Model Faint Blue Galaxy Depth Threshold Analysis for the Newly Proposed Sirenas Survey

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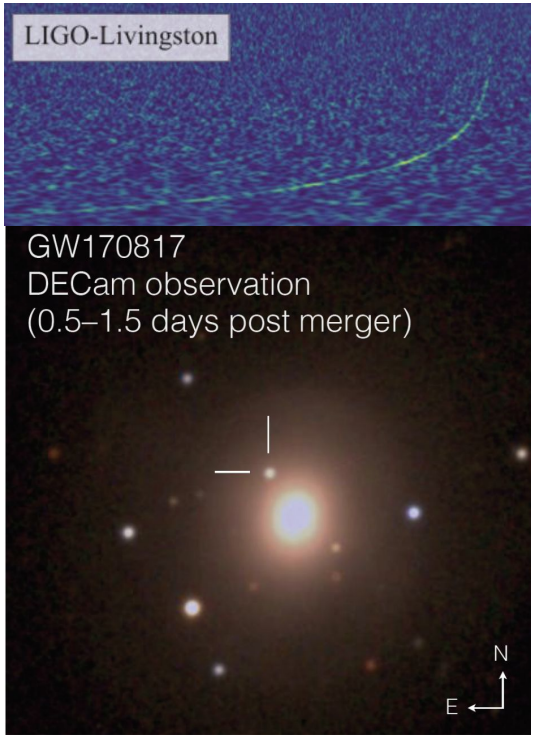
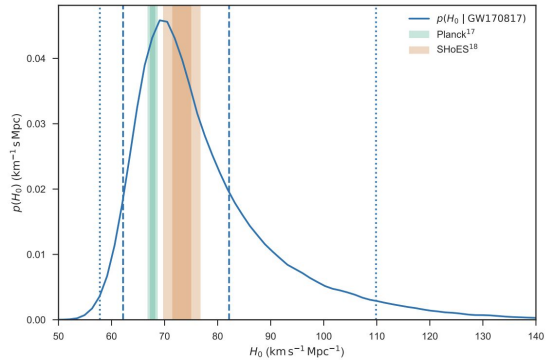
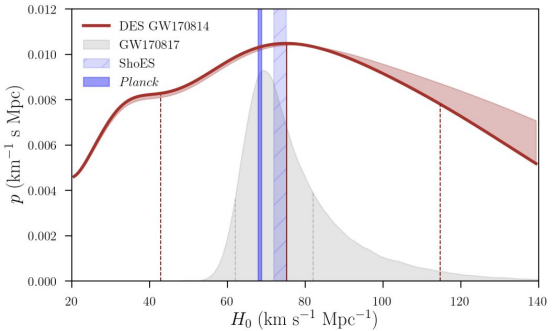
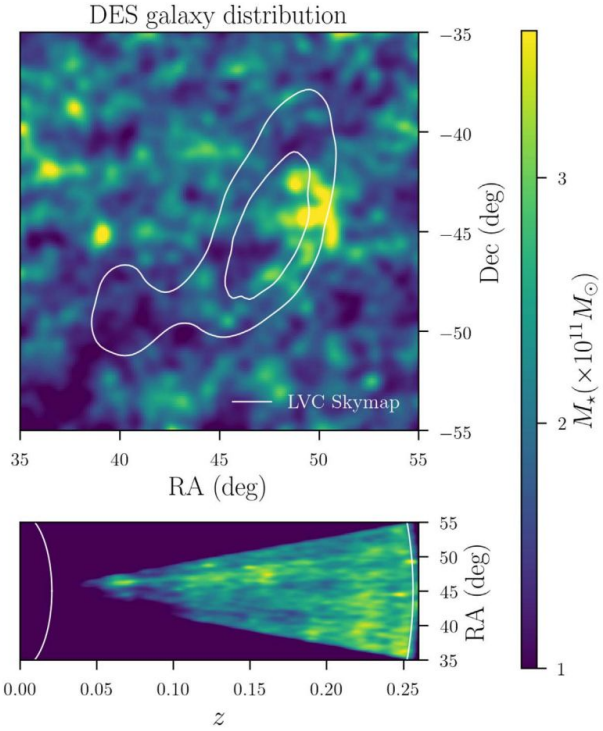
GW cosmology: How it started

LIGO/ Virgo Collaboration, **PRL** 119 161101, 2017.
LIGO/Virgo & partner collaborations, **ApJL** 12 59, 2017.
LIGO/Virgo & partner collaborations, **Nature** 551 85, 2017.
DES and LIGO/Virgo Collaborations, **ApJ** 876L 7, 2019.



