



Metric template placement for exotic BBH regions

Stefano Schmidt, Bhooshan Gadre and Sarah Caudill

Lunteren

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**Utrecht
University**

Nik|hef

Intro

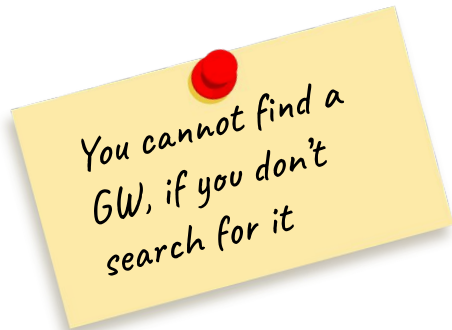
What and why?



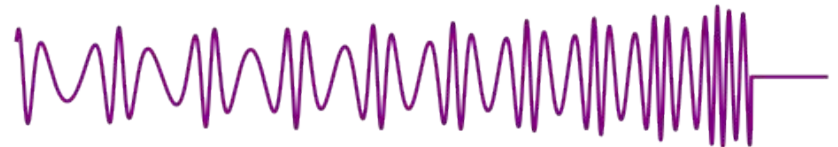
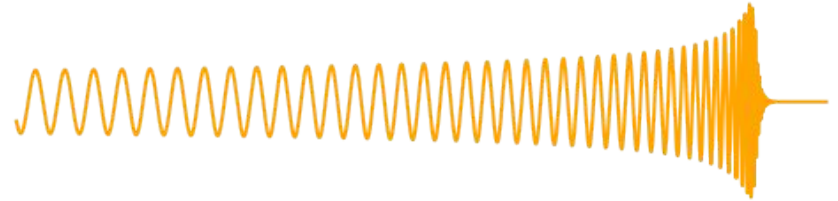
Do you want to detect more GWs?

Want to learn about

- BBH formation channels?
- Cosmology?
- Fundamental physics?
- ...



You cannot find a GW, if you don't search for it



How we detect a GW signal?

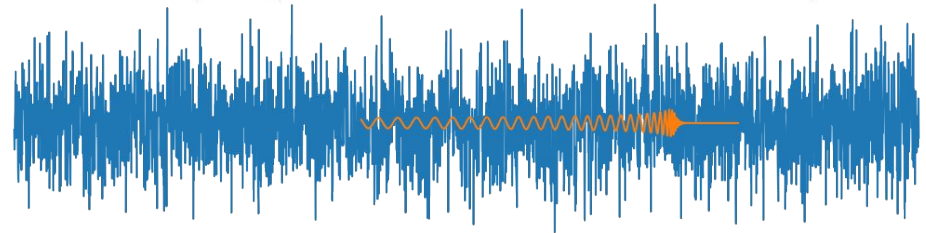
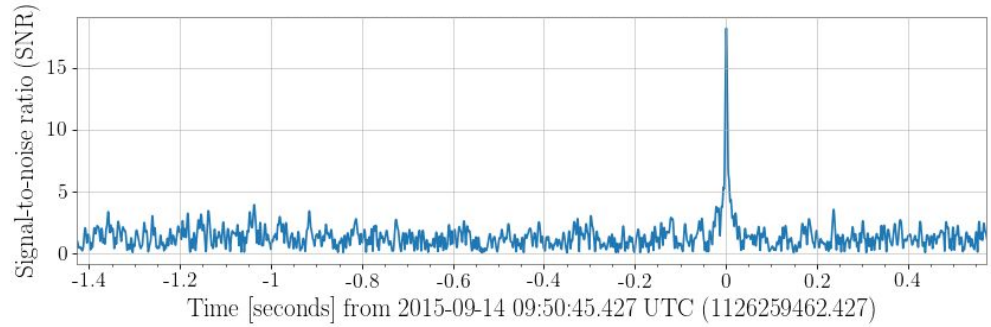
Matched filtering

Our problem

Takes months to prepare 🤯



Template





mbank



Code for template bank generation

- Metric approximation to the match
- **Super fast**
- Nice accuracy
- *Suitable for preprocessing and/or eccentric banks*

Take a look at the docs! mbank.readthedocs.io/en/latest/

Some details

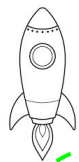
How does mbank work?

