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Letter to the Editor

HS0922+1333: another low accretion rate polar with a pronounced cyclotron line spectrum*

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Abstract. We present time resolved spectroscopy of the newly discovered magnetic CV HS 0922+1333. Our observations show that it has a period of 244±2 min. Its optical spectra are dominated by a strong single spot cyclotron line at 5334 Å. A detailed analysis shows that further cyclotron harmonics are at 7800 Å (hidden by the M dwarf companion) and at 4034 Å which yields a field strength of 66 MG (n = 2, 3 and 4). A much weaker spot appears to be present at antiphase with $B \simeq$ 81 MG (n = 2 and 3 visible). HS 0922+1333 does not show any emission lines (like Balmer, HeII) except the cyclotron harmonics. It has an extremely low accretion rate of the order of $3 \cdot 10^{-13} \mathrm{M}_{\odot} \mathrm{yr}^{-1}$, atypical for its long period. It has not been detected by ROSAT. HS 0922+1333 is the third member of a class of strong cylotron line emitters (low accretion rates) defined by HS 1023+3900 and 1RXS J012851.9−233933, both probably in the CV period gap, while HS 0922+1333 is clearly above the period gap. At a distance of 190 pc the WD primary is rather faint (M_{B} = 12.6) and cool ($T_{\mathrm{eff}} \leq$ 10 000 K) implying the system is old.

Key words: stars: individual: HS0922+1333 – stars: novae, cataclysmic variables – stars: magnetic fields – stars: white dwarfs – stars: binaries: general

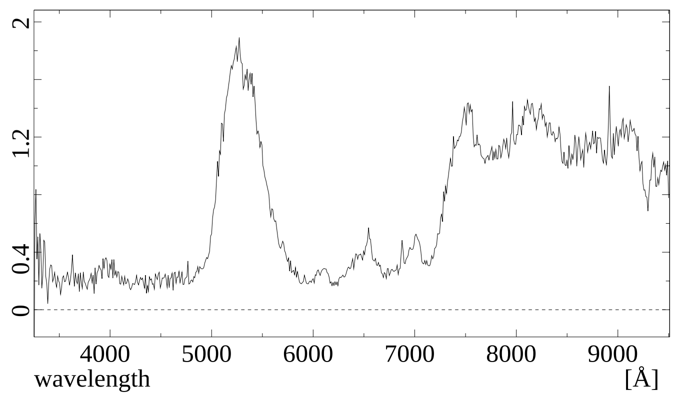

Fig. 1. Discovery spectrum of HS 0922+1333 taken with CAFOS at the Calar Alto 2.2m telescope. The spectral resolution is 19 Å. Notice the exceptionally strong n=3 cyclotron harmonic at 5334 Å and the much weaker n=4 harmonic at 4034 Å. Flux units are 10^{-15} erg cm^{-2} s^{-1} Å^{-1}.

1. Introduction

The number of known polars (AM Her stars) has increased steeply in the last decade mainly due to the RASS (ROSAT - All - Sky Survey), Thomas et al. (1998). The selection of bright, soft X-ray sources introduces a strong bias since the selection favours sources with high accretion rates. Magnetic CVs with low accretion rates, on the other hand, are difficult to detect, since they are neither strong X-ray sources nor do they show broad-band optical variability with amplitudes high enough to be discovered in classical variable star search programs. Two polars with low accretion rates, and therefore with distinctive cyclotron emission lines have been discovered last year: HS 1023+3900 was spectroscopically observed as a z = 3 QSO candidate due to its n = 3 cyclotron harmonic at $\sim$ 5200 Å (68 MG), and it was found with P = 167.6 min to be located in the CV period gap (Reimers et al. 1999). It has an estimated accretion rate $\dot{M} < 3 \cdot 10^{-13}$ M$_{\odot}$yr^{-1}, consistent with its location in the CV period gap according to the standard scenarios for the evolution of CVs. The other object is 1RX J012851.9−233931 (Schwope et al. 1999) which has a similar dominating single line cyclotron-spectrum, from which a low accretion rate was estimated. This appears to be inconsistent with the high soft X-ray flux in the RASS which led to the discovery of the system. As a possible explanation, Schwope et al. (1999) proposed a high accretion state during the RASS observations in contrast to the later optical spectroscopy. The period is either 90 min or 146 min, the latter in the period gap. If the location in the period gap would be confirmed, HS 1023+3900 and 1RXS J01285 both would support the mentioned standard CV picture with accretion rate switched off, or greatly reduced, in the period gap. On the other hand there are X-ray bright polars in the period gap like RX J0501.7−0359 (Burwitz et al.

