ChETEC-INFRA – WP6

Task 6.1

Heavy element formation & binary star database

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WP6.1 Astro-Nuclear-Physics

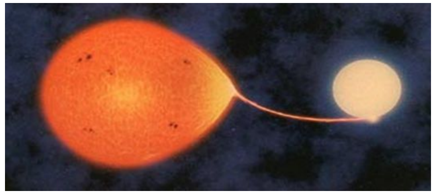
Task 6.1 Binary Star Database to support observations

- Goal: To further our understanding of the ***s-process and binary stars*** through combined investigations in theory, observations & experiments
- Method: Use TNA facilities (observations & experiments) to improve cross sections and reaction rates, binary star follow-up observations (radial velocity database including abundances), theory (stellar evolution)
- Target stars: CEMP, AGB, binaries
- How to: Collaboration & hire PhD student (starting fall this year)

Scientific background of WP6.1

Goal: To understand s-process synthesis in AGB stars & their mass transfer better using stellar abundances, RVs, nuclear reactions and detailed stellar evolution modelling.

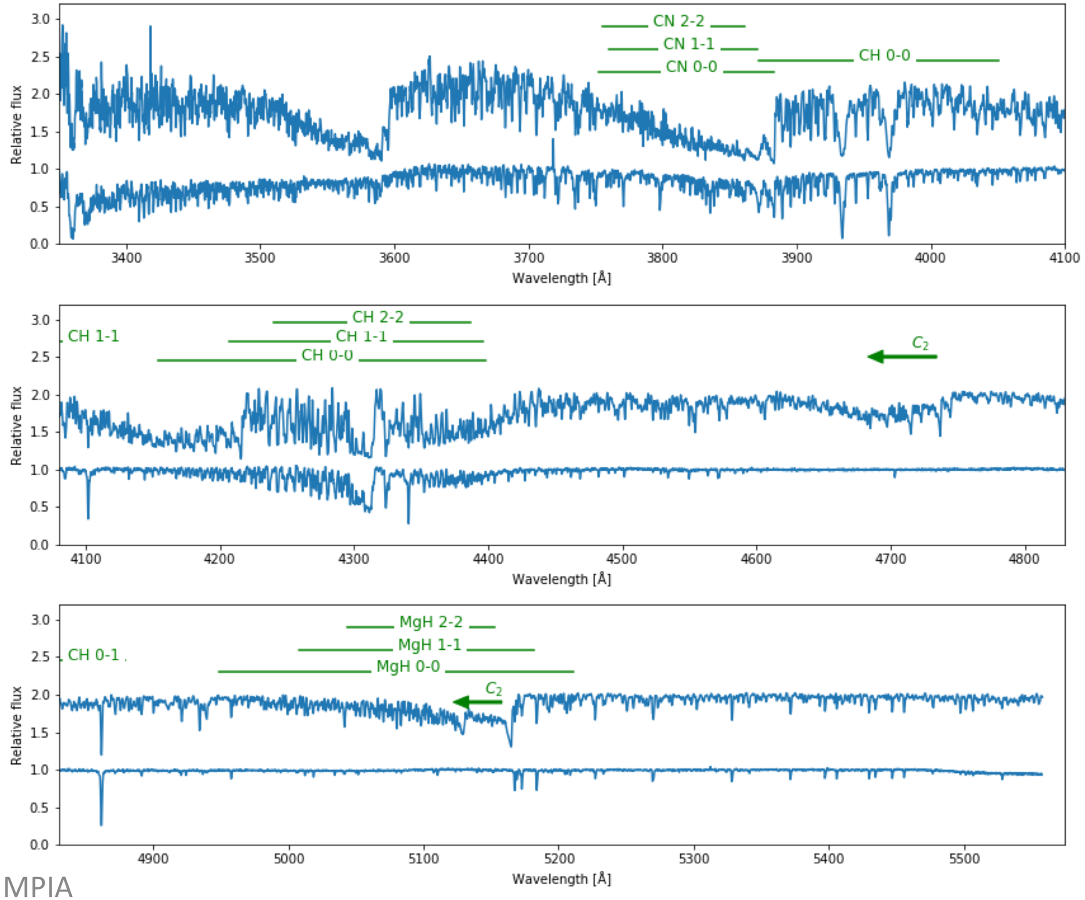
- Central to this study is to create a large database with radial velocities and abundances for binary, AGB, and Carbon Enhanced Metal-Poor (CEMP) stars with s-process enhancement



