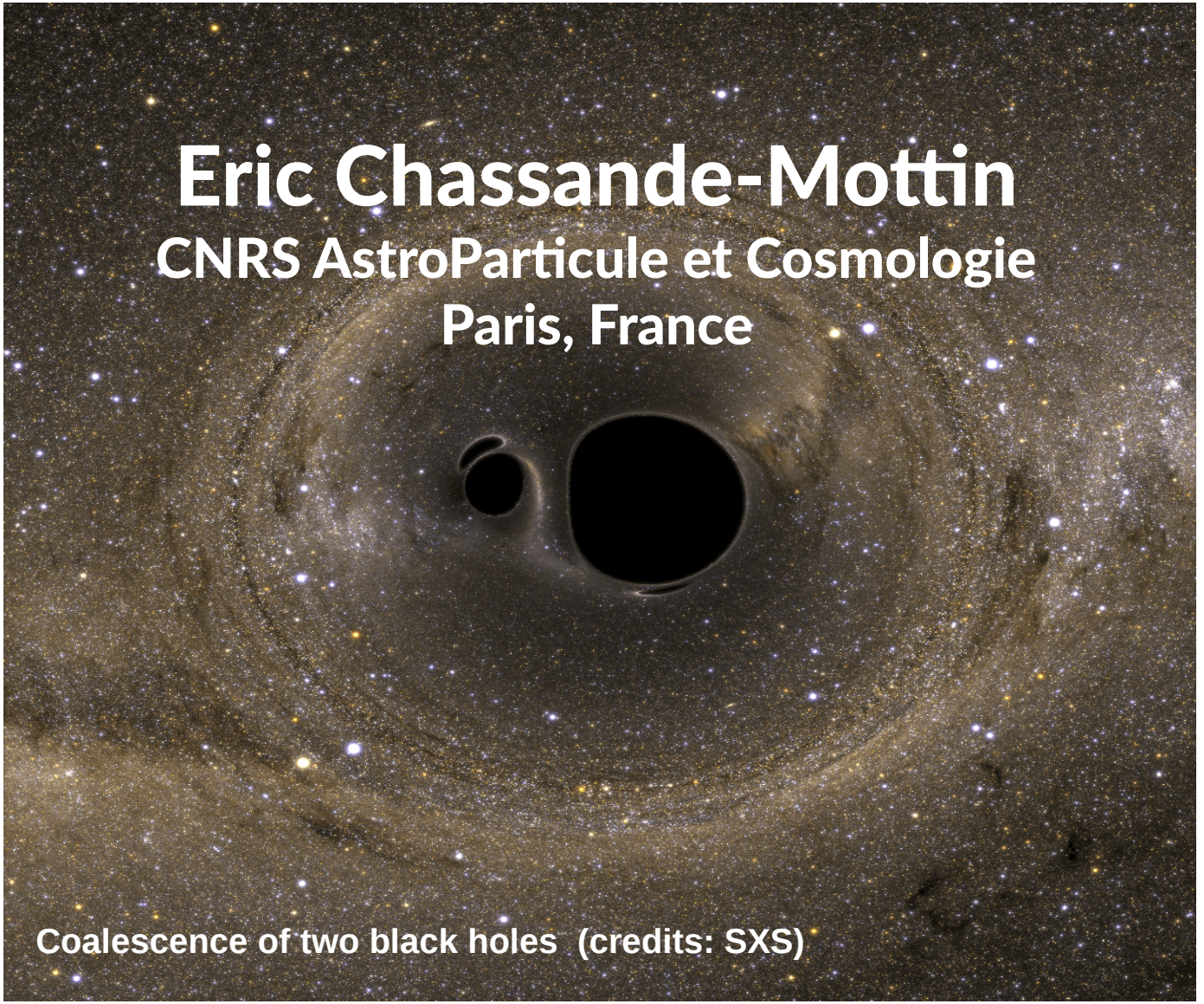
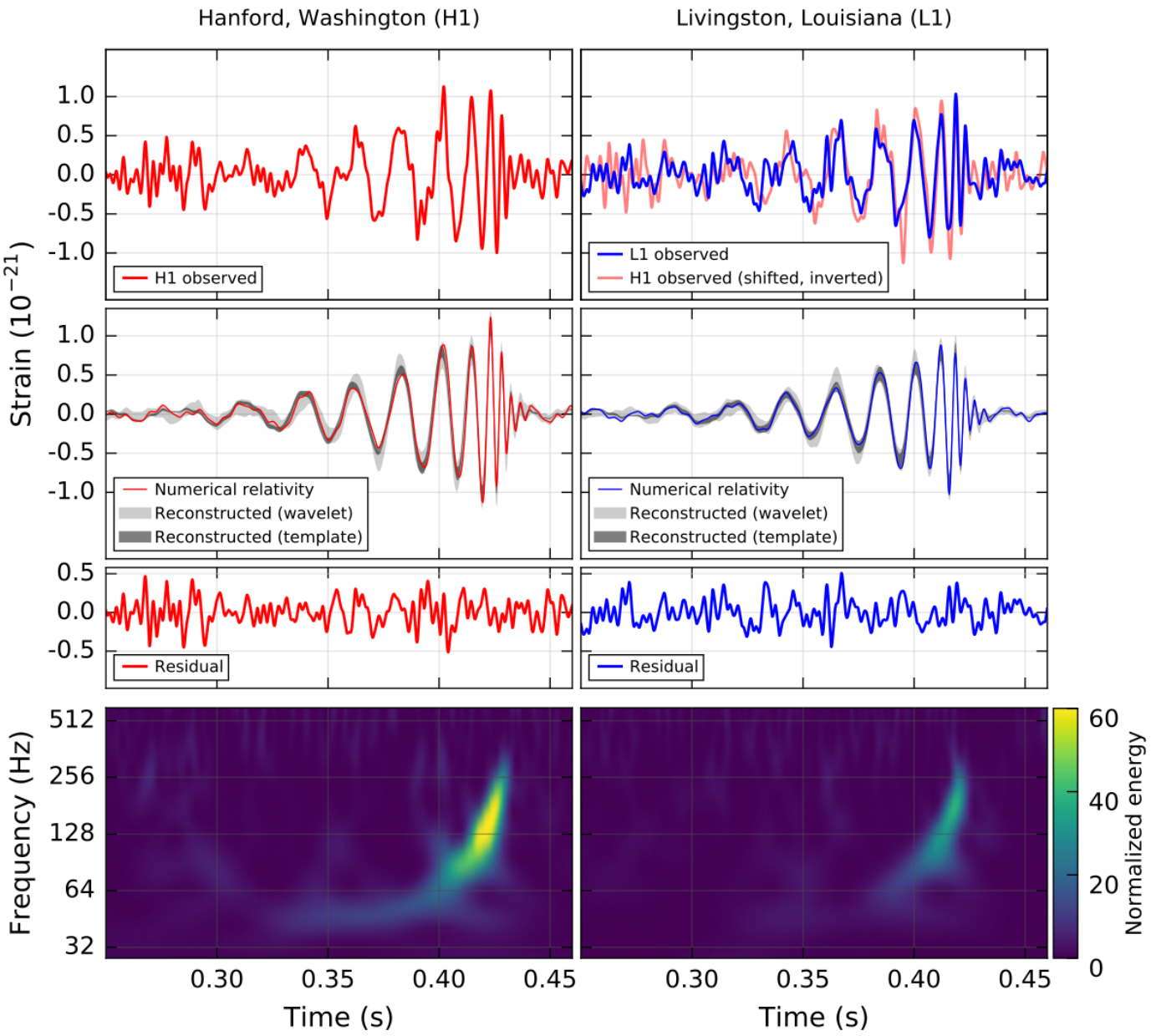
Observation of gravitational waves: the big picture



