THE PHOTOSPHERIC VELOCITY FIELD OF PROCYON

C. DE JAGER
The Astronomical Institute at Utrecht, Holland

and

L. NEVEN
Royal Observatory, Brussels, Belgium

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Abstract. BUSS observations of the profiles of two well observed spectral lines in the ultraviolet spectrum of αCMi (Procyon; F5 IV–V) are analysed with a Fourier transform method in order to determine values of various parameters of the velocity field of the upper photosphere. We find a microturbulent line-of-sight velocity component \( v_t = 0.9 \pm 0.4 \text{ km s}^{-1} \), a macroturbulent velocity component \( v_M = 5.3 \pm 0.2 \text{ km s}^{-1} \), and a rotational velocity component \( v_R \sin i = 10.0 \pm 1.2 \text{ km s}^{-1} \). In these calculations a single-moded sinusoidal isotropic macroturbulent velocity function was assumed. The result appears to be sensitive to the assumed shape of the macroturbulence function: for an assumed Gaussian shape the observations can be described with \( v_R \sin i = 4 \text{ km s}^{-1} \) and \( v_M = 11.6 \pm 2.7 \text{ km s}^{-1} \). A comparison is made with other results and theoretical predictions.

1. Introduction

In four flights, during 1976 and 1978, of the Balloon-borne Ultraviolet Stellar Spectrometer BUSS (cf. Kondo et al., 1979; De Jager et al., 1979) some 70 spectra of 55 stars have been obtained in the spectral interval 2000–3200 Å with a resolution slightly better than 0.1 Å, the highest resolution obtained so far in this spectral range. A topic that lends itself for a systematic determination in these spectra is the value of the three main parameters of the photospheric velocity field, viz. the line-of-sight components of micro- and macroturbulence, and of rotation. Such an analysis may appear to be particularly interesting for extreme types of stars, such as supergiants, observed in the BUSS-campaigns. However, for developing a method of analysis we choose the star αCMi (Procyon, F5 IV–V) for several reasons:

— The photospheric properties are well-known.
— Procyon is a near-Main-Sequence star with sharp lines, of which the rotational velocity is so small that it is not yet known.
— Theoretical predictions show that stars of — approximately — this spectral type and luminosity would have the largest convective velocities. It seems useful to verify such predictions.
— In addition, when once the micro- and macroturbulent velocity components are known, and if the velocity field has one dominant component, it is possible to obtain information on the approximate length scale of the photospheric motions (Vermue and De Jager, 1979).

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There are additional reasons that support the interest of a determination of the stellar photospheric velocities by the observation of ultraviolet lines:

— For stars of medium and low temperatures, the ultraviolet lines give information on higher layers than those in the visual spectrum.
— A determination of $v_{\text{rot}} \sin i$ in the visual and ultraviolet ranges enables one, in principle, to determine $i$ (Hutchings, 1976).

While the former point does well apply to Procyon, the latter is not applicable because of the smallness of the rotational velocity of Procyon: very accurate $v_{\text{rot}} \sin i$-values would be needed in the two spectral ranges to determine $i$ with some precision.

2. The Observed and Calculated Line Profiles

Two spectra of $\alpha$ CMi were obtained during the flight of BUSS VIII on 16–17 September 1976, with exposure times of 3 and 10 minutes. The UV spectrum is very crowded with lines, and it is hard to find well-isolated lines. We decided to investigate line-profiles in the shortest wavelength part of the spectra, near 2100 Å which is least crowded. Only two lines appeared sufficiently free from blends, viz. $\lambda 2137.19$ (Fe III) and 2081.83 Å (Si I), although the first of these ($\lambda 2137.19$) is not completely ‘clean’: it has a small blending line on its long-wavelength wing, but it seems that the influence of that component can be overcome.

For the photospheric parameters of Procyon we adopted $T_{\text{eff}} = 6500$ K and $\log g = 4.0$ (Strom and Kurucz, 1966; Talbert and Edmonds, 1966; cf. also Morton et al., 1977). We calculated theoretical profiles for the two lines for two line-of-sight microturbulent velocity components: $\zeta_{\text{rad}} = 0$ and 4 km s$^{-1}$. In these calculations we made use of the grid of photospheric models published by Kurucz et al. (1976). Solar-type abundances and LTE were assumed, and the line profile was calculated as broadened by collisions with neutral H and He atoms and with free electrons, and by radiation damping (De Jager and Neven, 1957).

3. Fourier Transforms

We choose to analyse the profile with the Fourier method, so far mostly used by Gray (1973, 1976), and coworkers (cf. Smith and Gray, 1976; Smith, 1976, 1980) and others. The reason for making this choice is the clear signature of the various broadening mechanisms in the Fourier domain, in contrast to their influence on the line profile itself. We extended the method with a least-squares fitting technique.