INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: NO

Statistical mechanics of magnets with disorders

Real world materials are never perfect: they contain disorders such as defects, vacancies, and impurities, and they challenge the theoretical description of clean systems to apply to those with disorder. In this case, statistical mechanics is our best friend [1]: treating disorder average as an ensemble average, one can characterize the macroscopic properties of disordered system with just a few parameters.

While statistical mechanics for classical spin systems is a highly developed subject [2], much less is known about quantum systems with disorders. For quantum spins with random couplings or dilution, it is not always clear whether a statistical description (scaling limit) exists. On the experimental side, dilution, doping, and random substitutions are efficient ways to introducing tuning parameters to probe various phases of materials. This provides strong motivation to develop a macroscopic theory for disordered quantum systems.

This M2 internship project tries to study the effect of randomness in prototypical classical/quantum spin systems. We will start from various toy models, such as the Ising [2], Heisenberg [4], ice [5], and loop models, and introduce various disorders such as random dilution and substitutions. We will use methods in statistical mechanics (numerical/analytical) [1, 3] to study observable quantities such as density of states, magnetization, specific heat, and susceptibility. A particular focus will be on the possibility of disorder induced phase transitions, and if they exist, their universality classes.

This internship can be extended to a full PhD project in quantum condensed matter physics on the following aspects: 1. To develop efficient numerical algorithms in the simulation of disordered quantum spin systems, especially in frustrated systems where quantum Monte Carlo method suffers from sign problems; 2. To explore the classical statistical mechanics aspects of certain exotic quantum spin states, such as topologically ordered states and quantum spin liquids; 3. To model the dynamics of random spin systems and explore their experimental relevance.

[1] Vojta, Thomas. "Rare region effects at classical, quantum and nonequilibrium phase transitions." *Journal of Physics A: Mathematical and General* 39, no. 22 (2006): R143.

[2] Folk, R., Yu Holovatch, and Taras Yavorskii. "Critical exponents of a three-dimensional weakly diluted quenched Ising model." *Physics-Uspekhi* 46, no. 2 (2003): 169.

[3] Iglói, Ferenc, and Cécile Monthus. "Strong disorder RG approach–a short review of recent developments." *The European Physical Journal B* 91, no. 11 (2018): 290.

[4] Sandvik, Anders W. "Classical percolation transition in the diluted two-dimensional S= 1 2 Heisenberg antiferromagnet." *Physical Review B* 66, no. 2 (2002): 024418.

[5] Sen, Arnab, and Roderich Moessner. "Topological spin glass in diluted spin ice." *Physical review letters* 114, no. 24 (2015): 247207z

Condensed Matter Physics: YES	Quantum Physics: NO
Soft Matter and Biological Physics: YES	Theoretical Physics: YES