Sep 14, 2015 09:50:45 UTC



Why is this important?

- First **direct detection of gravitational waves**
  - First confirmation of their existence from the Hulse-Taylor binary
- First **direct observation of a black hole**
  - inferred from the characteristic ringdown of the observed signal
  - … and not from the influence on gas surrounding black hole
- First **observation of a black hole binary**
- The **most luminous** event ever detected $3.6^{+0.5}_{-0.4} \times 10^{56}\ \mathrm{erg/s}$

Electromagnetic follow-up

Rationale: GW150914 is very luminous, it is located at ~400 Mpc (z~.1) relatively nearby

What if a tiny fraction of energy emitted in EM or neutrinos?

But we don't expect for binary black hole merger

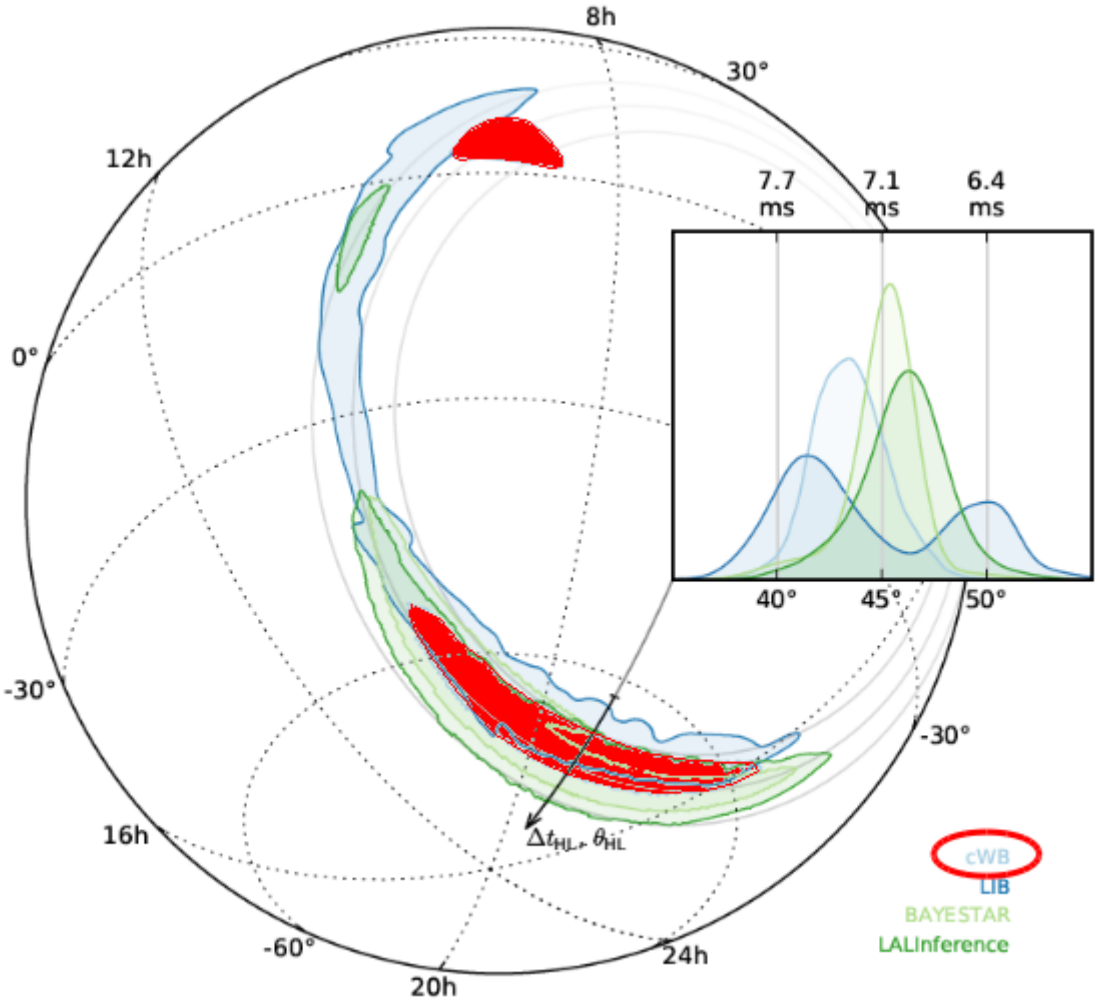
Low latency search

Four **low-latency search pipelines**

T0+3 min = Event uploaded to DB
T0+17 min = First sky map
T0+2 days = Alert sent
T0+2 months = Final sky map

GW error region is ~600 deg^2

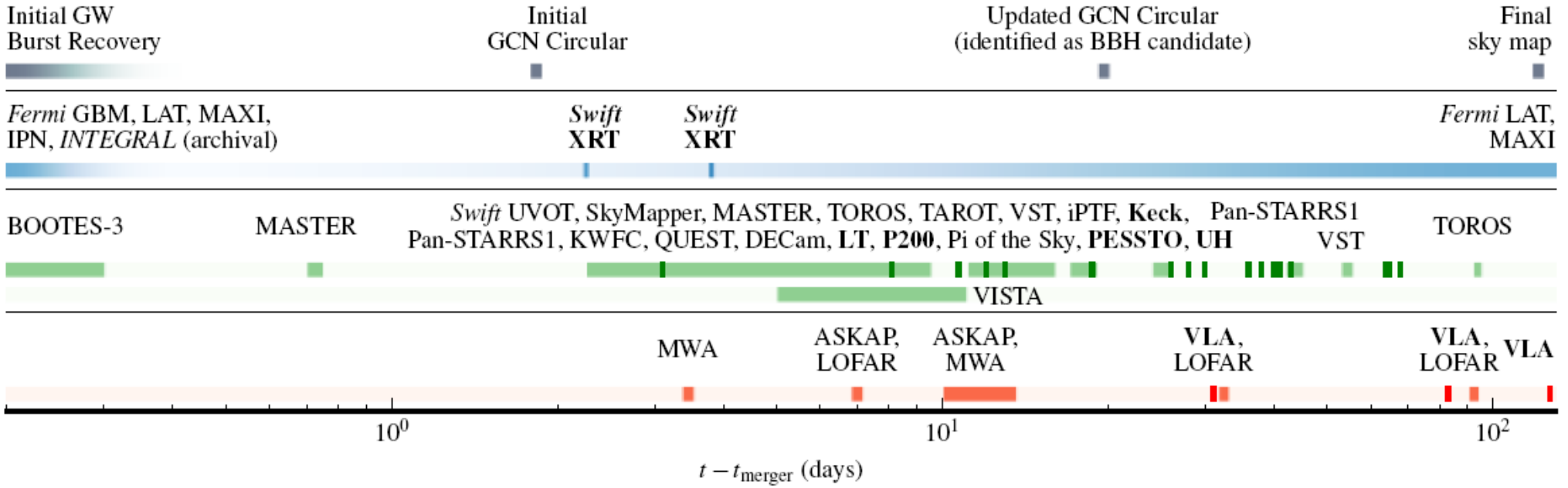
With Virgo on, with full sensitivity, the GW error region reduces to ~10 deg^2



