Turbulence and Nonlinear Physics in the 21st Century: The Pioneering Science of Robert H. Kraichnan

May 11-12, 2009

La Posada de Santa Fe Resort and Spa

Santa Fe, New Mexico

Conference Schedule

Monday, May 11th

Opening Remarks
8:00 AM – 8:10 AM

Conference Sessions
8:10 AM – 5:15 PM

Poster Session / Reception
5:30 PM – 6:30 PM

Dinner Banquet
7:00 PM – 9:00 PM

Tuesday, May 12th

Conference Sessions
8:30 AM – 4:50 PM

Conference Closing
4:50 PM – 5:00 PM

Conference Organizers:
Robert Ecke (LANL), Gregory Eyink (JHU), Shiyi Chen (JHU), Misha Chertkov (LANL), and Katepalli Sreenivasan (ICTP/U Maryland)

Center for Nonlinear Studies

LA-UR-09-02383

This event is classified as:
Open to the Public with Registration

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Monday, May 11 2009

8:00-8:10 am	Welcome – Robert Ecke (Los Alamos National Laboratory)

Morning Session - Chair Robert Ecke

8:10-9:00 am	**Katepalli Sreenivasan** (ICTP/University of Maryland) *A Perspective on Kraichnan's Work and Person*
9:00-9:50 am	**Jorge Kurchan** (École Supérieure de Physique et de Chimie Industrielles) *Correlation Length for Amorphous Systems*
9:50-10:20 am	COFFEE BREAK
10:20-11:10 am	**Gordon Baym** (University of Illinois – Urbana-Champaign) *Quantum Many-Body Theory*
11:10-12:00 pm	**Gregory Eyink** (Johns Hopkins University) *DIA and the Random-Coupling Model: Past, Present, Future*
12:00-1:30 pm	LUNCH

Afternoon Session - Chair Gregory Eyink

1:30-2:20 pm	**Harvey Rose** (Los Alamos National Laboratory) *Nonequilibrium Quantum Field Theory: More Work Needed*
2:20-3:10 pm	**Guido Boffetta** (University of Torino) *Statistics of Two-Dimensional Navier-Stokes Turbulence*
3:10-4:00 pm	COFFEE BREAK
4:00-4:50 pm	**Vladimir Zakharov** (University of Arizona) *Inverse and Direct Cascades in Wind-Driven Sea*
4:50-5:15 pm	**David Montgomery** (Dartmouth University) *Spontaneous Spin-up: A Possible Explanation*
5:30-6:30 pm	POSTER SESSION with wine & cheese
7:00-9:00 pm	DINNER BANQUET (Chair - Shiyi Chen)

A Perspective on Kraichnan's Work and Person

K.R. Sreenivasan
International Centre for Theoretical Physics / University of Maryland

R.H. Kraichnan appears as quite quaint from today's perspective of big science, multi-scientist grants and networks of large collaborations. Except for a few early years of his scientific career, Bob was not attached substantially to any institution and supported himself through research grants awarded to him. He seemed to have derived the inspiration for his work essentially from within. Bob's work on areas outside fluid turbulence, though substantial, was essentially ignored because he chose not to be in the mainstream. His work in fluid turbulence was unappreciated and sometimes misrepresented, partly for the same reason, and partly because he was well ahead of his time. Indeed, his work lay dormant for many years, known only among the initiated few. However, Bob's work showed resurgence some twenty years ago when the field became increasingly populated by a new generation that took less notice of the institutional memory. The overdue adulation for Bob's work and corresponding honors followed. The talk attempts a perspective on Bob's contributions in the context of his times.

Correlation Length for Amorphous Systems

Jorge Kurchan
École Supérieure de Physique et de Chimie Industrielles

There comes a moment in almost every introductory talk on glasses when two pictures are projected showing a liquid and a glass configuration (blown up so that their densities appear to be identical), and the speaker defies the audience to tell which is which -- the implication being that it is impossible to do so. I will argue that, perhaps surprisingly, one can rise to this challenge successfully.

