

Detection of X-ray pulsations from the Be/X-ray transient A 0535+26 during a disc loss phase of the primary

I. Negueruela¹, P. Reig^{2,3}, M.H. Finger⁴, and P. Roche⁵

¹ SAX SDC, ASI, c/o Nuova Telespazio, via Corcolle 19, 00131 Rome, Italy

² Foundation for Research and Technology-Hellas, 711 10 Heraklion, Crete, Greece

³ Physics Department, University of Crete, 710 03 Heraklion, Crete, Greece

⁴ Space Science Laboratory, ES84, NASA/Marshall Space Flight Center, Huntsville, AL 35812, USA

⁵ Department of Physics & Astronomy, University of Leicester, Leicester LE1 7RH, UK

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Abstract. Using the *RossixTE* experiment, we detect weak X-ray emission from the recurrent Be/X-ray transient A 0535+26 at a time when the optical counterpart V725 Tau displayed H α in absorption, indicating the absence of a circumstellar disc. The X-ray radiation is strongly modulated at the 103.5-s pulse period of the neutron star, confirming that it originates from A 0535+26. The source is weaker than in previous quiescence detections by two orders of magnitude and should be in the centrifugal inhibition regime. We show that the X-ray luminosity cannot be due to accretion on to the magnetosphere of the neutron star. Therefore this detection represents a new state of the accreting pulsar. We speculate that the X-ray emission can be due to some matter leaking through the magnetospheric barrier or thermal radiation from the neutron star surface due to crustal heating. The observed luminosity is probably compatible with recent predictions of thermal radiation from X-ray transients in quiescence. The detection of the X-ray source in the inhibition regime implies a reduced density in the outflow from the Be companion during its disc-less phase.

Key words: stars: circumstellar matter – stars: emission-line, Be – stars: individual: A 0535+26 – stars: binaries: close – stars: neutron – X-rays: stars

1. Introduction

Be/X-ray binaries are X-ray sources composed of a Be star and a neutron star. Most of these systems are transient X-ray pulsars displaying strong outbursts in which their X-ray luminosity increases by a factor $\gtrsim 100$ (see Negueruela 1998). In addition, those systems in which the neutron star does not rotate fast enough for centrifugal inhibition of accretion to be effective (see Stella et al. 1986) display persistent X-ray luminosity at a level $\lesssim 10^{35}$ erg s⁻¹. The high-energy radiation is believed to arise due to accretion of material associated with the Be star by the compact object. It has long been known that accretion from the fast polar wind that is detected in the UV resonance lines of

the Be primaries cannot provide the observed luminosities, even for detections at the weakest level (see Waters et al. 1988 and references therein; see also the calculations made for X Persei by Telting et al. 1998). Therefore it is believed that the material accreted comes from the dense equatorial disc that surrounds the Be star. Waters et al. (1989) modelled the radial outflow as a relatively slow (~ 100 km s⁻¹) dense wind. However most modern models for Be stars consider much slower outflows, due to strong evidence for rotationally dominated motion (quasi-Keplerian discs). This is due not only to the line shapes (see Hanuschik et al. 1996), which set an upper limit on the bulk motion at $v \lesssim 3$ km s⁻¹ (Hanuschik 2000), but also to the success of the Global One-Armed Oscillation model (which can only work in quasi-Keplerian discs) at explaining V/R variability in Be stars (Hummel & Hanuschik 1997; Okazaki 1997a,b). The viscous decretion disc model (Okazaki 1997b; Porter 1999; Negueruela & Okazaki 2000) considers material in quasi-Keplerian orbit with an initially very subsonic outflow velocity that is gradually accelerated by gas pressure and becomes supersonic at distances $\sim 100R_*$, i.e., much further than the orbits of neutron stars in Be/X-ray transients.

The transient A 0535+26 is one of the best studied Be/X-ray binaries (Clark et al. 1998 and references therein). It contains a slowly rotating ($P_s = 103$ s) neutron star in a relatively wide ($P_{\text{orb}} = 110.3$ d) and eccentric ($e = 0.47$) orbit around the B0IIIe star V725 Tau (see Finger et al. 1996; Steele et al. 1998). After its last giant outburst in February 1994 (Clark et al. 1998; Negueruela et al. 1998), the strength of the emission lines in the optical spectrum of V725 Tau has declined steadily. The last normal (periodic) outburst took place in September 1994 and the source has since not been detected by the BATSE experiment on board *CGRO*.

