BayesHopper

Joint Search for Isolated Sources and a Stochastic Background in PTA Data

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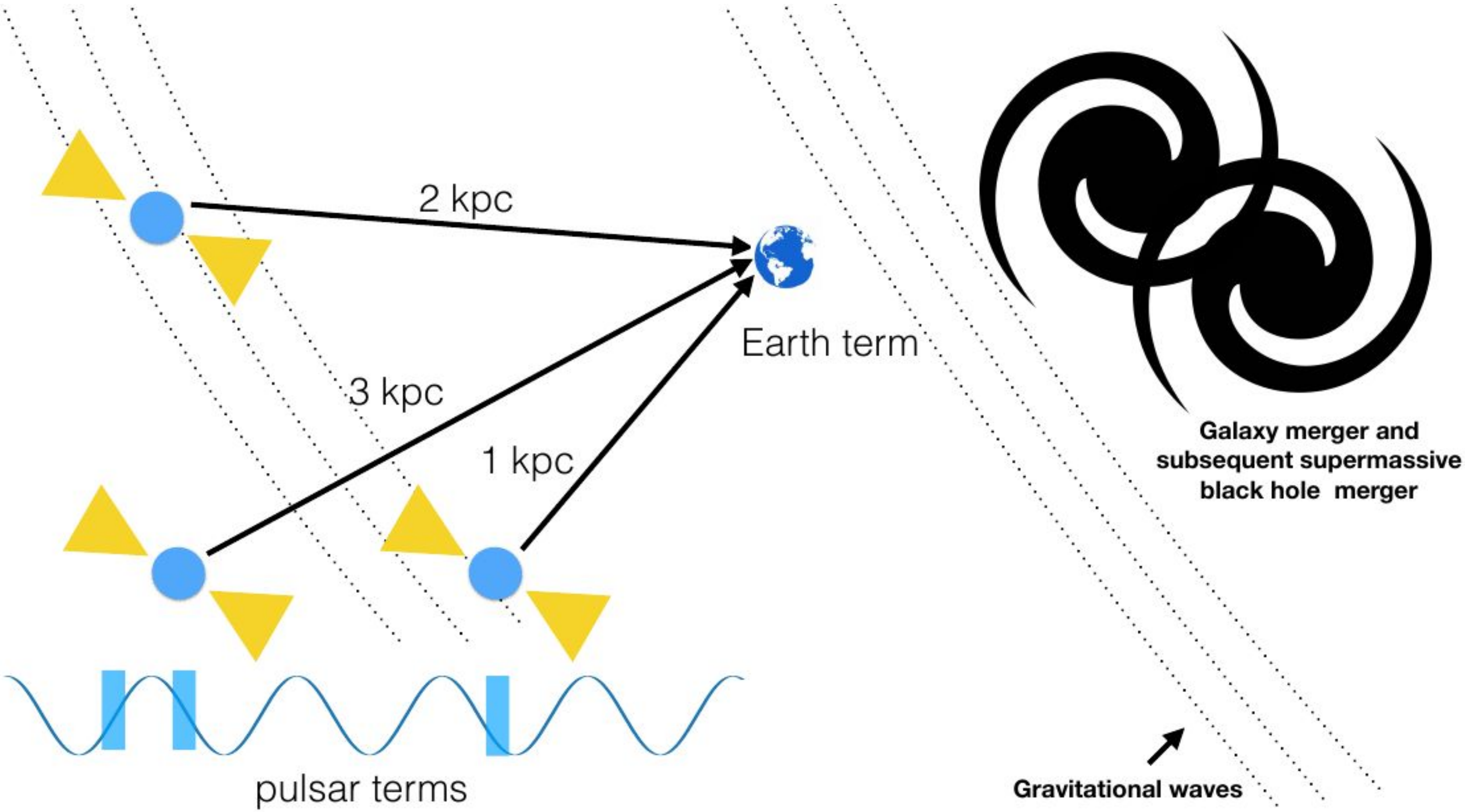
MONTANA STATE UNIVERSITY

eXtreme Gravity Institute

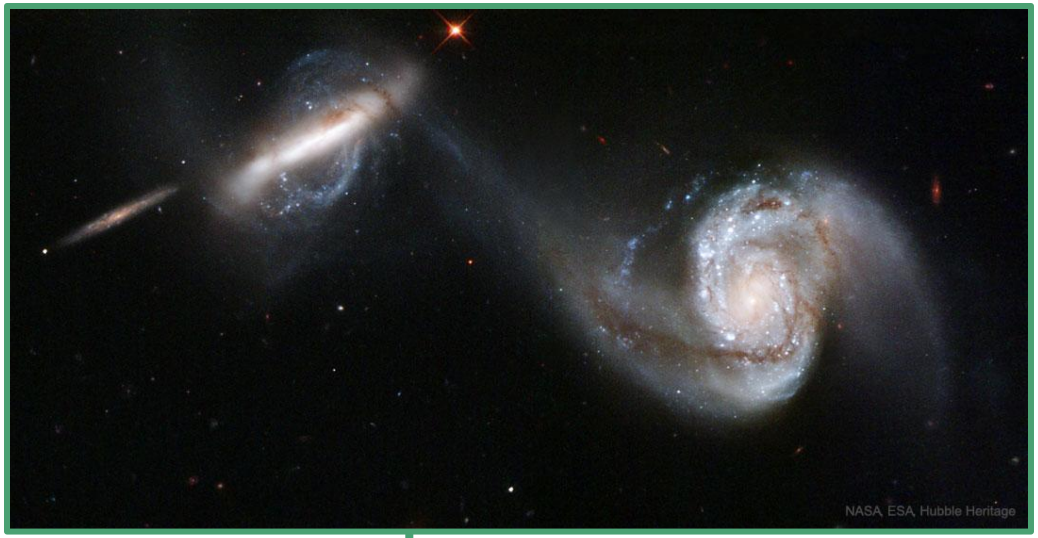
Gravitational Wave Astronomy Northwest Meeting
06/29/2020

