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Hunting for Axion-like particles with the nEDM Experiment

N. Ayres, S. Emmenegger, M. Rawlik, N. Ziehl on behalf of the nEDM collaboration.

1. Introduction

Ultralight axion-like particles are dark matter candidates and could tackle the strong CP problem in QCD. Interactions of a coherently oscillating axion field could induce and oscillation in the nEDM.

$$d_n(t) \approx 2.4 \times 10^{-16} \frac{C_g a_0}{f_a} \cos(m_a t) ecm$$

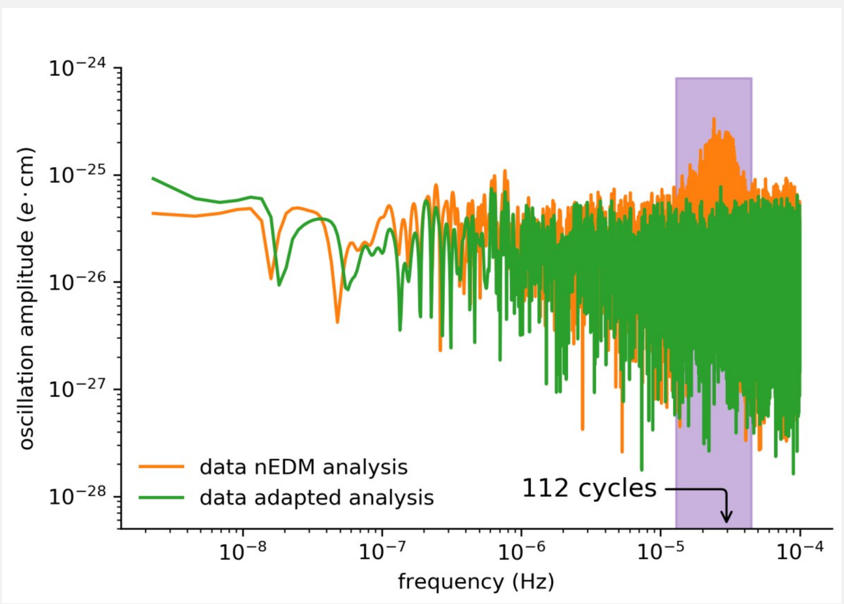
We looked at data from the nEDM experiments at ILL and PSI to search for ultralight axions[1].

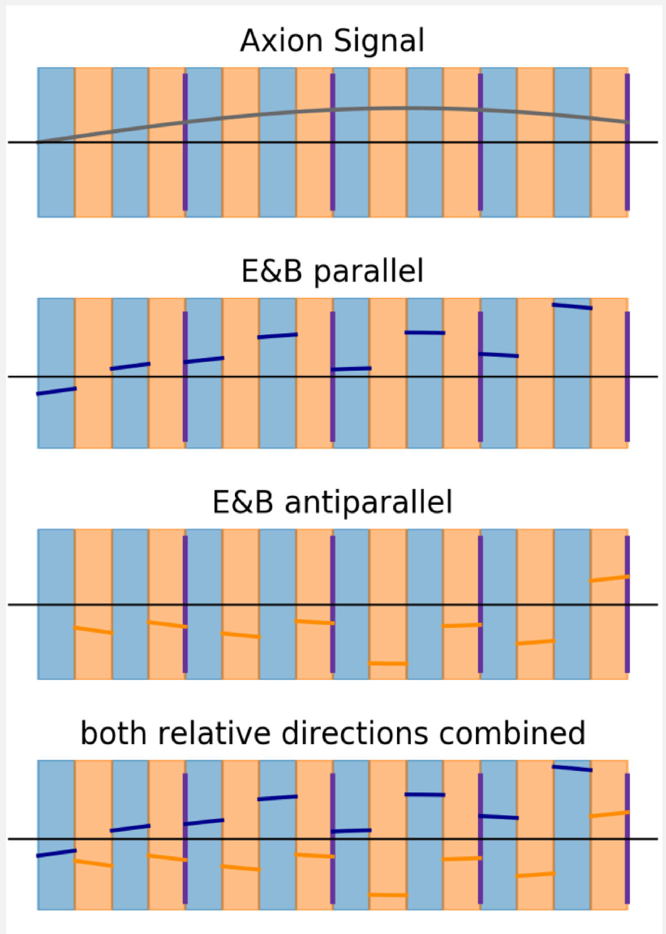
3. Recent Analysis Improvements[3]

Better fitting:

In the nEDM Experiment at PSI, data was taken alternating between $EB\uparrow\uparrow$ and $EB\uparrow\downarrow$. In the previous analysis, before unblinding, these data were fitted separately. Therefore the fit was not sensitive to frequencies below the inverse of $t_{EB\uparrow\uparrow} \longrightarrow t_{EB\uparrow\downarrow}$.

