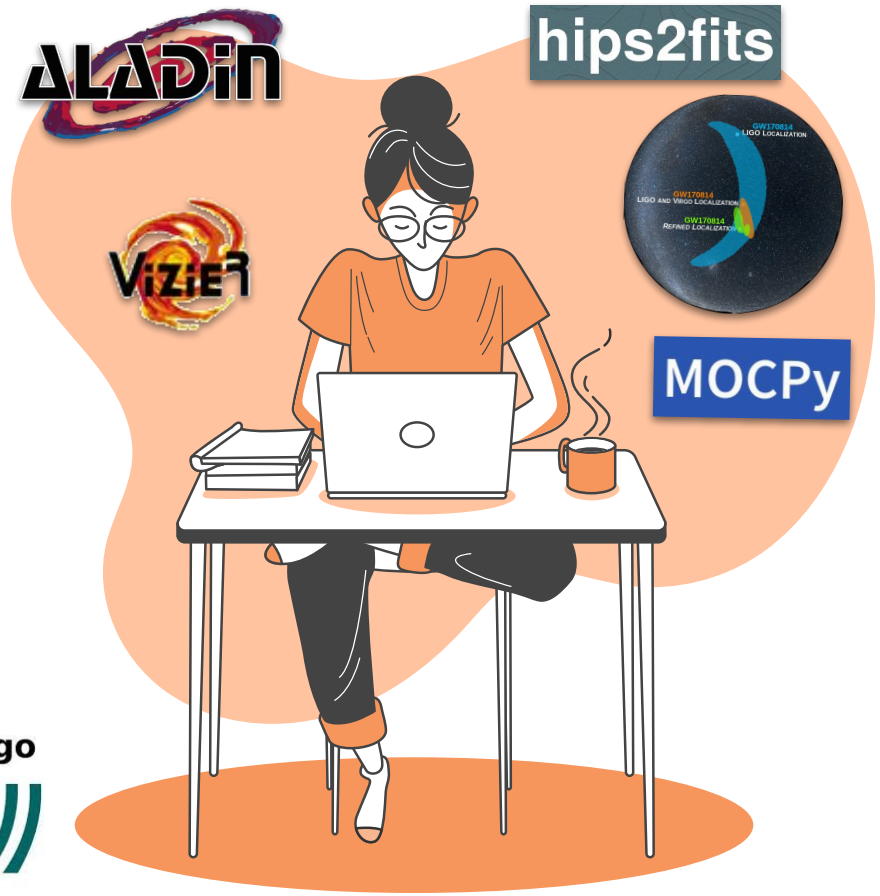
Practical Tools and methods supported by ESCAPE for gravitational-wave localisations

Giuseppe Greco
ESCAPE/CEVO



ESCAPE
European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

EGO - Virgo

Contents

1. OPA ERA

Overview of the O3 LIGO/Virgo run

2. Aladin

Multi-messenger with GW

3. Edu Activity

REINFORCE
REsearch INFrastructures FOR Citizens in Europe

Aladin Lite, Sonification,
3D images, GIF, VR

4. GWsky

Tiling using SAMP protocol

5. MOCpy

Intereperability with *ligo.skymap*

6. Multiorder

Developed by L. Singer
Support new format in O4

GraceDB and Open Public Alerts

GraceDB — Gravitational-Wave Candidate Event Database

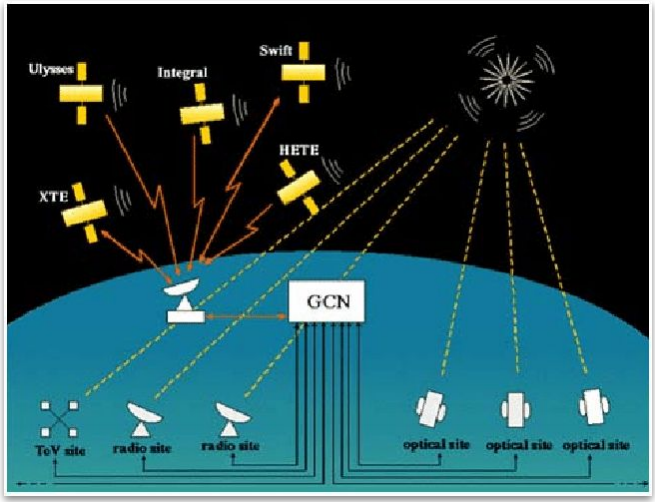
HOME | PUBLIC ALERTS | SEARCH | LATEST | DOCUMENTATION

LIGO/Virgo O3 Public Alerts

Detection candidates: 48

SORT: EVENT ID (A-Z)

