GLADEnet : a progressive Web App for Multi-messenger Cosmology

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GLADEnet role in the multi messenger context

Why GLADEnet ?

- **Localization problem**: big 3D volumes for GW events, a lot of possible galaxies
- **Big deal** for GW+EM events (*Standard Sirens*) and a really **big problem** for GW events only (Dark Standard Sirens)
- Rapid and effective follow up campaign (also with narrow field view telescopes)

Multi-messenger Issues

- **Catalogs are important**: use the *Catalog-Based Search* to reduce the observing region
- Galaxies targeting for multi messenger purposes
- With GLADEnet **we visualize in real time** the GLADE+ completeness In the 3D sky locations
- Promote dedicated campaigns to **increase** catalogues completeness
- Calculate **Hubble's constant** in *dark standard sirens* case

Improvements

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Improvements

GLADE+ galaxy catalogue

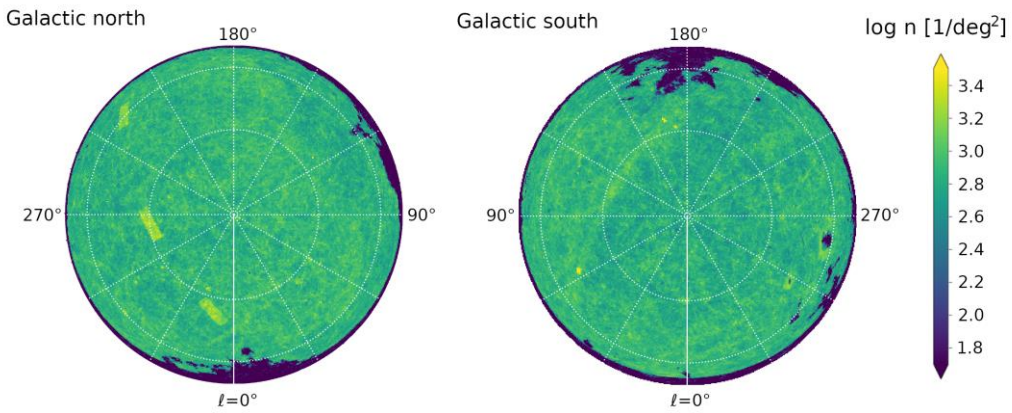
- GLADE+ is the last version of the GLADE catalogue (**G**alaxy **L**ist for the **A**dvanced **D**etector **E**ra) devolped by Dàlya et al.

- Includes ~22,5 million **galaxies** and ~ 750 thousand quasars

- The latest version is formed by **cross-matching** six different astronomical catalogues: GWGC, 2MPZ, 2MASS XSC, HyperLEDA, WISExSCOSPZ and SDSS-DR16Q

- GLADE+ is **complete** up to $d_L = 47^{+4}_{-2}$ Mpc (cumulative B-band luminosity)

Dálya, G., Galgóczi, G., Dobos, L., et al. 2018



Base-10 logarithm of the number density(n) of objects in GLADE+

It contains all of the brightest galaxies contributing to 90% of the total B-band luminosity up to $d_L \cong 130$ Mpc

Schechter function parameters evaluation

Schechter proposed a model for a galaxy number density in a given comoving volume with a given luminosity

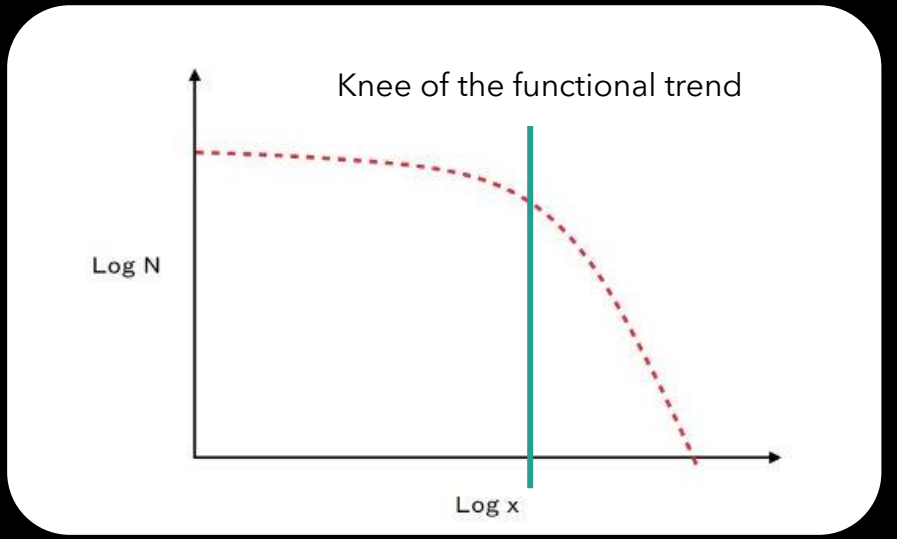
Schechter function

$\phi = \rho_{gal}\, dx = \phi^*\, x^{\alpha}\, e^{-x}\, dx$

ϕ^* : normalization factor

$x = L/L_B^*$ *with* $[L_B^*] = 10^{10} h^{-2} L_{B,\odot}$

characteristic luminosity where the power-law truncates

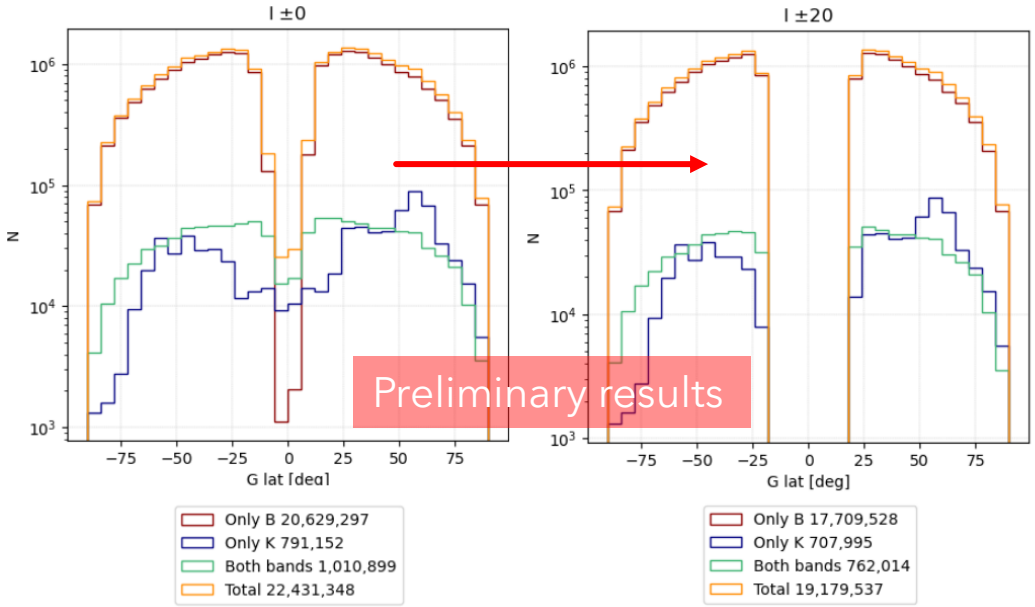


From luminosity to absolute magnitude : $\Phi(M) = 0.4\, ln_{10}\left(10^{0.4(M^*-M_i)}\right)^{(a^*+1)}\, e^{-10^{0.4(M^*-M_i)}}$ (M_i^*: absolute magnitude)

