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THE SPOTTED STAR BD+52°1602

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By studying stars with active regions we hope to further our understanding of the solar dynamo. These stars are generally X-ray sources with periodic sinusoidal photometric variations. The ROSAT satellite has scanned the sky and an entry in the catalog (Voges et al., 1999) of the X-ray sources: 1RXSJ120027.6+515722 is the star BD+52°1602 = GSC 3457-1012. The Hipparcos Input Catalogue (ESA 1997) denotes it as HIP 58557 and has its parallax listed as 14.58 ± 2.71 mas giving a nominal distance of about 58 to 84 parsecs. Its (B-V) is listed as 1.22 and $(V - I)_C = 1.38$, which indicate a spectral class of K6V±1; and 2MASS measurements of BD+52°1602 reveal that J=9.24, H=8.63 and K=8.46 all with an uncertainty of about ±0.02. All these colour measurements are consistent with a spectral class of K7V±1. Assuming a main sequence K star implies an absolute magnitude of about $M_V = 7.9 \pm 0.3$ so with an apparent magnitude of $V_T = 11.7 \pm 0.1$ a second estimate of the distance would be about 56 ± 8 parsecs, in agreement with the Hipparcos parallax.

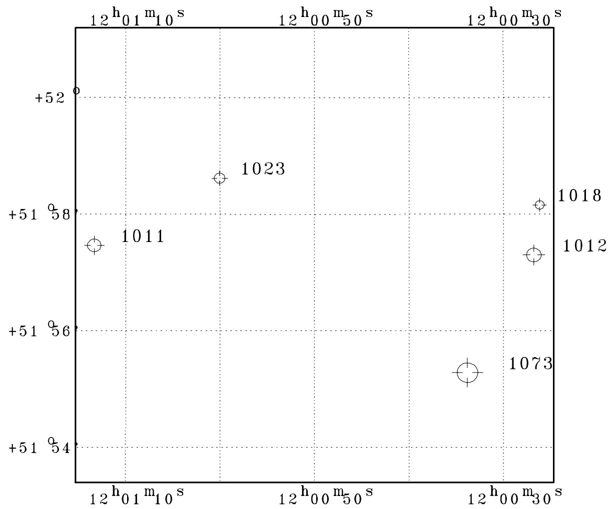

Figure 1. Finder chart labelled with the GSC identification numbers from region 3457.

Table 1: Stars observed in the field of GSC 3457-1012

Star GSC Id	R.A. J2000	Dec. J2000	GSC Mag.	ΔR Mag.	Std Dev Between	Std Dev Within
1012	$12^h00^m27^s$	51°57′18″	11.4	1.540	0.015	0.006
1073	$12^h00^m34^s$	51°55′17″	9.9	-	-	-
1018	$12^h00^m26^s$	51°58′09″	12.8	3.052	0.005	0.012
1023	$12^h01^m00^s$	51°58′37″	12.4	2.591	0.004	0.007
1011	$12^h01^m13^s$	51°57′28″	11.6	2.015	0.004	0.006

The University of Victoria (UVic) observations were made with our automated 0.5m telescope, Star I CCD and reduced in a fashion similar to that described in Robb and Greimel (1999). The field of stars observed is shown in Figure 1. The Julian Dates of observation (-2450000) are 3104-6, 3111-12, and 3117-26. Table 1 lists the stars' identification numbers and magnitudes from the Hubble Space Telescope Guide Star Catalogue (GSC) (Jenkner et al., 1990). All UVic observations were made using a filter identical to the Cousins R.

The period of variations was indeterminate from our observations so TJK began observations from Tashkent. He used a Celestron C-11 telescope with a SBIG ST-7 CCD binned 2×2. His exposure times were 30 seconds with no filter. He used the same comparison star and we found that his observations could be combined with our Cousins R observations with zero offset and no scale change. His observations were made on Julian Dates (-2450000) 3126, 3128 and 3129.

Our differential ΔR magnitudes are calculated in the sense of the star minus GSC 3457-1073 . Brightness variations during a night were measured by the standard deviation of the differential magnitudes and are listed for the most photometric night in the last column as "Std Dev Within". A "Std Dev Within" one night of 0.006 sets an upper limit on variations of an hourly timescale. For each star the mean of the nightly means is shown as ΔR in Table 1. The standard deviation of the nightly means is a measure of the night to night variations and is called "Std Dev Between" in Table 1. The smallest "Std Dev Between" is 0.004 magnitudes. This excellent photometry shows that night to night variations in GSC 3457-1073 must be less than a few millimagnitudes.

