Multi-messenger astronomy

Ed Daw, Univ. of Sheffield, LSC, GOTO collaboration

Electromagnetic counterparts matter!

1.) As a way of establishing the validity of putative gravitational-wave signals.

2.) To test ideas about the sources of detected electromagnetic transients (for example, are short hard GRBs generated in compact binary coalescences ? How beamed are short hard GRBs ? What is the physics of other astronomical transients such as soft gamma repeaters?)

3.) As probes of fundamental astrophysics (eg, neutron star equation of state, strong gravity).

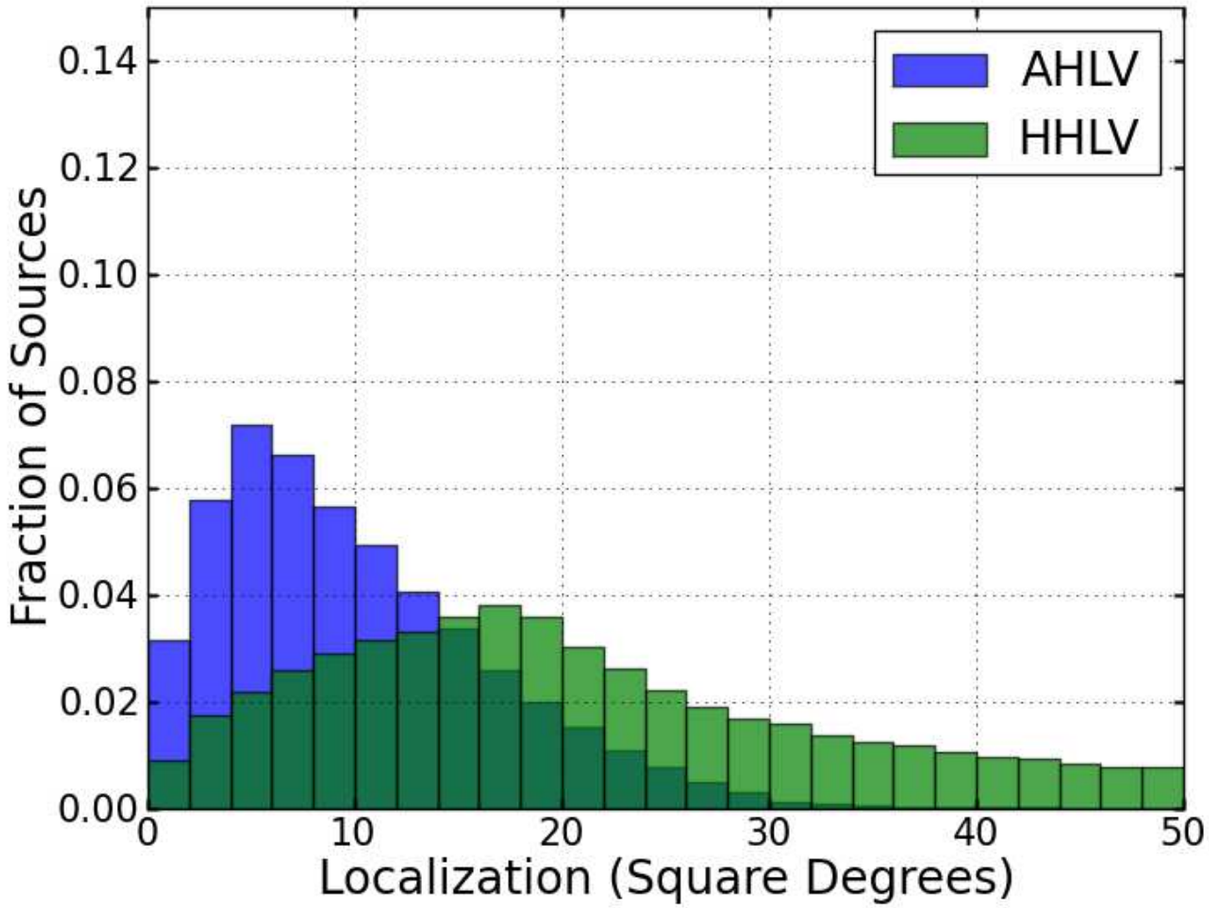
4.) To do fundamental cosmology (eg, distance ladder independent measures of H_0).

