The dark matter interpretation of the 3.5-keV line is inconsistent with blank-sky observations

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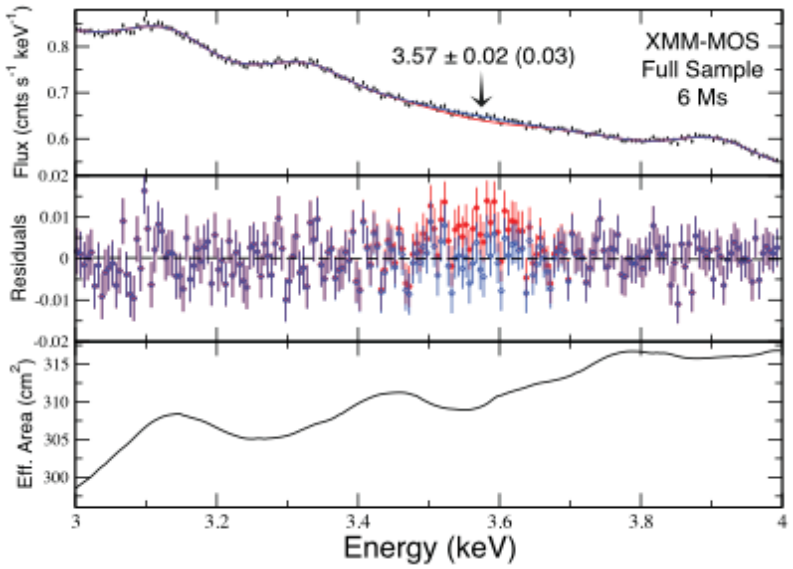
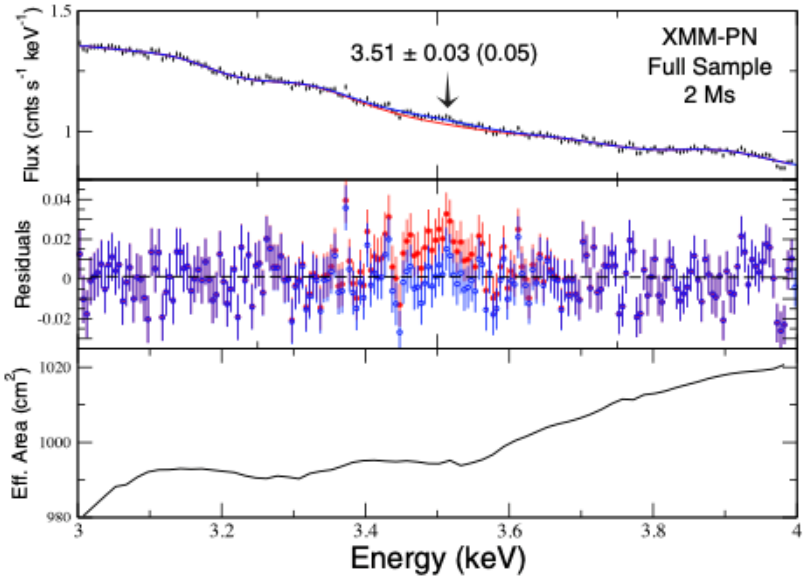
Background

An unidentified 3.5 keV line was found in Galaxy Clusters.

- 73 galaxy clusters of redshift in [0.01, 0.35]
- Seen in both MOS and PN detector of XMM-Newton
- Seen by Chandra independently



