

NSVS 14256825: A NEW HW Vir TYPE SYSTEM

WILS, PATRICK¹; DI SCALA, GIORGIO²; OTERO, SEBASTIÁN A.³

¹ Vereniging voor Sterrenkunde, Belgium, email: patrickwils@yahoo.com

² Carnes Hill Obs., 34 Perisher St., Horningsea Park, NSW, Sydney Australia, e-mail: lgdiscala@aapt.net.au

³ Grupo Wezen 1 88, Centro de Estudios Astronómicos (CEA), e-mail: varsao@fullzero.com.ar

The object NSVS 14256825 = 2MASS J20200045+0437564 = UCAC2 33483055 = USNO-B1.0 0946-0525128 at position $\alpha_{2000} = 20^{\text{h}}20^{\text{m}}00^{\text{s}}.458$, $\delta_{2000} = +04^{\circ}37'56''.50$ (UCAC2; Zacharias et al., 2004), has been found to be a new eclipsing binary in the public data release from the Northern Sky Variability Survey (NSVS, Wozniak et al., 2004). A very short period of 0.1104 days was found, revealing the peculiar nature of the system, also justified by the extremely blue colour measured by the 2MASS survey (Cutri et. al, 2003): $J - K_s = -0.29$ and $H - K_s = -0.15$.

Multi-band CCD observations of NSVS 14256825 were carried out with a 12'' LX200 GPS Schmidt-Cassegrain telescope located at Carnes Hill Observatory. The CCD employed was primarily a SBIG ST9XE camera coupled to a CFW8A filter wheel. BVR_CI_C Custom Scientific Photometric filters were used with this camera. Some observations were also performed with a SBIG ST402ME camera utilising the internal filter wheel and SBIG supplied BVI_C filters.

All images were reduced by applying bias, dark and flat fields before instrumental magnitudes were extracted using AIP4WIN 1.4 software (Berry & Burnell, 2000). This was done using typical aperture photometry techniques. The observation log is given in Table 1.

On two occasions, all sky photometry was performed under photometric conditions to measure the targets and surrounding field stars so that accurate photometric data could be obtained. For the all sky data, the Landolt standards SA111 717, SA111 2009 and SA111 2522 were the primary standards employed. First order extinction coefficients were applied to the instrumental magnitudes. Typical first order extinction values in Sydney at that time of year are 0.28, 0.16, 0.12 and 0.09 for BVR_CI_C respectively. Extinction values were measured using a scatter technique by observing a number of E and Landolt standards at a variety of air masses (typically ranging from ~ 1.0 to ~ 1.9). Second order extinction corrections were partially applied by using standards that were close in colour to the targets. Transformation coefficients were applied to produce properly standardised magnitudes (see Table 2 for a summary of the photometry for all stars). For the differential time series photometry, the bright field star UCAC2 33483104 was used as the comparison and UCAC2 33483048 was used as the check star. The full range of variation for NSVS 14256825 thus obtained is 13.22-14.03V, the magnitude of secondary minimum is 13.34V. All data are available in the electronic edition and from the AAVSO.

Table 1: Observation log for NSVS 14256825.

| Filter | JD - 2400000 | Nights | Hours | Points |
|----------------------|--------------|--------|-------|--------|
| <i>B</i> | 54280-54294 | 4 | 13.2 | 962 |
| <i>V</i> | 54274-54326 | 16 | 41.0 | 3010 |
| <i>I_C</i> | 54317-54318 | 2 | 5.5 | 464 |

Table 2: Absolute photometry of the variables and comparison stars.

| Star | JD-2400000 | <i>V</i> | <i>B</i> - <i>V</i> | <i>V</i> - <i>R_C</i> | <i>V</i> - <i>I_C</i> |
|-------------------|----------------------|------------------------------|------------------------------|---------------------------------|---------------------------------|
| NSVS 14256825 | 54274.14 54316.66 | 13.24 ± 0.02 13.24 ± 0.03 | -0.18 ± 0.03 -0.16 ± 0.04 | -0.06 ± 0.03 | -0.20 ± 0.03 -0.24 ± 0.04 |
| NSVS 14256492 | 54274.14 54316.66 | 14.25 ± 0.02 14.29 ± 0.03 | +0.44 ± 0.03 +0.41 ± 0.04 | +0.20 ± 0.02 | +0.54 ± 0.03 +0.47 ± 0.04 |
| UCAC2 33483104 | 54274.14 54316.66 | 11.23 ± 0.02 11.23 ± 0.02 | +0.75 ± 0.01 +0.76 ± 0.02 | +0.42 ± 0.01 | +0.80 ± 0.02 +0.78 ± 0.02 |
| UCAC2 33483048 | 54274.14 | 11.50 ± 0.02 | +1.10 ± 0.01 | +0.59 ± 0.02 | +1.14 ± 0.02 |

