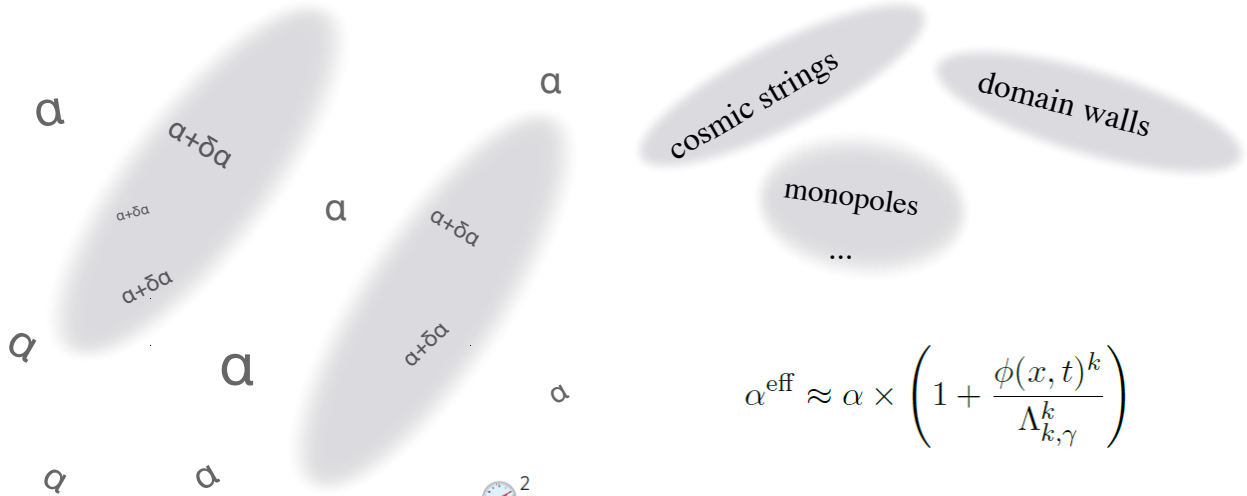
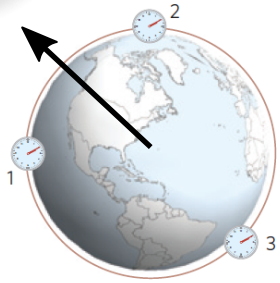
Dark matter in the form of topological defects

A. Vilenkin, Physics Reports 121, 263 (1985)



$$\alpha^{\text{eff}} \approx \alpha \times \left(1 + \frac{\phi(x,t)^k}{\Lambda_{k,\gamma}^k}\right)$$

