Photometry of V407 Vul and RXJ0806.3+1527: Twin systems ?

S. C. C. Barros, T. R. Marsh, V. S. Dhillon, P. J. Groot, S. Littlefair et al.

Citation: AIP Conf. Proc. **924**, 873 (2007); doi: 10.1063/1.2774955
View online: http://dx.doi.org/10.1063/1.2774955
View Table of Contents: http://proceedings.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=924&Issue=1
Published by the American Institute of Physics.

Photometry of V407 Vul and RXJ0806.3+1527: Twin systems ?

S.C.C. Barros[*], T.R. Marsh[*], V. S. Dhillon[†], P. J. Groot[**], S. Littlefair[†], G. Nelemans[**], G. Roelofs[**], D. Steeghs[‡] and P. J. Wheatley[*]

[*]*Department of Physics, University of Warwick, Coventry, CV4 7AL,UK*
[†]*Department of Physics and Astronomy, University of Sheffield,Sheffield , S3 7RH, UK*
[**]*Department of Astrophysics/IMAPP, Radboud University Nijmegen, P.O. Box 9010, NL - 6500 GL Nijmegen, The Netherlands*
[‡]*Harvard-Smithsonian Center for Astrophysics, Cambridge, USA*

Abstract. We present new photometry of V407 Vul and RXJ0806.3+1527. These stars are thought to be ultra-compact pairs of white dwarfs and the shortest period binaries known. They have periods of 569 and 321 sec respectively. We found that the X-ray and optical light curves of RXJ0806.3+1527 are not anti-phased as was previously thought. Instead, the X-ray lags the optical by 0.2 of cycle, indistinguishable from the phase offset seen in V407 Vul.

Although very similar to RXJ0806.3+1527, V407 Vul surprisingly is observed to have the spectrum of a G star. We test whether this could be a line-of-sight coincidence by searching for variations in the V407 Vul's position on the sky on the 569 second period. We find that the G star is separated from the variable by 0.03 arcsec, and has no direct connection with the 569 second source. This supports a common nature for V407 Vul and RXJ0806.3+1527.

Keywords: close binaries, V407 Vul, RXJ0806.3+1527,white dwarfs, magnetic fields, X-rays
PACS: 97.80.-d,97.30.Qt,97.80.Gm

INTRODUCTION

V407 Vul and RXJ0806.3+1527 are X-ray emitting starts with X-ray light curves that 100% modulated on periods of $P = 569$ sec [1, 2] and $P = 321$ sec [3] respectively. These are the only periods seen. Several models were suggested for these systems but there is no clear winner. For a discussion please see Hakala et al. [4]. The intermediate polar (IP) model [2] is the only one where the observed periods are interpreted as being the spin periods of an accreting magnetic white dwarf and not the orbital periods of the system. This model requires a non-degenerate secondary star. In the other three models the periods are thought to be the orbital periods of ultracompact pairs of white dwarfs. One is a detached model (non accreting), it is called the unipolar inductor model or electric star model and it was suggested by Wu et al. [5]. In this model an asynchronism between the spin period of a magnetic white dwarf and the orbital period within a detached double white dwarf binary creates an electric current between the two components of the binary, the dissipation of which powers the observed X-ray variations. The other two models are both semi-detached, accreting models but one is magnetic, a "double degenerate" polar [1, 6, 7] and the other is non-magnetic, the direct impact model [8, 9, 10]. Due to the compact dimensions of these systems, the mass transfer streams crash directly onto the accreting white dwarfs therefore their names.

CP924, *The Multicolored Landscape of Compact Objects and their Explosive Origins - Cefalù 2006,*
edited by T. Di Salvo, L. A. Antonelli, G. L. Israel, L. Piersanti, A. Tornambè, L. Burderi, F. Fiore, G. Matt, and M. T. Menna

We present high speed simultaneous photometry of these stars in the hope of using the optical characteristics to learn more about the systems and hence to help decide which are the models that best describe their optical light curves.

V407 VUL AND RXJ0806.3+1527 LIGHT CURVES

Our V407 Vul data were taken with ULTRACAM mounted on the William Hershel telescope (WHT) on May 2003 and August 2005. For RXJ0806.3+1527 we have data taken with ULTRACAM mounted on the WHT on May 2003 and mounted on the Very Large telescope (VLT) in November 2005. We have simultaneous photometry in the i' or r' (depending on the run), g' and u' filters. The data ware reduced using the ULTRACAM pipeline.

