Magnetic Activity in Low Mass Stars: SDSS Results

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Abstract. We present a study of the magnetic activity properties of low-mass stars in the Sloan Digital Sky Survey. Using the Hα emission line as an activity indicator, we examine the fraction of active stars as a function of spectral type and find a peak near type M7, confirming previous results. However, contrary to past findings, we find that not all M7 stars are active. We investigate the ratio of the luminosity emitted in Hα compared to the bolometric luminosity for each star, and find a roughly constant ratio (with large scatter) over the range M0-M7. There appears to be a slight decrease in this ratio for types M8-L0, in agreement with previous determinations. We also explore the effect of metallicity on activity, and examine whether activity is correlated with changes in SDSS colors.

1. Introduction

Magnetic activity in late-type stars is characterized by strong surface magnetic fields that lead to heating of the chromosphere, transition region and corona. In the optical, Hα emission is an excellent probe of chromospheric activity. Previous results indicate that the fraction of M dwarfs with Hα in emission increases from early to mid M spectral types (Hawley, Gizis & Reid 1996), reaches a peak near type M7 where essentially all stars are active, and declines toward later types (Gizis et al. 2000). The activity strength, measured by the ratio of the luminosity emitted in Hα to the bolometric luminosity ($L_{H\alpha}/L_{bol}$ - Figure 2), is apparently constant (with large scatter) through the M0-M7 range (Hawley,
Neither of these results is explained by current models. However, the sample at types later than M7 on which these results are based was limited to fewer than 100 objects. Here we investigate these correlations with a much larger sample obtained from the Sloan Digital Sky Survey (SDSS) database.

2. Data

The SDSS is an optimal tool for large scale spectroscopic studies. When completed, SDSS will cover one quarter of the entire sky and will comprise more than one million spectra. The SDSS spectra are produced with a uniform reduction pipeline and well understood errors, making it possible to undertake statistically robust studies.

Our sample was obtained in spring 2002, using the color cuts defined in Hawley et al. (2002): 0.8 < r-i < 3.0 and 0.3 < i-z < 3.5 to identify ~17000 candidate M and L dwarfs in the spectroscopic database. Using the spectral typing method from Hawley et al. (2002), we have obtained spectral types for all of these stars. Roughly 40% (6000) are M and L dwarfs with sufficient signal to noise for analysis. We have added an additional 5000 stars (3000 of which can be used) from a set of SDSS spectra that were targeted specifically for the study of late type dwarfs.

3. Results

Our results for the activity fraction and activity strength as a function of spectral type are in substantial agreement with the previous work described above (Figure 1). With our much larger sample and better defined uncertainties, we find that the activity fraction peaks at ~60%, while there may be a second peak near L0. The latter effect requires a larger sample for confirmation. The decline in activity strength at types later than M7 appears to be real, but is much less marked in our data than in previous studies (Gizis et al. 2000; Hawley et al. 1996; Schneider et al. 1991; Burgasser et al. 2002a).

We also investigated the colors of the active stars in our sample, and find that the (u-g, r-i) and (u-g, i-z) color-color diagrams both show that early type active stars are significantly bluer in u-g than their inactive counterparts (Figure 2). This demonstrates that the activity has a marked effect on the radiation in the bluer passbands. This may be the result of unresolved flare activity, as suggested by Amado & Byrne (1997).

A metallicity estimate obtained by comparing CaH and TiO molecular features (Gizis 1997) indicates that a small fraction of our sample are subdwarfs, and that these objects are less likely to be active than the normal disk dwarfs (Figure 3). There are 99 subdwarfs in our sample, with 13 of them showing activity (13%) compared to 21% in the disk dwarf sample. This is likely an age effect, with the older subdwarfs being less active, especially at earlier types (Reid & Hawley 2000).
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References

Figure 1. (Top) The fraction of late type dwarfs with magnetic activity is shown as a function of spectral type. The SDSS sample contains more than 800 stars per bin for types less than M8. The M8 bin contains 254 stars, the M9 bin contains 101 stars, the L0 bin contains 26 stars, the L1 bin contains 14 stars and all other L bins have less than 10 stars per bin. The error bars represent the true propagated error in the SDSS data. We find a statistically significant peak at M7, in agreement with the previous results, but the fraction of stars that are active at M7 is only 60%. (Middle and Bottom) The ratio of the luminosity in $H\alpha$ to the bolometric luminosity as a function of spectral type. The plot shows a slight decrease in the median activity strength, but the decrease is not as steep as in previous results.
Figure 2. Average u-g colors as a function of r-i and i-z (proxies for spectral type). The red diamonds represent active stars and the black asterisks show inactive sources. The r-i and i-z data have been binned in order to show global trends.

Figure 3. The variation of CaH bandstrength with TiO bandstrength provides a metallicity estimate, with (top) The CaH1 band used for early M dwarfs; and (bottom) the CaH2 band used for later types. Red lines in both plots represent the delineations between normal dwarfs and low metallicity subdwarfs (Gizis 1997). The points with error bars show the stars which lie statistically below the dwarf/subdwarf boundary. The blue line in (bottom) is the delineation between subdwarfs and extreme subdwarfs.