GW230529: identifying objects in the lower mass gap

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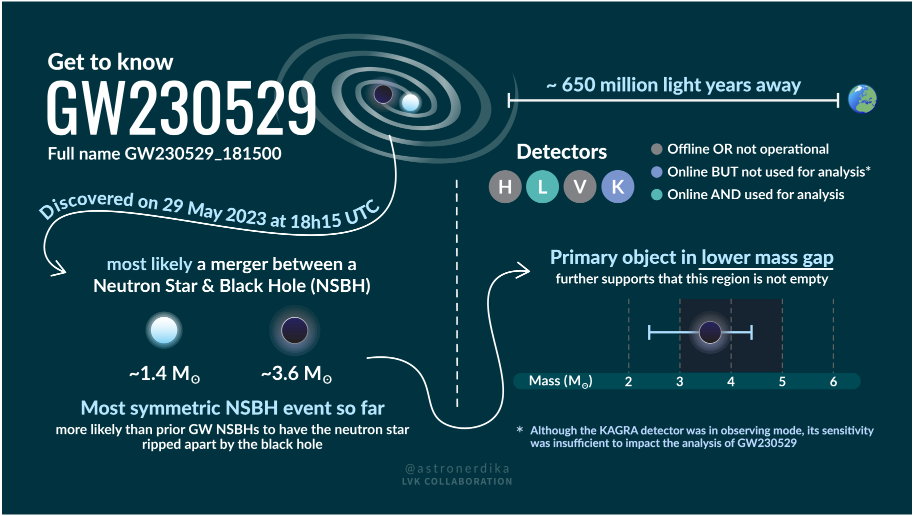
GW230529



Credit: Shanika Galaudage

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Identifying GW230529's primary

What information can we get from GW230529?

- Tidal information? uninformative
- Electromagnetic counterpart? not observed
- $\mathrm{SNR} \approx 11$: hard
- Masses? Well-measured!

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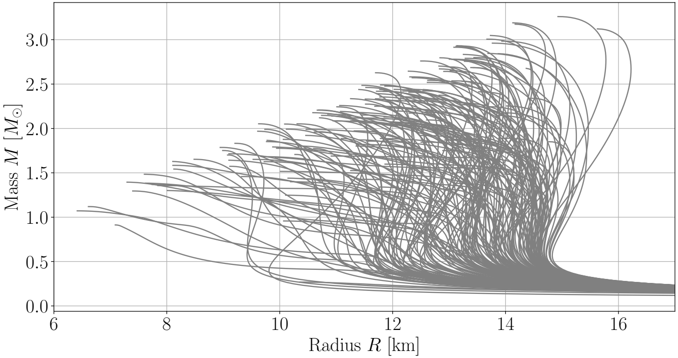
Neutron stars have a maximal mass M_{max}, which depends on the (unknown) equation of state and spin of the neutron star.

Approach: compare the mass distribution with expected upper bound

Equation of state

- Microscopically: nuclear interactions, $P(\epsilon, \rho)$,...
- Macroscopically: $M(R) \to M_{\mathrm{TOV}}$: maximum mass non-spinning neutron star
- Stars with spin χ: $M_{\mathrm{max}}(\mathrm{EOS}, \chi) \lesssim 1.3\ \mathrm{M_{TOV}}$.



Current equation of state constraints: NMMA

NMMA compiled a set of constraints on the equation of state:

- Nuclear theory and experiments
- Radio observations pulsars, NICER, bursters, X-ray binaries
- GW170817, EM counterparts, postmerger remnant

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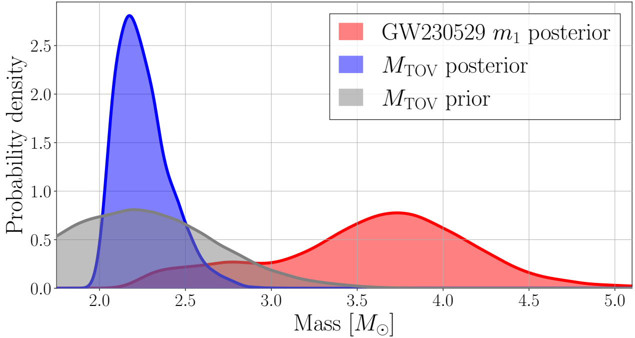
Result: M_{TOV} posterior



Identifying GW230529's primary: results

$P(NS)$: probability of primary being a neutron star

Posterior set	P(NS)
default	$(2.9 \pm 0.4)\%$
population-informed	$(8.8 \pm 2.8)\%$

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Without spin information, *i.e.*, $M_{\rm max} = M_{\rm TOV}$:

default	$\sim$ 1.63%
population-informed	$\sim$ 8.26%

NMMA

PRELIMINARY!

