



Access, discovery and interoperability of multi-messenger/multi-wavelength data

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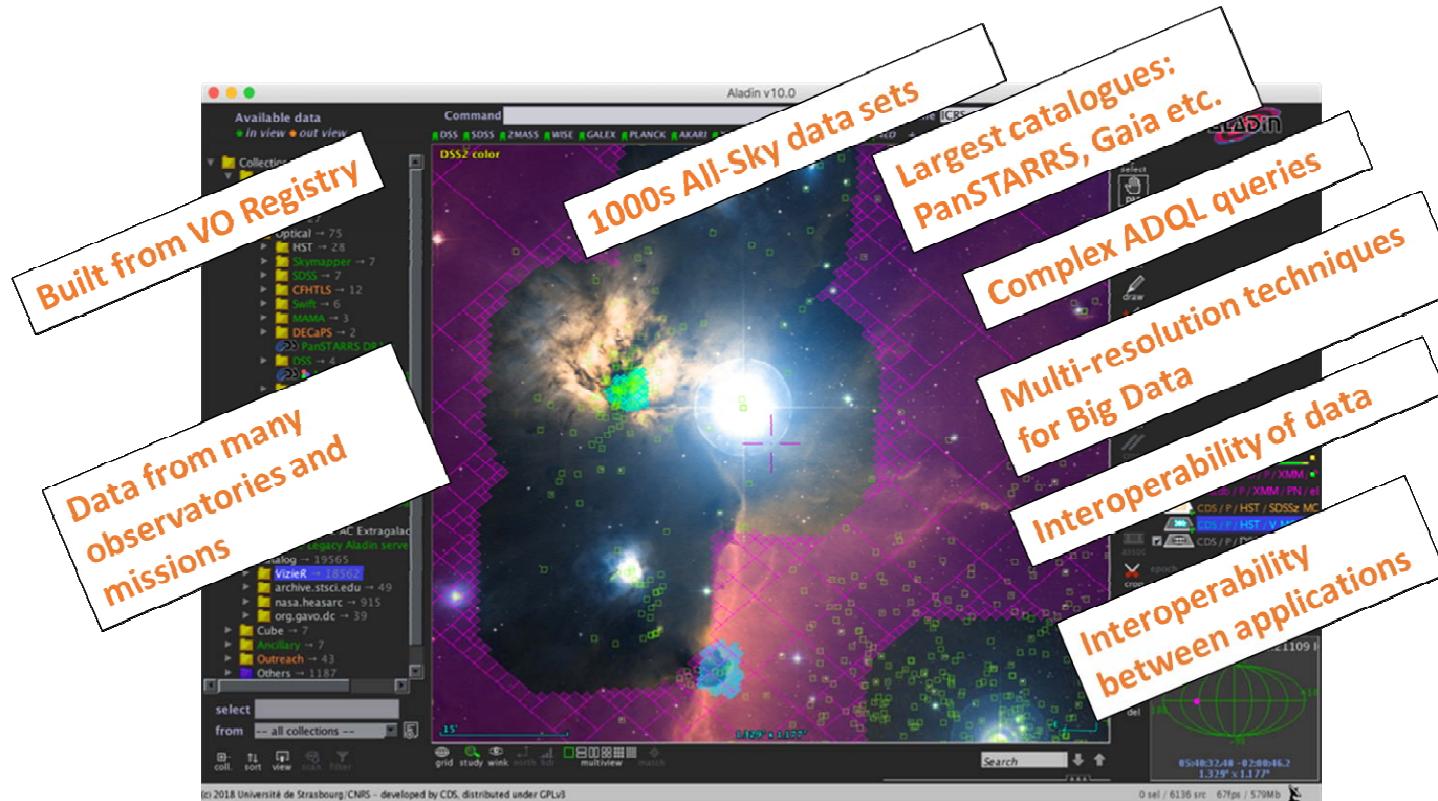


Astronomy in the Open Science context

- Astronomy has been a pioneer of Open Science and FAIRness
 - FITS – 1977, data + metadata
 - Data can be shared and Reused
 - Common tools
 - Bibcode/refcode (CDS/NED/ADS) – end of the 90's
 - Identifier for bibliographic information
 - Early links between databases and journals
 - Virtual Observatory – started ~2001
 - Data is **Findable, Accessible, Interoperable**

