Strong Limits on Decaying and Annihilation Dark Matter

Vladislav Barinov (INR RAS)

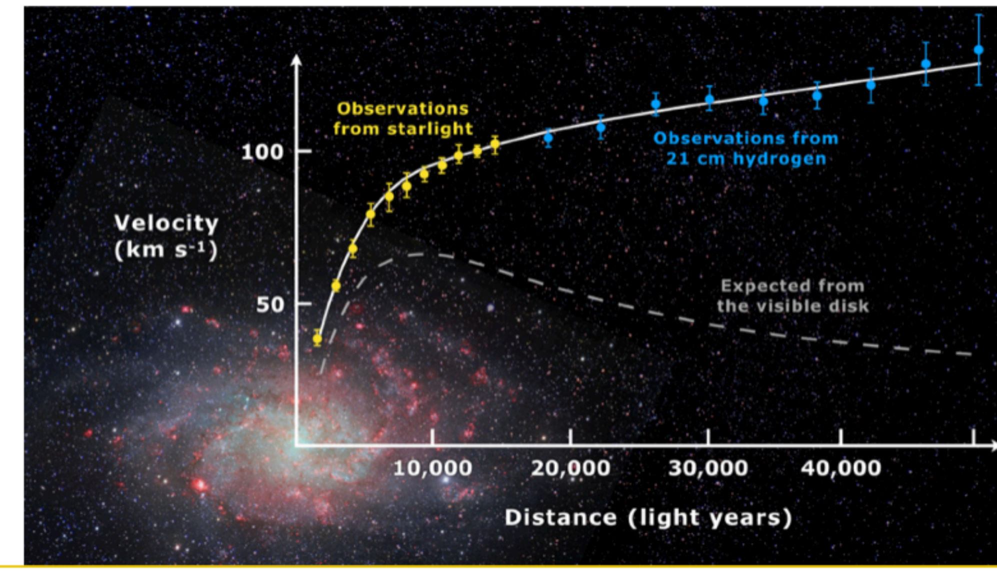
19 Feb 2025, Moscow

Dark Matter: *What is dark matter? How was it generated?*

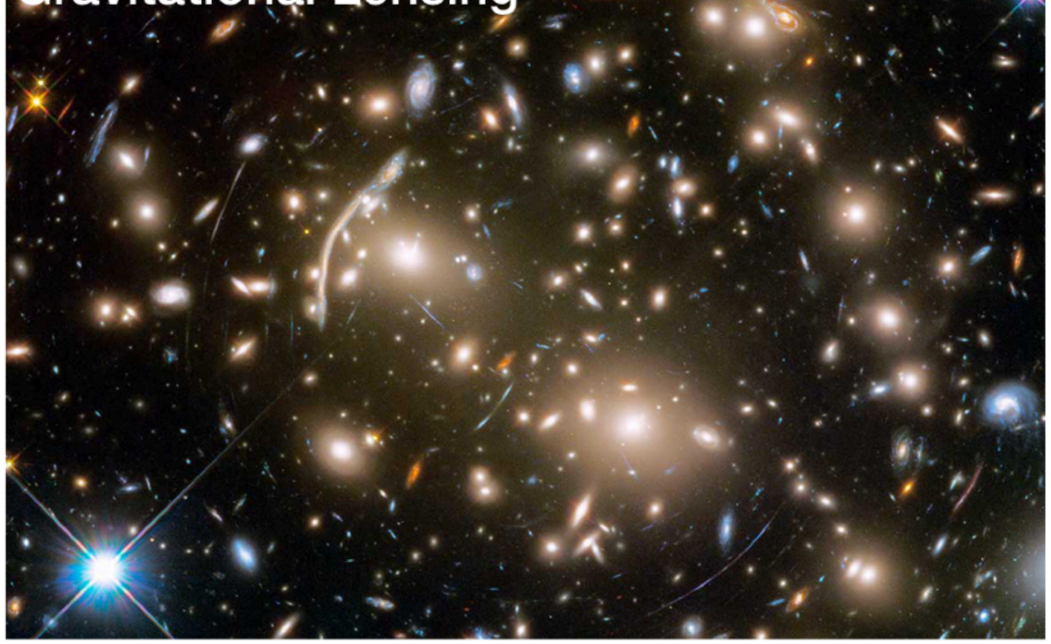
Fritz Zwicky 1933

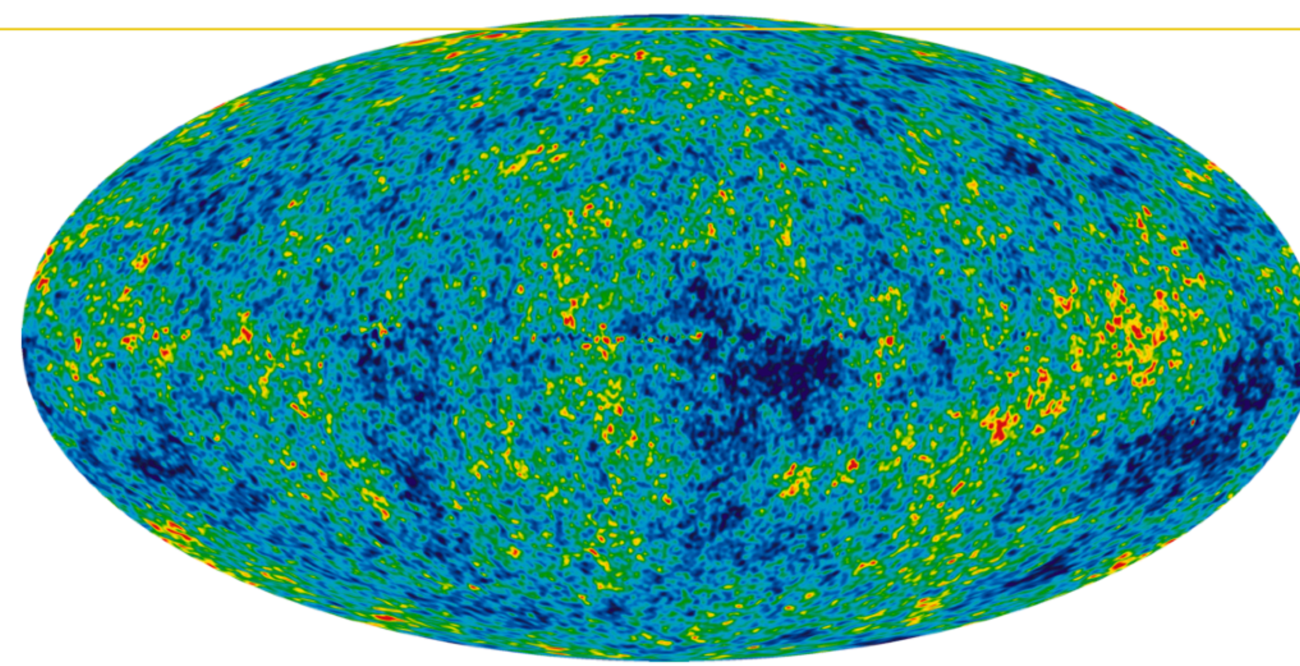
Virial Mass of the Coma Cluster

Rotation Curves



Gravitational Lensing





Undefined Line in X-Ray Spectra

