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

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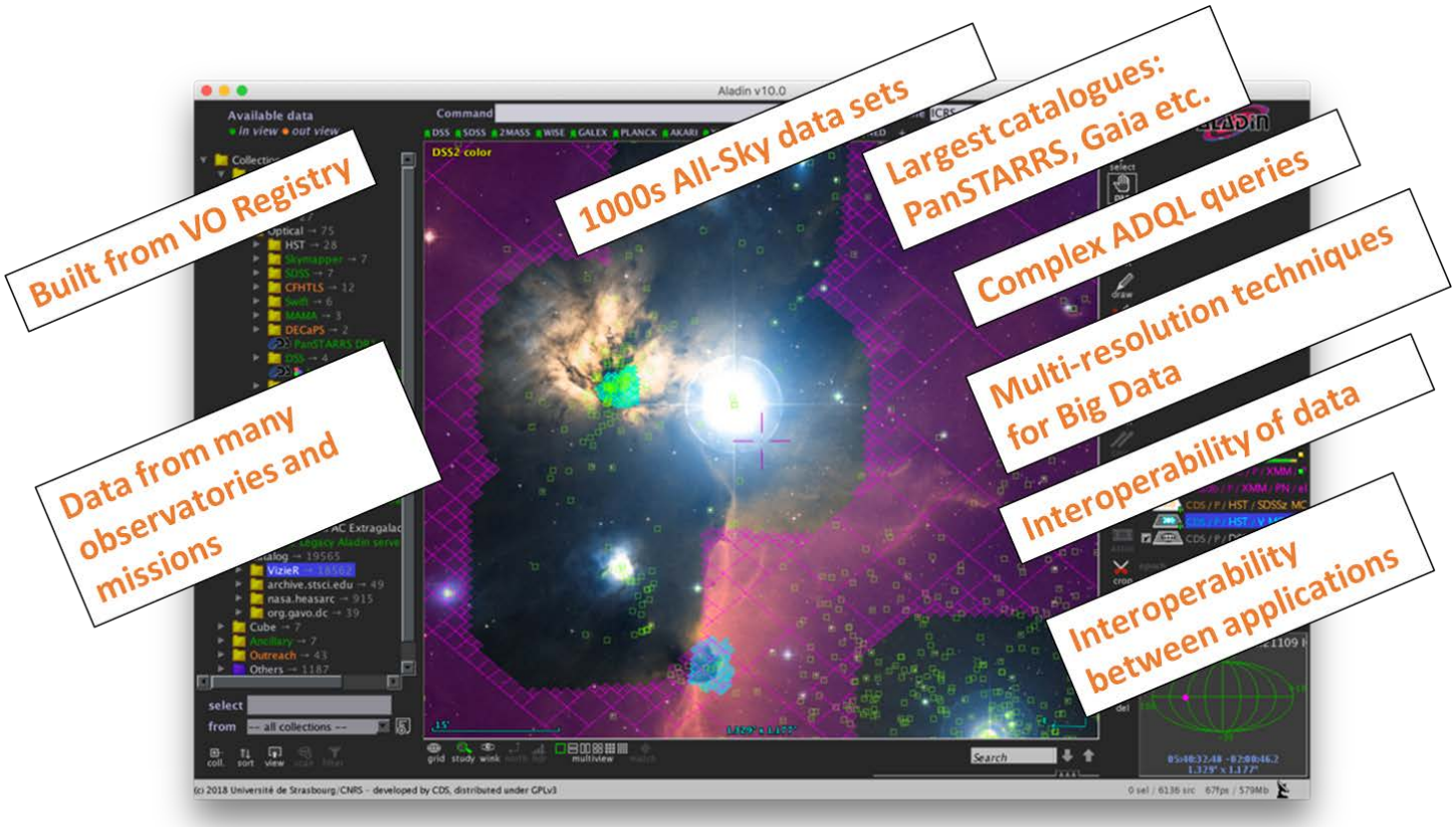
Catherine Boisson, Eric Chassande-Mottin, Paschal Coyle, Andrew Lawrence, Marco Molinaro, Enrique Solano, Joachim Wambsganss, Michael Wise
and ASTERICS WP4 team