Parameters we need to fit : M^*_{GLADE+} α^*_{GLADE+} ϕ^*_{GLADE+}

Schechter function parameters evaluation

- Galactic Plane latitudes **cut off**: $|b| > 20°$
- Three **volume shells**: 25, 50, 75 Mpc
- Only B-band magnitude selected
- *Curve_fit* method from Scipy library



M.L. Brozzetti et al.: GLADEnet: a progressive web app for multi-messenger and follow-ups (under submission)

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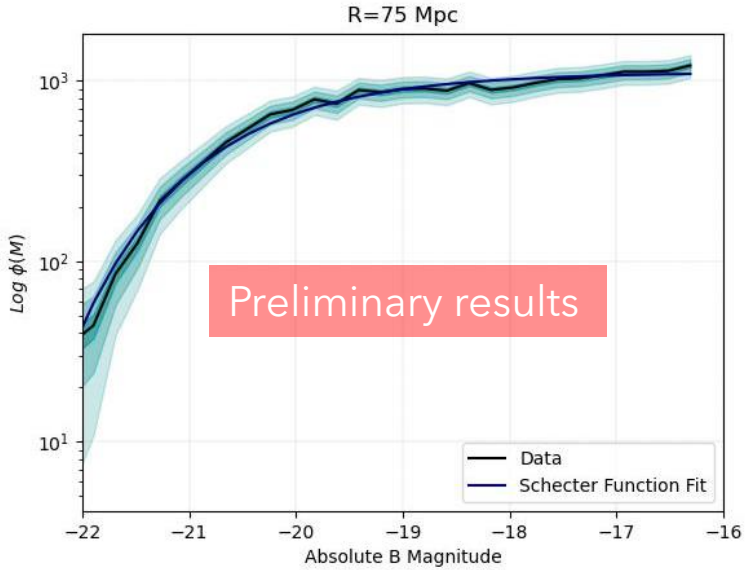

Schecter function fitting for GLADE+ up to 75 Mpc. B-band filter. The galaxy distribution is in balck with 1σ, 2σ and 5σ error bands in light blue.

--------→ **Parameters evaluation**

Bands	ϕ^* [h^3 Mpc^{-3}]	α^*	M^*[mag]
B (our work)	$(1.69 \pm 0.38) \times 10^{-2}$	-1.03 ± 0.03	-20.59 ± 0.08
B (Gehrels et al.)	$(1.6 \pm 0.3) \times 10^{-2}$	-1.07 ± 0.07	-20.47

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The Completeness Coefficient $\mathcal{C}$

GW event signal

- 3D skymap credible volume with dP/dV < 90%
- Different waveform models (SEOB, PHENOM, Mixed…)
- Data from GWTC-1, GWTC-2.1 and O4 alerts

Cross match with GLADE+

- Number of galaxies in the credible volume
- Summing the L_B of each galaxy in the 3D gw event

$$\frac{\mathcal{L}_{GW \times GLADE+}}{\mathcal{L}_{Sch}}$$

Total luminosity of galaxies inside the credible volume of a GW sky localisation

Total luminosity expected based on the Schechter function

$$\mathcal{L}_{Sch} = j_L \times V_{GW}$$

$$j_L = \int_{x_1=0}^{\infty} L\Phi dL = \Phi^* L^* \Gamma(\alpha + 2, x_1)$$

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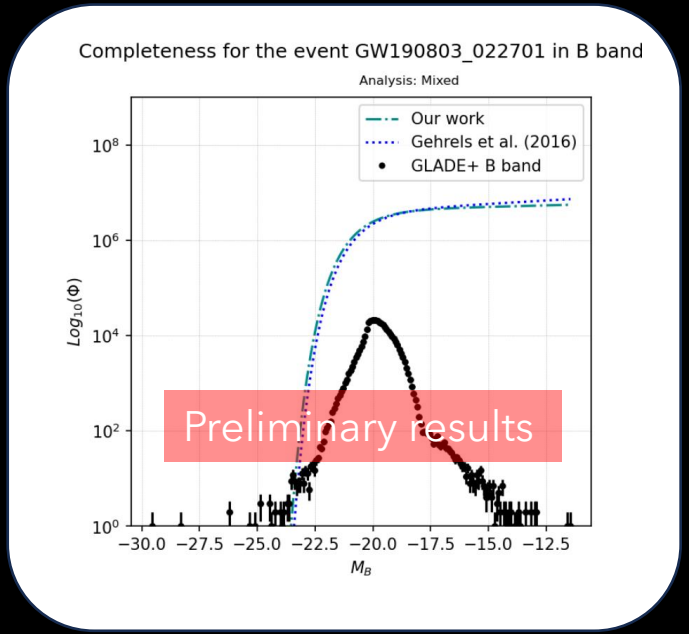
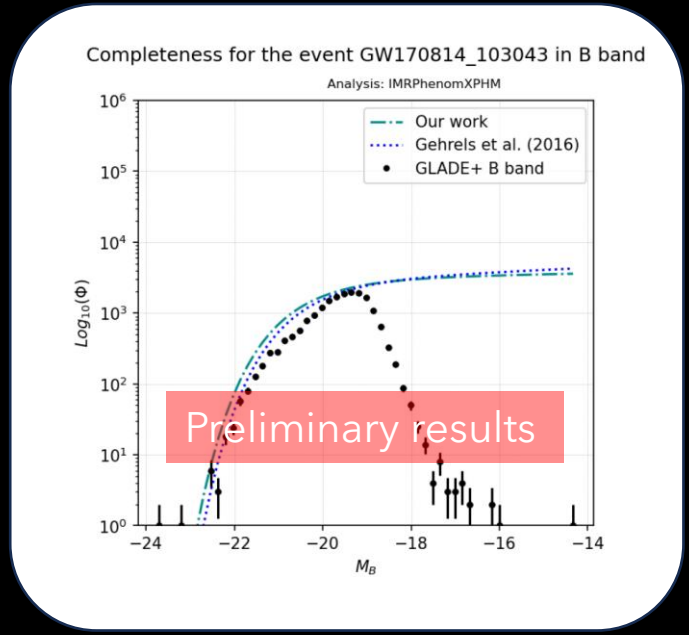
The Completeness Coefficient $\mathcal{C}$