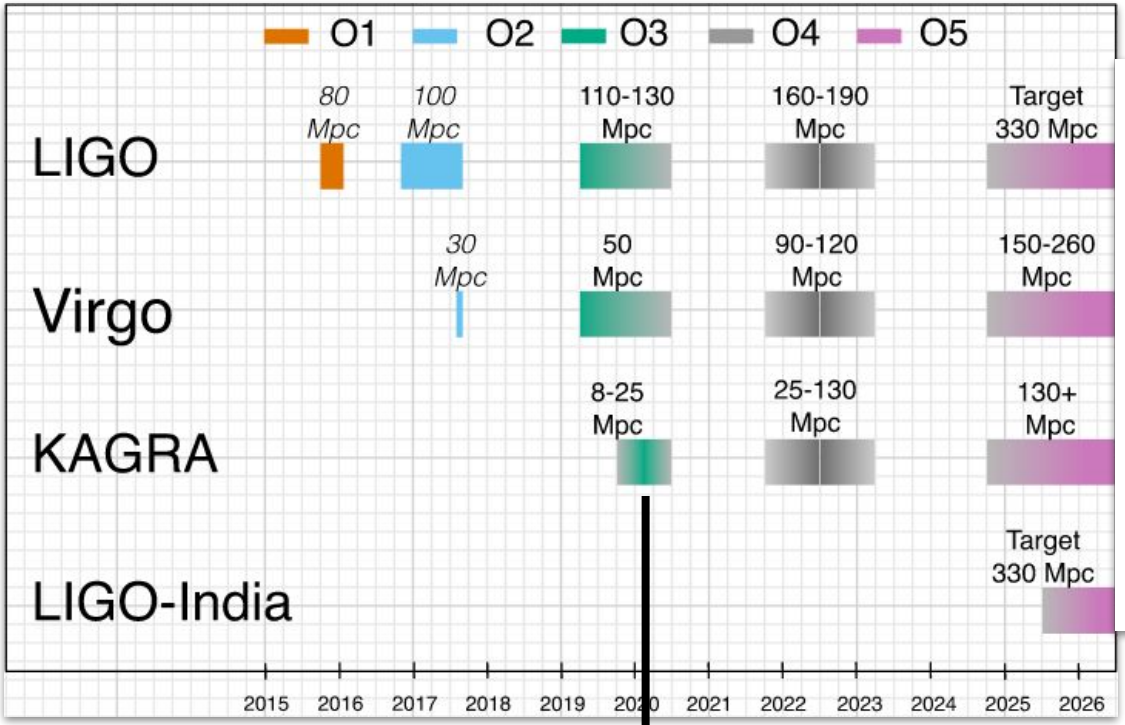
Event ID	Possible Source (Probability)	UTC	GCN	Location
S200129m	BBH (>99%)	Jan. 29, 2020 06:54:58 UTC	GCN Circulars Notices | VOE	

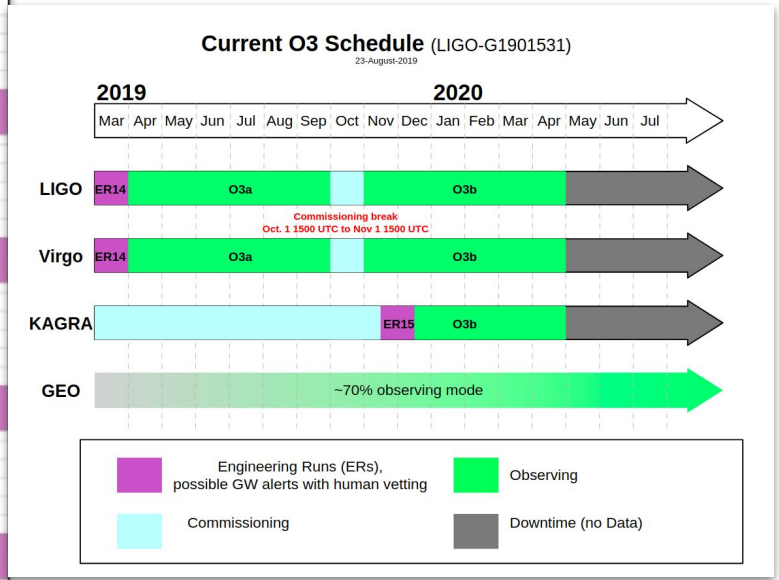


https://gracedb.ligo.org/

- GraceDB, LIGO/Virgo's online portal for alerts and real-time results.
- The Open Public Alerts are distributed through NASA Gamma-ray Coordinates Network (GCN).

TIMELINE


O1
O2
O3
O4
O5
LIGO
80 Mpc
100 Mpc
110-130 Mpc
160-190 Mpc
Target 330 Mpc
Virgo
30 Mpc
50 Mpc
90-120 Mpc
150-260 Mpc
KAGRA
8-25 Mpc
25-130 Mpc
130+ Mpc
LIGO-India
Target 330 Mpc
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026


Current O3 Schedule (LIGO-G1901531)
23-August-2019
2019
2020
Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
LIGO
ER14
O3a
O3b
Commissioning break
Oct. 1 1500 UTC to Nov 1 1500 UTC
Virgo
ER14
O3a
O3b
KAGRA
ER15
O3b
GEO
~70% observing mode
Engineering Runs (ERs), possible GW alerts with human vetting
Observing
Commissioning
Downtime (no Data)

LIGO and Virgo Public Alert User Guide

Welcome to the LIGO/Virgo Public Alerts User Guide! This document is intended for both professional astronomers and science enthusiasts who are interested in receiving alerts and real-time data products related to gravitational-wave (GW) events.

LIGO Scientific Collaboration

VIRGO

Public Alerts

User Guide

Primer on public alerts for astronomers from the LIGO and Virgo gravitational-wave observatories.

Navigation

- Getting Started Checklist
- Observing Capabilities
- Data Analysis
- Alert Contents
- Sample Code
- Additional Resources
  - ligo.skymap: Advanced Python Tools for Probability Sky Maps

← ligo.skymap: Advanced Python Tools for Probability Sky Maps | Mobile Apps →

Sky Map Visualizations and Credible Regions in Aladin

In this section, we demonstrate working with gravitational-wave sky localizations in Aladin Desktop. The following main topics are addressed.

- MOC and GW Sky Localizations
- Running Aladin Desktop
- Loading a GW Sky Localization
- Building a Credible Region
- Area Within a Credible Region
- Querying and Filtering a Galaxy Catalog
- Thumbnail View Generator

MOC and GW Sky Localizations

The enclosed area within a given probability level contour of a GW sky map can be effectively

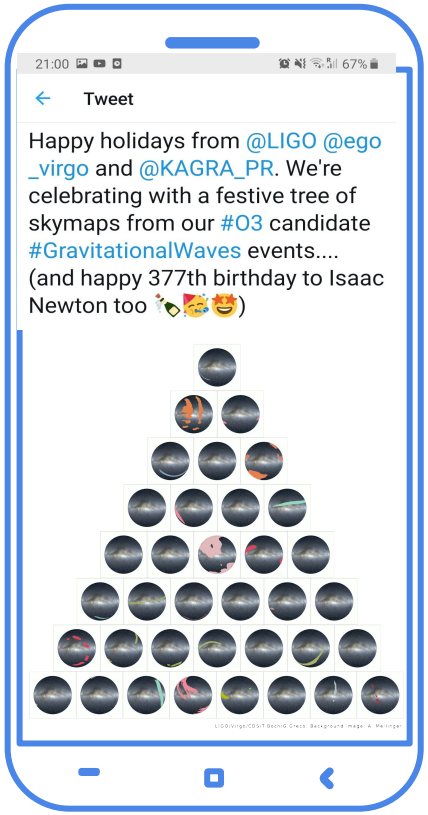
Many thanks to Leo Singer (User Guide librarian) to improve the Aladin Section and review some EPO products!

