LINE ASYMMETRIES IN LATE-TYPE DWARF PHOTOSPHERES

David H. Bruning\textsuperscript{1*} and Steven H. Saar\textsuperscript{2*}

\textsuperscript{1}Dept. of Physics, University of Louisville, Louisville, KY 40292, USA
\textsuperscript{2}Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

Abstract

We have begun a program to observe photospheric line asymmetries in late-type dwarfs. Analysis of spectral line profiles of 61 Cyg A suggests that the combination of line blends and the line asymmetry may give rise to false magnetic field detection. The effects of rotational velocity and excitation potential on line asymmetry are shown for several stars.

1 Introduction

The study of stellar photospheric line asymmetries was begun a short time ago by Gray (1980; 1982) and by Dravins (1987b). Their observations have largely concentrated on F, G and early K spectral types of luminosity classes I-V. Recent work has focussed on the interpretation of stellar line asymmetries as the correlation between granular velocities and intensities (Gray and Toner, 1985; Dravins, 1987c), extending the explanation of solar line asymmetries to stars (see review by Dravins, 1982).

Livingston (1982) has shown that the asymmetry of solar spectral lines is different in magnetic regions and in non-magnetic regions, and that the line asymmetry appears to vary with the solar cycle (Livingston, 1983). Bruning and LaBonte (1986) describe this cyclic variation not in terms of a change in the global characteristics of surface convection, but rather as a change in the amount of surface covered by magnetic field. Temporal variations in line asymmetries for ξ Boo A have been observed by Toner and Gray (1988) which suggests that regions of stronger and weaker granulation are being rotationally modulated. Although Toner and Gray define the modulation in terms of a new phenomenon they call a “starpatch”, the variations are perhaps due to magnetic fields (Saar et al., 1987), similar to the case for the sun. Temporal variations of line asymmetries may prove to be a powerful diagnostic for the analysis of magnetic field distributions since field distributions are presently found from simultaneous measurements of Zeeman broadening and linear polarization, two difficult measurements.

\textsuperscript{*}Visiting Astronomer, National Solar Observatory, operated by the Association of Universities for Research in Astronomy, Inc. under contract with the National Science Foundation.

Despite the potential of the study of stellar line asymmetries to tell us about surface convection in stars and, perhaps, about magnetic fields, few stars have actually been observed. This paper describes an on-going program to observe late-type dwarfs and the possibility of using the infrared for these observations.

2 Observations

A series of optical measurements of stellar line bisectors has begun at the McMath telescope of the National Solar Observatory. The TI4 CCD camera is used along with the echelle grating to obtain spectra near 6250 Å with a signal-to-noise ratio of several hundred and a spectral resolution of 80000. As pointed out by Dravins (1987a) and Livingston and Huang (1986), line asymmetries are degraded at spectral resolutions below 100,000. To provide higher resolution at the McMath telescope, a new image slicer is being built (completion Fall 1988) which should permit a spectral resolution of 160,000 with no loss in the signal-to-noise ratio.

Observations from stellar magnetic field studies have also been pressed into service for our study of stellar line asymmetries. Several K and M dwarfs were observed at the 2.5 m Hooker telescope at Mt. Wilson, several FTS observations of late-type stars were made at the 4 m telescope at Kitt Peak, and several late-type stars have been observed at the ESO Coudé Auxiliary Telescope. A total of 17 dwarfs with spectral types ranging from F5 to M0.5 have been observed, and 4 giants have been studied for comparison of our data with that of other authors.

3 Results

The initial observing run at the McMath was exploratory in nature to determine whether line asymmetries could be effectively observed with this telescope. The line asymmetries we observe for Arcturus and Procyon are similar to those reported by Gray (1982, 1983) and Dravins (1987b), and the variation of the line bisector slope with excitation potential (Dravins, 1982) is also seen (Figure 1).

