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An ASCA X-ray observation of 1E 1724-3045 in the globular cluster Terzan 2

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Abstract. The bright persistent X-ray source and type I X-ray burster 1E 1724-3045 located in the globular cluster Terzan 2 was observed by ASCA for about 10 ksec on September 24-25th, 1995 while it was in its hard state, with a luminosity of $\sim 6 \times 10^{36}$ ergs s^{-1} in the 0.5–10 keV band (d=7.7 kpc). The ASCA spectrum is hard, and reveals the presence of a soft component below 2-3 keV. When combined with non simultaneous RXTE/HEXTE data, we show that the ASCA spectrum can be adequately fitted by a Comptonization model for which the electron temperature is ~ 30 keV, the optical depth is ~ 3 for a spherical scattering cloud. The soft component carries off about 13%, and 35% of the 0.1-200 keV luminosity for a blackbody and disk blackbody fit respectively. It is more likely to arise from the accretion disk, whereas the hard Comptonized component is generated in a hot boundary layer interior to the disk. The column density measured towards the source ($N_H \sim 1.0 \times 10^{22}$ cm^{-2}) is consistent with the value expected from the optical reddening of the cluster. No emission lines were detected, and an upper limit of 30 eV for the equivalent width of a 6.4 keV line ($\sigma = 0.1$ keV) has been derived.

Key words: stars: individual: 1E 1724-3045 – galaxy: globular clusters: individual: Terzan 2 – X-rays: stars

1. Introduction

1E 1724-3045 is a bright persistent Low-Mass X-ray Binary (LMXB) located in the globular cluster Terzan 2 (Grindlay et al., 1980). Terzan 2 is a metal-rich globular cluster of the galactic bulge with a reddening E(B-V)=1.57 (Ortolani et al., 1997). Depending on the relation R=$A_V/E(B-V)$, Ortolani et al. (1997) estimated a distance of 7.7 kpc for the "canonical" value of 3.1 for R (Savage and Mathis, 1979), and d=5.3 kpc for R=3.6 (Grebel and Roberts, 1995) respectively.

The type I X-ray bursts observed from 1E 1724-3045 indicate that the compact object is a weakly magnetized neutron star (Swank et al., 1977; Grindlay et al., 1980). Analysis of these bursts, in particular the one observed by EINSTEIN that showed photospheric radius expansion, and therefore likely reached the Eddington limit, places the source at a distance of 7 kpc (Tanaka, 1981), consistent with the estimate for R=3.1. Recent monitoring of the source, by the All Sky Monitor aboard the Rossi X-ray Timing Explorer (Bradt et al., 1993), as well as snapshot observations performed earlier, indicate that 1E 1724-3045 is weakly variable in X-rays (less than about a factor of 3 on a few day time scale) with a mean flux level of 45 mCrab in the 2-12 keV range.

Prior to ASCA, EXOSAT, TTM and ROSAT X-ray observations ($\sim$1-20 keV) have shown that the source spectrum could be simply fit by a power law of photon index $\sim 2.0 - 2.4$ (Mereghetti et al., 1995; In't Zand, 1992; Verbunt et al., 1995). At higher energies, 1E 1724-3045 is one of the first neutron star systems from which hard X-ray emission (E$\gtrsim$35 keV) was detected (Barret et al., 1991). Additional observations of the source with SIGMA demonstrated that 1E 1724-3045 was a persistent, though variable, hard X-ray source emitting at the mean level of 22 mCrab in the 35-75 keV range (Goldwurm et al., 1993; Goldwurm et al., 1994; Goldwurm et al., 1995). Fitting of the time-averaged SIGMA spectrum yields a photon index of 3.0 ± 0.3 for a power law fit, thus suggesting the existence of a cutoff or a break between the X-ray and hard X-ray bands (Tavani and Barret, 1997).

