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A Critical Look at the 3.5 keV Line

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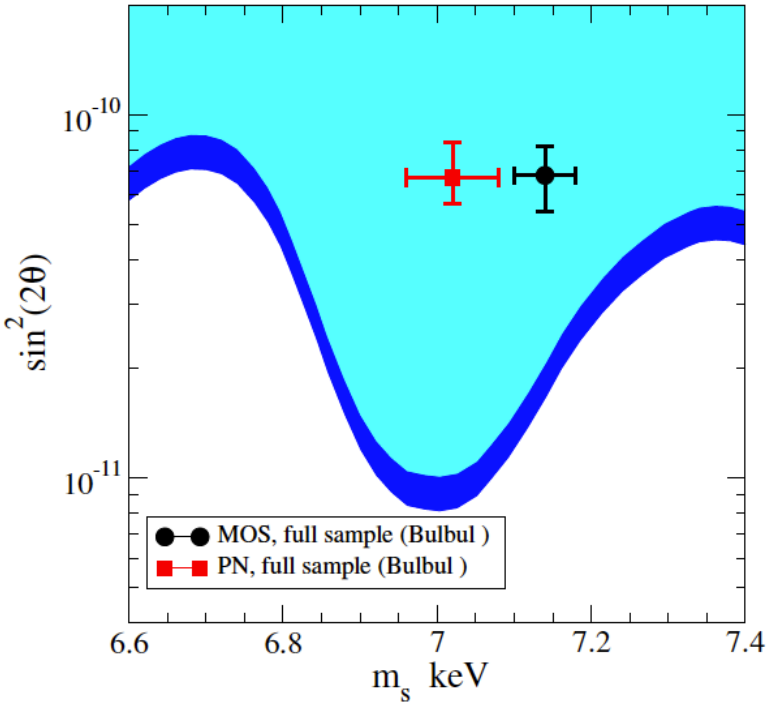
UCLA Dark Matter 2016

Main Conclusions

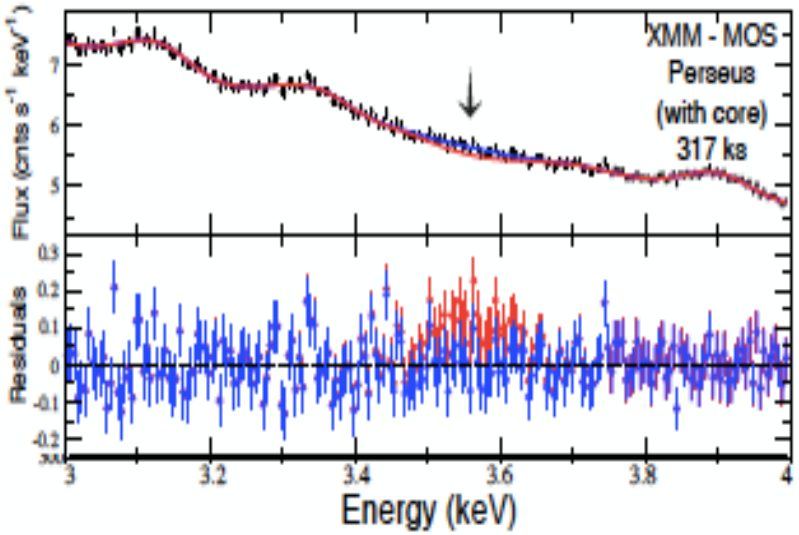
- Simple dark matter decay origin is excluded
- There are plausible astrophysical explanations
- More exotic new physics models are still possible



