Scope

With exciting progress occurring now, involving crucial interaction between mathematicians and theoretical physicists, in the many-body theory of (to date, mainly dilute) inhomogeneous superfluids, it is proposed to bring together some 30 scientists in July 2007, for a period of 3 weeks, at the Centro De Giorgi of Scuola Normale Superiore di Pisa.

Topics

A. Superfluid turbulence and vortex entanglement
B. Inhomogenous superconductivity

(A) *Superfluid turbulence and vortex entanglement*

The area has been singled out as one where very recent progress in the quantitative understanding of superfluidity, Bose-Einstein condensation, and ultracold Fermi fluids shows promise for close and beneficial interplay with classical turbulence theory. Though parts of this latter field are well established through pioneering studies associated with the names of Kolmogorov (especially scaling properties), Onsager and Kraichman, to mention but three, much remains to be done by both mathematicians and theoretical physicists. The invited participants in this area have made major contributions, having intimate knowledge of classical turbulence and with many-body expertise which will enable them to combine this with additional features acquired in the area of superfluid turbulence. We cite just two of these features by way of illustration: (i) one has to deal with two interpenetrating sub-species: i.e. a frictionless superfluid and a viscous normal component, in relative concentrations that are temperature dependent; and (ii) the vorticity of the superfluid component is quantized in terms of the so-called circulation quantum.

It is relevant to add here that if both normal and superfluid components are in motion, the turbulent state then bears a closer resemblance to the turbulence of classical viscous liquids.

As a final point to conclude this sub-section, it may well be that current studies of nonlinear Schrödinger equations (*e.g.* the so-called Gross-Pitaevskii equation for a dilute inhomogeneous Bose-Einstein condensate) and of Vlasov-Landau-type equations for the one-body distribution functions in quantum fluids will provide insight more readily (by both analytical and numerical means) than can be gained by starting from a classical viewpoint embodied in the Navier-Stokes equation. But the Gross-Pitaevskii equation is structurally affine to the Navier-Stokes equation, so that consolidated techniques of solution may be transferable between them.

(B) *Inhomogeneous superconductivity*

The ideas from which this area has quite recently emerged can be traced back at least some 40 years. Then, and quite independently, Larkin and Ovchinnikov (LO) and Fulde and Ferrell (FF) proposed on purely theoretical grounds what amounted to a new type of superconductivity, now often referred to as the LOFF phase.

This phase of inhomogeneous superconductivity can be usefully viewed as a proposed generalization of the Bardeen-Cooper-Schrieffer (BCS) state which is appropriate to describe many properties of elemental metallic superconductors. Whereas the basic building block of the BCS theory is the Cooper pair, where the two electrons have momenta equal in magnitude and opposite in direction, in the so-called LOFF phase a salient feature is that momenta do not add to zero. Then an almost immediate consequence of the LOFF proposal is that the energy gap, or order parameter, has a spatial variation.

The LOFF proposal, to our knowledge, has not yet been confirmed beyond reasonable doubt in condensed matter, but expectations are high that such a phase will come up in real materials in the foreseeable future. But what seems remarkable, and worthy of much fuller exploration, is that the same basic ideas of LOFF may also prove to play an important role in the future in nuclear physics and in the theory of some aspects of the properties of pulsars wliich are commonly identified with neutron stars.

Thus, we propose a second specific specialist group which will embrace the three themes stated above. We add some brief, and somewhat more technical, details of these fields immediately below.

(a) Condensed matter. In the condensed matter field, the observation of the LOFF phase (if indeed it proves to exist in any class of superconducting materials!) seems to necessitate the employment of type-II superconductors which should be essentially devoid of impurities. Organic superconductors seem a promising class of materials for many-body studies in this context. Because high-magnetic fields are needed, layered superconductors and magnetic fields parallel to the layers are deemed presently to offer fruitful possibilities and we propose this as one specific area to be explored.

(b) Nuclear physics. Here, neutron-proton pair correlations and the likelihood of n-p Cooper pair condensation are at present being studied in a number of different contexts, including the field of heavy-ion collisions. Another context relates to quark matter in neutron stars (see (c) below). Quite recently, the possibility of a spatially inhomogeneous condensate in asymmetric nuclear matter has been studied. We sense that further progress to be expected in this general area will allow exploitation in 2007 by the group of experts invited here.

(c) Astrophysics. Inhomogeneous superconductivity in the context of astrophysics could, it is presently conjectured by leading groups of theoretical physicists, be generated by the difference in quark chemical potentials brought about by weak interactions in the inner core of pulsars. This, it seems currently, might well afford a mechanism for explaining glitches in pulsars.

More generally, in concluding this survey, we presently believe that a valuable focus and indeed a common mathematical basis may well be provided by 2007 via effective Lagrangians, based on the mathematical background afforded by the renormalization group.

Organization

Organizing Committee

Prof. N. H. March, *Director*
Prof. M. P. Tosi, *Director*
Prof. G. G. N. Angilella, *Secretary*
Dr. M. Polini, *Secretary*

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Registration

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/inhomogeneous_superfluids

Venue

The workshop will take place in Pisa, Italy, at the Centro di Ricerca Matematica Ennio De Giorgi, Collegio Puteano.

The workshop will be directed by Emeritus Professor Norman H. March (Oxford University, Oxford, UK) and Professor Mario P. Tosi (Scuola Normale Superiore, Pisa, Italy).

Invited Speakers

C. F. Barenghi, University of Newcastle, UK
G. Baskaran, Inst. for Mathematical Sciences, India
M. A. Cazalilla, DIPC, Donostia, Spain
R. Fazio, SNS & SISSA, Pisa & Trieste, Italy
P. Fulde, Max-Planck Institute, Dresden, Germany
A. H. MacDonald, Univ. of Texas, Austin, USA
J. Mayers, Rutherford Appleton Lab., UK
A. J. Schofield, University of Birmingham, UK
A. Sedrakian, University of Tubingen, Germany
S. Succi, IAC-CNR, Italy
A. Sudbø, NTNU, Trondheim, Norway
A. A. Varlamov, INFM-CNR, Italy
W. F. Vinen, University of Birmingham, UK

Registration

There is no participation fee. Participants should cover their own travel and stay expenses. Please, contact Dr. Ilaria Gabbani (see address) for further information. Do register online on http://www.crm.sns.it/inhomogeneous_superfluids **not later than June 22nd, 2007**.

Scuola Normale Superiore di Pisa

Centro di Ricerca Matematica Ennio De Giorgi

International Workshop on

Many-body theory of inhomogeneous superfluids

Pisa, Italy
July 9 – 29, 2007

Final announcement