The Use of Dielectrics for Enhanced Axion-Photon Coupling in RF-Cavity Dark Matter Searches

Samantha Valenteen
University of Washington Physics REU Program

The Axion

Initial motivation: solution to Strong CP Problem.

Interacts gravitationally and electromagnetically (weakly).

Mass is not predicted by theory, but limits can be placed with observations.

Example

Axions carry energy from a star much more quickly than a photon.

Lifetime of star will be shortened .

Observed stellar ages give upper limit.

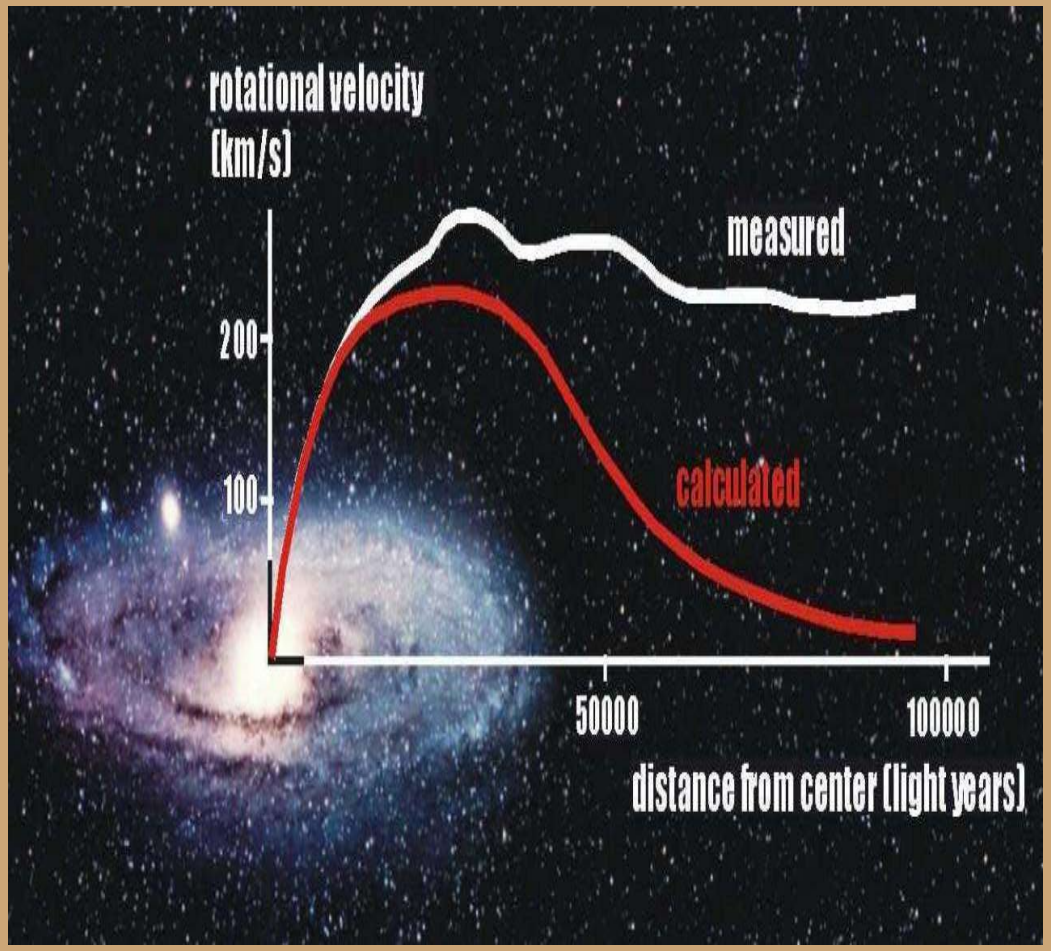
Colder star gives shorter neutrino burst.

Observed neutrino burst durations give more stringent upper limit.

