MASTER ICFP 2018 – 2019

GENERAL RELATIVITY

SUMMARY

This course aims at presenting a selection of advanced topics in gravitational classical dynamics. It starts with a reminder of the basics of general relativity and Riemannian geometry. The equations of motion are displayed, and Schwarzschild and Kerr solutions obtained. The black-hole properties of the latter are then discussed with special emphasis on their thermodynamic interpretation. Follows the general study of the energy-momentum tensor accompanied with the analysis of the conserved charges of the gravitational field. The last part of the course is devoted to Cartan's formalism and exterior calculus. These are the building blocks for cosmological applications and primer tools for gravitational instantons, useful for the quantum theory.

PREREQUISITE KNOWLEDGE

Special relativity and basics of general relativity: elements of differential geometry, Schwarzschild solution, tests of Einstein's theory of gravity. This can be found in any modern textbook – see bibliography.

PROGRAMME

1. Wed Sept 5 – course 1 – *From Newton to Einstein along geometry, Lie derivative, covariant derivative*
2. Wed Sept 12 – course 2 – *Torsion, Riemann, Weyl, geodesics*
3. Wed Sept 19 – tutorial 1 – *Killing vectors*
4. Wed Sept 26 – course 3 – *Einstein's field equations, Killings, non-coordinate frames, Nœther's theorem*
5. Wed Oct 3 – tutorial 2 – *Geodesics*
6. Wed Oct 10 – course 4 – *Schwarzschild solution, black-hole structure*
7. Wed Oct 17 – course 5 – *General black-hole properties, Kerr solution, thermodynamics*
8. Wed Oct 24 – tutorial 3 – *Binary systems*
9. Wed Nov 7 – course 6 – *Back to the energy-momentum tensor: conserved quantities, Komar charges*
10. Wed Nov 14 – tutorial 4 – *3+1 formalism*
11. Wed Nov 21 – course 7 – *Exterior calculus and Cartan formalism*
12. Thu Nov 29 – course 8 – *Exotic items: gravitational self-duality, Bianchi foliations, instantons*
13. Wed Dec 5 – tutorial 5 – *Cartan formalism and GHY boundary term*
14. Wed Dec 19 – exam

All lectures are scheduled at the ENS, rue Lhomond, room L361 from 9:00 to 12:30.

BIBLIOGRAPHY

1. Modern textbooks in French:
    1. David Langlois, *Relativité génerale*, Vuibert – level M1.
    2. Nathalie Deruelle et Jean-Philippe Uzan, *Théories de la Relativité*, Belin – level M2.
2. Modern textbooks in English:
    1. Sean M. Carroll, *An Introduction to General Relativity – Spacetime and Geometry*, Addison Wesley.
    2. James B. Hartle, *Gravity – An Introduction to Einstein's General Relativity*, Addison Wesley.
    3. Antony Zee, *Einstein Gravity in a Nutshell*, Princeton University Press.
3. Classics:
    1. Lev Landau et Evguéni Lifchitz, *Physique Théorique vol. 2 Théorie des champs*, MIR.[1]
    2. Steven Weinberg, *Gravitation and cosmology – Principles and Applications of the General Theory of Relativity*, Wiley.
    3. Robert M. Wald, *General Relativity*, The University of Chicago Press.
    4. Charles W. Misner, Kip S. Thorne, John Archibald Wheeler, *Gravitation*, W.H. Freeman and Co.
4. Textbooks in geometry:
    1. Mikio Nakahara, *Geometry, Topology and Physics*, Graduate student series in Physics.
    2. Boris Doubrovine, Anatoli Fomenko et Sergeï Novikov, *Géométrie contemporaine – méthodes et applications*, MIR.[2]
5. Notes available on the web:

   Matthias Blau http://www.blau.itp.unibe.ch/Lecturenotes.html

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[1]Available also in English – Pergamon Press.

[2]Available also in English – Springer.