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SPECTROSCOPY OF CANDIDATE EM COUNTERPARTS TO GW SOURCES

http://telescope.livjm.ac.uk/

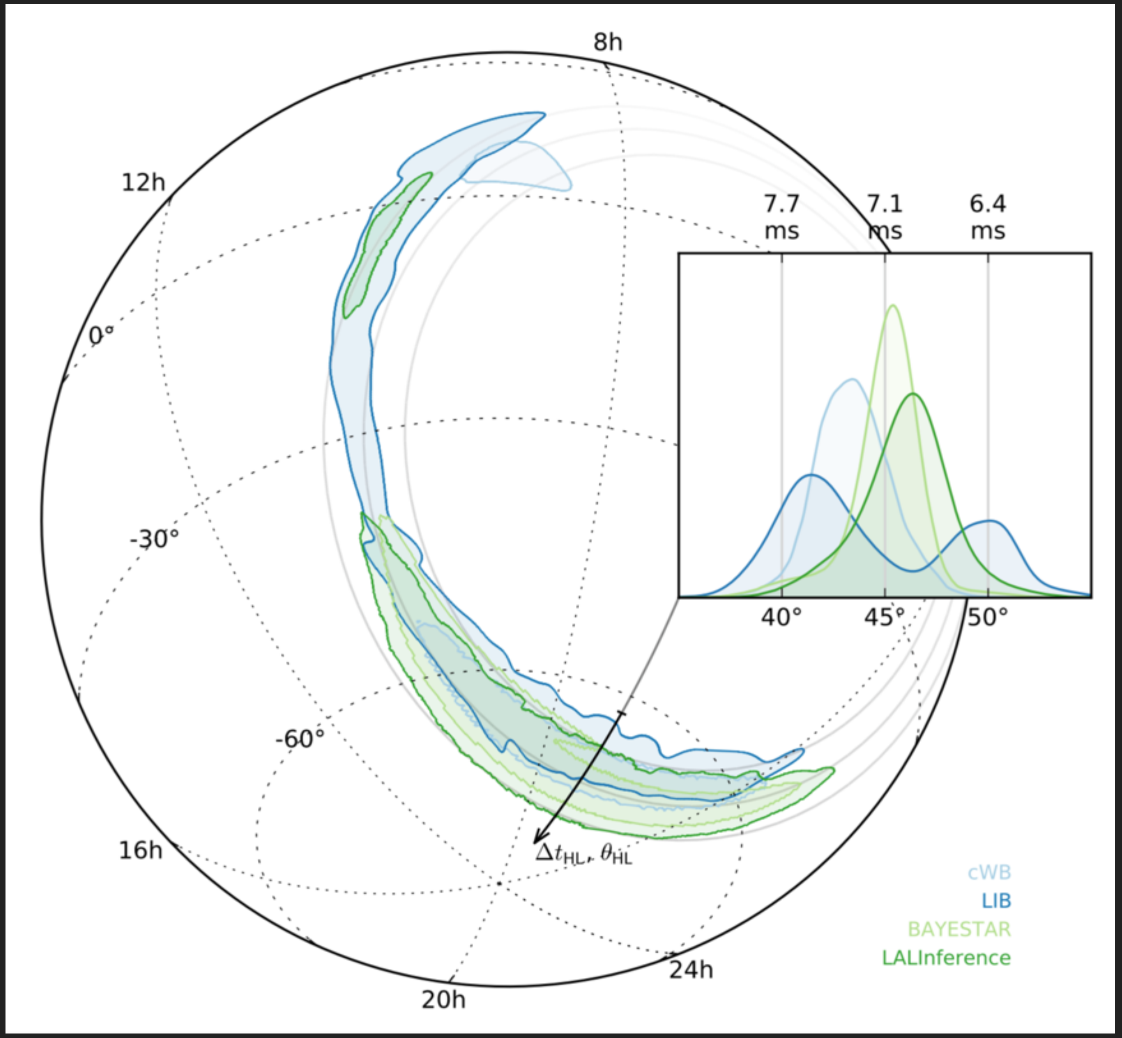
ELECTROMAGENTIC COUNTERPARTS

- binary mergers involving one or more neutron star (i.e. NS+NS or NS+BH) should show a transient EM signature due to energetic outflows:
  - If observer within jet opening angle could be similar spectral signature to "prompt" short GRB
  - Red kilo-nova emission from radioactive decay of heavy elements synthesised in merger ejecta
  - Low Lorentz factor jets - "failed GRBs" - orphan afterglow
- very nearby supernovae may also produce GW

WHERE TO LOOK?

