Grids of synthetic spectra for the GAIA mission

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Abstract. Two sets of grids of Kurucz ATLAS 9 model spectra are presented. The first one covers the GAIA spectral interval, while the second one which is still being computed covers the whole range from 2500 – 10500 Å. Both grids include parameters needed for realistic spectral simulation, e.g. stellar rotation and are computed at $R = 20000$ and lower spectral resolutions. They can be useful for preparation of the GAIA and RAVE missions and also for a general radial velocity correlation work.

1. Introduction

GAIA mission will observe an unprecedented number of stars and will set a new standard reference in stellar photometry and spectroscopy. Preparations for such a mission need to build on a vast body of observed and synthetic spectra. On one hand the spectra should cover the baselined GAIA spectral interval (8490 – 8750 Å) at different resolutions and spectral samplings. But the wavelength range of ground-based Echelle spectrographs is much wider. Synthetic spectra covering the whole range from the near-UV to the near-IR can be useful for general radial velocity correlation work. They can also help to optimize the scientific output of broad and narrow-band photometric filters aboard GAIA (Jordi 2002).

Observed spectra of normal stars in the GAIA spectral interval were presented by Munari & Tomasella (1999). The first grid of Kurucz synthetic spectra was published by Munari & Castelli (2000) and Castelli & Munari (2001). Here we report on the ongoing effort to expand this theoretical grid using the same sets of abundancies and atomic constants.
2. Spectra in the GAIA spectrograph wavelength range

Synthetic spectra are needed as templates for measurement of radial velocity by correlation techniques (Zwitter 2002). But another use may be less obvious and equally important. Virtually all spectra obtained by GAIA will suffer from overlaps of faint spectral tracings of neighboring stars (Zwitter & Henden 2002). Most of the overlappers will be too faint to recover their spectrum from GAIA observations. So one will have to rely on photometric classification of the overlapping stars and a proper synthetic spectra database to generate a combined spectrum of the overlapping background stars, subtract it from the studied spectrum and finally analyze it (Zwitter 2002a). One could therefore refer to the synthetic spectra database as a critical part of the data reduction code, as no information could be extracted from the spectrograph without subtraction of the calculated background signal.

Most of the GAIA stars will be normal stars of spectral types G and K (Zwitter & Henden 2002). Thus Kurucz ATLAS 9 stellar atmosphere models can be used as an initial approach to synthetic grid calculation. They are also adequate for instrument and reduction procedure planning. We note that non-LTE effects, presence of dust at low temperatures and other peculiarities need to be taken into account in certain cases (Hauschildt 2002).

The primary goal of the GAIA spectrograph is to measure radial velocities. Moreover, the spectra can be used to calculate or confirm the effective temperature, gravity and metallicity of observed stars and so supplement the photometric results. Finally, in the case of bright targets and provided that spectral resolution is high-enough, the GAIA spectra can also be used to obtain abundances of individual elements, measure stellar rotation and explore spectral peculiarities (Munari 2002; Thevenin 2002; Gomboc 2002).

Table 1. Grid of spectra in the GAIA spectrograph wavelength range. Some models were calculated also for an α-enhanced composition.

| parameter | min   | max    | step  | comment                                    |
|-----------|-------|--------|-------|--------------------------------------------|
| $T_{\text{eff}}$ | 3500 K | 50000 K | 250 K | larger steps for $T_{\text{eff}} > 10000$ K |
| log $g$   | 0.0   | 5.0    | 0.5   | till 4.0 for hot stars                      |
| [Z/$Z_\odot$] | -3.5  | +0.5   | 0.5   |                                             |
| $v_{\text{rot}} \sin i$ | 0 km/s | 500 km/s |        | 14 values for O-F stars                    |
| $R$       | 5000  | 20000  |       | 5000, 10000, 20000                         |

With these goals in mind we generated a grid of synthetic spectra based on the Kurucz ATLAS 9 models computed for a microturbulent velocity of 2 km s$^{-1}$, a mixing-length convection with parameter $l/H = 1.25$ and no overshooting. The spectra were computed with the SYNTHE code from Kurucz and cover the spectral range 8490-8750 Å of the GAIA RVS spectrograph. Details on the database computation will be published elsewhere (Zwitter et al. 2003, in preparation). Table 1 gives the ranges of the spectral grid parameters.
Apart from the basic quantities ($T_{\text{eff}}$, $\log g$ and $[Z/Z_\odot]$) we include additional dimensions, i.e. rotational velocity ($v \sin i$) and spectral resolution ($R$). Thus the spectral tracings are ready to be included in realistic GAIA simulations. Altogether the database now consists of $\sim 2 \times 10^5$ spectra.

3. Spectra from the near ultraviolet to the near infrared

Recent advances in storage space and computing power permit a calculation of a database of spectra covering the 2500 Å to 10500 Å wavelength range. It was computed with Kurucz’s codes at a resolution of $R = 500000$ and degraded to $R = 20000$, i.e. the one typical for Echelle spectrographs. The spectra can be used for general radial velocity correlation work. Moreover the radial velocity solutions based on the GAIA spectral interval can be compared to the velocities extracted from the whole wavelength range. Such spectra can be also degraded to lower resolutions and so of interest for optimization of the scientific output from the GAIA’s narrow and broad band photometric observations.

In Table 2 we report on the grid calculated so far, which covers the most common stars to be observed by GAIA.

Figure 1 compares an observed and synthetic spectrum of an A5 V star. The observed spectrum was obtained by combining several observed standard star spectra (Pickles 1998) and has a resolution of 500 sampled at 5 Å wavelength bins. The calculated spectrum was resampled to the same resolution and
Figure 2. Blue part of the synthetic spectrum with $T_{\text{eff}} = 8250$ K, $\log g = 4.0$, solar composition and resolution $R = 20000$. Numbers on the right give the central wavelength and those on the left the maximum flux in each window. The lower limit of the ordinate is always zero.
Figure 3. Red part of the synthetic spectrum from Fig. 2.
Table 2. Grid of spectra with $R = 20000$ for the 2500 Å < $\lambda$ < 10500 Å range. They can be degraded to any lower resolution.

| parameter | min   | max   | step | comment               |
|-----------|-------|-------|------|-----------------------|
| $T_{\text{eff}}$ | 5250 K | 10000 K | 250 K |                       |
| log $g$   | 0.0   | 5.0   | 0.5  |                       |
| $[Z/Z_0]$ | -3.5  | +0.5  | 0.5  |                       |
| $v_{\text{rot}} \sin i$ | 0 km/s | 500 km/s |       | 14 values for O-F stars |
|           |       |       |      | 11 values ≤ 100 km/s for G-M |

sampling. It was not optimized to match the observed one, still the differences are small. Figures 2 and 3 show the same calculated spectrum at full resolution ($R = 20000$).

4. Conclusions

The grid of synthetic spectra based on the Kurucz models and covering the GAIA spectral interval 8490-8750 Å is almost complete. The computation of the other grid with full wavelength coverage is still being done. We note that these spectral databases should be useful for the GAIA as well as the forthcoming RAVE missions, and also for general tasks of radial velocity correlations.

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