Big Answers From Small Experiments

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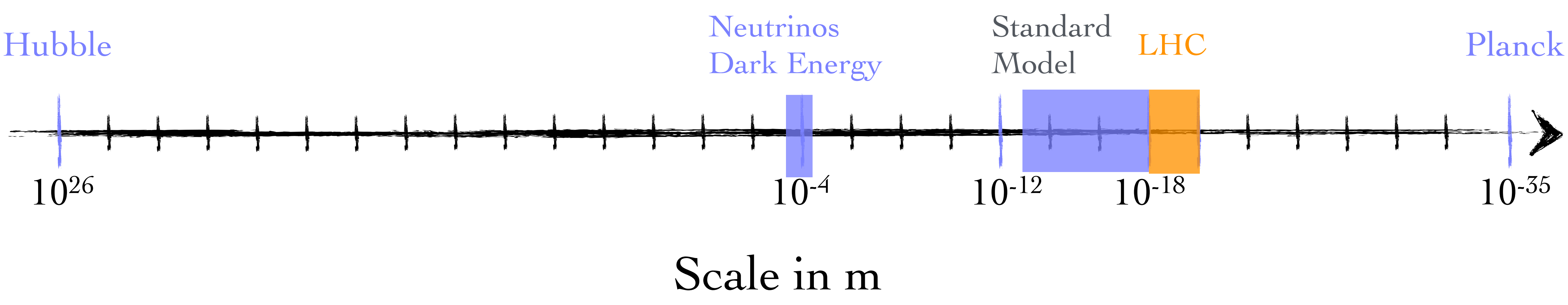
Stanford University

Big Answers From Small Experiments



80% of the energy scale left to explore

Dark Matter, Strong CP, String theory suggests there is more

Why Small?

- Theoretical

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- Theoretical

- Experimental

    Precision Frontier

Why Small?

- Theoretical
- Experimental

  Precision Frontier
- Sociological

  Time and Money

The Low Energy Frontier

- In the Standard Model
  - Gravitons
  - Cosmic Neutrinos
- In String Theory
  - Axion(s) Also DM and Strong CP!
  - Photons kinetically mixing with our photon $\epsilon\, F_{\mu\nu}^{EM} F^{\mu\nu\prime}$
  - Dilaton, moduli, new dimensions

How Do You Probe The Low Energy Frontier?

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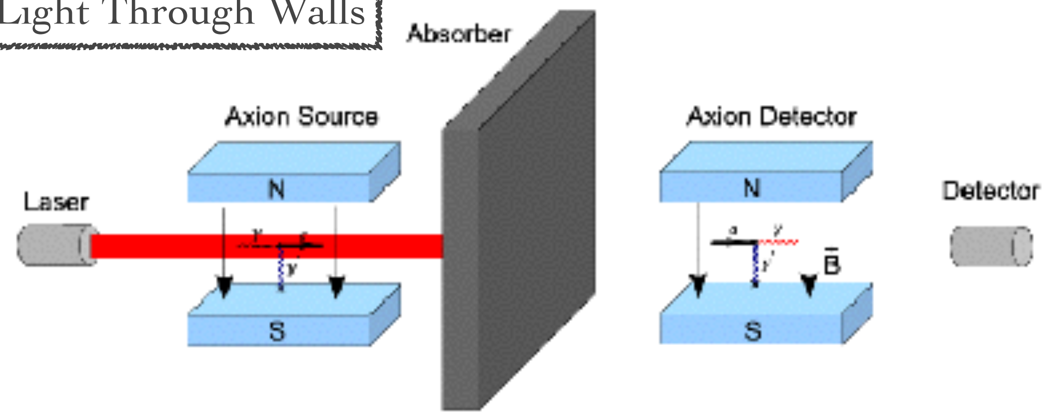
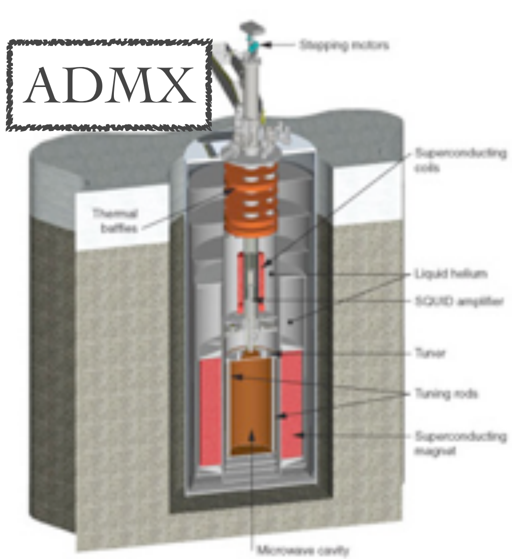
Light Through Walls



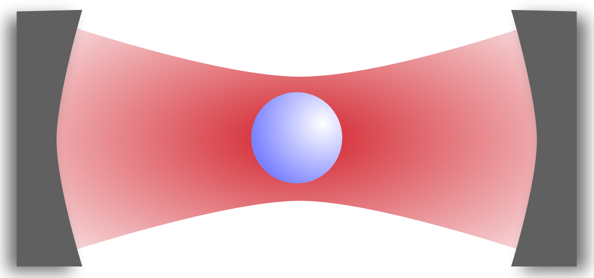
LIGO

ADMX



How Do You Probe The Low Energy Frontier?

Optically Levitated Objects



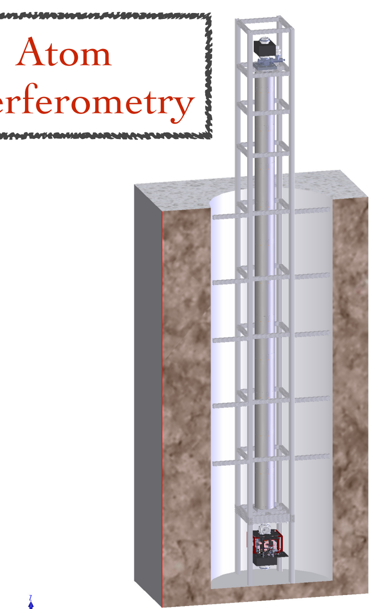
- Short Range Forces
- Gravitational Wave detection at high frequencies
- Tests of Quantum Mechanics

- Axion Field Detection

NMR

LIGO

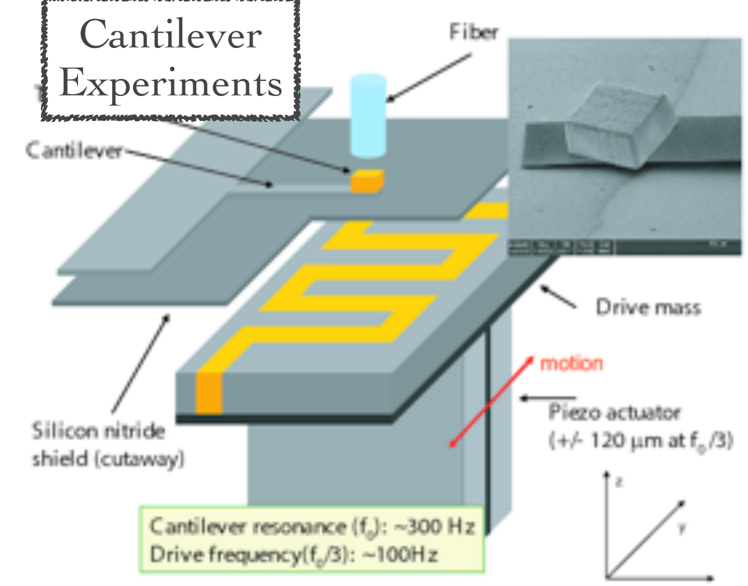
Atom Interferometry



- Equivalence principle at 15 decimals
- Gravitational Wave detection at low frequencies
- EDM searches
- Tests of Atom Neutrality at 30 decimals