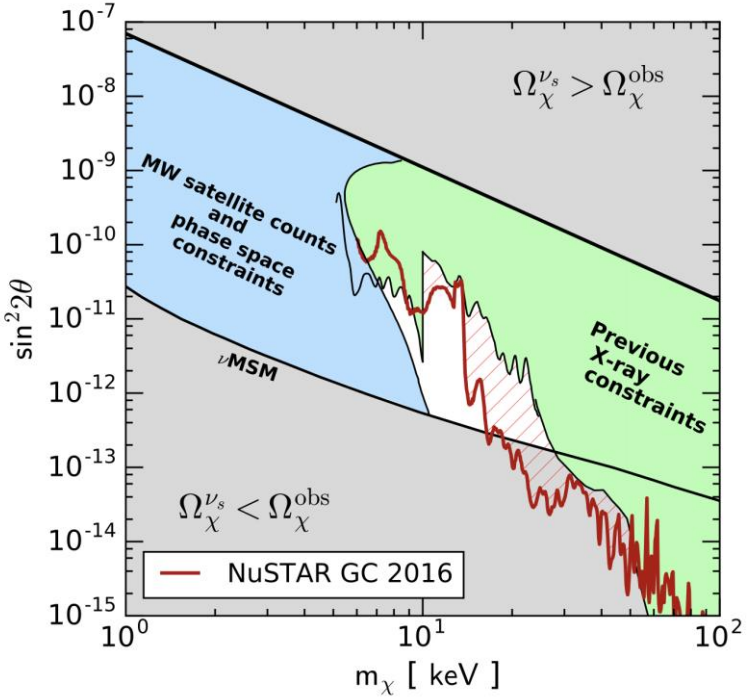


Bulbul et al. 2014

Background

Sterile neutrino is an compelling dark matter candidate.

- All fermions are with both chirality, except for the neutrinos.
- Non-zero mass and no electromagnetic charge



Perez et al. 2017

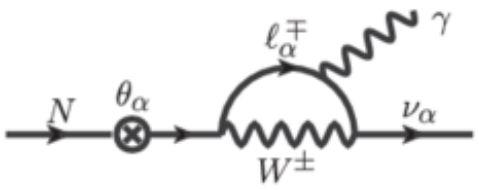
If ν_α and ν_β mix with angle θ

$$P_{\alpha\to\beta} \propto \sin^2 2\theta$$

Background

The 3.5 keV emission may come from sterile neutrino.

- The decay of keV sterile neutrino emits X-ray photons.