Exclusion based on non-detection in 1.6 Msec of observations of Draco

The 3.5 keV Line

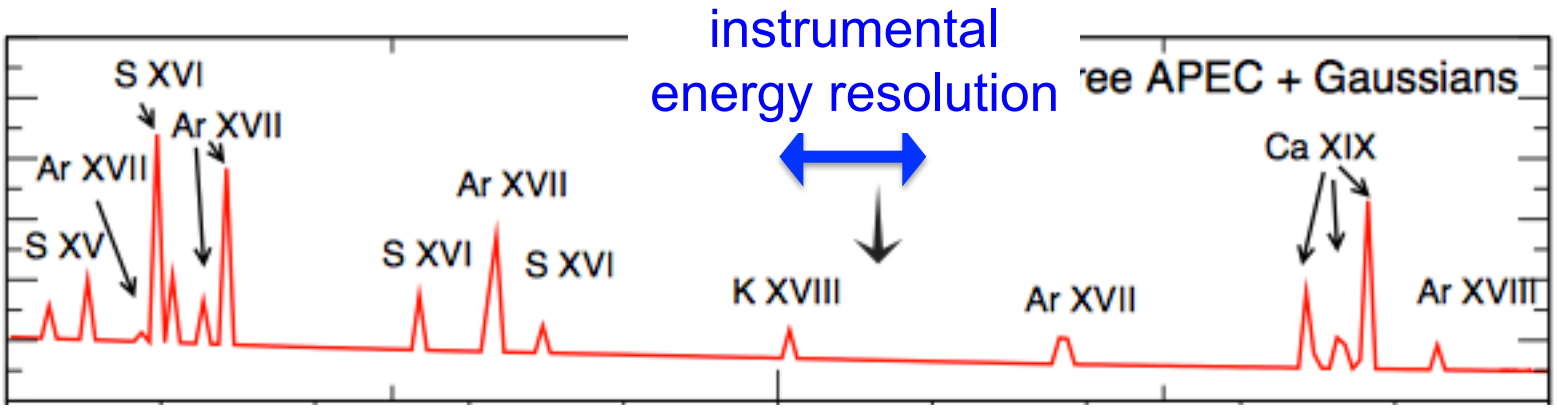
Detected, with **mild significance** (~4σ) with **XMM** and Chandra observations of **Perseus**, **M31**, stacked clusters (Balbul et al. 2014, Boyarsky et al. 2014)



Bulbul et al. 2014

These papers argue that the line is not explained by **astrophysical** lines, and may stem from **DM decay**

Several **atomic lines** nearby, especially K XVIII
(i.e. K ion with 18-1 electrons missing, i.e. “He-like”)



Bulbul et al. 2014

Determination of line intensity non-trivial:

(1) solar abundances?

(2) plasma temperature?

Discovery of a 3.5 keV line in the Galactic Center and a Critical Look at the Origin of the Line Across Astronomical Targets

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1. New analysis of XMM **Galactic Center** data
2. Re-analysis of XMM **M31** data
3. Assess **systematics of lines strengths** for Galactic Center and clusters

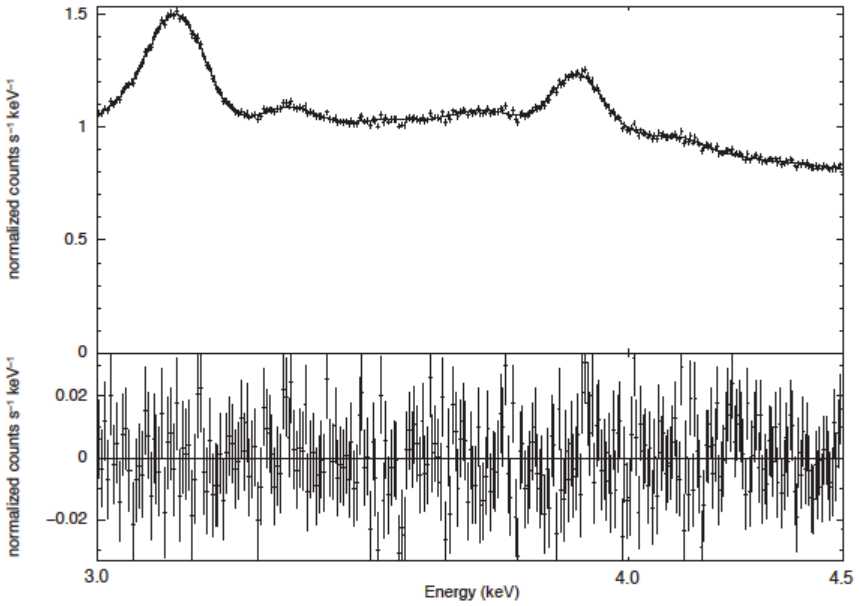
Investigating the 3.5 keV Line

1. New analysis of XMM Galactic Center data

=> There is a **line at 3.5 keV**

Line is compatible with an **atomic emission line from K XVIII**;

