Detecting Solar Relic Axions with ADMX

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8/20/2015
UW REU Presentation

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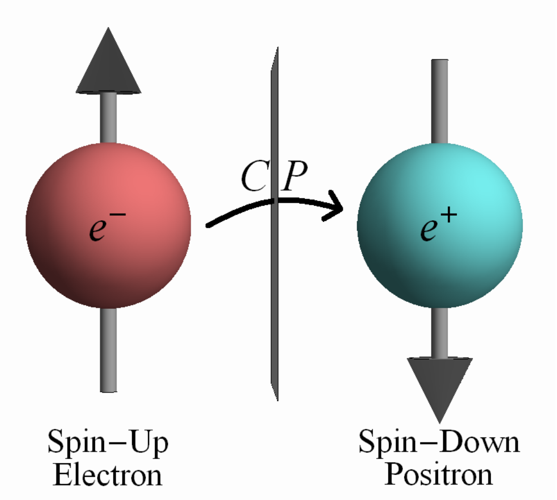
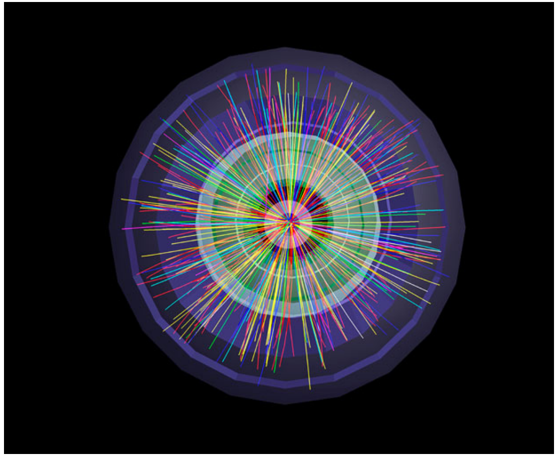
Strong CP Problem

- CP = Charge Conjugation and Parity
- Strong Force Conserves CP, Weak does not
- One explanation: Peccei-Quinn Mechanism



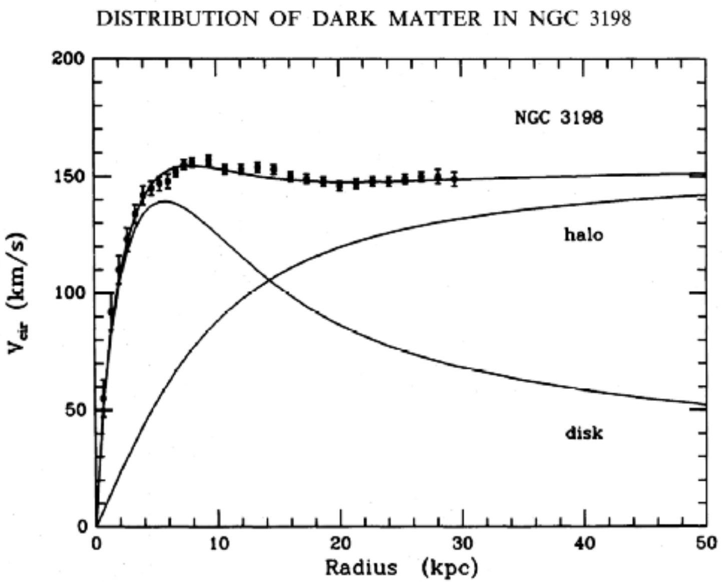
Axion's Emergence

- Consequence of Peccei Quinn Mechanism
- Neutral charged axion: original mass range of 10keV-1000keV
- Quickly dismissed because of observations



Dark Matter

- Gravitating matter not in the standard model
- Example: rotating galaxies
- Orbiting velocities of galaxies not in accordance with Kepler's Laws



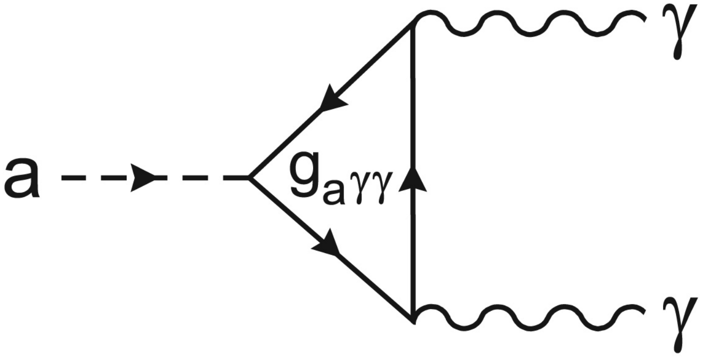
Properties of Dark Matter

- Primarily interacts Gravitationally
- Energy density at earth ~ 0.6 GeV/cm^3
- Candidates:
- WIMPS, SUSY, axions
- Others(Sterile neutrinos, primordial Black Holes)

