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

07/06/2023

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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 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

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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

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ChETEC INFRA WP5: goals and deliverables

THE GOAL

Perform tasks aimed at homogenising stellar abundance analyses and at providing the nuclear-astrophysics community with the new abundance analysis tools

THE DELIVERABLES

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

THE TEAM

27 participants from 19 institutions (13 countries)

Partners

Associated partners

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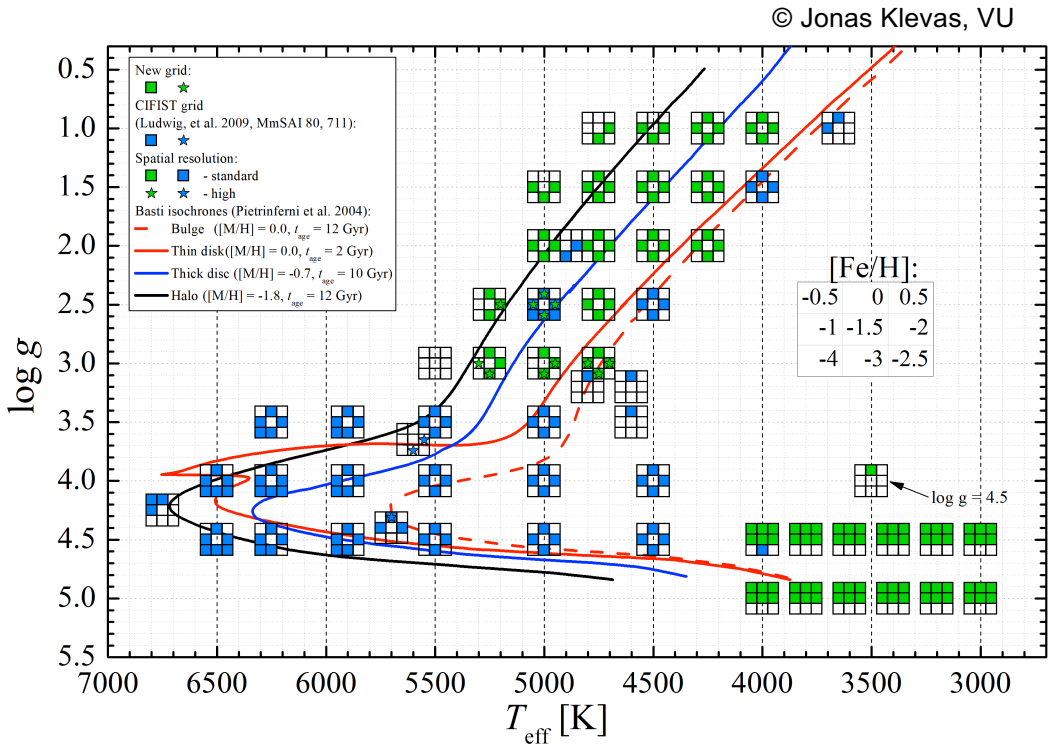
ChETEC INFRA WP5: results

