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X-RAY WARM ABSORBER VARIABILITY OF THE SEYFERT GALAXY ARAKELIAN 564

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We studied the variability of warm absorber clouds of ionised gas within AGN for the Seyfert 1 galaxy Arakelian 564. The X-ray spectra for four XMM-Newton observations of this object are analyzed using EPIC and RGS instruments. These four observations covered 11 years. The ionization parameter ξ of the absorbing matter changed between observations ($\log \xi = 0.889 \pm 3.1 \times 10^{-2}$ for the 2000 observation and $0.437 \pm 7.60 \times 10^{-2}$ for the year 2001). The X-ray soft excess is studied for the four observations using two black body parameters in EPIC spectra (the first black-body temperature is $0.129 \pm 2.0 \times 10^{-3}$ KeV and the second is $1.74 \pm 7.6 \times 10^{-2}$ KeV) and one black body parameter in RGS spectra.

Keywords: galaxies: AGN X-rays: warm absorber: Arakelian 564

1. Introduction. The first suggestion of warm absorbers (absorption in the X-ray spectrum of AGN from ionized matter) was introduced in [1] to investigate Einstein data of the quasar MR 2251-178. We note the warm absorber in the spectrum as a deficit of the soft-X-ray counts with respect to the power law energy distribution at energy ≈ 2 KeV. Most Seyfert galaxies contain ionized absorbing gas in their lines of sight [2], and there are various explanations for this warm absorber. One explanation is a wind formed by photoionized evaporation from the inner edge of the torus [3]. It is clear that no definitive idea exists of the position of warm absorbers in AGN. Some speculate is they could lie anywhere from the broad-line region to tens of parsecs out [3]. The warm absorber also varies; indeed, the first discovered absorber was variable [4].

Arakelian 564 (Ark 564) [5,6] is the X-ray brightest Narrow-line Seyfert 1 (NLS1) galaxy with a 2-10 Kev flux of $\sim 2 \times 10^{11}$ erg cm² s¹ and X-ray power law slope $\Gamma = 2.43 \pm 0.03$, located at a redshift z=0.02468. The presence of a soft excess was verified but neither the existence of a strong edge-like absorption feature at 0.712 KeV nor a reported emission-like feature at 1 KeV could be confirmed [7]. Khanna et al. [8] found through long XMM-Newton RGS observations that the low ionization warm absorber is unusually low-velocity compared with other Seyferts. In addition to its broadband spectral features, Ark 564 has been studied with high-resolution spectrometers, and a low-ionization warm absorber was found [9].

W.KORANY, M.I.NOUH

We report in this paper on the variability of the warm absorber by studying four XMM-Newton observations (selected from 13 observations) over eleven years. We organized the paper as follows: the observations and data reduction appear in section 2, section 3 is devoted to the spectral analysis, and the results are summarized and discussed in section 4.

2. Observations and data reduction. The data used for the object were taken from the XMM-Newton archive. These data are taken from four different years (2000, 2001, 2005 and 2011). Table 1 contains the observations log of the data. All EPIC cameras were operated in the small-window mode and in the medium filter (except observation of 2011 in this filter). The data from the two EPIC MOS [10] cameras and the EPIC PN camera [11] are used. The raw data were processed with the EPIC pipeline chains of the Science Analysis System

Table 1

Year	Instr.	Mode	Filter	Exposure start time	Exposure end time
2000	MOS1	Small-window	Medium filter	2000-06-17@12:59:10	2000-06-17@16:12:19
	MOS2	Small-window	Medium filter	2000-06-17@12:56:5	2000-06-17@16:12:20
	PN	Small-window	Medium filter	2000-06-17@12:08:54	2000-06-17@16:12:52
2001	MOS1	Small-window	Medium filter	2001-06-09@08:28:08	2001-06-09@11:54:45
	MOS2	Small-window	Medium filter	2001-06-09@08:30:14	2001-06-09@11:54:45
	PN	Small-window	Medium filter	2001-06-09@08:38:08	2001-06-09@11:55:50
2005	MOS1	Small-window	Medium filter	2005-01-05@19:39:58	2005-01-06@23:17:22
	MOS2	Small-window	Medium filter	2005-01-05@19:39:59	2005-01-06@23:17:27
	PN	Small-window	Medium filter	2005-01-05@19:47:37	2005-01-06@23:17:42
2011	MOS1	Small-window	Thin filter 1	2011-05-24@05:56:32	2011-05-24@22:27:09
	MOS2	Small-window	Thin filter 1	2011-05-24@05:56:32	2011-05-24@22:27:14
	PN	Small-window	Thin filter 1	2011-05-24@06:02:05	2011-05-24@22:27:29

