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Contribution of GT-Mus to the 6.7 keV Emission Line from the Galactic Ridge

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Abstract: We performed the spectral analysis of Suzaku data on GT-Mus which was observed to emit 6.7 keV during its flaring period. GT-Mus was observed by the Suzaku team on December 12, 2007, with observation identity (402095010) for 96 kilo seconds. We downloaded GT-Mus data from the high energy astrophysics Suzaku archive. Our data reduction and analysis were done using XSELECT version 6.9 and XSPEC version 12.8. Errors reported in this work were done using the XPEC error command. We generated the spectrum and deduced a strong He-like (6.70 keV) emission from the source with Equivalent width of 282 ± 0.02 eV. This observed 6.7 keV emission line has an equivalent width which compares favorably with the equivalent width of 6.7 keV emission line from the galactic ridge (300-980 eV) depending on the Galactic position. From our analysis, we generated the light curve of the source which showed strong evidence of stellar flare. We therefore conclude that this observed stellar flare might be responsible for the observed 6.7 keV emission line. We however suggest that GT-Mus (HD101379) and other RS CVn stars that emit in 6.7 keV line could contribute to the 6.7 kev emission line from the galactic ridge during their flaring periods, since they exhibit the same level of chromospheric activities.

Keywords: Flare Stars, RS CVn, Galactic Ridge X-ray Emission

1. Introduction

Most red dwarf stars of late spectral type which increases in brightness within a few minutes are flares stars. Some researchers accept that flaring in stars occurs due to magnetic activities. The brightness can be seen across the electromagnetic spectrum from radio to X-ray wavelength. Examples of flare stars are found in some cataclysmic variable (CVs), Coronally active binaries (ABs) and Rs Cvn stars etc. though some brown dwarf stars have been reported to flare as well. The population of these red dwarf stars and their high flare activity suggest thatthese objects can give an essential contribution to the galactic background radiation [1-4]. This background radiation in the galactic plane and galactic center is referred as galactic x-ray emissions. Prominent features of these emissions are hard x-ray emissions which are associated with 6.4KeV, 6.7 KeV and 6.9 KeV. This hard galactic ridge X-ray emission has before now, remained a major puzzle in the galactic X-ray astronomy [5].

RS CVn are closed detached binaries which are tidally locked and rotate rapidly around each other at inclination of ~ 81° with orbital periods of about 2.87 days [6]. The rapid rotation of the component stars combined with deep convection envelopes produces a variety of magnetic activities and magnetic reconnection in the corona led to the release of energetic long duration sporadic stellar flare [7]. Hall classified RS CVn system as one in which the hotter star is of spectral type F-G, IV-V, in which the orbital period of the system is between one and fourteen daysand the cooler star shows a strong Call Hand K emission in its spectrum [8]. A prominent feature of RS CVn systems is their intense activity at radio, ultraviolet and x-ray wavelengths. Their X-ray luminosities which are inthe order of 10^{24} watts had been observed [9-13]. It was also proposed that the coronal model for this X-ray emission is different from that of the Sun only in scale [13]. Further research also demonstrates that there was a strong correlation between its rotational period and X-ray emission[14-15]. VLA observations showthat the average radio emission from RS CVn systems is about 10^{20} watts as compared with 10^{13} watts for the Sun [14]. Drake et al In 1986studied the radio emission of the short period RS CVn systems and found that they had a slightly lower mean radio luminosity (observed fluxes in the range 0.3 to 5.0 mJy) than active binaries of longer orbital period.

GT-Mus usually called a quadruple system consist of a Rs Cvn type binary and an eclipsing binary companion. This system had been mentioned by Mitrou et al as a type without any proven EUVE detection in the AI/Ti/C (160-240 A) and Lex/B (50-180 A) bands [15]. The system was reported by Dempsey et al [16] to be a ROSAT position-sensitive proportional counter PSPC of about 0·1-2·4 keV X-ray source, with a count rate of about 2·85±0·18 counts/s. The calculated X-ray luminosity was deduced to be Lx =39·43 x 10^{23} W. Gurzadyan & Cholakyan noted GT Mus for its unique stellar separation and strength of emission in the Mg II, 2800 ultraviolet doublet [17]. He thus concluded that it belonged to a class of close (a ~2·7 R0) binaries with a common chromosphere. This chromospheresurrounds both stars such that the source of chromospheric emissions may be a highly excited region between the stars.

Murdoch et al provided an orbital solution for the single-lined binary system HD 101379, derived from radial velocities [18]. This research is focused on RS CVn type binary source (HD 101379). The source under consideration is a detached binary driven by a high level of chromospheric activity [19]. Due to the active nature of the system's chromospheres, large stellar spots are detected. Powerful magnetic field in the stellar spots is generated due to the flow of gas and plasma down the surfaces of these stars. Being a detached binary, it centers of mass is within the binary separation hence, we can extrapolate that as the stars rotate, the magnetic field will move. Moreover, moving magnetic field can create an electric field, hence a moving electric field can equally create a magnetic field so if they can create each other, they will oscillate. This oscillation creates an electromagnetic radiation, which is likely what we observed as stellar flares that emit in 6.7 KeV.

