Prof. K. R. Sreenivasan

University Professor, New York University

Prof. K.R. Sreenivasan is one of the most well-known scientists in the area of turbulence, intermittency, convection and quantum turbulence. He has received numerous awards and prizes in recognition of his scientific work, mostly in fluid mechanics, nonlinear and statistical physics, and service to scientific community. He is presently University Professor at New York University and also Senior Vice Provost. He has held visiting positions at the Indian Institute of Science, Caltech, Rockefeller University, Institute for Advanced Study at Princeton University and, as the Sir C.V. Raman Professor, at the Indian Academy of Sciences.

Cool Stuff at Cold Temperatures

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Superfluids flow without friction and possess other interesting properties. One of them is the formation of line vortices with diameters of the order of atomic dimensions. Their circulation is quantized. The vortices can form a random tangle whose flow properties resemble those of classical turbulence. The lecture explored some of these fascinating aspects without delving into technical specifications.

Prof. K.R. Sreenivasan gave an overview of 'Quantum Turbulence' starting with an interesting historical account of the discovery of superfluid Helium. Highlights of major discoveries were presented through a brief account of their originators. He developed the subject on a historical basis, connected recent developments to the classical theory of turbulence, and showed their resemblance to quantum turbulence---in terms of the energy spectrum, for example. There are, however, some fundamental differences. For example, the circulation in superfluids is quantized. The reconnection of these quantized vortices leads to several important differences from classical turbulence, such as in the nature of the tails of the probability density functions of velocity fluctuations. Prof. Sreenivasan's lab has been able to visualize for the first time, quantized vortices and has been able to track their motion by creating the right particles which stick to the vortices. He discussed some of these recent experimental results and proposed a possible statistical mechanical view for understanding the observed coarse-grained phenomena. One of the greatest puzzles in this field is to identify the effective viscosity that is quite critical for dissipation at small scales.

CONVERSATIONS

Excerpts from an interview with Prof. K.R. Sreenivasan by the NERD team

Your career interests include fluid dynamics, turbulence, complex fluids, cryogenic Helium and nonlinear dynamics. Please tell us in brief about your significant contributions to these fields.

I am primarily a fluid dynamicist. I often do things that are of some interest to physicists and mathematicians and influence their thinking. My interest in nonlinear dynamics and cryogenic helium came about through an interest in fluid dynamics. First, I worked on relaminarisation of turbulent flows, i.e., how to make a turbulent flow laminar. That was the main contribution in the first few years of my career, and it is of particular interest in aerodynamics and other applications. Turbulence increases drag, and has some adverse consequences, and that led me to the topic of turbulence control which is about how to control a turbulent flow and make it behave the way you want it to behave. And then I got interested in how substances can be mixed in a turbulent flow. It is like you take your coffee and put milk in it, and you want to mix the two together, by stirring it. Stirring enhances mixing. For instance, in combustion, fuel and air mix together and there you want a uniform mixture and that's possible on a reasonable time scale only if you have a turbulent flow. And here I drew attention to some attractive features of turbulence---especially at the interface between mixed and unmixed substances. I was then involved in nonlinear dynamics type problems such as the flow behind a blunt object having multiple oscillations which interact in a very complex but yet a very fundamental way. And all of this I was able to characterize up to some level of detail---and that is the nonlinear dynamics and fractal part.

The other important aspect, which I suppose is better known, is the intermittency. If you have a quantity that fluctuates modestly around the mean, the mean value will tell a lot about the quantity. A few further moments may be all you need to give an adequate statistical description. But sometimes things are more complex---for example, the monsoon rains in India. Things don't happen uniformly in space or time, and when they happen, they happen very irregularly, sometimes very strongly, sometimes very little. So you cannot characterize these by standard methods. The stock market behavior is similar. The stock market sort of goes up and down a little bit most of the time. Those are the events through which people make or loose lots of money. These intermittent events are very rare but still very important. How to characterize them is a fundamental issue. It happens in turbulence in this way. If you look at a finite volume of a flow, the turbulence is not doing dissipation over most of the space, but in some locations it really dissipates a large amount. So I studied the phenomenon for a few years and this is what is called a multi-scaling problem or a multi-fractal problem.

And then I got interested in cryogenic helium. The issue there is that if you want to measure forces on an aircraft or a submarine, normally what you do is you make a scale model, which you put in a wind or water tunnel, measure the forces and by similarity you project what it might be on the true object. Now, the parameter you most want to match between the model and the true object is the Reynolds number. And what is Reynolds number? It is [length x velocity/viscosity]. You can't usually do this, because the models are small, the attainable flow velocities are small, and so on. If you don't match the Reynolds number, you have to extrapolate whatever results you get, and extrapolation is a tricky business. There is always interest in trying to measure the forces on a model on which the Reynolds number is the same as that on the true object. The length can't be of the true scale of the object, the velocity sometimes can't be much larger than that of the true object, but there's no reason why viscosity can't be made so low for the model that the Reynolds number for a small scale model would be as high as that for the large object. Cryogenic helium has the lowest viscosity of any fluid we know.

So, I got interested in it. If you take Helium-4 at 4K, its viscosity is some 100 times smaller than that of air, so if you take an object 100 times smaller than the real object, you'll get the same Reynolds number if you maintain the speed. That is the idea.

Then I got interested in Helium itself. If you go below 2.17K you have a phase transition which is very interesting because you then have superfluidity. Superfluidity means that if you put the flow through a pipe, you don't observe any resistance, unlike normal fluid which gives rise to resistance and requires some pumping power to maintain a flow. And there I was interested very much in the spontaneous formation of the so-called quantized vortices, which are very thin, 1 A diameter or a few A. They become tangled like spaghetti, or something like that, and that gives rise to a new type of turbulence. I am very much interested in that and have tried to make some progress in the study of the phenomenon.

What one question would you like to see answered about your research field in the near future?

In the near future I have many things to do relating to what I have already been doing and what I have done. There are one or two areas I'll definitely continue working in and one or two areas where I’ll definitely stop. And it also depends on what kinds of resources can be generated. I'll continue work on quantum turbulence and convection for a while, for sure. I've to finish one or two things on mixing and then I’ll write up something and move on. The way I see it, I have 10 - 15 years of active scientific life left. May be I don't have that much time. So, I want to do something that is difficult and interesting. I don't want to do just anything that comes my way. So I am working a little bit on a few possibilities; ultimately, it depends on how much money I may be able to raise and things like that. I had better not talk about it too prematurely.

Complete Interview can be accessed at: ***http://www.iitk.ac.in/drpg/anreport.htm***