



Publication Year	2016
Acceptance in OA	2021-01-07T13:32:27Z
Title	NuSTAR and XMM-Newton Observations of 1E1743.1-2843: Indications of a Neutron Star LMXB Nature of the Compact Object
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Publisher's version (DOI)	10.3847/0004-637X/822/1/57
Handle	http://hdl.handle.net/20.500.12386/29549
Journal	THE ASTROPHYSICAL JOURNAL
Volume	822

NUSTAR AND *XMM-NEWTON* OBSERVATIONS OF 1E1743.1-2843: INDICATIONS OF A NEUTRON STAR LMXB NATURE OF THE COMPACT OBJECT

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Submitted to Astrophysical Journal

ABSTRACT

We report on the results of *NuSTAR* and *XMM-Newton* observations of the persistent X-ray source 1E1743.1-2843, located in the Galactic Center region. The source was observed between September and October 2012 by *NuSTAR* and *XMM-Newton*, providing almost simultaneous observations in the hard and soft X-ray bands. The high X-ray luminosity points to the presence of an accreting compact object. We analyze the possibilities of this accreting compact object being either a neutron star (NS) or a black hole, and conclude that the joint *XMM-Newton* and *NuSTAR* spectrum from 0.3 to 40 keV fits to a black body spectrum with $kT \sim 1.8$ keV emitted from a hot spot or an equatorial strip on a neutron star surface. This spectrum is thermally Comptonized by electrons with $kT_e \sim 4.6$ keV. Accepting this neutron star hypothesis, we probe the Low Mass (LMXB) or High Mass (HMXB) X-ray Binary nature of the source. While the lack of Type-I bursts can be explained in the LMXB scenario, the absence of pulsations in the 2 mHz - 49 Hz frequency range, the lack of eclipses and of an IR companion, and the lack of a K_α line from neutral or moderately ionized iron strongly disfavor interpreting this source as a HMXB. We therefore conclude that 1E1743.1-2843 is most likely a NS-LMXB located beyond the Galactic Center. There is weak statistical evidence for a soft X-ray excess possibly indicating thermal emission from an accretion disk. However, the disk normalization remains unconstrained due to the high hydrogen column density ($N_H \sim 1.6 \times 10^{23} \text{ cm}^{-2}$).

Keywords: accretion, accretion disks — stars: neutron — X-rays: binaries — X-rays: individual (1E1743.1-2843)

1. INTRODUCTION

The X-ray source 1E1743.1-2843 was discovered during the first soft X-ray imaging observation of the Galactic Center, performed by the *Einstein Observatory* (Watson et al. 1981), and has been detected in all the subsequent observations performed by X-ray satellites with imaging capabilities above 2 keV (Kawai et al. 1988; Sunyaev et al. 1991; Pavlinsky et al. 1994; Lu 1996; Cremonesi et al. 1999; Munro et al. 2009; Bird et al. 2010; Porquet et al. 2003). Its position has been determined with *Chandra* to be

$\alpha_{J2000} = 17^h 46^m 21.09^s$, $\delta_{J2000} = -28^\circ 43' 42.67''$ with a reported $0.21''$ 1σ accuracy (Evans et al. 2010). Because of its high column absorption ($N_H = 1.3 \pm 0.1 \times 10^{23} \text{ cm}^{-2}$, see Cremonesi et al. 1999), the source is likely in the Galactic Center ($d = 7.9 \pm 0.3$ kpc, McNamara et al. 2000) or beyond, while the orbital inclination is smaller than 70° (Cowley et al. 1983). The analysis performed by Porquet et al. (2003) detected no pulsations or quasi-periodic oscillations (QPO) in the 2.4 mHz – 2.5 Hz frequency range using EPIC-MOS and PN fullframe mode (time resolution 2.6 s and 200 ms, respectively). However, since many X-Ray Binaries (XRB) present quasi-periodic variations above 2.5 Hz, the *XMM-Newton* data were not suitable to probe the millisecond pulsations that could indicate a Low Mass X-ray Binary (LMXB) nature. In their analysis, Porquet tested several single-component spectral models (i.e., absorbed power-law, absorbed black body, absorbed disk-black body) but could not distinguish between these models due to the narrow bandpass from 2 to 10 keV. In this regard the *NuSTAR* capabilities to perform high resolution broadband spectroscopy allow us to probe into the nature of the high-energy emission from this source more deeply.

The presence of an accreting object is required to explain the unabsorbed source luminosity, which is of the order of $L_{2-10 \text{ keV}} \sim 10^{36} d_{10 \text{ kpc}}^2 \text{ erg s}^{-1}$, where $d_{10 \text{ kpc}}$ is the source distance expressed in units of 10 kpc, while the absence of periodic oscillations and eclipses favors a scenario in which a compact object (either a neutron star or a black hole) accretes matter from a low mass

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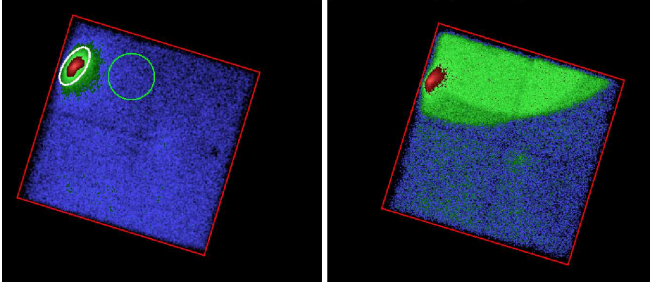


Figure 1. Images from *NuSTAR* focal plane modules in the 3–79 keV energy band, FPMA (left) and FPMB (right), the target source is $\sim 7'$ off-axis during the observation. FPMB is highly contaminated by stray light, and moreover the source is cut in half by two different stray light zones, therefore only data from FPMA were used in the analysis.

companion (LMXB systems). LMXBs in this luminosity range containing a neutron star are usually characterized by thermonuclear flashes of the accreted matter that ignites on the neutron star surface (Type 1 X-ray bursts), but these bursts have never been observed for 1E1743.1-2843 in 20 years of X-ray observations. This has led so far to the conclusion that (1) the accretion rate is high enough to allow stable burning of the accreted material, which would imply a $\dot{M}$ value comparable to the Eddington limit (Bildsten 2000), and thus distance greater than 8 kpc, (2) the bursts are suppressed by the presence of intense magnetic fields (at least 10^9 G), (3) the accreting compact object is a black hole (Porquet et al. 2003). The presence of strong magnetic fields ($> 10^{12}$ G), however, should be accompanied by cyclotron absorption features and pulsations, neither of which have been observed in 1E1743.1-2843. The source showed marginal variability on month timescales in the 20–40 keV range (Del Santo et al. 2006), some variability on hour timescales (10–20%) in the 1.3–10 keV energy range (Cremonesi et al. 1999), and less than 18% of variability between 10^{-4} and 2.5 Hz in the 2–10 keV energy range (Porquet et al. 2003).

