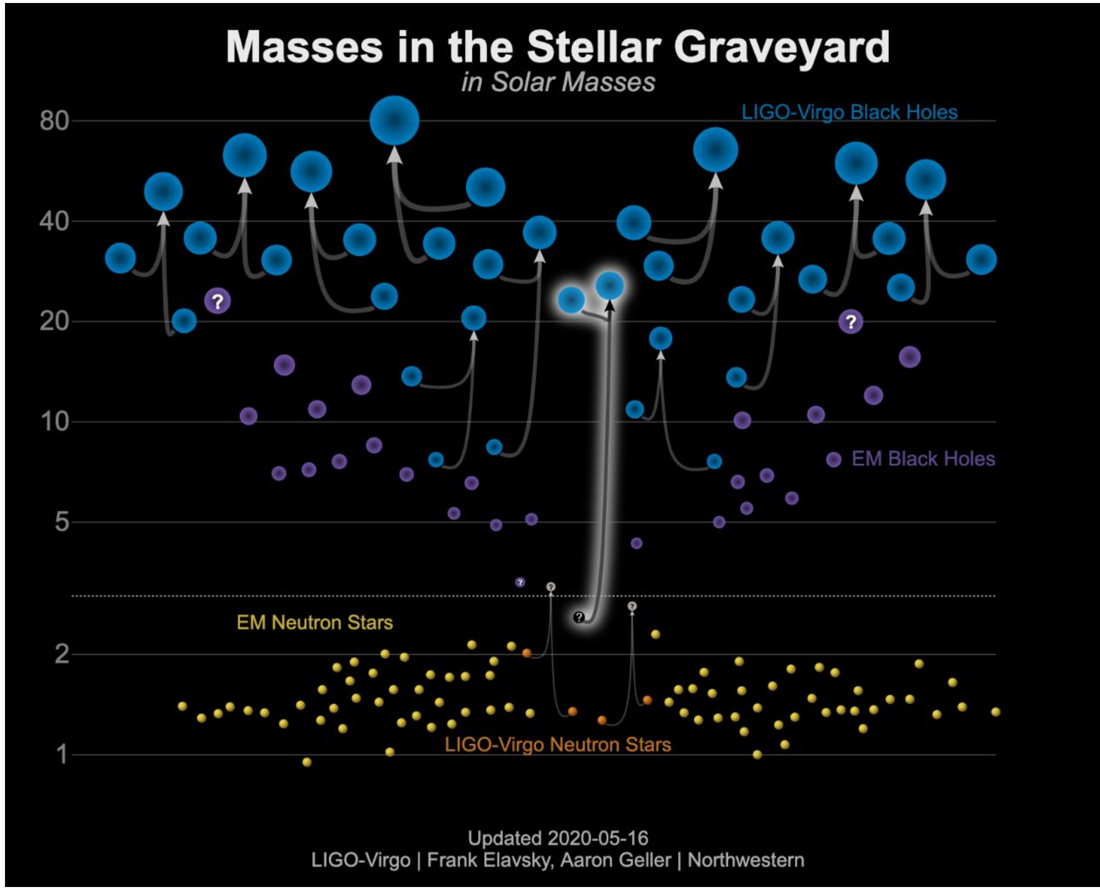
RECENT RESULTS AND PERSPECTIVES

Giancarlo Cella – July 1 2020



GW190425: a large mass BNS system

THE ASTROPHYSICAL JOURNAL LETTERS, 892:L3 (24pp), 2020 March 20 https://doi.org/10.3847/2041-8213/ab75f5

GW190425: Observation of a Compact Binary Coalescence with Total Mass $\sim 3.4\,M_\odot$

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Abstract

On 2019 April 25, the LIGO Livingston detector observed a compact binary coalescence with signal-to-noise ratio 12.9. The Virgo detector was also taking data that did not contribute to detection due to a low signal-to-noise ratio, but were used for subsequent parameter estimation. The 90% credible intervals for the component masses range from 1.12 to 2.52 $M_\odot$ (1.46–1.87 $M_\odot$ if we restrict the dimensionless component spin magnitudes to be smaller than 0.05). These mass parameters are consistent with the individual binary components being neutron stars. However, both the source-frame chirp mass $1.44^{+0.02}_{-0.02}\,M_\odot$ and the total mass $3.4^{+0.3}_{-0.1}M_\odot$ of this system are significantly larger than those of any other known binary neutron star (BNS) system. The possibility that one or both binary components of the system are black holes cannot be ruled out from gravitational-wave data. We discuss possible origins of the system based on its inconsistency with the known Galactic BNS population. Under the assumption that the signal was produced by a BNS coalescence, the local rate of neutron star mergers is updated to 250–2810 $\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Unified Astronomy Thesaurus concepts: Neutron stars (1108); Gravitational waves (678)