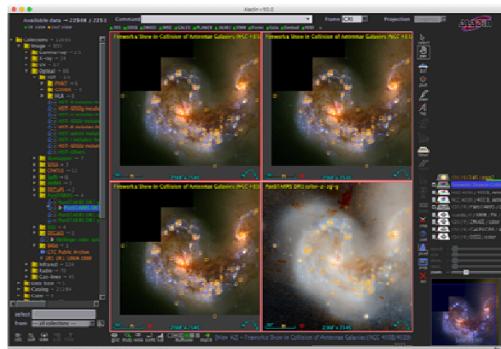


A view of the VO from one application

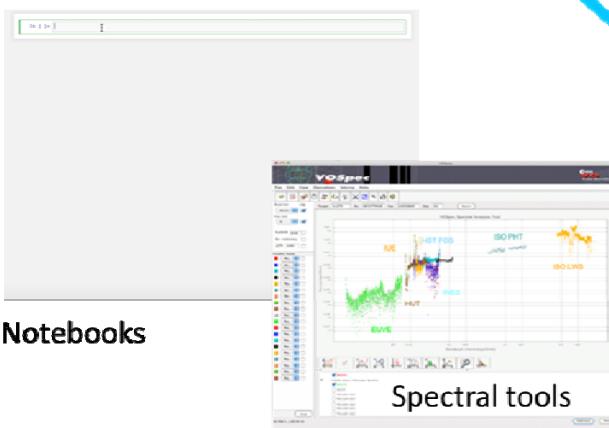




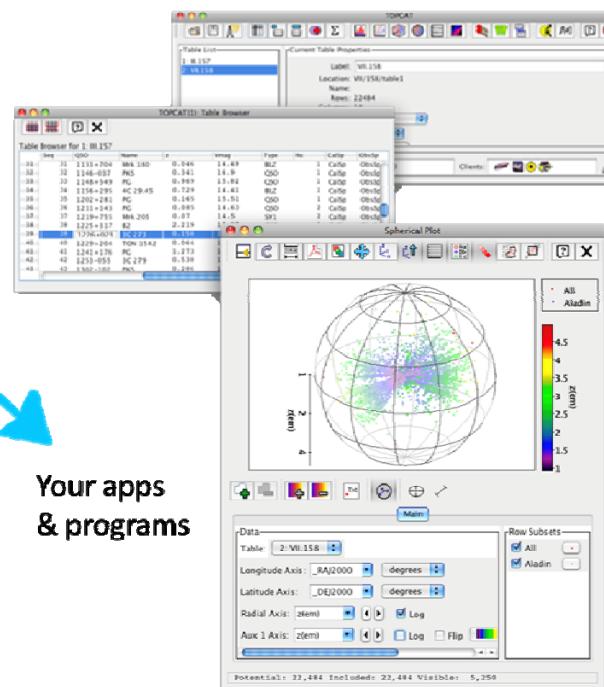
Interoperable applications



Aladin



Your apps
& programs





WP4 in ASTERICS proposal

- DADI (WP4) - Francoise Genova (CNRS-OAS):



ASTERICS WP4: DADI (Data Access, Discovery and Interoperability)

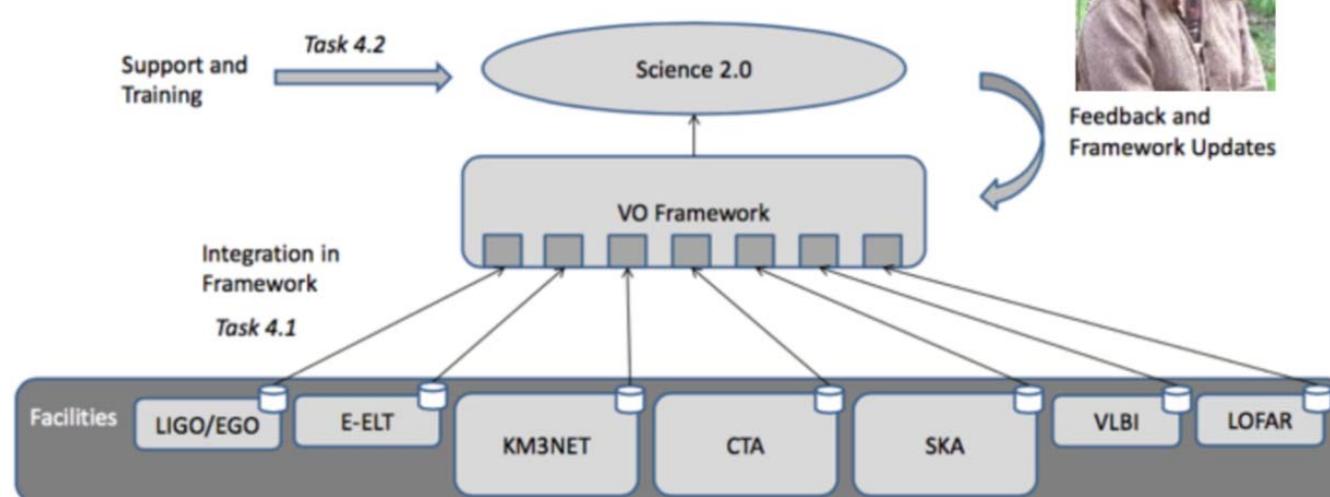


Figure 6: The ESFRI projects integrated in the VO Framework offers users uniform access.



The aims

Make the ESFRI and pathfinder project data available for discovery and usage by the whole astronomical community, interoperable in a homogeneous international framework, and accessible with a set of common tools.

- Train and support ESFRIs in use and implementation of VO
- Train and support wider community in scientific use of VO
- Adapt VO framework for ESFRI needs

Astronomy + Astroparticle physics



Who's involved

- Euro-VO partners, i.e. VO initiatives from France (CNRS/OAS- CDS+UNISTRA), Germany (UHEI), Italy (INAF), Spain (INTA), UK (UEDIN)
- Representatives of ESFRI and pathfinders
 - CTA (CNRS/LUTH + OBSPAR)
 - EGO/VIRGO and ET (CNRS/APC)
 - KM3Net (CNRS/CPPM)
 - SKA (ASTRON)
- ESO is associated to the project
- ESA (ESAC) is working in close collaboration with Euro-VO
- EST joined in 2018!



