COMMISSION 27 OF THE I. A. U.
INFORMATION BULLETIN ON VARIABLE STARS
Number 3564

Konkoly Observatory
Budapest
15 February 1991
HU ISSN 0374 - 0676

Light Curves for AB Doradus

AB Doradus (HD 36705) is a bright (V ≈ 7.0), rapidly rotating (0.51^d), chromospherically active single star possessing a highly variable light curve (see Innis *et al.*, 1988). Only some of the Pleiades K dwarfs (Van Leeuwen and Alphenaar, 1982) rotate faster, and indeed the star's kinematical data and strong Lithium line (Rucinski, 1982) suggest that this is no coincidence with AB Doradus quite likely to be a member of the Local Association under going a late stage of Pre-Main Sequence contraction. It is widely accepted that the star's variability is due to large "star spots" which evolve rapidly, altering both the shape and amplitude of the light curve. Such a situation could be expected in such a rapidly rotating cool star, if the underlying magnetic field generation is essentially dynamo in nature (Weiss *et al.*, 1984).

Recently several light curves for AB Doradus have been analysed using a χ^2 minimisation Fortran program (see Banks and Budding, 1990, and Banks *et al.*, 1991, for details of the methodology) which demonstrated that two dark circular regions could adequately account for the differential light curve. A general background of maculation effects distributed uniformly in longitude was assumed to explain the variation in AB Dor's "immaculate" (unspotted) magnitude - which has progressively dimmed since the star's discovery in 1979 (Pakull, 1981). A range of inclinations was trialed by these two studies, in the hope that a better fit to the data would be obtained at one value, which might be near to AB Dor's real inclination. It was tentatively concluded that a low inclination around 65° might be preferred. This bulletin details a small continuation of these previous spot modelling efforts, analysing the February 1987 UBVRI light curves obtained by Cutispoto (1990) using the 50 cm ESO Cassegrain telescope.

Each waveband was modelled assuming two dark (i.e. 0 Kelvin) spots, Al-Naimiy's (1978) limb darkening coefficient appropriate for each passband, and a photospheric temperature of 5250 Kelvin (Allen, 1973) corresponding to Rucinski's (1985) spectral classification. The S/N ratio was arbitrarily assumed to be 100:1. Checking for indeterminacy using the Hessian matrix (see Budding and Najim, 1980) is an important part of our approach, preventing excessive over-parameterisation of the data (see also Banks and Budding, 1990a). Most of the fits (bar three) were determinate, indicating that the information content of the data was not being blatantly exceeded.A range of inclinations were trialed (90°, 80°, 70°, 60°, 50°) for each waveband, and their χ^2 values examined (see Table 1). Table 2 gives the "best fit" model parameters.

Parameters for the larger, second spot are more consistent between the wave bands, as could be expected as its greater photometric effect defines the values better. Observational noise in the few data points defining the first spot's effect has a considerable effect on its derived

Table 1: The values of χ^2 are plotted for each waveband and inclination trialed. Gaps are left when indeterminacy resulted. The actual numbers depend on the arbitrarily chosen observational error of 1%. An asterisk mark the best fit for each band.

Inclination	U Band	B band	V band	R band	I Band
90°	16.3	3.24	5.06	1.74 *	4.01
80°	15.3	2.86	5.38	1.85	3.63 *
70°	13.7	3.02	5.07	1.87	4.21
60°	13.6 *	2.57 *	4.79 *	-	-
50°	13.7	-	5.07	2.75	6.74

Table 2: The parameters for the best model fits from table 1 are given. All units are degrees. The number refers to the spot, i.e longitude 1 for the first spot's longitude.