The Astrophysical Journal, 789:13 (23pp), 2014 July 1 doi:10.1088/0004-637X/789/1/13

DETECTION OF AN UNIDENTIFIED EMISSION LINE IN THE STACKED X-RAY SPECTRUM OF GALAXY CLUSTERS

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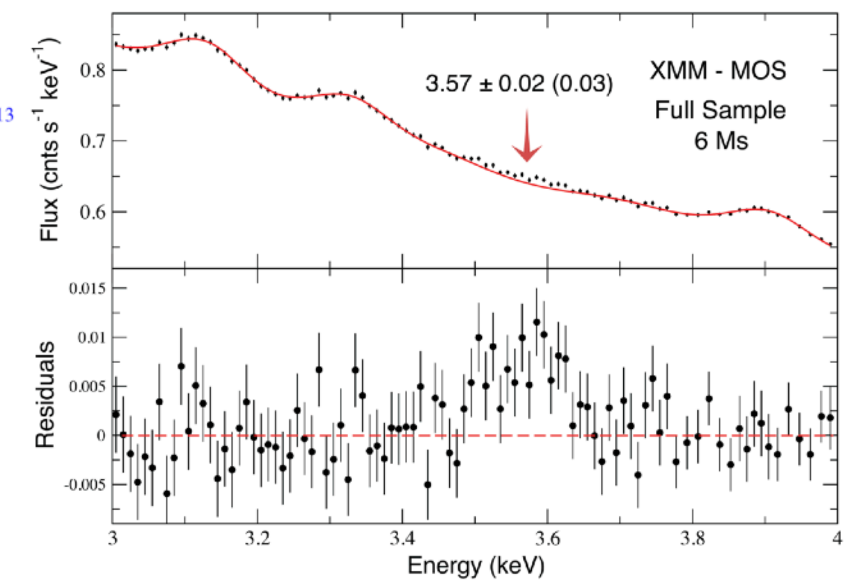

Selected for a Viewpoint in *Physics*
PRL **113**, 251301 (2014) PHYSICAL REVIEW LETTERS week ending 19 DECEMBER 2014

Unidentified Line in X-Ray Spectra of the Andromeda Galaxy and Perseus Galaxy Cluster

