Reconstructing early universe physics from future LISA data

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(they/them)

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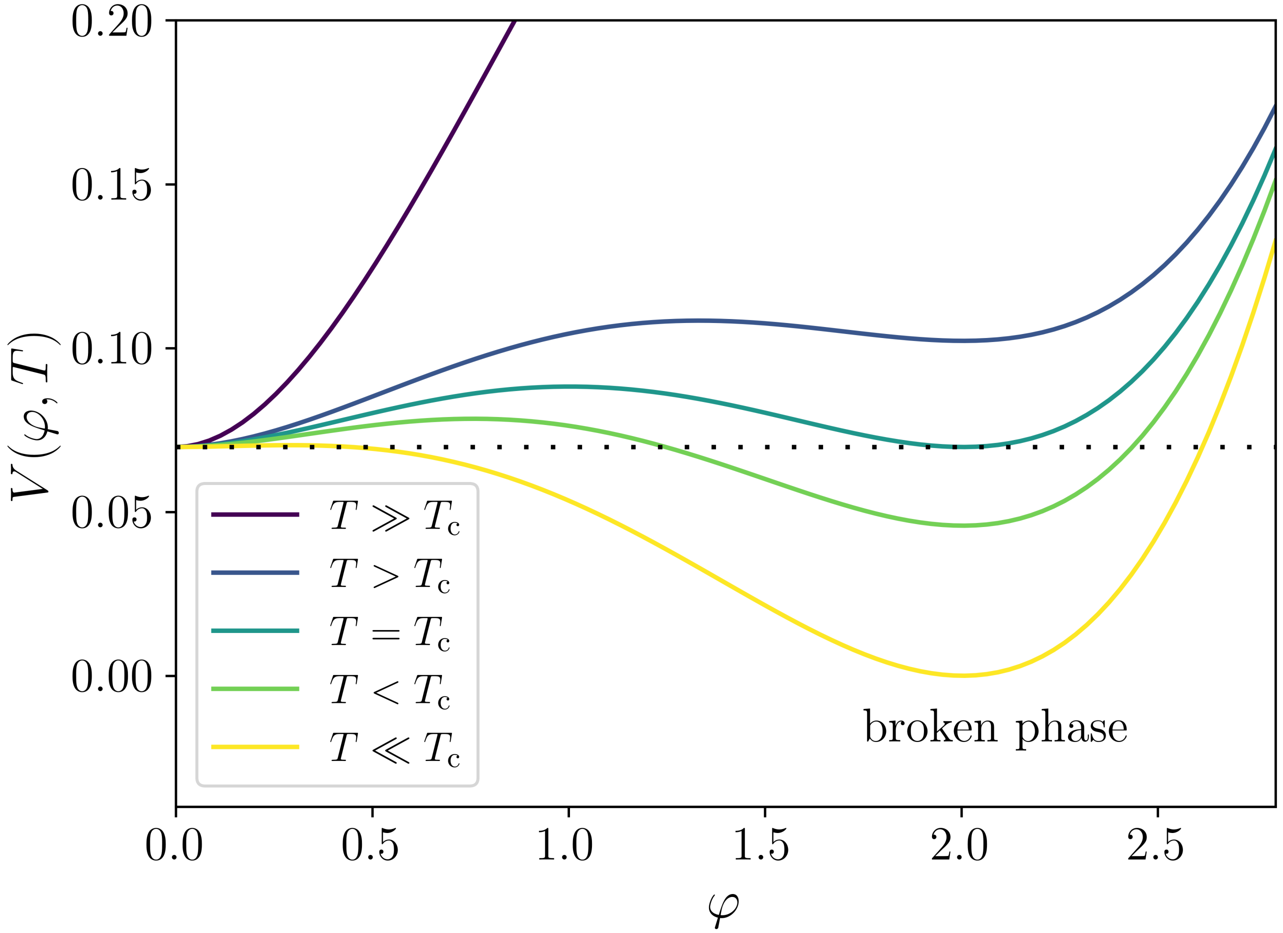
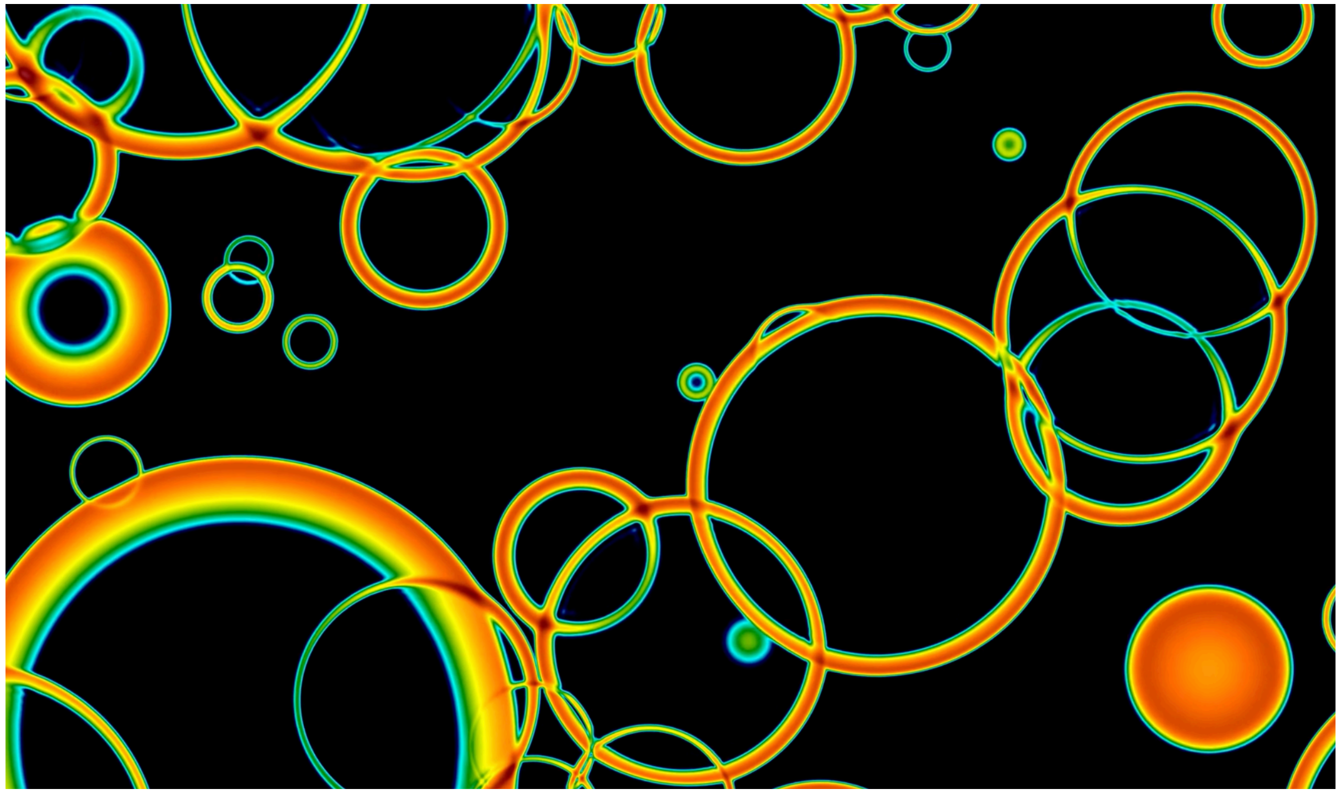
First order phase transitions in the early universe can source gravitational waves