XMM-NEWTON OBSERVATION log FOR ARK 564

software version 13.0.0. The event files of the individual observations have been cleaned from some bad time intervals characterized by high background events (termed soft-proton fares). These bad time intervals are rejected by creating light-curves for the observations (PN, MOS1, and MOS2), which are most visible above 10 KeV. The object's spectrum was extracted using circular extraction regions centered on the object, with a radius of 45 arcsec for both the MOS and PN cameras. For the background spectrum, we used the same circular size from the source-free region [12]. All the spectra were subsequently analyzed using the *xspec* software (v12.8.2).

By using the RGSPROC task in XMMSAS the RGS data are decreased, and we extracted the spectra of the source and background with standard procedures.

The first and second order spectra and response matrices from RGS1 and RGS2 were resampled to the first order RGS1 spectrum and combined to produce a single spectrum and a single response matrix.

3. *Spectral analyses*. To check whether there is a warm absorber, a spectral analysis of the four EPIC camera (PN and MOS) observations in the broad band (0.4-10 KeV) is conducted. The X-ray spectra were rebinned to contain at least



Fig.1. The fit of power law model with Nh freez for pn data of 2000.



Fig.2. The fit of power law model with Nh freez for pn data of 2001.

W.KORANY, M.I.NOUH

20 counts in each spectral bin using the grppha command. All data are fitted assuming a simple power law absorbed by the Galactic column density in the direction of the source, which is fixed in the model with a constant value 5.24×10^{20} cm⁻² [13]. The simple absorbed power law model gives a poor fit to the data (the best-fit models and residuals are shown in Fig.1 to 4) and provides a reduced χ^2/odf . For example, for PN data this is 3.2113/122 and 2.9809/111 for the first and second observations, respectively (Table 2 list the Reduced χ^2/odf



Fig.3. The fit of power law model with Nh freez for pn data of 2005.



Fig.4. The fit of power law model with Nh freez for pn data of 2011.

Year	Instrument	Reduced χ^2/odf
2000	MOS1 MOS2 PN	9.51407 for 144 3.1984 for 116 3.2113 for 122
2001	MOS1 MOS2 PN	6.8267 for 139 3.6585 for 109 2.9809 for 111
2005	MOS1 MOS2 PN	6.1554 for 164 3.097 for 145 2.5113 for 150
2011	MOS1 MOS2 PN	3.1328 for 162 16.2792 for 141 13.9961 for 146

THE FIT PARAMETERS FOR PI WITH Nh FOR ALL DATA

for all the data). From the figures, it is clear that the fits are bad, but one determine from the residuals a broad absorption trough between approximately 1 and 2 KeV, and a soft excess under 1 KeV. There is some difference in the soft parts of the four spectra, which suggests some changes in the absorptions from one observation to another (Fig.5-7).

3.1. *Soft excess*. We started the treatment for the soft excess using the EPIC data for all observations. The hard band (2.5-10 KeV) data are fitted with a simple



Fig.5. Four XMM-Newton data spectra shown together for comparison (PN)



Fig.6. Four XMM-Newton data spectra shown together for comparison (MOS1).



Fig.7. Four XMM-Newton data spectra shown together for comparison (MOS2).

power-law model with the column of absorbing hydrogen atoms, as mentioned above, to avoid any soft excess. The fit is not bad; for the PN camera, the power law photon index Γ is $2.42 \pm 2.62 \times 10^{-2}$, $2.49 \pm 4.28 \times 10^{-2}$, $2.398 \pm 1.04 \times 10^{-2}$ and $2.432 \pm 1.49 \times 10^{-2}$ and the reduced χ^2 /odf are 3.211/122, 2.981/111, 2.511/150 and 1.40/114 for 2000, 2001, 2005 and 2011 observations, respectively, Table 3 summarizes the fit parameters of all data. The average Γ value is $2.41 \pm 3.3 \times 10^{-2}$, which agrees with [13,14]. We then used *zphabs* (Multiplicative Model in *xspec*) component at

the source redshift 0.024 [15] to test the presence of intrinsic cold absorption, and *pcfabs* (Multiplicative Model in *xspec* also) to test the partial covering cold absorption. The fit statistics are not improved, which signifies the absence of a fully and partial covering intrinsic cold absorption. We did not add the Gaussian line model for FeK α emission line because it is not seen in the spectra [14].