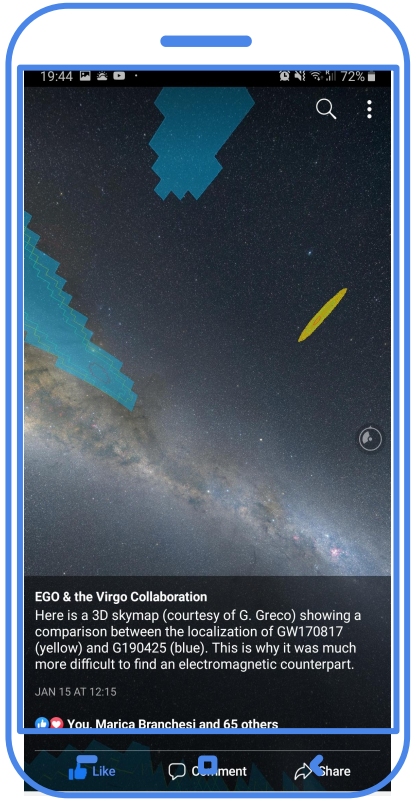
MMA Section

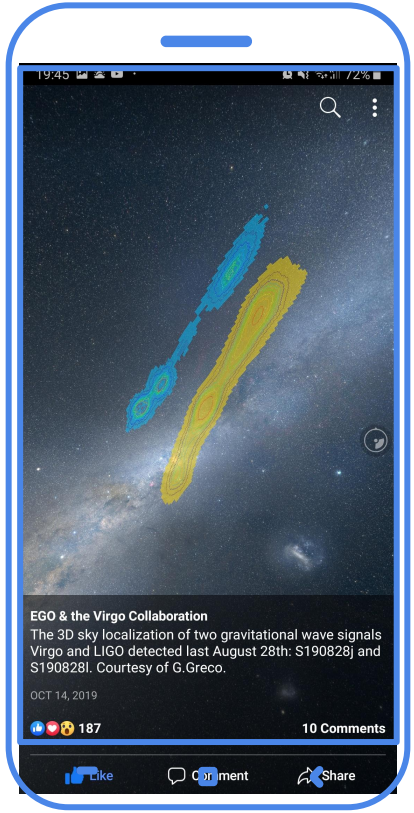
Live Demo

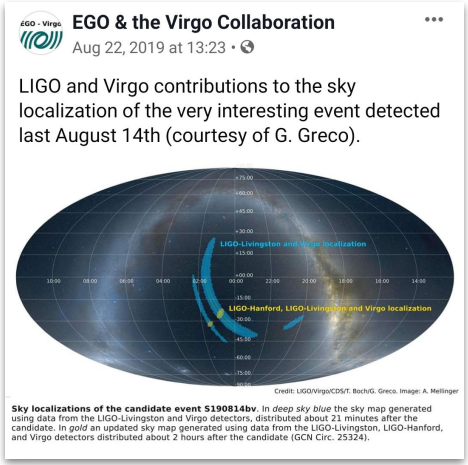
HIPS and MOC for Educational: GIF and 3D images

