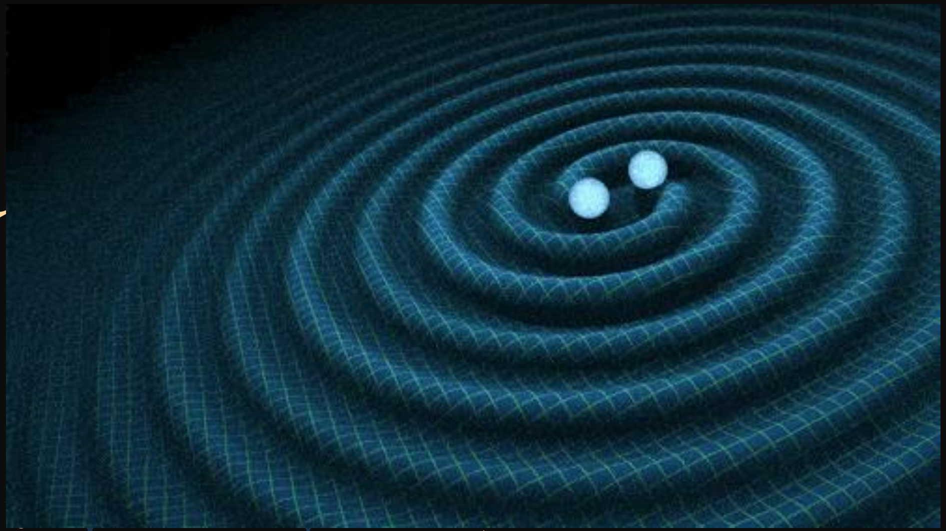
Cold Atoms, Cool Physics: Progress in the AION Project

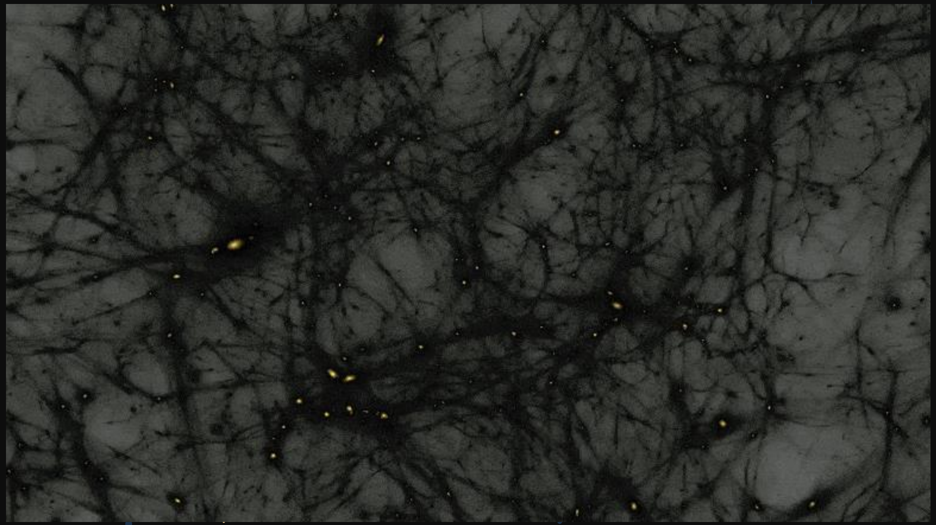
Imperial College London

AION

Elizabeth Pasatembou

On Behalf of the AION Collaboration





1

What is AION?

2

Atom Interferometry

3

How we use cold atoms and atom interferometry to detect GW

4

Current state of the Project

Atom **I**nterferometer **O**bservatory and **N**etwork

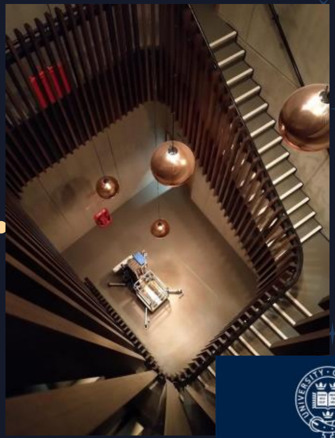
arXiv:1911.11755

Atom **I**nterferometer **O**bservatory and **N**etwork

QTFP – Quantum Technology for Fundamental Physics Programme

The AION Programme

10m detector



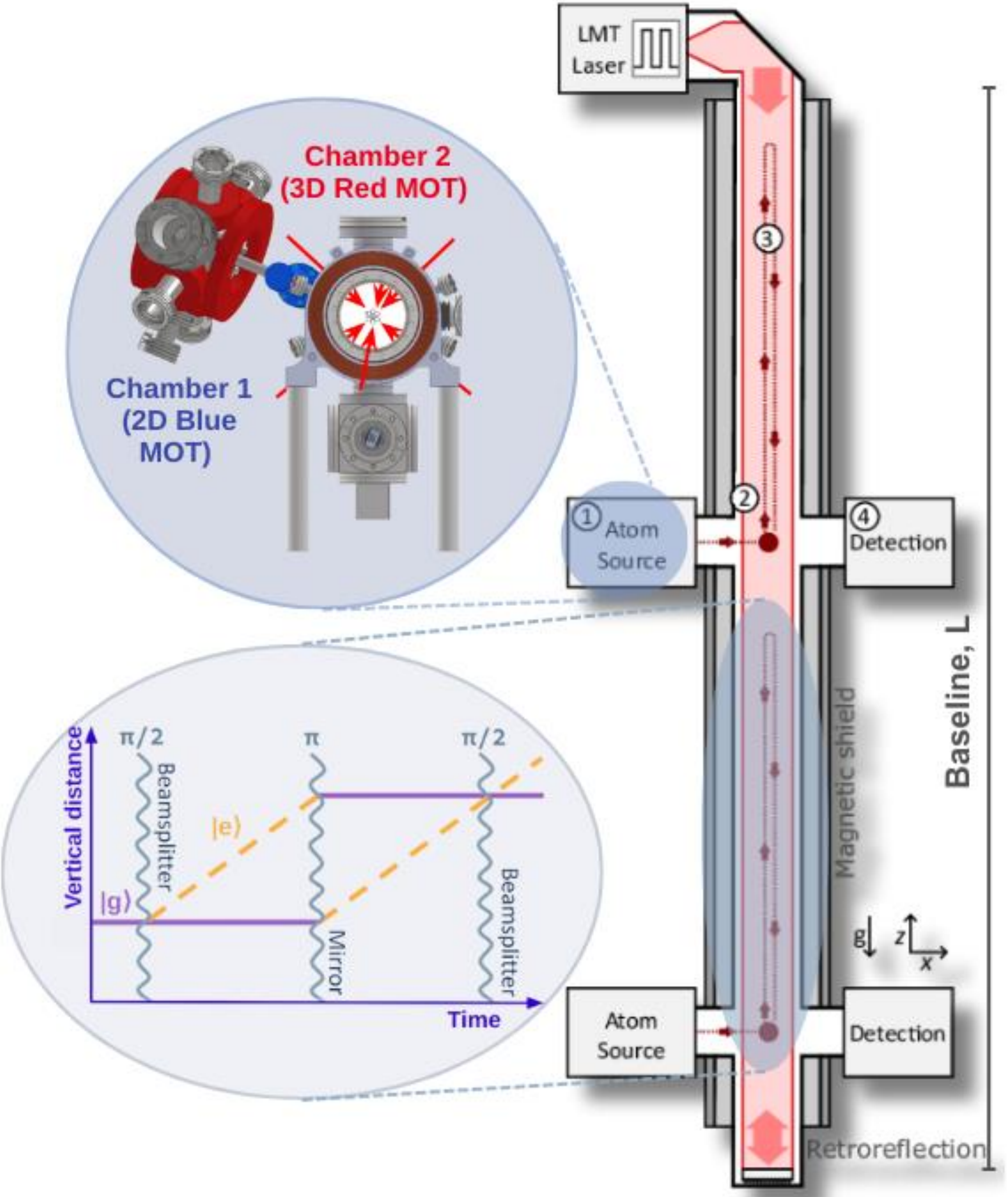
UNIVERSITY OF OXFORD

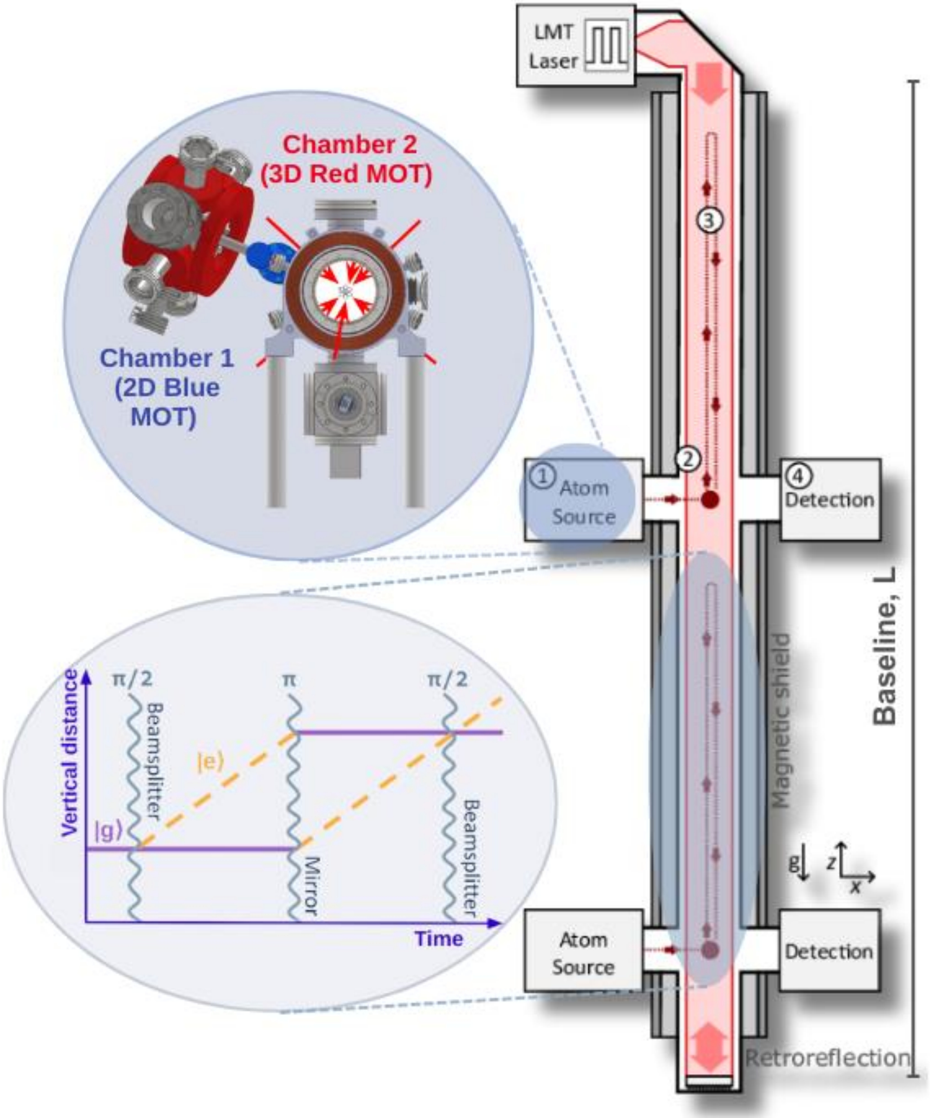
100m detector

km-scale terrestrial detector

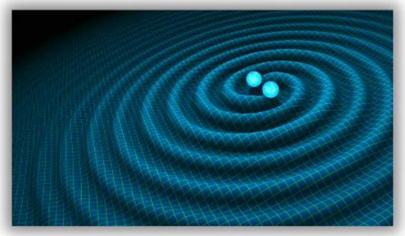
AEDGE [2]

