Dark Cosmology Centre

X-ray constraints on late decaying dark matter majorons - or other soft X-ray emitting candidates

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arXiv:astro-ph/0805.2372, accepted for JCAP:

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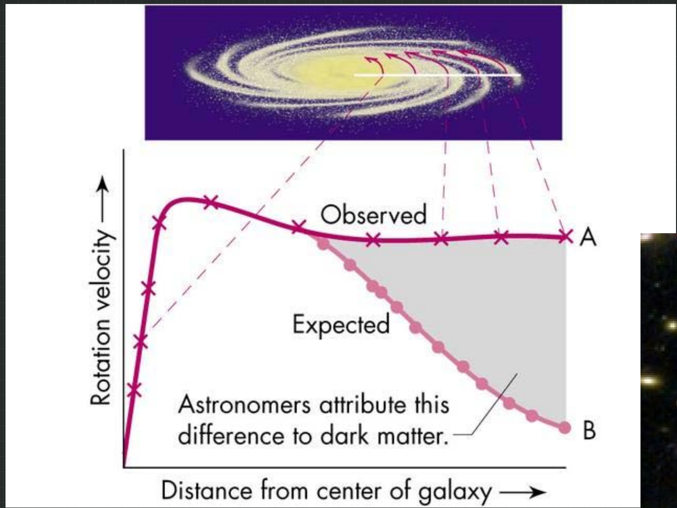

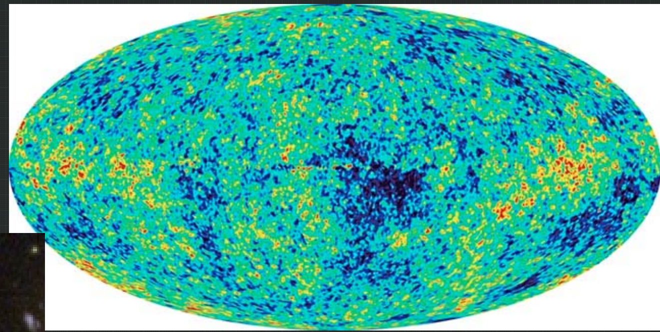

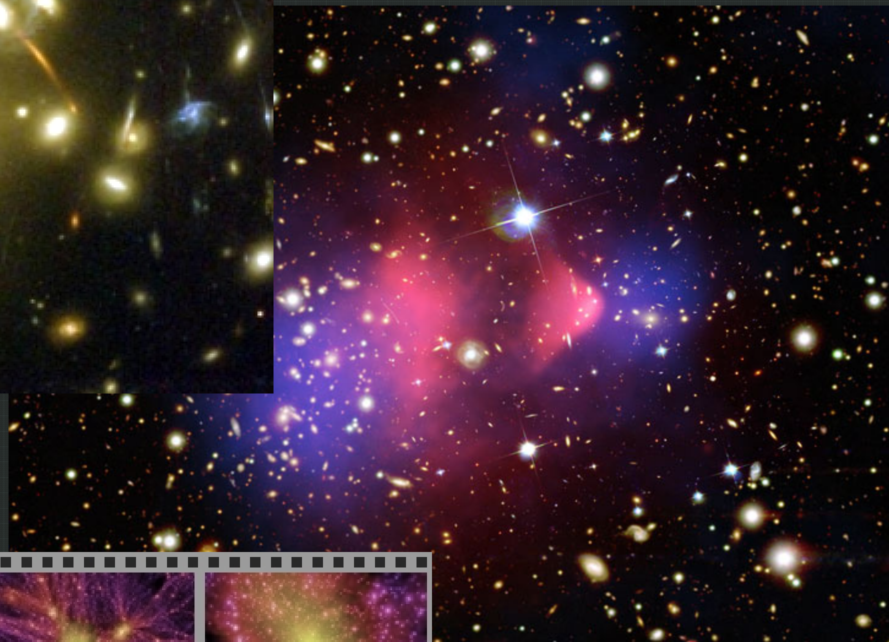

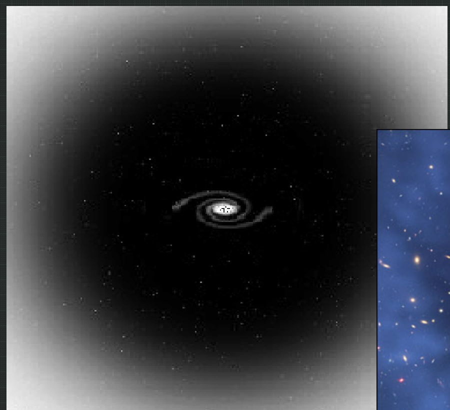

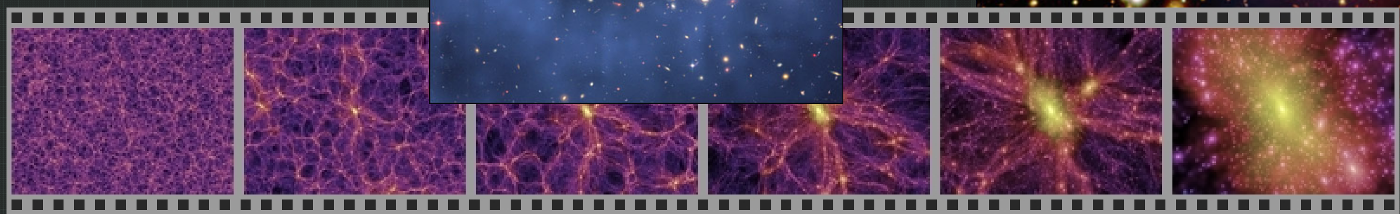

New physics

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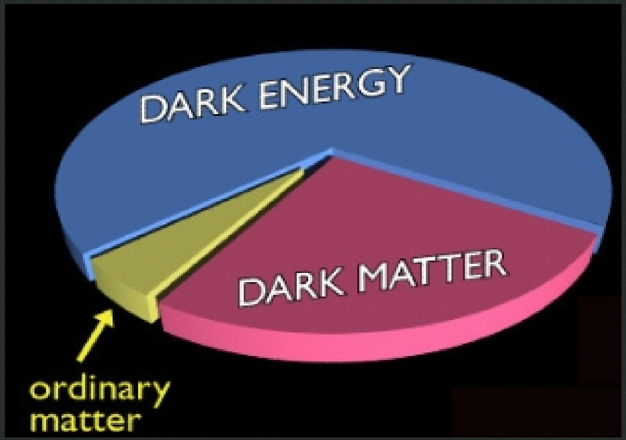
General properties of a dark matter candidate:

- Particle behavior
- Massive (gravitational effect)
- Not too much interacting
- Long lifetime (if thermal relic)



No Standard Model candidate!
Cosmology -> only 4% Standard Model

Experimental evidence for problems with the Standard Model e.g.:

- Neutrino flavour mixing
- Neutrino masses
- Baryon asymmetry
- Dark matter
- Dark energy

Neutrino mass generation

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Neutrinos massless in the Standard Model BUT experimental evidence for masses

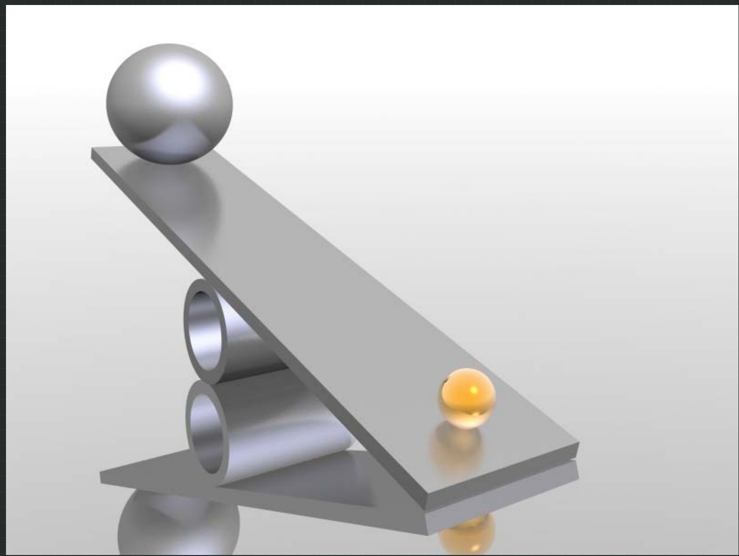
Seesaw mechanism popular to generate masses

Two types of neutrino mass terms:

Dirac particles -> Lepton number conserving

Majorana particles -> Lepton number violating

Global lepton symmetry, neutrino masses acquired by spontaneous violation



Majorons

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Neutrino masses can arise from the spontaneously breaking of un-gauged lepton number

Pseudoscalar massless Nambu-Goldstone gauge boson: The majoron

(Chikashige, Mohapatra & Peccei 1981, Schechter & Valle 1982)

Majoron acquire mass from non-pertubative gravitational effects that explicitly break global symmetries

(Akhmedov et al. 1993)

Dark matter majorons

Dark matter: Non Standard Model, massive, little interacting

(Berezinsky & Valle 1993)

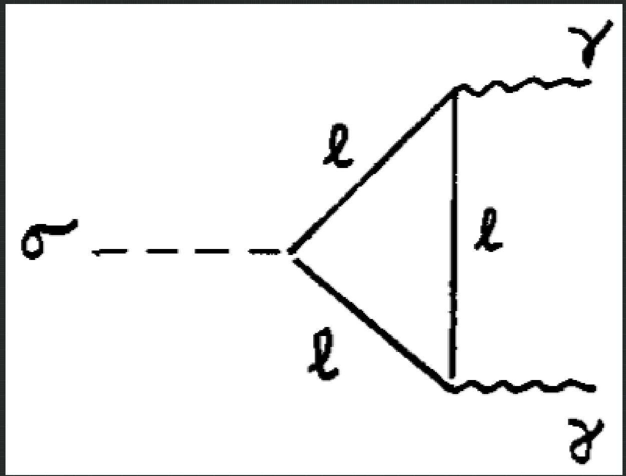
Dominating decay into neutrinos

Can decay to photons - loop suppressed

(Berezinsky & Valle 1993)

$J \rightarrow \gamma\,\gamma$

$E_\gamma = m_{J/2}$



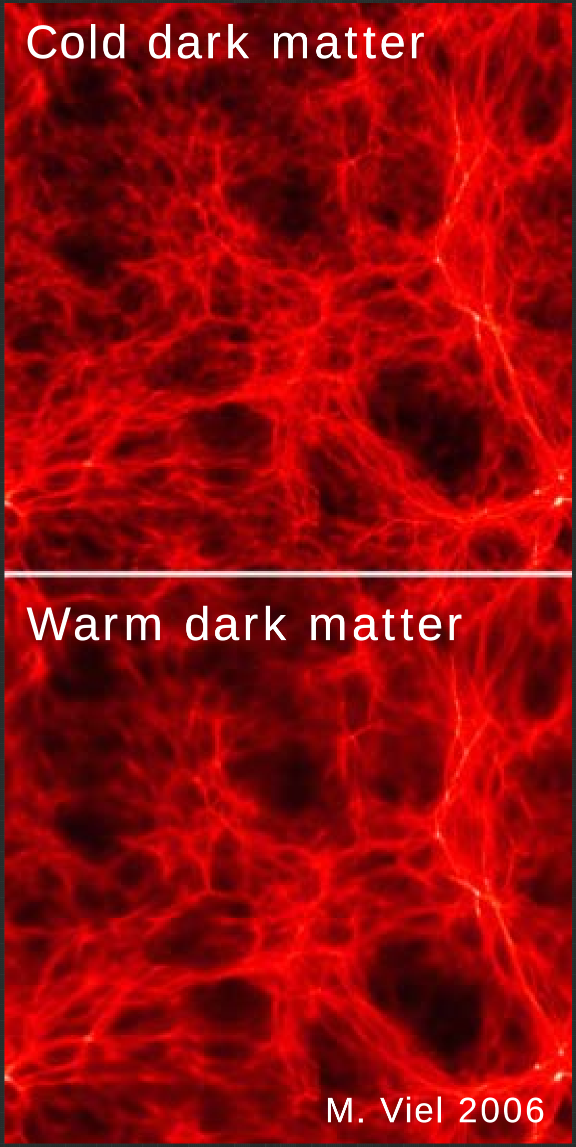
keV mass majorons

IF produced thermally and very early:

keV mass provides present day dark matter density

(Lattanzi & Valle, 2006)