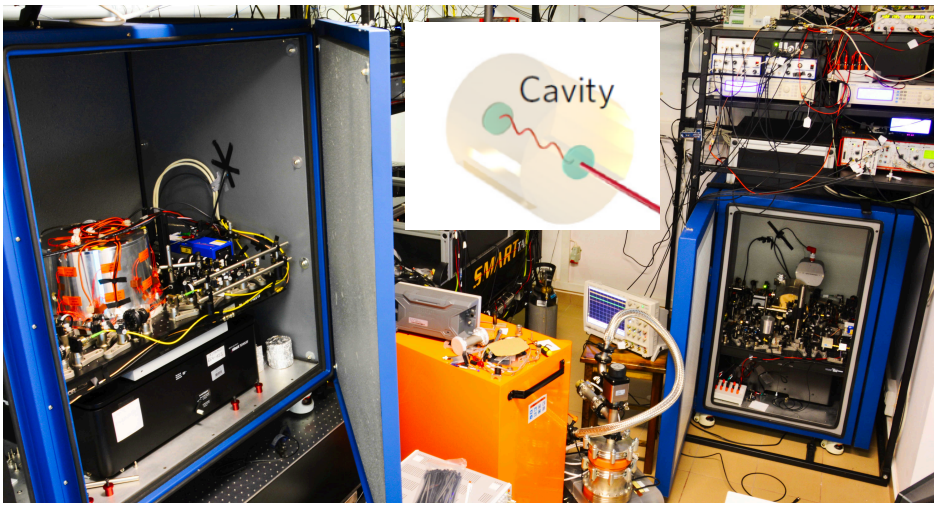


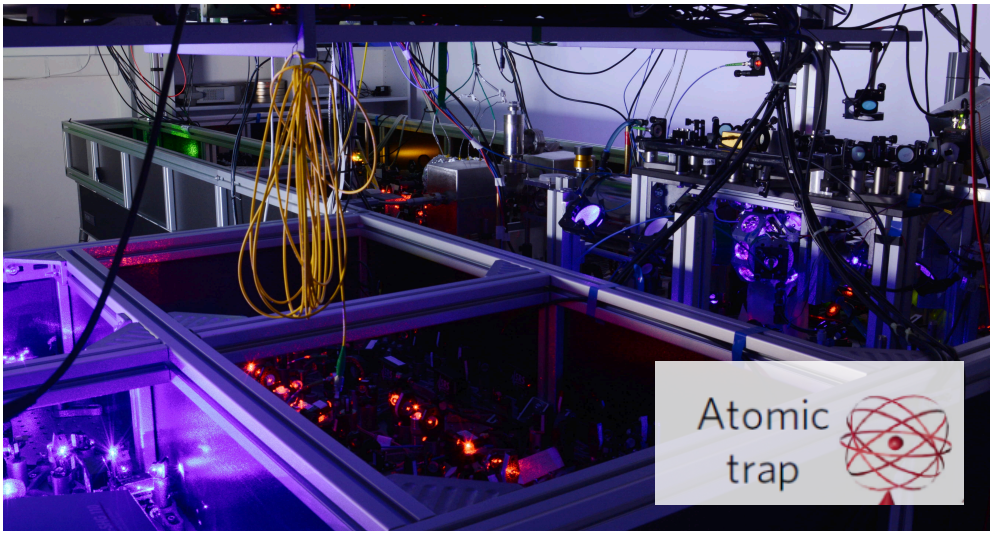
$$\frac{d\omega_0}{\omega_0} = K_\alpha \frac{d\alpha}{\alpha}$$

$$\frac{\delta\alpha}{\alpha} = \frac{\phi_{\text{inside}}^2}{\Lambda_\alpha^2}$$

