THE Hα BALMER LINE AS AN EFFECTIVE TEMPERATURE CRITERION

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Abstract.   For eleven stars with an accurate effective temperature derived from their apparent angular diameter we determine the effective temperature of the Kurucz Atlas9 model that provides the best fit of the computed theoretical Hα profile (using the recent theoretical advances) with the corresponding observed profile, extracted from the S4N spectroscopic database. The two sets of effective temperatures have a significant offset, but are tightly correlated, with a correlation coefficient of 0.9976. The regression straight line of T_{eff}(direct) versus T_{eff}(Hα) enables us to reach the true effective temperature from the spectroscopic observation of the Hα profile, with an rms error of only 30 K. This provides a way of obtaining the true effective temperature of a reddened star.

Keywords: stars:atmospheres, stars:fundamental parameters, line:profile

1   Introduction

Already many authors have used the Hα Balmer line as effective temperature criterion. Two events justify to derive a new calibration of Hα versus effective temperature.

The first one is a continuous improvement in the physics of the broadening of the line, from 1999 to 2008. The second one is the enormous gain in the accuracy of apparent angular diameter diameter measurements by interferometric methods. This enables to derive the effective temperatures of a dozen of stars with an accuracy of the order of one per cent by the relation:

$$T_{\mathrm{eff}} \quad = \quad (4/\sigma)^{1/4} fbol^{1/4} \theta^{-1/2}$$

where σ is the Stefan-Boltzmann constant, and $fbol$ and θ are respectively the apparent bolometric flux and limb-darkened angular diameter of the object. This is the so-called direct method, less model dependent than the Infrared Flux Method, largely used before. Our work has been to connect the effective temperature obtained by the direct method, to the effective temperature of the model giving the best fit between the computed and the observed profile of Hα for this dozen of stars.

2   Effective temperatures from the Hα fitting procedure

2.1   Observations

We selected the spectra of the S4N spectral library (Allende Prieto et al. 2004) for the 10 stars having apparent angular diameters measurements better than 2 per cent. These spectra are very suited for the study of the Hα wings, usually difficult to get with cross-dispersed spectrographs.

2.2   Model atmosphere

We used Kurucz ATLAS9, BALMER9 codes, after incorporating the Stark broadening of Stehlé & Hutcheon (1999) and the collisional broadening by neutral H of Allard et al. (2008). We used a mixing length over pressure scale height ratio of 0.5.

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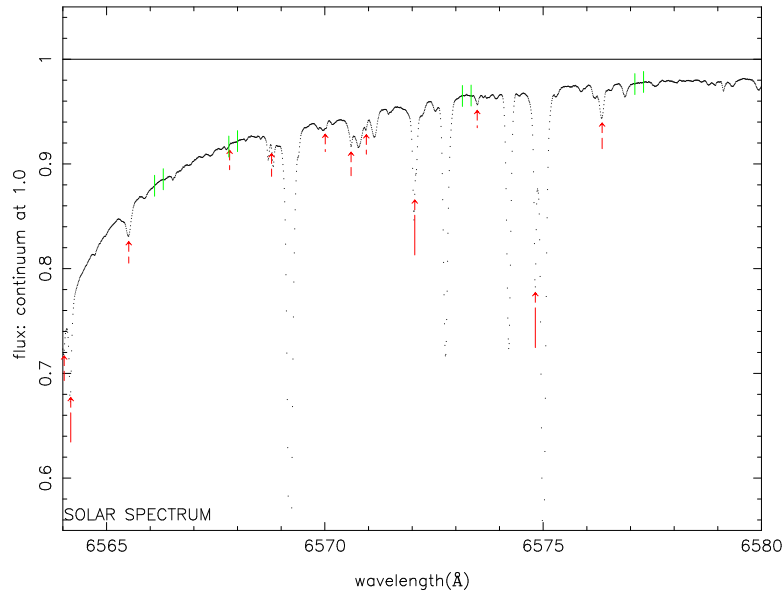[4]   Observatoire de Paris, LERMA, 5 Place J. Janssen, 92195 Meudon, France

Fig. 1. Red wing of the observed solar Hα profile. The windows free of other lines contamination are indicated by a couple of green vertical lines.