Line is also **compatible** with **DM** interpretation

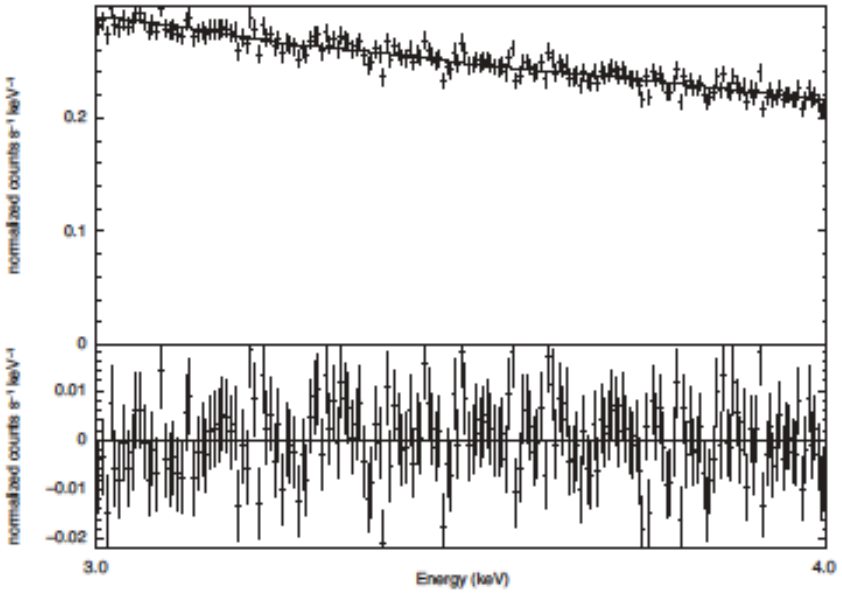


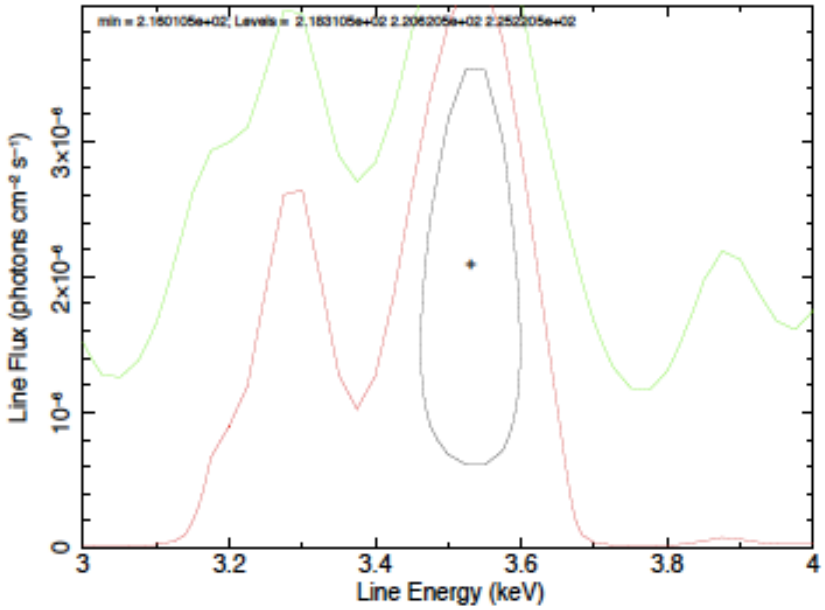
See also
Riemer-Sorensen 2014

Investigating the 3.5 keV Line

2. Re-analysis of XMM M31 data

We find no evidence for any line between 3 and 4 keV

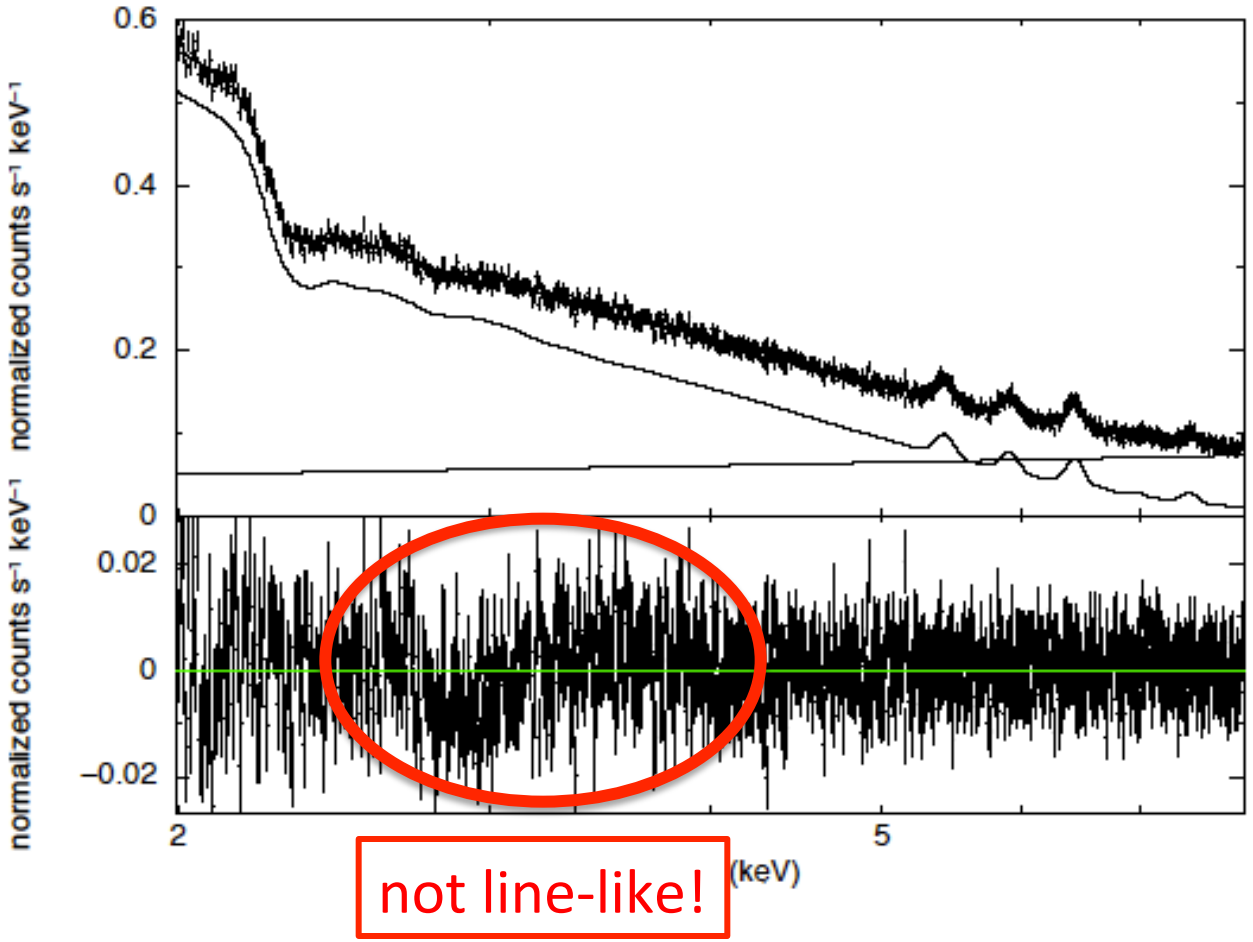




* Also no significant line when fitting 3-7 keV

Boyarsky et al. 2014 – fit 2-8 keV energy range

- requires > 20 fit parameters instead of 2
- creates spurious residuals near 3 keV



Investigating the 3.5 keV Line

3. Assess systematics of atomic line strengths

We find that the **K XVIII lines** might, within systematics, **explain the 3.5 keV lines** in the GC and clusters

In this case,

