

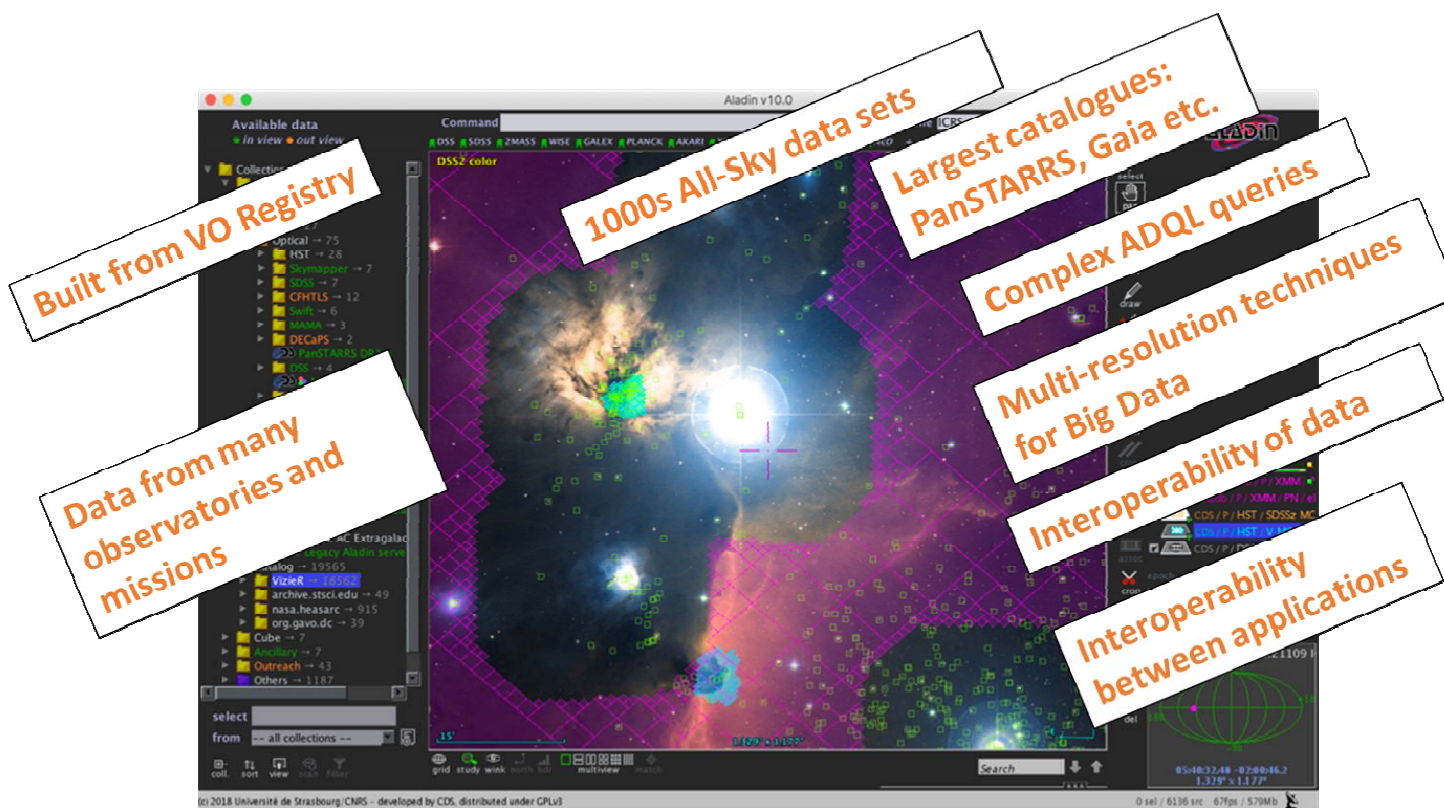
Access, discovery and interoperability of multi- messenger/multi-wavelength data

