DCC: LIGO-G2401296-v2

BinaryWeave: A New Semicoherent Pipeline for Detecting a CW Signal From Scorpius X-1

Implementing Semicoherent F-stat templates on optimal lattices

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Sources of CW-Signals: a Quick Reminder

- (Rapidly) spinning neutron stars with mass-quadrupolar deformations => equatorial ellipticity (ε)
- Various non-radial oscillation modes, e.g., r-mode, g-mode, f-mode, in old and newly born neutron stars
- Ideal test beds:
    - ➡ spinning neutron stars in “messy environments”, e.g., NS in accreting binaries, LMXB systems
    - ➡ newly born neutron star that has yet to settle down to its long-term structures, e.g., supernova remnants
    - ➡ Unknown sources of special interests, e.g., galactic centre, globular clusters, etc.

Here I will specifically focus on Sco X-1, a known accreting NS in LMXB system

Scorpius X-1: the Brightest Extra-Solar X-Ray Source in the Sky

- Scorpius X-1 (Sco X-1) is the brightest extra-solar X-ray sources in the sky
- A low-mass X-ray binary (LMXB) system with a companion with mass ~ 0.42 M_{sun}
- X-ray and optical spectra from Sco X-1 suggests it harbours a neutron star as the primary object
- High X-ray luminosity => proxy for high mass-accretion rate => plausible large non-axisymmetric deformation
- Torque balance scenario: accretion induced spin-up torque = spin-down torque combined by all the dissipative mechanisms
- Certain astrophysical properties and spin-distributions of neutron stars advocates for strong CW emission as one of the most natural braking mechanisms

Sco X-1 Source Properties

- Although the brightest and persistent X-ray emitter, NO pulsation is seen from Sco X-1 [Galaudage et al., MNRAS **509,** 1745 (2022)]
- Optical and radio observations have measured different orbital parameters to a varied degrees of accuracies
- Eccentricity is well constrained: $e \leq 0.0132$

Galloway et al., ApJ 781:14 (2014);
Cherepashchuk et al., MNRAS 508, 1389 (2021);
Killestein et. al., MNRAS 520, 5317 (2023)

TABLE I. Scorpius X-1: system parameters.

Sco X-1 parameter	Value	Uncertainty
Period	68023.70 sec	0.04 sec
Orbital semimajor axis	1.44 sec	0.18 sec
Time of ascension	897753994	100 sec
Orbital eccentricity	< 0.068	3σ
Right Ascension	$16^h 19^m 55^s.067$	$0''.06$
Declination	$-15°38'25''.02$	$0''.06$
System inclination	44°	6°
Companion mass	$0.42 M_{Sol}$	
X-ray flux	$3.9 \times 10^{-10}\ \mathrm{Wm}^{-2}$	

Ref: Messenger et al., PRD 92, 023006 (2015)

Note: these observations are ***old now***, and a new set of refined source parameter space has been reported in T. L. Killestein et. al., MNRAS 520, 5317–5330 (2023)

Searching for a CW-Signal From Sco X-1

- **Problem at hand: detecting a CW-signal from Sco X-1**
- The source emits quasi-monochromatic continuous gravitational waves in its rest frame
  - ➡ However, its spin-frequency is completely unknown
- Being in a stellar binary system, the CW-signal goes through significant doppler modulations
  - ➡ We need to search over the orbital parameters of the binary system

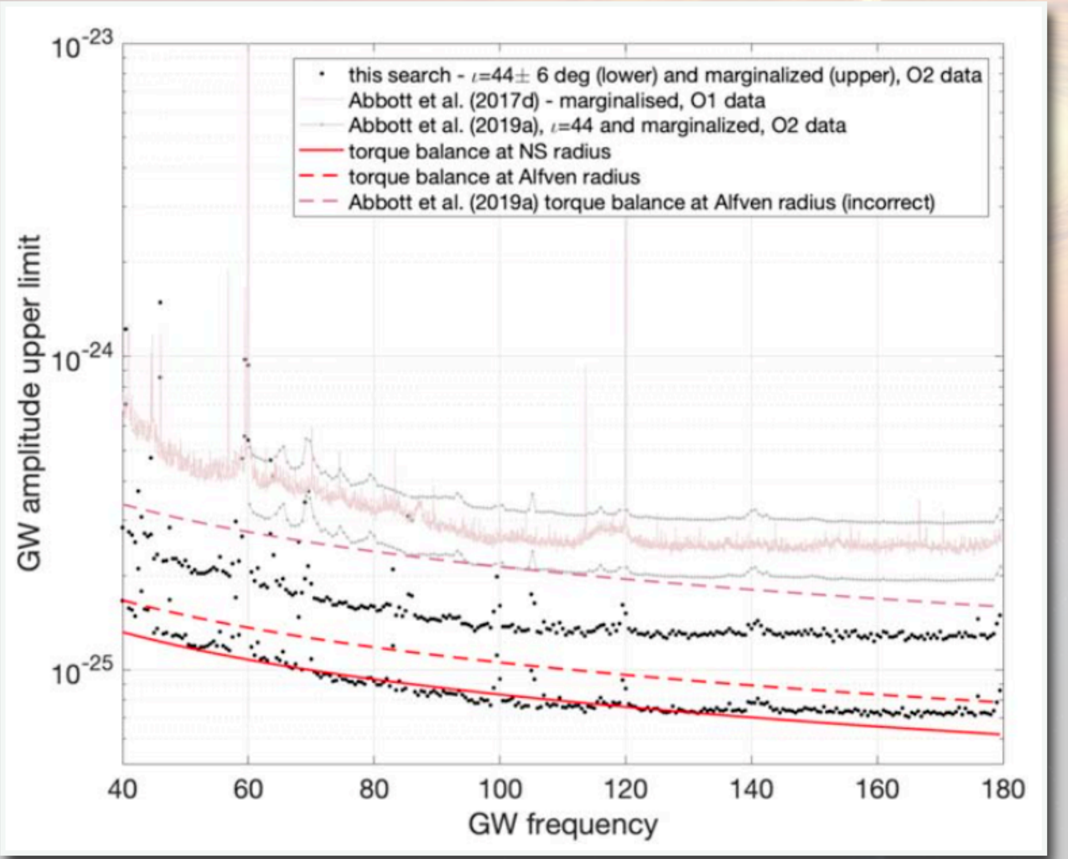
Sco X-1 Search Results

- Sco X-1 has been searched extensively in GW detectors, including Advanced-LIGO, Advanced-VIRGO, KAGRA over a couple of decades
- However, only recently we have been able to beat the torque-balance limit in the low-frequency regime (< 200 Hz)

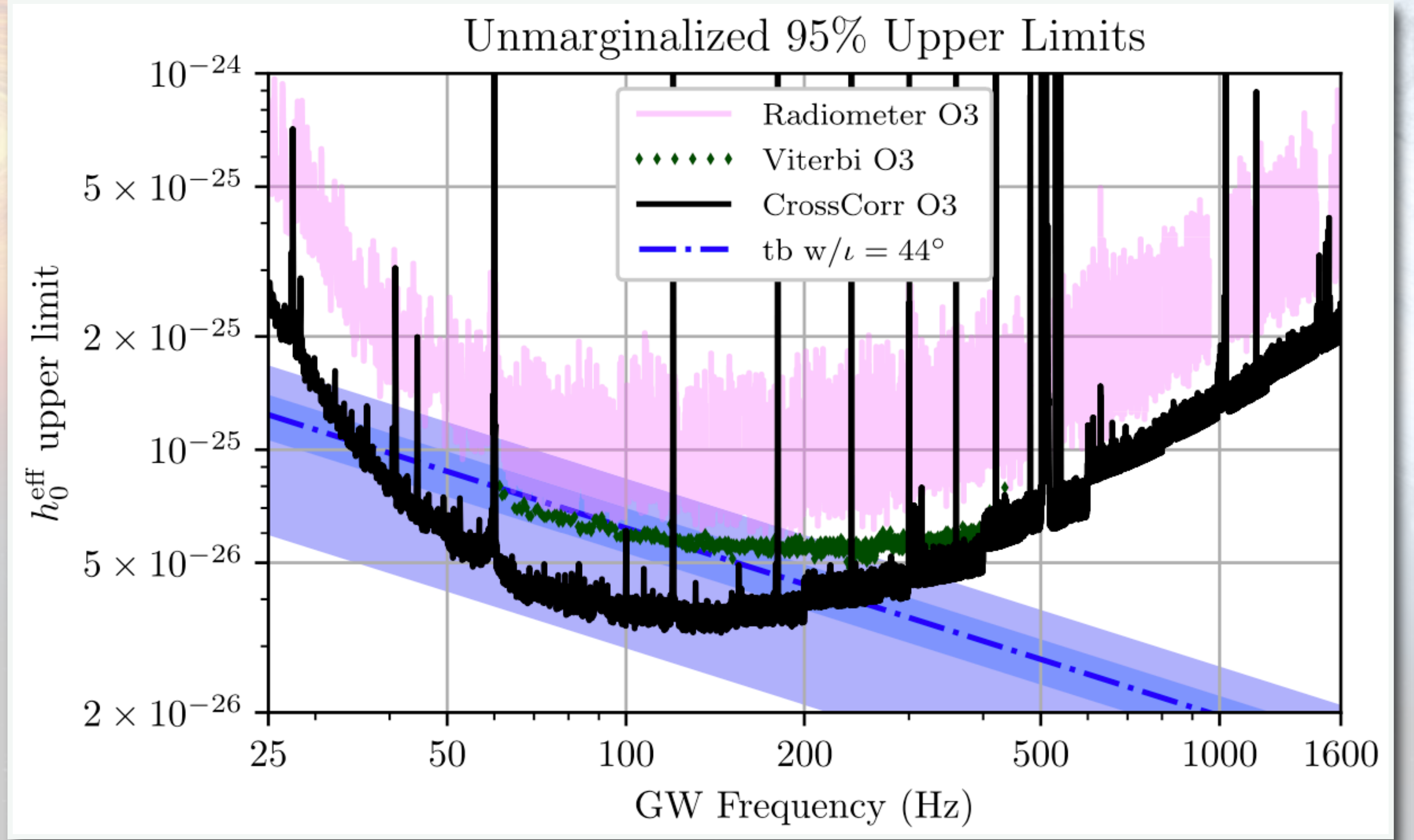
B. Abbott et al., PRD 76, 082001 (2007); J. Aasi et al., PRD 91, 062008 (2015); B. P. Abbott et al., PRD 100, 122002 (2019); Y. Zhang et al., ApJL 906:L14 (2021); R. Abbott et al., ApJL 941:L30 (2022)

