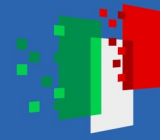




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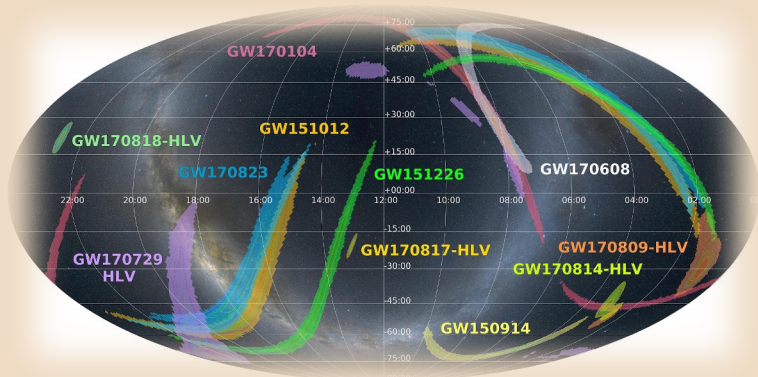
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# Virtual Observatory Standards and tools

## Multi-messenger applications

Giuseppe Greco  
INFN - Perugia

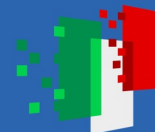




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Home Astronomers Deployers Members About

## INTERNATIONAL VIRTUAL OBSERVATORY ALLIANCE


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.

To learn more about the IVOA as an organisation, read the "About" section.

To learn more about the VO from a user's point of view, including how to find VO tools and services, read the "Astronomers" section. There is also a page about the VO for students and the public.

To learn how to publish VO services, or write VO-compatible software, start by reading the "Deployers/Developers" section.


Internal IVOA discussions are publicly viewable in the "Members" section.



**IVOA NEWS**  
March 2022 Issue of the IVOA Newsletter


**UPCOMING MEETINGS**  
IVOA May 2024 Interoperability Meeting  
19-24 May 2024 Sydney (NSW, AUstralia)

**For Astronomers**




Getting Started / Using the VO  
VO Glossary / VO Applications  
IVOA newsletter / VO for Students & Public

**For Deployers/Developers**



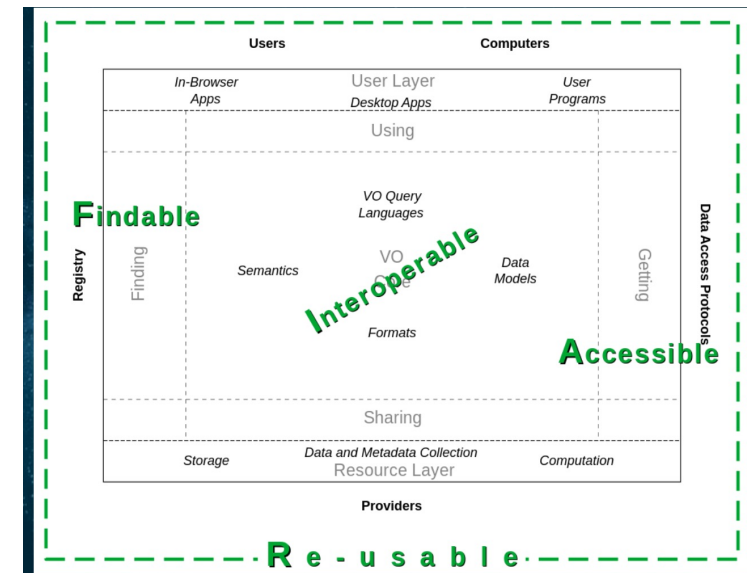
Intro to VO Concepts /  
IVOA Standards / Guide to  
Publishing in the VO / Technical  
Glossary

**For Members**

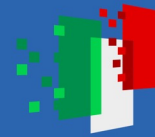


IVOA Calendar / Working Groups/  
Twiki / Documents in Progress /  
Mailing Lists / IVOA Roadmap

# IVOA Architecture – FAIR data management

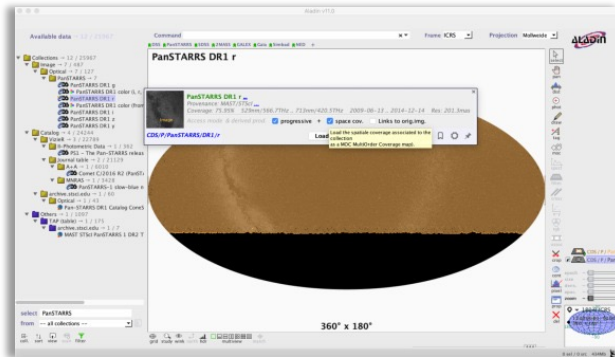


The Virtual Observatory (VO) is the international data sharing framework which enables data to be **FAIR** - **F**indable, **A**ccessible, **I**nteroperable and **R**e-usable for the astronomers' needs.