For each event GLADEnet computes the completeness of the catalog in that precise localization volume and gives the relative plot to the user

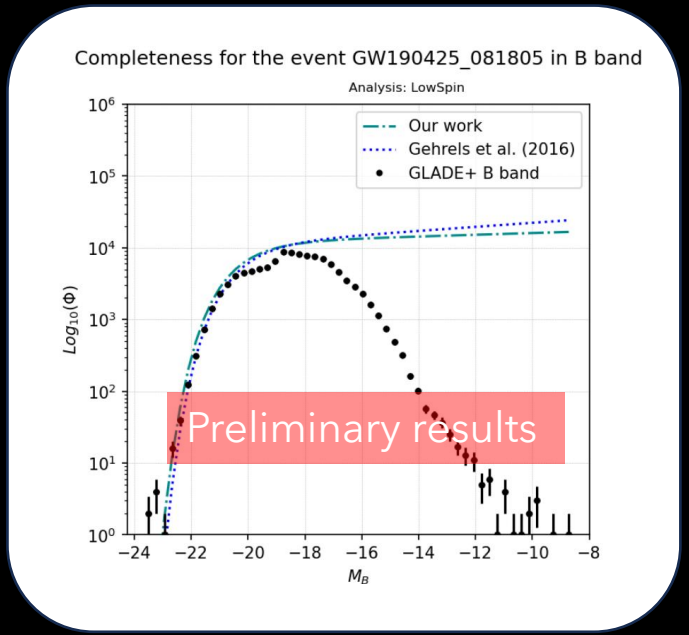
Result of our work :



Volume [Mpc^3]: 1.16e^{+10}
$\mathcal{C}$: 3.30e^{-03}



Volume [Mpc^3]: 3.80e^{+06}
$\mathcal{C}$: 4.99e^{-01}



Volume [Mpc^3]: 9.03e^{+06}
$\mathcal{C}$: 6.98e^{-01}

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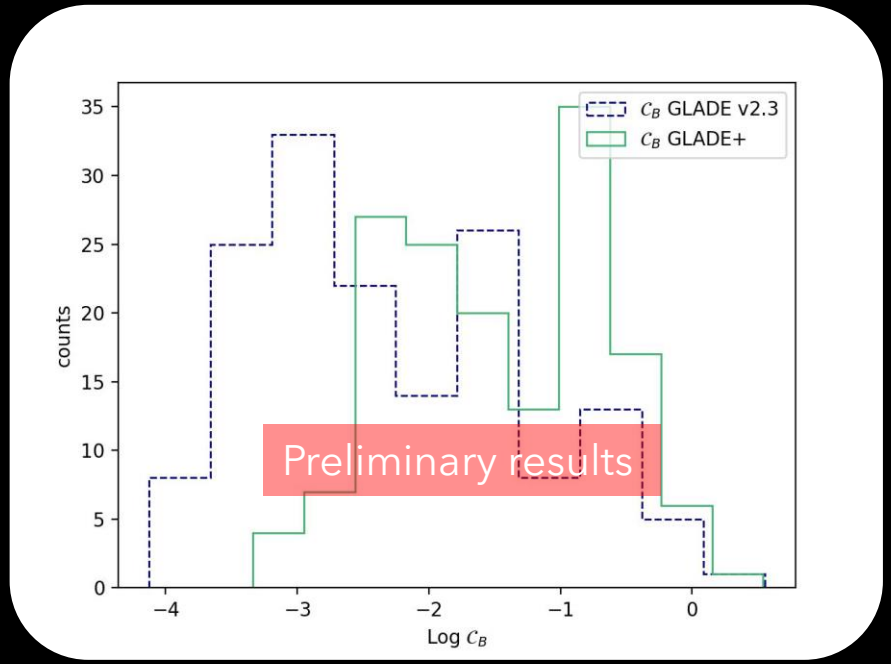
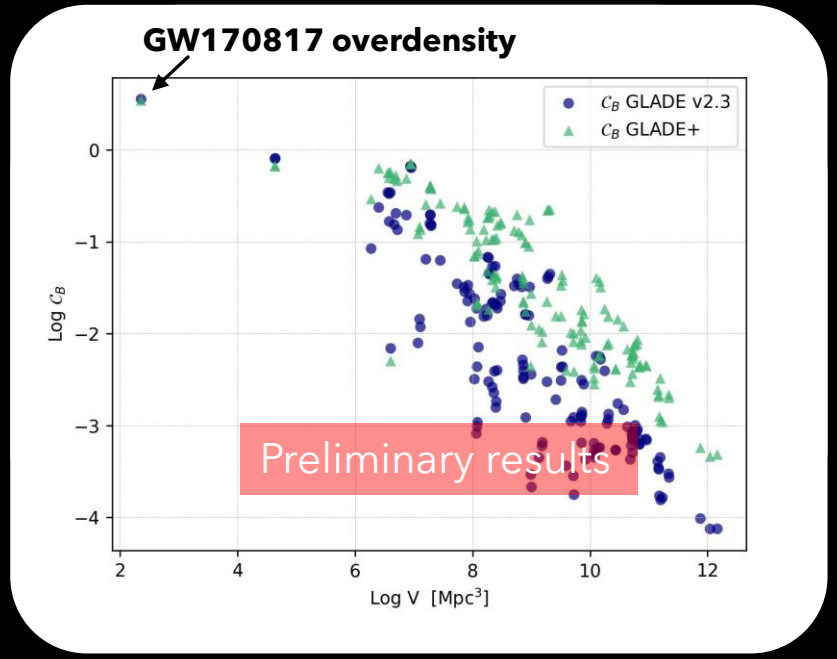


Completeness coefficient distribution for GLADE+ and the previous version GLADE v2.3



Scatter plot of $\mathcal{C}_B$ dependency on localization volume for GLADE+ and GLADE v2.3

