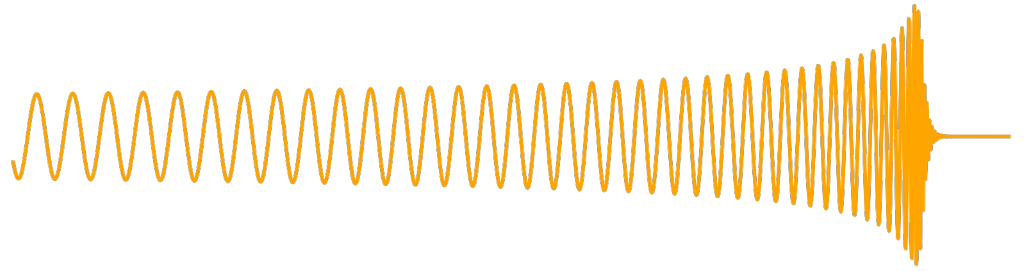
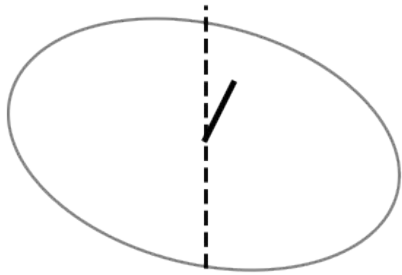

A precessing template bank

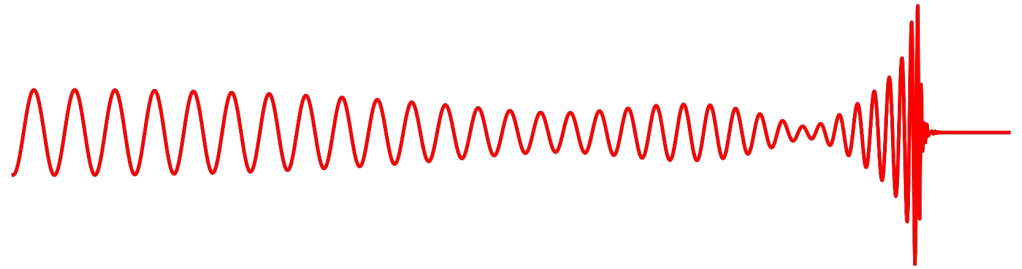
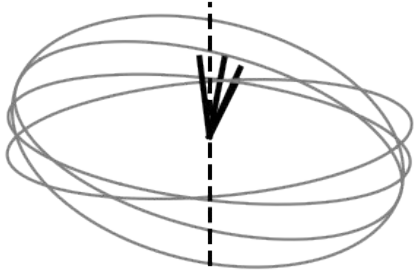
Stefano Schmidt

Belgian-Dutch Gravitational Wave Meeting 2023

A binary system



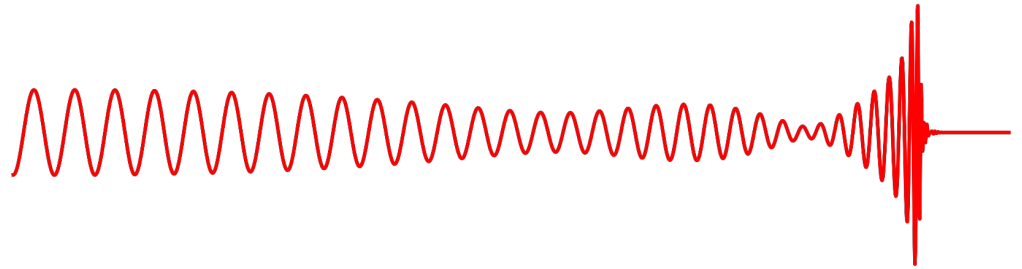
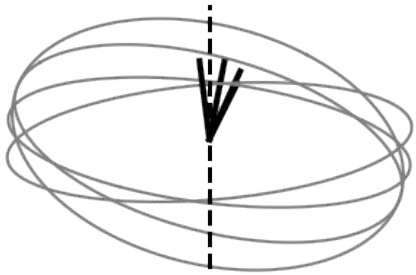
A binary system*



***(with precession)**

A binary system*

Mis-aligned spins



*(with precession)

Why precession?

Good measure of:

- Inclination
- Distance
- Spins

Why precession?

Good measure of:

- Inclination
- Distance
- Spins

Cosmology

- Break distance-inclination degeneracy

Theory

- Test of GR
- Multidimensional gravity?