The AION Detector

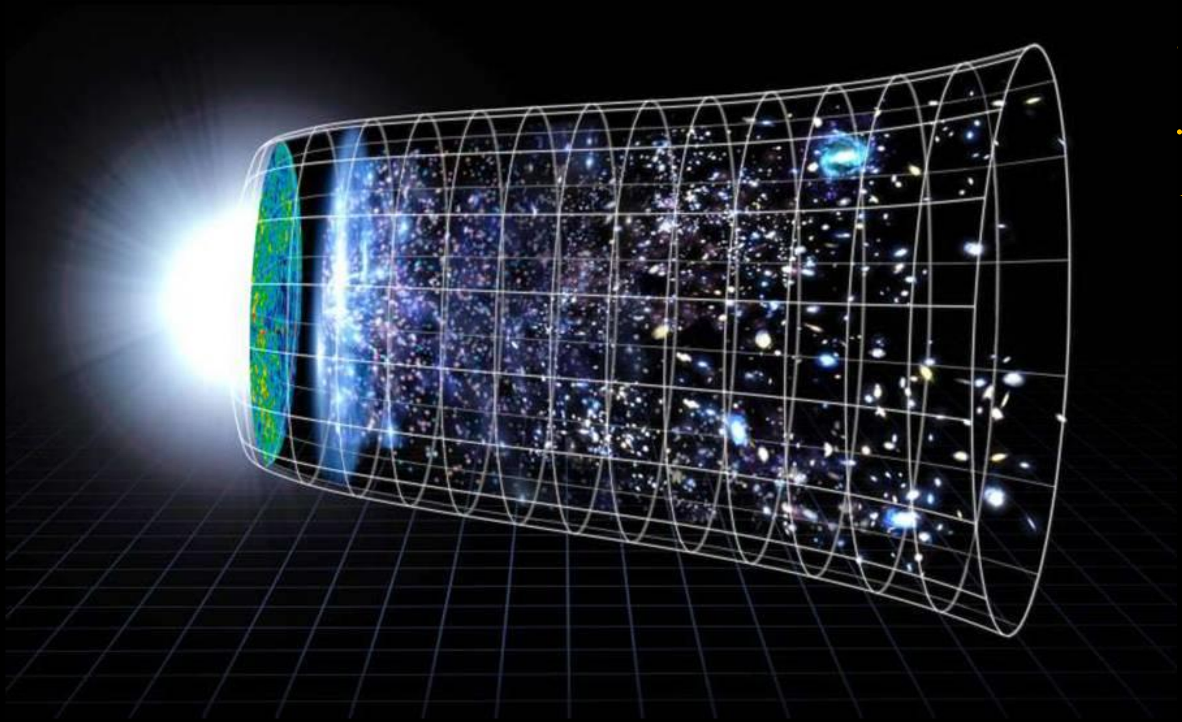




Scalar Ultra-Light **Dark Matter**

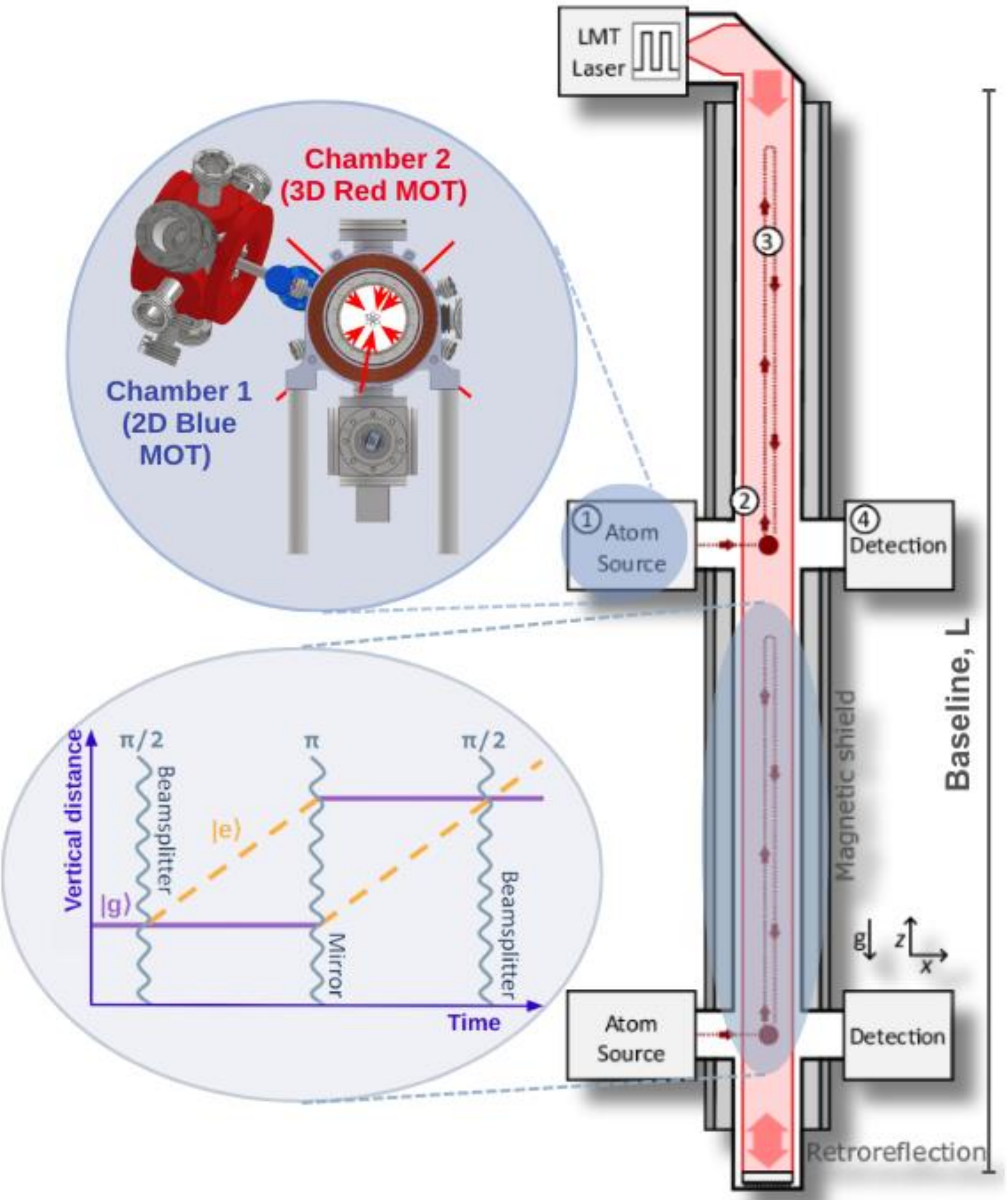


Gravitational Waves (~0.01 Hz to a few Hz)