Thanks to SAX and RXTE, simultaneous X-ray to hard X-ray observations have now been performed and have demonstrated that the 1-200 keV spectrum of the source was indeed a power law below ~ 30 keV, attenuated at high energies by an exponential cutoff at $\sim$70 keV (Guainazzi et al., 1998; Barret et al., 1998). This broad band spectrum was interpreted as resulting from the Comptonization of soft photons in a spherical scattering region of optical depth ~ 3 and electron temperature ~ 30 keV. Furthermore, the latter observations have suggested the presence of an additional soft component below 2-3 keV, which could be fit either by a blackbody or a muticolor disk blackbody model (See Table 1). Beside the continuum, no emission lines were found in the SAX/LECS-MECS data (Guainazzi et al., 1998).

The absorbing column density (N_H) has been poorly determined: depending on the model and the instrument, it varies

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Table 1. X-ray and hard X-ray spectral observations of 1E1724-3045 in the globular cluster Terzan 2. The models are defined as follows: PL=Power Law, BB=Single temperature blackbody, DBB=Disk Blackbody (Mitsuda et al. 1984), C=Comptt Comptonization model (Titarchuk 1994). $\alpha_{\rm PL}$ is the power law photon index. For the single temperature blackbody model: $kT_{\rm BB}$ is the Blackbody temperature, $R_{\rm BB}$ is the source radius in km. For the multi-color blackbody model: $kT_{\rm in}$ is the temperature at the inner disk radius, $R_{\rm in}$ is the inner disk radius scaled at the source distance (7.7 kpc), θ is the inclination angle of the source. The column density ($N_{\rm H}$) is given in units of 10^{22} H atoms cm^{-2}. E refers to the energy range of the observation in keV. References are: 1) Mereghetti et al. (1995), 2) Zand (1992), 3) Verbunt et al. (1995), 4) Goldwurm et al. (1993), 5) Goldwurm et al. (1994), 6) Guainazzi et al. (1998), 7) Barret et al. (1998). The flux is the unabsorbed flux given in the energy band of the observation in units of 10^{-10} ergs s^{-1} cm^{-2}.

Experiment	Date	E (keV)	Model	Flux	Ref.
EXOSAT ME+LE	3/14/85	2–10	PL: $\alpha_{\rm PL} = 2.34^{+0.03}_{-0.04}$ $N_{\rm H} = 1.8^{+0.1}_{-0.1}$	2.3	1
TTM	10/88-02/92	2–28	PL: $\alpha_{\rm PL} = 2.1^{+0.2}_{-0.1}$ $N_{\rm H} = 4.0^{+1.0}_{-2.0}$	7.9	2
ROSAT PSPC	6/19-21/19	0.5–2.5	PL: $\alpha_{\rm PL} = 2.3$ $N_{\rm H}$=1.8 (assumed)	3.1	3
SIGMA	03/90-10/93	35–75	PL: $\alpha_{\rm PL} = 3.0 \pm 0.3$	1.8	4,5
SAX	08/17/96	0.1–100	C+BB:$N_{\rm H} = 0.84^{+0.08}_{-0.07}$ $kT_e = 29^{+9}_{-4}$ $\tau = 3.0^{+0.4}_{-0.5}$ $kT_W = 1.1^{+0.10}_{-0.09}$ $kT_{\rm BB} = 0.6^{+0.05}_{-0.06}$ $R_{\rm BB} = 12.0^{+2.0}_{-2.0}$	15.8	6
SAX	...	...	C+DBB:$N_{\rm H} = 1.22^{+0.04}_{-0.07}$ $kT_e = 27^{+11}_{-4}$ $\tau = 3.2^{+0.5}_{-0.7}$ $kT_W = 1.94^{+0.30}_{-0.16}$ $kT_{\rm in} = 1.4^{+0.15}_{-0.08}$ $R_{\rm in}\sqrt{\cos\theta} = 3.0^{+0.3}_{-0.4}$	15.8	6
RXTE	11/04-08/96	1–200	C+DBB:$N_{\rm H}$=1.0 (assumed) $kT_e = 33.8^{+14.0}_{-8.0}$ $\tau = 2.4^{+0.4}_{-0.5}$ $kT_W = 1.6^{+0.2}_{-0.3}$ $kT_{\rm BB} = 0.8^{+0.1}_{-0.1}$ $R_{\rm BB} = 7.0^{+1.7}_{-0.6}$	22.2	7

