



# The VO: A Powerful Tool for Global Astronomy

*Christophe Arviset,  
Head of ESAC Science Data Centre, IVOA Chair*

*26/10/2015*

Issue/Revision: 1.0

Reference: VO: A powerful tool for astronomy

Status: Draft

ESA UNCLASSIFIED - Releasable to the Public

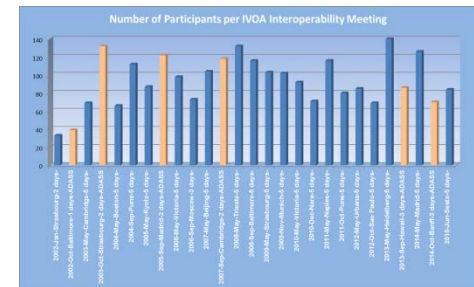
European Space Agency

# IVOA Today



1. Created in 2002, IVOA today has 20 diverse member projects

2. 2 well attended interoperability meetings per year



3. Technical Coordination Group

- 6 active Working Groups (Applications, Data Access Layer, Data Model, Grid and Web Services, Registry and Semantics)
- 7 Interest Groups (Data Curation and Preservation, Education, Theory, Time Domain, Operations, Knowledge Discovery in Databases)

4. Members have come and gone, some projects have persisted and some others have stopped

5. Hard lessons learnt on management and developing standards

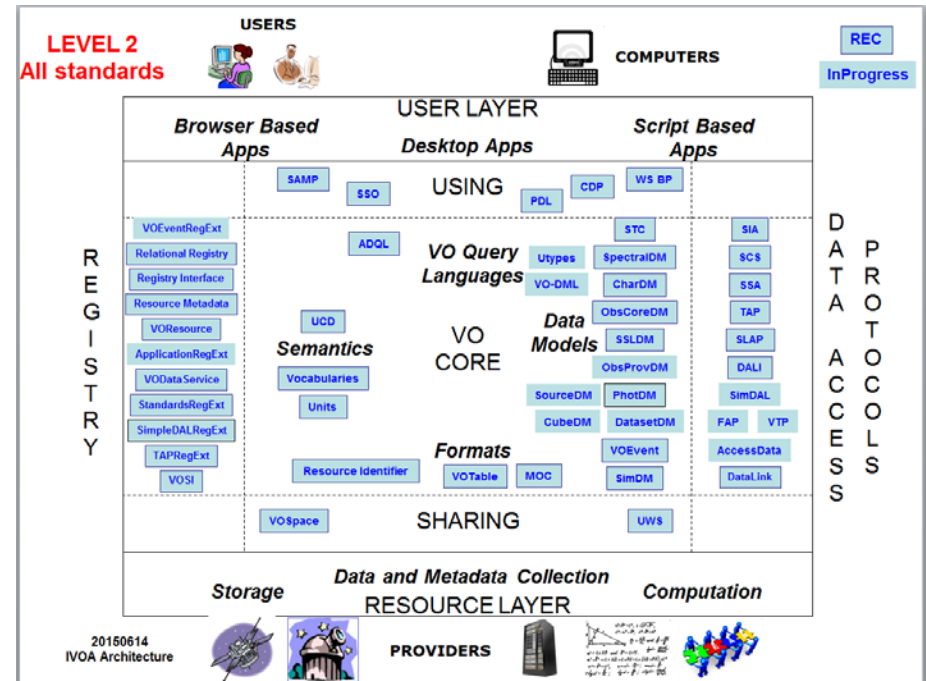
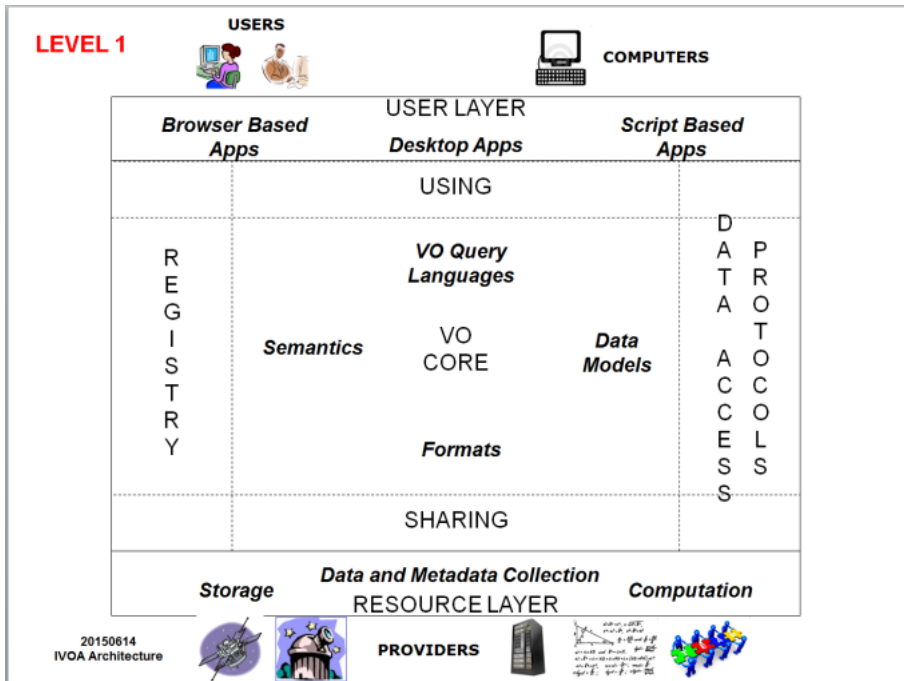
6. IVOA has survived because VO is a good idea