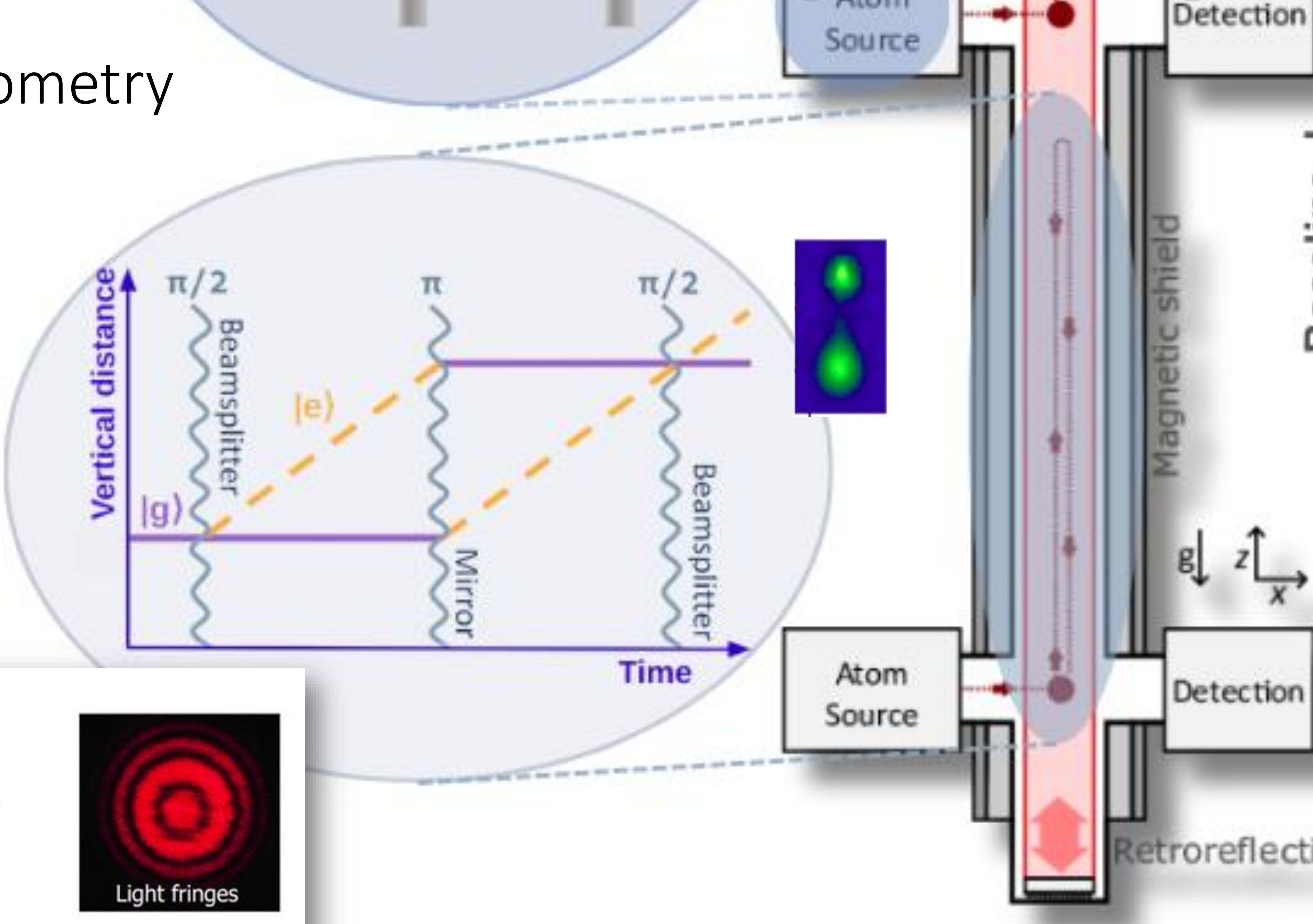


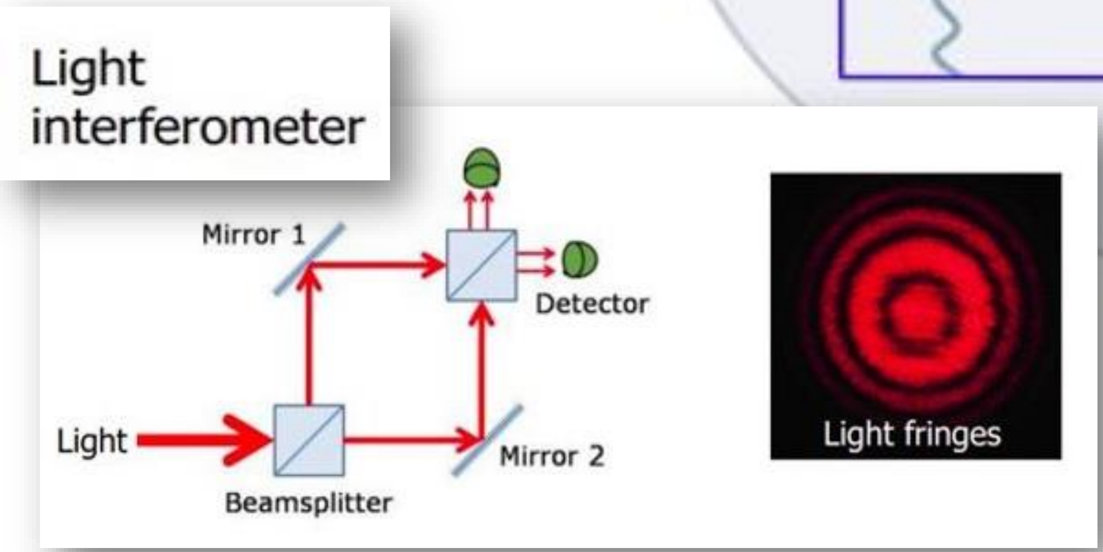
10^2 - 10^5 x

The AION Detector

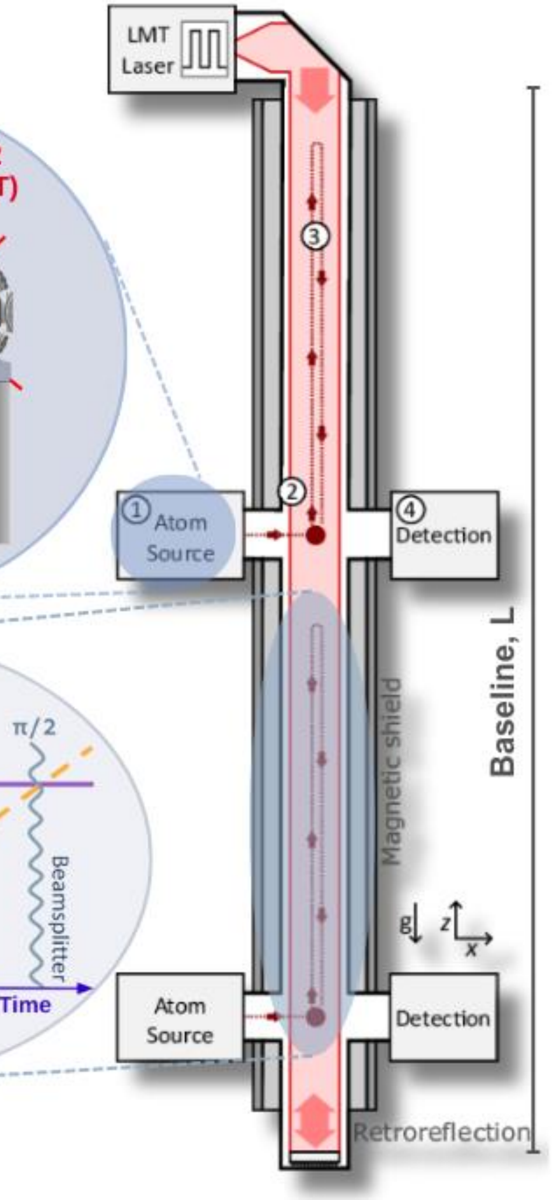


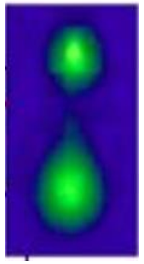
Atom Interferometry





Atom Interferometry





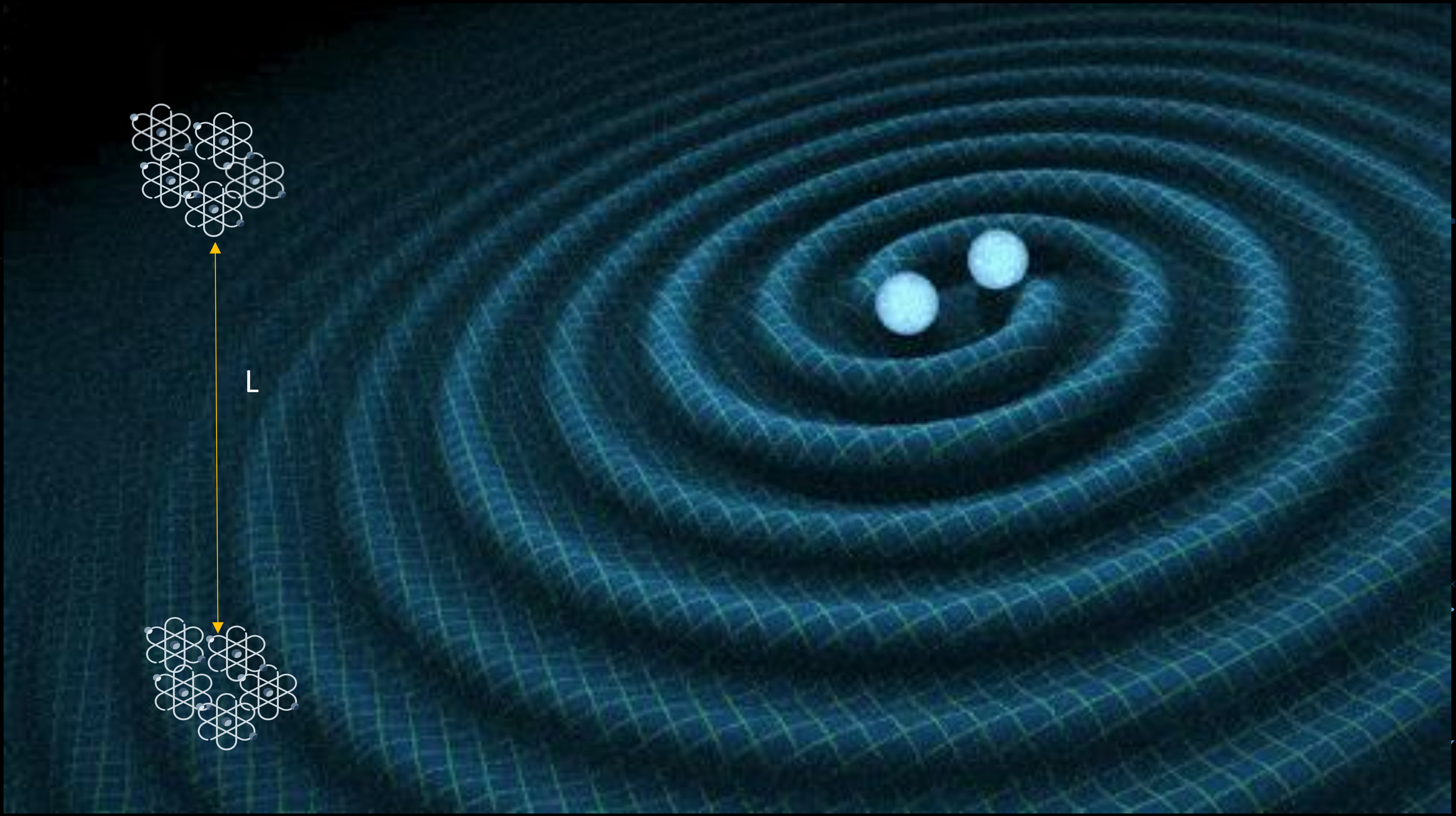
Phase measurement → Measure the fraction of atoms in the excited vs ground state

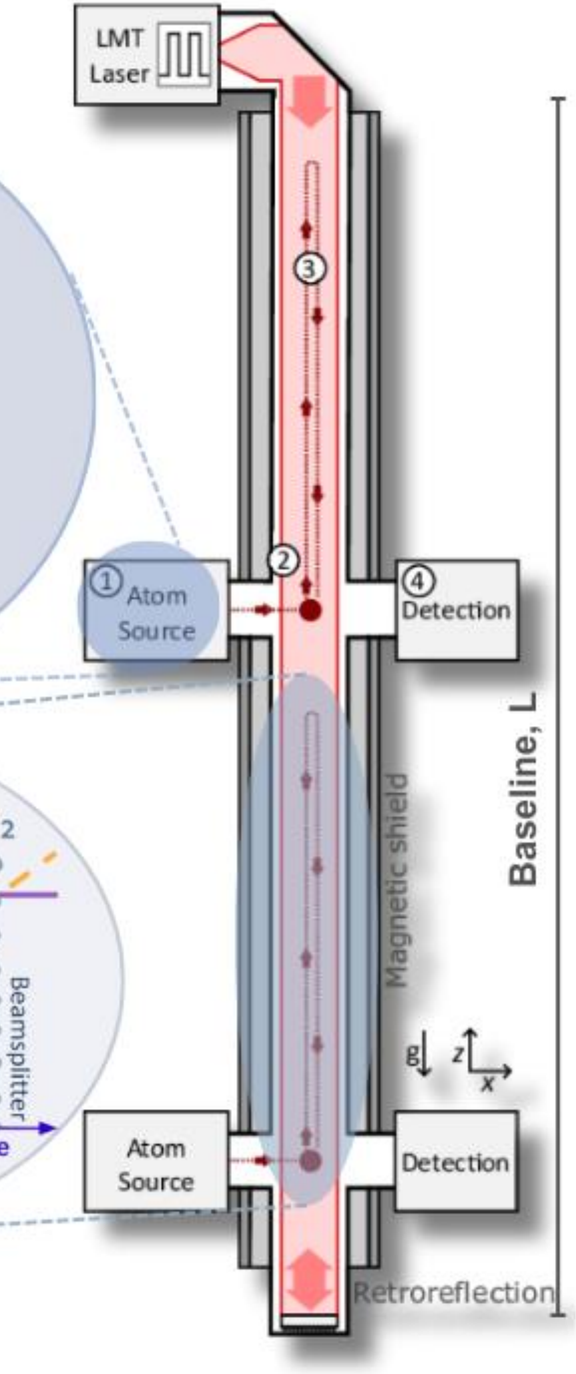
$$\frac{N_e - N_g}{N_e + N_g} = \cos(\Delta\phi)$$

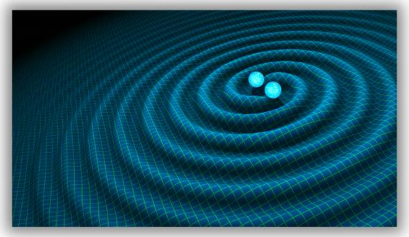
The experimental resolution is affected by Poisson statistics