TRIGGERS FROM ALIGO / VIRGO TO 63 MOU PARTNERS

- GCN Notices (machine interface)
- GCN Circulars (human interface)
- GraceDB (API and human interface)
  - Burst Time
  - Localisation (Sky Maps)
  - False Alarm Rate (Hz)
- Email list for discussion/speculation

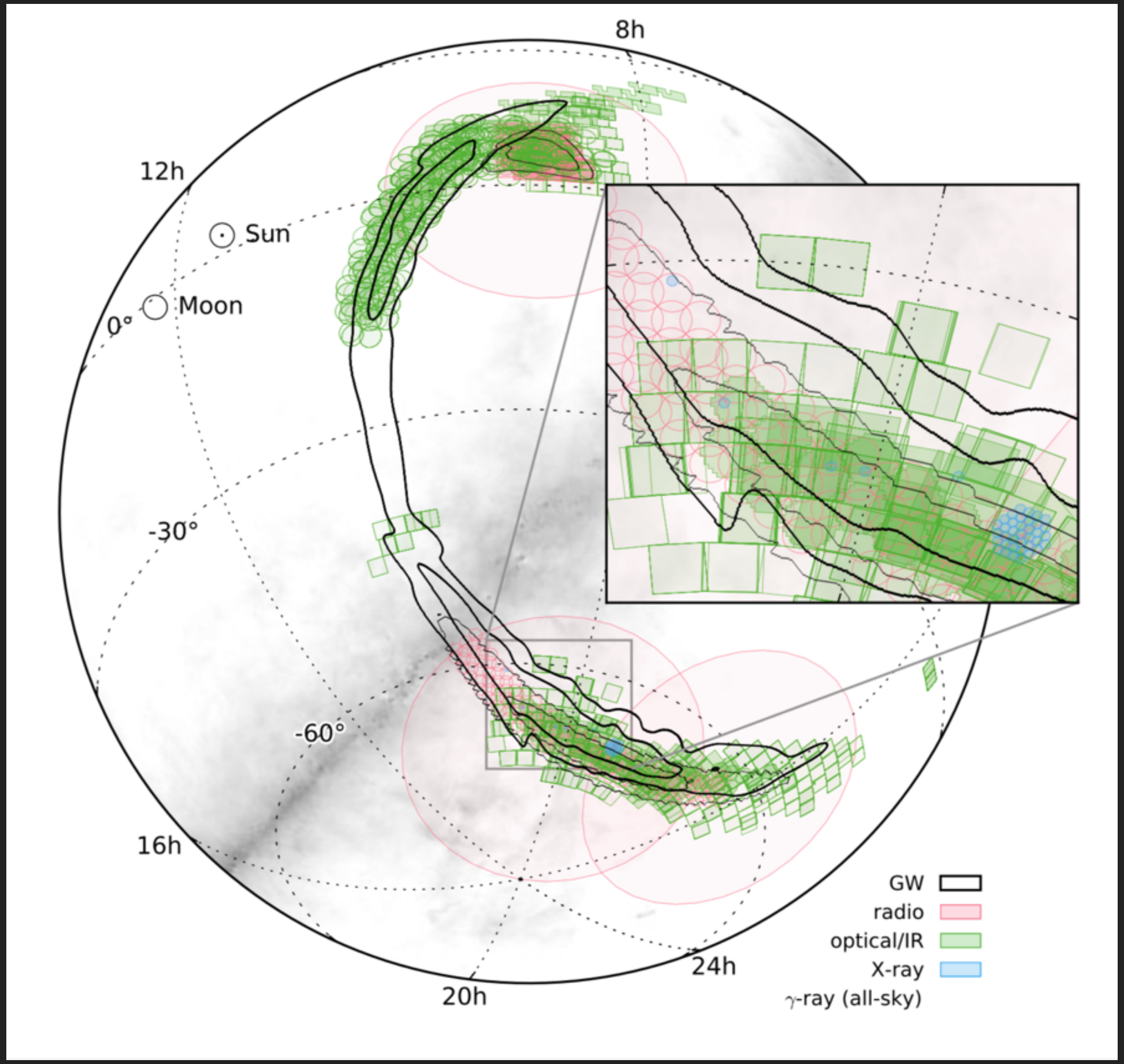