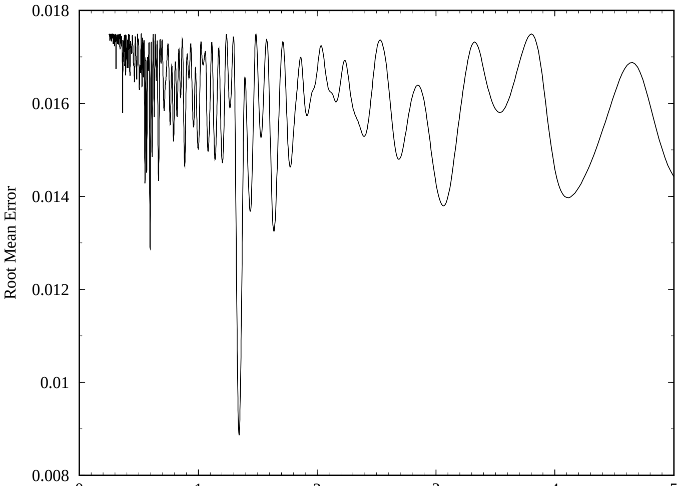

Figure 2. Periodogram for sine curve fit to all photometric data

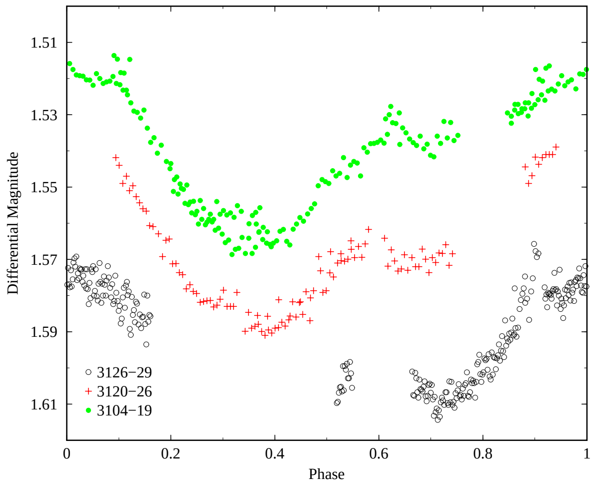

Figure 3. R filtered light curve of BD+52 1602 with different runs offset by +0.02 magnitudes and marked with different symbols.

The star BD+52°1602 varied in brightness during some nights and had variations from night to night. Sine curves of various periods were fitted to the data and the Root Mean Square Error is plotted as a function of period in Figure 2. Plots of the light curve at the period corresponding to each of the minima of chi squared showed that the only reasonable period was approximately $1.336 \pm .006$ days. A plot at twice this period did not show any improvement in the scatter. Our best estimate of the present ephemeris is:

$$\text{HJD of Maximum Brightness} = 2453104\overset{\text{d}}{.}2(1) + 1\overset{\text{d}}{.}336(6) \times \text{E}.$$

where the uncertainty in each final digit is given in brackets. Six of the individual ΔR_C magnitudes were averaged and in Figure 3 these normal points phased at this period are plotted. The data are divided into three parts to show that there have been changes in the shape of the light curve even over the month of observations. These changes are typical of spotted stars such as BY Draconis and are probably due to spot area and/or position changes.

There exist Hipparcos/Tycho (ESA 1997) photometric data of this star and the data from Julian Date 2448136-8142 clearly show a photometric variation with a period of $1.36 \pm .16$ days. The data from Julian Date 2448100-8500 show the variation less clearly but refine the period to $1.339 \pm .003$ and indicate that the variation can stay in phase for about a year. This period agrees with the period found from our data, but the error is too large to determine if the variation is in phase. The rest of the Hipparcos data and the ROTSE (Wozniak et al., 2004) data do not show a clear variation. It is likely that the amplitude of the variation changes with time and this hinders our determination of a precise period. The period may not even be constant over long time spans since the star may experience differential rotation.

A spectrum of BD+52°1602 observed with the Dominion Astrophysical Observatory's 1.8m telescope is shown in Figure 4. The time of observation was 06:00 UT 6 May 2004, which corresponds to a phase of approximately 0.62. The Calcium II emission lines are a characteristic of stars with active regions. The strength of the Calcium I 4227Å line is typical of a mid-K spectrum and the Cr I 4290Å and Fe I 4326Å lines indicate a K6V±1 spectral classification consistent with the color measurements.

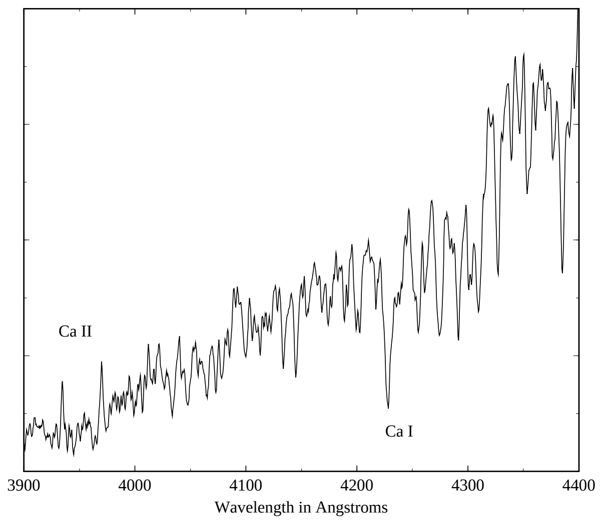

Figure 4. Spectrum of BD+52°1602 showing the Calcium I absorption line and the Calcium II emission lines

BD+52°1602 seems to be a rapidly rotating late type dwarf star with active regions covering a significant part of its surface and energizing a hot corona producing X-rays. Further spectral observations will be of interest to see if the Ca II emission will vary in intensity with phase. Further photometric observations will be important to tell if differential rotation will modify the period and/or shape of the light curve and to determine the period of the spot cycle (Oláh et al. 2000)

Acknowledgements

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