An Unidentified X-ray Line in Andromeda and Perseus

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DETECTION OF AN UNIDENTIFIED LINE

An unidentified line in X-ray spectra of the Andromeda galaxy and Perseus galaxy cluster

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

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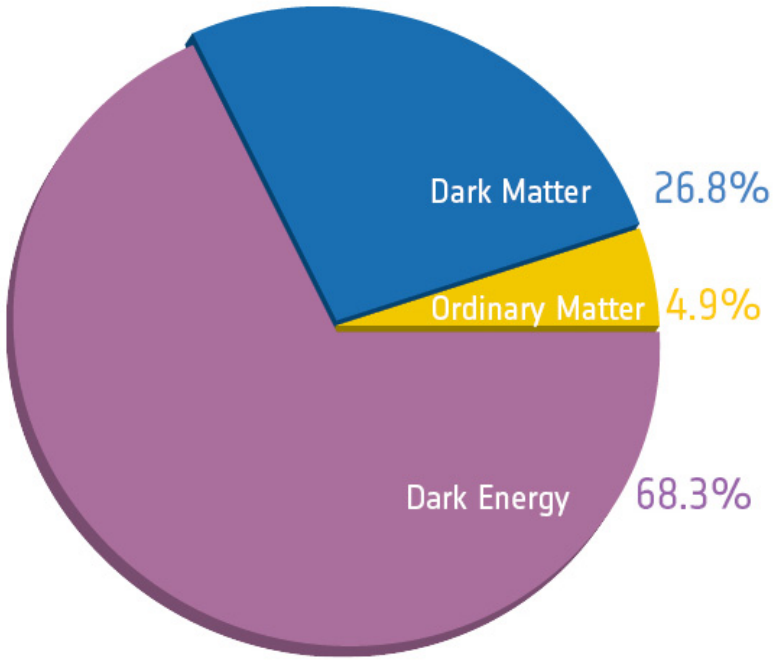
Submitted to ApJ, 2014 February 10

Dark Matter

Contents of the Universe



source: Planck Collaboration

Dark Matter

STANDARD MODEL OF PARTICLE PHYSICS

There are no Dark Matter candidates in the Standard Model.

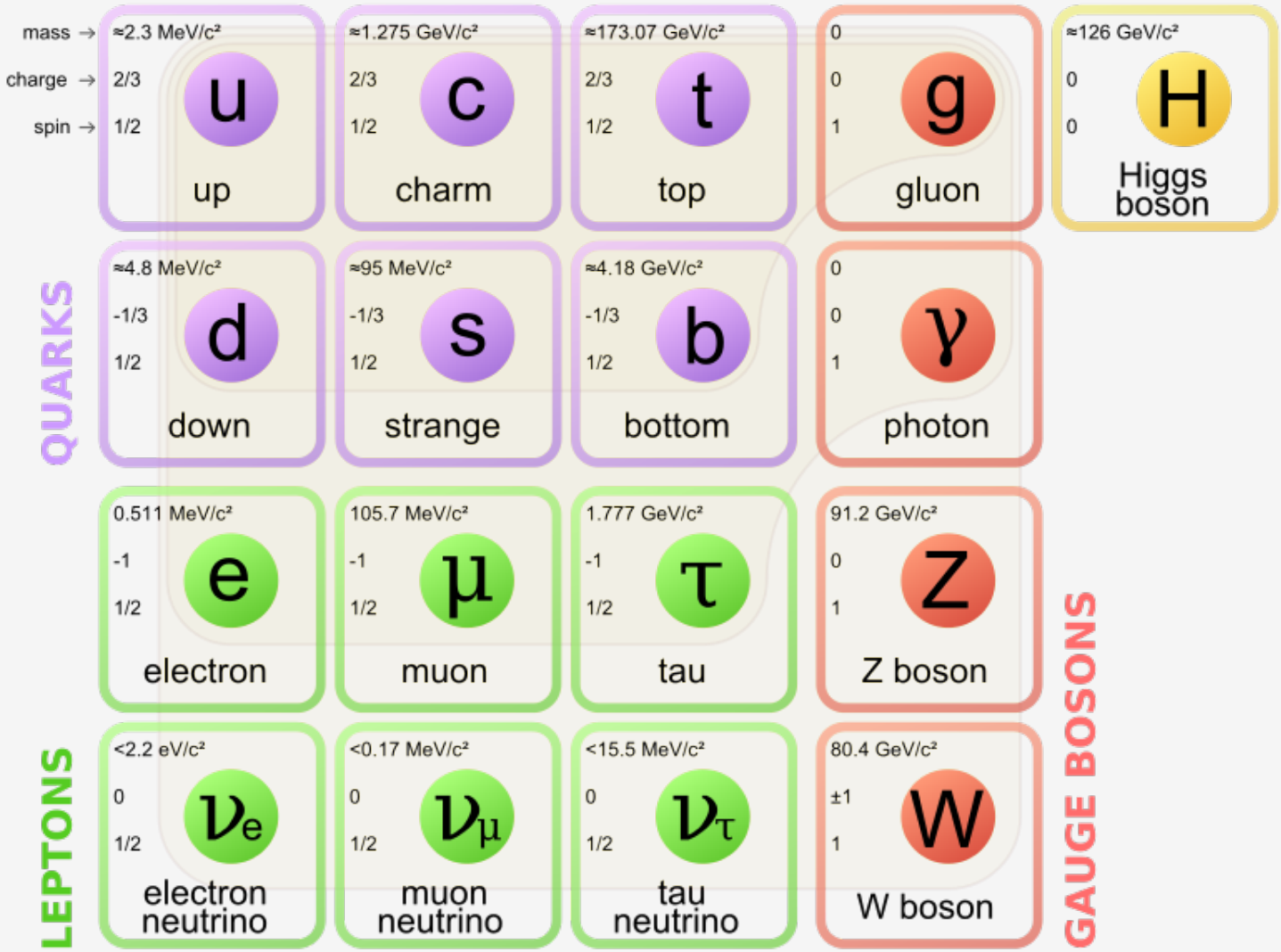


image: wikipedia

Standard Model of Particle Physics

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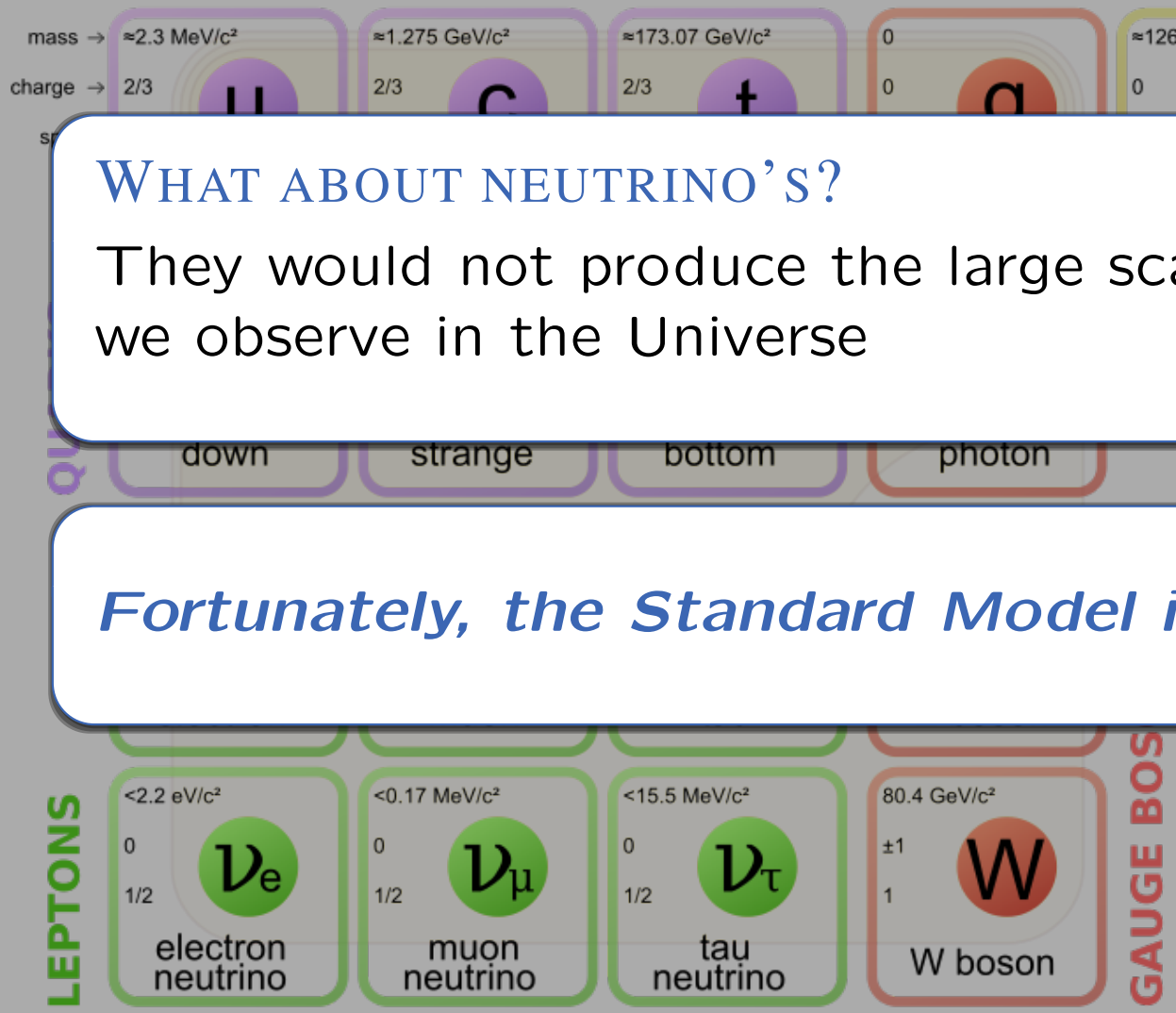


What about neutrino's?