We present here the results of four observations of 1E1743.1-2843 performed with the *NuSTAR* and *XMM-Newton* satellites in September–October 2012. The two satellites provided almost simultaneous broad-band X-ray spectroscopy from 0.1 to 79 keV and, thanks to the *NuSTAR* timing capabilities, we can also probe pulsations down to 2 milli-second timescales, providing unprecedented opportunities to investigate this source. In section 2 we describe the observations, in section 3 we discuss the timing and spectral analysis. Our results and discussion are presented in section 4.

2. OBSERVATIONS

All the observations were performed between September and October 2012. *NuSTAR* observed 1E1743.1-2843 during the a so-called “mini-survey” of the Galactic Center, which took place shortly after the *NuSTAR* in-orbit checkout. The observation was performed on October 15th 2012, and the total exposure time was 26 ks. The source was $\sim 7'$ off-axis in the *NuSTAR* observation and appears distorted due to the asymmetric PSF shape at a large off-axis angle (Madsen et al. 2015), as can be seen in Figure 1.

NuSTAR is the first X-ray satellite with multilayer hard X-ray optics and is operational in the energy range

3–79 keV (Harrison et al. 2013). The mission carries two identical telescopes with grazing incidence optics, each one focusing on separate detector modules, Focal Plane Modules A and B (FPMA, FPMB), at a distance of 10 m. These CdZnTe detectors have a total Field of View (FoV) of $13' \times 13'$ (Harrison et al. 2013). The telescope Point Spread Function (PSF) has an $18''$ FWHM with extended tails resulting in a Half-Power-Diameter of $58''$ (Harrison et al. 2013).

To improve the low-energy sampling of the source spectrum we looked for other high-energy observations of 1E1743.1-2843, performed approximately during the same period. We adopted three *XMM-Newton* observations performed in imaging mode during September 2012, for a total exposure time of 90 ks. Observation 0694640401 however, is strongly contaminated by solar emission, we therefore decided to not use it, reducing the useful exposure time to 65 ks. The *XMM-Newton* EPIC-pn camera provides data with nominal accuracy in the 0.3–10 keV energy band (XMM-Newton SOC team 2014), providing a good overlap with the *NuSTAR* data, thereby minimizing possible bias in the spectral modeling.

The *NuSTAR* observations are not simultaneous with *XMM-Newton*, but due to the small difference in time (few weeks, see Table 1), and since 1E1743.1-2843 does not usually exhibit substantial spectral variability (Cremonesi et al. 1999), we jointly fit the two datasets with a cross-normalization factor to account for any flux variation. During the observations the difference of source fluxes measured by the two instruments in the overlapping energy band (3–10 keV) was below 1.3%, indicating a good compatibility of the datasets.

3. DATA ANALYSIS

3.1. NuSTAR

We analyzed the *NuSTAR* data set (obsID 40010005001) using the *NuSTAR* Data Analysis Software (NuSTARDAS) version 1.3.1 (9 December 2013), HEASOFT 6.15.1, and the most updated calibration files and responses. The software applies offset correction factors to the energy response to account for the movement of the mast that causes a varying position of the focal spots on the detector planes. For the data from each of the two modules, the pipeline produces an image, spectrum and deadtime corrected lightcurve. For each *NuSTAR* observation, the source and background subtraction regions must be carefully evaluated due to the possible presence of contaminating sources outside the FoV that induce stray light patterns on the detectors. Unfortunately the *NuSTAR* detectors are not entirely shielded from unfocused X-rays, and this stray light can be significant if there are bright X-ray sources within $\sim 2–3$ degrees from the pointing direction (Krivonos et al. 2014; Wik et al. 2014; Mori et al. 2015). In this observation FPMB is highly contaminated by two different stray light patterns, as can be seen in Figure 1, and furthermore the source focal spot straddles the two different patterns. Due to the complexity of separating the source emission from the stray light we decided to discard all the data from FPMB.

The source spectra are shown in Figure 2, and were

Table 1
NuSTAR and XMM-Newton observations of 1E1743.1-2843.

Obs.Id	Revolution	Satellite	Start (UTC)	End (UTC)	Exposure time (s)
40010005001	-	NuSTAR	2012-10-15 13:31:07	2012-10-16 05:41:07	25993
0694640401*	2332	XMM-Newton	2012-09-02 19:33:02	2012-09-03 11:20:55	24830
0694640501	2334	XMM-Newton	2012-09-05 21:16:14	2012-09-06 09:46:55	29581
0694641201	2344	XMM-Newton	2012-09-26 06:17:37	2012-09-26 17:24:59	35540

Note. — * Data from obs. 0694640401 were not used in the analysis.

obtained by extracting photons in an elliptical region of $95'' \times 46''$ semi axis, rotated by 35 degrees clockwise relative to north and centered on the source centroid, and subtracting count rate measured in a nearby circular background region of radius $114''$ (see Figure 1). The different area normalizations were taken into account in the background subtraction. The dead layer thickness of the two modules varies depending on the location on the detector and, since the pipeline could fail to correct the response matrix for this effect to a suitable accuracy for high off-axis angles, we decided to ignore the data below 5 keV. Also, due to imperfect background subtraction, the data above 40 keV were ignored. All data bins were grouped to reach at least 30 counts. The total source count rate in this energy range is 2.10 ± 0.01 cts/s.

