1H 0419-577 and Beyond:
The Importance of the Hard X-ray Excess in AGN

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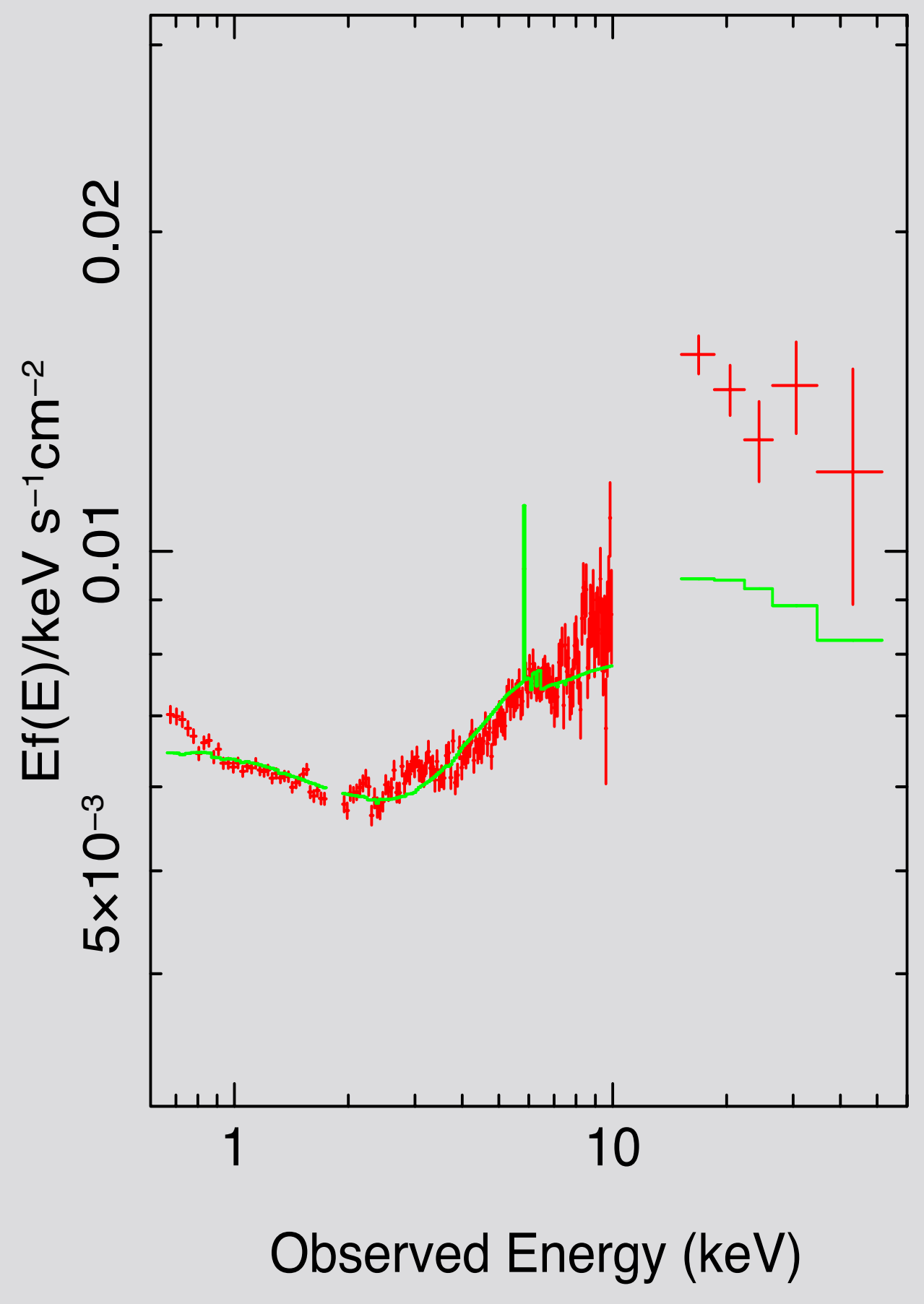
Abstract:

We have conducted an exploratory study of the 'hard X-ray excess' phenomenon in the local population of type I AGN. Source hardness ratios and Fe Kα equivalent widths reveal the presence of clumpy Compton-thick gas in the line-of-sight for 70% of the sample sources.

