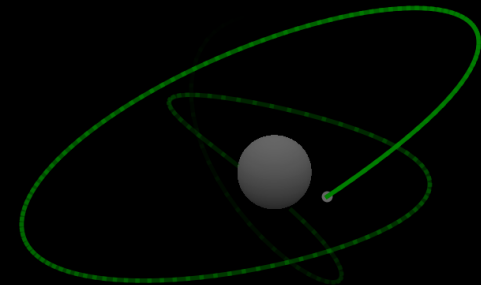
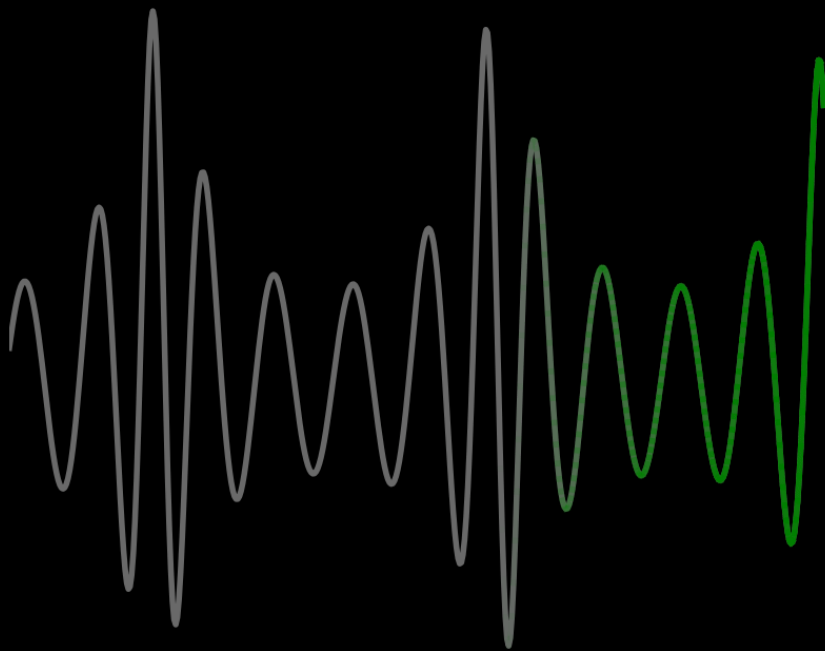


Single-harmonic search for extreme mass-ratio inspirals

Lorenzo Speri

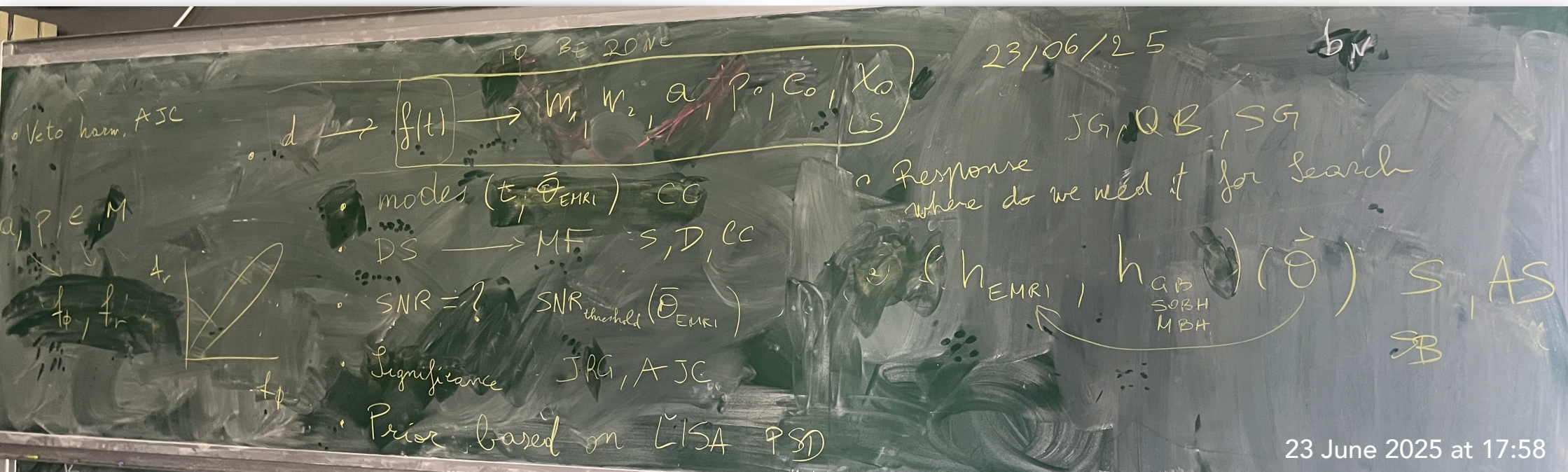
 Research Fellow (ESTEC the Netherlands)



EMRI Search and Inference within the LISA Global Fit - Part II

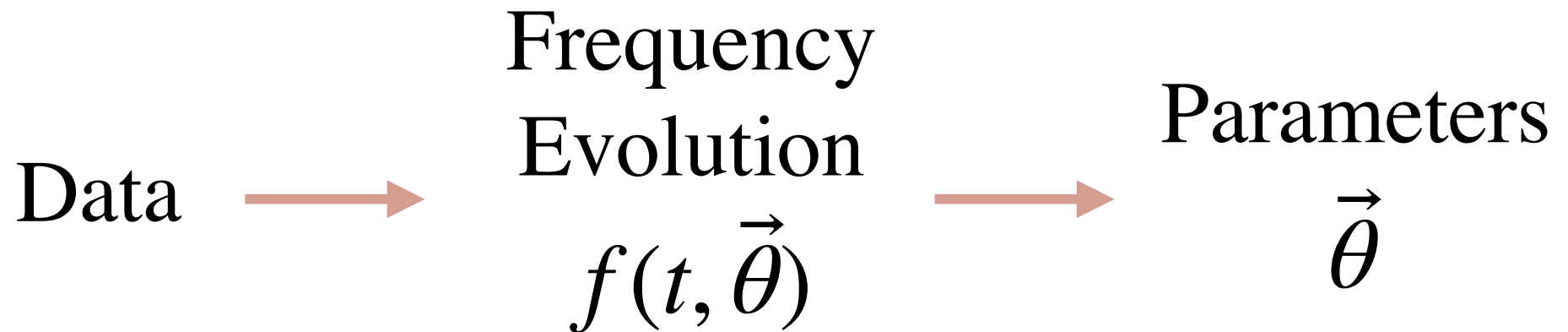
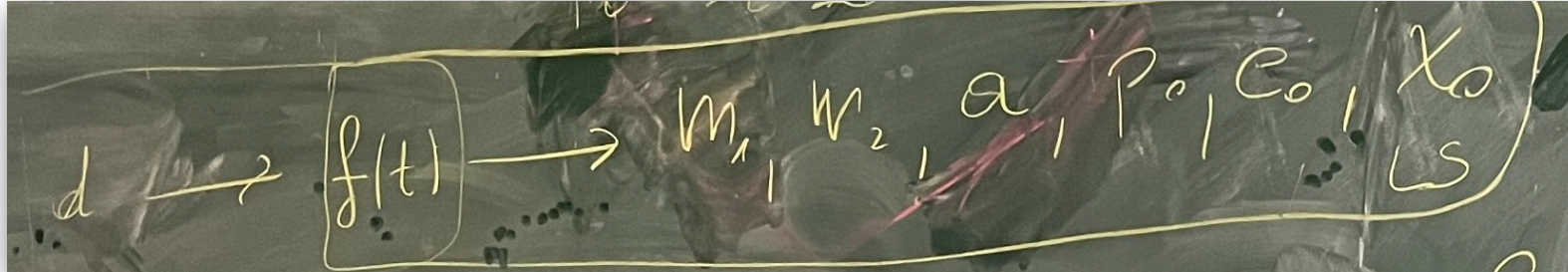
16 July, 2026

Discussion from previous workshop Part I



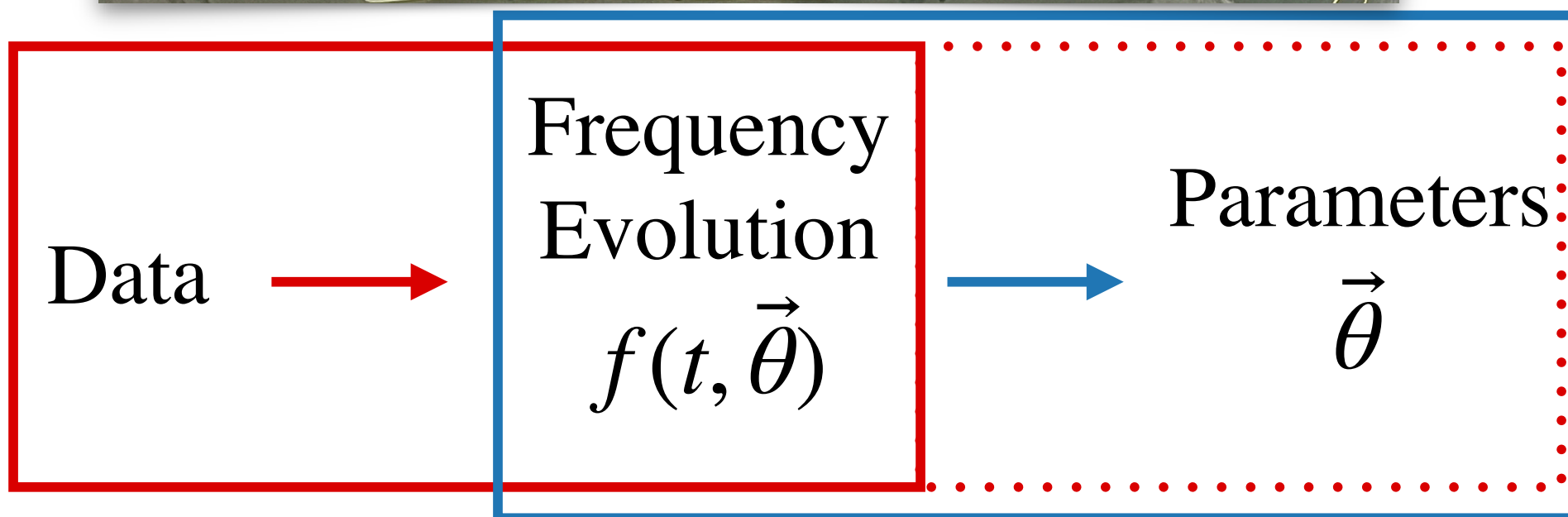
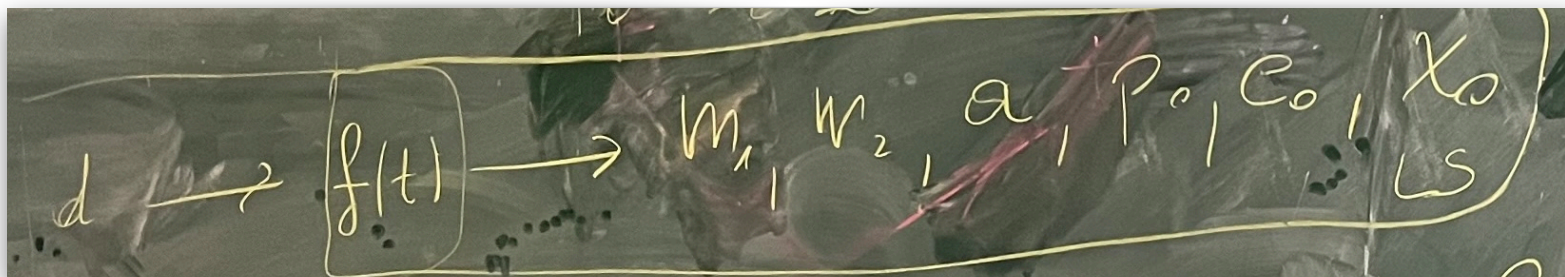
23 June 2025 at 17:58

