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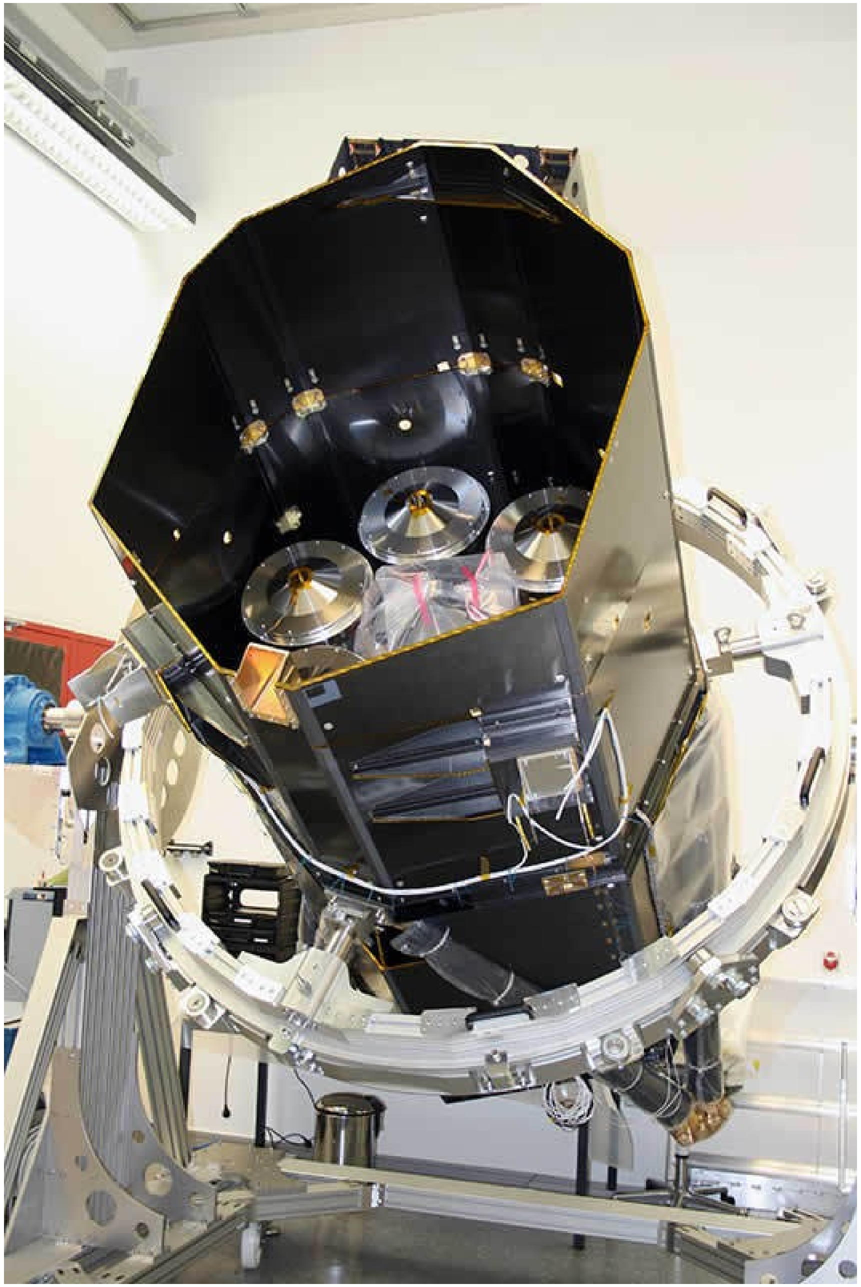
Decaying dark matter search with eROSITA



