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# Garçon: Spins Please (Or Some Other Pun-y Title)

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## ABSTRACT

We show various models for the distribution of black hole spin vectors in GWTC-3 and discuss what they might imply about the evolution of these systems.

## 1. INTRODUCTION

Blah.

## 2. BUILDING INTUITION

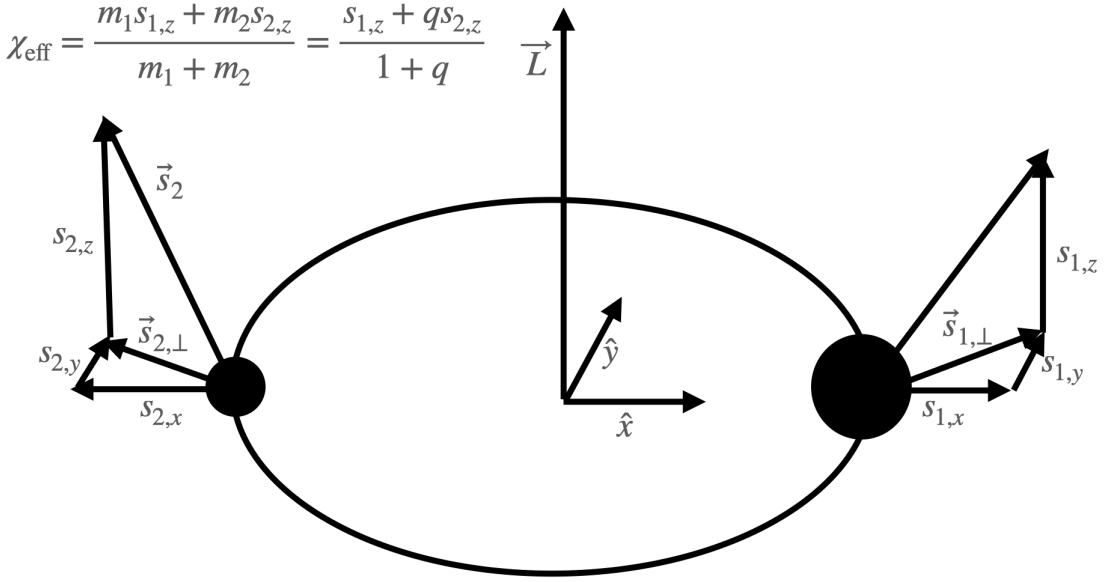


**Figure 1.** A figure showing the coordinate system we use for spins.

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[This argument was originally suggested by Maya, and fleshed out by Vicky and Will at Aspen.] Note that

$$\chi_{\rm eff} = \frac{s_{1,z} + q s_{2,z}}{1+q} \tag{1}$$

where $s_{i,z}$ is the $z$-component (the out-of-orbital-plane component) of the spin of the $i$ object and $q = m_2/m_1 < 1$. If we assume that the distribution of the $\vec{s}_i$ in the population do not depend on $q$, then by linearity of expectation values, we have

$$\langle \chi_{\rm eff} \rangle = \frac{\langle s_{1,z} \rangle + q \langle s_{2,z} \rangle}{1+q} \tag{2}$$

and

$$\frac{{\rm d}\langle \chi_{\rm eff} \rangle}{{\rm d}q} = \frac{\langle s_{2,z} \rangle - \langle s_{1,z} \rangle}{(1+q)^2}. \tag{3}$$

Callister et al. (2021) showed that the GWTC-2 (Abbott et al. 2021) population of binary black hole mergers have

$$\langle \chi_{\rm eff} \rangle \, (q = 0.8) \simeq 0.04 \tag{4}$$

and

$$\frac{{\rm d}\langle \chi_{\rm eff} \rangle}{{\rm d}q} \simeq -0.46 \tag{5}$$

(we have chosen to evaluate the Callister et al. (2021) mean $\chi_{\rm eff}$ at the best-constrained mass ratio of $q \simeq 0.8$). The GWTC-3 catalog exhibits the same correlations, with reduced uncertainty (The LIGO Scientific Collaboration et al. 2021). These properties of the population imply

$$\langle s_{1,z} \rangle \simeq 0.70 \tag{6}$$

$$\langle s_{2,z} \rangle \simeq -0.79. \tag{7}$$

Even accounting for the uncertainties in Callister et al. (2021)'s population, that the mean $\chi_{\rm eff}$ is close to zero at nearly-equal masses imples that $\langle s_{1,z} \rangle \simeq -\langle s_{2,z} \rangle$. That $\chi_{\rm eff}$ decreases with increasing $q$ implies that $\langle s_{2,z} \rangle < \langle s_{1,z} \rangle$, so that $\langle s_{2,z} \rangle$ must be negative while $\langle s_{1,z} \rangle$ is positive *assuming that the spin distribution is independent of the system mass ratio $q$.*

## REFERENCES


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Callister, T. A., Haster, C.-J., Ng, K. K. Y., Vitale, S., & Farr, W. M. 2021, ApJL, 922, L5, doi: 10.3847/2041-8213/ac2ccc

The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration, et al. 2021, arXiv e-prints, arXiv:2111.03634. https://arxiv.org/abs/2111.03634