Exceptionally high signal-to-noise spectroscopy of the ionised outflow from NGC 7469

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We present a very high signal-to-noise soft X-ray spectrum of NGC 7469 from a 150 ks observation with the XMM-Newton RGS. This enables us to do detailed spectroscopy on the absorption lines from its ionised outflow (warm absorber). This outflow contains one main ionisation phase with an ionisation parameter of log ξ = 2.5, a total absorbing column of 2.9 x 10^{21} cm^{-2} and a line-of-sight outflow speed of 690 km/s. There is also a broad absorption feature consistent with the presence of an Unresolved Transition Array of M-shell iron (at log ξ of ~1), although, interestingly, there is little evidence of the lowly ionised states of oxygen that we would expect to observe accompanying it. We compare our results with previous X-ray spectroscopic observations of this source.

Introduction

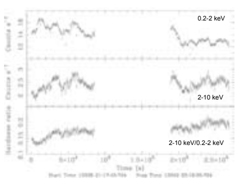

Fig. 1: X-ray lightcurves and hardness ratio

NGC 7469 is a bright nearby Seyfert (z = 0.0164) which was observed for 150 ks by XMM-Newton in November/December 2004. The total exposure time was split into two parts over consecutive orbits.

The source was at a similar flux level to the previous XMM-Newton observation (Blustin et al. 2003). The count rate varied by ~ 30% over the course of these new observations.

Above 3 keV, the EPIC-pn spectrum (right) was well-fitted with a Galactic-absorbed power-law (excluding the region around the prominent Fe Kα emission line). The lowest energies reveal a curved soft excess with deviations that could be due to absorption and emission features below the resolution of EPIC. In the ion-by-ion and photoionised absorber fits below, we use a continuum consisting of the hard power-law (Γ = 1.81) plus a heuristic blackbody component (kT = 0.144 keV).

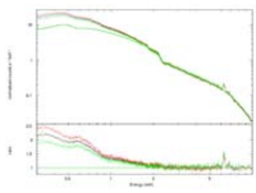

Fig. 2: (top) EPIC-pn spectra from the whole observation (black), and the first (red) and second (green) halves of the observation separately. The best fit Galactic-absorbed power-law fit to the 3-5.5 keV and 7-10 keV ranges is superimposed; (bottom) ratio of this power-law fit to the three spectra plotted above

References

Blustin et al. 2003, A&A 403, 481
Blustin et al. 2005, A&A 431, 111
Kriss et al. 2003, A&A 403, 473
Scott et al. 2005, ApJ 634, 193
Steenbrugge et al., A&A 434, 569

Ionic abundances in the outflow

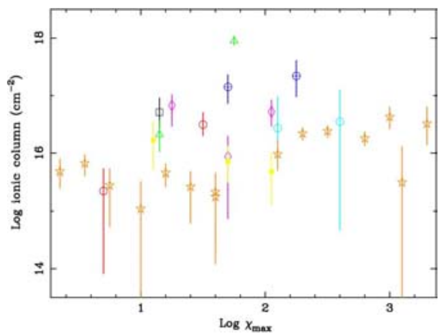

Fig. 5: fitted columns of the ions detected in the RGS spectrum of NGC 7469, plotted against log ξ where the ions are most abundant given the ionisation balance used in our *xabs* models below (black square C VI; red circles N VI – N VII; green triangles O VII – O VIII; blue crossed circles Ne IX – Ne X; light blue circles Mg XI – Mg XII; purple diamonds Si X – Si XII; yellow squares S X, S XII and S XIII; orange stars Fe IX – Fe XXIII). The usual pattern (c.f. Steenbrugge et al. 2005, Blustin et al. 2005) of increasing column with increasing ionisation is observed; this is a selection effect due to higher columns being required for highly ionised gas to be visible.

