Aix-Marseille University
Master 2 Fundamental Physics 2021-2022

Field Theoretical Aspects of General Relativity

Simone Speziale
Centre de Physique Théorique
CNRS-UMR 7332, Luminy Case 907
13288 Marseille, France
`simone.speziale@cpt.univ-mrs.fr`

LECTURES PROGRAM

1. **Lagrangian formalism**

   Maxwell and Einstein-Hilbert Lagrangians; variational principle; role of boundary terms and boundary conditions; first order variational principle; unicity of the Levi-Civita connection

2. **Hamiltonian formalism: electromagnetism**

   Legendre transform; Gauss law; Dirac's theory of constrained systems; physical phase space and counting of degrees of freedom

3. **Hypersurfaces**

   Embeddings; Intrinsic and extrinsic curvature; Gauss-Codazzi equations; Gibbons-Hawking boundary term; space-like versus light-like hypersurfaces

4. **Hamiltonian formalism: general relativity**

   ADM variables; constraint structure and Dirac's hypersurface deformation algebroid; ADM energy

5. **Noether theorem for theories with gauge symmetries**

   Symmetries and conservation laws; canonical generators; global and local (small and large) gauge symmetries; surface charges in electromagnetism and gravity

6. **Tetrad variables**

   Isomorphism between the tangent space and the vectorial bundle; Spin connection; Einstein-Cartan Lagrangian

7. **Hamiltonian formalism: tetrad variables**

   Constraint structure in tetrad variables; gauge theory phase space; second class constraints; Ashtekar-Barbero-Immirzi canonical transformation

8. **Elements of loop quantum gravity**

   Wilson loops and spin networks; quanta of space and fuzzy polyhedra

SUGGESTED BIBLIOGRAPHY

- E. Poisson, *A Relativist's Toolkit*, Cambridge University Press (for lectures 1, 3)
- P. Dona and S. Speziale, *Introductory Lectures to Loop Quantum Gravity*, ArXiv link (for 4, 6, 7, 8)
- M. Henneaux and C. Teitelboim, *Quantization of Gauge Systems* (for 2, 4)