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ChETEC-INFRA

Chemical Elements as Tracers for the Evolution of the Cosmos – Infrastructures for Nuclear Astrophysics

JRA3–WP5 „Astronuclear abundances"

Arūnas Kučinskas, Vilnius University

Partners

Associated partners

JRA3–WP5: RATIONALE

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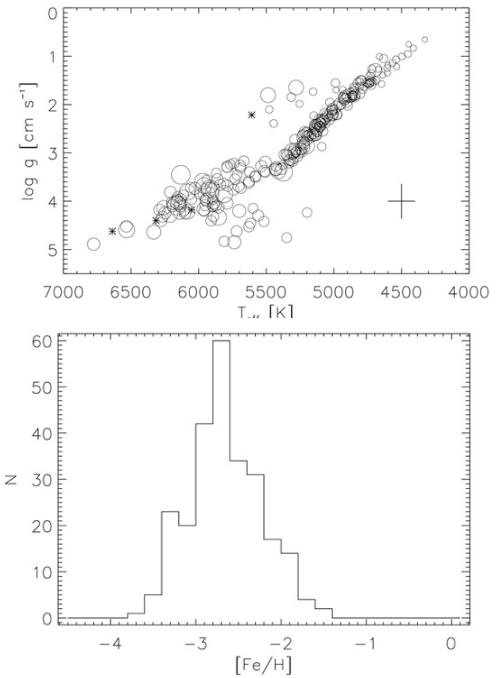
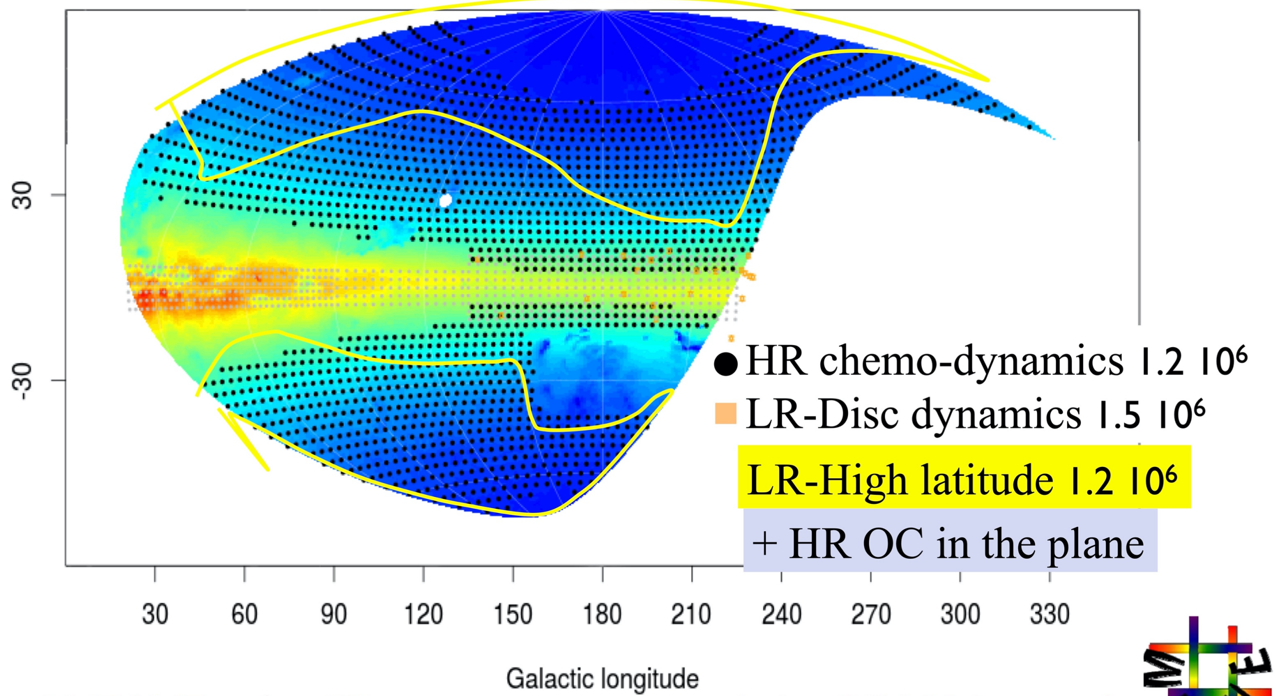
RECENT ADVANCES IN THE FIELD OF STELLAR SPECTROSCOPY

- Massive spectroscopic surveys are becoming mainstream (see Andreas talk):
  - early surveys: 100-1000s of stars (e.g. HERES, etc.)
  - ongoing & planned surveys: 10^5–10^6s stars (Gaia-ESO, APOGEE, WEAVE, 4MOST, etc.)

