This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101008324 (ChETEC-INFRA).

Astronuclear Abundances

Report of Work Package 5

2023-2024

28/05/2024

Arūnas Kučinskas, Vilnius University, Lithuania, arunas.kucinskas@tfai.vu.lt

From starlight to abundances of chemical elements

ABUNDANCES OF CHEMICAL ELEMENTS IN STARS: CURRENT TRENDS AND ADVANCES

- Millions of stars studied with modern spectroscopic surveys
- Impressive advances in automated state-of-the-art abundance analysis tools

HOWEVER

- “Classical” approaches *still* dominate automated abundance analysis:
  - 1D hydrostatic model atmospheres, local thermodynamic equilibrium (LTE) abundance analysis
  - 3D NLTE stellar abundances still rare, even in the contexts where this may make a difference
- Diverse landscape of abundance analysis tools:
  - Methods and tools differ, sizeable systematic differences in the results of different groups
  - Automated stellar abundance pipelines rarely open-source
  - AI forthcoming!

From starlight to abundances of chemical elements

ABUNDANCES OF CHEMICAL ELEMENTS IN STARS: HOW TO IMPROVE?

- 3D hydrodynamical model atmospheres instead of “classical” 1D hydrostatic
- Non-local thermodynamic equilibrium (NLTE) abundance analysis instead of ”classical” LTE

} 3D NLTE abundances instead of 1D LTE

- Automated open-source abundance pipeline

} stellar parameters & 3D NLTE abundances for large numbers of stars

ChETEC INFRA WP5: goals and deliverables

THE GOAL

Homogenize stellar abundance analyses by providing new abundance analysis methods and tools

THE DELIVERABLES

- Database of 3D NLTE Abundance Corrections:
  - ***D5.1***, month 24 - DONE
  - ***D5.3***, month 36 – (NEARLY) FINISHED
  - ***D5.5***, month 48 – IN PROGRESS
- Homogeneous Open-Source Stellar Pipeline:
  - deliverables ***D5.2***, month 30 – DONE
  - ***D5.4***, month 42 – IN PROGRESS

THE TEAM

27 participants from 19 institutions (13 countries)