Final Sky Localisation map for GW150914

(Abbott et al 2016)

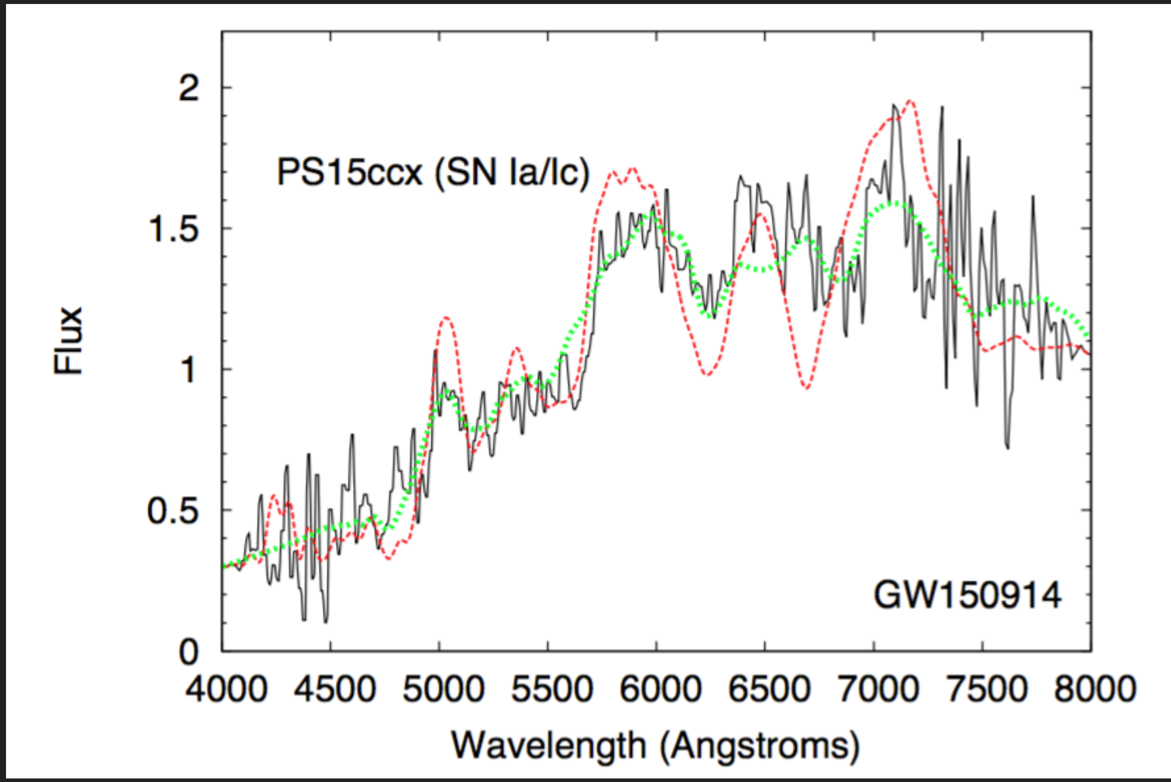
WIDE FIELD SURVEYS

- OPTICAL / IR
  - iPTF, PanSTARRS, SkyMapper, VISTA, MASTER, TOROS, TAROT, VST, DECam, Pi of the Sky
- High Energy
  - Fermi (LAT, GBM), MASTER, INTEGRAL, SWIFT
- Radio
  - MWA, ASKAP, LOFAR