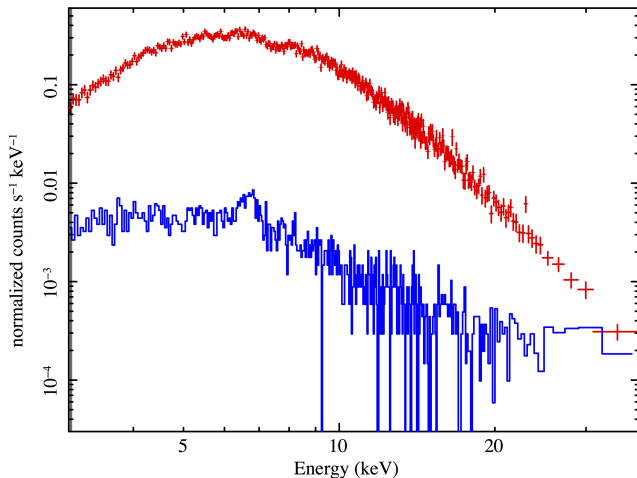


Figure 2. Spectrum acquired from the NuSTAR FPMA extraction region. The red crosses indicate the source spectrum rebinned to have at least 5σ significance and 30 counts for each bin. The blue line is the background spectrum.

3.2. XMM-Newton

We extracted the spectra of the EPIC-pn camera in the 0.3 – 10 keV energy range following the standard procedure described in the XMM-Newton software analysis guide¹³ for the observations 0694640401, 0694640501, and 0694641201, using the SAS software release xmm-sas_20131209_1901-13.5.0. The lightcurves and spectra of 1E1743.1-2843 were extracted from annular extraction regions excluding zones where the number of counts exceeded 800 to avoid pileup if present (see Figure 3). The lightcurves are shown in Figure 4.

EPIC-pn data below 0.3 keV are mostly related to artifacts and noise and were excluded (XMM-Newton SOC team 2014), and all the bins were grouped to reach at least 30 counts. The mean count rate for the two observations is 2.62 ± 0.01 cts/s.

3.3. Timing analysis

A lightcurve of the NuSTAR observation with 10 ms time bin resolution was extracted for FPMA in the energy range 3–60 keV¹⁴ using *nuproducts*. Timing data were corrected for deadtime and for arrival times at the Solar System barycenter, using the JPL 2000 ephemeris (Standish 1982) (for this purpose, we used the barycorr tool in the HEASOFT 6.16 distribution). We then calculated the power spectra on different contiguous time intervals and averaged them into a total spectrum. Each single spectrum was built using intervals of 32768 bins, and the total spectrum was built averaging 87 intervals in a single frame. This was finally rebinned in frequency channels for more statistics. An offset constant term was subtracted from the total spectrum to remove the Poisson noise level and compensate for residual effects of the deadtime correction (this term was evaluated as the average power in the frequency interval 10–49 Hz). The resulting power spectrum is shown in Figure 5. The statistics is too poor to model the power spectrum with a multi-parameter function (such as a Lorentzian). Signal is detected only up to frequencies of ~ 0.1 Hz, with some hint of complex structure, like the presence of a possible break at frequencies > 0.02 Hz.

We also performed a Lomb-Scargle periodogram of the same frequency interval as the power spectrum, and found no significant signal. The power spectrum and Lomb period analysis were also performed for the two XMM-Newton observations, also yielding no positive detection of periodicities.

3.4. Spectral analysis

We analyzed the NuSTAR and the XMM-Newton datasets using XSPEC (Arnaud et al. 1996) version 12.8.0, using the TBabs with abundances set as in Wilms et al. (2000) and cross sections set as in Verner et al. (1996) to model the effect of X-ray absorption. We performed the fit allowing the normalizations among the three different observations to vary. These normalizations relative to the different XMM-Newton datasets remained constant for every model, and were found to be $C_1 = 0.99 \pm 0.01$, $C_2 = 1.00 \pm 0.01$ for observations 0694641201 and 0694640501, respectively.

We used the following four models to figure out the nature of the source, the first three of which were used to test the origin of the low-energy emission:

¹³ The XMM-Newton ABC Guide: An Introduction to XMM-Newton Spectral Analysis

¹⁴ The low energy range is different from the one used in the Spectral analysis section, in the attempt to maximize the SNR

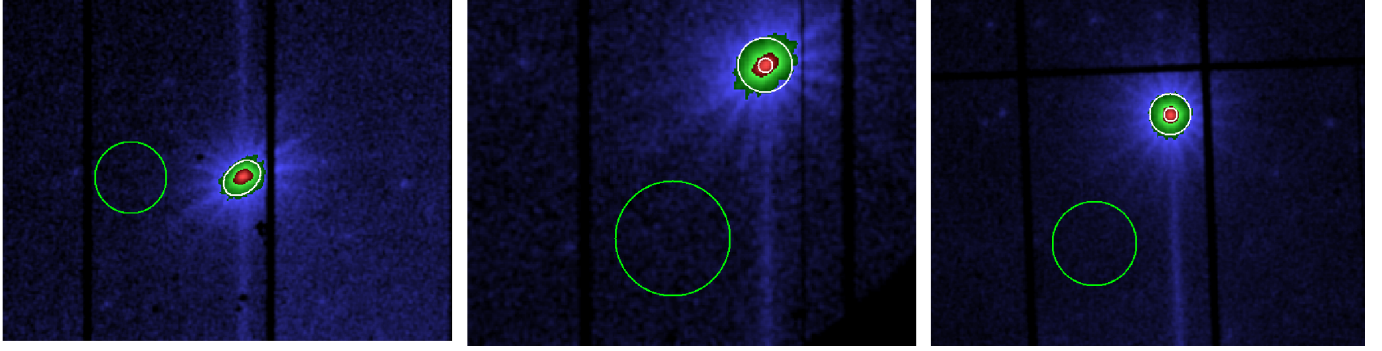


Figure 3. Images of 1E1743.1-2843 from *XMM-Newton* EPIC-pn camera. White ellipses show the annular extraction region, and green circles show the background regions. The bright central zone of the source was excluded due to pileup in the central and rightmost panels, while the pileup threshold was not exceeded in the leftmost one (thus no inner ellipse was plotted on the image).

