Model atmosphere calibration for synthetic photometry applications: the uvby Strömgren photometric system

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Abstract. Strömgren synthetic photometry from an empirically calibrated grid of stellar atmosphere models has been used to derive the effective temperature of each component of double lined spectroscopic (SB2) eclipsing binaries. For this purpose, we have selected a sub-sample of 20 SB2s for which \((b-y), m_1, \text{and}\ c_1\) individual indices are available. This new determination of effective temperature has been performed in a homogeneous way for all these stars. As the effective temperature determination is related to the assumed metallicity, we explore simultaneous solutions in the \((T_{\text{eff}},[\text{Fe/H}])\)-plane and present our results as confidence regions computed to match the observed values of surface gravity, \((b-y), m_1, \text{and}\ c_1\), taking into account interstellar reddening. These confidence regions, presented in detail in Lastennet et al. 1999, show that previous estimates of \(T_{\text{eff}}\) are often too optimistic, and that \([\text{Fe/H}]\) should not be neglected in such determinations. We present some comparisons with Ribas et al. (1998) using Hipparcos parallaxes for 8 binaries of our working sample, showing good agreement with the most reliable parallaxes. This point gives a significant weight to the validity of the BaSeL models for synthetic photometry applications.

1. Introduction

Since predictions based on stellar-atmosphere models are useful for “Spectro-photometric dating of stars and galaxies”, main subject of this conference, we present some of the results obtained from an empirically calibrated grid of stellar atmosphere models for simultaneously deriving homogeneous effective temperatures and metallicities of 40 stars from observed data.
2. BaSeL models

We use the Basel Stellar Library (BaSeL) photometric calibrations, extensively tested and regularly updated for a larger set of parameters (see Lejeune et al. 1997, 1998 and Lastennet et al. 1999). The BaSeL models cover a large range of fundamental parameters: \(2000 \, \text{K} \leq T_{\text{eff}} \leq 50,000 \, \text{K}, \ -1.02 \leq \log g \leq 5.5, \) and \(-5.0 \leq [\text{Fe/H}] \leq +1.0\). This library combines theoretical stellar energy distributions which are based on several original grids of blanketed model atmospheres, and which have been corrected in such a way as to provide synthetic colours consistent with extant empirical calibrations at all wavelengths from the near-UV through the far-IR. For more details and references on the BaSeL library, see contributions of Lejeune et al., Lastennet et al. and Westera et al. in this volume.

3. Comparison with Hipparcos parallax

Very recently, Ribas et al. (1998) have computed the effective temperatures of 19 eclipsing binaries included in the Hipparcos catalogue from their radii, Hipparcos trigonometric parallaxes, and apparent visual magnitudes corrected for absorption. They used Flower’s (1996) calibration to derive bolometric corrections. Only 8 systems are in common with our working sample. The comparison with our results is made in Table 1. The \(T_{\text{eff}}\) being highly related with metallicity, a direct comparison is not possible because, unlike the Hipparcos-derived data, our results are not given in terms of temperatures with error bars, but as ranges of \(T_{\text{eff}}\) compatible with a given \([\text{Fe/H}]\). Thus, the ranges reported in Tab. 1 are given assuming three different hypotheses: \([\text{Fe/H}] = -0.2, [\text{Fe/H}] = 0, \) and \([\text{Fe/H}] = 0.2\). The overall agreement is quite satisfactory, as illustrated in Fig. 1. The disagreement for the temperatures of CW Cephei can be explained by the large error of the Hipparcos parallax \((\sigma_{\pi}/\pi \approx 70\%)\). For such large errors, the Lutz-Kelker correction (Lutz & Kelker 1973) cannot be neglected: the average distance is certainly underestimated and, as a consequence, the \(T_{\text{eff}}\) is also underestimated in Ribas et al.’s (1998) calculation. Thus, the agreement with the results obtained from the BaSeL models is certainly better than it would appear in Fig. 1 and Tab. 1. Similar corrections, of slightly lesser extent, are probably also indicated for the \(T_{\text{eff}}\) of RZ Cha and GG Lup, which have \(\sigma_{\pi}/\pi > 10\%\) (11.6% and 11.4%, respectively). Finally, it is worth noting that the system with the smallest relative error in Tab. 1, \(\beta\) Aur, shows excellent agreement between \(T_{\text{eff}}\) (Hipparcos) and \(T_{\text{eff}}\) (BaSeL), which underlines the validity of the BaSeL models.