They would not produce the large scale structure that we observe in the Universe

Fortunately, the Standard Model is not complete

image: wikipedia

Candidate: WIMP

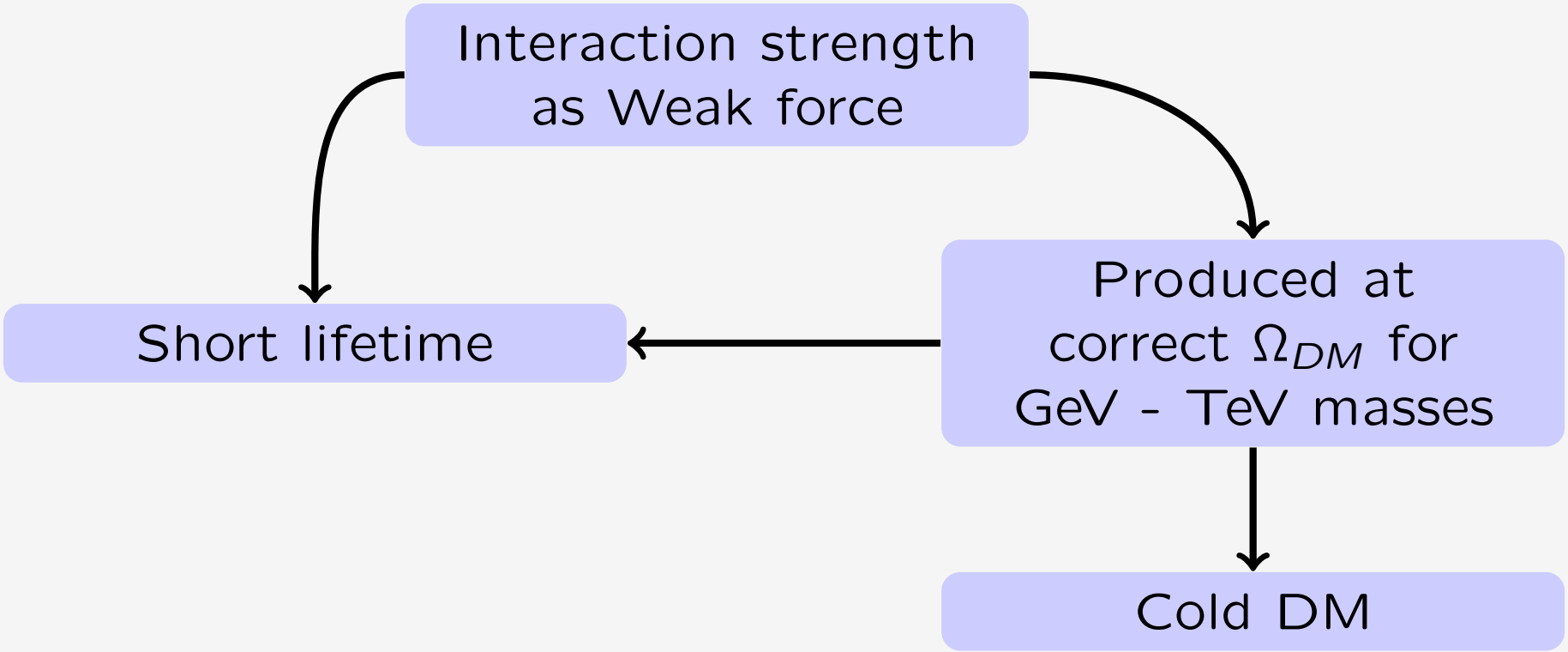
Weakly Interacting Massive Particle

Interaction strength as Weak force

Produced at correct Ω_{DM} for GeV - TeV masses

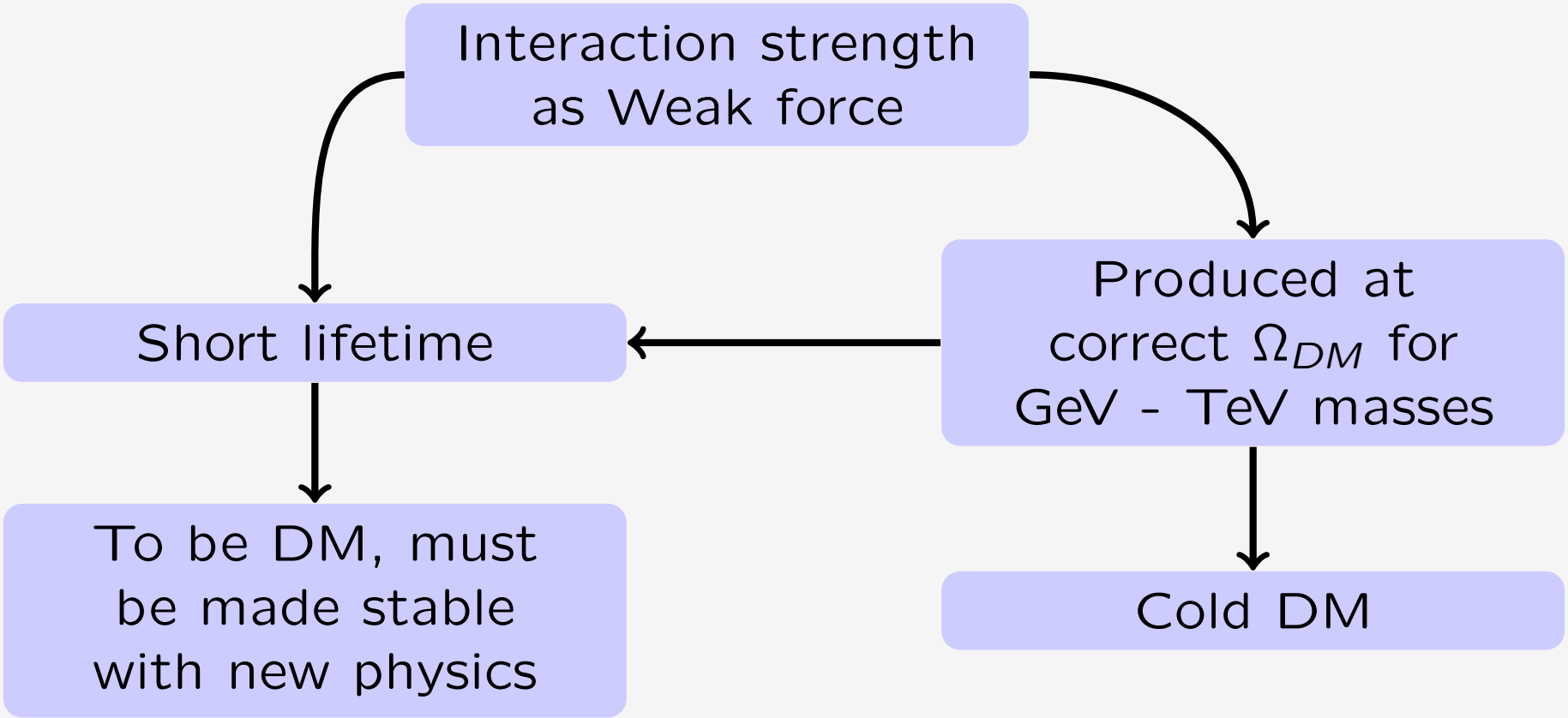
Candidate: WIMP

Weakly Interacting Massive Particle



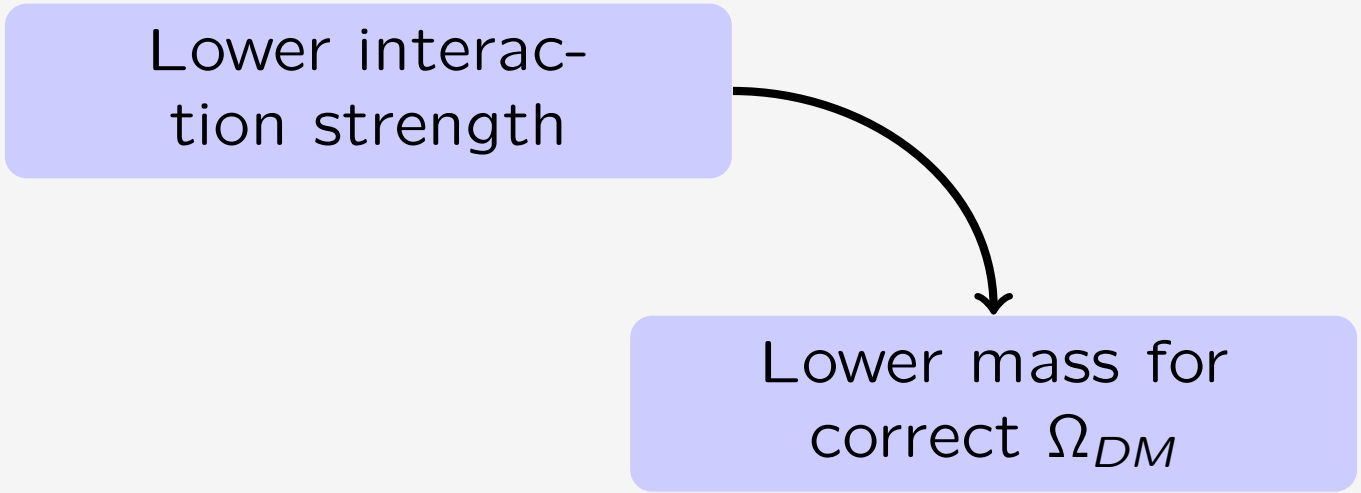