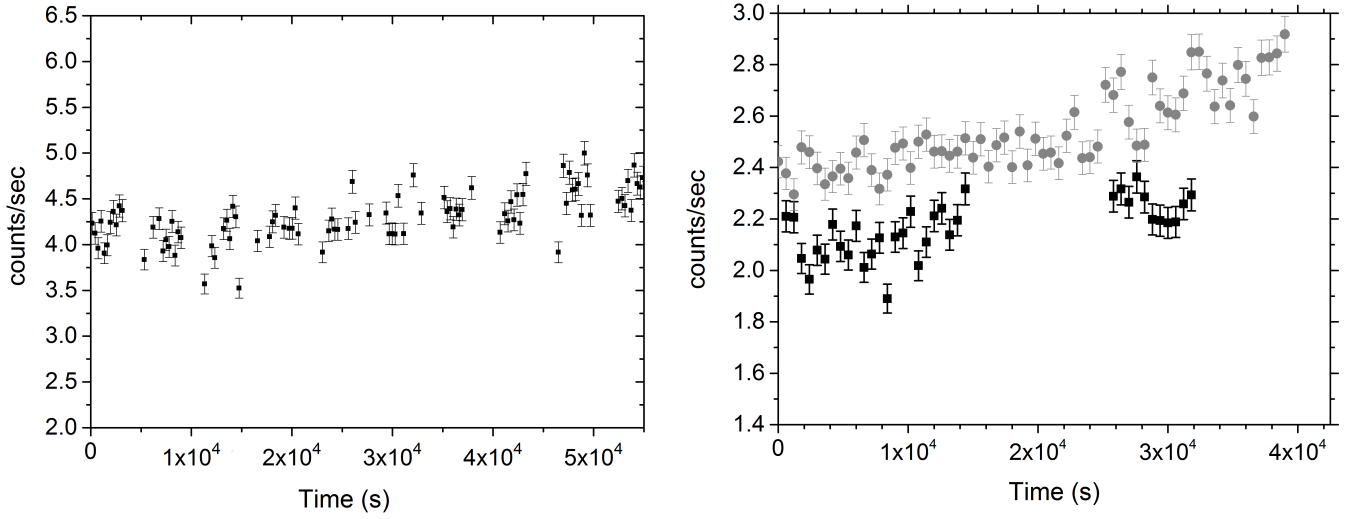


Figure 4. Light curves of 1E1743.1-2843 acquired from the *NuSTAR* FPMA in the 3 – 80 keV energy range (left, 300 s bins), and from the two *XMM-Newton* analyzed observations in the 0.3 – 10 keV energy range (right, 600 s bins, observation 0694640501 and 0694641201 in black and grey, respectively).

- Model 1: a black body (`bbodyrad`) and a power-law with a high-energy cutoff (`power-law × highEcut`). This is a typical single-component spectral model, and assumes the source is a neutron star binary.
- Model 2: a disk black body (`diskbb`) plus a `power-law × highEcut`. This is also a typical single-component spectral model, but assumes the compact source is a black hole binary.
- Model 3: a disk black body (`diskbb`), a black body (`bbodyrad`), and the `power-law × highEcut`. This model probes deeper into the neutron star hypothesis, adding an accretion disk component to model 1.
- Model 4: a disk black body (`diskbb`), a black body (`bbodyrad`), and the `compTT` Comptonization model. In this model the powerlaw in model 3 is replaced by a more physical model.

To model the emission from the accretion disk we used the multi-color disk black body `diskbb` model mentioned before (Mitsuda et al. 1984; Makishima et al. 1986).

The fit results shown in Table 2 indicate that the source emission is mainly contributed by a prominent blackbody component at ~ 2 keV plus a high energy continuum which can be described equally well by an empirical law (`power-law × highEcut`) or by a thermal Comptonization (`compTT`) component. As can be seen from Table 2 all the models provide a good fit of the data. In the following we will assume as baseline model 3, since it provides the lowest χ^2 value, and a reasonable physical interpretation of the data, as discussed in section 4.

Adding another absorption component with partial covering (`pcfabs`) to model 1 did not improve the fit results, therefore we conclude that the source is not partially obscured. Also, the spectroscopic data do not need the addition of further high energy components such as, for instance, reflection, as we verified by adding the `coplrefl` (Ballantyne et al. 2012) reflection component

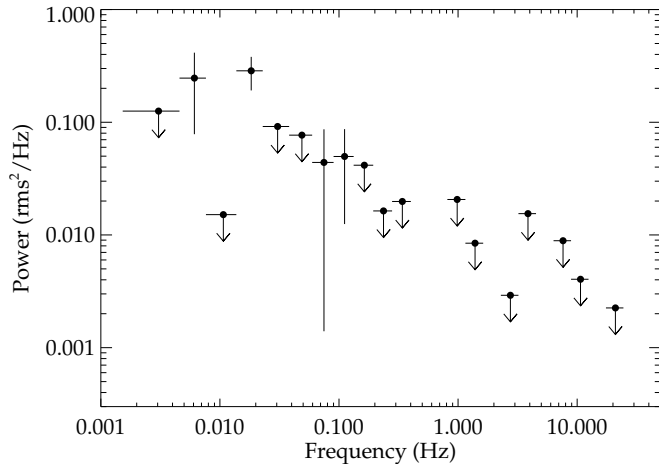


Figure 5. Power spectrum of the *NuSTAR* observation of 1E1743.1-2843, with indication of a low frequency break at frequencies > 0.02 Hz. Upper limits are 1σ .

to model 3.

We then addressed the high-energy component taking as a baseline model 3 and replacing the power-law plus cutoff component with a more physical model, specifically `compTT` (Titarchuk et al. 1994), which describes the Comptonization of soft photons in a thermal plasma of high-energy electrons above the accreting source. In the resulting model 4 the `compTT` component gives a worse fit than the power-law with an exponential cutoff (model 3). However, model 4 still yields a better fit than models 1 and 2, and has the advantage of allowing a more physical interpretation of the source spectrum than the empirical model 3. Furthermore, we tested if a single thermal component and a Comptonized one could fit the data, and replaced the power-law in model 1 with the `compTT` model. However this resulted in a worse fit ($\chi^2_{red} \sim 1.07$). Finally, if we test model 4 for the presence of the fluorescence line of neutral iron, χ^2_{red} rises to 1.2. Therefore the presence of the iron K_α line is also not required. From model 4 we derive an upper limit on the iron K_α equivalent width (EW) of 4.9 eV.