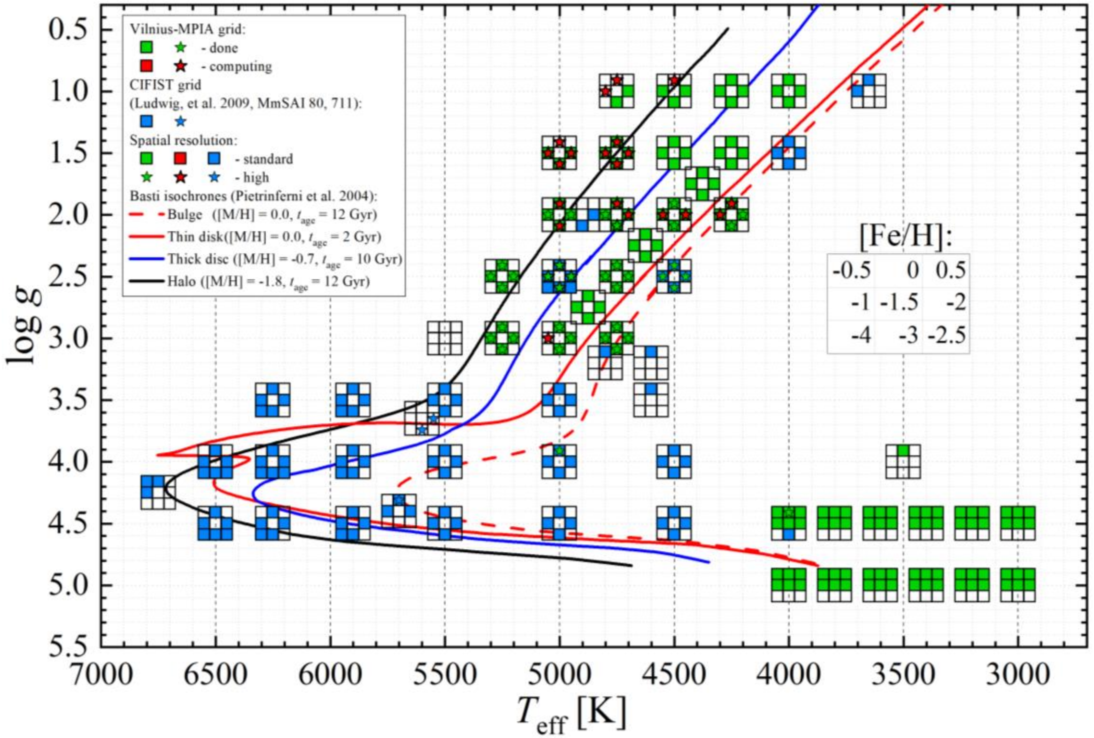
Partners

Associated partners

ChETEC INFRA WP5: results

