NEWS

H2020-MSCA-RISE-2016 – Grant Agreement N° 734303

GW Physics

Massimiliano Razzano

General Meeting - March 13, 2018

NEWS from GW Physics

- Second observing run (O2) finished successfully this summer
- Joint LIGO-Virgo run (1-25 August) yielded 2 detections
- Now moving toward O3
- Improving detectors and data analysis infrastructures
- Higher sensitivity → higher events (and noise transients rate)
- Both search pipelines and detector characterization activities
- Aiming at lowest latency possible

The era of Advanced detectors

- Abbott et al. 2017, “observing scenario” paper, arxiv:1304.0670

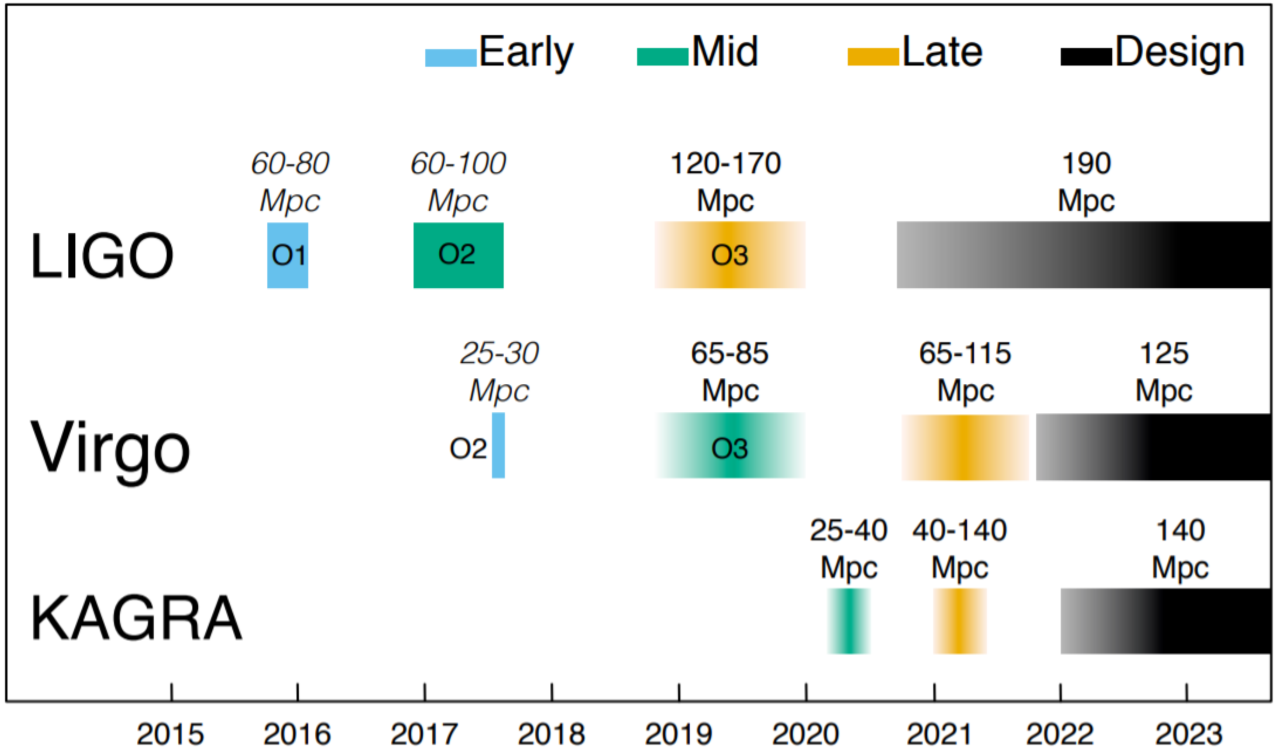


Fig. 2 The planned sensitivity evolution and observing runs of the aLIGO, AdV and KAGRA detectors over the coming years. The colored bars show the observing runs, with the expected sensitivities given by the data in Figure 1 for future runs, and the achieved sensitivities in O1 and in O2. There is significant uncertainty in the start and end times of planned the observing runs, especially for those further in the future, and these could move forward or backwards relative to what is shown above. The plan is summarised in

The era of Advanced detectors

- Abbott et al. 2017, “observing scenario” paper,
- arxiv:1304.0670

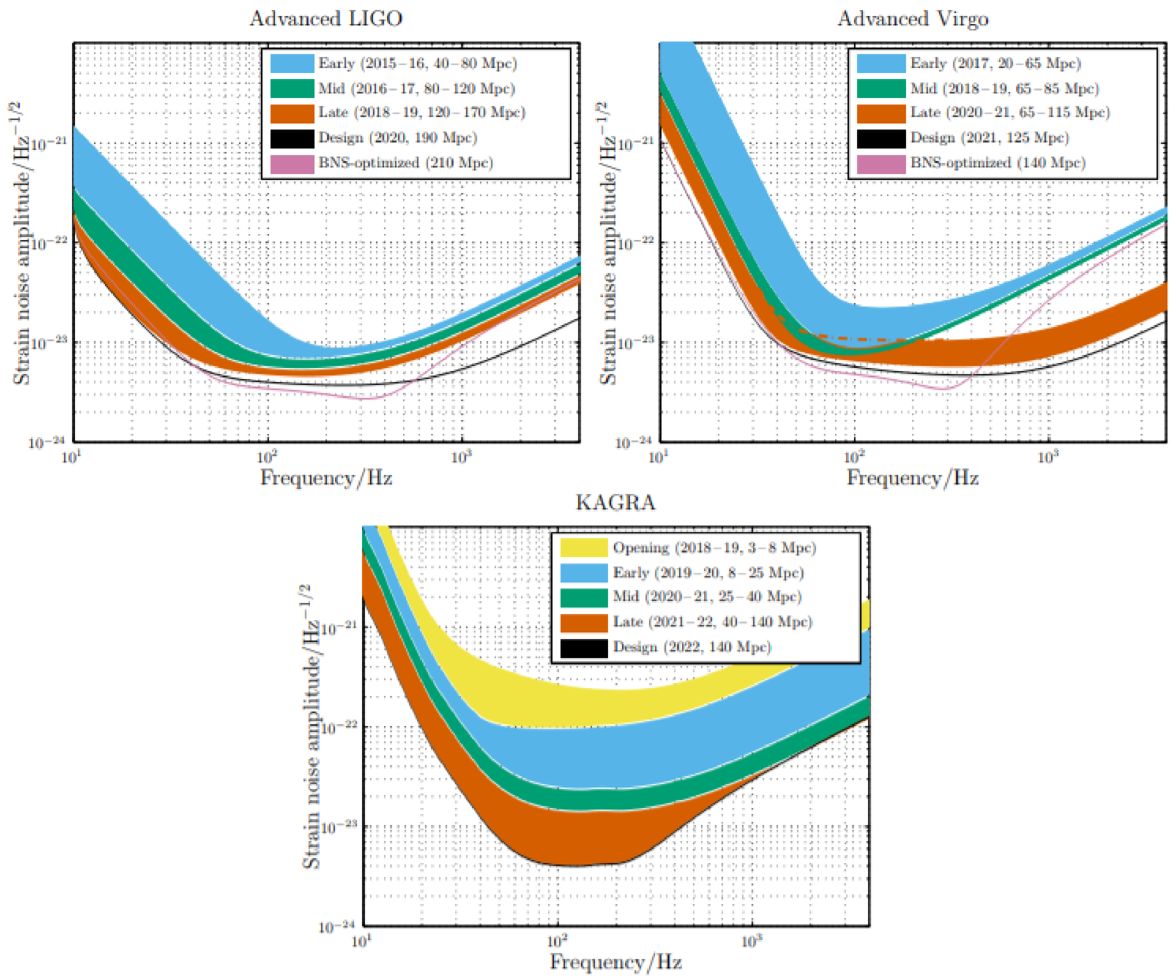
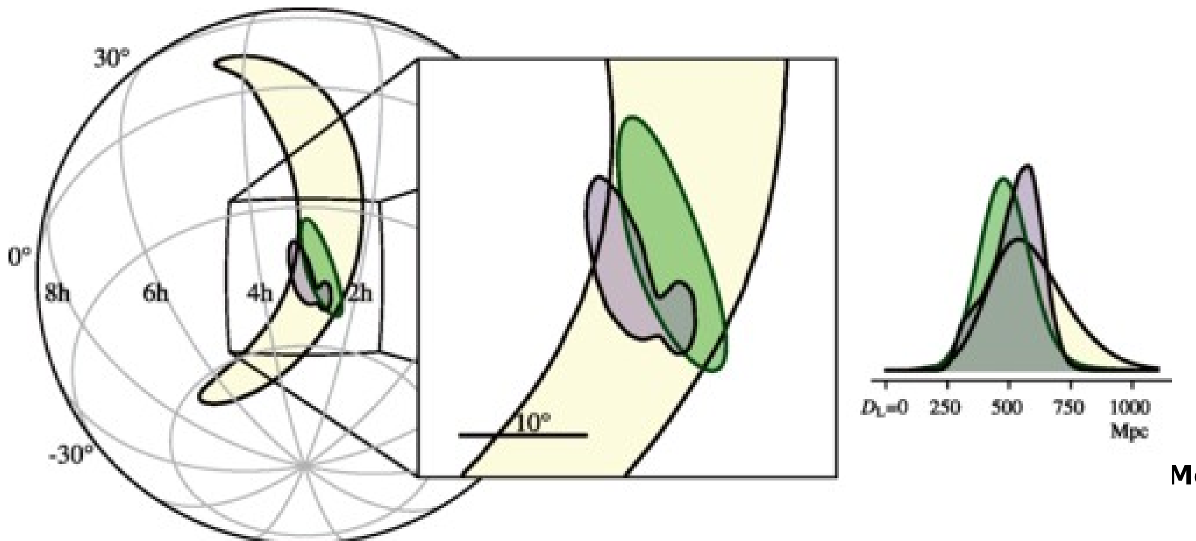