Credits: D. J. Weir





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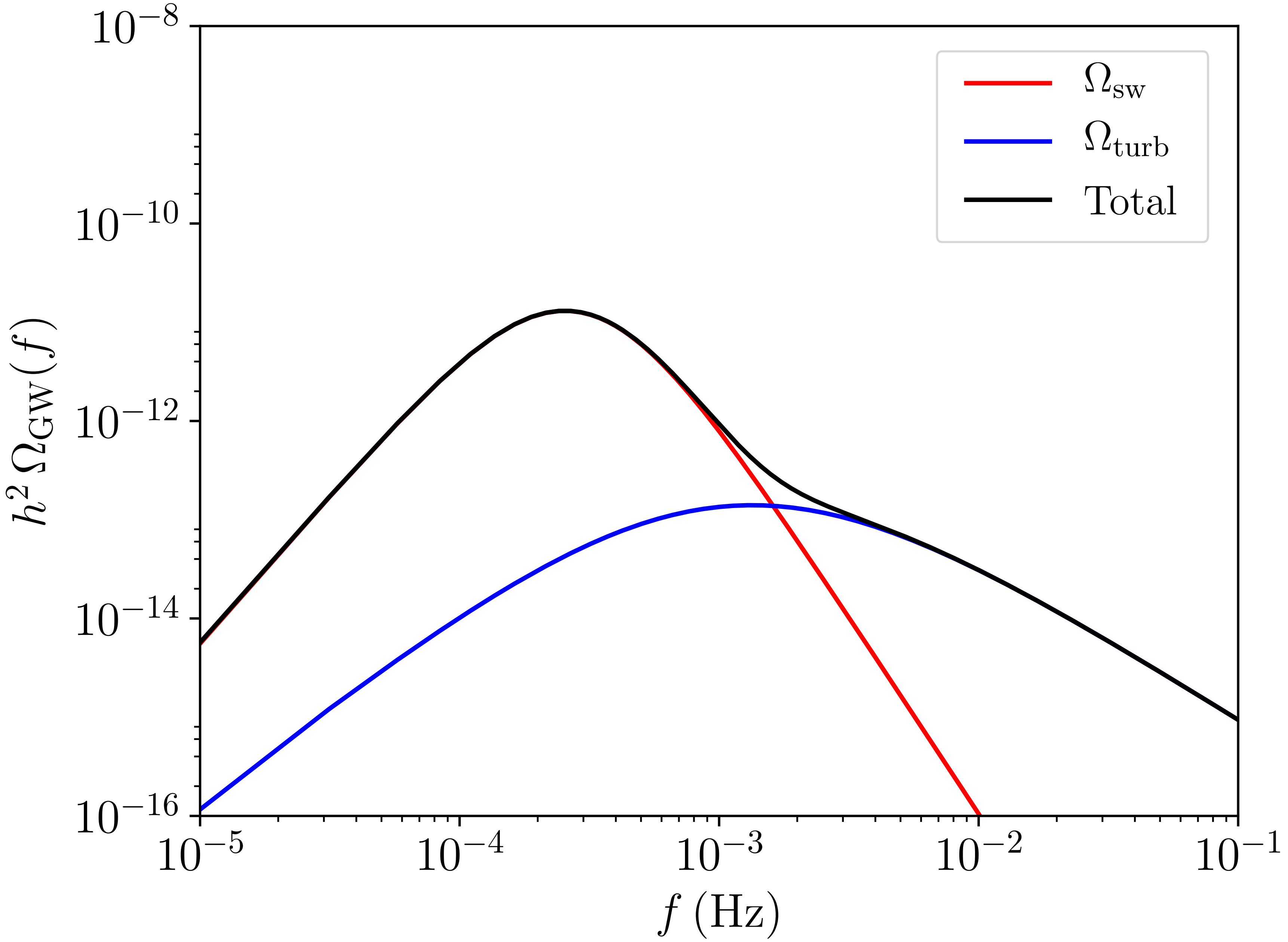
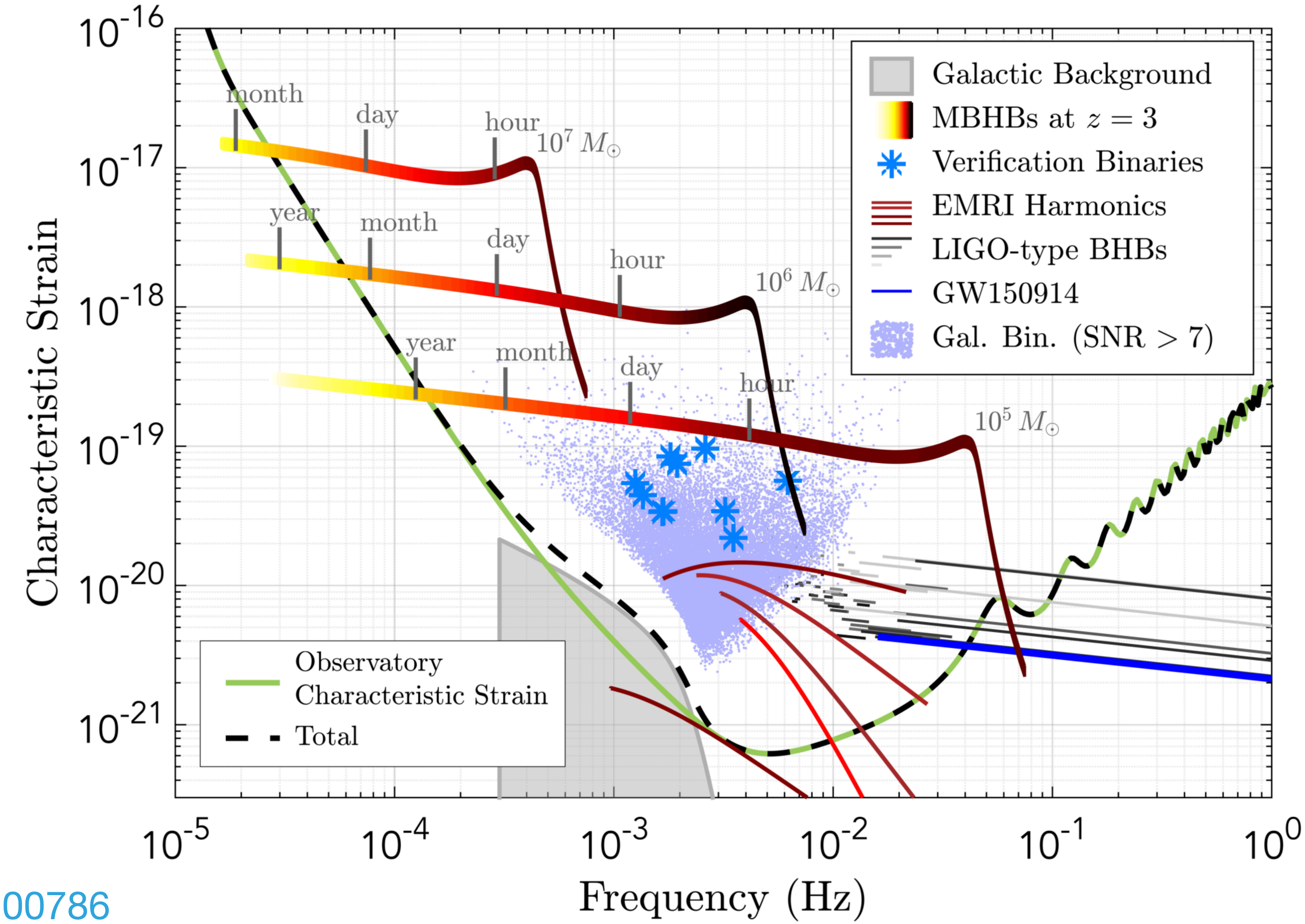


Modified from arXiv: 1705.01783

Finding a SGWB coming from a phase transition in LISA data will be difficult



arXiv:1702.00786

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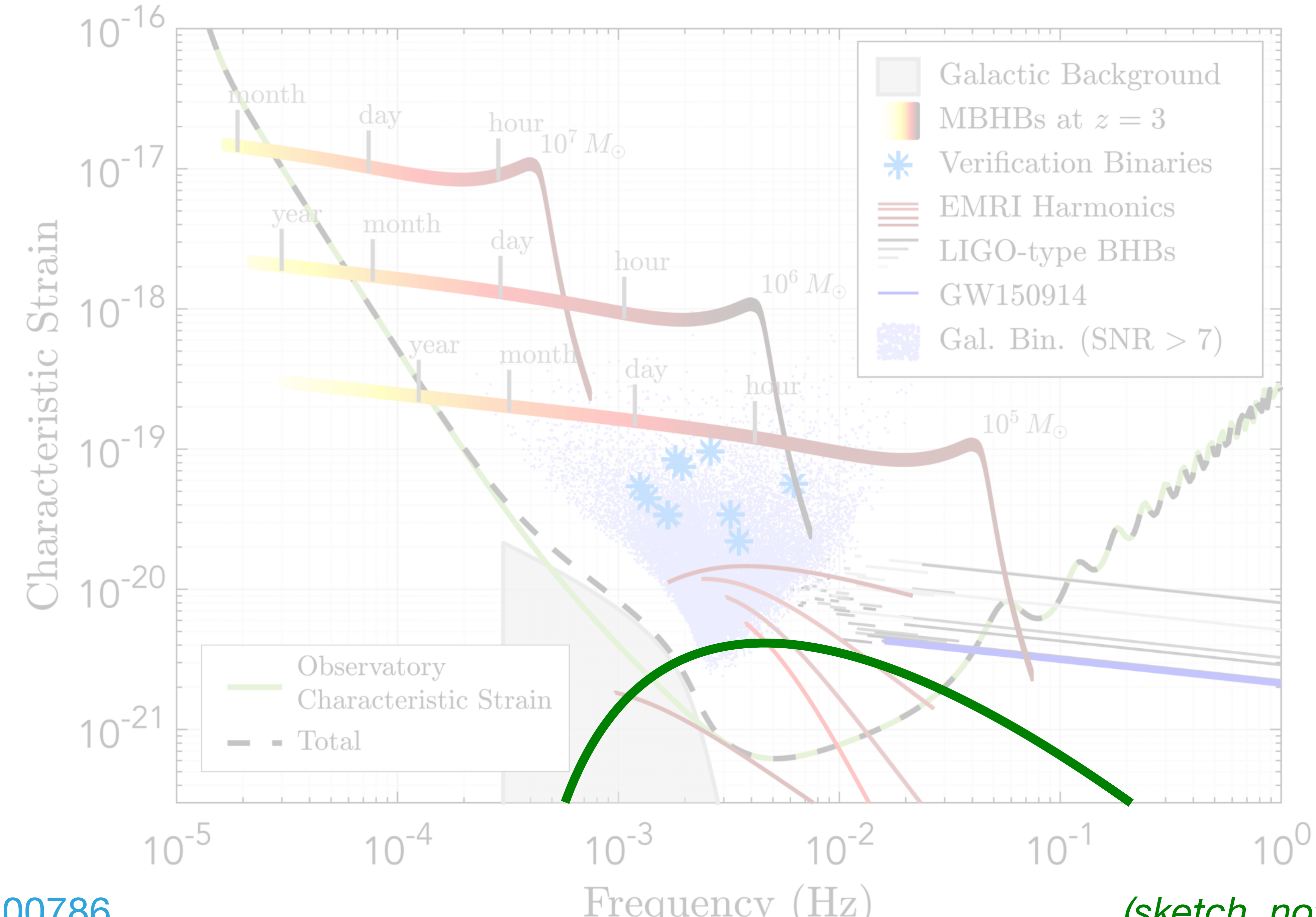

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(sketch, not a real model)