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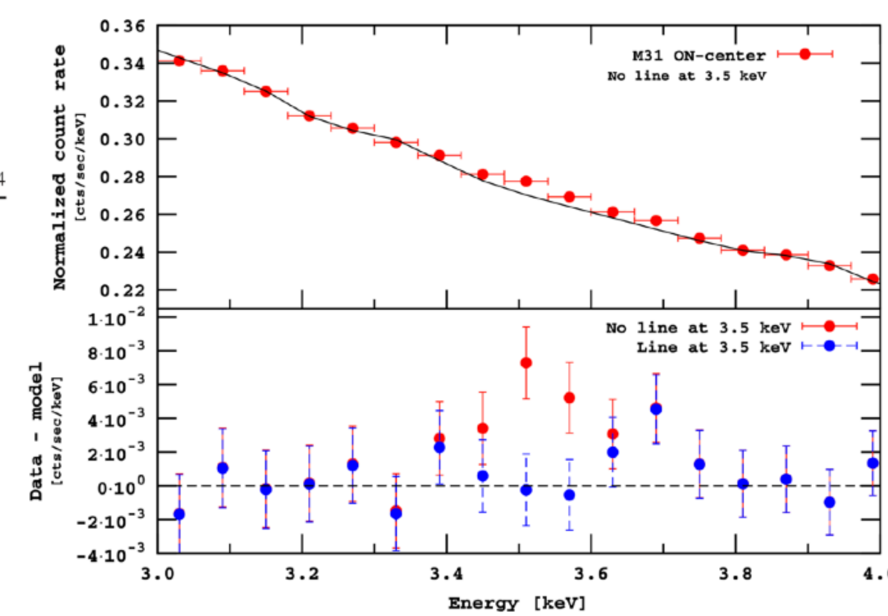
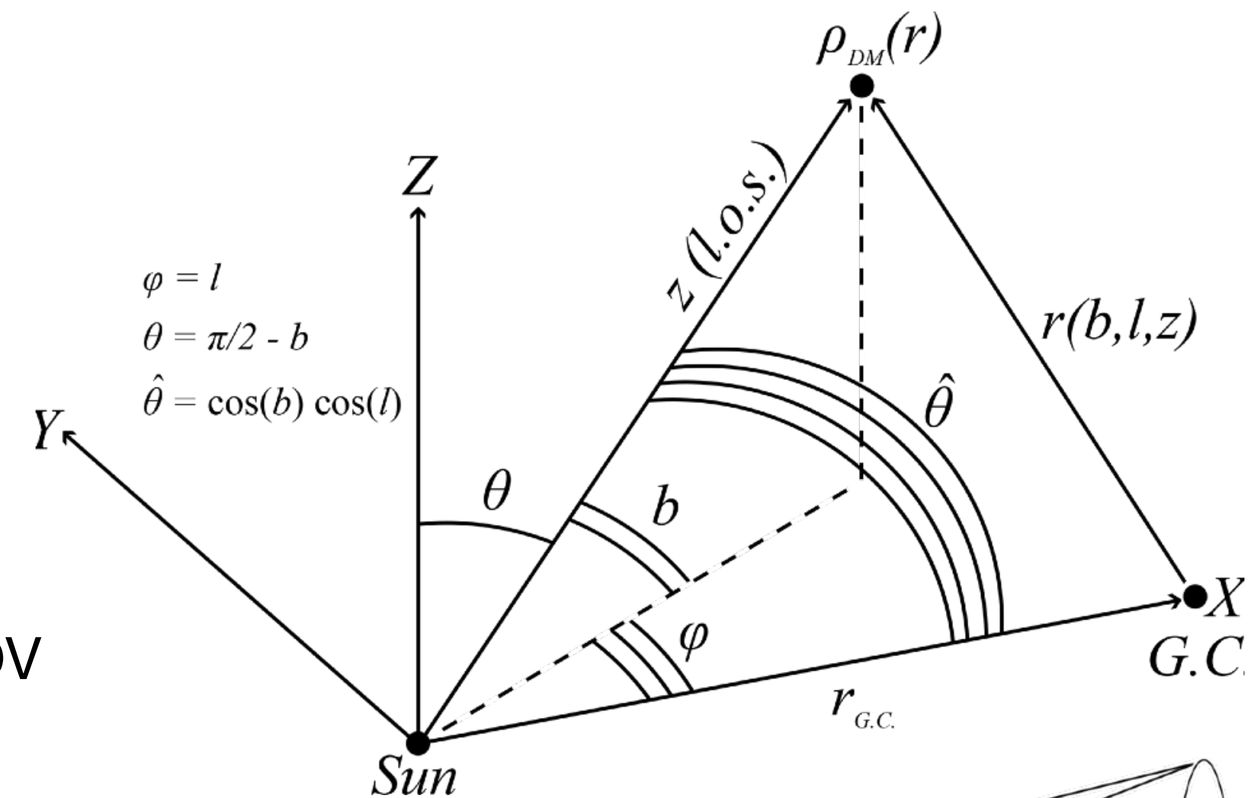


