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The gap of differential rotation in early F-type stars

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Abstract. We present new measurements of the rotational profile of 56 nearby stars of spectral types A-F obtained by line profile analysis. Together with earlier work, we now know of 33 stars in which Sun-like differential rotation was identified by line profile analysis. We find evidence of two populations of differential rotators, one group of rapidly rotating A stars at the granulation boundary with strong horizontal shear, and another group of mid- to late-F type stars with moderate rates of rotation and less shear. There is a gap between A and F stars, in which the stars appear to exhibit very little shear. Apparently, the physical conditions of differential rotation change at early-F spectral types.

Keywords. Stars: rotation – Stars: fundamental parameters – Hertzsprung-Russell diagram

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The rotational speed of the polar regions on the Sun is lower than the speed at the equator by about 20%. This latitudinal differential rotation has been observed on other stars by several techniques. Here, we discuss results from line profile analysis presented by Reiners *et al.* (2003-2006) and Ammler-von Eiff & Reiners (2012).

Latitudinal differential rotation can be described by a simple surface rotation law with dependence on the latitude θ:

$$\Omega(\theta) = \Omega_{\rm Equ}(1 - \alpha \sin^2\theta) \tag{0.1}$$

$$\alpha = \frac{\Omega_{\rm Equ} - \Omega_{\rm Pol}}{\Omega_{\rm Equ}} = \frac{\Delta\Omega}{\Omega_{\rm Equ}} \tag{0.2}$$

$\Delta\Omega$ is the horizontal shear, the difference between equatorial ($\Omega_{\rm Equ}$) and polar ($\Omega_{\rm Pol}$) angular velocity. The parameter α of relative differential rotation relates the horizontal shear to the equatorial angular velocity. α is the quantity actually measured by line profile analysis. The reader is referred to Ammler-von Eiff & Reiners (2012) for a full presentation of the new measurements obtained. Here, we discuss in short the lack of differential rotators identified at early-F spectral types. Possible explanations are:

- The detection limit of line profile analysis increases towards earlier spectral types.
- Differential rotation is inhibited at early-F spectral types.

Indeed, the detection limit depends on spectral type though not directly. The detection limit on the measured quantity, α, is about 0.05 at all rotational periods. Therefore, low values of horizontal shear can only be detected at longer rotational period (Eq. 0.2) typical of magnetically-braked late-type stars. Nevertheless, differential rotation has been observed at the granulation boundary at earlier spectral types (late-A), close to the point where deep convective envelopes start to form (Reiners & Royer, 2004; Reiners, 2006). There, horizontal shear can be dramatically strong so that differential rotation is observed

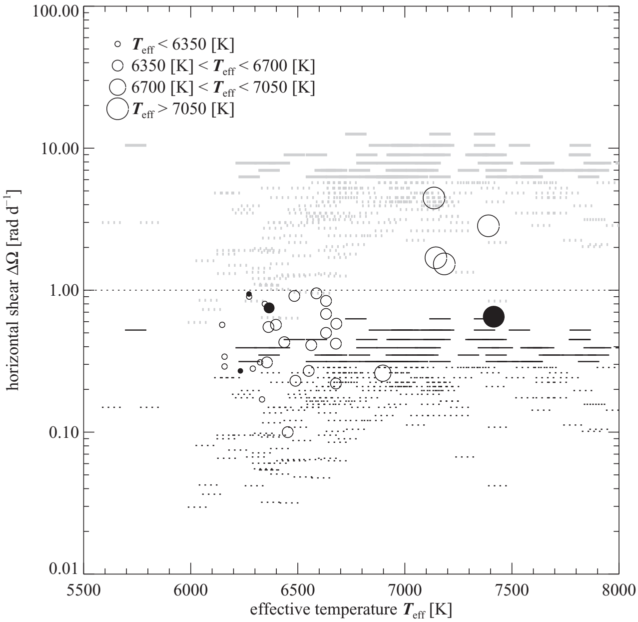

Figure 1. The amount of horizontal shear measured is displayed vs. effective temperature. Circles denote measurements of differential rotation (Reiners *et al.*, 2003-2006; Ammler-von Eiff & Reiners, 2012). The horizontal bars display the detection limits for stars with no differential rotation detected. To be more precise, grey bars identify the maximum value corresponding to $\alpha = 1$ and black bars the minimum according to the detection limit of $\alpha = 0.05$ of line profile analysis. Solid bars are fast rotators with rotational periods of less than a day while dotted bars indicate longer rotation periods. The upper limit of 1.0 rad d^{-1} on late-type stars is highlighted by a dotted line. The gap of differential rotation appears at effective temperatures of about 7000 K, at early-F spectral types.

despite fast rotation. At later spectral types, however, there is evidence that horizontal shear is limited to $\Delta\Omega \approx 1$ rad d^{-1} so that differential rotation of fast-rotating F and G-type stars would not be detected.

Yet, close inspection of the temperature dependence in Fig. 1 reveals a domain of early-F type stars (≈ 7000 K) where differential rotation must have been detected despite the upper bound of 1.0 rad d^{-1}. There are many rigid rotators or stars with undetected differential rotation although moderate amounts of differential rotation of $\Delta\Omega \approx 0.5 - 1$ rad d^{-1} should be detectable (encompassed in the figure by the horizontal bars and the dotted line). However, there are none such objects. Therefore, we conclude that the lack of early-F type differential rotators is not solely due to the detection limits of line profile analysis. Differential rotation seems to be inhibited in this temperature range and reappears at higher temperatures with extreme amounts of horizontal shear.

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