A tale of two stellar characterisation codes STEPAR and STEPARSYN

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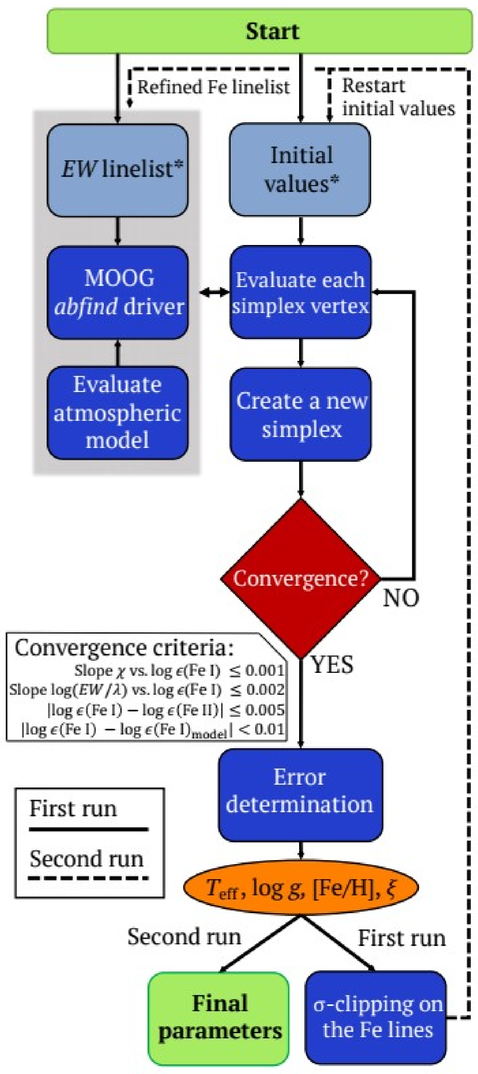
ABSTRACT: We report on two state-of-the-art codes designed to characterise the spectra of late-type stars. **STEPAR** is a Python 3.X code that implements the EW method to calculate stellar atmospheric parameters (T_{eff}, *log(g)*, and [Fe/H]) of FGK stars. This code has already been extensively used to analyse high-resolution stellar spectra of thousands of *Gaia*-ESO Survey stars, among others. On the other hand, **STEPARSYN** is a Bayesian code designed to retrieve the distribution of stellar parameters of an observed spectrum using the spectral synthesis method combined with a robust scheme that rests on a Markov Chain Monte Carlo sampler.



STEPAR (EW method, see Tabernero et al. 2019)

STEPAR is an implementation of the EW method that is based on four different well-curated Fe I-II line lists. It uses MARCS models (**Gustafsson et al. 2008**) alongside the MOOG code (**Sneden 1973**) combined with a Nelder-Mead algorithm. However, it can only be used on slow rotators (vsini < 15 km/s) and stars with spectral types F5 to K4. StePar is available at:

https://github.com/hmtabernero/StePar/

The code has been used to characterise Gaia-ESO FGK stars (see e.g., **Smiljanic et al. 2014**), FGK+M binary systems (**Montes et al. 2018**), CARMENES spectra (**Marfil et al. 2020**), and ESPRESSO exoplanet host stars (see,**Toledo-Padrón et al. 2020, Tabernero et al. 2021b**, and **Casasayas-Barris et al. 2021**).

← **Fig 1.** STEPAR workflow diagram (figure taken from **Tabernero et al. 2019**)

