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The Wilson-Bappu effect of the MgII k line – dependence on stellar temperature, activity and metallicity

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Abstract. The Wilson-Bappu effect is investigated using accurate absolute magnitudes of 65 stars obtained through early release of data from the Hipparcos satellite together with MgII k line widths determined from high resolution spectra observed with the International Ultraviolet Explorer (IUE) observatory.

Stars of spectral classes F, G, K and M and luminosity classes I-V are represented in the sample. Wilson-Bappu relations for the Mg II k line for stars of different temperatures i.e. spectral classes are determined. The relation varies with spectral class and there is a significant scatter of the line widths around the regression lines.

The sample contains slowly rotating stars of different activity levels and is suitable for investigations of a possible relation between line width and stellar activity. A difference in behavior between dwarfs and giants (and supergiants) of spectral class K seems to be present. Magnetic activity affects the width of the Mg II k line in dwarfs. Metallicity is found to influence the Mg II k line width in giants and supergiants. Possible interpretations of the new results are briefly discussed.

Key words: stars: activity – stars: chromospheres

1. Introduction

The systematic broadening of the bright CaII emission lines in spectra of late type stars (surface temperature equal to that of the Sun or cooler) with increasing stellar luminosity (Wilson & Bappu 1957) is of fundamental interest for the understanding of the temperature and density structure of stellar atmospheres. Also the Mg II h and k lines and H Lyα show a similar effect (McClintock et al. 1975). Various Wilson-Bappu relations have been established by a number of authors. Engvold & Elgarøy (1987) found that several chromospheric and transition region lines observed with the IUE satellite obeyed W-B relationships. A study of the relation between stellar activity and the W-B relation using a sample of 78 single stars has recently been carried out by Elgarøy et al. (1997). A numerical simulation of the Wilson-Bappu relationship has recently been carried out by (Cheng et al. 1997).

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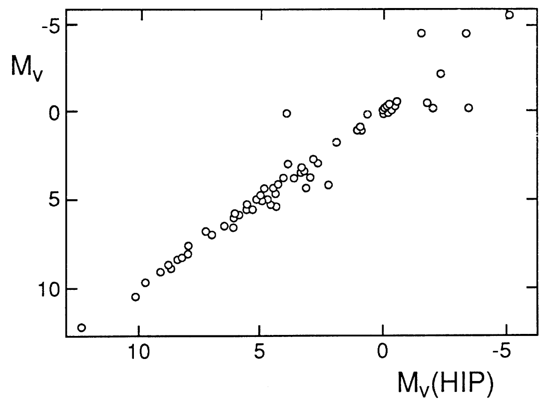

Fig. 1. Absolute magnitudes as derived from Hipparcos data (HIP) plotted against absolute magnitudes given in “Sky Catalogue 2000” (Hirshfeld & Sinnott, 1982) and “Catalogue of nearby stars” (Gliese 1969; Gliese & Jahreiss, 1979). See also Elgarøy et al.(1997)

A problem encountered in previous investigations is uncertainties in the absolute magnitude of the sample stars, since this parameter enters directly in the Wilson-Bappu relation. The uncertainties were not likely to severely affect the general trend of the relationship in a comprehensive sample of stars, but investigations of fine structure in the diagrams such as deviations from the regression line met with difficulties. The problem was that the errors in absolute magnitudes of the stars, in particular the more distant ones were unknown. Uncertainties in the line widths were more easy to handle since these could be estimated during the processing of the data.

2. Data

Accurate absolute magnitudes have been obtained through early release of data from the Hipparcos satellite. The errors in the derived M_v values are now well known. In general they are so small that they can safely be neglected.

In Table 1 the sample of 65 stars taken from our sample of 78 stars, for which we have IUE observations of Mg II h and k line widths and Hipparcos magnitudes is given. Earth-based absolute magnitudes and a detailed description of the data sample may be found in Elgarøy et al. (1997).

Table 1. Data for the observed stars. The estimated errors apply to $\log W_k$ as well as to $\log\ W_k^{'}$.