- CEMP-s stars are typically* binaries (low-mass star + AGB) where the AGB transfers C- and s-process rich material onto the smaller secondary

*The fraction is believed to be between 80-100 % (Lucatello et al. 2005, Starkenburg et al. 2014, Hansen et al. 2016, Abate et al. 2019)

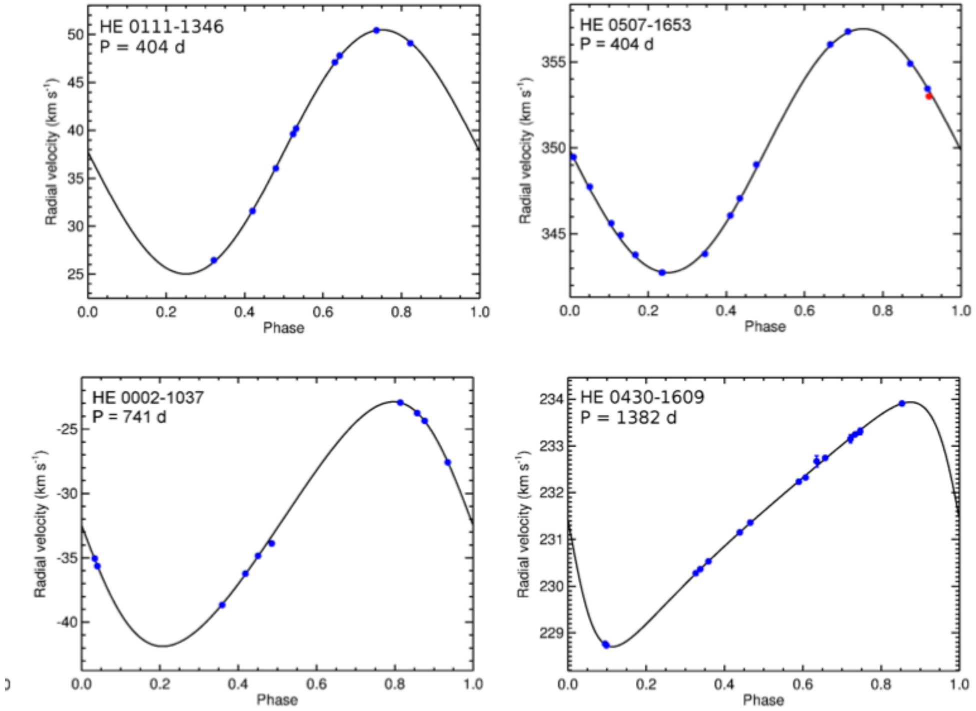
Singh et al. 2020

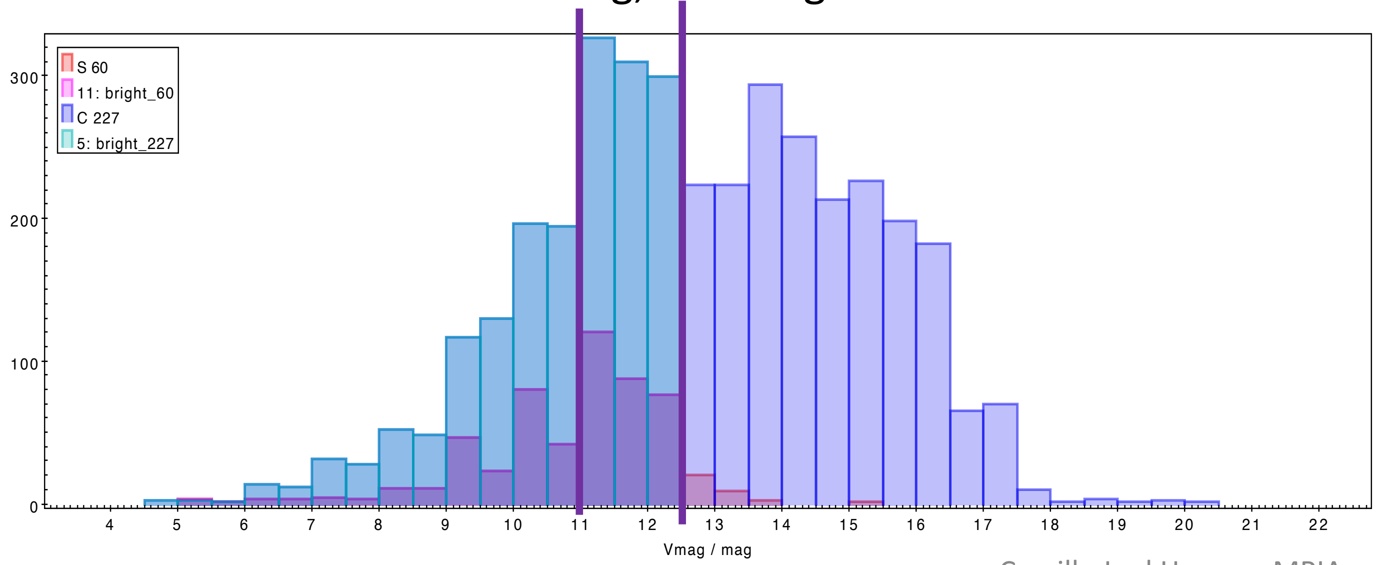


Observations

Hansen et al. 2016

- Sample selections – **input & collaboration welcome!**
- Goal: > 500 stars with a mix of binaries, CEMP-s, AGB stars
- Several revisits per star over 4 years to RV monitor
- Abundances → Yields, stellar evolution, GCE…





Preliminary sample search:

Alksnis et al. 2001 (C 227): General catalog of Galactic Carbon stars – 1762 stars brighter than 12.5 mag & 828 stars brighter than 11 mag.

Stephenson 1976 (S 60): General catalog of S stars (514 * w mag<12.5mag, 231 * w mag<11mag)

Observations

- Database (RV and Abundances) for CEMP-s, AGB, and binaries (early deliverable)
- Need (observations): Data, data reduction, stellar parameters & abundances
- Need (experiments): S-process yields & nuclear input
- Need (theory): RV period code, stellar evolution code, AGB theory

