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LETTER

Letter to the Editor

HS 0907+1902: a new 4.2 hr eclipsing dwarf nova

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Abstract. We report on follow-up spectroscopy and photometry of the cataclysmic variable candidate HS 0907+1902 selected from the Hamburg Quasar Survey. B, V, and R photometry obtained during the first observed outburst of HS 0907+1902 ($V \approx 13$) reveals deep eclipses ($\Delta V \approx 2.1 - 2.8$) and an orbital period $P_{\rm orb} = 4.2$ h with the eclipse depth decreasing to the red. The outburst eclipse profiles are symmetric, indicating an axisymmetrical brightness distribution in the accretion disc. We derive an inclination $i \approx 73° - 79°$ from the eclipse duration. The quiescent spectrum obtained with the Hobby-Eberly Telescope shows double peaked emission lines of H I, He I and Fe I,II and clearly identifies the system as a dwarf nova. Absorption features of the secondary star are detected at red wavelengths from which a spectral class M3 $\pm$ 1.5 and a distance of $d = 320 \pm 100$ pc are derived.

Key words: accretion, accretion disks – surveys – stars: binaries: close – stars: binaries: eclipsing – stars: individual: HS 0907+1902 – stars: novae, cataclysmic variables

1. Introduction

Cataclysmic variables (CVs) may be discovered by various means. Historically, most of them were found because of their *cataclysmic* nature, i.e. strong variability. This is especially valid for dwarf novae, which show quasi-regular outbursts in the visual of up to 8 magnitudes. With the advent of space-based X-ray telescopes, a new class of CVs was discovered, containing magnetic white dwarfs as accretors. The ROSAT and EUVE missions were extremely successful in discovering this type of CVs (e.g. Beuermann 1998).

However, a large number of CVs are neither prominent X-ray sources, nor strongly variable. In non-magnetic CVs with a constantly high mass transfer rate – novalike variables – the accretion disc remains in a perpetual hot state, turning them into unspectacular blue objects. Similarly, dwarf novae with low outburst amplitudes or long outburst cycles are likely to slip the attention of sky patrols. As a result, the sample of known CVs Downes et al. 1997 is skewed by selection effects, and the actual space density of CVs is a matter of serious debate (e.g. de Kool 1992 and Patterson 1998).

The Hamburg Schmidt objective prism survey (HQS, Hagen et al. 1995), originally aimed at the detection of a magnitude-limited sample of bright quasars (V=13–17.5), provides a rich source of CV candidates selected because of their *spectroscopic* properties. Up to date, only few CVs have been serendipitously identified from the HQS: HS 0551+7241 Dobrzycka et al. 1998; HS 1023+3900 Reimers et al. 1999; and HS 1804+6753 (=EX Dra) Billington et al. 1996; Fiedler et al. 1997. The latter two objects show the strength of the spectroscopic selection of CV candidates: HS 1023+3900 is a magnetic CV with a very low accretion rate and no X-ray emission, and HS 1804+6753 is a bright eclipsing dwarf nova with low-amplitude outbursts, both stars were unlikely to be detected with the "classic" selection mechanisms described above.

We have initiated a search for new CVs selected from the HQS with follow-up observations of CV candidates detected also in the ROSAT Bright Source catalogue Voges et al. 1999. They were identified as possible CVs by Bade et al. 1998 because of the Balmer line emission seen in their HQS prism spectra. HS 0907+1902 (= 1RXS J090950.6+184956) was independently confirmed spectroscopically as CV at the BAO (X. Jiang, private communication). Here we report on the first photometric and spectroscopic results for HS 0907+1902.

2. Observations and results

2.1. Photometry

Several nights of differential photometry of HS 0907+1902 (Fig. 1) were obtained at Braeside Observatory, Arizona, with a 41 cm reflector equipped with a SITe 512 CCD camera (Table 1). B and V magnitudes of HS 0907+1902 were derived relative to the $V = 11.08$ and $B - V = 0.86$ comparison star (= Tycho2 1404-1852-1).

