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Preliminar Determination of the Basal Chromospheric Emission for Late-Type Stars

L. Terranegra, M. Oliviero and V. Andretta

Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Capodimonte, Via Moiariello 16, I-80131 Napoli, Italy, e-mail: terraneg@na.astro.it

Abstract. We present a preliminar determinations of the basal emission for chromospheric very inactive dwarf and giant late type stars using data collected from the literature. We also derive the activity indeces S_{HK} and R_{HK} for about 550 solar type dwarf and giant using the 1Å FWHM resolution spectra of the Indo-U.S. library. All the sample stars where in addition selected in the distance range 20 < d < 100 pc. The new fitting curves of the basal emission extend previous calibrations of the activity index R_{HK} to the range 0.2 < B-V < 2.2 .

Key words. Stars: activity of – Stars: chromospheres of – Stars: late-type

1. Introduction

The Ca II H and K emission of solar-type stars is a good diagnostic of chromospheric activity believed to be due to the stellar magnetic field generated by the dynamo and which is correlated to the stellar rotation velocity (Noyes et al. 1984). Stars with very slow rotation, show a minimum chromospheric line core emission; they are called "basal flux stars" or "flat activity stars" (Schrijver 1987, Rutten et al . 1991). In this work we present chromospheric emission level of a large sample of solar-type stars collected from the literature, and new determinations of R_{HK} for about 550 late type dwarf and giant stars using the Indo-U.S spectroscopic library (Valdes et al. 2004). For the first time we derive chromospheric emission indices for a consistent sample (about 250) of late type giants.

Send offprint requests to: L. Terranegra

2. The CaII H and K data

The basic data are the observed flux indices S_{MW} for Ca II H and K lines, as defined in the Mount Wilson (MW) HK Project (Vaughan et al. 1978). The underlying assumption is that the summed Ca II H and K flux reflects the amount of non thermal chromospheric heating, which in turn is associated with surface fields. The S_{MW} is insensitive to the local slope of the continuum in the vicinity of the Ca II H and K lines as defined by Vaughan et al. (1978). Our database consists of the S_{HK} indices for stars with spectral types between F0 and M5 ($0.35 < B - V < 1.7$) and $20 < d < 100pc$ (see Fig. 1) collected from many sources including: 1) the large surveys of Vaughan et al. (1978), Henry et al. (1996), Wright et al. (2004), Gray et al. (2006), Jenkins et al. 2006; and 2) the large spectroscopic database of the Indo-U.S. (IUS) library of coudé feed stellar spectra (Valdes et al. 2004). All the spectra selected from the IUS library include the Ca II H and

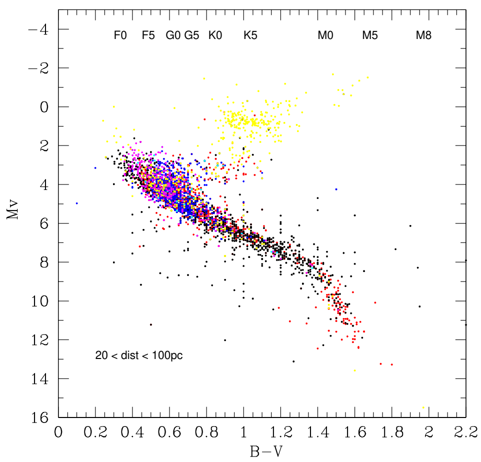

Fig. 1. The Color-Magnitude diagram for the selected sample of solar type and late-type stars with distance between 20 and 100 pc.

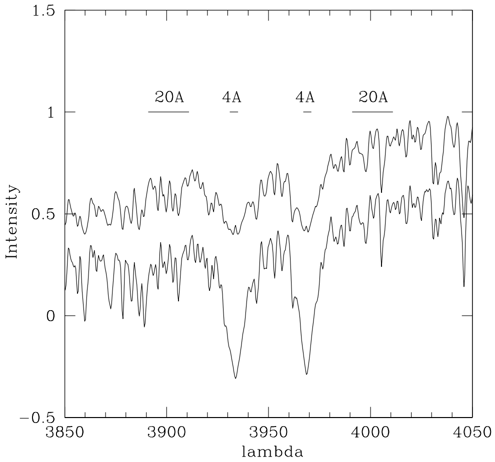

Fig. 2. The H and K region for a non active G2V star (down) and an active K1V star (up) from the Indo-U.S. library. The four bands used for determination of the S index are also shown.

K lines and thus can be used to obtain measures of the chromospheric emission, as emission from the chromosphere can be detected in the cores of these very strong lines.