Search Strategy / Expected Signal & Observation Scheme

$$\nu_s \rightarrow \nu_{e,\mu,\tau} + \gamma$$

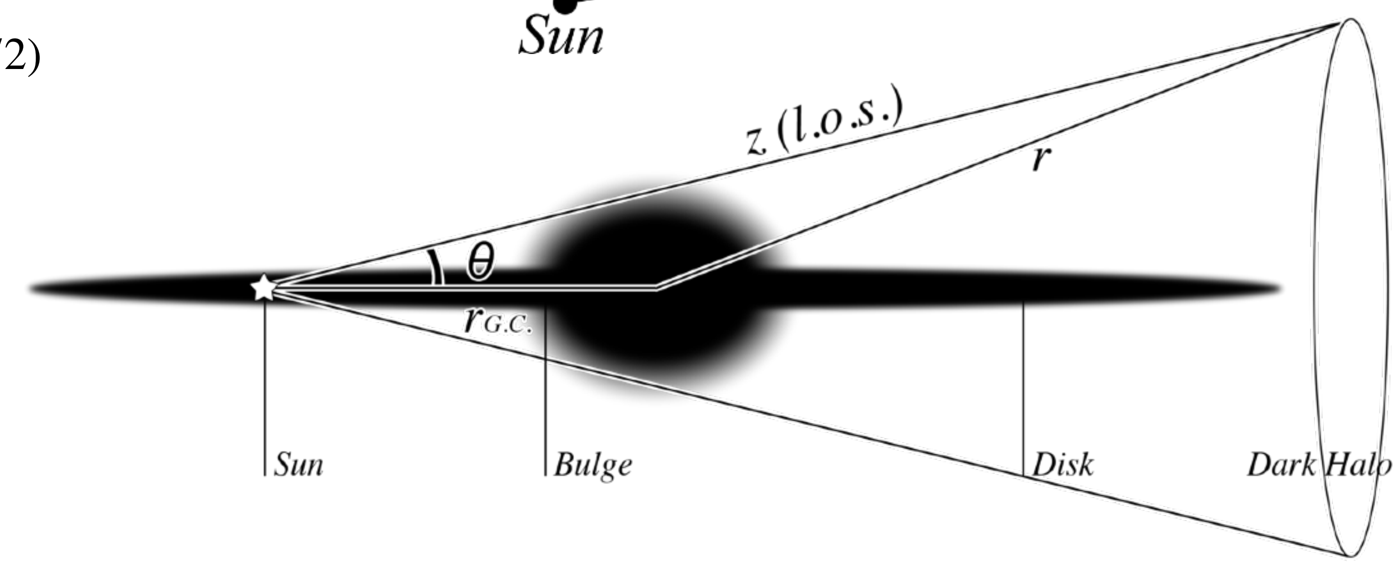


Intensity from Sterile Neutrino Decays

$$I_\gamma \equiv \frac{d^2 F_\gamma}{dE_\gamma d\Omega} \left[\frac{\text{cts}}{\text{cm}^2\text{skeVSr}}\right]$$

Dark Matter Flux and Column Density in given FOV

$$F_\gamma = \frac{1}{4\pi}\frac{\Gamma_{\nu_s}}{m_{\nu_s}} \int\int \frac{dN}{dE_\gamma}\frac{d\mathcal{D}_{DM}}{d\Omega} dE_\gamma d\Omega \qquad \frac{dN}{dE_\gamma} \sim \delta(E_\gamma - m_\nu/2)$$

