CATALOG COMPLETENESS IN GW SKY LOCALIZATIONS

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Introduction

We discuss the development of a new Python plug-in in the context of the multi-messenger with gravitational waves. When searching for host galaxies of gravitational-wave sources, the completeness of the galaxy catalog is a significant parameter to be considered [1]. Our plug-in estimates the completeness in the sky localization of a gravitational-wave source computing the intersection with high Galactic dust extinction regions as selected by users.

Completeness of a catalog

Following the method described in Dalya et al. [2], we calculate the completeness of a galaxy catalog.
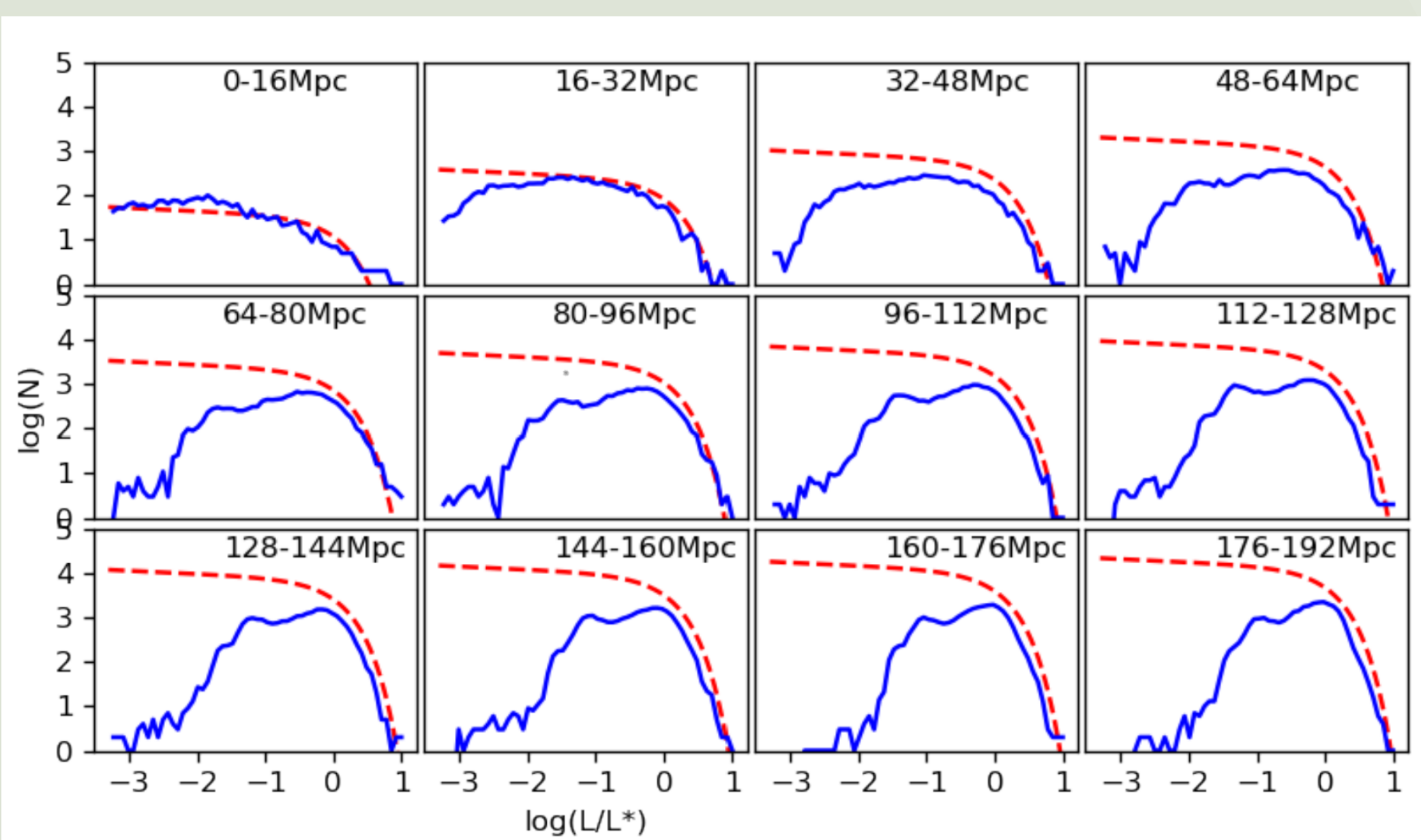
Figure 1: *Luminosity histograms of GLADE 2.3 galaxies within different distance shells in terms of their measured B-band luminosities (blue solid line), compared to the same histograms we expect for complete catalogues based on B-band Schechter function measurements (red dashed line).*

