Non-detection of the "3.55 keV line" from M31/ Galactic center/Limiting Window with Chandra

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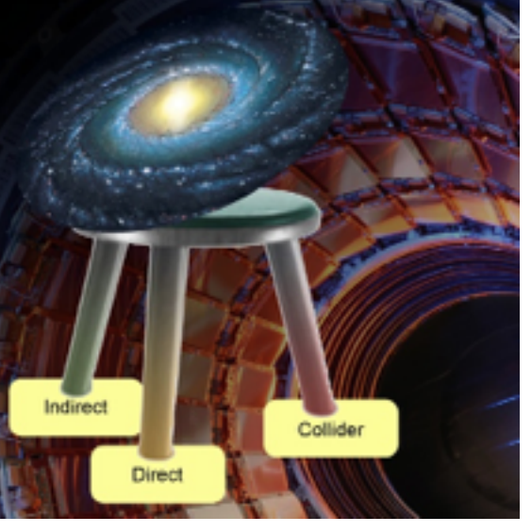
Pappalardo/Einstein fellow

In Collaboration with Zhiyuan Li (NJU)

15 Years of Science with Chandra

Boston, Nov. 21st, 2014



Efficient scattering now
(direct detection)

Efficient annihilation
(indirect detection)

X

X

New
Physics?

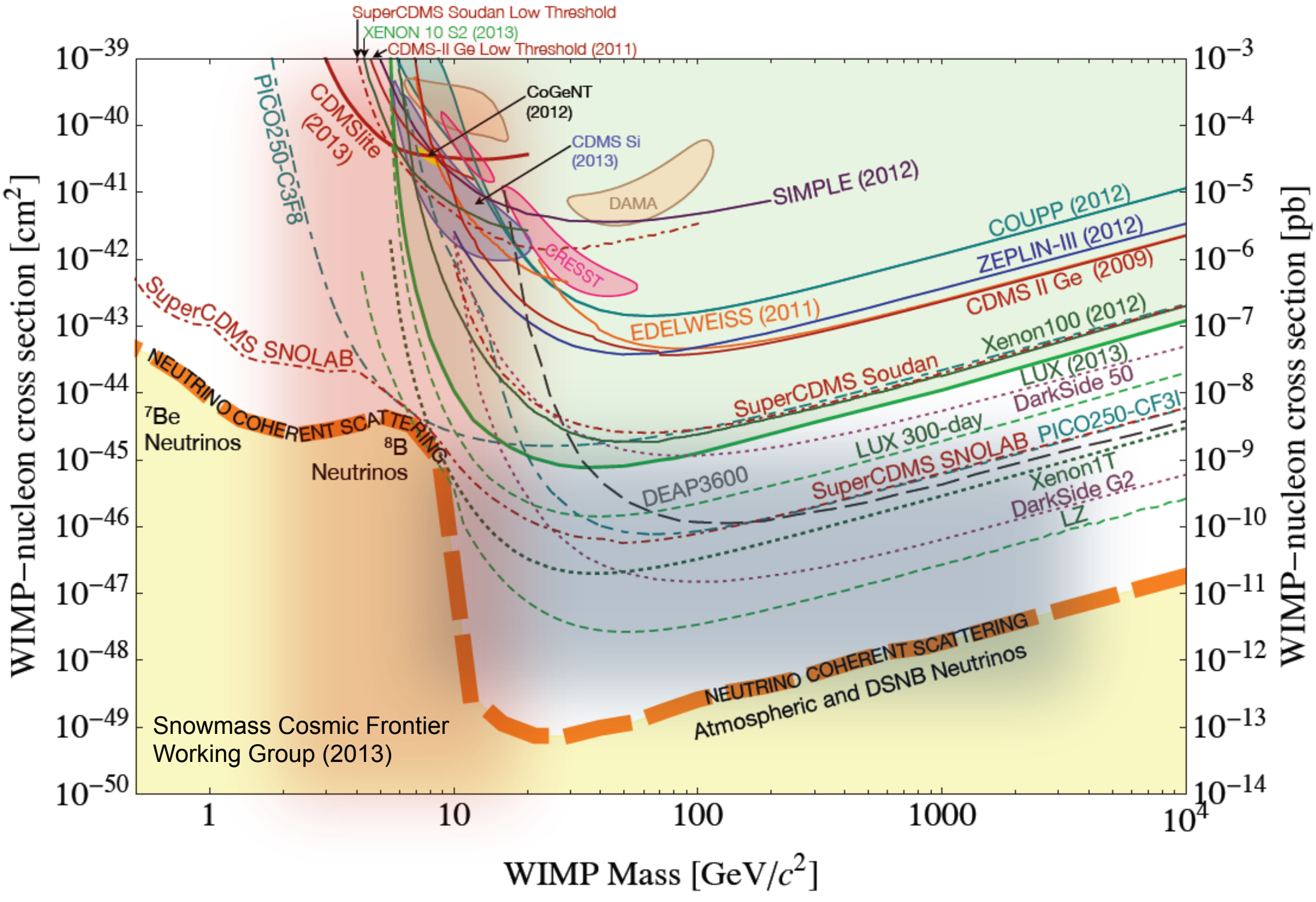
SM

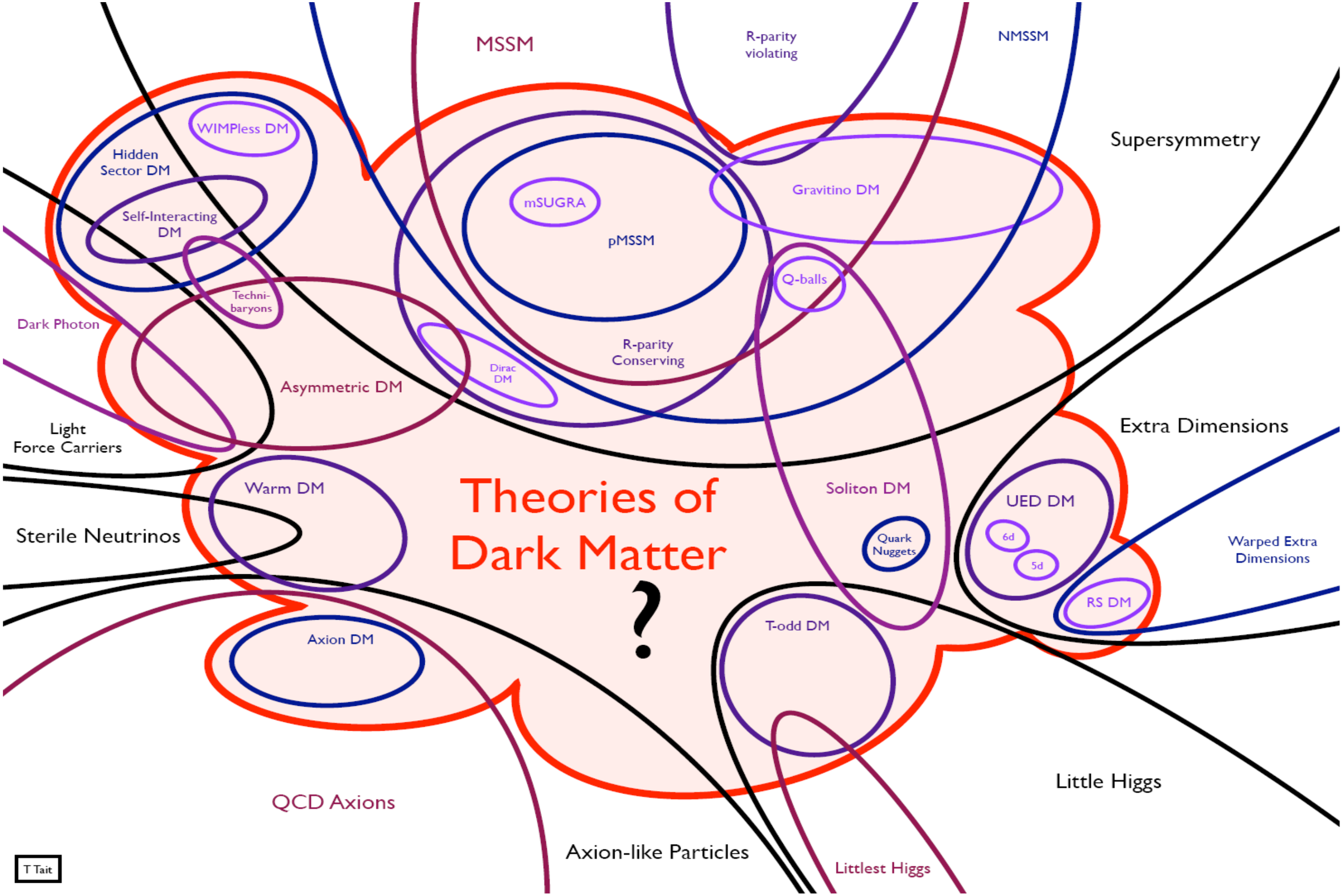
SM

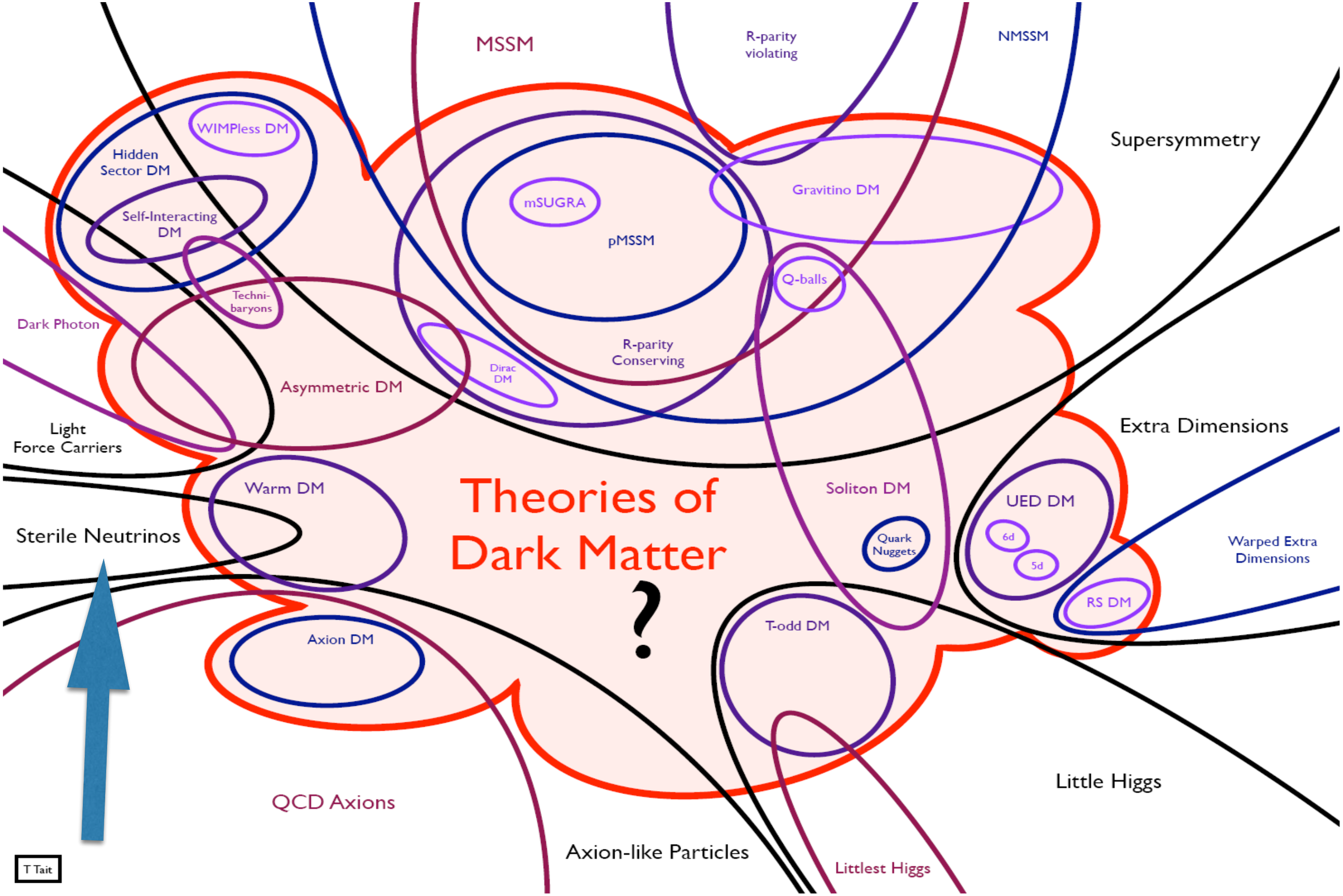
Efficient production now
(collider detection)

All evidence for dark matter is gravitational. Perhaps it's in a hidden sector, composed of particles with no SM gauge interactions (electromagnetic, weak, strong)

