LOFAR's role in searching for EM counterparts to compact binary mergers detected by ALIGO

Antonia Rowlinson

6th April 2016

Thanks to Jess Broderick & the LOFAR GW follow-up team

ANTON PANNEKOEK INSTITUTE
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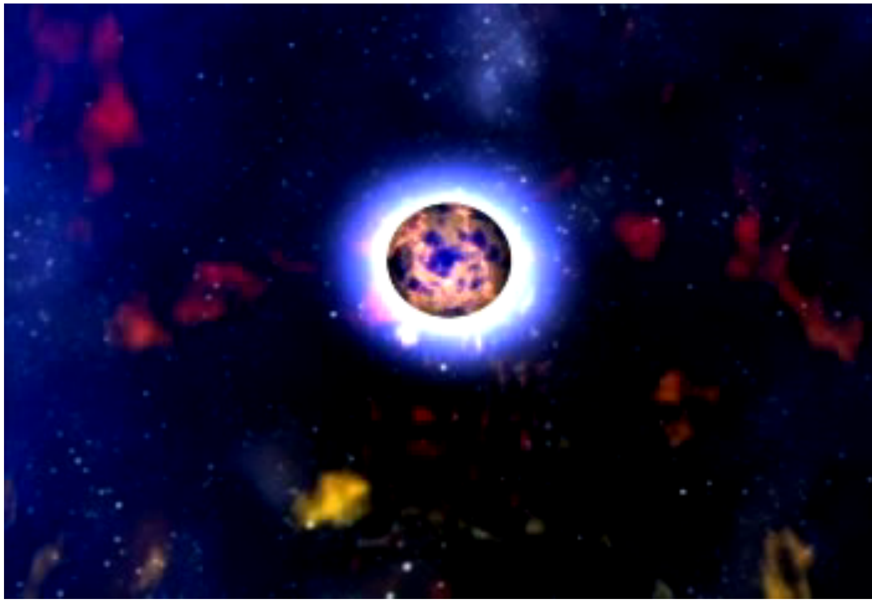
LOFAR

Compact binary mergers

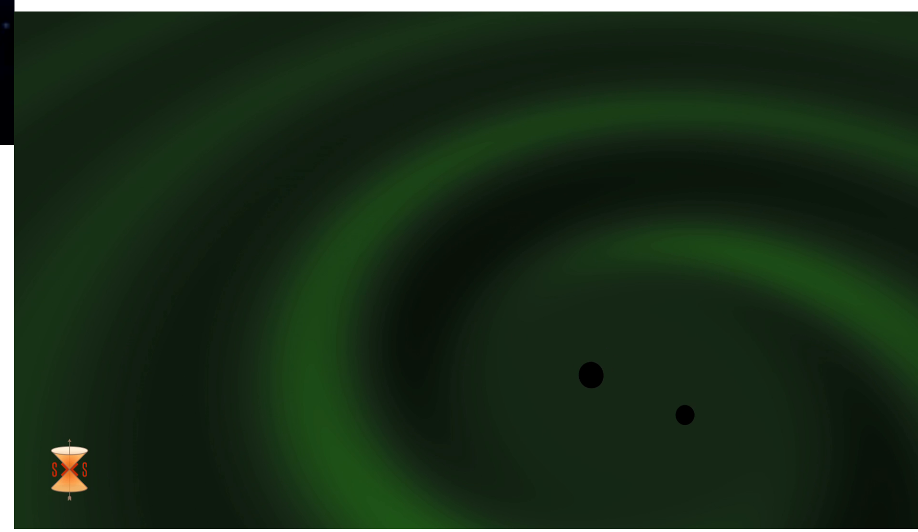


Expected sources:

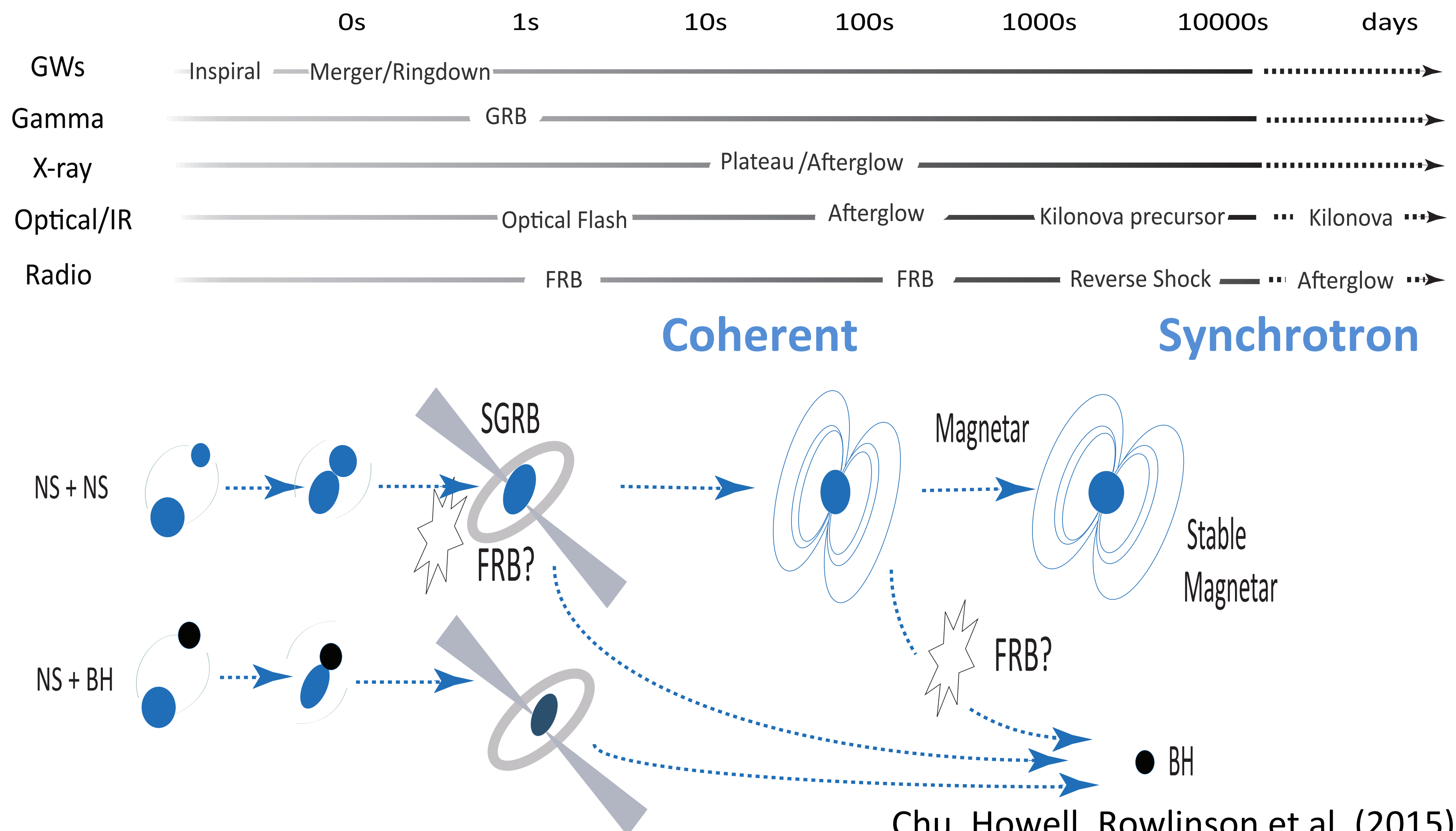
- Neutron star binaries
- Neutron star + Black hole
- Black hole binaries

