Tc-rich M stars: platypuses of low-mass star evolution

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1 INTRODUCTION

What are M-type giants?

- Late-type stars with **TiO** molecular bands
- M-type giants have *oxygen-rich* atmospheres: they have a carbon to oxygen ratio C/O < 0.5

Asymptotic giant branch (AGB) evolution:

As an AGB star evolves, it ascends M-S-C sequence and its oxygen-rich chemistry turns into a carbon-rich one because of the third dredge-ups bringing to the surface freshly synthetized C and s-process elements (Figure 1).

What is the status of the M stars that show heavy-element abundances in their spectra?

There has been several observations of Technetium (Tc)-rich M-type stars [1]. Tc is a radioactive s-process element (half life: 2.1 10^5 years). Hence, the detection of Tc is a direct indication of an active s-process nucleosynthesis. Tc-rich M stars are thus intriguing since they show clear absorption lines of Tc but a low C/O ratio (i.e., C/O<0.5). Through this work, ***our aim is to understand the evolutionary status of the Tc-rich M stars.***

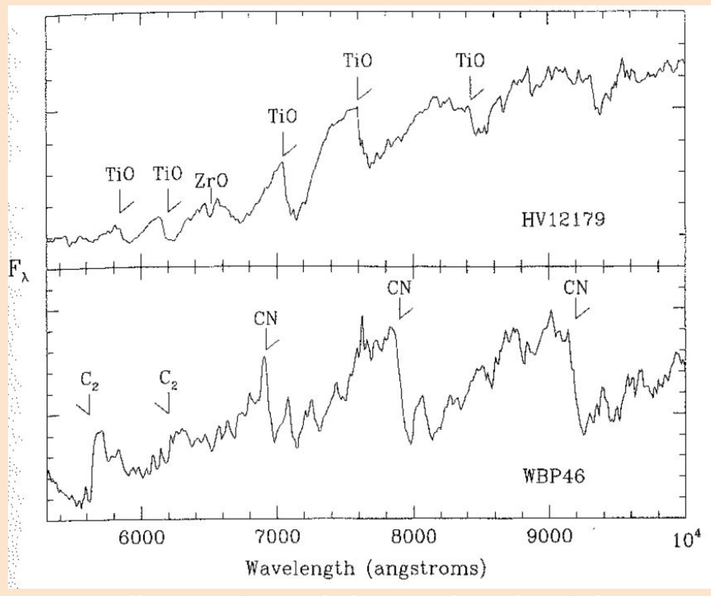
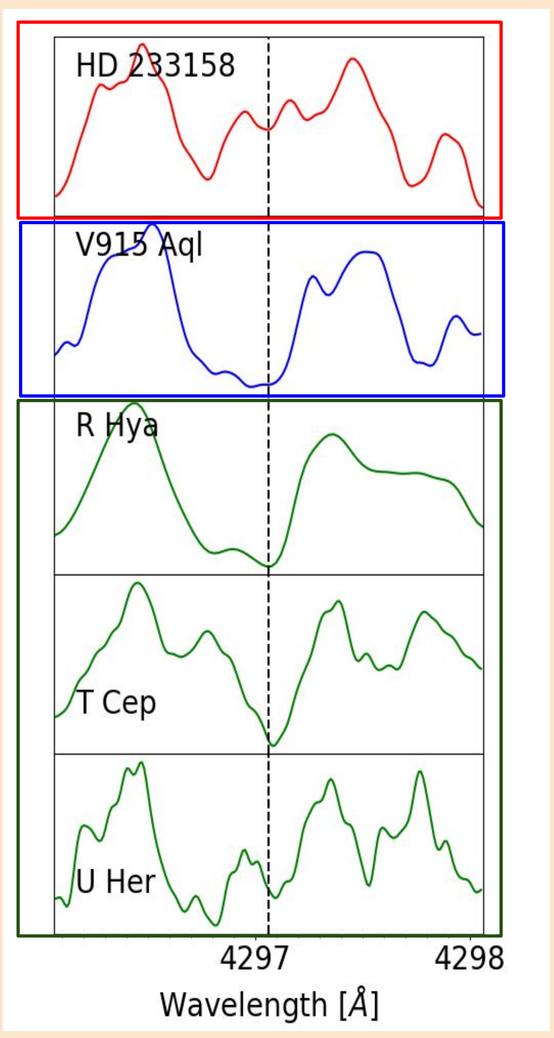


Figure 1: Illustration of the molecule-rich spectra of an M-type (top panel) and a carbon (bottom panel) star, figure from Lattanzio & Wood (2004).

2 TECHNETIUM LINES OF M and S STARS



Technetium-poor S star

Technetium-rich S star

Technetium lines of the intriguing M stars

Confirmation of the Tc-rich nature of these M stars from 3 different Tc lines: 4238A, 4262A, and 4297A (the latter is illustrated in Figure 2).

Figure 2: Tc I line at 4297.06 A for some M and S stars.

