Recent LIGO-Virgo searches for gravitational waves from neutron stars

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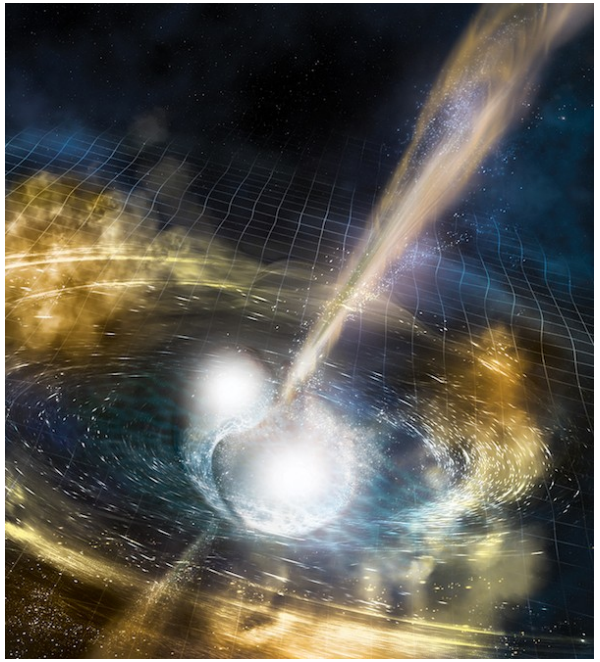
Abstract: As celestial laboratories of nuclear physics under extreme conditions, neutron stars are among the prime targets of ground-based gravitational-wave detectors. In this talk I will summarize LIGO-Virgo searches and results from recent observing runs including the ongoing legacy of the multi-messenger discovery GW170817, the second detection of a likely binary neutron star merger GW190425, searches for gravitational-wave transients from gamma-ray bursts and magnetars, as well as the latest results on continuous waves from individual spinning neutron stars. I will briefly discuss the implications of our results for astrophysics, cosmology and nuclear physics.

Context of the research

- Gravitational Waves first detected with LIGO 2015-09-14 and announced by LVC in 2016. (binary black hole)
- First detection of GWs from binary neutron star: GW170817 (and historic multi-messenger campaign)
- Most recent, third observing run O3: 2019/04–2020/03



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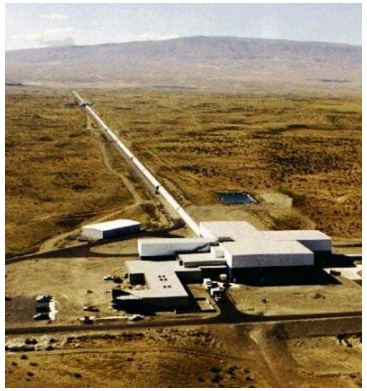


- Ground-based GW detectors search for 4 main astrophysical signal classes:

1) Compact binary coalescences (including binary neutron stars)
2) Unmodelled bursts (including supernovae and magnetar flares)
3) Continuous waves (primarily from galactic neutron stars)
4) Stochastic background

Description of the work: LVC searches (focus on neutron stars)

Compact Binary Searches

- Short, “loud” (still ~10^{-22}!) signals from late inspiral, merger and ringdown.
- Mergers involving neutron stars can have bright counterparts.
- Public low-latency alerts since O3 (incl. sky maps), more detailed results later with improved significance estimates and full Bayesian parameter estimation.

Unmodelled Burst Searches

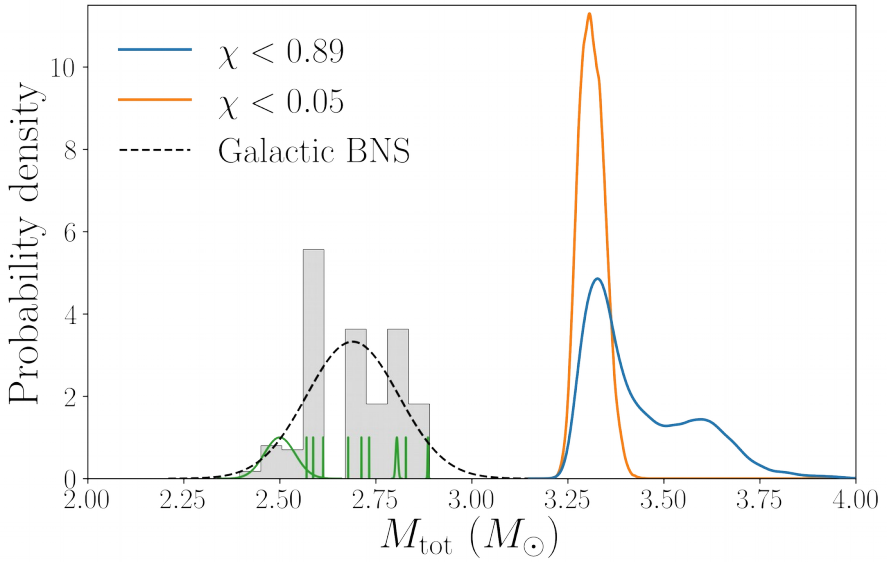
- Can find compact binary signals too, but also many more source types such as nearby core-collapse supernovae or signals from flaring magnetars.