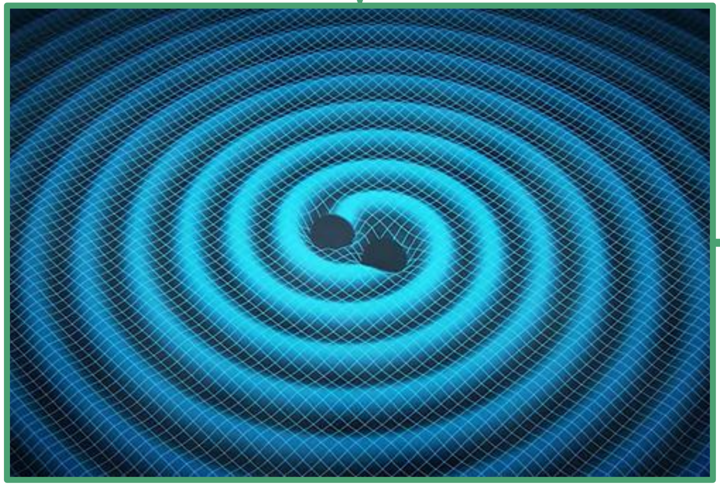
Pulsar Timing Arrays



[1] Image credit: Burke-Spolaor, Taylor et al. (2018) arXiv:1811.08826

nHz gravitational wave sources





× many

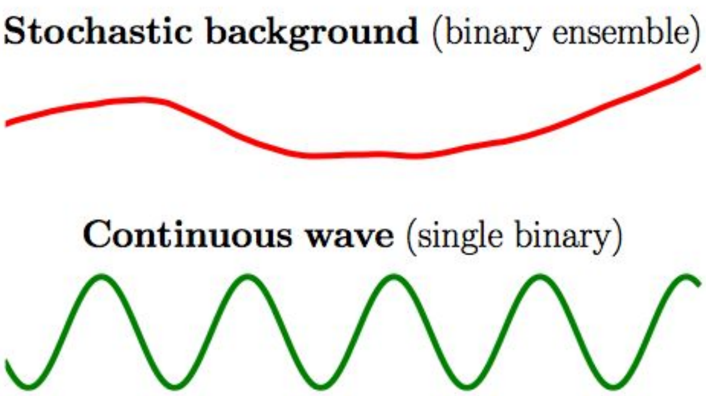
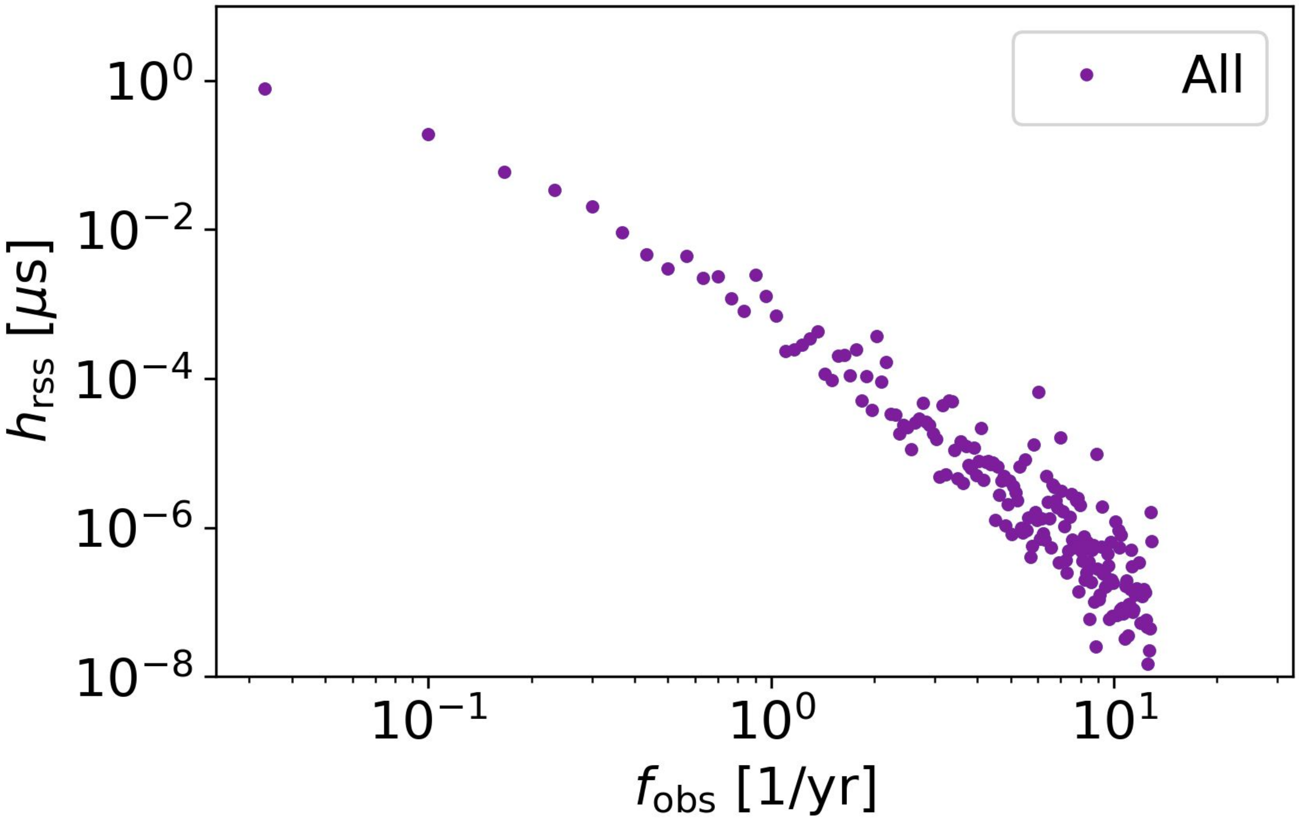


Image credit: [1] NASA, ESA, Hubble Heritage Team (STScI, AURA), APOD (apod.nasa.gov/apod/ap190811.html); [2] Swinburne Astronomy Productions; [3] NANOGrav Public Slide Deck (http://nanograv.org/press/)

Motivation - true model vs. best model

∼3.7 million simulated BBH source - 15 yr baseline



Dataset: Kelley et al. (2017) arXiv:1711.00075

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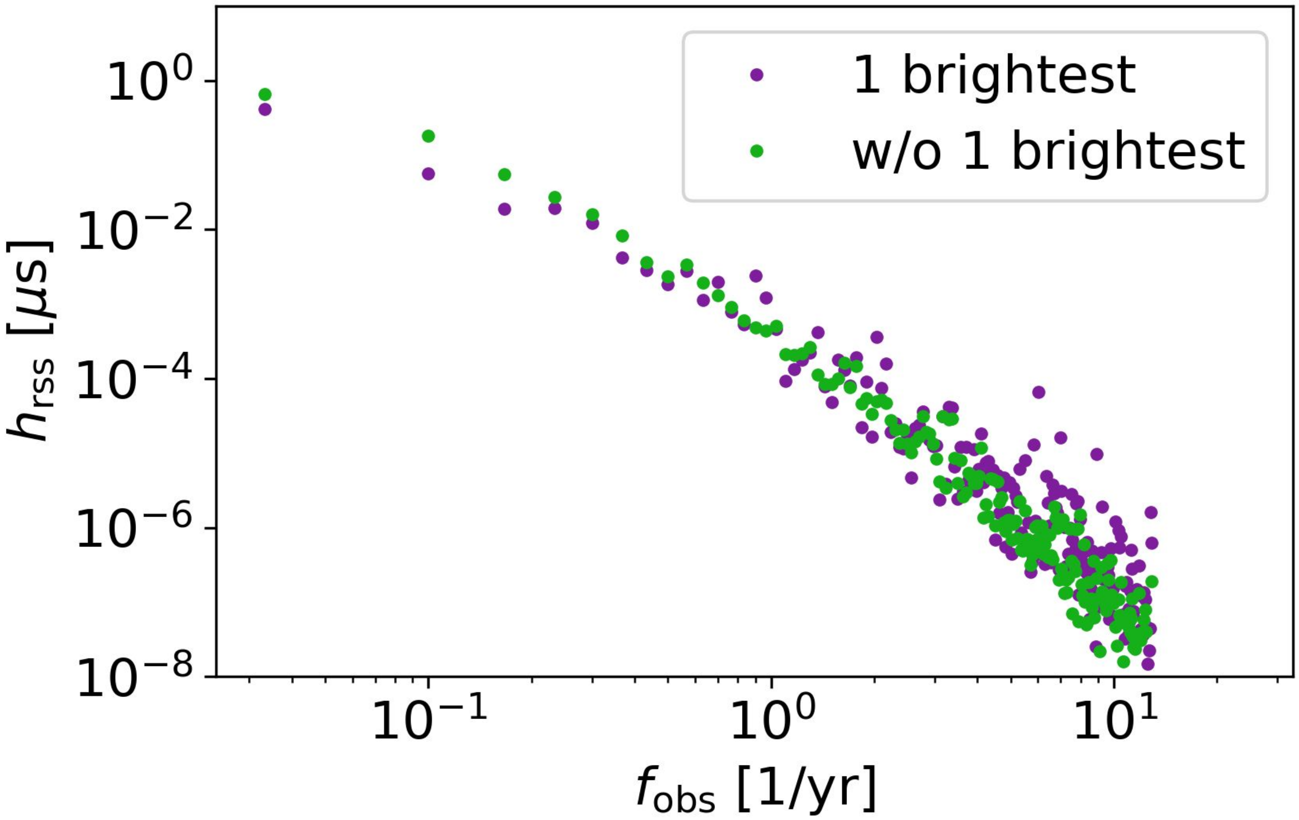

