What comes next for LIGO?
Planning for the post-detection era in gravitational-wave detectors and astrophysics

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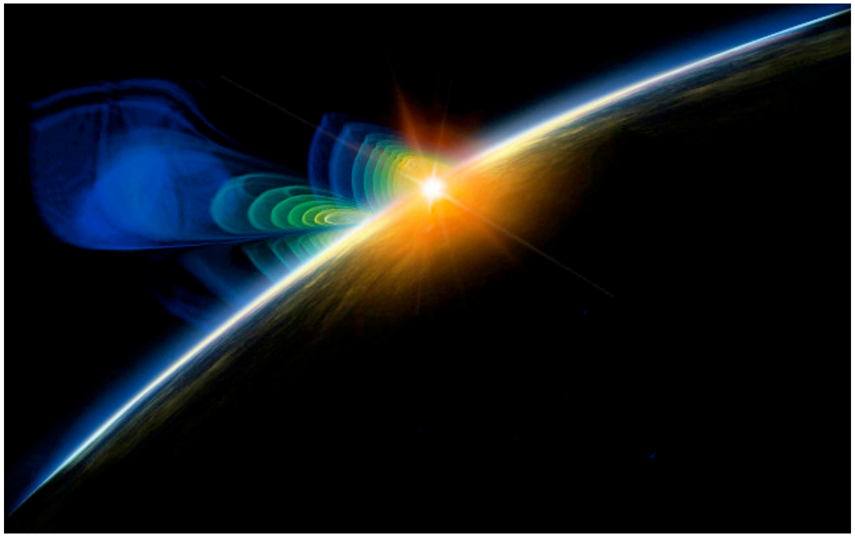


LIGO-G1500608

Why are we here?

- Advanced LIGO detectors, a concept that was part of the original LIGO proposal, will soon discover gravitational waves;
- What happens after Advanced LIGO discoveries?
- Will those discoveries affect…
  - … the short term R&D for Advanced LIGO detectors improvements?
  - … the searches for astrophysical sources?
  - … the plans for multi-messenger astronomy?
  - … US plans for GW science?
  - …the dynamics of the international network?
- The answer is YES.
- The real question is HOW those discoveries may affect these aspects: this is what we want to discuss here.

When? Soon!

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

Table 1: Summary of a plausible observing schedule, expected sensitivities, and source localization with the advanced LIGO and Virgo detectors, which will be strongly dependent on the detectors' commissioning progress. The burst ranges assume standard-candle emission of $10^{-2}M_{\odot}c^2$ in GWs at 150 Hz and scale as $E_{\mathrm{GW}}^{1/2}$. The burst and binary neutron star (BNS) ranges and the BNS localizations reflect the uncertainty in the detector noise spectra shown in Fig. 1. The BNS detection numbers also account for the uncertainty in the BNS source rate density [28], and are computed assuming a false alarm rate of $10^{-2}\,\mathrm{yr}^{-1}$. Burst localizations are expected to be broadly similar to those for BNS systems, but will vary depending on the signal bandwidth. Localization and detection numbers assume an 80% duty cycle for each instrument.

A reminder: Observing Scenario

- Prospects for Localization of Gravitational Wave Transients by the Advanced LIGO and Advanced Virgo Observatories, The LIGO Scientific Collaboration and The Virgo Collaboration, arXiv:1304.0670