3 STELLAR PARAMETER DETERMINATION

Models

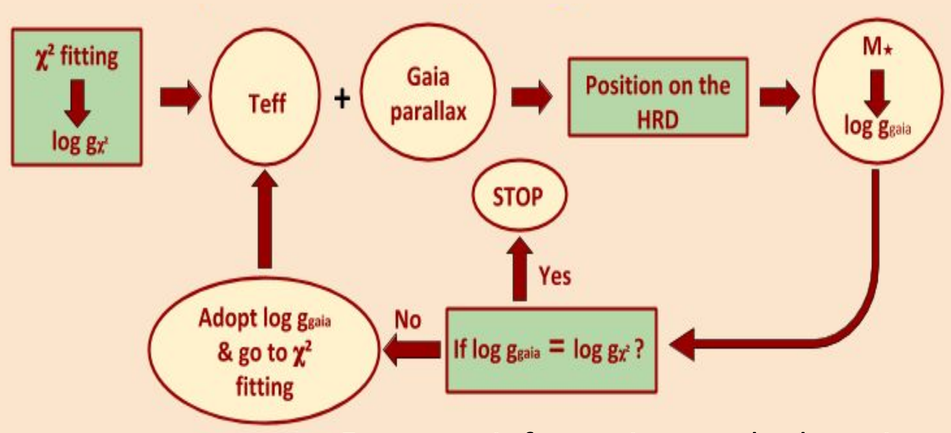
MARCS model atmospheres for M- and S-type stars [2]

- $2700 \leq T_{eff}(K) \leq 4000$
- $0 \leq \log g \leq 5$
- [Fe/H] = 0.0 and -0.5
- [α/Fe] = -0.4*[Fe/H]
- **$0.50 \leq C/O \leq 0.99$**
- **[s/Fe] = +0,+1 and +2 dex**

Atmospheric parameters using spectral fitting + photometric indices

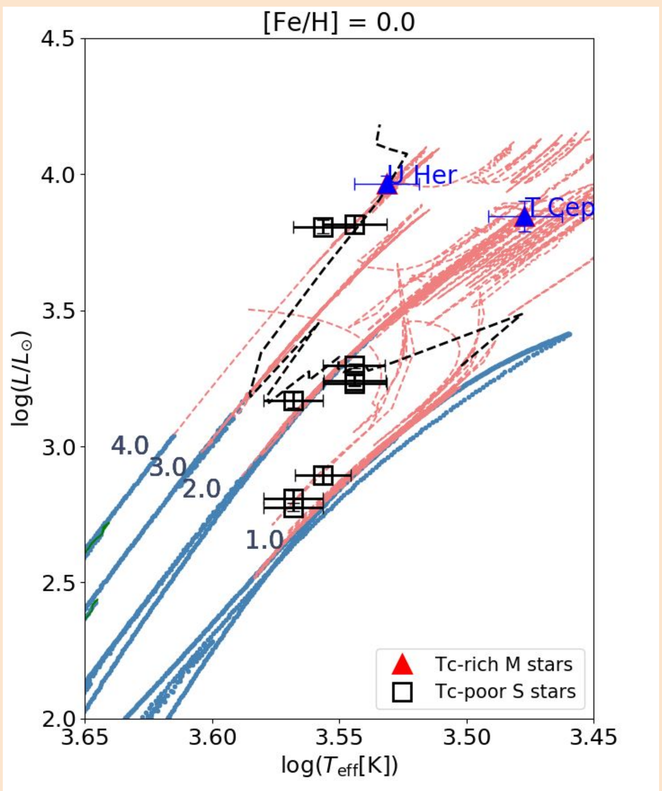
- Initial T_{eff} estimate using the photometric indices from [2].
- Spectropic confirmation of the initial estimate of the stellar parameters.
- Derivation of the metallicity and C/O ratio of the stars using the method from [5].

Gaia parallaxes can help us constrain log g by iterating on parameters from χ^2 fitting and Hertzsprung-Russell (HR) diagram :



For more information on the log g iterations check [5]

4 PRELIMINARY HR diagram (*GAIA* EDR3)



Tc-rich M stars lie well above the predicted onset of the third dredge-up (black dashed line in Figure 3) in the HR diagram.

Their location in the HR diagram hints towards intermediate-masses (2 - 4 Msun), however, a confirmation of these mass estimates is needed.

Figure 3: HR diagram of Tc-rich M stars and Tc-poor S stars. The STAREVOL evolutionary tracks are overplotted, In blue → RGB; In pink → AGB

5 CONCLUSION AND PROSPECTS

- *GAIA* EDR3 allows to locate the Tc-rich M stars in the HR diagram.
- Fundamental parameter determination of M stars is well constrained by the combination of high-resolution spectra, dedicated model atmospheres and GAIA EDR3 parallaxes.
- The preliminary GAIA HR diagram of the M stars hints at these stars being intermediate-mass AGB stars.
- Detailed abundance determination of the Tc-rich M stars and comparison with theoretical predictions is a work in progress [6].

If numerous, the Tc-rich M stars pose a significant challenge for our current understanding of the stellar luminosity at the onset of the TDU and the anticipated length of the thermally-pulsing AGB phase. Hence, Tc-rich M stars will bring novel constraints on the stellar evolutionary models.

References:
[1] Little-Marenin, I. R., & Little, S. J., 1979, AJ, 84, 1374 , Uttenthaler, S. 2013, A&A, 556A, 38U
[2] Van Eck, S. et al. (2017), A&A 601, A10
[3] Siess L. ; Arnould M. (2008). Astronomy and Astrophysics, Volume 489, Issue 1, 2008, pp.395-402
[4] Goriely S. and Siess L., 2018, A&A, 609, A29
[5] Shetye S. et al., 2018, A&A, 620, A148
[6] Shetye S. et al., 2021, A&A, in preparation