



# StePar: an automatic code for stellar parameter determination



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## Abstract

We introduce a new automatic code (StePar) for determining stellar atmospheric parameters ( $T_{\text{eff}}$ ,  $\log g$ ,  $\xi$  and  $[\text{Fe}/\text{H}]$ ) in an automated way. StePar employs the 2002 version of the MOOG code (Sneden 1973) and a grid of Kurucz ATLAS9 plane-parallel model atmospheres (Kurucz 1993). The atmospheric parameters are obtained from the EWs of 263 Fe I and 36 Fe II lines (obtained from Sousa et al. 2008) iterating until the excitation and ionization equilibrium are fulfilled. StePar uses a Downhill Simplex method (Press et al. 1992) that minimizes a quadratic form composed by the excitation and ionization equilibrium conditions. Atmospheric parameters determined by StePar are independent of the stellar parameters initial-guess for the problem star, therefore we employ the canonical solar values as initial input. StePar can only deal with FGK stars from F6 to K4, also it can not work with fast rotators, veiled spectra, very metal poor stars or Signal to noise ratio below 30. Optionally StePar can operate with MARCS models (Gustafsson et al. 2008) instead of Kurucz ATLAS9 models, additionally Turbospectrum (Álvarez and Plez 1998) can replace the MOOG code and play its role during the parameter determination. StePar has been used to determine stellar parameters for some studies (Taberero et al. 2012 and Wisniewski et al. 2012). In addition StePar is being used to obtain parameters for FGK stars from the GAIA-ESO Survey.

## Methodology

The EW determination of the Fe lines was carried out with the ARES code (Sousa et al. 2007). We followed the approach of Sousa et al. (2008) to modify the  $rejt$  parameter of ARES according to the  $S/N$  of each spectrum. The other ARES parameters we employed were:  $smoother = 4$ ,  $space = 3$ ,  $lineresol = 0.07$ , and  $miniline = 2$ .

Stellar atmospheric parameters are derived imposing the following conditions:

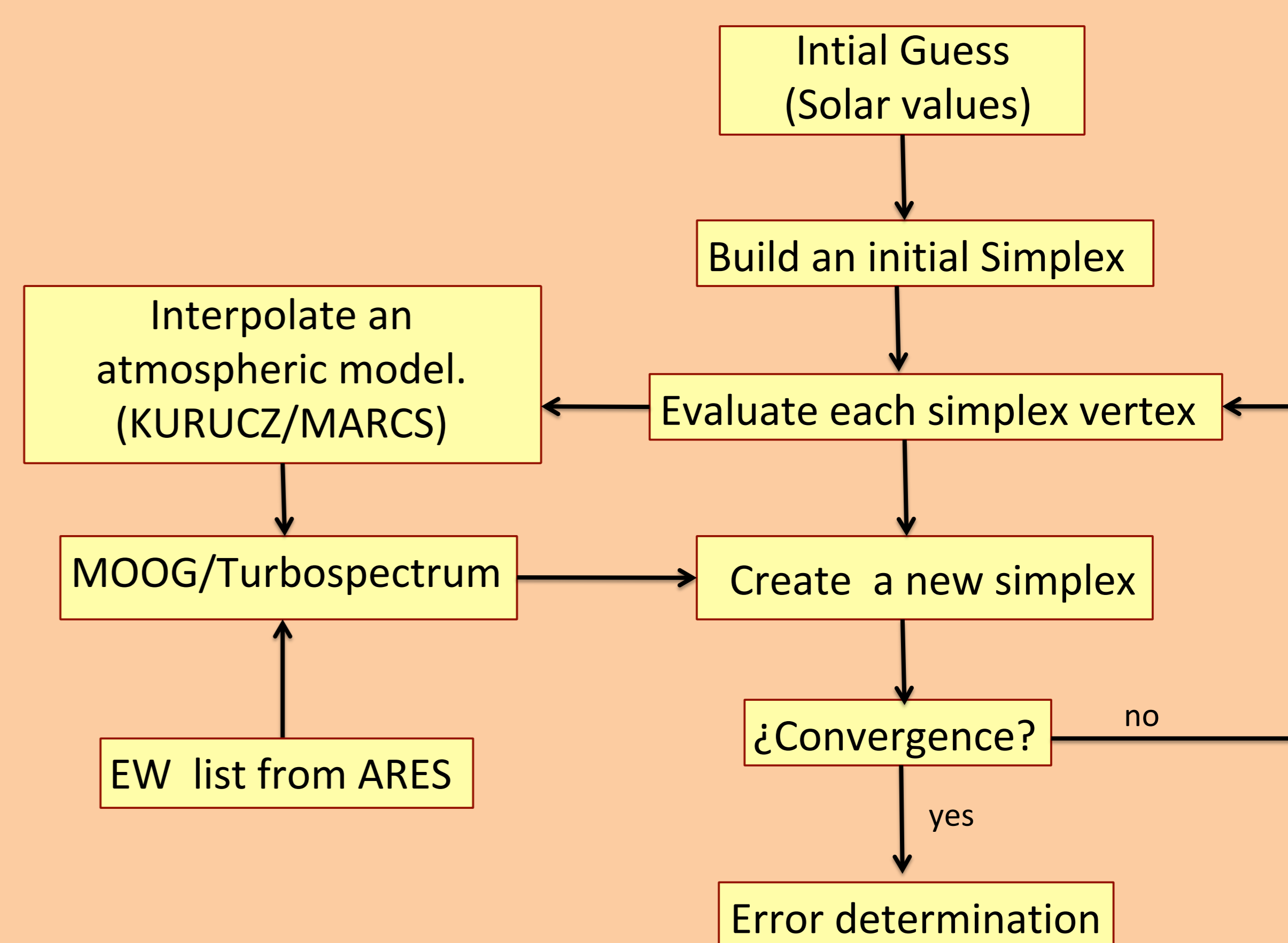
**Excitation equilibrium:** Slopes of  $\chi$  vs.  $\log \epsilon$  (Fe I) and  $\log (EW/\lambda)$  vs.  $\log \epsilon$  (Fe I) are zero.

**Ionization equilibrium:**  $\log \epsilon$  (Fe I) =  $\log \epsilon$  (Fe II)

We impose that the mean Fe abundance ( $\log \epsilon$  (Fe I)) and the metallicity of the atmospheric model are the same. This four conditions are combined in a quadratic form that will be minimized with a Downhill Simplex Method (Press et al. 1992).

In addition, we performed a  $3\text{-}\sigma$  rejection of the Fe I and Fe II lines after a first determination of the stellar parameters, therefore we re-run the StePar program again without the rejected lines.

Fig. 1: StePar internal workflow.



