly, by restricting interaction between grid elements to high-level interaction with the following level in a hierarchy.

Many applications cannot be so easily partitioned. One example are searches of related bodies (pairs or triplets of galaxies, for instance): the partitioning technique can be used, but either the partitioning needs overlapping, or special border cases have to be considered, reducing efficiency in any case.

In the above discussion of astrophysical applications of the grid we have not mentioned the Virtual Observatory. There are different aspects of the VO where grid computing might be beneficial:

**Visualisation:** most of the VO visualisation data comes directly from web services. However, some of those images can be generated on-the-fly by powerful enough systems. If the *ad-hoc* generation tools are gridified, the system would make transparent use of the grid infrastructure without passing the complexity of the system to the user.

**Data access:** VO protocols such as the VOSpace (Graham et al., 2008) for always available storage can be mapped on top of the Data Grid by means of implementations that make use of protocols such as Grid-FTP, IBM's Global Parallel FileSystem, et cetera. However, access policies still hinder the adoption of these protocols.

**Data processing:** the VO paradigm is to perform analysis as near to the data as possible, in order to reduce network bottlenecks. A pervasive grid computing facility makes it easier for data providers to allow for sophisticated analysis tools running against the data, without having to worry about computing resources and scalability. There is an IVOA Note on the Common Execution Architecture (Harrison, 2005), an API for making VO aware analysis tools available as web services. This services are the facade client applications see, and again, the grid can be used in a transparent way.

**Data mining:** given the rich metadata available for VO-compatible data sets, data mining applications are particularly well suited to the VO. Additionally, more and more algorithms are being deployed in the form of web-services, what helps in the development of a distributed infrastructure for knowledge extraction.

Most of grid experience in Spain, even in the field of astrophysics, has not been connected with the Virtual Observatory in any way, but more and more users are planning to make use of it. High level data analysis techniques are being prepared by the AMIGA group for 3D data sets, jointly with the SVO-core, that will make use of the grid. Groups at IAA working on stellar structure and evolution are starting to their code bases aware of the grid within the e-CA project framework, and many data mining projects, such as VSOP, will make use of the grid for their processing. And the Spanish members of the IVOA Theory Interest Group, as part of the SVO, wish to use VO tools, and keep developing access protocols such as TSAP, for micro simulations, i.e. not cosmological simulation, but special interest simulations, such as stellar structures, initial mass function distributions, et cetera.

## 5. Conclusions

We have shown that pure Virtual Observatory activities in Spain have a very good health, and there is ample experience both inside and (specially) outside the astrophysics community, but more and more services will be deployed on the grid as it becomes more pervasive. Spain will have in the near future a mature enough grid infrastructure within the European Grid Initiative, and different research groups are already porting, or planning to port, their code bases to the grid, taking as much as possible from existing VO infrastructures.

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## References

Caballero, J. A. & Solano, E. 2008, ArXiv e-prints, 804

Chervenak, A., Foster, I., Kesselman, C., Salisbury, C., & Tuecke, S. 2001, Journal of Network and Computer Applications, 23, 187

Dall, T. H., Foellmi, C., Pritchard, J., et al. 2007, A&A, 470, 1201

Foster, I. & Kesselman, C. 1999, Computational Grids (Morgan-Kaufman)

Graham, M., Morris, D., & Rixon, G. 2008, VOSpace service specification, IVOA Working Draft Version 1.10, International Virtual Observatory Alliance

Gutiérrez, R., Rodrigo, C., & Solano, E. 2006, in ASP Conference Series, Vol. 351, Astronomical Data Analysis Software and Systems XV, ed. C. Gabriel, C. Arviset, D. Ponz, & E. Solano, 19–+

Gutiérrez, R., Solano, E., Domingo, A., & García, J. 2004, in ASP Conference Series, Vol. 314, Astronomical Data Analysis Software and Systems XIII, ed. F. Ochsenbein, M. G. Allen, & D. Egret, 153–+

Harrison, P. 2005, A proposal for a Common Execution Architecture, IVOA WG Internal Draft 2005-05-12 Version 1.2, International Virtual Observatory Alliance

Jansky, K. G. 1933, Proceedings of the Institute of Radio Engineers, 21, 1387

Karachentseva, V. E. 1973, Soobshcheniya Spetsial'noj Astrofizicheskoj Observatorii, 8, 3

Karachentseva, V. E., Lebedev, V. S., & Shcherbanovskij, A. L. 1997, VizieR Online Data Catalog, 7082, 0

Marco, J. 2008, Infraestructura Grid de Investigación Avanzada en el CSIC: GRID-CSIC, Research Proposal v0.9, CSIC

Ochsenbein, F., Williams, R., Davenhall, C., et al. 2004, VOTable Format Definition, Proposed Recommendation Version 1.1, International Virtual Observatory Alliance

Padovani, P. 2005, in Astronomical Society of the Pacific Conference Series, Vol. 347, Astronomical Data Analysis Software and Systems XIV, ed. P. Shopbell, M. Britton, & R. Ebert, 183–+

Rodrigo, C., Gutiérrez, R., Solano, E., & Cerviño, M. 2007, ArXiv e-prints, 711

Sarro, L. M., Sánchez-Fernández, C., & Giménez, Á. 2006, A&A, 446, 395

Solano, E. & Caballero, J. A. 2007, ArXiv e-prints, 707

Solano, E., Catala, C., Garrido, R., et al. 2005, Astrophysical Journal, 129, 547

Szalay, A. S. & Gray, J. 2001, Science, 293, 2037

Tody, D. & Dolensky, M. 2007, Simple Spectral Access Protocol, IVOA Proposed Recommendation Version 1.01, International Virtual Observatory Alliance

Valentijn, E. A. 2008, in Proceedings of the EuroVO-DCA Workshop on Grid and the Virtual Observatory, April 2008

Verdes-Montenegro, L., Sulentic, J., Lisenfeld, U., et al. 2005, A&A, 436, 443

Williams, R., Hanisch, R., Szalay, A., & Plante, R. 2008, Simple Cone Search, Proposed Recommendation Version 1.03, International Virtual Observatory Alliance