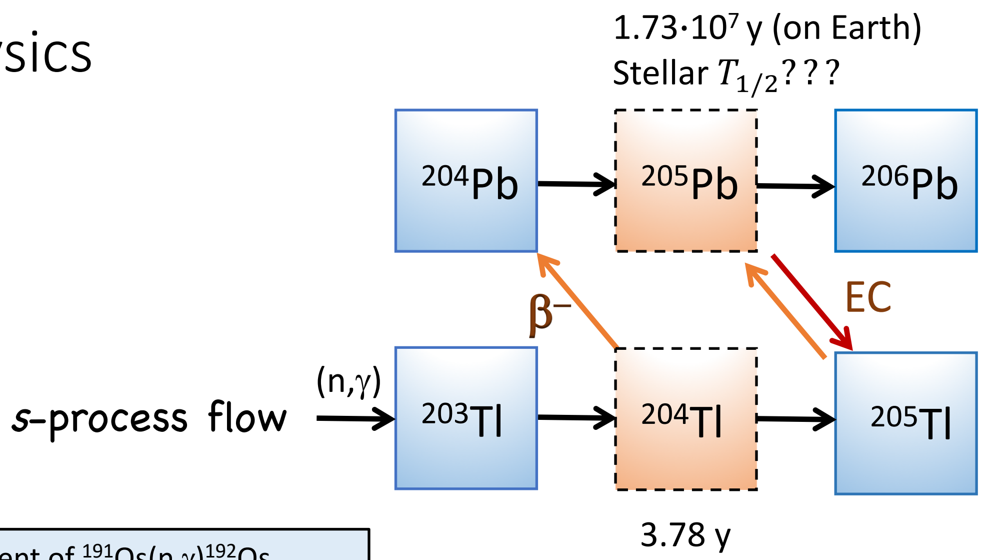
<u>Key elements and challenges:</u>

- Weak s elements (maybe Rb?), main s (Pb – Oslo)
- Molecules
- Model atmospheres (of evolved stars)
- AGB stars

We need input and interaction with WP5 & several TNA facilities!

Experiments in WP6.1: Comprehensive Nuclear Astrophysics

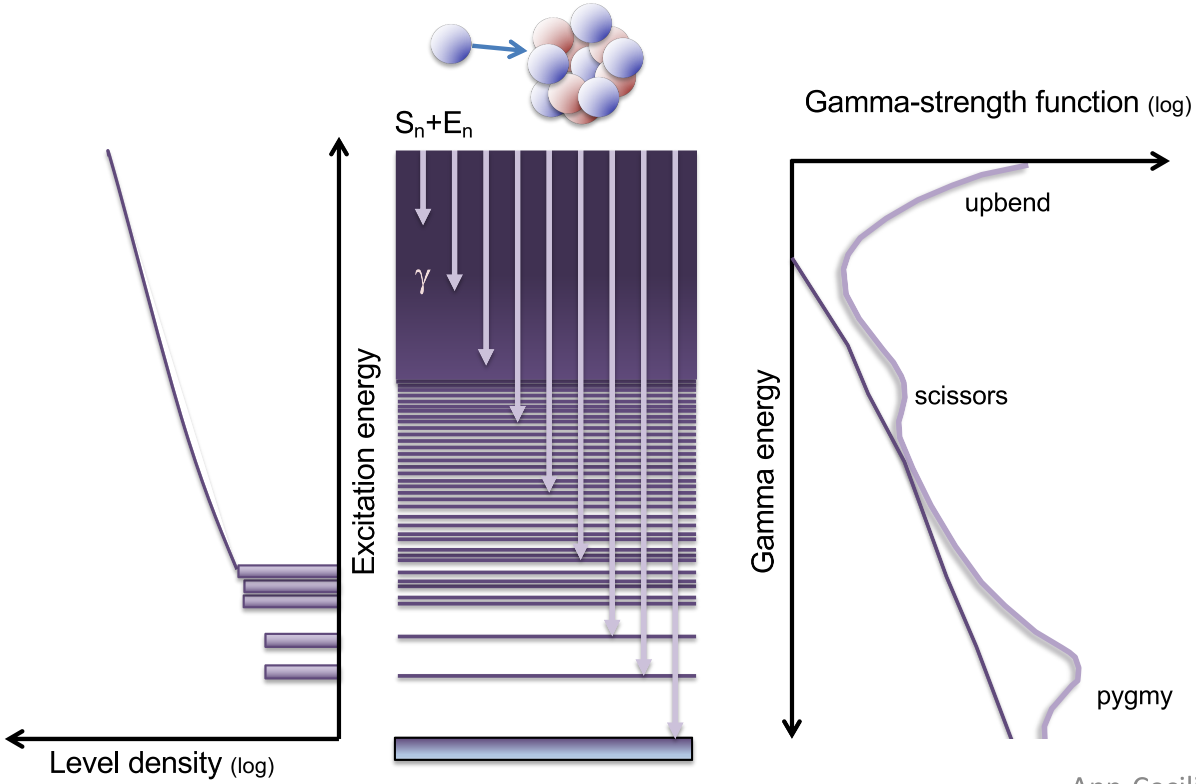
<u>Constraining (n,γ) cross sections for *s*-process branch point nuclei</u>