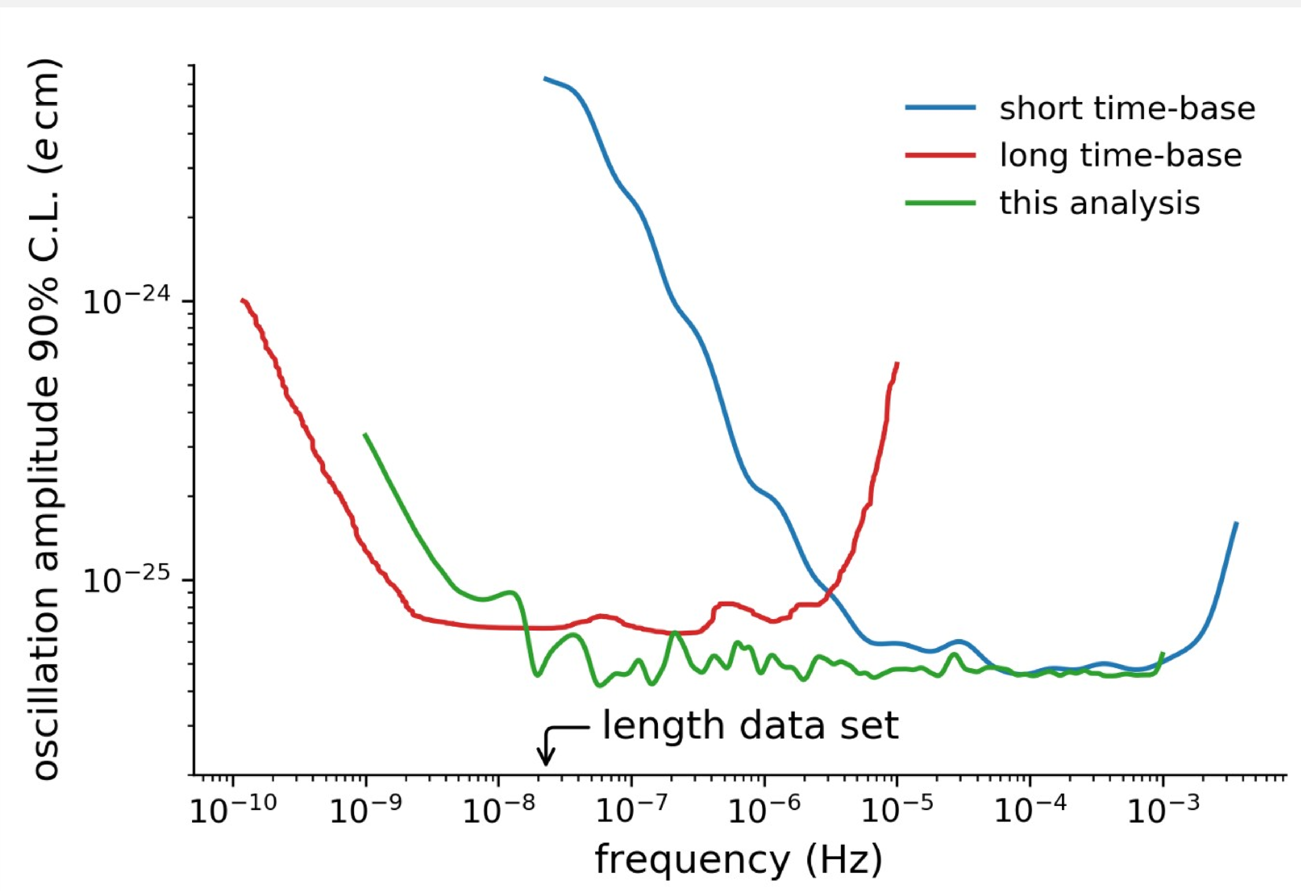
Solution: perform a **common fit** instead.

