Axion Searches from Chandra Observation of Magnetic White Dwarf
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Abstract
White dwarfs (WD) may emit axions produced in their dense cores through electron bremsstrahlung. These axions may convert to x-rays under the presence of strong magnetic fields surrounding the star. We use 40 ks observation from the Chandra X-ray Observatory of the magnetic white dwarf (MWD) ZTF J1901+1458 to potentially set the strongest constraints to date on the combination of the axion-electron coupling times the axion-photon coupling $|\alpha_{\text{ae}}\gamma_{\text{eff}}| \lesssim 3 \times 10^{-28} \text{GeV}^{-1}$. Our results severely constrain axions arising from string theory models as well as astronomical anomalies such as anomalous stellar cooling.

Introduction
The composition of dark matter has posed an important issue in cosmology. One strong dark matter candidate, the axion, was first proposed to resolve the strong CP problem of QCD. It is well known that axions may convert to photons in the presence of strong magnetic fields. In this project, we seek to unveil the first evidence for axions or place new limits in unexplored axion parameter space by observing X-ray emissions from the white dwarf ZTF J1901+1458.

Astrophysical Modeling
• All parameters needed to predict the axion luminosity are directly measurable except for the core temperature, radius, and the mass.
• We combine photometric observations of the MWD with simulations and modeling of the MWD interior structure in order to constrain the relevant MWD parameters [3].

Predicted Photon Flux
• The axion emissivity, shown below, is found through a matrix element calculation [2].

$$\frac{dF_e}{d\omega} = \frac{a^2 m_e g_{\text{ae}}}{4\pi m^2_e e^{\omega/\gamma_\text{eff}}} \sum_i \frac{Z_i^2 \rho_i F_i}{A_i}$$

• The total X-ray flux is determined by convolving the axion luminosity with the conversion probability.

$$\frac{dF_e}{d\omega} = \frac{dL_x}{d\omega} \times \rho_{\text{an}} \times \frac{1}{4\pi m^2_e}$$

• Our modeling predicts a peak X-ray flux of 3.48 erg cm$^{-2}$ s$^{-1}$ for $m_a \ll 10^{-9}$ eV and $|\alpha_{\text{ae}}\gamma_{\text{eff}}| = 10^{-28}$ GeV. The X-ray spectrum peaks at roughly $7$ keV.

Results
We observed the MWD ZTF J1901+1458 on 12/9/2022 and 12/10/2022 with the ACIS-I instrument with no grating for a total of 40ks (PI Safdi, observation ID 27597).

• 10 counts are observed in the 1-3 keV range. The data is analyzed using a Poisson likelihood function
• The observed spectrum is inconsistent with the predicted spectrum.
• The best fit coupling combination is $|\alpha_{\text{ae}}\gamma_{\text{eff}}| = 3.1 \times 10^{-28} \text{GeV}^{-1}$

References