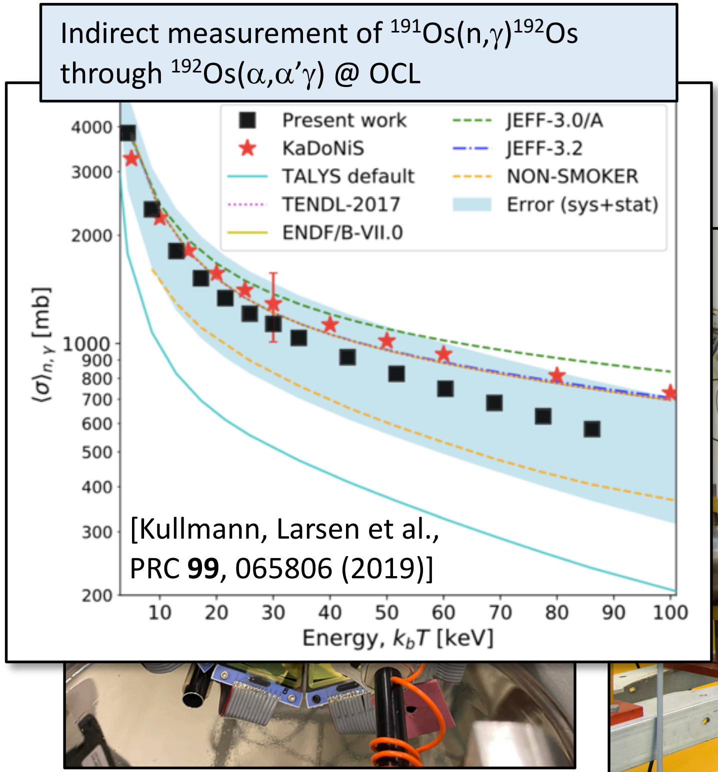


Indirect technique:

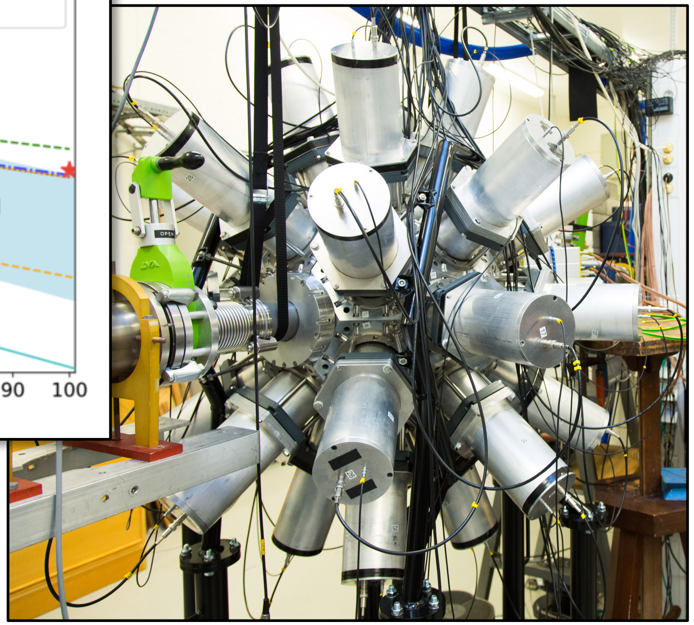
1. Measure the quantum levels and their decay probability of the *residual* nucleus @ the Oslo Cyclotron Laboratory, Norway
2. Plug the results into a nuclear reaction code, and get a data-constrained cross section ☺