# IVOA Successes - 1



1. International collaboration of many VO projects worldwide
2. Stable IVOA Architecture, with well established interoperability standards
  - tables, images, spectra, registries



# Standards Matter!

1.

2.

- Astronomy has done better than most at keeping to standards.
- This allows everyone to write software to the standard - It worked for the web, its worked for Astronomy
- But we need to be vigilant! WCS systems as an example...

LEVEL 1

REC

InProgress

D  
A  
T  
A  
P  
R  
O  
T  
O  
C  
O  
L  
L  
S

201506  
IVOA Archi

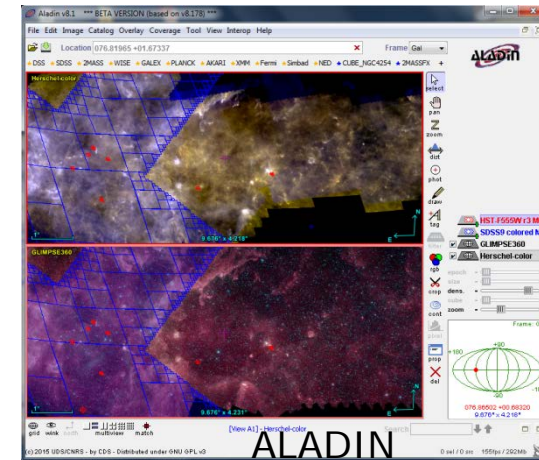
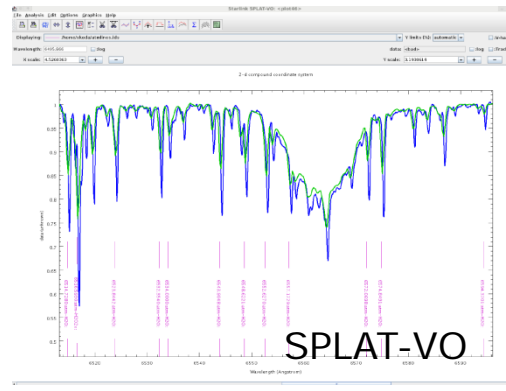
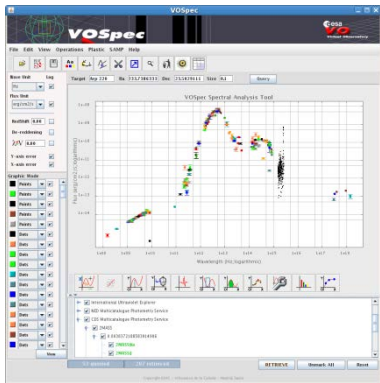
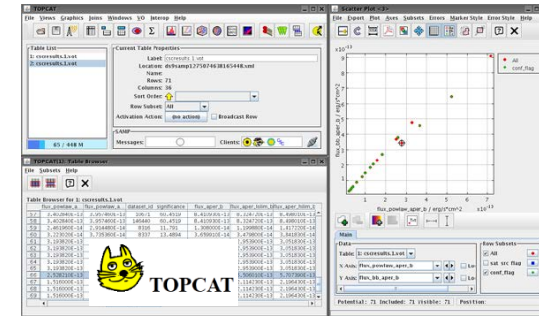
Brian Schmidt, Nobel Laureate  
Big Data and Big Astronomy  
ADASS 2015, Sydney

Christo

# IVOA Successes - 1



1. International collaboration of many VO projects worldwide
2. Stable IVOA Architecture, with well established interoperability standards
  - tables, images, spectra registries
3. VO *interoperable* applications
  - Topcat, Aladin, VOSpec, SPLAT-VO, Iris, ...