hips2fits



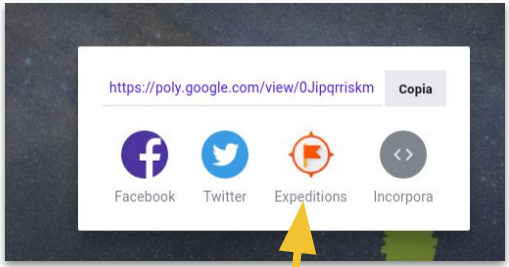




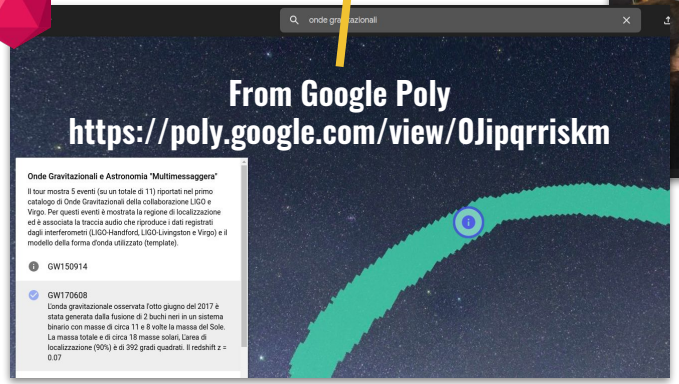


Click on the Figures to direct to the original post

HIPS and MOC for Educational: VR and HR images

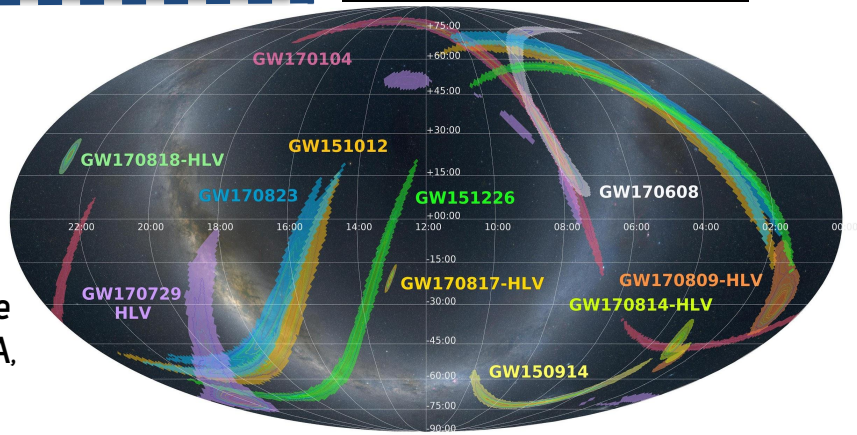


From Google Poly
https://poly.google.com/view/0Jipqrriskm



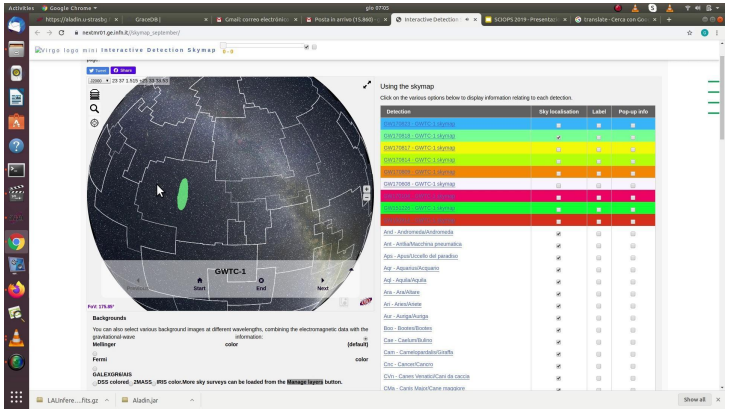
Fermhamente, Fermo 2019

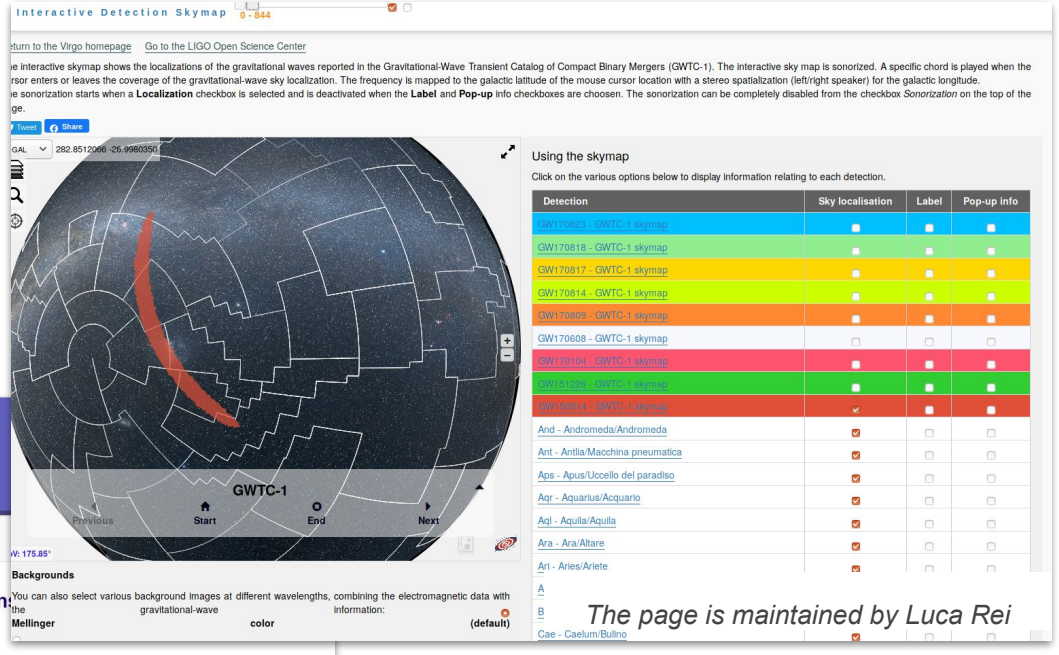
Palais de la Découverte, Paris

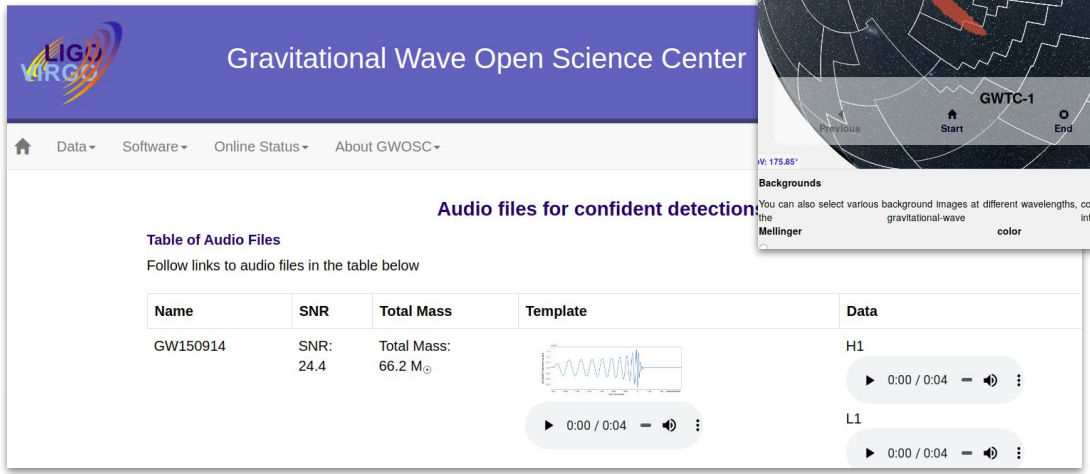


Prospects for Observing and Localizing Gravitational-Wave Transients with Advanced LIGO, Advanced Virgo and KAGRA, *Living Rev Relativ*