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The plug-in algorithm

To calculate the galaxy completeness for a gravitational-wave sky localization, we adapt the method described in the previous section. We select the galaxies between $R_1 = d - 3\sigma_d$ and $R2 = d + 3\sigma_d$ (with d mean distance of the event and σ_d standard deviation), contained in a credible volume corresponding to the 90%. We also calculate the intersection area between the 90% credible area and high Galactic dust extintion regions as selected by users.
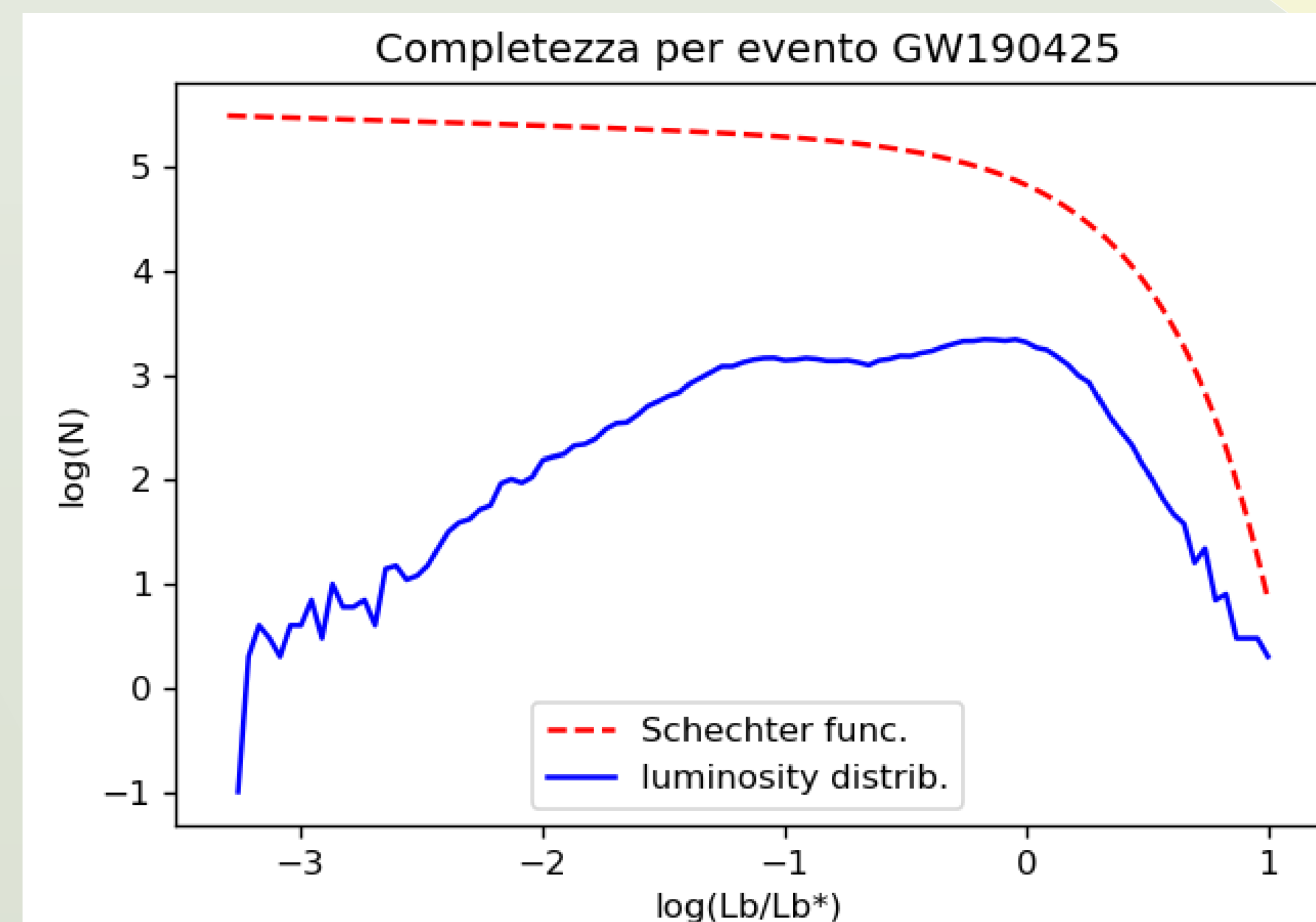
Figure 2: *Plug-in at work. Sky localization of GW190425 [3] cross-matched with the galaxy catalog GLADE 2.3*