## MOC and HiPS

A coverage map represents a region covered by a data collection called MOC for Multi-Order Coverage map . A MOC can not only describe a spatial coverage, but also a temporal one, or both simultaneously.



HiPS is the hierarchical tiling mechanism which allows one to access, visualize and browse seamlessly image, catalogue and cube data.

<https://aladin.cds.unistra.fr/java/AladinManual.pdf>

## Aladin Installation



### Official version v12.060

#### Any Operating System (WebStart java installer)

- Aladin.jar
  - 1) [Click here](#)
  - 2) Follows the instructions...

#### OS specific packages with or without Java runtime

- |  |   |
|--|---|
| <ul style="list-style-type: none"> <li>Windows           <ol style="list-style-type: none"> <li>1) Download the MSI installer (*)</li> <li>2) Execute it (**)</li> </ol> </li> </ul> | <ul style="list-style-type: none"> <li>Windows - without Java           <ol style="list-style-type: none"> <li>1) Download it on your desktop</li> <li>2) Launch it (**)</li> </ol> </li> </ul>       |
| <ul style="list-style-type: none"> <li>Linux           <ol style="list-style-type: none"> <li>1) Download the installer</li> <li>2) Double-click on it</li> </ol> </li> </ul>        | <ul style="list-style-type: none"> <li>Linux - without Java           <ol style="list-style-type: none"> <li>1) Download it and untar it</li> <li>2) Use aladin shell launcher</li> </ol> </li> </ul> |
| <ul style="list-style-type: none"> <li>Mac ARM</li> </ul>  | <ul style="list-style-type: none"> <li>Mac - without Java           <ol style="list-style-type: none"> <li>1) Download it and untar it</li> </ol> </li> </ul>   |

### Running Aladin Desktop

Aladin Desktop is a Java application. To run it, you must first have the Java Virtual Machine (JVM) installed. More details are in Aladin's [download page](#).

#### Note

Aladin may fail to load some LIGO/Virgo/KAGRA sky maps and display a `java.lang.OutOfMemoryError` error message. This is because the highest resolution LIGO/Virgo/KAGRA sky maps do not fit inside Aladin's default memory size.

You can increase the maximum memory size used by your Java runtime environment by following the instructions below.

Download the Aladin.jar from the [Aladin download page](#). Execute it from a terminal by typing:

```
$ java -Xmx2g -jar Aladin.jar
```

The flag `-Xmx<amount of memory>` specifies the maximum memory allocation pool for a JVM. Here 2GB of memory is allocated. For GW sky localizations with `inside=2048`, increase the memory allocated up to 3GB, `-Xmx3g`.



## Aladin Desktop - hands on section – GW170814 and GW190814

Featured in Physics

Editors' Suggestion

Open Access

### GW170814: A Three-Detector Observation of Gravitational Waves from a Binary Black Hole Coalescence

B. P. Abbott *et al.* (LIGO Scientific Collaboration and Virgo Collaboration)  
Phys. Rev. Lett. **119**, 141101 – Published 6 October 2017

**PhysiCS** See Focus story: [Three-Way Detection of Gravitational Waves](#)

### THE ASTROPHYSICAL JOURNAL LETTERS

OPEN ACCESS

### GW190814: Gravitational Waves from the Coalescence of a 23 Solar Mass Black Hole with a 2.6 Solar Mass Compact Object

R. Abbott<sup>1</sup>, T. D. Abbott<sup>2</sup>, S. Abraham<sup>3</sup>, F. Acernese<sup>4,5</sup>, K. Ackley<sup>6</sup>, C. Adams<sup>7</sup>, R. X. Adhikari<sup>1</sup>, V. B. Adya<sup>8</sup>, C. Affeldt<sup>9,10</sup>, M. Agathos<sup>11,12</sup> [+ Show full author list](#)

Published 2020 June 23 · © 2020. The American Astronomical Society.

