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DISCOVERY OF THE OPTICAL VARIABILITY OF THE STAR GSC 2003_139 = 1RXS J133146+291631

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The star 1RXS J133146+291631 (Hünsch et al. 1999) = GSC 2003_139 (Jenkner et al. 1990) = G 165-8 (Giclas et al. 1980) was found to have significant X-ray emission in a survey by the ROSAT satellite (Bade et al. 1998). Beers et al. (1994) discovered the star to have Ca H&K lines in emission. It was classified as an M4 star by Henry et al. (1994) with an apparent magnitude of $V = 11.95$, and $B-V = 1.57$ as measured by Weis (1991). As part of a search for radial velocity variations of nearby M dwarfs, Delfosse et al. (1998) observed the hydrogen lines to be in emission, measured the radial velocity to be 8 km/s, with a $v \sin i$ of 55 km/s, and concluded that the star had a space motion consistent with it being a member of the young disk at a distance of 7.9 ± 1.2 pc.

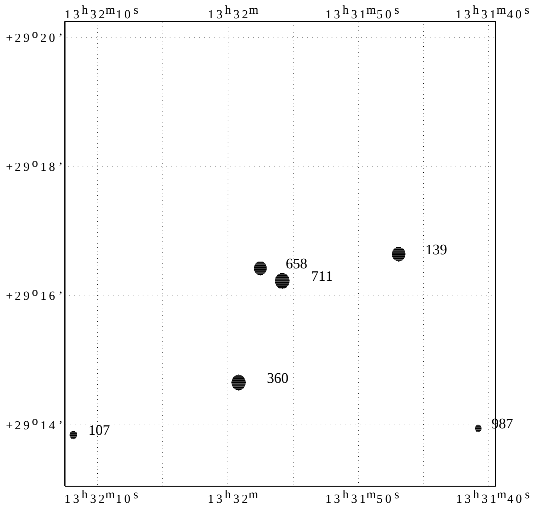

Figure 1. Chart of our observed field, labeled with the GSC numbers from Region 2003.

Table 1: Stars observed in the field of GSC 2003_139

ID No.	R.A. J2000	Dec. J2000	Cat. Mag.	ΔR Mag.
1RXS J133146+291631 =				
= GSC 2003_139	$13^{h}31^{m}47^{s}$	$+29°16'39''$	11.8	$-0.434 \pm .005$
GSC 2003_360	$13^{h}31^{m}59^{s}$	$+29°14'39''$	11.5	—
GSC 2003_711	$13^{h}31^{m}56^{s}$	$+29°16'14''$	11.3	$-0.065 \pm .003$
GSC 2003_658	$13^{h}31^{m}58^{s}$	$+29°16'26''$	12.1	$0.641 \pm .011$
GSC 2003_987	$13^{h}31^{m}41^{s}$	$+29°13'57''$	14.7	$2.995 \pm .115$
GSC 2003_107	$13^{h}32^{m}12^{s}$	$+29°13'51''$	14.3	$3.161 \pm .034$

The field of stars observed with the automated 0.5-m telescope is plotted in Figure 1. The data were reduced in a fashion identical to that described in Robb et al. (1997). The stars' identification numbers, coordinates and magnitudes from the Hubble Space Telescope Guide Star Catalog (GSC) (Jenkner et al. 1990) are included in Table 1. The standard deviation of the differential magnitudes from point to point during a night ranged from $0^{m}.004$ for bright stars on a good night to $0^{m}.300$ for the faintest star on poor nights. This measures the precision of the brightness variations on the time scale of a few minutes.

We measure the night to night precision of the data by calculating the standard deviation of the nine nightly means. The run means and standard deviations are tabulated in Table 1 as ΔR, in the sense of star minus GSC 2003_360. The high precision of these data can be seen from the standard deviation of the ΔR, in the sense of GSC 2003_711 minus GSC 2003_360, which is $0^{m}.003$ and shows that these two stars are constant at this level of precision. The star GSC 2003_987 has a large standard deviation making us suspect it of variability, however our data are inconclusive. The star GSC 2003_139 had obvious variations of approximately $0^{m}.03$ peak to peak.

