# ChETEC-INFRA WP6.1 Trans-National Access Spectral Database

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Image: NightCafe

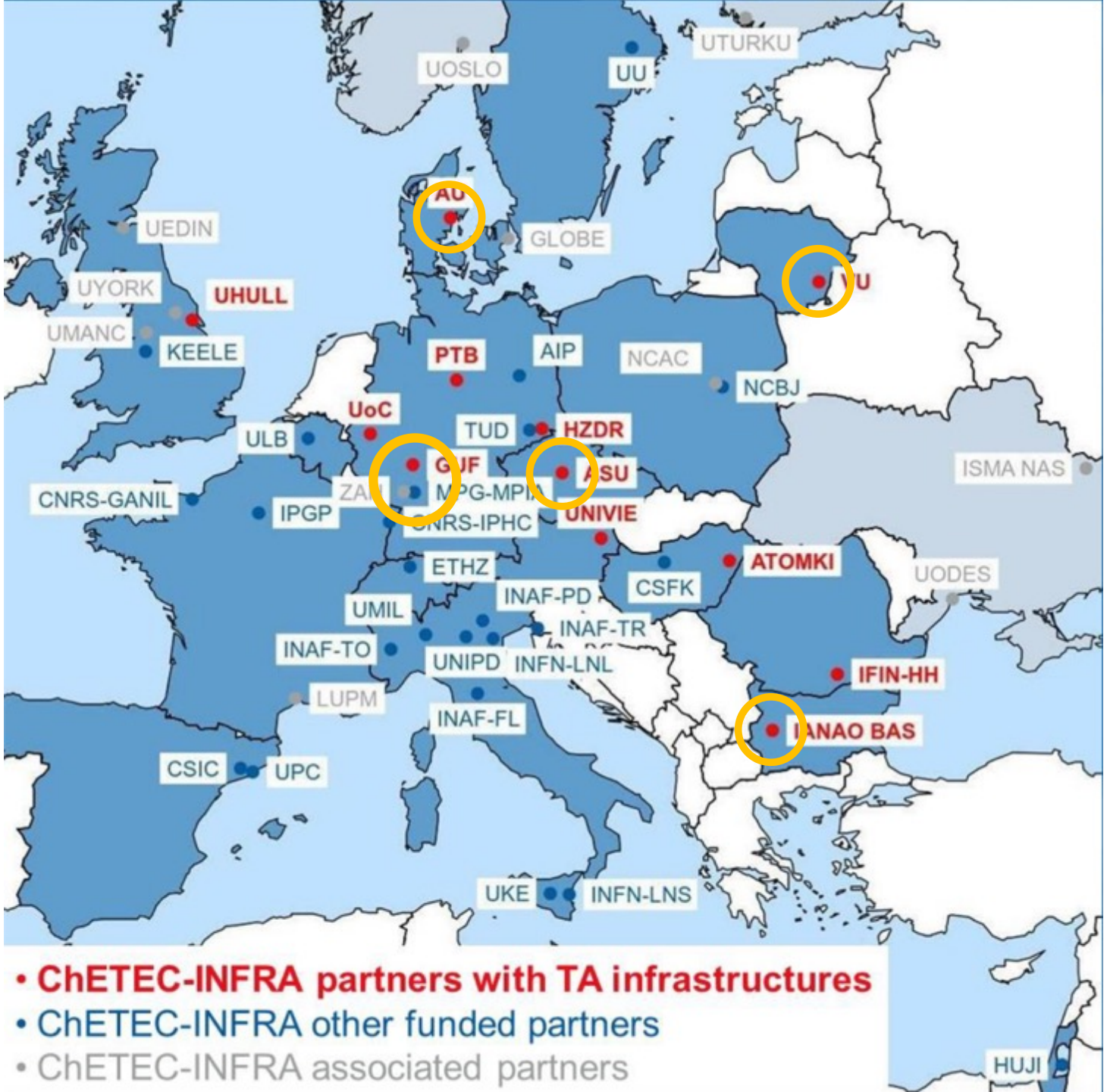
# Overview

- ChETEC-INFRA Work Package 6 “Comprehensive Nuclear Astrophysics”
- Task 6.1: Spectral Database
- The s-process in Asymptotic Giant Branch (AGB) stars
- Contents of the Database
- What can we do with the data?
- Data availability

# WP6 and Task 6.1: The Last 4 Years

- Specific goal of training students in all astro-nuclear disciplines
  - *Observe* s-process enhanced stars (MPIA, GUF)
  - *Model* stellar evolution with accretion and mixing (U. Bristol)
  - *Experiment* neutron interaction cross section (GUF)

- TNA infrastructures contribute to the spectral database
  - Focus on chemically interesting and binary stars
  - Support of observations and modeling efforts


UOSLO
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VU
UYORK
UHULL
UMANC
KEELE
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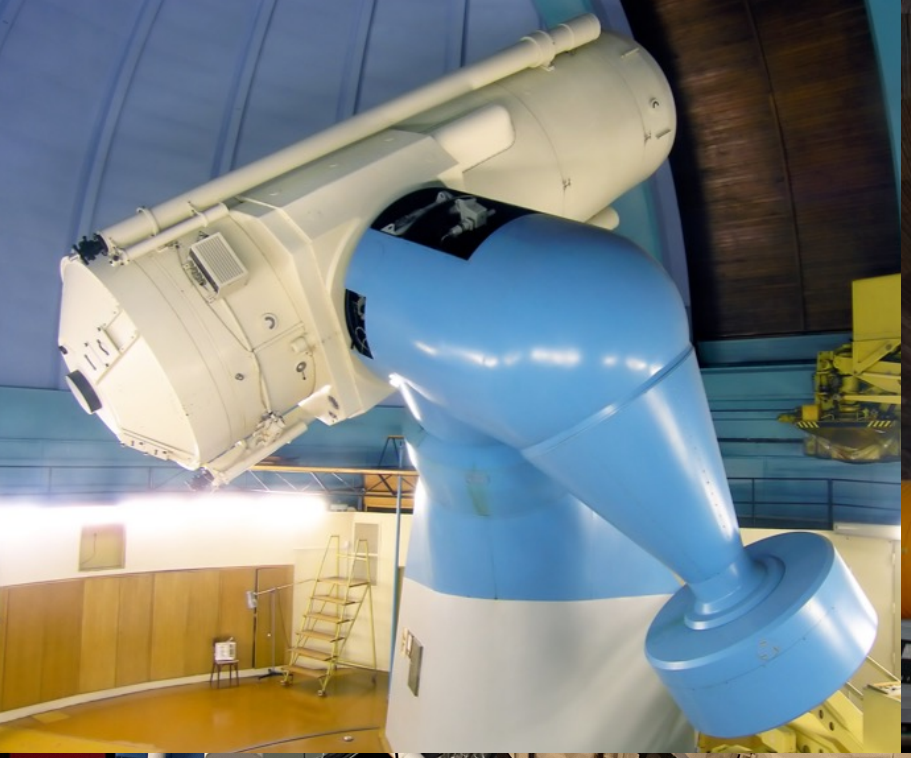
NCAC
NCBJ
UoC
TUD
HZDR
ULB
GUF
ASU
ISMA NAS
CNRS-GANIL
ZAU
MPG-MPIA
IPGP
CNRS-IPHC
UNIVIE
ETHZ
ATOMKI
UODES
CSFK
INAF-PD
UMIL
INAF-TR
INAF-TO
UNIPD
INFN-LNL
IFIN-HH
LUPM
INAF-FL
NANAO BAS
CSIC
UPC
UKE
INFN-LNS
HUJI
• ChETEC-INFRA partners with TA infrastructures
• ChETEC-INFRA other funded partners
• ChETEC-INFRA associated partners






# By The Numbers

| Infrastructure / Instrument | Resolution (R) (~5500 Å) | Telescope Diameter [m] | Obs. Nights Awarded ’21-’25 | # Spectra Collected |
|---|---|---|---|---|
| Moletai / VUES | 30000 | 1.65 | 57 | 538 |
| Ondrejov / OES | 51000 | 2.00 | 46 | 474 |
| Rozhen / ESpeRo | 30000 | 2.00 | 39 | 254 |
| NOT / FIES | 67000 | 2.56 | 10 | 138 |
| MPG / FEROS | 48000 | 2.20 | 36 | 561 |
| GUF VdG | … | … | (5) | (30) |
| **TOTAL** | | | **188** | **1965** |

# Overall Contributions

- Total stars observed: 404
  - Individual observations: 1965
- Measured Radial Velocities: 1628
  - Orbits computed: 47
- Stellar atmospheric parameters computed: 312
  - $T_{\text{eff}}$, log(g), [Fe/H]
  - Critical model inputs
- Derived abundances and patterns:
  - 343 individual abundances computed
  - 18 detections of Pb in stellar atmospheres

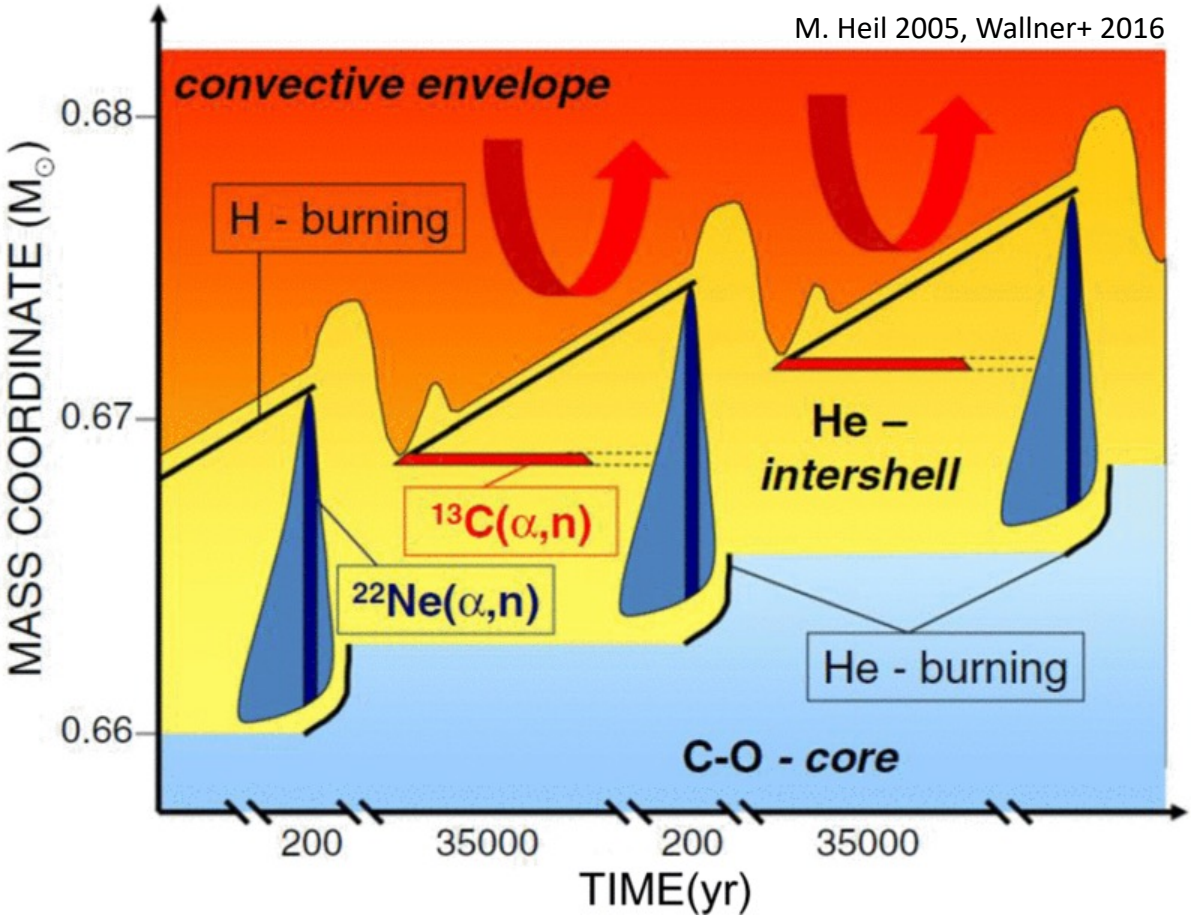
# Main Science Goals

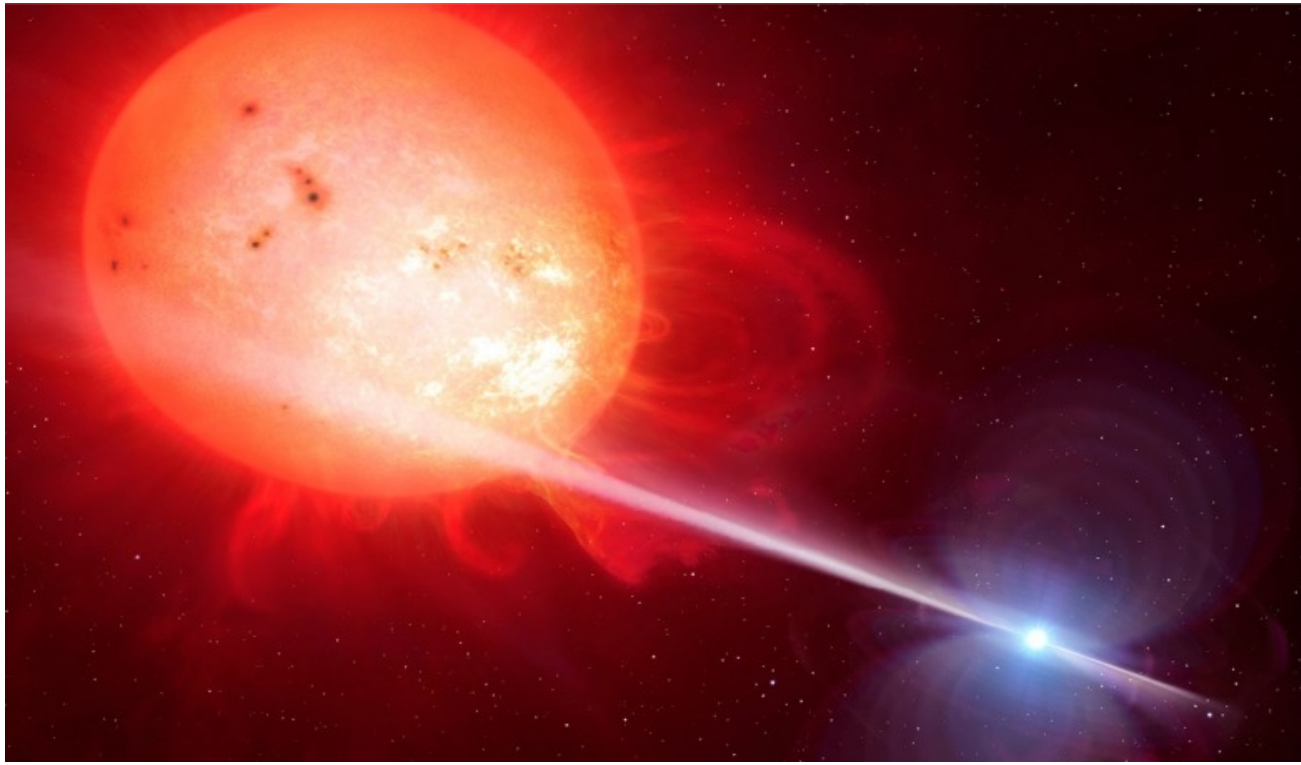
- Comprehensive perspective of the s-process

- s-Process as a way to probe binary stellar evolution
  - Orbital properties of AGB binaries
  - AGB donor masses
  - Mass transfer processes and efficiencies
  - (Refine nucleosynthesis models)

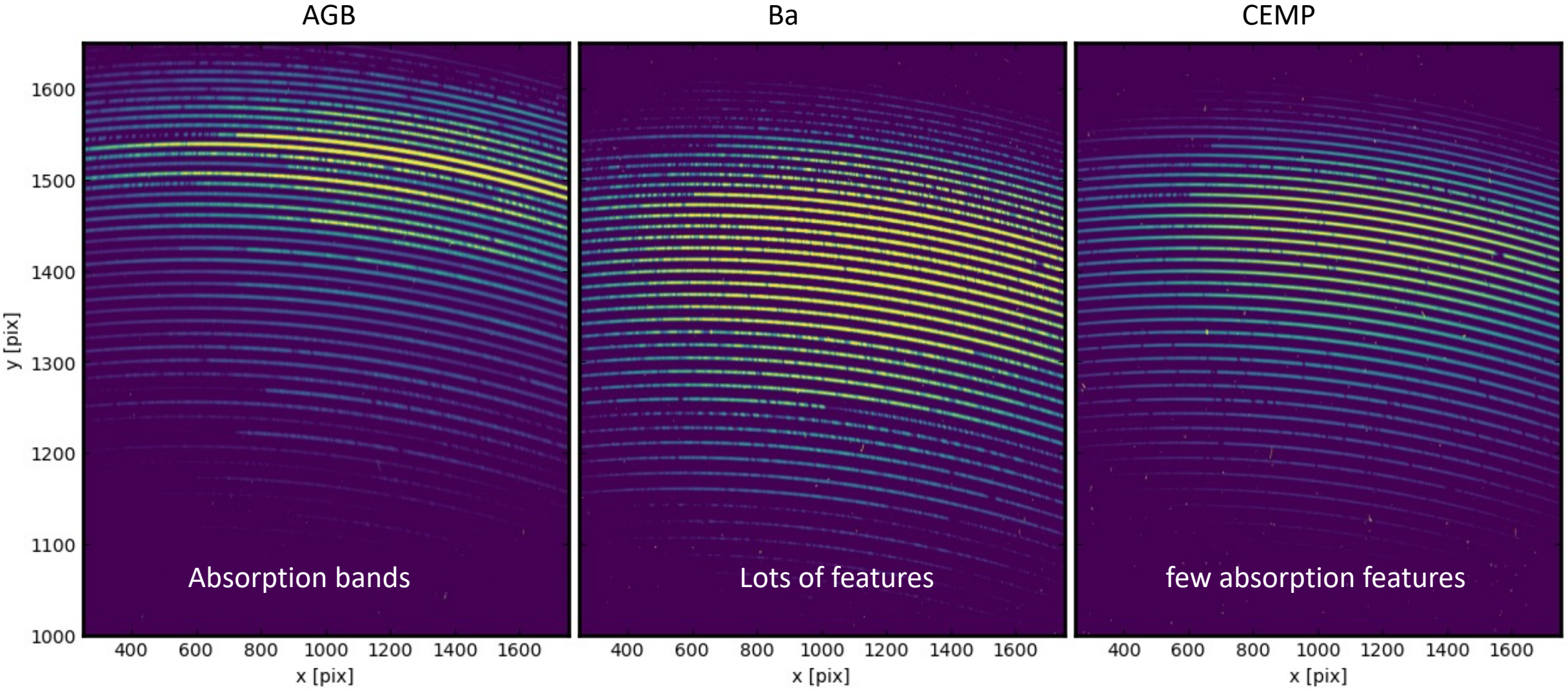
# Tracing the s-Process in and from AGB Stars