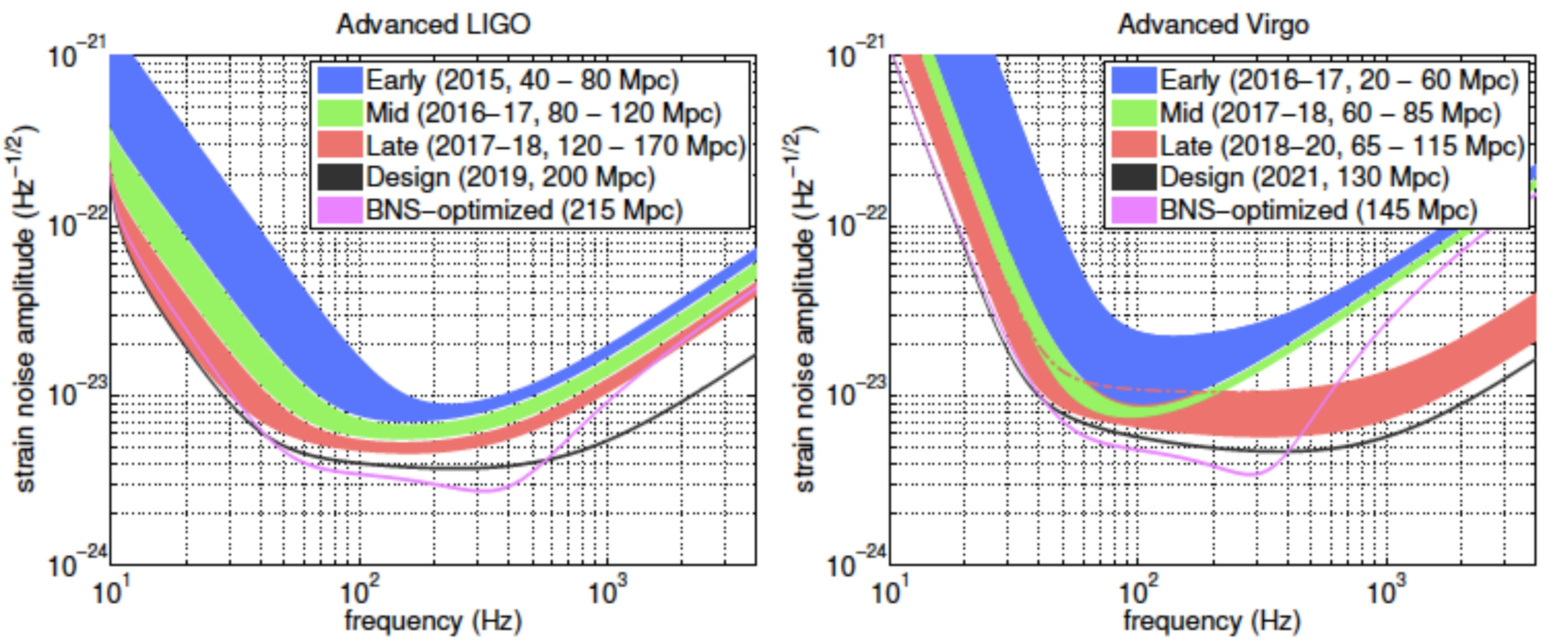
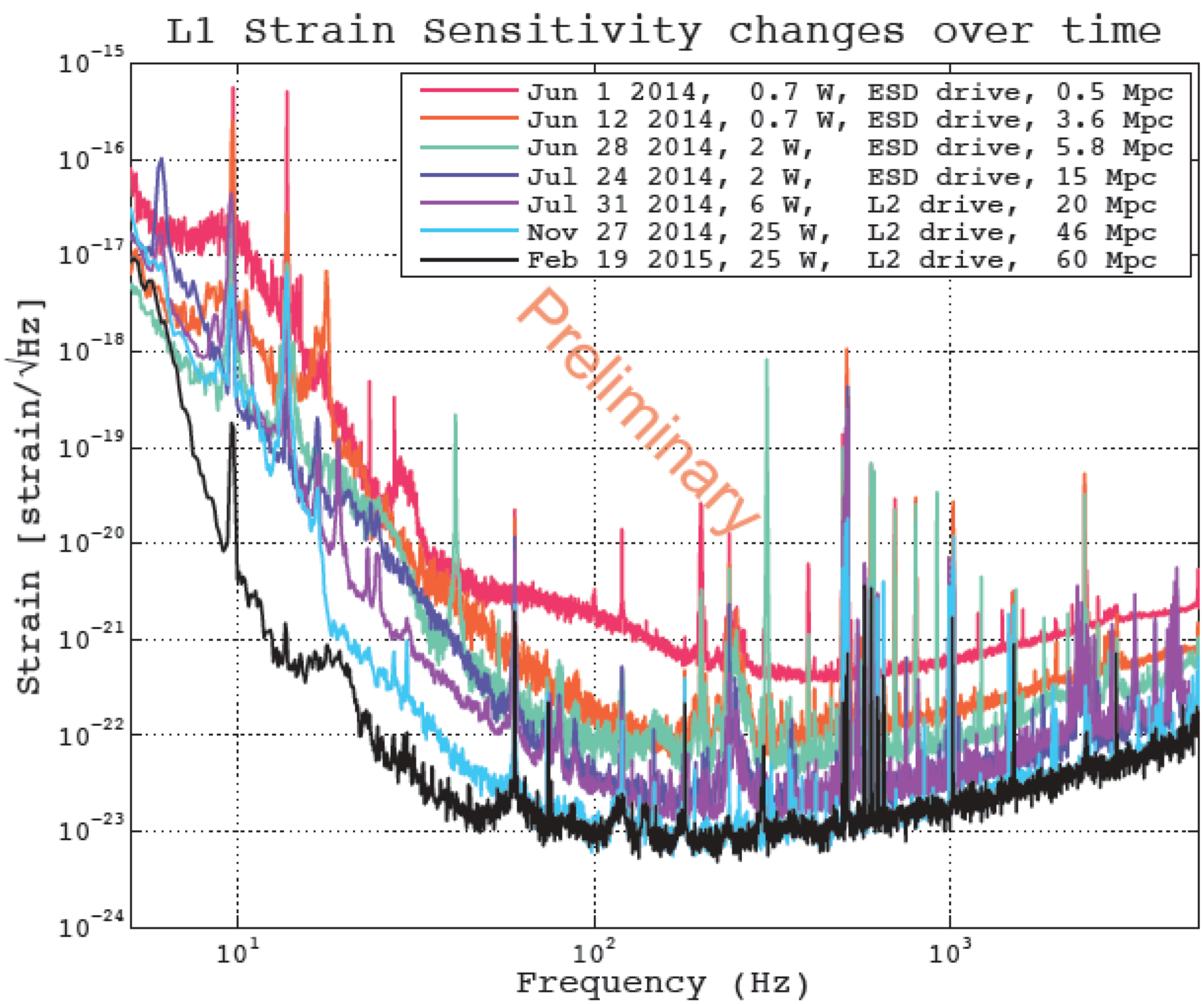


