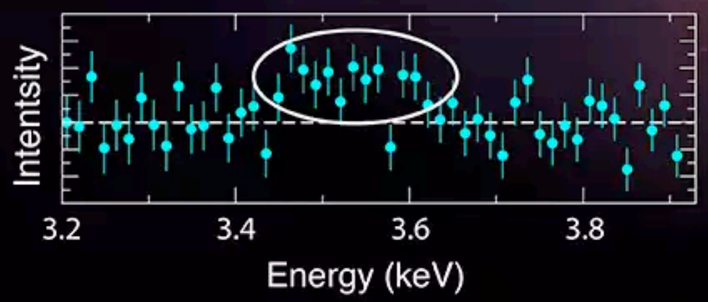
Was there a 3.5 keV line?



Credits: X-ray: NASA/CXC/SAO/E.Bulbul, et al.

Christopher Dessert

2309.03254 w/ Foster, Park, Safdi

2305.17160, 2102.02207, 2006.03974, 1812.06976

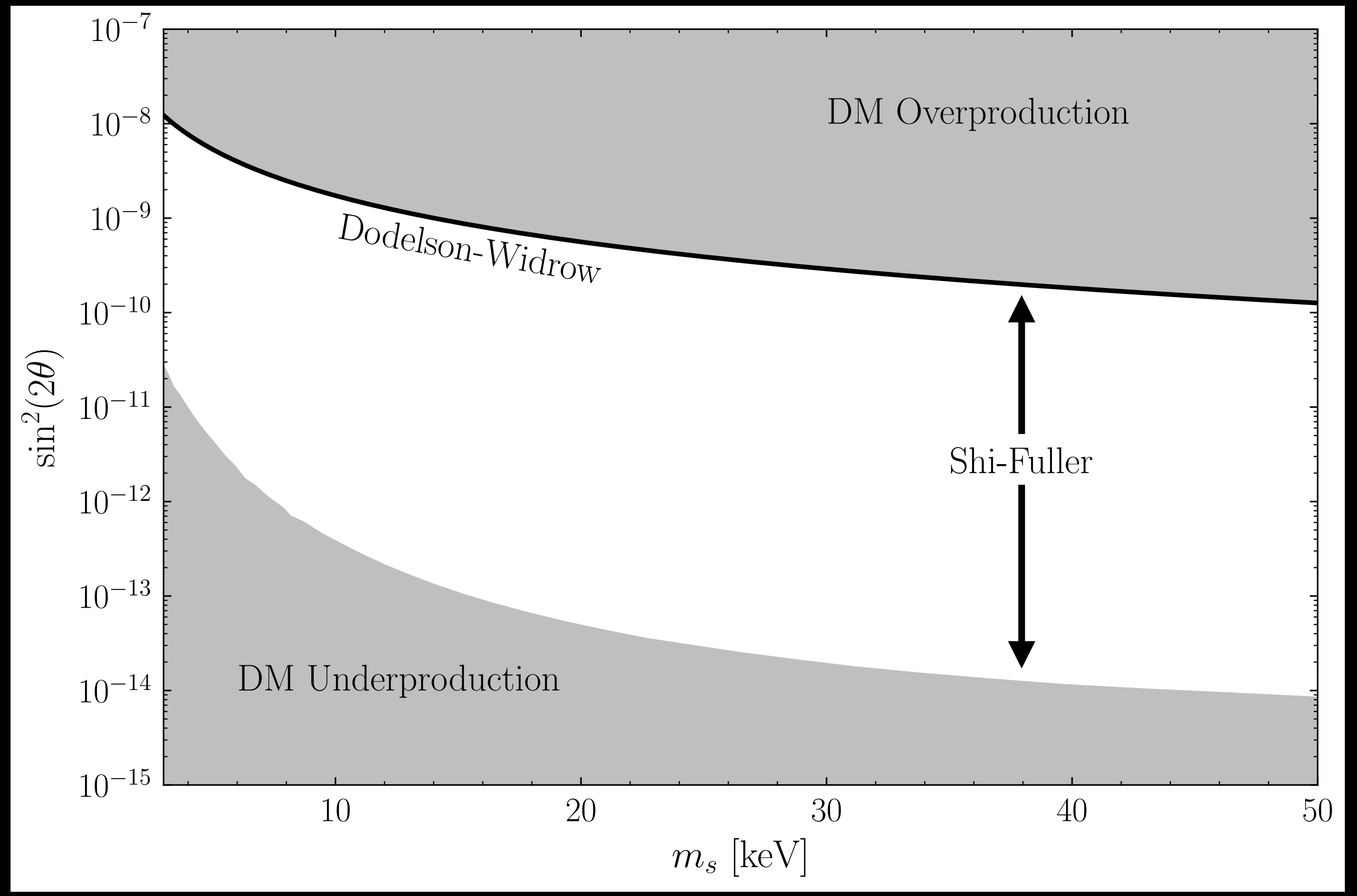
Dark Matter Beyond the Weak Scale

NYU

FLATIRON INSTITUTE

Why X-ray lines?

- Sterile neutrinos are a natural extension of the SM
- DM abundance if keV-scale
  - Dodelson-Widrow, Shi-Fuller
- Observables?
  - Small-scale structure
  - Radiative decay to X-rays



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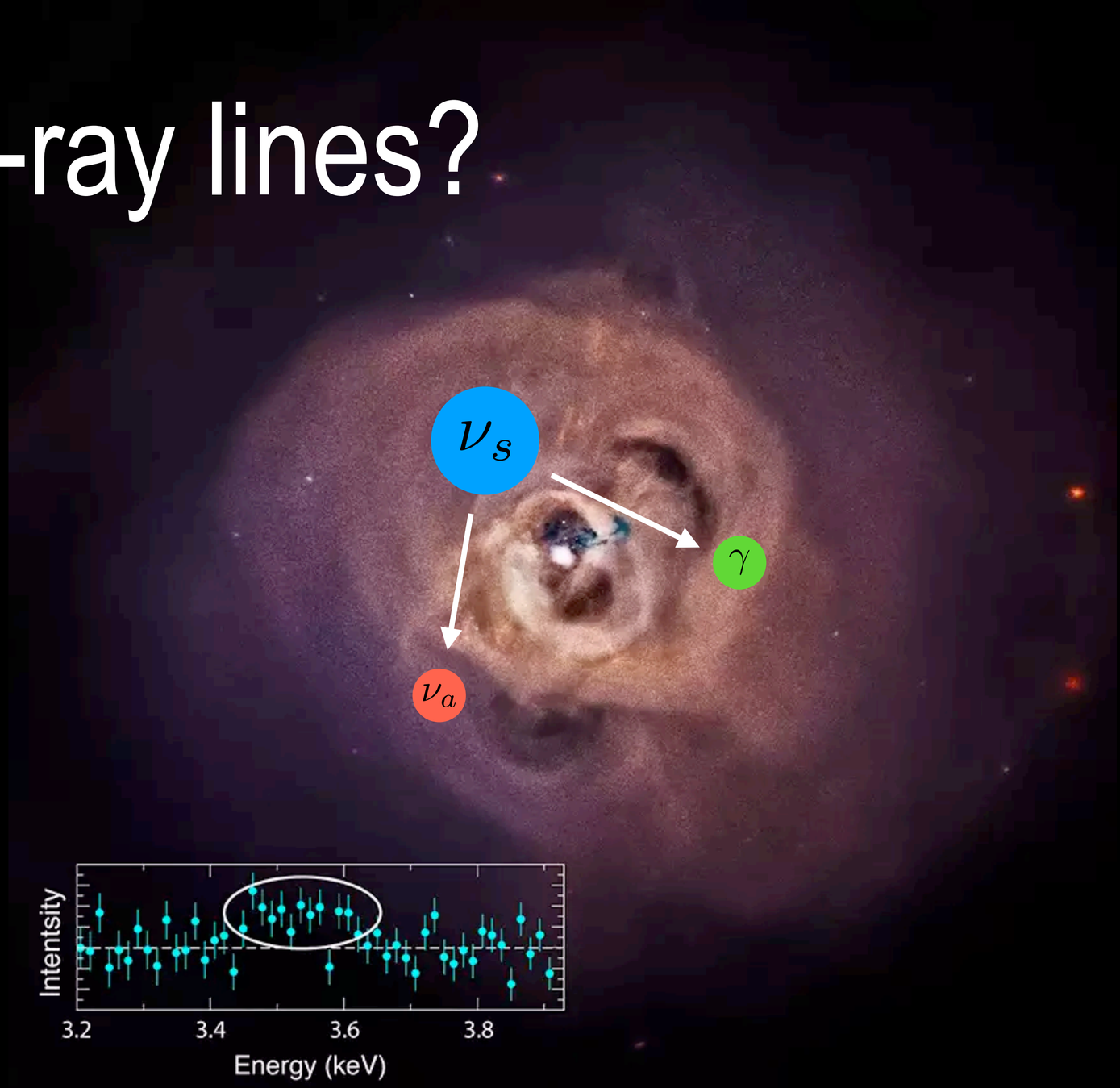

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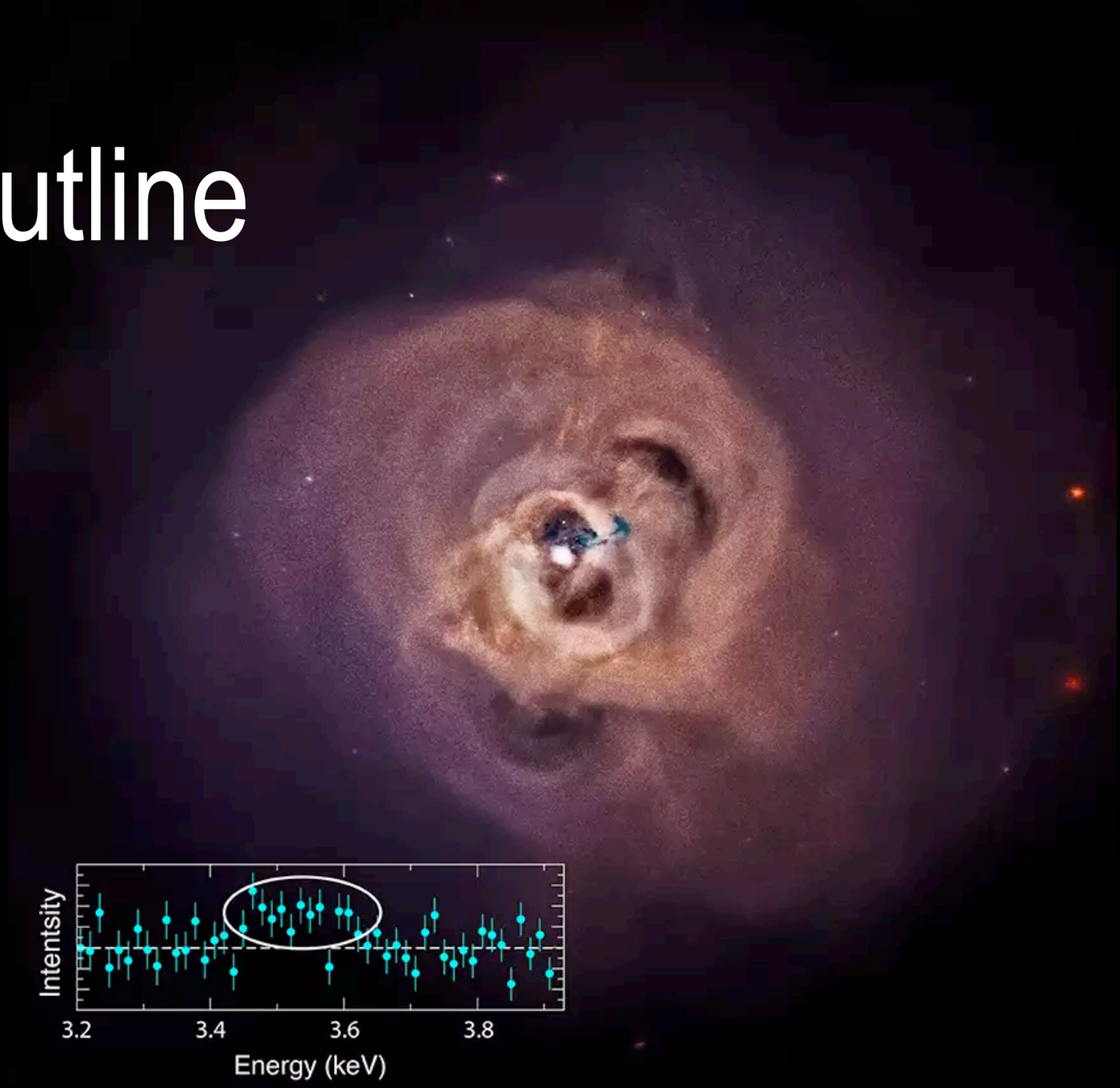
Outline

- A decade of the 3.5 keV line
- Was there a 3.5 keV line?
- Looking forward to next-gen DM line searches



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A decade of the 3.5 keV line

2014 — Discovery in

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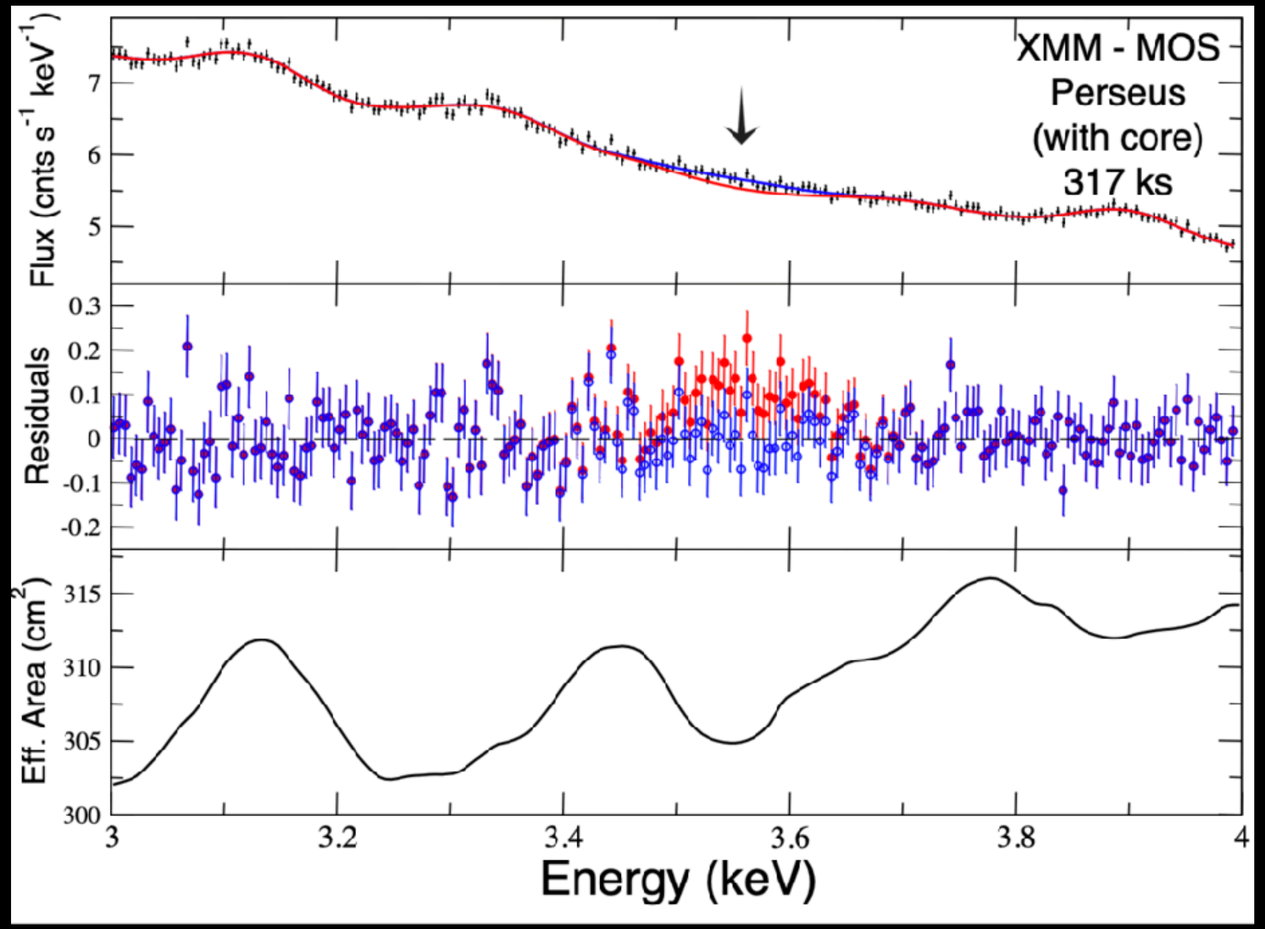

Bulbul et. al. ApJ (2014)

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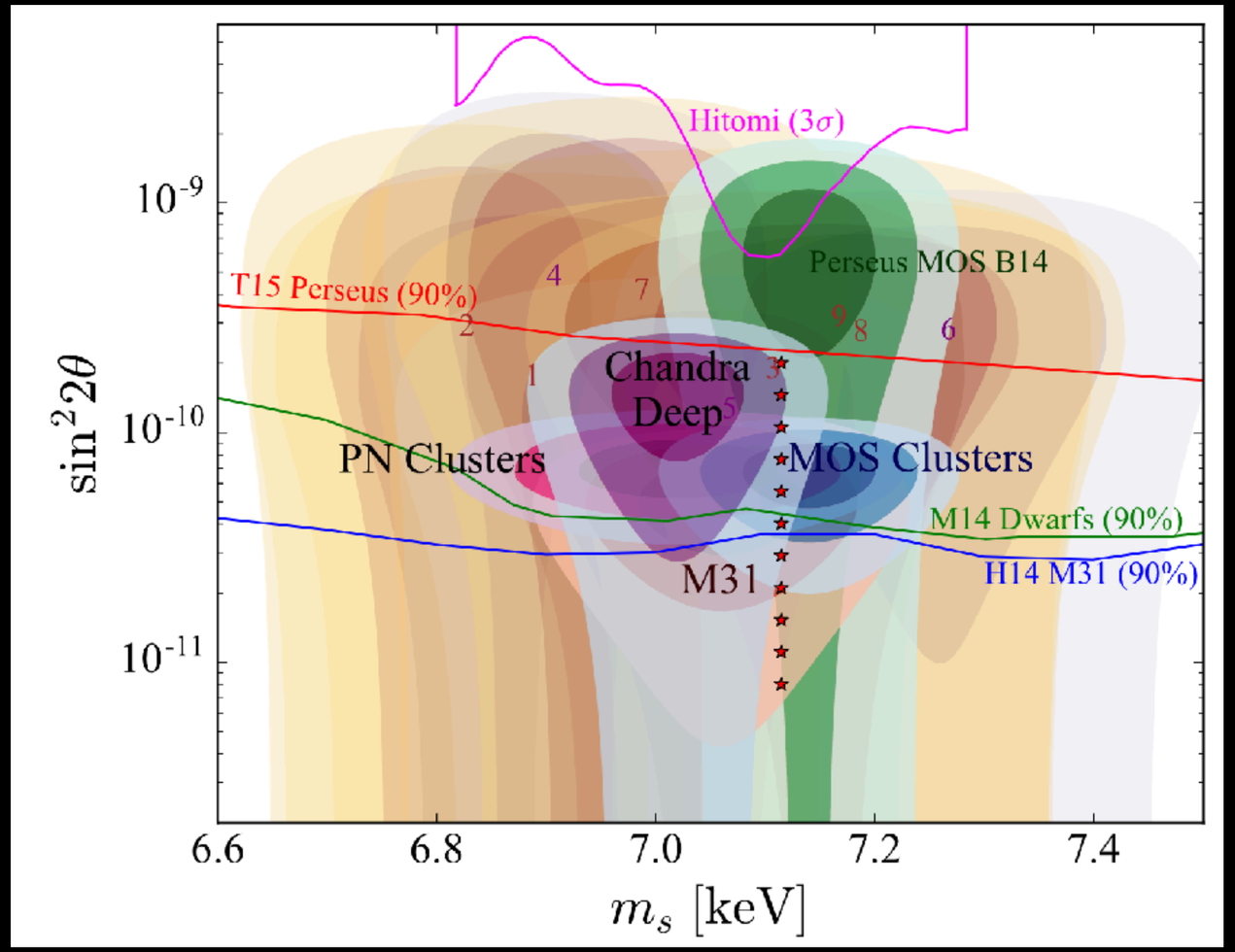

Abazajian 1705.01837

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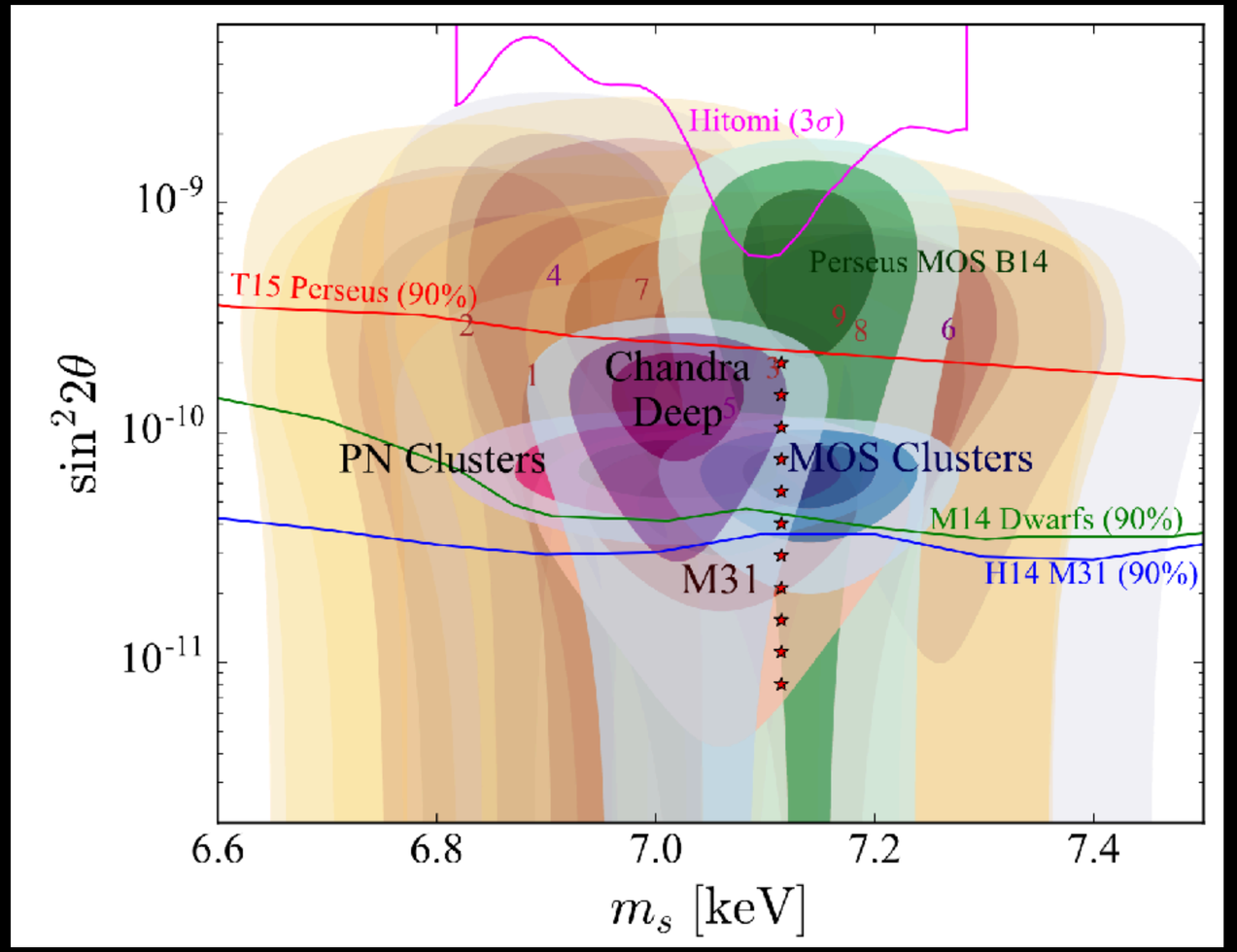

