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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
ICSC Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

Chemical tagging of field RR Lyrae to constrain the early formation and evolution of the Milky Way

K. Baeza-Villagra, G. Bono, V. D'Orazi

Spoke 3 Technical Workshop, Trieste October 9 / 11, 2023

ICSC Italian Research Center on High-Performance Computing, Big Data and Quantum Computing

Missione 4 • **Istruzione e Ricerca**

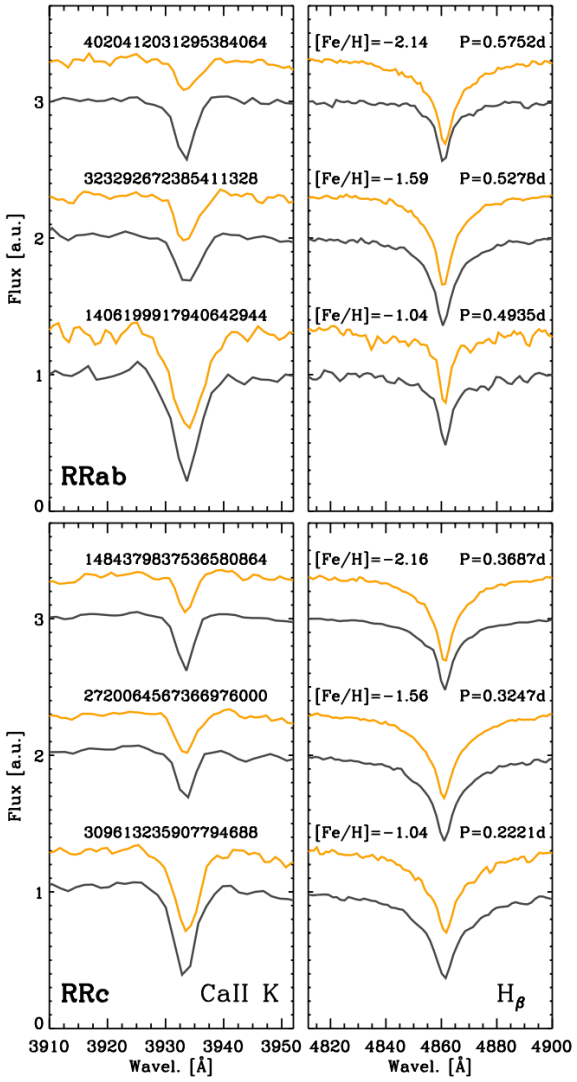
Scientific Rationale

RR Lyrae Stars

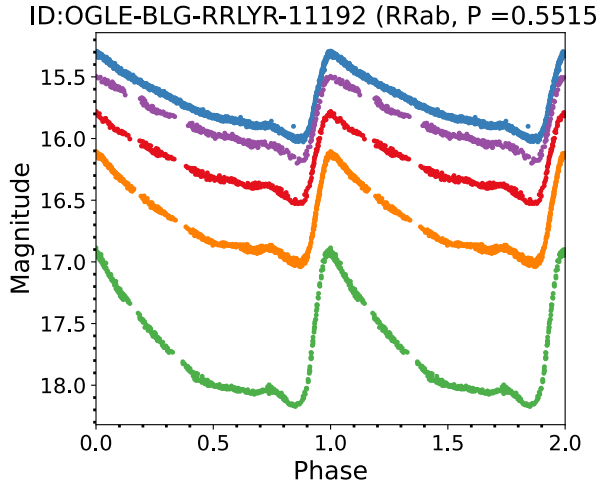
- Radially pulsating stars
- Periods between 0.2 and 1 day
- Low- mass: 0.6 $M_{\odot}$
- Very metal-poor

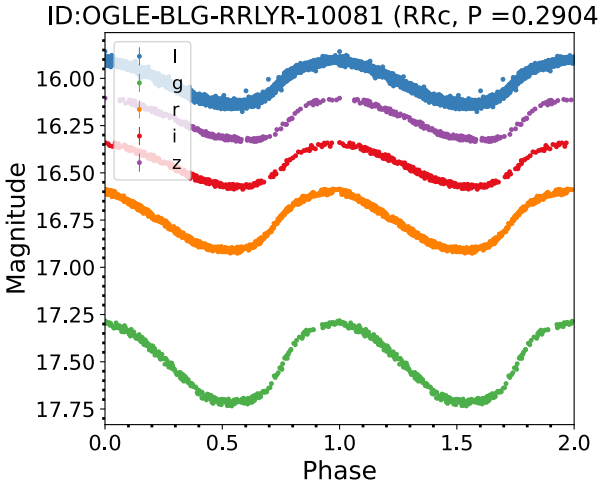
Problems:

1. We still lack precise and homogeneous measurements of their elemental abundances.
2. **Turbospectrum Spectral Fitting with Python (TSFitPy)** is a pipeline designed to determine stellar abundances and atmospheric parameters, however, it useful for small datasets of ~100 stars and fewer.