from 0.5 to 4 $\times 10^{22}$ H atoms cm^{-2} from SAX to TTM. Table 1 summarizes the X-ray/hard X-ray observations performed so far. Normalized to the "classical" 1-20 keV band, the fluxes listed in Table 1 indicate a variability of about a factor of 3 between EXOSAT and TTM, SAX and RXTE. A similar variability factor could be inferred in hard X-rays (Goldwurm et al., 1993). From the most recent measurements performed by SAX and RXTE, the 1-200 keV luminosity lies in the range ~ 1.0 to 1.5×10^{37} ergs s^{-1} (d=7.7 kpc).

Here we report on a short ASCA observation of 1E 1724-3045 in the 0.5–10 keV range. Our observation provides an independent confirmation of the existence of a soft component in the source spectrum, yields the best $N_{\rm H}$ measurement obtained so far, puts stringent upper limit on disk line emission, and finally by a combination with RXTE data enables us to discuss on the origin of the soft and hard components.

2. Spectral analysis

The ASCA observation of 1E 1724-3045 were carried out on September 24-25th, 1995. Data were screened and analyzed using the standard procedure described in the *The ASCA Guide to data reduction, version 2* available at the ASCA Guest Observer Facility.[1] In particular, data were rejected during times when the satellite was traversing regions of low Cut-Off Rigidity (COR ≤ 6) and when the Earth limb elevation angle was $\leq 10°$. The data were also masked spatially in order to remove the outer ring of high background as well as the calibration source events.[2] We also performed background rejection on GIS data based on the rise-time of the signal. The SIS screening criteria for extracting spectral information were very similar to the ones applied to

1 http://heasarc.gsfc.nasa.gov/docs/asca/abc/abc.htm
2 see The ASCA Guide to data reduction, p. 36

the GIS: same minimum elevation angle and same minimum rigidity cutoff. Because of the possibility for contamination in the SIS of fluorescence lines of oxygen from the Earth's atmosphere, data selection was done on the bright-Earth angle, and only data above 40° (20°) for the SIS0 (SIS1) were retained. Finally, only events with CCD grades 0, 2, 3, or 4 were used in further analysis.

The position of the source from the image analysis is consistent with ROSAT and EINSTEIN positions (Mereghetti et al., 1995; Grindlay et al., 1984). In order to check for time and spectral variability, we have produced background subtracted light curves, as well as hardness-intensity and color-color diagrams. This showed that the source is remarkably steady within our observation, both in intensity and spectral shape.

The GIS spectrum was extracted from a circular region of radius $7'$ centered at the position of the source. In order to correctly subtract the contribution from the galactic plane diffuse emission, we have extracted the background from multiple fields within the FOV of the instrument. The same procedure was applied to the SIS data, except that a smaller region ($3'15''$ of radius) was used to extract the source spectrum. As mentioned above, no spectral variations could be found within the observation, we have therefore combined for each detector the whole data set to derive a time averaged spectrum. The spectral analysis has been restricted to the 0.8 to 10 keV range for the GIS2 and GIS3 and 0.4, 0.5 to 10 keV for SIS0 and SIS1. In these energy bands, the source count rates are 7.20±0.03, 8.77±0.03, 8.40±0.03 and 7.04±0.03 count s^{-1} in the GIS2, GIS3, SIS0, SIS1 respectively. All fits were done using XSPEC version 10.00. We started by fitting the detectors separately and then, merged them in a combined 4-detector analysis. Remarkable agreement is found between all the detectors and we decide to keep the normalization equal for all the four instruments. Leaving the relative normalizations of the four data sets as free parameters gives consistent results; the only noticeable difference is that it leads to a reduction of the reduced χ^2 values of about 0.2 (for more than 1300 degrees of freedom).

