Mem. S.A.It. Suppl. Vol. 8, 197

Memorie della
Supplementi

SYNTHE spectral calculations matched to high-resolution UV/optical observations

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Abstract. Progress is shown in matching SYNTHE spectral calculations to the observed high-resolution spectra of standard stars. In the mid-UV these are the Sun, Procyon, and solar-type stars ranging in metallicity. Redward of 3000Å, the K giant Arcturus is added. In the mid-UV, from 2300Åto 3000Å, good reproduction of individual spectral absorption lines in solar-type stars is achieved to an iron abundance [Fe/H] = –0.5. At higher metallicities, many atomic lines appear which are unidentified in the laboratory and so are missing from the calculations. We are fixing this with STIS echelle spectra already in hand. In the near-UV, 3000Å– 3800Å, good agreement is found at solar metallicity for solar-type stars, but missing atomic lines pose problems for Arcturus. In the optical, the fit to Arcturus is not good from 4090Åto about 4500Å, due to lines of the molecule SiH, whose wavelengths are poorly known. Beyond 4500Å, excellent agreement is seen in regions of low to moderate telluric molecular absorption, for all stars considered.

Key words. Stars: abundances – Stars: atmospheres – Stars: abundances

1. Background

My NASA Long-Term Space Astrophysics and Hubble Treasury programs, now in their third year, aim to provide theoretical templates for interpreting the age, metallicity, and populations of galaxies and stellar clusters as young as 1 Gyr from their ultraviolet (UV) and optical spectra. The first task is to calculate stellar spectra as precisely as possible. The first two years were designed to improve the list of line parameters input to spectral calculations, to the point where the spectra of stars of F type and later can be reproduced reliably line-by-line. This paper presents the status of this effort. This work will provide both theoretical and observations products to the community through the Space Telescope Science Institute's MAST archive service at http://archive.stsci.edu. The theoretical products will include extensive grids of spectral calculations, as well as high-resolution atlases comparing calculations to standard stars. Shown here are several atlas comparisons.

2. Observational Data

To improve the spectral calculations and to ensure their validity, we match calculations to real spectra of standard stars. Improvements are best done using spectra of high resolution and high signal-to-noise covering as wide

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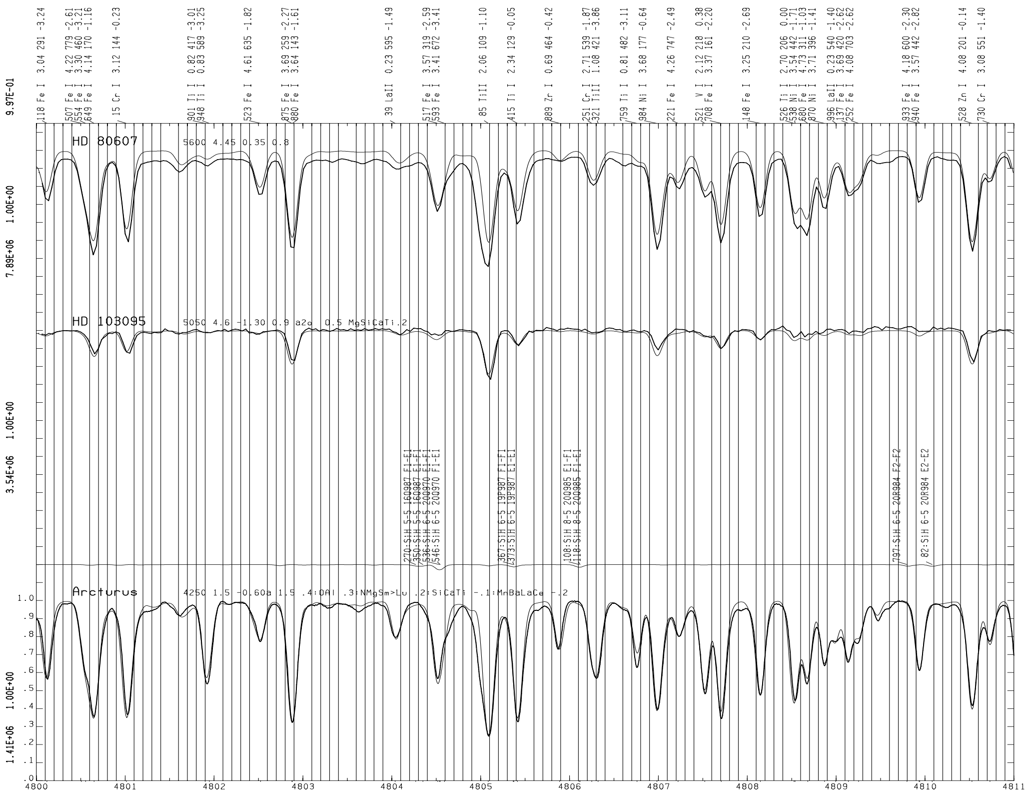