With the ESFRIs and European Data Centres

- Forums to exchange on practices and requirements
 - ESFRIs - Trieste, Dec. 2015, Dec. 2017
 - European Data Centres – Heidelberg, June 2016, June 2018
- Newcomer session, Training/« Consulting » session

M. MOLINARO'S TALK



Heidelberg, June 2018

Towards the science community

- Annual School targetting early career researchers and ESFRI staff
 - Madrid, Dec. 2015, Nov. 2017
 - Strasbourg, Nov. 2016, Nov. 2018
 - Tutorials updated for each School
 - Treasure hunt
 - Students' own project
- *Requirements and feedback*



E. SOLANO/A. NEBOT'S POSTER



The screenshot shows a web browser window with the URL www.euro-vo.org/?q=science/scientific-tutorials. The page title is "EURO VO". The left sidebar has a "Science" tab selected, showing links for Home, Science (Software, Scientific Tutorials, Scientific Papers, Advisory Committee, Euro-VO Mailing List), EDUCATION (Data Centres, IVOA 'VO Publishing', Technical, IVOA Standards, Registries), News, About (Contacts, Partners, Calendar, EC support, Acknowledging, Admin), and a "Science" section with links to the current project (EuroVO-CoSADIE) and past projects (VOTECH, EuroVO-DCA, EuroVO-AIDA, EuroVO-ICE). The main content area is titled "Scientific Tutorials" and contains a list of tutorials:

- The CDS tutorial [ASTERICS VO School, Nov 2018]**
This tutorial describes the basis of the VO program hosted at CDS. The three major VO programs are described: SIMBAD (astronomical database), VizieR (catalog service) and Aladin (interactive sky atlas). The user gets familiar with the programs 1) searching for the galaxy NGC4039 through the CDS portal to get direct access to SIMBAD, VizieR and Aladin, 2) comparing the sky coverage between SDSS and GALEX surveys using Aladin and 3) selecting interacting galaxies with Aladin.
- Determination of stellar physical parameters using VOSA [ASTERICS VO School, Nov 2018]**
This tutorial uses the advanced VO functionalities of VOSA (VO Sed Analyzer) and TOPCAT to determine empirically the masses and radii of stars surrounded by planets. The user needs to register to get access to the functionalities of VOSA (online tool). They can then upload a list of objects to study, build their SEDs and analyze them (by fitting models). Using the interoperability between VOSA and TOPCAT, the user can compare the empirical values obtained with VOSA to those published in papers.
- Accessing and cross matching big datasets with ADQL [ASTERICS VO School, Nov 2018]**
This tutorial allows the user to get familiar with ADQL (Astronomical Data Query Language) and TAP (Table Access Protocol) through using GAIA data. ADQL and TAP are widely used in VOs to handle large datasets that cannot be handled locally.
- Electromagnetic follow-up of gravitational-wave events [ASTERICS VO School, Nov 2018]**
This online tutorial uses mostly Aladin functionalities to locate the sources of latest gravitational wave events on the sky
- Exploring Gaia with Topcat and STILTS [ASTERICS VO School, Nov 2018]**
This tutorial uses TOPCAT and STILTS to study the Pleiades open star cluster. The user starts with getting TGAS data for the Pleiades and identifies its as a comoving subset. In a second step, the user matches HST data with Gaia observations using the interoperability of TOPCAT with VizieR to access the catalogs. The cross-match is refined using a color-magnitude diagram. The user can also use the TAP (Table Access Protocole) service of TOPCAT to run scripts for Gaia data. Finally, the user can upload the full TGAS catalog and investigate it with STILTS.
- Advanced usage of HiPS and MOCs [ASTERICS, updated June 2018 for VO School Nov 2018]**
This is a hands-on tutorial demonstrating an advanced usage of Hierarchical Progressive Surveys (HiPS) and Multi-Order Coverage (MOC) maps in Aladin. Using this document, you will learn how to handle a problem like : I have an image survey. I would like to select regions in my observations that are above a given threshold in another survey (e.g. at low extinction), retrieve objects from very large catalogs (e.g. Gaia + WISE) in these non-trivial shapes and not-necessarily-connected regions, and combine them to visualise some quantities (e.g. color magnitude diagram).
- Classifying the SEDs of Herbig Ae/Be stars [ASTERICS VO School, Nov 2017]**
Herbig Ae/Be stars are 2-8 solar mass. These stars show Balmer emission lines in their stellar spectrum and infrared excess due to circumstellar dust. They roughly fall into two groups: Group I sources have a relatively strong far-IR flux. Group II sources show a similar near-IR excess as group I sources, but their flux falls off steeply towards

<http://www.euro-vo.org/?q=science/scientific-tutorials>



Technological activities

- Five Technology Forums
 - Strasbourg, *Sept. 2015*, March 2017, *Feb. 2019*
 - Edinburgh, March 2016, March 2018
- IVOA standards and tools
 - The IVOA semestrial meetings have been DADI milestones