- Potassium would be a factor of 2-3 brighter/more abundant
- Sulphur would be a factor of 2-3 less abundant

than nominally predicted based on solar photospheric abundances.

Additional Recent Data Papers

1. Malyshev et al. 2014 – non-detection in stacked dwarfs
   excludes Bulbul at 4.6 σ
2. Anderson et al. 2014 – non-detection in stacked galaxies
   excludes Bulbul at 11.8 σ
3. Urban et al. 2014 – Suzaku observations
   line detected in Perseus but not other clusters
   inconsistent with DM interpretation
4. Tamura et al. 2014 – argue systematics effect line detection
5. Iakubovskyi et al. 2015 – 2 σ detection in 8 clusters
   similar to Bulbul, but less conservative

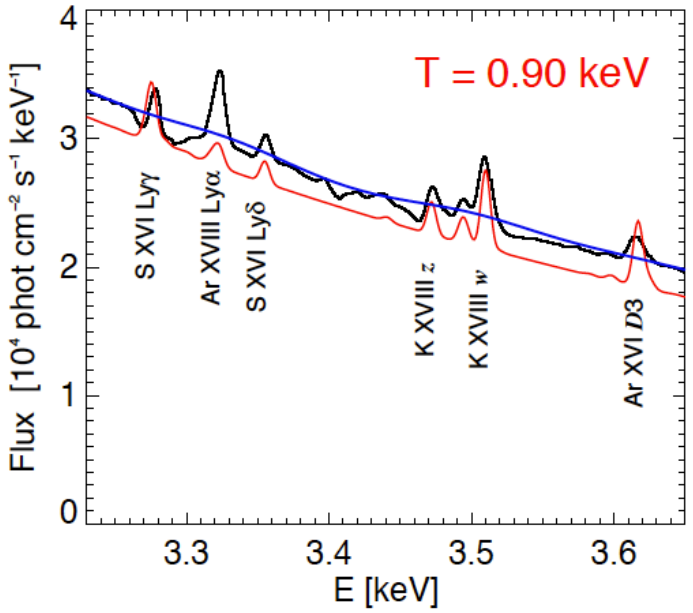
Systematics?

