Recherche de contre-parties optiques aux ondes gravitationnelles

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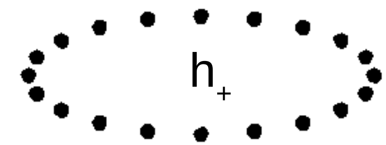
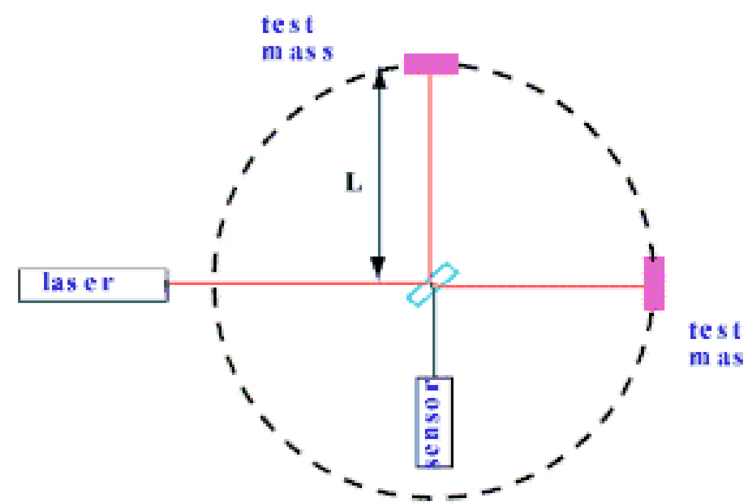
1-slide primer on Virgo

- Gravitational waves GW
  - Propagating space-time distorsion predicted by General Relativity
  - Goal: measure GW directly (*in situ)*

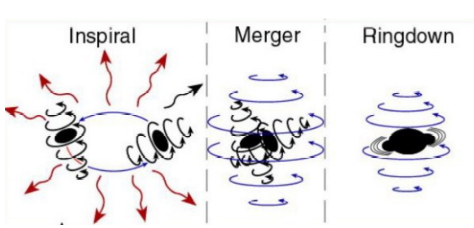


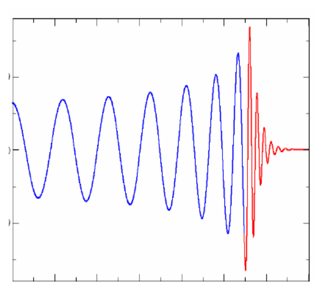
- Kilometric Michelson interferometer
  - Measure relative difference in optical path length to 10^{-21}, or 10^{-18} m over km
  - Sensitive about few 100 Hz



- Target distant astrophysical sources
  - Typically: binaries of stellar mass compact objects (neutron star or black hole)