Warm dark matter



Constraints from CMB

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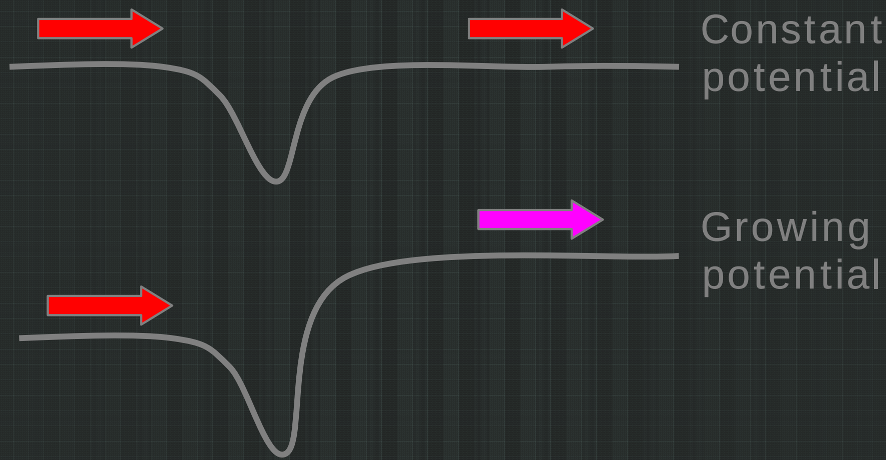
Late decay of majorons change gravitational potential



Late integrated sachs-wolfe effect causes excess of power at small multipoles (in CMB)

(Lattanzi & Valle 2007)

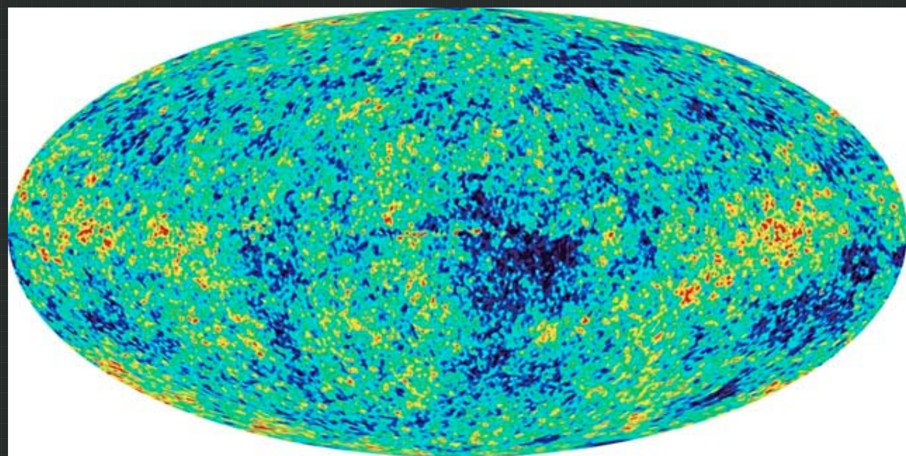
Constraints:

$0.11\ \text{keV} < \beta m_J < 0.18\ \text{keV}$

$t_J > 250\ \text{Gyr}$

$\Gamma_{J\nu\nu} < 1.3 \cdot 10^{-19}\ \text{s}^{-1}$

(Lattanzi & Valle 2007)



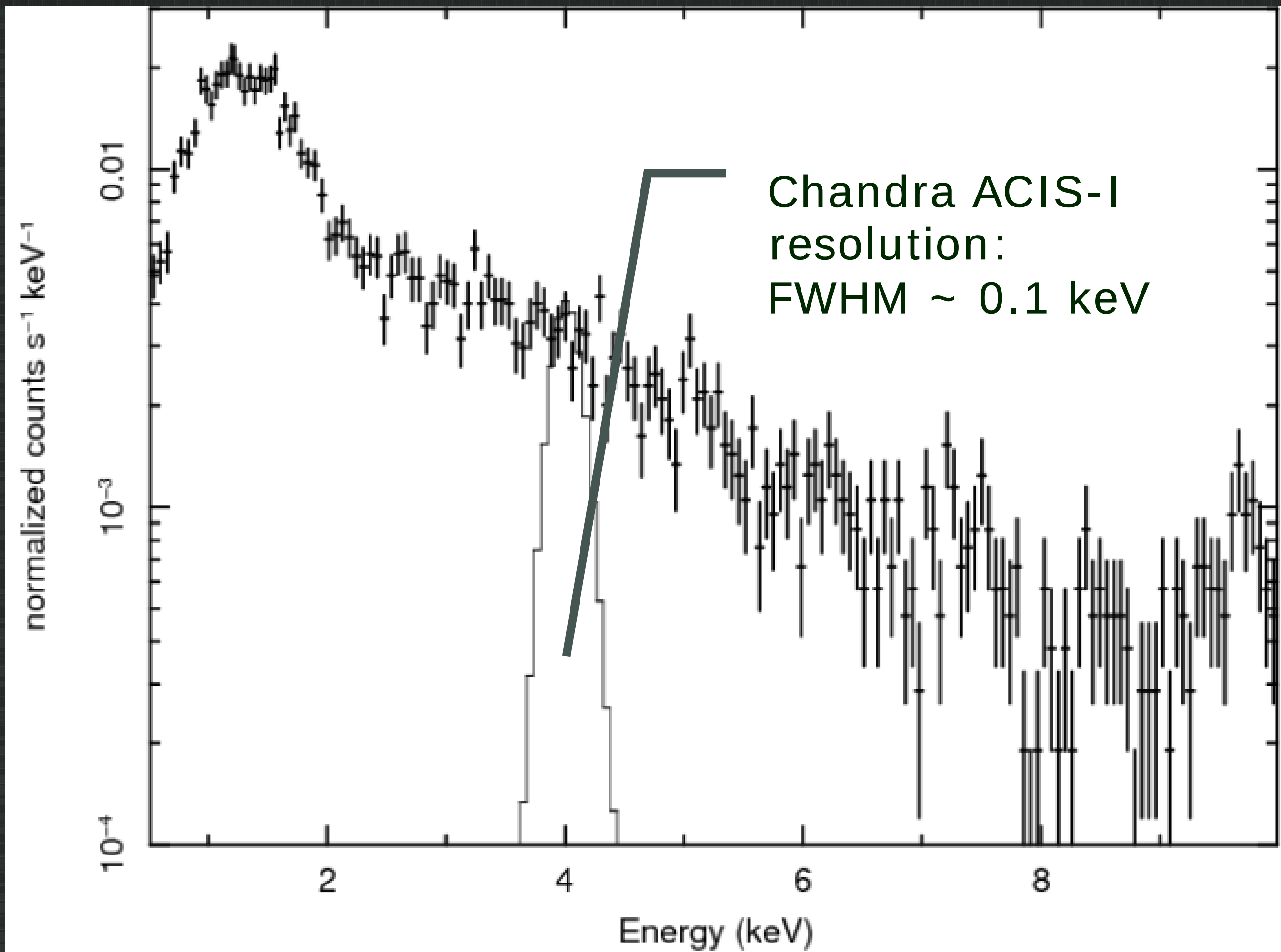
Assumptions:

- Thermally produced and in equilibrium in early Universe
- Decouple while all SM degrees of freedom are excited

Line search

Dark matter decaying into photons, $E_\gamma = m_{J/2}$

Mono-energetic emission -> Gaussian because of instrumental resolution



$$F \propto \frac{M\Gamma}{D_L^2}$$

Low energy X-rays

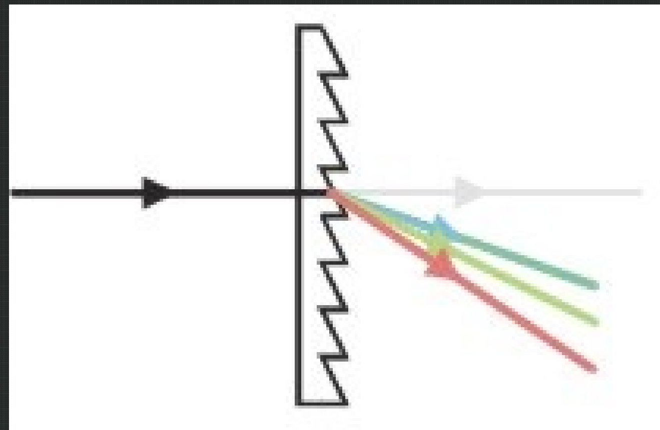
X-ray absorbed by atmosphere -> space borne instruments

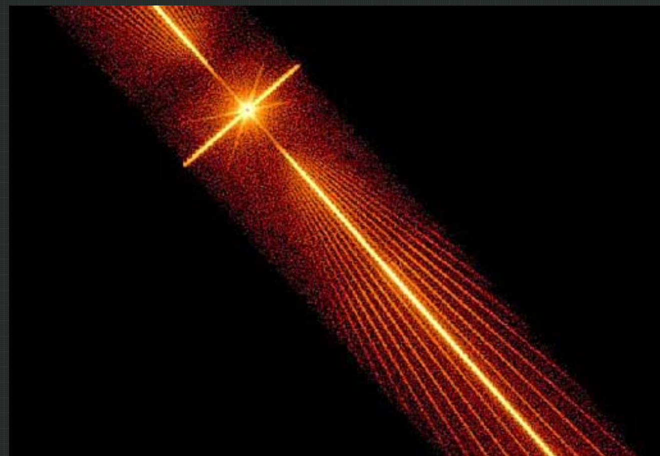
Chandra and XMM imaging spectrographs only sensitive down to 0.3 keV

BUT Chandra carries an imaging instrument sensitive down to 0.07 keV, which unfortunately can't do spectra...

Unless combined with a grating:

- Separate wavelengths -> resolution of 0.005 keV for point sources
- Extended sources reduces resolution (line broadening)
- All information on origin of photon is lost
- Requires bright sources





Observations of NGC3227

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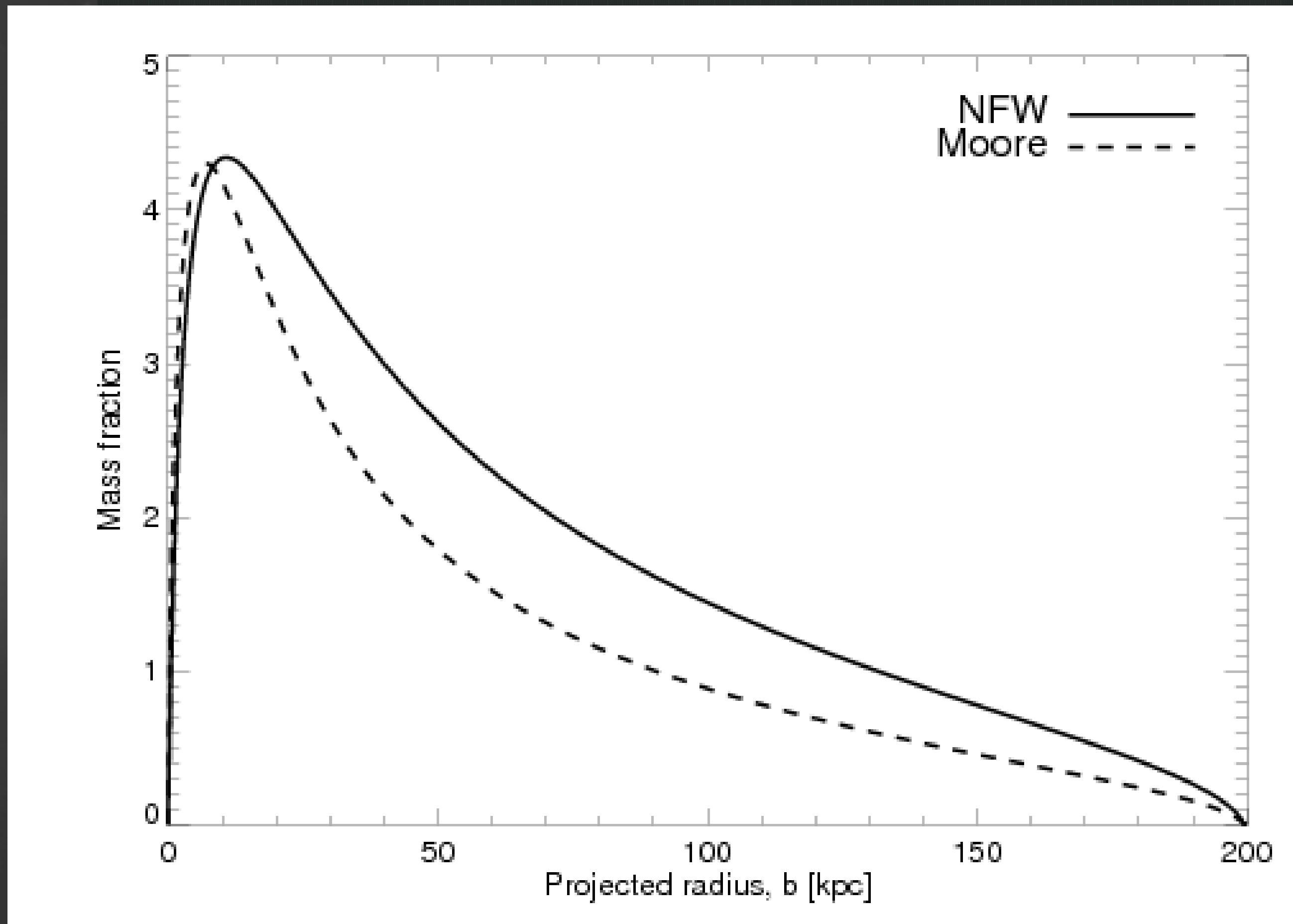
NGC3227 is Seyfert 1 galaxy at z=0.004