Figure 1: aLIGO (left) and AdV (right) target strain sensitivity as a function of frequency. The average distance to which binary neutron star (BNS) signals could be seen is given in Mpc. Current notions of the progression of sensitivity are given for early, middle, and late commissioning phases, as 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.

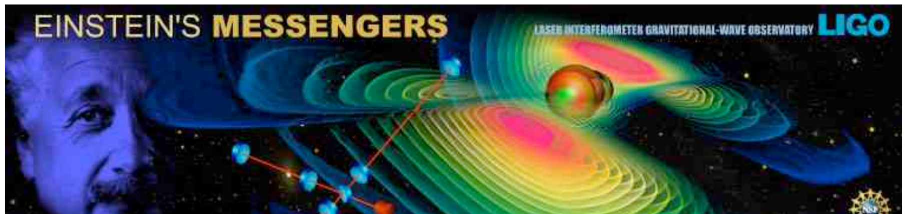
Very rapid commissioning progress

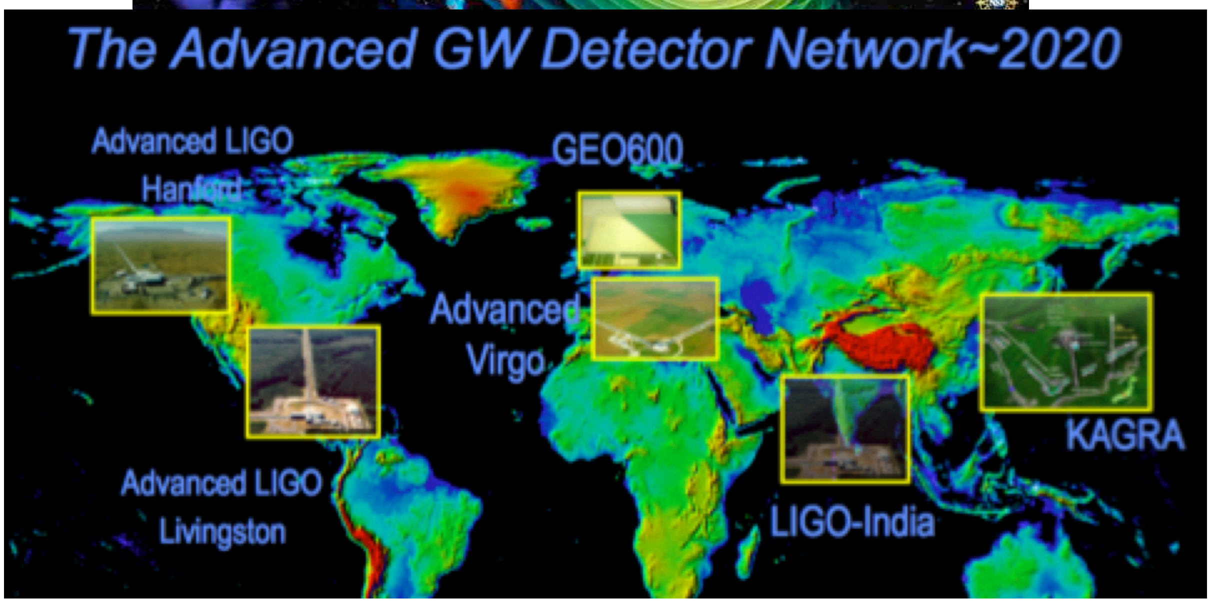


Latest calibrated spectra in https://dcc.ligo.org/LIGO-G1401390/public

Detections are coming

- It will be a milestone discovery!





