SIMULATION BASED INFERENCE: UNRAVELLING THE MYSTERIES OF GRAVITATIONAL WAVES

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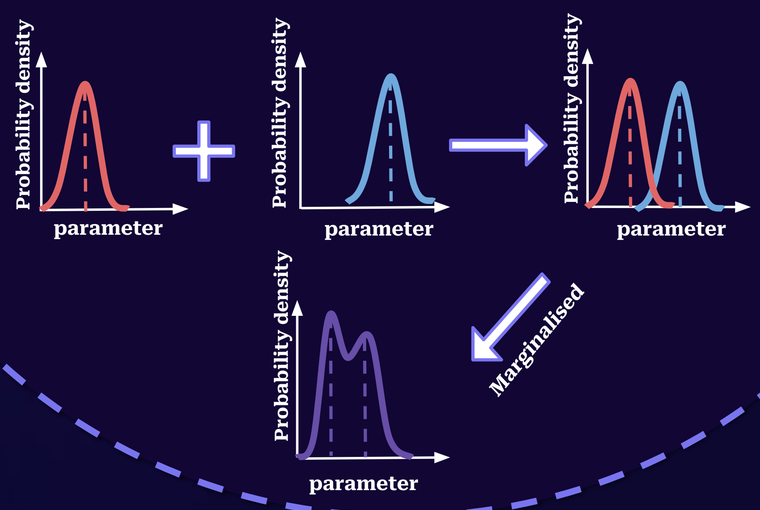
The problem

- **Gravitational waves** are ripples in the fabric of space-time, caused by moving massive objects, such as **merging black holes**.
- The **source** of gravitational waves is revealed through careful study of their **signal patterns**, or **waveforms**.
- By **analysing using different waveform models**, we check how accurate our predictions are.
- Our predictions are **less certain** for objects **spinning very fast** or with **extreme mass differences**.
- We train a **SBI neural network** to better predict signal parameters by learning from a mix of, or **marginalise over, different waveforms:**



Method

Simulation-based inference neural networks require two important inputs: **Waveform models** and **prior constraints** on model parameters.

1

We **sample parameters** from the **prior** and utilise the waveform models to create **simulated data.**

2

This data is passed into a **normalising flow neural network**, learning the **association** between the data and the parameters.

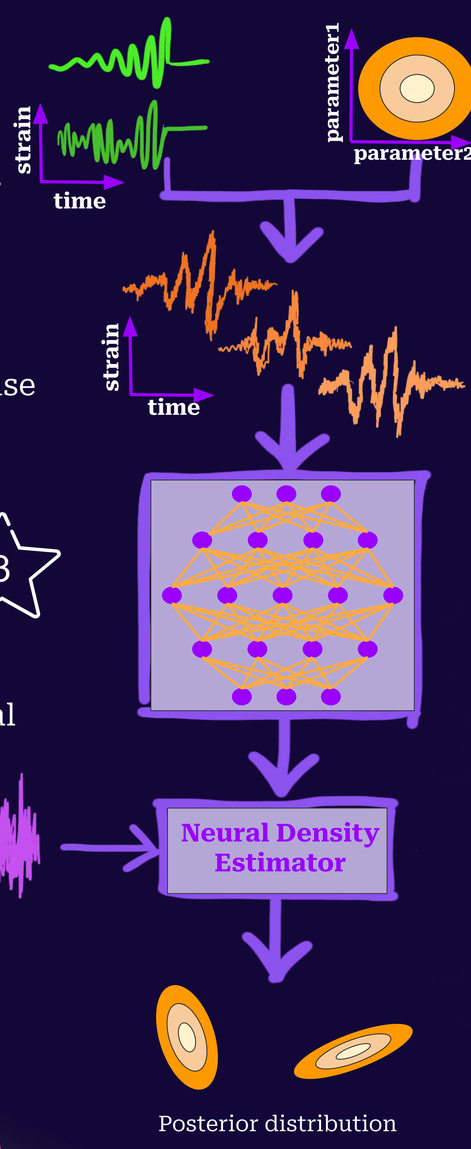
3

The neural network learns how to do statistical inference, thus we are creating a **density estimator**.

