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Constraining the physics of rotation in stellar interiors

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In this contribution I review the current theoretical description of angular momentum transport in stellar interiors, constrained by results obtained with asteroseismic techniques.

Space-borne missions such as Kepler or Tess provided light curves of unique quality for stars in different evolutionary phases, which enabled their asteroseismic characterization by exploiting the properties of their pulsation modes. Initial studies based on those data revealed that the internal rotation rates of red giants are two to three orders of magnitude lower than what stellar models with pure hydrodynamical processes predicted. Moreover, the problem of inefficient angular momentum transport in stellar models is present in several evolutionary phases and for different types of stars. Nowadays, measurements on the inner rotation rates of stars are available for hundreds of stars in different evolutionary phases, and different masses (Aerts, 2021).

Currently, the presence of magnetic fields in stellar interiors provides the best agreement with observations. This is achieved through a dynamo process based on the combined action of differential rotation and the Tayler instability which acts on the azimuthal component of magnetic fields; this process is known as the Tayler-Spruit dynamo (Spruit, 2002). Based on this theory, a better agreement with observations was obtained, although a revision of the theory, as proposed by Fuller et al. (2019) improved the theory drastically for post-main sequence stars. This led to major achievements such as the successful reproduction of core rotation rates of red giants and white dwarfs (Fuller et al. 2019), the rotation profile of the Sun and its surface lithium and helium abundances (Eggenberger et al., 2022), and the near-core rotation rates and surface rotational velocities of low-mass main sequence stars (Moyano et al., 2023).

An illustration of the evolution of the core-rotation rate is shown in Figure 1, where we show the results obtained in stellar evolution computations assuming either models

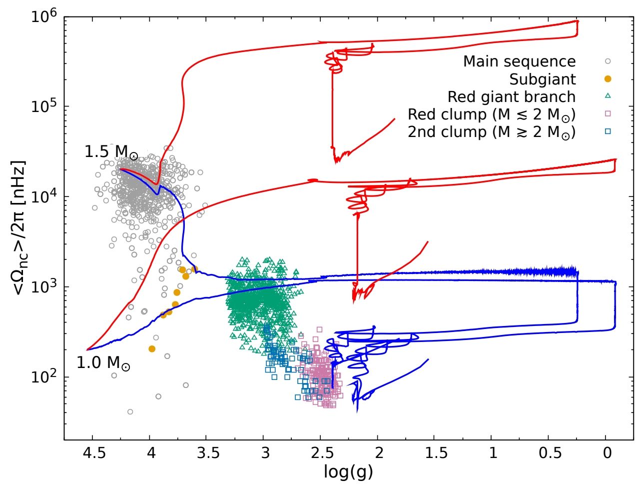

Figure 1. Near-core rotation rate as a function of the surface gravity. The data points correspond to stars in different evolutionary phases as explained in the legend, while the lines correspond to four different stellar evolution models computed from the ZAMS with (blue) and without internal magnetic fields (red) at two different initial rotation rates. The initial masses of the models are indicated in the plot.

with and without internal magnetic fields, from the ZAMS until the end of the core-helium burning phase.

However, despite the advances brought by this theory, various problems remain open, like the rotation rates of subgiants (Eggenberger et al., 2019), the unexplored rotation rates of hot subdwarfs (Charpinet et al., 2018), and the presence of large-scale internal magnetic fields in the cores of red giants (Li et al., 2022).

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