The first night of the observation run on 2000 February 7 showed HS 0907+1902 at a magnitude of $V \sim 13$. As Bade et al. 1998 estimated $B \approx 16.4$ from the HQS prism spectra, this clearly indicated that we had detected the first dwarf

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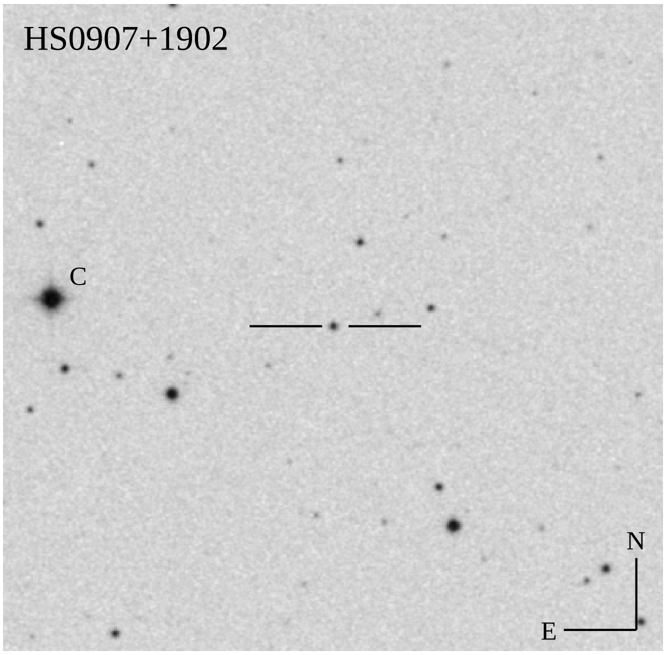

Fig. 1. Finding chart ($7' \times 7'$) for HS 0907+1902 obtained from the Digitized Sky Survey. The coordinates of the star are $\alpha(2000) = 09^h09^m50.5^s$ and $\delta(2000) = +18°49'47''$. The TYCHO comparison star is marked 'C'

Table 1. Observation log.

HJD Start (2 450 000+)	Int. time [s]	# of observations	Mode	Filter / Resolution
1471.9798	600	2	spect	7−13 Å
1581.7493	58	330, 334, 333	phot	B, V, R
1585.6124	78	209, 209, 202	phot	B, V, R
1589.7248	50	390	phot	white light
1590.6193	75	389	phot	V
1597.6189	35	64	phot	white light
1599.6479	35	462	phot	white light

nova outburst of HS 0907+1902. The light curves (Fig. 2) show deep eclipses ($\Delta B = 3.0$, $\Delta V = 2.6$, and $\Delta R = 2.1$) with a period of 4.2 h and low flickering activity. The mean V magnitude increased by ~ 0.2 throughout the night, indicating that HS 0907+1902 was still on the rise to the maximum of the outburst. No orbital modulation (hump) was detected. The outburst was independently discovered by observers of the Variable Star Network (VSNET) who reported the outburst of HS 0907+1902 on February 11 (vsnet-alert 4176)[1].

The B, V, and R light curves obtained on February 11 cover one eclipse and are very similar to those of February 7, but the system was somewhat fainter ($V \approx 13.8$) and a decline by ~ 0.1 mag is observed during the night. Hence, the maximum of the outburst occurred between February 7 and 11. HS 0907+1902 was apparently in outburst during the epoch of

[1] http://www.kusastro.kyoto-u.ac.jp/vsnet/Mail/vsnet-alert/msg04176.html

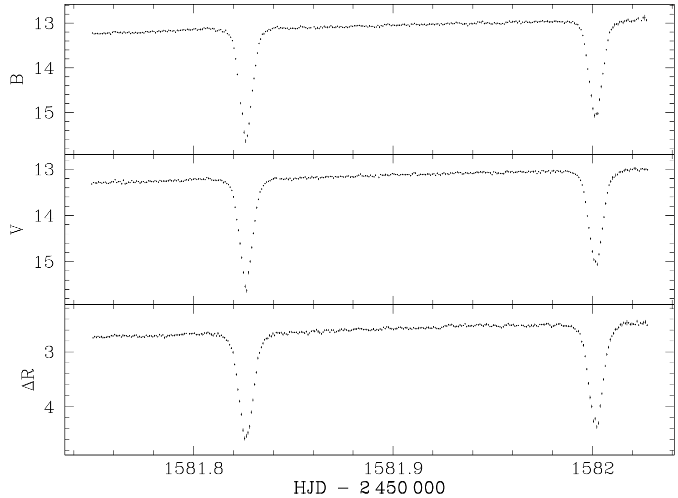

Fig. 2. B, V, R light curves obtained on February 7, 2000.