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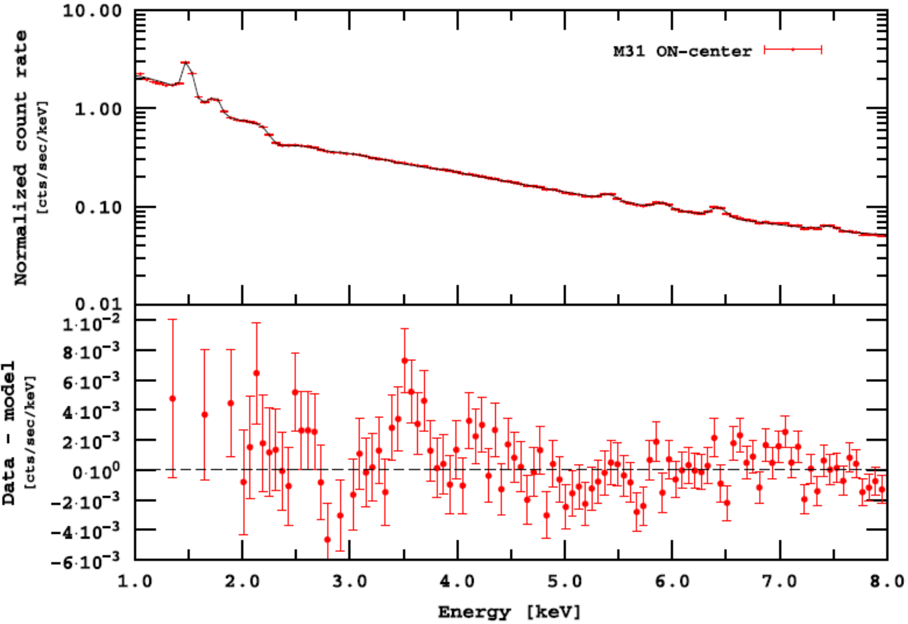
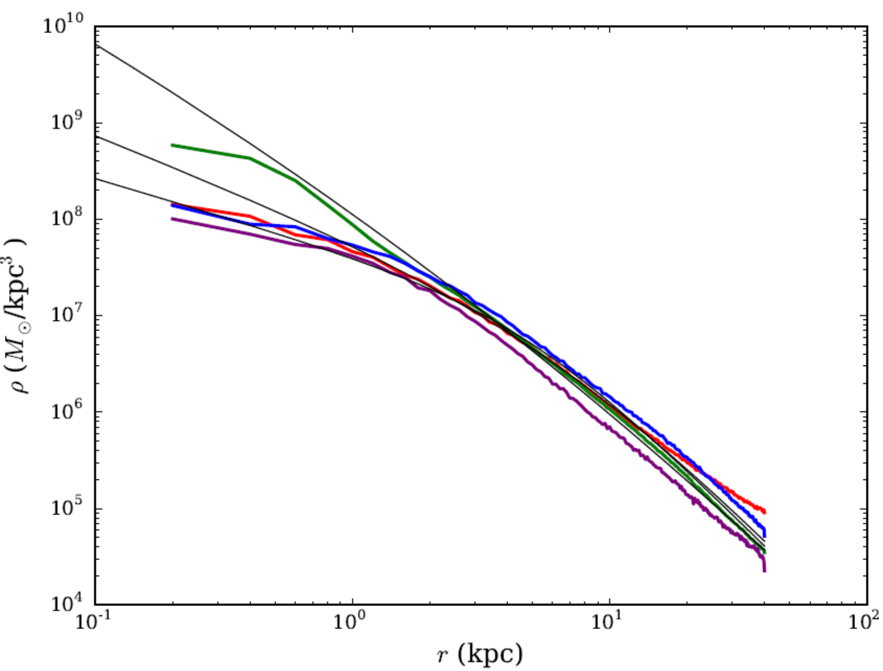
General remarks...



3.55 keV line in M31 from Boyarsky et al (1402.4119)



Uncertainties in DM density in LMC, from Buckley et al 1502.01020

– In astrophysics there is ***no way to directly measure*** the parameters (e.g. mass) of DM particle.

– The only option is to ***deduce*** these parameters ***from*** the ***observations*** that do not have convenient astrophysical explanations.

– The most straightforward way to detect decaying/annihilating dark matter is to ***observe*** the corresponding feature in DM-dominated objects' ***(photon) spectra***. The signal depends on the ammount (and spatial distribution in annihilating DM case) of DM in instrument's FoV

Caveats:

– DM profiles can have ***large uncertainties***, especially near the centers of DM dominated object, from where the most of the DM signal is naturally expected.

– DM decay/annihilating spectral feature can be confused with the ***convenient astrophysical line/feature***. Or with the feature in instrument's effective area.

– The expected feature is generally weak and requires the analysis of a large ammount of the data. At this step one can encounter previously ***unknown instrument systematic*** effects.

