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RX J1838.4-0301: an accreting pulsar or coronal X-ray emission?⋆

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Abstract. The X-ray source RX J1838.4-0301 is of particular interest since it is a possible member of a small subclass of pulsars with anomalous properties. A spectroscopic study of its proposed optical counterpart and a reanalysis of the ROSAT data indicate that the observed optical and X-ray properties, with the exception of the reported $\sim 5s$ periodicity (Schwentker 1994), are consistent with coronal emission from an active late type star. In the lack of an independent confirmation, the presence of X-ray pulsations in RX J1838.4-0301 should be considered with caution.

Key words: pulsars – X-rays: stars – stars: RX J1838.4-0301

1. Introduction

The soft X-ray source RX J1838.4-0301 (Schwentker 1994) lies in a region of diffuse X-ray and radio emission, possibly a 32,000 years old supernova remnant. Schwentker (1994) reported the presence of periodic pulsations with a period of 5.45 seconds and suggested that RX J1838.4-0301 is a low mass X-ray binary (LMXB), probably associated to the supernova remnant. The similarity with the 7 second pulsar 1E 2259+586 in the supernova remnant G109.1-1.0 (Fahlman & Gregory 1981) led to the inclusion of RX J1838.4-0301 in a small class of peculiar X-ray pulsars characterized by spin periods in the 5-9 s range and by the absence of massive companion stars (Mereghetti & Stella 1995, van Paradijs, Taam & van den Heuvel 1995). Based on optical spectroscopy of the candidate counterpart of RX J1838.4-0301, as well as our own reexamination of the ROSAT data, we reconsider the possible nature of this poorly studied X-ray source.

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⋆ Based on observations collected at the European Southern Observatory, La Silla, Chile.

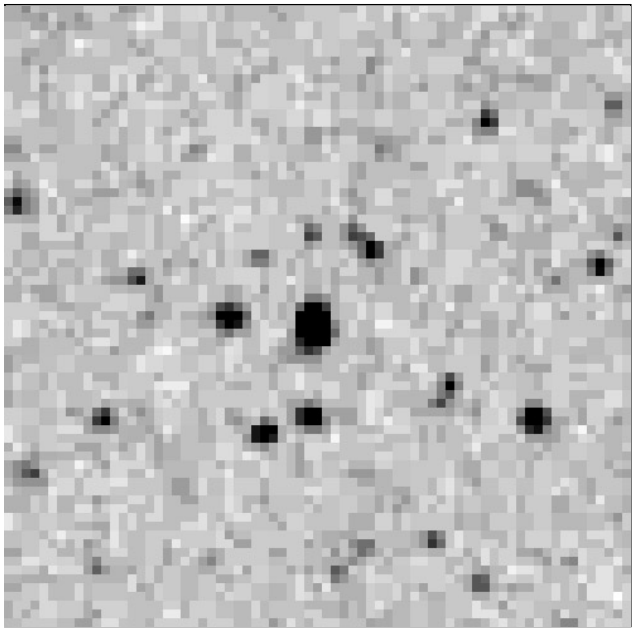

Fig. 1. Optical image of a 2x2 arcmin field centered at the X-ray position of RX J1838.4-0301. North is to the top, East to the left.

2. The candidate optical counterpart

In Fig. 1 we show an optical image of the field of RX J1838.4-0301, obtained from the SERC sky plates digitized by the STScI (Postman et al. 1996). The image is centered at the X-ray position of RX J1838.4-0301 derived from our reanalysis of the ROSAT data: α_{2000}=$18^h\ 38^m\ 27.04^s$, $\delta_{2000} = -03^\circ\ 01'\ 10.7''$. The identification of another X-ray source detected in the PSPC field with the bright star BD-02° 4680 allows us to reduce the possible systematic error on the satellite aspect solution. The 90% confidence level uncertainty on the above coordinates is thus only 5". One candidate counterpart, listed in the HST Guide Star Catalogue with V$\sim$ 14 is visible in Fig.1 within this error circle. It is slightly elongated in the North-South direction, probably due to a second nearby star.

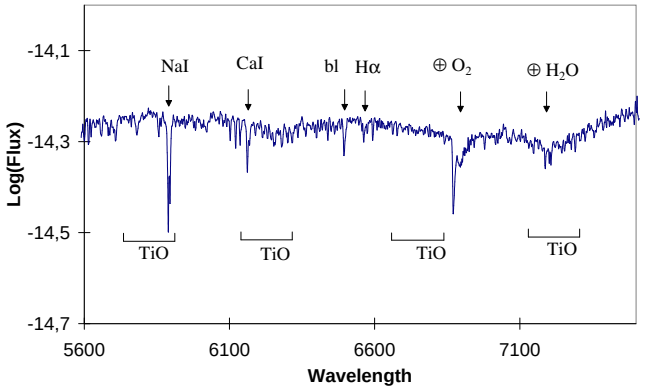

Fig. 2. Background-subtracted and flux-calibrated spectrum of the RX J1838.4-0301 candidate counterpart obtained with a 30 minutes exposure.