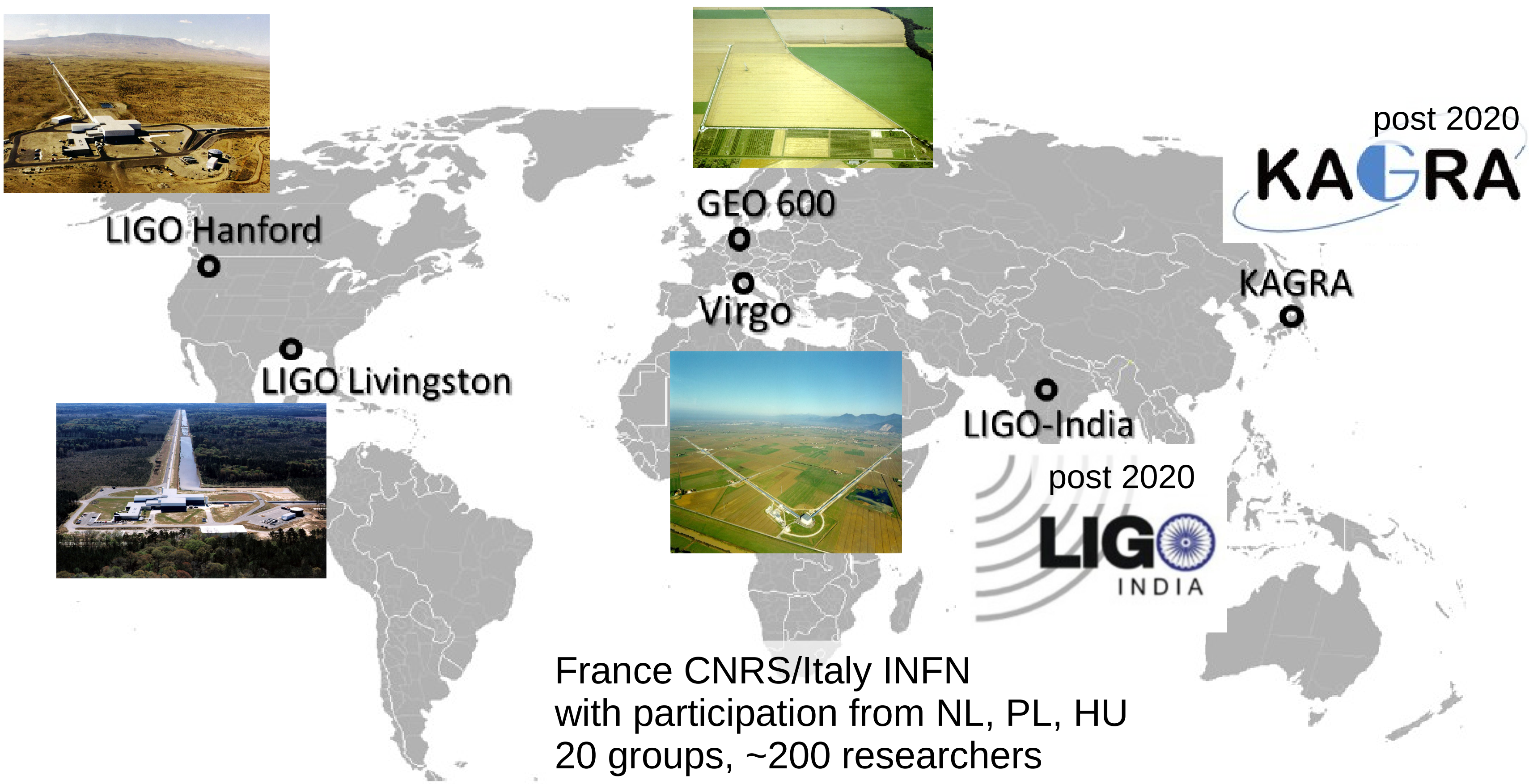
$h \sim 10^{-21}$ for NS binaries at 15 Mpc





