WP 5.2: Heat-Driven Oscillators

Deliverable 5.5:
Inclusion of spectroscopic information

Introduction

Nowadays, spectrum analysis is the main source of precise atmospheric parameters and chemical compositions of stars. The problem of chemical composition determination in different classes of stars is directly linked to the problems of production and evolution of chemical elements, stellar and galactic evolution, etc.

Thanks to the launches of several space missions such as MOST (Walker et al. 2003, PASP, 115, 1023), CoRoT (Auvergne et al. 2009, A&A, 506, 411), and Kepler (Gilliland et al. 2010, PASP, 122, 131), astrophysical fields such as, e.g., asteroseismology and exoplanetary science have been revolutionized the past decade. High quality photometric data obtained from space revealed a countless number of interesting physical effects in different types of stellar objects and led to very interesting discoveries. Needless to say, however, that both fields still heavily depend on high-quality, high-resolution spectroscopic data, and a significant fraction of the analyses rely on the interpretation of combined space-based photometric and ground-based spectroscopic data. The recently launched GAIA mission (Perryman et al. 2001, A&A, 369, 339) and missions such as TESS (Ricker et al. 2014, Proc SPIE, 9143, 914320) and PLATO2.0 (Rauer et al. 2014, ExA, 38, 249) that will be launched in the near future, will provide high-quality data for a few million stellar objects suitable for spectroscopic follow-up from the ground. As such, efficient and fast tools are particularly needed for the analysis of ground-based spectroscopic data of single and multiple stellar objects.

About the GSSP software package

The Grid Search in Stellar Parameters (GSSP) software package is based on a grid search in the fundamental atmospheric parameters and (optionally) individual chemical abundances of the star (or binary stellar components) in question. We use the method of atmosphere models and spectrum synthesis, which assumes a comparison of the observations with each theoretical spectrum from the grid. For the calculation of synthetic spectra, we use the SynthV LTE-based radiative transfer code (Tsymbal 1996, ASPC, 108, 198) and a grid of atmosphere models pre-computed with the LLmodels code (Shulyak et al. 2004, A&A, 428, 993). Our grid of models covers large ranges in all fundamental atmospheric parameters and is freely distributed together with the software package itself.

We allow for optimization of five stellar parameters at a time: effective temperature, surface gravity, metallicity, microturbulent velocity, and projected rotational velocity of the star. The synthetic spectra can be computed in any number of wavelength ranges, and each considered spectral interval can be from a few Angstroem up to a few thousands Angstroem wide. As long as the global metallicity of the star is determined/known, the [M/H] parameter can be replaced in the grid by the abundance of an arbitrary chemical element. The individual abundances have to be iterated element by element, thus there is no option to optimize abundances of more than one element at the same time.

The grid of theoretical spectra is built from all possible combinations of the above mentioned parameters. Each spectrum from the grid is compared to the observed spectrum of the star and the chi-square merit function is used to judge the goodness of fit. The code delivers the set of best fit parameters, the corresponding synthetic spectrum, and the ASCII file containing the individual parameter values for all grid points and the corresponding chi-square values. We also account for possible global-scale imperfection in the normalization of the observed spectrum by means of a scaling factor that is computed from the least-squares fit of the synthetic spectrum to the observations and is applied to the latter. The value of the scaling factor is provided in the final chi-square table along with the other grid search parameters.

The GSSP package modules

The GSSP package is written in the Fortran 90 language and consists of three independent modules. The GSSP_single module treats the observed spectrum as the one of a single star. The module is thus applicable to spectra of single stellar objects as well as to the disentangled spectra of multiple stellar systems. In the latter case, we assume that the light of the star in question is diluted by a certain wavelength-independent factor, which can be set as a free parameter. The GSSP_binary module has been specifically designed for fitting disentangled spectra of both binary components simultaneously. The procedure is in a sense similar to the one of "constrained fitting" suggested by Tamajo et al. (2011, A&A, 526, A76), were one assumes that the sum of the two light factors is identical to unity, and thus the change in light dilution of one of the components affects the amount of diluted light for the companion star. Instead of assuming wavelength-independent light dilution for each of the components, we optimize the ratio of the radii of the binary components which is obviously the same for both stars. The GSSP_composite software module was designed for fitting composite spectra of double-lined spectroscopic binary systems. The algorithm implemented in this module is very similar to the one implemented in the GSSP_binary module, with the two differences being: i) there is a possibility to set the radial velocities of individual binary components as free parameters, and ii) instead of comparing theoretical spectra to the disentangled observed spectra of both components, all possible combinations of synthetic primary and secondary spectra from the computed grid are used to build composite theoretical spectra of a binary which are then compared to the observed spectrum on the scale of the latter.

The GSSP_single_v1.1 module recently added includes the possibility to use the macroturbulence velocity as a free parameter. The version 1.1 of this particular module, just as the previous release, includes the source files, an example of the input file (which is only slightly different from the original version, and the simulated data sets)

All software and data packages are currently available at:

https://fys.kuleuven.be/ster/meetings/binary-2015/gssp-software-package

and will become available on the SpaceInn website, too.