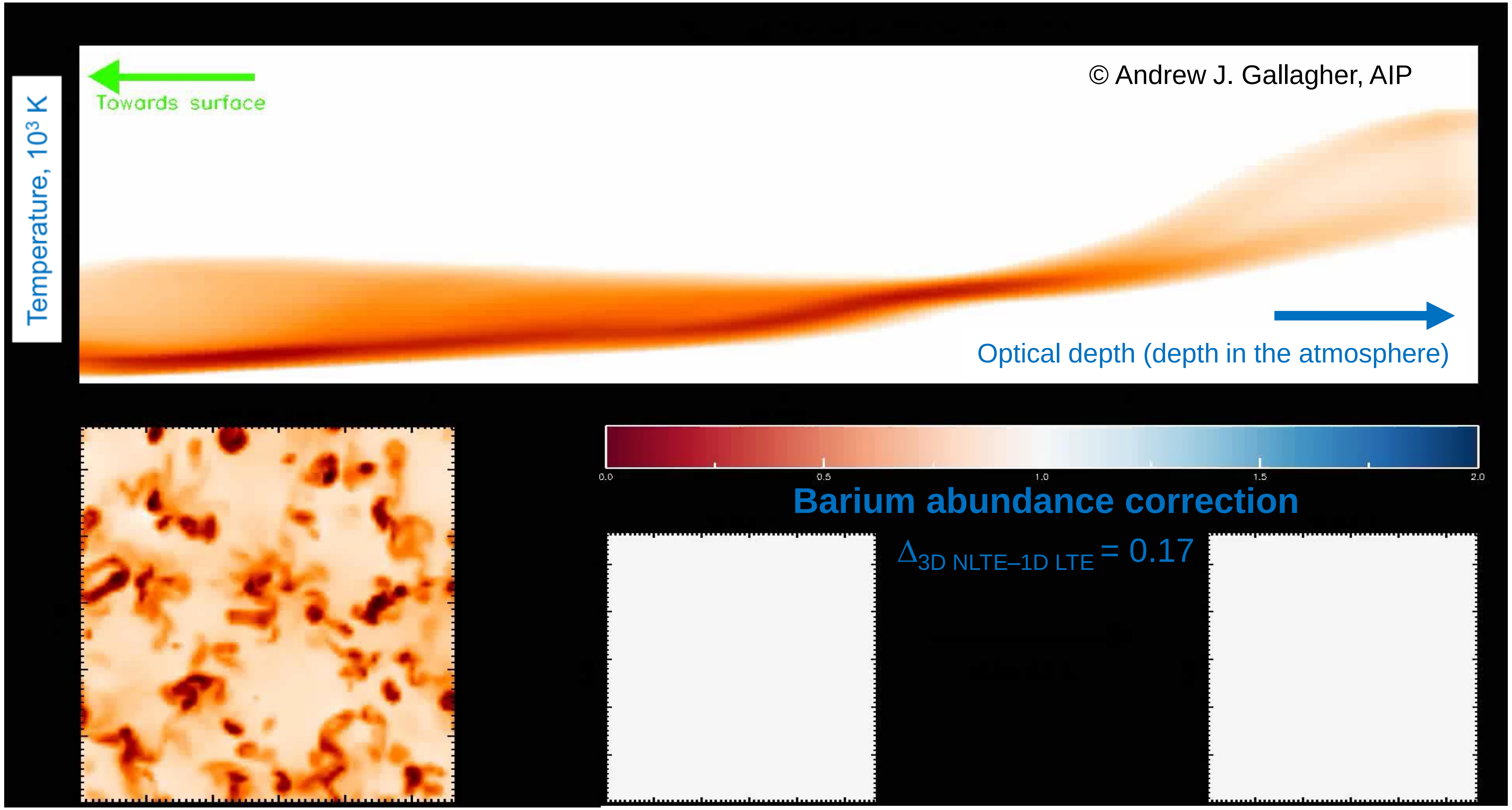
TASK 5.1: 3D NLTE ABUNDANCE CORRECTIONS DATABASE