A region in the galactic plane which emits in X-ray band is called a Galactic ridge X-ray emission. A hard continuum X-ray sources associated with 6.7 keV emission line from helium-like iron are some prominent features of GRXE. If this emission is thermal in origin, it implies a detectable plasma at a temperature of about 5-10 keV [20]. However, the 6.7 keV emission line is very bright in the Galactic Centre [21]. Muno et al. In 2003 and 2004, studied the galactic ridge and reported that binaries of a white dwarf, late-type dwarf star and cataclysmic variables (CVs), are the major contributors to the 6.7 keV emission line considering its population and thermal plasma with emission line [22-23]. In 2006, Revnivtsev et al. studied the contribution of X-ray sources from active binaries and demonstrated that active binaries (ABs) together with cataclysmic variables (CVs) produce the bulk of the galactic ridge X-ray emissions [24]. In this study, we have carried out a spectral analysis on GT-MUs (HD101379) and resolved a strong 6.7 keV emission line with an equivalent width of 282 eV. Our result compares favorably with the equivalent width of 6.7 keV emission line from the galactic ridge (300 - 980 eV) depending on the Galactic position [25-27]. Since GT-MUs (HD101379) is a member of RS CVn stars, we suggest that other RS CVn stars located at the galactic center which emit in 6.7 keV during their flaring periods could also contribute to 6.7 Kev emissions from the galactic ridge due to their similar chromospheric activities.

2. Data Analysis Results

We downloaded GT-Mus data from the high energy astrophysics Suzaku archive. GT-Mus was observed by the Suzaku team on December 12, 2007, with OBSID (402095010) for 96 kilo seconds. The data reduction and analysis were done using the High energy astrophysics software (HEAsoft) version 6.9 and XSPEC version 12.8. The desired extraction regions (source and background spectra) were done using XSELECT. We also extracted the XIS background with 200 arc radii from a circular region to create the background spectra. We made sure that there was no captured light from any apparent source that was offset from both the source and other corner calibrated source. On the X-ray imaging spectrometry, we extracted all events within 250 arc radii of GT-Mus for each of the X-ray imaging spectrometer (XIS) detectors to create the source spectra. The 250 arc radii suit the extraction well; hence there was no need for adjustment. The light curve was generated and we extracted only the portion where the source showed stellar flare (see Figure 1). The Response Matrix Files and Ancillary Response Matrix Files (RMF and ARF) were generated using X-ray imaging spectrometer Response Matrix Files generator (xisrmf-gene) and X-ray imaging spectrometer Ancillary Response Matrix Files generator (xissarmf-gene) software. The object under consideration is a point source;hence we centered our extraction region on the source specifically to deconvolve light from instrumental background.

We combined data from X-ray imaging spectrometers XIS0, XIS1 and XIS3 using XSPEC.

We also extracted the background and source spectra for each observation using the XSELECT filter time file routine program. Spectral analysis of our data was done using XSPEC version 12.8. We obtained all reported errors from the XSPEC error command embedded in the software. XSPEC is available via the High Energy Astrophysical Science Archive Research Center (HEASARC) online service, provided by NASA/GSFC. We modeled the spectrum using thermal bremsstrahlung model with a Gaussian line at 6.7 keV. Since we are primarily interested in the 6.7 keV emission line, we concentrated our spectral fittings within the energy band 4 - 8 keV. We resolved a strong He-like (6.70 keV) emission from the source with Equivalent width of 282 ± 0.02 eV which compares with the Equivalent width (300 - 980 eV) of 6.7 keV emission linefrom the Galactic ridge depending on the Galactic position [25-27]. The light curve is shown in Figure 1 and the spectrum of GT-Mus is shown in Figure 2.

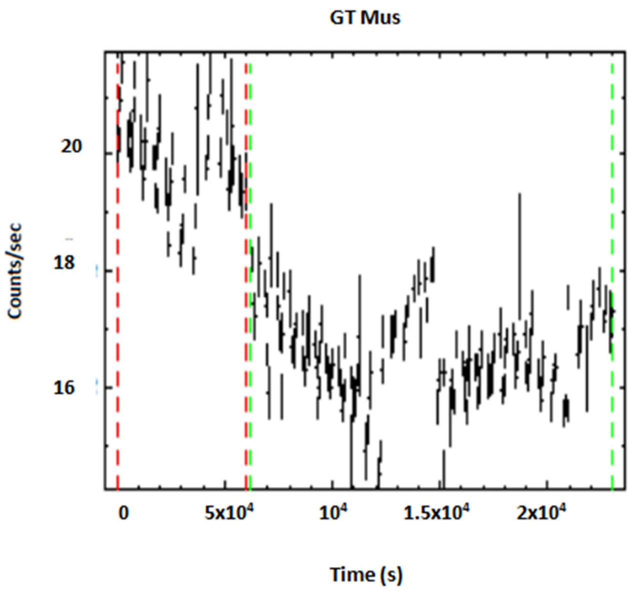

Figure 1. *Light curve of GT Mus.*

Figure 1 shows Light curve of GT Mus, the left hand side of figure 1 (region enclosed by red broken lines) shows evidence of stellar flare which results in increase in count/sec (brightness).

