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Time-dependent Turbulence in Stars

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(Submitted on 27 Oct 2010)

Three-dimensional (3D) hydrodynamic simulations of shell oxygen burning (Meakin and Arnett 2007) exhibit bursty, recurrent fluctuations in turbulent kinetic energy. These are shown to be due to a global instability in the convective region, which has been suppressed in calculations of stellar evolution which use mixing-length theory (MLT). Quantitatively similar behavior occurs in the model of a convective roll (cell) of Lorenz (1963), which is known to have a strange attractor that gives rise to random fluctuations in time.An extension of the Lorenz model, which includes Kolmogorov damping and nuclear burning, is shown to exhibit bursty, recurrent fluctuations like those seen in the 3D simulations. A simple model of a convective layer (composed of multiple Lorenz cells) gives luminosity fluctuations which are suggestive of irregular variables (red giants and supergiants, Schwarzschild 1975). Apparent inconsistencies between Arnett, Meakin, and Young (2009) and Nordlund, Stein, and Asplund (2009) on the nature of convective driving have been resolved, and are discussed.

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