Determination of stellar parameters via state-of-the-art Non-LTE calculations

LOTUS: LTE & NLTE Optimizing Tool for compUtations of Stellar parameters (open-source tool soon)

Yangyang Li (yangyangli@ufl.edu)
Rana Ezzeddine(rezzeddine@ufl.edu)
Department of Astronomy, University of Florida

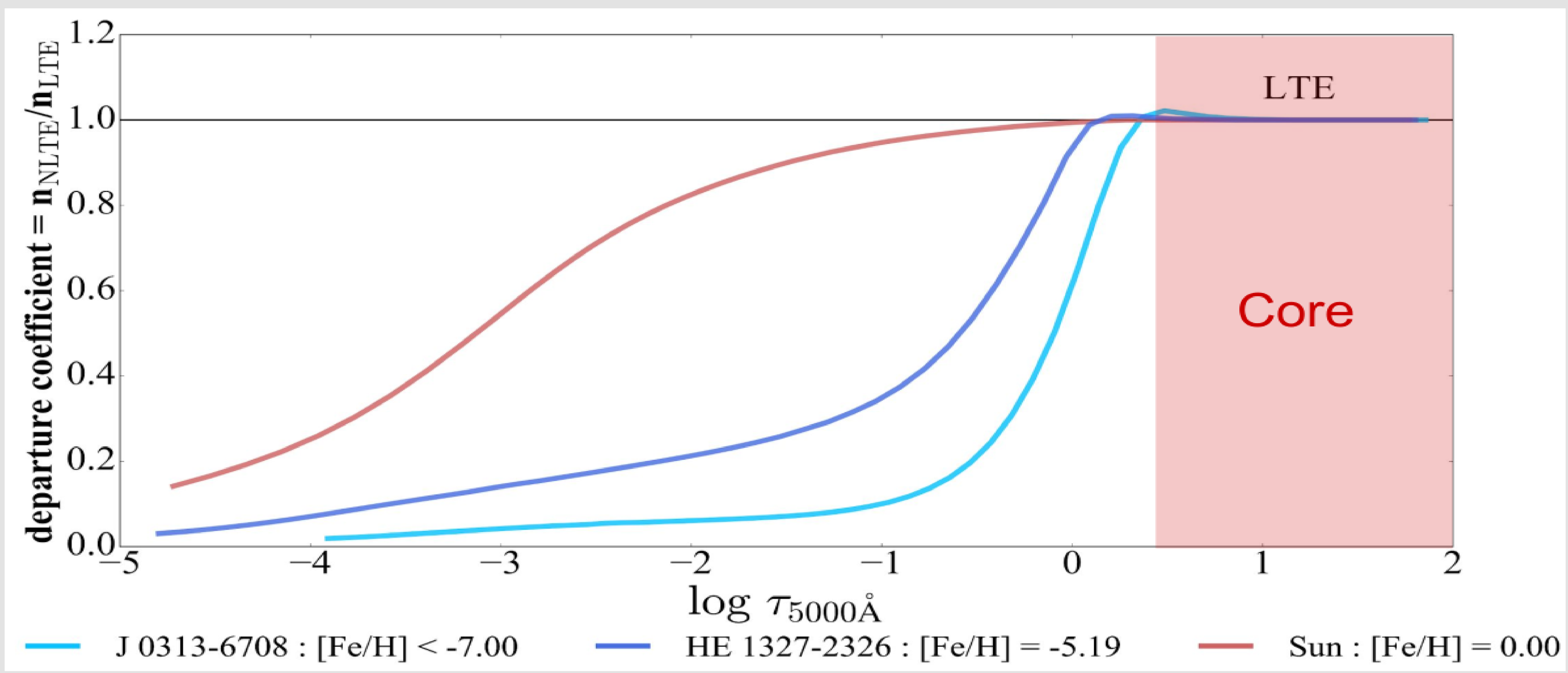
Introduction

Non-LTE models are the way forward to obtain more accurate absolute abundances,which is crucial for the understanding of the history of stars, galaxies and the cosmo as a whole. The classical and most common methods to determine abundances are based on the measurement of equivalent widths (EWs) or the computation of synthetic spectra of absorption lines of the chemical element in question. However, due to the high expense of Non-LTE computation of line formation, it is impossible to measure abundance via recursively fitting synthetic spectra. Even with the help of using pre-computed grids of synthetic spectra, large spectra library is still a heavy burden for data storage. Therefore, abundance inference based on EW data is very promising for Non-LTE chemical abundance determination. We aim to propose a robust multivariate interpolation tool to quantify the effect of dependencies between stellar parameters and constrain errors of inferred abundance and Non-LTE correction more accurately. We construct an EW library for a grid of stellar parameters . The EWs of each line are fit by a multivariate polynomial function that describes the EW of the line as a function of the stellar parameters. We utilized several global optimizer, including differential evolution and simplicial homology global optimization algorithms towards the predicted EWs with observed EWs to obtain optimized stellar parameters. Finally we intend to give our community a complete and robust library and series of an LTE&NLTE optimizer tool based on simulation to infer stellar parameters (LOTUS)

Background

There are two main framework for astronomers to do the calculation of line formation, one is Local Thermal Equilibrium (LTE), which is adopted when we need tremendously simplifies the calculation of number densities of atoms and molecules. While Non-LTE make line formation approaches more to the reality: radiation field inside and outside of the atom, collisional rate depend how lines form.

