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Magnetohydrodynamic 3–D Models of the Solar Convection Zone

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We have conducted 3–D simulations of the complex magnetohydrodynamics of the solar convective envelope in spherical shells using our anelastic spherical harmonics (ASH) code (Brun & Toomre 2002). We here briefly discuss the properties of the kinetic and current helicities established in such systems.

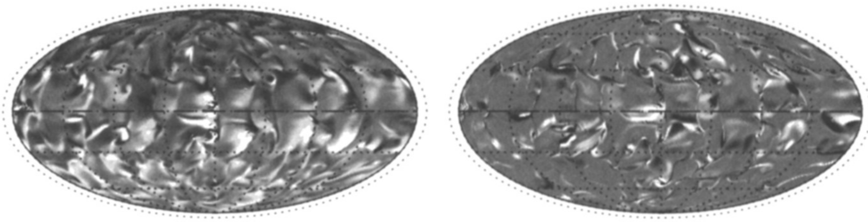

Figure 1. Snapshots of the kinetic (left) and current (right) helicities achieved in case $M3$ near the top of the domain ($r = 0.96R_\odot$). Positive values appear bright. Clearly the kinetic helicity possesses a sign preference in a given hemisphere (negative in the northern hemisphere for the displayed depth) whereas the current helicity does not.

In Figure 1, we represent at a given time the kinetic and current helicities achieved in one of our simulations of turbulent convection under the influence of rotation and magnetic fields (namely case $M3$ of Brun, Miesch & Toomre 2004). This solution possesses both a realistic solar-like differential rotation and sustained dynamo generated magnetic fields (the magnetic energy being about 10% of the kinetic energy contained in the shell). The kinetic helicity is mostly negative in the northern hemisphere, possessing its highest value near the strongest downflow lanes where cyclonic vortical structures are present. In contrast the current helicity does not show such a sign preference, having both negative and positive values distributed over the whole surface; it also delineates the downflow lanes, into which the magnetic fields have been swept and concentrated. This indicates that turbulent convection does not favor a particular sign for current helicity. In order to explain the dominant S-shape seen in active regions of the southern hemisphere (Pevtsov, Canfield & Latushko 2001), such topological 'twist' is more likely arising from the region where the flux tubes are formed, namely the tachocline at the base of the solar convective zone ($r \sim 0.7R_\odot$).

Brun, A.S. & Toomre, J. 2002, ApJ, 570, 865.
Brun, A.S., Miesch, M.S. & Toomre, J. 2004, ApJ 614, 1073.
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