The fitted model (power law with absorbed column density) of the hard X-ray band (2.5 - 10.0 KeV) is extrapolated to the broadband spectral data (0.3 - 10 KeV)



Fig.8. Extrapolated the fit of Hard to soft X-ray (Example for PN data of 2011).

Table 3

Year	Instrument Γ		Normalization	Reduced χ^2/odf	
2000	MOS1 MOS2 PN	$\begin{array}{c} 2.37 \pm 5.14 \times 10^{-2} \\ 2.54 \pm 5.05 \times 10^{-2} \\ 2.42 \pm 2.62 \times 10^{-2} \end{array}$	$\begin{array}{c} 1.49 \times 10^{-2} \pm 1.03 \times 10^{-3} \\ 1.9 \times 10^{-2} \pm 1.30 \times 10^{-3} \\ 1.65 \times 10^{-2} \pm 6.0 \times 10^{-4} \end{array}$	1.02 for 63 1.25 for 67 3.211 for 122	
2001	MOS1 MOS2 PN	$\begin{array}{c} 2.39 \pm 6.29 \times 10^{-2} \\ 2.34 \pm 6.29 \times 10^{-2} \\ 2.49 \pm 4.28 \times 10^{-2} \end{array}$	$\begin{array}{c} 9.09 \times 10^{-3} \pm 7.0 \times 10^{-4} \\ 7.94 \times 10^{-3} \pm 6.8 \times 10^{-4} \\ 8.72 \times 10^{-3} \pm 5.0 \times 10^{-4} \end{array}$	6.827 for 139 3.659 for 109 2.981 for 111	
2005	MOS1 MOS2 PN	$\begin{array}{c} 2.35 \pm 1.60 \times 10^{-2} \\ 2.39 \pm 1.61 \times 10^{-2} \\ 2.398 \pm 1.04 \times 10^{-2} \end{array}$	$\begin{array}{c} 1.12\times10^{-2}\pm2.4\times10^{-4}\\ 1.164\times10^{-2}\pm2.5\times10^{-4}\\ 1.141\times10^{-2}\pm1.7\times10^{-4} \end{array}$	6.156 for 164 1.52 for 116 2.511 for 150	
2011	MOS1 MOS2 PN	$\begin{array}{c} 2.377 \pm 2.28 \times 10^{-2} \\ 2.430 \pm 2.24 \times 10^{-2} \\ 2.432 \pm 1.49 \times 10^{-2} \end{array}$	$ \begin{array}{c} 1.081 \times 10^{-2} \pm 3.0 \times 10^{-4} \\ 1.164 \times 10^{-2} \pm 3.5 \times 10^{-4} \\ 1.124 \times 10^{-2} \pm 2.3 \times 10^{-4} \end{array} $	1.51 for 94 1.10 for 98 1.40 for 114	

THE FIT PARAMETERS FOR PL WITH Nh FOR ALL DATA IN THE HARD BAND (2.5 - 10.0 KeV) KeV). A huge soft X-ray excess was found (Fig.8).

We can provide a good fit to this soft excess using several models, such as single black bodies, multiple black bodies, multicolor dick black body, blurred reflection from partially ionized material, smeared absorption, and thermal computerization in the optically thick medium [16].

Using single black body model to fit the data after using power law model with absorption because of the hydrogen column density in our galaxy (all parameters are free) improves the fit for all observations, with $\Delta\chi^2$ measuring 312, 210, 626 and 846 in 2000, 2001, 2005 and 2011, respectively. The black body temperature for all PN data are between $0.129 \pm 3.0 \times 10^{-3}$ KeV to $0.160 \pm 4.0 \times 10^{-3}$ KeV. The average is 0.132 KeV. After adding another black body model, the fit is improved by $\Delta\chi^2 = 35.8$, 37.7, 88.9 and 80.2 in 2000, 2001, 2005 and 2011, respectively. The first black body temperature lies in the range $0.125 \pm 3.0 \times 10^{-3}$ to $0.131 \pm 2.2 \times 10^{-3}$ KeV; the average value is $0.129 \pm 2.0 \times 10^{-3}$. The second temperature lies in the range $1.59 \pm 9.9 \times 10^{-2}$ to $1.95 \pm 8.8 \times 10^{-2}$ KeV; the average value is $1.74 \pm 7.6 \times 10^{-2}$ KeV.