Star	Sp.class	Mv(Hip)	W_k' (log)	W_k (log)	Error ±	Star	Sp.class	Mv(Hip)	W_k'	W_k	Error
44 And	F8V	2.19	1.78	1.94	0.03	αTau	K5III	-0.50	1.90	2.08	0.01
νPhe	F8V	4.20	1.67	1.67	0.13	Gl 783 A	K3V	6.53	1.64	1.64	0.05
βCae	F2V	2.92	2.00	2.10	0.06	Gl 201	K5Ve	7.28	1.59	1.59	0.04
50 Per	F7V	3.99	1.86	1.90	0.03	Gl 845	K5Ve	7.03	1.60	1.60	0.03
Gl 297.1	F5V	3.19	1.85	1.91	0.02	Gl 142	K7V	7.98	1.51	1.56	0.05
αCrv	F2IV	3.25	1.89	2.06	0.07	θ Cen	K0III-IV	0.87	1.88	2.03	0.03
βDra	G2II	-2.28	2.26	2.42	0.03	ϵRet	K2IVa	3.29	1.80	1.92	0.08
ζCap	G4Ibpe	-1.51	2.14	2.31	0.01	ηCep	K0IVe	2.79	1.80	1.91	0.02
αAur	G6III+F9III	-0.32	2.17	2.24	0.02	ϵSco	K2III	0.94	1.88	2.04	0.02
λAnd	G8III-IV	1.91	2.03	2.10	0.01	αAri	K2IIIe	0.65	1.87	2.04	0.04
βAqr	G0Ib	-3.34	2.20	2.33	0.02	αSer	K2IIIe	1.04	1.91	2.04	0.01
αAqr	G2Ib	-3.72	2.20	2.37	0.02	Gl 117	K0Ve	6.11	1.70	1.83	0.03
αCen A	G2V	3.09	1.71	1.71	0.02	Gl 5	K0Ve	5.53	1.74	1.77	0.03
χOri	G0V	4.82	1.72	1.72	0.02	Gl 211	K1Ve	5.91	1.74	1.74	0.06
70 Vir	G5IV-V	3.81	1.77	1.90	0.03	Gl 224.1	K3IV	2.62	1.89	1.96	0.07
72 Her	G0V	4.30	1.68	1.78	0.02	δSgr	K2III	-1.99	2.03	2.14	0.03
47 UMa	G0V	4.41	1.69	1.82	0.05	Gl 380	K7Ve	8.22	1.49	1.53	0.04
61 UMa	G8Ve	5.55	1.73	1.76	0.01	Gl 113.1	K0III	3.87	1.88	1.88	0.01
ζTuc	G0V	4.67	1.81	1.87	0.05	Gl 259	K0Ve	6.03	1.70	1.79	0.03
39 Tau	G5V	4.92	1.73	1.78	0.04	Gl 309	K0V	6.09	1.69	1.77	0.08
9 Cet	G2V	4.98	1.79	1.88	0.02	Gl 320	K1V	6.49	1.66	1.66	0.01
11 LMi	G8IV-Ve	5.30	1.70	1.80	0.02	Gl 454	K0IV	5.13	1.72	1.90	0.05
Gl 761.1	G5V	4.29	1.74	1.89	0.08	Gl 593.1	K4III	-0.22	2.01	2.12	0.05
Gl 503.2	G1.5Ve	4.53	1.70	1.70	0.06	WαOri	M1-2Ia-Iab	-5.09	2.26	2.38	0.01
κCet	G5Ve	5.16	1.71	1.81	0.03	βAnd	M0IIIa	-1.76	1.96	2.07	0.01
HN Peg	G0Ve	4.67	1.76	1.85	0.03	γCru	M3III	-0.52	2.00	2.25	0.02
βHyi	G1IV	3.56	1.75	1.83	0.03	Gl 169	M1Ve	7.98	1.53	1.53	0.05
Gl 484	G0V	4.87	1.73	1.81	0.10	Gl 825	M0Ve	8.77	1.49	1.57	0.04
βCet	K0III	-0.13	1.93	2.07	0.01	Gl 616.2	M1.5Ve	8.42	1.63	1.63	0.03
αTr A	K3III	-3.45	2.16	2.27	0.02	Gl 803	M0Ve	8.72	1.61	1.61	0.02
αBoo	K2III	-0.14	1.88	2.07	0.01	Gl 96	M1.5Ve	9.10	1.52	1.52	0.13
						Gl 239	M1V	9.73	1.43	1.43	0.12
						Gl 799	M4.5Ve	10.13	1.41	1.41	0.03
						Gl 285	M4.5Ve	12.33	1.49	1.49	0.06

As clearly demonstrated from Fig. 1 there is good correspondence between Hipparchos magnitudes and those deduced from Earth-based observations in most cases, but for about 20% of the stars the correspondence is less satisfactory.