Discussion from previous workshop Part I



Phys. Rev. D 113, 024061
Speri, Tenorio, Chapman-Bird, Gerosa

Discussion from previous workshop Part I



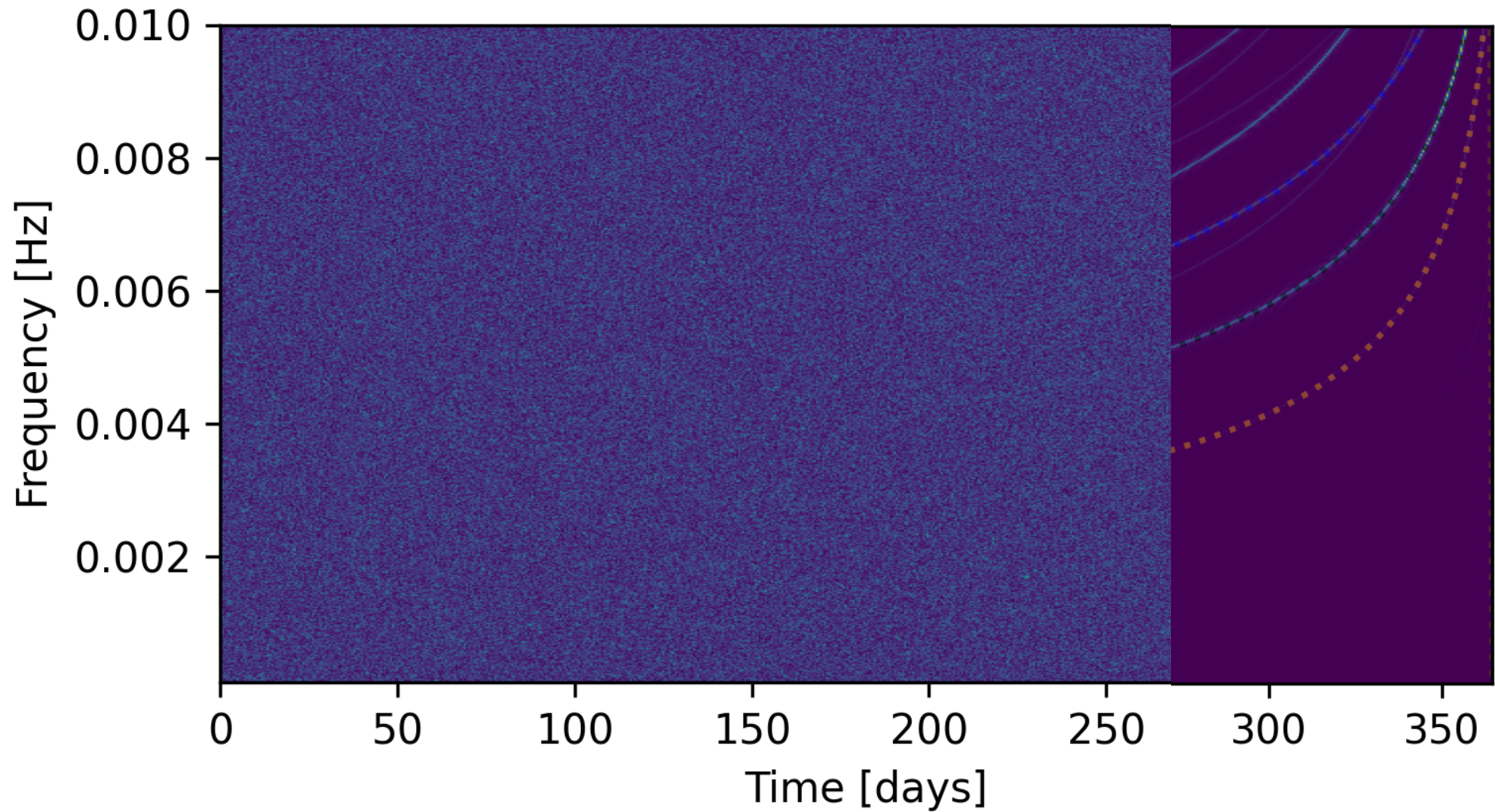
Today's talk

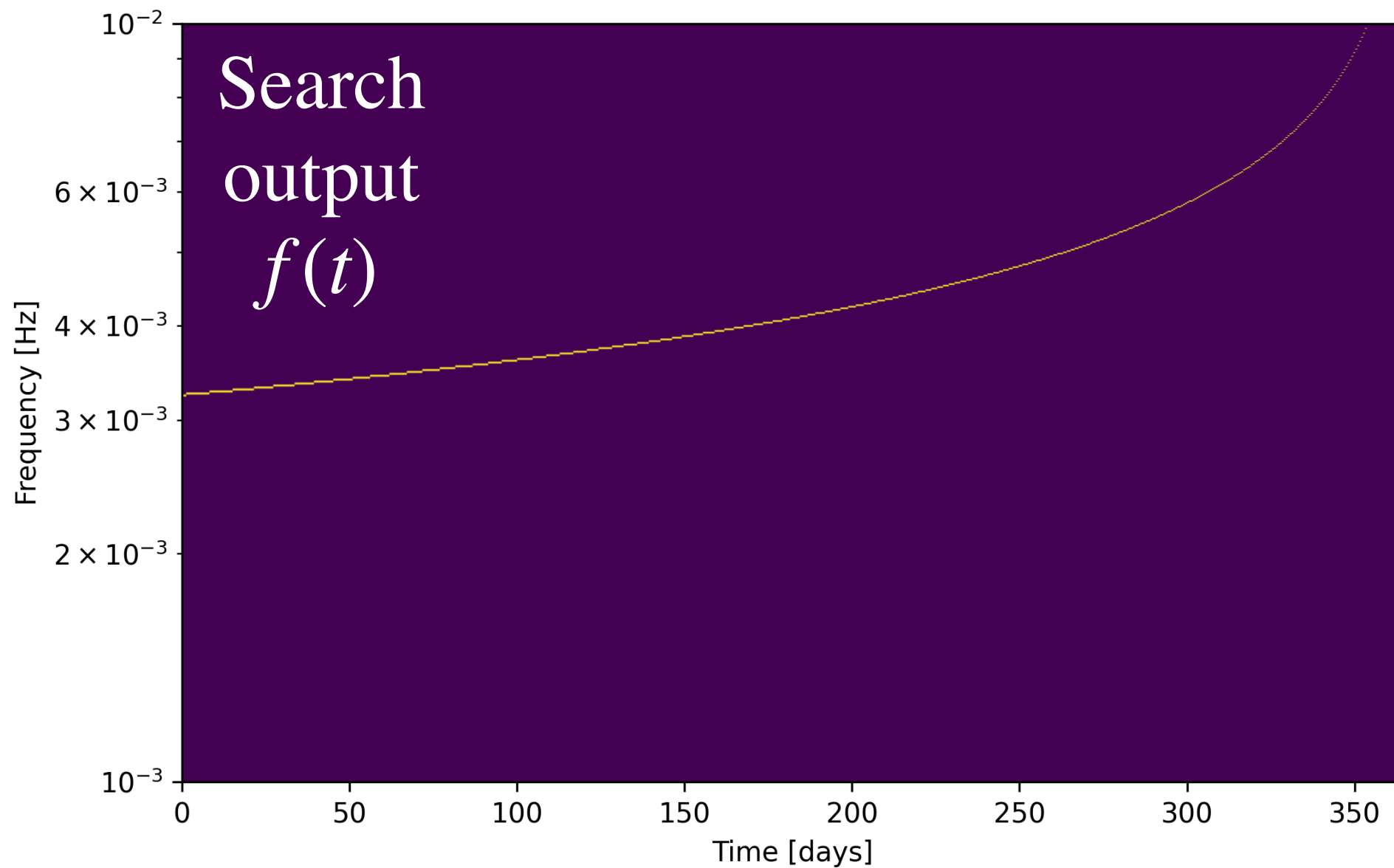
Speri+2026PRD

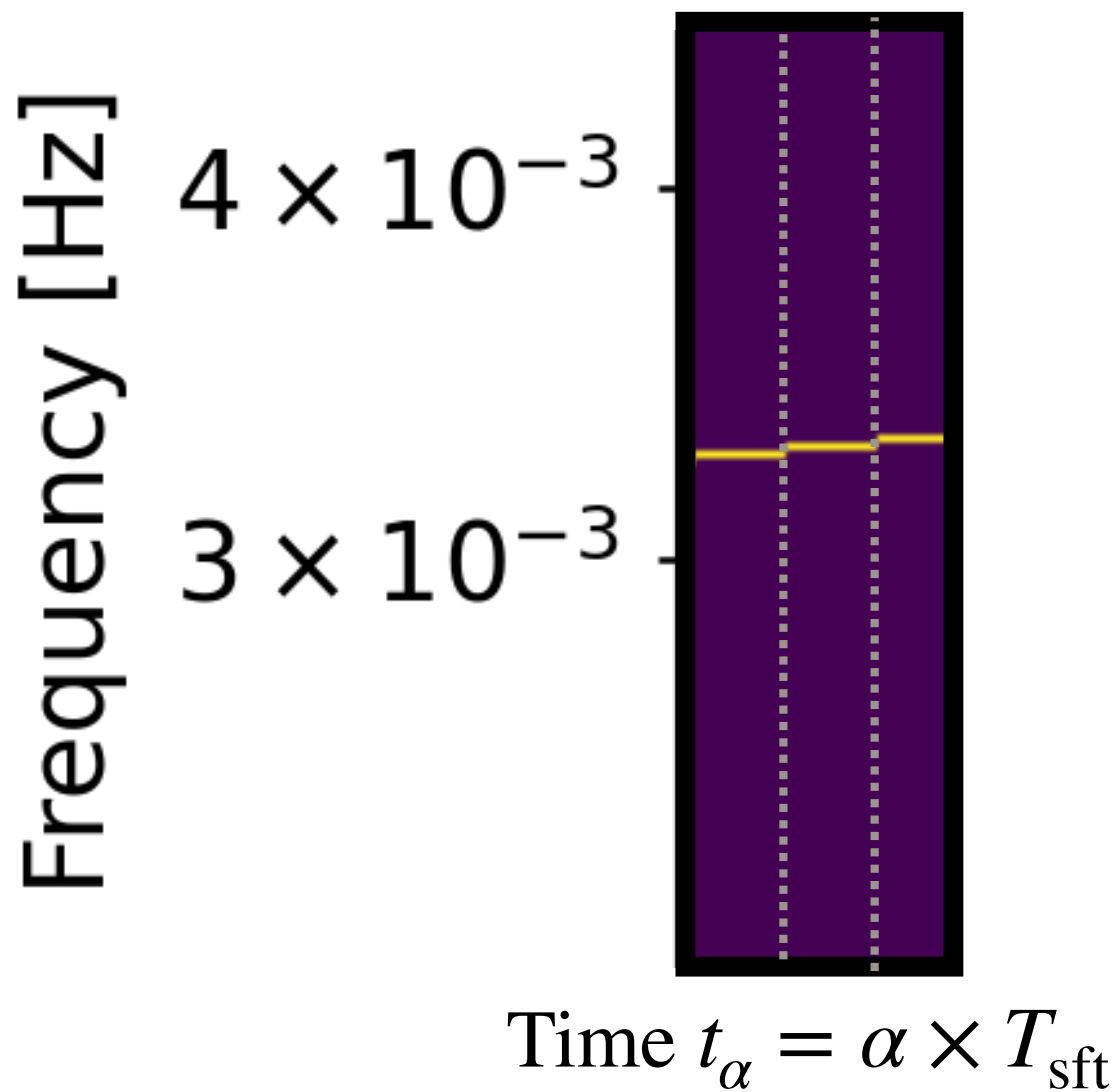
Fantoccoli in prep.