GW190425

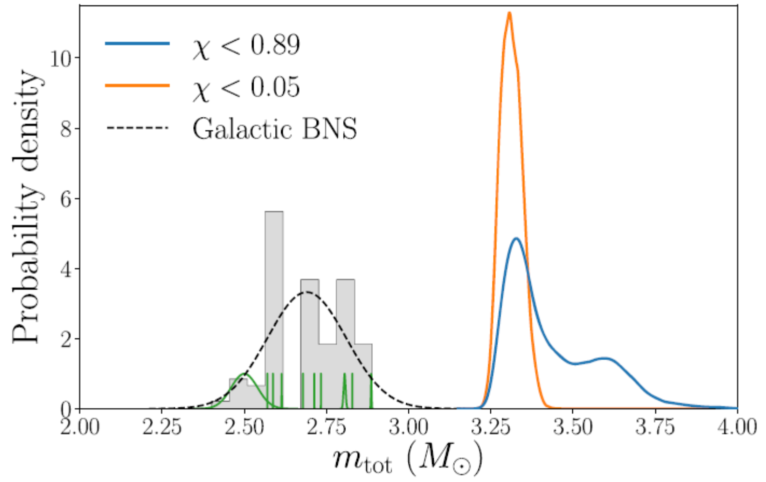
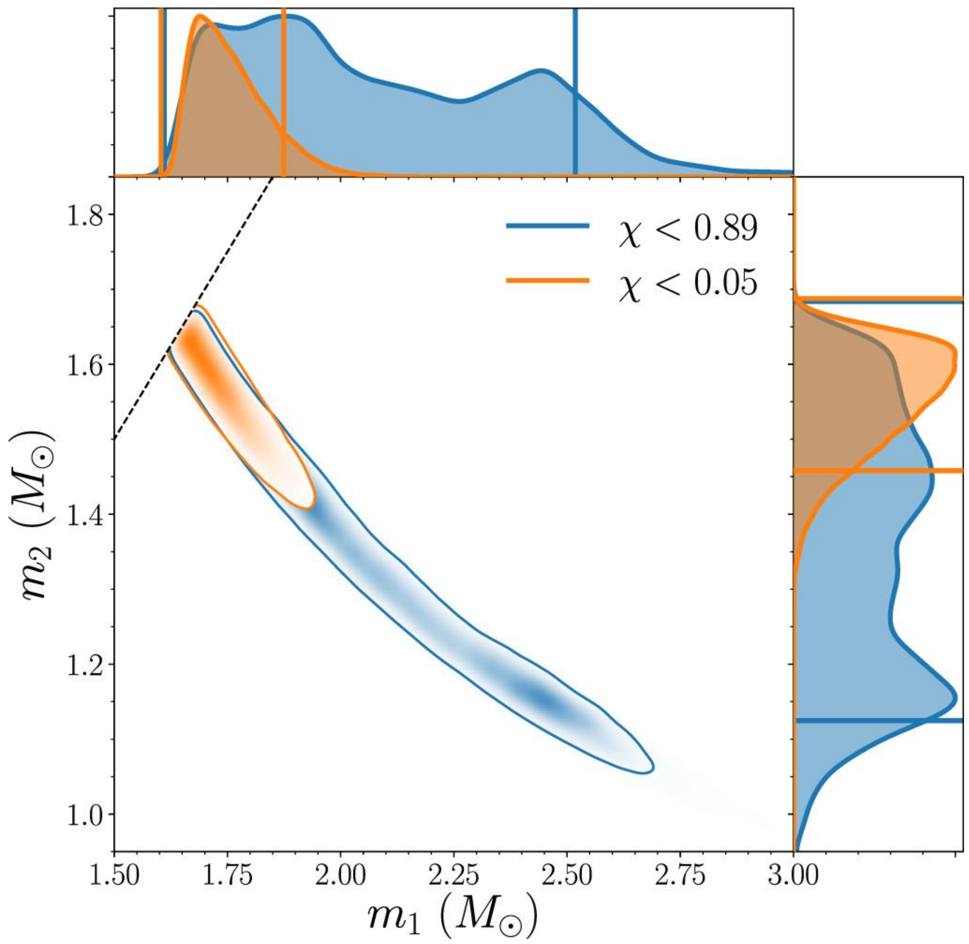


Figure 5. Total system masses for GW190425 under different spin priors, and those for the 10 Galactic BNSs from Farrow et al. (2019) that are expected to merge within a Hubble time. The distribution of the total masses of the latter is shown and fit using a normal distribution shown by the dashed black curve. The green curves are for individual Galactic BNS total mass distributions rescaled to the same ordinate axis height of 1.



- *Most likely BNS system*
- *Total mass* $3.4^{+0.3}_{-0.1}$
- *Significantly different from the known population of Galactic BNS systems*
- *Cannot rule out BBH or BHNS*

Accepted by Physical Review D

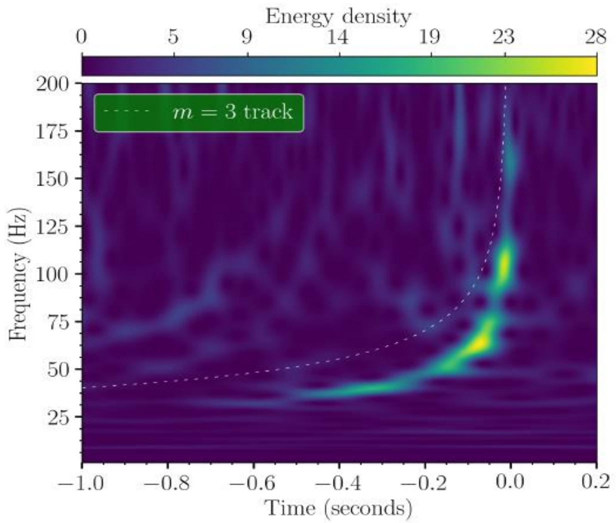
GW190412: an asymmetric BBH system

GW190412: Observation of a Binary-Black-Hole Coalescence with Asymmetric Masses

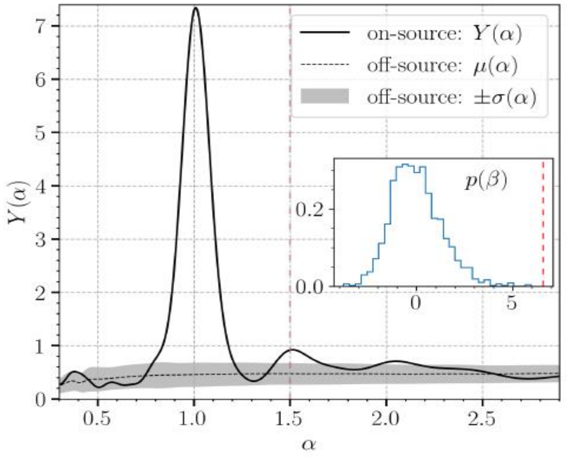
LIGO Scientific Collaboration and Virgo Collaboration

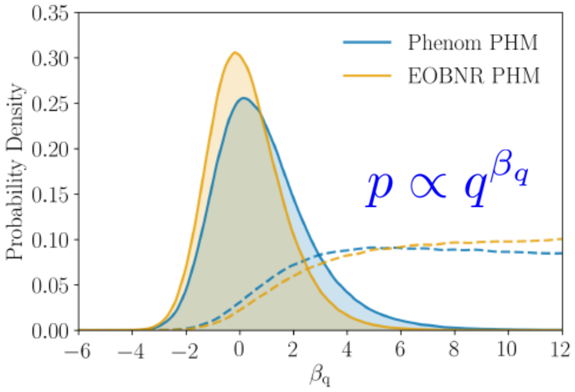
We report the observation of gravitational waves from a binary-black-hole coalescence during the first two weeks of LIGO's and Virgo's third observing run. The signal was recorded on April 12, 2019 at 05:30:44 UTC with a network signal-to-noise ratio of 19. The binary is different from observations during the first two observing runs most notably due to its asymmetric masses: a $\sim 30\, M_\odot$ black hole merged with a $\sim 8\, M_\odot$ black hole companion. The more massive black hole rotated with a dimensionless spin magnitude between 0.17 and 0.59 (90% probability). Asymmetric systems are predicted to emit gravitational waves with stronger contributions from higher multipoles, and indeed we find strong evidence for gravitational radiation beyond the leading quadrupolar order in the observed signal. A suite of tests performed on GW190412 indicates consistency with Einstein's general theory of relativity. While the mass ratio of this system differs from all previous detections, we show that it is consistent with the population model of stellar binary black holes inferred from the first two observing runs.

