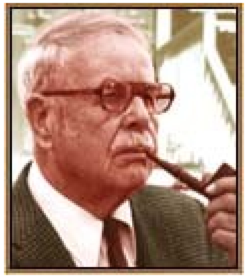
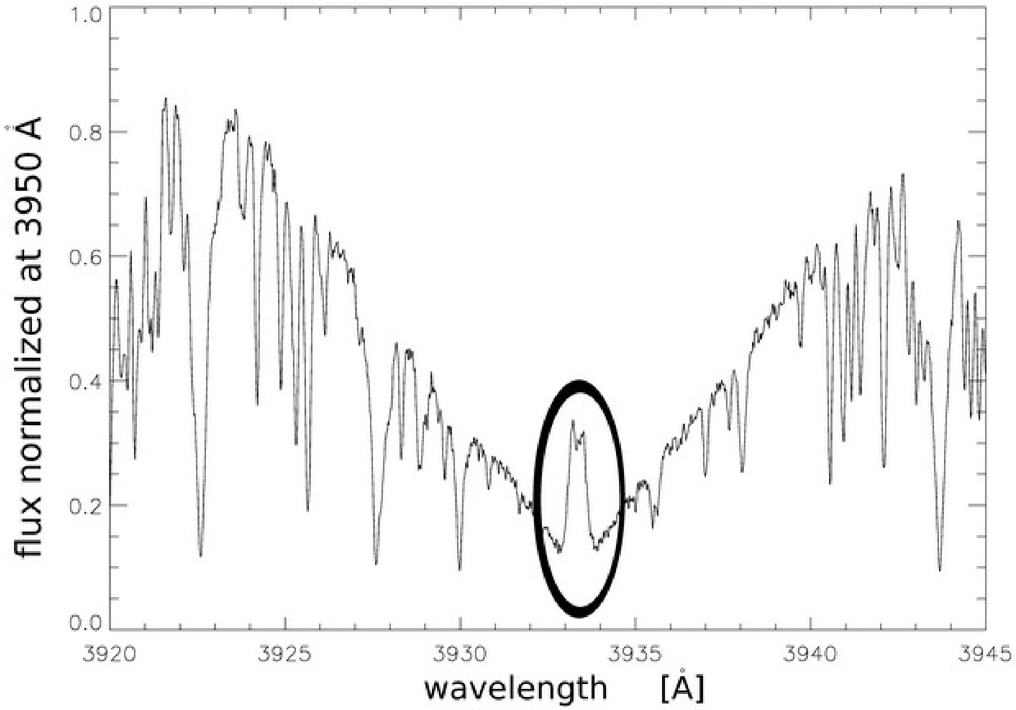


Wilson-Bappu efekat

(1957)



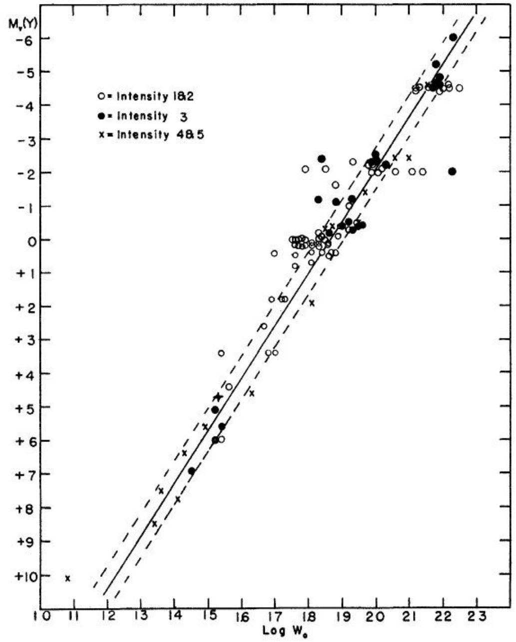
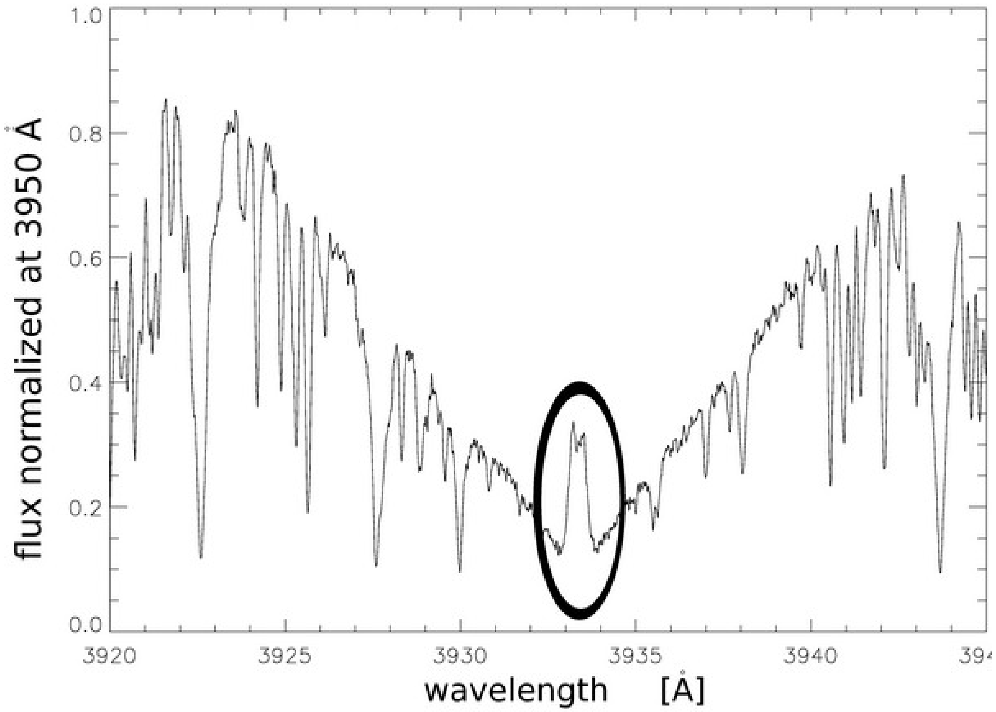


FIG. 1.—Logarithm of corrected Ca II emission-line widths plotted against Yerkes spectroscopic absolute magnitude. Stars divided into three intensity groups

Andrej Obuljen

Wilson-Bappu efekat

- Ca II H i K linije (3968.5 Å, 3933.7 Å) (Mg II K 2796.34 Å)
- Jake apsorpcione linije kod hladnih zvezda G, K, M spektralnih klasa
- Jezgro u emisiji, a centar u samo-apsorpciji (double reversal profile)
- Otkrio ih Schwarzschild 1913



- Otkrivena veza između FWHM i M_v

$$M_v = 33.2 - 18.0 \log(W_0)$$

- Empirijska veza pogodna za određivanje udaljenosti do zvezda(?)