Aladin Lite MOC-sonification







The page is maintained by Luca Rei

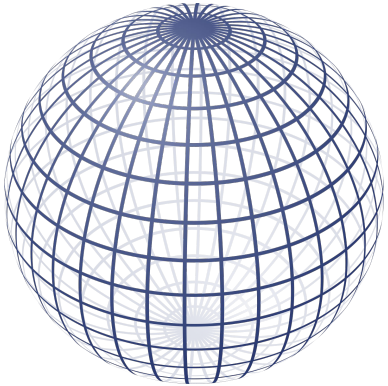
The Audio files for confident detections in GWTC-1 are provided by GWOSC

An augmented reality app to visualize gravitational events for *Android* and *iOS*

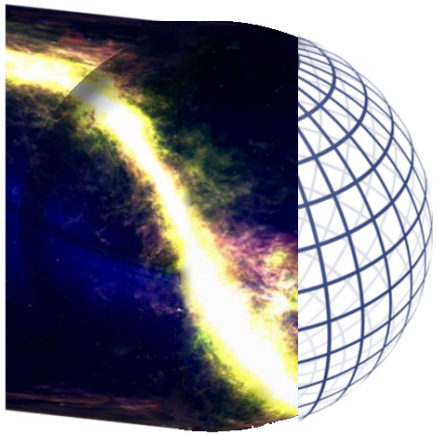
Valerio Tonelli *(student) - University of Urbino*
in collaboration with Thomas and Sébastien

How the app works

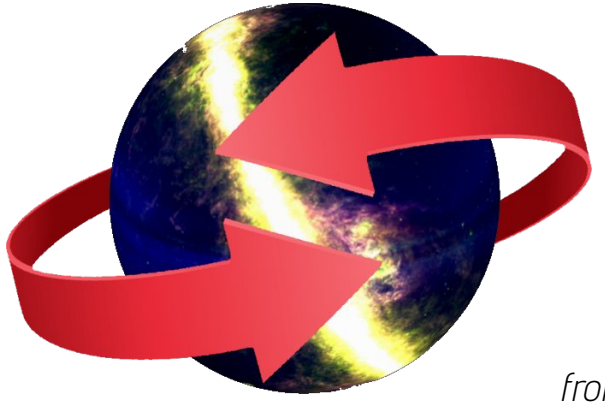
1. Model a 3D Sphere with a Camera on its center