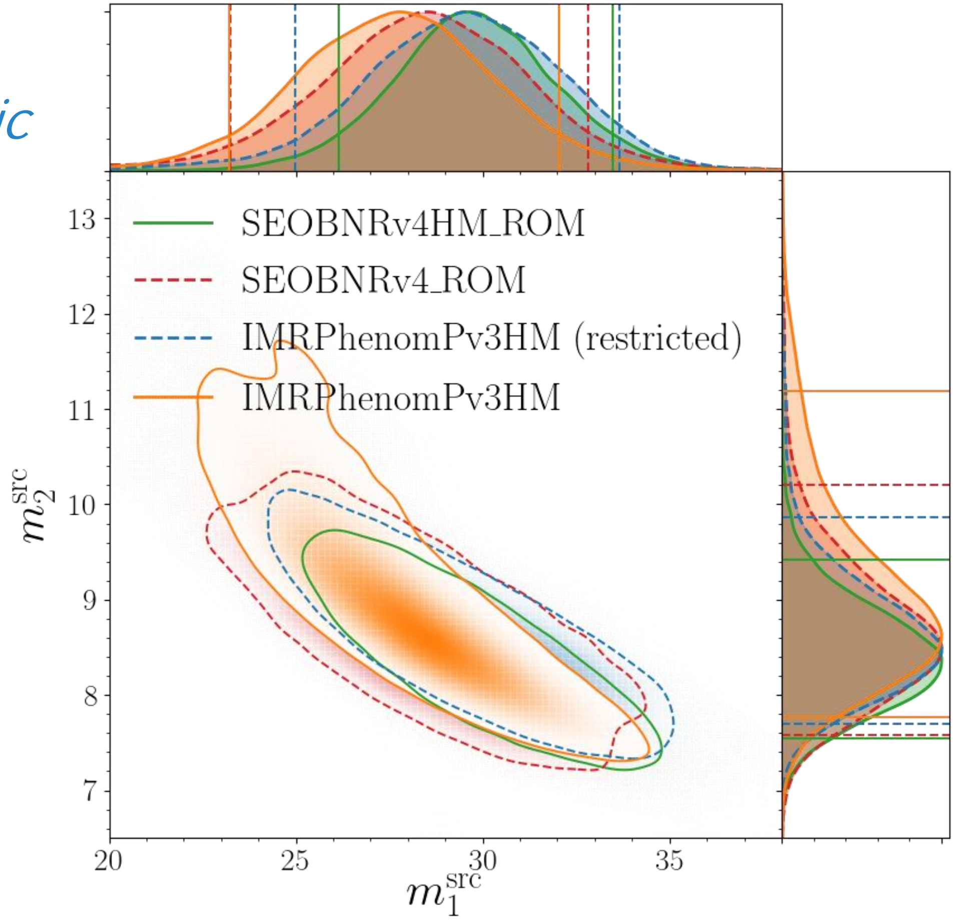
GW190412



- *Evidence for (3,3) multipole: $f_\alpha(t) = \alpha f_{22}(t)$*
- *Tighter bounds on intrinsic source parameters*
- *Bounds on abundances*
- *Consistency with GR*







Astrophys. J. Lett. **896**, L44 (2020)

GW190814: a BBH system with very large asymmetry

GW190814: Gravitational Waves from the Coalescence of a 23 $M_\odot$ Black Hole with a 2.6 $M_\odot$ Compact Object

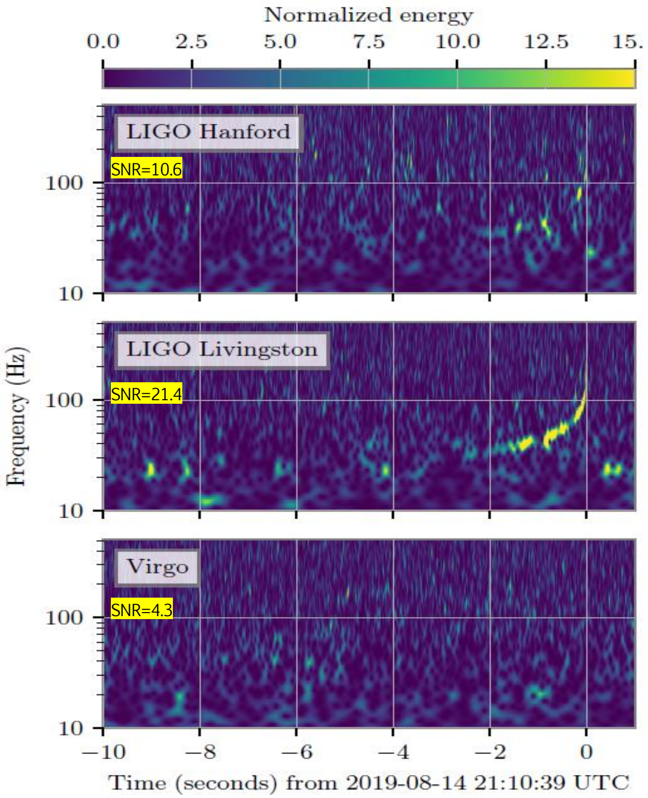
LIGO Scientific Collaboration and Virgo Collaboration

(Dated: May 14, 2020)

ABSTRACT

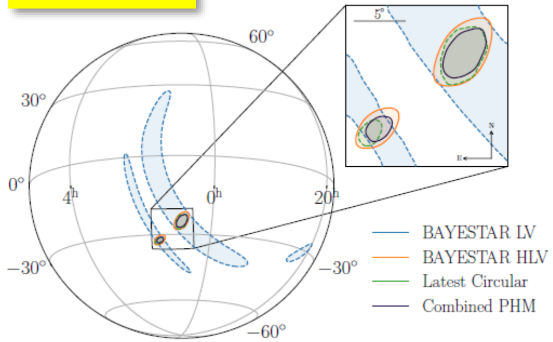
We report the observation of a compact binary coalescence involving a $22.2 - 24.3\, M_\odot$ black hole and a compact object with a mass of $2.50 - 2.67\, M_\odot$ (all measurements quoted at the 90% credible level). The gravitational-wave signal, GW190814, was observed during LIGO's and Virgo's third observing run on August 14, 2019 at 21:10:39 UTC and has a signal-to-noise ratio of 25 in the three-detector network. The source was localized to 18.5 deg^2 at a distance of 241^{+41}_{-45} Mpc; no electromagnetic counterpart has been confirmed to date. The source has the most unequal mass ratio yet measured with gravitational waves, $0.112^{+0.008}_{-0.009}$, and its secondary component is either the lightest black hole or the heaviest neutron star ever discovered in a double compact-object system. The dimensionless spin of the primary black hole is tightly constrained to ≤ 0.07. Tests of general relativity reveal no measurable deviations from the theory, and its prediction of higher-multipole emission is confirmed at high confidence. We estimate a merger rate density of 1–23 $\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ for the new class of binary coalescence sources that GW190814 represents. Astrophysical models predict that binaries with mass ratios similar to this event can form through several channels, but are unlikely to have formed in globular clusters. The combination of mass ratio, component masses, and the inferred merger rate for this event challenges current models for the formation and mass distribution of compact-object binaries.

