Intensity interferometry for ultralight bosonic dark matter detection

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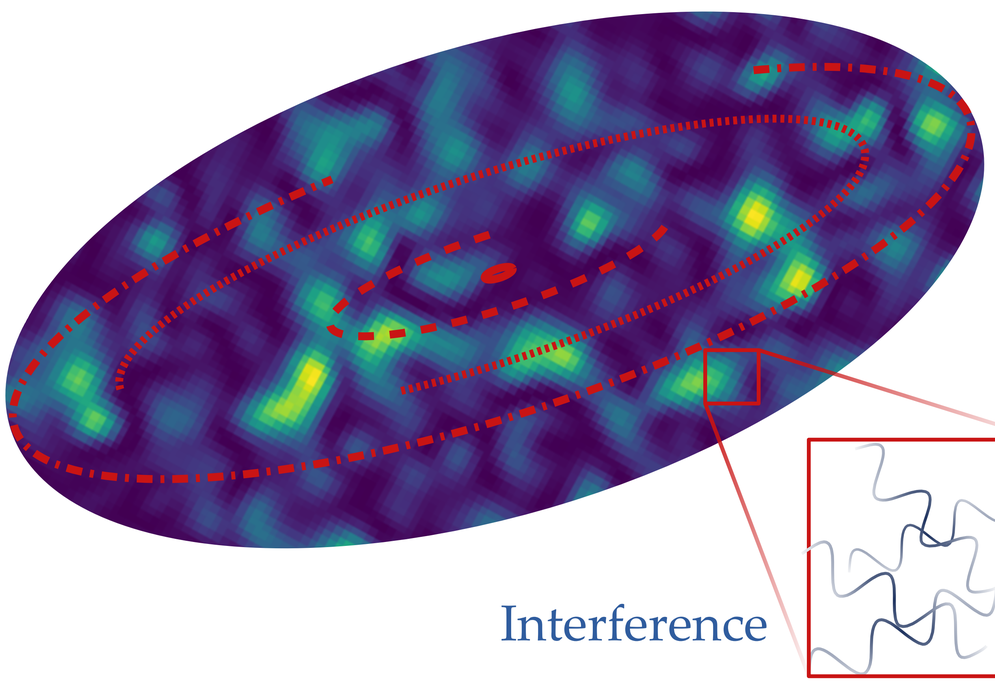
Introduction

Dark matter:

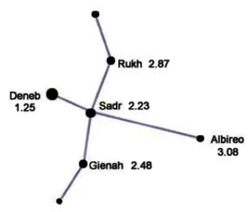
- Ultraligth bosons, $m_\phi \ll 1\ eV/c^2$
- Virialized cloud
- Trapped in gravitational potential Milky way



Interference

Sensor networks

Cygnus



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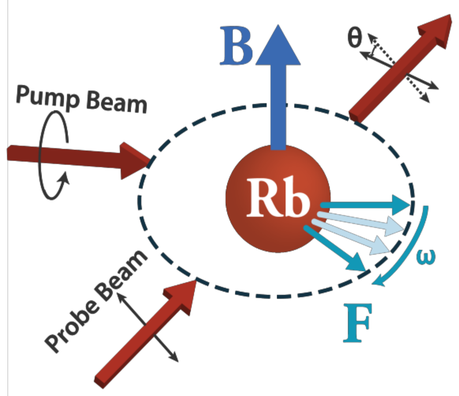
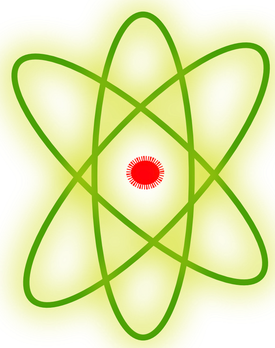
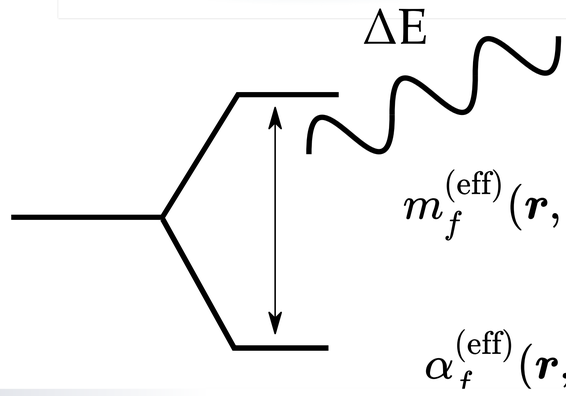
Atomic magnetometers



$$\mathcal{H}_\varphi = \mp \frac{2\hbar^2 c^2}{f_q^2} \boldsymbol{S} \cdot \boldsymbol{\nabla} \varphi^2(\boldsymbol{r}, t)$$