Initial HERES sample (Barklem et al. 2005)



Coverage of the WEAVE HR/LR surveys (Hill 2017)



WEAVE ~4 million stars to unravel the MW history !

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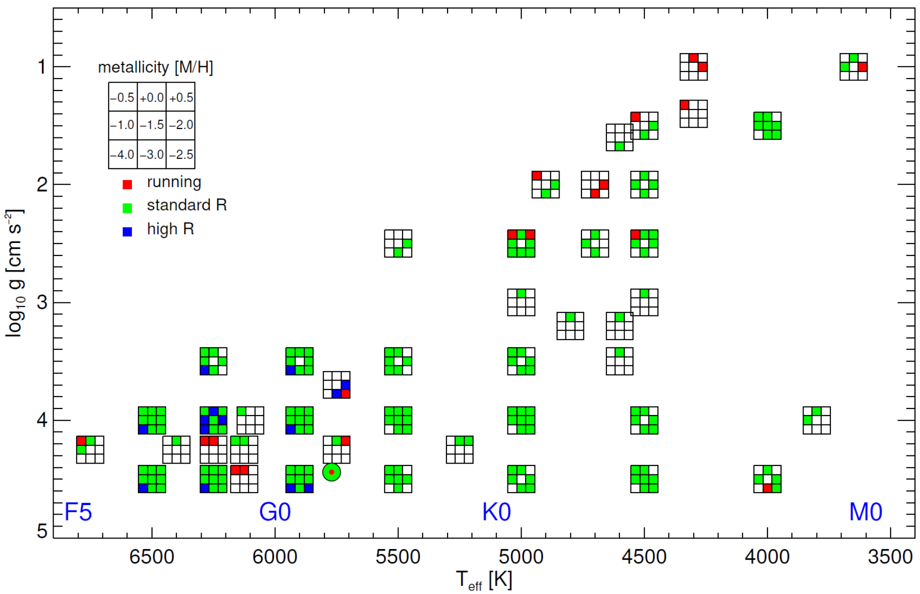
RECENT ADVANCES IN THE FIELD OF STELLAR SPECTROSCOPY

- Massive spectroscopic surveys are becoming mainstream (see Andreas talk)
- Impressive developments in 3D hydrodynamical modelling of stellar atmospheres and NLTE spectral synthesis (see Matthias talk)

3D hydro model atmosphere grids (CO5BOLD: Ludwig et al. (2009) + updates)



3D NLTE abundance correction databases (3D NLTE Li: https://pages.aip.de/li67nlte3d/

3D non-LTE corrections for Li abundance and ^{6}Li/^{7}Li isotopic ratio in solar-type stars

Tool explanation

This tool utilizes the analytical expressions developed in Harutyunyan G., Steffen M., Mott A. et al. (2018) to compute the 3D non-LTE (NLTE) corrections for lithium abundance (A(Li)) and ^{6}Li/^{7}Li isotopic ratio. The 3D NLTE correction of A(Li), defined as Δ A(Li), is computed as a function of effective temperature (T_{eff}), metallicity ([Fe/H]) and 1D LTE A(Li), whereas the 3D NLTE correction of ^{6}Li/^{7}Li isotopic ratio, defined as Δ ^{6}Li/^{7}Li, is a function of T_{eff}, [Fe/H], surface gravity (log g), projected rotational velocity (v sin$i$), 1D LTE A(Li) and ^{6}Li/^{7}Li ratio.