Self-Consistent Approximations and the Stochastic Dynamics of Non-Linear Many-Body Systems

Gordon Baym
University of Illinois

At the time Leo Kadanoff and I were developing self-consistent approximations to many-body systems via diagrammatic methods for Green's functions,[1] Bob Kraichnan was independently tackling the problem from a very different point of view, that of exact solutions to model Hamiltonians with an infinite number of stochastic parameters.[2] This talk will trace the development of these closely related approaches.

[1] G. Baym and L. Kadanoff, Phys. Rev. 124, 287-299 (1961); G. Baym, Phys. Rev. 127, 1391-1410 (1962).

[2] R. Kraichnan, J. Math. Phys. 2, 124 (1961).

DIA and the Random-Coupling Model: Past, Present, Future

Gregory Eyink
Johns Hopkins University

There is probably no scientific contribution more closely associated with the name of Robert Kraichnan in the general physics community than his "Direct Interaction Approximation" (DIA) closure. Less commonly known outside the turbulence field is his "Random Coupling Model" (1958, 1961), which realizes the DIA closure as the exact solution of an N-replica model coupled with quenched random coefficients, in the limit N, going to infinity. My talk will review some of the brilliant successes and, also, brilliant failures, of the RCM and the DIA, including its Lagrangian reformulations "LHDIA" and "ALHDIA". I'll discuss further developments of Kraichnan's ideas that are widely employed today by engineers and physicists (often without realizing Kraichnan's critical role). Attention will be given particularly to developments in quantum chromodynamics (QCD) and quantum gravity in the last 25 years, very closely related to Kraichnan's remarkable work on the RCM in the late 1950's.

Nonequilibrium Quantum Field Theory: More Work Needed

Harvey A. Rose
Los Alamos National Laboratory, Physics of Condensed Matter and Complex Systems

Kraichnan's 1962 paper on nonequilibrium quantum field theory arrived at a time when the already challenging endeavor to determine the time dependence of correlation functions in thermal equilibrium was the focus of much research. While the quantum Boltzmann equation, which may be viewed as a perturbative solution to Kraichnan's theory, has been applied to nonequilibrium BEC formation dynamics, the broader implications of his theory have by comparison not received much attention. Application of his theory to related classical systems, and possible modification for application to BEC formation, will be discussed.

Statistics of Two-Dimensional Navier-Stokes Turbulence

Guido Boffetta
University of Torino

The existence of a double cascade in two-dimensional turbulences is one of the most interesting phenomena in fluid dynamics. The double cascade were predicted theoretically by Robert Kraichnan in a remarkable paper in 1967, as a consequence of the two conservation laws in the inviscid limit. After 40 years of experimental and numerical investigations, we are finally able to verify quantitatively Kraichnan's predictions for the double cascade. This is not the end of the story, as two-dimensional turbulence is still source of new research and discoveries, such as conformal invariance in the inverse cascade.

Inverse and Direct Cascades in Wind-Driven Sea

V.E. Zakharov
University of Arizona

Everybody knows that when wind starts blowing over the sea, in the first moment relatively short but steep waves are excited. Gradually an average wavelength increases until it reaches its characteristic value $\lambda_{crit} = 2\pi u^2/g$; u - wind velocity. In certain situations (in the zone of the trade winds), the leading wavelength can exceed this critical value in 2-3 times. This phenomenon, which is called in physical oceanography as frequency downshift, is nothing but an analog of the inverse cascade in 2-D hydrodynamics, discovered by Robert Kraichnan. It takes place due to existence of the additional motion constant: the wave action. This motion constant is approximate; it is preserved only at relatively small value of average steepness, which is an overall measure of the wave nonlinearity.