[The Astrophysical Journal Letters, Volume 896, Number 2](#)

Citation R. Abbott *et al* 2020 *ApJL* **896** L44

DOI 10.3847/2041-8213/ab960f



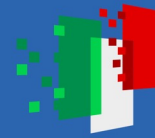
### Skymaps

<https://dcc.ligo.org/LIGO-T1700453/public>

### Skymaps

<https://gracedb.ligo.org/superevents/S190814bv/view/>

Building managing and compare credible regions



# Aladin Desktop - hands on section GW190425

## THE ASTROPHYSICAL JOURNAL LETTERS

### OPEN ACCESS

### GW190425: Observation of a Compact Binary Coalescence with Total Mass $\sim 3.4 M_{\odot}$

B. P. Abbott<sup>1</sup>, R. Abbott<sup>1</sup>, T. D. Abbott<sup>2</sup>, S. Abraham<sup>3</sup>, F. Acernese<sup>4,5</sup>, K. Ackley<sup>6</sup>, C. Adams<sup>7</sup>, R. X. Adhikari<sup>1</sup>, V. B. Adya<sup>8</sup>, C. Affeldt<sup>9,10</sup> [+ Show full author list](#)

Published 2020 March 19 • © 2020. The Author(s). Published by the American Astronomical Society.

[The Astrophysical Journal Letters](#), Volume 892, Number 1

Citation B. P. Abbott *et al* 2020 *ApJL* 892 L3

DOI 10.3847/2041-8213/ab75f5

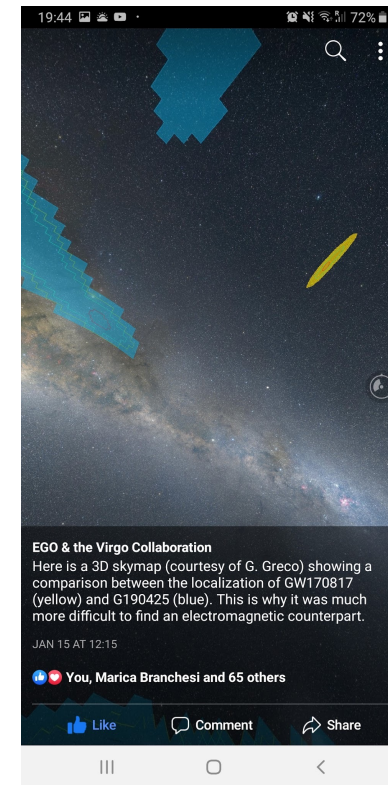


## Skymaps

<https://gracedb.ligo.org/superevents/S190425z/view/>

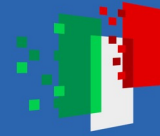


[https://cade.irap.omp.eu/dokuwiki/doku.php?id=galactic\\_reddening](https://cade.irap.omp.eu/dokuwiki/doku.php?id=galactic_reddening)



