NEAR-INFRARED SPECTRAL FEATURES IN SINGLE-AGED STELLAR POPULATIONS

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ABSTRACT

Synthetic spectra for single-aged stellar populations of metallicities \([M/H] = -0.5, 0.0, \) and \(+0.5,\) ages = 3–17 Gyr, and initial mass function indices \(x = 0.1–2.0\) were built in the wavelength range \(\lambda \lambda 6000–10200\). We have employed the grid of synthetic spectra described in Schiavon & Barbuy, computed for the stellar parameters \(2500 \leq T_{\text{eff}} \leq 6000\) K, \(-0.5 \leq \log g \leq 5.0, [M/H] = -0.5, 0.0, \) and \(+0.5,\) and \([\text{[Fe/Fe]}] = 0.0,\) together with the isochrones by Bertelli et al. and Baraffe et al. The behavior of the features Na i \(\lambda 8190,\) Ca ii \(\lambda 8662,\) TiO \(\lambda 6600,\) and FeH \(\lambda 9900\) Å in the integrated spectra of single-aged stellar populations was studied in terms of metallicity, initial mass function (IMF), and age variations. The main conclusions are that the Na i doublet is an IMF-sensitive feature, which is, however, sensitive also to metallicity and age, whereas TiO, Ca ii, and FeH are very sensitive to metallicity and essentially insensitive to IMF and age.

Subject headings: globular clusters: general — infrared: stars — stars: fundamental parameters — stars: late-type

1. INTRODUCTION

The analysis of near-infrared (NIR) features in the spectral region \(\lambda \lambda 6000–10000\) in the integrated light of globular clusters and galaxies has become of common use for inferring the parameters of their stellar populations. The NIR spectral region is especially interesting for stellar population studies, because M stars (giants and dwarfs) give their maximum contribution to the integrated spectra of galaxies and clusters in these wavelengths. For example, NIR line indices that are sensitive to the surface gravity of M stars can be used to constrain the low-mass end of the mass function. Also, NIR indices are suitable for deriving metallicities because of their remarkable insensitivity to age. The metallicity calibration of globular clusters using the Ca ii triplet has been carried out by Bica et al. (1998) for globular clusters in the Galactic bulge and by Olszewski et al. (1991) for clusters in the Magellanic Clouds.

Long-standing problems with the use of initial mass function (IMF) sensitive NIR features in composite systems were discussed in Whitford (1977), Cohen (1978, 1979), Faber & French (1980), Alloin & Bica (1989), Xu, Véron-Cetty, & Véron (1989), Boroson & Thompson (1991), Delisle & Hardy (1992), and Couture & Hardy (1993), who studied the Na i, Ca ii, and FeH indices in integrated spectra of galaxies and clusters.

In spite of the above-mentioned efforts, the strong spectral features that appear in the integrated NIR spectrum of globular clusters and normal galaxies have been far less exploited in stellar population studies than the indices in the optical region, such as Mg ii, Fe5270, and Fe5335 (Burstein et al. 1984; Worthey 1994; Trager et al. 1998). This is probably due to two main reasons: the NIR features show a more complex behavior than the “green” features, and the NIR region presents numerous telluric lines that require a proper and careful subtraction.

In this context, spectrum synthesis based on model stellar photospheres and comprehensive line lists can play a key role in disentangling the degenerate behavior of line indices as a function of metallicity, effective temperature, and surface gravity. In an attempt to improve our understanding of the NIR features, Schiavon & Barbuy (1999, hereafter SB99) have built an extensive grid of synthetic spectra, based on state-of-the-art model photospheres and molecular and atomic line lists. The Na i “doublet” at 8190 Å and the FeH Wing-Ford band (WFB) at 9900 Å (Wing & Ford 1969) were studied as a function of stellar photospheric parameters by Schiavon et al. (Schiavon et al. 1997a; Schiavon, Barbuy, & Singh 1997b), whereas the behavior of the TiO bands and the Ca ii triplet were described in Milone & Barbuy (1994), SB99, and Erderlyi-Mendes & Barbuy (1991).

In this paper we use the grid of high-resolution synthetic stellar spectra presented in SB99 to build integrated spectra of single-aged stellar populations (SSPs) in the wavelength range \(\lambda \lambda 6000–10200\). Previous work with similar aims was presented by Garcia-Vargas, Molla, & Bressan (1998) and Milone, Barbuy, & Bica (1995), in which equivalent widths of the Ca ii triplet and TiO, respectively, were given. These models are a useful guide in the interpretation of the integrated spectra of early-type galaxies, which in the NIR are dominated by M-type stars, and may provide a better understanding of the age-metallicity degeneracy of old and intermediate-age stellar populations.