2.1. Detection of the soft component

Given previous observations of the source, we first fit the spectrum with a single absorbed power law. The power law fit is not good as there is a clear low energy excess which is not accounted for in the residuals. We then tried to fit this excess with a blackbody (BB) component. This results in a significant improvement of the fits ($\Delta\chi^2 \geq 200$). Taking advantage of the better spectral resolution of the SIS, we have checked that adding such a soft component is also required when fitting the SIS0 and SIS1 spectra ($\Delta\chi^2 \geq 150$ for 408 degrees of freedom). We have also tried to fit the soft component with a multi-color disk blackbody (DBB, Mitsuda et al. 1984). This model provides an equally good fit. The $\Delta\chi^2$ is less than 10 (1313 d.o.f) for the two models. Other models such as a thermal Bremsstrahlung, a cutoff power law, or a broken power law combined with a BB or a DBB could fit the data as well, but the flatness of the spectrum and the restricted energy range of ASCA do not allow to put interesting constraints on the fitted parameters.

2.2. A comptonization model to fit the ASCA data

The source flux at the time of our observation was within 5% of the flux seen by SAX and within 30% of the one observed by RXTE. Likewise, the source spectrum was also very hard and a soft component was also present; therefore it was legitimate to use the SAX and RXTE models to try to fit the ASCA data as well. This model is made of the sum of either a BB or DBB component and the so-called *comptt* model in XSPEC (Titarchuk, 1994). This model is an improvement over the former *compst* model as the theory is extended to include relativistics effects, and to work for both the optically thin and thick cases (Titarchuk, 1994). The free parameters of the model are: the temperature of the seed photons (kT_W), assumed to follow a Wien law, the optical depth of the scattering region (τ), the electron temperature (kT_e), and a parameter defining the geometry (a disk or a sphere). In the following, we consider the spherical case. Obviously in the absence of significant cutoffs in the spectrum, the electron temperature cannot be easily constrained by the ASCA data. Therefore, to begin with, we have set kT_W, τ, kT_e to their best fit values listed in Guainazzi et al. (1998); i.e. 1. keV, 3., and 30 keV respectively (see Table 1). We thus fit the normalization of the *comptt* model, and the soft excess modeled either by a BB or a DBB (a fit is not possible when such a component is not added). The results of the fit are listed in Table 2. The lowest reduced χ^2 value is obtained when the soft component is fit by a BB. A comparison with the values listed in Table 1 indicates that our best fit parameters are consistent with SAX for the *Comptt*+BB model, but differs in the inner disk temperature for the *Comptt*+DBB model. Assuming a disk geometry instead of a spherical one leads to the same conclusion. As a further test of the validity of the latter model, we have let kT_W and τ as free parameters of the fit in the *Comptt*+BB model. The parameters so recovered are: $N_H=0.94 \pm 0.03 \times 10^{22}$ H atoms cm^{-2}, $\tau = 3.2^{+0.4}_{-0.7}$, $kT_W=1.1^{+0.1}_{-0.2}$ keV, while the parameters of the BB component remained unchanged.

2.3. Joint fit of the ASCA and RXTE data

We have shown above that the ASCA spectrum alone could be fit by the SAX and RXTE model. As a final test, we have tried to fit jointly the ASCA data and the non simultaneous RXTE/HEXTE hard X-ray spectrum. 1E 1724-3045 was observed by RXTE about one year after ASCA (from November 4th to 8th for a total of ~ 100 ksec, see Barret et al. 1998 for details about the observation). The HEXTE spectrum is a time-averaged spectrum over the entire observation, and is made of the cluster A and B spectra. We do not include the PCA data, as the PCA has no sensitivity below 3 keV (i.e. N_H and kT_W will be better constrained with ASCA alone), and the power law part of the ASCA spectrum is sufficient to determine reliably the parameter τ of the *Comptt* model (see below). For the fit, we have let the relative normalizations of the ASCA and two