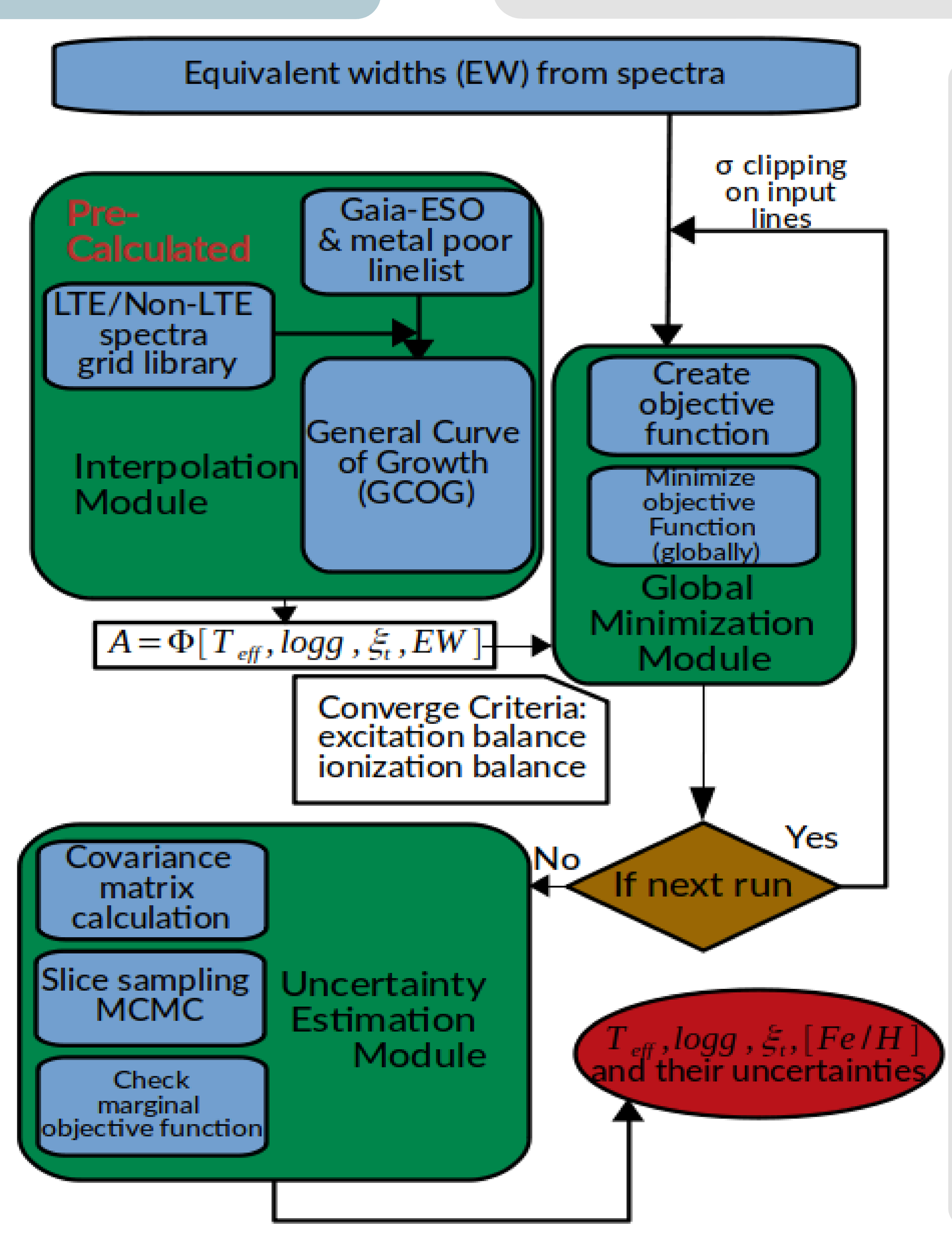
Non-LTE effects



Non-LTE effects can be significant in difference metallicity of stars and even in different optical depth. We can clearly see that for stars having lowest metallicity they are easily suffered the most from the impact of non-lte effects, which has the largest deviation. And such effect will be enhanced in the upper layer of a star.