Direct DM search as an example




MSSM
R-parity violating
NMSSM
Supersymmetry
WIMPless DM
Hidden Sector DM
Self-Interacting DM
Techni-baryons
Dark Photon
mSUGRA
pMSSM
Gravitino DM
Q-balls
R-parity Conserving
Dirac DM
Asymmetric DM
Light Force Carriers
Extra Dimensions
Warm DM
Sterile Neutrinos
Theories of Dark Matter
?
Soliton DM
Quark Nuggets
UED DM
6d
5d
Warped Extra Dimensions
RS DM
Axion DM
T-odd DM
Little Higgs
QCD Axions
Axion-like Particles
Littlest Higgs
T Tait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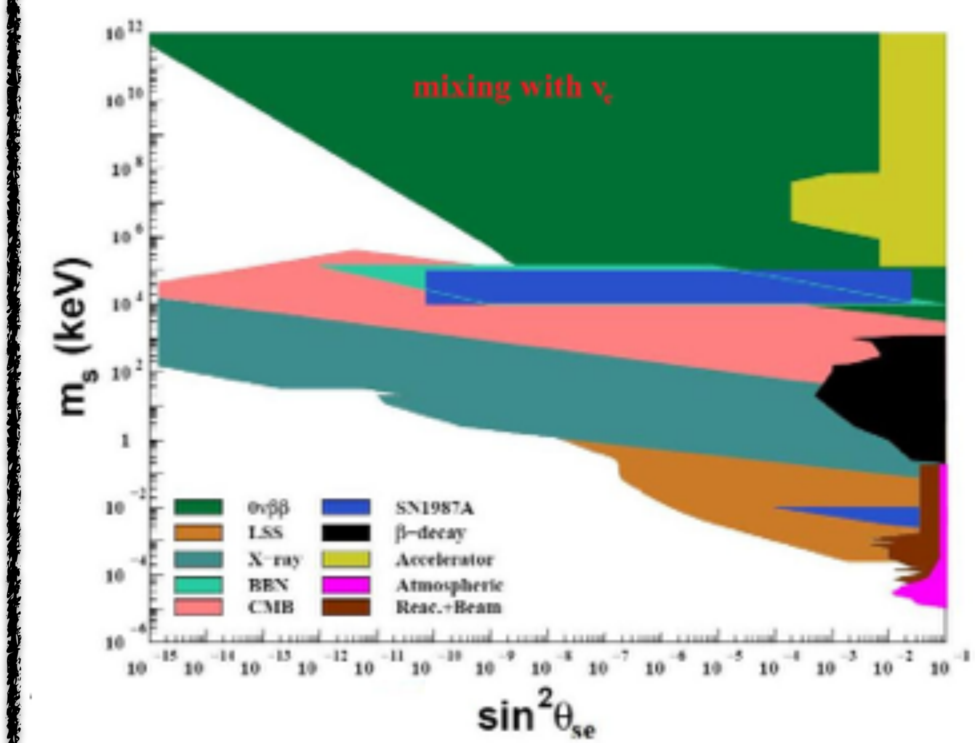
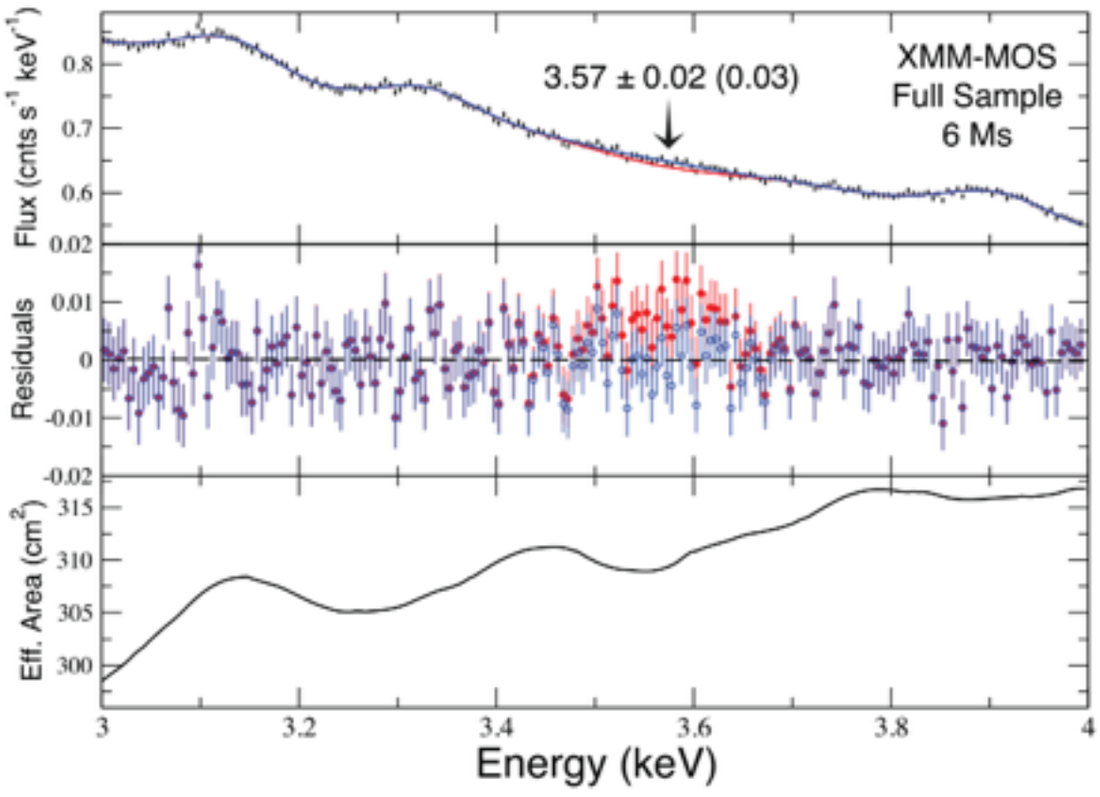
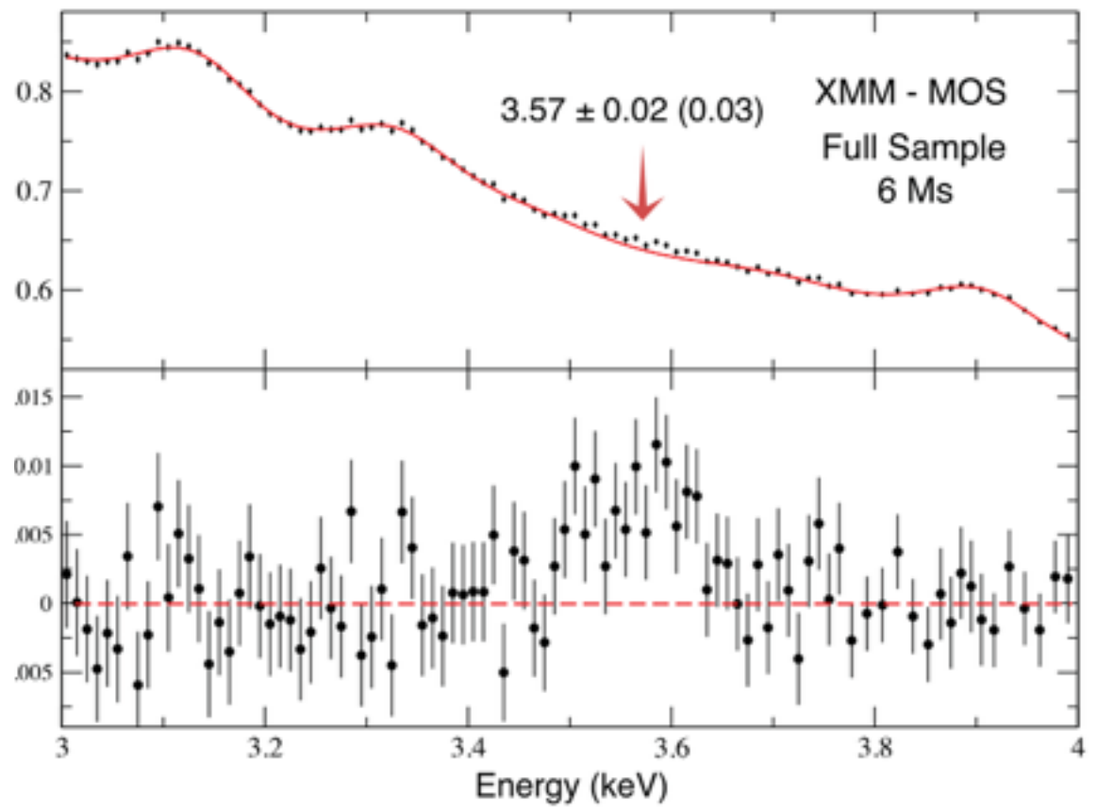
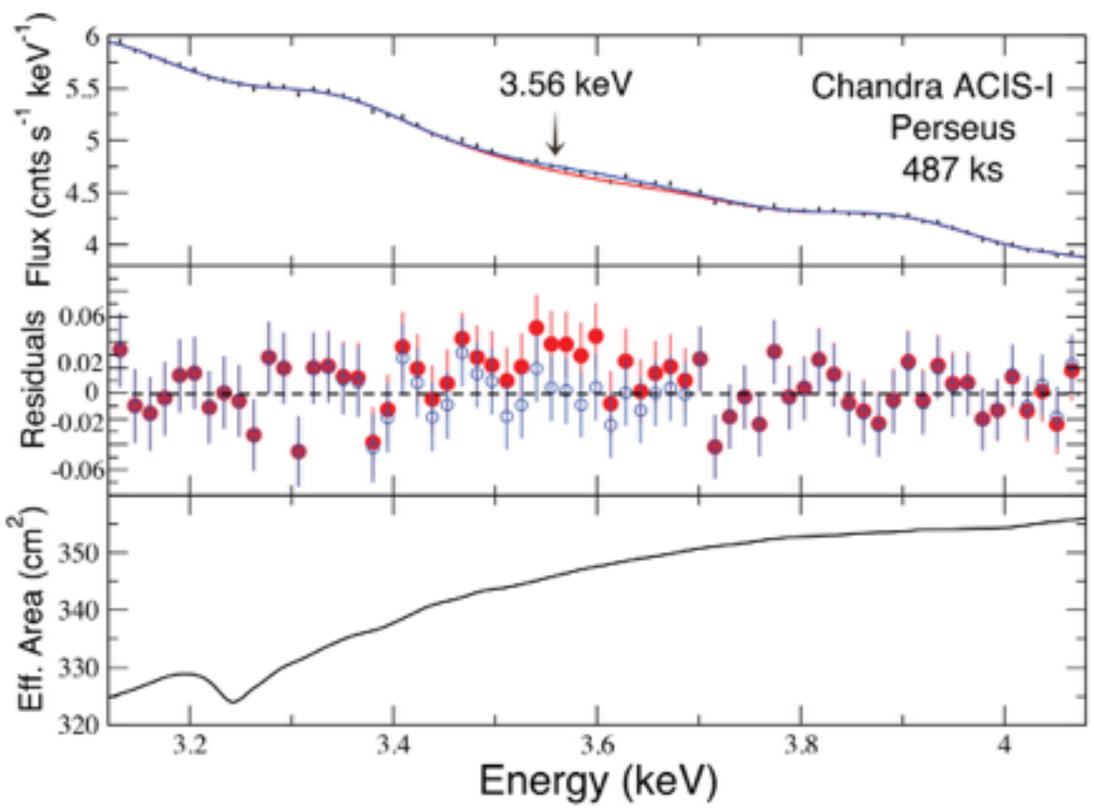
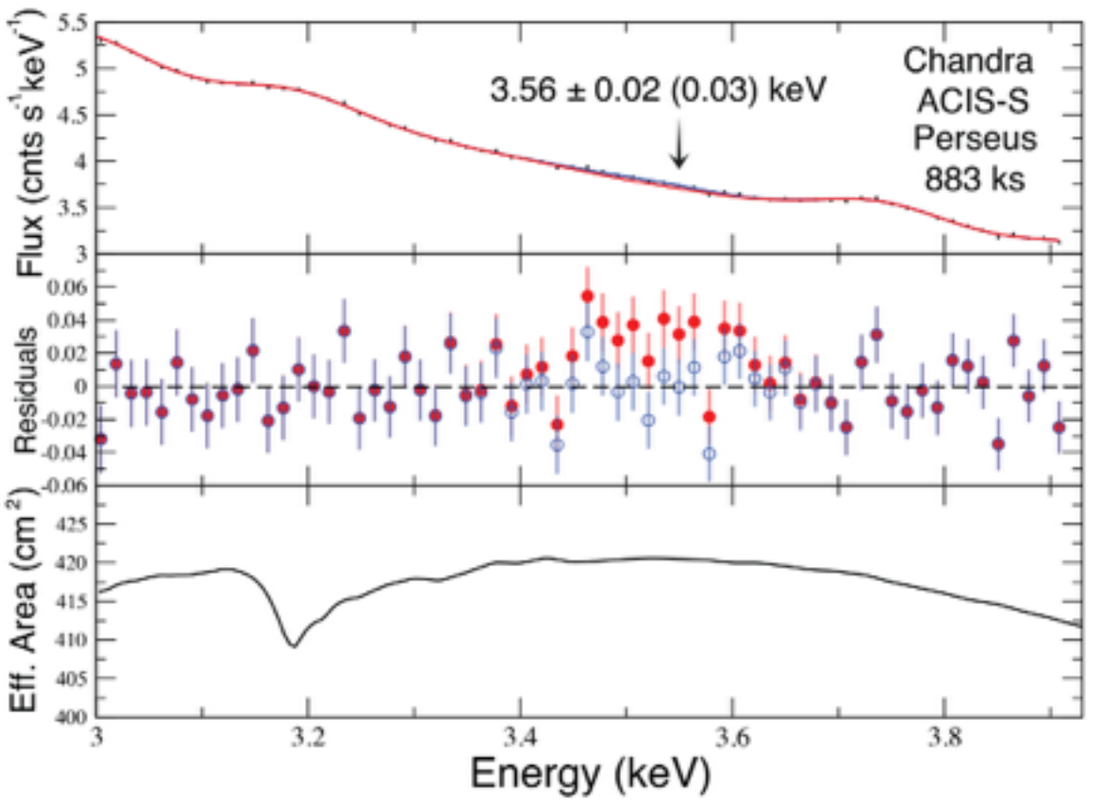
Sterile neutrino?



