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Internal rotation, meridional flow, and the solar dynamo

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Mean field MHD not only provides a framework for modeling the generation of large-scale magnetic fields in stars and planets as well as their internal rotation and large-scale meridional flows.

The current model for the generation of solar magnetic activity is the flux transport dynamo. In this type of dynamo the magnetic field is generated by the same mechanisms as in the traditional $\alpha\Omega$ dynamo but the two effects no longer operate in the same place. The toroidal field is generated in the tachocline, the transition layer between the outer convection zone and the radiative zone below. The α effect, on the other hand, is located in the convection zone proper or even in its upper part. The two effects can combine to form a working dynamo because the layers they exist in are connected through the large-scale meridional flow, which acts as a conveyor belt.

Based on the second order correlation approximation (SOCA) we model the internal rotation, meridional flow, and convective heat transport in the solar convection zone. The model not only reproduces the solar internal rotation as revealed by helioseismology, it also allows predictions for other late-type stars.

In a rotating, stratified convection zone the angular momentum transport by Reynolds stress is not purely diffusive and will actually prevent rigid rotation. On the other hand, the meridional flow is a powerful transporter of angular momentum even if it is itself much slower than the stellar rotation or the convective gas motions. Two effects drive meridional flows. While flows driven by the differential rotation itself counteract their cause, i.e. make the rotation more uniform, circulations caused by the baroclinicity of the rotating, stratified convection zone enhance the differential rotation. The flow pattern is the result of an equilibrium between the two effects.

We present results for several types of star and discuss the implications for dynamo processes in these stars.