Continuous Wave Searches

- Spinning deformed NS emit very weak, persistent, quasi-monochromatic GWs.
- Detection strategy: integrate signal over long data set; very costly.

Results: GW190425 and GW190814

- GW190425: most likely a binary neutron star, but unusually high total mass.



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

B. P. Abbott[1], R. Abbott[1], T. D. Abbott[2], S. Abraham[3], F. Acernese[4,5], K. Ackley[6], C. Adams[7], R. X. Adhikari[1], V. B. Adya[8], C. Affeldt[9,10] + Show full author list

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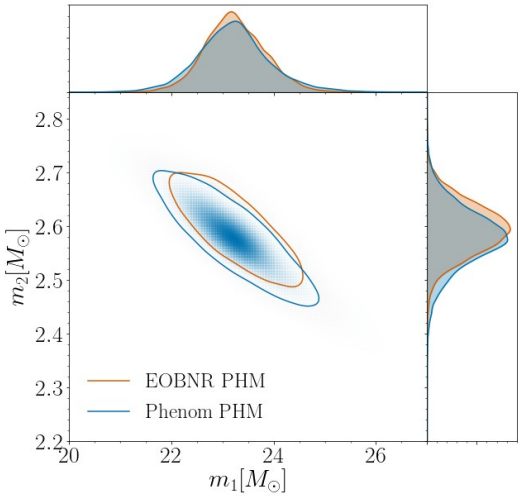
The Astrophysical Journal Letters, Volume 892, Number 1

- GW190814: lighter object either the heaviest NS or lightest BH known.



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GW190814: Gravitational Waves from the Coalescence of a 23 Solar Mass Black Hole with a 2.6 Solar Mass Compact Object

R. Abbott[1], T. D. Abbott[2], S. Abraham[3], F. Acernese[4,5], K. Ackley[6], C. Adams[7], R. X. Adhikari[1], V. B. Adya[8], C. Affeldt[9,10], M. Agathos[11,12] + Show full author list

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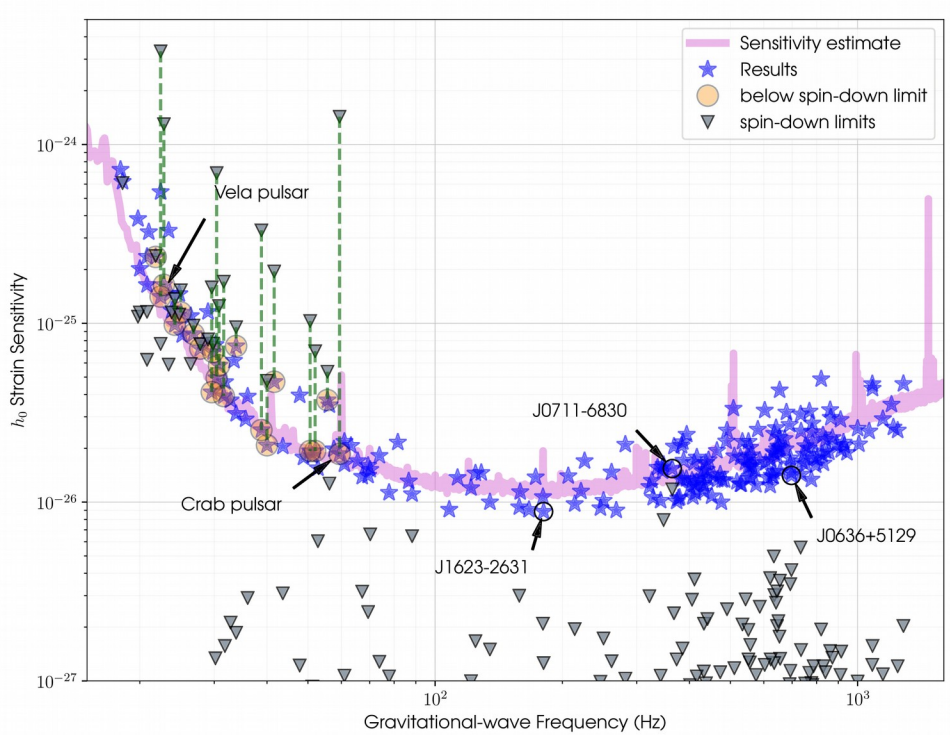
The Astrophysical Journal Letters, Volume 896, Number 2