Detectable as:

- Short gamma-ray bursts (GRBs)?
- Gravitational wave sources

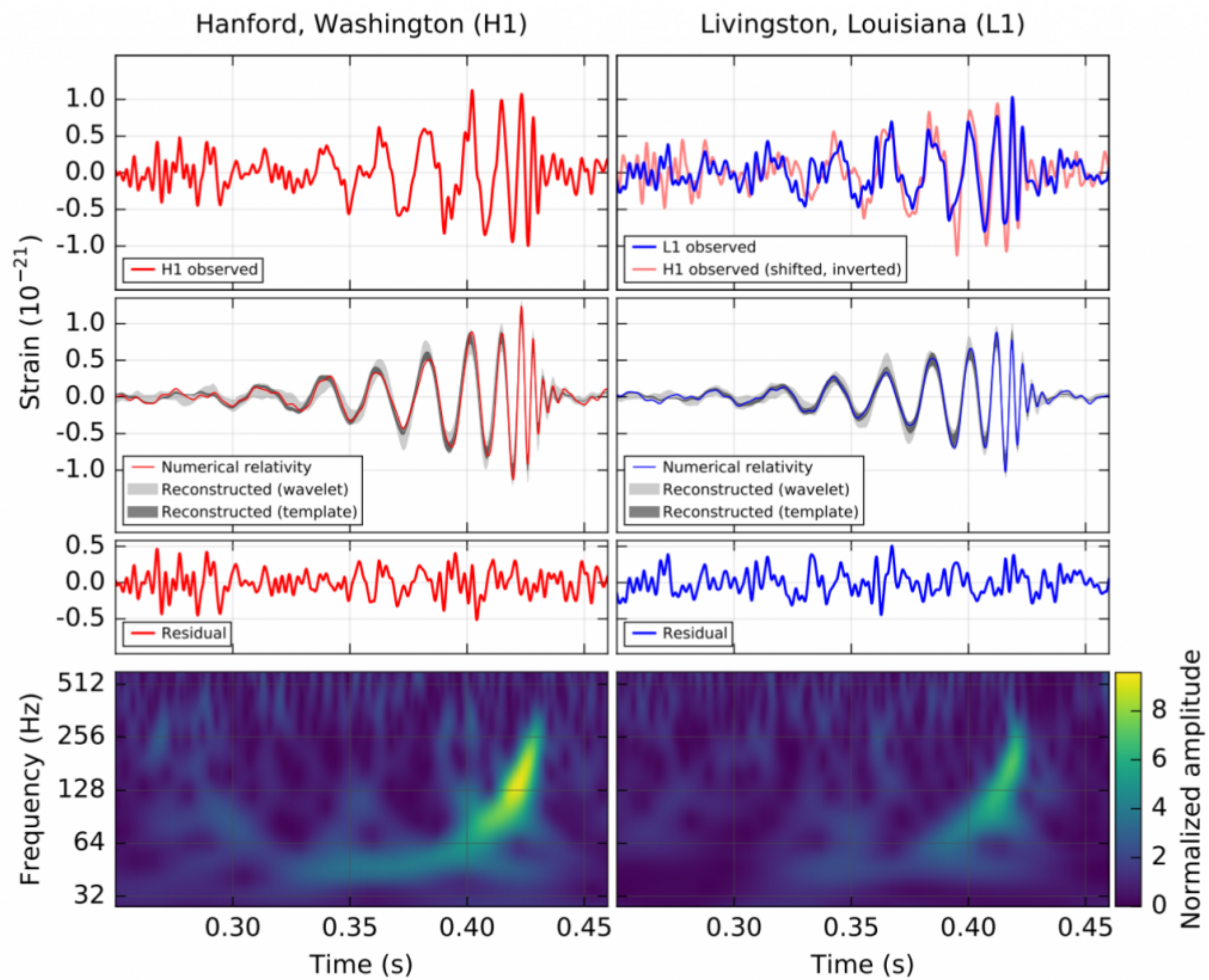


Expected emission
(with 1 or more neutron stars)



Chu, Howell, Rowlinson et al. (2015)

Detection of GW 150914



- Two black holes
- Distance of ~400 Mpc
- Masses of 36 and 29 $M_{\odot}$
- 3 $M_{\odot}$ of energy released

