Preface

This section of the journal contains papers stemming from a workshop, "Progress in Statistical Hydrodynamics," held in Santa Fe, New Mexico on March 25–29, 2002, sponsored by the Center for Nonlinear Studies, Theoretical Division, Material Science Division, and Turbulence Working Group at the Los Alamos National Laboratory.

As a problem in statistical physics, turbulence is widely recognized as a challenging and difficult area of research. Fluids at high Reynolds numbers are strongly nonlinear and there is no small parameter that allows a perturbative or asymptotic approximation. Turbulence is also strongly dissipative with statistics far from thermal equilibrium and Gibbsian ensemble methods simply do not apply. These difficulties have sometimes lent an aura of impregnability to the field, which was dubbed by Richard Feynman as the "last unsolved problem of classical physics." It is often stated—mainly by those *outside* the field—that little progress has been made since the breakthroughs of the 1940's by Kolmogorov, Onsager, Heisenberg, and von Weiszäcker.

This reputation as an especially intractable, even deadly, area of research is undeserved on several grounds. First, it is clear to those of us working actively on the subject that there has been significant progress during the past few decades in experiment, simulation, and theory applied to turbulence. Second, the difficulties encountered in research on turbulence are no longer so unique or so isolated as they may once have appeared,but now recur in many problems at the forefront of statistical physics of condensed matter. Strongly-correlated electron systems, e.g., in high-temperature and heavy-fermion superconductors, are also a problem where non-perturbative techniques are required: in the physically-appropriate strong interaction regimes, many-body perturbation techniques are not applicable. Likewise, glassy and disordered systems are generally far from thermal equilibrium, because of their long relaxation times. For such systems also, conventional results for Gibbsian ensembles, such as fluctuation-dissipation theorems, break down.

It therefore seemed timely to organize a workshop that would enhance communication between researchers in turbulence and those in other challenging areas of statistical physics, to the benefit of both. The aim of the workshop was to bring some fresh perspectives and ideas to the turbulence field and to facilitate discussion of the latest progress in statistical hydrodynamics with the rest of the statistical physics community. In addition to experts and specialists in selected areas of turbulence, leaders in related topics in statistical physics were invited. The workshop was structured in a somewhat unusual fashion. It was organized into approximately ten half-day sessions of invited talks on a particular subtopic in statistical hydrodynamics. The major areas covered were scalar turbulence, wave turbulence, turbulence experiments, Navier–Stokes turbulence, Burgers equation, MHD and other complex turbulence, direct numerical simulations, and large-eddy simulations. The sessions were chaired by one of the invited statistical mechanics provocateurs who then led a following round-table discussion of the subject. The session opened with a survey talk by an eminent specialist reviewer who introduced the subject by explaining briefly the major approaches, results and perspectives within the subject and also by putting the subject in the general context of statistical hydrodynamics.

We believe that this novel format was quite successful and many participants, both turbulence workers and outside experts, indicated that they enjoyed the experience. The program of the meeting, which is published following this preface, shows the wide range of topics considered. In each of the areas there were exciting new developments. At the risk of being selective, we will mention the many really beautiful new experiments: turbulence in low temperature helium fluids, measurement of particle acceleration statistics, holographic PIV measurements of turbulent structure, realizations of two-dimensional turbulence, and experiments revealing chaotic instability and mixing in dilute polymer solutions. There were also remarkable theoretical developments discussed, e.g., analytical results on passive-scalar and Burgers turbulences based on new Lagrangian understanding of fluid particle separation statistics and progress in modeling of turbulence leading to improvements of large eddy simulation strategies. We believe that all participants left having learned something new, and, we hope, with fresh ideas that will stimulate progress in turbulence and other related fields.