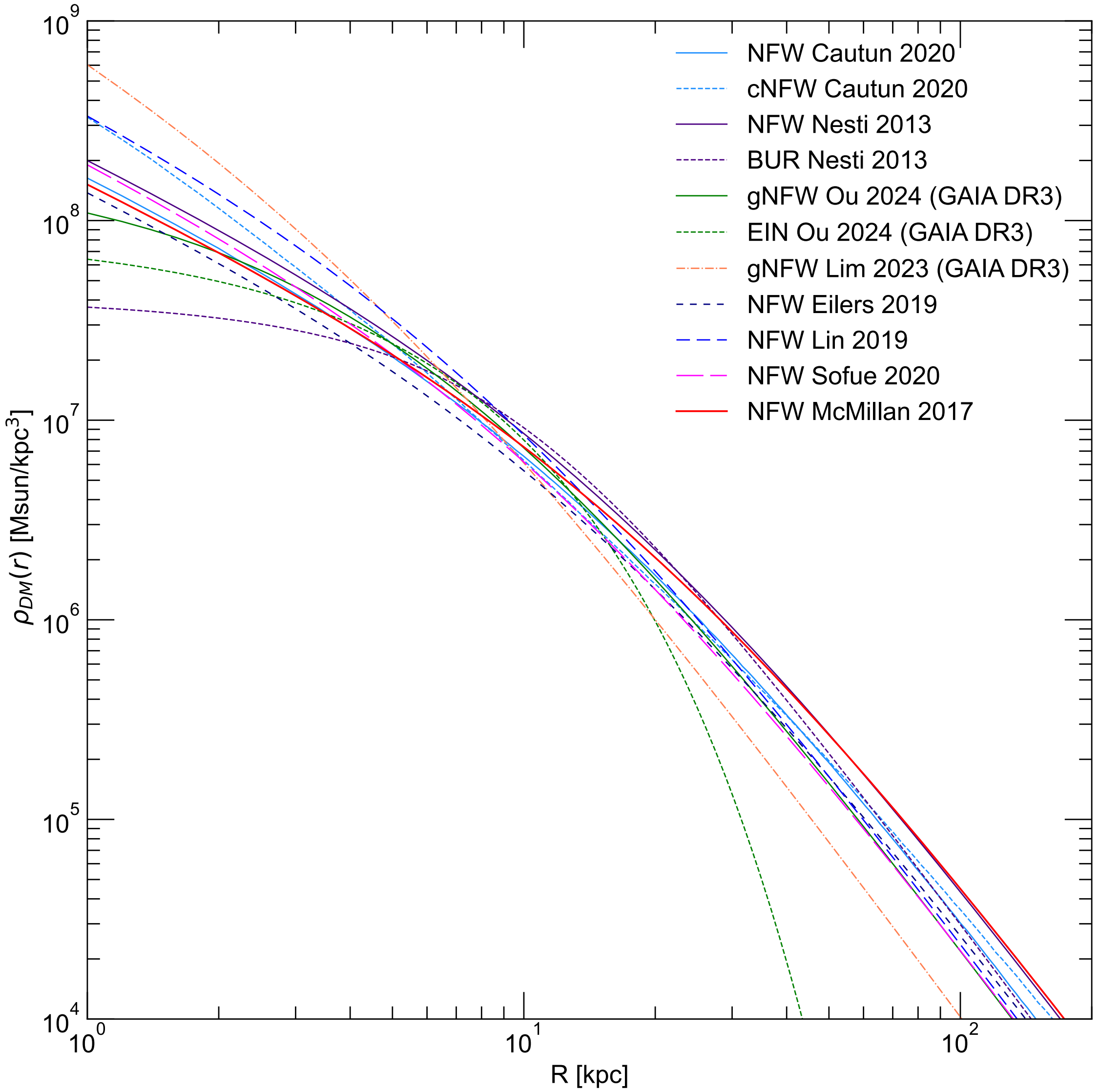


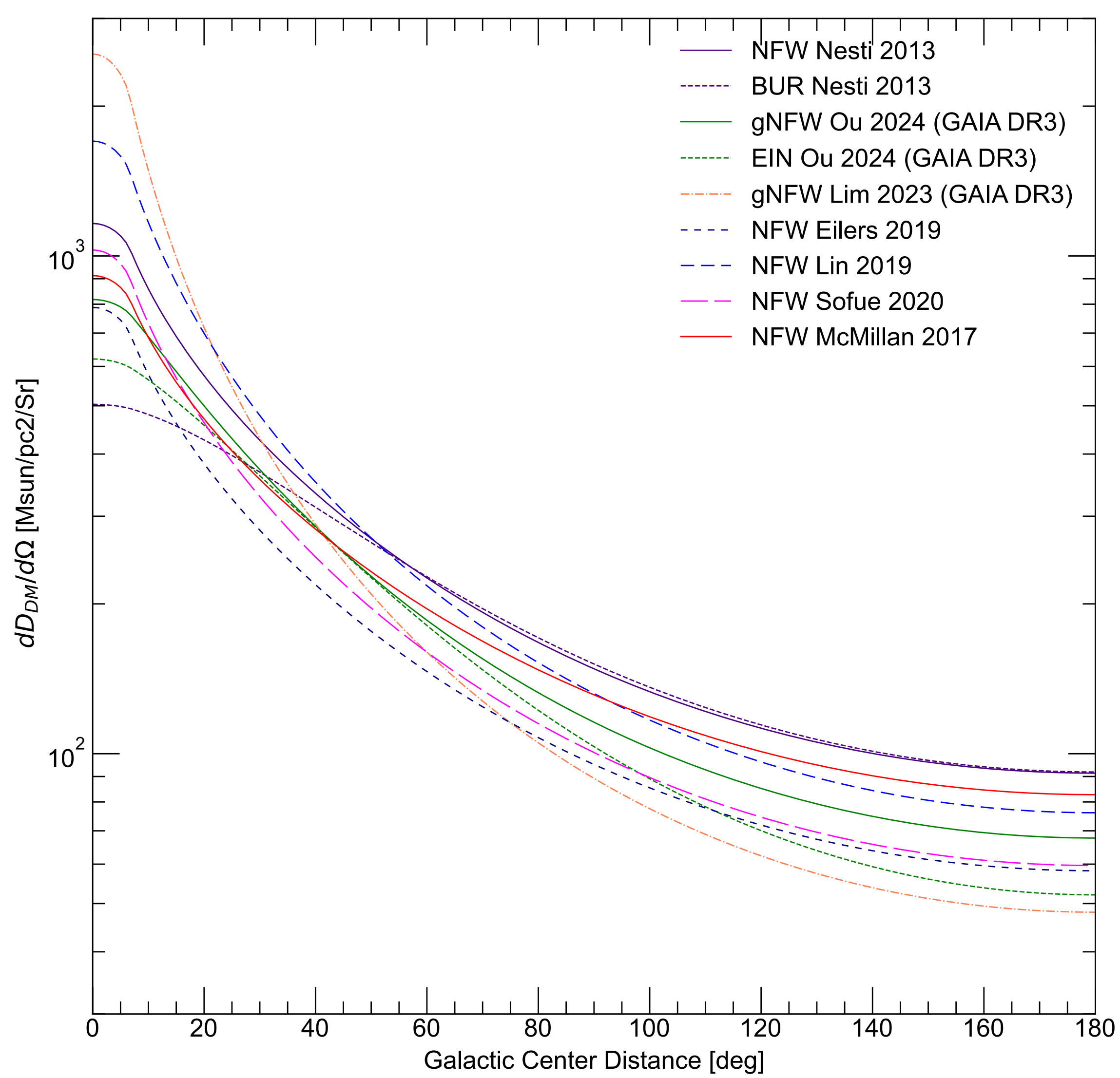
$$\mathcal{D}_{DM} = \int_{f.o.v.} \int_{l.o.s.} \frac{\rho_{DM}(r)}{z^2} z^2 \mathrm{d}z \mathrm{d}\Omega$$