Multimessenger campaigns with GW during S6/VSR3

- ExtTrig effort using Gamma Ray Burst triggers to constrain search of gravitational wave data.
- LoocUP optical follow-up effort with ROTSE, Pi-of-the-sky, Zadko, Wyse, Liverpool telescope
- Limits on known pulsars using CW gravitational wave searches.
- Collaboration with Fermi
- Collaboration with high energy neutrino detectors - ice cube
- Collaboration with radio telescopes such as LOFAR and ARECIBO
- Probably many others …. (apologies if your favourite was emitted)

Challenges of electromagnetic follow-up

Position reconstruction from gravitational wave events yields astronomically large error boxes on the sky

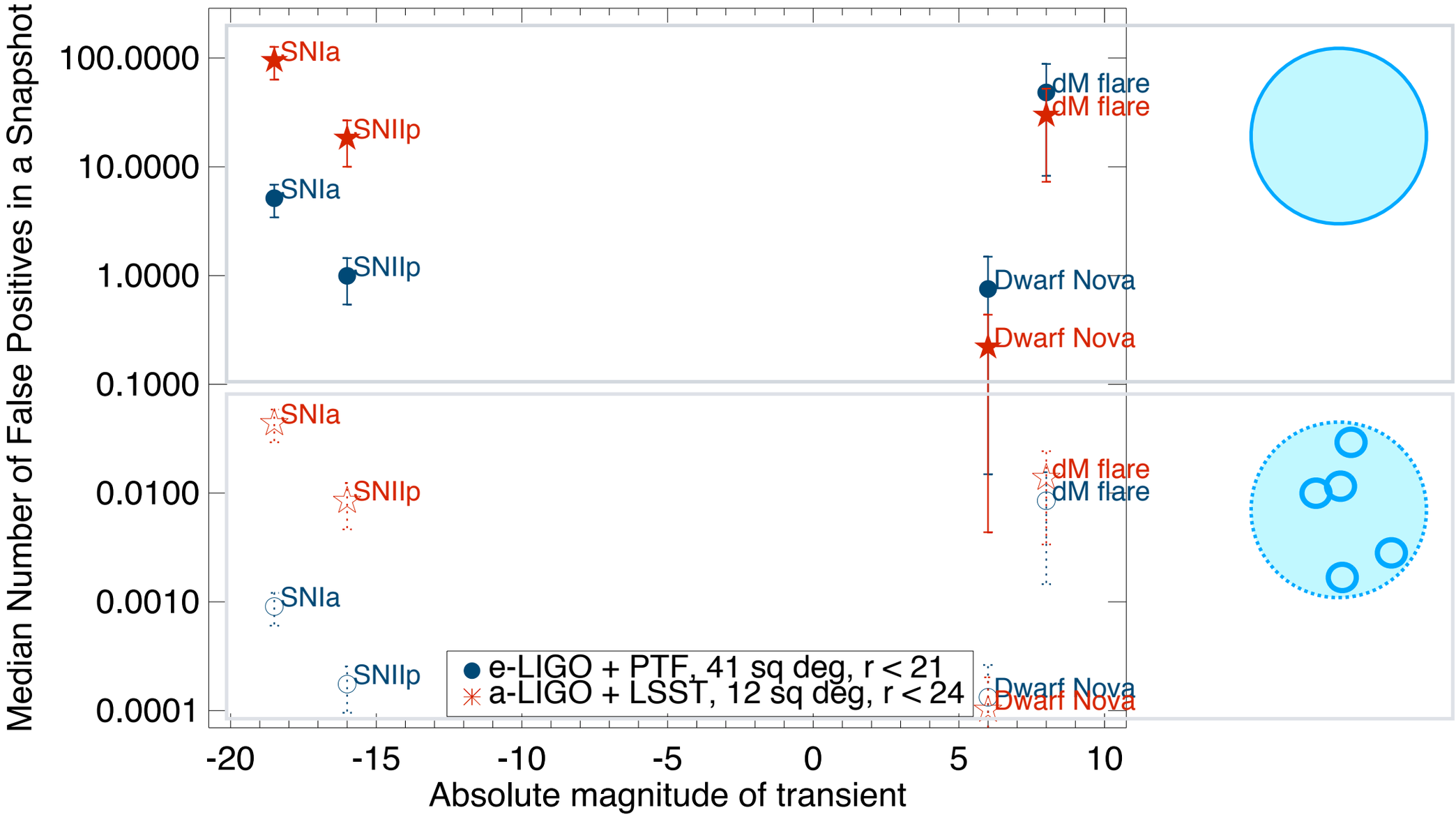


Fairhurst: arxiv:1010.6192v2

Foreground fog and background haze

Fairhurst et. al. and others, plus S6/VSR3 experience shows that reconstructed position of source has error box of 10s of square degrees [1]

[2]



[1] Fairhurst, arxiv:0908:2356

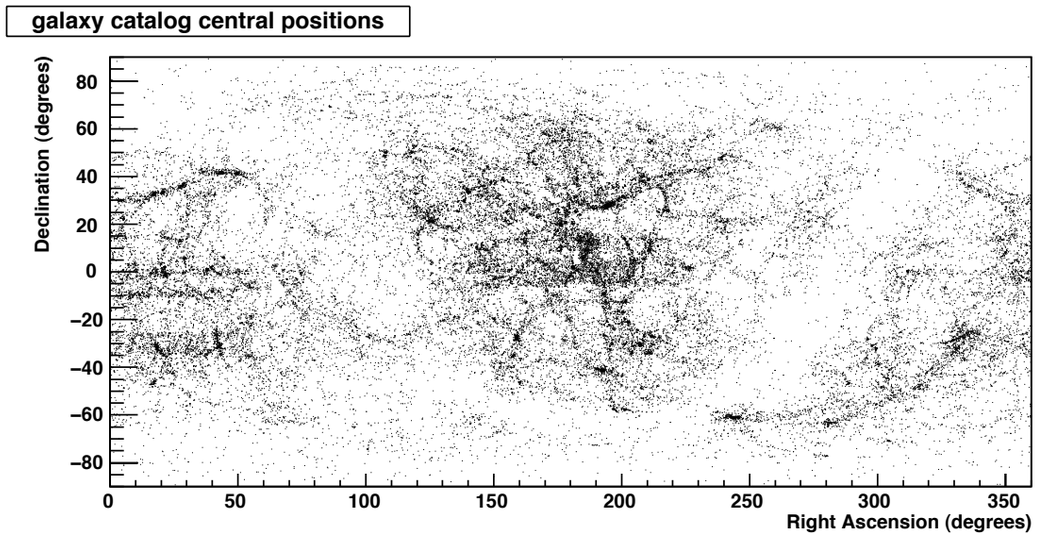
[2] S. R. Kulkarni and M. M. Kasliwal, arxiv:0903.0218

