CONSTRAINING COSMIC STRING NETWORKS WITH EPTA

6e AG du GdR Ondes Gravitationnelles – Octobre 2022

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COSMIC STRINGS

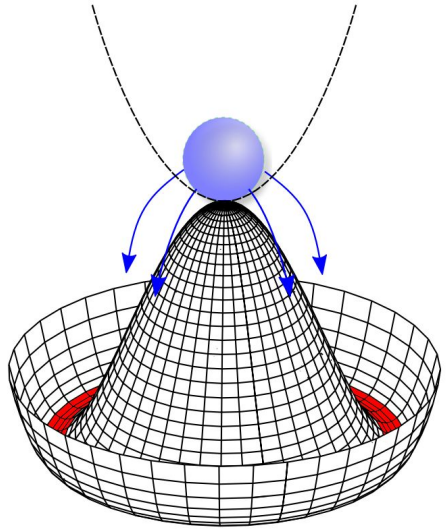
- Topological strings

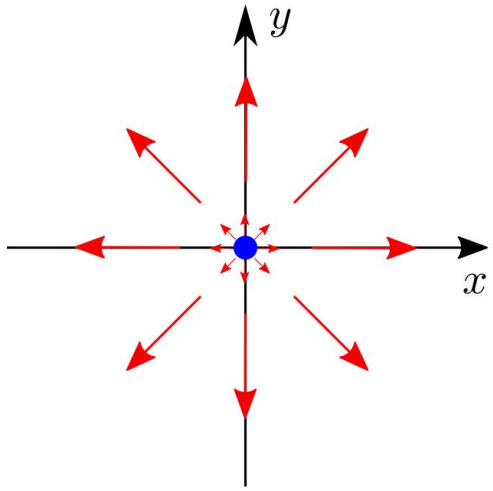
  As it expands and cools down, the Universe might have acquired a domain structure

- Energy scale of the phase transition $\eta \leftrightarrow$ String tension μ

$$\frac{G\mu}{c^4} \approx 10^{-6}\left(\frac{\eta}{10^{16}\ \mathrm{GeV}}\right)^2$$

