

# Search for topological defect dark matter with a global network of optical magnetometers (GNOME)

1<sup>st</sup> General Meeting of COST Action COSMIC WISPerS

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on behalf of the GNOME collaboration

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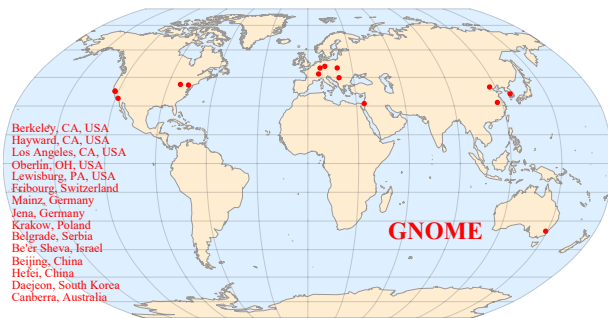
September 6, 2023



# What is a GNOME?<sup>1</sup>

- **G**lobal **N**etwork of **O**ptical **M**agnetometers for **E**xotic physics searches
- Looking for transient dark matter signals
- Sensitive to Axion-fermion coupling:

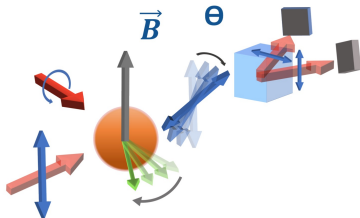
$$H_{int} = -\frac{\hbar c^{3/2}}{f_{int}} \frac{S_i}{|S_i|} \cdot \nabla a$$



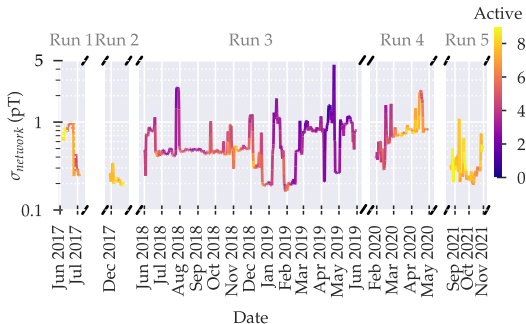
<sup>1</sup>Phys.Dark Univ. 22 (2018), 162-180

# How does a GNOME work?

- Magnetometers as Dark Matter sensors



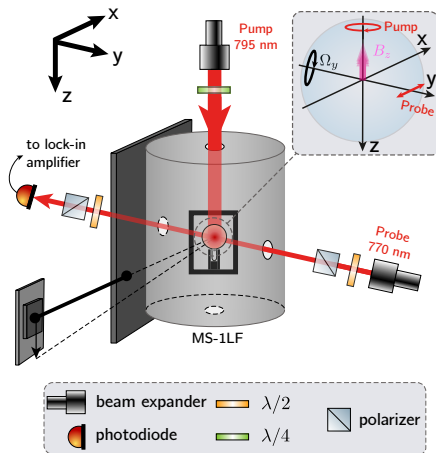
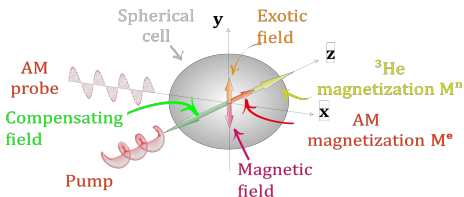
- 5 Science Runs since 2017
- Science Run 6 starting soon!



<sup>1</sup>Phys.Dark Univ. 22 (2018), 162-180

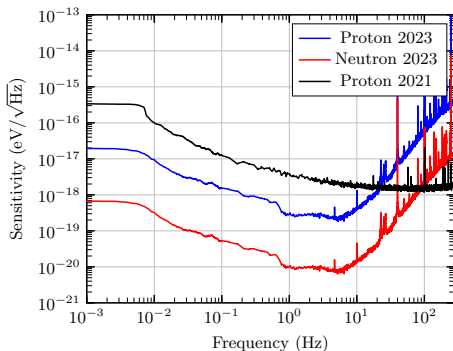
# Advanced GNOME: Comagnetometers

- Noble gas and Alkali metal in vapor cell with high spin density
- Compensation magnetic field
- Insensitive to first order magnetic perturbations