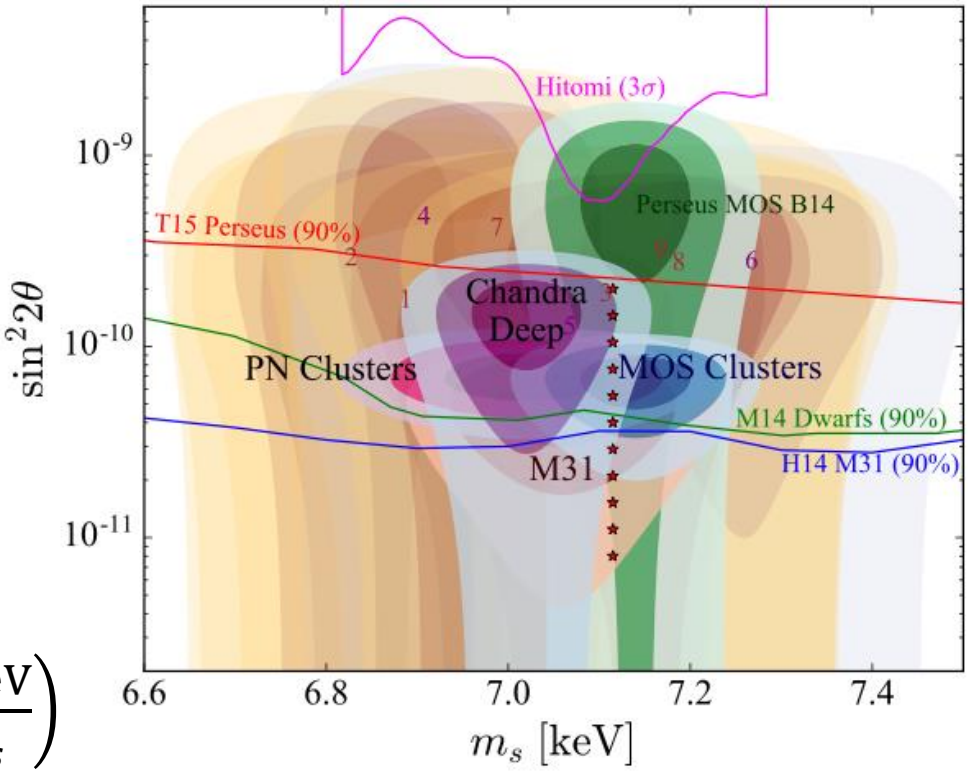


$$\nu_s \rightarrow \nu_\alpha + \gamma$$

$$E_\gamma \sim 1/2 M_{\nu_s}$$

- Decay leads to a finite ν_s lifetime.

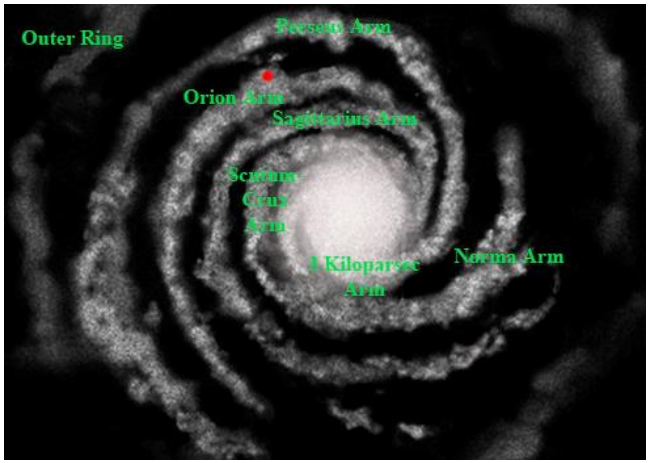
$$\tau = 4.37 \times 10^{38}\ \mathrm{s} \left(\frac{10^{-11}}{\sin^2 2\theta}\right) \left(\frac{7\ \mathrm{keV}}{m_s}\right)$$



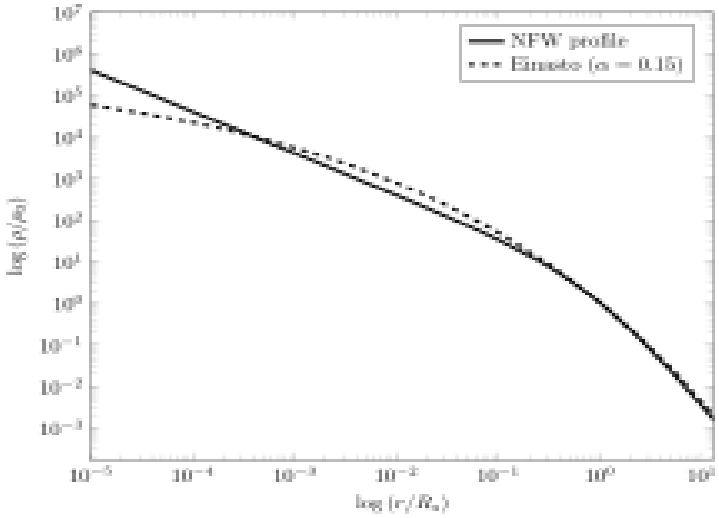
Abazajian et al. 2017

Strategy

- Traditional Strategy: focused on high DM flux area



- New Strategy: blank-sky observation



Example

Compare the sensitivity between Perseus and blank sky observation.