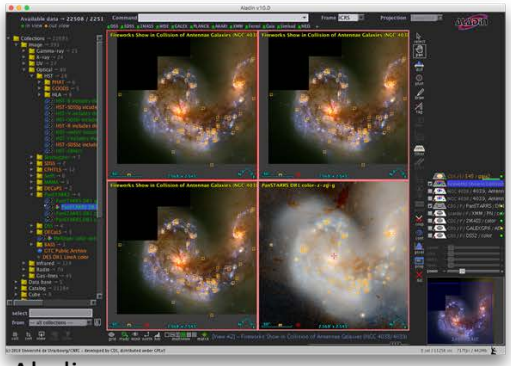
Astronomy in the Open Science context

- 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

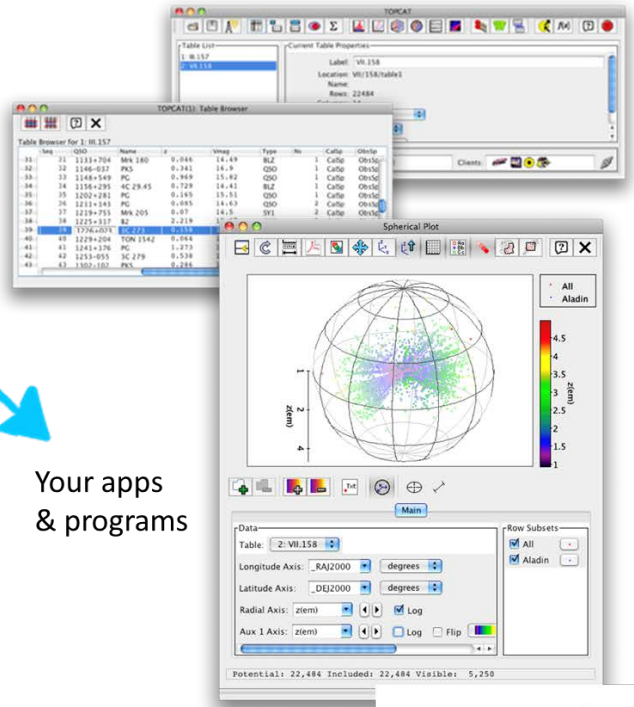
A view of the VO from one application



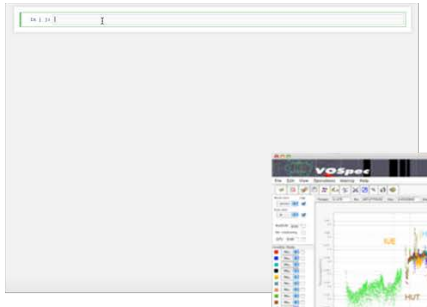
Interoperable applications



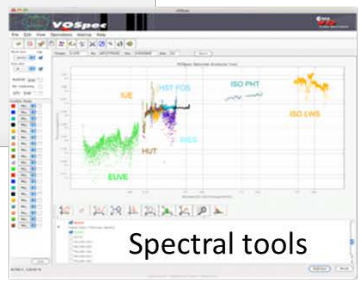
Aladin



TOPCAT



Notebooks



Spectral tools

Your apps
& programs

Broadcast

WP4 in ASTERICS proposal

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

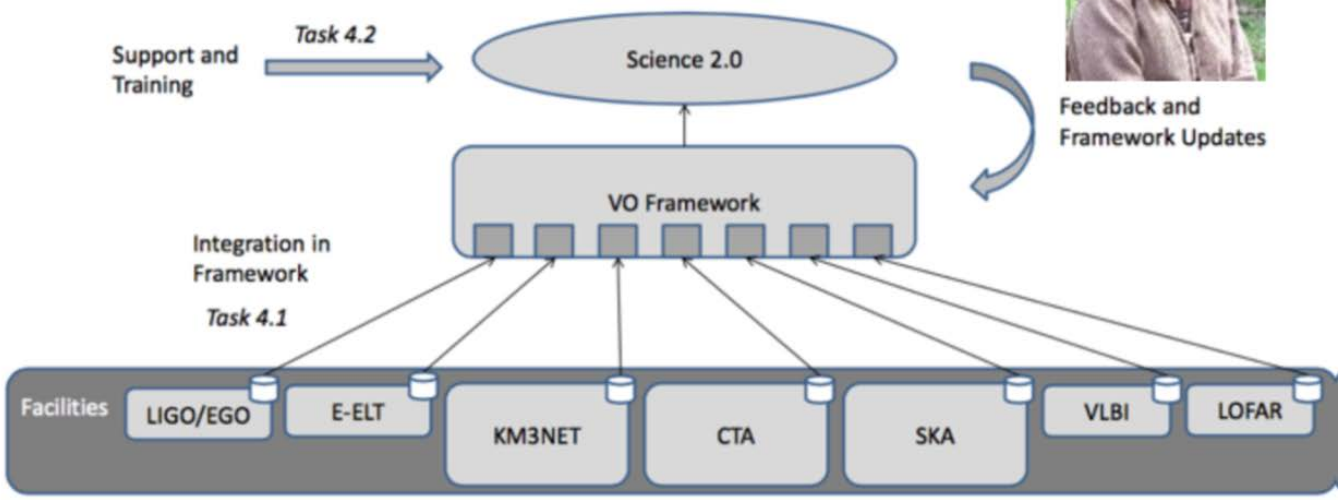


Figure 6: The ESFRI projects integrated in the VO Framework offers users uniform access.