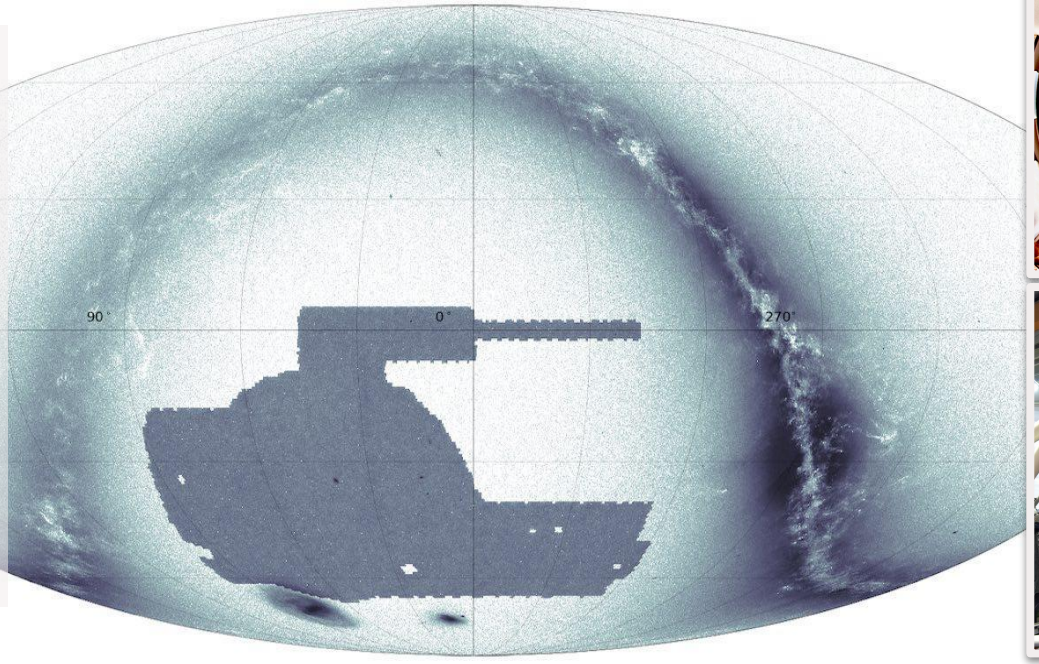






The Dark Energy Survey

- 570 Megapixel camera for the Blanco 4m telescope in Chile.
- Full survey 2013-2019
- **Wide field:** 5000 sq. deg. in 5 bands. *i*~24 magnitude.
- **DES Year 6 Legacy results analysing**: positions and shapes of > 140M galaxies.