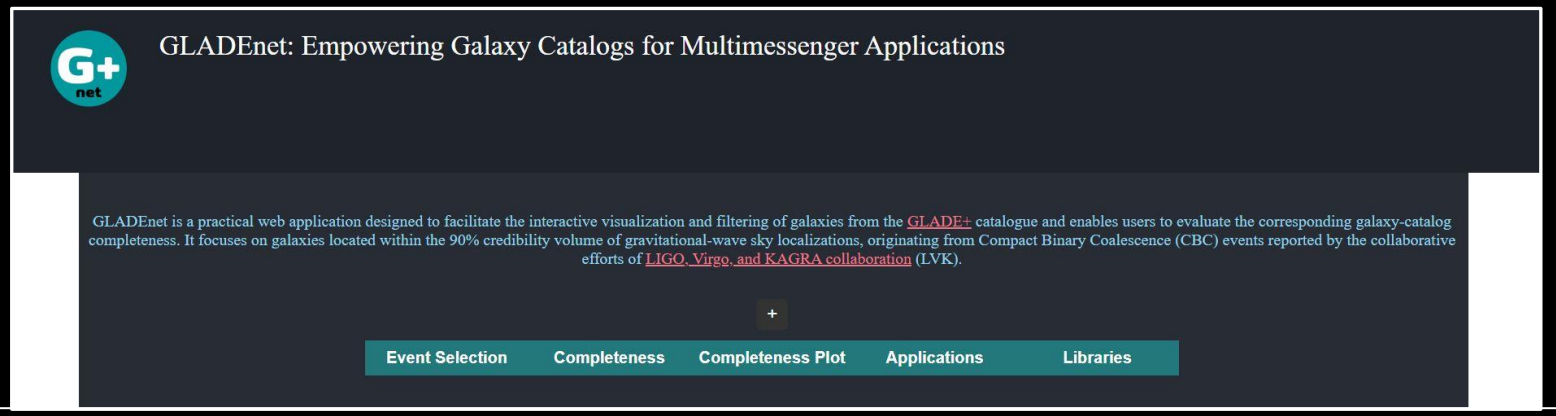
GLADE v2.3 $\mathcal{C}\sim10^{-4}$ ⟶ GLADE+ $\mathcal{C}\sim10^{-3}$

Completeness decrease as the volume (and so the distance) increase

GLADEnet – web App

A Progressive Web App with **REACT JS** and the **Virtual Observatory** standards

- ReactJS is a declarative, efficient, and flexible **JavaScript library** for building reusable UI (User Interface) components.
- It is an **open-source**, component-based front end library. It was initially developed and maintained by Facebook and later used in products like WhatsApp, Instagram, Netflix etc.
- It looks very **promising to create MMA applications** for push notifications in connection with the NASA GCN



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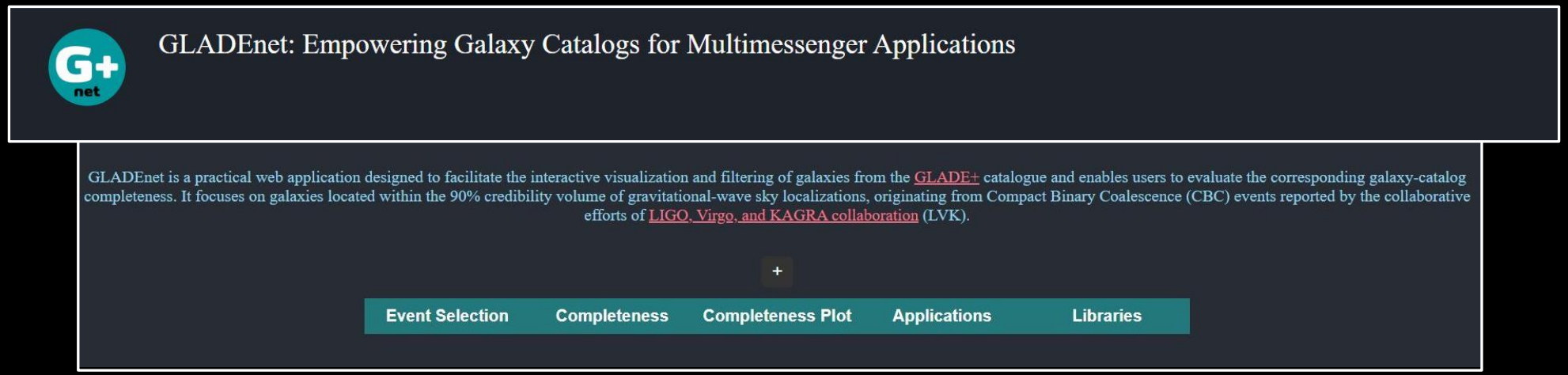

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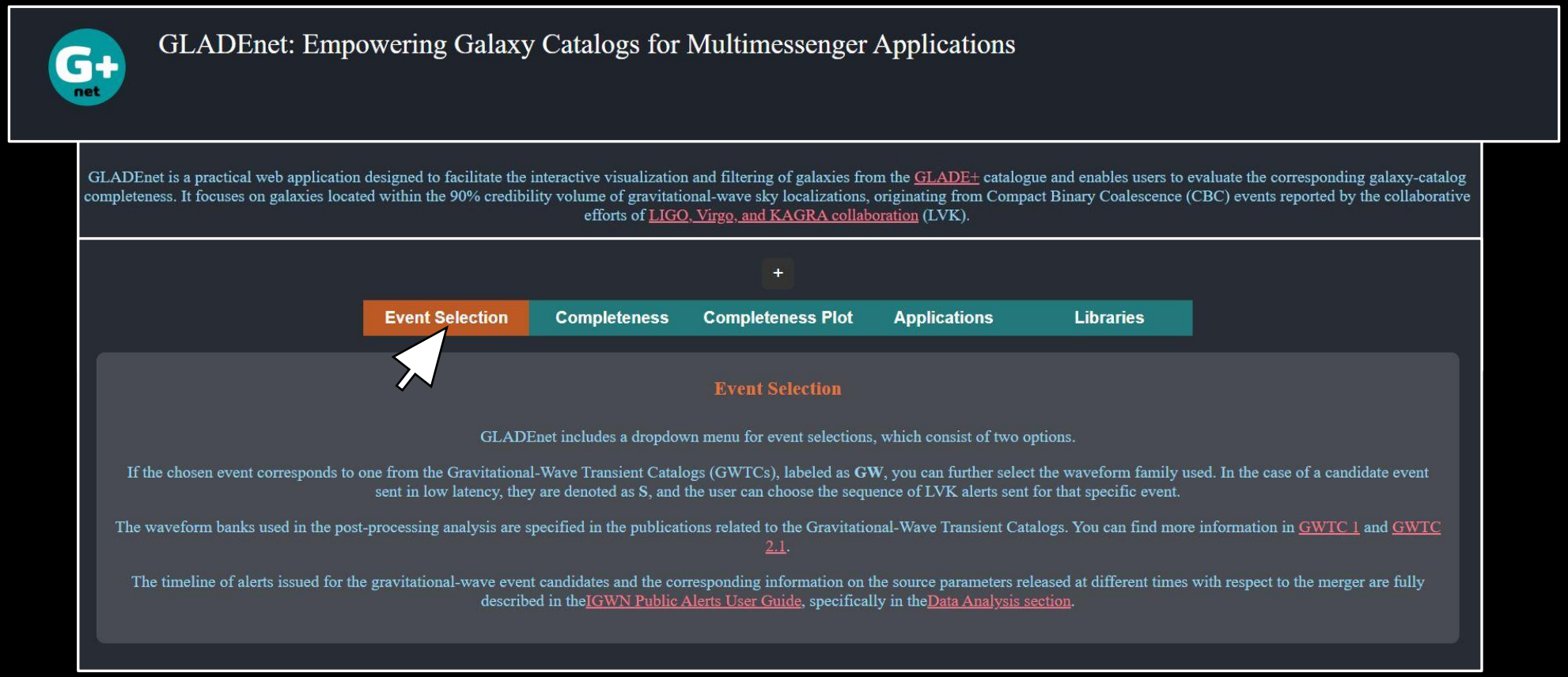

