An X-ray cluster hidden in the glare of a bright quasar

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We report the discovery of a z=0.68 X-ray cluster in the field of the unusual z=0.96 quasar PG1407+265. The cluster contributes about 10% of the X-ray flux of the source..

This quasar is strange

PG1407+265 was discovered by Richard Green (Green et al 1983) in the PG survey.
It is a luminous (Lbol=9 x 10^{13} Lsun), massive (M_{BH}~ 5 x 10^9 M_{sun}) quasar
Its optical lines are anomalously weak (Fig 1, left) and show velocity shifts up to 13000 km/s (McDowell et al 1995)
It is the prototype X-ray-strong **Weak Line Quasar** (in contrast to X-ray weak WLQs like PHL1811)
It is nominally radio-quiet but has a weak parsec-scale radio jet (Blundell, Beasley and Bicknell 2003)
Gallo (2006) saw factor 2 X-ray variability in 2 months with XMM
Here (Fig 2, right) we present the 40-year X-ray light curve with a factor 10 amplitude

It has (almost) no emission lines

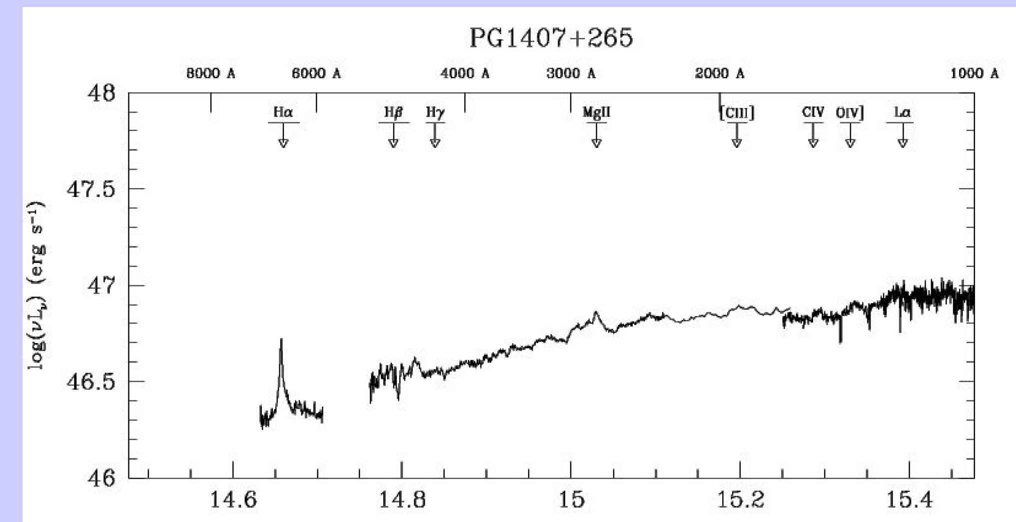


Fig 1. UV to near IR spectrum of PG1407+265 (updated from McDowell et al 1995). Note the extremely weak emission lines. But it's not a blazar!

