The Convection Conundrum: Mystery and Intrigue Below the Solar Surface

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Abstract

Helioseismology has revolutionized the discipline of solar internal dynamics. For the first time in human history we can peer below the surface of a star. But interpreting helioseismic measurements is not easy. Some signals are more subtle than others. Though there is general agreement on helioseismic inversions of the internal rotation profile, a definitive characterization of the convective motions and meridional circulation remains elusive. In particular, some (not all) helioseismic investigations suggest that convective velocity amplitudes are much smaller than predicted by global convection models. The models themselves seem to be consistent with this assessment; they generally yield unrealistic differential rotation profiles if solar values are used for the luminosity and rotation rate. Furthermore, local-area models of solar surface convection also seem to over-estimate the power at the largest scales they can capture. But if large-scale convective motions are really so weak, then how can they carry the solar luminosity and how can they establish the mean flows that are observed? These questions define the "convection conundrum". In this talk I will review the recent observational, theoretical and numerical modeling results that are challenging our understanding of deep solar convection. I will also consider several possible ways to resolve the convective conundrum, involving physical processes that are not yet reliably captured in global convection simulations.