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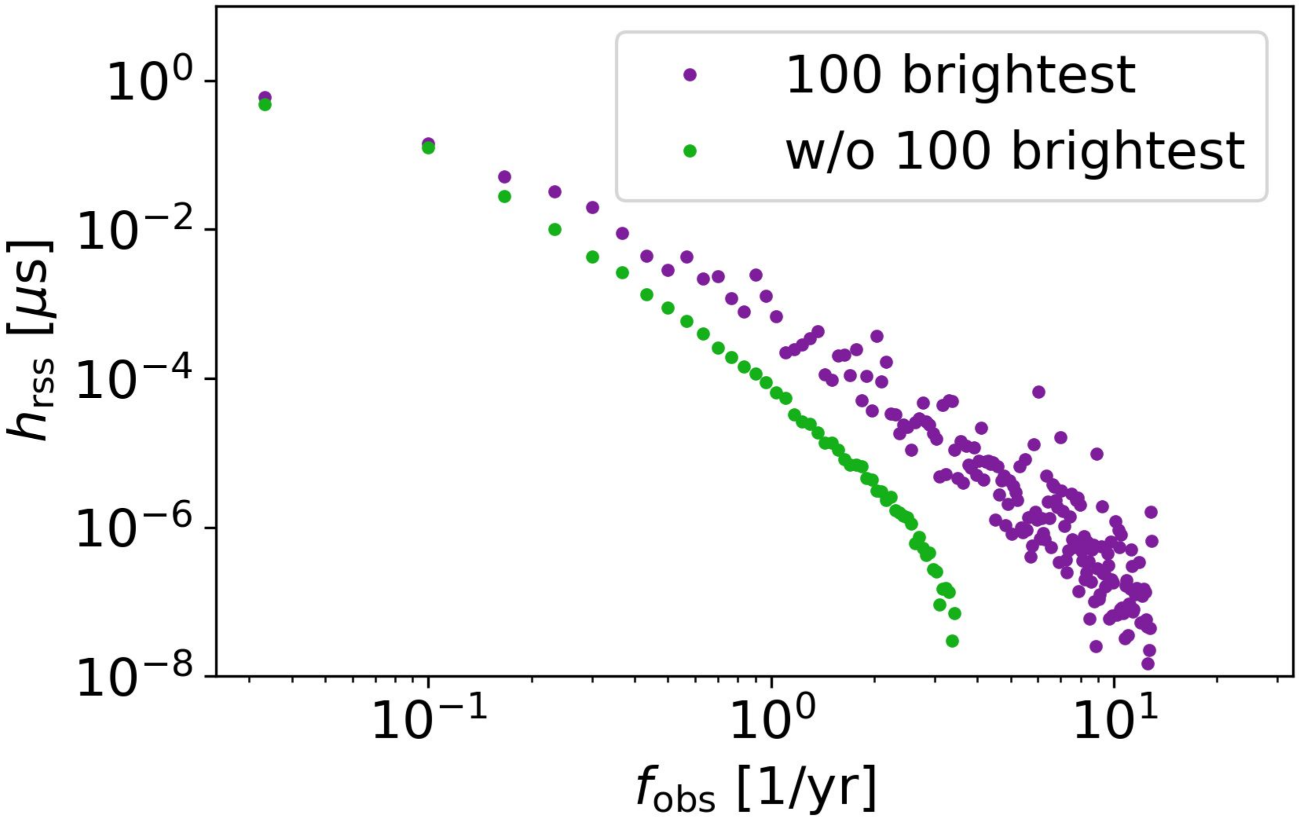

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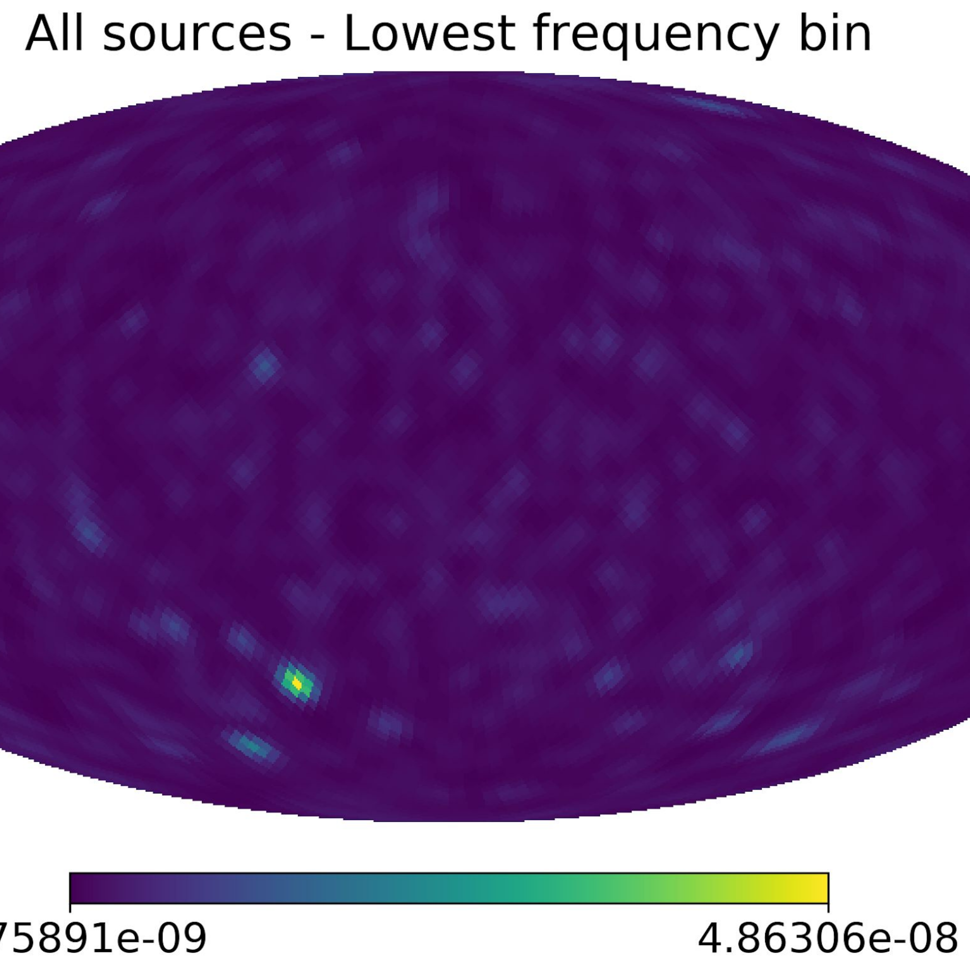

