

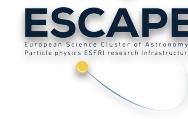
# Laboratorio di Astrofisica multimessaggera

Workshop di orientamento alle tesi nelle attività di ricerca svolte  
presso INFN e Università Perugia

Giuseppe Greco  
INFN-Perugia

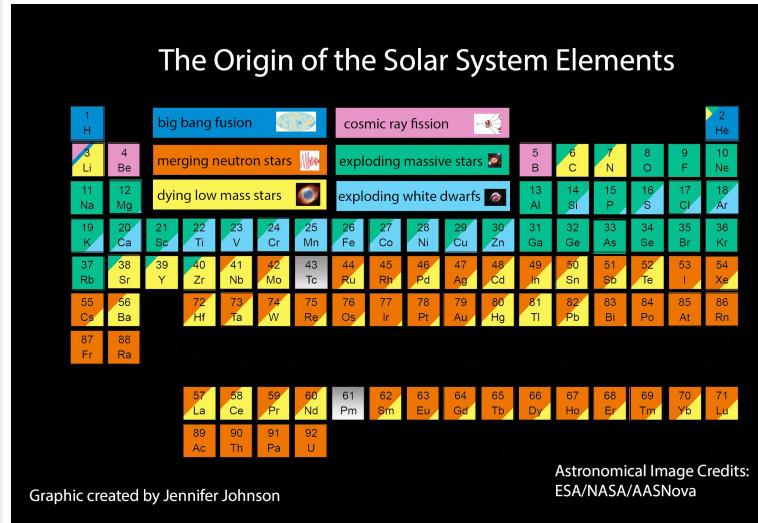
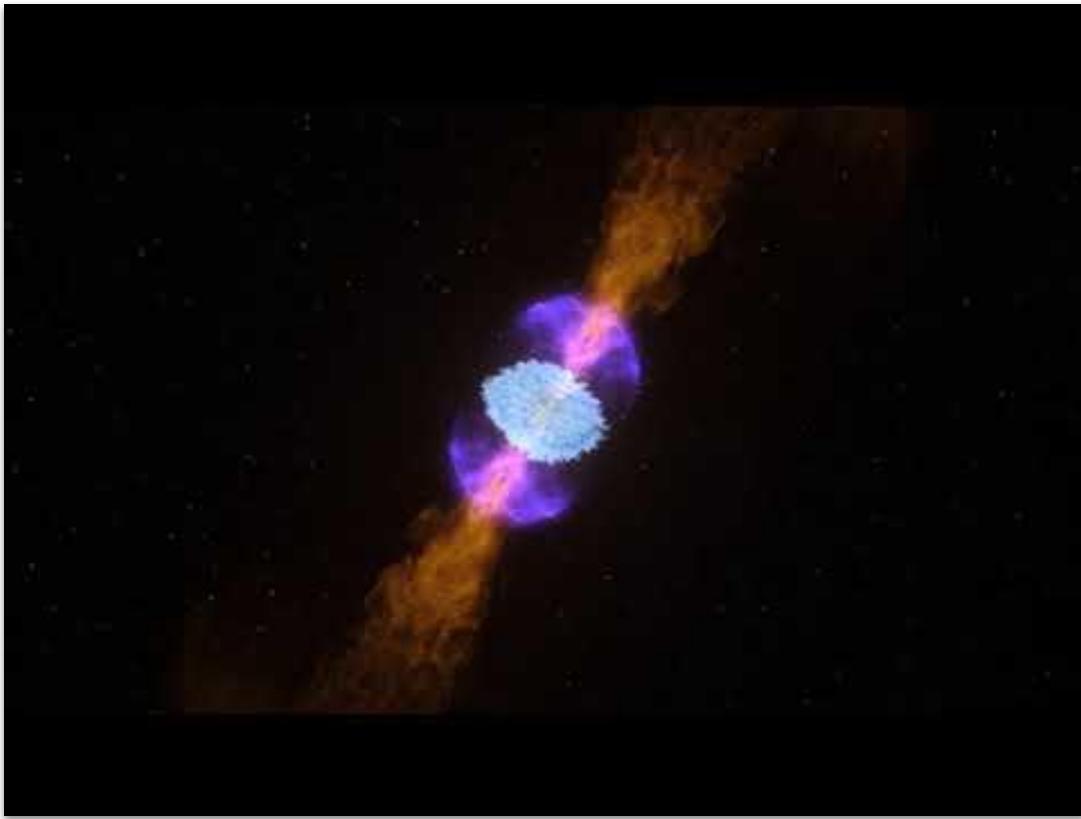


