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RECENT CCD PHOTOMETRY OF AB Dor, AND A COMMENT ON THE LONG-TERM ACTIVITY CYCLE

INNIS, J. L.[1]; BUDDING, E.[2,3]; OLÁH, K.[4]; JÄRVINEN, S. P.[5,6,7]; COATES, D. W.[8]; MESSINA, S.[9]; KAYE, T. G.[10]

[1] Brightwater Observatory, 280 Brightwater Rd., Howden, TAS, 7054, Australia. Email: brightwater@iraf.net

[2] Physics Department, University of Canakkale, TR 17020, Turkey

[3] Carter Observatory, Wellington, New Zealand

[4] Konkoly Observatory, H-1525 Budapest, P.O.Box 67, Hungary

[5] Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany

[6] Tuorla Observatory, University of Turku, FI-21500 Piikkiö, Finland

[7] Astronomy Division, P.O. Box 3000, FI-90014 University of Oulu, Finland

[8] School of Physics, Building 27, Monash University, VIC, 3800, Australia

[9] INAF Catania Astrophysical Observatory, via S. Sofia 78, 95123 Catania, Italy

[10] Spectrashift, 404 Hillcrest, Prospect Heights, IL 60090, USA

AB Doradus (HD 36705) is a young, active, K–type dwarf. Recent work has shown the AB Dor system to consist of at least four stars (e.g. Guirado et al., 2006), but AB Dor itself is not a close binary. The rapid rotation and the high level of activity are a consequence of the star's relative youth. Activity signatures have been detected at radio, UV, and X-ray wavelengths.

AB Dor has been systematically observed since attention was drawn to it by Pakull (1981), who discovered the ~0.5 d rotation period, although in recent seasons optical coverage has decreased. An analysis of the photometric data to 2000 by Järvinen et al. (2005) noted evidence for a possible ~20–year activity cycle.

We obtained CCD B and V data at the Brightwater Observatory, Tasmania, in 2007 March 03–April 13 and 2007 December 15–2008 March 22. See Innis et al. (2007) for more details of the photometric equipment and method. The CCD field of view is $0.^\circ80\times0.^\circ55$, allowing us to observe both AB Dor and the comparison stars HD 36316 and HD 37082 simultaneously. Instrumental magnitudes were found using standard aperture photometry techniques. We corrected for extinction (including the second–order colour–dependent term in the B–band) and transformed our instrumental magnitudes to the standard Cousins system.

The mean and standard deviations for our observed V and $B-V$ differences HD 37082 − HD 36316 were 1.72 ± 0.01 and -1.30 ± 0.03 respectively, which agree reasonably well with previous work (Grothues et al., 1997, HD 37082: $V = 9.651$, $B-V = 0.169$, HD 36316: $V = 7.951$, $B-V = 1.451$; Cutispoto, 1998, HD 36316: $V = 7.95$, $B-V = 1.46$). Our final magnitudes and colours for AB Dor have been derived relative to HD 37082 (using $V = 9.651$, $B-V = 0.169$, from Grothues et al., 1997).

Just over 1800 individual exposures were obtained in each of *B* (exposure time 45s) and *V* (exposure time 30s) filters, yielding around 450 data points in each filter as we average four consecutive exposures to reduce scintillation noise (datafiles are available through the IBVS website as `5832-t1.txt`, `5832-t2.txt`). We use the period and epoch of P=0.51479 d and HJD 2444296.575 (Innis et al., 1988) for the following phase plots.

In 2007 March–April AB Dor varied in *V* by approximately 0.08 mag, from *V* ∼6.98 to *V* ∼7.06, as shown in the top left panel of Figure 1. Minimum light is very nearly at phase zero. The top right panel shows the check−comparison star magnitude differences at the same scale.