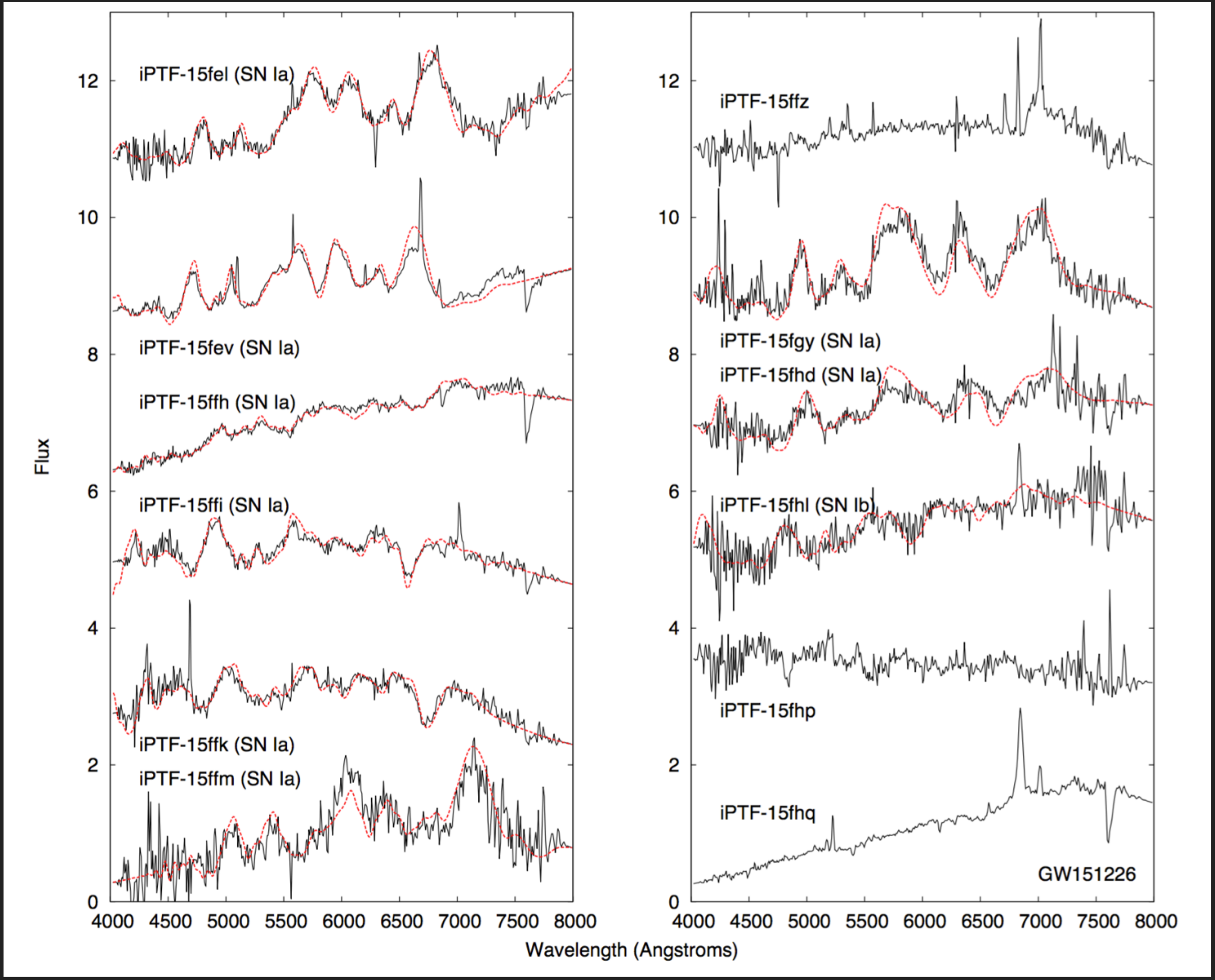


GW150914

- 36 + 29 $M_\odot$ black hole merger at ~410 Mpc (z~0.09)
- Detection made 2015 Sept 14. Alert issued 2015 Sept 16.
- PanSTARRS identified 56 candidates in northern error box (Smartt et al. 2016)
- Spectra by Keck, PESSTO, UH2.2 and Liverpool Telescope



