Gravitational Wave Parameter Guide

What is Parameter Estimation?

Parameter estimation refers to inferring the values of unknown model parameters from gravitational wave data. Statistical techniques, such as Bayesian inference, are used to determine which parameter values are most consistent with the measured waveform. Certain parameters have a stronger impact on the waveform's structure; these are indicated below as "sensitive" or "insensitive."

Component Masses - Sensitive

The component masses are the masses of each individual black hole measured in solar masses $(M_\odot)$.

► Symbol: m_1, m_2

► Equation: N/A

Component Spins - Sensitive

The component spins are the dimensionless measures of each black hole's intrinsic angular momentum.

► Symbol: χ_1, χ_2

► Equations:

$$\chi_1 = \frac{m_1 + m_2}{2m_1}(\chi_+ - \chi_-) \tag{1}$$

$$\chi_2 = \frac{m_1 + m_2}{2m_2}(\chi_+ - \chi_-) \tag{2}$$

Chirp Mass - Sensitive

The chirp mass is an effective combination of the two masses in a binary system. It is usually the most precisely measured parameter from gravitational wave signals and is therefore commonly used in parameter estimation.

► Symbol: $\mathcal{M}$

► Equation:

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

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:

$$q = \frac{m_1}{m_2} \leq 1 \tag{4}$$

Effective Spin - Sensitive

The effective spin represents the mass-weighted averages of the binary system. It encodes the alignment of the system with its orbital angular momentum.

► Symbol: χ_+, χ_{eff}

► Equation:

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

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:

$$\chi_- = \frac{\chi_1 m_1 - \chi_2 m_2}{m_1 + m_2} \tag{6}$$

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.

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