- Recent searches with updated source parameters of *Killestein et. al. (2023)*

Whelan et al., ApJ, Vol. 949, Issue 2, id.117 (2023); Vargas & Melatos, arXiv:2310.19183



Ref: Y. Zhang et al., ApJL 906:L14 (2021)

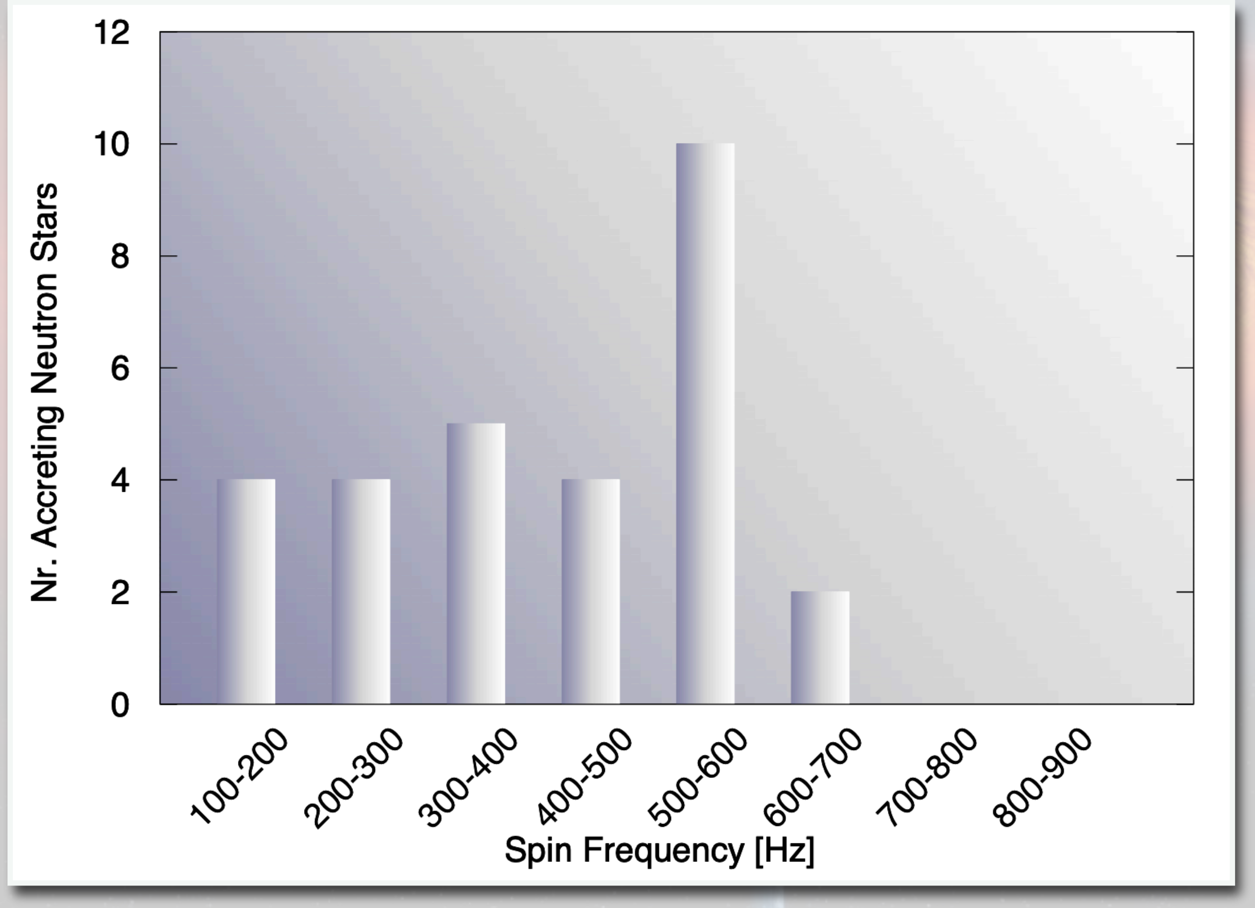


Ref: R. Abbott et al., ApJL 941:L30 (2022)

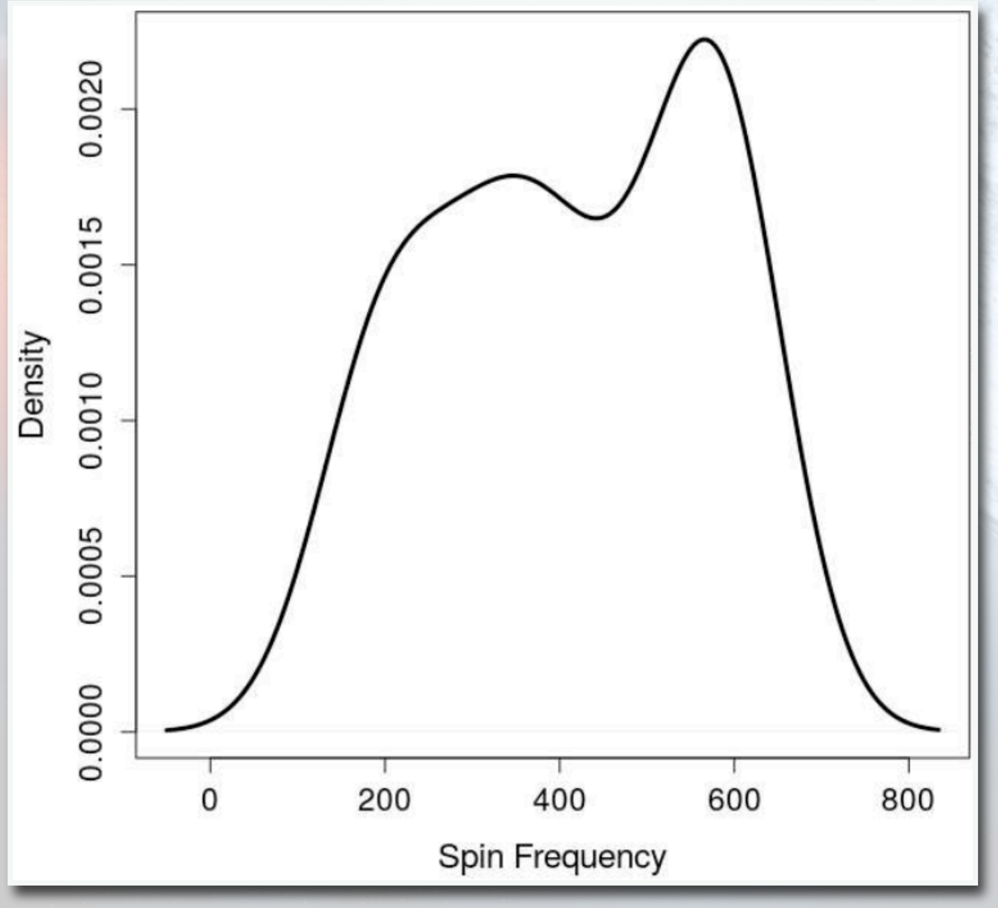
Spin Frequency of Accreting NSs

- Accreting neutron stars (in LMXBs) are generally fast spinning objects; frequency in [200, 700 Hz] D. Chakrabarty, AIPC Proc., Vol. 1068, pp. 67-74 (2008); A. Patruno, et al., ApJ 850:106 (2017)
- Accretion transfer (+ve) angular momentum to the NSs, acts as the primary mechanism for spin-up
- Sco X-1 is one of the highest accreting NS LMXB systems; it likely to host a rapidly spinning neutron star, possibly in the range of ~ **300 — 700 Hz**

Ref: A. Patruno, et al., ApJ 850:106 (2017)



Histogram of accreting neutron stars comprising all known AMXPs and NXPs.



KDE estimates of all known accreting neutron stars (AMXPs + NXPs).

Searching for a CW-Signal From Sco X-1 [Revisited …]

- **Problem at hand: detecting a CW-signal from Sco X-1**
- The source emits quasi-monochromatic continuous gravitational waves in its rest frame
  - ➡ However, its spin-frequency is completely unknown
- Being in a stellar binary system, the CW-signal goes through significant doppler modulations
  - ➡ We need to search over the orbital parameters of the binary system

The target parameter space becomes enormous due to limited observational constraints!

A New Search Pipeline for Sco X-1:

BinaryWeave

Overview: BinaryWeave

- This is a **semi-coherent** CW search pipeline for signals from a spinning neutron star in **binary system with known sky-position**
- The primary target is **Sco X-1** over a wide range of frequency band and orbital parameter space
- However, it can be used for directed searches from other binary systems with known sky-position (including **other LMXBs**)
- This pipeline is developed following the method in Leaci & Prix, PRD 91, 102003 (2015)
- The pipeline has been implemented in the "WEAVE-infrastructure" initially developed by K. Wette and R. Prix [K. Wette et al., PRD 97, 123016 (2018)] (see: [K. Wette at LVC-meeting, Glasgow (2016); DCC: <LIGO-G1601794-v2])

Basic Structure

- The entire observation time is **split** into **N** number of **segments**
- Each segments is searched with match-filtering the data against a bank of templates of phase/doppler-parameters (denoted by, λ)
- Results in well-known coherent $\mathcal{F}$-statistic for each of the N segments by maximising over the four amplitude-parameters (denoted by, $\mathscr{A}$)

JKS, PRD 58, 063001 (1998); R. Prix, PRD 75, 023004 (2007)

- **Sum** over the **$\mathcal{F}$-statistic** values from those **N-segments incoherently** to get the final **semi-coherent $\mathcal{F}$-statistic** distribution
- Search over the source parameter space (P): orbital-parameters (ASINI, PORB, TASC) along with FREQ (CW-frequency), etc., …

Weave Modus Operandi

- Tile (near) optimal covering lattice A^*_n or usual Z^*_n lattice grids in D-dim search parameter space (P) for each coherent-segment [R. Prix, PRD 75, 023004 (2007), R. Prix, LVC CW F2F (Ref: 8)]

- Perform coherent $\mathcal{F}$**-statistic** searches at each of the lattice points in P

- Sum over the $\mathcal{F}$**-statistic** values from those N-segments incoherently to get the final semi-coherent $\mathcal{F}$**-statistic** distribution

  - While summing one can opt for either nearest-neighbor interpolation for each of the coherent segments [K. Wette, PRD 90, 122010 (2014)]

  - OR exactly at the same lattice points in parameter space (non-interpolating)

Developer: K. Wette, R. Prix

BinaryWeave presently incorporates only the non-interpolating searches.