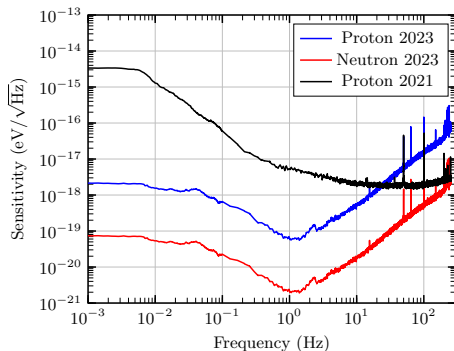


# Advanced GNOME: Sensitivity

Mainz Station

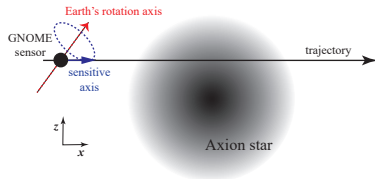
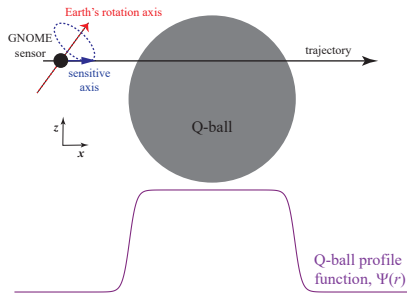
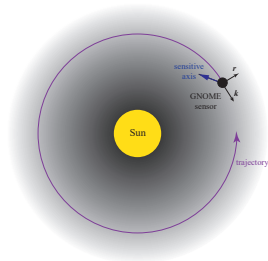


Kraków Station



# What can a GNOME do?<sup>2</sup>

- Q-balls
- Axion Stars
- Solar Axion Halo
- Stochastic fluctuations of galactic DM
- Bursts of Exotic Low-mass Fields (ELF)
- Axion Domain Walls



<sup>2</sup>Afach et al. ANNALEN DER PHYSIK 2023, 2300083

# Contents

- 1 Axion Domain Walls
- 2 New algorithm for DW signal
- 3 Results
- 4 Exclusion plot

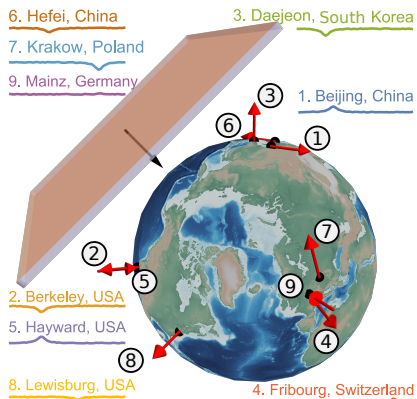
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# Axion Domain Walls<sup>3</sup>

- Compact spatial regions
- Regions of space with different axion vacuum
- Effective magnetic field
- Correlated time measurement