UNIVERSITÀ DEGLI STUDI  
DI PERUGIA

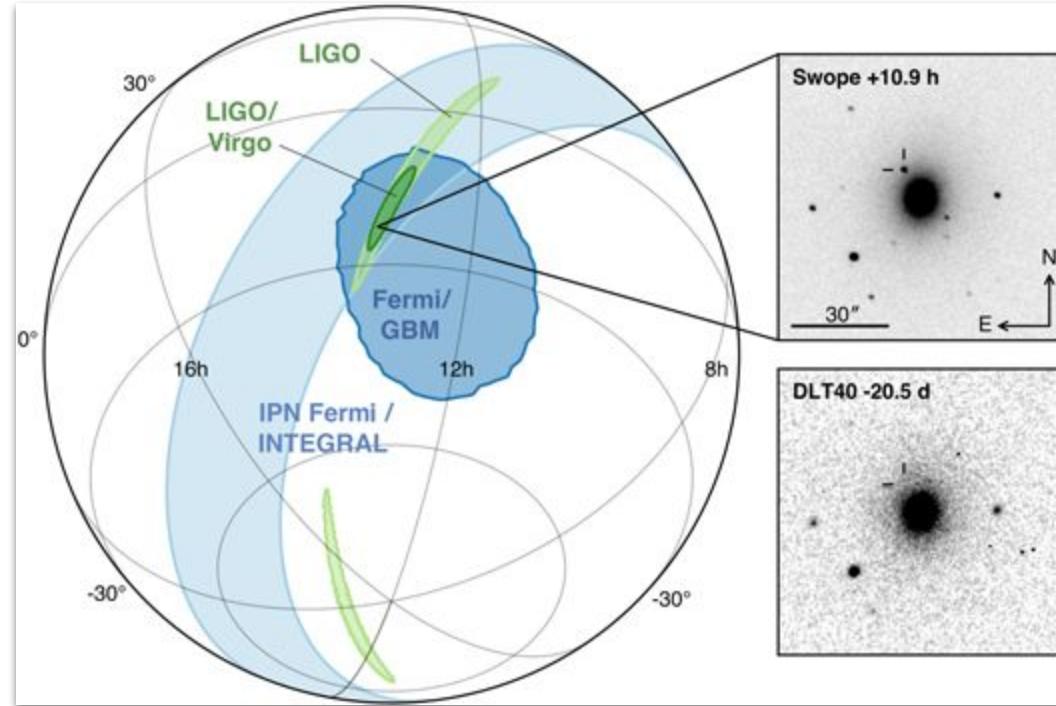


EGO || VIRGO ET EINSTEIN TELESCOPE





Animazione video di GW170817/GRB 170817/AT2017gfo

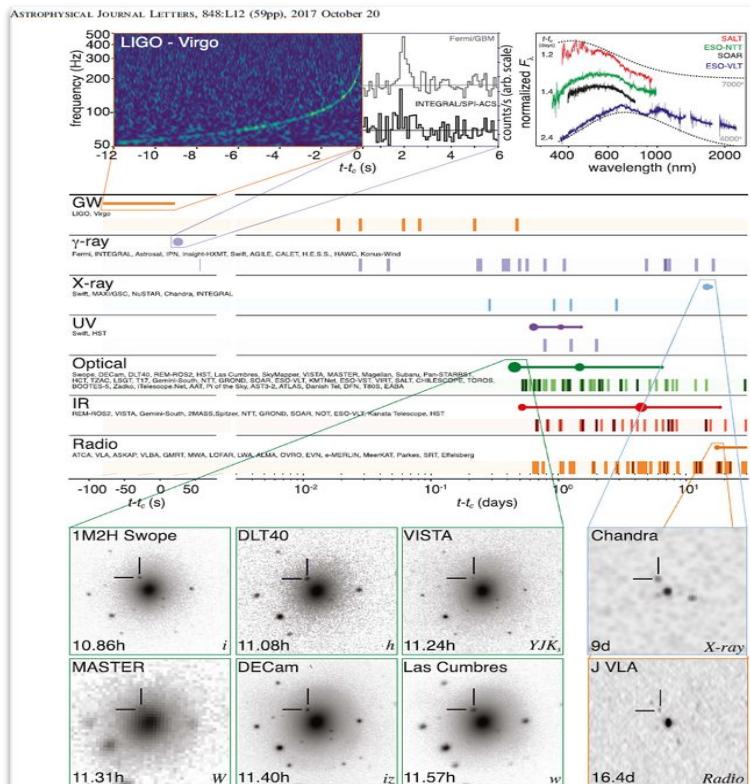


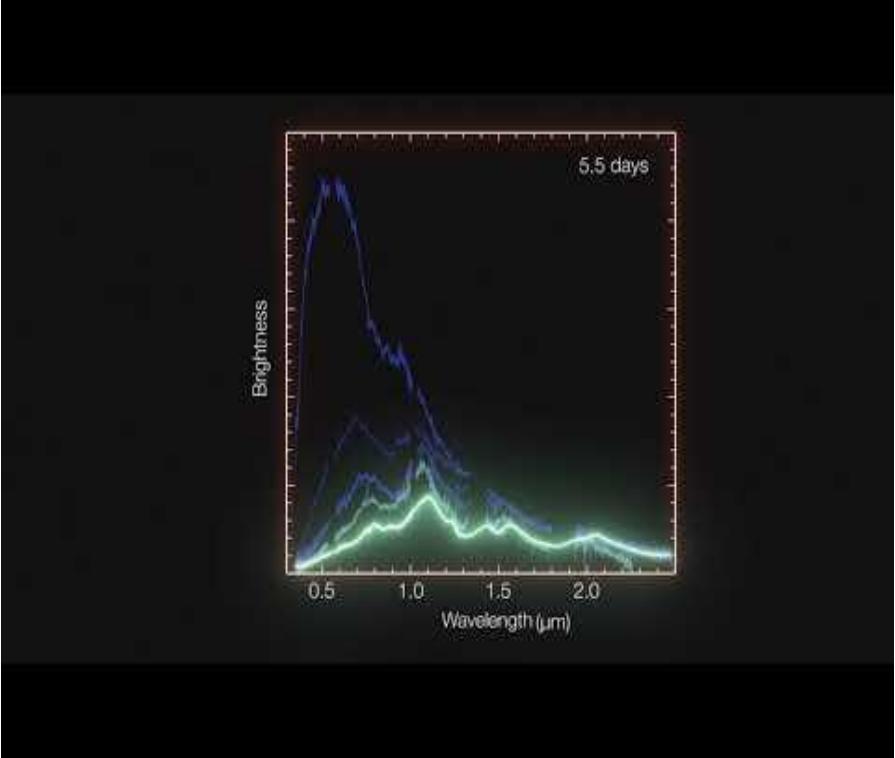
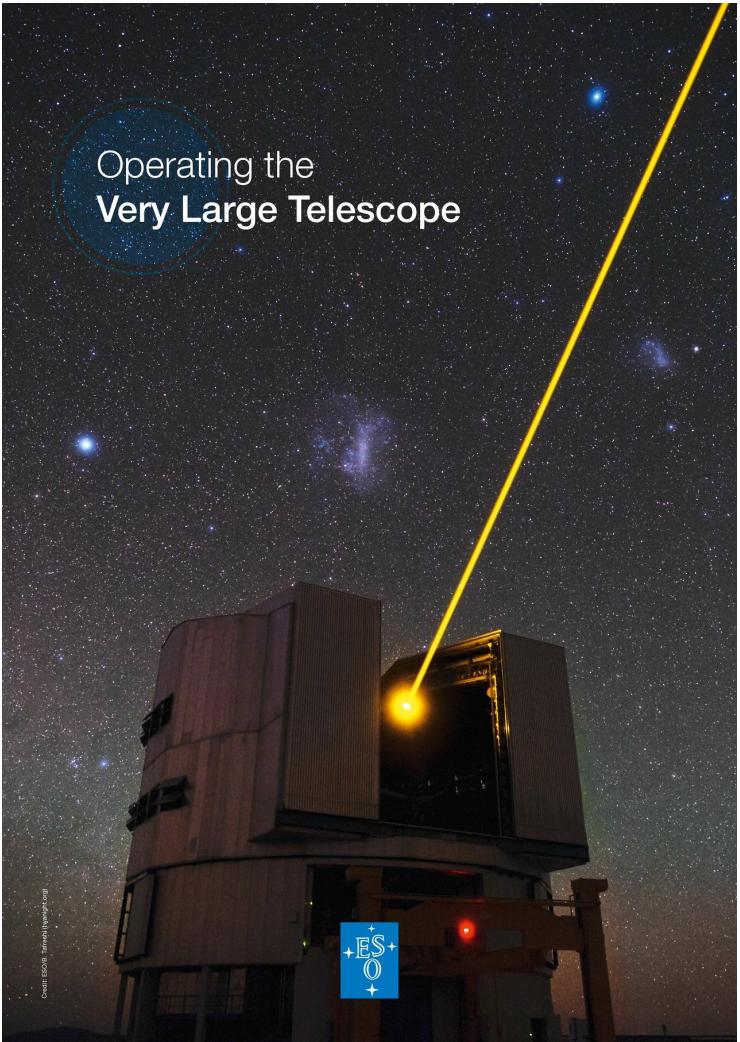
**La Nascita dell'astronomia multimessaggera!**

**GW170817/GRB170817/AT2017gfo (NGC4993)**

B. P. Abbott et al 2017 ApJL 848 L12

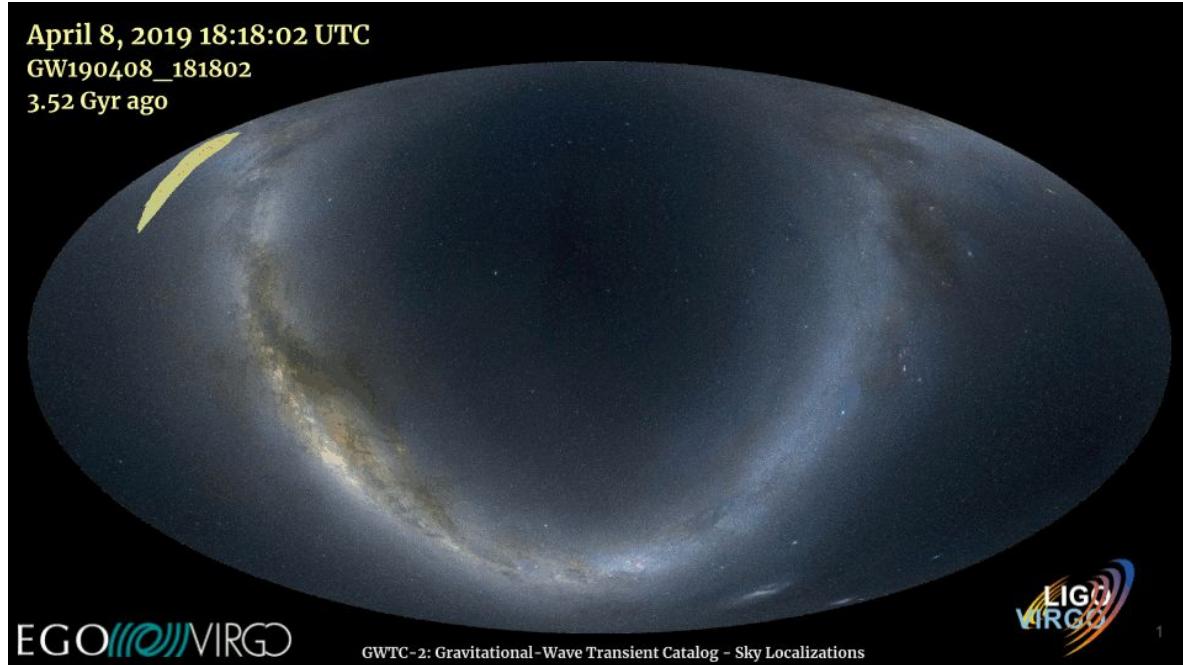
## Multi-messenger Observations of a Binary Neutron Star Merger