Optimal Covering Lattice

- One of the primary goals is to put templates on A^*_n lattice-grid
- A^*_n is optimal/near-optimal covering lattice for D = 2, …, 16 dimensions [ref: 4]

Compared to Z^*_n, the efficiency of coverage for A^*_n is:

Dimension	**3**	**4**	**5**	**6**	**7**
Efficiency	1.9	2.8	4.3	6.8	10.9

- This results in saving computational cost to search a signal over wide parameter space

Constant Metric Requirement for A^*_n Lattice Tiling

In the long segment limit ($T_{obs} >> P_{orb}$) the coherent metric is defined as :

$$\tilde{g}^{\mathrm{LS}}_{ff} = \pi^2 \frac{\Delta T^2}{3}$$

$$\tilde{g}^{\mathrm{LS}}_{a_p a_p} = 2\pi^2 f^2$$

$$\tilde{g}^{\mathrm{LS}}_{\Omega\Omega} = 2\pi^2 f^2 a_p^2 \left(\frac{\Delta T^2}{12} + \Delta^2_{ma}\right)$$

$$\tilde{g}^{\mathrm{LS}}_{t_{asc} t_{asc}} = 2\pi^2 f^2 (a_p \Omega)^2$$

$$\tilde{g}^{\mathrm{LS}}_{\kappa\kappa} = \frac{\pi^2}{2} f^2 a_p^2$$

$$\tilde{g}^{\mathrm{LS}}_{\eta\eta} = \frac{\pi^2}{2} f^2 a_p^2$$

$$\tilde{g}^{\mathrm{LS}}_{\Omega t_{asc}} = \tilde{g}^{\mathrm{LS}}_{t_{asc}\Omega} = 2\pi^2 f^2 a_p^2 \Omega \Delta_{ma}$$

where, $\Delta_{ma} = t_{mid} - t_{asc}$
and ΔT = segment length

[Leaci & Prix, PRD 91, 102003 (2015)]

Implement a New Coordinate System for Lattice Tiling

- Old (i.e., observer/user) set of coordinates are

$$\lambda := \{a_p, \Omega, t_{asc}, \kappa, \eta\}$$

- We get a new set of coordinates for lattice/internal param-space

$$\lambda_{int} := \{a_p, v_p, d_{asc}, \kappa_p, \eta_p\}$$

$$a_p = a_p$$

$$v_p = a_p \times \Omega = 2\pi(a_p/P_{orb})$$

$$d_{asc} = a_p \times \Omega \times t_{asc} = v_p \times t_{asc}$$

$$\kappa_p = a_p \times \kappa$$

$$\eta_p = a_p \times \eta$$

The coordinate transformation functions

[AM, Prix & Wette, PRD 107, 062005 (2023)]

The Metric in the New Lattice Coordinate

Corresponding non-zero terms in the new form of metric are

$$\tilde{g}^{\mathrm{LS}}_{ff} = \pi^2 \frac{\Delta T^2}{3}$$

$$\tilde{g}^{\mathrm{LS}}_{a_p a_p} = 2\pi^2 f^2$$

$$\tilde{g}^{\mathrm{LS}}_{v_p v_p} = 2\pi^2 f^2 \left(\frac{\Delta T^2}{12} + \Delta^2_{ma}\right)$$

$$\tilde{g}^{\mathrm{LS}}_{d_{asc} d_{asc}} = 2\pi^2 f^2$$

$$\tilde{g}^{\mathrm{LS}}_{\kappa\kappa} = \frac{\pi^2}{2} f^2$$

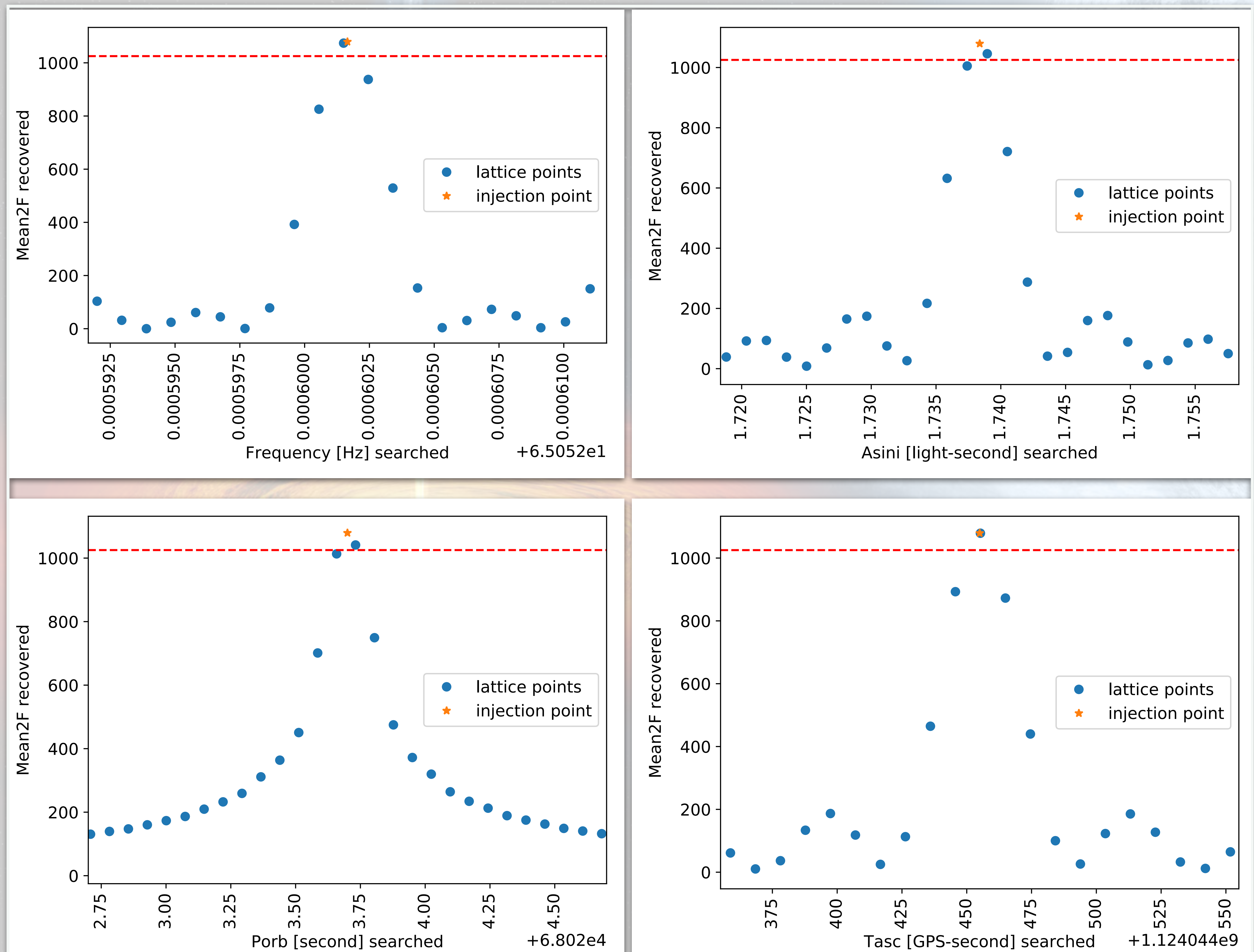
$$\tilde{g}^{\mathrm{LS}}_{\eta\eta} = \frac{\pi^2}{2} f^2$$

$$\tilde{g}^{\mathrm{LS}}_{v_p d_{asc}} = \tilde{g}^{\mathrm{LS}}_{d_{asc} v_p} = 2\pi^2 f^2 \Delta_{ma}$$

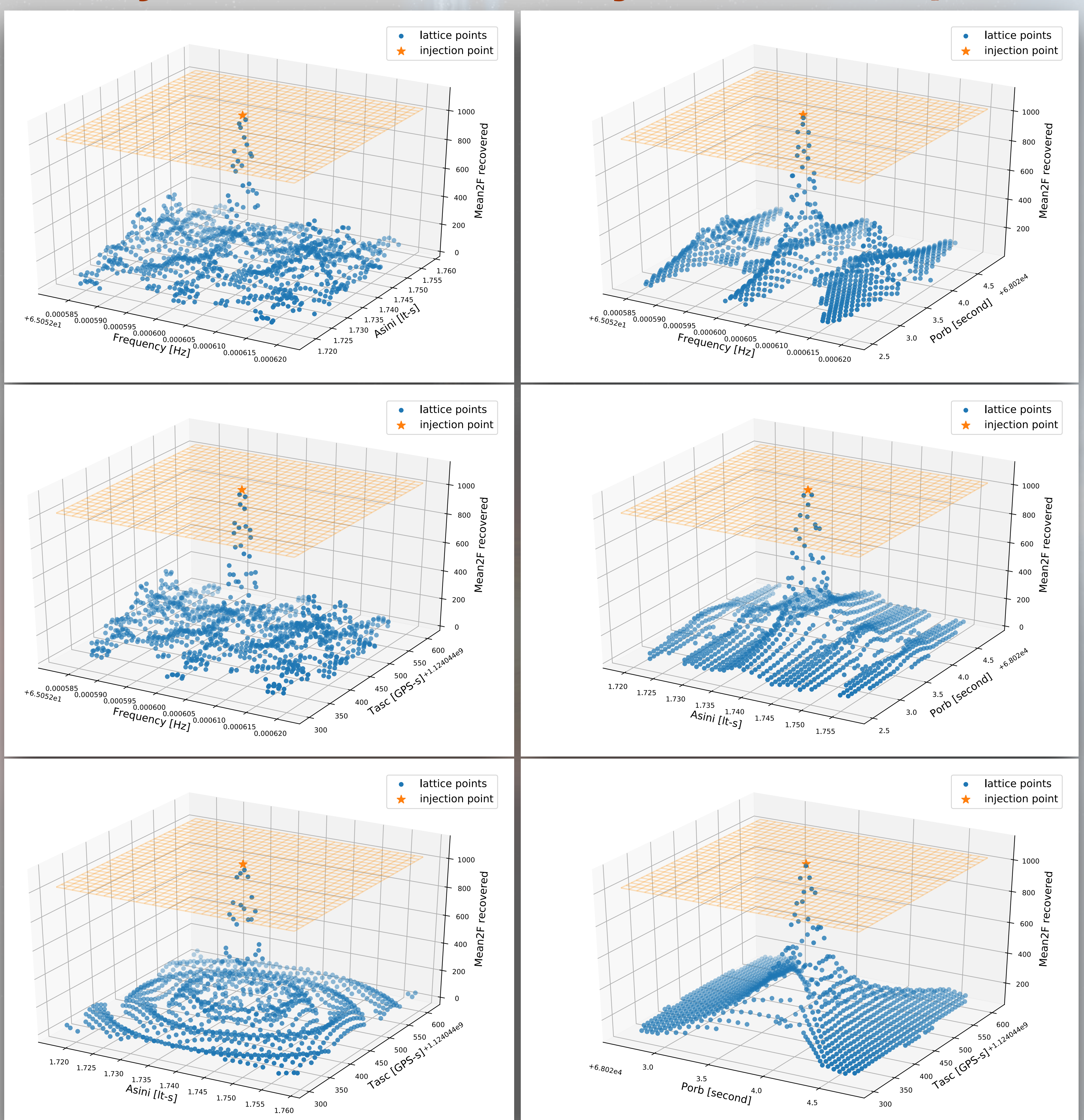
[AM, Prix & Wette, PRD 107, 062005 (2023)]