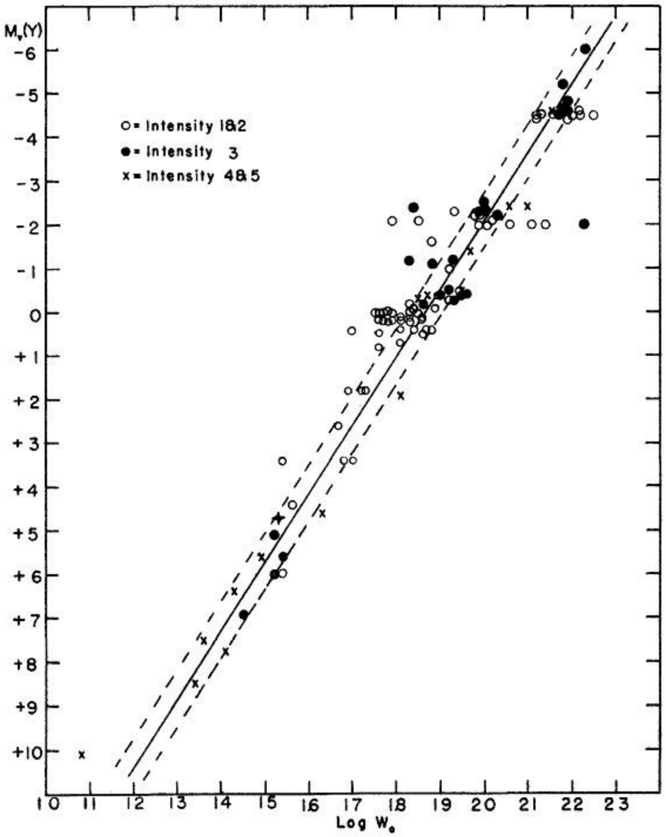


FIG. 1.—Logarithm of corrected Ca II emission-line widths plotted against Yerkes spectroscopic absolute magnitude. Stars divided into three intensity groups

Originalni rad

H AND K EMISSION IN LATE-TYPE STARS: DEPENDENCE OF LINE WIDTH ON LUMINOSITY AND RELATED TOPICS

O. C. Wilson and M. K. Vainu Bappu*
Mount Wilson and Palomar Observatories
Carnegie Institution of Washington, California Institute of Technology

Received December 17, 1956

The principal aim of the investigation is to see how the emission-line widths behave as a function of (*a*) the emission intensity, (*b*) the stellar luminosity, and (*c*) the spectral type. It is known from previous work that there is likely to be a considerable range in Ca II emission strength in any reasonably sized group of late-type stars of otherwise similar characteristics. No attempt, therefore, was made to consider item *a* in forming an observing list. Both spectral types and absolute magnitudes must be known in advance, however, and the observations should include stars of all intrinsic luminosities.

The H and K emission lines of Ca II have been studied on 10-A/mm spectrograms of 185 stars of types G, K, and M. Nearly all stars of type G0 or later in the list of MK standards (Johnson and Morgan 1953) have been included. Emission-line widths have been measured, as well as displacements of the emission and absorption components. The displacements are determined with respect to nearby low-excitation reversing-layer absorption lines.

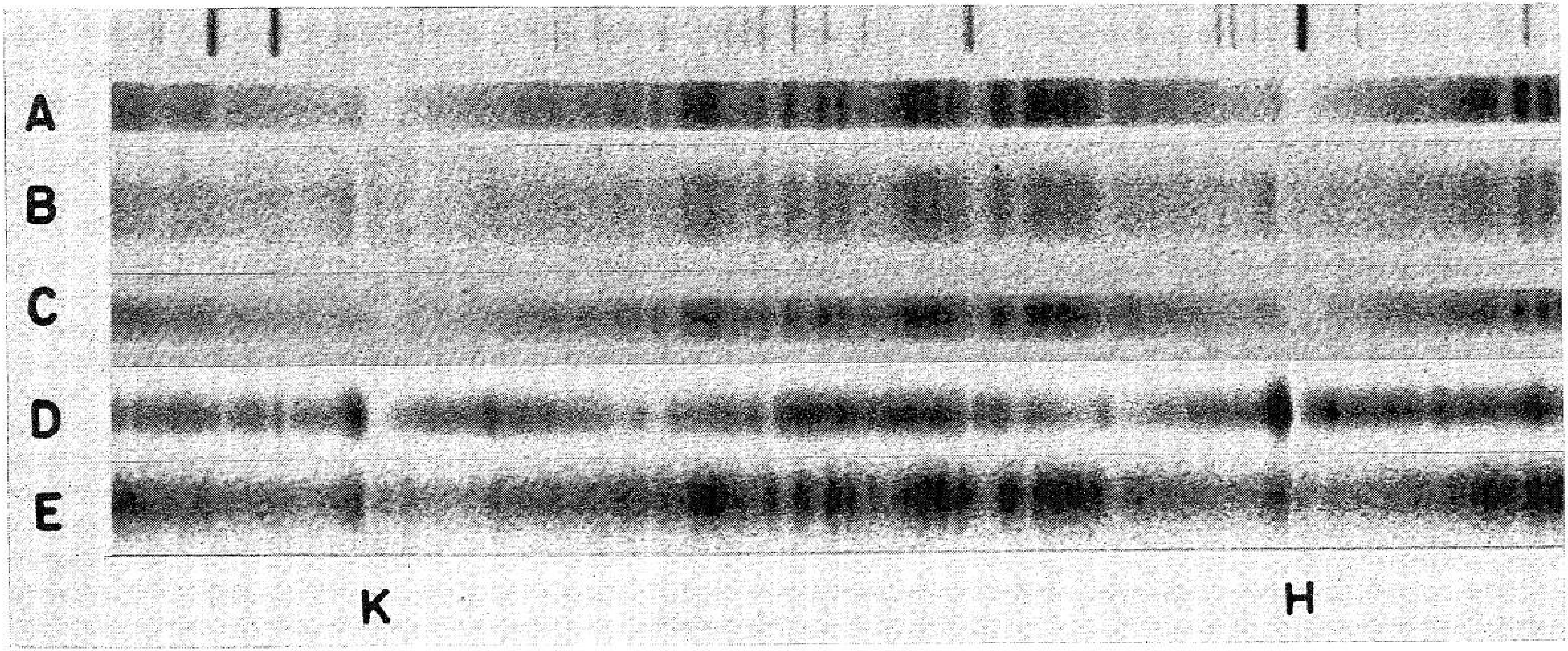


FIG. 1.—The H and K emission lines in S Sagittae, X Cygni, and R Leonis. *A:* S Sagittae ($P = 8^{d}4$), Ce 6708, phase $0^{p}85$, 1950 Dec. 1.09 U.T. *B:* X Cygni ($P = 16^{d}4$), Ce 9217, phase $0^{p}82$, 1954 May 18.46 U.T. *C:* X Cygni, Ce 9239, phase $0^{p}02$, 1954 May 21.49 U.T. *D:* R Leonis ($P = 313^{d}$), Pc 66, phase $+144^{d}$, 1951 Mar. 23.24 U.T. *E:* X Cygni, Ce 5403, phase $0^{p}87$, 1948 Oct. 25.13 U.T.