GW151226 – 14.2 + 7.5 $M_\odot$ AT ~440 MPC (Z=0.09)



SUMMARY OF LT CLASSIFICATIONS FOR G194575 AND GW151226

Candidate ID	Comments
iPTF-15dkk	No obvious transient detected. Emission from host galaxy with $z = 0.061$
iPTF-15dkm	Supernova Type II, $z = 0.03$, $t = +4$ d, 96.5 per cent template fit
iPTF-15dkn	No obvious transient detected. Emission from host galaxy with $z = 0.074$
iPTF-15dld	Some broad emission features, with evidence of contamination by the host galaxy. Consistent with Type Ic supernova.
iPTF-15dln	No obvious transient detected. Spectrum shows host galaxy with $z = 0.051$
iPTF-15dmk	Supernova Type II, $z = 0.069$, $t = +2$ d, 98.1 per cent template fit
iPTF-15dmn	Narrow emission lines, consistent with AGN at $z = 0.056$
iPTF-15dnh	No obvious transient detected. Emission from host galaxy with $z = 0.056$
iPTF-15dni	Weak H-alpha emission with host galaxy absorption at $z = 0.020$

Candidate ID	Comments
iPTF-15fed	No transient detected to limiting magnitude of $R{\sim}19.1$
iPTF-15fel	Supernova Type Ia, $z = 0.038$, $t = +40$ d, 97.7 per cent template fit
iPTF-15fev	Supernova Type Ia, $z = 0.023$, $t = +50$ d, 94.7 per cent template fit
iPTF-15ffh	Possible supernova Type Ia, $z = 0.061$ $t = +15$d
iPTF-15ffi	Supernova Type Ia, $z = 0.085$, $t = +3$ d, 89.1 per cent template fit
iPTF-15ffk	Supernova Type Ia, $z = 0.102$, $t = +5$ d
iPTF-15ffm	Supernova Type Ia, $z = 0.094$, $t = +36$ d
iPTF-15ffz	Emission lines consistent with AGN at $z{\sim}0.07$
iPTF-15fgy	Supernova Type Ia, $z = 0.076$, $t = +20$ d, 84.7 per cent template fit
iPTF-15fhd	Possible supernova Type Ia, $z = 0.091$, $t = +11$ d
iPTF-15fhl	Possible supernova Type Ib, $z = 0.043$, $t = +18$ d
iPTF-15fhp	Possible supernova Type Ic, $z = 0.129$, $t = +1$ d
iPTF-15fhq	Narrow emission lines, consistent with AGN at $z = 0.043$
iPTF-15fib	Slow moving asteroid
LSQ15bvw	No transient detected to limiting magnitude R∼19.5
MASTER OTJ020906	No transient detected to limiting magnitude R∼20
UGC 1410 transient	No transient detected. ID'd as minor planet 2 606 Odessa (Cenko et al. 2015; D'Avanzo, et al. 2015c)

