A NEW ROTATION-ACTIVITY RELATION FOR EVOLVED G AND K STARS

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ABSTRACT We obtained high-resolution CCD spectra of Ca II H and K emission lines of 59 evolved stars of spectral type G and K and luminosity class III, III-IV, and IV. We find that the Ca II surface fluxes scale linearly with stellar rotational velocity and that the flux from the cooler stars depends more strongly upon rotation than the flux from the hotter stars, in agreement with previous findings for main-sequence stars. We also present some evidence for the existence of a "basal" flux for evolved stars that scales approximately with the eighth power of the effective surface temperature.

THE BASAL FLUX FOR EVOLVED STARS
Flux-color diagrams for convective main-sequence stars exhibit a minimum radiative loss in the H and K lines that decreases with decreasing stellar surface temperature. Schrijver (1987) argued that this "basal" contribution to the net chromospheric radiative loss is independent of magnetic activity and is possibly contributed by acoustic heating. A similar conclusion is reached from transition-region lines and coronal soft X-rays (Rutten et al. 1991) and possibly also from the infrared triplet lines of Ca II (Dempsey et al. 1993). So far, this is only well established for main-sequence stars. Here we attempt to demonstrate, at least phenomenologically, that the chromospheric radiative loss from evolved stars behaves in a similar way.

The existence of a temperature dependent lower boundary in the observed fluxes is apparent from Fig. I. This lower boundary is identified as the basal flux for evolved stars and we trace it by a power function with a $T_{\text{eff}}^8$ dependence. Our sample for the temperature range 5000–6500 K includes about two dozen stars well below the basal flux observed by Rutten et al. (1991) and Rutten (1987). Note that we use high-resolution spectra while Rutten et al. (and other workers using the Mt. Wilson H and K data) rely on photometrically determined fluxes. For stars cooler than 5000 K the basal flux from the mixed sample of Rutten et al. seems to agree well with ours for luminosity class III and IV stars.

ONCE AGAIN: ROTATION AND ACTIVITY
A clear tendency of decreasing flux with decreasing rotational velocity or increasing period is observed (Fig. II). However, for a given rotation rate, the scatter in the observed surface fluxes is enormous, about 1 dex. This is only
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FIGURE I  Ca II K line flux versus effective surface temperature. Dots are binary components and plusses are single stars. The dotted line is the "basal flux" observed by Rutten et al. (1991). The full line segment shows our empirical lower limit for giants and subgiants with a $T_{\text{eff}}$ dependence.

FIGURE II  The rotation-activity relation for evolved stars. The abscissas show $\log v_{\text{rot}}$ in the upper panels, and $\log P_{\text{rot}}$ in the lower panels. The ordinates are always Ca II K-line surface flux. The observed flux at a given rotation rate can span over almost an order of magnitude but a general decline of activity with slower rotation is obvious.
partially due to errors in the rotation rates, and strengthens the current view that it is not solely stellar rotation that scales the emerging magnetic flux.

The diagrams in Fig. II indicate several other interesting features. First, subgiants generally show shorter rotational periods than giants. This is obvious because their radii are smaller and surface velocity is probably the more appropriate description for rotation. Unfortunately, measured radii are only very seldomly available and the use of empirical radii for giants might introduce additional scatter. Second, binary components are, on average, rotating faster than their single counterparts and are thus also more active (e.g., Strassmeier et al. 1990). Third, when binning our sample into narrow intervals of effective temperature (as indicated in Fig. Iie and IIf), a change in the slope of the correlations is seen; similar to that previously found for main-sequence stars (e.g., Rutten 1986, Stepien 1989). We performed linear least-squares fits to the data in consecutive temperature intervals and obtained rotation-activity relations of the form

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\begin{align*}
\log F'(K) &= 3.79 + 1.74 \log v_{\text{rot}} \quad \text{for} \quad T_{\text{eff}} \leq 4500 \\
\log F'(K) &= 4.97 + 0.85 \log v_{\text{rot}} \quad \text{for} \quad 4500 < T_{\text{eff}} < 5000 \\
\log F'(K) &= 4.99 + 0.91 \log v_{\text{rot}} \quad \text{for} \quad T_{\text{eff}} = 5000 \\
\log F'(K) &= 5.51 + 0.45 \log v_{\text{rot}} \quad \text{for} \quad T_{\text{eff}} \geq 5500
\end{align*}
\]

(1) (2) (3) (4)

It was originally shown by Walter (1983) for X-ray emission that the intense activity of early-to-mid F stars is uncorrelated with stellar rotation. Subsequently, this was shown also from C IV emission by Simon & Drake (1989). Thus, our new observations from Ca II H and K are in agreement with those from other wavelength regions and we conclude that stellar magnetic activity of cooler giants and subgiants with, say, \( T_{\text{eff}} \leq 5500 \) K generally has a stronger dependence upon rotation than the hotter stars, in agreement with previous findings for main-sequence stars.

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REFERENCES