
DECODING PHYSICS OF CONVECTIVE TURBULENCE

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In this abstract we present the turbulence phenomenology of turbulent thermal convection (Rayleigh-Bénard convection). We performed numerical simulation of the flow for Rayleigh number $Ra = 10^{10}$ and Prandtl number $Pr = 1$ on 2048^3 grid points. We observed that in the inertial range, the energy spectrum $E(k) \sim k^{-5/3}$ and energy flux $\Pi(k)$ is a constant [1], consistent with he Kolmogorov's theory of fluid turbulence [see Fig. 1(a,b)]. We rule out the Bolgiano-Obukhov's spectrum $E(k) \sim k^{-11/5}$for convective turbulence due to the positive energy feed by the buoyancy; this is in contrast to the negative energy feed by the buoyancy in the stably stratified flows for which the Bolgiano-Obukhov theory is valid [1].

We also compute the rms values of various terms of the momentum equation of turbulent convection. As shown in Fig. 1(c), the acceleration of a fluid parcel is provided mainly by the pressure gradient $-\nabla p$, while the buoyancy $\alpha g\theta$and dissipation term $\nu\nabla^2\mathbf{u}$ are quite close to each other [2]. Here α, ν, $\theta$are the thermal expansion coefficient, kinematic viscosity, and temperature fluctuation of the fluid, and g is the acceleration due to gravity. The above force balance is also observed in the inertial range [1]. Thus, the effect of buoyancy is annulled in convective turbulence, leading to Kolmogorov's theory of turbulence. In addition, we observe that $0.5E_{\square}(k)/E_{\|}(k) \approx 0.7$, where $\|$ is the direction along the buoyancy. Thus the flow in convective turbulence is quite close to isotropy, consistent with the Kolmogorov's spectrum for the flow.

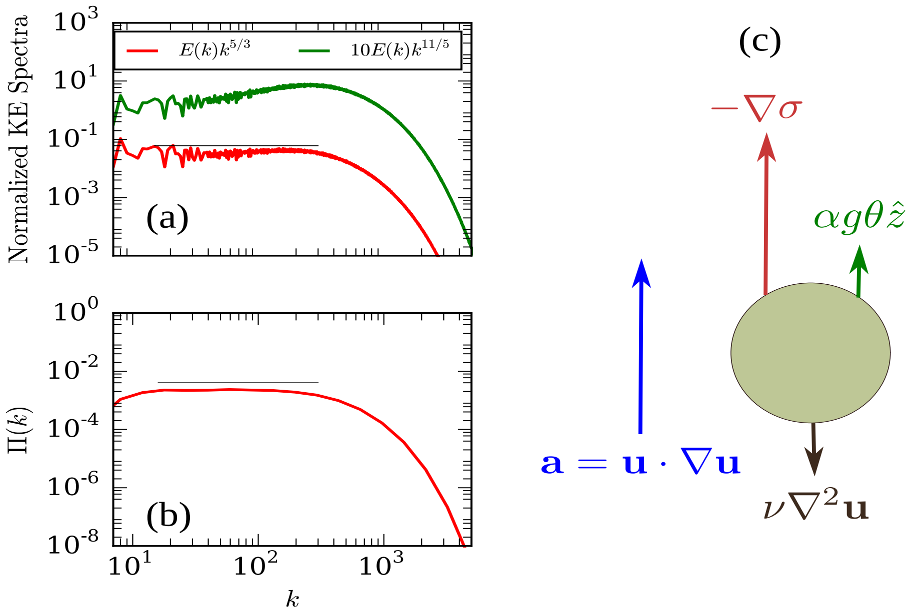

Figure 1.(a) The normalized energy spectrum $E(k) \sim k^{-5/3}$and (b) a constant energy flux, consistent with Kolmogorov's theory; (c) rms values of various terms of the momentum equation.

In summary, we show that the physics of convective turbulence is quite close to that of fluid turbulence. This result would enable us to model the convective flows in the interiors and atmospheres of planets and stars.

References

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