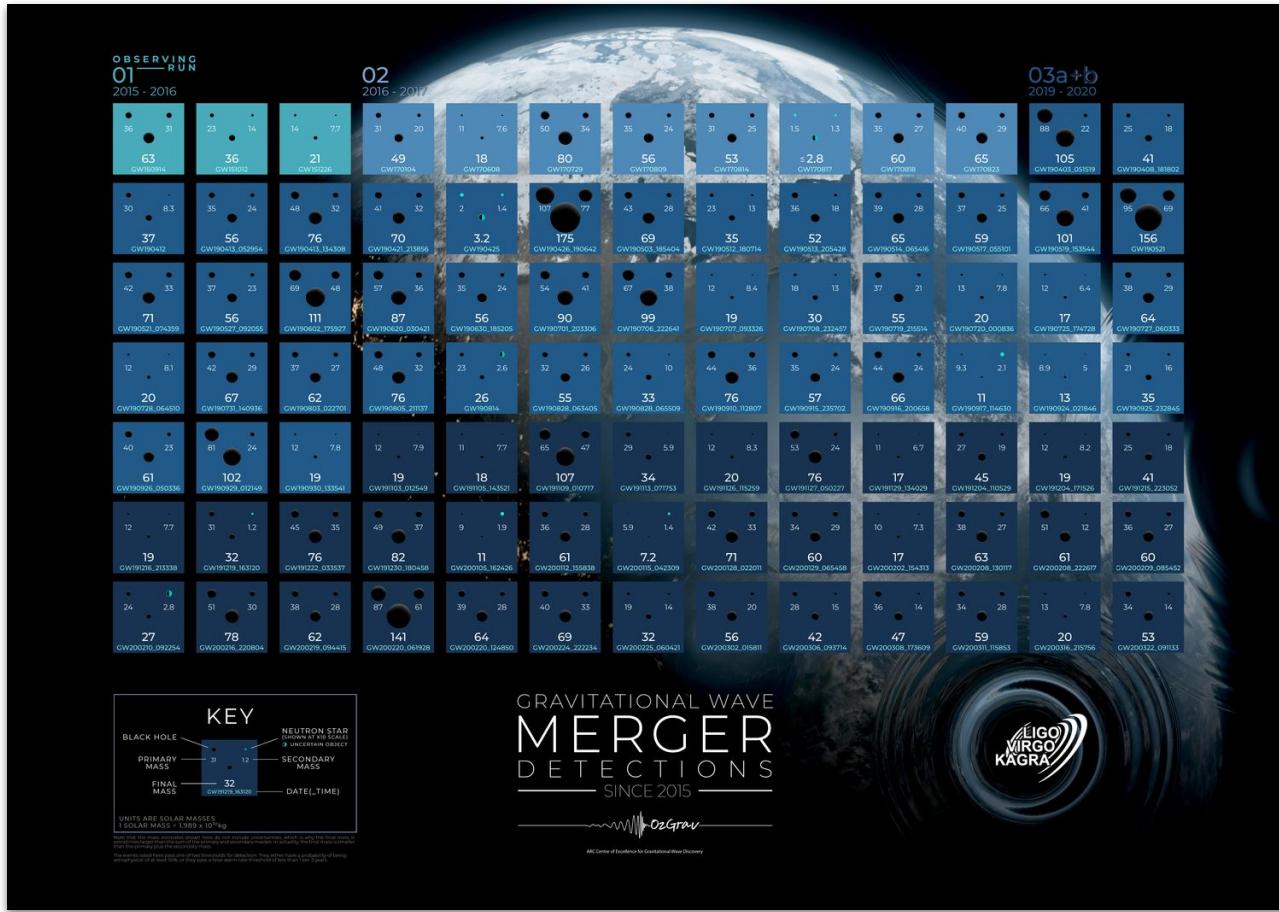


This animation is based on a series of spectra of the kilonova in NGC 4993 observed by the X-shooter instrument on ESO's Very Large Telescope in Chile. They cover a period of 12 days after the initial explosion on 17 August 2017. The kilonova is very blue initially but then brightens in the red and fades.

# Localizzazioni di sorgenti di onde gravitazionali

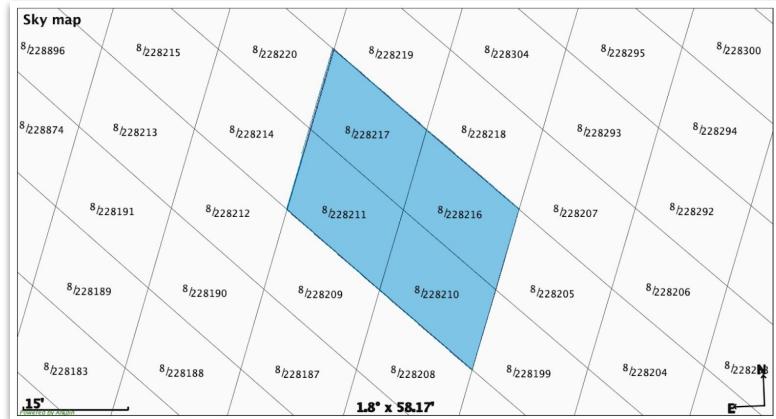
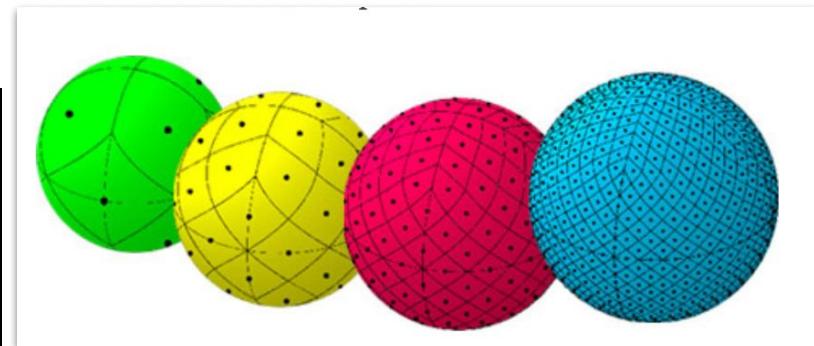
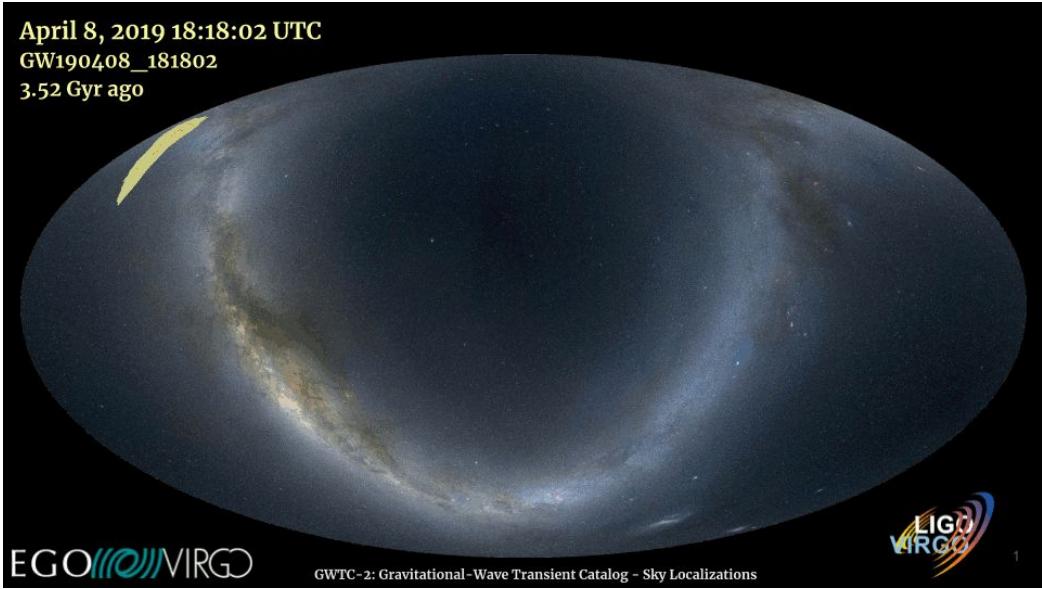