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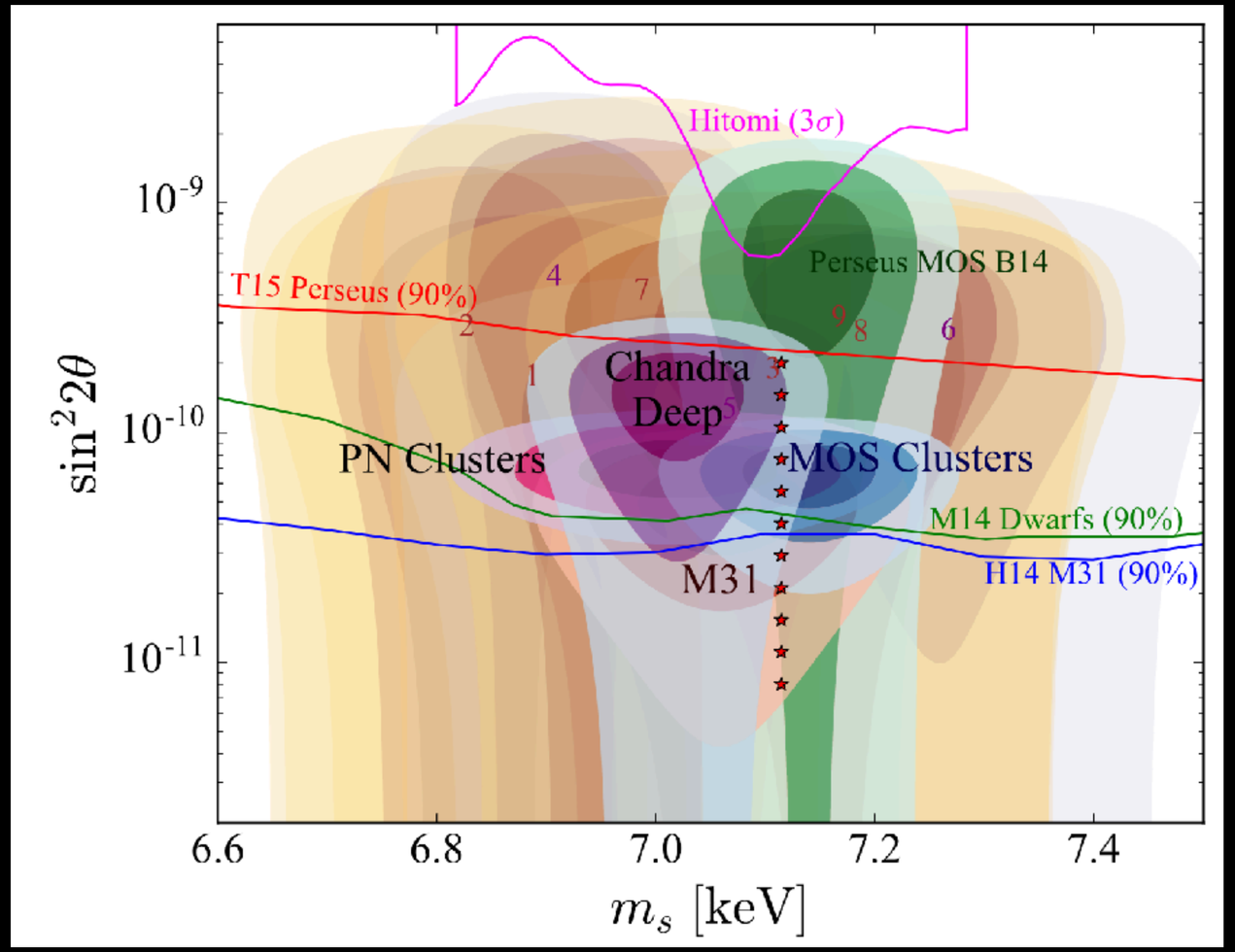

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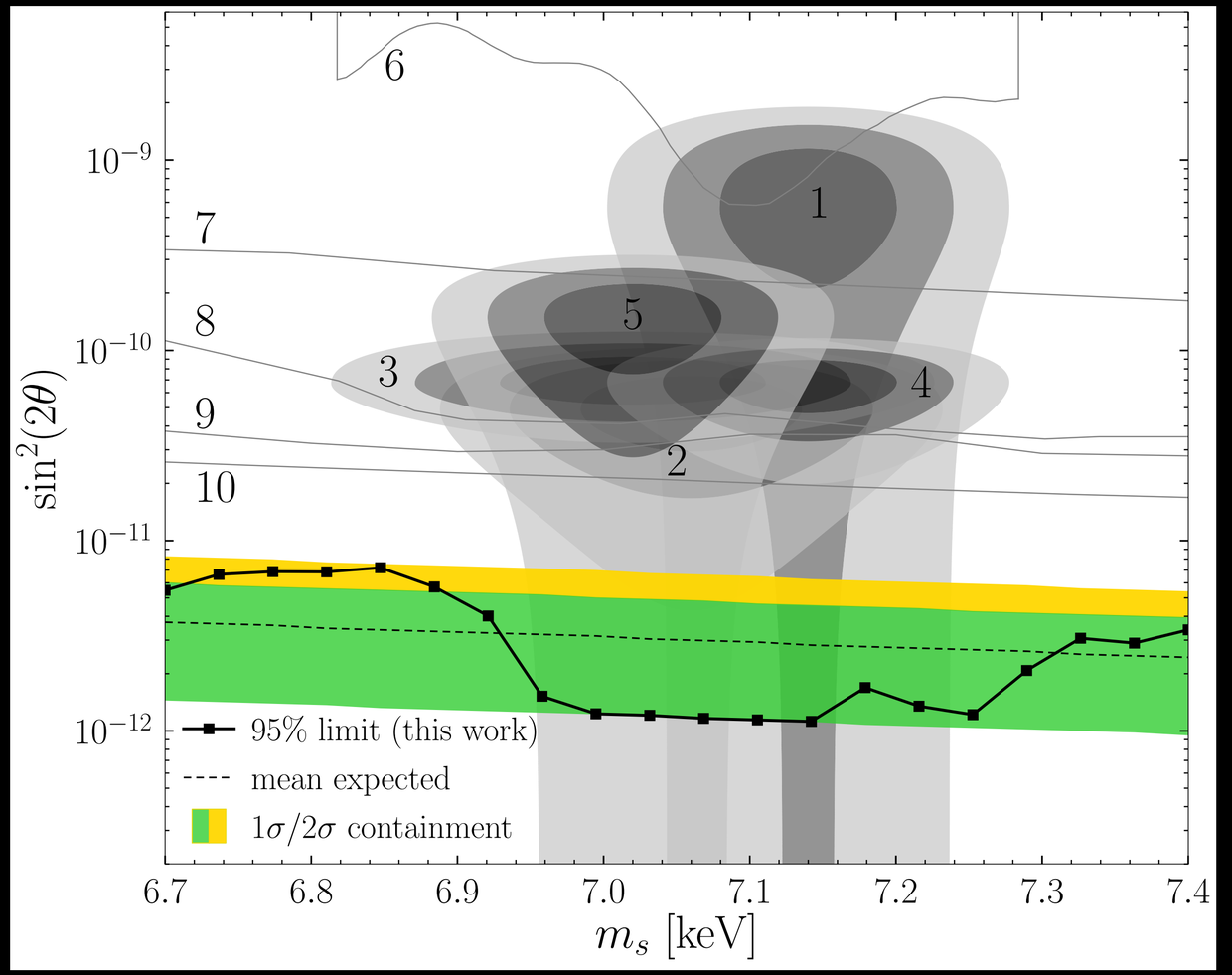

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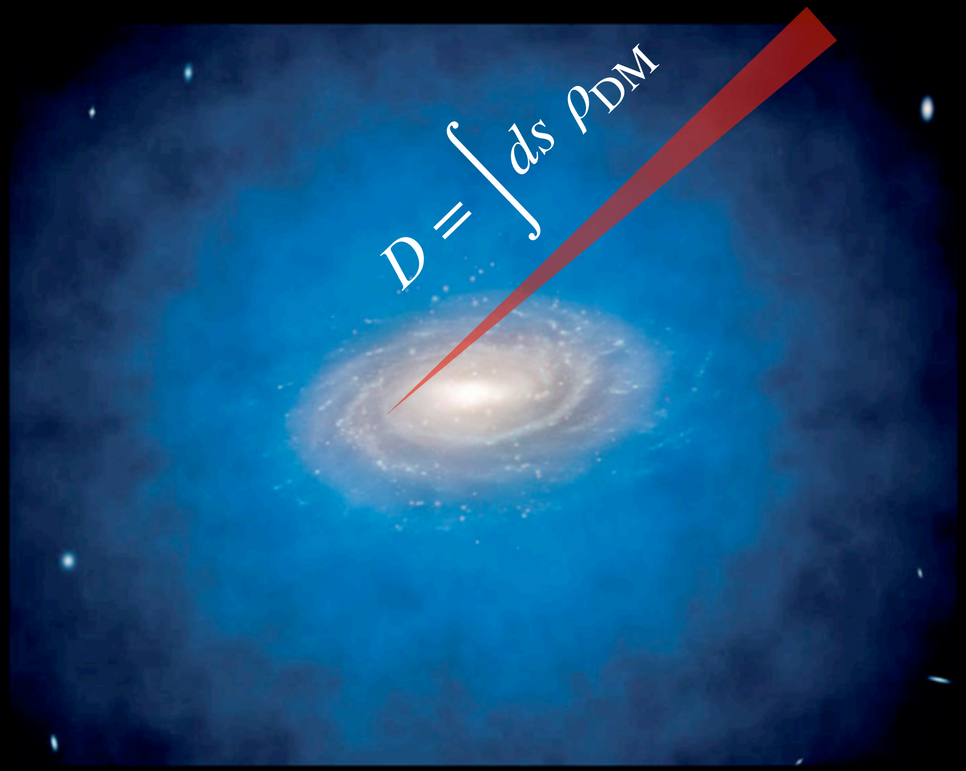

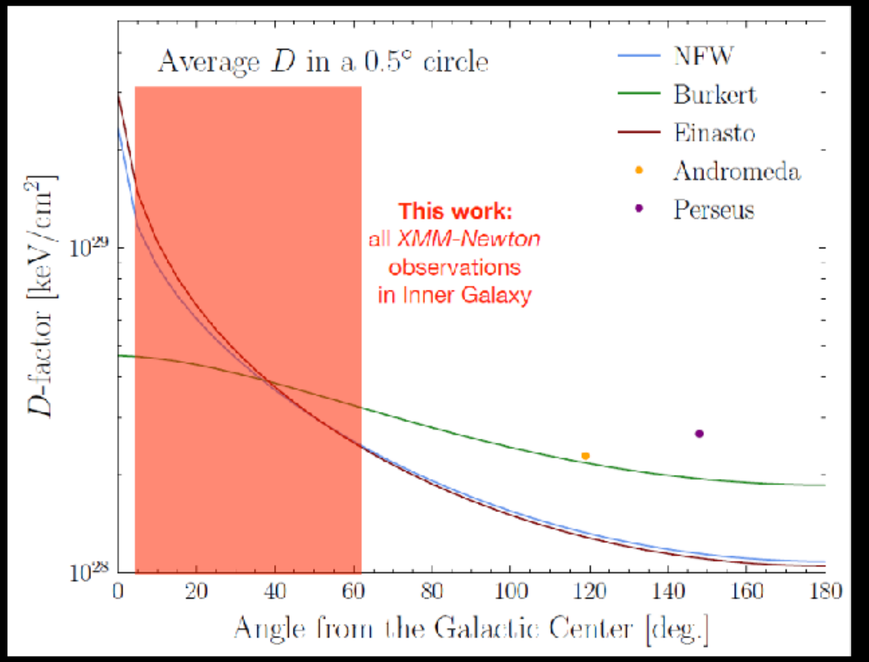

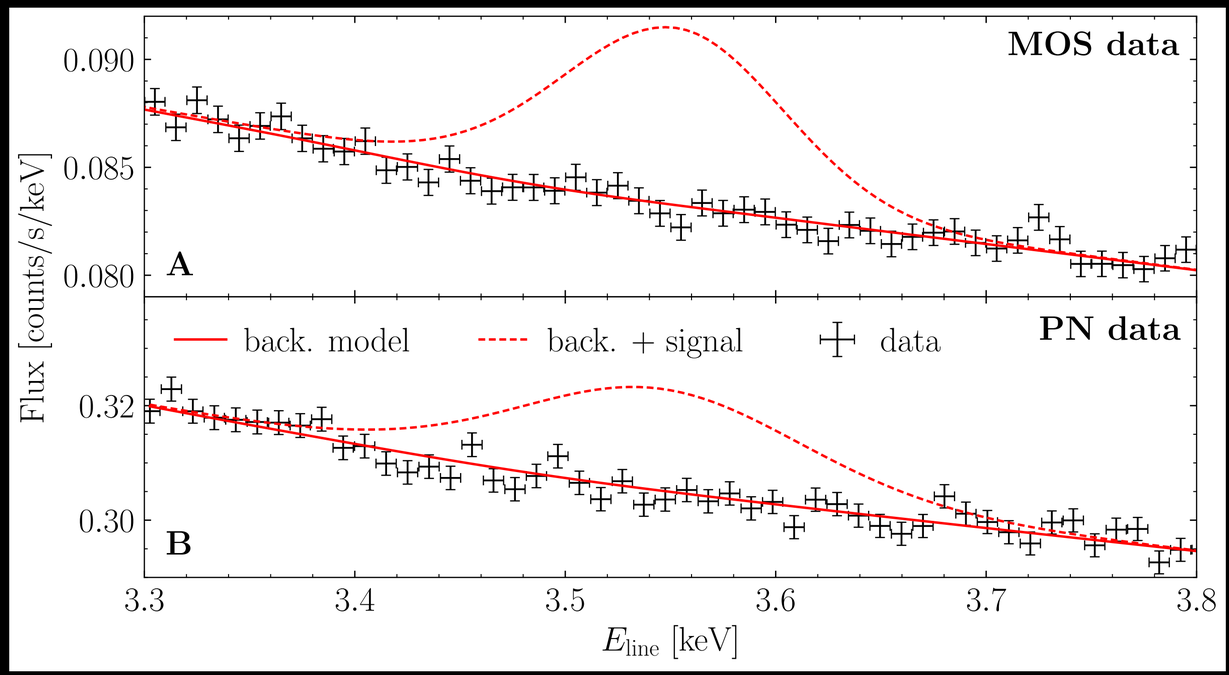

A decade of the 3.5 keV line

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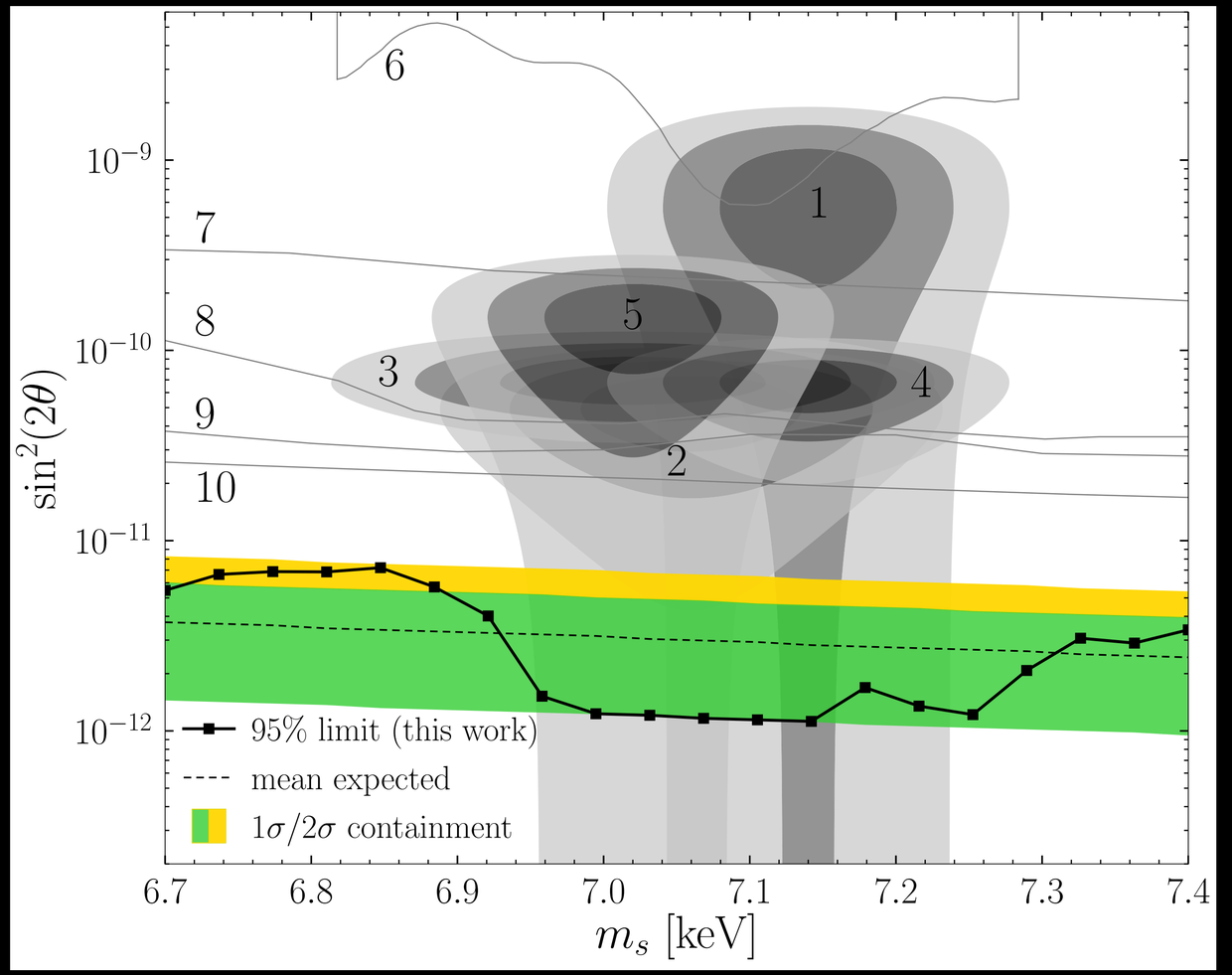

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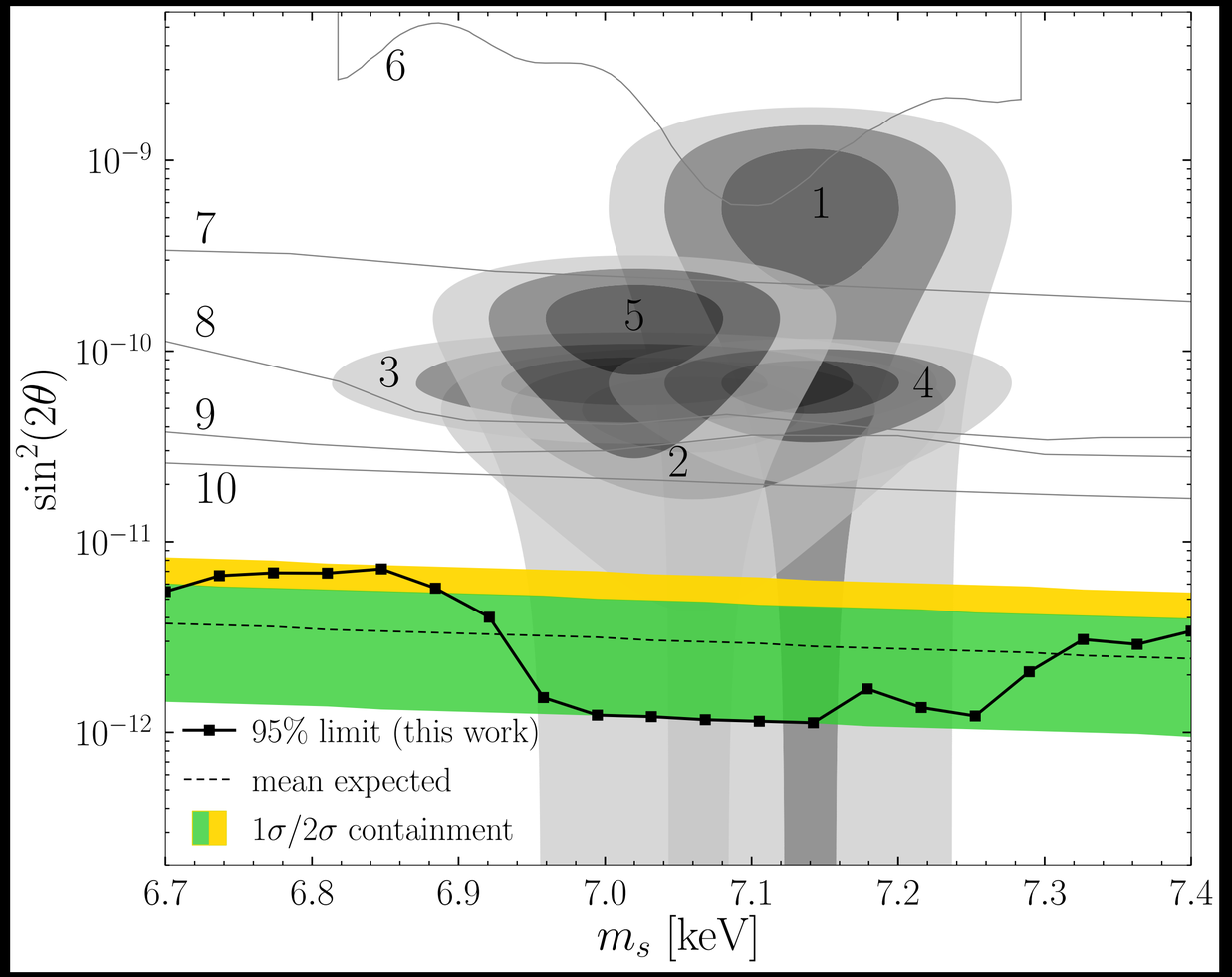
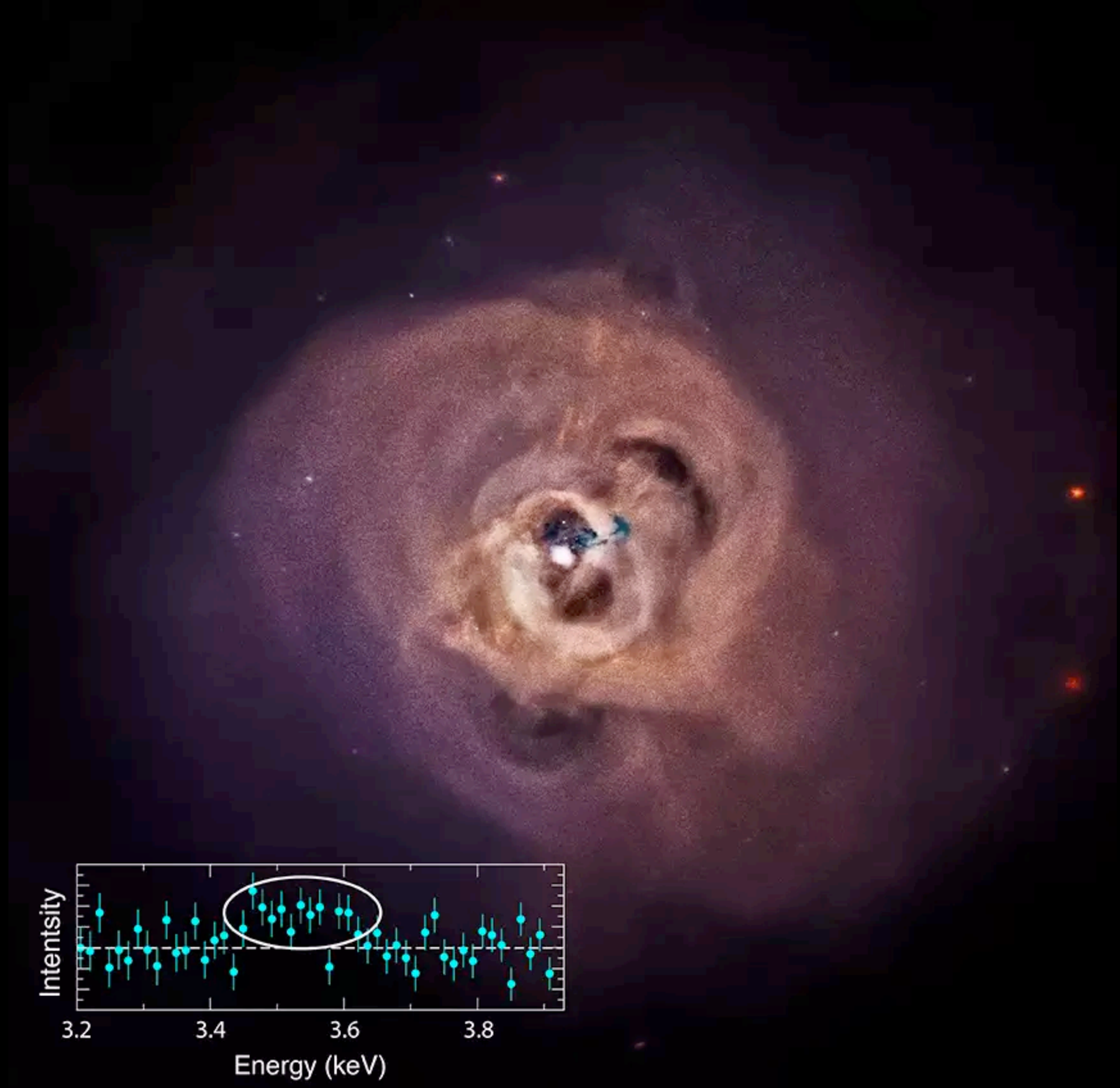


The 3.5 keV line

Possible origins:

- ~~Sterile neutrino DM decay~~



Credits: X-ray: NASA/CXC/SAO/E.Bulbul, et al.