Introduction

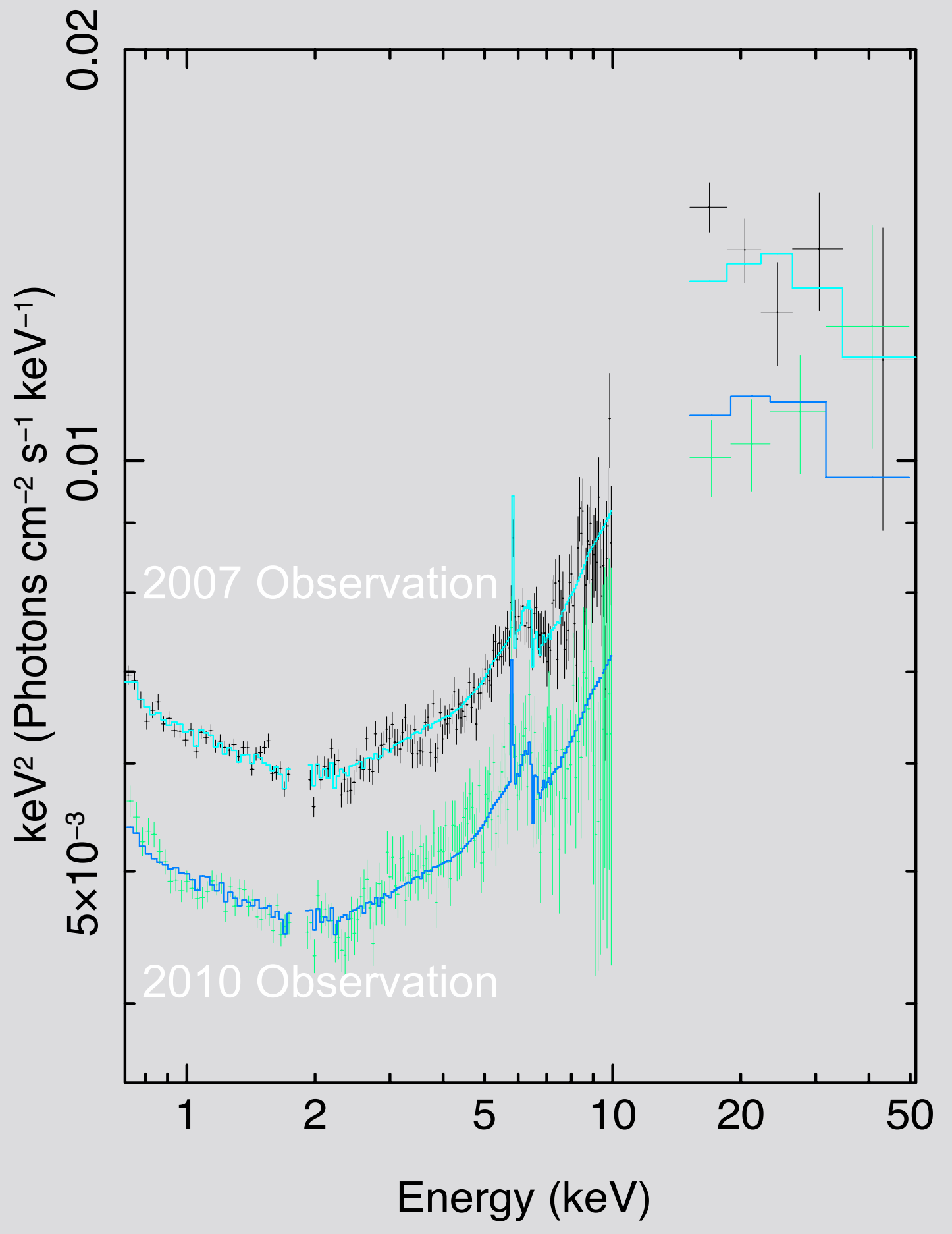


A 2007 Suzaku observation of the type I AGN 1H 0419-577 revealed an unexpectedly high X-ray flux above 10 keV; this phenomenon was dubbed a 'hard excess', and is most naturally explained by the presence of a Compton-thick partial-covering absorber in the line-of-sight. A follow-up observation in 2010 confirmed the hard excess to be a persistent phenomenon in 1H 0419-577.

