# Spectral Analysis in the Virtual Observatory

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## Abstract

In a collaboration of the German Astrophysical Virtual Observatory (GAVO) and AstroGrid-D, the German Astronomy Community Grid (GACG), we provide the VO service *TheoSSA* for the access and the calculation of stellar synthetic energy distributions (SEDs) based on static as well as expanding non-LTE model atmospheres.

However, the determination of stellar parameters within a spectral analysis is commonly still done in the “classical way”, where the astronomer's experience ($\chi^2$ by eye) decides about the “best fit”.

An extension of *TheoSSA* will offer a service to perform an automatical classification based on pre-calculated template SEDs. This will be an option for multi-object spectroscopy that changed the observation technique from obtaining a few single spectra per night to receiving some hundreds in the same exposure time. In addition, preliminary spectral analysis based on individually calculated SEDs will be possible.

We present our concept and the progress in preparatory work.

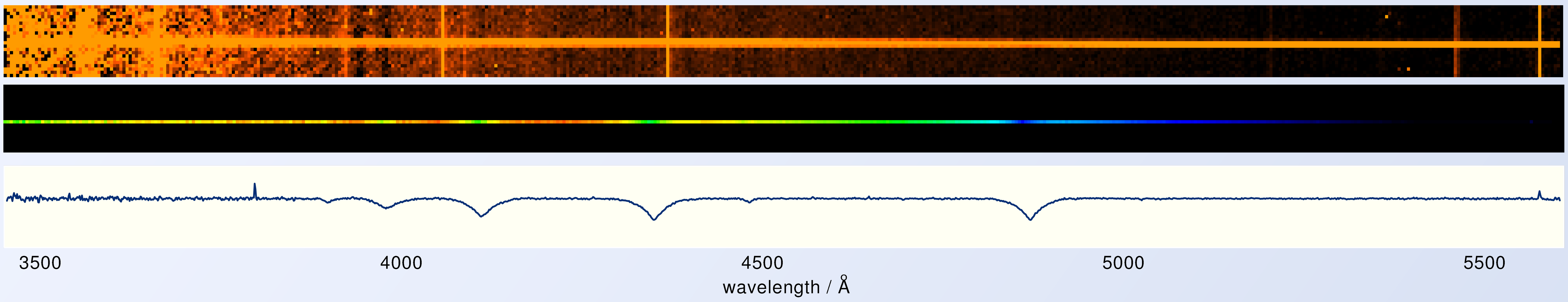


Fig. 1: Spectrum of a DA white dwarf on the CCD chip (upper box), on the star trace (middle), and extracted (lower box).

## “Classical” Spectral Analysis

In a “classical” spectral analysis, the analyzer determines the parameters, according to his experience and personal view. He is doing a $\chi^2$ fit by eye. Thereby the ionization equilibria are used to determine $T_{\mathrm{eff}}$, the line wings provide information about log $g$ and the equivalent widths are indicative of the abundances.

This is an important way to analyze spectra and perhaps, depending on the experience of the astronomer, can not be replaced by an automated analysis. But the machine-aided one can provide a first classification of spectra that can simplify the “classical” analysis a lot.

## *TheoSSA, TMAP,* and HotBlast

To perform spectral analyses, our working group uses our Tübingen NLTE Model-Atmosphere Package (*TMAP*) and the wind code HotBlast.

With *TMAP (*http://astro.uni-tuebingen.de/~rauch/TMAP/TMAP.html*),* model atmospheres for hot, compact objects with effective temperatures between 20 000 K and about 200 000 K and surface gravities from log $g = 4$ to 9 can be calculated. *TMAP* uses a so-called Accelerated Lambda Iteration (ALI) and it considers about 1000 NLTE levels and hundreds of millions of lines.

HotBlast takes *TMAP* models as an input and calculates expanding stellar atmospheres. Therefore it is used to model stellar wind lines.

The VO service *TheoSSA* provides already calculated SEDs (http://vo.ari.uni-tuebingen.de/ssatr-0.01/TrSpectra.jsp?). At the moment the SEDs were computed with *TMAP*, but we will include HotBlast SEDs in the next step. *TheoSSA* can also be complemented by other SEDs if they are provided.

*TheoSSA* is an important tool for everybody, non professionals included, to perform spectral analysis. To support analyzers further, we want to develop the following new tools and services.

We will create a Java applet where uploaded observations can be compared with a selected grid of, e.g., H+He models. With scrollbars $T_{\mathrm{eff}}$, log $g$, the H/He ratio, wavelength range, and the flux level will be adjusted.

For a more detailed analysis an uploaded observation can be compared to grids including C, N and O additionally. In this way analyses with an accuracy of about 20 % can be performed.

An even better accuracy (about 5 %) can be achieved calculating more individual spectra with the *TMAP* web interface (*TMAW*, http://astro.uni-tuebingen.de/~TMAW/TMAW.shtml). With this service it is also possible to request grids of SEDs.

## Compute Resources

AstroGrid-D (www.gac-grid.de/) is an institution to provide compute power, storage, and the like. It was established in 2005 and was run until 2009. With the Globus Toolkit registered users are able to use the AstroGrid-D tools.

If the number of via *TMAW* requested SEDs is larger than 64, the grids are calculated with compute resources of AstroGrid-D. In this way even huge requests can be processed within a small period.

## Multi-Object Spectroscopy

With Multi-Object Spectroscopy thousands of spectra are obtained within a short time. To handle the amount of observations automated spectral analysis is needed to make a first classification and a coarse analysis. We want to create a service doing this in two stages:

At first, template SEDs are used. Therefore pre-calculated H+He grids available via *TheoSSA* will be employed for a first classification, e.g DA-/ non-DA. The input will be single observations or lists of observations and two lists containing files of DA- and non-DA spectra will be the response.

In the second step more individual fitting will be done. After the lists with DA and non-DA spectra are created, a determination of $T_{\mathrm{eff}}$ and log $g$ with an accuracy of about 20 % is possible. Therefore a $\chi^2$ fit and a neural network are advantageous.

## *TMAD* and *IrOnIc*

We also provide access to the model-atom database *TMAD* which was extended over the years. For the elements H-Ca ready-to-use model atoms are provided, including level energies and radiative and collisional transition data for all ionization stages. Therefore, it can be used for every code although its format was created for *TMAP*. All the model-atom data can be downloaded and individually modified.

Because the number of levels of iron-group elements exceeds the possibilities of *TMAP*, a statistical treatment is necessary. This is implemented in *IrOnIc* (Iron Opacity and Interface) which divides the energy range into several bands with a superlevel (NLTE). By now it needs 3-4 days to calculate a model-atom for iron-group elements. We will create a new, fully parallel version of *IrOnIc* that needs only a few hours and can be controlled via a web interface.

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