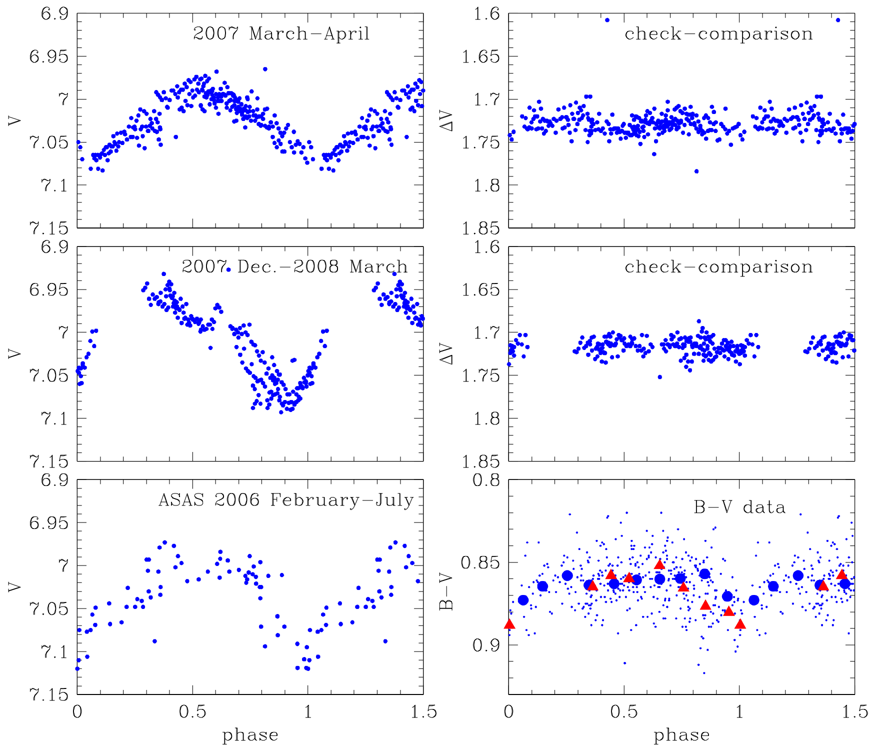

Figure 1. Photometry from the Brightwater Observatory: Top left panel AB Dor *V* light curve for 2007 March–April; top right panel: check− comparison star *V* magnitude differences 2007 March–April. Middle left panel: 2007 December–2008 March *V* AB Dor light curve; middle right panel: check−comparison star *V* magnitude differences 2007 December–2008 March. Lower left panel: *V* light curve for AB Dor for aperture 4 of the ASAS data set (Pojmanski and Maciejewski, 2005) for 2006 February–July. Lower right: observed (small dots) and phase–binned $B-V$ data (big dots: 2007, triangles: 2008) for the Brightwater photometry.

In 2007 December–2008 March (middle left panel of Figure 1) the light curve was less stable, with maximum light somewhat brighter, near 6.95, and with a clear shift in minimum to near phase 0.9. Minimum light at the two epochs are comparable. We show again the check−comparison star differences in the middle right panel to support the case that it is AB Dor which has changed – similar changes have of course been noted earlier.

The lower left panel of Figure 1 shows *V* data for AB Dor for 2006 February to July, taken in aperture 4 as part of the All Sky Automated Survey (ASAS, Pojmanski and Maciejewski, 2005). We include this to show that the amplitude of variation and the phasing of minimum light in mid 2006 was close to that seen in our 2007 March–April observations.

Our B data are somewhat more scattered than our V data, most likely due to the lower sensitivity of the CCD at shorter wavelengths. Small $B-V$ changes were noted, however these were of comparable size to the observational noise. We have binned our $B-V$ data in 0.1 phase bins to reduce noise. The lower right panel of Figure 1 shows the original and phase–binned $B-V$ data. There is an indication that the star is about 0.02-0.03 mag redder when fainter in both seasons observed at Brightwater. The mean and sample standard deviation for our determination of $B-V$ (for our entire CCD data, 2007 March–2008 March) is 0.86±0.02 mag.

For interest, we performed a spot modeling analysis on our 2007 March–April data. Adopting maximum light observed at that epoch as the unspotted flux level, we find that a single, circular midlatitude spot of radius ∼14° produces a good fit to the data. However, if we take the historical maximum (equivalent to V ∼6.74) a polar spot near 40° in radius (some 11% by area) is required to reduce the overall flux, in addition to a midlatitude spot of around 12° needed to produce the rotational modulation. Supposing T_{star}= 5000 K and T_{spot}= 3500 K we get excellent simultaneous fits both to the B and V light curves. For the modeling technique see Ribárik et al., 2003.