Françoise Genova, Mark Allen
Catherine Boisson, Eric Chassande-Mottin, Paschal
Coyle, Andrew Lawrence, Marco Molinaro, Enrique
Solano, Joachim Wambsganss, Michael Wise
and ASTERICS WP4 team

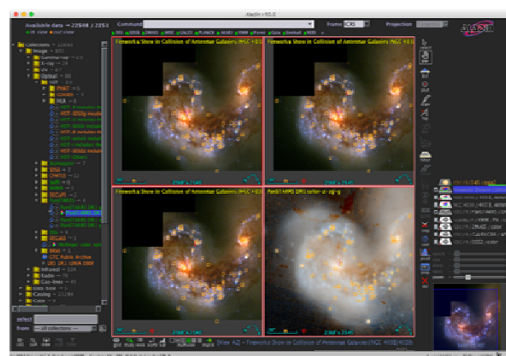
Astronomy in the Open Science context

- Astronomy has been a pioneer of Open Science and FAIRness
 - FITS – 1977, data + metadata
 - Data can be shared and **R**eused
 - 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 **F**indable, **A**ccessible, **I**nteroperable

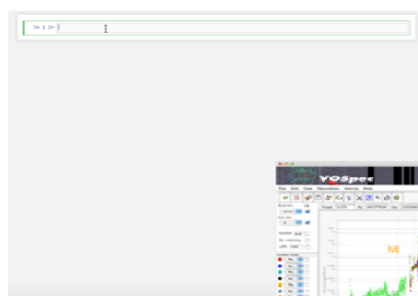
A view of the VO from one application



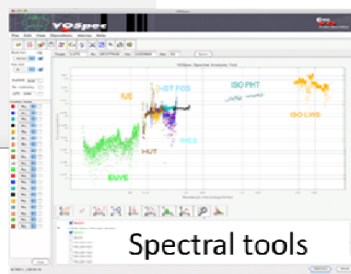
Interoperable applications



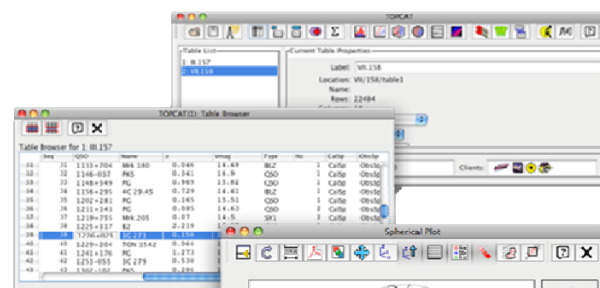
Aladin



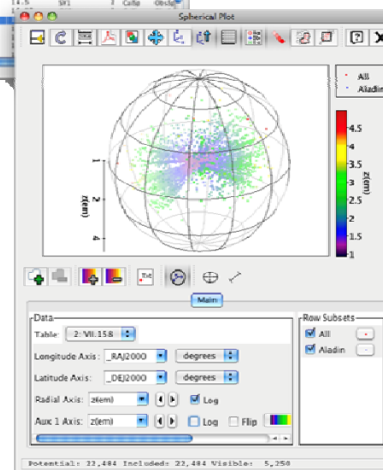
Notebooks



Spectral tools



Your apps
& programs



TOPCAT



WP4 in ASTERICS proposal

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



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