GW190814

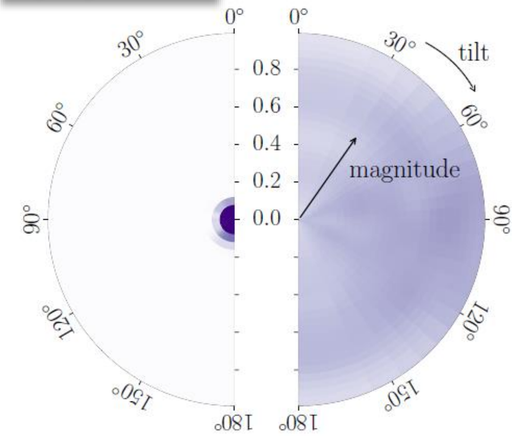


- *Network SNR=25*
- *No em counterpart*
- $q = 0.112^{+0.008}_{-0.009}$
- *Multipole evidence*
- *No GR violation evidence*
- *Clear evidence for inclination*

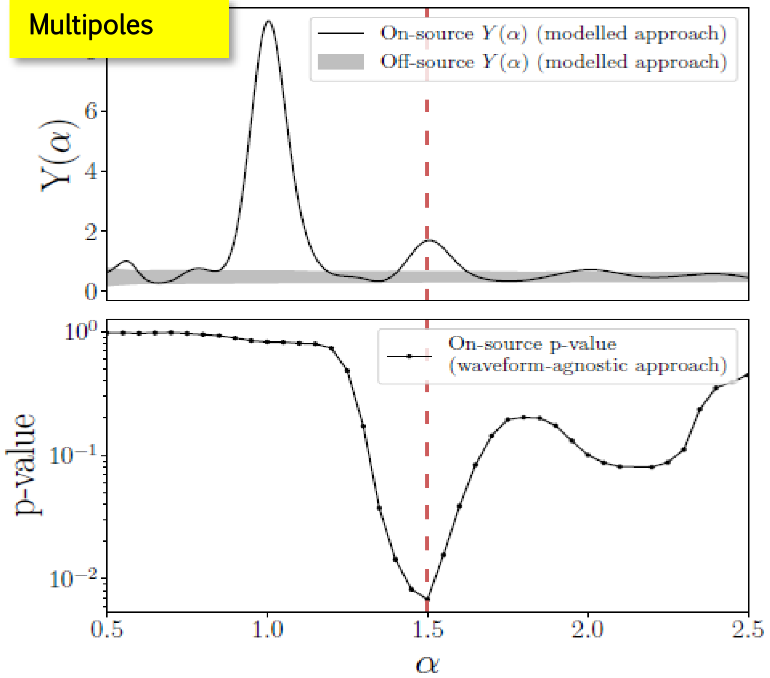
Localisation



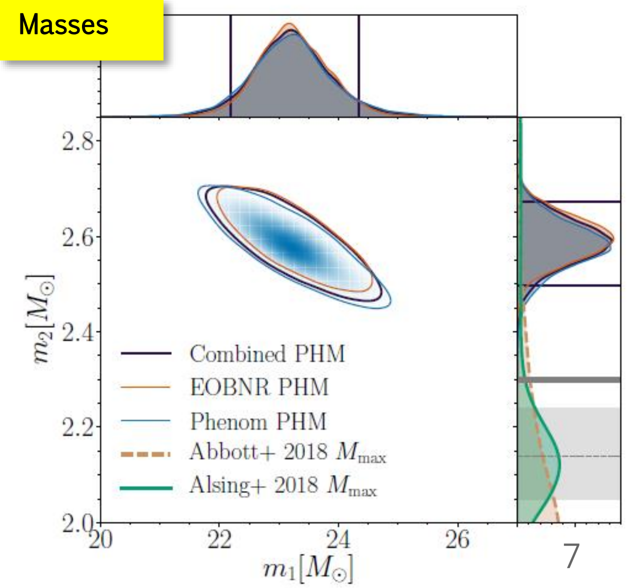
Spin posterior



Multipoles



Masses



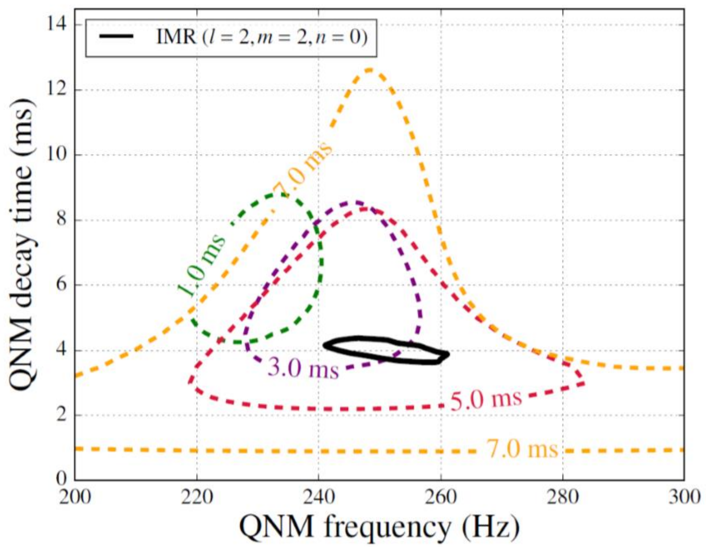
Tests of General Relativity

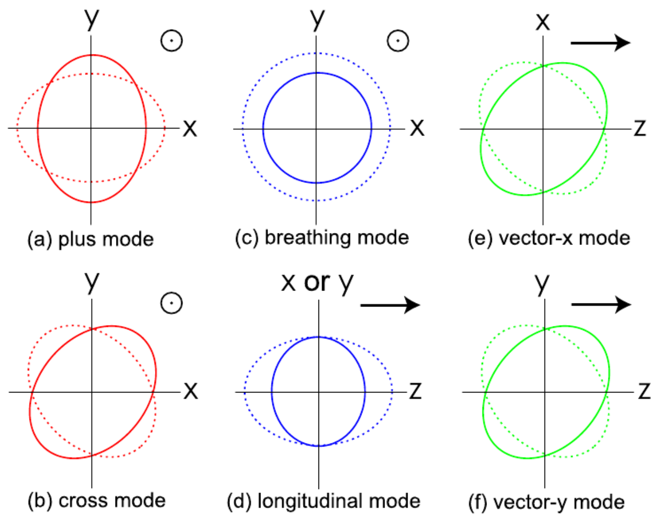
- *Residual test*
- *Inspiral Merger Ringdown consistency test*
- *Higher order Multipole consistency test*
- *PARameterized test of GW generation*
- *Spin Induced Moments:* $Q = -\kappa \chi^2 m^3$
- *Modified Dispersion Relations:*