Specific targets

- Multi-D data
- Time domain – *a new start in IVOA!* **A. NEBOT's TALK**
- All-Sky **M. ALLEN'S TALK**
- Multi-messenger – *EGO + VO teams* **G. GRECO's TALK**
- Provenance – *CTA + VO teams* **C. BOISSON'S TALK**
- *See also A. Trovato's talk*

Multi-dimensional data

- « Caravan » of VO standards completed
 - Multi-D data discovery
 - Link resources
 - Cutouts
 - HiPS – hierarchical tiling of the sky using HEALPix
- They are in action in widely used services and adopted by data providers

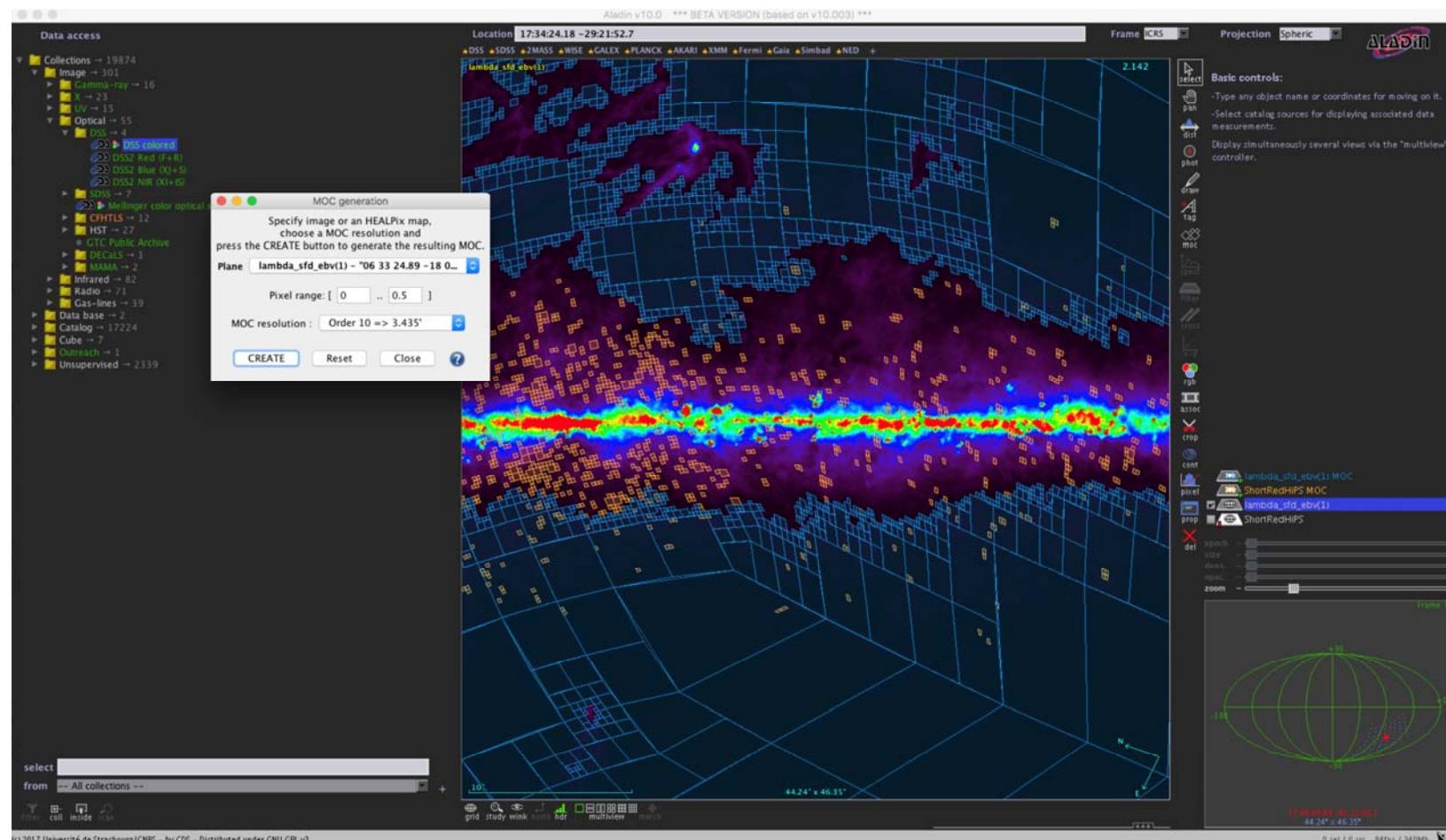


DADI impact

- Continued collaboration between the European VO teams – started ~2001
- Collaborations built with the ESFRI/ESFRI-like projects in astronomy/astroparticle physics/... solar physics
 - Brainstorming on requirements and feedback
 - VO development and usage
- VO School training activities
- High impact on the IVOA standards, tools and topics
 - Requirements/feedback/effort/expertise
 - Decisive contribution to IVOA developments

