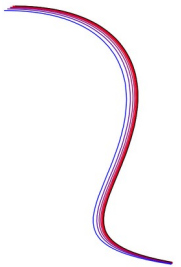
Measuring the impact of DM on BNS with Einstein Telescope



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Based on work together with Edoardo Giangrandi, Nina Kunert, Rahul Somasundaram, Violetta Sagun, Tim Dietrich and on work with Henrik Rose, Peter Pang, Rahul Somasundaram, Ingo Tews and others

NMMA

Universität Potsdam

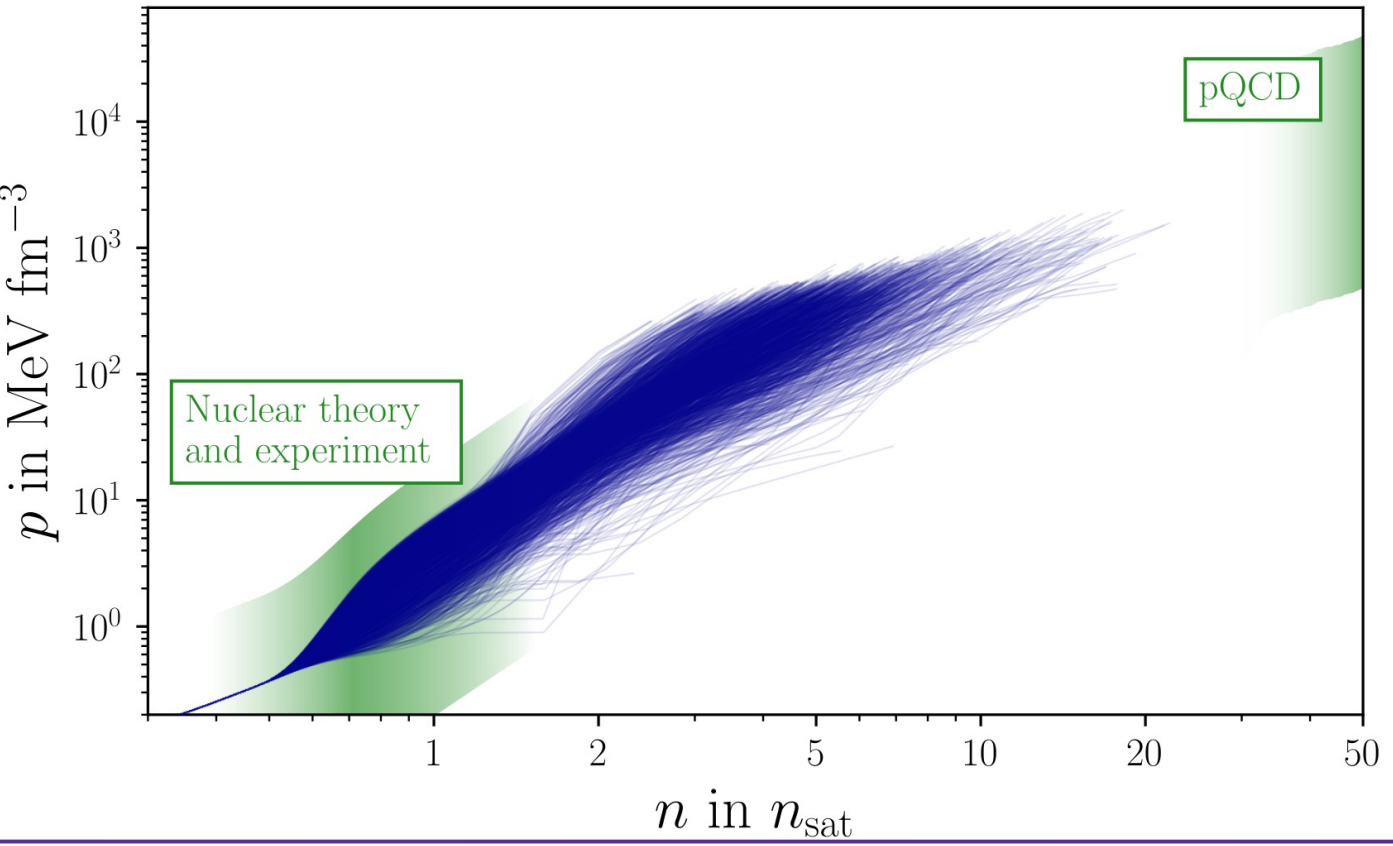
Overview

I. Current constraints on the EOS [arXiv 2402.04172]

II. EOS constraints with next-generation GW telescopes and DM [arXiv 2408.14711]

I. Current constraints on the EOS

How do we constrain the EOS?



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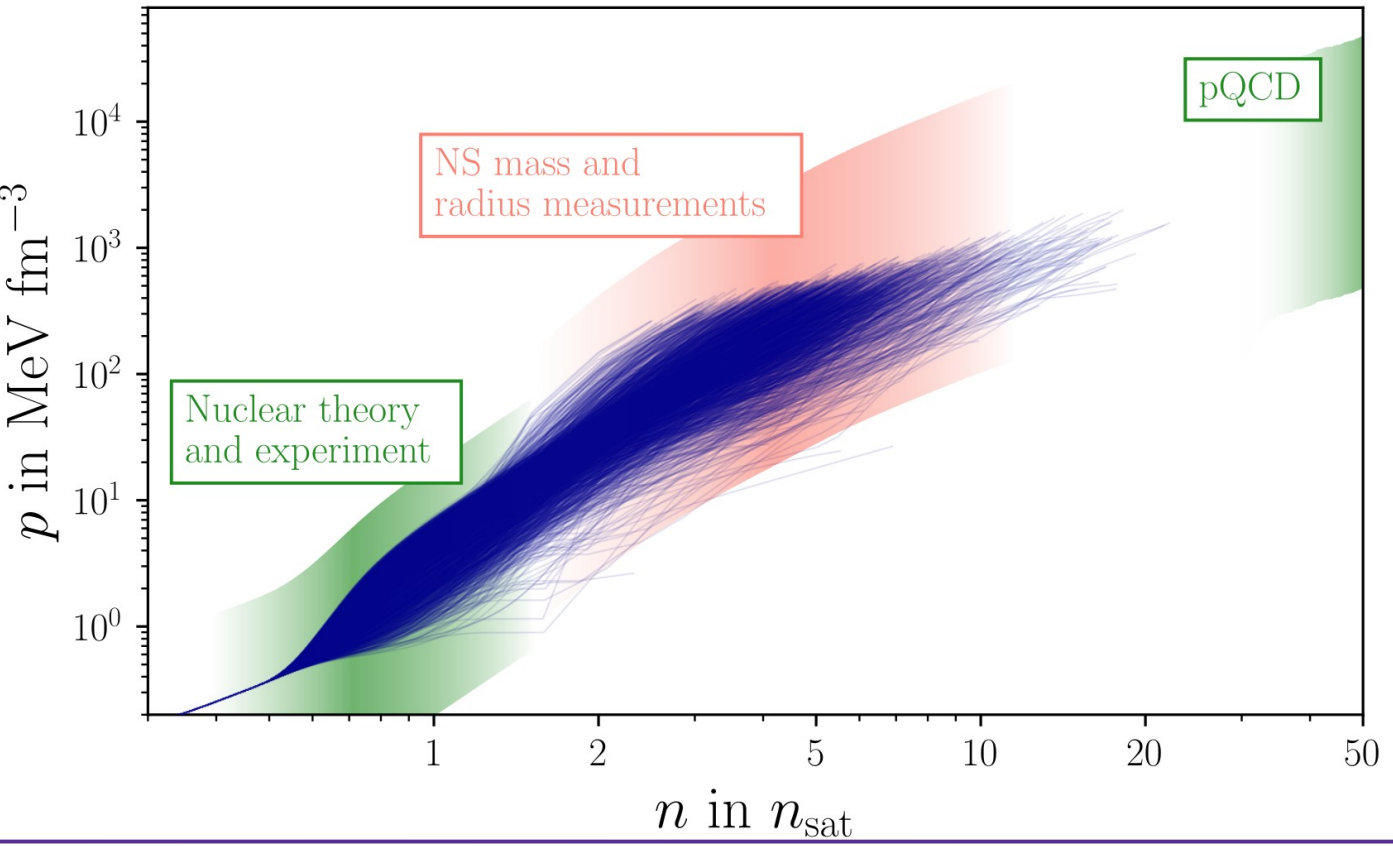