- Each of the metric coefficient is nearly-constant now.
- Internally we use
  $$\lambda_{int} := \{a_p, v_p, d_{asc}, \kappa_p, \eta_p\}$$
  coordinates to perform lattice-tiling
- For the remaining parameters (f and Δ_{ma}) we put templates in a conservative way
- We set f = f_{max} and Δ_{ma} = max(Δ_{ma}) over the search range
- Good approximation when, Δf << f and ΔTasc << Δ_{ma}

Injection-Recovery: 1-D Template Banks



Injection-Recovery: 2-D Template Banks



[AM, Prix & Wette, PRD 107, 062005 (2023)]

Mismatch Distribution: Semi-Coherent Case

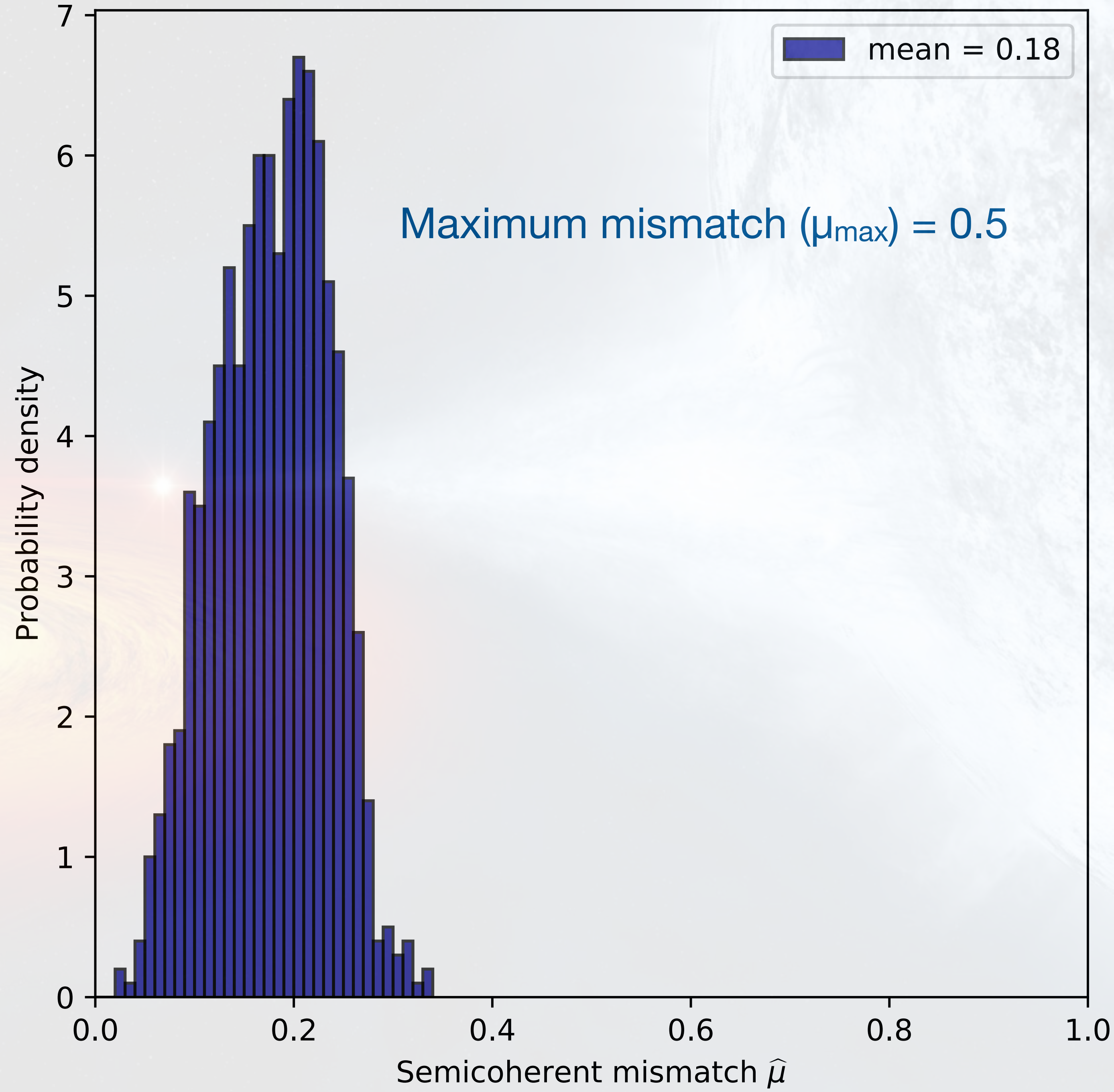
Mismatch (μ) is defined as:

$$\mu = \frac{\rho^2(\mathcal{A}, \lambda_s; \lambda_s) - \rho^2(\mathcal{A}, \lambda_s; \lambda)}{\rho^2(\mathcal{A}, \lambda_s; \lambda_s)}$$

T_{obs} = 30 days, T_{seg} = 1 day
1000 randomly drawn samples for injection-recovery test ever large parameter space: $\mathcal{P}_0$

$\mathcal{P}_0$

FREQ: 10 —700 Hz
ASINI: 0.3 — 3.5 lt-sec
PORB: 68023.7 ± 0.2 sec
TASC: 1124044455 ± 1000 sec



Semi-coherent mismatch distribution for the 4D template bank searching {FREQ, ASINI, PORB, TASC} for an injected signal

[MPW, PRD 107, 062005 (2023)]

Results From Two Realistic Search Setups

- Example of BinaryWeave pipeline characteristics and timing model for two search setups:

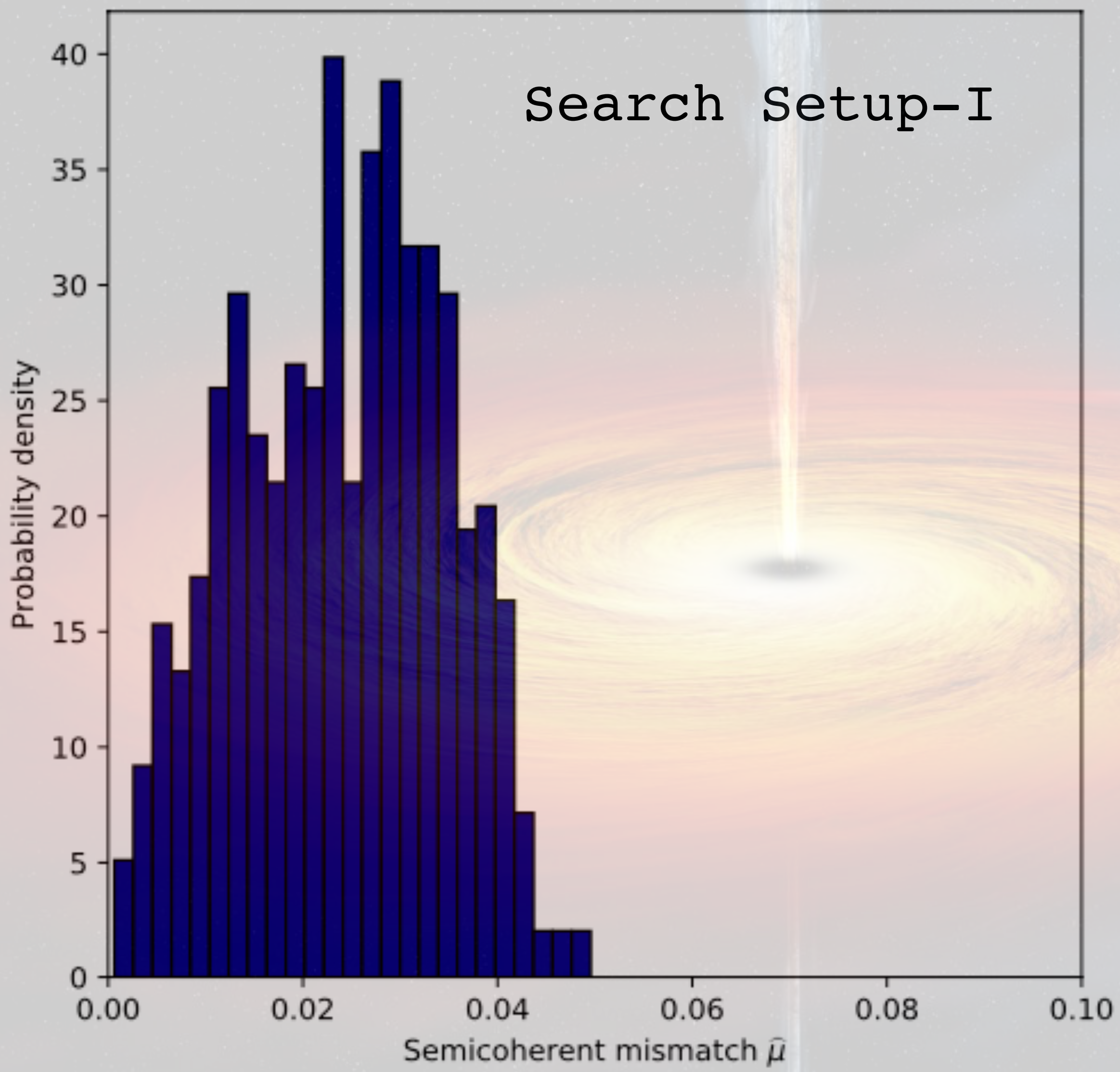
Table I

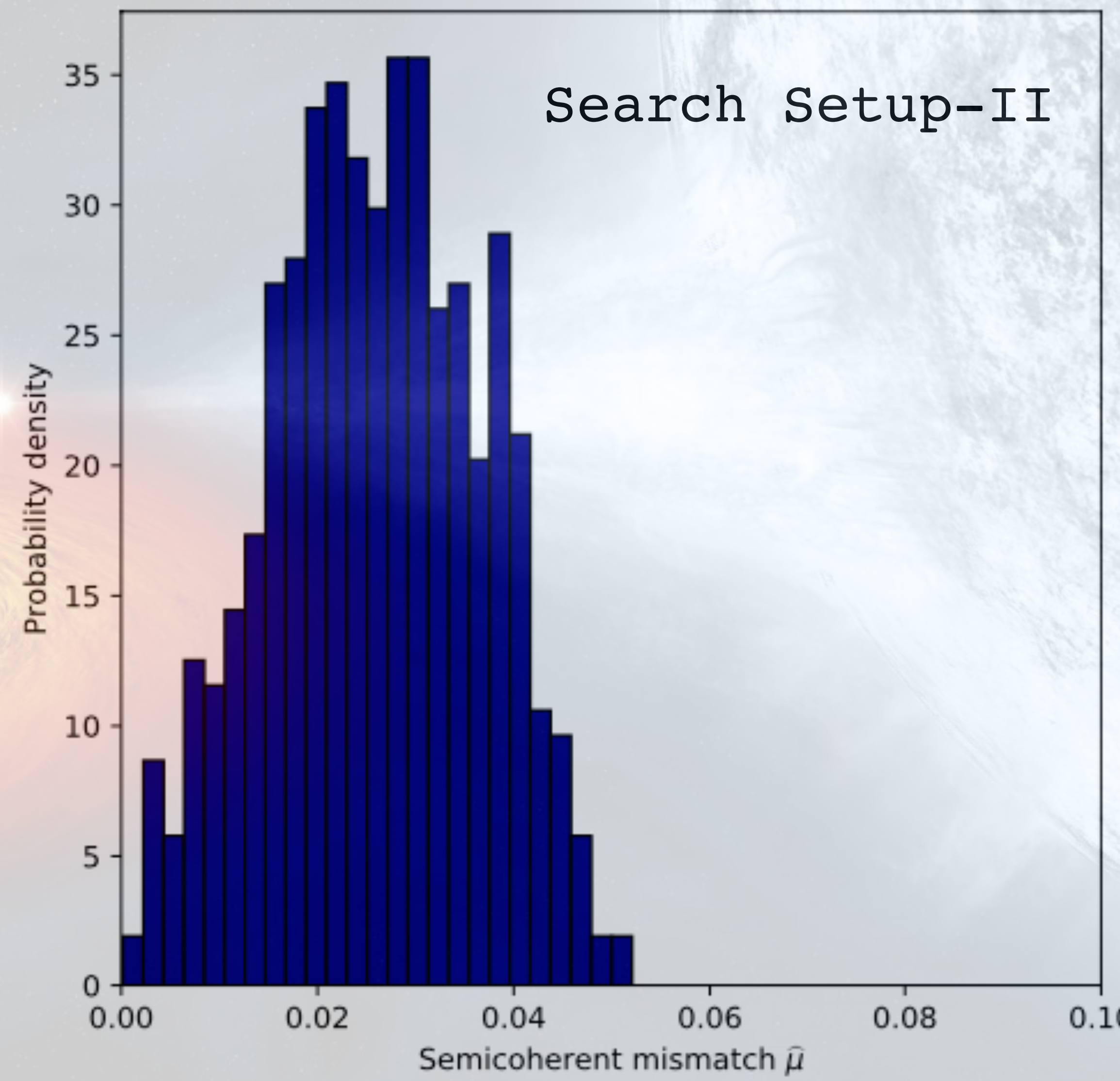
Search setup	$T_{\rm obs}$ [months]	ΔT [days]	N	$\mu_{\rm max}$
`search setup-I`	6	1	180	0.031
`search setup-II`	12	3	120	0.056

[MPW, PRD 107, 062005 (2023)]

Mismatch Distribution: Small Mismatch Test

- ❖ Two sets of 500 randomly drawn injection-recovery samples for small mismatch maximum mismatch (μ_{max}) = 0.05:





Semicoherent mismatch distribution for the 4D template bank searching {FREQ, ASINI, PERIOD, TASC} for an injected signal

[MPW, PRD 107, 062005 (2023)]

Number of Templates

Number of templates (=$\mathcal{N}$) can be calculated as:

$$\mathcal{N} = \theta_n \mu_{\max}^{-n/2} \int_{\mathcal{P}} \sqrt{\det g(\lambda)}\, d^n\lambda,$$

where,
$$\theta_n = \begin{cases} 2^{-n} n^{n/2} & \text{for } \mathbb{Z}_n, \\ \sqrt{n+1}\left[\frac{n(n+2)}{12(n+1)}\right]^{n/2} & \text{for } A_n^*. \end{cases}$$

n: number of dimension

$\mu_{\max}$: maximum mismatch

Total number of templates for the 4D search of {FREQ, ASINI, PERIOD, TASC} is:

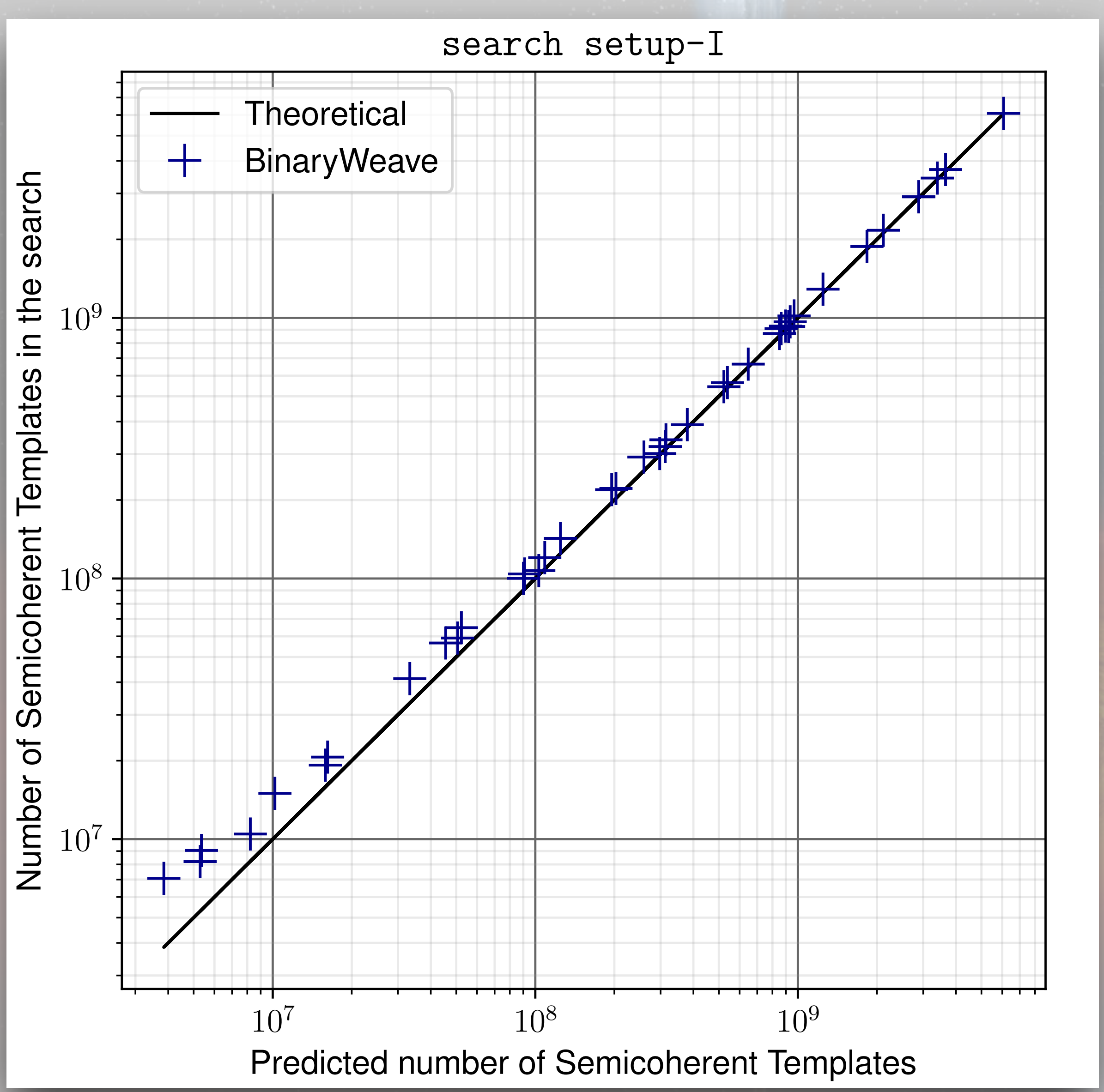
$$\hat{\mathcal{N}}_{4\mathrm{D}} = \frac{\theta_4}{\mu_{\max}^2} \frac{\pi^4 \gamma \Delta T^2}{36\sqrt{2}} (f_{\max}^4 - f_{\min}^4)(a_{\mathrm{p},\max}^{\ 3} - a_{\mathrm{p},\min}^{\ 3}) \times (\Omega_{\max}^2 - \Omega_{\min}^2)(t_{\mathrm{asc},\max} - t_{\mathrm{asc},\min}),$$

