

Spectroscopic Indices of Stars: a Theoretical Approach

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Abstract. We present a new grid of theoretical absorption indices based on an updated library of synthetic spectra. These were computed using a subset of LTE Kurucz model atmospheres and his series of codes SYNTHE. Spectra encompass the wavelength interval from 850 to 7000 Å, with an inverse resolution of $R = 50\,000$ (UV range) and 500 000 (optical). A wide space domain in the atmosphere parameters has been probed such as to account for stars along the whole spectral-type sequence (from O to M) and luminosity class (MK type from I to V). Metallicity ranges from $[\text{Fe}/\text{H}] = -3 \rightarrow +0.5$ dex. A total of 51 ultraviolet and optical narrow-band indices defined in the literature have been measured and calibrated in terms of the atmosphere parameters. We foresee ample use of this grid for stellar and extragalactic studies.

1. Introduction

Over the past decade the study of spectral properties of stars, through the definition of narrow-band indices, has received considerable attention. Spectroscopic indices have quickly become a basic and popular interpretative tool, not only for the study of single stars (e.g. Gray, Scott & Postma 2002), but also to assess the overall evolutionary status of stellar aggregates as a whole (e.g. Buzzoni, Gariboldi & Mantegazza 1992; Worthey et al. 1994). There is at least a threefold advantage in using such a narrow-band approach to stellar spectra:

- indices can easily be measured from stellar or galaxy spectral energy distributions;
- they do not depend on interstellar extinction;
- different atomic or molecular species can be studied separately.

In addition, narrow-band indices are especially suitable to analytical handling via the so-called fitting functions (i.e. polynomials describing the relation of index behaviour vs. leading atmosphere parameters), thus easing their application for population synthesis purposes (Buzzoni et al. 2001).

Most of the index datasets currently available in the literature rely on empirical spectral libraries. While such databases have played a key role in studying e.g. chemical evolution of galaxies, there are still some important problems to be tackled down. First of all, empirical databases are constructed upon stars in the solar neighborhood, and therefore implicitly carry on the imprints of the local chemical history. Furthermore, observed spectra may usually not be systematically labeled in terms of atmosphere fundamental parameters, and in most libraries the parameter space is not homogeneously covered, especially at the high and very low metallicity regimes (see for example Cenarro et al. 2002 for a discussion on the CaII triplet).

This is not the case for theoretical databases, which naturally overcome all these problems (see Chavez, Malagnini & Morossi 1996 and references therein). A theoretical spectrum is in fact labeled by the parent model, and it can be computed for virtually any combination of atmosphere parameters and at any desired wavelength resolution. The material presented in this paper complements and updates previous investigations on the analysis of theoretical spectroscopic indices based on high-resolution synthetic spectra.

2. Model Atmospheres and Library of Synthetic Spectra

For the calculation of theoretical spectra we have extracted a subset of the grid of LTE model atmospheres developed by Kurucz (1993). In brief, these models consider local thermodynamic equilibrium and plane parallel geometry while line opacity is accounted for through a set of opacity distribution functions. The selected subset of models consists of 2482 entries and covers a large volume of the parameter space; effective temperature (T_{eff}) in the interval 3500–50 000 K with a variable step ranging from 250 K for models with $T_{\text{eff}} \leq 7000$ K to 2500 K for hotter models. Surface gravities vary from 0.0 to 5.0 dex and chemical compositions are $[M/H] = -3.0, -2.0, -1.5, -1.0, -0.5, -0.3, 0.0, +0.3$ and $+0.5$. In all cases we have considered a microturbulence velocity of 2 km/s.

The library consists of two datasets computed independently covering two overlapping spectral regions. The first set includes the far ultraviolet (FUV)-optical region (850–4750 Å) at an inverse resolution $R = 50\,000$. The latter spans from 3500 to 7000 Å at a resolution of 500 000. Calculations of both sets were carried out by using the SYNTHE series of codes developed by Kurucz (1993) and included the opacities of several million atomic and molecular transitions for the most important diatomic species. It is important to note that unlike previous investigations in the optical re-