Rezultati

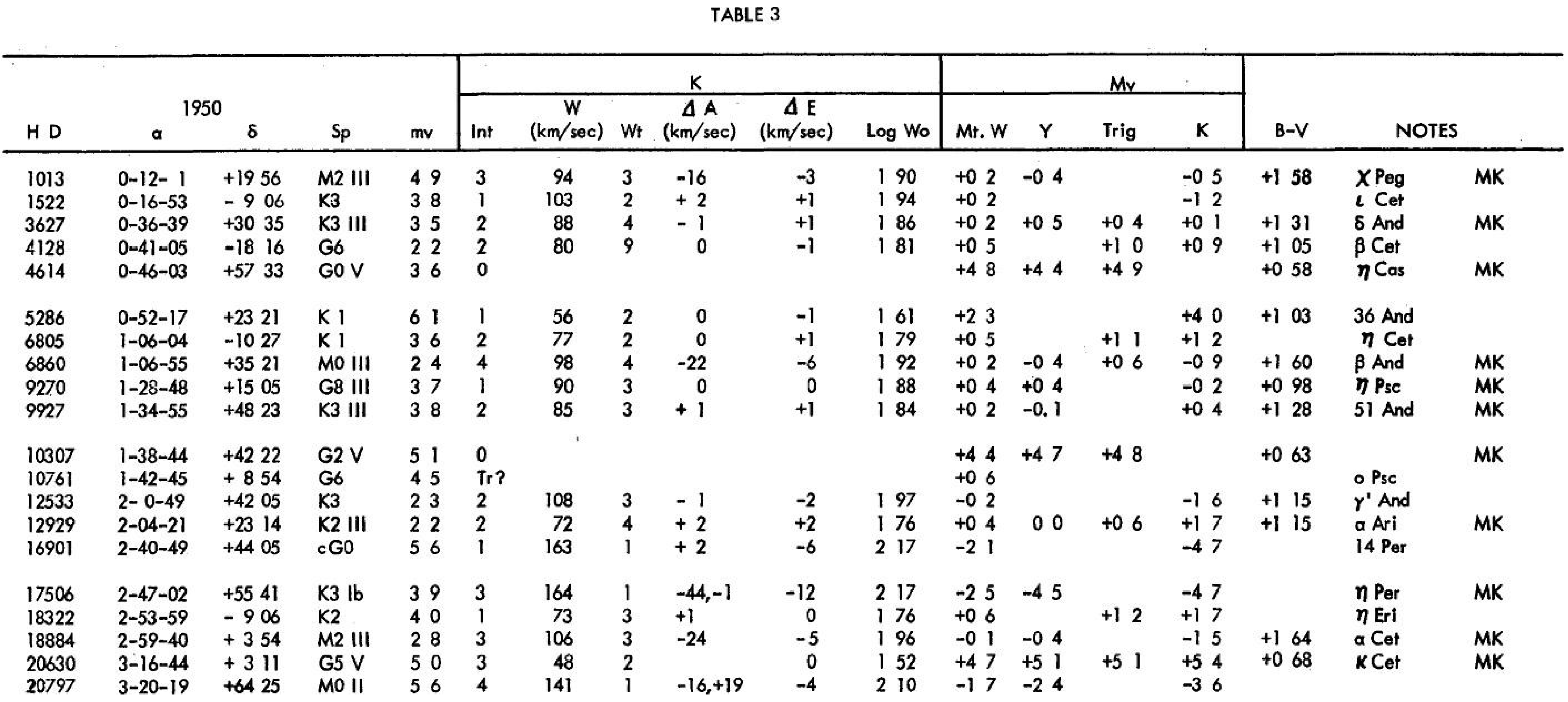


TABLE 3

	1950				K						Mv						
H D	α	δ	Sp	mv	Int	W (km/sec)	Wt	Δ A (km/sec)	Δ E (km/sec)	Log Wo	Mt. W	Y	Trig	K	B-V	NOTES	
1013	0-12- 1	+19 56	M2 III	4 9	3	94	3	-16	-3	1 90	+0 2	-0 4		-0 5	+1 58	χ Peg	MK
1522	0-16-53	- 9 06	K3	3 8	1	103	2	+ 2	+1	1 94	+0 2			-1 2		ι Cet	
3627	0-36-39	+30 35	K3 III	3 5	2	88	4	- 1	+1	1 86	+0 2	+0 5	+0 4	+0 1	+1 31	δ And	MK
4128	0-41-05	-18 16	G6	2 2	2	80	9	0	-1	1 81	+0 5		+1 0	+0 9	+1 05	β Cet	
4614	0-46-03	+57 33	G0 V	3 6	0						+4 8	+4 4	+4 9		+0 58	η Cas	MK
5286	0-52-17	+23 21	K 1	6 1	1	56	2	0	-1	1 61	+2 3			+4 0	+1 03	36 And	
6805	1-06-04	-10 27	K 1	3 6	2	77	2	0	+1	1 79	+0 5		+1 1	+1 2		η Cet	
6860	1-06-55	+35 21	M0 III	2 4	4	98	4	-22	-6	1 92	+0 2	-0 4	+0 6	-0 9	+1 60	β And	MK
9270	1-28-48	+15 05	G8 III	3 7	1	90	3	0	0	1 88	+0 4	+0 4		-0 2	+0 98	η Psc	MK
9927	1-34-55	+48 23	K3 III	3 8	2	85	3	+ 1	+1	1 84	+0 2	-0. 1		+0 4	+1 28	51 And	MK
10307	1-38-44	+42 22	G2 V	5 1	0						+4 4	+4 7	+4 8		+0 63		MK
10761	1-42-45	+ 8 54	G6	4 5	Tr?						+0 6					o Psc	
12533	2- 0-49	+42 05	K3	2 3	2	108	3	- 1	-2	1 97	-0 2			-1 6	+1 15	γ' And	
12929	2-04-21	+23 14	K2 III	2 2	2	72	4	+ 2	+2	1 76	+0 4	0 0	+0 6	+1 7	+1 15	α Ari	MK
16901	2-40-49	+44 05	cG0	5 6	1	163	1	+ 2	-6	2 17	-2 1			-4 7		14 Per	
17506	2-47-02	+55 41	K3 Ib	3 9	3	164	1	-44,-1	-12	2 17	-2 5	-4 5		-4 7		η Per	MK
18322	2-53-59	- 9 06	K2	4 0	1	73	3	+1	0	1 76	+0 6		+1 2	+1 7		η Eri	
18884	2-59-40	+ 3 54	M2 III	2 8	3	106	3	-24	-5	1 96	-0 1	-0 4		-1 5	+1 64	α Cet	MK
20630	3-16-44	+ 3 11	G5 V	5 0	3	48	2		0	1 52	+4 7	+5 1	+5 1	+5 4	+0 68	κ Cet	MK
20797	3-20-19	+64 25	M0 II	5 6	4	141	1	-16,+19	-4	2 10	-1 7	-2 4		-3 6			

In the earlier plot (Wilson 1954) of Ca II emission-line widths against Mount Wilson spectroscopic absolute magnitudes, the relationship turned out to be a curve. At least some of the curvature may originate in three probable sources: (*a*) no correction was applied for instrumental line width, a factor of great importance for intrinsically narrow lines; (*b*) the Mount Wilson spectroscopic absolute magnitudes are known to be systematically too faint for stars brighter than about $M_v = 0$; and (*c*) the plot is logarithmic in one co-ordinate only. In the present version these three items have been modified as follows:

First, 15 km/sec have been subtracted from all measured line widths to allow for the instrumental contribution. Primarily, this figure was arrived at because it represents approximately the mean projected slit-width, which was generally in the range of 15–20 μ for the spectrograms used, plus a small additional allowance for optical imperfections, photographic spreading in the emulsion, etc. Measures of some of the weaker iron lines in the comparison spectrum yielded widths of about this value, which, it seems, cannot be far from correct. It must be borne in mind, however, that spectrograms do differ somewhat in sharpness of definition, sometimes for reasons which are quite obscure, and, while the use of individual corrections for each plate is quite impractical, the use of a constant correction for all may contribute appreciably to the scatter of the measured widths for stars with very narrow lines, i.e., for objects in the lower portion of the main sequence. Second, the Yerkes absolute-magnitude system has been adopted, since it is undoubtedly more nearly correct for the brighter stars; and, third, the logarithms of the corrected widths have been plotted against absolute magnitude.

Relacija M_v-W_0

When the logarithms of the emission-line widths (corrected for instrumental width) are plotted against the Yerkes absolute spectroscopic magnitudes, the points define a straight line which extends over a 15-mag. range of M_v and which indicates that the line width varies as the one-sixth power of the luminosity. Stars with weak or strong lines and of all spectral types later than G0 seem to fit the linear relationship equally well. The widths therefore cannot be dependent upon line intensity or stellar surface temperature.