$$\delta\phi \sim \frac{1}{\sqrt{N}} \quad \text{per cycle}$$

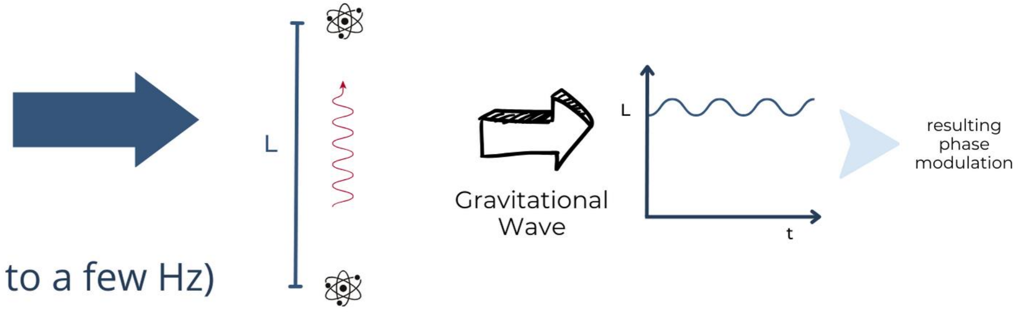
Detecting Gravitational Waves



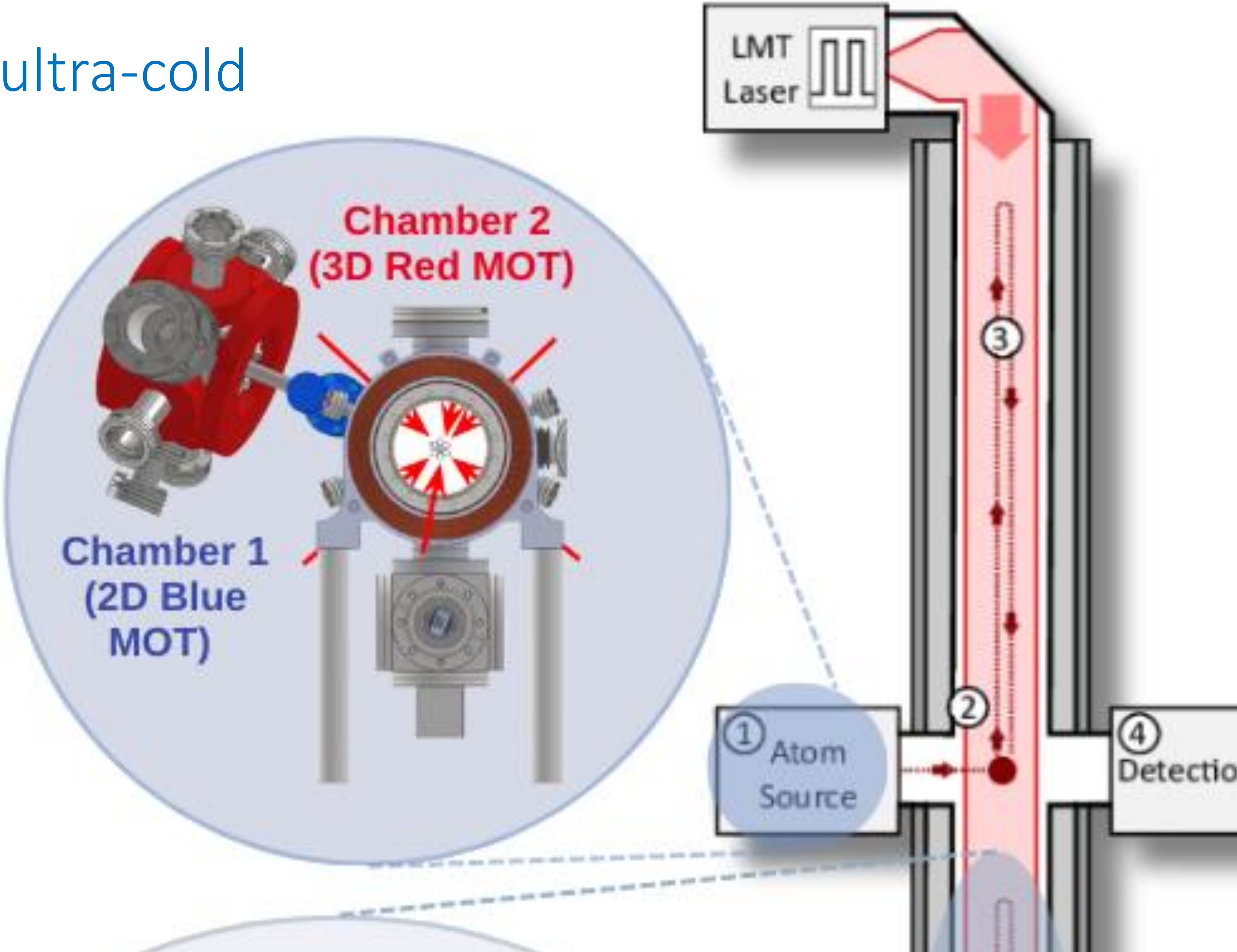




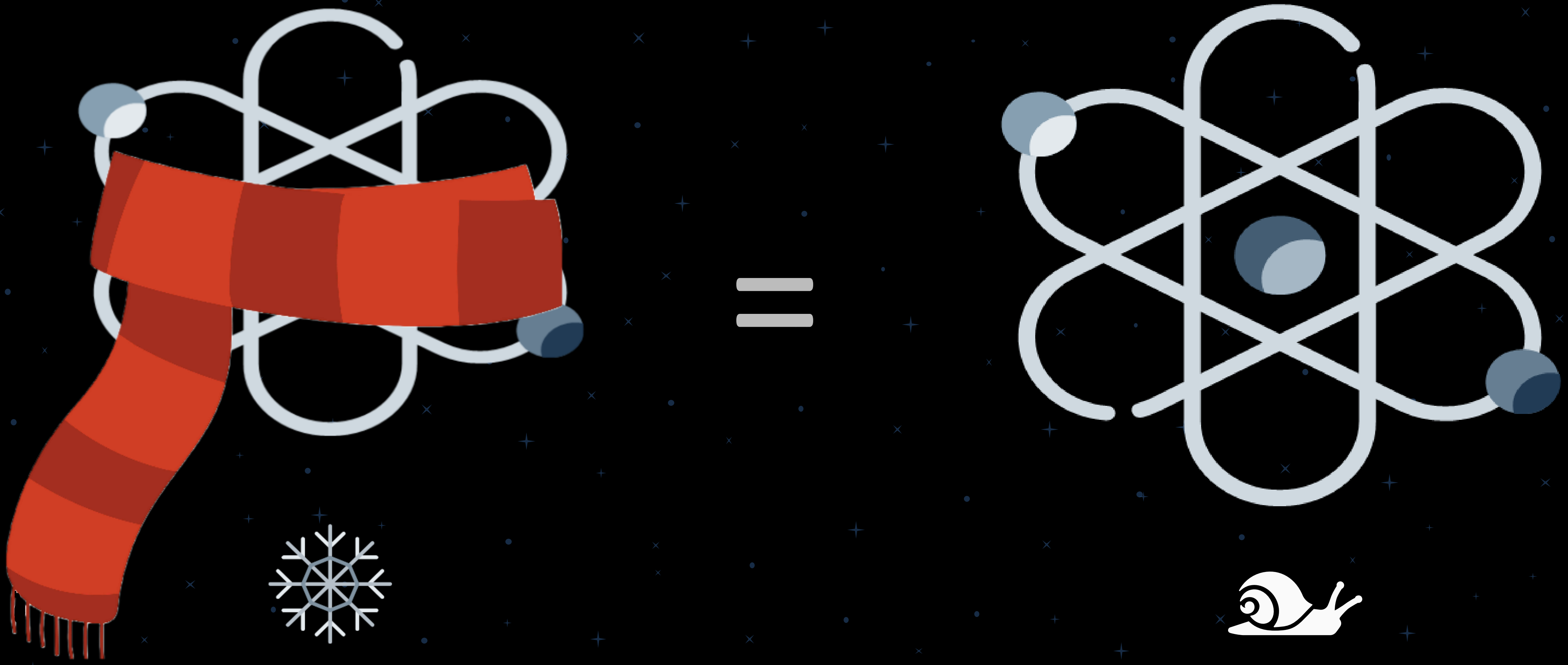
Gravitational Waves (~0.01 Hz to a few Hz)



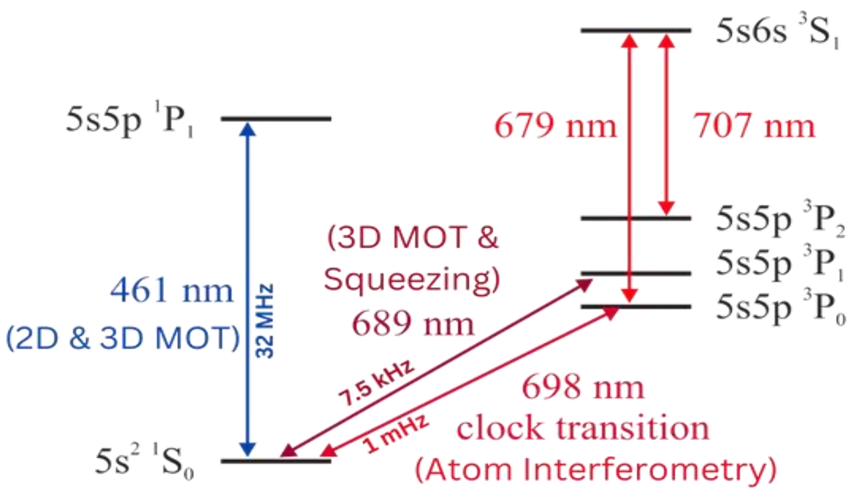
We need many ultra-cold atoms!