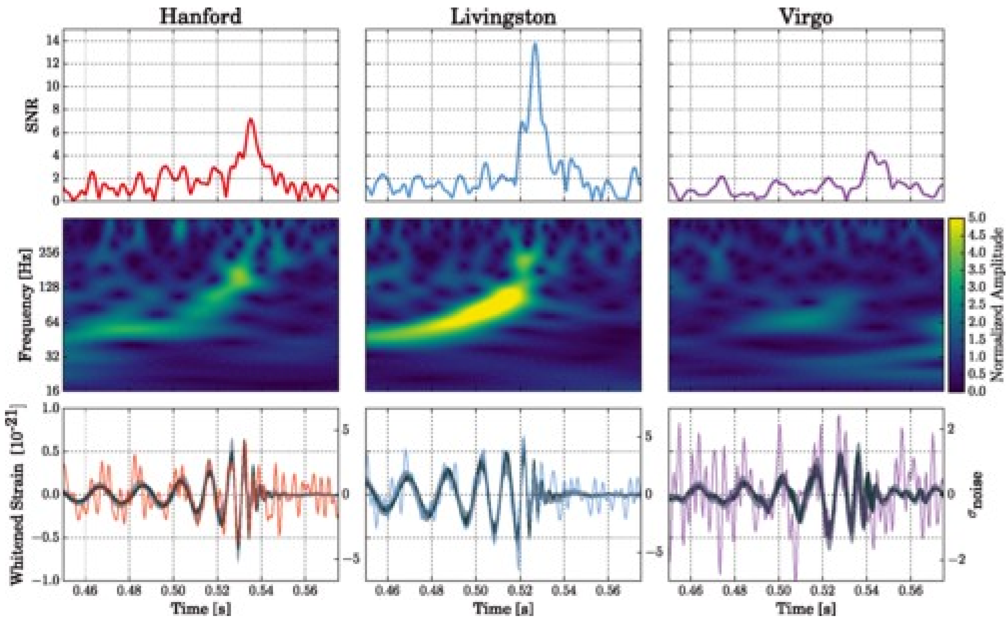
Fig. 1 Regions of aLIGO (*top left*), AdV (*top right*) and KAGRA (*bottom*) target strain sensitivities as a function of frequency. The binary neutron star (BNS) range, the average distance to which these signals could be detected, is given in megaparsec. Current notions of the progression of sensitivity are given for early, mid and late commissioning phases, as well as the final design sensitivity target and the BNS-optimized sensitivity. While both dates and sensitivity curves are subject to change, the overall progression represents our best current estimates.

NEWS from O2

- GW170814 was the first event observed by LIGO AND Virgo
- Binary black hole merger like the previous events
- Sky localization accuracy thanks to Virgo (from 1160 deg^2 to 60 deg^2)



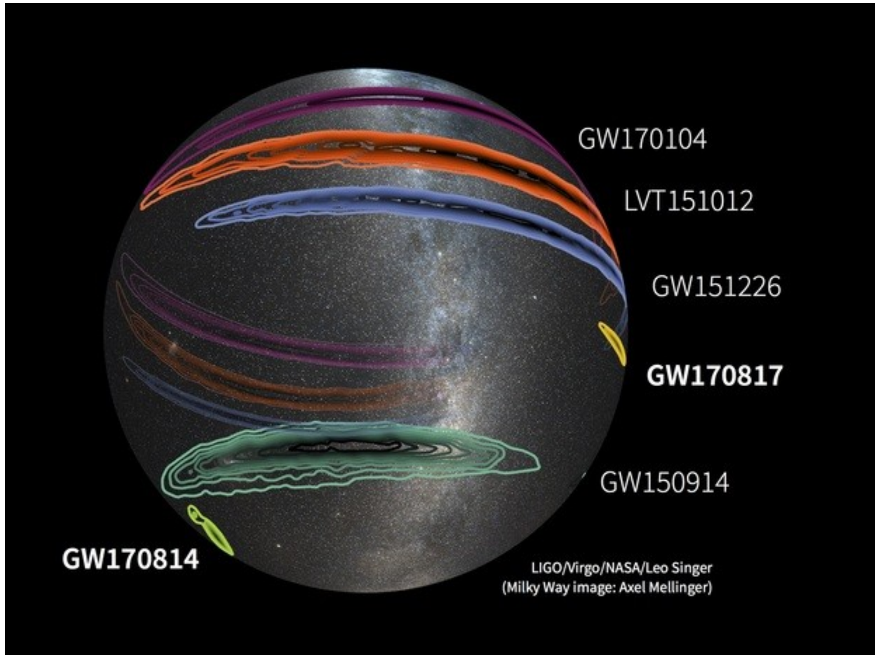
Meeting

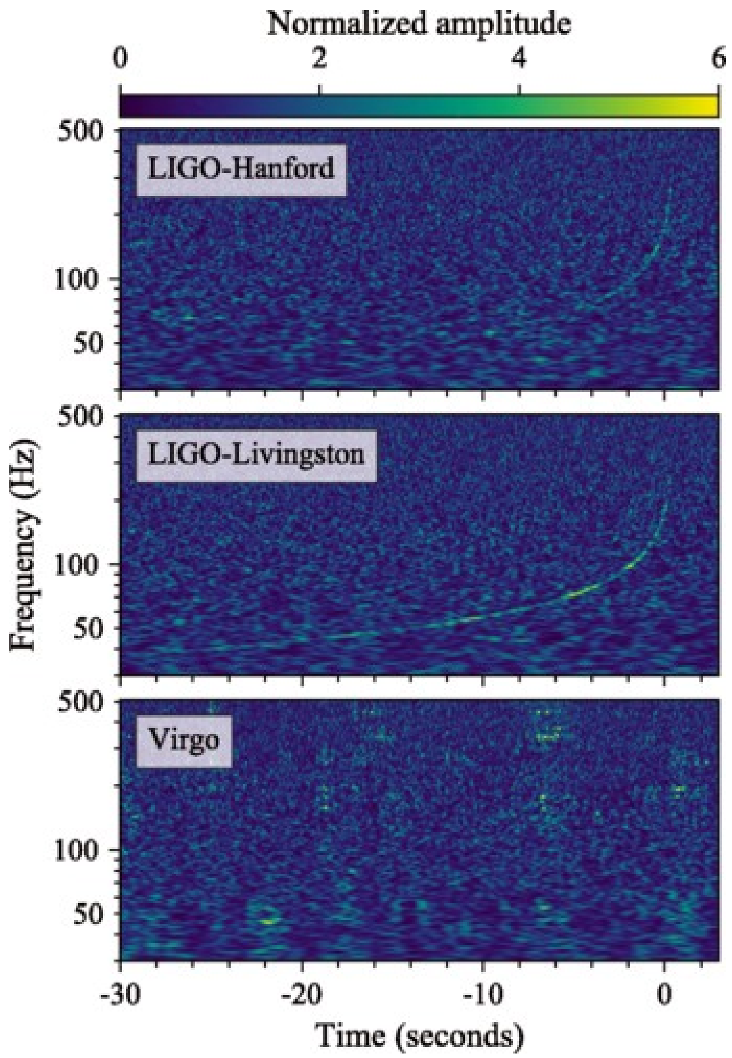


GW170817 detection by LIGO and Virgo

- **Highest combined SNR (32.4)**
- **Consistent with neutron star merger**

	Low-spin priors ($|\chi| \leq 0.05$)	High-spin priors ($|\chi| \leq 0.89$)
Primary mass m_1	1.36–$1.60\ M_\odot$	1.36–$2.26\ M_\odot$
Secondary mass m_2	1.17–$1.36\ M_\odot$	0.86–$1.36\ M_\odot$
Chirp mass $\mathscr{M}$	$1.188^{+0.004}_{-0.002} M_\odot$	$1.188^{+0.004}_{-0.002} M_\odot$
Mass ratio m_2/m_1	0.7–1.0	0.4–1.0
Total mass m_{tot}	$2.74^{+0.04}_{-0.01} M_\odot$	$2.82^{+0.47}_{-0.09} M_\odot$
Radiated energy E_{rad}	$> 0.025 M_\odot c^2$	$> 0.025 M_\odot c^2$
Luminosity distance D_L	40^{+8}_{-14} Mpc	40^{+8}_{-14} Mpc
Viewing angle Θ	$\leq 55^\circ$	$\leq 56^\circ$
Using NGC 4993 location	$\leq 28^\circ$	$\leq 28^\circ$
Combined dimensionless tidal deformability $\tilde{\Lambda}$	≤ 800	≤ 700
Dimensionless tidal deformability $\Lambda(1.4 M_\odot)$	≤ 800	≤ 1400