It has factor 10 X-ray variability

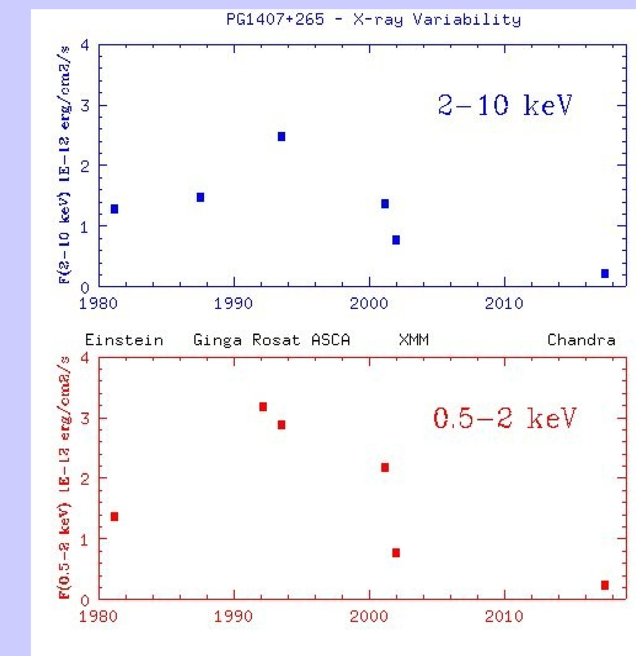


Fig 2. X-ray light curve in soft (0.5-2 keV) and hard (2-10 keV) bands showing factor 10 variability over 40 years. Data from Einstein, Ginga, ROSAT, ASCA, XMM, and Chandra. Details in McDowell et al (in prep).

Chandra's spatial resolution reveals a large X-ray nebulosity next to it
We think it's a foreground cluster.