Wang, Shang, Babak 2012

$$\text{Data} = \text{Noise} + \text{Signal}$$







Physical
parameters

$$\vec{\theta}$$



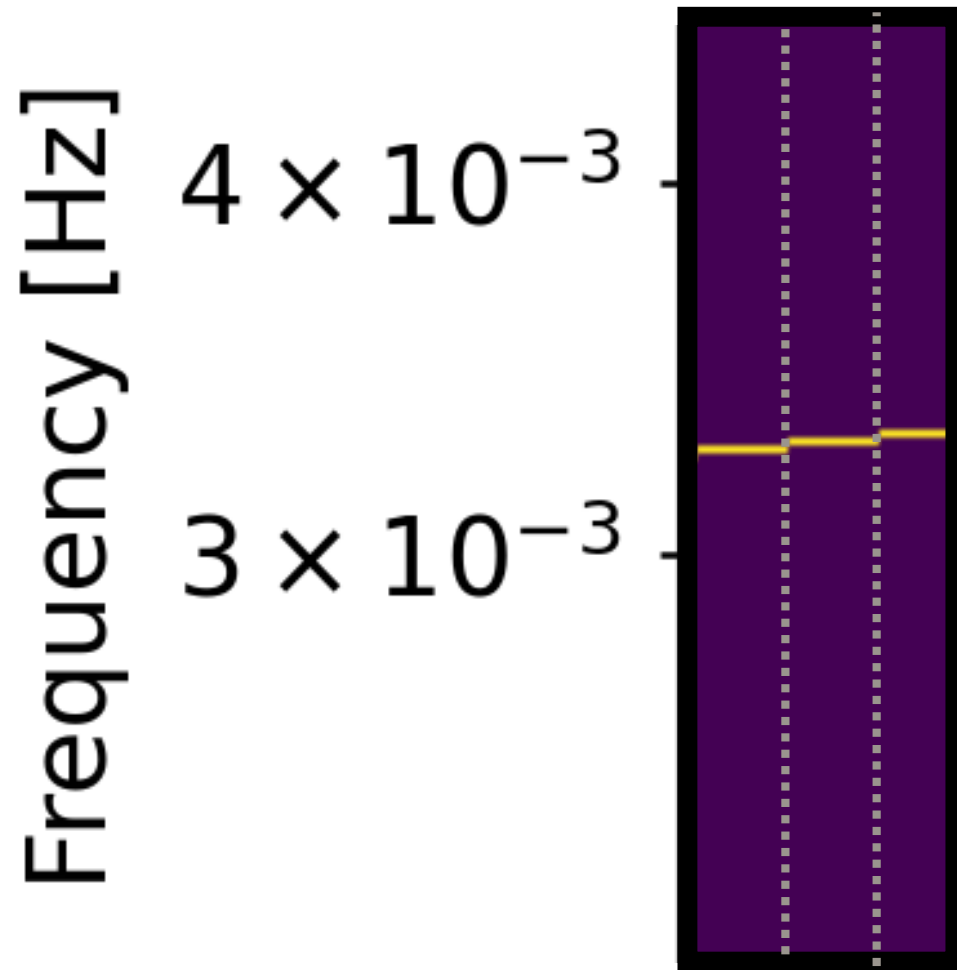
$$f_\phi(t, \vec{\theta})$$



$$(f_\alpha, \dot{f}_\alpha)$$

Speri+2026 PRD

Template: piecewise linear frequency



$$(f_{\alpha}, \dot{f}_{\alpha})$$

$$h_{\alpha}(t) = e^{-i2\pi(f_{\alpha}t + \dot{f}_{\alpha}t^2)}$$

$$\tilde{h}_{\alpha}(f) \propto K(f_{\alpha} - f, \dot{f}_{\alpha}, T_{\text{sft}})$$

$$\text{Time } t_{\alpha} = \alpha \times T_{\text{sft}}$$

Tenorio & Gerosa 2025

Physical
parameters

$$\vec{\theta}$$

General
Relativity

nonlinear
degenerate

$$f_{\phi}(t, \vec{\theta})$$

Template($f_{\alpha}, \dot{f}_{\alpha}$)

Physical
parameters

$\vec{\theta}$

General
Relativity

nonlinear
degenerate

$$f_{\phi}(t, \vec{\theta})$$



Template $f_{\alpha}, \dot{f}_{\alpha}$

Phenomenological
parameters

$\vec{c}$

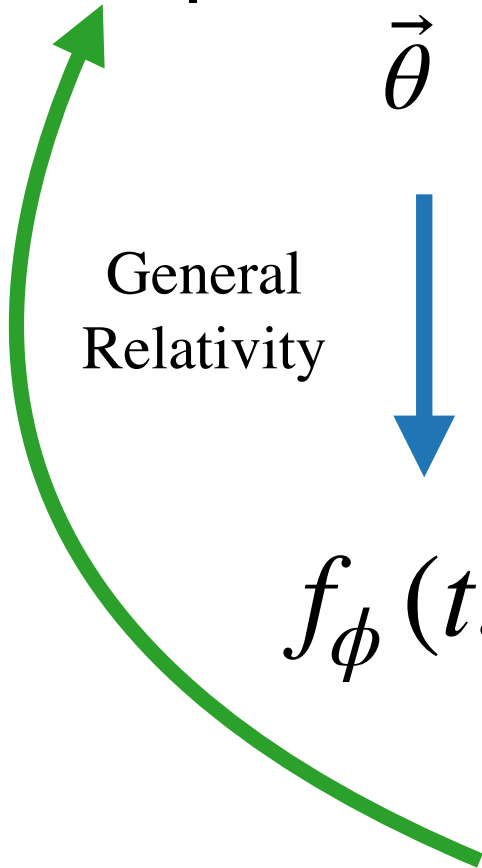
linear
orthogonal

Singular Value
Decomposition
Roulet+2019

$$f_{\phi}(t, \vec{c}) = \sum_k V_k(t) c_k$$



Speri+2026 PRD



**Physical
parameters**

$$\vec{\theta}$$

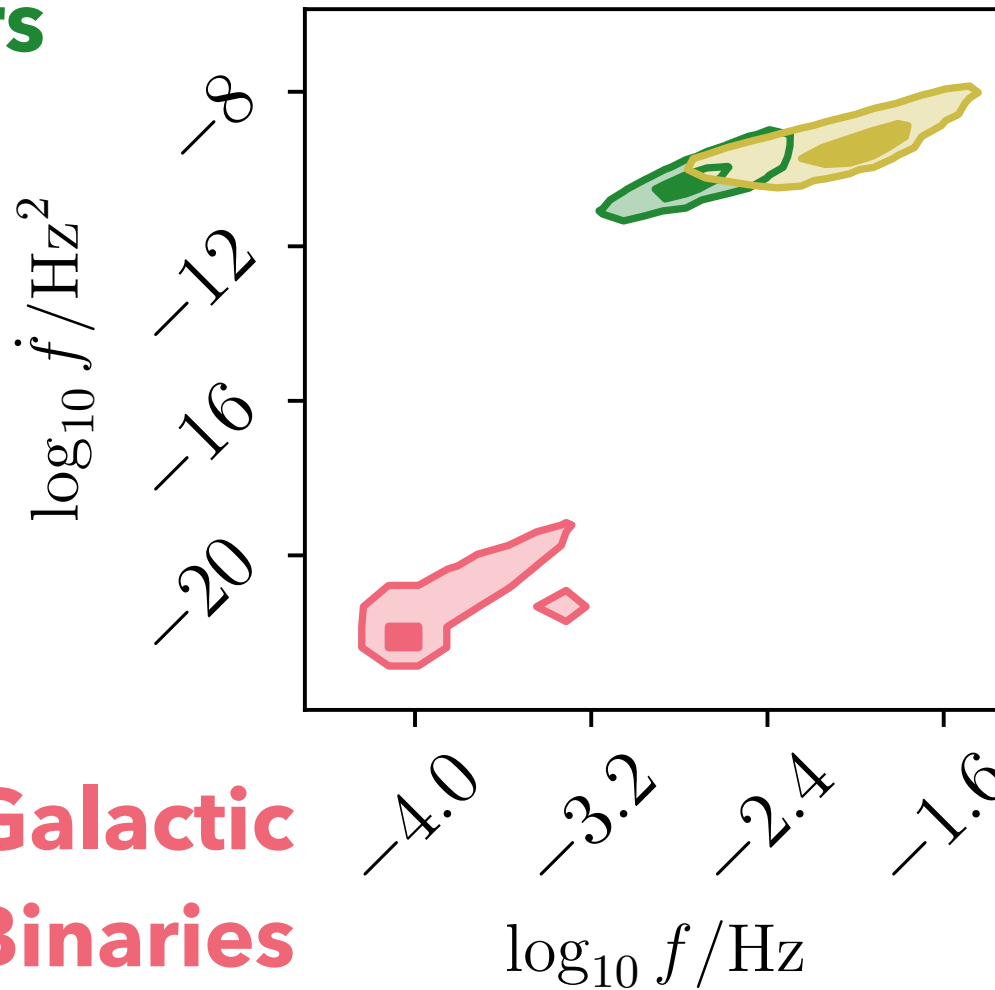
$$f(t_\alpha, \vec{\theta})$$

**Phenomenological
parameters**

$$\vec{c}$$

$$f_\alpha = \mathbf{V}_\alpha^i c_i$$

**Galactic
Binaries**



Detection statistic

$$\mathcal{S}_\alpha = \int \frac{\tilde{d}_\alpha^*(f) \tilde{h}_\alpha(f)}{S_n(f)} df = \int_{f_\alpha - \delta}^{f_\alpha + \delta} \frac{\tilde{d}_\alpha^*(f) \tilde{h}_\alpha(f)}{S_n(f)} df$$

