theoretical predictions and observations.

We now turn to the discussion of some similarities in mechanisms among the three subjects under discussion: galaxies, turbulence, and plasmas. In this extended abstract, we shall just list some of the relevant items.

1. As mentioned at the beginning, the basic equations in plasma physics (the Vlasov equations) are of the same nature as those for the study of stellar systems.

2. Both in the study of hydrodynamic stability and in the study of spiral waves in galaxies, the critical layer (or the corotation circle in the case of galaxies) plays an important role in the transfer of energy between the waves and the basic motion. Indeed, the behavior of wave trains and wave packets in this region, involving the phenomenon of over-reflection (or WASER) is of basic importance to a number of natural phenomena.

3. The WASER mechanism (wave amplification by stimulation of emission of radiation) is important for spiral wave patterns in galaxies, as well as in plasma dynamics and in the instability of supersonic shear layers. It includes the interaction of waves of positive and negative energy densities.

4. There is similarity (but there is also essential difference) between the density waves in galaxies and the Bernstein waves in magnetically contained plasmas. This is due to the similarity between the Coriolis force in the former case and the Lorentz force in the latter case. The law of inverse square holds in both cases.

5. Analogous mechanisms may also be found between the instability of ballooning modes in magnetically contained plasmas and the instability of Couette flow between rotating cylinders, with the inner cylinder rotating.

The fact that diverse scientific problems exhibit similar behavior is indeed the basis for the possibility to have them treated by similar mathematical concepts and methods. Indeed, by providing a unified mathematical approach to diverse scientific problems, one can hope to gain deeper understanding — e.g., on the matter of interaction of waves of positive and negative energy. This is indeed one of the principal roles of the applied mathematician.

SEDIMENTATION : A REVIEW OF DEVELOPMENTS IN A CLASSICAL PROBLEM

G.K. Batchelor
Department of Applied Mathematics and Theoretical Physics,
University of Cambridge.

The term 'sedimentation' conventionally refers to a large number of small particles falling under gravity through fluid which is otherwise at rest. Sedimentation is used often in chemical and biological laboratories, perhaps with an ultra-centrifuge giving an enhanced gravitational force, as a means of separating the particles and the fluid. It is also used widely in chemical industry and water engineering and mining for the same purpose of separation, and in chemical industry the related process of fluidization is exploited to achieve a high rate of mass or heat transfer between the particles and the fluid. In nature we see sedimentation of ash, dust and water droplets in the atmosphere, silt particles in the rivers and oceans, and fat globules in milk. A full understanding of the dynamical problems involved in sedimentation of small particles would consequently have considerable practical value. The total research effort over the years has been massive, but it has proved to be difficult to obtain quantitative theoretical results, mainly because we lack suitable methods of analysing the motion of many interacting particles. However, a variety of intriguing phenomena have been revealed and a qualitative understanding of most (but not all) of the relevant processes has been obtained.

The purpose of this lecture is to take stock of the developments in basic aspects of sedimentation of particles smaller than about 0.1mm in diameter, and to review, in fundamental terms, our present picture of the dynamical processes involved. Many of the developments are recent, and for those interested in sedimentation, and colloidal dispersions generally, this is a stimulating period. Research on colloidal dispersions is not a part of main-stream fluid mechanics, but specialists in fluid mechanics are now providing their own distinctive insights and expertise and are developing their own approach to the subject.

An indication of the contents and scope of the lecture is given by the following headings:

1. The distinction between local influences (from neighbouring particles) and global influences (from distant parts of the flow field) on the mean velocity of a particle.

2. The mean velocity of a particle in a statistically homogeneous dispersion in a container. Calculation of the mean velocity for a dilute monodisperse system; what determines the pair-distribution function in the case of larger particles for which Brownian diffusion is weak? Polydisperse systems. Relevance of these calculations for the Brownian diffusivity of particles.

3. The formation of streaming columns in a bidisperse system.

4. Dispersions with vertical variations of particle concentration. Concentration waves. Shock transitions in batch settling. The notion of particle stress. The contribution to particle diffusion due to fluctuations in the configuration of neighbouring particles. Growth of the small amplitude of a concentration wave due to particle inertia, and formation of 'bubbles' in fluidized beds.

5. Steady states with both sedimentation and bulk motion of the mixture. Examples: (a) a spherical cloud of particles falling through clear fluid (or a spherical region of clear fluid rising through the mixture); (b) settling beneath an inclined wall of a container and the Boycott effect.

COGNITION AND DESCRIPTION OF PATTERNS IN TURBULENT FLOWS

Hiroshi Sato
School of Engineering, University of Tokyo, Japan

I INTRODUCTION

In the past decade extensive experimental investigations have been made on ordered motions or patterns of fluctuation in turbulent flows. There are many interesting findings on the patterns but none of them are conclusive and convincing. There are several reasons for that. First of all most of the reported results are inclined to be subjective. For instance an author claims that he found eddies in a flow. In his picture circular streaks are seen but it is not clear if they are really eddies in a strict sense. It is extremely difficult to conclude the existence of an eddy in random fluctuations. Another difficulty lies in the quantitative description. Usually patterns are so vague that they can not be described with enough accuracy. Therefore, very often the discussions diverge and every experimenter keeps his own 'pet'.

In the present paper I discuss about the process of cognition of ordered motions and also about the method of describing them for communicating to public. In order to avoid the confusion I restrict my discussion only on patterns in the 'fully-developed' turbulent flow. In other words, I do not discuss patterns in the process of laminar-turbulent transition. Obviously, they are formed by the linear or nonlinear growth of periodic fluctuations before the turbulent flow is established. On the contrary, patterns in the fully developed turbulent flow are burried in random fluctuations and have no definite 'roots'.

II ACQUISITION OF DATA

The methods for acquiring informations out of a turbulent flow are classified in various ways:

1 Point Data and Field Data

More than 90 % of quantitative informations are acquired by hot-wire anemometers and laser-Doppler velocity meters. They provide accurate velocity data but only at one point in the flow. On the other hand, one-shot flow pictures give infinite amount of information about the whole flow field but they are hardly quantitative.

2 Eulerean Information and Lagrangean Information

What we acquire by hot wire or laser are Eulerean informations, namely, they illustrate the temporal change of velocity at a fixed point in the flow. These informations are not sufficient for constructing three-dimensional patterns which move around in the flow. The acquisition of Lagrangean informations is seriously wanted.

It is very difficult to find a pattern burried in random fluctuations by one-point data. If the flow field is periodic, we can repeat the measurement at each phase and construct a whole picture. But fully-developed turbulent flows have no periodicity. What we should do for acquiring more informations is to increase the number of hot wires and laser beams. If we can manage 20 hot wires in a flow without mutual interactions, we can obtain enough spatial resolution about ordered motions.

It has been pointed out that the pictures of flow fields are sometimes misleading. The reason is that the displacement of the tracer in the flow