Astronomy

- Characterize spin population
- BBH formation channels

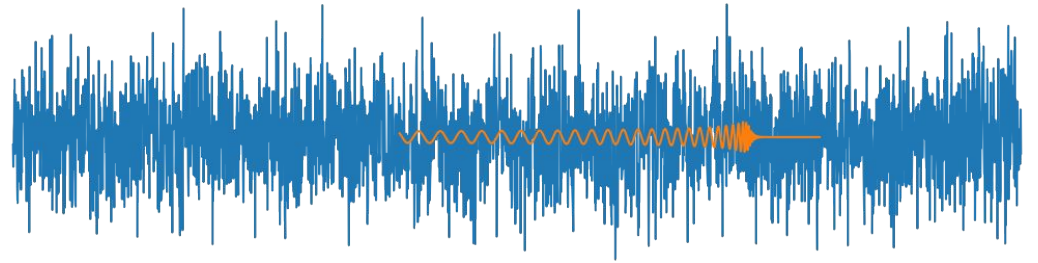
Do you want to search for precession?

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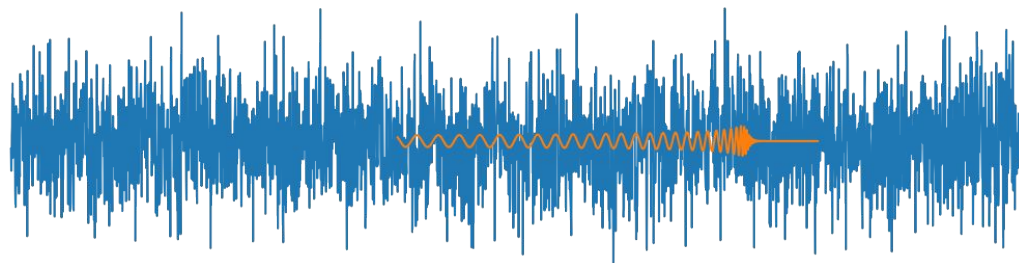
YES!!

But... It's hard!

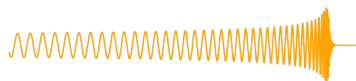
But... It's hard!



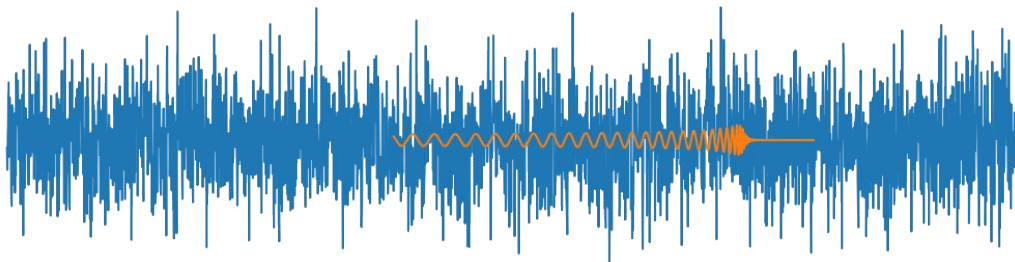
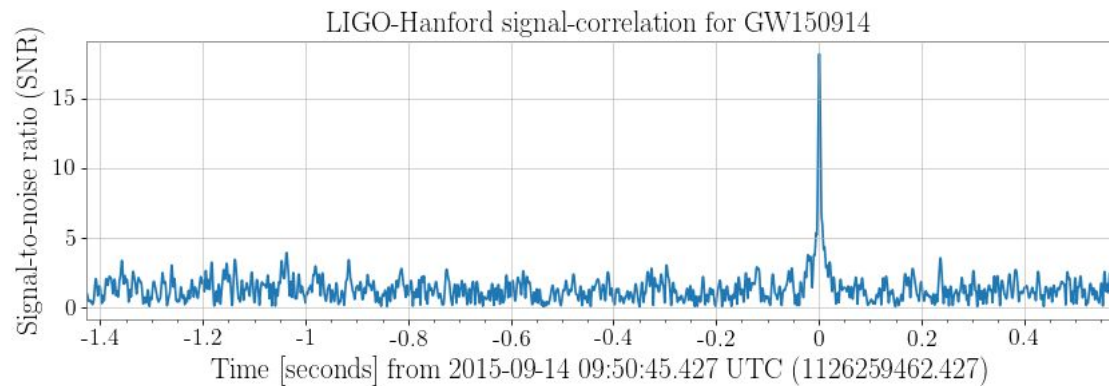
But... It's hard!



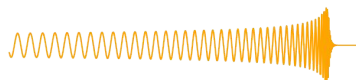
Template



But... It's hard!