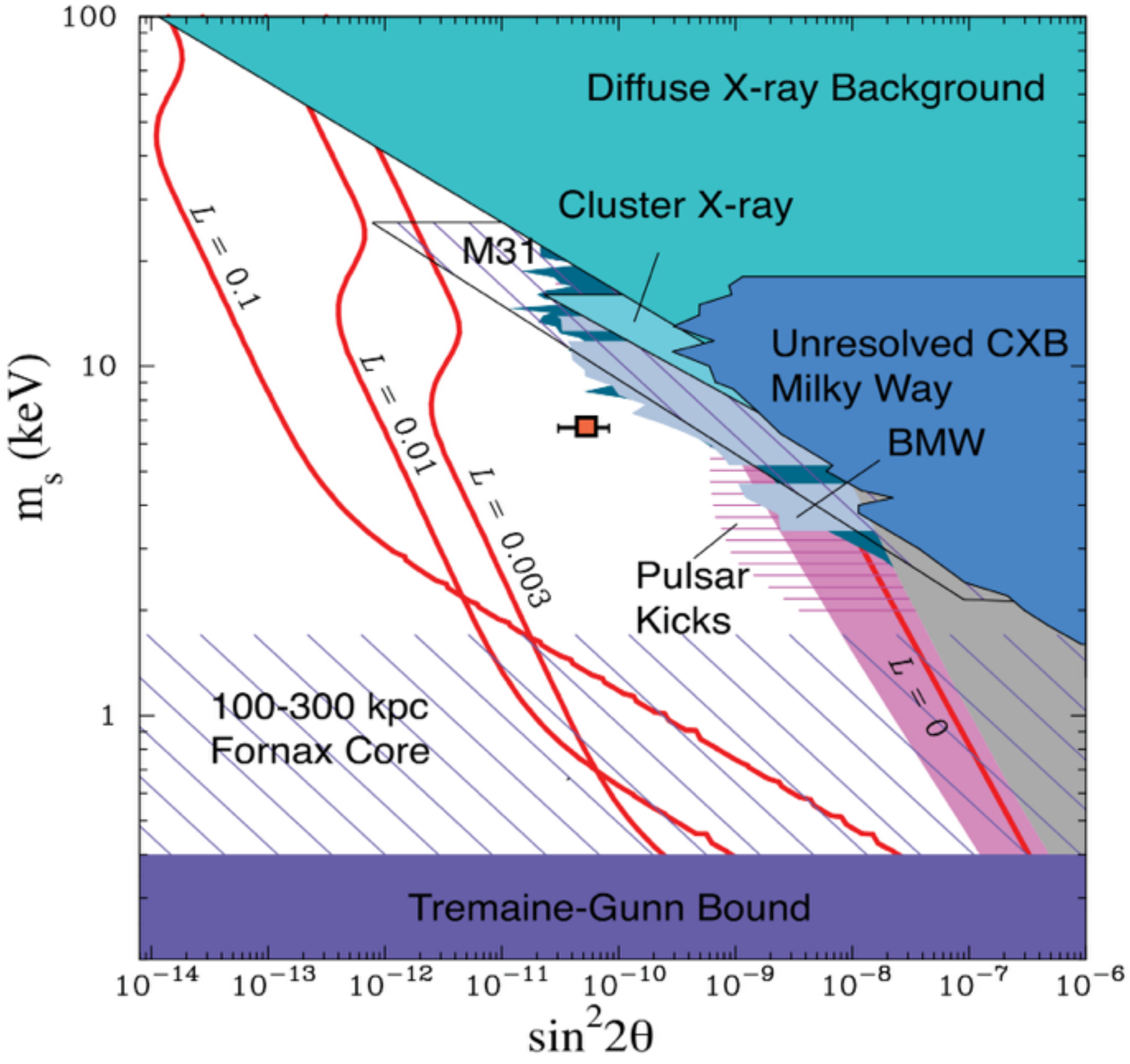






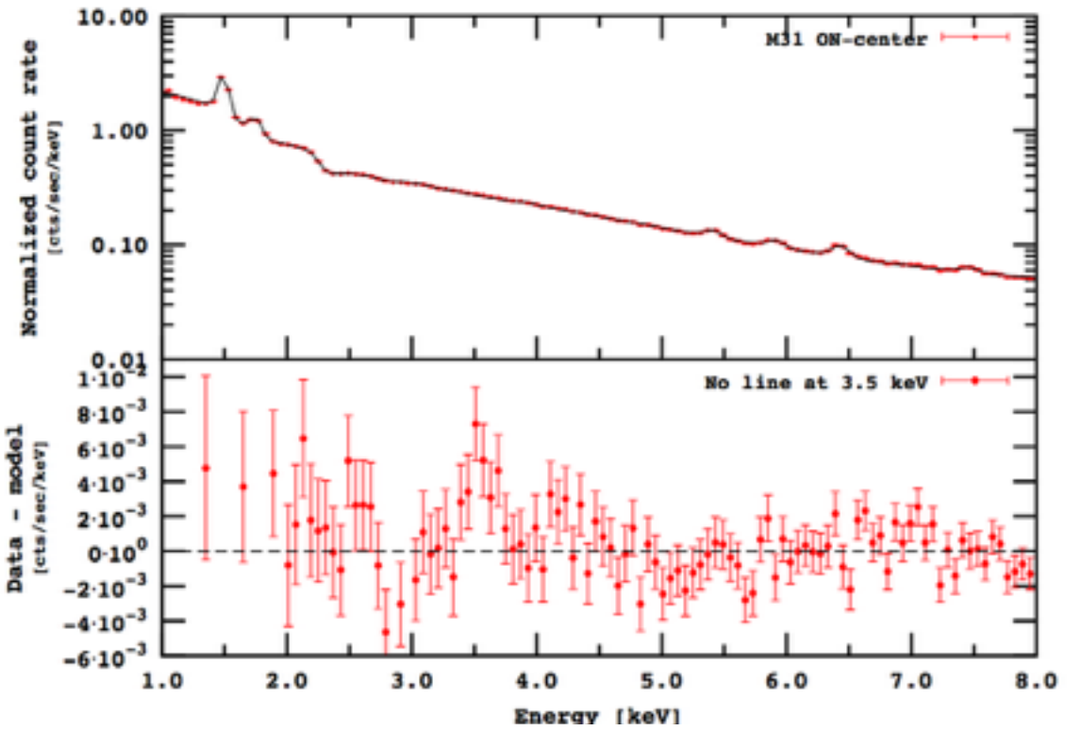


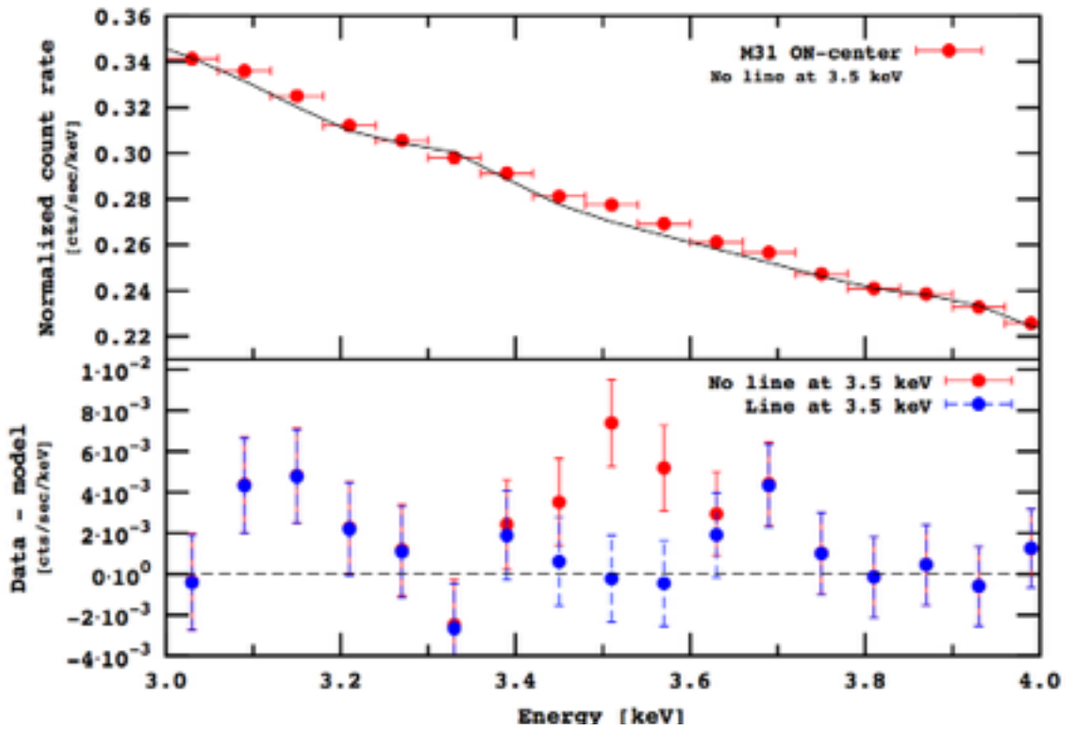
Bulbul et al., 2014

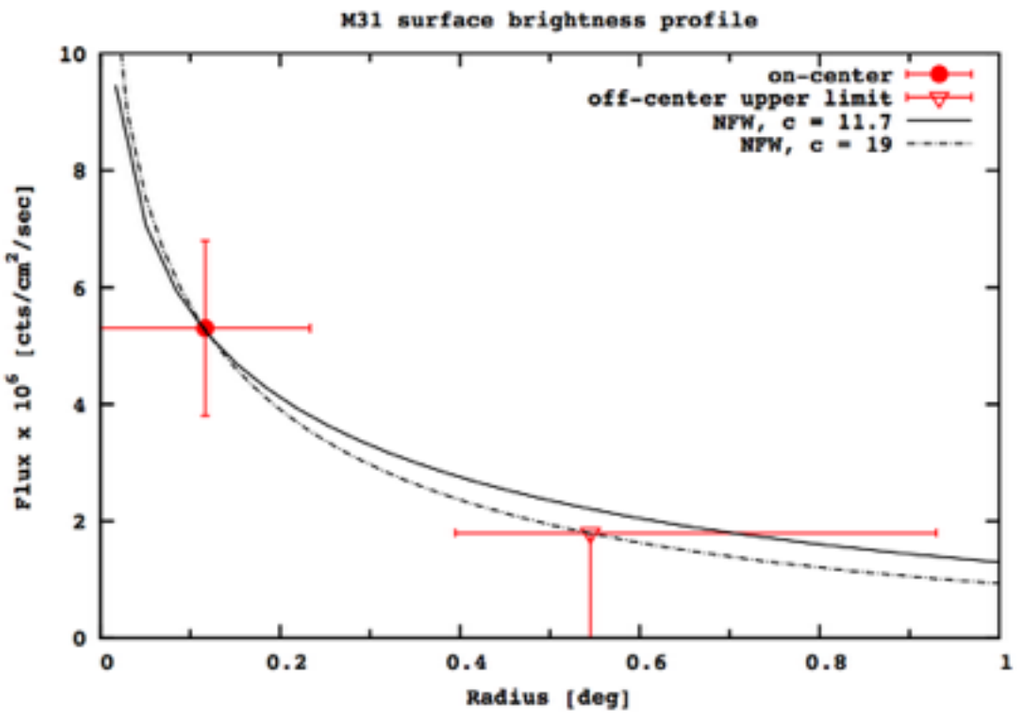


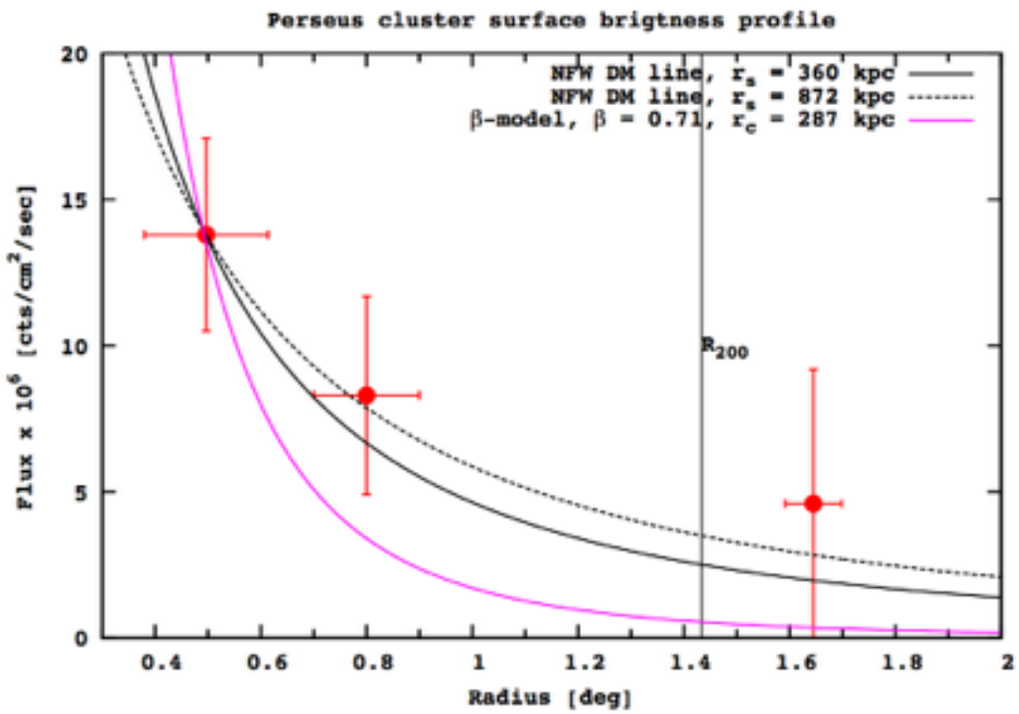
Bulbul et al., 2014 (115 citations by Nov. 21st)

MOS spectrum of the central region of M31







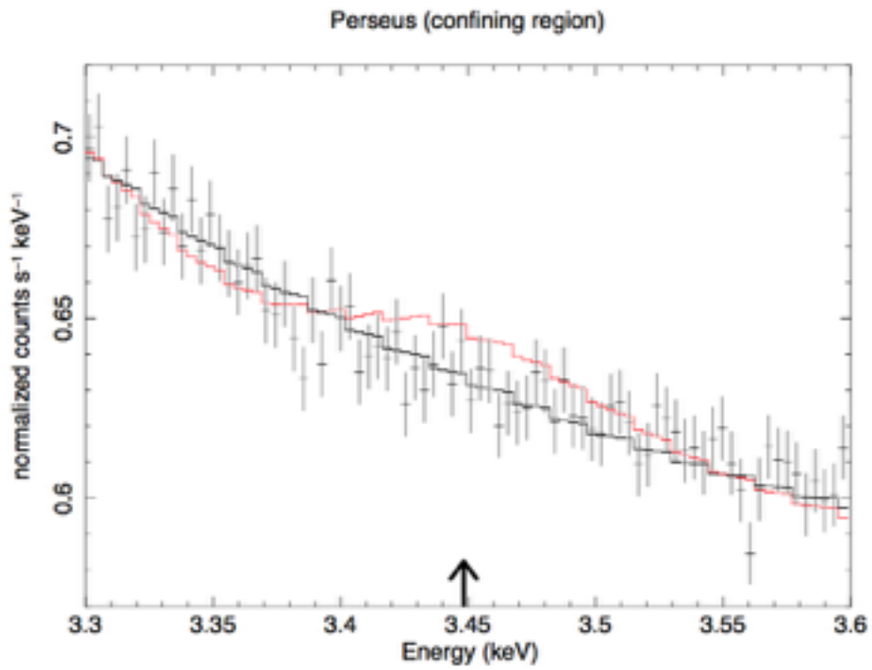


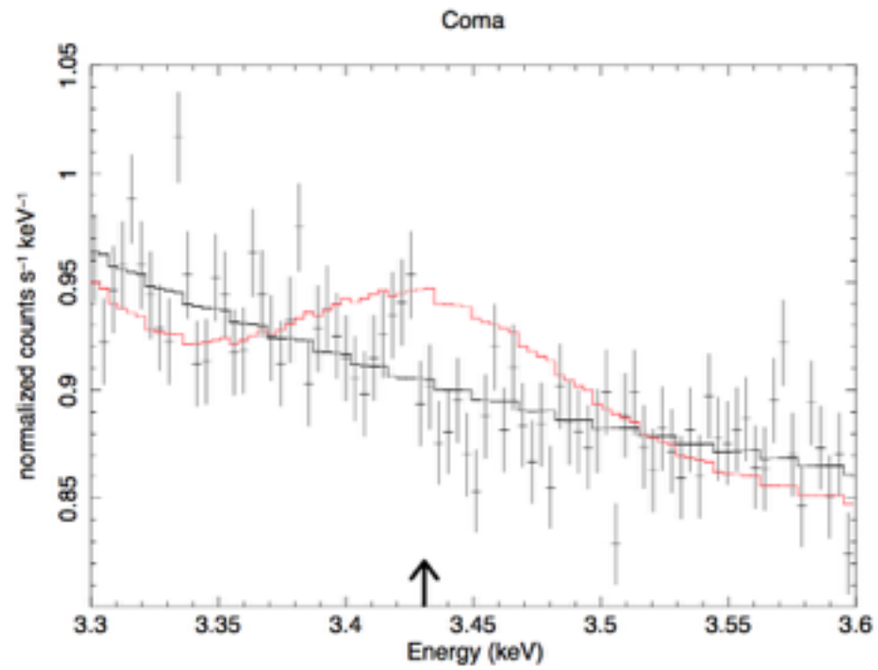
Boyarsky et al., arXiv:1402.4119 (113+ citations)

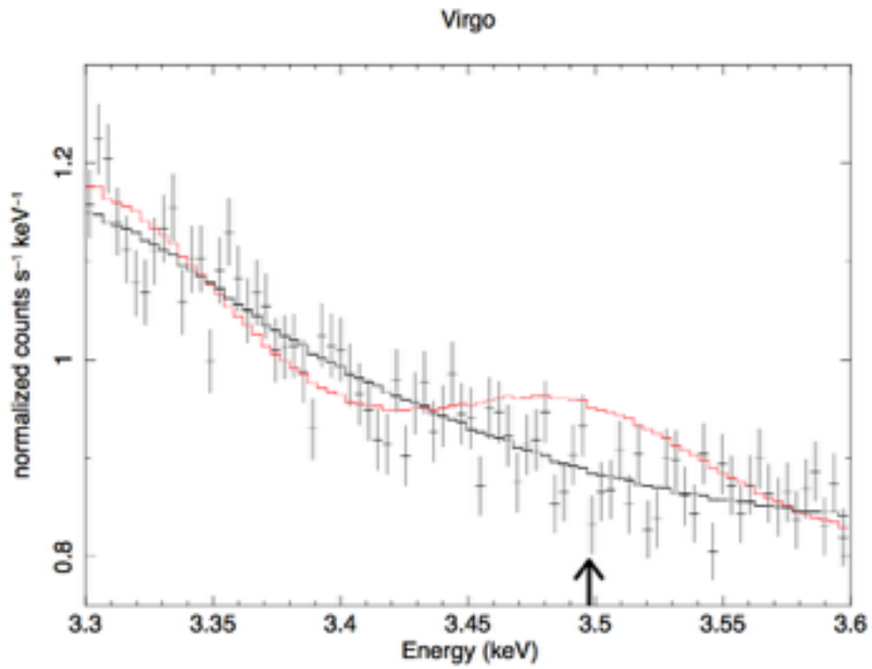
A very incomplete list of proposed dark matter models

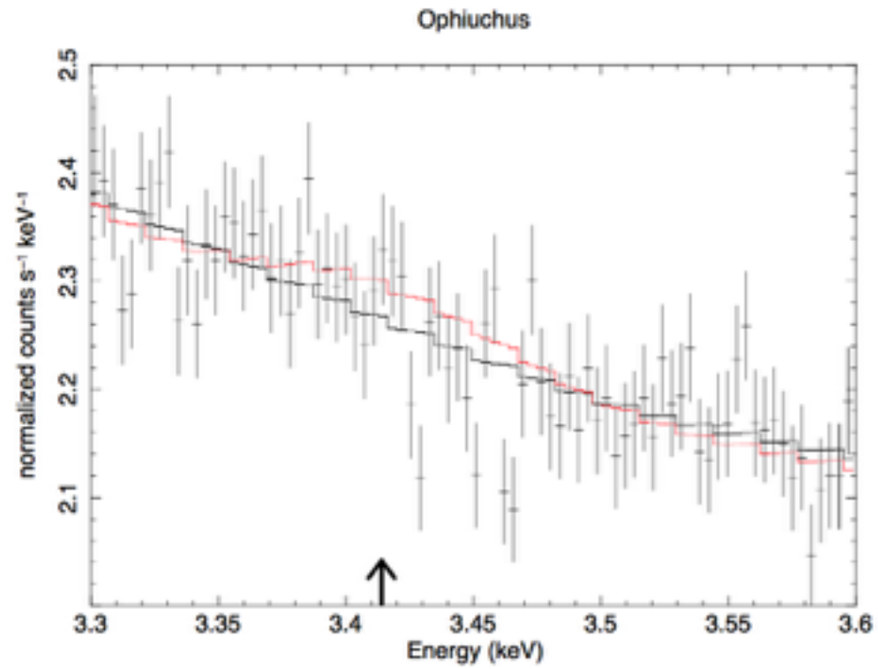
- Exciting Dark Matter (inelastic scattering of dark matter)
- Sterile neutrino dark matter
- Axions and Axion-Like Particles
- Non-abelian dark matter solutions for Galactic gamma-ray excess and the 3.5 keV line
- Light neutralino dark matter in U(1)' models
- Weak-scale thermal dark matter consists of two nearly degenerate states near the weak scale
- Magnetic dark matter
- Dark matter decay to an axion-like particle
- Decaying vector dark matter
- SIMPle dark matter with self-interactions
- X-ray line from the dark transition electric dipole
- Axino dark matter decay
- Annihilating and decaying dark matter in Weinberg model
- Decaying moduli with low cutoff scale
- Nearly-degenerate WIMP dark matter decays
- “21 cm line” of dark atoms

