Week 5: Chern-Simons gauge theory

	Discussion of outline	Discussion of talk	Your talk
Important dates	before 06.11.2015	before 13.11.2015	20.11.2015

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

- This gauge theory with Lie group G is specific to 2+1D
- Lagrangian $\mathrm{tr}(A \wedge dA + \frac{2}{3} A \wedge A \wedge A)$ plus coupling to matter
- Only first order in derivatives (this has important implications if one tries to quantize the theory)
- Equations of motion
- Behavior of the Lagrangian under large gauge transformations: Existence of a boundary term and topological term
- Winding number and quantization of the coupling constant k (invariance of path integral measure)
- Large k corresponds to weak coupling
- Calculation of the winding number for SU(2) [1]
- Breaking of parity and time reversal symmetries (but not charge conjugation)
- Gauge invariant observables: Wilson loops
- Specialization to the abelian case ($G = \mathrm{U}(1)$)
- Pinning of flux to particles, anyonic statistics
- Mass generation in the coupled abelian Maxwell-Chern-Simons theory (long-range interactions $\rightarrow$ short-range), use the wave equation or the propagators to show this
- Outlook: Definition in general (odd) dimensions (see [2, Chapter 11.5] and [3, Section III])

Important aspects that should be emphasized:

- The independence of the Lagrangian from the metric (this displays the purely topological nature of Chern-Simons theory).
- The special features of the theory on manifolds with boundary (e.g. the disc)
- The relevance to FQH systems
- The possibility to generate mass (alternative to the Higgs mechanism)

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 formulas above are only given for guidance. Please make sure to correct them where necessary and to fill in all the correct signs, prefactors etc.

References:

- The presentation should mostly be based on the review by Dunne: Parts of Sections 1 and 2, in particular Sections 2.1 and 2.6 [1]
- Some aspects of relevance are also covered in the original article [3]
- A compact but neat presentation with a focus on FQH physics is contained in the review [4], see Section III.A.1.
- If you have access to it you can check out Chapter II.4 in the book of Baez and Muniain [5]

References

[1] G. V. Dunne, *Course 3: Aspects of Chern-Simons Theory*, in Topological Aspects of Low Dimensional Systems (A. Comtet, T. Jolicoeur, S. Ouvry and F. David, eds.), p. 177, 1999. `hep-th/9902115`.

[2] M. Nakahara, Geometry, Topology and Physics. Taylor & Francis, 2nd ed., 2003.

[3] S. Deser, R. Jackiw and S. Templeton, *Topologically massive gauge theories*, Annals Phys. **140** (May, 1982) 372–411.

[4] C. Nayak, S. H. Simon, A. Stern, M. Freedman and S. Das Sarma, *Non-Abelian anyons and topological quantum computation*, Reviews of Modern Physics **80** (July, 2008) 1083–1159 [`0707.1889`].

[5] J. Baez and J. Muniain, Gauge fields, knots and gravity. World Scientific, 1994.