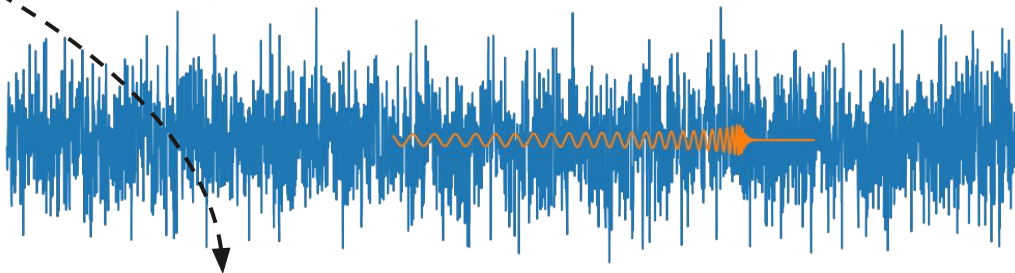
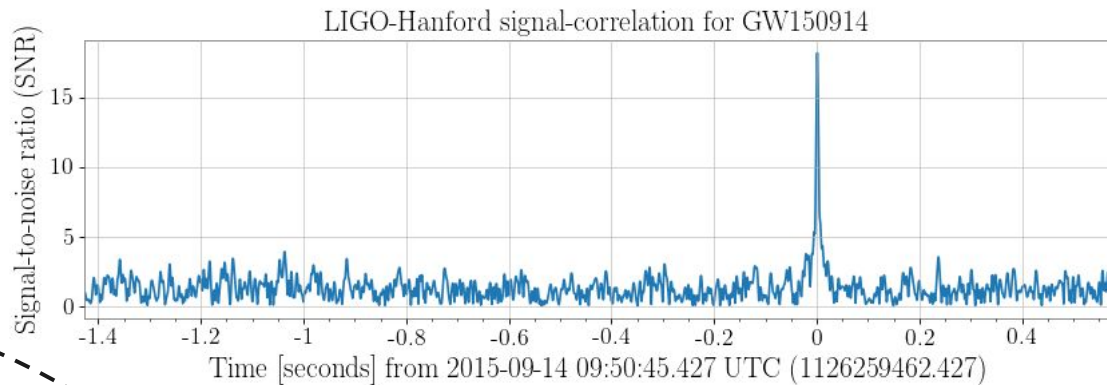
Template



But... It's hard!



Template bank



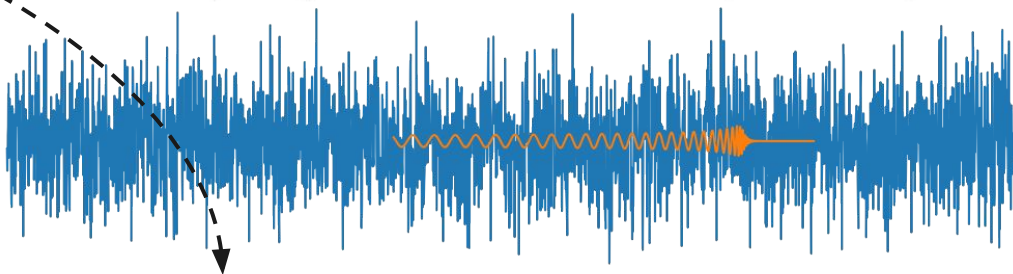
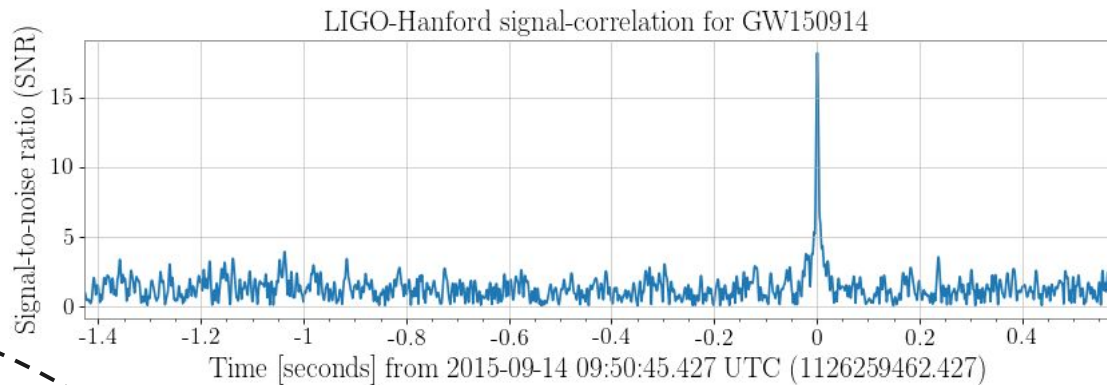
Template



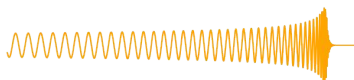
But... It's hard!