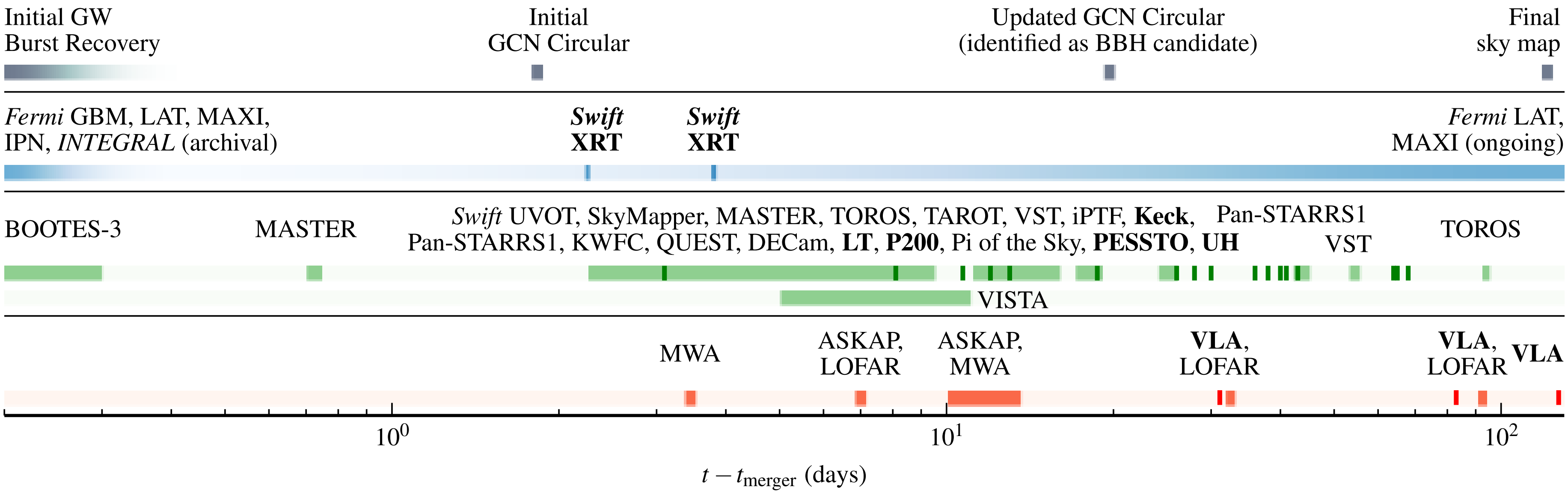
Abbott et al. (2016a)

Electromagnetic follow-up partners

- Hold Memorandums of Understanding (MoUs) with the LIGO-VIRGO Collaboration (LVC):
  - LVC communicate triggers
  - We communicate follow-up completed to the collaboration
  - Confidential for the first 5 triggers
  - 63 teams hold MoUs

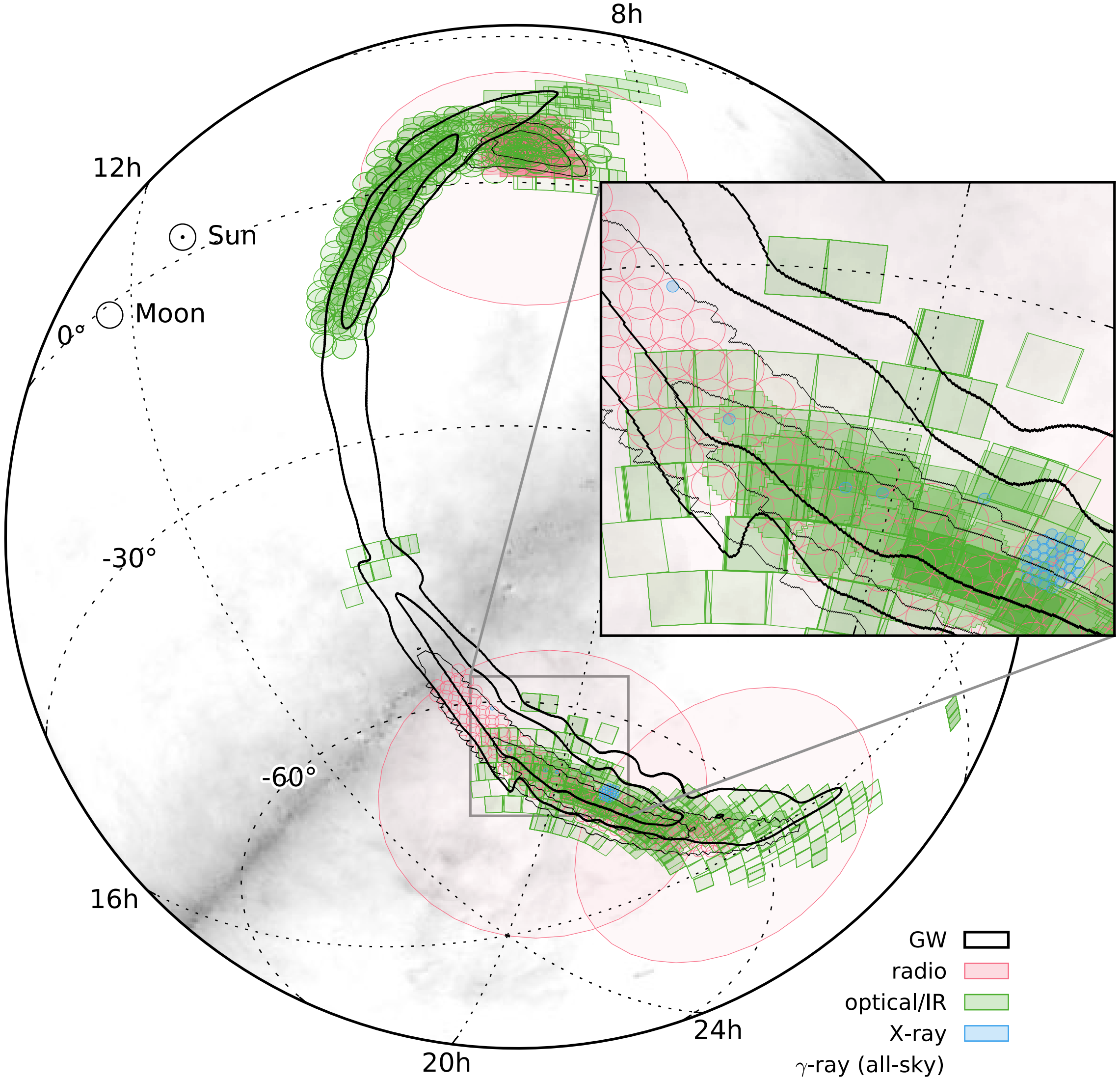
- Joint publication from LVC and partners to describe the large scale follow-up of GW150914: Abbott et al. (2016b)
  - 1562 authors including the LOFAR follow-up team
  - 25 teams conducted follow up