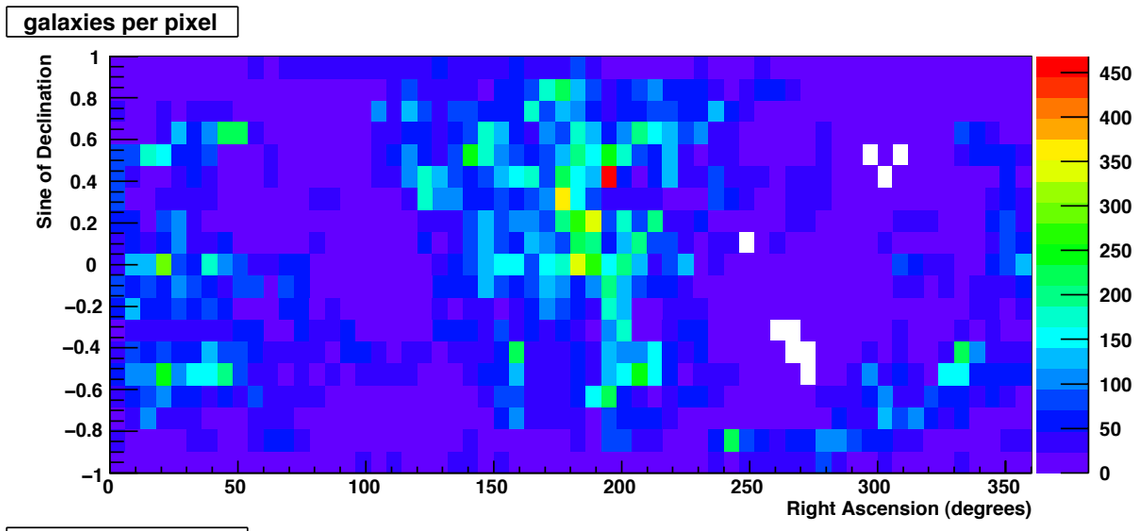
Galaxy Catalogues

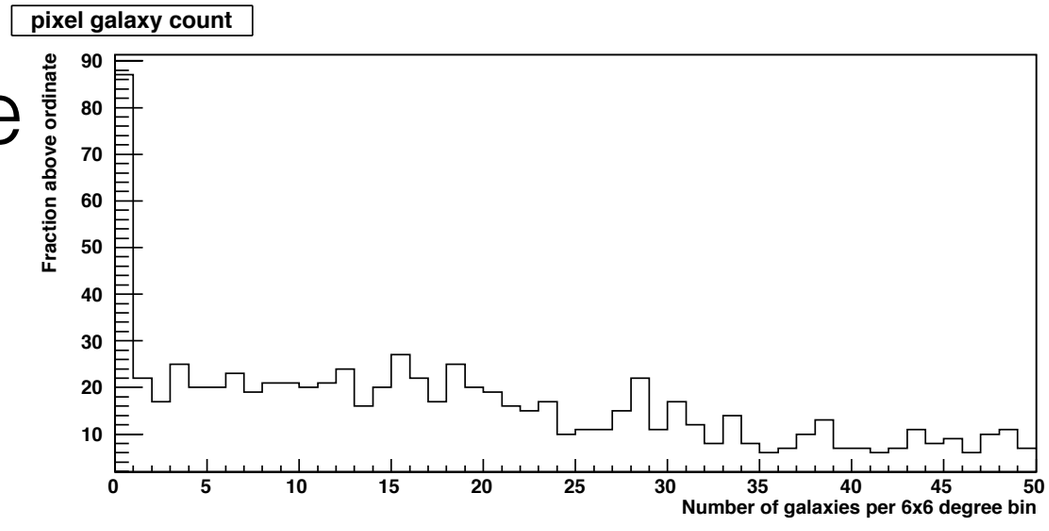
GWGC (white et al) 55k galaxies out to 100 MPc; estimated 50% complete to this distance.

Need more compete catalogues out to 100MPc.

In a 11 square degree field we will see a order of 10 galaxies.



