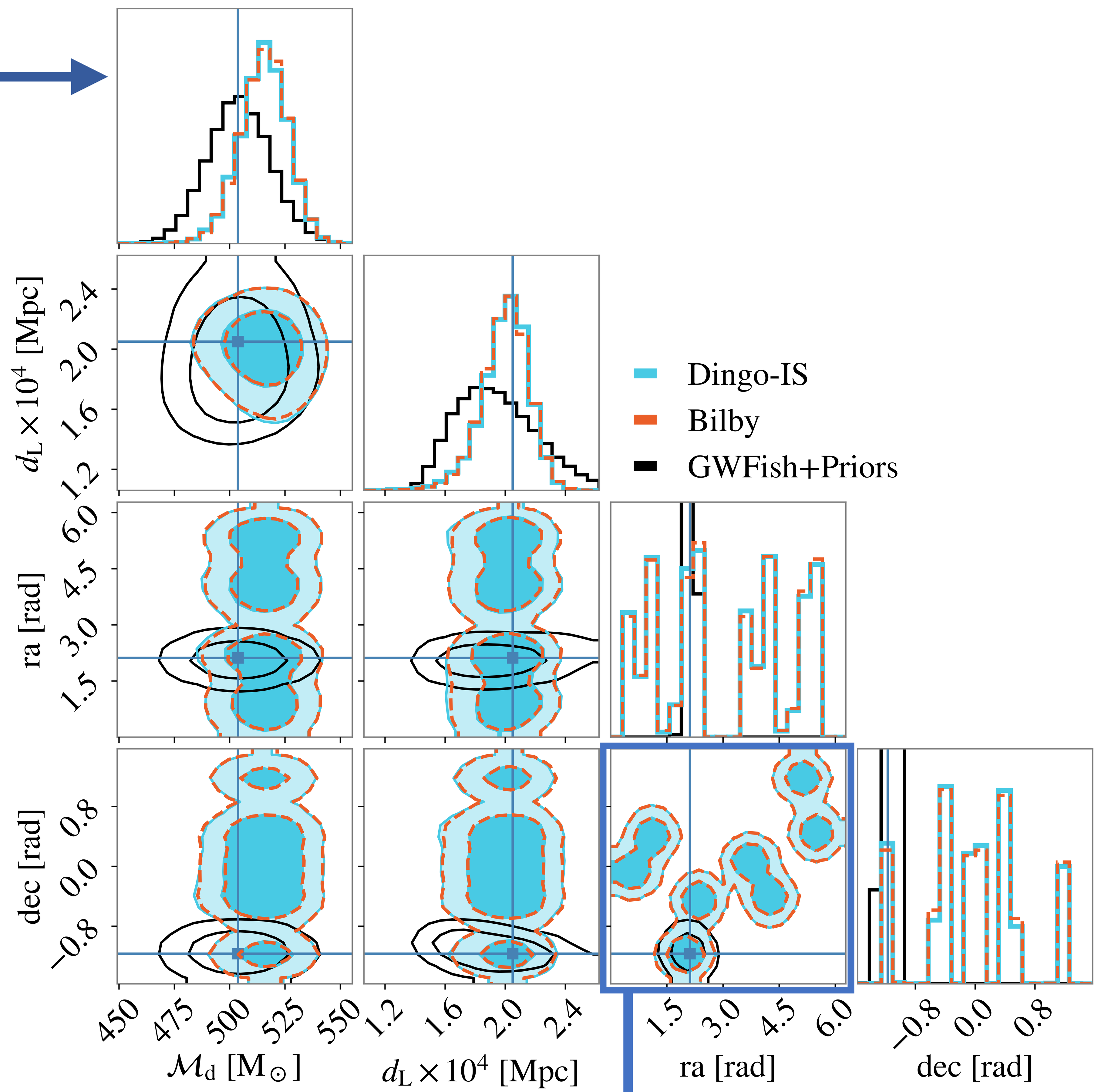
Fast and accurate parameter estimation of high-redshift sources with the Einstein Telescope

In its triangular configuration and for short-lived sources, the Einstein Telescope will provide more precise distance measurements than sky localization.

