Week 12: Synthetic gauge fields

	Discussion of outline	Discussion of talk	Your talk
Important dates	before 8.1.2016	before 15.1.2016	22.1.2016

Your seminar talk should roughly cover the following keywords and concepts:

- Various occurrences of synthetic/artificial/emergent gauge fields:
  - Spin ice (with "magnetic monopoles" as excitations)
  - Skyrmions
  - Time-periodic driving (lattice shaking)
  - Rotating system (Coriolis force = Lorentz force)
- Abelian vs. non-abelian gauge fields
- Dynamical vs. non-dynamical gauge fields

Important aspects that should be emphasized:

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Remarks:

- It is your task to turn the material related to your topic into a coherent story. This requires a detailed examination and understanding of the subject. Merely giving definitions without motivation and without pointing out the bigger picture is not sufficient.
- You will realize that time is rather limited and that you will need to focus on essentials.
- Personally, I am using 6-7 handwritten A4 pages for a 90 minutes lecture. It is recommended to aim at no more than 4-5 pages for your own presentation (and do not try to gain extra space by writing extra small).
- Please emphasize the physical ideas, not the mathematical formalism. Also avoid detailed calculations (except where they add to the conceptual understanding).
- In the two preparatory meetings you will be able to get feedback and assistance by your supervisor before you give your presentation, both on content and style. In order to maximize the benefit of these meetings it is important that you are well prepared.
- The synthetic gauge fields considered here can also couple to neutral particles.

References:

- [1, 2]
- [3] [4] (the latter has a section on dynamical gauge fields) [5] (review) [6] (review) [7]
- Cooper [8], in particular Section 2.1 (this is the rather formal statement that the Hamiltonian looks like the one with magnetic field)
- Semi-experimental proposal for non-abelian fields [9, 10]
- The emergence of a U(1) Maxwell theory and of monopoles is discussed in [11], unfortunately without much focus on the gauge theory aspect
- A discrete gauge theory (non-dynamical) on a lattice arises in Kitaev's honeycomb model
- Wikipedia (to get a quick overview)
  - a

References

[1] F. Wilczek and A. Zee, *Appearance of gauge structure in simple dynamical systems*, Phys. Rev. Lett. **52** (June, 1984) 2111–2114.

[2] J. Moody, A. Shapere and F. Wilczek, *Realizations of magnetic-monopole gauge fields - Diatoms and spin precession*, Phys. Rev. Lett. **56** (Mar., 1986) 893–896.

[3] D. Jaksch and P. Zoller, *Creation of effective magnetic fields in optical lattices: the Hofstadter butterfly for cold neutral atoms*, New Journal of Physics **5** (May, 2003) 56 [quant-ph/0304038].

[4] N. Goldman, G. Juzeliūnas, P. Öhberg and I. B. Spielman, *Light-induced gauge fields for ultracold atoms*, Reports on Progress in Physics **77** (Dec., 2014) 126401 [1308.6533].

[5] J. Dalibard, F. Gerbier, G. Juzeliūnas and P. Öhberg, *Colloquium: Artificial gauge potentials for neutral atoms*, Reviews of Modern Physics **83** (Oct., 2011) 1523–1543 [1008.5378].

[6] I. Bloch, J. Dalibard and S. Nascimbène, *Quantum simulations with ultracold quantum gases*, Nature Physics **8** (Apr., 2012) 267–276.

[7] P. Hauke, O. Tieleman, A. Celi, C. Ölschläger, J. Simonet, J. Struck, M. Weinberg, P. Windpassinger, K. Sengstock, M. Lewenstein and A. Eckardt, *Non-Abelian Gauge Fields and Topological Insulators in Shaken Optical Lattices*, Physical Review Letters **109** (Oct., 2012) 145301 [1205.1398].

[8] N. R. Cooper, *Rapidly rotating atomic gases*, Adv. Phys. **57** (Nov., 2008) 539–616 [0810.4398].

[9] J. Ruseckas, G. Juzeliūnas, P. Öhberg and M. Fleischhauer, *Non-Abelian Gauge Potentials for Ultracold Atoms with Degenerate Dark States*, Phys. Rev. Lett. **95** (June, 2005) 010404 [cond-mat/0503187].

[10] K. Osterloh, M. Baig, L. Santos, P. Zoller and M. Lewenstein, *Cold Atoms in Non-Abelian Gauge Potentials: From the Hofstadter "Moth" to Lattice Gauge Theory*, Phys. Rev. Lett. **95** (June, 2005) 010403 [cond-mat/0502251].

[11] C. Castelnovo, R. Moessner and S. L. Sondhi, *Spin Ice, Fractionalization and Topological Order*, ArXiv e-prints (Dec., 2011) [1112.3793].