1. Come mapparle?
2. Come effettuare confronti?
3. Come interagire con i database?



## Studi sulle popolazioni e conseguenze astrofisiche

April 8, 2019 18:18:02 UTC  
GW190408\_181802  
3.52 Gyr ago



Virtual Observatory: software e librerie standard (HEALPix, MOC maps... )

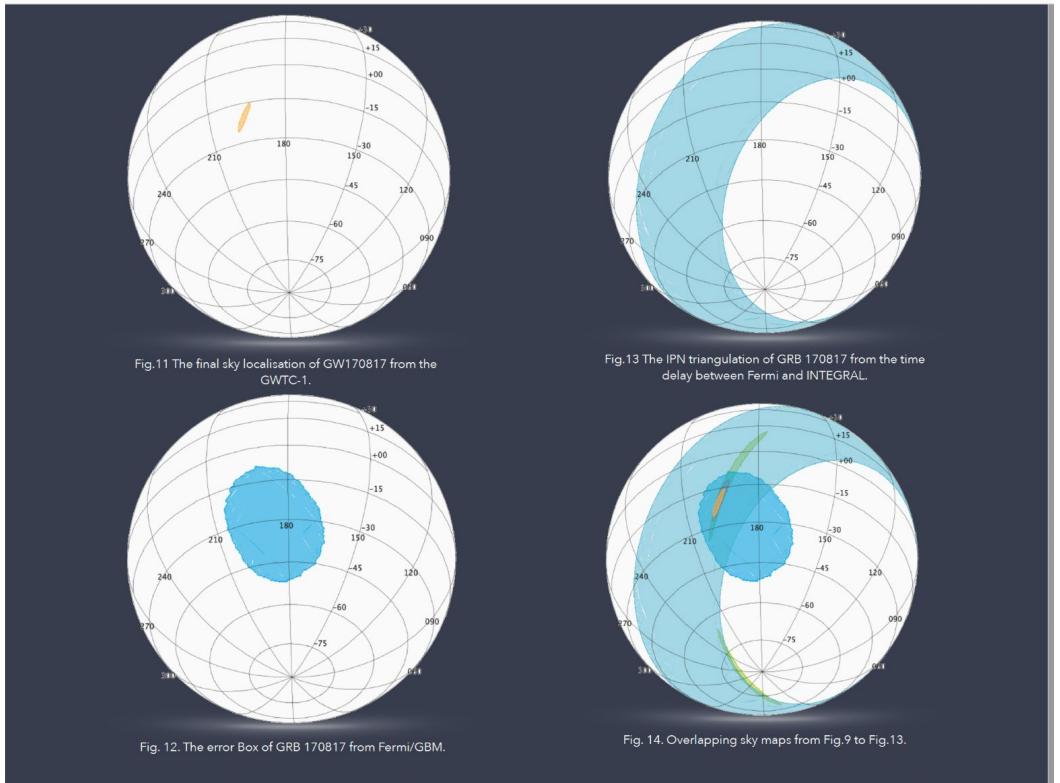
# IVOA and VO



The Virtual Observatory (VO) is a collective term referring to an ecosystem of standards and the organizations and tools which use those standards.

VO standards are defined by the International Virtual Observatory Alliance (IVOA) which is composed of nation-level organizations.

Good Ingredients to be FAIR!

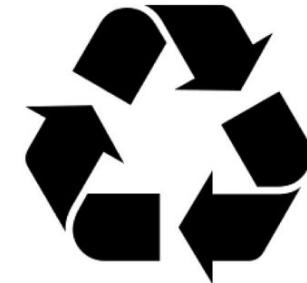
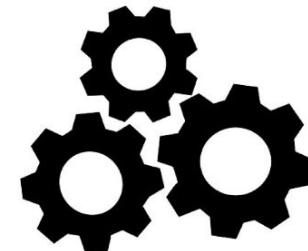


**Esercitazioni con il software Aladin, Topcat and Jupyter notebook in python**



Possibilità di tirocini e periodi di studio presso il VO dell’Osservatorio Astronomico di Strasburgo.

F indable A ccessible I nteroperable R eusable



Good Ingredients for Open Science

# La Ue dice sì al caricatore unico per tutti i dispositivi elettronici

di Bruno Ruffilli

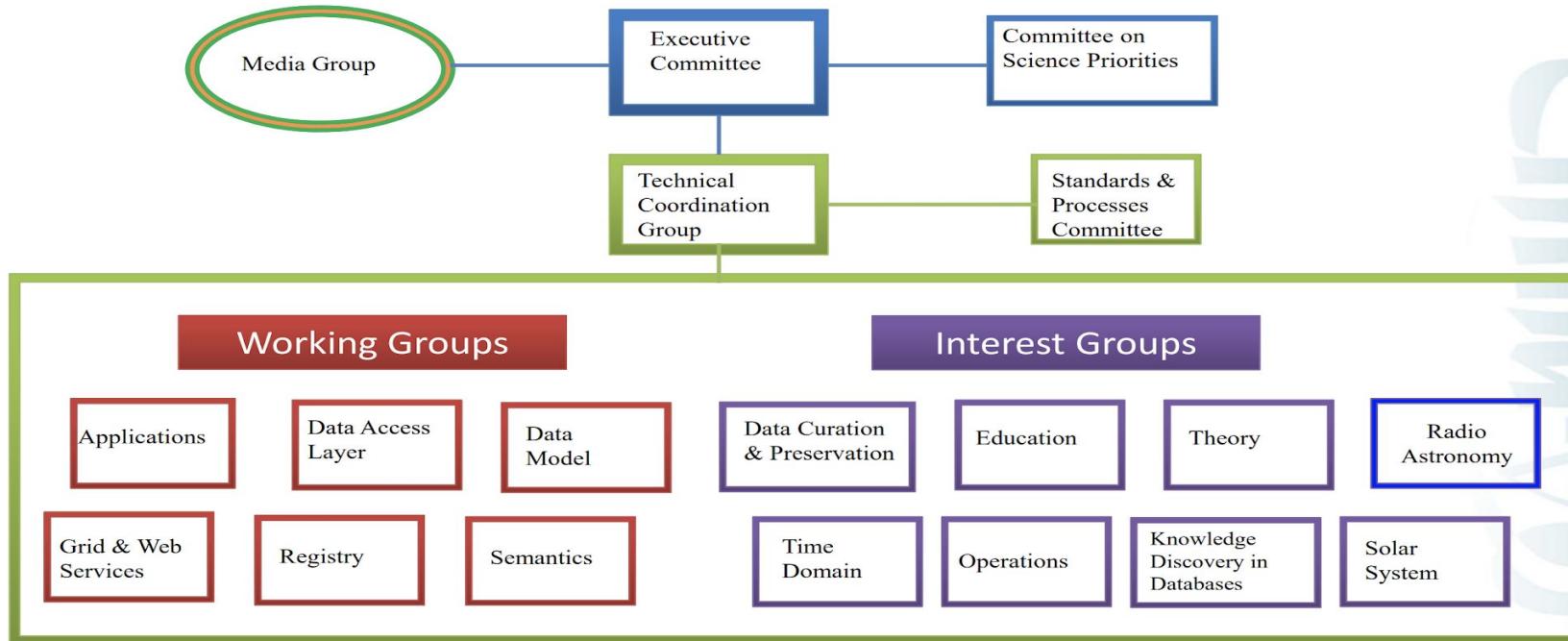


*Oggi la discussione finale all'Europarlamento: approvate le nuove norme, obbligatorie dal 2024. La situazione attuale sarà solo "un ricordo di vecchi, strani tempi di costi inutili, sprechi e disagi", per la vicepresidente della Commissione Margrethe Vestager*