Stacked Intensity

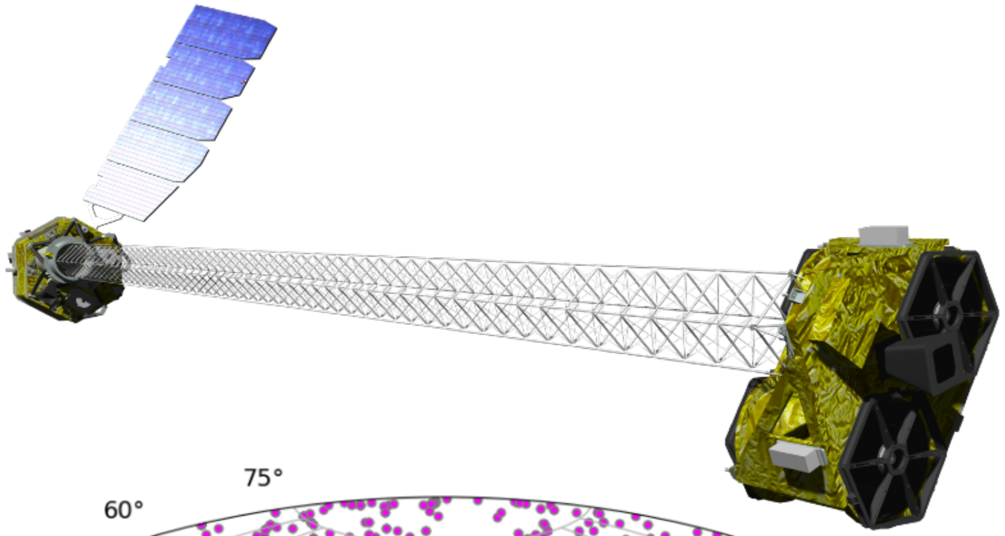
$$\langle I_\gamma \rangle = \frac{1}{4\pi}\frac{\Gamma_{\nu_s}}{m_{\nu_s}}\frac{dN}{dE_\gamma}\left[\frac{1}{\mathrm{T_{tot}}}\sum_i \mathrm{T}_i \frac{\mathrm{d}\mathcal{D}_{DM,i}}{\mathrm{d}\Omega}\right] = \frac{1}{4\pi}\frac{\Gamma_{\nu_s}}{m_{\nu_s}}\frac{dN}{dE_\gamma}\left\langle \frac{\mathrm{d}\mathcal{D}_{DM}}{\mathrm{d}\Omega} \right\rangle$$

Dark Matter Profiles / Uncertainty





NuSTAR Sterile Neutrino Constraints



- 11 years of Observations
- Exposure ~ 234Ms
- Combined A + B Modules
- Stacked Spectra ~ 3917 Observations