4

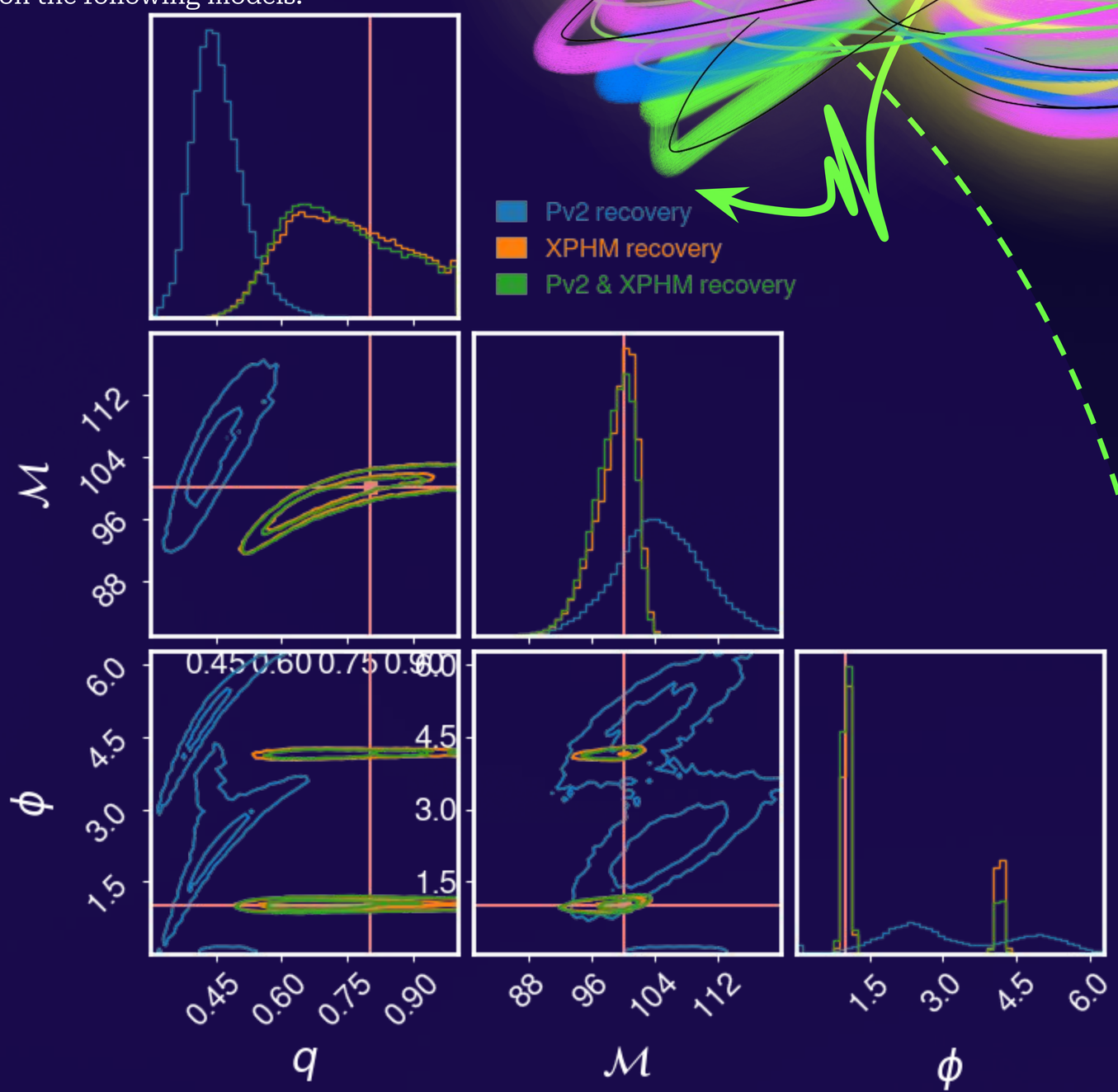
The density estimator is then used on empirical data to derive the **posterior distribution.**