Cases: ^{205}Pb(n,γ)^{206}Pb, ^{86}Rb(n,γ)^{87}Rb and ^{95}Zr(n,γ)^{96}Zr



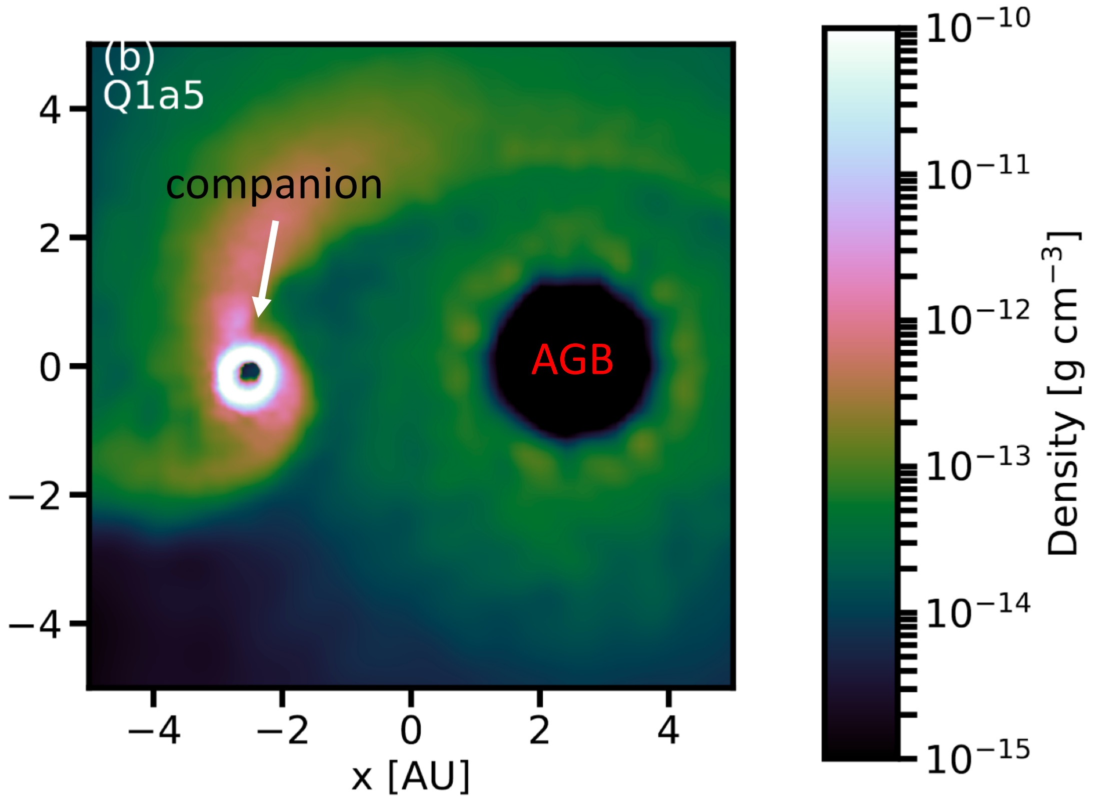


OSCAR for γ rays



Theory in WP6.1: Mass transfer binary systems

- Objects like barium stars and s-process rich CEMP stars are the result of mass transfer
- Their orbital properties tell us about tides and mass transfer
- Their abundances hold clues to AGB star nucleosynthesis