**Click on the figure to direct to the original post**

Extinction Region and searching for reference image coverages



# Aladin Desktop - hands on section SPACE AND TIME MOC

IVOA Recommendation



International  
Virtual  
Observatory  
Alliance

## MOC: Multi-Order Coverage map

Version 2.0

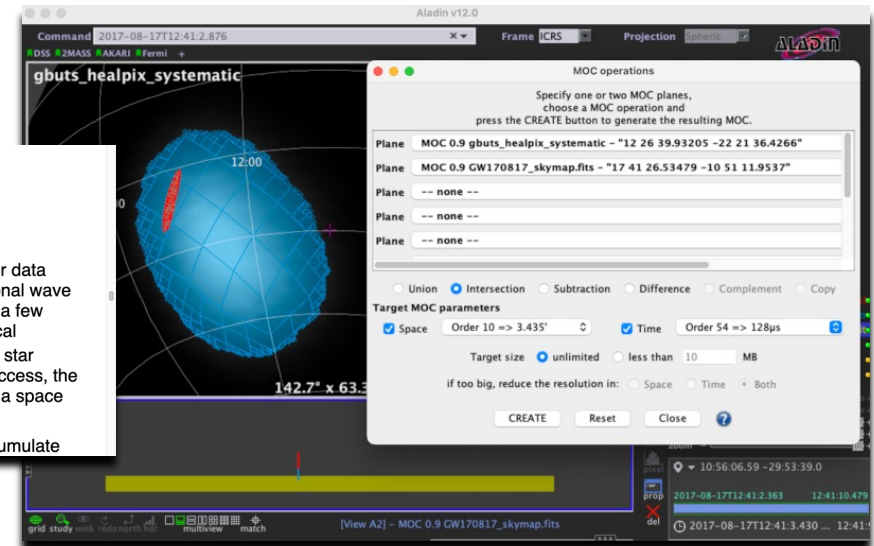
IVOA Recommendation 2022-07-27

and associated spatial coverage (bottom right).

### 2.4 Space and Time MOC: Einstein Telescope and Early Warning Alerts

The space and time MOC provides us with an effective way to develop new multi-messenger data analysis tools that will have a crucial role when the third-generation interferometric gravitational wave observatories, such as the Einstein Telescope (ET), will begin operation. Here we figure out a few potential applications. ET will explore the universe with gravitational waves up to cosmological distances with an expected detection rate of order  $10^5 - 10^6$  black holes and  $7 \times 10^4$  neutron star mergers per year (Maggiore and Van Den Broeck et al., 2020). For fast and real time data access, the user can query by a specific time range the gravitational-wave sky localizations encoded as a space and time MOC.

In addition, the ET sensitivity at low frequencies enables enough signal-to-noise ratio to accumulate



<https://emfollow.docs.ligo.org/userguide/resources/aladin.html>

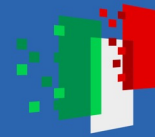
## Spatial and Temporal analysis



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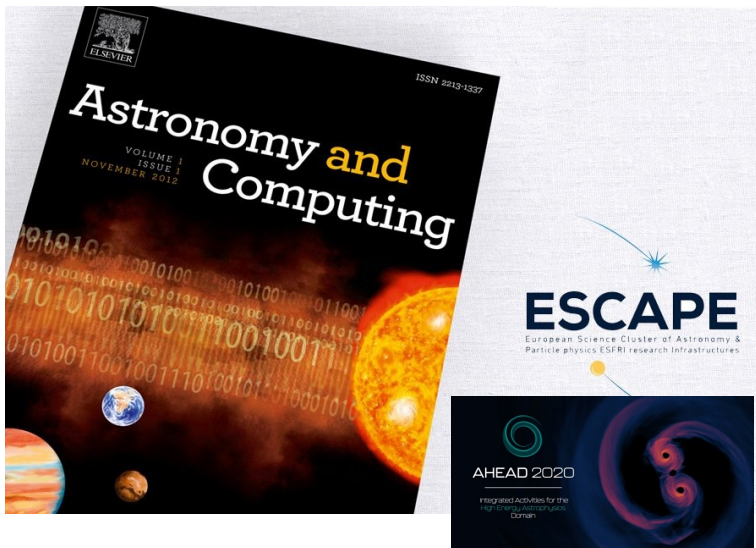
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# Aladin Desktop - hands on section VIDEO TUTORIAL



Full length article

## Multi Order Coverage data structure to plan multi-messenger observations

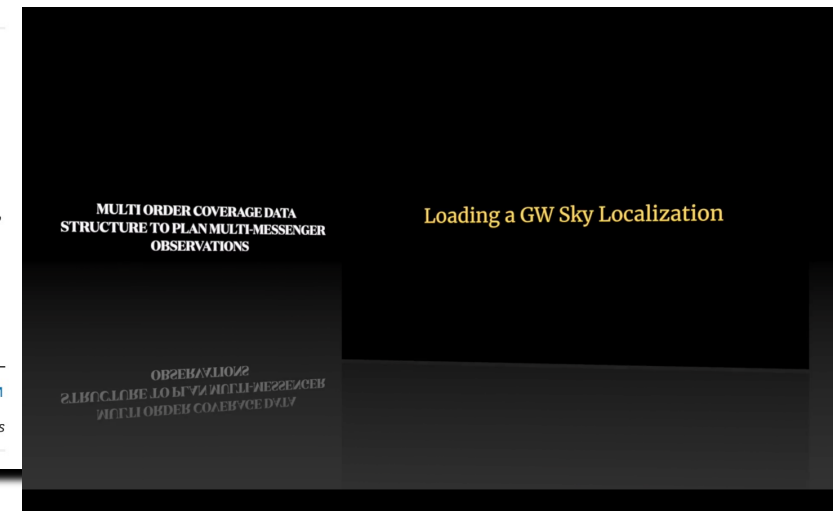
G. Greco<sup>a</sup>, M. Punturo<sup>a</sup>, M. Allen<sup>b</sup>, A. Nebot<sup>b</sup>, P. Fernique<sup>b</sup>, M. Baumann<sup>b</sup>, F.-X. Pineau<sup>b</sup>, T. Boch<sup>b</sup>, S. Derriere<sup>b</sup>, M. Branchesi<sup>c,d</sup>, M. Bawaj<sup>e,f</sup>, H. Vocca<sup>e,f</sup>