Candidate: WIMP

Weakly Interacting Massive Particle



Candidate: SuperWIMP

Super-Weakly Interacting Massive Particle



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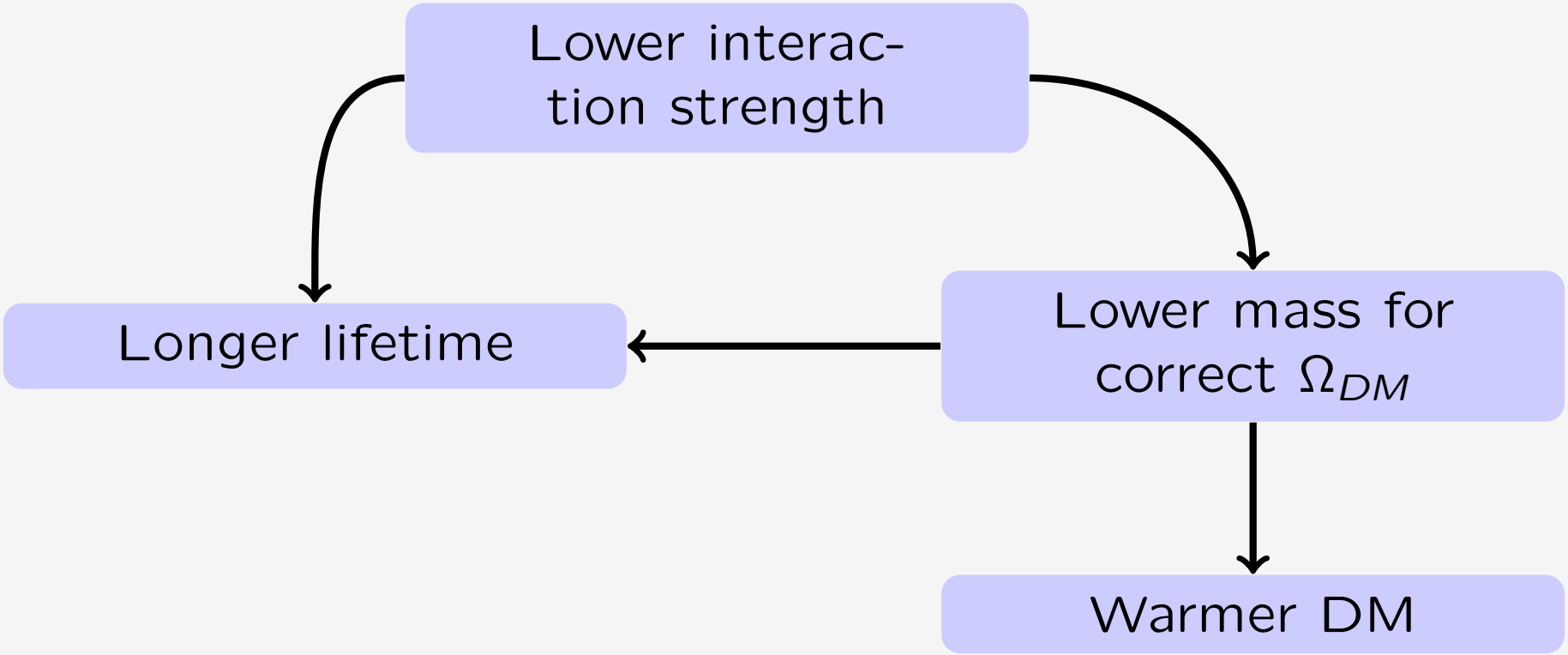

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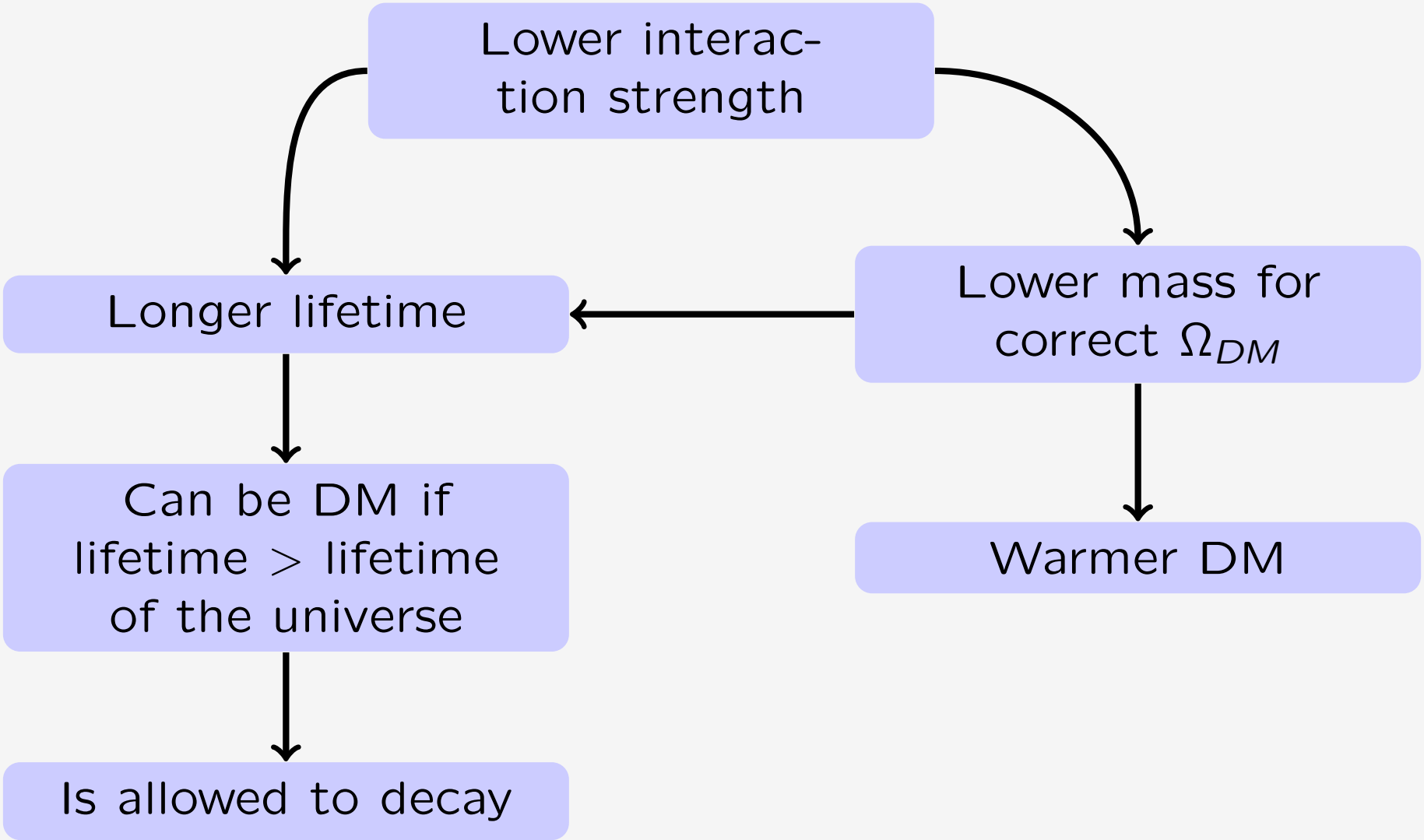
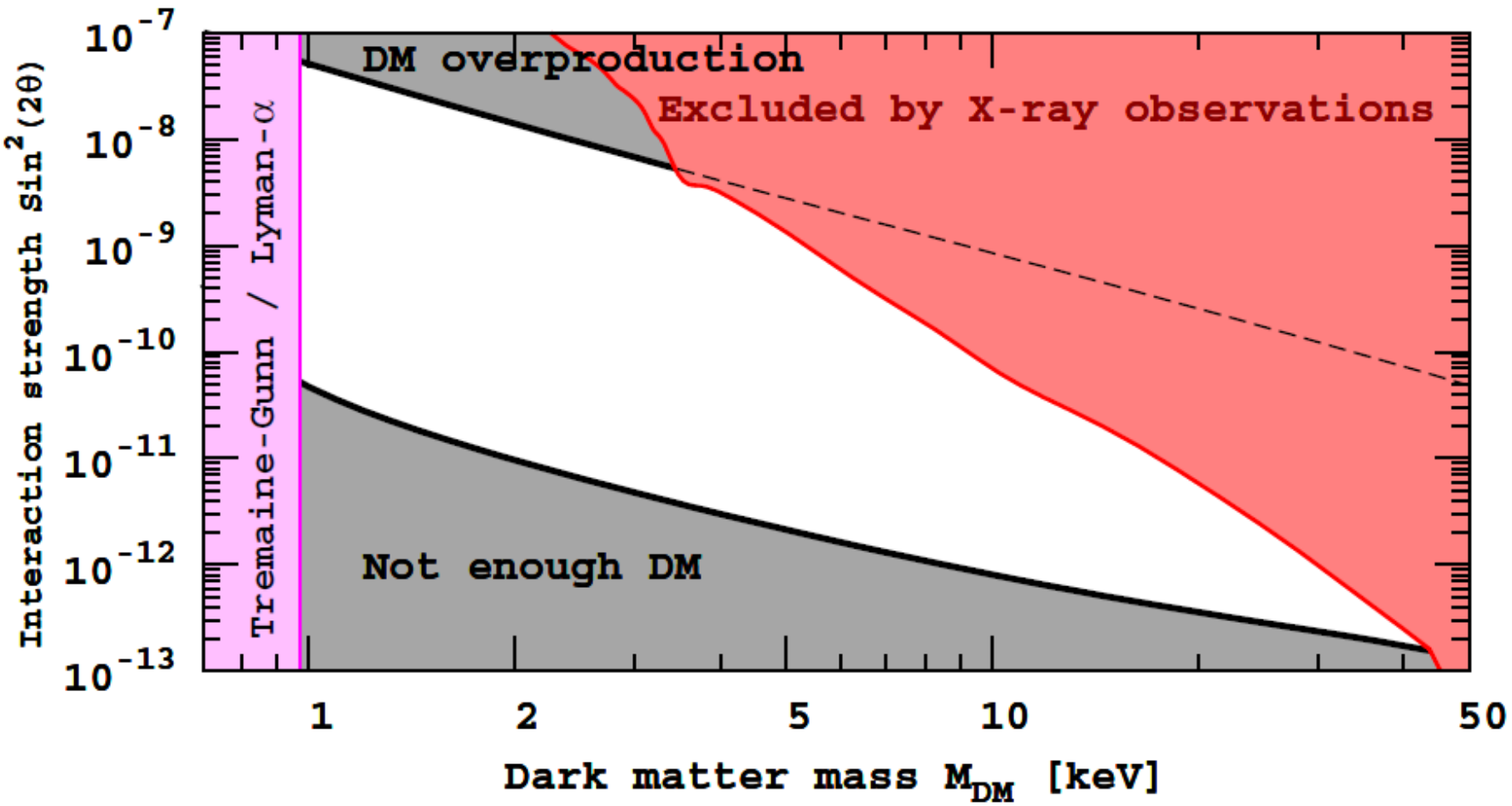


SuperWIMPs in X-Rays

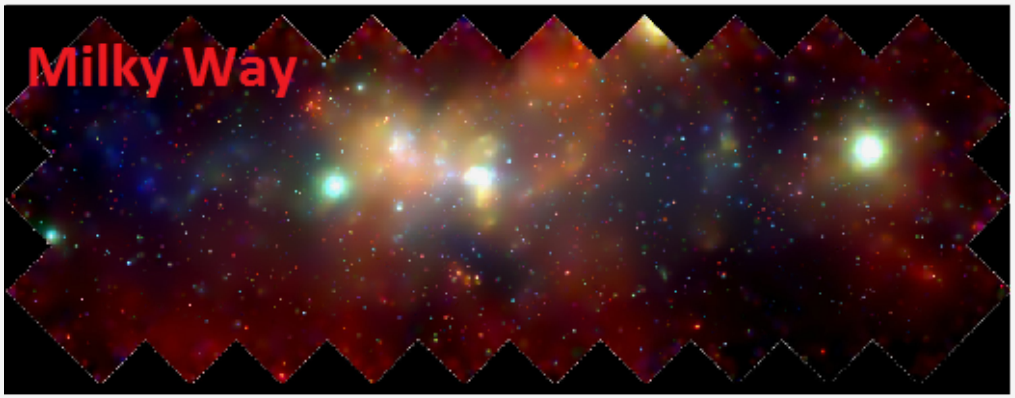
Decaying dark matter should decay into X-rays