(metric) bank generation



$$d^2(\theta_1, \theta_2) = 1 - \mathcal{M}(\theta_1, \theta_2)$$

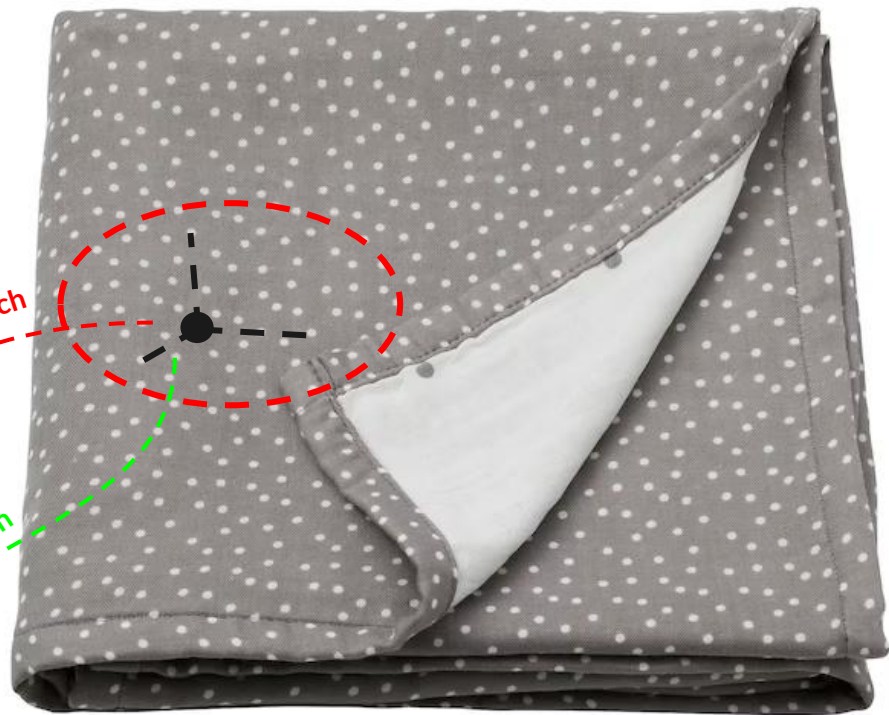
$$\mathcal{M}(\theta_1, \theta_2) = \max_t \left| \int_{f_{\min}}^{f_{\max}} df \frac{\tilde{h}^*(f; \theta_1) \tilde{h}(f; \theta_2) e^{i2\pi ft}}{S_n(f)} \right|^2$$