With spin information, *i.e.*, $M_{\rm max} = M_{\rm max}(\mathrm{EOS}, \chi)$:

default	$\sim$ 3.96%
population-informed	$\sim$ 17.96%

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Conclusion

- GW230529: GW event with a component in the lower mass gap
- Hard to identify the primary: no electromagnetic counterpart, low SNR,...
- Can use observational constraints on maximum mass of neutron stars
- NMMA: Extensive set of constraints on $M_{\max}$
- Primary object is a black hole (probability 82.04%)

APPENDIX

$P(NS)$ definition

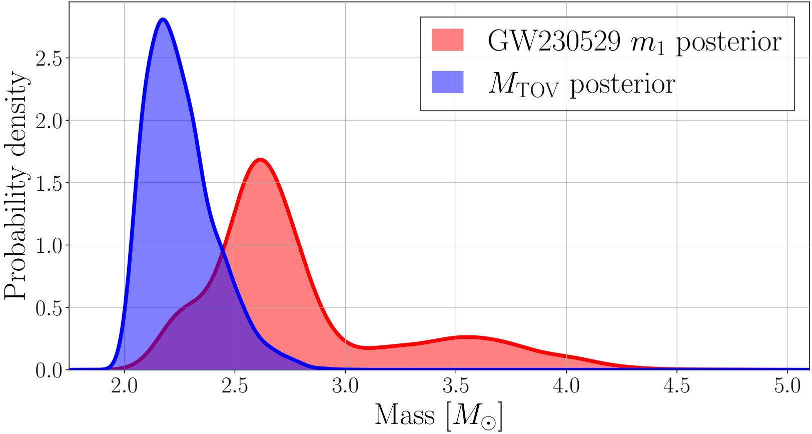
$$
\begin{aligned}
P(\mathrm{NS}) &= \sum_{\mathrm{EOS}} P(\mathrm{EOS}|d) \int_0^{M_{\mathrm{TOV}}(\mathrm{EOS})} dm\ P(m|O) \\
&= \int dM_{\mathrm{TOV}} \int_0^{M_{\mathrm{TOV}}} dm\ P(M_{\mathrm{TOV}}|d) P(m|O) \\
&= \int_0^{\infty} d\Delta m \int_{-\infty}^{\infty} dm\ P(m + \Delta m|d) P(m|O).
\end{aligned}
$$

Equation of state constraint sets

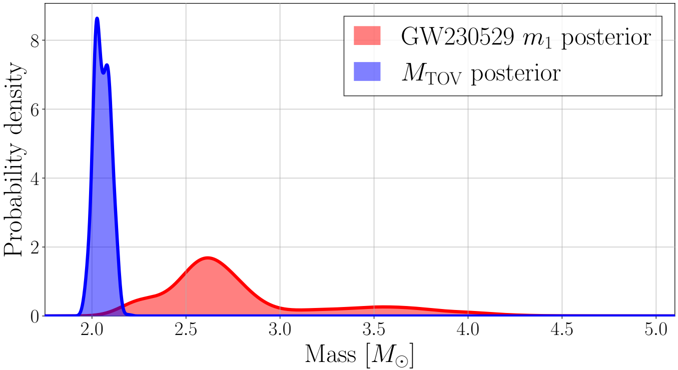
Table 1: Overview on the constraints contained within the three different constraint sets.

Set	Label	Description
High confidence	1	Chiral EFT, pQCD, heavy radio pulsars, NICER J0740+6620, NICER J0030+0451, (NICER J0437-4715), GW170817
More vigorous	2	Set 1, Black Widow J0952-0607, heavy ion-collisions, qLMXBs, GW170817+KN+GRB afterglow, CREX, PREX-II, Burster 4U 1702-429, Burster J1808.8-3658, GW170817 postmerger
Aggressive	3	Same as set 2, but for the remnant of GW170817 a hypermassive neutron star above the Kepler limit is assumed

Population informed posterior



TOV mass posterior with set 3 (“Aggressive”)



All probabilities for GW230529 primary being a NS

		spin	1	2	3
GW230529	default	$\times$	1.63%	1.37%	0.02%
		$\checkmark$	3.96%	3.97%	0.82%
	PDB	$\times$	8.26%	6.98%	0.38%
		$\checkmark$	17.96%	17.83%	1.79%