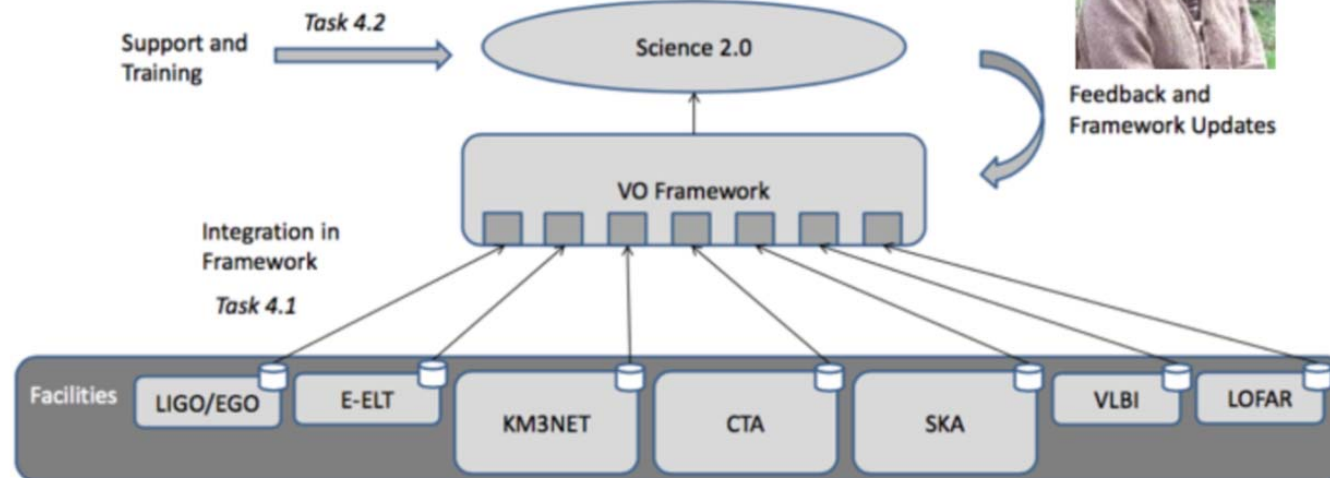


Figure 6: The ESFRI projects integrated in the VO Framework offers users uniform access.

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 displaying the EURO-VO Scientific Tutorials page. The browser's address bar shows the URL www.euro-vo.org/?q=science/scientific-tutorials. The page features a large header with the EURO-VO logo and a navigation menu on the left. The main content area is titled "Scientific Tutorials" and includes a list of tutorials with brief descriptions.

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Scientific Tutorials

The latest tutorials to learn how to use VO-enabled tools for your research:

- 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 Protocol) 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** [for 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 strongly 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*

