[Lecture]
Quantum Hydrodynamics and Turbulence

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In this crush course I would discuss some important topics on quantum hydrodynamics and turbulence [1-3]. Quantum turbulence (QT) was discovered in superfluid ^{4}He in the 1950s, but the field moved in a new direction starting around the mid 1990s. Quantum turbulence is comprised of quantized vortices that are definite topological defects arising from the order parameter appearing in Bose-Einstein condensation. Hence QT may yield a simpler model of turbulence than does conventional classical turbulence (CT). The innovation has come from two facts. First, the scientists have started to consider the comparison between QT and CT chiefly in superfluid helium. For example, the Kolmogorov spectrum, which is the most important statistical law in turbulence, is confirmed experimentally and numerically. Secondly, the realization of atomic Bose-Einstein condensation in 1995 has proposed another important stage for this issue. A general introduction to this issue and a brief review of the basic concepts are followed by the recent developments of the studies of QT. The contents are

Wednesday 18th 16:00-18:00 @C015, Lab1
1. Introduction -What is turbulence?
2. Basics of quantum hydrodynamics

Thursday 19th 10:00-12:00 @C015, Lab1
3. QT in superfluid helium
4. Energy spectrum in QT

Friday 20th 10:00-12:00 @C016, Lab1
5. Vortex lattice formation in a rotating atomic Bose-Einstein condensate(BEC)
6. QT in atomic BECs

[1] *Progress in Low Temperature Physics*, ed. W. P. Halperin and M. Tsubota (Elsevier, Amsterdam, 2009) Vol.16.
[2] M. Tsubota, M. Kobayashi and H. Takeuchi, Phys. Rep. **522**, 191 (2013).
[3] M. Tsubota, K. Kasamatsu and M. Kobayashi, in *Novel Superfluids*, ed. K. H. Bennemann and J. B. Ketterson (Oxford University Press, Oxford, 2013), Vol. 1, p.156.