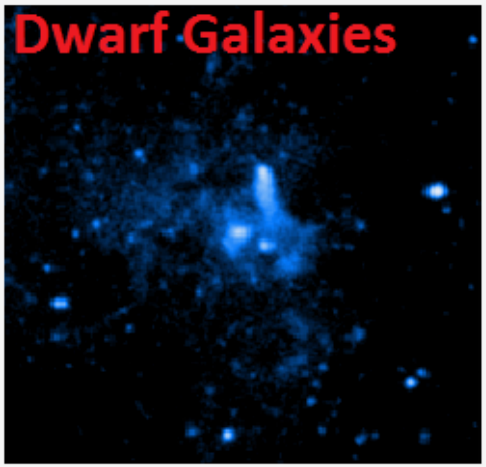


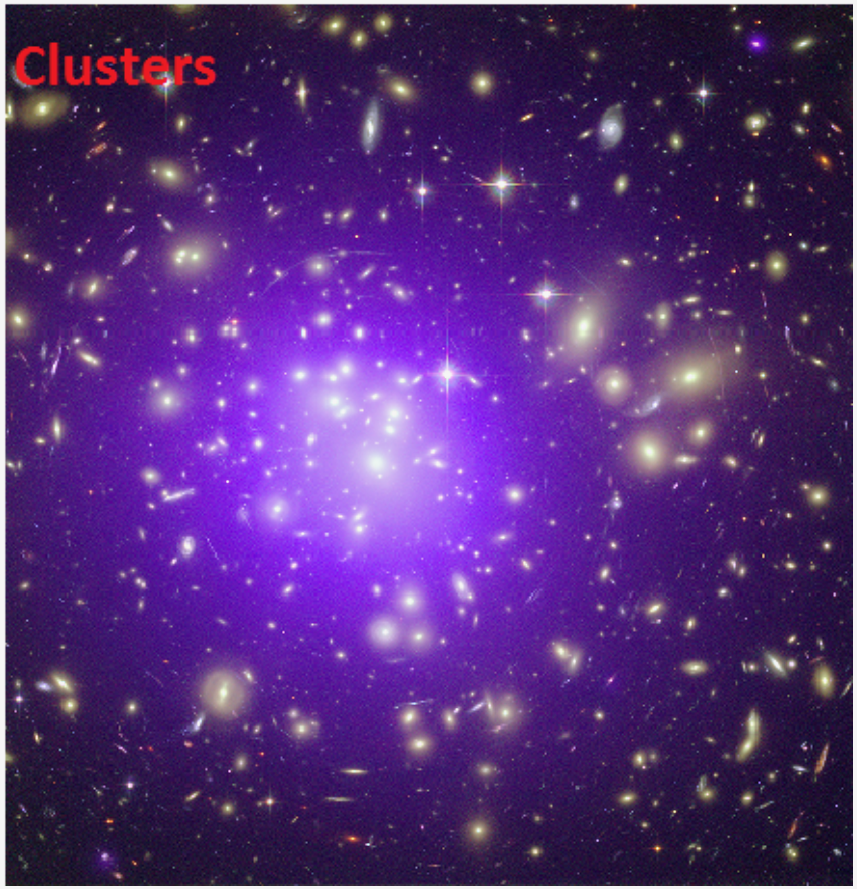
Potential Target Sources

Dark matter dominated objects. Specifically, sources with high expected decay signal strength