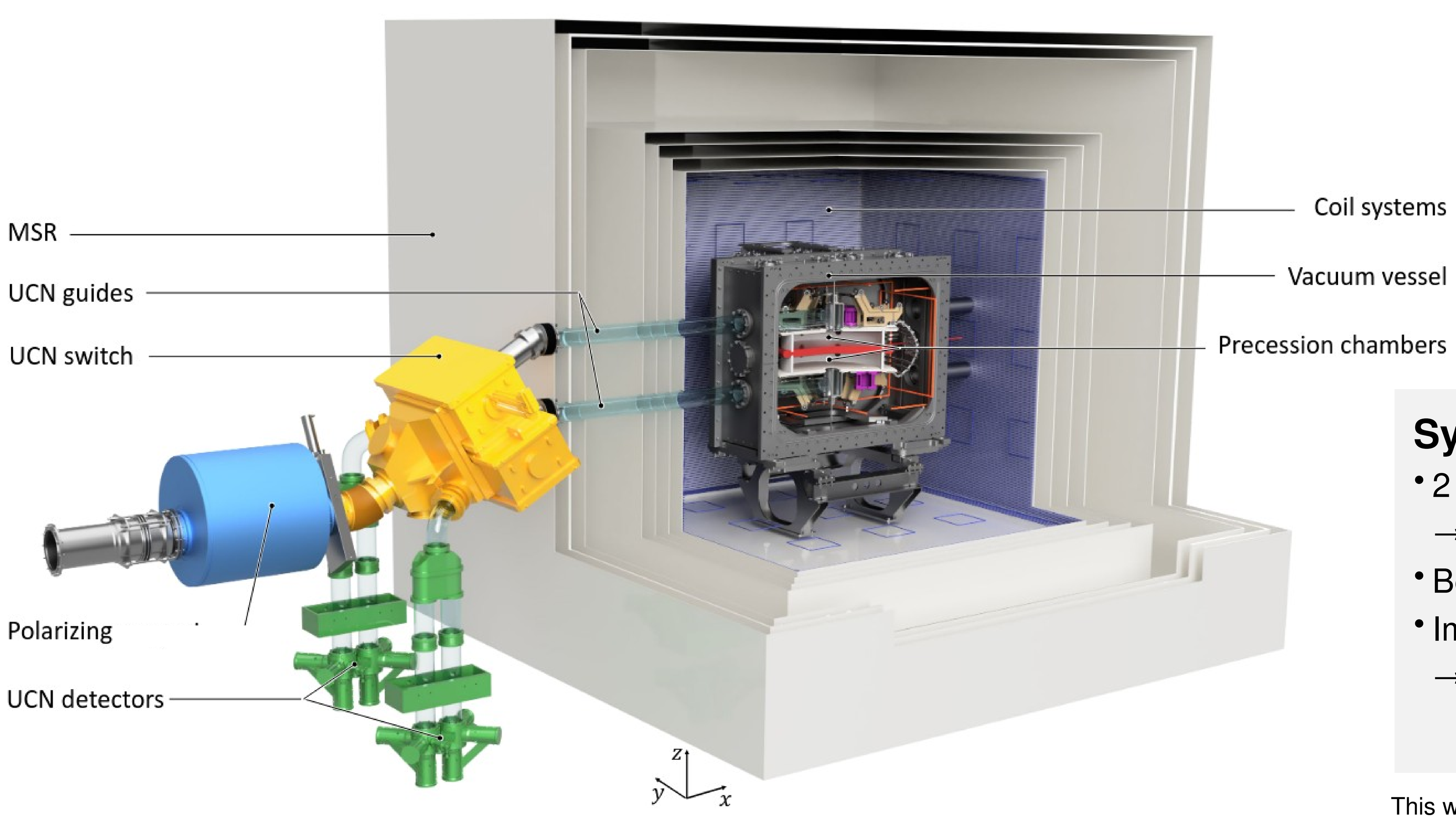




Sampling Artifacts:

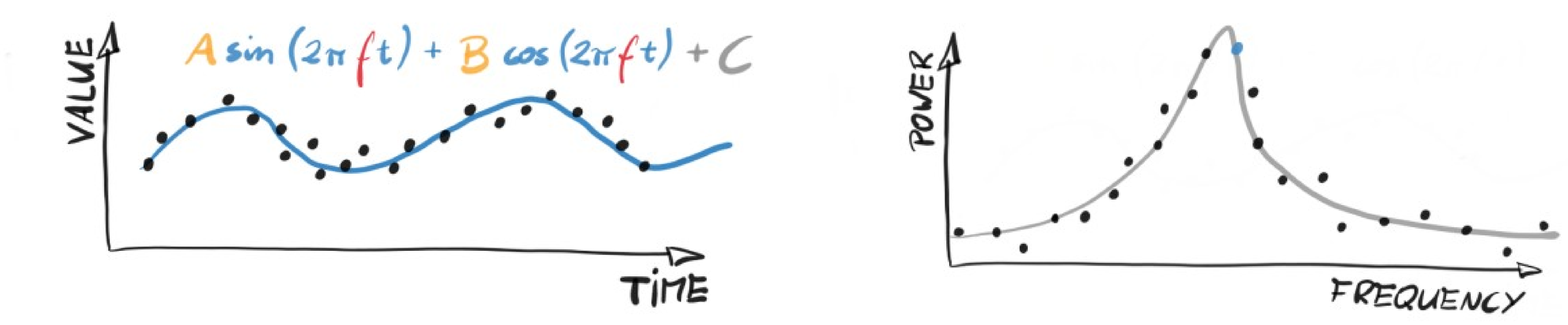
The original analysis contains corrections of the relative directions of E and B that were updated every 112 cycles. These are needed to determine the nEDM. However, they introduce artifacts in the periodograms. Performing the corrections only once for the whole dataset gets rid of the problem.



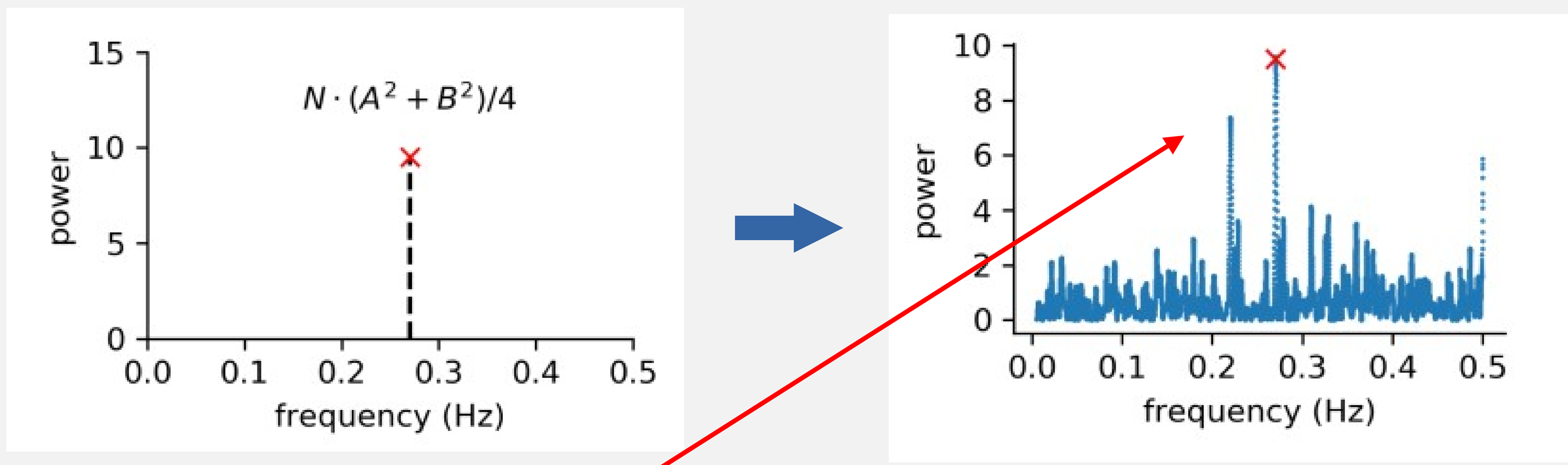


2. Spectral Analysis[2]

We are looking for an oscillation in our nEDM data. To find it, we perform a least squares spectral analysis (LSSA) on the data. Oscillations show up as a signal in frequency domain.