- Probably followed soon (or preceded) by other gravitational wave detections (pulsar timing, CMB polarization)

What comes next for LIGO?

- We have a "default" plan for LIGO – will need adapting to known sources after we have detections.

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
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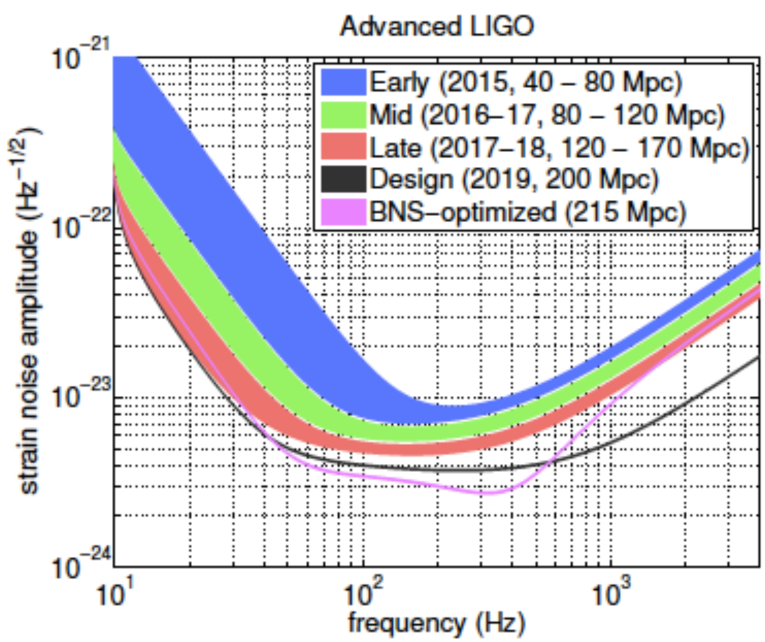


Current plan: white papers

LSC Instrument Science White Paper
https://dcc.ligo.org/LIGO-T1400316/public

2 Roadmap 2015-2035 and Executive Summary

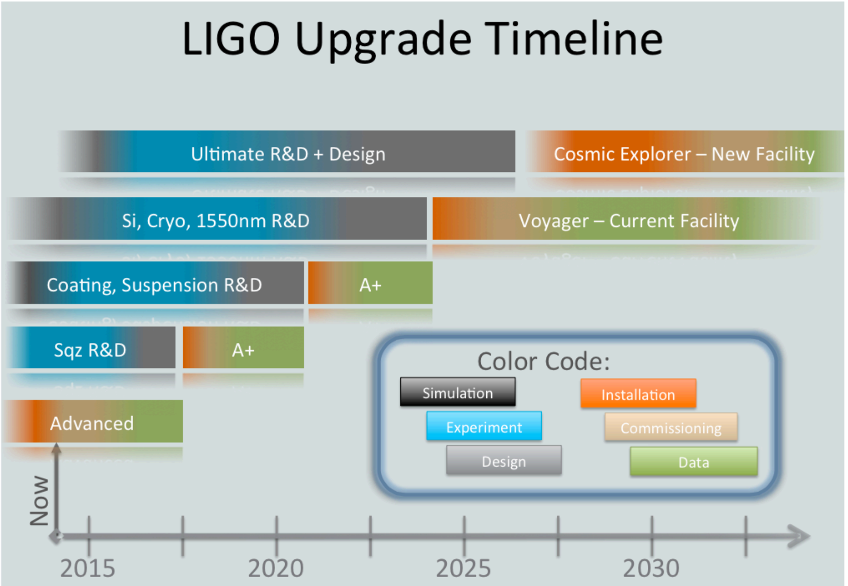
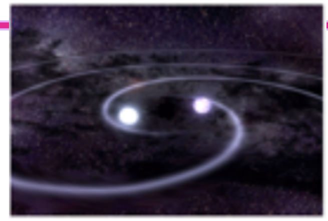
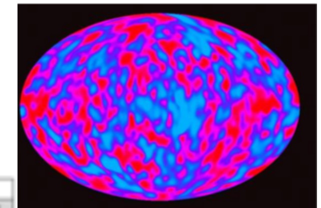


