A Webtool for working with GW sky localizations

Giuseppe Greco, Mateusz Bawaj, Roberto de Pietri and many others









Targets and Technology

- Based on the Virtual Observatory standards and technologies (Aladin Lite v3, MOC, HiPS).
- You can create credible regions on the fly in your browser.
- Sky Operations: unions, intersections, differences or subtractions.
- Filtering transient candidates.



ESFRI

Gravitational-Wave Sky Localizations:

Online Calculator and Interactive Viewer of Credible Areas

Version beta 0.5

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 analysis 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.

Tested on all major web browsers such as Chrome, Firefox, Safari, Opera. Work in progress to develop a <u>responsive design</u> that adjusts itself to different screens.

GW Multi Order Coverage map



HEALPix grid



G. Greco, PoS Asterics2019 (2019) 031. doi:10.22323/1.357.0031

Big-data window

Fully access to VO resources with a few clicks or a few command lines in python





Sky Map Visualizations and Credible Regions in Aladin

- 3 well known services: Simbad, VizieR & Aladin, (+Xmatch,Sesame...)
- 500 TB of data

- **16** operational sites/servers on 5 continents (7 local servers + 9 mirrors)
- Over 2 million requests per day

 \rightarrow Available pixels 3.61E+14 (all HiPS resolutions, formats, 1.06E+15 with mirrors = 1060.1 thousands of billions pixels)

 \rightarrow (equivalent to a photo album of all inhabitants of the earth with one 372x372 picture per human)

 \rightarrow Nb catalog rows: 3.27E+10 = 32.7 billions of rows

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

Towards a standard(s)

2015; Singer & Price 2016; Youngren & Petty 2017). It has also been utilized by the multiorder coverage (MOC) map International Virtual Observatory Alliance (IVOA) standard (Fernique et al. 2019) to specify arbitrary sky regions, which has been shown useful for the planning of multimessenger observations (Greco et al. 2022). The MOC standard was recently generalized by associating a value to each pixel of a full-coverage map, and is now used to distribute LIGO-Virgo gravitational wave sky localizations.⁸

I. Martinez-Castellanos et al 2022 AJ 163 259

in the Aladin sky atlas (Bonnarel et al. 2000; Boch & Fernique 2014) and many other Virtual Observatory (VO) tools and platforms. Greco et al. (2019) brought MOCs to prominence in the GW community by adding MOC contouring of GW probability maps and cross-matching with catalogs to Aladin. The hierarchical nature of HEALPix also underlies the IVOA hierarchical progressive surveys (HiPS) standard (Fernique et al. 2015, 2017), an astronomy map tile technology that enables interactive panning and zooming, similar to Google Maps, in Aladin.





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

C 2 MINUTI DI LETTURA



New features

- Improved display: thanks to GPU rendering using WebGL2, the application is smoother and more reactive, in particular when zooming or panning the view.
- Access to HiPS FITS tiles: HiPS FITS tiles can now be loaded and visualised in Aladin Lite, giving access to the whole dynamic range of corresponding HiPS dataset. The HiPS tile format can be changed from the *Stack* GUI: click on the Elogo to open it, then click on the black triangle to open the image options

panel, as shown below:

Space and Time MOC

MOC: Multi-Order Coverage map

Version 2.0 IVOA Proposed Recommendation 2021-11-01 Command

-15:00

-30:00

15°

grid study wink

Working Group

Applications

This Version

http://www.ivoa.net/documents/moc/20211101

Latest Version

http://www.ivoa.net/documents/moc

Previous Versions

Version1.1 Version1.0

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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 10⁵



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Graphical User Interface: GW transient Catalogs



The skymaps are taken from the GWOSC website following the last publication data in Zenodo. Last publication date: May 11, 2022

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Graphical User Interface: Real time

Real time: latest LVK public alert in real time and visibility plot (with Google Earth?)

Night time shading for September 14, 2015 at 09:50:45 UTC

GWTC-1/2: Gravitational-Wave Transient Catalogs - Sky Localizations

Transient Localizations

virgo.pg.infn.it dice

Also for transients stored in the **Transient Name Data Server**

Matryos KY

Low frequency: Multi-messenger astronomy

- If we are able to cumulate enough SNR before the merging phase, we can trigger e.m. observations before the emission of photons
- Keyword: low frequency sensitivity:

Real-time search, post-processing and data storage...

The idea is to develop nested ET sky localizations from the first early warning alerts to the final ET localization. Nested also EM/neutrino transients and EM/neutrino surveys.

Many THANKS!

https://virgo.pg.infn.it/maps/webtool evolution2/index evolution v2.html