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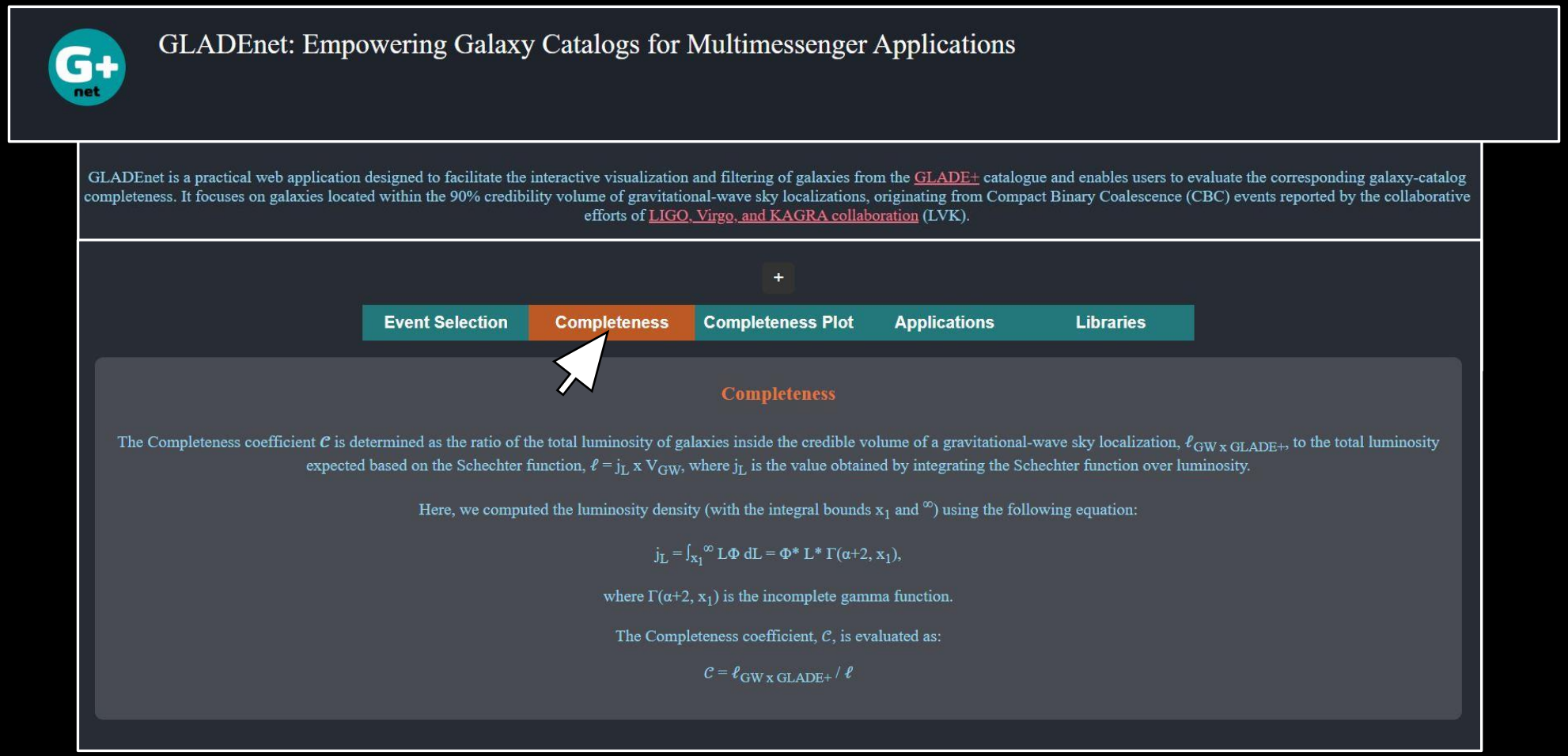