In § 2 we present basic information on the spectrum synthesis of individual stellar models and on the other ingredients required for building the SSP models. In § 3 we discuss the behavior of selected NIR features as functions of SSP parameters: metallicity, age, and IMF. A summary is presented in § 4.
2. INTEGRATED SYNTHETIC SPECTRA OF SINGLE-AGED STELLAR POPULATIONS

2.1. Synthetic Spectra of Individual Stars

SB99 computed a grid of high-resolution synthetic spectra in the wavelength range $\lambda 6000$–10200. The photospheric models by Kurucz (1992) and Plez, Brett, & Nordlund (1992) and additional unpublished models by B. Plez (1997, private communication) and Allard & Hauschildt (1995) were adopted. The grid covers the following ranges of stellar parameters: $T_{\text{eff}}$ = 2500 to 6000 K, $\log g = 0.5$ to 5.0, $[\text{M/H}] = 0.5$, 0.0, and 0.5, and $[\alpha/\text{Fe}] = 0.0$. The molecular electronic systems included in the calculations are the CN ($A^2 \Pi - X^2 \Sigma$) red system, the Swan system, the TiO ($A^3 \Pi - X^3 \Delta$), $\delta(b^1 \Pi - a^1 \Delta)$, $e(E^3 \Pi - X^3 \Delta)$, and $\phi(b^1 \Pi - d^1 \Sigma)$ systems, and the FeH ($A^4 \Pi - X^4 \Delta$) system, which includes the WFB. The synthetic spectra were computed in steps of 0.02 Å and rebinned to 1.0 Å with FWHM = 2.0 Å. More details on the atmospheric models and the atomic and molecular data employed are given in SB99.

2.2. Integrated Spectra of Single-aged Stellar Populations

We have combined our grid of synthetic stellar spectra with isochrones collected from the literature to build SSP synthetic spectra. We adopted the Padova isochrones (Bertelli et al. 1994) for $M > 0.6 M_\odot$ and the isochrones from Baraffe et al. (1998) for $M \leq 0.6 M_\odot$. We have built integrated spectra of SSPs for $[\text{M/H}] = -0.5, 0.0, +0.5$ and two different IMF slopes: $x = 1.35$ (Salpeter) and $x = 2.0$ (dwarf enriched). In Figure 1 we show examples of the computed spectra in the wavelength range $\lambda 6000$–10200, normalized at $\lambda = 8157$ Å and convolved with a Gaussian of FWHM = 9 Å for a range of ages (Fig. 1a), metallicities (Fig. 1b), and IMFs (Fig. 1c). As expected, NIR features are stronger in the more metal-rich and older SSPs, since their spectra are dominated by the cooler and redder stars. With a higher contribution of M dwarfs to the integrated light (Fig. 1c), the spectrum becomes somewhat redder.

In order to test our SSP integrated spectra, we have (1) compared results obtained with Padova and Geneva isochrones, and (2) applied our calculations to the metal-rich globular cluster NGC 6553, as described below.

![Figure 1](image-url)

**Fig. 1.**—Synthetic spectra in the wavelength range $\lambda 6000$–10200 for (a) Salpeter IMF, $[\text{M/H}] = 0.0$, and ages of 3 Gyr (solid line), 8 Gyr (dashed line), and 13 Gyr (dotted line); (b) Salpeter IMF and $[\text{M/H}] = -0.5$ (solid line), 0.0 (dashed line), and +0.5 (dotted line), normalized at $\lambda = 8170$ Å; (c) $[\text{M/H}]$ and IMF index $x = 1.35$ (solid line) and 2.0 (dashed line).
2.2.1. Geneva versus Padova Isochrones

We checked the results we had obtained with the Padova isochrones by using the isochrones from the Geneva group (Schaller et al. 1992, as given in CD-ROM by Leitherer et al. 1996) for stars with $M > 0.6 M_\odot$ to compute the integrated spectrum of a 13 Gyr old SSP with solar metallicity and Salpeter IMF. For lower masses, we use the isochrones of Baraffe et al. in all cases. In Figures 2 and 3 we compare, respectively, the Geneva and Padova isochrones and the corresponding integrated spectra (normalized at $\lambda = 8170 \, \text{Å}$).