2.3 Fitting procedure

As done by Barklem et al. (2002) we have selected windows, where Hα is not contaminated by other stellar lines (see Fig. 1). The telluric lines, indicated by red arrows, have been a worry as they move with the radial velocity of the object and must be avoided too. Some windows may be lost. Taking the parameters gravity and metallicity from the PASTEL database (Soubiran et al. 2010), we vary the effective temperature of the model until we get the best fit with the observed profile. See examples in Fig. 2. The procedure is repeated for the selected ten spectra from the S4N library plus the Sun.
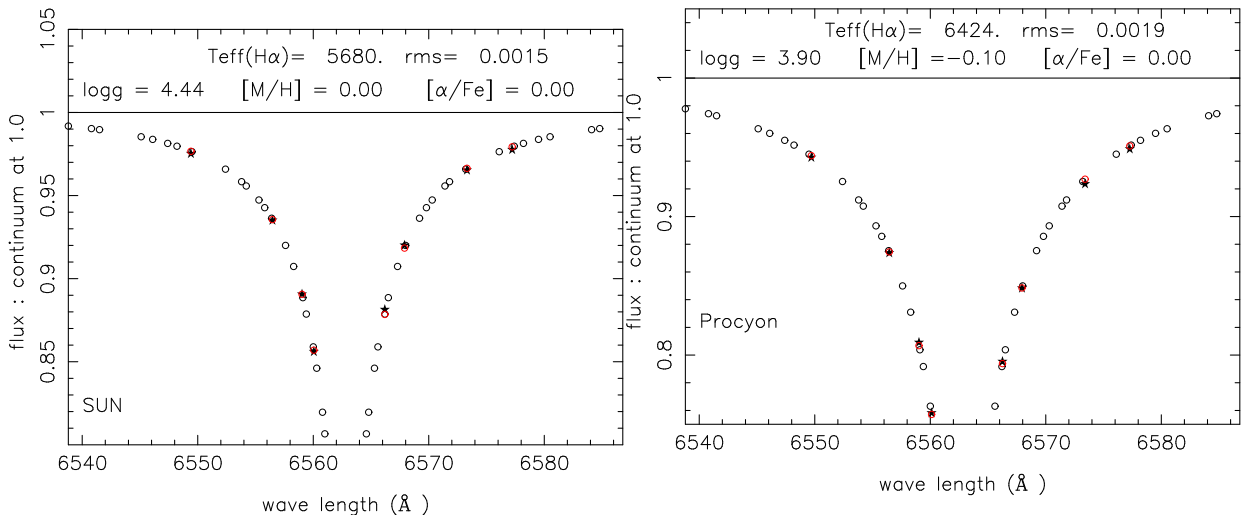

Fig. 2. Left: Fitting of the computed to the observed fluxes of the solar Hα profile.
Right: Fitting of the computed to the observed fluxes on the Hα profile of Procyon.
Open circles are the theoretical profile, the red ones corresponding to the wavelength of the observed points represented by full black stars.

3 T_eff(direct) and results

The apparent angular diameters have been taken from the literature. Most of them come from the Mount Wilson interferometer (now CHARA) and a few from the ESO VLTI. A list of them can be found in Casagrande et al. (2010). The apparent bolometric magnitudes have been derived from colour indices by relations established by Casagrande et al. (2010). The dispersion of the points around the regression line of T_{eff}(direct) versus T_{eff}(Hα) is remarkably small, with a root mean square deviation of only 30 K. The relation between the two sets of effective temperatures is represented by:

$$T_{eff}(\text{direct}) \quad = \quad 20.3 + 1.014 \times T_{eff}(\text{H}\alpha)$$

The correlation coefficient between the two sets is 0.9976, a very tight connection (Fig. 3). The principal aim of our paper has been met, a simple procedure for deriving the true effective temperature from the observed Hα Balmer line profiles, enabling to bypass the uncertainties in the amount of interstellar reddening, critical for temperatures derived from photometric indices. All the calibration stars are all at distances less than 15 parsecs, therefore not affected by reddening. The remaining interesting problem is to understand why the two sets of temperatures have an offset instead of being equal.This is clearly a problem for 3D hydrodynamical models, that we are investigating now.
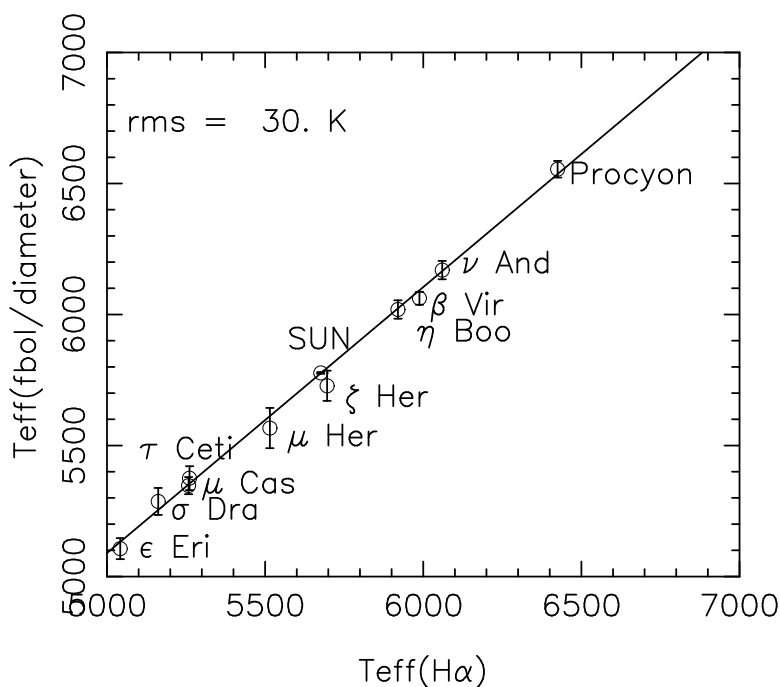

Fig. 3. Regression line between T_{eff}(Hα) and T_{eff}(direct). The rms of the fit is 30 K.

The details of this research are available in Cayrel et al. (2011).

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