The deviations are largest for the more luminous stars. This could be expected since these are the most distant ones and consequently may have large errors in the previously derived parallaxes.

2.1. Uncertainties in the data

The standard errors in the Hipparcos parallaxes correspond to errors in absolute magnitudes less than 0.1 magnitude in all cases except for the 10 most distant stars in our sample, as shown in Table 2. In the table the possible errors in magnitude are given for the 13 stars that have parallaxes less than 28 mas. In addition three stars with parallaxes of around 50 *mas*, one with about 100 mas and one with about 200 *mas* are listed together with the uncertainties in their absolute magnitudes.

One may conclude that the Hipparcos observations have reduced the uncertainties in the absolute magnitudes of our sample stars to a very satisfactory low level, and most important; the possible errors are now known.

The line widths of the MgII h and k lines are the same as derived in the investigation by Elgarøy et al. (1997), where the reduction procedure and a discussion of errors may be found.

In the present contribution the analysis is restricted to the MgII k line, since the results for the k and h lines differ very little. In the conventional method the width is defined as the full width of the line at the 50% level of the peak line flux. However, since the spectrum usually is noisy and often difficult to define, the actual measurement is better done at a Gaussian fit rather than at the emission line. Besides, the spectrum may in some cases be so asymmetric that the lowest peak doesn't even reach the 50% level. Direct measurement of the FWHM width would then be meaningless, since it would give the width of the dominating peak rather than the width of the whole line. By using the Gaussian fit as an extrapolation to "fill in" the

Table 2. Uncertainties in absolute magnitudes as determined from standard errors in Hipparcos parallaxes.

Star	M_v	Error	Parallax (mas)	Distance (parsec)
αCen A	3.09	+0.89/-1.54	3.68	271
αAqr	-3.72	+0.38/-0.47	4.30	233
βAqr	-3.33	+0.36/-0.42	5.33	188
αOri	-5.09	+0.42/-0.53	7.63	131
αTrA	-3.45	+0.16/-0.19	7.85	127
ζCap	-1.51	+0.23/-0.25	8.19	122
Gl 593.1	-0.22	+0.06/-0.05	8.55	117
βDra	-2.28	+0.12/-0.12	9.02	110
δSgr	-1.99	+0.18/-0.20	10.67	94
βAnd	-1.76	+0.10/-0.10	16.63	60
44 And	2.19	+0.08/-0.08	18.98	53
Gl 113.1	3.87	+0.08/-0.09	22.73	44
Gl 761.1	4.29	+0.05/-0.06	27.47	36
ϵSco	0.50	+0.04/-0.03	49.85	20
αTau	-0.50	+0.06/-0.04	50.09	20
39 Tau	4.92	+0.03/-0.07	59.79	17
61 Uma	5.55	+0.01/-0.02	104.81	9.5
Gl 380	8.23	+0.01/-0.01	205.22	4.9

Table 3. Comparison of line width measurements

Star	Robinson & Carpenter	Present paper	
	$\log W_k$	$\log W_k'$	$\log W_k$
βDra	2.30	2.26	2.42
ηCep	1.82	1.80	1.91
αOri	2.27	2.26	2.38
γCru	1.94	2.00	2.25

missing flux a much better estimate of the width (denoted W) is obtained. The flux is then defined as the integrated flux under the line profile (denoted F). But the width may also be defined as the full width of the fit at 50% of its peak level (denoted W′). The flux is defined as the integrated flux under the Gaussian fit (denoted F').

A further explanation and discussion of the parameters is given in Elgarøy et al. (1997).