Atomic clocks





$$m_f^{(\mathrm{eff})}(\boldsymbol{r}, t) = m_f \left[1 \mp \frac{\hbar c}{\Lambda_f^2} \varphi^2(\boldsymbol{r}, t) \right]$$

$$\alpha_f^{(\mathrm{eff})}(\boldsymbol{r}, t) = \alpha_f \left[1 \pm \frac{\hbar c}{\Lambda_f^2} \varphi^2(\boldsymbol{r}, t) \right]$$

Ultraligh bosonic dark matter field

- Stochastic field

$$\varphi(\boldsymbol{r}, t) = \frac{\varphi_0}{\sqrt{N}} \sum_n^N \cos(\omega_n t - \boldsymbol{k}_n \cdot \boldsymbol{r} + \theta_n)$$

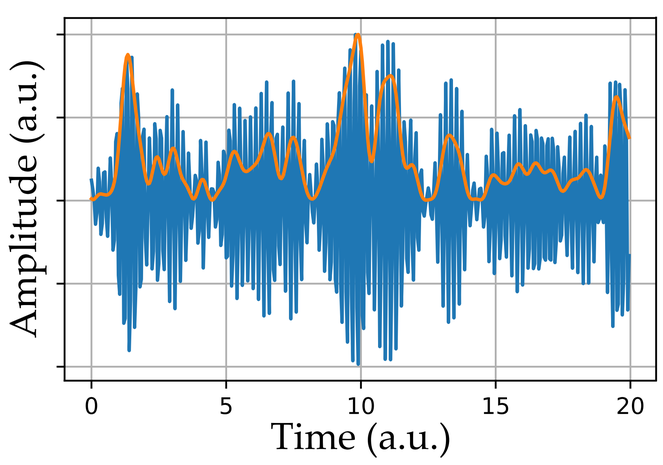
- Virialized velocities

$$\boldsymbol{k}_n = m_\varphi \boldsymbol{v}_n / \hbar$$

- Second order doppler effect

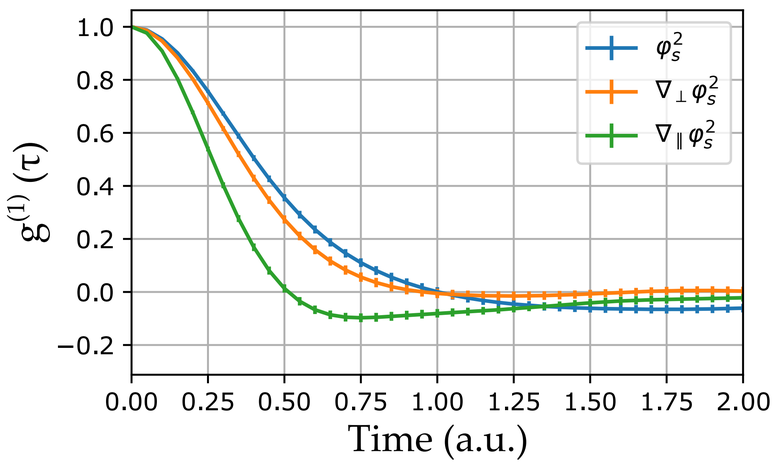
$$\omega_n = \omega_c (1 + \frac{\boldsymbol{v}_n^2}{2c^2})$$

Signature



- Quadratic coupling
- Stochastic Intensity fluctuations → Characteristic coherence time