- Testing Statistics

$$TS \sim S^2/B \sim \frac{\Phi_S^2}{\Phi_B} t$$

- DM column density

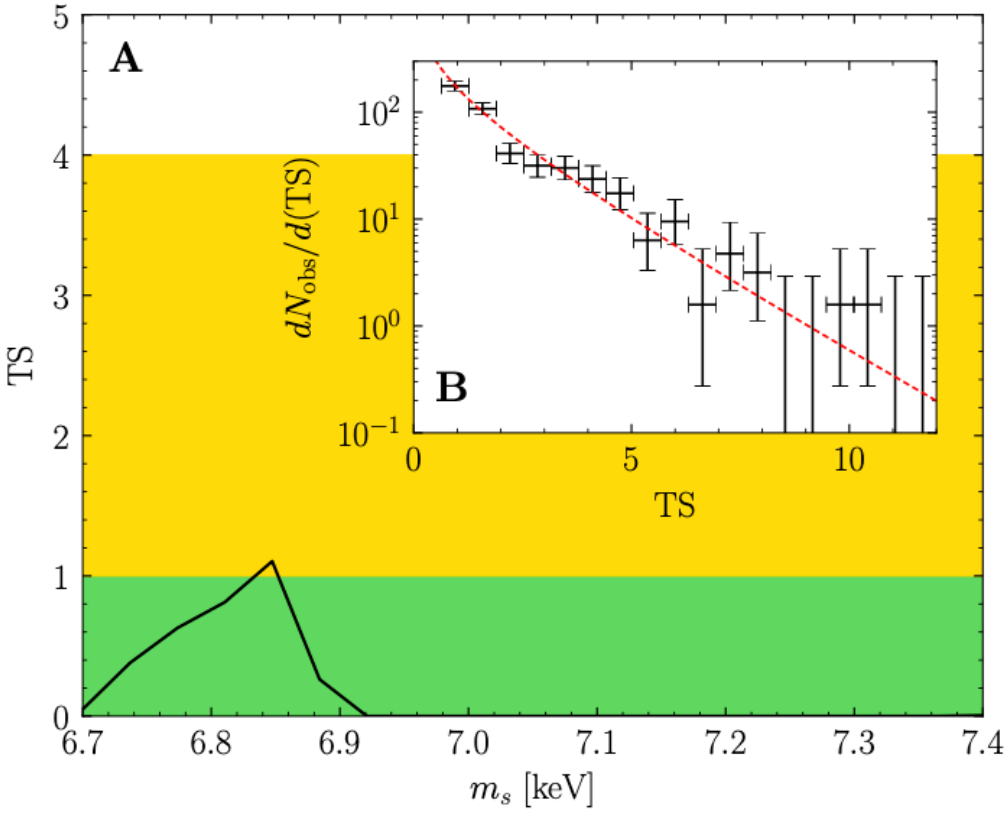
$$D = \int \rho(s) ds$$

$$D_{\mathrm{Pers}} \sim D_{\mathrm{MW}}(45°)$$

- Sensitivity comparison

320ks Perseus $\sim 4\sigma$

30.6Ms BSO $> 100\sigma$



Analysis and Results

- Sample Selection

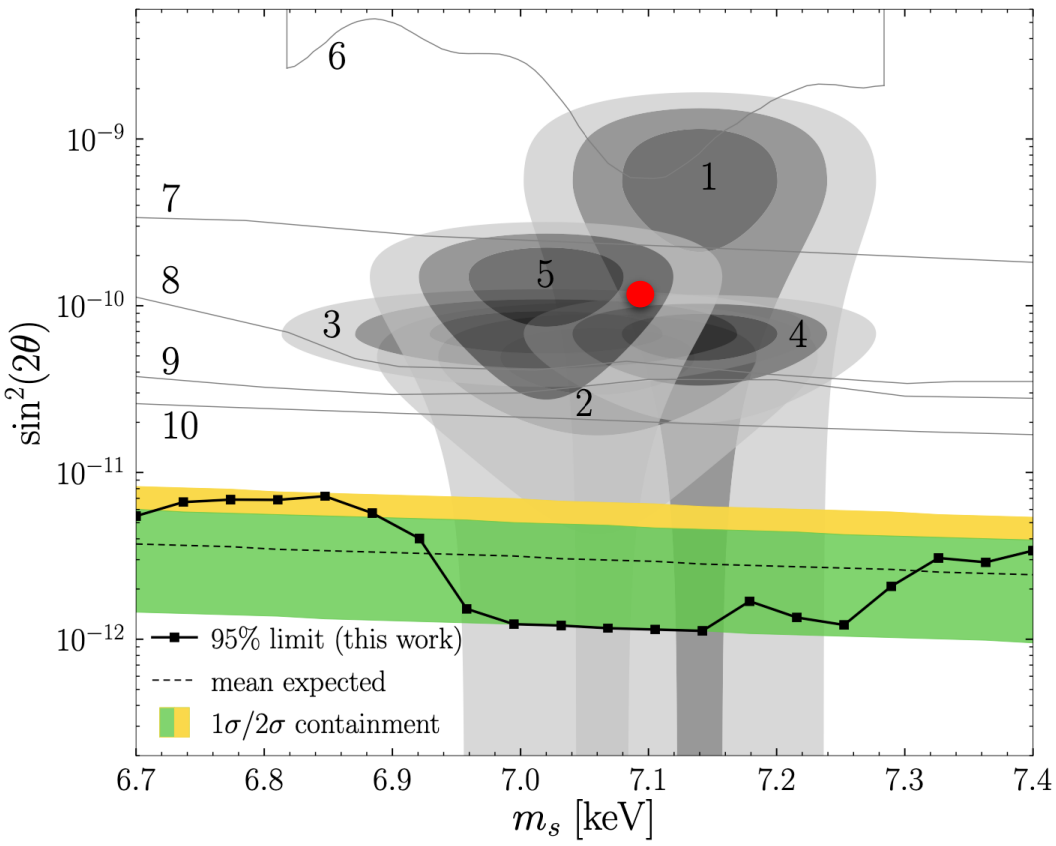
- Profile likelihoods for individual exposure