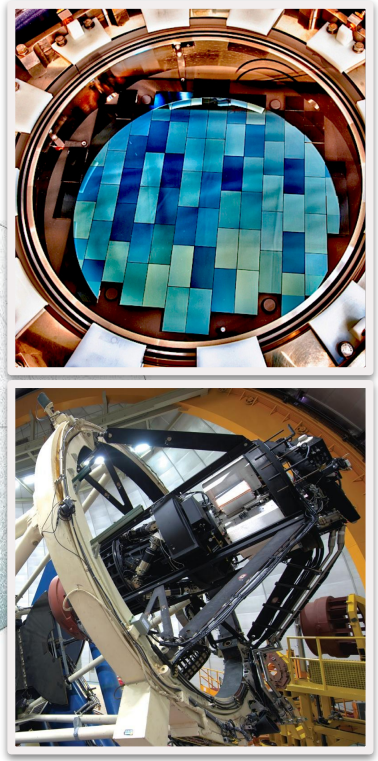
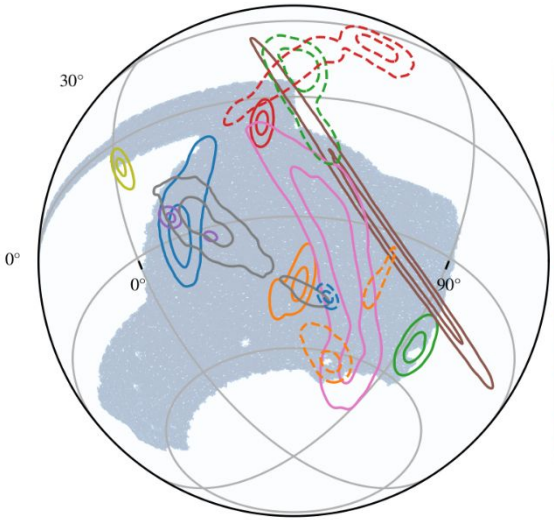


Image Credit: CosmoHub, Port d'Informació Científica (PIC)

Many exciting developments in the community (only a few shown here):

- **Hernandez & Ray 2024: GWTC-3 events only,**
  - H0 = 73 + 13 - 7
- **Bom et al 2024: 15 events in DELVE/DESI Legacy Survey,**
  - H0 = 70.4 + 13.6 - 11.7
- **Alfradique et al 2024: 10 events in DELVE,**
  - H0 = 76.0 + 17.6 - 13.5
- **Stachurski et al 2023: 47 events in GLADE+,**
  - H0= 74 + 14 - 13
- **Palmese et al 2023: 8 events in DESI Legacy Survey,**
  - H0 = 79.8 + 19.1 - 12.8
- **LVK 2023: 47 events in GLADE+,**
  - H0 = 68 + 12 - 8
- **MacMahon et al (in prep): 8 events in DES,**
  - H0= 67 + 12 - 11 (preliminary)