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* Based on observations at the German - Spanish observatory (DSAZ) on Calar Alto, Spain

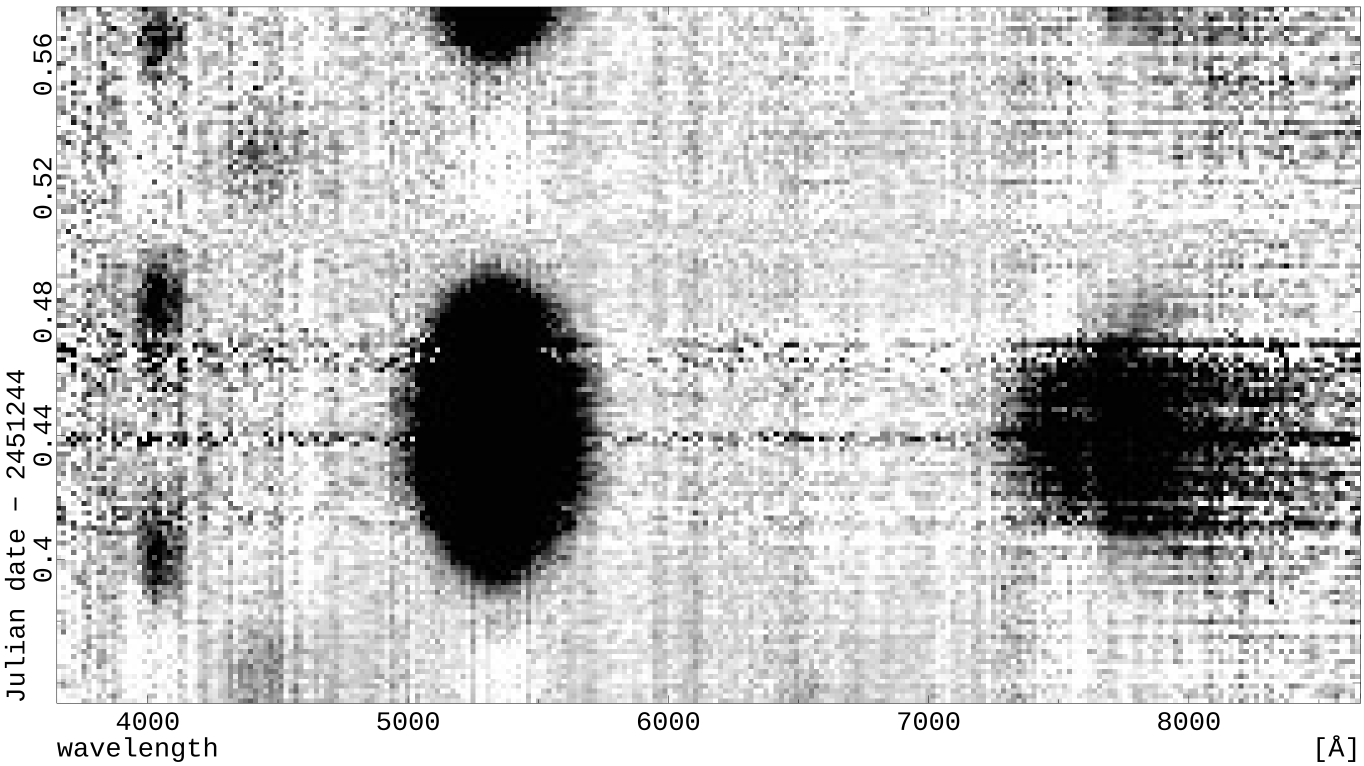

Fig. 2. Phase resolved cyclotron line spectrum of HS 0922+1333 after subtraction of both the M dwarf and the WD spectrum. 142 spectra of each 100 s exposure time every 138 s have been assembled. The features at 4034 Å, 5034 Å, and 7800 Å are the n=4,3,2 cyclotron harmonics of the main pole, the features at 4400 Å and 6600 Å are the n=3,2 harmonics of the secondary pole.

