LIGO-Virgo O2 Population Results

What is the *underlying* rate of events and the *underlying* distribution of their individual properties?

The LVC performs population model selection using a Bayesian analysis which computes the probability of a population model given a handful of detected GWs

The LVC Mass Spectrum Models (so far…)

Models A and B (power law in primary mass, power law in mass ratio):

$$p(m_1, m_2|m_{\rm min}, m_{\rm max}, \alpha, \beta_q) \propto \begin{cases} C(m_1) m_1^{-\alpha} q^{\beta_q} & \text{if } m_{\rm min} \leq m_2 \leq m_1 \leq m_{\rm max} \\ 0 & \text{otherwise} \end{cases},$$

Model C (same as Model B, but with a Gaussian component in primary mass):

$$p(m_1|\theta) = \left[(1-\lambda_m) A(\theta) m_1^{-\alpha} \Theta(m_{\rm max} - m_1) + \lambda_m B(\theta) \exp\left(-\frac{(m_1 - \mu_m)^2}{2\sigma_m^2}\right)\right] S(m_1, m_{\rm min}, \delta m),$$

$$p(q|m_1, \theta) = C(m_1, \theta) q^{\beta_q} S(m_2, m_{\rm min}, \delta m).$$

LVC Spin Spectrum Models (so far…)

Spin models are mass-independent
(but observed spins and masses simultaneously fit)

- Treat spins parametrically (spin magnitudes ~ beta distribution
- Non-parametrically by constraining heights of histogram bins

How do we compare these models to the data?

$$\mathcal{L}(\{d_n\}|\theta) \propto e^{-\mu(\theta)} \prod_{n=1}^{N_{\rm obs}} \int \mathcal{L}(d_n|\xi, z) \frac{\mathrm{d}N}{\mathrm{d}\xi \mathrm{d}z}(\theta)\, \mathrm{d}\xi \mathrm{d}z,$$