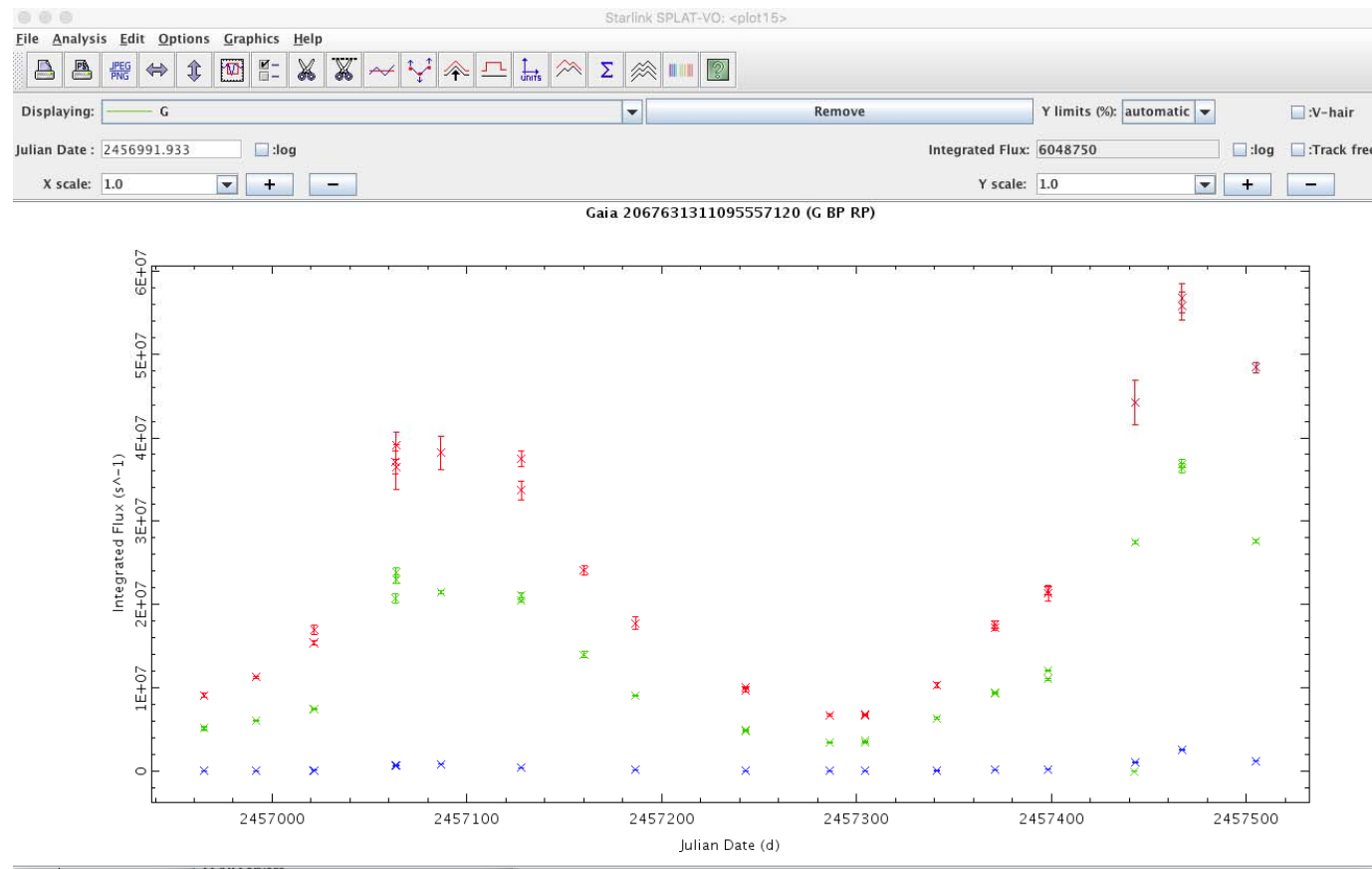
Multi-dimensional data

- « 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

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

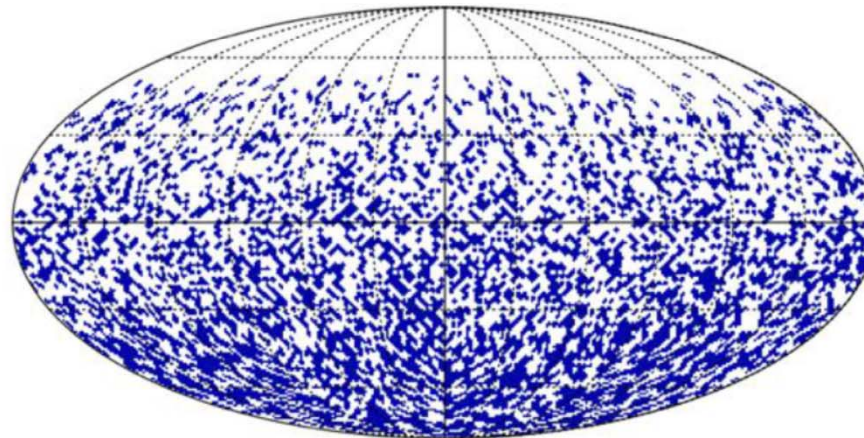
Graf, Second DADI Data Provider Forum 2018