- **Should we really rely on solar abundances?**

Phillips et al. 2015, arXiv:1507.04619
Sylwester et al. 2015, arXiv:1503.00979

Analyze > 9000 solar flare spectra with high resolution crystal spectrometer. They find:

- Potassium 9-11x more abundant than solar photospheric
- Sulfur 2x less abundant than photospheric



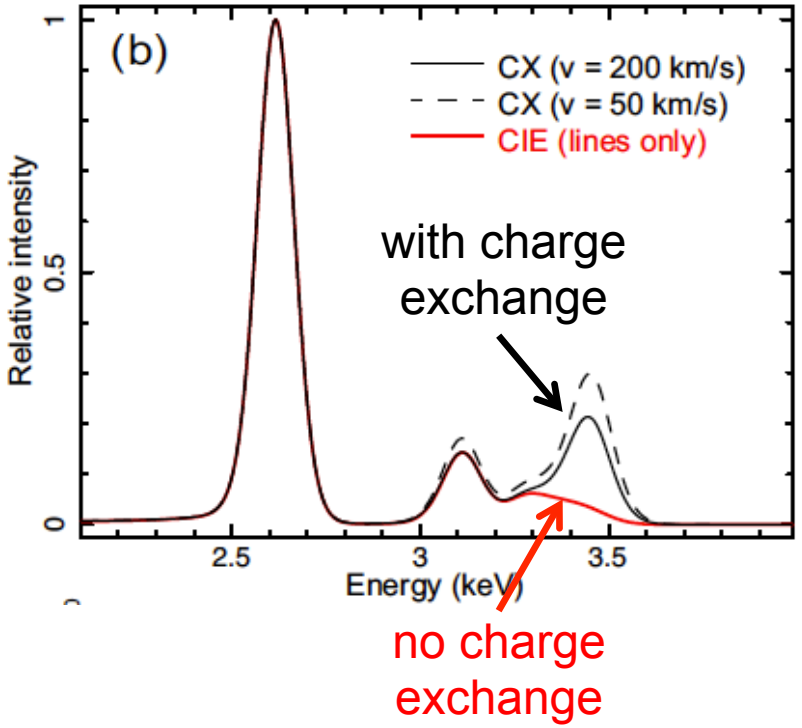
Systematics?

- **Are there additional astrophysical processes we aren't including?**

Gu et al. 2015, arXiv:1511.06557

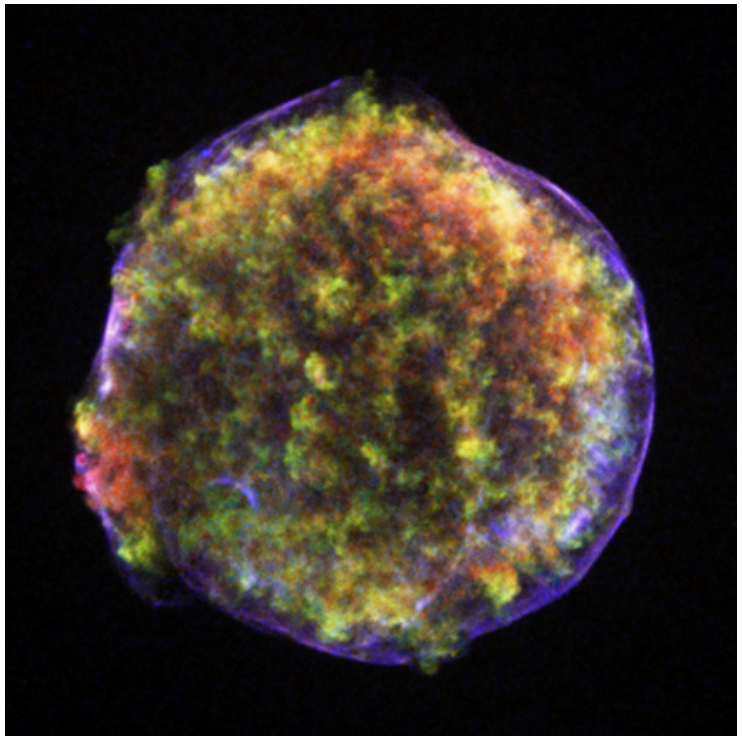
- Charge exchange between the hot plasma and neutral gas creates unique emission features

- The 3.5 keV emission can be from high-n S XVI transitions



Systematics?

Tycho Supernova Remnant



Credit: NASA/CXC/Rutgers/Warren, Hughes et al.

175 ksec XMM observations

Line at 3.55 keV detected:

- potassium with high abundance?
- systematics in line flux?
- *NOT dark matter*

Jeltema & Profumo 2015

Spectral analysis ambiguous at best

What next?