3.2. Warm absorber. We now study the warm absorber in the broad band (0.4-10 KeV) spectra for EPIC data. In addition to the absorbed power law model and the models used to study the soft excess, we added a warm absorber phase that could be defined as a gas at a particular ionization parameter ξ and column density. The ionization parameter is presented as $\xi = L/nr^2$ erg cm s⁻¹, where L is the ionizing luminosity, n is the gas density, and r the distance of the ionizing source from the absorbing gas [17]. This warm absorber was modeled using partial covering absorption by partially ionized material (*zxipcf* in *xspec*), which uses a grid of XSTAR photoionized absorption models for the absorption and assumes that this only covers some fraction f of the source, while the remaining (1-f) of the spectrum is seen directly. The micro-turbulent velocity is assumed to be 200 km/s. The proposed model is added to all free parameters except the redshift component. The redshift is frozen at 0.024 [15]. An improvement to the fit is found ($\Delta \chi^2$ are 27, 9, 22, and 98 for 2000, 2001, 2005 and 2011, respectively). Fig.9 plots the fit of the all parameters.

From the fitting, we can see that adding the warm absorber model does not change the parameters except for a small change in the black body temperatures and in the photon index Γ of the power law model for 2000 and 2001. Γ changed from 2.84 to 3.08 and from 2.9 to 3.07. The temperatures changed from 0.13 and 1.7 KeV to 0.158 and 2.02 KeV for 2000, and from 0.125 and 1.5 KeV to 0.16 and 1.9 KeV for 2001. The best fit values of the parameters of the partial covering absorption by partially ionized material model are the column density *Nhwa*, 2.34×10^{22} ; 2.7×10^{22} ; 2.34×10^{22} and 1.7×10^{22} for observations in 2000, 2001,

2005 and 2011, respectively. Table 4 shows values of the photoionized absorption parameter log ξ , which provides evidence of the warm absorber in the range 1.0 - 2.0 KeV. The log ξ values are $0.889 \pm 3.11 \times 10^{-2}$; $0.437 \pm 7.60 \times 10^{-2}$; $0.578 \pm 1.07 \times 10^{-2}$; and $0.653 \pm 8.7 \times 10^{-2}$, respectively (Table 4). The different values of the log ξ parameter from one observation to another mean that the warm

