Searches After Gravitational-waves Using ARizona Observatories (SAGUARO): Updating Optical Counterpart Search Methods

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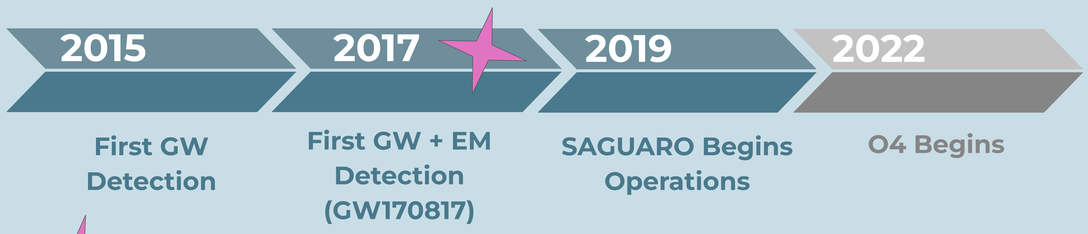
Gravitational Wave Sources

When two neutron stars merge into one, the resulting explosion emits both gravitational waves (GW) and electromagnetic (EM) waves. One such EM emission is a kilonova that can be seen in the optical band, termed the **"optical counterpart"** to a GW event.



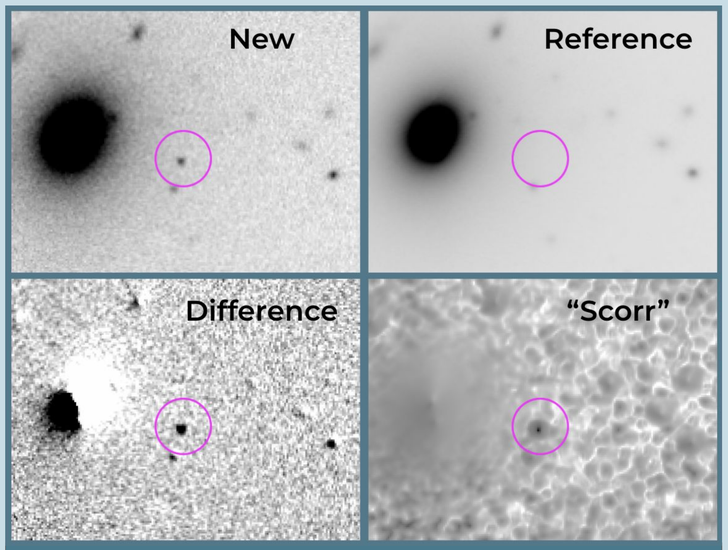
GW170817 is the first and **only** well-studied GW + EM event to date, thus motivating a search for future counterpart discovery.

*taken shortly after GW alert
Bok telescope data

*stack of several images to create a deep template
BASS data

*visualizes differences between new and reference

*visualizes signal-to-noise ratio (significance)



An example of image subtraction results using ZOGY. With BASS data as a reference, ZOGY successfully identified the transient SN2018aaz.

Our Team

SAGUARO

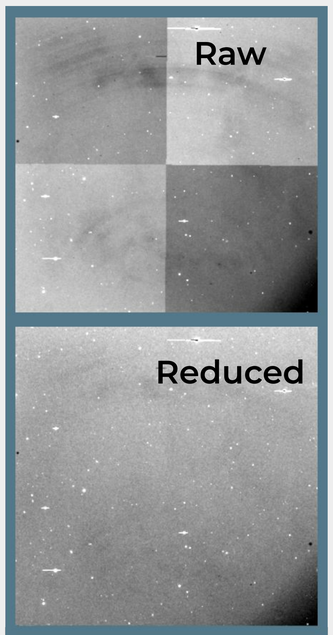
Searches After Gravitational-waves Using ARizona Observatories **(SAGUARO)** is a telescope network dedicated to GW optical counterpart discovery. We began operations in 2019, coinciding with LIGO-Virgo's[1] 3rd observing run (O3). During O3, we utilized the 1.5m Mt. Lemmon telescope near Tucson, Arizona as our search engine.

In preparation for O4, we have made updates to our telescope network and software to facilitate optical counterpart identification. Scan these QR codes to access a paper with more information on SAGUARO and our data reduction software!

Results: Updates for O4

New Discovery Engine Telescope

- Integrated the **2.3m Bok Telescope** to work alongside the 1.5m Mt. Lemmon telescope as a 2nd discovery engine
- Bok has a deeper field of view and can offer more color information
  - Advantageous for EM counterparts that are fainter or farther away

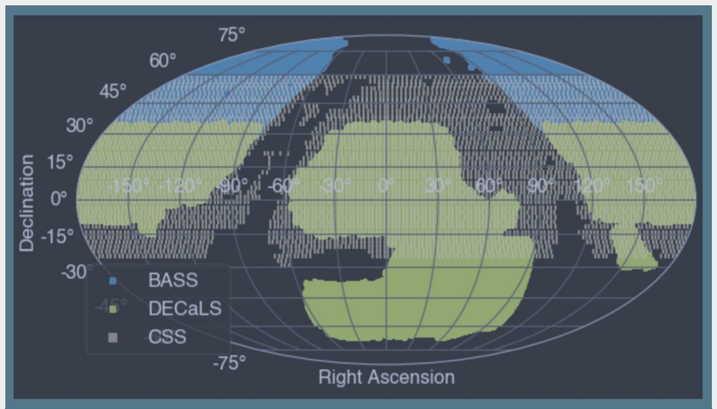


Data from the Bok telescope

Integrating New Telescope Data

- Data from Bok has been reduced and adapted to work with our **image subtraction software, ZOGY[2]**

Compatible Reference Images



Sky coverage of BASS, DECaLS, and CSS

- Analyzed Beijing Arizona Sky Survey (BASS)[3] and Dark Energy Camera Legacy Survey (DECaLS)[4] data for use as reference images
- Assessed quality of ZOGY results using BASS reference data and Bok new data
- Made recommendations on reference images and improvements for image subtraction

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1. Abbott, B. P., Abbott, R., Adhikari, R., et al. 2009, Reports on Progress in Physics, 72, 076901
2. Zackay, B., Ofek, E. O., & Gal-Yam, A. 2016, ApJ, 830, 27
3. Zou, H., Zhou, X., Fan, X., et al. 2017, Publications of the Astronomical Society of the Pacific, 129, 064101.
4. Dey, A., Schlegel, D. J., Lang, D., et al. 2019, The Astronomical Journal, 157, 168.

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