## Testing the Sun

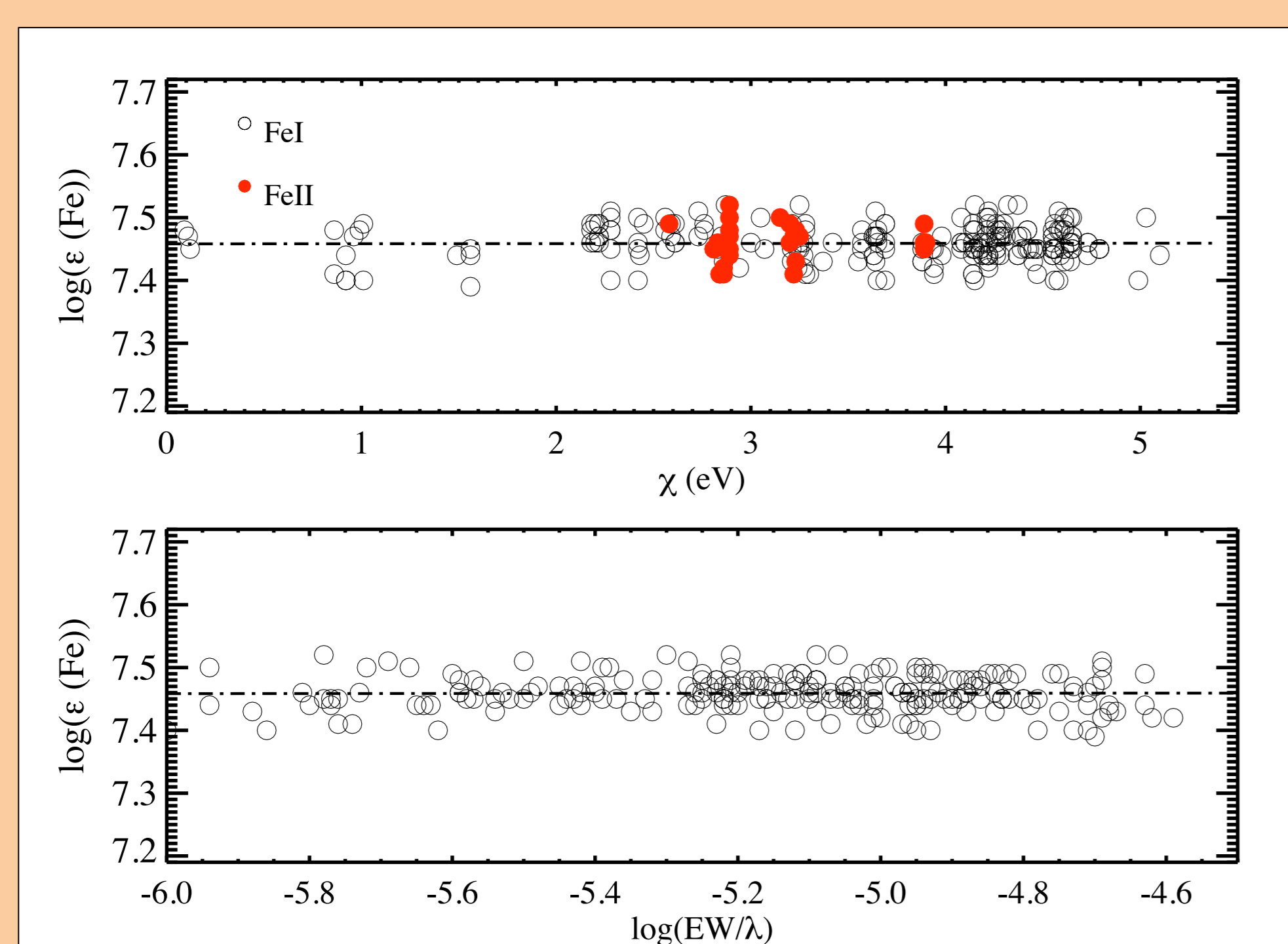


Fig. 2:  $\log \epsilon$  (Fe I, II) versus the excitation potential,  $\chi$ , and the reduced equivalent width,  $\log (EW/\lambda)$ , for the Sun (spectrum of the asteroid Vesta). The dashed lines represent the least squares fit to the data points, which are very close to a constant fit as expected from the iterative procedure of the stellar parameter determination.

We performed the parameter determination with MOOG (Sneden 1973) and KURUCZ models (KURUCZ 1993) in the case of the Sun. Employing a HERMES/MERCATOR spectrum of the asteroid Vesta. In this case, we obtained:  $T_{\text{eff}} = 5775 \pm 15$  (K),  $\log g = 4.48 \pm 0.04$  (dex),  $\xi = 0.97 \pm 0.02$  (km/s), and  $\log \epsilon$  (Fe I) =  $7.46 \pm 0.01$  (dex), which are very close to the canonical solar values of the atmospheric parameters. We ended up with 220 Fe I and 27 Fe II spectral lines for this solar reference (See Fig 2).