- New grid of 3D hydrodynamical model atmospheres – ONGOING
  - 75 low-res + 35 high-res 3D model atmospheres (2023: 77)
  - 11 million CPU hours used (2023: 7 CPU Mhrs)
- New tools for 1.5D NLTE abundance analysis – FINISHED
  - NLTE15D: a new tool for the computation of 1.5D NLTE abundance corrections



ChETEC INFRA WP5: results

Ba II 4554.033 Å line formation in the atmosphere of red giant star



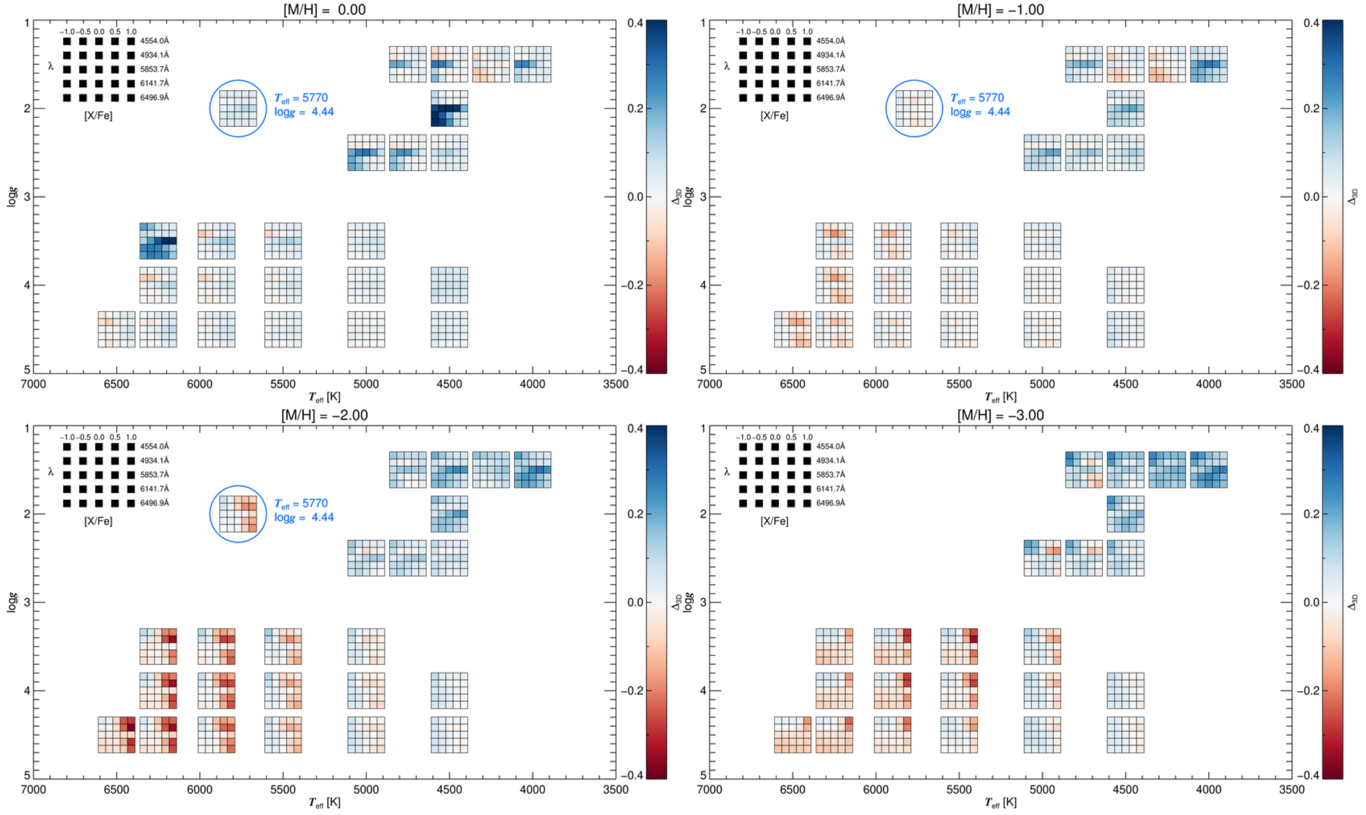
Temperature map | Departure, lower level | **Ba II 4554 line** | Departure, upper level