Electromagnetic follow-up

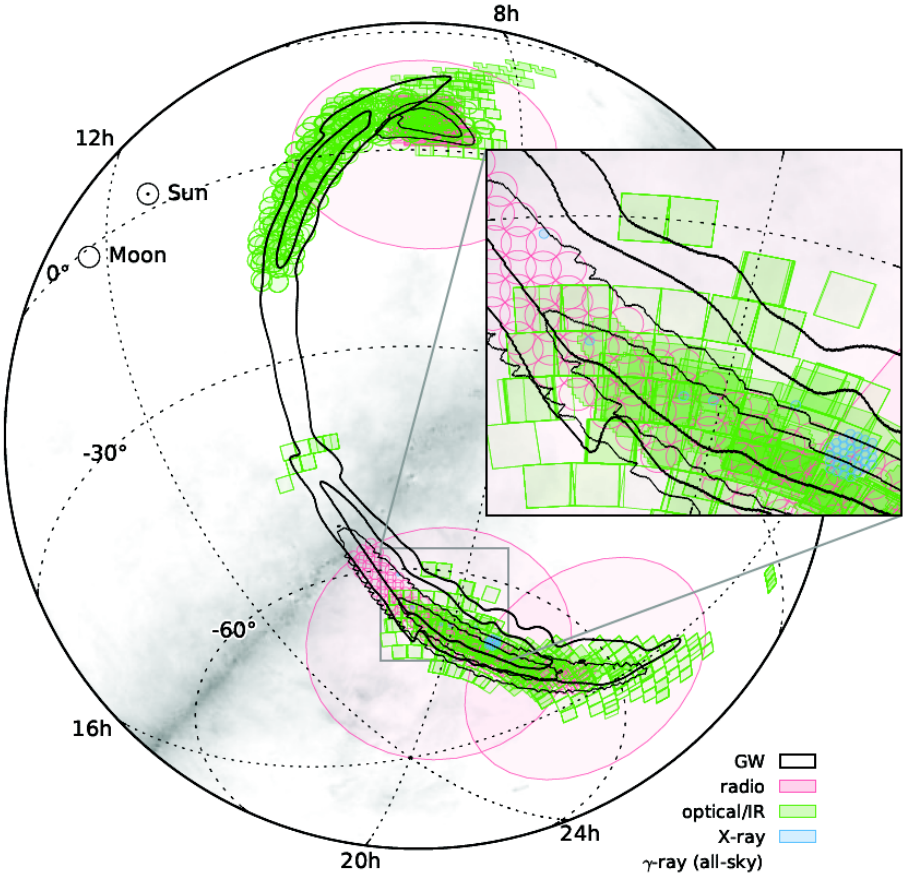
25 teams of observers responded to the GW alert