Where do the 3.5 keV photons come from? A morphological study of the Galactic Center and of Perseus

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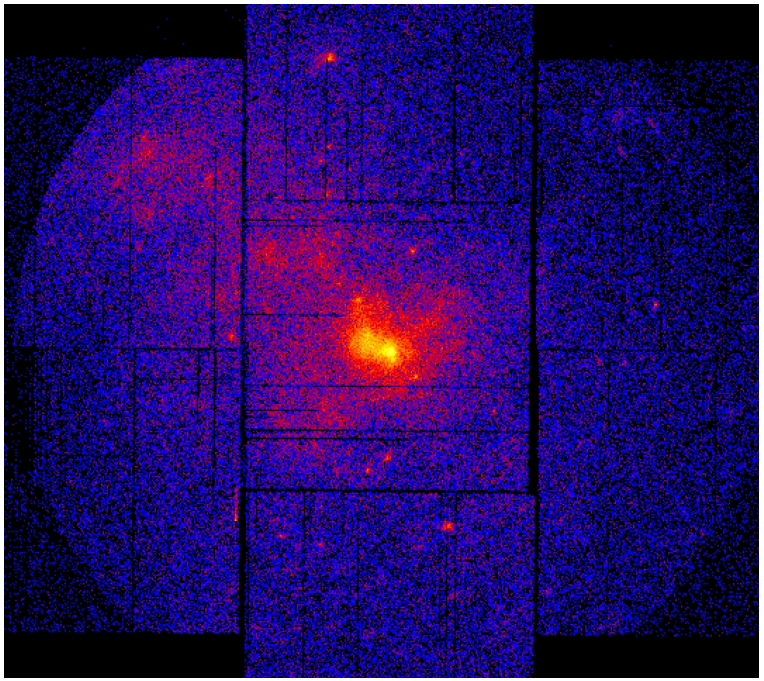
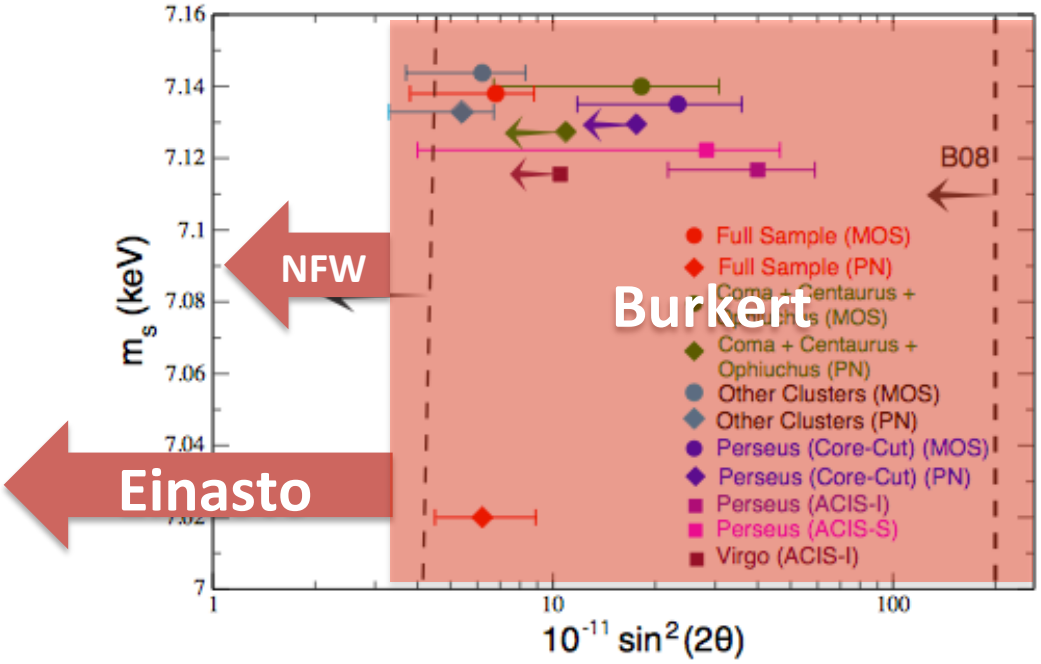


3.5 keV Line Morphology

- The 3.5 keV morphology in GC (asymmetric) and Perseus (cool-core) follows astrophysical plasma not DM
- Limits inconsistent with DM decay origin of Bulbul line