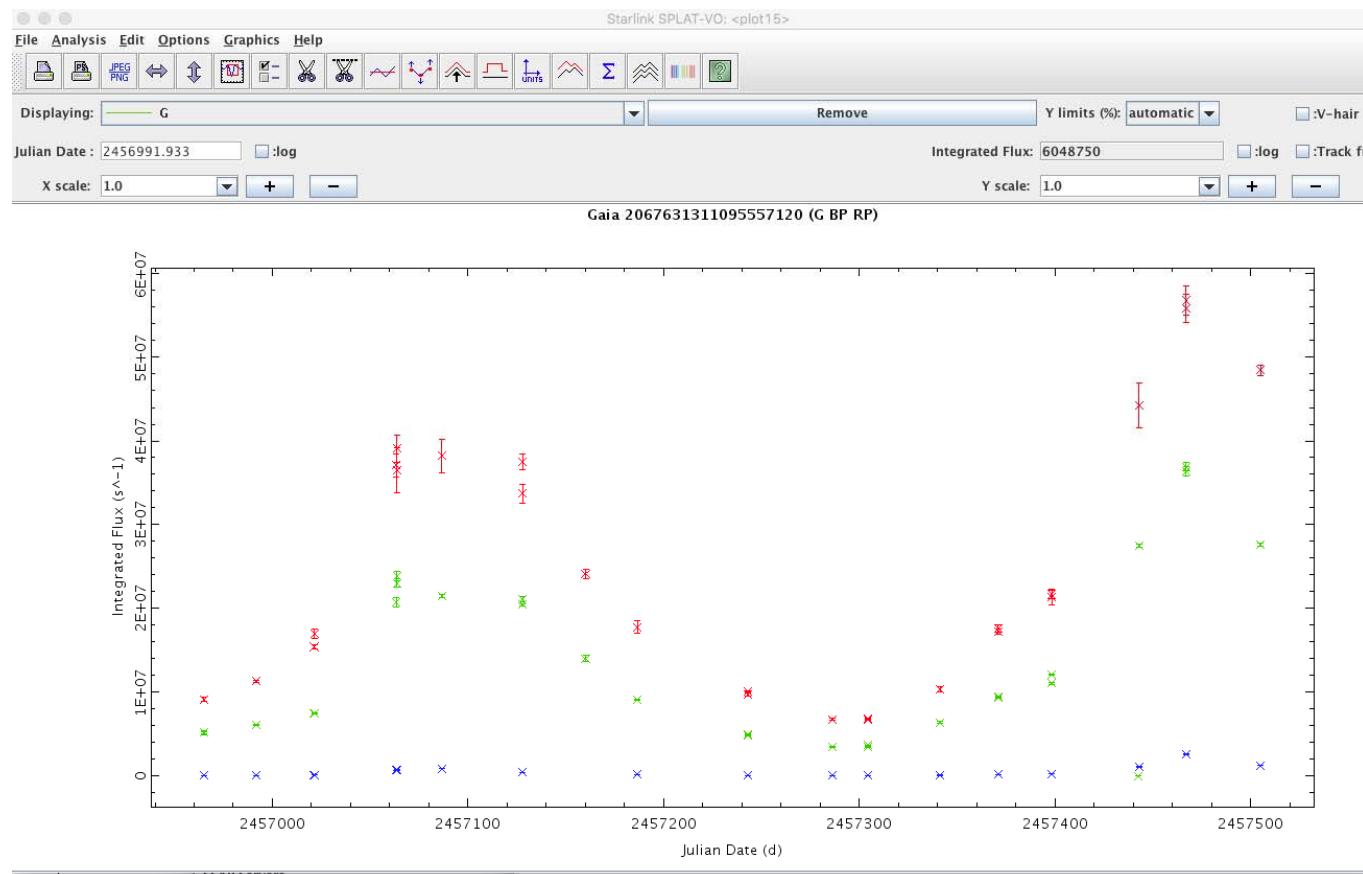


Example of tool: ALADIN





Exemple of tool: SPLAT-VO



Examples of VO impact for ESFRIs

- Support to VO usage by RIs
 - ANTARES – KM3Net
- VO building blocks in the research infrastructure pipelines/services
 - Provenance for CTA
 - GWSky
 - VO in ESO system

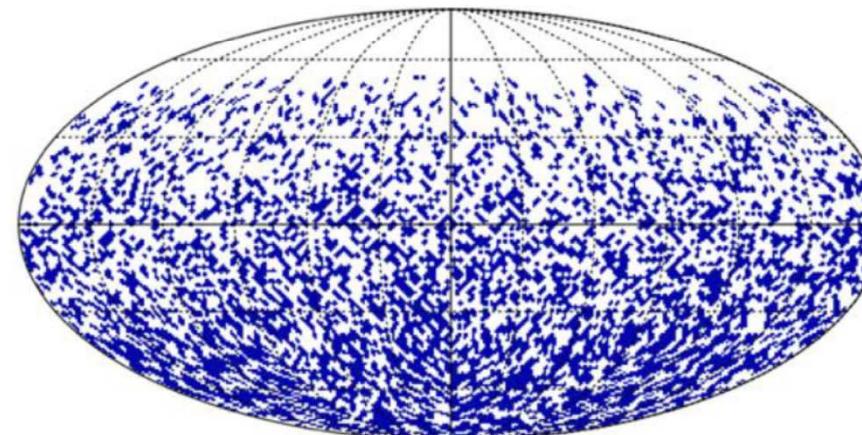


Graf, Second DADI Data Provider Forum 2018

ANTARES Data in GAVO Data Centre



- “2007-2012 ANTARES search for cosmic neutrino point sources”
 - Update from 2010 to 2012 in Dec. 2017
- 5921 events obtained during the effective lifetime of 1338 days.
- Coordinates, simple energy estimator (number of photons detected)