From Figure 2 it can be seen that the Geneva and Padova isochrones present differences in the red giant branch (RGB). In the Geneva isochrones, first-ascent giant branch stars are systematically cooler ($\sim 100$ K) than in Padova isochrones, while, in the red giant tip, Geneva isochrones are much hotter and brighter (for a given $T_{\text{eff}}$) than Padova isochrones. The coolest red giant stars in the Geneva isochrone have $T_{\text{eff}} \sim 3300$ K, while in the Padova isochrone, red giants can be as cool as $T_{\text{eff}} \sim 2600$ K.

In spite of these large differences in the isochrones, the integrated spectra look remarkably similar in Figure 3. The integrated spectrum computed from the Padova isochrones is brighter than the Geneva one by less than 5% in both ends of the interval. By looking at Figure 11 of SB99, these small differences can be explained by the fact that stars from the tip of the red giant branch (stars later than M4), which are cooler in the Padova isochrones, dominate the integrated light of old SSPs at $\lambda \gtrsim 8500$ Å, while stars from the warmer part of the RGB (spectral types from mid-K to early-M), which are cooler in the Geneva isochrones, are dominant in the bluer part of the spectral interval under study. The differences in the studied indices are small (<10% in equivalent width) except for the Wing-Ford band, for which a 30% difference in equivalent width is found, because of the sensitivity of this feature to the temperature of RGB tip stars.

The fact that we obtain such small spectral differences suggests the existence of a mutual compensation between the above-mentioned differences in the isochrones.

2.2.2. The Metal-rich Globular Cluster NGC 6553

Our decision to adopt the Padova set of isochrones is based on our recent study of the $T_{\text{eff}}$ scale of M giants in the bulge metal-rich globular cluster NGC 6553 (SB99). The metallicity of NGC 6553 found in the literature ranges from $-0.70 < [\text{Fe/H}] < +0.47$ (see Table 5 in Barbuy et al. 1999). High-resolution spectroscopy tends to give lower values: $-0.7 < [\text{Fe/H}] < -0.2$, whereas integrated photometry or spectroscopy give higher values: $-0.33 < [\text{Fe/H}] < +0.47$. Rutledge, Hesser, & Stetson (1997) give $[\text{Fe/H}] = -0.18$ or $-0.60$ depending whether they use the metallicity scale of globular clusters by Zinn & West (1984) or the one by Carretta & Gratton (1997). Barbuy et al. (1999) obtained $[\text{Fe/H}] \approx -0.55$ and $[\alpha/\text{Fe}] \approx +0.4$, which would explain the discrepancy between results obtained from high-resolution measurements of Fe lines and integrated spectra where lines of Fe and $\alpha$ elements together give $[Z/Z_\odot] \approx 0.0$. Cohen et al. (1999), on the other hand, obtained $[\text{Fe/H}] \approx -0.2$ and $[\alpha/\text{Fe}] \approx 0.2$. In terms of our present purposes, since the spectra are dominated by the M giants, whose spectra are in turn dominated by TiO bands, and given that both Ti and O are $\alpha$ elements, the use of an overall metallicity of $[\text{M/H}] \approx 0.0$ is in agreement with the above two results (Barbuy et al. 1999; Cohen et al. 1999).

The $T_{\text{eff}}$ scale inferred by SB99 for NGC 6553, based on TiO bands, is more compatible with the temperature values in the Padova isochrones, which in particular have a more extended RGB tip; the extension of the RGB of NGC 6553 can be seen in Bruzual et al. (1997) and Guarnieri et al.
(1998). Moreover, in a study of the $T_{\text{eff}}$ values of M giants from NGC 6528 (another metal-rich globular cluster from the Galactic bulge, see Ortolani et al. 1995), we determined $T_{\text{eff}} = 3000$ K for a bona fide M giant of this cluster, which is 300 K cooler than the lowest $T_{\text{eff}}$ predicted by the Geneva isochrone (Schiavon et al. 2000, in preparation).