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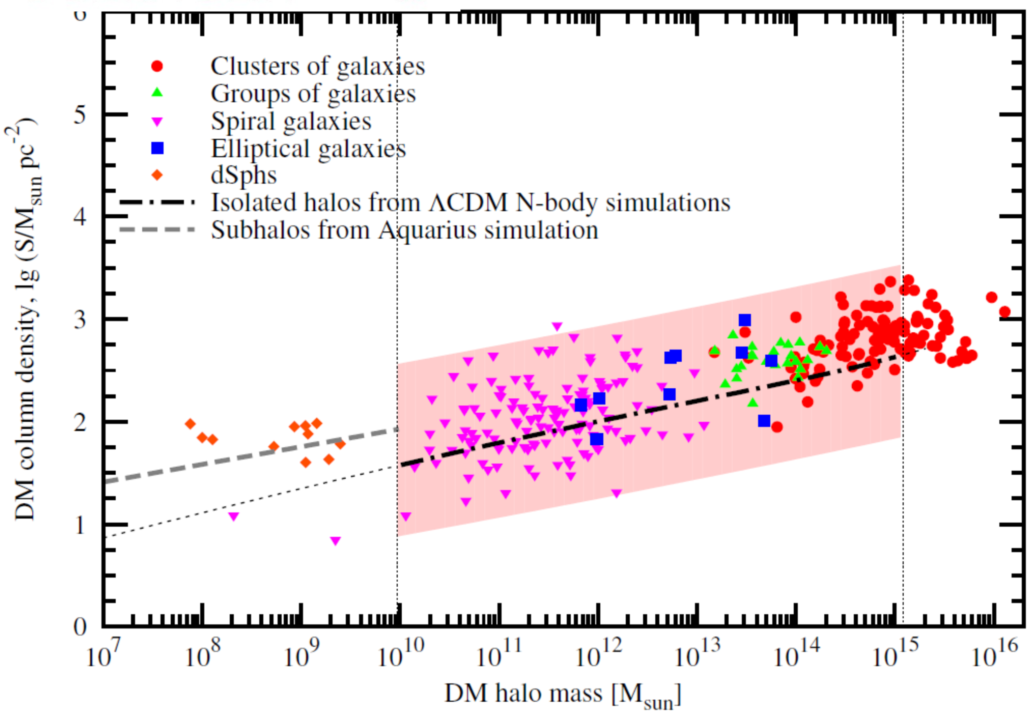
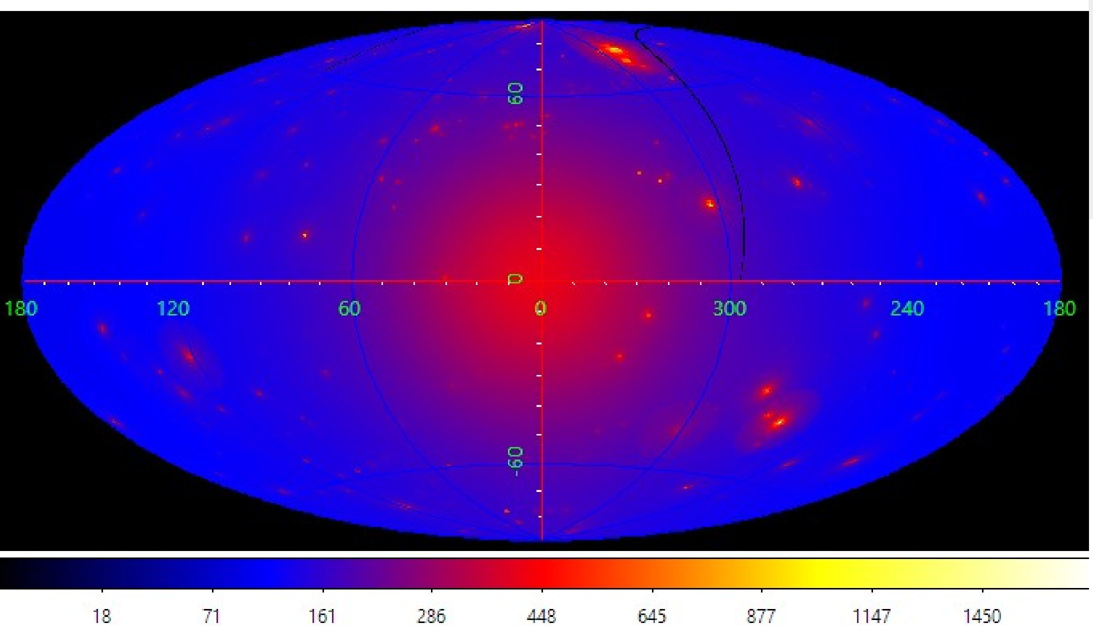
General remarks...



From Boyarsky et al 0911.1774



Where to search for decaying dark matter?

– Our galaxy?
– Clusters?
– Dwarf spheroidals?
– something else?

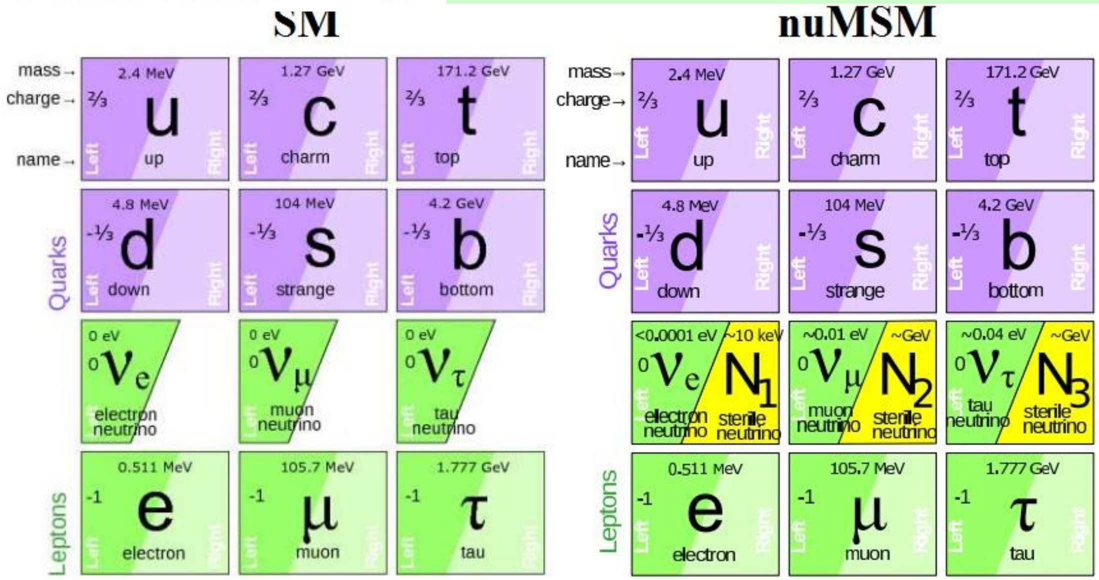
The expected flux F from DM decay (annihialtion) is proportional to the DM column density

dF~ S dΩ $S_{dec} \sim \int \rho \, d\ell$

Note dΩ in the formula for the expected signal. If FoV of the instrument is much larger than the size of the object – the contribution of the object to the signal will not be significant!

If the size of the object is comparable with the FoV – it appears that ***S is compatible for different types of objects***, from dSphs to Clusters. Other considerations (e.g. lower astrophysical background ; quality of the knowledge of DM density distribution) should be invoked in this case.