We wish to thank Joel Lebowitz and *The Journal of Statistical Physics* for kindly agreeing to act as host to the conference proceedings. We also acknowledge the outstanding personal and organizational support of Rod Garcia and the staff of the Los Alamos Center for Nonlinear Studies. Their contributions in hosting this international workshop were crucial to the

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Misha Chertkov, Bob Ecke, Gregory Eyink, and Darryl Holm

SCIENTIFIC PROGRAM OF THE WORKSHOP

Monday, Mar 25, 2002
8:00am Registration Opens
9:00–9:15 Welcome Hans Frauenfelder (CNLS director)
Scalar Turbulence. Chair: D. Fisher (Harvard)
9:15–10:00 G. Falkovich (Weizmann) Review "Passive, active, and emancipated scalars"
10:00–10:35 P. Constantin (Chicago)
Break 10:35–10:50
10:50–11:25 A. Kupiainen (Helsinki) "Lagrangian dispersion in gaussian self-similair velocities"
11:25–11:45 E. Balkovsky (Rutgers) (20 min) "Instanton approach in scalar turbulence"
11:45–12:05 A. Fouxon (Weizmann) (20 min) "Collision rate of water droplets in a cloud"
Lunch Break 12:05–2:00pm
2:00–3:00 Discussions
Wave Turbulence. Chair: J. Cardy (Oxford)
3:00–3:45 V. Zakharov (Tucson) Review "New results in weak turbulence"
Break 3:45–4:00
4:00–4:35 S. Putterman (UCLA) "Is wave turbulence as challenging as vortex turbulence?"
4:35–5:10 W. Goldburg (Pittsburg) "Turbulence on a free surface"
5:10–5:30 O. Zaboronskii (Warwick) (20 min) "On intermittency in stochastic aggregation"
5:30–6:10 Discussions

Tuesday, Mar 26, 2002
New Perspectives in Turbulence Experiment. Chair: R. Ecke (LANL)
9:00–9:45 K. Sreenivasan (Maryland Yale) Review "The impact of using low temperature fluids on classical turbulence research"
9:45–10:20 E. Bodenschatz (Cornell) "Acceleration measurements in turbulence with and without polymers"

10:20–10:55 J. Katz (Johns Hopkins) "Experimental techniques in turbulence measurements: Recent advances and future challenges"

Break 10:55–11:10

11:10–11:45 H. Swinney (Austin) "Scaling in 2D and 3D turbulence in a rotating annulus"

11:45–12:20 P. Tabeling (Paris) "Experiments on turbulent dispersion"

Lunch Break 12:20–2:00pm

2:00–2:35 V. Steinberg (Weizmann) "Elastic turbulence and polymer stretching in polymer solution flows"

2:35–2:55 A. Groisman (CalTech) (20 min) "Elastic turbulence in polymer solutions at low Reynolds numbers—a realization of the Batchelor regime of mixing"

2:55–3:30 Z. Warhaft (Cornell) "Anisotropy of inertial and dissipation-scale statistics in high Reynolds number turbulence"

3:30–3:50 B. Tao (Johns Hopkins) (20 min) "Characterizing the structures of turbulence by using holographic PIV measurements"

Break 3:50–4:05

4:05–4:40 J.-F. Pinton (Lyon) "Lagrangian velocity measurement in fully developed turbulence"

4:40–5:15 M. Rivera (LANL) "The effects of external drag on the direct cascade of two dimensional turbulence"

5:15–6:15 Discussions

7:00 Workshop Banquet Radisson Inn restaurant

Wednesday, Mar 27, 2002

Navier–Stokes Turbulence. Chair: P. Hohenberg (Yale)

9:00–9:45 U. Frisch (Nice) "A review of Navier–Stokes turbulence with emphasis on multifractality and finite-time singularities: What is the evidence and do we need them?"

