probing COMPACTNESS PEAKS with MERGING BBH

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$10\,M_\odot$ $15\,M_\odot$

is there a gap?

or is this region "polluted" by formation channels that differ from isolated binary evolution?

component masses

BACKGROUND

Gravitational waves from merging binaries encode information about the masses and spins of the binary components; providing clues as to how the binary formed and evolved. With ~100 gravitational wave events we are beginning to probe the structure in the mass distribution of the population of binary black hole mergers. Studies [e.g. 1, 2] have found there are peaks at 8, 14 and 28 $M_\odot$ in the chirp mass distribution, with a lack of binary black holes between 10 and 12 $M_\odot$. Is this gap a consequence of some astrophysical process?

WHAT DO WE KNOW ABOUT THE POPULATION?

Considering the black hole binaries, about 4 – 44% are in the powerlaw component compared to 56 – 96% in the peaks with the majority of binaries, 48 – 87%, in the low mass peak (90% credible intervals).

WHAT IS NEXT?

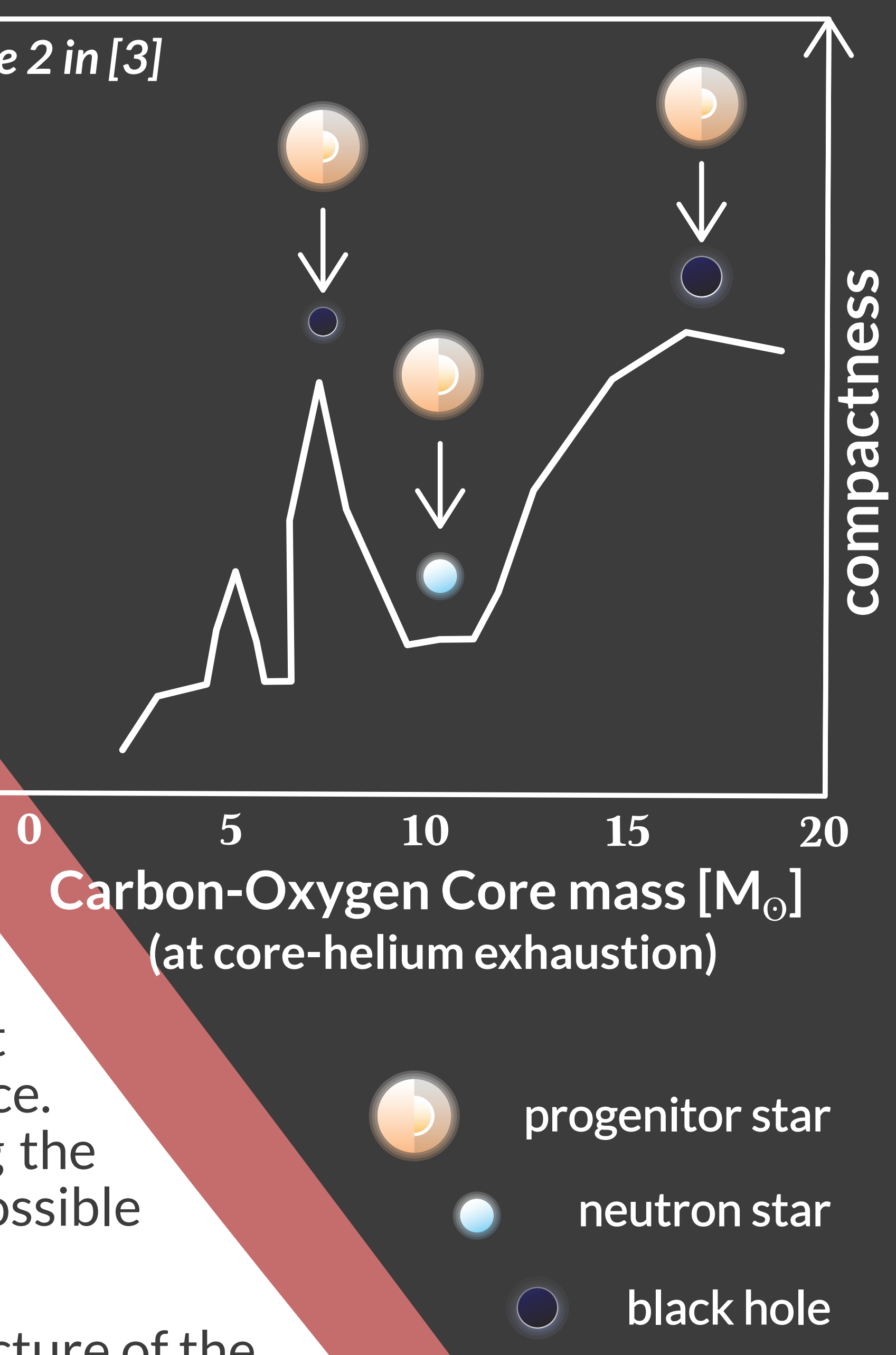
A recent study [5] also probing this gap finds that we will not resolve this feature with O4.