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

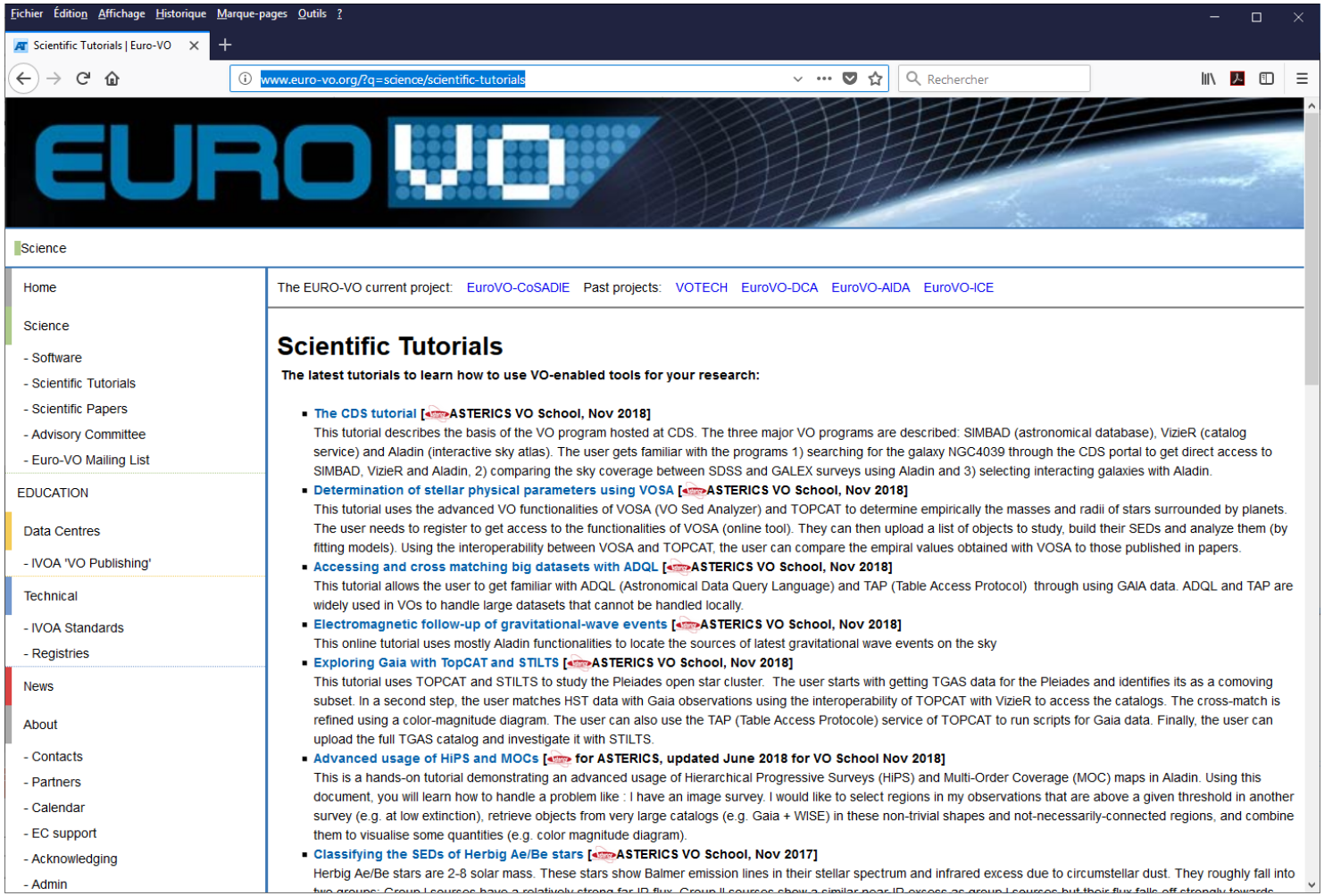
Heidelberg, June 2018

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



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*