a) DM-induced flux

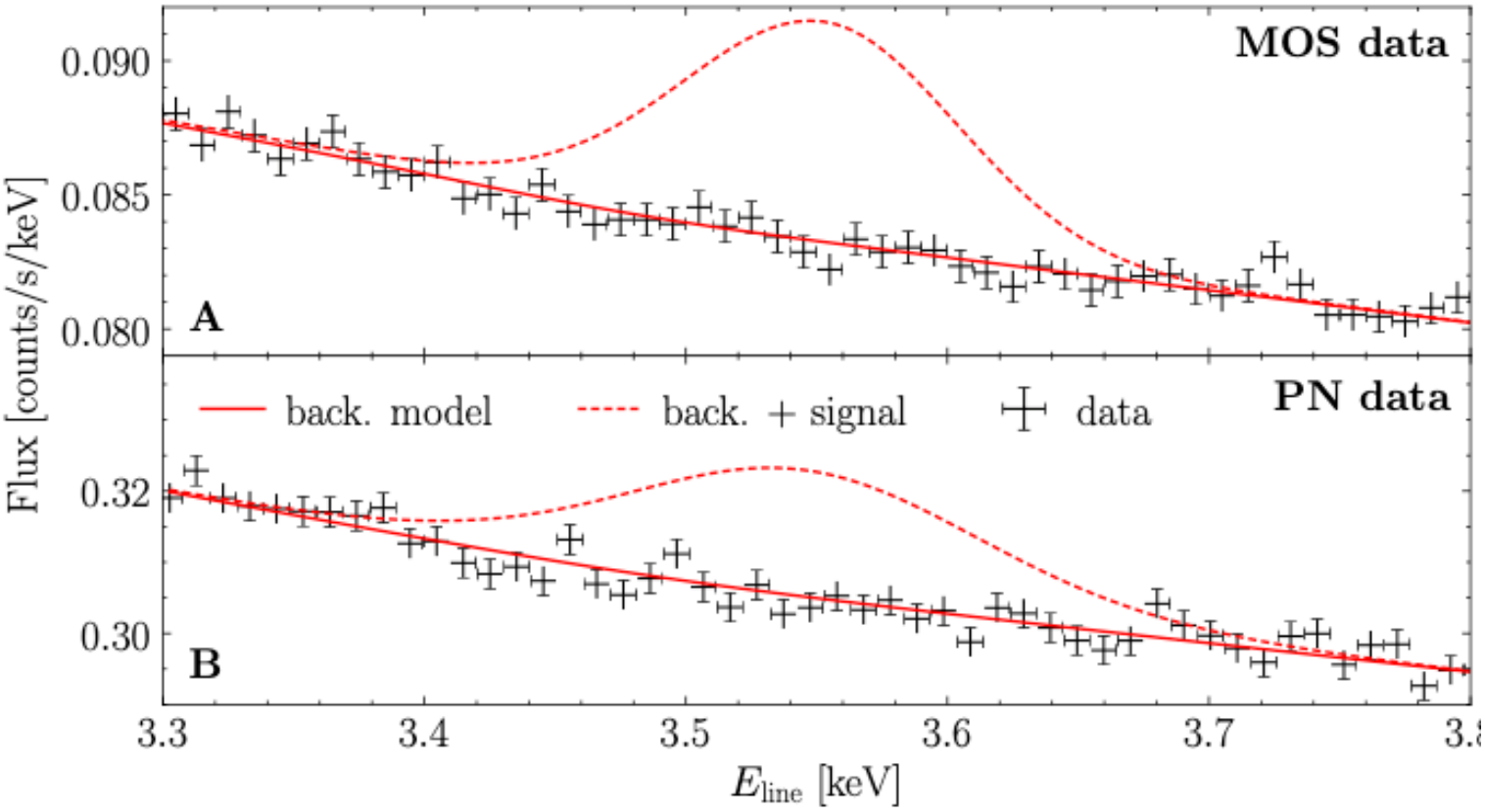
b) Background emission

c) Quiescent particle background

- Final joint likelihood for $\sin^2 2\theta$



Intuitive Illustration



Comparison between the summed background model and the model with DM flux

Summary for this paper

- They propose a new strategy, blank sky observation, to test the DM flux. Thus the existing XMM-Newton data is exploited to reach a better sensitivity.

