XMM-Newton High Resolution X-ray Spectroscopy of NGC 3516

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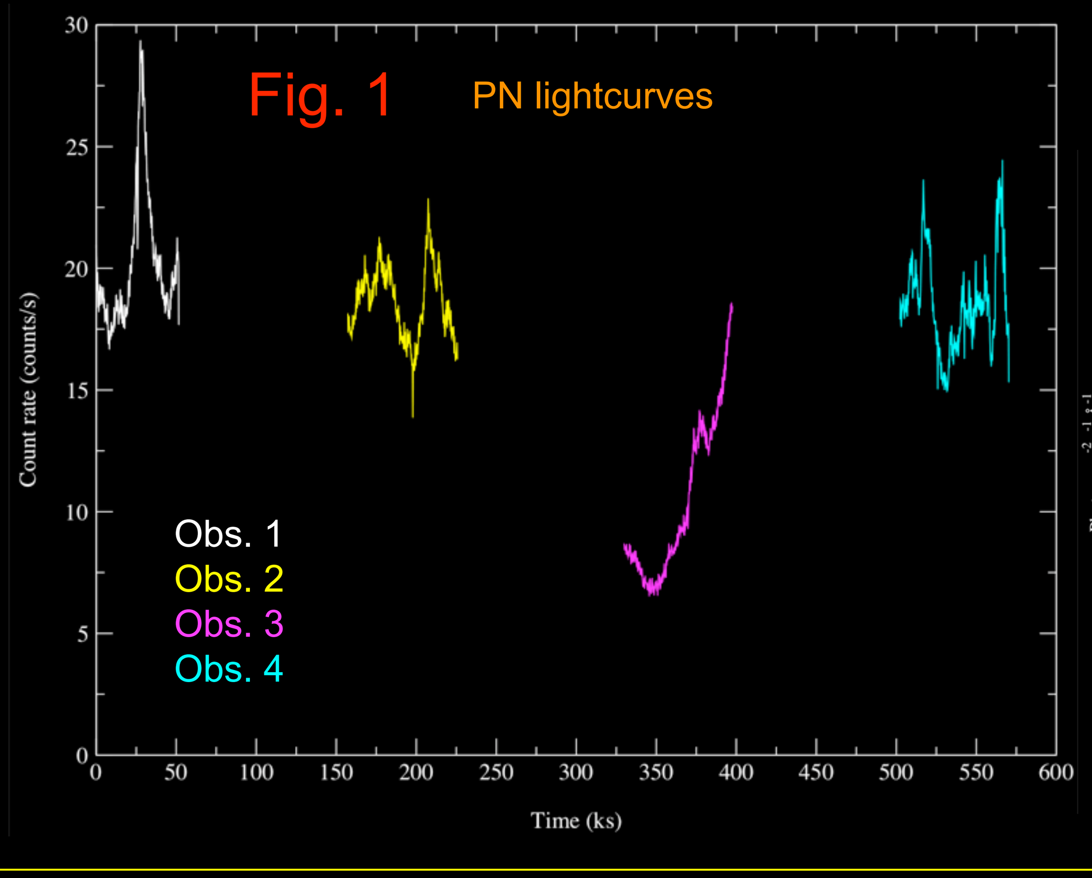
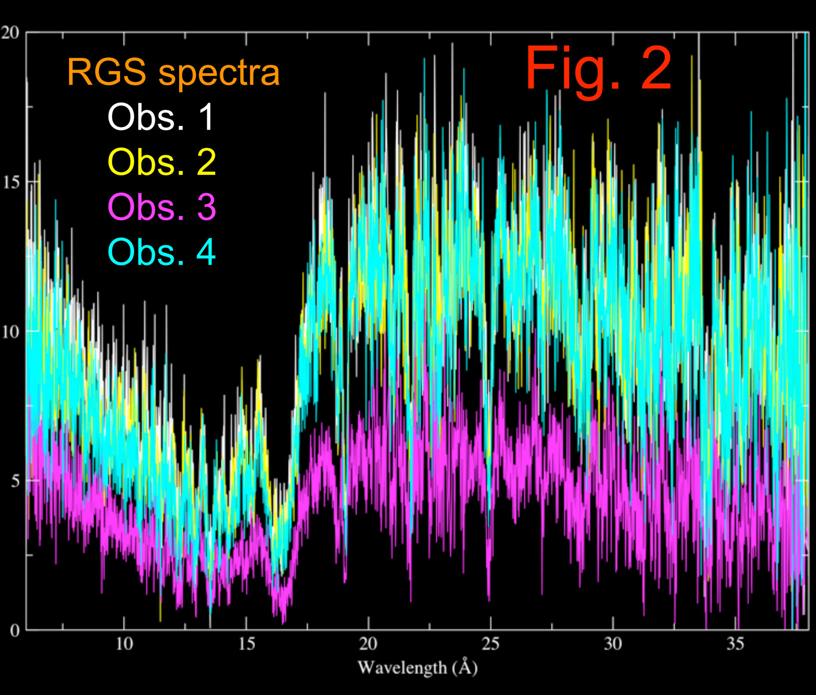
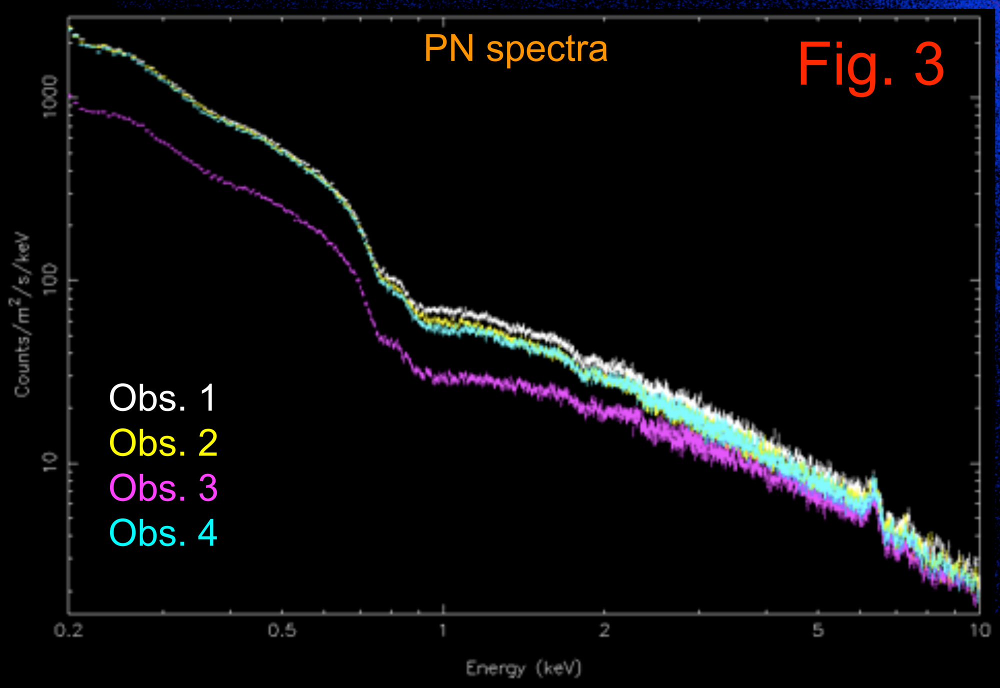
NGC 3516 is a Seyfert 1 galaxy at a redshift of 0.0088. In October of 2006, 4 observations of this AGN were made by XMM-Newton. Using the RGS and EPIC-PN data from the XMM-Newton Science Archive (XSA), we present a new analysis of the X-ray spectrum.