2.2. Test of the reliability of the determination of line widths

MgII h and k line profiles have been determined by Robinson & Carpenter (1995) using high-resolution spectrographic data taken with the Goddard High Resolution Spectrograph connected to the Hubble Space Telescope and with the IUE satellite. Four of their sample stars are also present in our data sample, i.e. βDra, ηCep, αOri and γCru. Of these α Ori and γ Cru were observed both with the GHRS at the Hubble Telescope as well as with the IUE. The width of the lines were determined at 10% maximum intensity. If a Gaussian line profile is assumed, their data can be converted to FWHM values and compared with our results.

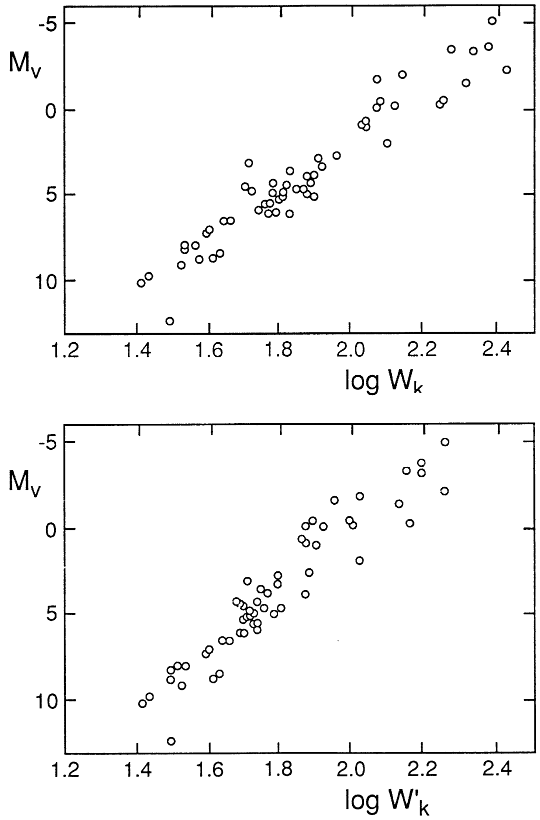

Fig. 2. Width-luminosity relation of the Mg II k line for all sample stars of spectral classes G, K and M using both log W (above) and log W′ (below) as parameters of the line width

Table 3 shows that there is very close agreement between the derived widths. As might be expected (cfr. discussion in Elgarøy et al. 1997) our values for log W_k' are particularly close to the values obtained by Robinson and Carpenter.

3. Results

Fig. 2 shows the width-luminosity relation of the MgII k line for our sample of 59 stars of spectral classes G, K and M. Six stars of spectral class F have been left out because they seem not to follow a Wilson-Bappu relation, as will be demonstrated in Sect. 3.1.

When the diagrams in Fig. 2 are compared with previous results in Elgarøy et al. (1997), it is seen that the difference is extremely small. The scatter of the data around the regression line is about the same in the two cases. But whereas one previously had to take into account that an unknown part of the scatter might be due to erroneous absolute magnitudes, the new results are free of this deficiency. It is now possible to look for physical mechanisms causing deviations from the average behavior.

The following Wilson-Bappu relations are obtained for the 59 G, K and M stars in the sample:

$$M_v = (35.25 \pm 2.17) - (17.61 \pm 1.10) \times \log W' [r = -0.95] \quad (1)$$

