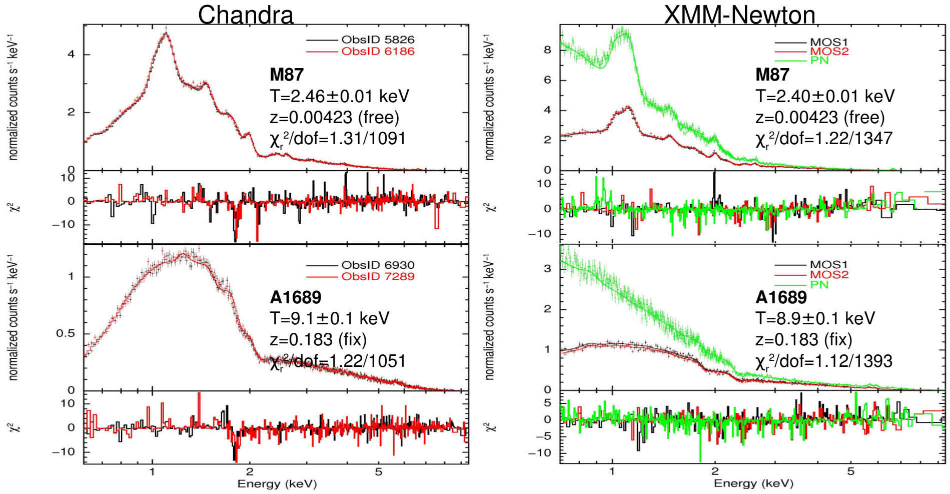
An edge-like feature in high signal-to-noise ratio spectra of galaxy clusters

En-Hsin Peng, K. Andersson, M. W. Bautz

MIT Kavli Institute for Astrophysics and Space Research

❑ Introduction

Measuring broad-band and hard-band temperature is a common practice to infer the presence of additional components for CCD spectra. For this technique to work, calibration around 2 keV, the often-adopted cut-off energy for the hard-band, is crucial. A recent study finds a very high hard-band to broad-band temperature ratio for some Chandra clusters that cannot completely explained physical models (Cavagnolo et al. 2008). This motivates us to investigate this issue.



Left: 0.6–9.5 keV Chandra ACIS-I spectra of M87 from r=6'-7.5' (top) and A1689 from r<3' (bottom) plotted against an absorbed VAPEC model. The column density is fixed at the galactic value, 2.1x10^{20} cm^{-2} (M87) and 1.8x10^{20} cm^{-2} (A1689). All the elemental abundances are free to vary. *Right*: XMM-Newton EPIC spectra (processed with SAS 8.0.1). An edge-like feature at 1.74 keV is seen in Chandra spectra, but not obvious in XMM-Newton spectra.

❑ Data Preparation

All of the observations in this analysis are carried out by ACIS-I array. We follow the standard CIAO threads to process Chandra data (CIAO version 4.1.2; CALDB version 4.1.3). Since the observations have gone through Reprocessing III, updated charge-transfer inefficiency and time-dependent gain corrections have already been applied. For data taken in VFAINT telemetry mode, we run *acis_process_events* with *check_vf_pha=yes* to reject particle background and remove events with bad CCD columns and bad grades. Light curves are extracted from four I-chips with cluster core and point sources masked and filtered by lc_clean which used 3σ clipping and a cut at 20% above the mean. Spectra are extracted in PI channels with weighted response matrices and effective area files created by *mkacisrmf* and *mkwarf*. Background spectra are extracted from reprojected and renormalized (in 9.5-12 keV band) blank-sky data sets.

❑ Analysis & Results

To determine the absorption depth of this feature, we fit the spectra extracted from r<3' region with an absorbed APEC model multiplied by an edge model, give by

$$C = Exp\left[-\tau\left(\frac{E}{E_{thresh}}\right)^{-3}\right] \text{ for } E > E_{thresh}$$

The observations, except for M87, are chosen from the sample of Cavagnolo et al. (2008) for clusters that have high-hard to broad-band temperature ratios. To avoid the confusion of the cool gas from the cluster core, the spectra from the central 0.5' region is excluded. The best-fit parameters are listed in the table.

Name	ObsID	ccd	z	E_{thresh} (keV)	τ	T (keV)	χ^2/dof
M87	5826, 6186	0,1,2,3	0.004	$1.75^{+0.01}_{-0.01}$	$0.10^{+0.01}_{-0.01}$	$2.46^{+0.01}_{-0.01}$	1295/1089
A3376	3202, 3450	3	0.046	$1.69^{+0.04}_{-0.04}$	$0.15^{+0.03}_{-0.03}$	$4.02^{+0.09}_{-0.09}$	509.1/510
A3266	899	1	0.055	$1.72^{+0.05}_{-0.05}$	$0.09^{+0.02}_{-0.02}$	$8.09^{+0.19}_{-0.19}$	436.5/398
A401	2309	2	0.074	$1.78^{+0.03}_{-0.03}$	$0.14^{+0.03}_{-0.03}$	$7.73^{+0.26}_{-0.25}$	312.2/333
A2255	894	3	0.081	$1.77^{+0.04}_{-0.05}$	$0.12^{+0.03}_{-0.03}$	$6.20^{+0.18}_{-0.18}$	353.2/361
A2034	2204	3	0.113	$1.79^{+0.02}_{-0.02}$	$0.14^{+0.02}_{-0.02}$	$6.99^{+0.18}_{-0.16}$	387.4/431
A1413	5002, 5003	1,2	0.143	$1.75^{+0.02}_{-0.02}$	$0.07^{+0.01}_{-0.01}$	$6.97^{+0.12}_{-0.11}$	875.6/860
A1204	2205	3	0.171	$1.78^{+0.16}_{-0.05}$	$0.19^{+0.07}_{-0.07}$	$3.62^{+0.16}_{-0.15}$	197.8/197
A2218	1666	0	0.176	$1.64^{+0.17}_{-0.06}$	$0.15^{+0.07}_{-0.07}$	$7.00^{+0.60}_{-0.56}$	167.9/147
A1689	5004,6930,7289	3	0.183	$1.74^{+0.01}_{-0.01}$	$0.11^{+0.01}_{-0.01}$	$9.40^{+0.13}_{-0.13}$	1561.6/1379
1E0657-56	4984,5356,5357,5361	0,1,2,3	0.296	$1.74^{+0.02}_{-0.02}$	$0.08^{+0.01}_{-0.01}$	$11.96^{+0.18}_{-0.18}$	2011.3/1995

Although the isothermality might not be the correct assumption for spectra extracted from such a large region, adding additional thermal component does not greatly change the edge parameters (Peng et al. 2009). Moreover, there is no apparent correlation between E_{thresh} and the redshift, which strengthens the finding that this absorption feature is probably not related to the astronomical sources.

❑ Conclusions

We find an edge-like feature in multiple ICM spectra, which can be described by an absorption edge model with an optical depth of 0.1 around 1.74 keV. Although not present in every spectra we have seen, caution must be taken when fitting spectra with multiple components or comparing temperatures measured at different bands under this uncertainty.

References

Cavagnolo, K. W., Donahue, M., Voit, G. M., & Sun, M. 2008, ApJ, 682, 821
Peng, E.-H., Andersson, K., Bautz, M. W., & Garmire, G. P. 2009, ApJ, 701, 1283