A. Derevianko and M. Pospelov, Nature Physics 10, 933 (2014)
B. Roberts et al., Nature Communications 8, 1195 (2017)

Optical atomic clock



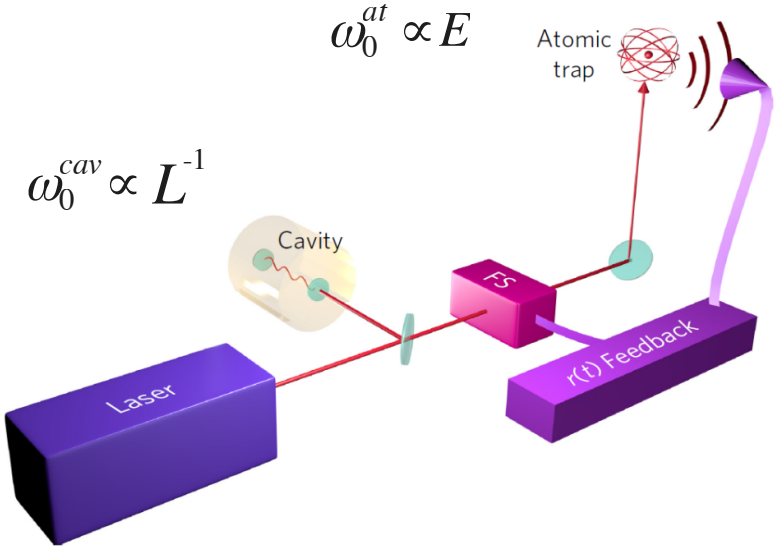


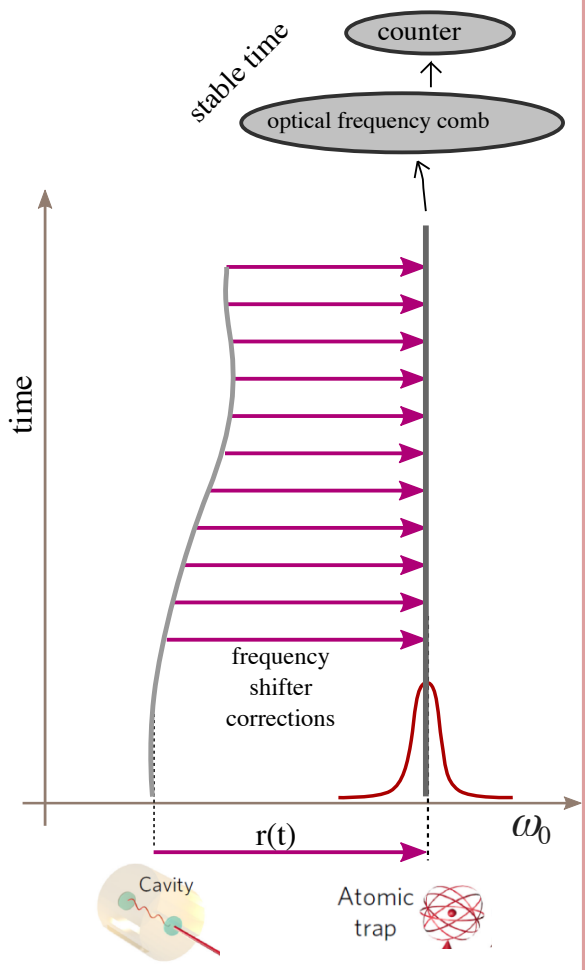
The most precise measuring tool

State-of-the-art clocks

relative uncertainty 10^{-18}

Optical atomic clock





Piotr Morzynski, Osaka 21.12.2017

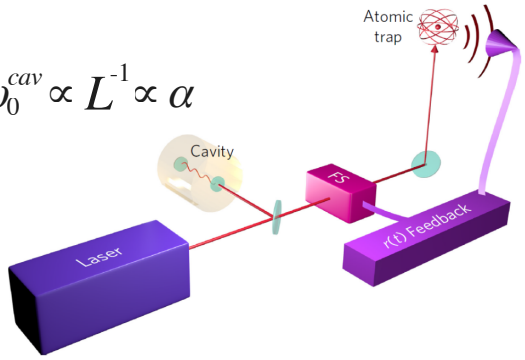
Optical atomic clock

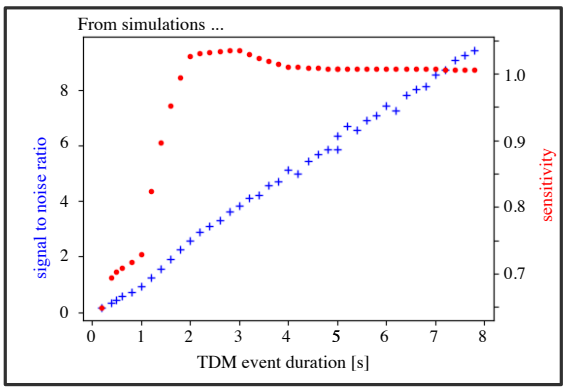
... is sensitive to α variation

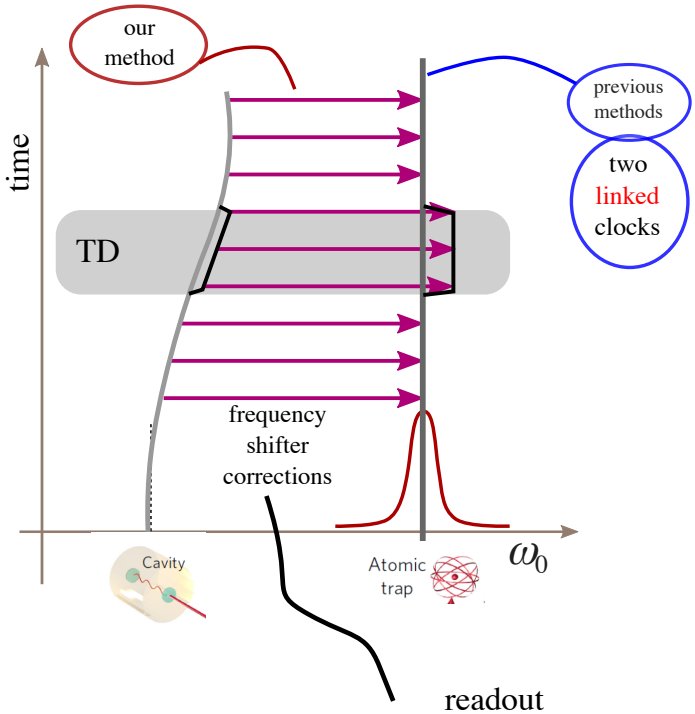
P. Wcislo et al., Nat. Astron. 1, 0009 (2016)