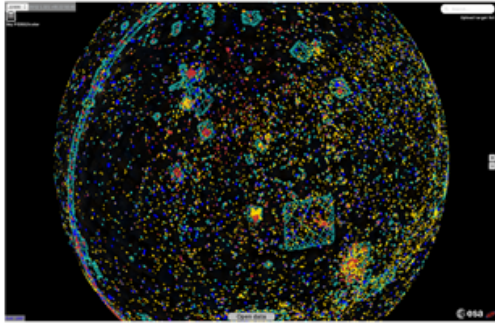


# IVOA Successes - 1

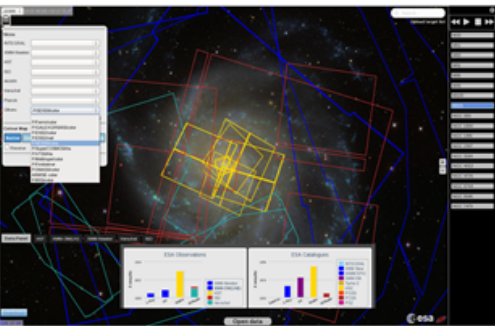


## ESA Sky

- science driven discovery portal for all ESA Astronomy missions
- facilitates data discovery and archival science for ALL users
- all-sky multi-resolution HiPS maps of full mission datasets



- detailed geometrical footprints to connect the all-sky mosaics to individual observations
- direct access to the underlying mission-specific science archives
- seamless access to mission source catalogues



## Integration of many VO projects

ADASS XXV (2015) P999  
**Current Status of JVO portal!**  
 Y. Shirasaki, C. Zapart, M. Ohishi, Y. Mizumoto, W.Kawasaki, T. Kobayashi, G. Kosugi (NAO), T. Kawabuchi (Sapporo Medical Univ.), S. Eguchi (Fukuoka Univ.), Y. Ishihara, H. Yamada, T. Hiyaama (Fujitsu), M. Nishimoto (SEC)

JVO portal is an astronomical data discovery service utilizing the Virtual Observatory as a basic concept. It is accessible at <http://jvo.nao.ac.jp/portal>. The main features of the JVO portal are: (1) quick search via logs, (2) dedicated search interface for Subaru and ALMA dataset, (3) VO-enabled data search. We update the VO search interface in 2013 to improve the usability of VO data search functionalities, and the redesign is open to the public as an experimental version of JVO portal v2. On this version, most of the fundamental interfaces such as "SingleScope", "MultiScope", "OTable viewer", "JVOSpace" and so on are implemented. User interfaces which are easy to foresee the flow of the search procedure and provide unified look-and-feel are one of the search interfaces provided on JVO portal, and it was first developed based on the Google Sky. ASAS has a disadvantage in displaying data at polar regions, we updated the JVOsky, utilizing the Aladin-Lite development. ALMA data search interface has also been updated since the last Demo presentation at ADASS XXIII.

### 1. JVO portal v2 (newly developed)

Fig. 1. portal v2 top page  
 Fig. 2. SingleScope page  
 Fig. 3. Search result page (VOTable)

Fig. 2 shows an example of SingleScope interface. This is used to query to a selected service with detailed search criteria. This interface will appear by clicking the "SingleScope" icon at the top of the page.

The following interfaces are also available: "MultiScope", "CatalogViewer", "VOTableScope" which are interfaces to VO-enabled services, and "Digital Universe", which is an interface to a JVO-specific multi-catalog service. The layout of the query form is common for all these interfaces. The querying process is navigated with tabbed forms, which enable a user easily to foresee the flow of the query steps and go back to the previous step.

Fig. 3 shows an example of VOTable viewer, which is used to look at search results. This interface will appear by clicking the "TableStack" at the left part. The user easily to refer to search results previously. The search result can be narrowed or filtered condition in the textbox of each column. Headers of columns is shown by clicking (3).

