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Ba II LINE AS CEPHEID LUMINOSITY INDICATOR. I

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Absolute magnitudes of the supergiant stars are the values of paramount importance for stellar evolution theory and investigation of galactic structure. The period−luminosity relation for pulsating stars, which is frequently used for rapid M_v determination, has nevertheless two limiting factors: it cannot be applied in case of the non-variable supergiants and, at least for galactic Cepheids, it does not allow to find an accurate absolute magnitude if we do not know exactly about the excited pulsational mode of the investigated star. In particular, such a problem arises in connection with so-called galactic s-Cepheids.

Spectroscopic luminosity indicators (provided they are reliably calibrated), in this sense, are more universal tool of M_v determination for various kinds of supergiant stars. For example, Sorvari (1974) and Baker (1974) applied O I 7774 Å line (triplet) as a luminosity indicator for F-supergiants.

Table 1. Ba II line equivalent widths in spectra of program stars

Star	Period	Phase	W(5853),mÅ	M_v
V473 Lyr	1.4908	0.899	244	−2.25
		0.095	251	
		0.793	247	
		0.559	253	
		0.136	248	
EU Tau	2.1025	0.758	183	−2.69
IR Cep	2.1141	0.137	175	−2.69
DT Cyg	2.4991	0.774	222	−2.90
V526 Mon	2.6750	0.674	191	−2.99
SZ Tau	3.1484	0.501	217	−3.19
		0.573	239	
		0.577	228	
α UMi[1]	3.9696	0.516	275	−3.49
		0.775	256	
		0.015	239	
		0.775	228	
V1162 Aql	5.3761	0.273	267	−3.87
V924 Cyg	5.5715	0.702	266	−3.91
V440 Per	7.57	0.080	283	−4.30
		0.534	310	
FN Aql	9.4816	0.464	320	−4.58
		0.525	315	
		0.841	317	
SZ Cas	13.6377	0.047	315	−5.04
Y Oph	17.1269	0.530	342	−5.33

Remarks: 1 − W values are from Sanval et al. (1988)

In this paper another luminosity indicator is proposed. In contradiction to near-infrared O I triplet, its location in the spectrum is more favourable for spectroscopic observations. Below it will be shown that Ba II 5853.6 Å line appears to be a rather sensitive indicator of the luminosity of supergiants. Its equivalent width depends upon luminosity of the star as a result of the increasing of non-LTE effects in stellar atmosphere with the luminosity increase.

At the first step of the study, an existence of the possible relation between equivalent width of Ba II 5853.6 Å line and M_v was investigated only for small-amplitude s-Cepheids. Equivalent widths measured in the spectra of the program stars are listed in Table 1.

To investigate a possible dependence between Ba II line equivalent width and luminosity (or absolute magnitude M_v) we first calculated M_v for program Cepheids using recent results by Gieren & Fouqué (1993):

$$M_v = -2.9 \times logP - 1.30 \quad (1)$$

Pulsational periods were selected from Fernie et al. (1995) catalogue. The s-Cepheids are assumed to be overtone pulsators. Therefore for those stars we used observed period as the first overtone one P_1. Period of the fundamental mode P_0 for each s-Cepheid was determined using a period ratio P_1/P_0=0.7 (see Szabados, 1997).

Equivalent width of barium line was precisely measured for all the program stars using the spectra collected with an echelle spectrometer LYNX on 6-m telescope (Special Astrophysical Observatory of the Russian Academy of Sciences, Russia, Northern Caucasus; the detailed description of the spectrometer is given by Panchuk et al., 1993), AURELIE spectrograph (Gillet et al., 1994) on the 1.52m telescope of Haute Provence Observatory (France) and with ELODIE, a fibre-fed echelle spectrograph installed on the 1.93m telescope of Observatoire de Haute-Provence, France (Baranne et al., 1996 give detailed descriptions of the spectrograph). Some of the collected spectra were previously analysed (for determination of elemental abundances) in several papers by Andrievsky et al. (1996), Kovtyukh et al. (1996), Andrievsky et al. (1998). The necessary information about the spectra of program stars (telescope, spectrograph, resolving power, S/N ratio), as well as information concerning the procedure of the equivalent width measurements, can be found in the above mentioned works. The internal accuracy of the equivalent widths is of the order of 5%. This estimate is based on the comparison of values derived from the lines presented in two overlapping spectral orders.
Note also, that in none of those works the Ba II lines were used for abundance determination. The main problem is connected with their large equivalent widths that completely excludes an application of LTE approach for abundance analysis.

The relation $M_v - W(BaII\ 5853.6\ \AA)$ is shown in Fig. 1 for program s-Cepheids. Very clear dependence between visual absolute magnitude and equivalent width of Ba II 5853.6 Å line is seen.

Taking into account that s-Cepheids are small-amplitude pulsators, one can expect that equivalent width variations during the pulsational cycle will be small (it is confirmed, e.g. by V473 Lyr data, see Table 1).

