Chin. J. Astron. Astrophys. Vol. 8 (2008), **Supplement**, 119–123
(*http://www.chjaa.org*)

Chinese Journal of
Astronomy and
Astrophysics

6 Years of Dedicated Service with XMM-Newton and Chandra: What have we really learned about the inner regions of AGN?

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Abstract In this paper I concentrate on three issues (i) What is the nature of the soft X-ray excess, (ii) the status of the detection of gravitative redshifted soft X-ray lines, and our understanding of the nature of sharp spectral drops observed in the high-energy spectra of Narrow-Line Seyfert 1 Galaxies (NLS1).

Key words: galaxies: active – X-rays

1 THE NATURE OF THE SOFT X-RAY EXCESS

The nature of the soft X-ray excess in AGN is controversially discussed. Models which might account for the soft X-ray excess are (i) the thermal disc interpretation, (ii) the reflection spectrum interpretation (c.f. Fig. 1), and (iii) and absorption model which mimics a soft X-ray excess. The problem with the thermal disc interpretation is that there is a rather uniform shape of the soft X-ray excess. The spread in the black body temperatures is small, ranging from about 50 to 120 eV, however, the spread in the emitted luminosities span at least three orders of magnitude. This is not easy to understand in terms of any existing accretion disc theories. One possible solution might be a compact source above an optically thick accretion disc. In the reflection model this compact source is moving in height above a reflection dominated accretion disc and result in strong variations of the power-law flux. Putting this compact source above an optically thick accretion disc might solve some of the problems with the large variation in the emitted luminosity Boller (2006).

Miniutti et al. (2003) suggested that the soft X-ray excess is explained by blurred emission lines and bremsstrahlung from the hot disc surface. The benefit of the reflection model is, that it explains th missing response of the Fe K α line to varying illumination strengths due to strong light bending effect of the power-law emission of a compact source above the accretion disc. One problem with the reflection model might be the steepness of the spectral energy distribution in the 0.3–2.0 keV band. The photon index for a power-law fit ranges only between about 2 to 3, while Narrow-Line Seyfert 1 Galaxies exhibit values of the photon indices up to about 5 (Boller 2006).

The absorption model Done et al. (2007) do not predict the presence of any soft X-ray excess. It is assumed that an outflowing wind results into absorption at around 1 keV, which then mimics an excess below 1 keV. The problem with the absorption model might be the extreme conditions which are required. The presence of an outflowing wind is required, the disc must not be in hydrostatic equilibrium and an extreme geometry, smearing and emissivity values are needed.

2 SEARCH FOR GRAVITATIVE REDSHIFTED SOFT X-RAY LINES

Presently there is convincing evidence on the detection of the relativistic 6.4 keV Fe K α line in 8 AGN. The accretion disc line interpretation for broad relativistic Fe K α line is robust against other models which can mimic a red wing (Reeves et al. 2004). The most convincing example is MCG-6-30-15 (Fabian 2002). In the past there were claims on the detection on GR effects on the soft X-ray lines from the disc by Mason

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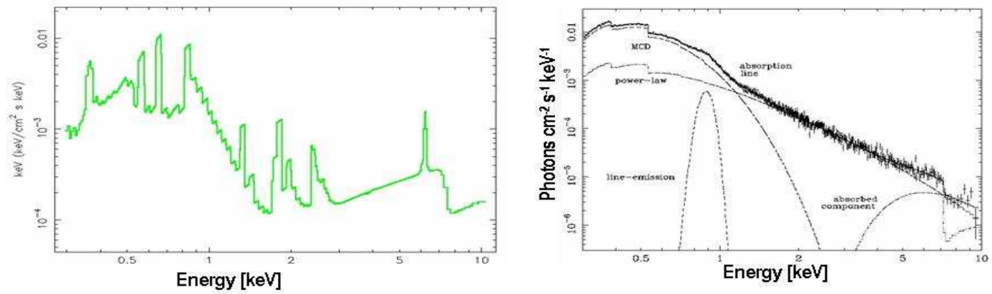

