OFFICE OF NAVAL RESEARCH
FINAL REPORT
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS/STUDENTS REPORT

for

GRANT: N00014-9510444

PR Number 96PR03405

Scalings in Homogeneous and Inhomogeneous Turbulence

Zhen-Su She, Principal Investigator

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December 20, 1997

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PR Number:	96PR03405
Grant Number:	N00014-9510444
Grant Title:	Scalings in Homogeneous and Inhomogenous Turbulence
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a. Number of papers submitted to referred journals, but not yet published: **3**

- She, Z.-S. & Leveque, E., *Invariance Principle and Hierarchical Structures in Turbulence* Phys. Rev. Lett., submitted (1997).
- Liu, Li & She, Z.-S. *Scaling Laws in High Reynolds Number Liquid Helium Turbulence* Phys. Fluid, submitted (1997).
- Yoon, J.-M. & She, Z.-S. *Hierarchical Structures in Spatio-temporal Chaos* Phys. Rev. E., submitted (1997).

b. Number of papers published in referred journal: **3**

Published Papers in Referred Journals

- Leveque, E. & She, Z.-S., *Viscous Effects on Inertial Range Scalings in a Dynamical Model of Turbulence*, Phys. Rev. Lett., **75**, 2690 (1995).
- Cao, N., Chen, S. & She, Z.-S., *Scaling and Relative Scaling in Navier-Stokes Turbulence*, Phys. Rev. Lett. **76**, 3711 (1996).
- Leveque, E. & She, Z.-S., *Cascade Structures and Scaling Exponents in a Dynamical Model of Turbulence: Measurements and Comparison*, Phys. Rev. E., **55** (3), 2789 (1997).

c. Number of books or chapters submitted, but not yet published: **1**

- She, Z.-S., *Non-equilibrium Dynamics of Turbulent Fluctu-*

ations, Proceeding of 12th Nishinomiya Symposium on "Dynamic Organizations", will appear in Prog. Mod. Phys. (Japan) (1998).

d. Number of books or chapters published: 1

• She, Z.-S., *Scaling Laws and Hierarchical Structures in Turbulence*, Lecture Notes in Physics, Springer-Verlag (1997).

e. Number of printed technical reports/non-referred papers: 0

f. Number of patent filed: 0

g. Number of patent granted: 0

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- h. Number of invited presentations: 16

Invited Presentations

∘ Z.-S. She, "Hierarchical Structures and Scalings in Turbulence", Gordon Conference on "Fractals", NH, June 1996.
∘ Z.-S. She, "A Simple Scaling Model of Turbulence", at the International Workshop on "Turbulence in Ultrahigh Reynolds Number Flows", NY, June 1996.
∘ Z.-S. She, "On a Scaling Theory of Turbulence", at the '96 Symposium on Computational Physics, China, June 1996.
∘ Z.-S. She, "Analysis of Statistical Errors for Numerical PDE", at the '96 Symposium on "Numeircal PDE", China, July 1996.
∘ Z.-S. She, "Geometrical Structures and Statistics of Turbulence", at the workshop on "Vortex Dynamics and Turbulence", China, July 1996.
∘ Z.-S. She, "Structures and Scalings in Turbulence", at the workshop on "Turbulence Modeling and Vortex Dynamics, Turkey, September 1996.
∘ Z.-S. She, "Simplicity in Turbulence", at the workshop on "Turbulence Modeling and Vortex Dynamics, Turkey, September 1996.
∘ Z.-S. She, "A New Symmetry in Turbulence", at the International Workshop on "Dynamical Models of Turbulence", Observatoire de Nice (France), December 1996.
∘ Z.-S. She, "A New Scaling Theory of Turbulence", Special Invited Lecture at the National Turbulence Workshop (China),

Wuhan (China), May 1997.

∘ Z.-S. She, "Inertial Range Dynamics of Turbulence", A series of four lectures at the Summer School on "Turbulence", Beijing University (China), June 1997.

∘ Z.-S. She, "Hierarchical Symmtry in Turbulence", Invited talk at the IMS/ASA Annual Meeting, Anaheim, California, August 1997.

∘ Z.-S. She, "Invariance Principle and Hierarchical Structures in Turbulence", Invited talk at the 12th Nishinomiya Symposium on the "Dynamics Orgonization" (Japan), November 1997.

∘ Z.-S. She, "Nonlinear Fluctuation Dynamics of Turbulence", Invited talk at the workshop "Nonlinear Phenomenology", Kyoto University (Japan), November 1997.

∘ Z.-S. She, "A New Scaling Model of Turbulence", at the Colloqium at UC San Diego, Mech. Eng. Dept., Oct. 1995.

∘ Z.-S. She, "Structures and Scalings in Turbulence", at the Colloqium at UC Los Angeles, Atmosph. Sci. Dept., Nov. 1995.

∘ Z.-S. She, "On the Development of Scaling Theory of Turbulence", at the Colloqium at Univ. Arizona, Physics Dept., Nov. 1995.

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- i. Number of submitted presentations: 0

- j. Honors/Awards/Prizes for contract/grant employees: 0

- k. Total number of Full-time equivalent Graduate Students and Post-Doctoral associates supported during this period, under this R&T; project number: 2

    - Graduate Students: 2
    - Post-Doctoral Associates: 0.2
    - including the number of
        - Female Graduate Students; 1
        - Asian Graduate Students: 1

- l. Other funding:

Sloan Foundation Research Fellowship, $8,000. Total of $30,000 over three years. This fund mostly supports international travels to scientific meetings.

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FINAL REPORT
(PART II)

a. P. I.: Zhen-Su She

b. Phone Number: (310) 8258576

c. Program Officer: Michael F. Shlesinger

d. Program Objective:

Understand the fundamental processes which leads to the generation of small-scale fluctuations. Describe the scaling properties of turbulence based on features of fluid structures. Develop theories of turbulence for universal scaling laws and for applications

e. Significant Results:

- Using direct numerical simulations, we show clear evidence for the scaling deviation from Kolmogorov law for all structure functions in the Navier-Stokes flow
- We show that the She-Leveque model give accurate prdictions about the scaling exponents for the NS flow as well as for other dynamical system of energy cascade.
- We show that the high Reynolds number liquid Helium turbulent flows are also characterized by a hierarchy of structures (S-L model), but with slightly different

leading singularity from homogeneous open turbulent flows

- We show that spatially extended chaotic system is also characterized by a hierarchy of structures predicted by the She-Leveque model
- We develop a "special relativity" theory for the study of the multiscaling field of turbulence. This theory postulates the existence of an invariance property for any generic scaling field with finite fluctuation range, and explain therefore the success of the She-Leveque model for a large variety of systems