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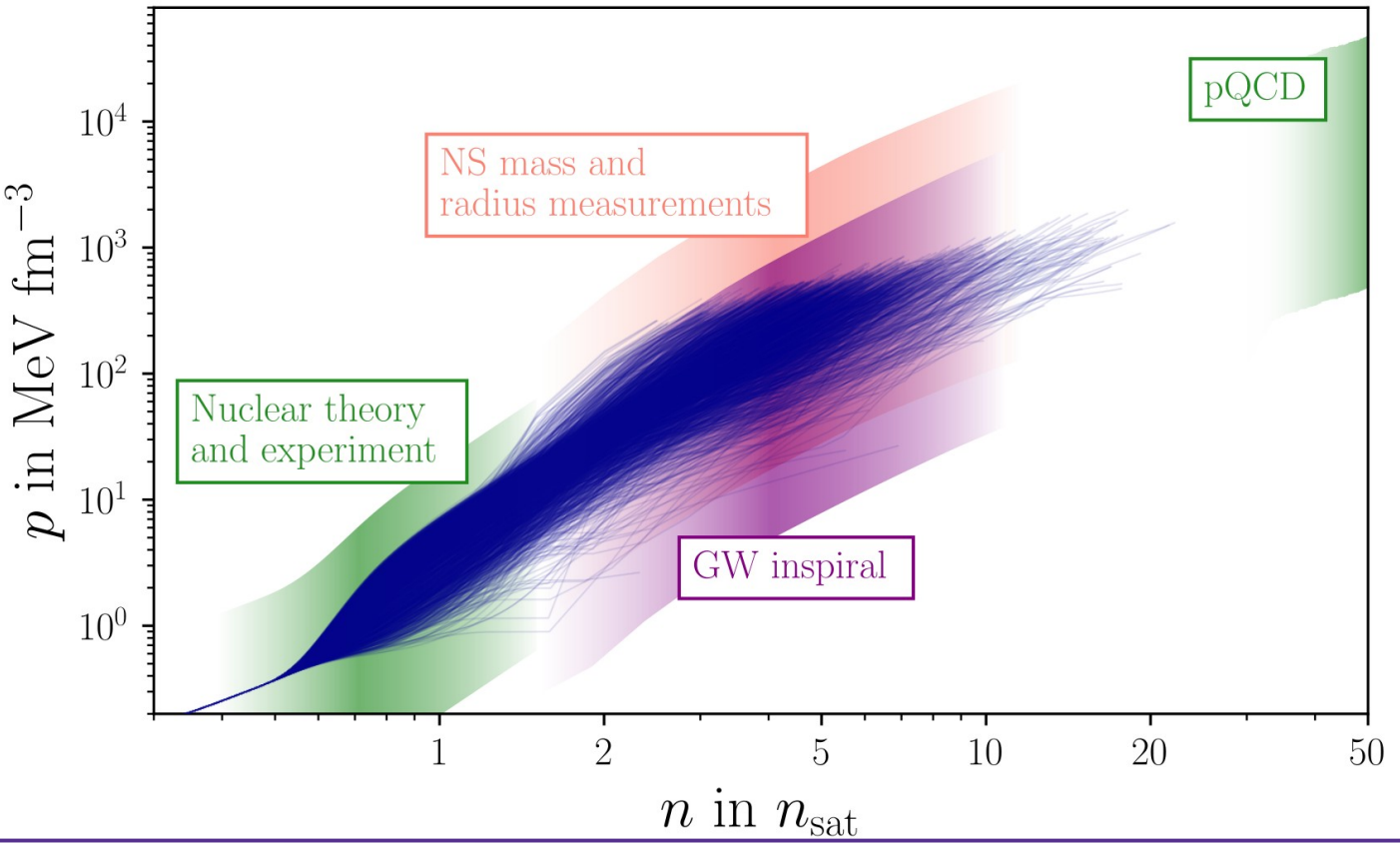

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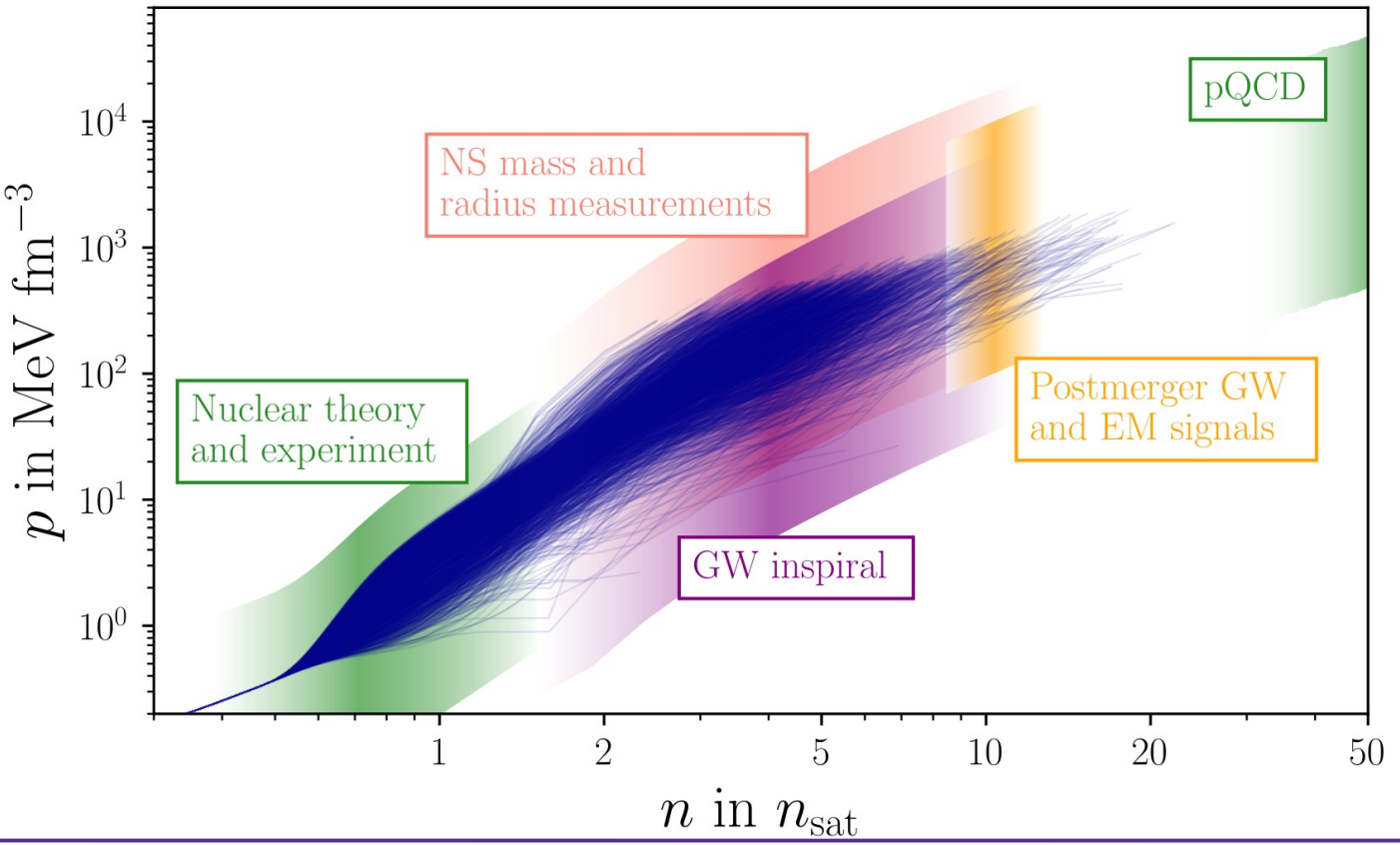