3. The Chromospheric Emission

The spectra of the IUS library have a spectral coverage of 3460 Å to 9464 Å, at a resolution of about 1 Å FWHM. We measure the chromospheric emission in our program stars by calculating relative fluxes in four wavelength bands (see Fig. 2). These bands are essentially identical to those used in the MW chromospheric activity survey program (Baliunas et al. 1995), except that the bands centered on Ca II K and H are wider (4 Å) than those used at MW (1 Å) because the IUS spectra are of lower resolution. To place this chromospheric index on the MW scale, it is necessary to use standard stars to derive a transformation equation. Unfortunately, all solar-type stars show some variability in the chromospheric index, and those with higher values of S_{HK} are generally more variable. This implies that unless one has observations taken near in time to MW observations, it is impossible to derive an exact transformation equation. One, however, can derive a transformation of sufficient accuracy to characterize stars as active, inactive, etc., by selecting as calibration stars those stars of the MW list (Baliunas et al. 1995) that do not show long-term secular trends or irregular behavior. We find only seven MW standard stars from the IUS library and for each star we compute the S index. The relation between S_{IUS} and S_{MW} calibration stars is reported below and shown in Fig. 3.

$$S_{IUS} = -0.16 + 1.60 \cdot S_{MW} - 0.40 \cdot S_{MW}^2 \qquad (1)$$
$$RMS = 0.02$$

4. Results

In Fig. 4 we show the log S_{HK}, (B-V) diagram for all the stars in our database (about 4600), and the S_{HK} values for very active young cluster stars (White et al. 2007). This diagram is the same as derived by Vaughan et al. (1980) for 396 neighborhood field stars. In the figure we also indicate the boundaries of the four distinct segregation groups of stars as defined by Vaughan et al. (1980). We note that the very inactive main sequence stars show a sharp, nearly horizontal lower boundary in their S_{HK}

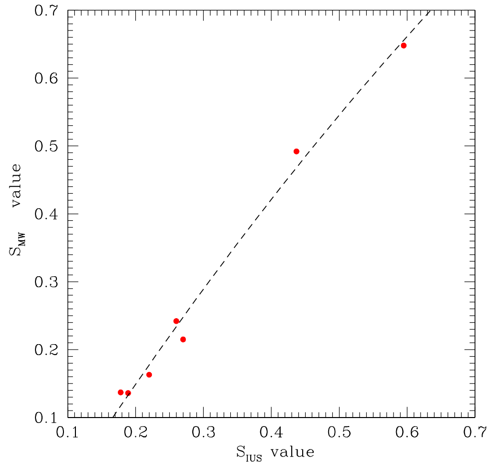

Fig. 3. Calibration curve for the Mount Wilson standard stars present in the Indo-U.S. library.

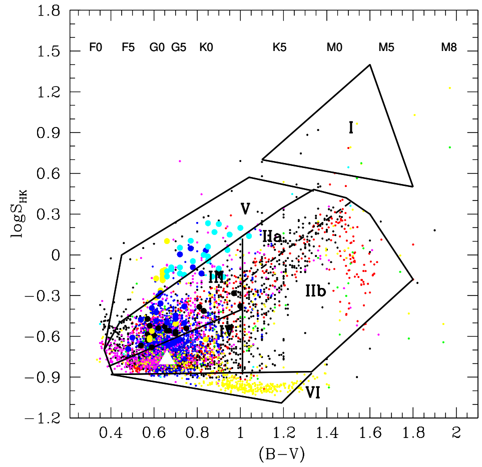

Fig. 4. The log S_{HK}, (B-V) diagram for the selected stars with $20 < d < 100$pc. The regions distinguished according to S_{HK} flux and color (see Table 1 and Vaughan et al. 1980) are shown. The triangle indicates the position of the Sun.

values. The quiet Sun, indicated with a triangle, lies above this limit, suggesting that there are many stars of comparable spectral type whose quiet chromospheric emission is even weaker than the Sun's. We defined two new segregation regions in Fig. 4 beside those indicated by Vaughan et al. (1980). The region V which includes the very active F-K young cluster stars and the region VI where we find the very inactive G-K giant stars. All the regions are reported in Table 1. As the continuum fluxes vary rapidly with spectral type in late- type stars, it is difficult to compare S_{HK} of stars with very different effective temperature. Middelkoop (1982) and Rutten (1984) have presented relations which converts S_{HK} into a physical quantity using a correction factor which depends only on B-V. These calibrations provide the ratio $R_{HK} = (F_{HK}$ flux)/(bolometric flux), i.e, R_{HK} is the fraction of the stellar luminosity which appears as emission in the H and K lines,

$$R_{HK} = F_{HK}/T^4_{eff} \equiv S_{HK} \cdot C_{cf} \cdot cost \qquad (2)$$

C_{cf} is a factor that removes the color term from S_{HK}.