04 OTTOBRE 2022 AGGIORNATO ALLE 14:20

2 MINUTI DI LETTURA

# IVOA Organization Chart





SCHOOL OF SCIENCE AND TECHNOLOGY

Bachelor's Degree in Physics (L-30)

LOCALISATION OF ELECTROMAGNETIC  
COUNTERPARTS AND GRAVITATIONAL-WAVE  
SIGNALS: A VIRTUAL OBSERVATORY PLUG-IN TO  
HANDLE 3D VOLUME RECONSTRUCTIONS

Thesis in Physics

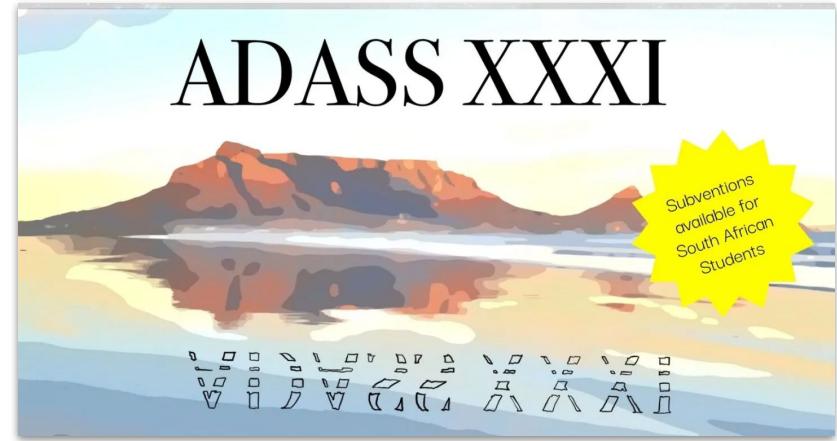
Student

Arianna Bartolomei

Supervisor

Dott. Flavio Travassos

Tesi presentata a Astronomical Data Analysis  
Software and Systems

Logos for various organizations involved in the conference: ESCAPE (European Science Cluster of Astroparticle Physics research infrastructures), INFN PERUGIA, eDS (European Data Service), UNICAM (Università di Camerino), and AHEAD 2020 HIGH ENERGY ASTROPHYSICS.

ESCAPE European Science Cluster of Astroparticle Physics research infrastructures

INFN PERUGIA

eDS

UNICAM Università di Camerino

AHEAD 2020 HIGH ENERGY ASTROPHYSICS

**LOCALIZATION OF EM COUNTERPARTS AND GW SIGNALS: A NEW PYTHON PLUG-IN FOR ALADIN**

Arianna Bartolomei<sup>1</sup>, Elisa Cartechini<sup>1</sup>, Giuseppe Greco<sup>2,3</sup>, Flavio Travassos<sup>1,3</sup>, Mateusz Bawa<sup>2,3</sup>

<sup>1</sup>University of Camerino; <sup>2</sup>University of Perugia; <sup>3</sup>INFN Perugia

**Abstract**

We describe a new plug-in for Aladin Desktop to analyze 3D sky maps of gravitational-wave sources. Aladin is the most used VO (Virtual Observatory) software for digitized astronomical images and

Tesi triennale: plugin per Aladin Desktop



Università degli Studi di Perugia

DEPARTMENT OF PHYSICS AND GEOLOGY

MASTER THESIS IN PHYSICS

CURRICULUM OF ASTROPHYSICS AND ASTROPARTICLES

## Evaluating catalogues completeness extending the *Virtual Observatory* framework to estimate the $H_0$ Hubble constant with *dark standard sirens*

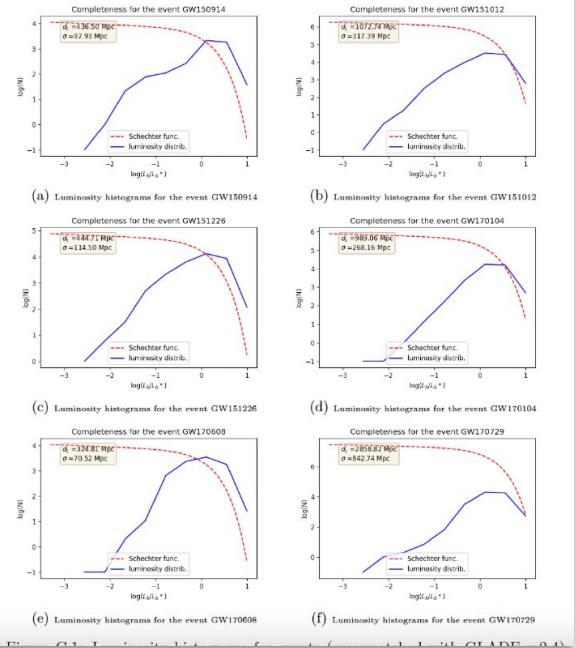
SUPERVISOR

PROF. MATEUSZ BAWAJ

UNIVERSITÀ DEGLI STUDI DI PERUGIA

MASTER CANDIDATE

MARIA LISA BROZZETTI



# Tesi magistrale: cosmologia con le onde gravitazionali



# LIGO-VIRGO-KAGRA COLLABORATION MEETING

MARCH 2023 | EVANSTON, IL

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PARTICIPANT GUIDE

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## ACCOMMODATIONS

TRAVEL IN

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## ABOUT CIERA AND NORTHWESTERN

## **ABOUT CIERA AND NORTHWESTERN**



!0230316-....jpg

8

**et al.: A Progressive Web App for Multi-messenger Cosmology**

Zoletti<sup>1,2</sup>, G. D'Alù<sup>3</sup>, G. Greco<sup>3</sup>, M. Bavaj<sup>1,3</sup>, M. Punturo<sup>4</sup>, H. Voccai<sup>1,3</sup>

<sup>1</sup>di Perugia, Perugia, Italy  
<sup>2</sup>9-9006 Ghent, Belgium  
<sup>3</sup>Institute for Nuclear Physics | Perugia Unit, J-06123 Perugia, Italy

**The Completeness Coefficient**

The completeness of the catalog in the 3D comoving volume of GRB events is determined by the ratio between the number of GRBs found in the catalog and the credible volume  $W \Delta V$ , using the comoving function  $\chi$  with the density value obtained from the integral of the Schechter function in the same volume:

$$\eta = \frac{N_{\text{GRB}}}{W \int_{\chi} \chi^2 \phi(\chi) d\chi}$$

Moreover, the use of the full depth  $\Delta V$  instead of the events of the 10-12 GRB observational runs, reduced in the GRBC catalog. The  $\eta$  values for each event are recorded and used to fit the underlying distribution of the completeness of the catalog.

**inosity Function of the GLACIE+ catalog**

The inosity properties of the GLACIE+ catalog [1] define the function that link the galaxies in it, and reducing the three parameters of the Schechter Function.