Fabrizio et al. 2021



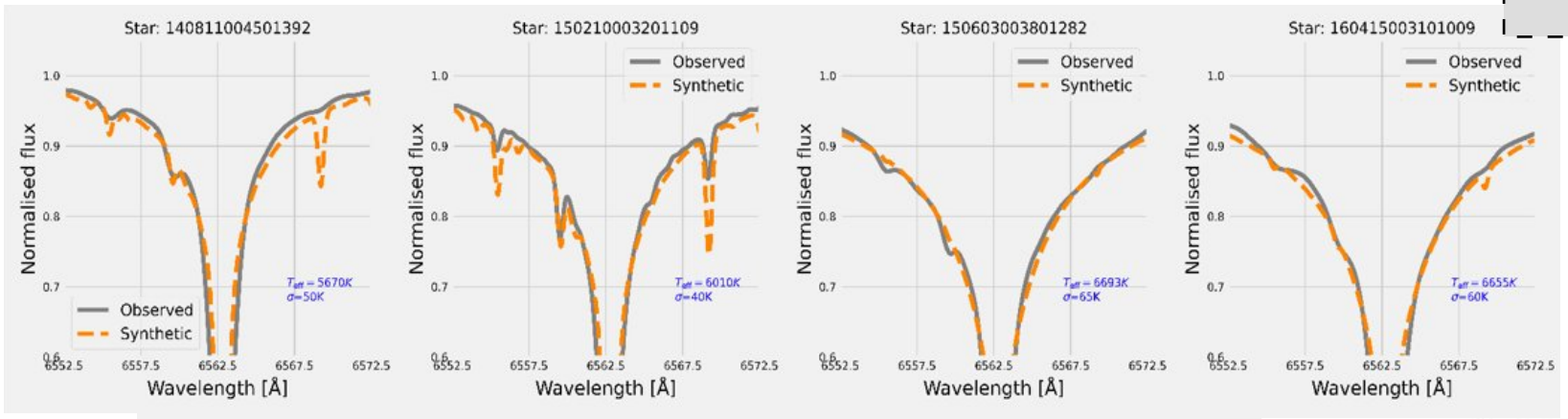


Baeza-Villagra et al. (in prep.)

Technical Objectives, Methodologies and Solutions

Turbospectrum Spectral Fitting with Python (TSFitPy)

~ 3 minutes per line



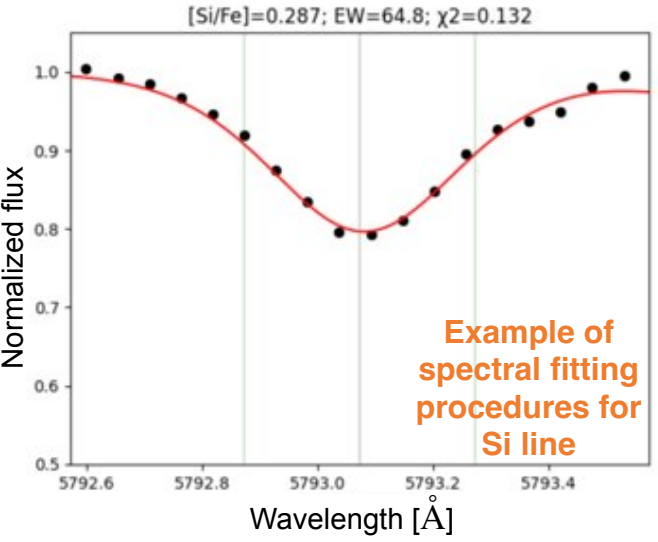
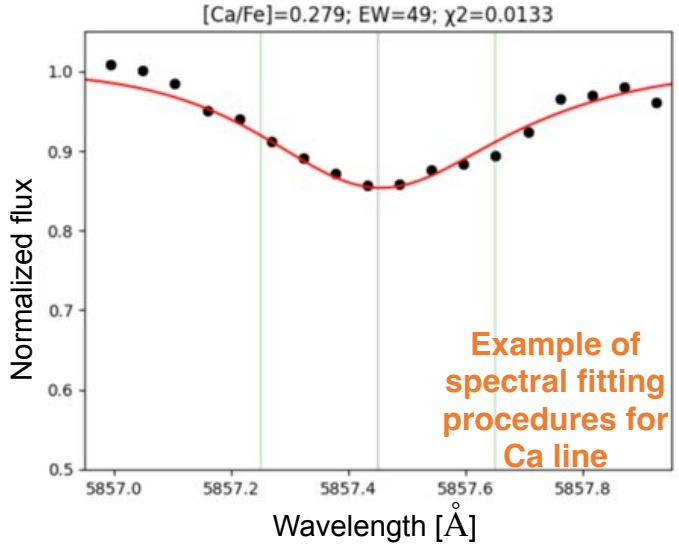


Figure 1. Example of spectral fitting of Hα profile in 1D NLTE by TSFitPy.