### 2. ALMA data archive (updated)

Fig. 4. Data search by Project Code  
 Fig. 5. Search by sky coordinates  
 Fig. 6. Search by obs. frequency

Fig. 4. Data search by Project Code  
 Data are automatically transferred to the JVO system after they become public.

Fig. 5. Search by sky coordinates  
 Selecting the "Coords" tab (Fig. 5), you can search data by sky coordinates of object name. It is also possible to search on the JVOsky.

Fig. 6. Search by obs. frequency  
 Selecting the "Frequency" tab (Fig. 6), you can search: 1. data which covers some specific frequency range (observation logs) 2. data whose observed frequency range overlaps with the specified range.

### 3. JVOsky (updated)

Fig. 7. JVOsky3 half sky map  
 Fig. 8. AKARI all sky image

Fig. 7 is an overview of ALMA observation locations plot all sky image.

Fig. 8 shows footprints of AKARI all-sky images, appears when the zoom level reaches a predetermined level. "More Info" link in the information window, one can jump to summary page where one can download the corresponding data.

## CASSIS, a VO-Tool software package to analyse high spectral resolution observations

Observatoire Midi-Pyrénées  
 Observatoire de Toulouse, UPS, IRAP, CNRS  
 emmanuel.caux@irap.omp.eu

**ABSTRACT**  
 CASSIS (Centre d'Analyse Scientifique de Spectres Instrumentaux et Synthétiques) is a standalone VO-Tool software package aimed to speed-up the scientific analysis of high spectral resolution observations, particularly suited for broad-band spectral surveys. CASSIS is written in Java and can be run on any platform. It has been extensively tested on Mac OS X, Linux and Windows operating systems. CASSIS is regularly enhanced, and can be easily installed and updated on any modern laptop. To read the JPL2 and CDMS<sup>2</sup> molecular spectroscopic databases and the atomic spectroscopic database NIST<sup>3</sup>, it uses either the VAMDC protocol or a fast SQLite access to a local database. The tools available in the currently distributed version (3.8.1) include, among others, a LTE model and the RADEX<sup>4</sup> model connected to the LAMDA<sup>5</sup> molecular collisional database, a module building line lists fitting the various transitions of a given species and producing rotational diagrams from these lists, a complete set of spectral tools, a scripting interface and a SSAP query module. CASSIS is also fully integrated into HIPE<sup>7</sup>, the Herschel Interactive Processing Environment, as a plug-in.

**CASSIS website:** <http://cassis.irap.omp.eu>

**Easy installation to be ready to work with CASSIS within minutes**  
 CASSIS links all needed data to compare them with observed spectra

**Rotational Diagram Module**  
 - Allows to quickly build up user templates showing species in any available database.

**Line Analysis Module**  
 - Quick search of line lists from the fit module.

**Jython Scripting Module**  
 - Allows to quickly build up user templates showing species in any available database.

**SSAP Module**  
 - Allows to query any SSAP VO.

**Development Plan**  
 - Use of instrumental profiles (PACE, SPIRE, ISO, SMILES) ...

**REFERENCES**  
 [1] ... [2] ... [3] ... [4] ... [5] ... [6] ... [7] ...

# IVOA Successes - 1



1. International collaboration of many VO projects worldwide



2. Stable IVOA Architecture, with well established interoperability standards

- tables, images, spectra registries

3. VO applications

- Topcat, Aladin, VOSpec, SPLAT-VO, Iris, ...
- ESASky, JVO Portal, Cassis, ...

4. VO recognized and supported as an e-Infrastructure

- E.g. ASTRONET European Infrastructure Roadmap
- NASA support to US-VOA
- Open and shared software and infrastructure components
- Registries, TAP libraries, VOTable parsers, Data publishing SW
- Embeddable interface components coming (e.g. Aladin Lite)



# IVOA Successes - 2



## 1. Major astronomical data collections accessible through the VO

- CDS, CADC, MAST, ESA, Chandra, ...

The screenshot shows the Virtual Observatory (VO) interface. At the top, there is a search bar with the text "Select a collection..." and "and enter target:". The search bar contains "m31" and a search button. Below the search bar, there are links for "About Collections...", "Show Examples...", and "Random Search".

The main interface displays a table of data resources. The table has columns for "Actions", "Short Name", "Type", "Title", "Waveband", "Records Found", "FITS Images", and "Other Images". The table lists 18 data resources, with the first 10 highlighted in yellow.

