StePar/SteParSyn: two automatic codes to infer stellar atmospheric parameters

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StePar and SteParSyn are two codes designed to automatically infer the stellar atmospheric parameters of any FGKM-type star. StePar is a Python 3.X code designed to compute the stellar atmospheric parameters (Teff, log g, [Fe/H]) of FGK-type stars by means of the equivalent width (EW) method. This code has already been extensively tested in different spectroscopic studies of FGK-type stars with several spectrographs and against thousands of Gaia-ESO Survey UVES U580 spectra of late-type, low-mass stars. SteParSyn is yet another automatic code designed to infer the stellar atmospheric parameters of FGKM s tars using spectral synthesis alongside a Markov Chain Monte Carlo algorithm combined with a realistic modelling of the stellar noise by means of Gaussian Processes.

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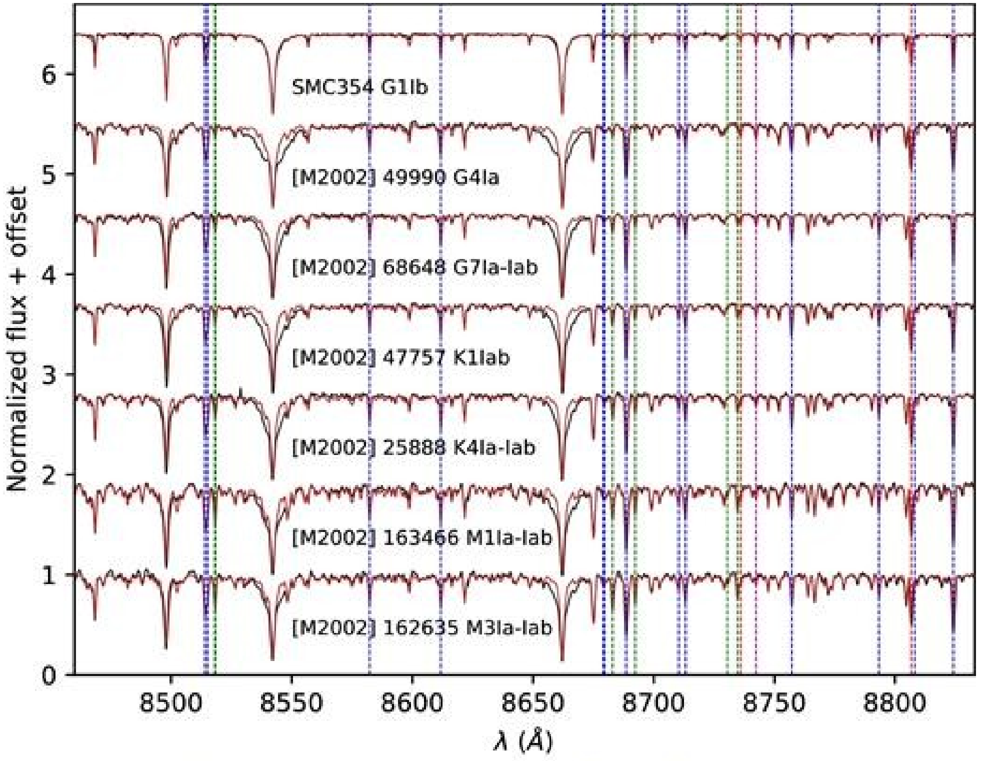
Context



Spectral synthesis arround the CaT region. Figure from Tabernero et al. 2018.

Key spectral lines are in different colors:
Mg I (Red), Si I (Magenta), Ti I (green), Fe I(blue)

The characterisation of stellar spectra is of great importance to modern stellar astrophysics. It plays an important role in many different fields including exoplanets (Santos et al. 2013, Brewer et al. 2016), nearby field cosmology (De Silva et al. 2015), or even resolved stellar populations in nearby galaxies (see Tabernero et al. 2018)

Automated methods to infer stellar atmospheric parameters from stellar spectra, including effective temperature (Teff), surface gravity (log g), and stellar metallicity ([Fe/H]). Cool FGKM stars remain among the most interesting targets for a number of reasons. They are ubiquitous in the Milky Way accounting for a big proportion of the stellar population. In addition, their spectra are dominated by atomic and molecular features that are highly sensitive to the stellar atmospheric parameters. The computation of the stellar atmospheric parameterscan be performed with different methods: spectral synthesis and the equivalent width (*EW*) method. These two methods have been discussed extensively in the literature (e.g., Jofre et al. 2018, Blanco Cuaresma et al. 2019).