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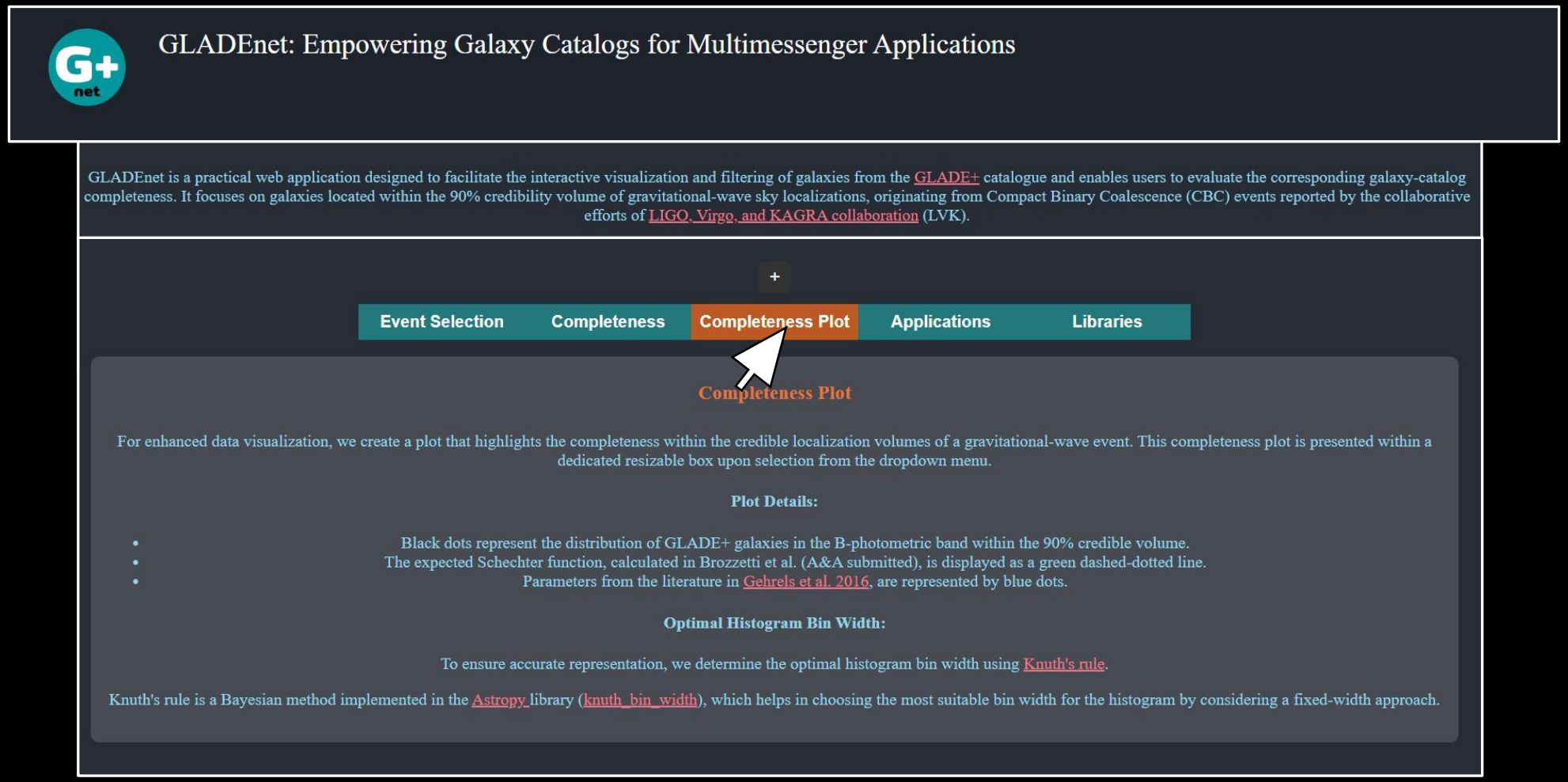

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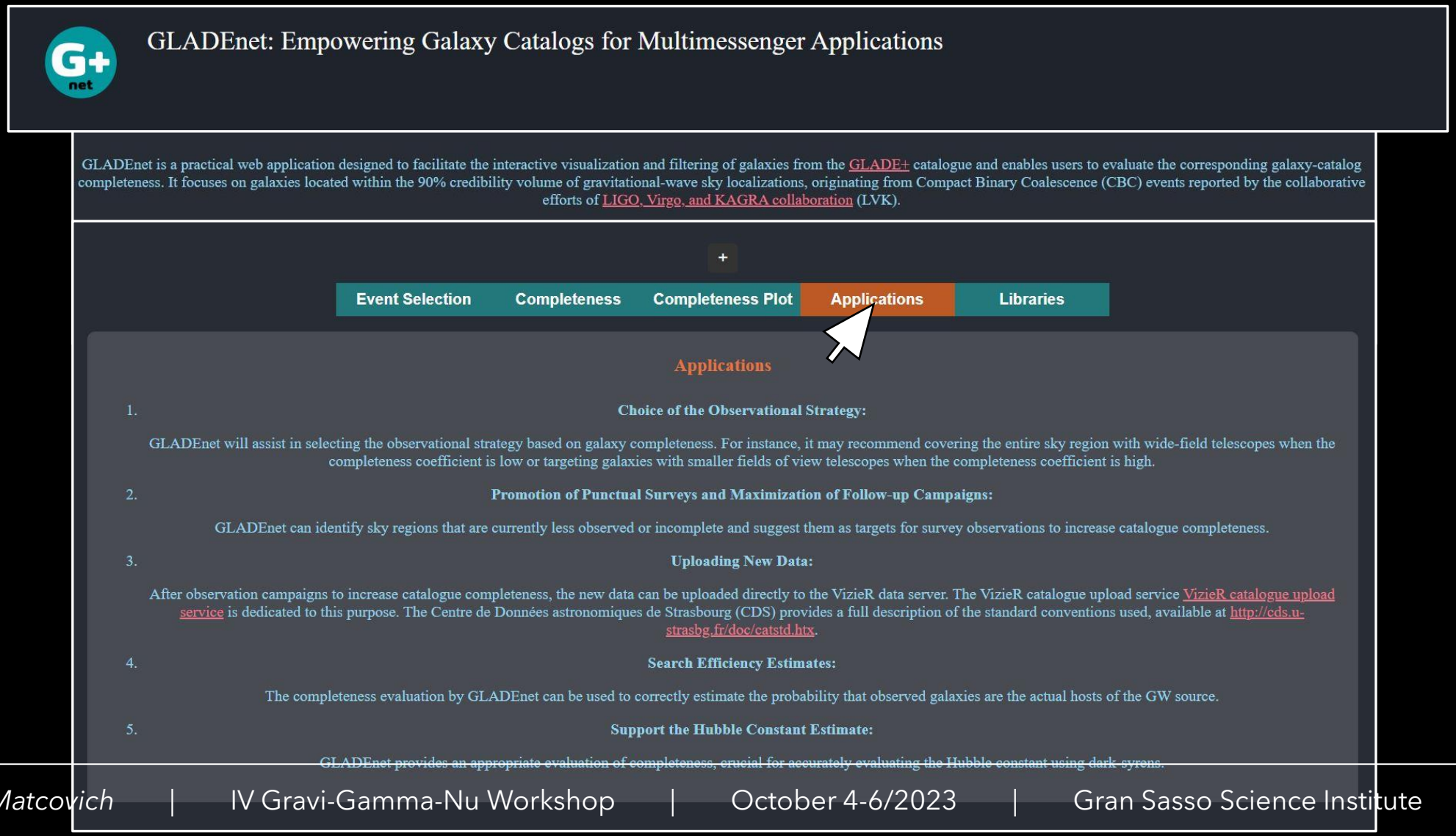