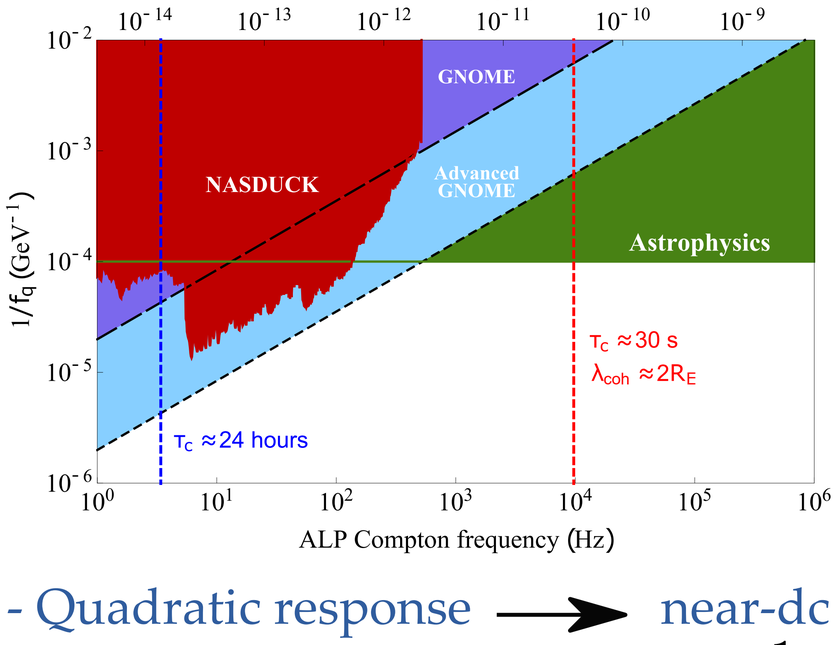
$$g_{AB}^{(1)}(\tau) \propto \langle \mathcal{S}_A(t) \mathcal{S}_B(t+\tau) \rangle_t$$



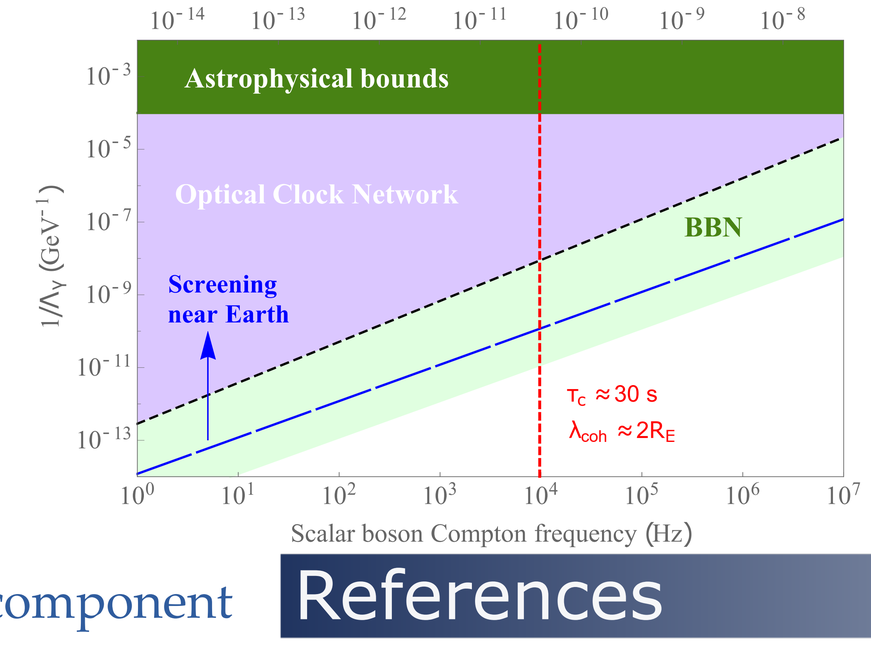
$$\frac{1}{\tau_\varphi} \approx m_\varphi$$

Projected sensitivity

Optical magnetometers



Atomic clocks



Correlation between sensors

↓

Hint for UBDM

- Quadratic response → near-dc component
- Enchance detection bandwidth $\frac{1}{\tau_\varphi} = 10^{-6}\, \omega_c$
- Broadband search
- Sense beyond cosmological bounds

References

- Intensity interferometry for ultralight bosonic dark matter detection H.Masia et al. arxiv.org/abs/2202.02645
- Stochastic fluctuations of bosonic dark matter G. Centers et al. Nature Communications 2021

More details