Sterile neutrino Dark Matter

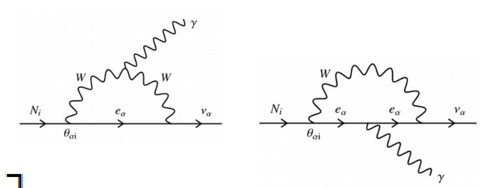


– νMSM Dark Matter

All particles in the SM except neutrino can have positive («right handed») and negative («left-handed») projection of the spin onto their momentum. Standard neutrinos can be only left-handed. νMSM proposes to add right-handed «sterile» companions to the neutrinos.

NuMSM is nice because:
- it is a «natural» extension of the SM
- It can expain low neutrino masses (seesaw mechanism) / neutrino oscillations
- it provides a way to explain baryon number generation in the Early Universe
- gives candidate(s) for the Dark Matter
- probably accounts for some observed phenomena (e.g. pulsar kicks)

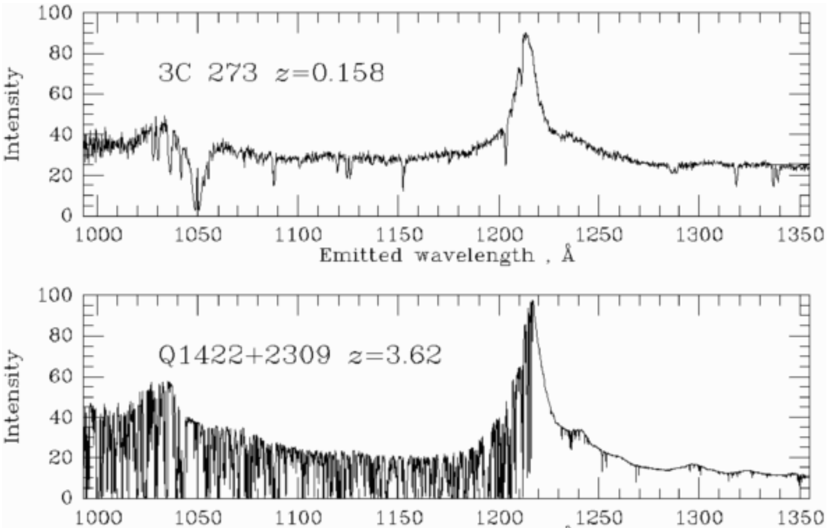
There are straightforward ways to observe decays of the sterile neutrino. Radiative decay chanel suggests the narrow line at energy $E=M_s/2$



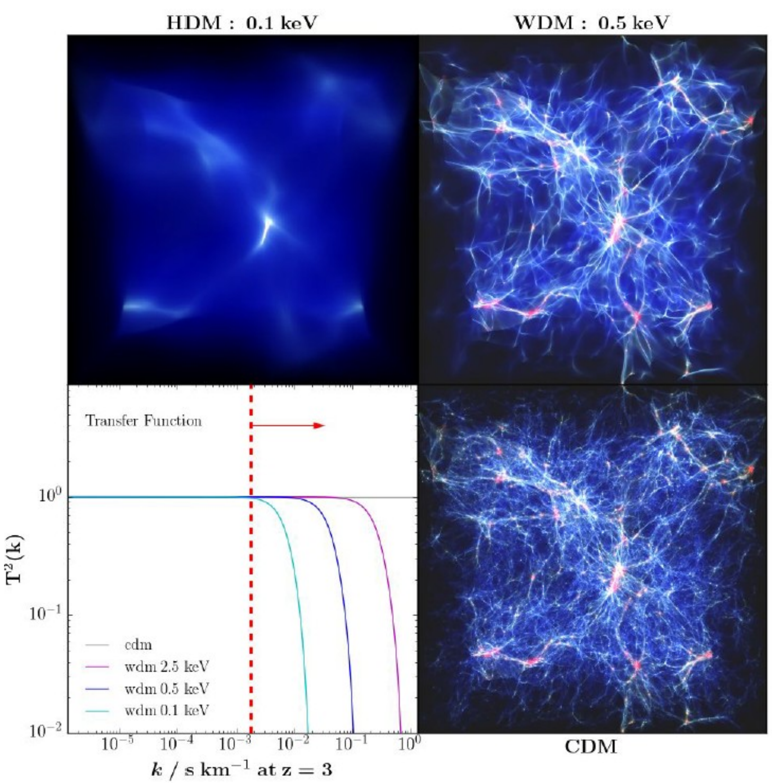
$$F_{DM} \approx 1.4\times 10^{-7}\left[\frac{\sin^2(2\theta)}{10^{-11}}\right]\left[\frac{m_{DM}}{10\text{keV}}\right]^4\left[\frac{d}{100\text{kpc}}\right]^{-2}\left[\frac{M_{DM,FoV}}{10^7 M_\odot}\right]\frac{\text{ph}}{\text{cm}^2\text{s}}$$

Note: the signal for decaying DM does not depend on the exact DM distribution profile, but just on a total mass within instrument's FoV!

Sterile neutrino Dark Matter



Credit: astro.ucla.edu



From Baur et al: 1512.01981

Non-spectral bounds

– ***Tremaine-Gunn bound*** (phase space density limit)
Since sterile neutrinos are fermions it is not possible to put too much particles within some DM-dominated objects (e.g. dSphs) within allowed velocity dispersion range.
See S. Tremaine & J. E. Gunn, Phys. Rev. Lett. 42 (1979) 407.

