Kibble-Zurek mechanism in magnetization of a spinor Bose-Einstein condensate

Hiroki Saito[1], Yuki Kawaguchi[2], and Masahito Ueda[2,3]

[1] *The University of Electro-Communications, Tokyo 182-8585, Japan*
[2] *Department of Physics, Tokyo Institute of Technology, Tokyo 152-8551, Japan*
[3] *Macroscopic Quantum Control Project, ERATO, JST, Tokyo 113-8656, Japan*

A phase transition is accompanied by spontaneous symmetry breaking of an order parameter. If the domains grow with random phases, and they merge with each other, topological defects are eventually left. This scenario of topological-defect formation in symmetry breaking is known as the Kibble-Zurek (KZ) mechanism [1,2].

Recently, spontaneous magnetization in a spinor Bose-Einstein condensate (BEC) has been observed by the Berkeley group [3]. In this experiment, magnetic field in the z direction is quenched below a critical strength, which results in spontaneous magnetization of the BEC in the x-y direction. Accompanied by this U(1) symmetry breaking, the KZ mechanism is expected to emerge, resulting in the formation of spin vortices.

We will show that the KZ mechanism do emerge in this process [4]. We numerically solve the dynamics of the system and show that the spin winding numbers follow the power laws predicted by the KZ theory: the winding number is proportional to the square root of the length of the path to take it, and when the magnetic field is gradually quenched, the winding number is proportional to the -1/6$^{\text{th}}$ power of the quench time.

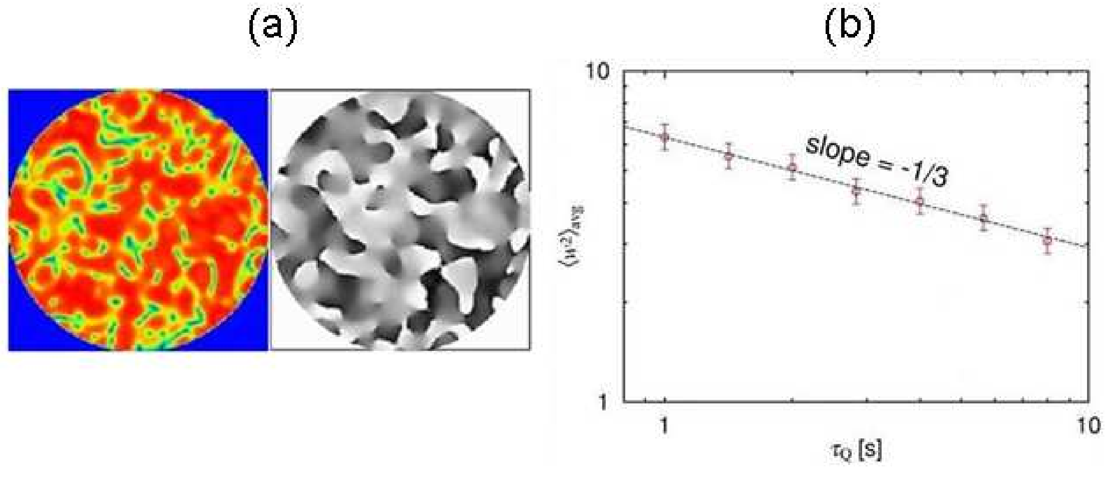

Fig. 1: (a) Profiles of magnitude (left) and direction (right) of the spontaneously developed magnetization. (b) Logarithmic plot of the variance of the winding number as a function of the quench time.

[1] T. W. B Kibble, J. Phys. A **9**, 1387 (1976).
[2] W. H. Zurek, Nature **317**, 505 (1985); Phys. Rep. **276**, 177 (1996).
[3] L. E. Sadler et al., Nature **443**, 312 (2006).
[4] H. Saito, Y. Kawaguchi, and M. Ueda, arXiv:0704:1377.