$$\omega_0^{at} \propto E \propto \alpha^2$$

$$\omega_0^{cav} \propto L^{-1} \propto \alpha$$







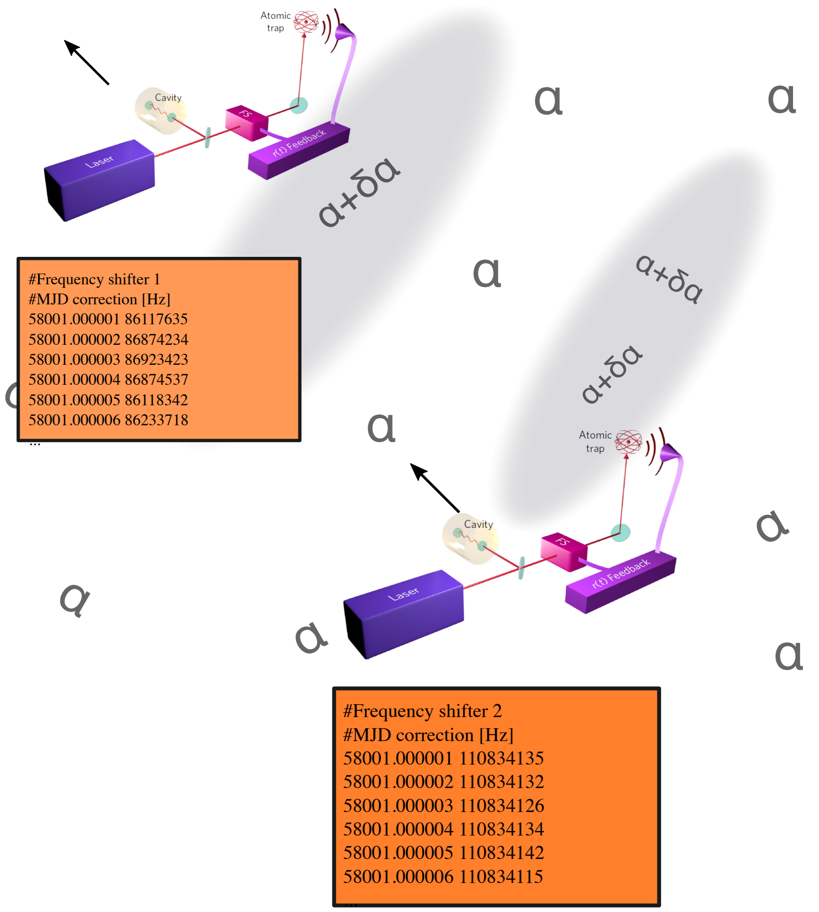
#Frequency shifter
#MJD correction [Hz]
58001.000001 110834135
58001.000002 110834132
58001.000003 110834126
58001.000004 110834134
...

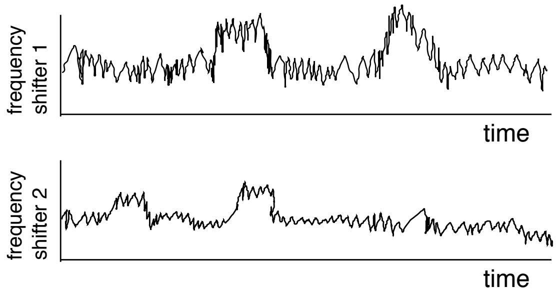
$$\left(-\frac{1}{2}\sum_{i=1}^{n}\nabla_{x_i}^2-\sum_{i,j=1}^{n,m}\frac{Z_j}{r_{ji}}+\frac{1}{2}\sum_{\substack{i,k=1\\ i\neq k}}^{n,n}\frac{1}{r_{ik}}\right)\psi=\epsilon\psi$$

$$x_i=\frac{r_i}{a_0} \qquad \epsilon=\frac{E}{E_h}$$

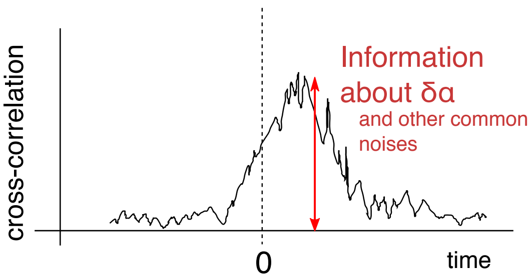
$$a_0=\frac{\hbar}{m\,\alpha\,c} \qquad E_h=\alpha^2 m_e c^2$$

Piotr Morzynski, Osaka 21.12.2017





$$(r_1 * r_2)(\Delta t) = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} r_1(t) r_2(t + \Delta t) dt$$



$$\frac{\delta\alpha}{\alpha} < \frac{1}{K_\alpha} \frac{\sqrt{A_0/\eta_T}}{\omega_0}$$

$$\Downarrow$$

$$\Lambda_\alpha > d^{1/2} \sqrt{\sqrt{\frac{\eta_T}{A_0}} \rho_{TDM} \hbar c K_\alpha \mathcal{T} v \omega_0}$$

