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The Variability of Sunlike Stars on Decadal Timescales

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Abstract. We have combined observations of about 30 sunlike stars from Mount Wilson, Lowell, and Fairborn Observatories to extend our joint time series from 12 to 17 years. The full range of variation on the decadal timescale has probably now been observed for most of our program stars. Statistical relationships between chromospheric and brightness variability derived earlier by us are confirmed. Young active stars become fainter as their chromospheric Ca II HK emission increases, while older less active stars such as the Sun become brighter as their HK emission increases. The Sun's photometric variation still appears somewhat small in amplitude compared to the other stars in this sample with similar mean chromospheric activity.

1. Introduction

Chromospheric Ca II HK emission for almost 100 stars has been monitored since 1966 from Mount Wilson Observatory (Wilson 1978; Baliunas et al. 1995). Overlapping Strömgren b, y photometric observations for about $^1/_3$ of this sample were made between 1984-2000 from Lowell Observatory (Lockwood et al. 1997), and since 1993 from Fairborn Observatory (Henry et al. 2000; Fekel et al. 2004). We previously reported results from the first 12 years (1984-1996) of the joint program (Radick et al. 1998). We have now successfully merged the Lowell and Fairborn data, extending the joint time series from 12 to 17 years. Here, we will discuss the merger process, illustrate the outcome, and update key statistical relationships reported previously.

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2. Merging the Photometric Data

Differential photometric observations of 34 stars similar to the Sun, using a dedicated 0.5-m telescope, began at Lowell Observatory in March 1984 and ended in June 2000. Typically 5-10 groups, each comprising a program star plus 2 or 3 comparison stars, were measured each night. Each group was observed as many as 30 times, but more typically, about 10 times per season. The same equipment and filters were used throughout the entire observing program, so there was no need to transform the data to a particular reference system. We did, however, finally apply a small color correction to account for a slight drift in the photomultiplier color response.

Parallel observations of most of these stars were begun in 1993 with a 0.75-m automated photometric telecope (APT) of the Fairborn Observatory, located at Washington Camp, AZ. Fairborn obtained many more observations per season than Lowell, and its data are transformed to the standard Strömgren photometric system.

The Lowell and Fairborn observations overlapped by up to seven years before the Lowell observations ceased. This overlap permitted us to establish accurate magnitude offsets between the Lowell instrumental system and the Fairborn standard system, typically 0.01-0.02 mag, that are adequate to provide artifact-free combined time series for most stars. The night-to-night precision of both databases is almost identical, a bit more than 0.0010 mag rms for the best star pairs.

The merged data are illustrated for the program star HD1835 and its two comparisons, HD2488 and HD1388, in the upper two panels of Figure 1. These two panels show photometric brightness, measured in units of $(b+y)/2$ magnitudes, plotted on a common scale in the sense that brightness increases upward. Filled and open symbols are used to plot the Lowell and Fairborn observations, respectively. This group is one of the best behaved in the program: the comparison star pair (upper panel) shows an rms dispersion of 0.0018 mag over the entire 16-year time series. In obvious contrast, the program star, HD1835, measured relative to the average brightness of the two comparison stars, is clearly variable (center panel). The lower panel shows chromospheric HK emission variations for HD1835, plotted in the sense that emission increases upward. Each time series includes an embedded cubic spline fitted to the annual means.

Ideally, all groups would behave this well. For many stars, however, variations of the comparison stars were comparable to, or even larger than, those of the program star. Indeed, both the Lowell and Fairborn programs found that well over half of the stars observed are demonstrably variable, both on short (night to night within seasons) and long (year to year) time scales (Lockwood et al. 1997; Henry 1999).