Expected number of *detections*

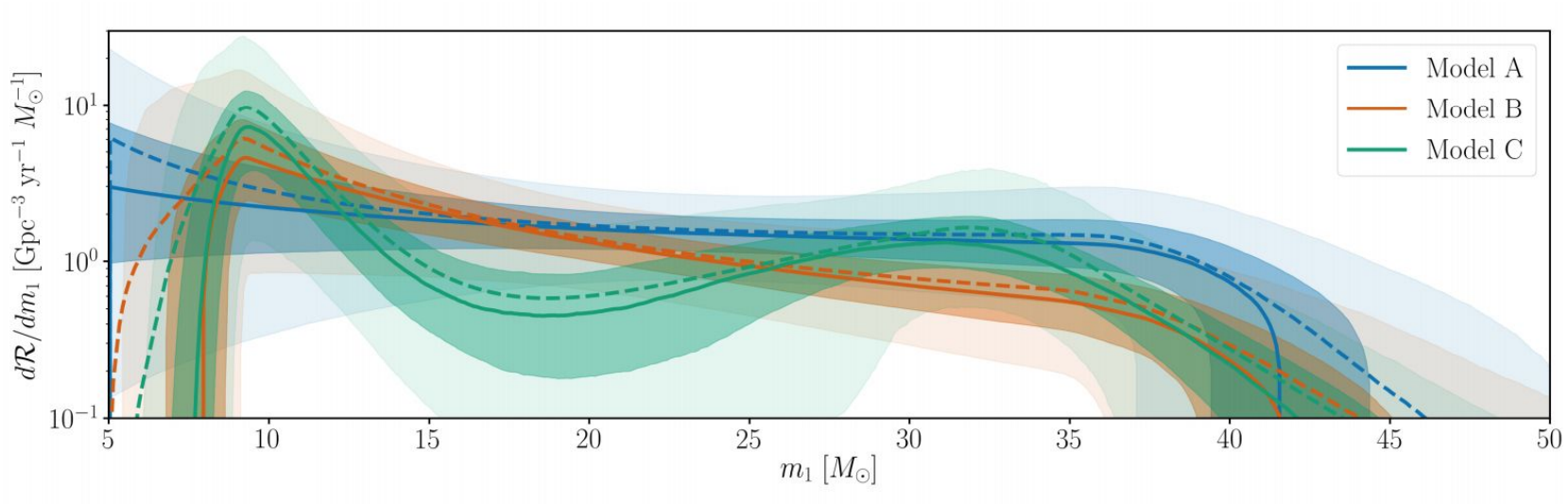
Multiply over all events in the sample

Likelihood of event's recorded data given possible parameters

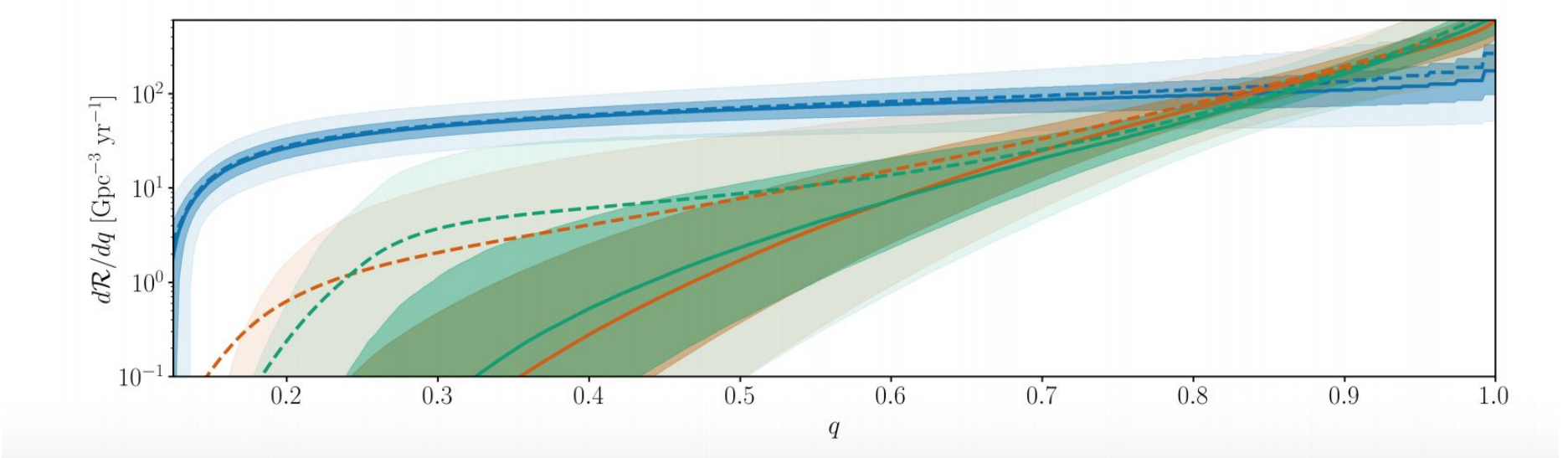
Intrinsic number of events per parameter interval per redshift interval