Actions	Short Name	Type	Title	Waveband	Records Found	FITS Images	Other Images
	HST Previews		Hubble Space Telescope Preview Images	Optical	2000	1001	999
	CDA		Chandra X-ray Observatory Data Archive	X-ray	1526	754	772
	CSC		Chandra Source Catalog	X-ray	692	290	402
	SDSS SIAP		Sloan Digital Sky Survey Images (Latest Release)	Optical	630	630	0
	XMM-Newton SIAP		XMM-Newton SIAP Service for Slew Observations		462	462	0
	ASCC-2.5_Search		Simple cone search for the All Sky Compiled Catalogue (...)	Optical	444	0	0
	GALEX		Galaxy Evolution Explorer	UV	204	128	76
	hdap_siap		HDAP -- Heidelberg Digitized Astronomical Plates	Optical	132	132	0
	USNO-A2.0		USNO-A2.0	Optical	102	0	0
	USNO-SA2.0		USNO-SA2.0	Optical	102	0	0
	XMM-Newton SIAP		XMM-Newton SIAP Service for Pointed Observation		78	78	0
	ISO SIAP		The ISO Data Archive InterOperability System		54	54	0
	TGCat SIA		Chandra Transmission Grating Catalog and Archive, Sim...	X-ray	27	9	18
	HST.APPP		HST Archival Pure Parallels Project	Optical	22	22	0
	ELODIE		ELODIE archive		20	0	0
	DSS ESO		Digitized Sky Survey		16	8	8
	DSS ESO		Digitized Sky Survey	Infrared, Opti...	16	8	8
	TGCat SCS		Chandra Transmission Grating Catalog and Archive, Sim...	X-ray	9	0	0

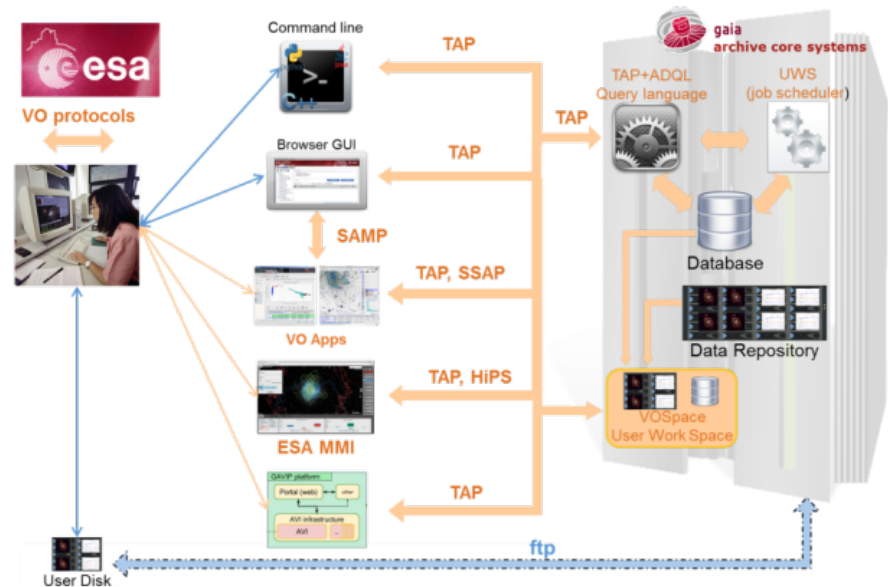
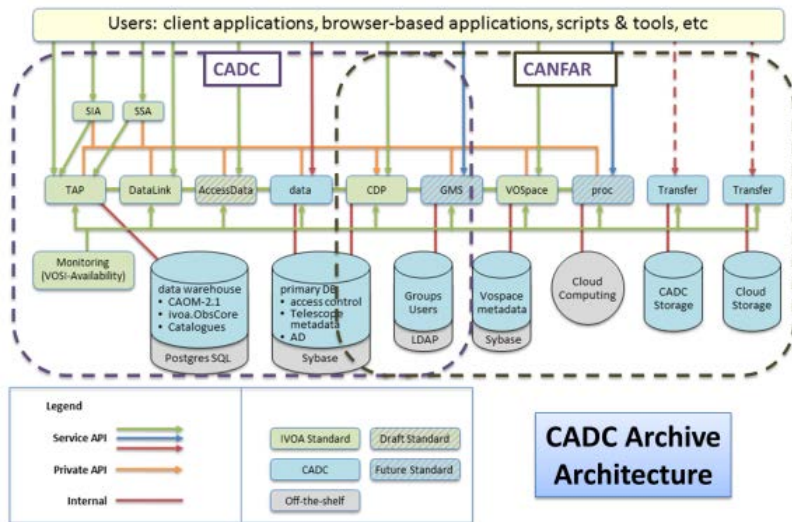
On the right side of the interface, there is an "AstroView" window showing a galaxy image with a crosshair and coordinates: "00:43:21.069 +41:13:27.44" and "00:42:44.350 +41:16:08.62".



