Warm absorber and truncated accretion disc in IRAS 05078+1626

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X-ray observations of unabsorbed active galactic nuclei provide an opportunity to explore the innermost regions of supermassive black hole accretion discs. We report the results of XMM-Newton observation of Seyfert 1.5 galaxy IRAS 05078+1626 which was performed in August 2007. This observation represents the first X-ray spectroscopic measurement of this source and unveils some of the standard ingredients in Seyfert galaxies, such as a power-law primary continuum, modified by reflection from the accretion disc and by the effect of complex, multi-phase obscuration. However, data constrains the accretion disc, if present, not to extend closer than to 60 gravitational radii from the black hole.

IRAS 05078+1626

- nearby Seyfert 1.5 galaxy ($z \approx 0.018$)
- Galactic coordinates: $l = 186.1$ and $b = -13.5$ (also known as CSV 6150)
- it had never been spectroscopically examined in X-ray prior to the observation discussed here

XMM-Newton observation

- 2007/08/21, observation duration: 62 ks
- PN, MOS 1, MOS 2, RGS (PN and MOS in small window mode)
- exposure time: ≈ 40 ks for PN, ≈ 56 ks for MOS, ≈ 58 ks for RGS

EPIC spectrum

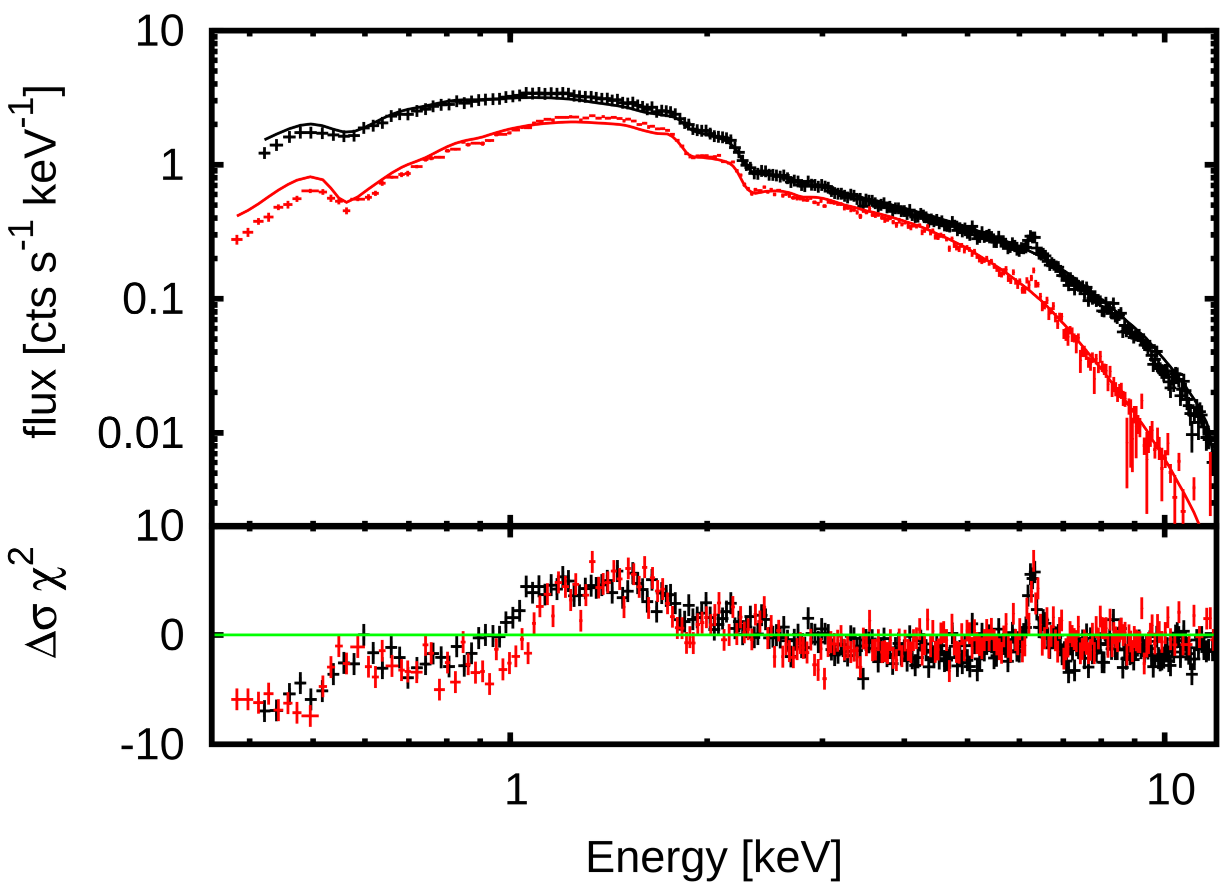

Figure 1: XMM-Newton PN (black) and joint MOS (red) spectrum of IRAS05078+1626 described by a simple power law model absorbed by Galactic neutral hydrogen in the line of sight with $n_{\rm H} = 0.188 \times 10^{22}\,{\rm cm}^{-2}$. The photon index of the power law is $\Gamma = 1.49$.

The simple TBABS*POWERLAW model applied to both PN and MOS spectra (Fig. 1) reveals an apparent excess at $E = 6.4$ keV associated with the iron Kα line and some residuals at lower energies which can be attributed to a warm absorber, i.e. absorption by totally or partially ionised matter, and to soft excess due to ionised reflection (Crummy et al. 2006).

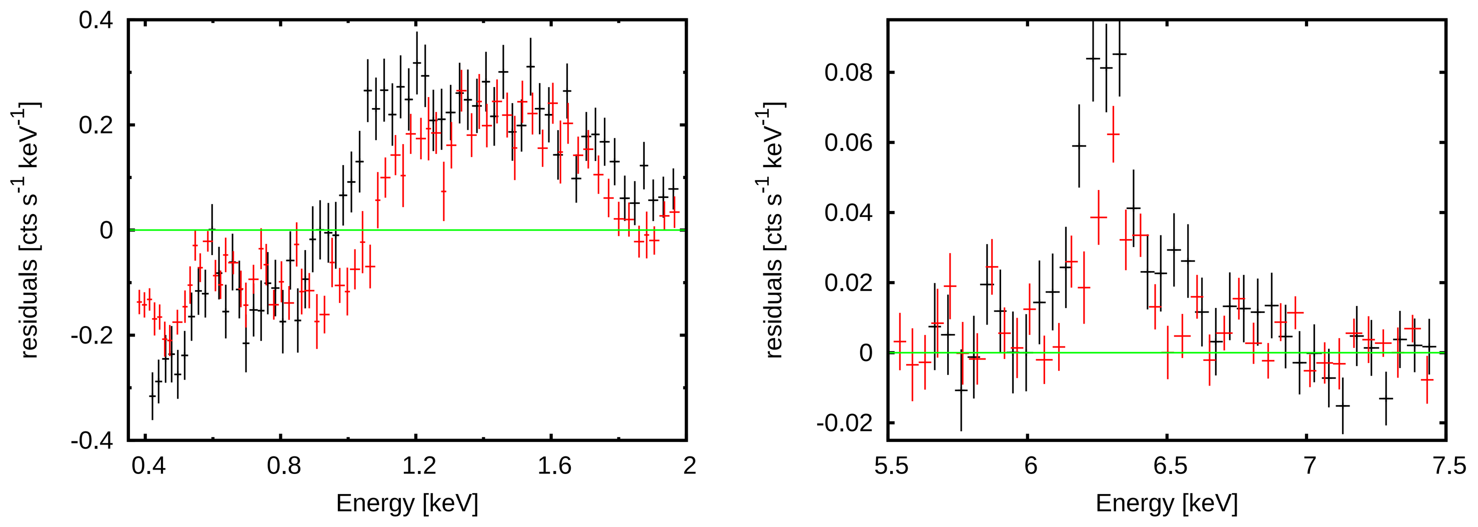

Figure 2: A detailed view on residuals against the simple power law model (the same as in Fig. 1) in different energy bands: **left:** at lower energies, **right:** in the iron line band, where the narrow Kα line at the rest energy $E = 6.4$ keV is prominent (observed at $E = 6.29$ keV due to the cosmological redshift). PN: black, MOS: red.