Table 2. Best fit results for the *Comptt* + BB or DBB model. The first data set corresponds to the ASCA GIS+SIS data. The parameters of the *Comptt* model have been fixed to those observed by SAX and RXTE (see Table 1). The second data set corresponds to the combination of the ASCA/GIS3 and RXTE/HEXTE spectra. The number of degrees of freedom for the first data set is 1314, whereas it is 537 for the second one. The data are not simultaneous so the relative normalization between the ASCA and HEXTE spectra has been left as a free parameter. For the *Comptt* model, a spherical geometry has been assumed. F_T is the unabsorbed flux in the 0.1-200 keV band, F_{BB} is the flux carried of by the soft component in the same energy band. They are given in units of 10^{-10} ergs s^{-1} cm^{-2}.

Set	Model	N_H	kT_e	τ	kT_W	kT_{BB}	R_{BB}	kT_{in}	$R_{in}\sqrt{\cos\theta}$	χ^2	F_T	F_{BB}
1	C+BB	$0.97^{+0.04}_{-0.04}$	30.0 (fixed)	3.0 (fixed)	1.0 (fixed)	$0.54^{+0.02}_{-0.02}$	$10.8^{+0.2}_{-0.2}$			1.35	16.4	1.9
...	C+DBB	$1.28^{+0.01}_{-0.01}$	30.0 (fixed)	3.0 (fixed)	1.0 (fixed)			$0.76^{+0.02}_{-0.02}$	$5.2^{+0.2}_{-0.2}$	1.40	17.5	3.3
2	C+BB	$0.91^{+0.08}_{-0.07}$	$27.0^{+11.0}_{-5.0}$	$\tau = 3.2^{+0.7}_{-0.9}$	$1.15^{+0.13}_{-0.13}$	$0.58^{+0.05}_{-0.05}$	$10.0^{+1.2}_{-1.2}$	...	...	1.09	16.0	2.1
...	C+DBB	$1.21^{+0.07}_{-0.05}$	$27.9^{+12.0}_{-5.0}$	$\tau = 3.0^{+0.8}_{-0.6}$	$1.23^{+0.17}_{-0.23}$	...	...	$0.58^{+0.05}_{-0.05}$	$2.45^{+0.5}_{-0.5}$	1.09	17.8	5.0

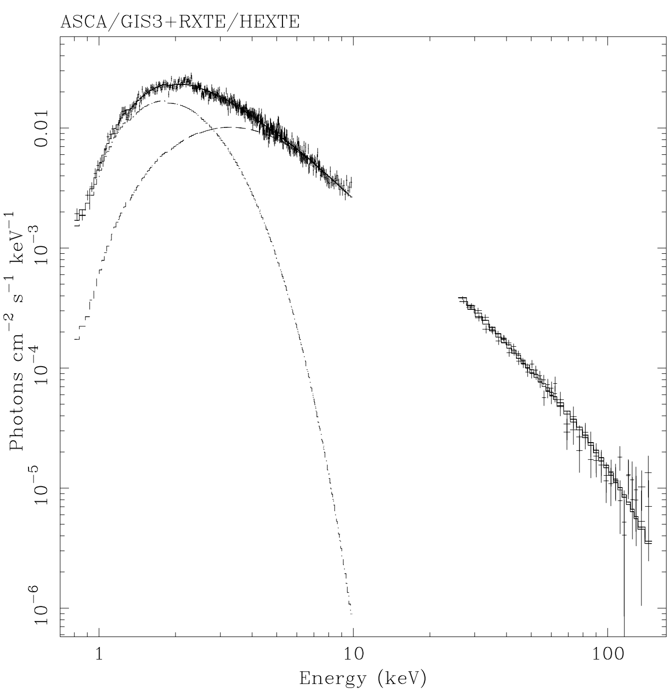

Fig. 1. The unfolded ASCA/GIS3 and RXTE/HEXTE data (Barret et al. 1998) for the *Comptt*+BB model with parameters listed in Table 2. The blackbody component is indicated by a dashed line.