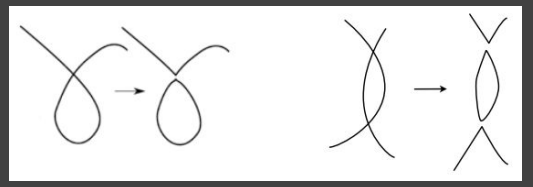
- A gateway to high energy physics





credits: Pierre Auclair

SGWB PRODUCED BY COSMIC STRING

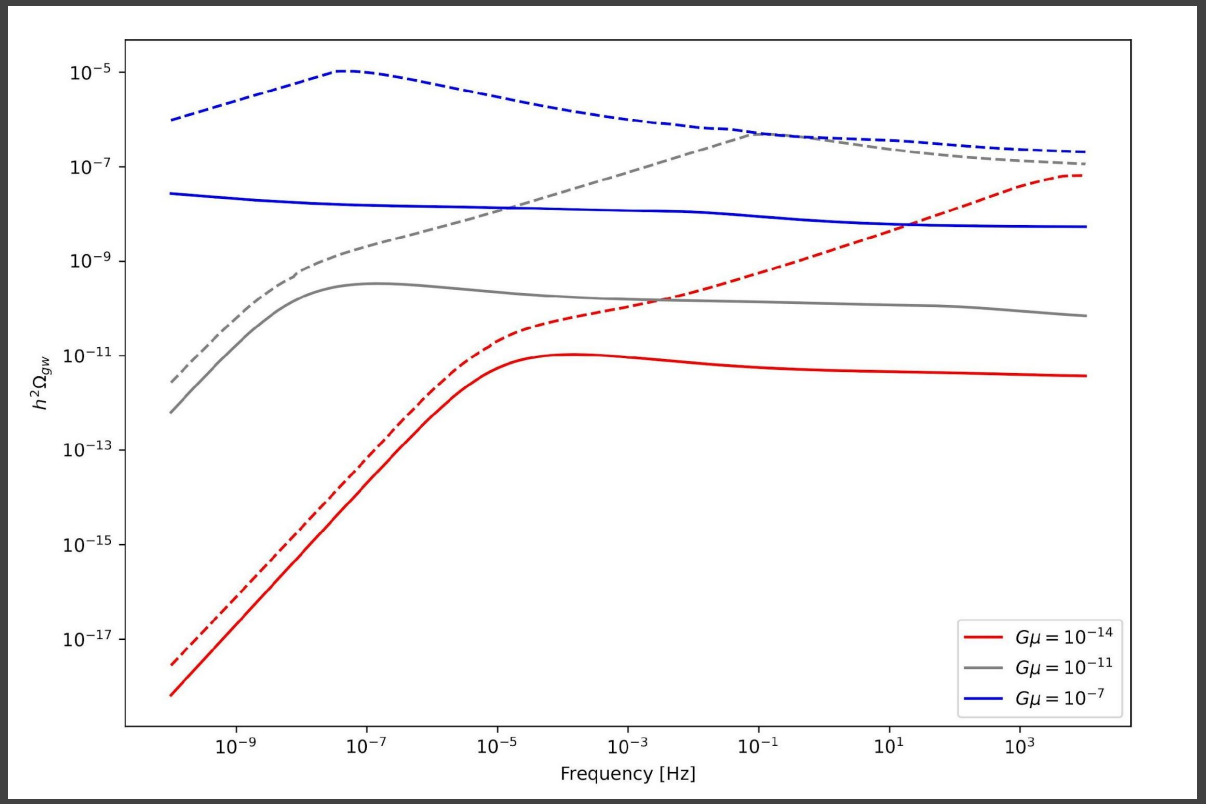


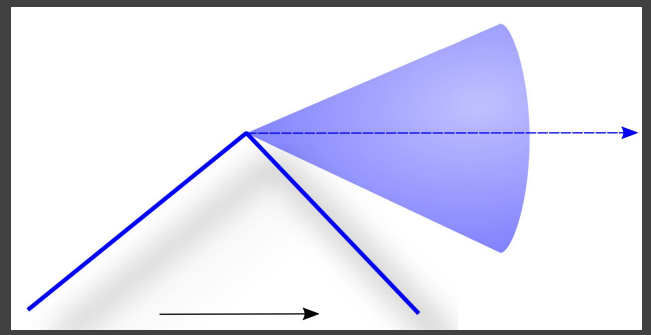
$$\Omega_{gw}(t_0, f) \propto (G\mu)^2 f \int_0^{t_0} dt \left(\frac{a(t)}{a(t_0)}\right)^3 \int_0^{\infty} d\ell\, \ell\, n(\ell, t)\, P\left(\frac{a_0}{a(t)} f \ell\right)$$

String tension

- BOS model (solid) – [1309.6637]
- LRS model (dashed) – [1006.0931]

Power radiated
Number of kinks





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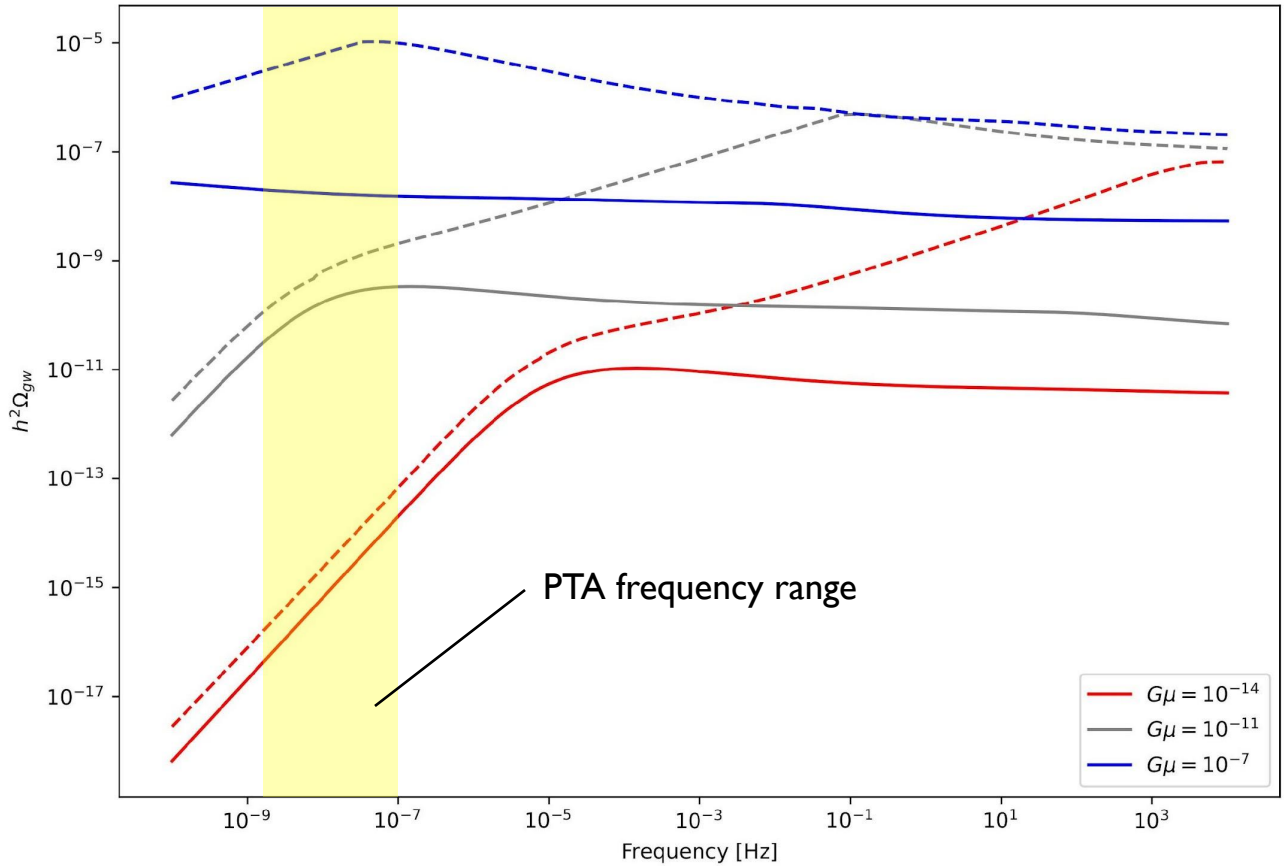
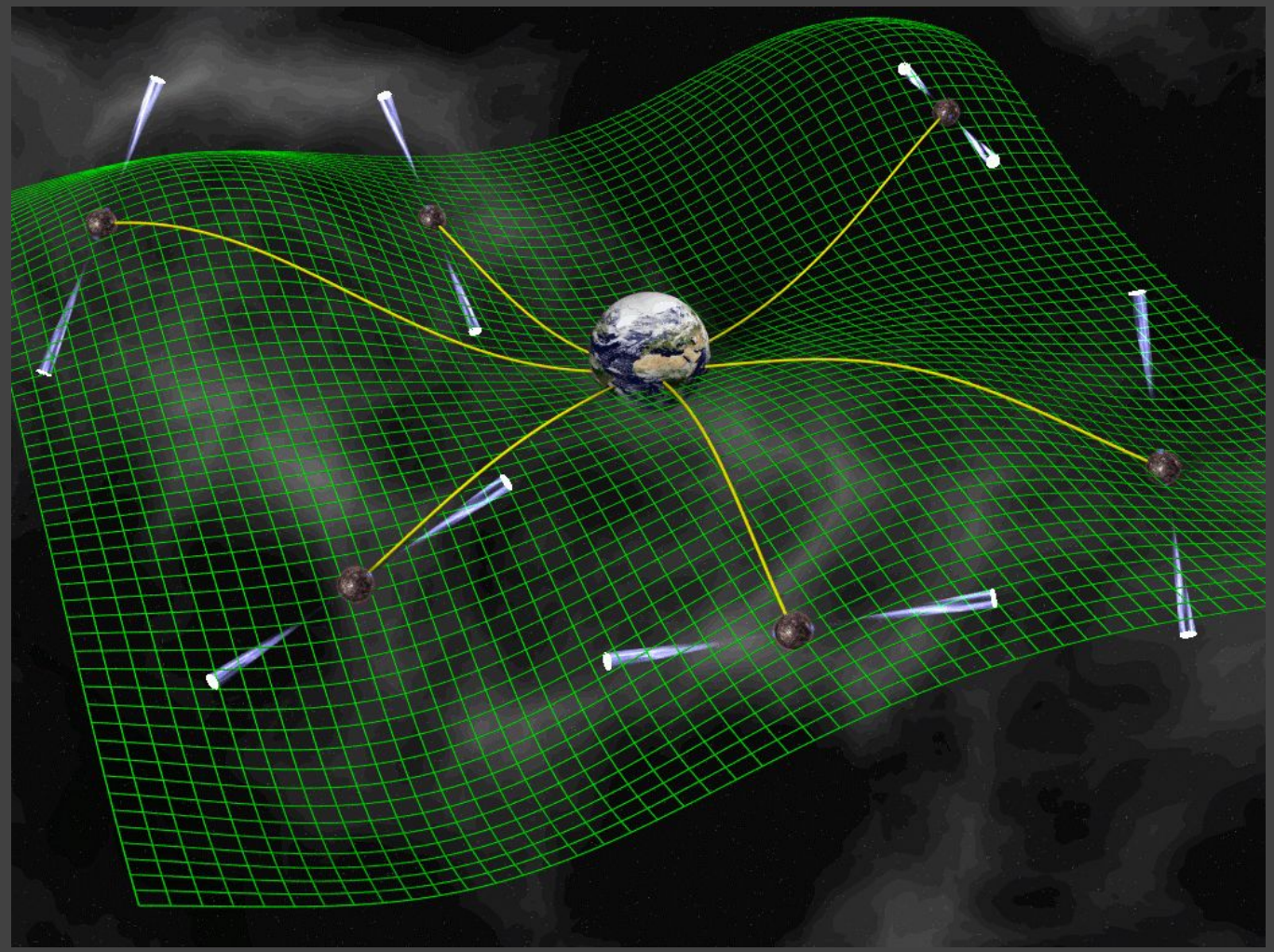