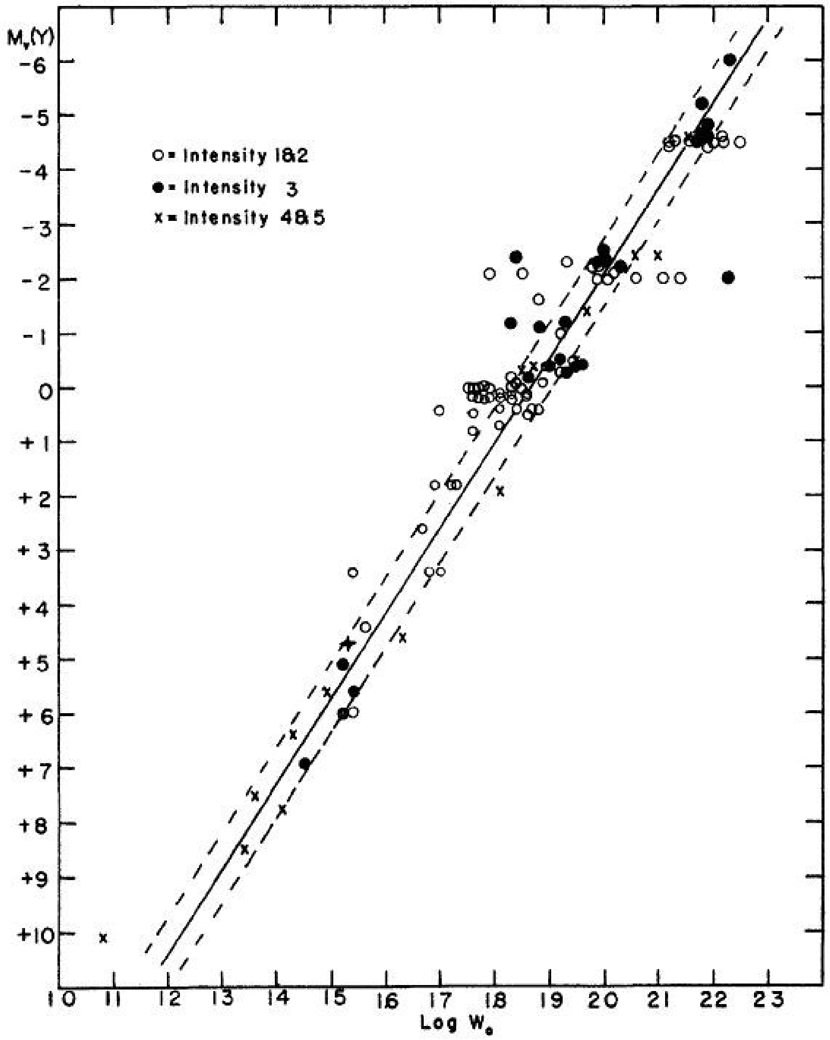


FIG. 1.—Logarithm of corrected Ca II emission-line widths plotted against Yerkes spectroscopic absolute magnitude. Stars divided into three intensity groups

Spektralni tip (T_{eff})

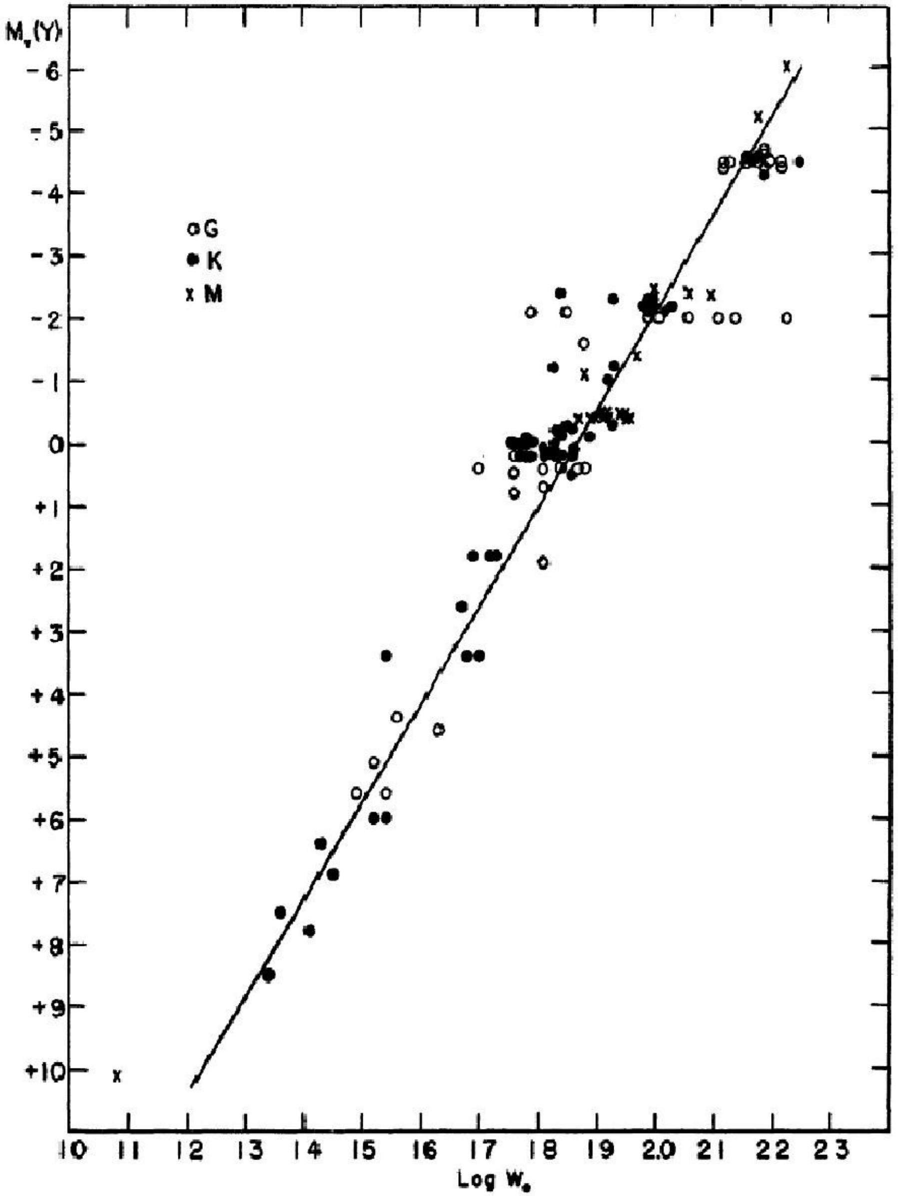
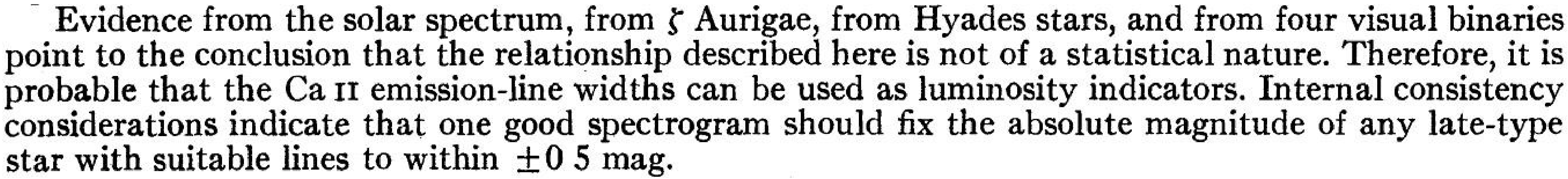


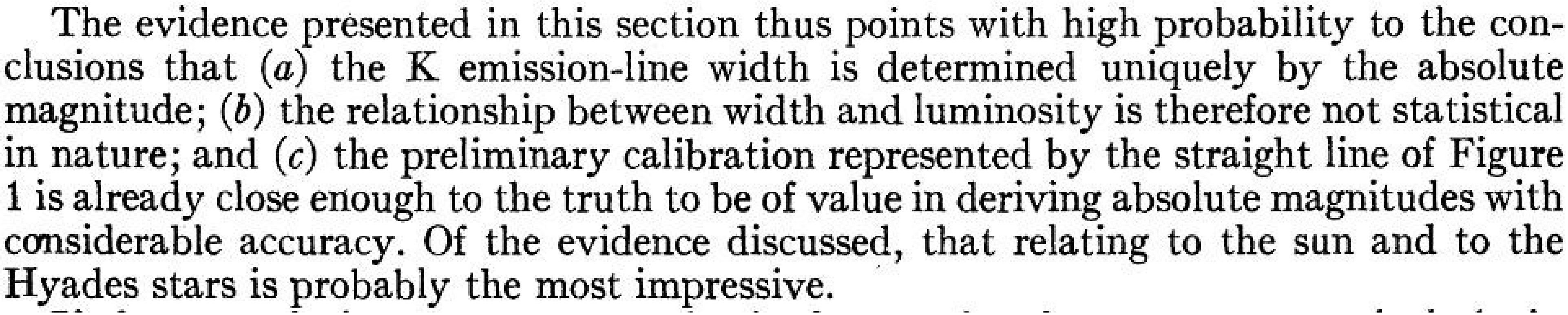
Fig. 2.—Same plot as Fig. 1 except that stars are grouped by spectral type G, K, or M. Line intensities not indicated.