ChETEC INFRA WP5: results

TASK 5.1: 3D NLTE ABUNDANCE CORRECTIONS DATABASE

- Grid of 1.5D NLTE abundance corrections for Ba – FINISHED
  - 1.5D NLTE corrections for 92 3D models
  - part of computations: VIPER HPC cluster at Hull University
  - database: https://www.chetec-infra.eu/3DNLTE/

3D NLTE abundance corrections for Ba II lines
© Andrew J. Gallagher, AIP

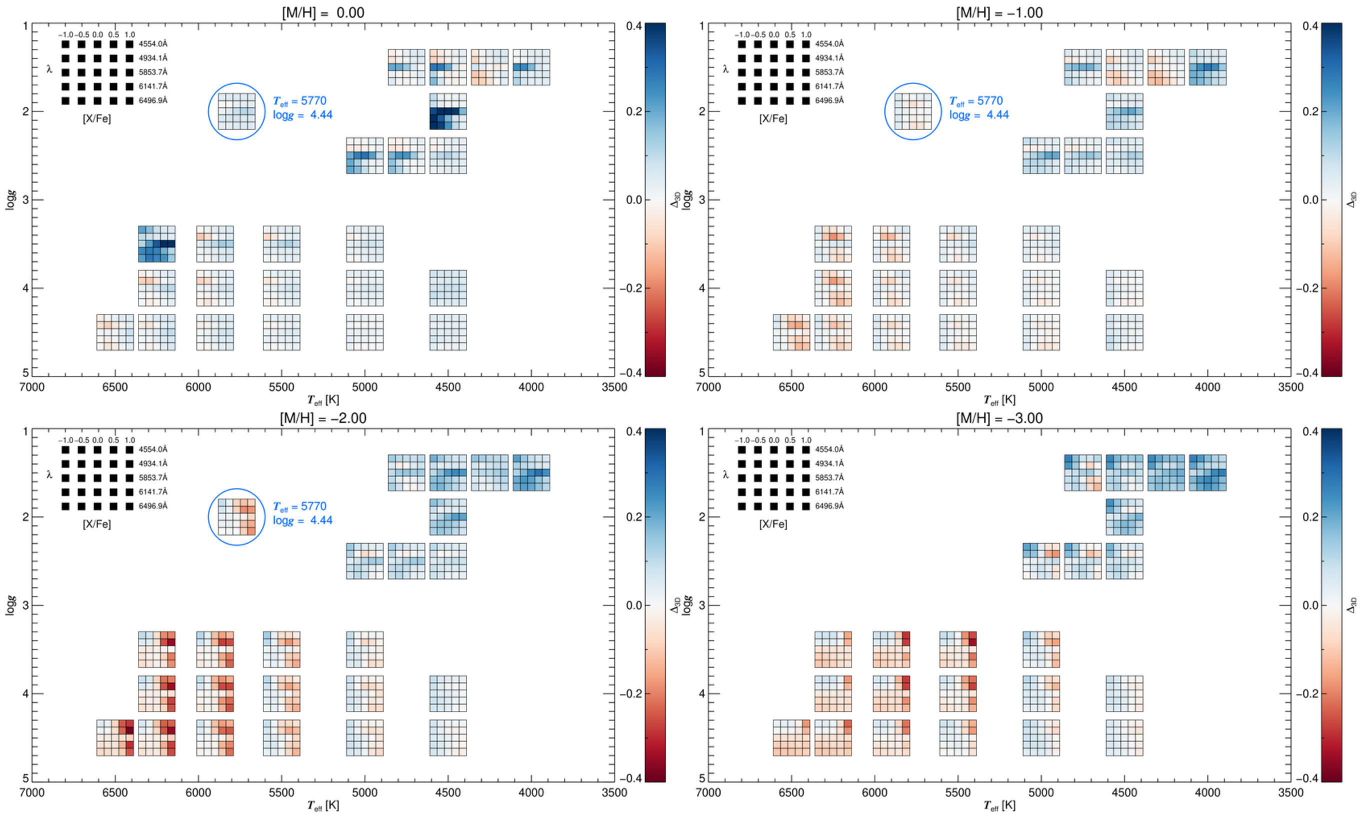


ChETEC INFRA WP5: results