Integrate over all possible parameters and redshifts

Likelihood of data given population θ

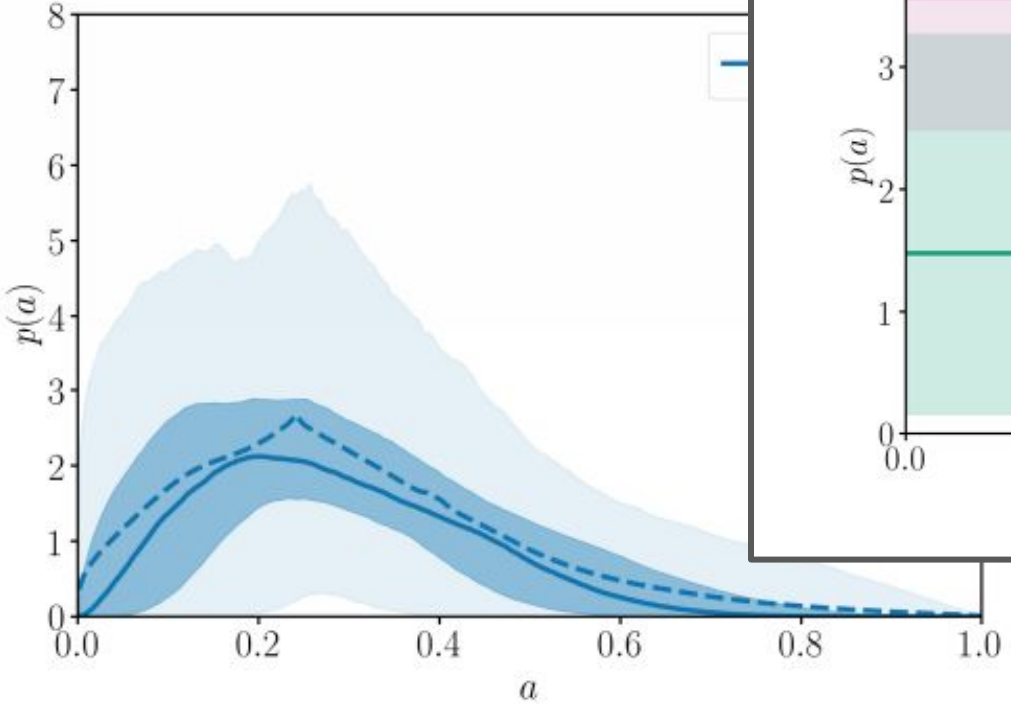


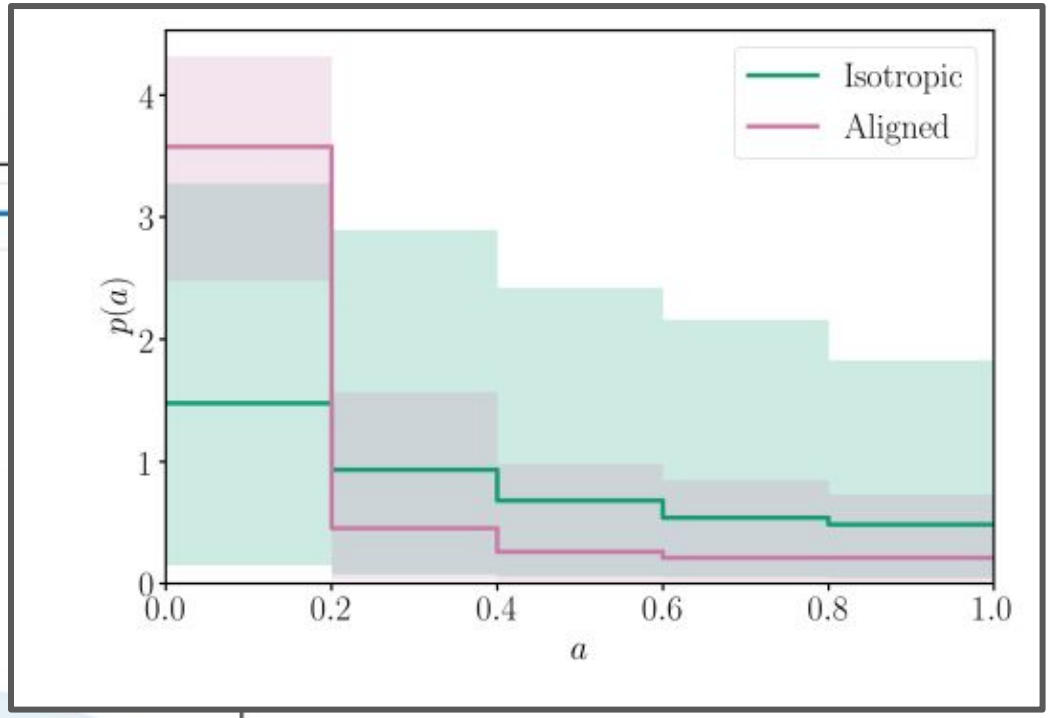
Inferred primary mass distributions



Inferred mass ratio distribuion

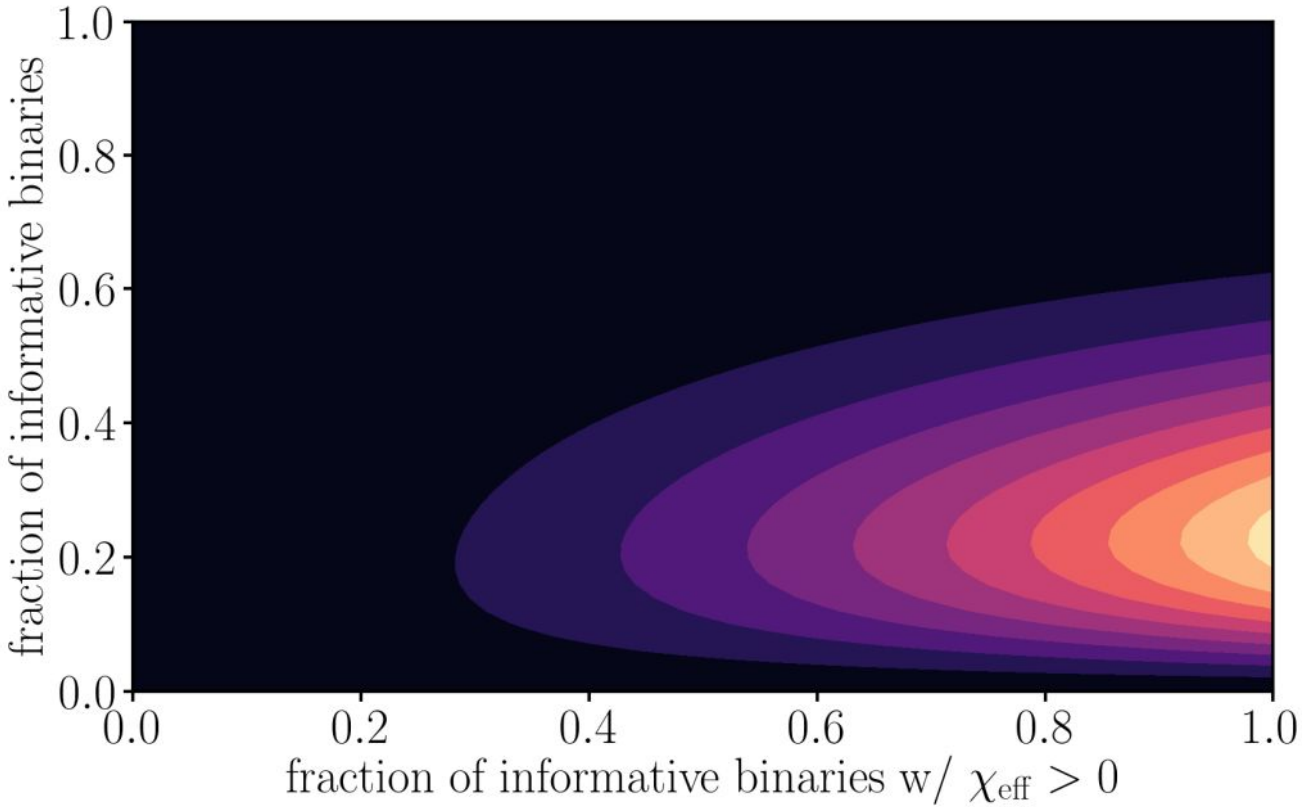
Mixture of aligned
and isotropic spins





Isotropic vs. aligned treated
separately

Inferred spin magnitude distributions



3-bin model of effective spins

Take-aways

- The population likelihood can be used to compare population models in a way that self-consistently fits the data (e.g. rate and spectrum simultaneously fit).
- Using population priors affects individual event posteriors
- Equal mass ratios preferred
- Low effective spins preferred