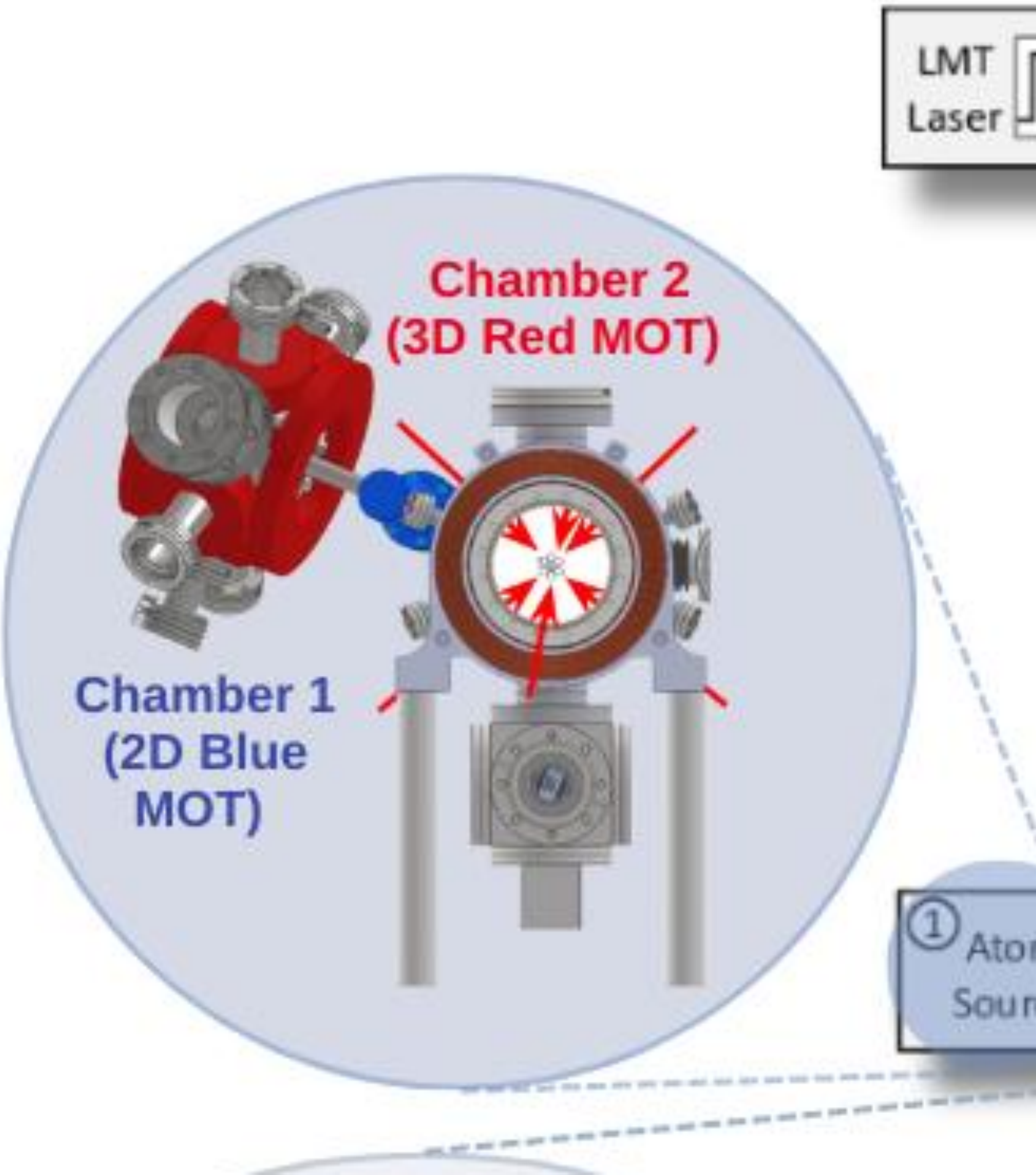


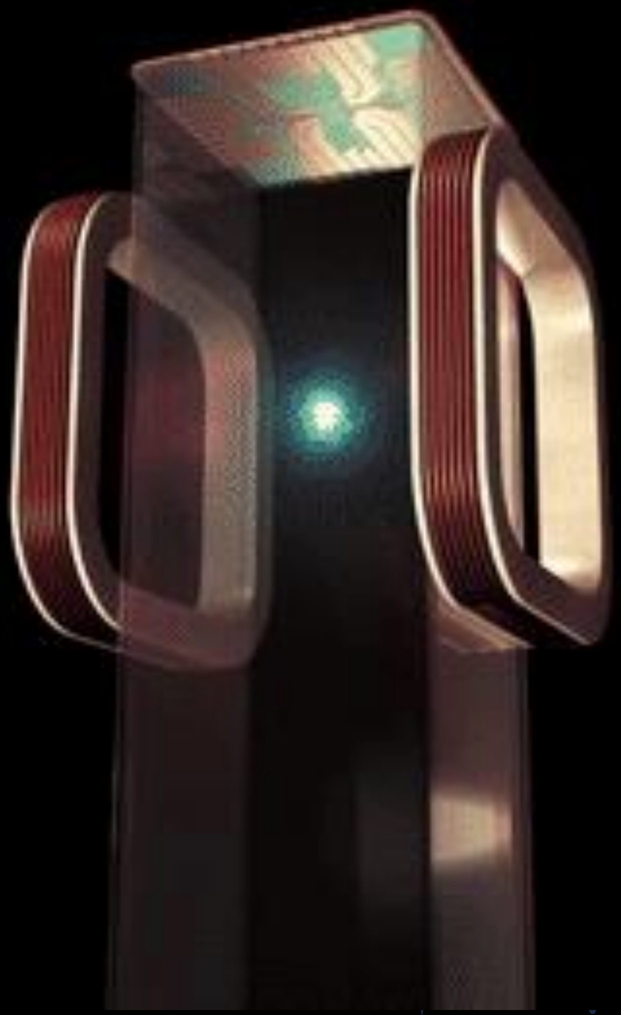
What are cold atoms?

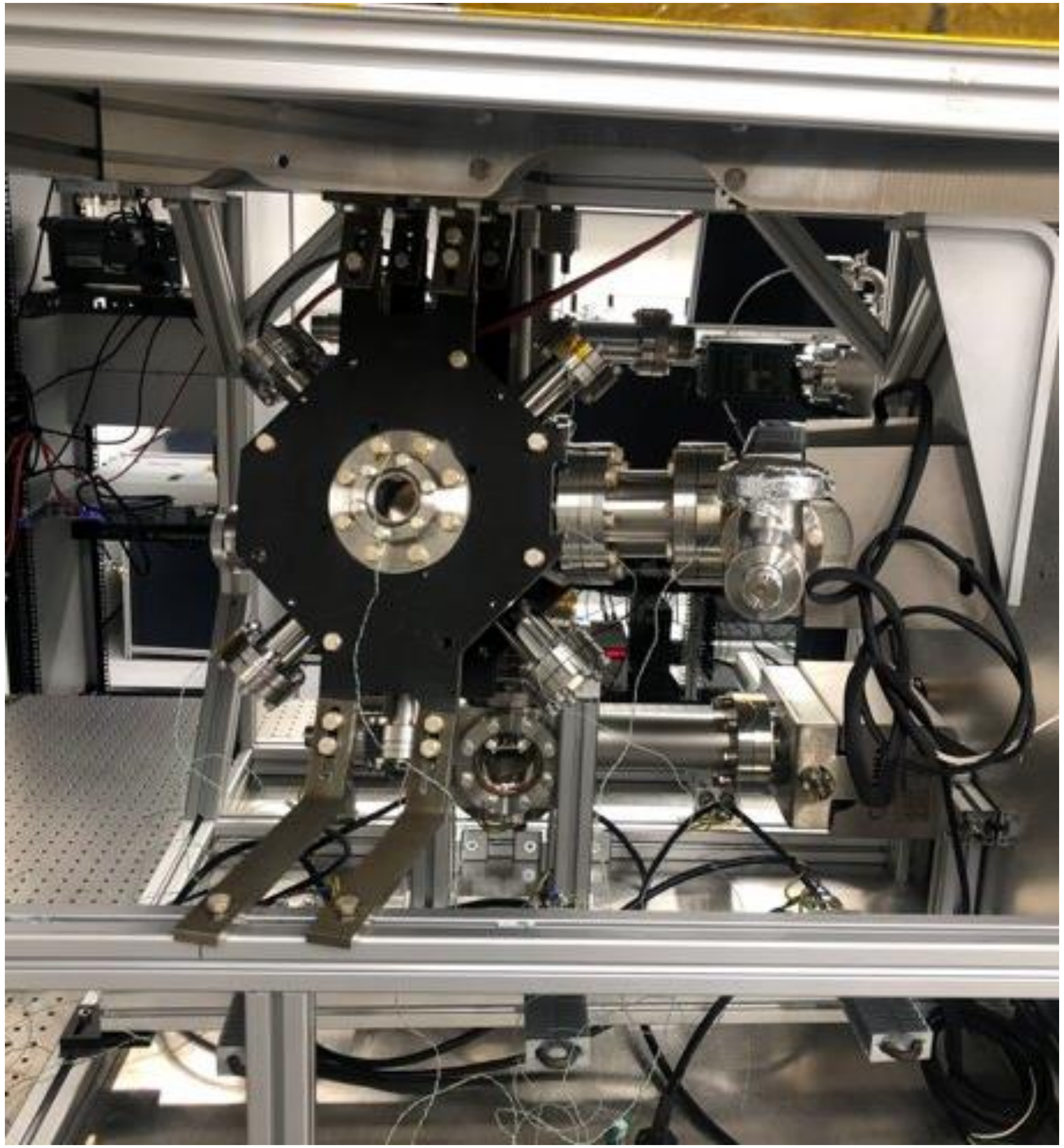


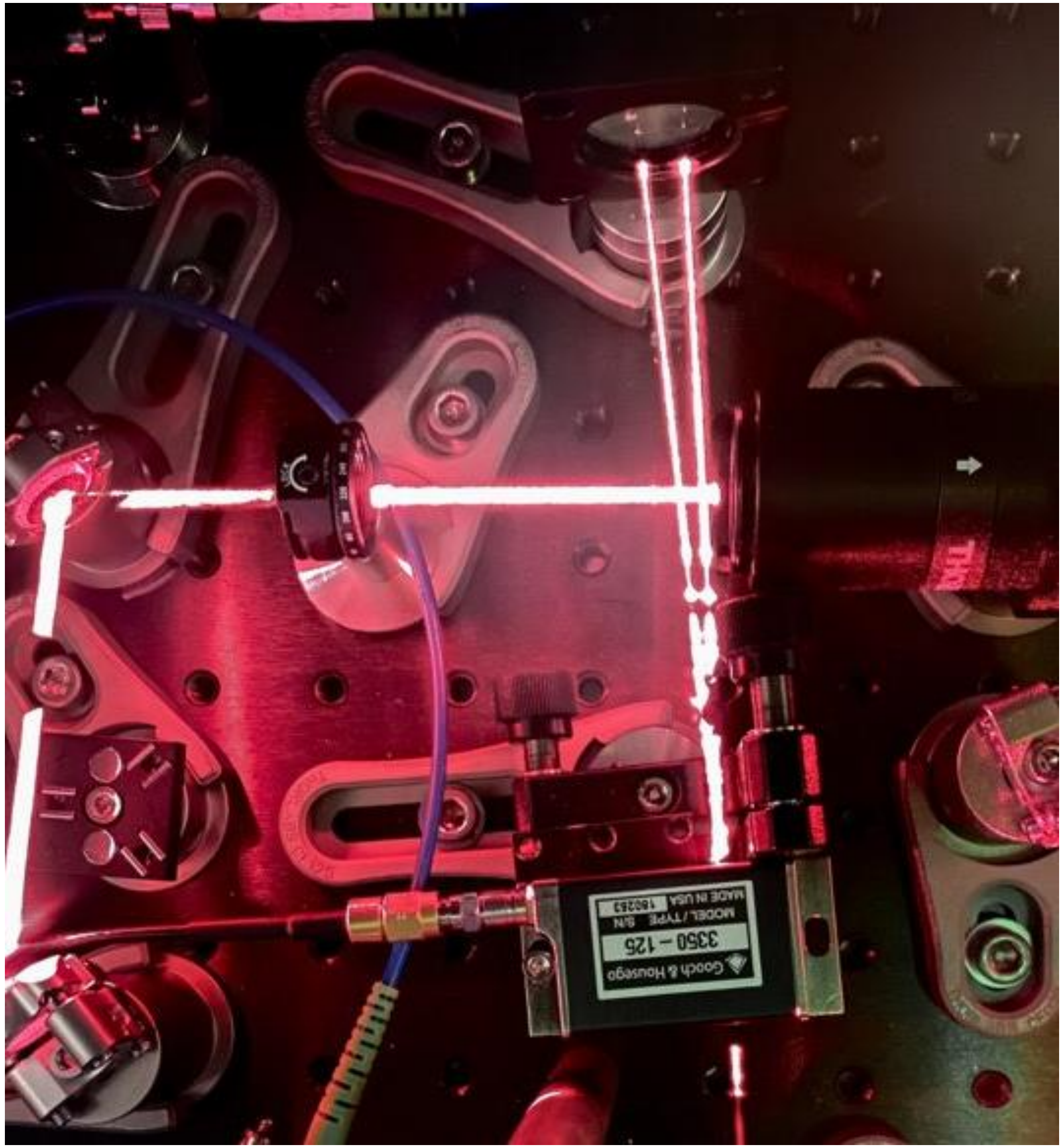
How do we get them?