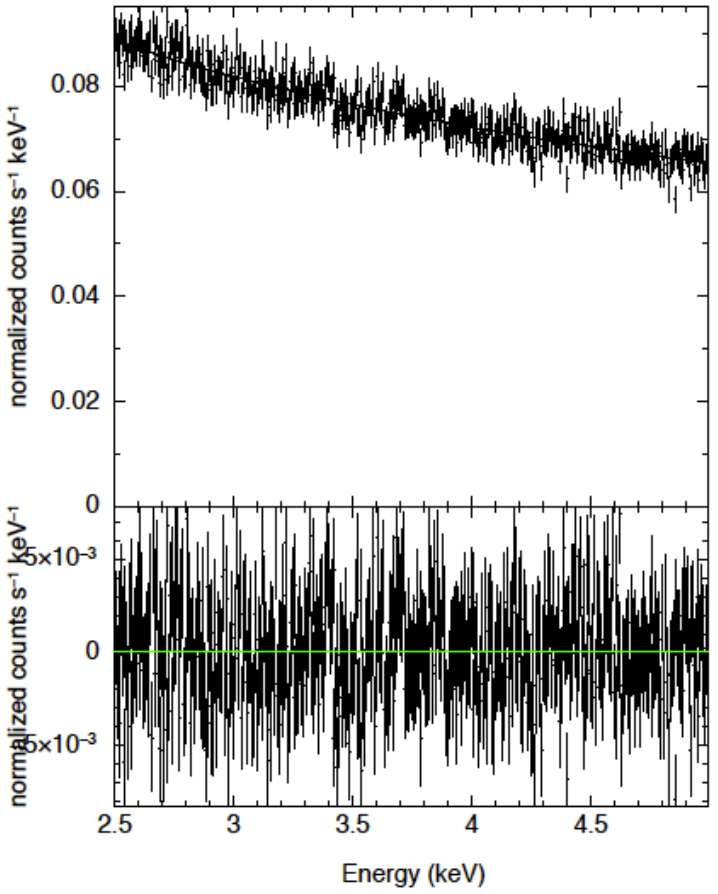
Carlson, Jeltema and Profumo 2015

Deep Observations of Draco

Jeltema & Profumo, arXiv:1512.01239

- Draco dSph observed for 1.66 Msec with XMM (19 days)
  - no expected plasma emission
- Spectrum well fit by simple power law background in 2.5-5 keV band

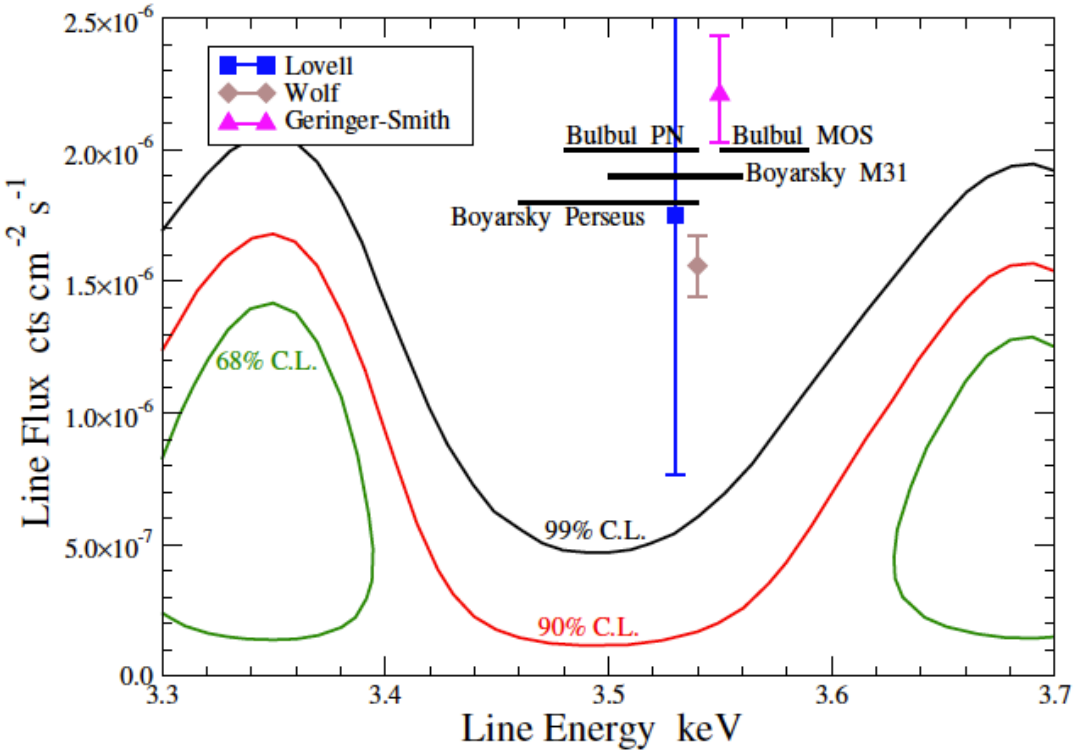
Stacked MOS Spectrum



Deep Observations of Draco

- Non-detection inconsistent with flux observed from clusters and GC for DM decay origin
- Dark matter decay excluded at > 99%