$$M_v = 31.19 - 14.66 \log W \quad [r = -0.96] \quad (2)$$

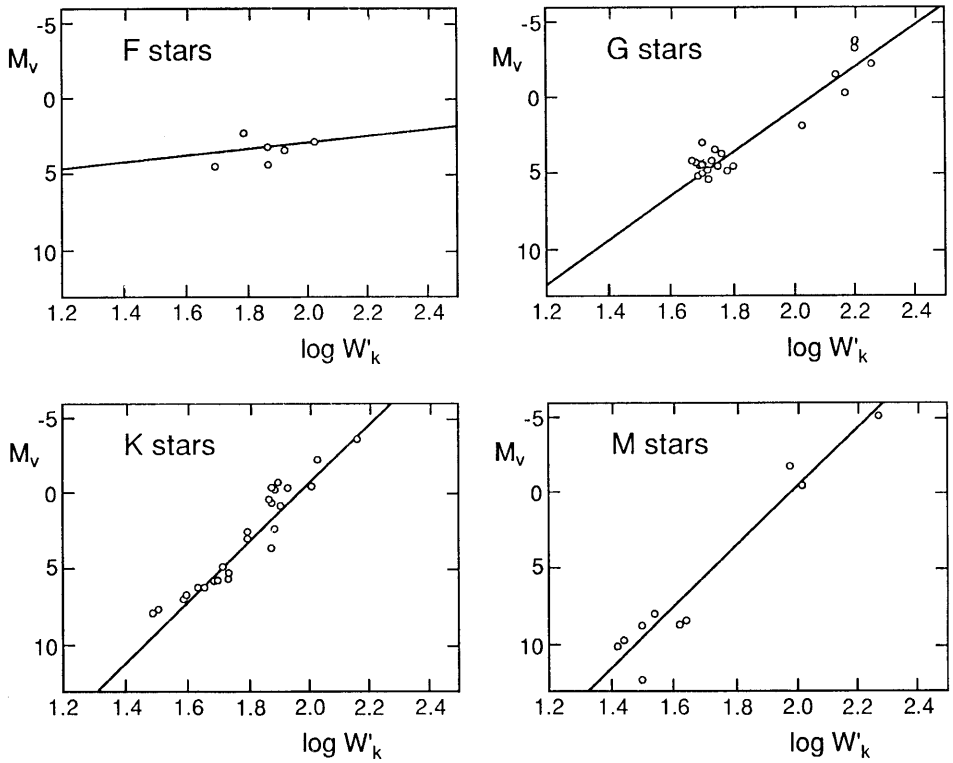

Fig. 3. Width-luminosity relations for stars of different spectral classes. The regression lines are given as solid lines

(r is the correlation coefficient).

The uncertainties are roughly the same in the expressions (1) and (2).

Almost the same results are obtained using classical, earth-based absolute magnitudes.

3.1. Possible dependence on stellar temperature

The accurate Hipparcos absolute magnitudes permit a further differentiation of the material according to temperature, as given by stellar spectral classes. Width-luminosity relations for the MgII k line for stars according to spectral class are shown in Fig. 3.

From the data the following Wilson-Bappu relations are derived:
F stars, n= 6 stars.

$$M_v = (7.4 \pm 5.8) - (2.2 \pm 3.1) \log W' \; [r = -0.34] \quad (3)$$

G stars, n= 22 stars.

$$M_v = (28.5 \pm 1.9) - (13.8 \pm 1.0) \log W' \; [r = -0.95] \quad (4)$$

K stars, n = 26 stars.

$$M_v = (38.9 \pm 2.3) - (19.8 \pm 1.2) \log W' \; [r = -0.95] \quad (5)$$

M stars, n = 11 stars.

$$M_v = (39.5 \pm 2.4) - (20.0 \pm 1.4) \log W' \; [r = -0.97] \quad (6)$$

From Fig. 3 and from the regression line derived for the F stars it is seen that our data reveal no relation between the luminosity and the width of the MgII k line for the F stars. But one must take into account that there are 6 F stars only in the sample and that they cover a relatively small range in absolute magnitudes (M_v = 2.2 to 4.0). In addition the MgII lines become weak and noisy for F stars and show strong central reversals, making good determinations of their widths difficult. We conclude that a weak relation between luminosity and width for F stars can not be completely excluded, although our present data reveal no connection.

For the stars of spectral classes G, K and M, there is a very good correlation between luminosity and line width. The respective Wilson-Bappu relations are well defined. It is seen that the slope of the regression line for the G stars is less steep than for the K and M stars. Between K and M stars there is no significant difference.

Since main sequence stars dominate in the lower left of the diagrams whereas giants and supergiants occupy the upper right the difference in slope of the G stars and the K-M stars suggest that there is a larger difference in line width between G dwarfs and giants than is the case for K-M dwarfs and giants.

3.2. Deviations from the Wilson-Bappu relation

In Elgarøy et al. (1997) it was found that active stars had broader lines and showed larger variations in line widths than quiet stars. In particular observations of the active RS CVn binary σGem taken at epochs of different levels of activity, clearly demonstrated line broadening accompanying increased activity.