2. Paste the Photosphere on the inside of the Sphere

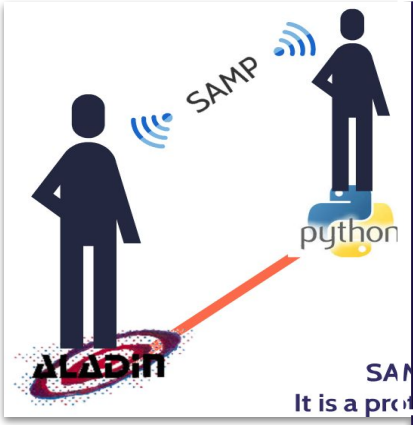


3. Align the Sphere to the real world via sensors

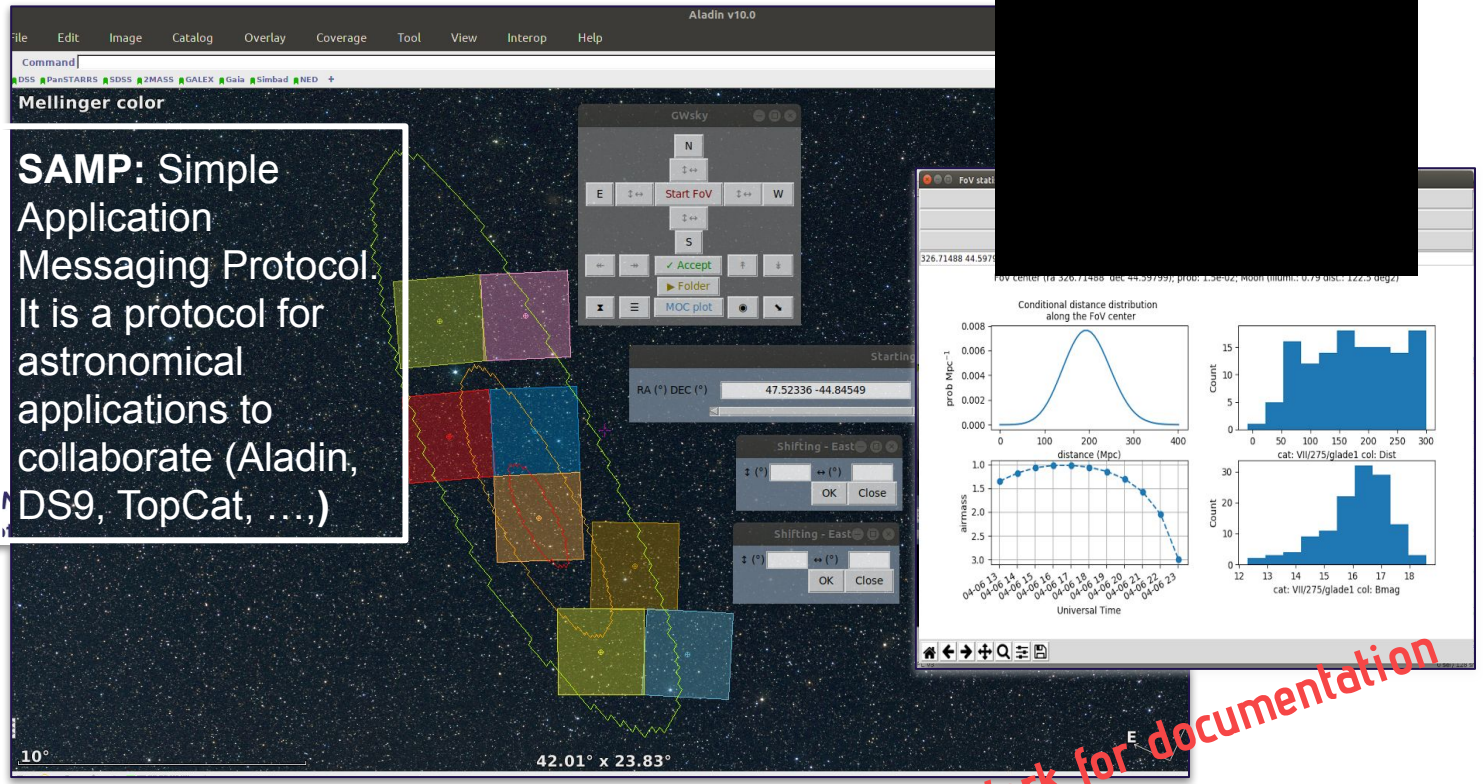


from V. Tonelli

GWsky: Interactive Tiling based on SAMP

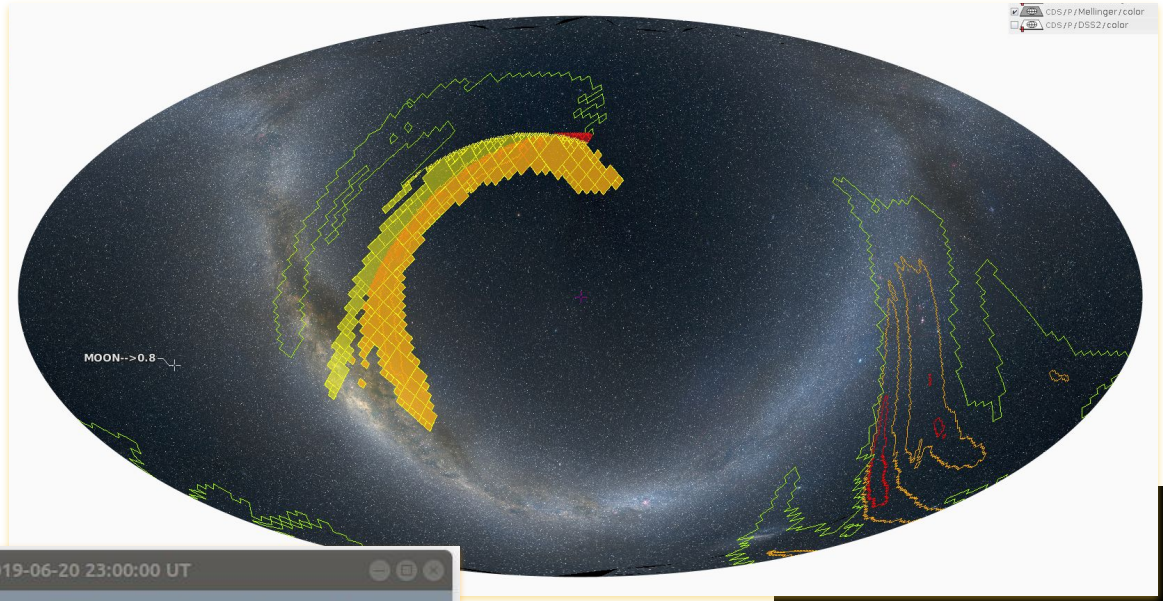


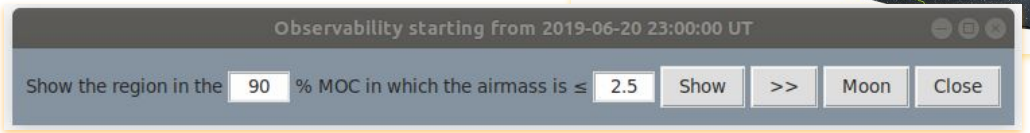
SAMP: Simple Application Messaging Protocol. It is a protocol for astronomical applications to collaborate (Aladin, DS9, TopCat, …,)