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

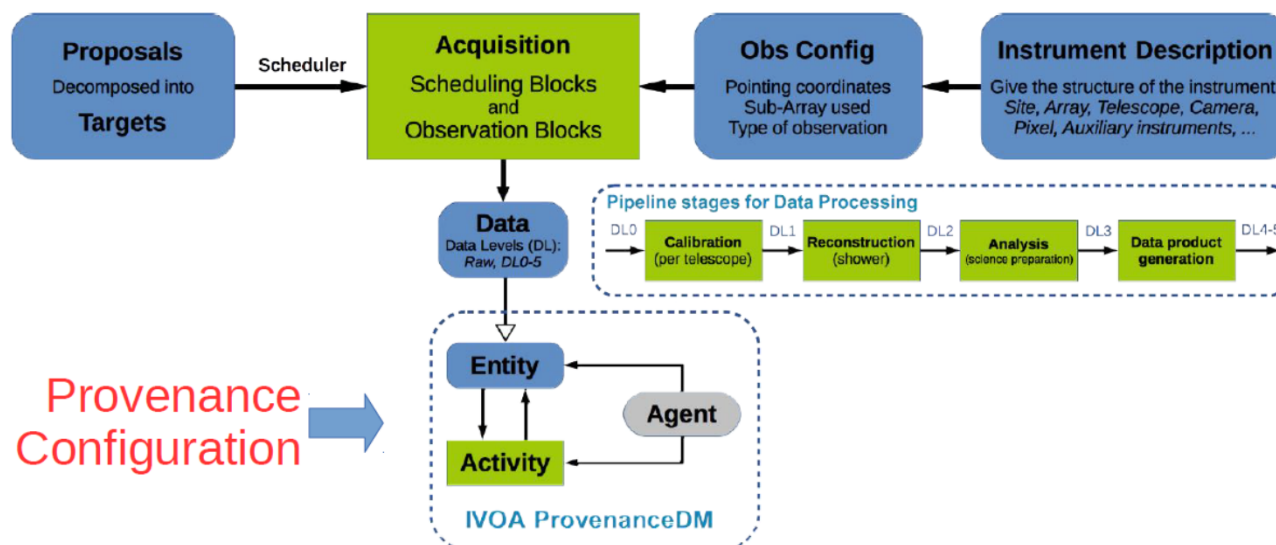


from: <http://dc.zah.uni-heidelberg.de/antares/q/cone/info>

Servillat, Second DADI ESFRI Forum, 2017

High level metadata model

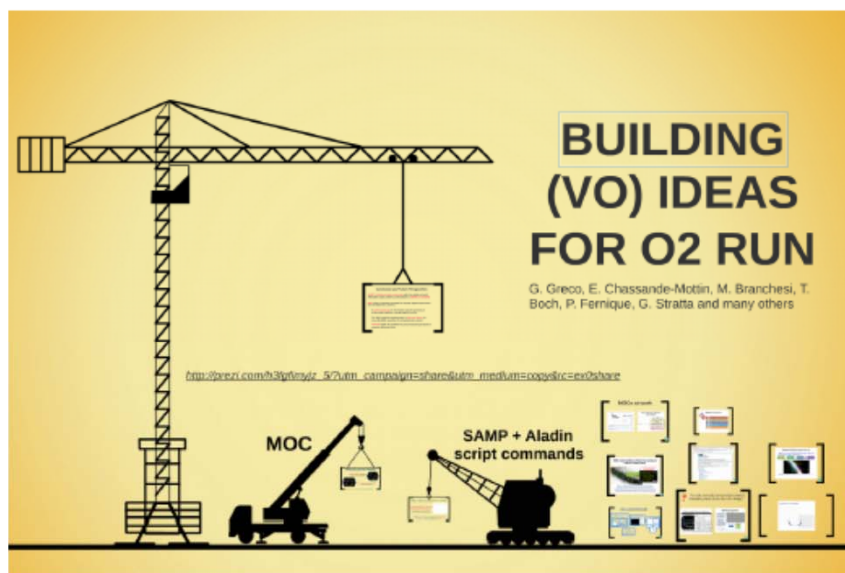
- ◆ Defines **structure** of services, content and context of data
- ◆ Can be seen as a **global interface**



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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New Gravitational Wave Detection From Colliding Black Holes

