BROAD-BAND SPECTRAL ANALYSIS OF GX 9+9: AN IRON FEATURELESS SOURCE

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Introduction

GX 9+9, is a low mass X-ray binary (LMXB) discovered during a sounding rocket observation of the Galactic Center (Bradt et al. 1968); together with GX 9+1, GX 3+1 and GX 13+1, the source has been classified as a bright atoll-type neutron star binary (Hasinger & van der Klis 1989). The distance to GX 9+9 is not well estabilished however, since the system is considered to be a Galactic bulge object, a distance of 5–7 kpc is usually adopted (Christian & Swank 1997; Schaefer 1990; Vilhu et al. 2007).

In this work we present a broad-band analysis of GX 9+9 in the 0.7–35.0 keV energy range from all the available, high quality BeppoSAX, XMM-Newton and Suzaku observations and we show that the Iron K emission line at 6.4–6.9 keV, which is a common spectral feature of many luminous LMXBs, is not significantly detected in the GX 9+9 spectrum.

Spectral Analysis

The aim of this work is to characterize the broad-band spectral properties of the source GX 9+9. As a first step, we investigated the spectral properties of GX 9+9 using a model consisting of a Comptonization component (*comptt*, Titarchuk 1994) plus a blackbody (*bbody*) and a soft component (*diskbb*), absorbed with *tbabs*. This model was able to satisfactorily describe the continuum emission and it gave a good spectral fit with a χ^2/dof = 5183.54/4177 (see Figure 1). Since the XMM-Newton, Suzaku and BeppoSAX observations were not simultaneous, we carefully took into account possible spectral variations, in particular leaving free to vary the column density and the blackbody component. We did not expect large changes in the absorption of the interstellar medium, but rather some small differences in the local absorber. By letting the column density to vary independently in the XMM-Newton, Suzaku and BeppoSAX spectra (*Model 1*), we found a slight variation of the equivalent hydrogen absorption column, N_H. In addition, we also left free to vary, among the instruments, the temperature and the normalization of the blackbody component. We noted that the temperature (kT_{bb}), for all of the spectra, was consistent with ~ 0.6 keV, that we could infer an emission radius of 27 ± 1 km (assuming a distance of 7 kpc). The *diskbb* component provided an inner disc temperature (T_{in}) of 0.29 keV, from which we estimated an inner radius in a range of 88–121 km using an inclination of 20° and 60°, respectively.

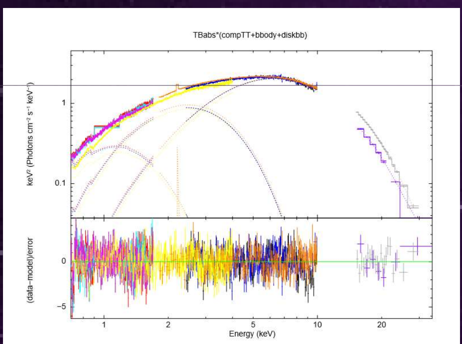

Figure 1: *Top panel*: Unfolded E2f(E) XMM-Newton/Epic-pn (black), XMM-Newton/RGS (red and green) [Obs. ID. 0090340601]; XMM-Newton/Epic-PN (blue), XMM-Newton/RGS (cyan and magenta) [Obs. ID. 0090340101]; BeppoSAX/LECS (yellow), BeppoSAX/MECS (orange), BeppoSAX/PDS (violet); Suzaku/PIN (grey). *Bottom panel*: Residuals with respect to the best fit model in unit of σ.

In order to test the possible presence of a reflection component we added to our continuum spectral model a self-consistent reflection model: the *rfxconv* convolution model (Kolehmainen et al. 2011); we convolved *rfxconv* with the Comptonization component and the multiplicative kernel (*rdblur*).

At first, we let free to vary only the reflection fraction for different values of the inclination angle (20° for the *Model 2-a* and 60° for the *Model 2-b*), whereas the other parameters were fixed at values tipically observed in many other accreting NS binary systems.

The relative reflection normalization took, in both model (*2-a* and *2-b*), a value lower than the typical values reported in literatures (Egron et al. 2013; Pintore et al. 2015; Di Salvo et al. 2015), but we cannot exclude that a weak reflection component is still present in the spectra.

Then, we fixed the reflection fraction at the tipically value of 0.3 and we let free to vary the Iron abundance, Fe_{abund}, for an inclination angle of 20° (*Model 2-c*) and 60° (*Model 2-d*) (see Table 1), respectively. The Fe_{abund} took a value of 0.1 that is very lower compared to the solar abundance; probabily the iron emission line is very weak and it cannot be produced by the reflection.

As expected, the best-fit with the self-consistent model did not show any significant statistical improvement compared to the results obtained with the *Model 1*. The blackbody and the disc temperature were consistent, within the errors, with the values reported for *Model 1*.