Template bank



Template



Let's make a precessing bank (part I)

$$d_M^2(\theta_1, \theta_2) := M_{ij}(\theta) \Delta\theta_i \Delta\theta_j$$

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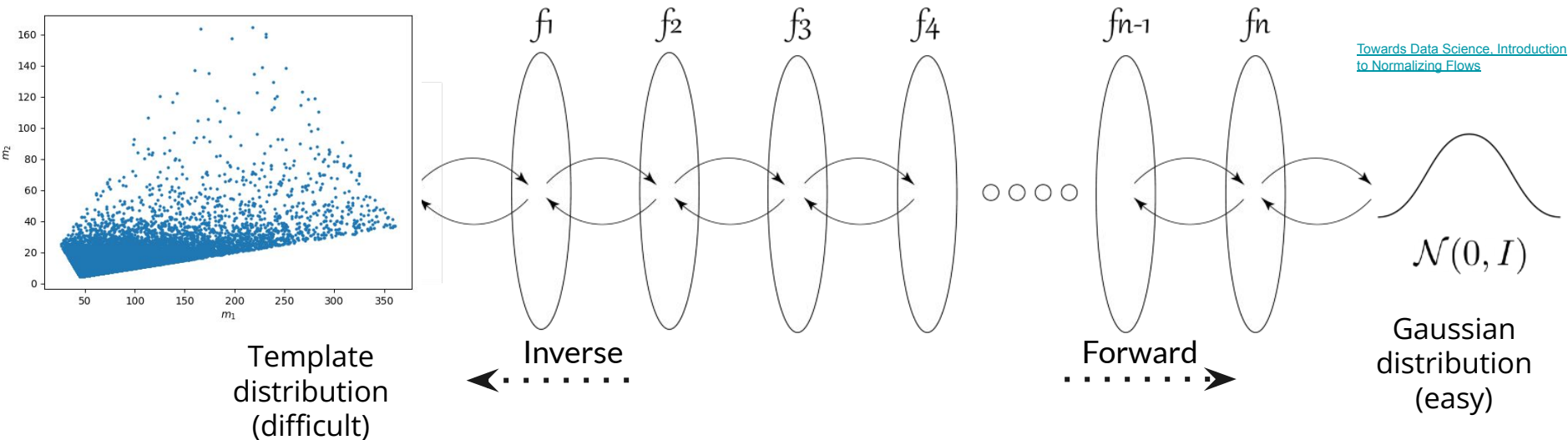
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$$d_M^2(\theta_1, \theta_2) := \underbrace{M_{ij}(\theta)}_{\text{THE metric}} \Delta\theta_i \Delta\theta_j$$

$$p(\theta) \propto \sqrt{|\det M(\theta)|}$$

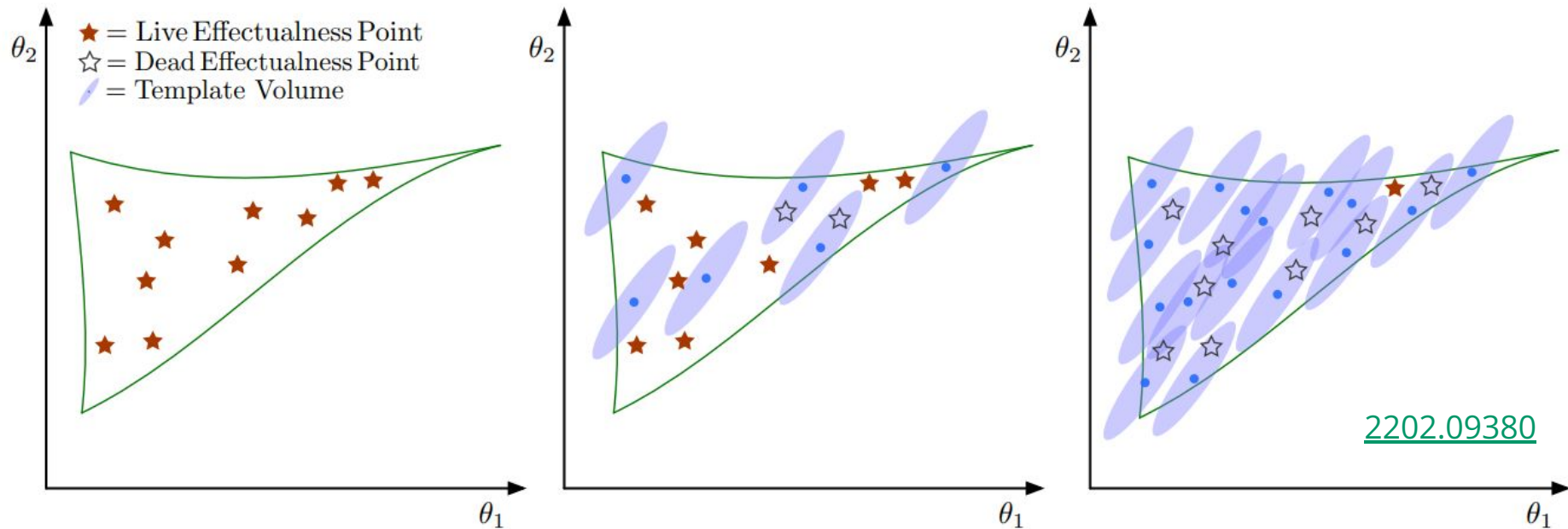
Let's make a preprocessing bank (part II)