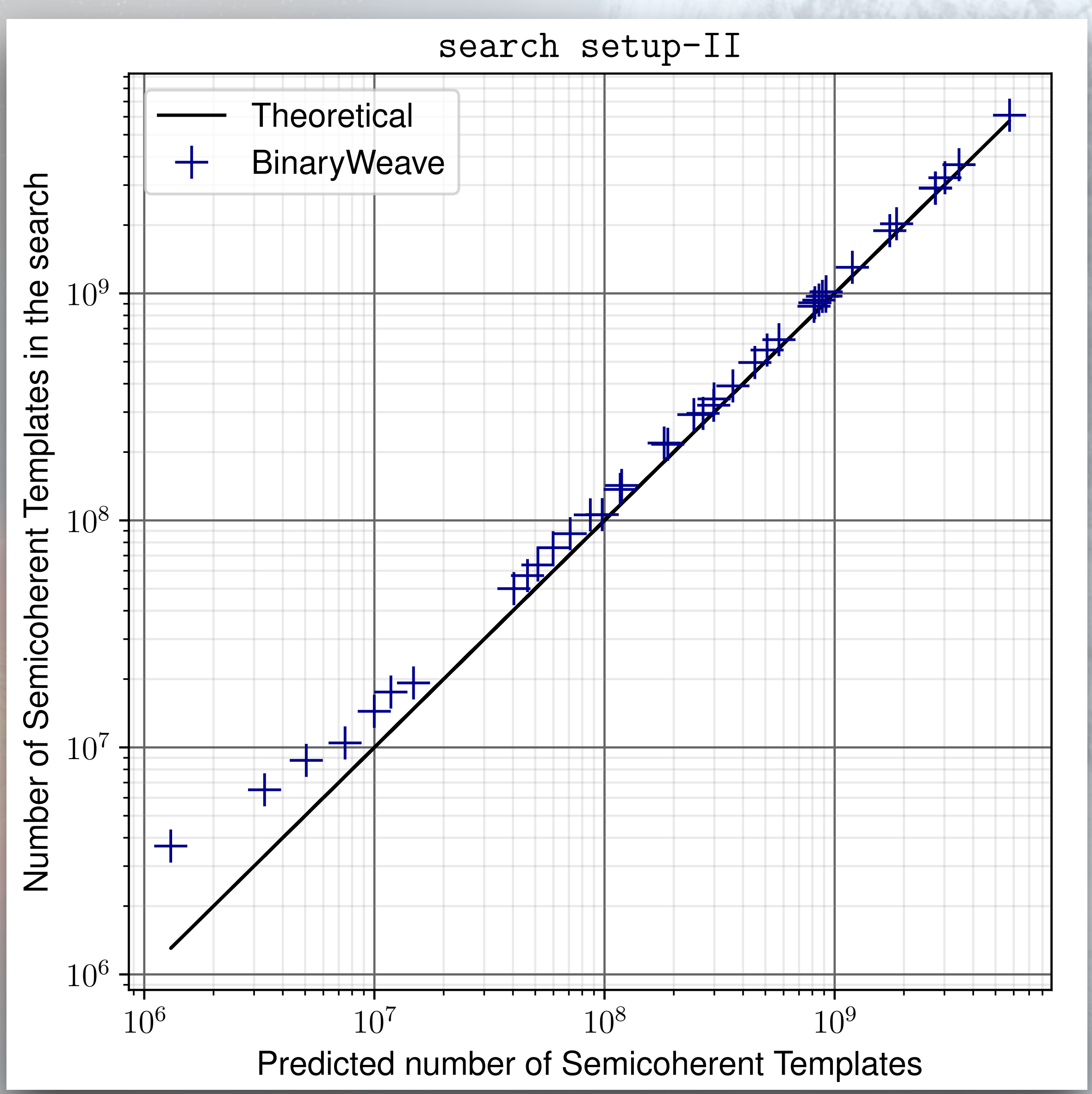
with,

$$\gamma = \sqrt{1 + 12\frac{(\overline{\Delta}_{\mathrm{ma}}^2 - \overline{\Delta_{\mathrm{ma}}^2})}{\Delta T^2}}.$$

[Leaci & Prix, PRD 91, 102003 (2015)]