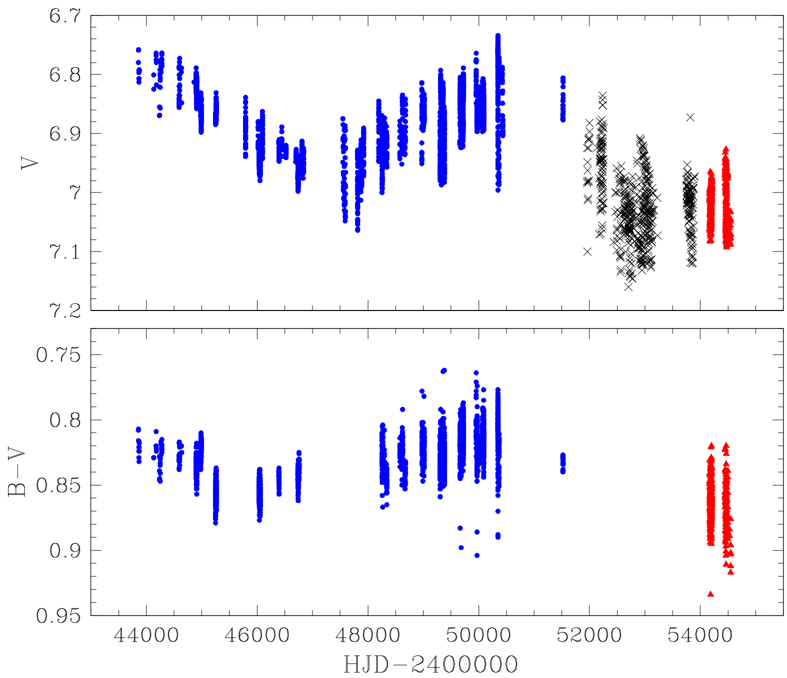

Figure 2. Top panel: V–band data for AB Dor, from the compilation of Järvinen et al. (2005) (dots), with our recent data (extreme right, triangles), and ASAS aperture 4 data (crosses).The mean value of the ASAS data may be uncertain by 0.05 mag. Our new data support the ∼ 20–year activity cycle proposed by Järvinen et al. (2005). Lower Panel: $B-V$ data for AB Dor, from the unpublished compilation of Messina (in preparation) and including our new $B-V$ data. A clear variation is seen.

In the top panel of Figure 2 we show the complete V history of AB Dor, as far as it is known, using the photometric compilation of Järvinen et al. (2005) and including our 2007–2008 data. We include all the currently available 'aperture 4' ASAS data as crosses. For bright stars like AB Dor the biggest 'aperture 4' photometry (diameter = 6 pixels, one pixel ≈15 arcsecs, see Pojmanski, 2002) gives magnitudes with the lowest noise. These data cover a recent gap in the record, but we note there are systematic differences of

$\sim$0.05 mag between the various ASAS apertures. However, the ASAS data also suggest that AB Dor was at the fainter part of its brightness range over this interval (e.g. as seen in the data in the lower panel of Fig. 1). Järvinen et al. (2005) deduced the likely presence of two different cycles, one a 'flip–flop' (spot–longitude) cycle of about 5.5 years, and another, longer-term, mean–brightness cycle of near 20 years. Our recent data, showing the star to be even fainter than at the minimum recorded some 18 years ago, appears to support the $\sim$20–year cycle proposed by Järvinen et al. (2005). Our new analysis, including the 2007–2008 data, yields a period of 19$\pm$3 y, with a false alarm probability (FAP) of 1.4×10^{-4}, as determined using the Lomb method for unevenly sampled data (Press et al., 1992).

In the lower panel of Figure 2 we plot the $B-V$ history of AB Dor, from published observations compiled by Messina (in preparation), also with our recent data. A clear, long–term, colour change is seen. Messina's analysis (in preparation) shows that the long-term $B-V$ variations are in phase with the V variations, with the same cycle period, but with a smaller variation amplitude. The new $B-V$ data seem to further support the cyclic color variation of AB Dor, with the star getting redder when it is fainter. We are continuing the analysis.

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