EMISSION AND ABSORPTION FEATURES IN TON S180 CHANDRA DATA

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We present a new interpretation of the Ton S180 spectrum obtained by the *Chandra* Imaging Spectrometer. Several narrow absorption lines and a few emission disk lines have been successfully fitted to the data. We have not found any significant edges accompanying line emission. Detected features are faint and their presence do not alter the broad band continuum.

1. Introduction

Ton S180 ($z = 0.06198$, NED, corresponding to 286 Mpc for Hubble constant 65 km s^{-1} Mpc^{-1}) is a NLS1 (Narrow Line Seyfert 1 galaxy) with its low value of the FWHM of H_β line ($\sim$ 900 km s^{-1}; [1]) and steep soft X-ray spectrum of photon index $\Gamma = 2.68$ ([2]). The Galactic absorption toward the object is low ($N_H = 1.52 \times 10^{20}$ cm^{-2}; [3]). The source was extensively observed in all energy bands, indicating that most of the energy is emitted in the band $10 - 100$ eV ([4]).

High resolution X-ray spectra of this object were recently obtained with *XMM-Newton* and *Chandra* satellites. *XMM-Newton* spectrum was steep and featureless ([5]). *Chandra* data also appeared predominantly featureless and well represented by a single power law with some soft excess ([6], [4]). The shape of the soft excess was fitted by a DISKBB model, however plotted residues hinted for the possible presence of sharp spectral features (Fig. 1 in [6]).

In the present paper we reanalyze *Chandra* data, using a new response matrix and including any effects related to the contamination layer on ACIS-S. Observation of Ton S180 was performed on day 143 of the *Chandra* mission when the effects of the contaminant were much smaller than currently observed. We detected several weak narrow absorption lines due to the material located at the line of sight to the source. Also, several individual disk lines are fitted with equivalent widths in rough agreement with the predictions of the model of illuminated accretion disk spectrum presented by [7] and [8].

2. *Chandra* observations and data reduction

Ton S180 was observed with the *Chandra* satellite in December 14, 1999, for about 80 ksec in Low-Energy Transmission Grating in ACIS-S/LETG configuration, as described by [6] and [4]. The resolution of LETG corresponds to an FWHM $\approx 1200 E_{keV}$ km s^{-1} for the range of energies from 0.1 up to 6 keV. The source luminosity at this epoch (2–10 keV unabsorbed flux equal 4.6×10^{-12} erg s^{-1} cm^{-2} and 0.3–10 keV unabsorbed flux equal 2.2×10^{-11} erg s^{-1} cm^{-2}) was comparable to that during *XMM-Newton* observation (0.3 - 10 keV: 2.2×10^{-11} erg s^{-1} cm^{-2}; [5]).

The first order spectra were extracted using CIAO Version 2.2 and applying acisleg1D1999-07-22rmfN0002.fits as response matrix. After removing bad pixels and rebinning the data to achieve at least 20 counts per channel we are able to study in details the energy band between 0.18 and 6 keVs. All spectral fits have been performed with the XSPEC 9.0 fitting package.

3. Spectral analysis

In the first step, we fit a value of Galactic absorption with a broken power-law continuum. Our best fit value of $N_{H(Gal.)}$ (see Table 1 first line) is slightly larger than this determined by [3].

In the next step we fit broken power low with fixed value of Galactic absorption (Table 1 second line). It results in slightly higher χ^2, but the power law index below 2 keV agrees with the best fit slope $\Gamma = 2.68$ for *BeppoSAX* data ([2]).

