Future of GLADE

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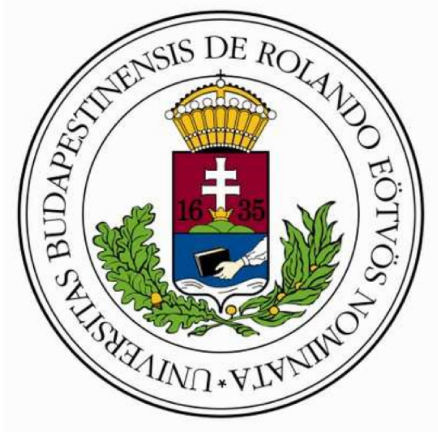

May 31, 2016

Outline

1. Motivation
2. Current status of GLADE
3. Future of GLADE
4. Discussion about VO tools

Motivation

One of the next main goals of LIGO is to find the EM-counterpart of binary neutron star mergers

Method:

1. GW alert
2. Resconstruced position of the source
3. Scanning the reconstructed area using several telescopes

The reconstruced area is currently $\sim$ 100-1000 deg^2[1]
Using galaxy catalogs, the area can be reduced by a factor of 1000 [2]

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[1]LIGO Scientific Collaboration, Virgo Collaboration, Aasi, J., et al. 2013, ArXiv e-prints, arXiv:1304.0670

[2] Bartos, I., Crotts, A. P. S., & Marka, S. 2015, ApJ, 801, L1

Requirements

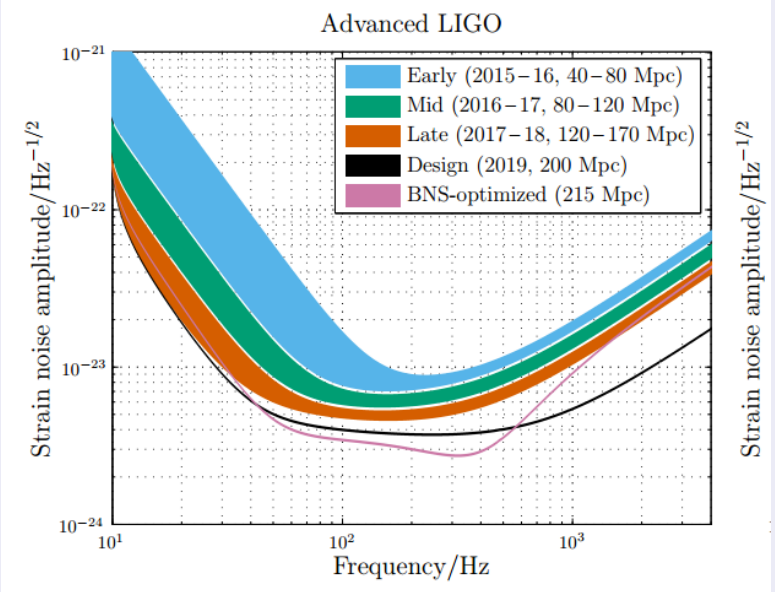
Horizon distances of Advanced LIGO-VIRGO network [3]

Binary Neutron Star: 445 Mpc
Neutron Star-Black Hole: 927 Mpc
Black Hole-Black Hole: 2187 Mpc

GLADE capabilites

Complete to 73 Mpc
53 % complete at 300 Mpc [4]
Catalogs with 75 % completeness perform comparably to the complete ones [5]

Inspiral ranges of BNS with the Advanced LIGO[6]



[3]LIGO Scientific Collaboration, Virgo Collaboration, 2010, arXiv:1003.2480

[4]Dalya et al., 2016 (in prep.)

[5] C. Hanna et al., 2013, ArXiv e-prints, arXiv:1312.2077

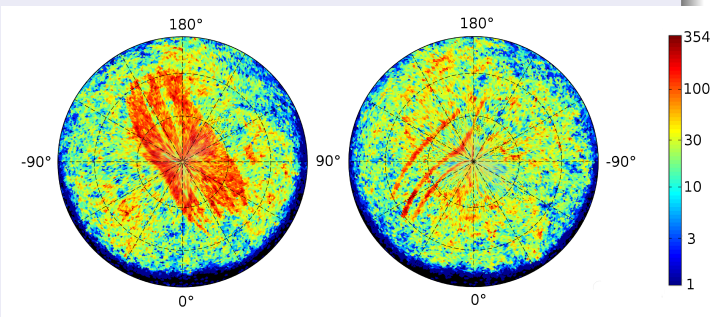
[6]LIGO Scientific Collaboration, Virgo Collaboration, 2016, arXiv:1304.0670