$$\text{signal} \propto \text{DM mass in FoV} \;/\; \text{distance}^2$$

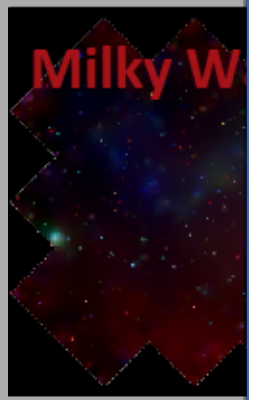


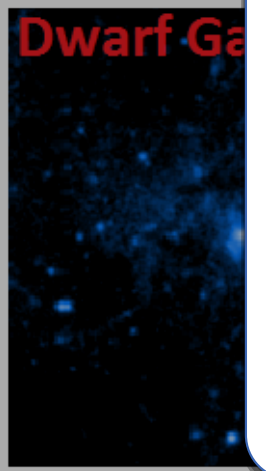


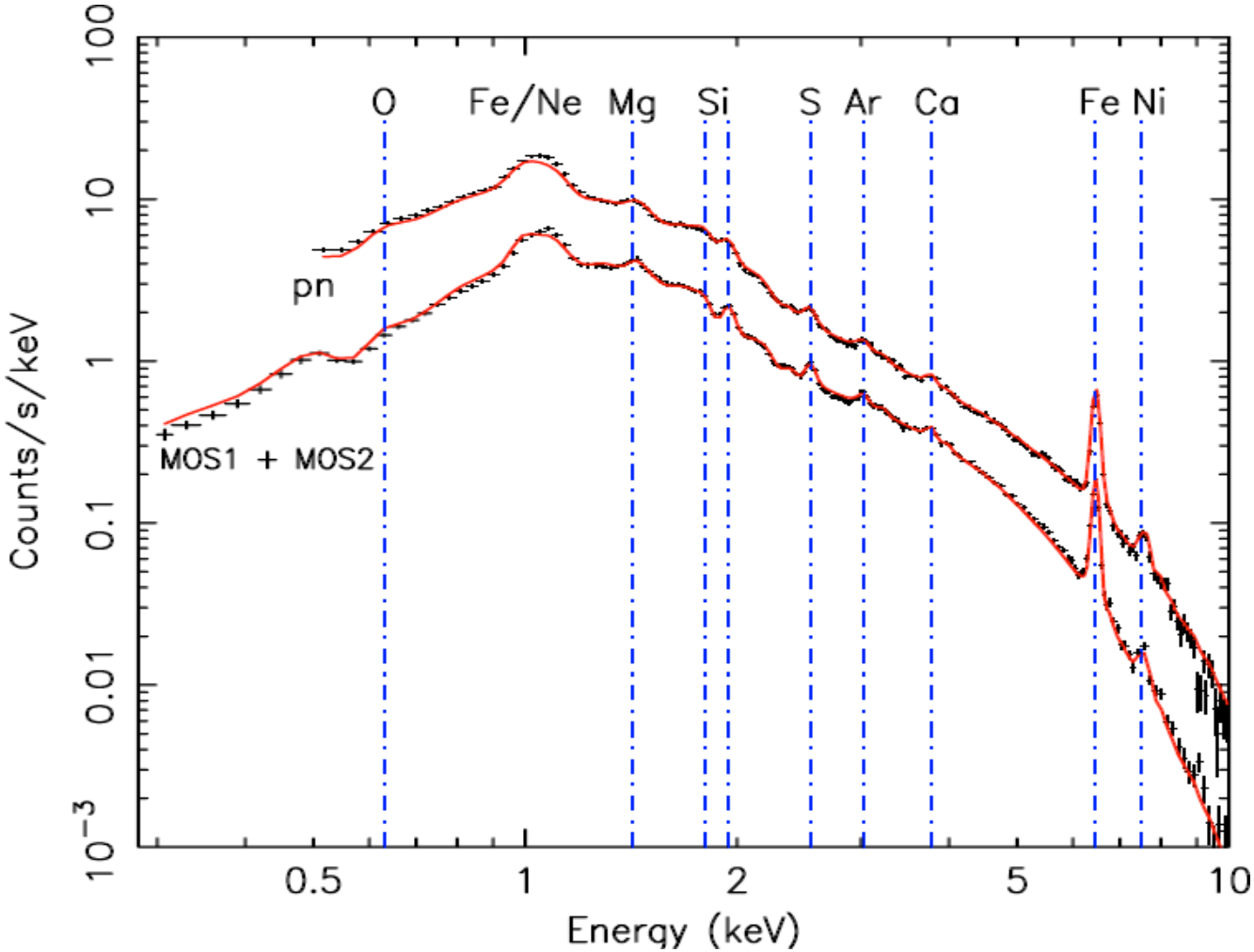


Potential Target Sources

Dark m… …with high exp…



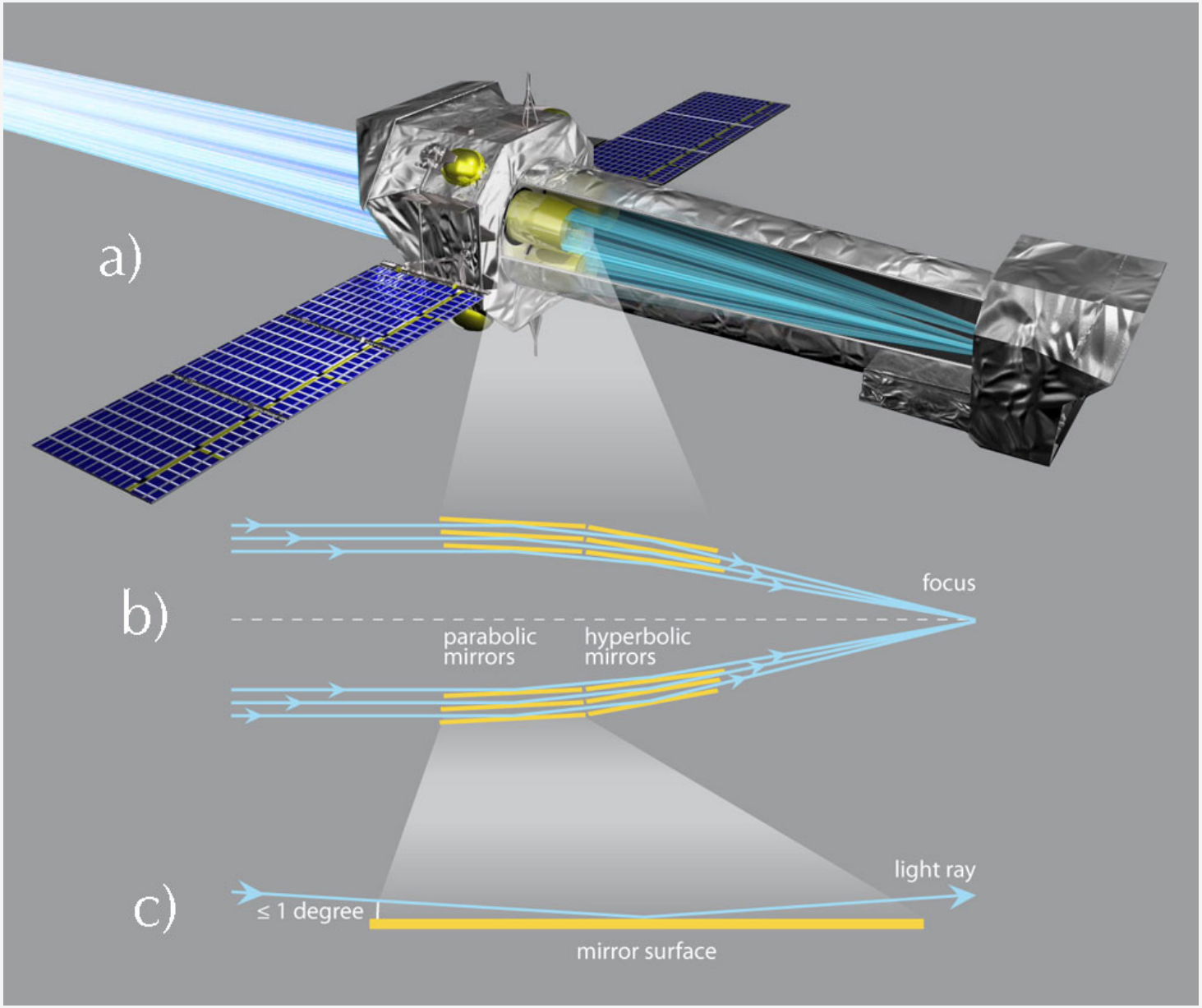




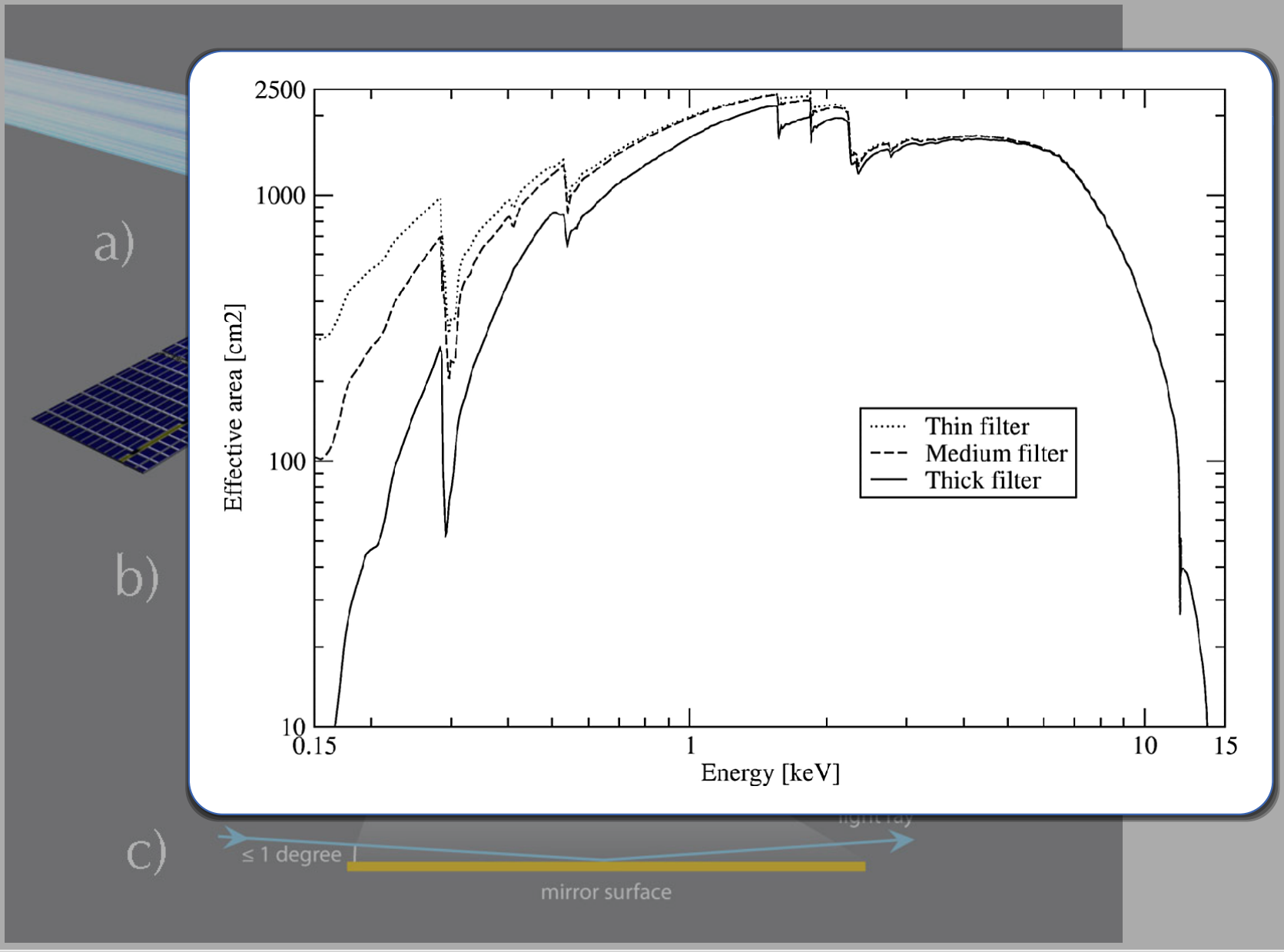
Typical cluster spectrum

Werner et al. 2006

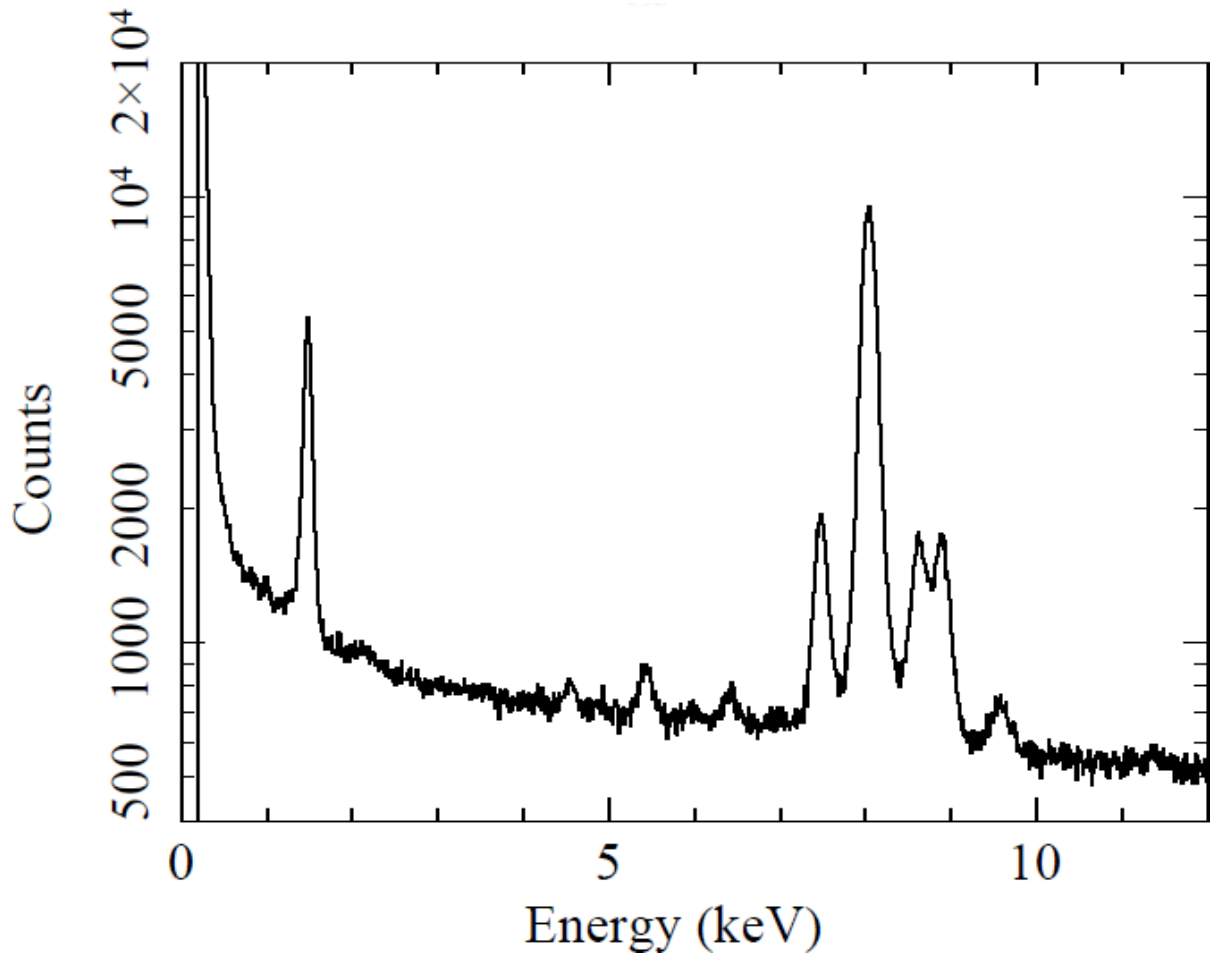
Mirrors & Effective Area



Mirrors & Effective Area



Instrumental Background



XMM-Newton's "dark exposure" spectrum.