We have approximately 300 stars and 100 lines per star.
30000 lines to syntesise in NLTE (and possibly 3D).

~ 90000 minutes= 1500 hours = 63 days



Technical Objectives, Methodologies and Solutions

Solution: Develop new algorithms to computer the atmospheric parameters and the elemental abundances

☆ **PhD project:** From high resolution optical spectra of RR Lyrae stars, measure iron peak, alpha and neutron capture elements collected with 2-8 m class telescope. → we need to computer a detailed grid of atmospheric models covering more than **three dex** in iron abundance and more than **one dex** in surface gravity.

What does it mean?

The abundance ratio is the common logarithm of the ratio of a star's iron abundance compared to that of the Sun and is calculated as:

$$[Fe/H] = log(N_{Fe}/N_H)_\star + log(N_{Fe}/N_H)_\odot$$

$$[Fe/H] = log(N_{Fe}/N_H)_\star + 12$$

N_H : Number of hydrogen atoms per unit of volume

N_{Fe} : Number of iron atoms per unit of volume

We will explore 3 order of magnitudes less than the Sun!

Timescale, Milestones and KPIs

1 Kinematics

- Radial velocity measurements
- Use of radial velocity curve (RVC) templates
- Calculation of gamma velocities
- RRLs as tracers of Galactic components

Work in progress (1-2 months: ending in December 2023)

2 Abundance analysis

- Fitting of H_α profile under NLTE condition to infer T_{eff}
- Fitting of Fe I / Fe II lines to surface get gravity, micro-turbulence velocity and metallicity [Fe/H]
- Fitting of other line species (Mg, Si, Ca, Ba, Y)

Future work (estimated time: months / 1 year)

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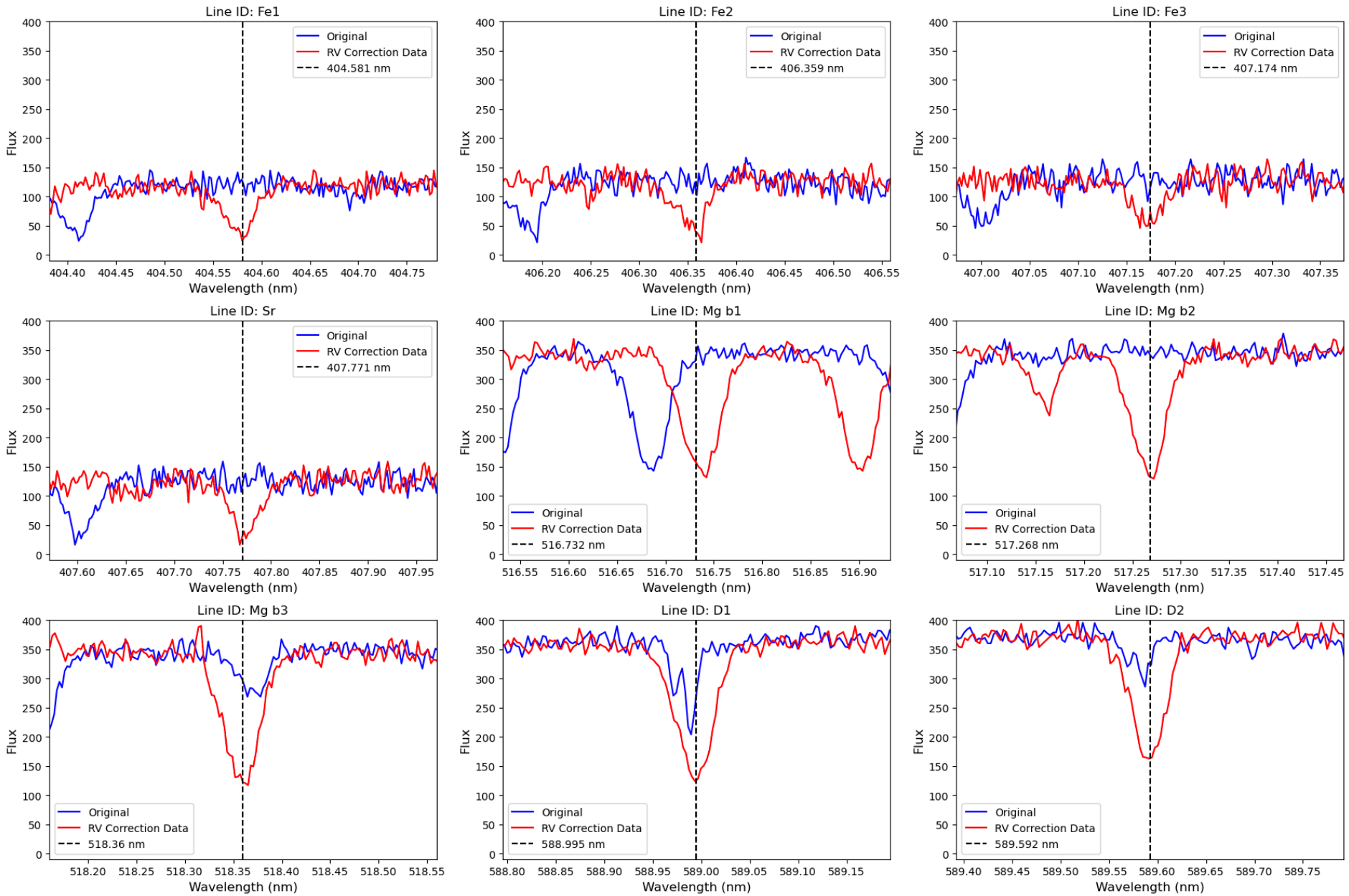
Results