GLADE

Parameters

1.9 million galaxies after matching
71% complete at O2 BNS inspiral range
Catalogs included:

- GWGC (53.000) [7]
- 2MASS XSC (1.6 million) [8]
- 2MPZ (0.9 million) [9]
- HyperLEDA (0.8 million) [10]



[7] White, D. J., Daw, E. J., & Dhillon, V. S. 2011, Classical and Quantum Gravity, 28, 085016

[8] Skrutskie, M. F., Cutri, R. M., Stiening, R., et al. 2006, AJ, 131, 1163

[9] Bilicki, M., Jarrett, T. H., Peacock, J. A., Cluver, M. E., & Steward, L. 2014, ApJS, 210, 9

[10] Makarov, D., Prugniel, P., Terekhova, N., Courtois, H., & Vauglin, I. 2014, A&A, 570, A13

Challenges

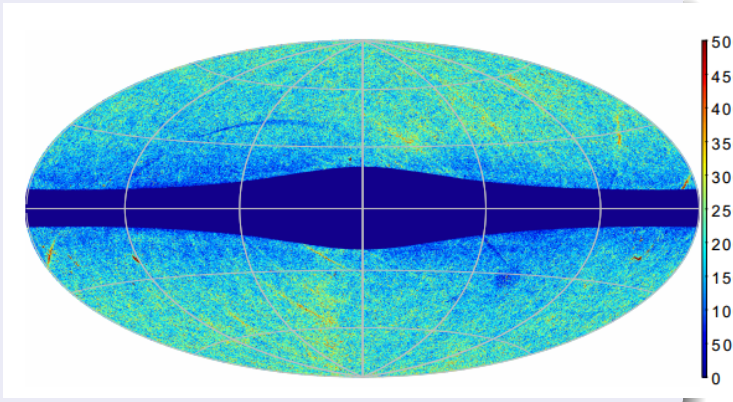
- None of the deep catalogs cover the full southern sky
- Southern sky: WISE (only IR)

- Large photometric surveys:
  - There are no spectra
  - No spectro-z $\rightarrow$ photo-z
  - Star, galaxy and quasar classification without spectra $\rightarrow$ machine learning
- Introducing classification probability

Development of galaxy/star/qso classification of WISE [11]

WISE source classification

- Support Vector Machine for SDSSxWISE
- Flux-limitation of W1 < 16 mag
- Three classification parameters:
  - W1 magitude
  - W1-W2 color
  - Differential aperture magnitude
- $\sim$ 45 million galaxy candidates
- Completness of galaxy sample:96-80%
- Purity is $\sim$ 80%
- Photo-z must be done



[11] A. K... et al., 2016, A&A ...

Pan-STARRS

Pan-STARRS parameters

- EGRG is a member of the Pan-STARRS project
- Soon to be published
- 3 π
- Galaxy/star/quasar classification is partly done