By DENNIS OVERBYE SEPT. 27, 2017

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

JUNE 1, 2017

STERIAL MEETING ON SCIENCE

REALE, TORINO 17-28 SEPTEMBER 2017

3

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

3/27/2019

Multi-messenger/Groningen

21

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

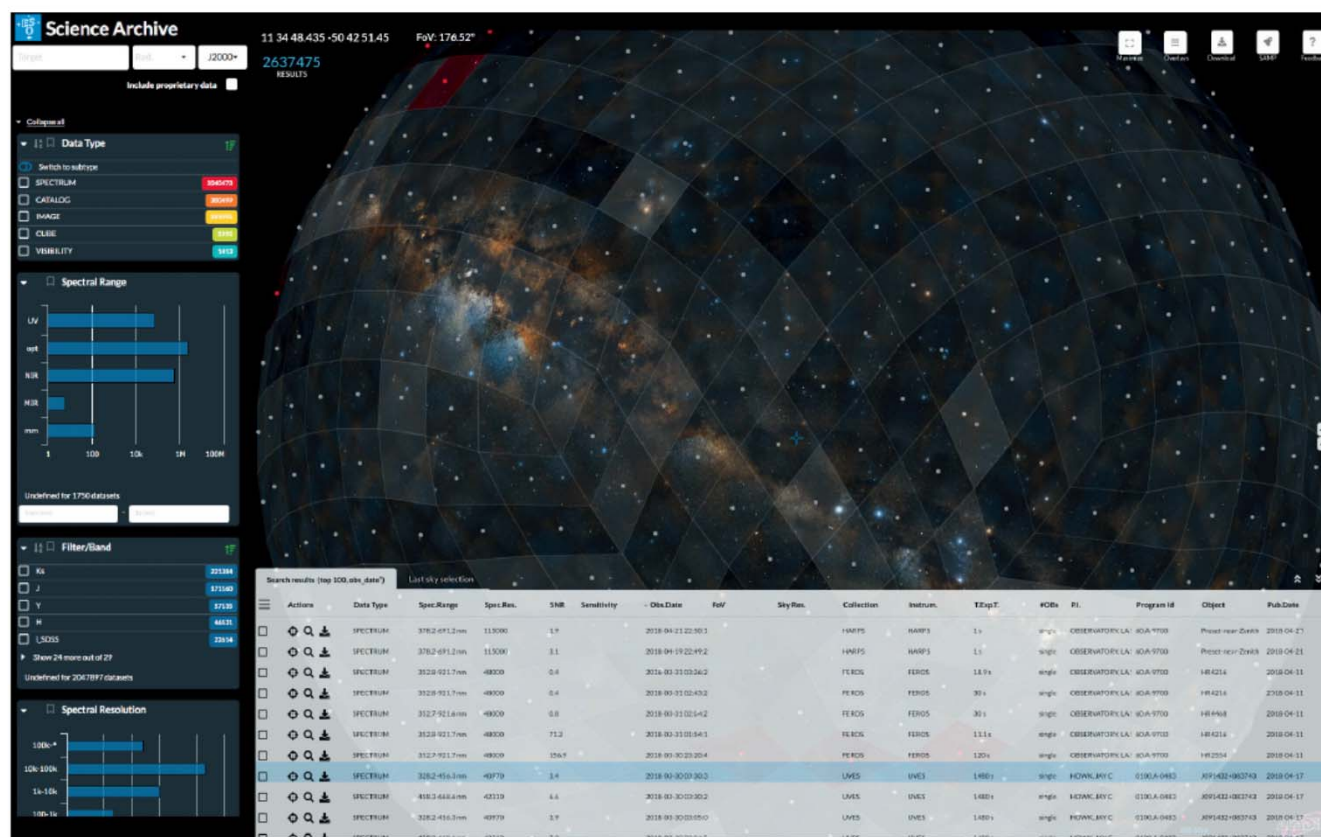
Sterzik, First DADI Data provider meeting, 2016