A Suzaku search for dark matter emission lines in Perseus and Coma



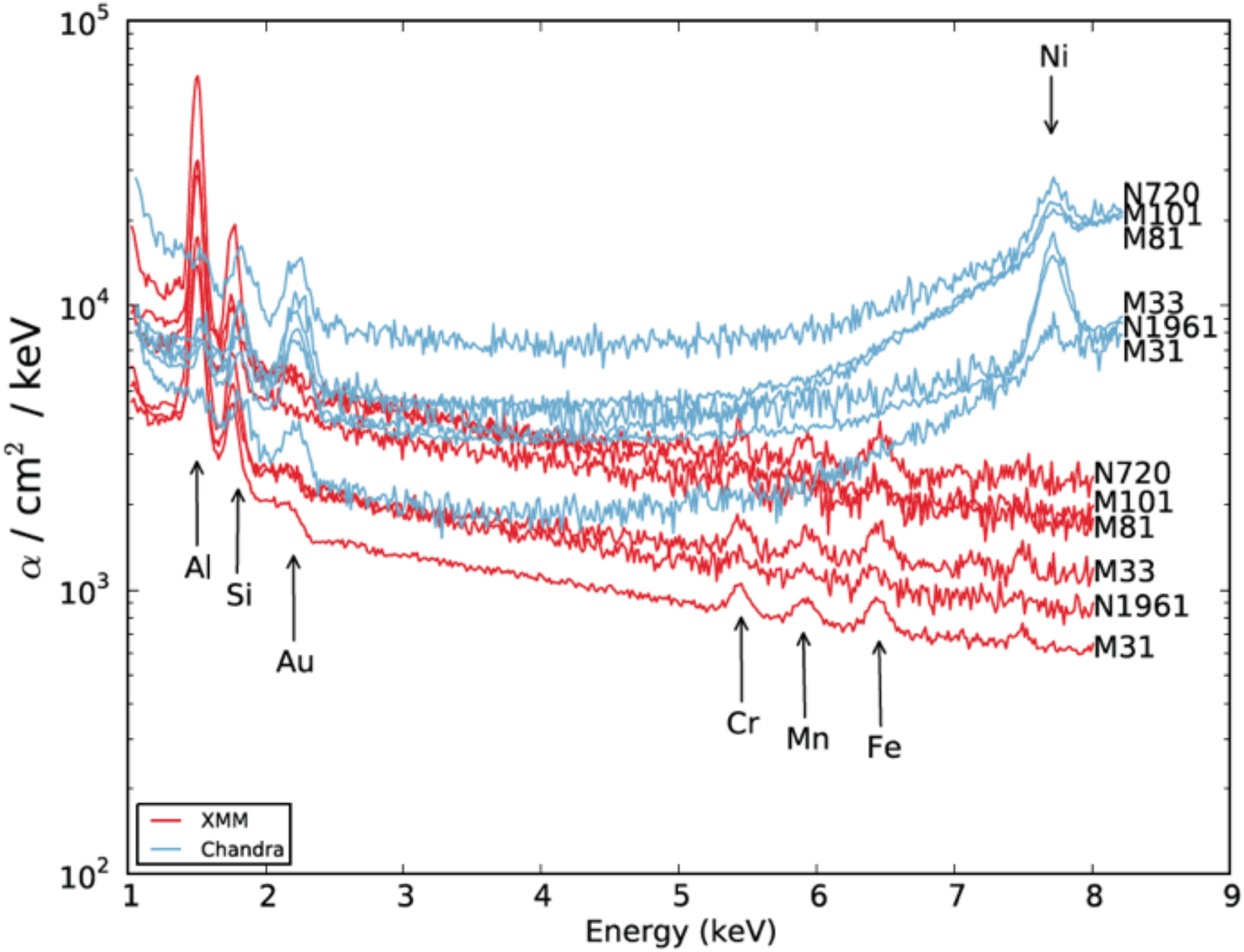






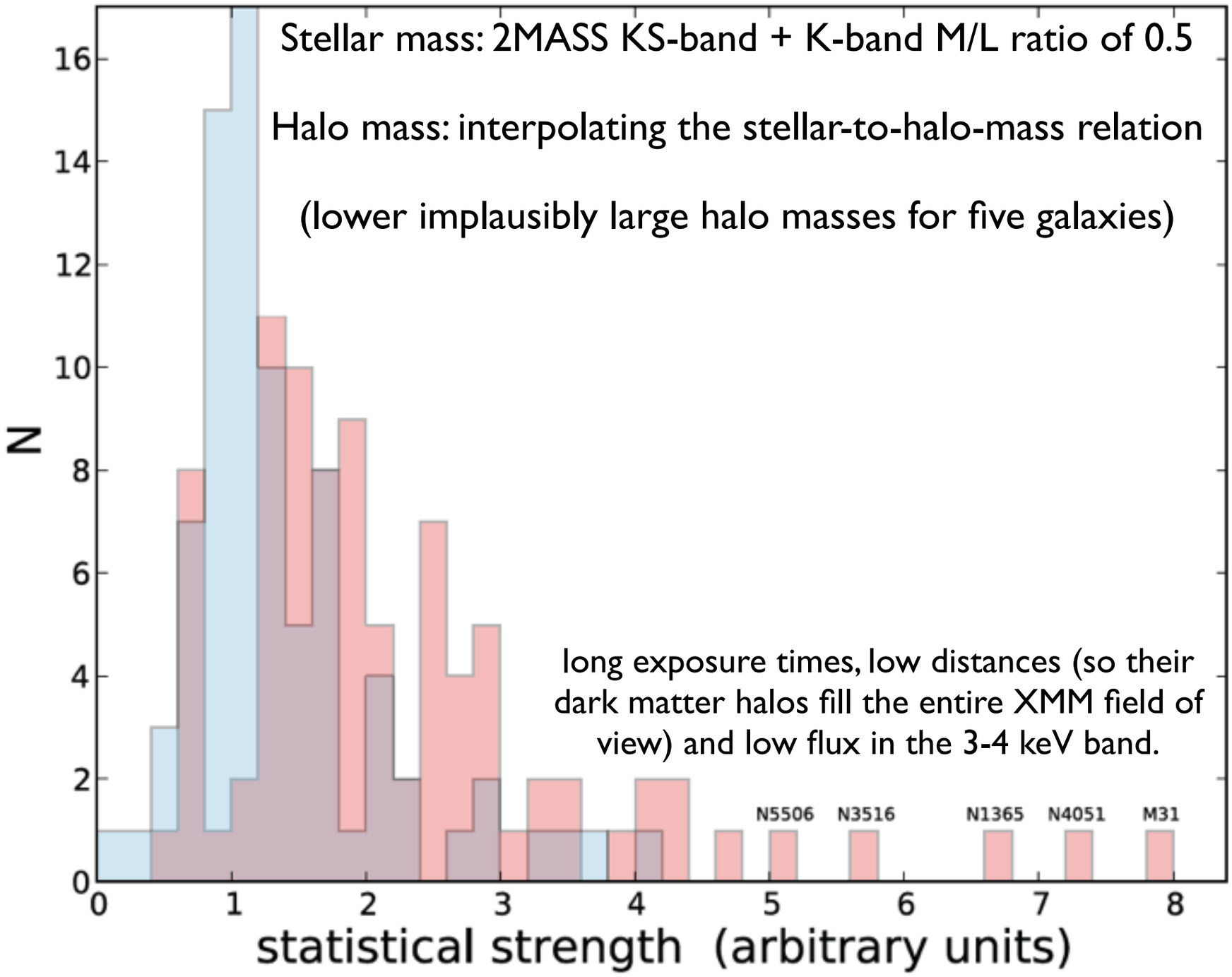
Urban et al., arXiv:1411.0050

Non-Detection of X-Ray Emission From Sterile Neutrinos in Stacked Galaxy Spectra



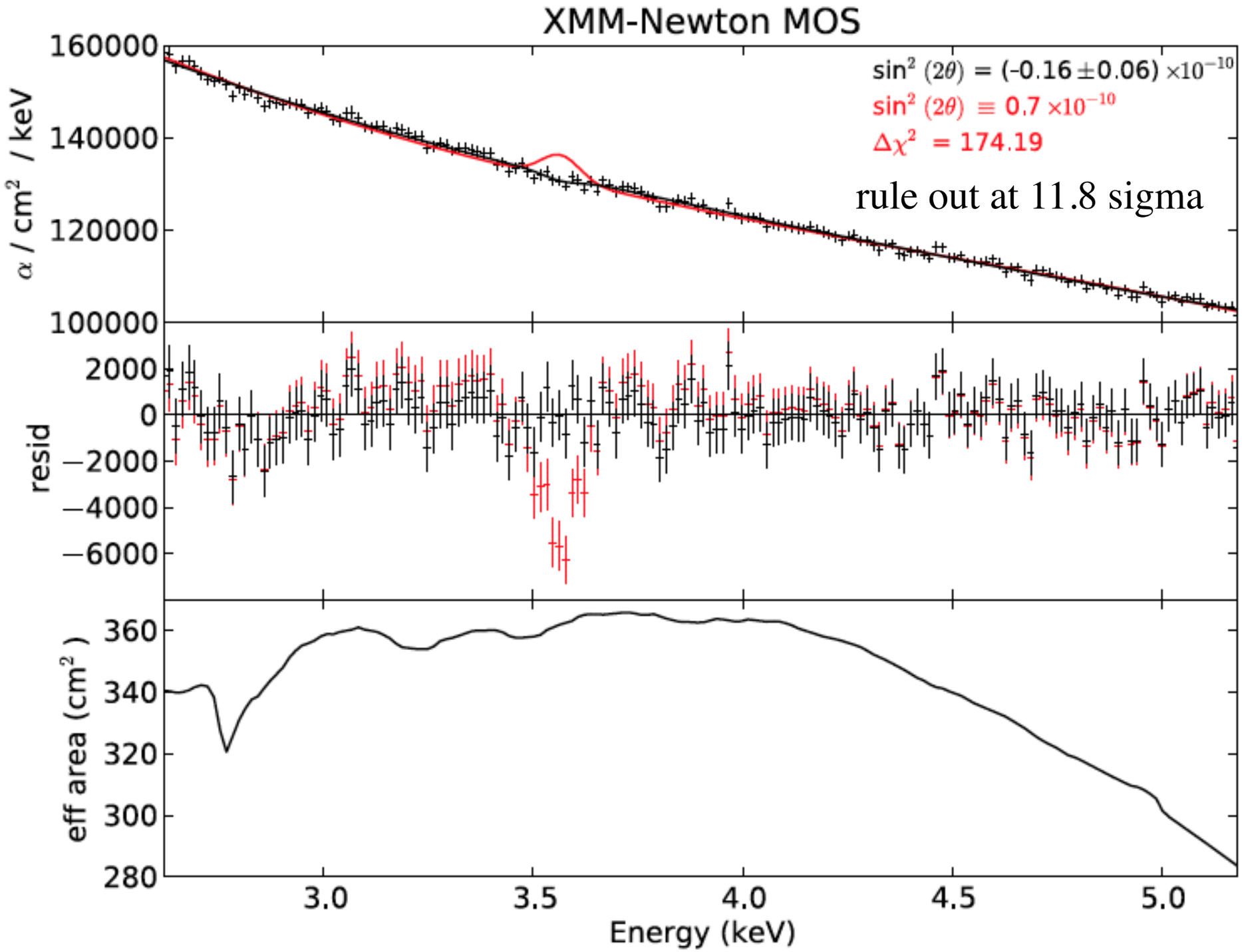
Anderson et al., arXiv:1408.4115

Distribution of selected 81 Chandra (blue) and 89 XMM-Newton (red) galaxies



Anderson et al., arXiv:1408.4115

Stacked MOS spectra and best-fit spline model



Anderson et al., arXiv:1408.4115

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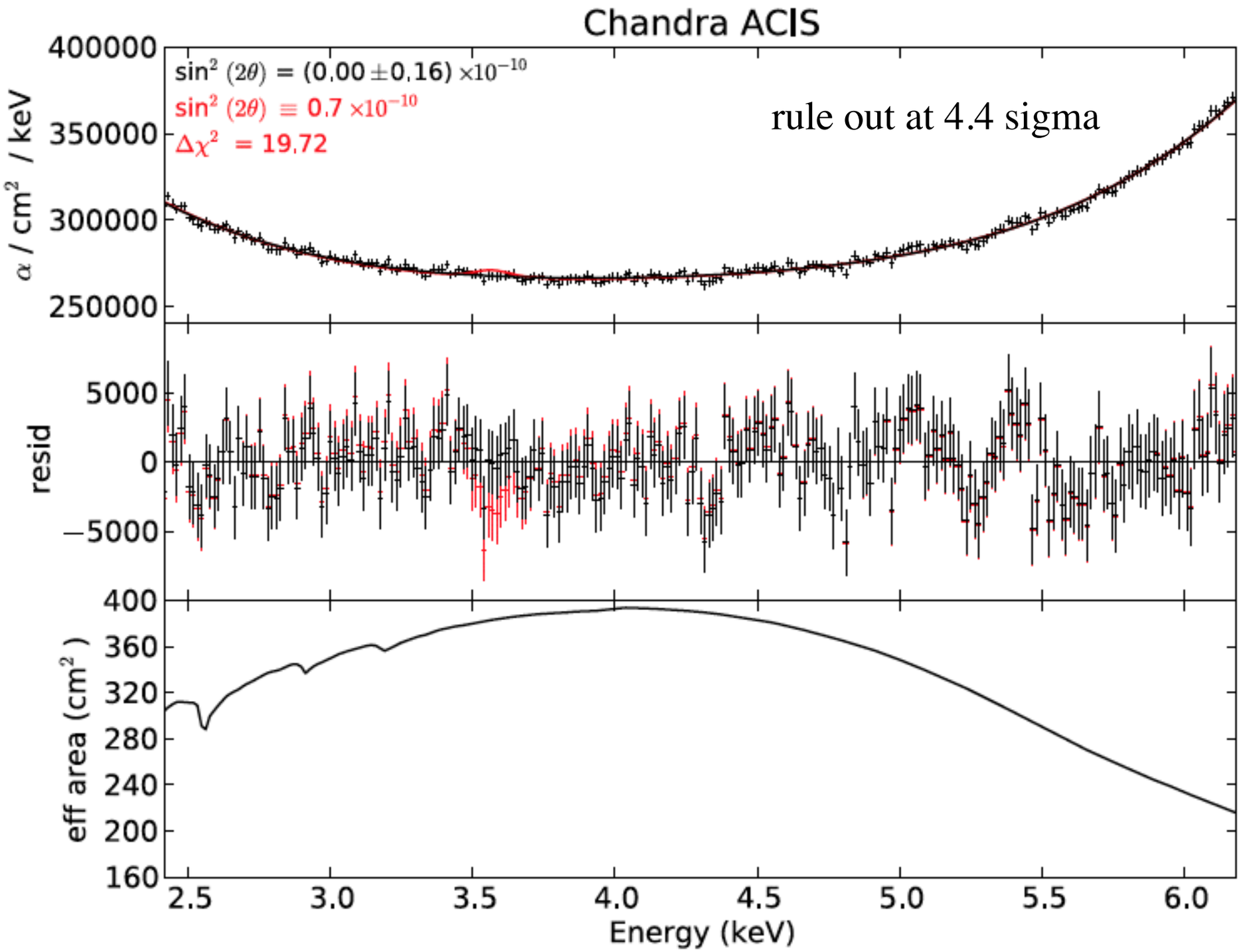
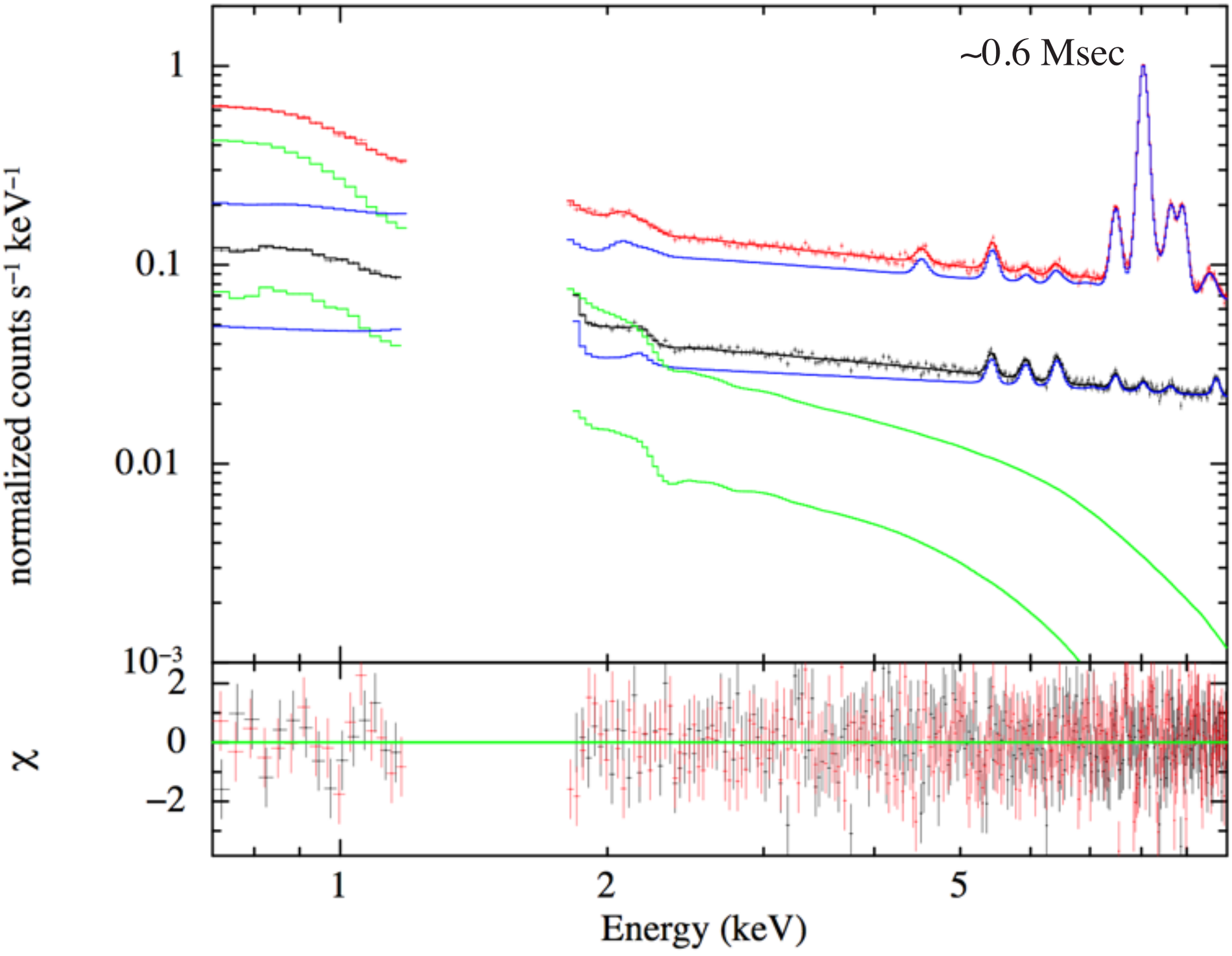


