Anglis ir azotas kaip papildomų maišymo procesų indikatoriai evoliucionavusiose žvaigždėse

Carbon and nitrogen as tracers of extra mixing processes in evolved stars

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Stars spend most of their lives on the main sequence of the Hertzprung-Russel diagram, where they burn hydrogen to helium in hydrostatic equilibrium. During this phase, the material from the stellar core does not reach the surface of the star, and the chemical composition of the stellar atmosphere stays constant. In later evolutionary stages, the fusion reactions in the stellar core change, and the stars move towards the red giant branch of the Hertzsprung-Russel diagram. Now convective mixing processes can transport material from the core of the star all the way to its surface, and vice versa. As a consequence of this ”dredge-up”, changes in the chemical composition of the stellar atmosphere can be observed [1].

Among other effects, the mixing leads to a decrease of the observed carbon-to-nitrogen ratio [C/N] and a reduction of the $^{12}C/^{13}C$ ratio. However, recent works observe [C/N] and $^{12}C/^{13}C$ ratios that are too low to be explained by the standard convective mixing alone. Several mechanisms have been suggested as explanations for the observed extra mixing. The effects of thermohaline instability and rotation-induced mixing on the observable surface abundances of carbon, nitrogen, and the carbon isotopic ratio have been studied by [3]. To constrain their stellar evolution models, we have investigated high-resolution, high signal-to-noise spectra of 350 evolved red giant stars.

Our analysis of the atmospheric [C/N] and carbon isotopic ratios of these stars confirm the presence of non-standard mixing processes. The model calculations from [3], which include the extra mixing effects of rotation and thermohaline instability, fit better to our determined abundances, than the models that include only the standard convective ”dredge-up” mixing. Our results therefore supply further evidence that rotation and the thermohaline instability are the key mechanisms that cause the extra mixing of stellar material.

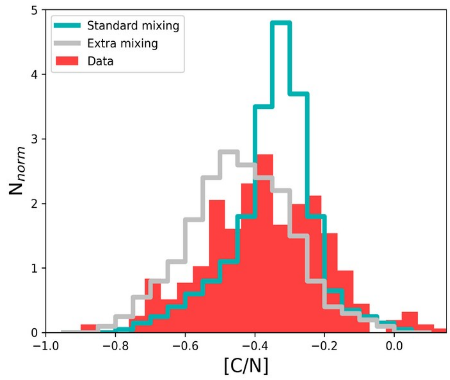

Figure 1: Normalized histogram of the [C/N] ratios of our sample stars (red). Unfilled histograms show model predictions from [3] for standard convective mixing (cyan) and additional extra mixing induced by rotation and thermohaline instability (gray).

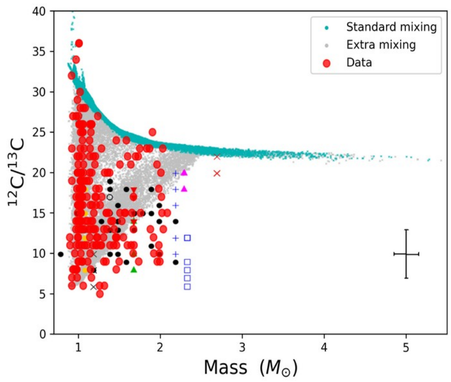

Figure 2: Carbon isotopic ratios $^{12}C/^{13}C$ relative to stellar mass. Stellar evolution models from [3] that include extra mixing, are depicted as small gray data points. Standard mixing models are shown in cyan. Our results are shown as red data points, other colorful symbols are results from other works.

References

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Key words:
Stars: abundances, stellar evolution
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