We adopt the improved relations for the conversion factor C_{cf} as given by Rutten (1984) for main-sequence stars with $0.3 < B-V < 1.6$ and for giants with $0.3 < B-V < 1.7$. The result, a chromospheric color-magnitude diagram, is illustrated in Fig. 5 for all the stars of our database.

Table 1. Activity Regions

Region	Description
I	dMe dwarf
II	all K-M dwarf
IIa	more active K-M dwarf
IIb	less active K-M dwarf
III	more active F-G dwarf
IV	less active F-G dwarf
V	very active F-K young stars
VI	very inactive G-K giant

5. Conclusions

One obvious feature of Fig. 5 is a concentration of stars along the lower edge of the distribution for both dwarf and giant stars, with an absence of stars in the lower left-hand corner.

We refer to this lower limit as the basal choromospheric emission of the late-type stars.

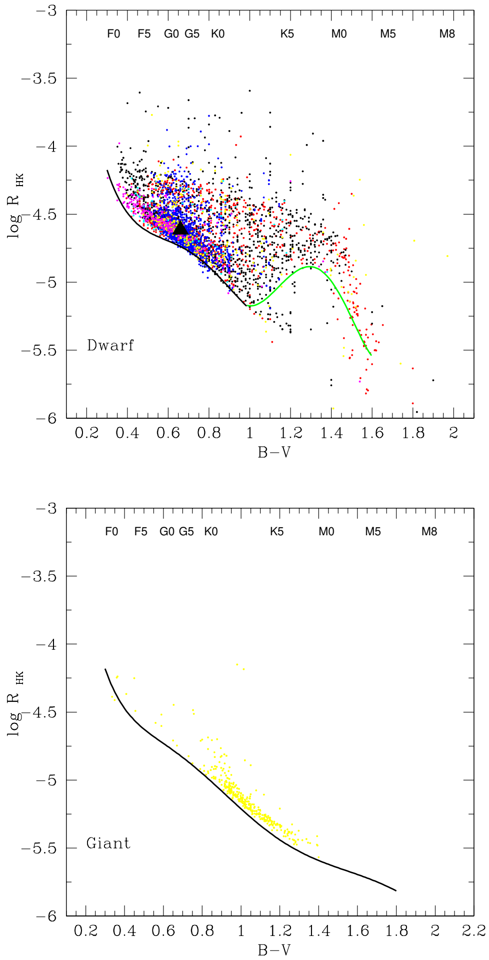

Fig. 5. The log R_{HK}, (B-V) diagram for the selected stars with $20 < d < 100$pc. The upper pannel shows the diagram for the main sequence F-M dwarf stars; the lower pannel shows the diagram for the F-K giant stars. The triangle in the upper pannel indicates the position of the Sun.

Table 2.

B-V	a0	a1	a2	a3	a4	a5	a6	a7
Dwarf 0.3-1.0	-0.48	-23.45	49.74	46.68	15.67			
Dwarf 1.1-2.2	-18.52	138.67	-360.98	396.13	-197.19	36.71		
Giant 0.3-2.2	-0.38	-26.99	72.35	-104.20	83.51	-37.49	8.83	-0.85

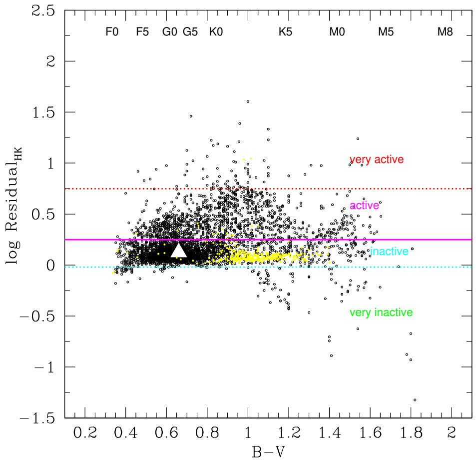

Fig. 6. The logResidual$_{HK}$, (B-V) diagram for the selected sample of solar type and late-type stars. Regions of different activity level are indicated.

The presence of these empirical basal limit for both dwarf and giant stars in Fig. 5, suggests contributions to the measured flux (i.e. S_{HK}) which do not originate in the active chromosphere. In Fig. 5 we show the empirical lower envelope curves for dwarf (black line for $0.3 < B - V < 1.0$, green line for $1.1 < B - V < 2.2$,upper pannel) and giant stars (black line, $0.3 < B - V < 2.2$, lower pannel). The extimated coefficients for these curves are reported in Table 2. The residual chromospheric emission (Residual$_{HK}$), obtained subtracting from the R_{HK} data the lower basal envelope curves for our sample of stars, is shown in Fig. 6 in which we also indicate regions of different activity level according to Henry et al. 1996.

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