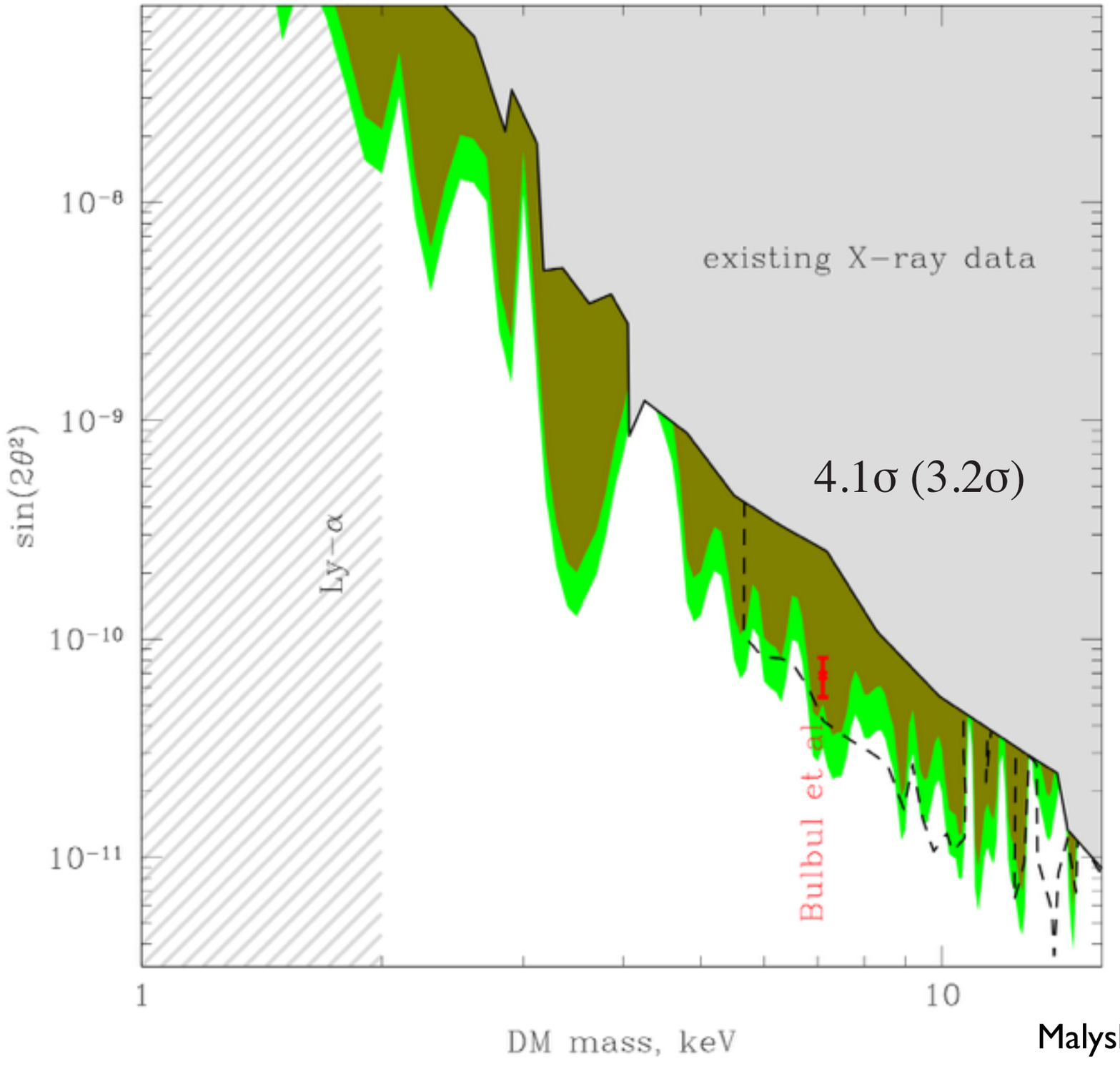
Anderson et al., arXiv:1408.4115

Stacked XMM-Newton spectra of dSph galaxies



Malyshev et al., arXiv:1408.3531

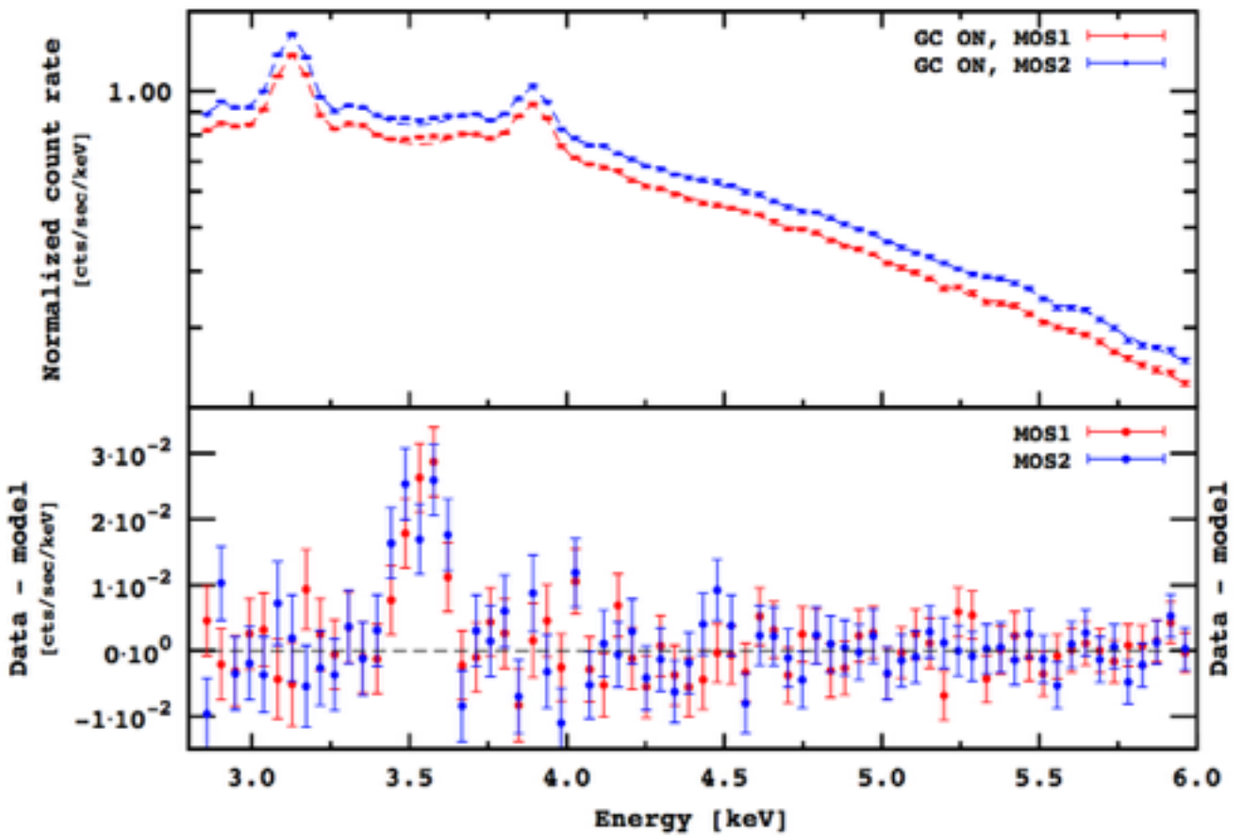
Constraints on 3.55 keV line emission from stacked observations of dwarf spheroidal galaxies

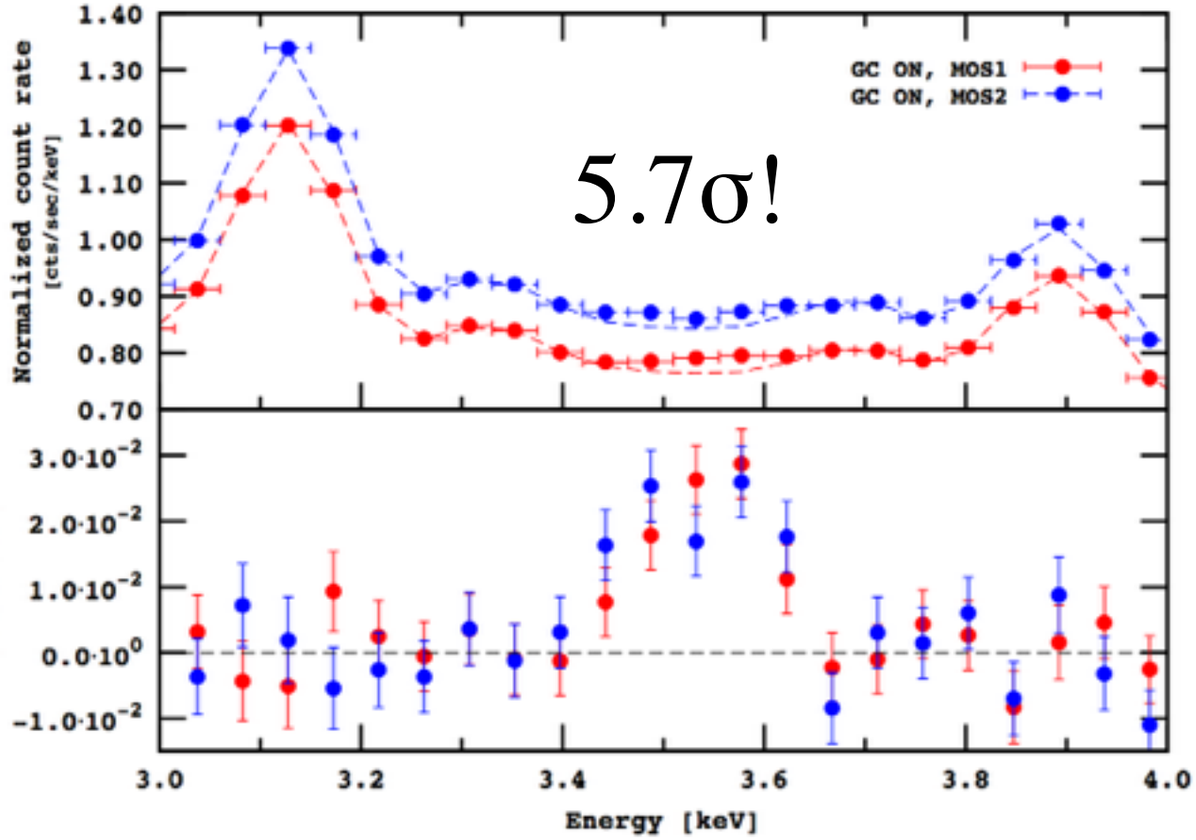


Malyshev et al., arXiv:1408.3531

3.53 keV line with the Milky Way center?

?



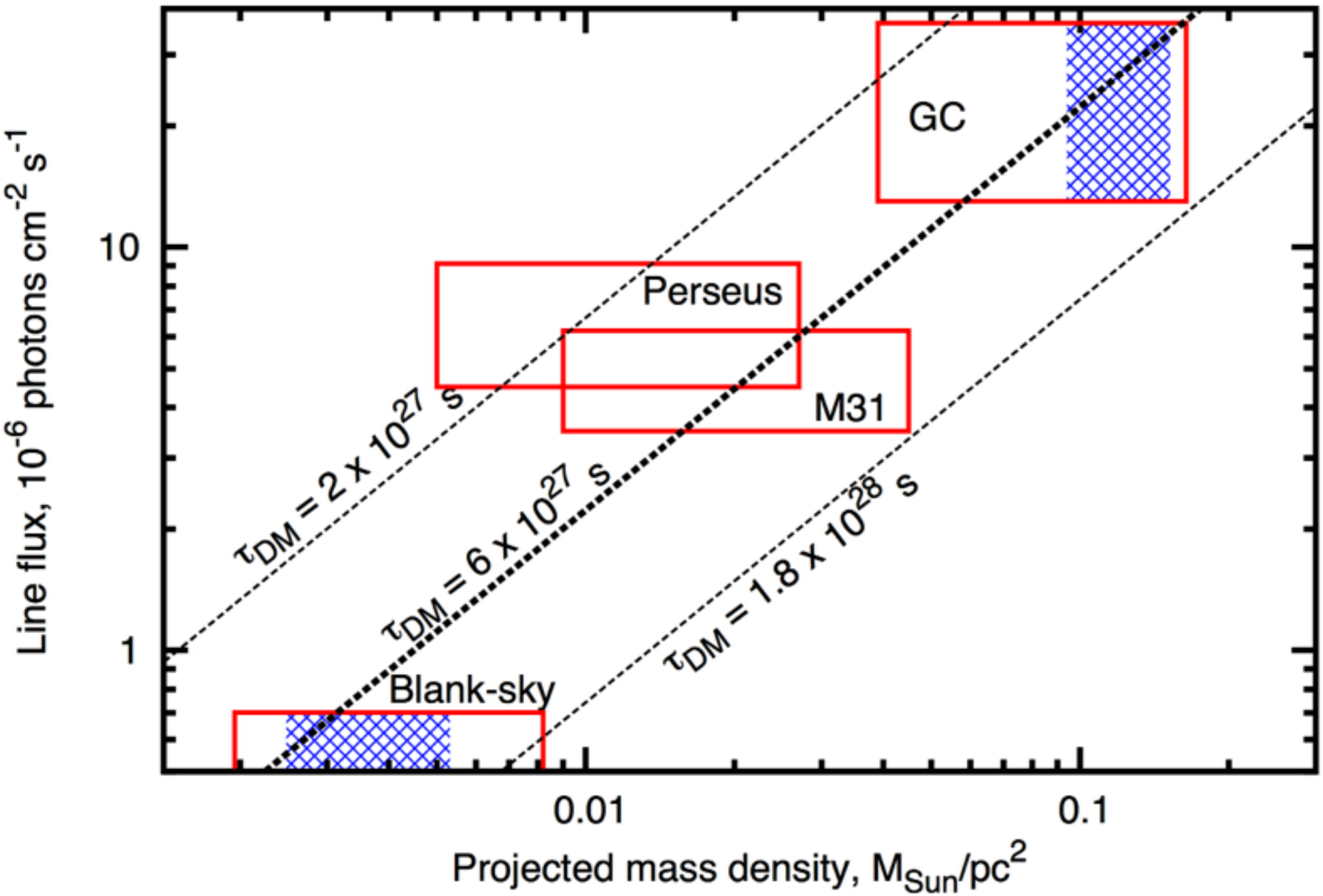


The simultaneous fitting of GC, Perseus and M31 provides a ~6.7σ significant signal at the same position, with the detected fluxes being consistent with the DM interpretation

Boyarsky et al., arXiv:1408.2503

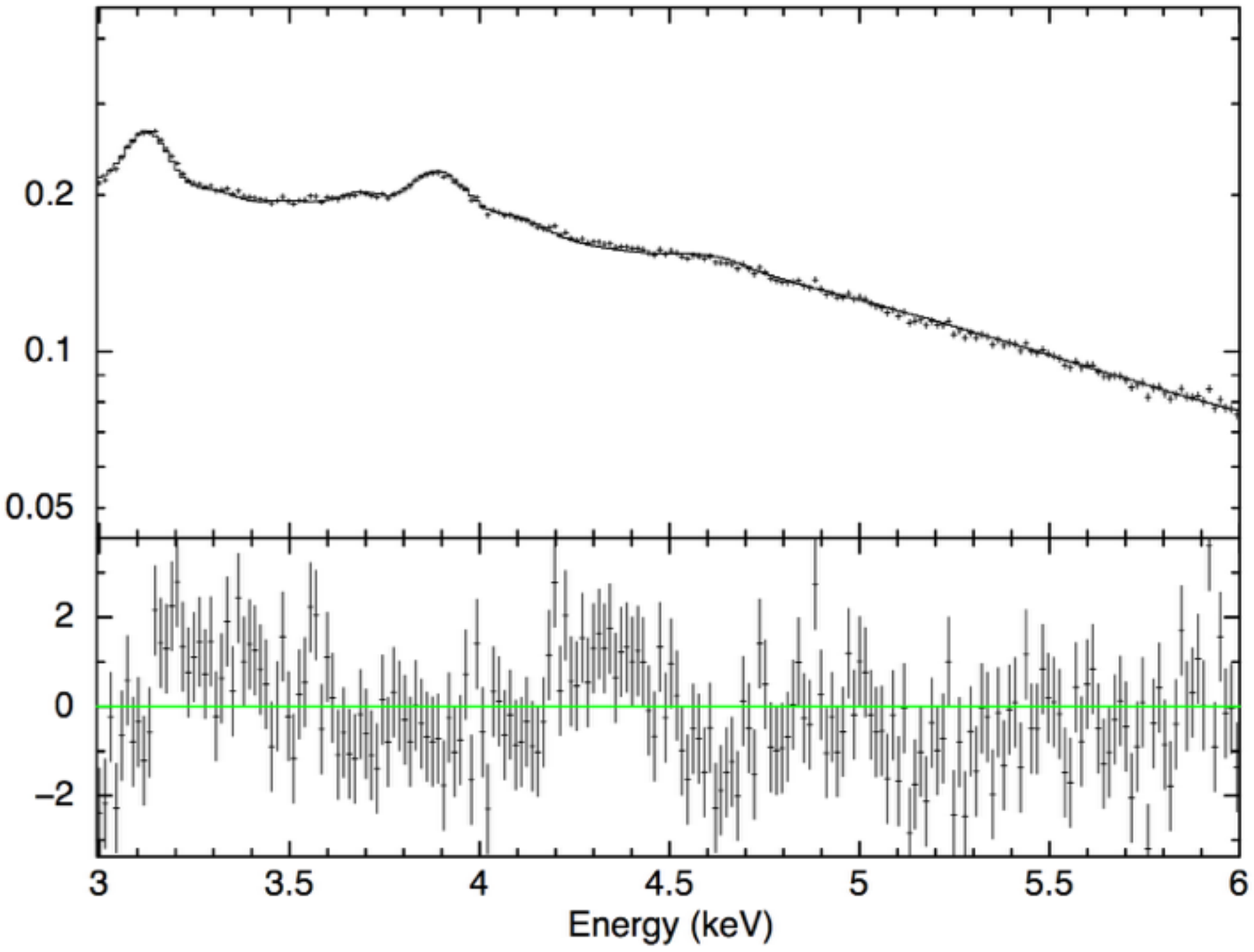
A consistent (exciting!) dark matter decay picture?