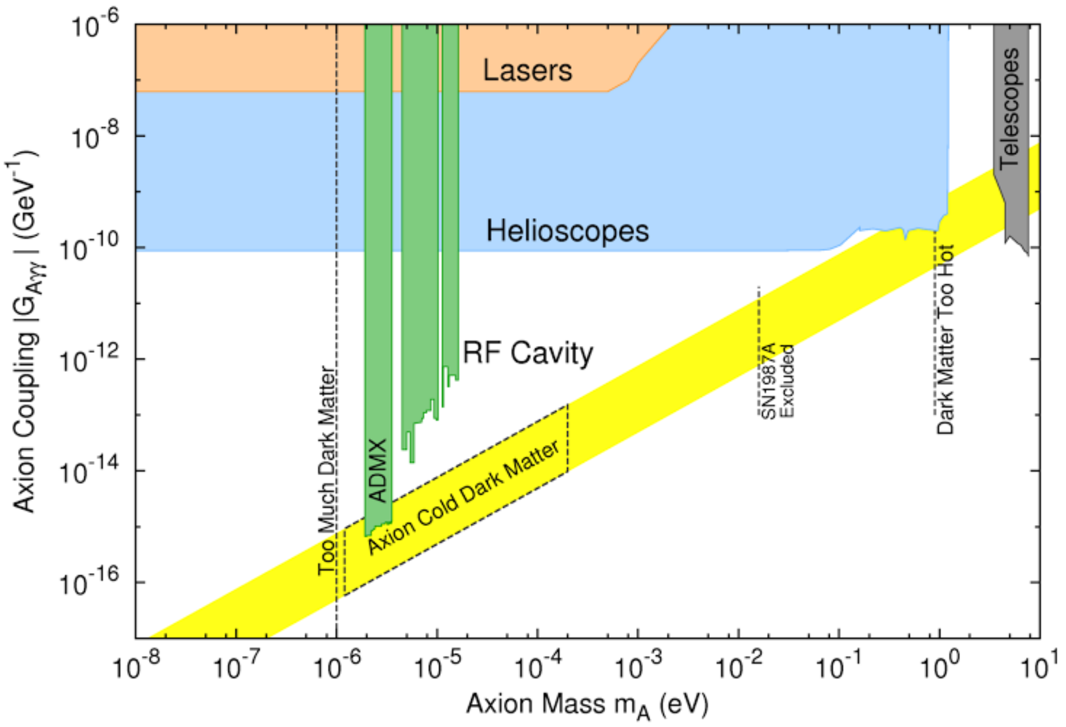
Composite: NASA, Markevitch etal., Clowe et al.

Sources of Axions

- Dark Matter from early universe
- Fluctuating electric and magnetic fields produce Axions
- Sun would be source of Axions