- Short Distance Tests of Gravity
- Extra Dimensions

Cantilever Experiments



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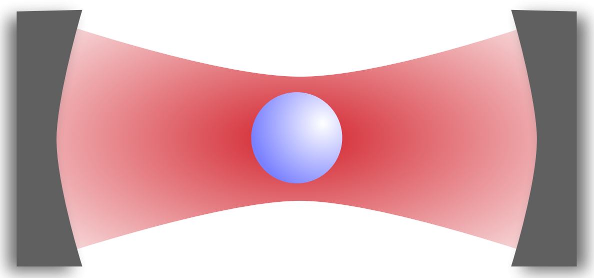

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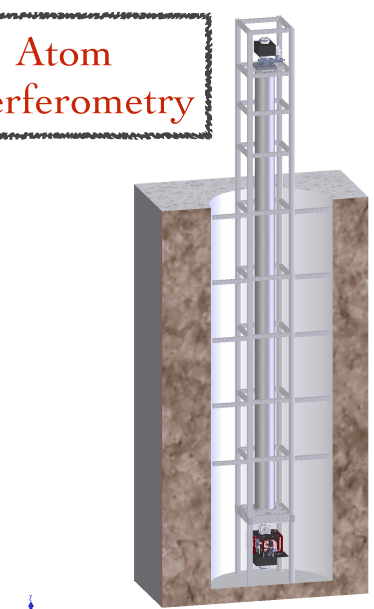

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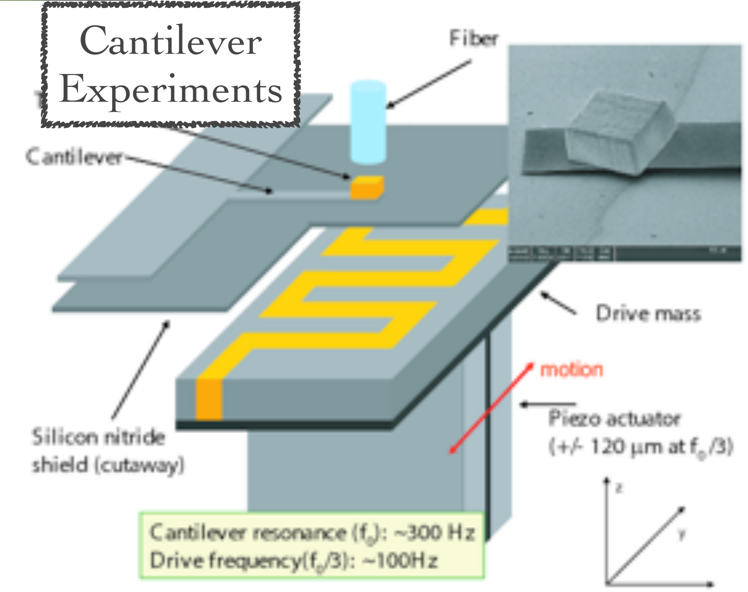
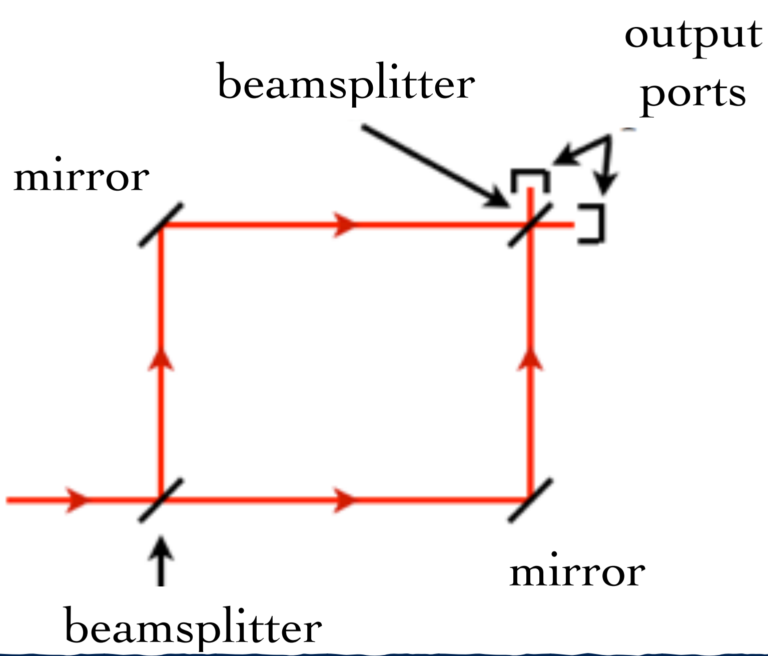