3. Na I Doublet, Ca II Triplet, FeH Wing-Ford Band, and TiO Bands in Single-Aged Stellar Populations

In this section we discuss the effects of metallicity and IMF upon NIR spectral indices commonly used for stellar population diagnosis in integrated spectra of galaxies and clusters (e.g., Cohen 1978, 1979; Delisle & Hardy 1992). The dependence of the TiO bands, Na I doublet, Ca II triplet, and the WFB on stellar atmospheric parameters has been studied in previous papers (Erdelyi-Mendes & Barbuy 1991; Milone & Barbuy 1994; Schiavon et al. 1997a, 1997b; SB99). In Table 1 we report the definition of the spectral indices used in this work, including TiO $\lambda$6600, Na I $\lambda$8190, Ca II $\lambda$8662, and the FeH WFB at $\lambda$9900, as given in the literature. In Table 2 we list the equivalent widths of the indices measured on the spectra of 13 Gyr old SSPs, as a function of metallicity and IMF, where convolutions with Gaussian profiles of FWHM = 9 and 25 Å were adopted. We note that two definitions of the Na I index are used: Na$_{a\beta}$ and Na$_{8597}$, as defined in Faber & French (1980, hereafter FF) and Schiavon et al. (1997a, hereafter S97a), respectively.

### Table 1

**Definition of Spectral Indices Measured**

| Index          | Blue Continuum | Bandpass | Red Continuum |
|----------------|----------------|----------|---------------|
| EW$_{6600}$    | 6512.1–6538.1  | 6617.2–6922.5 | 7036.9–7048.0 |
| EW$_{8190}$    | 8169.0–8171.0  | 8172.0–8209.0 | 8209.0–8211.0 |
| EW$_{8662}$    | 8171.5–8172    | 8172–8197    | 8233.5–8234.2 |
| EW$_{8662}$    | 8637.2–8646.2  | 8653.2–8668.4 | 8847.6–8854.0 |
| EW$_{WFB}$    | 9891.8–9895.1  | 9895.1      | 9958.6–9962.2 |

### Table 2

**Spectral Indices (Equivalent Widths in Angstroms) in Synthetic Single-Aged Stellar Populations of 13 Gyr, for Convolutions of 9 and 25 Å**

| [M/H] | $x$ | Na$_{a\beta}$ | Na$_{8597}$ | TiO$_{6600}$ | Ca$_{8662}$ | WFB |
|-------|-----|--------------|-------------|--------------|-------------|-----|
|       |     |              |             |              |             |     |
|       | 0.5 | 1.35         | 1.43        | 2.58         | 3.19        | 0.56|
|       | 0.5 | 0.85         | 0.90        | 1.00         | 1.20        | 0.80|
|       | +0.5| 2.0          | 2.10        | 2.50         | 2.70        | 2.00|
|       | 0.0 | 1.50         | 1.60        | 2.00         | 2.20        | 0.70|
|       |     |              |             |              |             |     |

#### 3.1. Ca II Triplet, TiO Bands, and FeH WFB

Figures 4a–4f show synthetic spectra of 13 Gyr old SSPs in the regions of the TiO band ($\lambda = 6600$ Å), the WFB ($\lambda = 9900$ Å), and Ca II ($\lambda = 8662$ Å). Figures 4a, 4c, and 4e correspond to the [M/H] = $-0.5$, 0.0, and +0.5 models for the Salpeter IMF, and Figures 4b, 4d, and 4f, to the [M/H] = $-0.5$ model for the Salpeter and the $x = 2.0$ IMF.

Figures 4a, 4c, and 4e show that the TiO bands are the most metallicity-sensitive feature under analysis. We restrict our discussion to the TiO$_{6600}$ band, since all bands of the same molecule have essentially the same behavior.

The WFB and the Ca II triplet are also very sensitive to metallicity and weakly sensitive to IMF variations. It has been suggested in the literature (Couture & Hardy 1993 and references therein) that the WFB and the Ca II triplet (Delisle & Hardy 1992; Jones, Alloin, & Jones 1984) are sensitive to the contribution of M dwarfs to the integrated spectrum. Our computations do not confirm this. Figure 4b shows a residual sensitivity of the TiO$_{6600}$ index to IMF variations, while the WFB (Figs. 4c and 4d) is only weakly IMF-sensitive, but its response to metallicity is much stronger, it being due to the contamination by TiO lines from the (2, 3) vibrational band of the δ system.

#### 3.2. The Na I Doublet

Figures 5a and 5b show spectra of 13 Gyr old SSPs in the region of the Na I $\lambda$8190 feature. Figure 5a corresponds to the [M/H] = $-0.5$, 0.0, and +0.5 models for the Salpeter IMF, and Figure 5b, to the [M/H] = $-0.5$ model for the Salpeter and the $x = 2.0$ IMF.