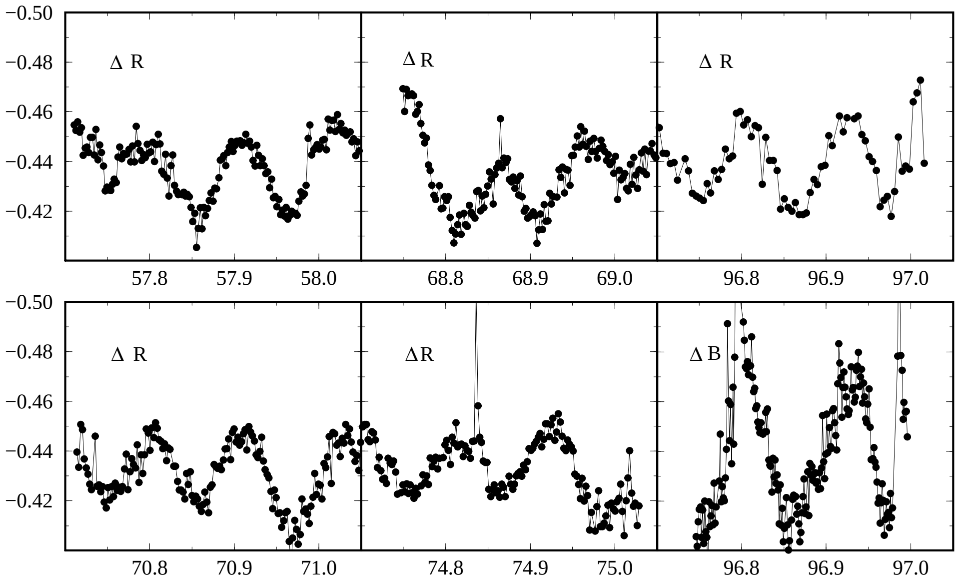

Figure 2. Individual nights' (HJD − 2451200) data for 1RXS J133146+291631

Examples of individual nights' data are all plotted at the same scales in Figure 2 with the ΔB data shifted by -1.86. The abscissa is the Julian Date − 2451200.0 and the rightmost plots were observed simultaneously on Julian Date 2451296. The telescope at the University of Victoria was used to measure in the R and I filters and the 1.82-m telescope of the National Research Council of Canada was used to observe the B data. The light curve amplitude in B ($0\overset{m}{.}07$) is double the amplitude in R ($0\overset{m}{.}03$), which is double the amplitude in I ($0\overset{m}{.}015$). Neither the maxima nor minima were consistent in brightness, during a night. Flares were observed at HJD = 2451274.836, 2451296.793 and 2451296.986 indicating that this is a UV Ceti type star.

The nine nights were searched for periodicity by fitting a single sine curve of various frequencies to the data. In Figure 3 we have plotted the RMS deviation of a point from a single sine curve as a function of frequency.