We can go from a particle physics model to an SNR; we want to invert the process

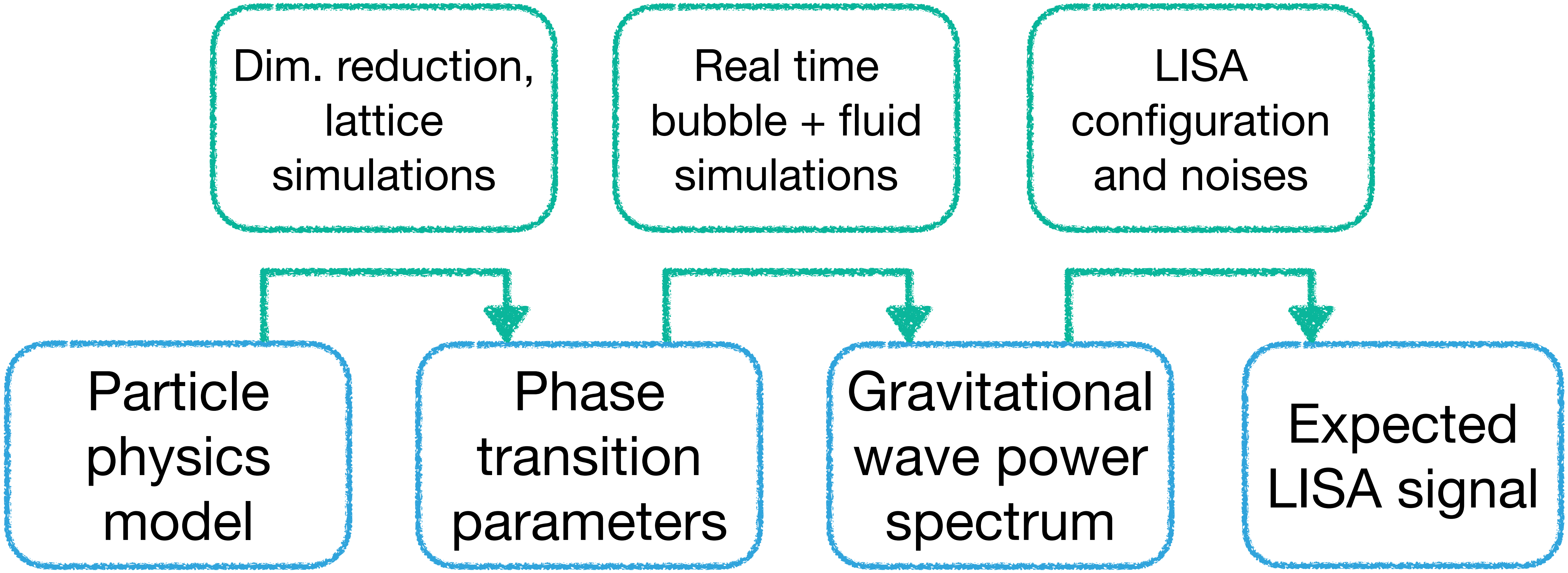
Particle physics model

Phase transition parameters

Gravitational wave power spectrum

Expected LISA signal

We can go from a particle physics model to an SNR; we want to invert the process



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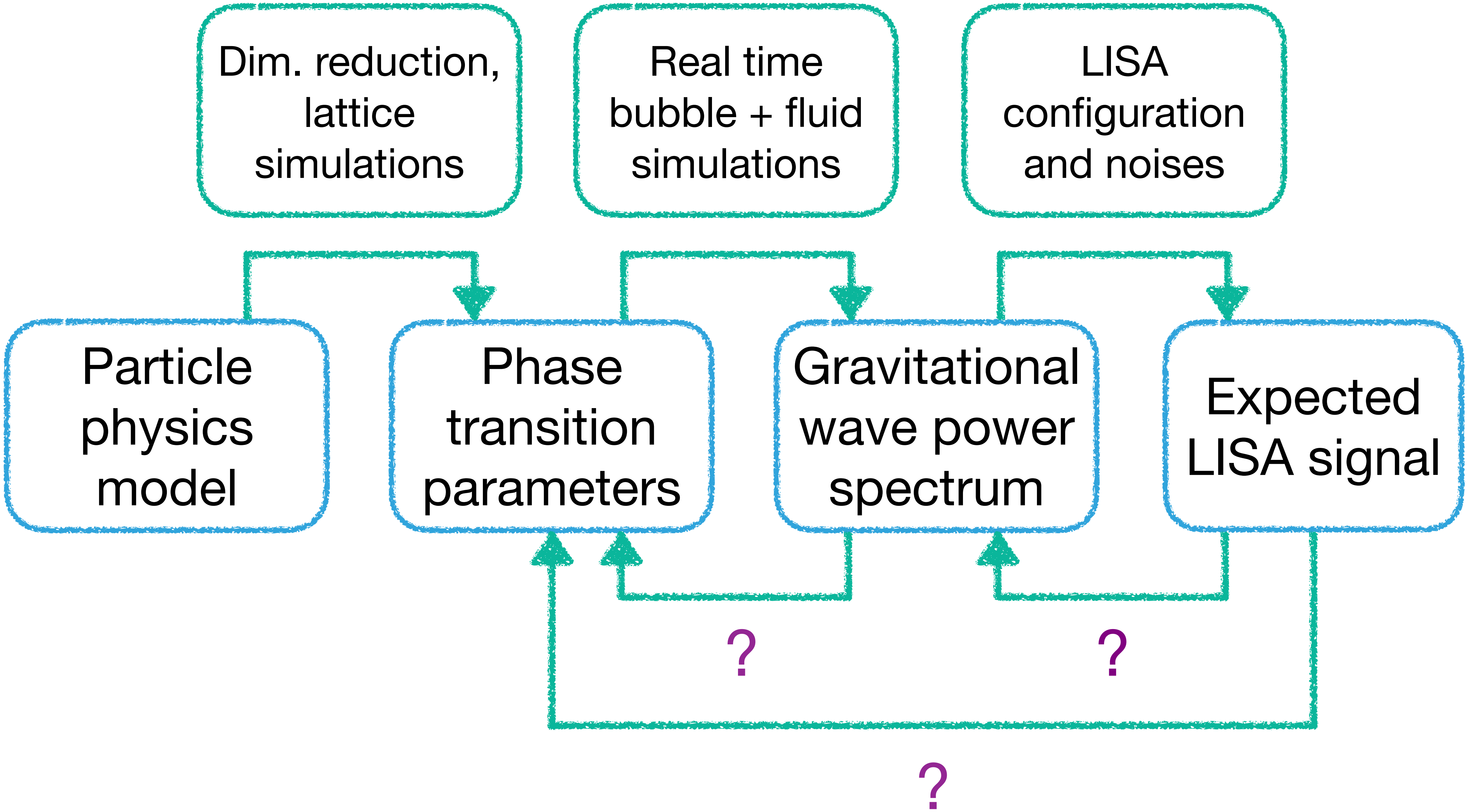
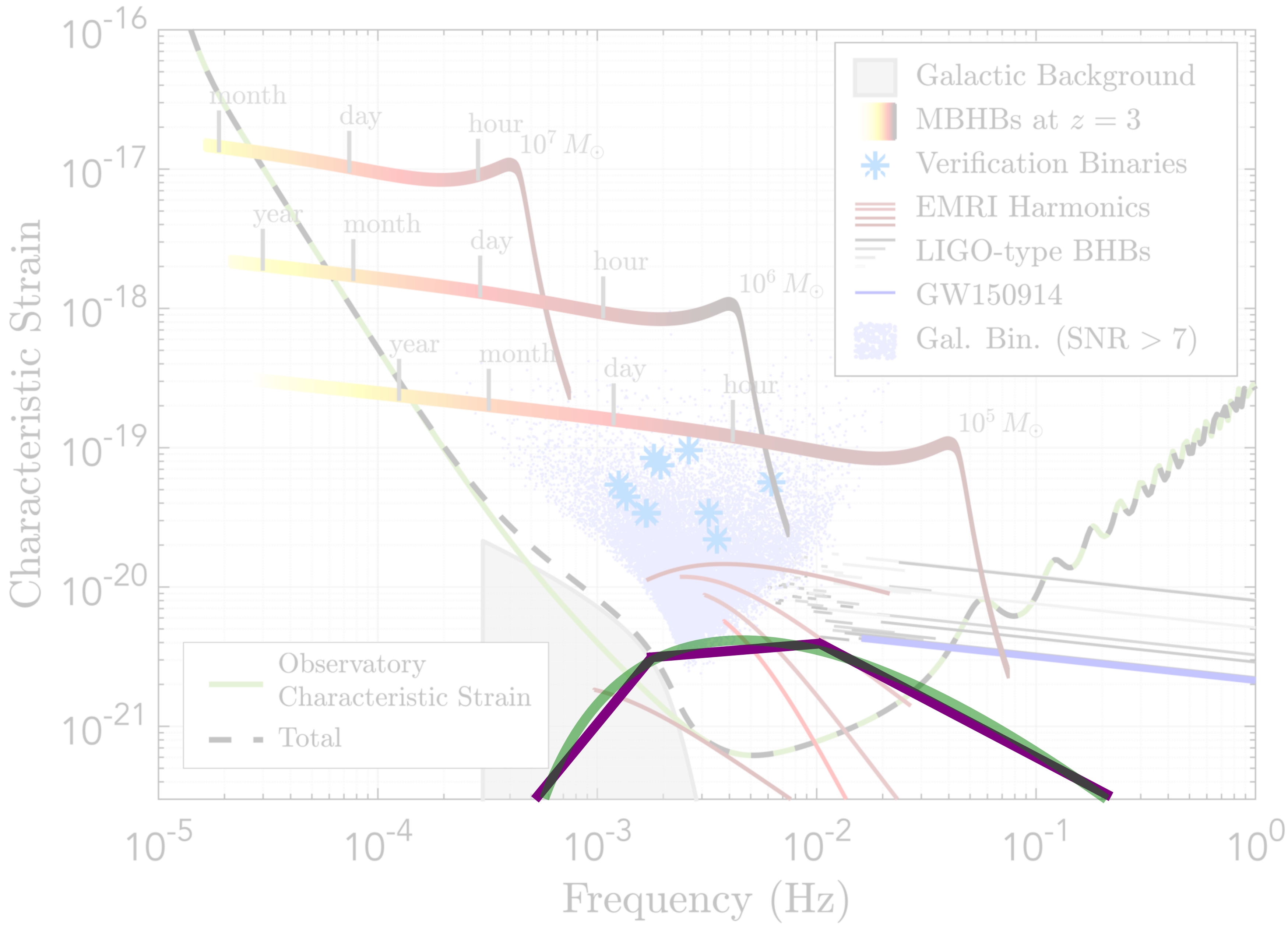


We want to recover the PT parameters from a double broken power law

arXiv: 2209.13551



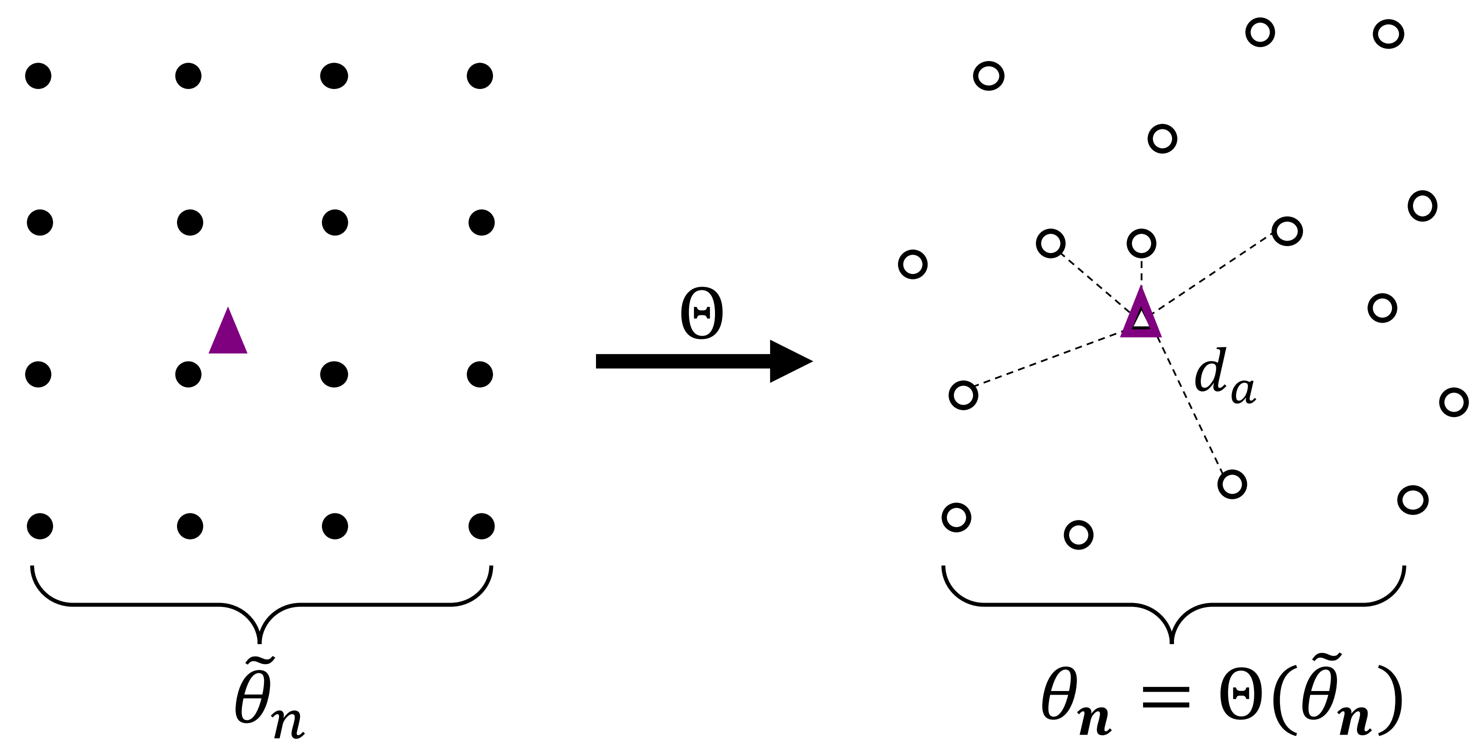
Create a mapping between PT and shape parameters - only needs to be done once!