Figures 5a and 5b show that the Na I doublet is by far the most IMF-sensitive index studied here. The Na$_{8597}$ index displays a strong dependence on IMF (Table 2). It also shows a dependence on metallicity. Moreover, the Na I doublet is contaminated by TiO lines (which are very sensitive to metallicity) at the red side of the feature.

It has been suggested in the literature (Cohen 1978; Xu et al. 1989; Alloin & Bica 1989; Terndrup, Frogel, & Whitford 1990; Delisle & Hardy 1992) that the Na I doublet is more sensitive to metallicity than to IMF variations. Figures 5a and 5c show that the Na I lines are indeed strongly sensitive
Fig. 4.—Synthetic spectra for single-aged stellar populations with 13 Gyr, a Salpeter IMF, and \([M/H] = -0.5\) (solid lines), 0.0 (dashed lines), and +0.5 (dotted lines) for the features (a) TiO\(_{6600}\), (c) WFB, and (e) Ca II triplet; and synthetic spectra for SSPs of \([M/H] = -0.5\) for Salpeter (solid lines) and dwarf-enriched (dashed lines) IMFs for (b) the TiO\(_{6600}\), (d) WFB, and (f) Ca II triplet.

Fig. 5.—Synthetic spectra of the Na I feature for SSPs of 13 Gyr, Bertelli et al. (1994) isochrones, and (a) Salpeter IMF and \([M/H] = -0.5\) (solid line), 0.0 (dashed line), and +0.5 (dotted line); (b) \([M/H] = -0.5\) and IMF index \(x = 1.35\) (solid line) and 2.0 (dashed line).
to metallicity. However, the Na\textsubscript{I} index, as defined in the literature (Table 1), has its metallicity sensitivity reduced by the TiO lines that contaminate the red continuum window, which is thus lowered in the spectra of metal-rich stellar populations.

Figure 5 and the values in Table 2 suggest that the Na\textsubscript{I} index is very sensitive to IMF. In Figure 6 the equivalent widths of Na\textsubscript{I}, according to the definitions by FF and Schiavon et al. (1997a), and Ca\textsubscript{II} lines (both normalized by the values corresponding to a SSP of 13 Gyr, solar metallicity, and Salpeter IMF) are plotted against the exponent of a power-law IMF for different metallicities and an age of 13 Gyr. The Na\textsubscript{I} index, in both definitions, is as sensitive to IMF as to metallicity. We therefore conclude that the possibility that an enhancement of the Na\textsubscript{I} lines may be due to a dwarf-enriched IMF cannot be excluded. An uncertainty in metallicity of $\pm 0.25$ dex translates into an uncertainty of $\pm 0.5$ for $x > 1$, and $\pm 1$ for $x < 1$; therefore, the use of the Na\textsubscript{I} doublet as an IMF indicator requires narrow constraints on the average metallicity of the stellar population.

Figure 5 suggests that in the integrated spectra of galaxies, where lines are broadened by stellar velocity dispersion, IMF and metallicity effects may be distinguished by their different influence on the line shape, as proposed by Boroson & Thompson (1991). A higher metallicity leads to a profile with a deeper red side, while a profile with a deeper blue side can be due to either a stronger metallicity or a dwarf-enriched IMF.

### 3.3. Sensitivity of the Features to Age

In Table 3 are given computed synthetic indices convolved with FWHM $= 25$ Å for single-aged stellar populations as a function of age and metallicity, for a Salpeter IMF, adopting a convolution of FWHM $= 25$ Å.