Typical mass of ~10^{11}-10^{12} M_{sun}, 1/10 in field of view, approx. 80% dark matter



Observed flux

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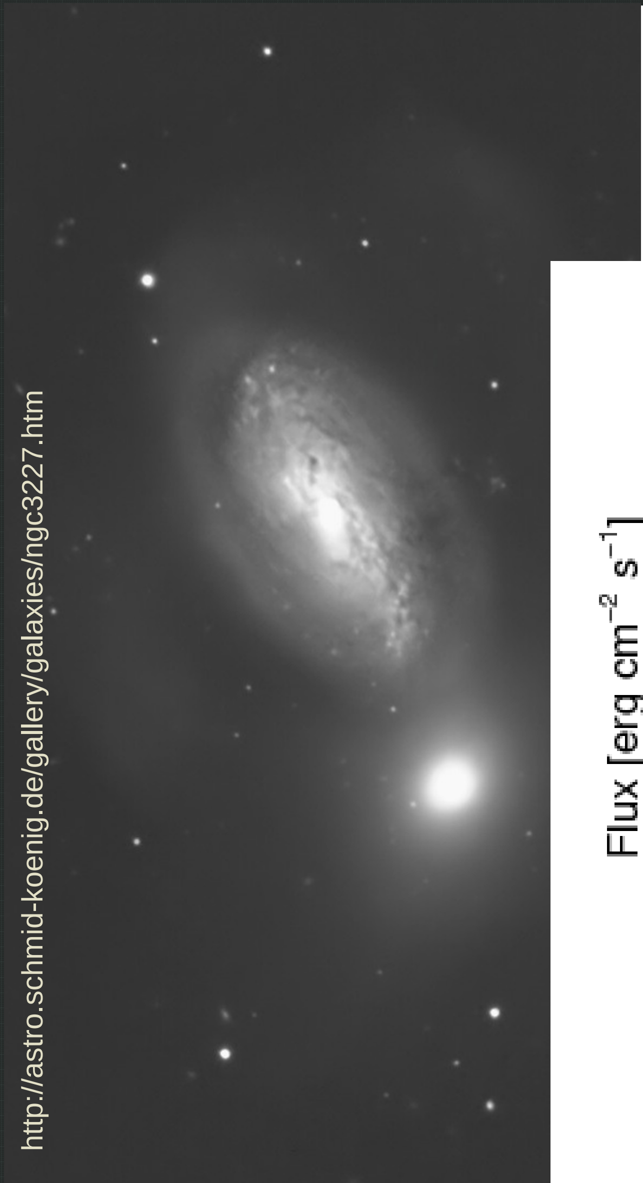

