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THEORETICAL CALIBRATION OF MAGNESIUM AND IRON STELLAR INDICES

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ABSTRACT We present the calibration of absorption-line indices which measure the strength of prominent Magnesium and Iron features in the spectral interval 4850-5400 Å. The results presented here are based on improved model atmosphere and spectrum synthesis codes developed by R.L. Kurucz as well as on revised atomic and molecular data.

Satisfactory results are obtained when comparing the observed and synthetic solar central intensity spectra which favors the use of the present collection of spectra and indices over sets of data computed with previous versions of models and codes.

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We computed 693 synthetic spectra starting from the atmosphere models release by Kurucz 1993 (CD-ROM 13), and codes (CD-ROM 18) (details in Chavez et al. 1995c). They refer to the following set of parameters:

- $T_{\rm eff}$ range 4000–6000 K (step 250 K), plus 7000 and 8000 K;
- log g = 1.0–5.0 dex (step 0.5 dex);
- [M/H] = -1.0, -0.5, 0.0, +0.1, +0.2, +0.3 and +0.5;
- λ range 4850–5400 Å;
- resolving power $\lambda/\Delta\lambda$=250,000;

- microturbulence velocity, $\xi = 2$ km/s.

In the above mentioned wavelength interval, about 45,000 lines are expected for the lowest temperatures: their effect was checked against the solar observed intensity spectrum, and modified accordingly. A total of 2000 modifications (in van der Waals and log *gf* values) were done on ~1500 lines. A satisfactory match for lines with residual intensity ≤ 0.8, better than 6% over the complete λ range, was obtained (see Chavez 1995 for a complete analysis on the subject).

From the synthetic spectra, fluxes in the bands defined by S. Faber and co-workers (Worthey et al. 1994, hereafter WFGB94, and references therein) were computed, in order to obtain equivalent widths of features which are prominent in cool stars and elliptical galaxies. We will refer to them as "Lick-like" indices, since we computed the indices (Mg_1, Mg_2, Mg *b*, Fe5015, Fe5270 and Fe5335) starting from theoretical absolutely calibrated fluxes.

The availability of such fluxes, both in the feature and in the so-called pseudocontinuum, for any combination of the ($T_{\rm eff}$, log g, [M/H]) parameters, makes it straightforward the derivation of integrated theoretical indices, by the method of isochrone fitting (these data are available in the CD–ROM produced as part of this meeting proceedings). As an example, figure 1 shows the trend with age of the Mg_2 index, for SSP's with three different values of Z (the whole set of isochrones was kindly made available by A. Bressan in computer readable form; we refer to Bressan, Chiosi & Tantalo (1995) for complete description of the isochrone fitting procedure).

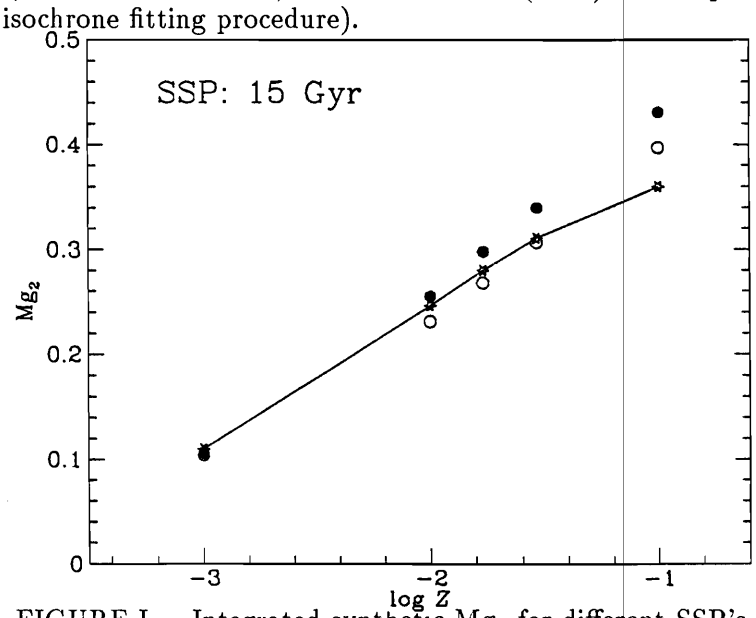

FIGURE I Integrated synthetic Mg_2 for different SSP's

After a quick onset of the feature at early epochs, the index appears to reach a saturation level, different for different metallicities.

We remark the fact that the integrated indices referred to are purely theoretical, thus they may be not directly comparable with observations. Moreover, in order to cover the whole parameters range spanned by different SSP's, conservative assumptions have been made on the Mg_2 behaviour outside the limits of our grid.

CALIBRATIONS

The theoretical calibration of indices in terms of atmosphere parameters is straightforward, in the sense that each computed index is labelled with the atmospheric parameters of the starting model. Thus, calibration is inherent, for example, in Tables and figures by Chavez et al. (1995a) for Mg_2, and Chavez (1995) for other indices.