Burst sources try to include quasars, and their effect is subtracted three times. The galaxy density distribution can be calculated using the Catalogue (EMC) step with redshift ranges. The effect of the presence of dust and reddened material is addressed, reducing the related to the whole information of the catalog. The inosity function is the ratio of the total luminosity of the catalog to the northern point source histograms, measured in the range of 50 Mpc to 100 Mpc. The broadening function in different redshift bins ( $1 < z < 1.5$ ,  $1.5 < z < 2$ ,  $2 < z < 3$ ,  $3 < z < 4$ ,  $4 < z < 5$ ,  $5 < z < 6$ ,  $6 < z < 7$ ,  $7 < z < 8$ ,  $8 < z < 9$ ,  $9 < z < 10$ ,  $10 < z < 11$ ,  $11 < z < 12$ ,  $12 < z < 13$ ,  $13 < z < 14$ ,  $14 < z < 15$ ,  $15 < z < 16$ ,  $16 < z < 17$ ,  $17 < z < 18$ ,  $18 < z < 19$ ,  $19 < z < 20$ ,  $20 < z < 21$ ,  $21 < z < 22$ ,  $22 < z < 23$ ,  $23 < z < 24$ ,  $24 < z < 25$ ,  $25 < z < 26$ ,  $26 < z < 27$ ,  $27 < z < 28$ ,  $28 < z < 29$ ,  $29 < z < 30$ ,  $30 < z < 31$ ,  $31 < z < 32$ ,  $32 < z < 33$ ,  $33 < z < 34$ ,  $34 < z < 35$ ,  $35 < z < 36$ ,  $36 < z < 37$ ,  $37 < z < 38$ ,  $38 < z < 39$ ,  $39 < z < 40$ ,  $40 < z < 41$ ,  $41 < z < 42$ ,  $42 < z < 43$ ,  $43 < z < 44$ ,  $44 < z < 45$ ,  $45 < z < 46$ ,  $46 < z < 47$ ,  $47 < z < 48$ ,  $48 < z < 49$ ,  $49 < z < 50$ ,  $50 < z < 51$ ,  $51 < z < 52$ ,  $52 < z < 53$ ,  $53 < z < 54$ ,  $54 < z < 55$ ,  $55 < z < 56$ ,  $56 < z < 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# GLADEnet: Catalog Service



About

## Select Event

GW Event



## Select Analysis

Analisy



- Completeness [0-1]:

- Number of possible host galaxies:

# Spatial and Temporal MOC: ST-MOC

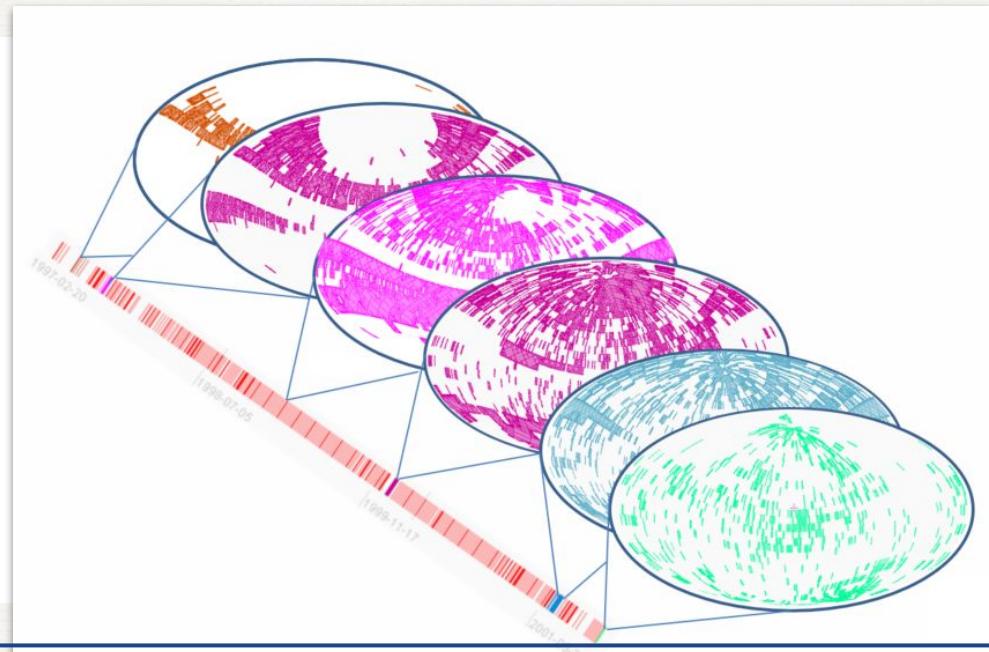


*International  
Virtual  
Observatory  
Alliance*

MOC: Multi-Order Coverage map

Version 2.0

IVOA Working Draft 2020-10-30



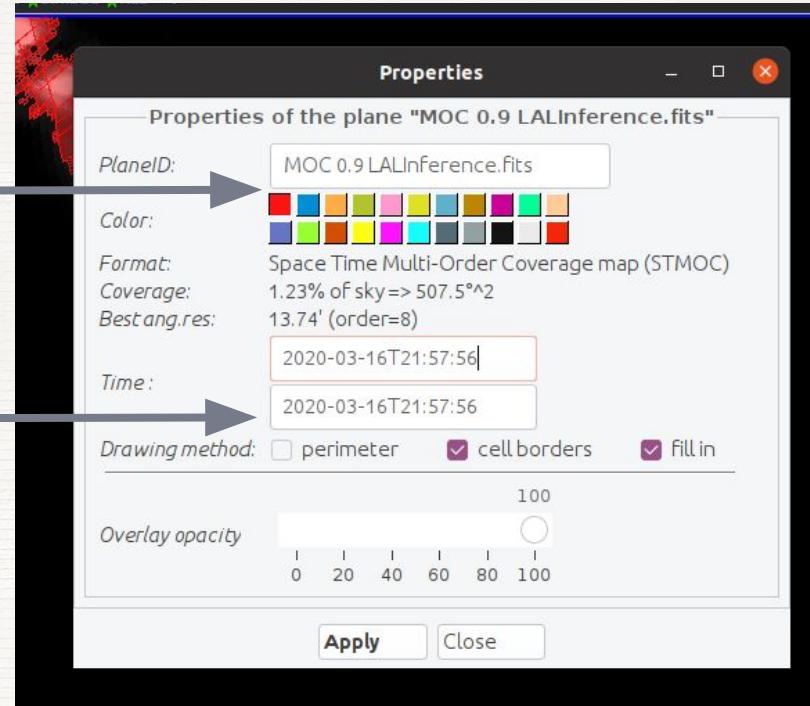
At a given Time range we obtain the corresponding Spatial coverage.