Coupling vs Axion Mass



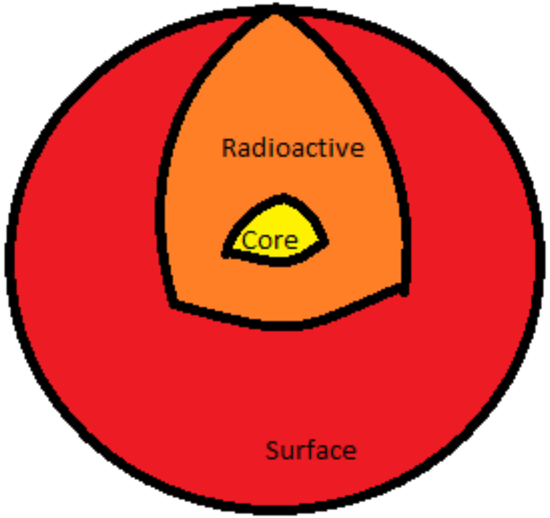
CAST Experiment

- Thermal photons can be converted to axions
- Primakoff Process

off electrons well

Studied

$$Ze^- + \gamma \rightarrow Ze^- + a$$



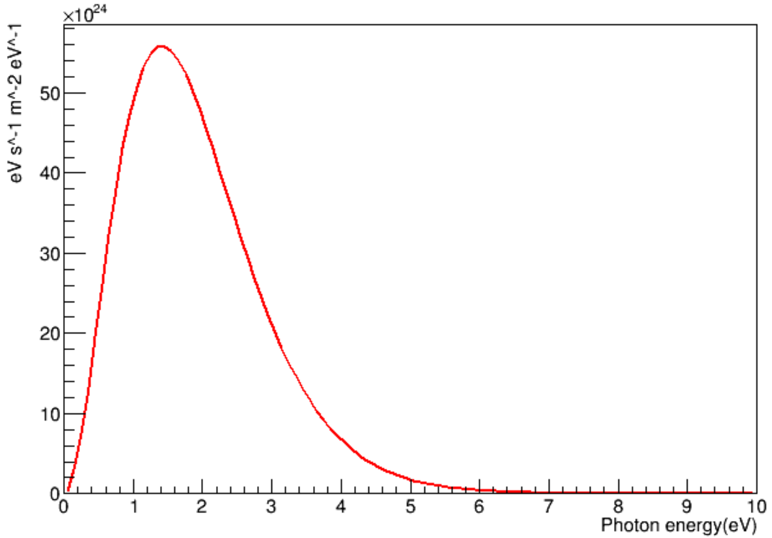
My Project

- Low energy axions created from the Sun
- Assume 1% of photons convert to axions
- What is the energy density of low energy axions at Earth?
- Can we use the CAST experiment calculation setup?

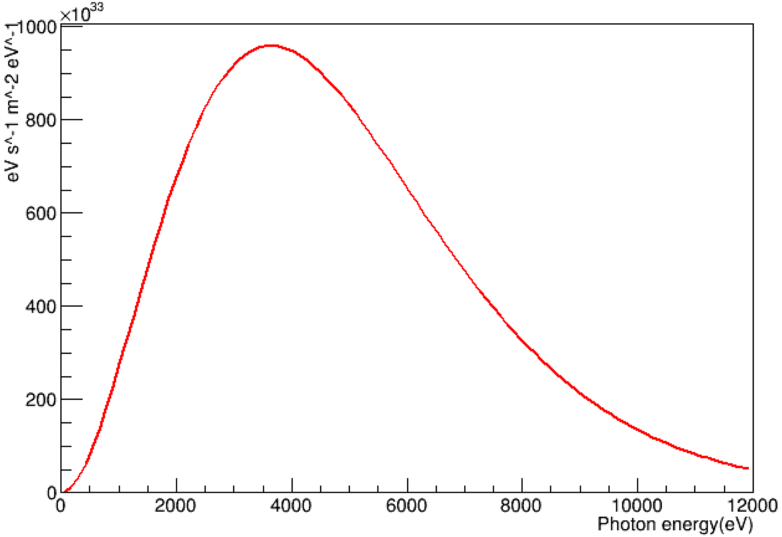
Spectral Radiance

$$B(E,T) = \frac{2}{h^3c^2}\frac{E^3}{e^{E/kT}-1}$$

Spectral Radiance of Low Energy Photons at the Surface of Sun

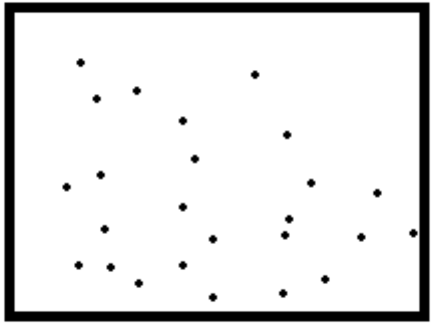


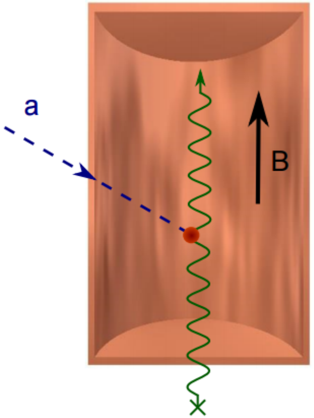
Spectral Radiance of High Energy Photons in the Sun