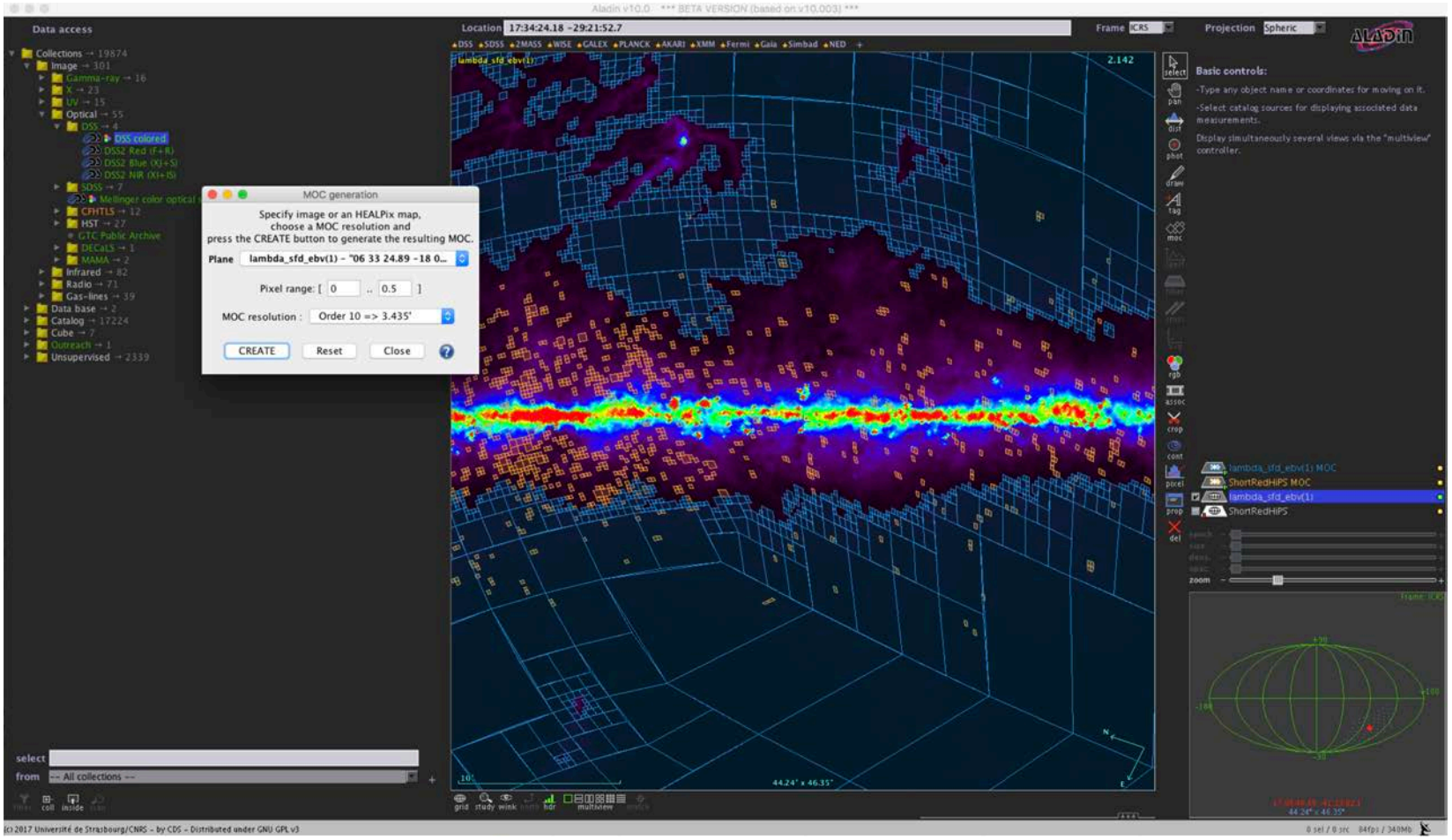
Multi-dimensional data

- « 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

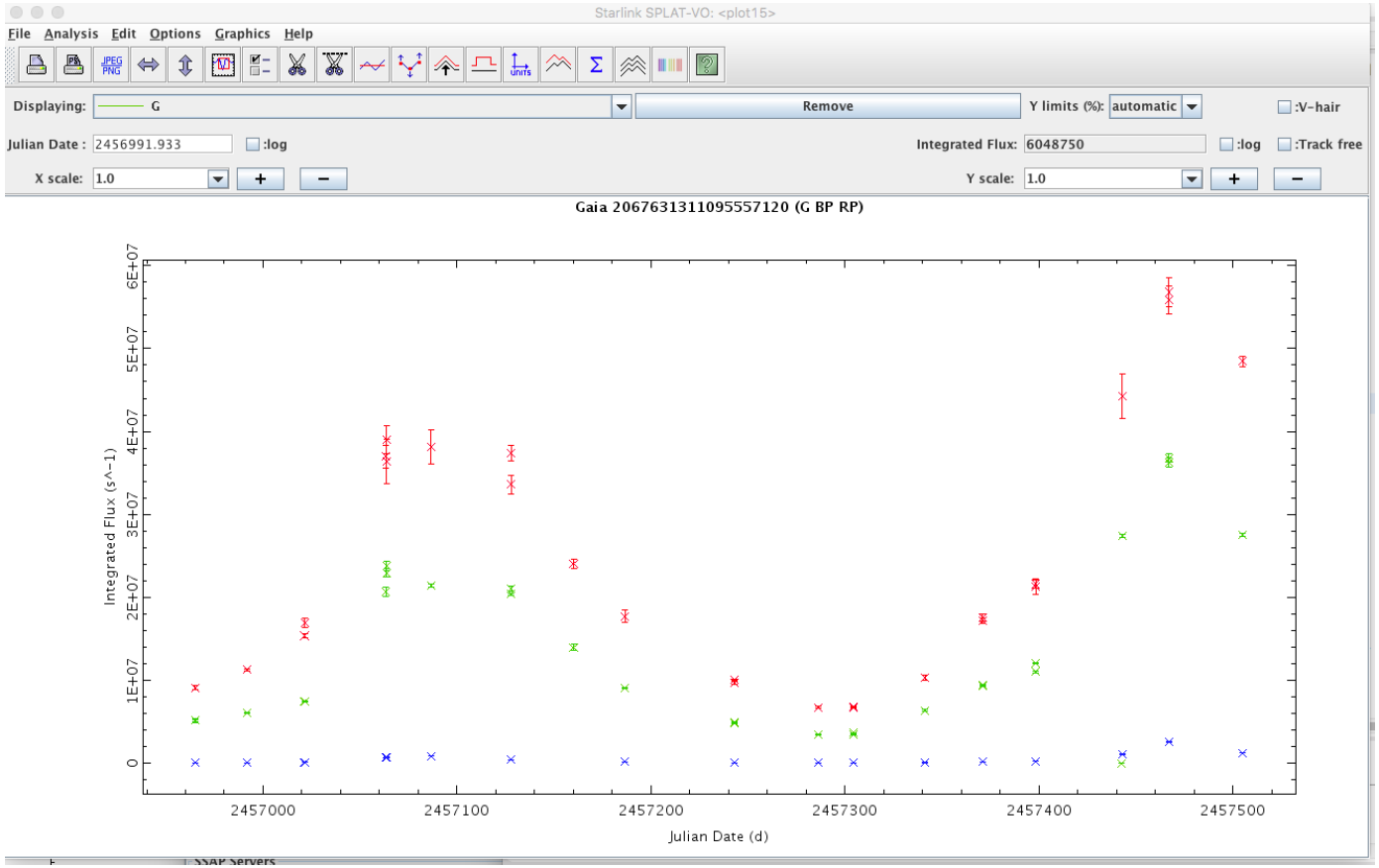
DADI impact

- 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