Mapping done by building a grid and interpolating with nearest neighbours

arXiv: 2209.13551

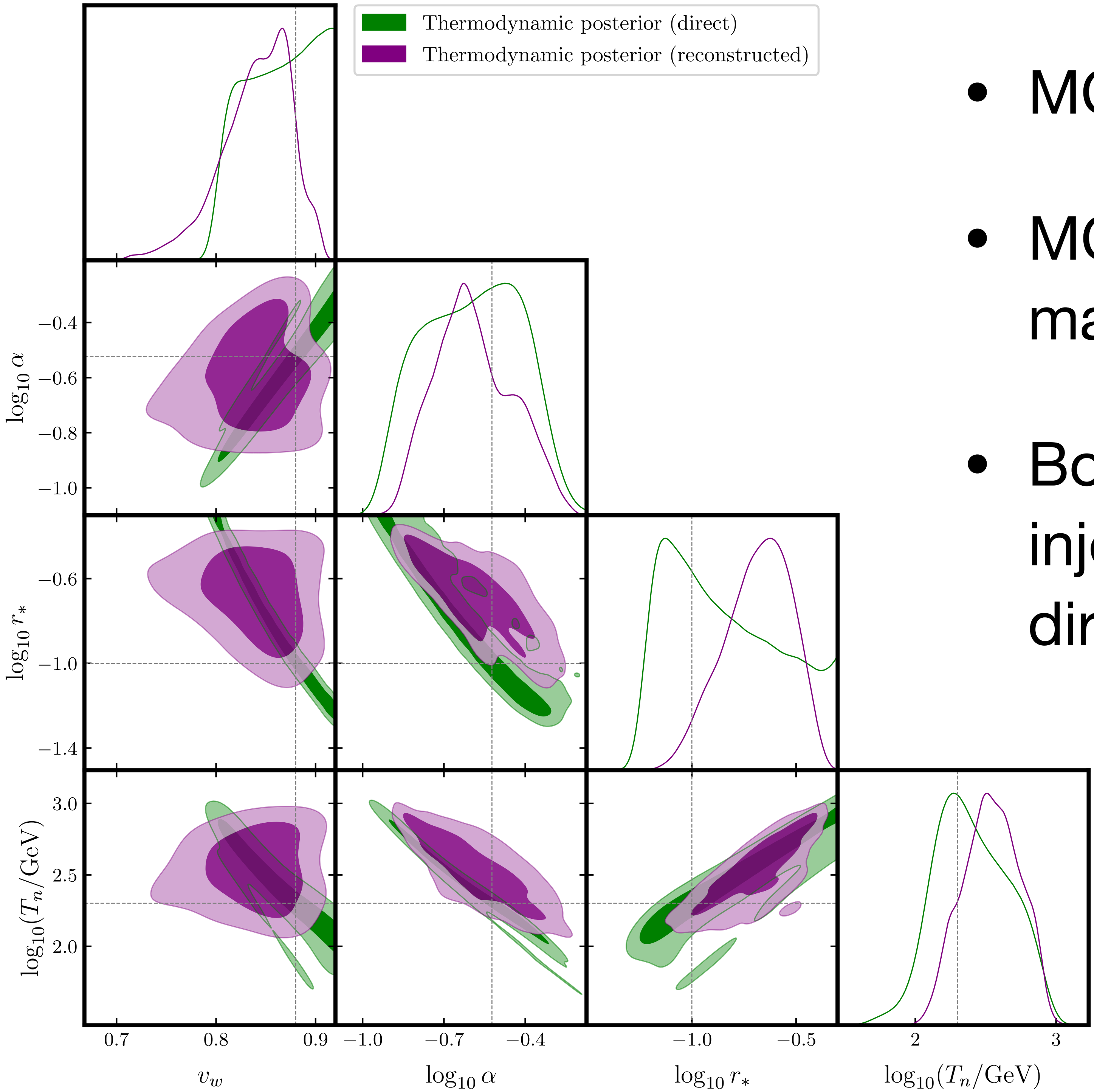
1. Build grid of PT parameters

2. Find corresponding shape parameters



3. For a point in shape parameter space, use a weighted interpolation in grid to reconstruct PT parameters

Direct sampling and reconstruction give similar results, latter is $\mathcal{O}(10^3)$ faster



- MCMC on PT parameters (green)
- MCMC on shape parameters, map to PT parameters (purple)
- Both approaches recover injected signal (dashed lines), direct is more precise

α : Phase transition strength

r_* : Hubble-scaled mean bubble spacing

T_n : Bubble nucleation temperature

v_w : Wall velocity

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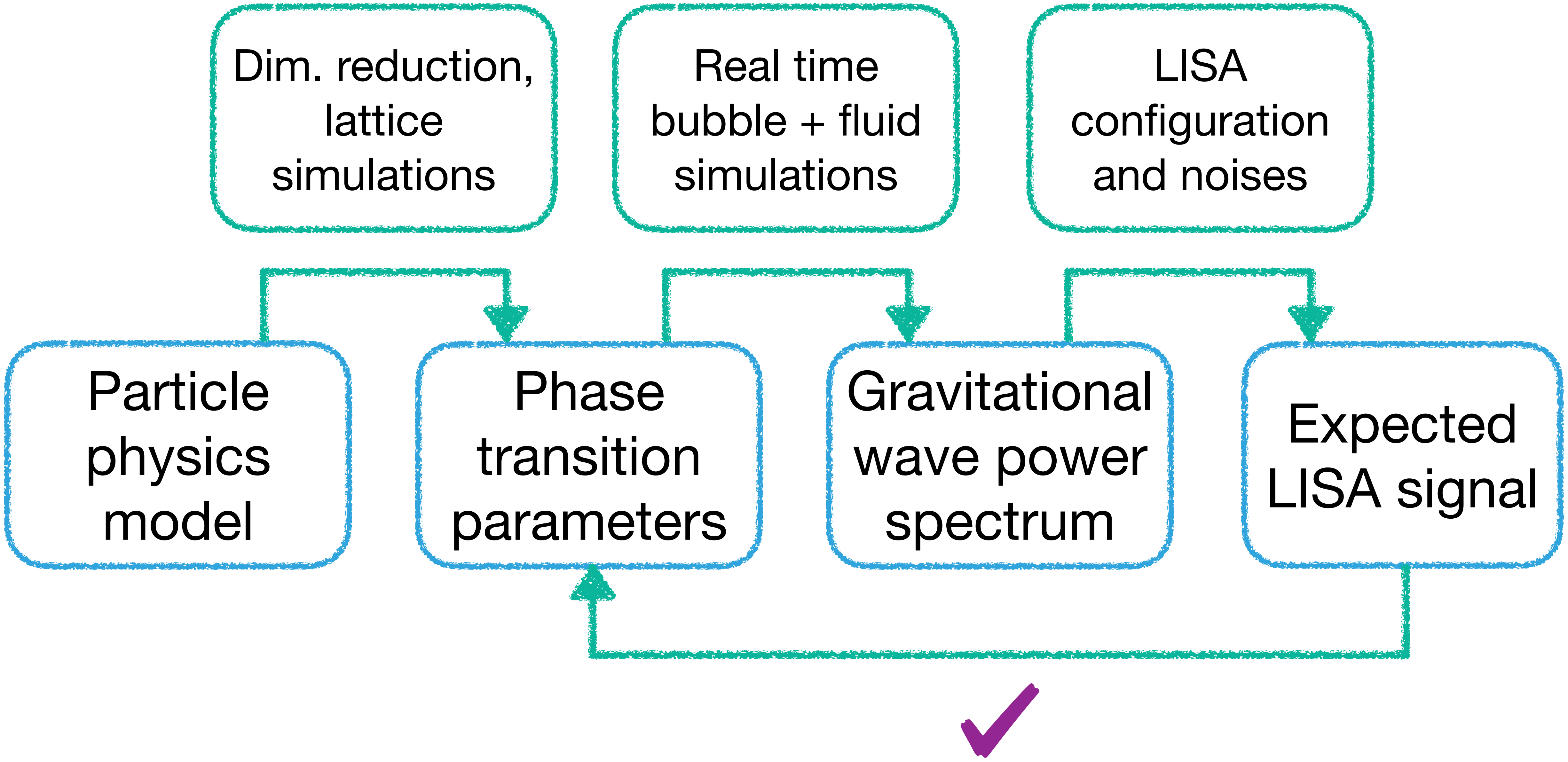
We can get PT parameters from GW spectrum. Can we get a SGWB spectrum from LISA?