Background: The Einstein Telescope will be a key instrument for detecting GWs in the coming decades [Punturo et al. 2010, Maggiore et al. 2020, Branchesi et al. 2023, Abac et al. 2025]. However, analyzing the data and estimating source parameters will be challenging, especially given the large number of expected detections – of order 10^5 per year – which makes current methods based on stochastic sampling impractical [Couvares et al. 2021]

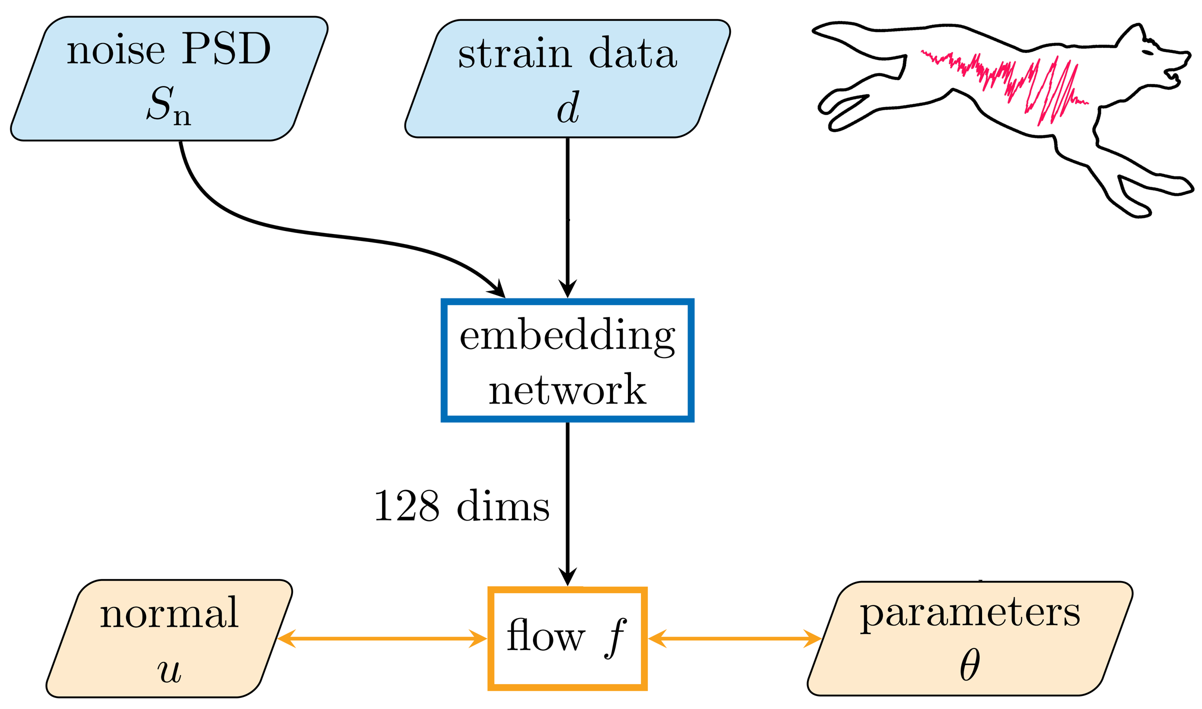
Main result

Posterior samples from `Dingo-IS` [Dax et al. 2021] and `Bilby` [Romero-Shaw et al. 2020] indicate that the two distributions are effectively identical. The corner plot shows also multimodalities that arise due to the geometry of a triangular co-located detector [Singh and Bulik 2021]. These modes are absent when using the Fisher information matrix approximation [`GWFish+Priors`, Dupletsa et al. 2025].