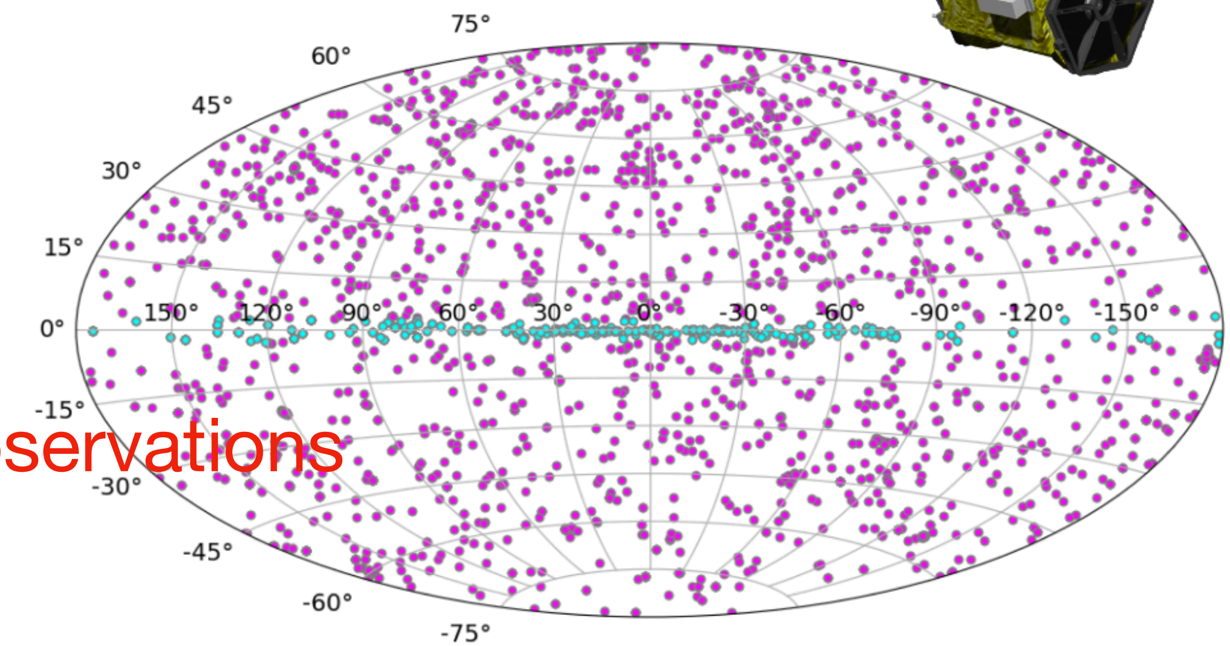
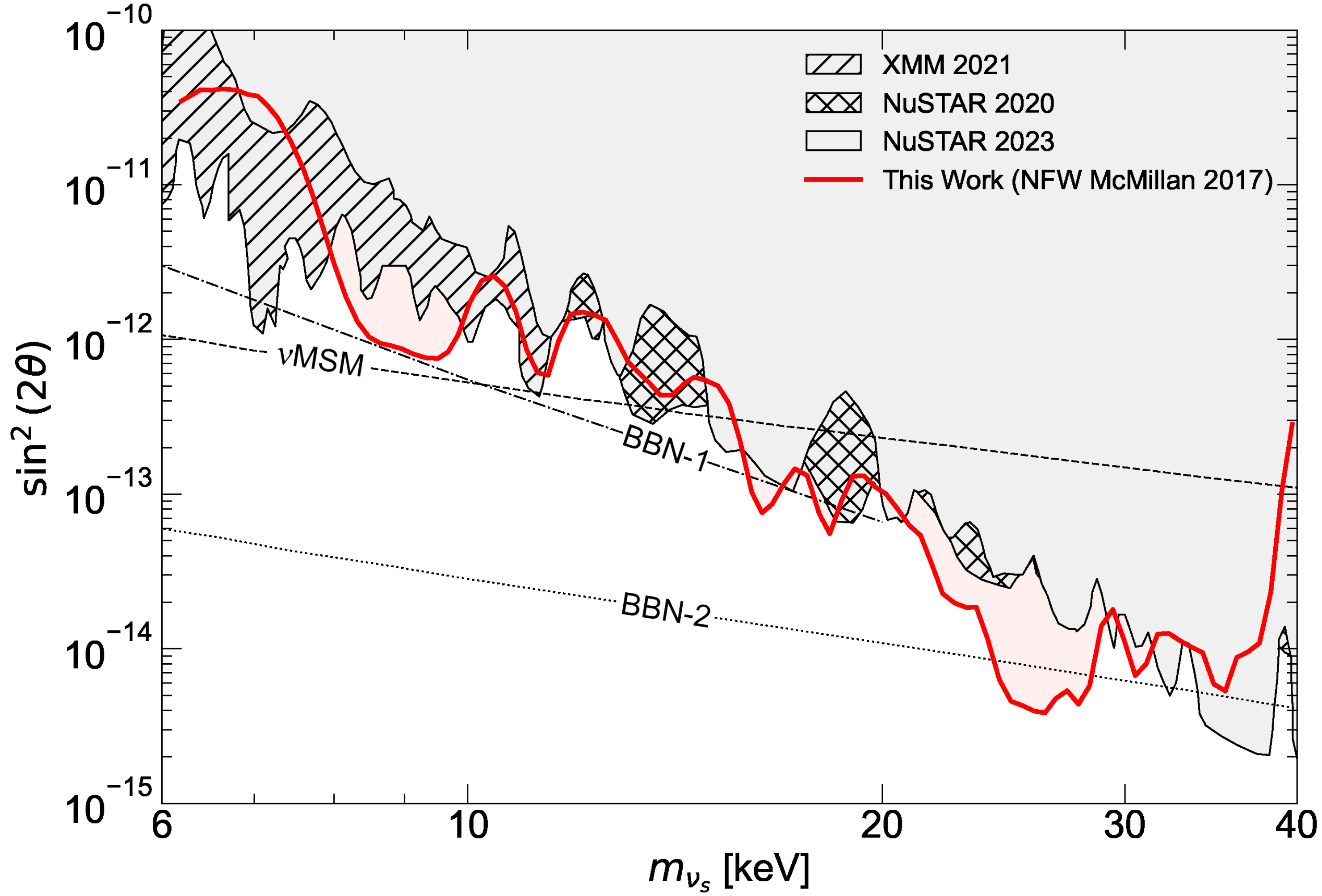


FIG. 4. The distribution of 3248 (FPMA) and 3139 (FPMB) *NuSTAR* observations on the sky in Galactic coordinates. Cyan and magenta points show *NuSTAR* observations at $|b| < 3°$ and $|b| > 3°$, respectively.