Fig. 1 Reflection (Left) and thermal disc interpretation (Right) interpretation for the soft X-ray excess. See text for details.

et al. (2002) (Mrk 766) and by Branduardi et al. (2001) (Mrk 766 and MCG-6-30-15). The argumentation was that a relativistic line model results into a better statistical fit compared to a dusty warm absorber fit (c.f. Fig. 2). One of the key feature of the line interpretation was that the jump of the blue horn of the O VIII line is redshifted (by about 16 000 $\mathrm{km\,s^{-1}}$) with the respect to the detected energy of 707 eV. Fabian (2002) pointed out that there might be potential problems with the relativistic disc line interpretation. Firstly, there appears to be a sharpness problem in the line interpretation. Oxygen in the accretion disc is produced by highly ionized gas, suffer Compton scattering, and relativistic Doppler and GR effects broaden the 707 eV jump considerable more than 3 eV as measured with Chandra. Consequently, the sharp drop at 707 eV in MCG-6-30-15 cannot be produced by a relativistic line in an optically thick accretion disc. Secondly, there is an equivalent (EW) problem in the line interpretation. Weak soft X-ray lines are theoretically calculated following Ross et al. (1993). The EW values for soft X-ray lines range between 1 to 10(50) eV. The EW values resulting from the relativistic line models reach values up to about 170 eV, in contrast to the theoretical predictions. It appears unlikely that soft X-ray lines has been detected in Mrk 766 and MCG-6-30-15. The most likely interpretation is the absorption model.

An interesting spectral feature has been detected in the XMM-Newton observations on Mrk 110 (Boller et al. 2007). The data show a broad (13 eV) and redshifted emission hump with respect to the O VII triplet (O VII recombination (r), intercombination (i) and fluorescence (f) lines at 572.9, 567.9 and 559.9 eV, respectively). The narrow lines are unresolved and neither red- nor blueshifted given the present data quality. The broad component is detected above the three σ limit and the redshift is $z = 0.023$. The data do not allow to reveal the physical nature of this feature with the present statistics as Gaussian- and relativistic disc line fits give the same statistical significance. If future observation would confirm the relativistic line interpretation, then the broad O VII line is expected at a distance of about 400 $\mathrm{R_G}$ with GR effects of the order of about 4 per cent. This would fill the gap between relativistic effects in the Optical at about $700\ \mathrm{R_G}$ as discussed by Kollatschny (2003) and the high-energy relativistic Fe K line emission at around $10\ \mathrm{R_G}$. Two baseline models might account for relativistic effects measured in the BLR, either pure GR effects and GR effects plus bulk infall motions towards the central black hole. Figure 3 shows simulation for both scenarios Müller (2006). While the gravitational redshift is nearly the same, the ratio of the blue to the red horn of the relativistic line (the DPR ratio) is significantly different. Therefore, the DPR ratio will be the critical discriminator between these two models if future observation would confirm the relativistic line interpretation.

3 THE NATURE OF THE HIGH-ENERGY SHARP SPECTRAL DROPS IN NLS1S

Sharp spectral drops have been discovered in two NLS1s: 1H 0707–495 (Boller et al. 2002) and IRAS 13224–3809 (Boller et al. 2003). In Figure 4 I show the spectral energy distribution of both galaxies as observed with the XMM-Newton telescope. The spectral energy distribution is reminiscent of galactic black hole binaries in their soft states, suggesting very high accretion rates. Both galaxies show a common char-