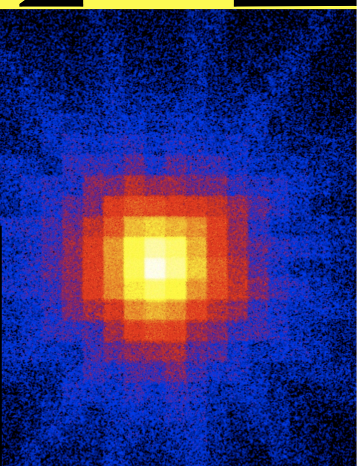
As seen in the X-ray lightcurve (Fig. 1), the source shows significant flux variability between observations, notably the dip in Obs. 3. Turner et al. 2008 who analysed the PN and the interwoven Chandra observations, interpreted the dip in Obs. 3 as a passage of a cloud in front of the nuclear source. We however find that intrinsic changes in the source continuum play a more significant role than previously thought in explaining the observed flux and spectral variability.



The RGS and PN spectra (Figs. 2 & 3) show how the spectrum of Obs. 3 differs considerably from the other three observations.





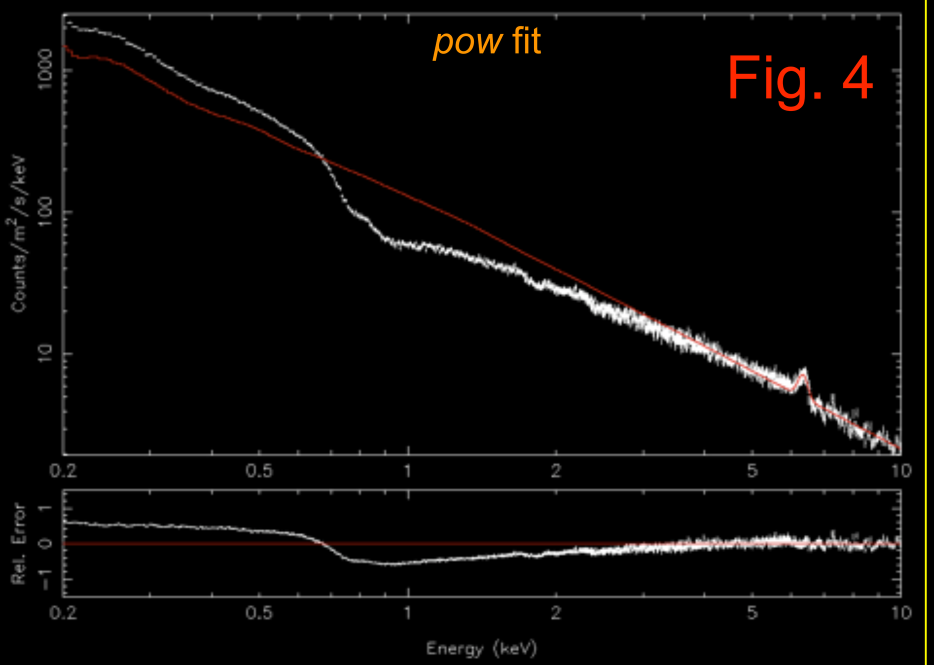


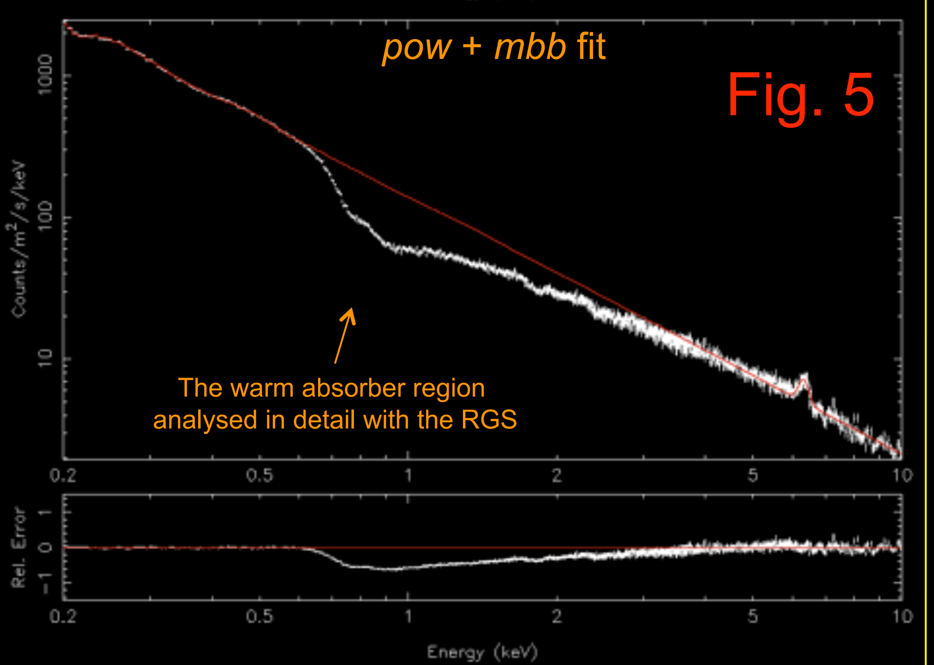
EPIC-PN X-ray image of NGC 3516

We used the SPEX code (Kaastra et al. 1996) to fit the spectra. The continuum was modeled with two components: a power-law (*pow*) and a modified black body (*mbb*) (Kaastra & Bar 1989).

