Abstract Submitted
for the DFD14 Meeting of
The American Physical Society

Fiber bundles and geometric phases of turbulent pipe flows

FRANCESCO FEDELE, Georgia Institute of Technology — In this talk, I will discuss the role of continuous translation symmetries in the dynamics of turbulent pipe flows. Drawing from differential geometry, the geometric structure of the N-dimensional state space V of the Navier Stokes pipe flow can be defined by means of a base manifold P of dimension N-1 (quotient space) and 1-D fibers attached to any point p of P (fiber bundle). In V, a trajectory can be observed in a special comoving frame, from which the motion is locally transversal to the fibers (horizontal transport). The proper shift along the fibers to bring the motion in the comoving frame is called dynamical phase. This is, for example, the translational shift induced by the constant speed of a traveling wave (TW), or relative fixed point. A TW in state space projects to a fixed point on the base manifold P, whereas a relative periodic orbit (RPO) reduces to a periodic orbit (PO). In this case, the shift along the fibers includes also a geometric phase, induced by curvature of the base manifold P. As an application, I will present results on symmetry reduction of experimental pipe flow data acquired by means of Laser Induced Fluorescence (LIF) techniques exploiting a generalization of Hopf fibrations and complex projective spaces. A chaotic Lorenz-type dynamics is unveiled in the desymmetrized state space. Moreover, the analysis reveals that the time-varying speed of a turbulent peak during bursts is related to the geometric phase associated with the motion in the fiber bundle.

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Date submitted: 14 Jun 2014 Electronic form version 1.4