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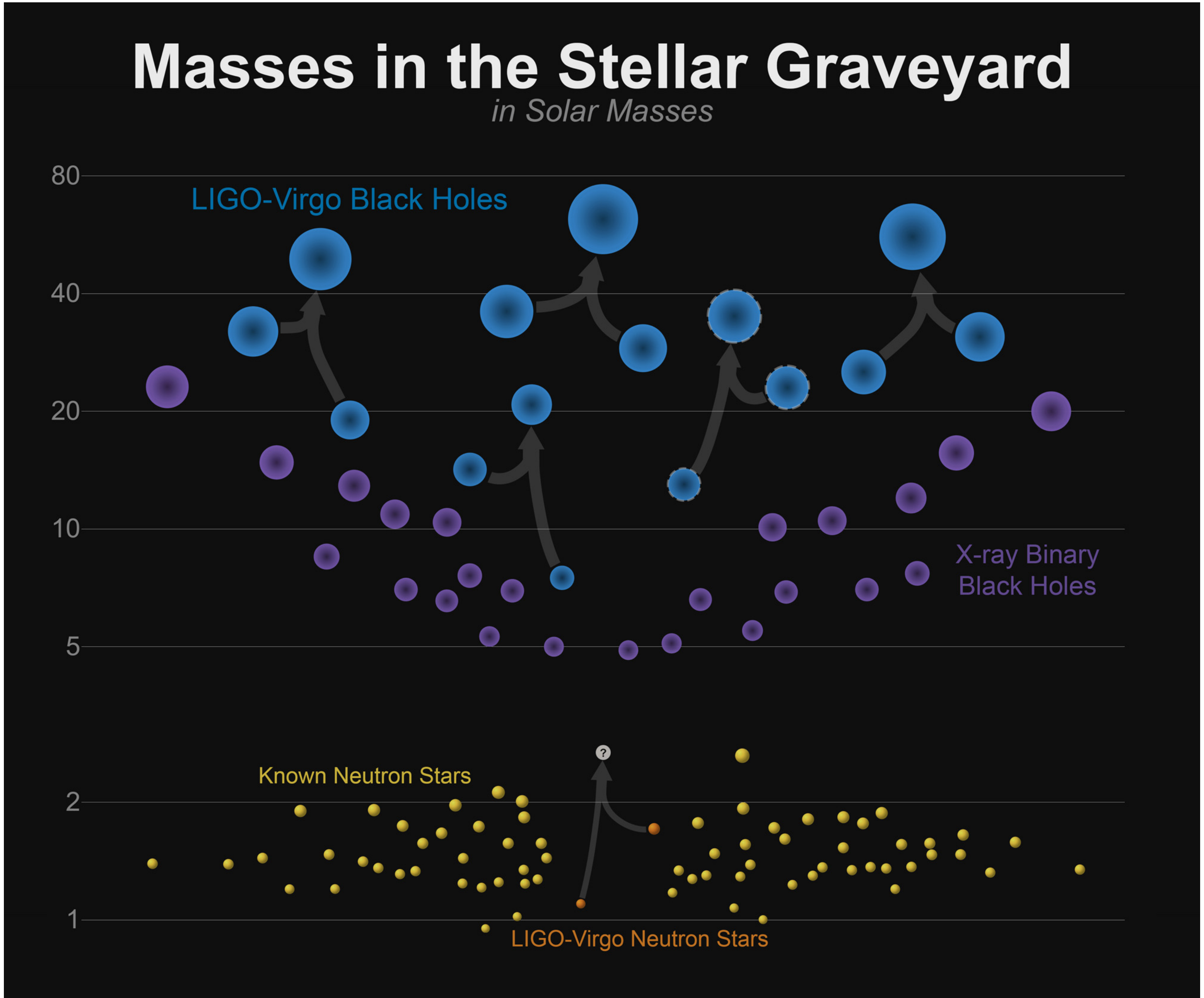
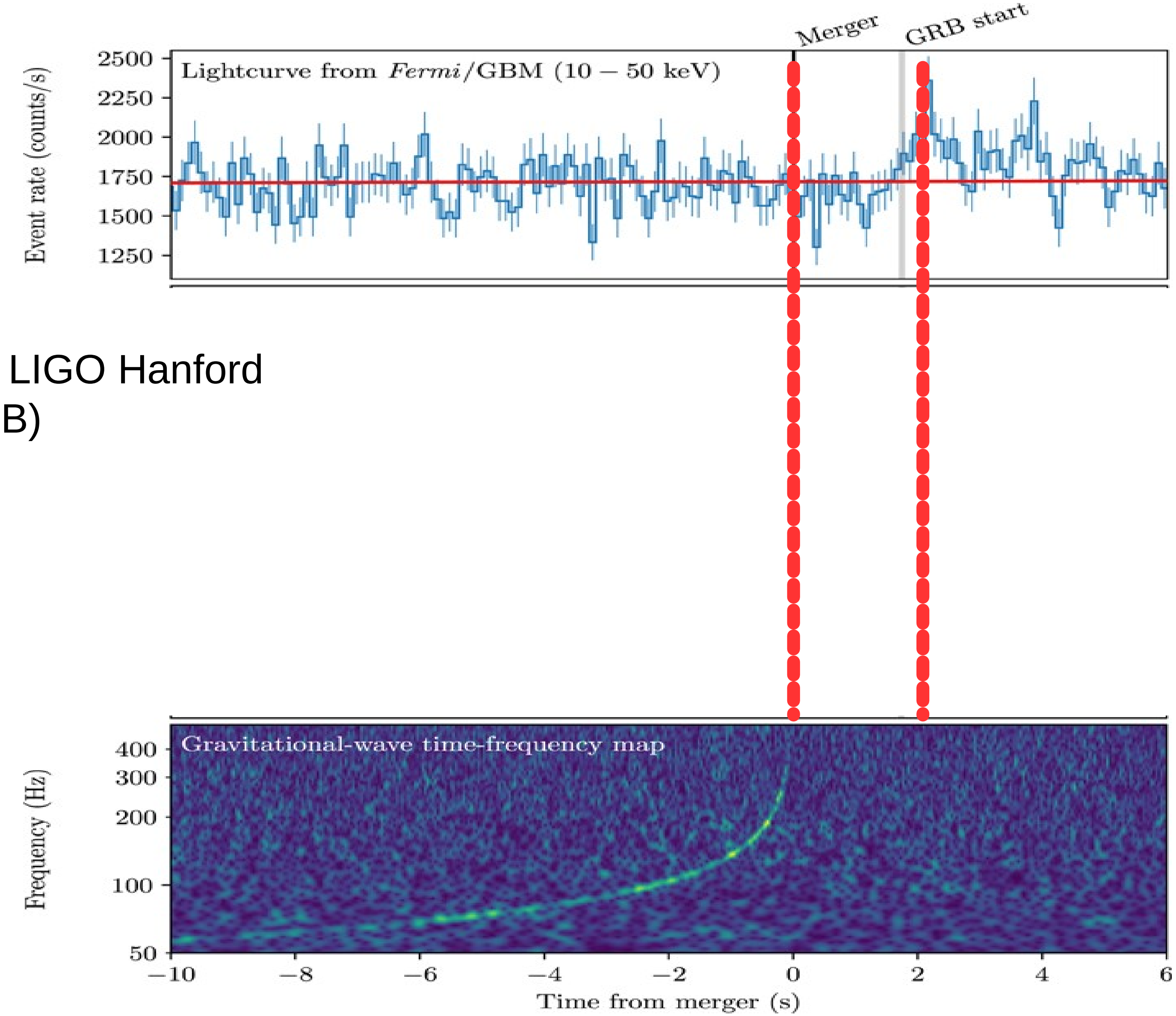
GW170817 and the era of multimessenger astronomy



Timeline of the GW170817 discovery

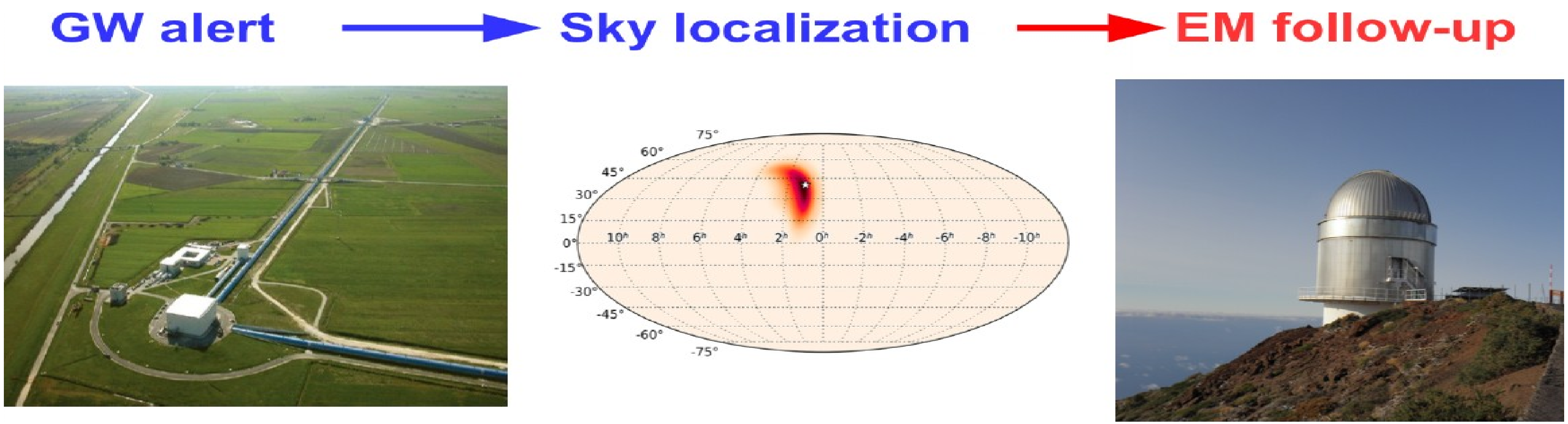
- **12:41:06 UTC** : onboard *Fermi*-GBM trigger
- **12:14:20 UTC** : Automatic Fermi Gamma-ray Coordinates Network (GCN)