4. Brief summary of the results

- The large range of \([\text{Fe/H}]\) associated with acceptable confidence levels makes it evident that the classical method to derive \(T_{\text{eff}}\) from metallicity-independent calibrations should be considered with caution.
- By exploring the best \(\chi^2\)-fits to the photometric data, we have re-derived new reddening values for some stars.
Figure 1. Hipparcos- versus BaSeL-derived effective temperatures for \( \beta \) Aur, YZ Cas, CW Cep, RZ Cha, KW Hya, GG Lup, TZ Men, and \( \zeta \) Phe. The errors are not shown on the Hipparcos axis for CW Cephei (the hottest binary in these figures). See text for explanation.
Table 1. Effective temperatures from Hipparcos (after Ribas et al. 1998) and from BaSeL models matching \((b-y)_0, m_0, c_0,\) and \(\log g\) for the three following metallicities: \([\text{Fe/H}] = -0.2, 0\) and 0.2.

| Name     | \([\text{Fe/H}] = -0.2\) | \([\text{Fe/H}] = 0\) | \([\text{Fe/H}] = 0.2\) |
|----------|-----------------------------|-------------------------|-----------------------------|
|          |  \(T_{\text{eff}}\) (Hipp.) \([\text{K}]\) |  \(T_{\text{eff}}\) (BaSeL) \([\text{K}]\) |  \(\sigma\)  \(T_{\text{eff}}\) (BaSeL) \([\text{K}]\) |  \(\sigma\)  \(T_{\text{eff}}\) (BaSeL) \([\text{K}]\) |
| \(\beta\) Aur | 9230±150 \([8780,9620]\) 1 | 8780,9560 1 | 8900,9500 1 |
| YZ Cas   | 9186±145 \([8540,9500]\) 1 | 8600,9440 1 | 8660,9320 1 |
| CW Cep   | 8624±290 \([8000,9120]\) 2 | 8920,9240 3 | 9260,9060 1 |
| RZ Cha   | 6528±155 \([6100,7114]\) 1 | 6180,7060 1 | 6260,7060 1 |
| CW Cep   | 23804 \([26000,27200]\) 1 | 25600,26600 1 | 24600,26600 2 |
| RZ Cha   | 6621±400 \([6140,6560]\) 1 | 6380,6640 2 | 6340,6640 3 |
| KW Hya   | 7826±340 \([8080,8100]\) 3 | 8460,6530 1 | 6420,6580 2 |
| GG Lup   | 6626±230 \([6780,7120]\) 3 | 6860,6980 1 | 6860,7000 3 |
| 12129±2080 | 14080,14260 1 | 14020,14140 1 | 13780,14140 2 |
| 10920,11320 1 | 10920,11320 1 | 10920,11320 1 |
| Tz Men   | 9489±490 \([10300,10420]\) 1 | 10390,10380 2 | 10260,10460 2 |
| ζ Phe    | 14631±1150 \([13540,14020]\) 3 | 13460,13860 1 | 13380,13860 1 |
| 12249±1100 | 11240,11560 1 | 11280,11480 1 | 11040,11680 2 |

- Comparisons for 16 stars with Hipparcos-based \(T_{\text{eff}}\) determinations show good agreement with the temperatures derived from the BaSeL models. The agreement is even excellent for the star having the most reliable Hipparcos data in the sample studied.

See Lastennet et al. 1999 for details about the method, the determination of reddening, the influence of gravity, etc... These comparisons also demonstrate that, while originally calibrated in order to reproduce the broad-band (UBVRIJHKL) colours, the BaSeL models also provide reliable results for medium-band photometry such as the Strömgren photometry. This point gives a significant weight to the validity of the BaSeL library for synthetic photometry applications in general.

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