

# Projects – Advanced Quantum Field Theory, spring 2022

19th April 2022

Below is a list of possible projects. If you have an idea of another project, send me an email. For most topics I have included some possible references, but these are only there to get you started.

## 1. Grand Unified Theories:

- *The Algebra of Grand Unified Theories*, by John C. Baez, John Huerta [2].

## 2. Renormalization Group Equations and Critical Exponents

- Condensed Matter Field Theory, Altland and Simons, Ch. 8. [1]
- An Introduction to Quantum Field Theory, by M. Peskin and D. Schroeder, Ch. 13. [13]

## 3. Unitary Irreducible Representations of the Poincare Group

- *The unitary representations of the Poincare group in any spacetime dimension*, by Xavier Bekaert, Nicolas Boulanger [3].

## 4. Axions and the Strong CP Problem

- *The Strong CP Problem and Axions*, by R. D. Peccei [12].

## 5. Gauge Fixing and the Gribov Problem

- *On gauge fixing*, by Axel Maas [9].
- *Note on the Gauge Fixing in Gauge Theory*, by Kazuo Fujikawa, Hiroaki Terashima [8].

- *Covariant gauges without Gribov ambiguities in Yang-Mills theories*, by Julien Serreau, Matthieu Tissier, Andréas Tresmontant [14].

## 6. The Quantum Hall Effect(s) and Topology

- The Quantum Hall Effect, by David Tong [16]
- Field Theories of Condensed Matter Physics, by Eduardo Fradkin [7]

## 7. Gravity as an Effective Quantum Field Theory

- *Introduction to the Effective Field Theory Description of Gravity*, by John F. Donoghue [5]

## 8. Quantization of General Relativity

- *A fundamental problem in quantizing general relativity*, by Lorenzo Maccone [10].

## 9. Quantum Field Theory in Curved Space

- *Quantum Field Theory in Curved Spacetime*, by L.H. Ford [6].

## 10. Quantum Field Theory and Differential Geometry

- *Quantum Field Theory and Differential Geometry* [4].

## 11. Supersymmetry and Index Theorems

- Supersymmetry and the Atiyah-Singer Index Theorem I: Peierls Brackets, Green's Functions, and a Supersymmetric Proof of the Index Theorem, by Ali Mostafazadeh [11]

## 12. Instantons and Baryon Number Non-Conservation in the Standard Model

- Advanced Topics in Quantum Field Theory, by M.Shifman, Ch. 5. [15]

## 13. Consequences of Anomalies: Anomalies and Chiral Gauge Theory

- An Introduction to Quantum Field Theory, by M.Peskin and D.Schroeder, Ch. 19.4. [13]

## 14. Monopoles and Confinement

- Advanced Topics in QFT, by M. Shifman, Ch.9. [15]

## 15. False Vacuum Decay and the Standard Model

## 16. Chern-Simons Theories and Topological Invariants

## 17. BRST Quantization of Gauge Theories

## 18. Kalusza-Klein Theories

## 19. BV-Formalism and Renormalization of non-Abelian Gauge Theories

## 20. Gauge-Gravity Duality and the AdS/CFT Conjecture

## References

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- [2] John C. Baez and John Huerta. *The Algebra of Grand Unified Theories*. 2010. arXiv: 0904.1556 [hep-th].
- [3] Xavier Bekaert and Nicolas Boulanger. *The unitary representations of the Poincare group in any spacetime dimension*. 2021. arXiv: hep-th/0611263 [hep-th].
- [4] W. F. Chen. “Quantum Field Theory and Differential Geometry”. In: *Int. J. Geom. Meth. Mod. Phys.* 10 (2013), p. 1350003. DOI: 10.1142/S0219887813500035. arXiv: 0803.1340 [physics.pop-ph].
- [5] John F. Donoghue. *Introduction to the Effective Field Theory Description of Gravity*. 1995. arXiv: gr-qc/9512024 [gr-qc].
- [6] L. H. Ford. *Quantum Field Theory in Curved Spacetime*. 1997. arXiv: gr-qc/9707062 [gr-qc].
- [7] Eduardo Fradkin. “Topology and the quantum Hall effect”. In: *Field Theories of Condensed Matter Physics*. 2nd ed. Cambridge University Press, 2013, pp. 432–479. DOI: 10.1017/CBO9781139015509.014.
- [8] Kazuo Fujikawa and Hiroaki Terashima. “Note on the gauge fixing in gauge theory”. In: *Nucl. Phys. B* 577 (2000), pp. 405–415. DOI: 10.1016/S0550-3213(00)00102-4. arXiv: hep-th/9912253.
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- [10] Lorenzo Maccone. “A fundamental problem in quantizing general relativity”. In: *Found. Phys.* 49.12 (2019), pp. 1394–1403. DOI: 10.1007/s10701-019-00311-w. arXiv: 1807.01307 [quant-ph].
- [11] Ali Mostafazadeh. “Supersymmetry and the Atiyah-Singer index theorem. 1: Peierls brackets, Green’s functions, and a supersymmetric proof of the index theorem”. In: *J. Math. Phys.* 35 (1994), pp. 1095–1124. DOI: 10.1063/1.530630. arXiv: hep-th/9309059.
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- [13] Michael E. Peskin and Daniel V. Schroeder. *An Introduction to quantum field theory*. Reading, USA: Addison-Wesley, 1995. ISBN: 978-0-201-50397-5.
- [14] Julien Serreau, Matthieu Tissier and Andréas Tresmontant. “Covariant gauges without Gribov ambiguities in Yang-Mills theories”. In: *Phys. Rev. D* 89 (2014), p. 125019. DOI: 10.1103/PhysRevD.89.125019. arXiv: 1307.6019 [hep-th].
- [15] M. Shifman. *Advanced topics in quantum field theory.: A lecture course*. Cambridge, UK: Cambridge Univ. Press, Feb. 2012. ISBN: 978-1-139-21036-2, 978-0-521-19084-8.
- [16] David Tong. *Lecture Notes on The Quantum Hall Effect*. Jan. 2016. URL: <https://www.damtp.cam.ac.uk/user/tong/qhe/qhe.pdf>.