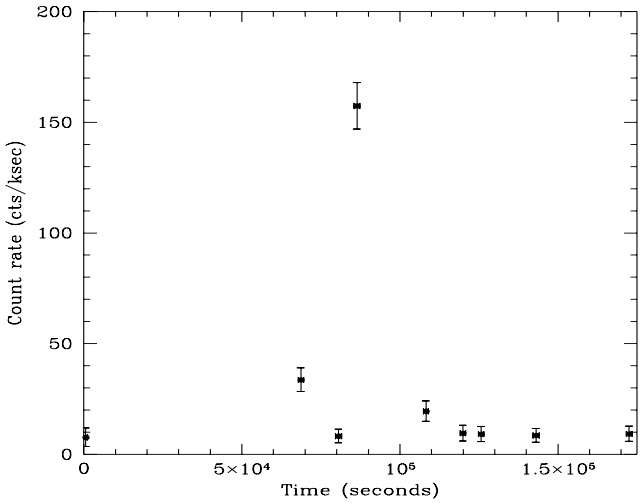

Fig. 3. X-ray light curve of RX J1838.4-0301. Time 0 corresponds to 1992 October 6, 17:31 UT.

We obtained spectra of this object using the 1.5 m ESO telescope at La Silla on 1995 May 14-15. The observations were done with a 2048×2048 pixels UV coated CCD and a Boller & Chivens spectrograph giving a resolution of 2Å. The 2" wide slit was oriented in the E-W directrion. A total of five spectra were accumulated, each for an exposure of 30 minutes. Two spectra on May 14th (starting times 8:00 and 9:16 UT), and three spectra on May 15th (starting times 7:57, 8:35 and 9:08 UT).

The data were analyzed using the spectral analysis package distributed in the MIDAS software. After the standard reduction and cleaning from cosmic ray hits, the spectrum was wavelength and flux calibrated (Fig.2). This clearly indicates a normal late type star, without the typical emission lines characterizing the spectra of accreting LMXB. Comparison with spectral standard stars leads us to classify this object as a main sequence K5 star. Integrating the spectrum convolved with the BVR model filter responses (Bessel, 1990) we estimate a magnitude V=14.7 $\pm$ 0.2. The colours are also consistent, within the large errors, with a K type star with a small amount of interstellar reddening.

3. Discussion

In the lack of an independent confirmation of the 5.45 s periodicity from RX J1838.4-0301, we discuss the possiblity that the X-ray flux observed with ROSAT is due to coronal emission from the K star, without the need of invoking accretion onto a compact object.

In Fig. 3 we show the X-ray light curve of RX J1838.4-0301 derived from our reanalysis of the PSPC data. During most of the observation the source was detected with a low count rate of 0.0085 ± 0.0014 counts s^{-1}. Only in three observation intervals it had a higher flux, reaching a level of 0.15 ± 0.01 counts s^{-1} during a $\sim$1800 s long interval. The amplitude and time scale of this flux variation are typical of stellar flares. An analysis of the spectral hardness ratios does not show evidence for spectral variations during the flare.

The conversion between count rate and energy flux depends on the source spectral parameters, which are poorly constrained by the PSPC data. Fleming et al. (1995) derived an average relation between the flux conversion factor and the PSPC hardness ratio, appropriate for late-type stars. By applying this relation, we obtain a conversion factor of 1.3 10^{-11}, corresponding to a flux of 1.1 10^{-13} ergs cm^{-2} s^{-1} (0.1-2.4 keV) in the "quiescent" state and of 2 10^{-12} ergs cm^{-2} s^{-1} during the flare.

Adopting a bolometric correction appropriate for a K5 star (BC=-0.60) and $V_0 \sim 14.5$, the distance independent ratio between X-ray and bolometric luminosity is $\log(L_x/L_{bol}) \sim -2.8$. Though higher than the average value observed in late type stars, this is consistent with coronal emission from the K5 candidate counterpart (Fleming, Schmitt & Giampapa 1995). Such relatively high value of L_x/L_{bol} values are easily observed in X-ray selected objects as RX J1838.4-0301 (Fleming, Schmitt & Giampapa 1995).

The observed variability supports the coronal interpretation. For an assumed distance of the order of $\sim$300 pc (consistent with the apparent magnitude for a K5 main sequence star) the luminosity at the flare maximum is $\sim$ 2 10^{31} ergs s^{-1}. This rather high value suggests that RX J1838.4-0301 might be an RS CVn system (Dempsey et al. 1993). No signs of coronal activity are visible in our spectrum, particularly in the region of the Ca H-K lines. Note however that our spectrum has a relatively poor signal to noise ratio blueward than 4500Å

4. Conclusions

The optical spectrum of the proposed RX J1838.4-0301 counterpart does not support the LMXB hypothesis. If this K type star is the true counterpart of the X-ray source, its properties can be explained without invoking accretion onto a compact object. Furthermore, the other sources belonging to the class of 'anomalous' 5-9 second pulsars are rather constant in flux

(Mereghetti & Stella 1995), while the $\sim$20 variability seen in RX J1838.4-0301 also supports the stellar flare hypothesis.

This interpretation would imply that the statistical significance of the 5.45 s pulsations has been overestimated by Schwentker (1994). Of course, this cannot be verified *a posteriori* by a new analysis of the same data. Were the pulsation confirmed by new observations, more detailed optical observations would be needed to investigate the possible presence of a fainter counterpart close to the star studied here.

Pending a confirmation of the X-ray periodicity, we believe that the most likely explanation for RX J1838.4-0301 is that of an active late star, possibly of the RS CVn type.

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