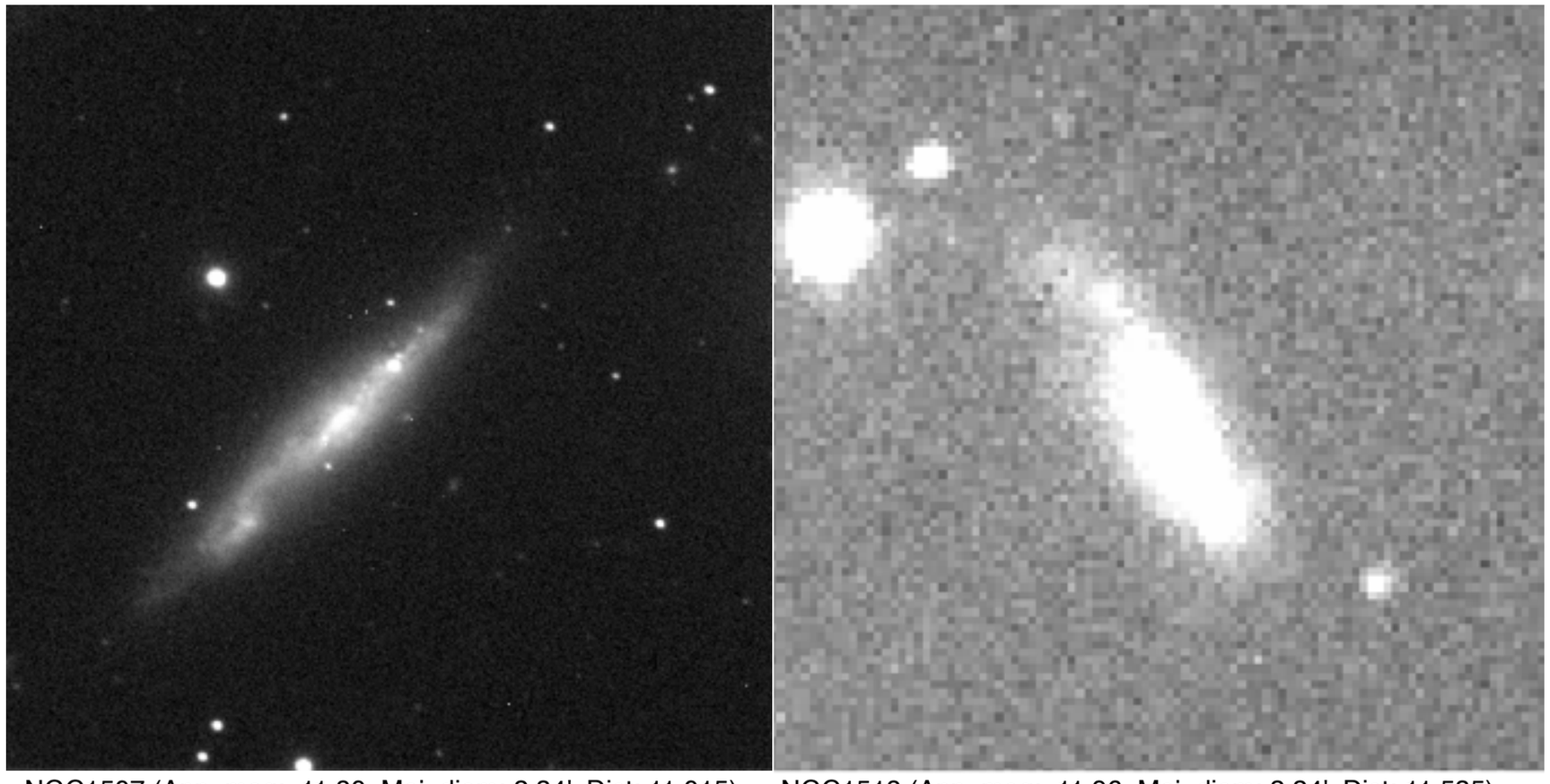




Instruments used for optical follow-up during S6/VSR3

Zadko
Liverpool Telescope

Pi of the sky
Rotse



NGC1507 (App. mag: 11.80, Maj. diam: 2.34', Dist: 11.015)
Liverpool telescope image