Multi-wavelength follow-up



- Three wide-field radio telescopes followed up this trigger:
  – LOFAR (DDT time requested, P.I. Jess Broderick)
  – MWA
  – ASKAP

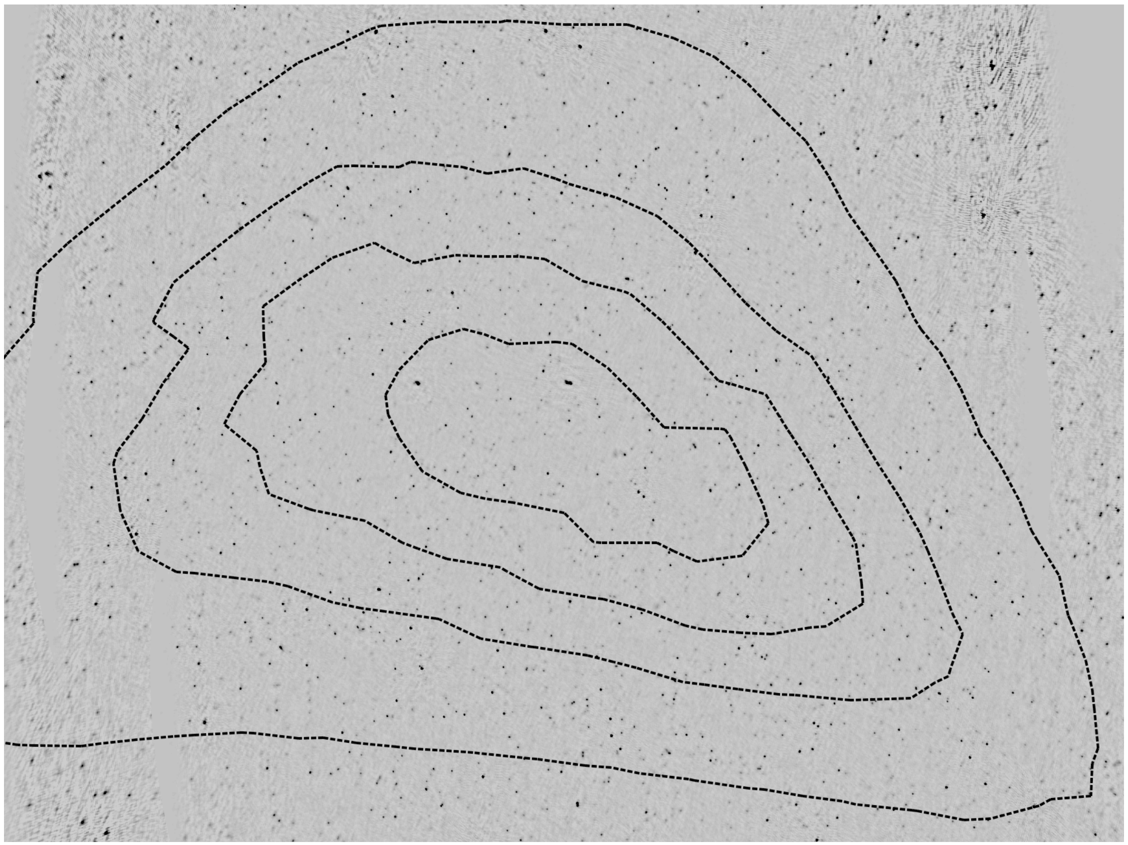
Multi-wavelength follow-up



- Majority of localisation region covered at each wavelength
- Follow-up teams used a range of strategies