Provera



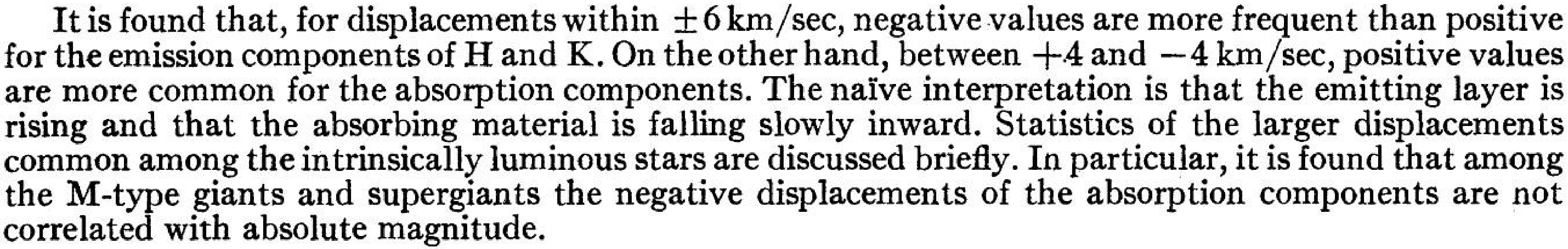
Evidence from the solar spectrum, from ζ Aurigae, from Hyades stars, and from four visual binaries point to the conclusion that the relationship described here is not of a statistical nature. Therefore, it is probable that the Ca II emission-line widths can be used as luminosity indicators. Internal consistency considerations indicate that one good spectrogram should fix the absolute magnitude of any late-type star with suitable lines to within ±0 5 mag.

- Sunce $M_v = +4.7$
- ζ Aurigae – binarni sistem, jedna komponenta K4 II, $M_v = -2.5$
- 4 zvezde iz zvezdanog jata Hijade
  srednje odstupanje za 4 zvezde na osnovu dobijene relacije 0.15 mag
- 4 vizuelno dvojnih zvezda (0.1 mag)



The evidence presented in this section thus points with high probability to the conclusions that (*a*) the K emission-line width is determined uniquely by the absolute magnitude; (*b*) the relationship between width and luminosity is therefore not statistical in nature; and (*c*) the preliminary calibration represented by the straight line of Figure 1 is already close enough to the truth to be of value in deriving absolute magnitudes with considerable accuracy. Of the evidence discussed, that relating to the sun and to the Hyades stars is probably the most impressive.

Apsorpcioni i emisioni koeficijent



It is found that, for displacements within ±6 km/sec, negative values are more frequent than positive for the emission components of H and K. On the other hand, between +4 and −4 km/sec, positive values are more common for the absorption components. The naïve interpretation is that the emitting layer is rising and that the absorbing material is falling slowly inward. Statistics of the larger displacements common among the intrinsically luminous stars are discussed briefly. In particular, it is found that among the M-type giants and supergiants the negative displacements of the absorption components are not correlated with absolute magnitude.