Dark Matter

Axion existing within a certain mass range would be a candidate for dark matter.

$$Vo = \sqrt{\frac{GM}{r}}$$



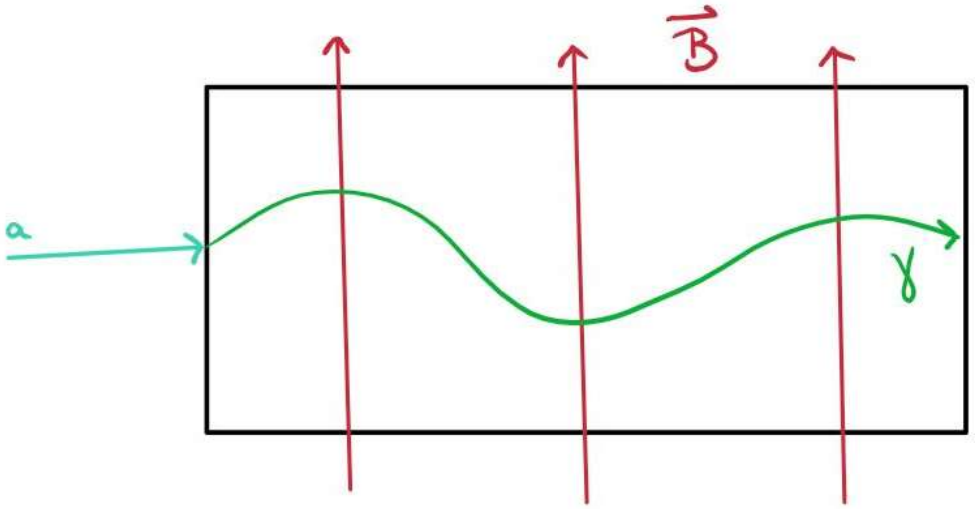
Axion Detection

Axions are difficult to see, photons are not.

Stimulate decay with virtual photon.

Axion Haloscope Idea

Cavity inside a strong magnetic field should measure excess power from converted photons.