Fig. 1. Example of a portion of the spectra of Arcturus, HD 103095 and HD 80607 and their matching synthetic spectra.

a spectral range as feasible. In the ultraviolet (2200Å to 3150Å), the Treasury program obtained about a dozen echelle spectra for standards such as Procyon with the Space Telescope Imaging Spectrograph (STIS), missing only three strong-lined stars before its failure. For the Sun itself, we use the two rocket-based spectral scans of the center of the solar disk, of moderate quality. In the optical, for the Sun we adopt the Kurucz (1984) solar flux atlas. For Arcturus we have used the version of Hinkle et al. (2000) (3727Å–9300Å) with the continuum rectified and telluric absorption removed. For Procyon, we are renormalizing the continuum of the high-quality spectrum obtained with the Ultraviolet Echelle Spectrograph (UVES) by Bagnulo et al. (2003). For a Procyon spectrum which fills in the UVES gaps, and for optical echelle spectra of other stars, we rely on high-quality spectra from Lick and Keck observatories.

3. Procedure

Our procedure is detailed by Peterson et al. (2001). We synthesize standard spectra, beginning with weakest-lined stars and the Kurucz laboratory line list. We change input atomic line parameters based on mismatches, then recalculate the stellar spectra. Once gf's are revised, we add missing lines, first seeking candidates from the lab line list. We repeat all calculations and comparisons, iterating until a satisfactory match is achieved with the same set of gf values for all stars simultaneously. We assume local thermal equilibrium (LTE), and adopt the ODFNEW models of Castelli & Kurucz (2003). We first redetermine the standards' parameters by demanding matches for all stars in the profiles of strong lines and Hα as well as in the weak-line strengths and in mid-UV flux levels. Our Arcturus and Procyon values determined in this way agree well with recent results. The missing lines we add as Fe I, or Ti I if the feature is stronger in HD 184499 than HD 157466. Their line strengths are similar, but HD 184499 has the typical halo $\alpha-$element enhancement, while the disk star HD 157466 has scaled-solar abundances.

4. Plots of atlases

Plots are shown comparing our theoretical spectra (light black line) with observational echelle spectra (heavy black line). In color appear theoretical calculations for a single element only. Wavelength in Å appears at the bottom, and Y-axis ticks represent 10% of the full scale. Stars are offset for visibility. Identifications for the strongest lines appear at the top. The values are (1) the decimal digits of the wavelength in Å, (2) a colon if it is a missing Fe I line, (3) the species and its excitation potential in electron volts (or band), and (4) the residual intensity in the solar or Arcturus spectrum. Next to each star's name are best-fit model parameters $T_{\rm eff}$, log g, [Fe/H] (log of the stellar-to-solar iron abundance ratio), and microturbulent velocity in km s^{-1}. In the mid-UV, a single flux normalization constant is adopted at all wavelengths. This is possible because the STIS spectra are fluxed. It provides a critical constraint on the modeling. We find a normalization constant for Procyon that is 8.5% larger than that implied by its angular diameter, marginally consistent with the current accuracy of STIS spectroscopic fluxes.

Acknowledgements. We thank Dr. Kurucz and Dr. Castelli for making their atlases, line lists and model grids available. By the kind permission of the Astronomical Society of the Pacific Conference Series, we plot the Arcturus data from Hinkle et al. (2000). We thank the STScI TAC for its allocation of observing time to the Treasury program. We thank the UVES Paranal Observatory Project for making its spectra of Arcturus available. We are indebted to Jon Fulbright, Debra Fischer, Steve Vogt, Mike Bolte, and Jennifer Johnson for generously contributing their spectra towards this end. This work has been supported by grants from the Space Telescope Science Institute (GO 9455/9974/10094) and the NASA Long-Term Space Astrophysics program.

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