$$E^2 = p^2 c^2 + A_\alpha p^\alpha c^\alpha$$

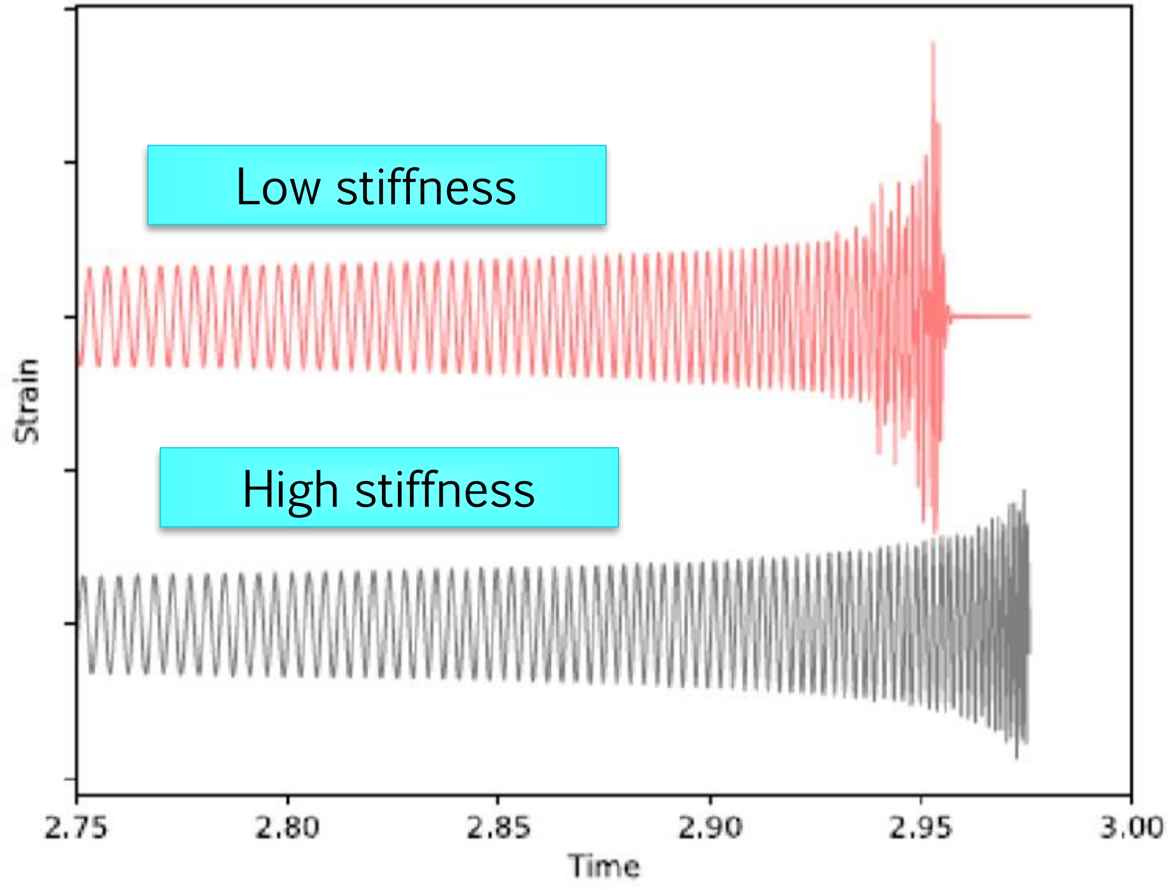
- *Ringdown*
- *Echoes*
- *Polarization content*

Theoretical Model	e_{ij}^{+}	$e_{ij}^{\times}$	e_{ij}^{b}	e_{ij}^{ℓ}	e_{ij}^{x}	e_{ij}^{y}
Einstein's General Relativity (GR)	*	*				
GR in a noncompactified 5D Minkowski sp.	*	*	*1	*1	*	*
GR in a noncompactified 6D Minkowski sp.	*	*	*	*	*	*
5D Kaluza-Klein theory	*	*	*		*	*
Randall-Sundrum braneworld	*	*				
DGP braneworld (normal branch)	*	*				
DGP braneworld (self-accelerating branch)	*	*	*2	*2		
Brans-Dicke theory	*	*	*2	*2		
$f(R)$ theory	*	*	*2	*2		
Bimetric theory	*	*	*2	*2	*	*

