Population Analysis of Binary Black Holes Estimated with Uniform Effective Spin Prior

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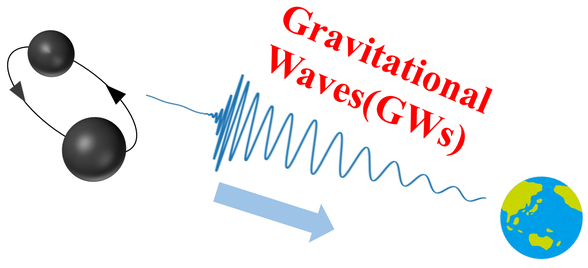
Background

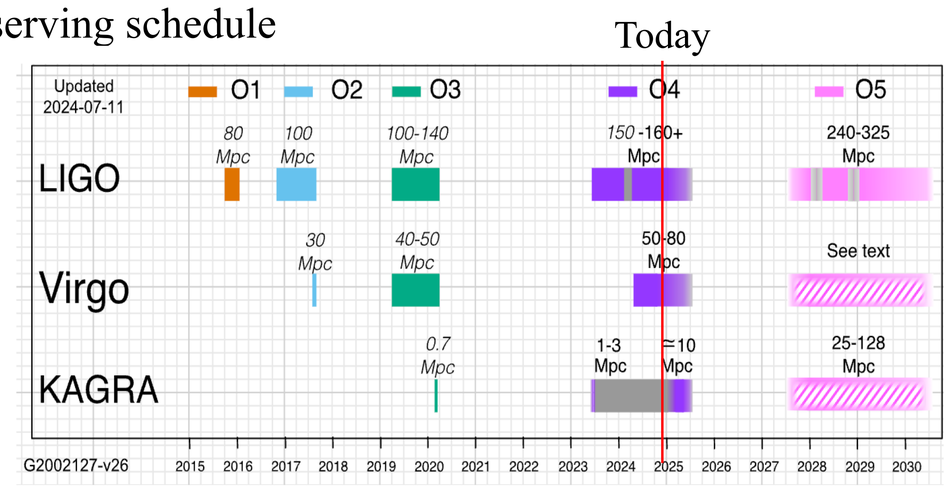


Compact binary merger generates **Gravitational Waves(GWs).**

Information of source can be extracted from GWs. e.g., masses, spins, distance etc.

LIGO Hanford | LIGO Livingston | Virgo | KAGRA

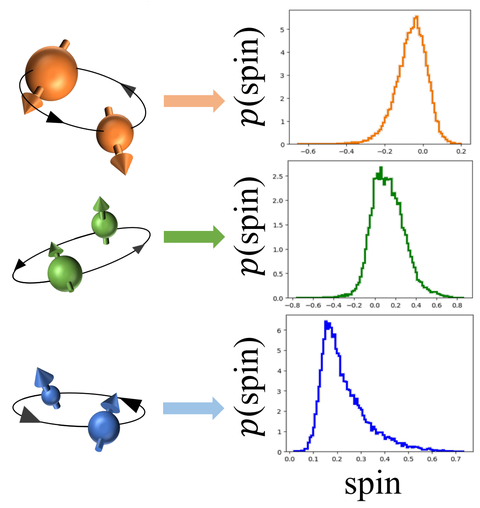
Observing schedule



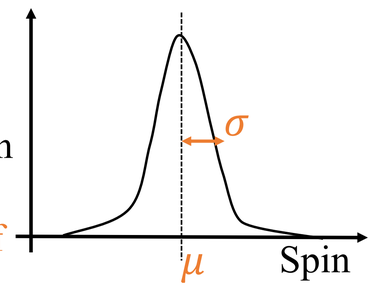
~90 compact binary mergers were observed up to O3, and **over 200 events have been detected in total so far.**

Method

1st Bayesian estimation



Overall distributions of spin parameter in the universe.

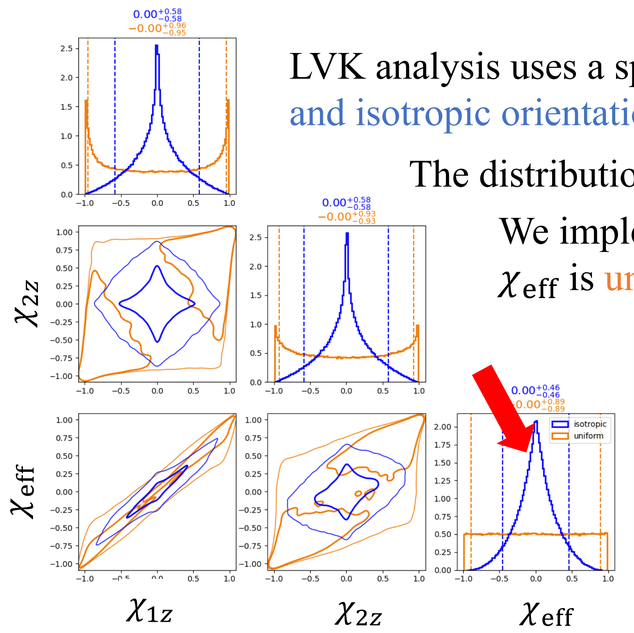


2nd Bayesian estimation of parameters describing the shape of overall distribution.