We phase folded the V407 Vul data on the ephemeris of Ramsay et al. [11] and the RXJ0806.3+1527 data on the ephemeris of Strohmayer [12]. We note that there are problems with the ephemerides of both objects; see Barros et al. [13] for a detailed discussion. Our phase folded light curves are shown in Fig. 1, where we superimpose the X-ray data adapted from Strohmayer [14, 12] folded on the same ephemerides.

From Fig. 1 we can see that for RXJ0806.3+1527 our results contradict the anti-phasing between the X-rays and the optical reported by Israel et al. [15, 16]. The anti-phasing was expected on the unipolar inductor model but our new phasing favours the double degenerate accreting models for V407 Vul and RXJ0806.3+1527, namely the direct impact and the polar models. In a high accretion state a polar could show no signs of polarisation and therefore may appear similar to a non-magnetic direct impact system. We concluded that we can reproduce the observed relative phasing between the optical and X-ray light curves if we have an X-ray emitting spot on the primary star rotated ~ 0.3 cycles from directly facing the secondary. In this model the optical light would come from the irradiation of the secondary either by the X-ray spot or simply by a very hot primary star. The majority of the optical pulsations seem to originate on the irradiated secondary but for RXJ0806.3+1527 we also found evidence for the existence of a second optical emission site near the X-ray emission spot.

PULSATION ASTROMETRY OF V407 VUL

A surprising feature of V407 Vul is that its spectrum is of a G star whose lack of radial velocity seems to indicate that it is not the secondary star of the IP model [17]. We tested whether this could be a line-of-sight coincidence. If the G star is separated from V407 Vul on the sky, we expect to see a variation in the position of V407 Vul on its 569 sec pulsation period. In Fig. 2 we show the amplitude of the best-fitting sinusoid over a range of frequencies for y-positions and the filters where we have a detection r' and g'. We detected a semi-amplitude of 0.005 pixels in the position corresponding to a separation of V407 Vul and the G star of 0.03 arcsec. We conclude that, although the G star may be gravitationally bound to the variable (it could be part of a triple system), it plays no role in the X-ray and optical variability of V407 Vul. Specifically it cannot be Roche lobe filling. We also note that the change in period which is a popular method to

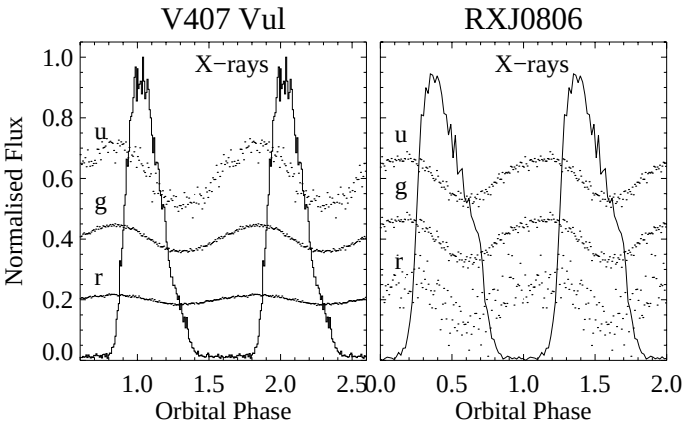

FIGURE 1. Phase-folded light curves of V407 Vul (left) and RXJ0806.3+1527 (right) in three filters r', g' and u' using the ephemeris of Ramsay et al. [11] and Strohmayer [12] respectively. Our data is superimposed with the X-Rays adapted from Strohmayer [14, 12]

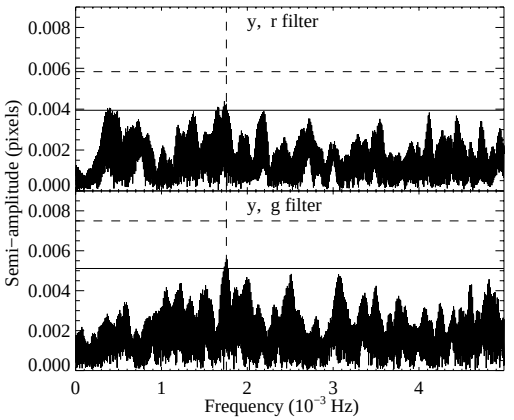

FIGURE 2. Amplitude spectra of the y variation of the position of V407 Vul with time for the r' and the g' filters of ULTRACAM. The vertical dashed lines show the position of the 569 sec period. The solid horizontal lines show the 99.9 percent significance level for a known period and the dashed horizontal lines show the same level for an arbitrary period.

choose between the models for V407 Vul could be affected by binary motion if V407 Vul is a triple star system.