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

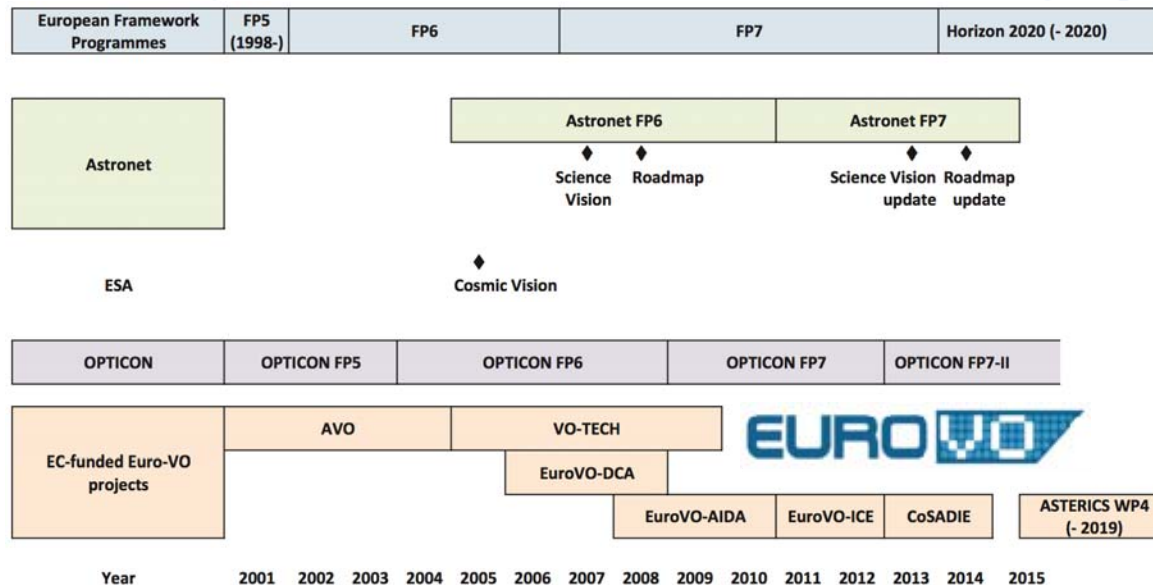
- ESFRIs consumers/actors/agents of the VO
- Astronomy/Astroparticle working hand in hand
 - Inclusion of astroparticle needs in the VO
- First contact with EST, ESFRI 2016
- Leadership in/strong contribution to IVOA activities
- Schools/tutorials
- A set of standards
- Evolution of existing tools/new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

Background...

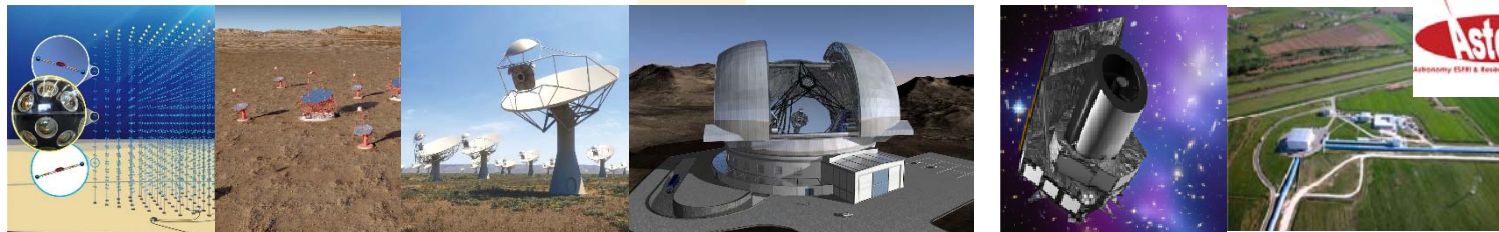
M. Allen, ESCAPE Kick-off

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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