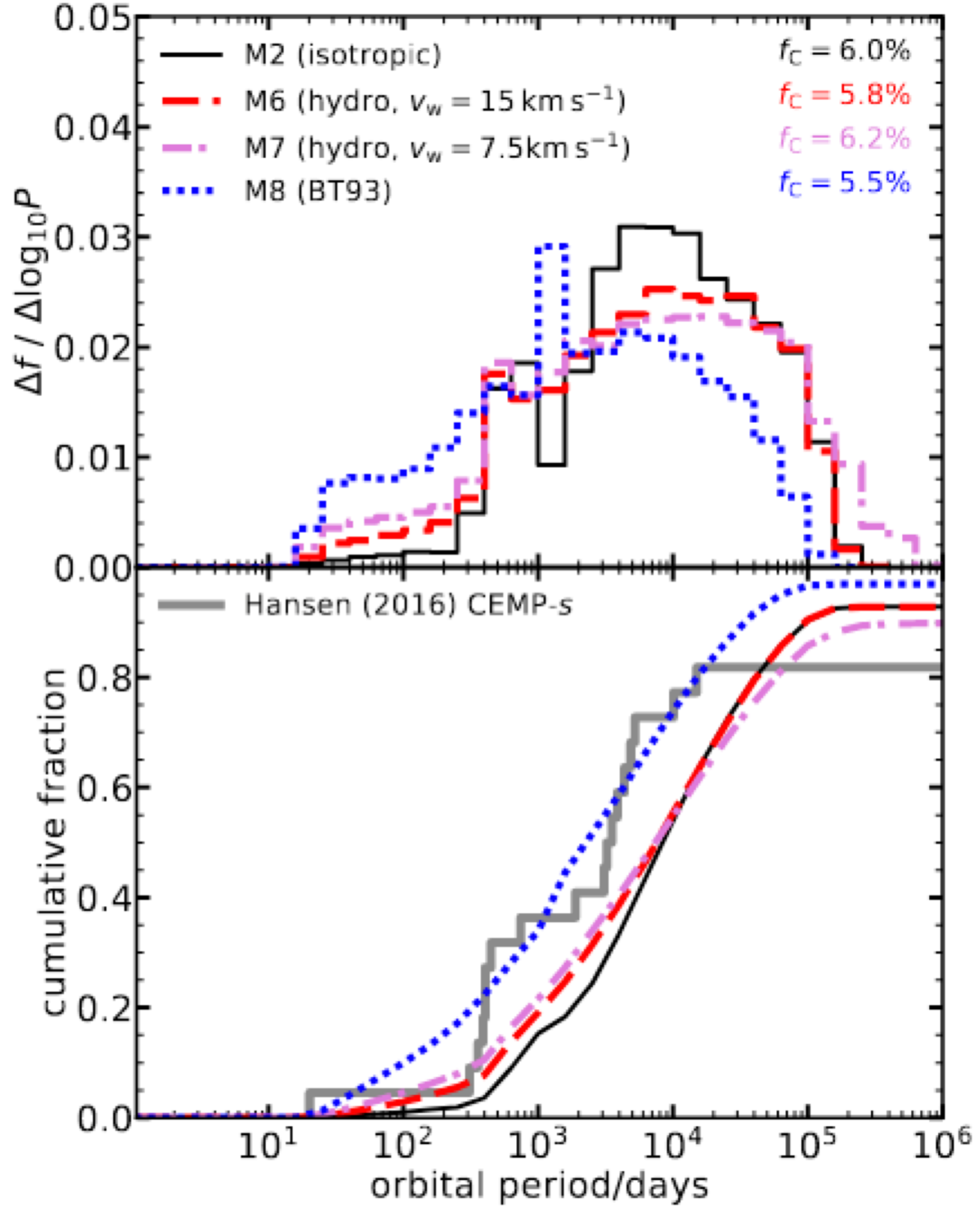


Saladino, Pols & Abate (2019)

Abate, Pols & Stancliffe (2018)

Orbital properties

- Use population synthesis (binary_c) to model binary systems
- It is difficult to reproduce the observed period distribution of CEMP stars
  - Some very short period systems
  - Few very long period systems
- Data suffers from low number statistics, hence the need for more RV monitoring