Passband	longitude 1	latitude 1	radius 1	longitude 2	latitude 2	radius 2
U	69.2 ± 46.2	84.4 ± 0.6	30.2 ± 0.3	315.8 ± 16.5	55.6 ± 22.7	12.1 ± 7.2
B	82.8 ± 36.7	85.3 ± 2.6	30.1 ± 1.2	309.4 ± 30.1	44.8 ± 36.9	11.9 ± 2.5
V	88.9 ± 28.0	35.3 ± 4.3	17.8 ± 0.2	327.3 ± 1.3	46.2 ± 2.4	11.5 ± 0.2
R	38.0 ± 28.8	87.3 ± 3.0	30.1 ± 1.3	305.0 ± 14.0	62.9 ± 11.6	15.5 ± 1.8
I	34.5 ± 14.2	67.8 ± 5.0	15.9 ± 1.0	311.0 ± 22.2	58.7 ± 25.2	17.0 ± 3.5

parameters (see Figures 1 and 2) - particularly as the spot's effect overlaps considerably with the other spot's. Innis *et al.* (1988) asserted that while two spot groups were apparent on AB Dor during the period 1979 to 1987, they remained ≈ 180° apart in longitude, suggesting that the star might be an oblique-dipole rotator (see Stibbs, 1950). However the derived spots for February 1987 are closer to 120 degrees apart, as were those for January 1990 (Banks *et al.*, 1991). Further quantitative modelling of other light curves is required to resolve this issue. Budding and Zeilik (1987) noted that starspots appear to be located at relatively high latitudes, and that this is a feature of chromospherically active, short period stars. Support is lent to this conclusion. However the rather tentative suggestion that a low inclination might be preferred by AB Dor is not clearly supported by this study.

The spot temperature method outlined by Zeilik *et al.* (1989), based on the assumption that both the surrounding photosphere and the spot radiate as black bodies, was used on the R and I band data with the best V band model as the reference. Spot temperatures of 3860 ± 470 (I) and 3980 ± 40 (R) Kelvin were reached, in reasonable agreement with the values of 3840 ± 150 (I) and 3710 ± 230 (R) Kelvin that Banks and Budding (1990) derived for Lloyd Evans' (1987) 1984 data using the same method.

It is hoped that this small contribution will be of use to the many other investigators studying AB Dor. It is unfortunate that the only published light curves close in time to this one are

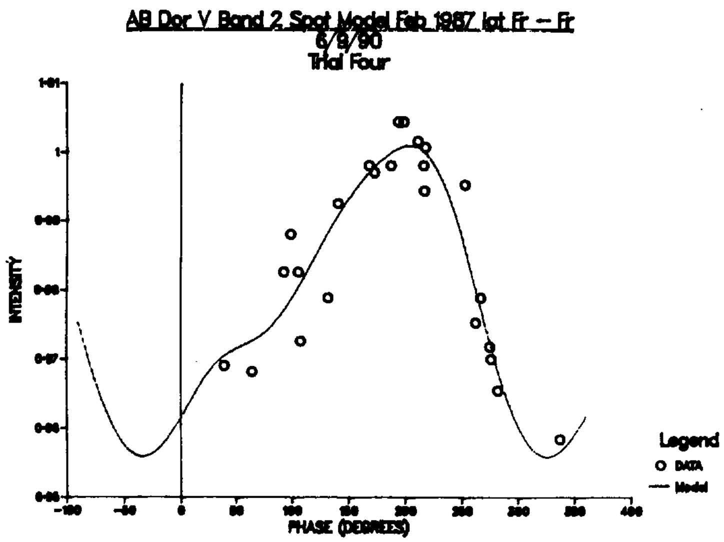

Figure 1 : The inclination 60° V band model fit (smooth line) is plotted against the data (rings).