The sample of K stars may be used for a study of the dispersion of the data points around the regression line. Δlog W' is defined as the difference between log W' (measured) and log

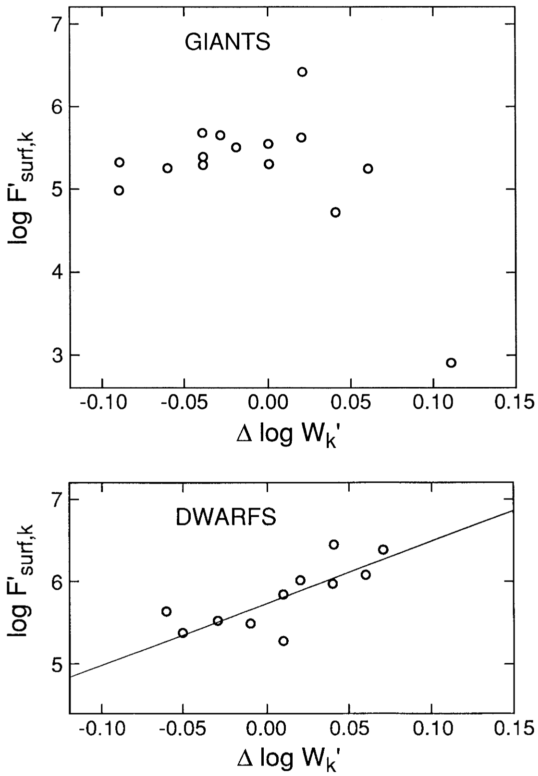

Fig. 4. Deviation from the Wilson-Bappu relation (Δlog $W_k^{'}$) plotted against surface flux ($logF^{'}_{surf,k}$) for K giants and supergiants (above) and K dwarfs (below)

Table 4. Surface fluxes of the Mg II k line as determined by Elgarøy et al. (1997) updated with new parallaxes from the Hipparchos data together with deviations from the regression line.

Star	Sp.kl.	$F'_{surf,k}$	$\Delta W^{'}$
βCet	K0III	5.70	-0.04
αTr A	K3III	6.43	0.02
αBoo	K2III	5.35	-0.09
αTau	K5III	4.98	-0.09
θCen	K0III-IV	5.39	-0.04
ϵRet	K2IVa	5.55	0.00
ηCep	K0IVe	5.51	-0.02
ϵSco	K2III	5.33	-0.04
αAri	K2IIIe	5.25	-0.06
αSer	K2IIIe	5.29	0.00
Gl 224.1	K3IV	5.24	0.06
δSgr	K2III	5.66	-0.03
Gl 113.1	K0III	2.91	0.11
Gl 454	K0IV	5.62	0.02
Gl 593.1	K4III	4.74	0.04
Gl 783 A	K3V	5.3	0.01
Gl 201	K5Ve	5.86	0.01
Gl 845	K5Ve	5.50	-0.01
Gl 142	K7V	5.39	-0.05
Gl 117	K0Ve	6.47	0.04
Gl 5	K0Ve	6.11	0.06
Gl 211	K1Ve	6.41	0.07
Gl 380	K7Ve	5.64	-0.06
Gl 259	K0Ve	5.97	0.04
Gl 309	K0V	5.56	-0.03
Gl 320	K1V	6.23	0.02

W$^{'}$ (average). The latter is obtained from the W-B relation using the absolute magnitudes of the chosen stars. The MgII k-line surface flux (Table 4) may be used as a parameter of activity. According to Robinson & Carpenter (1995) the strength of the emission is a direct measure of chromospheric activity. In Fig. 4 Δlog W$^{'}$ has been plotted against surface flux as given by log $F^{'}_{surf,k}$. It was found useful to make a further division of the material into dwarfs (KV) and giants (KIV, III, II, I).

We estimate the error in the derived surface fluxes to amount to approximately 50%, corresponding to an uncertainty of 0.3 in the logarithm of the surface flux. The errors in Δlog W$^{'}$ are equal to the errors in log W$^{'}$ (see Table 1).

