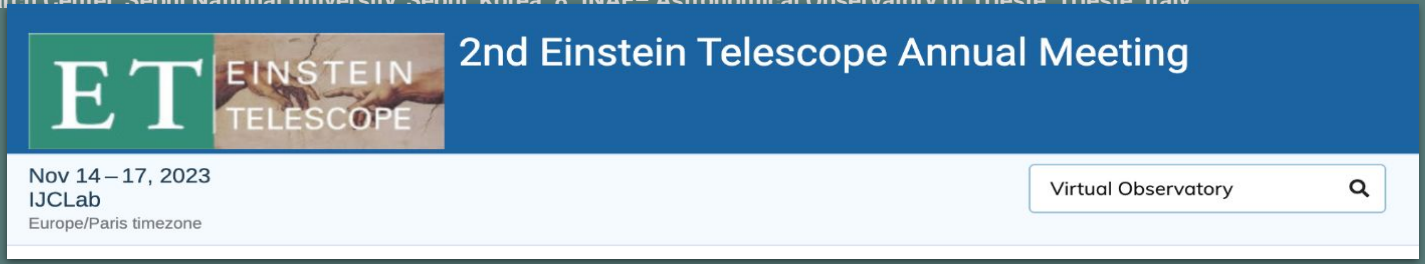
Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INFN PERUGIA

Advancing Multimessenger Science through the Virtual Observatory: Current and Future Outlook

Giuseppe Greco[1]

M. Allen[2], M. Baumann[2], M. Bawaj[1,3], M. Branchesi[4], M.L. Brozzetti[3], M. Bossi[1], S. Cutini[1], G. Dálya[5], R. De Pietri[6], S. Derriere[2], P. Fernique[2], E. Khalouei[7], M. Marchand[2], T. Matcovich[1], M. Molinaro[8], A. Nebot[2], F. Pasian, F.-X. Pineau[2], M. Punturo[1], H. Vocca[1,3]

1. INFN–Section of Perugia, Perugia, Italy; 2. Université de Strasbourg, CNRS, Observatoire astronomique de Strasbourg, Strasbourg, France; 3. Università degli Studi di Perugia, Perugia, Italy; 4. Gran Sasso Science Institute (GSSI), Aquila, Italy; 5. Universiteit Gent, B-9000 Ghent, Belgium; 6. Università degli Studi di Parma, Parma, Italy; 7. Astronomy Research Center, Seoul National University, Seoul, Korea; 8. INAF– Astronomical Observatory of Trieste, Trieste, Italy



IVOA

A Brief Overview

Applications

How (a few) IVOA Standards
Operate in the Current MMA Context

Thinking IVOA

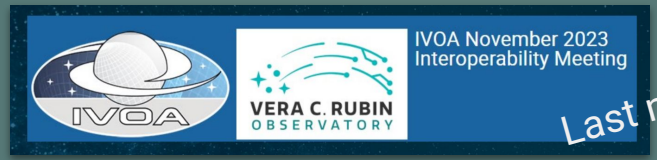
Future Challenges: 3rd Gen.
Interferometers & EM Facilities
in Multimessenger Astronomy