Demo tutorial

MOC Observability

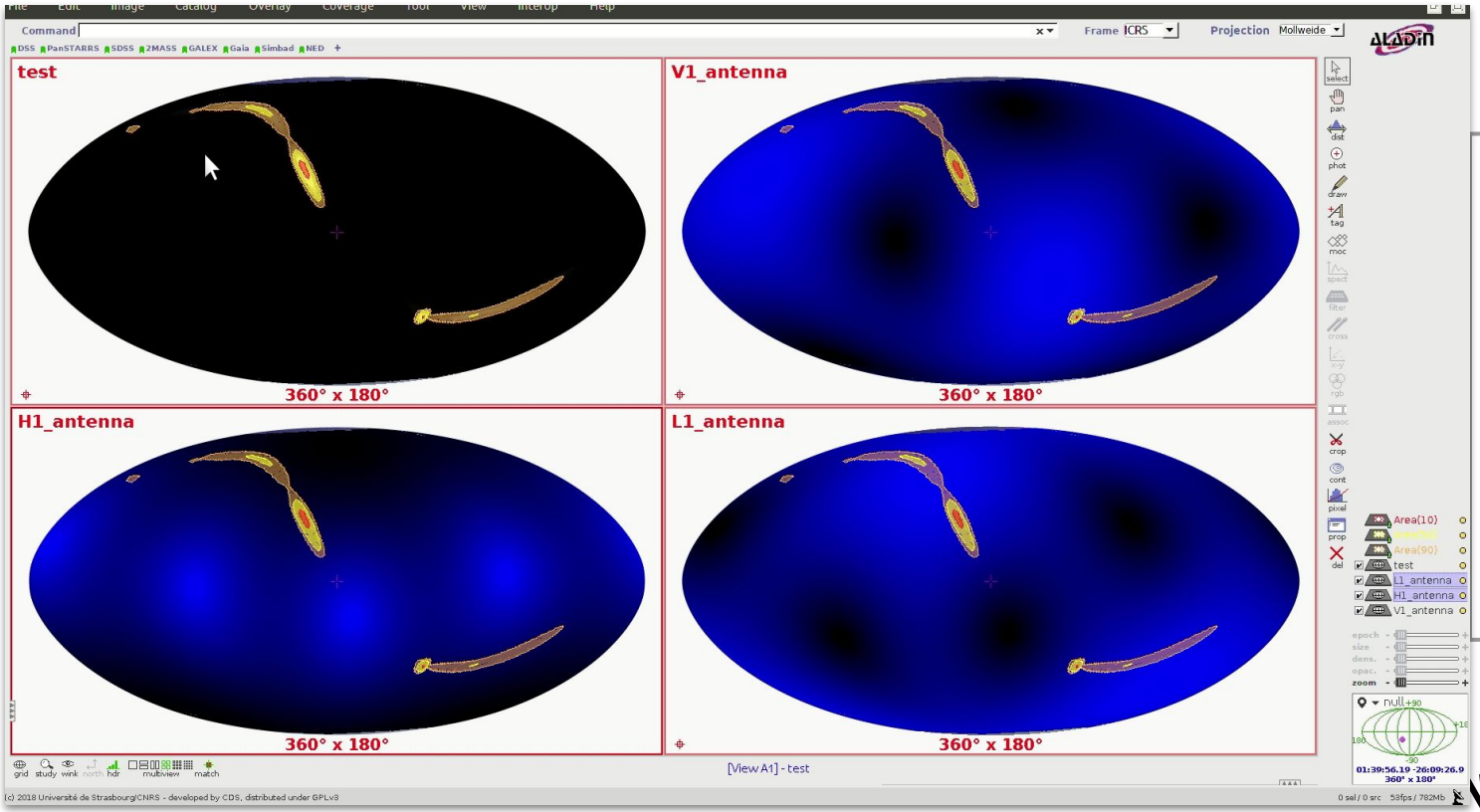




Sky regions observable from a particular site on the Earth at a particular times with an user-defined airmass in a given MOC contour plot.

Demo tutorial

Antenna Patterns: a DetChar Virgo tool

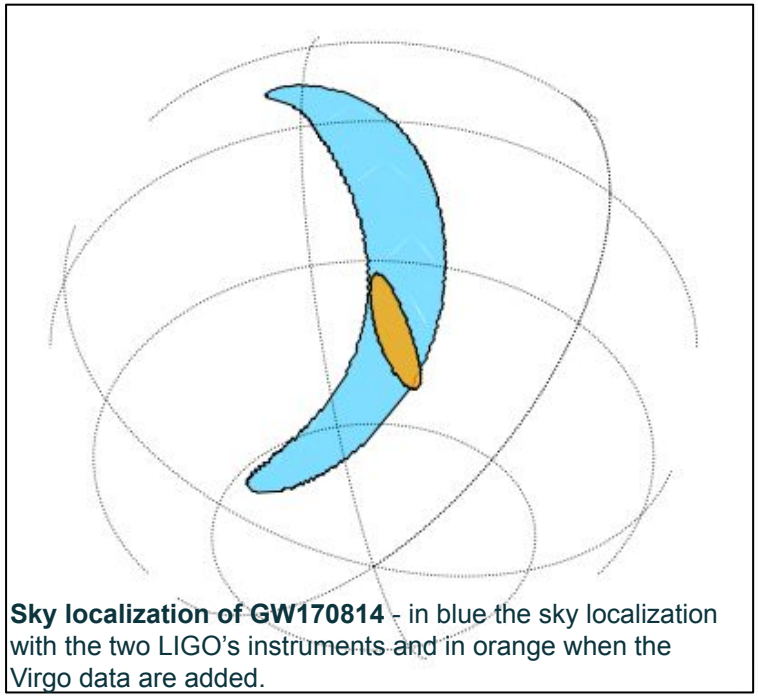


The tool automatically displays the antenna patterns and the credible regions at different confidence levels.

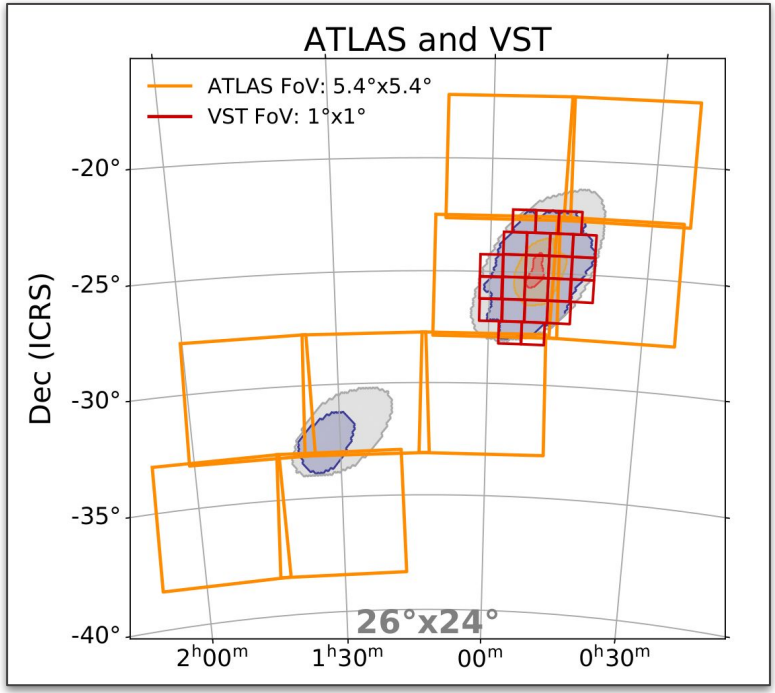
Work in progress

Proposal from Nicolas Arnaud.