- Assuming a NFW density profile and a powerlaw background emission, they construct a joint likelihood for $\sin^2 2\theta$ and m_s.

- After analyzing 30.6Ms BSO data, they gain a new limit for sterile neutrino, which rules out the decaying DM interpretation of 3.5 keV line.

Comment From Kevork N. Abazajian

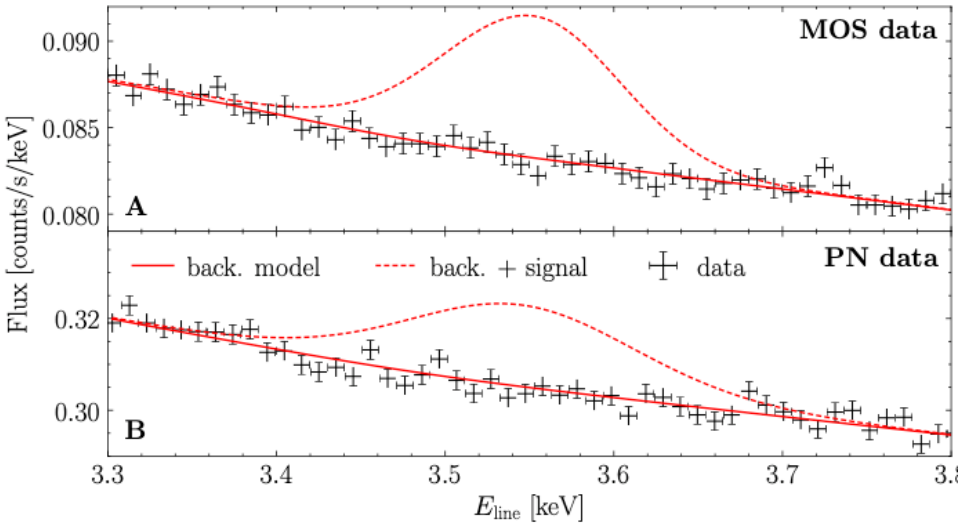
- Dark matter density normalization and profile