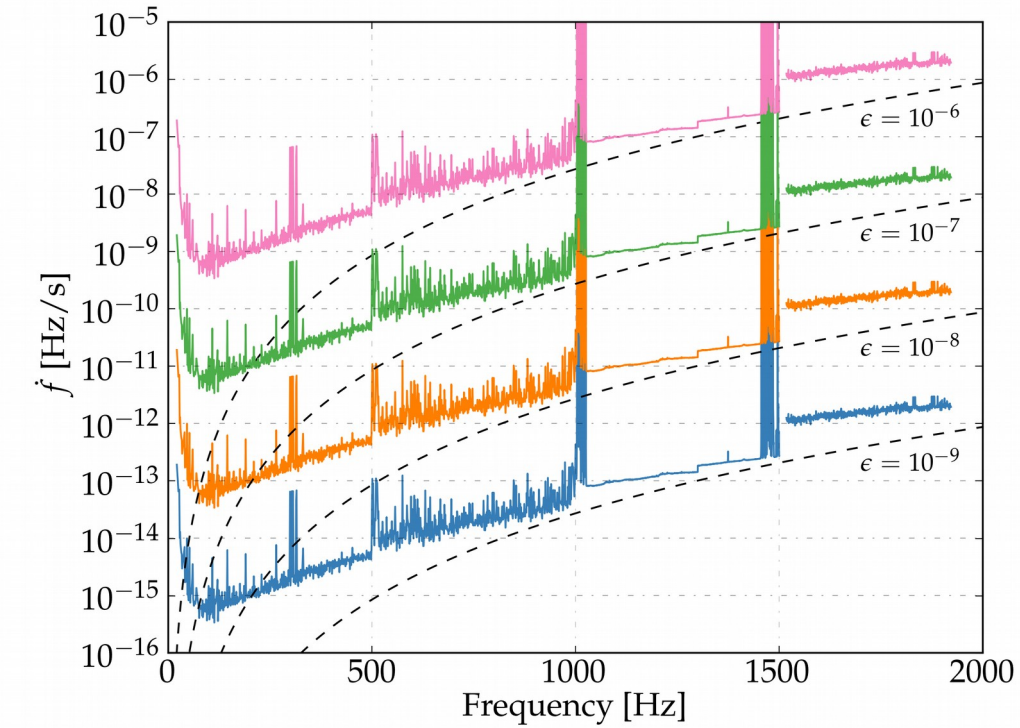
- No counterpart or clear tidal deformation measurement in either case.

Results: Continuous Waves

- Spinning deformed NS emit very weak, persistent, quasi-monochromatic GW.
- Detection strategy: integrate signal over long data set; very costly.
- Results from most recent O3 run: stay tuned!
- <u>Some highlights from O1 and O2:</u>



O1-O2 upper limits on CW strain from 221 known pulsars
Abbott et al. (LVC) Astrophys. J. 879, 10 (2019)

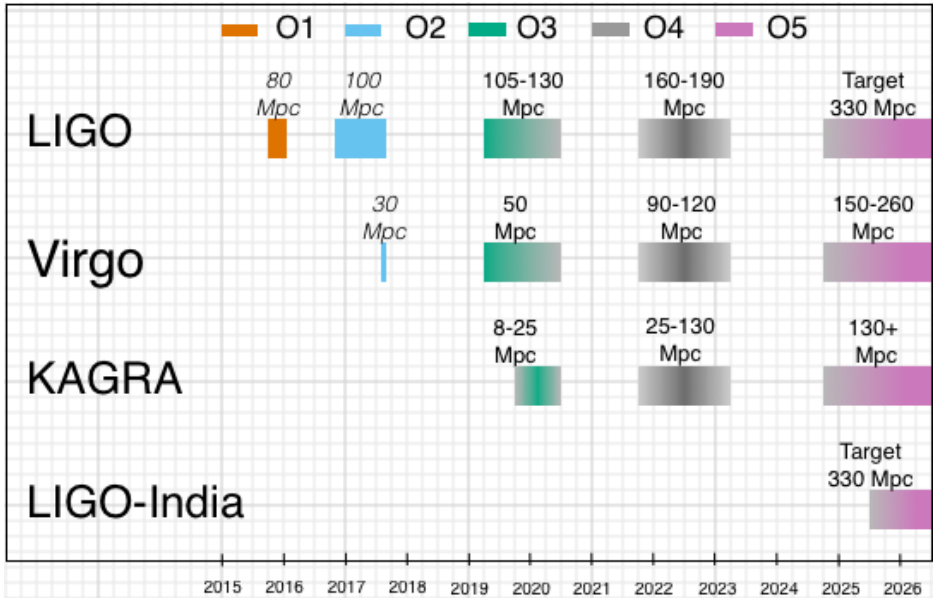


astrophysical reach of all-sky O2 CW search for neutron stars with ellipticity ε and distances [10,100,1000,10000] pc (coloured curves)
Abbott et al. (LVC) Phys. Rev. D 100, 024004 (2019)

Impact and prospects for the future

- KAGRA (underground cryogenic 3km detector in Japan) now joining the international network.
- LIGO and Virgo receiving further upgrades towards increased sensitivity in next observing run (O4).

- Meanwhile, expect more LVC papers on O3 data soon:
  - exceptional CBC events
  - full catalogs of confirmed CBC detections
  - burst, CW and stochastic analyses



- With increased numbers of binary neutron stars, hopefully some with counterparts, we can probe their population and nuclear properties.
- CBCs are “standard sirens” for cosmology!
- CW detections will explore the population of galactic neutron stars and their condensed matter properties.