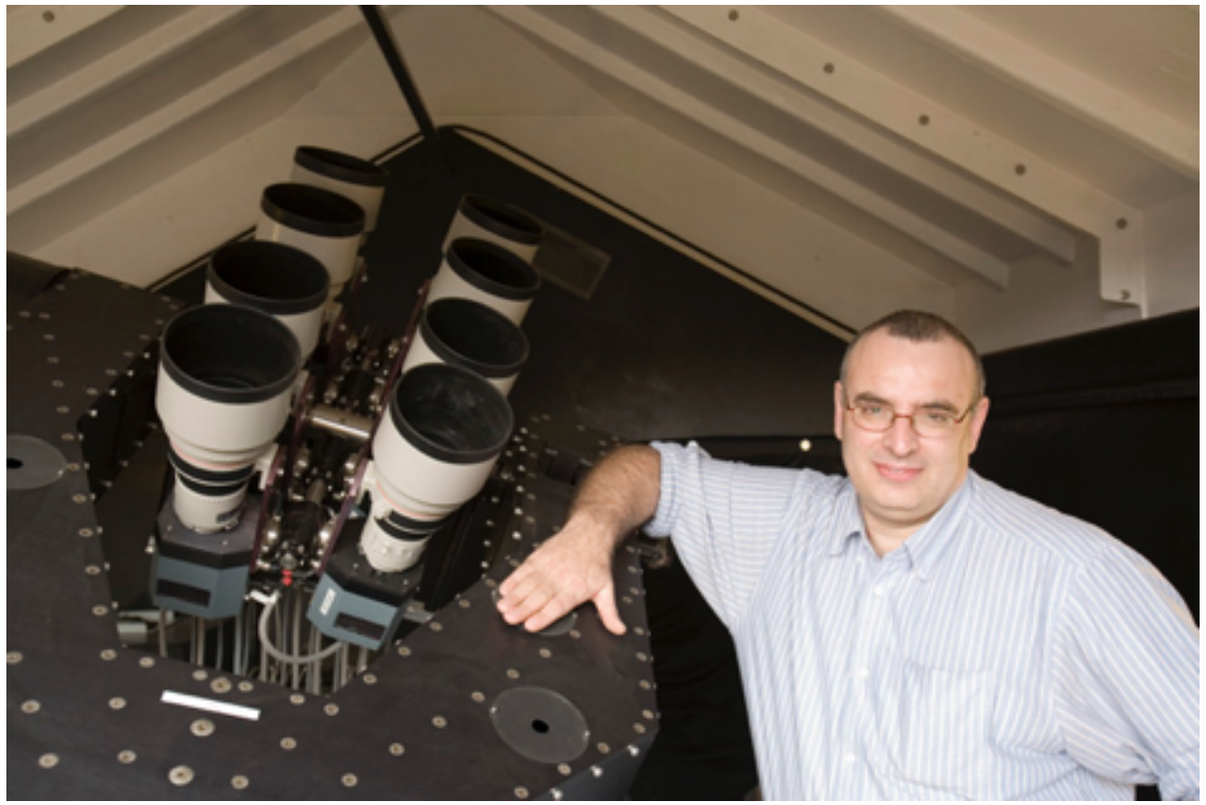
NGC1518 (App. mag: 11.96, Maj. diam: 2.24', Dist: 11.535)
ROTSE image

The LT image has arcsecond pixels, but the telescope FOV is 5 by 5 minutes. The ROTSE FOV is 4 square degrees, with 3.3 arcsecond pixels, but limited to 16th mag.

Gravitational–wave Optical Transient Observer

superWASP

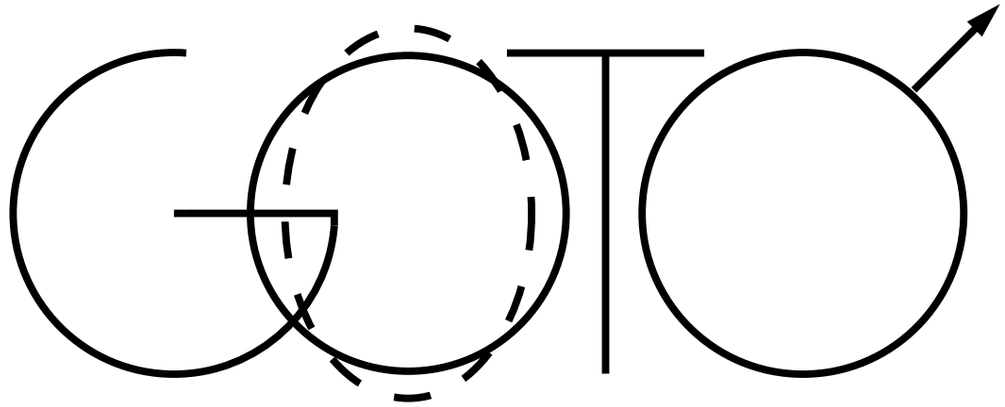
Don Pollacco and superWASP (wide angle search for planets)