<sup>3</sup>Pospelov et al. Phys.Rev.Lett. 110 (2013) 2, 021803

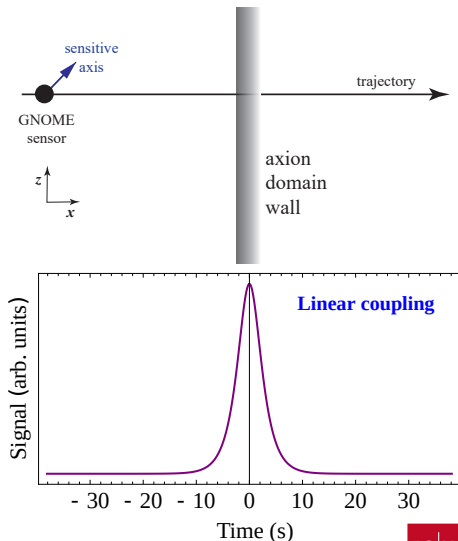
# Parameters of Domain Walls

- Coupling ratio  $\xi = \frac{f_{\text{SB}}}{f_{\text{int}}}$

- Duration  $\Delta t \propto \frac{1}{m_a}$

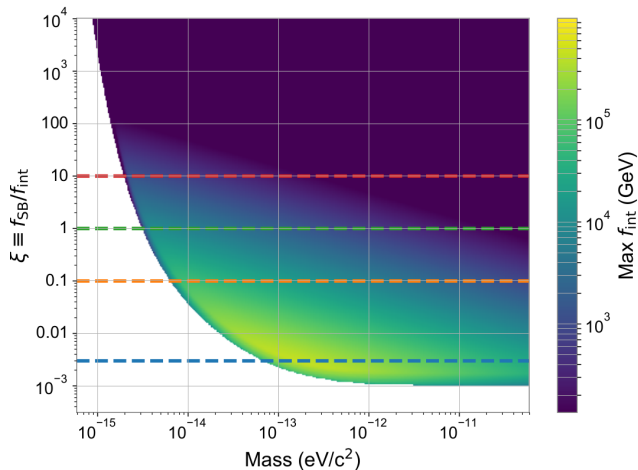
- Pseudo magnetic field  
 $\mathcal{B}'_P = \frac{4m_a\xi}{\mu_B}$

- Rate of encounters  
 $r = \frac{\bar{v}\rho_{\text{DW}}}{\sigma_{\text{DW}}} = \frac{\bar{v}\rho_{\text{DW}}}{8m_a f_{\text{SB}}^2}$



## 2021 Domain Wall search <sup>4,5</sup>

- Computer intensive procedure
- Not sensitive to short width DW



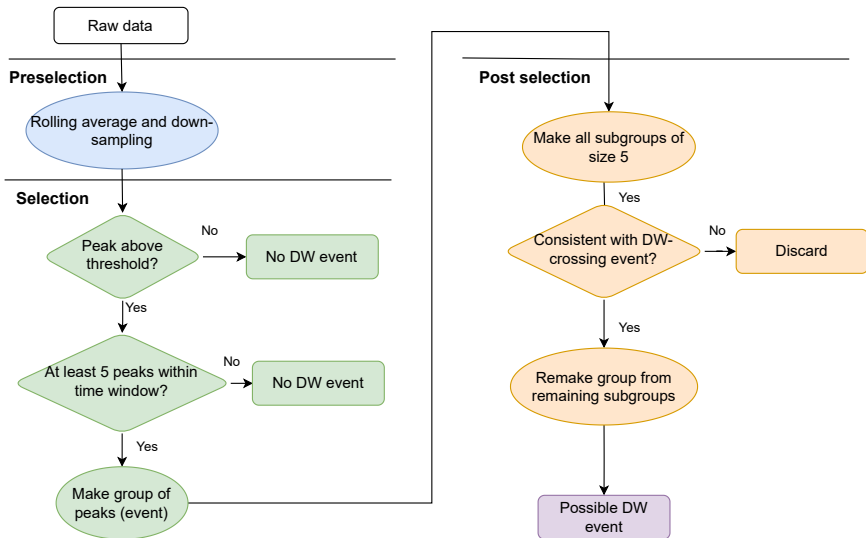
<sup>4</sup>Masia-Roig et al. Phys.Dark Univ. 28 (2020), 100494

<sup>5</sup>Afach et al. Nat. Phys. 17, 1396–1401 (2021).

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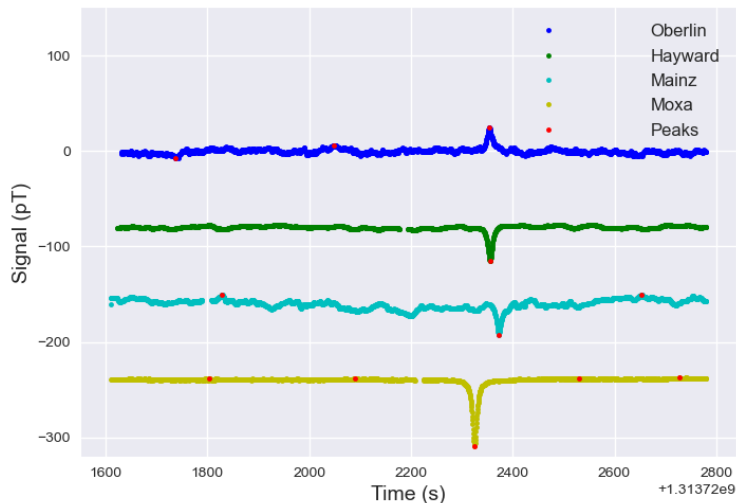
# New analysis pipeline