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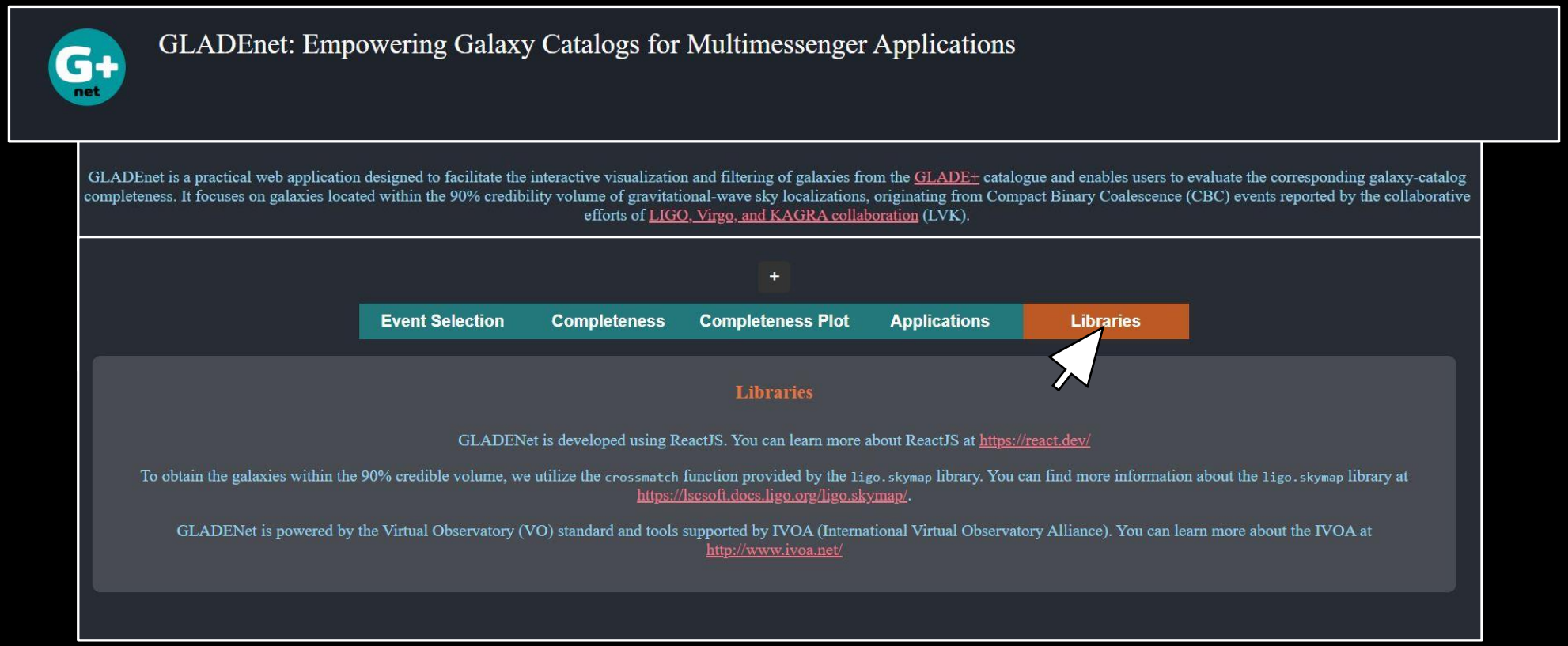


GLADEnet – web App

GLADEnet: Empowering Galaxy Catalogs for Multimessenger Applications

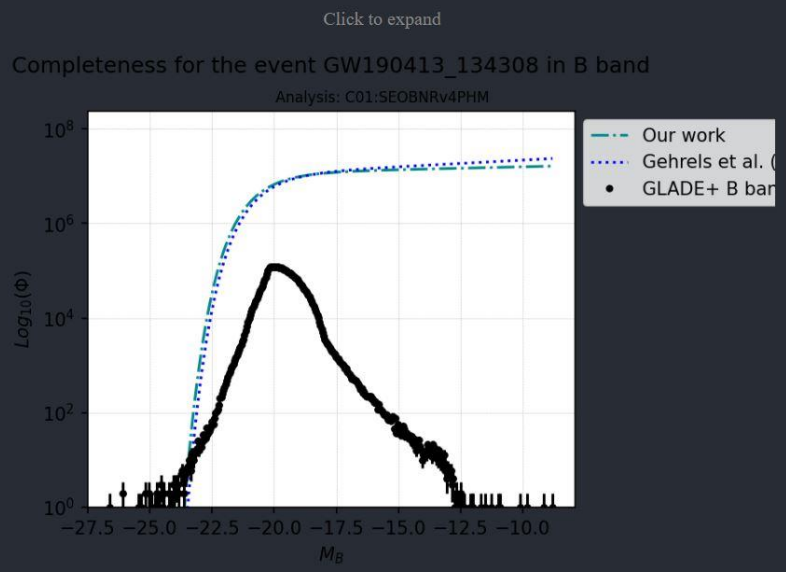
Select catalog (GW) or candidate event (S):

GW190413_134308

Select waveform analysis or alert type:

C01:SEOBNRv4PHM

Click to expand



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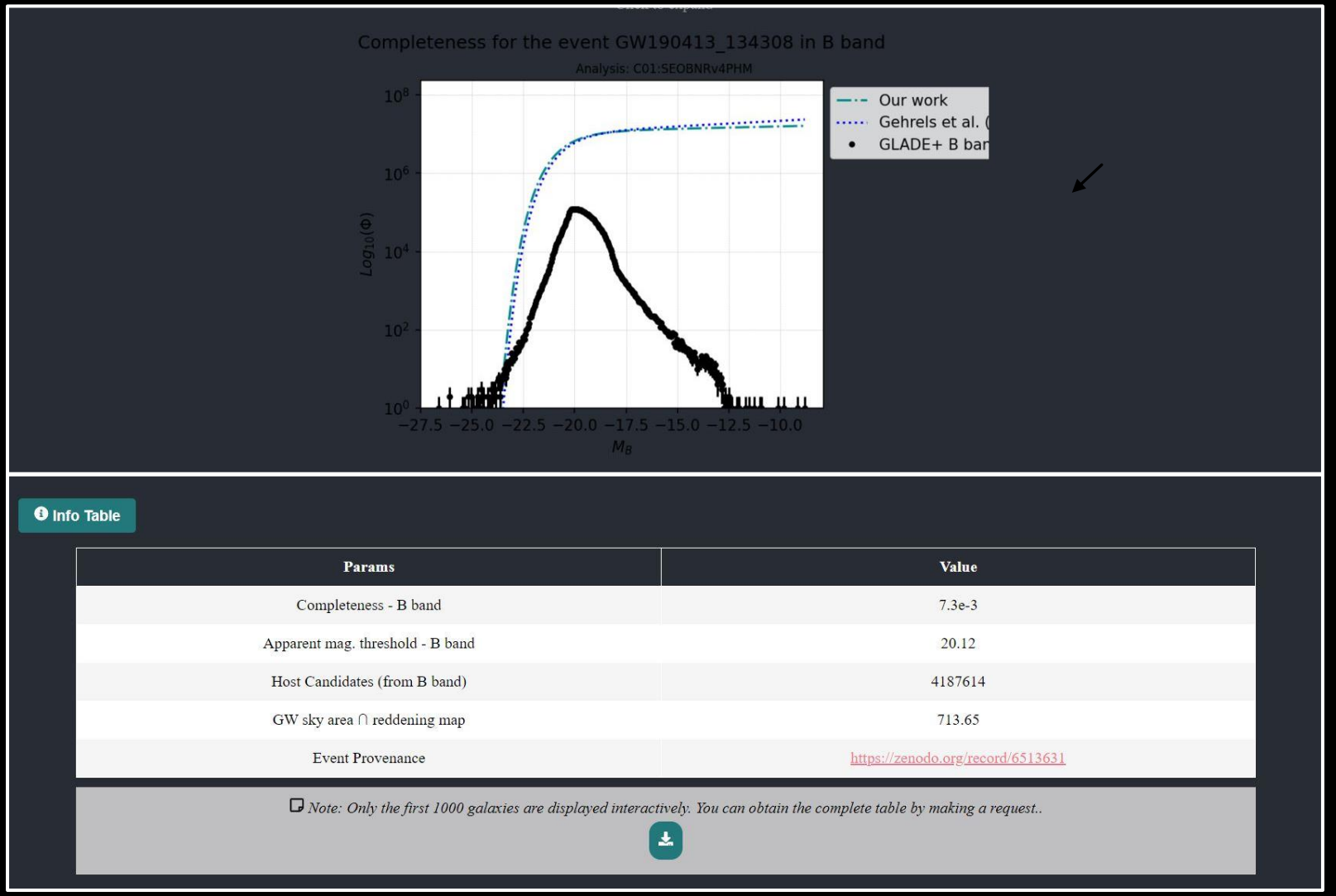
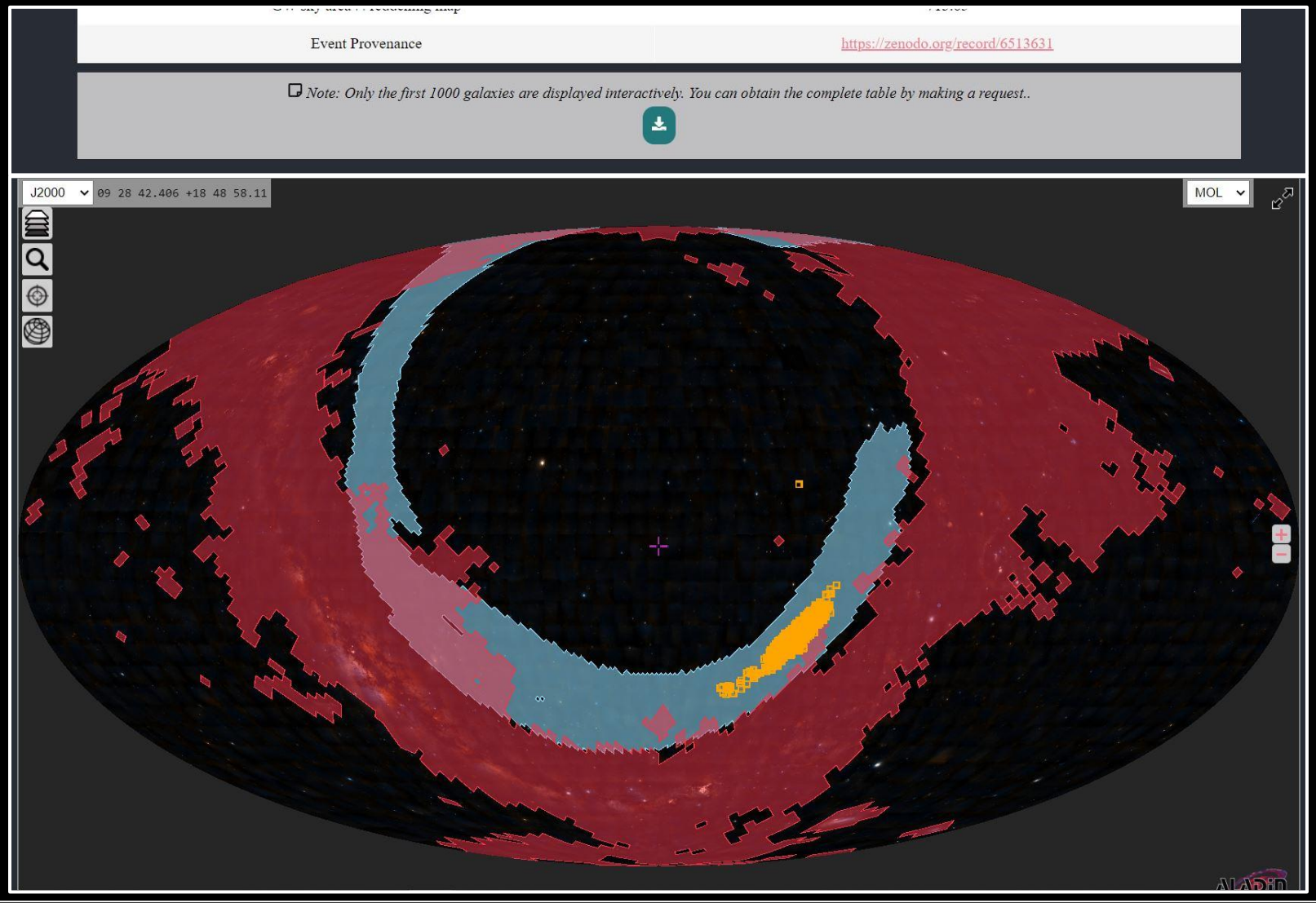


Params	Value
Completeness - B band	7.3e-3
Apparent mag. threshold - B band	20.12
Host Candidates (from B band)	4187614
GW sky area ∩ reddening map	713.65
Event Provenance	https://zenodo.org/record/6513631

Note: Only the first 1000 galaxies are displayed interactively. You can obtain the complete table by making a request..

GLADEnet – web App



Outlook for the future

It is just a step, many more have to come!

- Technical **upgrades** to add features on GLADEnet
- We want to include also other electromagnetic band in the analysis (as K-band)
- Help the **Pre-selection** of gw-events in future observing runs
- Extend this method to other catalogues
- Use the completeness evaluation to support the **Hubble constant** estimate
- Insert the **redshift** (z) dependency of Schechter function and study its implications
- Add simulated events to develop observational strategies for upcoming runs

Thanks for your attention

GLADEnet: https://virgo.pg.infn.it/gladenet/catalogs/