The 3.5 keV line

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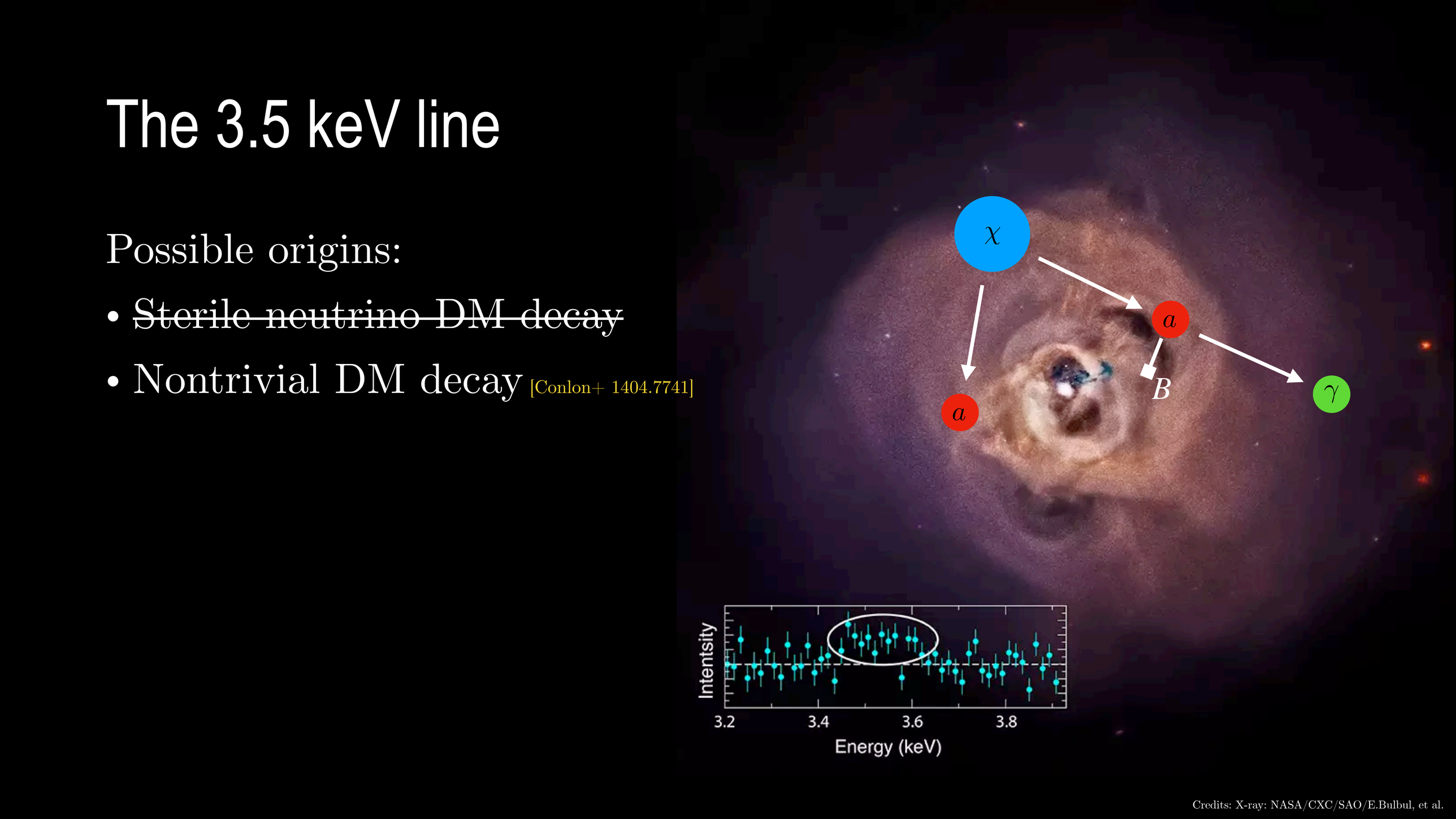

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Possible origins:

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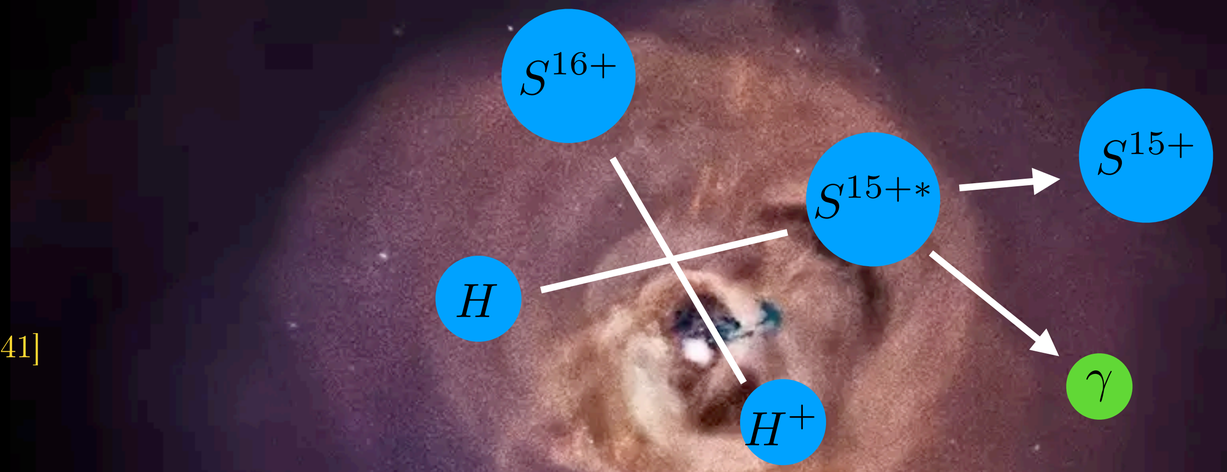

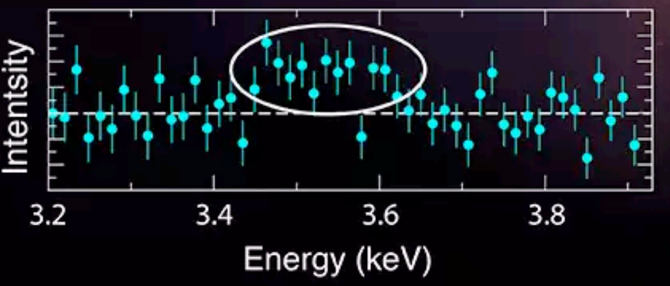

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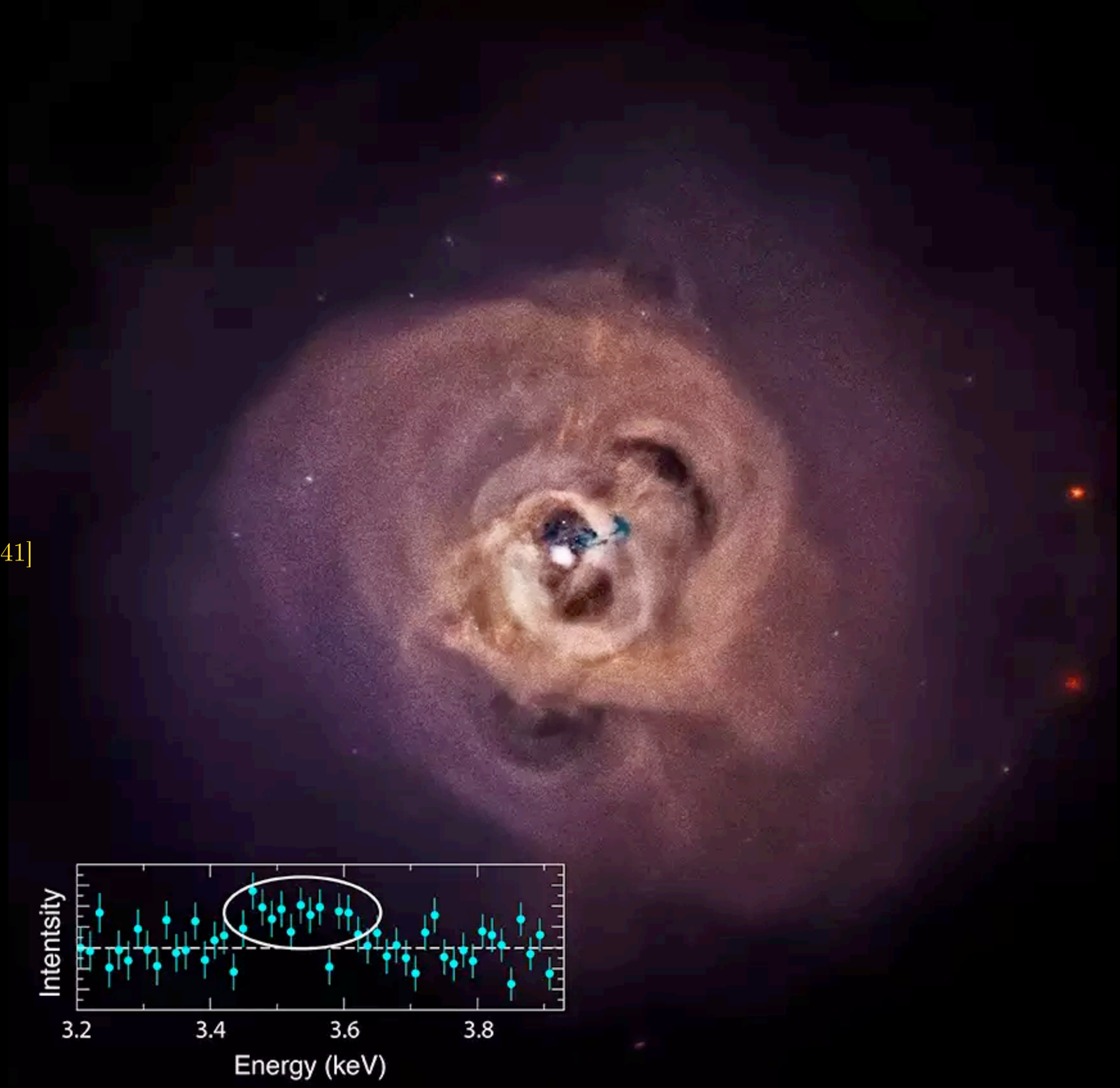
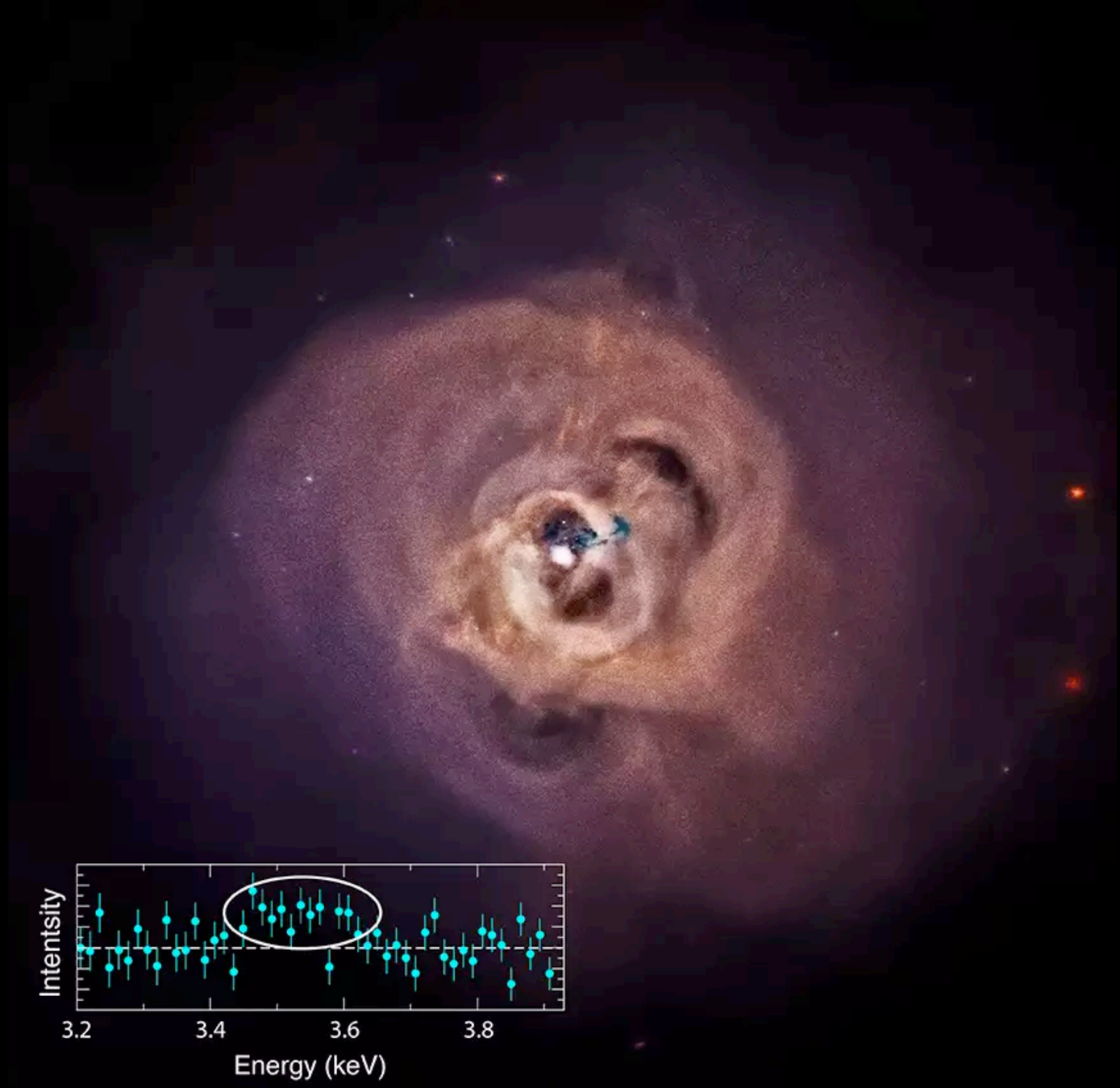
- Systematic Artifact?



Credits: X-ray: NASA/CXC/SAO/E.Bulbul, et al.

The 3.5 keV line

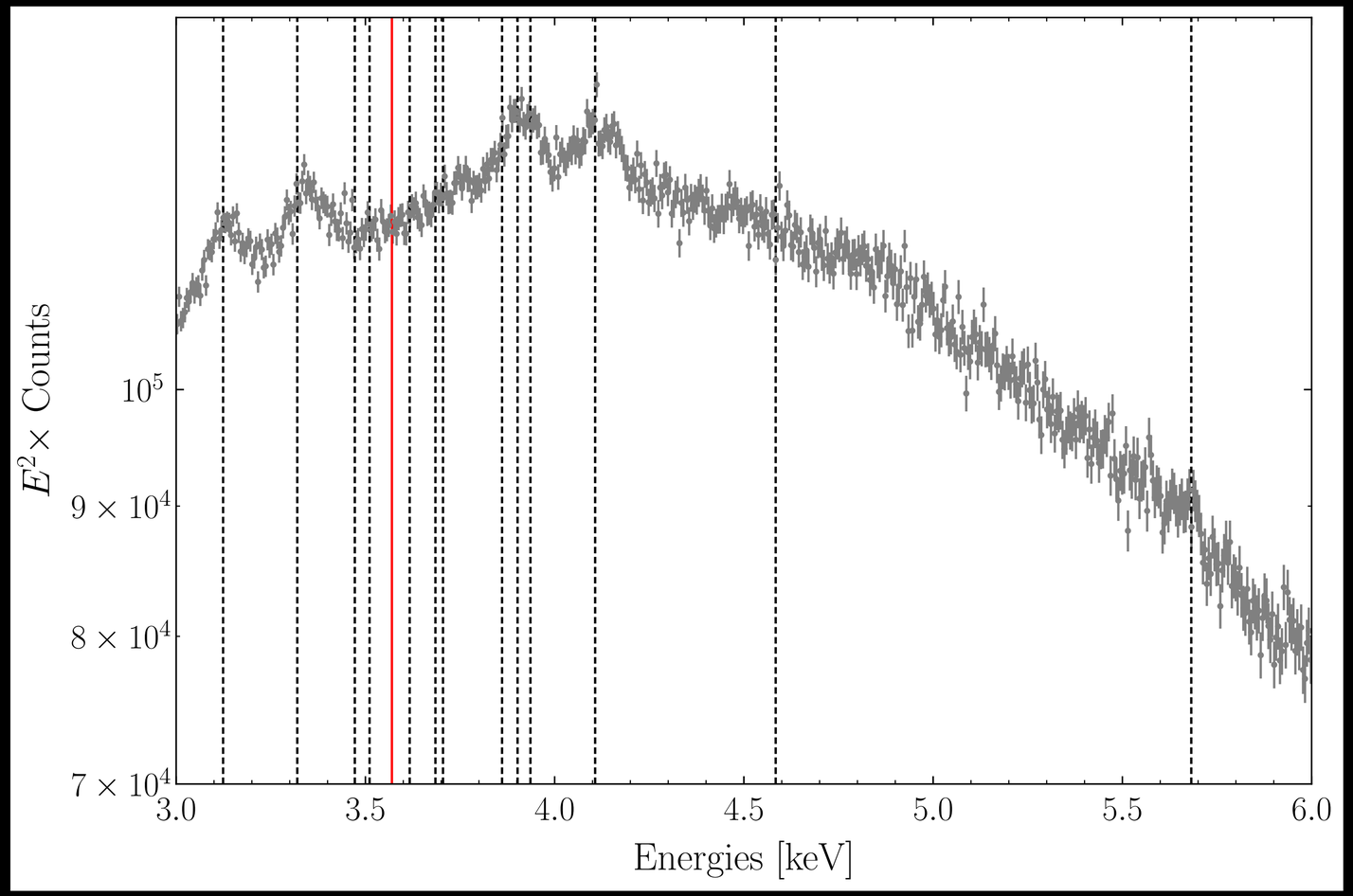
- Goals:
  - (i) reproduce original evidence for the 3.5 keV line
  - (ii) examine robustness of evidence
- Datasets:
  1. XMM/Perseus cluster
  2. XMM/Perseus cluster, Cored
  3. XMM/Stacked clusters
  4. XMM/M31
  5. Chandra/Perseus
  6. Chandra/Deep Fields



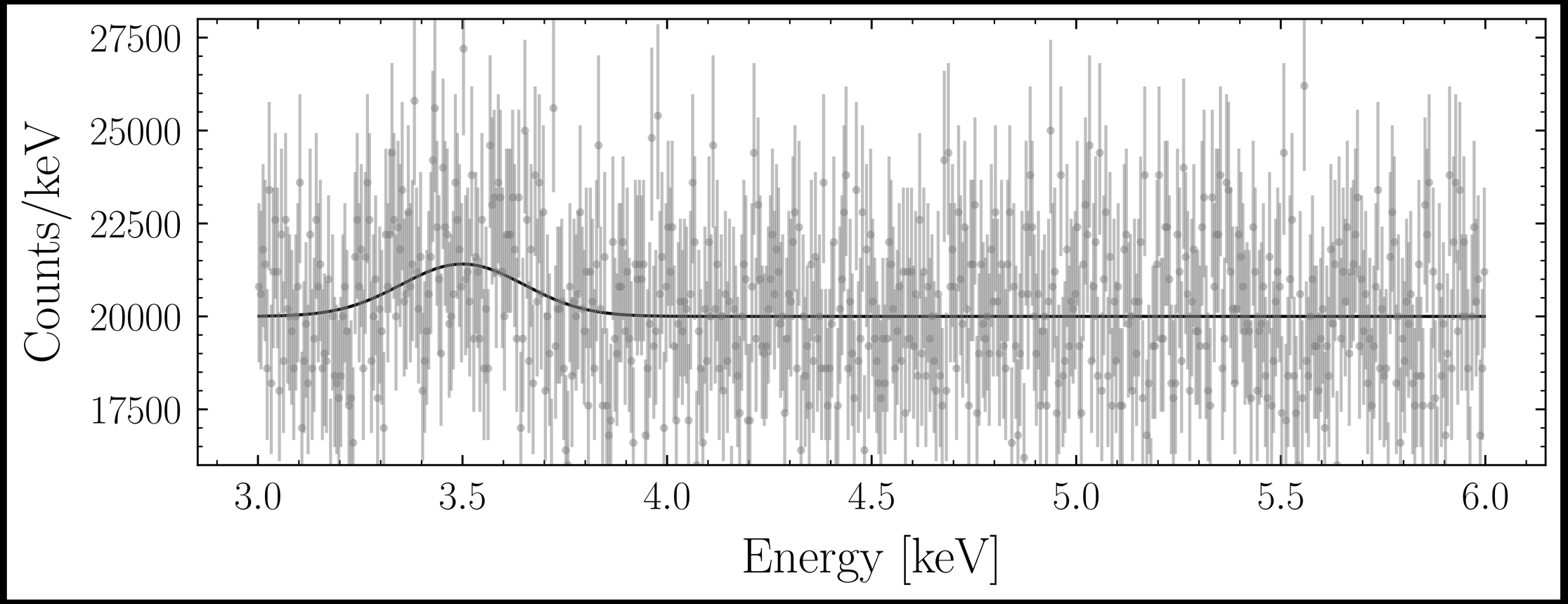
Credits: X-ray: NASA/CXC/SAO/E.Bulbul, et al.

Challenges in X-ray line searches

- Model signal line + continuum + lines over a wide energy range
- Concerns:
  - Mismodeling
  - Likelihood optimization



Background Mismodeling



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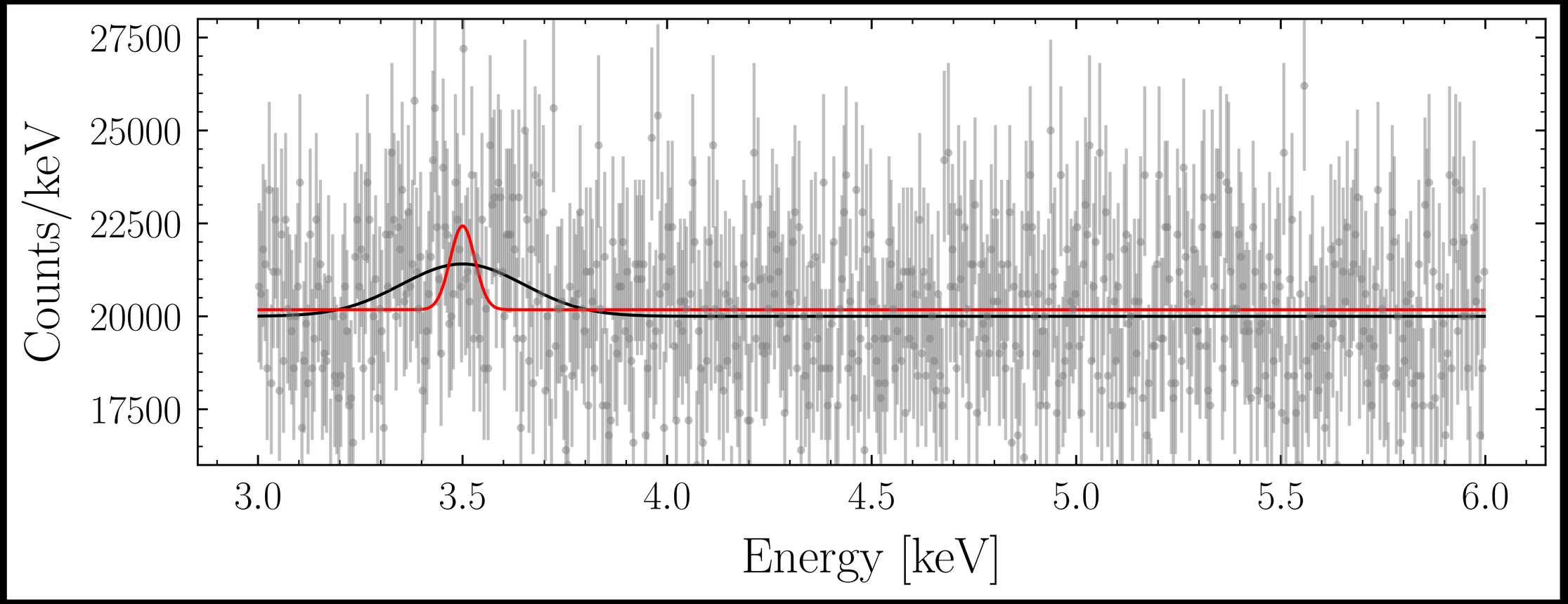

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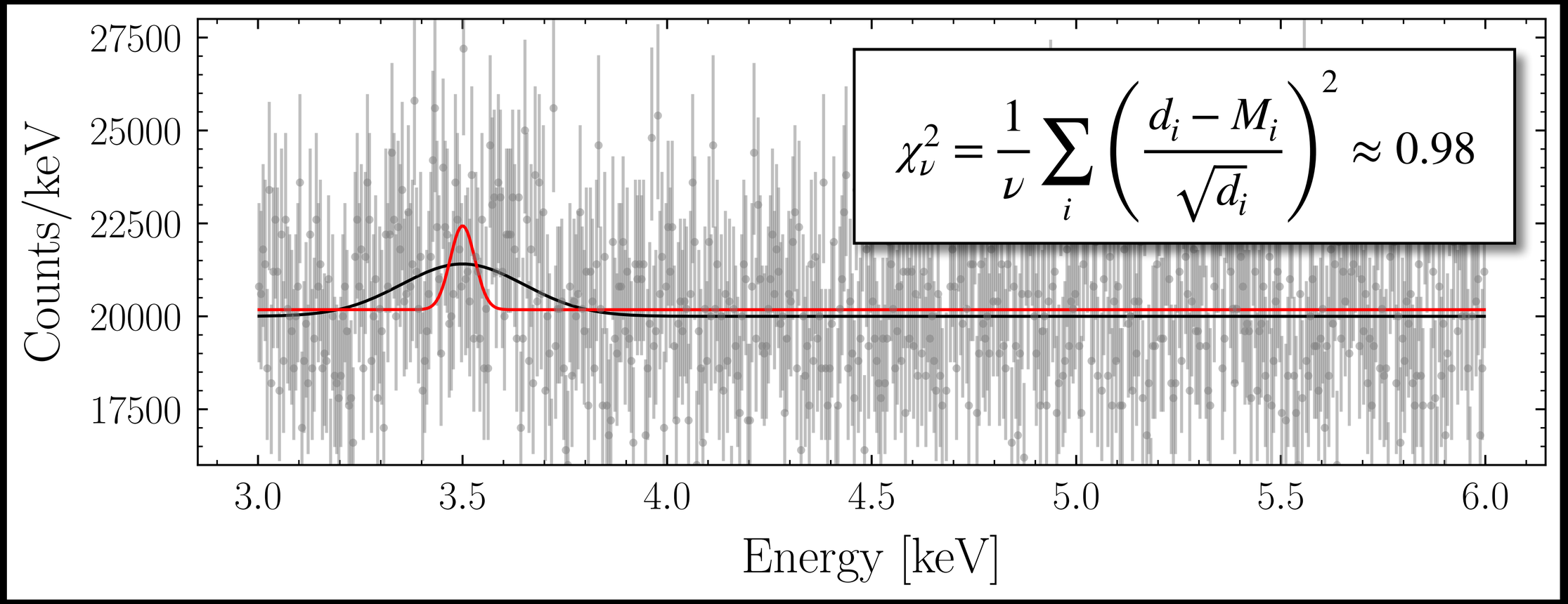