TASK 5.1: 3D NLTE ABUNDANCE CORRECTIONS DATABASE

- Grid of 1.5D NLTE abundance corrections for Ba – FINISHED
  - 1.5D NLTE corrections for 92 3D models
  - part of computations: VIPER HPC cluster at Hull University
  - database: https://www.chetec-infra.eu/3DNLTE/
- Grid of 1.5D NLTE abundance corrections for Sr – STARTED
- Other s/r-process elements - FORTHCOMING

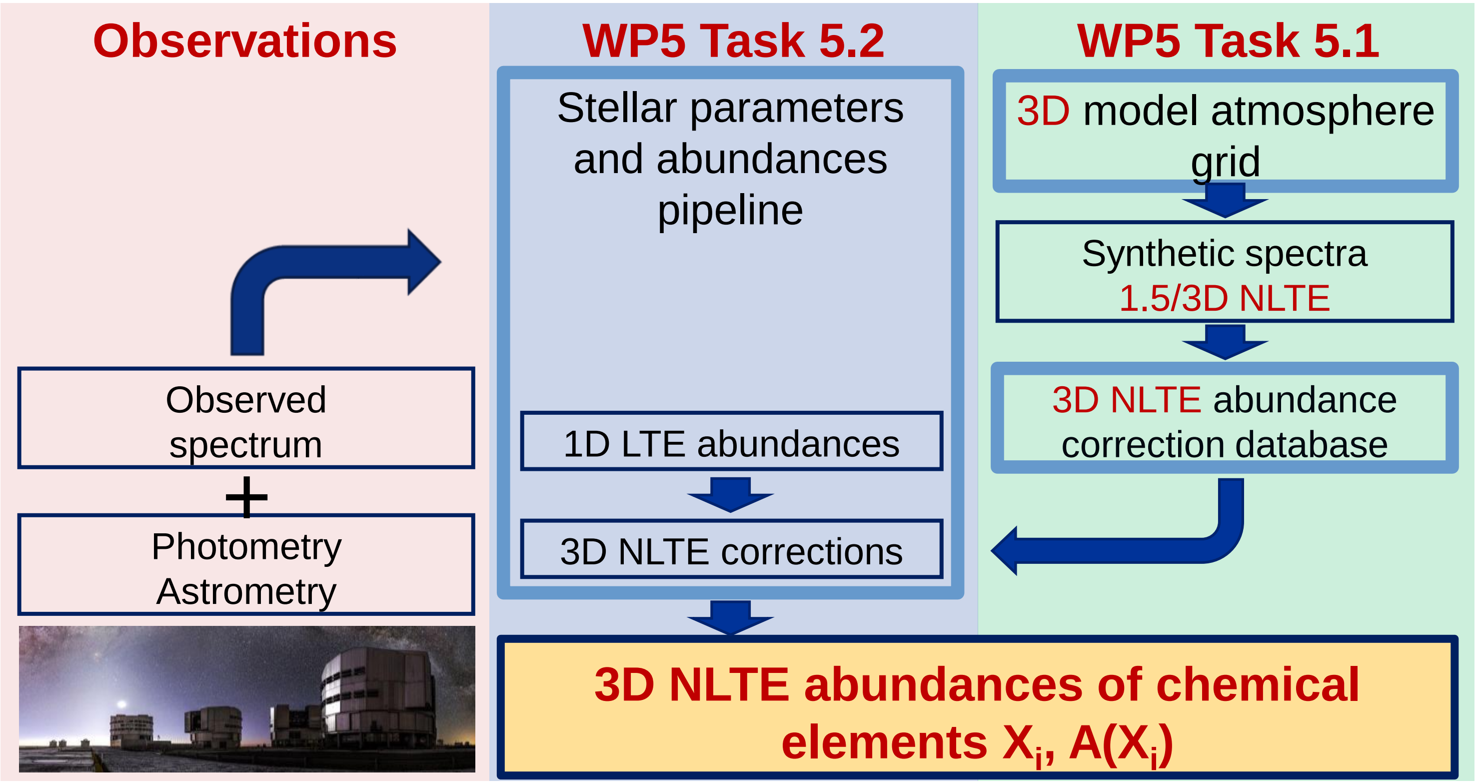
3D NLTE abundance corrections for Ba II lines
© Andrew J. Gallagher, AIP