The least squares fit for $M_v - W(BaII\ 5853.6\ \AA)$ relation is following:

$$M_v = -0.016 \times W(5853) + 0.28 \quad (2)$$

The unusual Cepheid V473 Lyr strongly deviates from the least squares fit found for s-Cepheids. Even supposing that it pulsates in the second overtone (see Andrievsky et al.,

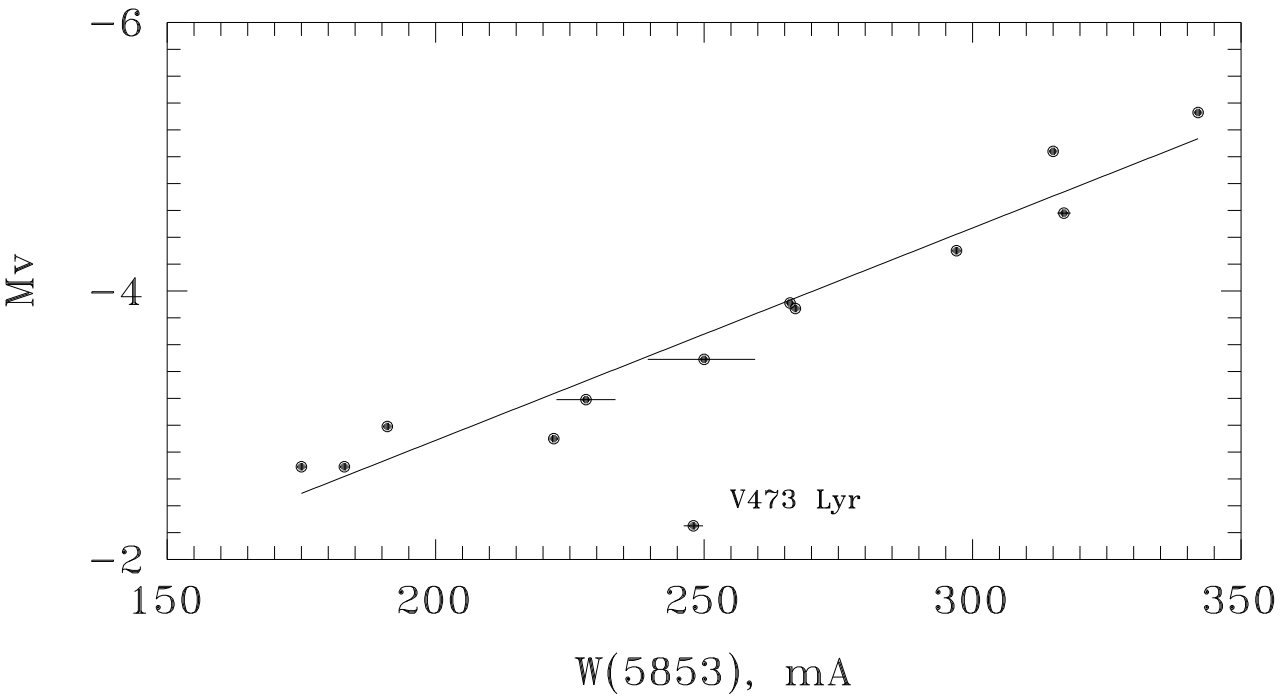

Figure 1. M_v vs. Ba II 5853.6 Å line equivalent width for s-Cepheids. Horizontal lines indicate σ values

1998), we can not adjust its calculated absolute magnitude with the predicted one from the sample of investigated s-Cepheids.

A careful investigation of the possible relations between equivalent widths of Ba II 5853.6 Å and 6141.7 Å lines and absolute magnitude for a sample of classical Cepheids and non-variable F−G supergiant will be a subject of the next paper.

Of course, the relations between M_v and equivalent width of Ba II 5853.6 Å will not substitute a dependence between absolute magnitude and pulsational period for Cepheids which is usually used by the specialists. Nevertheless, the found relation given in Eq.(2) can be considered as a complementary one, allowing to reveal in some cases unusual Cepheids (pulsating in high overtones) and to determine absolute magnitudes for non-variable supergiants using, in particular, spectra collected for those stars during previous years.

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References:

Andrievsky, S.M., Kovtyukh, V.V., Usenko, I.A., 1996, *Astron. Astrophys.*, **305**, 551

Andrievsky, S.M., Kovtyukh, V.V., Bersier, D., Luck, R.E., Gopka, V.P., Yushchenko, A.V., Usenko, A.V., 1998, *Astron. Astrophys.*, **329**, 599

Baker, P.W., 1974, *Publ. Astron. Soc. Pacif.*, **86**, 33

Baranne, A., Queloz, D., Mayor, M., Adrianzyk, G., Knispel, G., Kohler, D., Lacroix, D., Meunier, J.−P., Rimbaud, G., Vin, A., 1996, *Astron. Astrophys. Suppl. Ser*, **119**, 373

Fernie, J.D, Beattie, B., Evans, N.R., Seager, S., 1995, *IBVS*, No. 4148

Gieren, W.P, Fouqué, P., 1993, *Astron. J*, **106**, 734

Gillet, D., Burnage, R., Kohler, D., Lacroix, D., Adrianzyk, G., Baietto, J.C., Berger, J.P., Goillandeau, M., Guillaume, G., Joly, C., Meunier, J.P., Rimbaud, G., Vin, A., 1994, *Astron. Astrophys. Suppl. Ser*, **108**, 181

Kovtyukh, V.V., Andrievsky, S.M., Usenko, I.A., Klochkova, V.G., 1996, *Astron. Astrophys.*, **316**, 155

Panchuk, V.E., Klochkova, V.G., Galazutdinov, G.A., Ryadchenko, V.P., Chentsov, E.L., 1993, *Sov. Astron. Lett.*, **19**, 11

Sanval, B.B., Rautela, B.S., Joshi, G.C., 1988, *Astrophys. Space Sci.*, **140**, 131

Sorvari, J.M., 1974, *Astron. J.*, **79**, 1416

Szabados, L., 1997, *Proc. ESA Symp. "Hipparcos−Venice 97", ESA SP−402*, 657