Kitaev's model and quantum computation

Masafumi Udagawa

Department of Physics, Gakushuin University, Tokyo, Japan

Kitaev's model provides a precious opportunity to understand the nature of quantum spin liquid (QSL) state through an exactly solvable model [1].

$$\mathcal{H} = -J_{\mathrm{K}} \sum_{i \in A-\mathrm{sub.}} s_i^x s_{i_x}^x + s_i^y s_{i_y}^y + s_i^z s_{i_z}^z \tag{1}$$

In contrast to many other "artificial" integrable models, Kitaev's model is defined by natural short-ranged interactions, and indeed, lots of compounds have been proposed as candidate materials to realize this model. In particular, α-$RuCl_3$ is considered as the most promising compound, due to the observation of the half-integer quantization of thermal Hall conductivity [2], which is one of the most outstanding phenomena predicted for Kitaev's QSL.

In this lecture, among many fascinating properties of Kitaev's QSL, we take up Majorana zero mode (MZM) of the chiral spin liquid phase and its application to quantum computation. To this aim, we first give a concise summary on the structure of exact solution of Kitaev's model. Then, on the basis of that, we present an intuitive discussion on how MZM appears in the chiral spin liquid phase, from the analogy to the integer quantum Hall effect exhibited by Haldane model on the honeycomb lattice [3]. Finally, we will introduce the braiding characteristic of vison excitation accompanying MZM, and discuss how it realizes elementary operations of quantum computation.

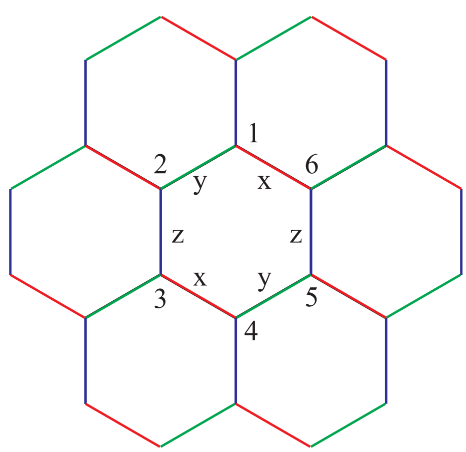

Figure 1: Honeycomb lattice to define the Kitaev's model (1).

[1] A. Kitaev, Ann. Phys. **321**, 2 (2006).
[2] Y. Kasahara et al., Nature **559**, 227 (2018).
[3] F. D. M. Haldane, Phys. Rev. Lett. **61**, 2015 (1988).