Assuming overall distribution is Gaussian $\mathcal{N}(\theta;\mu,\sigma)$.

Hierarchical Bayesian inference

Spin priors for 1st Bayesian estimation



LVK analysis uses a spin prior with uniform magnitudes and isotropic orientations[1] (blue line).

The distribution of $\chi_{\rm eff}$ is peaked around $\chi_{\rm eff}\sim 0$.

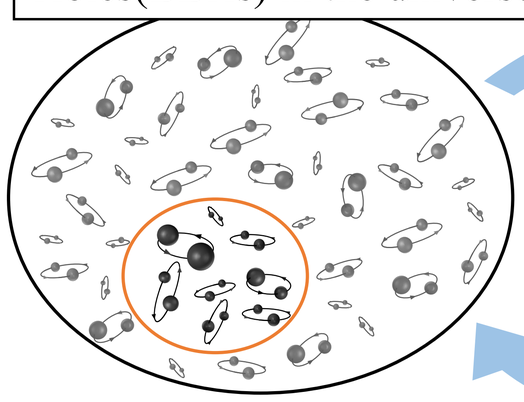
We implement a prior which distribution of $\chi_{\rm eff}$ is uniform[2] in bilby[3](orange line).

We investigate the **systematic errors caused by insufficient sampling around $|\chi_{\rm eff}|\sim 1$** from 1st Bayesian estimation.

[1] R. Abbott et al. PHYSICAL REVIEW X 13, 011048 (2023)
[2] Barak Zackay et al. PHYSICAL REVIEW D 100, 023007 (2019)
[3] Bilby, Gregory Ashton et al. ApJS 241, 27 (2019)

What is a population inference?

Population of Binary Black Holes(BBHs) in the universe.



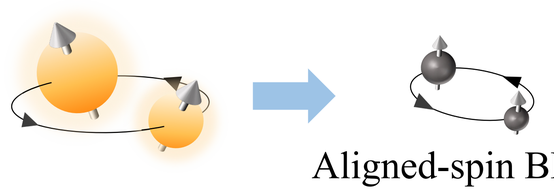
Observation through GWs.

- Mass and spin spectrum?
- Red shift distribution?
- Merger rate?

Population inference

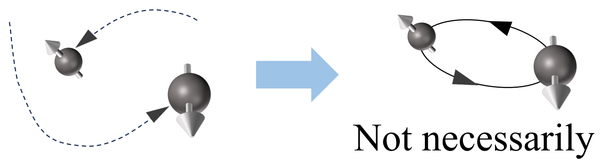
Simulation of populations of BBHs based on scenarios.

Isolated stellar evolution scenario



Aligned-spin BBH

Dynamical formation scenario

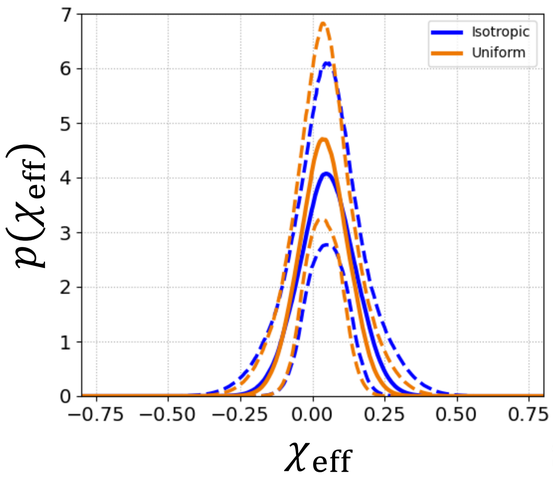


Not necessarily aligned-spin BBH

Reveal the formation scenarios of BBHs through **dual approach comparing observations and simulations.**

Result

Overall distributions of $\chi_{\rm eff}$ in the universe.



We perform population inference for up to O3 events using two results of 1st Bayesian estimation.

Prior of uniform magnitudes and isotropic orientations (used in LVK analysis, blue line)

vs.

Prior of uniform $\chi_{\rm eff}$ (this study, orange line)

Solid line is median, dashed line is 90% area.

Regarding the inference of the $\chi_{\rm eff}$ distribution for up to O3 events, **the tendency for $\chi_{\rm eff}$ to peak around 0.05 is consistent** between the LVK results and this study.

Conclusion

- The LVK prior may insufficient sampling $\chi_{\rm eff}\approx\pm1$, causing potential systematic errors in population inference.
- We implement the prior that uniformly distributes $\chi_{\rm eff}$.
- No significant systematic errors in population inference of $\chi_{\rm eff}$ caused by insufficient sampling.