Summarizing, model 3 and model 4 give the best results. Model 3 has the lower reduced χ^2 value among the two, though the `compTT` model allows the determination of the physical parameters of the source. The resulting spectra for model 4 are shown in Figure 3.4, and the results of the overall fits in are reported in Table 2.

4. DISCUSSION

In this work we have reported on a broad band (0.3 – 40 keV) spectral analysis of 1E1743.1-2843, observed with *NuSTAR* and *XMM-Newton*. A similar analysis had previously been performed using *INTEGRAL* data (Del Santo et al. 2006), but the improved energy resolution and sensitivity of *NuSTAR* allows us to better constrain the hard X-ray continuum, identifying the presence of Comptonization and of a cutoff in the high-energy emission for the first time. This allowed to use more sophisticated models compared to previous works (Del Santo et al. 2006; Porquet et al. 2003; Cremonesi et al. 1999). Below we summarize the results obtained and discuss the ones that support either

the LMXB or HMXB nature of the system.

Regarding the low-energy emission of the source, the presence of the $kT=1.8$ keV black body is a strong indication of a neutron star nature of the compact object. The black body radius is ~ 1 km if we assume the source to be located in the Galactic Center, at $d \sim 8.8$ kpc. This is not compatible with emission from a boundary layer near the neutron star surface ($R_{BL} - R_{NS} \sim 2$ km for low $\dot{M}$, Popham & Sunyaev 2001), but is consistent with emission from a restricted region of the neutron star surface (i.e., from an equatorial belt in the orbital plane, or with magnetically driven accretion onto polar caps). In the latter case the magnetic field strength of the compact source should be $> 10^9$ G. There is possibly a soft excess which could be interpreted as weak emission from an accretion disk ($kT \sim 0.1$ keV). However, the *XMM-Newton* data were unable to constrain the black body normalization due to the high hydrogen column absorption ($N_H \sim 1.6 \times 10^{23} \text{ cm}^{-2}$). In the HMXB scenario this soft excess could also be interpreted as a blend of emission lines, as thermal emission from the neutron star surface, or Thomson scattering of the hot spot emission by the accreting material (van der Meer et al. 2004). The reliability of the soft excess detection is worth discussing, because the χ^2 improvement it provides is moderate. The use of the F-test could result in unreliable results (Protassov et al. 2002), so we performed a series of Monte Carlo simulations with the *simftest* routine to confirm the presence of such component, following the approach described by Bhalerao et al. (2015). The highest $\Delta\chi^2$ obtained in 10000 simulations is 18.7, significantly lower than $\Delta\chi^2 = 43.2$ obtained by the real data (see Figure 7). We estimate that $> 10^9$ simulations would be required to get $\Delta\chi^2 > 40$, corresponding to a significance higher than 6σ . Nevertheless, even if the presence of the soft excess is statistically preferred, we cannot exclude that the low energy spectrum is affected by systematics, which could arise, e.g., in adding two exposures taken at different epochs. We regard this as a result that needs to be confirmed by better quality low energy data from future observations of this source.

The presence of a neutral iron K_α line at 6.4 keV is not statistically required, with an upper limit on the EW of 4.9 eV from model 4 (6.7 eV from model 3). This value is compatible with the expected properties of LMXB (Asai et al. 2000) and radio-quiet quasars (George et al. 2000), as already pointed out by Porquet et al. (2003). This weakens the HMXB hypothesis for this source, since the iron line is usually detected in such systems. On the other hand, lack of the Fe K_α line in LMXBs is very common, and is usually associated with the Baldwin effect: the high luminosity of the X-ray source increases the degree of iron ionization (Torrejon et al. 2010).

The high-energy emission is characterized by a power-law ($\Gamma \sim 1.3$) with a high-energy cutoff ($E_{cut} \sim 7.2$ keV), identified for the first time thanks to the *NuSTAR* hard X-Ray sensitivity. The *NuSTAR* data also unambiguously identified the presence of a Comptonization component, induced by an electron population with temperature of a few keV ($kT_0 \sim 4.6$ keV, in accordance with the exponential cutoff value found), indicating a large viewing angle (see Matsuoka et al. 2013). Even

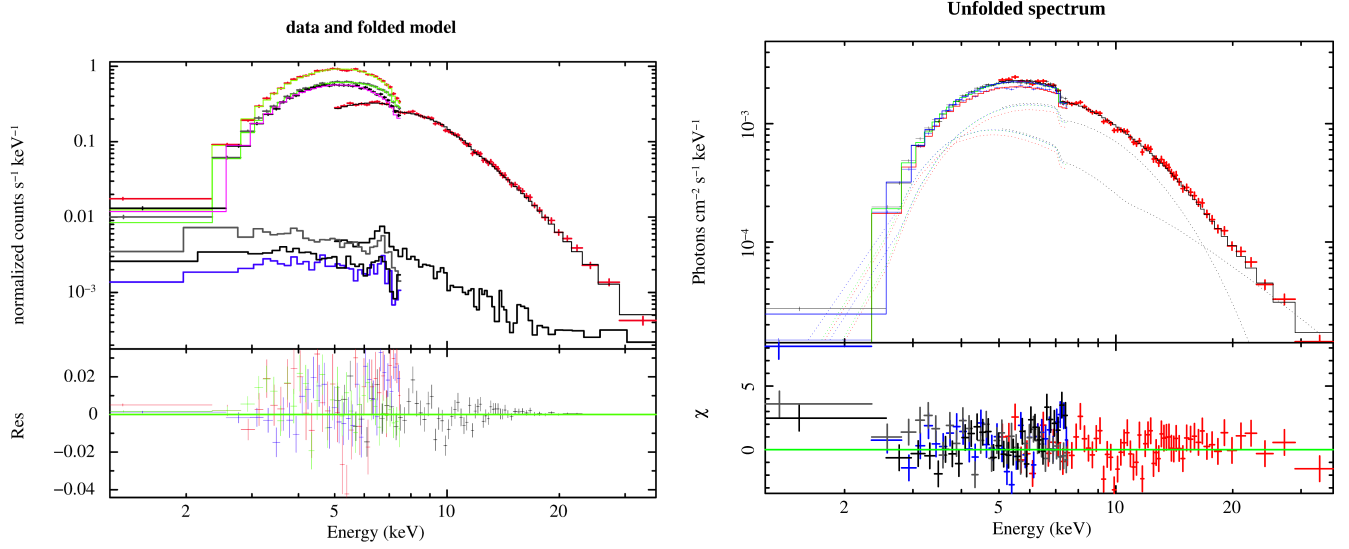


Figure 6. Left - folded spectra, backgrounds and residuals with respect to model 4 for all the spectra analyzed. Right - the analyzed spectra, unfolded through model 4. The plots are rebinned in groups of 30 channels for display purposes.