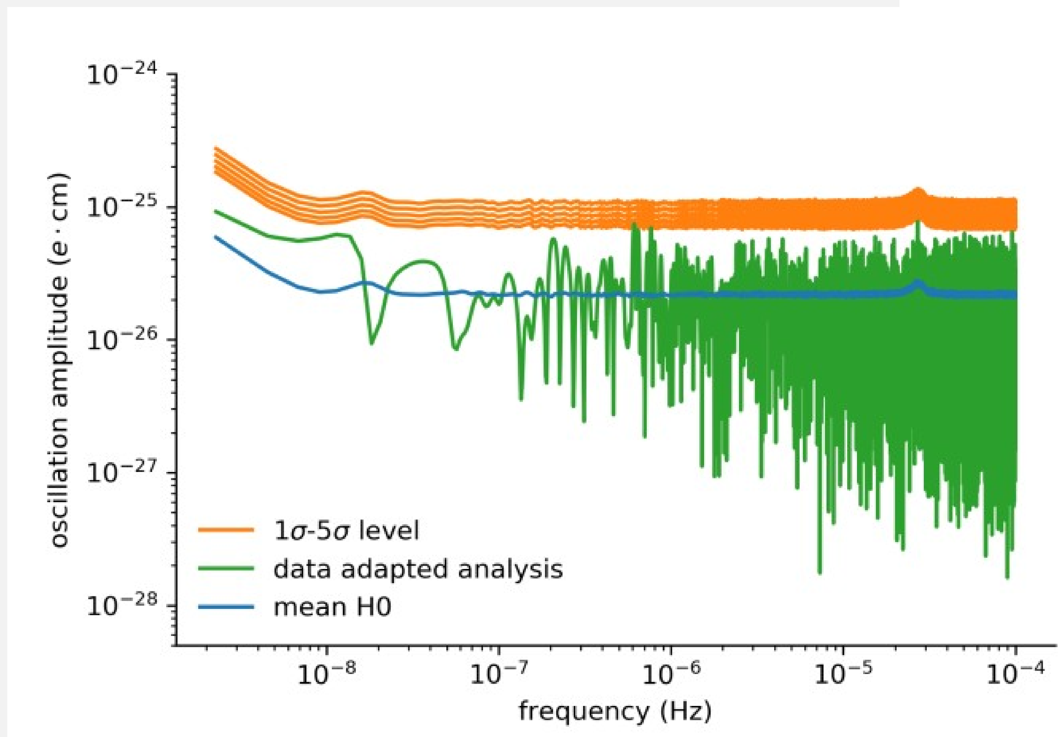
Repeat the fit for all frequencies to obtain the periodogram of the data.



Rare events happen!