3. Patterns of Variation

When we began our study in 1984, we already knew that stars much younger than the Sun (in particular, Hyades stars) had detectable brightness variations of a few percent (Radick et al. 1987.) We also knew that downward fluctuations in brightness over time scales of days were related to the disk transit of spots or

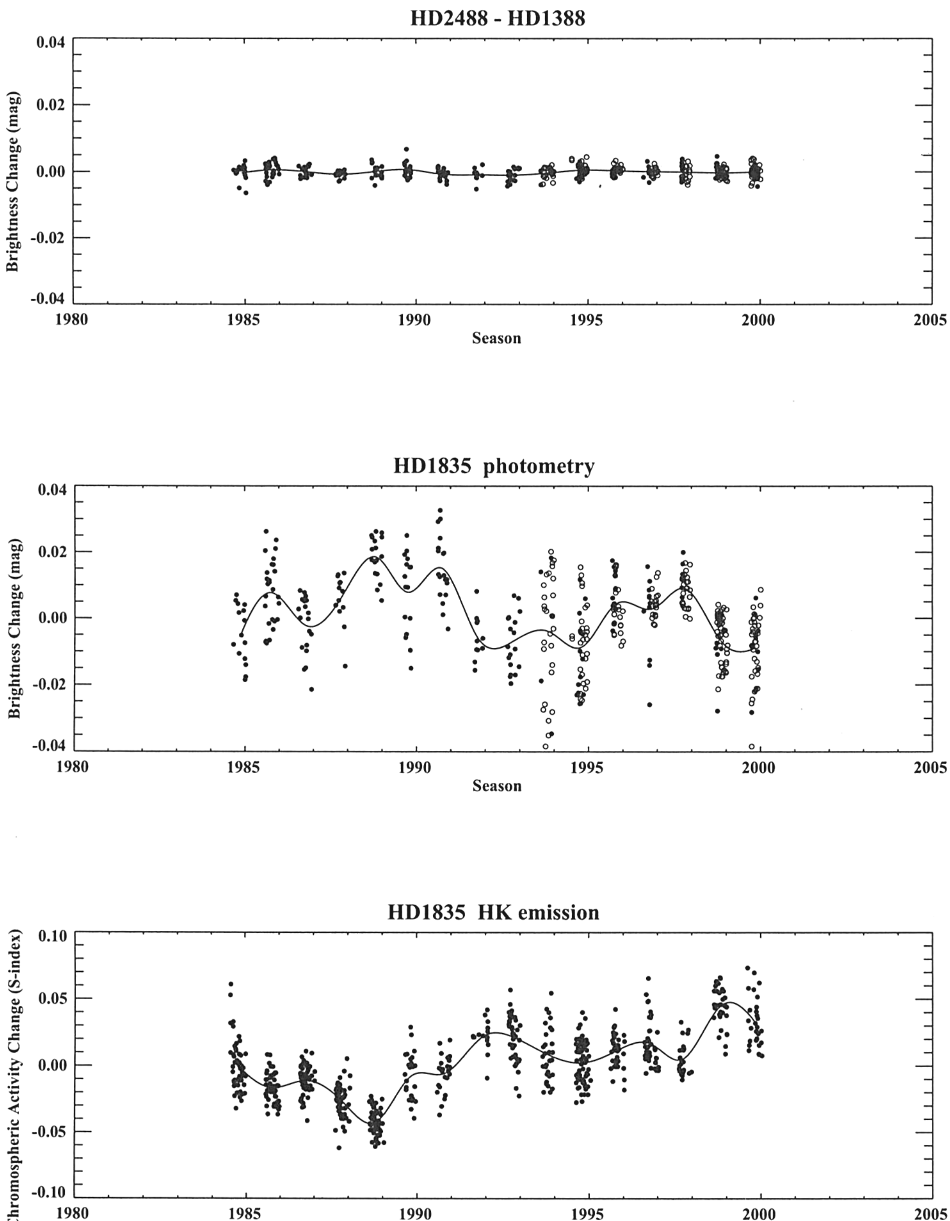

Figure 1. The joint time series for the HD1835 group: (upper panel) the merged differential photometry for the two comparison stars; (center panel) the photometric variability of HD1835; and (lower panel) its corresponding chromospheric HK emission variations.