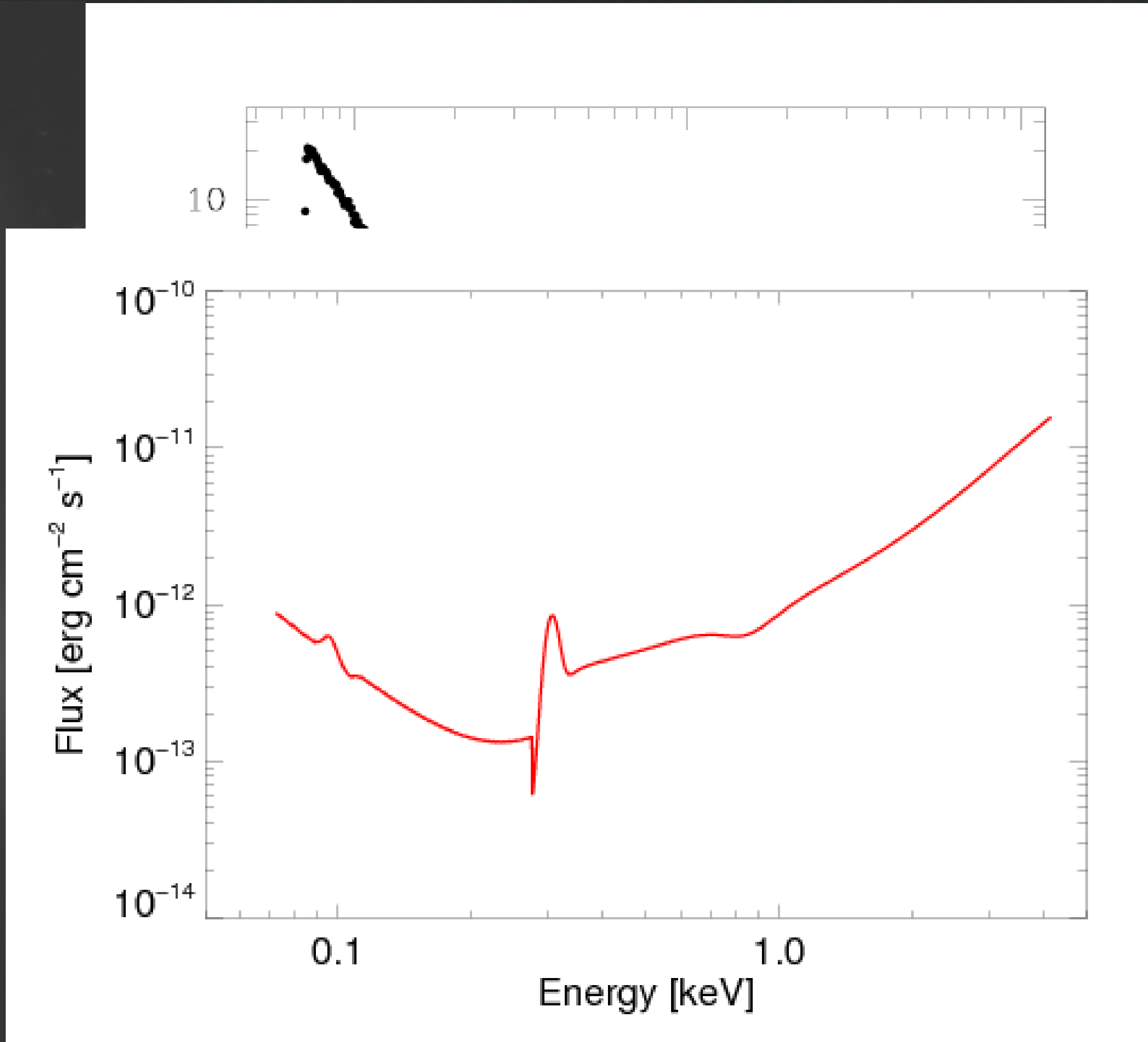

Constraints on decay rate

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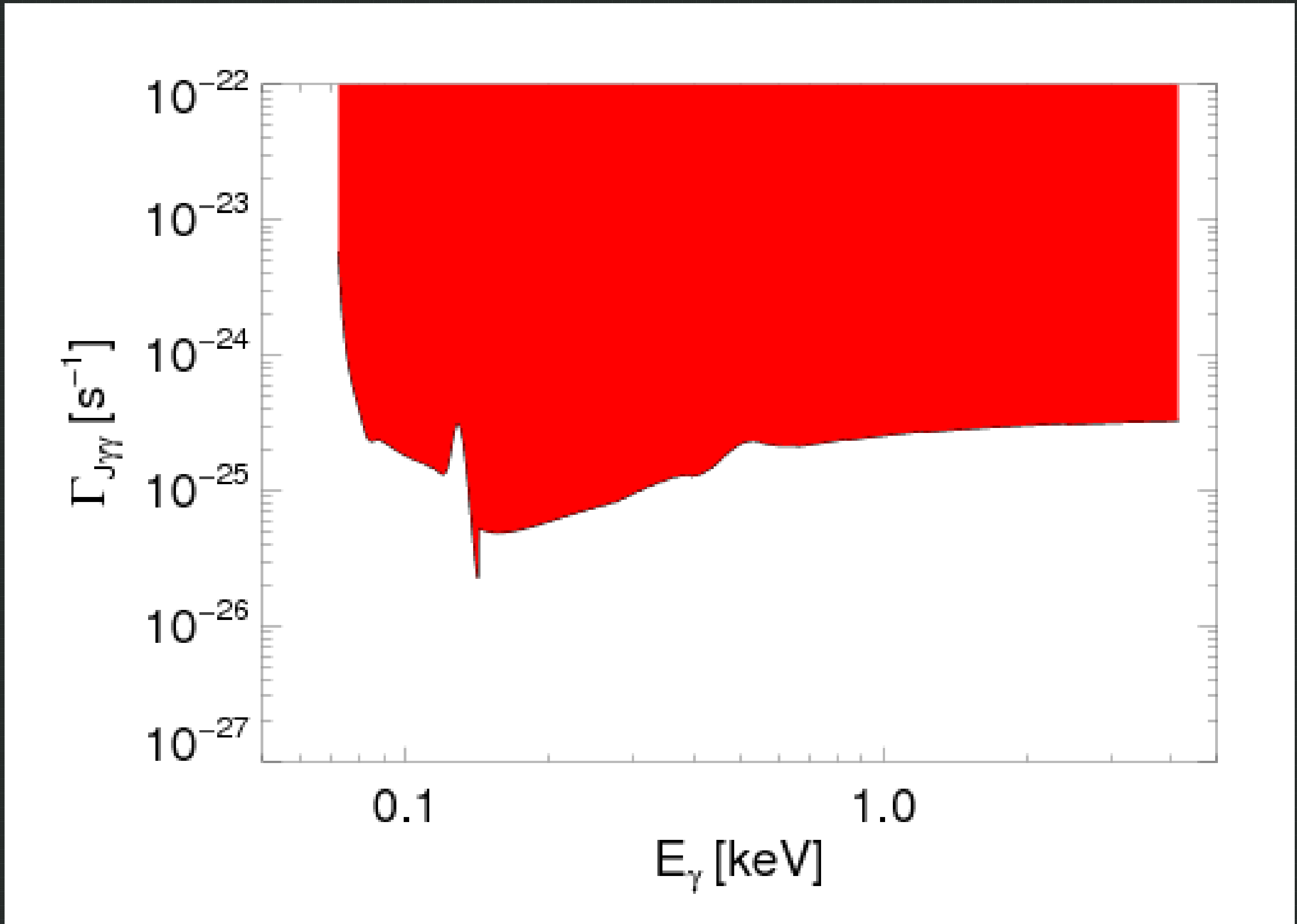
$\Gamma_{J\gamma\gamma} < 10^{-24}\ s^{-1}$ consistent with $\Gamma_{J\gamma\gamma} << \Gamma_{J\nu\nu} < 1.3\cdot10^{-19}\ s^{-1}$