## Benchmark stars, MARCS/KURUCZ, MOOG/Turbospectrum

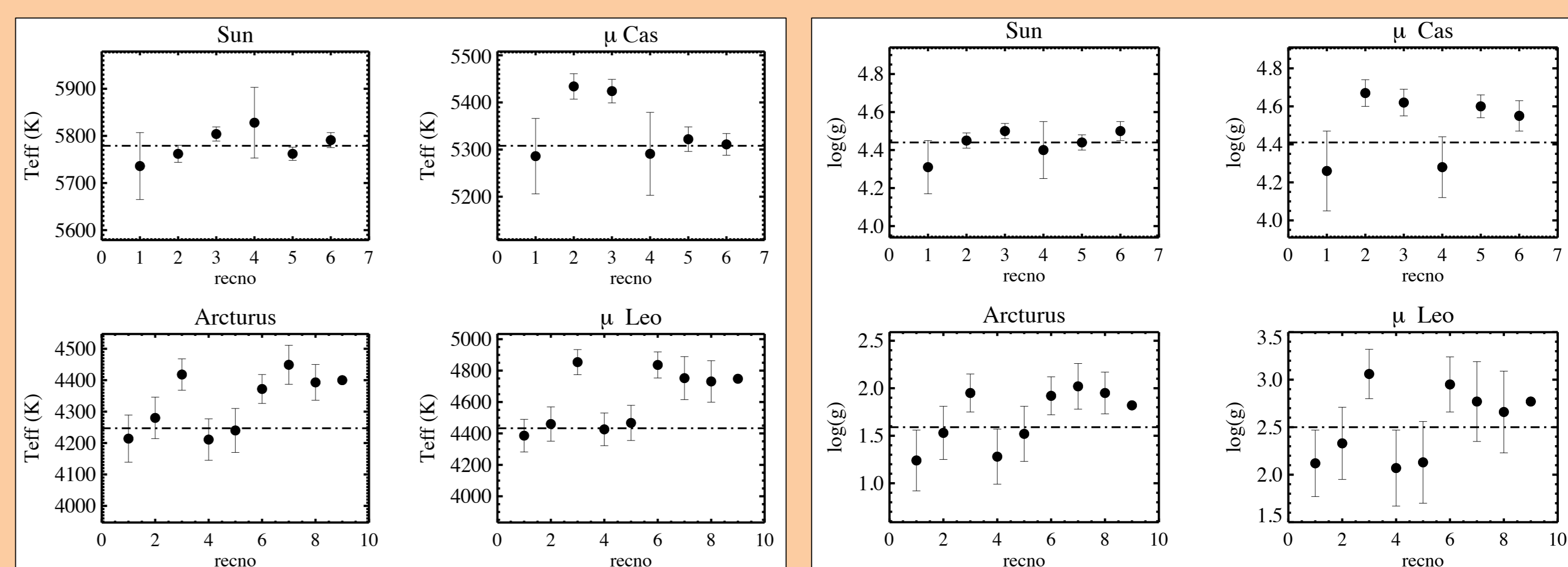
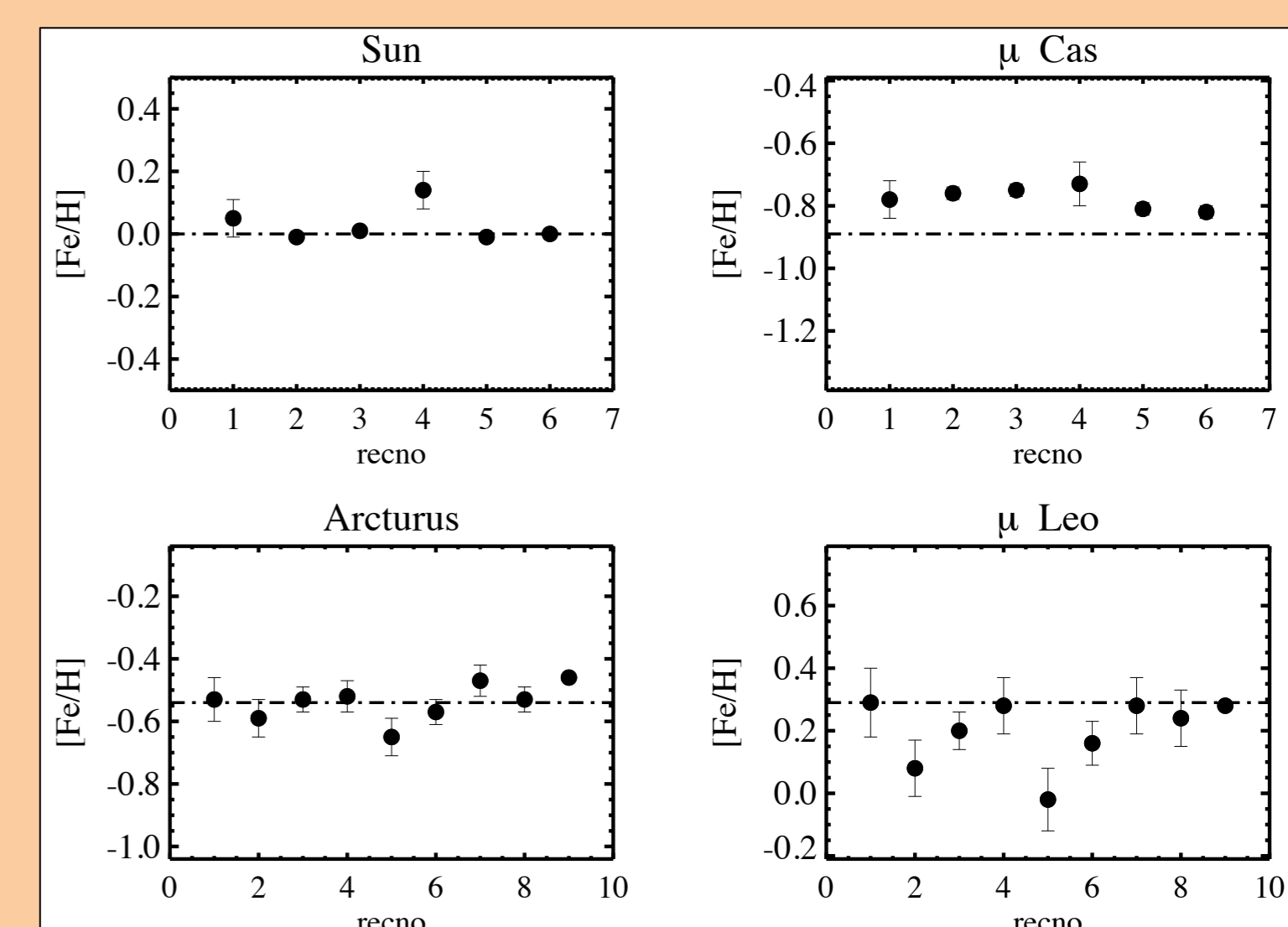