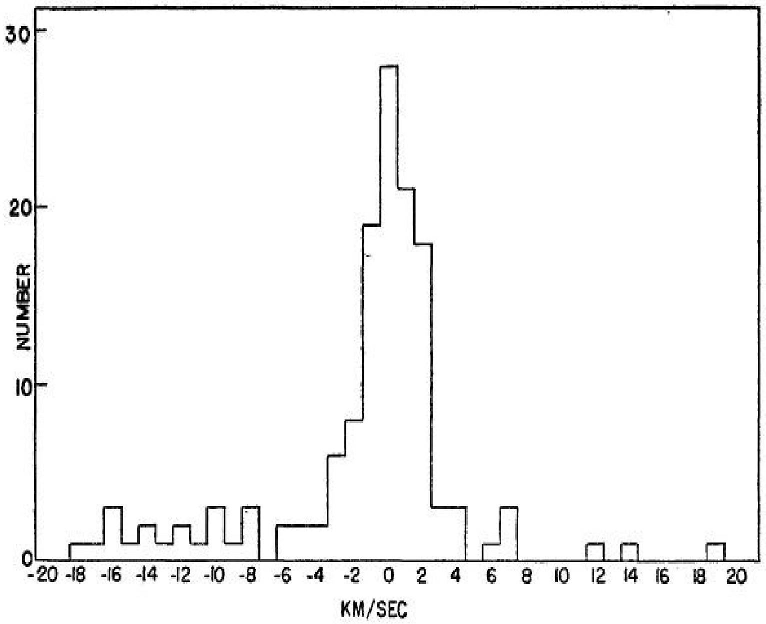


FIG. 7.—Frequency distribution of displacements of Ca II absorption components

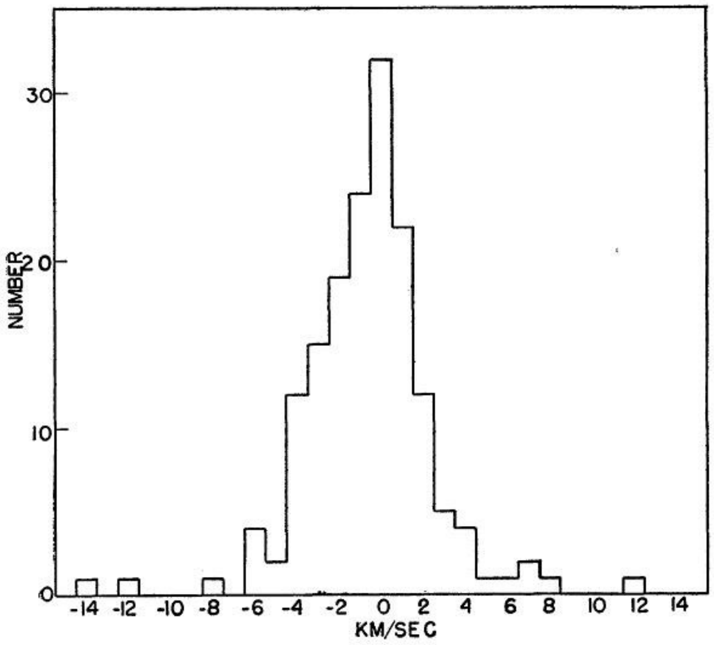
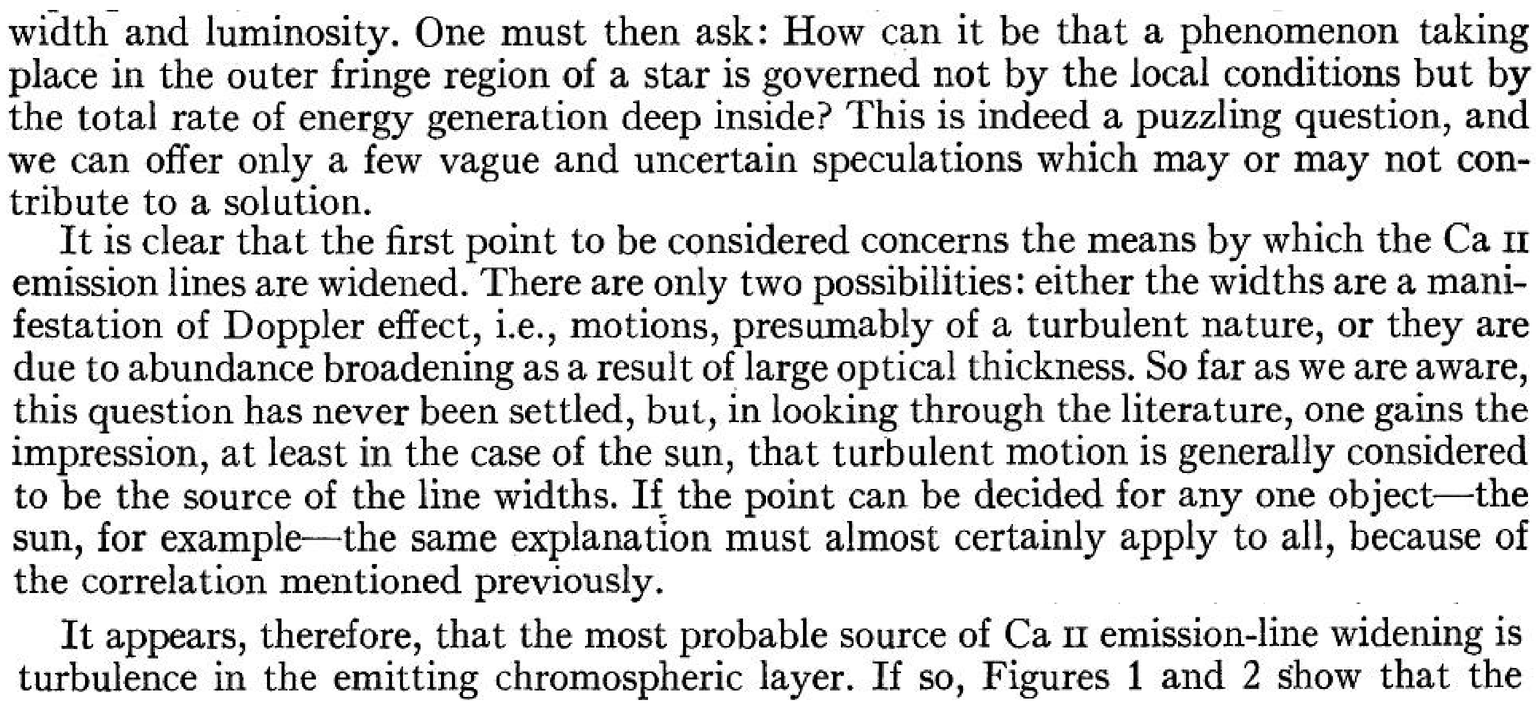


FIG. 6 —Frequency distribution of displacements of Ca II emission lines

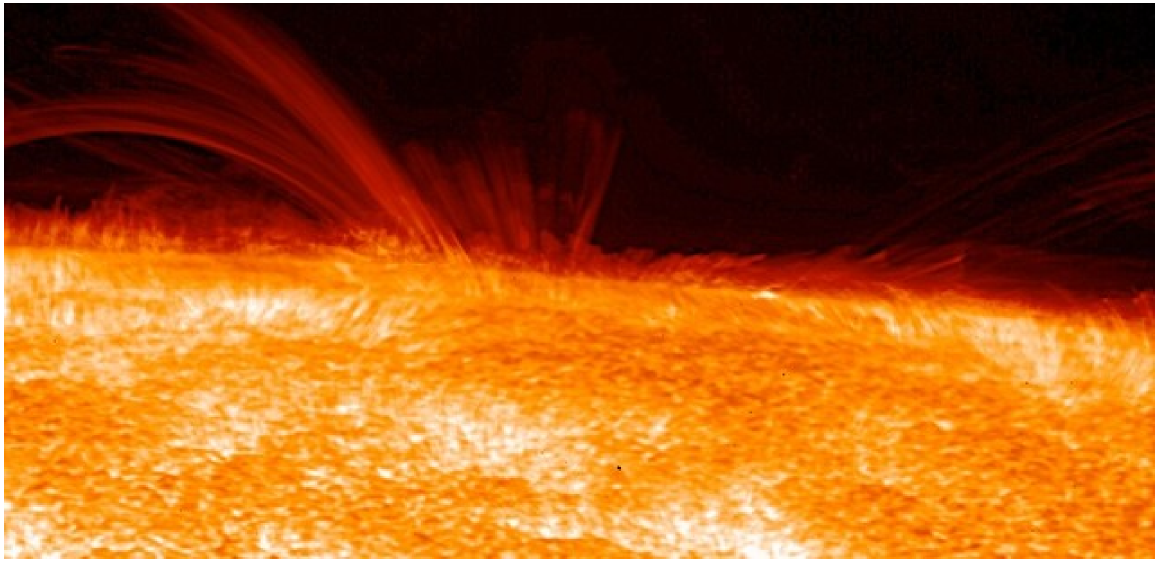
Interpretacija



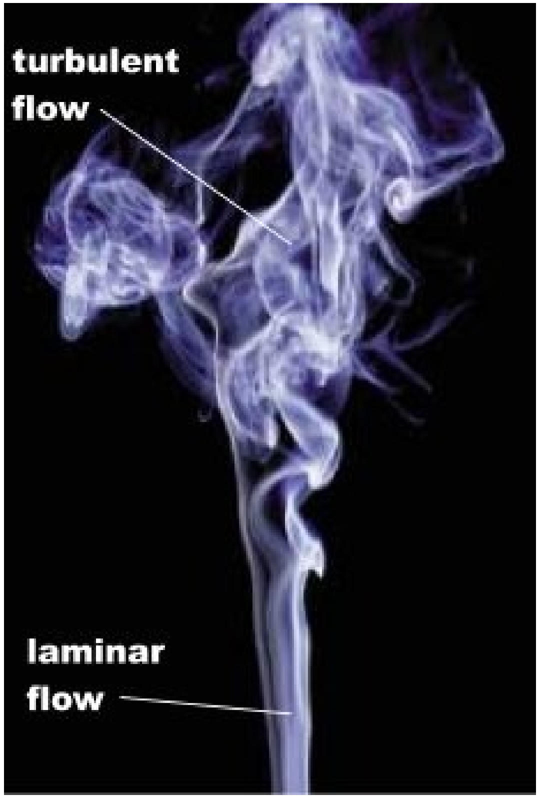
width and luminosity. One must then ask: How can it be that a phenomenon taking place in the outer fringe region of a star is governed not by the local conditions but by the total rate of energy generation deep inside? This is indeed a puzzling question, and we can offer only a few vague and uncertain speculations which may or may not contribute to a solution.

It is clear that the first point to be considered concerns the means by which the Ca II emission lines are widened. There are only two possibilities: either the widths are a manifestation of Doppler effect, i.e., motions, presumably of a turbulent nature, or they are due to abundance broadening as a result of large optical thickness. So far as we are aware, this question has never been settled, but, in looking through the literature, one gains the impression, at least in the case of the sun, that turbulent motion is generally considered to be the source of the line widths. If the point can be decided for any one object—the sun, for example—the same explanation must almost certainly apply to all, because of the correlation mentioned previously.