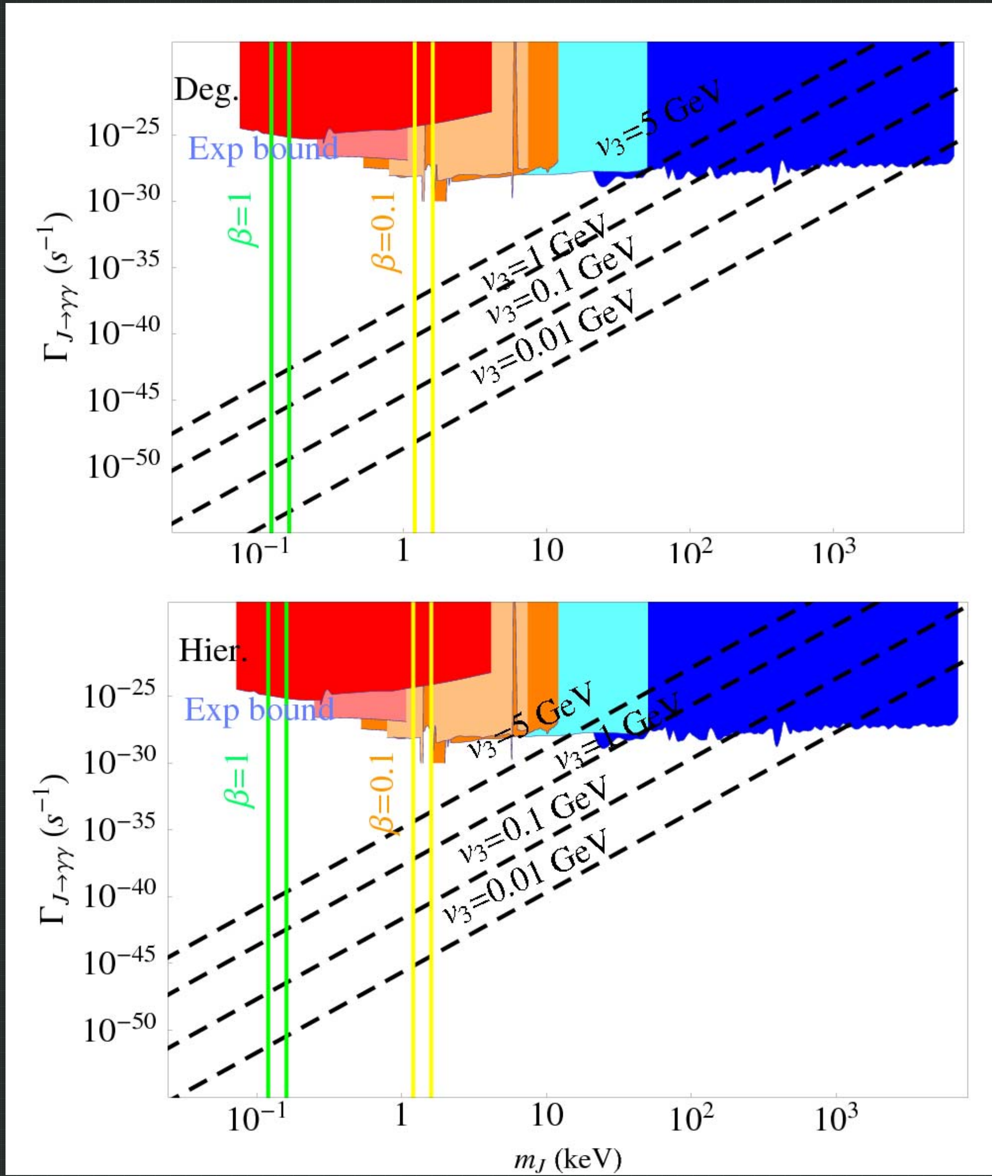


Relaxing assumptions

CMB constraints:

0.11 keV < βm_J < 0.18 keV

Relaxing assumptions about thermal equilibrium and early decoupling switches the relevant mass scale (change β)



Boyarsky et al. (2007) Astropart. Phys. 28, 303 (salmon), Boyarsky et al. (2007) Astron. Astrophys. 471, 51 (sand), Boyarsky et al. (2008) Astrophys. J. 673, 752 & Boyarsky et al. (2007), arXiv:0709.2301 (orange), Boyarsky et al. (2006) MNRAS 370, 213 & Boyarsky et al. (2006) Phys. Rev. Lett. 97, 261302 (aquamarine), Boyarsky et al. (2007) arXiv:0710.4922 (blue)

Which constraint is stronger

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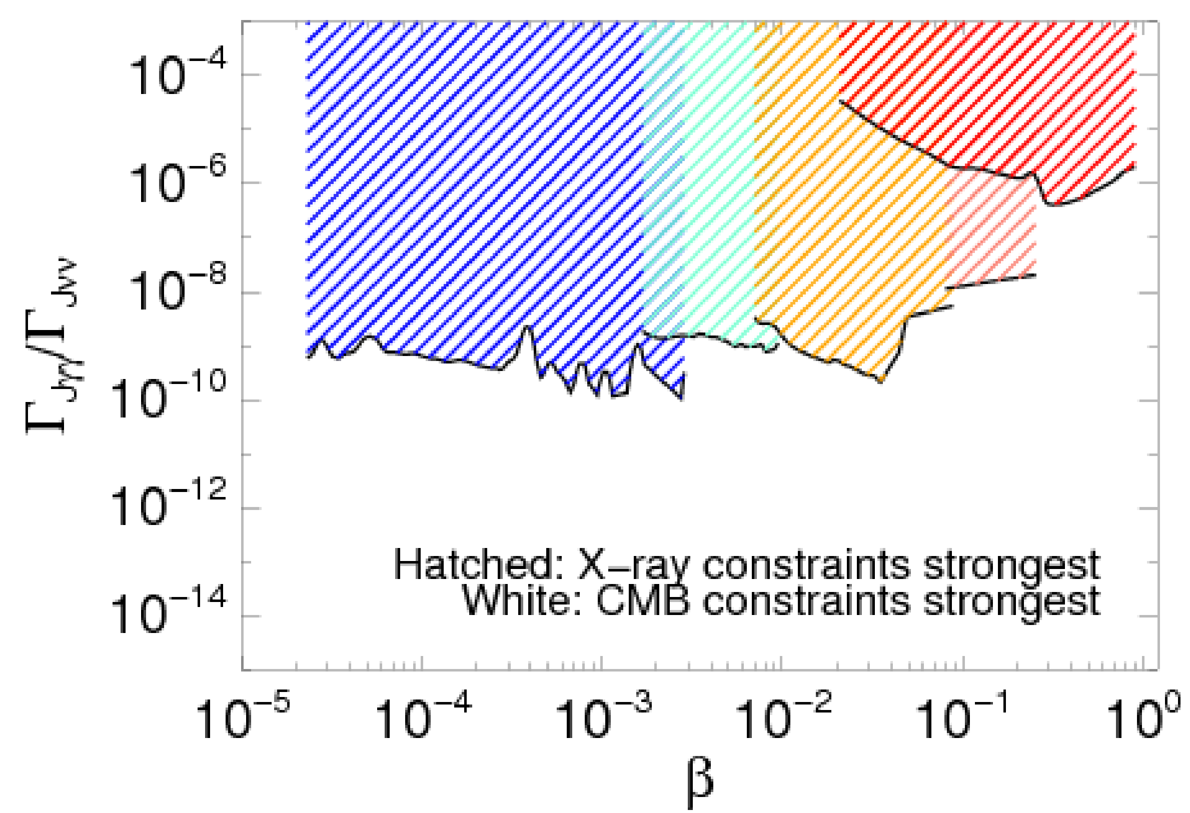
Depends on branching ratio and β