# IVOA Successes - 2



1. Major astronomical data collections accessible through the VO
  - CDS, CADC, MAST, ESA, ...
2. VO being used to build new astronomical data infrastructure
  - CADC, Gaia, Euclid, ...



# SkyMapper Database



- SDSS-depth 5-year survey 20,000 sq deg
- Volume
  - 300,000 images
  - 5 Giga-rows of measurements × 100 features
  - Tables with images, measurements, distilled objects

- Query functions & IVOA standards

- ADQL catalogue query – Table Access Protocol TAP
- Cone search – Cone search
- Image cutouts – Simple Image Access Protocol SIAP

- Service discoverable in TopCat
- Web access wrapped around backend functions



Legend

Service API

Private API

Internal

# IVOA Successes - 2



1. Major astronomical data collections accessible through the VO

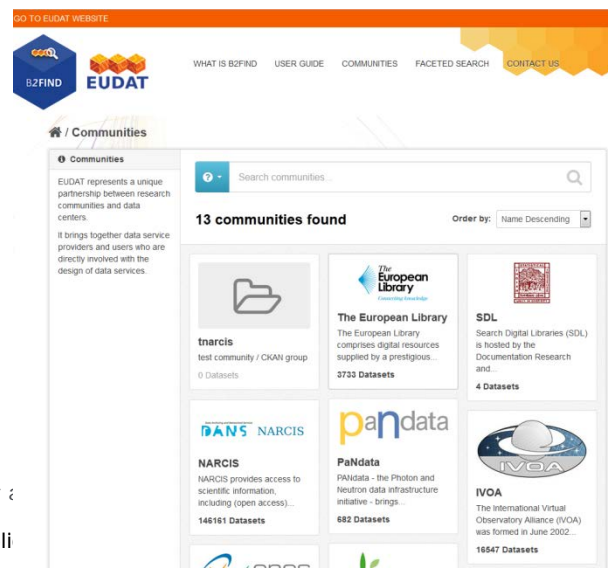
- CDS, CADC, MAST, ESA, ...

2. VO being used to build new astronomical data infrastructure

- CADC, Gaia, Euclid, ...

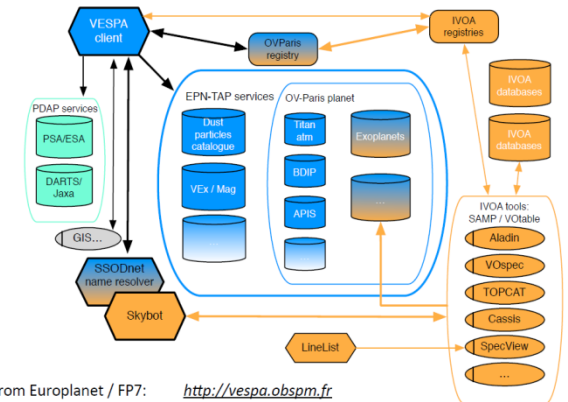
3. VO re-used by neighbour disciplines

- Planetary Science,
- VAMDC,
- EUDAT



## VESPA Architecture

- Centered on data services
- Specific access protocol / user interface to query services together
- Connected to visualization tools from astro community
- All standards are maintained by world-wide alliances



Existing prototype from Europlanet / FP7: <http://vespa.obspm.fr>

European Space Agency

# IVOA Problem Areas



## 1. Unrealistic initial expectations

- Big ideas were needed to get off the ground
- Some aspects were “over-sold”

## 2. Sometimes VO perceived as a closed-shop

- VO standards seen as too complex
- Difficulty to implement rich VO services

## 3. Long time to deliver VO standards

## 4. Wrong perception, many people initially thought VO was a killer application, but

- IVOA defines VO “ecosystem” and interoperability standards
- Astronomy projects and data services build VO services and VO applications

**VO is a data management interoperability infrastructure  
rather than an astronomy “app”**



# VO Challenges – take up



## 1. Engagement of big projects and how the VO can help them ?

- How to capture their requirements into IVOA standards development process ?
- How to adapt to their development timelines and constraints ?
- How the VO can help with “Big Data” and bring the code to the data ?