- **~12:47 UTC** : low-latency GW pipeline detection on LIGO Hanford
  - Detected time 12:41:04 (1.7 sec *before* Fermi GRB)
- **13:21:42 UTC** : First alert sent from LIGO/Virgo
- **17:54:51 UTC**: First LIGO-Virgo skymap
  - Error region ~31 deg^2
  - Distance 40 Mpc
- **23:54:40 UTC**: Refined LIGO-Virgo skymap
  - Error region ~34 deg^2

The follow-up strategy

- Advanced Era (2015-)
  - Memorandum of Understanding (MoU) that regulates the follow-up activities
  - >90 team, > 200 instruments
  - Detection from GW pipelines → quick meeting (follow-up “advocates”+experts)
  - → Alert !
  - Alerts sent to astronomers via LVC GCN (covered by MoU)
  - Broadband coverage (EM+neutrinos)



Why the multimessenger astronomy?

- Providing a deeper insight into the most extreme events in the Universe

- Exploring the nature of their progenitors (mass, spin, distance..) and their environment (temperature, density, redshift..)

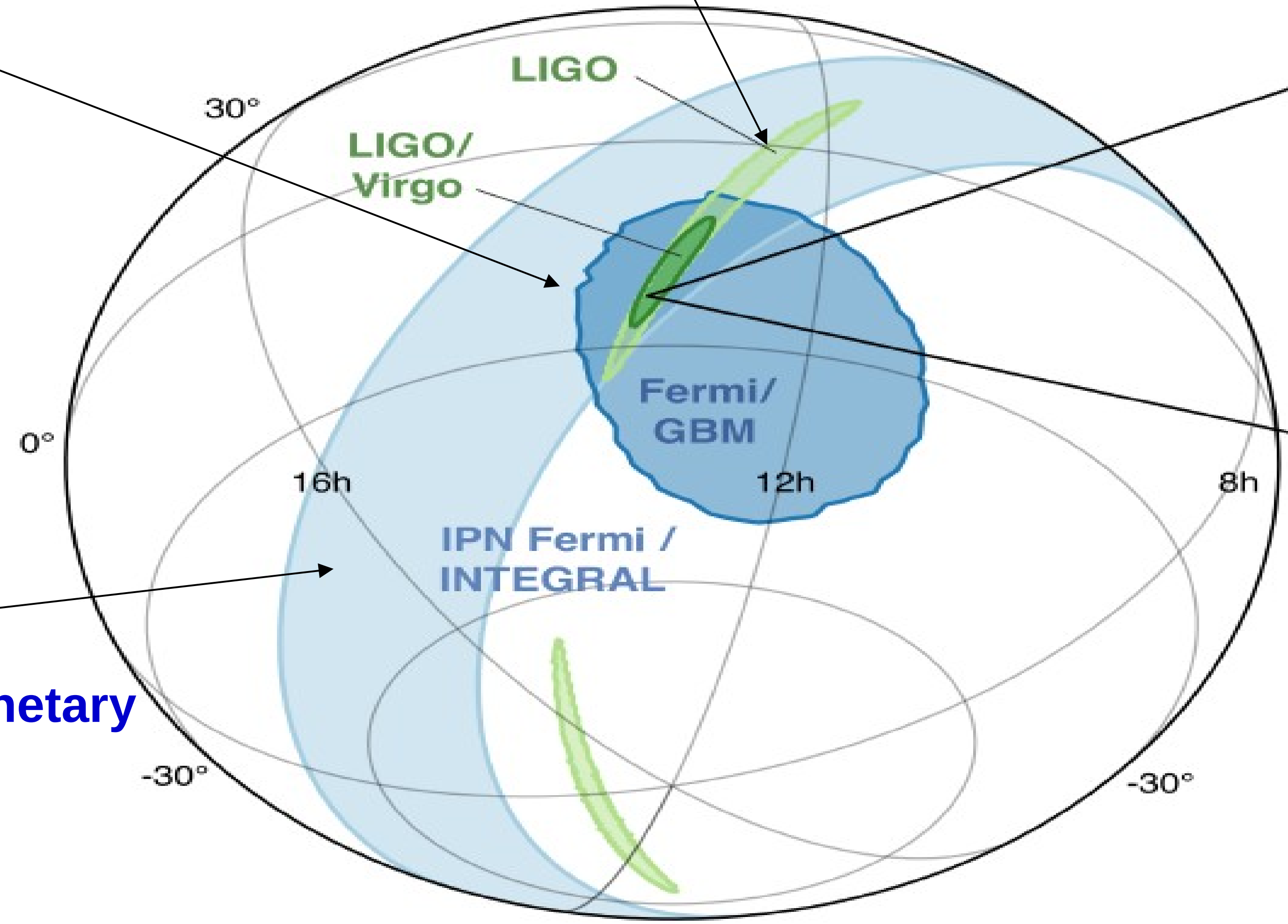
- Accessing complementary information:
  - EM → emission processes, acceleration mechanisms, environment
  - GW → mass distribution
  - Neutrinos → hadronic/nuclear processes, etc.

- How? Rely on precise (arcmin/arcsecond) localization
  - Identify an EM counterpart
  - Pinpoint host galaxy of a merger

Sky localization

LIGO: 190 deg²

Fermi GBM: 1100 deg²



LIGO
+
Virgo
=
31 deg²

Fermi GBM
+
INTEGRAL SPI (Interplanetary Network)
Additional constraints

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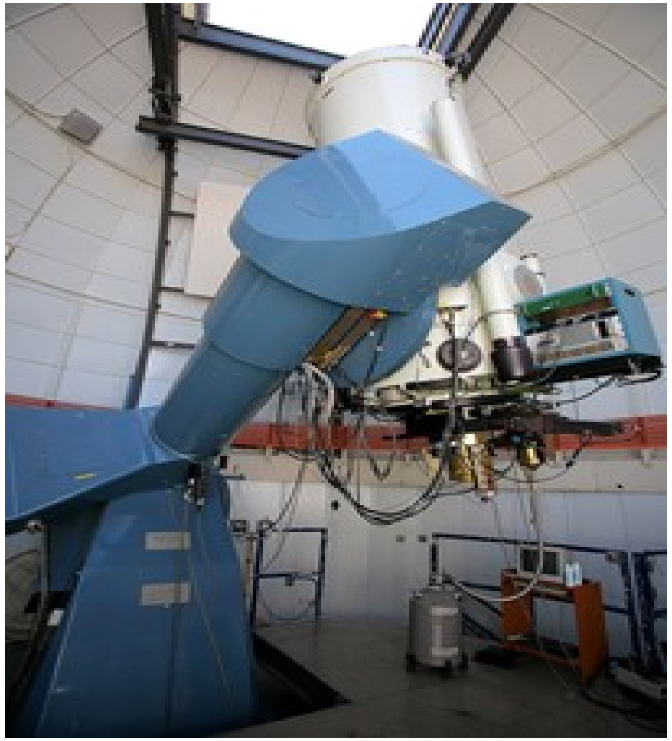
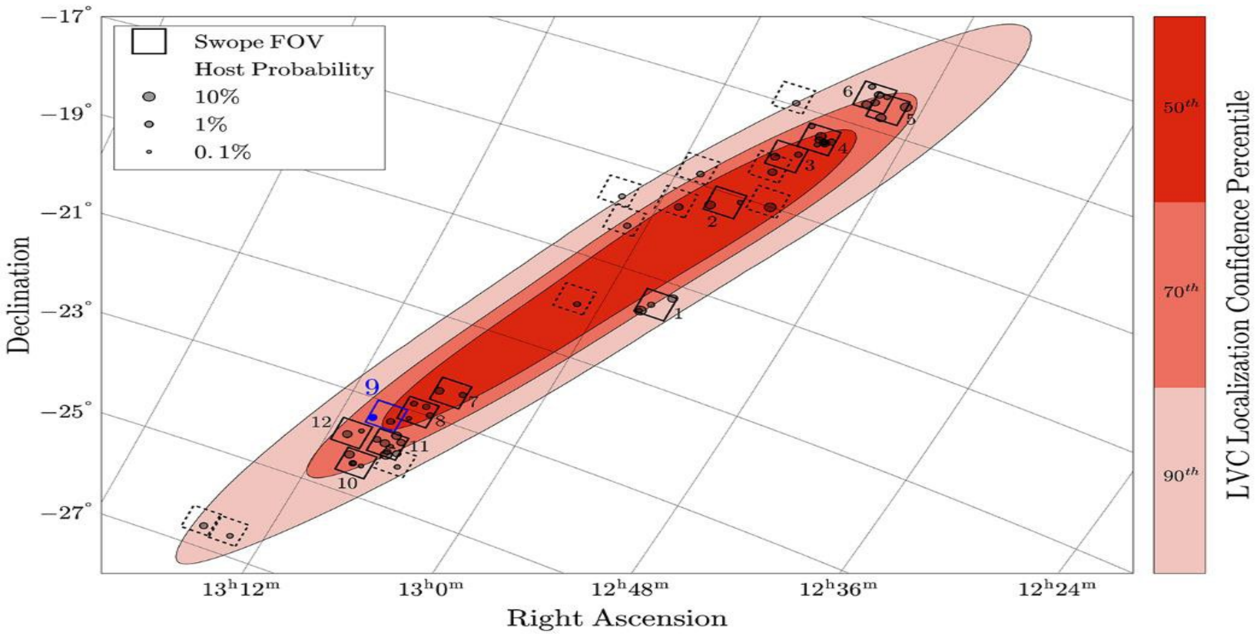
The optical transient