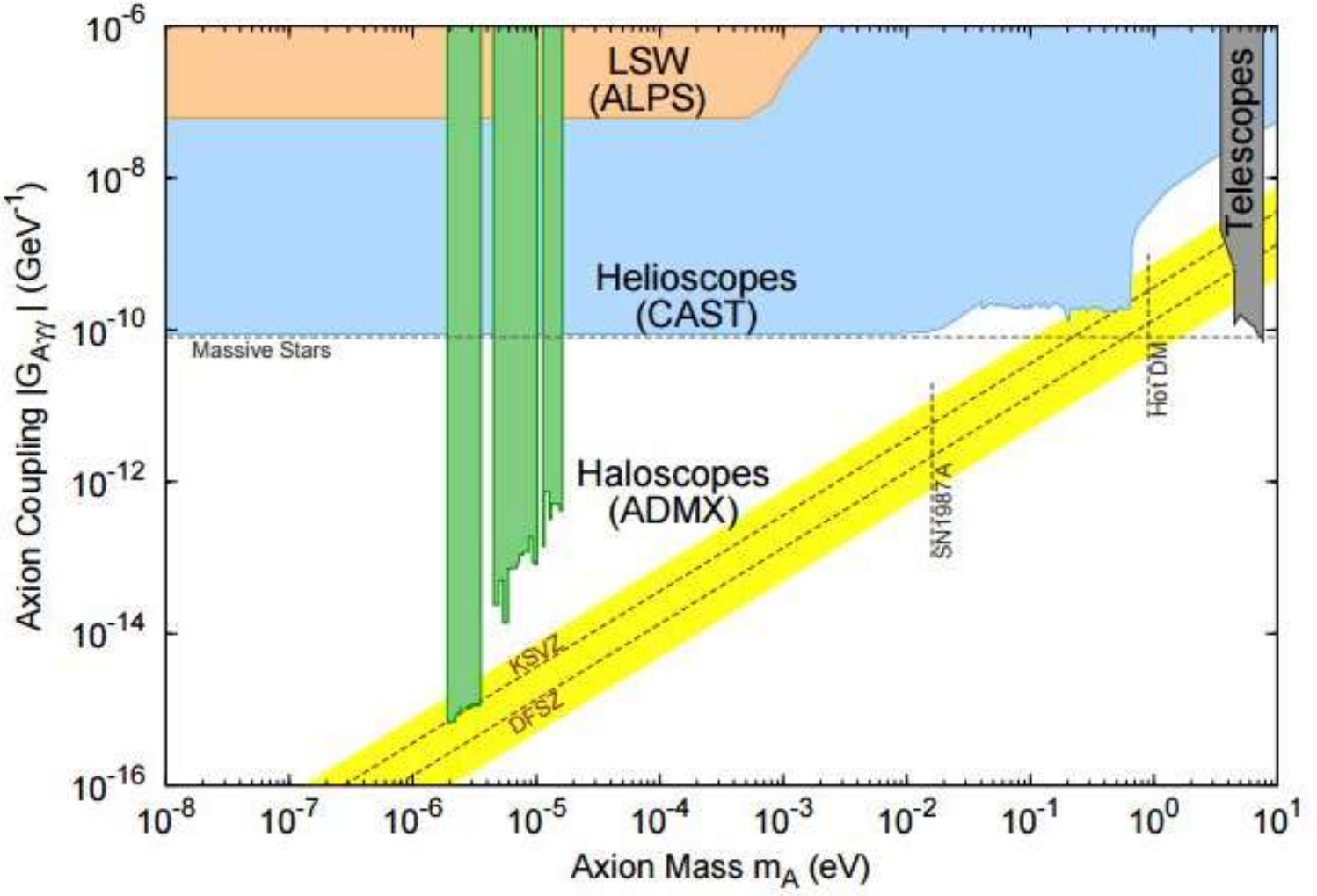


However, excess power will

be weak.

Set limits on

particle properties



Axion Haloscope Considerations

Resonant Frequency - Less power absorbed by cavity.

Axion Haloscope Considerations

Resonant Frequency - Less power absorbed by cavity.

Form Factor - How well axion couples to **B** field. $\propto \int \mathbf{E} \cdot \mathbf{B}$

Axion Haloscope Considerations

Resonant Frequency - Less power absorbed by cavity.

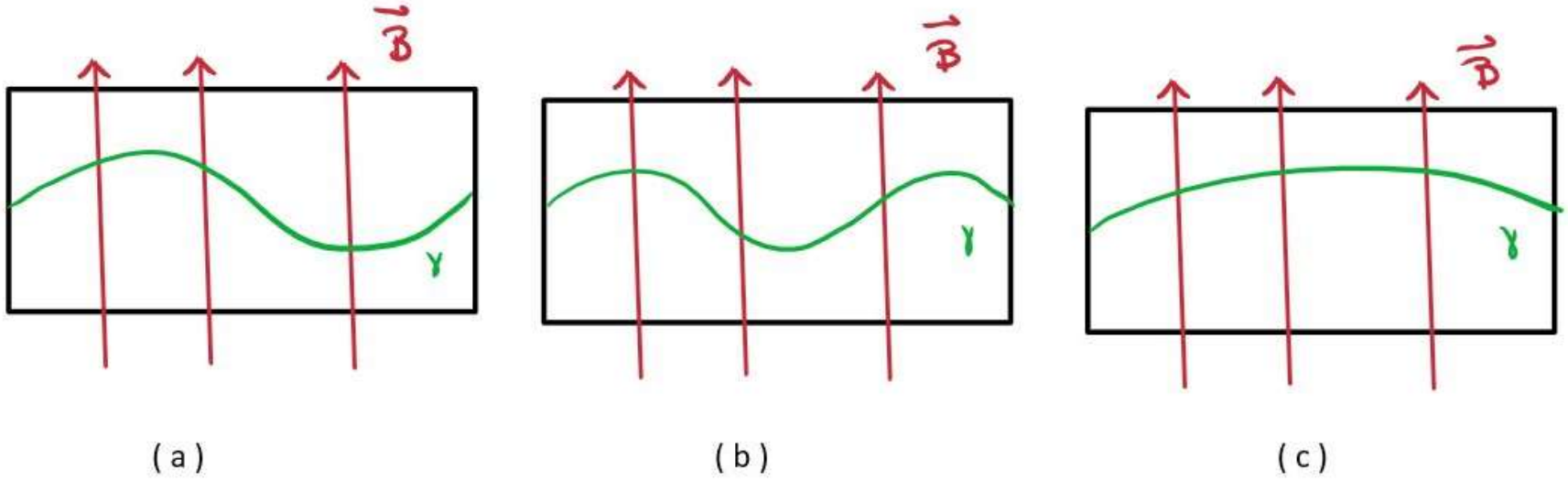
Form Factor - How well axion couples to **B** field. $\propto \int \mathbf{E} \cdot \mathbf{B}$