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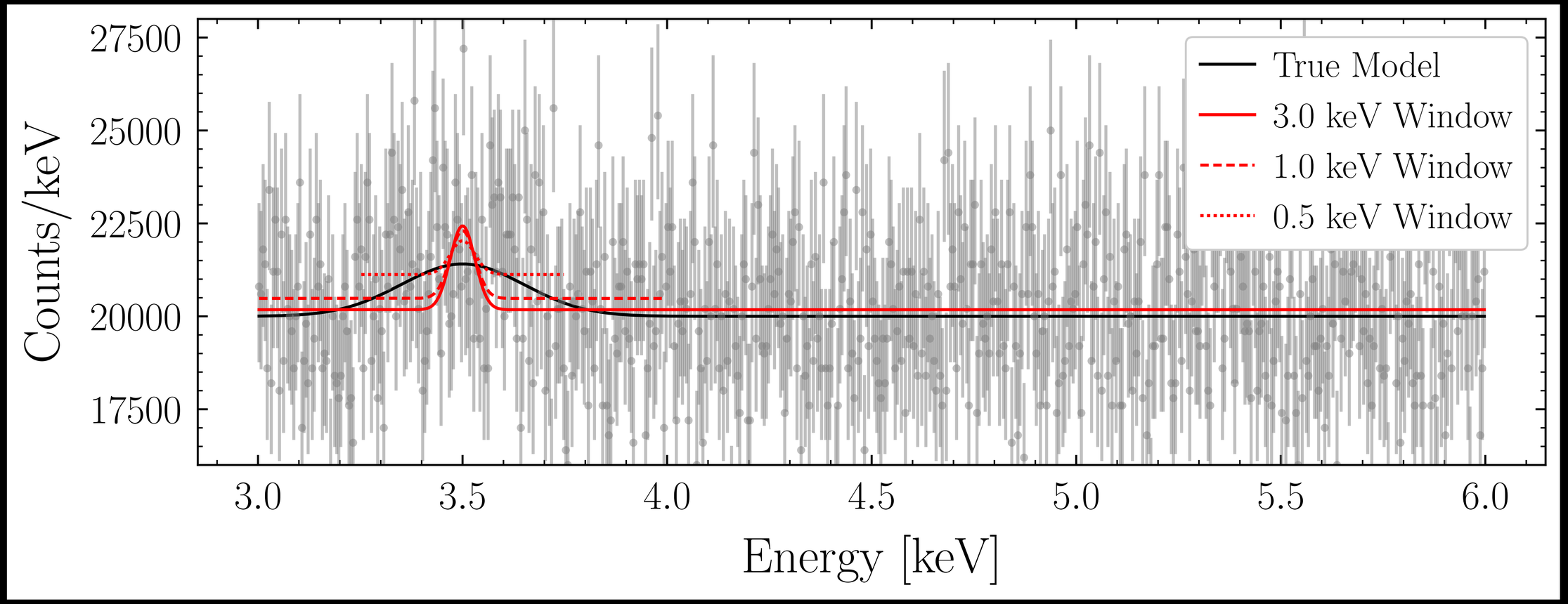

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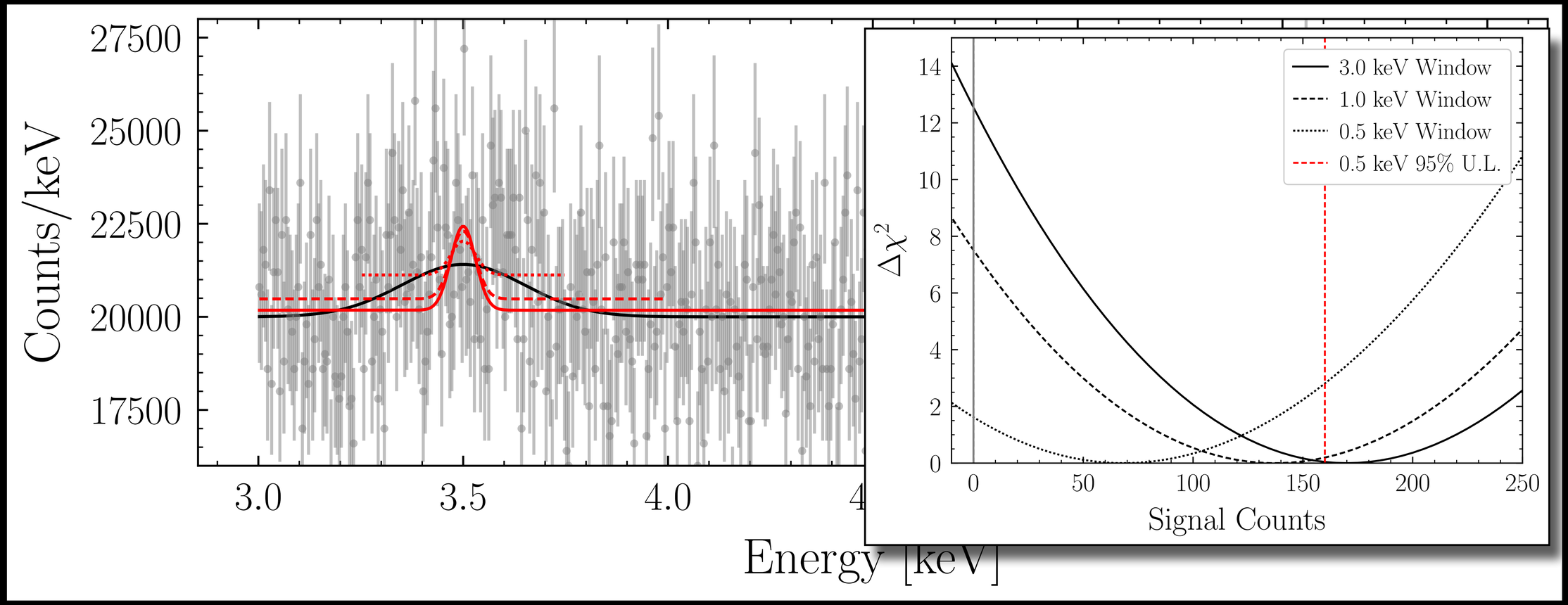
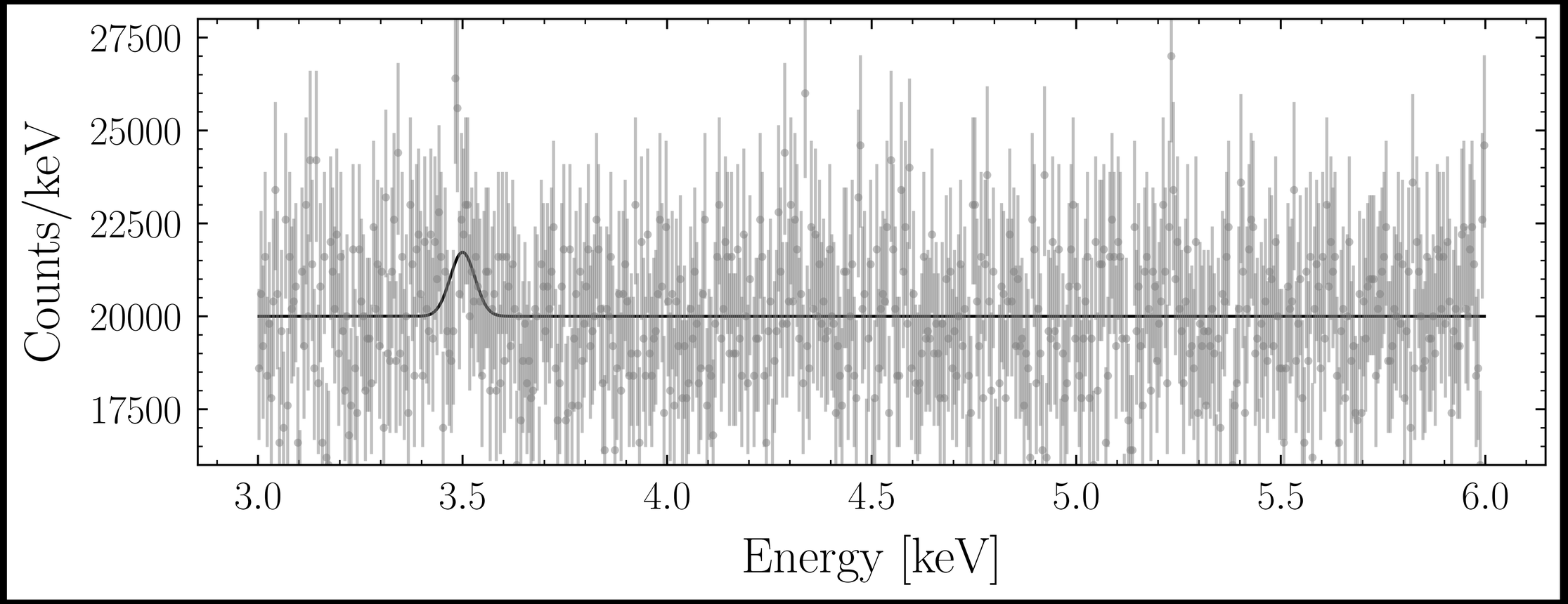
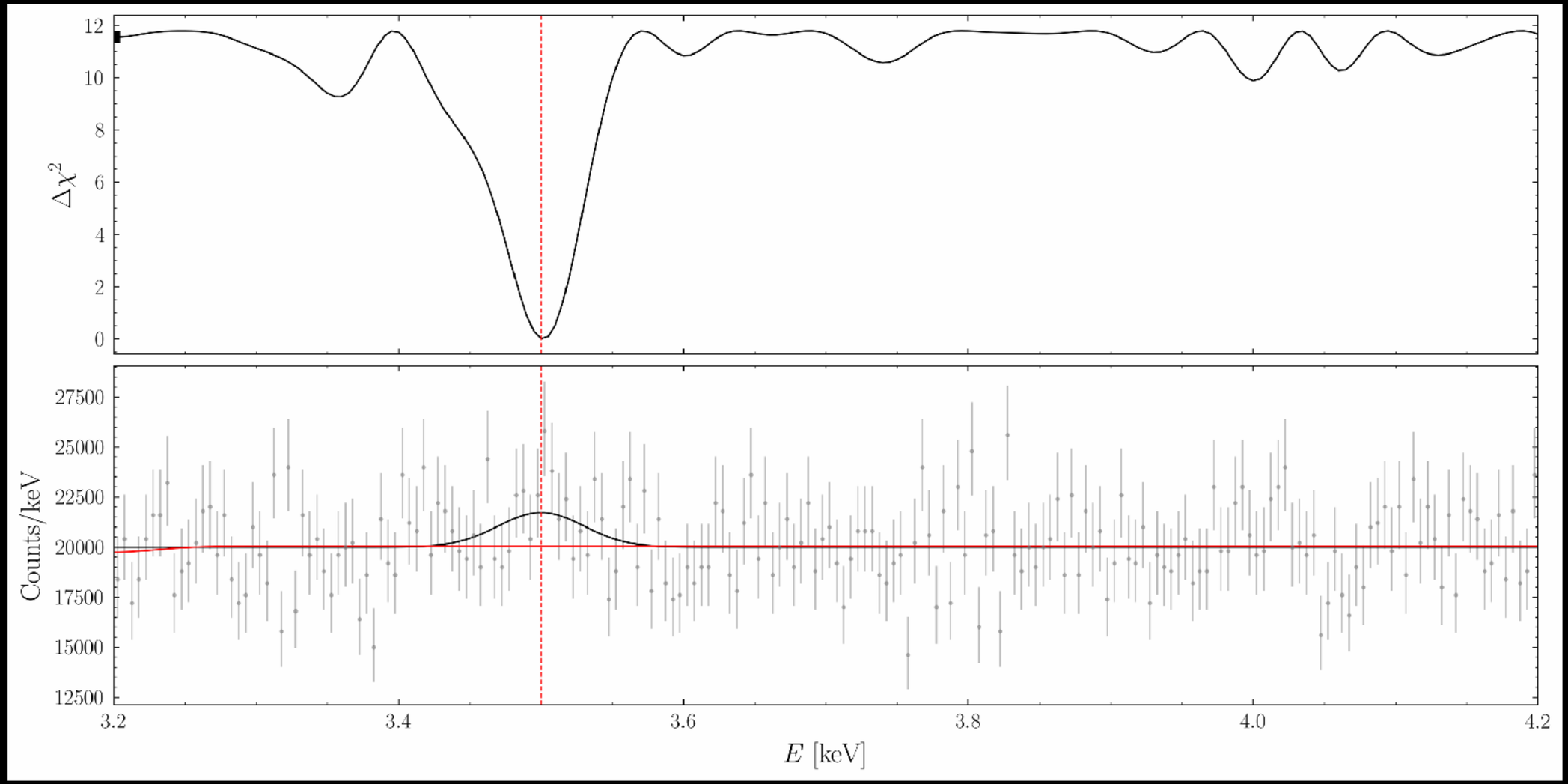


What about a real signal?



Likelihood Optimization



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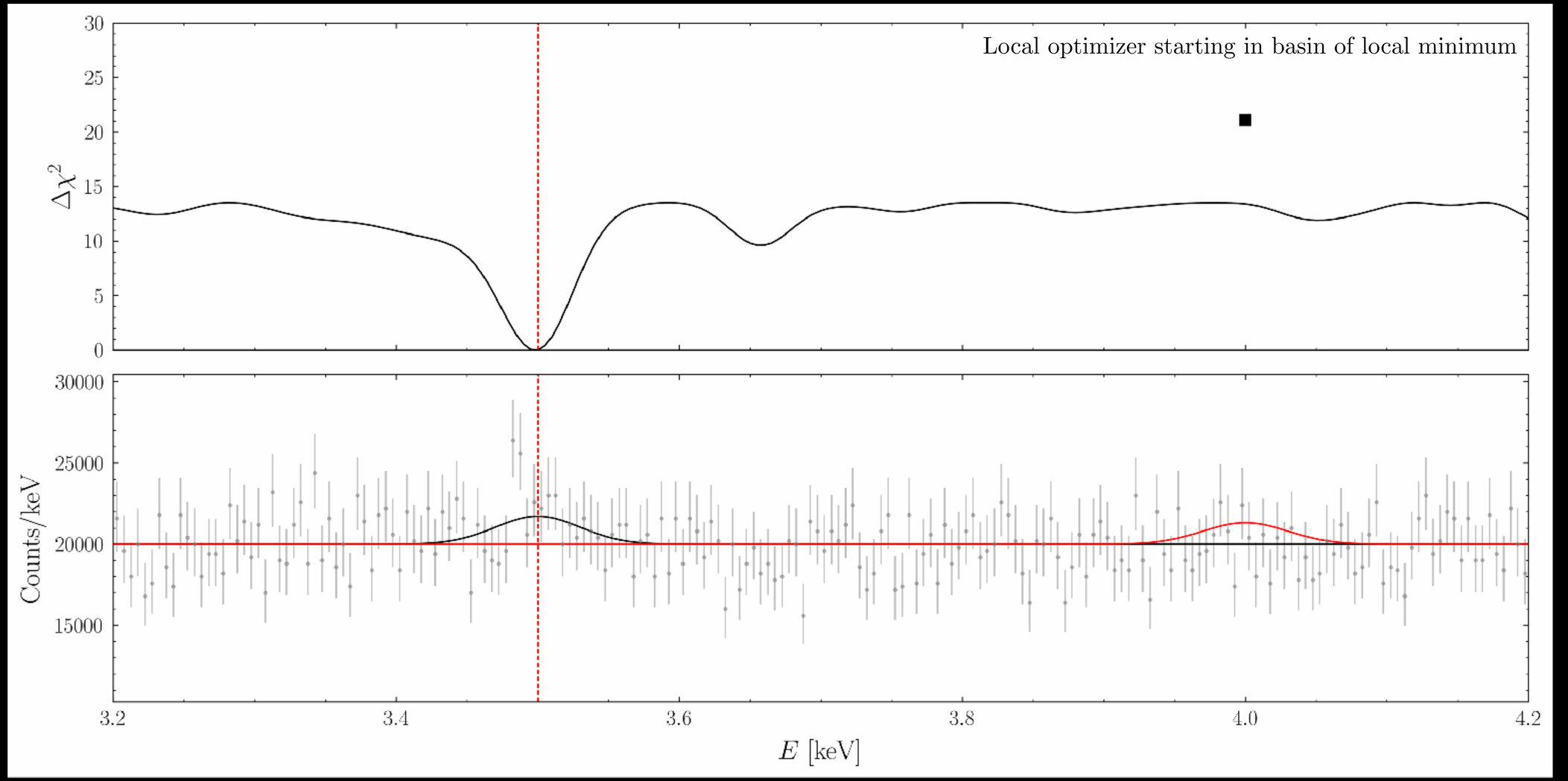

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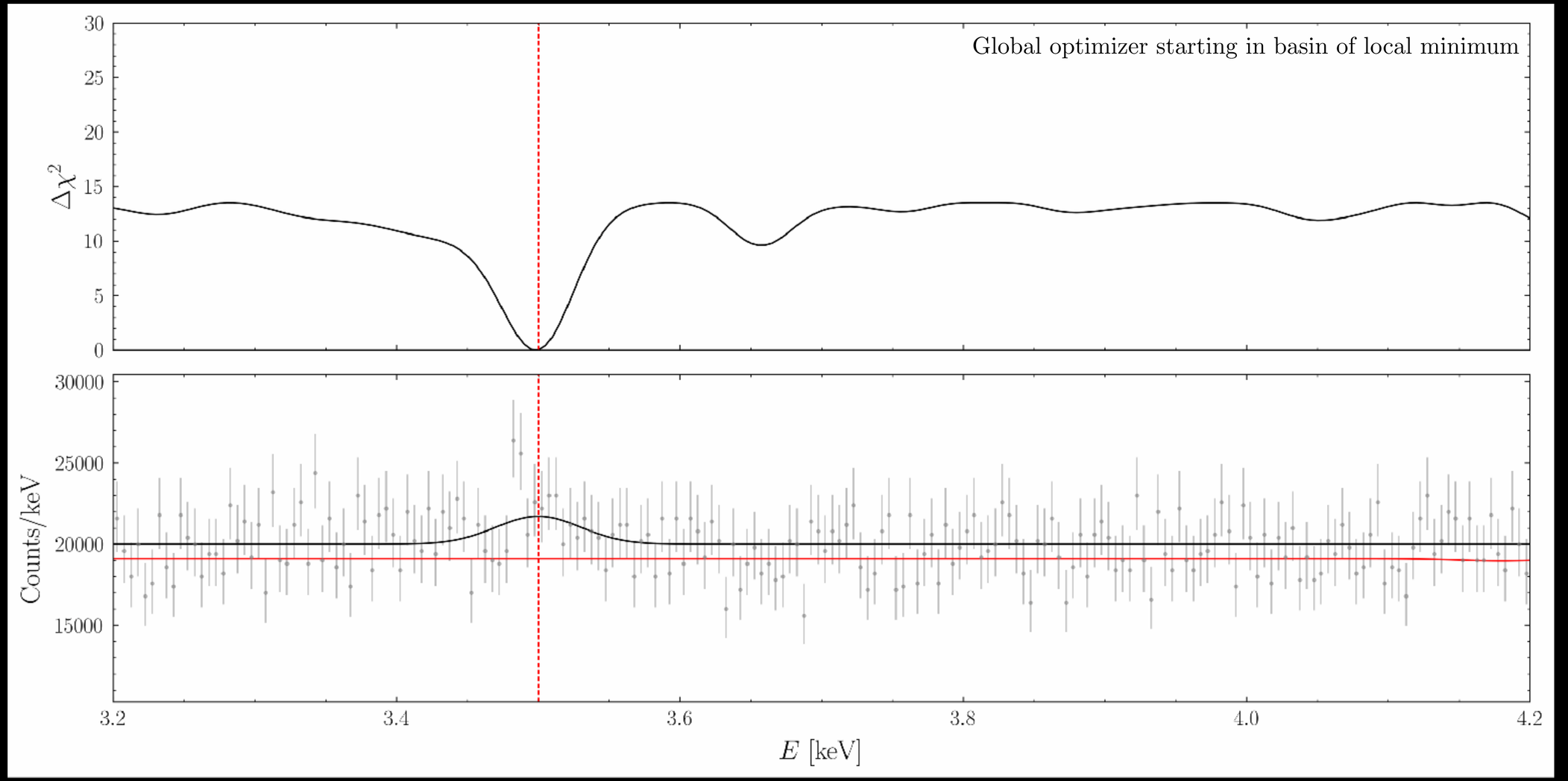
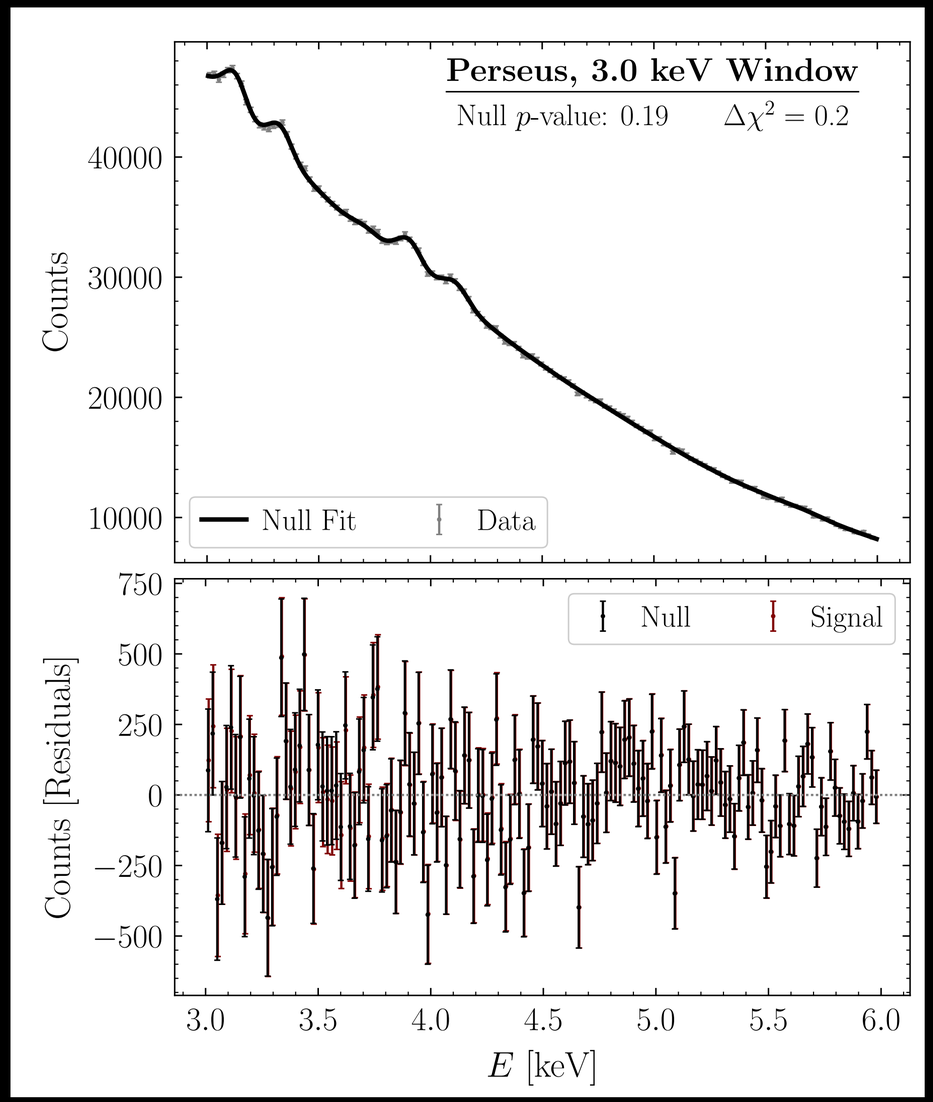
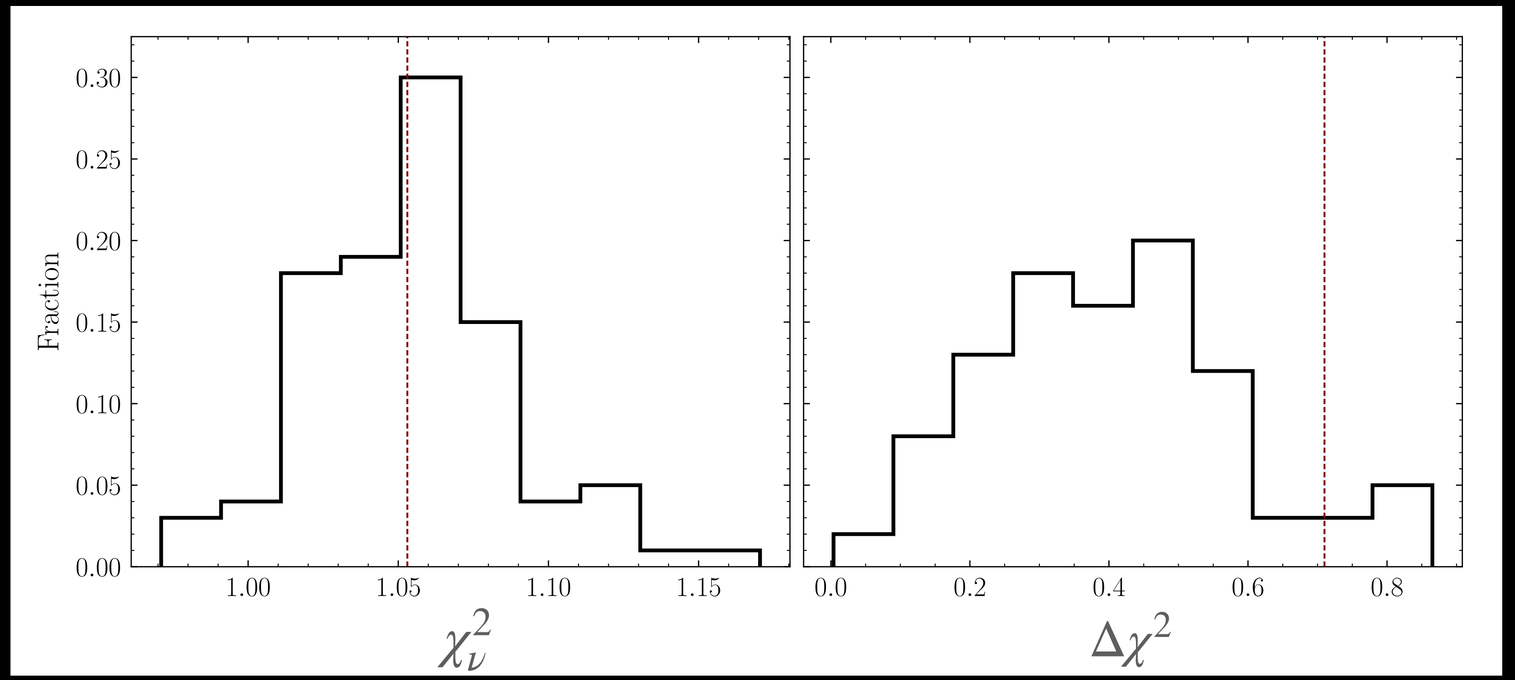