CONCLUSIONS

We have presented optical photometry of V407 Vul and RXJ0806.3+1527 taken with ULTRACAM. We found a new phasing of the optical and X-ray light curves of

RXJ0806.3+1527 which makes it indistinguishable from V407 Vul. Our data favour the double degenerate accreting models for V407 Vul and RXJ0806.3+1527, namely the direct impact and the polar models. For V407 Vul we have a hint of a detection of a third star in the system, which is thought to be the G star seen in V407 Vul's spectra. This star is at 0.04 arcsec from the variable and plays no role in the variability of the system. We conclude that V407 Vul and RXJ0806.3+1527 have very similar characteristics and that the same model should be able to describe both systems.

ACKNOWLEDGMENTS

SCC Barros is supported by Fundação para a Ciência e Tecnologia e Fundo Social Europeu no âmbito do III Quadro Comunitário de Apoio. TRM acknowledges the support of a PPARC Senior Research Fellowship. DS acknowledges support of a Smithsonian Astrophysical Observatory Clay Fellowship. PJG and GR are supported by NWO VIDI grant 639.042.201 and GN by NWO VENI grant 639.041.405. Our data were acquired on the 4.2m WHT of the Isaac Newton Group of Telescopes, La Palma, on the Liverpool Telescope and on the ESO VLT at Paranal in Chile. The ESO proposal was 076.D-0228. We also made use of the ESO Paranal, NASA ADS and SIMBAD data archives.

REFERENCES

1. M. Cropper, M. K. Harrop-Allin, K. O. Mason, J. P. D. Mittaz, S. B. Potter, and G. Ramsay, *MNRAS* **293**, L57–L60 (1998).
2. C. Motch, F. Haberl, P. Guillout, M. Pakull, K. Reinsch, and J. Krautter, *A&A* **307**, 459–469 (1996).
3. G. L. Israel, M. R. Panzera, S. Campana, D. Lazzati, S. Covino, G. Tagliaferri, and L. Stella, *A&A* **349**, L1–L4 (1999).
4. P. Hakala, G. Ramsay, and K. Byckling, *MNRAS* **353**, 453–456 (2004).
5. K. Wu, M. Cropper, G. Ramsay, and K. Sekiguchi, *MNRAS* **331**, 221–227 (2002).
6. G. Ramsay, P. Hakala, and M. Cropper, *MNRAS* **332**, L7–L10 (2002).
7. G. L. Israel, W. Hummel, S. Covino, S. Campana, I. Appenzeller, W. Gässler, K.-H. Mantel, G. Marconi, C. W. Mauche, U. Munari, I. Negueruela, H. Nicklas, G. Rupprecht, R. L. Smart, O. Stahl, and L. Stella, *A&A* **386**, L13–L17 (2002), `astro-ph/0203043`.
8. G. Nelemans, S. F. Portegies Zwart, F. Verbunt, and L. R. Yungelson, *A&A* **368**, 939–949 (2001).
9. T. R. Marsh, and D. Steeghs, *MNRAS* **331**, L7–L11 (2002).
10. G. Ramsay, K. Wu, M. Cropper, G. Schmidt, K. Sekiguchi, F. Iwamuro, and T. Maihara, *MNRAS* **333**, 575–582 (2002).
11. G. Ramsay, M. Cropper, and P. Hakala, *MNRAS* **367**, L62–L65 (2006), `astro-ph/0601104`.
12. T. E. Strohmayer, *ApJ* **627**, 920–925 (2005).
13. S. C. C. Barros, T. R. Marsh, V. S. Dhillon, P. Groot, S. Littlefair, G. Nelemans, G. Roelofs, D. Steeghs, and P. J. Wheatley, *MNRAS* (in press).
14. T. E. Strohmayer, *ApJ* **610**, 416–421 (2004).
15. G. L. Israel, S. Covino, L. Stella, C. W. Mauche, S. Campana, G. Marconi, W. Hummel, S. Mereghetti, U. Munari, and I. Negueruela, *ApJ* **598**, 492–500 (2003).
16. G. L. Israel, S. Covino, S. Dall'Osso, D. Fugazza, C. W. Mouche, L. Stella, S. Campana, V. Mangano, G. Marconi, S. Bagnulo, and U. Munari, *Memorie della Societa Astronomica Italiana Supplement* **5**, 148–+ (2004).
17. D. Steeghs, T. R. Marsh, S. C. C. Barros, G. Nelemans, P. J. Groot, G. H. A. Roelofs, G. Ramsay, and M. Cropper, *ApJ* **649**, 382–388 (2006), `astro-ph/0605727`.