Comparison of the line bisectors for β CVn (v sin i = 1.8 km s⁻¹), β Com (v sin i = 4.3 km s⁻¹) and χ² Ori (v sin i = 9.4 km s⁻¹), three G0 V stars, reveals the so-called rotation effect whereby stellar rotation enhances the line asymmetry (Figure 2). The enhancement observed for these three stars is different from that predicted by Gray (1986) and Smith, Huang and Livingston (1987). Smith, Huang and Livingston predict a blueward asymmetry, increasing as the square of the rotational velocity. Gray predicts that rotation will produce a pronounced redward asymmetry. The observed bisectors show an enhanced redward asymmetry that increases with increasing rotational velocity, but the bisector changes less quickly than predicted by Gray or Smith, Huang and Livingston.
Figure 1: The variation of line asymmetry as a function of excitation potential for Arcturus. The excitation potentials are: 0.29 eV (6251.8 Å), 2.40 eV (6252.6 Å) and 3.60 eV (6246.3 Å).

The Mt. Wilson data were obtained at 6173 Å, which is not an optimum region for observing line asymmetries. However, one interesting result has come from these observations. Saar’s (1987) observation of 61 Cyg A in the infrared fails to detect a magnetic field for this star, while measurements of the Fe I 6173 line show strong field strengths with 30 percent filling factors (Marcy, 1984; Bruning, Chenoweth and Marcy, 1987). If the optical measurements are corrected for the line asymmetry, the filling factor and field strength for 61 Cyg A are decreased radically. Since line blends are also a problem at λ6173 (Hartmann, 1987; Saar, 1987), the discrepancy between the optical and infrared magnetic field measurements appears to result from a combination of the line asymmetry and line blends for the optical lines. Future magnetic field measurements should, therefore, take the line asymmetry into account.
Figure 2: Increasing rotational velocity enhances the line asymmetry as shown for three GO V stars: \( \beta \) CVn (1.8 km/s), \( \beta \) Com (4.3 km/s) and \( \chi^1 \) Ori (9.4 km/s). The Fe I line at 6246.3 Å is shown for all three stars.

The infrared is intriguing for the study of line asymmetries since line blends are less severe than at \( \lambda \)6200. It is difficult, however, to obtain the high spectral resolution necessary to properly observe the line shape. Our present observations obtained a spectral resolution of 45,000 at the expense of long integration times with a 4 meter telescope. Higher spectral resolution measurements of dwarf stars, at least at 2.2 microns, do not appear to be practical at this time.

4 Interpretation of Line Bisectors

Several models are being used to interpret the observed line bisectors in terms of stellar granulation. Our present model uses either three or four streams and includes properties from the two-stream model by Gray and Toner (1985) and the multi-stream model of Dravins (1987c). Three or four streams permit the use of one or two velocities for the granule, one for the neutral regions and one for the inter-granular lanes.
In addition, models of solar line asymmetry by Beckers and Nelson (1978) and observations by Balthasar (1985) suggest that horizontal motions are important, and these motions will therefore be included in our model.

As shown by Bruning (1984), convolutions are not an appropriate way to treat rotation for slowly rotating stars. Rotation is included in our model as an explicit disk integration which also permits the inclusion of limb darkening and the variation of line shape from disk-center to the limb. Input line profiles are calculated from LTE model atmospheres. Future models will include magnetic fields and line blends for direct comparison with the observations.

Acknowledgements

This work has been supported in part by an NSF EPSCoR grant and by the Harvard-Smithsonian Postdoctoral Fellowship program.
References


© Springer-Verlag • Provided by the NASA Astrophysics Data System
Discussion

MAILLARD — With respect to other line bisector measurements, you used a somewhat lower resolution than what seems to be required. Can you comment on that?

BRUNING — The Mt Wilson and Kitt Peak 4m observations were taken for magnetic field analyses, where lower spectral resolution is permissible. We thought it would be interesting to use these data for line bisector studies in spite of the low resolution, since it would extend our knowledge to cooler dwarfs.