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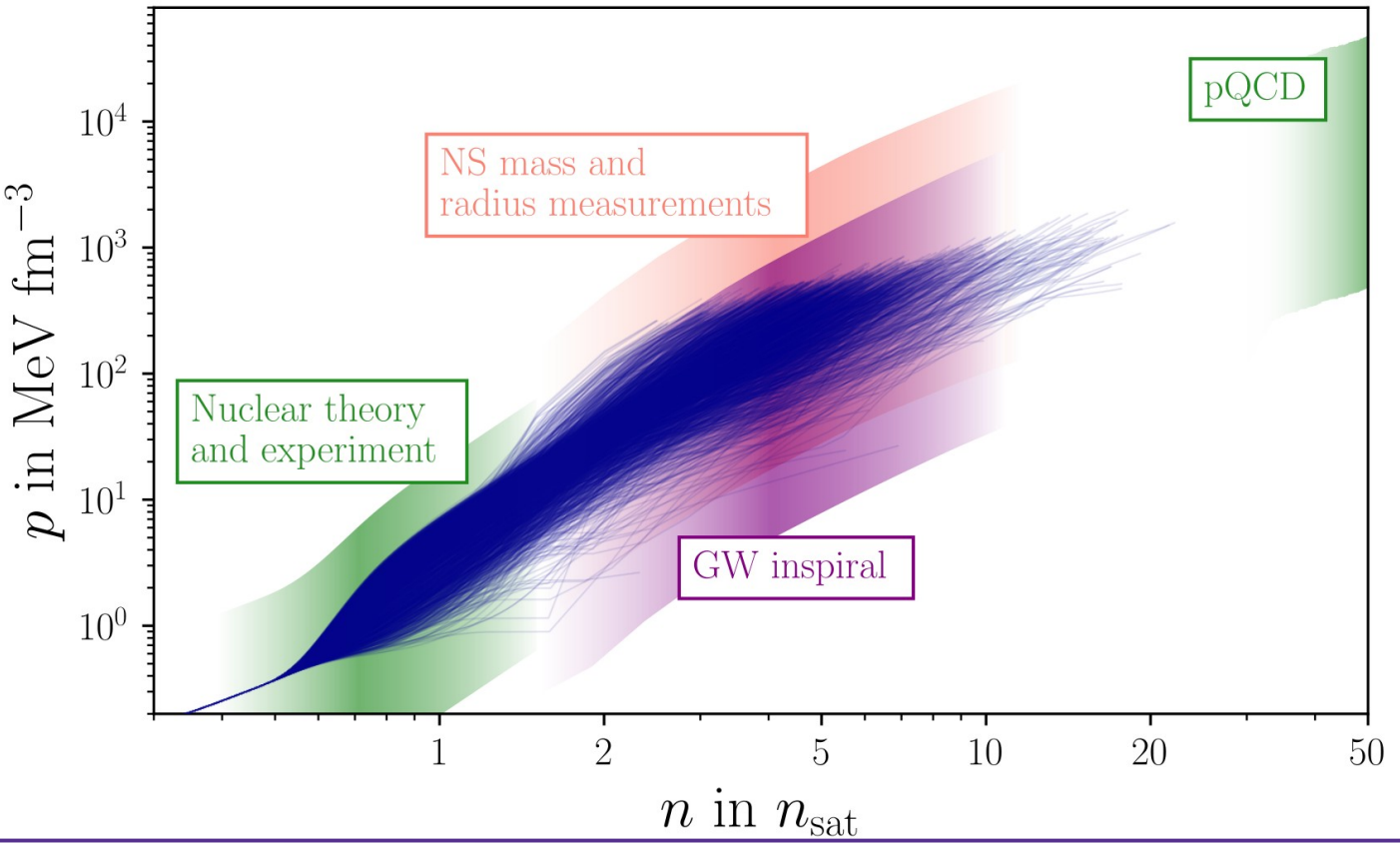
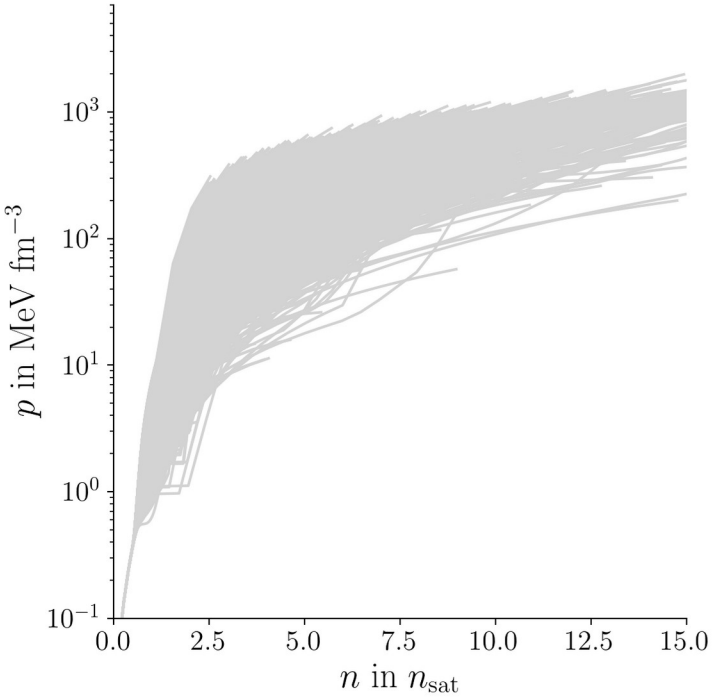
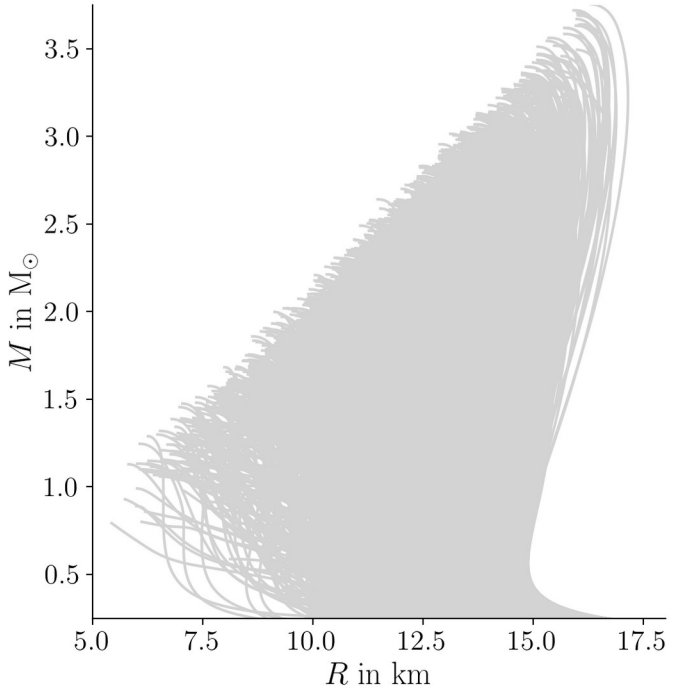
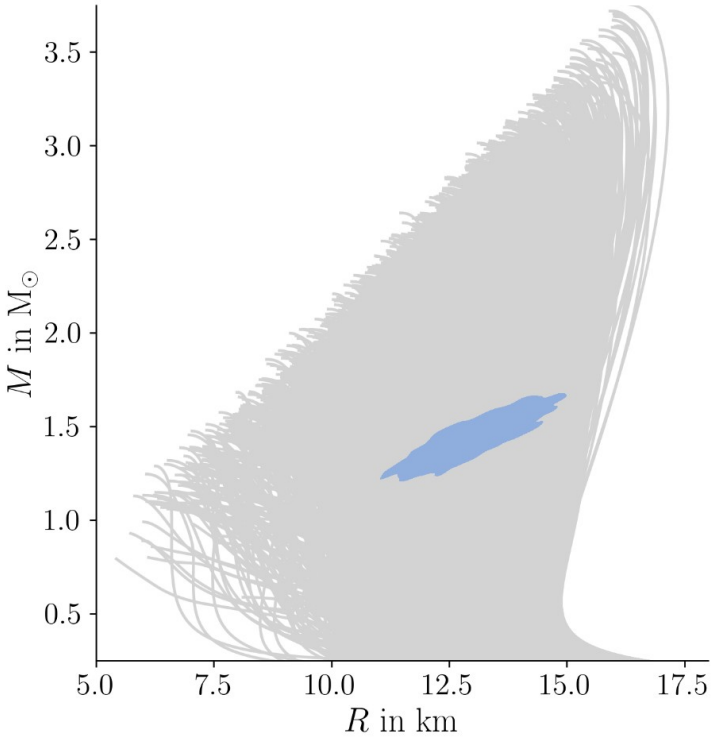