General constraint

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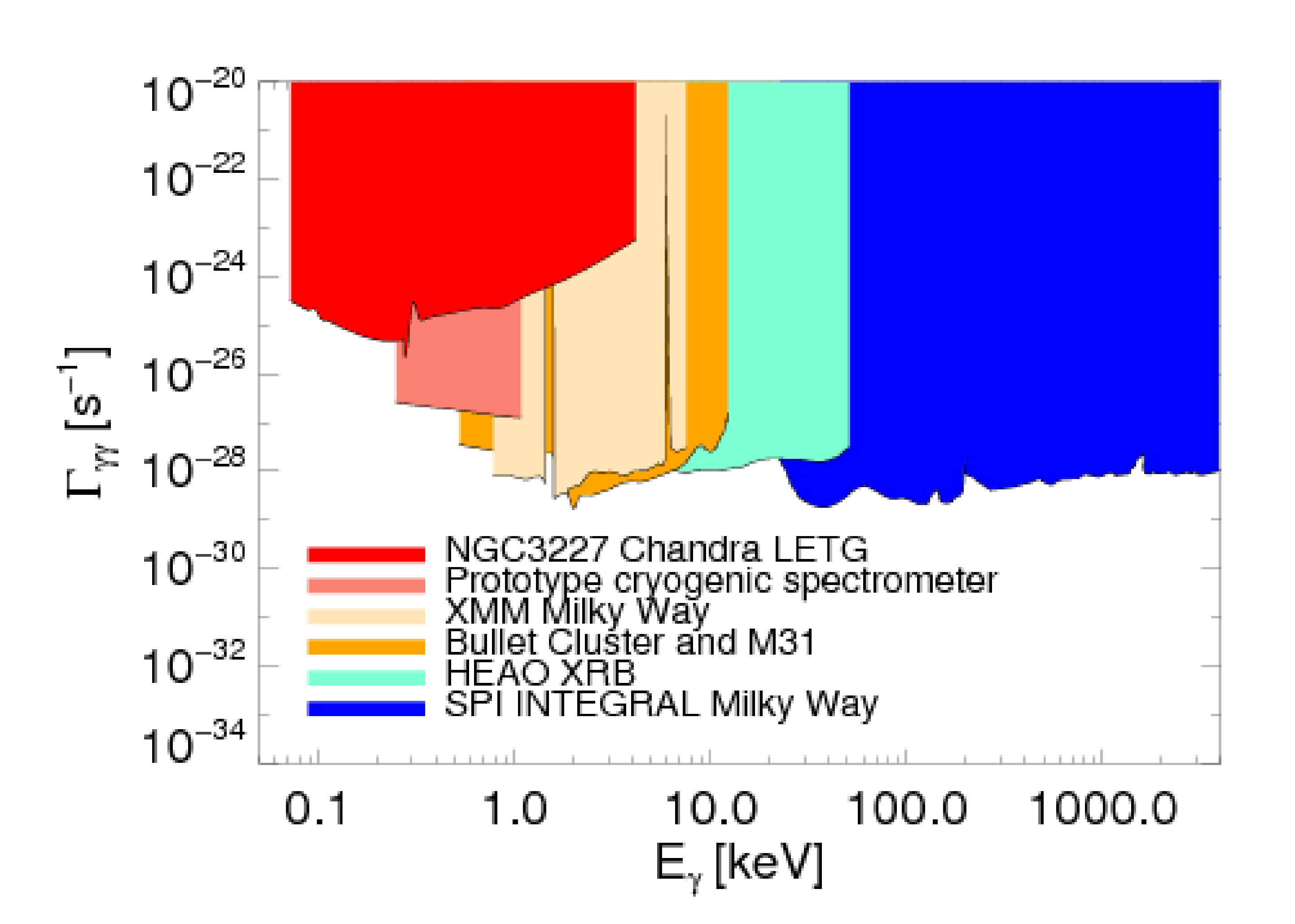

Applies also to your favorite candidate!

Boyarsky et al. (2007) Astropart. Phys. 28, 303 (salmon), Boyarsky et al. (2007) Astron. Astrophys. 471, 51 (sand), Boyarsky et al. (2008) Astrophys. J. 673, 752 & Boyarsky et al. (2007), arXiv:0709.2301 (orange), Boyarsky et al. (2006) MNRAS 370, 213 & Boyarsky et al. (2006) Phys. Rev. Lett. 97, 261302 (aquamarine), Boyarsky et al. (2007) arXiv:0710.4922 (blue)

Resumé

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- Majorons from lepton number violation might be massive -> DM candidate

- Late integrated Sachse-Wolfe effect points towards ~0.15 keV mass

- Observationally constrained decayrate - unfortunately far from sensitivity needed to constrain models

- Wide range of observations - applies to all dark matter candidates with a two-body radiative decay