M. Heil 2005, Wallner+ 2016

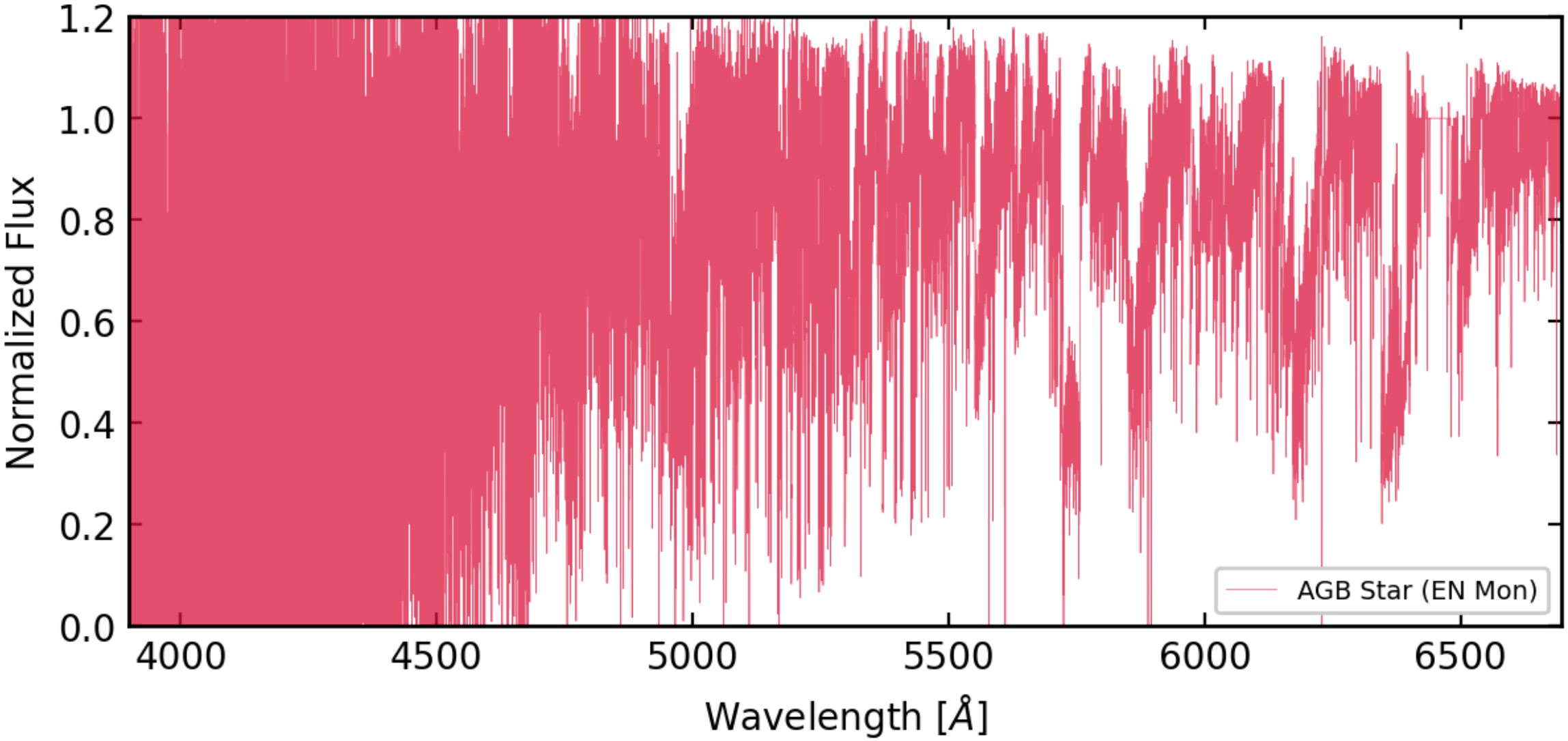


# From Raw Spectra



# To Reduced Spectra



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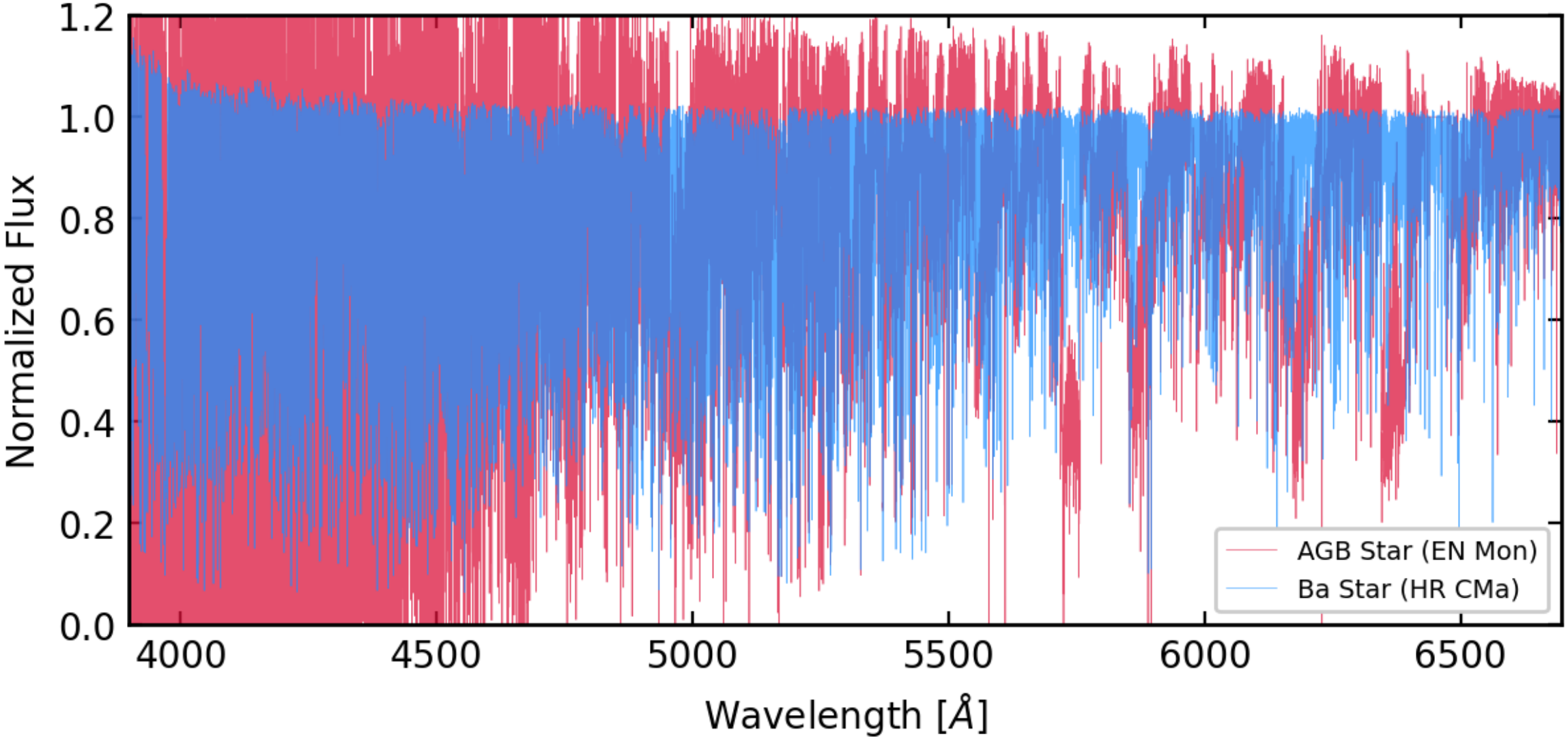

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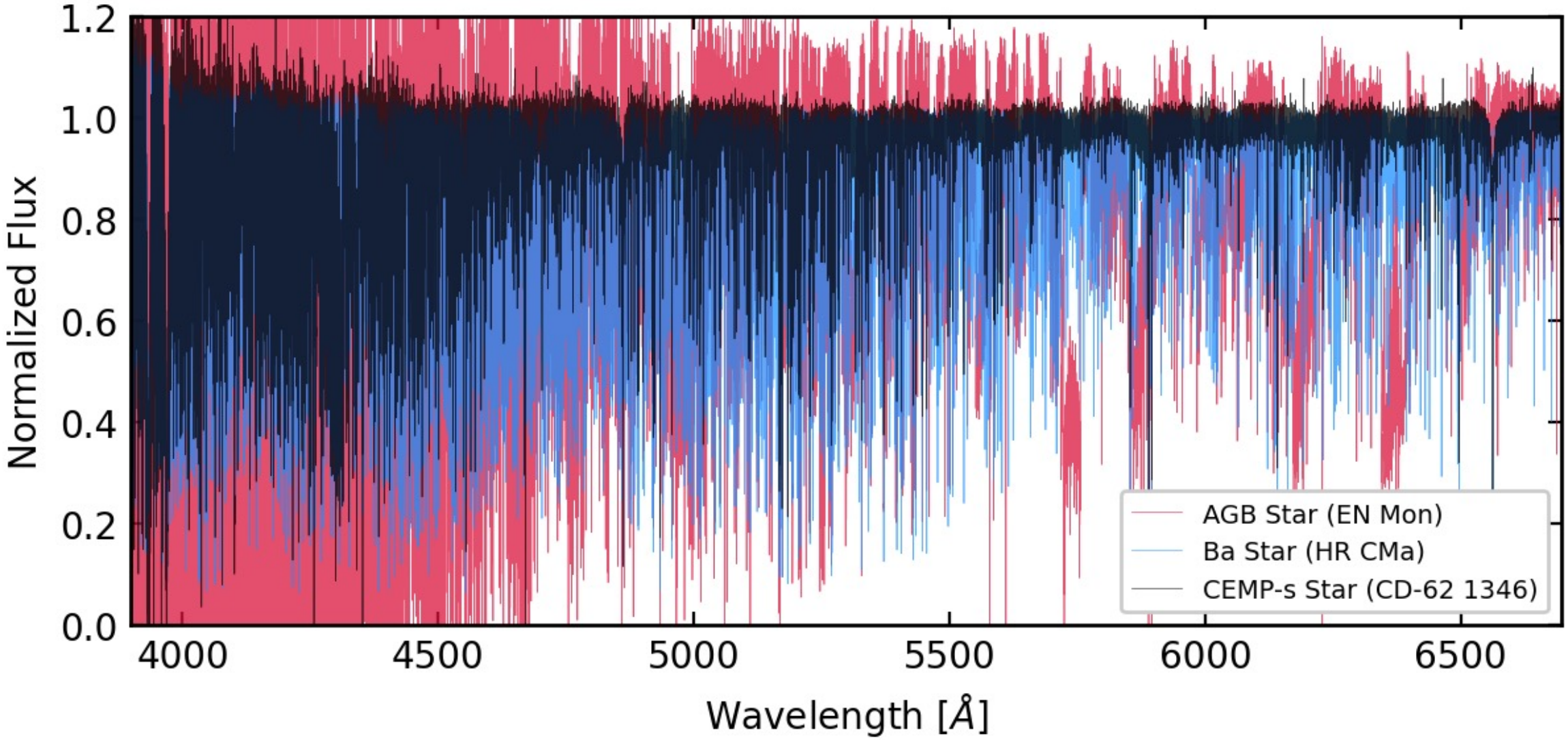
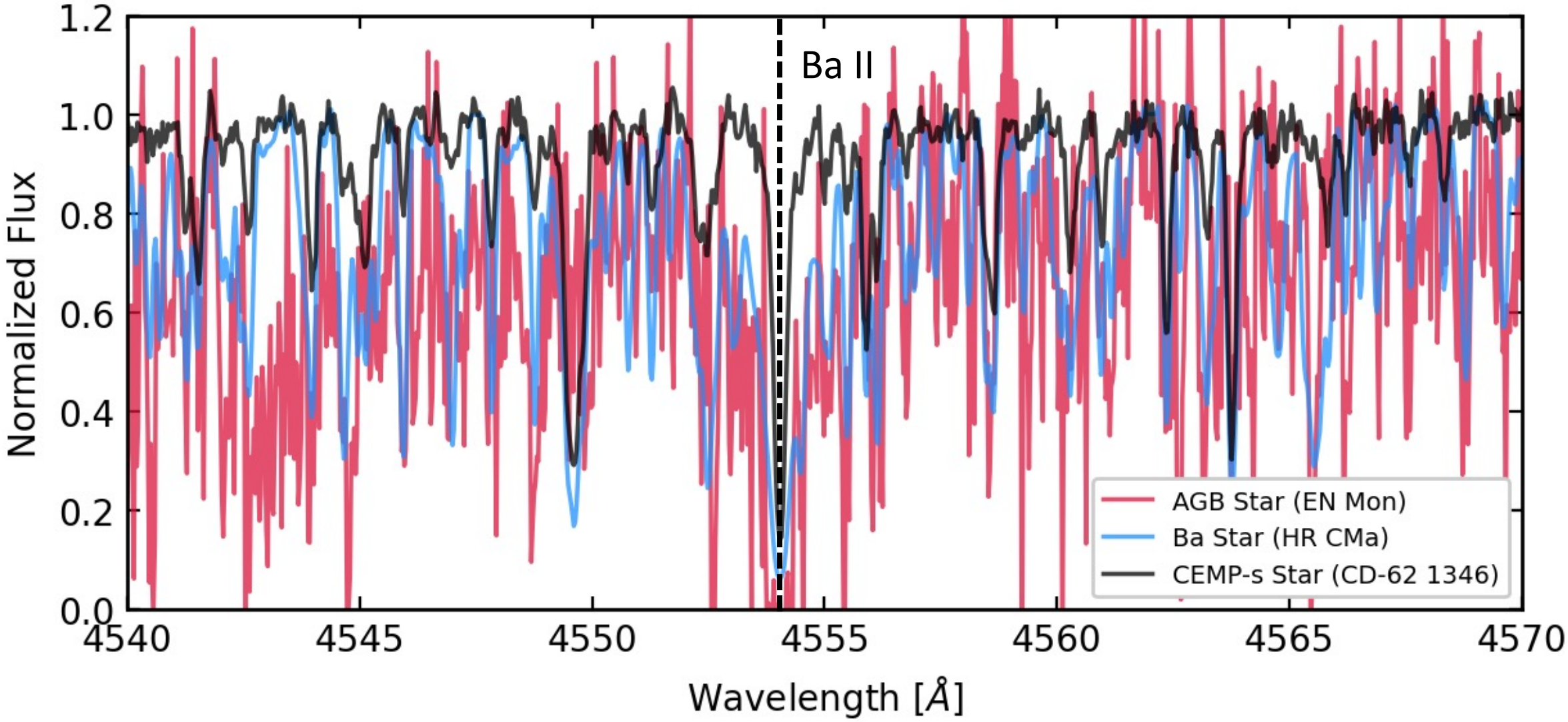
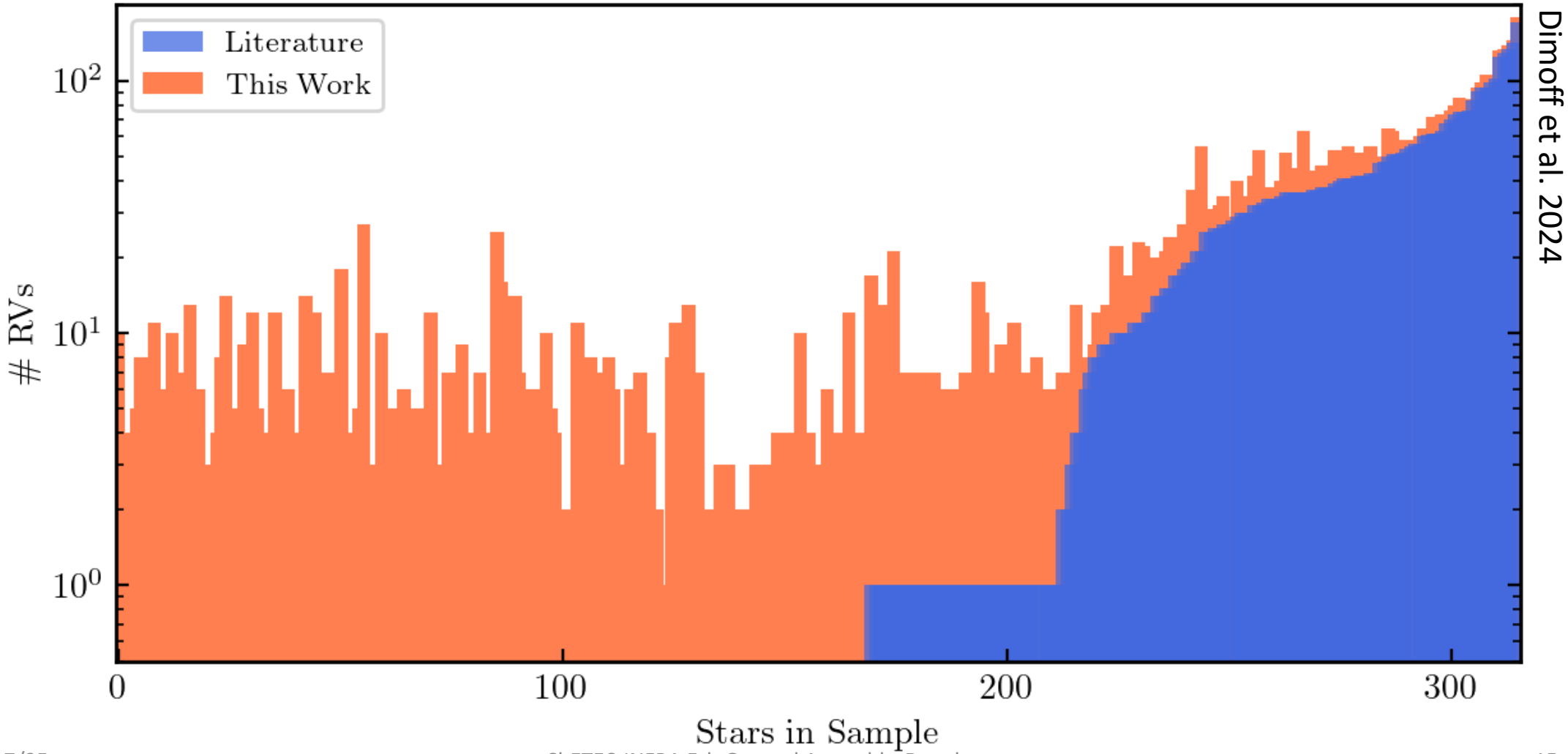