We note that future analyses extending the prior range on q for individual events may help resolve the structure and edges of the compactness peaks (refer to [4] for more details.)

COMPACTNESS PEAKS

A study [3] proposes that isolated binary evolution of stripped stars naturally gives rise to the 8 and 14 $M_\odot$ peaks in the chirp mass distribution and the dearth of black holes between 10 to 12 $M_\odot$. The gap in chirp mass results from an apparent gap in the component mass distribution between $m_1, m_2 \approx 10$ - $15\ M_\odot$ and the specific pairing of these black holes. This component mass gap results from the variation in core compactness of the progenitor, where a drop in compactness of Carbon-Oxygen core mass will form neutron stars instead from core collapse (see illustration).

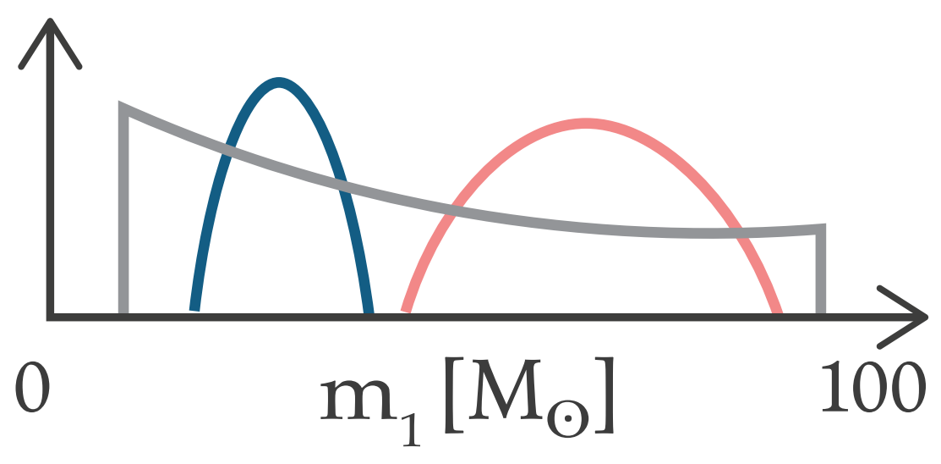
illustration based on Figure 2 in [3]



BUILDING THE POPULATION MODEL

If we look at the individual component mass posteriors (see Figure 1 in [4]) of the gravitational wave events from the third gravitational-wave transient catalogue (GWTC-3), there appears to be no gap in the component mass space. This may suggest there are other formation channels responsible for filling the space between the $m_1, m_2 \approx 10$ - $15\ M_\odot$ range, but of course, to study this possible gap properly, we need to perform a population analysis.