⇒ test case
for KM3NeT

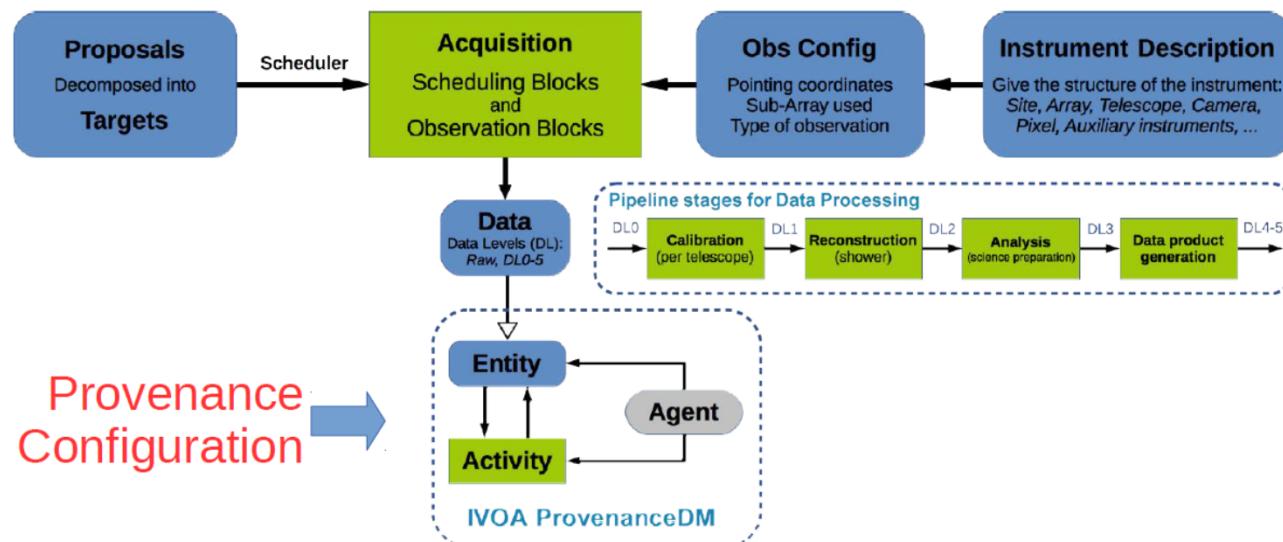
from: <http://dc.zah.uni-heidelberg.de/antares/q/cone/info>



Servillat, Second DADI ESFRI Forum, 2017

High level metadata model

- ◆ Defines **structure** of services, content and context of data
- ◆ Can be seen as a **global interface**

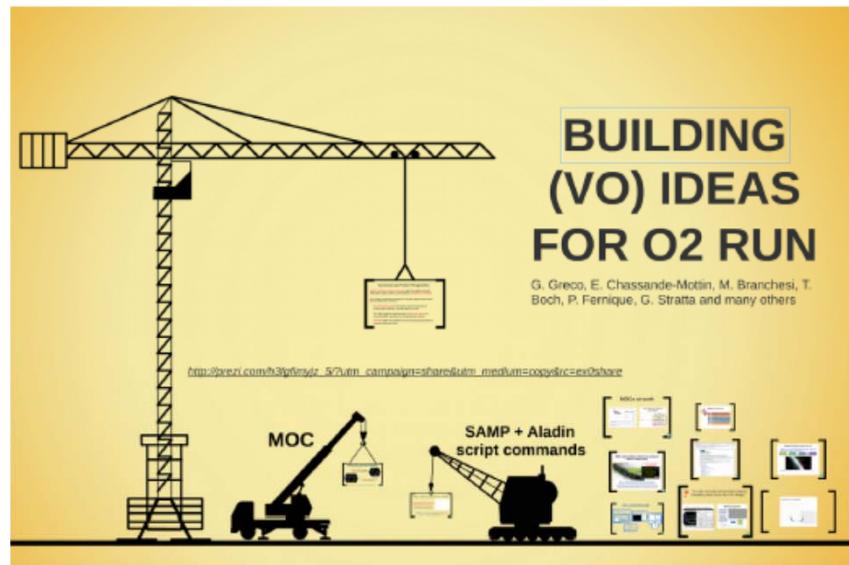


Servillat et al. 2017, ADASS Trieste



Chassande-Mottin, First DADI Data Provider Forum 2016

GW alerts and skymaps (2)



Credits: Giuseppe Greco (INFN)