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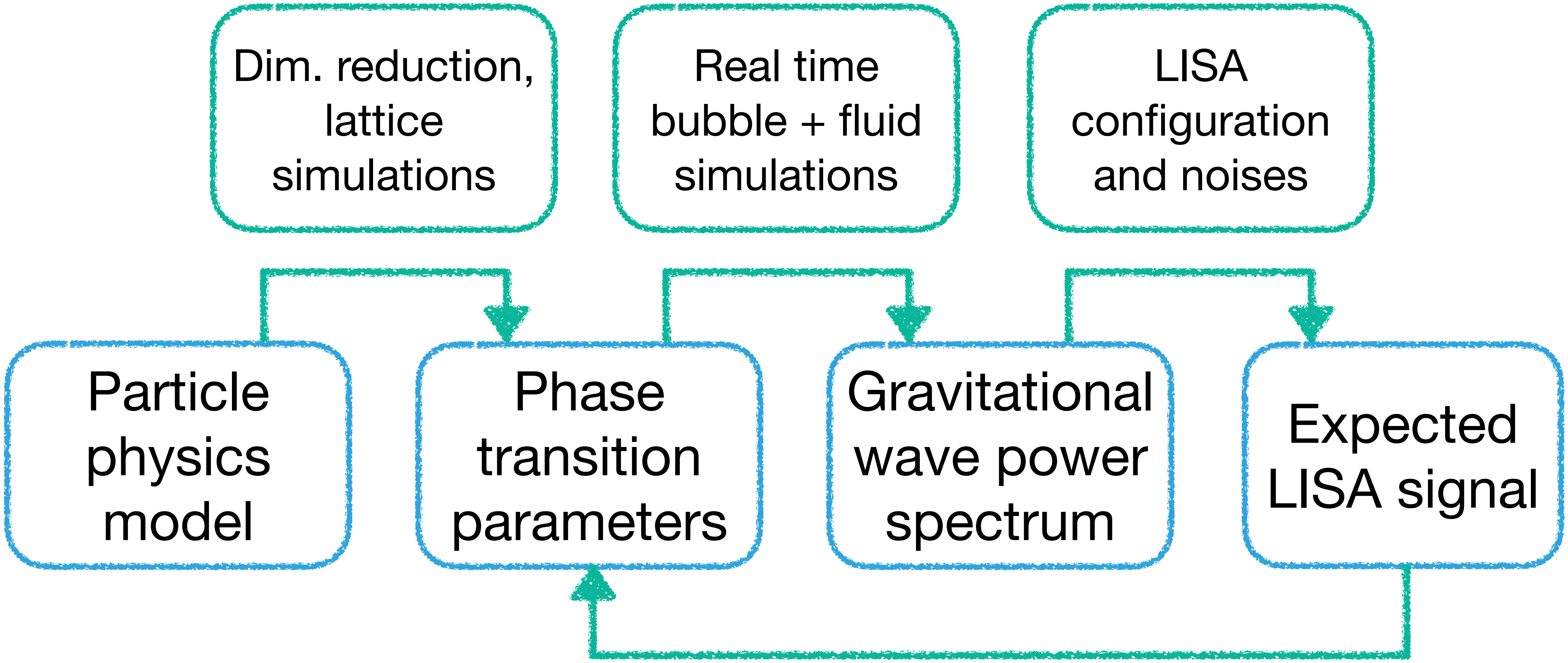
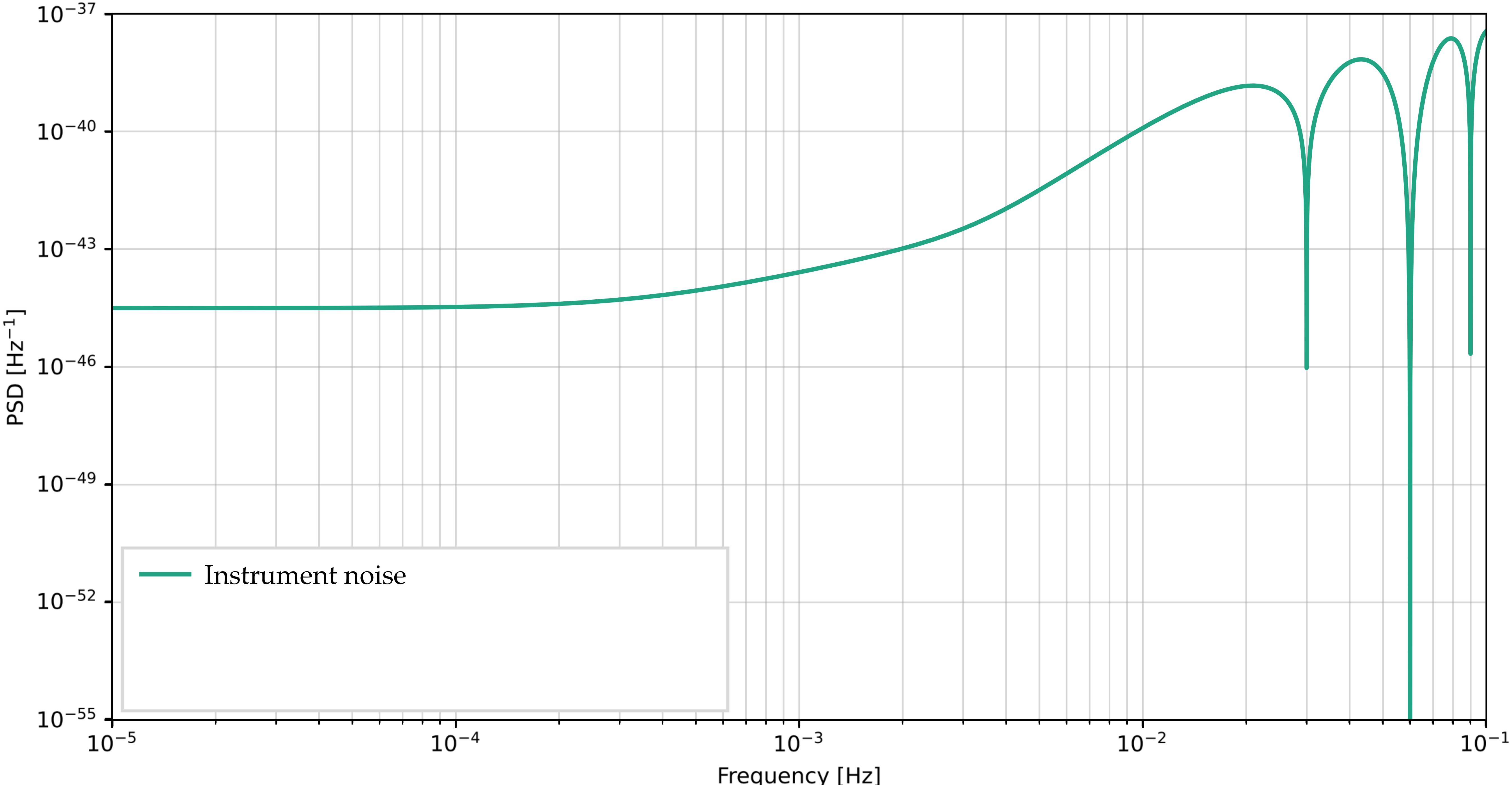


What if we add more realistic noise?

We create mock data with instrument noise, galactic binaries and PT signal



Preliminary figures by T. Minkkinen

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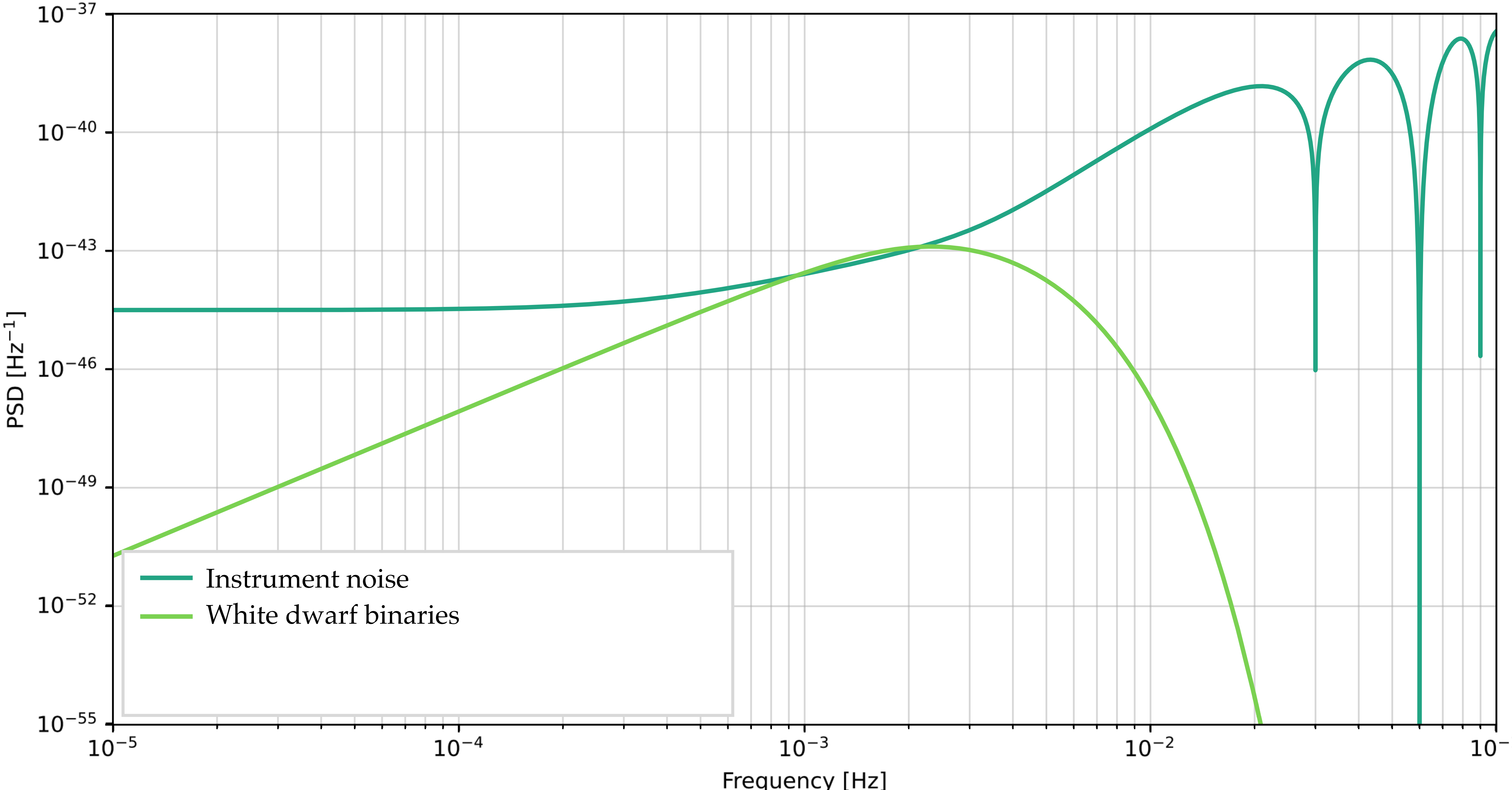