The analytical expressions used by this tool were derived for a typical range of stellar parameters for solar-type stars, and they are valid for the following ranges of input parameters:

$5800 \le T_{eff} \le 6500$ [K]

$-1.0 \le$ [Fe/H] $\le +0.5$

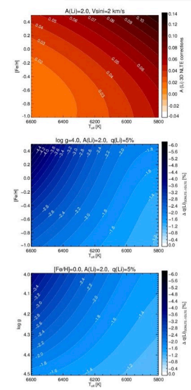
$4.0 \le \log g \le 4.5$

$0 \le v \sin i \le 6$ [km s^{-1}]

$1.0 \le A(\mathrm{Li}) \le 2.7$

$0 \le {}^6\mathrm{Li}/{}^7\mathrm{Li} \le 15$ [%]

$A(\mathrm{Li})_{3D\ NLTE} = A(\mathrm{Li})_{1D\ LTE} + \Delta A(\mathrm{Li})$



Contour plots of 3D NLTE A(Li) corrections, Δ A(Li) (upper panel), and ^{6}Li/^{7}Li ratio corrections, Δ ^{6}Li/^{7}Li (middle panel) in the T_{eff} - [Fe/H] plane. The same 3D NLTE ^{6}Li/^{7}Li corrections in the T_{eff} - log g plane are shown in the bottom panel. The contours are computed for [Fe/H]=0, v sin$i$=2 km s^{-1}, 1D LTE A(Li)=2.0 and ^{6}Li/^{7}Li=5%.

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- Massive spectroscopic surveys are becoming mainstream (see Andreas talk)
- Impressive developments in 3D hydrodynamical modelling of stellar atmospheres and NLTE spectral synthesis (see Matthias talk)

HOWEVER

- Methods and tools used to analyse stellar spectra very diverse
- Sizeable systematic differences in the results obtained by different groups and surveys
- Automated stellar abundance pipelines rarely open-source
- 3D NLTE stellar abundances still a rarity, even in the contexts where this may truly make a difference

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GOAL

- Develop open-access tools for automated 3D NLTE abundance analysis of large stellar samples

JRA3–WP5: TASKS

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- Task 5.1 (PI Arūnas K.): Develop a new, innovative tool for stellar abundance work based on state-of-the-art 3D hydrodynamical model atmospheres and NLTE spectral analysis techniques (see Matthias talk)

3D NLTE abundance corrections

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- Task 5.2 (PI Andreas K.): Device a pipeline that can serve as a starting point for homogeneous abundance analyses of stars used to constrain the chemical evolution of the Galaxy (see Andreas talk)

3D NLTE abundance corrections

↓

Automated pipeline for stellar abundances

JRA3–WP5: TASKS

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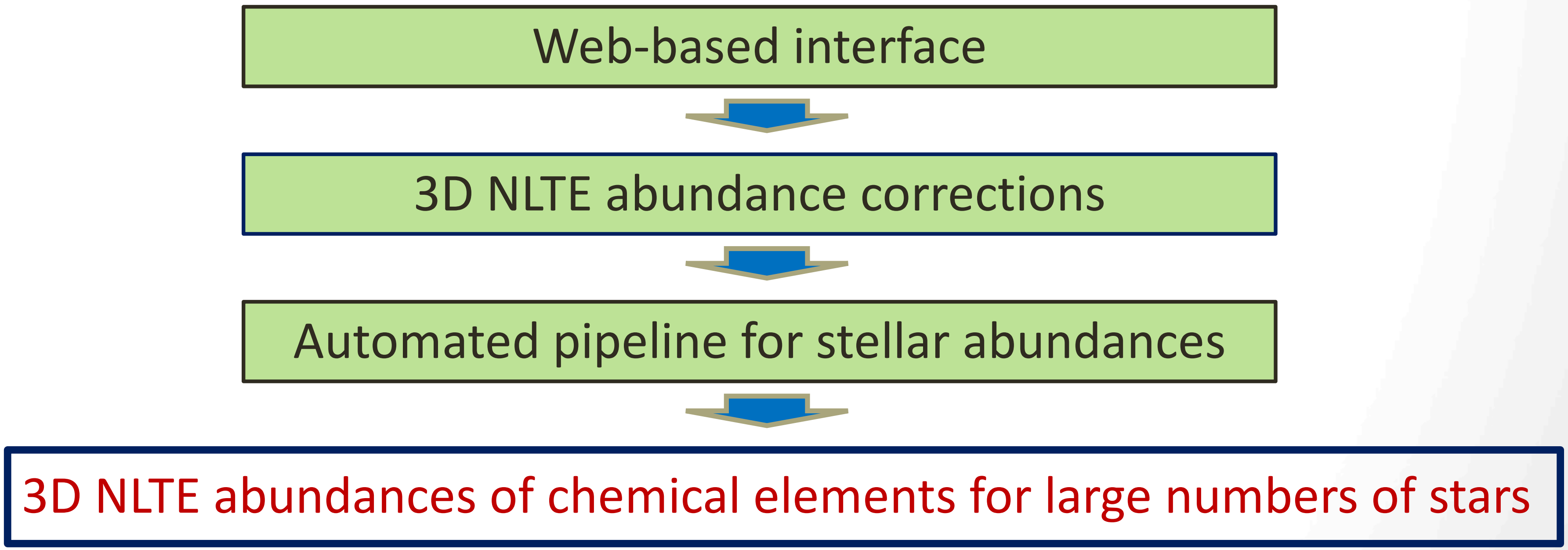
- Task 5.2 (PI Andreas K.): Device a pipeline that can serve as a starting point for homogeneous abundance analyses of stars used to constrain the chemical evolution of the Galaxy (see Andreas talk)
- Tasks 5.1-5.2: Build web-based interfaces to enable open access to the above-mentioned data products and tools (see Andreas/Matthias talks)