Data

Our Data

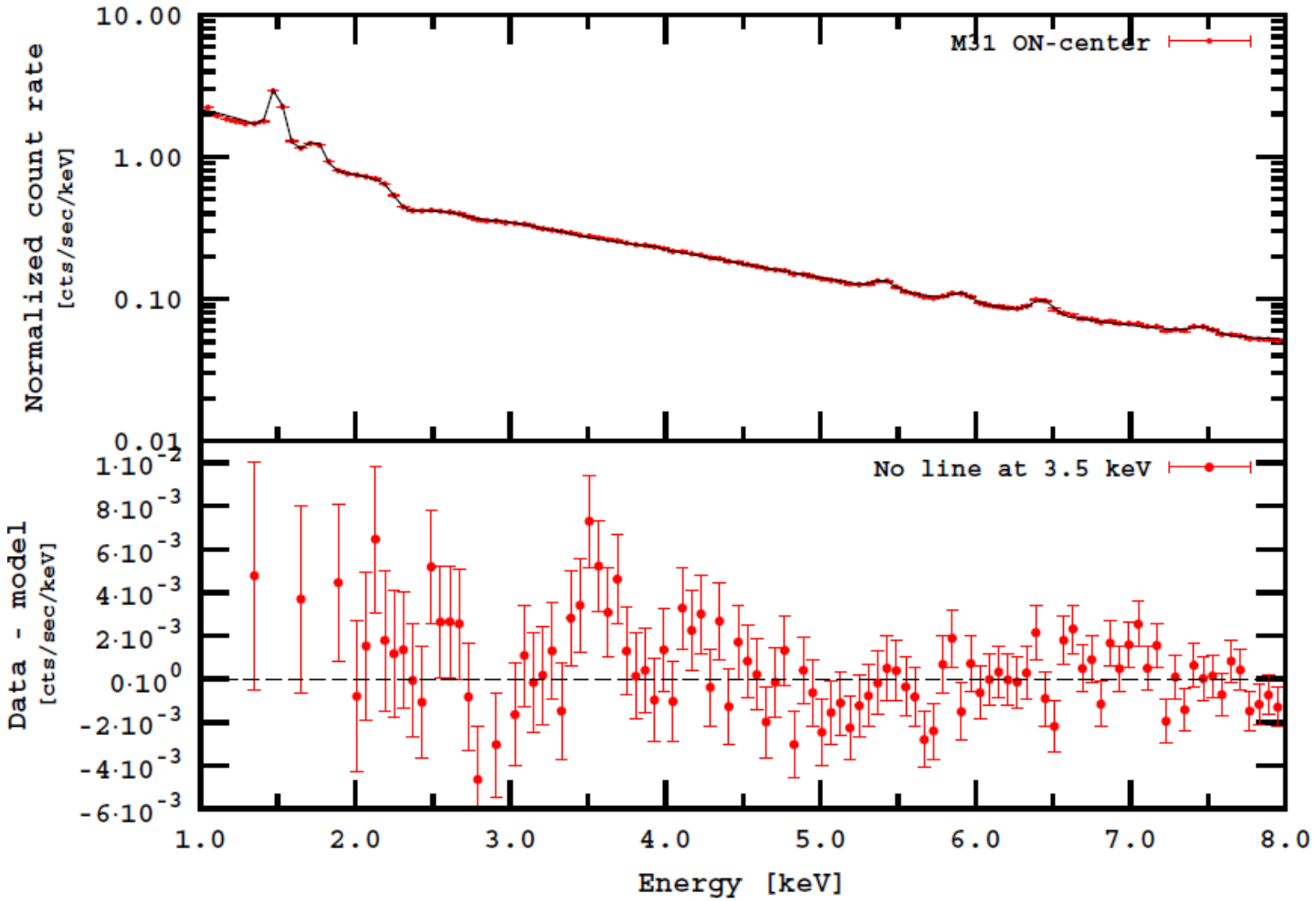
M31 galaxy	XMM-Newton, center & outskirts
Perseus cluster	XMM-Newton, outskirts only
Blank sky	XMM-Newton

Bulbul et al. 2014

73 clusters	XMM-Newton, centers only Up to $z = 0.4$, including Coma, Perseus
Perseus cluster	Chandra, center only
Virgo cluster	Chandra, center only

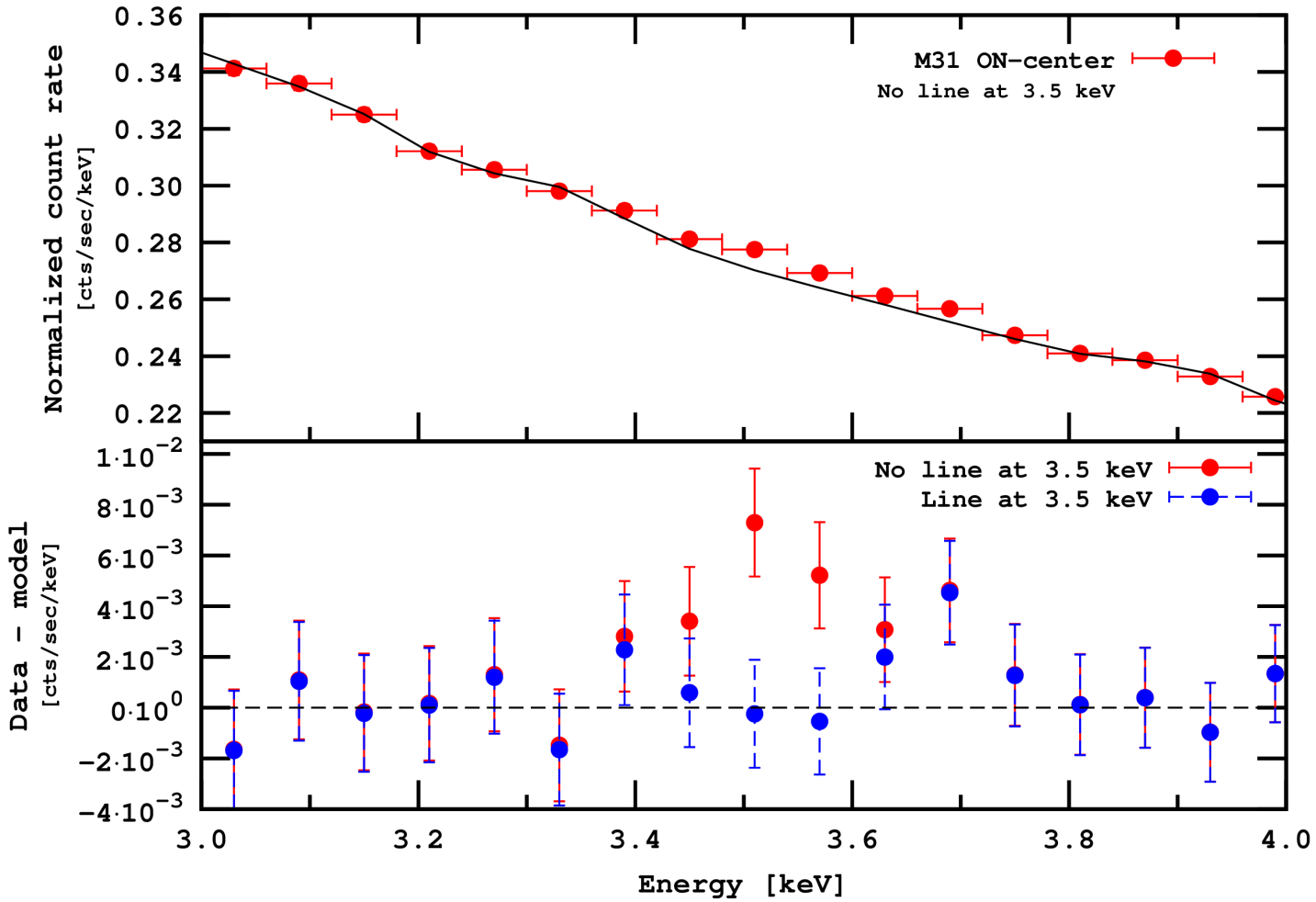
DETECTION AT $E \sim 3.5$ KEV

Andromeda (M31)



DETECTION AT $E \sim 3.5$ KEV

Andromeda (M31) zoom-in of 3 – 4 keV



Significances

Our Data

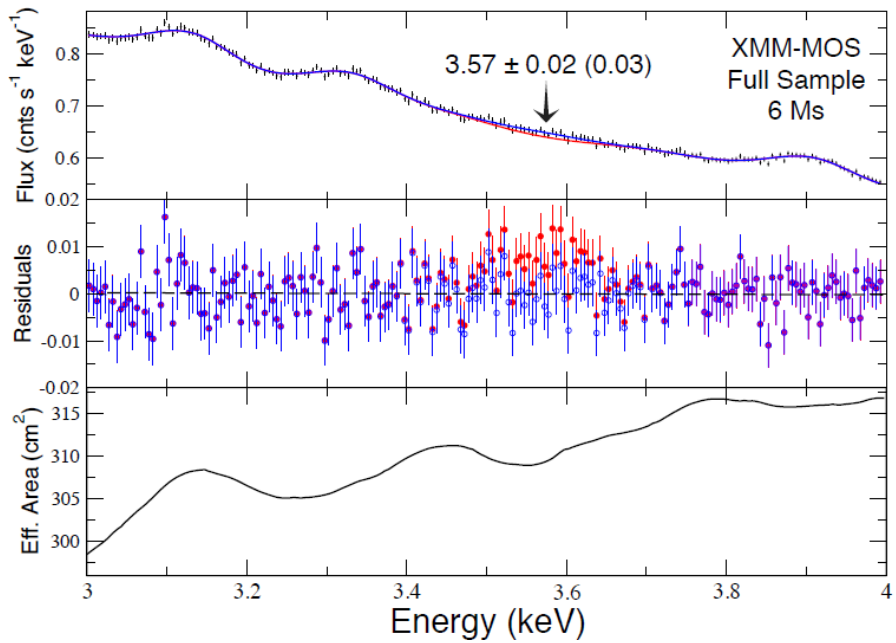
Perseus + M31	4.4σ
Blank sky	No detection

