ICTS International Centre for Theoretical Sciences
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Constraining black hole mimickers

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With input from

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LIGO observations are fully consistent being binary black holes

- **GW150914** Observed freq evolution points compact binary of M ~70 $M_\odot$ and separation of ~300 km.
  Inference ⇒ binary black holes.

- Signals fully consistent with BBH solutions in GR.
  Based on several consistency tests (including residuals).

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Still, the possibility of massive, dark, compact, exotic objects as potential explanations of the LIGO events is not completely ruled out

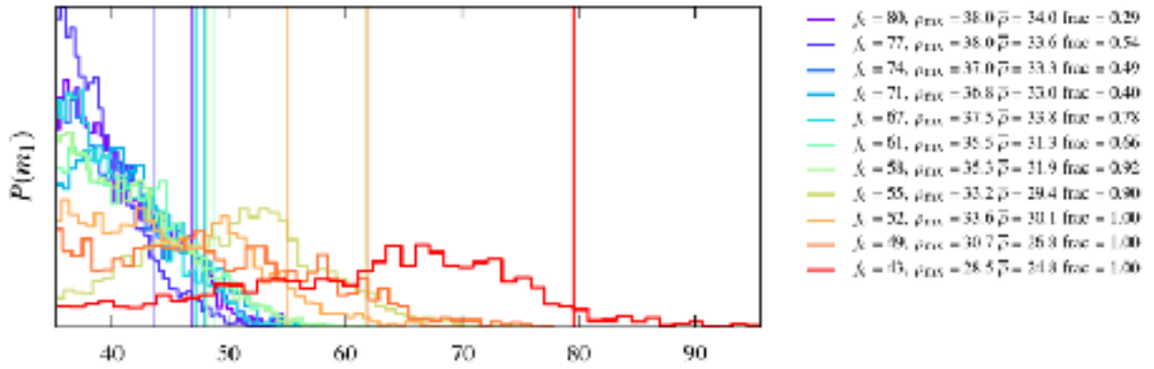
Black hole mimickers

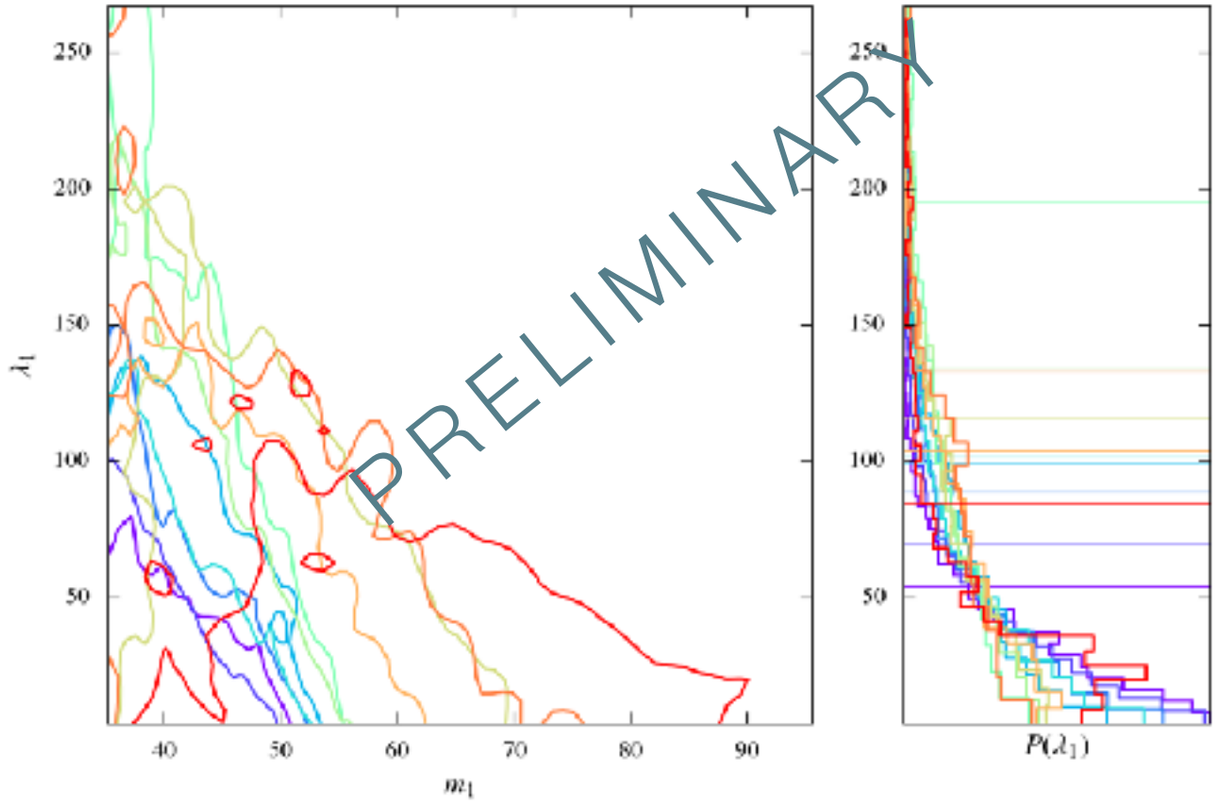
- Many theoretical models potentially suffer from conceptual, physical and mathematical difficulties.
  - Very little results from NR simulations, currently. Merger dynamics poorly studied, in general.
- Look for generic features in the GW signal
  - Imprints of tidal deformation [Sennett et al 2017, Cardoso et al 2017, …]
  - Spin-induced quadrupole moment [Krishnendu et al 2017]
  - Quasi-normal modes [Macedo, Cardoso, Pani, …]