IVOA created in 2002

IVOA in a Nutshell

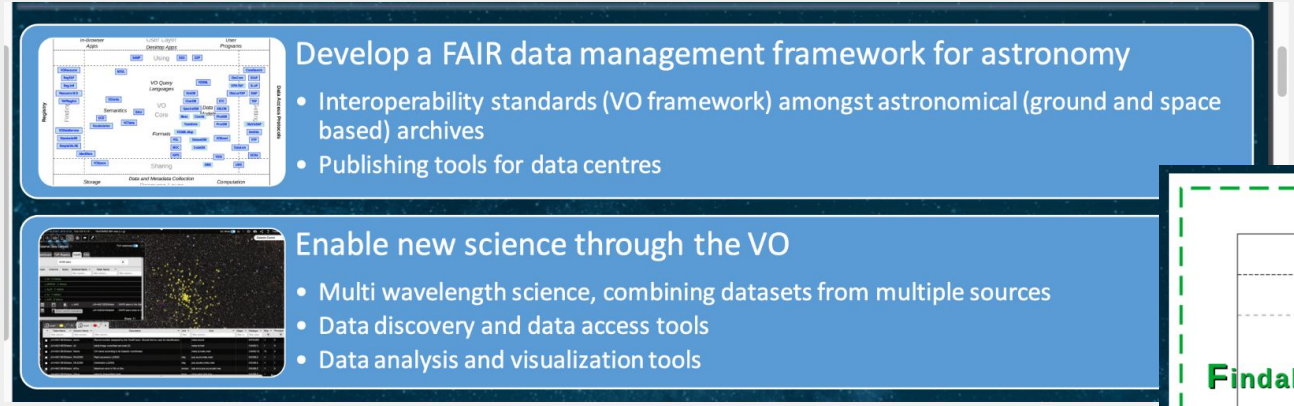
The Virtual Observatory (VO) is the vision that astronomical datasets and other resources should work as a seamless whole. Many projects and data centres worldwide are working towards this goal. The International Virtual Observatory Alliance (IVOA) is an organisation that debates and agrees the technical standards that are needed to make the VO possible. It also acts as a focus for VO aspirations, a framework for discussing and sharing VO ideas and technology, and body for promoting and publicising the VO.

- 23 member VO (Virtual Observatory) Projects
- 2 interoperability meetings per year
  - 5 days around May
  - 3 days around Oct/Nov after ADASS
- No formal funding, nationally funded projects

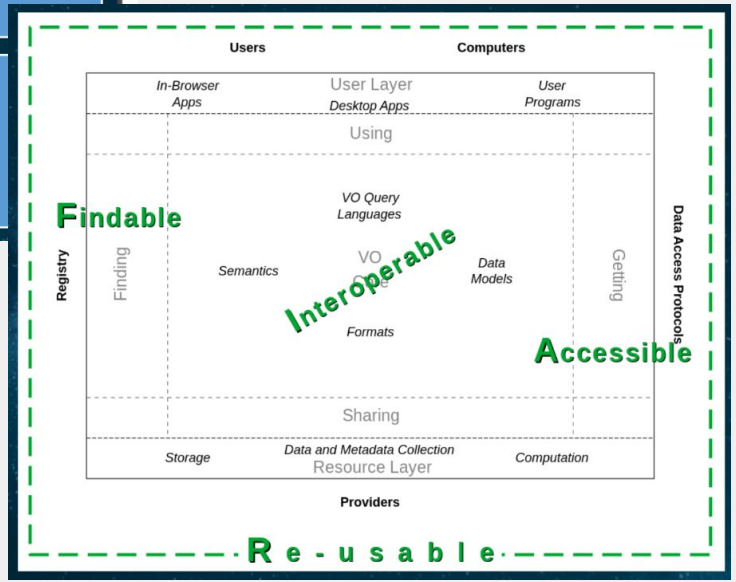


Last meeting in Tucson

IVOA Vision and Architecture



VO has been FAIR from the beginning.



IVOA is an open community –If a standard is close but doesn't fit – implement an extension & provide feedback to influence change to the standard.

Screenshots taken from Christophe Arviset, Interop. 2023

See FAIR principles in IVOA
https://zenodo.org/records/7049804

Discussion, Testing and Implementations of IVOA Standards and Tools for Multi-messenger Astronomy with GW

- ASTERICS DADI ESFRI Forum & Training Event 1 – 3 & 4 December, 2015 – Trieste.
- ASTERICS DADI Technology Forum 2 – 7 & 8 March, 2016 – Edinburgh.
- DADI Meeting on Gravitational Waves – 31 May–1 June 2016 – Strasbourg.
- ASTERICS DADI ESFRI Forum & Training Event 2, 13 & 14 December, 2017 – Trieste.