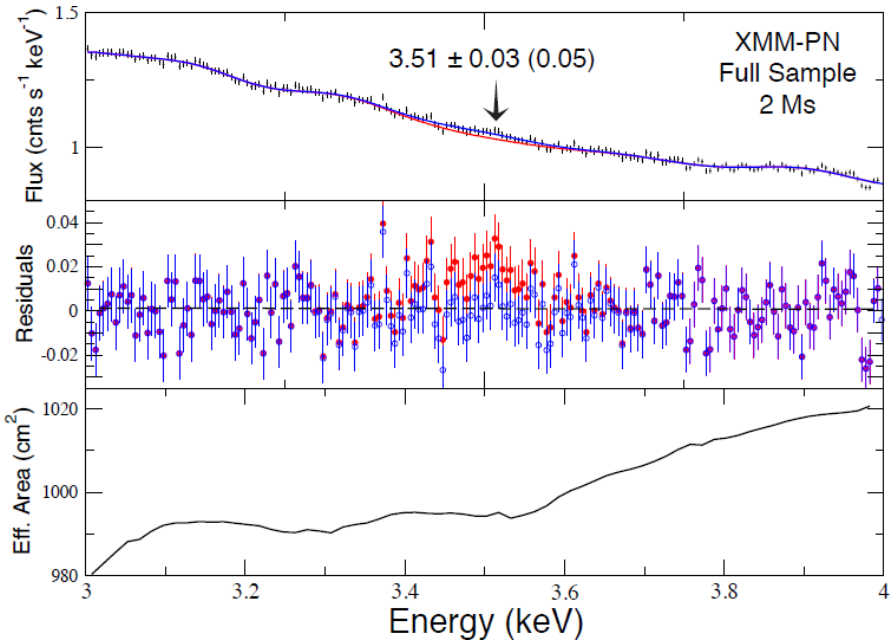
Bulbul et al. 2014

full MOS	$\sim 5\sigma$
full PN	$\sim 4\sigma$
Perseus ACIS-S	3.4σ
Perseus ACIS-I	2.5σ
Virgo ACIS-I	No detection

DETECTION AT $E \sim 3.5$ KEV

Bulbul et al. 2014 XMM full sample, MOS & PN cameras





Instrumental Origin?

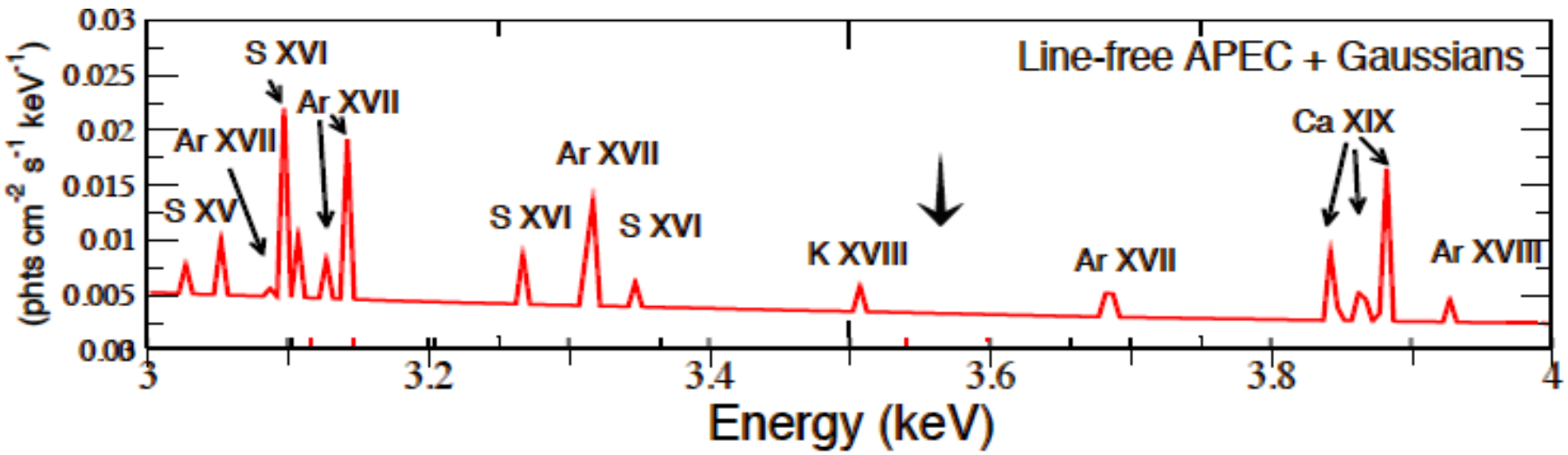
Instrumental origin unlikely

- Detected in 4 different detectors
- Line redshifts correctly with sources
- Not detected in blank sky dataset

More tests in future work

- More single objects at different redshifts
- Pure powerlaw objects (Supernova remnants, AGN)

ATOMIC LINE?

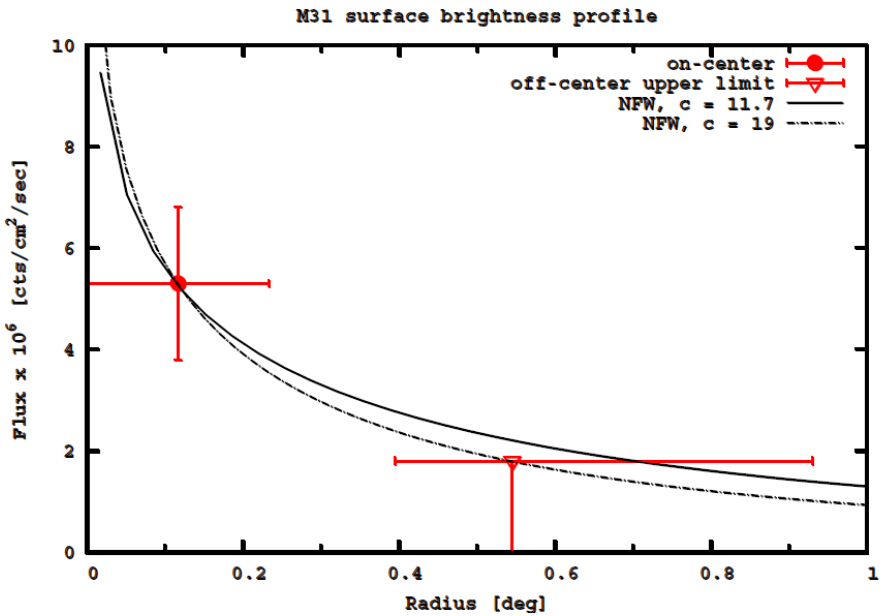


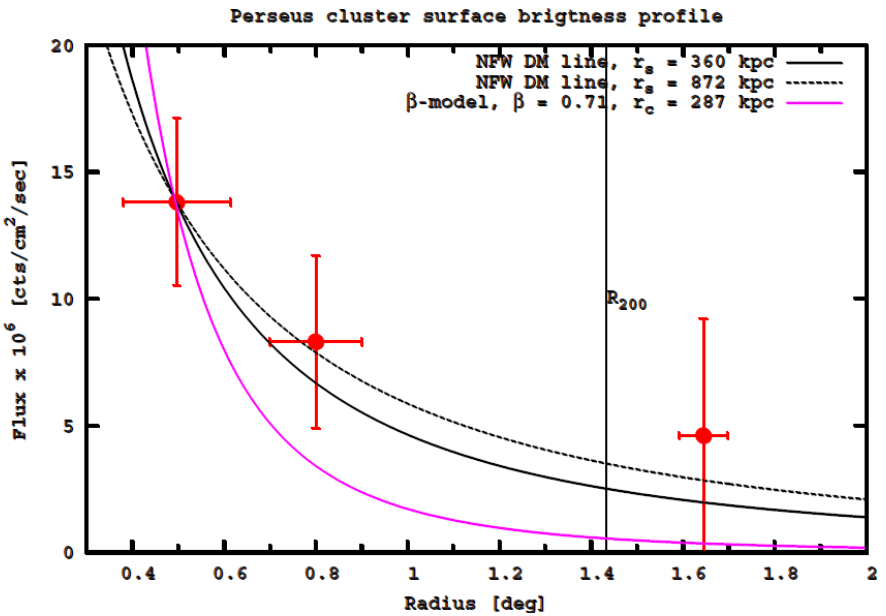
Bulbul et al. 2014

Unlikely: need anomalous line ratios of a factor $\sim 20-30$

DARK MATTER DECAY?

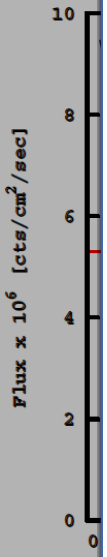
The line flux should be directly proportional to DM mass