Table 4

Y	M *	Nh (Pha)	Г	bb ₁	bb ₂	Nh (zvincf)	logξ	χ^2/odf
		(Tha)				(Zxipei)		
2000	M1	5.22×10^{20}	2.89	-	-	-	-	1674/152
			$\pm 7.7 \times 10^{-3}$	-	-	-	-	
	M2	3.7×10^{20}	2.55	0.133	-	-	-	324/150
			$\pm 1.2 \times 10^{-2}$	$\pm 1.25 \times 10^{-3}$	-	-	-	
	M3	5.6×10^{20}	2.84	0.130	1.7	-	-	218/148
			$\pm 3.2 \times 10^{-3}$	$\pm 2.2 \times 10^{-3}$	$\pm 8.7 \times 10^{-2}$	-	-	
	M4	6.9×10^{20}	3.08	0.158	2.02	2.34×10^{22}	0.889	140/145
			$\pm 1.2 \times 10^{-1}$	$\pm 1.4 \times 10^{-3}$	$\pm 2.0 \times 10^{-1}$		$\pm 3.11 \times 10^{-2}$	
	M1	4.27×10^{20}	2.99	-	-	-	-	1001/146
			$\pm 1.21 \times 10^{-2}$	-	-	-	-	
	M2	2.44×10^{20}	2.59	0.129	-	-	-	255/144
2001			$\pm 1.8 \times 10^{-2}$	$\pm 2.04 \times 10^{-3}$	-	-	-	
	M3	5.08×10^{20}	2.9	0.125	1.59	-	-	166/142
			$\pm 4.7 \times 10^{-2}$	$\pm 3.02 \times 10^{-3}$	$\pm 9.9 \times 10^{-2}$	-	-	
	M4	7.12×10^{20}	3.07	0.160	1.90	2.7×10^{22}	0.437	140/139
			$\pm 9.5 \times 10^{-2}$	$\pm 4.1 \times 10^{-3}$	$\pm 1.7 \times 10^{-1}$		$\pm 7.60 \times 10^{-2}$	
	M1	5.37×10^{20}	2.93	-	-	-	-	12394/172
			$\pm 2.37 \times 10^{-3}$	-	-	-	-	
	M2	3.9×10^{20}	2.55	0.130	-	-	-	1482/170
2005			$\pm 1.2 \times 10^{-2}$	$\pm 5.1 \times 10^{-4}$	-	-	-	
	M3	5.78×10^{20}	2.86	0.130	1.7	-	-	632/168
			$\pm 1.2 \times 10^{-2}$	$\pm 7.2 \times 10^{-4}$	$\pm 3.0 \times 10^{-2}$	-	-	
	M4	3.7×10^{20}	2.71	0.137	1.8	2.34×10^{22}	0.578	301/160
			$\pm 1.85 \times 10^{-3}$	$\pm 1.7 \times 10^{-3}$	$\pm 6.5 \times 10^{-2}$		$\pm 1.07 \times 10^{-2}$	
	M1	7.28×10^{20}	3.01	-	-	-	-	8536/169
2011			$\pm 4.33 \times 10^{-3}$	-	-	-	-	,
	M2	4.68×10^{20}	2.59	0.135	-	-	-	767/167
			$\pm 6.56 \times 10^{-3}$	$\pm 6.7 \times 10^{-4}$	-	-	-	
	M3	6.2×10^{20}	2.80	0.131	1.95	-	-	487/165
			$\pm 1.66 \times 10^{-2}$	$\pm 2.2 \times 10^{-3}$	$\pm 8.8 \times 10^{-2}$	-	-	
	M4	5.78×10^{20}	2.78	0.136	2.11	1.7×10^{22}	0.653	221/163
			$\pm 2.03 \times 10^{-2}$	$\pm 1.3 \times 10^{-3}$	$\pm 1.4 \times 10^{-1}$		$\pm 8.7 \times 10^{-2}$	

RESULTS FOR WARM ABSORBER (PN DATA)

* M means the model name, where M1 = Pha + PL (power low), M2 = Pha + PL + bb (black body model), M3 = Pha + PL + bb + bb, and M4 = Pha + PL + bb + bb + zxipcf (partial covering absorption by partially ionized material model).

v	М	Nh(Pha)	Г	bb	Nh(zyincf)	loge	χ^2/odf
	141		1	001		1055	λ /001
	M1	8.97×10^{20}	3.24				2911/2457
			$\pm 3.9 \times 10^{-2}$				
2000	M2	6.56×10^{20}	2.89	0.127			2756/2455
			$\pm 5.0 \times 10^{-2}$	$\pm 3.7 \times 10^{-3}$			
	M3	6.13×10^{20}	2.82	0.131	6.39×10^{20}	0.800	2697/2452
			$\pm 5.5 \times 10^{-2}$	$\pm 3.3 \times 10^{-3}$		$\pm 1.1 \times 10^{-1}$	
	M1	8.92×10^{20}	3.36				2706/2446
			$\pm 5.1 \times 10^{-2}$				
2001	M2	6.50×10^{20}	3.10	0.134			2650/2444
			$\pm 8.5 \times 10^{-2}$	$\pm 9.2 \times 10^{-3}$			
	M3	4.71×10^{20}	2.98	0.131	0.14×10^{22}	0.434	2633/2441
			$\pm 1.1 \times 10^{-1}$	$\pm 5.1 \times 10^{-3}$		$\pm 9.2 \times 10^{-2}$,
	M1	7.74×10^{20}	3.20				3878/2445
			$\pm 1.7 \times 10^{-2}$				
2005	M2	5.14×10^{20}	2.76	0.123			3340/2443
			$\pm 3.2 \times 10^{-2}$	$\pm 1.7 \times 10^{-3}$			
	M3	4.58×10^{20}	2.68	0.130	0.10×10^{22}	0.562	3167/2440
			$\pm 3.4 \times 10^{-2}$	$\pm 1.7 \times 10^{-3}$		$\pm 6.1 \times 10^{-2}$	
	M1	9.28×10^{20}	3.31				3317/2448
			$\pm 2.3 \times 10^{-2}$				
2011	M2	5.82×10^{20}	2.78	0.127			2867/2446
			$\pm 4.4 \times 10^{-2}$	$\pm 2.2 \times 10^{-3}$			
	M3	5.34×10^{20}	2.71	0.133	0.15×10^{22}	0.607	2780/2443
			$\pm 5.0 \times 10^{-2}$	$\pm 1.3 \times 10^{-3}$		$\pm 8.0 \times 10^{-2}$	