Light vs Atom Interferometry

Light



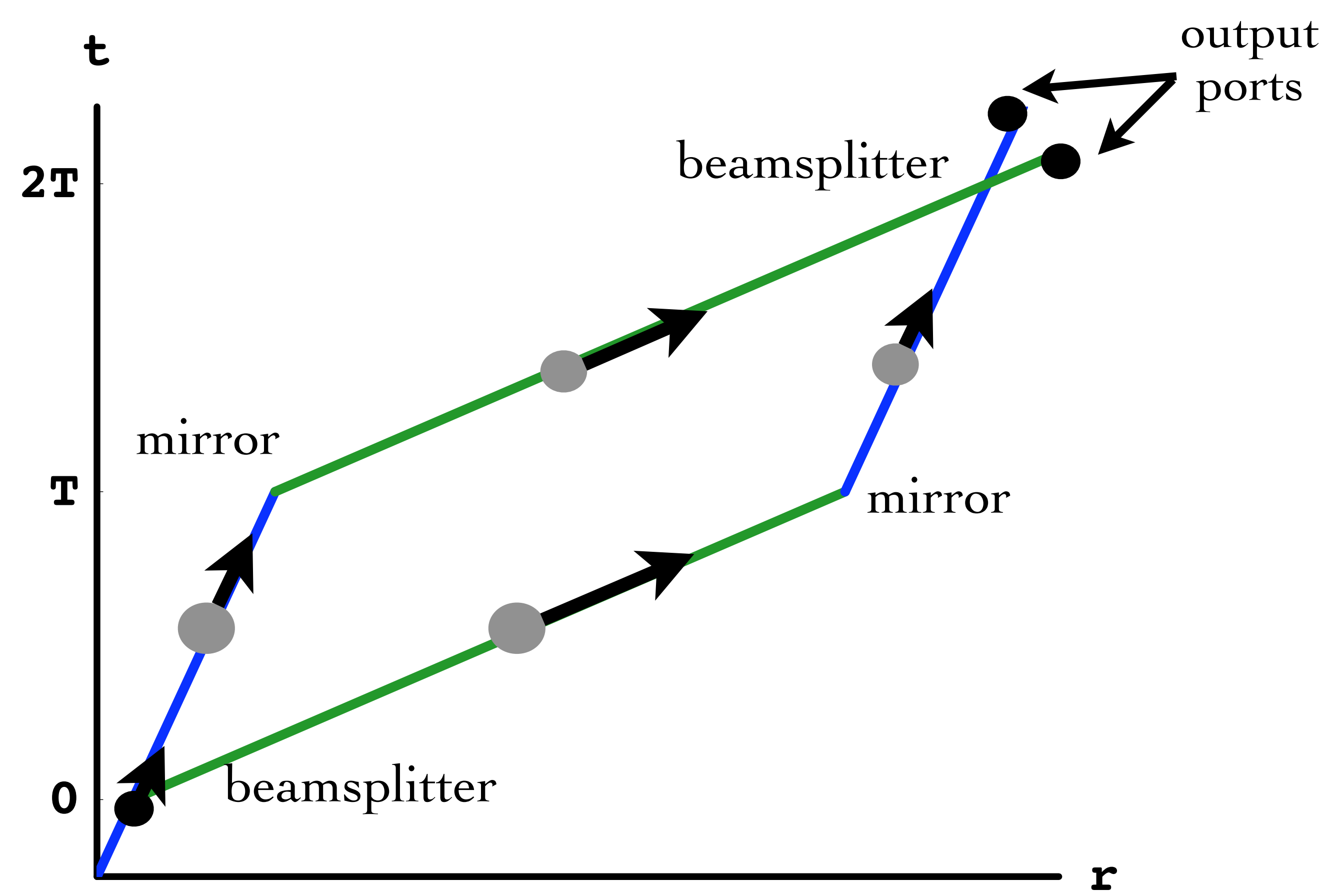
accuracy of measurement

$$\frac{\delta L}{L} \approx \frac{\lambda}{L} \times \text{ phase resolution}$$

Atoms

For atoms T~ 1 sec

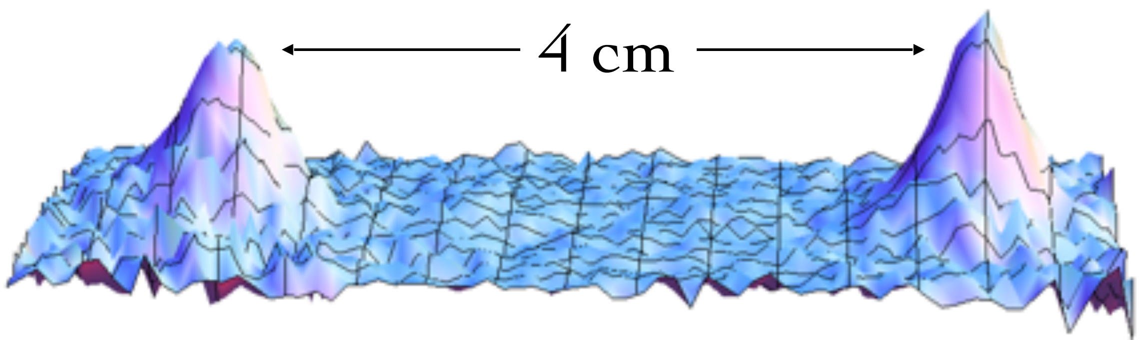
⇒ L= cT ~ Earth-Moon distance!

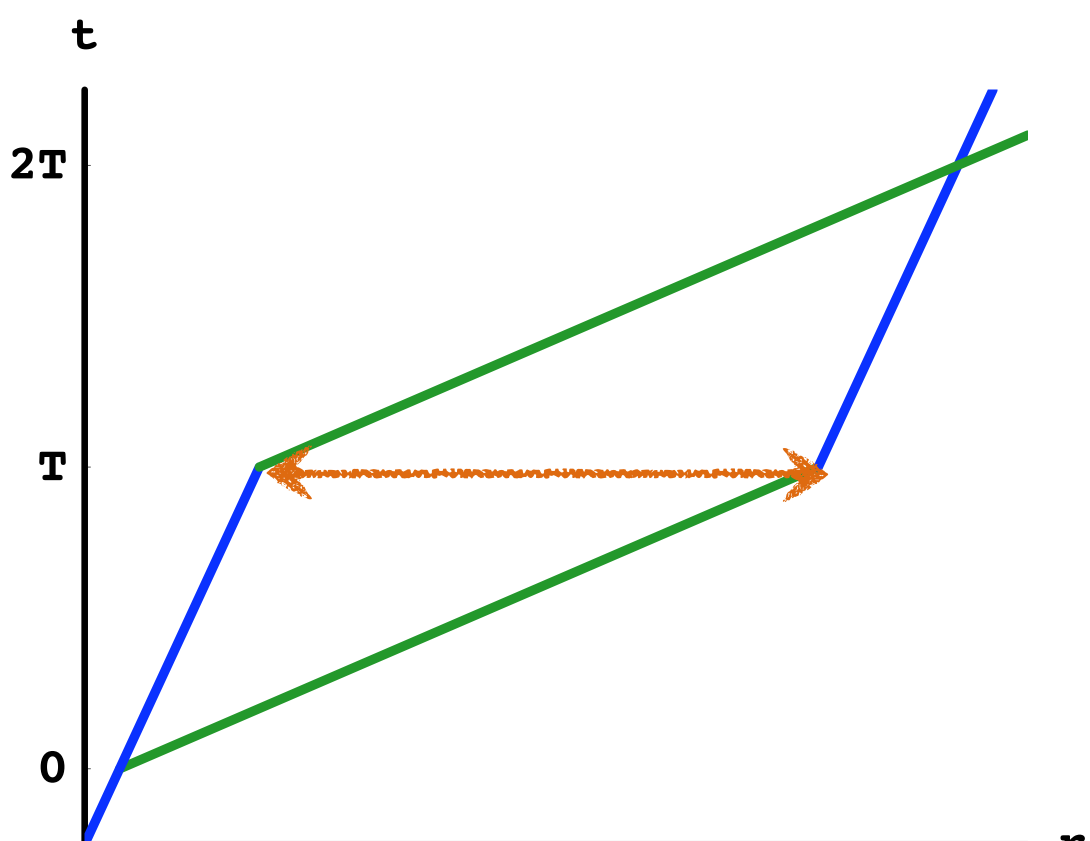


10 m Atom Interferometer (2013)

Hogan, Kasevich et. al.

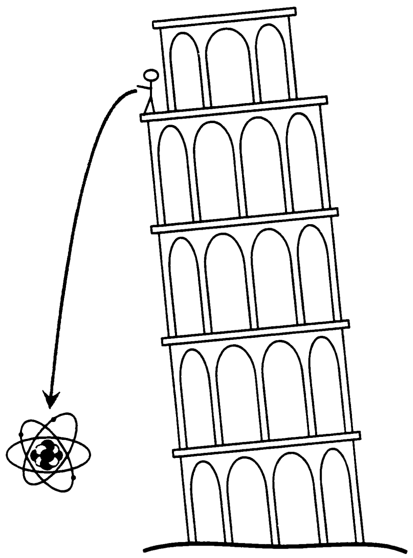
Maximum Wavepacket Separation





Testing Gravity at Large Distances

SD, Graham, Hogan, Kasevich
2006



An atom interferometer is a precision accelerometer

- Tests of the equivalence principle

Galileo $\sim g$

Future $\sim 10^{-17} g$

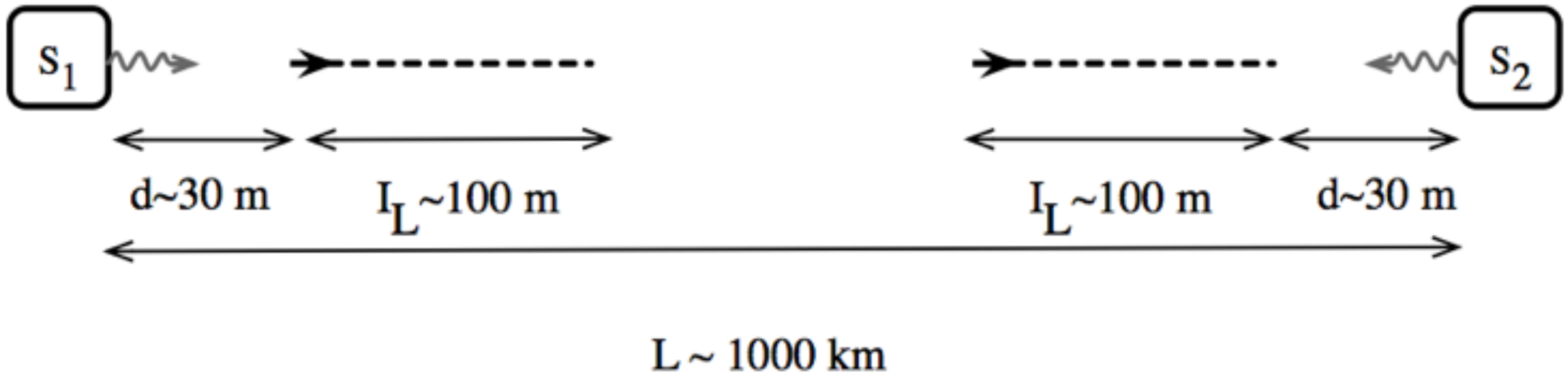
- Tests of General Relativity

$$\frac{d\vec{v}}{dt} = -\nabla\phi \qquad -\nabla\phi^2 \qquad -\vec{v}^2\nabla\phi$$