Sampling from the volume with Normalizing Flow

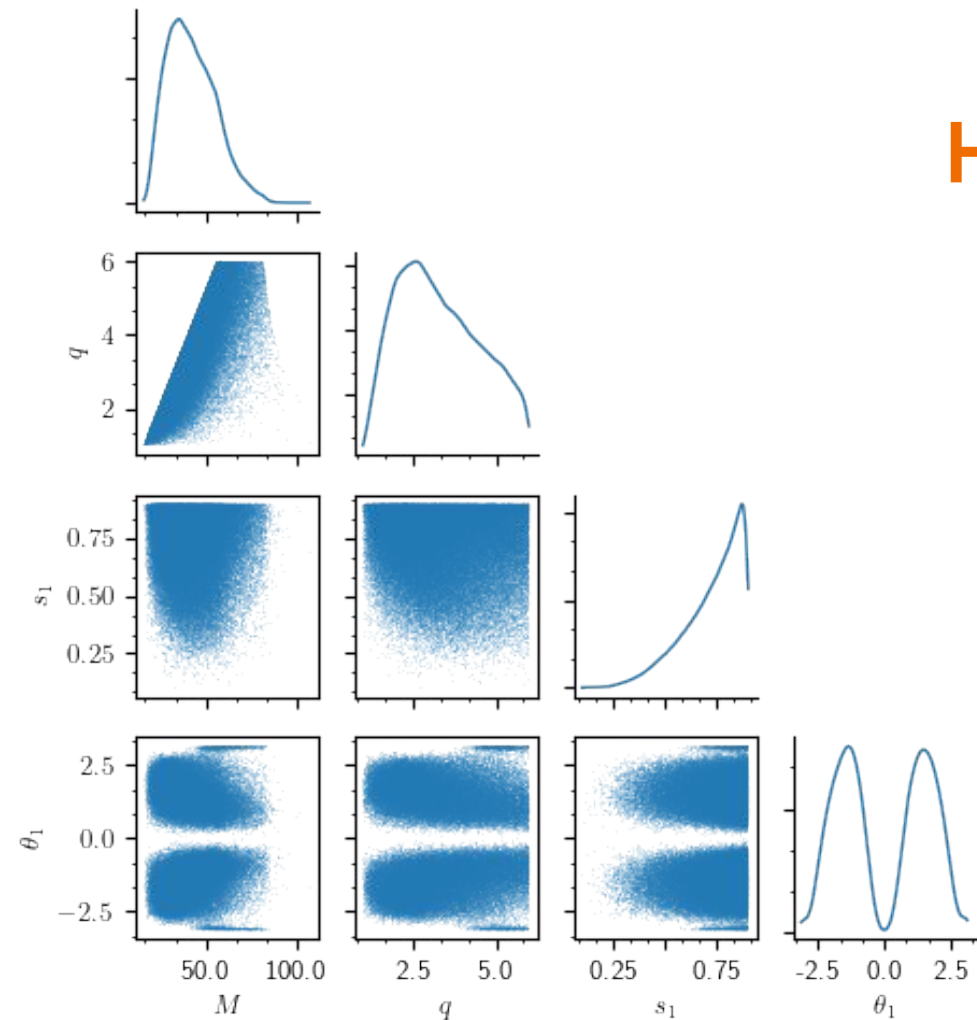


Let's make a preprocessing bank (part III)

When to stop?



How does the bank look like?