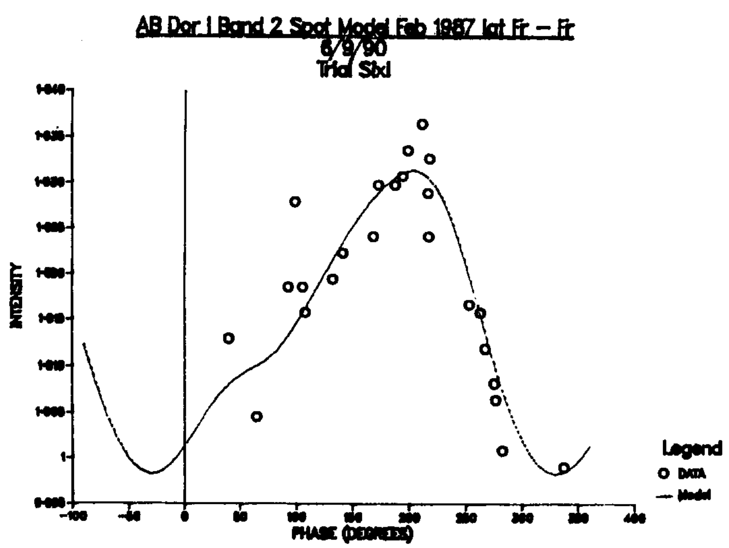

Figure 2: The inclination 80° I band model is plotted against that waveband's data.

the January 1987 and Sept/Nov 1986 curves of Innis *et al.* (1988), followed by December 1988 (Thompson and Thompson, 1989) and Anders' (1990) November 1989 data. Thus only general trends in AB Dor's spot evolution will be identifiable over this period, although modelling should still be worthwhile, particularly of the December 1988 data which is of high quality and complete phase coverage. However incomplete phase coverage and the low number of observational points inhibited the analysis of the Feb 1987 light curves, allowing observational errors to become overly influential. Many literature light curves also (see Innis *et al.*, 1988) exhibit these problems. To increase their information potential, future observations need to avoid these. Indeed, further observations are crucial, as AB Dor is a highly active star, and rightly deserves intensive scrutiny in the hope that a definitive spot evolution sequence can be obtained.

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References :

Allen, C.W., *Astrophysical Quantities*, Third Edition, University of London Press, London, 1973.
Al-Naimiy, H., 1978, *Astrophys. Spa. Sci.*, **53**, 181, 1978.
Anders, G., *IBVS # 3437*, 1990.
Banks, T., and Budding, E., *Astrophys. Spa. Sci.*, **167**, 221, 1990.
Banks, T., and Budding, E., *Earth, Moon, and Planets*, **49**, 15, 1990a.
Banks, T., Kilmartin, P.M., and Budding, E., accepted for *Astrophys. Spa. Sci.*, 1991.
Budding, E., and Najim, N.N., *Astrophys. Spa. Sci.*, **72**, 369, 1980.
Budding, E., and Zeilik, M., *Astrophys. J.*, **319**, 827, 1987.
Cutispoto, G., *Astron. Astrophys. Suppl. Series*, **84**, 397, 1990.
Innis, J.L., Thompson, K., Coates, D.W., and Lloyd-Evans, T., *Mon. Not. R. astr. Soc.*, **235**, 1411, 1988.
Lloyd-Evans, T., *South African Astron. Obs. Circ.*, **11**, 73, 1987.
Pakull, M.W., *Astron. Astrophys.*, **104**, 33, 1981.
Rucinski, S.M., 1982, *Astron. Astrophys. Suppl. Ser.*, **52**, 281, 1982.
Rucinski, S.M., *Mon. Not. R. astr. Soc.*, **215**, 591, 1985.
Stibbs, D.W.N., *Mon. Not. R. astr. Soc.*, **110**, 395, 1950.
Thompson, K., and Thompson, I., *IBVS 3320*, 1989.
Van Leuuwen, F., and Alphenaar, P., in *Activity in Red Dwarfs*, Eds : M.Rodono and P.D. Byrne, IAU Colloq **71**, 379, 1982.
Weiss, N.O., Cattaneo, F., and Jones, C.A., *Geophys. Astrophys. Fluid Dynamics*, **30**, 305, 1984.
Zeilik, M., Cox, D.A., De Blasi, C., Rhodes, M., and Budding, E., *Astrophys.J.*, **345**, 991, 1989.