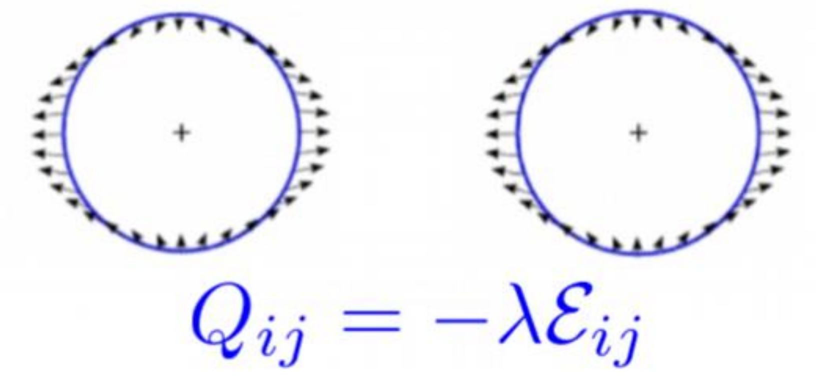


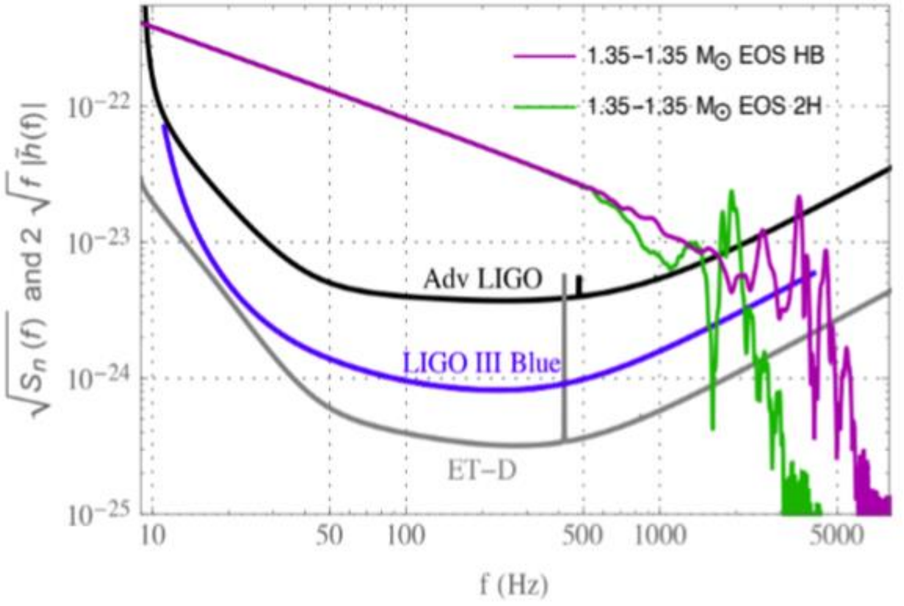


Perspectives: Nuclear EOS

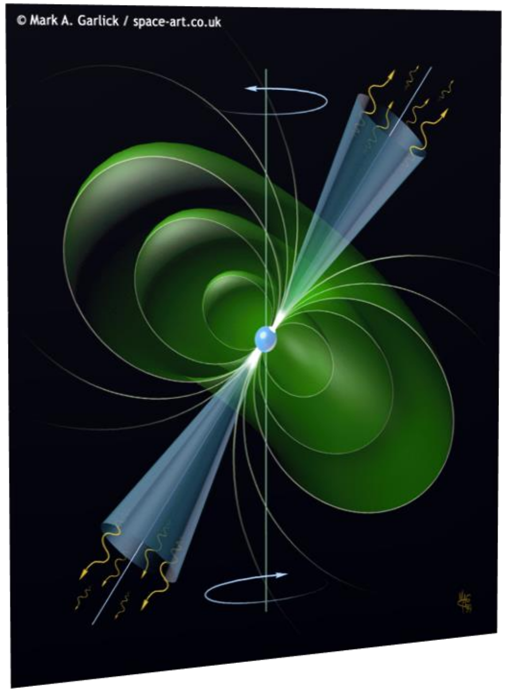


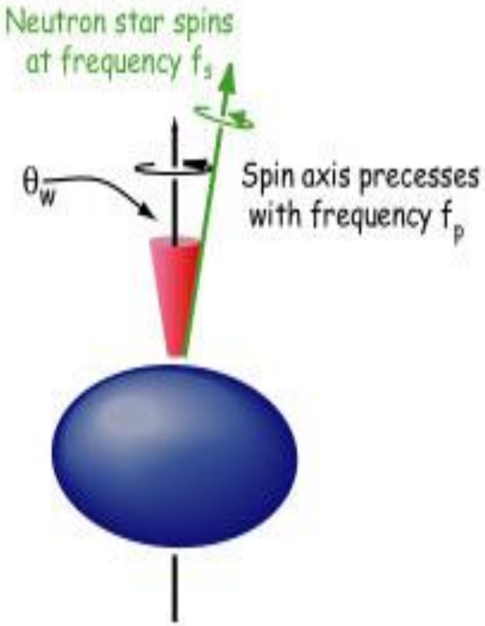
Phys. Rev. Lett. 111, 071101

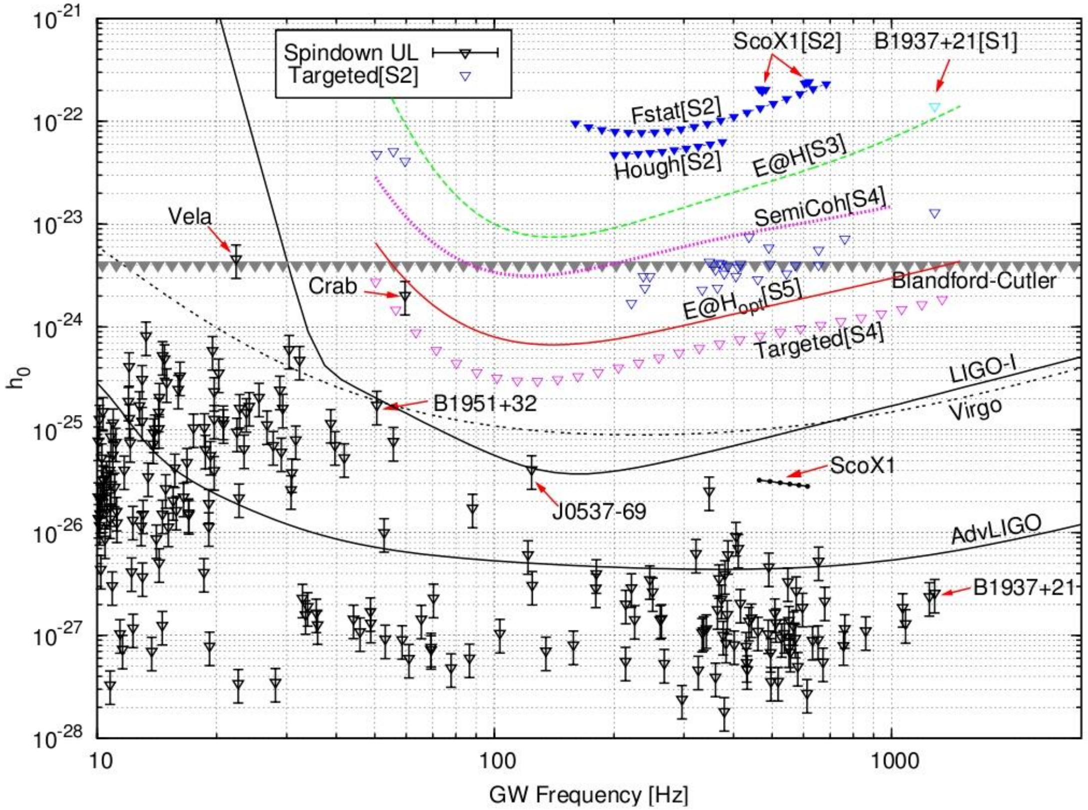




Continuous waves

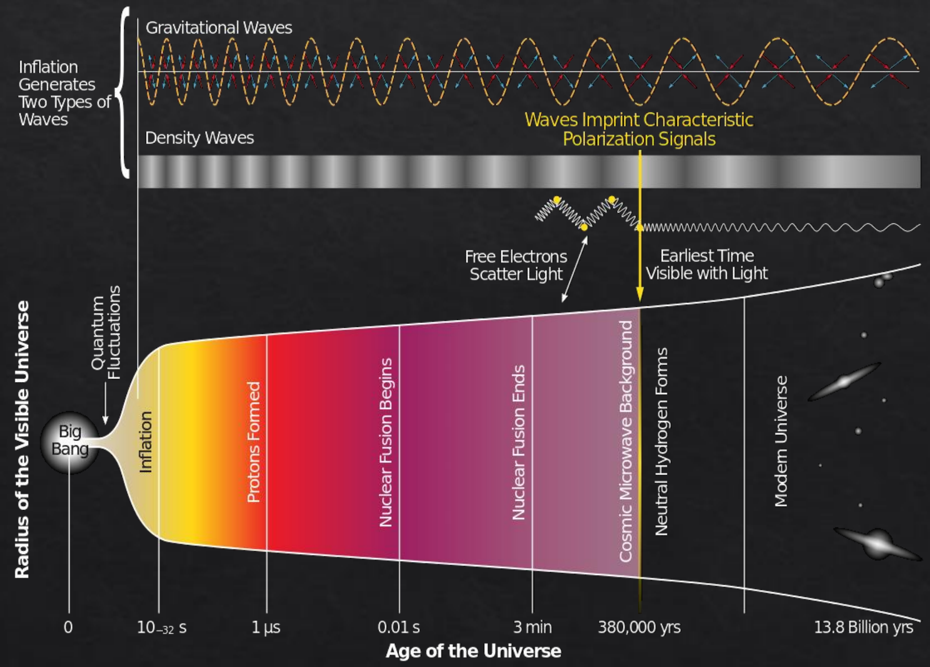


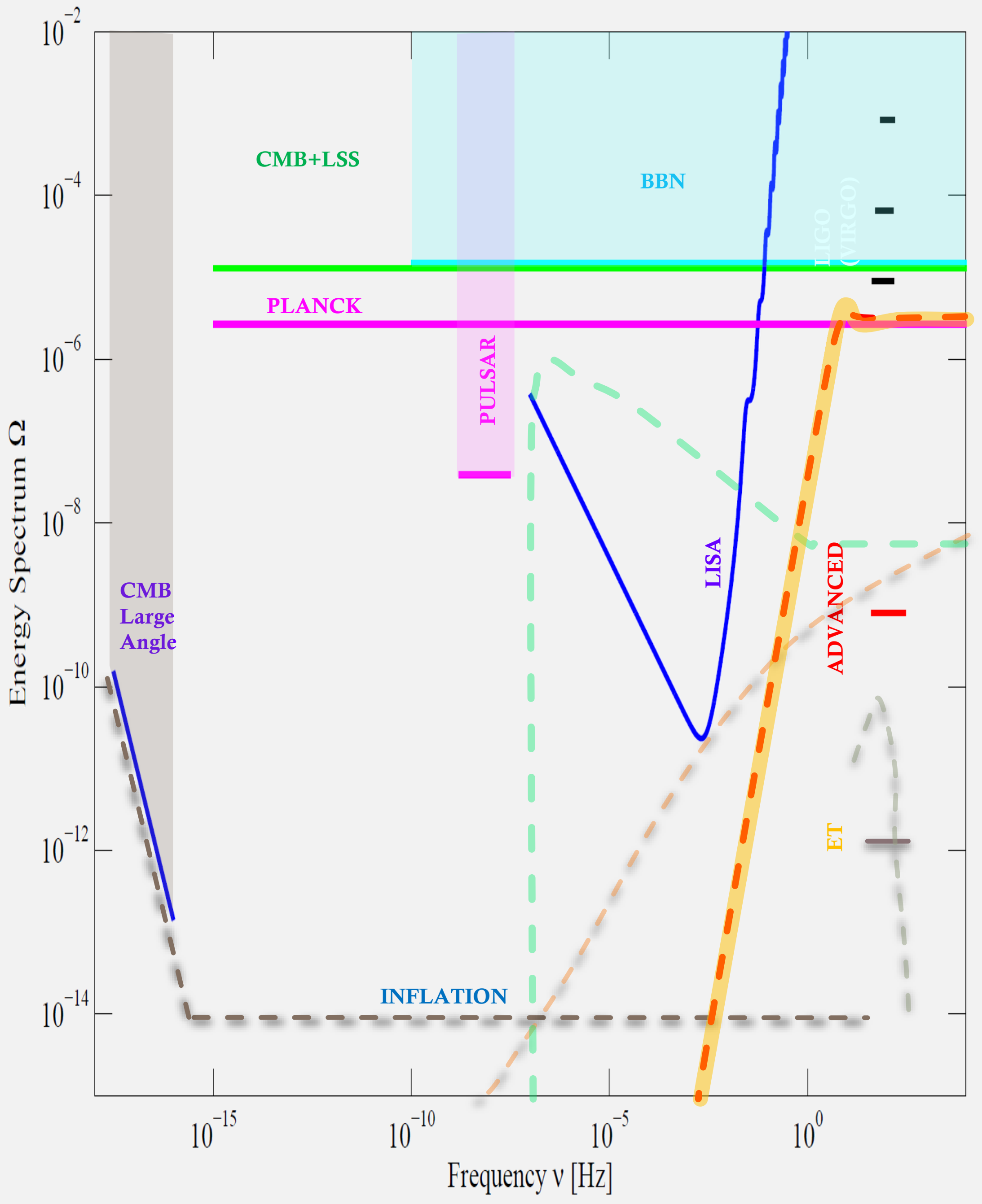




Stochastic Background

- Inflation (parametric amplification, preheating)