On the other side, empirical calibrations have been proposed by many authors in the form of analytical expressions, in order to smooth out and fill in the unavoidable ripples or gaps in the observational datasets.

To compare with empirical fitting functions, we proceeded in a similar way but starting from our theoretical grid. First of all, we studied the possible correlation of each index with the atmosphere parameters. We applied a multiregression linear analysis, including terms up to the third degree in all the independent variables (i.e. $\log \Theta_{\rm eff} = 5040./T_{\rm eff}$, $\log g$, and [M/H]).

TABLE I Mg_2 and Mg_1 fitting function coefficients and RMS of the multiregression linear fit

Term	Mg_2	Mg_1
Additive Constant	0.9119	0.1082
$(\log \Theta)$	26.6029	...
$(\log \Theta)^2$	...	6.6106
$(\log \Theta)^3$	-917.3561	46.7404
[M/H]	0.7667	0.0917
$[M/H]^2$	...	...
$[M/H]^3$	...	...
$(\log g)$	...	...
$(\log g)^2$	0.1951	...
$(\log g)^3$	...	...
$(\log \Theta)$ [M/H]	...	0.5829
$(\log \Theta)$ $(\log g)$	...	0.7345
$(\log \Theta)$ $(\log g)^2$	-0.4163	...
$(\log g)$ $(\log \Theta)^2$	-44.4918	...
$(\log \Theta)^2$ [M/H]	...	...
$(\log \Theta)$ $[M/H]^2$	...	...
$(\log g)^2$ [M/H]	...	...
RMS (mag)	0.041	0.043
RMS-all variables (mag)	0.040	0.032

The procedure was iterated by rejecting the terms with low values of the

partial regression coefficients, while checking the goodness of the obtained fitting functions with respect to the original data. In general, even retaining all the terms we could not improve the quality (RMS) of the fit (see for example Table 1 where the Mg_2 RMS is 5 times the estimated observational error). It is worth noting that the use of analytical function may introduce undesirable ripples and we strongly recommend the use of intra-grid interpolation as a better approach.

Integrated Mg_2: preliminary results

Our indices grid is mostly intended for population synthesis work, and, in order to compare with observations, transformation relationships may be needed. For example, we derived a linear transformation to convert our "Lick-like" Mg_2 indices into the Lick/IDS system (WFGB94) by using a set of observed indices and the corresponding theoretical one derived from our grid. By using our data, integrated synthetic Mg_2's have been derived as in Buzzoni et al. (1992), and the results for a 15 Gyr SSP are illustrated in figure 2. Starred symbols (connected by a solid line) refer to Buzzoni et al. (1992) predictions of the trend of the index with population metallicity, Z, under the assumptions of Salpeter law for the IMF, 0.3 for the mass loss parameter, and a red horizontal branch morphology. Open and filled circles represent the new results, under the same assumptions, and refer to two different kinds of extrapolations of Mg_2 for the atmosphere parameters outside the grid limits.

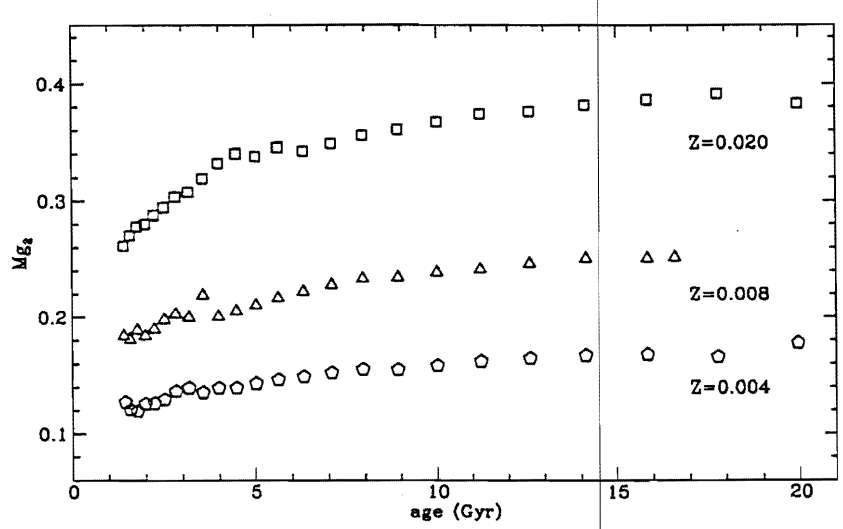

FIGURE II Integrated synthetic Mg_2 for a 15 Gyr SSP vs metallicity

It appears that the new results would predict higher index values at high metallicity. Nevertheless, possible implications in the context of galaxy evolution have to be deferred after more detailed analyses and a careful calibration based

on theoretical and observed indices for super metal rich stars (see Chavez et al. 1995b for a progress report).

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