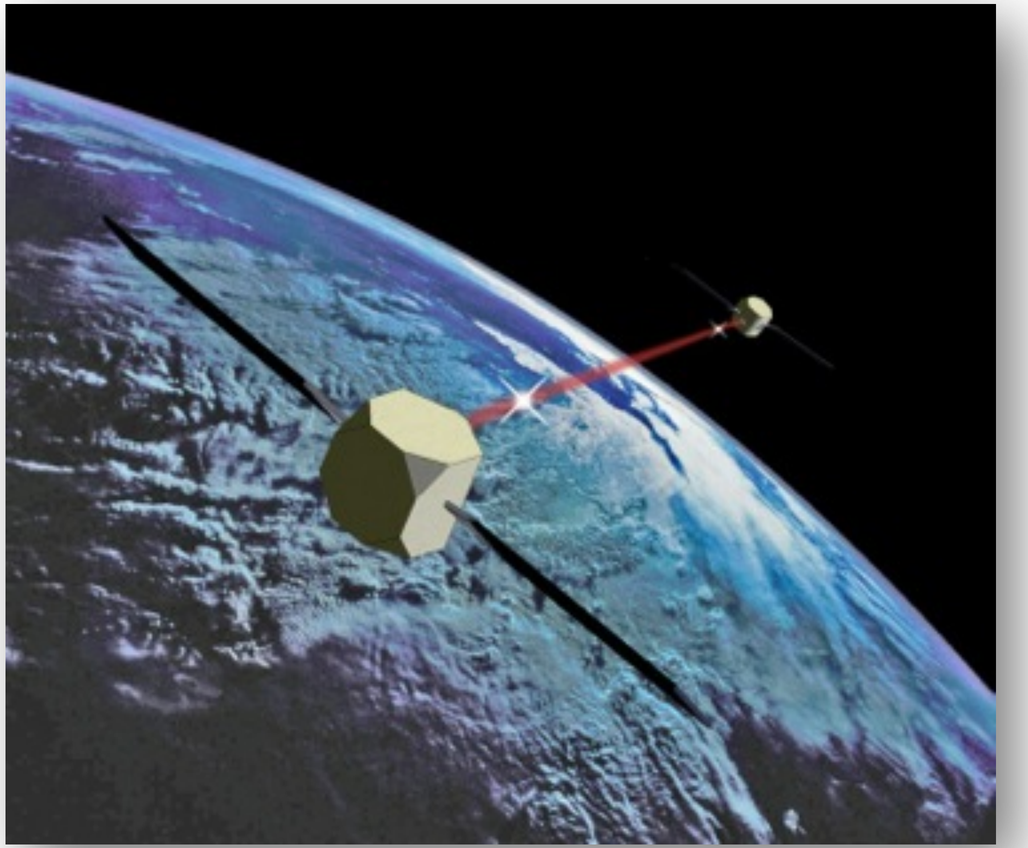
Newton's Gravity | Gravity Gravitates | Kinetic Energy Gravitates

Gravitational Wave Detection with Atom Interferometry

SD, Graham, Hogan, Kasevich, Rajendran
2008



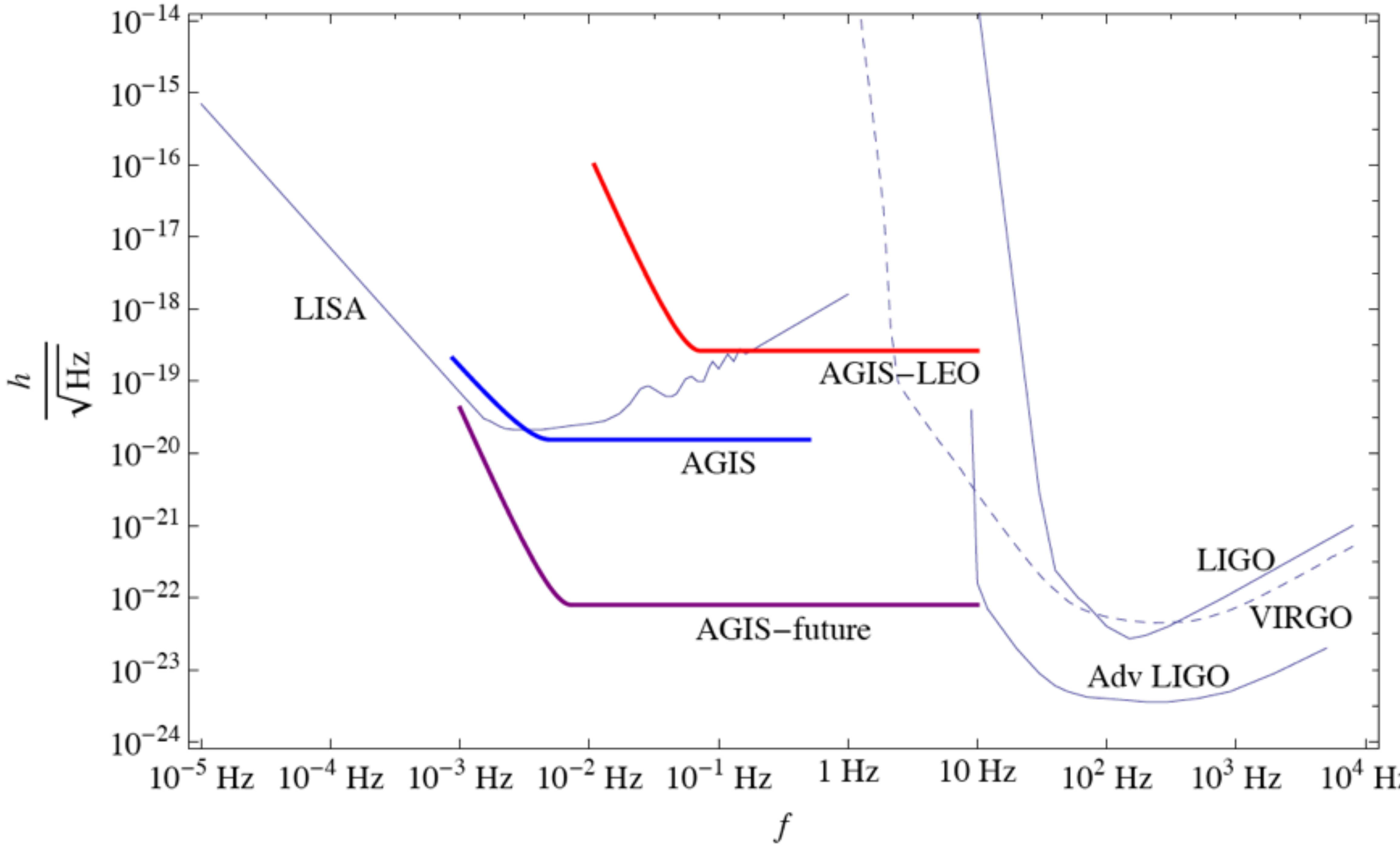
Physical Distances between atoms oscillate with the GW amplitude:
$L=Lo(1+ h \cos(\omega t))$



- Currently funded by NASA NIAC grant (NASA Innovative Advanced Concepts)