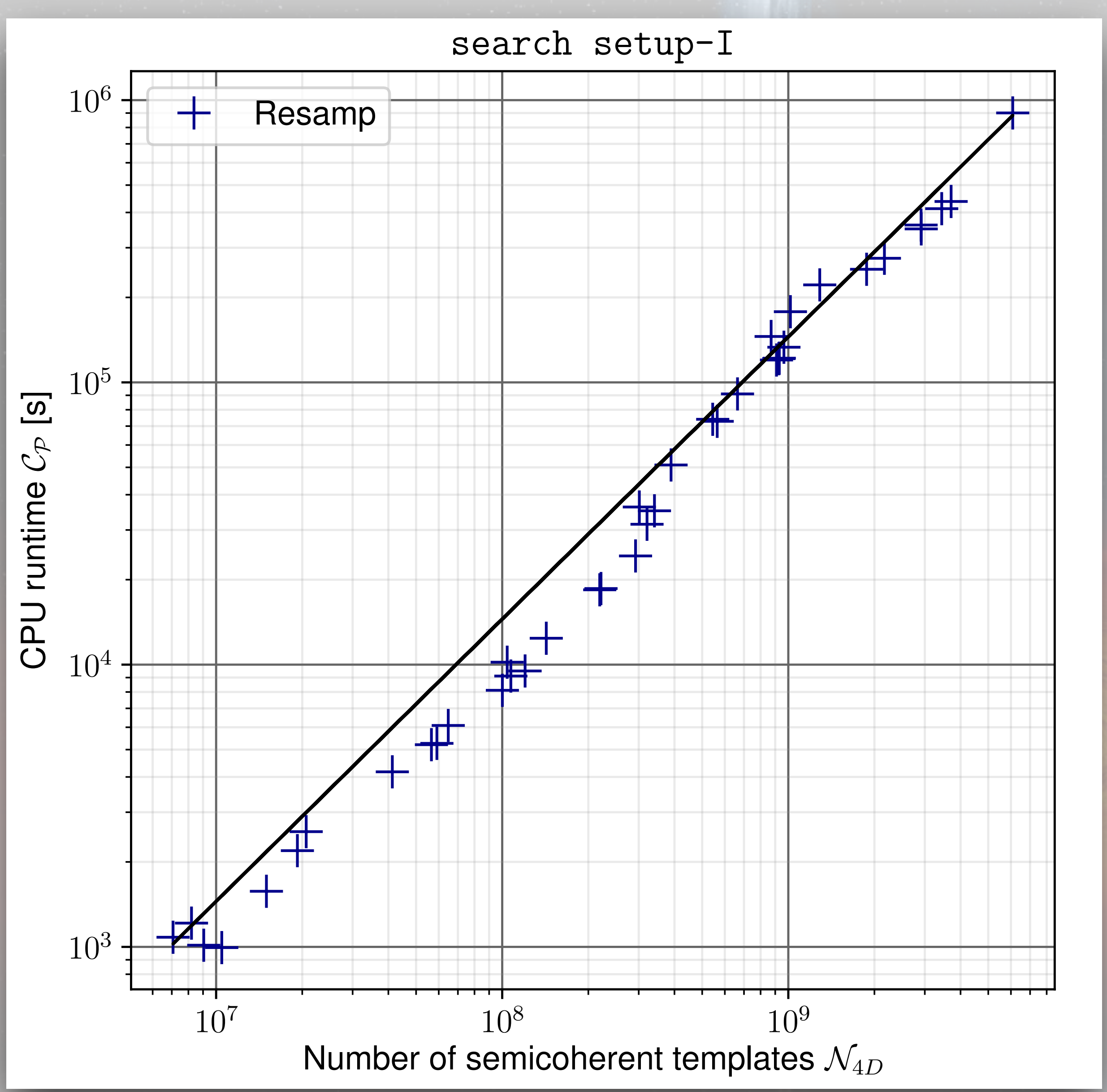
BinaryWeave: Template Bank Size

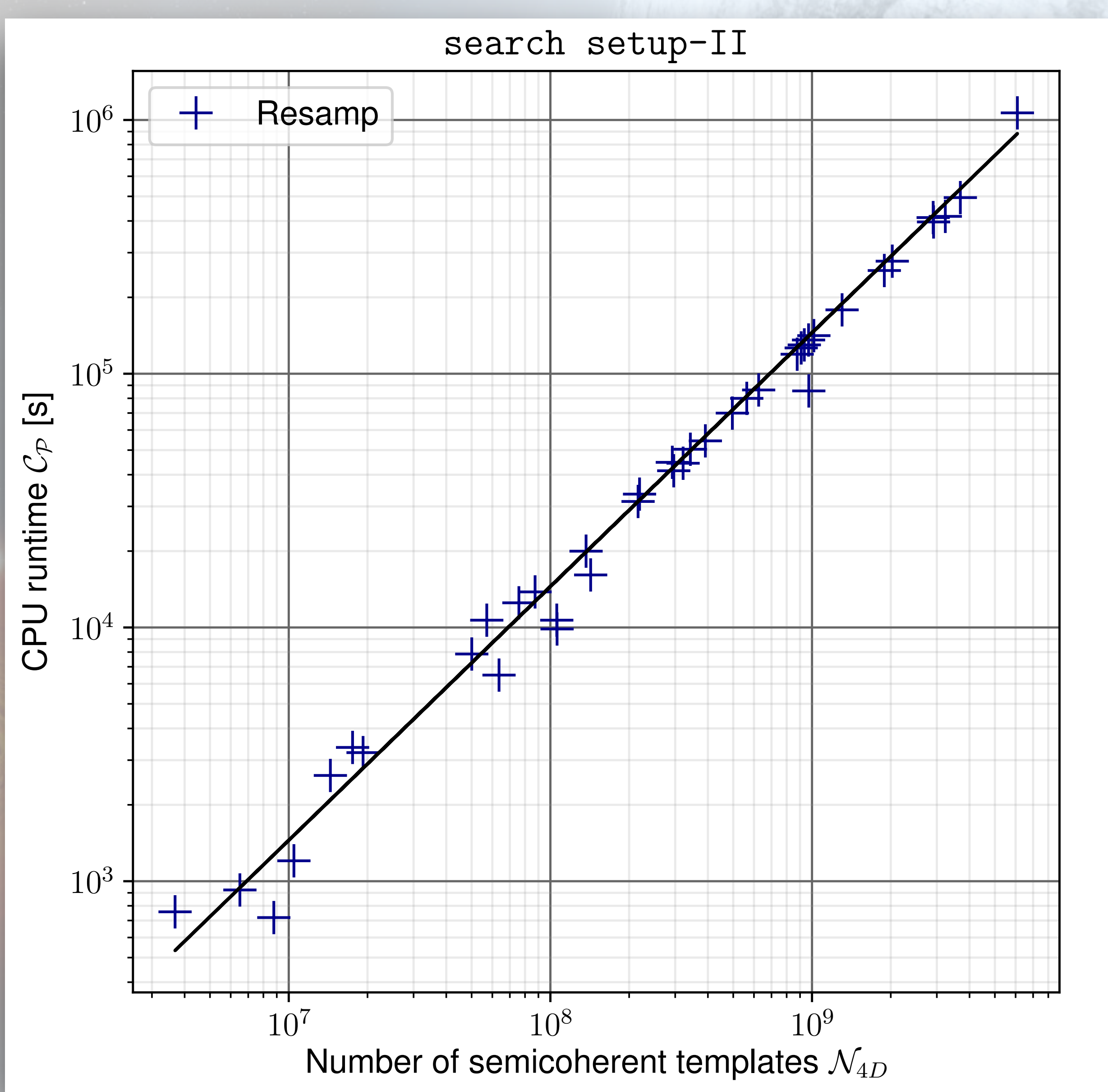




Number of semicoherent templates N_{4D} constructed by BinaryWeave versus with the theoretical predictions. Each point '+' corresponds to a simulated 4D-box search around a randomly chosen parameter-space location.

BinaryWeave: Timing Model





CPU run-time C_P per search box as a function of the number of (semi-coherent) templates N_{4D} for that box, for SEARCH SETUP-I (left plot) and SEARCH SETUP-II (right plot), defined in Table. II. The points '+' mark the measured BINARYWEAVE run times, while the solid line indicates the effective cost model prediction, using an effective cost per template of $C_t = 0.145$ms.

Sensitivity Depths

- Sensitivity Depths (with per-template false-alarm probability ‘p_{fa}’ and detection probability ‘p_{det}’) is defined as:

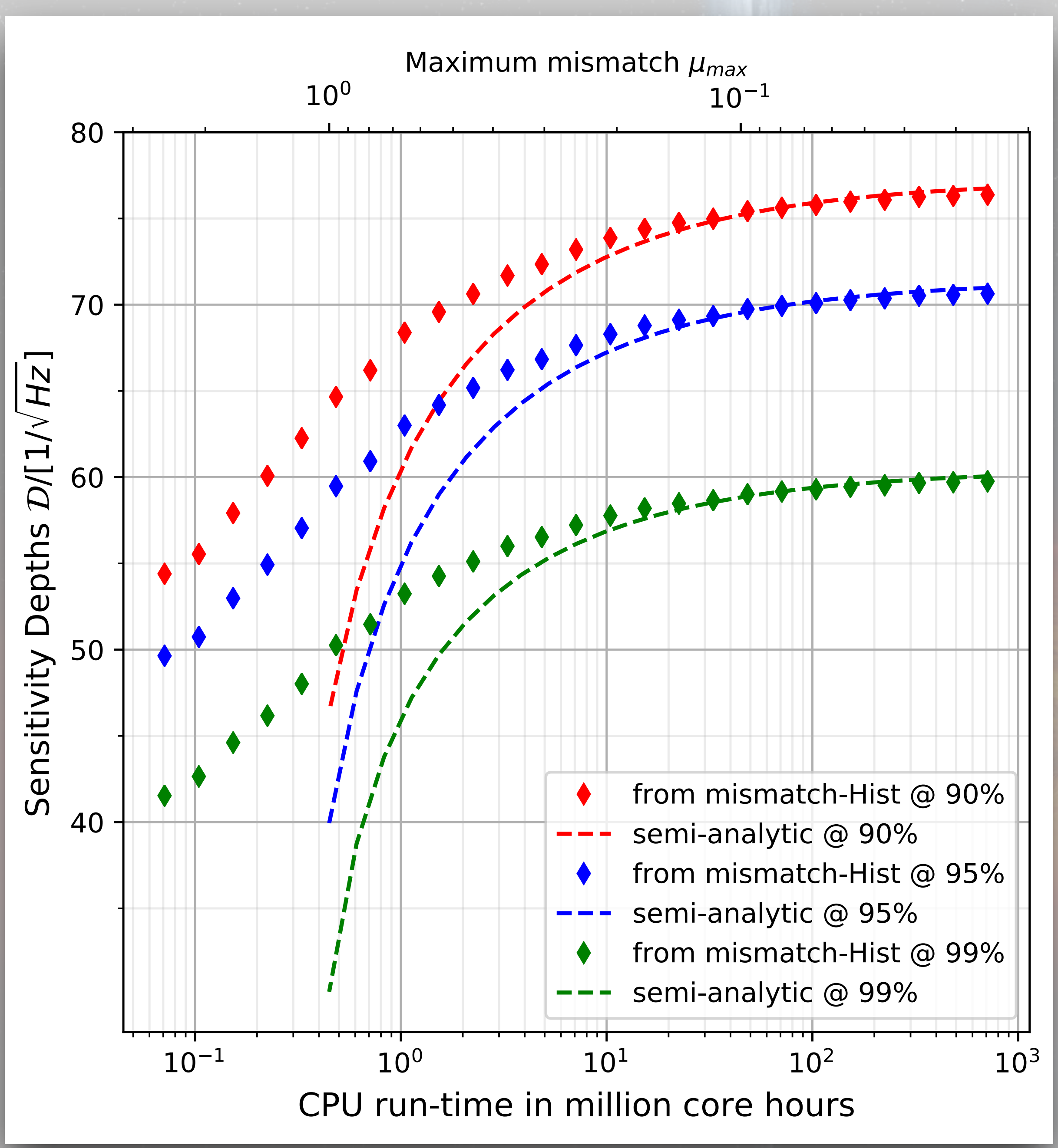
$$\mathcal{D}^{p_{\mathrm{det}}}_{p_{\mathrm{fa}}} \equiv \frac{\sqrt{S_{\mathrm{n}}}}{h^{p_{\mathrm{det}}}_{p_{\mathrm{fa}}}}$$

- Sensitivity Depths for 6 different search setups at ‘p_{fa}’ = 10^{-10} are:

Table II

Search setup	T_{obs} [months]	ΔT [days]	N	$\mu_{\max}$	$\mathcal{D}^{90\%}_{p_{\mathrm{fa}}}$ [$1/\sqrt{\mathrm{Hz}}$]	$\mathcal{D}^{95\%}_{p_{\mathrm{fa}}}$ [$1/\sqrt{\mathrm{Hz}}$]	$\mathcal{D}^{99\%}_{p_{\mathrm{fa}}}$ [$1/\sqrt{\mathrm{Hz}}$]
search setup-I	6	1	180	0.031	77	72	60
search setup-II	12	3	120	0.056	116	107	91
search setup-III	6	3	60	0.025	96	89	75
search setup-IV	12	1	360	0.025	93	86	73
search setup-V	6	10	18	0.025	120	111	94
search setup-VI	12	10	36	0.025	150	138	117