It appears, therefore, that the most probable source of Ca II emission-line widening is turbulence in the emitting chromospheric layer. If so, Figures 1 and 2 show that the



We have no theory to account for the proportionality of log W_0 to log L. The observed fact seems to suggest something like the following picture: In all late-type stars there is an outflow of matter from the interior to the surface, perhaps in the form of jets or streams and perhaps related to the hydrogen convective zone. The flow velocity is a function only of luminosity. At some height, corresponding to that of the lower chromosphere in the sun, the laminar flow in the jets is transformed into turbulence, the mean velocity spread of which bears some simple relationship to the original outward-flow velocity. In this region, perhaps owing partly to the transformation of kinetic energy of flow into heat and thermal excitation, line emission takes place. Probably the observation of this emission has been restricted to the H and K lines simply because they are resonance lines of large f-value and because they are seen against a favorably reduced background of photospheric radiation. In this emitting region, although most of the original outward-flow velocity is lost, a fraction of it remains, and there is a slow residual upward drift. Somewhere above the emitting region the material is cooler, and absorption components of H and K are produced by matter which is falling slowly inward.



Noviji rad

Pace *et al.* (2003)

Here we present a new calibration of the Wilson–Bappu effect based on a sample of 119 nearby stars. We use,for the first time, width measurements based on **high resolution and high signal to noise ratio CCD spectra** and absolute visual magnitudes from the **Hipparcos database.**

Our primary goal is to investigate the possibility of using the Wilson–Bappu effect to determine accurate distances to single stars and groups.

The result of our calibration fitting of the Wilson–Bappu relationship is

$$\mathbf{M_V = 33.2 - 18.0 \cdot \log W_0},$$

and the determination seems free of systematic effects. The root mean square error of the fitting is **0.6 magnitudes**.

This error is mostly accounted for by measurement errors and intrinsic variability of W_0, but in addition a possible dependence on the metallicity is found, which becomes clearly noticeable **for metallicities below [Fe/H]-0.4**. This detection is possible because in our sample [Fe/H] ranges from -1.5 to 0.4.

M67

The Wilson–Bappu effect can be used confidently for all metallicities not lower than -0.4, including the LMC.

While it does not provide accurate distances to single stars, it is a useful tool to determine accurate distances to clusters and aggregates, where a sufficient number of stars can be observed.

We apply the Wilson–Bappu effect to published data of the open cluster M67; the retrieved distance modulus is of 9.65 magnitude, in very good agreement with the best distance estimations for this cluster, based on main sequence fitting.

Podaci

- The full sample for which spectra have been collected consists of 152 stars, but the present study is limited to stars with relative parallax errors smaller than 10%. We have also excluded from the original sample known multiple systems. After this trimming, the final sample includes **119 stars**.
- $M_V \simeq -5$ to $M_V \simeq 9$
- ESO, La Silla, Coudé Echelle Spectrometar, R=60000, S/N from 30 to 100 at the bottom of the line

G. Pace et al.: Wilson–Bappu effect 15

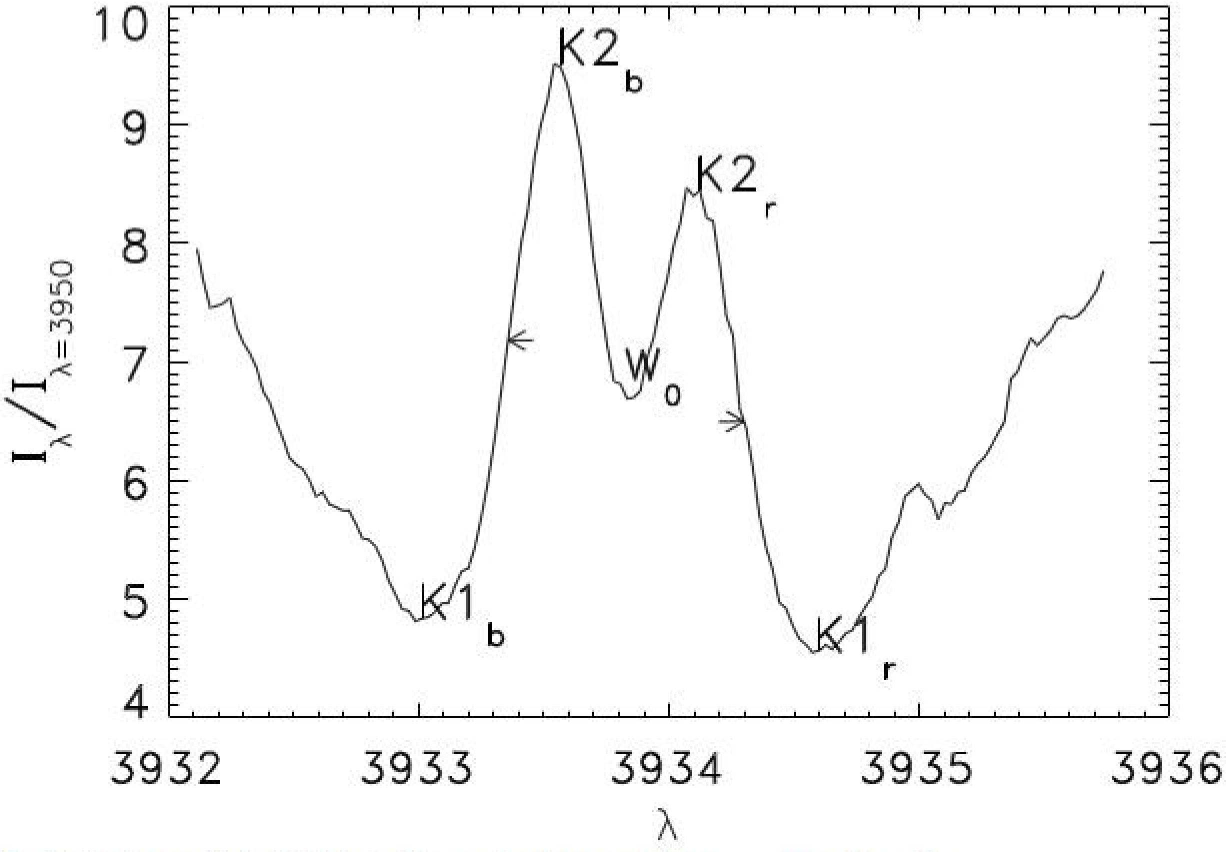


Fig. 2. Spectrum of HD 4128. Most of the spectra of our sample have a comparable quality.