Bayesian approach

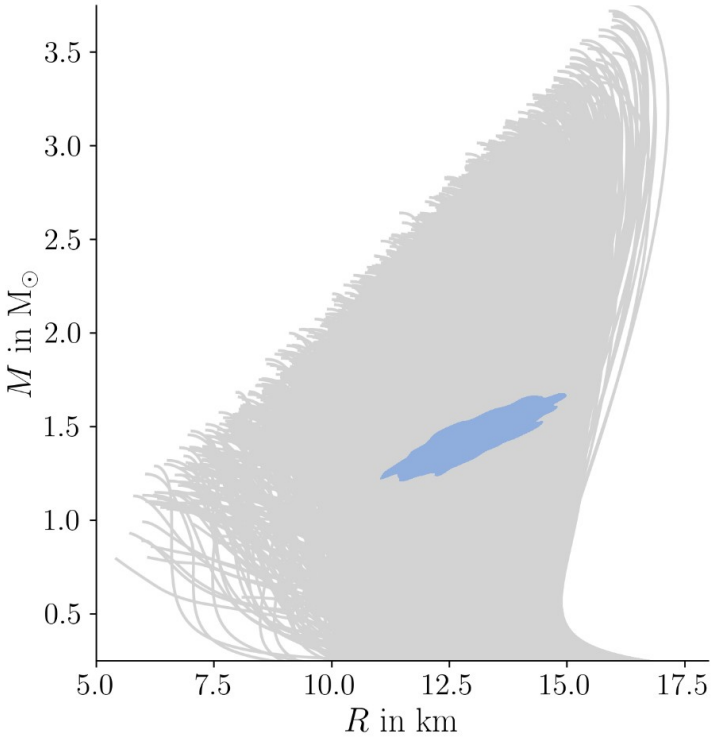




Bayesian approach

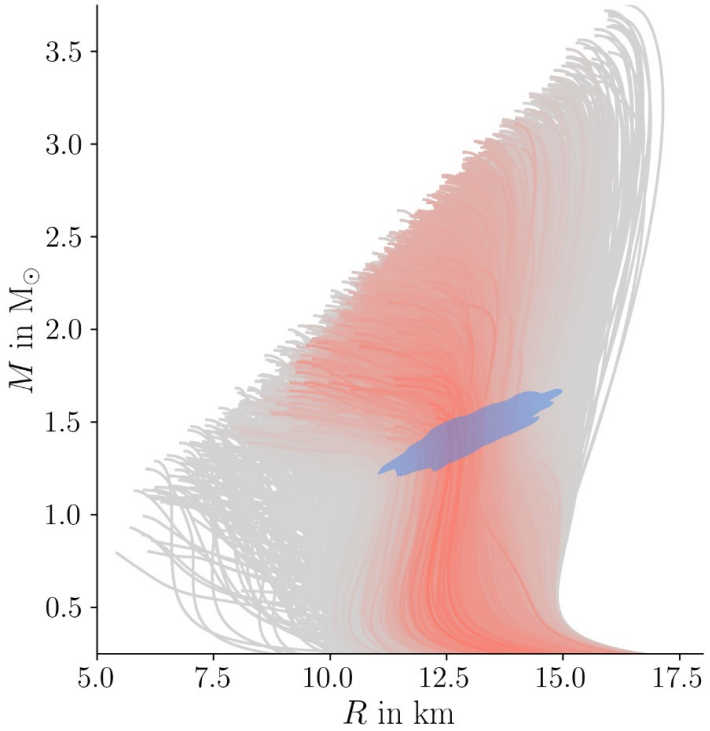


Bayesian approach



$$\mathcal{L}(\mathrm{EOS}|d) = \ldots$$

Bayesian approach

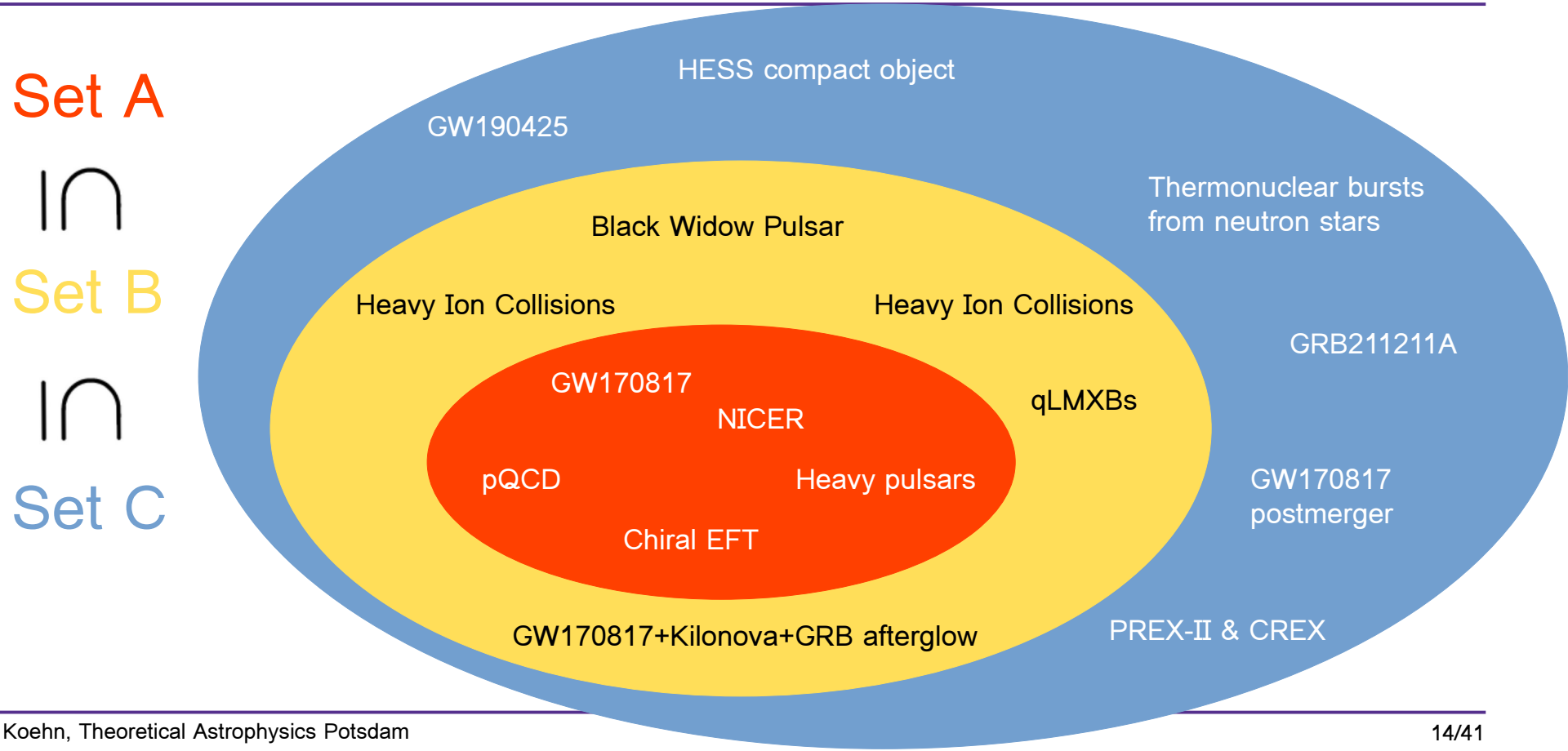


$$\mathcal{L}(\mathrm{EOS}|d) = \ldots$$

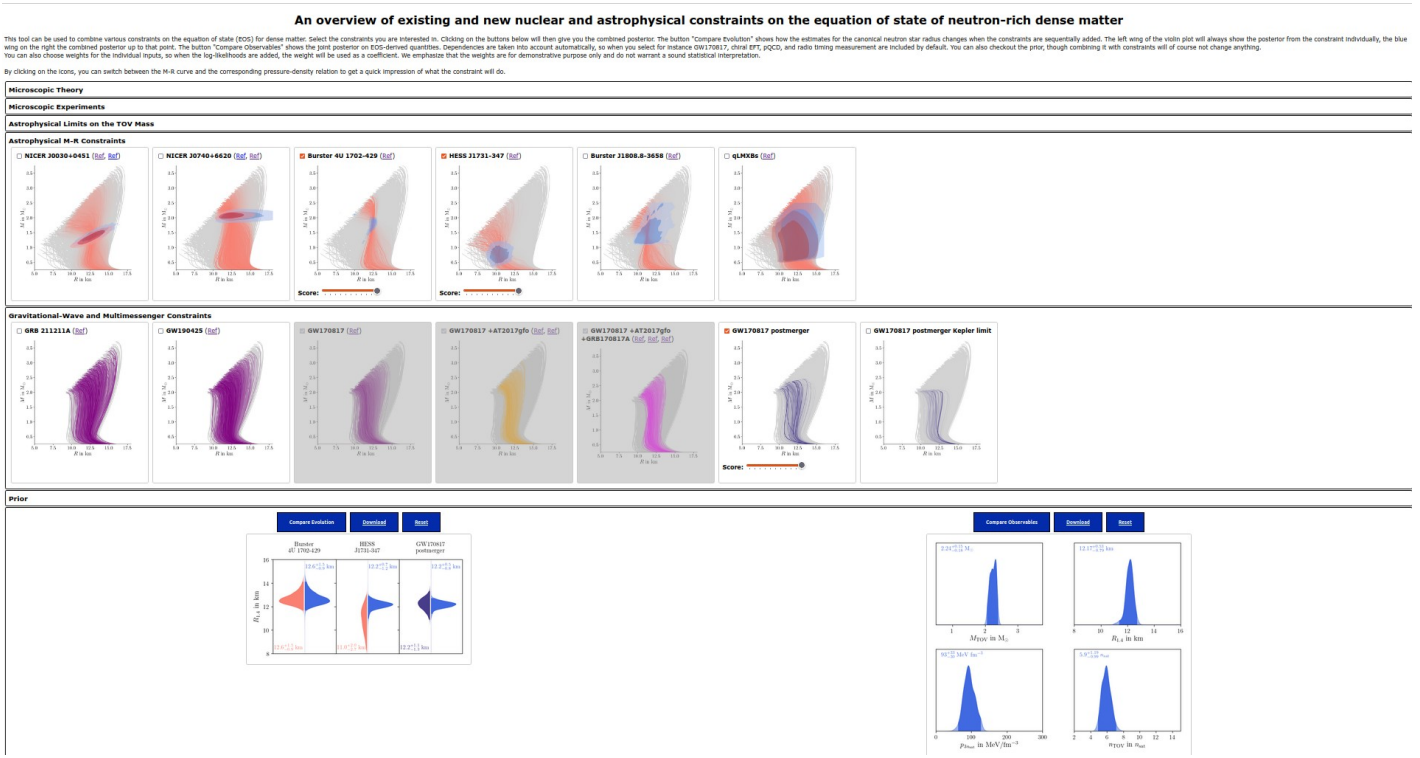
Bayesian approach

$$\mathcal{L}(\mathrm{EOS}|d) = \ldots$$

Which constraints to use?



Custom combinations now available



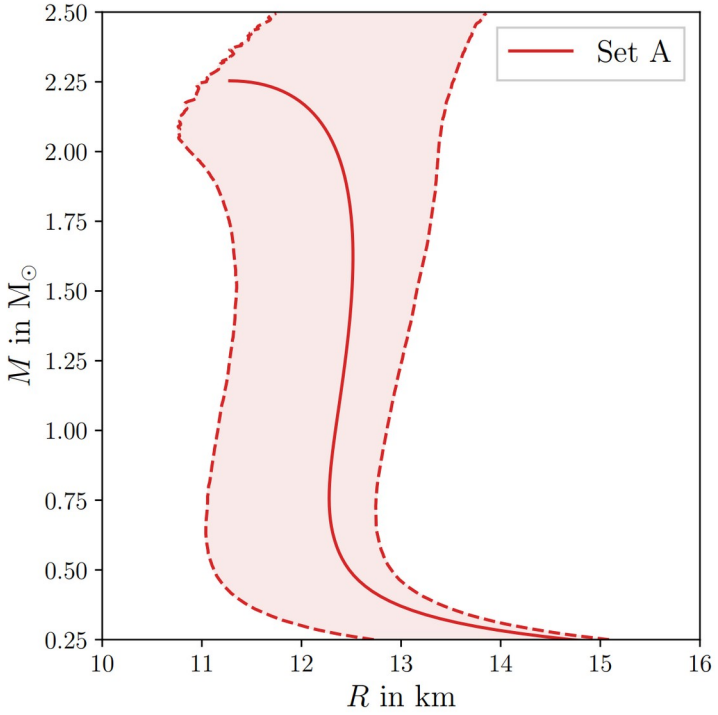
https://enlil.gw.physik.uni-potsdam.de/eos_constraints/