	DRS	Comment
DM density normalization	$0.4\ \mathrm{GeV/cm^3}$	a large range like $0.28 \pm 0.08\ \mathrm{GeV/cm^3}$
DM density profile	NFW density profile	cored density profile

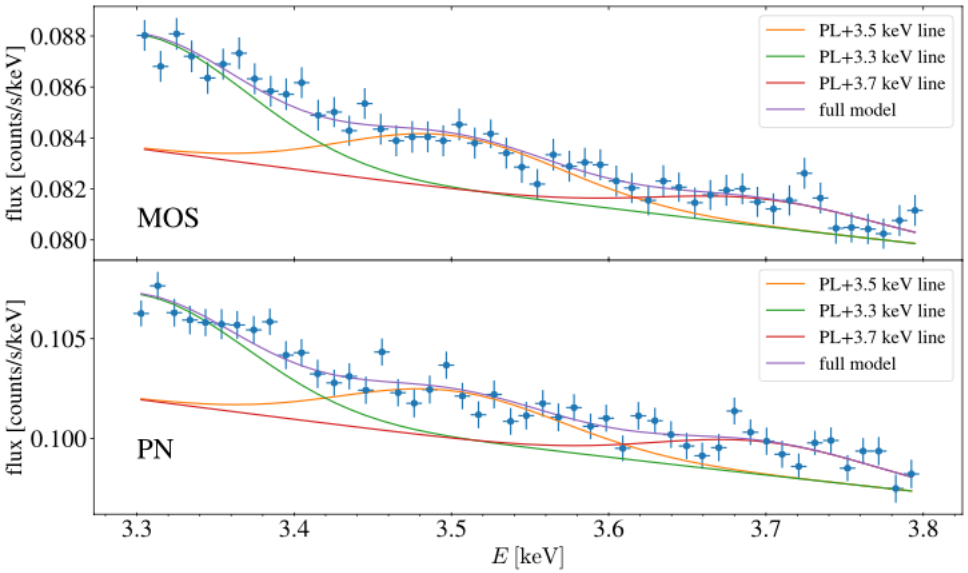
- Other X-ray Lines within the Energy Range

	DRS	Comment
Energy range of analyzation	3.3~3.8 keV	A broader energy range will give better constraint
X-ray background emission	Powerlaw Background	Including 3.3 and 3.7 keV lines

