CALIBRATION OF LUMINOSITY OF HOT STARS (PRELIMINARY RESULTS)

B. Nicolet

Observatoire de Genève, CH-1290 Sauverny, Switzerland

ABSTRACT

For more than 15 years, Cramer & Maeder (1979) uses X, Y and Z parameters from the Geneva photometric system in order to estimate $T_{\rm eff}$, $\log(g)$ and χ for B3 to A3 stars. These methods are especially efficient for dwarf stars. The Cramer calibration will be refined thanks to the Hipparcos parallaxes. The photometric boxes (set of stars having almost the same colour indices) provide collection of stars often similar and allow the determination of very accurate statistical parallaxes.

The criterium of the boxes can be more selective for hot stars having well-measured flux in the far UV by the TD-1 satellite for instance. With the Hipparcos parallaxes and the joint use of TD-1 and Geneva fluxes a calibration of hotter stars (B0.5 to B3 or so) seems realistic.

Key words: space astrometry; stars: early types; techniques: Geneva photometry; TD-1 photometry; Methods: photometric boxes.

1. INTRODUCTION

For about 35 years the Geneva 7-colour photometry has provided highly coherent results. Currently more than 45 000 stars are measured and reduced in this system of which about 6000 are hot. On an other hand the TD1 and IUE experiments measured fluxes and spectra in the far UV for numerous stars. Finally the survey of Hipparcos is providing astrometric data for such objects. The accuracy of the parallaxes is by far better than hoped, nevertheless a large number of hot stars have a σ_π/π too high for a direct use. A method to extract information together from Hipparcos and photometry is sketched here.

Estimation of the parallaxes and standard errors $\pi \pm \sigma_\pi$ is an essential preliminary. Let us start with an example: HD 46064 (central star), for which the Hipparcos parallax is $\pi = 2.84 \pm 0.89$ mas.

2. PHOTOMETRIC BOXES

Golay et al. 1969 created the concept of a photometric box. The basic hypothesis is the following: Two stars having very close colour indices should hopefully have similar physical properties. Nicolet 1981 refined this concept using only intermediate filters or parameters. Basically, a box around a star is a neighbourhood around that star in a photometric space.

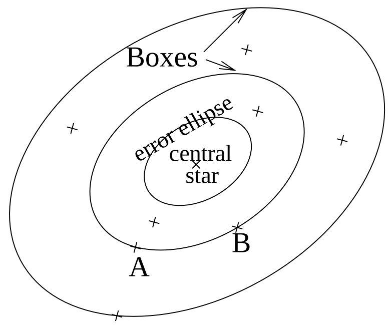

Figure 1. Using elliptical photometric boxes allows a better working of the data. Their shape is homothetical to the ellipse (or ellipsoid) error defined by the covariance matrix. Photometric distance is defined in such a manner that $\delta(A,\ C) = \delta(B,\ C)$, where C is the central star, for A and B are both on the same ellipse.

The shape of a box should not be necessarely cubic. The information is extracted with more efficiency by using boxes homothetical to the error ellipse. See Figure 1 and Nicolet 1981.

If all stars in the box had the same absolute magnitude, the solution of the problem would be very simple. The parallaxes in the Hipparcos Catalogue had to be converted into $\pi_{\rm redu}$ with a relation:

$$\pi_{\rm redu} = \pi_{\rm Hp}\, 10^{-0.2\Delta mag}$$

and the mean of the $\pi_{\rm redu}$ would give the best estimate of π.

Things are not so simple and weighting is actually an important matter. If $\rho_{\rm box} = \sigma_{\rm box}(\pi)/\pi$is a relative error in the boxes, the relative variance is the

Table 1. Box around the central star HD 46064. $\pi_{\rm redu}/\pi_{\rm Hp} = 10^{-0.2(m_c - m_{\rm box})}$ *The distance is based on the photometric differences between the various member stars and the central star. Weighting: See text.*