Table 3: List of primary minima of NSVS 14256825. *O* - *C* values are derived from Eq. 1.

| Epoch HJD-2400000 | Uncertainty [days] | <i>O</i> - <i>C</i> [days] | Points used | Filter |
|----------------------|-----------------------|-------------------------------|----------------|----------------------|
| 54274.2081 | 0.0001 | +0.0000 | 16 | <i>V</i> |
| 54282.1552 | 0.0002 | +0.0002 | 20 | <i>B/V</i> |
| 54282.2654 | 0.0002 | +0.0000 | 21 | <i>B/V</i> |
| 54286.1284 | 0.0001 | -0.0001 | 18 | <i>V</i> |
| 54293.1925 | 0.0001 | +0.0000 | 21 | <i>B</i> |
| 54294.0755 | 0.0001 | +0.0000 | 24 | <i>B</i> |
| 54294.1859 | 0.0001 | +0.0001 | 24 | <i>B</i> |
| 54295.1792 | 0.0001 | -0.0000 | 17 | <i>V</i> |
| 54309.0863 | 0.0001 | +0.0000 | 17 | <i>V</i> |
| 54309.1966 | 0.0001 | -0.0000 | 19 | <i>V</i> |
| 54310.0797 | 0.0001 | +0.0001 | 21 | <i>V</i> |
| 54314.1635 | 0.0001 | -0.0000 | 15 | <i>V</i> |
| 54316.1502 | 0.0001 | -0.0001 | 18 | <i>V</i> |
| 54318.0267 | 0.0001 | +0.0001 | 22 | <i>I_C</i> |
| 54319.0199 | 0.0001 | -0.0001 | 20 | <i>I_C</i> |
| 54319.1305 | 0.0001 | +0.0002 | 22 | <i>I_C</i> |
| 54323.1038 | 0.0001 | -0.0001 | 18 | <i>V</i> |
| 54324.0972 | 0.0001 | -0.0000 | 22 | <i>V</i> |
| 54366.0394 | 0.0001 | +0.0000 | 21 | <i>V</i> |

From the CCD data twenty one times of primary eclipse could be determined. These are listed in Table 3. The given uncertainties are those derived from fitting a second degree polynomial through the data around the minimum. From these timings and single data points showing the star in eclipse from NSVS and the All Sky Automated Survey (ASAS3; Pojmanski, 2002), the following ephemeris could be derived:

$$\text{HJD} = 2451288.9198(5) + 0.11037410(2)\text{E}. \quad (1)$$

The short orbital period in the period gap for cataclysmic variables, blue colour and strong reflection effect seen in its light curve suggest that the system is made up of a hot subdwarf and a red dwarf showing a large reflection effect. The period and light curve are strikingly similar to that of the other short period eclipsing sdOB+dM systems HW Vir (0.1167 d, Wood et al., 1993), NY Vir (0.1010 d, Kilkenny et al., 1998) and HS 0705+6700 (0.0956 d, Drechsel et al., 2001).

To determine the photometric parameters of the system, the 2003 version of the WD program (Wilson & Devinney, 1971) was used. Calculations were done in mode 2 (for detached systems). As is usual when only photometric data is available and no radial velocity curves, it is very difficult to obtain a precise value for the mass ratio q . Furthermore, the secondary is so faint compared to the primary, that it practically does not contribute to the total brightness, unless through reflection of the light from the primary. Therefore it is hard to determine a precise value of the surface temperature T_2 of the secondary. This means that when using the differential correction program *dc* of WD, convergence is not easily obtained. To remedy this, a large range of values for T_1 , T_2 and q were tried, and the resulting residual values compared. The values used ranged between 20 000 and 50 000K for T_1 (in line with the $B - V$ and $J - K_s$ colours), between 2400 and 6500K for T_2 and between 0.3 and 0.9 for q . Within this range of parameters a shallow minimum for the residuals was obtained. The final parameters obtained in this case are given in Table 4. The phased light curve with the model curve is given in Fig. 1. The uncertainties for the assumed parameters are those for when the resulting residual curve began to show systematic differences, especially near secondary minimum. The uncertainties for the calculated parameters are those based on their extreme values calculated with *dc* considering the range of assumed parameters. Values for the limb darkening coefficients (not listed) were taken from the tables of van Hamme (1993).