- Help to define follow-up strategy
 - **Visualize, tile and combine skymaps with other information** (e.g., galaxy catalog for “mass targetting”)
 - On-going collaboration to demonstrate usage of VO tools (Multi Order Coverage Map)
 - Skymaps will soon include a distance estimate for binary mergers



Greco et al, DADI ESFRI Forum Trieste 2017

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The New York Times

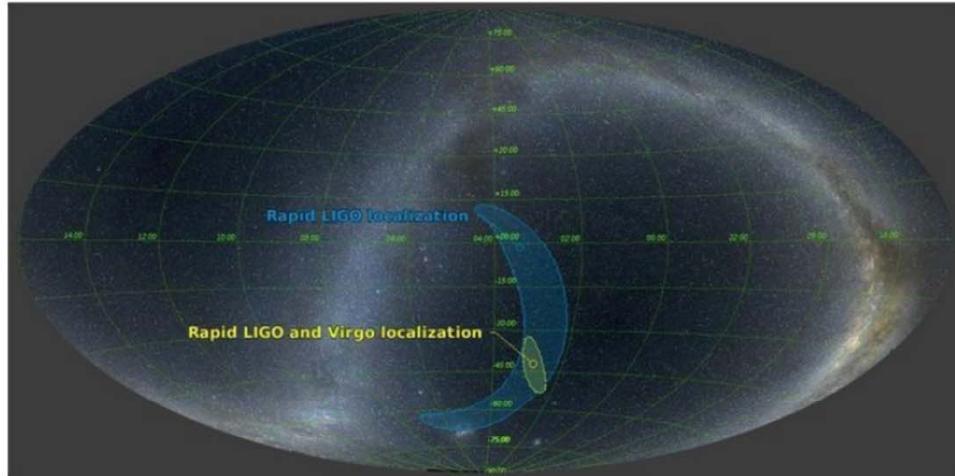
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SCIENCE

New Gravitational Wave Detection From Colliding Black Holes

By DENNIS OVERBYE SEPT. 27, 2017

[f](#) [t](#) [e](#) [r](#) [b](#)



The LIGO and Virgo detectors in the United States and Europe identified gravitational waves emitted by the two black holes 1.8 billion light years away. The location of the black holes in the night skies is shown above. [Read more](#)

4 ARTICLES REMAINING THIS MONTH

Press Statement from Dr. France A. Córdova at G7 Science Ministerial Meeting

RELATED COVERAGE



Third Gravitational Wave Detection, From Black-Hole Merger 3 Billion Light Years Away JUNE 1, 2017





Sterzik, First DADI Data provider meeting, 2016



NEW ESO Archive Services: programmatic interface

- deploy VO services and protocols
 - incl. ADQL, TAP, ObsTAP/ObsCore, DataLink, AccessData (Simple Data Access)...
- Convergence to few stable VO protocols for data access
- Authenticated VO access
 - Access statistics are vital to understand our community, hence serve them better
 - Balance with ease of access and removal of access barriers
- VO accessibility of textual release descriptions
 - Vital information on global data quality, limitations and usability beyond mere file-by-file metadata