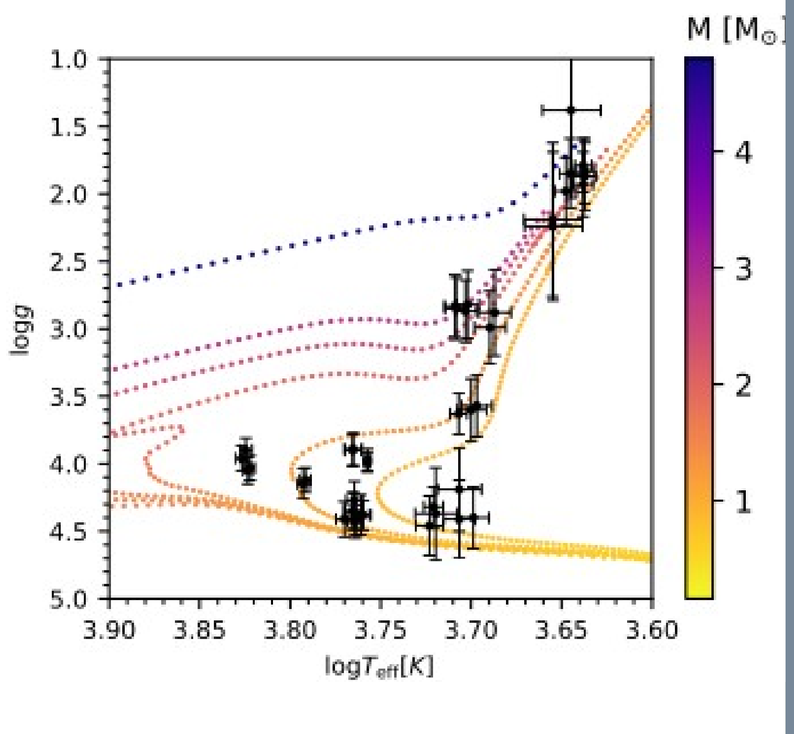


Fig. 2. Kiel diagram (log(g) vs. log(T_{eff})) for a few FGK stars alongside the YaPSI isochrones for 0.1, 0.4, 0.6, 1, 4, and 13 Ga (for Z=0.016, see **Spada et al. 2017**). Figure taken from **Tabernero et al. (2019)**.

STEPARSYN (Spectral synthesis, Tabernero et al. 2021c, in prep)

STEPARSYN is an automatic code written in Python 3.X designed to infer the stellar atmospheric parameters of late-type stars following the spectral synthesis method. It uses the Markov Chain Monte Carlo sampler emcee (see **Foreman-Mackey et al. 2013**). In all, STEPARSYN was implemented to overcome the limitations of the STEPAR code. It can use three sets of model atmospheres: PHOENIX (see, e.g., **Allard et al. 2012**), MARCS (**Gustafsson et al. 2008**), and KURUCZ (**Meszaros et al. 2013**). The radiative transfer is performed using *Turbospectrum* (**Plez 2012**) or *Spectrum* (**Gray and Corbally 1994**). Whereas the atomic parameters are gathered from **VALD3**, **exomol**, **Kurucz**, and/or **B. Plez** databases.STEPARSYN has been employed to characterise Massive stars (see, e.g., **Tabernero et al. 2018**, **Negueruela et al. 2018**, **Alonso-Santiago et al. 2019**, **Tabernero et al. 2021a**). It has also been employed to characterise stars belonging to the CARMENES GTO sample (**Marfil et al. 2021**, in prep) and to the ESPRESSO GTO (**Borsa et al. 2021**).

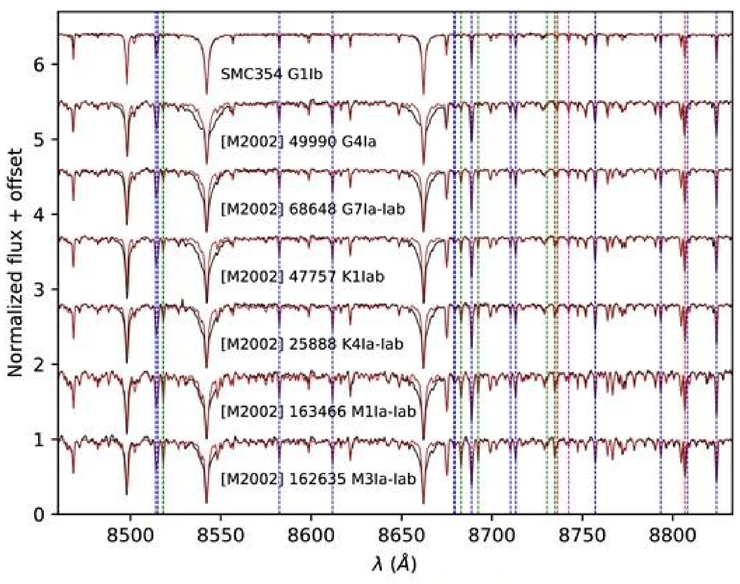


Fig 3. Spectral synthesis around the CaT region for a few RSG stars. This figure taken from **Tabernero et al. (2018).** Key spectral lines are in different colors: **Mg I (Red), Si I (Magenta), Ti I (green), Fe I (blue).**