$$h(t) = \frac{\delta L(t)}{L} \propto \delta\Phi(t)$$

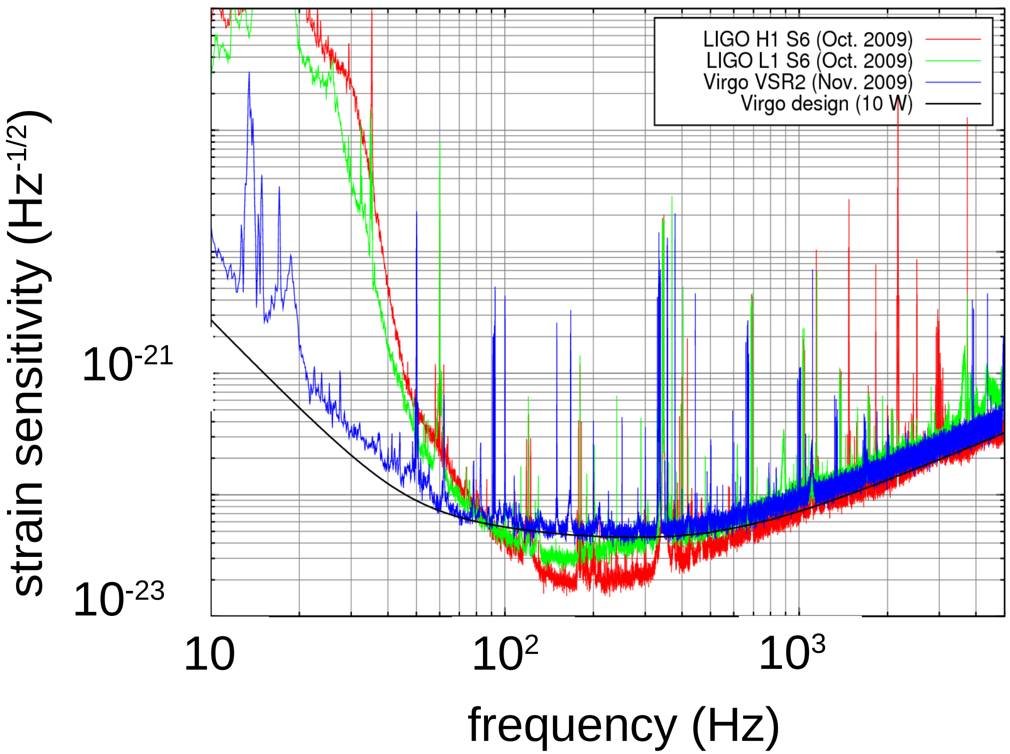
GW detectors in the world



Since 2007, partnership and data exchange agreement
> 1,000 researchers involved

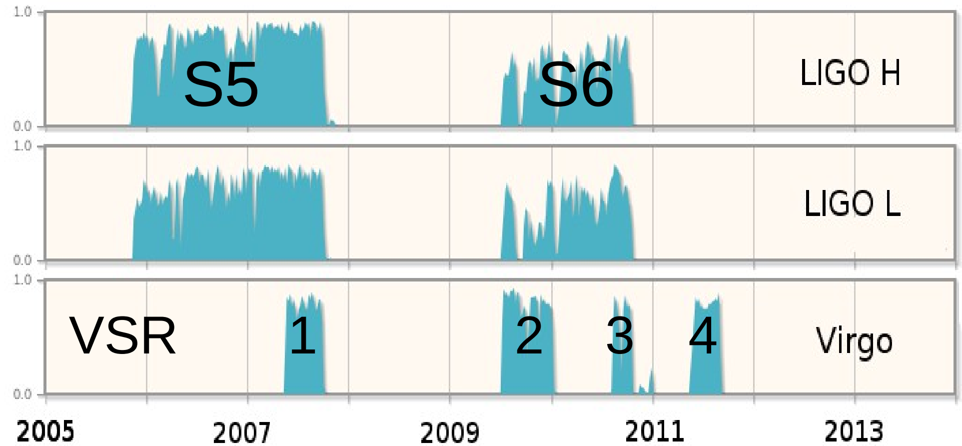
Science from 1st generation 2005-11

Reached design sensitivity!



"horizon" = detection range of coalescing binaries of neutron stars (BNS)

LIGO ~ 40 Mpc and Virgo ~ 20 Mpc



3 joint LIGO – Virgo science runs

~2 yrs total

40 papers published and more to come

Transient sources (BNS, BBH and bursts; in connection with astrophysical triggers, e.g., GRB or neutrinos)

Continuous sources (pulsars)

Stochastic background

Toward 2nd generation detectors

- Advanced Virgo
  - x 10 more sensitive → x 1000 more sources
  - Same infrastructure – new instrumentation