Implies limit m≥ 1 keV

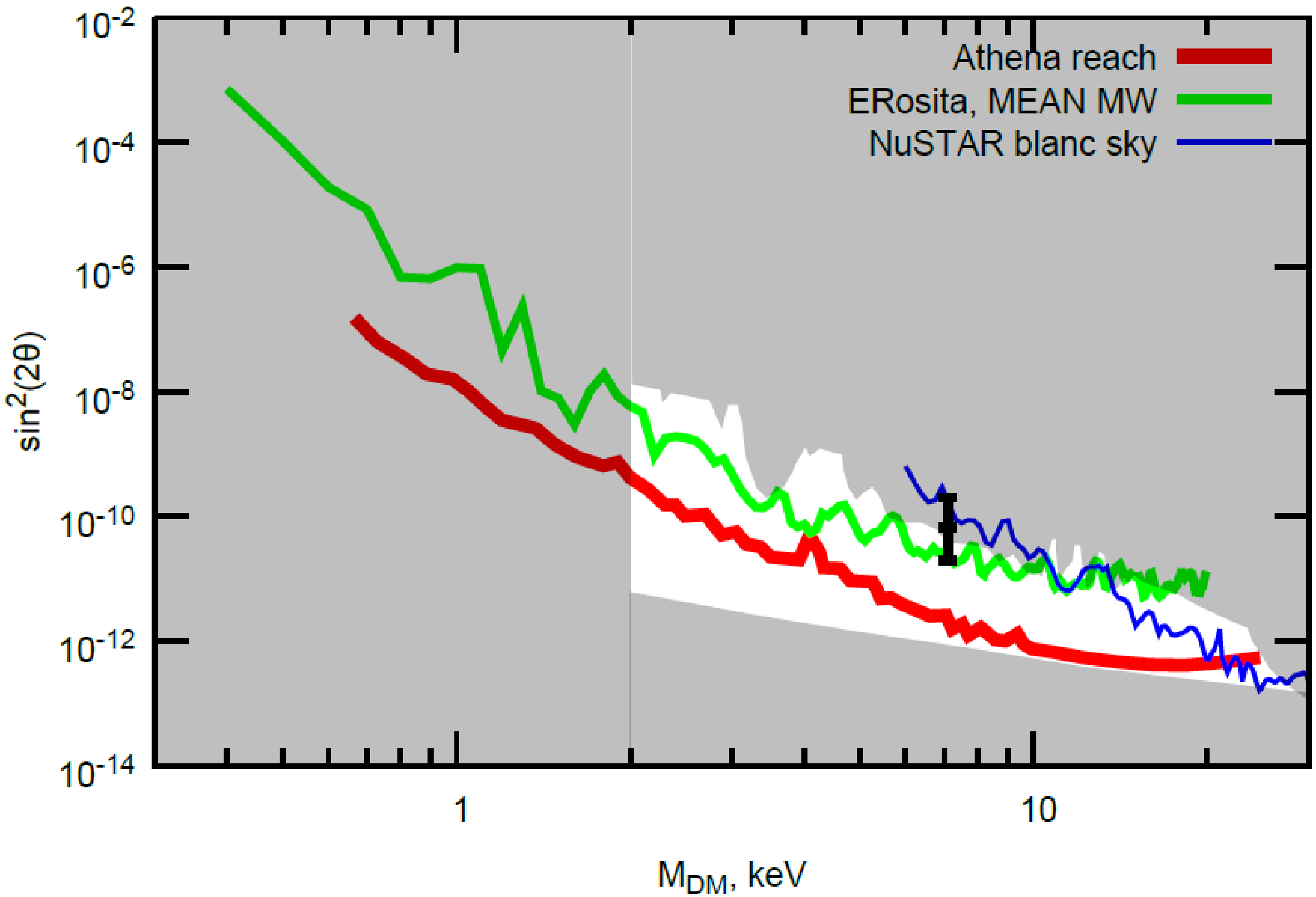
– ***Lyman-alpha bound***
High-z AGN light travelling through the Universe can be absorbed and re-radiated by the neutral hydrogen all way to us. The frequency of re-radiated photon is const in neutral hydrogen frame and z-shifted for us. Absorbtion and re-radiation lead to the numerous (z-shifted) Ly-alpha lines.

Neutral hydrogen is a tracer of DM distribution. Power spectrum of the DM distribution is a function of DM particle mass and can be compared with the deduced from neutral hydrogen distribution.