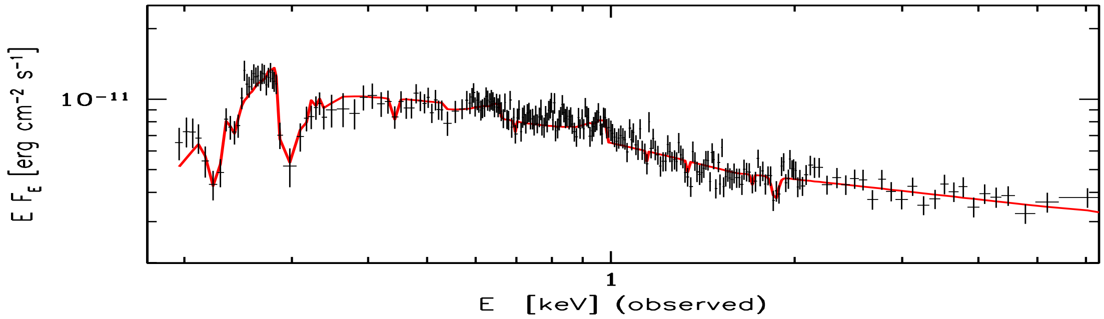

Figure 1. The LETG spectrum of Ton S180. Solid line denotes total model after broken power law, galactic absorption and all lines have been fitted.

Table 1
LETG continuum fit in the 0.1– 6. keV energy range

Model	$N_{H(Gal.)}$ 10^{20} cm^{-2}	Γ_1	E_{break} keV	Γ_2	χ^2/d.o.f.
Plain Cont.	$1.8277^{+0.152}_{-0.149}$	$2.755^{+0.038}_{-0.0367}$	$1.659^{+0.153}_{-0.109}$	$2.265^{+0.062}_{-0.065}$	1185/1686
Fixed $N_{H(Gal.)}$	1.52	$2.689^{+0.022}_{-0.019}$	$1.771^{+0.134}_{-0.169}$	$2.261^{+0.074}_{-0.070}$	1197/1686
With lines	$1.527^{+0.1512}_{-0.14}$	$2.682^{+0.039}_{-0.0359}$	$1.604^{+0.12}_{-0.147}$	$2.295^{+0.0549}_{-0.0564}$	932/1686

The energy break obtained by us in both models is somewhat lower than the value determined by [2] ($E_{break} = 2.5$), but the spectral slope above this energy break agrees with results of [2].

Since both broken power-law indices are very similar to those obtained from other satellites we adopt second model (fixed Galactic absorption) for further analysis.

After fitting the continuum, we have tried to determine column density of gas in the simplest way, by fitting O VII, O VIII, and C VI edges. Surprisingly, such edges appeared to be very weak in the data of Ton S180. We were able only to give upper limits for $\tau_{\rm OVII}$ $\tau_{\rm OVIII}$, and $\tau_{\rm CVI}$ of order of 10^{-4}, which practically indicate the lack of those edges.

3.1. Absorption lines

We have successfully fitted several absorption lines using standard Gaussian model for each line separately (see Figs. 1, 2 and 3). We include in the fit only those features which are significant (i.e. χ^2 decreased more than simply expected from an increase of the number of free parameters). All absorption lines are presented in Table 2. For each line we list its central energy in keVs, equivalent width (EW) in eVs, best identification with observed and rest frame energy and other possible identifications.

Some of those lines, especially the softest ones, may be caused by dust presented on *Chandra* mirrors. possible instrumental lines are labeled in Table 2.

Lines are very faint. They usually have equivalent width less or about 2 eVs, and several of them are just marginal detections, as clearly seen from the line EW error, given at 90% confidence level. Only two of them are stronger, most possibly created from several transitions blended with each other. There is therefore no major discrepancy between the *Chandra* results and the *XMM-Newton* observations ([5]) where only upper limits of order of 1 eV at energies 0.35 - 0.7 keV were provided. Most lines originate from hydrogen or helium like ions indicating that matter is highly ionized. There is an absence of lines from mildly ionized spices.

