THEODORE Y. WU LECTURE in Aerospace

Graduate Aerospace Laboratories of the California Institute of Technology

Blow-up or No Blow-up? Fluid Dynamic Perspective of the Clay Millennium Problem

Whether the 3D incompressible Navier-Stokes equations can develop a finite time singularity from smooth initial data with finite energy is one of the Seven Millennium Problems posted by the Clay Mathematical Institute. We review some recent theoretical and computational studies of the 3D Euler equations, which show that there is a subtle dynamic depletion of nonlinear vortex stretching due to local geometric regularity of vortex filaments. Our study shows that the convection term could have a stabilizing effect for certain flow geometry. This is demonstrated through two reduced models of the 3D incompressible Navier-Stokes equations, which show that local flattening of the vortex structure, and the effect of convection could lead to dynamic depletion of the vortex stretching term. Finally we present a new class of solutions to the 3D Euler and Navier-Stokes equations that could lead to a strong nonlinear alignment in the vortex stretching term and have the potential to develop a finite time vortex sheet singularity. However, the Kelvin-Helmholtz instability of the fluid flow eventually destroys such nonlinear alignment and lead to the development of turbulence instead of forming a finite time singularity.

Thomas Yizhao Hou

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Thomas Yizhao Hou is the Charles Lee Powell professor of Applied and Computational Mathematics at Caltech. He is one of the leading experts in vortex dynamics and multiscale problems. His research interests are centered around developing analytical tools and effective numerical methods for vortex dynamics, interfacial flows, and multiscale problems. He received his Ph.D. from UCLA in 1987, and joined the Courant Institute as a faculty member in 1989. He moved to Caltech in 1993 and was named the Charles Lee Powell Professor in 2004. Dr. Hou has received a number of honors and awards, including Member of American Academy of Art and Sciences in 2011, a member of the inaugural class of SIAM Fellows in 2009, the Computational and Applied Sciences Award from USACM in 2005, the Morningside Gold Medal in Applied Mathematics in 2004, the SIAM Wilkinson Prize in Numerical Analysis and Scientific Computing in 2001, the Frenkiel Award from the Division of Fluid Mechanics of APS in 1998, the Feng Kang Prize in Scientific Computing in 1997, a Sloan Fellow from 1990 to 1992. He was also the founding Editor-in-Chief of the SIAM Journal on Multiscale Modeling and Simulation from 2002 to 2007.

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This lecture is given in honor of Dr. Theodore Y. Wu, Professor of Engineering Science, Emeritus, a faculty member of Caltech from 1952. He has made pioneering contributions to naval hydrodynamics and architecture, fluid mechanics and stability theory, nonlinear evolution phenomena, fish swimming and bird flight, microorganism locomotion, geo- and bio-dynamics, mathematics and mathematical physics..

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