?



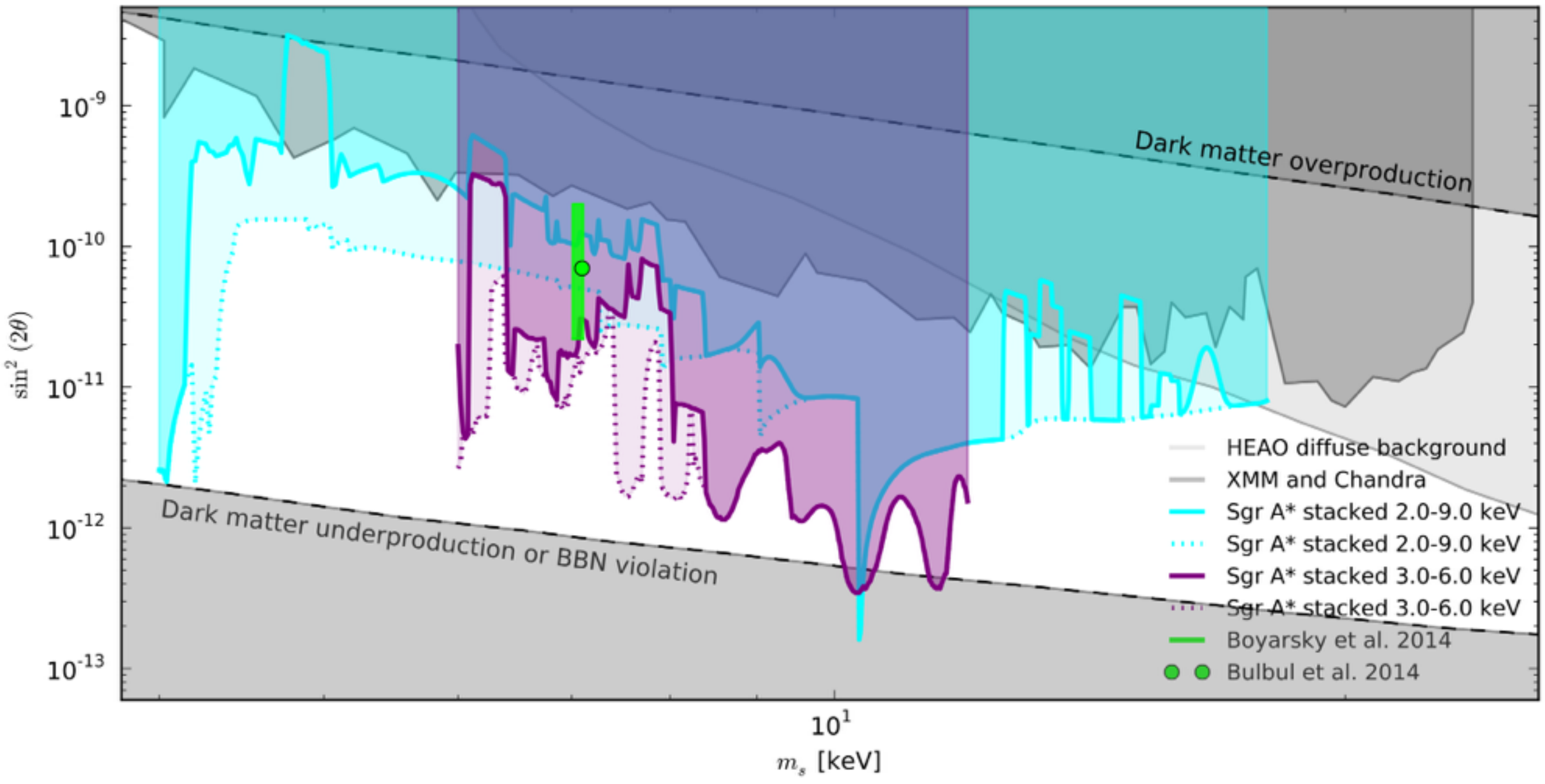
Boyarsky et al., arXiv:1408.2503

Questioning a 3.5 keV dark matter emission line



Signe Riemer-Sørensen, arXiv:1405.7943

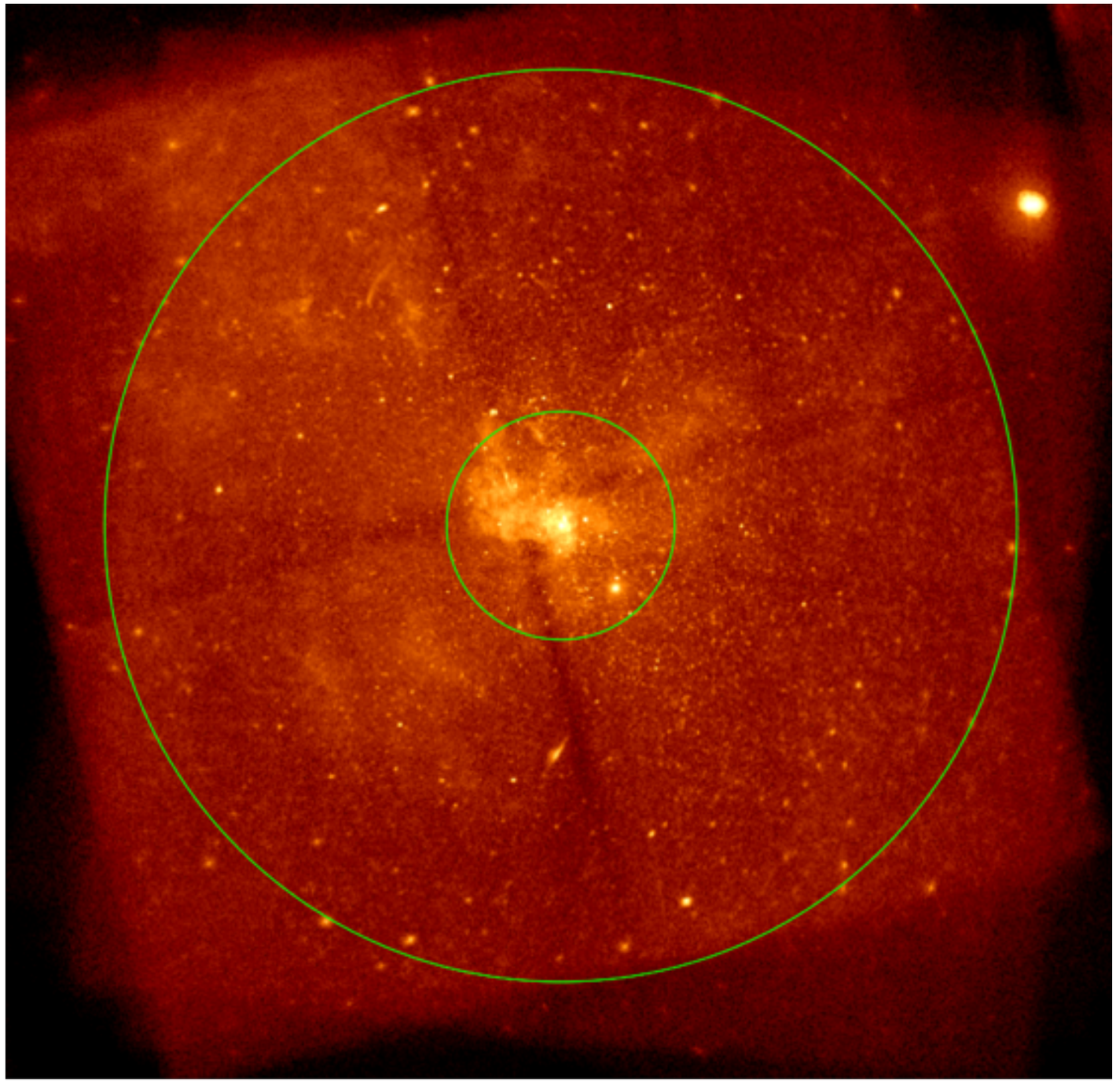
Questioning a 3.5 keV dark matter emission line



Signe Riemer-Sørensen, arXiv:1405.7943

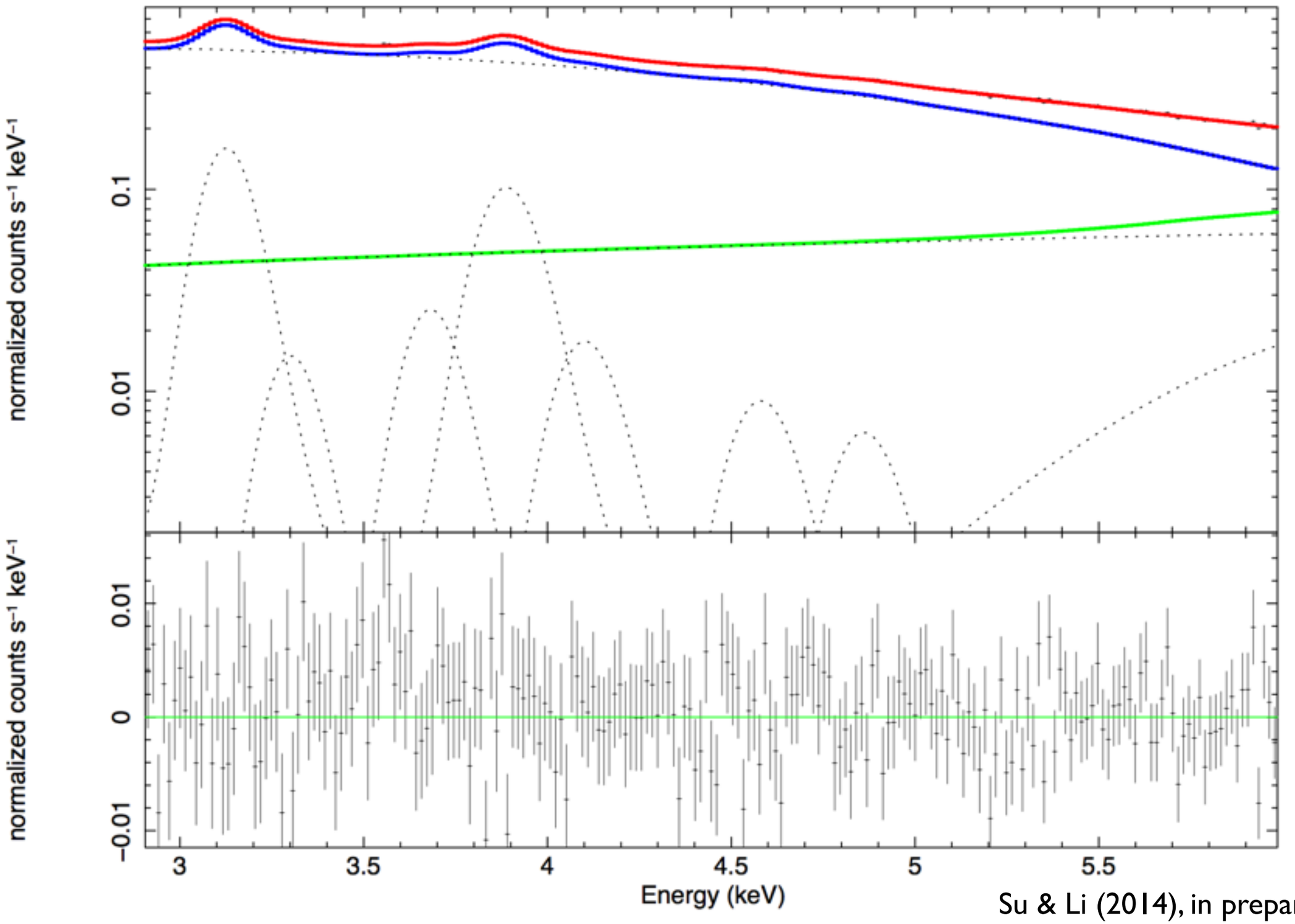
Constraints from the Galactic Center:

- Galactic center: 1.5 Ms ACIS-I exposure based on ~50 observations; spectra extracted from a 2'-8' (~5-19 pc)