Table 2
Fit results of the *NuSTAR* and *XMM-Newton* observations.

XSPEC Model	Parameter	Units	Model 1	Model 2	Model 3	Model 4
TBabs	N_H	10^{22} cm^{-2}	$14.8^{+0.9}_{-0.8}$	16.6 ± 0.5	$16.5^{+1.0}_{-1.3}$	$15.3^{+0.8}_{-1.1}$
bbbodyrad	kT	keV	1.8 ± 0.1		$1.8^{+0.1}_{-0.2}$	1.83 ± 0.05
bbbodyrad	norm ^a		$1.3^{+0.5}_{-0.3}$		1.0 ± 0.3	$1.7^{+0.4}_{-0.2}$
diskbb	kT_{in}	keV		$2.4^{+0.2}_{-0.3}$	$0.12^{+0.04}_{-0.02}$	$0.12^{+0.04}_{-0.03}$
diskbb	norm ^b			$0.19^{+0.1}_{-0.08}$	—	—
power-law	Γ		$1.0^{+0.3}_{-0.5}$	$0.9^{+0.3}_{-0.4}$	$1.3^{+0.2}_{-0.3}$	
power-law	norm ^c		$0.009^{+0.007}_{-0.006}$	$0.01^{+0.01}_{-0.005}$	0.02 ± 0.01	
highcut	cutoffE	keV	6.6 ± 0.4	6.9 ± 0.30	$7.2^{+0.4}_{-0.7}$	
highcut	foldE	keV	$8.1^{+1.7}_{-1.5}$	$6.3^{+0.5}_{-1.3}$	$9.0^{+1.8}_{-1.3}$	
compTT	T_0	keV				$0.014^{+8.4}_{-2.9}$
compTT	kT	keV				$4.6^{+0.6}_{-0.4}$
compTT	τ_p					$6.2^{+6.5}_{-1.4}$
compTT	norm ^d					$0.031^{+93}_{-0.013}$
χ^2			2798.3	2835.4	2766.4	2785.0
d.o.f.			2637	2637	2635	2635
reduced χ^2			1.061	1.075	1.050	1.057

Note. — The errors are expressed with 90% confidence. Parameters not reported were not constrained by the fit.

^a R_{km}^2/D_{10}^2 , where R_{km} is the source radius in km, and D_{10} is the distance to the source in units of 10 kpc.

^b $(R_{in[km]}/D_{10})^2 \cos\theta$, where $R_{in[km]}$ is the apparent disk radius, and θ is the angle of the disk ($\theta = 0$ is face-on)

^c The powerlaw component normalization in units of photons $\text{keV}^{-1} \text{ cm}^{-2} \text{ s}^{-1}$

^d The thermal Comptonization component normalization in units of photons $\text{keV}^{-1} \text{ cm}^{-2} \text{ s}^{-1}$

if X-rays are produced near the neutron star at energies of several tens of keV, the observed X-rays will be shifted to lower energy due to Comptonization by the more distant low-energy plasma with a temperature several keV. This Comptonization component has a strong interplay with the 1.8 keV black body up to ~ 20 keV, since the total hard X-ray spectrum cannot be described as a single power-law. We tested for the presence of a reflection component, and found that it is not required to explain the data. A fit with a power-law model without breaks brought higher values of the

photon index ($\Gamma = 2.3^{+0.08}_{-0.09}$), compatible with previous results (Del Santo et al. 2006; Porquet et al. 2003; Cremonesi et al. 1999), but also produced a higher value of the $\chi^2/d.o.f. = 2880.79/2639 = 1.09$ compared to the one obtained with the high-energy cutoff ($\chi_{red}^2 = 1.05$; see Table 2), indicating that using the former description for the higher-energy data is marginally justified at best.

The source luminosity is $L_{2-10 \text{ keV}} \sim 1.5 \times 10^{36} d_{10 \text{ kpc}}^2 \text{ erg s}^{-1}$, so if we assume that the source is located in the Galactic Center we obtain $L_{2-10 \text{ keV}} \sim 10^{36} \text{ erg s}^{-1}$, within the typical range of luminosity

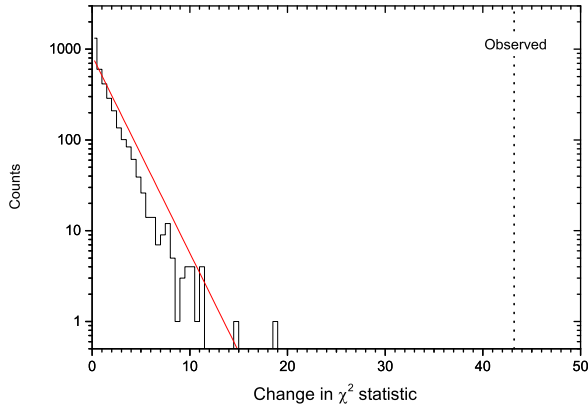


Figure 7. Results of Monte Carlo simulations for testing the presence of the disk component. We simulated the spectra from model 3 without (our null-hypothesis) and with the disk component. The histogram shows the $\Delta\chi^2$ obtained in 10000 simulations (in black), together with the $\Delta\chi^2$ distribution expected from the addition of 2 free parameters (red line). The vertical dashed line is the $\Delta\chi^2$ value obtained from the actual data (43.19).