JRA3–WP5: TASKS

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TNA

NA1-WP6

Observed spectrum
+
Photometry
Astrometry

JRA3-WP5

Web-based interface

3D NLTE abundance corrections

Automated pipeline for stellar abundances

3D NLTE abundances of chemical elements for large numbers of stars

JRA3–WP5: TASKS

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Table 3.1b5: Work package description (JRA3 - WP5)

Work package number	**5**	**Lead beneficiary**			**VU/24**	
Work package title	**JRA3 Astronuclear Abundances**					
Participant number	4	5	6	10	12	19
Short name of participant	IANAO	ASU	AU	AIP	MPG	INAF
Person-months per participant	0	0	0	24	3	22
Participant number	24	29	Assoc	Assoc	Assoc	
Short name of participant	VU	UU	LSW Heidelberg	UiO Oslo	OAO Odessa	
Person-months per participant	9	10	0	0	0	
Start month	1				**End month**	48

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JRA3–WP5 TASK 5.1
„Database of 3D NLTE abundance corrections"

TASKS

- Compute a new grid of 3D hydrodynamical model atmospheres (VU, AIP, UiO, LSW Heidelberg)
- Develop a set of model atoms for the 3D NLTE abundance analysis (AIP, VU, LSW, OAO)
- Compute a grid of 3D NLTE – 1D LTE abundance corrections for a subset of elements that are of key importance for understanding stellar nucleosynthesis and chemical evolution of stars (AIP, VU, LSW, UU, MPG)
- Develop a dedicated web-based interface and tools to make the new grid of abundance corrections accessible to the nuclear-astrophysics community (VU, AIP, UU, MPG)

EXPECTED RESULT

A homogeneous open-source web-based database of 3D NLTE abundance corrections for the analysis of chemical abundances in different types of stars

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JRA3–WP5 TASK 5.2
„Homogeneous open-source stellar pipeline“

TASKS

- Device a tool to determine stellar parameters by using Gaia DR2/DR3 and results from Task 5.1 (UU, INAF, VU, AIP, LSH)
- Optimize its performance by using additional constraints from well-studied (so-called benchmark) stars and techniques independent of spectroscopy, e.g. asteroseismology (UU, INAF, MPG, VU)
- Device a tool for homogeneous abundance analysis, implement the correction for effects of stellar evolution like atomic diffusion and dredge-up episodes that systematically modify surface abundances (INAF, UU)
- Implement the correction for 3D/NLTE effects (UU, VU, AIP)

EXPECTED RESULT

Open-source stellar analysis pipeline that will homogeneously derive stellar parameters (effective temperature, surface gravity, metallicity, auxiliary parameters) and some chemical surface abundances relevant for nuclear-astrophysics studies (depending on specific target properties)

JRA3–WP5
„Astronuclear abundances“

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Let's start discussing, see how we can cooperate and make things happen together!

JRA3-WP5 is open to new ideas and collaborations!