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The magnetic field and rotational period of 53 Camelopardalis

G. M. Hill[1,2,3,4], D. A. Bohlender[1,3,5], J. D. Landstreet[1], G. A. Wade[1],
N. Manset[2], and P. Bastien[2]

[1] *Physics and Astronomy Dept., University of Western Ontario, London, ON, N6A 3K7 Canada*
[2] *Dept. de Physique and Observatoire du Mont Mégantic, C.P. 6128, Succ. A, Université de Montréal, Montréal, PQ, H3C 3J7 Canada*
[3] *Dominion Astrophysical Observatory, National Research Council, 5071 West Saanich Road, Victoria, BC, V8X 4M6 Canada*
[4] *Visiting Astronomer, Canada-France-Hawaii Telescope, operated by the National Research Council of Canada, the Centre National de la Recherche Scientifique of France and the University of Hawaii*
[5] *Canada-France-Hawaii Telescope, P.O. Box 1597, Kamuela, HI 96743, USA*

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ABSTRACT

The magnetic Ap star 53 Cam has been described as the best object for testing theories of elemental diffusion in the presence of a stellar magnetic field. It is thus vital to determine the rotational period of this very important star as accurately as possible. An improved period (8.02681 ± 0.00004 days) is derived here by combining new measurements of the effective magnetic field with previously published values.

Key words: Stars: chemically peculiar – Stars: individual: HD 65339 – Stars: magnetic fields.

1 INTRODUCTION

When looking for an example of the interplay between theory and observation in astronomy, one need look no further than the magnetic Ap star 53 Cam (HD 65339). This object has become one of the most thoroughly studied Ap stars and is frequently used as the prototypical magnetic Ap star for comparison with theories which attempt to further our understanding of chemically peculiar stars.

53 Cam owes its popularity to several factors. It is relatively bright ($V = 6.01$), and its 8-day period is short enough to make the acquisition of detailed observations realistic but long enough that its spectral lines are still relatively strong and sharp. Its magnetic field, first discovered by Babcock (1958), is also very strong. In fact, Preston (1969) showed that the magnetic field produces resolved Zeeman components in the spectra of 53 Cam and he was able to make a quantitative evaluation of the star's surface magnetic field strength. The magnetic field was modeled in detail by Landstreet (1970), Huchra (1972), and Borra and Landstreet (1977, hereafter BL77). Michaud, Mégessier, and Charland (1981) showed that elemental diffusion in the presence of magnetic fields can explain the inhomogenous distribution of elements observed on Ap stars. They concluded that 53 Cam was the best object to compare with their theoretical predictions. Landstreet (1988) subsequently obtained high signal-to-noise spectra of 53 Cam and for the first time simultaneously modelled both the abundance distribution and magnetic field geometry of an Ap star. Within a few years, Babel and Michaud (1991a,b,c) had shown that a parameter-free model of diffusion can not account for the distribution of elements on 53 Cam's surface, but suggested that the inclusion of mass loss modified by the magnetic field may help. Babel (1992) then demonstrated that a weak, magnetically confined wind does indeed affect the surface abundances and is able to explain the distribution of most, but not all, of the elements studied by Landstreet (1988). Babel's model also predicted the existence of a steep abundance gradient within the atmosphere of 53 Cam for several elements. Babel and Lanz (1992) were then able to find evidence for such gradients by comparing and modelling line profiles of several elements obtained in UV and optical spectra.

We expect that 53 Cam will continue to be the benchmark against which new models are measured in the quest to improve our understanding of the magnetic Ap stars. Detailed observational studies of this star are almost certain to continue so it is important that its physical parameters be as precisely determined as possible. One of these is the rotational period. It has been over twenty years since the observations of BL77 which provide the currently adopted period. Given their uncertainty of 0.0002 days in the rotational period, new spectra acquired today will have a phase uncertainty, relative to the magnetic field ephemeris, of 0.050

cycle. This amounts to an uncertainty of approximately 20° in the relative location of any portion of the star's surface and its magnetic axis, and is clearly an undesirable situation. To obtain an uncertainty of 0.0002 days, BL77 were forced to combine their photoelectric Hβ measurements with older photographic measurements using metallic lines. Since these two types of measurements are not measuring precisely the same quantity, there exists the possibility that the situation is worse. As a result, in this paper, we present new measurements of the magnetic field of 53 Cam which allow us to determine an improved value for the rotational period of this vital star.

2 OBSERVATIONS

Because 53 Cam is such a well-known magnetic star we frequently observe it as one of a number of check stars in other observing programs in order to confirm that our instrumentation is functioning properly. Consequently, we have not observed the star extensively during a single observing season, but rather one or two times each year for a period of approximately nine years. These magnetic field measurements are presented in Table 1 and in all cases the data have been obtained with photoelectric Pockels cell polarimeters (Angel & Landstreet 1970), the same type of instrument used by BL77. The University of Western Ontario polarimeter was used on either the UWO 1.2m telescope or the CFHT 3.6 telescope. A closely similar polarimeter (Manset & Bastien 1995) was used on the 1.6m Observatoire du Mont Mégantic telescope.