## 2. Facilitate and improve VO take-up by Data Centres

- Two different models of VO implementations (VO layer or VO built-in)
- VO publishing tools for small data centres with little IT expertise
- VO software libraries for bigger data centres with more IT expertise
- Simple services (S\*AP) vs advanced services (TAP, DM)

Need to make big projects and data centres  
“participants” not “customers”



# VO Challenges – Operations



1. VO is in use, but how to see it ?
2. How to define VO success (or failure) metrics ?
  - Counting scientific publications ?
    - But doesn't capture VO use...
  - VO services access statistics ?
    - But not uniformly collectable and comparable...
3. VO Services Operations
  - Reliability of existing VO Ecosystem
  - Hundreds of VO services in the IVOA Registries...
    - Compliance of VO services ?, VO Services validators
  - IVOA to become more active in this

Is the VO success to be “invisible” ?





1. VO very good for data discovery and quick exploration of data (e.g. ObsCoreDM, HiPS, MOC)
  - From various data sources and data centres
  - Then push to VO applications for display and analysis (SAMP)
  - Well defined for table and images, spectra not yet reached full exploitation potential
2. Getting science use cases from scientists
  - IVOA Committee on Science Priorities
    - ObsCore DM, SED, Multi Dimensional data, TimeDomain
  - IVOA to define standards and infrastructure to enable implementation of science use cases

**The goal of the VO is to make access to and use of data easier  
to enable science !**

# Conclusions



1. *“The VO is **not** a magic solution to all astronomy data management challenges but it offers a **powerful tool** and **useful solutions** to some of them”*

- Interoperability amongst datasets
  - and VO science applications will be the key
- IVOA Standards to help building archive data centre infrastructure
- Need to address “bring and run code next to the data”

2. *“If one wants to **take something out** of the IVOA, one needs to **bring something in**”*

- a. Need to convince big projects to participate in standards development so they can better fit their needs
- b. And IVOA needs to go faster so we can meet projects deadlines

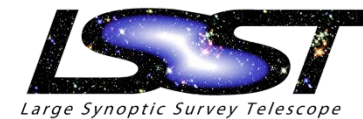




# Special Thanks to my co-authors



1. Allen, Mark, CDS
2. Aloisi, Alessandra, STScI / MAST
3. Berriman, Bruce, IPAC
4. Boisson, Catherine, Observatoire de Paris / CTA
5. Cecconi, Baptiste, Observatoire de Paris / Europlanet/VESPA
6. Ciardi, David, NASA Exoplanet Science Institute, IPAC
7. Evans, Janet, SAO / CXC
8. Fabbiano, Giuseppina, SAO / CXC
9. Genova, Françoise, CDS
10. Groom, Steve, IRSA / IPAC
11. Jenness, Tim, LSST
12. Mann, Bob, Wide-Field Astronomy Unit, University of Edinburgh
13. McGlynn, Tom, NASA / HEASARC
14. O'Mullane, Wil, ESA-ESAC / Gaia
15. Schade, David, CADC
16. Stoehr, Felix, ESO / ALMA
17. Zacchei, Andrea, INAF-OATs / Euclid



# We want the VO because...



**(CADC)** *"it makes implementation easier by leveraging the collective inputs of a large community through the use of the VO standards."*

**(CDS)** *"it helps astronomers do science with our services and it enables the services to interoperate with others"*

**(CXC)** *"VO cone search is our most popular interface to the Chandra Source Catalog"*

**(ESA)** *"it helps us built up new generation of archives (e.g. Gaia, Euclid) and makes our data reachable via other interfaces"*

**(ESO/ALMA)** *"VO technology (ADQL, ObsCoreDM) is at the core of our archive interfaces."*

**(LSST)** *"we want our alert stream to be usable by the broadest user community through VOEvent"*

**(STScI/MAST)** *"it helps our users to tap into new scientific opportunities by cross-correlating data collections spread throughout the world!. The era of "Global Astronomy" has become a reality!"*

**(WFAU)** *"it enables our users to do multi-wavelength astronomy using our data"*