$$d^2(\theta_1, \theta_2) = (M(\theta)_{ij}) \Delta\theta_i \Delta\theta_j$$

Standard approach

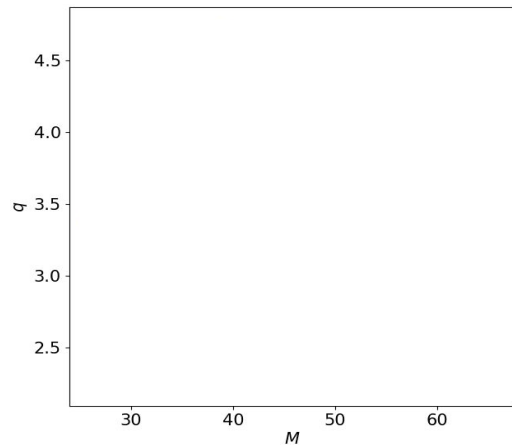
Metric approach



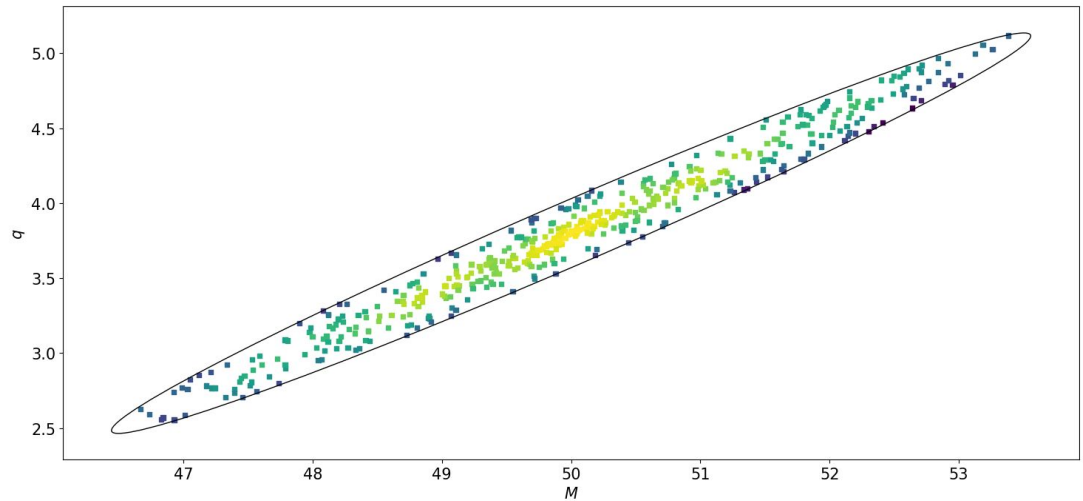


Recipe to generate a bank

Step 0: choose the space



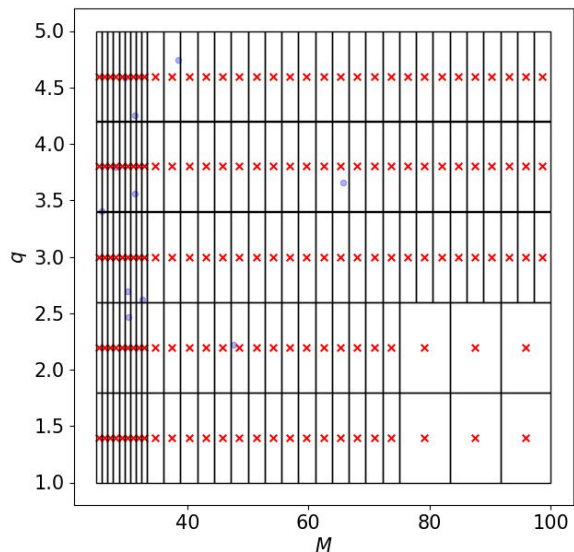
Step 1: set up the metric



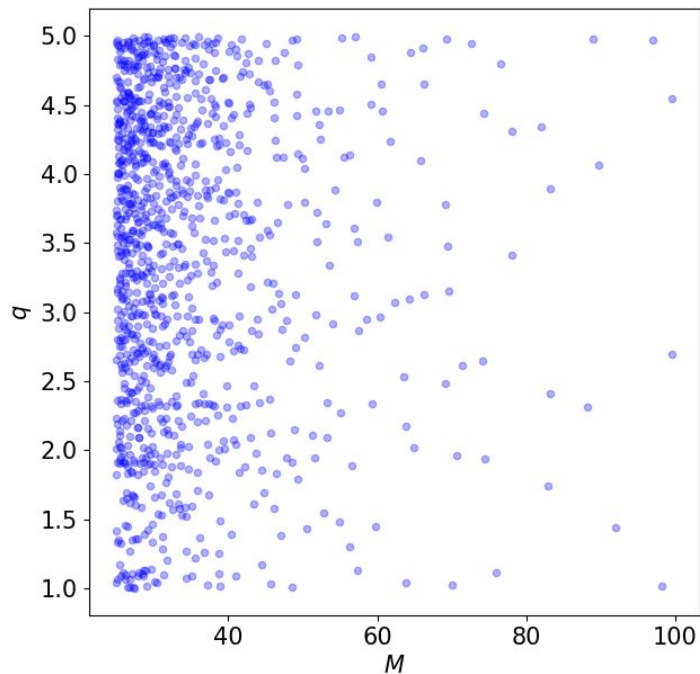


Recipe to generate a bank

Step 2: tile the space

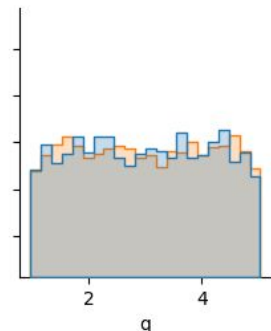
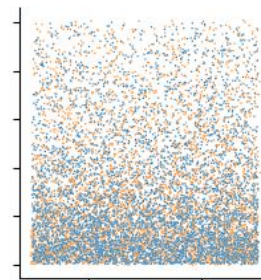
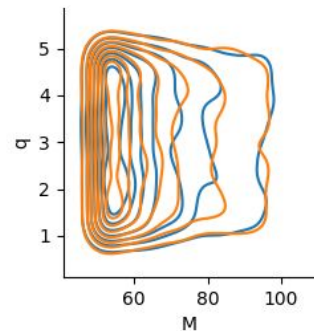
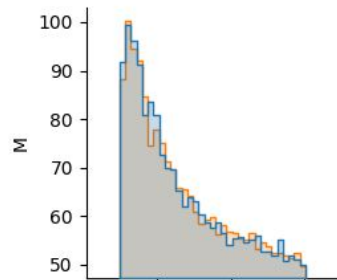
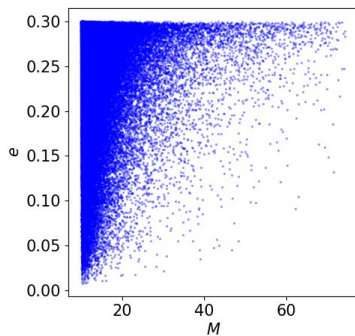
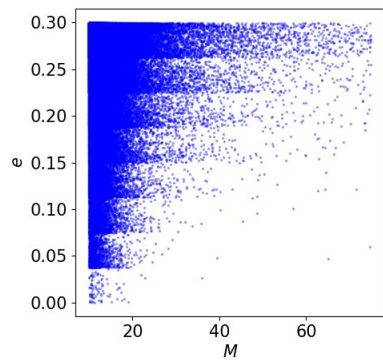