Implies limit m≥ 2..4 keV

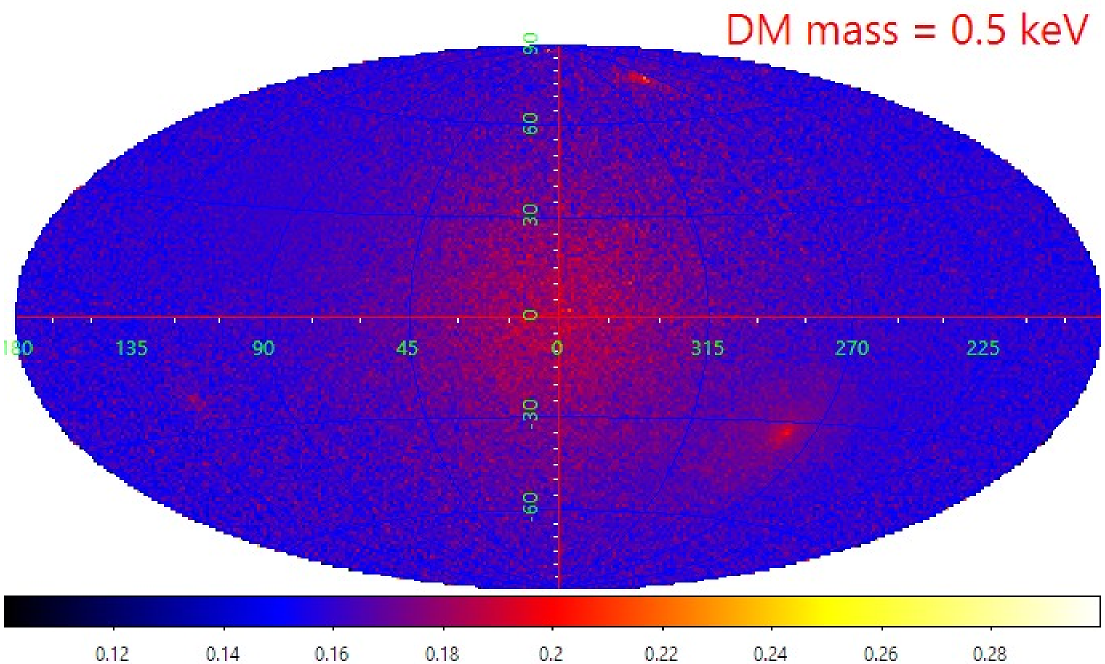
– ***BBN upper bound***, see e.g. Dolgov et al 0201287

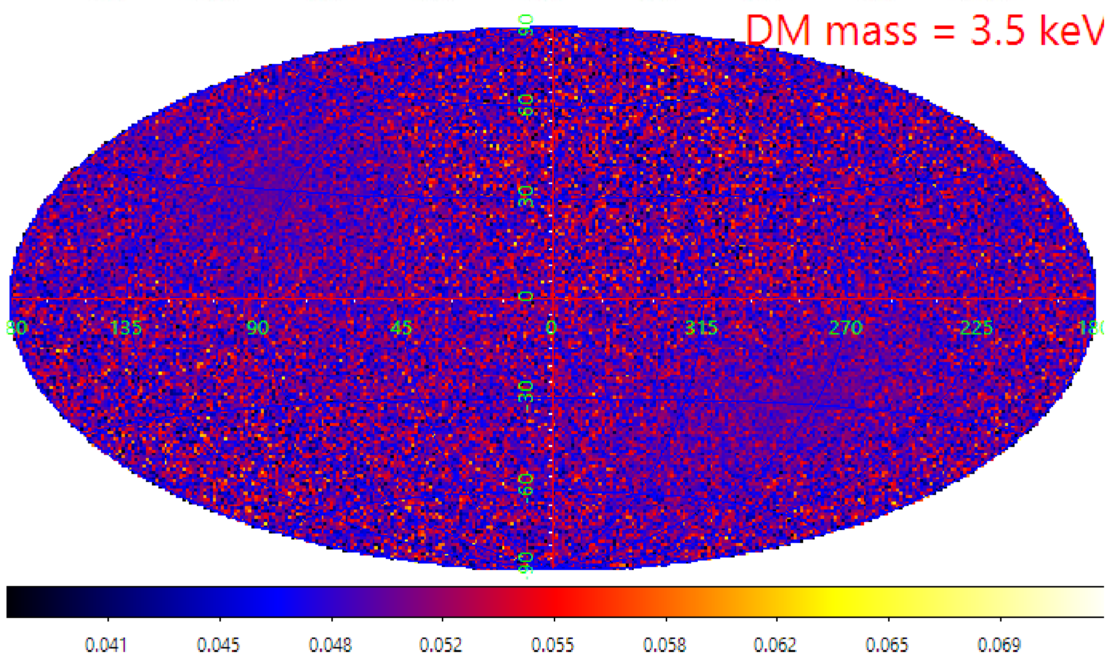
Sterile neutrino Dark Matter



eROSITA limits on decaying sterile neutrino dark matter. The estimations for 1Msec observations of Segue I dSph (similar to Athena reach limits).