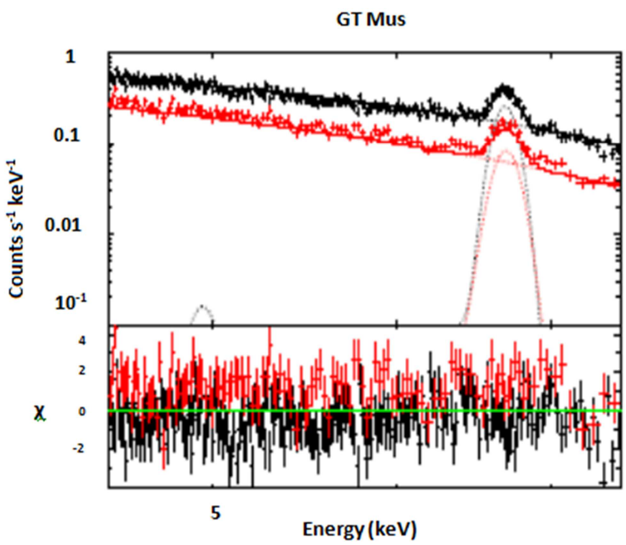

Figure 2. *Suzaku spectra of GT-Mus.*

Figure 2 shows Suzaku spectra of GT-Mus, the upper panel shows spectrum of the GT-Mus with the crosses and solid lines representing the data and the model respectively. The peak of the spectrum is the 6.7 keV line as represented by dotted lines from the energy axis. (Black color is front illuminated X-ray imaging spectrometer while the red color is back illuminated X-ray imaging spectrometer).

Table 1. *The spectral parameters.*

SPECTRAL PARAMETERS	VALUE	UNIT
C	0.76±0.01	-
KT	3.72± 0.12	keV
Fcount	0.19± 0.34	Photons^{-1}cm^{-2}
E6.7	6.67 ± 0.03	keV
EW6.7	282±0.02	eV
RX^2	1.65	-
d.o.f.	220	-

Table 1 shows our spectral parameters where C is for the covering fraction. KT is for the energy of the continuum, where K is the Boltzmann constant and T is the temperature. Fcount is for the continuum photon counts. E6.7 is for the 6.7 keV emission line energy. EW 6.7 is for the Equivalent width of the 6.7 keV emission line. RX^2 is for the reduced chi-squared value and d.o.f. is the degrees of freedom.

3. Discussions/Conclusions

3.1. Comparison of the 6.7 keV Line of GT Mus from Other Flare Stars from the Galactic Ridge

Previous studies reveal that the equivalent width (EW) of the 6.7 keV emission line from the galactic ridge is in the range of 300 - 980 eV depending on the galactic position [25-27]. This compares with the equivalent width (EW) we got in this work as shown in the table1. The emission measure distribution shape (X-ray light curve) of Algol during quiescent and flare phases is similar to that of some observed flare stars and X-ray binaries that exhibit sporadic flare activities. The 6.7 keV line emission (with an equivalent width; 510 eV) resolved during the flare epoch suggests that Algol is a Galactic X-ray emitter, and Algol could be among the probable sources of 6.7 keV in the galactic ridge [7].

3.2. Contribution of Stars to the 6.7 keV Emission Line from Galactic Ridge

The bulk of the galactic ridge is believed to be composed of X-ray sources from active binaries (ABs), cataclysmic variables (CVs), binaries of white dwarf and symbiotic stars [24-27]. However, the contributions of these sources to 6.7 keV from the galactic ridge have not been completely addressed. Stellar flares are known to produce strong 6.7 keV lines and it is generally believed that this line may disappear when the star goes into quiescence [28]. The observed light curve shows flaring activities which result in an increase in count/sec (brightness) as shown at the left hand side of the Figure 1 (the region enclosed by the red dotted lines).

3.3. Conclusion

We carried out spectral analysis of GT-MUs (HD 101379), and resolved a strong 6.7 keV emission line, which was emitted as a result of flaring activities from the source. We generated the light curve and deduce clearly that the source is flaring. This stellar flare appears to be responsible for the observed 6.7 keV emission line. It is possible that as the GT-Mus (HD101379) returns to its quiescence, the emission of this line may disappear. In other words, GT-Mus (HD 101379) which emit in 6.7 keV could contribute to the 6.7 keV emission in the Galactic Ridge only during its flaring activities. Thus it can be argued that other RS CVn stars located at the galactic center which emit in 6.7 keV line could contribute to 6.7 keV emission since they exhibit the same level of chromospheric activities.

We conclude that the star could contribute to 6.7 keV emission line from the galactic ridge based on the fact that both has a comparable Equivalent Width. We are of the view that a collection of other RS CVn stars, which undergo flaring activities and emit 6.7 keV line in the galactic center could contribute to the 6.7 keV emission from the galactic ridge.

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