Methodology

EW method for the analysis of FGK-type stars (Tabernero et al. 2019):

StePar code → available at https://github.com/hmtabernero/StePar

Based on the Ionisation and excitation balance of Fe I and Fe II lines under LTE.

Tested against a Library of benchmark stars (Jofre et al. 2018)

Spectral synthesis:

Use of synthetic spectra to match observed stellar spectra

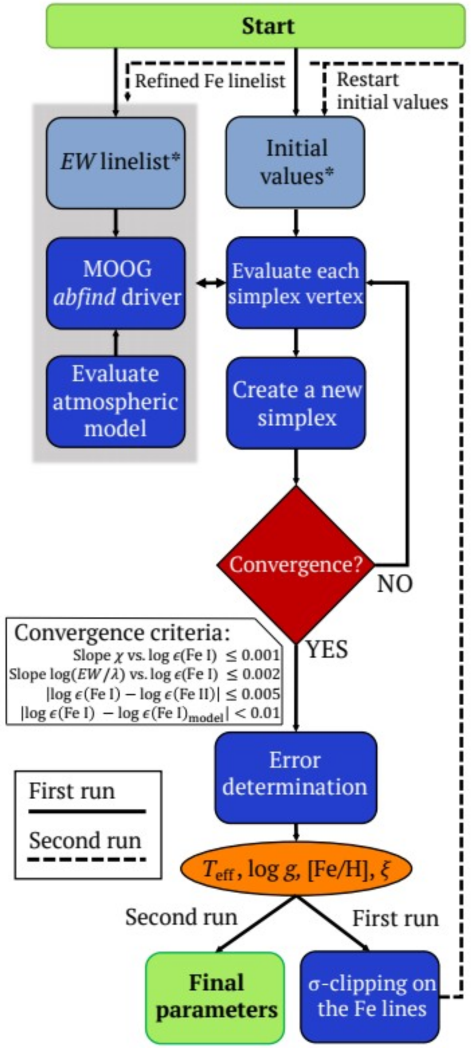
SteParSyn code → Tabernero et al. 2018

MCMC method to fit individual spectral lines or molecular bands

Results

A&A 628, A131 (2019)
https://doi.org/10.1051/0004-6361/201935465

Astronomy & Astrophysics



StePar: an automatic code to infer stellar atmospheric parameters

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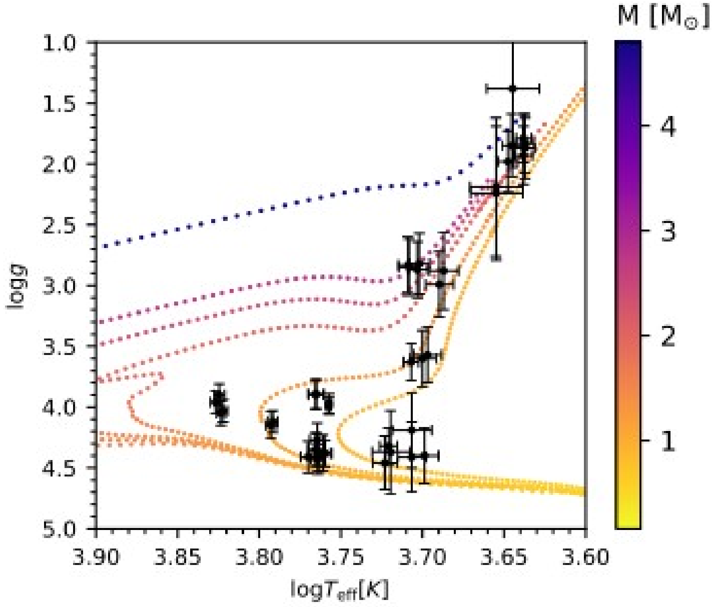
EW method based on four different Fe I-II line lists:
Tabernero et al. 2019