# To Reduced Spectra

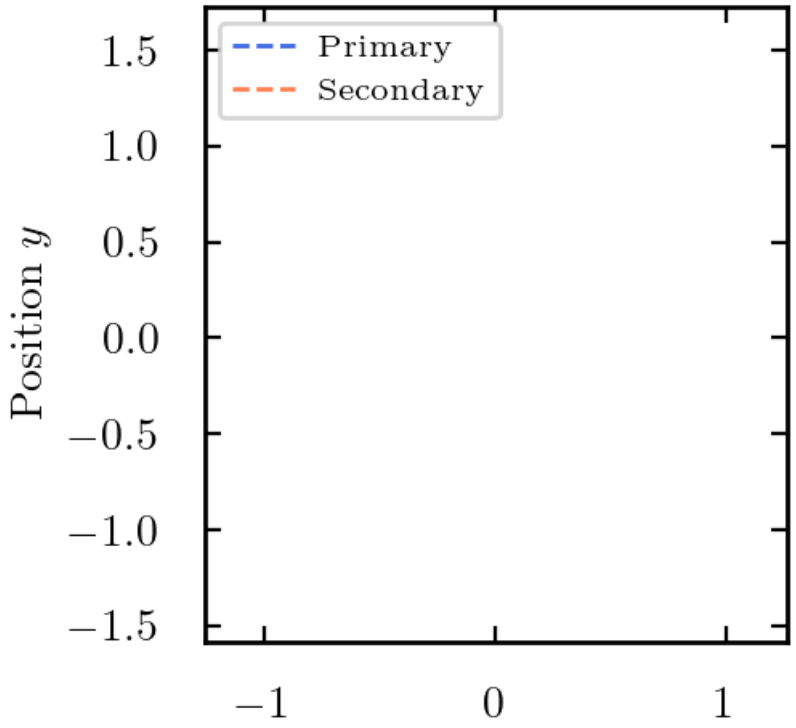


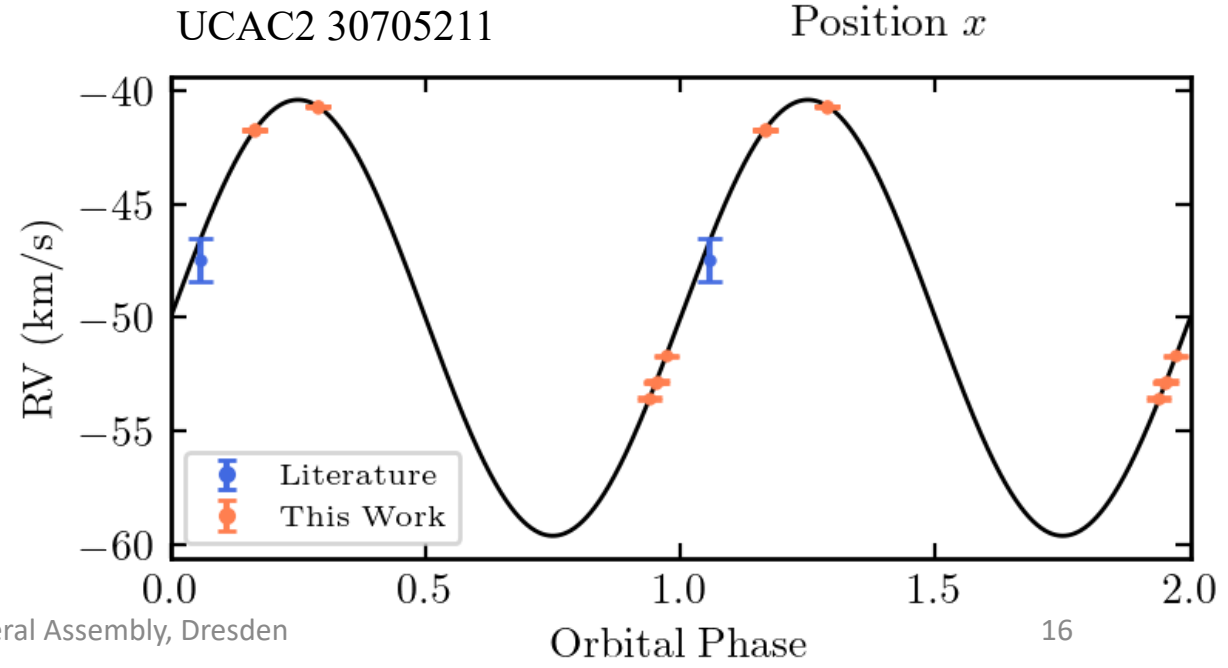
# Using the Data: Enhancing the Literature



# Using the Data: Confirming Binarity

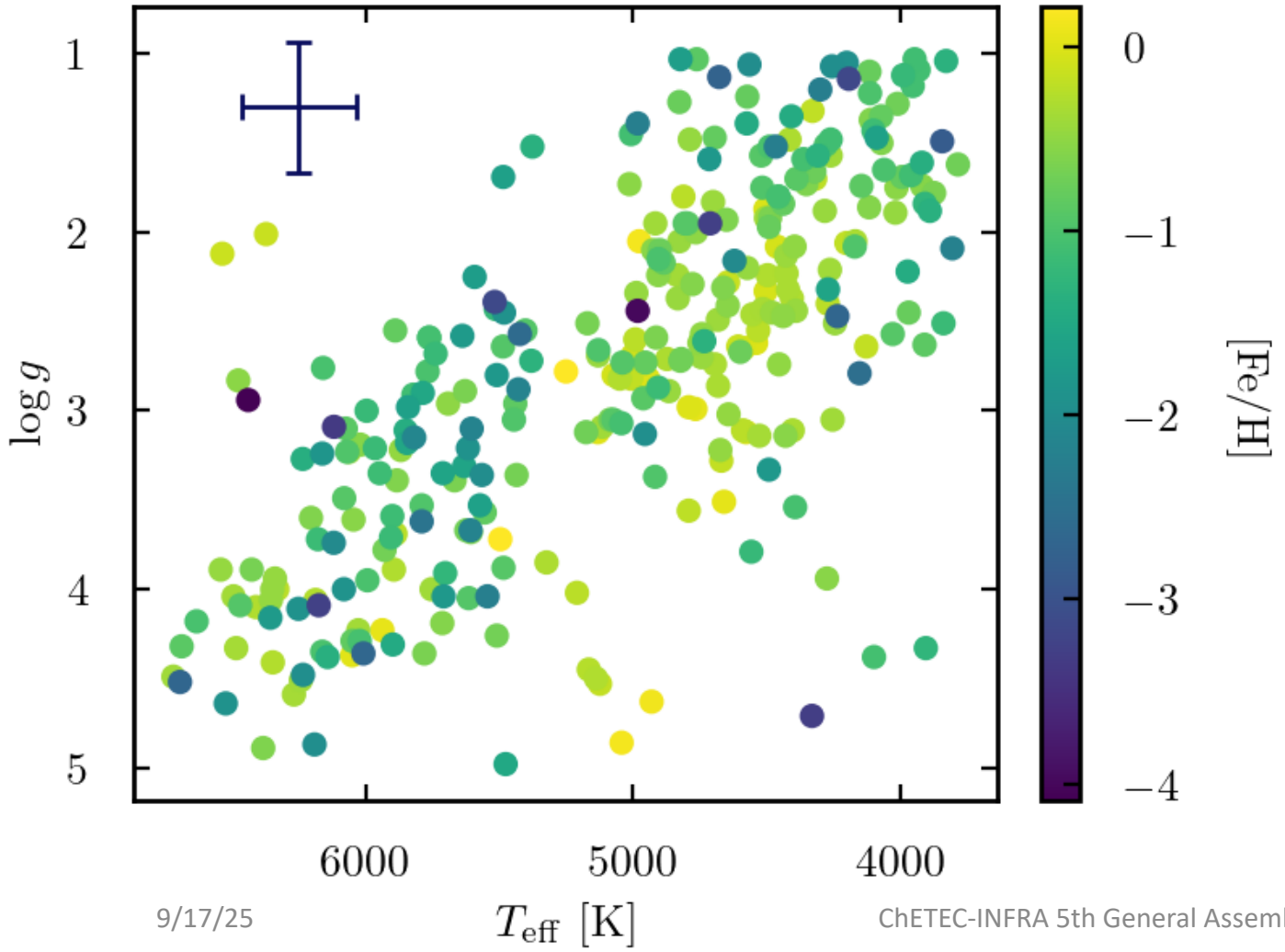
- Measure doppler shift to extract RV
- Monitor, characterize, and model binary orbits
- Orbital data provides a check on AGB mass



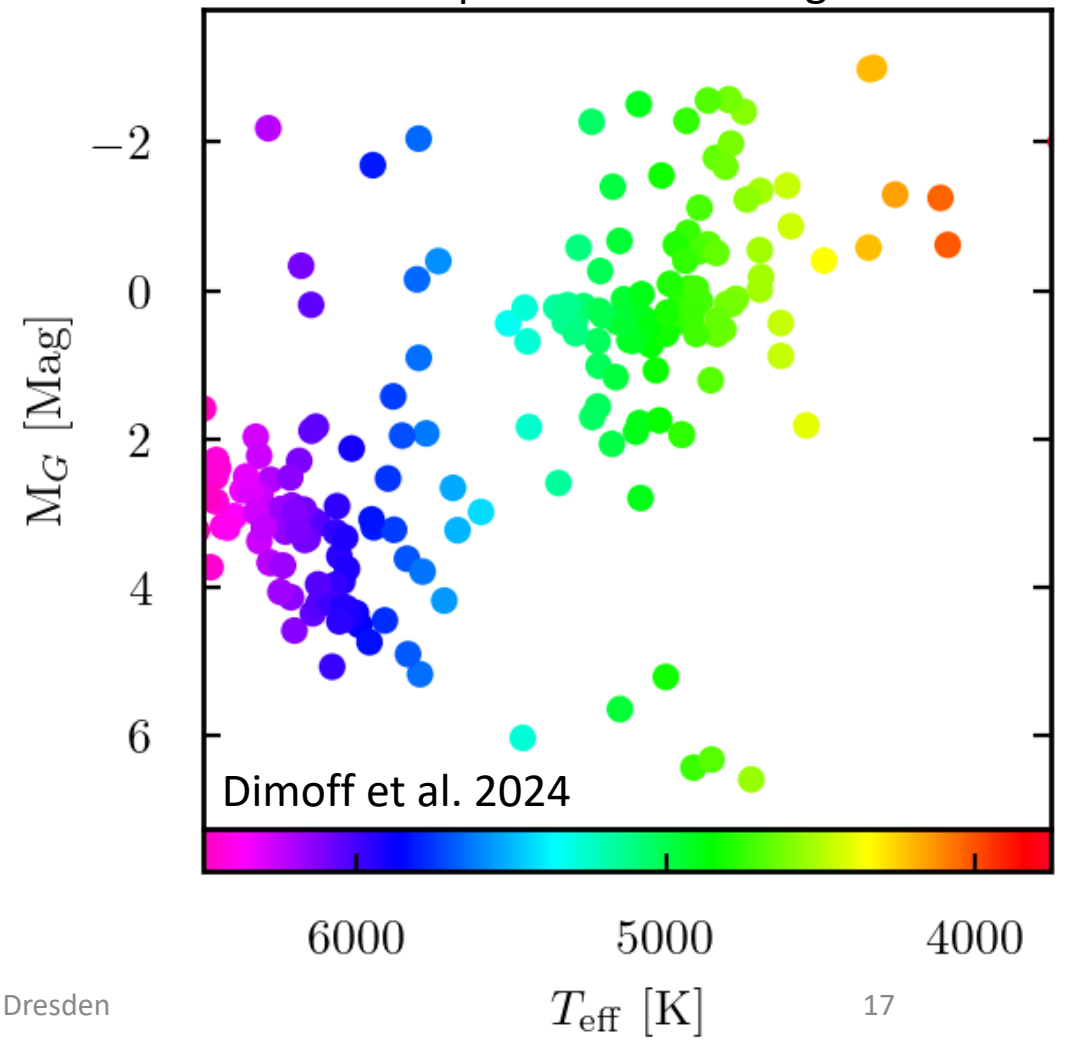



# Stellar Atmospheric Parameters: Visualizing the Sample with ATHOS and Gaia

ATHOS Parameters

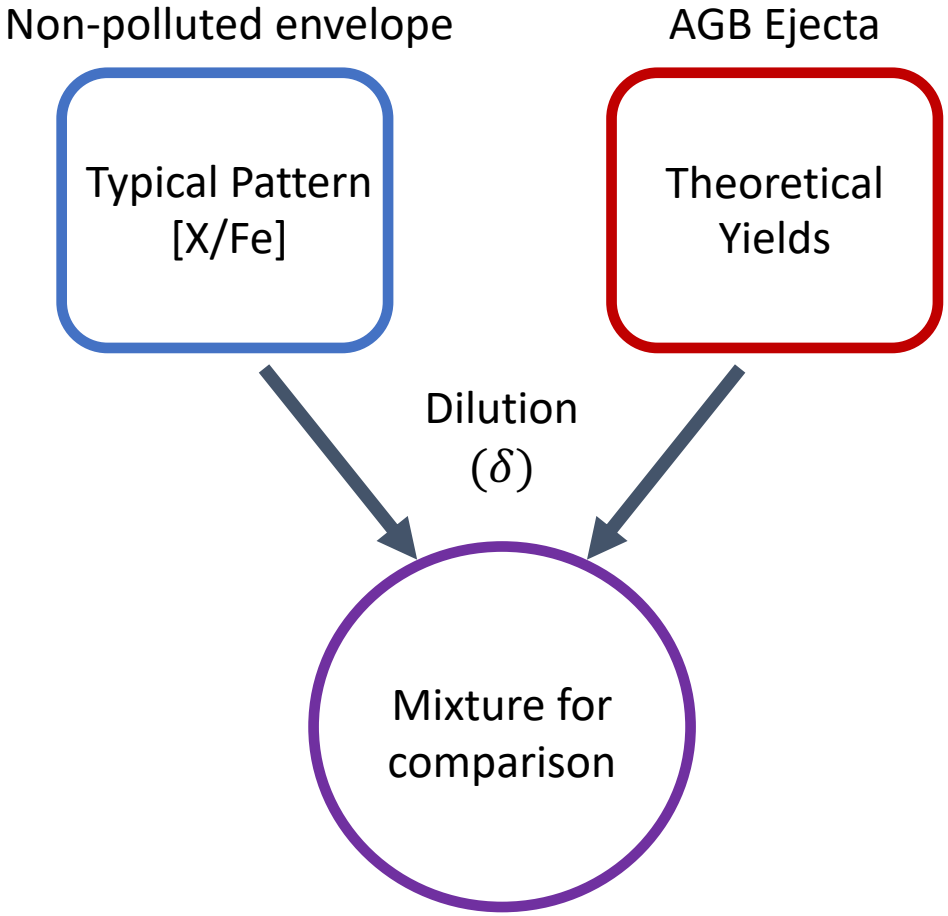



Gaia Temperatures and Magnitudes



# Using the Data:
# Deriving Abundances Patterns

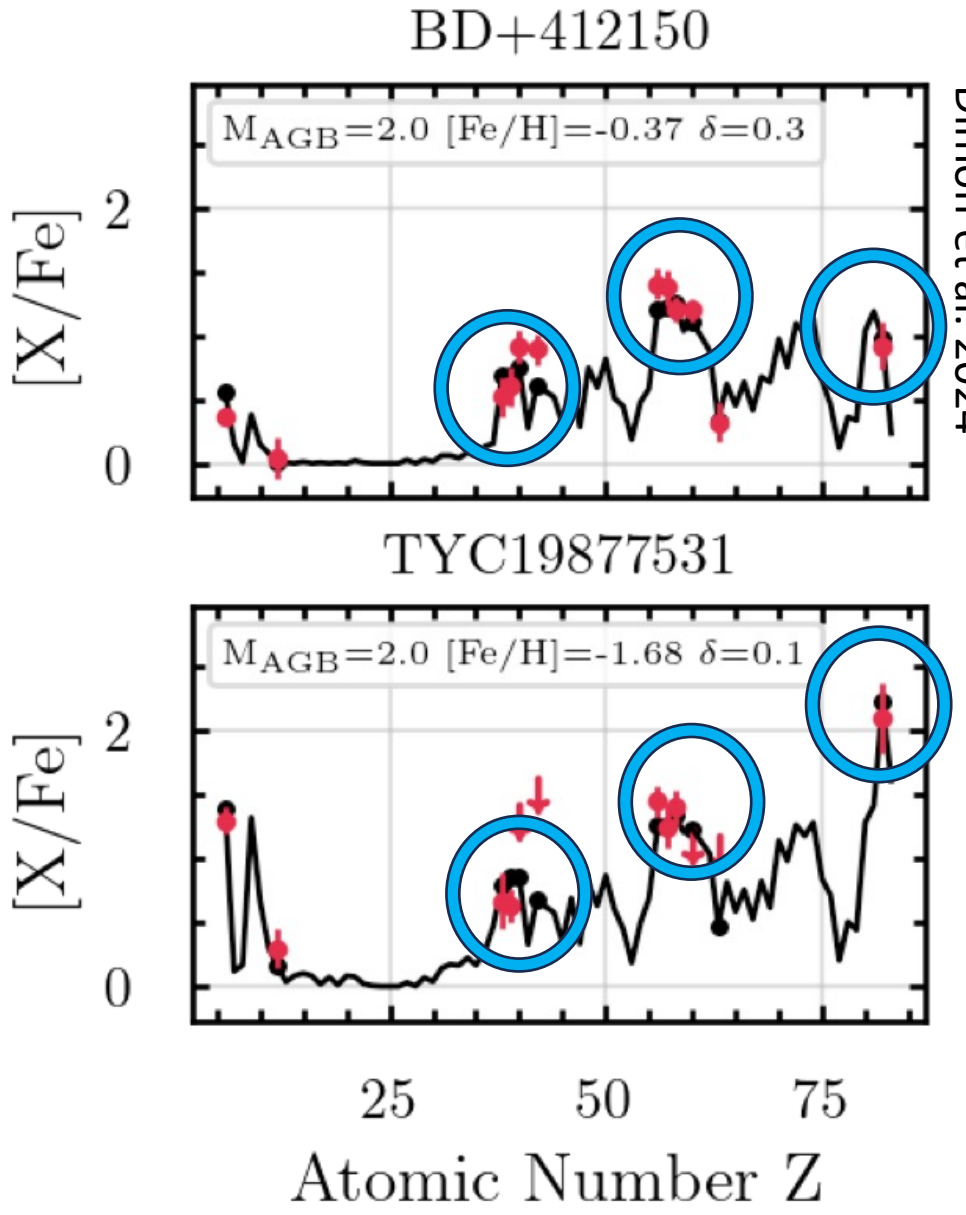
- Enable spectral classifications
  - (CEMP-s / -r / -no) (Ba-strong / -weak)
  - 1 new CH star and Ba star
- Explain origins of peculiar enrichment
  - Comparison to yield models (FRUITY)
- Investigate mass transfer processes
  - Efficiencies and amount of mass



# Abundance Patterns: Modeling AGB masses

- Yield models constrain the mass of the donor star
- Modify with dilution / mixing

- AGB mass is generally consistent across metallicities

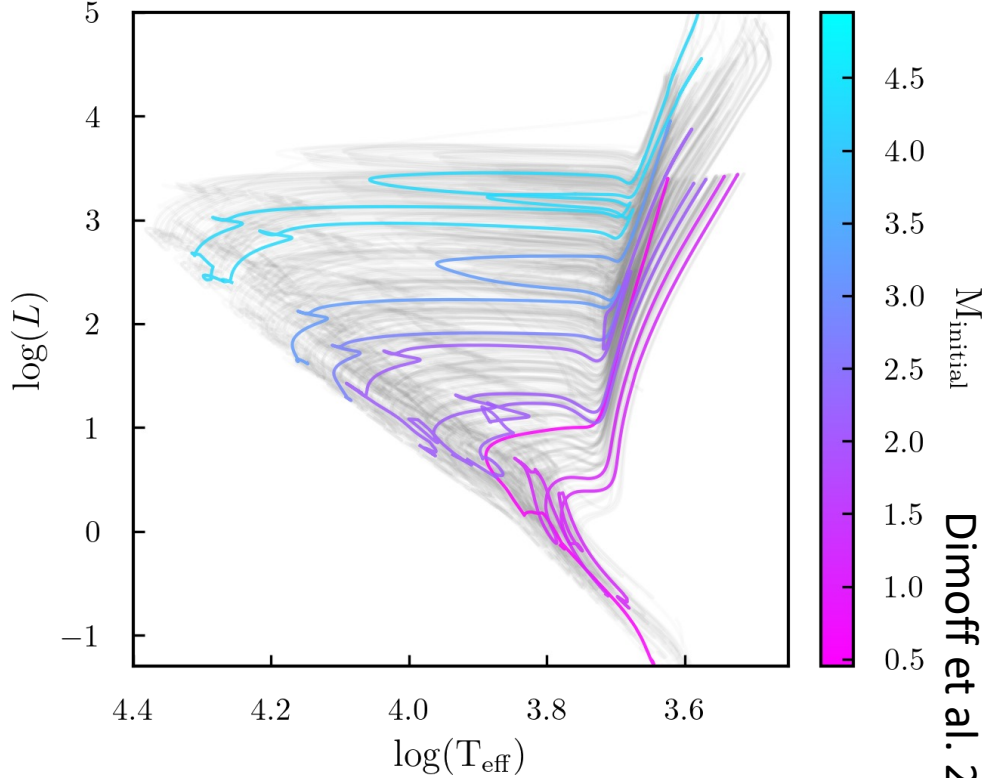


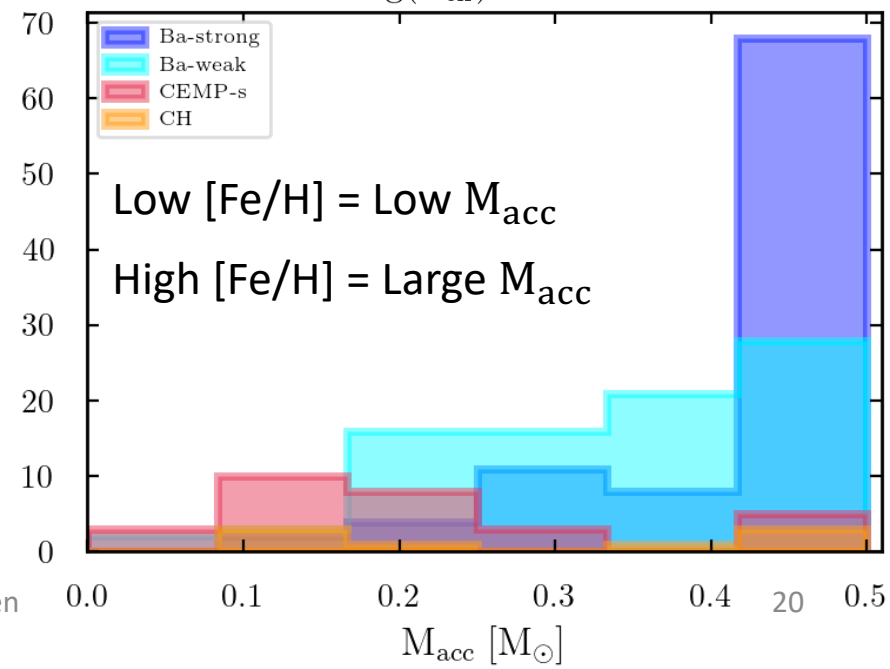

Dimoff et al. 2024

# Abundance Patterns: Modeling mass transfer

- Compute a grid of evolution models, compare to observations
  - Mass transfer efficiency
  - Amount of mass transferred

- Metal-rich stars accrete more than metal-poor stars

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# Presenting Opportunities for more Science

- Identify new RV variables, follow-up
- Kinematics for stellar origins
- Rotation from high-resolution spectra
- Spectral types, ages, evolutionary states
- Spectral + chemical classification
- Galactic chemical evolution, tracing chemical enrichment through cosmic time
- Derive new abundances from spectra to investigate other nucleosynthesis pathways

# Open Access Data

- Zenodo: ChETEC-INFRA WP6: Astronuclear Spectral Database


Scan Me!