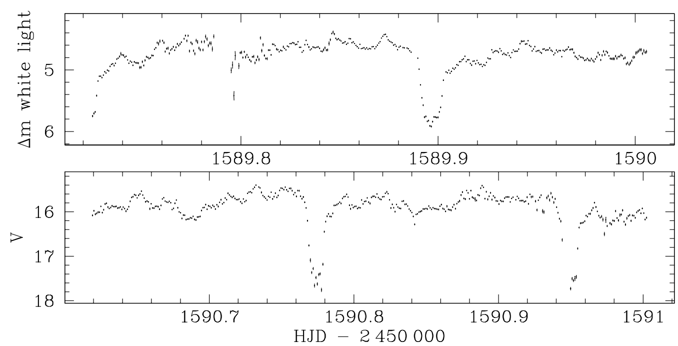

Fig. 3. Top panel: White light curve obtained on February 15. Bottom panel: V light curve obtained on February 16.

the plates of the Hubble Space Telescope Guide Star Catalogue, which lists $V = 12.53$. This value might be taken as the brightest outburst magnitude so far recorded.

On February 15, the system appeared to be much fainter, and, due to poor weather conditions, we decided to obtain filterless photometry to maximise the time resolution. Flickering with an amplitude of ~ 0.4 mag was apparent, typical of dwarf novae in quiescence. Surprisingly, the light curve shows no strong orbital modulation, which is normally the signature of a bright spot where the accretion stream impacts the disc. One eclipse egress and one full eclipse were covered. On February 16, we obtained a V band light curve near $V \approx 16$ (Fig. 3). Finally, an eclipse egress and one complete eclipse were covered on February 23 and 25, respectively, again in white light photometry, with the same out-of-eclipse magnitude as on February 15. HS 0907+1902 was, therefore, already in quiescence on the $15^{\rm th}$.

Ephemeris. From the seven observed eclipses we derive the following ephemeris:

$$\phi_0 = \mathrm{HJD}\,2451581.8263(1) + 0.175446(3) \times E \quad (1)$$

where $\phi = 0$ is defined as the mid-eclipse phase, equivalent to the inferior conjunction of the secondary star. Errors in the last digit are given in brackets. Table 2 lists the eclipse timings.

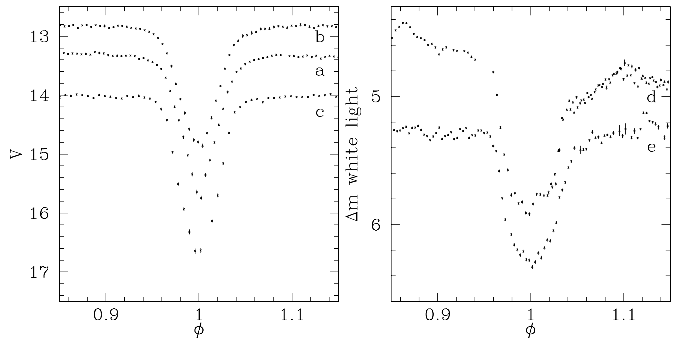

Fig. 4. Left: V band eclipse profiles obtained during the outburst on February 7 (a and b, b has been offset by -0.5 mag) and 11 (c), folded with the ephemeris Eq. (1). The light curves have been detrended from the linear increase/decrease of the out-of-eclipse magnitude (see Fig. 2). Right: white light eclipses obtained during quiescence on February 15 (d) and 25 (e, offset by +0.5 mag).

Eclipse shape. We observed three eclipses during the dwarf nova outburst. In order to compare the eclipse profiles, a linear fit was made to the out-of-eclipse light curves and subsequently used to detrend the light curves. The detrended eclipse profiles, folded with the above ephemeris, are displayed in Fig. 4. The wings of the eclipse profiles are perfectly symmetric with respect to $\phi = 0.0$, indicating an axisymmetrical brightness distribution in the accretion disc in HS 0907+1902. The brightness at eclipse minimum is higher than that observed during quiescence ($V \approx 17.6$, Fig. 3), so the accretion disc is not totally eclipsed. Interestingly, the centre of the eclipse profile is variable in shape: while the first eclipse (labelled 'a') on February 7 has a round minimum, the second one ('b') has a flat bottom, which hints to an increase in brightness of the non-eclipsed part of the accretion disc and could explain the observed increase of the overall brightness of the system. In the context of disc-outburst theory (e.g. Osaki 1996) this behaviour would be expected if the observed outburst is of inside-out nature. The width of the eclipse at half depth is $\Delta\phi_{1/2} \approx 0.06$ during outburst, which is somewhat lower than e.g. in IP Peg ($\Delta\phi_{1/2} \approx 0.09$). The measured eclipse duration implies $i \approx 73° - 79°$ for a mass ratio $q = M_{\rm wd}/M_{\rm sec}$ in the range $1.25 - 3$.