PULSAR TIMING ARRAY



credits: David J. Champion

- Use pulsar as astrophysical clocks as they emit periodic radio pulses due to a fast & stable spin
- Imprints of GWs are expected in the difference between the ToAs of the expected and the observed radio pulses
  → spatial correlations between pulsars
- Catalog of pulsars used : EPTA (DR2 – 6 pulsars)
  Chen et al [2110.13184]

PTA – NOISE MODEL & HYPOTHESIS

Noise model used on EPTA DR2 (6 pulsars) - Chen et al (2021)

- For individual pulsar - Chalumeau et al (2021)
  - Radiometer Noise (White Noise) : fixed parameters
  - Spin noise (Red noise) : Power law PSD → 2 parameters for each pulsar
  - Dispersion measure variation (Red noise) : Power law PSD → 2 parameters for each pulsar

- A Common Red Noise (CRN) is already observed in all PTAs

  → Aim : can we use this common noise to constrain cosmic strings (CS) networks ?

  1. Constrain the string tension Gμ
  2. Compare the gravitational CS noise model with a common uncorrelated noise (CURN)
  3. Study the influence of power radiated by loops in GWs on these results

H1 – GW SIGNAL FROM COSMIC STRINGS

- BOS model (blue line)

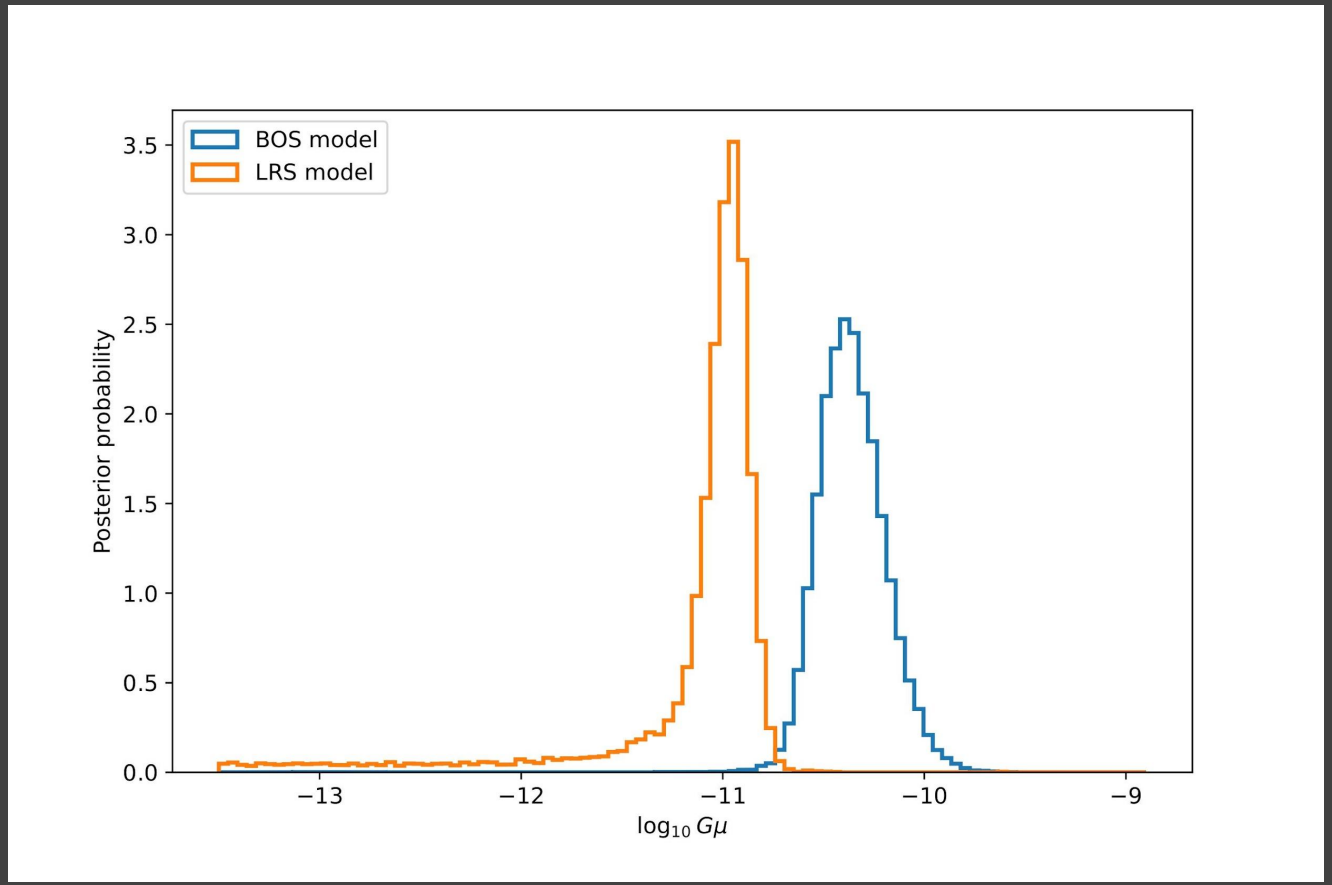
  $\log_{10}(G\mu) = -10{,}37^{+0{,}18}_{-0{,}15}$ (1-sigma)

  $\log_{10}(B^{CURN}_{BOS}) = 1{,}5^{+0{,}3}_{-0{,}3} < 2$

- LRS model (orange line)

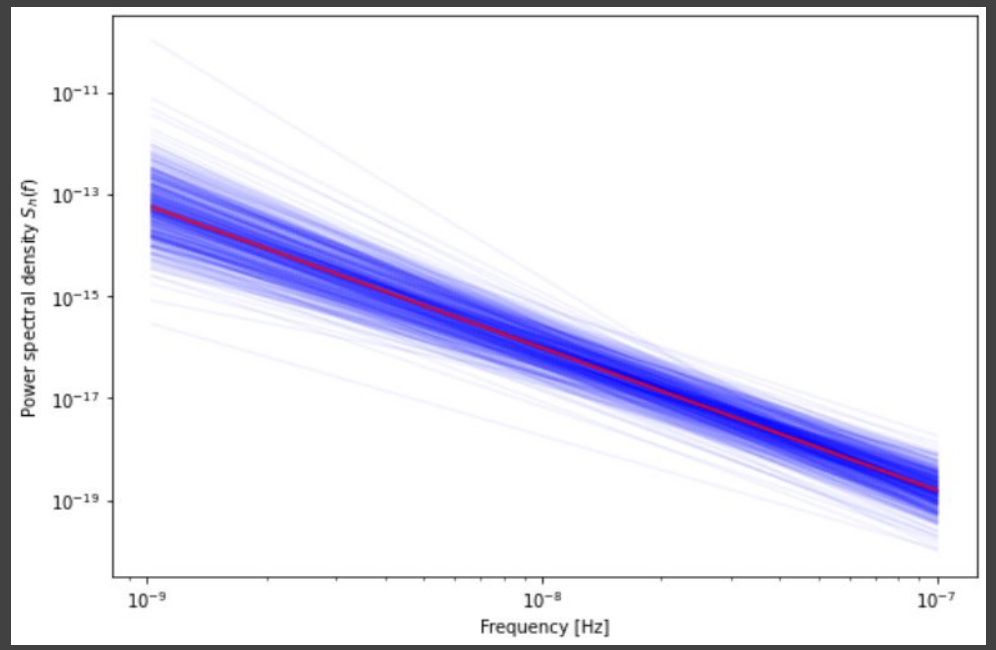
  $\log_{10}(G\mu) = -11{,}01^{+0{,}12}_{-1{,}27}$ (1-sigma)