Methodology

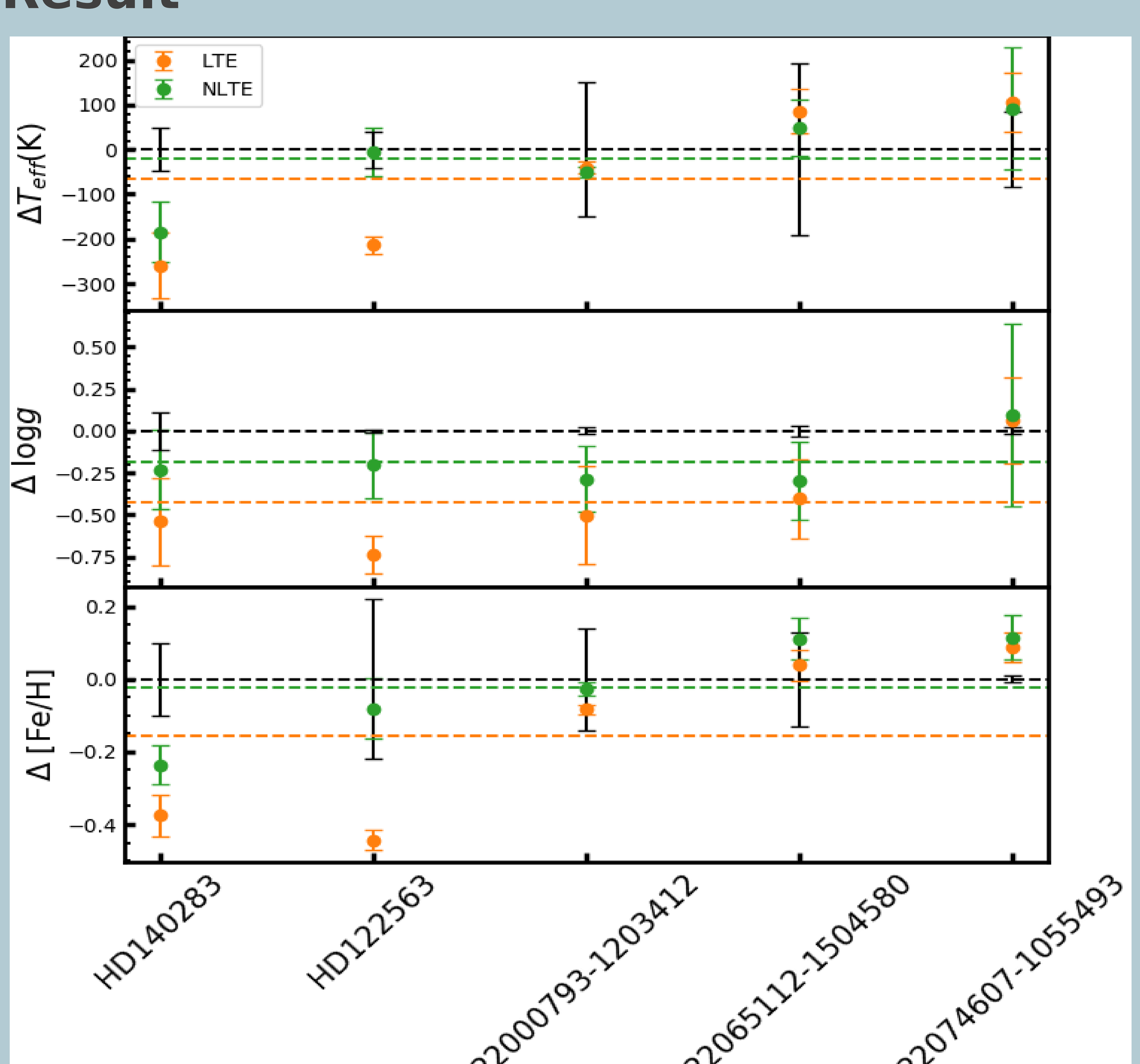
Here we adopt EW method as the core part of our code. Left shows the flow chart of our code LOTUS. LOTUS mainly contains three modules to promote derivation of stellar parameters and their uncertainties, they are: Interpolation Module, Global Minimization Module and Uncertainty Estimation Module. Users can define the stop condition of running optimization themselves. The EWs from spectral measurement with wavelength and excitation potential are needed as input data. It is worth noting that we calculated interpolation module ahead in order to save time for late procedures.



The following are necessary ingredients ahead of running our code:

1. A gird of stellar atmosphere models using MARCS (Gustafsson et al. 2008).
2. Calculation of theoretical line with radiative transfer code MULTI 2.3(Carlsson et al. 1986) under the assumption of LTE and Non-LTE.
3. A line list of target star containing spectral info and atomic parameters for FeI and FeII.
4. A robust interpolation program to obtain theoretical EWs under the condition of any combination of stellar parameters other than those on the nodes of grid.

Result



We perform our code towards several benchmark stars with accurate non spectroscopic measurements: effective temperature determined via infrared flux method(Creevey et al. 2014, Creevey et al. 2020), surface gravity via asterseismology (Creevey et al. 2020, Worley et al. 2020). We obtained extremely consistent with these results and well-constrained uncertainties.