Turner et al. (2009) show how the 2-10 keV model extrapolation fails to explain the observed data above 10 keV in some sources (left).

Turner et al. (2009) find a satisfactory fit using a partial covering model with 16% and 67% of the line of sight obscured with $N_H \sim 5.4 \times 10^{23}$ and $\sim 1.9 \times 10^{24}$ cm^{-2}, respectively, and 17% of the line of sight unobscured (below).

The flux state of the 2010 observation is 78% of that during 2007 while the spectral shape remains unchanged. This confirms the existence of the 'hard excess' and shows that it is a persistent phenomenon in 1H0 419-577. This result motivated an exploratory study of the hard X-ray spectra of type 1 AGN in the local universe.

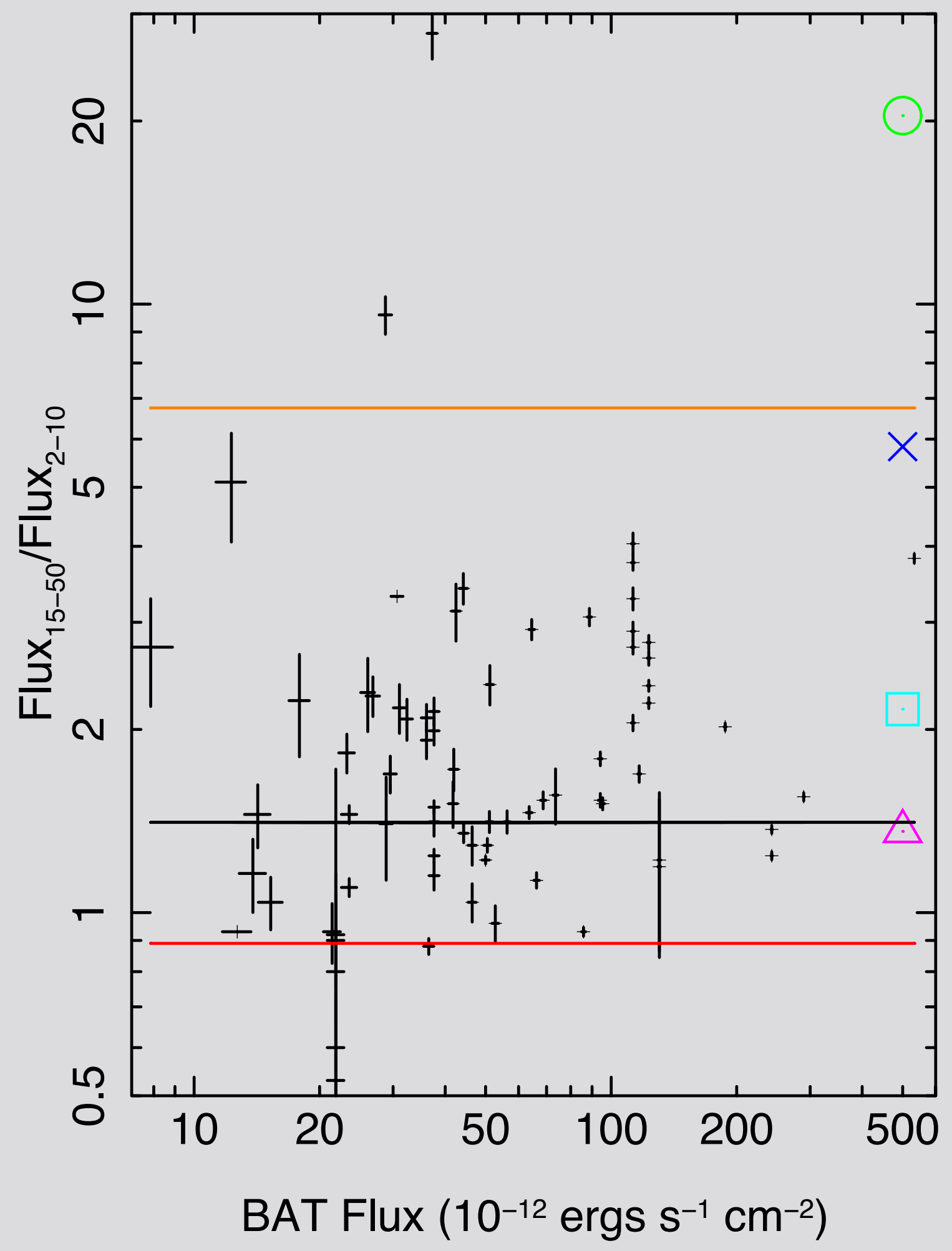


Sample Selection

We cross-correlated the list of type I AGN detected in the BAT 58-month survey with the holdings of the Suzaku public archive to construct an exploratory sample for which we had simultaneous data over ~0.5 - 50 keV. The sample comprised 50 objects, totaling 65 observations.

We have determined a "hardness ratio", i.e. $\mathrm{Flux}_{15\text{-}50}/\mathrm{Flux}_{2\text{-}10}$ of all such AGN, where the flux is measured in erg s^{-1} cm^{-2}.

Results



The black line is the weighted hardness ratio mean (1.407) for the sample. The red line (.89) is the expected hardness ratio from a power law and standard neutral reflection model (R=1) with Γ=2.09 (Ajello et al. 2008). The orange line is the expected hardness from a pure reflection model (illuminated by Γ=2.1 but where the continuum itself is not observed). The green, blue, cyan, and magenta markers represent the hardness ratios for a partial covering model with $N_H = 2 \times 10^{24}$ cm^{-2} for 98%, 90%, 70%, and 50% covering fractions, respectively.

The observed hardness ratios of 35 objects (46 observations) can be characterized with at least 50% partial covering, indicating that 70% of local type 1 AGN have significant coverage by Compton-thick gas in their line-of-sight.

This plot suggests that it is difficult to understand the sample properties in context of reflection from a standard thin disk.

