Spins of stellar-mass black holes: tension between the X-ray binaries and gravitational wave measurements

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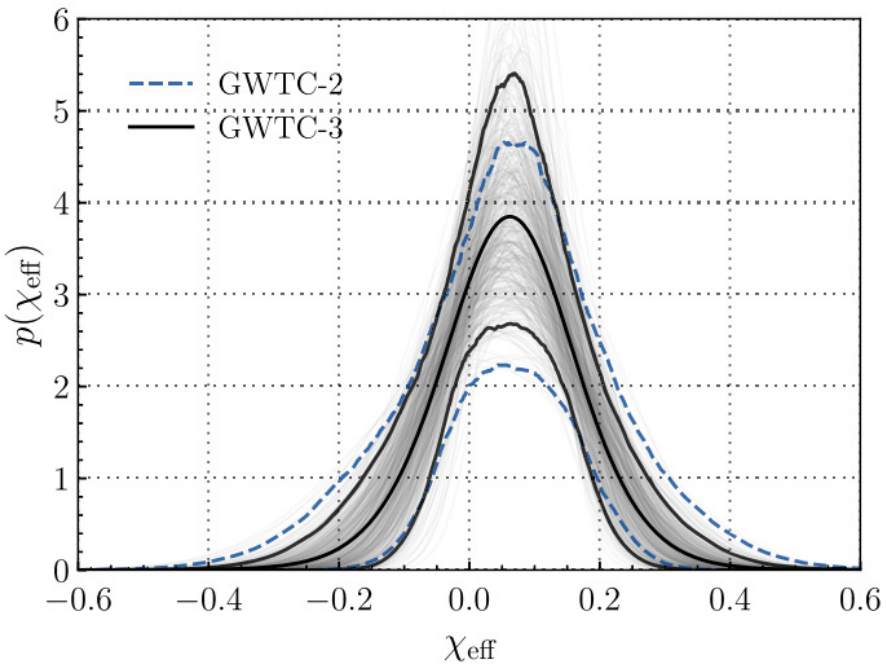
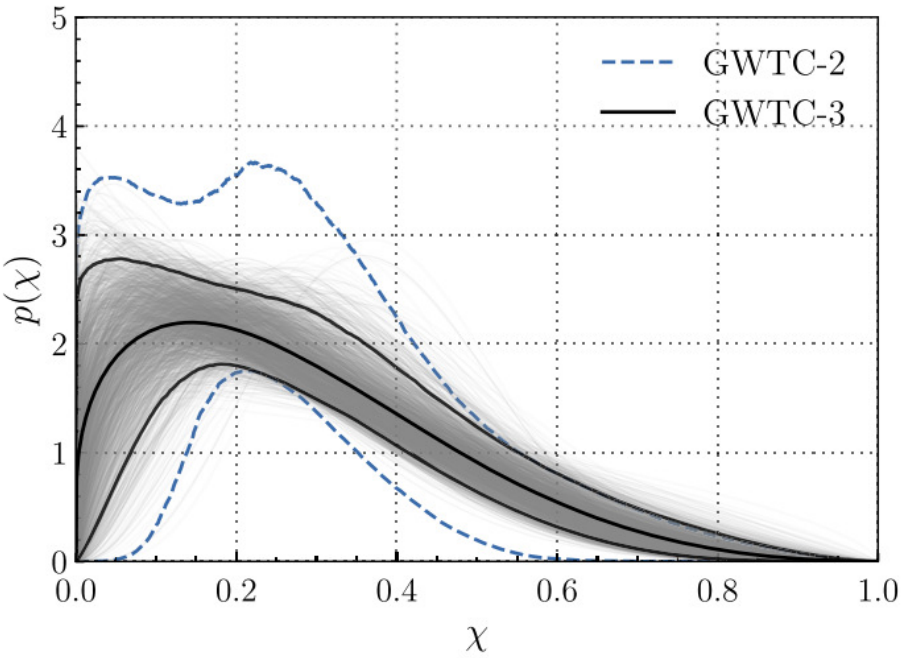
The low spins from gravitational waves

The effective spin measured from the form of gravitational waves emitted during the merger:

$$a_{\rm eff} \equiv \frac{M_1 a_1 \cos\theta_1 + M_2 a_2 \cos\theta_2}{M_1 + M_2}$$





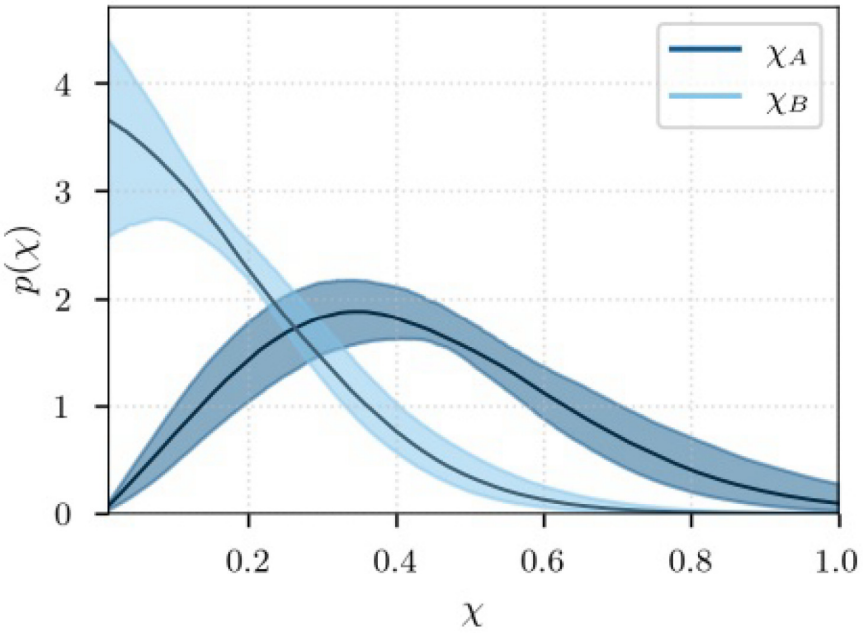
$$\langle a_{\rm eff} \rangle \approx 0.06^{+0.04}_{-0.05}$$

$$\langle a_* \rangle \approx 0.13^{+0.12}_{-0.11}$$

LVK collaboration 2023

Different distributions of the faster and slower BHs

LVK collaboration 2025



Interpreted as the first-born BH with a low natal spin. The second-born BH acquires the spin via tidal spin-up.

⇨ The BH natal spins are low.

High spins measured in BH X-ray binaries

- The published values for the three known high-mass BH XRBs:

  Cyg X-1 >0.9995 (3σ), LMC X-1 0.92, M33 X-7 0.84.

- According to recent papers, all values measured in low-mass BH XRBs are consistent with a_*>0.7, and there are many with a_*~1.

How much can the spin grow by accretion?

- Short lifetimes of HMXBs, e.g., ≈4 Myr for Cyg X-1. The mass e-folding Eddington time is ≈40 Myr (M-independent).
- Doubling the mass is required to get $a_* \sim 1$.

- Long lifetimes of LMXBs $>10^9$yr, but the observed donor masses are low, $\lesssim(1\text{–}2)M_\odot$.
- Models with initial intermediate-mass donors (up to $10M_\odot$) required to spin up the BH from a low natal spin.

- See our paper for possible resolutions of this tension.