- MIGA - Philip Bouyer: Ground based GW detector in Bordeaux

Projected Sensitivity in Space



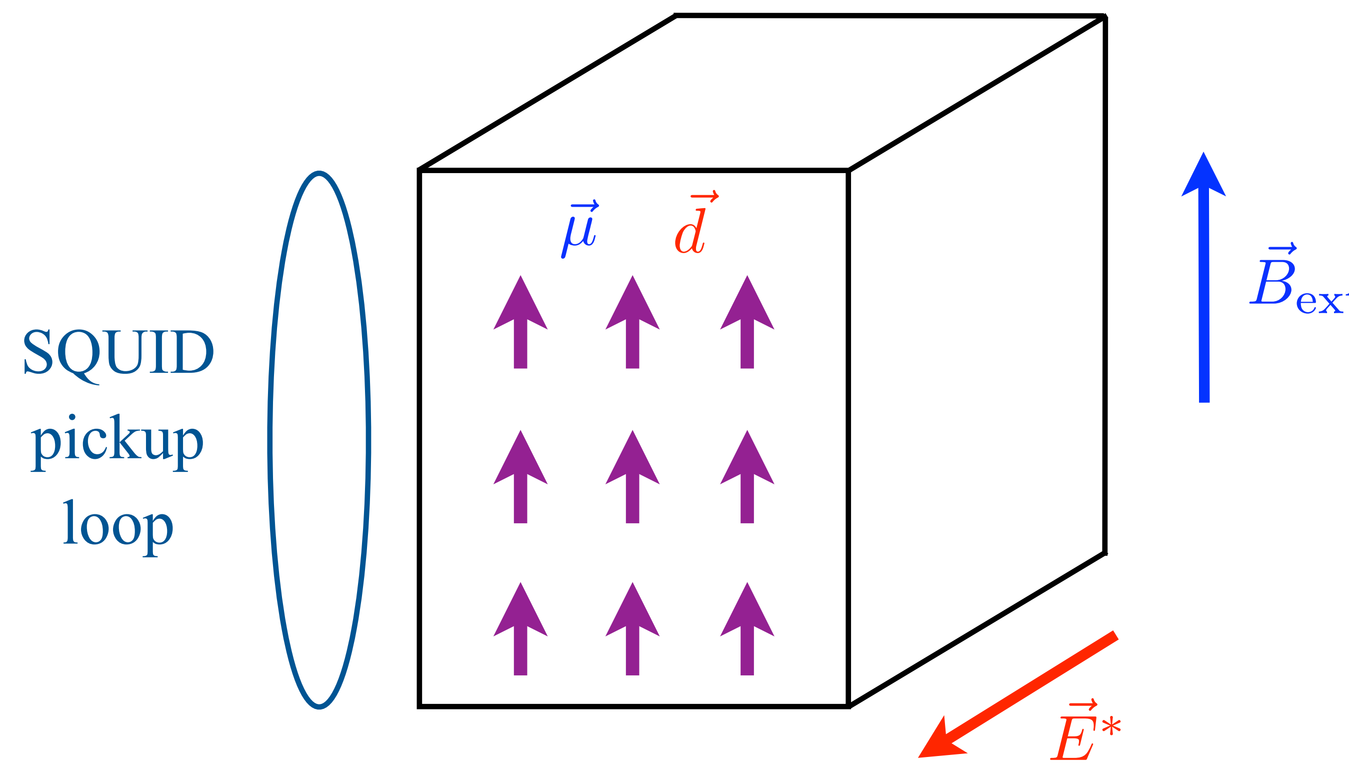
AGIS: 1000 km
LISA: 5000000 km

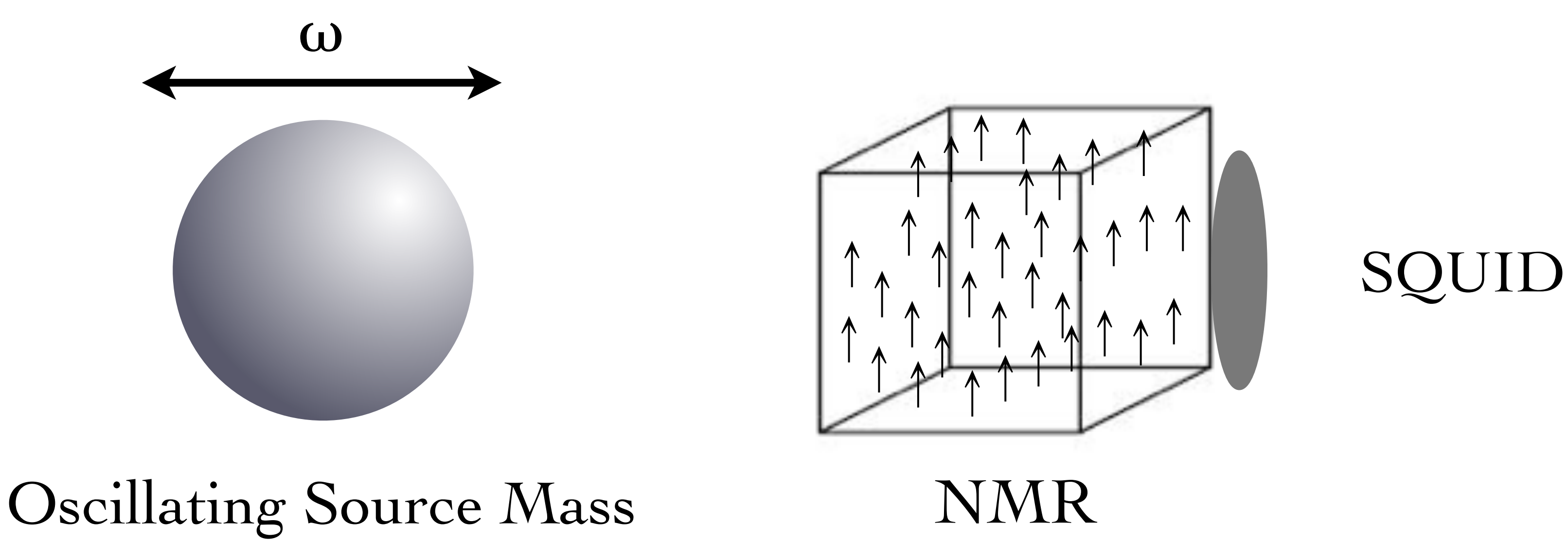
Precision Magnetometry

Nuclear Magnetic Resonance

Cosmic Axion Detection

Budker, Graham, Rajendran, et. al.

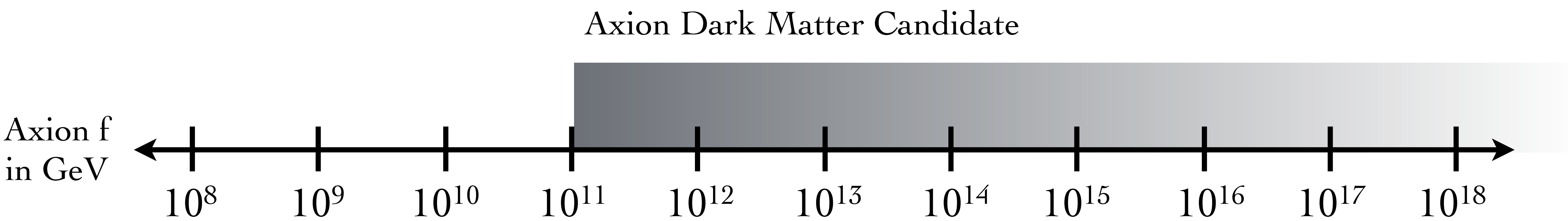




Short-range axion exchange

Arvanitaki and Geraci

Reach of New QCD Axion Detection Ideas



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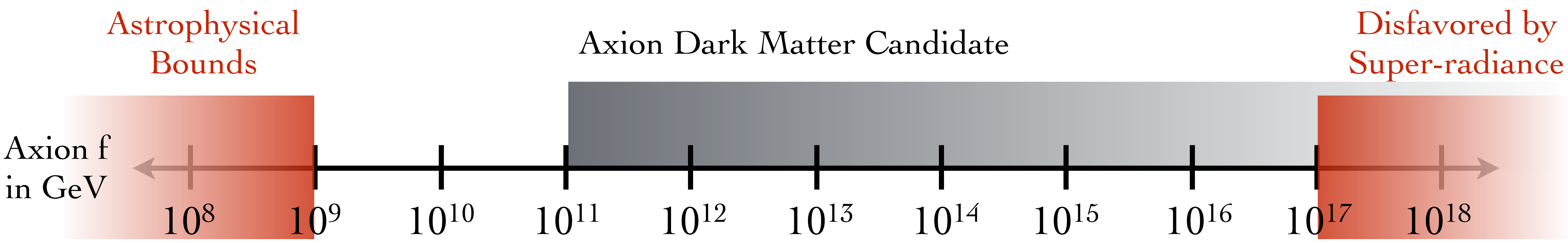