Multiwavelength: from radio to gamma-rays



T0+2 days

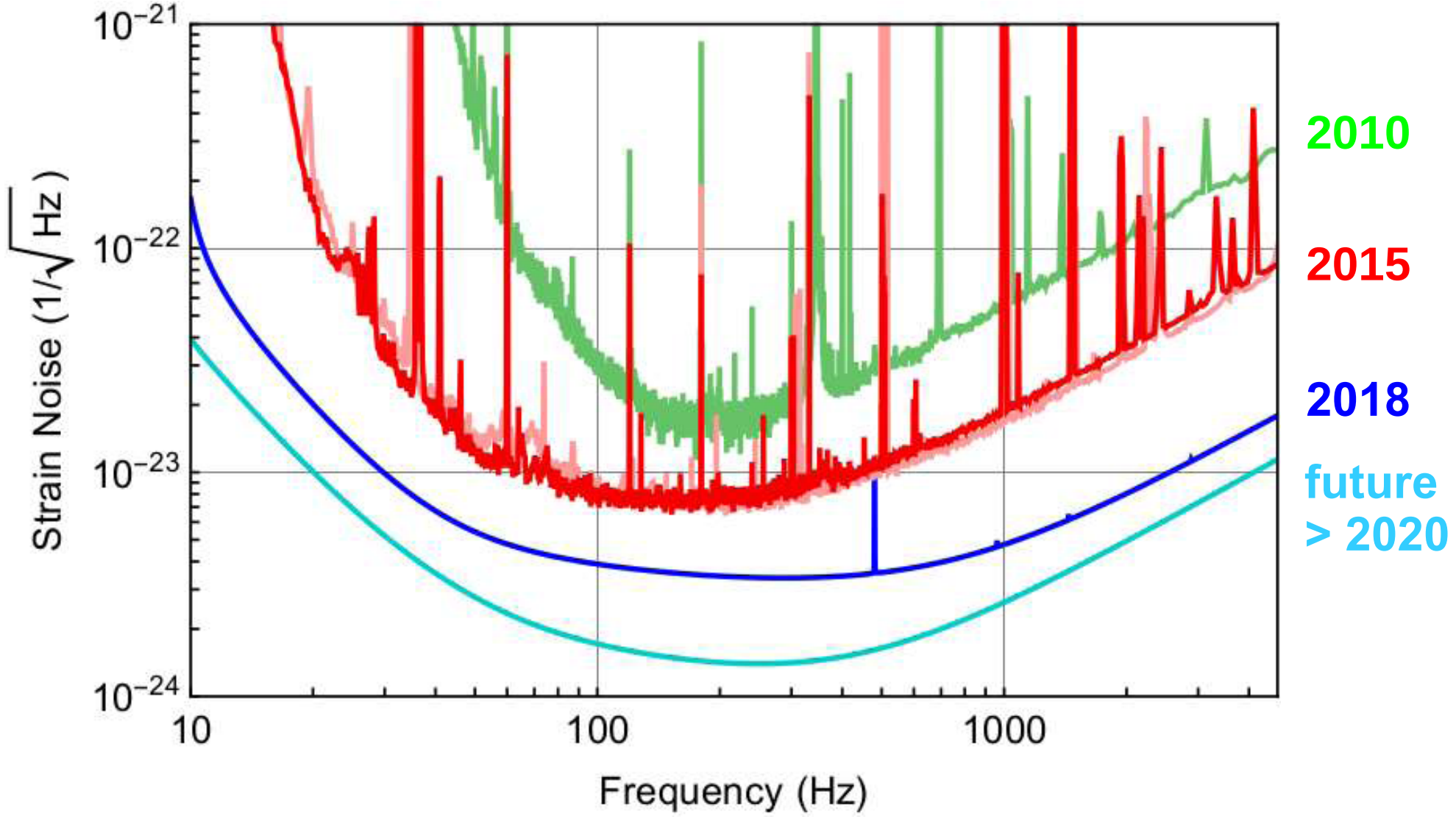
Electromagnetic follow-up



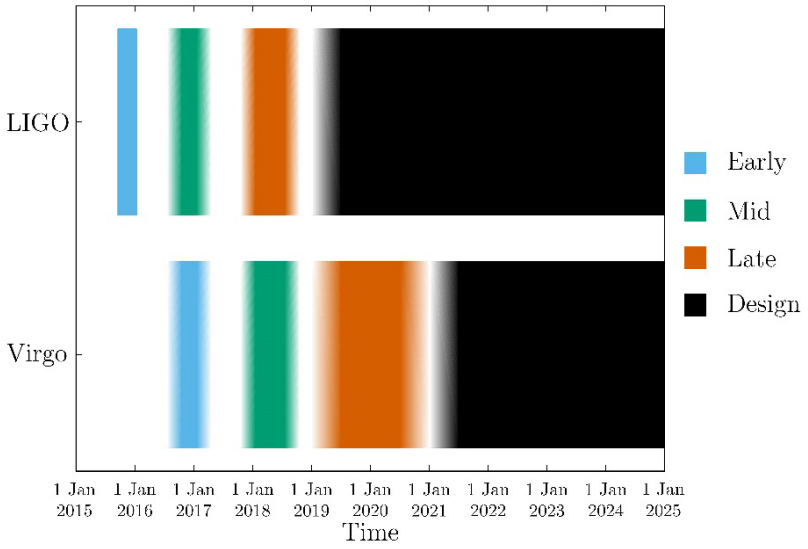
No convincing counterpart found

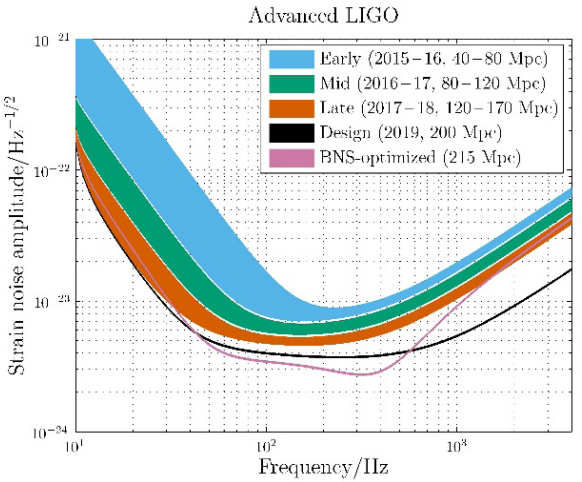
Fermi/GBM case

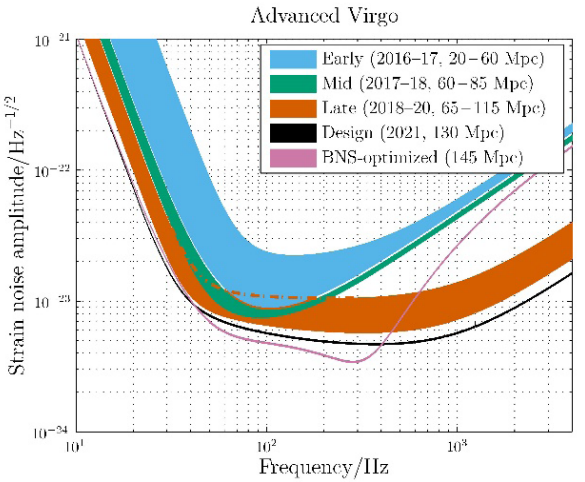
What's next?


10^{-21}
10^{-22}
10^{-23}
10^{-24}
Strain Noise ($1/\sqrt{\text{Hz}}$)
10
100
1000
Frequency (Hz)
2010
2015
2018
future
> 2020

What's next?





