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Convective Overshooting in Stars

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Mysterious mixing in stars

How does material from the deep interior of a star get mixed up with the star's surface layers? Astronomers have been observing evidence of such effects for decades now, but some of them still defy explanation. In particular, the light element lithium is known to gradually disappear from the surface of solar-type stars over most of their lifetime. Stellar surface layers are too cool for lithium to be destroyed by nuclear reactions in situ. Thus, some process must be transporting material between the surface and the hot interior, where lithium is burnt.

The outer layers of solar-type stars are somewhat akin to a glass of hot water. The strong cooling at the surface of the water/star gives rise to cold plumes sinking down and pushing the hot material from the deeper layers to the surface. This process, known as convection, does not extend deep enough in solar-type stars to reach the hot, lithium-burning layers, so it cannot account for the observed lithium depletion on its own.

Several physical processes can extend the mixing beyond the boundary of a convection zone. Most of them do not have the right properties to resolve the lithium problem, though. We propose a new one, in which a small fraction of the plumes from the surface is thought to stay cold enough for them to keep sinking below the convection zone after they have reached its bottom. We show that this process can provide the slow but deep kind of mixing needed to explain the lithium depletion in solar-type stars. Our results are also compatible with the observed depletion of beryllium, which is burnt somewhat deeper in the star. Additionally, we investigate a different process, in which a slow flow is set off in the radiative zone of a star owing to the uneven heating of that zone provided by a neighbouring convection zone. Although the layer influenced by the flow is too shallow to make this process relevant for the lithium problem, it could influence the evolution of massive stars.