Figure 2: Example of radial velocity obtained for an RRL star using IRAF.

Wavelengths of the Lines Adopted for Radial Velocity Measurements

Species	Line ID	λ(Å)
Fe group		
Fe I	Fe1	4045.81
Fe II	Fe2	4063.59
Fe II	Fe3	4071.74
Sr II	Sr	4077.71
Mg group		
Mg I	Mg b1	5167.32
Mg I	Mg b2	5172.68
Mg I	Mg b3	5183.60
Na group		
Na I	D1	5889.95
Na I	D2	5895.92



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Next Steps and Expected Results (by next checkpoint: April 2024)

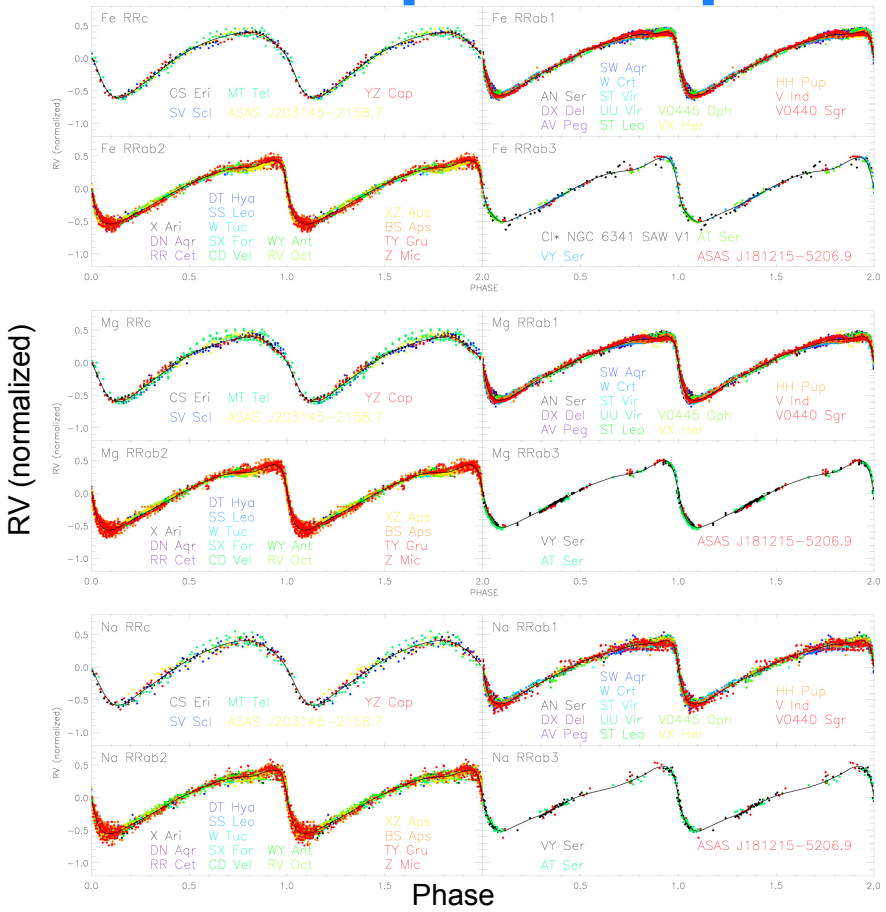

Figure 3: From top to bottom: cumulative and normalized radial velocity curves based on metallic (Fe, Mg, and Na) lines. Small circles are color-coded by variables and their names are labeled at the bottom. The solid line displays the analytical form of the RVC templates. Braga et al, 2021.