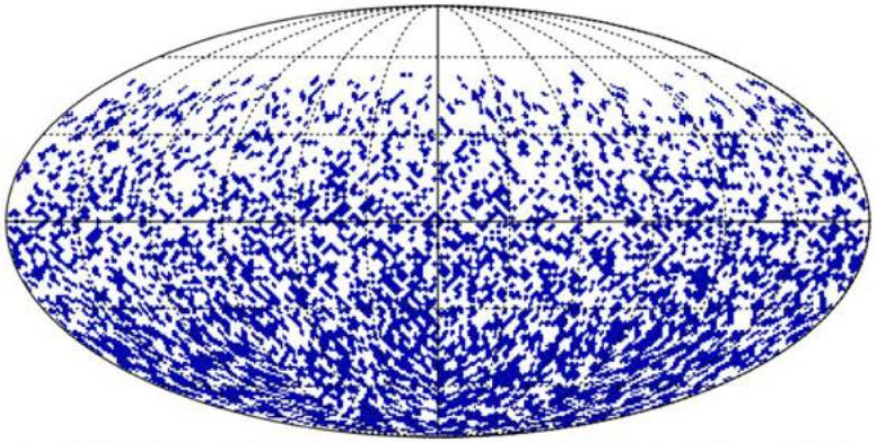
- Support to VO usage by RIs
  - ANTARES – KM3Net
- VO building blocks in the research infrastructure pipelines/services
  - Provenance for CTA
  - GWSky
  - VO in ESO system