for X-ray bursters (Cremonesi et al. 1999; Bildsten 2000). To investigate further, we have extracted the *K*-band image of the Vista survey “VISTA Variables in the Via Lactea (VVV)” (Minniti et al. 2010) (see Figure 4). Both the *XMM-Newton* and *Chandra* positions of 1E1743.1-2843 are visible in the image, as well as the position of the source UGPS J174621.12284343.3 as reported in the UKIDSS catalogue (Lawrence et al. 2007). The nominal accuracy of UKIDSS is ~ 0.1 arcsec, but to account for source confusion in this crowded region we used a larger 0.3 arcsec positional error, as suggested by Lucas et al. (2008). We should consider whether this source might be the counterpart. In the UKIDSS catalog, this source does not have a *K*-band magnitude listed, but it has $H = 16.82 \pm 0.09$ and $J = 18.39 \pm 0.08$. Assuming the $0.21''$ uncertainty on the *Chandra* position (Evans et al. 2010), then this source is excluded, as can be seen in the figure. Also, given the extreme IR source crowding in the GC, the fraction of true-to-candidate counterparts for hard *Chandra* sources is very low (see, for instance De Witt et al. 2010). Furthermore, since the *NuSTAR*/*XMM-Newton* column densities are consistent with the overall Galactic Center value, it is not likely that the companion star is hidden by a cloud either. However, we cannot exclude a high mass companion solely on the basis of the absence of a bright IR source. In fact, a B-type star placed at the distance of 8.5 kpc could have IR magnitudes fainter than the limiting *H*-band magnitude of the vista surveys of the Galactic Center (McMahon et al. 2013), assuming an IR absorption corresponding to the hydrogen column density we measured for 1E1743.1-2843 (see Table 2).

In the LMXB hypothesis the fact that not a single burst has been observed in over 20 years suggests that the source is a rare burster (in ’t Zand et al. 2004). In principle, the lack of bursts could be explained if the source is located outside the Galaxy. Specifically, to reach $L = 2.9 \times 10^{37} \text{ erg s}^{-1}$, corresponding to the stable

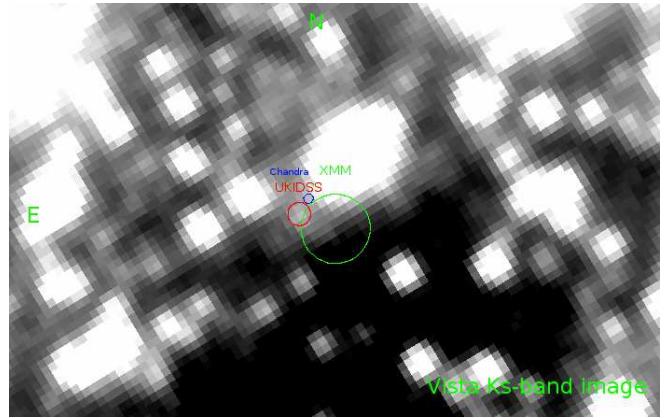


Figure 8. The *Ks*-band image of 1E1743.1-2843 obtained with Vista. The *Chandra* and *XMM-Newton* positions of 1E1743.1-2843 are shown, together with the position of UGPS J174621.12284343.3 as reported in the UKIDSS catalogue (coordinates: R.A. = 17:46:21.13, $\delta = -28:43:43.17$ J2000). The *Chandra* error circle excludes the possibility of this source being the counterpart.

burning of accreted material, 1E1743.1-2843 would need to be placed at $d \sim 40$ kpc. However, a study of the stability conditions for accreting objects (Narayan et al. 2002) indicates that, for a neutron star with a surface temperature of ~ 2 keV, there is a luminosity range where stable accretion is possible, between the instability regions where He and H bursts are triggered. This “stability strip” corresponds roughly¹⁵ to luminosities $1.3 \times 10^{36} < L < 6.5 \times 10^{36} \text{ erg s}^{-1}$. This implies that if the source is located between the Galactic Center and ~ 16 kpc the lack of bursts is to be expected, as well as the lack of the detection of an IR companion.

Church et al. (2014) recently proposed a unified model for the LMXB sources. The model assumes the presence of an extended accretion disk corona (ADC). For $L > 1 - 2 \times 10^{37} \text{ erg s}^{-1}$ the ADC is in thermal equilibrium with the neutron star surface, giving rise to a Comptonized spectrum with $E_{\text{cut}} \sim 6$ keV, which corresponds roughly to three times the actual temperature of the electrons (in the assumption of high optical depth). For lower luminosities, the Comptonization becomes inefficient in cooling the corona, the thermal equilibrium assumption breaks down and, as a consequence, the extended ADC heats up to several tens of keV. In this scenario the ~ 1 km black body radii in LMXBs are explained by an emitting region in the shape of an equatorial strip in the orbital plane with a half height $h \sim 100$ m. This scenario is described by a black body plus a cutoff power-law (our model 1). The authors also note that compTT is not consistent with the evidence for an extended corona. The outer regions of the accretion disk ($kT \sim 0.1$ keV), which provide the seed photons for the Compton scattering, are not expected to be detected. Our results for the black body temperature ($kT \sim 1.8$ keV) and radius ($r \sim 1$ km), for the $E_{\text{cut}} \sim 3kT_{e-} \sim 6.6$ keV of the Comptonized component, and for the ratio of total to black body luminosity for 1E1743.1-2843 fit within the expected ranges

¹⁵ Exact boundaries depend weakly on the neutron star radius.

for the scenario they depict as the Banana state of the Atoll sources. This interpretation, however, implies $L > 2 \times 10^{37} \text{ erg s}^{-1}$ to explain the spectral cutoff value and the lack of bursting activity. This would require a distance of a few tens of kpc to account for the observed flux, which could be explained if 1E1743.1-2843 were in the Sagittarius dwarf elliptical galaxy (SAGDEG), one of the small dwarf spheroidal galaxies that orbits the Milky Way. SAGDEG is currently behind the GC at distance $d \sim 26 \text{ kpc}$ (Cole et al. 2009), and is in an advanced state of destruction due to tidal interactions with the Galaxy. Therefore a fraction of the stars that composed this dwarf galaxy have likely scattered to even greater distances.

In the HMXB scenario, the presence of a strong magnetic field ($B \sim 10^{12-13} \text{ G}$) suppresses the propagation of the bursts across the neutron star surface (Gilfanov et al. 2014). However the lack of eclipses, Fe K_α line, and pulsations in the light curve, as well as the missing detection of a companion star, makes the HMXB hypothesis less favored, even though the value of the spectral cutoff ($9 \pm 1.8 \text{ keV}$) is compatible with the one expected from HMXBs ($10 - 20 \text{ keV}$).

