LINE ASYMMETRIES IN G AND K DWARFS:
DEPENDENCE ON SPECTRAL TYPE AND ACTIVITY

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ABSTRACT New observations of photospheric line asymmetries in 23
dwarf stars confirm and extend previous work on G dwarfs to cooler K
stars, where we find many trends reversed, broadly consistent with the
latest hydrodynamical models.

1. OBSERVATIONS AND ANALYSIS

Observations of 12 G and 11 K dwarfs were made with the ESO 1.4m CAT/CES
system and a CCD detector, yielding a resolution of $\lambda/\Delta\lambda = 10^5$ and S/N ratios
of 150–400 per pixel. In our analysis, we concentrated on the Fe I 6151.62 Å line
(excitation potential $\chi_L = 2.18$ eV). This feature is a remarkably “clean” line
with little apparent blending in the Sun (Rutten and van der Zalm 1984), cooler
stars, or even sunspots (Fig. 1 of Saar 1988).

We began the analysis by determining the line minima through parabolic fits
to the line cores. Next, for each point in the profile up to 0.95 of the continuum,
a corresponding point at equal depth was determined on the opposite side of the
profile using a cubic spline. The bisector was then defined as the wavelength of
the midpoint of the line connecting the observed and interpolated points. No
artificial smoothing of the line profiles or bisectors was attempted and we have
not averaged bisectors of many different lines together, since line strength and
excitation affect the bisectors (Dravins 1982; Bruning and Saar 1988).

We defined two parameters to quantify the amplitude and shape of the bi-
sector (see Fig. 1). The bisector slope (obtained from a linear least squares fit)
is defined such that a vertical bisector has slope zero, and one slanted slightly to
the blue has a small negative value. The curvature is defined as the value of the
second derivative of a quadratic fit to the bisector; it is a measure of the degree
of “C” shape in the bisector (negative values indicate a reversed “C”).

2. RESULTS AND DISCUSSION

Previous work suggests that bisector shapes of a given line will be a function of
spectral type (Gray 1982), $v \sin i$ (Gray 1986), and magnetic activity (Livingston
Gray (1982) studied bisectors in a group of stars which included 7 G0–K2 dwarfs and subgiants. Our targets consist of 23 G0–K5 dwarfs with $0.58 \leq B-V \leq 1.11$, extending Gray’s sample to late K stars. We show excellent agreement for our one star in common ($\tau$ Ceti; G8V).

If we divide our sample into magnetically inactive and active stars (based on Ca II emission), we see solar–like “C” shaped bisectors (positive curvature; see Fig. 1) in inactive G stars, consistent with Gray (1982). There is considerable spread in the curvature within a given B–V interval, however, probably due to a combination of rotational enhancement and varying magnetic activity (Bruning and Saar 1989). The curvature weakens and changes into a reversed “C” shapes for $B-V \geq 0.90$. Active stars show no clear trends in curvature with $B-V$, probably because combined rotational and activity effects dominate the bisector. The general trend of curvature change for inactive stars is consistent with the latest hydrodynamical models of Dravins and Nordlund (1989).

If we consider the slope of the bisector in inactive stars (Fig. 2a), we find a gradual change from positive (G stars) to negative (K stars) values, with nearly vertical bisectors near $0.7 \leq B-V \leq 0.8$ (consistent with Gray’s minimum near G8). The negative slopes in inactive K stars are roughly consistent with the calculations of Dravins and Nordlund (1989) for the K1V star $\alpha$ Cen B.

Since the “activity” designation is only qualitative, we also studied correlations between slope and the stellar angular velocity, $\Omega$ (Fig. 2b). Even though only nine of our stars have measured periods (forcing us to estimate $\Omega$ from $v \sin i$), the results are intriguing. When divided at the bisector minimum into G stars ($B-V \leq 0.78$) and K stars, the bisectors show quantitatively different behavior: G stars show increasingly negative slopes with larger $\Omega$ and K stars exhibit more positive slopes as $\Omega$ increases. Since $\Omega$, $v \sin i$, and activity are not independent, it is not clear whether rotational enhancement or magnetic activity is the dominant effect. Behavior in G stars, however, is basically confirmed by “spun–up” disk–integrated solar models (Bruning and Saar 1989). The opposite behavior in the K stars appears to be related to the different temperature structure in these stars (Dravins and Nordlund 1989). A plausible scenario then has rotation enhancing the existing trends, and variable activity (Toner and Gray 1988) providing the scatter to produce the observed results.

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REFERENCES


Figure 1. The derived bisectors vs. $\Delta v$ for Fe I 6165 Å in the target stars. Bisectors, shifted by an arbitrary $\Delta v$, are arranged in order of increasing B-V starting at the top left. An example of the analysis is shown for HD 102365 (G5 V), with linear and quadratic fits to the bisector, and the line profile (on a $\Delta v/20$ velocity scale) superimposed (dashed lines).

Figure 2. Bisector slope vs. B–V (a) and $\Omega$ (b). In (a), active stars are denoted by stars and inactive stars by crosses; in (b), K stars are denoted by stars and G stars by crosses. Trends in the groups are shown.