# GW credible regions in Space and in Time

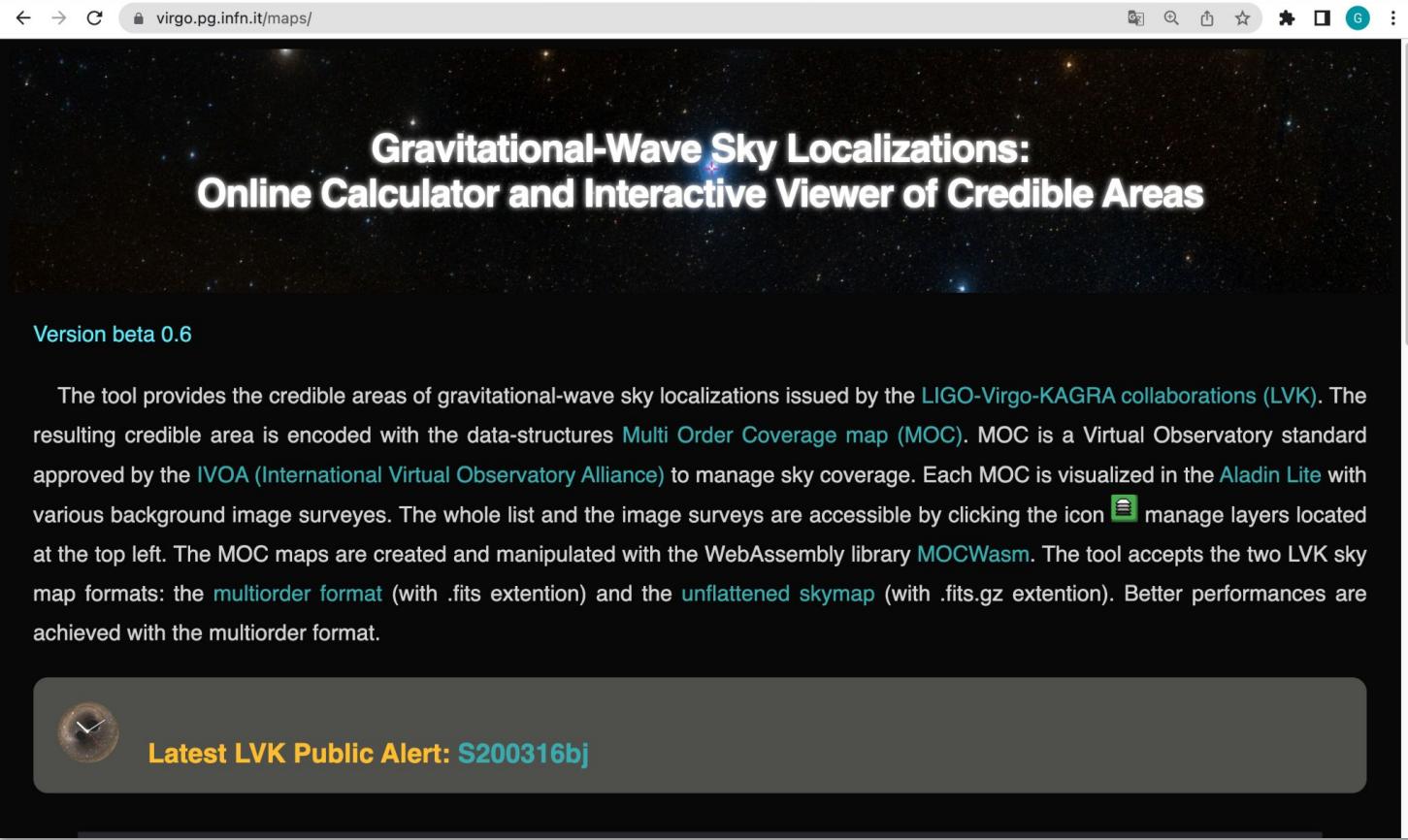
In **PlaneID** a credible region is selected.

In **Time** the merger time is added.

To search for any electromagnetic emissions before or after the compact binary coalescence, the time values can be modified accordingly producing a new ST-MOC.



Generation of a ST-MOC from a gravitational-wave sky localization using Aladin Desktop (beta version).

A screenshot of a web browser window showing the "Gravitational-Wave Sky Localizations" website. The URL in the address bar is "virgo.pg.infn.it/maps/". The page title is "Gravitational-Wave Sky Localizations: Online Calculator and Interactive Viewer of Credible Areas". Below the title, it says "Version beta 0.6". The main text describes the tool as providing credible areas of gravitational-wave sky localizations issued by the LIGO-Virgo-KAGRA collaborations (LVK). It uses Multi Order Coverage map (MOC) data, which is a Virtual Observatory standard approved by the IVOA (International Virtual Observatory Alliance). The MOC maps are visualized in Aladin Lite with various background image surveys. The tool uses the MOCWasm library and supports LVK sky map formats: multiorder format (.fits extension) and unflattened skymap (.fits.gz extension). Better performances are achieved with the multiorder format. A dark grey banner at the bottom left displays a clock icon and the text "Latest LVK Public Alert: S200316bj".

Gravitational-Wave Sky Localizations:  
Online Calculator and Interactive Viewer of Credible Areas

Version beta 0.6

The tool provides the credible areas of gravitational-wave sky localizations issued by the [LIGO-Virgo-KAGRA collaborations \(LVK\)](#). The resulting credible area is encoded with the data-structures [Multi Order Coverage map \(MOC\)](#). MOC is a Virtual Observatory standard approved by the [IVOA \(International Virtual Observatory Alliance\)](#) to manage sky coverage. Each MOC is visualized in the [Aladin Lite](#) with various background image surveyes. The whole list and the image surveys are accessible by clicking the icon  manage layers located at the top left. The MOC maps are created and manipulated with the WebAssembly library [MOCWasm](#). The tool accepts the two LVK sky map formats: the [multiorder format](#) (with .fits extention) and the [unflattened skymap](#) (with .fits.gz extention). Better performances are achieved with the multiorder format.

 Latest LVK Public Alert: [S200316bj](#)

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

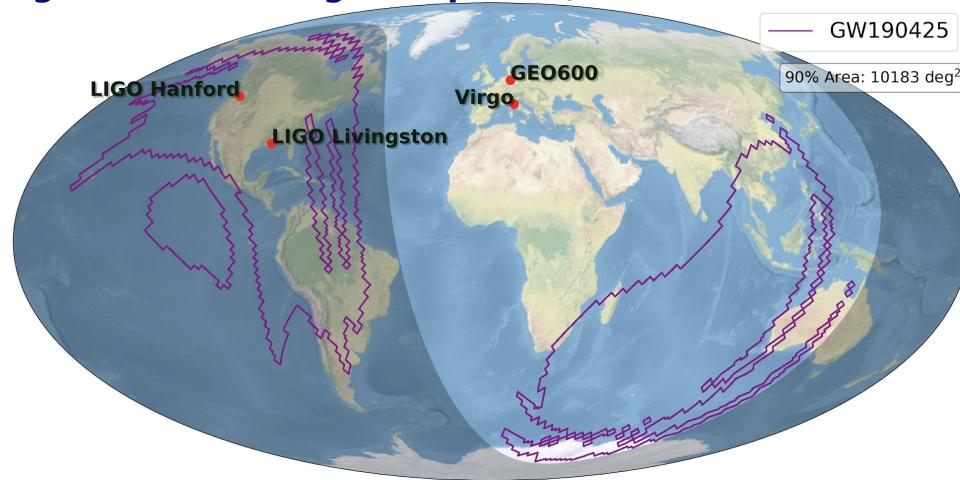
# A practical example: an ideal observation campaign

## Multi-messenger team:

1. Haleakala Observatories in Hawaii, USA
2. Paranal Observatory in Chile
3. Siding Spring Observatory (SSO) in Australia