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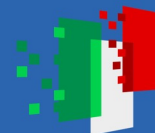
[https://virgo.pg.infn.it/multimedia/tuto\\_A\\_C\\_mid.mp4](https://virgo.pg.infn.it/multimedia/tuto_A_C_mid.mp4)



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# Aladin Lite – Application GLADEnet

<https://virgo.pg.infn.it/gladenet/catalogs/>

Numerical methods and coc

Astronomy  
&  
Astrophysics

Free Access

GLADEnet: A progressive web app for multi-messenger cosmology and electromagnetic follow-ups of gravitational-wave sources

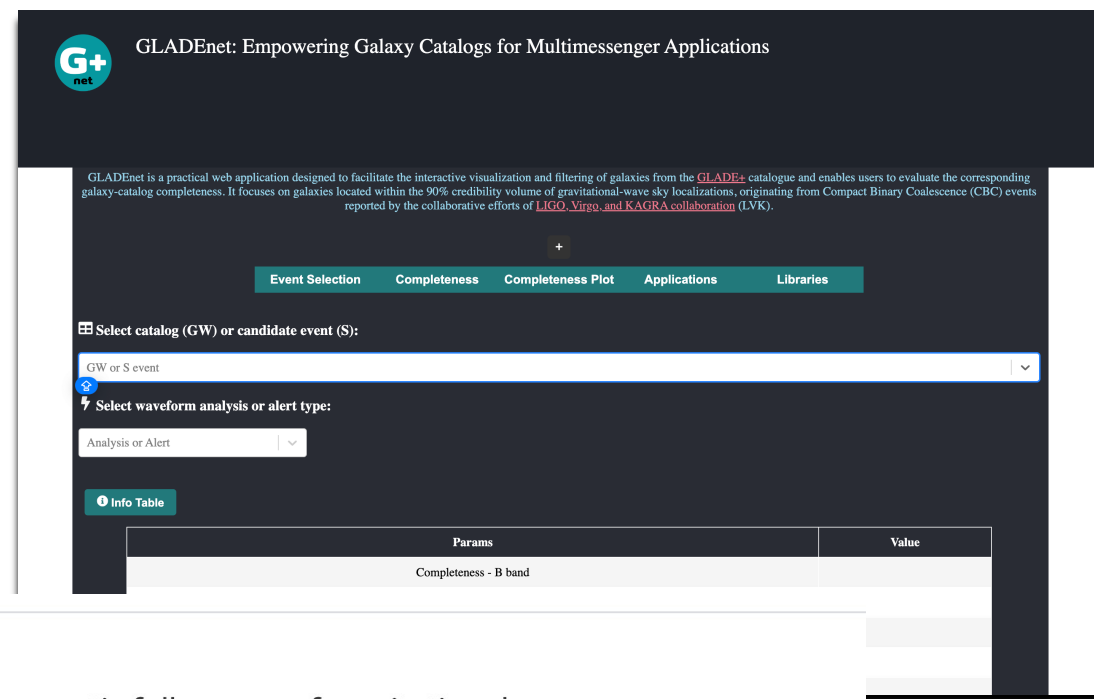
M.L. Brozzetti, G. D'alya, G. Greco, M. Bawaj, T. Matcovich, M. Branchesi, T. Boch, M. Baumann, S. Cutini, R. De Pietri, E. Khalouei, P. Fernique, M. Punturo, H. Vocca

A&A, Forthcoming article

Received: 26 September 2023 / Accepted: 09 January 2024

DOI: <https://doi.org/10.1051/0004-6361/202348073>

PDF (1.615 MB)



