Nuclear physics and stellar MHD coupled together solve the puzzle of oxide grain composition

Palmerini S.1,2, Busso M.1,2, La Cognata M.3, Sergi, M. L.3, Trippella O.1,2

1Dipartimento di fisica e Geologia Università degli Studi di Perugia, Italia
2I.N.F.N. sezione di Perugia, Italia
3I.N.F.N. Laboratori Nazionali del Sud, Catania, Italia

Cool Bottom Process

Wasserburg et al. (1995) suggested the presence of a deep matter circulation to account for oxygen isotopic ratios and several large excesses of $^{18}$O found in Al$_2$O$_3$. These authors developed the model of a "Cool Bottom Process" model in which currents transport matter downward, from the bottom of the envelope to the regions where H-burning occurs, and upward, in the opposite direction, enriching the stellar surface with fresh products of the CNO cycle.

Netolli et al. (2004) examined the effects of CBP by using a parametric model in which deep mixing is characterized by the mass circulation rate and the maximum temperature/depth experienced by the circulating material. Despite the results achieved applying CBP model to low mass AGB stars, some grains belong to a "forbidden" area not accessible by nucleosynthesis models and were found to be the intermediate mass stars nucleosynthesis needed to account for formation of group 1 grains showing the larger value of $^{16}$O/$^{18}$O.

The full MHD equations can be solved analytically in an exact way when the plasma density distribution has the form $p_{\rho\rho}$, where $k < 1$; Magnetic Prandtl number $P_{Pr} > 1$; Magnetic diffusion $v_{\mu} \ll 1$.

The solution implies a natural expansion of magnetized zones, carrying matter from near the H-burning shell to the envelope and then pushing down envelope matter to the radiative zone for mass conservation. In other words, the solution proves that stellar MHD might promote deep mixing mechanisms, or CBP, in evolved low mass stars.