Volume - More axions can fit inside.

Previous Haloscope Designs

Limited to low frequencies to avoid choosing between

form factor ($\propto \int \mathbf{E}\cdot\mathbf{B}$) and volume.

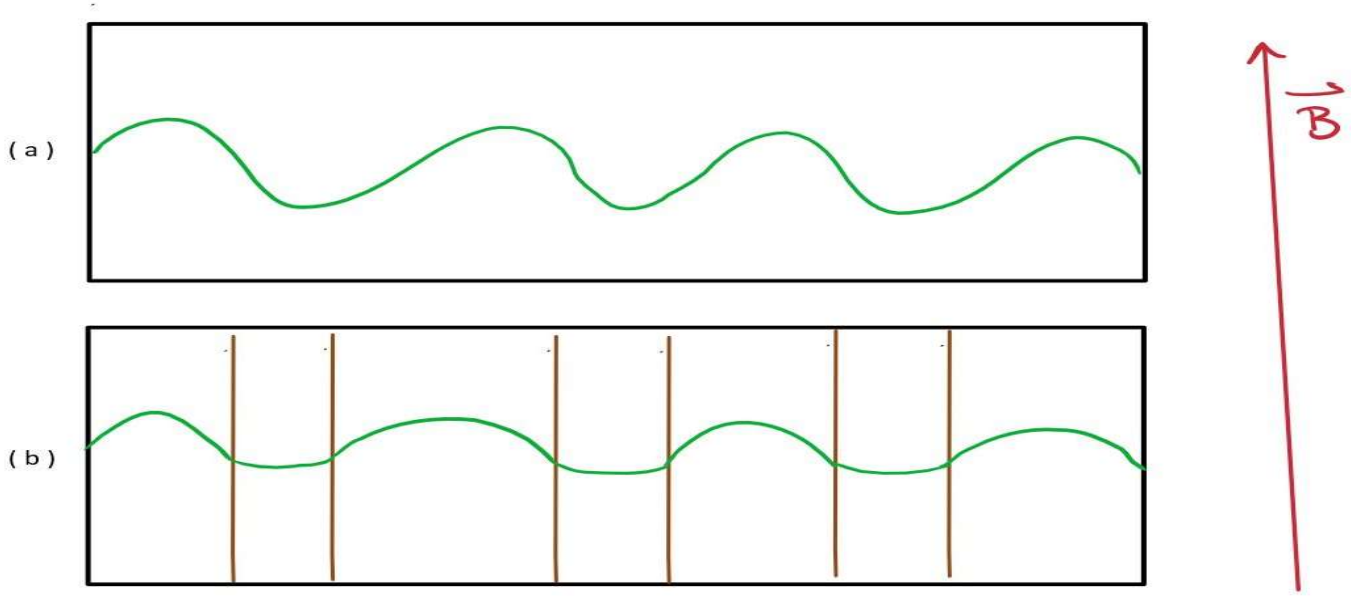


(a) (b) (c)

Use of Dielectrics

Allow for multi-wavelength waves while still maximizing form factor.