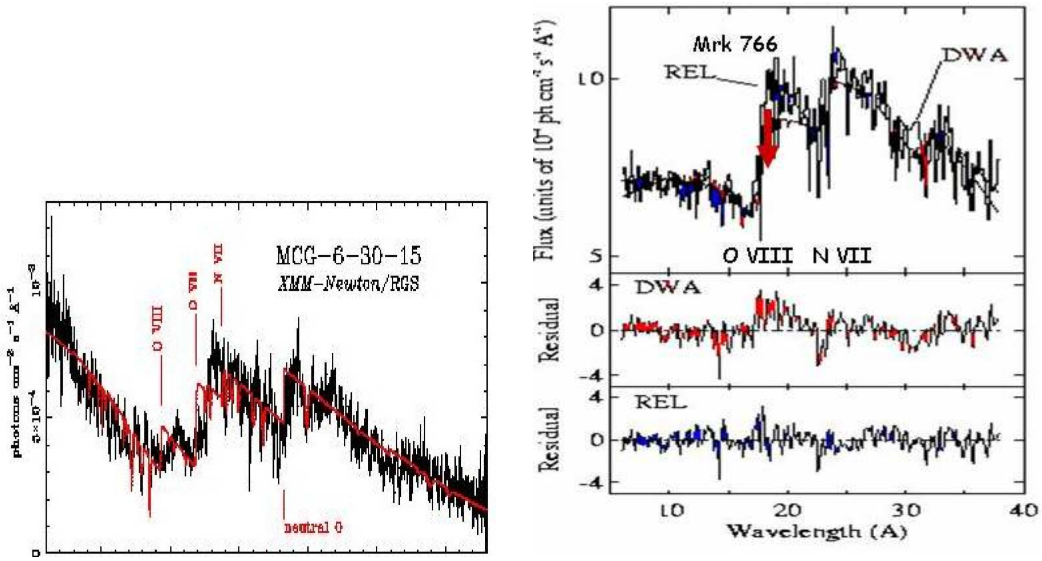

Fig. 2 Left: XMM-Newton RGS spectra of MCG-6-30-15 and Mrk 766 (Right) in the soft energy band. Branduardi et al. (2001) and Mason et al. (2002) explain the soft X-ray excess as a superposition of accretion disc lines. Fabian (2002) points out that there might be a problem with the line interpretation due to the sharpness of the spectral features and the resulting equivalent width values of the lines.

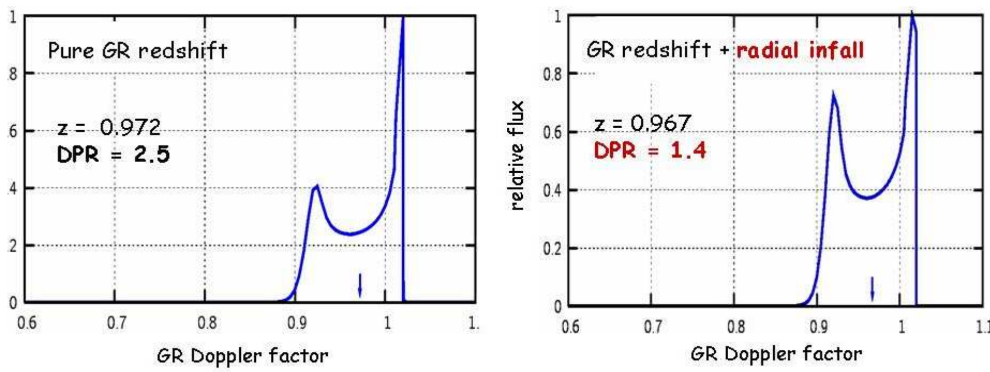

Fig. 3 Simulations for a relativistically broadened X-ray line emitted at a distance of 40 $\mathrm{R_G}$ assuming pure GR effects (left panel) and GR plus bulk infall motions (right panel). The critical discriminator between the two models is the double-peak ratio (DPR).

acteristic shape, (i) a strong soft X-ray excess, and (ii) steep 2–10 keV power slopes with photon indices of about 2.5. The hard tail gradually flattens towards high energies and abruptly drops at around 7–8 keV. The drop energy is not always the same. For 1H 0707–495 it strikingly shifted from 7.1 keV (as observed in 2000) to 7.5 keV (in 2002). For IRAS 13224–3809 the drop energy is found even at higher energies of 8.2 keV. If the drop is due to absorption, then the sharpness of the drops (less than 200 eV) points to high outflow velocities of 0.05 and 0.15 c, respectively, as ionized Fe at 8.2 keV is arising from Fe XIX to XXIII which exhibits a width of 600 eV in contrast to the observations. These features are typical for either a partial covering phenomenon (Boller et al. 2002) or a reflection dominated accretion disc (Fabian et al. 2004).