Reduction per SFT

$$10^4 \rightarrow 10$$

Detection statistic

$$\mathcal{S}_\alpha = \int \frac{\tilde{d}_\alpha^*(f) \tilde{h}_\alpha(f)}{S_n(f)} df$$

$$\mathcal{S} = \sum_\alpha \Re(\mathcal{S}_\alpha)$$

$$\mathcal{S} = \sum_\alpha |\mathcal{S}_\alpha|$$

Brady & Creighton 2000

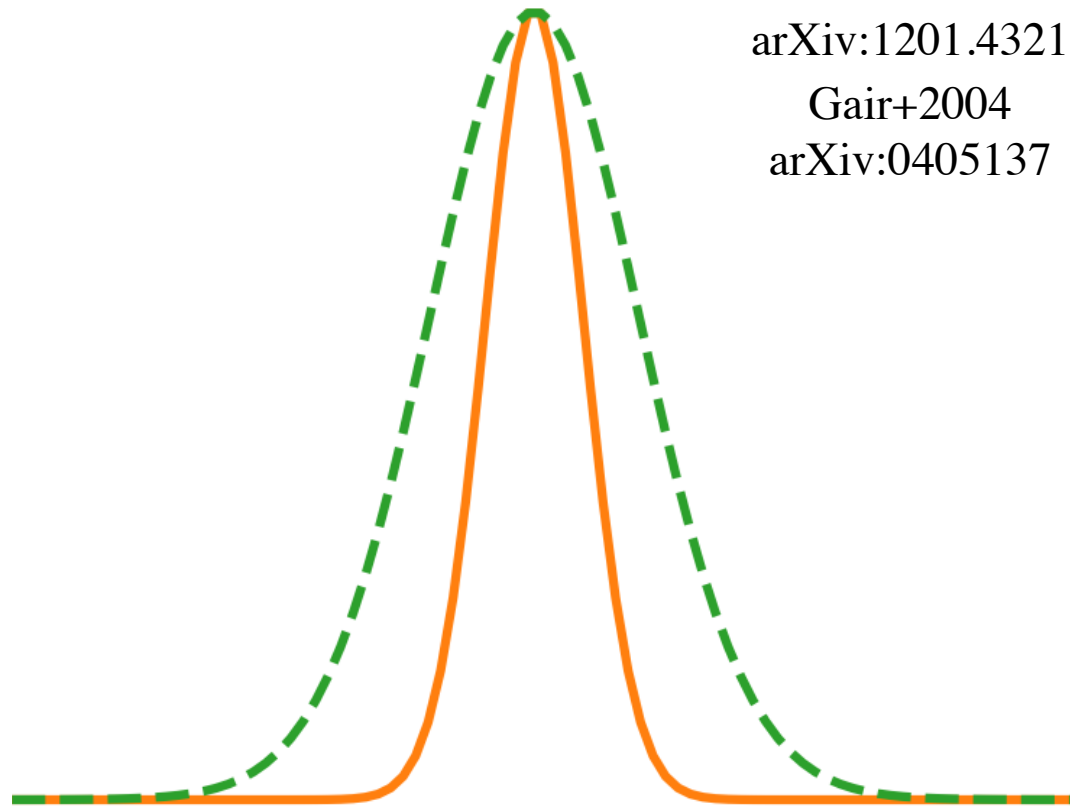
arXiv:9812014

Prix & Shaltev 2012

arXiv:1201.4321

Gair+2004

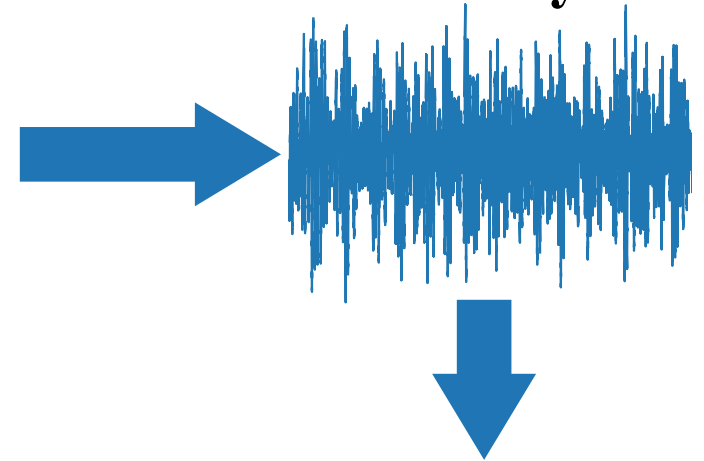
arXiv:0405137



(1) Draw

Parameter	Symbol	Prior Range
Primary mass	m_1	$[0.5, 5] \times 10^6 M_\odot$
Secondary mass	m_2	$[1, 100] M_\odot$
Primary spin	a	$[0, 0.998]$
Plunge time	T_{pl}	$[0.1, 1.0] \text{ yr}$
Final eccentricity	e_f	$[0, 0.1]$

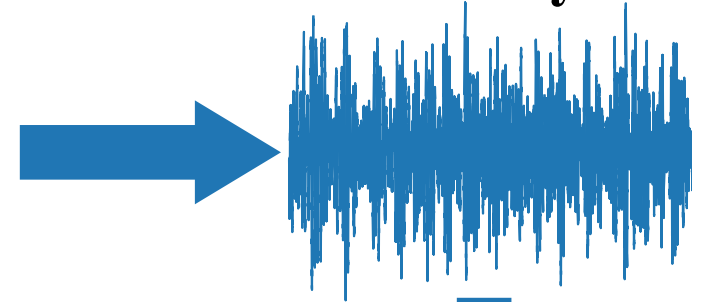
(2) Inject one EMRI FEWv2 with LISA response + noise Duration: 1 year



(1) Draw

Parameter	Symbol	Prior Range
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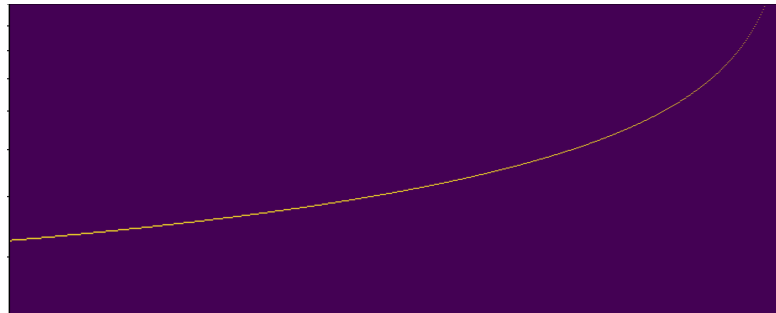


(3)