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



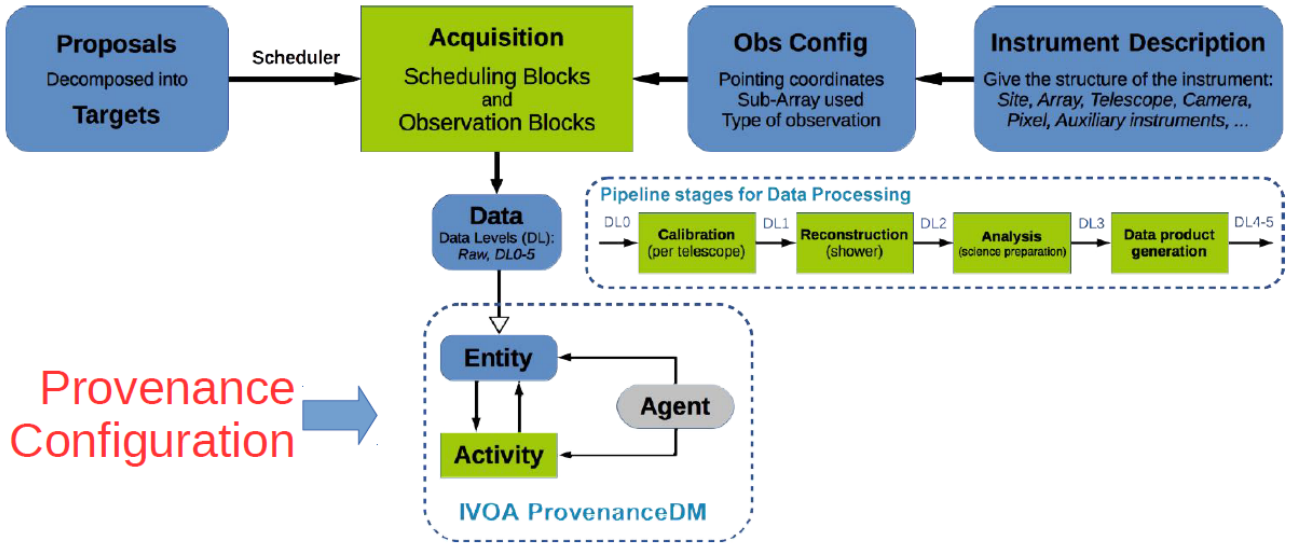
from: http://dc.zah.uni-heidelberg.de/antares/q/cone/info

ASTERICS EDP Forum, Heidelberg - June 2018 - K. Graf, ECAP 13

Servillat, Second DADI ESFRI Forum, 2017

High level metadata model

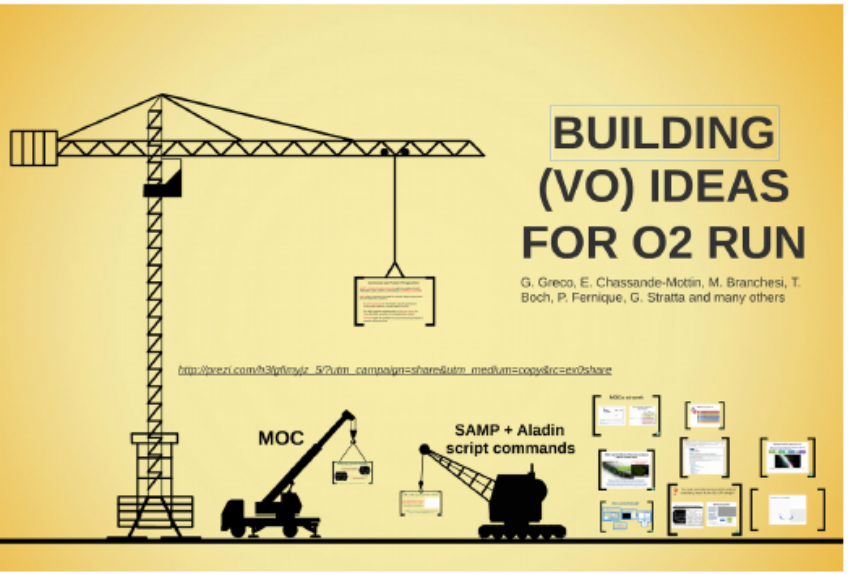
- Defines **structure** of services, content and context of data
- Can be seen as a **global interface**