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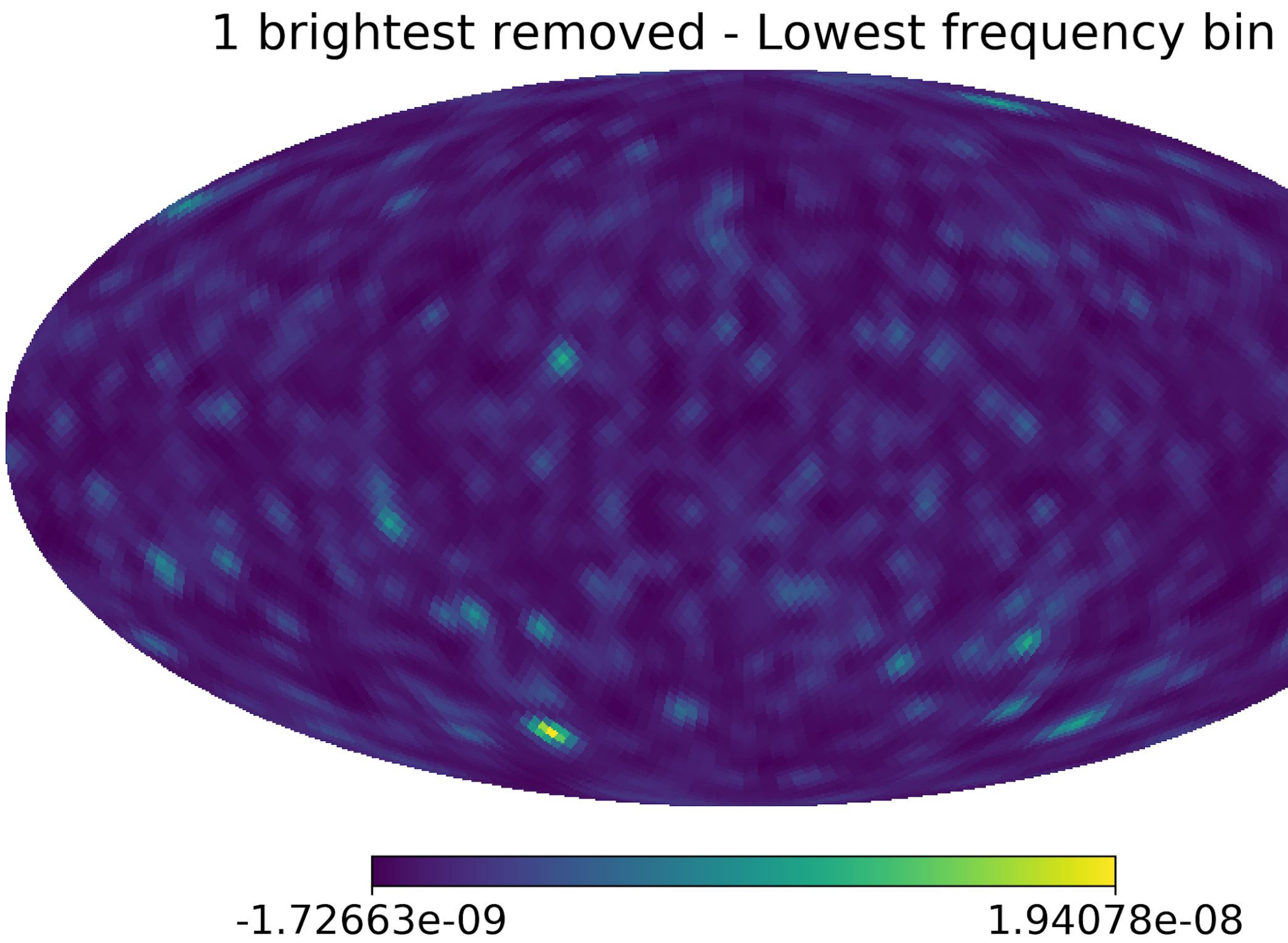

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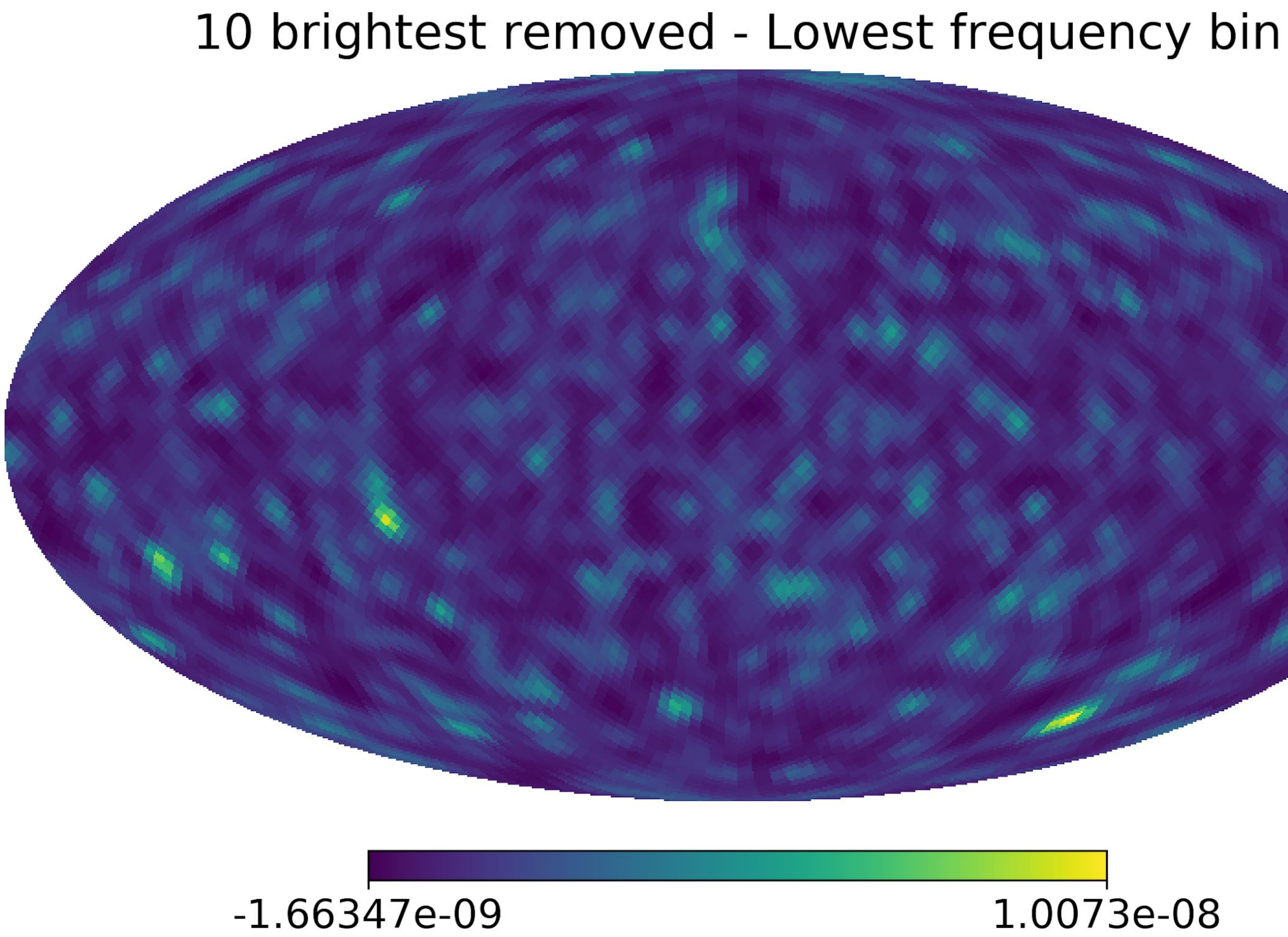