Figure 2: Timeline for A+, LIGO Voyager and LIGO Cosmic Explorer.

Current plan: white papers



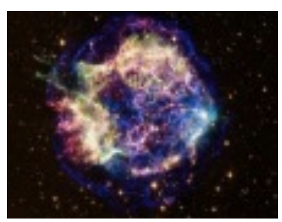


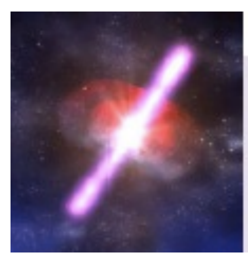
	Burst	CBC	CW	SGWB
Highest priority	All-sky search for generic GW transients, in low latency for EM followup and deep, offline for 4σ detection confidence	All-sky matched-filter search for binary neutron star (BNS) systems, deep and low latency	All-sky search for isolated neutron stars, both as a *quick-look* on owned resources and as a deep/broad search on Einstein@Home	Directional search for stochastic GW background
	Parameter estimation for the astrophysical interpretation of detected burst events	All-sky matched filter search for binary neutron-star and black-hole (NSBH) systems, deep and low latency	Targeted search for high value, known pulsars	Isotropic search for stochastic GW background
	Search for GW bursts triggered by outstanding GRB alerts	All-sky matched-filter, deep search for binary black-hole (BBH) systems	Directed searches for Cas-A	Constraints of a detected background of astrophysical origin with long transients
	Searches triggered by outstanding astrophysical events (a galactic supernova, neutron star transients, an exceptional high energy neutrino alert)	Parameter estimation of detected CBC events	Directed searches for X-ray binaries SCO-X1 and J1751-305	
	Search for cosmic string kinks and cusps	CBC searches triggered by all GRB alerts		
		Tests of General Relativity with CBC events		
High priority	Searches triggered by high energy neutrinos, extra-galactic supernovae, and GRB observations	All sky search for spinning binary neutron star systems (deep and low latency)	Targeted search for other known pulsars	Long transient follow up of CBC and burst candidates
	Burst search for intermediate mass and eccentric black hole binary systems	Matched filtered search for intermediate mass black hole binary systems	Directed searches for other isolated stars and X-ray binaries	
	All-sky search for long bursts of $> 10\,\mathrm{s}$ duration			
Additional priority	GRB-triggered search for long-duration bursts and plateaus	Exploring effects of detector noise on parameter estimation	All sky search for isolated stars (alternative approaches)	
	Hypermassive neutron star followup		All-sky search for binaries	
	Burst searches triggered by radio transients and by SGR/SGR-QPO		Spotlight deep sky-patch search **	
	Burst tests of alternative gravity theories **		Search for Supernova post birth signals **	
			Search for continuous wave transients **	

LIGO-T1500055 - Table 2, page 2

Current plan: astronomy partners

- http://www.ligo.org/scientists/GWEMalerts.php
- More than 70 agreements signed from 20 countries, with about 150 instruments covering the full spectrum, from radio to high-energy gamma-rays.
- Shortly after a few detections, LSC/Virgo will publicly release GW triggers for follow up: dcc.ligo.org, LIGO-M1200055.





Current plans have multiple paths

- How will first few detections influence paths in the years that follow? In short term, different paths may compete with each other…

- How can the community be prepared with appropriate plans? We may consider different scenarios if they depend on the nature of the first detections.

- Five sessions on plans for:
  - multi-messenger astronomy;
  - data analysis;
  - aLIGO improvements;
  - international network;
  - GW science in the context of US science.

What's next?

- Expect from each session active discussion, converging in consensus (of attendants) or description of plans following detections.
- A brief write-up of results of discussions will be compiled by session chairs and circulated within ~ a month; later posted in conference website.
- Let's get to work!