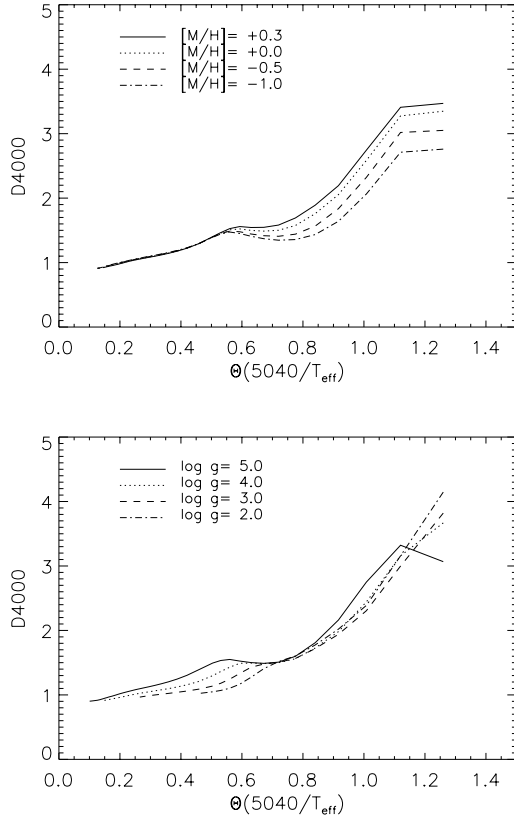


Figure 1. Theoretical D_{4000} index from our Far-UV optical database as a function of the effective temperature parameter, $\Theta_{\text{eff}} = 5040/T_{\text{eff}}$, vs. chemical composition for dwarf models ($\log g = 5.0$) (*upper panel*), and vs. stellar gravity for fixed solar metallicity (*lower panel*). The index gives a measure of the Balmer spectral break around 4000 \AA in magnitude scale.

gion conducted by some of us (Chavez, Malagnini & Morossi 1996) we have included the opacity due to TiO (Schwenke 1998) and we considered the so-called approximate overshooting in the treatment of convection (Castelli, Gratton & Kurucz, 1997). This composite library largely superseeds any other dataset available in the literature computed at an increased resolution. Details of the library and the library itself will be available soon (Bertone 2002; Rodriguez-Merino et al. 2003, in preparation, and Bertone et al. 2003, in preparation).

3. The new Grid of theoretical Indices

Calculation of the 25 spectral indices in the optical range (4080–6400 Å) has been carried out following the Lick/IDS system definitions (Worthey et al. 1994); we also added the D_{4000} index according to Bruzual (1983), and the far and mid ultraviolet indices from Fanelli et al. (1992). As an illustrative example, in Fig. 1 we display the behaviour of the D_{4000} index (which gives a measure of the 4000 Å Balmer break) vs. stellar fundamental parameters (i.e. temperature, surface gravity and metallicity). Our results nicely match the work of Gorgas et al. (1999), that relies on the contrary on a fully empirical approach. Our theoretical dataset has been calibrated as a function of the atmosphere parameters and spectral resolution. Work is in progress to extend the wavelength interval up to 9000 Å and complement our database with non solar-scaled metal abundances.

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References

- Bertone E. 2002, PhD thesis, University of Milan, Italy
- Buzzoni, A., Gariboldi, G., and Mantegazza, L. 1992, *AJ*, 103, 1814
- Buzzoni, A., Chavez, M., Malagnini, M.L., Morossi, C. 2001, *PASP*, 113, 1365
- Bruzual, G. 1983, *ApJ*, 273, 105
- Castelli, F., Gratton, R., and Kurucz, R. L. 1997, *A&A*, 318, 841
- Chavez, M., Malagnini, M., and Morossi, C. 1996, *ApJ*, 471, 726
- Cenarro, A. J., Gorgas, J., Cardiel, N., Vazdekis, A., and Peletier, R. F. 2002, *MNRAS*, 329, 863
- Fanelli, M. N., O’Connell, R. W., Burstein, D., and Wu C. 1992, *ApJS*, 82, 197
- Gorgas, J., Cardiel, N., Pedraz, S., and Gonzalez, J. J. 1999, *A&AS*, 139, 29
- Gray, D. F., Scott, H. R., and Postma, J. E. 2002, *PASP*, 114, 536
- Kurucz, R. L. 1993, CD-ROM 13, ATLAS9 Stellar Atmosphere Programs and 2 km/s grid (Cambridge; SAO). CD-ROM 18, SYNTHE Spectrum Synthesis Programs and Line Data (Cambridge; SAO)
- Schwenke, D. W. 1998, *Faraday Discuss*, 109, 321
- Worthey, G., Faber, S., Gonzalez, J.J., and Burstein, D. 1994, *ApJS*, 94, 687