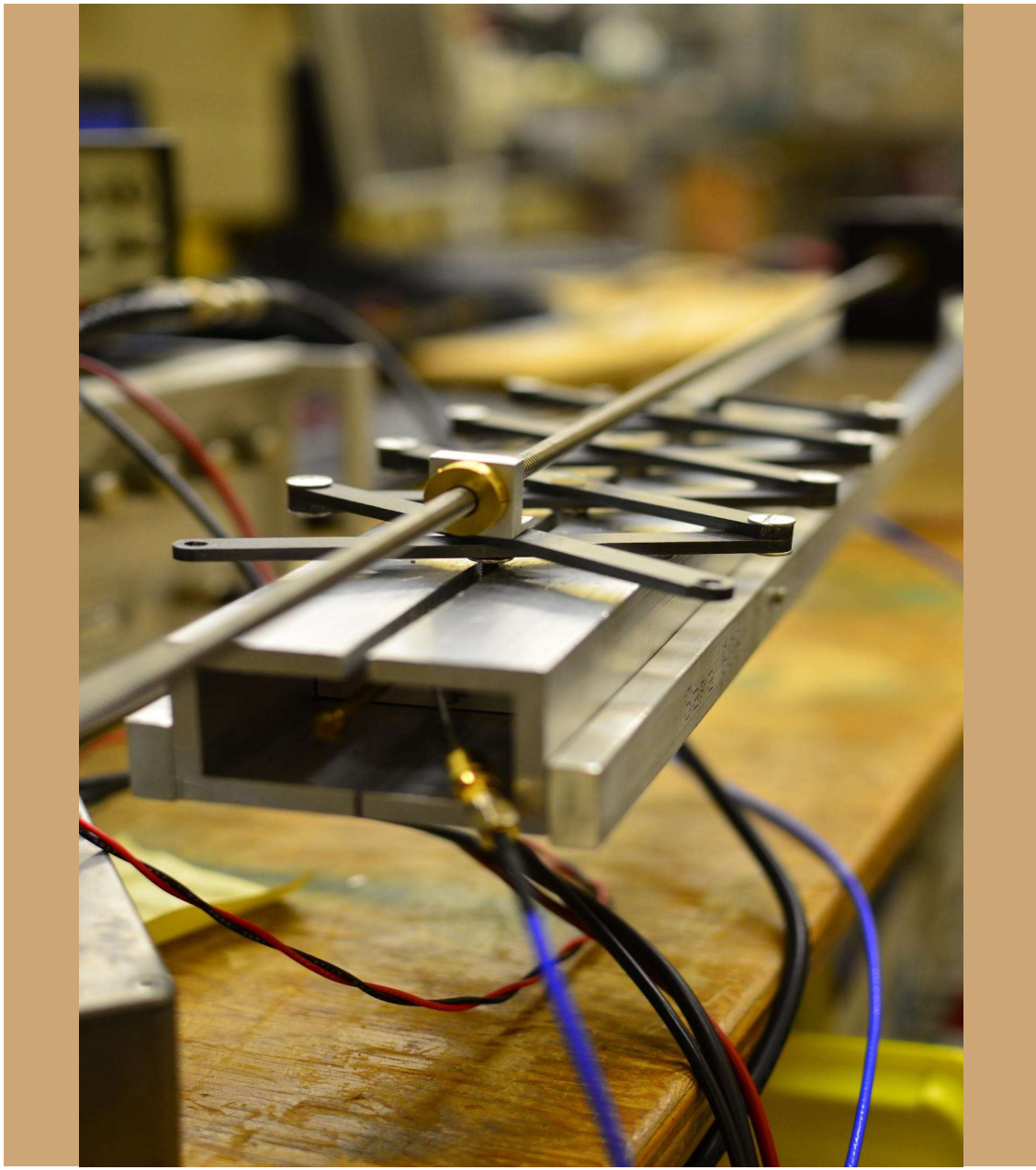
This allows higher-frequency axion searches without sacrificing volume.