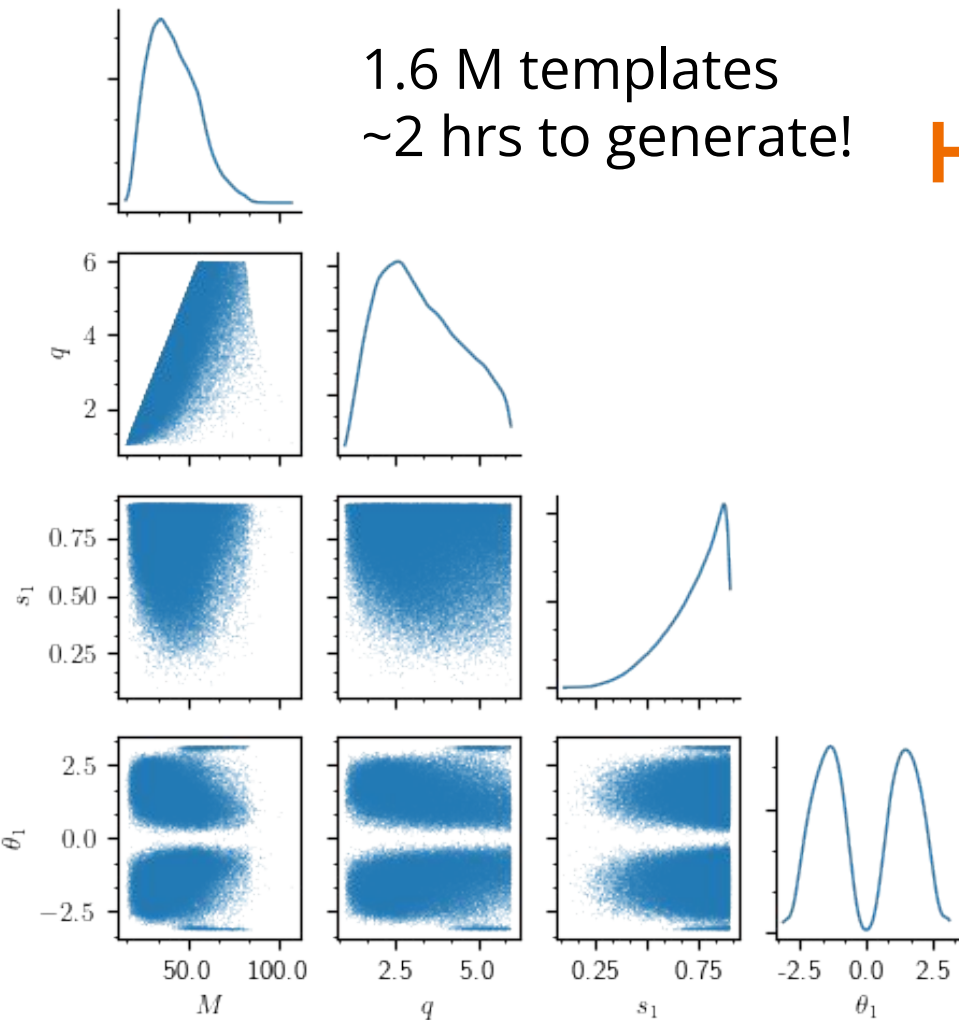
Parameter space

$$\begin{aligned} m_1, m_2 &\in [8, 70] M_{\odot} \\ q &\in [1, 6] \\ s_1 &\in [0, 0.99] \\ \theta_1 &\in [-\pi, \pi] \\ s_2 &\in [-0.99, 0.99] \\ \iota &\in [0, \pi] \end{aligned}$$

$$\begin{aligned} s_{1x} &= s_1 \sin(\theta_1) \\ s_{1y} &= 0 \\ s_{1z} &= s_1 \cos(\theta_1) \end{aligned}$$

1.6 M templates
~2 hrs to generate!

How does the bank look like?