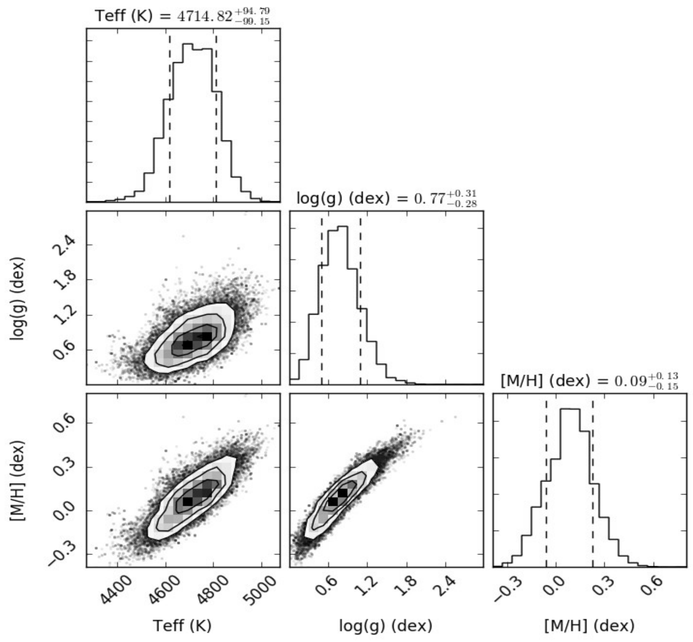


Fig. 4. Example cornerplot obtained using STEPARSYN to analyse the spectrum of an evolved K star.

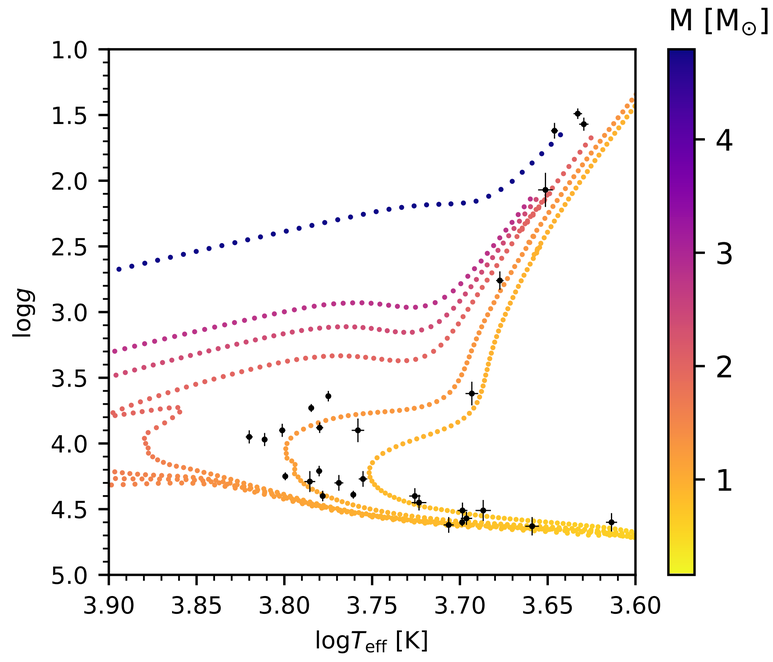


Fig. 5. Same as Fig. 2 but for parameters derived with STEPARSYN for a sample of FGK stars (**Tabernero et al. 2021c**, in prep.)

References: Unless in preparation, each citation is an ADS link to the corresponding paper.

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