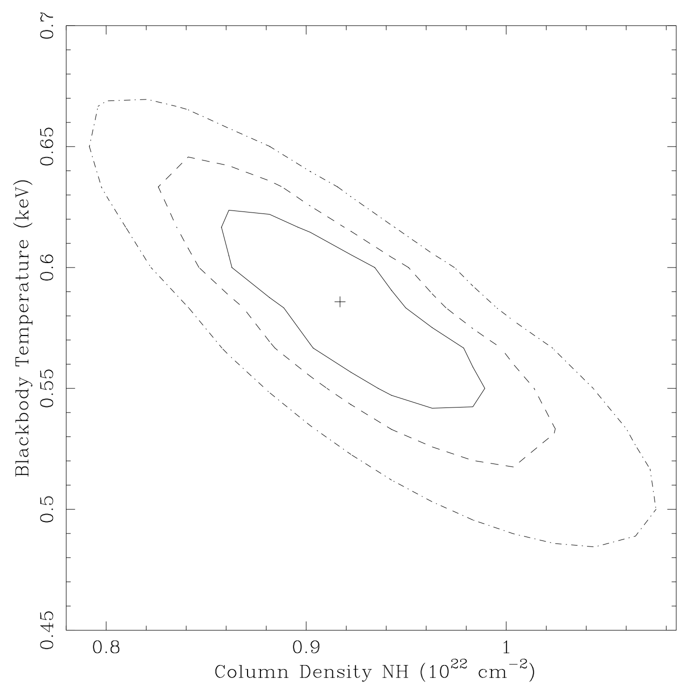

Fig. 2. Contours of confidence level for N_H and the blackbody temperature for the *comptt*+BB model fitting the ASCA/GIS3 and RXTE/HEXTE data. The contour levels shown are respectively: 68%, 90%, 99% confidence level. The best fit is marked by a small cross on the plot.

HEXTE cluster spectra be a free parameter of the fit, to account for the fact that the observations are not simultaneous as well as relative calibration uncertainties between the instruments. In order not to give too much weight to the ASCA data in the fit, we used only the GIS3 spectrum. We used the *Comptt* model assuming a spherical geometry. The results of the fit are listed in Table 2. As can be seen, an excellent fit is obtained. Unfortunately, once again we are unable to distinguish between the BB and DBB model to fit the soft component. In Fig. 1, we show the unfolded broad-band ASCA/GIS3 and RXTE/HEXTE spectrum of the source associated with the *Comptt*+BB best fit. In Fig. 2, we show the allowed grid of variations for the N_H and the blackbody temperature for that model.

2.4. No emission lines

No visible emission lines are present in the source spectrum. We have set an upper limit on the presence of an Iron line by adding a gaussian line centered at 6.4 keV to the model described above. For a line width of 0.1 keV (σ), the upper limit on its equivalent width is ~ 30 eV. This limit increases up to ~ 80 eV when $\sigma = 0.5$ keV (both values are given at the 90% confidence level).

3. Discussion

Our observation confirmed the existence of a soft component in the X-ray spectrum of 1E 1724-3045 at a luminosity around 5.7×10^{36} ergs s^{-1} (0.5-10.0 keV, 7.7 kpc). The non-detection of this soft component in the EXOSAT and TTM data could be explained by a lack of sensitivity below 2 keV. If this soft component is a multi-color disk blackbody, then our estimate of $R_{in}\sqrt{\cos\theta}$ is consistent with the low value generally observed from neutron star systems, and much smaller than the values derived from black hole candidates. On the other hand, this is not the case for kT_{in} which is much smaller than the 1.5 keV neutron star value, and closer to the black hole values (Tanaka and Lewin, 1995). As for R_{in}, as pointed out by Guainazzi et al. (1998), in order for this radius to accommodate a neutron star radius, a large inclination $\theta \gtrsim 70^0$ is required, in contradiction with the fact that no sizable orbital modulations have been observed from the source (Olive et al., 1998).