Step 3: place the templates



Recipe to generate a bank (optional)

Step 2-bis: *normalizing flow model*



distribution
— tiling
— flow

Results

What we used mbank for?

Sorry if we're
getting too
technical :(

Exotic banks

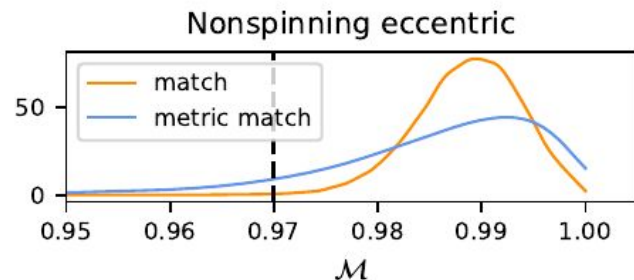
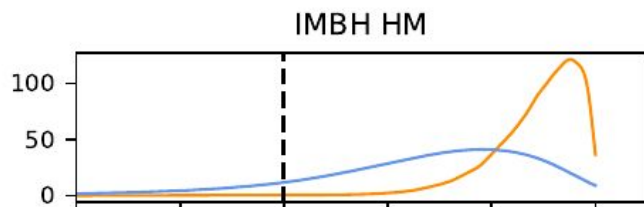
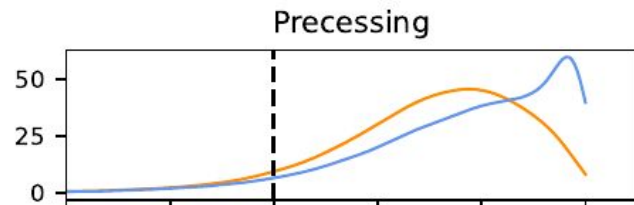
Minimum match: 0.97

No flow is used here

	Ranges	Settings	Size	
			$N_{\text{templates}}$	N_{tiles}
Precessing	$M \in [25, 100] M_{\odot}$ $q \in [1, 5]$ $s_1 \in [0, 0.99]$ $\theta_1 \in [0, \pi]$ $f \in [15, 1024] \text{Hz}$	IMRPhenomPv2 $\epsilon = 0.1$ max-depth: 10 $N_{\text{max}} = 100$	45265	33774
IMBH HM	$M \in [50, 600] M_{\odot}$ $q \in [1, 5]$ $\chi \in [0, 0.99]$ $f \in [10, 1024] \text{Hz}$	IMRPhenomXPHM $\epsilon = 0.2$ max-depth: 8 $N_{\text{max}} = 100$	168010	33792
Nonspinning eccentric	$M \in [10, 75] M_{\odot}$ $q \in [1, 5]$ $e \in [0, 0.3]$ $f \in [15, 1024] \text{Hz}$	EccentricFD $\epsilon = 0.1$ max-depth: 9 $N_{\text{max}} = 100$	115748	4238