Sterile neutrino Dark Matter

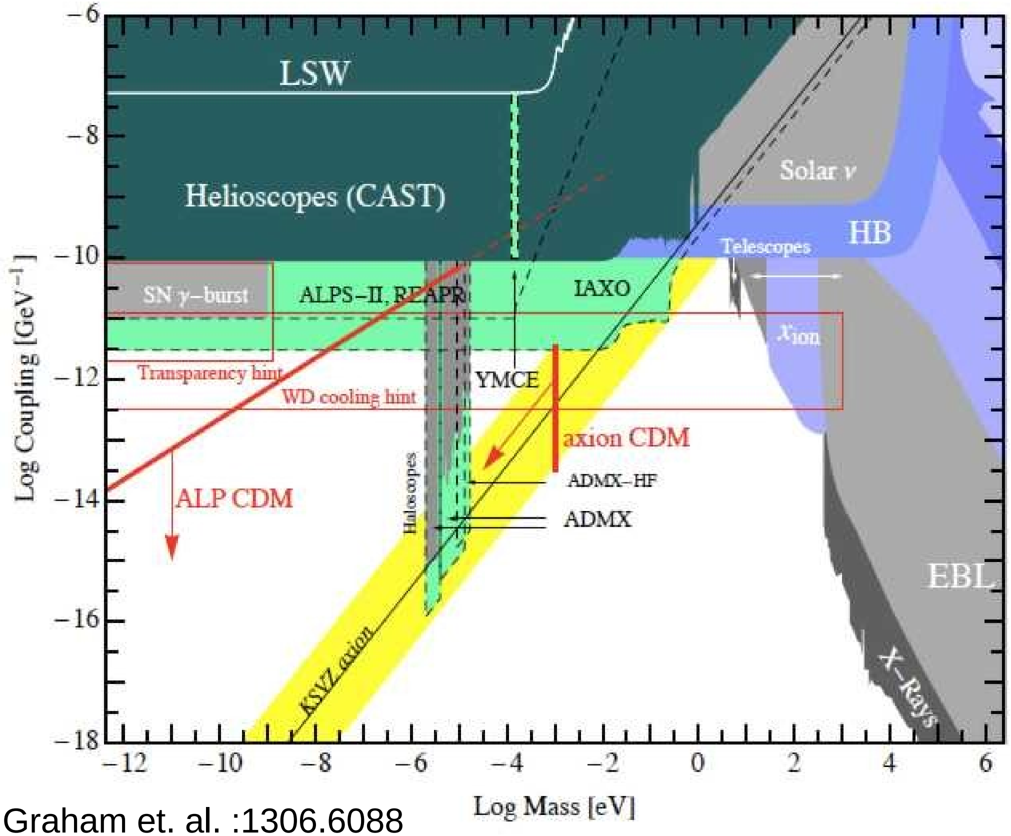




eROSITA view of decaying sterile neutrino dark matter for m_{DM} = 0.5 keV and m_{DM} = 3.5 keV (assuming the DM parameters from existing upper bounds)

DM is clearly seen for energies below ~1.5 keV. Possibility for ON-OFF analysis and/or for the correlation studies.

Axion Dark Matter



Graham et. al. :1306.6088

$$\Gamma_{a\to\gamma\gamma} = \frac{g^2_{a\gamma\gamma} m_a^3}{64\pi} = 7.6\cdot 10^{-26}\left(\frac{g_{a\to\gamma\gamma}}{10^{-10}GeV^{-1}}\right)^2\left(\frac{m_a}{1eV}\right)^3$$

$$P_{\gamma\to a} = (\Delta_{a\gamma}s)^2\,\frac{\sin^2(\Delta_{osc}s/2)}{(\Delta_{osc}s/2)^2}$$

$$\Delta^2_{osc} = (\Delta_{pl}-\Delta_a)^2 + 4\Delta^2_{a\gamma}$$

$$\Delta_{a\gamma}/Mpc^{-1} = 0.15\cdot\frac{g_{a\gamma\gamma}}{10^{-10}GeV^{-1}}B_{nG}$$

$$\Delta_a/Mpc^{-1} = -7.7\times 10^{28}\left(\frac{m_a}{1eV}\right)^2\left(\frac{\omega}{1eV}\right)^{-1}$$

$$\Delta_{pl}/Mpc^{-1} = -11.1\left(\frac{n_e}{10^{-7}cm^{-3}}\right)\cdot\left(\frac{\omega}{1eV}\right)^{-1}$$

Mirizzi et.al.:astro-ph/0607415

– Axion

Considered to solve strong CP problem in QCD and a good candidate to be DM, see e.g. Marsh, 1510.07633 for the review.

Depite the low mass of the axion, there are ways to make it cold – «misalignment mechanism»

Can be detected via two photon decay and conversion to photon (and v.v.) in a magnetic field (Primakoff effect).

Astrophysical consequences:

– additional energy loss chanel for stellar/SN evolution
– Features in pulsars/magnetars spectra
– Distant sources dimming
– Additional polarization of distant sources' light.

Opens a window for direct search for axions: ADMX, CAST, ALPS.