Figs. 4 & 5 show how the addition of the modified black body component improves the fit to the PN by modeling the excess at lower energies.

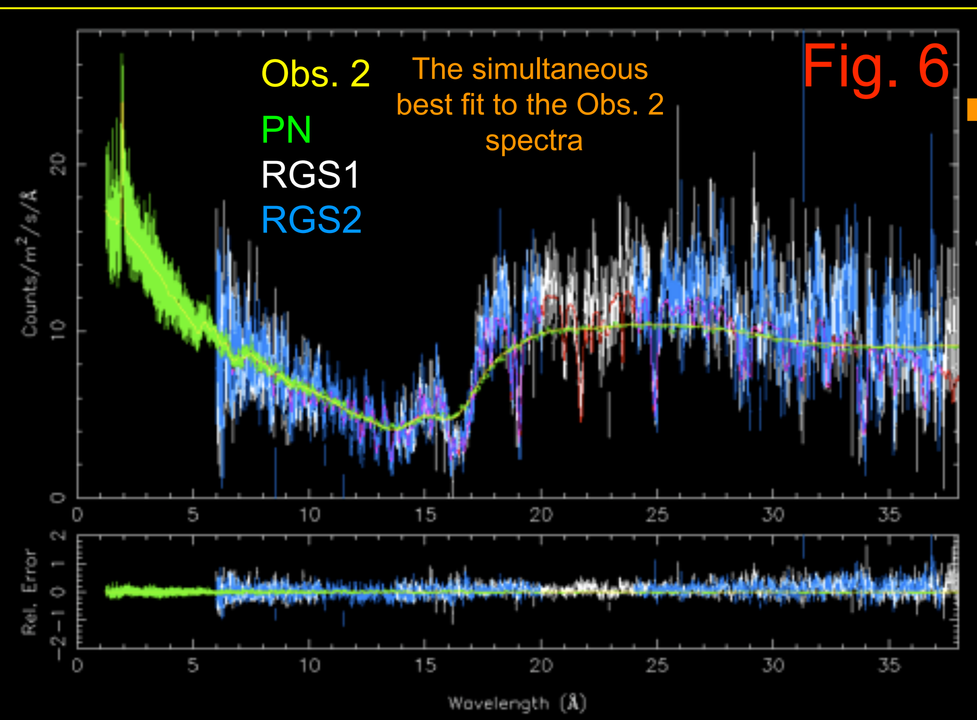
There is clear evidence for additional absorption in the band 0.7 to 2 keV which we have investigated with the RGS.