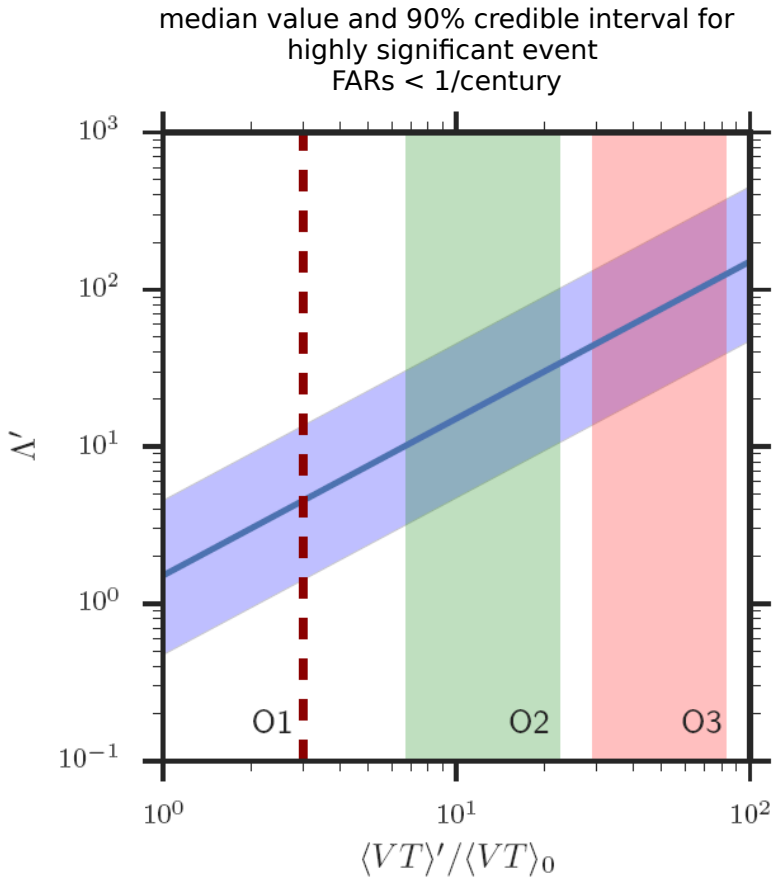


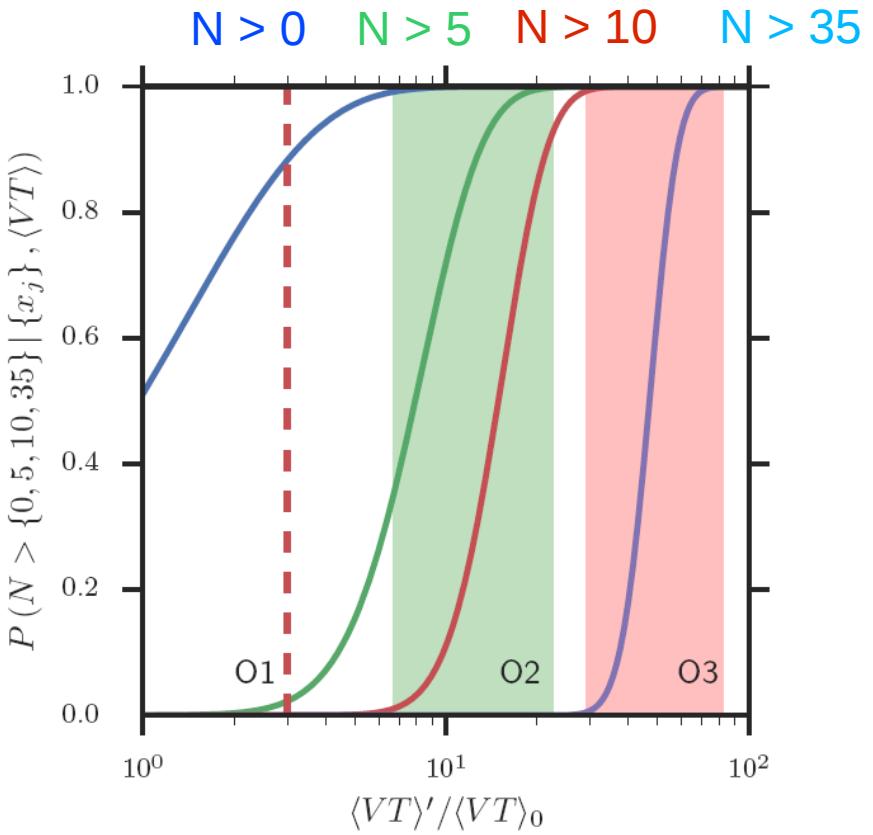
Epoch			2015–2016	2016–2017	2017–2018	2019+	2022+ (India)
Estimated run duration			4 months	6 months	9 months	(per year)	(per year)
Burst range/Mpc		LIGO	40–60	60–75	75–90	105	105
		Virgo	—	20–40	40–50	40–80	80
BNS range/Mpc		LIGO	40–80	80–120	120–170	200	200
		Virgo	—	20–60	60–85	65–115	130
Estimated BNS detections			0.0005–4	0.006–20	0.04–100	0.2–200	0.4–400
90% CR	% within	5 deg^2	< 1	2	*> 1–2*	*> 3–8*	*> 20*
		20 deg^2	< 1	14	*> 10*	*> 8–30*	*> 50*
	median/deg^2		480	230	—	—	—
searched area	% within	5 deg^2	6	20	—	—	—
		20 deg^2	16	44	—	—	—
	median/deg^2		88	29	—	—	—

The next big thing

- Dawn of GW astrophysics
  - Will continue to observe binary black-hole mergers (10 – 100 events?)
- **EM counterpart to GW** is the one of the next big things
  - A breath of science! [many 10^{th} of publications after Fermi/GBM announcement]
  - First case expected: neutron star binaries or black hole-neutron star
  - Virgo will help to get a better sky position
  - Need tools/software infrastructures to help connecting GW to conventional astronomy!

Prospects for BBH mergers





Real-time, open, public alerts after 4 published events. By beginning of O3?

EM signal from BBH mergers?

To explain possibly associated gamma-rays:

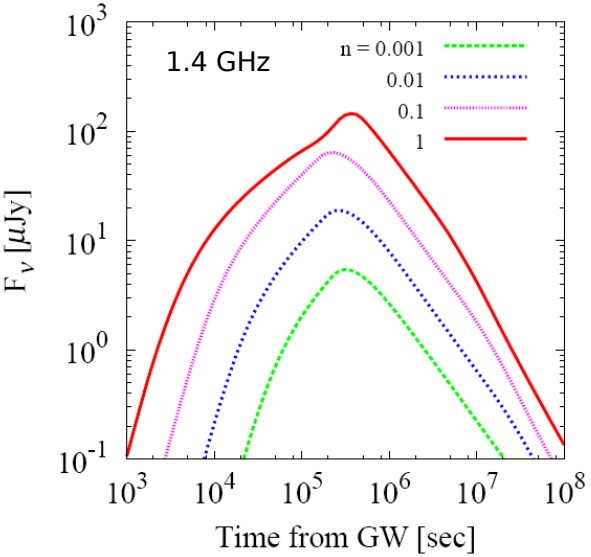
BBH with very small separation formed in the collapse of a massive star, resulting in GRB nearly simultaneously with GWs? (Loeb, 2016)

Unusually long-lived disk around BBH produces GRB at the time of coalescence? (Perna et al. 2016)