Barium stars

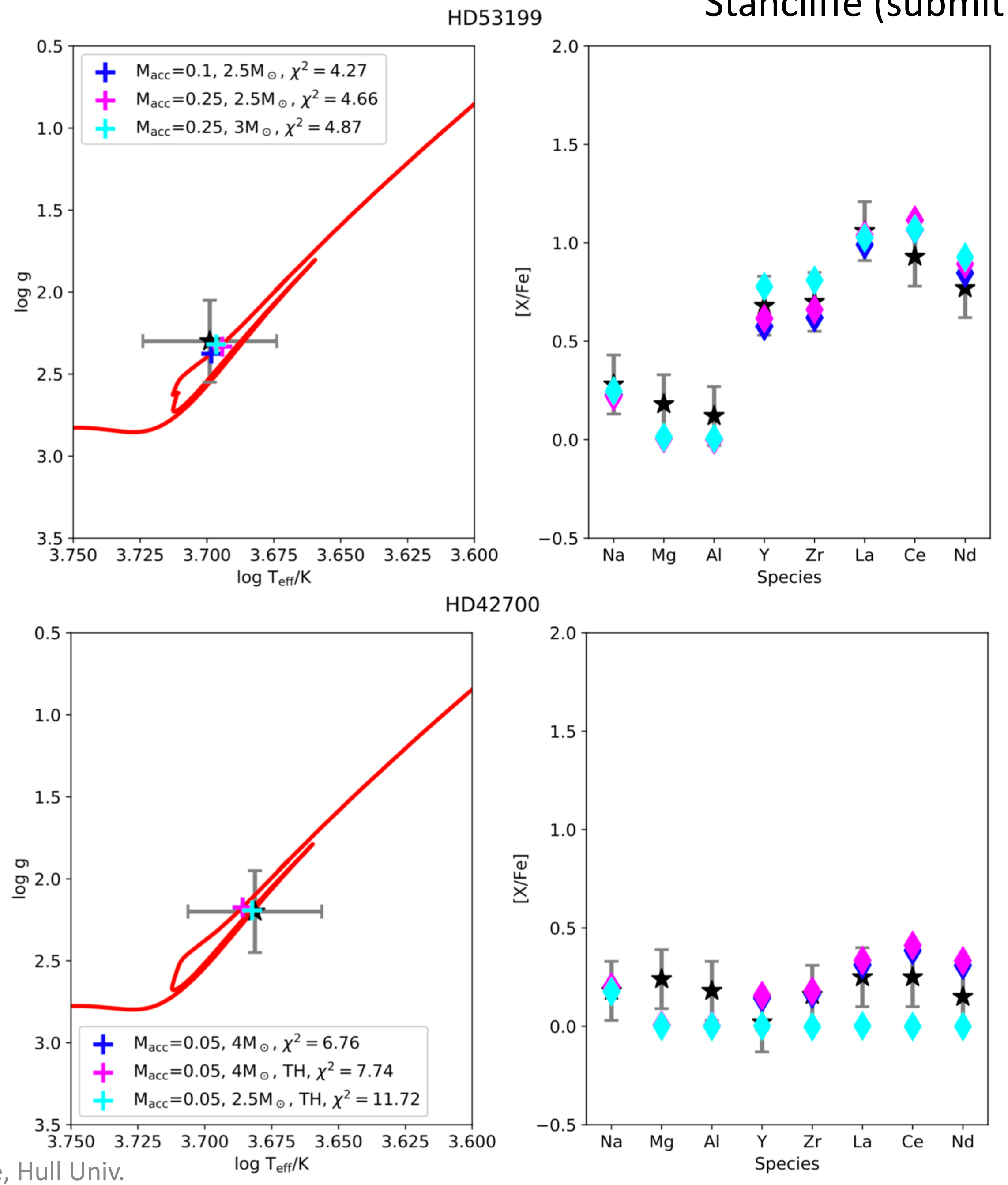
Stancliffe (submitted)

- To fit abundance patterns we need to follow:
  - Evolution of AGB stars
  - Nucleosynthesis
  - Evolution of secondary

- Stellar modelling via STARS code
- Nucleosynthesis via NuGrid's *mppnp*

- Then simultaneously fit abundances and evolutionary state

- Requires both good abundance data (e.g. de Castro et al. 2016) and mass determinations (Escorza et al. 2017)



Task 6.1

- We will collaborate on several aspects (observations, theory, experiments) of s-process nucleosynthesis and how we measure this in stars and the lab
- Step 1 - find a student who will work on observations, theory, and experiments for the PhD
- Step 2 – set up database for RV and 1D LTE s-process abundances

- In case you would like to collaborate, please contact Richard or me (hansen @ mpia.de)
- Input on sample selection very welcome!
- Students interested in a PhD in astro-nuclear-physics, please contact us