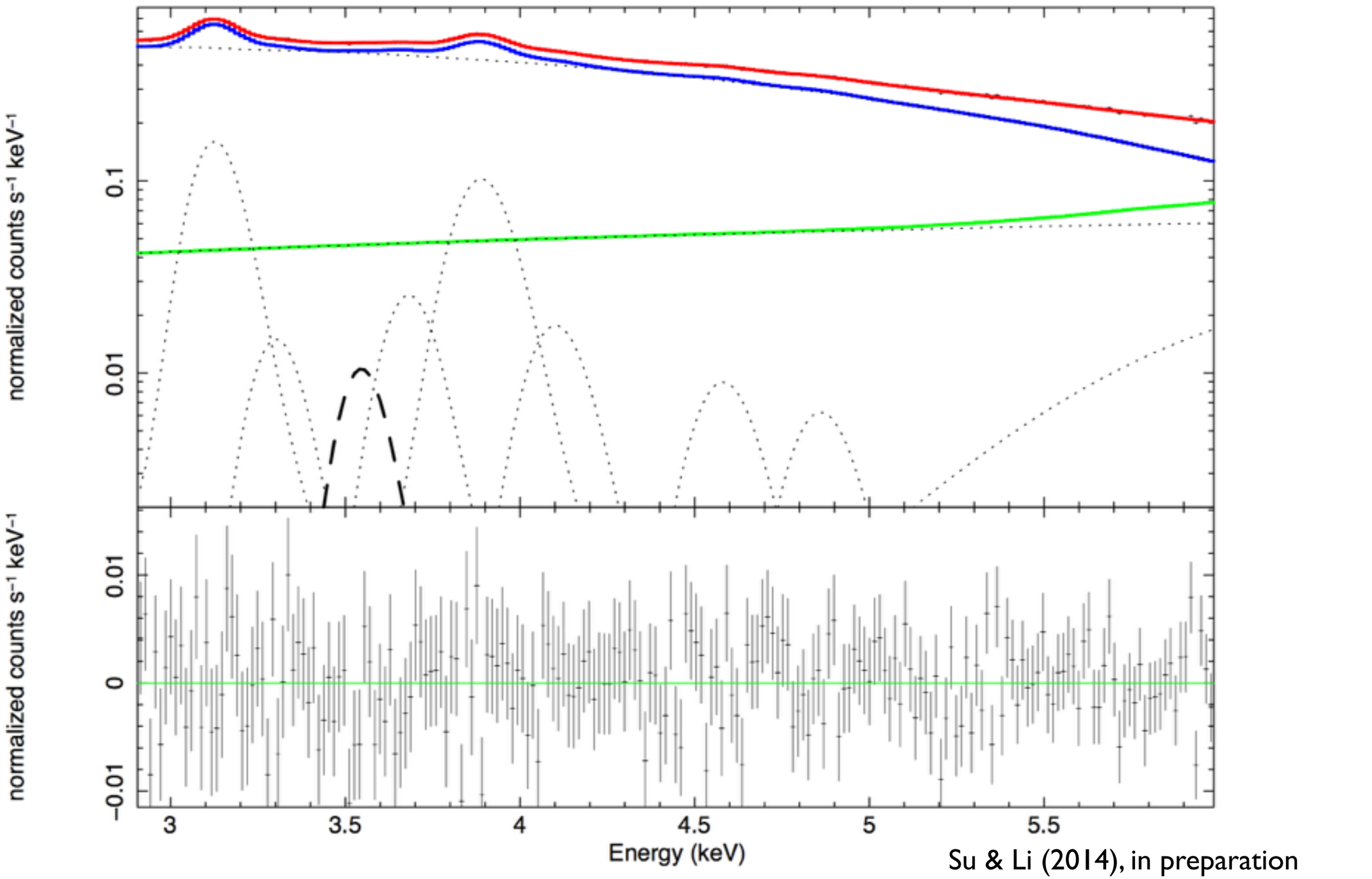
Su & Li (2014), in preparation

Galactic Center without a 3.55 keV line



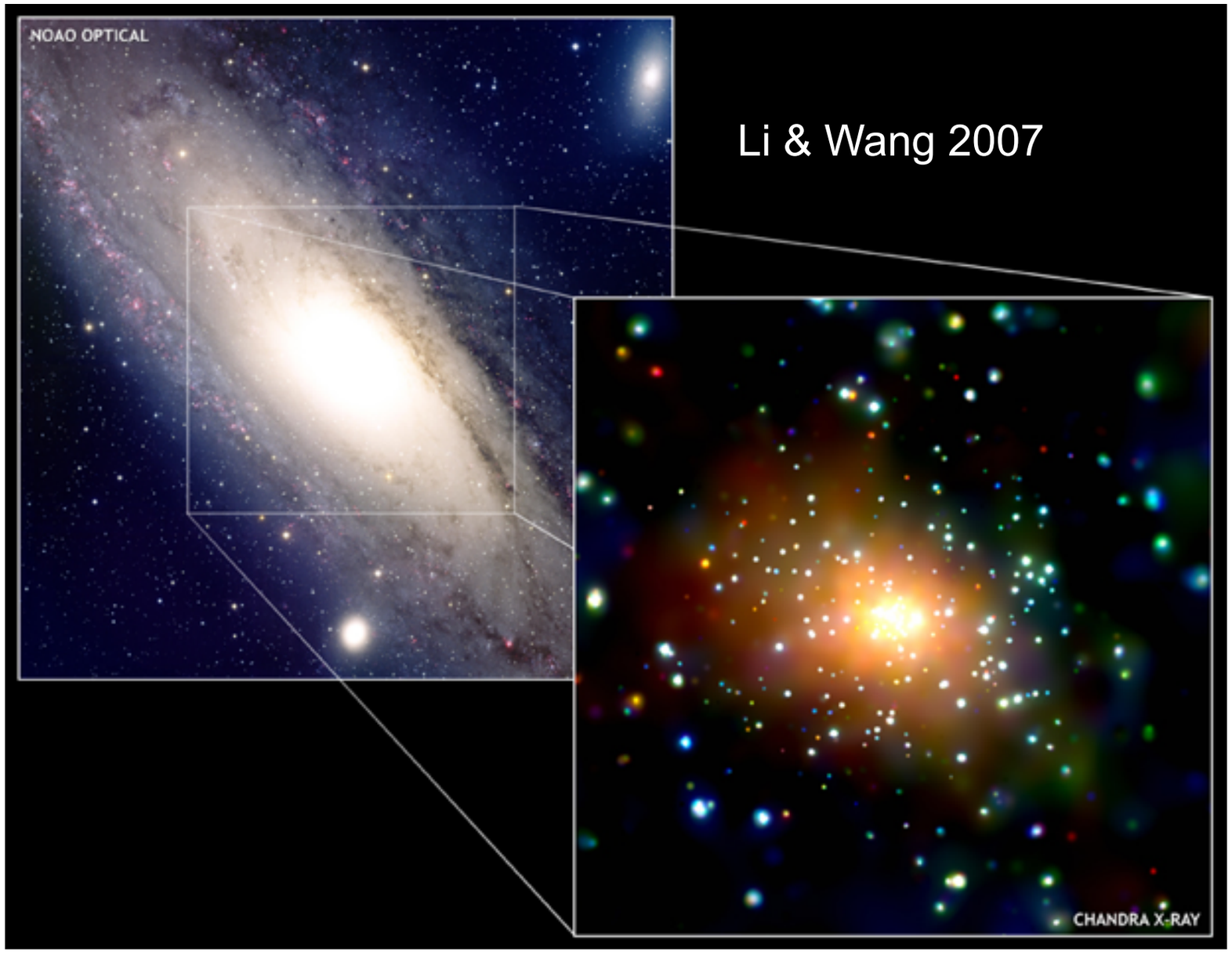
Su & Li (2014), in preparation

Galactic Center with a 3.55 keV line



Su & Li (2014), in preparation

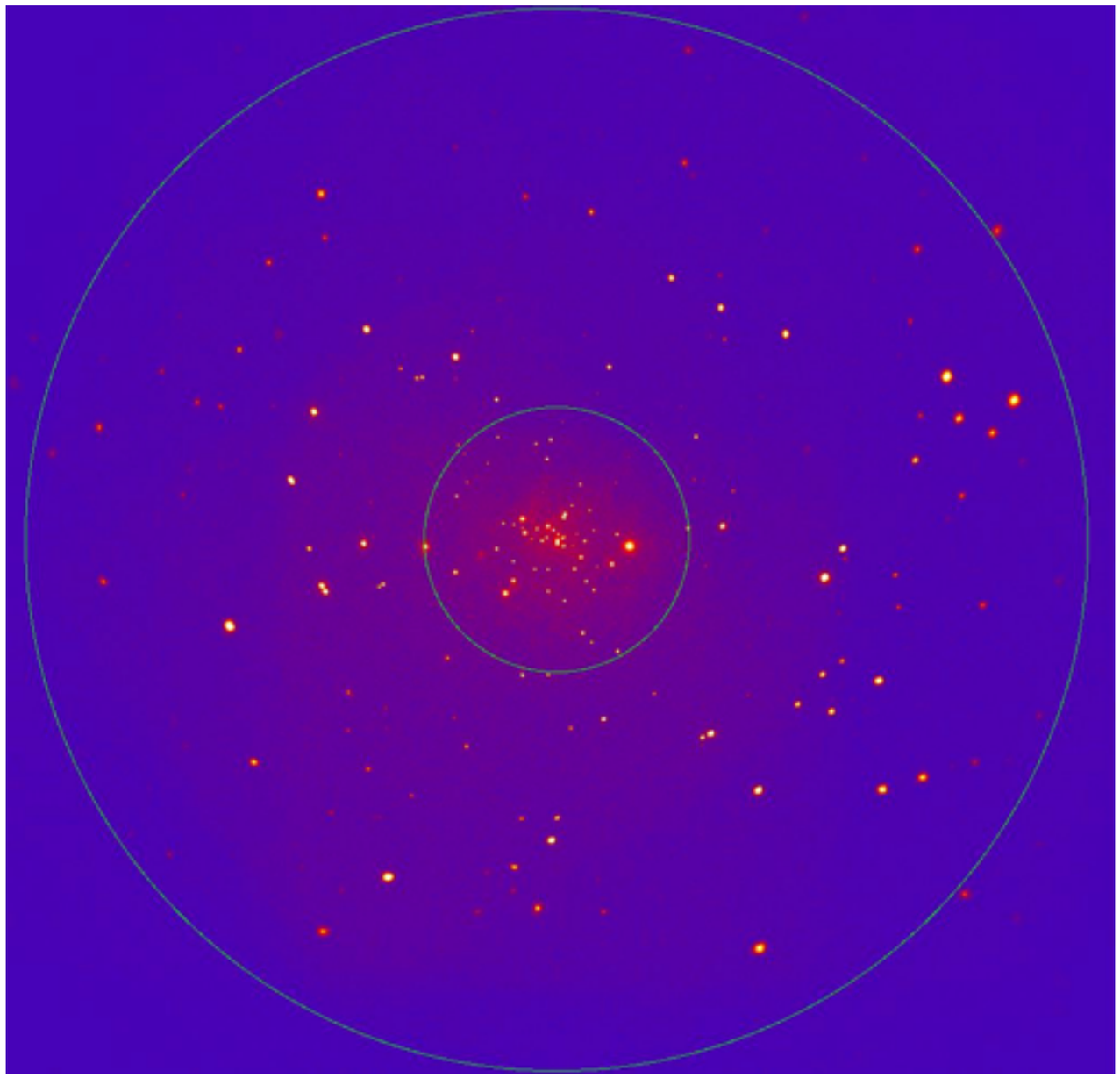
A Chandra/ACIS monitoring of the M31 bulge



- ~100 individual observations spanning 13 years, with a (still growing) total exposure of ~1 Ms
- ~0”5 resolution crucial for resolving X-ray binaries (down to a limiting luminosity of 10^34 erg/s)

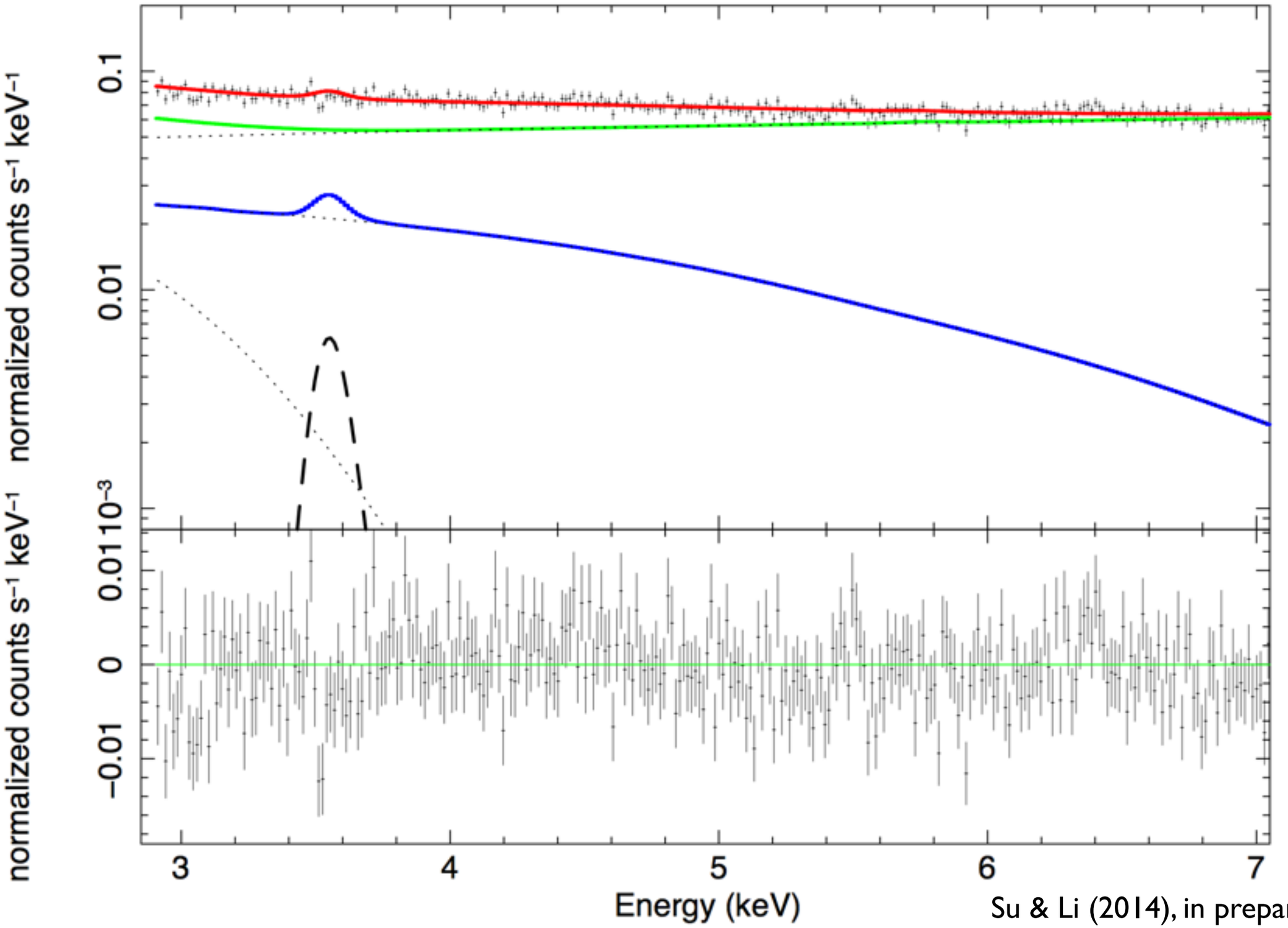
Constrain the 3.55 keV line from M31 Chandra data

- The M31 bulge: 330 ks ACIS-I exposure based on ~70 observations; spectra extracted from a 2'-8' (~0.5-2 kpc) annulus



Su & Li (2014), in preparation

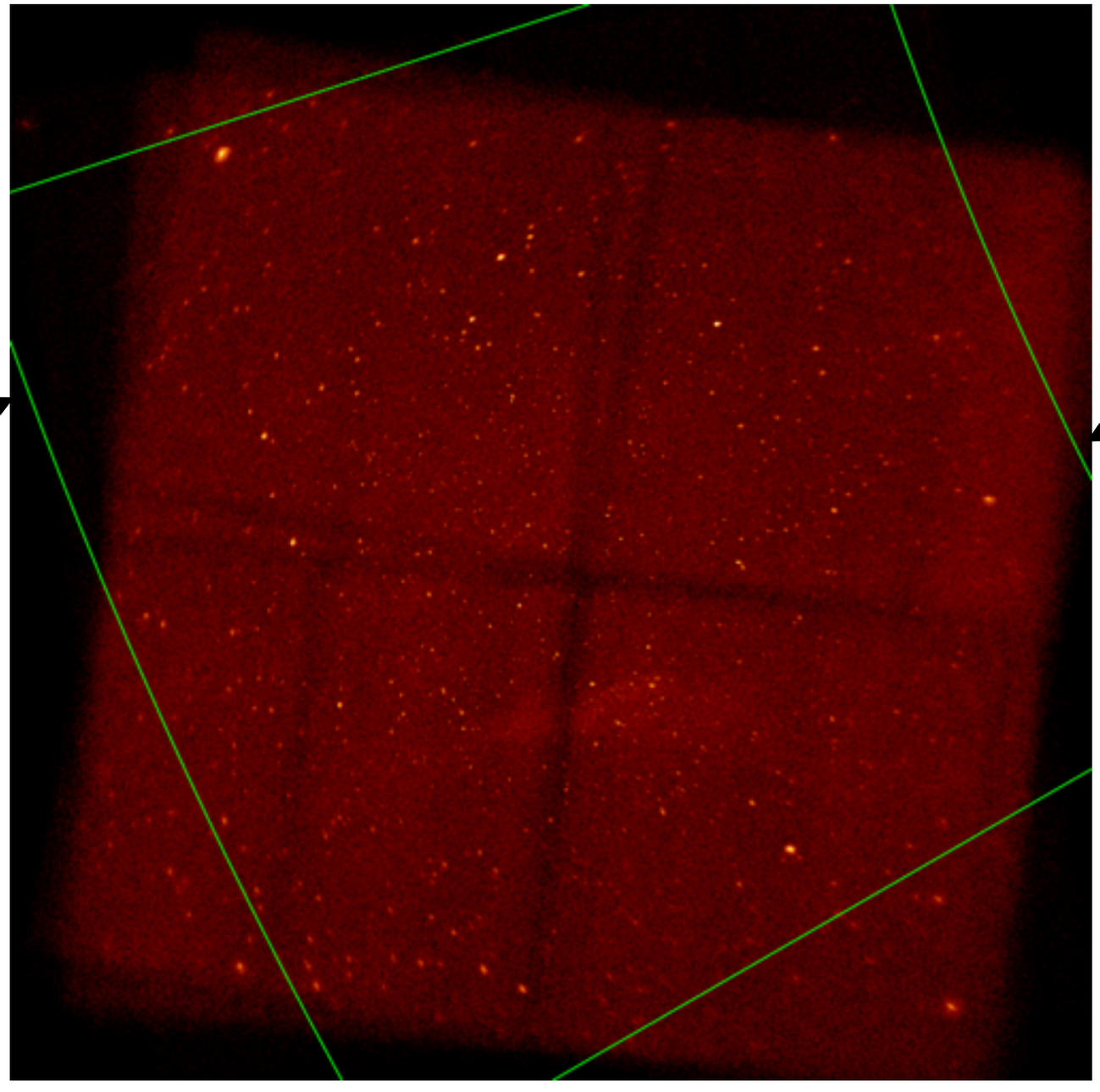
M31 with a 3.55 keV line



Su & Li (2014), in preparation

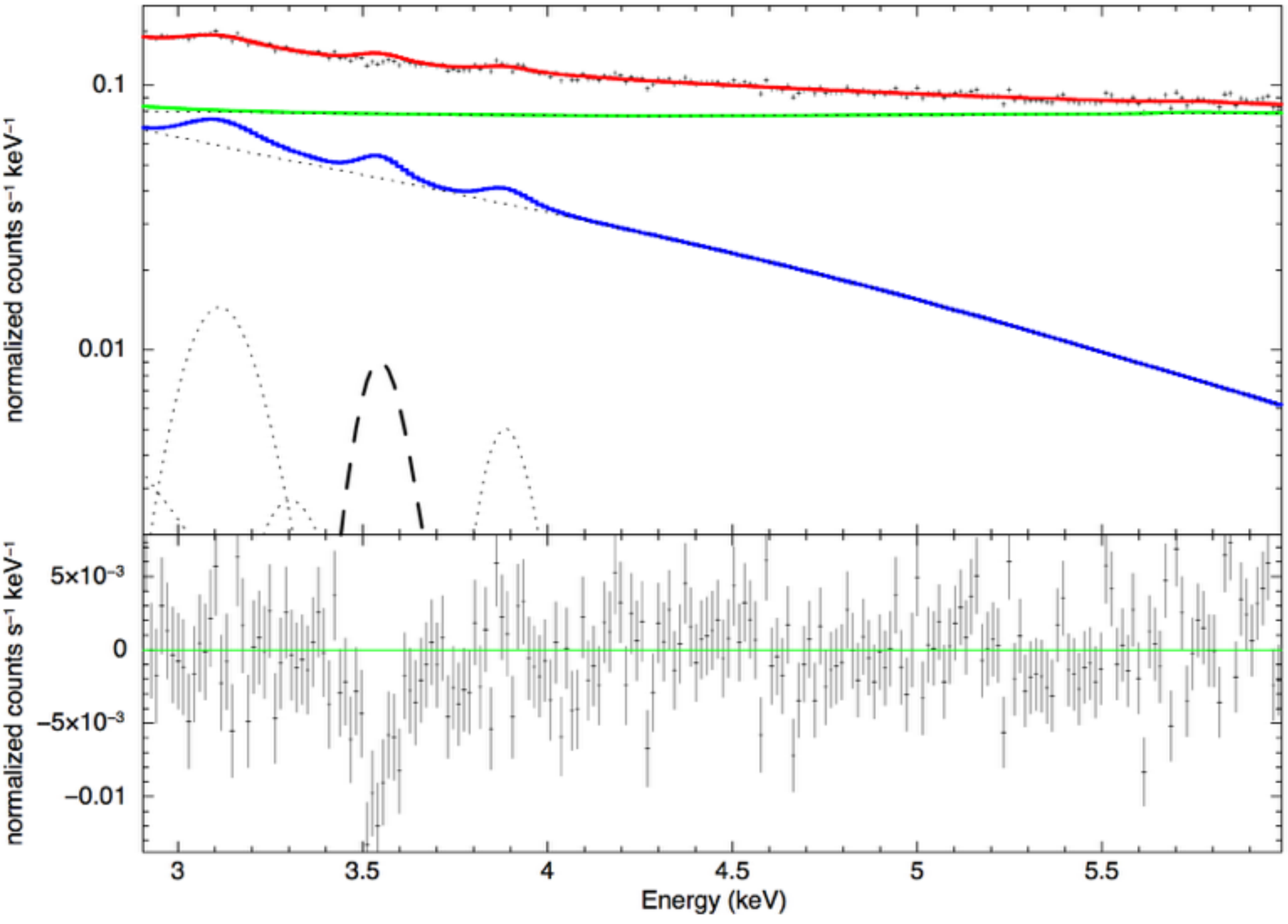
Constraints from the "Limiting Window":