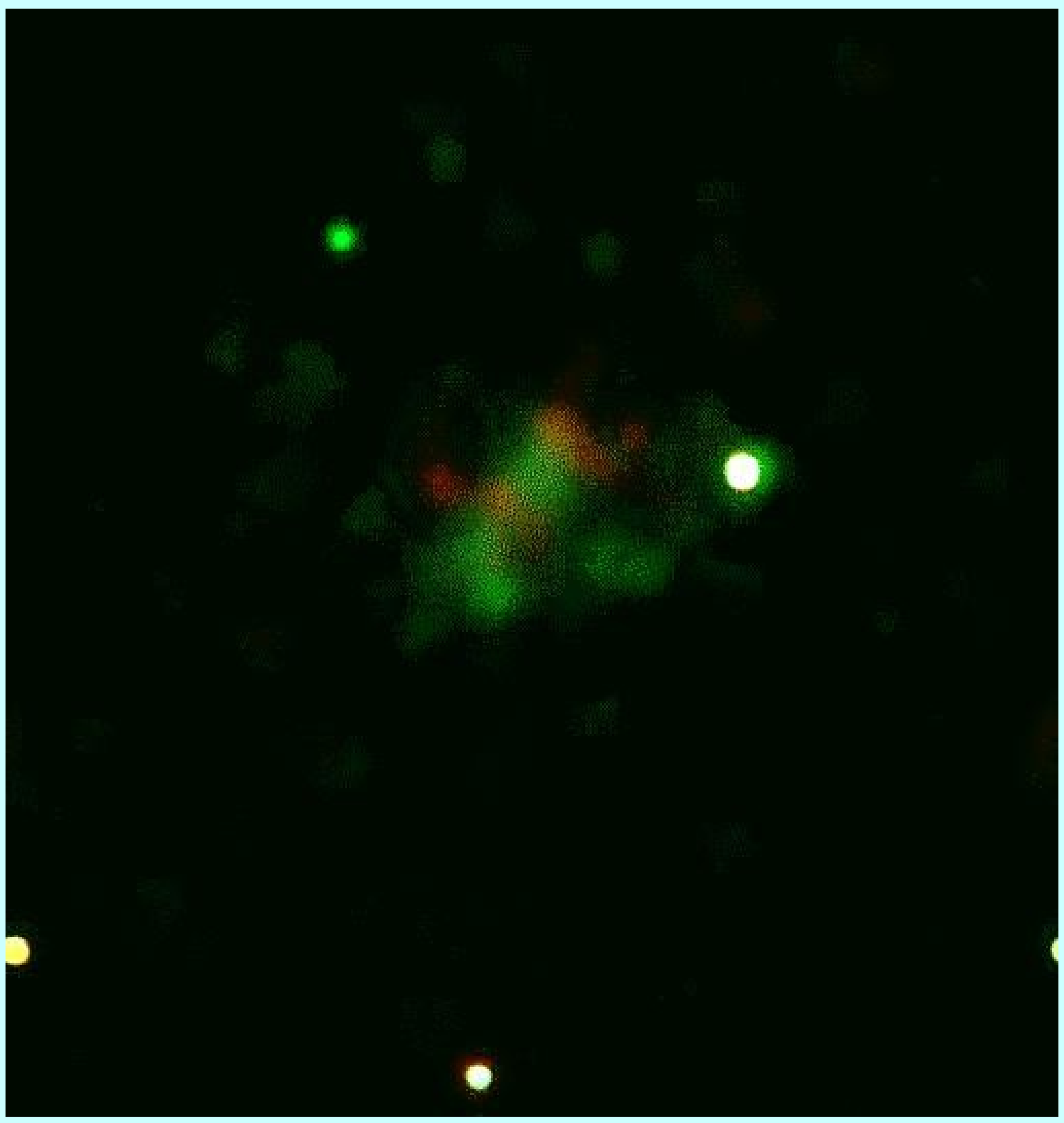
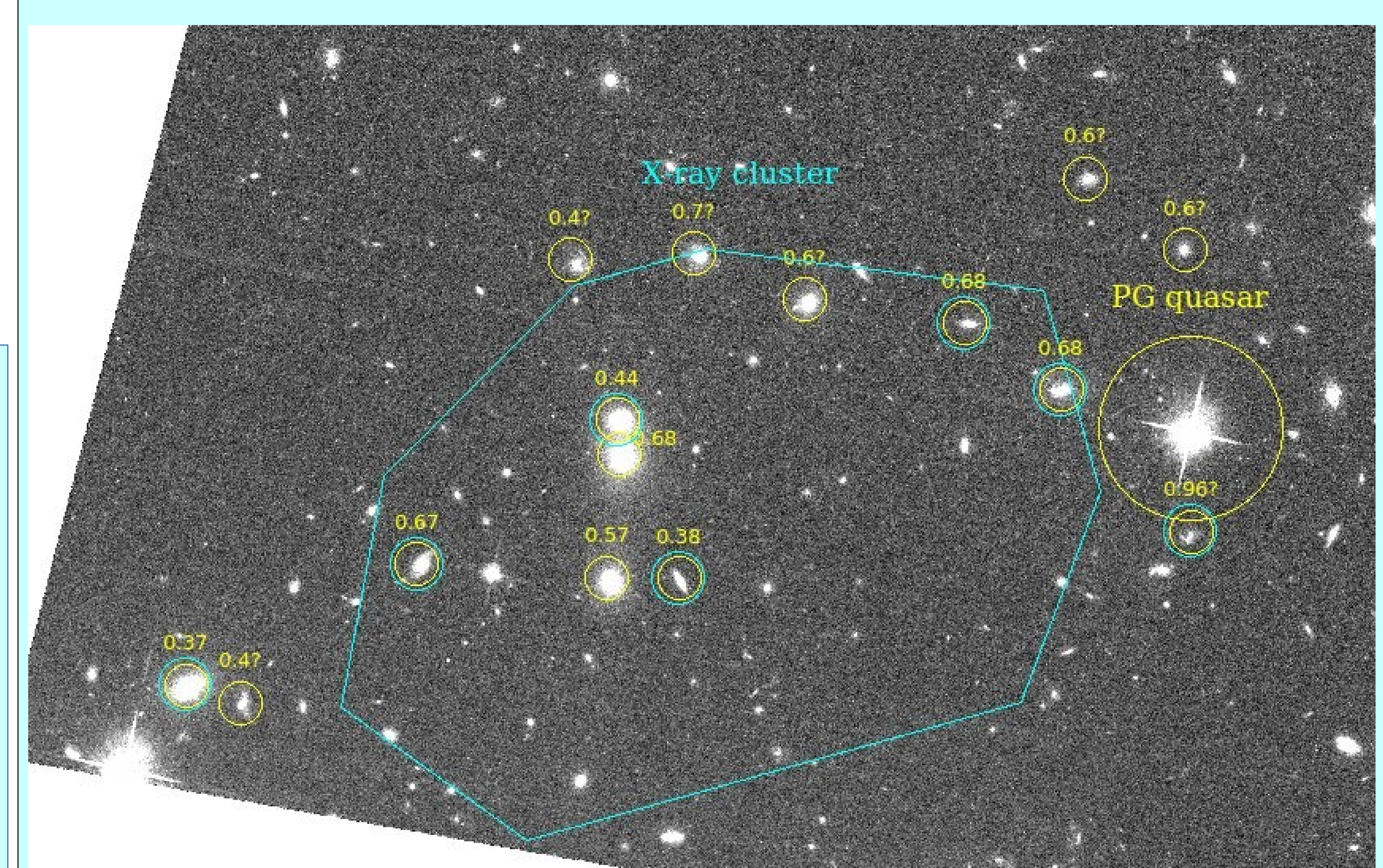