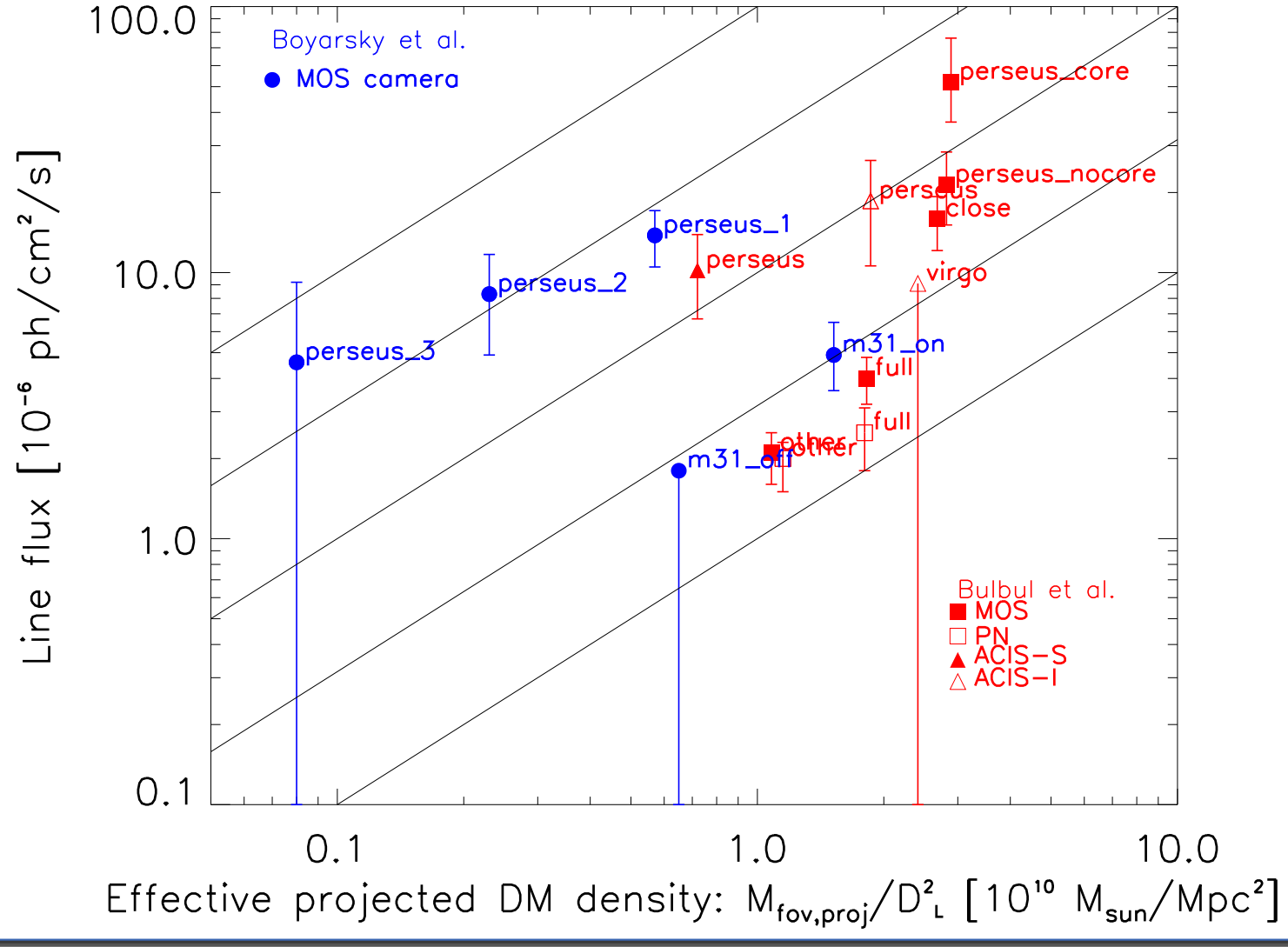


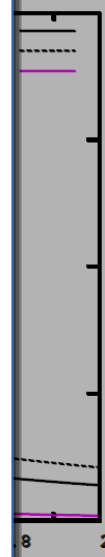


DARK MATTER DECAY?

The







What is Next?

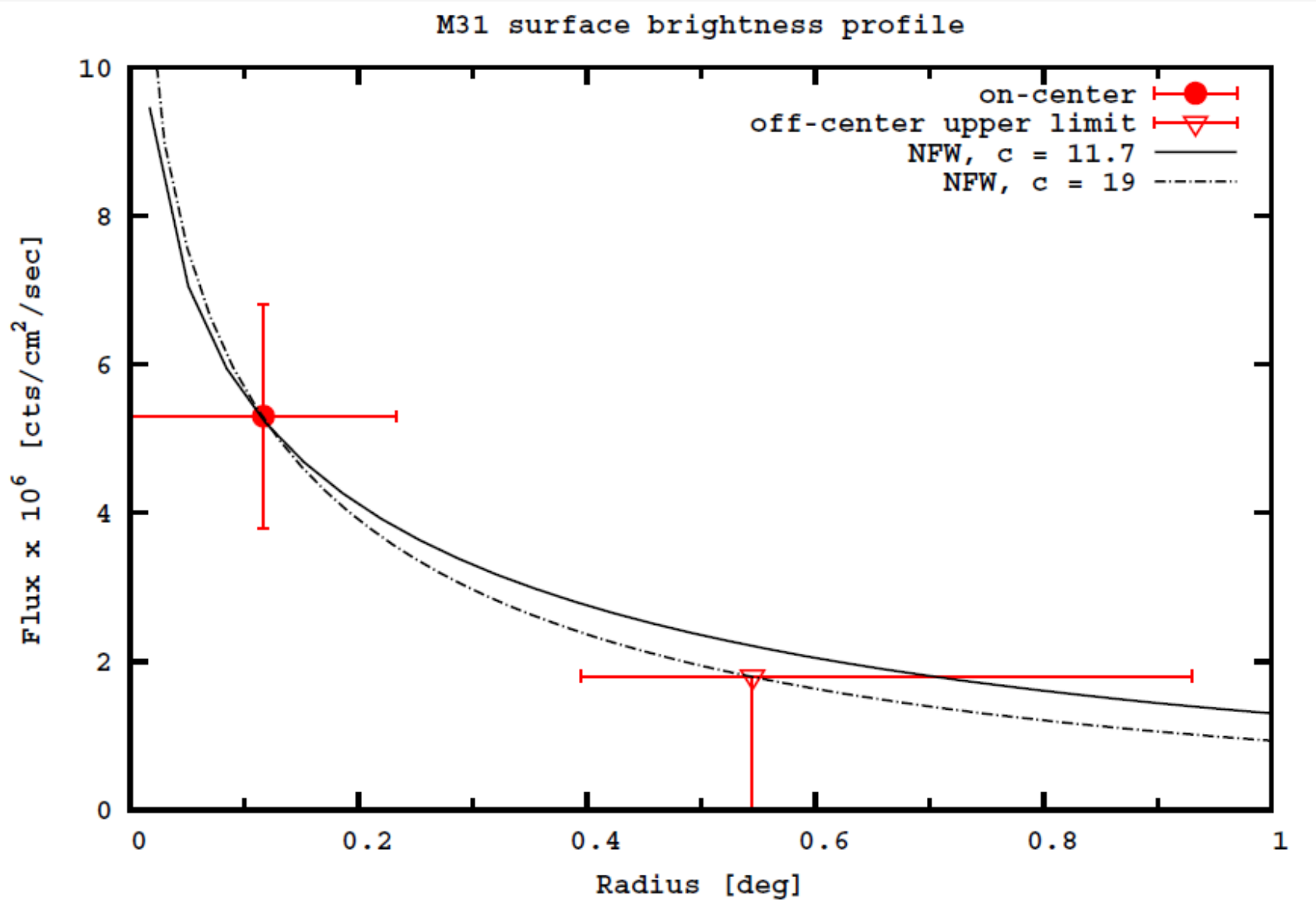
Current work

- Accurate and precise dark matter masses and profiles
- More archival data (GC, Abell 520, . . .)
- Cross-correlation of X-ray with dark matter maps
- Expected decay signal from cosmological simulations

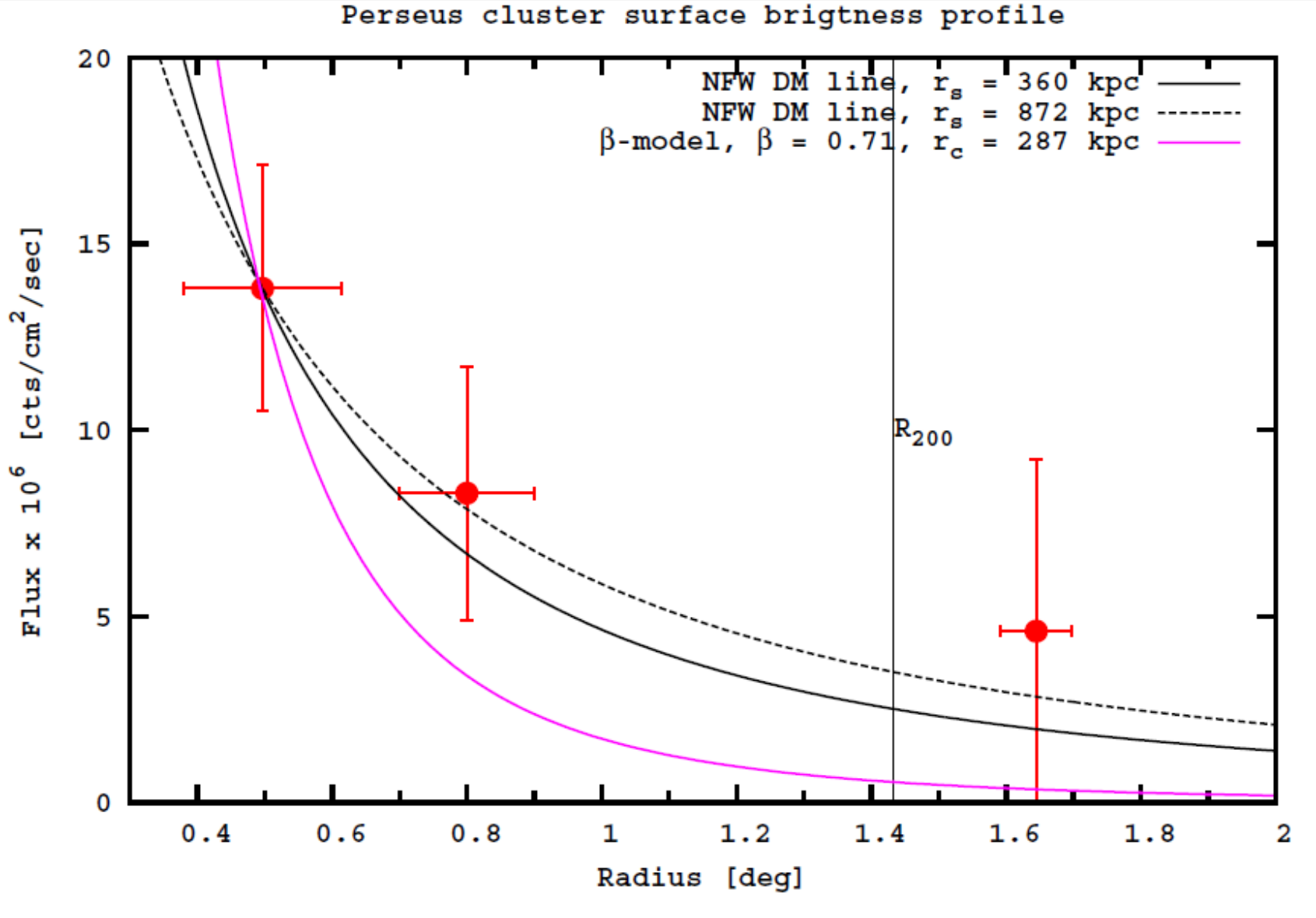
Future Work

- Spectrally resolve the line with *Astro-H* (2015)
  - measure velocity dispersion
  - distinguish from K and Ar lines

PROFILES


M31 surface brightness profile
on-center
off-center upper limit
NFW, c = 11.7
NFW, c = 19
Flux x 10^6 [cts/cm^2/sec]
Radius [deg]
0
2
4
6
8
10
0
0.2
0.4
0.6
0.8
1

PROFILES


Perseus cluster surface brigtness profile
NFW DM line, r_s = 360 kpc
NFW DM line, r_s = 872 kpc
β-model, β = 0.71, r_c = 287 kpc
R_{200}
Flux x 10^6 [cts/cm^2/sec]
Radius [deg]
0
5
10
15
20
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Parameter Space