- Cosmic strings
- Axion-based inflationary models
- Alternative cosmologies

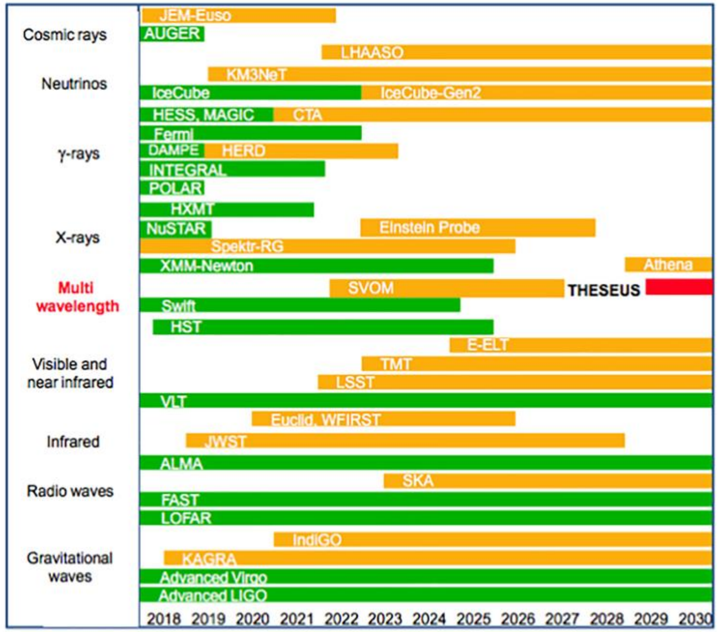




Summary

Multimessenger: some MoUs

- InterPlanetary Network collaboration
- Borexino Collaboration, IceCube Collaboration, LVD Collaboration
- FermiGBM/Swift for subthreshold transient analysis.
- DLT40/ASAS-SN for CCSN search
- CHIME for a joint FRB/GW sources
- Nevin N. Weinberg (nonlinear tides)