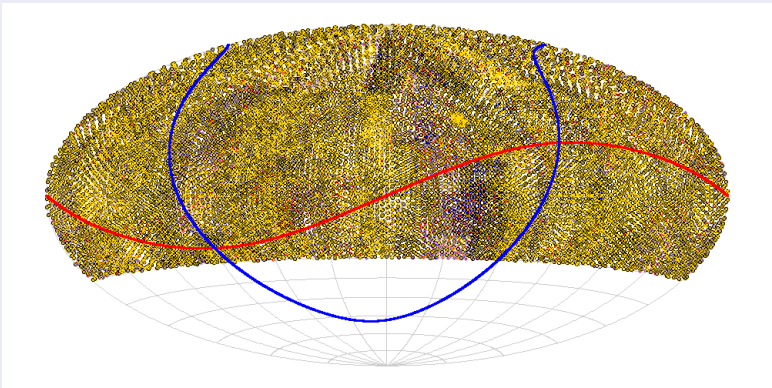
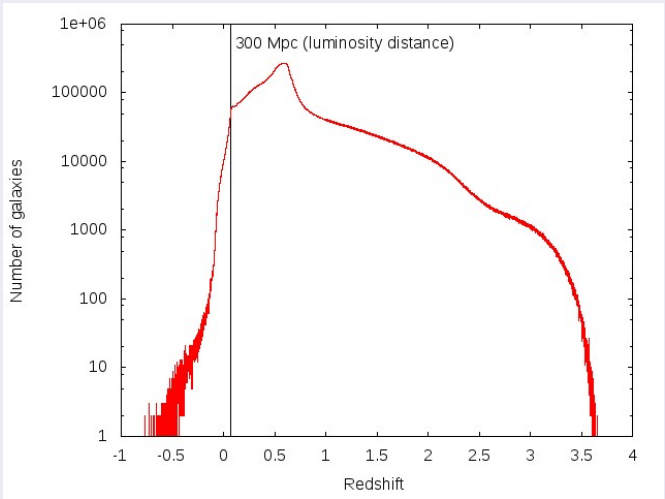
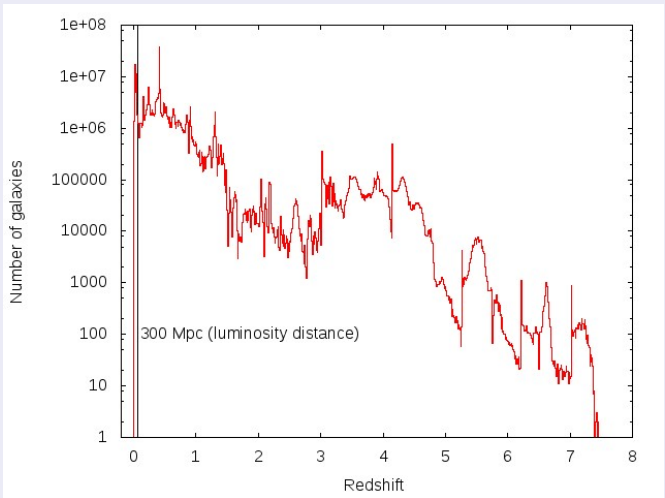


Photo-z histograms

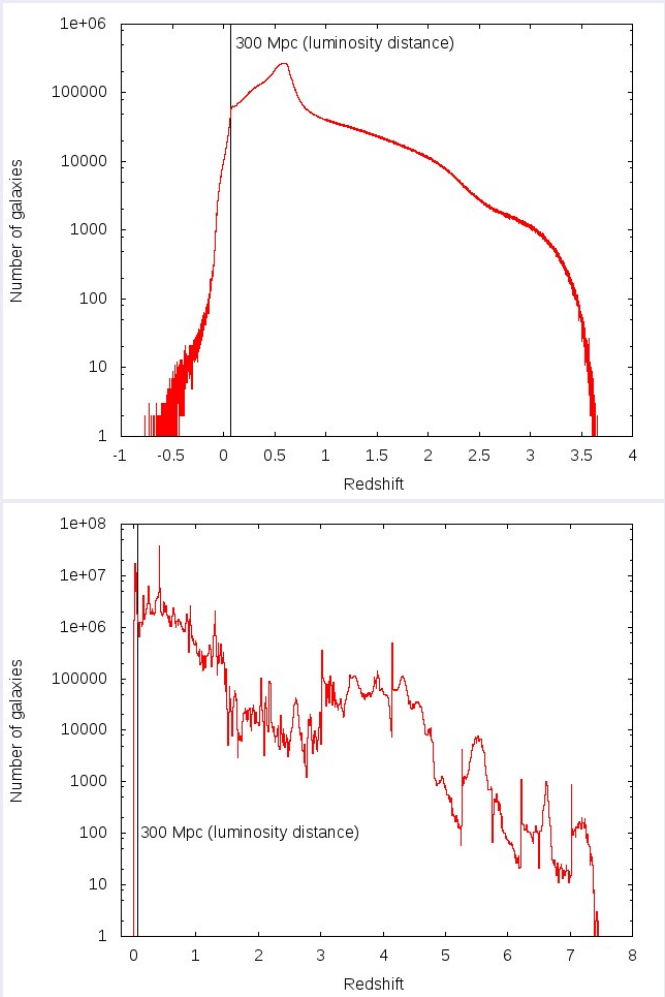




Current source classification

- 91 million gxs with $\geq 75\%$ probability
- 22 million gxs with $\geq 90\%$ probability
- At 300 Mpc:
  - $\sim$ 10 million gxs with $\geq 75\%$ probability
  - $\sim$ 1.5 million gxs with $\geq 90\%$ probability
- Photo-z must be done

Photo-z histograms



Future of GLADE

- Galaxy/star/quasar classification probability
- Target selection strategy
- BNS rate for EM-follow up searches:
  - B magnitude [7]
  - Stellar mass
- Photo-z