# Candidates for DW signal

- Peak info: time, amplitude, width, station, average noise
- Make groups of peaks from different stations

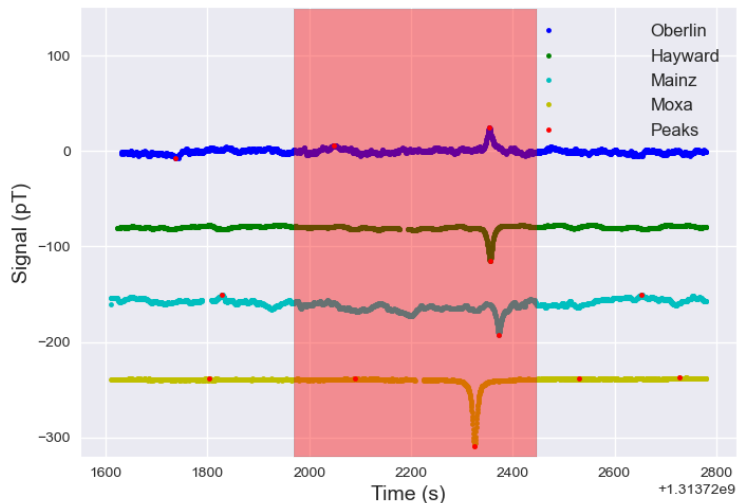
Insertion of a domain wall at different stations.



# Candidates for DW signal

- Peak info: time, amplitude, width, station, average noise
- Make groups of peaks from different stations

Insertion of a domain wall at different stations.



# Duration consistency and time fitting

- Same width for all peaks in the group

$$\frac{\sigma_{\text{width}}}{W} \leq a$$

- Relation between observed time and velocity of DW

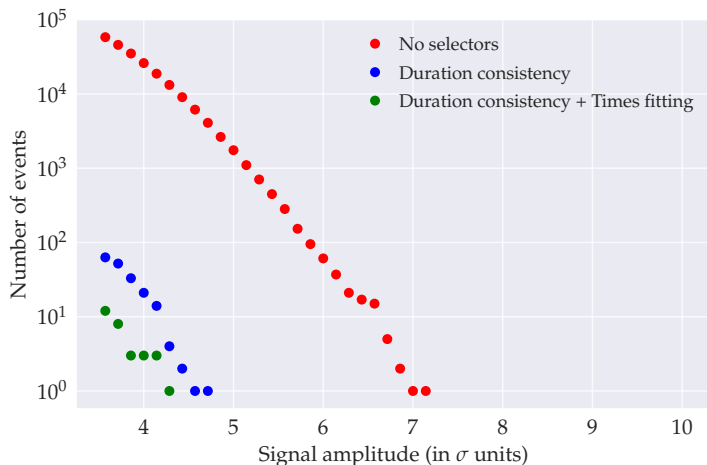
$$\vec{t} = \frac{1}{|\vec{v}|} L \hat{v} + t_0$$



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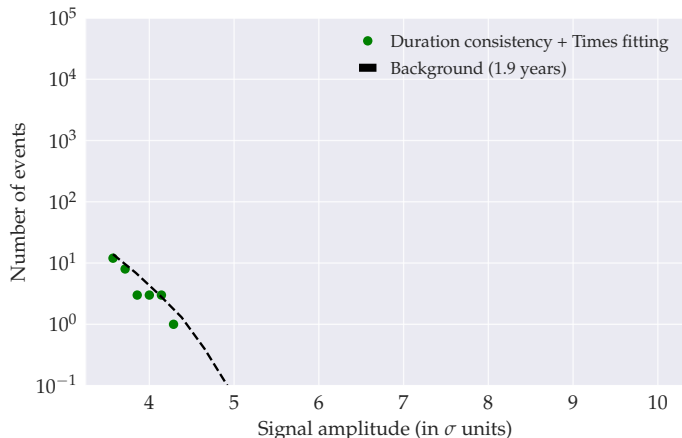
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# Events candidates for DW