Optimizations of the code and development of new tools for obtaining atmospheric parameters and elemental abundances.

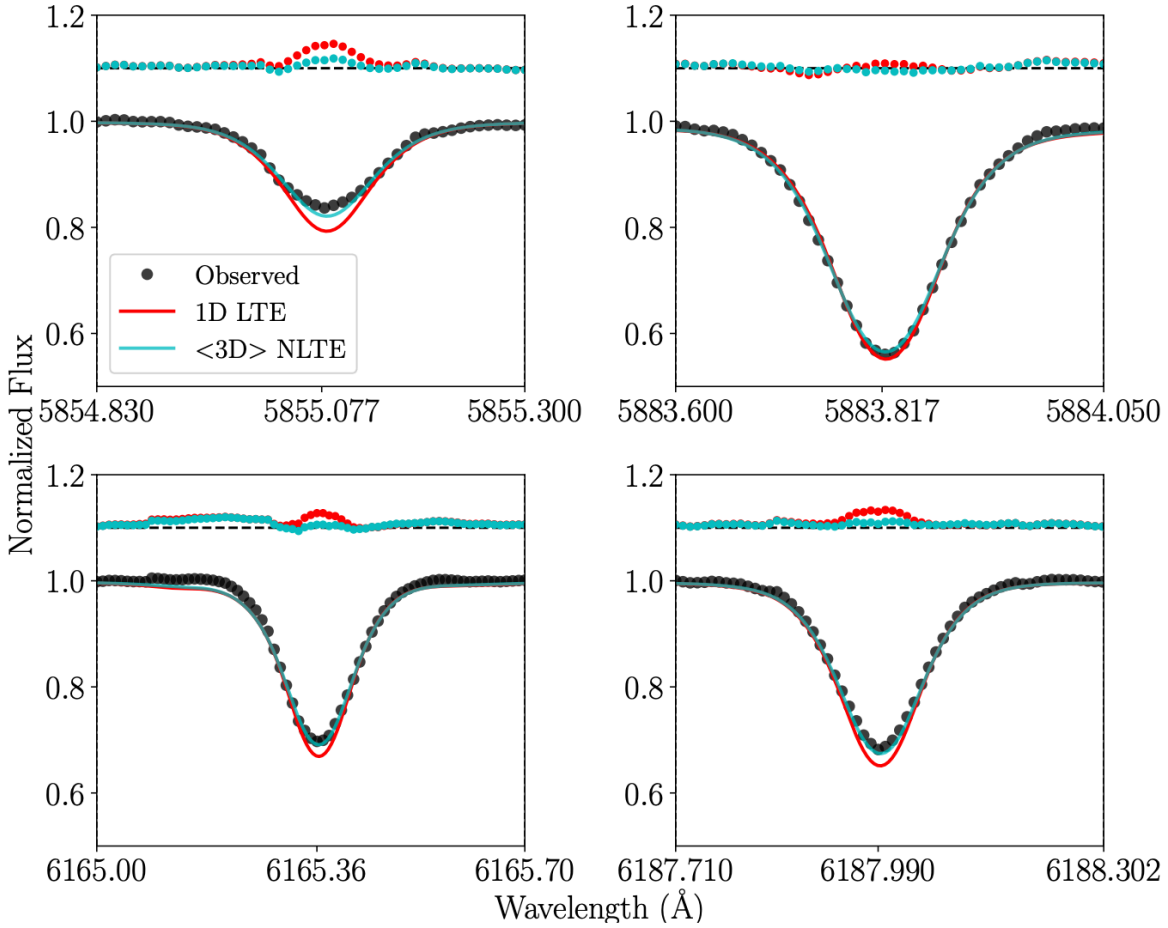

Figure 4: Normalized flux vs. wavelength for four sample Fe I lines in an observed solar spectrum together with model fits. Observations are shown as black circles, 1D LTE model fits are shown as red lines, and 3D NLTE model fits are shown as cyan lines. Gerber et al, 2022.