Assuming an absolute magnitude of $M_V = 4.0$ for the hot subdwarf, a distance of about 570 pc can be derived taking into account an interstellar extinction value $E(B - V) = 0.14$ and $A(V) = 0.46$ (from the NASA/IPAC Extragalactic Database, see also Schlegel et al. 1998). The mass of slightly less than $0.5 M_\odot$ for the hot subdwarf thus obtained, and the radius of $0.2 R_\odot$ do then agree very well with those found for the three other similar eclipsing binaries mentioned above.

Because of its low surface temperature, the secondary has a convective atmosphere. Its bolometric albedo A_2 is then normally assumed to be 0.5. However none of the combinations of the other parameters then gave a secondary minimum deep enough to fit the observations. Making A_2 an adjustable parameter resulted in a value slightly larger than 1, which it physically cannot be. Therefore A_2 was assumed to be 1. Fitting the individual light curves independently also indicated that much more light is absorbed at shorter wavelengths and re-emitted at longer wavelengths than is assumed by the WD code.

Pulsations of the subdwarf, known to occur in other hot subdwarfs such as NY Vir (Kilkenny et al., 1998), were not observed in NSVS 14256825. Any variations due to such pulsations should have an amplitude of less than 0.01 magnitude (which is the semi-

Table 4: System parameters for NSVS 14256825.

| Assumed parameters | | Calculated parameters | |
|-----------------------------------|------------------------|-----------------------------|---------------------------|
| Eccentricity e | 0 | Semi-major axis a | $0.85 \pm 0.10 R_{\odot}$ |
| Mass ratio q | $0.45^{+0.15}_{-0.10}$ | i | $81.9^{+0.5}_{-0.8}$ |
| Effective temperatures | | Ω_1 | 4.7 ± 0.2 |
| T_1 | $35\,000 \pm 5000$ K | Ω_2 | $3.7^{+0.8}_{-0.6}$ |
| T_2 | 3500^{+500}_{-800} K | Mass M_1 | $0.46 M_{\odot}$ |
| Bolometric albedos | | Mass M_2 | $0.21 M_{\odot}$ |
| A_1 | 1.0 | distance | 570 pc |
| A_2 | 1.0 | Surface gravity (cgs units) | |
| Gravitational darkening exponents | | $\log(g_1)$ | 5.50 ± 0.02 |
| g_1 | 1.0 | $\log(g_2)$ | 5.35 ± 0.11 |
| g_2 | 0.32 | Mean radii | |
| Absolute magnitude | | R_1 | $0.20 \pm 0.03 R_{\odot}$ |
| $M_{V,1}$ | 4.0 | R_2 | $0.16 \pm 0.03 R_{\odot}$ |
| | | Absolute magnitude | |
| | | $M_{V,2}$ | $12.9^{+3.1}_{-1.0}$ |