1998), or like RX J1313.2−3259 (Gänsicke et al. 2000) on the long-period side of the period-gap which has been in a prolonged state ($> 10^4$ years) of low accretion. Both objects raise questions concerning the standard explanation for the CV period gap in which the CVs evolve from longer to shorter periods and the secondary, as soon as it becomes fully convective, can switch off the mass-transfer temporarily (Spruit & Ritter, 1983). In this short note we present an even more extreme case of the RX J1313 type, which has a period of 4 hours, a spectrum like HS 1023+3900 and no X-ray emission.

2. Observations

2.1. Discovery and optical observations

HS 0922+1333 was discovered by the Hamburg Quasar Survey, an objective prism survey based on plates taken with the Calar Alto Schmidt telescope (the former Hamburg Schmidt). All 567 Schmidt fields (13 600 deg^2) are covered with two prism plates, all plates have been digitised and automatically searched for QSO candidates in Hamburg (Hagen et al. 1995). HS 0922+1333 was detected as a QSO candidate on two Schmidt plates taken on March 21, 1996 and February 27, 1997. On the basis of its blue colour and an apparent emission at the longest wavelength it was suspected to be a high redshift (z = 3.2) QSO. Coordinates are $\alpha = 9^h24^m56\overset{s}{.}1$, δ = +13°20^{m}52″(2000), the B magnitude is ≈19. The object was observed spectroscopically using CAFOS at the Calar Alto 2.2m telescope. The discovery spectrum (Fig. 1) with its extremely strong emission line at 5334 Å showed immediately the similarity to HS 1023+3900. Consequently, time-resolved spectroscopy of the suspected cyclotron-line emitter was undertaken in order to obtain the period, the magnetic field strengths, and the accretion spot geometry. HS 0922+1333 was monitored over 5 hours with 142 exposures of 100 sec each, every 138 sec. Spectral resolution is 38 Å.

The atmospheric conditions were slightly unstable in the first half of the observations, in particular during the bright phase of the 5334 Å harmonic, when cirrus cloud was present. In order to achieve a homogeneous set of cyclotron line data over the whole phase, we corrected for the varying atmospheric transparency by adjusting the band-heads of the constant M dwarf to the same flux level. Two highly variable cyclotron harmonics (5334 and 4034 Å) are seen at wavelengths shortward of where the M star spectrum dominates the red part of the spectrum. In order to recover an expected lower cyclotron harmonic in the red, we subtracted from all spectra a mean spectrum gained from line free phases (Julian Date 2451244.50–.51). The resulting "pure" cyclotron spectrum is displayed as a function of time in Fig. 2. The expected lower cyclotron harmonic is seen at ∼ 7800 Å. Roughly in antiphase there seems to be much weaker secondary pole emission at 4400 Å and (barely visible in Fig. 2) 6600 Å. The period can be determined uniquely from Fig. 2 and Fig. 3 as 244±2 min. The variation of the cyclotron line spectrum is obviously caused by rotation of a magnetic WD, and the

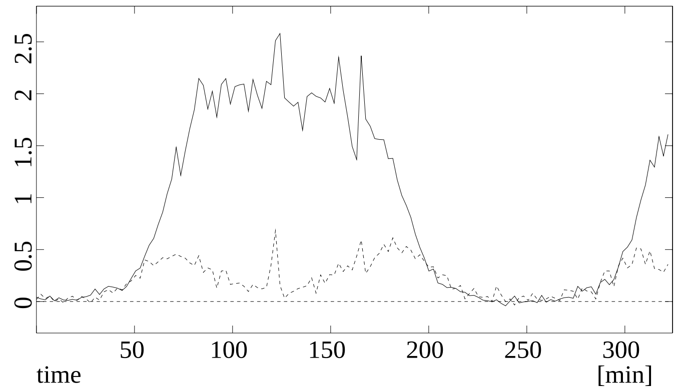

Fig. 3. Light curves of HS 0922+1333 at 5334 Å (n=3 harmonic, solid line) and 4034 Å (n=4 harmonic, dotted line) extracted from the data shown in Fig. 2. Flux units are 10^{-15} erg cm^{-2} s^{-1} Å^{-1}. The peak at $\approx$ 125 min is caused by temporarily bad weather conditions during 2 exposures.

accretion columns at the magnetic poles are self-occulted by the WD during its rotation cycle. There is no evidence for the presence of typical CV emission lines like Hα, HeII 4886 Å, or HeI 4471 Å.