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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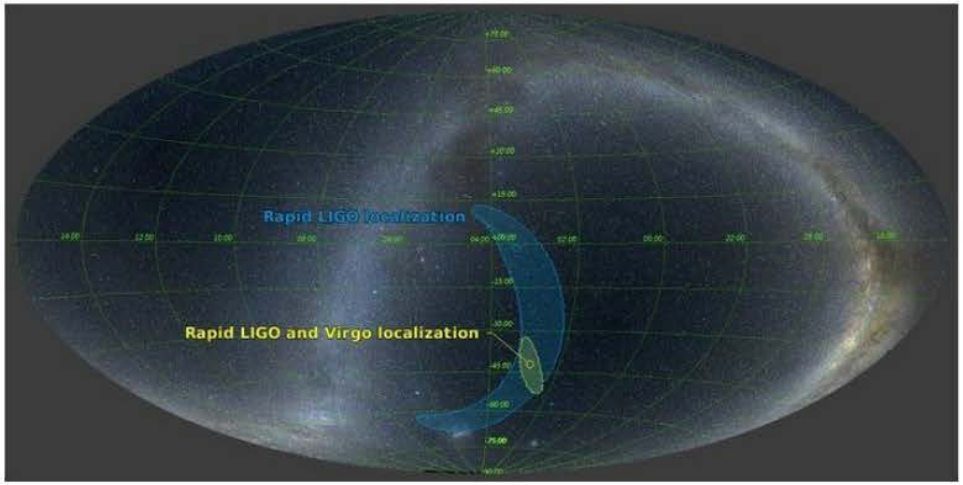
SCIENCE

New Gravitational Wave Detection From Colliding Black Holes

By DENNIS OVERBYE SEPT. 27, 2017



The LIGO and Virgo detectors in the United States and Europe identified gravitational waves emitted by the
holes 1.8 billion light years away. The location of the black holes in the night skies is
p. LIGO/Virgo

4
ARTICLES REMAINING THIS MONTH

RELATED COVERAGE

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

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

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

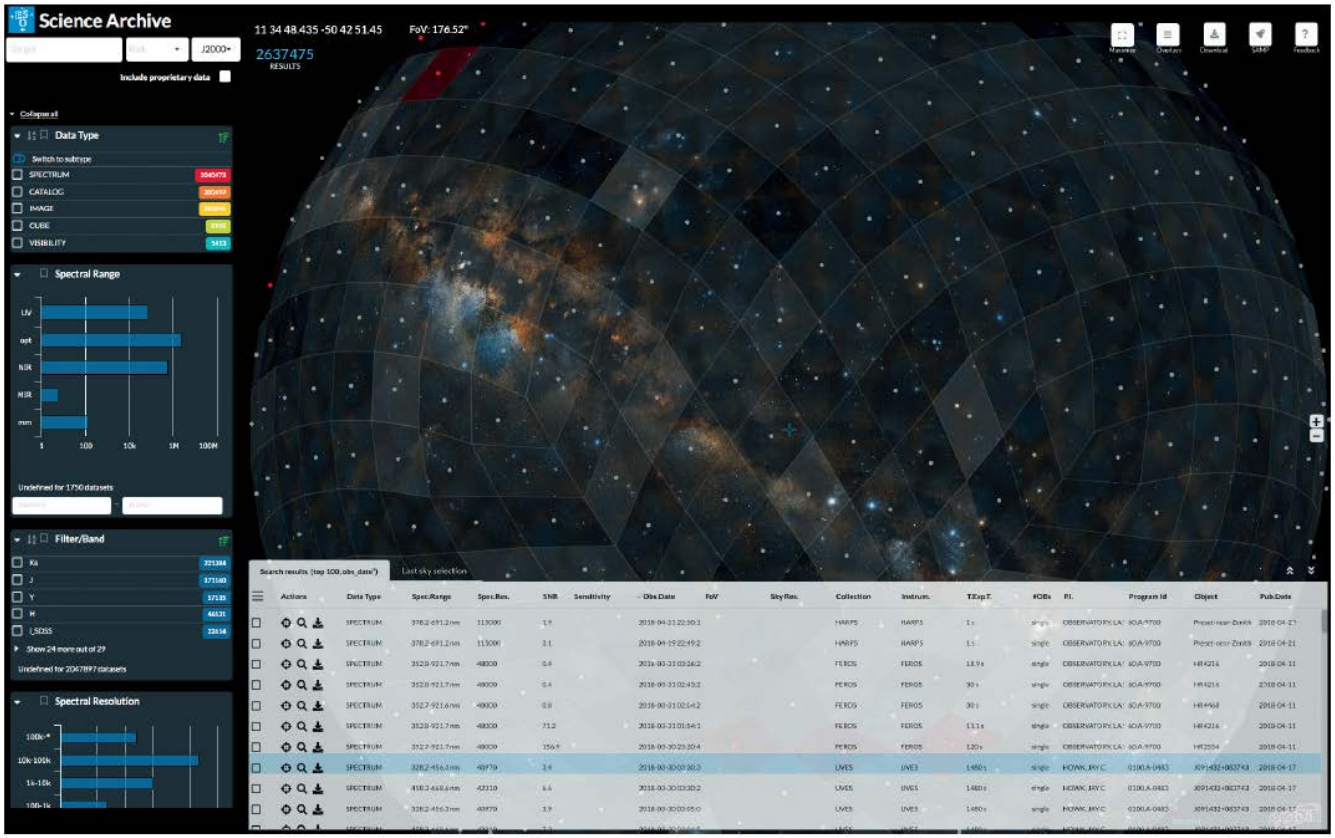
Sterzik, First DADI Data provider meeting, 2016