2. Observations

2.1. Optical spectroscopy

V725 Tau, the optical counterpart to A 0535+26, was observed on November 7th 1998, using the 4.2-m William Herschel Telescope, located at the Observatorio del Roque de los Muchachos,

La Palma, Spain. The telescope was equipped with the Utrecht Echelle Spectrograph using the 31.6 lines/mm echelle centred at $H\alpha$ and the SITe1 CCD camera. This configuration gives a resolution $R \sim 40000$ over the range $\sim 4600 - 10200 \text{ \AA}$. The data have been reduced using the *Starlink* packages CCDPACK (Draper 1998), ECHOMOP (Mills et al. 1997) and DIPSO (Howarth et al. 1997). A detailed analysis of the whole spectrum is left for a forthcoming paper. In Fig. 1, we show the shape of $H\alpha$, $H\beta$ and $\text{He I } \lambda 6678\text{\AA}$. When in emission, these three lines sample most of the radial extent of the circumstellar envelope. However, it is apparent that the lines seen in Fig. 1 correspond to photospheric absorption from the underlying star. The emission contribution from circumstellar material, if any, is certainly very small. The asymmetry in the shape of $H\alpha$ and $\text{He I } \lambda 6678\text{\AA}$ suggests that some fast-moving material is present close to the stellar surface (see Hanuschik et al. 1993; Rivinius et al. 1998 for the discussion of low-level activity in disc-less Be stars), but the circumstellar disc is basically absent. $H\beta$, which, when in emission, is typically produced at distances of a few R_* , looks completely photospheric. In Be stars $H\alpha$ probes a region extending to $\sim 10 R_*$, as measured from line-peak separation (Hummel & Vrancken 1995) and direct imaging (Quirrenbach et al. 1997). Again, circumstellar material seems to be almost absent from this region. There is weak emission in-filling at the line centre – transient emission components have been seen in this star during the disc-less state (Haigh et al. 2000), a behaviour typical of disc-less Be stars (Rivinius et al. 1998 and references therein).

2.2. X-ray observations

Observations of the source were taken using the Proportional Counter Array (PCA) on board *RossixTE* on 1998 August 21 and 1998 November 12 for a total on-source time of 4170 s and 2250 s, respectively.

In both observations there is an excess of ~ 4 counts/s/(5 PCU) in the 2.5–15 keV range of the Standard2 data compared to the faint source background model. Fits to power-law models with interstellar absorption result in flux estimates of 6×10^{-12} and $9 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$ (2–10 keV) for the two observations respectively. These can only be considered as upper limits on the flux, due to the uncertain contribution of diffuse Galactic Disc emission to the count rates (Valinia & Marshall 1998).

2.2.1. Timing analysis

The issue of whether the source of high energy radiation was active or not during the low activity optical phase can be solved by searching for the previously reported X-ray pulsations at ≈ 103.5 -s spin period (e.g., Finger et al. 1996). In order to improve the signal-to-noise, we accumulated events from the top anode layer of the detectors. We also used the latest version of the faint background model.

For the power spectral analysis we selected a stretch of continuous data and divided it into intervals of 309 s. A power spectrum was obtained for each interval and the results aver-