For the *Comptt*+BB model, the ratio of the 0.1–200 keV luminosities of the BB (L_{BB}) component versus the *Comptt* one (L_{Comptt}) is 0.13-0.15. The ratio of L_{DBB}/L_{Comptt} is 0.23-0.40 for the *Comptt*+DBB model. The origin of the soft component is unclear. Obviously it could come from the neutron star surface itself or from an optically thick boundary layer near the neutron star. In this scenario, the Comptonized component would be generated somewhere in a disk corona. The blackbody radius of ~ 10 km derived from the *Comptt*+BB clearly argues in favor of this scenario. Another possibility is that the soft component originates from the accretion disk, while the harder X-rays are generated in the boundary layer (Guainazzi et al., 1998). Sunyaev and Shakura (1986) predicted that the ratio between the disk and the boundary layer luminosities could be as low as 0.45, if the disk ends at the marginally stable orbit (which is larger than the neutron star radius). As noticed by Guainazzi et al. (1998), the properties of the high frequency quasi-periodic oscillations recently discovered in LMXBs (Van der Klis, 1997) indicates that these systems do not rotate at their break-up periods, and further do not have accretion disks that extend beyond the last marginally stable orbit. In other words, this means that the predicted ratio discussed above could be even smaller than ~ 0.45. Thus the low ratio of the soft/hard flux (i.e. BB or DBB vs. Comptonized flux) would favor the picture in which the weak soft component comes from the accretion disk and the Comptonized component originates from a hot and optically thin boundary layer. This in turn would support theoretical models predicting hard X-ray emission from such a boundary layer (e.g. Kluzniak and Wilson 1991; Walker 1992).

Our observation provides the most accurate N_H estimate obtained so far (see Fig. 2). Our values are consistent with the one derived by SAX (Guainazzi et al., 1998). Following Predehl and Schmitt (1995), the visual extinction is related to the X-ray absorbing column density as $N_H = A_V \times 10^{21} = R \times E(B-V) \times 10^{21}$ H atoms cm^{-2}. Taking E(B-V)=1.54 (Ortolani et al., 1997), we obtain N_H=0.9 and 1.0×10^{22} H atoms cm^{-2} for R=3.1 and 3.6 respectively. The "optical" value is remarkably close to the value derived with the *Comptt*+BB model (see Table 2). It is smaller than the value derived for the *Comptt*+DBB model (the systematic difference in the N_H value between the BB and DBB models is due to the fact that the DBB is steeper than the BB model at low energies). In any case, the difference between the observed and expected N_H, and the consistency between the SAX, RXTE values suggest that the source does not show intrinsic (and variable) absorption, as one might have suspected from previous measurements (see Table 1). The larger N_H observed by TTM and at a lower degree by EXOSAT might result from an overestimate of the photon index for a power law fit. We now know from SAX, RXTE and the present data (all of which were in a very similar spectral state) that the photon index in x-rays is less than 2 for a power law fit. Our results, which show agreement between the "optical" N_H and the X-ray N_H values, therefore eliminate the need for internal absorption in the source and therefore, any dependence upon the metallicity of Terzan 2 (which happens to be metal rich).

Consistent with the SAX/LECS-MECS observations, ASCA failed to detect any emission lines from 1E 1724-3045. For instance, an iron line and a broad absorption feature above 10 keV were detected from the X-ray burster 4U1608-522 by GINGA, and interpreted as due to absorption/reflection of a power law incident spectrum on a relatively cold medium (Yoshida et al., 1993). Therefore the lack of an iron line in our data is consistent with the absence of a reflected component in the broad-band SAX and RXTE spectra of 1E 1724-3045 (Guainazzi et al., 1998; Barret et al., 1998). It is also consistent with the emission line models of Ko and Kallman (1994) for this relatively low luminosity source (compared to Sco X-1 which does show Fe line emission), particularly if the disk in 1E 1724-3045 is illuminated at relatively grazing angles from the central x-ray source.

