The Global Implications of the Hard X-ray Excess in Type 1 AGN

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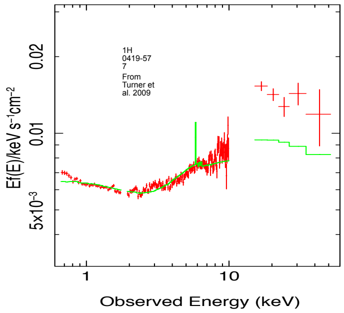
M.M. Tatum[1], T.J. Turner[2], L. Miller[3], J.N. Reeves[2,4]

[1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, U.S.A
[2]Department of Physics, University of Maryland Baltimore County, MD 21250, U.S.A.
[3]Department of Physics, University of Oxford, Denys Wilkinson Building, Keble Road, Oxford, OX1 3RH, U.K.
[4]Astrophysics Group, School of Physical and Geographical Sciences, Keele University, Keele,Staffordshire ST5 5BG, U.K

Introduction

Suzaku observations of the type 1 AGN 1H 0418-577 (Turner et al. 2009, ApJ, 698, 99), PDS 456 (Reeves et al. 2009, ApJ, 701, 493) and NGC 1365 (Risaliti et al. 2009, ApJ, 705, L1) revealed an unexpectedly high X-ray flux above 10 keV. This phenomenon was dubbed a 'hard excess', as the 2-10 keV model extrapolation failed to explain the excess of photons in the hard X-ray band (> 10 keV), and is most naturally explained by the presence of a Compton-thick ($N_H > 10^{24}$ cm^{-2}), partial-covering absorber in the line-of-sight. This motivated an exploratory study of the hard excess phenomenon in the local type 1 AGN population.



Suzaku observation of 1H 0419-577. The green line represents the 2-10 keV model fits with the extrapolation above 10 keV. The hard X-ray data lie well about the 2-10 keV model extrapolation.

Sample Selection

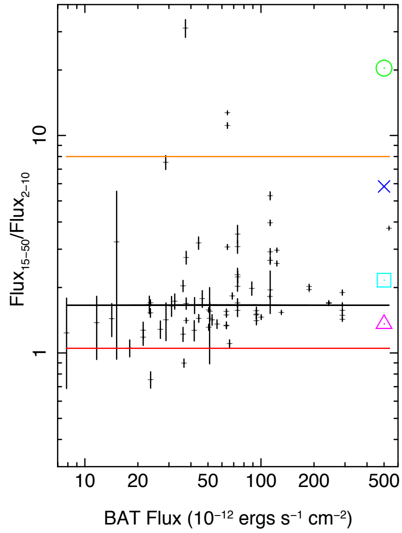
We selected type 1-1.9 AGN from the *Swift* Burst Alert Telescope (BAT) 58-month catalog as the bandpass of BAT (~15-150 keV) allows for an unbiased survey of the X-ray sky for column densities up to 10^{24} cm^{-2}. We cross-correlated this source list with holdings in the *Suzaku* public archive so that we obtained simultaneous medium (2-10 keV) and hard X-ray data. Only sources obtained from the *Suzaku* archive were used in our analysis. This yielded a total sample of 43 objects and 76 observations: 24 objects are classified as type 1-1.2, 16 objects are classified as type 1.5, and 3 objects are classified as type 1.8-1.9.

We have determined a "hardness ratio", $Flux_{15\text{-}50\ keV}/Flux_{2\text{-}10\ keV}$, where the flux is measured in erg s^{-1} cm^{-2}.

Conclusion

We find the hard excess phenomenon to be a ubiquitous property of type 1 AGN. Taken together, the spectral hardness and equivalent width of Fe Kα emission are consistent with reprocessing by an ensemble of Compton-thick clouds that partially cover the continuum source. In the context of such a model, ~80% of the sample has a hardness ratio consistent with > 50% covering of the continuum by low-ionization, Compton-thick gas.

Results



The black line is the weighted mean hardness ratio (1.65 +/- 0.01) of the sample.

We compared the hardness ratio distribution to simple model predictions assuming Γ=2.0 (Scott et al. 2011, MNRAS, 417, 992) :

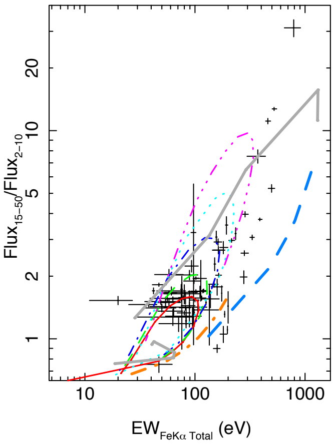
The red line represents simple disk reflection, a model combining a powerlaw distribution and reflection from a standard thin disk of neutral material subtending 2π sr at the continuum source. 90% of the objects are harder than this model prediction.

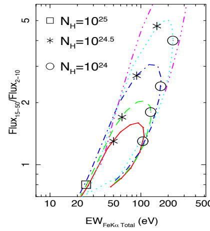
The orange line represents pure reflection, simple disk reflection with the continuum source completely hidden. Pure reflection cannot explain the most extreme objects.

The green, blue, cyan, and magenta markers represent a partial-covering, absorption model with N_H=2 x 10^{24} cm^{-2} for 98%, 90%, 70%, and 50% covering fractions, respectively.

The observed hardness ratios of 35 objects (63 observations) can be characterized with at least 50% partial covering, indicating that 80% of local type 1 AGN have significant coverage by Compton-thick gas in their line-of-sight.

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





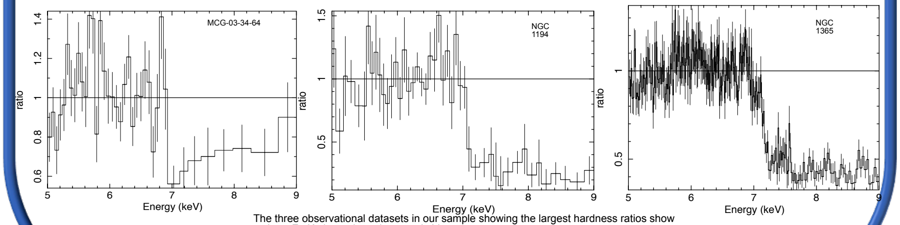
Models shown above are as follows:

MCRT: A Monte Carlo simulation that distributes cold gas clouds in a spherical shell around a primary X-ray continuum. The loops represent different volume filling factors.

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

MYTorus: A toroidal reprocessor model (light gray lines) valid in the Compton-thick regime (Murphy & Yaqoob 2009, MNRAS, 401, 411).

Simple disk reflection: Model predictions (blue line) for simple disk reflection to pure reflection.



The three observational datasets in our sample showing the largest hardness ratios show a sharp Fe K absorption edge a ~7 keV.

At 90% confidence, the depth and width of the edge for NGC 1194, NGC 1365 and MCG 3-34-64 were τ= 1.3 +\- 0.40 and σ < 0.15 keV, τ = 0.87 +\- 0.10 and σ < 0.14 keV, and τ = 0.95 +\- 0.30 and σ < 0.03 keV, respectively, showing that the absorption features are narrow and not likely to be reprocessed light from a blurred reflector.