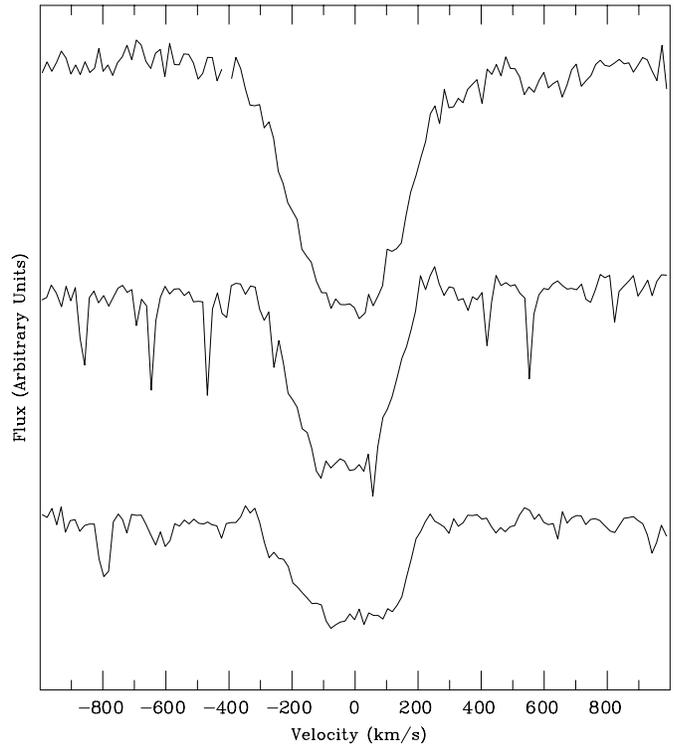


Fig. 1. Spectroscopy of V725 Tau taken on November 7, 1998, with the WHT and UES. The lines are, from top to bottom $H\beta$, $H\alpha$ and $\text{He I } \lambda 6678\text{\AA}$. The spectra have been divided by a spline fit to the continuum and arbitrarily offset for display. The sharp lines surrounding $H\alpha$ are atmospheric water vapour features.

aged together. Given that the pulse frequency ($\nu \approx 0.0097 \text{ Hz}$) lies on a region dominated by red noise, we have to correct for such noise if the statistical significance of the pulsations are to be established. First, we fitted the Poisson level by restricting ourselves to the frequency range 0.2–0.4 Hz, that is far away from the region where the red noise component may contribute appreciably. The strongest peak in the power spectrum corresponds to ≈ 103.5 s.

We also searched for periodicities in the light curves by folding the data over a period range and determining the χ^2 of the folded light-curve (epoch-folding technique). In this case we used 20 phase bins (19 degrees of freedom) and a range of 100 periods, around the expected period. This method has the advantage that the result is not affected by the presence of gaps in the data, hence a longer baseline can be considered than with Fourier analysis. Times in the background subtracted light-curve were converted into times at the solar-system barycentre. The result for the 1998 November observation is shown in Fig. 2. We found that the peak at ~ 103.5 s is significant at $> 5\sigma$, confirming that the source was active during the observations.

It is worth mentioning that the detection levels shown in Fig. 2 were obtained without *a priori* knowledge of the frequency of pulsations. In other words, we searched for pulsations in the frequency/period range shown in the figure. If we take into account the fact that we are interested in the pulse period at 103.5 s, the peak becomes still more significant.

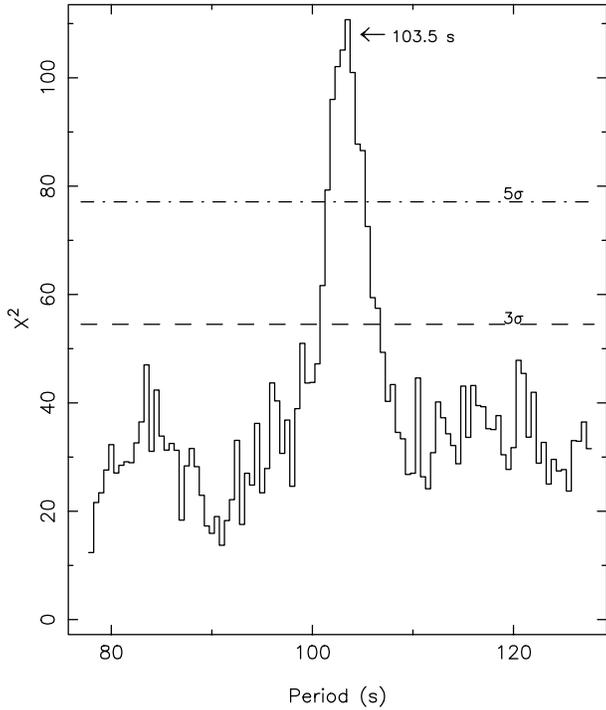


Fig. 2. 3–20 keV light-curve folded over a range of trial periods (epoch folding) for the November 1998 observation. The arrival times were corrected to the solar barycentre. The dashed and dash-dotted lines represent the 3- σ and 5- σ detection levels considering that all trial periods have the same probability.

The analysis of the 1998 August observation provides a much less significant detection. A peak at the expected frequency ($\nu \approx 0.0097$ Hz) is seen in the power spectrum. However, epoch-folding analysis gave a significance of 3σ only when we considered one single period, that is, the number of trials is one. A search for pulsations in a period range did not yield any maximum above the 3σ detection level although a peak at the 103-s period is present (see Fig. 3)

2.2.2. Pulse shape

The pulse shape (see Fig. 4) is nearly sinusoidal, as expected from the absence of second or higher harmonics in the power density spectra. The amplitude of the modulation is ~ 2 count s^{-1} in the 3–20 keV energy range, which implies a pulse fraction of $\sim 53\%$. Given the unknown contribution from Galactic Disc diffuse emission, this represents only a lower limit to the pulsed fraction in the signal from the source.