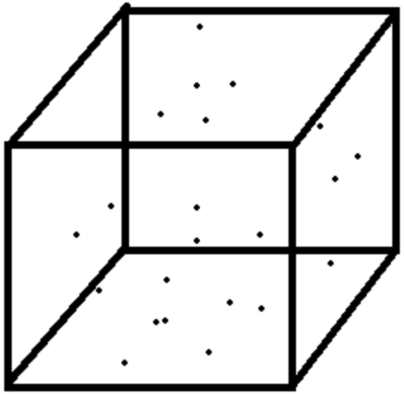


Low Energy Solar Axions

- Created at Solar Surface
- Axion Energy = Photon Energy
- Low energy axions gravitationally bound that build up in the Solar system over time-”Solar Relics”

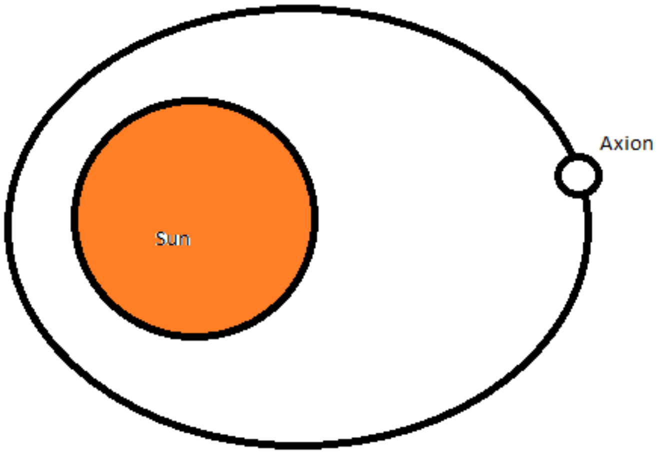




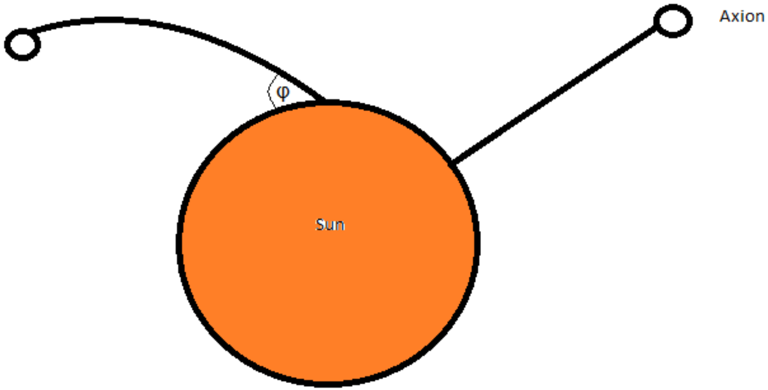


Distance Matters

Incorrect Axion Starting Position



Correct Axion Starting Position



- We will look perpendicular case

Axion Density Changes with Distance from Sun

- Lower energy axions do not go far out

$$\frac{d\Phi}{dr} = \frac{8\pi\eta kT}{h^3c^2}\left[m_ac^2 + GM_sm_a\left(\frac{1}{R_s} - \frac{1}{R_s + r}\right)\right]^2 \frac{GM_sm_a}{(R_s + r)^2}$$

- $R_s << r$ and Kinetic Energy $<< m_ac^2$

$$\frac{d\Phi}{dr} \approx \frac{8\pi\eta kT}{h^3c^2}(m_ac^2)^2\frac{GMm_a}{r^2} \qquad = \frac{8\pi\eta kTGMm_a^3c^2}{h^3r^2}$$