Model	Component	*1*	*2-a*	*2-b*	*2-c*	*2-d*
RDBLUR	*Betor*10 [a]	-	-2.5 (frozen)	-2.5 (frozen)	-2.5 (frozen)	-2.5 (frozen)
	R_{in} (R_g) [b]	-	10 (frozen)	10 (frozen)	10 (frozen)	10 (frozen)
	Inclination (degree) [c]	-	20 (frozen)	60 (frozen)	20 (frozen)	60 (frozen)
RFXCONV	Fe_{abund} [d]	-	1.0 (frozen)	1.0 (frozen)	$0.10^{+0.01}_{-0.1}$	0.1±0.1
	$log(\xi)$ [e]	-	2.65 (frozen)	2.65 (frozen)	2.65 (frozen)	2.65 (frozen)
	rel_{refl} [f]	-	$0.02^{+0.02}_{-0.01}$	$0.11^{+0.07}_{-0.06}$	0.3 (frozen)	0.3 (frozen)
TBABS	n_H (10^{22} cm^{-2}) [a]	0.27±0.01 *	0.27±0.02 *	0.27±0.02 *	$0.28^{+0.01}_{-0.02}$ *	0.28±0.01 *
COMPTT	kT_0 (keV) [b]	1.22±0.05	1.2±0.1	1.1±0.1	$1.10^{+0.07}_{-0.04}$	$1.12^{+0.03}_{-0.06}$
	kT_e (keV) [c]	$2.72^{+0.06}_{-0.05}$	$2.75^{+0.06}_{-0.05}$	$2.52^{+0.06}_{-0.04}$	$2.74^{+0.04}_{-0.03}$	$2.57^{+0.03}_{-0.04}$
	τ [d]	$10.5^{+0.6}_{-0.7}$	$11.0^{+0.6}_{-0.8}$	$12.4^{+0.6}_{-0.9}$	$11.5^{+0.3}_{-0.4}$	$11.6^{+0.6}_{-0.5}$
	$Norm_{Comp}$ [e]	$0.35^{+0.01}_{-0.02}$	0.35±0.02	0.40±0.02	0.34±0.02	$0.37^{+0.02}_{-0.01}$
BBODY	kT_{bb} (keV) [f]	0.60±0.01	0.60±0.02	0.57±0.02	0.59±0.02	$0.59^{+0.01}_{-0.02}$
	$Norm_{bb}$ (10^{-2}) [g]	2.5±0.1 *	2.4±0.1 *	2.1±0.2 *	1.9±0.1 *	2.1±0.1 *
DISKBB	T_{in} (keV) [h]	0.29±0.01	$0.29^{+0.02}_{-0.01}$	$0.29^{+0.02}_{-0.01}$	$0.30^{+0.02}_{-0.01}$	0.29±0.01
	$Norm_{disc}$ (10^4) [i]	$1.5^{+0.4}_{-0.3}$	$1.3^{+0.4}_{-0.3}$	$1.3^{+0.4}_{-0.3}$	$1.3^{+0.3}_{-0.4}$	1.4±0.3
	χ^2/dof	5183.53/4177	5178.45/4176	5171.67/4176	5226.51/4176	5175.54/4176

* Value for both *XMM-Newton* and *Suzaku* observations (*BeppoSAX* values are summarized in Table 2).
[a] Neutral column density. [b] Seed photons temperature; [c] electrons temperature; [d] electron optical depth; [e] normalization of the Comptonized component. [f] Blackbody temperature; [g] normalization of the blackbody in unit of L_{39}/D_{10}^2, where L_{39} is the source luminosity in units of 10^{39} erg/s and D_{10} is the distance to the source in units of 10 kpc. [h] Multicolor accretion disc blackbody temperature; [i] normalization of the disc.
Errors are at 90% for each parameter of interest.

Table 1: Best-fit spectral parameters obtained with the absorbed continuum *comptt+bbody+diskbb* for *Model 1* and *Model 2*. Errors are at 90% for each parameter of interest

Discussion and Conclusions

We analysed different observations of the source GX 9+9 taken, in timing mode, by different satellites (XMM-Newton, BeppoSAX and Suzaku) with the purpose to investigate the reflection properties of the source. We studied the X-ray emission from the source in the energy range 0.7–35.0 keV.

GX 9+9 is a bright accreting NS located in the direction of the Galactic Centre; from our best-fit continuum (*Model 1*), we estimated an unabsorbed total flux of ~ $4 \cdot 10^{-8}$ erg cm^{-2} s^{-1} and a luminosity of ~ $2 \cdot 10^{38}$ erg s^{-1} in an energy range 0.7–35.0 keV, assuming a distance of 7 kpc. To describe the properties of this source, we adopted a simple continuum model and a self-consistent model. From the continuum we found no evidence of significant residuals in the Iron line region. This makes GX 9+9 an atypical atoll source, since an broad iron emission line is usually detected in these systems. We noticed that no Iron emission feature was found in the spectra and that we could only estimate an upper limit to the equivalent width of the Iron line about 10^{-2}eV. These results suggest that the accretion geometry or the chemical properties of the source are different compared to with other atoll sources. To explain this lack, three possible scenario have been evaluated:

1. a high inclination angle of the system that would be able to damp the reflection component toward our line of sight;
2. 2. a high degree of ionization of the accretion disc which inhibits the formation of discrete emission features;
3. 3. a very low chemical abundance of the accreting matter due to a population II companion star.