Search
1 hour
1 GPU

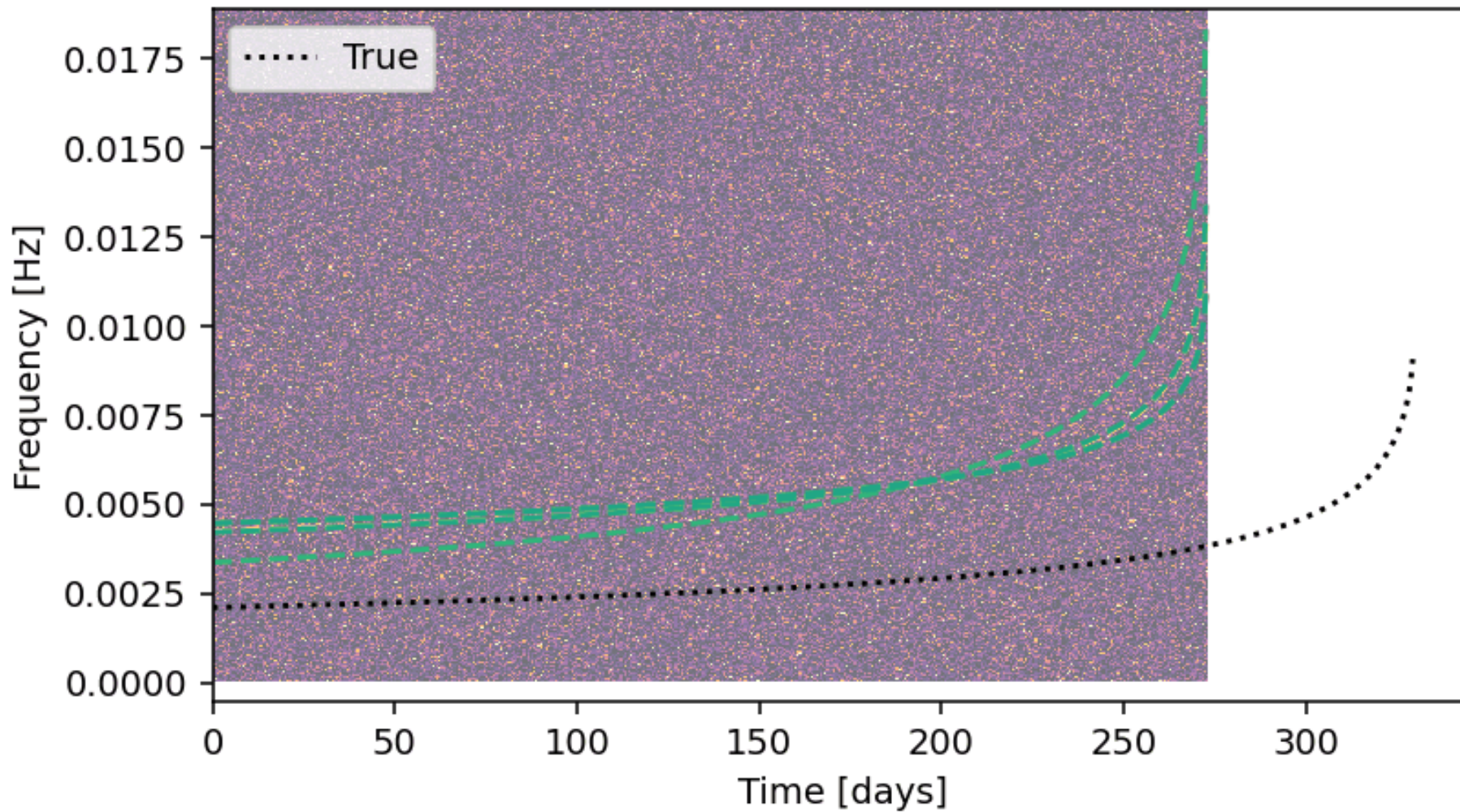


(4) Best fit track $f(t)$ and statistic

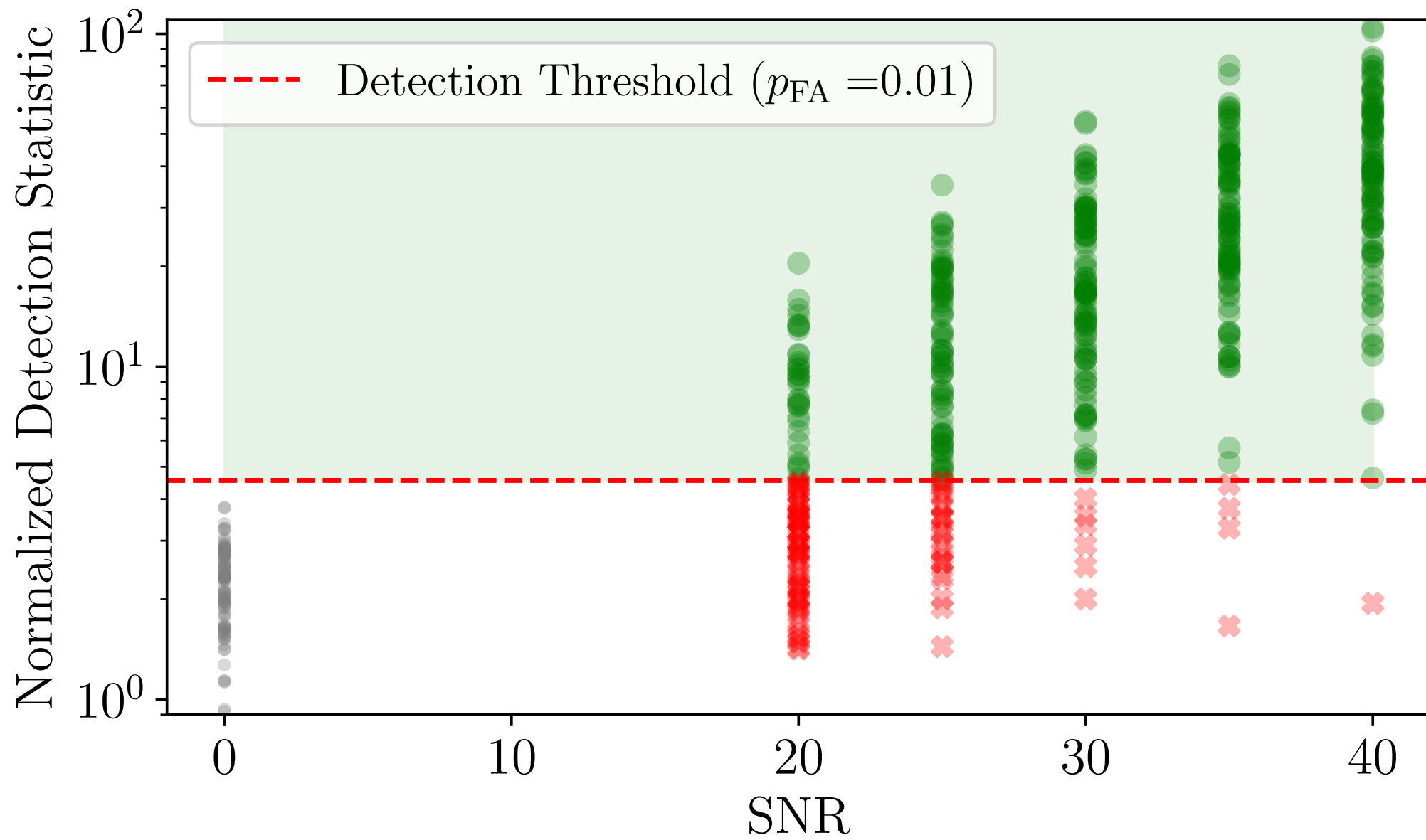


Search step=0 | duration=40.33 min

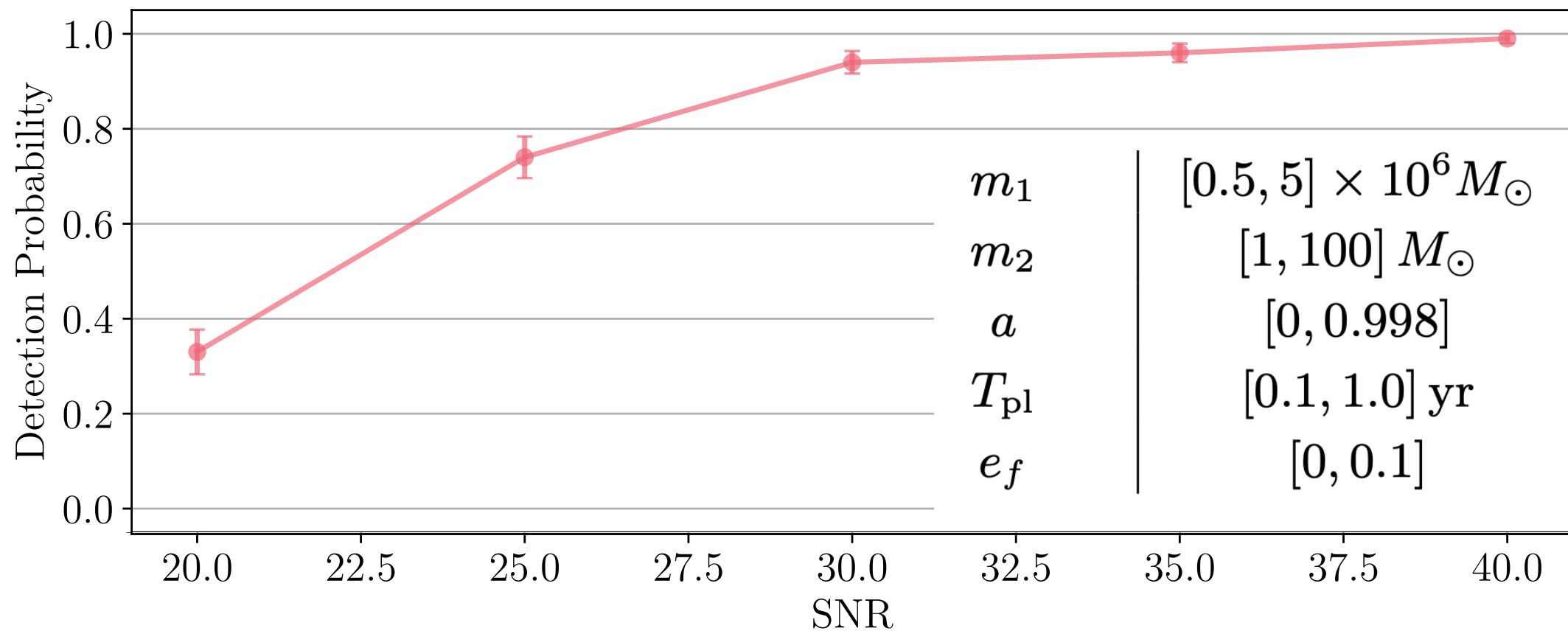
Normalised Detection Staistic : -4.18



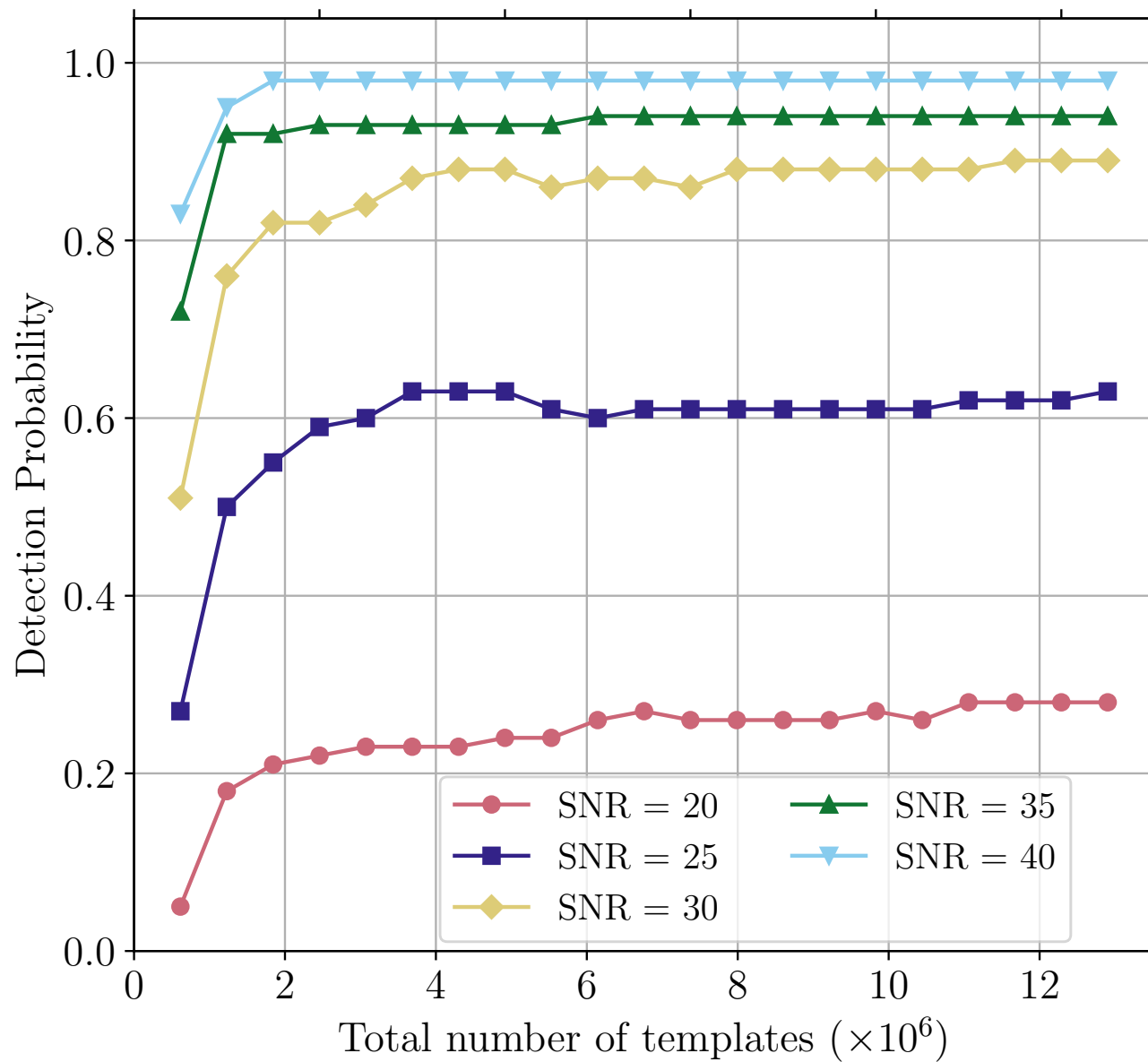
EMRI-Search



Detection Probability as function of injected SNR



Relative precision on recovered frequency 10^{-3}