- 1 Ms ACIS-I exposure based on 13 observations; spectra extracted from a 74'-91' (180-210 pc) sector with a 12-degree azimuthal range



Su & Li (2014), in preparation

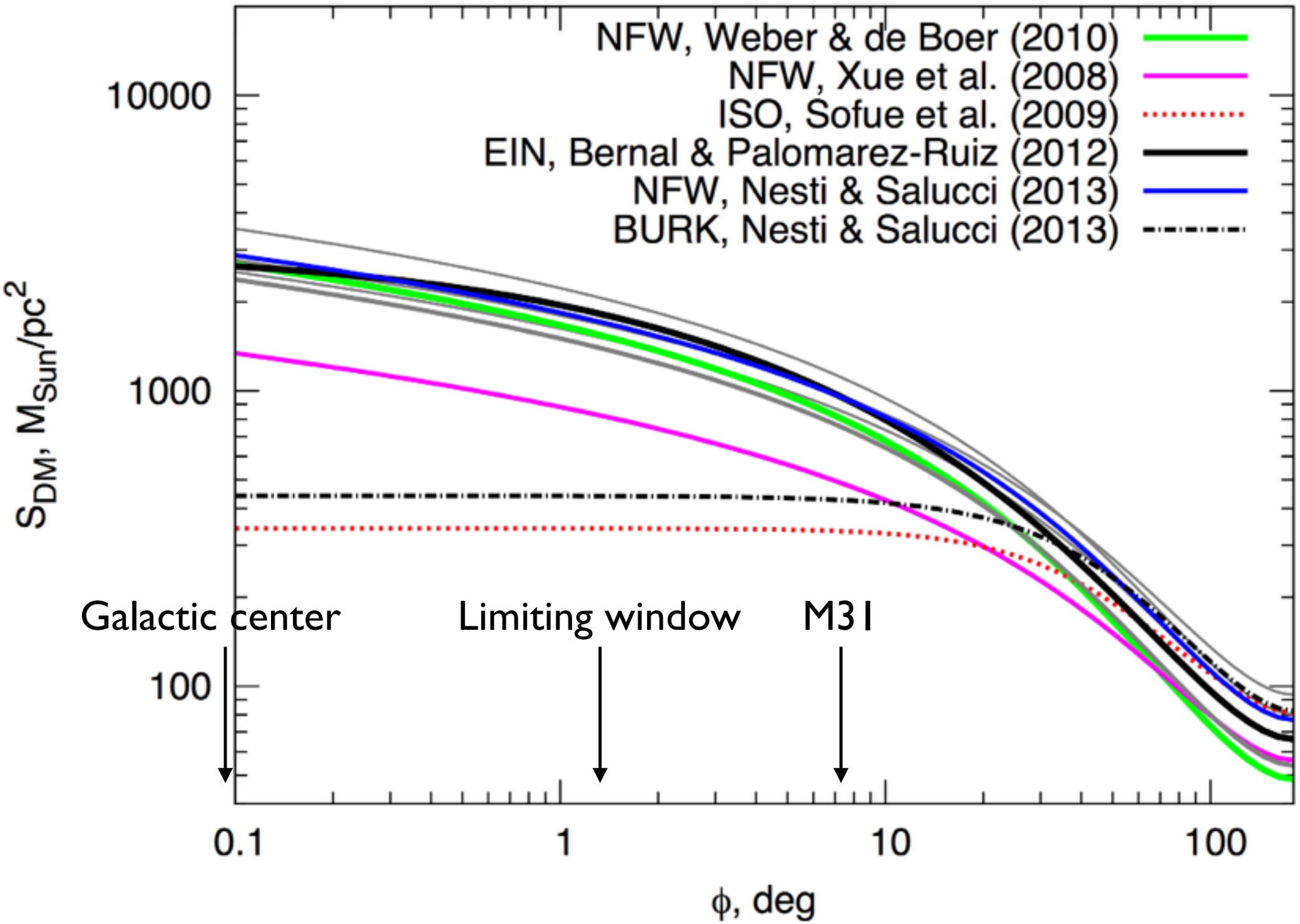
Constraints from the Limiting Window



Su & Li (2014), in preparation

How to reconcile/interpret the data?

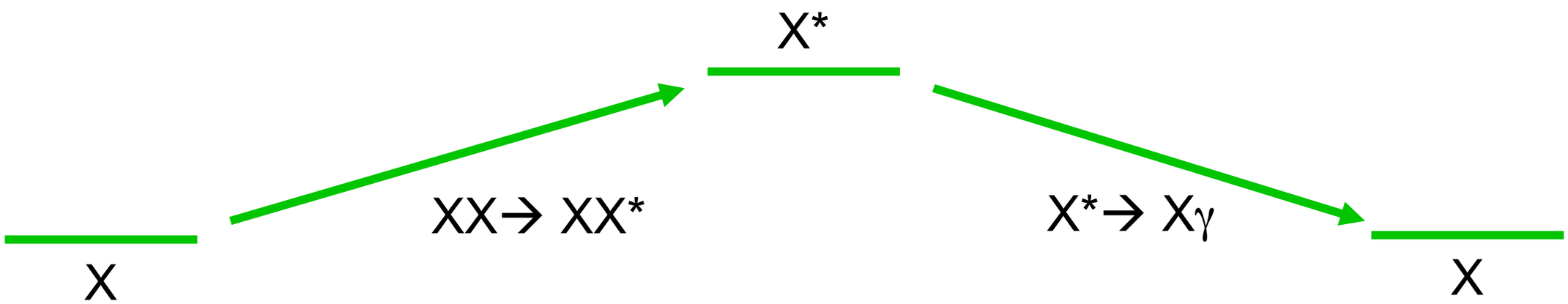
Systematics: the central part of the DM density profile in the Milky Way is uncertain



Boyarsky et al., arXiv:1408.2503

Physical models: exciting dark matter

WIMP dark matter X with a nearly degenerate state X*



X* created in collisions with kinetic energy > Δm ~ keV to MeV

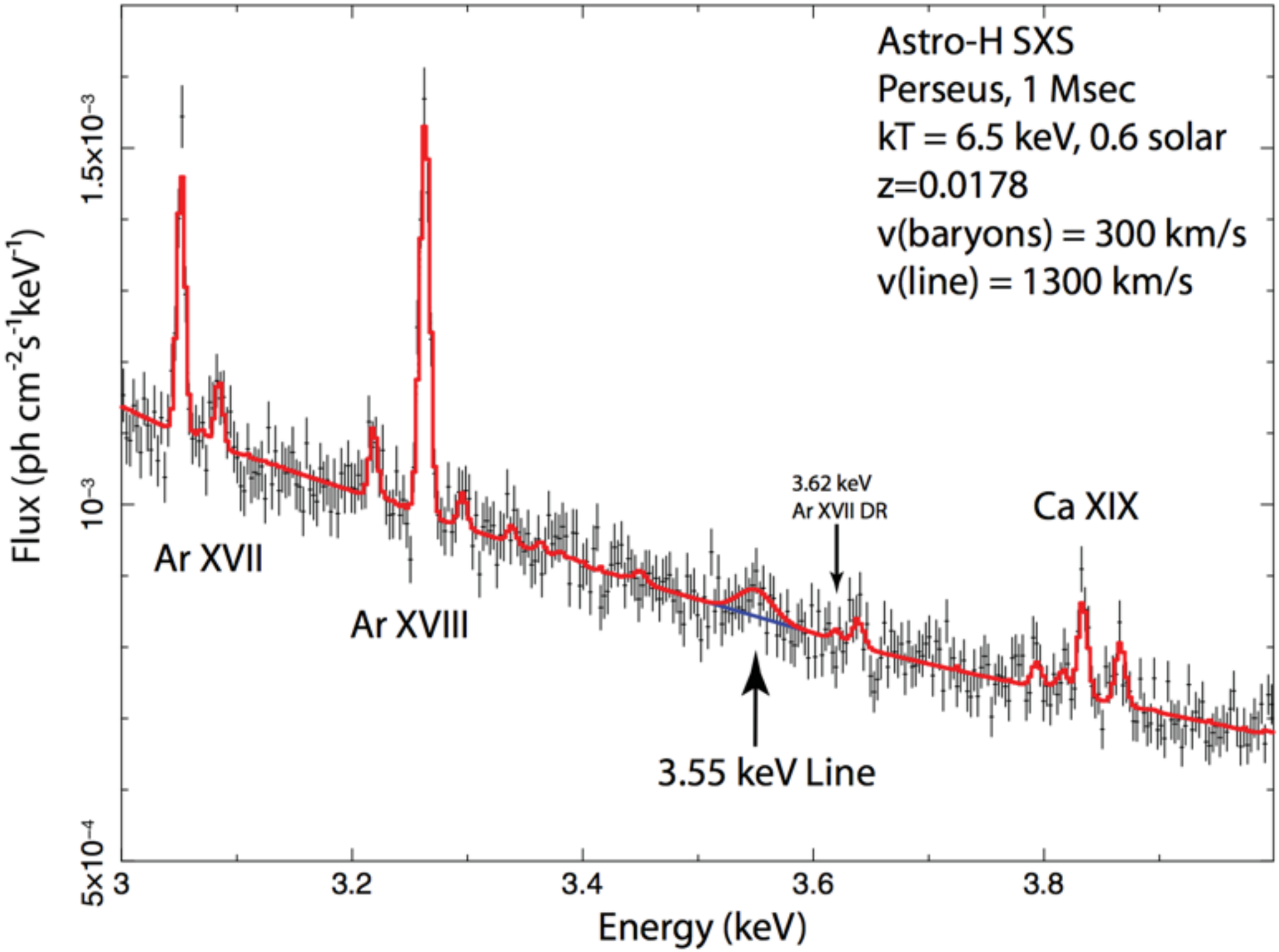
WIMP-like: TeV masses, correct thermal relic density

But completely different: dark photons to mediate up-scatter, de-excitation (INTEGRAL 511 keV), 3.5 keV line, …

Or some missing piece of intracluster medium astrophysics …

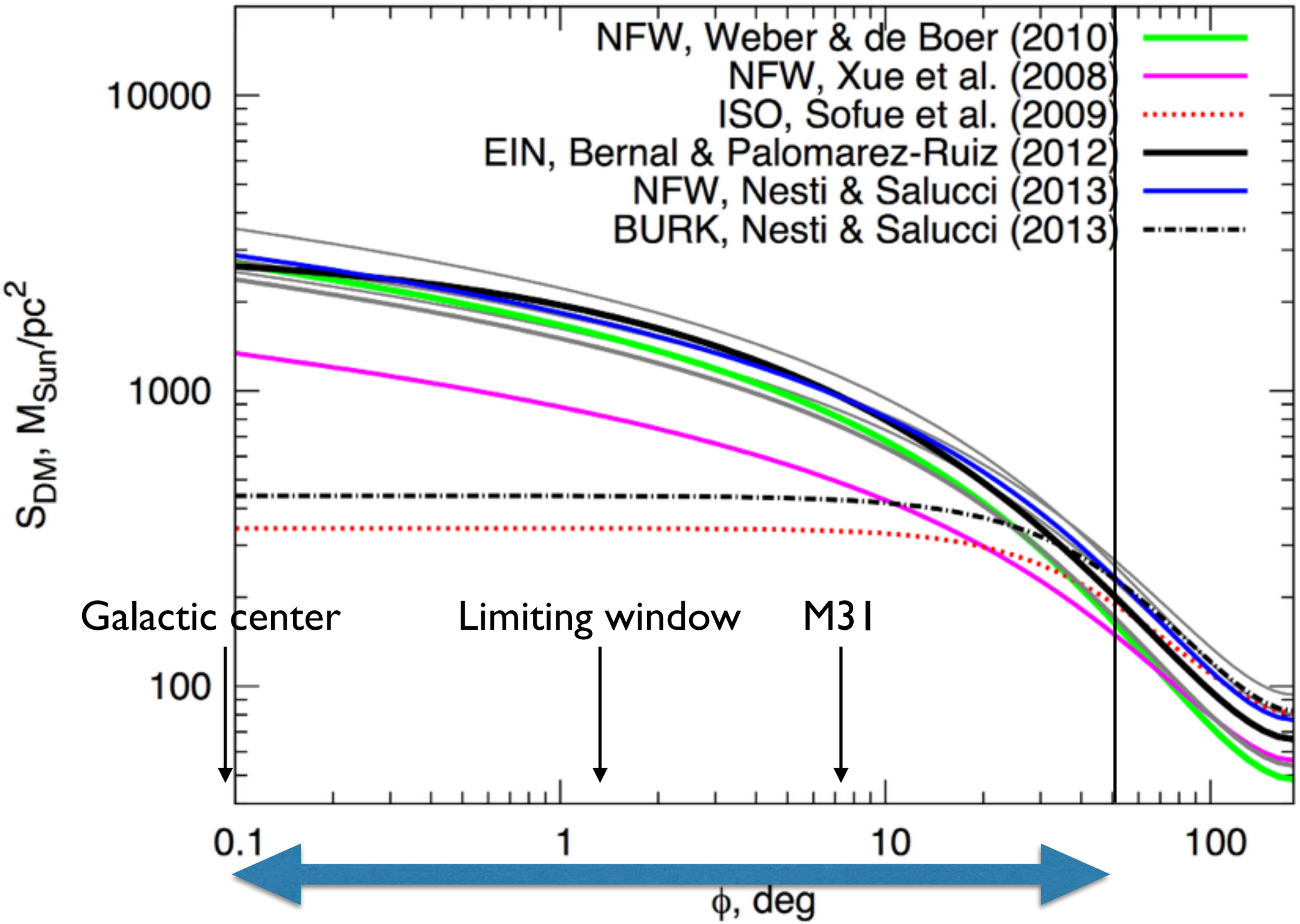
?

What's next?



Bulbul et al., 2014

The DM signal is distributed over the entire sky, so that it is not straightforward to look for this signal using narrow- field x-ray telescopes…



Boyarsky et al., arXiv:1408.2503

15 YEARS OF SCIENCE

WITH CHANDRA

November 18-21 • Boston Park Plaza Hotel • Boston, MA

Never be surprised by the universe!

15 YEARS OF CHANDRA

Thank you Chandra!

In 15 years of operation, NASA's Chandra X-ray Observatory has given us a view of the Universe that is largely hidden from telescopes sensitive only to visible light.

Chandra has captured galaxy clusters—the largest gravitationally bound objects in the Universe—in the process of forming, and provided the best evidence yet that the cosmos is dominated by a mysterious substance called dark matter.

Chandra has observed gas circling near a black hole's event horizon. The atoms of this gas are doomed to destruction by the extreme gravity of the black hole.

Most of the elements necessary for life are forged inside stars and blasted into interstellar space by supernovas.