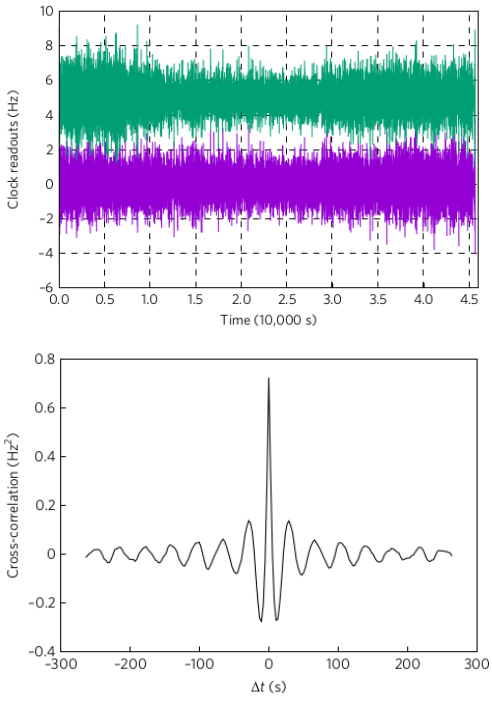
P. Wcislo et al., Nat. Astron. 1, 0009 (2016)

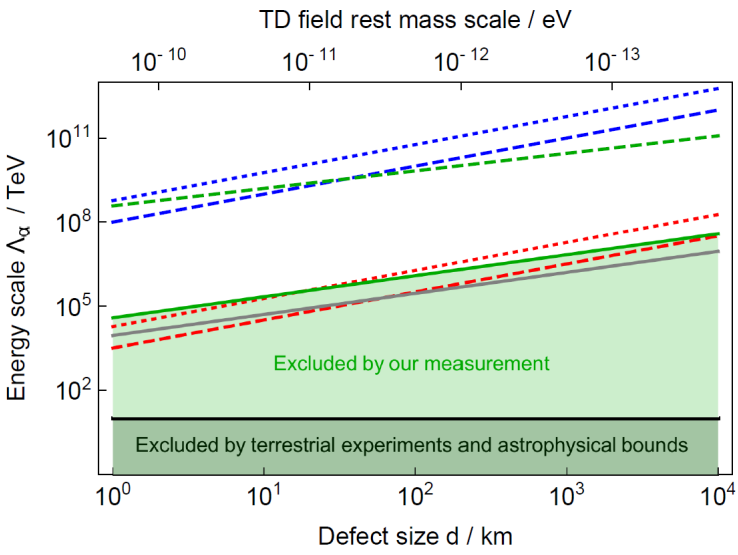
Experimental constraint

Two optical atomic clocks with neutral ^{88}Sr atoms trapped in optical lattices

P. Morzyński, Scientific Reports 5, 17495 (2015)

M. Bober et. al., Measurement Science and Technology 26, 075201 (2015)

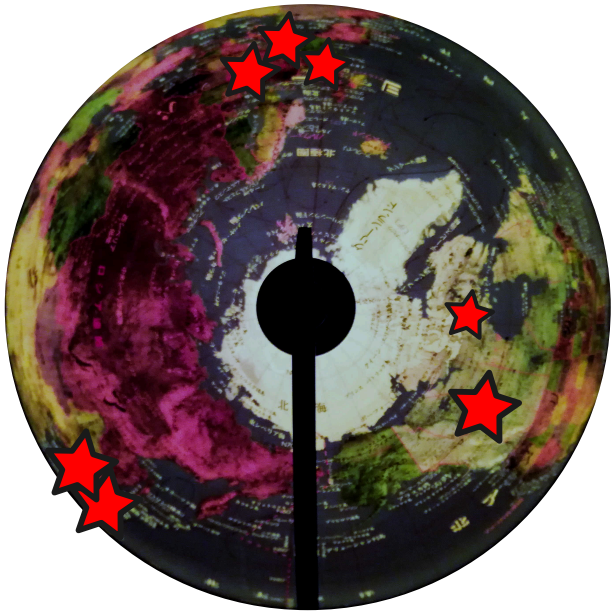




Assumptions:
- one event per 45 700 s
- d = 10 000 km

$$\frac{\delta\alpha}{\alpha} < 5 \times 10^{-15}$$

Summary



- New method for searching for transient α variation
- Simplicity and workability
- Measuring apparatus already exists
- Results

Thank You for your attention!

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Experimental constraint on dark matter detection with optical atomic clocks

P. Wcisło*, P. Morzyński, M. Bober, A. Cygan, D. Lisak, R. Ciuryło and M. Zawada

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JSPS Postdoctoral Fellowship for Overseas Researchers

Piotr Morzynski, Osaka 21.12.2017

Optical atomic clock and topological defect dark matter

Piotr Morzyński

Nicolaus Copernicus University, Toruń, Poland
National Institute of Information and Communications Technology, Tokyo
JSPS fellow