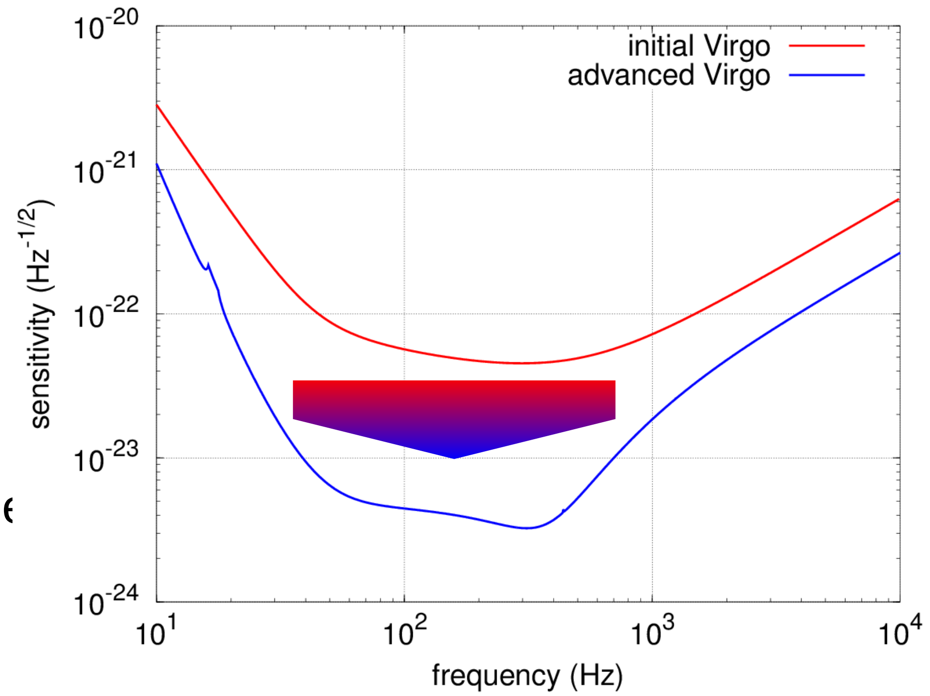
    x 10 more laser power

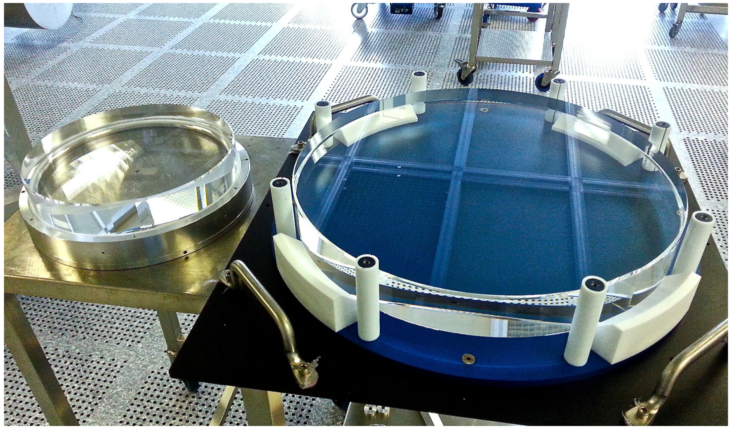
    x 65 more light power stored in the cavitie