HD	Sp.type	m_v	$\pi_{\rm Hp}\pm$	$\pi_{\rm redu}\pm$	Phot. dist.	Weight
46064	($B2$)	6.143	2.84±0.89	Central star		
46064	(B2)	6.143	2.84±0.89	2.84±0.89	0.000	0.287
138485	B2Vn	5.489	4.24±0.92	3.16±0.68	0.013	0.409
66765	B1/2V	6.620	1.56±0.81	1.99±1.03	0.020	0.201
188527	(B8)	7.749	1.76±0.99	3.69±2.07	0.020	0.060
71928	B2II-III	7.695	1.10±0.86	2.28±1.78	0.023	0.064
212076	B2Ve	4.986	3.36±0.89	1.99±0.53	0.023	0.367
78764	B2V	4.678	3.02±0.73	1.56±0.38	0.025	0.403
120640	B2Vp	5.750	2.78±0.88	2.38±0.76	0.027	0.173
180183	B3IV	6.777	4.10±0.89	5.69±1.24	0.027	0.081
69404	B2Vnn	6.440	2.45±0.76	2.84±0.88	0.027	0.134
34098	(B8)	8.743	1.12±1.09	3.61±3.50	0.030	0.008
59346	(B8)	9.104	6.40±0.93	25.20±3.67	0.030	0.007
51283	B3II-III	5.298	1.51±0.80	1.04±0.55	0.030	0.152
145482	B2V	4.566	6.97±0.89	3.47±0.44	0.030	0.179
158427	B2.5V	2.834	13.46±0.97	2.91±0.21	0.030	0.233
158906	B2.5IV	7.635	0.01±0.98	0.02±1.90	0.031	0.020
77320	B2.5Vn	6.040	3.26±0.74	3.17±0.72	0.031	0.091
60553	(B3)	6.904	1.28±0.86	1.87±1.26	0.034	0.009
				2.59±0.38	$\sigma_{\rm int} = 0.18$	
					$\sigma_{\rm ext} = 0.34$	

$\pi_{\rm box} = 2.59 \pm 0.38$

sum:

$$\rho_{\rm tot}^2 = \rho_{\rm box}^2 + [\sigma_{\rm redu}/\pi]^2$$

and a first weighting would be:

$$w_1 = [\rho_{\rm box}/\rho_{\rm tot}]^2 \leq 1$$

It is possible to refine by multiplying by a decreasing function of the distance: 1.0 for $d \leq 0.5\, d_{\rm lim}$, 0.0 for $d \geq d_{\rm lim} = 0.035$ and linear in the range $[0.5 d_{\rm lim},\ d_{\rm lim}]$. For each $\pi_i = \pi_{\rm redu}$ we thus obtain a weighting w_i. Small, and even, negative parallaxes are useful in such an approach.

The mean $\bar{\pi}$ and the external variance $\sigma_{\rm ext}^2$ are classical:

$$\sigma_{\rm int}^2 = [\bar{\pi}\, \rho_{\rm box}]^2 / \sum w_i$$

Note that the influence of the value of $\rho_{\rm box}$ is very moderate because a part of factors $\rho_{\rm box}$ disappears by simplifications. A value of $\rho_{\rm box} = 0.2$ was adopted here. Finally:

$$\sigma = \sqrt{\sigma_{\rm int}^2 + \sigma_{\rm ext}^2}$$

Even if without dispersion, we had $\sigma = \sigma_{\rm int} \neq 0$.

3. OTHER CRITERIA: EXAMPLE OF FAR UV FROM TD-1

The photometric boxes are a very powerful tool for numerous stellar types, but they are not a panacea. Figure 2 illustrated such a situation. Extreme UV photometry from the satellite TD-1 (for instance) allows a more severe selection.

For example, the 12th member star HD 59346 in Table 1 is obviously a supergiant, while the central star HD 46064 is a dwarf or a subgiant. Nevertheless the photometric distance is small. The resolving power of the Geneva photometry and of any groundbased photometry is poor for such stars.

The TD1-fluxes, however, are very different. In such a case the types of the box-star and of the central star are likely different. On this basis it is advisable to lessen (symbol * in Table 2) the weighting of such a star or even to discard it putting its weighting to 0.0 (blank symbol).

Without the aberrant value of $\pi_{\rm redu} = 25.20$ mas obtained for HD 59346 the variance $\sigma_{\rm ext}$ decreases from 0.34 (Table 1) to 0.21 (Table 2). Conversely $\sigma_{\rm int}$ slightly increases from 0.18 to 0.23 for the sum of weights diminishes.

4. CONCLUSION

In the best cases a statistical significative parallax can be obtained up to 1 kpc or so. A realistic estimate of the variance allows us to decide whether this method provides results better than the parallaxes directly obtained from the Hipparcos Catalogue. It is not always the case. Results are rather disappointing for extremely hot O and B0 type stars.