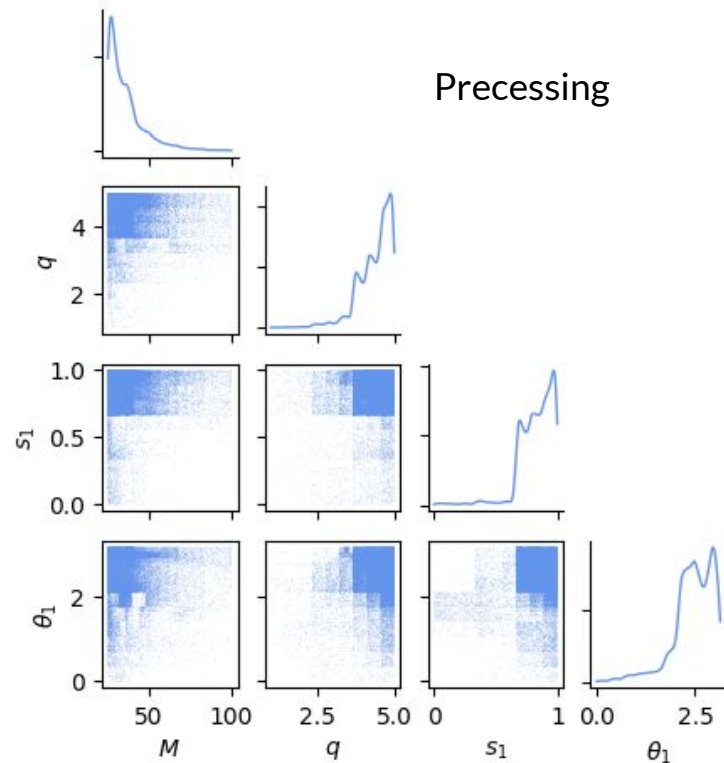
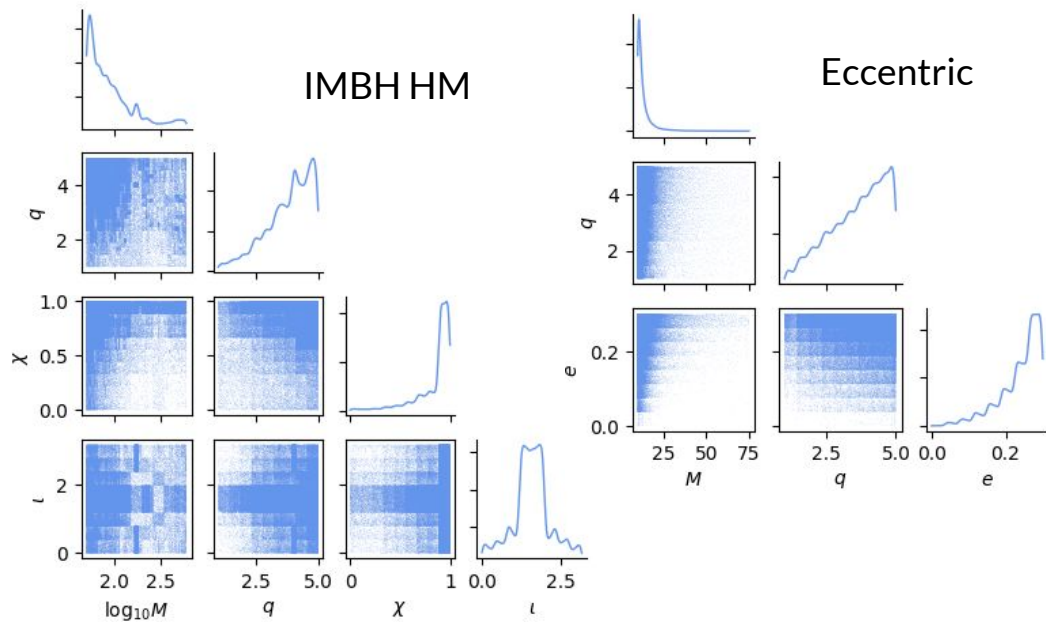
Intermediate Mass BH ($M_{\text{tot}} > 50 M_{\odot}$) with Higher Order Modes

$$\mathcal{M}(h_1, h_2) = 1 - \frac{(h_1|h_2)}{\sqrt{(h_1|h_1)(h_2|h_2)}} \quad (h_1|h_2) = \Re \int df \frac{\tilde{h}_1^* \tilde{h}_2}{S_n}$$