http://www2.warwick.ac.uk/fac/sci/physics/events/news/?tag=Staff+and+Department

- superWASP is an array of 8 paparazzi lenses instrumented with large format CCDs run by the U.K. for finding planets.
- located on la Palma off the NW coast of Africa.
- built for finding planets by the transit method - looking for dips in the brightness of stars as orbiting planets pass through the line of sight.

http://www.optcorp.com/edu/articleDetailEDU.aspx?aid=1879



GOTO will be a dedicated wide field arcsecond pixel telescope for LSC/Virgo multi-messenger observations.

The project is led by Warwick, PI Danny Steeghs, with Don Pollaco (superWASP) designer, plus postdocs. Sheffield involvement through Vik Dhillon, Ed Daw, Stuart Littlefair, Justin Maund

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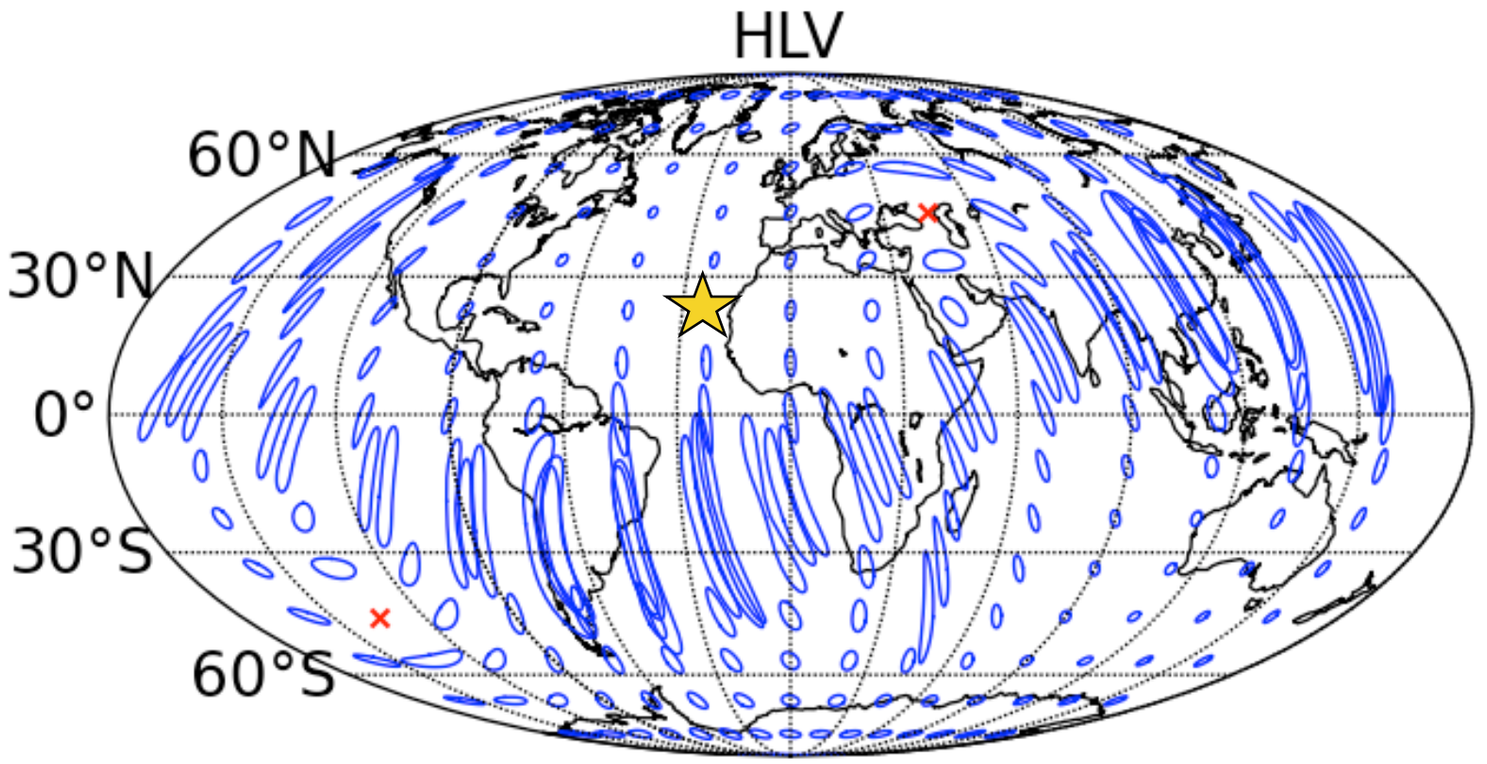
Gravitational–wave Optical Transient Observer