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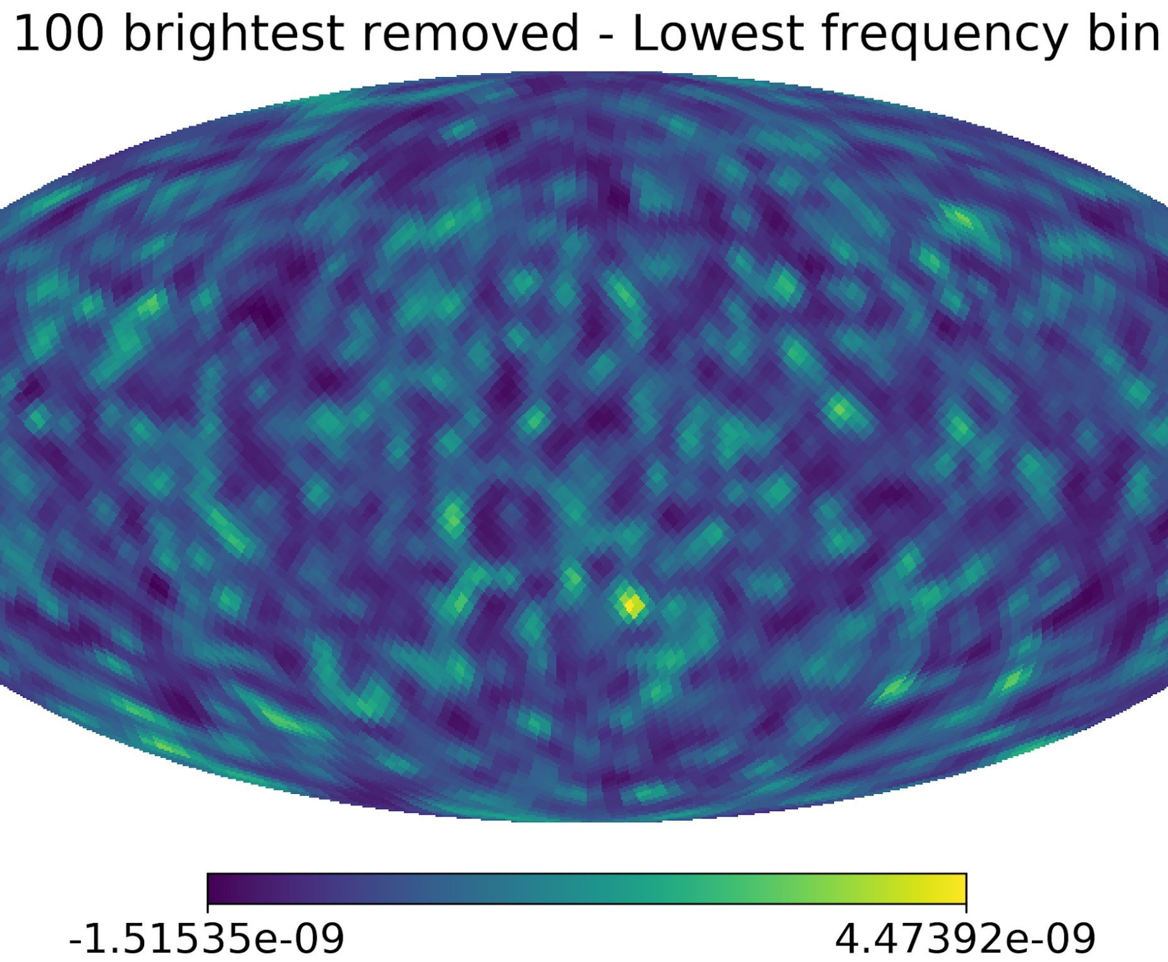

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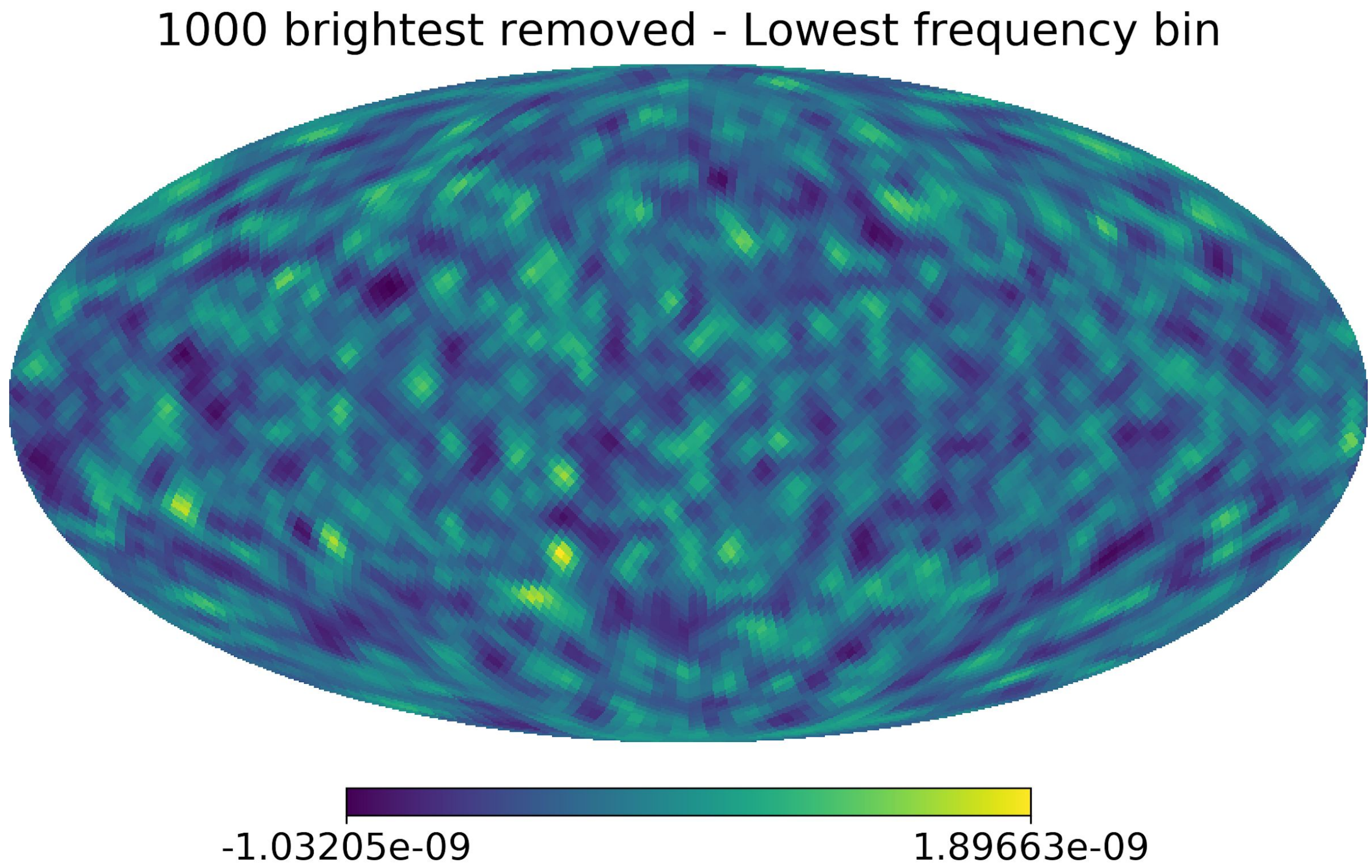