Fig. 3, 4, and 5: Several tests for four benchmark stars from the GAIA-ESO Survey (Gilmore et al. 2012) preliminary tests, Sun (5779 K, 4.44 dex, 0.00 dex),  $\mu$  Cas (5308 K, 4.41, 0.89), Arcturus (4247 K, 1.59 dex, -0.54 dex), and  $\mu$  Leo (4433 K, 2.50, +0.29). Dashed-dotted lines represent the "accepted" parameters values ( $T_{\text{eff}}$ ,  $\log(g)$ , and  $[\text{Fe}/\text{H}]$ ) for different runs:

- 1-3: MOOG with MARCS models.
- 5-8: MOOG with KURUCZ models.
- 9: Turbospectrum with MARCS models.
- 1,4: VALD (Piskunov et al. 1995)  $\log(gf)$ 's Fe I-II linelist
- 2,5: Same as above with calibrated  $\log(gf)$ 's
- 3,6-9: Calibrated  $\log(gf)$ 's linelist from Sousa et al. (2008)
- 7-9: Very Strong/Weak lines removed



## StePar and chemical abundances

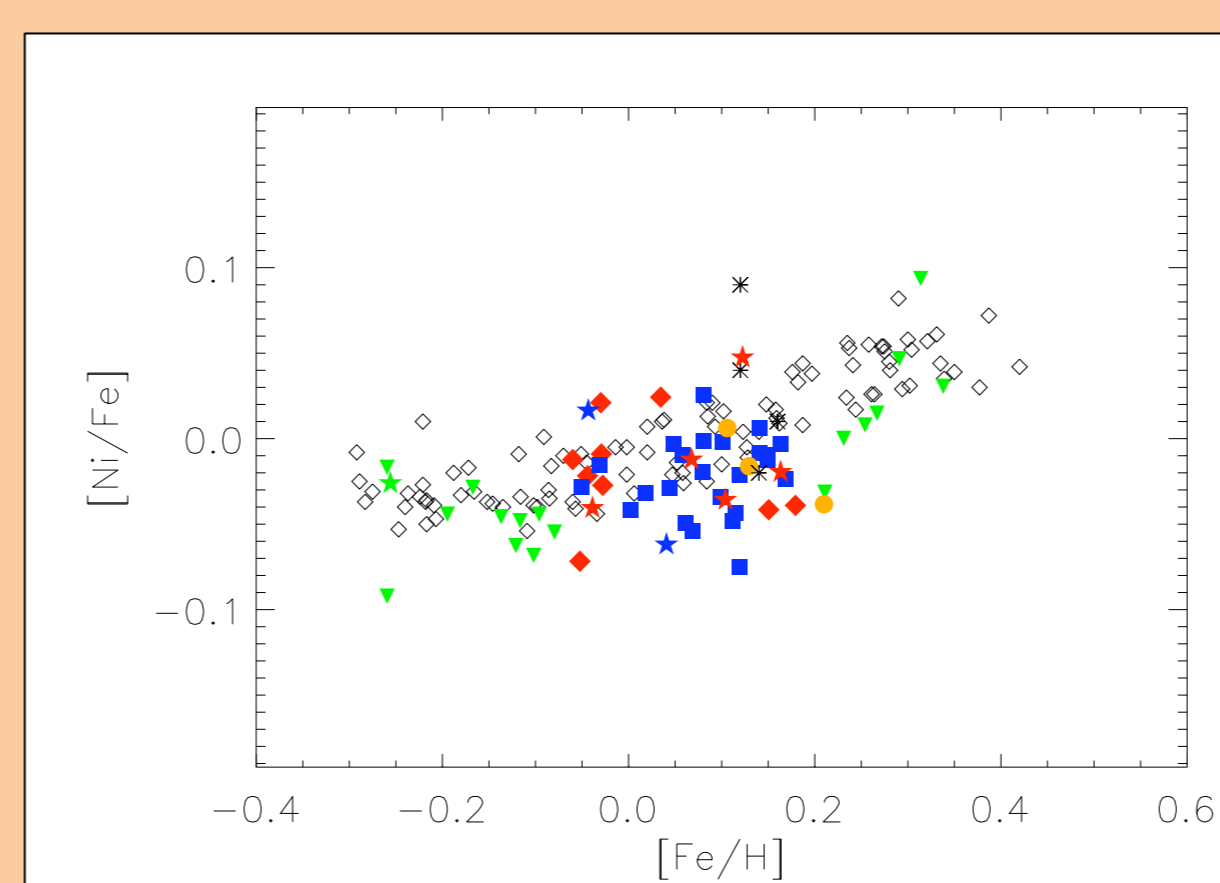


Fig. 6:  $[\text{Ni}/\text{Fe}]$  vs  $[\text{Fe}/\text{H}]$

The derived stellar parameters have been applied to Stellar Kinematic Groups, in particular to a sample from the Hyades Supercluster (Taberero et al. 2012). Elemental abundances for several chemical elements have been derived taking into account stellar parameters derived with StePar (Using KURUCZ models and MOOG). In Fig. 6 we plot  $[\text{Ni}/\text{Fe}]$  vs  $[\text{Fe}/\text{H}]$  for Hyades Supercluster stars (coloured points) vs thin disk solar analogs (open diamonds, González Hernández et al. 2010).

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