JOHNS HOPKINS
Center for Environmental
& Applied Fluid Mechanics

Friday, May 3, 2019
3:00 PM, 132 Gilman Hall

"Wall Bounded Turbulence and Polymer Drag Reduction"

Presented by Dr. Theodore D. Drivas
Princeton University

I will discuss two aspects of wall-bounded turbulence: anomalous dissipation and polymer drag reduction.

Regarding anomalous dissipation, I will discuss an extension of Onsager's theory of ideal turbulence to accommodate the presence of solid boundaries. Specifically, I will state conditions for energy dissipation to vanish in the infinite Reynolds number limit. These conditions are (roughly) that the third-order velocity structure function have inertial-range scaling exponent exceeding 1 and, on an arbitrary thin layer around the boundary, the wall-normal velocity remains continuous. Physically, this says that in order to be consistent with experimental observations of anomalous dissipation, either the velocity must become suitable rough in the interior or it must develop discontinuities in an ever-thinning boundary layer. The tools developed can serve as a framework for constructing LES models of wall-bounded flow.

The next part of the talk concerns polymer drag reduction. The problem of minimizing energy dissipation and wall drag in turbulent pipe and channel flows is a classical one which is of great importance in practical engineering applications. Remarkably, the addition of trace amounts of polymer into a turbulent flow has a pronounced effect on reducing friction drag. To study this mathematically, we introduce a new boundary condition for Navier-Stokes equations which models the situation where polymers are grafted to the wall. Our boundary condition - derived from a fluid-polymer stress balance - closes in the macroscopic fluid variables and becomes an evolution equation for the vorticity along the solid walls. In two spatial dimensions, we show that the energy dissipation (wall drag) vanishes inversely proportional to the Reynolds number, in qualitative agreement with observations of drag in laminar flow.

Part 1 of the talk is is based on joint work with Huy Nguyen (Brown University),
Part 2 with Joonhyun La (Princeton University).