Another analog of the downshift is Bose-condensation, however there is a serious difference between these two phenomena. When a Bose-particle moves to *k* 0, the nonlinearity is increased, but when the gravity wave endures downshift, the nonlinearity measured in terms of steepness is decreased. The most disastrous waves, forming "the perfect storm", are much more linear than the waves in a spring pool. During the downshift process the waves loose their energy; that leads to high wave numbers, forming the direct cascade of energy. In the talk are presented recent results obtained by analytical study of the sea-wave spectra and by their numerical simulation. These results are compared with the data accumulated in physical oceanography in the last five decades.

We will see how inverse and direct cascades play and interplay.

Spontaneous Spin-Up: A Possible Explanation

David C. Montgomery
Physics & Astronomy Dept., Dartmouth College

An explanation is suggested for “spontaneous spin-up,” one of the more unusual turbulent phenomena to be identified in recent years [1,2]. A two-dimensional turbulent Navier-Stokes fluid inside a rigid, square, no-slip boundary will spontaneously generate long-lived angular momentum, despite the vanishing of total integrated vorticity that is mandated by the boundary conditions. The assumption of the rigidity of the container is equivalent to an assumption that it is infinitely massive, so that it may exchange momentum or angular momentum with the fluid without itself moving. The effect is well studied computationally and has been demonstrated in the laboratory. Here, a theoretical framework in which it may be understood is suggested.

[1] H.J.H.Clercx, S.R.Maassen, and G.J.F.v.Heijst, PRL 80, 5129 (1998).
[2] G.J.F.v.Heijst, H.J.H.Clercx, and D.Molenaar, JFM 554, 411 (2006).

Tuesday, May 12, 2009

Morning Session - Chair Katepalli Sreenivasan

8:30-9:10 am **Annick Pouquet** (National Center for Atmospheric Research)
Turbulence in the Presence of Magnetic Fields

9:10-10:00 am **Guenter Ahlers** (University of California at Santa Barbara)
Search for the "Kraichnan state" in Turbulent Rayleigh-Benard Convection

10:00-10:30 am COFFEE BREAK

10:30-11:20 am **Gregory Falkovich** (Weizmann Institute)
Passive Scalar Turbulence

11:20-12:10 am **Stanley Deser** (Brandeis University)
Classical & Quantum Gravity

12:10-1:50 pm LUNCH

Afternoon Session - Chair: Misha Chertkov

1:50-2:40 pm **Misha Chertkov** (Los Alamos National Laboratory)
Lagrangian Turbulence

2:40-3:30 pm **Konstantin Khanin** (University of Toronto)
Burgers Equation in Turbulence and Beyond

3:30-4:00 pm COFFEE BREAK

4:00-4:50 pm **Charles Bennett** (IBM)
Quantum Information, Measurement, and the Birth and Death of Complexity

Turbulence in the Presence of Magnetic Fields

A. Pouquet
National Center for Atmospheric Research

Robert Kraichnan realized early on that the theories and concepts he developed for fluid turbulence were applicable, mutatis mutandis, to the coupling with a magnetic field in the magnetohydrodyamics (MHD) approach valid for velocities small compared to the speed of light. For example, the weak magnetic field case of a passive vector can be treated in analogous ways to that of the passive scalar. He thus considered the diffusion of (weak) magnetic fields by non-helical and helical turbulence, the instability of such a weak field in the so-called alpha effect due to helical small-scale motions, and the energy spectrum in MHD in which Alfvén waves play an important role.

In this talk, I shall comment on the influence of his seminal work in MHD and I will also mention some of the further developments that are taking place presently, in particular concerning the breakdown of universality in MHD turbulence under several effects. In so doing, I will mention the results of high-resolution numerical simulations up to grids of 15363 points, and more implementing symmetries in special cases.