- Raw / semi-reduced spectra from observatories
- Reduced 1D spectra
  - Doppler-corrected, median-combined spectra for highest SNR
- Radial velocities
- Atmospheric parameters
- 1D + LTE abundances

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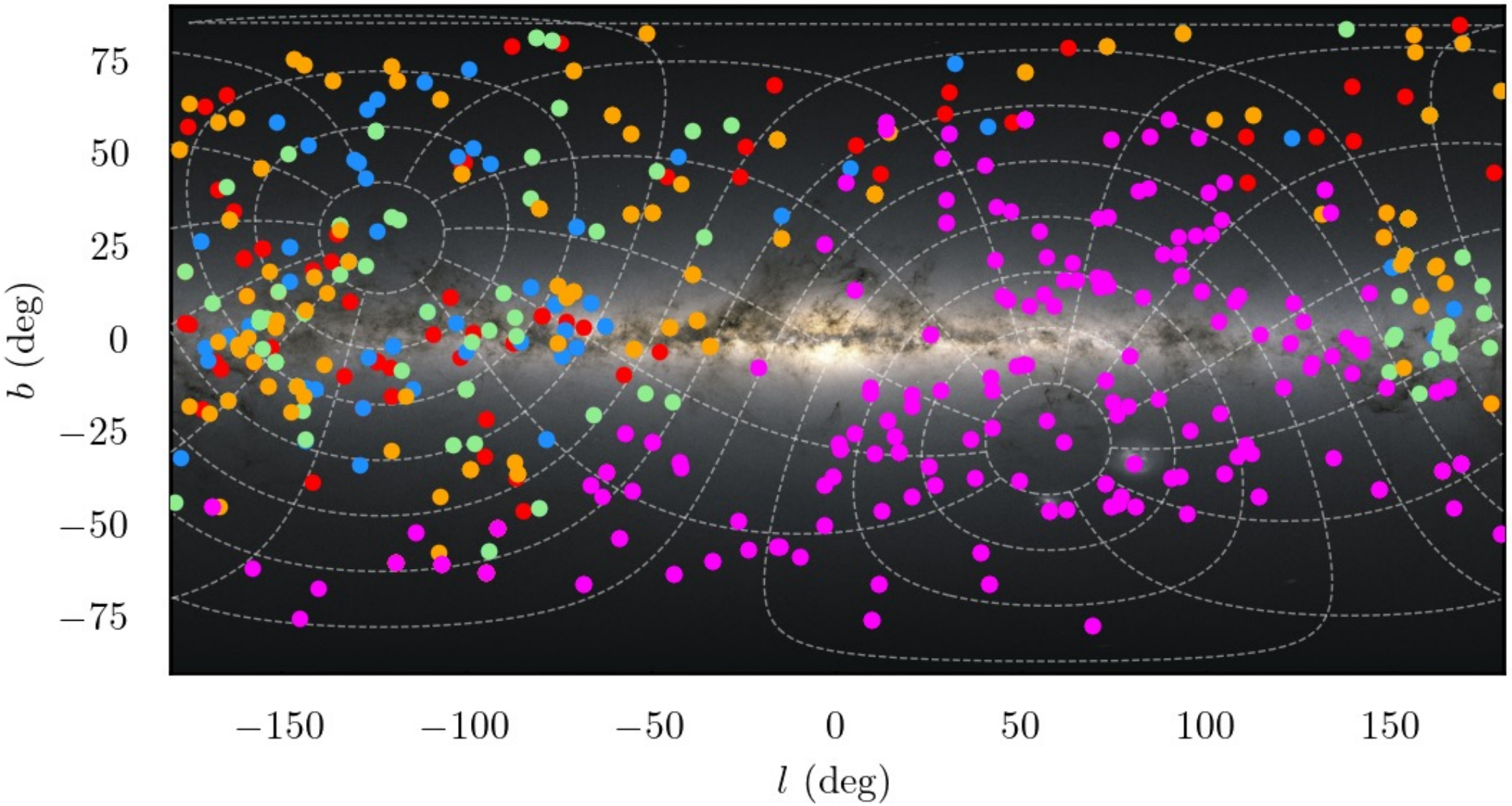
75
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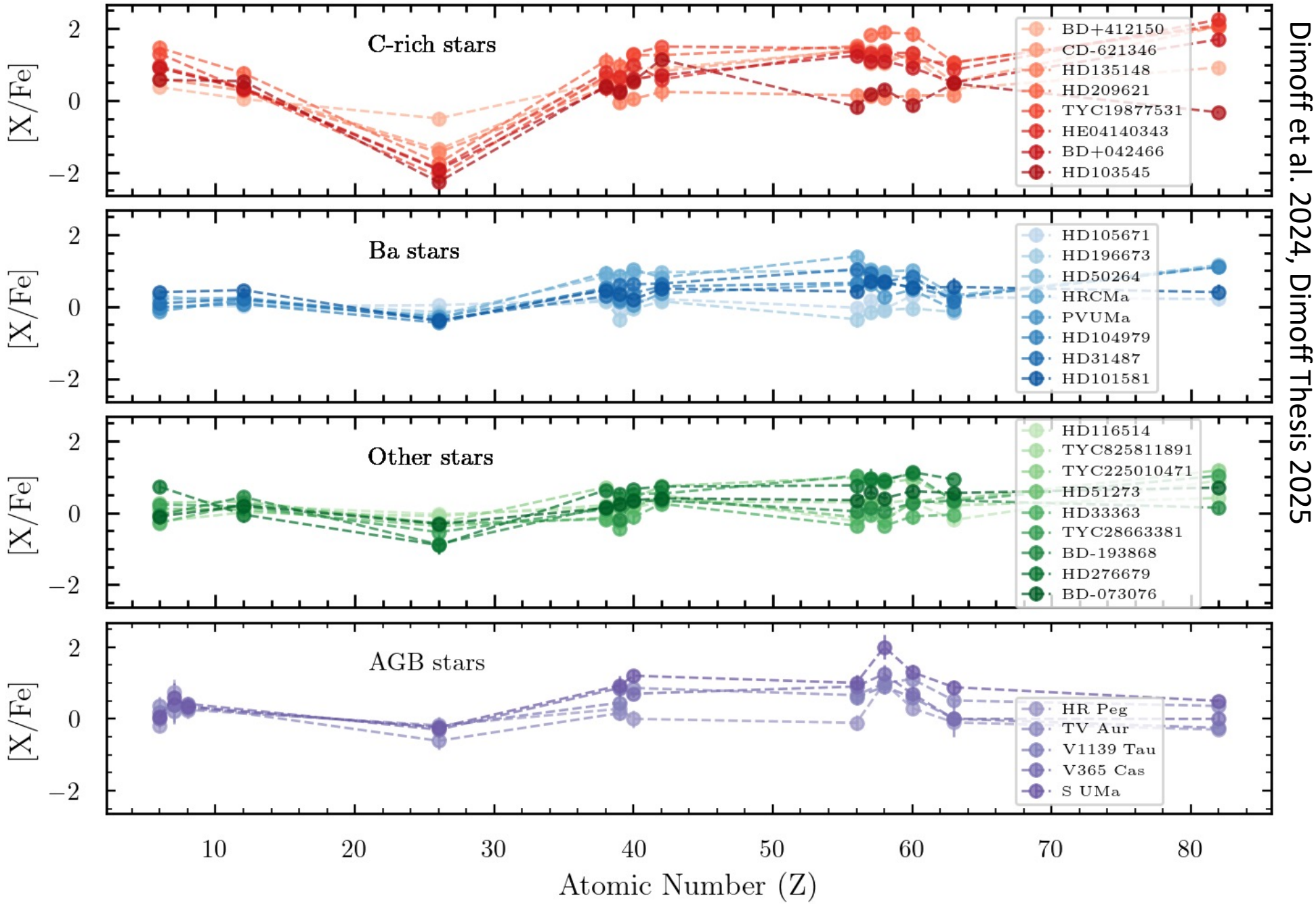
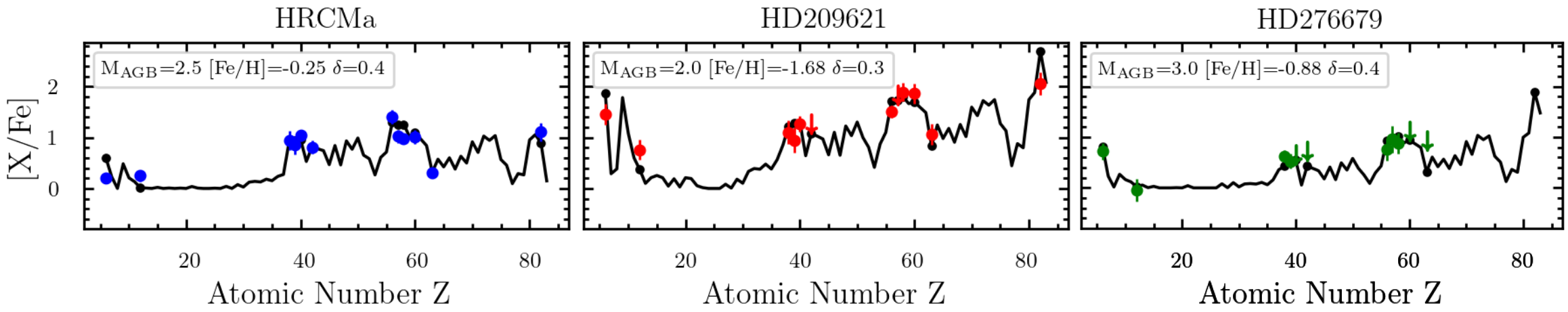
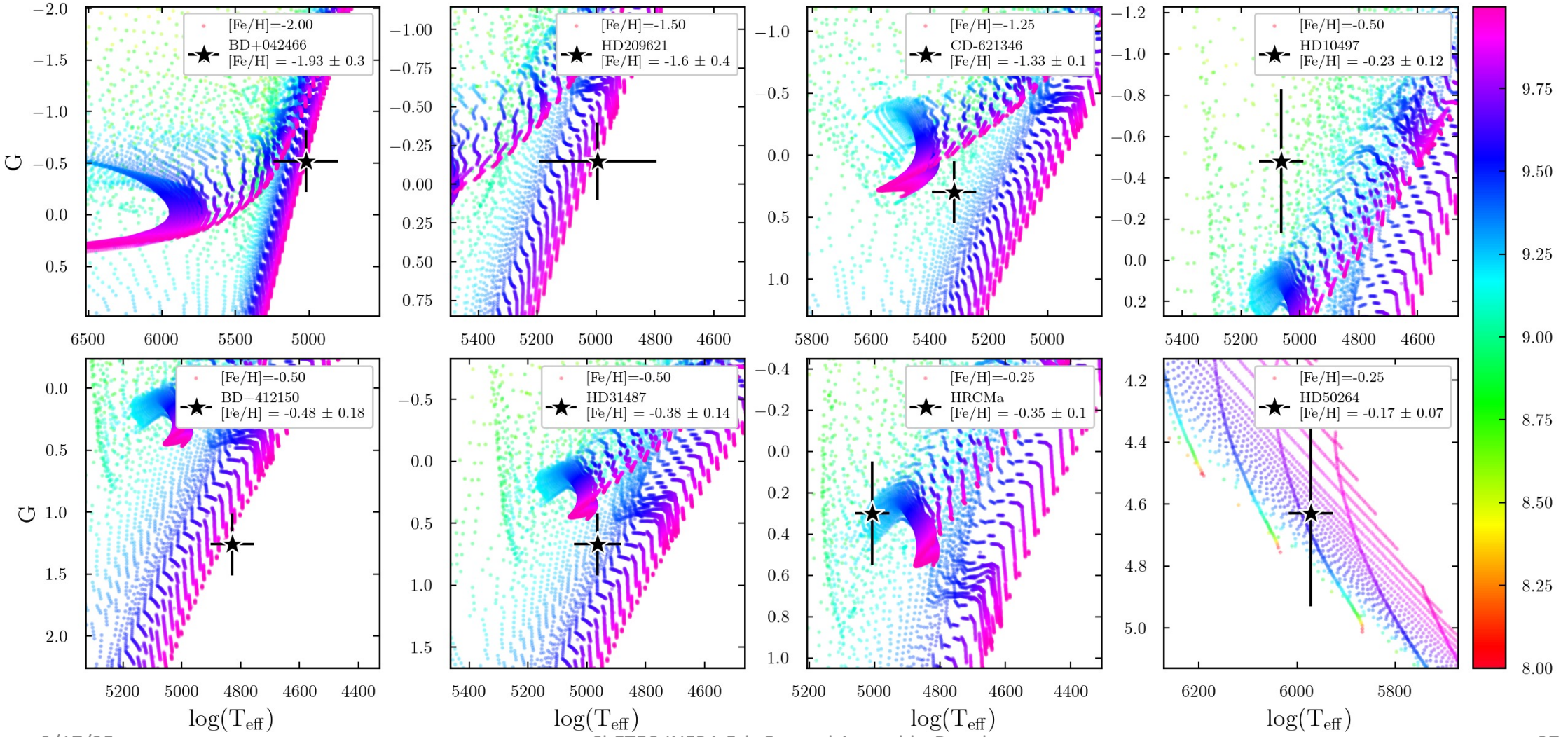



Dimoff et al. 2024, Dimoff Thesis 2025

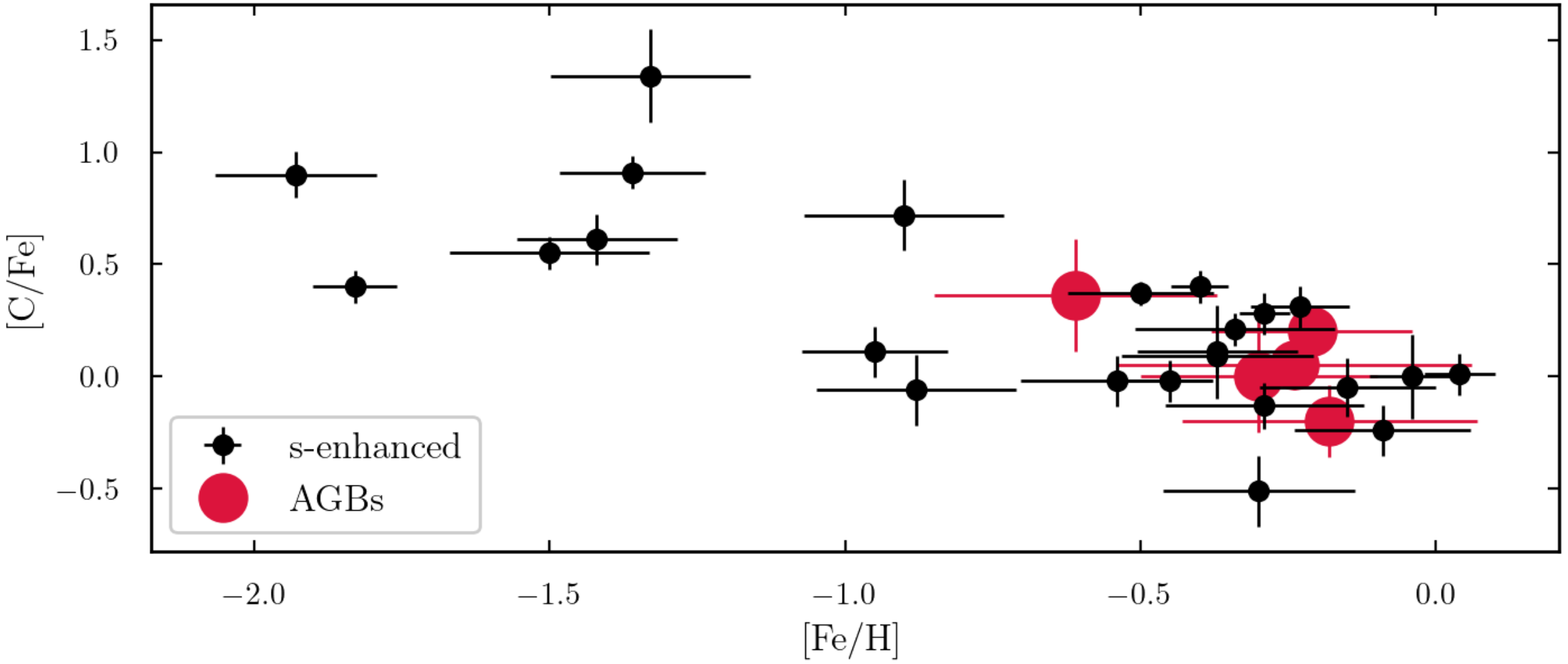
# Abundance Patterns Constrain AGB Mass Across Metallicity Space