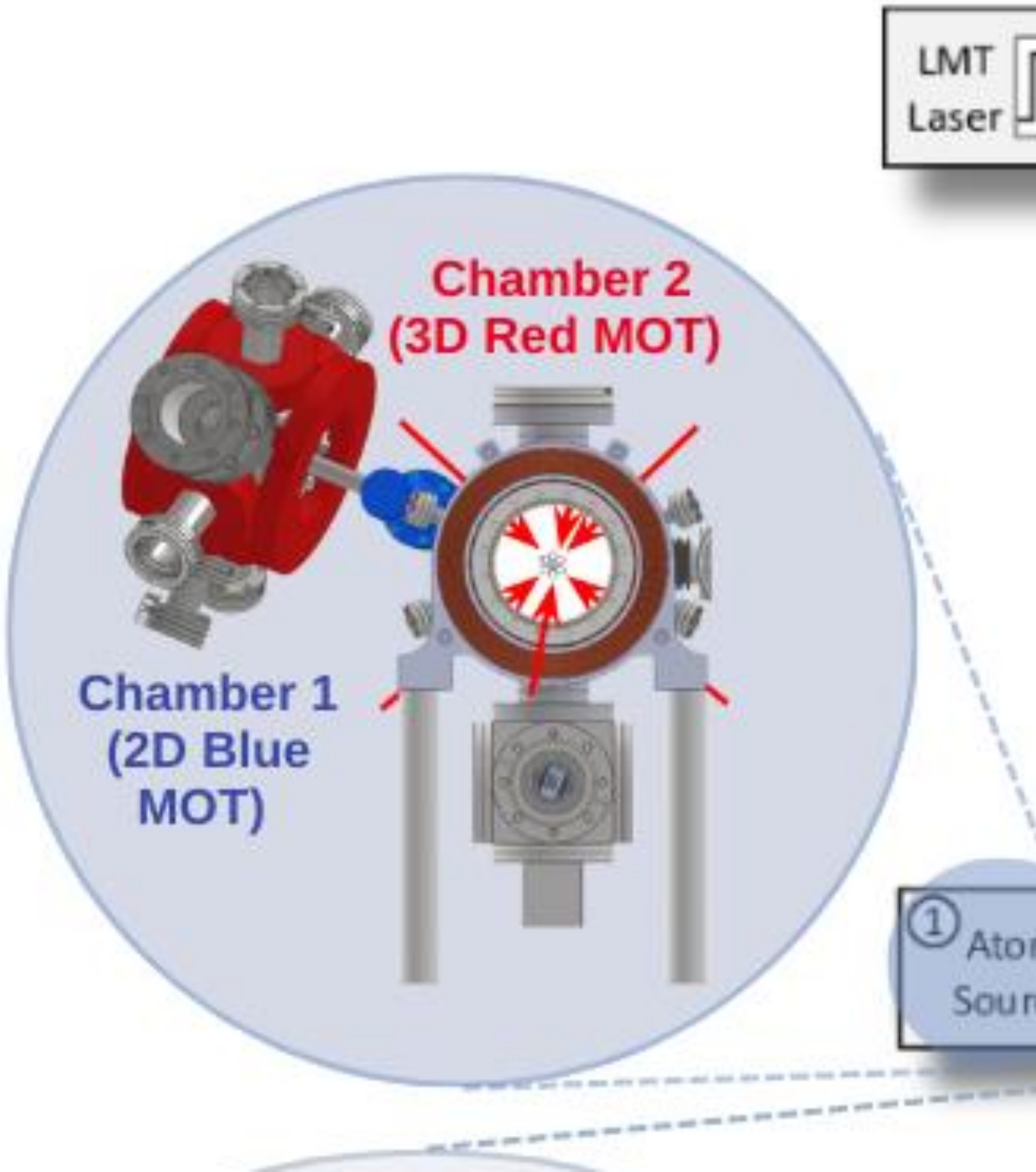




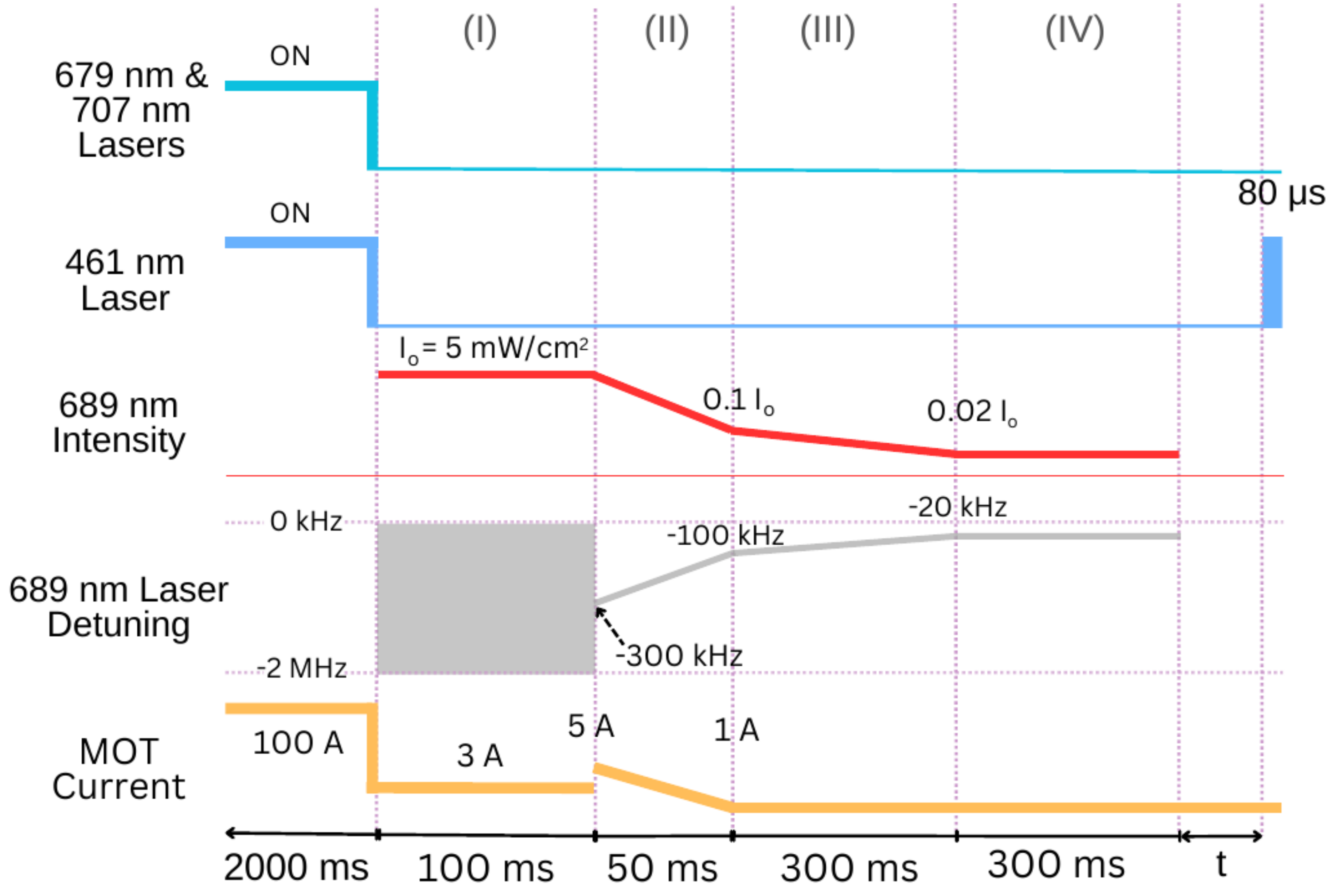

3350 – 125
Gooch & Housego

How do we get them?

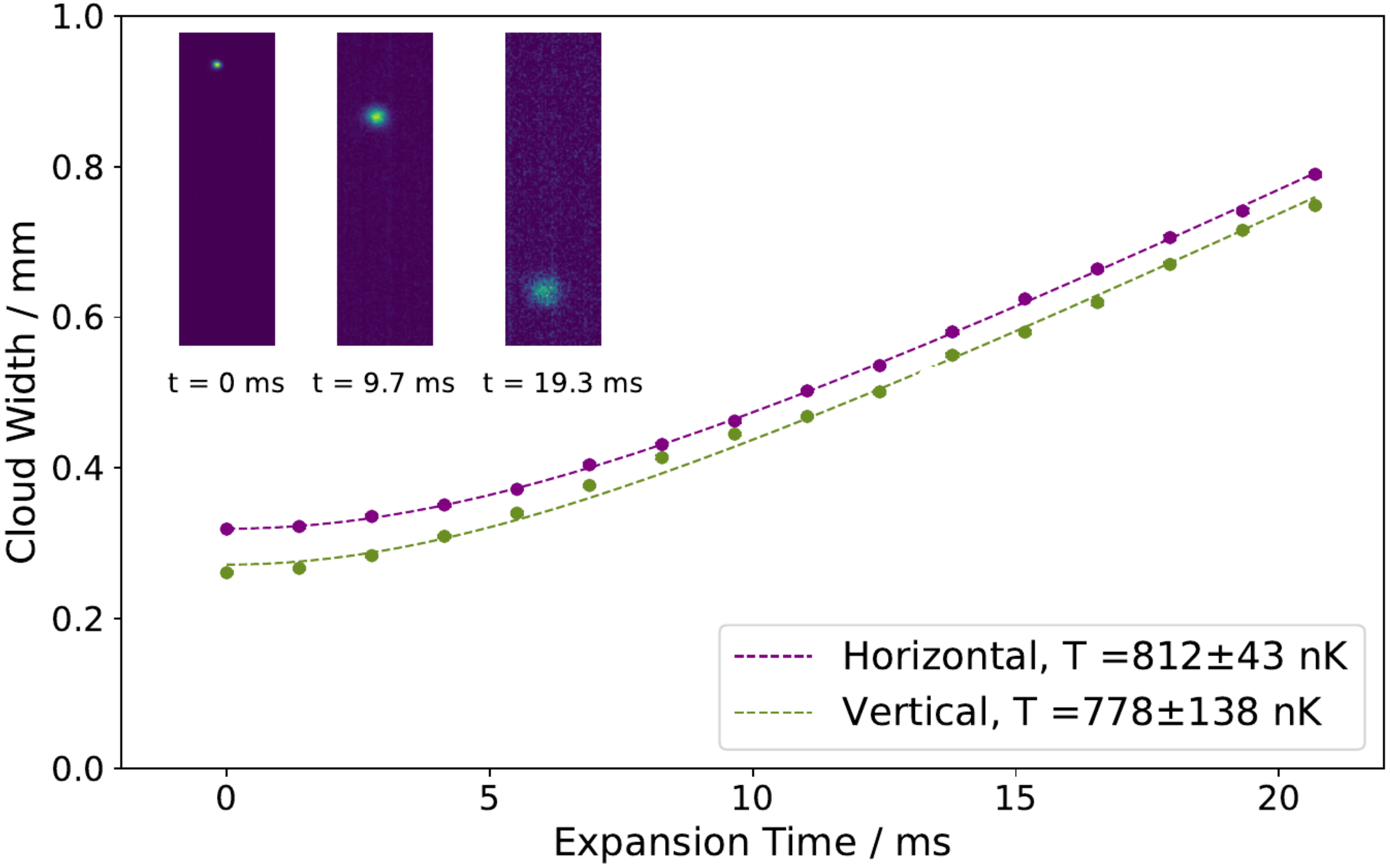
2D Blue MOT
↓
2D Red MOT
↓
3D Red MOT
↓
Dipole Trap
↓
Optical Lattice



We use lasers and magnetic fields



Sub-μK Temperatures in a narrowband red MOT!