Resulting model

Searching for the best-fit model:

- adding local neutral absorption TBABS*ZPHABS*(POWERLAW+ZGAUSS) gives $\chi^2/\nu = 402/270 \doteq 1.5$
- ionised absorption (XSTAR model) improves the fit to $\chi^2/\nu = 320/266 \doteq 1.2$
- ionised reflection (REFLION model) further improves the fit to $\chi^2/\nu = 246/264 \doteq 0.95$

The narrow iron Kα line represents cold reflection which may also contribute to the soft part of the spectrum. For this reason, we replaced the Gaussian profile in the model with another REFLION component (called as REFLION 2). Thus, the final model consists of the primary power-law, two reflection components (cold and ionised) and two absorbers (cold and ionised). Individual model components are shown in Fig. 3 and the parameter values are presented in Table 1.

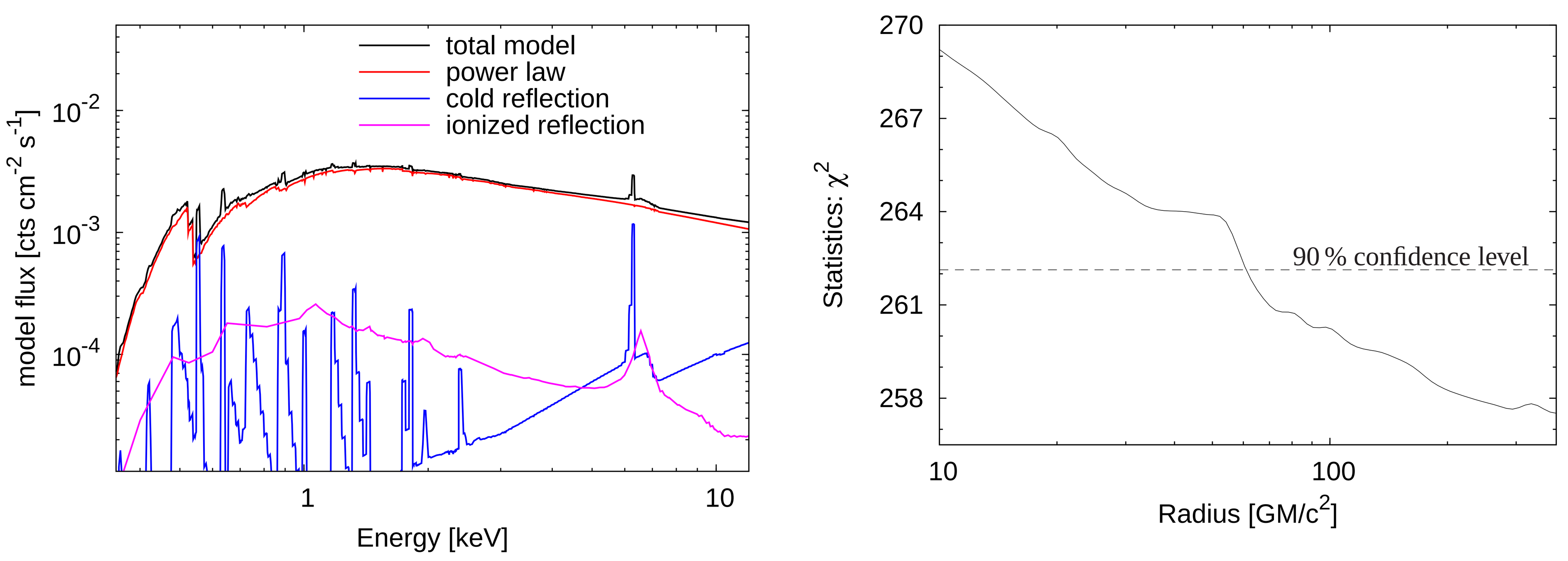

Figure 3: **Left:** The 'final' model. The total model is shown in black, the primary radiation is red, the REFLION components are blue for cold reflection and magenta for ionised reflection. **Right:** The best-fit values of χ^2 statistics for the inner disc radius parameter, which we obtained by gradually stepping it from the horizon radius to the outer radius of the disc ($400 R_{\rm g}$) when we convolved the ionised reflection component with the relativistic KYCONV model.