3.2. Disk emission lines

We have applied the standard DISKLINE model with fixed power law index in the radial dependence of the irradiating flux $\beta = 2.7$, assuming $r_{in} = 6R_g$ and $r_{out} = 1000R_g$ (where $R_g = GM/c^2$). We have found the best value of inclination angle $i = 30^o$ for the first fitted line C V, and we adopted it (keeping frozen) for the

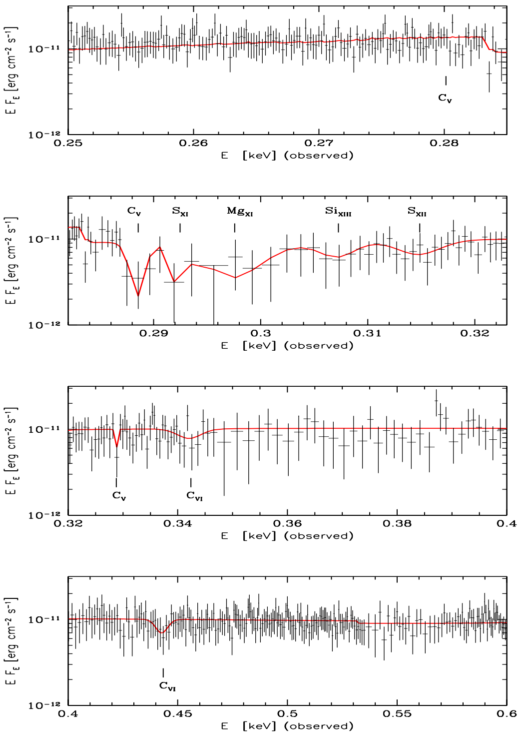

Figure 2. Observed spectra with the best fit model enlarged for various energy ranges in keV.

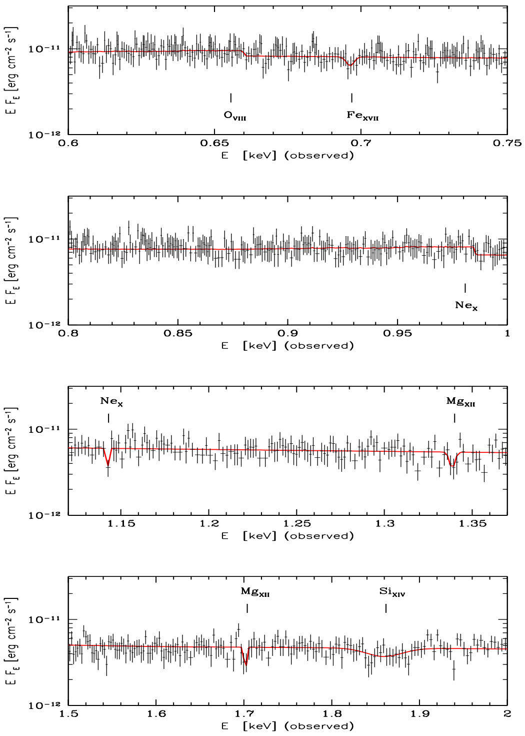

Figure 3. Continuation of Fig. 2.

other lines. Results are listed in Table 3.

The last column of Table 3 presents theoretical values of EWs of the same emission lines computed for accretion disk illuminated by hard X-rays (full model presented in [7] and [8]). Values are given in respect to the reflected continuum. The model takes into account harder incident radiation ($\Gamma = 1.9$), than it is seen in case of Ton S180, and solar metal abundances. Nevertheless, we claim that lines of order of 20 eVs are theoretically expected from illuminated disks.

After all lines have been fitted, we fit again broken power-law with galactic absorption. Results presented in Table 1 last verse indicate that lines do not affect continuum very strongly. The final value of reduced χ^2 appeared to be 0.5531.

4. Discussion

Reanalyzing *Chandra* data of NLS1 - Ton S180 we were able to identify several narrow absorption lines due to the warm absorber. Such lines were neither discussed by [6] and [4] nor seen in *XMM-Newton* data [5] because the lines are indeed very faint. We detected lines of highly ionized carbon and other elements, but we didn't detect any oxygen lines while in the FUSE data ([4]) OVI narrow absorption line components were observed. In any case, our result shows that the warm absorber in this source does not influence significantly the overall shape of the Ton S180 spectrum in soft X-ray band.