Intended Detector Site: La Palma

- LIGO 120-170 Mpc
- Virgo 60-85 Mpc
- Assume 80% duty cycles
- 0.04 - 100 BNS signals in 9 month run



Face on BNS @ 80 MPc
90% confidence regions

from Fairhurst, Gravitational-wave followup with electromagnetic facilities meeting, Warwick, 14th August 2013

Gravitational–wave Optical Transient Observer

specifications

- Phase 1 is an 11 square degree, 4 telescope prototype for deployment in 2015.
- 1st instrument deployed on La Palma, where the zenith has the sky positions of best angular reconstruction from LSC/Virgo.
- Each telescope is a 40cm, f2.5 astrograph having a 2.85 square degree field of view.
- Each telescope can reach 21st Magnitude in less than 5 minutes with 1.1 arcsecond pixels.
- Typical spiral galaxy occupies around 10000 pixels
- Deploy 4, plus another 4 contingent on additional funding.
- Upgrade will add 4 more telescopes, so a total of 8, all on the same mount, covering 22 square degrees.
- There is site space for a second mount, and the likelihood of a further upgrade to 44 square degrees.

Gravitational–wave Optical Transient Observer

Secondary alerts, spectroscopy

http://www.ice.csic.es/ca/view_project.php?PID=95

- An existing real-time pipeline for superWASP could be used to send follow-up alerts to the co-located 1m SQT telescope for high--resolution imaging in two colours.
- Tertiary alerts could then trigger TOO time on 4-8m class instruments for spectroscopy.

Source visibility at 100 Mpc

Let's make some cheeky assumptions and see where they get us. A core collapse supernova has an absolute magnitude of about -18. Let's assume that the optical signal from an extragalactic gravitational wave source has magnitude -15, which is 1/16 as intense.

$$m - M = 5(\log_{10} d - 1)$$

M=-15, d=10^8[pc], so m+15=35, therefore m=+20. This implies that with this absolute magnitude, significantly less bright than a core collapse supernova, the optical signal is above the magnitude threshold for GOTO at 100 Mpc.

It's not actually that simple, of course. The source is likely to be superposed on a background galaxy whose absolute magnitude is (assuming milky way) around -21. With these assumptions, the source to galaxy brightness ratio is about 1/250. BUT the galaxy is spread over many pixels, say 10000, in which case the SNR is 1/(250/10000)-1 = 39.

Gravitational–wave Optical Transient Observer

Funding

Warwick / Monash universities have provided £350k of funding for equipment and additional funds for 2 postdocs.

Sheffield provided £50k of funding for equipment and a departmental Ph.D. studentship (to be filled).

Other Universities (Glasgow, Leicester) have joined GOTO with a view to providing some support.

Status

La Palma site is certified and has IAP agreement
Quotes for the equipment are in process.
There's enough money for a 4 telescope (11 degree) instrument now, with (hopefully) more to come. The capacity of the 1st mount is 8 telescopes.