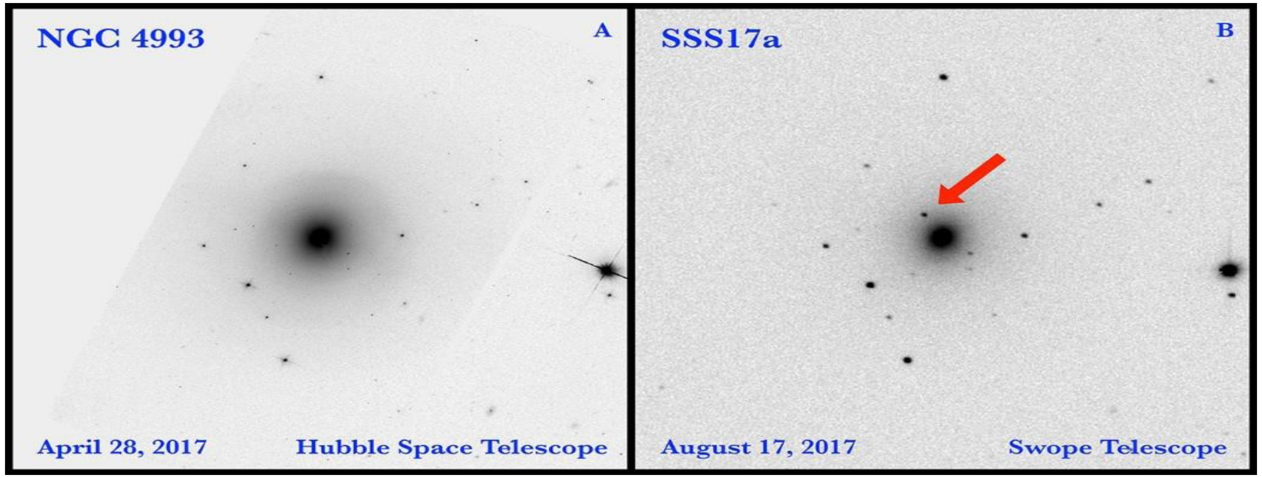


One-Meter, Two-Hemisphere (1M2H) team
1-m Swope telescope, Las Campanas (Chile)



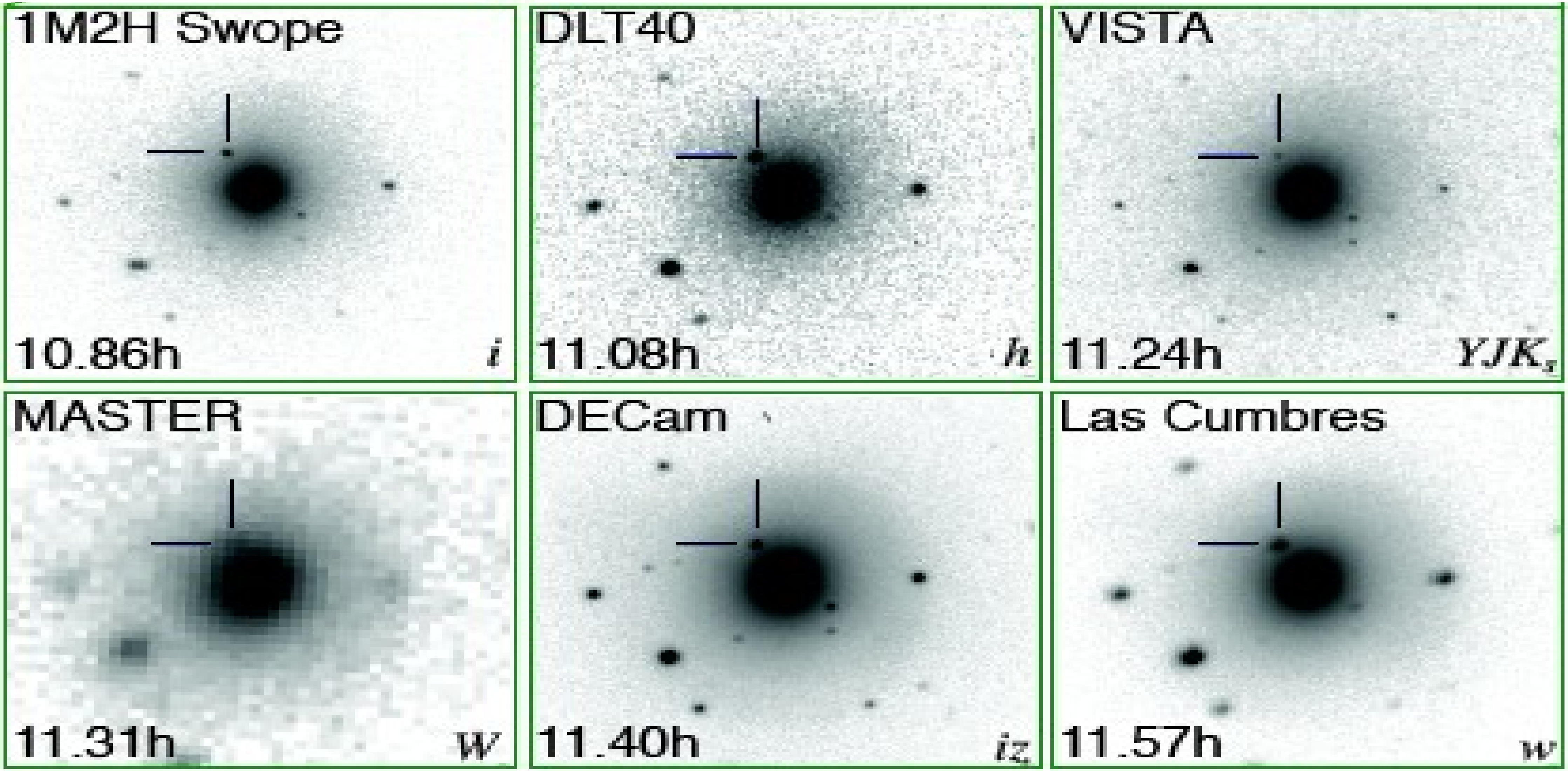
- Observation at t_0+10.8 hr
- mag(i) ~17
- Names SSS17a
- later AT2017gfo
- ESO 508 cluster at 40 Mpc

- *(Coulter et al. 2017)*



The fab six

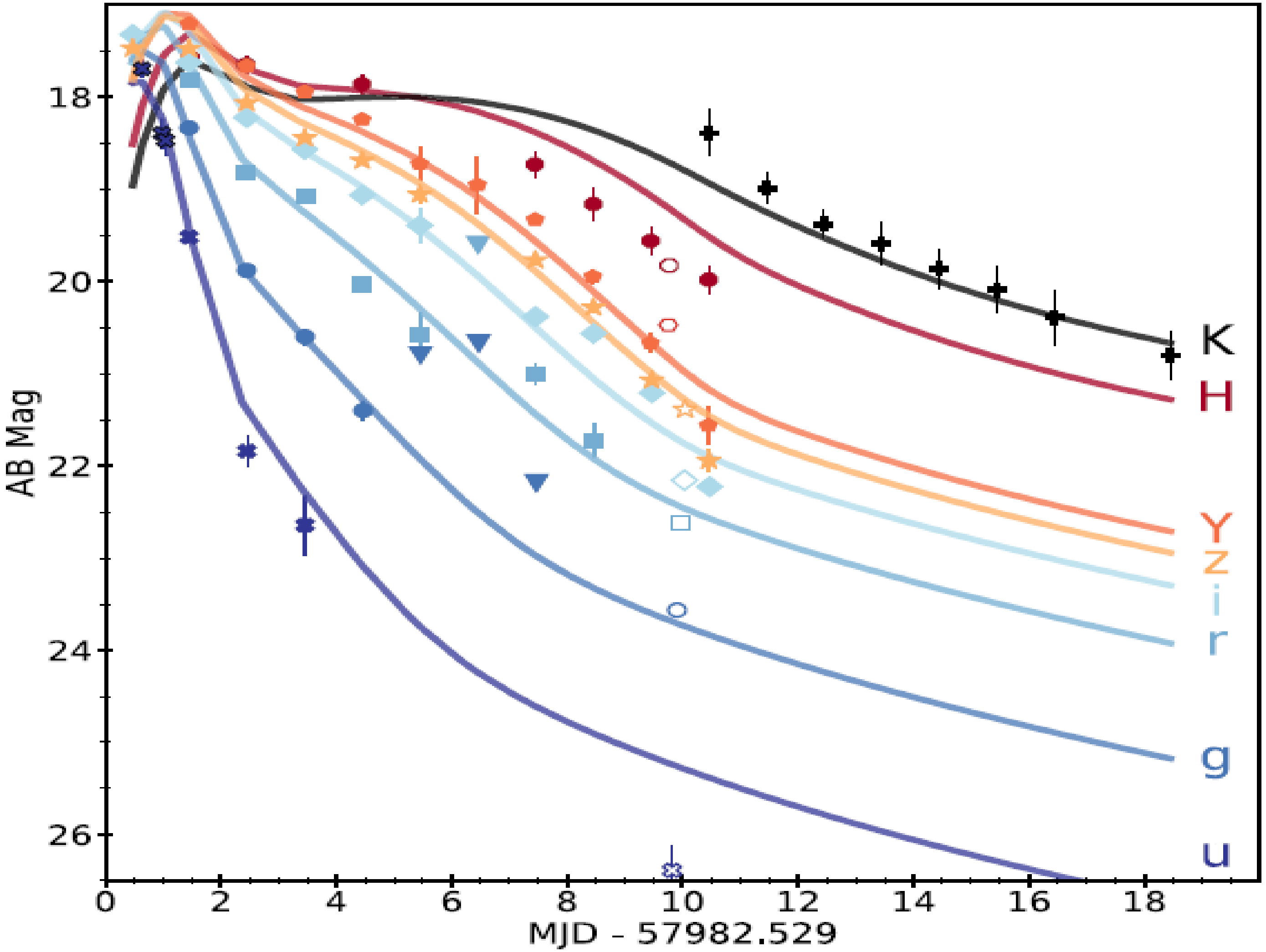
- *(Coulter et al. 2017)*
- *(Yang et al. 2017)*
- *(Tanvir et al. 2017)*