We have divided the November 1998 observation into two sections, corresponding to the peak of the pulse (phase bins 0.6 to 1.0) and the interpulse minimum (phase bin 0.1–0.5). An absorbed power-law fit in the energy range 2.7–10 keV to the two spectra gave $\Gamma = 2.9 \pm 0.4$, $N_H = 9 \pm 4$, $\chi_r^2 = 0.8$ (18 dof) for pulse maximum and $\Gamma = 3.3 \pm 0.5$, $N_H = 10 \pm 5$, $\chi_r^2 = 0.9$ (18 dof) for pulse minimum. The two values are consistent with each other within the error margins. The lack of spectral changes with phase requires any significant component of the detected

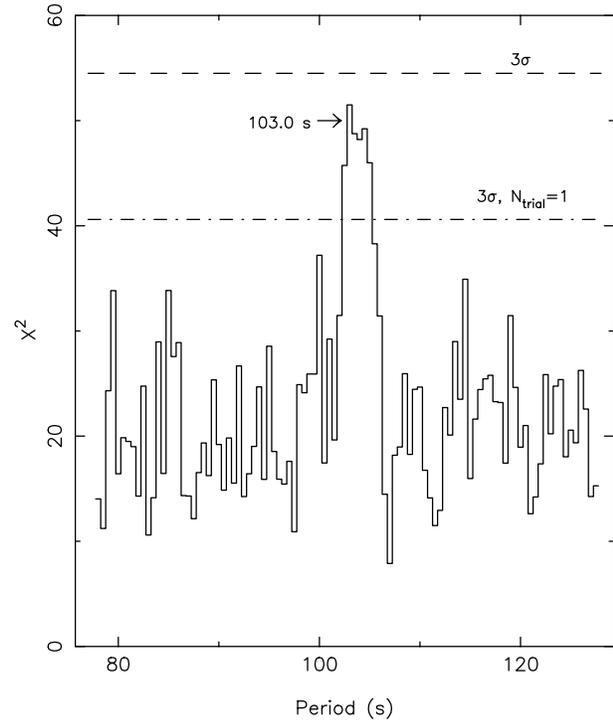


Fig. 3. Same as Fig. 2 but for the August 1998 observation. The dash-dotted line represents the 3- σ detection level and was obtained by considering one trial period only (that at which pulsations are expected).

flux due to diffuse emission to have a spectrum similar to that of the pulsar.

2.2.3. Spectral fit

Formally the X-ray spectra are equally well represented by an absorbed power-law, blackbody and bremsstrahlung models. Table 1 shows the spectral fit results. All these models gave fits of comparable quality, which means that we are unable to distinguish meaningfully between the different spectral models of Table 1, even though the blackbody fit is unlikely to have any physical meaning, because of very small emitting area and the fact that it does not require any absorption (introducing N_H does not improve the fit) – see Rutledge et al. (1999) for a discussion of the physical inadequacy of this model for neutron stars. The value of the hydrogen column density (N_H), which is consistent for the power-law and bremsstrahlung fits, is too high to be purely interstellar. The interstellar reddening to the source must be smaller than the measured $E(B - V) \approx 0.7$ (Steele et al. 1998), which is the sum of interstellar and circumstellar contribution from the disc surrounding the Be star. According to the relation by Bohlin et al. (1978), $E(B - V) = 0.7$ implies $N_H = 4.1 \times 10^{21} \text{ cm}^{-2}$ and therefore there must be a substantial contribution of local material to the absorption.