If matter ("mini-disk") exists around (B)BH

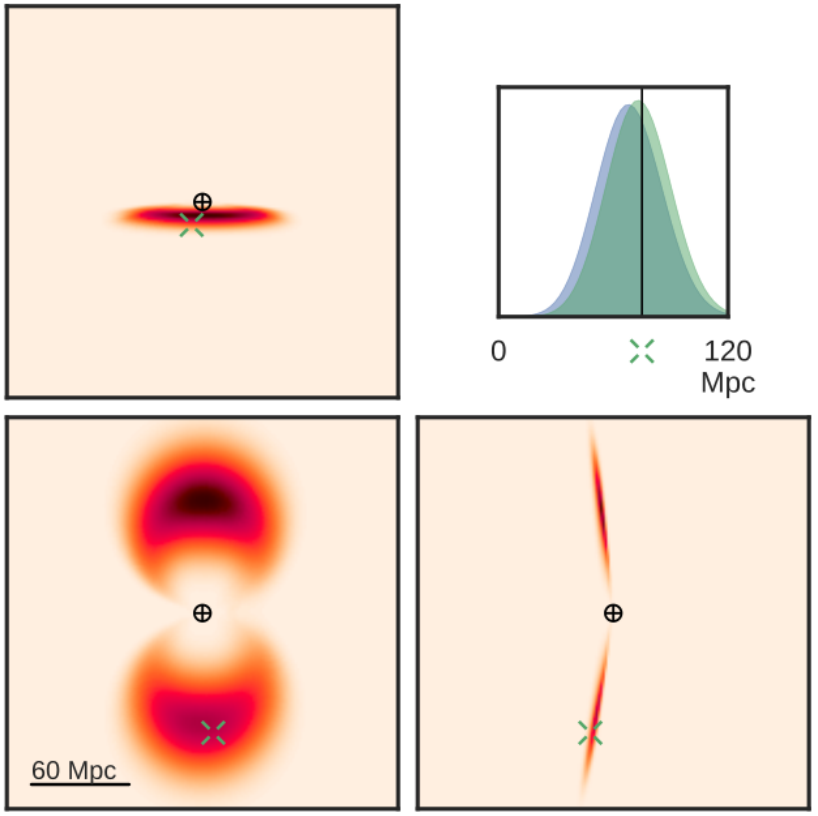
Strong disk wind may be driven by radiation or magnetic fields → **Fast optical transient around 22 mag in V-band** may be produced when thermal photons break out of the outflow

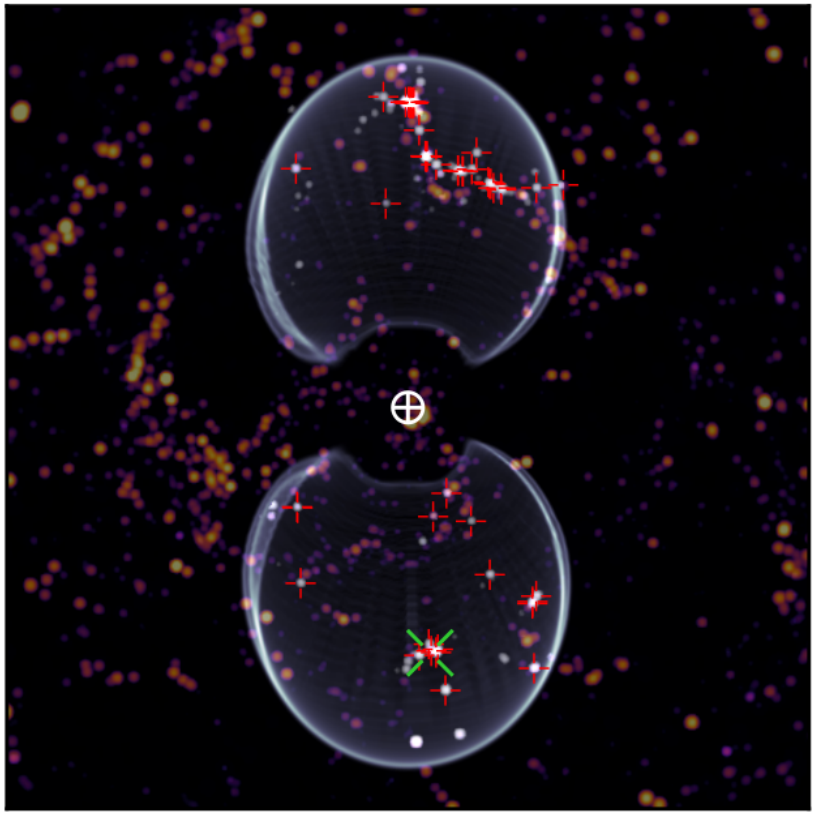
Ultra-fast flow associated with a mini-disk wind develops a blast wave which decelerates and can **generate a radio afterglow**



From Corsi, talk at APS April 2016
Murase et al Astrophys.J. 822 (2016) L9
Yamazaki et al. arXiv:1602.05050

3D skymaps





~1^{o} wide, 10-100^{o} breath, ~100 Mpc deep

Singer et al, arXiv:1603.07333

Volume ~30 x 10^{3} Mpc^{3}

Past and future visibility of GW150914