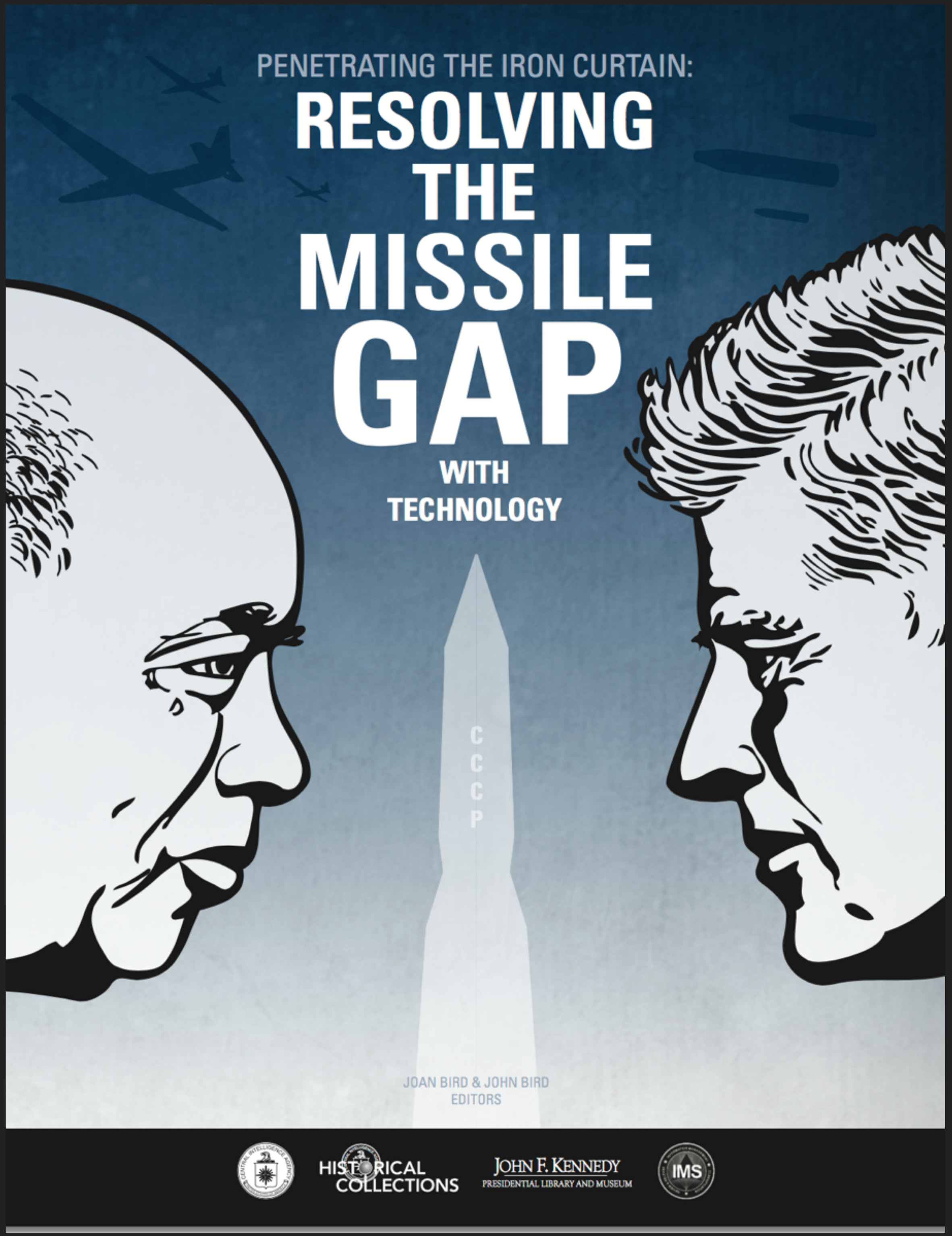
RATHER ENCOURAGING (GIVEN WE ONLY HAVE DETECTED BH+BH SYSTEMS SO FAR)

- Majority of transients were supernovae in the redshift range 0.02 - 0.13. Both GW candidates had z~0.09.
- aLIGO/Virgo at full sensitivity should reach to z~0.045 for NS+NS mergers
- We can eliminate candidates with 2 metre class telescopes at redshifts similar to the GW sources.
- Future aLIGO/Virgo observing runs will include a distance estimate (to ~30%) and a "EM-BRIGHT" flag if likely NS event. The localisations will also improve as more stations come on line. All of this will help with targeted followup of host galaxies in correct redshift range.