    Larger beam size & mirrors → lower thermal noise

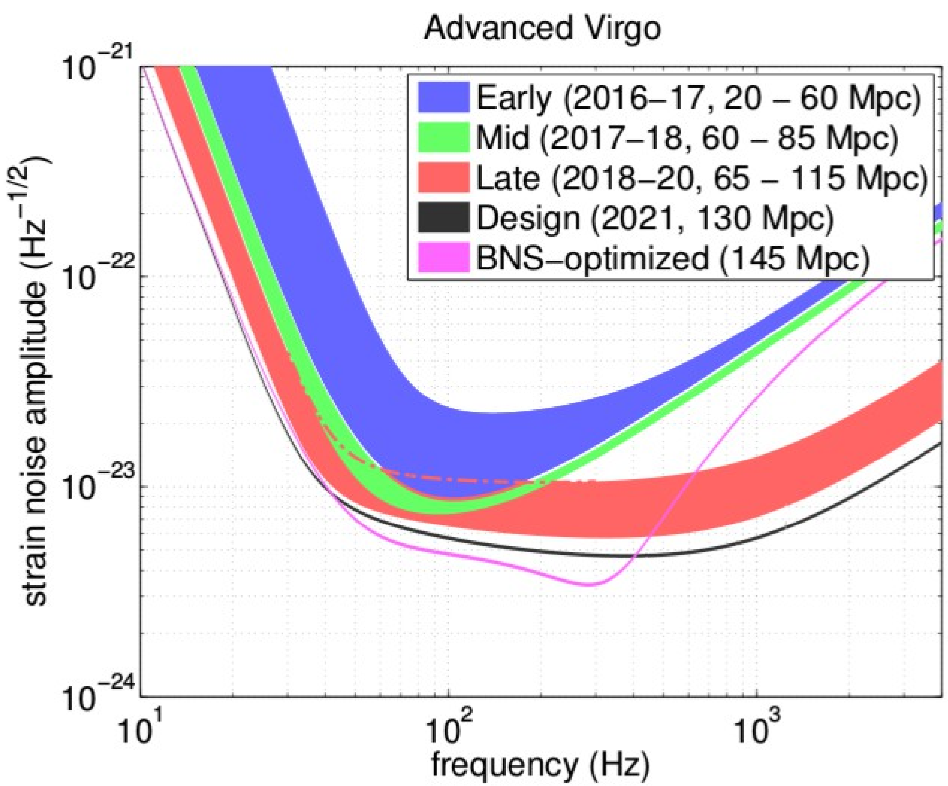
    GW signal recycling
  - Being installed