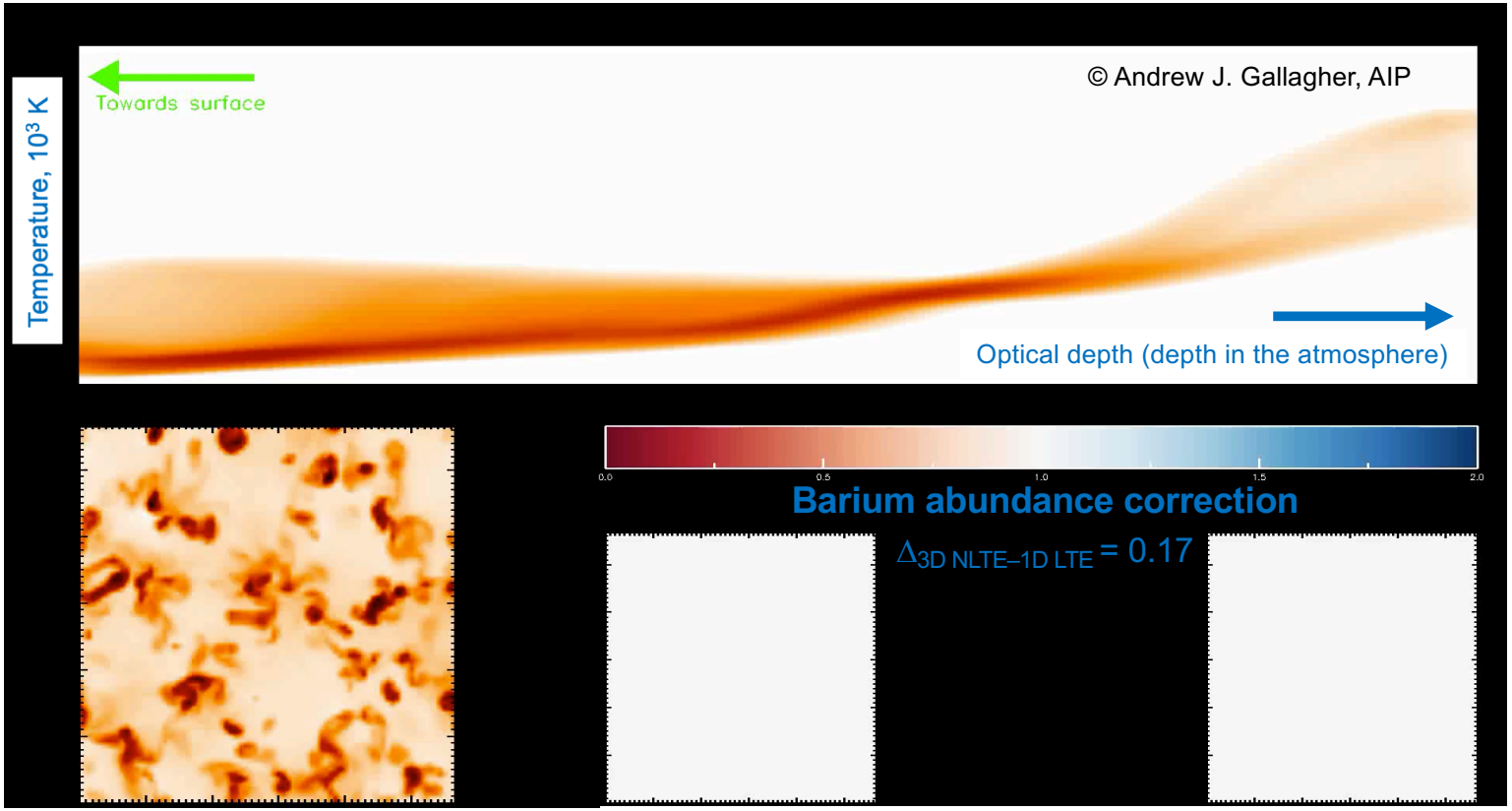
TASK 5.1: 3D NLTE ABUNDANCE CORRECTIONS DATABASE

- New grid of 3D hydrodynamical model atmospheres:
  - 77 3D model atmospheres of red giants
  - >7 million CPU hours used
- New tools for 1.5D NLTE abundance analysis (talk by A. J. Gallagher):
  - massive parallelized computations of 1.5D NLTE abundance corrections using 3D hydrodynamical model atmospheres