We have also fitted three disk emission lines with equivalent widths by a factor of 6 or more fainter than disk lines fitted by [9] in Mrk 766 but of similar order as disk lines found by [10] in NGC 5548.

For moderate illumination models do not predict lines with EWs higher than $\sim$ 20 eVs, when the disk is in the hydrostatic equilibrium. ([8]). Emission lines become by a factor of a few stronger when the dynamical flare model is adopted, i.e. the time-scale of the flare is shorter than the time-scale for a disk surface layer to achieve a hydrostatic equilibrium ([11]). However, in that case lines should be narrow and not

Table 2
Absorption lines fitted to the *Chandra* data of Ton S180

Obs. en. (keV)	EWs (eV)	Best identification (keV)	Other possible transiton
$0.2188^{+0.005}_{-0.014}$	1.39 ± 0.87	Instrumental	SVIII (0.2190; 0.2326)
$0.2222^{+0.0011}_{-0.0010}$	2.05 ± 1.38	Instrumental	FeXV (0.2207; 0.2344)
$0.2272^{+0.0008}_{-0.0009}$	3.62 ± 1.29	Instrumental	SiX (0.2305; 0.2448)
$0.2414^{+0.0028}_{-0.0036}$	1.87 ± 1.08	Instrumental	SX (0.2447; 0.2599)
$0.2884^{+0.0007}_{-0.0006}$	1.82 ± 0.83	Instrumental	CV (0.2899; 0.3078)
$0.2923^{+0.0012}_{-0.0012}$	1.39 ± 1.17	SXI (0.29187:0.30996)	
$0.2974^{+0.0018}_{-0.0022}$	6.31 ± 3.70	MgXI (0.2971; 0.3155)	SXI (0.2967; 0.3152)
$0.3071^{+0.0026}_{-0.0030}$	2.26 ± 1.95	SiXIII (0.30878; 0.3279)	SiXIII (0.30756; 0.3266)
$0.3147^{+0.018}_{-0.030}$	2.05 ± 1.28	SXII (0.31899; 0.3387)	
$0.3285^{+0.0009}_{-0.0006}$	0.39 ± 0.5	CV (0.33386; 0.3545)	
$0.3421^{+0.0037}_{-0.0045}$	1.38 ± 1.3	CVI (0.3459; 0.3673)	MgXII (0.3465; 0.3680)
$0.4426^{+0.024}_{-0.024}$	2.22 ± 1.58	CVI (0.4428; 0.4702)	
$0.6963^{+0.015}_{-0.032}$	0.74 ± 0.69	FeXVII (0.6868; 0.7293)	SXVI (0.68832; 0.73104)
$1.142^{+0.0034}_{-0.0095}$	0.992 ± 1.18	NeX (1.1387; 1.209)	FeXXV (1.1424; 1.213)
$1.339^{+0.0030}_{-0.0024}$	1.48 ± 1.84	MgXII (1.3861; 1.471)	
$1.702^{+0.030}_{-0.032}$	1.88 ± 2.38	MgXII (1.7327; 1.840)	SiXIII (1.7562; 1.865)
$1.860^{+0.013}_{-0.016}$	10.6 ± 5.24	SiXIV (1.8831; 2.000)	

Table 3
Emission disk lines fitted to the *Chandra* data of Ton S180

Obs. en. (keV)	EWs (eV)	Obs., rest en. (keV)	EWs of lines reflected from illum. disk
$0.2704^{+0.002}_{-0.0007}$	15.1 ± 2.63	CV (0.2899; 0.3079)	8.69
$0.6300^{+0.014}_{-0.01}$	13.5 ± 4.89	OVIII (0.6149, 0.653)	19.0
$0.9403^{+0.007}_{-0.021}$	30.7 ± 7.41	NeX (0.961, 1.020)	11.29

represented well by a DISKLINE shape.

Soft disk line detection is therefore a promising tool to constrain the conditions within the cold reprocessing medium. Detection of standard broad disk lines presented in this paper, if real, suggest no strong departure from hydrostatic equilibrium.

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