HOWEVER…

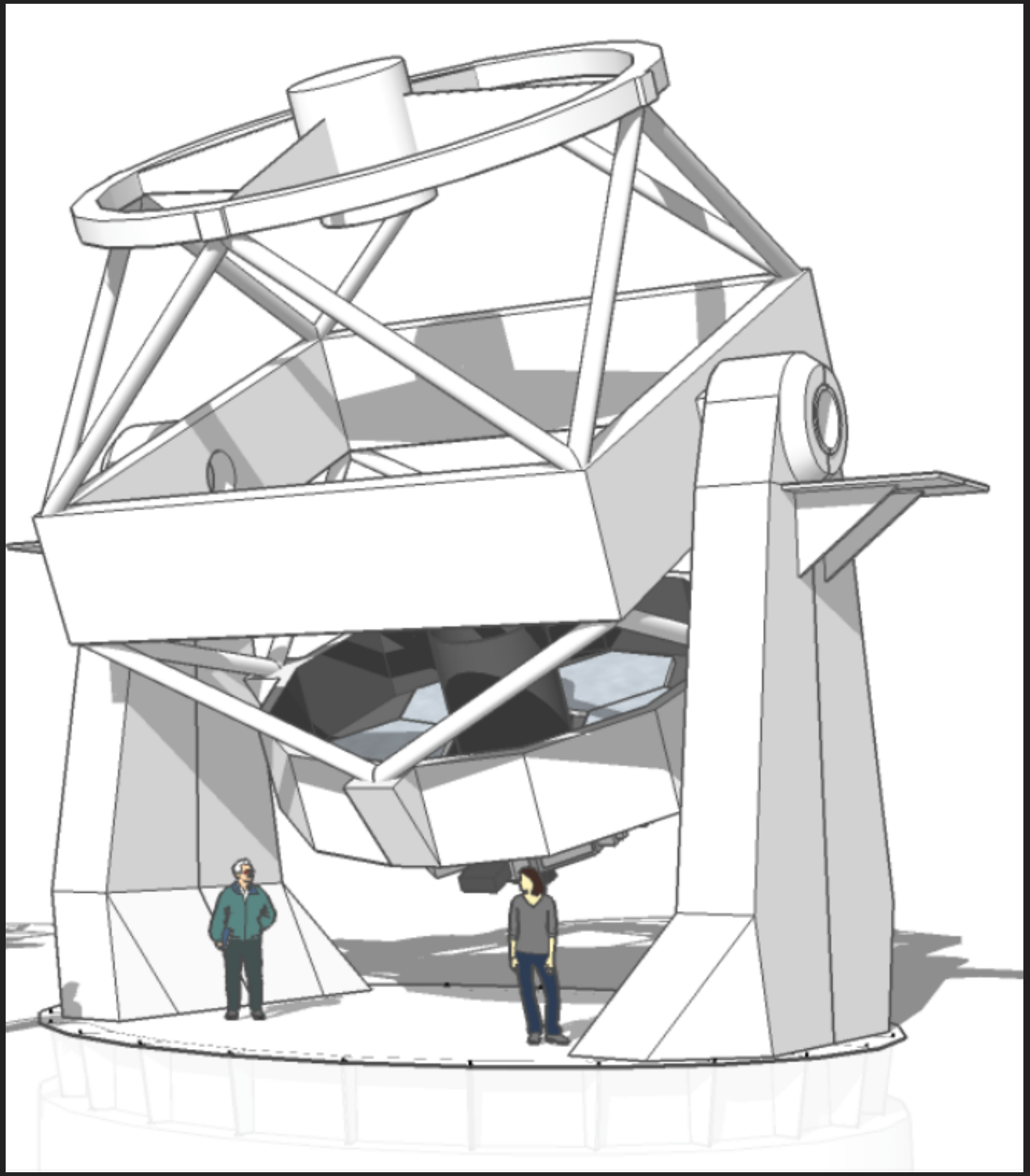
“THE CLASSIFICATION GAP”

- 77 candidate counterparts were announced for GW151226 via GCN
- 37 of these had a firm spectroscopic classification
- A further 18 had a more tentative classification based on photometric light curves
- 3 cases where the transient had faded into the host galaxy before spectroscopy was attempted
- 19 candidate counterparts were not followed up.



NEW MODES OF OPERATION AND NEW FACILITIES

- All spectroscopic follow-up so far has been “manually” triggered. Technologies (e.g. RTML and VO standards) exist to automate this, reducing response times and increasing efficiency.
- A fast slewing, robotic, 4 metre class telescope dedicated to this kind of science would make a huge contribution, especially in the era of LSST.



Liverpool Telescope 2

http://telescope.livjm.ac.uk/lt2