Methods

In Santoliquido et al. 2025, we use `Dingo-IS` to perform Neural Posterior Estimation (NPE) of high-redshift events observable with the Einstein Telescope. NPE is a likelihood-free inference technique that leverages normalizing flows to approximate posterior distributions [Dax et al. 2023]:

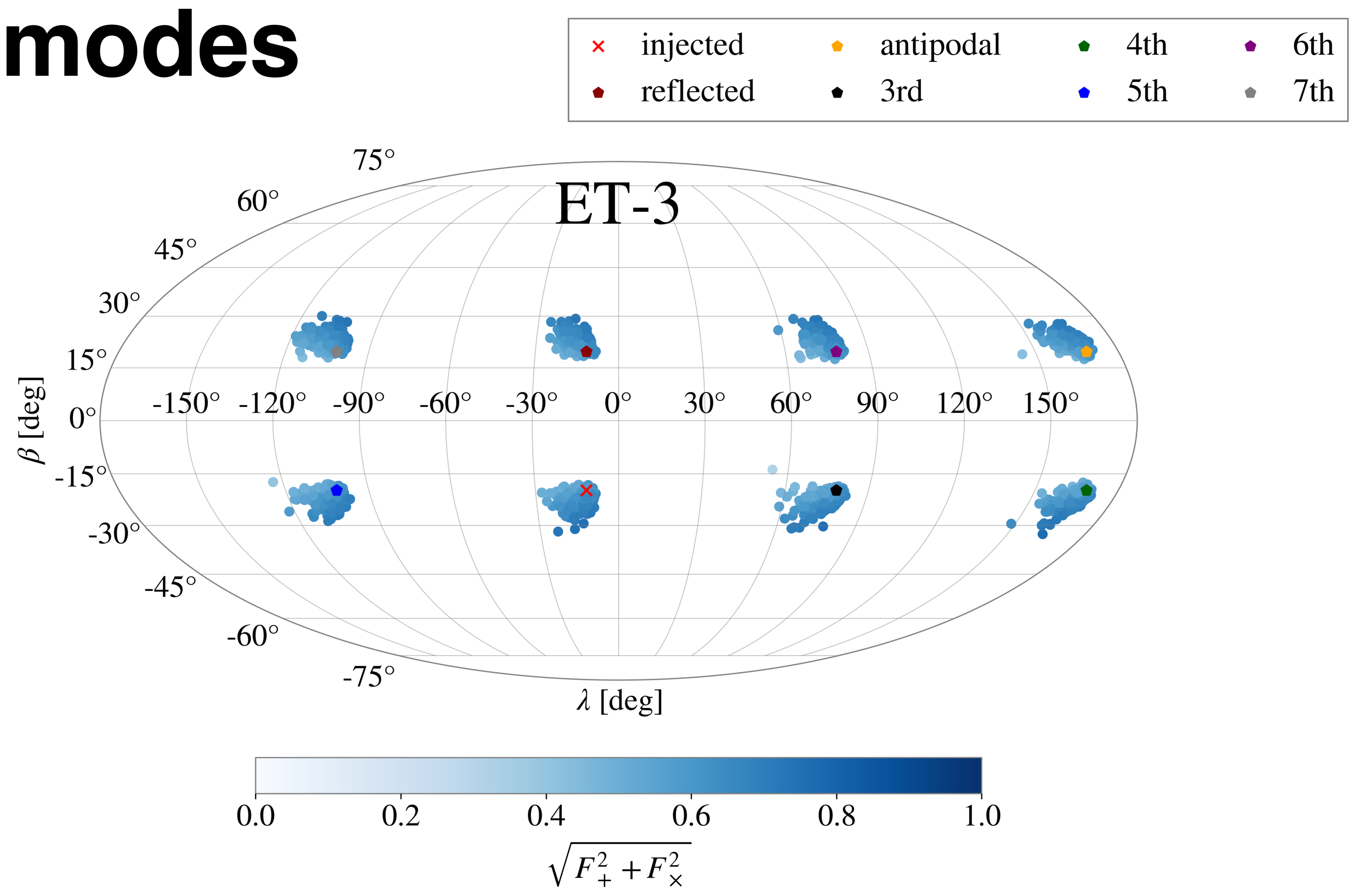


Once trained, this approach enables fast and accurate inference—typically requiring only a few minutes per source. To correct for any residual bias, we employ importance sampling,

$$w_i = \frac{\mathscr{L}(d\,|\,\theta)\pi(\theta)}{q(\theta\,|\,d)},$$

where $\mathscr{L}(d\,|\,\theta)$ is the likelihood, $\pi(\theta)$ the prior and $q(\theta\,|\,d)$ is the neural approximation of the posterior.

Sky modes



PDF version

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