References

Ajello et al. 2008, ApJ, 673, 96

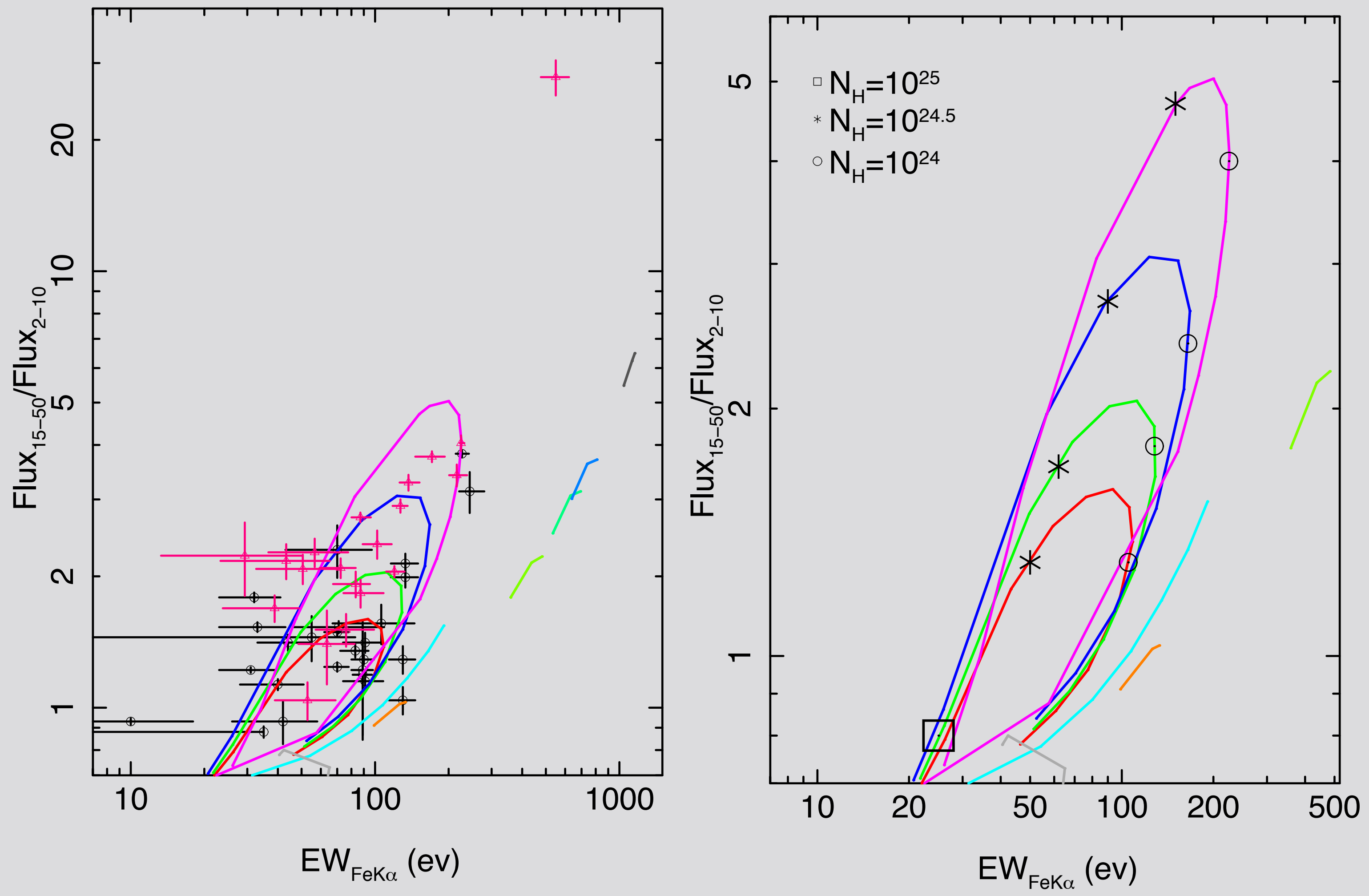
Magdziarz & Zdziarski 1995, MNRAS, 273, 837

Murphy & Yaqoob 2009, MNRAS, 397, 1549

Turner, Miller, Kraemer, Reeves, & Pounds 2009, ApJ, 698, 99

Winter, Mushotzky, Reynolds, & Tueller 2009, ApJ, 690, 1322

To investigate further we examined the equivalent width (EW) of the narrow core (FWHM ~ 3 eV) of the Fe Kα line (measured against the total continuum) shown below against the hardness ratio.



Models shown above are as follows:

Sponge-Blob: A Monte Carlo simulation by Lance Miller that distributes cold gas clouds in a spherical shell around a primary X-ray continuum. The loops represent different volume filling factors. The Sponge-Blob model lines are within the 1σ errors of 26/32 objects and 35/42 observations.

Thin Absorbing Shell: A model that predicts the expected values (cyan line) for a thin, uniform shell, neglecting Compton Scattering.

MYTorus: A toroidal reprocessor model valid in the Compton-thick regime based on the model by Murphy & Yaqoob (2009). The light gray line represents $N_H = 1 \times 10^{23}$ - 1×10^{25} cm^{-2} with a 60° inclination angle.

Standard reflection: A model combining a powerlaw distribution and reflection from a cold, distant optically thick medium (Magdziarz & Zdziarski 1995). R=1, 5, 10, and 15 (red, light green, dark green, and blue lines) and pure reflection (dark grey line).