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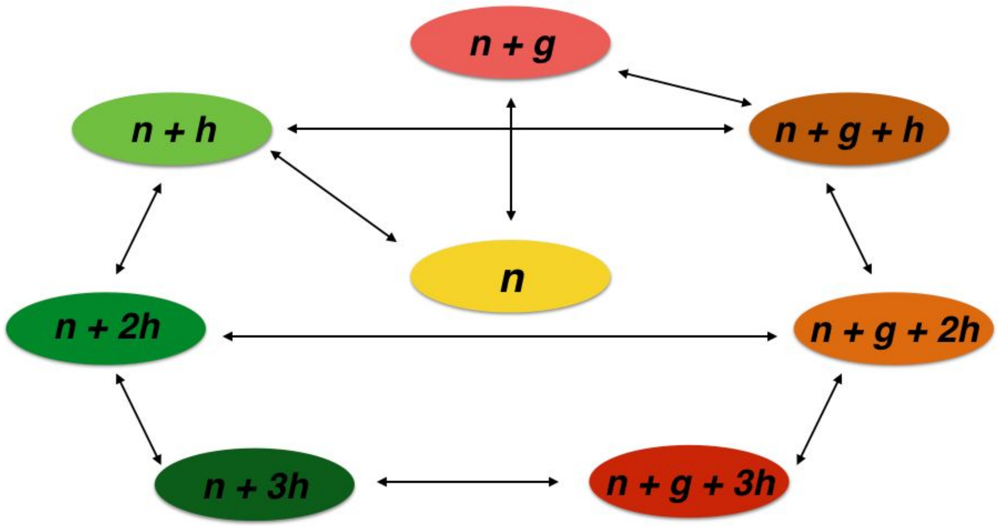
BayesHopper

Joint search for isolated sources and an unresolved background

→ Trans-dimensional MCMC



n: Gaussian noise

h: individual black hole binary

g: stochastic GW background

Paper: Bécsy & Cornish (2020) CQG 37 135011 (arXiv:1912.08807)

GitHub: https://github.com/bencebecsy/BayesHopper

MCMC proposals

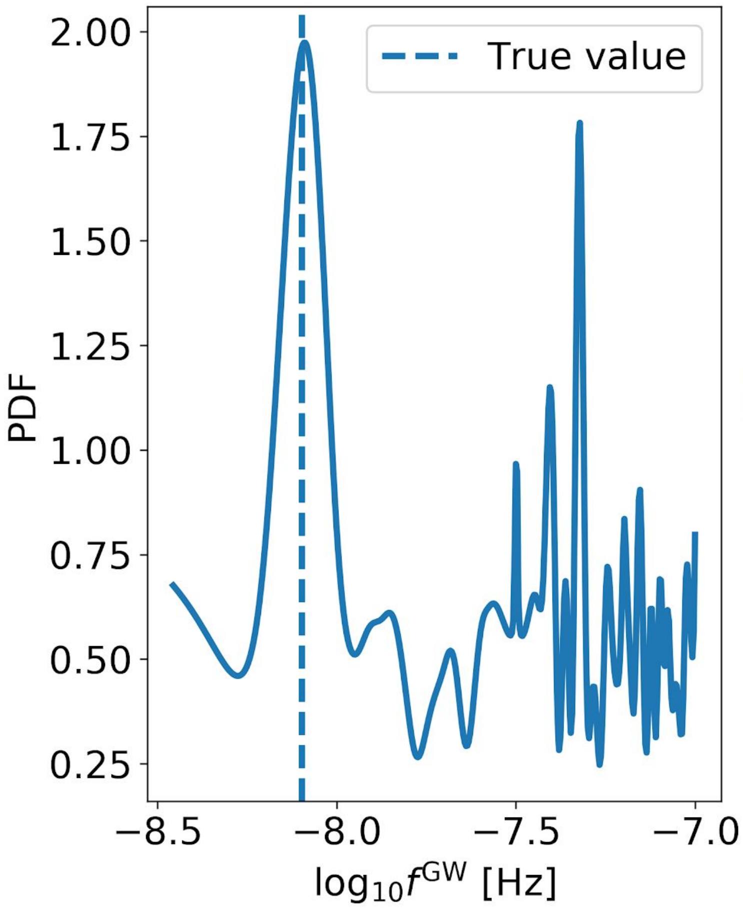
1) Fisher jumps
2) Parallel tempering
3) Add/remove a CW source (also using Fe-statistic)
4) Add/remove GW background
5) **Global proposal based on F_e-statistic**