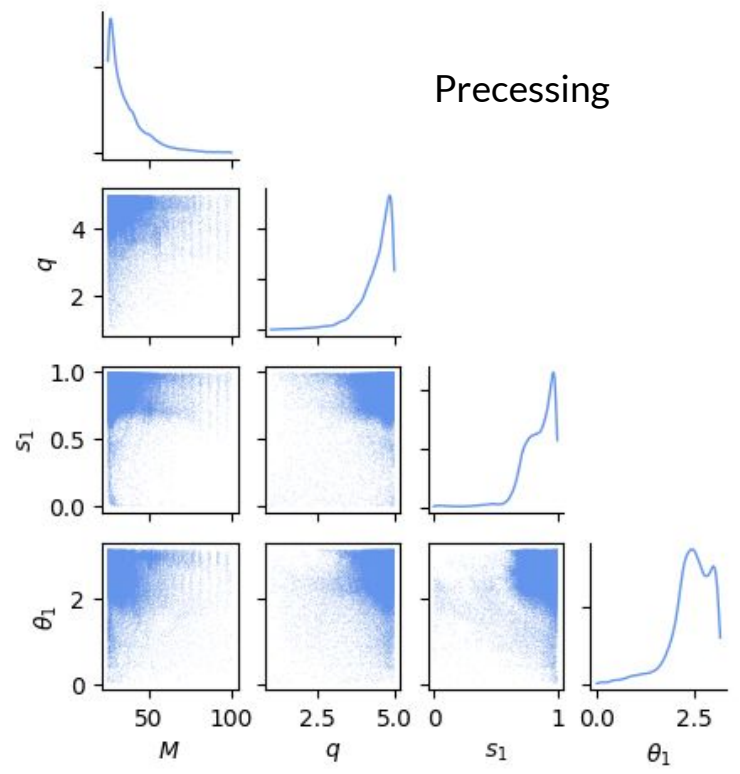
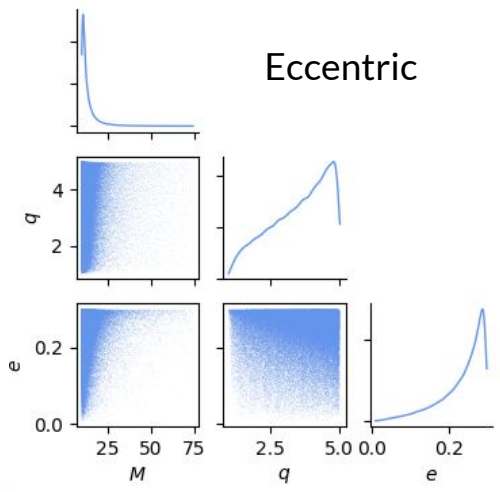
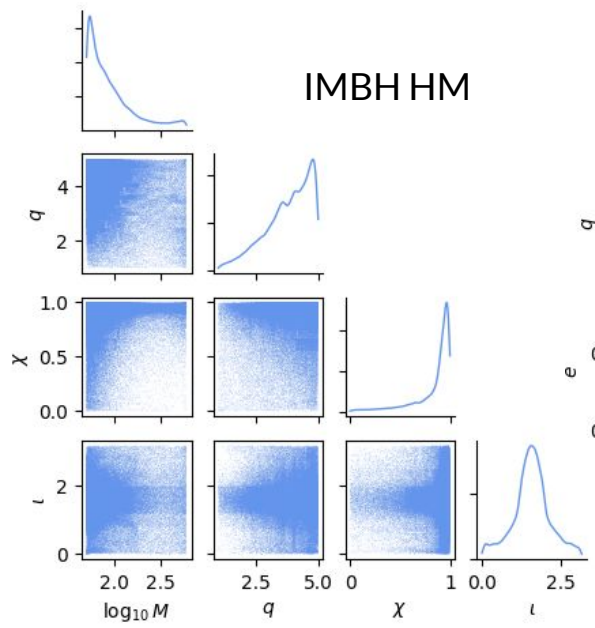
Let's look at the banks!

Without flow





Let's look at the banks! With flow



To wrap up

What's next?



Farewell



`mbank`: code for metric template placement in high dimensional BBH parameter space

What's next?

- Precessing bank
- Eccentric bank
- Your favourite bank?

Improvements:

- Explore Machine Learning to represent the metric
- Can we approximate distances with a neural network?

Exciting!

Thank you!

To get started:

- ~ `pip install gw-mbank`
- ~ Download ini file: [my_first_eccentric_bank.ini](#)
- ~ `mbank_run my_first_eccentric_bank.ini`
- ~ `mbank_injections my_first_eccentric_bank.ini`