From the spectral fits, we estimate the 3–20 keV X-ray flux to be $3.5 \times 10^{33} \text{ erg s}^{-1}$ and $4.5 \times 10^{33} \text{ erg s}^{-1}$ for the August 1998 and November 1998 observations respectively, assuming a distance of 2 kpc (Steele et al. 1998). Although the values of

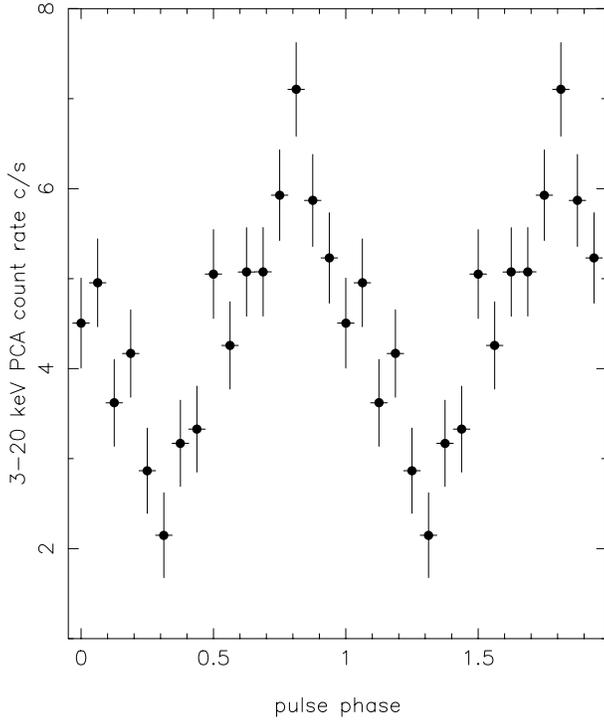


Fig. 4. PCA RXTE 3–20 keV background subtracted pulse profile corresponding to the November 1998 observation.

the spectral parameters are consistent with each other within the error margins, they all show the same trend, namely, a harder spectral state during the 1998 August observations (lower photon index and higher blackbody and bremsstrahlung temperatures).

3. Results

Our November 1998 X-ray observations represent a clear detection of A 0535+26 at a time when the optical counterpart showed no evidence for the presence of circumstellar material. Moreover, Haigh et al. (2000) present spectroscopy showing that the disc was already absent as early as late August 1998, when our first observation was taken. The observed luminosities in the 2–10 keV range ($2 \times 10^{33} \text{ erg s}^{-1} \lesssim L_x \lesssim 4.5 \times 10^{33} \text{ erg s}^{-1}$) are definitely smaller than the quiescence luminosity observed in other occasions when the equatorial disc surrounding the Be star was present. For example, Motch et al. (1991) observed the source on several occasions at a level $L_x \simeq 1.5 \times 10^{35} \text{ erg s}^{-1}$ in the 1–20 keV range (correcting their value to the adopted distance of 2 kpc) using *EXOSAT*.

The *EXOSAT* observation, as well as several other quiescence detections of Be/X-ray binaries with $P_s \gtrsim 100 \text{ s}$, have always been interpreted in terms of accretion on to the surface of the neutron star from the equatorial outflow from the Be star. However, on this occasion we have observed the source when the disc of the Be star had been absent for several months and at an X-ray luminosity two orders of magnitude lower. Therefore we cannot consider as an *a priori* assumption that the emission mechanism at operation is the same.

Table 1. Results of the spectral fits. Uncertainties are given at 90% confidence for one parameter of interest. All fits correspond to the energy range 3–20 keV

| August 1998 observation | |
|--|---------------------|
| Power-law | |
| Γ | 2.6 ± 0.2 |
| N_{H} ($10^{22} \text{ atoms cm}^{-2}$) | 5.6 ± 2.2 |
| $\chi_r^2(\text{dof})$ | 1.46(43) |
| Blackbody | |
| kT_1 (keV) | 1.45 ± 0.05 |
| R (km) | 0.09 ± 0.01 |
| $\chi_r^2(\text{dof})$ | 1.73(44) |
| Bremsstrahlung | |
| kT_{brem} (keV) | 6.4 ± 1.3 |
| N_{H} ($10^{22} \text{ atoms cm}^{-2}$) | $2.2^{+1.8}_{-1.3}$ |
| $\chi_r^2(\text{dof})$ | 1.31(44) |
| November 1998 observation | |
| Power-law | |
| Γ | 3.2 ± 0.3 |
| N_{H} ($10^{22} \text{ atoms cm}^{-2}$) | 10.3 ± 2.6 |
| $\chi_r^2(\text{dof})$ | 1.09(43) |
| Blackbody | |
| kT_1 (keV) | 1.40 ± 0.05 |
| R (km) | 0.11 ± 0.01 |
| $\chi_r^2(\text{dof})$ | 1.01(44) |
| Bremsstrahlung | |
| kT_{brem} (keV) | 4.4 ± 0.7 |
| N_{H} ($10^{22} \text{ atoms cm}^{-2}$) | 5.4 ± 2.1 |
| $\chi_r^2(\text{dof})$ | 0.96(44) |