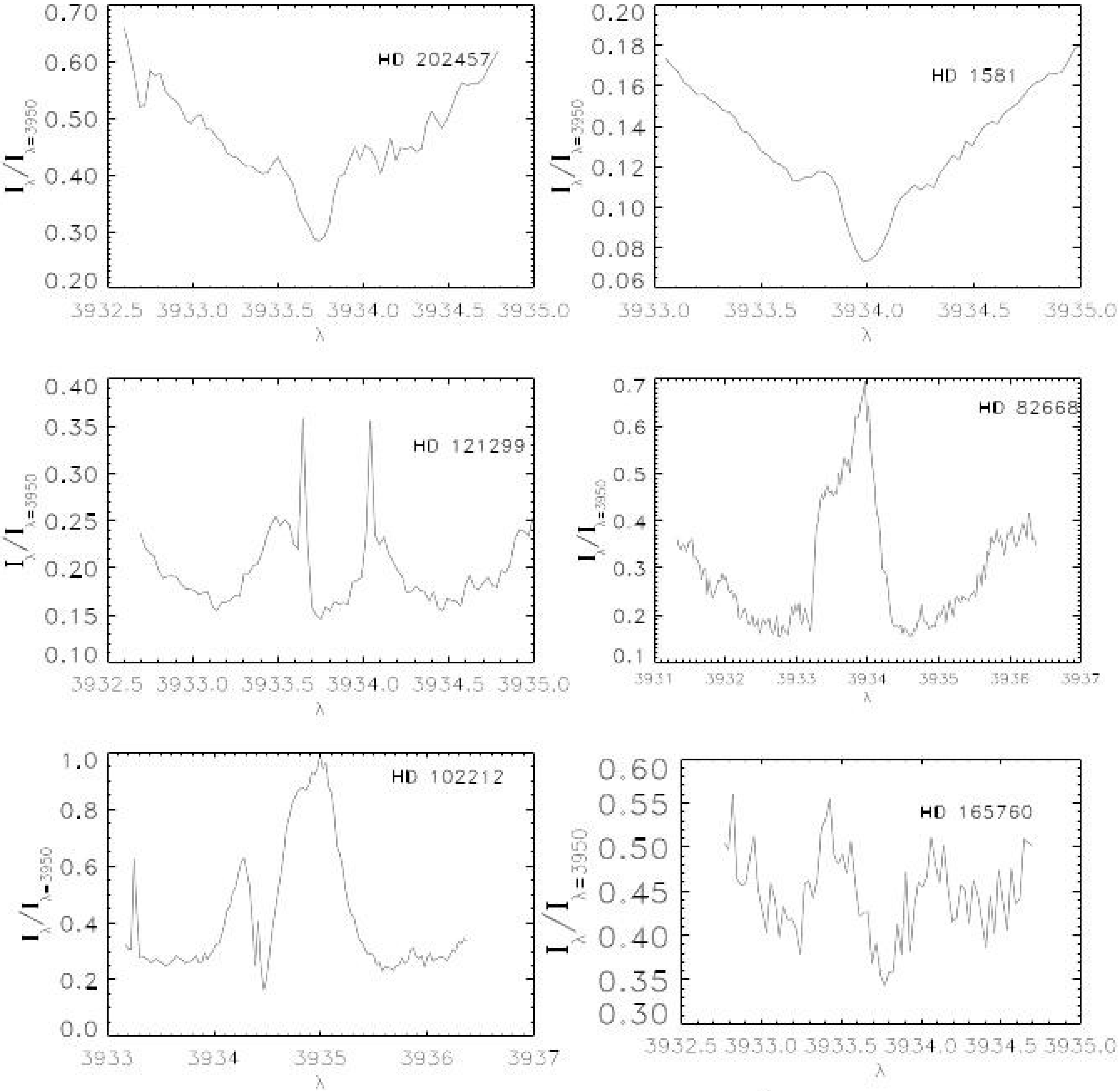


Fig. 1. Doubtful examples of Ca II K line profiles. The spectra are affected by cosmic rays, may be blended with interstellar absorption, which strongly influence the emission profile observed in HD 82668, or, as in the case of HD 102212, show a blueshifted wind. In other cases, such as in HD 1581, the emission is very weak.

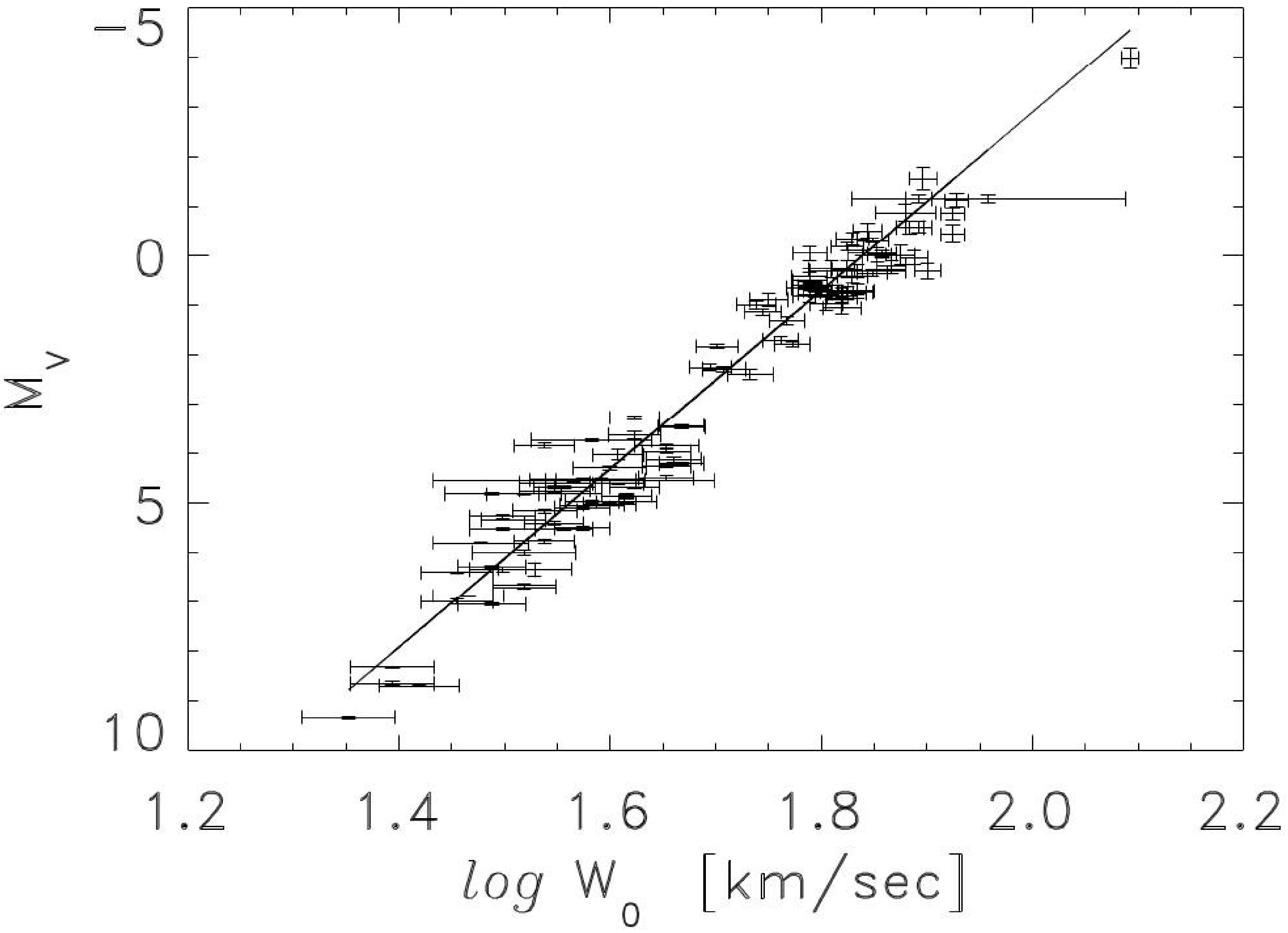


Fig. 5. Our calibration of the Wilson–Bappu Effect: $M_V = 33.2 - 18.0 \cdot \log W_0$. This calibration is the 3σ criterion one in Table 2 (HD 63077 and HD 211998 are not used). The error bars represent standard errors in both the coordinates.

Scatter

Among the possible causes of scatter, we mention:

· random effects:

- measurement errors,
- cyclic variation in the chromospheric activity ($\log W_0$ of about 0.05 during such a period (**Sun**),
- variability of some of the stars of the sample;

· systematic effects:

- reddening (100/119 in Local Bubble),
- instrumental effects (quadratic correction, negligible),
- Lutz–Kelker effect ($\sigma_\pi/\pi<0.1$),
- hidden parameters, i.e. parameters other than W_0 and M_V on which the WBR could depend.
- multiple systems (excluded)

Zaključak

- Sa najmodernijim merenjima: RMS 0.6 mag
- Nije pogodan metod za određivanje udaljenosti do usamljenih zvezda
- Pogodan za grupacije zvezda (jata, grupe zvezda, ne male metaličnosti)
- Greška modula rastojanja (m-M) može se smanjiti na 0.6mag/√n, gde je n broj zvezda

Zaključak

- Sa najmodernijim merenjima: RMS 0.6 mag
- Nije pogodan metod za određivanje udaljenosti do usamljenih zvezda
- Pogodan za grupacije zvezda (jata, grupe zvezda, ne male metaličnosti)
- Greška modula rastojanja (m-M) može se smanjiti na $0.6\text{mag}/\sqrt{n}$, gde je n broj zvezda

- **Potrebno bolje razumeti fizičku pozadinu!**
- Ispitati WBR za niske metaličnosti