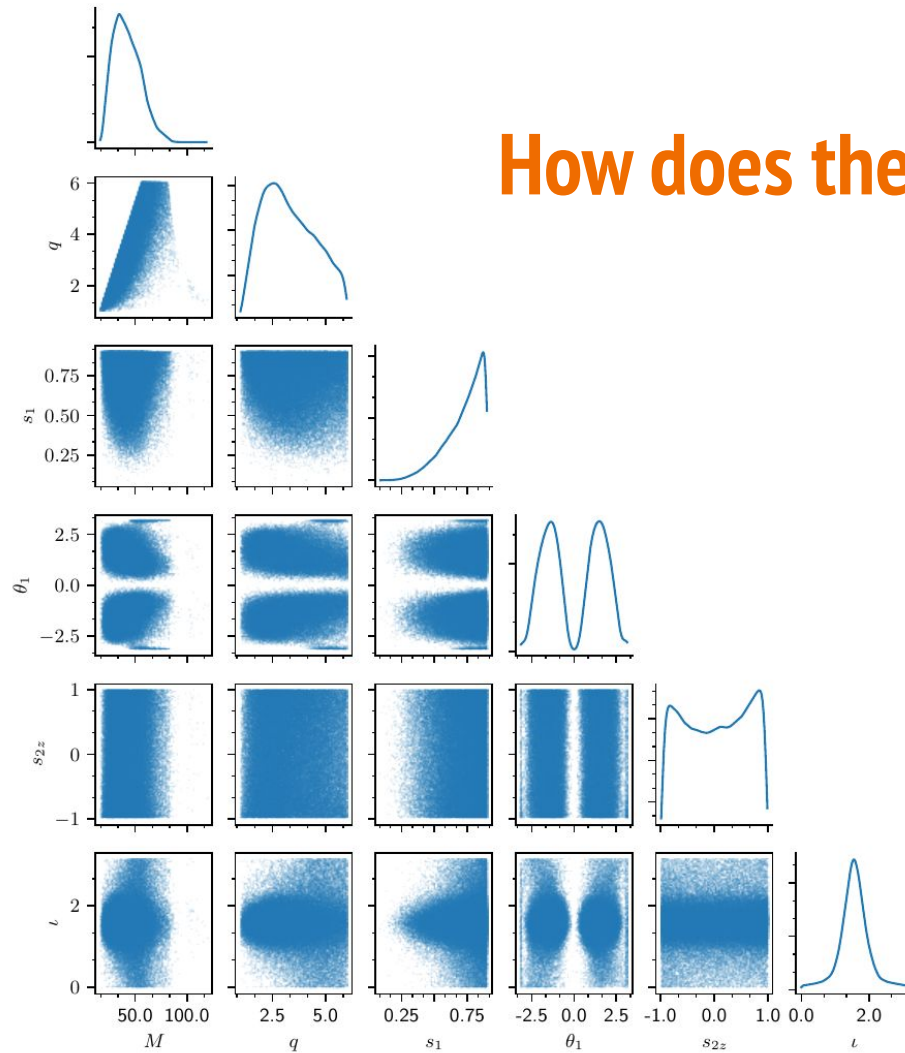


Parameter space

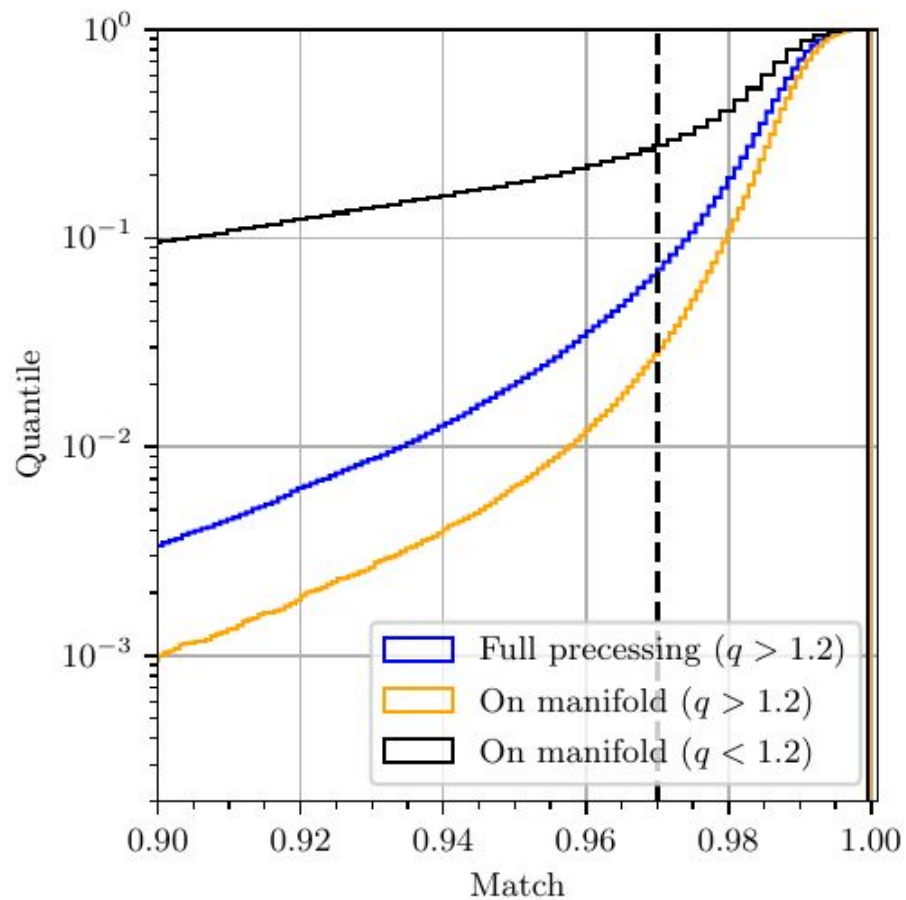
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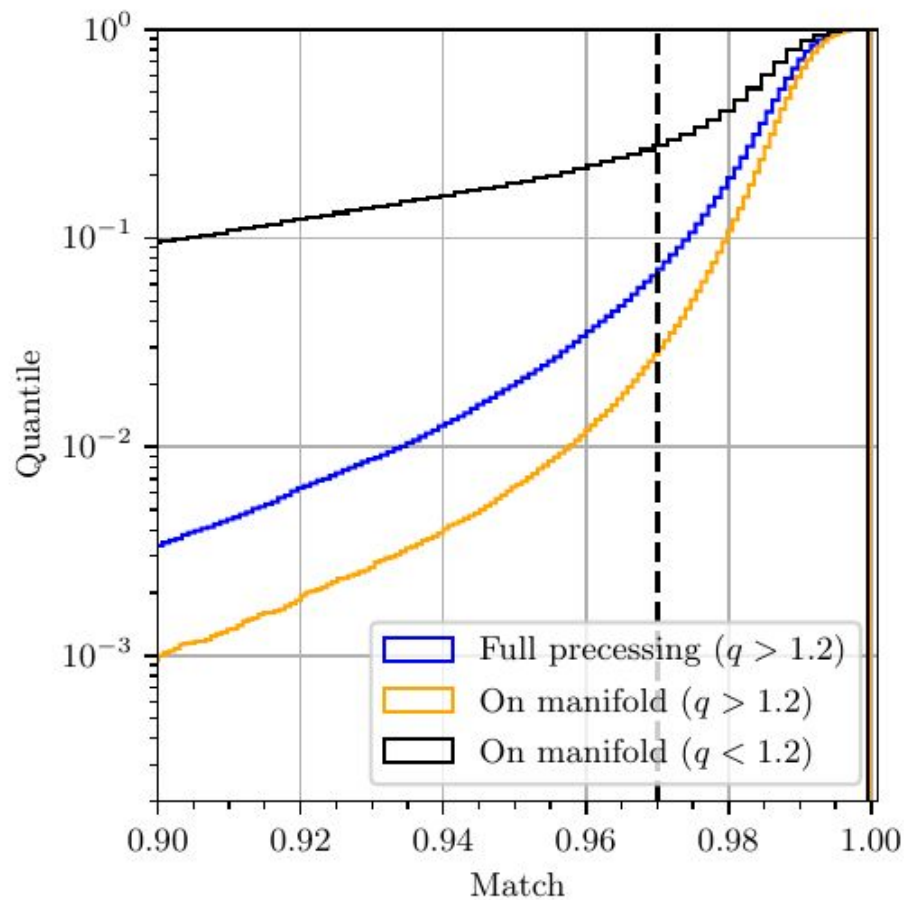
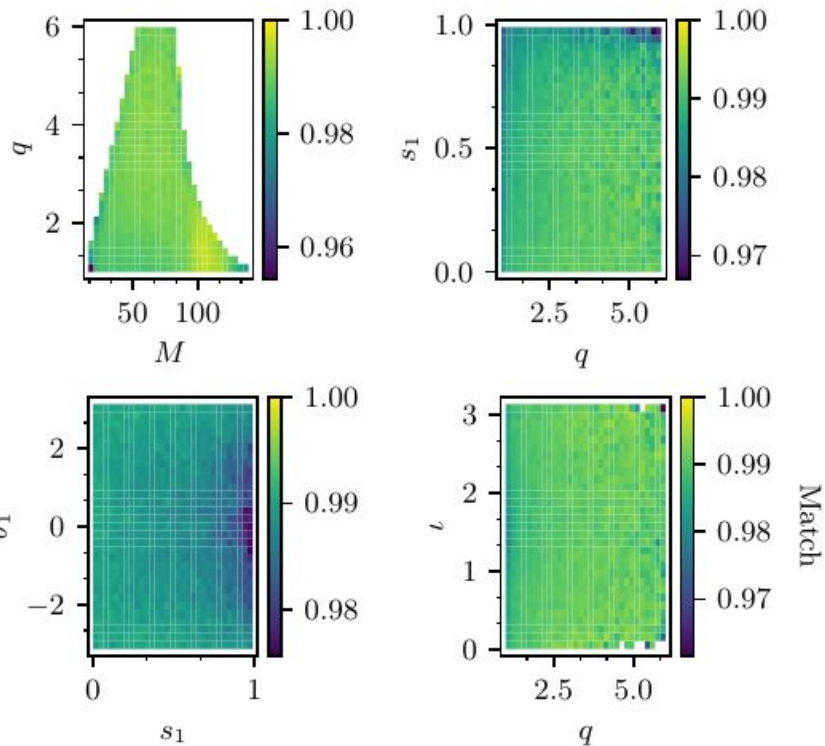
How does the bank look like?



Does it work?



Does it work?



mbank

Two innovations:

1. New metric expression (suitable for precession)
2. Normalizing flow for sampling

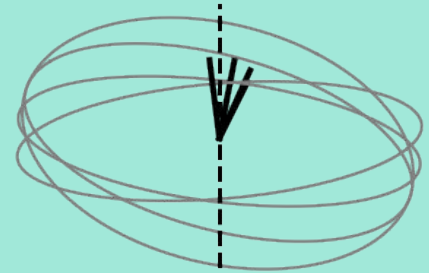
Suitable for high dimensions (HMs, eccentricity, ...)

```
pip install gw-mbank
```

[2302.00436](#)

<https://github.com/stefanoschmidt1995/mbank/>

We are ready to
search for precession



Looking forward to it!

Training the flow

$$\begin{aligned}\mathcal{L}_\phi(W) &= \frac{1}{N} \sum_{i=1}^N (\log p_W^{\text{flow}}(\theta_i) - \log p^{\text{target}}(\theta_i))^2 \\ &= \frac{1}{N} \sum_{i=1}^N \left(\log p_W^{\text{flow}}(\theta_i) - \log \sqrt{|M(\theta_i)|} + C \right)^2\end{aligned}$$