Strong Limits on Decaying Sterile Neutrinos

Strong limits on keV-scale galactic sterile neutrino dark matter with stray light from NuSTAR after 11 years of operation,
R. A. Krivonos, V. V. Barinov, A. A. Mukhin, D. S. Gorbunov,
arXiv:2405.17861

We find no solid evidence for a monochromatic line to be associated with sterile neutrino decay and place new strong upper limits on the active-sterile mixing angle for sterile neutrino masses (6 - 40) keV for the ***NuSTAR*** data



Strong Limits on Decaying Sterile Neutrinos
NuSTAR 234 Ms Constraints

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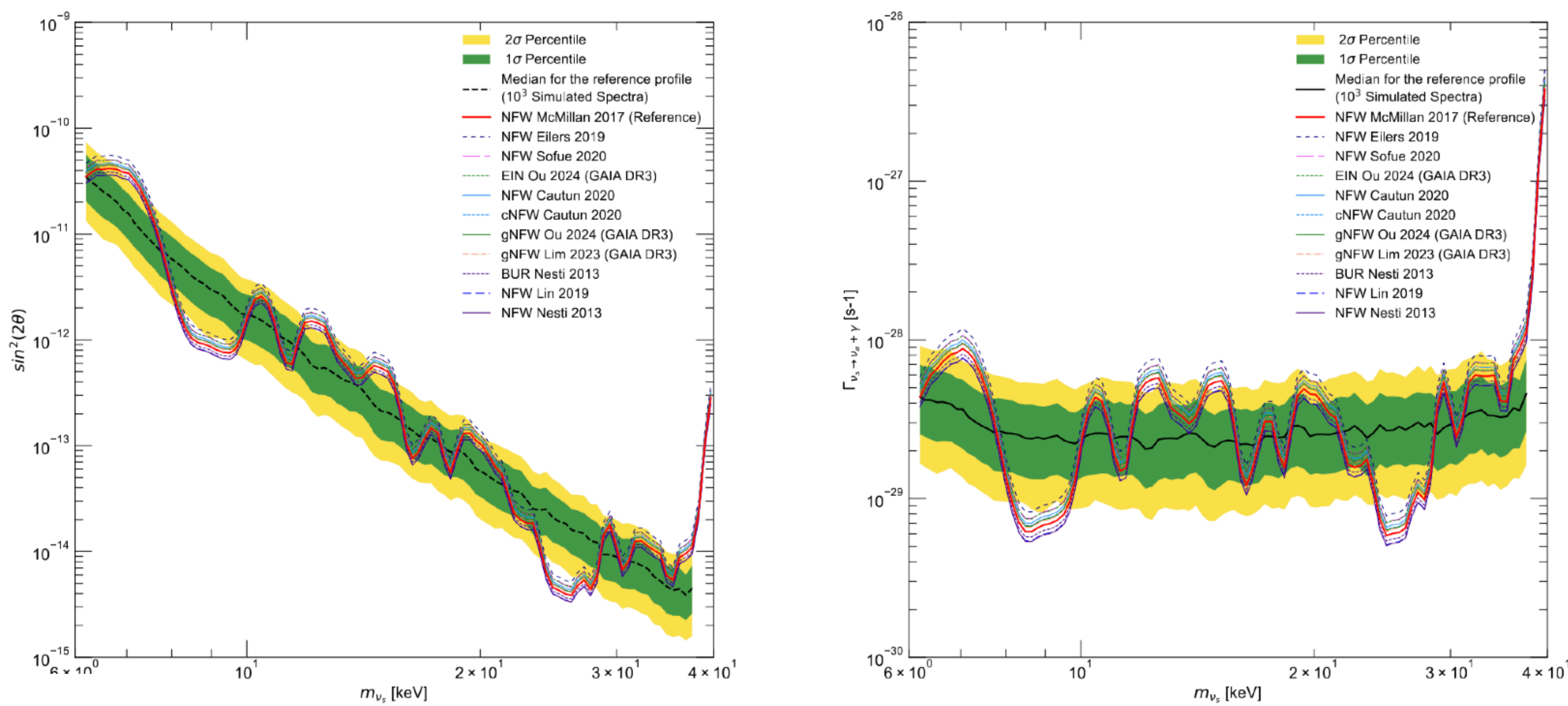

FIG. 9. 95 % upper limits on the parameters of sterile neutrinos obtained as part of our analysis. **Left:** upper limits on the $sin^2(2\theta)$ derived from the ASKY_AB_v4_poly20_b3 spectrum for different dark matter profiles. The black dashed line shows the median value for the constraints obtained from generating 10^3 spectra from spectrum ASKY_AB_v4_poly20_b3 for DM profile [30]. The green and yellow areas correspond to the 1σ and 2σ percentiles. **Right:** The same, but for the width of the decay of sterile neutrinos into active neutrinos and photons.

Strong Limits on Annihilating Dark Matter

Constraints on the parameters of keV-scale mass annihilating Dark Matter obtained with SRG/ART-XC observations,
E. I. Zakharov, V. V. Barinov, R. A. Burenin, D. S. Gorbunov, R. A. Krivonos,
arXiv:2407.18371

$$\chi + \chi \to \gamma + \gamma$$

$$dN/dE \sim \delta(E - m_\chi)$$

$$F_\chi = \frac{\sigma v}{4\pi m_\chi^2} J; J = \int \rho_{DM}^2(\vec{l}) dl d\Omega$$

We find that the SRG/ART-XC data collected in the survey mode over 4 full-sky surveys naturally makes MW the most promising source of the DM annihilation to be searched for. The limit obtained from MW is the strongest among all we found in literature, for the DM mass range 4 - 15 keV, and is competitive to those from NuSTAR observation of M31 galaxy and from analysis of the Planck data for 15 - 25 keV.