O VII in high resolution stacked spectra of clusters

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Introduction

Examining the emission lines seen in high resolution X-ray spectra of elliptical galaxies, clusters and groups provides an excellent way to measure the temperature distribution of the gas in these objects. The Reflection Grating Spectrometer (RGS) instruments on XMM-Newton are the only current detectors which can make high resolution X-ray spectra of galaxy clusters.

The Fe XVII emission lines are good indicators of gas below 1 keV in temperature (Fig 1). Fe XVII emission has been seen in several clusters of galaxies, including Centaurus (Sanders et al 2008) and Abell 2204 (Sanders et al 2009), indicating ranges in temperature of around a factor of 10. However, in these, and other clusters (e.g. Peterson et al 2003) there is much less material at low temperatures than is expected if there is radiative cooling without feedback (see Peterson & Fabian 2006). There is often a wide range of gas temperature, but something is likely preventing the cooling of the very coolest material (e.g. feedback).

O VII emission lines have never been seen from individual groups, ellipticals or clusters. These lines indicate material around 0.35 keV. We therefore stacked the X-ray spectra from a sample of objects to increase the signal to noise and to examine the average range of temperature.

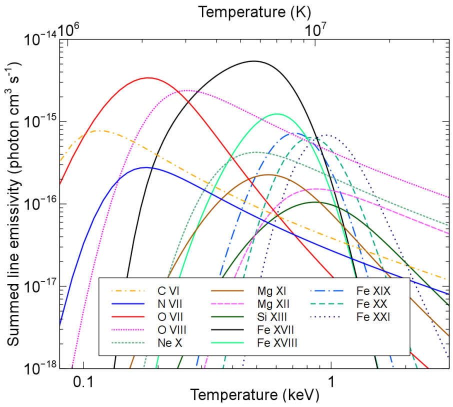

Figure 1: Line emissivities as a function of temperature

Sample and Results

The sample we examined was taken from a previous X-ray line width study of turbulence (Sanders et al 2011). The objects were chosen to have strong emission lines.

Temperature (keV)	Number of objects	<z>	Total exposure (ks)
<0.7	9	0.063	620
0.7-1	9	0.012	664
1-2	8	0.027	923
2+	34	0.13	2415

We split the objects into four ranges of central temperature. The stacked spectra are shown in Fig 2, plotted with representative model spectra. We do not see any unknown emission lines.

For the first time we detect OVII emission from the objects below 1 keV temperature. This is more easily seen in Fig 3, which shows the stacked spectra of both the first two temperature bins. The ratio of O VII to Fe XVII in these cool objects is about 1/4 to 1/8 of that expected for radiative cooling. Feedback must be preventing this material from cooling, or some sort of non-radiative cooling process is operating (e.g. mixing with still cooler gas). We also detect the C VI emission line in the stacked spectrum.

The average ratio of the N VII to O VIII emission line implies an average N/O metallicity of 4 ± 0.6 Solar, for those objects below 1 keV. This ratio depends little on the gas temperature and is robust (Fig 1). This high ratio has implications for understanding low to intermediate mass stars which are the main producers of nitrogen. High nitrogen metallicities have also be found in otther objects, e.g. Centaurus (Sanders et al 2008). The C VI/O VIII ratio implies a C/O metallicity of 0.9 ± 0.3 Solar.

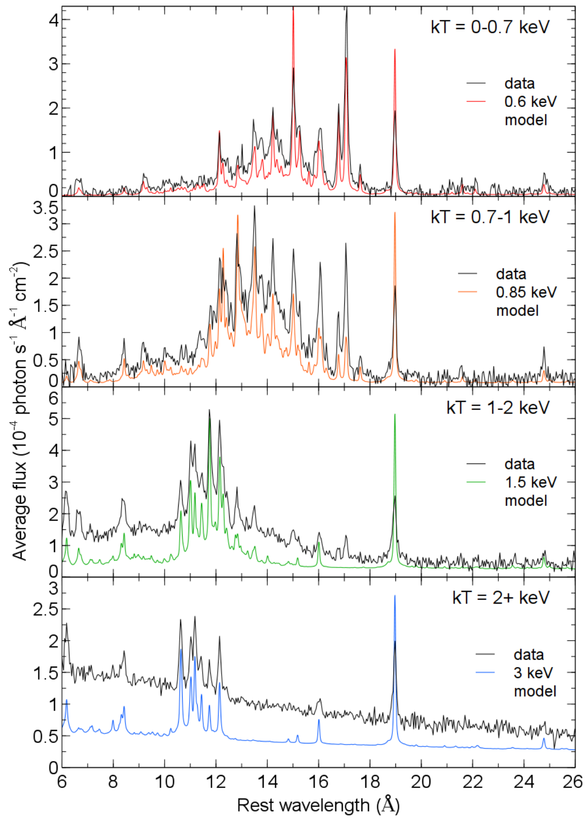

Figure 2: Stacked spectra in four different temperature ranges.

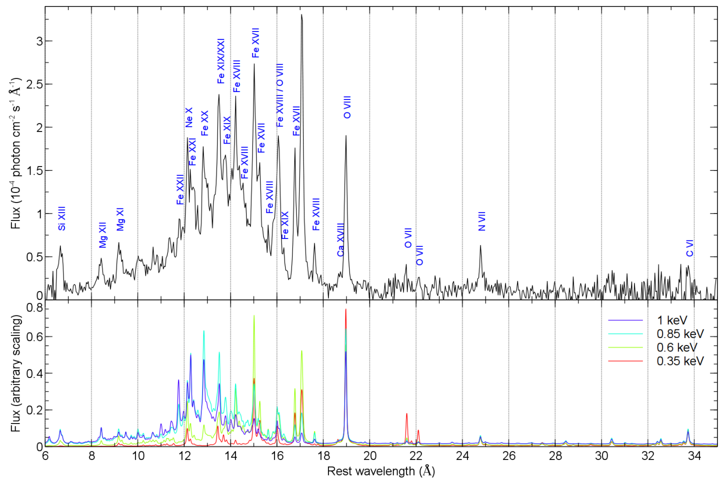

Figure 3: Stacked and labelled spectrum of the objects with temperatures of less than 1 keV.

References

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