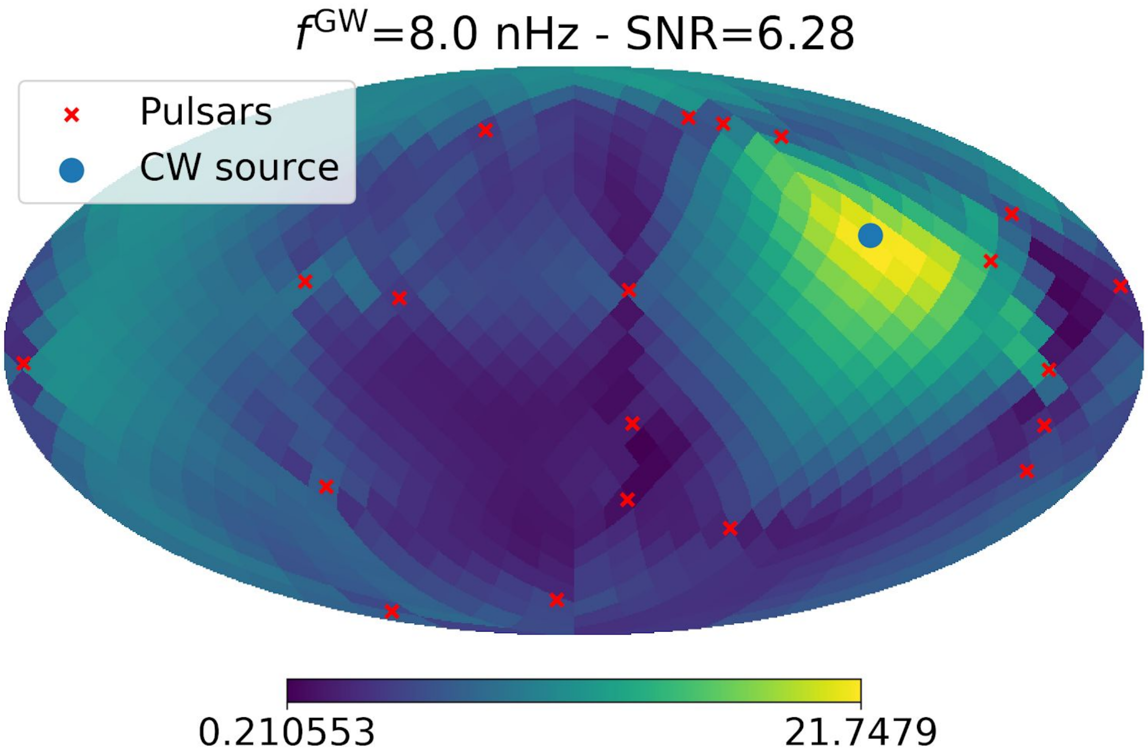
Likelihood = p(d|θ)

Θ = {frequency, sky location(2), inclination, polarization angle, initial phase, amplitude}

4 out of 7 parameters can be analytically maximized over ➜ F_e(frequency, sky location)

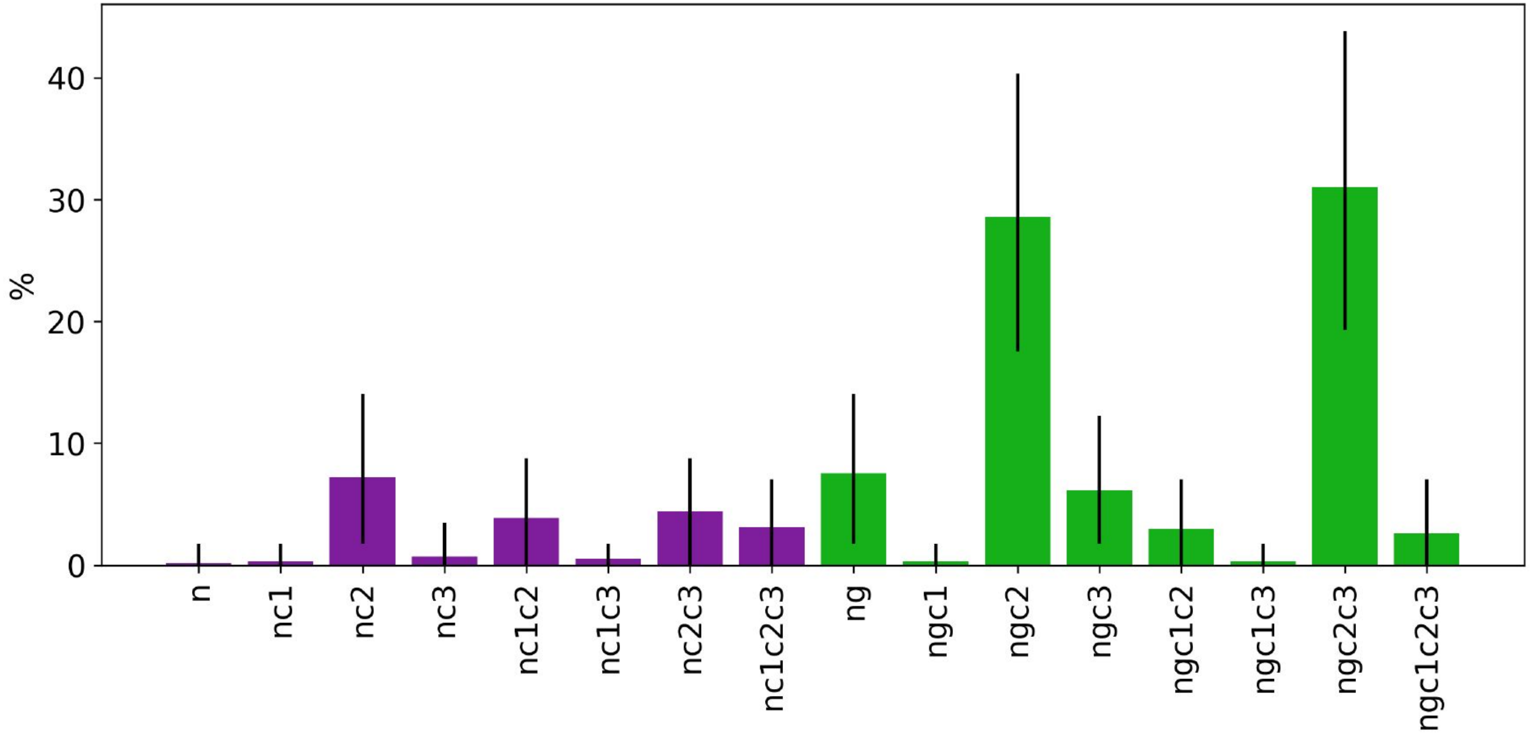
MCMC proposals



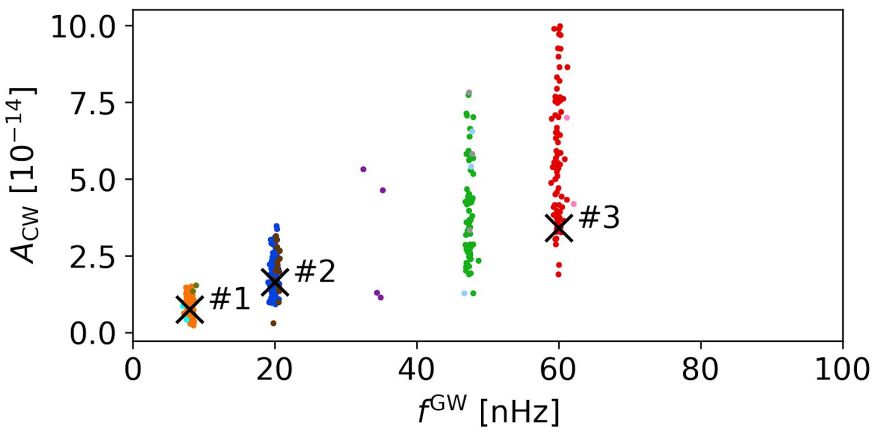


Testing on simple simulated datasets

1) Stochastic background
2) A single individual source
3) 3 individual sources
4) Stochastic background + 3 individual sources