Constraints on the location of the ionised reflector

- in the 'final' model: no component including the kinematical effects by the rapid orbital motion in the inner accretion disc
- the small excess at $E \approx 6.6$ keV is modelled by the ionised reflection (not yet relativisticaly blurred)
- tests with the relativistic model (KY, Dovčiak et al. 2004):
  1. broad component of the Kα line instead of the ionised reflection
  2. convolution of the ionised reflection model with the KYCONV model
- both converged to the condition: $R_{\rm in} \gtrsim 60 R_{\rm g}$
- the limit on the equivalent width of the broad component: $EW_{\rm KY} \leq 62.4$ eV

Discussion and conclusions

- **X-ray continuum spectrum is dominated by a power law with a standard value of the photon index ($\Gamma \cong 1.75$)**
- **Residuals from the power law continuum can be interpreted in terms of the warm absorber surrounding the accretion disc, and the reflection of the primary radiation from the ionised matter and on the cold torus (or outer parts of an accretion disc).**
- **Column density of the ionised warm absorber was found to be $n_{\rm H} \geq 1 \times 10^{24}$ cm^{-2}, which is a rather high value compared to the warm absorbers detected in the other Seyfert galaxies (Blustin et al. 2005). This may be because we are looking through a longer optical path of a conical non-relativistic outflow due to the high inclination of the system.**
- **Ionisation parameter of the warm absorber $\log \xi_{\rm WA} = 2.5 \pm 1.0$ is comparable to the value related to the ionised reflection $\log \xi_{\rm reflection} = 3.0 \pm 0.2$, suggesting a link between them.**
- **If the ionised reflection is associated to the warm absorber (e.g. the inner walls of a conical outflow), the lack of spectral features associated with the accretion disc is a natural consequence thereof. If, instead, the ionised reflection occurs at the accretion disc, it cannot extend up to the marginally stable orbit. The lack of the significant relativistic blurring of this model component requires the disc to be truncated (inner disc radius $R_{\rm in} \geq 60\,R_g$).**

Table 1: Parameters of the final model.

Model component	Model parameter	'final' ('double reflection') model PN	MOS	PN+MOS+RGS
ZPHABS	$n_{\rm H}[10^{22}\,{\rm cm}^{-2}]$	$0.102^{+0.009}_{-0.005}$	$0.120^{+0.008}_{-0.005}$	$0.106^{+0.004}_{-0.004}$
XSTAR	$n_{\rm H}[10^{22}\,{\rm cm}^{-2}]$	120^{+30}_{-30}	150^{+70}_{-20}	130^{+20}_{-20}
	$\log \xi$	$2.2^{+1.4}_{-0.6}$	$2.5^{+1.0}_{-0.5}$	$2.5^{+1.0}_{-0.4}$
	He/He$_{\rm Solar}$ - Ca/Ca$_{\rm Solar}$	1 (f)	1 (f)	1 (f)
	Fe/Fe$_{\rm Solar}$ - Ni/Ni$_{\rm Solar}$	$1.2^{+0.3}_{-0.3}$	$0.9^{+0.2}_{-0.2}$	$1.1^{+0.2}_{-0.2}$
POWERLAW	Γ	$1.75^{+0.10}_{-0.03}$	$1.74^{+0.07}_{-0.03}$	$1.76^{+0.04}_{-0.02}$
	normalisation	$(6 \pm 1) \times 10^{-4}$	$(7 \pm 2) \times 10^{-4}$	.....
REFLION	Γ	1.75 (b)	1.74 (b)	1.76 (b)
	$\log \xi$	$3.0^{+0.2}_{-0.2}$	3^{+2}_{-3}	$3.0^{+0.1}_{-0.2}$
	Fe/Fe$_{\rm Solar}$ - Ni/Ni$_{\rm Solar}$	1.2 (b)	0.9 (b)	1.1 (b)
	normalisation	$(2 \pm 1) \times 10^{-9}$	$(1 \pm 1) \times 10^{-9}$	.....
REFLION 2	$\log \xi$	1.477 (f)*	1.477 (f)*	1.477 (f)*
	normalisation	$3 \pm 1 \times 10^{-7}$	$4 \pm 1 \times 10^{-7}$	.....
χ^2/ν		256/266	404/244	C/ν = 1551/1347

Note: The sign (f) after a value means that the value was fixed during the fitting procedure. The sign (b) means that the parameter value was bound to the value of the corresponding parameter of the previous model component.
* the lowest possible value in the REFLION model

Further details

- can be found in a recent paper (Svoboda et al. 2010)

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