    Current plan : 1st science data in 2016

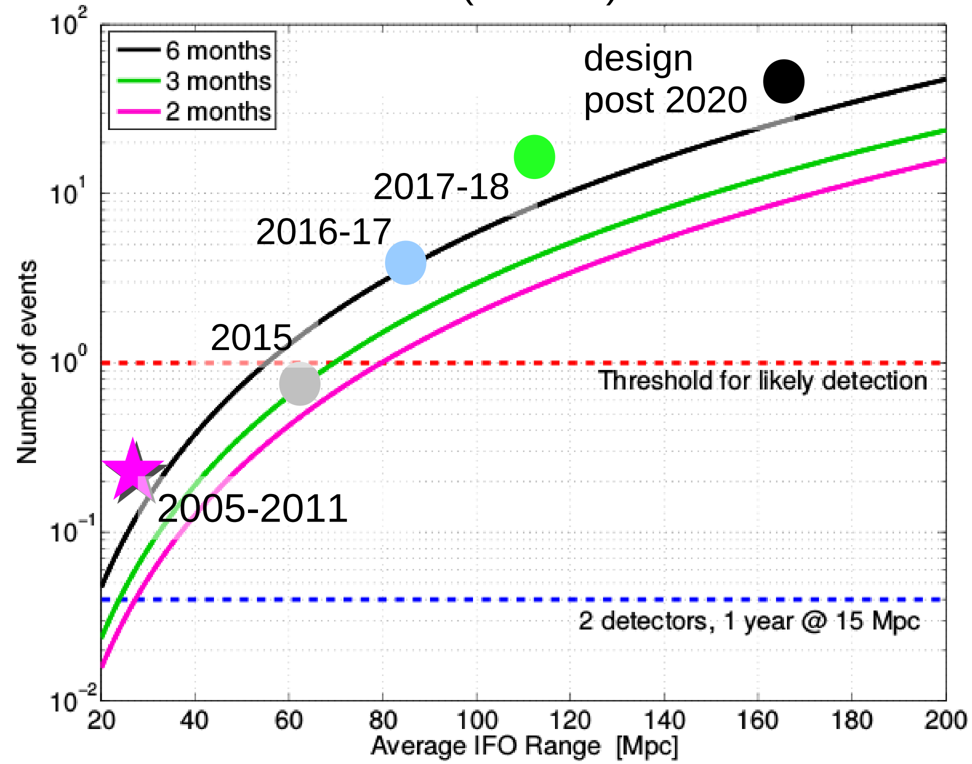




Science with 2nd generation 2015-2022+



# of detections $\propto$ (horizon)^3 x obs duration

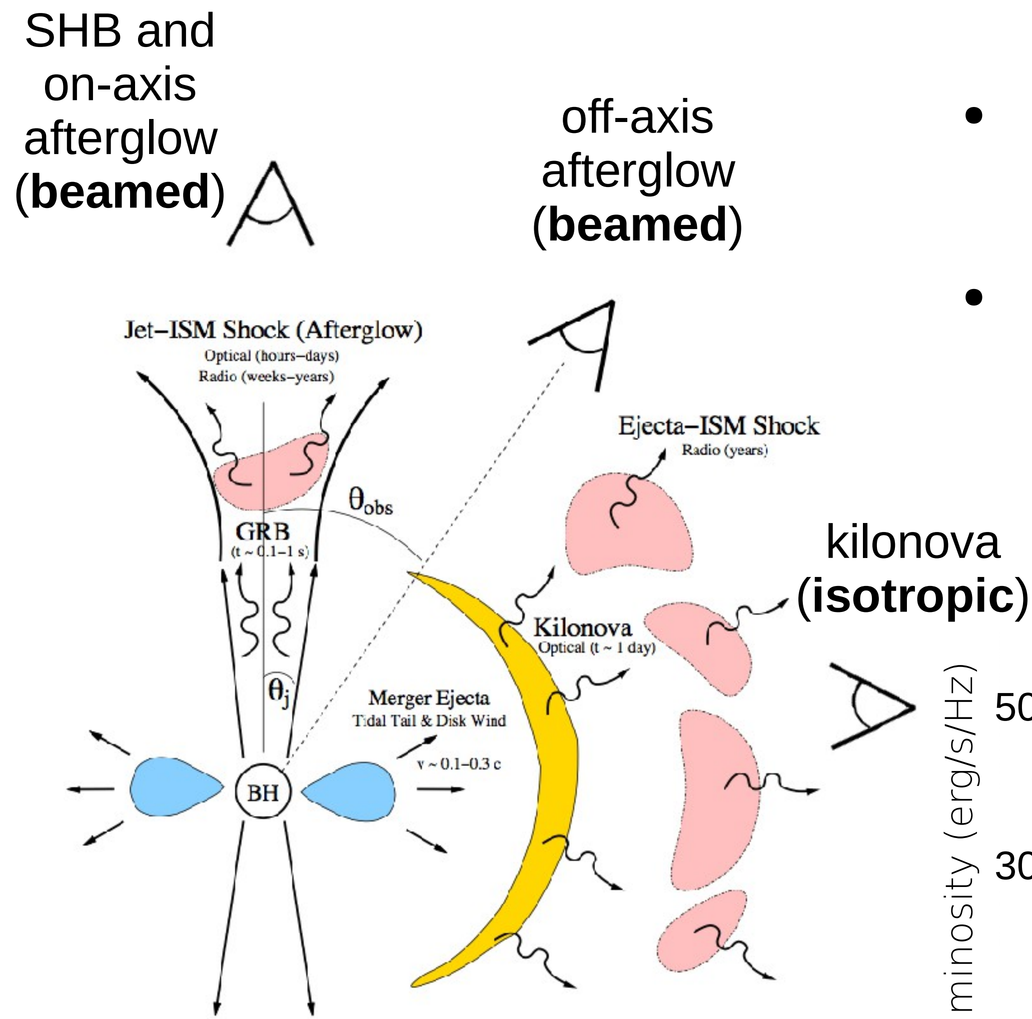


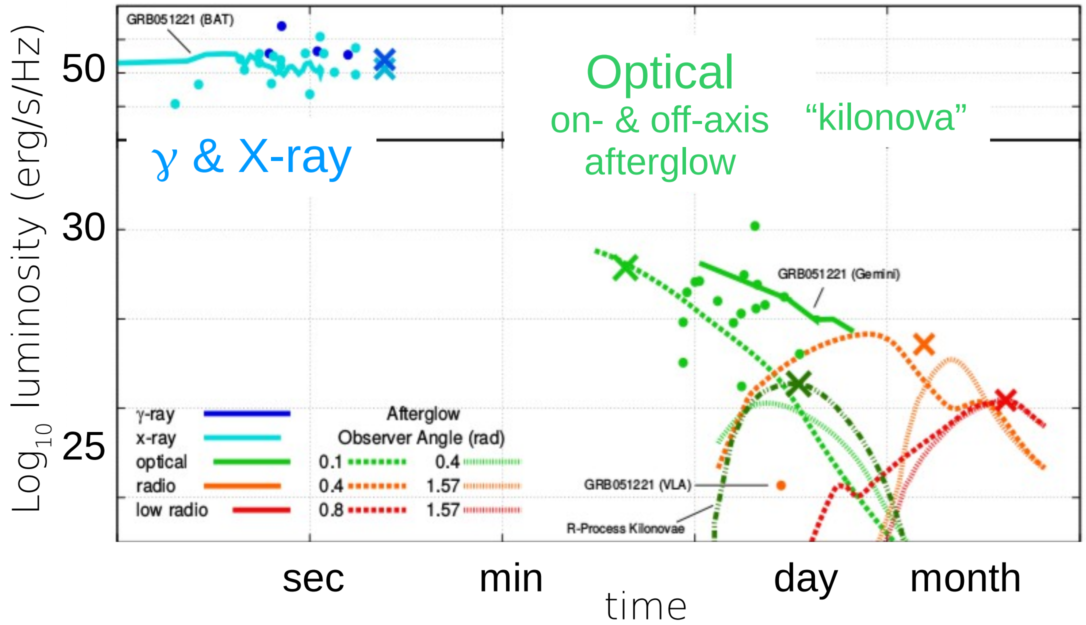
Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_\odot c^2$ Burst Range (Mpc) LIGO	Virgo	BNS Range (Mpc) LIGO	Virgo	Number of BNS Detections	% BNS Localized within 5 deg^2	20 deg^2
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48

ArXiv:1304.0670

EM counterparts to GW

- GW sources are likely sources of EM radiation as well
- Short gamma-ray bursts (SHB)
  - Potentially connected to BNS or BH-NS mergers





Courtesy of B. Metzger and Kelley et al, arXiv:1209.3027

Multimessenger observations

- **GW → EM: EM follow-up**
  - Transient sources will be searched on-line with few mins latency
  - Source direction reconstruction by triangulation with accuracy

    100 sq degrees (~min)

    30 sq degrees (~days)
  - Alerts sent through a “private” network to partner astronomical observatories
  - Confirm the astrophysical nature of the detected GW event
  - Open call issued in Dec 2014

    60 groups expressed interest

    ~150 instruments (12 space-based)