Conclusions

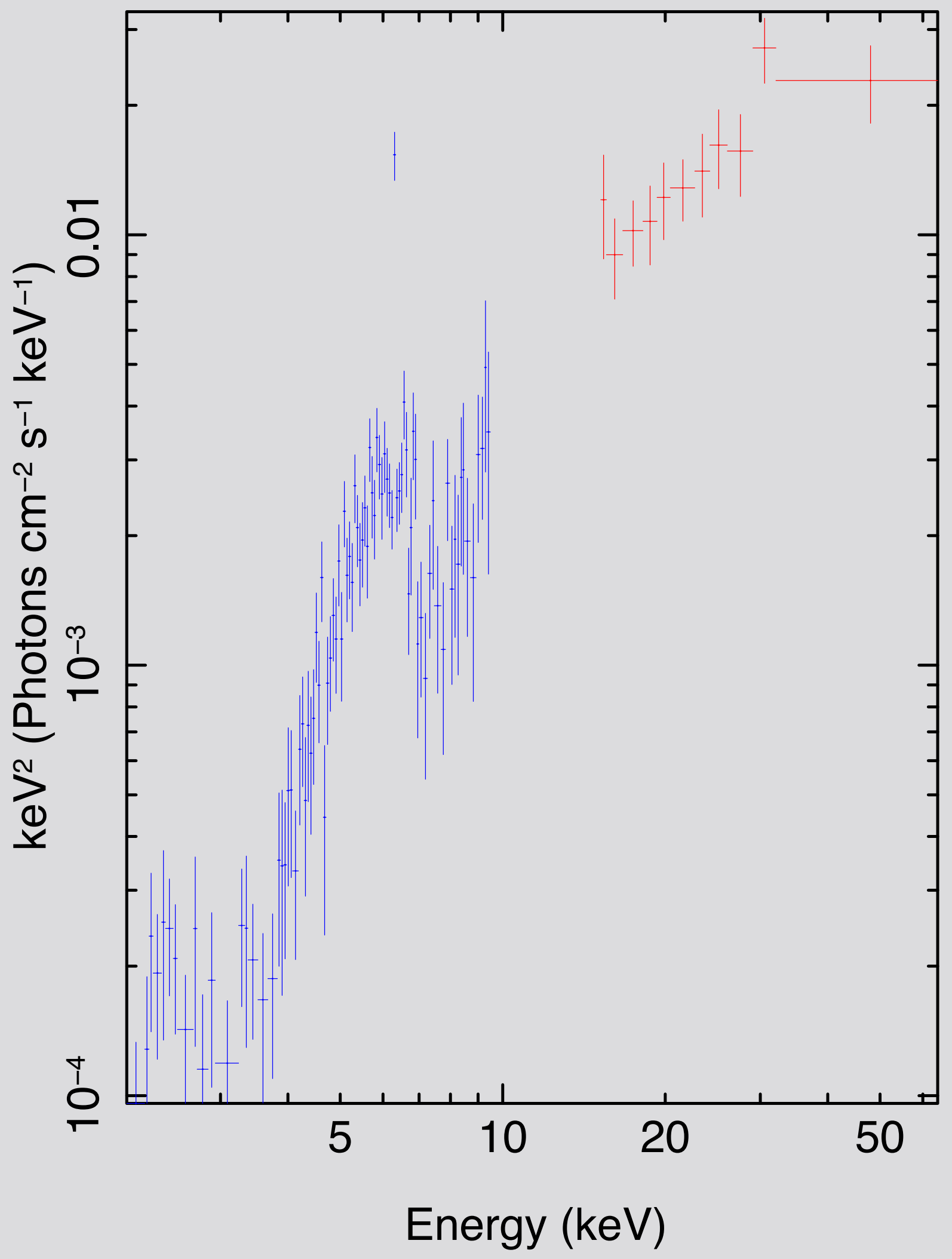
The sample distribution of hardness ratios suggest most of the sources are harder than expected from reflection of a powerlaw continuum from material subtending 2π steradians to the source. The sample reveals 35/50 objects and 43/65 observations to be harder than 1H 0419-577.

The Fe K line EWs are not explained by simple reflection, nor by reprocessing in a simple torus.

A clumpy, partial covering X-ray absorber model can explain the hardness ratio and line equivalent widths of ~70% of the objects in the sample.

We concur with the conclusion of Winter et al (2009) that BAT is finding new hard AGN, and find that consideration of partial-covering absorption models considerably increases the estimated fraction of objects with Compton-thick gas in the line-of-sight.

Work is in progress regarding the implications of our results for the X-ray background and for AGN luminosity functions.



An example spectrum:

The nature of the hardest AGN can be more closely examined by individual spectral analysis.

Above, we show MGC-03-34-06, which is shaped by complex, partial-covering absorption.

Acknowledgements

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