Comment From Kevork N. Abazajian

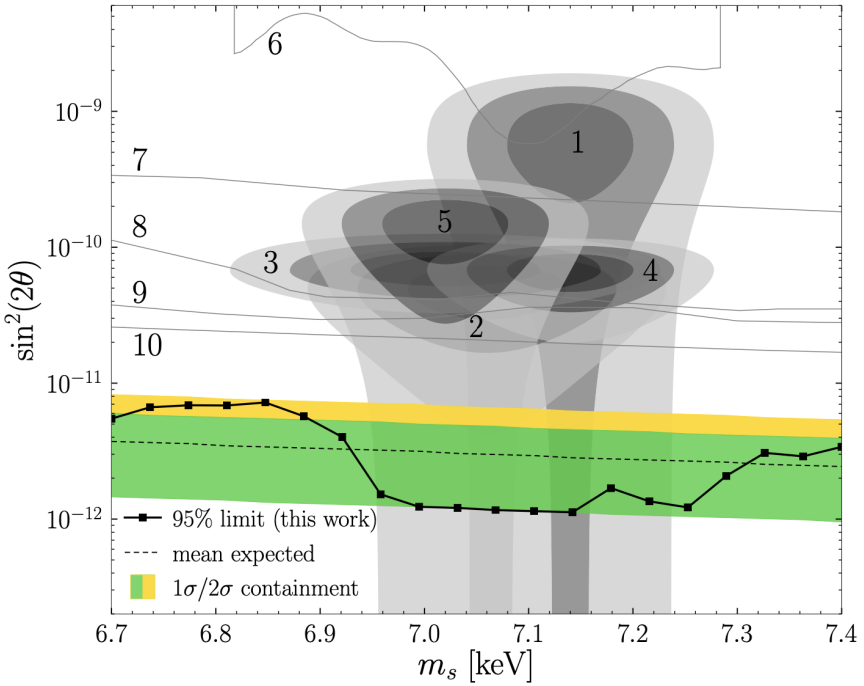


The refitted X-ray flux adding the 3.3 and 3.7 keV lines



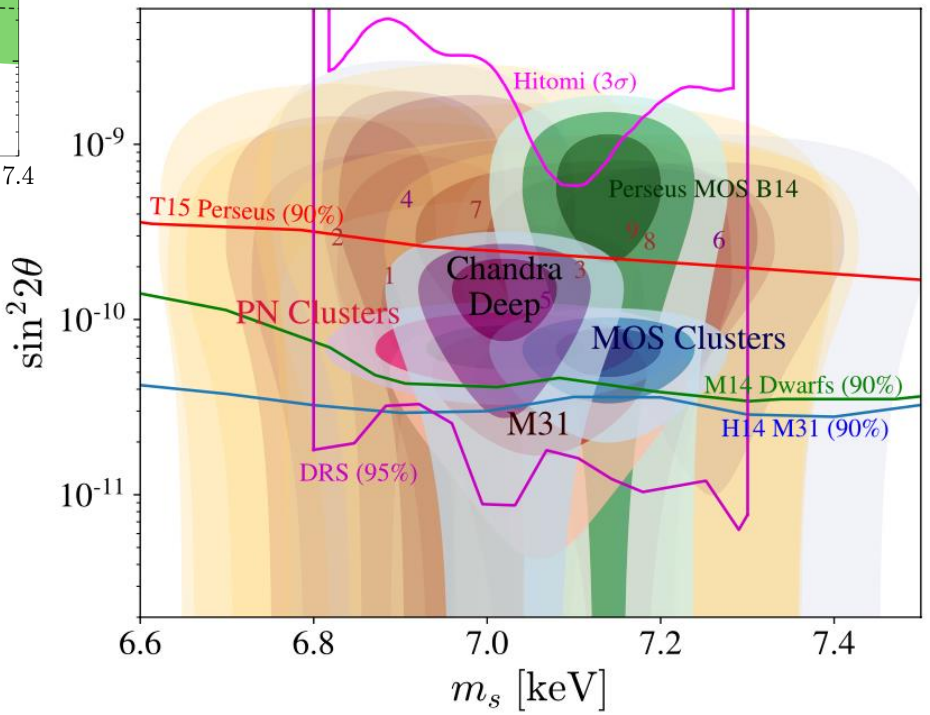
The fitted X-ray flux combined with the DM flux and powerlaw background emission

Comment From Kevork N. Abazajian



The 95% limit on sin 2θ derived by DRS

Newly derived limits when including the DM density profile uncertainties and the 3.3 and 3.7 keV lines



Take-home Message

- In this paper, they propose a new method of testing DM flux. Existed blank sky observation data can be exploited to gain a better sensitivity.

- Under their prescriptions, the result limit strongly disfavors the interpretation of sterile neutrino emitting 3.5 keV line.

- When talking about ruling out a theory, the most conservative condition should be considered. The research didn’t achieve the requirement, so the debate continues.

Questions

- Why do they chose powerlaw background to fit the signals?
- Is there other explanations for the unidentified 3.5 keV X-ray line?
- The theory of neutrino as dark matter has been almost ruled out. Why is sterile neutrino still a compelling candidate?
- How do the authors respond to the comment?