Catalogs to be included:

- **WISE** $\sim$ 5-10 million galaxies
- **Pan-STARRS** $\sim$ 10-20 million galaxies
- GALEX / DPOSS (?)
- On the fly catalogs [12]

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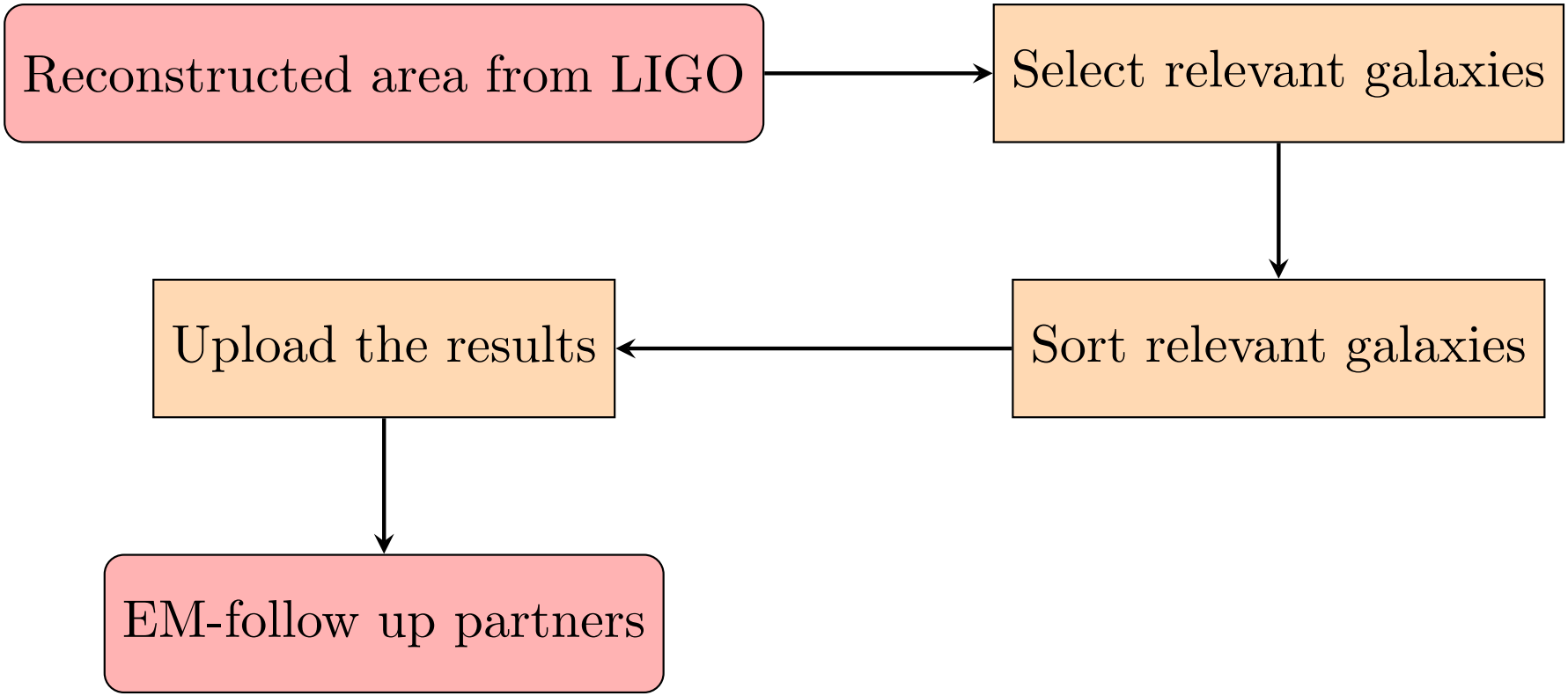
[7] White, D. J., Daw, E. J., & Dhillon, V. S. 2011, Classical and Quantum Gravity, 28, 085016

[12]Bartos, I., Crotts, A. P. S., & Marka, S. 2015, ApJ, 801, L1

Proposed EM-follow up search method

The key for a successful afterglow search is time
Automated pipeline is needed



Discussion about VO tools

We did not use VO tools so far
We would like to upload GLADE to VizieR

Scalable and multi-dimensional cross-matching of galaxies in multiple catalogs

Defining standardized full-sky and multi-directional completeness measures for galaxy catalogs:

- Using blue luminosity density
- Using Schechter function

Improving photo-z calculation with combined multi-catalog data