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)

ASTERICS European Data Provider Forum, Heidelberg, 15/16 June 2016

Access to ESO archive using VO tools and protocols



Romaniello et al, Messenger, 2018

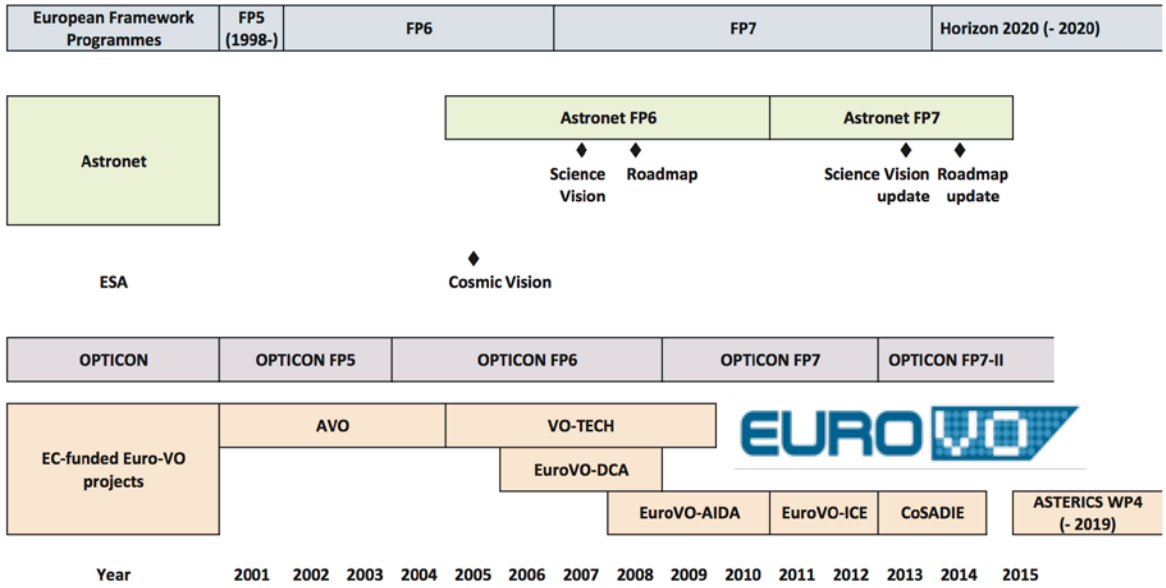
DADI legacy

- 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

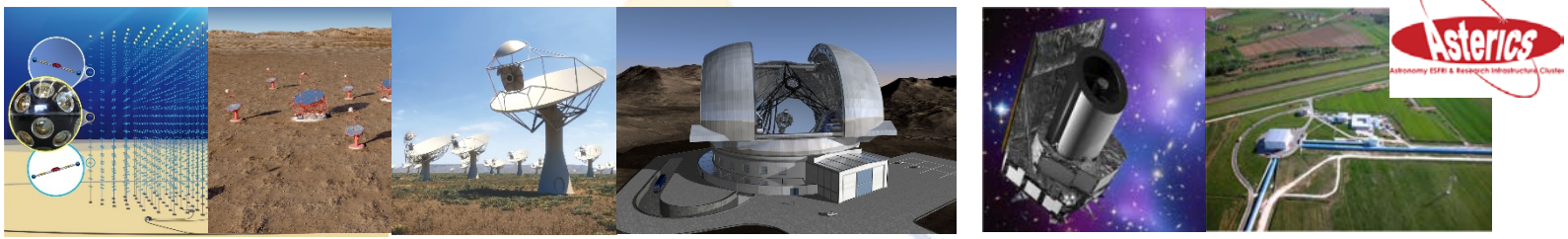
Background…

How we got here, and where we're going

- Virtual Observatory infrastructure for astronomy



Genova et al. 2015



Funded by the European Union's Horizon 2020 - Grant N° 824064