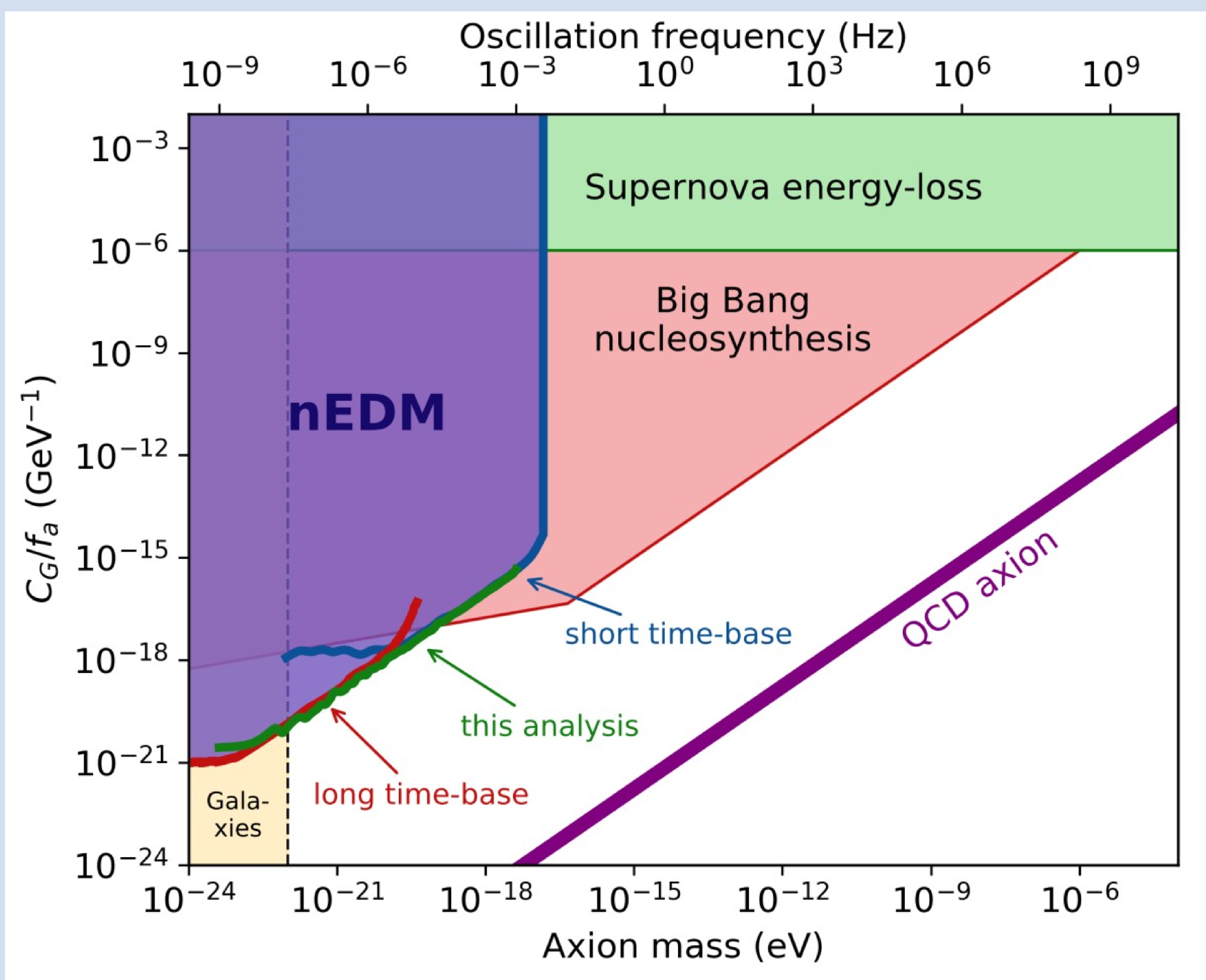
Sometimes an LSSA fits the data well even though there is no underlying signal there.
Sometimes a signal is there but isn't particularly visible in frequency domain.
This happens due to statistics: the more events happen, the likelier it is that a very unlikely event occurs.

Solution: perform many MC simulations of periodograms without underlying signal. Use these as detection thresholds for the actual data.



4. Results

- Fitting of $EB\uparrow\uparrow$ and $EB\uparrow\downarrow$ together leads to a higher sensitivity of the PSI data at low frequencies.
- Removal of sampling artifacts leads to better exclusions.
  → improves the limits on the oscillation amplitude by a factor of two for mass ranges between 10^{-24} eV ≤ m_a ≤ 10^{-17} eV



5. Outlook: n2EDM-Experiment

Systematic improvements:

- 2 chambers
  → $EB\uparrow\uparrow$ and $EB\uparrow\downarrow$ simultaneously!
- Better stability, control of main Bfield
- Improved magnetometry
  → better B-Field gradients

Statistical improvements

- Bigger chambers
- Better UCN transport
- 10^{-27} *e*cm sensitivity to nEDM

→ Expect one order of magnitude improvement for axion sensitivity!

References

1. C. Abel et. al, Phys. Rev. X 7, 041034 10.1103/PhysRevX.7.041034
2. PhD-Thesis M. Rawlik, 10.3929/ethz-b-000273039
3. PhD-Thesis S. Emmenegger, 10.3929/ethz-b-000515206
4. Ayres, N.J., Ban, G., Bienstman, L. et al., Eur. Phys. J. C 81, 512 (2021) doi.org/10.1140/epjc/s10052-021-09298-z

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