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 a VO service for the access and the calculation of stellar synthetic energy distributions (SEDs) based on static as well as expanding non-LTE model atmospheres.

At three levels, a VO user may directly compare observed and theoretical SEDs: The easiest and fastest way is to use pre-calculated SEDs from the GAVO database. For individual objects, grids of model atmospheres and SEDs can be calculated on the compute resources of AstroGrid-D within reasonable wallclock time. Experienced VO users may even create own atomic-data files for a more detailed analyses.

Key words: stars: atmospheres; Virtual Observatory.

1. INTRODUCTION

Spectral analysis of hot, compact stars by means of Non-LTE (local thermodynamic equilibrium) model-atmosphere techniques has for a long time been regarded as a domain of specialists. In contrast to the assumption of LTE, where occupation numbers of atomic levels are determined by Saha equation and Boltzmann statistics, radiative and collisional transitions have to be considered in detail (see, e.g., Werner \textsuperscript{[1985]}. This makes the calculation of an elaborated model and its spectral energy distribution (SED) time-consuming, although it can be performed on presently available PCs. Faster and easier is the use of blackbody SEDs, tempting, e.g., old-fashioned users of photoionization codes to use such for the (bad) representation of the exciting source of an ionized gaseous nebula – spoiling the advantages of the best of these codes.

Within the last four decades, Non-LTE model-atmospheres arrived at a high level of sophistication: fully line-blanketed models consider opacities of all elements from H to Ni (Rauch \textsuperscript{[2003]} Rauch et al. \textsuperscript{[2007]}). Within the GAVO\textsuperscript{[3]}, we provide access to SEDs of such models (Sect. 2).

In general, spectral analysis requires grids of SEDs over a wide parameter range (effective temperature \(T_{\text{eff}}\), surface gravity \(g\), element abundances). Since their calculation may exceed the available capabilities, model atmosphere calculations are performed on compute resources of AstroGrid-D.

2. THEOSSA – MODEL SED ON DEMAND

We have created the VO service TheoSSA (Theoretical Simple Spectra Access\textsuperscript{[4]}). At three levels it provides access to SEDs that are in a pilot phase calculated by the Tübingen Model Atmosphere Package TMAP\textsuperscript{[5]} (Werner et al. \textsuperscript{[2003]} Rauch & Deetjen \textsuperscript{[2003]} for hot, compact stars only:

\begin{itemize}
  \item \textbf{Fast and Easy} An unexperienced VO user (no detailed knowledge about the model-atmosphere code necessary) may use pre-calculated SEDs, interpolate in between.
  \item \textbf{Individual} An interested VO user can calculate own SEDs for the analysis of special objects.
  \item \textbf{ Experienced} The VO user can define own model atoms and upload them for the comparison with other codes, etc.
\end{itemize}

Figure \textsuperscript{1} shows the scheme of the dataflow within TheoSSA. If individual parameters are requested by a VO user, the GAVO database is checked for suitable SEDs (parameters match within error limits). If there is

\textsuperscript{1}http://www.g-vo.org
\textsuperscript{2}http://vo.ari.uni-heidelberg.de/ssatr-0.01/TrSpectra.jsp
\textsuperscript{3}http://astro.uni-tuebingen.de/~rauch/TMAP/TMAP.html
no match, the VO user is guided to TMAW\cite{4}. With this WWW interface, the VO user may calculate an individual model atmosphere, requesting effective temperature, surface gravity, and mass fractions of H, He, C, N, and O (more species will be included in the future). For this calculation, standard model atoms are used which are provided within the Tübingen Model-Atom Database TMAD\cite{5}. Since the VO user can do this without detailed knowledge of the programme code working in the background, the access to individually calculated SEDs is as simple as the use of pre-calculated SEDs – however, the calculation needs some time (depending on the number of species considered, the wall-clock time is ranging from hours to a few days). Standard SEDs of all calculated model atmospheres are automatically ingested into the GAVO database and, thus, it is growing in time.

If a detailed spectral analysis is performed, an experienced VO user may create an own atomic data file tailored for a specific purpose considering all necessary species and calculate own model atmospheres and SEDs. Using the Globus Toolkit (GT4) middleware, AstroGrid-D embeds existing computational facilities, dedicated resources and specialized hardware, such as robotic telescopes. Almost a hundred users from the German astronomical community use its compute and storage facilities. The project also resulted in several scientific applications and novel Grid services, such as the information service Stellaris\cite{7}.

The TMAP model calculations are carried out on the resources of AstroGrid-D to ensure a reliable service, even for a high number of requests. For job submission, a script package is used that allows to submit jobs to computational resources automatically. This script package was originally developed for a different AstroGrid-D use case\cite{8}, but can be easily adopted to other implementations of so-called atomic grid jobs. The term refers to a specific type of grid application, where all input data is transferred together with the software without need for inter-process communication. The grid is thus used as a task farming mechanism. But even if this is only a comparatively simple application for the use of the flexible GT4 middleware, we found task farming to be an important requirement of many use cases, such as TMAP.

The transfer of the TMAP model software and the input data, as well as the transmission of the results is part of the standard job submission process in Globus Toolkit. We make use of the GT4 web services and control the

\section{THEOSSA@GRID}

AstroGrid-D\cite{6} is a German research and development project to build an astronomical research infrastructure.

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\begin{itemize}
\item \cite{4}http://astro.uni-tuebingen.de/~TMAW/TMAW.shtml
\item \cite{5}http://astro.uni-tuebingen.de/~rauch/TMAD/TMAD.html
\item \cite{6}www.gac-grid.de/
\item \cite{7}http://stellaris.zib.de/
\item \cite{8}http://www.gac-grid.org/project-products/Applications/
process by a template written in a JSDL (Job Submission Description Language)\textsuperscript{9}. Whenever a user requests new model data to be calculated, the template is adopted to the specific case and a target machine is selected from a given list. Upon arrival, the results are passed on to the TheoSSA service to notify the user.

4. CONCLUSIONS AND FUTURE PLANS

TheoSSA is already fully functional and provides easy access to SEDs of hot stars – use them! E.g. the use of blackbody SEDs to represent stars in photoionization models belongs to the last millennium and is not adequate anymore.

The database of complete model atoms for other species (Ne, Na, Mg, Si, ...) up to the iron group will be extended. TMAW can already consider opacities of all elements from hydrogen to germanium.

The addition of other model codes for other types of stars will in future further improve the benefit for VO users. This is an invitation and challenge for other stellar-atmosphere working groups to contribute.

Precise spectral analysis requires extended grids of elaborated model atmospheres. In the framework of GRID computing (Foster, 2005, 2006), the calculation of model-atmosphere grids and flux tables, e.g. via TheoSSA, is an excellent application to efficiently calculate synthetic spectra on reasonable time scales.

One approach is already in preparation, using the newly developed HotBlast Non-LTE code for spherically expanding stellar atmospheres (Koesterke priv. comm.). HotBlast uses as an input the atmospheric structure of the static TMAP model atmospheres to simulate the atmosphere below the wind region.

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\textsuperscript{9}http://www.gridforum.org/documents/GFD.56.pdf