ChETEC INFRA WP5: results

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

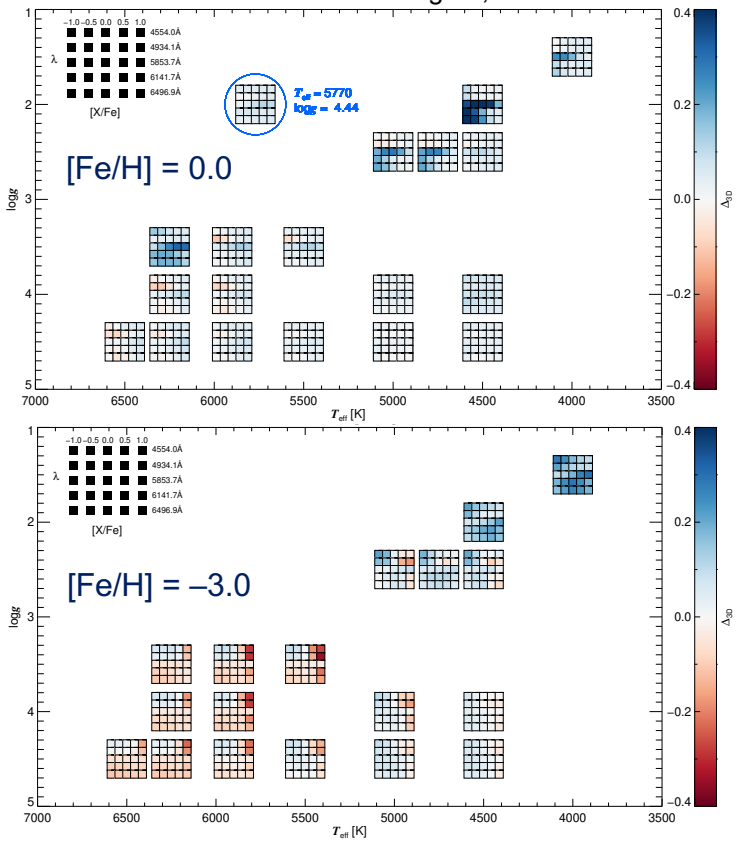


ChETEC INFRA WP5: results

TASK 5.1: 3D NLTE ABUNDANCE CORRECTIONS DATABASE

- New grid of 3D hydrodynamical model atmospheres:
  - 77 3D model atmospheres of red giants
  - >7 million CPU hours used
- New tools for 1.5D NLTE abundance analysis (talk by A. J. Gallagher):
  - massive parallelized computations of 1.5D NLTE abundance corrections using 3D hydrodynamical model atmospheres
- Grid of 1.5D NLTE abundance corrections for Ba (talk by A. J. Gallagher):
  - 1.5D NLTE corrections for 56 3D models
  - part of computations done on the VIPER HPC cluster at Hull University, via the ChETEC-INFRA TNA
  - >7.5 million CPU hours used
  - database (v1.0, 2023-04): https://web.vu.lt/tfai/j.klevas/

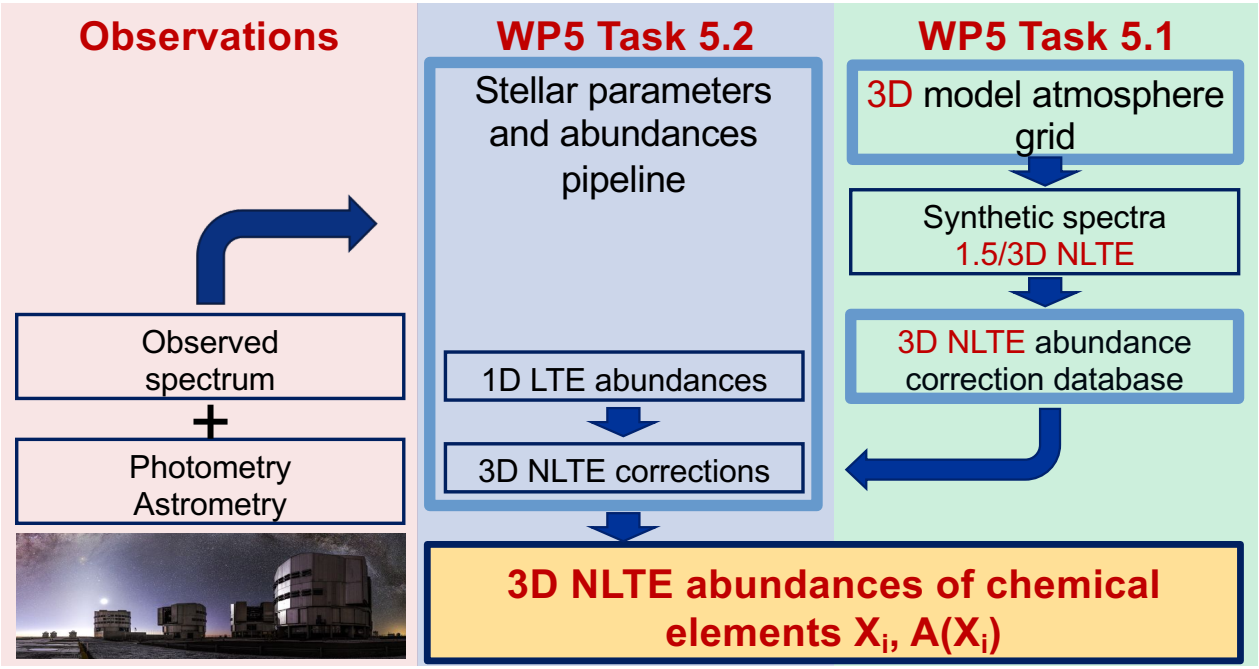
3D NLTE abundance corrections for Ba II lines
© Andrew J. Gallagher, AIP



ChETEC INFRA WP5: results

TASK 5.2: ABUNDANCE DETERMINATION PIPELINE

- Automated open-source abundance pipeline: stellar parameters, 3D/1D LTE/NLTE abundances
  - prototype of the abundance determination pipeline and its online interface available (talk of J. Puschnig)
  - preliminary results on the correction of the abundances due to stellar evolution



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ChETEC INFRA WP5: results

CONFERENCES, MEETINGS, SCHOOLS

- Organisation the 1st ChETEC-INFRA Observational school (ChINOS; 24-28 July 2023)
- Russbach School on Nuclear Astrophysics: lectures by G. Cescutti, A. Korn, J. Puschnig
- NPA-X summer school at CERN, Aug 29 – Sep 3, 2022: organisation of remote observations at the NOT (La Palma, Canaries) and hands-on experience with stellar analysis tools
- Presentation on ChETEC-INFRA at a workshop in Sexten “Stellar Ages and Galactic Archaeology” (G. Cescutti https://www.sexten-cfa.eu/event/stellar-ages-and-galactic-archaeology/)
- Regular online meetings of WP5 Task 5.1 & 5.2
- Involvement in organizing 12 SNAQs online schools since Feb 2021 (https://events.hifis.net/event/606/). Three SNAQs schools were organized by WP5 on topics related to WP5 matters