Bulbul et. al. ApJ (2014)

Perseus Cluster Reanalysis





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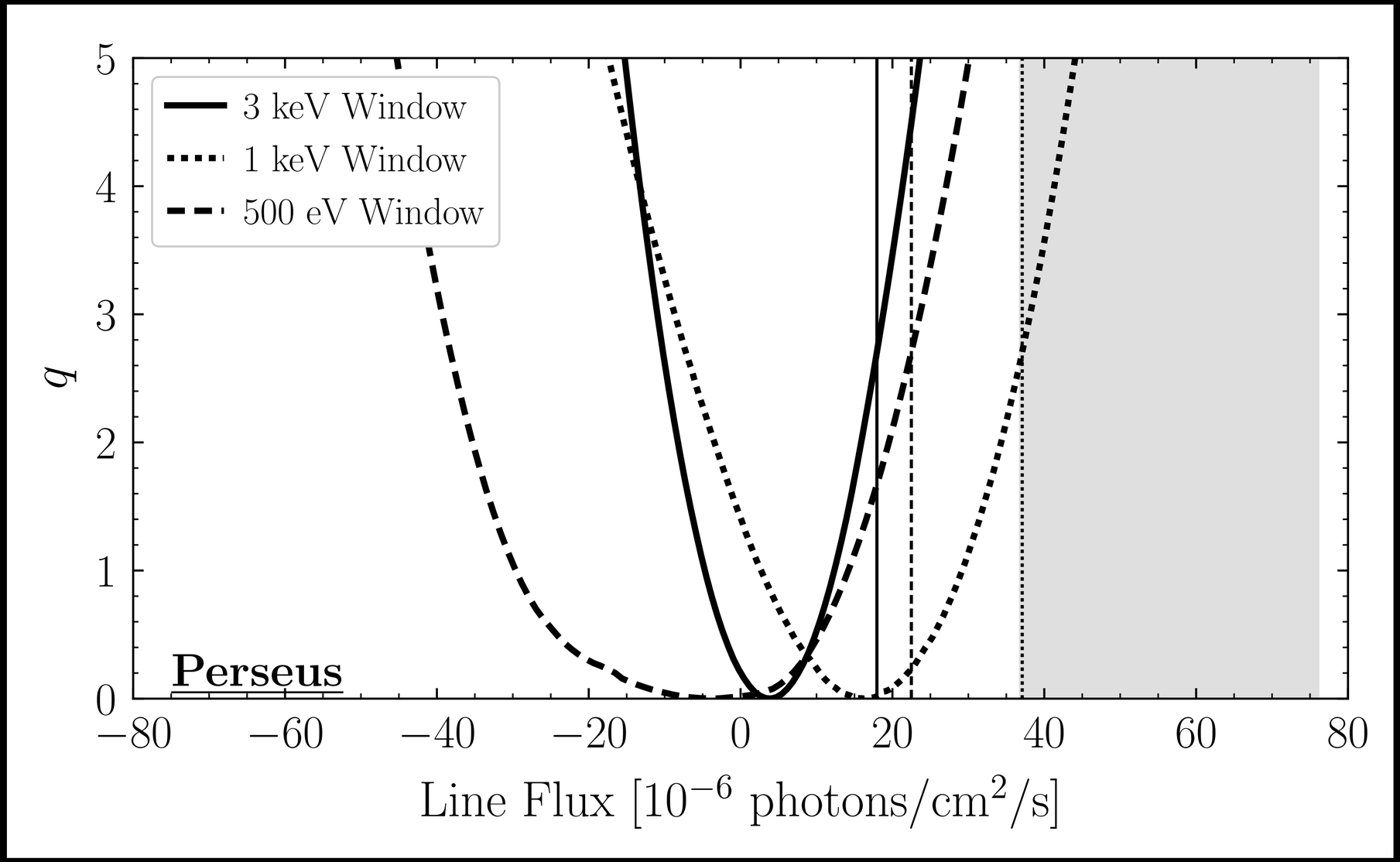


Bulbul et. al. ApJ (2014)

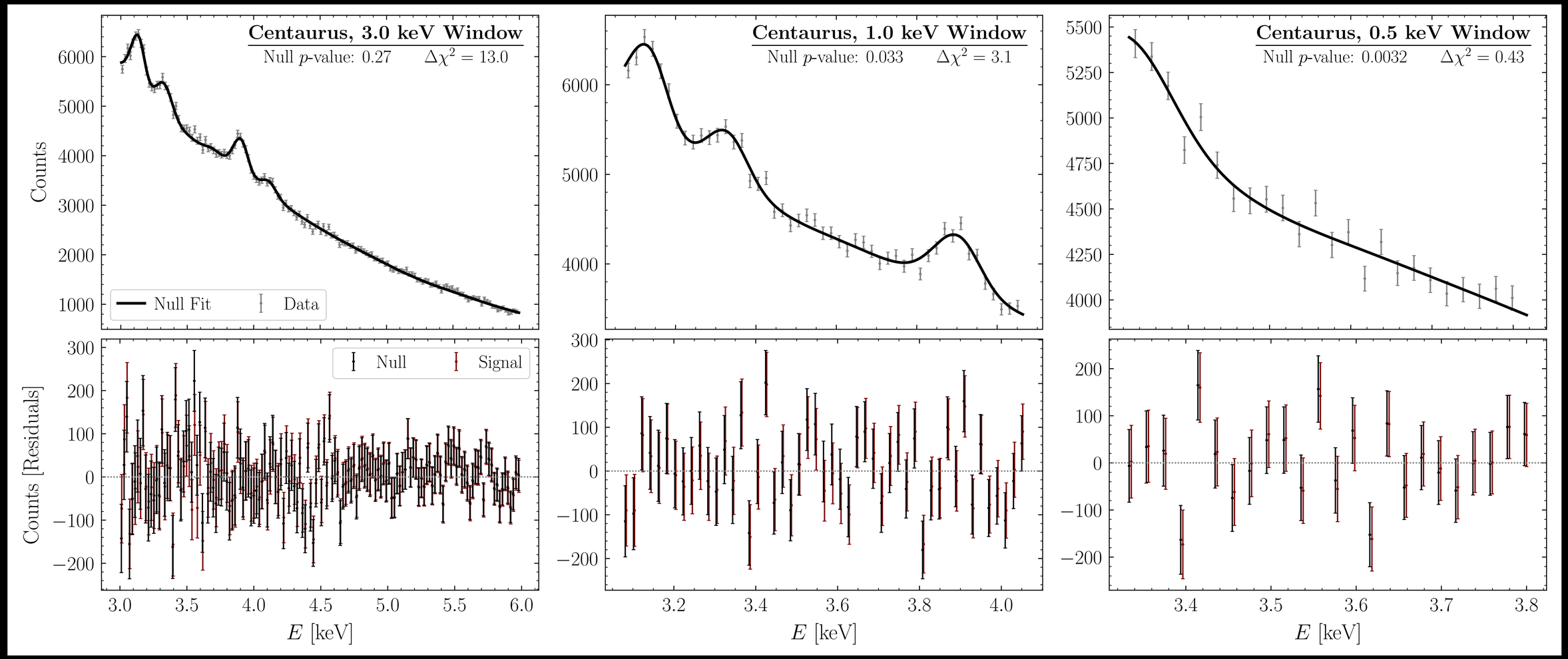
Perseus Analysis Issues?

This approach results in a very large number of parameters to fit simultaneously, among which are the line energies and widths that notoriously cause problems for the statistic minimization algorithms. It was difficult to make XSPEC find absolute minima; the convergence of all of the reported fits had to be verified by manually varying key parameters and refitting using different minimization algorithms. Nevertheless, it is not inconceivable that some of our fits did not find an absolute χ^2 minimum.

1402.2301

Bulbul et. al. ApJ (2014)

Bright Clusters Reanalysis



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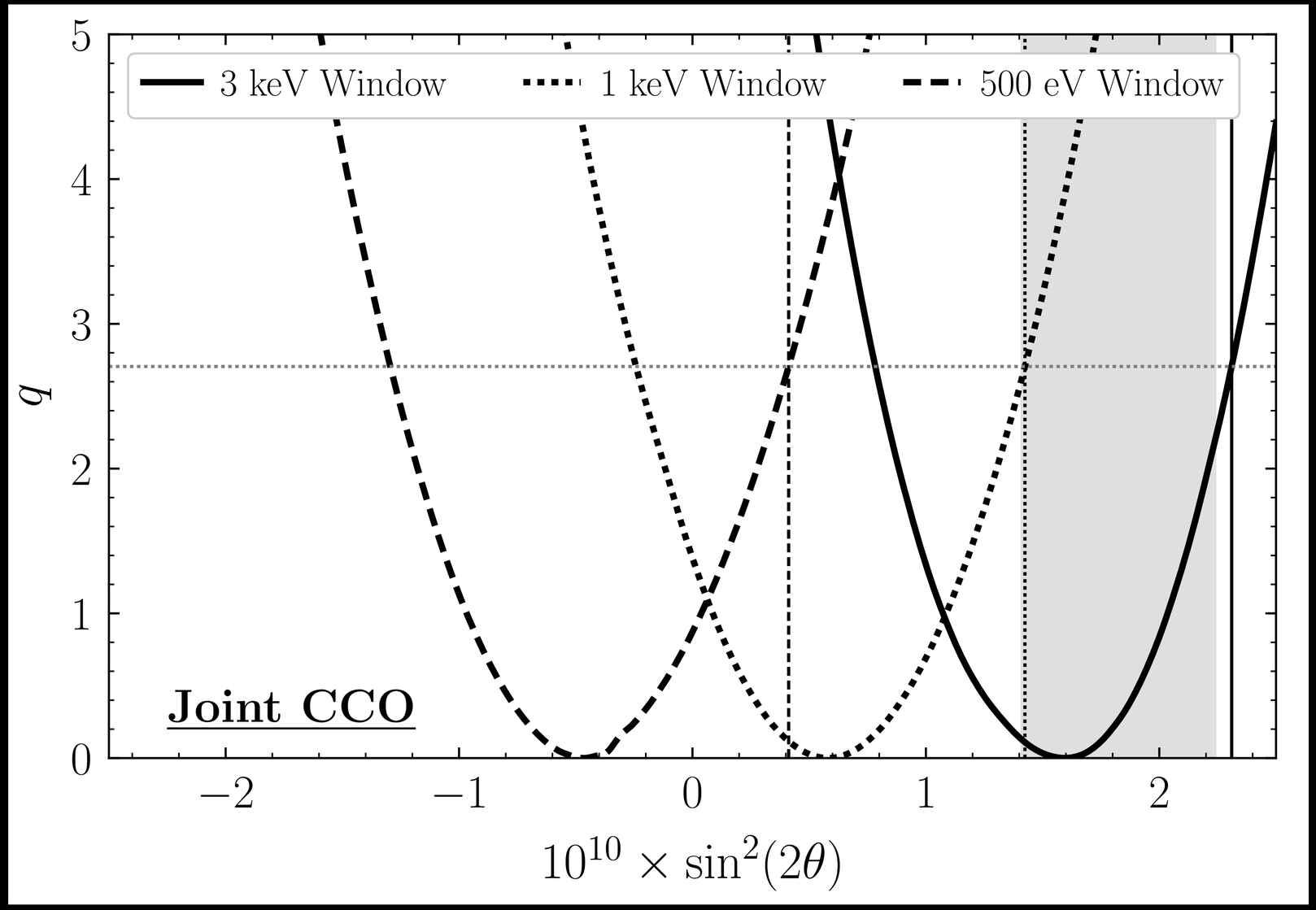
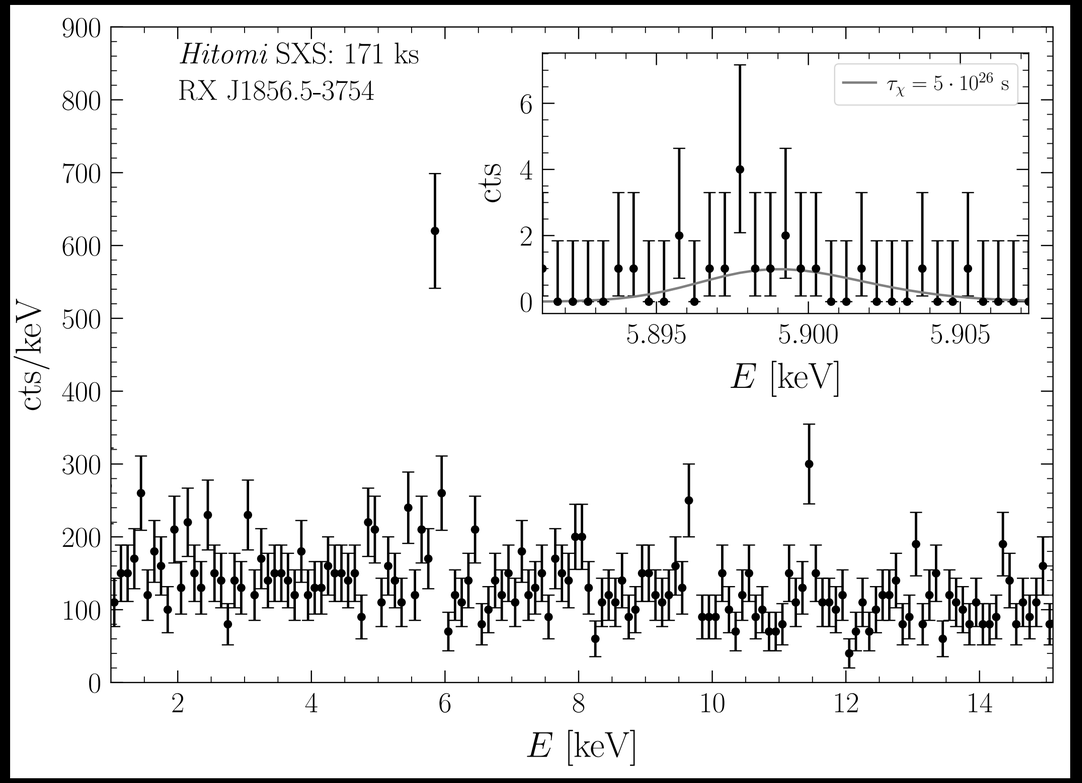


Looking forward to upcoming searches

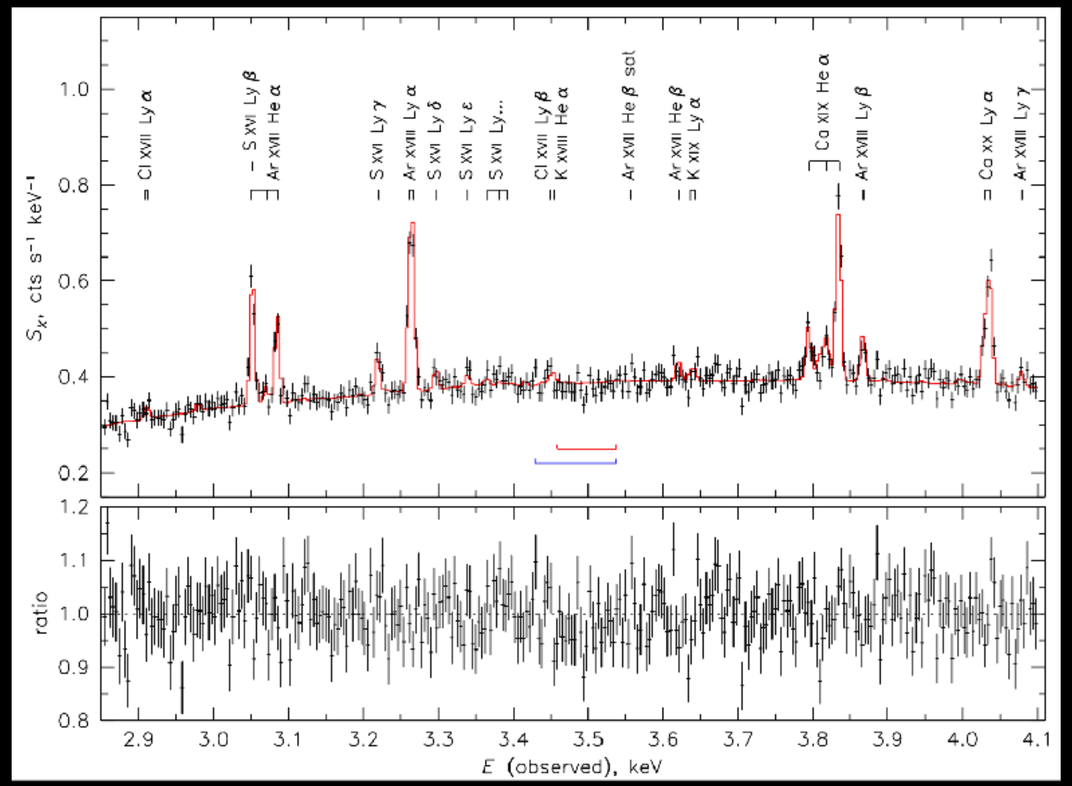
- No robust evidence for 3.5 keV line
- Line could have arisen from
  - Unconverged optimization
  - Mismodeled backgrounds
- Motivates searches at blank sky
  - Simple backgrounds, simple optimization



CD 2305.17160

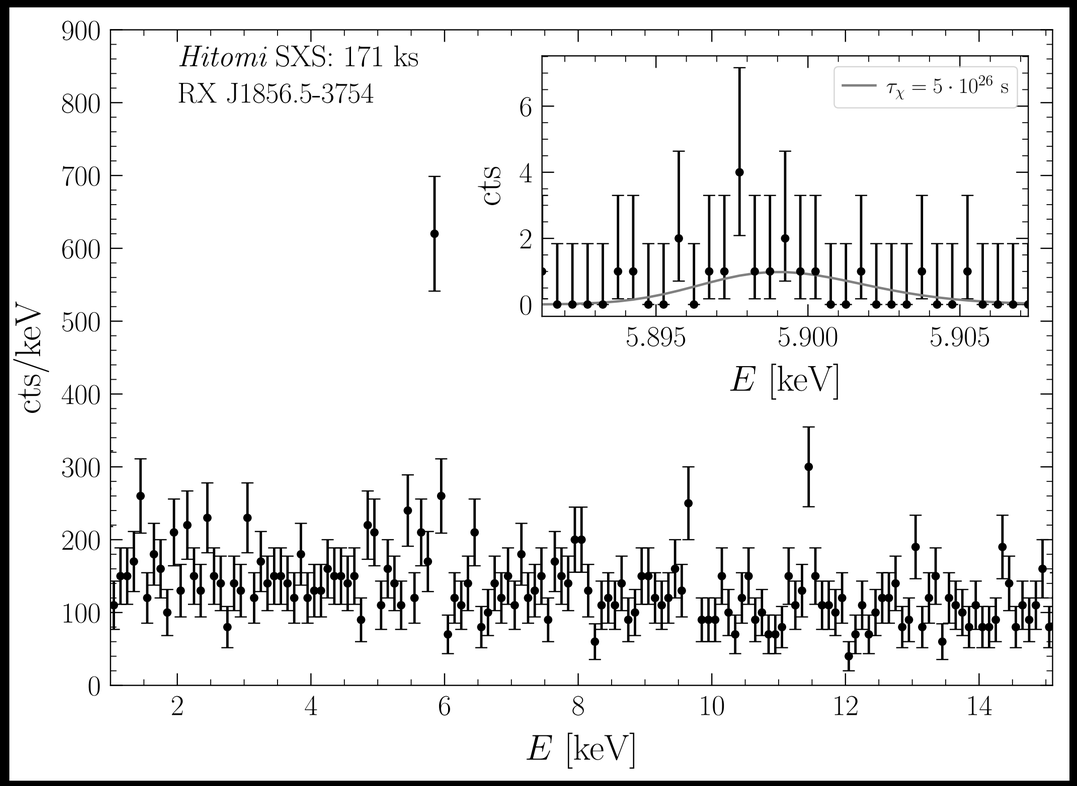
Looking forward to upcoming searches

- XRISM has $\Delta E \sim 5$ eV — blank sky *more* important
- Hitomi Perseus cluster:



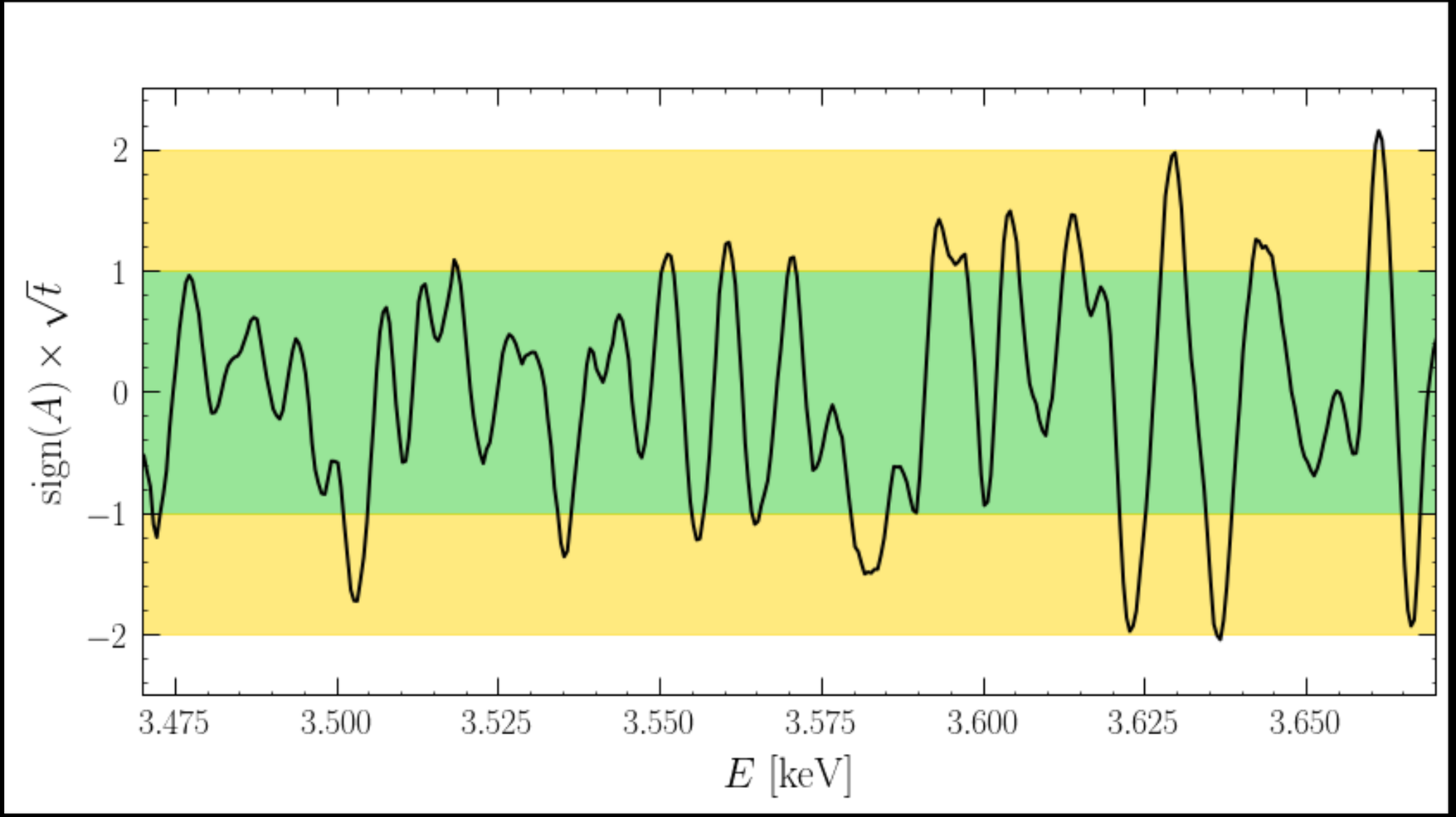
1607.07420

- Hitomi Blank Sky:

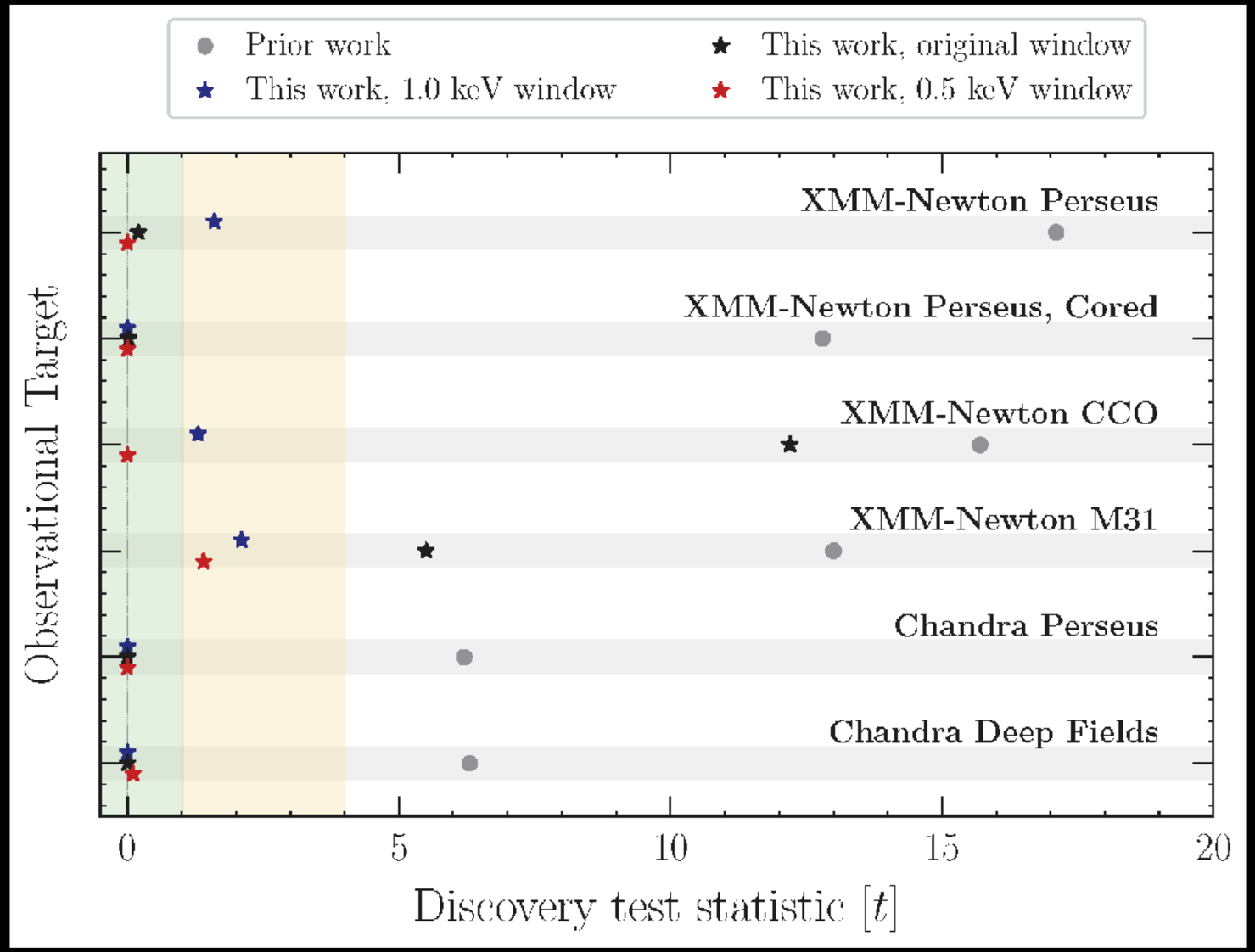


CD 2305.17160

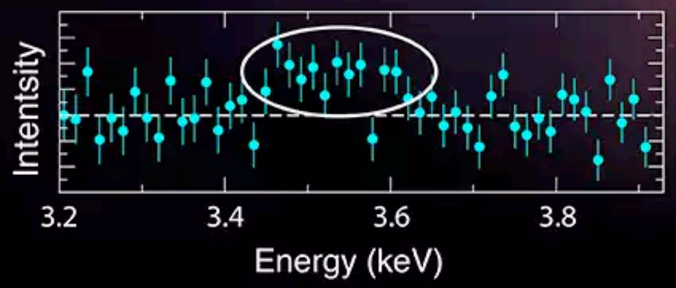
XRISM Early Data Results



Results Summary



Backup Slides



Bulbul et. al. ApJ (2014)

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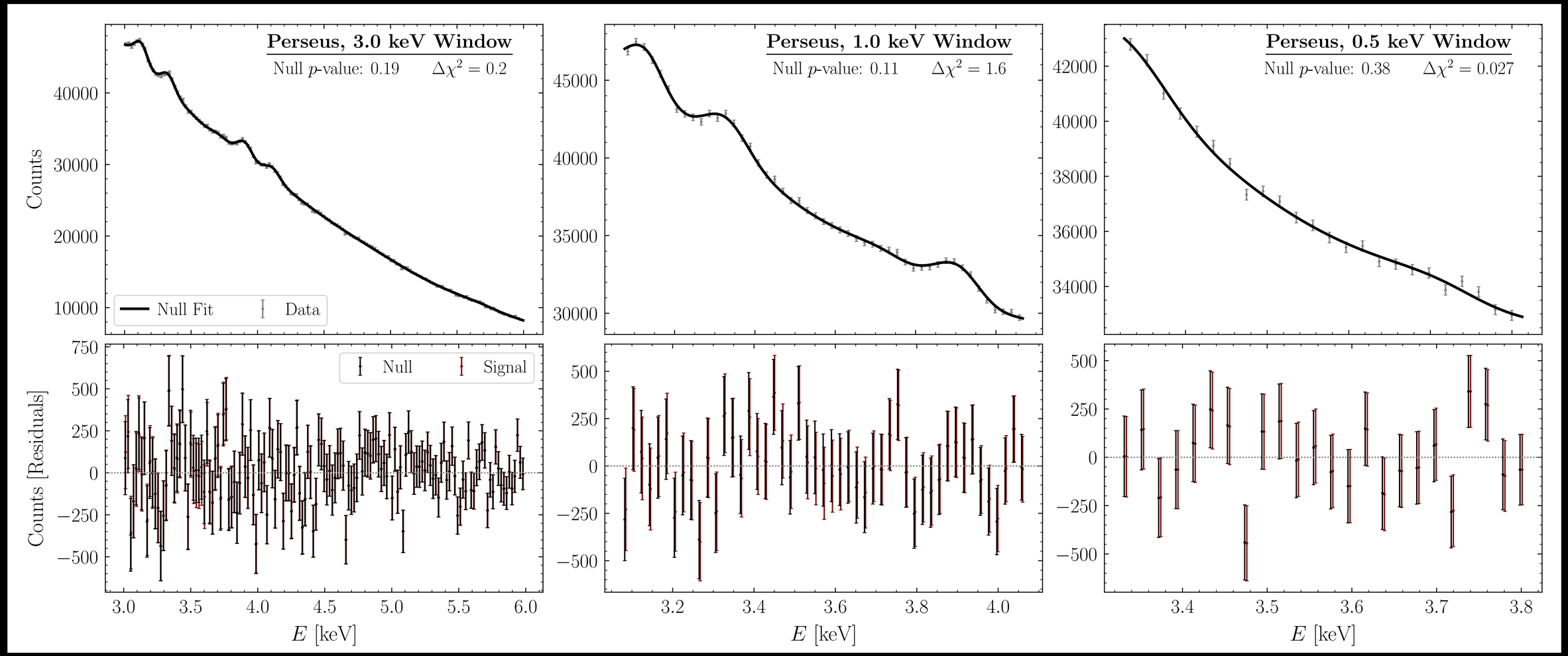
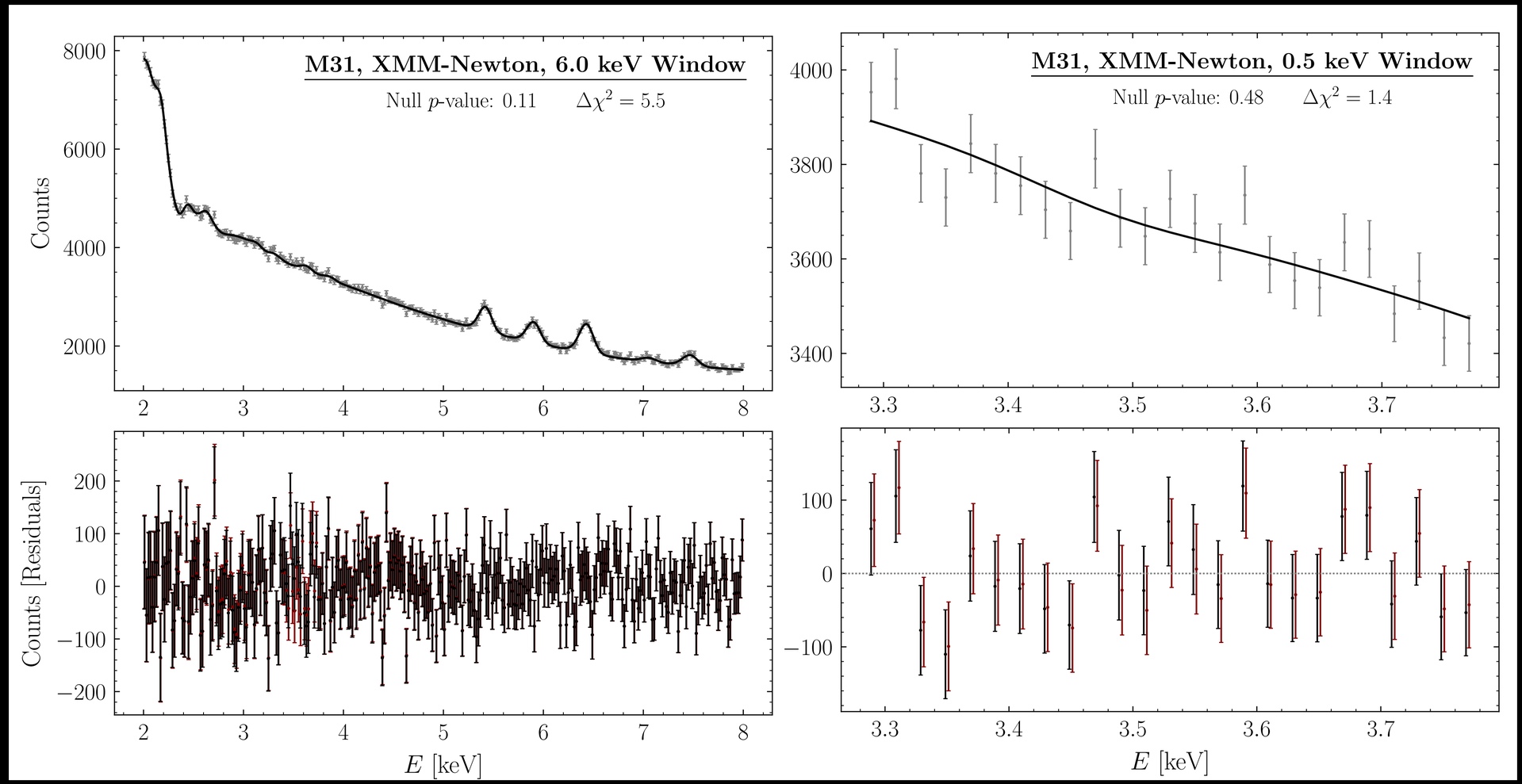
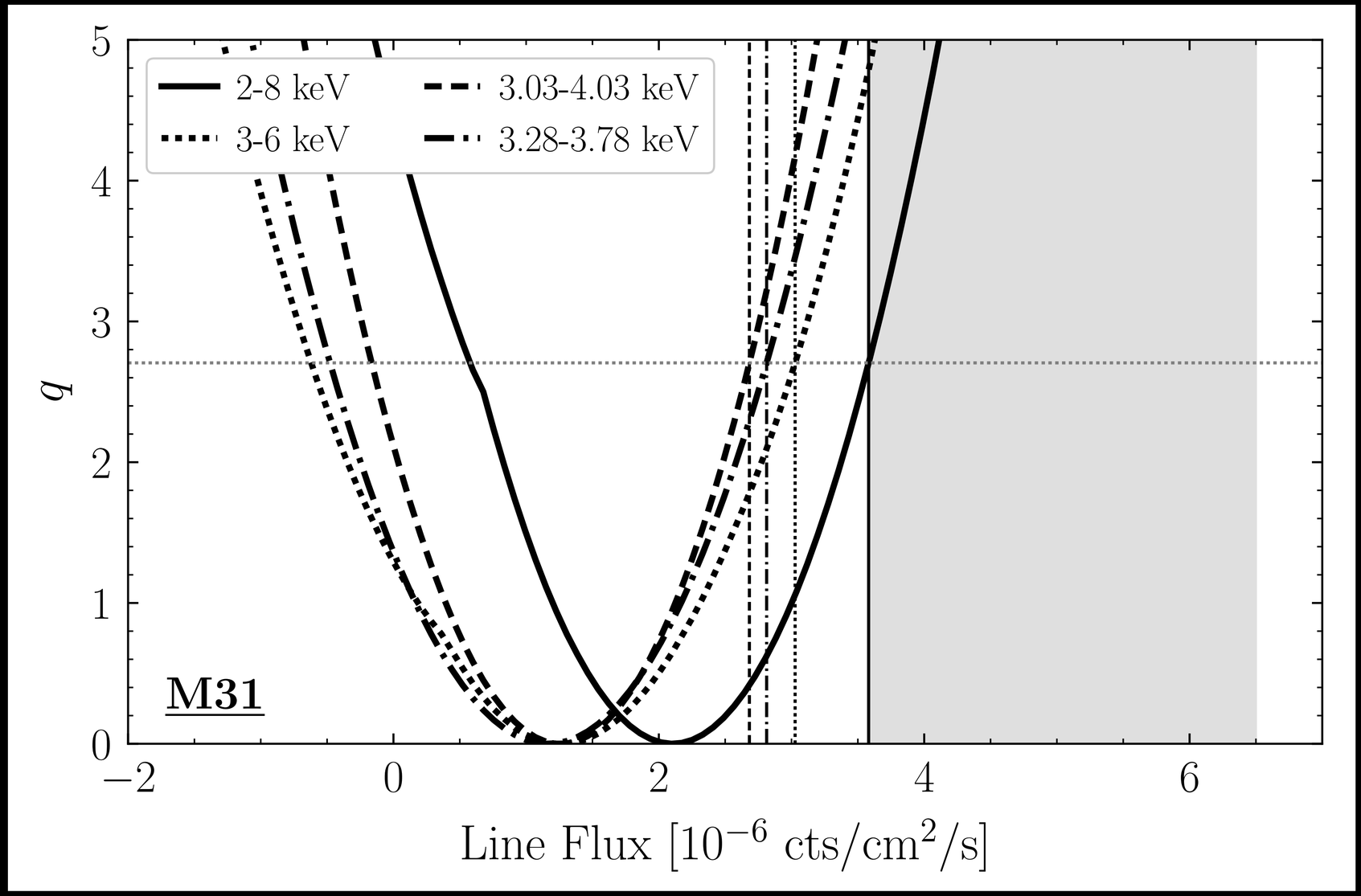


Boyarsky et. al. ApJ (2014)