Fig.3 Chandra ACIS S3. Red: 0.3-1 keV, Green: 1-2.5 keV Blue : 2.5-8 keV.
Extent is about 1 arcminute. Data reduction using CIAO 4.11
Exposure time 41.5 ksec. Quasar: 2077 net counts. Extended emission: 345 net count
Observed flux of extended emission: F(0.5-10 keV) = 6 E-14 erg/cm2/s

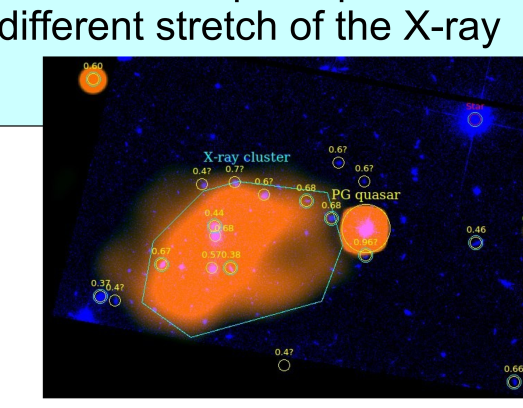
Fig 3b: XMM MOS image in which the cluster is barely resolved.
We needed Chandra to see the cluster properly!

Galaxy redshifts suggest a possible cluster at z=0.68



HST ACS image, with MMT/BINOSPEC redshifts

Fig 4. We observed the field with BINOSPEC Fabricant et al 2019) on the MMT and obtained redshifts of 10 objects (cyan and yellow double circles), supplemented with SDSS redshifts and SDSS photo z estimates (yellow). The cyan polygon indicates the approximate extent of the X-ray extended emission. Several galaxies in the region have z=0.68 – perhaps this is the cluster redshift? In the inset below right, a different stretch of the X-ray image is superimposed for context.



