# Wide field optical follow-up observations
## to gravitational wave triggers

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## Introduction

A detectable burst-like, gravitational wave (GW) event would likely originate with a close, highly energetic astrophysical process. Such an event could also emit noticeably in electro-magnetic (EM) radiation. Here we concentrate on the optical spectrum. **It is possible to search for dual GW/optical events with enhanced GW sensitivity by systematically seeking transient optical counterparts to candidate GW triggers.** This poster discusses some practical aspects of optical follow-up observations to GW triggers. We emphasize possibilities for future science runs of the LIGO/Virgo network in conjunction with optical instruments that see a few square degrees in each field of view.

## Gravitational Wave Position Reconstruction

An effort is currently underway in the LSC/Virgo collaborations to develop and characterize algorithms to determine source direction based on interferometer data [1]. The work is still in progress, however, we expect that reconstructions with a typical accuracy of ~3 degrees are possible. This position uncertainty motivates the choice of "wide field" instruments with fields of view of at least a few square degrees. For example, the ROTSE III and TAROT systems could cover such a typical region in ~8 tiles. The SkyMapper survey telescope would require ~5 tiles.

## Sources and Timing

A variety of possible source mechanisms motivate this search. Theoretical and numerical models predict nova-like transients from double neutron star and black hole/neutron star mergers [2]. GRB afterglows and supernovas are both well-studied phenomenon associated with gravitational radiation [3,4].

While GW and EM signals are expected to travel at the same speed, a common astrophysical source mechanism may induce a delay between them. For example, the afterglow to an off-axis GRB (orphan afterglow) might not be visible until after some loss of kinetic energy in the relativistic ejecta. The associated time scale is the jet-break time, typically between a few hours and a few days. Other models include similar or longer wait times for the source matter to become optically thin. The large uncertainty in time scales motivates observing as quickly as possible, and again with varying delays of hours to days.

## Background Coincidences

Optical follow-ups will effectively improve GW sensitivity by providing an additional coincidence test; in this analysis, we will reject any GW candidate with no transient optical counterpart. Following up GW triggers routinely could entail a large amount of sky coverage, and so lead to transients in images that are incidental, i.e. not associated with the GW emission. Expected sources of incidental transients include minor planets, cataclysmic variables/novas, and flare stars. Many of these can be removed from a sample based on distinctive properties and comparison with catalogs.

However, unidentified transients mimicking the properties we seek could also appear, unrelated to GW emission. What is this rate of incidental, afterglow like transients? Parameters including cuts on decay time and limiting magnitude affect this rate. As a case study, consider observing with the ROTSE III system. In a search for untriggered GRB afterglows [5], the ROTSE collaboration analyzed images with about 47,000 deg$^2$ of coverage. In this search, they found no transients with the properties of GRB afterglows. Using this, we estimate a limit of one non-removable transient for every 600 interferometer guided observations. The actual rate could be considerably less than this, leading to a statistically powerful coincidence test.

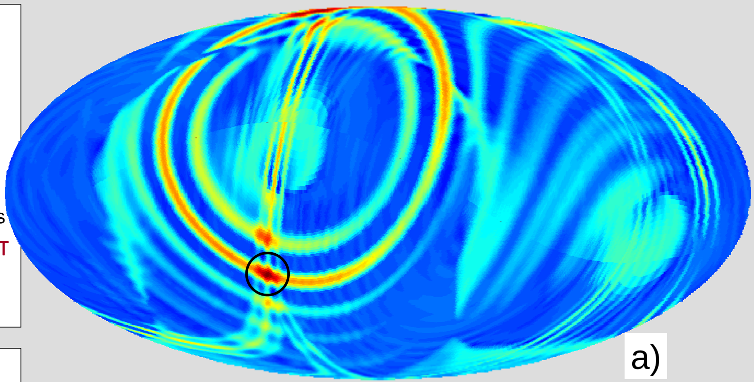
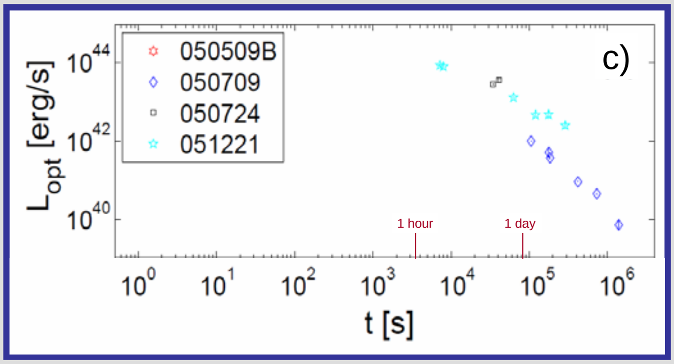



*Image courtesy Antony Searle*


*Photo courtesy ROTSE collaboration*

Guiding telescopes with GW data The anticipated process begins with GW position reconstruction. **a)** shows such a reconstruction for a simulated GW injected with an SNR of 10 at the circled location. The region to be viewed is passed to a wide-field optical instrument. The ROTSE IIIa telescope is shown in **b)**. It is unclear exactly what types of transients to expect, however, afterglows from short-hard GRB's, such as those shown in **c),** provide a rough guide [3].




This plot is adopted from Nakar E 2007 *Phys. Rept.* **442** 166-236


**References**

[1] See the talk *Reconstruction of coordinates of unmodeled burst sources with networks of gravitational wave detectors* at GWDAW 13
[2] Kulkarni S 2005 *Preprint* arXiv:astro-ph/0508138v1
[3] Nakar E 2007 *Phys. Rept.* **442** 166-236
[4] Müller E, Rampp M, Buras R, Janka H and Shoemaker D H 2004 *Astrophys. J.* **603** 221-30
[5] Rykoff E S *et al* 2005 *The Astrophys. J.* **631** 1032-38
[6] See https://geco.phys.columbia.edu/projects/loocup for more information on this project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