Custom combinations now available

https://multi-messenger.physik.uni-potsdam.de/eos_constraints/

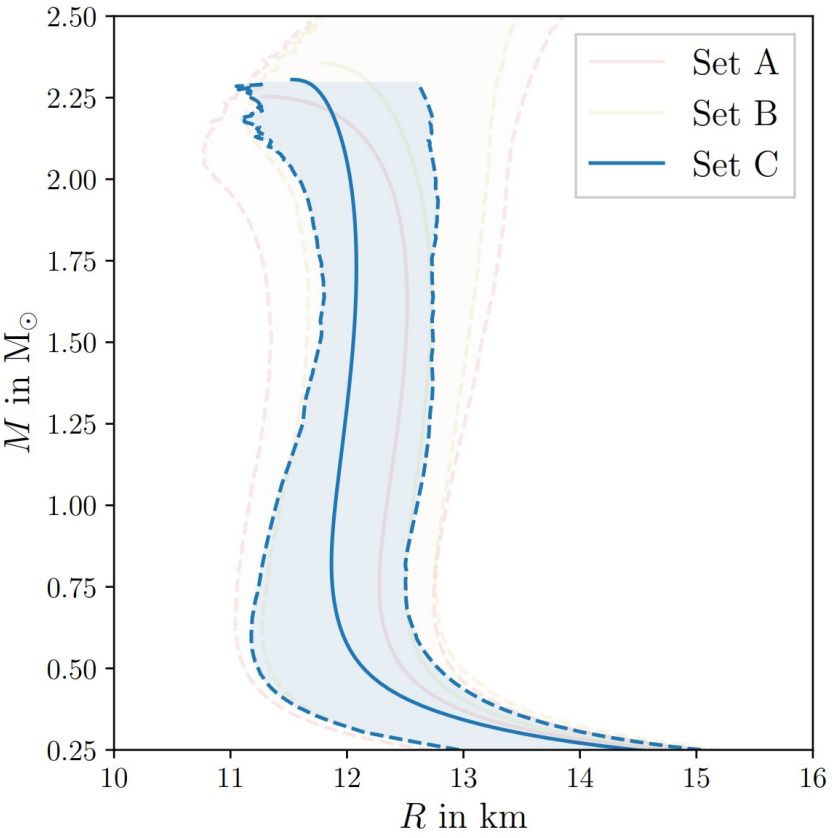
Results

- Common constraints, relatively reliable



Results

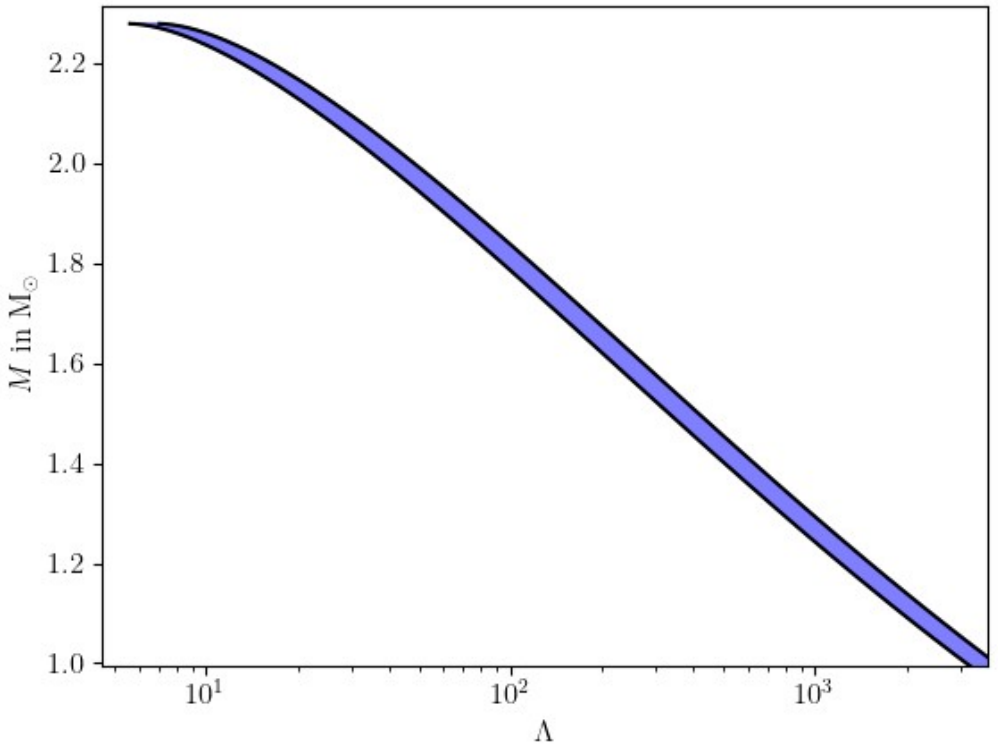
- More model-dependent
- Systematic biases might be dominant in some cases



II. EOS constraints with next-generation GW telescopes and DM

Next-generation GW telescopes

Next-generation GW telescopes

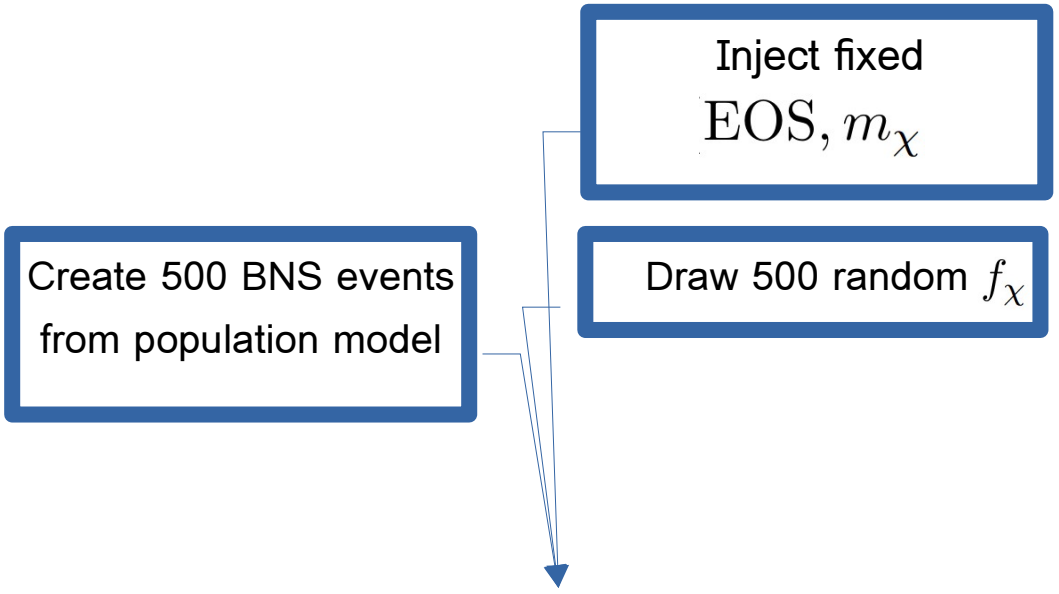


Next-generation GW telescopes

i. How does DM bias the inference of the EOS from next-generation telescope data?

ii. Can we distinguish between populations of NSs with and without DM using tidal deformability measurements from the Einstein Telescope and Cosmic Explorer?