Automated determination of Teff, log(g), [Fe/H], and ξ

MARCS models (Gustafsson et al. 2008)

MOOG code 2017 version (Sneden 1973)

Nelder-mead optimization (Press et al. 2002)



StePar is available in github:
https://github.com/hmtabernero/StePar

Results

SteParSyn (Spectral synthesis):

Automatic method to derive stellar atmospheric parameters (Tabernero et al. 2018)

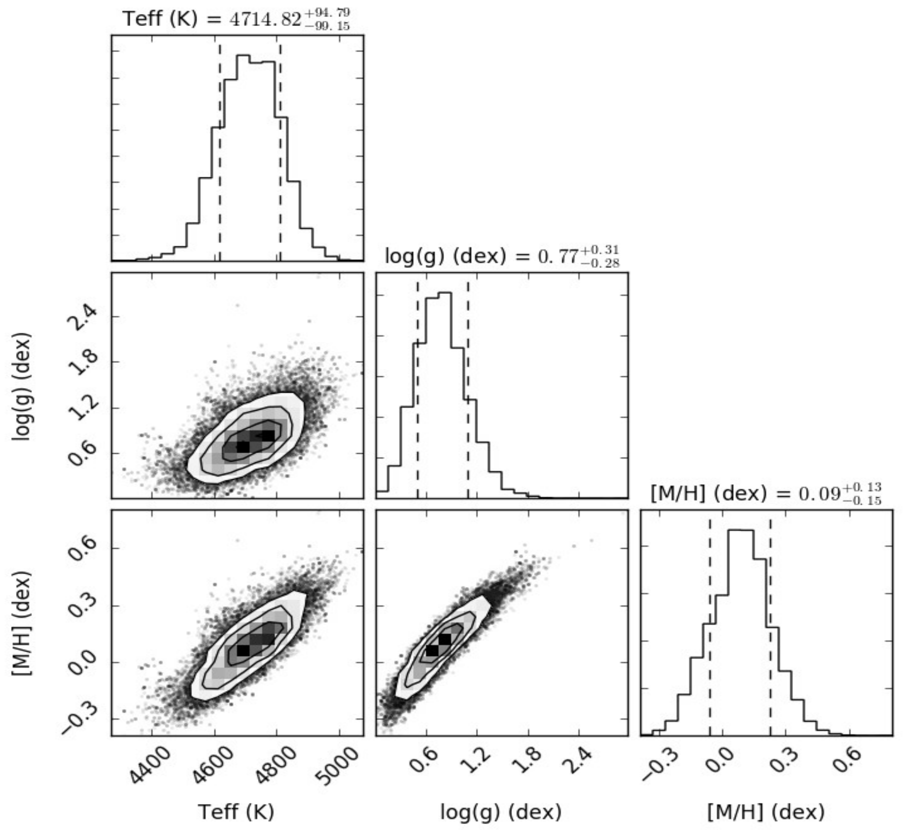
It can use three sets of model atmospheres:

PHOENIX BT-Settl (Allard et al. 2012)
MARCS (Gustafsson et al. 2008)
KURUCZ (Meszaros et al. 2013)

Atomic parameters obtained from VALD3, exomol, Kurucz, and/or B. Plez databases.

Radiative transfer performed using Turbospectrum (Plez 2012) or Spectrum (Gray and Corbally 1994)

MCMC algorithm to sample the parameter's posterior distribution (emcee, Foreman-Mackey 2013)



Example cornerplot from SteParSyn. This example corresponds to a luminous K star.

Impact and future prospects

Two automatic methods to derive stellar atmospheric parameters:

StePar → *EW*-method (**Tabernero et al. 2019**)

Available to the community → https://github.com/hmtabernero/StePar

Fe I-II line lists extended to the CARMENES wavelength range (**Marfil et al. 2020**)

SteParSyn → Spectral synthesis (**Tabernero et al. 2018**)

Characterization of planet hosts (e.g. CARMENES → **see Emilio Marfil SEA 2020 presentation**)

SteParSyn will be available to the community soon (**Tabernero et al. 2020, in prep**).

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