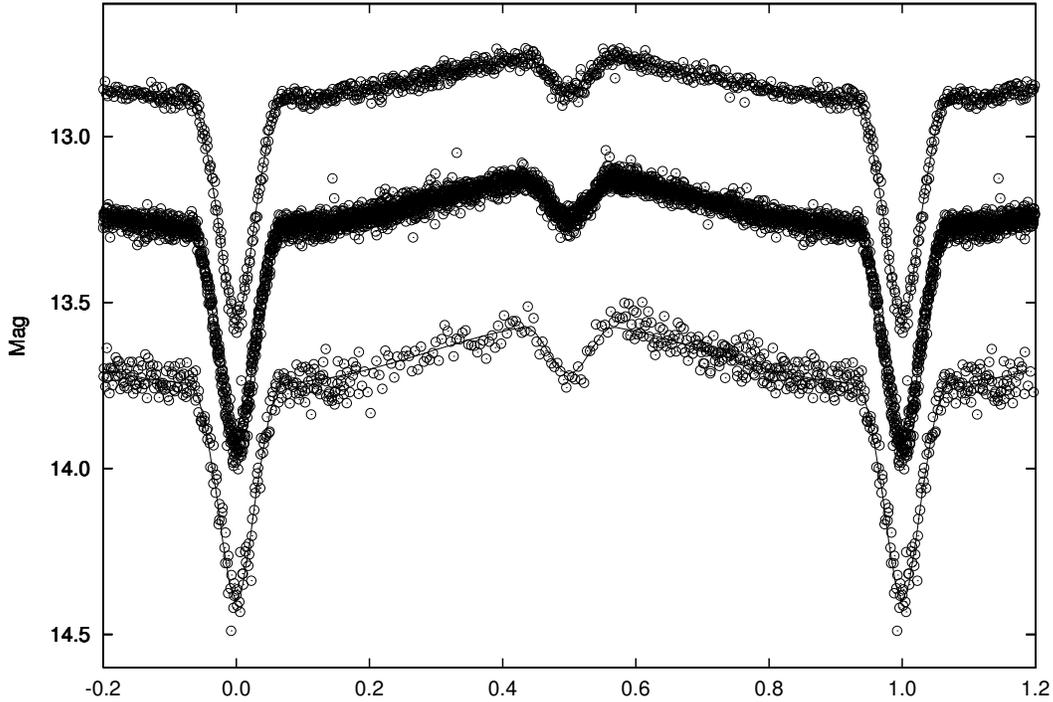


Figure 1. Phase plots of NSVS 14256825: from top to bottom respectively in B , V and I_C . The B and I_C light curves have been shifted vertically so as to not interfere with the V light curve. Note that the secondary eclipse is deeper for longer wavelengths.

amplitude of the pulsations in NY Vir). It is worthwhile to follow NSVS 14256825 further to study its period stability and to perform spectroscopic observations to determine the physical parameters more accurately.

When observing NSVS 14256825 care should be taken not to use NSVS 14256492 = UCAC2 33482998 = USNO-B1.0 0945-0527099, at position $\alpha_{2000} = 20^{\text{h}}19^{\text{m}}47^{\text{s}}.737$, $\delta_{2000} = +04^{\circ}34'01''.81$ (UCAC2), as a comparison star as it is a semi-detached eclipsing binary with a full range of 14.25-14.7V, amplitude of the secondary minimum about 0.1V, and the following ephemeris:

$$\text{HJD} = 2454326.04 + 0.963627\text{E}. \quad (2)$$

Acknowledgements: The authors thank Prof. Robert Wilson for making the WD code publicly available. The IBVS editors and John Greaves are acknowledged for suggestions improving the paper. This study made use of NASA's Astrophysics Data System, and the SIMBAD and VizieR databases operated at the Centre de Données Astronomiques (Strasbourg) in France.

References:

- Berry R., Burnell J., 2000, *The Handbook of Astronomical Image Processing*
- Cutri R.M., Skrutskie M.F., Van Dyk S., Beichman C.A., Carpenter J.M., Chester T., Cambresy L., Evans T., Fowler J., Gizis J., Howard E., Huchra J., Jarrett T., Kopan E.L., Kirkpatrick J.D., Light R.M., Marsh K.A., McCallon H., Schneider S., Stiening R., Sykes M., Weinberg M., Wheaton W.A., Wheelock S., Zacharias N., 2003, *The 2MASS All-Sky Catalog of Point Sources*
- Drechsel H., Heber U., Napiwotzki R., Østensen R., Solheim J.-E.; Johannessen F., Schuh S.L., Deetjen J., Zola S., 2001, *A&A*, **379**, 893
- Kilkenny D., O'Donoghue D., Koen C., Lynas-Gray A.E., van Wyk F., 1998, *MNRAS*, **296**, 329
- Pojmanski G., 2002, *Acta Astron.*, **52**, 397
- Schlegel D.J., Finkbeiner D.P., Davis M., 1998, *ApJ*, **500**, 525
- van Hamme W., 1993, *AJ*, **106**, 2096
- Wilson R.E., Devinney E.J. 1971, *ApJ*, **166**, 605
- Wood J.H., Zhang E.-H., Robinson E.L., 1993, *MNRAS*, **261**, 103
- Wozniak P.R., Vestrand W.T., Akerlof C.W., Balsano R., Bloch J., Casperson D., Fletcher S., Gisler G., Kehoe R., Kinemuchi K., Lee B.C., Marshall S., McGowan K.E., McKay T.A., Rykoff E.S., Smith D.A., Szymanski J., Wren J., 2004, *AJ*, **127**, 2436
- Zacharias N., Urban S. E., Zacharias M. I., Wycoff G. L., Hall D. M., Monet D. G., Rafferty T. J., 2004, *AJ*, **127**, 3043