  $\log_{10}(B^{CURN}_{LRS}) = 2{,}8^{+0{,}3}_{-0{,}3} > 2$



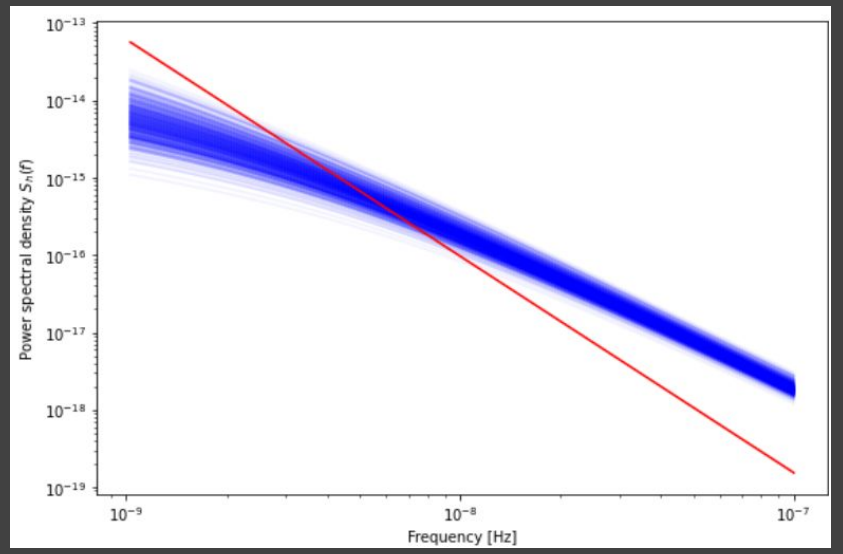
→ Cosmic String SGWB is disfavoured compared to a CURN, why ?

H1 – RESPECTIVE CRN SAMPLED SPECTRUMS

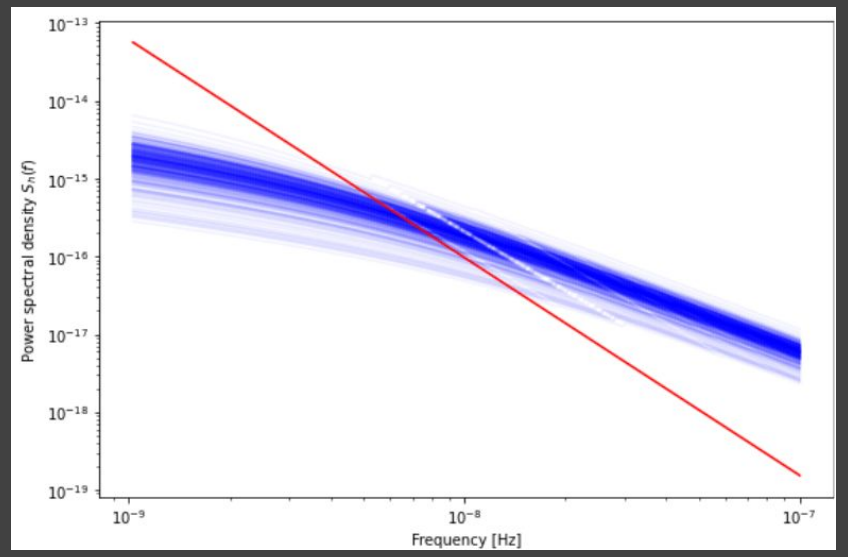


500 sampled PSD from an analysis with only a CURN (Power Law)