Large SNR requires
less template

SNR=20 still
increasing

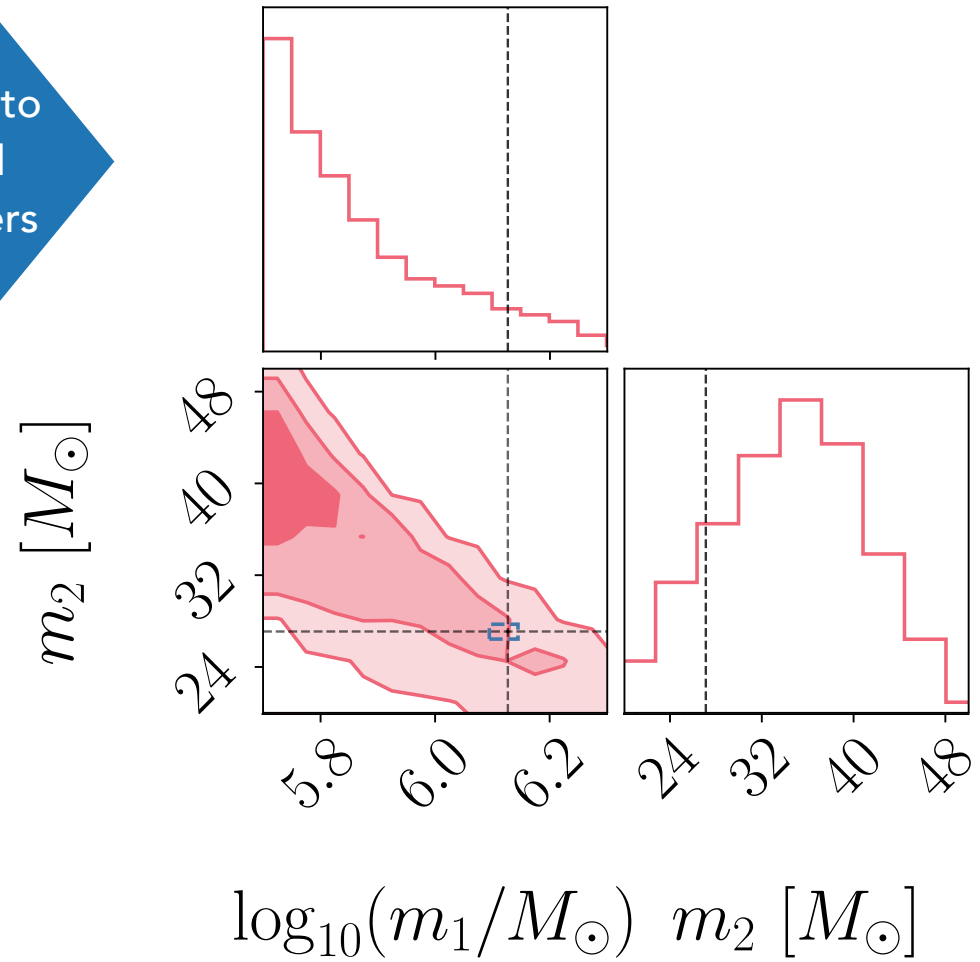
10^7 templates in 1 hour

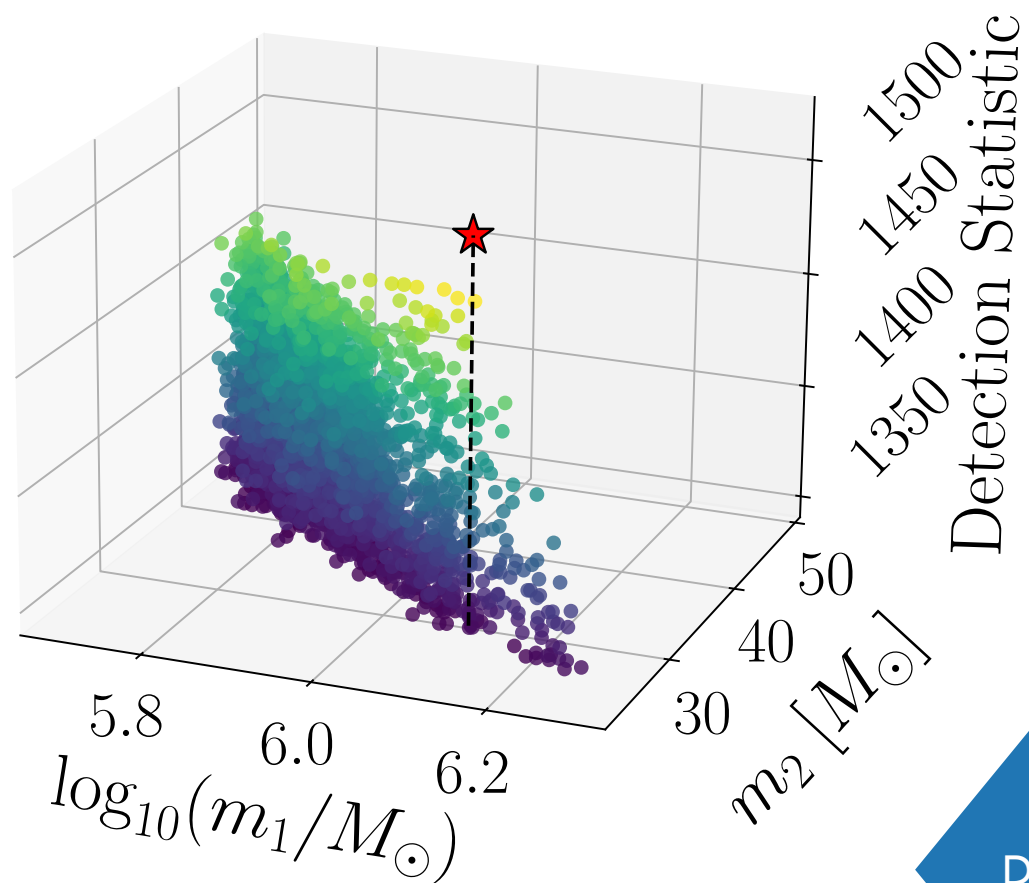
Best fit track $f(t)$ and statistic



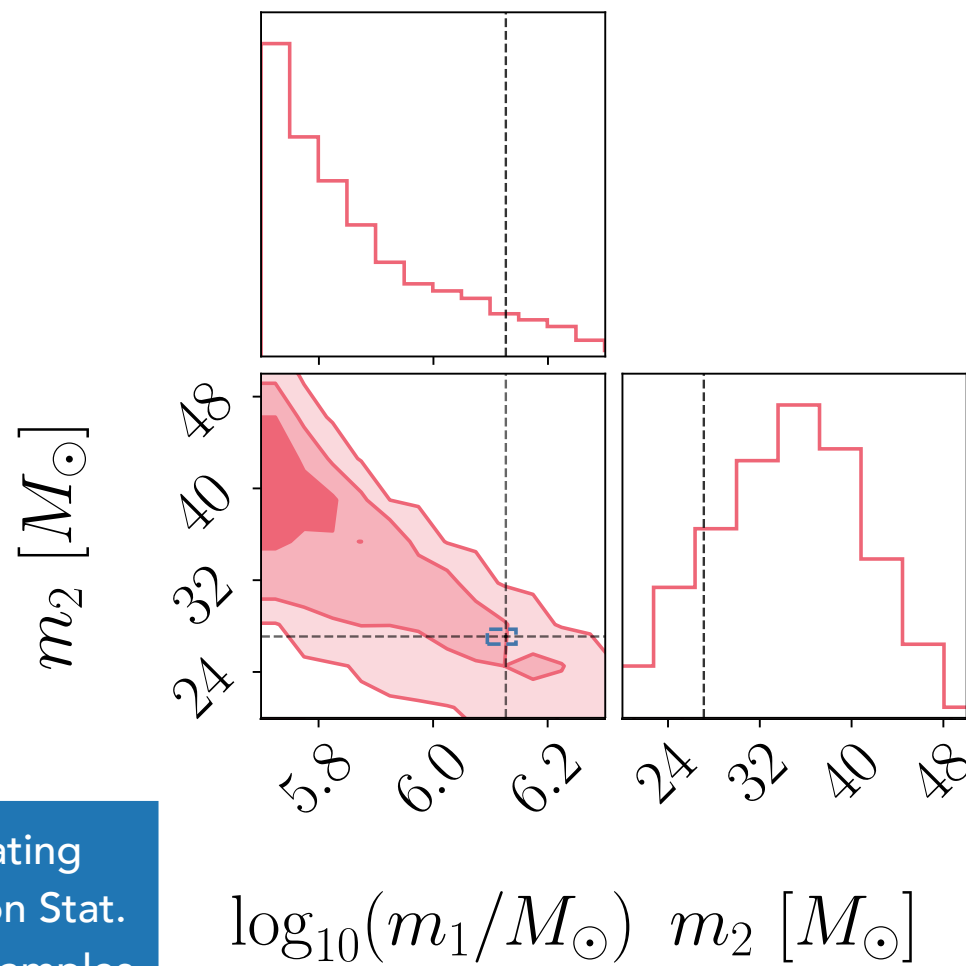
Fantoccoli in prep.

Mapping to
physical
parameters

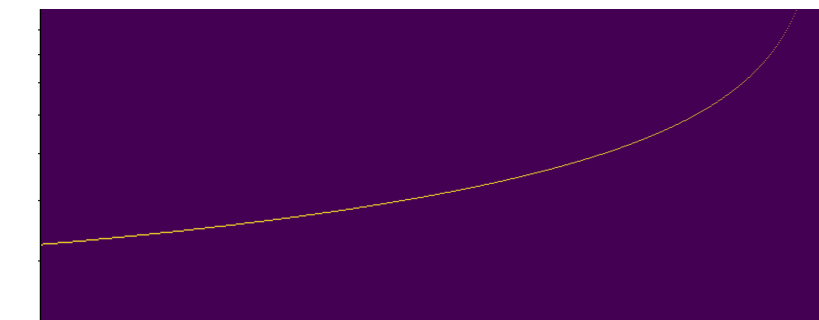




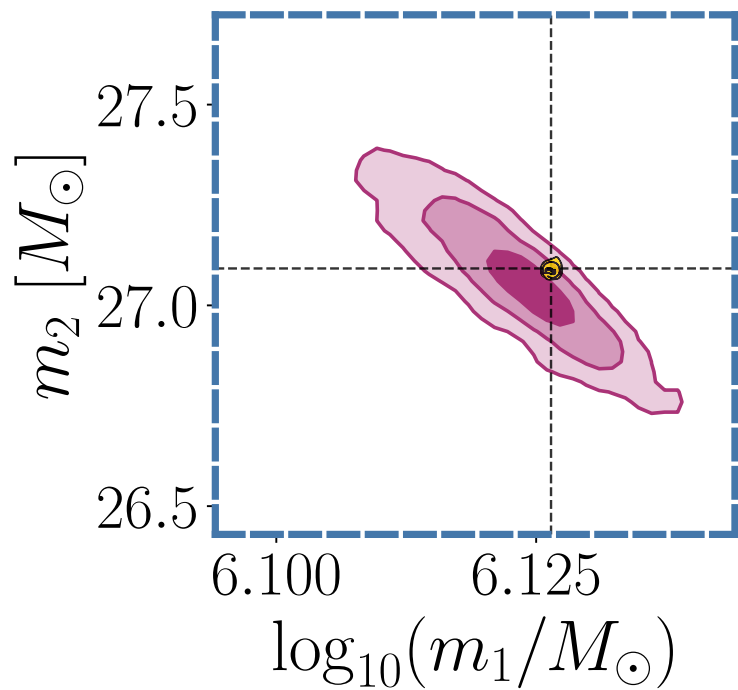
Evaluating
Detection Stat.
 10^6 SBI samples