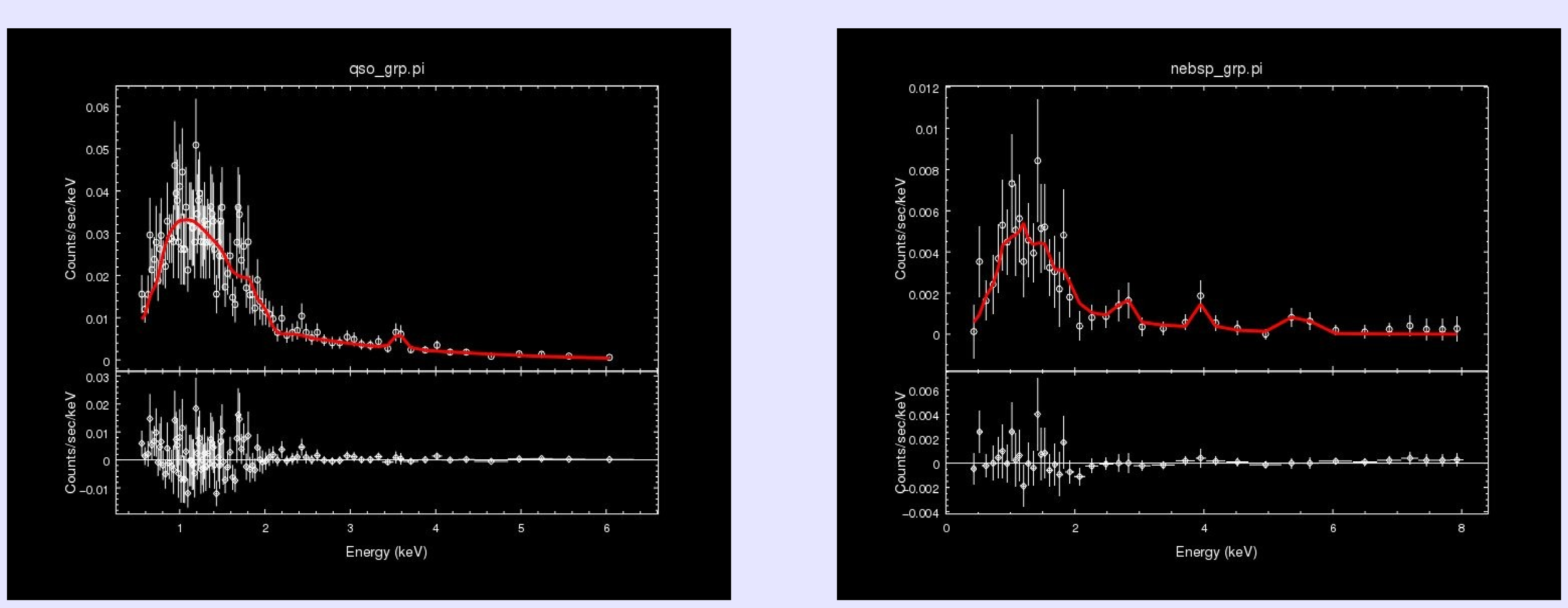


Fig. 5 X-ray spectra, fits and residuals. Left: nuclear region. Right: extended emission.

X-ray spectra confirm the z=0.68 cluster

We extract and fit X-ray spectra using CIAO and Sherpa (Fruscione et al 2006, Freeman et al 2001).

The nucleus is fit with a power law and an additional gaussian at 7.0+-0.1 keV (quasar rest frame) – is there a blueshifted Ka line?

The nebulosity is well fit by a MEKAL model with z=0.68; in partcular the feature at about 4 keV is fit by the redshifted Fe Ka line generated by MEKAL. To improve the fit, two additional lines have been added at observed energies of 2.77 and 5.49 keV (corresponding to E=4.65 and 9.22 keV at z=0.68); their nature is unclear. The temperature is poorly constrained at 2.5 < kT < 4.5 keV and varies across the region as is evident in the X-ray color image.

The presence of the feature at the energy expected for a redshifted Fe Ka line at z=0.68 combined with the presence of multiple z=0.68 galaxies in the region leads us to conclude that this is the cluster redshift.
The X-ray luminosity of the cluster is then L(0.1-2.4 keV) =1.4x10^{44} erg/s
The luminosity of the quasar in Mar 2017 was L(0.1-2.4 keV)=1.4x10^{45} erg/s and L(1-10 keV) = 2.0x10^{45} erg/s

References

Blundell, Beasley, Bicknell 2003
ApJ 591, L103
Fabricant et al 2019, PASP in press
Freeman et al 2001, SPIE 4777, 76
Fruscione et al 2006, SPIE 6270, 60
Gallo et al 2006 MNRAS 365,960
Green et al 1983 ApJ 269,352
McDowell et al 1995 ApJ 560,585

Not the culprit:: If cluster had been at the quasar z it might have been a clue that environment played a role in the unusual properties of the quasar. But it isn't – must look for other explanations
What else are we missing? How many other X-ray clusters are missed because of a bright X-ray AGN? Only Chandra can tell us...

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