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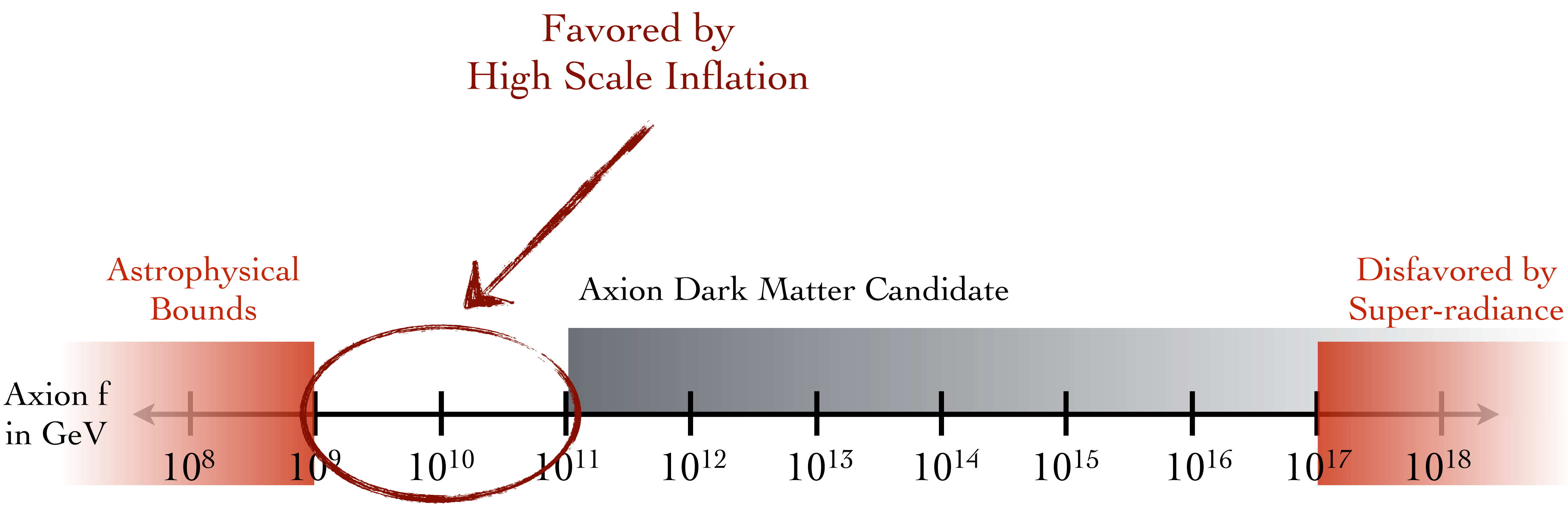

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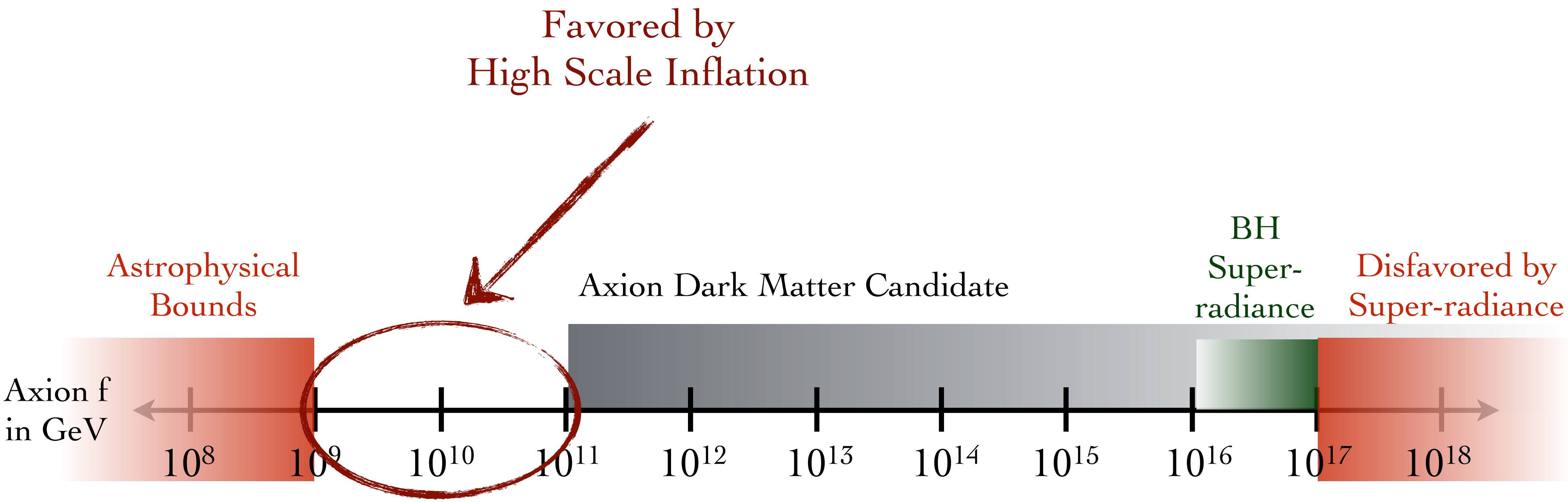

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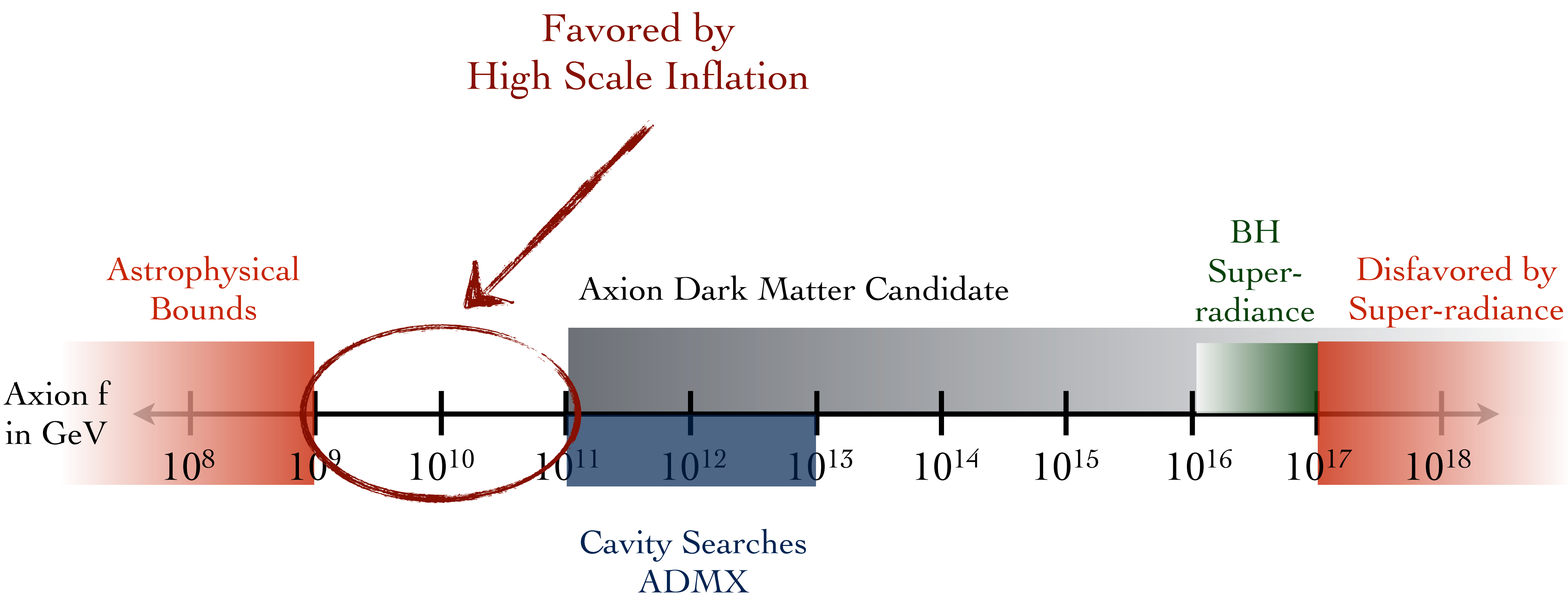