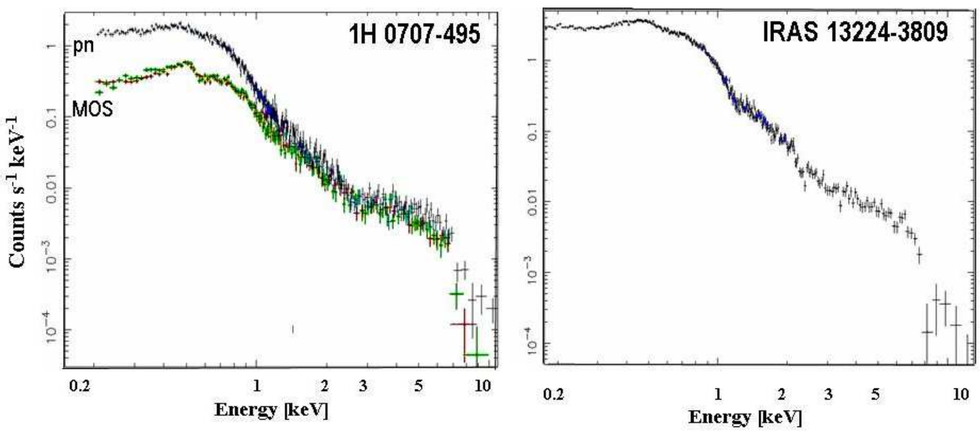

Fig. 4 Left: Spectral energy distribution of 1H 0707–495 and IRAS 13224–3809 (Right) as observed with the EPIC detectors on board XMM-Newton.

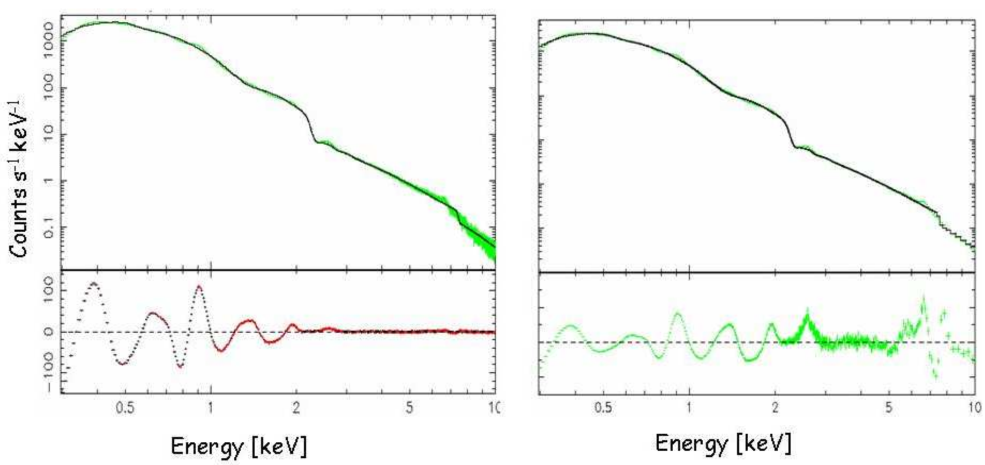

Fig. 5 Left: Reflection model fitted with a partial covering model. Right: Partial covering model fitted with the reflection model based on a 30 ks XEUS WFI simulation. Both models can clearly be disentangled with better statistics compared to present XMM-Newton observations.

With the present statistics we cannot disentangle between both models. Longer observations are required to disentangle the absorption model from the reflection dominated model, where the drop is interpreted as a strong relativistic Fe Kα line with equivalent widths values of about 1 keV. In Figure 5 I show a 30 ks XEUS simulation which clearly demonstrates that we can disentangle both models with better statistics.

Acknowledgements I would like to thank A. C. Fabian and W. N. Brandt for our longstanding collaboration on that project.

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