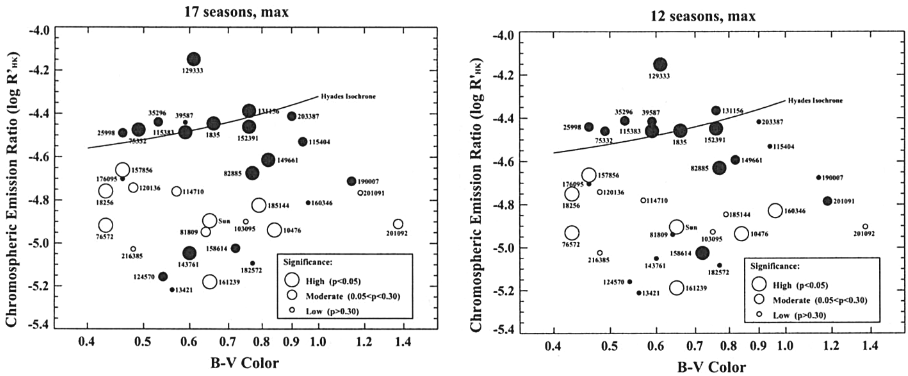

Figure 2. The correlation between photometric brightness and HK emission on year-to-year time scales, plotted as a color-activity diagram. Young, active stars appear in the upper portion of the diagram, while older, less active stars occupy the lower half. The Sun itself is at the lower left center. The size of each symbol indicates the significance of the correlation. Open symbols represent stars (like the Sun) that become brighter as their HK emission increases, and filled symbols indicate those that become fainter. The left panel shows the pattern after 17 years, the right, after 12.

spotted regions, and in some cases we were able to derive rotation periods from the photometric measurements. Within a few years, it also became apparent that young active stars, such as HD1835, become fainter as their chromospheric HK emission increases on the time scale of years, in contrast to older less active stars such as the Sun, which become brighter as their HK emission increases. This behavior has become even more obvious as the time series lengthened by five additional years, at least for the young stars (Figure 2). Among the older stars, there is still an example or two that violates the pattern, but we also know that comparison star variability is involved in the worst one of these cases, and perhaps others.

4. Photometric Variability as a Function of Activity

Photometric variation, measured on the decadal timescale, obeys a power law relationship with respect to time-averaged chromospheric activity, with the younger, more chromospherically active stars being the most variable (Figure 3). This power law has remained quite stable as the length of the time series has increased. The derived slope has changed by only some 10%, and the dispersion about the trend line has remained about the same, although the individual stars continue to shuffle about a bit, as we have gone from 12 (right panel) to 17 years (left panel). The Sun clearly lies below the trend line in both panels, implying that its photometric variations are relatively small compared with stars of similar mean chromospheric activity in this particular sample. Whether larger, better-controlled samples will also show this behavior remains to be seen.

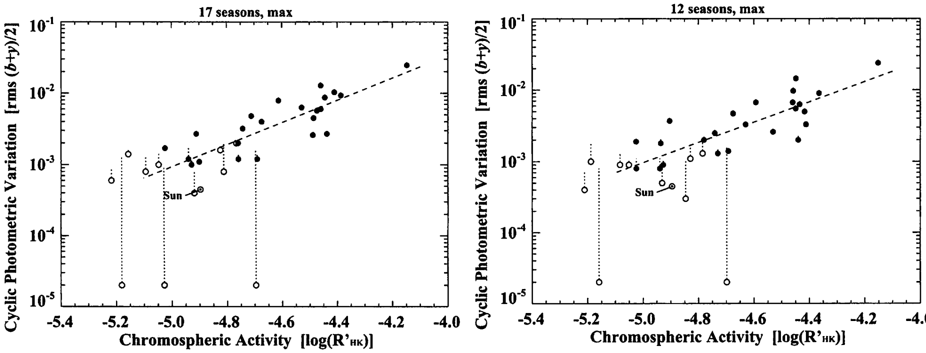

Figure 3. The power law relationship between photometric variability and mean chromospheric activity. Variable stars are represented by filled symbols - these only were used to determine the trend lines. Drop lines indicate a correction for the variability of comparison stars. The left panel shows the relationship after 17 years, the right, after 12.

5. Summary and Conclusions

We have successfully combined photometric observations of about 30 sunlike stars from Lowell and Fairborn Observatories, extending our time series from 12 to 17 years. The stability of the statistical relationships between chromospheric and brightness variability, derived previously, suggests that the full range of variation on the decadal timescale has probably now been observed for most of our program stars. The Sun's photometric variation still appears to be somewhat small at present, compared to other stars in this sample of similar activity.

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