Preliminary figures by T. Minkkinen

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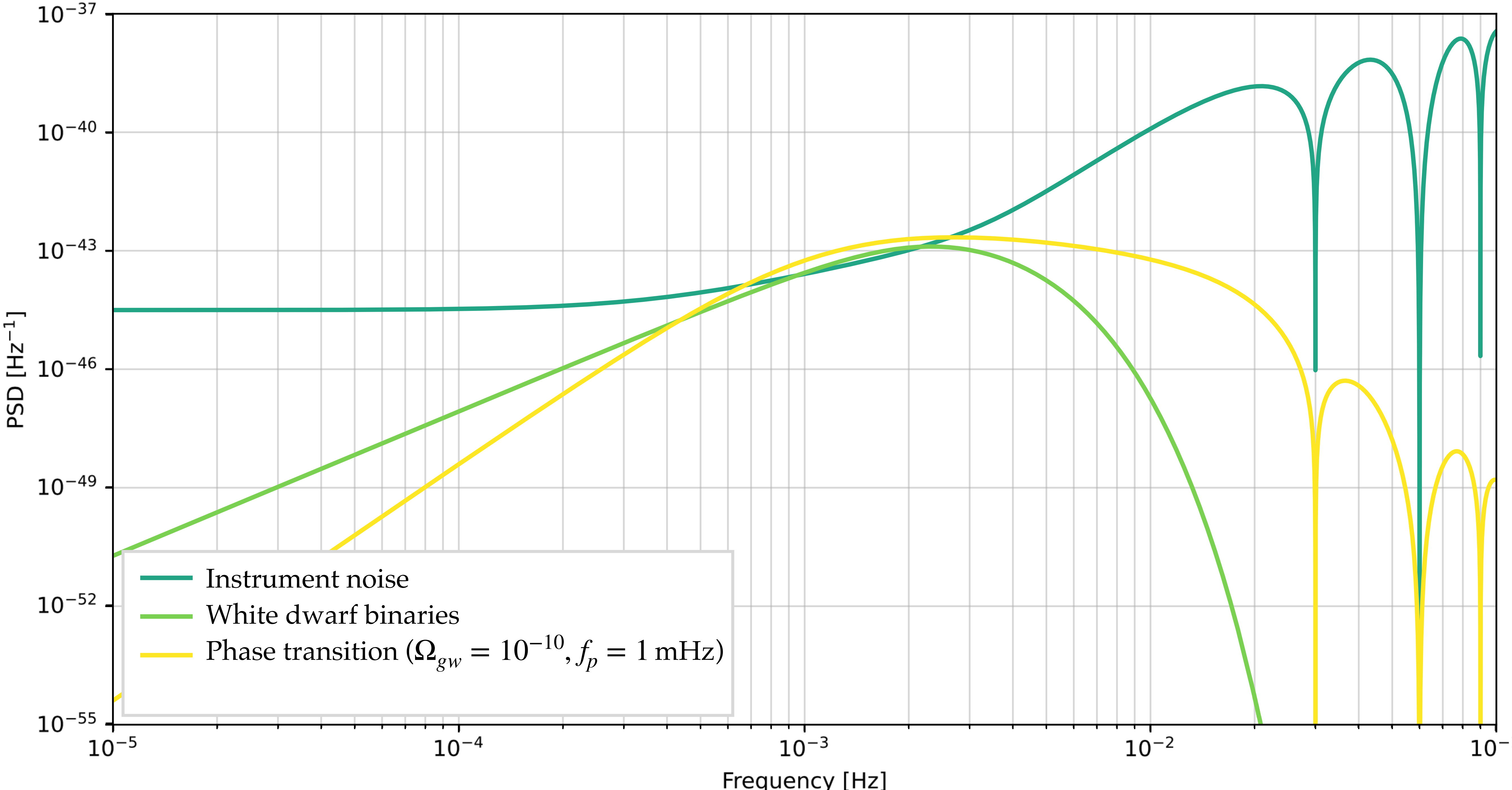

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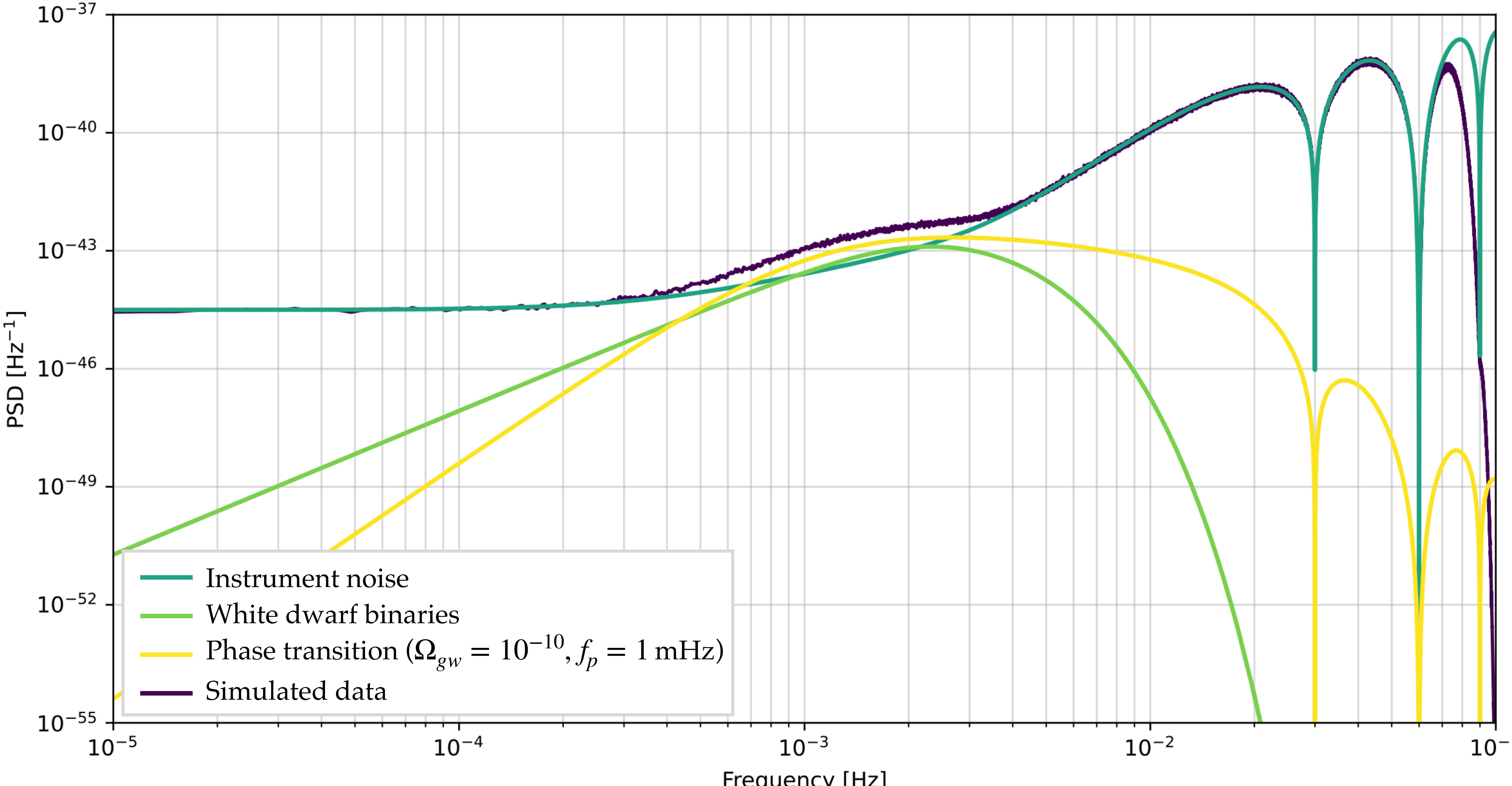

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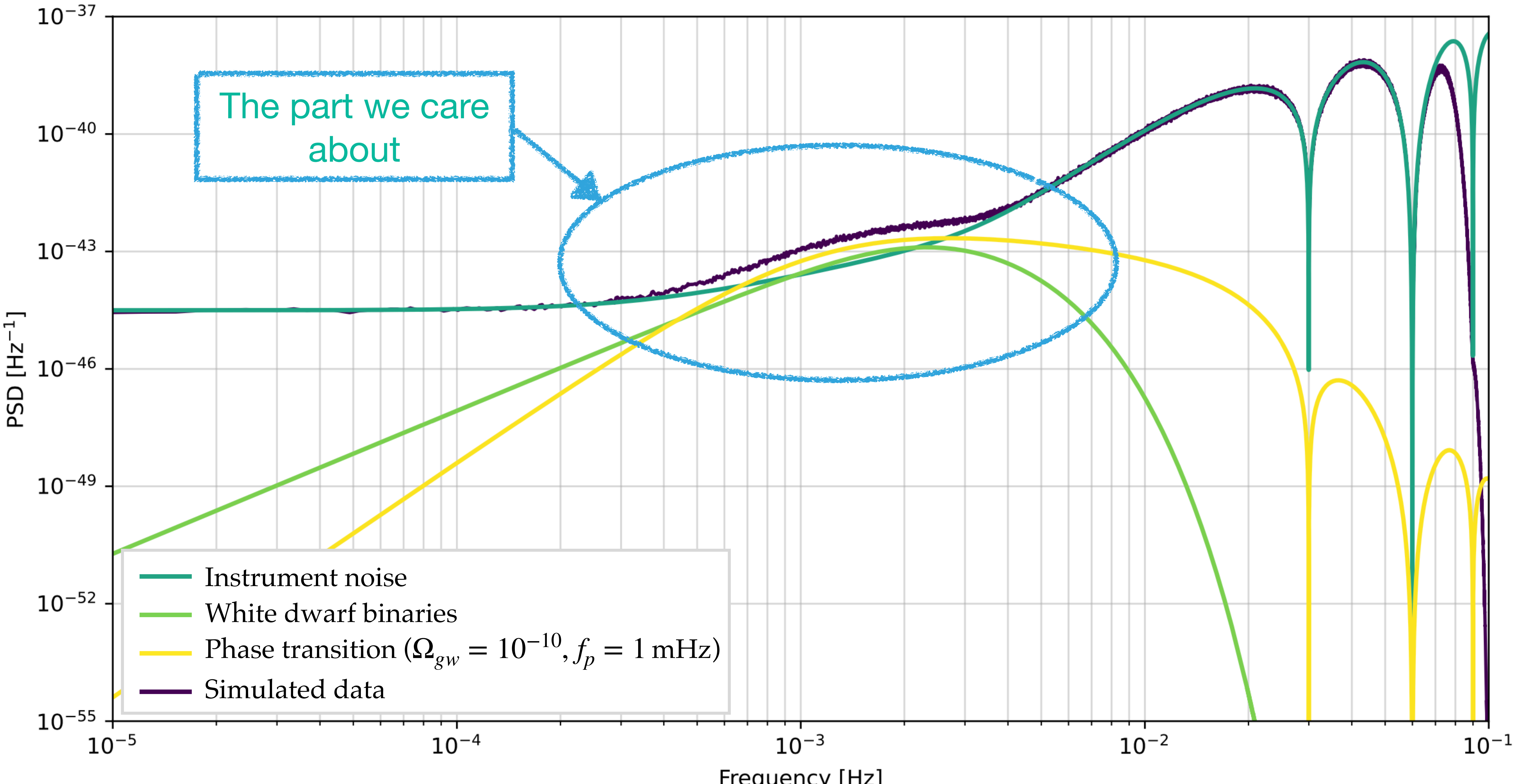
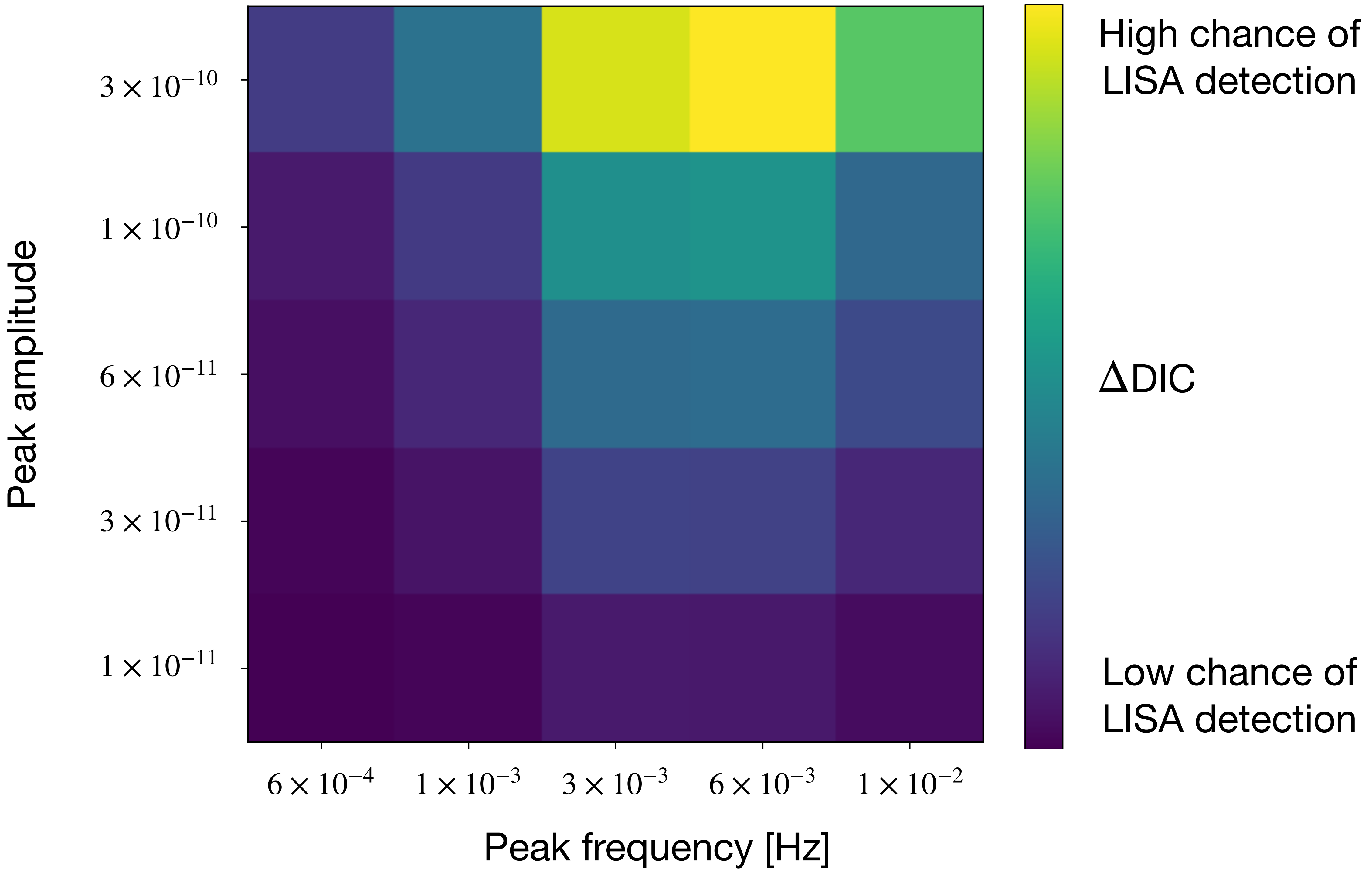