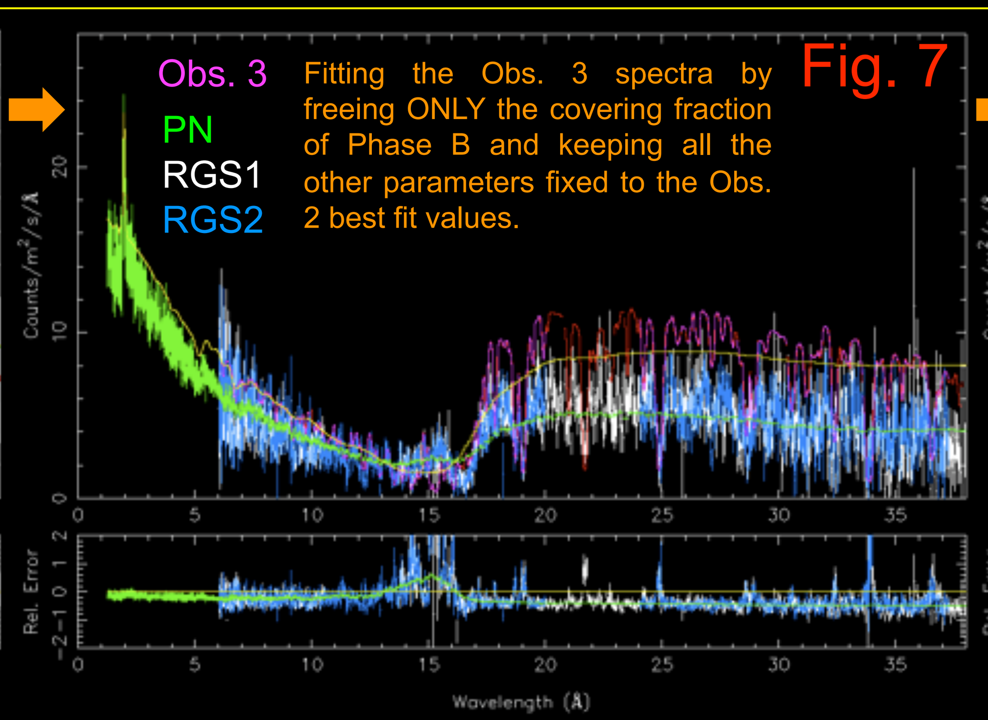


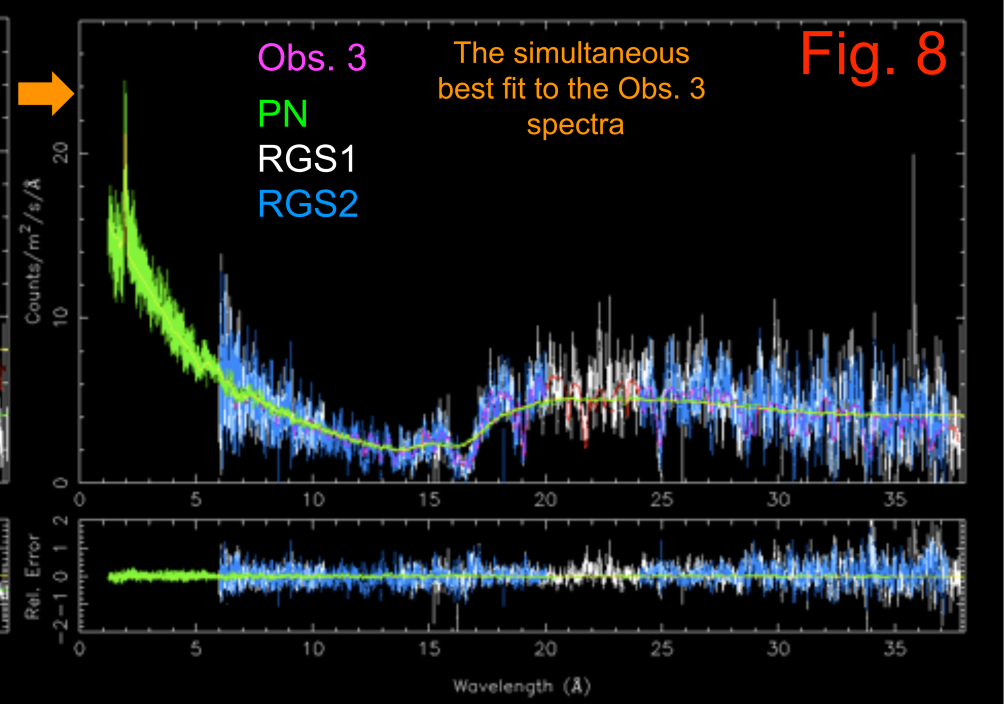


The results we present and compare here are from analysis of the Obs. 2 and Obs. 3. Similar results are obtained if one selects only the deep dip in the Obs. 3 and not the whole of the observation.

To model the Galactic column density we used the *hot* model (collisional ionisation equilibrium absorption) in SPEX and set the N_H to 3.45 × 10^{24} m^{-2} (Kalberla et al. 2005) and the temperature to 0.5 eV to mimic a neutral plasma.