- *(Lipunov et al. 2017)*
- *(Allam et al. 2017)*
- *(Accavi et al. 2017)*

Broadband follow-up: UV, optical, IR

Next days Follow-up observations to rule out chance coincidences
Photometry using DECam, HST, Gemini-south, Swift, from IR to UV

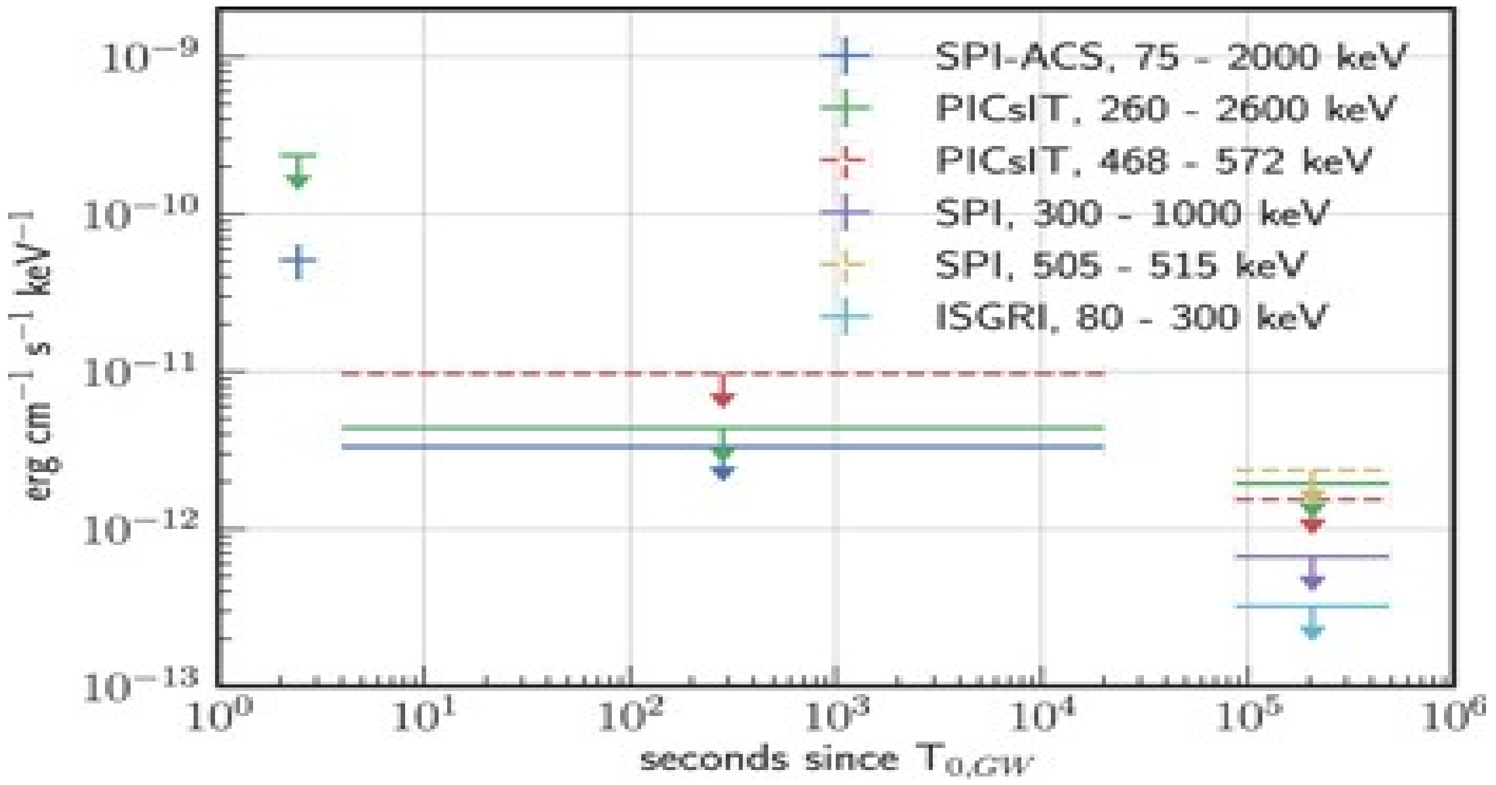


Cowperthwaite et al. 2017

Broadband follow-up: gamma rays

Gamma rays probe highly relativistic processes
Many high-energy facilities online (IPN)

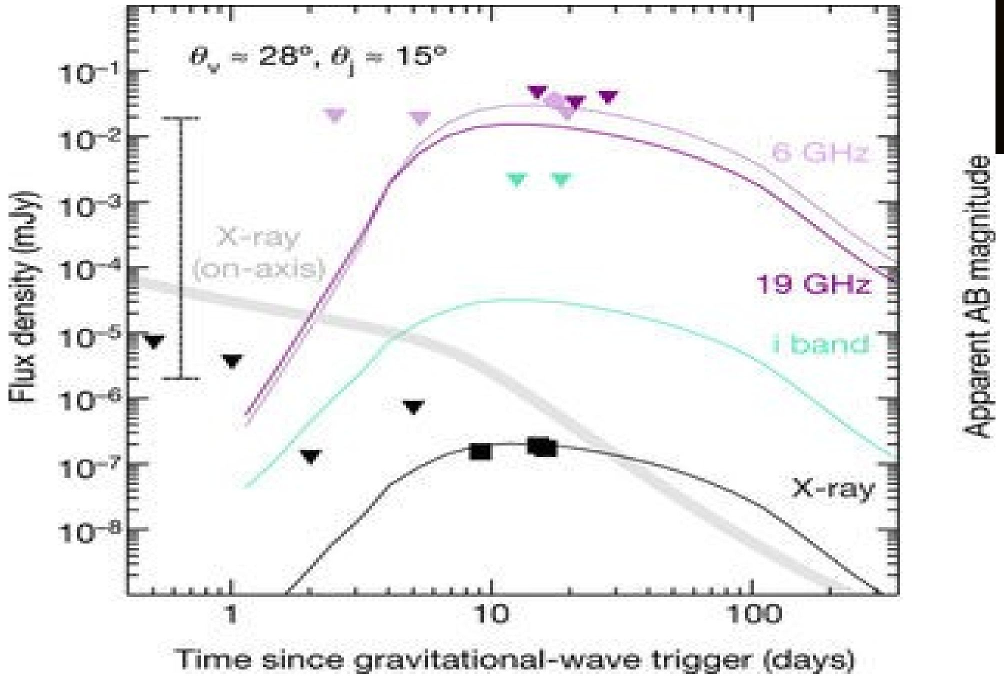
- Fermi GBM+Fermi LAT
- AGILE
- INTEGRAL
- HXMT
- CALET
- AstroSat
- HESS
- HAWC