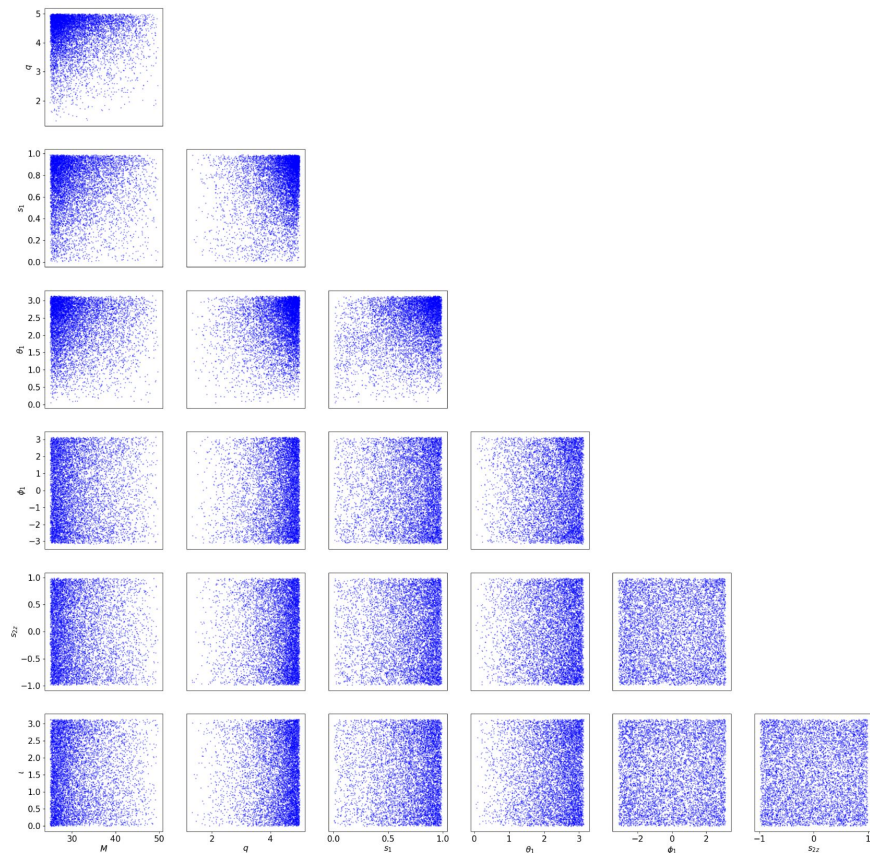
Backup



Why another template placement code?

Don't we have enough of them?

- High dimensions = too expensive!
- No preprocessing or eccentric bank available
- No code for volume estimation

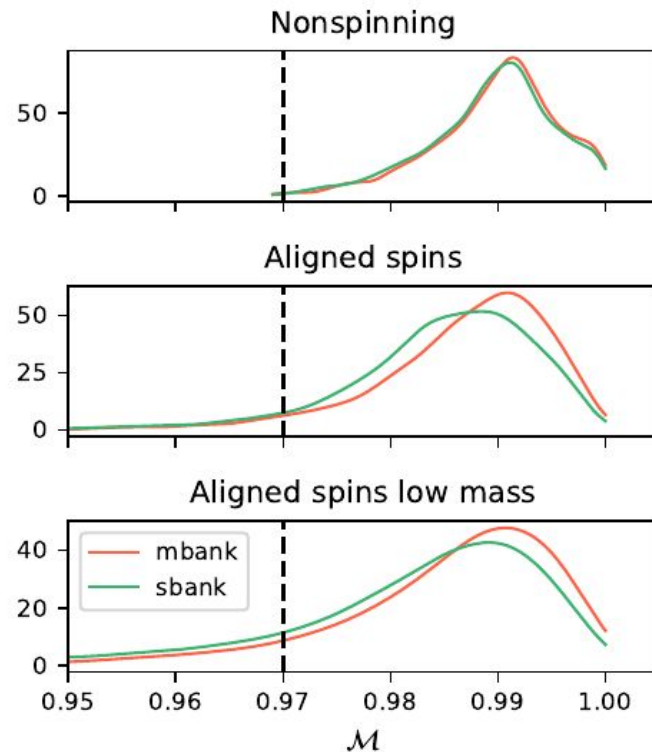


Comparison with sbank

Minimum match: 0.97

	Ranges	Size		Time	
		sbank	mbank	sbank	mbank
Nonspinning	$M \in [30, 50] M_{\odot}$ $q \in [1, 5]$	396	442	$O(\text{hours})$	$O(\text{seconds})$
Aligned spin	$M \in [30, 50]$ $q \in [1, 5]$ $s_{1z}, s_{2z} \in [-0.99, 0.99]$	3275	4108	$O(\text{days})$	$O(\text{minutes})$
Aligned spin low mass	$M \in [10, 30]$ $q \in [1, 5]$ $s_{1z}, s_{2z} \in [-0.99, 0.99]$	62009	80524	$O(\text{months})$	$O(\text{hours})$