Unfortunately, during quiescence only two full eclipses were covered with data of satisfactory quality (Fig. 4), which leaves the following statements somewhat speculative. Taken at face value, the eclipse observed on February 15 broadly resembles that of Z Cha during quiescence Cook & Warner 1984: the eclipse minimum is followed by a steep jump in brightness, which is followed by a smooth egress to the out-of-eclipse level. In Z Cha, the final egress is due to the appearance of the bright spot, whereas the sudden jump from eclipse minimum corresponds to the egress of the white dwarf. The hypothetical white dwarf egress in HS 0907+1902 would result in a relatively short eclipse of the primary ($\Delta\phi \sim 0.04$), which agrees with the conclusions on i and q obtained above from the high state eclipse profiles. However, the eclipse obtained on February 25 has a less structured shape, and higher S/N data are needed to decisively derive the binary parameters.

Table 2. Eclipse timings from the Braeside photometry.

HJD(ϕ_0) (2 450 000+)	O–C $P_{\rm orb}$	Filter	State
1581.8263	2.5×10^{-4}	B, V, R	outburst
1582.0017	-4.8×10^{-4}	B, V, R	outburst
1585.6861	-1.3×10^{-4}	B, V, R	outburst
1589.8969	2.4×10^{-4}	white light	quiescence
1590.7742	7.2×10^{-4}	V	quiescence
1590.9496	4.9×10^{-4}	V	quiescence
1599.7219	3.9×10^{-4}	white light	quiescence

2.2. Spectroscopy

On 1999 October 20, two identification spectra of HS 0907+1902 were obtained with the low resolution spectrograph (LRS, $\lambda/\Delta\lambda \approx 520$) on the 9.2 m Hobby-Eberly telescope (HET) on Mt. Fowlkes, Texas. An absolute flux calibration of these spectra was not possible due to thermal drift in the alignment of the 91 individual segments of the primary mirror. We, therefore, used the flux standard LDS749b to derive the instrumental response function and adjusted the spectra of HS 0907+1902 to the observed V magnitude. One of the HET spectra is shown in Fig. 5.

The spectrum of HS 0907+1902 is typical of a dwarf nova in quiescence, containing strong Balmer emission lines and weaker He I and Fe II lines. There is possibly some weak emission of He II λ 4686, blended with He I λ 4713 and with the C III/N III $\lambda\lambda 4640 - 4650$ complex. The double-peaked shape of the emission lines is typical for high-inclination dwarf novae. The equivalent widths of the most prominent lines are Hα = 90 Å, Hβ = 78 Å, Hγ = 46 Å, He I λ 5870 = 24 Å, He I λ 4474 = 10 Å. The FWHM, corrected for the instrumental resolution, are Hα = 32 Å, Hβ = 28 Å, Hγ = 26 Å, He I λ 5870 = 33 Å, He I λ 4474 = 26 Å.

The red end of the HET spectrum of HS 0907+1902 shows signatures of a late-type secondary star, namely the broad absorption blends of TiO/CaOH ($\lambda\lambda 6160 - 6320$) and of TiO ($\lambda\lambda 7190 - 7210$). The flux increases for $\lambda > 7210$ Å, as expected for the contribution of a late type star. Using a library of observed M-dwarf spectra, we derive a spectral type of M3 ± 1.5 for the secondary star in HS 0907+1902. This estimate agrees well with the observed spectral types of secondaries in CVs with similar $P_{\rm orb}$ Beuermann et al. 1998. Fig. 5 shows the M3-dwarf Gl352ab scaled according to the depth of the observed absorption features.

From the adjusted M-star spectra of stars with the above range of spectral types, we measure an observed surface brightness of the flux difference in the $\lambda\lambda 7500/7165$ Å band of $f_{\rm TiO} = (3.9 \pm 1.7) \times 10^{-16}\,{\rm erg\,cm^{-2}s^{-1}Å^{-1}}$. From Roche geometry and from Patterson's 1984 mass-radius relation for main-sequence stars we estimate that $M_{\rm sec} = 0.42 M_\odot$ and $R_{\rm sec} = 3.17 \times 10^{10}$ cm. Finally, applying the calibration for the $F_{\rm TiO}$ surface brightness of late-type stars of Beuermann & Weichold 1999, we obtain a distance of $d = 320 \pm 100$ pc, corresponding to a distance modulus of $m - M = 7.5 \pm 0.7$.