In conjunction with the X, Y, Z parameters defined by Cramer & Maeder (1979) many refined studies on the extinction at medium distance are now possible.

*Table 2. Weighting without and with TD-1. **: UV indices are close to those of the central star blank: large differences; * moderate differences. The weightings are modified accordingly.*

HD	$\pi_{\rm redu}\pm$	$W_{\rm box}$	$W_{\rm box,TD1}$	symb
46064	2.84±0.89		Central star	
46064	2.84±0.89	0.287	0.287	**
138485	3.16±0.68	0.409	0.388	**
66765	1.99±1.03	0.201	0.138	**
188527	3.69±2.07	0.060	0.052	**
71928	2.28±1.78	0.064	0.043	**
212076	1.99±0.53	0.367	0.325	**
78764	1.56±0.38	0.403	0.387	**
120640	2.38±0.76	0.173	0.173	**
180183	5.69±1.24	0.081	0.074	**
69404	2.84±0.88	0.134	0.125	**
34098	3.61±3.50	0.008	0.002	*
59346	25.20±3.67	0.007	0.000	
51283	1.04±0.55	0.152	0.044	*
145482	3.47±0.44	0.179	0.145	**
158427	2.91±0.21	0.233	0.002	
158906	0.02±1.90	0.020	0.012	**
77320	3.17±0.72	0.091	0.064	**
60553	1.87±1.26	0.009	0.007	**
	2.57±0.31	$\sigma_{\rm int} = 0.23$		
		$\sigma_{\rm ext} = 0.21$		
		$\pi_{\rm box,TD1} = 2.57 \pm 0.31$		

ACKNOWLEDGMENTS

A vast observing programme in the Geneva photometry was initiated. I am very grateful to the Foundation Jungfraujoch-Gornergrat and to the Swiss telescope at La Silla (ESO) who allotted observing time and to the numerous observers at the observing stations of Jungfraujoch and La Silla. Though the impossibility to mention all observers, I have the pleasure and the gratitude to give a special mention to Dr Michel Burnet, who keeps the Swiss station at La Silla in excellent standing and spends a lot of time beyond the telescope.

REFERENCES

Cramer, N., Maeder, A., 1979, A&A, 78, 305

Golay, M., Peytremann, E., Maeder, A., 1969, Publ. Obs Genève Série A, 76, 44

Kurucz, R. L., 1993, Kurucz CD-ROM 13, ATLAS9 stellar atmosphere program and 2 km/s grid

Nicolet, B. 1981, A&A, 97, 85

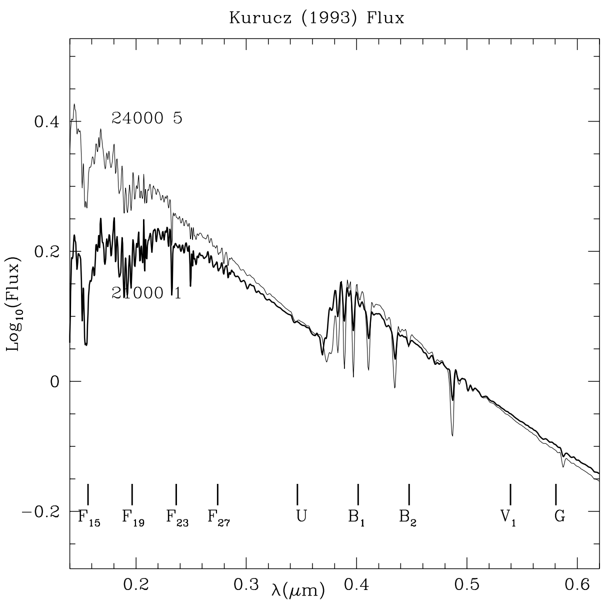

Figure 2. Kurucz (1993) fluxes normalized to $\lambda = .5\mu m$ for a hot dwarf (narrow line) and a supergiant (broad line). $T_{\rm eff}$ and log(g) are indicated. The λs of intermediate Geneva filters (U to G) are marked. This photometry is quite unable to classify such stars in luminosity. The photometric boxes contain thus a mixing of stars with highly dispersed absolute magnitudes. Far UV spectra or 'TD1 photometry' (passbands F_{15} to F_{27} are marked) allows to eliminate such confusions.