The circular polarization (V) observed in the wings of Hβ is converted to a measurement of the effective field using

$$B_e(G) = 2.14 \times 10^{12} V\, I(\lambda)\, (z\lambda^2 dI(\lambda)/d\lambda)^{-1} \quad (1)$$

where z is the Landé factor of the line and λ is in Angstroms. The line profile, I(λ), is obtained by using the polarimeter as a line scanner. Narrow band filters, tilt-tunable in wavelength, are used to isolate the line wings for the polarization measurements. A more detailed description of the instrument and observing technique can be found in Landstreet (1982).

3 PERIOD SEARCH

Since the magnetic field geometry of 53 Cam has been extensively discussed by Landstreet (1988) and others, we will confine ourselves to simply refining the rotational period of the star with these new data.

We have combined our new Hβ measurements of the magnetic field of 53 Cam with those listed in BL77 and carried out a least-squares fit to the equation

$$B_e = B_0 + B_1 \sin 2\pi(\phi). \quad (2)$$

The sinusoidal form of Equation (2) implies that 53 Cam has a magnetic field dominated by a dipole component, and this assumption is justified by Landstreet (1988). The best fit yields a period of 8.02681 ± 0.00004 days, with $B_0 = -53$ G, and $B_1 = 4572$ G. The epoch of magnetic field crossover is HJD 2448498.186 ±0.022. The B$_e$ measurements and the best fitting sine curve are presented in Fig. 1. The quoted uncertainties in the period and epoch of magnetic crossover correspond to those changes which would result in an increase of 1.0 in the χ^2 of the fit. The reduced χ^2 of the fit is 2.08.

Table 1. Effective magnetic field data for 53 Cam.

HJD (-2400000)	B$_e$ (G)	σ (G)	Phase	Obs.
47209.744	450	460	0.233	UWO
47608.608	4100	472	0.925	UWO
47957.786	−4230	260	0.426	UWO
48323.784	3639	345	0.023	UWO
48326.621	−3730	235	0.377	UWO
48327.566	−4591	270	0.494	UWO
48561.880	−1285	273	0.686	UWO
48616.879	−4400	419	0.538	UWO
48903.896	−2200	423	0.295	UWO
49104.634	−1676	320	0.303	UWO
49645.149	−2840	178	0.642	CFHT
49765.764	−1988	312	0.669	UWO
50046.788	−2197	264	0.679	OMM
50051.765	−1035	206	0.299	OMM
50105.546	3758	332	0.999	OMM
50130.726	2487	279	0.136	UWO
50540.619	2016	216	0.202	UWO

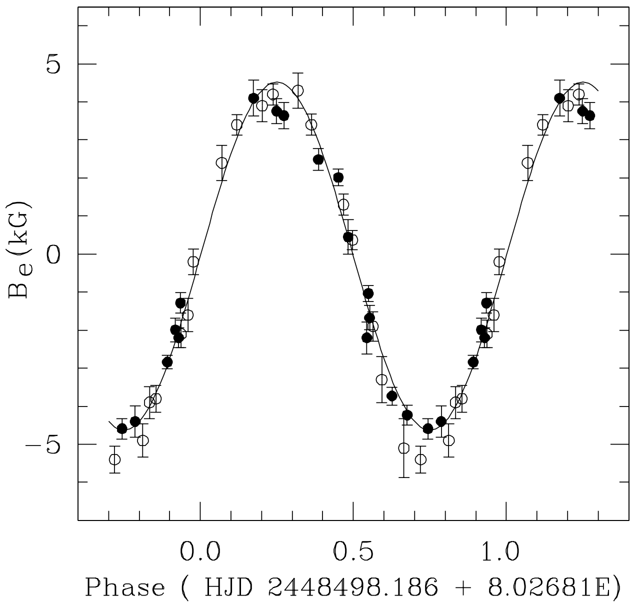

Figure 1. Magnetic field variations of 53 Cam. The parameters of the sinusoidal fit to the data are given in the text. Filled and empty points are the new data and data from BL77 respectively.

4 DISCUSSION

A period search of the data presented in BL77 provides a period of 8.027±0.002 days. By combining their data with older photographic measurements, they were able to refine the period to 8.0267 with an estimated uncertainty of 0.0002. The new period presented here (8.02681 ± 0.00004 days) agrees with this value.

Perhaps just as important as refining the period, is the fact that we have done so using a homogenous data set, whereas BL77 were forced to use a mixture of archival photographic metallic line data and their own photoelectric Hβ polarimetry. The observations of BL77 and those presented here were obtained with the same type of instrument. As shown in BL77, the magnetic curve for 53 Cam measured with photographic spectra has a markedly different shape than that found with Hβ photoelectric polarimetry. This is likely a result of the fact that the photographic data are based on measurements of centroids of metallic line profiles. Because of the well-established nonuniformity of the surface abundances of these elements on 53 Cam these elements do not sample the photospheric field as uniformly as the Hβ measurements do.

As both theoreticians and observers attempt to gain an improved understanding of the Ap stars, 53 Cam will likely be the star most often used as a test object. In many cases, new data will be combined with archival observations. The new period presented here should allow workers to do so, with confidence, for many years to come.

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