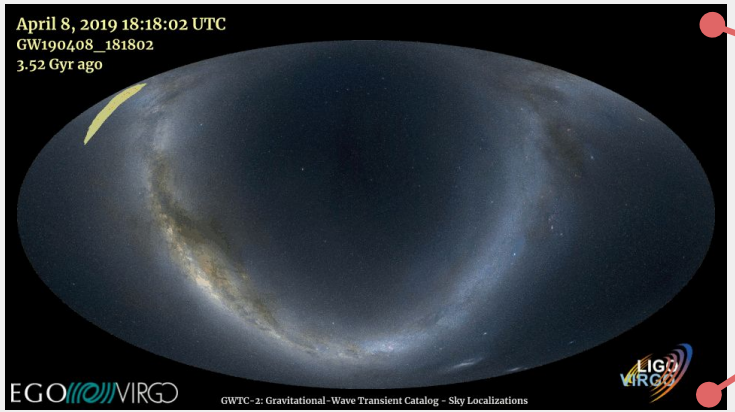
IVOA: Northern Spring 2016 Interoperability Meeting

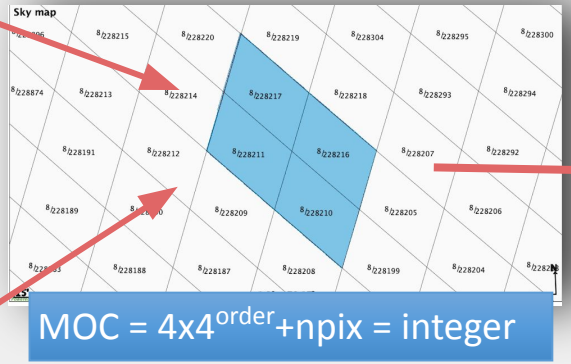
Focus session from Mark Allen

- AHEAD2020 WP12 F2F meeting 4 May, 2022 – Aquila.
- INFN–Perugia and SSDC–ASI dedicated periodic calls.
- ESCAPE to the Future 25–26 October 2022 – Brussels.
- WP4 Technology Forum 3 – 15–16 March 2022 –online
- WP4 Technology Forum 2 – 13–15 April 2021 –online
- WP4 Technology Forum 1 – 4–6 February 2020 – Strasbourg

Slide presented in IVOA May 2023 Interop. Meeting

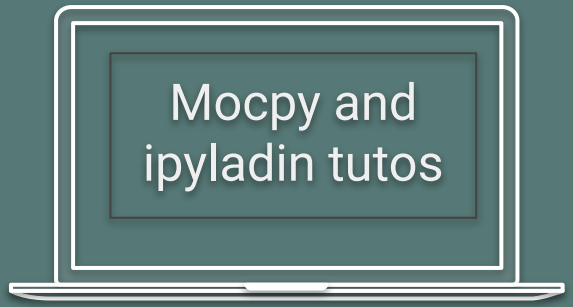
MOC VO Standard to encode GW sky localisations





MultiOrder Coverage map (or Space MultiOrder Coverage) is an efficient way of describing arbitrary patches of the sky, logical operations such as union, intersection of MOC can be calculated, tables can be filtered by MOC, (P. Fernique et al., 2015).

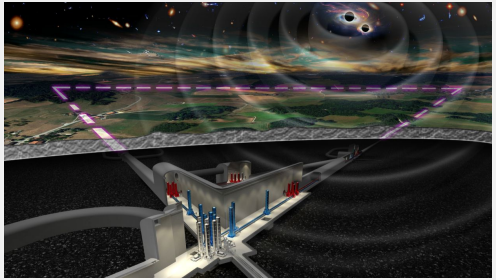
We show that complex and irregularly shaped gravitational-wave sky locations can be encoded as MOC maps (Greco et al., 2019; 2022). These maps can be used in visualization tools and processed (filtered, combined). Additionally, we highlight their usefulness for accessing Virtual Observatory services, enabling queries 'by MOC' for data within the region of interest.
The use of MOC maps promotes high interoperability to support observing schedule plans (G. Greco et al., 2022).



Dedicated Practical Applications

Click for Direct Online Access

Toward a Collaborative MMA Platform?



Managing a High Volume of Real-time Alerts: Decisive Decision-Making for Timely Classification. Is this a pathway to a collaborative platform? How might such a platform take shape?

Fully Centralized

Facilities within the collaborations automatically receive the schedule of observations to be carried out.