Conclusions

We developed a new plug-in, in the context of the Virtual Observatory standards and tools, to define the completeness of a catalog in the credible volume of the event under examination. The plug-in is named Catalog Completeness in GW Sky Localizations. Thanks to the SAMP-VO protocol and the Tkinter package, our Python plug-in is able to communicate with the Aladin software. We visualize the gravitational-wave sky localization in the Aladin Desktop and a new dedicated window shows the plot of the completeness. The complete algorithm is reported in a public GitHub repository (https://github.com/elisacart/Catalog-Completeness-in-SkyLocalizations.git) which indicates all of the Python modules necessary for this analysis.
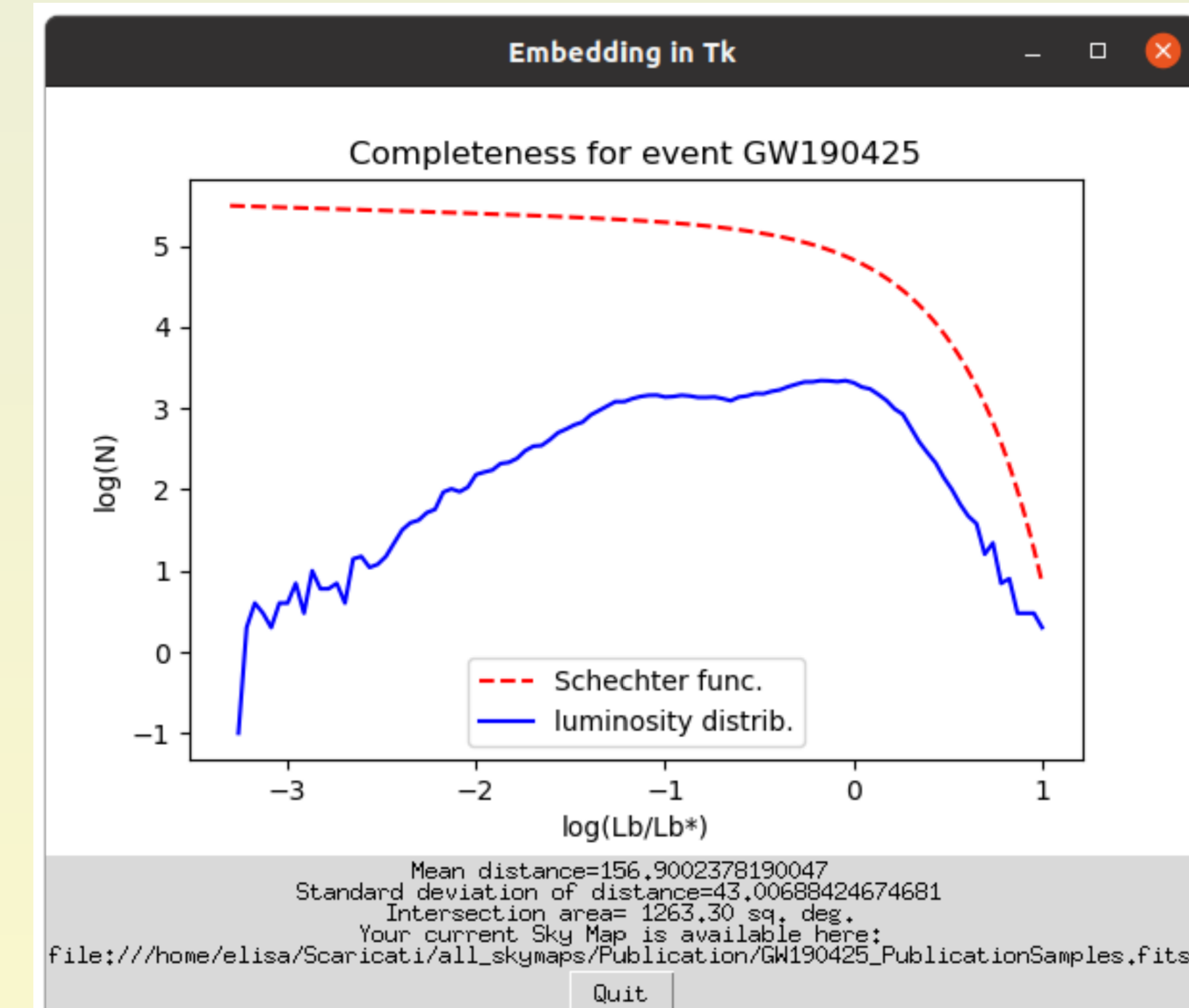
Interaction with Aladin Desktop