Create mock ET data



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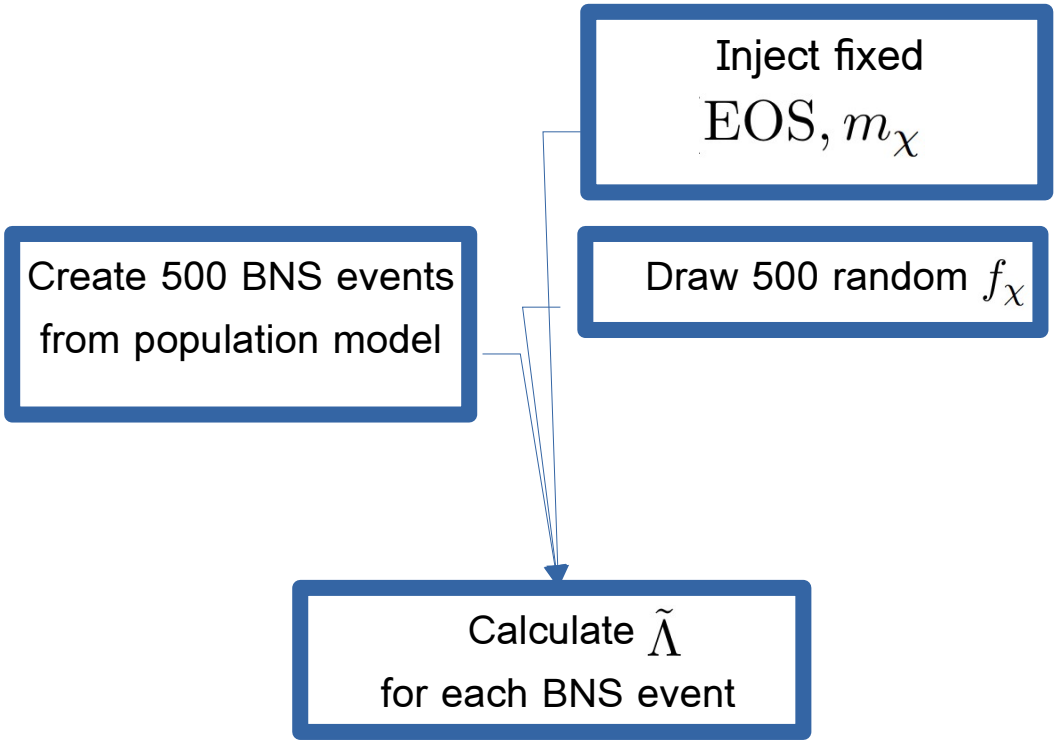
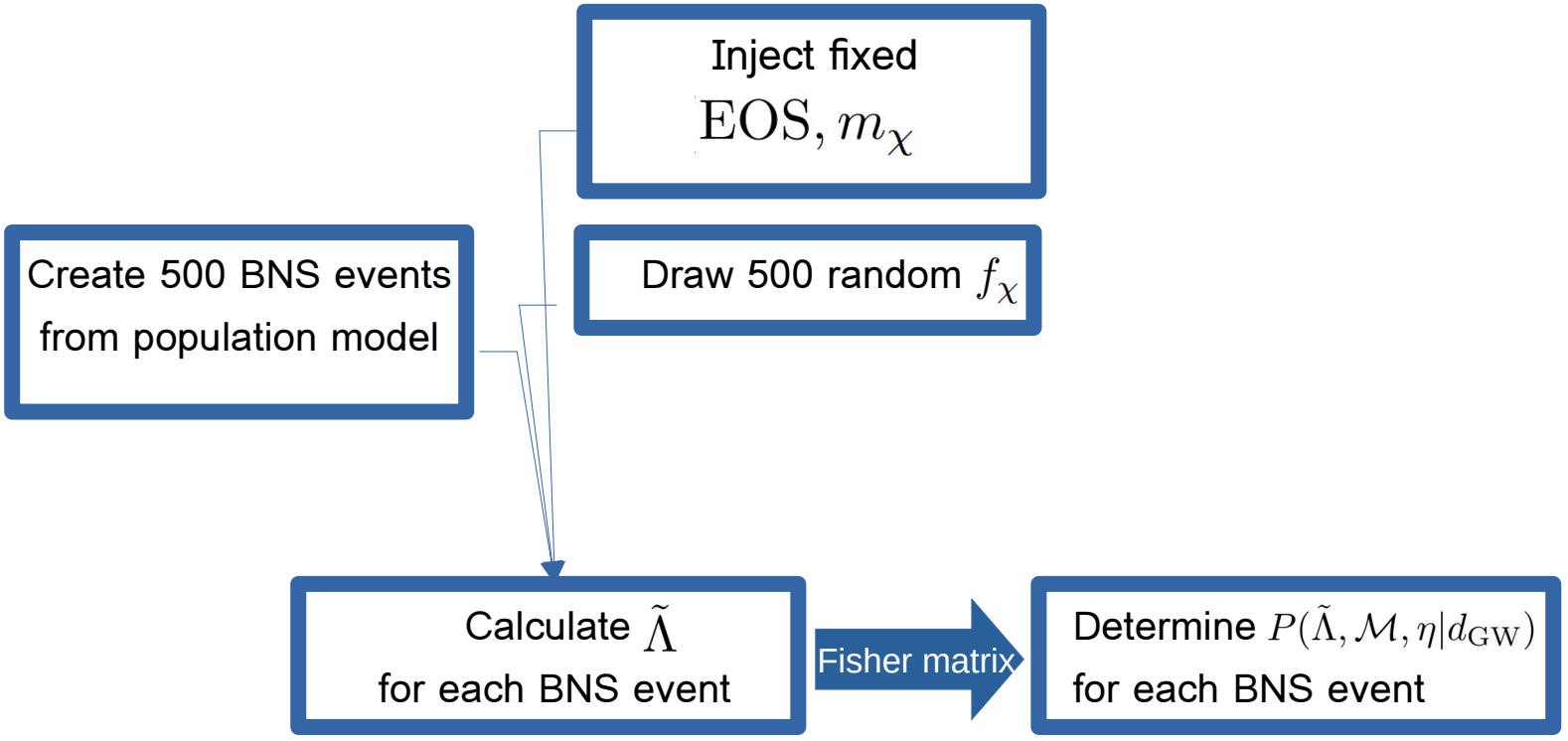


Create mock ET data



Create mock ET data

Select fixed

Create 5
from pc

“Easy way to create 500 mock posteriors for BNS events with DM with ET accuracy.”

for each BNS event

Fisher matrix

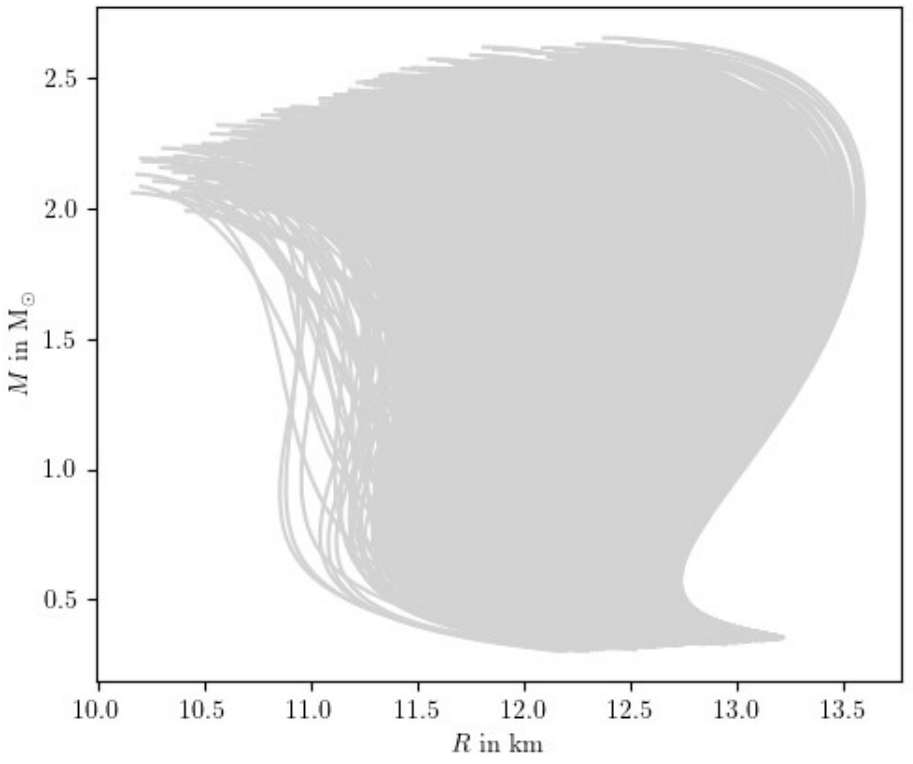
for each BNS event

Recovery of the EOS

i. How does DM bias the inference of the EOS from next-generation telescope data?

→ Get a posterior on baryonic EOS from mock ET data

Recovery of the EOS



Recovery of the EOS

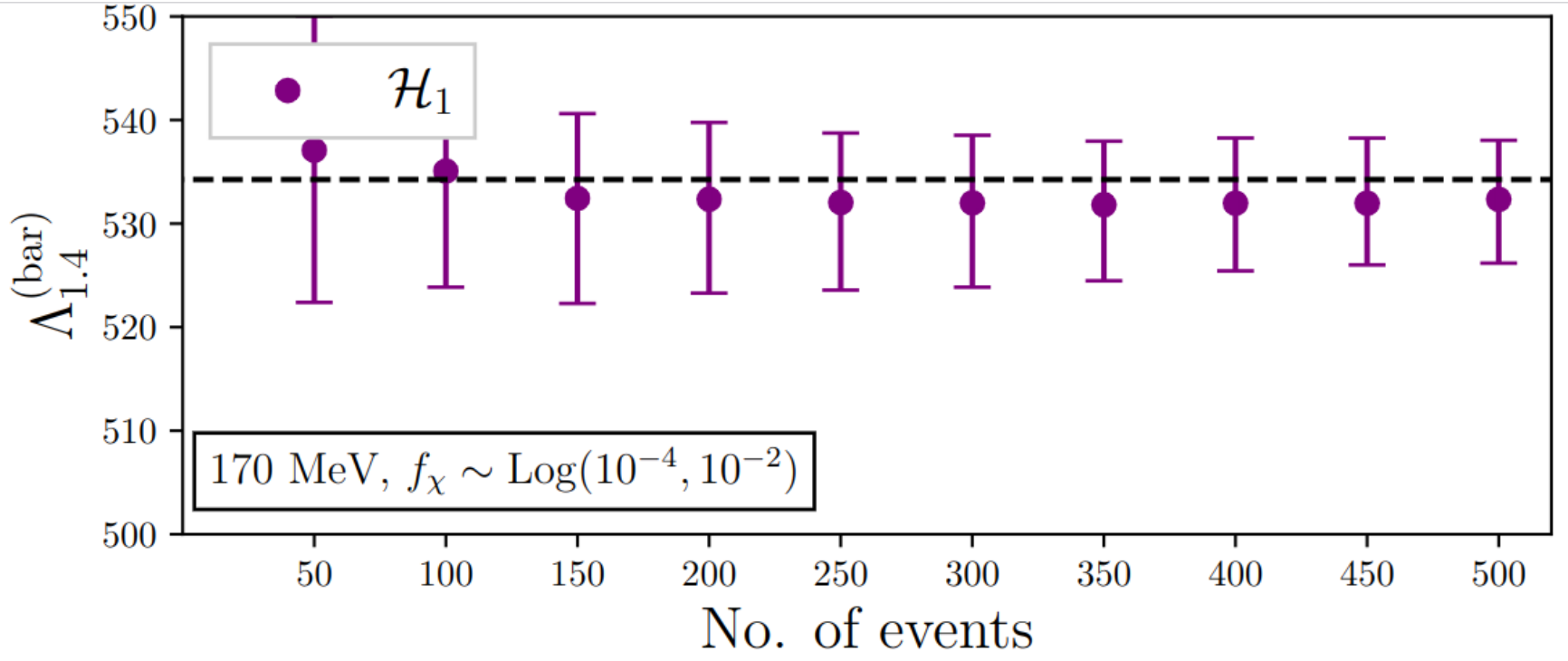
H_1: There is DM in the observed BNS population.