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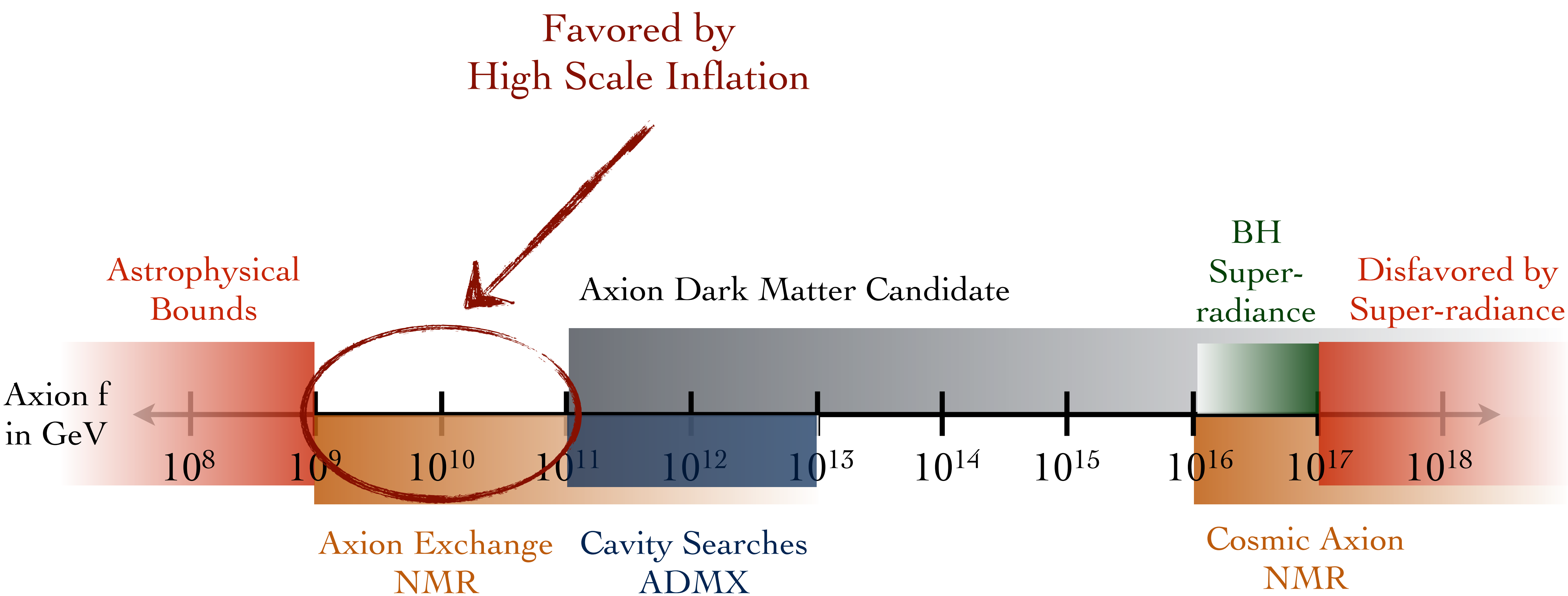
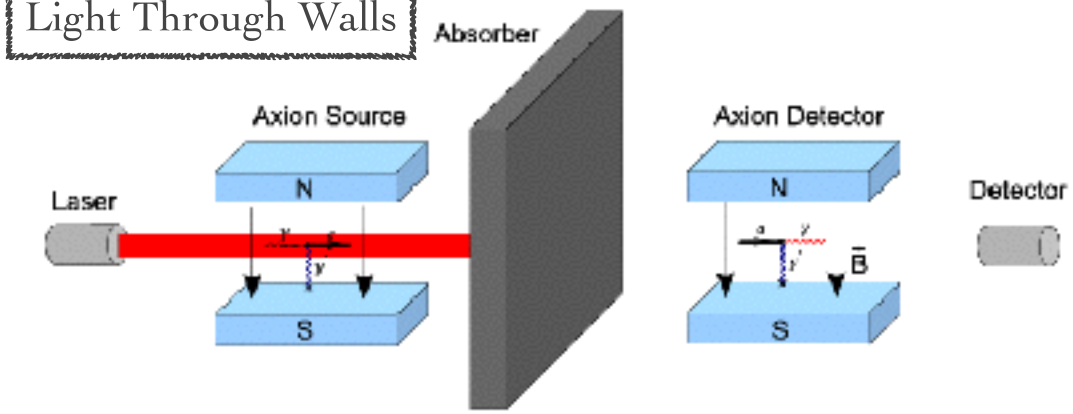


Scattered Experiments

Light Through Walls



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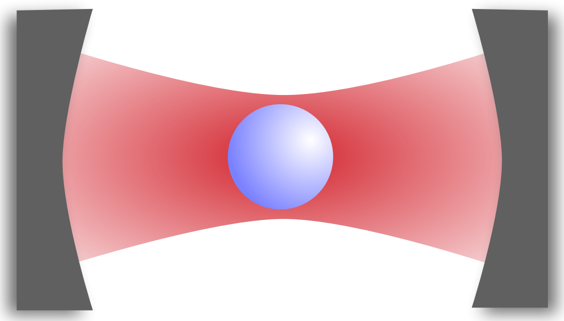
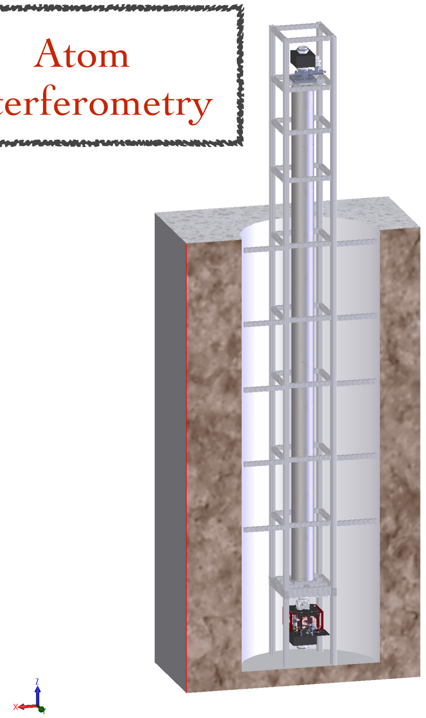


NMR

Atom Interferometry



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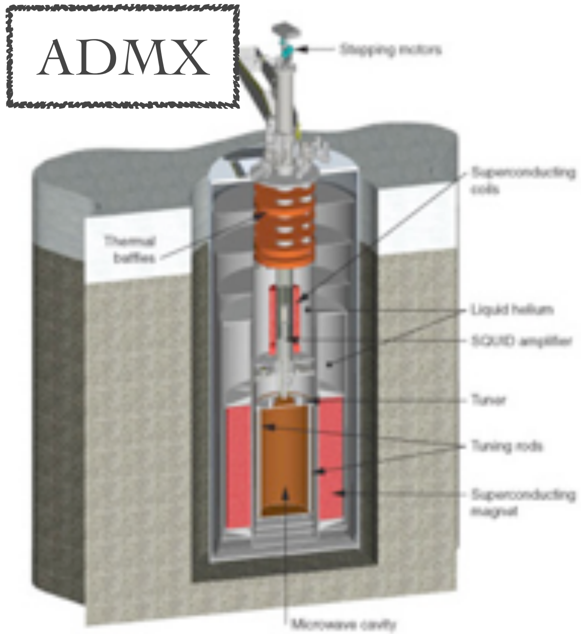

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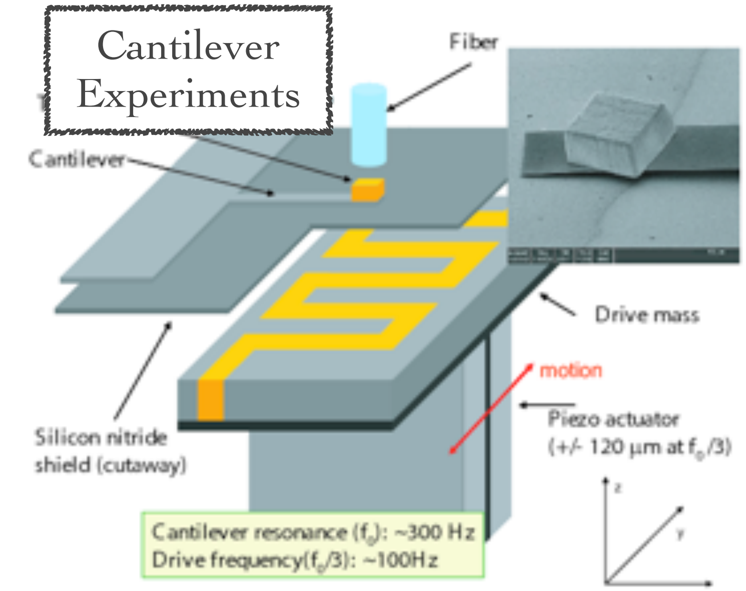