- **EM → GW: Astrophysically triggered GW searches**
  - e.g., GRBs, from radio or optical transient surveys
  - Search for GW transient coincident in time and direction with the trigger
  - Allows potentially deeper search (i.e., with lower detection threshold)

The potential of LSST

- **2021+, 2nd phase (with KAGRA, LIGO India)**
  - ✓ BNS horizon distance to ~200 Mpc, few tenth events/year
  - ✓ Angular resolution ~1 sq deg typ. (< 10 sq deg)
- **LSST transient survey**
  - ✓ SHB afterglow: 4 Gpc (70/yr); kilonova: 450 Mpc (150/yr) [optimistic!]
  - ✓ GW triggered search find +10 % more sources than GW-only search

    +3 kilonova/yr = +40 % in the number of multimessenger observations!
- **EM follow-up with LSST**
  - ✓ Ideal instrument: large FOV and depth!
  - ✓ Breaking survey cadence?

Predictions from Kelley et al, Phys. Rev. D 87, 123004 (2013)

Conclusions

- **Virgo has fullfilled its mission**
  Reach target sensitivity, major science objectives published
- **With Advanced Virgo, the next decade will probably see the 1st direct detection of GW**
- **Clear synergy with time-domain astronomy**
  Multimessenger observations have a lot of potential

Many challenges and a lot of excitement ahead!