$$\mathcal{L}(\mathrm{EOS}, m_\chi, f_\chi | d_{\mathrm{GW}}) = \int d\mathcal{M}\, d\eta\, P(\tilde{\Lambda}^{(\mathrm{DM})}(\mathcal{M},\eta), \mathcal{M}, \eta | d_{\mathrm{GW}})$$

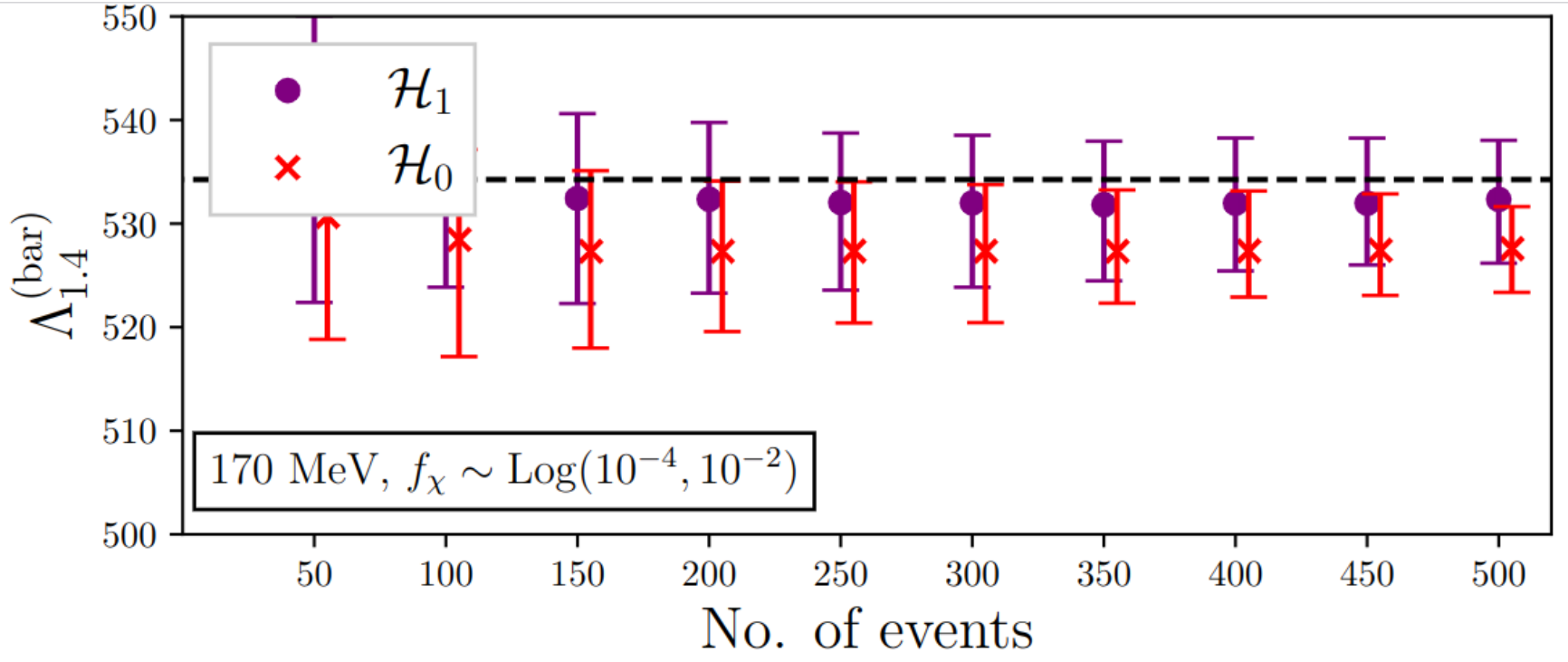
H_0: There is no DM in the observed BNS population.

$$\mathcal{L}(\mathrm{EOS} | d_{\mathrm{GW}}) = \int d\mathcal{M}\, d\eta\, P(\tilde{\Lambda}^{(\mathrm{bar})}(\mathcal{M},\eta), \mathcal{M}, \eta | d_{\mathrm{GW}})$$

Recovery of the EOS



Recovery of the EOS

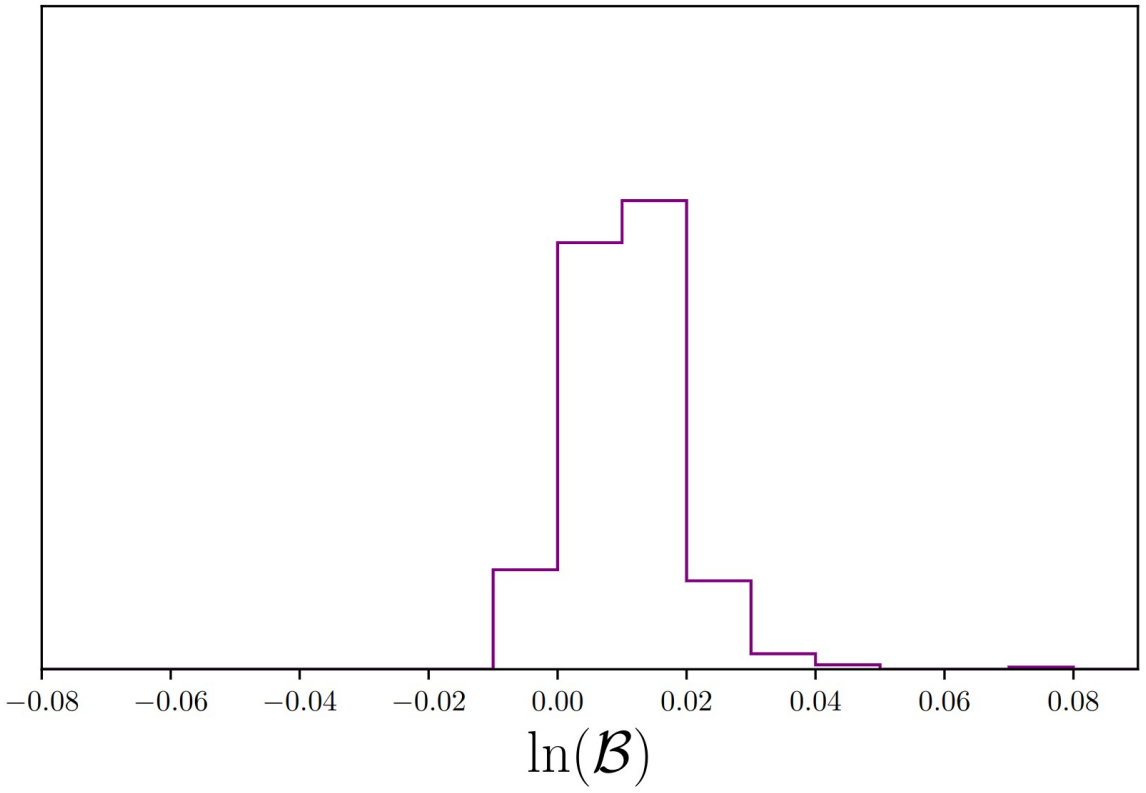


Detectability of DM

ii. Can we distinguish between populations of NSs with and without DM using tidal deformability measurements from the Einstein Telescope and Cosmic Explorer?