In order to explain the difference in the luminosity by two orders of magnitude, we can invoke accretion from a far less dense outflow or assume that some other emission mechanism is at work. We first consider the possibility that the observed luminosity is due to accretion on to the surface of the neutron star. Assuming an efficiency $\eta = 1$ in the conversion of gravitational energy into X-ray luminosity, $L_x = 4 \times 10^{33} \text{ erg s}^{-1}$ translates into an accretion rate $\dot{M} = 2.1 \times 10^{13} \text{ g s}^{-1} = 3.3 \times 10^{-13} M_{\odot} \text{ yr}^{-1}$.

Following Stella et al. (1986), we define the corotation radius as that at which the pulsar corotation velocity equals Keplerian velocity. The corotation radius is given by

$$r_c = \left(\frac{GM_x P_s^2}{4\pi^2} \right)^{\frac{1}{3}} \quad (1)$$

where G is the gravitational constant, M_x is the mass of the neutron star (assumed to be $1.44 M_{\odot}$) and P_s is the spin period. For A 0535+26, $r_c = 3.7 \times 10^9 \text{ cm}$.

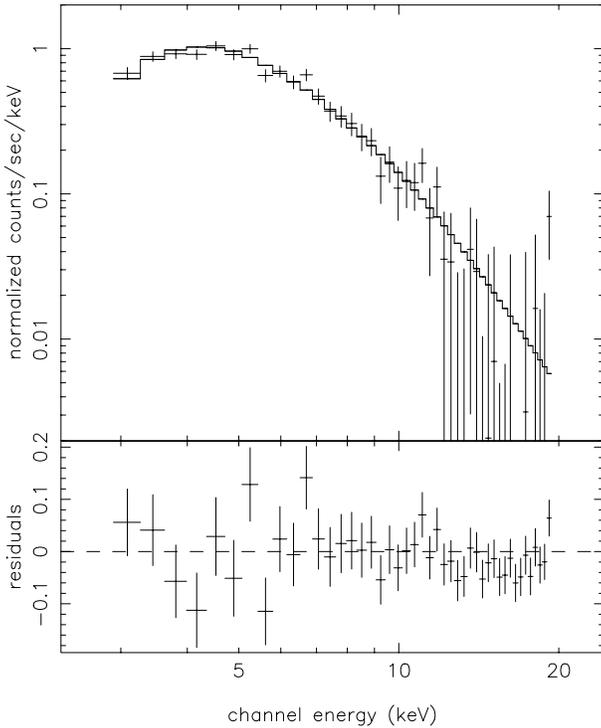


Fig. 5. PCA RXTE source spectrum for the November 1998 observation. Also shown is the best-fit power-law model and the residuals.

The magnetospheric radius at which the magnetic field begins to dominate the dynamics of the inflow depends on the accretion rate and can be expressed as

$$r_m = K (GM_x)^{-1/7} \mu^{4/7} \dot{M}^{-2/7} \quad (2)$$

where μ is the neutron star magnetic moment and \dot{M} is the accretion rate. K is a constant that in the case of A 0535+26 has been determined to be $K \simeq 1.0$ when an accretion disc is present (Finger et al. 1996) and from theoretical calculations is expected to have a similar value for wind accretion. Following Finger et al. (1996), we will assume a magnetic dipolar field 9.5×10^{12} G, resulting in $\mu = 4.75 \times 10^{30}$ G cm³.

For the accretion rate $\dot{M} = 2.1 \times 10^{13}$ g s⁻¹ derived above, the magnetospheric radius would be $r_m = 9.3 \times 10^9$ cm. Therefore $r_m > r_c$ and the neutron star must be in the centrifugal inhibition regime. In order to estimate the solidity of this result, we point out that if the 110 keV cyclotron line detected in the spectrum of A 0535+26 (Kendziorra et al. 1994; Grove et al. 1995) is the second harmonic instead of the first, as has been suggested, the magnetic field (and magnetic moment) would be smaller by a factor 2. However, this would require a higher value for K in order to fit the observations of a QPO in this system (Finger et al. 1996), leaving the value of r_m unaffected. An efficiency in the conversion of gravitational energy into radiation as low as $\eta = 0.5$ will translate into a reduction in r_m by only a factor ~ 0.8 . Therefore we conclude that the neutron star is certain to be in the inhibited regime.