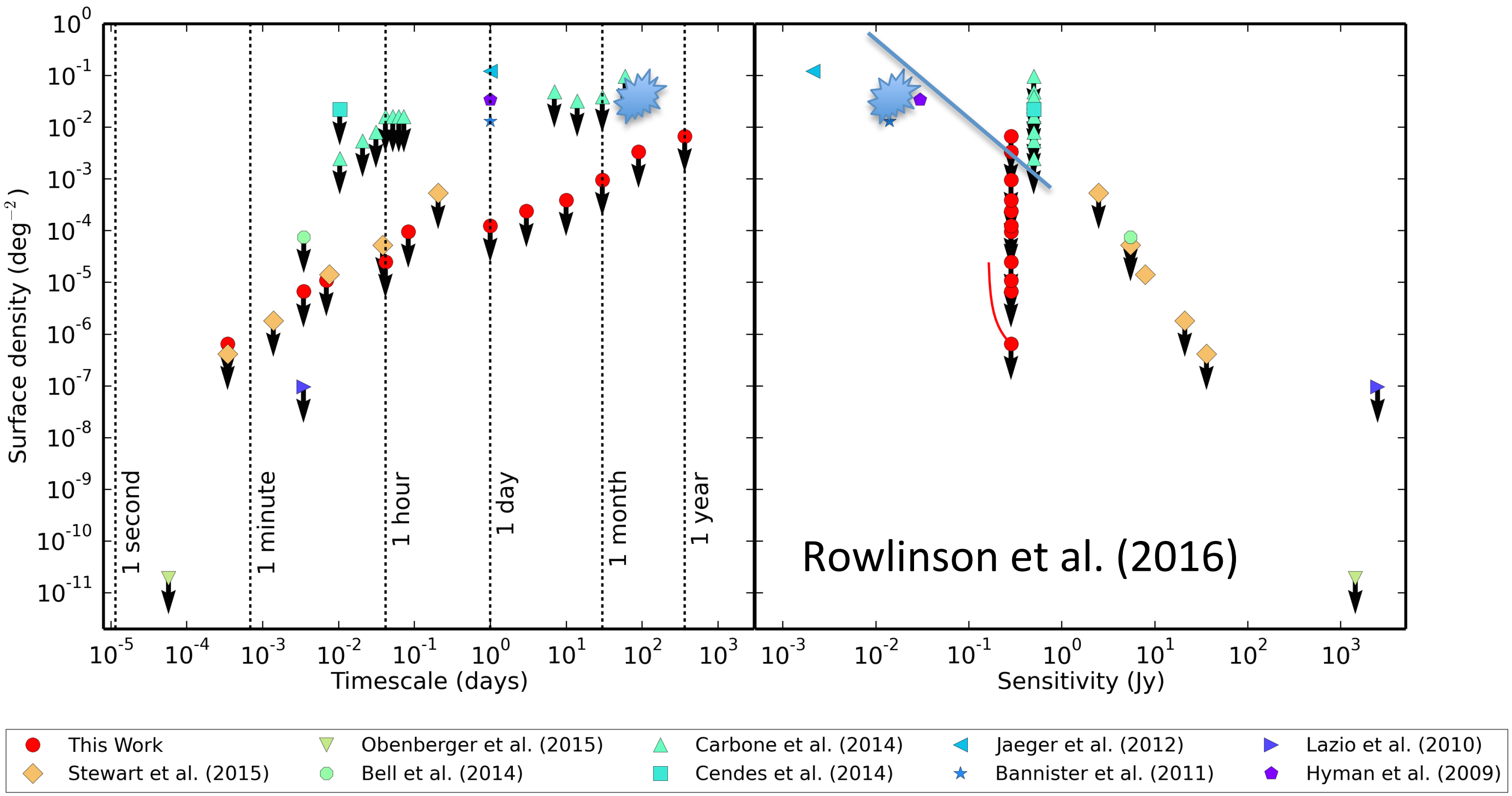
Abbott et al. (2016b)

LOFAR follow-up of GW 150914



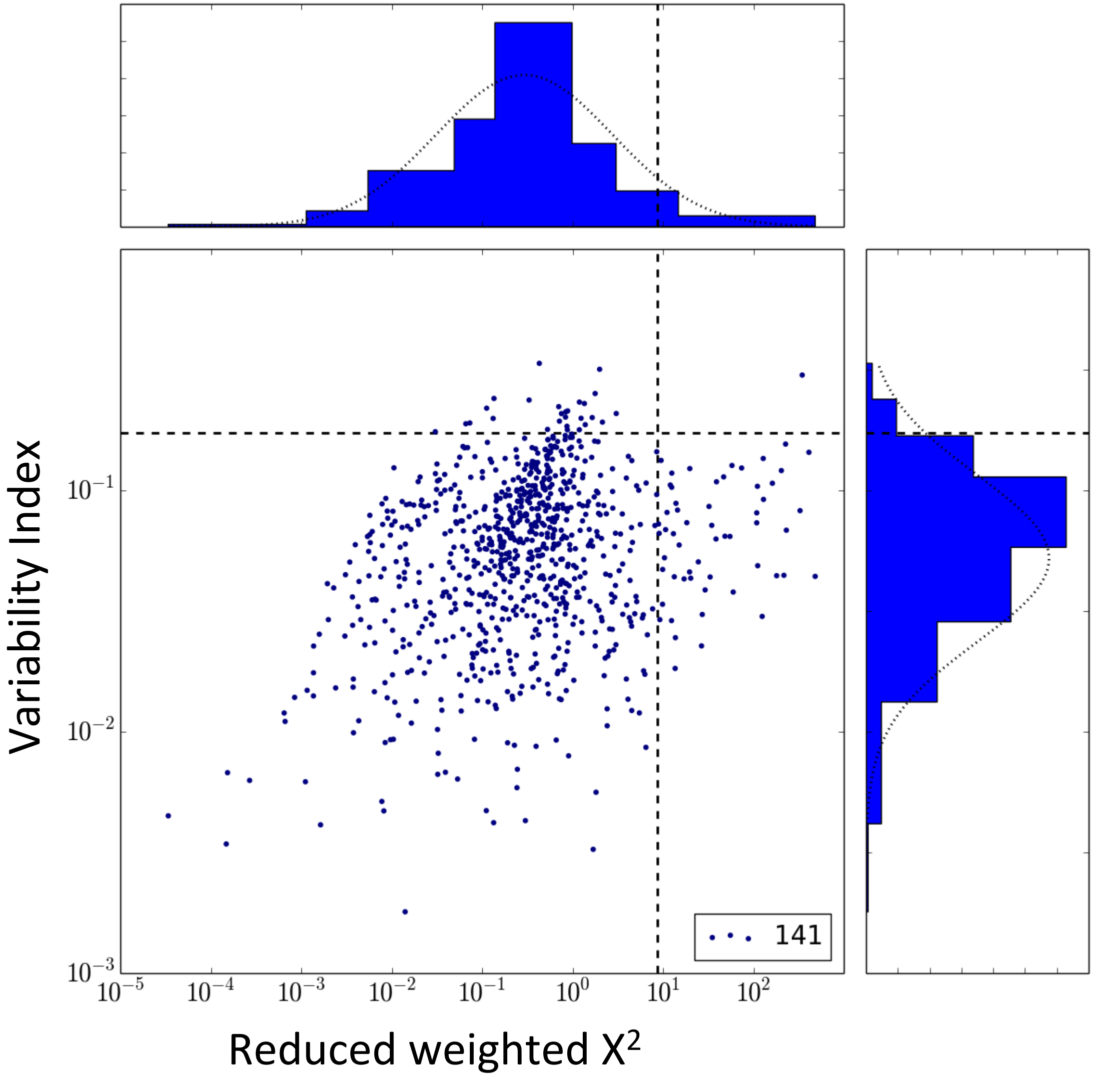
- Mosaic of 8 SAPs at 145 MHz with a bandwidth of 11.9 MHz
- Resolution 50”
- RMS noise ~2.5 mJy and >2000 sources
- Contours: cWB probability map
- Timescales of 1 week, 1 month and 3 months