Fig. 4 reveals an interesting difference between the behavior of K dwarfs and giants. Dwarfs show increasing line width with increasing surface flux. But in the case of giants, the line widths decrease with increasing surface flux for $\Delta \log W^{'}$ >0.02. Taking the limited material and the errors in the data into account, this suggests that there is a characteristic difference between dwarfs and giants in the case of the broadest line profiles.

The following regression line has been derived:
K dwarfs, n = 11

$$\log F^{'}_{surf,k} = 5.8 + 7.2\Delta \log W' \quad [r = 0.76] \tag{7}$$

For the K giants a linear regression line is clearly not appropriate (cf Fig. 4).

Rather than using Δlog W$^{'}$ (or Δlog W) one may use the relative deviation, i.e. $\frac{\Delta \log W'}{\overline{\log W'}}$ as a parameter, where $\overline{\log W'}$ is determined from the regression line.

Let $D = \frac{\Delta \log \mathrm{W}'}{\overline{\log \mathrm{W}'}} \times 100$, then one finds: K dwarfs

$$\log\ F^{'}_{surf,k} = 5.90 + 0.10D \quad [r = 0.61] \tag{8}$$

The two main results from the analysis of the log $F^{'}_{surf,k}$ – Δ logW$^{'}$ relations are:

1. For main sequence K stars Δlog W$^{'}$ increases with increasing activity (as given by log $F^{'}_{surf,k}$).
2. K giants and supergiants show the same behavior for Δlog W$^{'}$ <0.02. For broader profiles activity seems to decrease with increasing line widths. More stars in this range are needed since the current sample contains three stars only.

The different relations between activity and excess line width for dwarfs and giants may be associated with the fact that strong magnetic fields are present in active dwarfs, whereas activity in many giants and supergiants may be more non-magnetic in nature (Cuntz, 1996).

To explain the properties given in 1) and 2) one needs detailed calculations of atmospheric (chromospheric) models and calculations of the line profiles using hydrodynamic methods and theory of line formation. Before such work has been performed, which requires large resources, some effects which are important for the explanation of the observations may be pointed out.

3.2.1. Main sequence stars

For these stars the temperature gradient in the chromosphere increases in active regions and the fluxes and line widths both become larger. When a star is more active (increased heating) the Mg II lines are formed at a level where the column mass and therefore the opacity is larger than in the quiet case. Consequently the fluxes and the widths of the chromospheric lines increase.

3.2.2. Giants and supergiants

In this case the situation is more complex. These stars have a much smaller surface gravity in the chromosphere than main sequence stars. The surface gravity and the metal abundance, which are important for the chromospheric temperature structure, can show large variations from one star to another, and are also responsible for the difference between dwarfs and giants. Model calculations (Cuntz et al., 1994) suggest that the giants have a much more extended chromosphere than main sequence stars due to the smaller gravity. The chromospheres are quasi-isothermal, i.e. the temperature increases very slowly up to the transition region. In and above active regions giants show higher temperatures leading to more extended quasi-isothermal chromospheres. These calculations show that increased heating, i.e. increased activity, may lead to more narrow lines. Lower metal abundances also give narrow lines as a result. This occurs because the line opacity is proportional to the Mg II number density, and therefore decreases in proportion to the Mg II abundance (Cuntz et al., 1994). In short: individuality, effects of non-magnetic activity and variations in metal abundances may explain our results for the giant stars.

3.3. Metallicity

Since metallicity may be a factor influencing the Mg II k line width (Lutz & Pagel 1982), data on abundances have been compiled for the K stars in our sample. The abundances were derived from Cayrel de Strobel et al. (1992), Jones et al. (1992), Kovács (1983), Taylor (1991), McWilliam (1990), Fanelli et al. (1990), Pallavicini et al. (1992) and Tokovinin (1990).

In many cases several different results have been found for the same star. In such cases the average value was used. The data for giants and supergiants are given in Table 5 and plotted in Fig. 5. The regression line is given by:

$$A = (0.01 \pm 0.04) + (0.04 \pm 0.01)D \ \ [r = 0.67] \quad (9)$$

Data for 15 stars are used.

Even though the uncertainties in the abundance values (about 0.2 dex) and the relative deviations (Table 5) are large, our result clearly reveal an important relation between metallicity and line width, in qualitative agreement with the theoretical results of Cuntz et al. (1994).