According to Corbet (1996), when the source is in the inhibition regime, a luminosity comparable to that observed could be produced by release of gravitational energy at the magnetospheric radius (for short, accretion onto the magnetosphere). However, even assuming that the magnetosphere is at the corotation radius and an efficiency $\eta = 1$ (i.e., best case), in order to produce $L_x = 4 \times 10^{33}$ erg s⁻¹, the accretion rate needed is $\dot{M}_m = 8.2 \times 10^{16}$ g s⁻¹. With such an accretion rate, the magnetosphere would be driven in well within the corotation radius, and produce a luminosity of $L_x \approx 1.5 \times 10^{37}$ erg s⁻¹ by accretion on to the surface of the neutron star. Therefore we conclude that the observed luminosity is not due to accretion on to the magnetosphere.

Therefore we are left with the following possibilities for the origin of the X-ray emission:

- Accretion on to the neutron star through some sort of leakage through the magnetospheric barrier. This could adopt two forms. Either directly from the Be star outflow and only through a fairly limited region near the spin axis or mediated by an accretion torus, supported by the centrifugal barrier, with a small amount of material managing to penetrate the magnetosphere.
- Thermal emission from the heated core of the neutron star. Brown et al. (1998) and Rutledge et al. (1999) have studied thermal emission from X-ray transients in quiescence. They predict a thermal luminosity in quiescence

$$L_x = 6 \times 10^{32} \text{ erg s}^{-1} \times \frac{\dot{M}}{10^{-11} M_\odot \text{ yr}^{-1}} \quad (3)$$

where \dot{M} here represents the long term average mass accretion rate. From the number of observed Type II outbursts in A 0535+26, we assume one giant outburst every 5–10 years, which translates into a long-term average of $\dot{M} = 4–8 \times 10^{-11} M_\odot \text{ yr}^{-1}$. This would imply quiescence thermal emission in the range $L_x = 2–5 \times 10^{33}$ erg s⁻¹, which is consistent with our observations.

4. Discussion

It is very difficult to estimate the fraction of the signal that actually comes from the source, though the pulsed component is evidently a lower limit to it. The diffuse emission from the Galactic disc is not well described at high Galactic longitudes (for A 0535+26, $l = 181.5^\circ$), but if the assumption by Valinia & Marshall (1998) that its latitude distribution should be similar to that in the Galactic Ridge can be held, then it should not be very strong at the position of A 0535+26 ($b = -2.6^\circ$). In any case, the total (source + diffuse) flux detected is lower than the average diffuse emission from the Galactic Ridge, which is 2.4×10^{-11} erg cm⁻² s⁻¹ in the 2–10 keV band (Valinia & Marshall 1998).

Given that the fitted spectra are much softer than the model fits to Galactic Ridge diffuse emission by Valinia & Marshall (1998), which have photon indexes $\Gamma \sim 1.8$, and the similitude between the pulse-peak and pulse-minimum spectra, it seems

likely that most of the detected signal comes actually from the source. The high value of N_{H} obtained in all the non-thermal fits argues for the presence of large amounts of material in the vicinity of the neutron star. This could be caused by the pile-up of incoming material outside the magnetosphere. The observed spectrum is much softer than the spectra of Be/X-ray binaries at low luminosity during quiescence states (Motch et al. 1991 quote a photon index of 1.7 for their observations of A 0535+26) and could favour the thermal emission interpretation.

Brown et al. (1998) proposed that thermal reactions deep within the crust of an accreting neutron star would maintain the neutron star core at temperatures of $\sim 10^8$ K, similar to that in a young radio pulsar. During the quiescent state of transient accretors, the conduction of thermal energy from the core should result in a detectable thermal spectrum from the neutron star atmosphere. In a high magnetic field pulsar, this thermal emission should be pulsed due to both the anisotropic surface temperature distribution caused by the dependence of the thermal conductivity on the magnetic field (Shibanov & Yakovlev 1996), and the anisotropic radiation pattern from the neutron star atmosphere resulting from the magnetic field (Zavlin et al. 1995).

Our blackbody fit to the A0535+26 spectrum resulted in an emission radius much smaller than the neutron star. Rutledge et al. (1999) show that fits to Hydrogen atmosphere spectral models result in larger emission areas and lower effective temperature than blackbody fits. The spectra may therefore be consistent with thermal emission from the pulsar. However, if this interpretation is correct, most of the emitted luminosity should be below the energy band that we observe. In that case, the bolometric luminosity may well exceed that predicted from our estimates of the long-term average accretion rates.