To best fit the RGS spectrum of Obs. 2 (Fig. 6), we required three phases of absorption (phase A, B and C in Table 2) by photoionised gas to be added to the continuum model (parameters in Table 1). Using the *xabs* model in SPEX, we fitted the ionisation parameter (ξ), the hydrogen column density (N_H), the flow and RMS velocities of these three phases. The elemental abundances were also fitted within a range of 0 to 2 times the proto-solar model of Lodders (2003). The galactic column density of the AGN host galaxy was also modeled using the *abs* model in SPEX with cosmic abundances.

As shown in Table 2, one of the *xabs* phases (phase B) has a covering fraction (*fcov*) of 0.52. Our phase B is very similar to phase 3 of Turner et al. 2008, who explained the dip in the lightcurve (Obs. 3) by varying only the covering fraction of this phase.

Following their results, we applied the Obs. 2 fit to the Obs. 3 by keeping all the parameters fixed and freeing only the covering fraction. No good fit was achieved (Fig. 7); the covering fraction goes to 1 and a reduced Chi-squared (χ_ν^2) of 100 is obtained. On the other hand, by freeing the continuum parameters and the covering fraction, a much better fit is obtained; in this case the covering fraction becomes 0.66 and χ_ν^2 goes to 1.52. Finally, we freed the ionisation parameters and the N_H of the *xabs* phases, keeping all the abundances and velocities fixed. The best fit is shown in Fig. 8 and the best fit parameters in Tables 1 and 2.

We conclude that associated with the change in the covering fraction of phase B, there is also intrinsic variability in the continuum.

Table 1. Simultaneous best fit parameters of the continuum, obtained from the three-phase *xabs* model fit to the PN, RGS1 and RGS2.

Observation	*pow* Photon index	*pow* Normalisation [a]	*mbb* Temperature [b]	*mbb* Normalisation [c]
Obs. 2 (mid flux state)	$1.89^{+0.02}_{-0.04}$	$3.2^{+0.1}_{-0.3}$	141^{+29}_{-5}	$4.0^{+1.0}_{-2.0}$
Obs. 3 (low flux state)	1.75 ± 0.01	2.2 ± 0.1	146 ± 2	2.0 ± 0.2

[a] 10^{51} photons s^{-1} keV^{-1} at 1 keV
[b] eV
[c] 10^{32} $m^{0.5}$

There is a significant difference in the power-law parameters of the Obs. 2 and Obs. 3.

Table 2. The simultaneous best fit parameters of the three-phase *xabs* model for the Obs. 2 and Obs. 3, obtained from the PN, RGS1 and RGS2.

Host galactic $N_H = 0.7^{+0.2}_{-0.4} \times 10^{24}$ m^{-2} for Obs. 2 and fixed in Obs. 3 fit.

	Phase A					Phase B					Phase C					
Observation	log ξ [a]	log N_H [b]	Outflow v [c]	RMS v [d]	*fcov*	log ξ [a]	log N_H [b]	Outflow v [c]	RMS v [d]	*fcov*	log ξ [a]	log N_H [b]	Outflow v [c]	RMS v [d]	*fcov*	χ_ν^2 / D.O.F
Obs. 2 (mid flux state)	$0.81^{+0.03}_{-0.04}$	$0.8^{+0.5}_{-0.4}$	−200 ± 100	40 ± 10	1 (f)	$2.14^{+0.07}_{-0.09}$	2.6 ± 1.0	−1400 ± 100	700 ± 100	0.52 ± 0.04	2.93 ± 0.04	$9.0^{+6.0}_{-4.0}$	−1100 ± 100	200^{+50}_{-40}	1 (f)	1.42/2809
Obs. 3 (low flux state)	0.69 ± 0.02	1.1 ± 0.1	−200 (f)	40 (f)	1 (f)	$2.17^{+0.03}_{-0.04}$	4.1 ± 0.3	−1400 (f)	700 (f)	0.61 ± 0.01	2.91 ± 0.03	$7.6^{+0.7}_{-0.6}$	−1100 (f)	200 (f)	1 (f)	1.33/2711

[a] 10^{-9} W m
[b] 10^{26} m^{-2}
[c] km s^{-1}
[d] km s^{-1}

There is an increase in the covering fraction of Phase B

Absorption lines identified in the observed RGS spectrum of Obs.2.
The warm absorber here is modeled by three *slab* components with adjustable column densities and velocities.