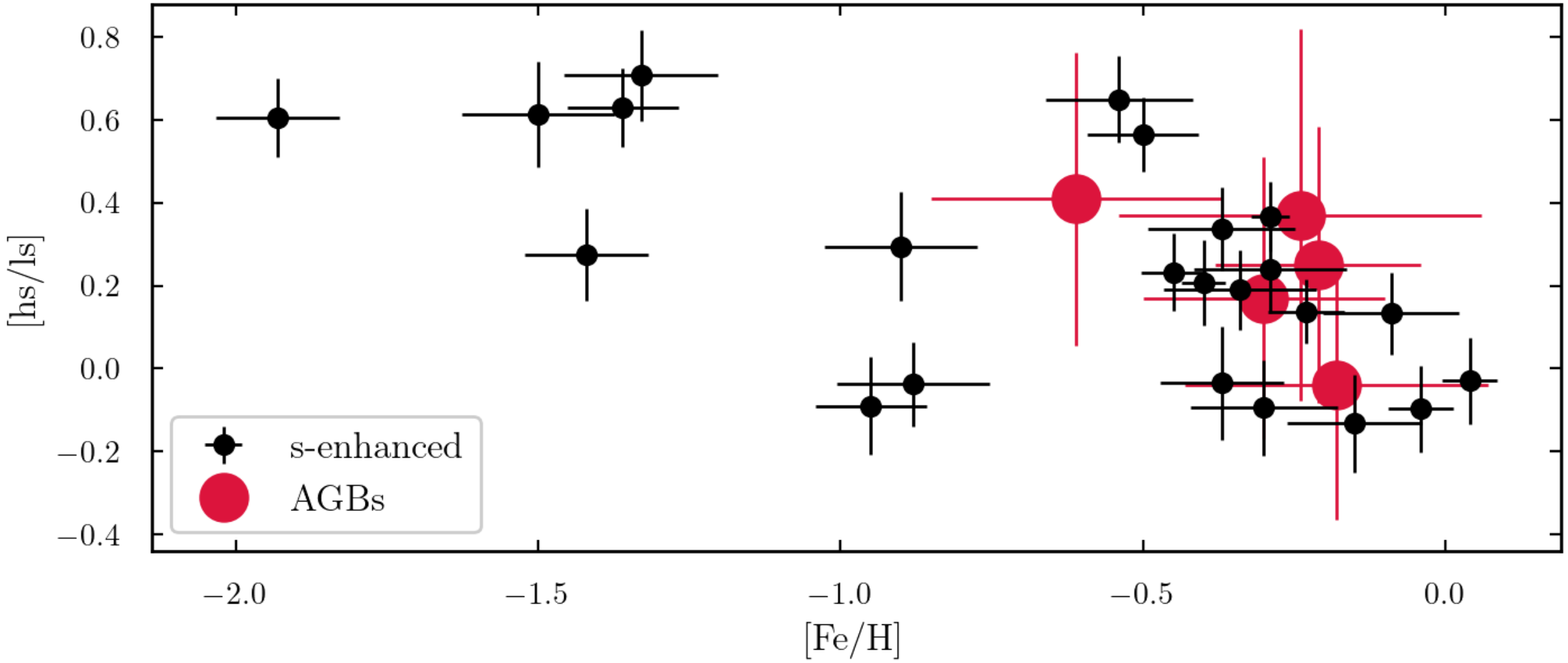
# Evolutionary Tracks Allow Age Estimates



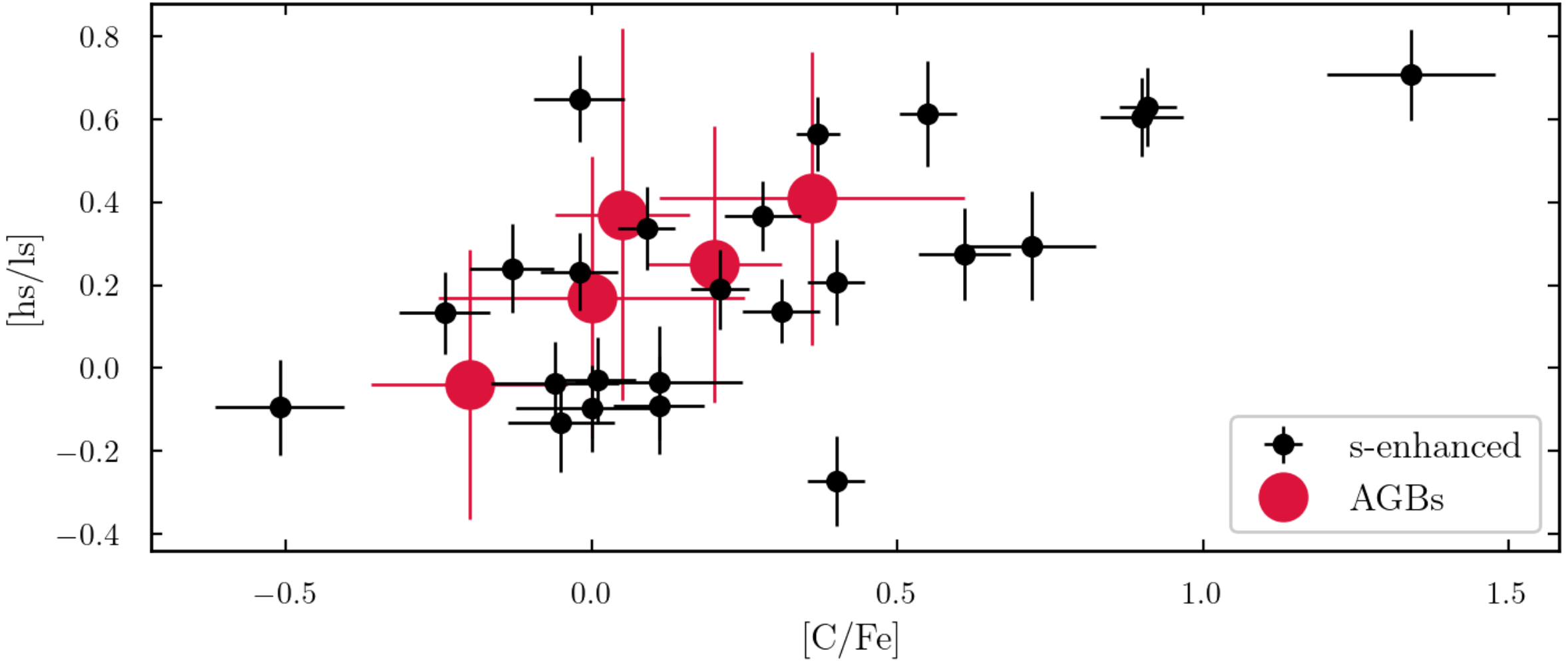
# Comparing AGBs and Companions: [C/Fe]



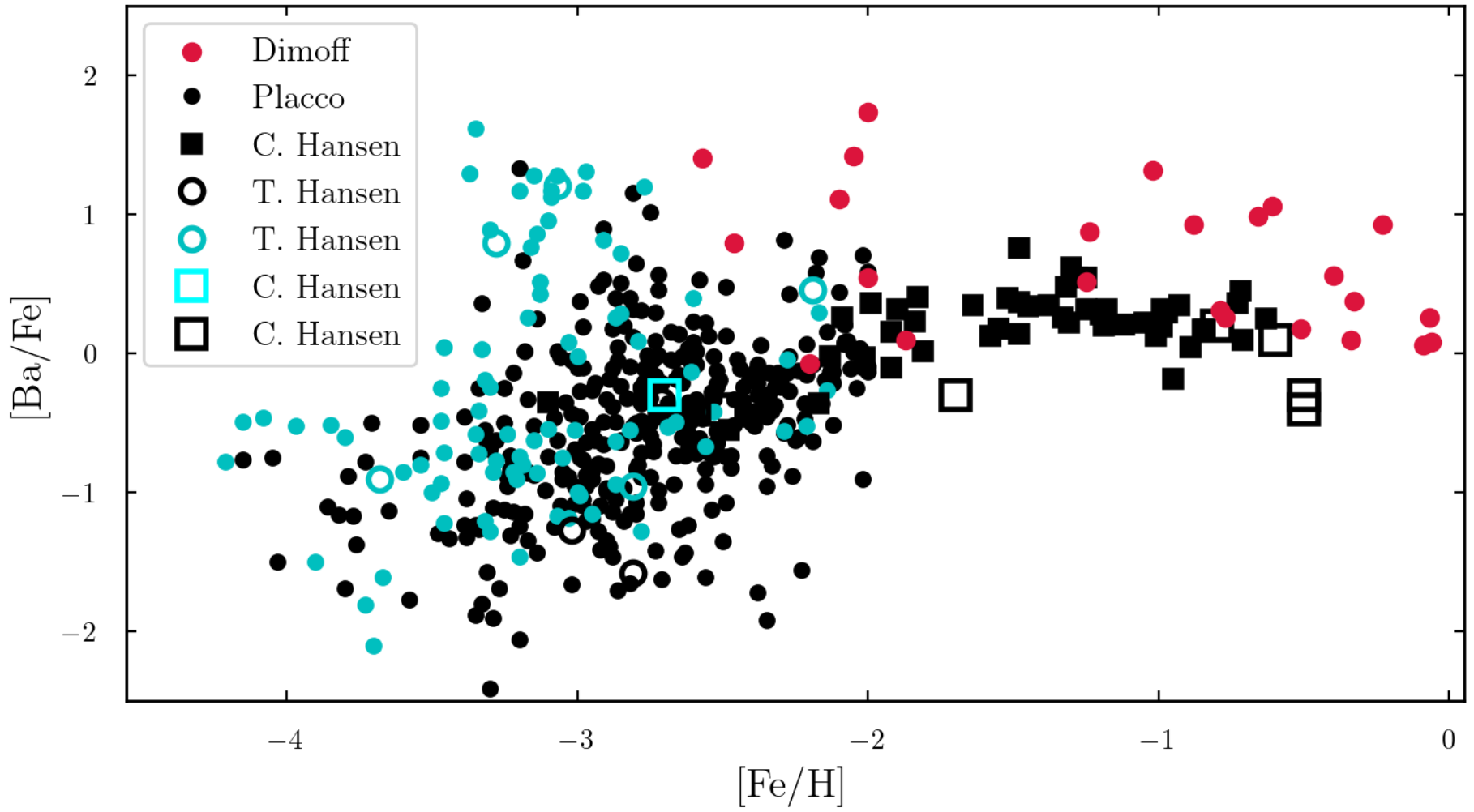
# Comparing AGBs and Companions: [hs/ls]



# Comparing AGBs and Companions: [hs/ls] and C

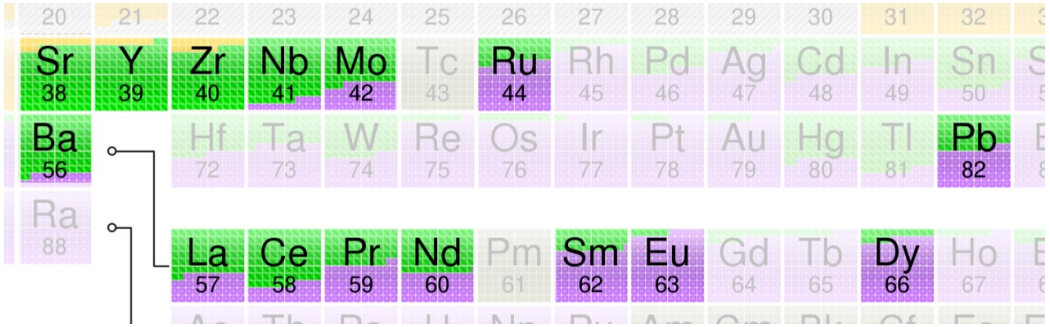


# Galactic Chemical Evolution: Ba



# Observational Samples

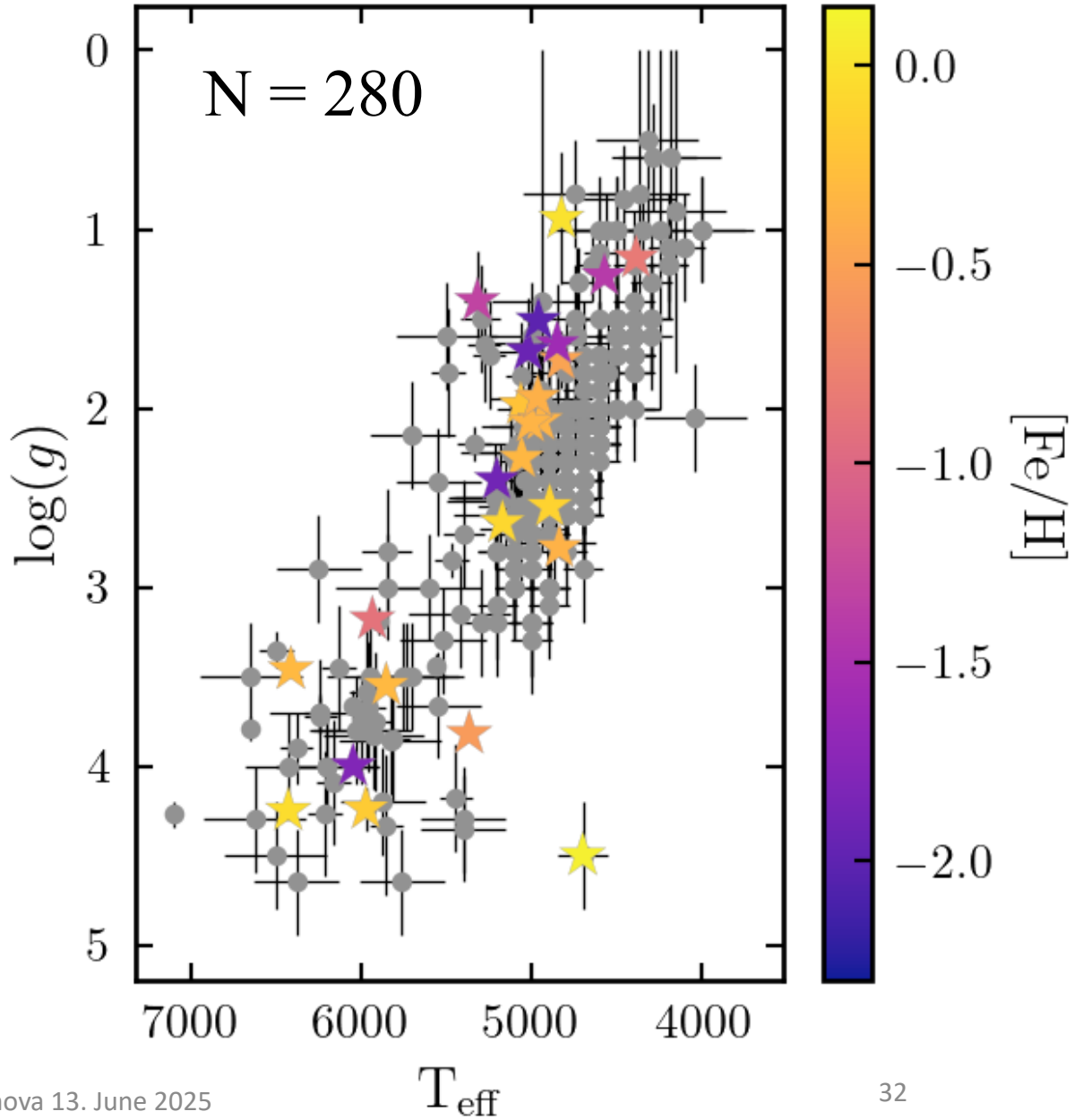
- Literature: $T_{eff}$ , log(g), [Fe/H], [X/Fe]



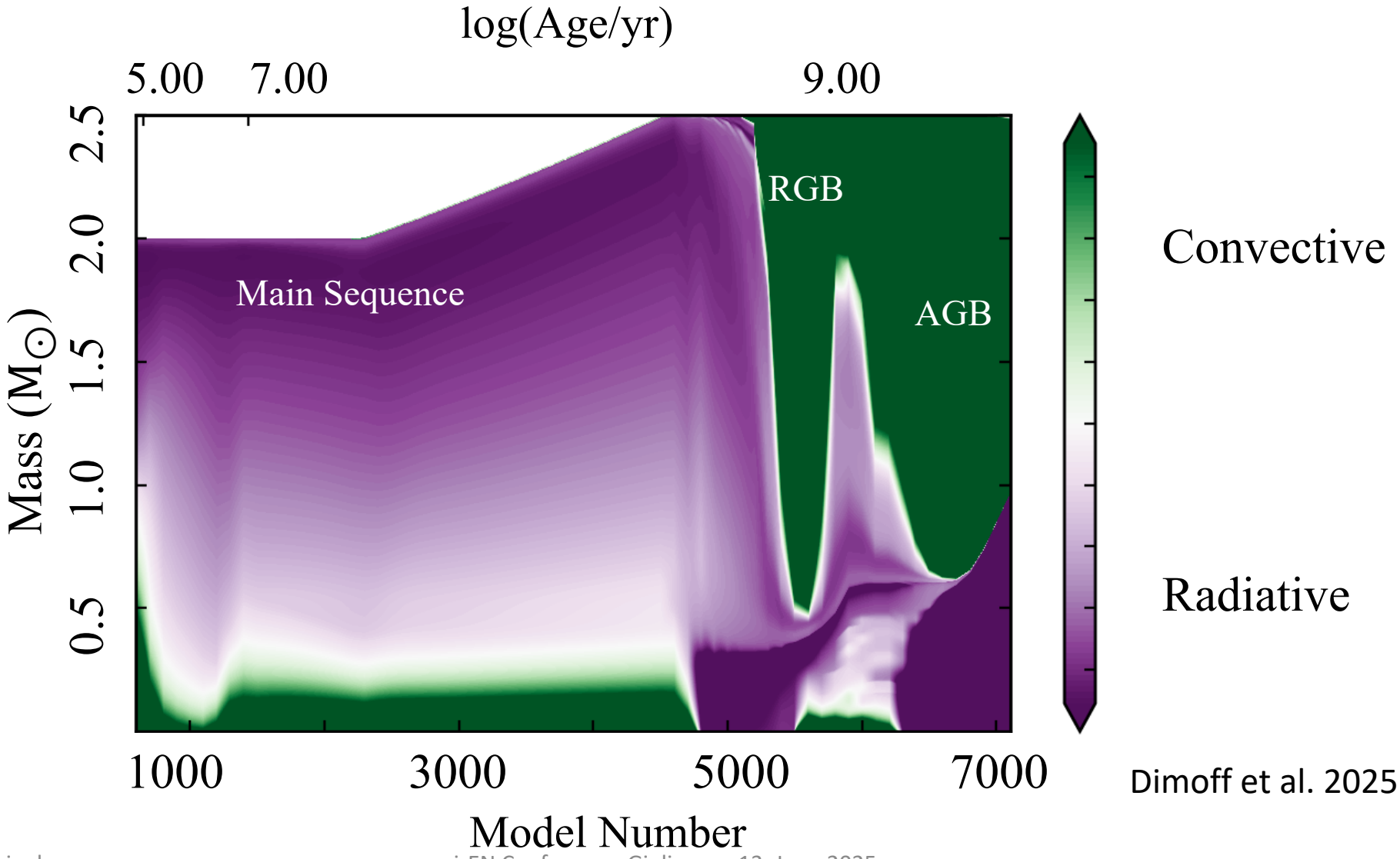

Based on data from Jennifer Johnson

- Goswami et al. 2014, 2015, 2021
- DeCastro et al. 2016 + Roriz 2021
- Cristallo et al. 2016
- Dimoff et al. 2024 ★