The primary itself is rather faint with a nearly flat, featureless spectrum. Its absolute magnitude and the distance of the system can be estimated from the secondary. A comparison of the red part of the spectrum (Fig. 1) with M dwarf spectra from Jacoby et al. (1984) shows, that LTT 12021, with spectral type M 3.5, is a good match to the secondary. With $p = 0''.263$ (Perryman et al. 1997) and a flux ratio HS 0922/LTT 12021 = $4 \cdot 10^{-4}$ we obtain a distance of 190 pc. After subtraction of the M dwarf the WD has $m_{\rm B} \simeq 19.0$ in the cyclotron line free phase which leads to $M_{\rm B}$ = 12.6 for the WD primary. Both the (uncertain) spectral energy distribution and the absolute magnitude yield a temperature clearly below 10 000 K. In case of unrecognized emission by the accretion stream, the WD flux would even be overestimated. Assuming $\log g$ = 8, $M_{\rm B} = 12.6$ gives a temperature slightly below 10 000 K and a cooling time of $\simeq 5 \cdot 10^8$ yr (Koester, priv. comm.). At accretion rates of the order of $10^{-13}{\rm M}_\odot{\rm yr}^{-1}$ heating of the WD photosphere does not significantly enhance the WD temperature (Gänsicke et al. 2000).

2.2. *X-ray observations*

We can merely notice here that HS 0922+1333 has not been seen in the ROSAT All Sky Survey (Voges, priv. comm.). The upper limit to the countrate is 0.01 cts s^{-1} in the 0.1–2.4 keV band.

3. Analysis and discussion

As can be seen from Fig. 2, the similarity with HS 1023+3900 (Reimers et al. 1999) is striking. HS 0922+1333 possesses a cyclotron harmonic spectrum which dominates the CV contribution after subtraction of the M secondary. The dominating main spot with harmonics at 7800 Å (n = 2), 5334 Å (n = 3) and 4034 Å (n = 4) has a field strength of 66 MG ($\lambda_n = \frac{1}{n} \cdot 10\ 700$ Å$/B[10^8 G]$). We should mention, however, that according to the n = 3 and n = 4 harmonics, the expected n = 2 position should be at 8000 Å. This reminds us of a similar problem with the n = 2 harmonic of the secondary spot of HS 1023+3900, which is highly assymmetric. In addition, a barely detectable secondary spot, seen in antiphase to the main spot, emits cyclotron harmonics at 6600 Å and 4400 Å (n = 2, 3 for 81 MG). We notice that, as in case of HS 1023+3900, the field strengths are at the upper limit of what is known among magnetic CVs (with the exception of AR UMa, Schmidt et al. 1996). This can be a pure selection effect, since the discovery was in both cases due to the presence of one strong cyclotron harmonic close to the long wavelength cutoff of the IIIaJ emulsion used for the QSO survey. A further similarity to HS 1023+3900 is the absence of phase-dependent shifts of the maxima of cyclotron harmonics seen in AM Her systems (cf. Schwope 1995) and the "secondary minimum" seen only in the n = 4 harmonics of the main pole (at 2451244.44 in Fig. 2). A similar splitting is seen only in the n = 3 secondary spot emission on HS 1023+3900. It is not clear whether this apparent splitting of the spot is a geometric effect due to substructures of the accretion spots which become visible only in optically thin cyclotron harmonics or whether it is a radiative transfer effect. Without having to repeat the estimate of the accretion luminosity (rate) from the cyclotron lines, the result will be similar to that in case of HS 1023+3900, i.e. the accretion rate must be extremely low ($\leq 10^{-13}{\rm M}_\odot{\rm yr}^{-1}$) which is unexpected for a polar outside the period gap, where of the order of $10^{-10}{\rm M}_\odot{\rm yr}^{-1}$ or more is typical (e.g. Beuermann & Burwitz 1995). What is the reason for this untypical behaviour? One possibility is that the system has just switched on its mass transfer. In this case, the binary period could be much longer than the observed cyclotron line period, due to asynchronous rotation of the WD. As a first step, a radial velocity study of the secondary should be performed with the aim to check for synchronisation of the system. An alternative would be a long-lasting phase with a low accretion rate, either due to a irradiation-driven limit cycle or a post-nova phase, as has been suggested for RX J1313 by Gänsicke et al. (2000). We plan to monitor the system photometrically in the future. We further plan to undertake a systematic search for objects like HS 1023+3900 and HS 0922+1333 in our data base of several 10^7 digitized objective prism spectra.

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