9:45–10:05 R. Kraichnan (Santa Fe) "Remarks on cascade and the growth of intermittency"

10:05–10:40 B. Shraiman (Lucent) "Lagrangian tetrads and statistical geometry of turbulence"

Break 10:40–10:55

10:55–11:30 A. Pumir (Nice) "The Lagrangian view of energy transfer in turbulent flows"

11:30–12:05 C. Meneveau (Johns Hopkins) "Dynamics and statistics of velocity gradients in spatially filtered turbulence"

Lunch Break 12:05–2:00pm

2:00–2:35 R. Kerr (Tucson) "A vorticity surge and helicity"

2:35–3:10 M. Nelkin (NYU) "Tuning intermittency, or how can we slightly change the Navier–Stokes equations to make Kolmogorov 1941 exact?"

3:10–4:10 Discussions
Break 4:10–4:25
Shell Models. Chair: D. Stein (Tucson)
4:25–5:10 L. Biferale (Rome) Review "Shell models for turbulence"
5:10–5:45 I. Procaccia (Weizmann) "Statistically preserved structures in passive and active scalar advection: Shell models, operators, and zero modes"
5:45–6:05 Q. Chen (Johns Hopkins) (20 min) "A Gibbs hypotesis in turbulence"
6:05–6:45 Discussions

Thursday, Mar 28, 2002
Burgulence. Chair: T. Spencer (IAS)
9:00–9:45 K. Khanin (Cambridge) Review "Global structure of shocks in Burgers turbulence"
9:45–10:05 E. Vanden-Eijnden (Courant) (20 min) "Statistical theory for the stochastic Burgers equation in the inviscid limit"
10:05–10:25 J. Beck (Nice) (20 min) "Hyperbolicity and statistics in forced Burgers turbulence"
10:25–11:00 I. Kolokolov (Novosibirsk) "Spatio-temporal intermittency in thermally activated Burgers turbulence"
Break 11:00–11:15
11:15–11:50 E. Ben-Naim (LANL) "Granular gases: Scaling, multiscaling, nontrivial exponents, and Burgers' shocks"
11:50–12:25 Discussions
Lunch Break 12:35–2:15pm
MHD and Other Complex Turbulences. Chair: G. Eyink (Tucson)
2:15–3:00 A. Pouquet (NCAR) Review "Some issues in geophysical turbulence"
3:00–3:35 M. Vergassola (Nice) "Kinematic dynamo theory"
3:35–3:55 S. Boldyrev (UCSB) (20 min) "Turbulent structure of star-forming molecular clouds"
Break 3:55–4:10
4:10–4:45 V. Lebedev (Moscow) "Turbulence of polymer solutions"
4:45–5:20 M. Hastings (LANL) DLA Turbulence
5:20–6:20 Discussions

Friday, Mar 29, 2002
New Results from Direct Numerical Simulations. Chair: A. Patashinski (NorthWestern)
9:00–9:45 S. Chen (Johns Hopkins) Review "Direct numerical simulation of isotropic turbulence"

9:45–10:20 T. Gotoh (Nagoya) "Inertial range statistics in homogeneous steady turbulence by DNS"

10:20–10:40 A. Lanotte (CNR/ISAC, Italy) "Direct numerical simulations of anisotropic turbulence"

Break 10:40–11:05

11:05–11:20 T. Matsumoto (Kyoto) 20 min "A numerical search for a singularity of 2D inviscid Boussinesq approximation equation"

11:25–12:05 Discussions

Lunch Break 12:05–2:00pm

New Ideas in LES. Chair: L. Kadanoff (Chicago)

2:00–2:45 J. A. Domaradzki (USC) Review "Modern methods for large eddy simulations of turbulent flows"

2:45–3:20 E. Titi (UC Irvine) "The Navier–Stokes-alpha model and Turbulence Theory"

Break 3:20–3:35

3:35–4:10 T. Clark (LANL) "Self-similarity of the turbulent Rayleigh–Taylor mixing layer"

4:10–4:30 B. Kosovic (Boulder) 20 min "A two-parameter spectral turbulence closure"

4:30–5:20 Discussions