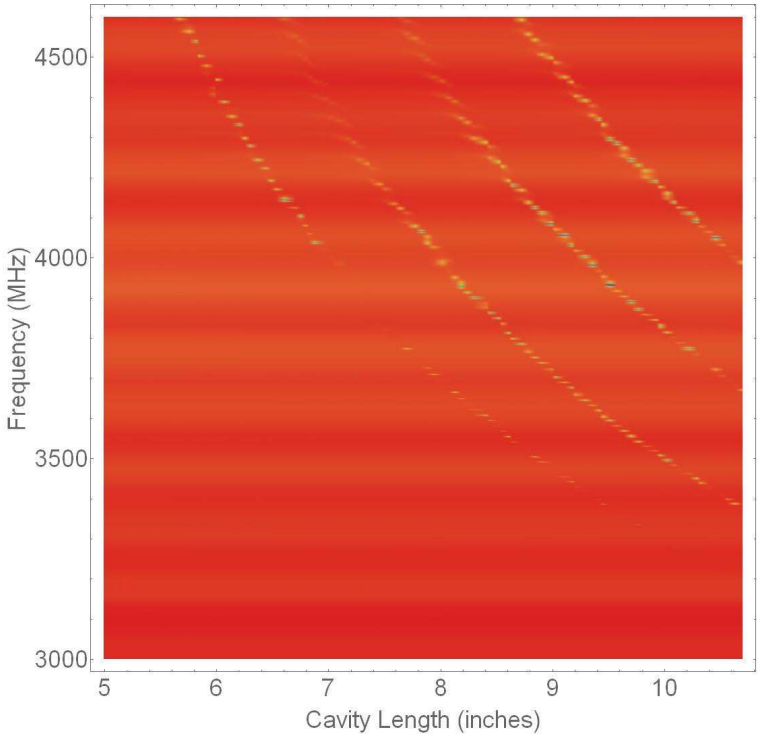
Electric Tiger

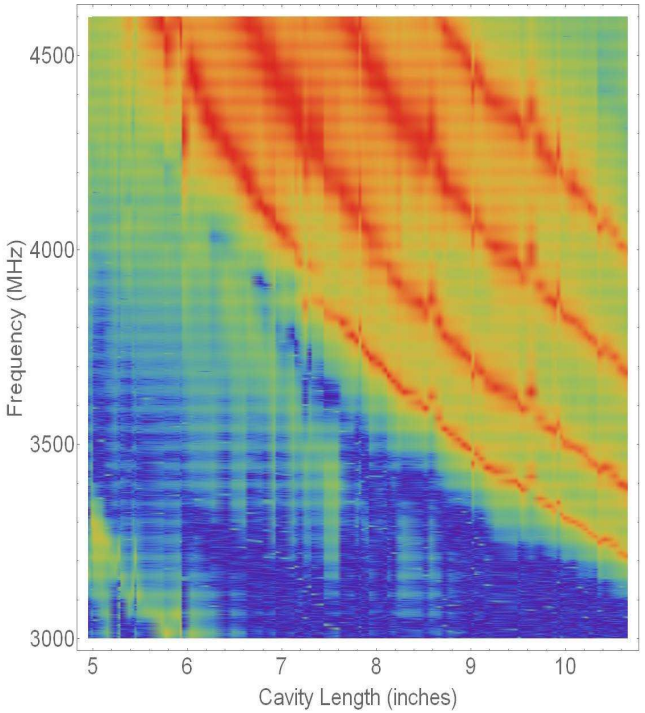
Expandable Cavity

Dielectric Blocks



Resonant Mode Tracking





Test

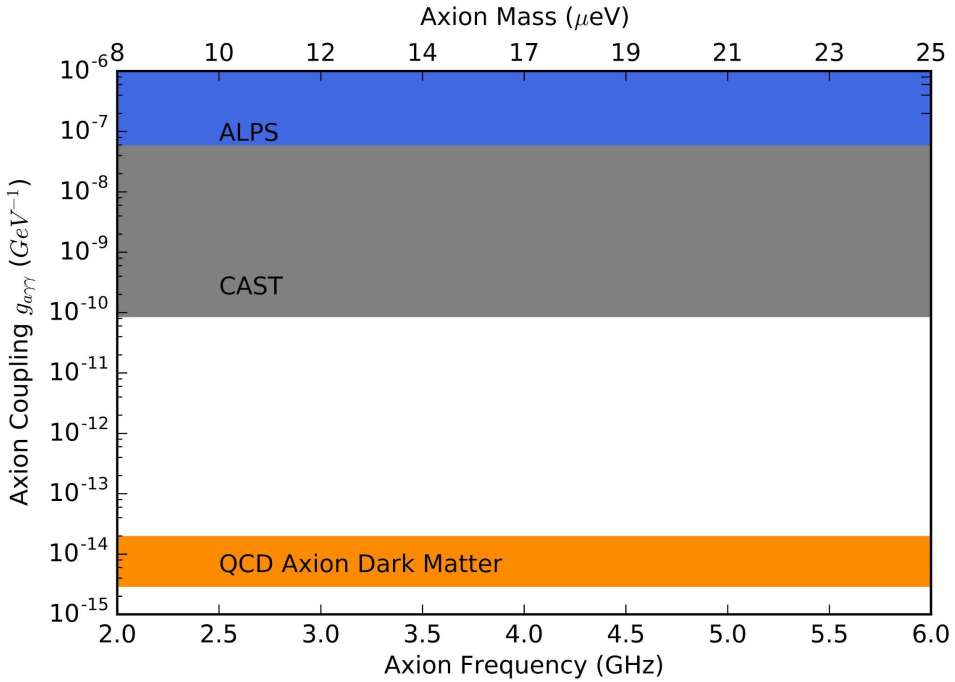
1.45 T field

4.1 - 4.3 GHz range

Expected Sensitivity

Compare to limits set

by ALPS and CAST.



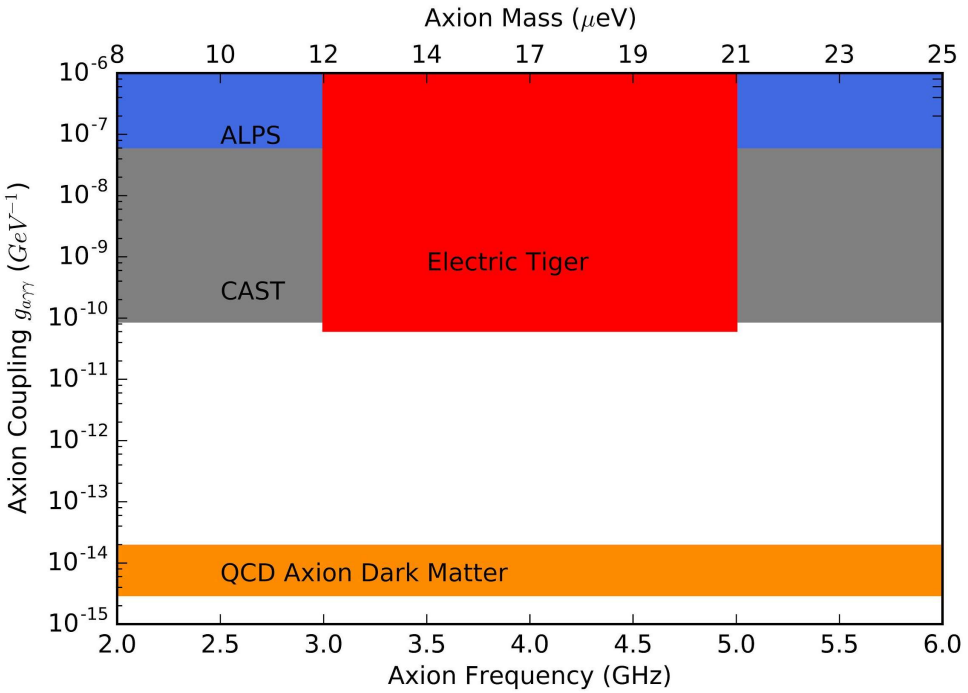
Expected Sensitivity

Compare to limits set

by ALPS and CAST.

Surpassed by room temperature,

low **B** field experiment!



Conclusion

Axion is a well motivated particle.

Use of dielectrics allows easy study of higher frequency ranges.

Electric Tiger design shows promise.

Small step towards finding dark matter.

Acknowledgements

This work was funded in part by:

The Department of Energy

Heising-Simons

The National Science Foundation

And built on work done by previous students:

Kunal Patel, Daniel Lindsay Garratt, Aryeh Brill, Benjamin Phillips, and James Sloan.


Questions?