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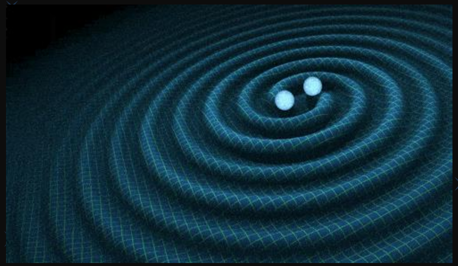

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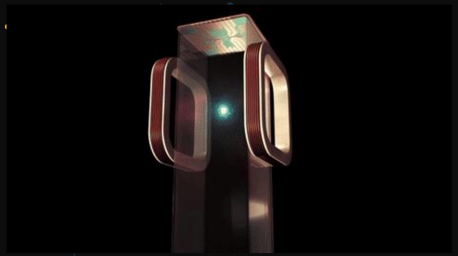
3



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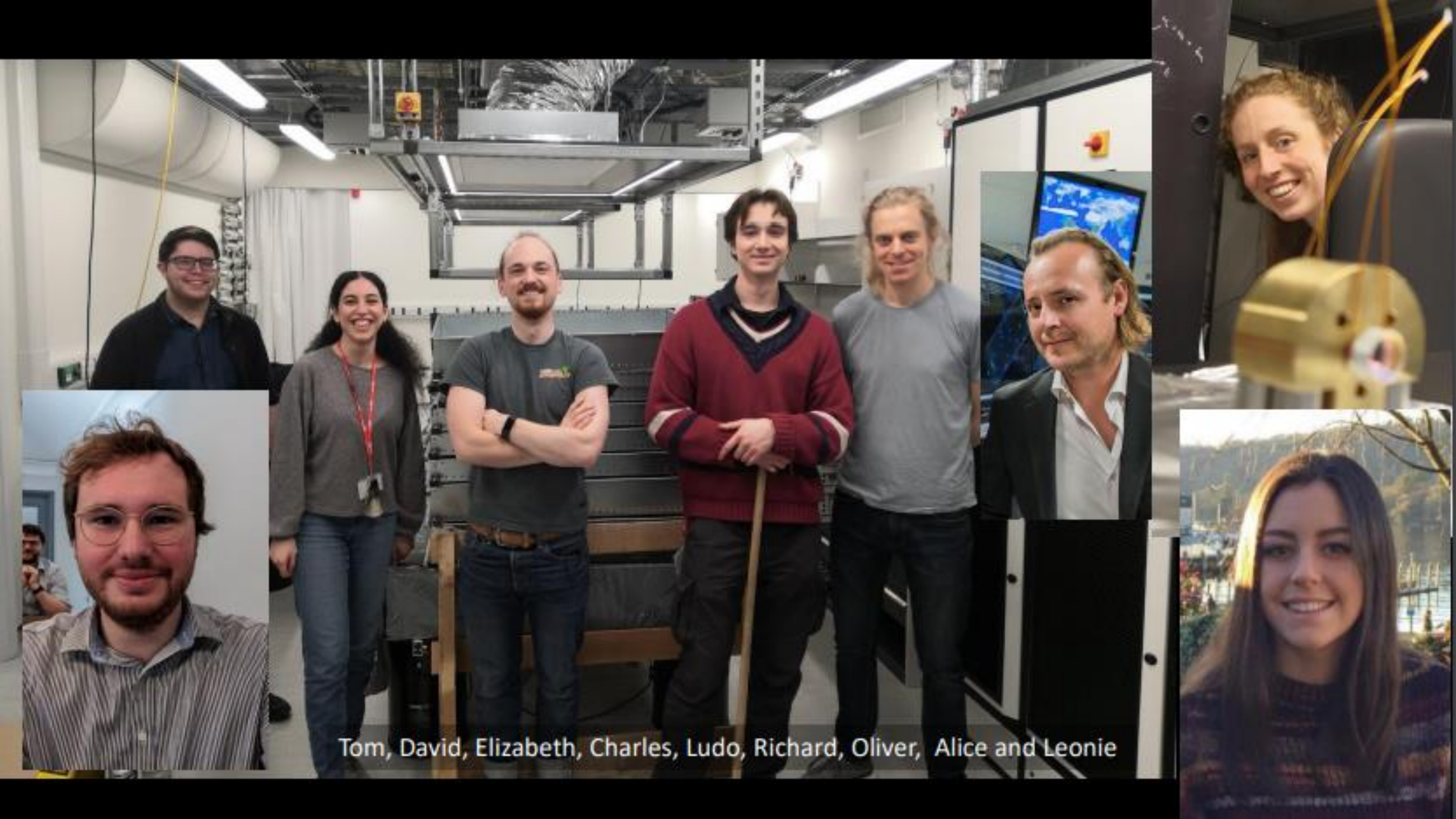
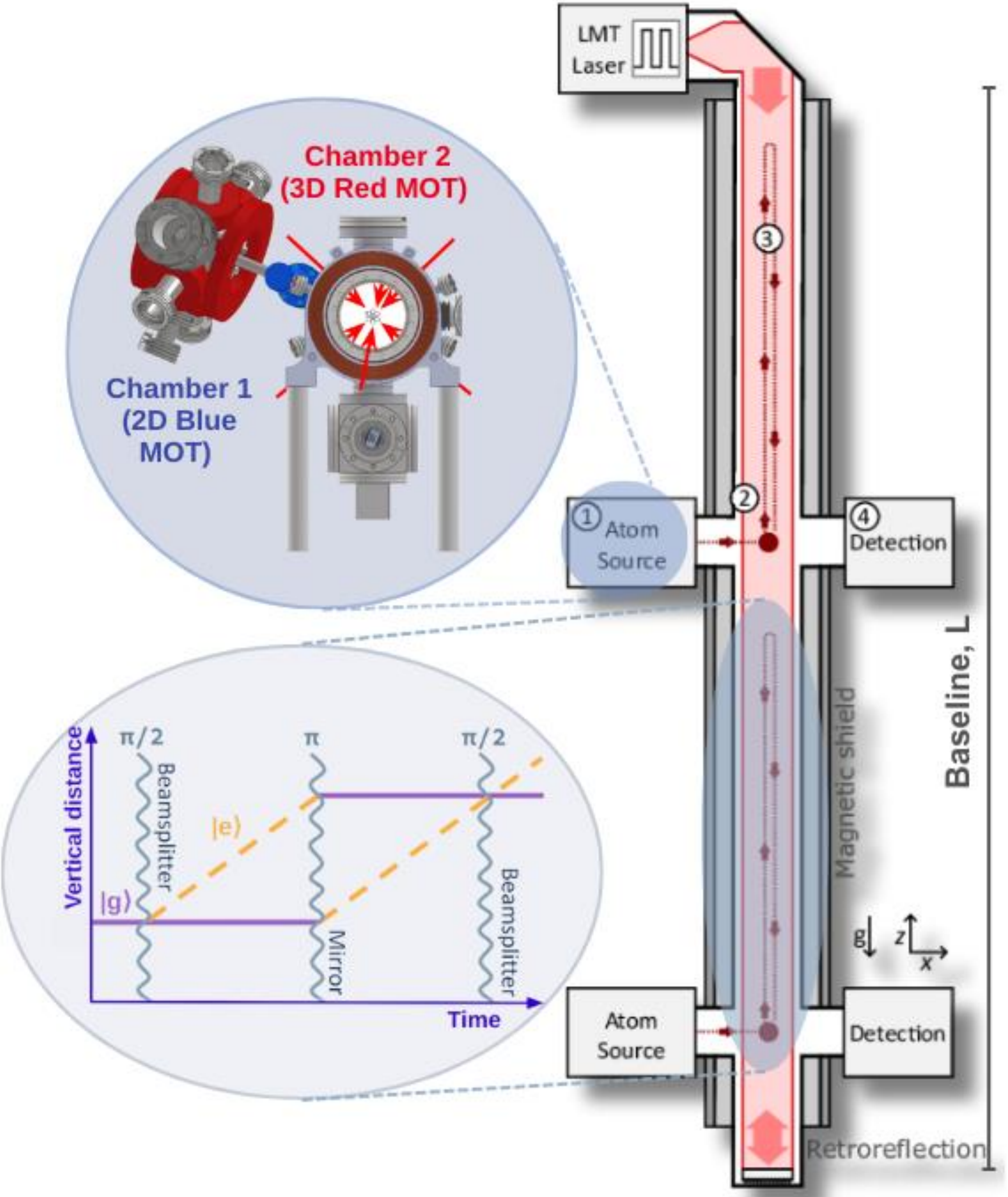
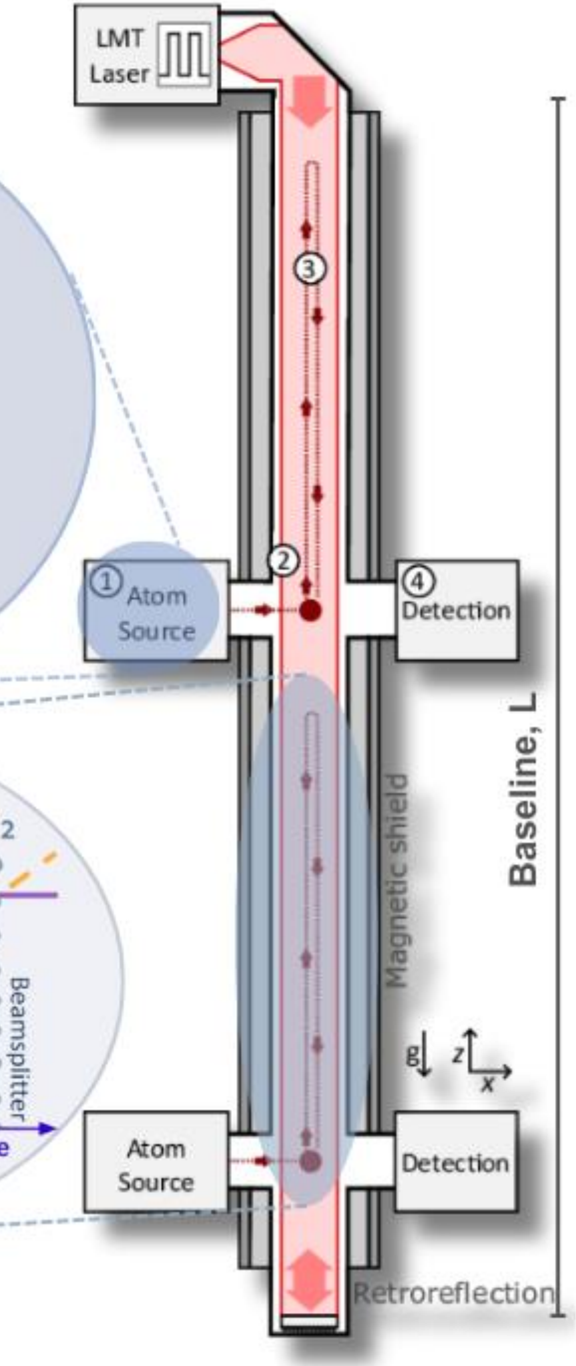


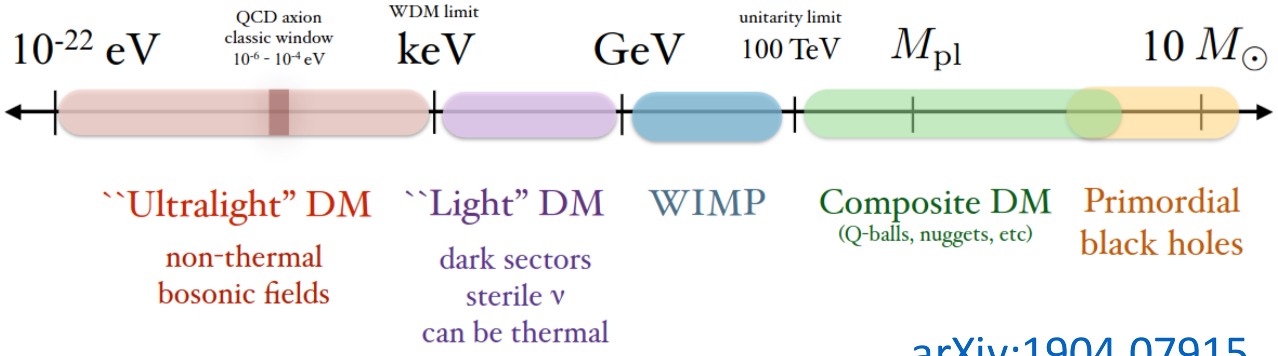
Tom, David, Elizabeth, Charles, Ludo, Richard, Oliver, Alice and Leonie