ChETEC INFRA WP5: results

TASK 5.2: ABUNDANCE DETERMINATION PIPELINE

- Automated open-source abundance pipeline: stellar parameters, 3D/1D LTE/NLTE abundances

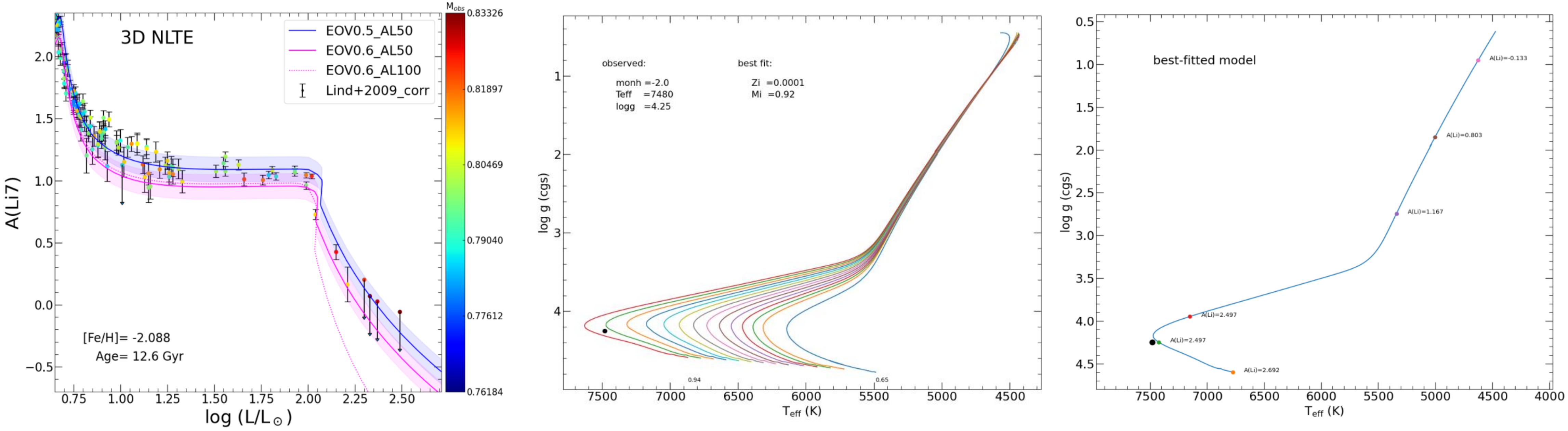


Arūnas Kučinskas, Vilnius University, Lithuania, arunas.kucinskas@tfai.vu.lt

ChETEC INFRA WP5: results

TASK 5.2: ABUNDANCE DETERMINATION PIPELINE

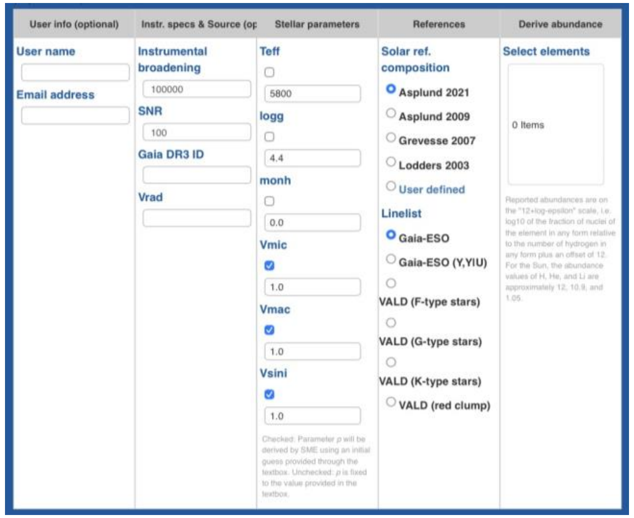
- Automated open-source abundance pipeline: stellar parameters, 3D/1D LTE/NLTE abundances
  - a new grid of stellar evolutionary track computed with the PARSEC code (new: calibrated thermohaline mixing and overshooting)

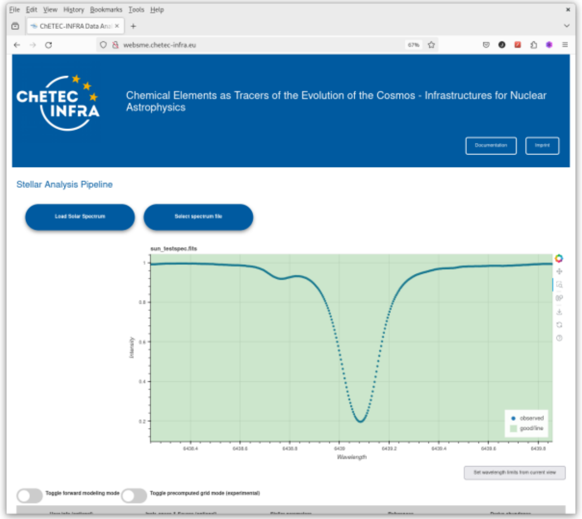


ChETEC INFRA WP5: results

TASK 5.2: ABUNDANCE DETERMINATION PIPELINE

- Automated open-source abundance pipeline: stellar parameters, 3D/1D LTE/NLTE abundances
  - a new grid of stellar evolutionary track computed with the PARSEC code (new: calibrated thermohaline mixing and overshooting)
  - webSME
    - abundance determination pipeline and its online interface - AVAILABLE FOR USE
    - 1.5D NLTE abundance corrections for Ba implemented already
    - already used for Bachelor/Master projects at Uppsala; paper on webSME forthcoming