MOCpy and Matplotlib



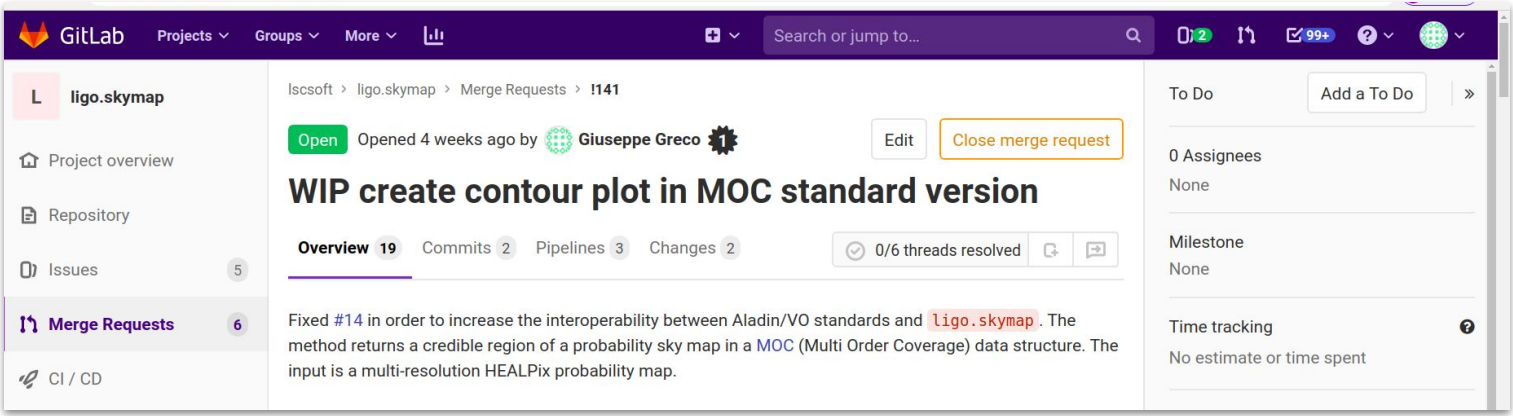
Sky localization of GW170814 - in blue the sky localization with the two LIGO's instruments and in orange when the Virgo data are added.



VST and ATLAS coverage of S190814bv

The method MOC.fill() and MOC.border() support the Matplotlib graphics library for high-quality publication plots.
The first methods draws the interior of a MOC map and the second one its perimeter.

MOCpy and ligo.skymap: interoperability



MOC from a multi-resolution skymap (see next slides)

Proposal for a Hack-a-thon!

Multi-Order format

Proposal for a Hack-a-thon!

To be ready for O4 (November 2021)!

In the next observational run the sky maps will be issued using the multi-order format.

GraceDB

Comment
Flat-resolution fits file created from "LALInference posterior samples LALInference.posterior_samples.hdf5" LALInference.fits.gz
FITS headers for LALInference.fits.gz LALInference.html
Multiresolution fits file generated from "LALInference posterior samples LALInference.posterior_samples.hdf5" LALInference.multiorder.fits
Flattened from multiresolution file bayestar.multiorder.fits bayestar.fits.gz
Localization copied from G361581 bayestar.multiorder.fits
FITS headers for bayestar.fits.gz bayestar.html
Flattened from multiresolution file bayestar.multiorder.fits bayestar.fits.gz
FITS headers for bayestar.fits.gz bayestar.html
Localization copied from G361581 bayestar.multiorder.fits

User Guide

LSC LIGO Scientific Collaboration

VIRGO

Public Alerts

User Guide

Primer on public alerts for astronomers from the LIGO and Virgo gravitational-wave observatories.

← Working with Sky Maps | Basic Observability Calculations →

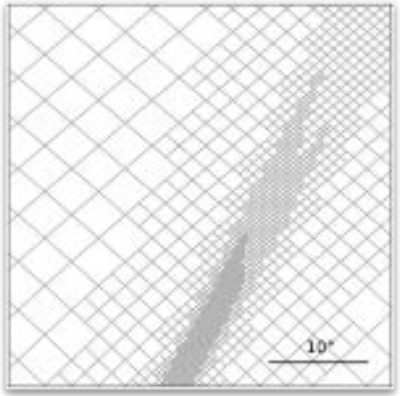
Multi-Order Sky Maps (For Advanced Users)

For most events, LIGO/Virgo distributes both the standard HEALPix format with the file extension `.fits.gz`, as well as an experimental multi-resolution HEALPix format, distinguished by the file extension `.multiorder.fits`.

What Problem Do Multi-Resolution Sky Maps

Why “multi-order”?

- Multi-order format is the *natural* representation of the BAYESTAR algorithm to localize a gravitational-wave source in real time.
- **This approach reduces the low-latency time to send an alert - no need to flatten to a single HEALPix resolution.**
- In O4, the network will be form by four interferometers and the multi-order will be necessary (eliminate computation time to flatten sky maps to a large Nside).
- Support from *astropy* and *ligo.skymap* and *mocpy* (?).



An example multi-resolution mesh from a typical two-detector (LHO and LLO) localization produced with BAYESTAR.
From *Singer, L. P., & Price, L. R. 2016, Phys. Rev. D, 93, 024013.*

What “multi-order” is

- Multi-order uses the **UNIQ** indexing scheme and is a superset of the FITS serialization for Multi-Order Coverage (MOC) maps specified by IVOA
- **The UNIQ indexing scheme encodes both the resolution and the sky position in a single integer.**
- From the standard HEALPix the key differences are.

1. The `ORDERING` key has changed from `NESTED` to `NUNIQ`.
2. The `INDXSCHM` key has changed from `IMPLICIT` to `EXPLICIT`.
3. There is an extra column, `UNIQ`, that explicitly identifies each pixel in the **UNIQ** indexing scheme.
4. The `PROB` column has been renamed to `PROBDENSITY`, and the units have change from probability to probability per steradian.

Many thanks for the attention and for the kindly hospitality!