Expected transient rates



- Surveyed ~50 square degrees on a 3 month timescale with 6 sensitivity of 15 mJy at 145 MHz
- We expect <14 transients in the field

Transient and Variability Analysis



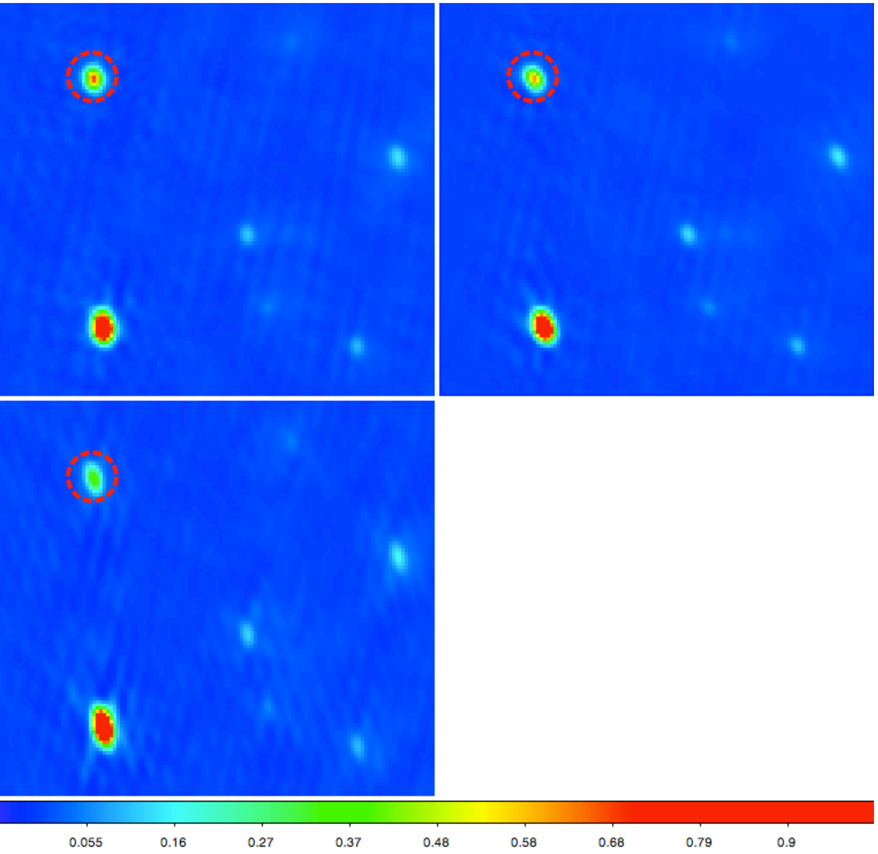
- Processed using the LOFAR Transients Pipeline (Swinbank et al. 2015)
- Two variability parameters measured for all sources
- No convincing transients detected above 6**σ**
- 1 variable source (scintillating pulsar)

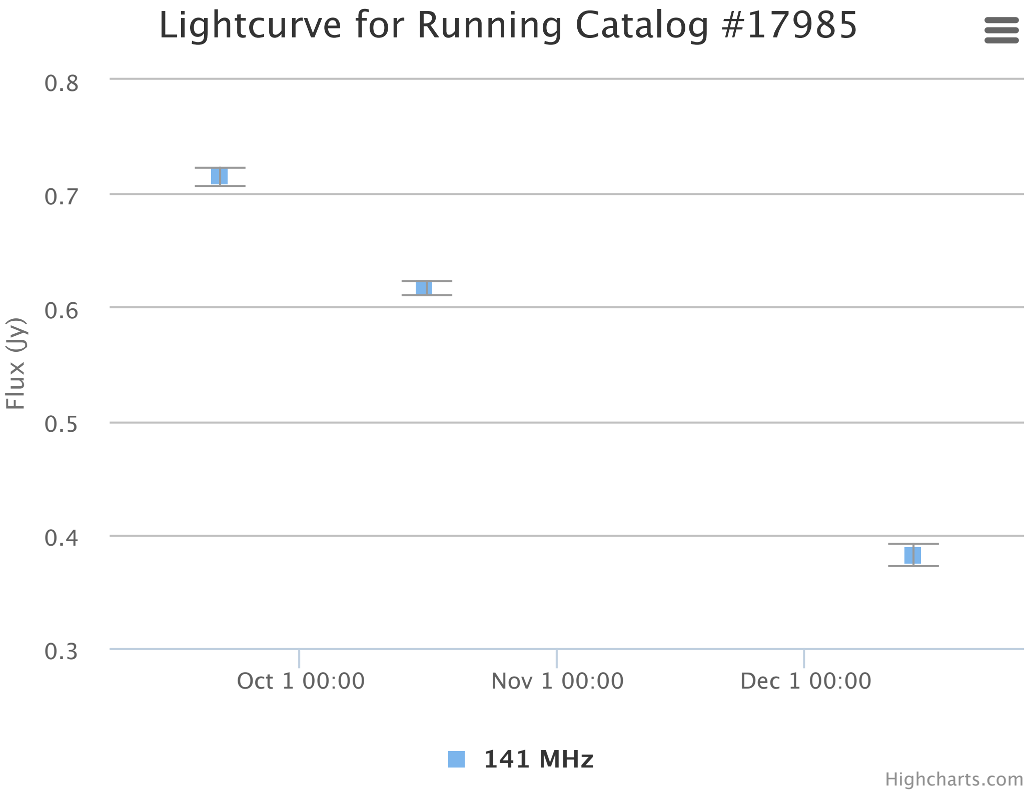
Summary

- Gravitational waves have been detected from a binary black hole merger although very uncertain expectations for EM counterparts
- LOFAR is one of 3 wide field radio facilities currently chasing these events (and only one in the Northern Hemisphere)
- Only a matter of time to get a neutron star merger (and known EM counterparts)
- LOFAR can chase the late-time synchrotron, but key discovery space is for coherent emission – requiring a rapid response mode