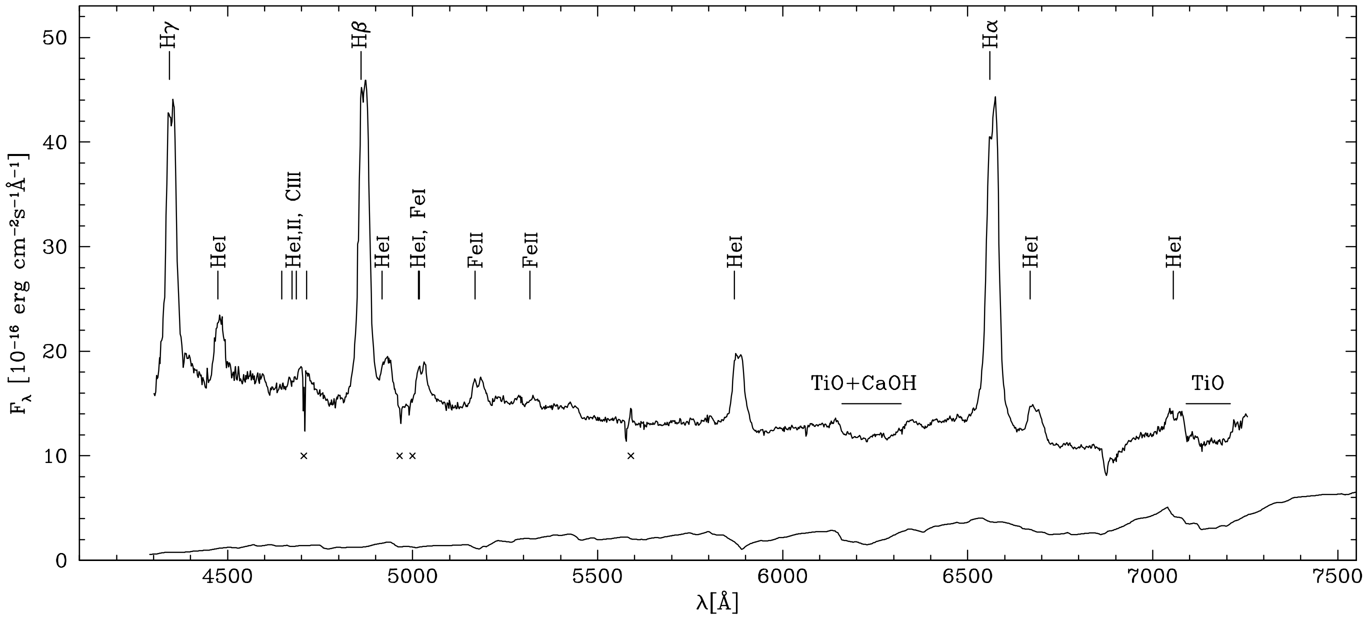

Fig. 5. HET/LRS spectrum of HS 0907+1902 in quiescence. Major emission lines are identified. Also shown is the spectrum of the M3 dwarf Gl352ab, which has been scaled to $V = 18.13$ in order to match the observed TiO and CaOH absorption observed in HS 0907+1902. Crosses mark structures due to CCD defects and poor sky line subtraction.

If we assume an outburst magnitude of $V = 12.5$ (Sect. 2.1), we derive an absolute magnitude in outburst of $M_V = 3.3$, where we applied a correction $\Delta M_V(i) = 1.6$ for an assumed inclination of $80°$. Warner's 1987 $M_V - P_{\rm orb}$ relation gives $M_V = 4.6$ for $P_{\rm orb} = 4.2$ h; this can be taken as a hint that the true distance is on the lower side of our error range and that the spectral type of the secondary is rather $\sim M4$.

3. Conclusion

We have discovered a bright new eclipsing dwarf nova with an orbital period of 4.2 h. Eclipsing CVs offer the best means of deriving the system parameters such as stellar masses, mass transfer rates, and the structure of the accretion disc. With its long orbital period, HS 0907+1902 is only the fourth deeply eclipsing dwarf nova above the $2 - 3$ h period gap, the other ones being IP Peg, HS 1804+6753 (=EX Dra), and BD Pav. With a quiescent and an outburst magnitude of $V \approx 16$ and $V \approx 12.5$, respectively, HS 0907+1902 is well suited for detailed follow-up studies.

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