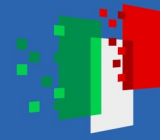




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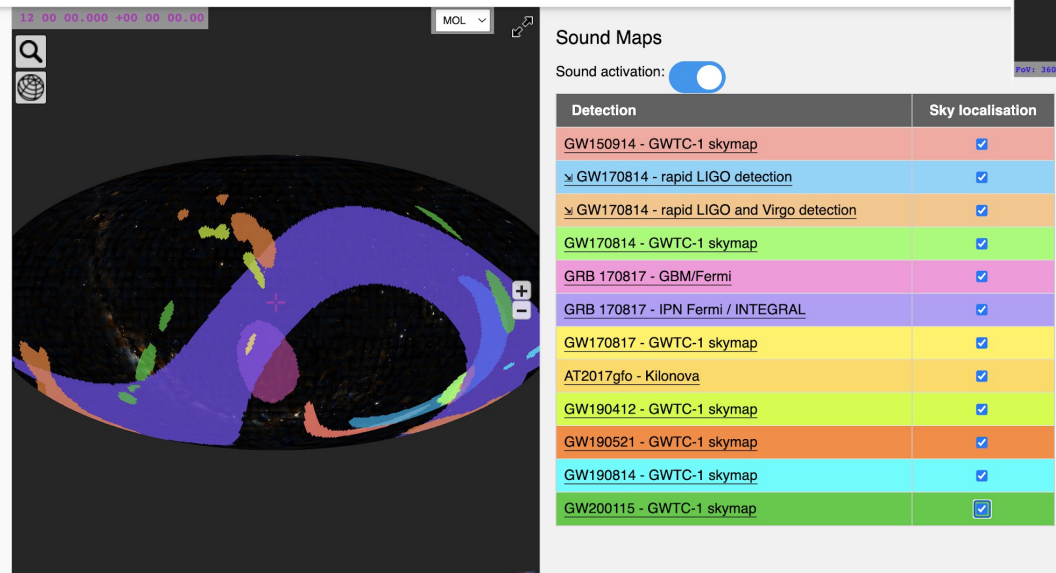


# Aladin Lite – Application SoundMap

<https://virgo.pg.infn.it/soundmap/>

← → C virgo.pg.infn.it/soundmap/

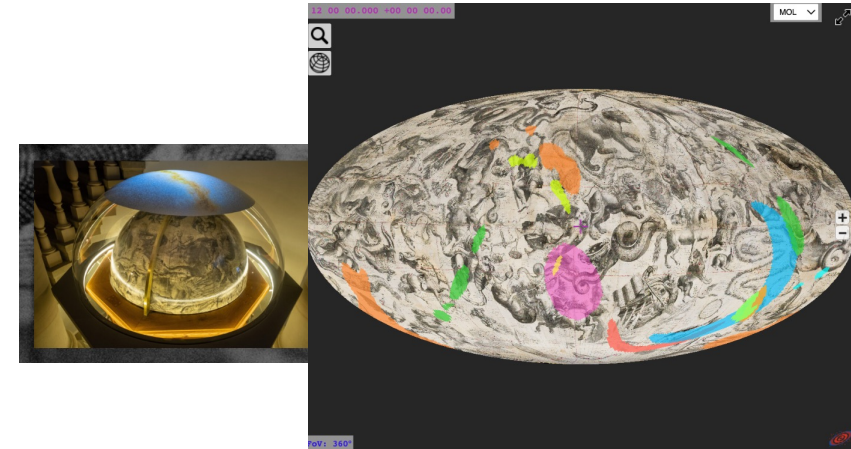
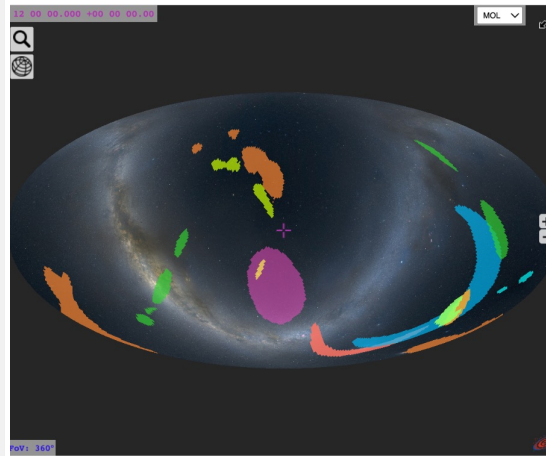
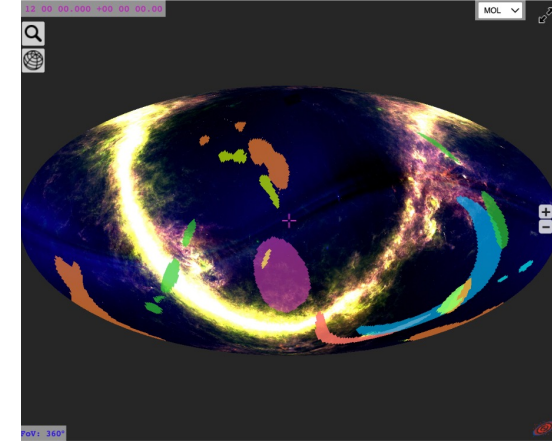
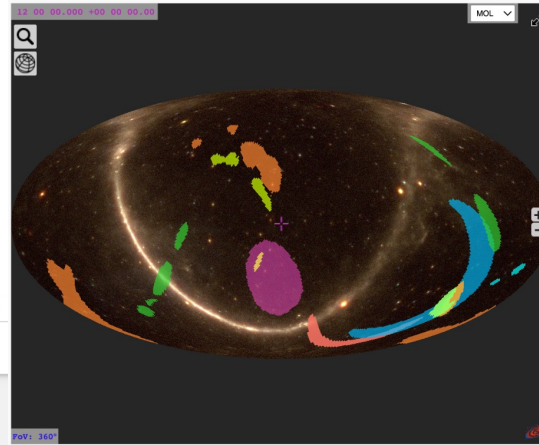
Educational Soundmap: exploring gravitational-wave transient events