Confidence contours on line flux vs. energy



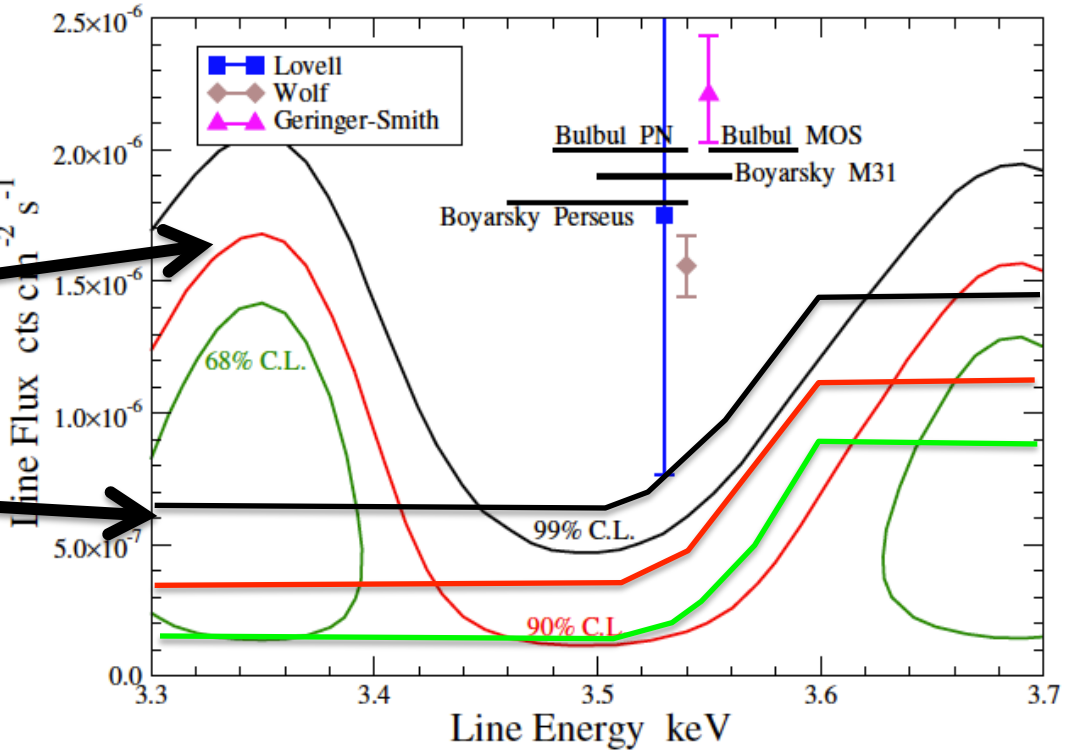
Deep Observations of Draco

- Also no excess in PN. Combining MOS and PN data has negligible effect on constraints.

- Adding instrumental lines at ~3.3 and ~3.7 keV and/or an extragalactic background component slightly improves constraints

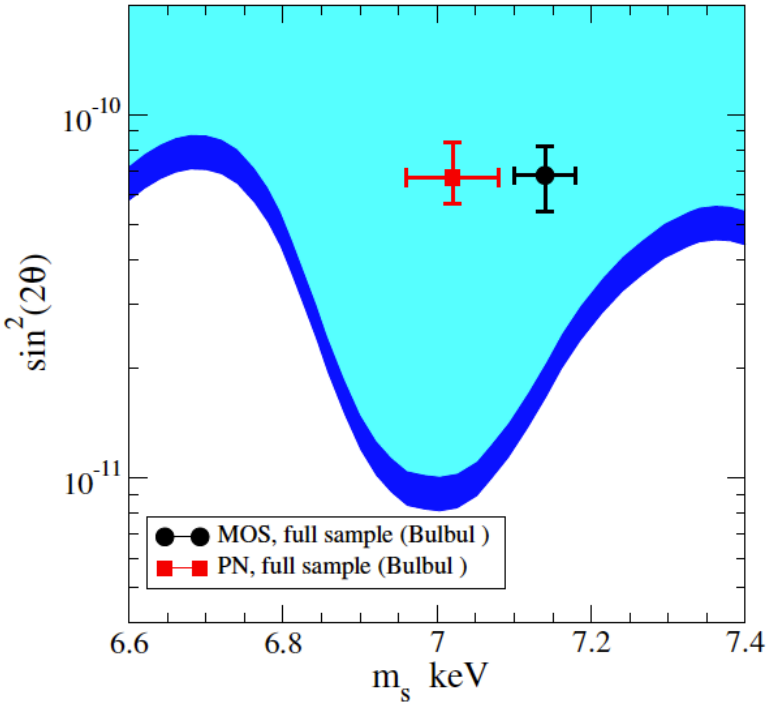
MOS only

MOS + PN joint



Summary

- A simple **DM decay** picture is **inconsistent** with non-detection in Draco and Galactic Center morphology
- There are plausible astrophysical explanations



Exclusion limits from Draco

Jeltema & Profumo, arXiv:1512.01239

Thank you!