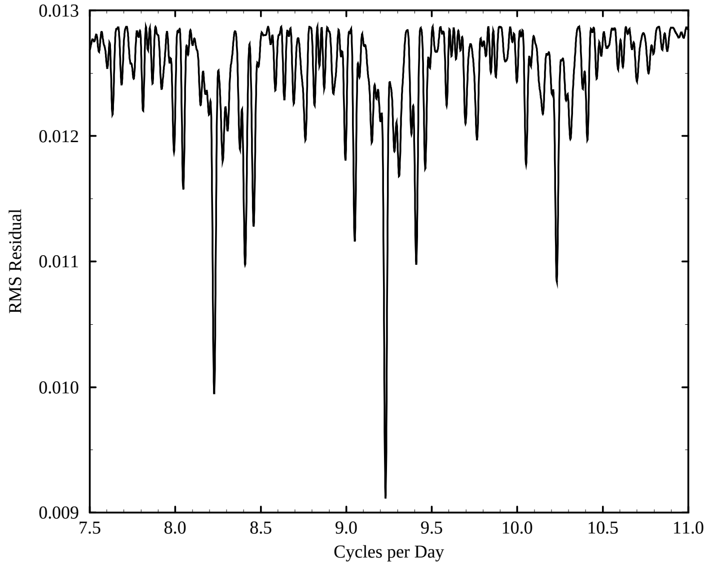

Figure 3. Periodogram for 1RXS J133146+291631 for 1999

Thirteen times of maximum brightness were found using the method of Kwee and van Woerden (1956) to be (HJD − 2451200) 57.9104, 58.0211, 68.8669, 69.8295, 70.8040, 70.9081, 74.9227, 91.8291(I), 91.8242, 96.8058, 96.9255, 96.8061(B), and 96.9266(B). The last two observations were made in B filter and are not significantly different from the second last two which were made in R, considering our uncertainty of approximately $\pm 0\overset{d}{.}0014$.

The photometric period and epoch of GSC 2003_139 are unambiguously determined to be:

$$\text{HJD of Maxima} = 2451257\overset{d}{.}6952(28) + 0\overset{d}{.}10836(2) \times E.$$

where the uncertainties in the final digits are given in brackets.

Using this ephemeris, the differential (GSC 2003_139 − GSC 2003_360) R magnitudes of all the nights are plotted in Figure 4 with different symbols for each of the nights. Plots at multiples of this period yielded no improvement in the scatter. From the variation in the brightness of successive maxima and minima we suspected a second periodicity would be found. Therefore the best fitting sine curve was subtracted from the data and another search for periodicities was performed. No significant periods were found.

Although we considered a pulsating model and a "superhumper" cataclysmic system, we suspect that this variation is due to a hot spot, whose projected area changes as the star rotates. The amplitude of the curves in B, R, and I are well fit by a spot approximately 3.5

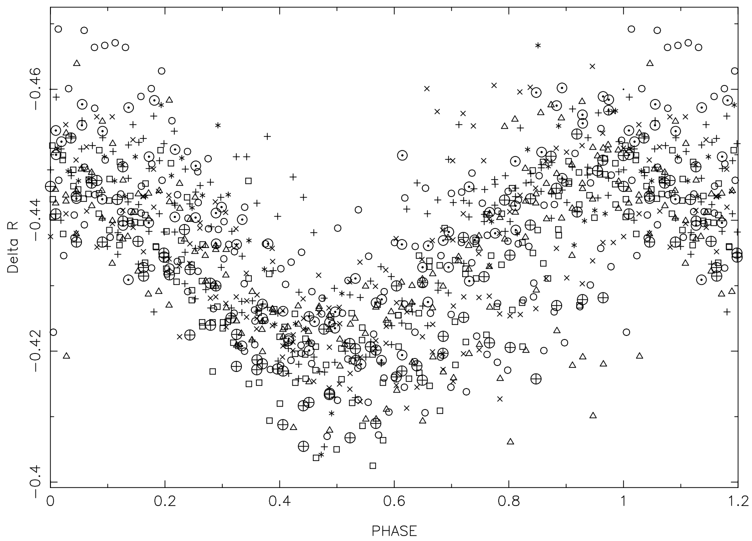

Figure 4. R band light curve of 1RXS J133146+291631 for 1999

degrees in projected radius with a temperature of 1.3 times the surrounding photosphere. The variation in the brightness of the maxima and minima could be caused by changes in the size or temperature of the spot(s). Our rotation period, a radius of 0.3 $R_{\odot}$, and the $v \sin i$ of Delfosse et al. (1998) give an inclination of $21 \pm 3°$ for the axis of rotation. The quoted uncertainty does not include a contribution from differential rotation, which could be significant.

Therefore we believe RX133146+291631 to be a very rapidly rotating M4Ve star with active regions generating an X-ray bright corona and emission lines and a hot spot modulating the light curve. For this star to rotate so rapidly we expect it to be orbited by a close companion and have begun spectroscopic observations to look for evidence of its existence.

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