| Age (Gyr) | [M/H] | Na\textsubscript{FF} | Na\textsubscript{S97} | TiO\textsubscript{6600} | Ca\textsubscript{8662} | WFB |
|----------|-------|----------------------|----------------------|----------------------|----------------------|-----|
| 3        | -0.5  | 0.532                | 0.578                | 0.379                | 0.749                | 0.339 |
| 5        | -0.5  | 0.634                | 0.633                | 0.377                | 0.644                | 0.381 |
| 6        | -0.5  | 0.676                | 0.663                | 0.387                | 0.689                | 0.393 |
| 8        | -0.5  | 0.723                | 0.691                | 0.397                | 0.691                | 0.391 |
| 10       | -0.5  | 0.799                | 0.736                | 0.385                | 0.599                | 0.411 |
| 12       | -0.5  | 0.886                | 0.773                | 0.326                | 0.717                | 0.379 |
| 13       | -0.5  | 0.925                | 0.796                | 0.345                | 0.663                | 0.394 |
| 15       | -0.5  | 0.992                | 0.832                | 0.341                | 0.748                | 0.407 |
| 17       | -0.5  | 1.073                | 0.878                | 0.319                | 0.640                | 0.401 |
| 3        | 0.0   | 0.422                | 0.660                | 0.809                | 0.926                | 0.884 |
| 5        | 0.0   | 0.558                | 0.739                | 0.864                | 0.993                | 0.886 |
| 6        | 0.0   | 0.647                | 0.788                | 0.893                | 1.037                | 0.961 |
| 8        | 0.0   | 0.698                | 0.828                | 0.928                | 0.955                | 0.975 |
| 10       | 0.0   | 0.784                | 0.879                | 0.971                | 0.946                | 1.020 |
| 12       | 0.0   | 0.888                | 0.940                | 0.970                | 0.908                | 1.019 |
| 13       | 0.0   | 1.000                | 1.000                | 1.000                | 1.000                | 1.000 |
| 15       | 0.0   | 1.077                | 1.034                | 0.945                | 0.891                | 0.957 |
| 17       | 0.0   | 1.071                | 1.043                | 1.058                | 1.016                | 1.010 |
| 3        | 0.5   | 0.530                | 0.813                | 0.892                | 1.178                | 1.005 |
| 5        | 0.5   | 0.673                | 0.900                | 0.994                | 1.174                | 1.163 |
| 6        | 0.5   | 0.775                | 0.966                | 1.128                | 1.193                | 1.264 |
| 8        | 0.5   | 0.912                | 1.038                | 1.139                | 1.276                | 1.246 |
| 10       | 0.5   | 0.973                | 1.078                | 1.237                | 1.080                | 1.280 |
| 12       | 0.5   | 1.220                | 1.214                | 1.303                | 0.895                | 1.364 |
| 13       | 0.5   | 1.315                | 1.272                | 1.367                | 1.150                | 1.436 |
| 15       | 0.5   | 1.353                | 1.299                | 1.467                | 1.164                | 1.514 |
| 17       | 0.5   | 1.406                | 1.325                | 1.403                | 1.051                | 1.353 |
FIG. 7.—Indices for TiO$_{6600}$, WFB, Na I, and Ca II, measured on the spectra of single-aged stellar populations as a function of age (in gigayears) for [M/H] = −0.5 (solid lines) and 0.0 (dotted lines). Equivalent widths are normalized to the value corresponding to a SSP with solar metallicity 13 Gyr and a Salpeter IMF.

populations for ages 3 Gyr < age < 17 Gyr and −0.5 < [M/H] < +0.5 for a Salpeter IMF.

In Figure 7 we plot the four indices versus the ages of SSPs for [M/H] = −0.5 and 0.0. It appears that the TiO band, the Ca II triplet, and the WFB are essentially insensitive to age. Note the strong metallicity dependence of the TiO bands. The Na I doublet is very sensitive to age, as well as to the IMF slope and metallicity, which makes the behavior of this feature quite complex. It is of interest to explore indices such as TiO bands and the Ca II triplet to help disentangle the age-metallicity degeneracy in composite stellar populations.

4. SUMMARY

We have built high-resolution synthetic spectra of SSPs in the wavelength range 7600–10200 for SSPs of [M/H] = −0.5, 0.0, and +0.5 and IMF index x = 0.1–2.0. The basic ingredients for such SSP models are the isochrones by Bertelli et al. (1994) and Baraffe et al. (1998), combined with a grid of synthetic spectra computed for a wide range of stellar parameters (SB99).

In order to make our computations useful for observers, we present a table of TiO $\lambda$6600, Na I $\lambda$8190, Ca II $\lambda$8662, and the FeH WFB at $\lambda$9900 indices in single-aged stellar populations, as a function of metallicity, IMF, and age.

The main conclusions of this paper are the following:

1. The TiO bands, the Ca II triplet, and the WFB are very sensitive to metallicity and essentially invariant with IMF and age.

2. The Na I doublet is far more intense for a dwarf-enriched IMF than for the Salpeter IMF, and the feature is also affected by metallicity and age variations.

3. The better understanding of the NIR indices as functions of metallicity, age, and IMF obtained through the present spectrum synthesis computations, provides us with tools that, combined with optical indices, can help disentangle the age-metallicity-IMF degeneracy in composite stellar systems.

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