→ Determine the Bayes factor for H_1 vs. H_0

Detectability of DM



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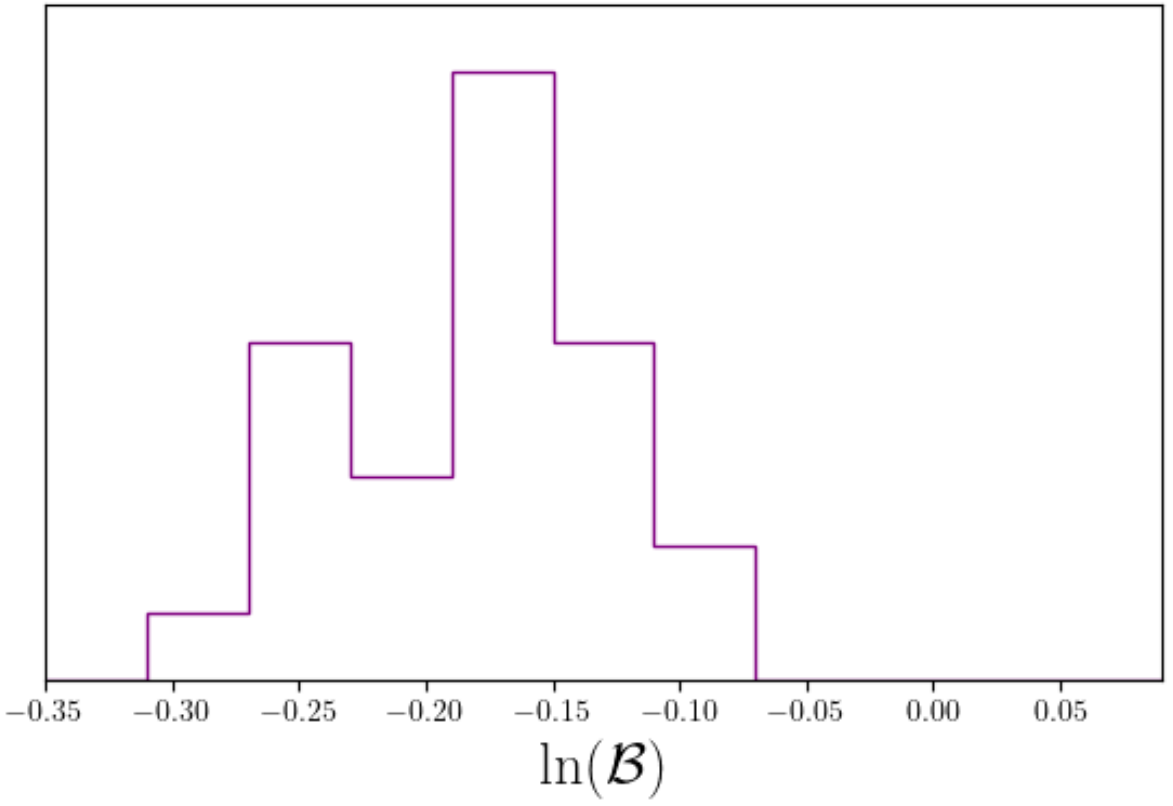
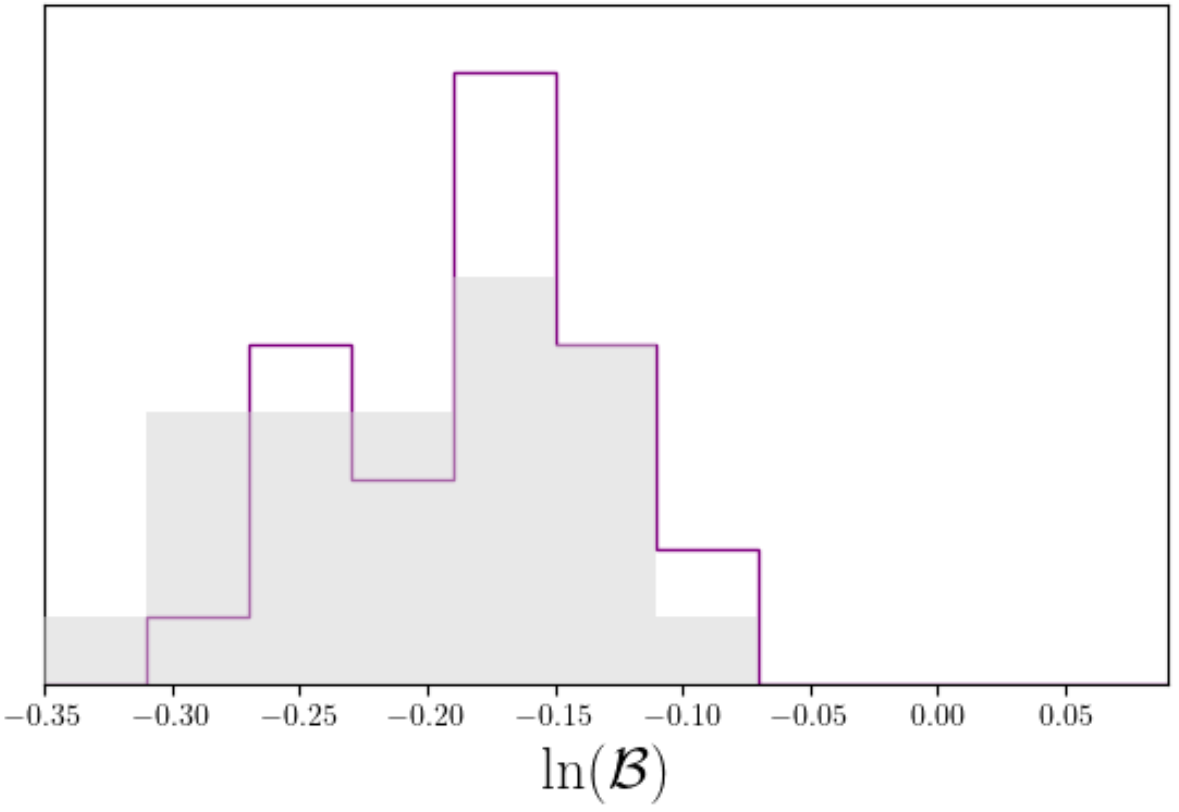


Detectability of DM



Detectability of DM

- Even when combining 500 events:

$$\ln(\mathcal{B}) = -4.23$$

$$\ln(\mathcal{B}) = -4.09$$

Take aways

- Many different **data points with varying reliability** out there
- **Neutron star radii** currently can be determined up to $\sim 12^{+0.5}_{-0.5}\,\mathrm{km}$ [1,2,3,4]
- DM could slightly bias the EOS in future detections, but is (within our assumptions) not detectable

[1] Capano et al. (2020)
[2] Raajimakers et al. (2021)
[3] Jiang et al. (2023)
[4] Biswas (2021)

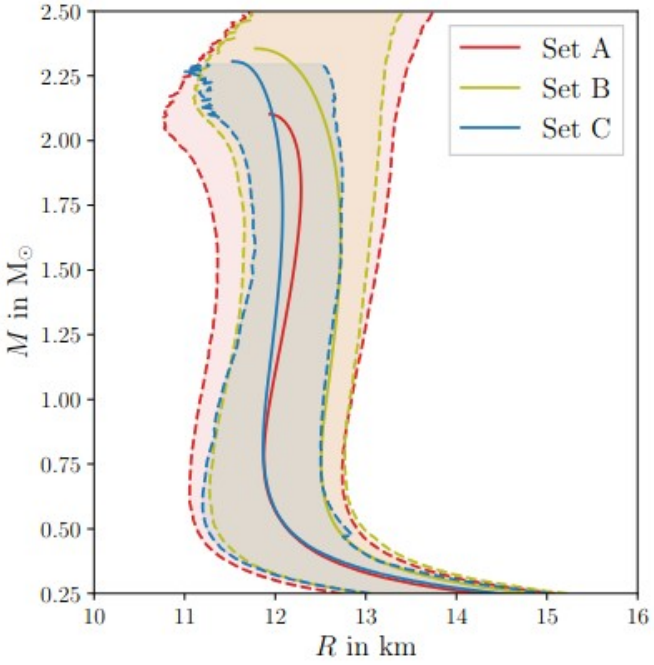
Thanks for listening!

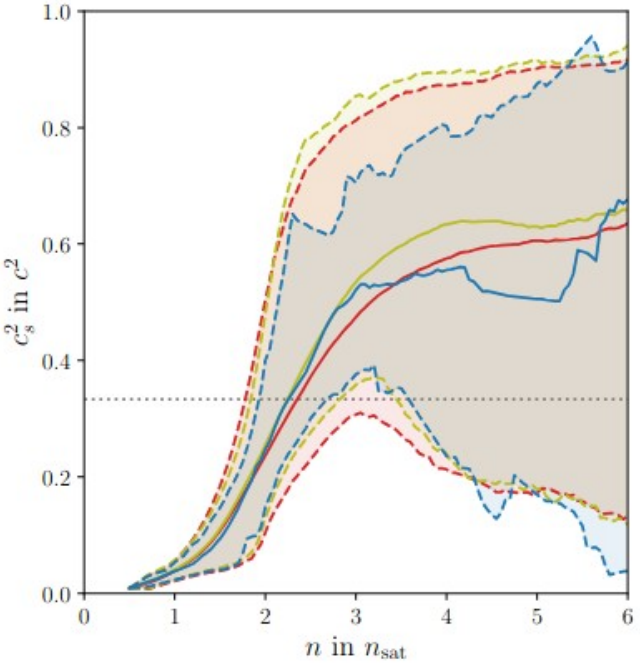
Koehn et al. (2024)
arXiv:2402.04172

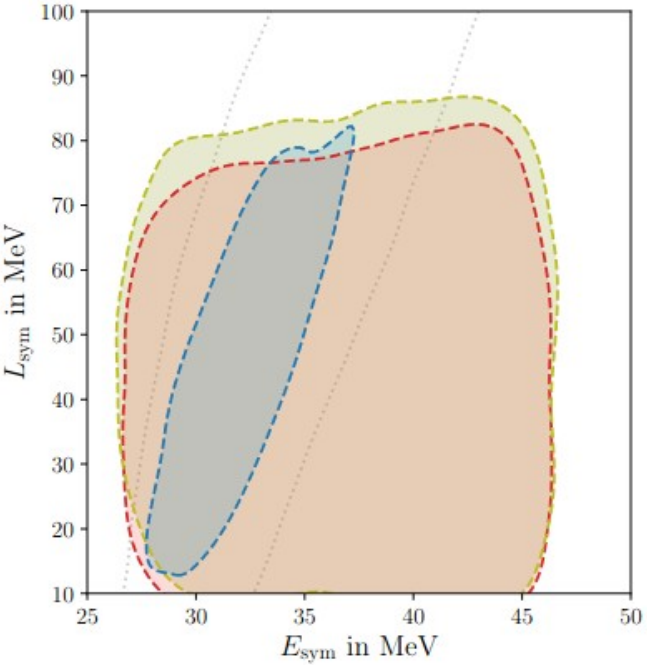
Koehn et al. (2024)
arXiv:2408.14711

Create your own constraint set!

Backup slides







Backup slides

$$\frac{M_{\rm ej,dyn}}{10^{-3}{\rm M}_\odot} = M_1 \left[\frac{a}{C_1} + b \left(\frac{M_2}{M_1} \right)^n + c\, C_1 \right] + (1 \leftrightarrow 2) + \alpha \,,$$

$$\log_{10}\left(\frac{M_{\rm disk}}{{\rm M}_\odot} \right) = a \left[1 + b \tanh\left(\frac{c - (M_1 + M_2)/M_{\rm threshold}}{d} \right) \right]$$

Backup slides