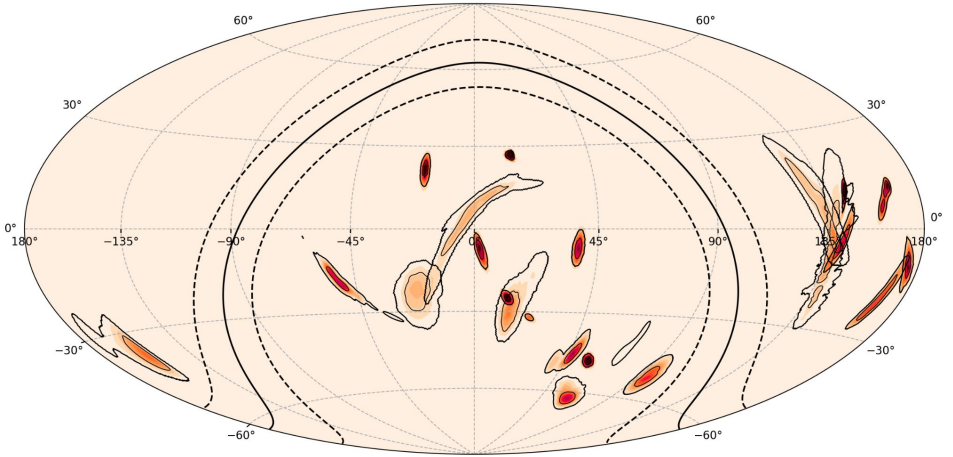
DES coverage of events



Sirenas

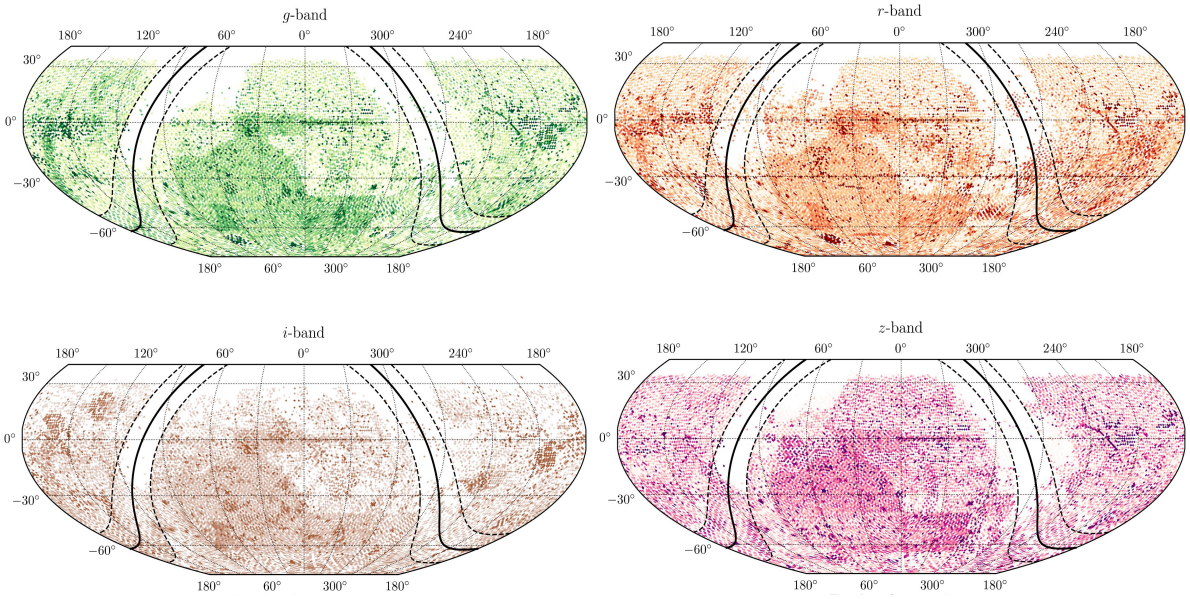
- Sirenas is a new photometric survey proposal for DECam's next observational cycle, that aims to create a new galaxy catalog for better cosmological constraints from GW events.
- Sirenas is a highly optimized survey, taking advantage of archival data and only doing complementary observations to achieve this goal.

Credit: MacBride/Sirenas



Selected LVK events up to March 28, 2025 (observable by DECam)

Existing DECam coverage



Credit:Sanchez-Cid/Sirenas

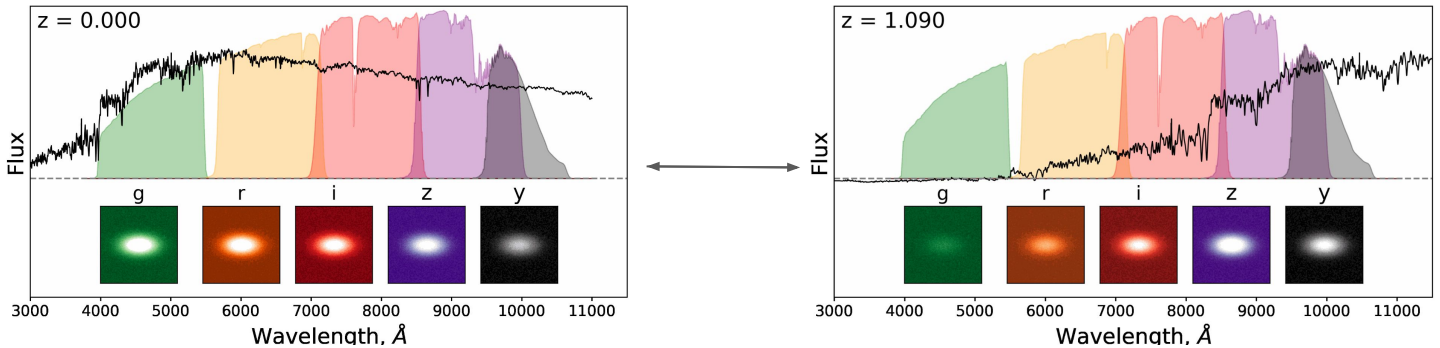
- The goal is to achieve DES-like completeness fraction for galaxies over the 90% regions of well-localized GW events.
  - DES Y3 resulted in a volume-limited (95% complete) sample to –17.2 mag in r-band (3.8 x 108 solar masses) for GW170814 which was at z~0.2.
  - We have ~20 well-localized events at various distances ranging up to z~0.7. This means we need to go deeper in some regions than others to achieve a uniform level of completeness.