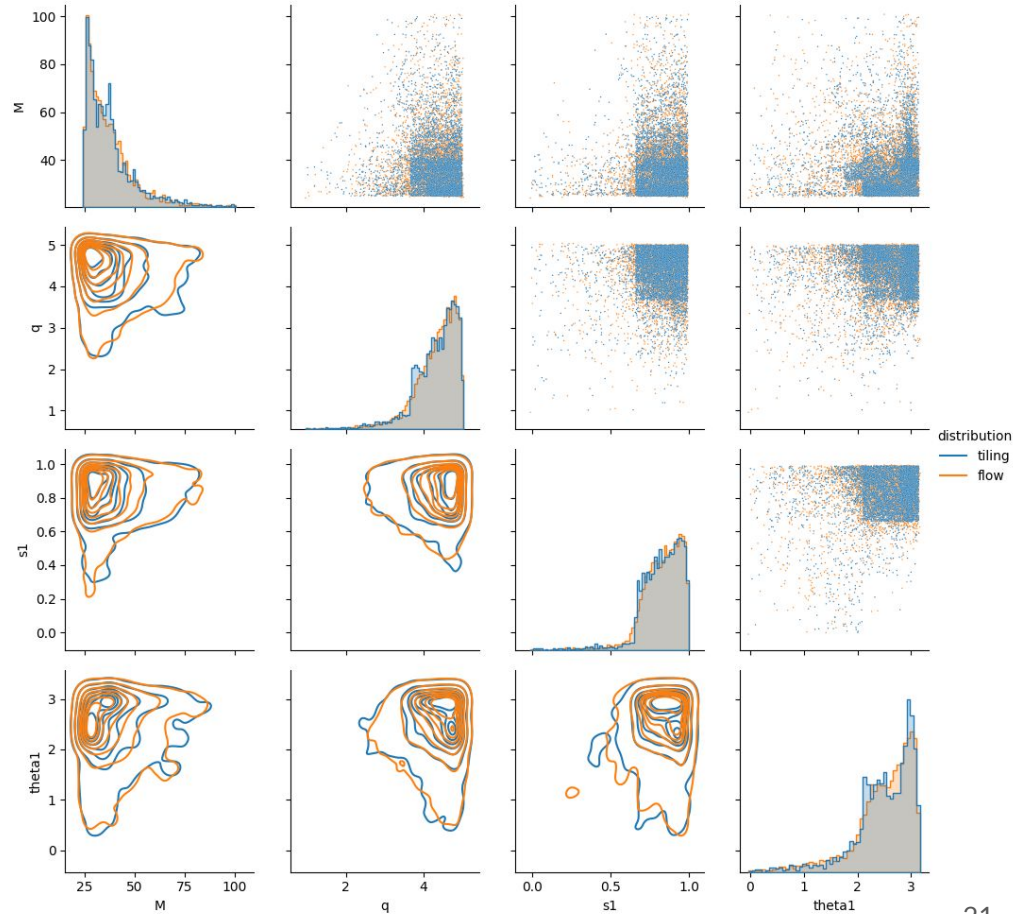
mbank overcovers the space by 20%





The trained flows

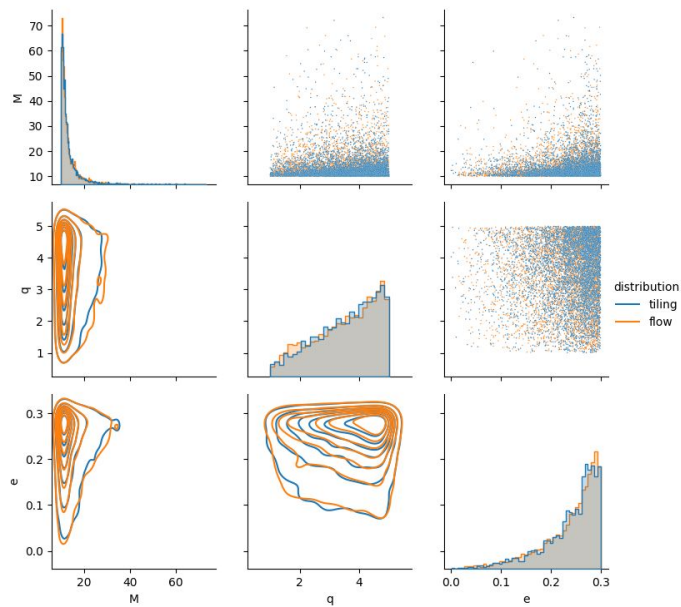
- Training samples drawn from the tiling
- Layers of *Masked Autoregressive flow* + *Linear transformation*
- Training with KL divergence





The trained flows

Eccentric bank



HM bank