Extra Slides

The AION Detector





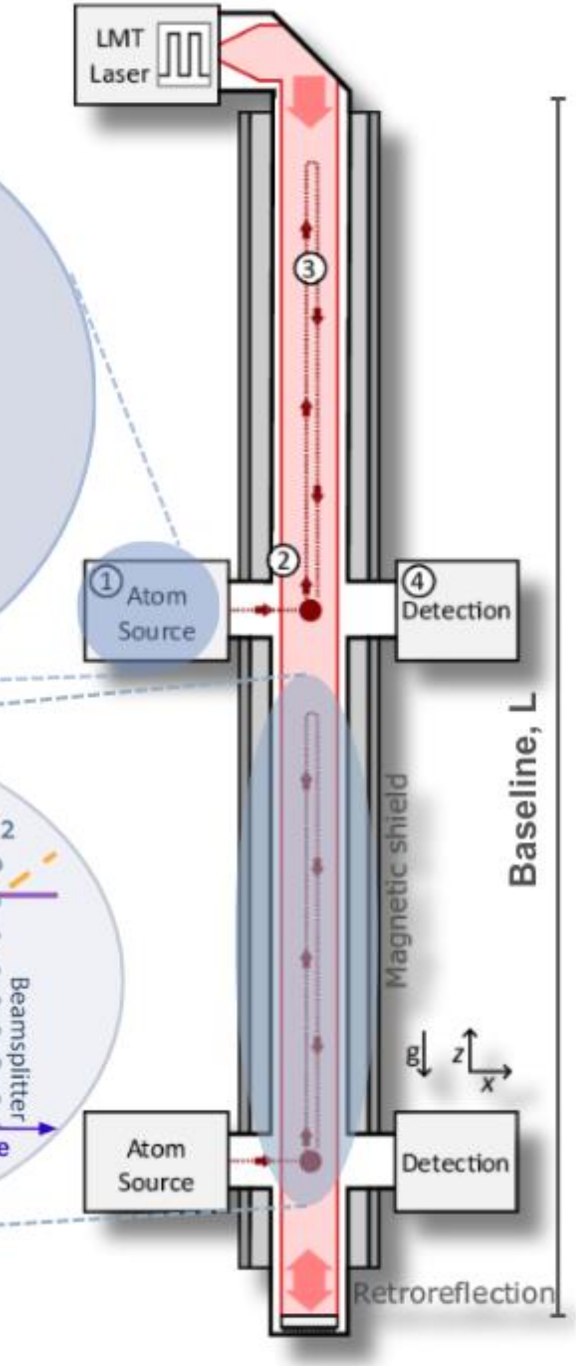


arXiv:1904.07915

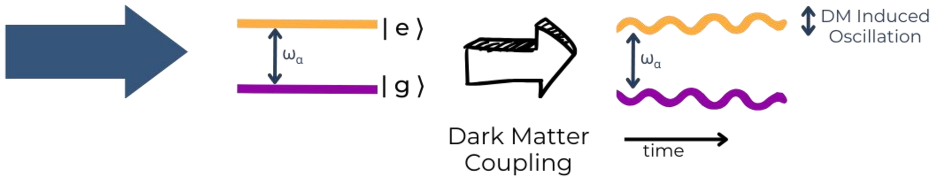
Scalar Ultra-Light **Dark Matter**

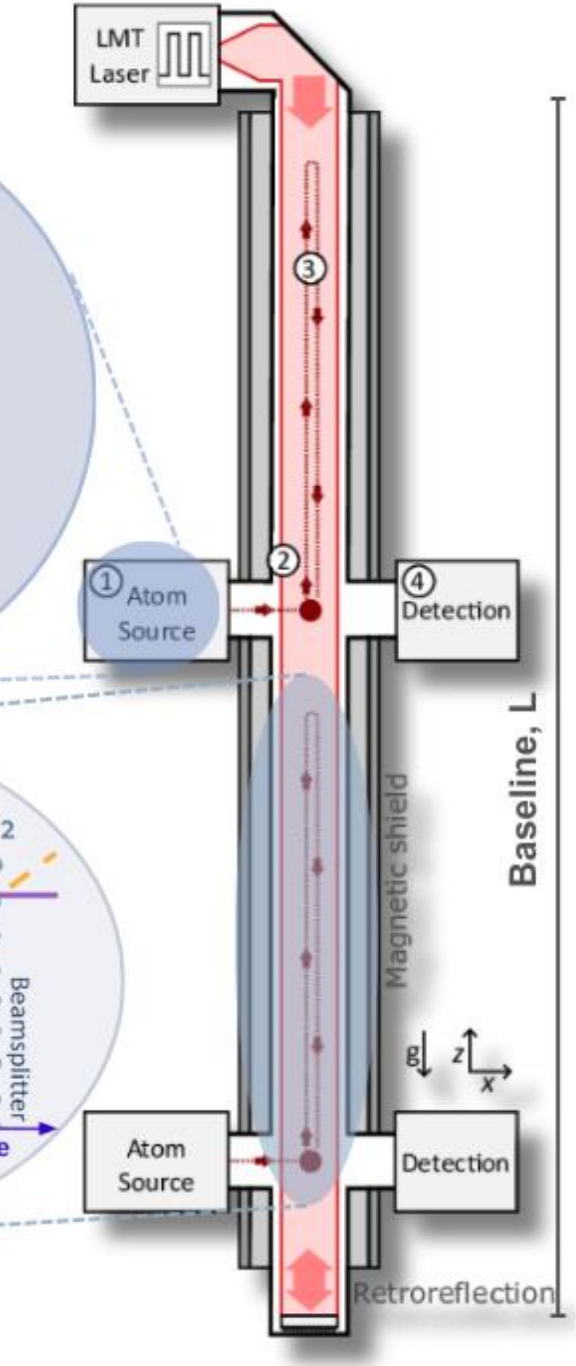
Time-dependent ULDM-induced signals

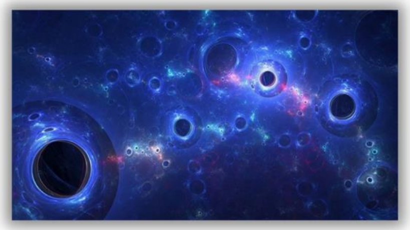
- Oscillating fundamental constants due to DM background



- Optical Transitions depend on electron mass and fine-structure constant
- Scalar DM induces oscillations in the transition frequencies/energies
- Amplitude set by the local DM density and a frequency given by the mass of the scalar DM particle







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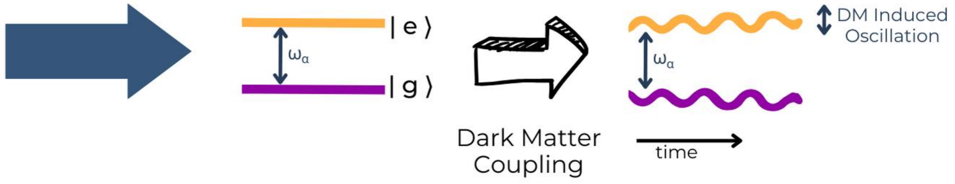

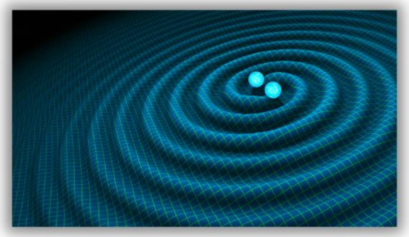

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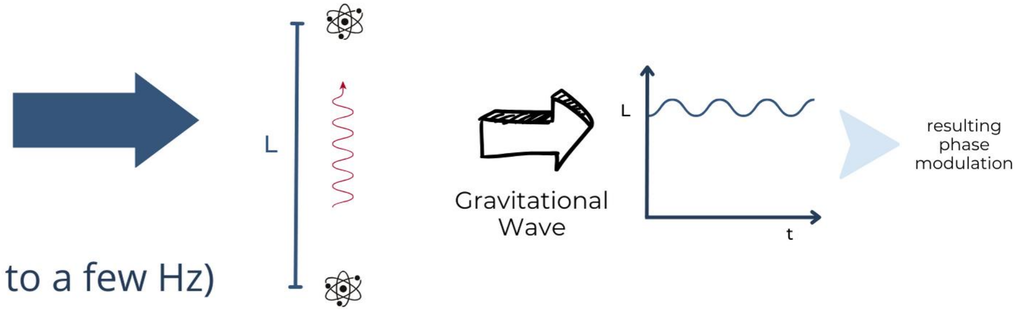

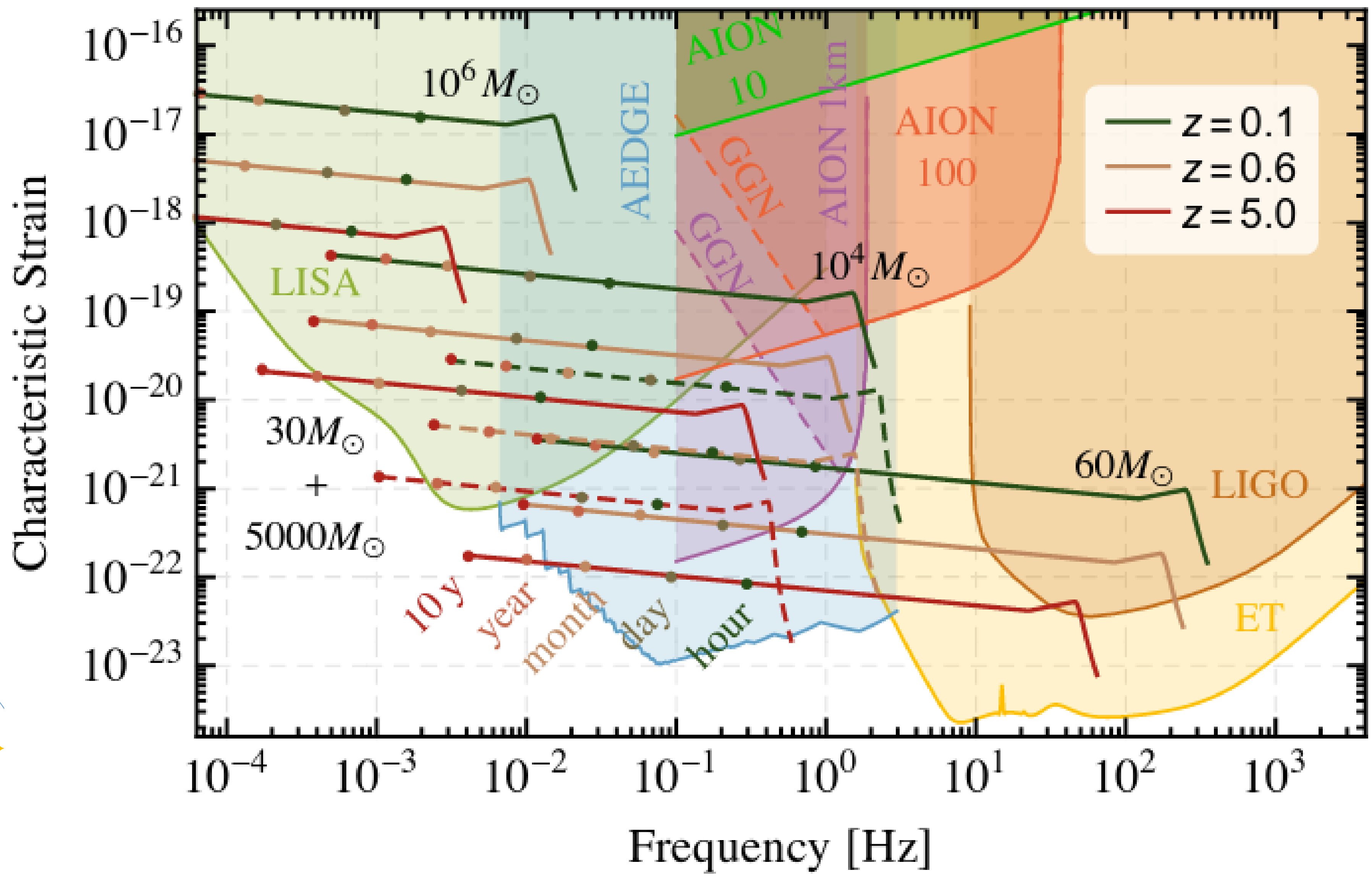

arXiv:1911.11755

Broadband Red MOT