$$\log_{10}(A) = -14{,}30 \qquad \gamma = 3{,}80$$



PSD of SGWB with BOS model



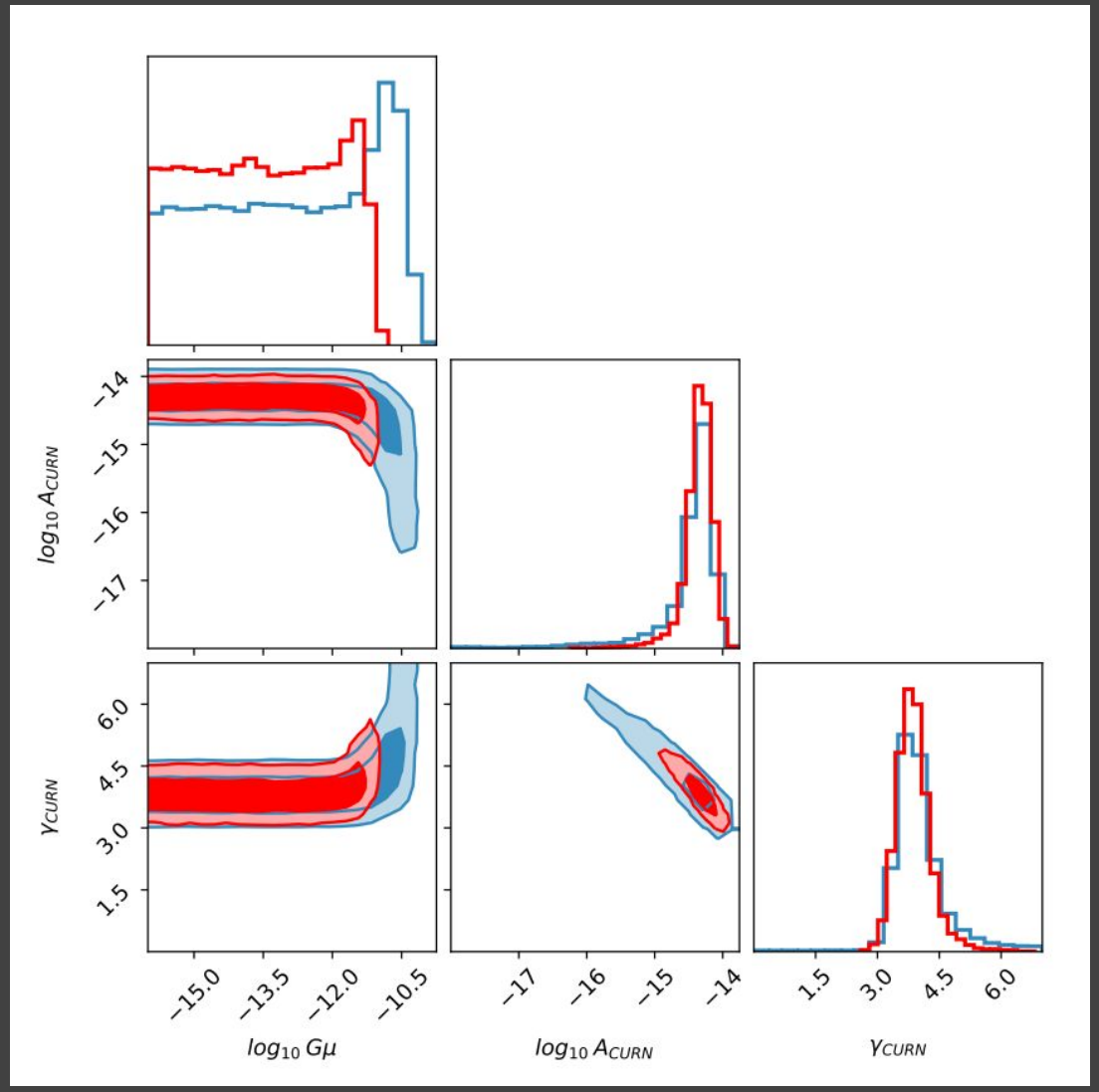
PSD of SGWB with LRS model

H2 – CURN + GW SIGNAL FROM COSMIC STRINGS

- BOS model (blue line)
  $\log_{10}(G\mu) \leq -10{,}5$ (1-sigma)

- LRS model (red line)
  $\log_{10}(G\mu) \leq -11{,}6$ (1-sigma)

→ Strong interplay between the GW signal and the CURN



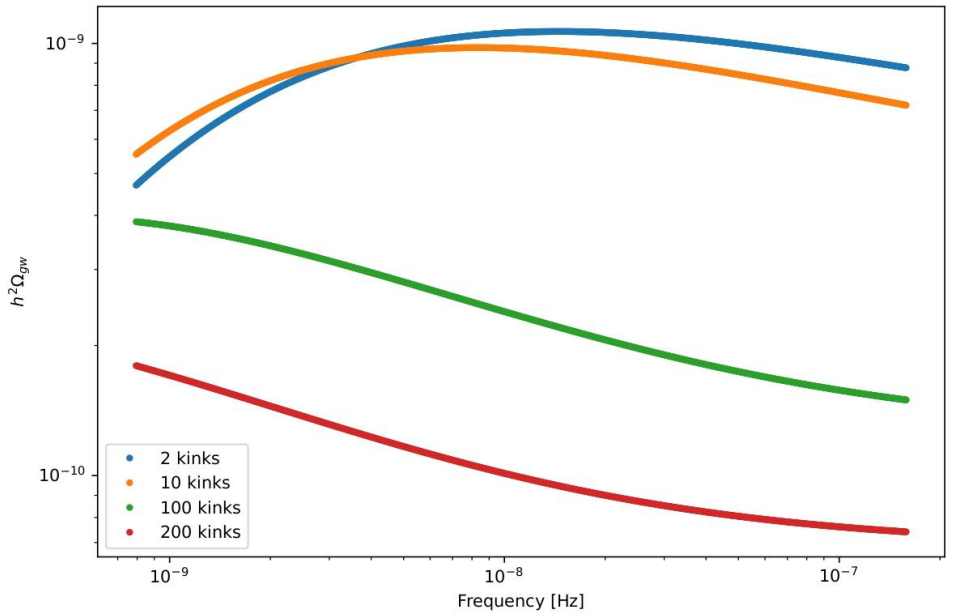
H3 – CS SGWB WITH VARYING KINK NUMBER

- Kinks appear with intercommutation of strings
- The more kinks there are, the greater the GW emission power of the loop is → Γ
- Number of kinks on loops is still poorly known (gravitational backreaction, limits in simulations…)