5



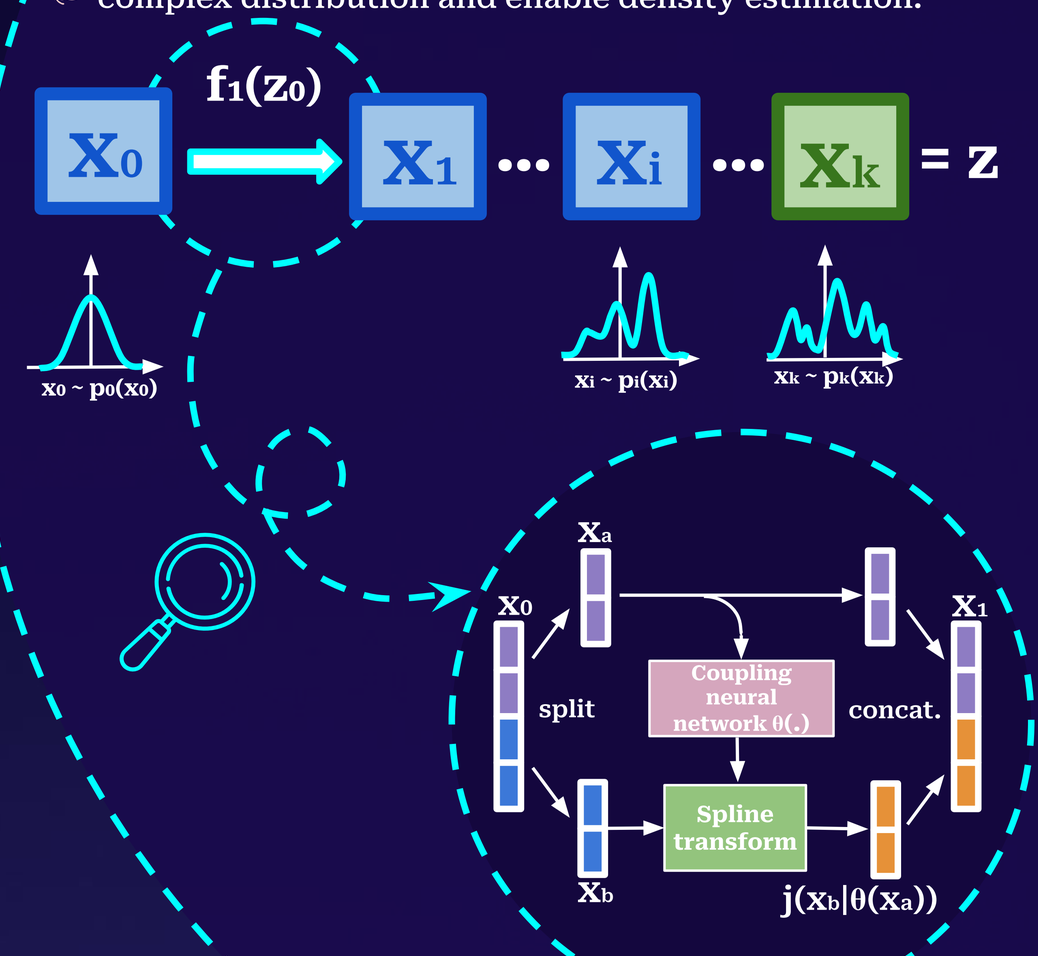
Results

In this plot, all analyses were run on the same waveform injection (with model XPHM) and recovered using SBI trained on the following models:



Normalising Flows

- Normalising flows are probabilistic models, enabling complex transformations of simple probability distributions.
- We are then able to transform a base distribution x into a more complicated one z using a series of invertible, differentiable functions f.
- Multiple spline functions j are chained together to model the complex distribution and enable density estimation.



References by print ID:
SBI: PMLR 97:2404-2414 ★ Phys. Rev. Lett. 127, 241103 ★ arXiv:2010.12931v5 ★ Phys. Rev. D 102, 104057
Normalising Flows: arXiv:1906.04032 ★ arXiv:1802.04908v1 ★ DOI: 10.1109/TPAMI.2020.2992934
Waveform systematics: Phys. Rev. D 104, 124027 ★ arXiv:1908.11170v3 ★ Phys. Rev. D 78, 124020