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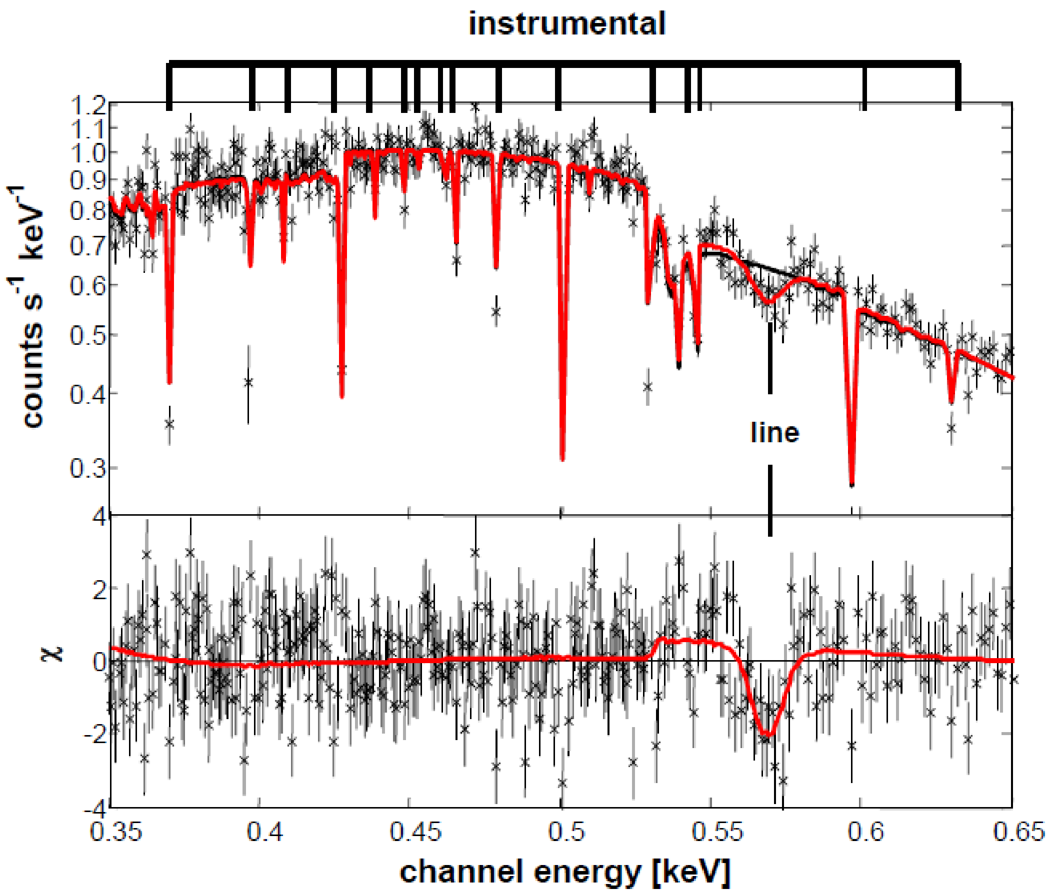
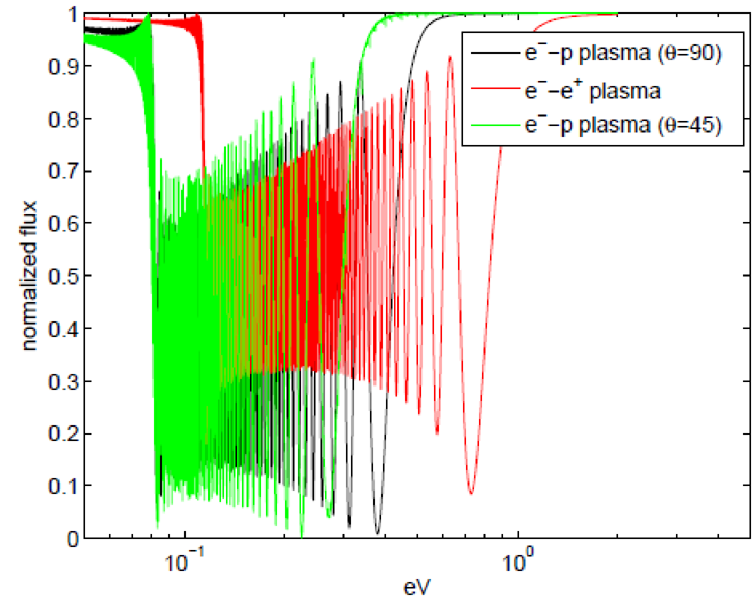
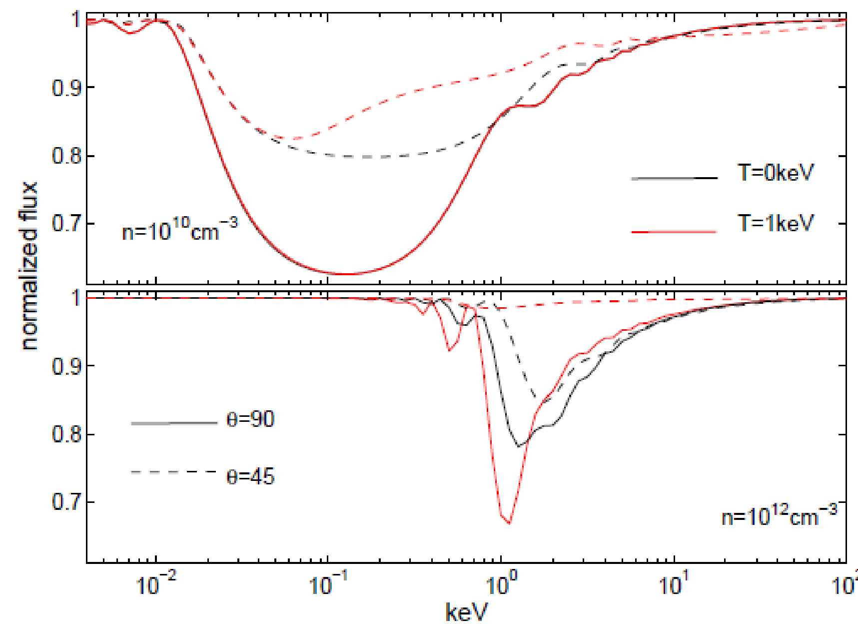
Axion Dark Matter



XMM/RGS spectrum of RXJ0720.4-3125
(adopted from 1109.2506)





Features in spectra of pulsars (top) and X-ray binaries from axion-photon conversion. Adopted from 0806.0411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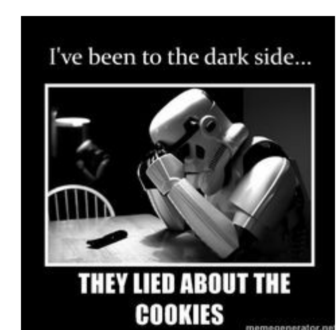
DARK SIDE
WE HAVE
COOKIES


I've been to the dark side...
THEY LIED ABOUT THE
COOKIES