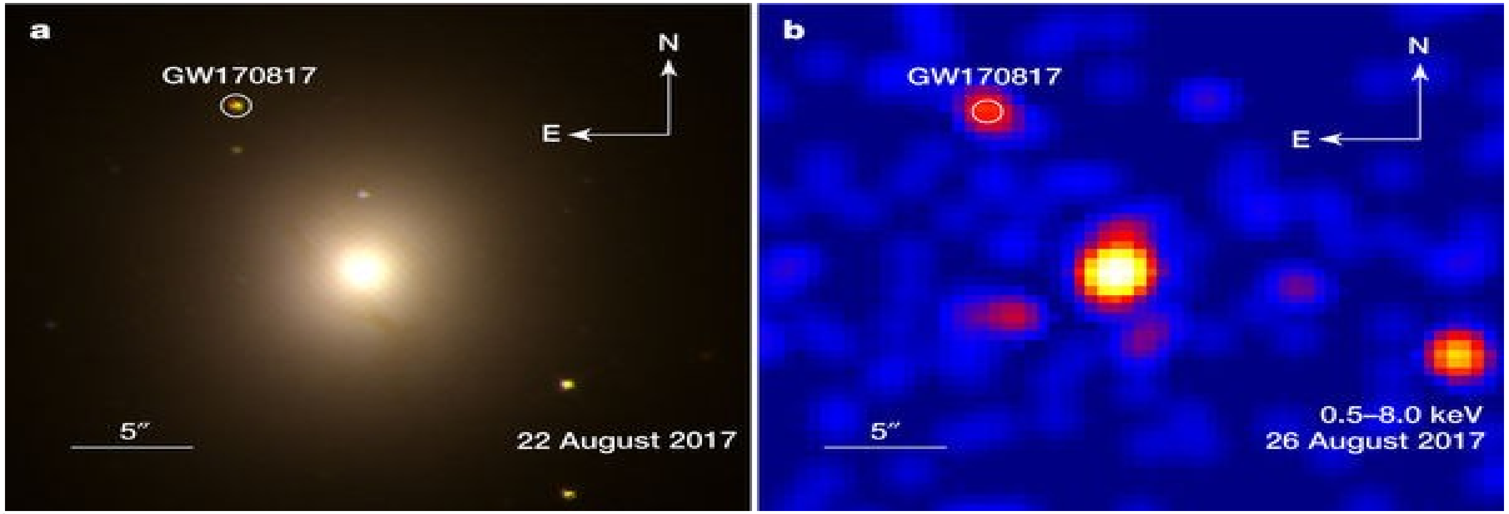


INTEGRAL upper limits
(Savchenko et al, 2017)

Broadband follow-up: X-rays

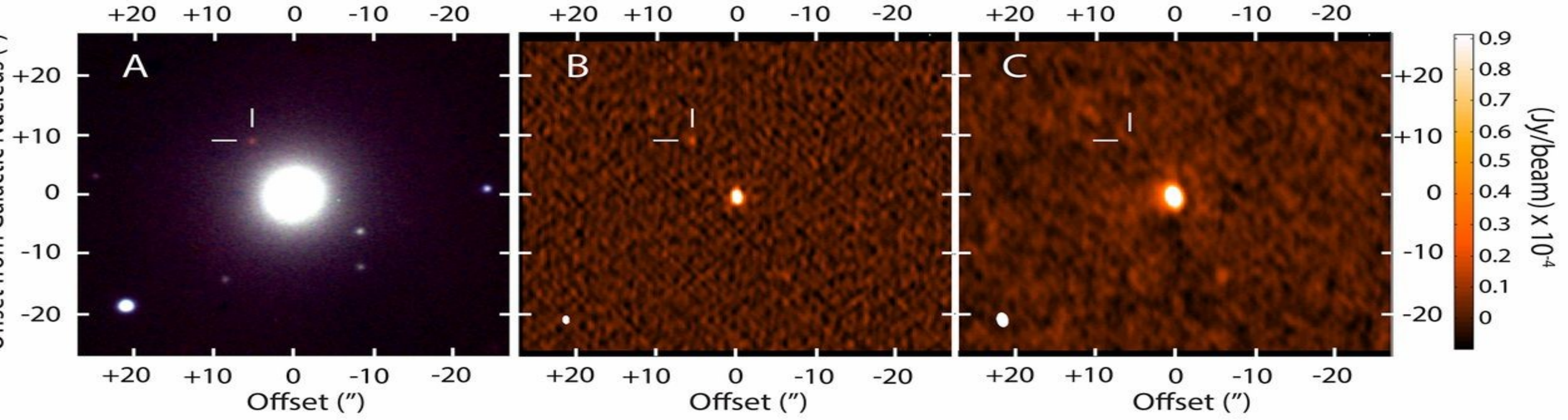
- No detections until t_0+9 days
- First detection by Chandra (Troja et al., 2017)
- Emission up to t0+15 days
- Now too close to the Sun





Broadband follow-up: radio

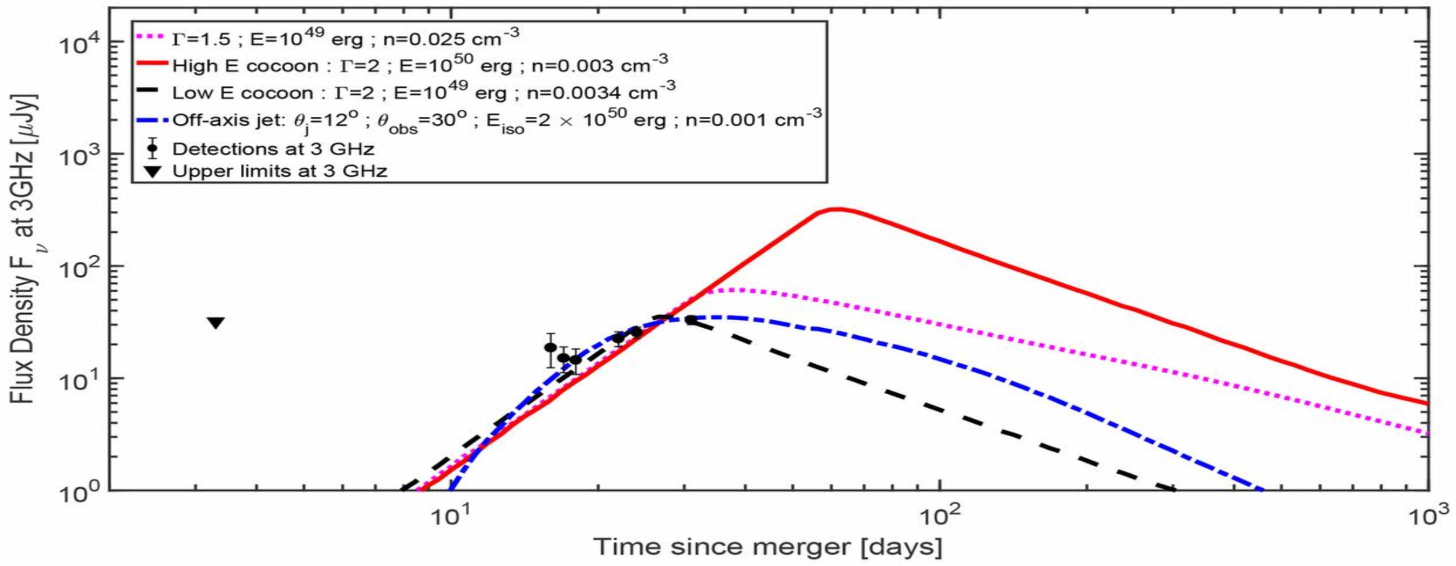
- First detection at t_0+16 days by VLA, confirmed by ATCA