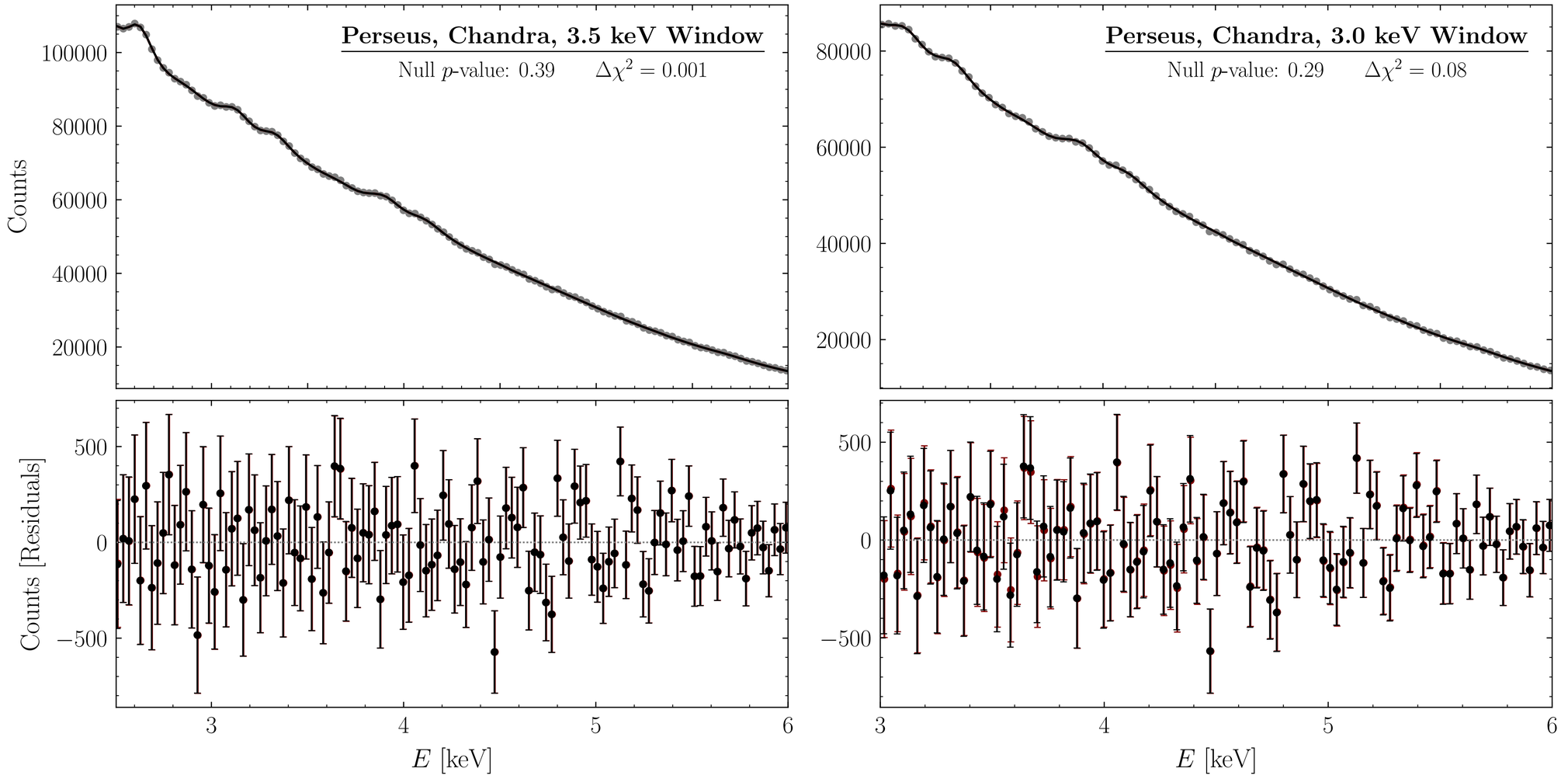
M31 Reanalysis



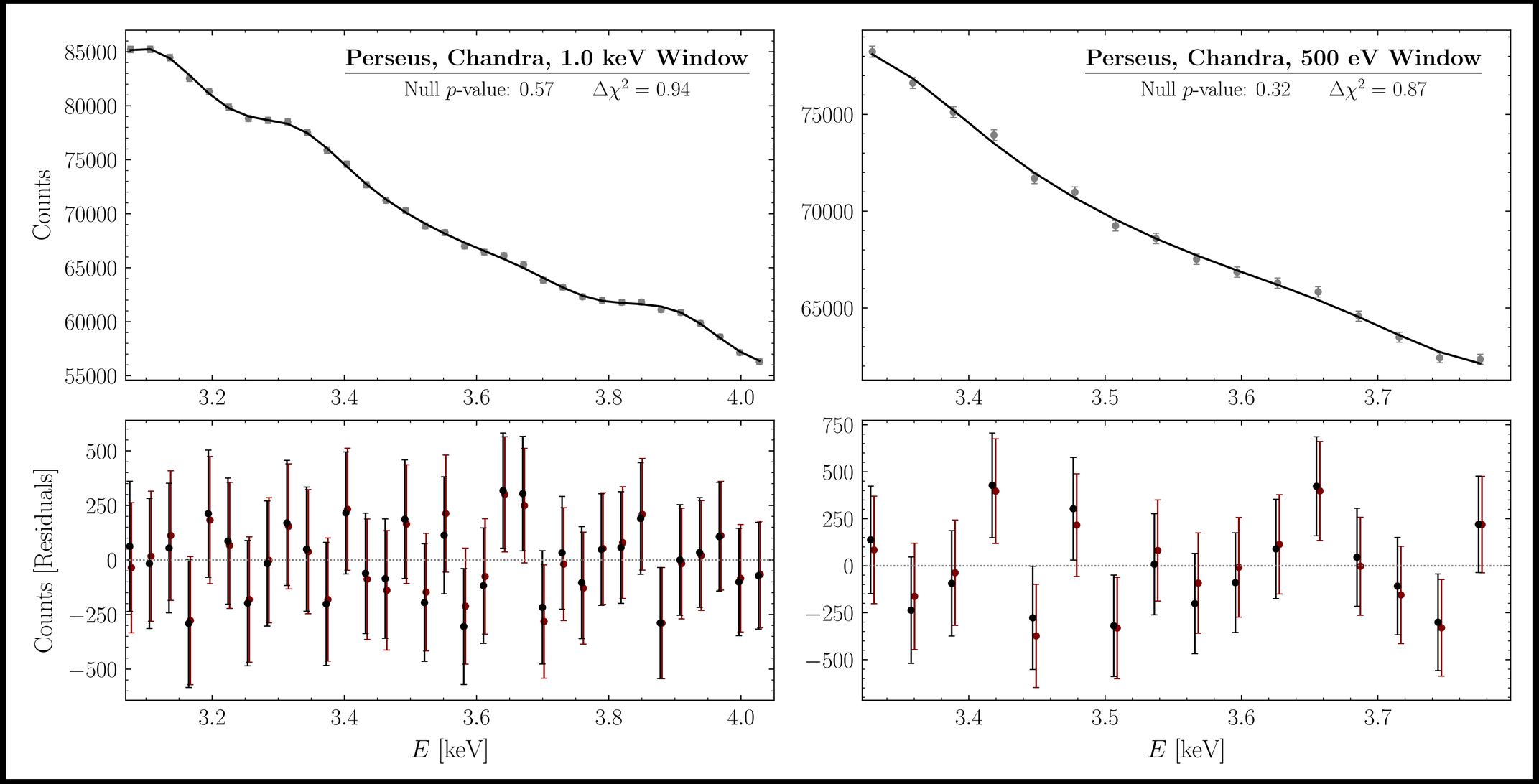
M31 Reanalysis



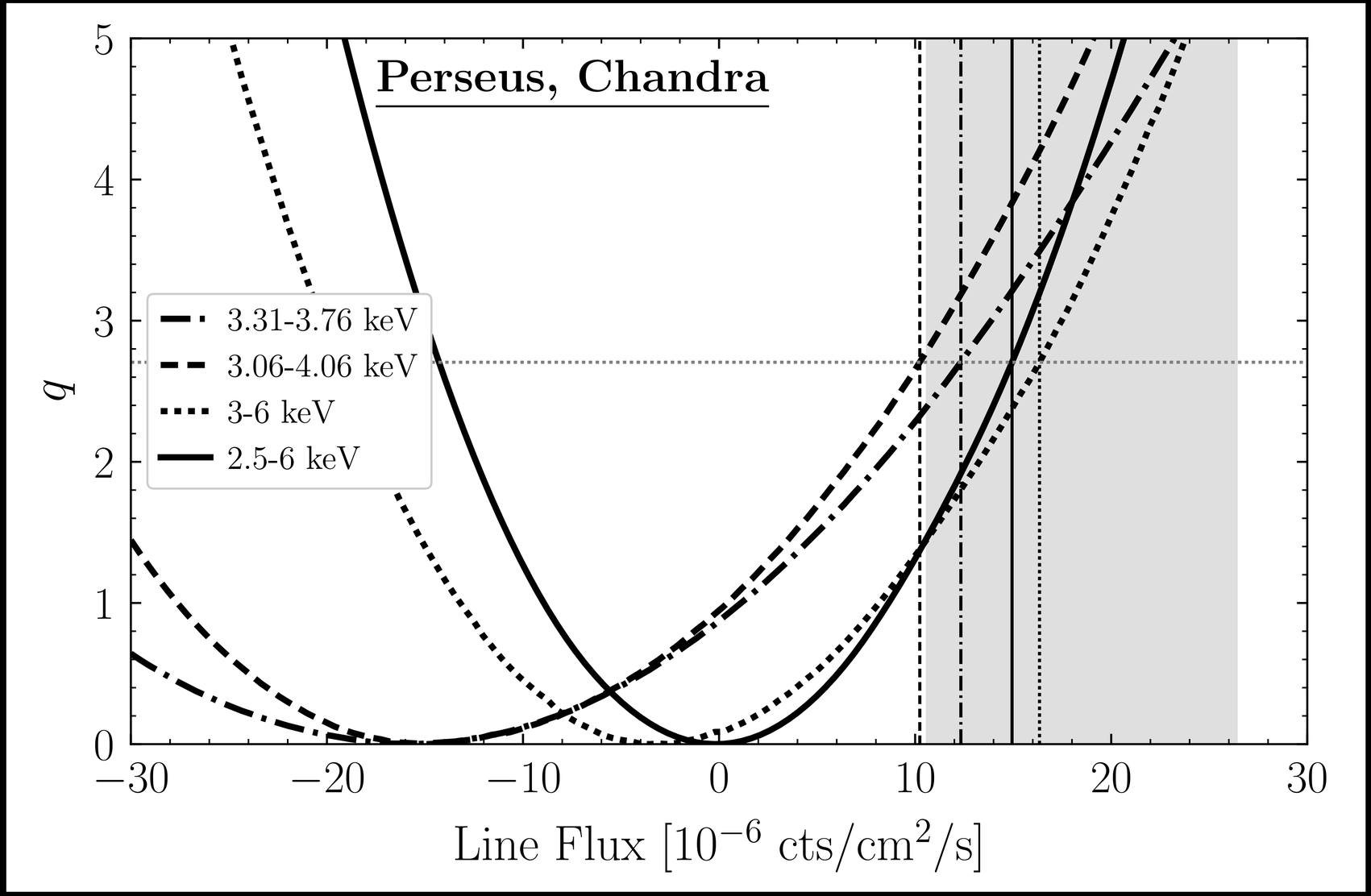
Chandra/Perseus Fits



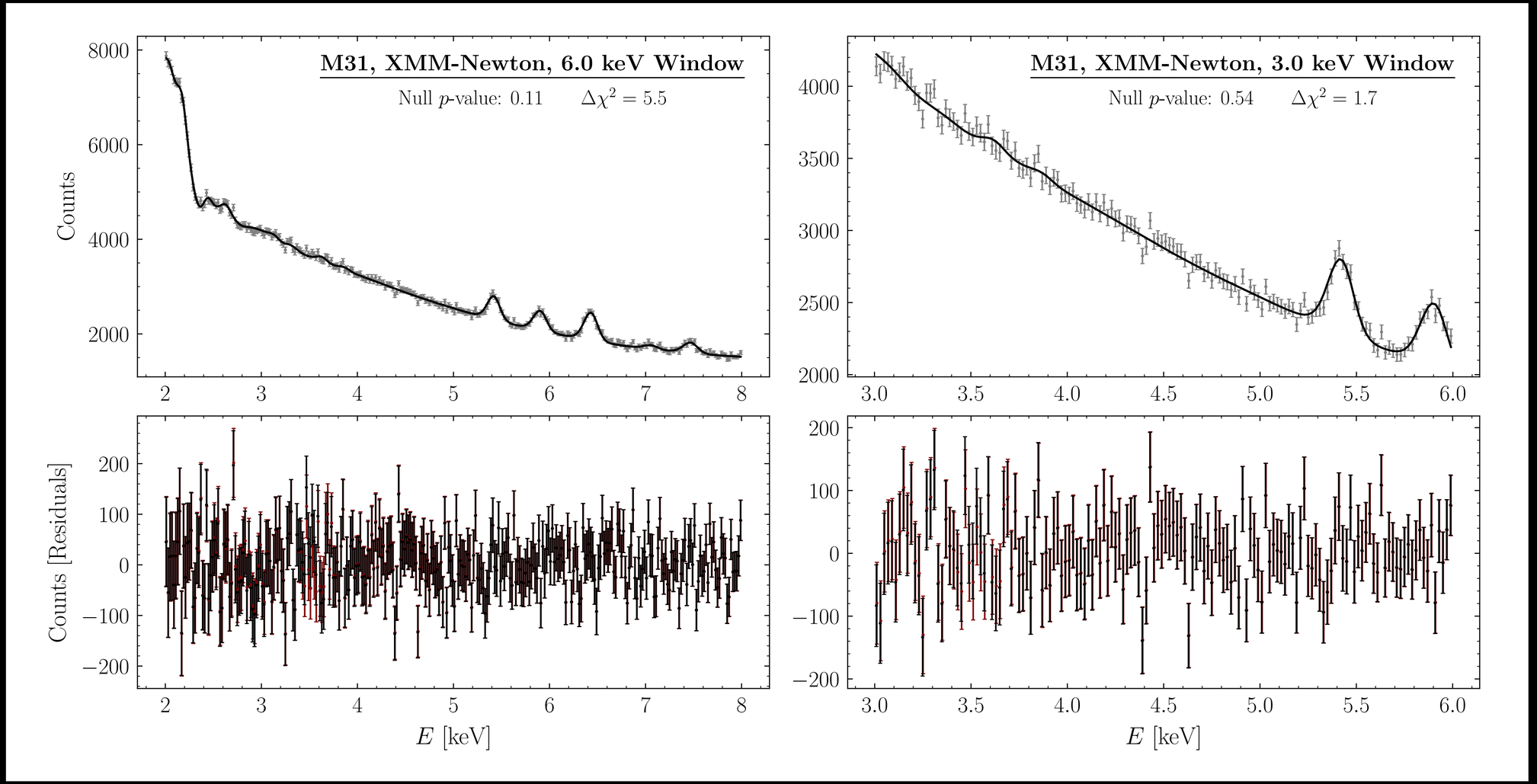
Chandra/Perseus Fits



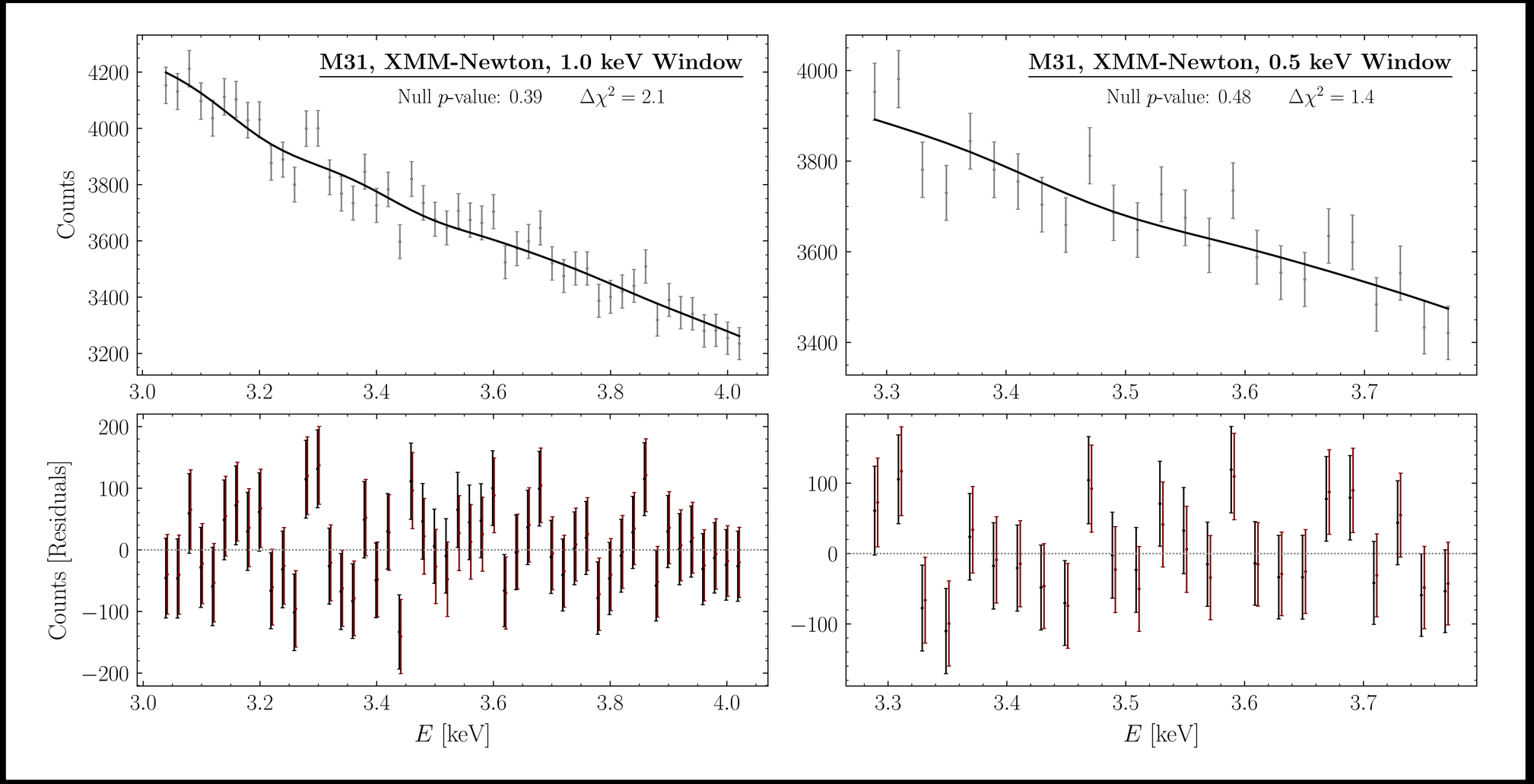
Chandra/Perseus Profiles



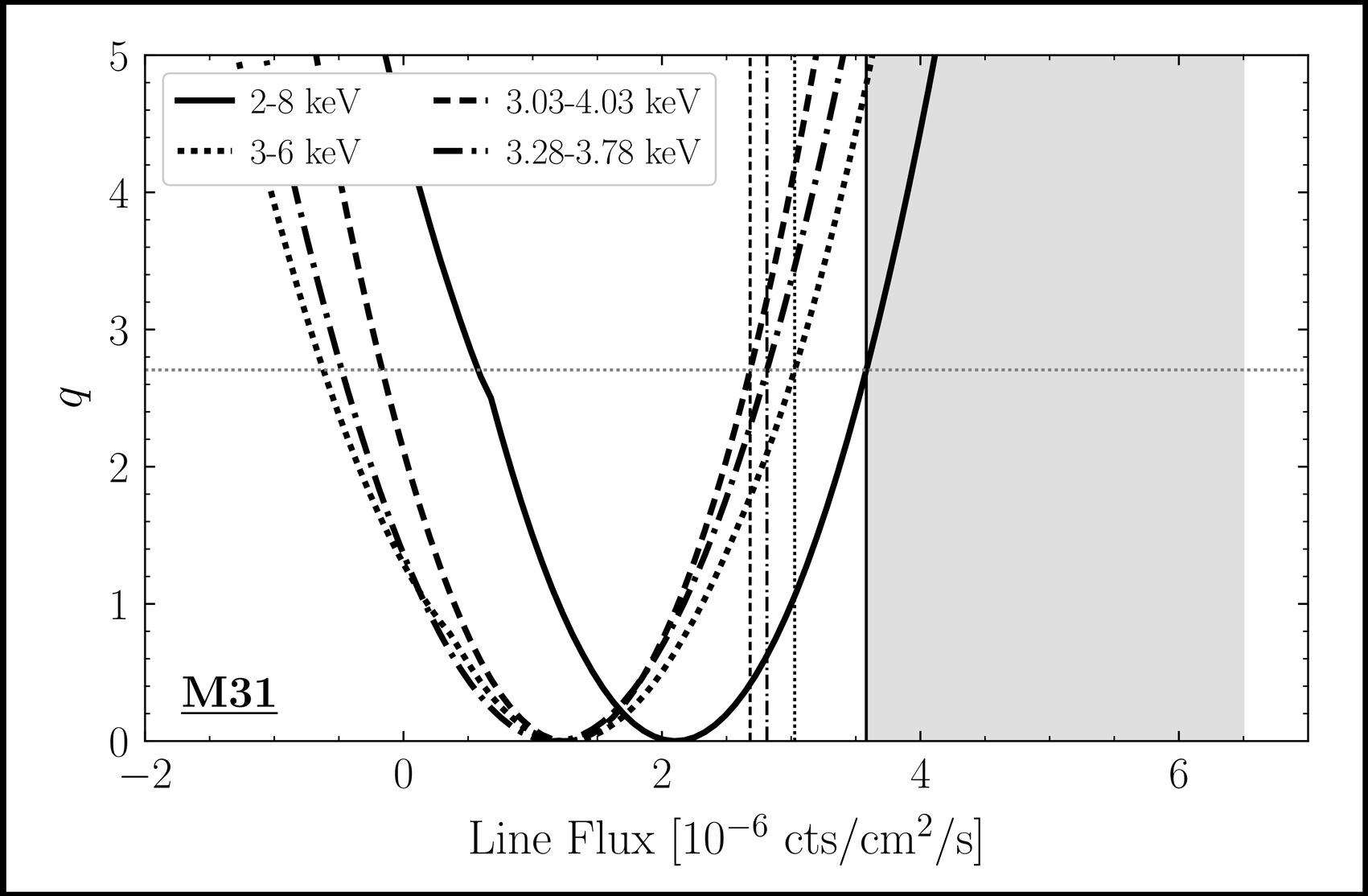
XMM/M31 Fits


M31, XMM-Newton, 6.0 keV Window
Null p-value: 0.11
$\Delta\chi^2 = 5.5$
Counts
Counts [Residuals]
E [keV]
M31, XMM-Newton, 3.0 keV Window
Null p-value: 0.54
$\Delta\chi^2 = 1.7$
E [keV]

XMM/M31 Fits

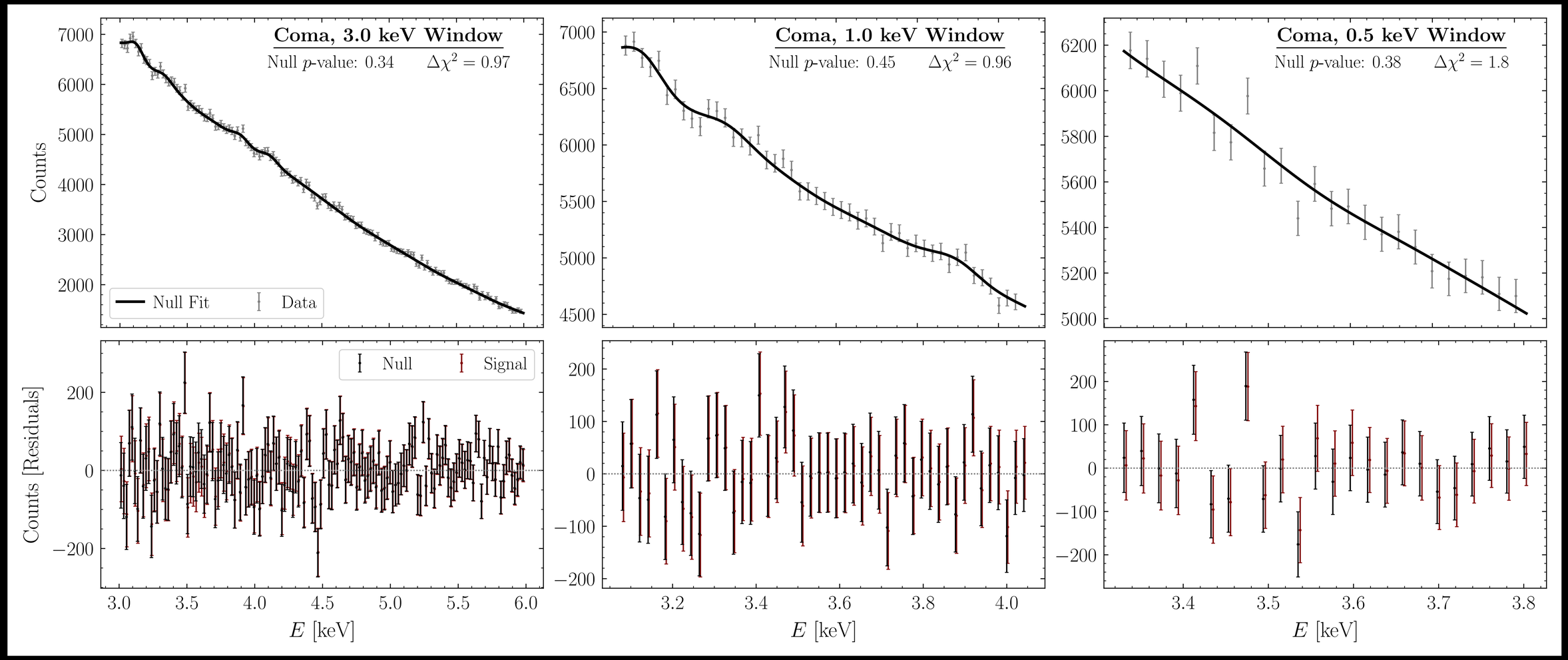

M31, XMM-Newton, 1.0 keV Window
Null p-value: 0.39
$\Delta\chi^2 = 2.1$
Counts
Counts [Residuals]
E [keV]
M31, XMM-Newton, 0.5 keV Window
Null p-value: 0.48
$\Delta\chi^2 = 1.4$
E [keV]

XMM/M31 Profiles



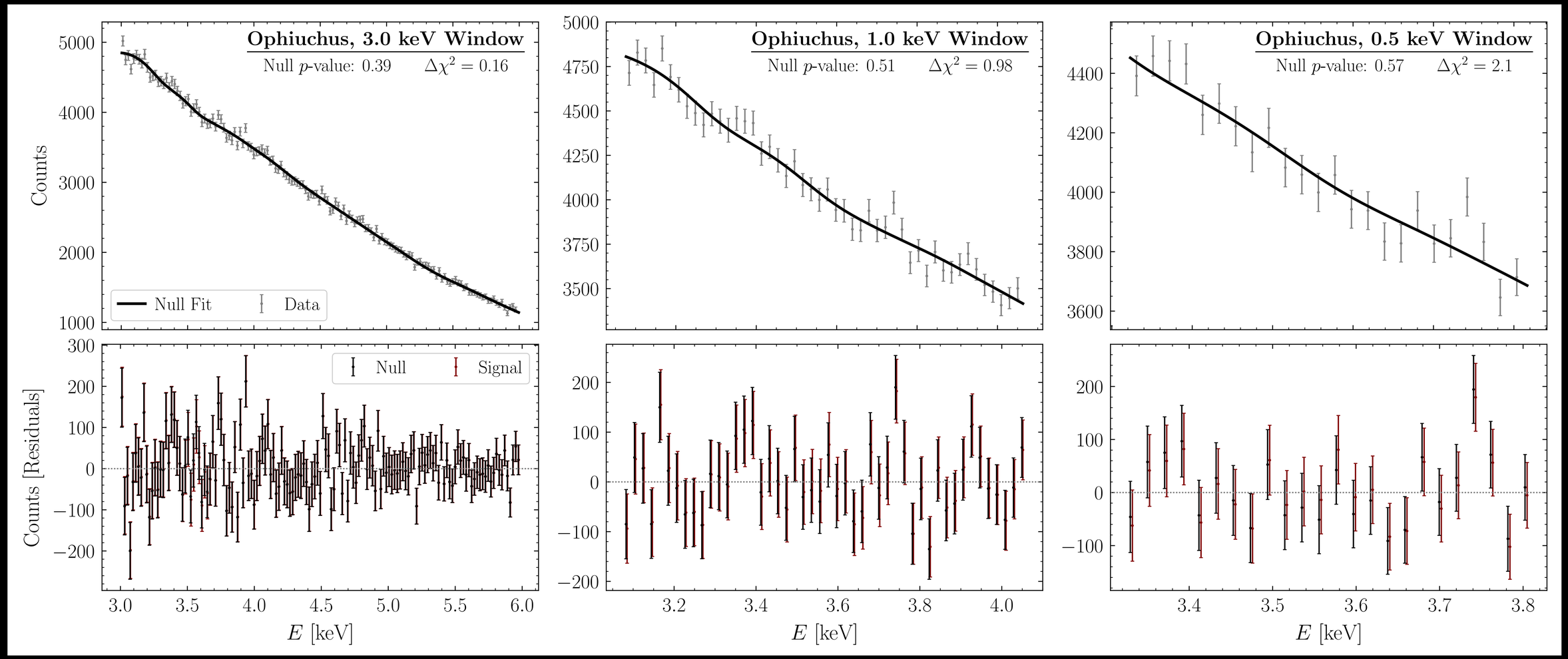
Bulbul et. al. ApJ (2014)

Bright Clusters Reanalysis

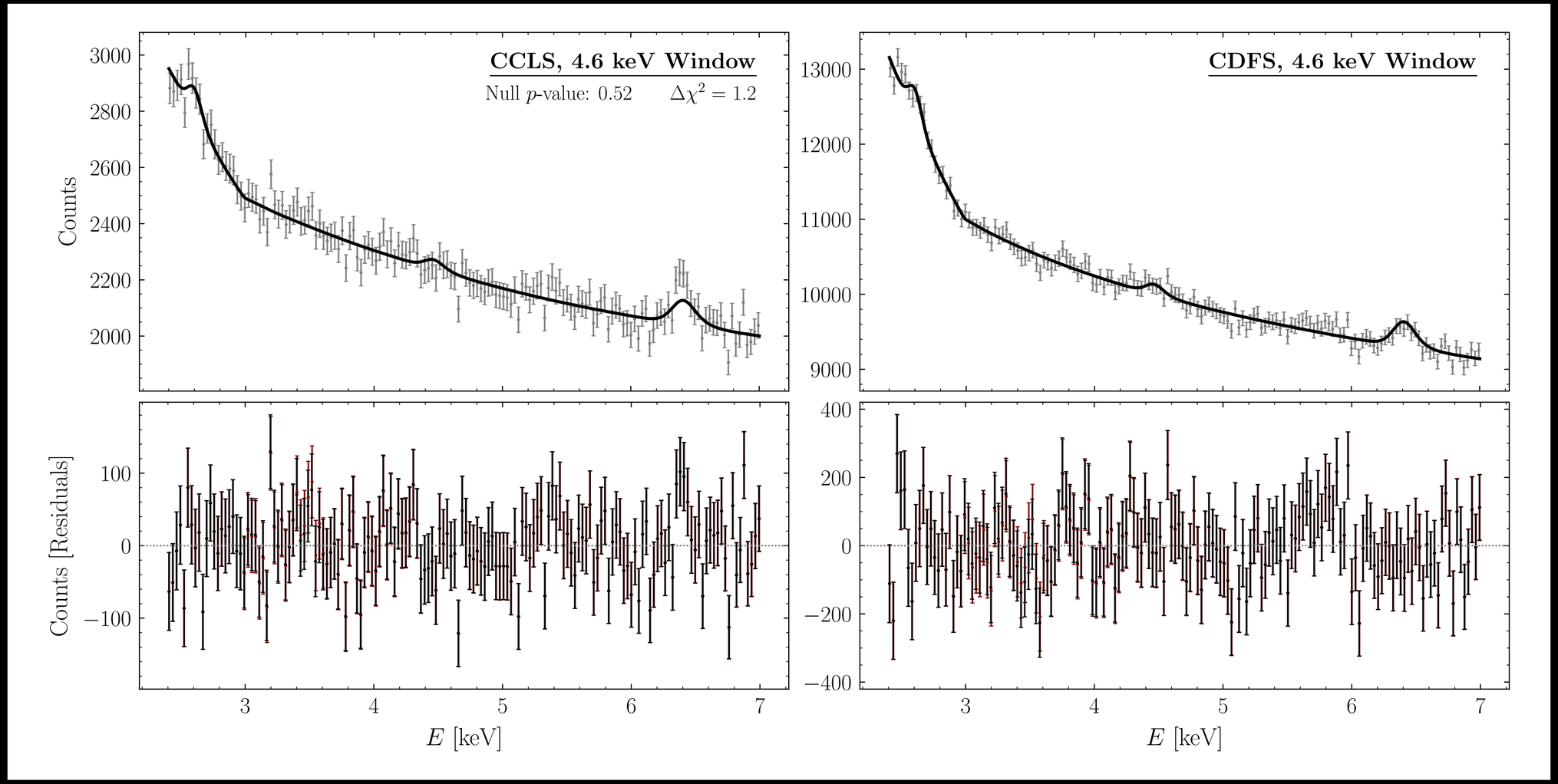


Bulbul et. al. ApJ (2014)