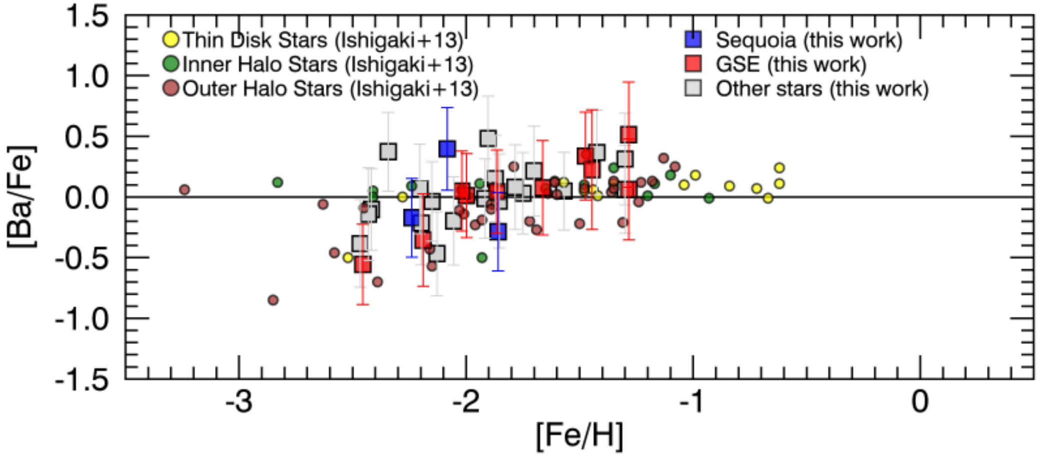


ChETEC INFRA WP5: results

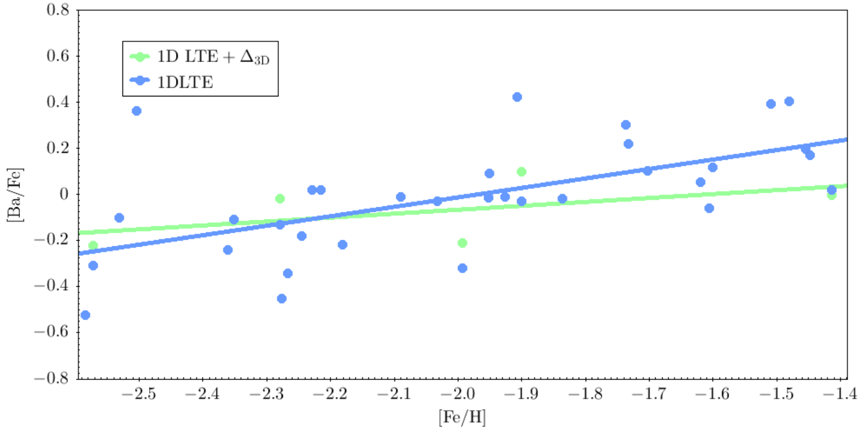
A SUCCESS STORY: PROJECT MINCE

- “Measuring at Intermediate Metallicity Neutron Capture Elements” (MINCE; talk by Gabriele Cescutti)
- Abundances in the Galactic halo stars at [Fe/H] = -1 … -2.
- Small-to-medium size telescopes, medium-to-high res spectra
- A significant amount of data via ChETEC-INFRA TNA
- MINCE Papers I+II published
- Public MINCE database: http://archives.ia2.inaf.it/mince/
- **Future**: final sample of 200-300 stars, **WP5 abundance pipeline to obtain 1.5D NLTE abundances of s-process elements**

Star	Teff	log g	[Fe/H]	Ba corr
Sun	5770	4.44	0.00	-
HD 115575	4393	1.50	-1.99	0.2
BD +48 2167	4468	1.50	-2.29	0.2
BD +11 2896	4254	1.50	-1.41	0.067
BD -00 4538	4482	1.50	-1.90	0.216
BD +03 4904	4497	1.50	-2.58	0.177



MINCE II
Francois et al. 2024 in press



ChETEC INFRA WP5: results

SCHOOLS, OUTREACH

- First ChETEC-INFRA Observational School in Ondrejov, July 2023:
    - ~20 students
    - 3 nights of remote observations with NOT, lots of data obtained for the analysis
    - successful usage of webSME pipeline by students to analyze the data obtained
    - students (and lecturers!) excited!
- Second ChETEC-INFRA Observational School: March (early April) 2025
- Masterclass by Hannes Nitsche et al. on cosmological lithium problem, utilizes the webSME pipeline

ChETEC INFRA WP5: results

HIRING OF PERSONNEL

- 2-year PDRA at the Astrophysical Institute Potsdam (Andrew J. Gallagher)
- 2-year PDRA (1-year funding from ChETEC-INFRA) at Uppsala Observatory (Johannes Puschnig)
- 2-year PDRA at the Trieste Astronomical Observatory (Chi Thanh Nguyen)
- 1-year PDRA at Vilnius University (Jonas Klevas / Edgaras Kolomiecas)

THANK YOU!

Partners

Associated partners