This study

- In this work we aim to determine the apparent magnitude thresholds corresponding to the target absolute magnitude of the Sirenas survey.
  - For a given absolute magnitude threshold, the apparent magnitudes will be different because the GW events are not at the same distances.
  - The thresholds help us optimize the telescope time which is limited and valuable. This way no excessive or insufficient time is used for each of the sky areas.

$m = -2.5 \log_{10}(\text{flux}) - \text{const.}$

$M = m - 5 \log_{10}(d_L/10\text{pc}) - K(z)$



Credit: McCullough, J.

Analysis Rationale

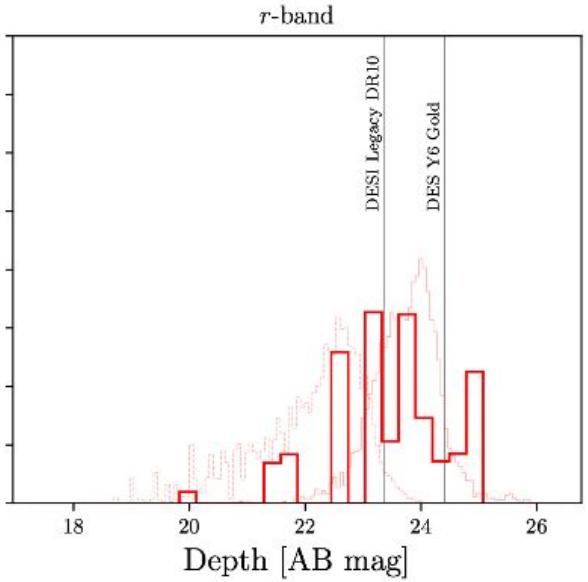
- Since faint blue galaxies are harder to observe, they are a better template to create our constraints
  - What is the apparent magnitude threshold to detect this galaxy at a given distance?
- To first order, the calculation uses only the distance modulus, but to refine our analysis, we need to include the K-correction which depends on the redshift. This introduces a dependency on cosmology, which we avoid by making a conservative choice:
  - We pick **extreme** cosmology parameters (**H_0=120 km s^{-1} Mpc^{-1}, Ω_m=0.5**) at the edge of the prior range we plan to use in the analysis.
  - We then pick Planck-18 parameters for real GW event distances for comparison.

Triangulum Galaxy
NASA, ESA and Durbin M., Dalcanton J., and Williams B. F. (University of Washington), Public Release, 2019.

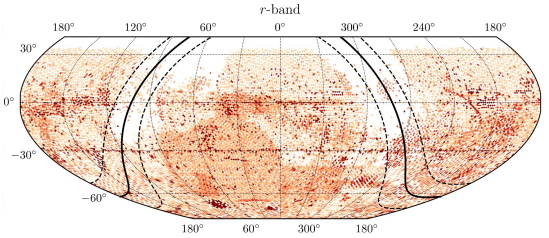
- Used libraries:
  - bagpipes (Carnall, A.C. et. al., **MNRAS** 480 4379, 2018.)
  - kcorrect (Blanton, Michael R.; Roweis, S., **ApJL** 133 734, 2007.)
- Due to faintness and considered distances ⇒ modeled after Triangulum galaxy
- DECam filters used to produce observation

Results: Sirenas Depth Requirements

- As a result of this study we have determined the depth requirement for each pixel in the sky. From here the observation time is computed.
- On the right is an example depth result for the r-band (this was done for all the 6 bands)
- In total, the survey will take 75 nights to obtain an optimized catalog for 18 GW events



Credit:Sanchez-Cid/Sirenas



Credit: MacBride/Sirenas