- Flux falls as we go further out

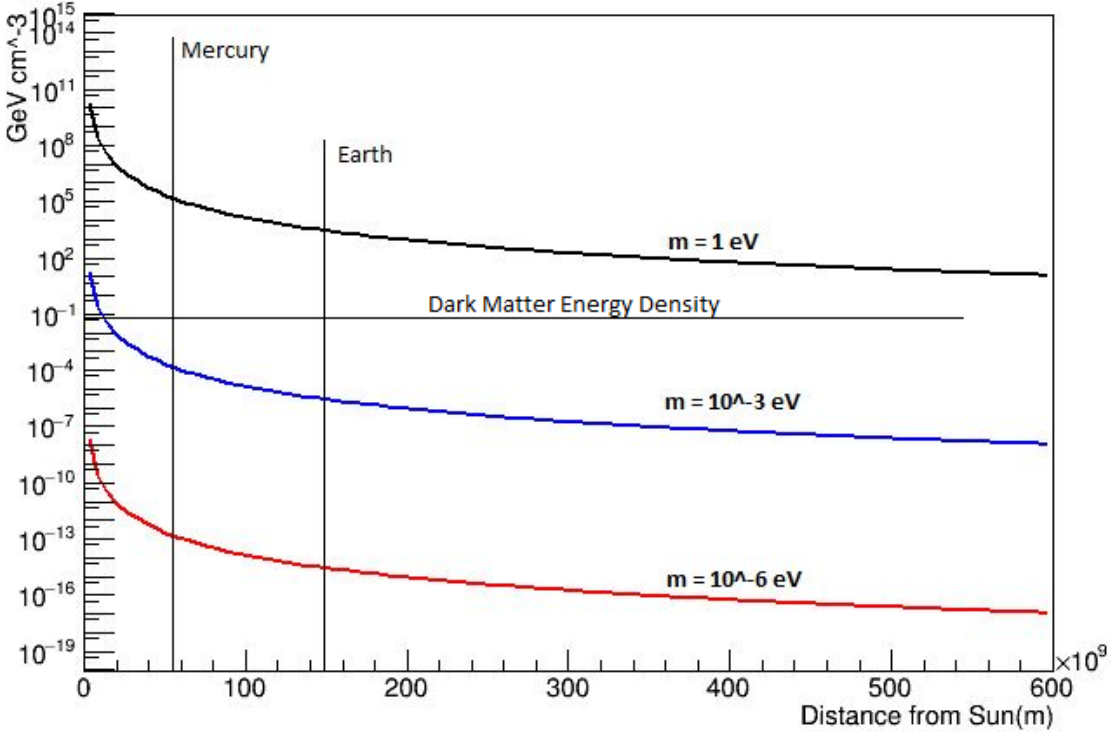
Energy Density Result

- Conservative Approximation: uniform energy density with maximum height
- Density falls off quickly with distance from the Sun

$$\rho_a = \frac{24\pi\eta kTGMR^2m_a^3c^2}{h^3}\int_{R_e}^{\infty}\frac{1}{r^5}\,dr = \frac{6\pi\eta kTGMR^2m_a^3c^2}{h^3}\frac{1}{R_e^4}$$

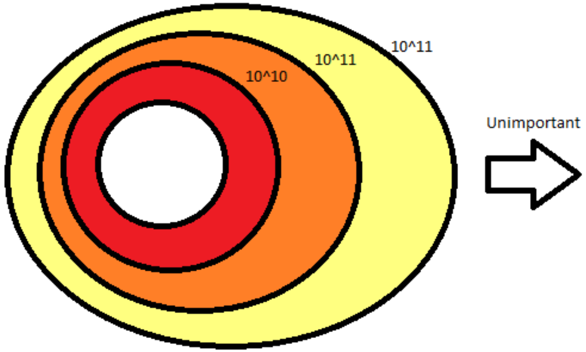
- Density increases with higher mass axions

Axion Energy Density vs Distance



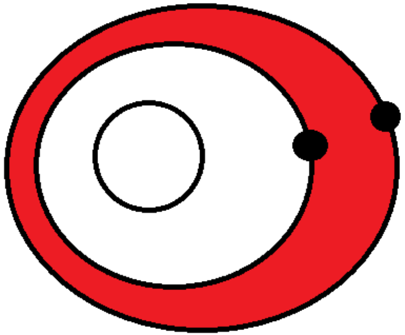
What does it All Mean?

- At current ADMX micro-eV target, solar relic axions are irrelevant
- However, above 40meV, solar relic axion energy density can exceed that of dark matter
- Keep in mind for future dark matter experiments
- Experiments closer to the Sun: impractical



Future Work

- Axions slow down as they reach their maximum solar radius
- This should increase our energy density
- Should make a unique detectable signal at ADMX



Conclusion

- Significant solar axion energy density for allowed axion masses
- More sensitive future dark matter experiments
- Current work is an underestimate of density, may become relevant with more detailed calculation

Useful Skills Learned

- Machine Shop
- Soldering Cables
- Autodesk inventor
- Learning to interpret results without the actual answer in the back of the book

Acknowledgement

- Gray Rybka
- Leslie Rosenberg
- Josh Povick
- ADMX Graduates and Undergraduates
- UW REU Staff
- NSF
- Ron from the machine shop

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