Constraints from tidal deformation

- **Self-consistent Bayesian PE** Estimate posterior distributions of the masses and tidal deformability from the "inspiral."
  - Waveforms: Point particle (IMRPhenomP, SEOBNRv2_ROM) + adiabatic tides (1PN).
  - Depending on the tidal deformation, the objects can come in contact before the end of the point particle inspiral.
- Upper bounds on the tidal deformation and mass ⇒ constraints on the compactness (as well as parameters describing the EoS, e.g., polytropic index/const for polytropic EoS).

[Mukherjee, Johnson-McDaniel, Ajith, Del Pozzo, Vitale, Hinderer]





Constraints from GW150914 like BBH signals in ~O3.

Constraints from spin induced quadrupole moment

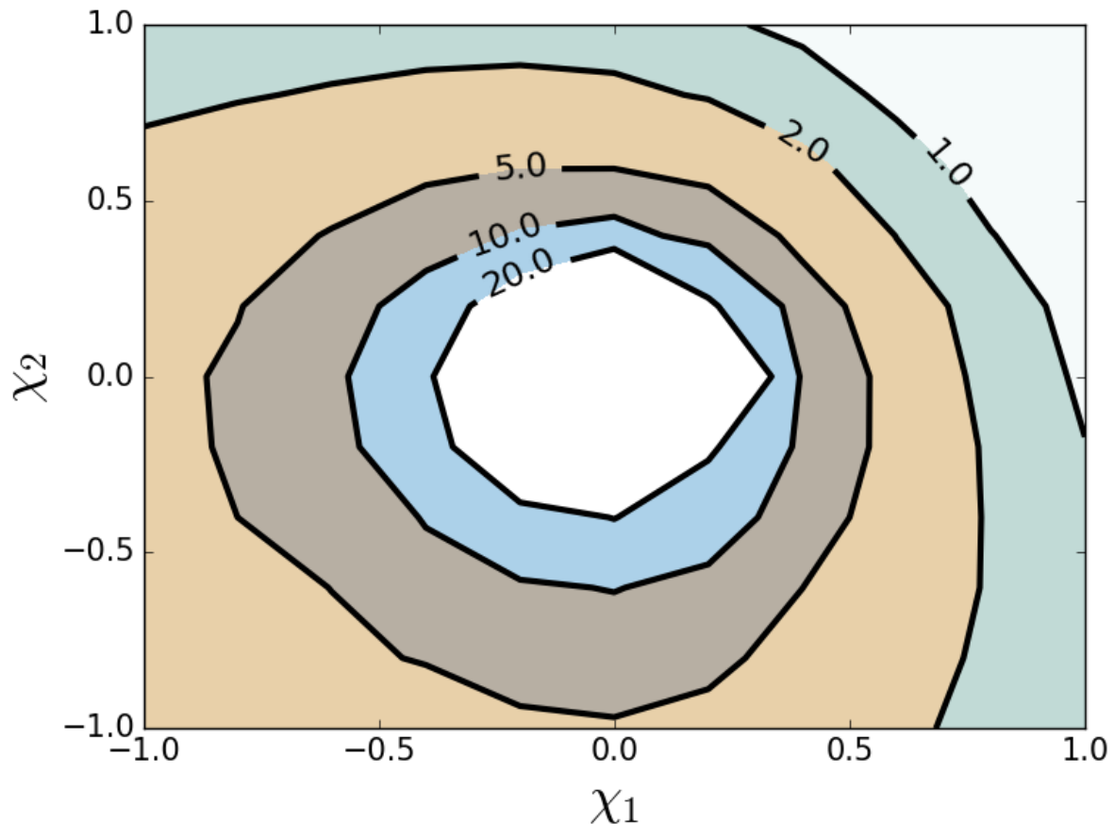
- Spinning compact objects acquire a quadrupole moment Q induced by the spin.

$$Q = -\kappa\, m^3 \chi^2$$

κ =1 for Kerr BHs. For other objects, depends on the EoS

- Method: Estimate κ from signal, treating it as free parameter (first appearing at 2PN in phase).

[Krishnendu, Arun, Mishra (2017)]



Fractional error in measuring the symmetric combination of κ from BBHs with masses (10,9) Msun and different dimensionless spins (SNR 10 in Adv LIGO).

Open questions

- Combining constraints from the inspiral and ringdown. Another version of the inspiral-ringdown consistency test?
- Waveform systematics: Spin-tidal coupling is neglected in the tidal PE. Accuracy of PN waveforms in the estimation of spin-induced Q.
  - Very useful to have some NR simulations of some of the BH mimickers.