Search for the "Kraichnan State" in Turbulent Rayleigh-Bénard Convection

G. Ahlers[1], D. Funfschilling[2], E. Bodenschatz[3].
[1]UCSB, [2]CNRS NANCY, [3]MPI for Dynamics and Self-org. Göttingen

Measurements of the Nusselt number n over the Rayleigh-number range $10^9 < R_a < 4\ 10^{14}$ for He (Prandtl number P_r=0.67), N_2 (P_r=0.785), and SF_6 (P_r=0.785 to 0.82) will be presented. They were made at pressures up to 15 bars and near-ambient temperatures for a cylindrical sample of height L=2.2 m and diameter D = 1.1 m in a new High-Pressure Convection Facility (HPCF) constructed at the Max Planck Institute for Dynamics and Self-Organization in Göttingen, Germany. Unfortunately the data have not yet shown the transition to the "ultimate regime" discussed by Kraichnan[1].

[1] R.H. Kraichnan, Phys. Fluids **5**, 1374 (1962).

Work at UCSB supported by NSF Grant DMR07-02111.

Passive Scalar Turbulence

Gregory Falkovich
Weizmann Institute

I will review the analytic theory of passive scalar turbulence and describe how the Kraichnan model [1,3] turned into an Ising model of turbulence. I will briefly describe Kraichnan's approach to mixing in spatially smooth flows [2] and his profound that the flow non-smoothness is crucial for the breakdown of scale invariance [3]. I will then describe recent advances in analytic theory of mixing in compressible flows and in finite domains, and an ongoing work on line statistics in random flows.

At the end, I will discuss future prospects.

References:

1. RH Kraichnan, Small-scale structure of a scalar field convected by turbulence, Phys. Fluids 11: 945-953 (1968).
2. RH Kraichnan, Convection of a passive scalar by a quasi-uniform random straining field, J. Fluid Mech. 64: 737-762 (1974).
3. RH Kraichnan, Anomalous scaling of a randomly advected passive scalar, Phys. Rev. Lett. 72: 1016-1019 (1994)

DE-GEOMETRIZING GENERAL RELATIVITY: What had Kraichnan Wrought?

Stanley Deser
Brandeis University

General Relativity was a sleepy backwater of applied mathematics when Kraichnan wrote his historic, but still almost unknown, paper in the late 40s, aiming to give GR a physical basis. I will discuss his idea, its historical evolution and final perfection, at a non-specialist level.

Lagrangian Turbulence

Misha Chertkov
Los Alamos National Laboratory

I will start this talk reviewing R. Kraichnan papers from '64, '66 and '70 on Lagrangian correlations and particle dispersion in models of turbulence, and also mentioning related works of others, e.g. of Belinicher-L'vov, Migdal and Polyakov on Eulerian and Lagrangian closures. I will then explain the Lagrangian tetrad model of turbulence we (Pumir, Shraiman and the speaker) developed more recently, and conclude emphasizing future opportunities in this field, and more generally in statistical hydrodynamics and non-equilibrium statistical physics.

Burgers Equation in Turbulence and Beyond

Konstantin Khanin
University of Toronto

We shall discuss Burgers equation in relation with many different physical and mathematical problems: turbulence, statistical mechanics, cosmology, hyperbolic conservation laws, Aubry-Mather theory etc.

We shall also present new results on dynamics of Lagrangian particles on the shock manifolds, and its connection to the optimal transport problem.

Quantum Information, Measurement, and the Birth and Death of Complexity

Charles Bennett
IBM

Quantum information theory provides the most coherent explanation of the emergence and obliteration of correlations, even in macroscopic systems exhibiting few traditional quantum hallmarks. Turbulence is a familiar example of a process generating not only correlations but also awe-inspiring complexity, and it is natural to wonder where this complexity comes from and how long it lasts. We sketch the basics of quantum information/computation theory, emphasizing the central role of entanglement, a perfect and private form of correlation without classical analog, then attempt to apply the theory to understand the birth and death of complexity, appropriately defined.

Participant List - Turbulence and Nonlinear Physics in the 21st Century

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