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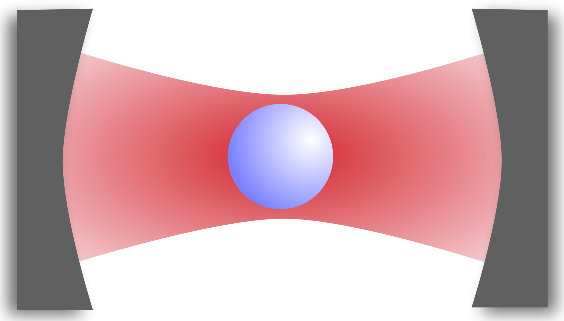

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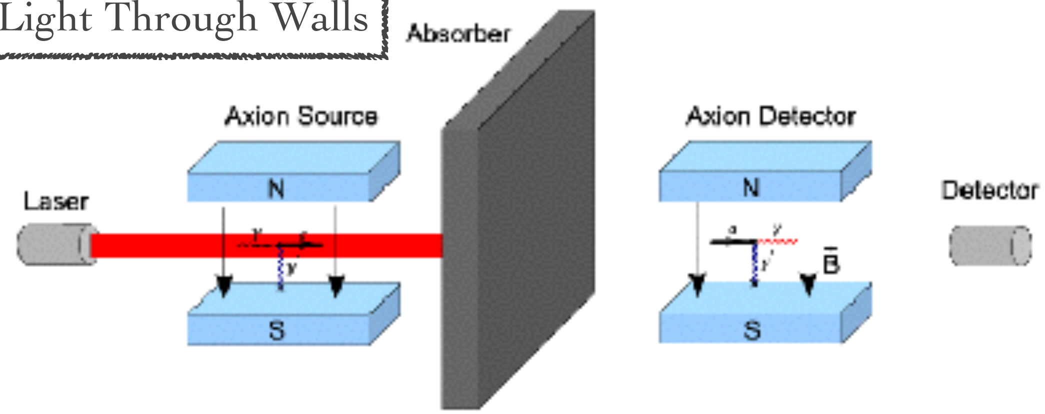

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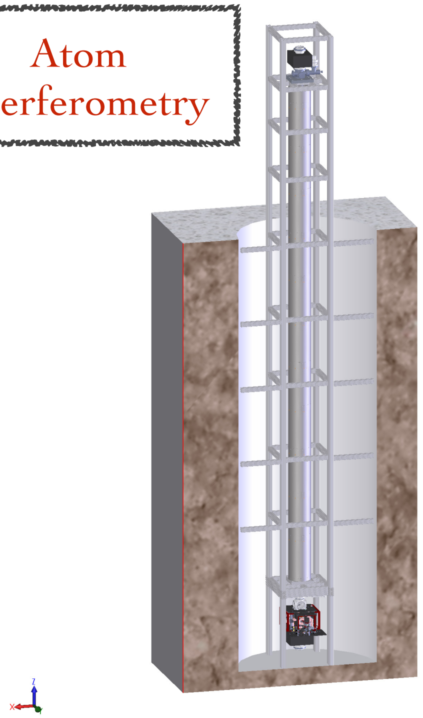

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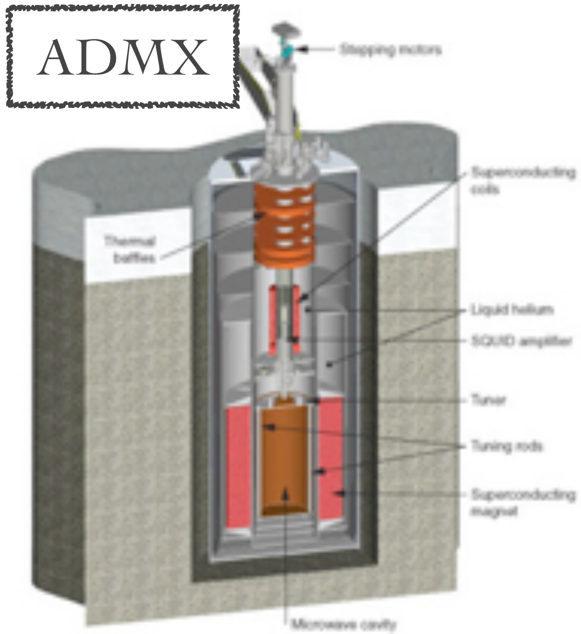

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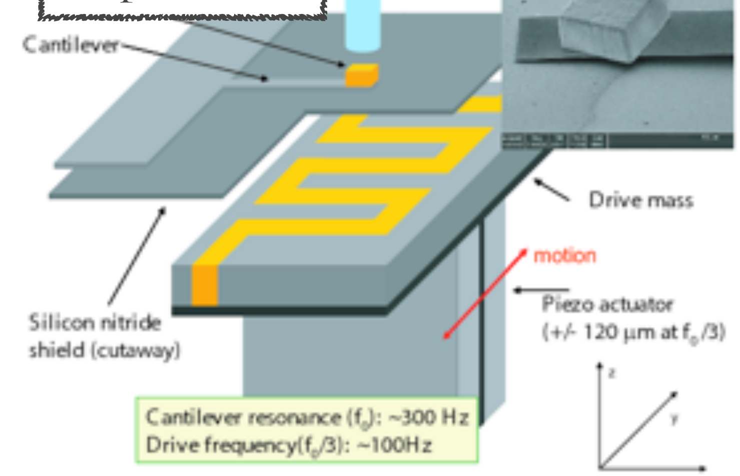


Scattered Experiments

Do They Need a Home?

Super-Lab for Fundamental Physics?

- Super-Lab: A Laboratory housing ≳ 20 small scale experiments on fundamental physics

- Fundamental Physics: New Forces, New Particles, New Dimensions, New phenomena…

- ANY Experimental Technique

- HEP Model of a Users Facility plus Local Personnel

Super-Lab for Fundamental Physics?

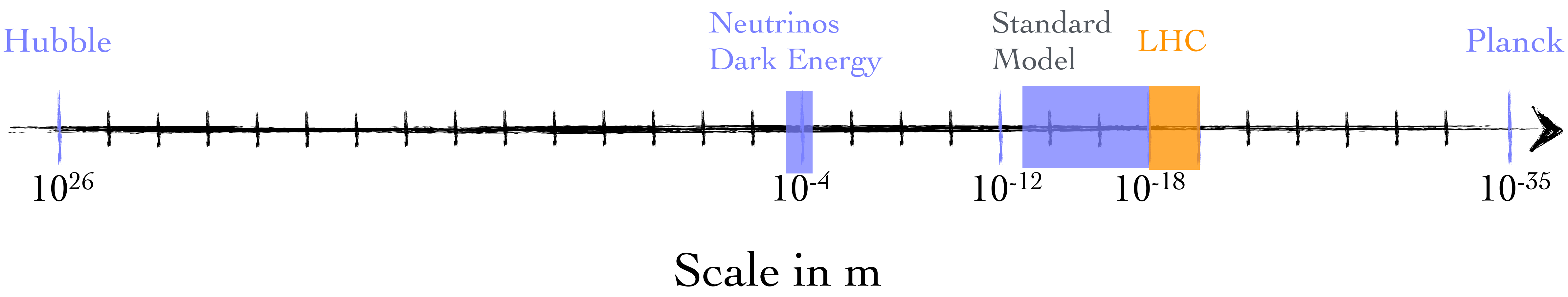
- Opportunity for Physics

  Ideas' Incubator
  Shared Lab Resources

- Sociological Opportunities

  Private funding can have big impact
  New vision for investing public resources

Length Scales in the Universe



There are more things in heaven and earth, Horatio,
Than are dreamt of in your philosophy.
- Hamlet