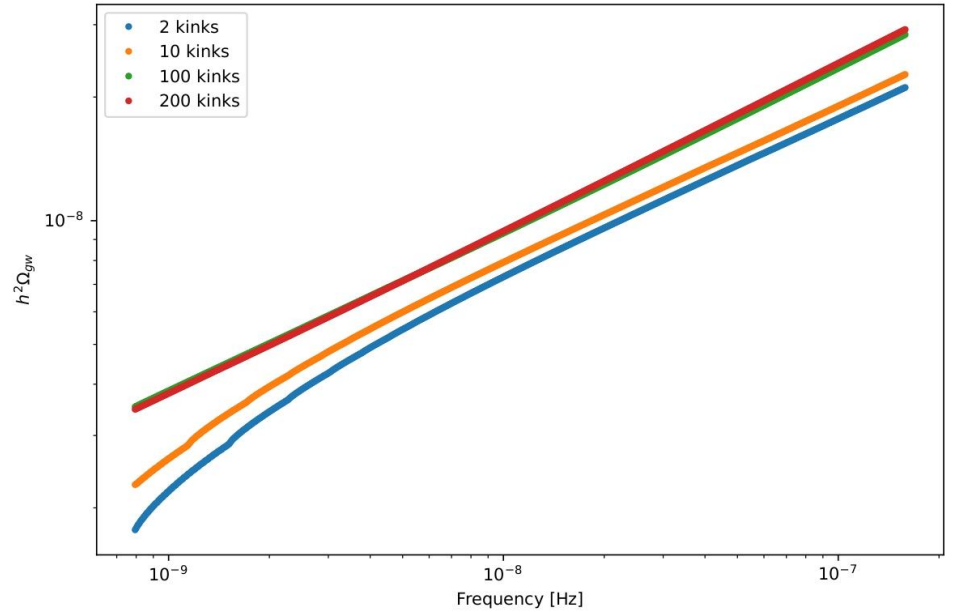
Effect of increasing kink number

- BOS model : increase spectral index, decrease amplitude
- LRS model : tend to constant spectral index, smaller effect on amplitude

For $G\mu = 10^{-10}$



BOS model

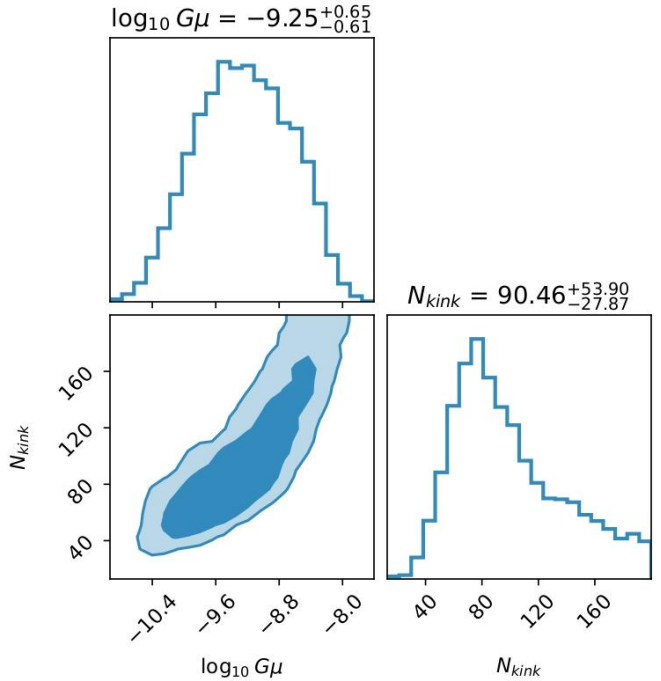


LRS model

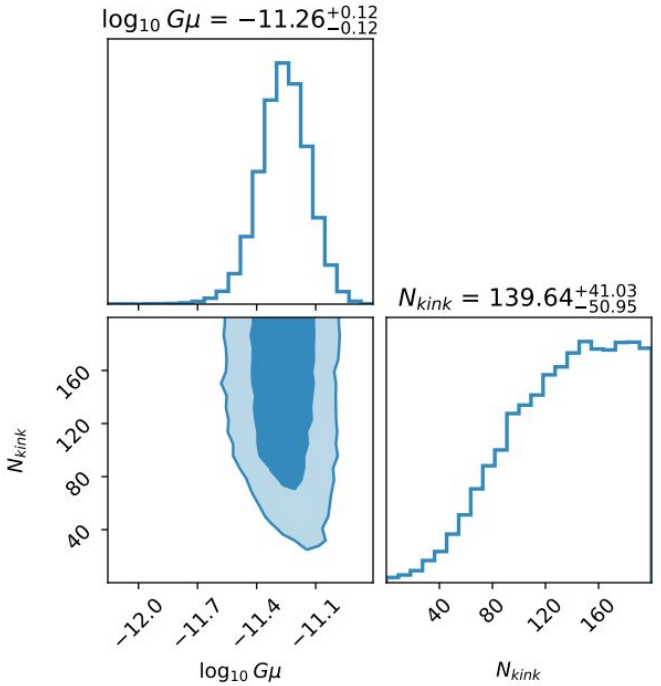
H3 – CS SGWB WITH VARYING KINK NUMBER

- BOS model
  - $G\mu$ is less constrained than with fixed 2 kinks
  - Correlation as opposite effects on amplitude