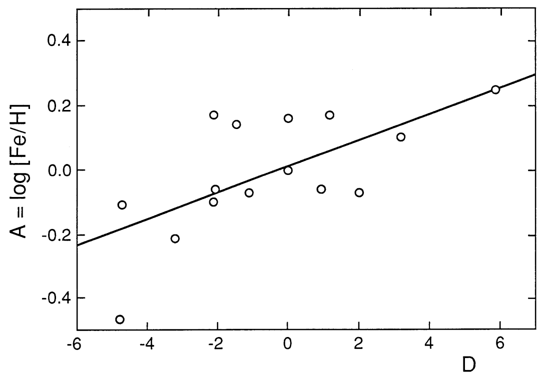

Fig. 5. Relative deviation from the Wilson-Bappu relation D plotted against metallicity A = log(Fe/H), for 15 K giants and supergiants

The variation of Mg II surface flux for the K giants in our sample is relatively small (cf Fig. 4). This is also in agreement with the theoretical results of Cuntz et al. (1994), who mention three factors contributing to this end: a) the mean chromospheric temperature is slightly higher in models with lower metallicity. This tends to increase the Mg II emission flux. b) In models with lower metallicity the optical depth in the Mg II k line is reduced, forcing the line to be formed at higher column mass densities, where larger total particle densities occur. As a consequence, the reduced metal abundance is compensated. c) The wave shape of the shock waves (assumed to heat the chromosphere (Cuntz & Ulmschneider, 1988) is the same in large portions of atmospheres of different metal abundances, allowing the Mg II k line to be formed under similar thermodynamic conditions. The fact that chromospheric Mg II h and k line fluxes are independent of metal abundances is also in accordance with the scaling laws of Ayres (1979), which were found to be valid for various semiempirical chromospheres based on IUE data.

As regards the K dwarfs, abundances were found for 7 of the 11 stars in the sample. No connection between Fe/H abundance and deviation from average line width could be detected. Since the dwarfs are subject to magnetic activity it is likely that a possible effect of metallicity is overshadowed by the variation of line width with activity.

4. Conclusions

Early release of data from the Hipparcos satellite has served to provide accurate absolute magnitudes for 65 stars for which the Mg II k line widths have been measured from high resolution spectra obtained with the International Ultraviolet Explorer (IUE) observatory.

Increased accuracy and knowledge of the uncertainty in the values of the absolute magnitudes has permitted new features of the Wilson-Bappu effect to be explored. Firstly, we have established that the scatter of the data around the regression line found by Elgarøy et al. (1997) is real, and not due to errors. Secondly, a differentiation of the material according to surface

Table 5. Abundances as given by log Fe/H = (log Fe/H)$_{star}$ – (log Fe/H)$_{Sun}$ and relative deviation.

Star	Sp.cl.	Abund.	$\frac{\Delta \log W'}{\log W'} \times 100$
βCet	K0III	-0.06	-2.07
αTr A	K3III	-0.06	0.93
αBoo	K2III	-0.47	-4.79
αTau	K5III	-0.11	-4.74
θCen	K0III-IV	+0.17	-2.13
ϵRet	K2IVa	0.00	0.00
ηCep	K0IVe	-0.07	-1.11
ϵSco	K2III	-0.10	-2.13
αAri	K2IIIe	-0.21	-3.21
αSer	K2IIIe	+0.16	0.00
Gl 224.1	K3IV	+0.10	3.17
δSgr	K2III	0.14	-1.48
Gl 113.1	K0III	+0.25	5.85
Gl 454	K0IV	+0.17	1.16
Gl 593.1	K4III	-0.07	1.99

temperature has been possible, and the Wilson-Bappu relations for stars of spectral classes F, G, K, and M have been determined. Thirdly, it has been noticed ed that the line width of K giants decreases with activity for $\Delta \log W_k'$ >0.02 (i.e. for the broadest cases), whereas the widths increase with activity for K dwarfs. Correlation between deviation from average line width and metallicity for K giants is suggested. However, K dwarfs do not show a similar relation, very likely because the effect of magnetic activity then is dominating.

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