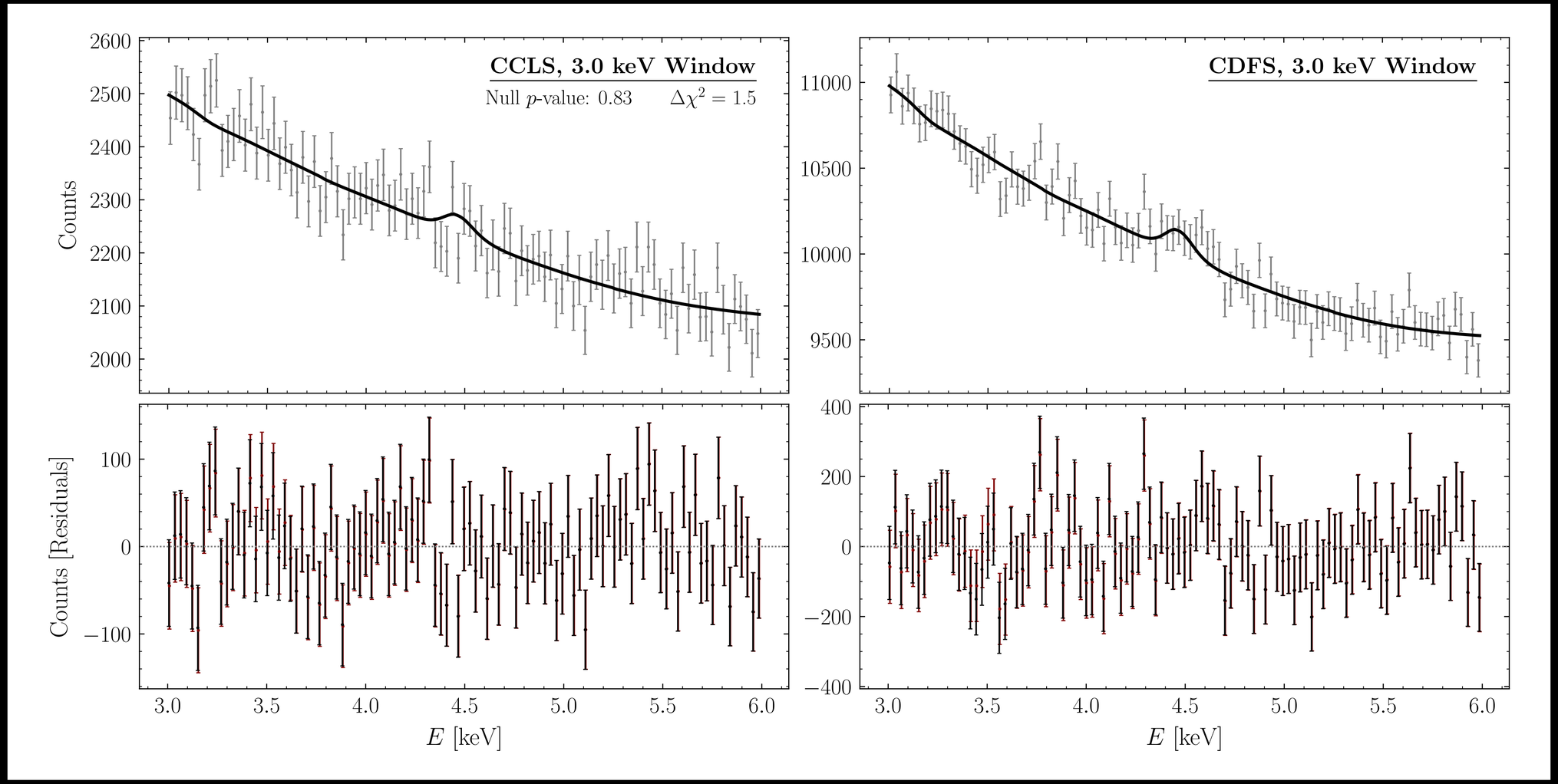
Bright Clusters Reanalysis



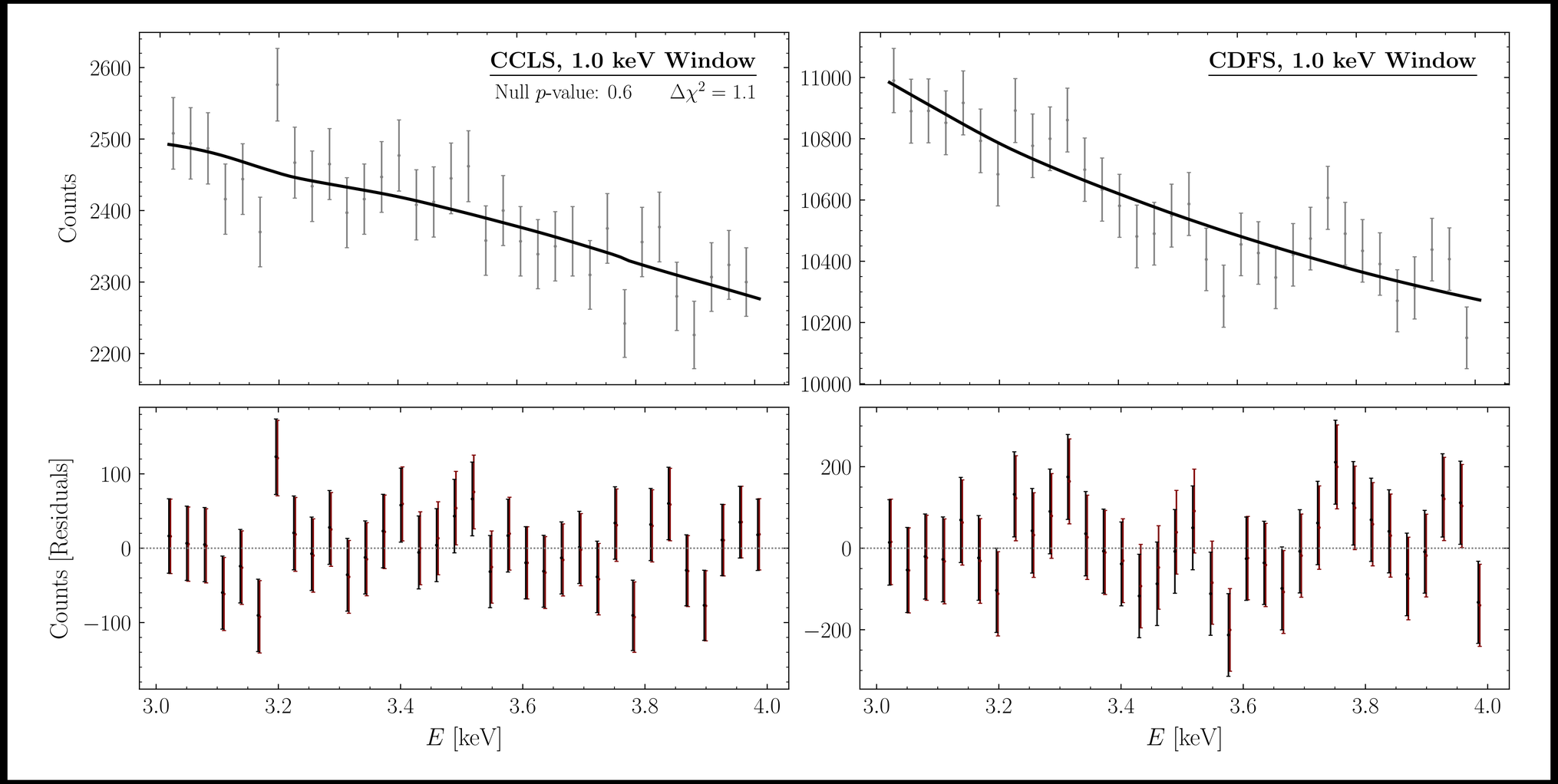
Chandra/Deep Field Fits



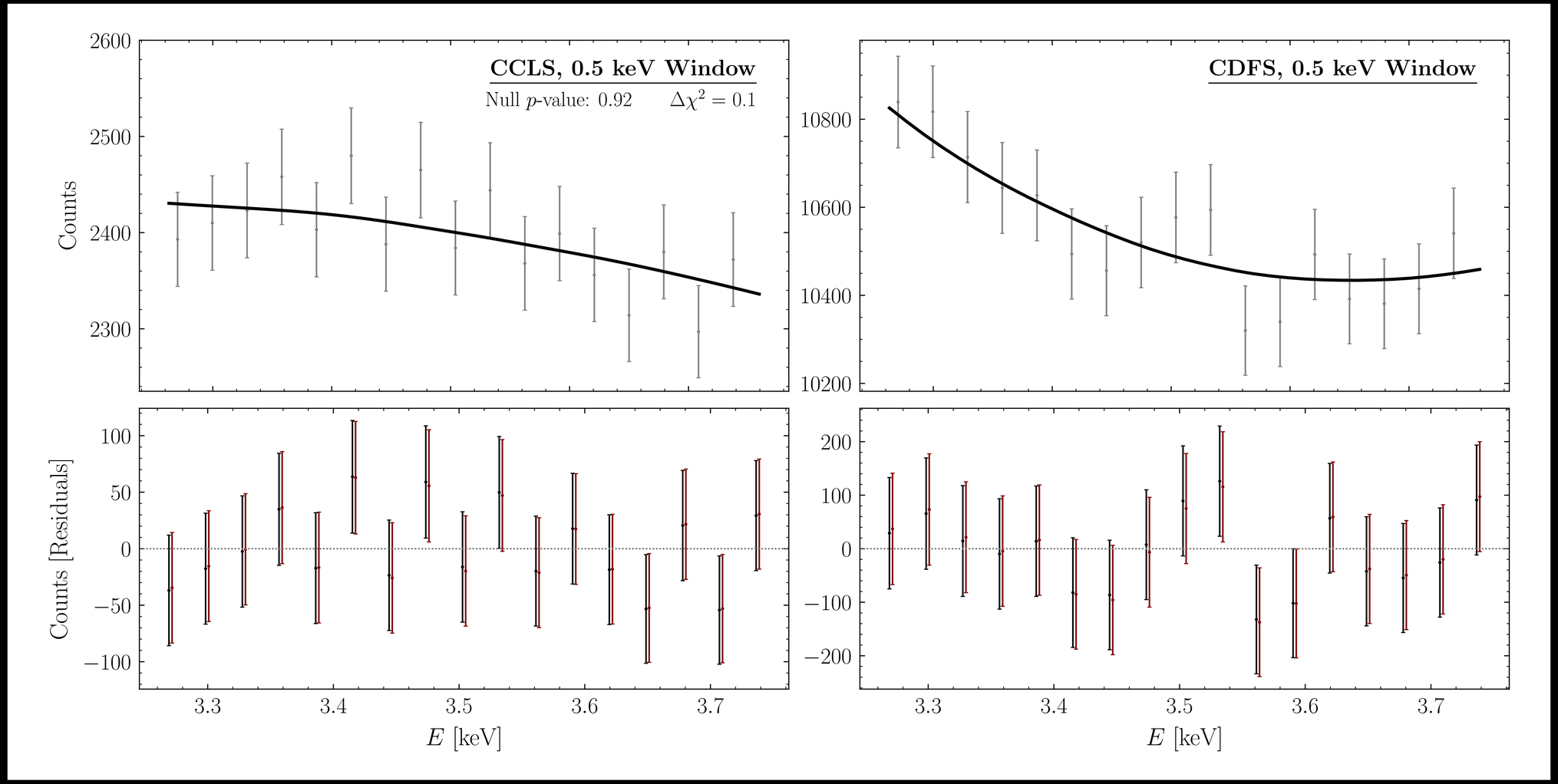
Chandra/Deep Field Fits



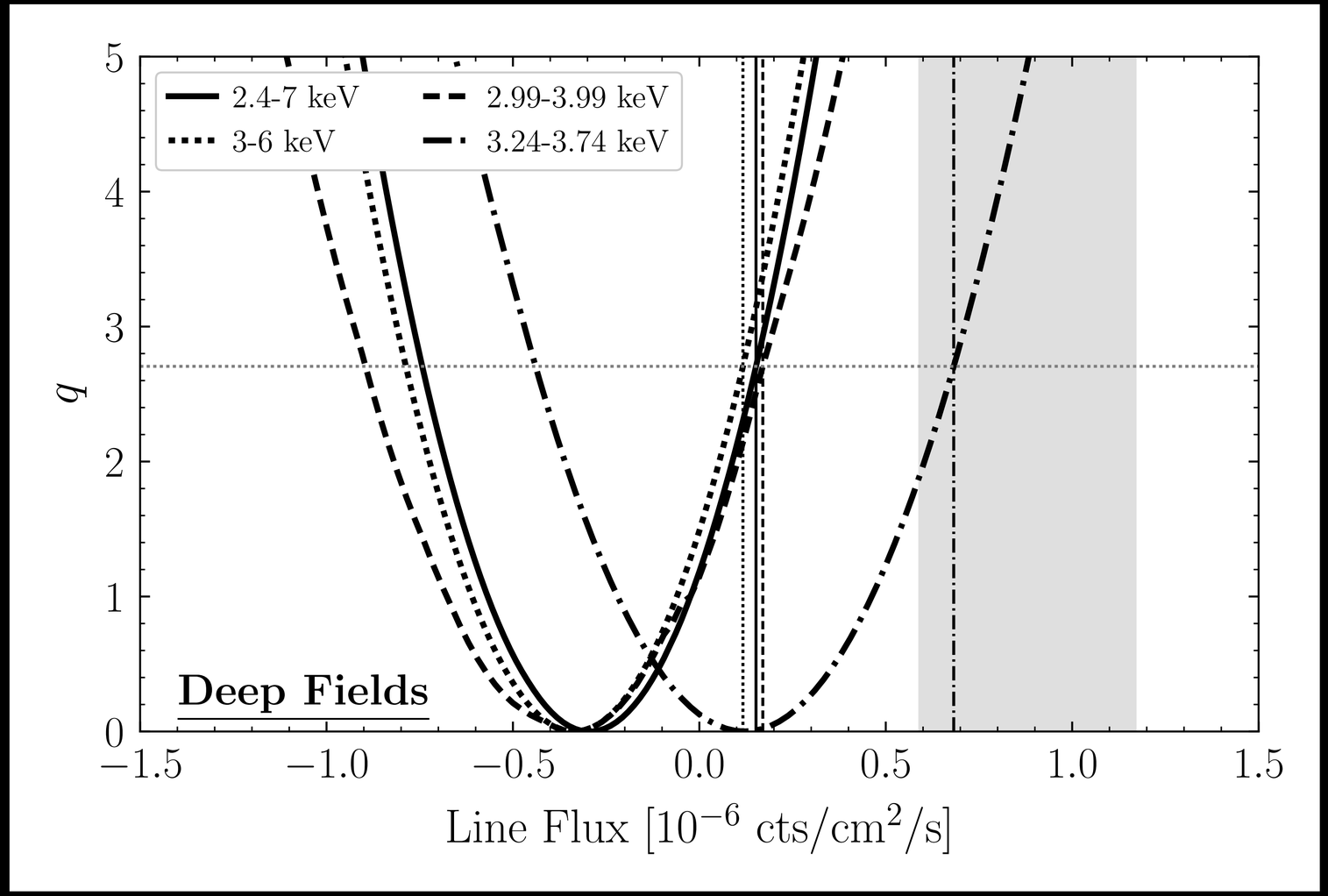
Chandra/Deep Field Fits



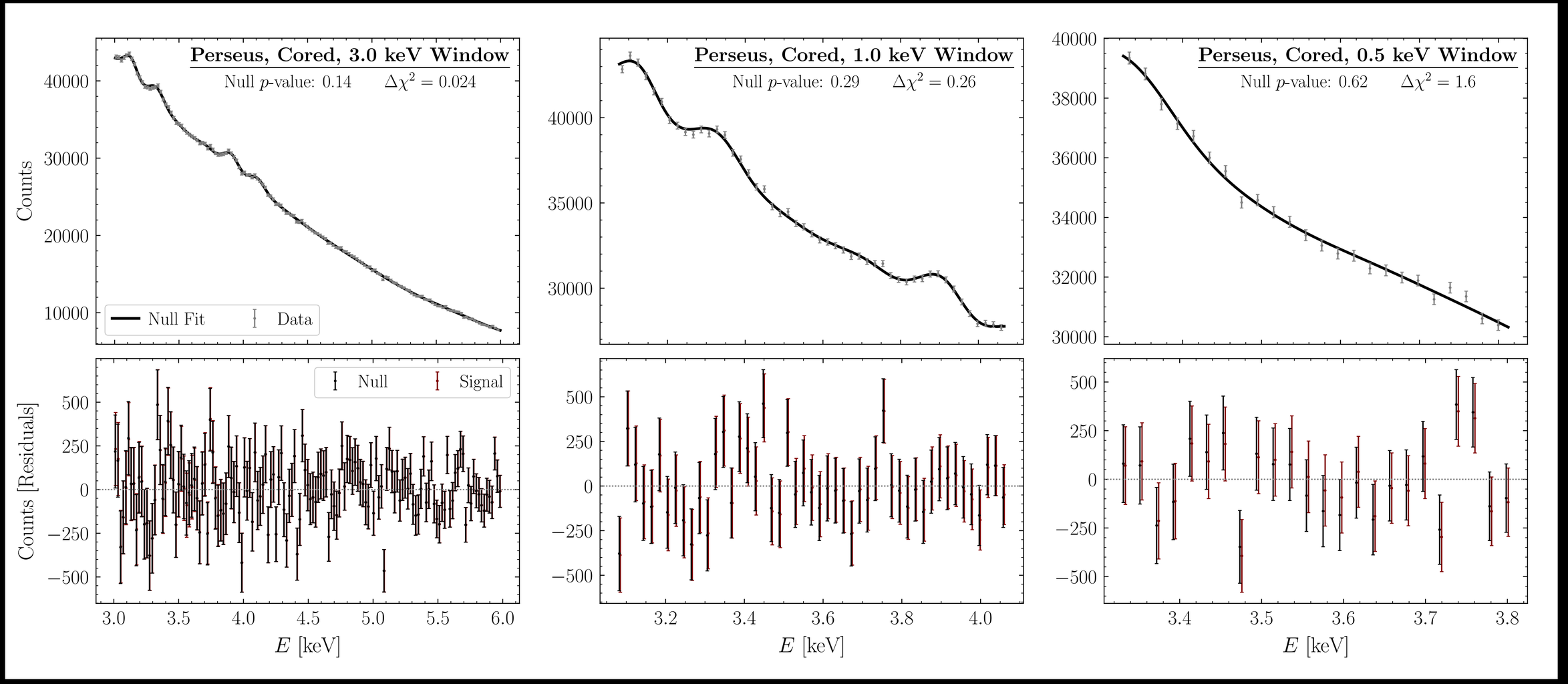
Chandra/Deep Field Fits



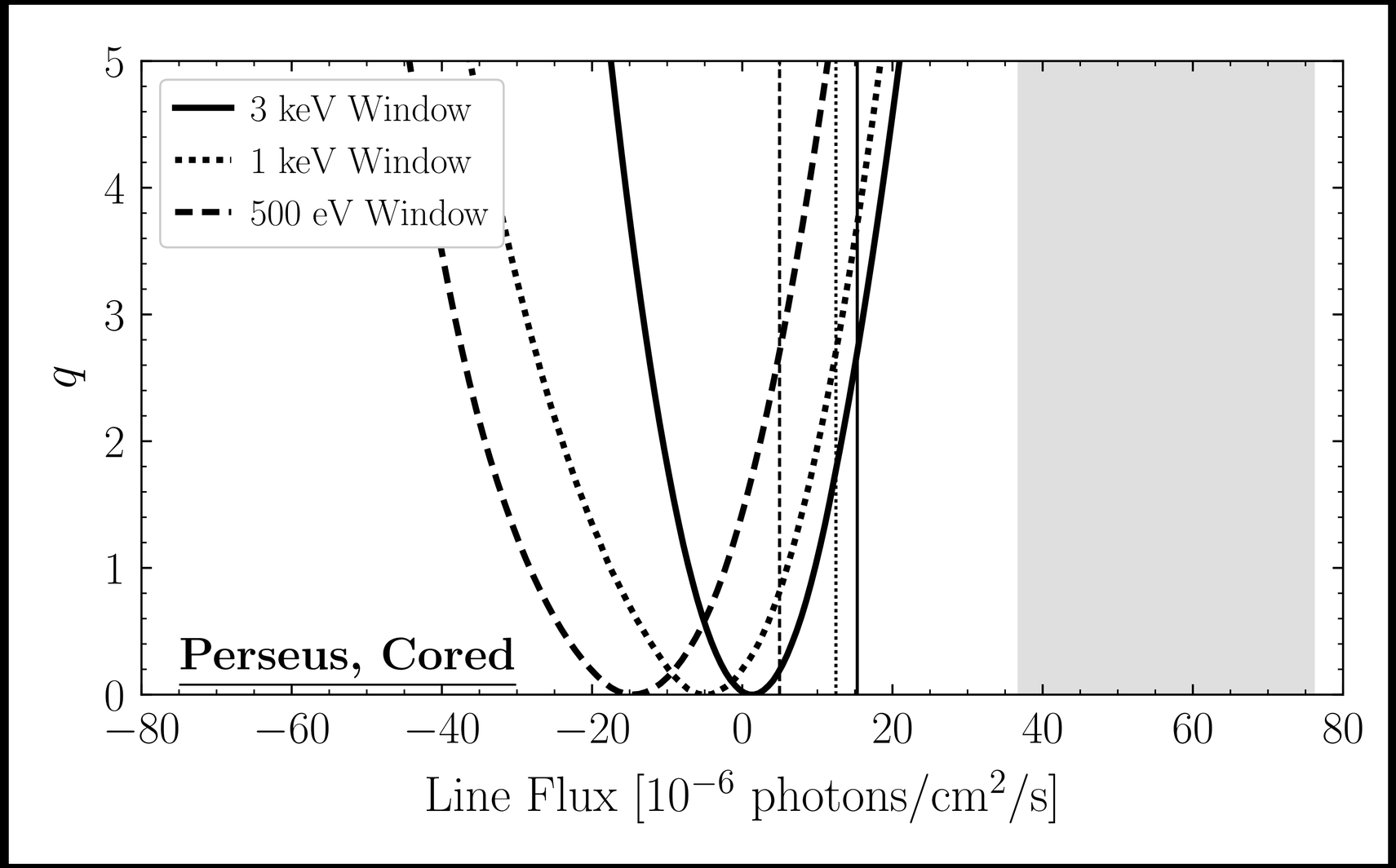
Chandra/Deep Field Profiles



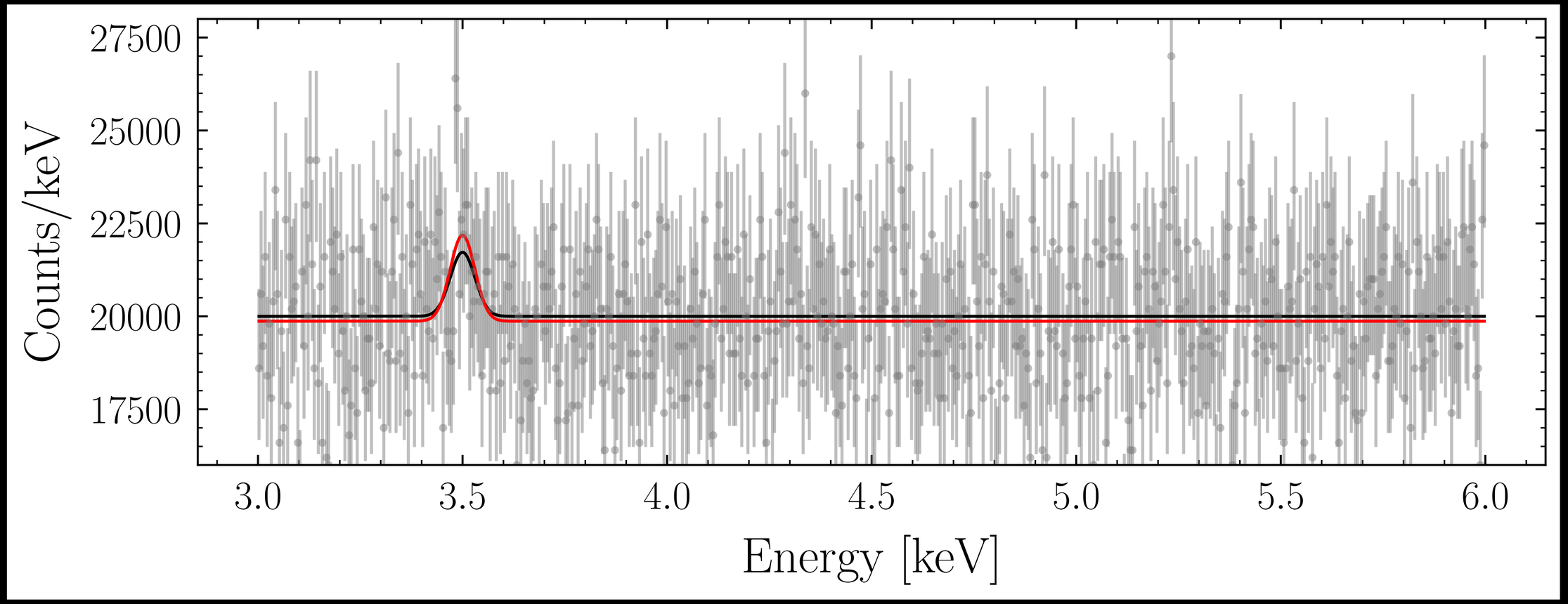
XMM/Cored Perseus Fits



XMM/Cored Perseus Profiles



What about a real signal?



What about a real signal?