Our detection of A 0535+26 can also be used to set limits on the outflow from the Be companion. The condition for centrifugal inhibition is $r_{\text{m}} \geq r_{\text{c}}$. Therefore the minimum accretion rate at which there is no inhibition corresponds to that at which $r_{\text{m}} = r_{\text{c}}$. Using the values above, we obtain an accretion rate onto the magnetosphere $\dot{M}_{\text{m}} = 5.3 \times 10^{14} \text{ g s}^{-1} = 8 \times 10^{-12} M_{\odot} \text{ yr}^{-1}$. If the observed luminosity is due to accretion on to the surface of the neutron star, the rate of mass flow into the vicinity of the neutron star is then constrained to be in the range $3 \times 10^{-13} M_{\odot} \text{ yr}^{-1} \lesssim \dot{M} \lesssim 8 \times 10^{-12} M_{\odot} \text{ yr}^{-1}$ (of course, if it is due to thermal emission, only the upper limit holds). The lower limit represents a small fraction of the mass lost from the Be star (which should be $\gtrsim 10^{-11} M_{\odot} \text{ yr}^{-1}$), but the upper limit is close to the mass-loss values derived in the decretion disc model (Okazaki 1997b; Porter 1999). This value is also close to the accretion rate needed to sustain the quiescence luminosity observed by Motch et al. (1991), which is $\dot{M} \sim 10^{-11} M_{\odot} \text{ yr}^{-1}$. Such an accretion rate would represent a substantial fraction of the stellar mass-loss, though still only a small fraction of the disc mass (estimated to be $10^{-9} - 10^{-10} M_{\odot}$). As has been calculated above, most of the long-term accretion rate is due to the giant outbursts, where a substantial fraction of the Be disc mass must be accreted.

From all the above, it is clear that the amount of material reaching the vicinity of the neutron star during the disc-less

phase of the companion is smaller than during previous quiescence states. This cannot be due to an orbital effect because Motch et al. (1991) observed the source at different orbital times and also because our two observations took place close to periastron (orbital phases $\phi \simeq 0$ for the August observation and $\phi \simeq 0.8$ for the November observation, according to the ephemeris of Finger et al. 1996).

Existing evidence seems to argue against the existence of a persistent accretion disc surrounding the neutron star in A 0535+26. The statistical analysis of Clark et al. (1999) showed that there is no significant contribution from an accretion disc to the optical/infrared luminosity of A 0535+26. This does not rule out the presence of an accretion disc (which could, for example, be too small to radiate a significant flux in comparison to the Be circumstellar disc). It is believed that A 0535+26 does indeed form an accretion disc around the neutron during Type II outbursts, since very fast spin-up and quasi-periodic oscillations have been observed (Finger et al. 1996). However, the lack of spin-up during Type I outbursts led Motch et al. (1991) to conclude that no persistent accretion disc was present. In contrast, the Be/X-ray binary 2S 1845–024 shows large spin-up during every Type I outburst (Finger et al. 1999). If no accretion disc is present, the reduced amount of material reaching the neutron star must be directly due to a change in the parameters of the outflow from the Be star. Within the framework of modern models for Be star discs, considering very subsonic outflow velocities, such a change can only be due to a lower outflow density. Unfortunately, since the details of the magnetic inhibition process are poorly understood, we can only constrain the mass rate reaching the neutron star to be below that corresponding to the transition at which inhibition occurs, which is very close to the rate deduced from previous quiescence observations in which the source was not in the inhibition regime.

5. Conclusions

A 0535+26 was active at a time when the optical counterpart V725 Tau showed no evidence for a circumstellar disc. The luminosity was two orders of magnitude lower than in previous quiescence detections and accretion was centrifugally inhibited. Given that the observed luminosity cannot be due to accretion onto the magnetosphere, we are observing either some material leaking through the magnetosphere or thermal emission from the heated core of the neutron star. In any case, this detection represents a state of an accreting X-ray pulsar that had not been observed before.

Further observations of Be/X-ray binaries in a similar state (when their companions have lost their discs and very little material can reach the vicinity of the neutron star) are needed. Observations with *Chandra* or *XMM*, which combine much higher sensitivities with more adequate energy ranges, could determine whether the observed spectrum is compatible with thermal emission models.

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