Searching for X-ray spectral features

To assess the significance of narrow absorption and emission features in the RGS spectrum, we used a routine which moves a sliding box through the spectrum, fitting a gaussian to deviations from the continuum. The results of this are plotted in Fig. 3, where the $\Delta\chi^2$ associated with adding the gaussian is equivalent to the square of the statistical significance σ of the feature. The much higher signal-to-noise of this spectrum in comparison with our previous RGS spectrum of this source makes it easier to be sure about the identification of most of the features. There is less evidence for a wide range of ionisation in this spectrum than we found in the earlier data (Blustin et al. 2003); this may be due to a change in the object itself, or alternatively a reflection of the difficulty of accurate identification of features in the previous lower-quality spectrum. We do make secure detections of more features than Scott et al. (2005) are able to in the Chandra spectrum, although again this is likely to be due to our higher signal-to-noise.

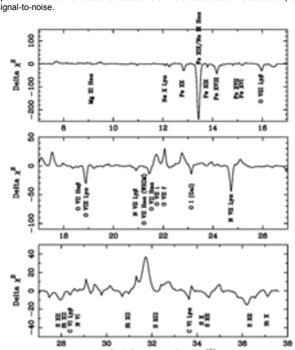

Fig. 3: significance of narrow absorption and emission features; the $\Delta\chi^2$ associated with adding a fitted gaussian to the continuum in a sliding box is plotted. Here $\Delta\chi^2$ is equivalent to the square of the statistical significance σ.

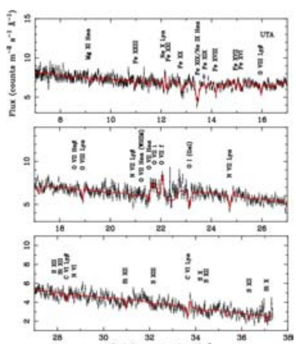

Fig. 4: Combined RGS spectrum of NGC 7469 from both observations, RGS1 plus RGS2, incorporating the first and second spectral orders. An ion-by-ion fit with *slab* in SPEX is overplotted, as well as the narrow emission features which are fitted with gaussians.

Modelling the outflow

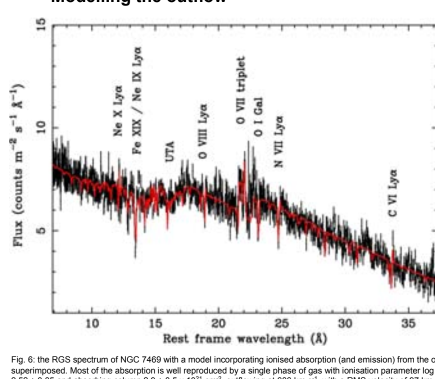

Fig. 6: the RGS spectrum of NGC 7469 with a model incorporating ionised absorption (and emission) from the outflow superimposed. Most of the absorption is well reproduced by a single phase of gas with ionisation parameter log ξ = 2.52 ± 0.05 and absorbing column 2.9 ± 0.5 x 10^{21} cm^{-2}, outflowing at 686 km s^{-1}, with a RMS velocity of 97 km s^{-1} (the latter two values, obtained from the ion-by-ion fit, were fixed, as well as the parameters of the emission lines previously fitted; the RMS velocity is consistent with that estimated from the combination of the multiple UV absorber components observed with FUSE by Kriss et al. (2003) and Scott et al. (2005)).

It is possible to fit the spectral dip at 16-17 Ä with absorption from an M-shell iron UTA (Unresolved Transition Array), as shown in the figure, with log ξ ~ 1. The addition of the UTA ions to the *slab* model fit improves the global fit statistic by $\Delta\chi^2$ = 82, but there is little evidence of states of e.g. oxygen at similar ionisation levels to the UTA. This could imply that either iron is very overabundant with respect to the oxygen in this phase, or that the observed dip in the spectrum is actually due to some other unidentified spectral feature (the profile of the dip and the depths of the O VII lines do not seem to indicate that an O VII edge is present).