Post-processing



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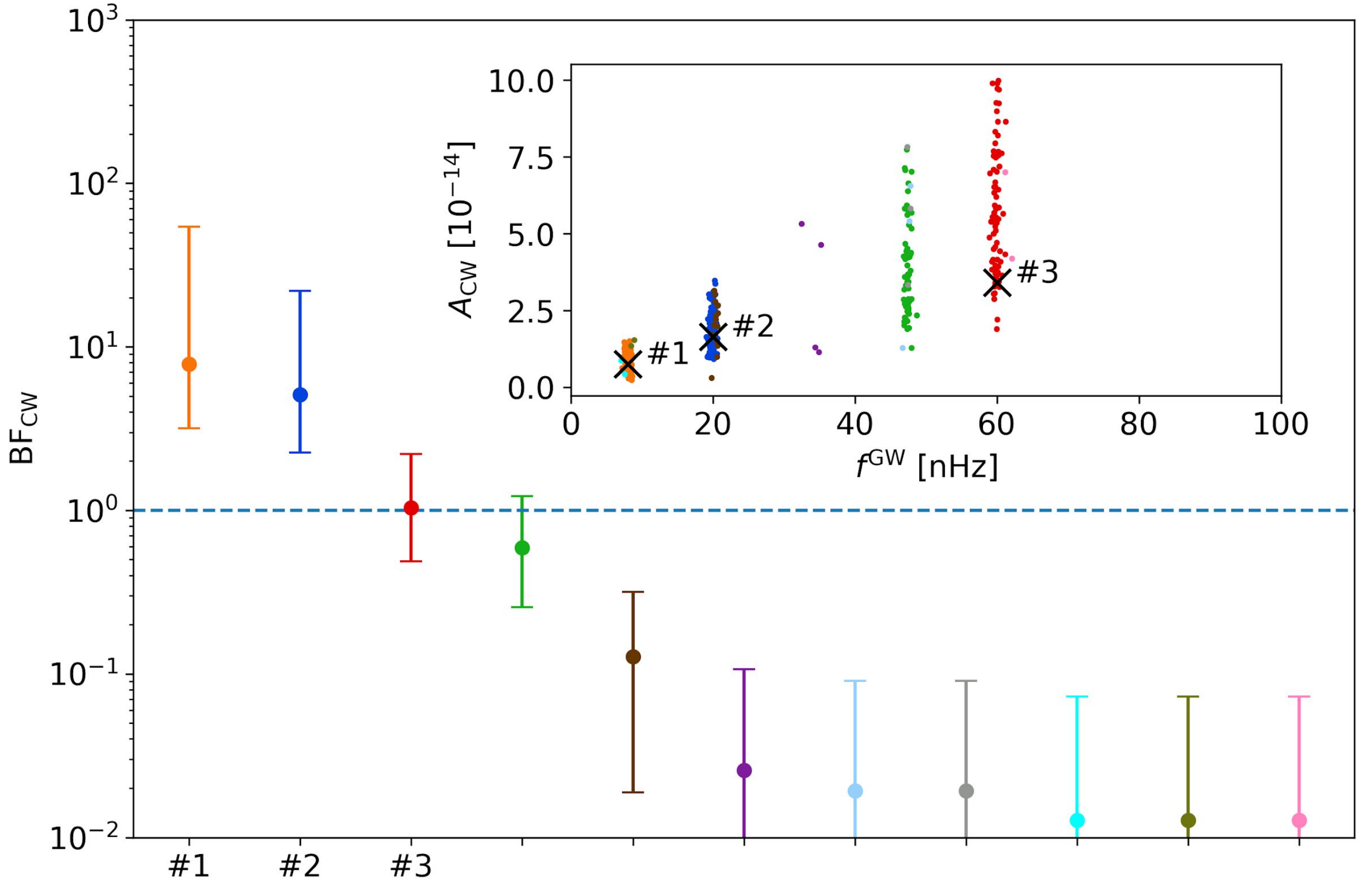


Conclusion & Future work

Conclusion

We have a working trans-dimensional sampler for PTA data.

➡ Let's use it!

Future work:

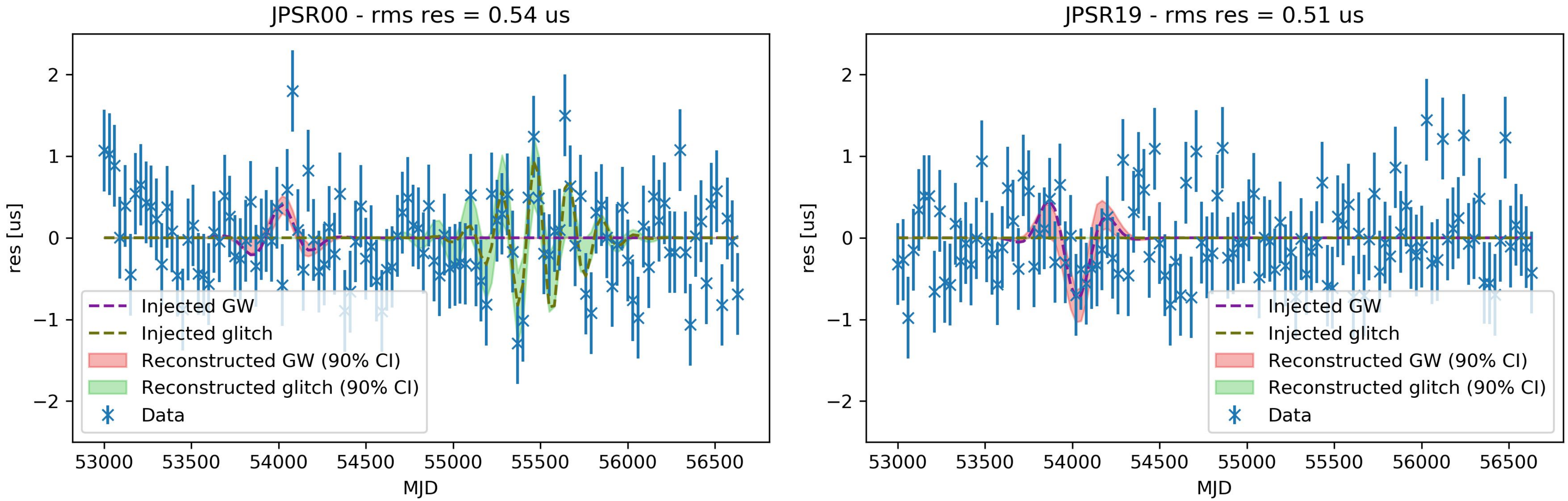
1) Multiple CW + GWB search
   a) Test on astrophysical simulated datasets (Project with Luke Kelley)
   b) Analyze NANOGrav data
2) Use same sampler with wavelets for a burst search

BayesHopperBurst

sine-Gaussian (Morlet-Gábor) wavelets form a frame ➔ "any" signal can be reconstructed

BayesWave [1] uses this for LIGO ➔ We are making the PTA version now!

Code almost done! Needs a few more details and testing on simulated datasets.



[1] Cornish and Littenberg 2015 CQG 32 135012 (arXiv:1410.3835)