Preliminary figures by T. Minkkinen

How strong does a PT signal need to be in LISA so that we can recover it?



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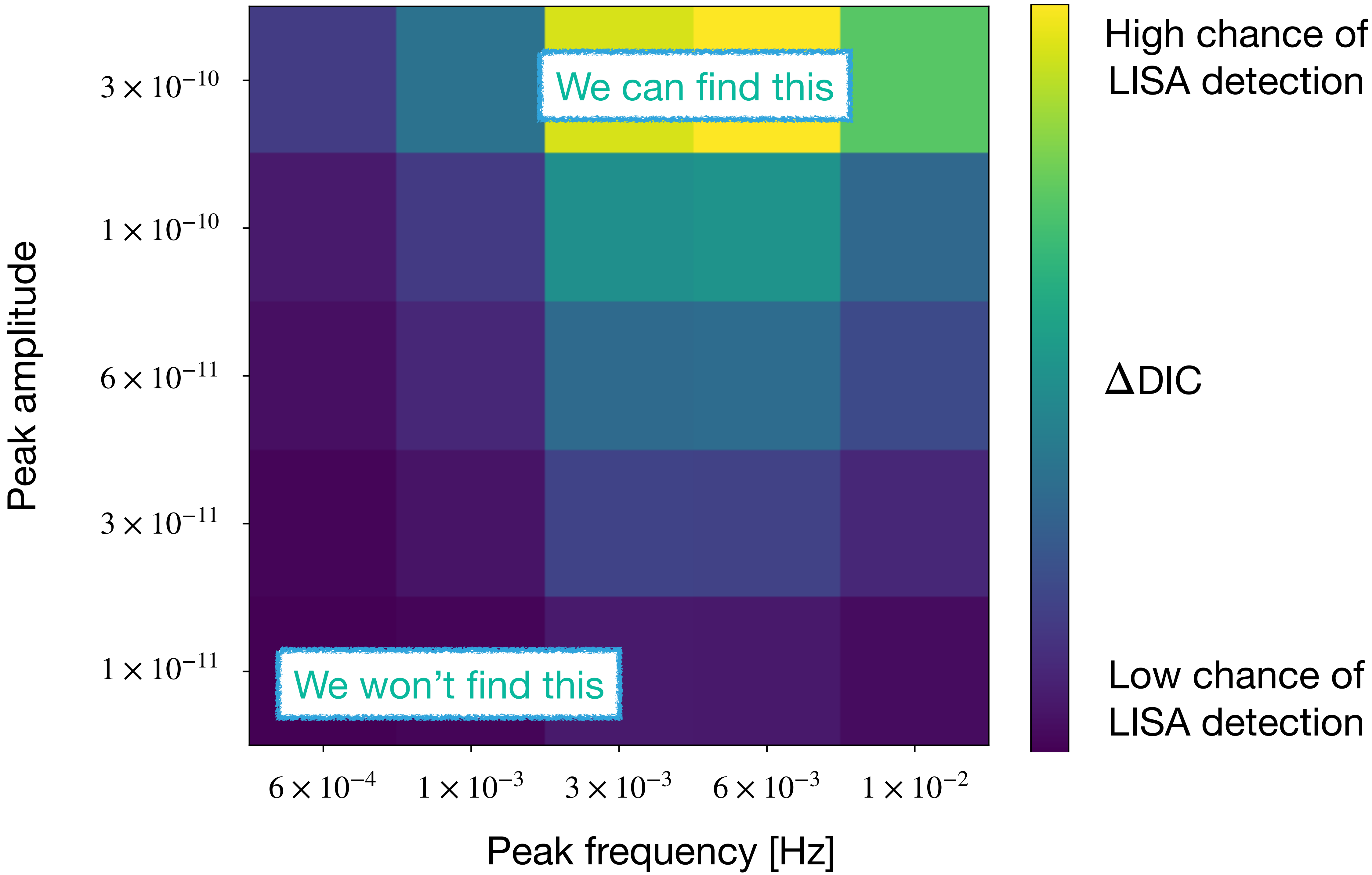
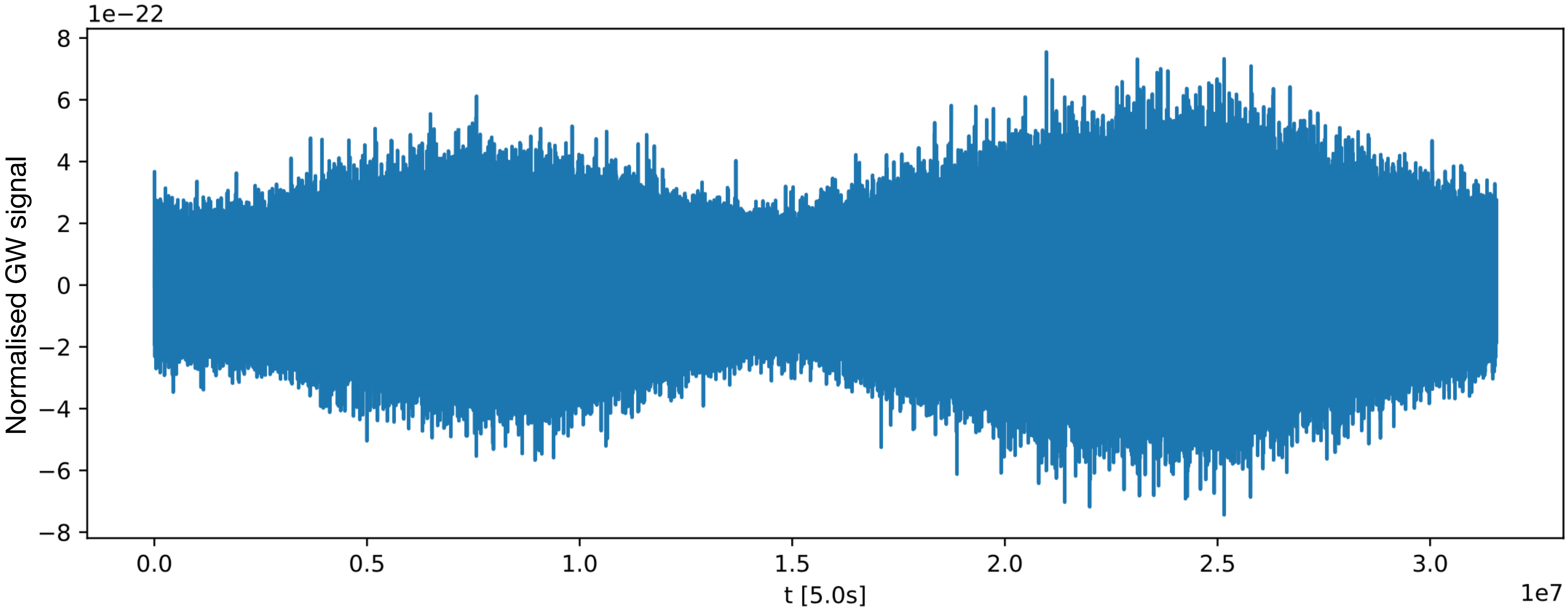


Some of the astrophysical signals will be modulated, we want to exploit this



We think the annual modulation of galactic binaries will help disentangle this from a PT signal

LISA will help shed light on early universe physics

Summary

- We can reconstruct (strong) PT signals using parametrised templates
- We are looking for PT signals in realistic mock data

Our goal

How small can we make the injected signal and how well do we need to know the astrophysical noises?

Thanks for listening!

Get in touch!