Sensitivity Depths at Different Computational Costs



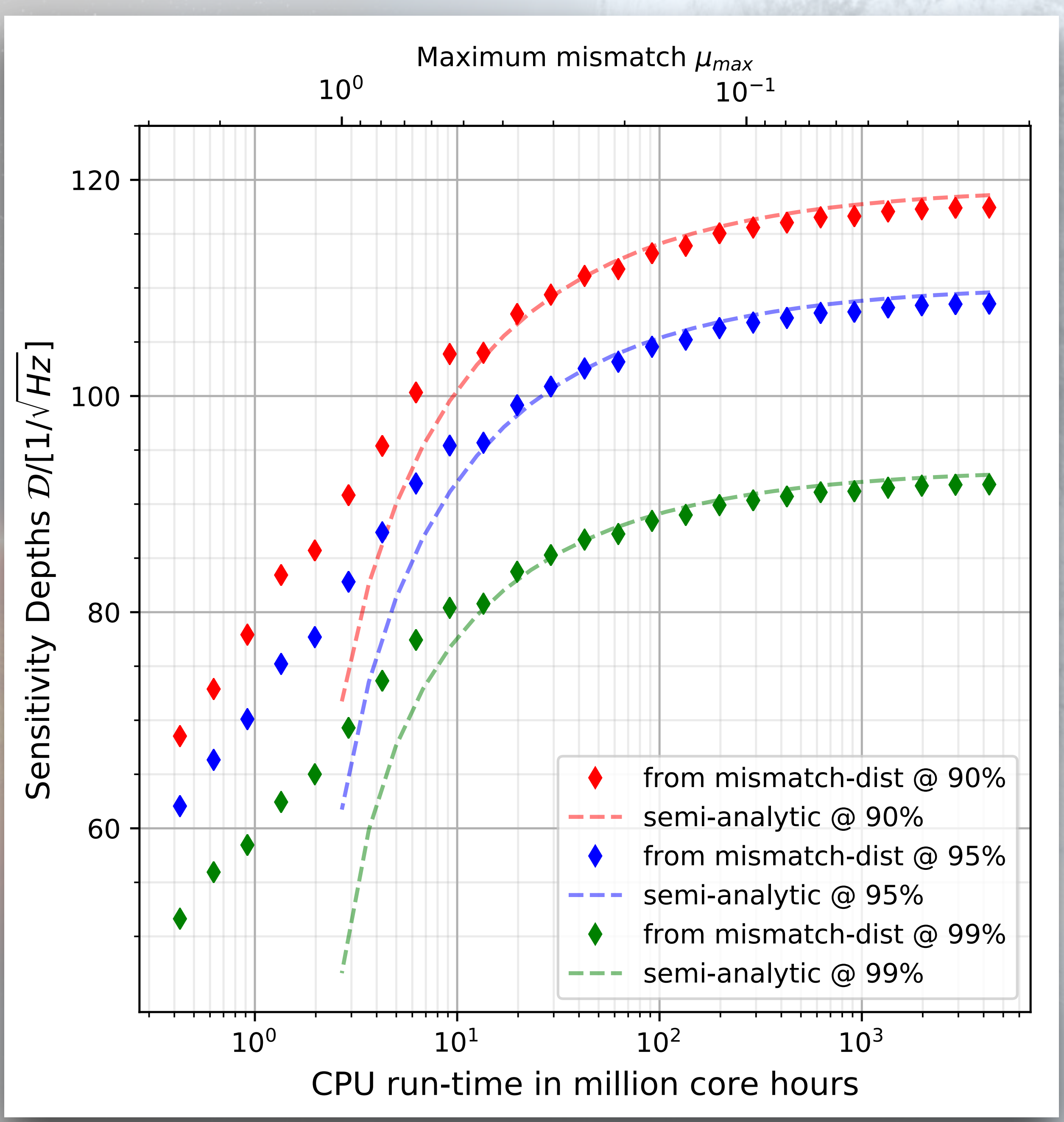


Fig: Lower-limit of search sensitivity as a function of computational cost is shown here. The left panel corresponds to SEARCH SETUP-I (T_{obs} = 180 days, T_{seg} = 1 day) and the right-panel corresponds to SEARCH SETUP-II (T_{obs} = 360 days, T_{seg} = 3 days).

[MPW, PRD 107, 062005 (2023)]

What BinaryWeave Can Say About High Frequency/Larger Parameter Space Search?

Observational Scenarios: Different Parameter Spaces

Table III

Search space $\mathcal{P}$	f [Hz]	a_p [ls]	P_{orb} [s]	t_{asc} [GPS s]	Reference(s)/comment(s)
$\mathcal{P}_0$	10–700	0.3–3.5	68023.7 $\pm$ 0.2	1124044455.0 $\pm$ 1000	BinaryWeave test range
$\mathcal{P}_1$	20–500	1.26–1.62	68023.70496 $\pm$ 0.0432	897753994 $\pm$ 100	Leaci and Prix [36]
$\mathcal{P}_2$	60–650	1.45–3.25	68023.86048 $\pm$ 0.0432	974416624 $\pm$ 50	Abbott *et al.* [28]
$\mathcal{P}_3$	40–180	1.45–3.25	68023.86 $\pm$ 0.12	1178556229 $\pm$ 417	Zhang *et al.* [29]
$\mathcal{P}_4$	600–700				
$\mathcal{P}_5$	1000–1100				
$\mathcal{P}_6$	1400–1500	1.45–3.25	68023.70496 $\pm$ 0.0432	974416624 $\pm$ 100	different ranges in frequency
$\mathcal{P}_7$	20–250				with broad range in a_p
$\mathcal{P}_8$	20–1000				
$\mathcal{P}_9$	20–1500				
$\mathcal{P}_{10}$	600–700				
$\mathcal{P}_{11}$	1000–1100				
$\mathcal{P}_{12}$	1400–1500	1.40–1.50	68023.70496 $\pm$ 0.0432	974416624 $\pm$ 100	different ranges in frequency
$\mathcal{P}_{13}$	20–500				with narrow range in a_p
$\mathcal{P}_{14}$	20–1000				
$\mathcal{P}_{15}$	20–1500				
$\mathcal{P}_{16}$	600–700				
$\mathcal{P}_{17}$	1000–1100				
$\mathcal{P}_{18}$	1400–1500	1.44–1.45	68023.70496 $\pm$ 0.0432	974416624 $\pm$ 100	different ranges in frequency
$\mathcal{P}_{19}$	20–500				with well-constrained a_p
$\mathcal{P}_{20}$	20–1000				
$\mathcal{P}_{21}$	20–1500				

Different parameter space search regions considered for Sco X-1. $\mathcal{P}_0$ has been used in this study as a test range for various Monte-Carlo tests of BinaryWeave. $\mathcal{P}_{1-3}$ represent observational constraints considered in recent CW searches and studies. In addition, various combinations of parameter-ranges are considered, $\mathcal{P}_{4-21}$, in order to explore the impact of improved observation constraints and reduced search ranges.

[MPW, PRD 107, 062005 (2023)]

Computational Costs for Different Parameter Space

Table IV

	(I,3D)	(I,4D)	(II,3D)	(II,4D)
$\mathcal{P}_1$	3.18	23.51	3.93	43.23
$\mathcal{P}_2$	28.50	466.48	35.22	857.69
$\mathcal{P}_3$	5.00	63.40	6.17	116.57
$\mathcal{P}_4$	26.38	577.57	32.60	1061.95
$\mathcal{P}_5$	68.76	2425.79	84.96	4460.17
$\mathcal{P}_6$	131.09	6381.48	161.97	11733.30
$\mathcal{P}_7$	3.24	20.42	4.01	37.54
$\mathcal{P}_8$	207.74	5226.87	256.69	9610.37
$\mathcal{P}_9$	701.14	26461.02	866.33	48652.49
$\mathcal{P}_{10}$	0.90	11.65	1.12	21.42
$\mathcal{P}_{11}$	2.36	48.94	2.91	89.97
$\mathcal{P}_{12}$	4.49	128.73	5.55	236.70
$\mathcal{P}_{13}$	0.11	0.41	0.14	0.76
$\mathcal{P}_{14}$	7.12	105.44	8.80	193.87
$\mathcal{P}_{15}$	24.03	533.80	29.70	981.46
$\mathcal{P}_{16}$	0.09	1.16	0.11	2.13
$\mathcal{P}_{17}$	0.23	4.86	0.29	8.93
$\mathcal{P}_{18}$	0.45	12.78	0.55	23.50
$\mathcal{P}_{19}$	0.01	0.04	0.01	0.08
$\mathcal{P}_{20}$	0.71	10.47	0.88	19.25
$\mathcal{P}_{21}$	2.40	52.99	2.96	97.43

- Computing-cost estimates in million core hours [Mh] for different parameter spaces $\mathcal{P}_n$ (n = 1, 2, …, n) defined in Table. III.
- We consider two setups, SEARCH SETUP-I and SEARCH SETUP-II of Table I, assuming either a 3D or 4D template-bank.

3D search: FREQ, ASINI, TASC
4D search: FREQ, ASINI, PORB, TASC

Table I

Search setup	$T_{\rm obs}$ [months]	ΔT [days]	N	$\mu_{\rm max}$
`search setup-I`	6	1	180	0.031
`search setup-II`	12	3	120	0.056

[MPW, PRD 107, 062005 (2023)]

Prospective Future Direction

- Communicate with **EM-observations for better constraints** on orbital parameters and spin-frequency of NS in Sco X-1: e.g. X-ray/Optical/IR/radio observers?

- Thoroughly searching for X-ray pulsation from Sco X-1 (*detection will be the game-changer!*) => challenging but worthwhile [Galaudage et al., MNRAS **509,** 1745 (2022)]

- Convince the EM-observer to make an updated observation of P_{ORB} and T_{ASC} near the middle of an observing run to maximise the benefits

  ➡ It is worth exploring if long-term (~ 5-10 yrs) phase-evolution of Sco X-1 binary orbit can provide stricter constraints on P_{ORB} and T_{ASC}

- Perhaps communicating with larger community to regarding tighter constraints on ASINI

  ➡ It will need deep observations in optical/IR/radio bands dedicated for this purpose; it will be critical for a breakthrough!

- Possibility of implementing GPU-based computation of $\mathcal{F}$-statistic (e.g., CUDA, OpenCL?) [Wette et al., PRD 103, 083020]

- Spin-wandering effect due to stochastic accretion rate [AM, Messenger & Riles, PRD 97, 043016 (2018)] has been neglected in this study; worth incorporating Viterbi-like summing of segments for $\mathcal{F}$-statistic [Melatos et al., PRD 104, 042003 (2021)]

References Important for BinaryWeave

1. P. Leaci & R. Prix, Phys. Rev. D 91, 102003 (2015)
2. CW F2F presentation by K. Wette at LVC-meeting, Glasgow (2016); DCC: <LIGO-G1601794-v2>
3. K. Wette, Phys. Rev. D 90, 122010 (2014)
4. K. Wette, S. Walsh, R. Prix, M. A. Papa, Phys. Rev. D 97, 123016 (2018)
5. P. Jaranowski, A. Krolak, and B. F. Schutz, Phys. Rev. D 58, 063001 (1998) [JKS]
6. R. Prix, Phys. Rev. D 75, 023004 (2007)
7. R. Prix, Classical Quantum Gravity 24, S481 (2007)
8. CW F2F presentation by R. Prix at LVC-meeting, Budapest (2015); DCC: <LIGO-G1501145-v2>
9. K. Wette, Phys. Rev. D 90, 122010 (2014)
10. A. Mukherjee, R. Prix, and K. Wette, Phys. Rev. D 107, 062005 (2023) [MPW]


THANK YOU!

Backup Slides

Optimal Covering Lattice OR Optimal Detection Lattice?

- Recently in a series of papers, Allen et. al. pointed out that an optimal covering lattice is NOT necessarily an optimal detection lattice

- The quantity that maximises detection probability is the optimal lattice quantiser [B. Allen, PRD (2021), B. Allen and E. Agrell, Ann. der Phys. (2021), B. Allen and A. Shoom, PRD (2021)]

- The quantiser constant $\mathcal{G}$ is the second moment, i.e., average squared distance from the nearest templates [B. Allen, PRD (2021)]

- However, it turned out that the advantage of optimal detection lattices (as pointed out by Allen+) offer only marginal improvements [B. Allen and A. Shoom, PRD (2021)]

➡ A^*_n lattices seem to be near-optimal choice for n = 3 - 8 dim