We conclude that while an HMXB framework leaves several unexplained features, interpreting 1E1743.1-2843 as a NS-LMXB scenario is more consistent, implying a peculiar but not a unique object. In this case the source could be located at a distance $9 < d < 16 \text{ kpc}$, between the two instability luminosity intervals where He and H bursts are triggered or, if we rely on the unified model proposed by Church et al. (2014), at a distance $d > 36 \text{ kpc}$, corresponding to the stable burning of accreted material.

This work was supported under NASA Contract No. NNG08FD60C, and made use of data from the *NuSTAR* mission, a project led by the California Institute of Technology, managed by the Jet Propulsion Laboratory, and funded by the National Aeronautics and Space Administration. We thank the *NuSTAR* Operations, Software and Calibration teams for support with the execution and analysis of these observations. This research has made use of the *NuSTAR* Data Analysis Software (NuSTARDAS) jointly developed by the ASI Science Data Center (ASDC, Italy) and the California Institute of Technology (USA). The Italian authors acknowledge the Italian Space Agency (ASI) for financial support by ASI/INAF grant I/037/12/0. RK acknowledges support from Russian Science Foundation (grant 14-22-00271).

REFERENCES

- Arnaud, K. A., 1996, in *Astronomical Data Analysis Software and Systems V*, ed. G. H. Jacoby, J. Barnes, Vol. 101, 17
- Asai, K., Dotani, T., Nagase, et al. 2000, *ApJS*, 131, 2, pp. 571-591
- Ballantyne, D. R., Purvis, J. D., Strausbaugh, R. G., et al. 2012, *ApJL*, 747, L35
- Bhalerao, V., Romano, P., Tomsick, J., 2015, *MNRAS*, 447, 3
- Bildsten, L., 2000, in *AIP Conf. Proc.* 522, *Cosmic Explosions: Tenth Astrophys. Conf.*, ed. S. S. Holt & W. W. Zhang (Melville, NY: AIP), 359
- Bird, A. J., Bazzano, A., Bassani, L., 2010, *ApJS*, Vol. 186, 1
- Church, M. J., Gibiec, A., Bałucińska-Church, M., 2014, *MNRAS*, 438, 4
- Cole, N., Newberg, H. J., Magdon-Ismael, M. et al., in *Astronomical Data Analysis Software and Systems XVIII ASP Conference Series*, Vol. 411, p. 221
- Cowley, A. P., Crampton, D., Hutchings, J. B., et al. 1983, *ApJ*, 272, 118
- Cremonesi, D., Mereghetti, S., Sidoli, L., & Israel, G. L. 1999, *A&A*, 345, 826
- Del Santo, M., Sidoli, L., Bazzano, A., et al. 2006, *A&A*, 456, 1105
- De Witt, C., Bandyopadhyay, R. M., Eikenberry, S. S., et al. 2010, *ApJ*, 721, 2
- Evans, I. N., Primini, F. A., Glotfelty, K. J., et al. 2010, *ApJS*, 189, 37
- George, I. M., Turner, T. J., Yaqoob, T., et al. 2000, *ApJ*, 531, 52
- Gilfanov, M. R. & Sunyaev, R. A. 2014, *Physics-Uspekhi* 50, 4
- Harrison, F. A., Craig, W. W., Christensen, F. E., et al. 2013, *ApJ*, 770, 103
- Kawai, N., et al. 1988, *ApJ*, 330, 130
- Krivonos, R. A., Tomsick, J. A., Bauer, F. E., et al. 2014, *ApJ*, 781, 107
- Lawrence, A., Warren, S. J., Almaini, O., et al. 2008, *MNRAS*, 379, 1599
- Lu, F. J., 1996, *A&A*, 115, 395
- Lucas, P. W., Hoare, M. G., Longmore, A., et al. 2008, *MNRAS*, 391, 136
- Madsen, K., Harrison, F. A., Markwardt, C. 2015, *ApJS*, 220, 1.
- Makishima, K., et al. 1986, *ApJ*, 308, 635.
- Matsuoka M., Asai K., 2013, *PASJ*, 65, 26
- Muno, M. P., Bauer, F. E., Baganoff, F. K., et al. 2009, *ApJS*, Vol. 181, 1
- McMahon, R. G., Banerji, M., Gonzalez, E., et al. 2013, *The Messenger*, 154, 35
- McNamara, D. H., Madsen, J. B., Barnes, J., et al. 2000, *PASP*, 112, 202
- van der Meer, A., di Salvo, T., Kaper, L., et al. 2004, in *Nuclear Physics B - Proceedings Supplements*, Vol. 132, p. 624-627
- Minniti, D., Lucas, P. W., Emerson, J. P., et al. 2010, *New Astronomy*, 15, 433
- Mitsuda, K., et al. 1984, *PASJ*, 36, 74,
- Mori, K., et al. 2015, Submitted to *ApJ*
- Narayan, R., & Heyl, J. S. 2002, *ApJ*, 574, L139
- Pavlinsky, M. N., Grebenev, S. A., & Sunyaev, R. A. 1994, *ApJ*, 425, 110
- Popham, R., & Sunyaev, R. 2001, *ApJ*, 547, 355
- Porquet, D., Rodríguez, J., Corbel, S., et al. 2003, *A&A*, 406, 299
- Protassov, R., & van Dyk, D. A. 2002, *ApJ*, 571, 545-559
- Standish, M., 1982, *A&A*, 114, 297
- Sunyaev, R., et al. 1991, *Adv. Space Res.*, 11, 177
- Titarchuk, L.G., et al. 1994, *ApJ*, 434, 570
- Torrejón, J. M., Schulz, N. S., Nowak, M. A., & Kallman, T. R. 2010, *ApJ*, 715, 947
- Verner, D. A., et al. 1996, *ApJ*, 465, 487
- Watson, M. G., Willingale, R., Hertz, P., & Grindlay, J. E. 1981, *ApJ*, 250, 142
- Wik, D.R., Hornstrup, A., Molendi, S., et al. 2014, *ApJ*, 792, 48
- Wilms, Allen & McCray, 2000, *ApJ*, 542, 914
- XMM-Newton Science Operations Centre Team, 2014¹⁶
- in 't Zand, J. J. M., et al. 2004, *Nucl. Phys. B Proc. Suppl.*, 132, 486