Sterzik, First DADI Data provider meeting, 2016

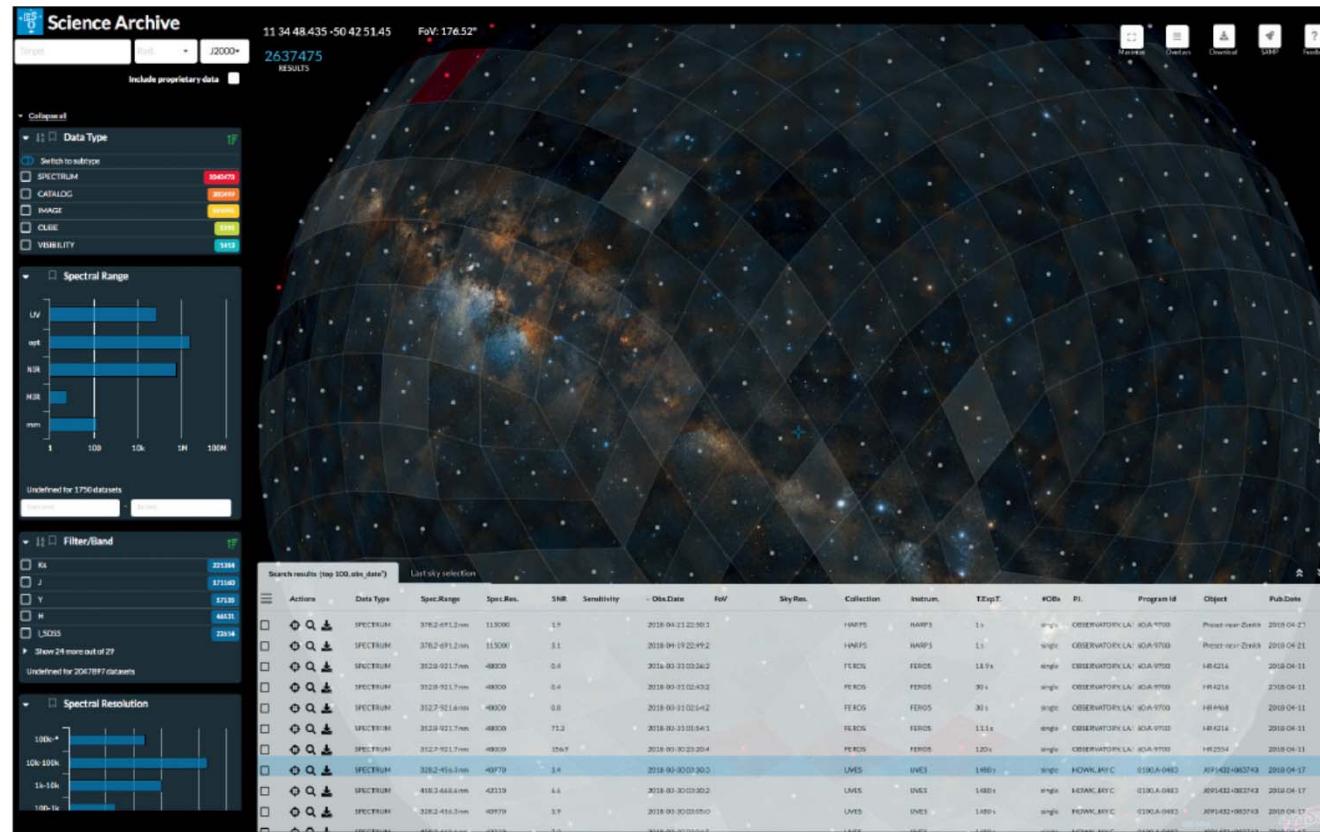


NEW ESO Archive Services: implementation strategy

- We want to reuse existing components (Aladin Lite, VO libraries, etc.) as much as possible to build archive services tailored to ESO's requirements
- We maintain ownership of the application but not of the building blocks
- ASTERICS collaboration as opportunity to improve/further develop existing components
- Possible new developments @ ESO
 - usage of NoSQL search platform (Apache Solr, Elastic Search) to enable "real-time" exploration of archive contents (multi-dimensional aggregations/histograms)
 - Problem: different back-ends for programmatic/VO access and web/interactive access (data replication)



Access to ESO archive using VO tools and protocols



Romaniello et al, Messenger, 2018



DADI legacy

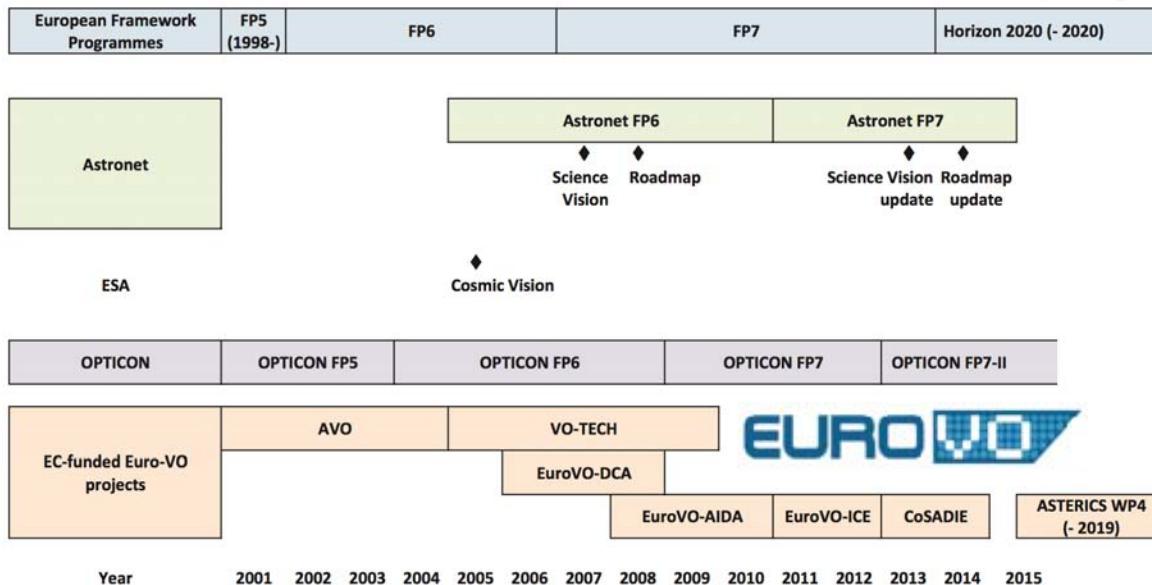
- ESFRIs consumers/actors/agents of the VO
- Astronomy/Astroparticle working hand in hand
 - Inclusion of astroparticle needs in the VO
- First contact with EST, ESFRI 2016
- Leadership in/strong contribution to IVOA activities
- Schools/tutorials
- A set of standards
- Evolution of existing tools/new tools
- Excellent starting point for ESCAPE WP4/Task 4.2
 - Interferometric data
 - Event based data
 - VO Scalability for extremely large datasets

Background...

M. Allen, ESCAPE Kick-off

How we got here, and where we're going

Virtual Observatory infrastructure for astronomy



Genova et al. 2015



Funded by the European Union's
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