6 GHz image @VLA

Consistent with cocoon or off-axis emission

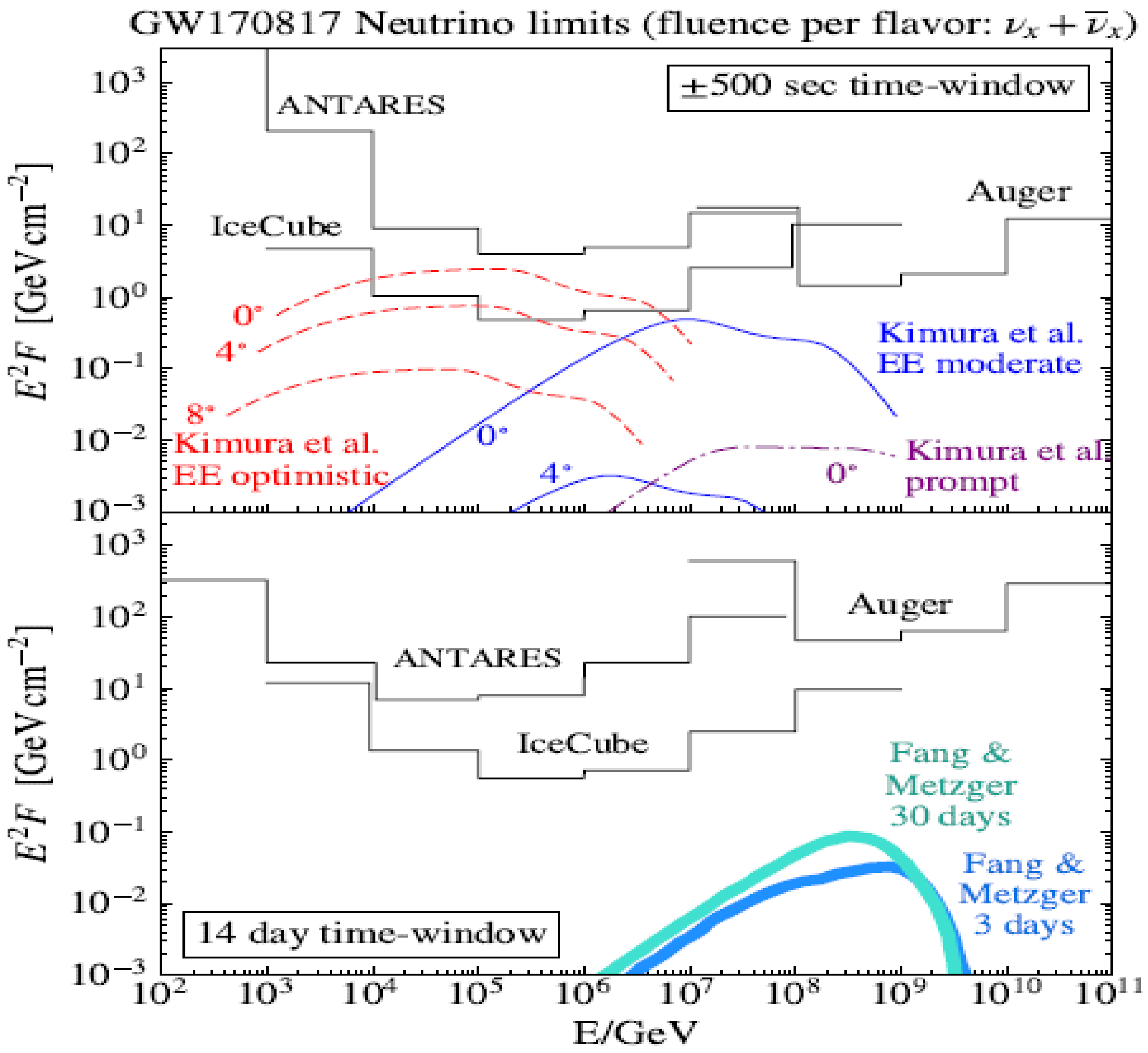
Hallinan et al 2017



Broadband follow-up: neutrinos

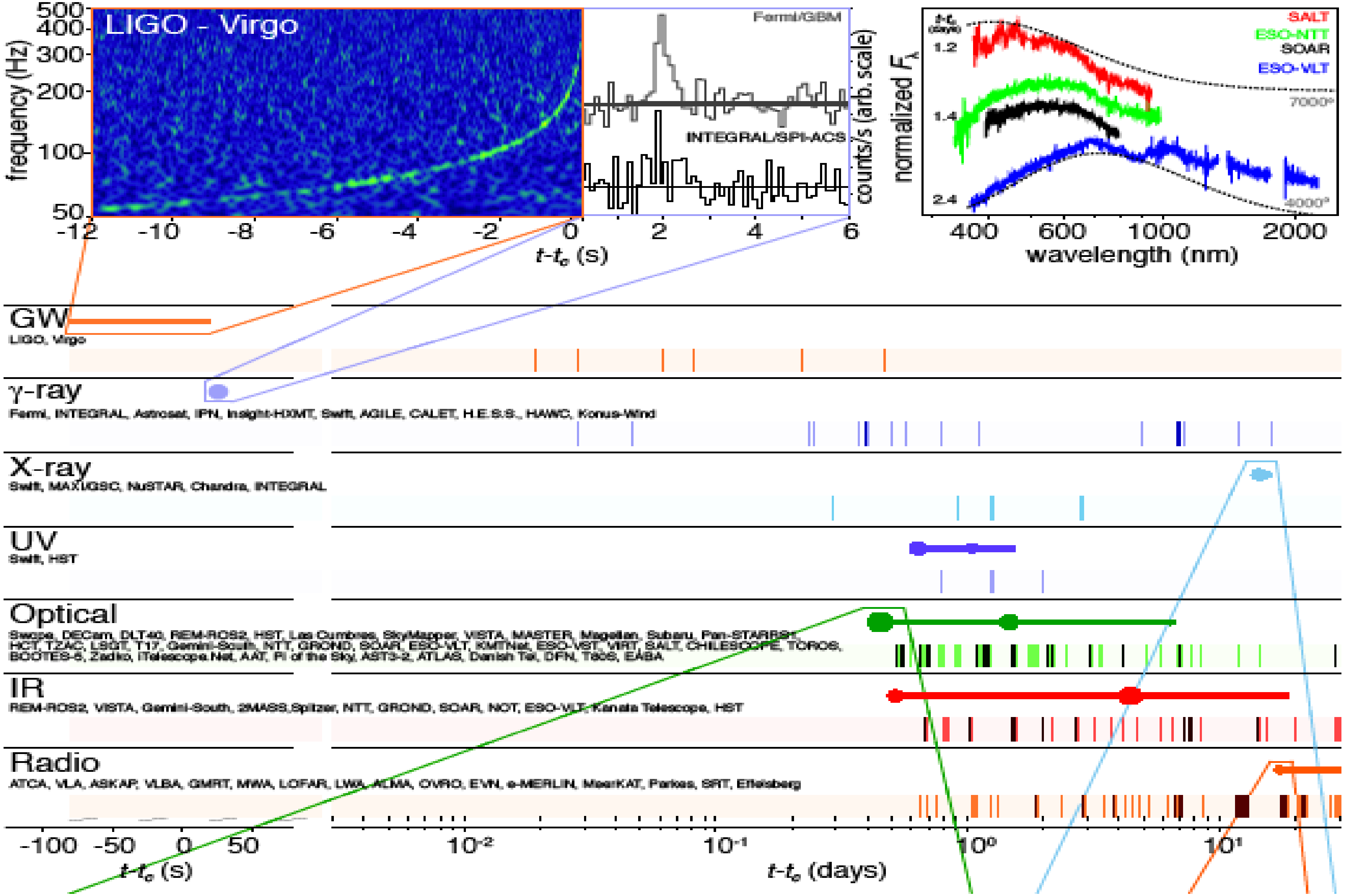
- Icecube
- ANTARES
- Pierre Auger Observatory

No detection
Upper limits computed



Albert et al 2017

The big picture



Abbott et al 2017

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Moving toward O3

- Longer LIGO + Virgo joint observations

- Higher sensitivity → New challenges

- (many) more astrophysical transients
  - → Need to have automatic, low-latency EM alert systems (e.g. localizations)
- BUT also more noise
  - → Automatically assess data quality & veto
- Transitioning toward public release of data
  - → Support and prepare web data distribution
- The people in the WP are working on these topics

Fast detector characterization

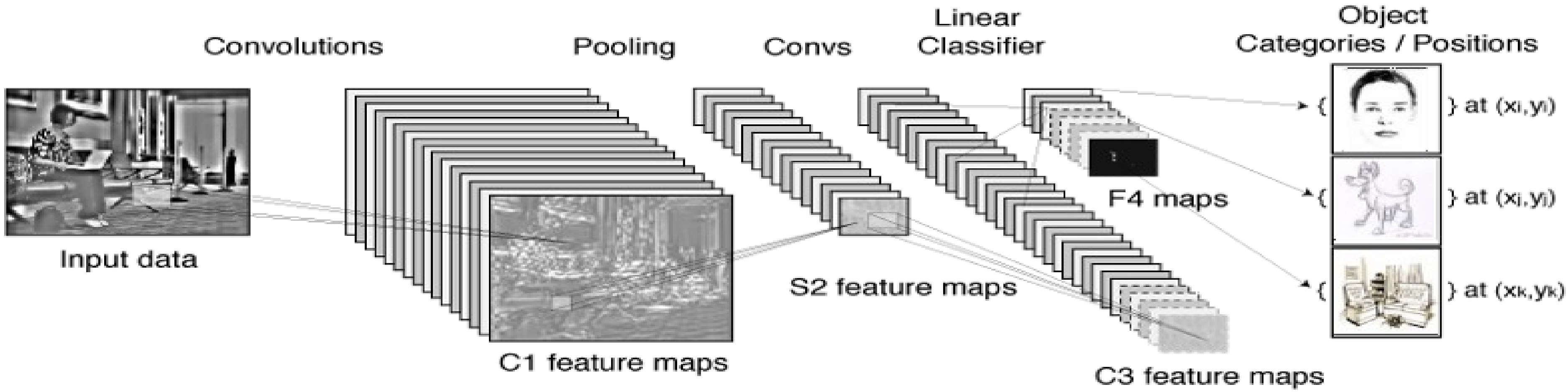
- Noise in GW detector has a non-stationary components (glitches)
- Detecting and classifying glitches is one of the key aspects for detector characterization and data analysis
- Various methods/pipelines to detect glitches in data
- Glitches can have complex time-frequency signatures → difficult to classify
- Manual classification impossible (too many & slow)
- Different automatic classification pipelines developed or under development

Why Deep Learning?

- We are exploring use of Machine Learning and Deep learning to classify glitches
- Burst of activity within LVC to apply ML and DL to GW studies
- In principle, a deep network can approximate any continuous function (universal approximation)
- In our case, the function F is:
  - F: glitch data → glitch class
- We developed a new classification pipeline that classify glitches using supervised deep learning
- We start from image-based classification, complementary to the existing methods (e.g. Powell+15, Powell+17)

Image-based glitch classification

- Many approaches to data: we choose image classification of time-frequency evolution of glitches
- For image classification, simple deep neural networks are not optimal (too CPU expensive)
- The architecture is based on Convolutional deep Neural Networks (CNNs).
- CNNs are more complex than simple NNs but are optimized to catch features in images, so they are the best choice for image classification
- Work in collaboration with E. Cuoco (EGO)



Contribute to open data release

- LIGO portal to release public data of events after publication
- LIGO Open Science Center (LOSC)

Conclusions

- GW astronomy has begun
- Dawn of multimessenger observations
- Activities toward next run (O3)
- Analysis activities focus on developing new low-latency pipelines to enable multimessenger observations (e.g. detchar, localization)
- Secondments started, will continue during this year