SPARE SLIDES

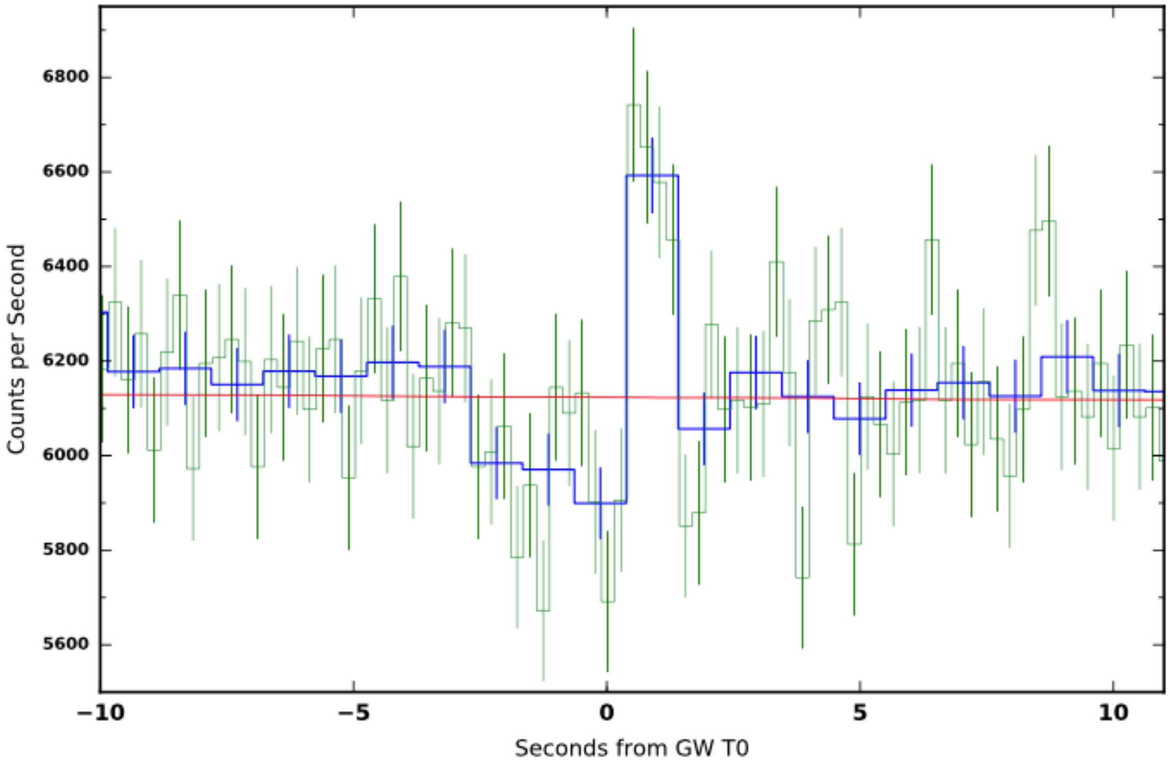
Variable source: PSR B0834+06

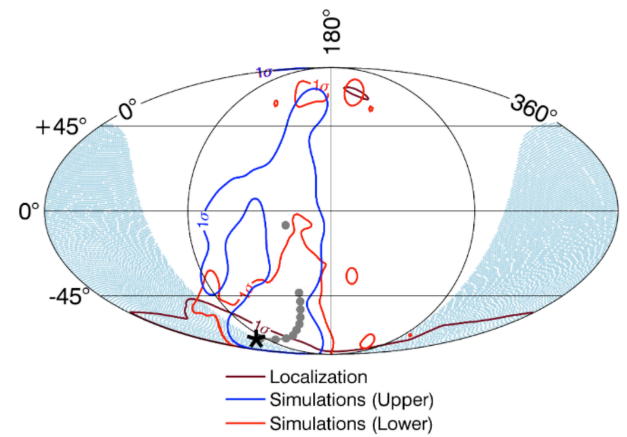




A possible associated Short GRB???

- Typically expect NO EM-counterpart from clean black hole – black hole mergers, but many theories are appearing saying otherwise and a possible EM-counterpart detection…