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)

ChETEC INFRA WP5: results

A SPIN-OFF PROJECT MINCE

- “Measuring at Intermediate Metallicity Neutron Capture Elements” (MINCE)
- Abundances in the Galactic halo stars at [Fe/H] = -1 … -2.
- Small-to-medium size telescopes, medium-to-high resolution spectra
- Significant amount of data via ChETEC-INFRA TNA
- MINCE Paper I published: analysis of the first year sample, 46 stars
- 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**

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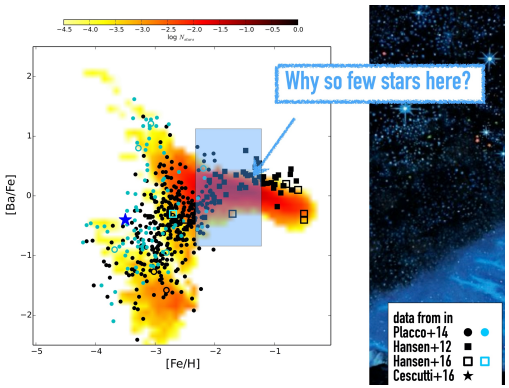
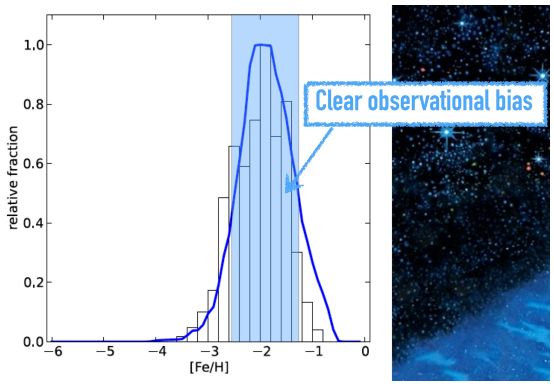




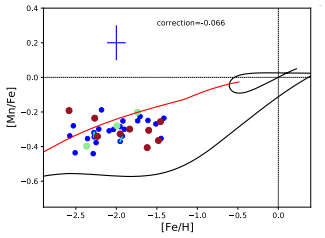
A&A 668, A168 (2022)
https://doi.org/10.1051/0004-6361/202244515

MINCE

Astronomy & Astrophysics

I. Presentation of the project and of the first year sample★,★★

G. Cescutti[1,2,3], P. Bonifacio[4], E. Caffau[4], L. Monaco[5], M. Franchini[2], L. Lombardo[4], A. M. Matas Pinto[4], F. Lucertini[5,6], P. François[4,7], E. Spitoni[8,9], R. Lallement[4], L. Sbordone[6], A. Mucciarelli[10,11], M. Spite[4], C. J. Hansen[12], P. Di Marcantonio[2], A. Kučinskas[13], V. Dobrovolskas[13], A. J. Korn[14], M. Valentini[15], L. Magrini[16], S. Cristallo[17,18], and F. Matteucci[1,2,3]



g. 19. [Mn/Fe] versus [Fe/H] abundances measured in the MINCE
urs; the details are the same as Fig. 6.

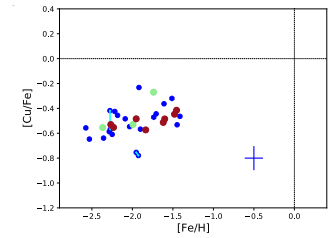
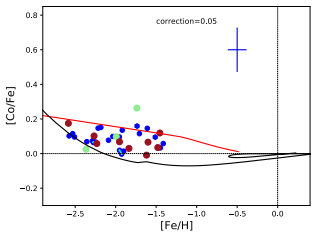


Fig. 22. [Cu/Fe] versus [Fe/H] abundances measured in the MINCE stars; the details are the same as Fig. 6, but without the lines of the models.



g. 20. [Co/Fe] versus [Fe/H] abundances measured in the MINCE
urs; the details are the same as Fig. 6.

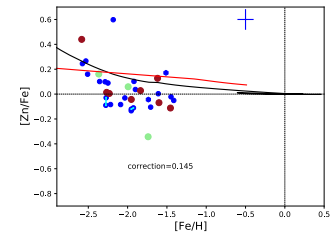


Fig. 23. [Zn/Fe] versus [Fe/H] abundances measured in the MINCE stars; the details are the same as Fig. 6.

THANK YOU!

Partners

Associated partners

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