Dimoff et al. 2025



# Modeling the Effect of Accretion on Evolution

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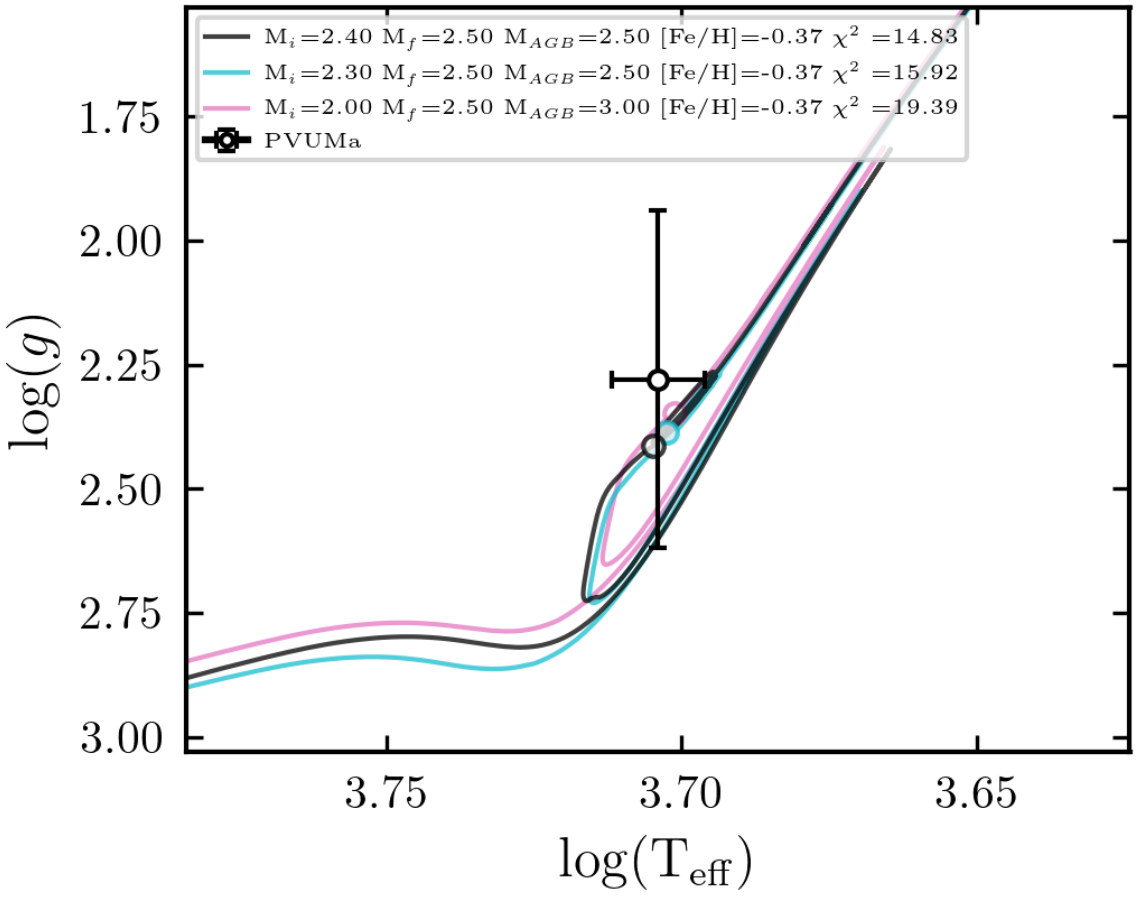
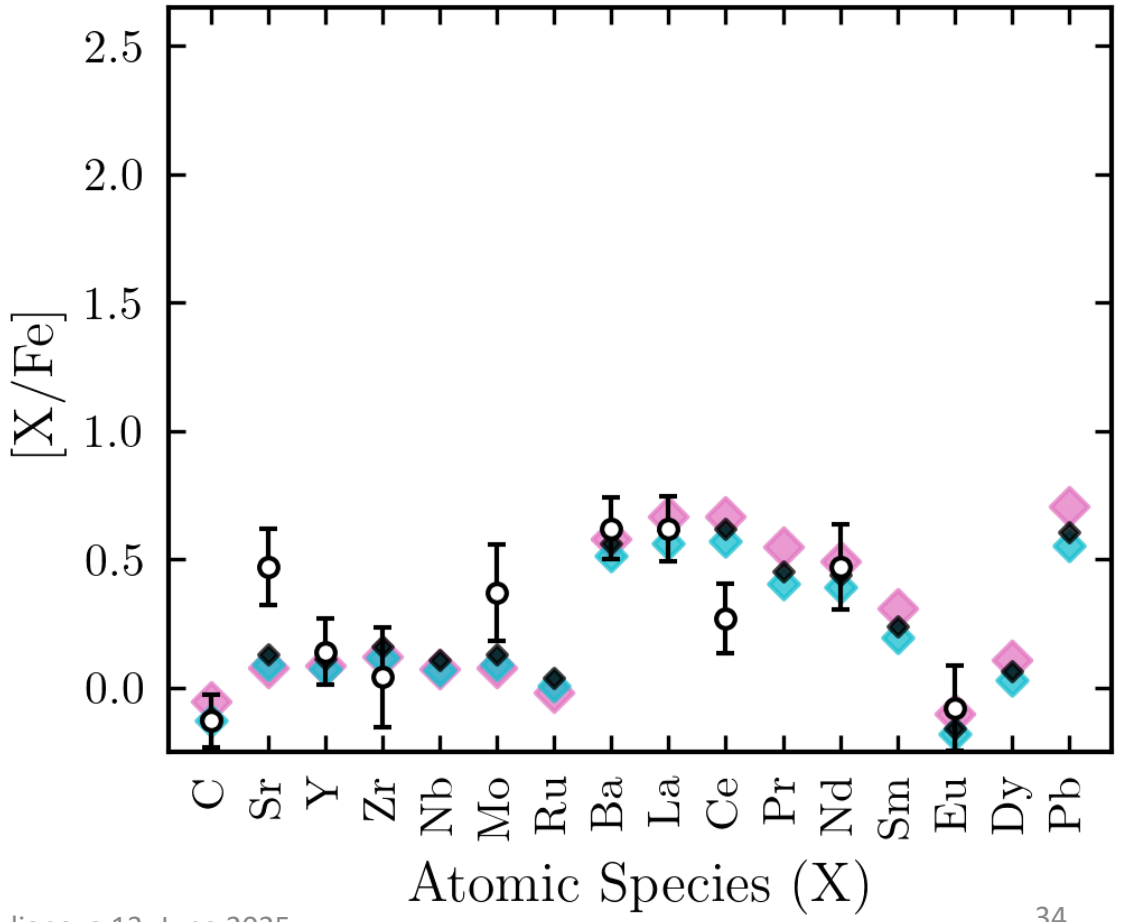
# Modeling the Evolution of Ba (weak) Stars

Kiel diagram constrains mass / surface params




Abundances constrain:
AGB mass, accreted mass, mixing processes

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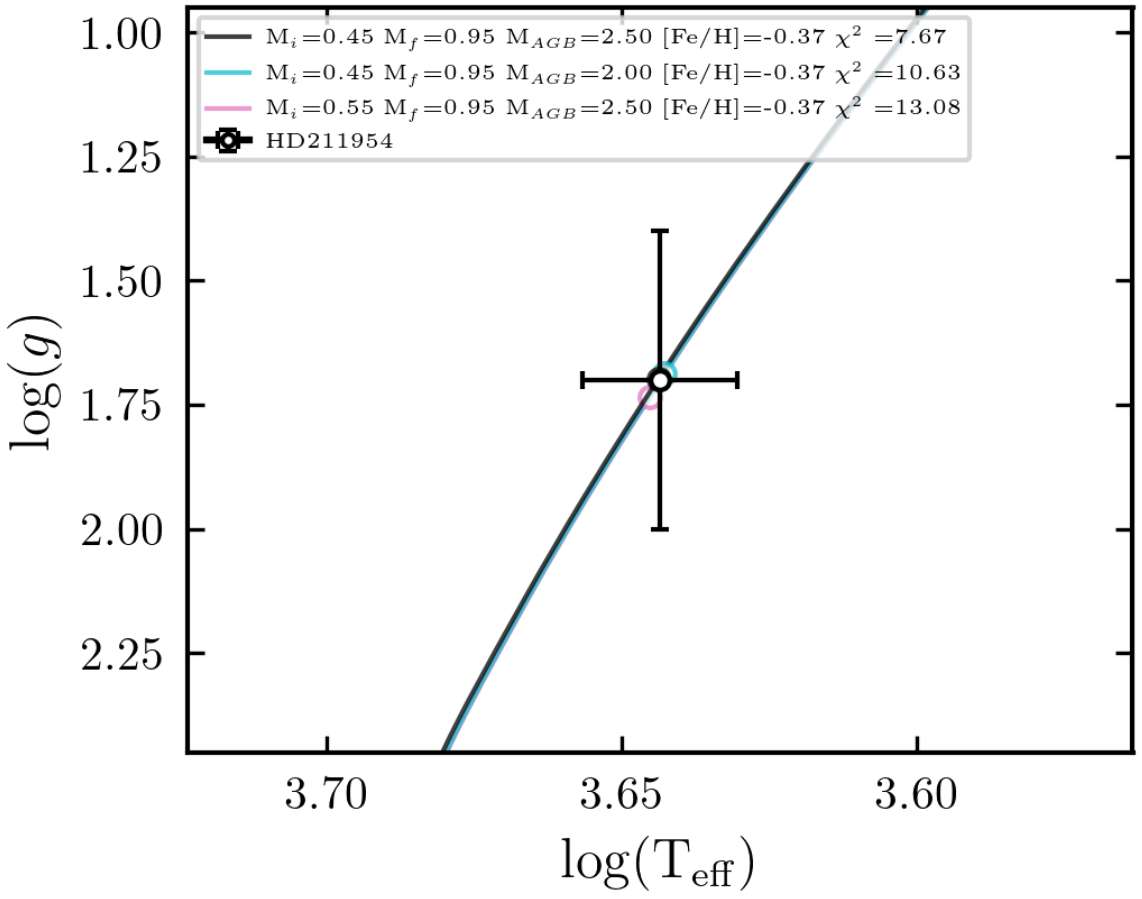
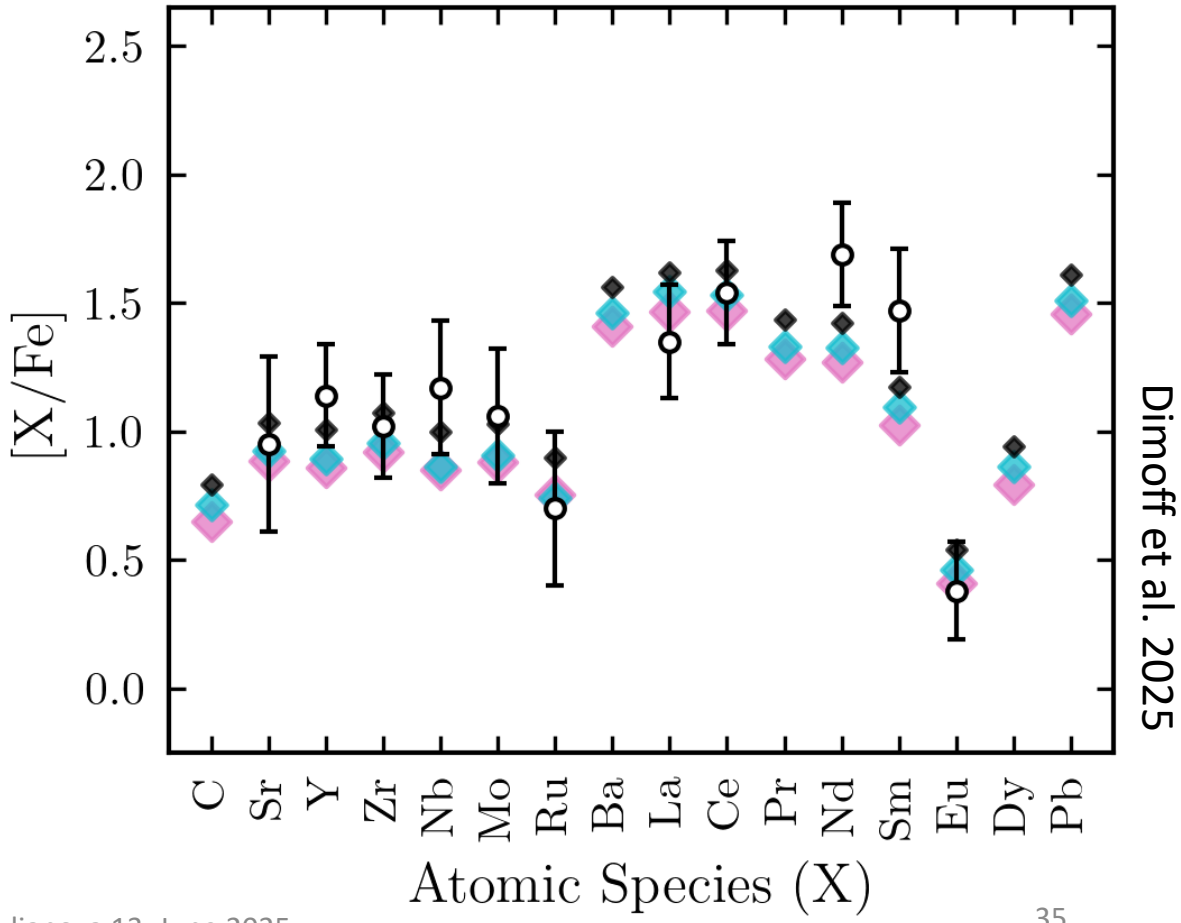
# Modeling the Evolution of Ba (strong) Stars

Kiel diagram constrains mass / surface params




Abundances constrain:
AGB mass, accreted mass, mixing processes

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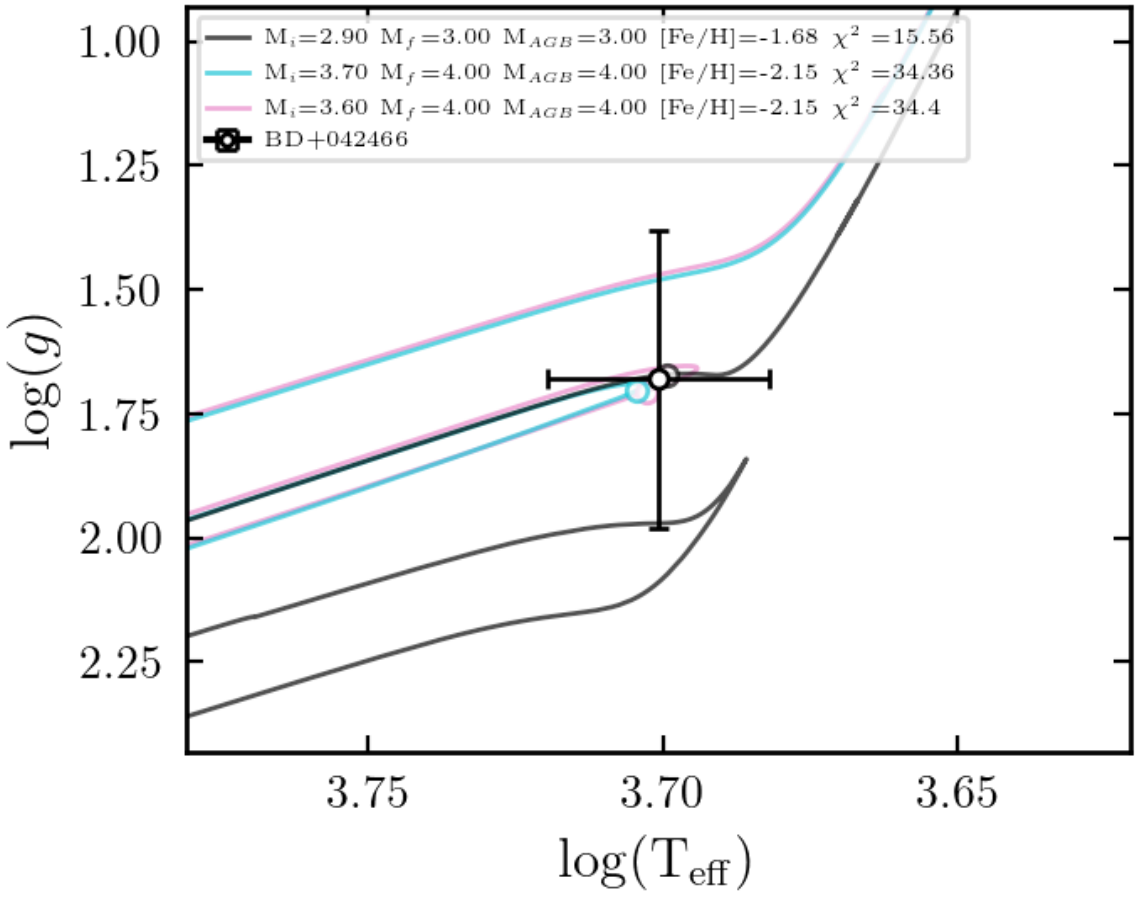
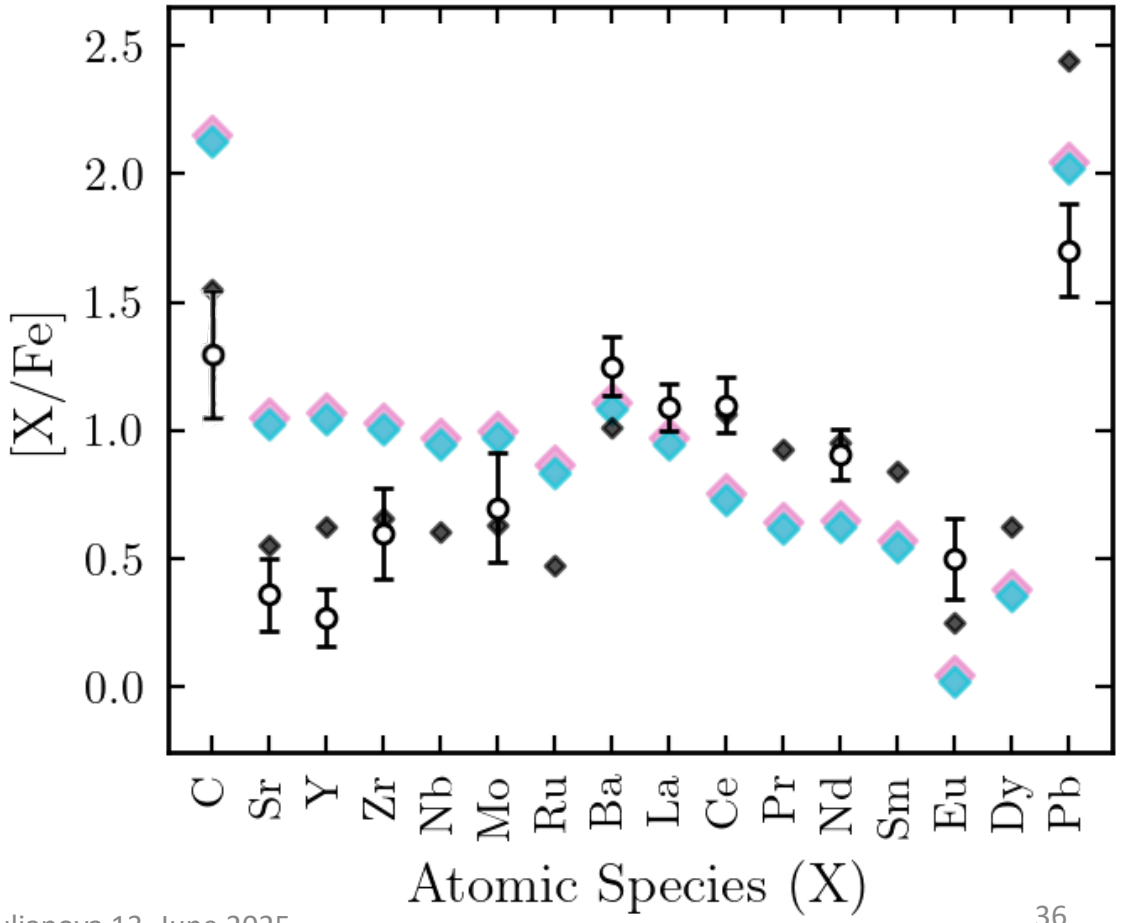
# Modeling the Evolution of CH Stars