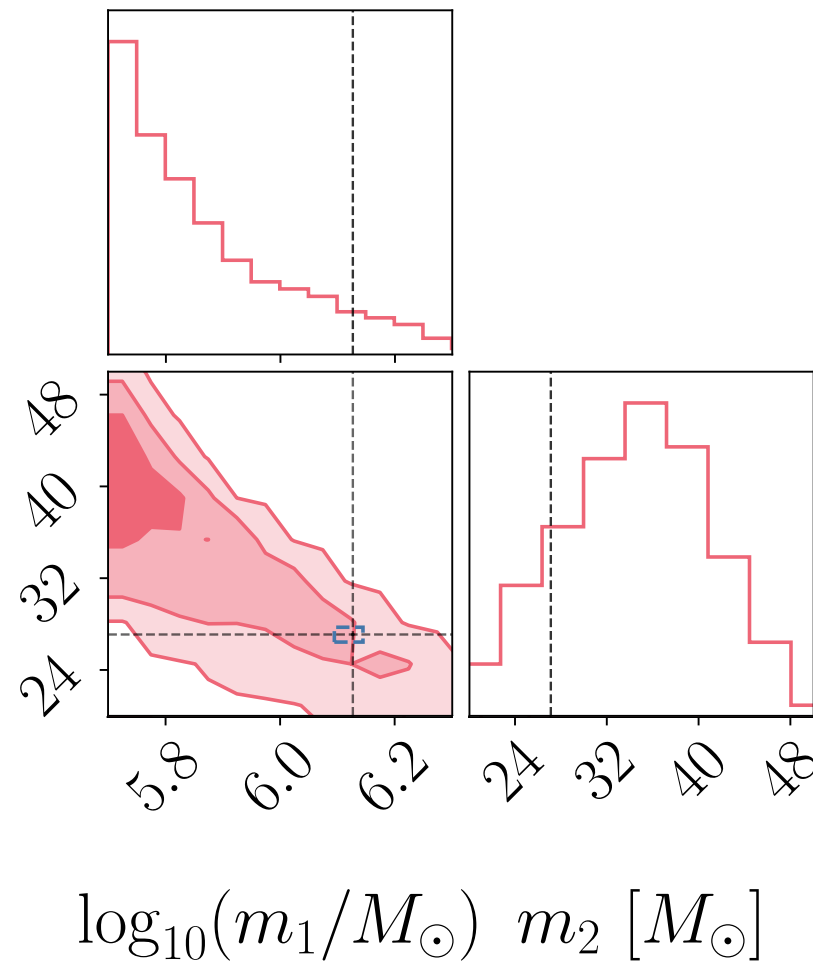
Best fit track $f(t)$ and statistic



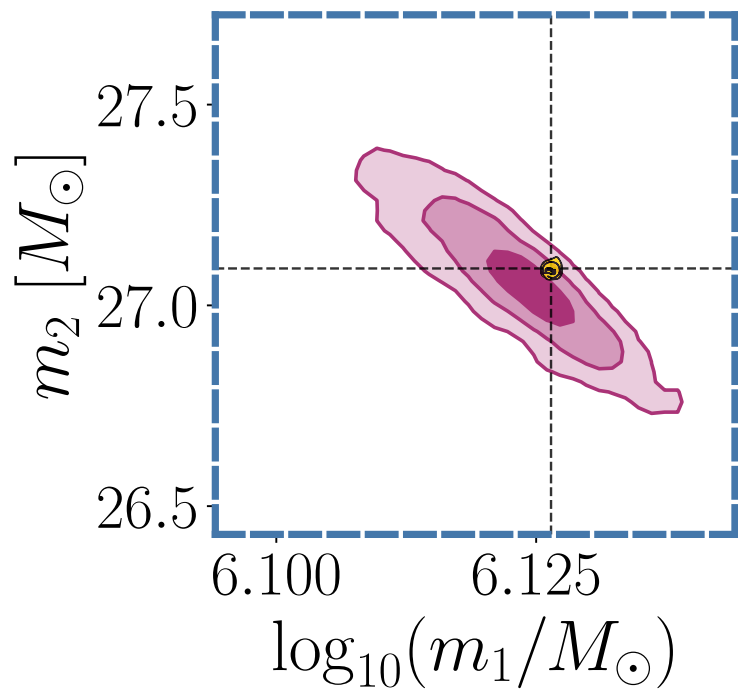
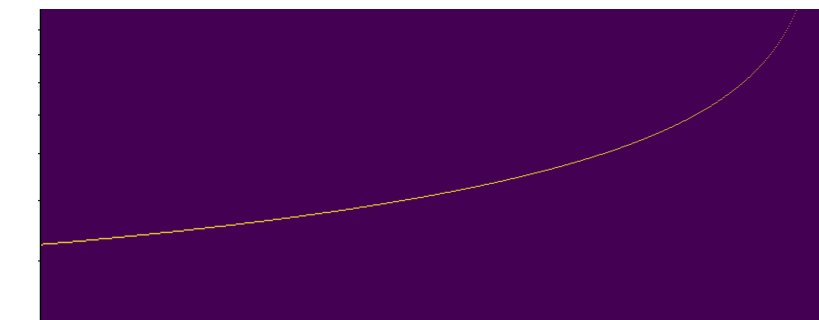
Mapping to
physical
parameters



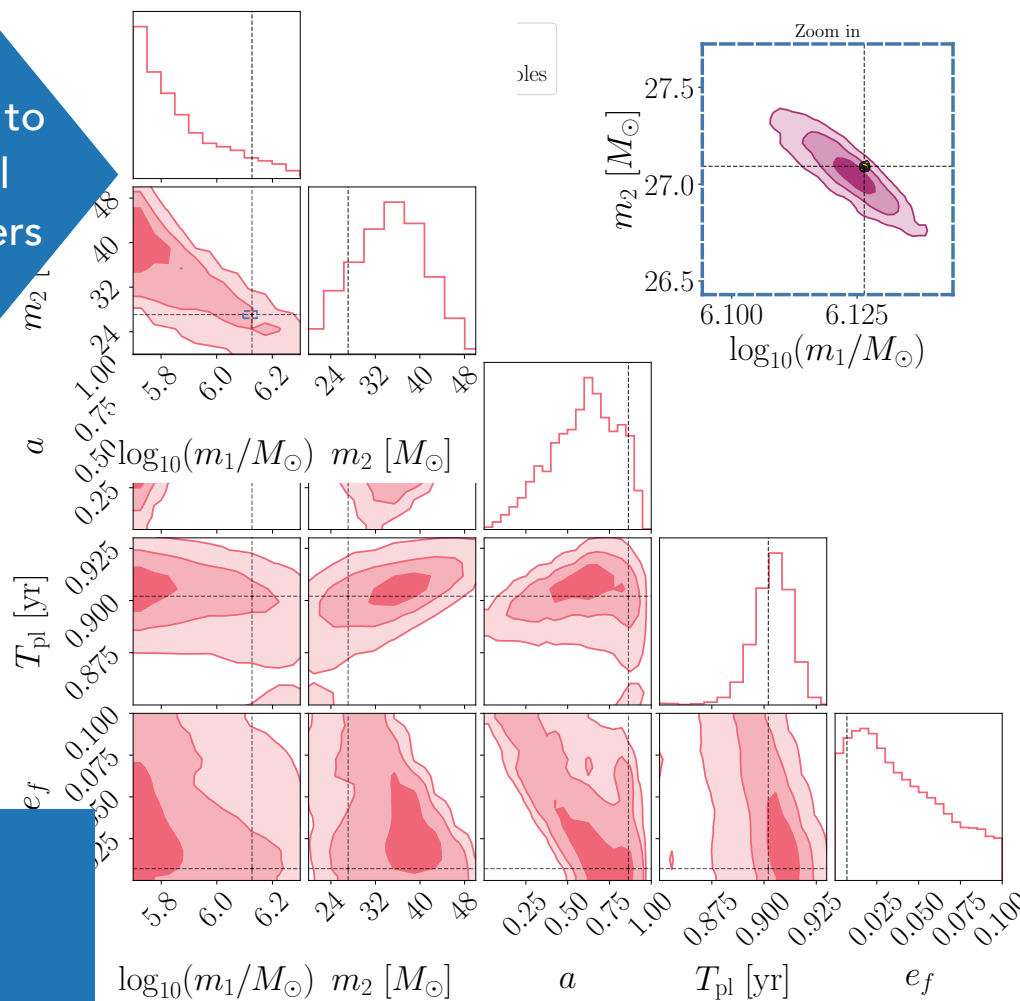
$m_2 [M_\odot]$



Best fit track $f(t)$ and statistic

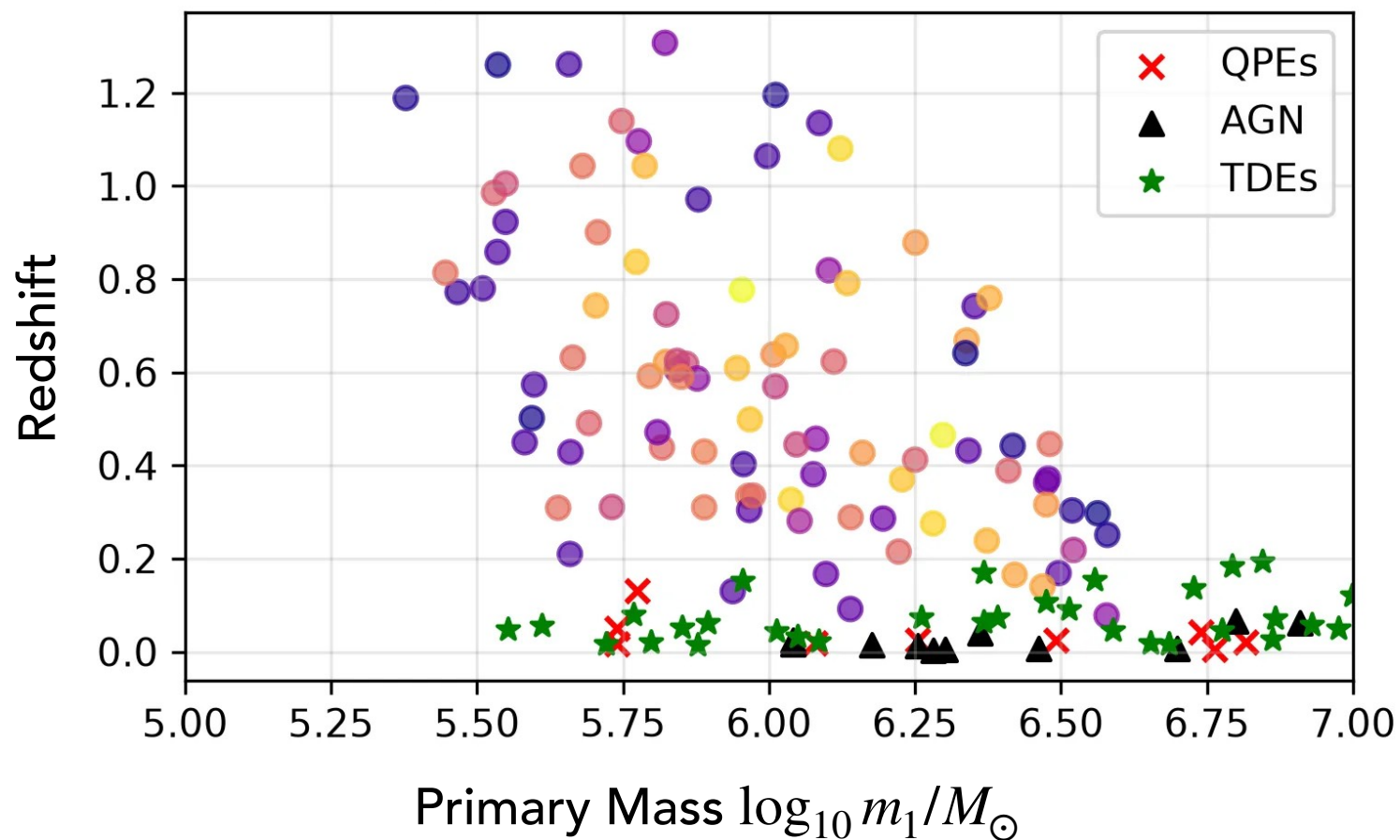


Mapping to
physical
parameters



Which EMRIs can we detect*?

