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Turbulent Scaling Laws from First Principles and What We Can Learn for Heat Transfer

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Abstract - Text-book knowledge proclaims that Lie symmetries such as Galilean transformation lie at the heart of fluid dynamics. These important properties also carry over to the statistical description of turbulence, i.e. to the Reynolds stress transport equations and its generalization, the multi-point correlation equations (MPCE). Interesting enough, the MPCE admit a much larger set of symmetries, in fact infinite dimensional, subsequently named statistical symmetries.

Most important, theses new symmetries have important consequences for our understanding of turbulent scaling laws. The symmetries form the essential foundation to construct exact solutions to the infinite set of MPCE, which in turn are identified as classical and new turbulent scaling laws. Examples on various classical and new shear flow scaling laws including higher order moments will be presented. Even new scaling have been forecasted from these symmetries and in turn validated by DNS.

Turbulence modellers have implicitly recognized at least one of the statistical symmetries as this is the basis for the usual log-law which has been employed for calibrating essentially all engineering turbulence models. An obvious conclusion is to generally make turbulence models consistent with the new statistical symmetries.