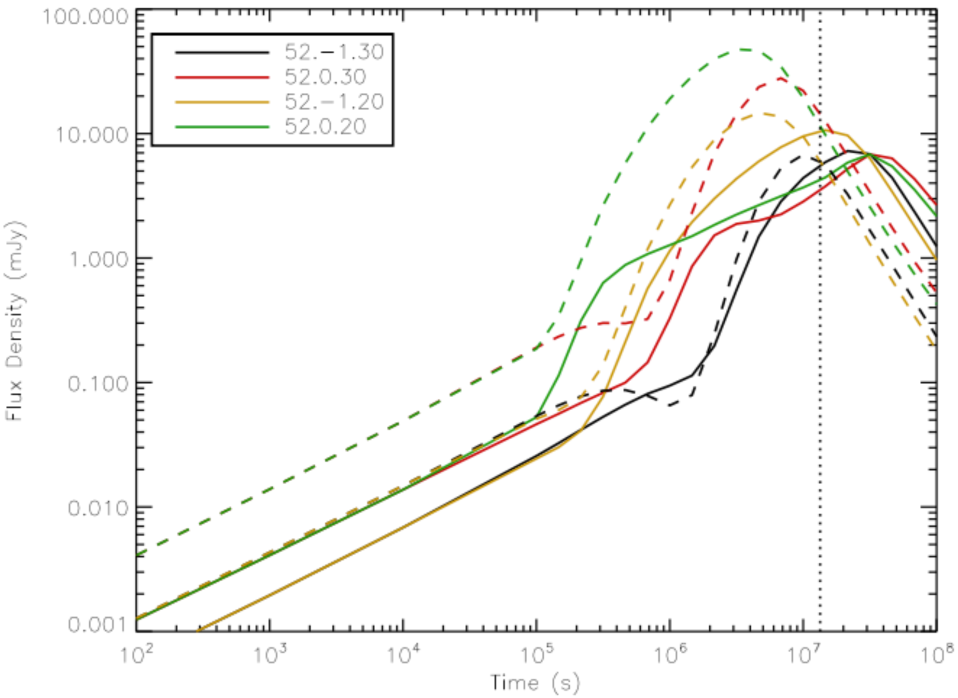




Candidate sub-threshold Short GRB detected by Fermi GBM

Connaughton et al. (2016)

Maybe late-time low frequency emission from BH-BH mergers?



150 MHz lightcurves predicted assuming a typical (but optimistic) synchrotron afterglow following a GRB
Morsony, Workman & Ryan (2016)

Modeling the Afterglow of GW150914-GBM

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[2] Dept. of Physical and Environmental Sciences, Colorado Mesa University, Grand Junction, CO, 81501, USA
[3] Dept. pf Astronomy, University of California, Berkeley, 501 Campdell Hall #3411, Berkeley, CA, 94720-4311, USA

18 February 2016

Electromagnetic Afterglows Associated with Gamma-Ray Emission Coincident with Binary Black Hole Merger Event GW150914

Ryo Yamazaki[1], Katsuaki Asano[2], Yutaka Ohira[1]
[1] *Department of Physics and Mathematics, Aoyama Gakuin University, 5-10-1 Fuchinobe, Sagamihara 252-5258, Japan*
[2] *Institute for Cosmic Ray Research, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8582, Japan*

ELECTROMAGNETIC COUNTERPARTS TO BLACK HOLE MERGERS DETECTED BY LIGO

Abraham Loeb[1]

Draft version February 24, 2016

SHORT GAMMA-RAY BURSTS FROM THE MERGER OF TWO BLACK HOLES

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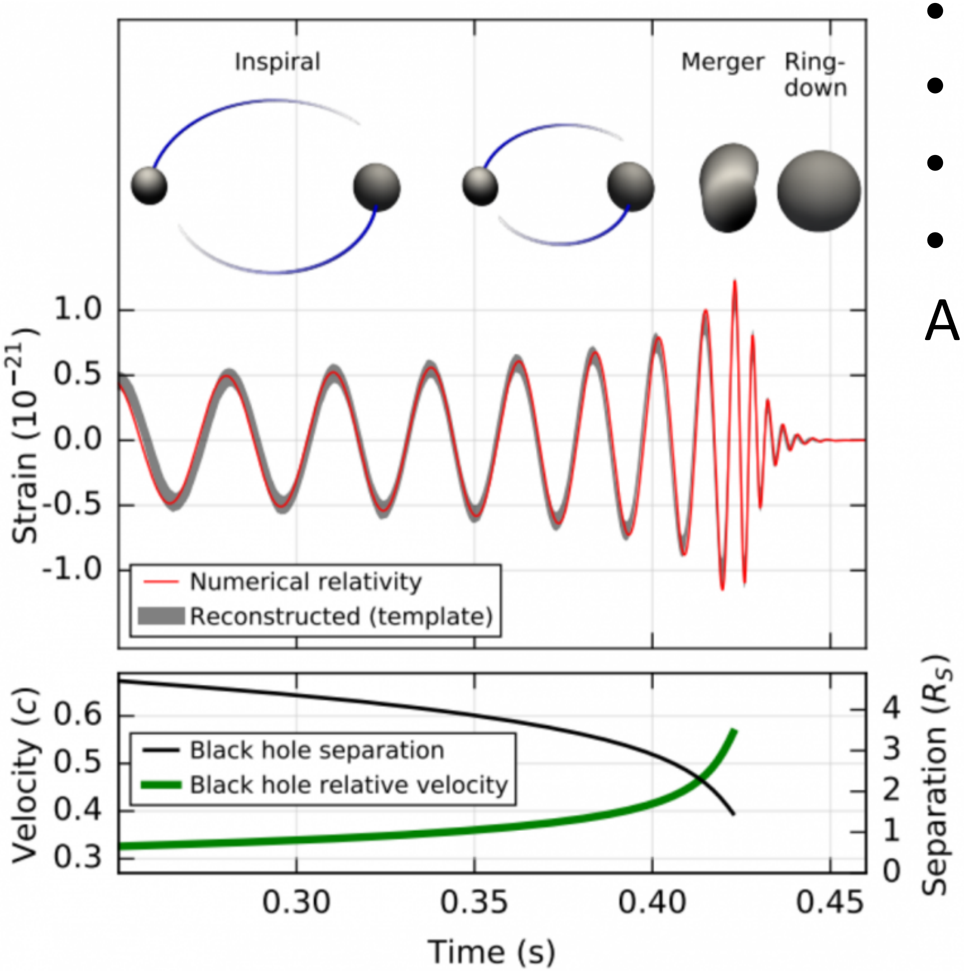
Draft version February 17, 2016

Detection of 2 black holes merging



- Distance of ~400 Mpc
- Masses of 36 and 29 $M_\odot$
- 3 $M_\odot$ of energy released
- Final remnant mass 62 $M_\odot$

Abbott et al. (2016)