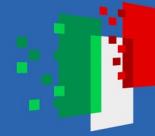
Sound Maps

Sound activation:

Detection	Sky localisation
GW150914 - GWTC-1 skymap	<input checked="" type="checkbox"/>
GW170814 - rapid LIGO detection	<input checked="" type="checkbox"/>
GW170814 - rapid LIGO and Virgo detection	<input checked="" type="checkbox"/>
GW170814 - GWTC-1 skymap	<input checked="" type="checkbox"/>
GRB 170817 - GBM/Fermi	<input checked="" type="checkbox"/>
GRB 170817 - IPN Fermi / INTEGRAL	<input checked="" type="checkbox"/>
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AT2017gfo - Kilonova	<input checked="" type="checkbox"/>
GW190412 - GWTC-1 skymap	<input checked="" type="checkbox"/>
GW190521 - GWTC-1 skymap	<input checked="" type="checkbox"/>
GW190814 - GWTC-1 skymap	<input checked="" type="checkbox"/>
GW200115 - GWTC-1 skymap	<input checked="" type="checkbox"/>



Educational and inclusive didactics



## References

- The ALADIN interactive sky atlas. A reference tool for identification of astronomical sources  
<https://ui.adsabs.harvard.edu/abs/2000A%26AS..143...33B/abstract>
- Aladin Lite v3: Behind the Scenes of a Major Overhaul  
<https://ui.adsabs.harvard.edu/abs/2022ASPC..532....7B/abstract>
- HiPS - Hierarchical Progressive Survey Version 1.0  
<https://ui.adsabs.harvard.edu/abs/2017ivoa.spec.0519F/abstract>
- Multi Order Coverage data structure to plan multi-messenger observations  
<https://www.sciencedirect.com/science/article/pii/S2213133722000026>
- MOC: Multi-Order Coverage map Version 2.0  
<https://ivoa.net/documents/MOC/>
- Working with Gravitational-Wave sky localizations: new methods and implementations  
<https://pos.sissa.it/357/031/pdf>
- Capability for Encoding Gravitational-wave Sky Localizations with the Multi Order Coverage Data Structure: Present and Future Developments  
[https://www.aspbooks.org/a/volumes/article\\_details/?paper\\_id=40522](https://www.aspbooks.org/a/volumes/article_details/?paper_id=40522)
- GLADEnet: A progressive web app for multi-messenger cosmology and electromagnetic follow-ups of gravitational-wave sources  
in press