- LRS model
  - No significant effect on tension and BF
  - High number of kinks only to increase spectral index at low frequency



BOS model

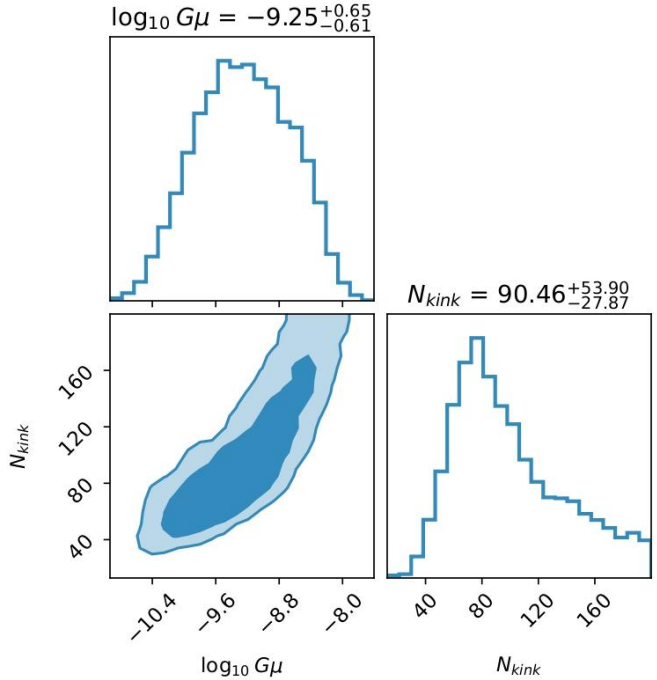


LRS model

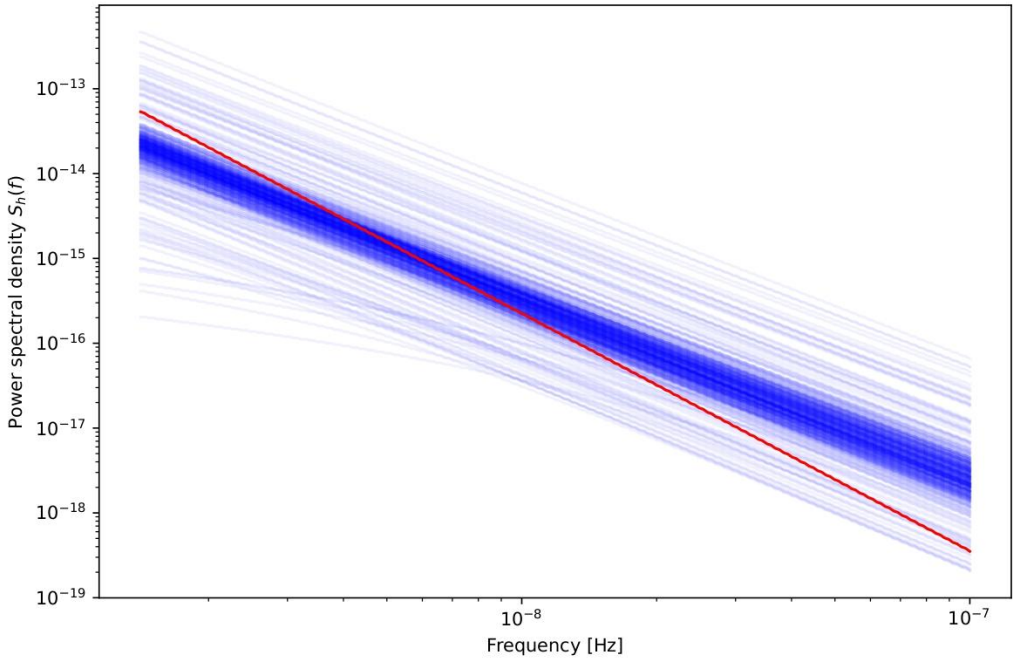
H3 – CS SGWB WITH VARYING KINK NUMBER

- BOS model
  - $G\mu$ is less constrained than with 2 kinks
  - Correlation as opposite effects on amplitude

  - $\log_{10}(G\mu) = -9{,}25^{+0{,}65}_{-0{,}61}$ (1-sigma)
  - $\log_{10}(B^{BOS}_{CURN}) \approx 0{,}1^{+0{,}1}_{-0{,}1}$



BOS model



CONCLUSIONS

- The CRN detected in EPTA data (DR2) can be interpreted by cosmic strings SGWB with:

  For BOS model : $\log_{10}(G\mu) \approx -10{,}4$ For LRS model : $\log_{10}(G\mu) \approx -11{,}1$

- But the PSD and the GW signature of the signal is, for the moment, disfavoured compared to a CURN (especially for the LRS model)

- Trying to probe a GW signal in addition to a CURN put upper bounds for the string tension

  For BOS model : $\log_{10}(G\mu) \leq -10{,}5$ For LRS model : $\log_{10}(G\mu) \leq -11{,}6$

- In comparison, the constraint obtained by CMB analysis is : $\log_{10}(G\mu) \leq -7$ *[Charnock et al, 2016]*

- However for the BOS model, the presence of numerous kinks ($\Gamma \sim 500$) could decrease this constraint by one order of magnitude and the model becomes indistinguishable from a CURN