Kiel diagram constrains mass / surface params




Abundances constrain:
AGB mass, accreted mass, mixing processes

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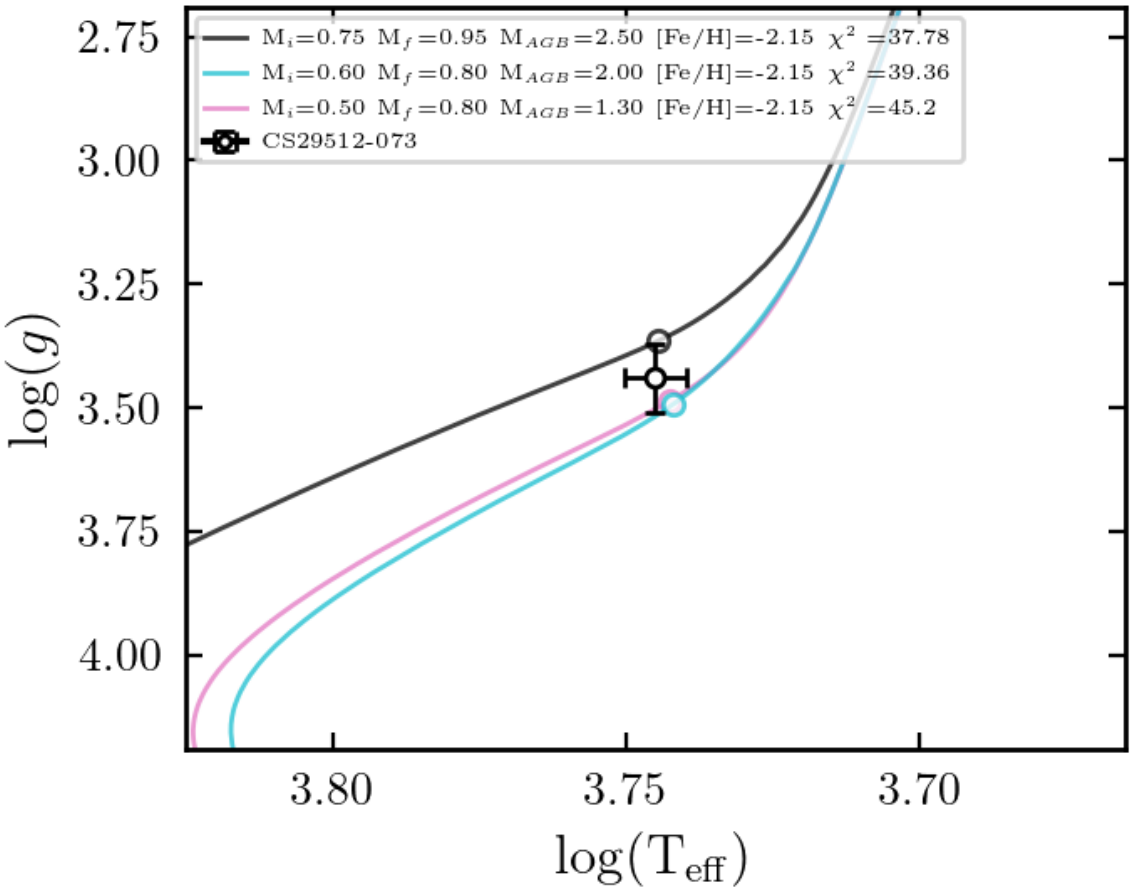
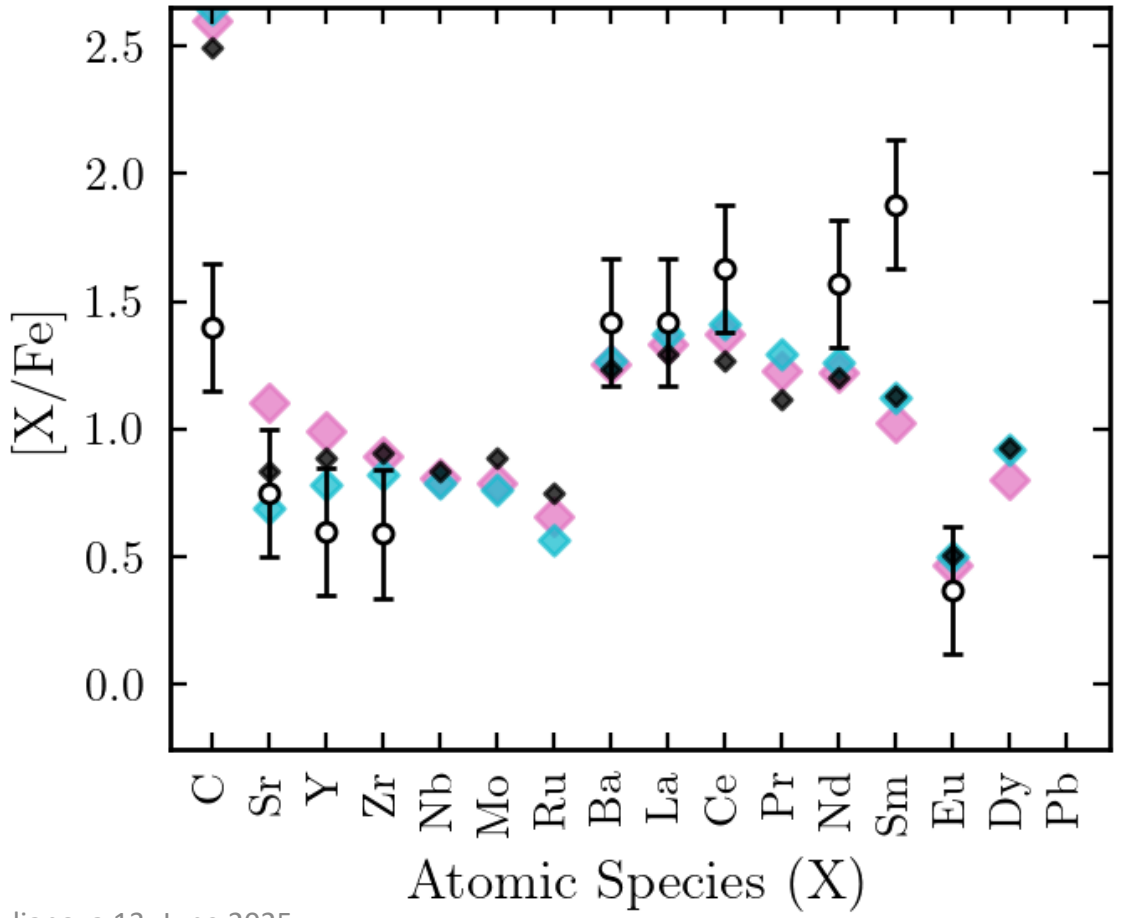
# Modeling the Evolution of CEMP-s Stars

Kiel diagram constrains mass / surface params




Abundances constrain:
AGB mass, accreted mass, mixing processes

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# Populations at Different Metallicity

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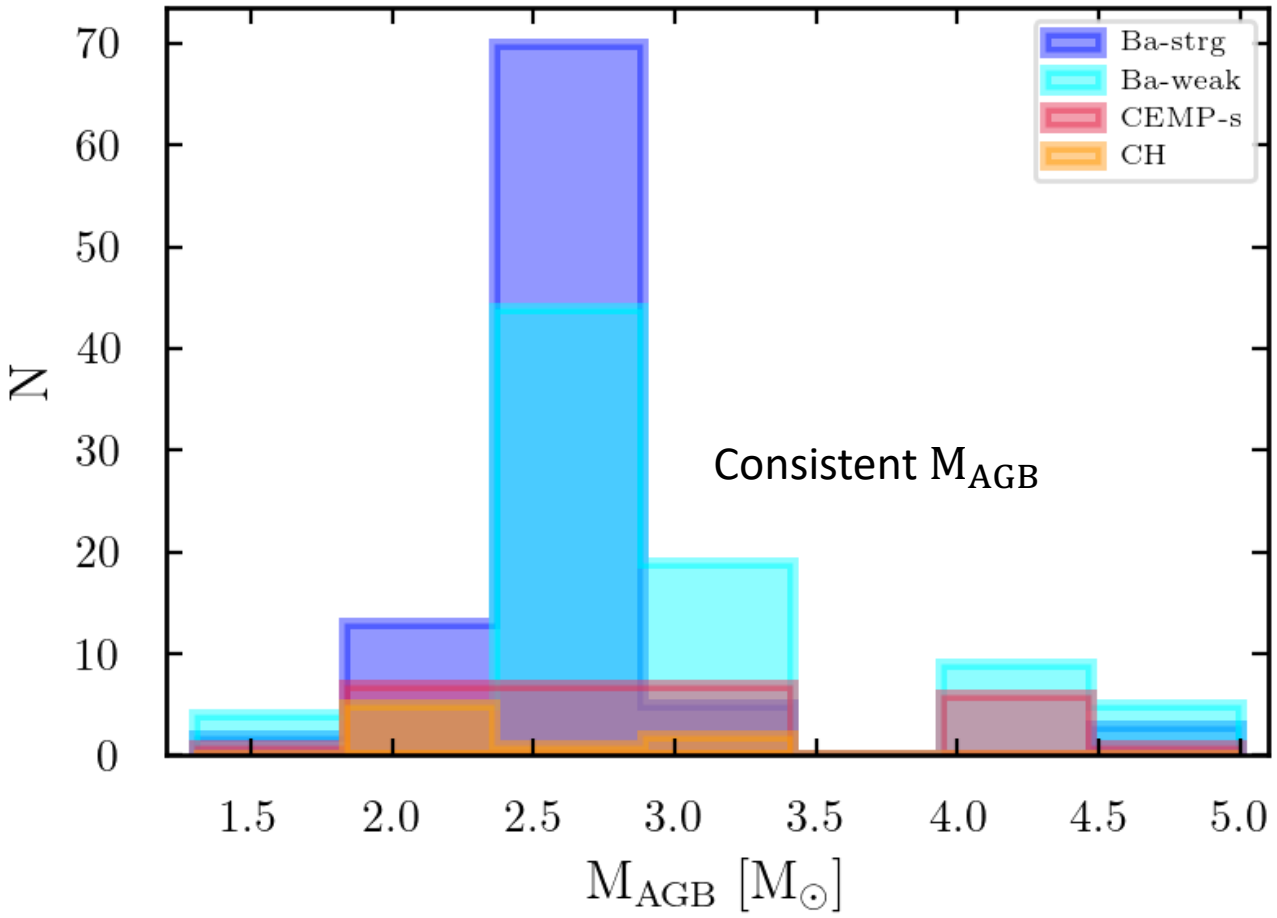


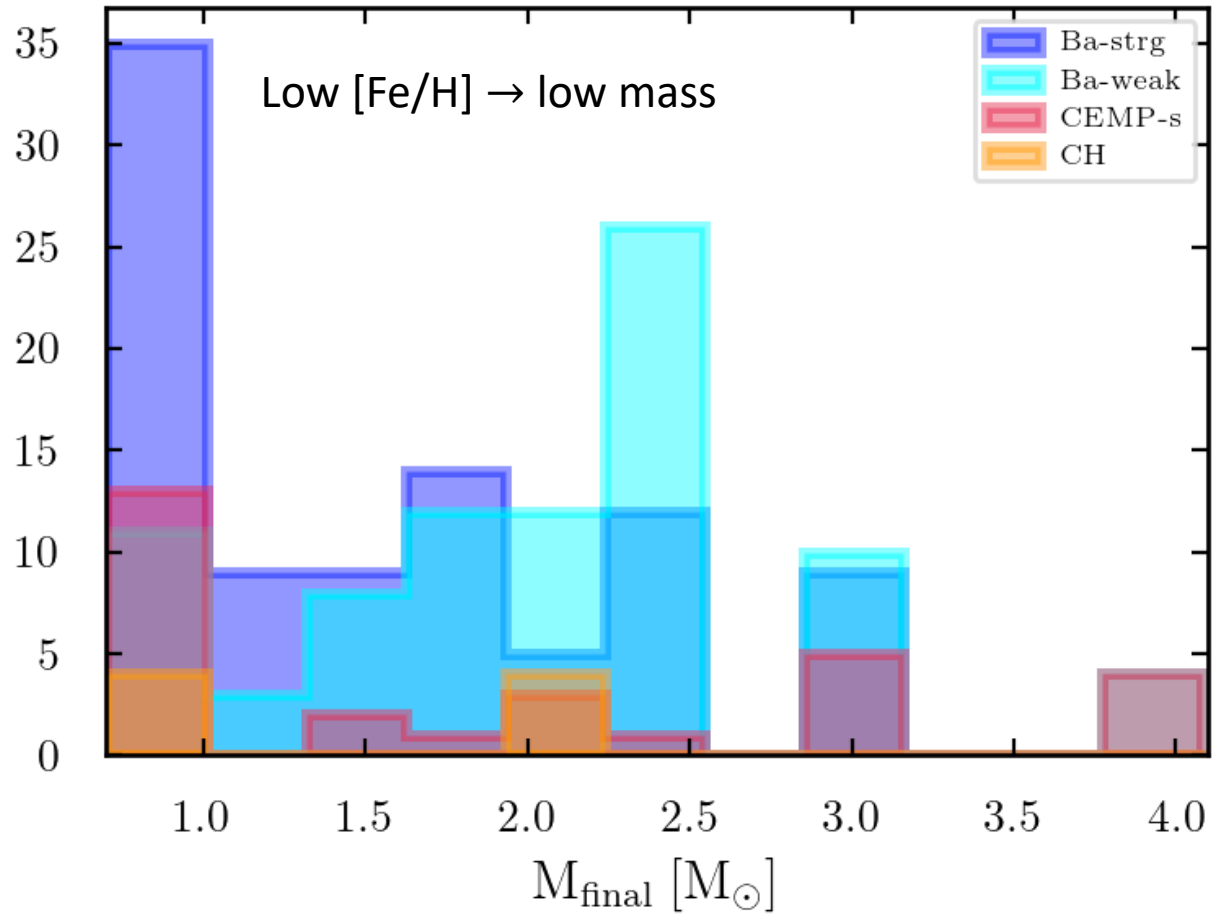

# Populations at different [Fe/H]

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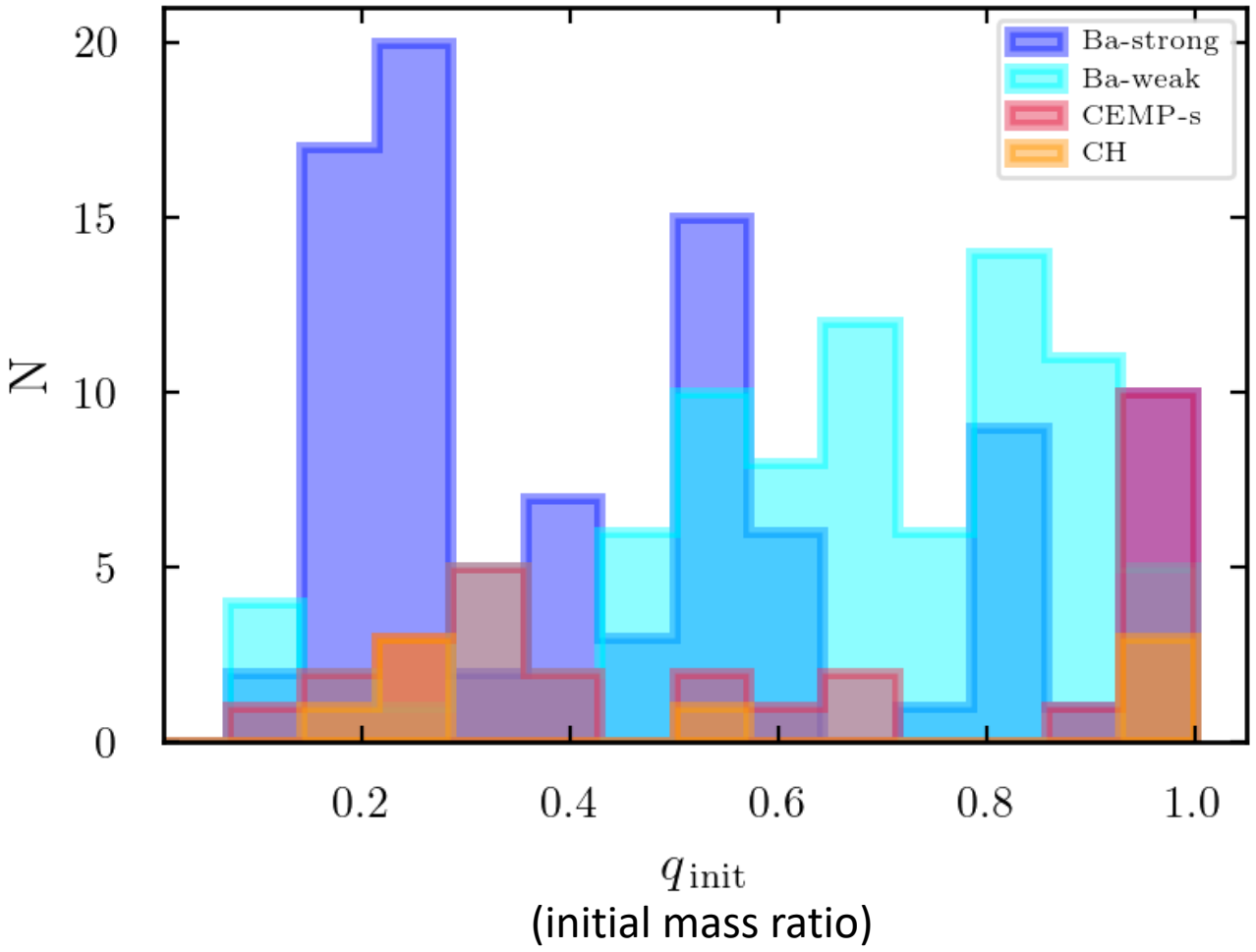
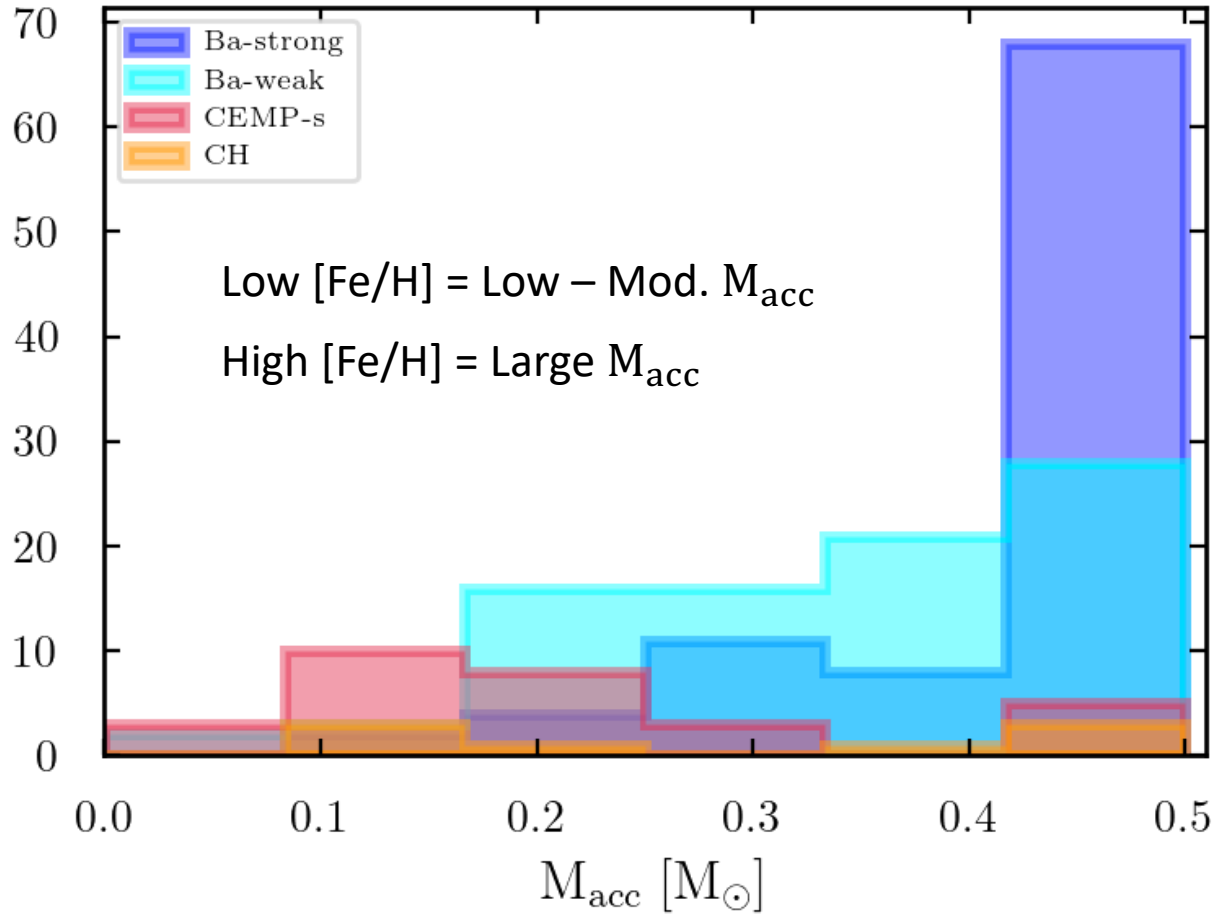