https://doi.org/10.1016/j.asr.2018.04.01

Continuous sources

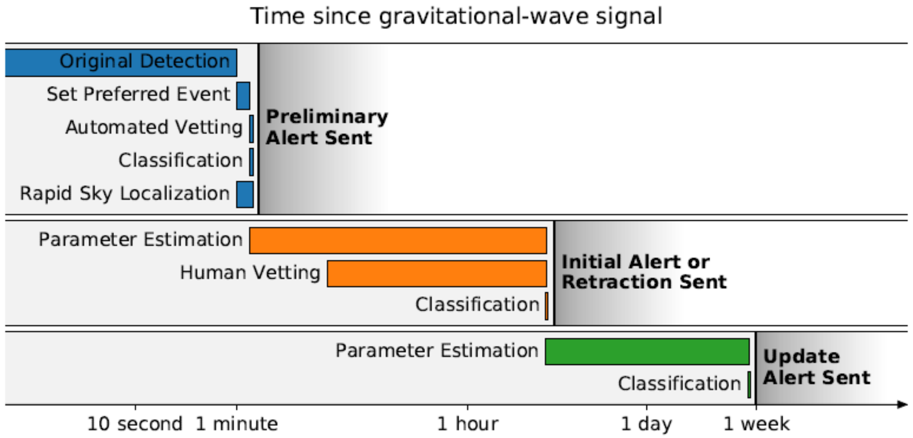
The next «first detection»?

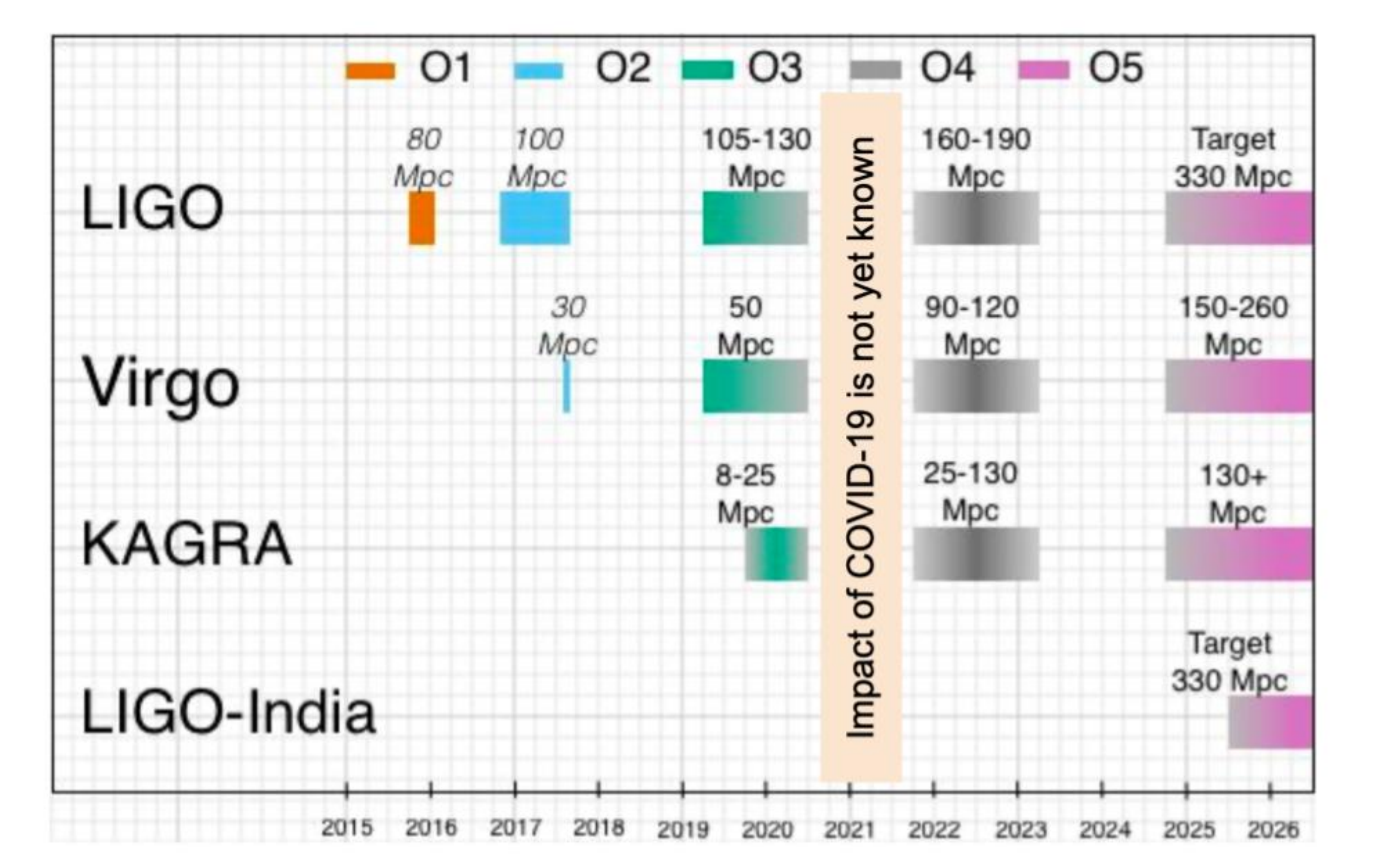
CCSN & Neutrinos

- One of the expected fundamental results for the future;
- Expertise in Virgo;

Stochastic background

- The next frontier
- Many implications of great scientific interest




O1
O2
O3
O4
O5
LIGO
80 Mpc
100 Mpc
105-130 Mpc
160-190 Mpc
Target 330 Mpc
Virgo
30 Mpc
50 Mpc
90-120 Mpc
150-260 Mpc
KAGRA
8-25 Mpc
25-130 Mpc
130+ Mpc
LIGO-India
Target 330 Mpc
Impact of COVID-19 is not yet known
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026