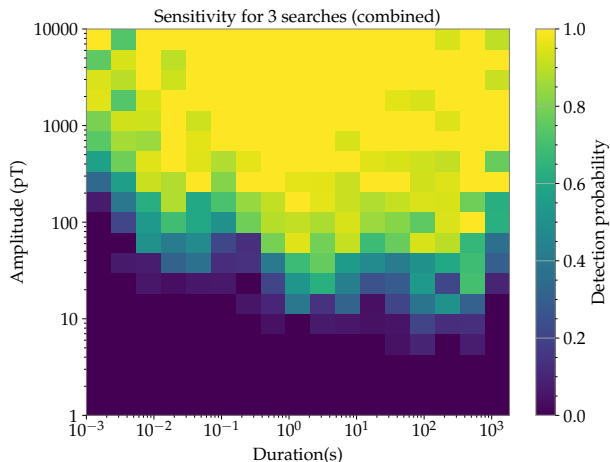
# Events candidates for DW and background

- Time shuffled data scaled for background



# Assesing the sensitivity

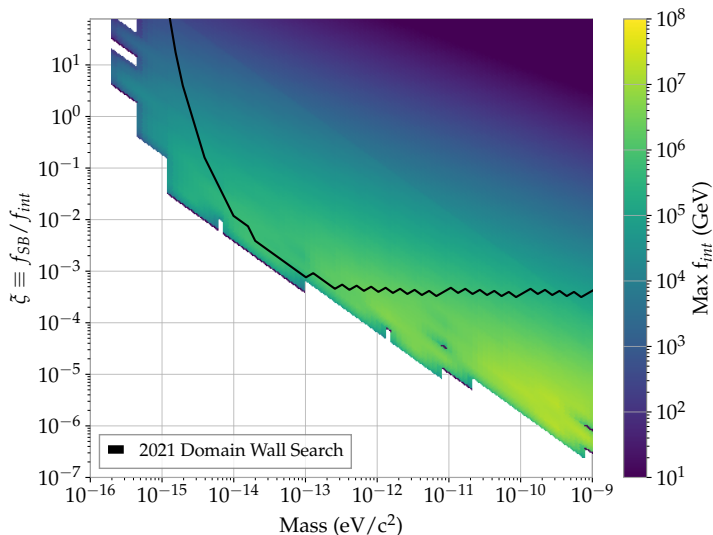
- DW-like signal inserted in time shuffled data
- 3 searches with different time constant average



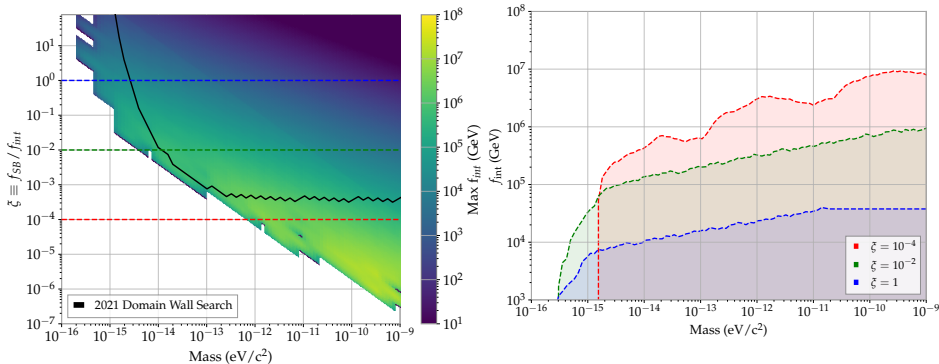
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# 2023 Domain Wall Search (Preliminary)



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# Conclusions

- New dataset with new analysis procedure for axion domain walls
- Sensitive to short width domain wall  $\rightarrow$  exclude higher  $f_{\text{int}}$
- Excluding up to  $f_{\text{int}} = 10^8$  GeV for certain  $f_{\text{SB}}$
- New run soon with comagnetometers that will increase our sensitivity (Advanced GNOME)



# Acknowledgements



Grzegorz  
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