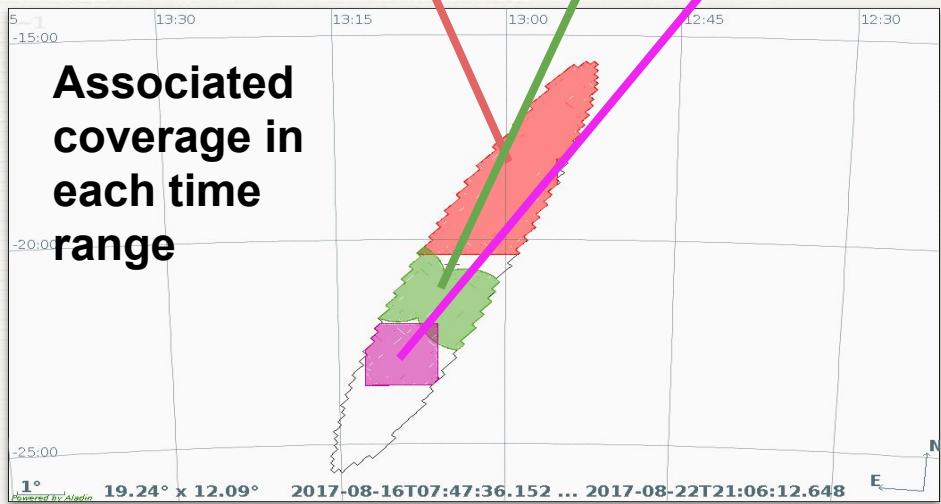
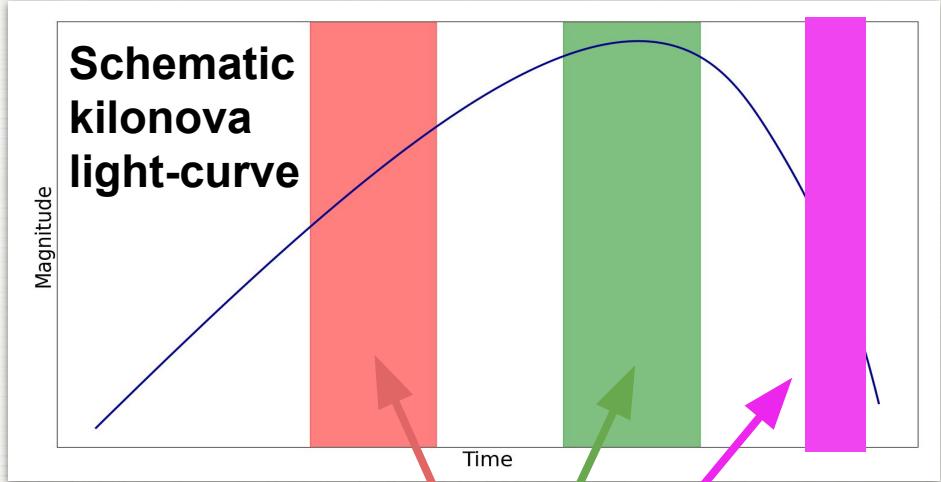
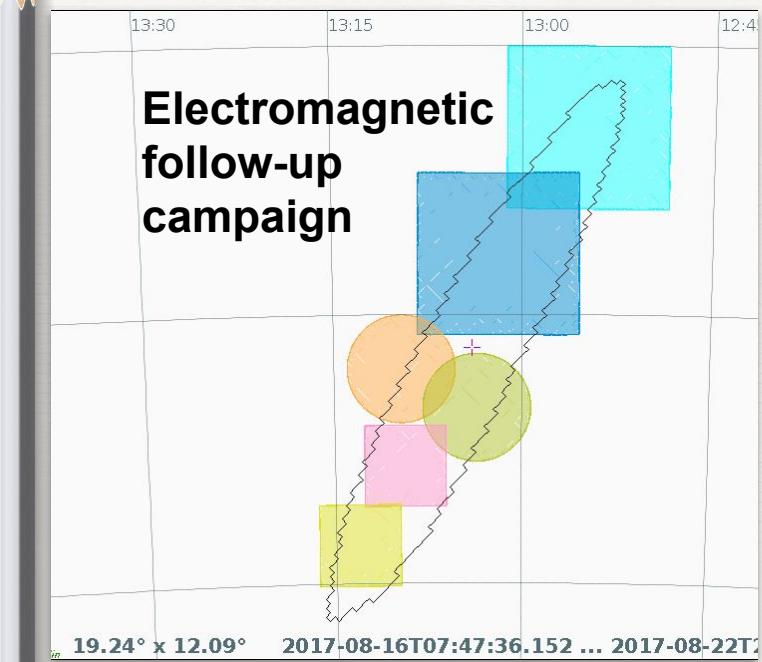
With **astroplan** we define three **Observer** classes. Observer is an astroplan container class for information about an observer's site

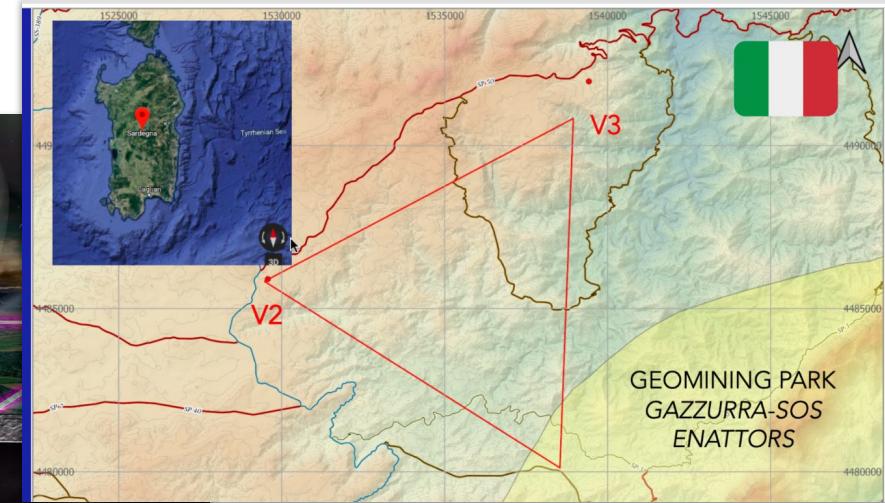
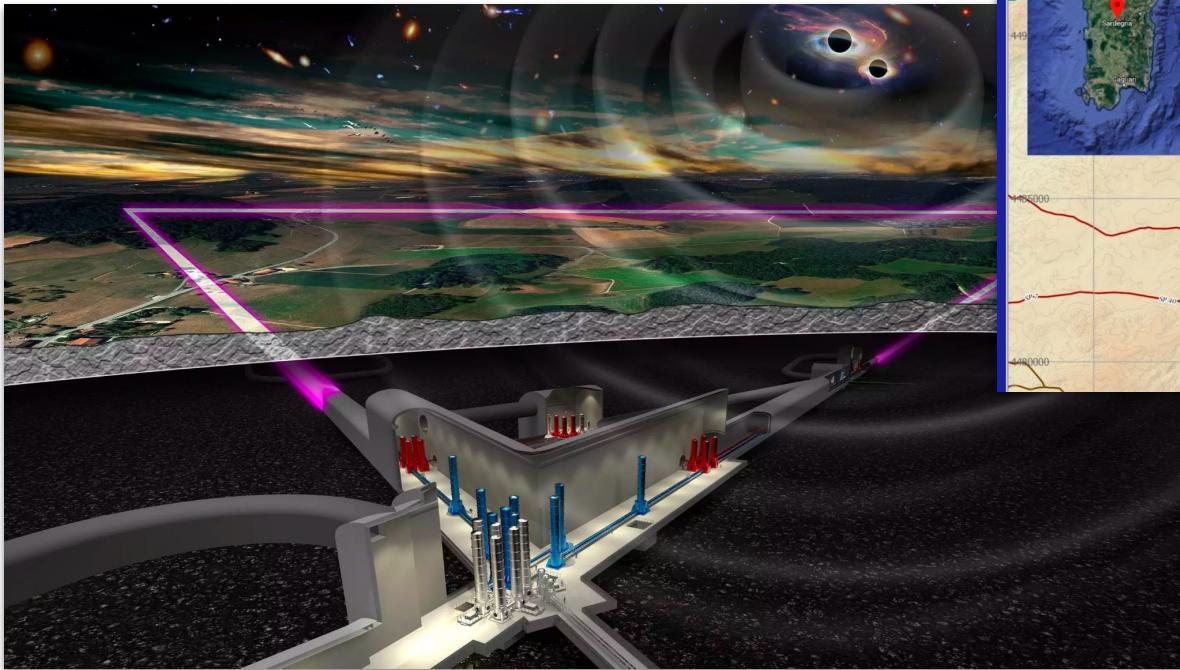
Night time shading for April 25, 2019 at 08:18:05 UTC



**Observation of GW190425.** The signal has been observed on 2019 April 25, 08:18:05 UTC, during the third observing run (O3) of the LIGO-Virgo network. The network consists of two Advanced LIGO interferometers in Hanford, Washington, USA (LHO) and Livingston, Louisiana, USA (LLO) and the Advanced Virgo interferometer in Cascina, Italy. At the time of GW190425, LHO was temporarily offline with only LLO and Virgo taking data.

# ST-MOC application: EM-followUP





**Italia candidata ad ospitare ET**

## Einstein Telescope Observatory

**Tesi sull'astrofisica multimessaggera con ET e sulla gestione del sistema di invio di allerte.**