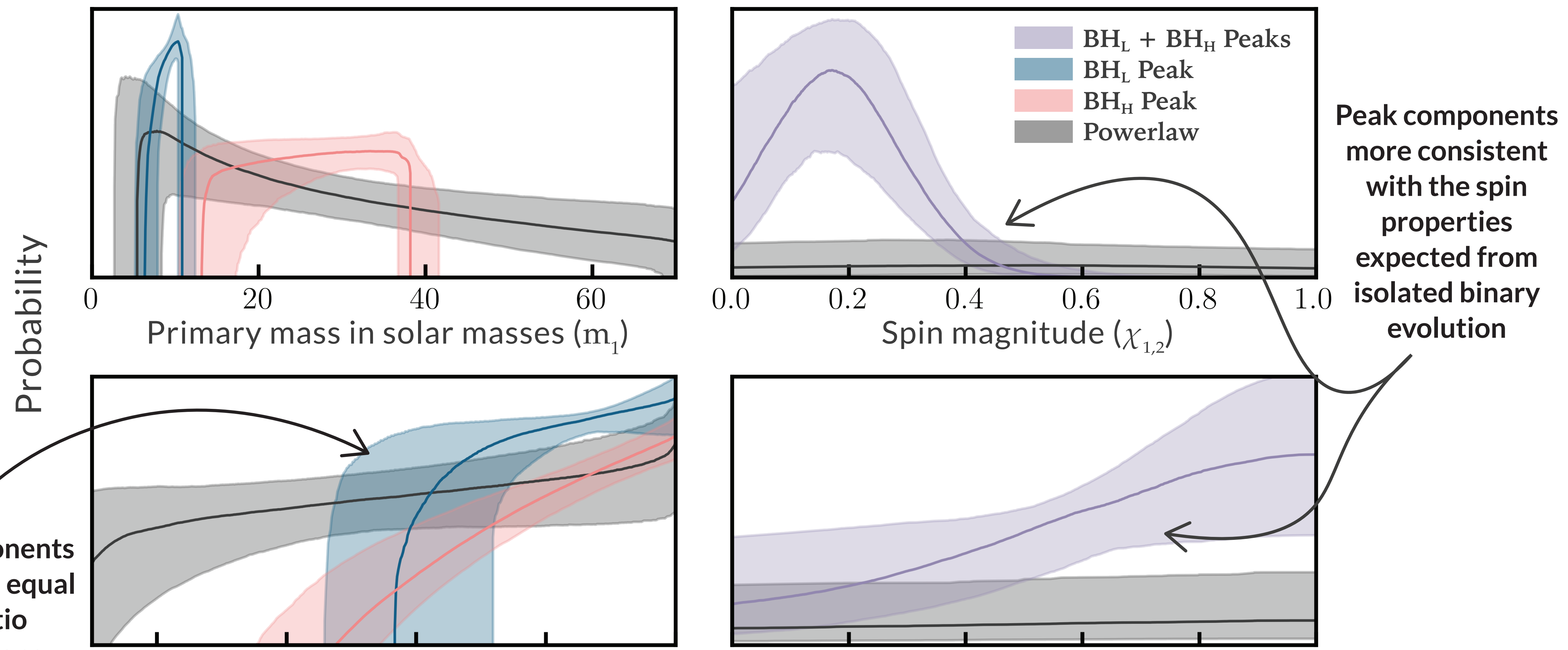
We develop a population model motivated by this scenario to probe the structure of the component mass distribution of binary black holes consisting of two populations: 1) two peak components ($\mathrm{BH_L}$ **Peak** and $\mathrm{BH_H}$ **Peak**) to represent black holes formed in the *compactness peaks* below and above the gap, and 2) a **Powerlaw** component to account for any *polluting events*, a.k.a. binaries that may have formed from different channels (e.g. dynamical).



NOTE Each component has a separate mass ratio distribution.
The peaks have a separate spin magnitude and orientation distribution to the powerlaw component. Details in [4].

We perform hierarchical Bayesian inference to analyse the events from GWTC-3 with this model.

RESULTS FROM GWTC-3



Peak components more consistent with the spin properties expected from isolated binary evolution

Peak components prefer more equal mass ratio distributions

We find that there is a preference for the lower mass peak to drop off sharply at ~11 $M_\odot$ and the upper mass peak to turn on at ~13 $M_\odot$, in line with predictions from [3], but there is no clear evidence for a gap in the component mass distribution. We also find mild support for the two populations to have different spin distributions.

REFERENCES

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