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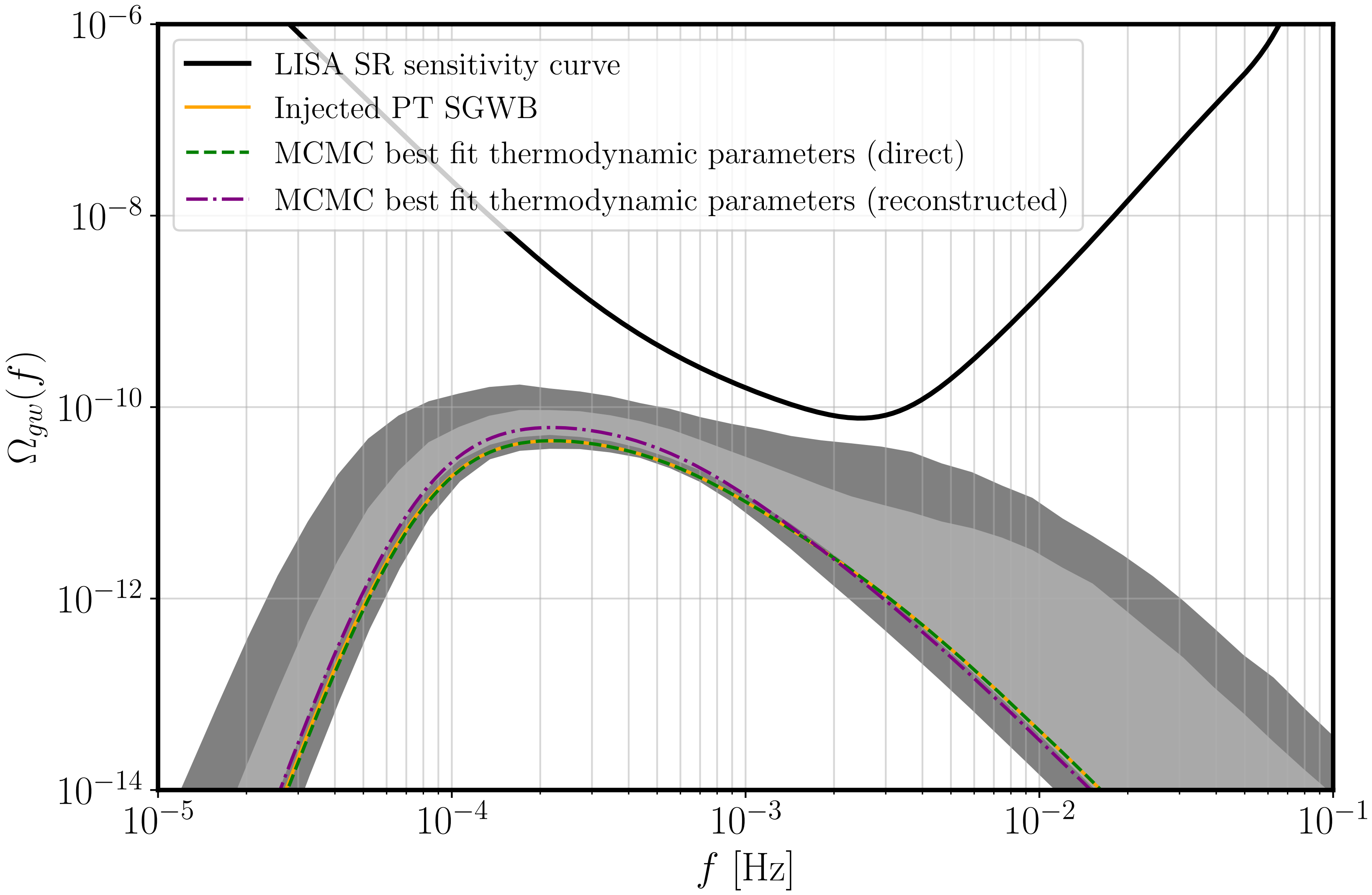
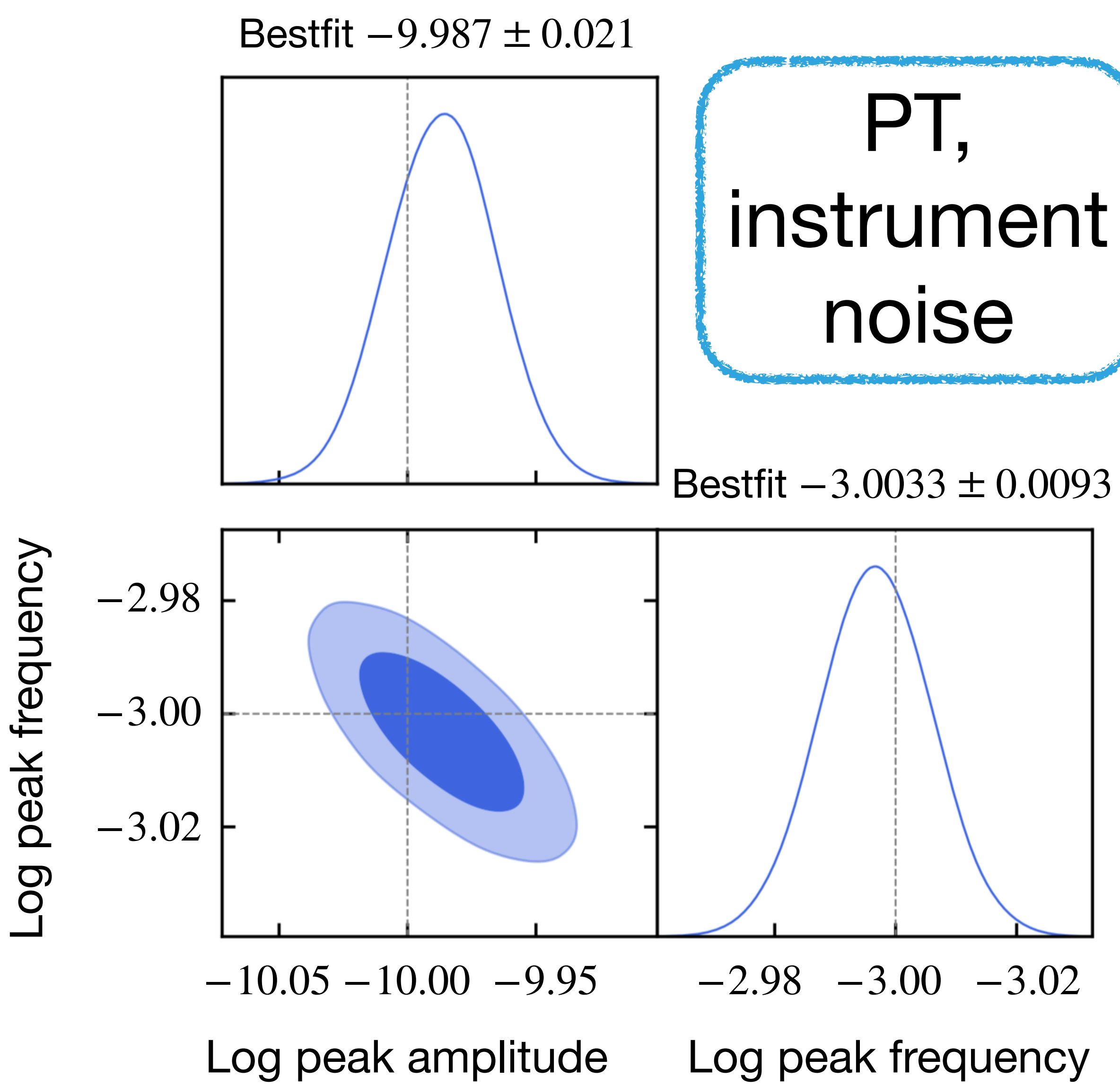
Two approaches to MCMC: sample on PT or spectral parameters

arXiv: 2209.13551



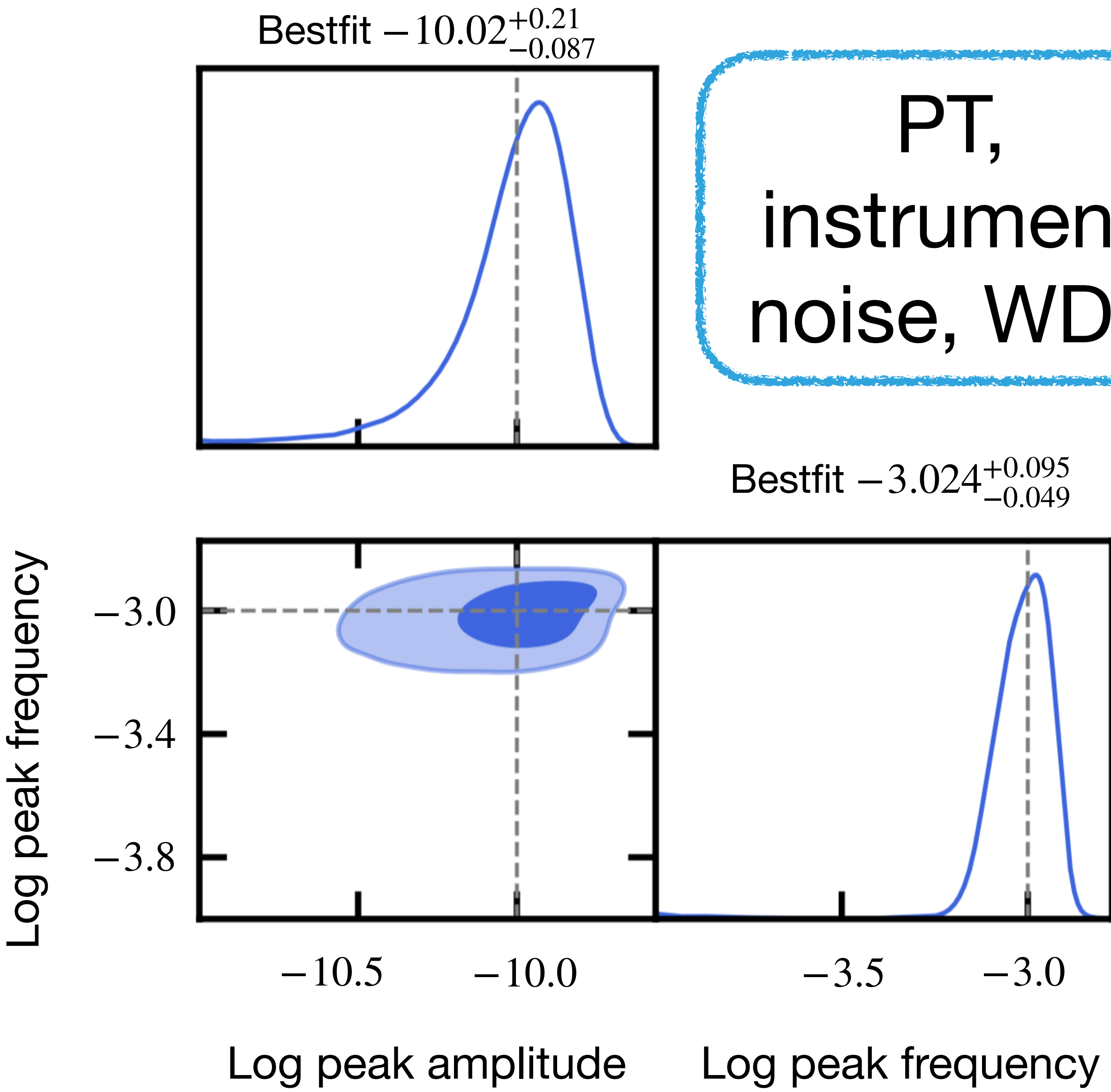
1. Run MCMC directly on PT parameters
2. Run MCMC on spectral parameters, use mapping to recover PT parameters

We run MCMCs to see if we can recover the injected PT parameters



PT, instrument noise

+2 parameters for instrument noise



PT, instrument noise, WDs

+2 parameters for instrument noise,
+4 parameters for white dwarf binaries