Gravitational Wave Parameter Guide

What is Parameter Estimation?

- Parameter estimation refers to inferring unknown model parameters that explain observed data under some model. In the case of the slider, we use the gravitational wave model IMRPhenomD. Certain parameters have a stronger impact on the waveform's structure; these are indicated below as **"sensitive"** or **"insensitive."**
- In gravitational wave analysis, as shown in the slider, a GW signal can be constructed from various parameter combinations, as long as it includes **two mass parameters** (e.g., m_1 and m_2 or $\mathcal{M}$ and q) and **two spin parameters** (e.g., χ_1 and χ_2 or χ_+ and χ_-).

Component Masses

The component masses are the detector-frame masses of the two individual black holes, measured in solar masses ($M_\odot$). They are calculated by multiplying the source-frame (or "rest") masses, m_{source}, by the redshift, z, of the system.

- Symbol: m_1, m_2
- Equation:

$$m = (1+z)\, m_{\text{source}} \tag{1}$$

Component Spins

The component spins are dimensionless measures of each black hole's intrinsic angular momentum and are oriented in the same direction as the binary's orbital angular momentum.

- Symbol: χ_1, χ_2
- Equation: inverse of effective spin/ weighted spin difference

Mass Ratio - Insensitive

The mass ratio is used together with the chirp mass because, although the chirp mass can be measured very precisely, it does not provide the individual masses of the binary components on its own.

- Symbol: q
- Equation:

$$q = \frac{m_1}{m_2} \leq 1 \tag{2}$$

Chirp Mass - Sensitive

The chirp mass is an effective combination of the two masses in a binary system, measured in solar masses ($M_\odot$). It is usually the most precisely measured parameter from gravitational wave signals and is therefore commonly used in parameter estimation.

- Symbol: $\mathcal{M}$
- Equation:

$$\mathcal{M} = \frac{(m_1 m_2)^{\frac{3}{5}}}{(m_1+m_2)^{\frac{1}{5}}}. \tag{3}$$

Effective Spin - Sensitive

The effective spin represents the mass-weighted sum of the component spins.

- Symbol: χ_+
- Equation:

$$\chi_+ = \frac{\chi_1 m_1 + \chi_2 m_2}{m_1+m_2} \tag{4}$$

Weighted-Spin Difference - Insensitive

The weighted spin difference has little effect on the morphology of the gravitational wave signal. It is used alongside the effective spin to help infer the individual spins of the binary components.

- Symbol: χ_-
- Equation:

$$\chi_- = \frac{\chi_1 m_1 - \chi_2 m_2}{m_1+m_2} \tag{5}$$

Extrinsic Parameters

Extrinsic parameters such as sky location, distance, and orbital orientation also affect the observed waveform. In the gravitational wave slider, these parameters were maximized over so that their influence is absorbed into the waveform's overall phase and amplitude.