4. Conclusions

We observed 1E 1724-3045 in its hard state, during which it emits hard X-rays. The weak variability of the source in X-rays suggests that it spends most of its time in such a hard state with a hard power law type spectrum in X-rays (0.5-10 keV). The soft excess detected at low energies is more likely originating from the accretion disk. As for the hard component, it more likely arises from the Comptonization of soft photons in a hot boundary layer. The N_H value we have measured is consistent with the value expected from the cluster redenning. The consistency of this result with recent N_H measurements by SAX and RXTE suggests that the source does not display intrinsic (and variable) absorption. The lack of iron line emission is consistent with the absence of a reflected component in the broad band spectrum of the source.

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References

Barret D., Mereghetti S., Roques J.P., et al., 1991, ApJL 379, L21

Barret D., Olive J.F., Boirin L., et al., 1998, A&A, in preparation

Bradt H.V., Rothschild R.E., Swank J.H., 1993, A&AS 97, 355

Goldwurm A., Cordier B., Paul J., et al., 1993, In: Fichtel N., Gherels C., Norris J. (eds.) The Second Compton Symposium. AIP No. 304, p. 421

Goldwurm A., Cordier B., Paul J., et al., 1994, Nat 371, 589

Goldwurm A., Denis M., Paul J., et al., 1995, Adv. Spa. Res. 15, 41

Grebel E.K., Roberts W.J., 1995, A&AS 109, 293

Grindlay J.E., Hertz P., Steiner, et al., 1984, ApJL 282, L13

Grindlay J.E., Marshall H.L., Hertz P., et al. 1980, ApJL 240, L121

Guainazzi M., Parmar A.N., Segreto A., et al., 1998, A&A 339, 802

In't Zand J., 1992, Ph.D. Thesis, University of Utrecht

Kluzniak W., Wilson J.R., 1991, ApJL 372, L87

Ko Y.-K., Kallman T.R., 1994, ApJ 431, 273

Mereghetti S., Barret D., Stella, et al., 1995, A&A 302, 713

Mitsuda K., Inoue H., Koyama K., et al., 1984, PASJ 36, 741

Olive J.F., Barret D., Boirin L., et al., 1998, A&A 333, 942

Ortolani S., Bica E., Barbuy B., 1997, A&A 326, 620

Predehl P., Schmitt J.H.M.M., 1995, A&A 293, 889

Savage B.D., Mathis J.S., 1979, ARA&A 17, 73

Swank J.H., Becker R.H., Boldt E.A., et al., 1977, ApJL 212, L73

Syunyaev R.A., Shakura N.I., 1986, Sov. Ast. Lett. 12, 117

Tanaka Y., 1981, In: Helfang D., Huang J. (eds.) The Origin and Evolution of Neutron Stars. IAU Symposium No 125, p. 161

Tanaka Y., Lewin W.H.G., 1995, In: Lewin W.H.G.; Van Paradijs J., Van den Heuvel E.P.J. (eds.) Cambridge Astrophysics Series. Cambridge University Press, Cambridge, MA, p. 126

Tavani M., Barret D., 1997, In: D.C.D., Strickman M., Kurfess J.D. (eds.) Proc. of the 4th Compto symp., AIP Conf. Proc. 410, p. 75

Titarchuk L., 1994, ApJ 434, 570

Van Der Klis M., 1997, The Many Faces of Neutron Stars. Lipari, Italy, October 1-10, Kluwer, Dordrecht. Ed. R. Buccheri, J. van Paradijs, M.A. Alpar, 337

Verbunt F., Bunk W., Hasinger G., et al., 1995, A&A 300, 732

Walker M., 1992, ApJ 385, 661

Yoshida K., Mitsuda K., Ebisawa K., et al. 1993, PASJ 45, 605