RESULTS FOR WARM ABSORBER (RGS DATA)

absorber varies across the data. The highest value is for $\log \xi$ ($0.889 \pm 3.11 \times 10^{-2}$) in 2000, while the lowest value ($0.437 \pm 7.60 \times 10^{-2}$) was recorded in 2001.

Because the presence of warm absorption features may become more evident in the RGS spectrum, the RGS data in the range 0.4 to 2.0 Kev is used with a model similar to that used with EPIC data, that is, the absorbed power law model with two black body parameters and one warm absorber model. However, by adding the first black body model to the absorbed power law model, the temperatures are $0.127 \pm 3.75 \times 10^{-3}$, $0.134 \pm 9.22 \times 10^{-3}$, $0.123 \pm 1.75 \times 10^{-3}$ and $0.127 \pm 2.25 \times 10^{-3}$. The average temperature is approximately the same that of the EPEC data. Adding the second black body does not improve the fit. In this model one, black body parameter is sufficient. Table 5 summaries the fitting output; we can see from the results that the values of the photoionization parameters are approximately the same as those in the EPIC data. Figure 10 illustrates the fitting after adding all models.



Fig.9. The final fit of the models after adding the warm absorber model (Example for PN data of 2011).



Fig.10. The final fit of the models after adding the warm absorber model for RGS data (observation of 2011 as example).

4. *Conclusions*. A detailed spectral analysis (EPIC and RGS) was performed for four XMM-Newton observations for the Seyfert galaxy Arakelian 564 in 2000, 2001, 2005 and 2011. The wide range (0.35-10.0 KeV) is described by a power law model with the photon index $\Gamma \sim 2.41$, and the soft excess comprises two black body components in the EPIC data with temperatures ~0.129 KeV and 1.74KeV, and one black body component in RGS data. The test for the presence of intrinsic cold absorption shows that there is no fully or partial covering intrinsic cold absorption. We did not add the Gaussian line model for Fe K α emission line because it is not seen in the spectra. The spectra were almost constant across the four observations at the hard part at >5 KeV, but the soft part differed across observations. We detected one-phase warm absorber in the four observation spectra using the partial covering absorption using a partially ionized material model. The value of the photoionization parameter changed across spectra. The highest value using EPIC was for log ξ (0.889 ± 3.11×10⁻²) in 2000, while the lowest value was for 2001. The output results from the RGS data are approximately matched with EPIC data. Long-term observation should be used in the near future to shed more light on the variability of the warm absorber.

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ПЕРЕМЕННОСТЬ ТЕПЛОГО ПОГЛОТИТЕЛЯ РЕНТГЕНОВСКОГО ИЗЛУЧЕНИЯ СЕЙФЕРТОВСКОЙ ГАЛАКТИКИ АРАКЕЛЯН 564

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Исследована переменность теплых поглощающих облаков ионизованного газа в AGN галактики типа Сейферт-I Аракелян 564. Рентгеновские спектры этого объекта, полученные из четырех наблюдений XMM-Newton, были проанализированы с использованием средств EPIC и RGS. Эти наблюдения охватывали 11 лет. Между наблюдениями параметр ионизации ξ поглощающего вещества изменился ($\log \xi = 0.889 \pm 3.11 \times 10^{-2}$ для наблюдений 2000г. и $0.437 \pm 7.60 \times 10^{-2}$ для 2001г.). Мягкий рентгеновский избыток изучался для четырех наблюдений с использованием параметров двух черных тел в спектрах EPIC (температура первого черного тела составляет ~ $0.129 \pm 2.04 \times 10^{-3}$ KэB, а второго ~ $1.74 \pm 7.6 \times 10^{-2}$ KэB) и одного черного тела в спектрах RGS.

Ключевые слова: галактики: темный поглотитель: Аракелян 564

X-RAY WARM ABSORBER IN Ark 564

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