The plug-in is able to communicate with Aladin via the SAMP protocol. Tkinter Python module is used to create the pop-up window which displays the completeness plot with additional information in a dedicated legend.
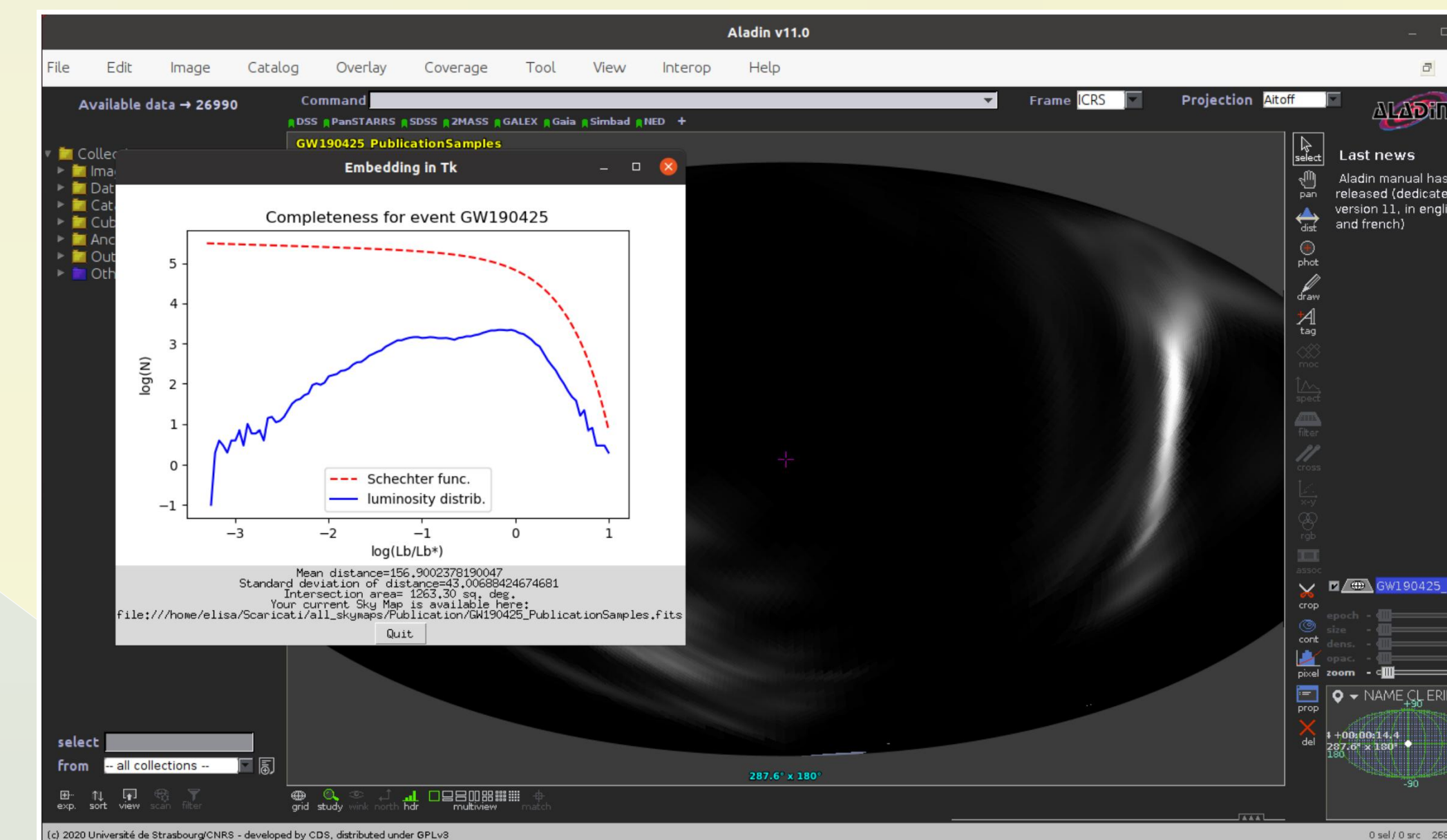
Figure 3: *Catalog Completeness in Sky Localizations plug-in. Aladin Desktop shows the gravitational-wave sky localization, while a pop-up window depicts the completeness plot and reports some relevant data.*

Figure 4: *Pop-up window containing the plot and a label that reports the mean distance of the event, the standard deviation, the intersection area between the sky localization area of the event and high Galactic dust extinction regions, and the url to access to the sky map [4] in the original FITS format.*

References

[1Schutz, B. F. 1986, Nat

[2] G Dalya et al, "Glade: A galaxy catalogue for multimessenger searches in the advanced gravitational-wave detector era", Monthly Notices of the Royal Astronomical Society, 479(2), 2018. ISSN 1365-2966

[3] B. P. Abbott et al, "GW190425: Observation of a Compact Binary Coalescence with Total Mass ~ 3.4 M⊙", ApJL, 892 L3, 2020

[4] Leo P. Singer et al. ligo.skymap 0.5.0 documentation. https://lscsoft.docs.ligo.org/ligo.skymap/. 2020