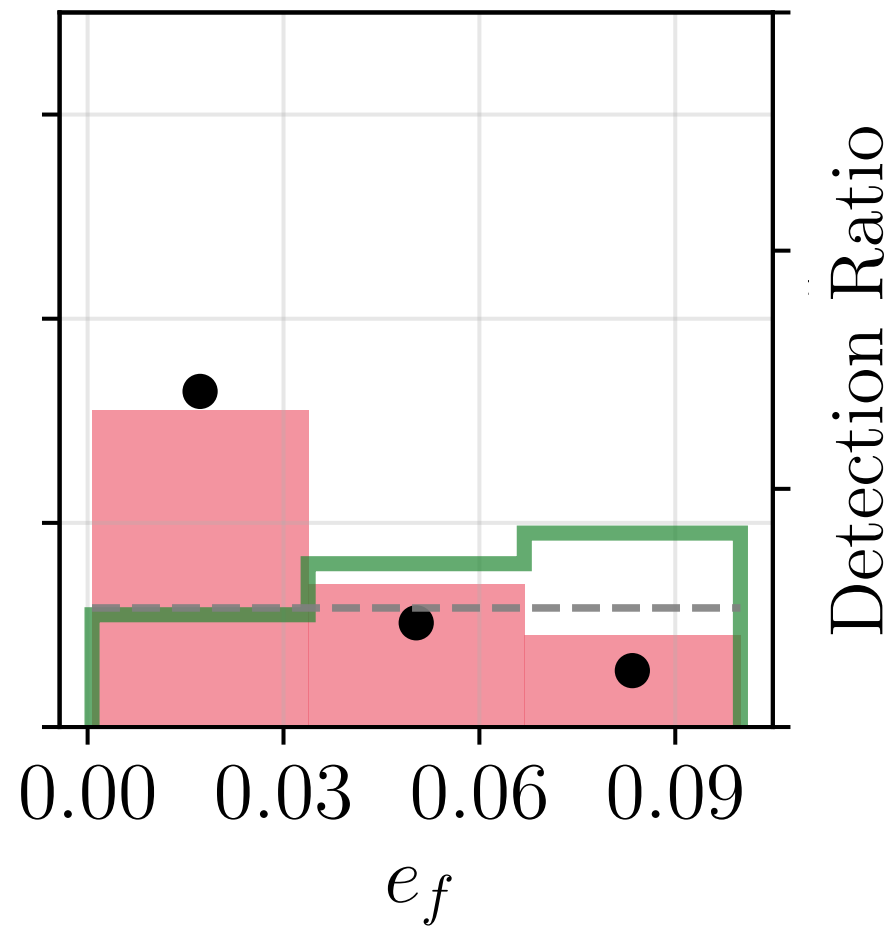
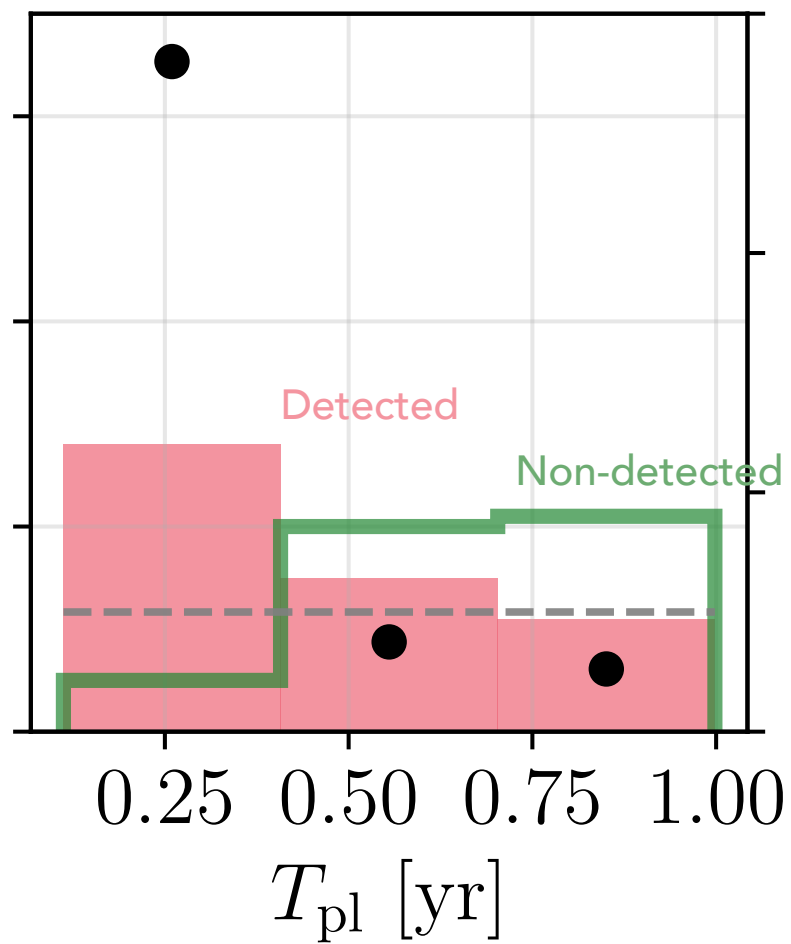
*=If there was a single EMRI in the LISA data



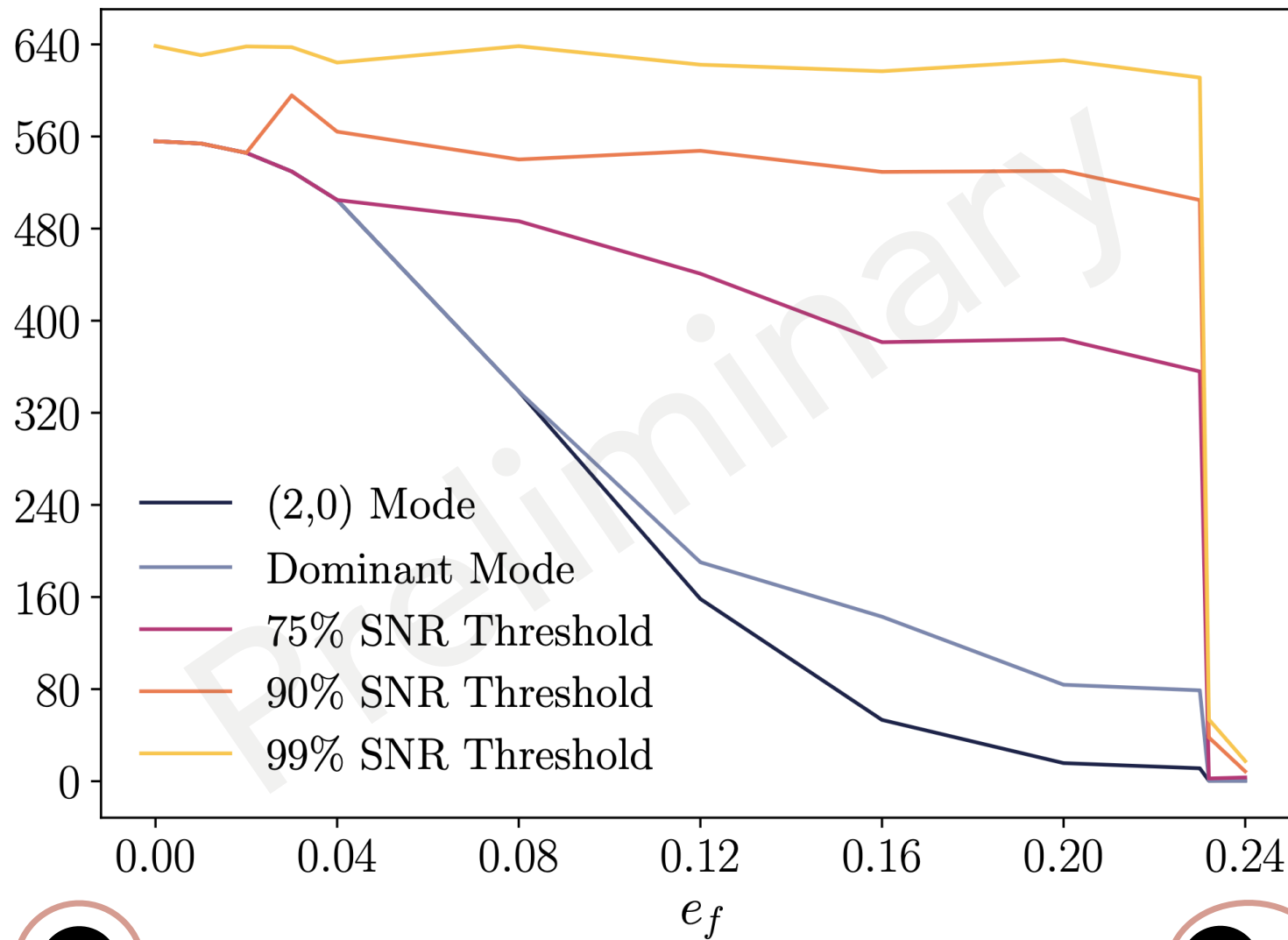
Explore Parameter
Space using
emrsearch



Semi-coherent EMRI Search



Detection Statistic

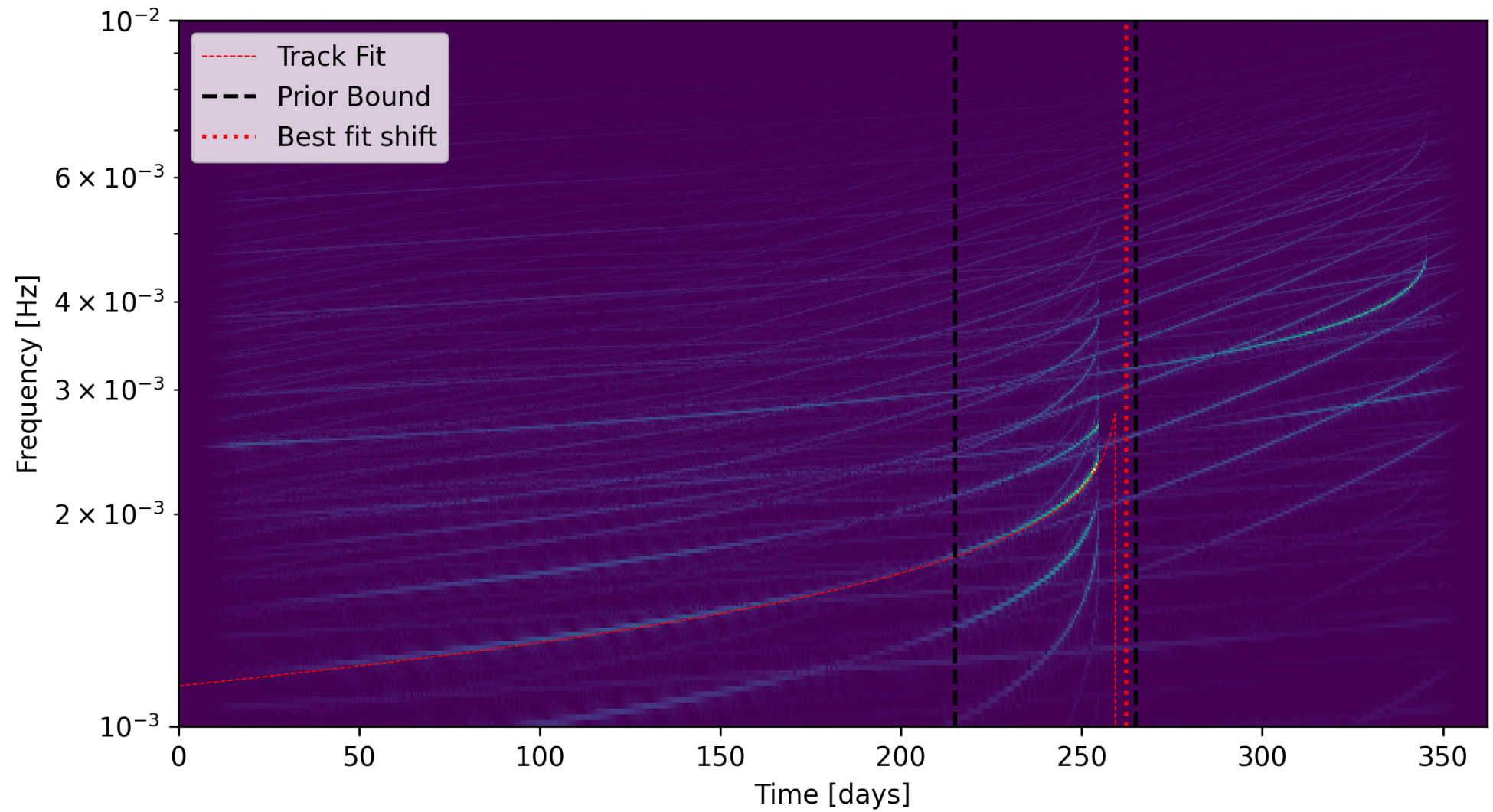


Final Eccentricity



Maria
Gonçalves
Salgado
MSc Leiden

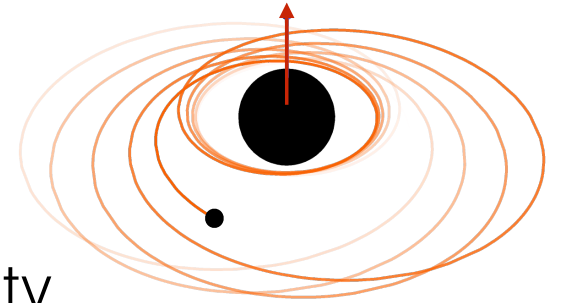
Application to Mojito light



Conclusions

1 year of data analysed in 1 hour on 1 GPU

Detection of single EMRI for $\text{SNR} > 30$ for low eccentricity



Future directions

Search extension to generic orbits

LISA data challenges and search in presence of other sources