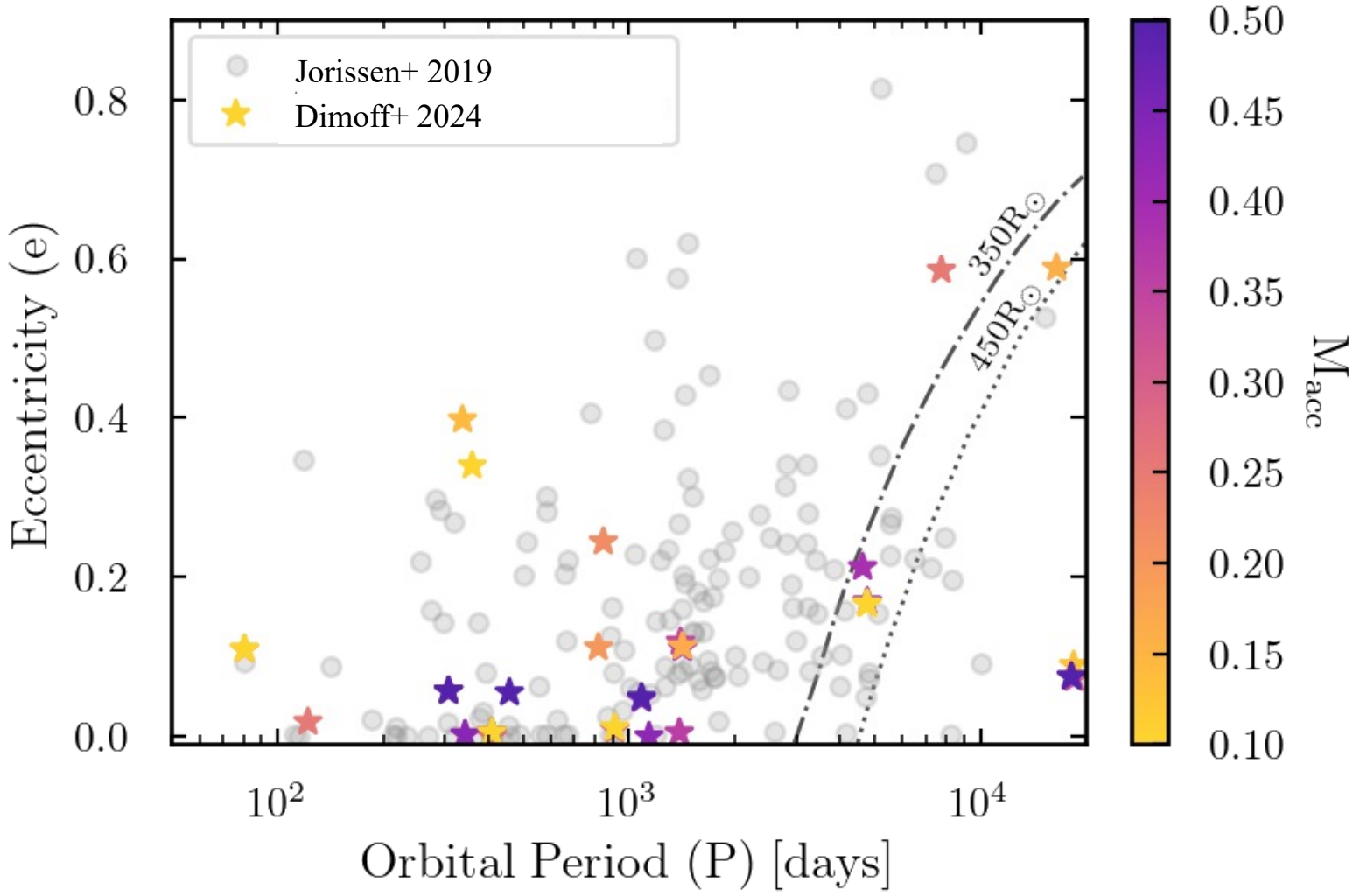

(initial mass ratio)



# Scatter in the $e - P$ diagram

- Significant scatter in $e$ vs. $P$
- Marinovic, Glebeek, Pols (2007) suggest tidally enhanced mass loss
- Dermine+ (2012) and Krinsky+ (2025) suggests circumbinary discs can high eccentricities

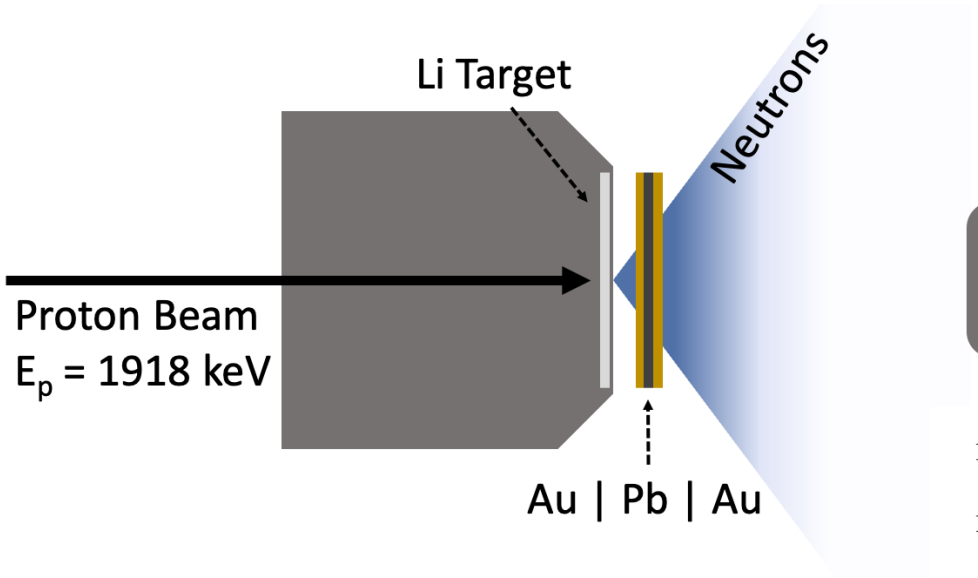
Dimoff et al. 2025



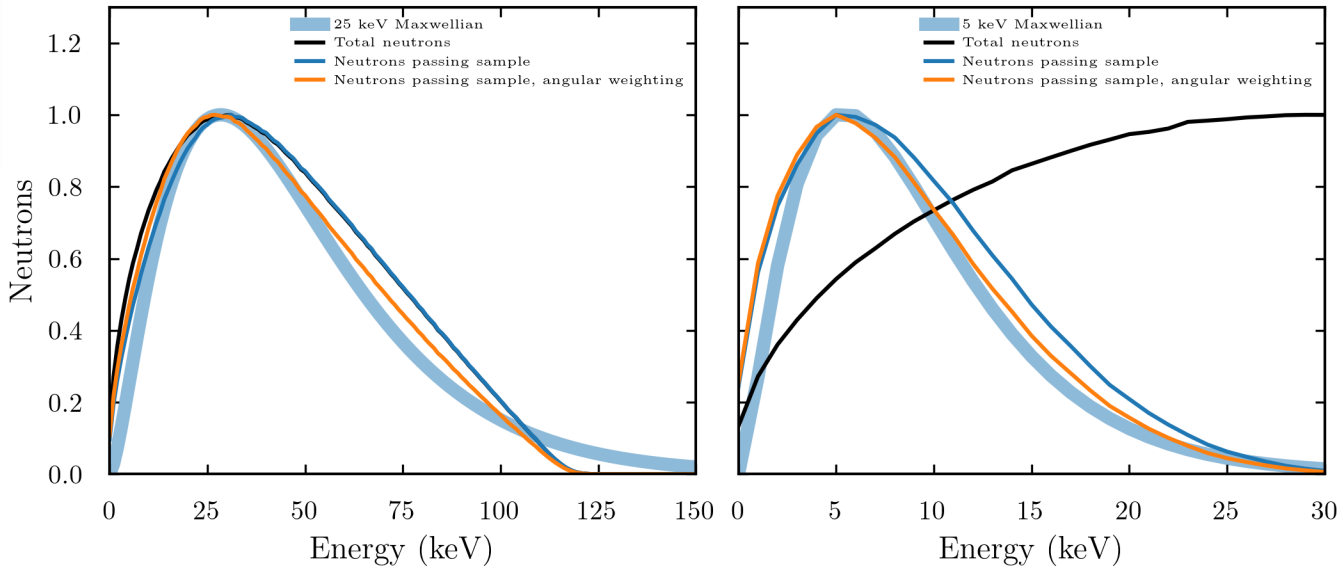
# Nuclear Physics Experiments: Measuring neutron-interaction cross sections

- Activation experiment at VdG of natural Pb targets
- Probe strong and weak s-process components, interpolate for cross section at 8 keV
- Upper limit at 5 keV, measurement at 25 keV
  - Low efficiency in detecting low-energy electrons

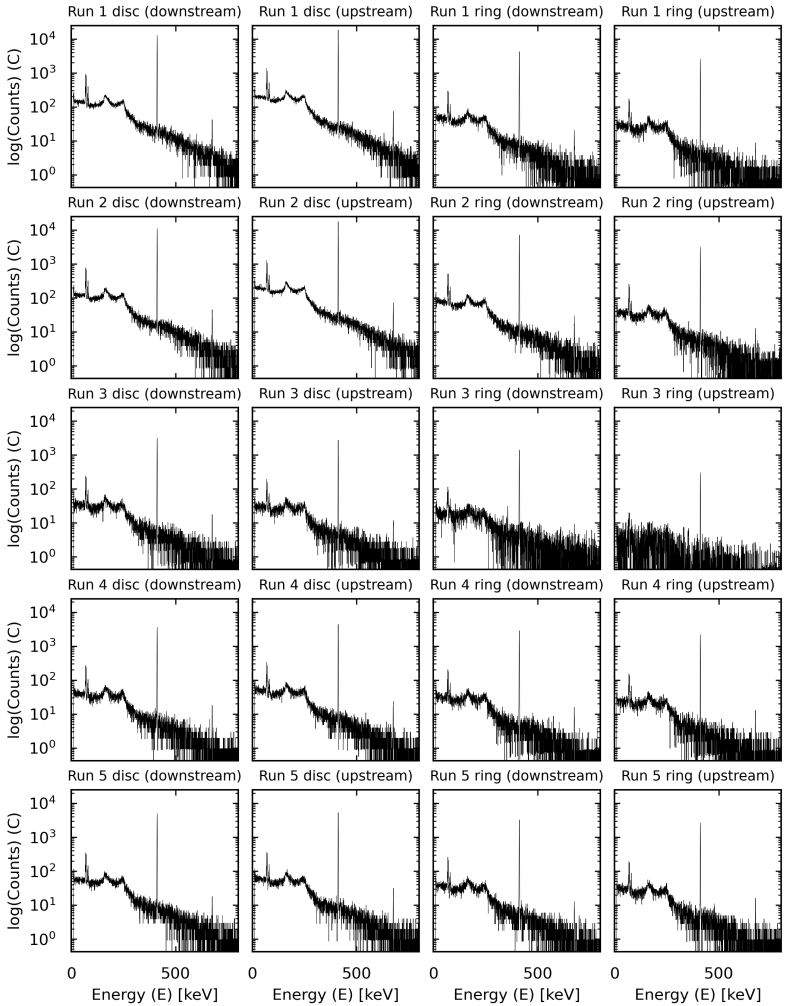
# Experimental Setup

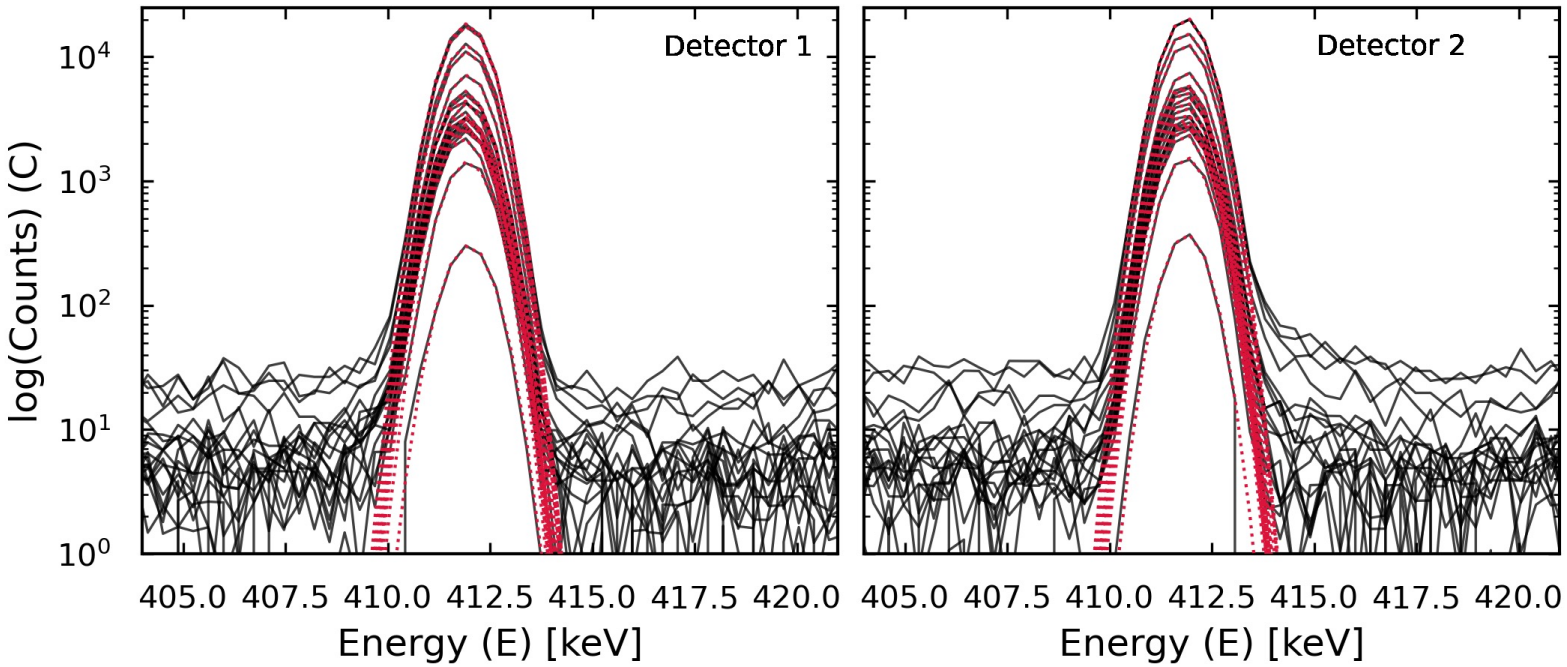



Neutron Monitor

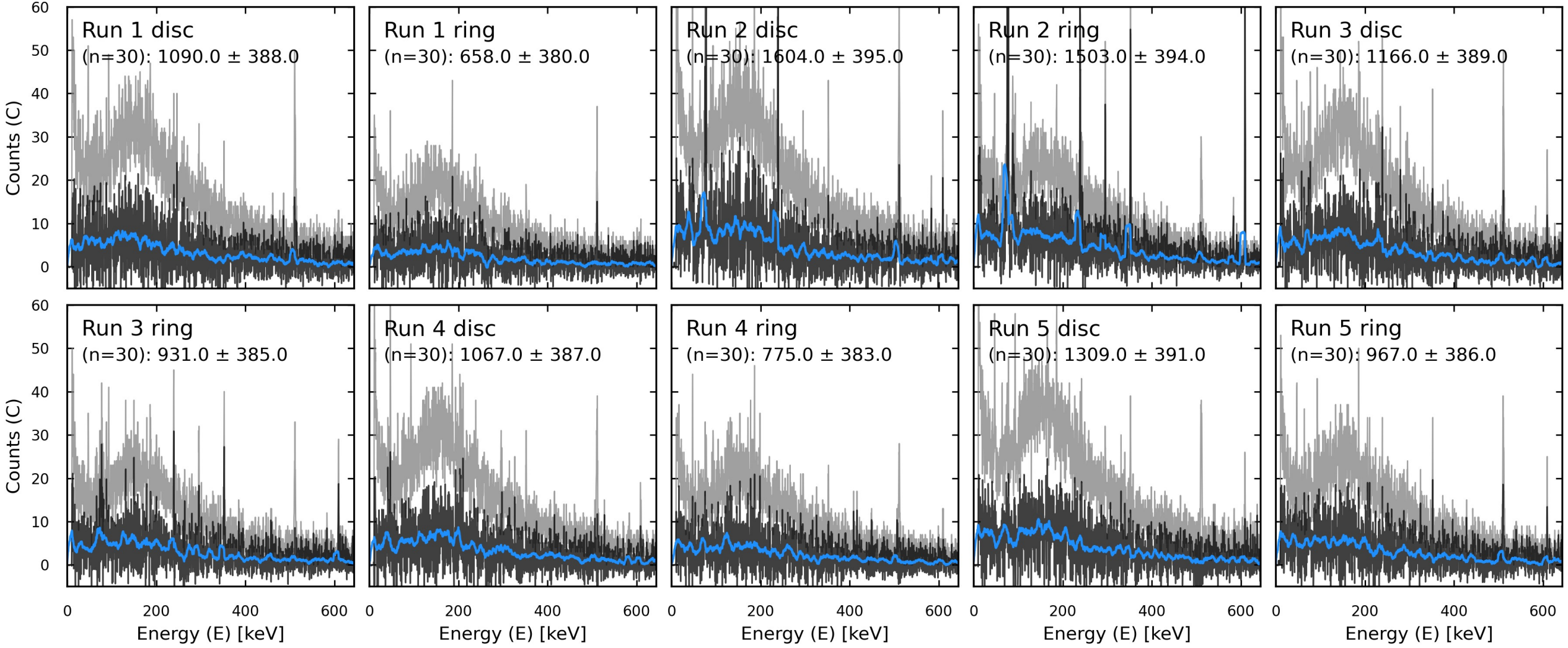


# Spectra of Activated Au



# Spectra of Activated Pb Samples



# Cross Sections Rule Out some Theoretical Models