Information-gathering

The decision to respond to alerts is independent, and the executed observations are logged on a shared platform.

Unified Alert System

The system compares alerts from various observers and generates an alert for potential temporal and spatial coincidences.

Space and Time Multi Order Coverage Map: Real time data access for alert generations

MOC: Multi-Order Coverage map
Version 2.0

IVOA Recommendation 27 July 2022 P. Fernique et al.,

Contents

At a given Time range we obtain the corresponding Spatial coverage.

ST-MOC Queries

Enabling fast and real-time data access involves encoding ET/CE sky localizations into ST–MOC and querying them within a specific time range. Transients can be ranked based on their position within credible regions and respect to the merge time.

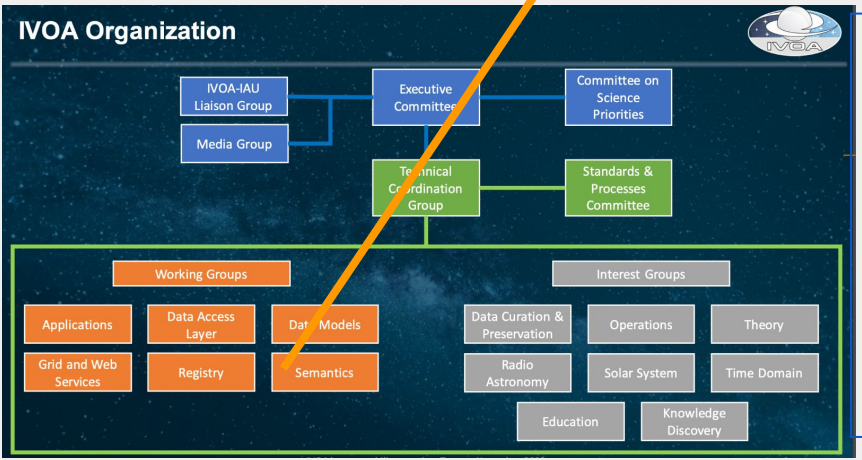
ST-MOC logical operations

Electromagnetic/neutrino surveys will dynamically explore ET sky localizations through multiple spatial and temporal intersections to investigate any electromagnetic/neutrino signals temporally and spatially associated with the inspiral, merger, or ring-down phases.

IVOA Semantic Working Groups

Chairs: B. Cecconi; Co-chair: S. Derriere

A possible starting point for interactions of the VO with future ground-based gravitational wave infrastructures is the definition of the UCD (Unified Content Descriptors).



The IVOA Semantics Working Group explores technology in the area of semantics with the aim of producing new standards that aid the interoperability of VO systems. The Semantics Working Group is concerned with the meaning or the interpretation of words, sentences, or other language forms in the context of astronomy. This includes standard descriptions of astrophysical objects, data types, concepts, events, or of any other phenomena in astronomy. The WG covers use of natural language in astronomy, including queries, translations, and internationalization of interfaces.

https://wiki.ivoa.net/internal/IVOA/IvoaUCD/Charter-Semantics.pdf

title: GW in the VO - ESFRI ET overview and EOSC connection
concise: GWEToverview
https://github.com/molinaro-m/GWEToverview

This collaborative document provides an overview based on the future Einstein Telescope (ET) and current Gravitational Waves (GW) about the possible use and potential updates of the VO ecosystem of standards.

Conclusions

Thinking (IVOA) Standards

Taking part in the development of **VO** standards and tools can be highly beneficial for projects that will emerge in the next decades.

FAIR Principles

The IVOA Vision Integrates FAIR Principles for Worldwide Collaboration.

Long term support

The adoption of standards enables long-term support for tools and software, optimizing preparation efforts for instruments that will be operational in a decade.

Current VO Standards&Tools

Currently a few VO standards and Tools are listed in IGWN (Gravitational-Wave Observatory Network). They are mocpy, ipyladin and Aladin Desktop.

IVOA working groups

Semantics Working Group: Expanding Vocabulary and Descriptors for Multimessenger science.

Computing Resources

The implementation of standards enables the quantification of resources required for establishing a potential multimessenger platform during the advanced stages of ET Mock data challenge.

Thank you for your attention!