UNIVERSITÀ DI PAVIA

## Anno Accademico 2020/2021

# GENERAL RELATIVITY

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| Enrollment year | 2020/2021 |
| Academic year | 2020/2021 |
| Regulations | DM270 |
| Academic discipline | FIS/02 (THEORETICAL PHYSICS, MATHEMATICAL MODELS AND METHODS) |
| Department | DEPARTMENT OF PHYSICS |
| Course | |
| Curriculum | Didattica e storia della fisica |
| Year of study | 1° |
| Period | 2nd semester (01/03/2021 - 11/06/2021) |
| ECTS | 6 |
| Lesson hours | 48 lesson hours |
| Language | Italian |
| Activity type | ORAL TEST |
| Teacher | CARFORA MAURO (titolare) - 6 ECTS |
| Prerequisites | ELECTRODYNAMICS & RELATIVITY (or an equivalent course in Special Relativity) |
| Learning outcomes | This is an advanced course in General relativity, aimed to provide a thoughtful introduction to the subject at the level of a beginning graduate student. The level of physical and mathematical sophistication is very high. Differential Geometry and geometric analysis are thoroghly used without apology. The objective is that the student can appreciate the nature and character of General relativity and how this theory fits into the general scheme of modern Physics. |
| Course contents | Introduction to the Physics of the gravitational field. The weak equivalence principle and the equivalence principle. Local inertial frames, gravitational field and spacetime geometry. Einstein equations. Variational derivation of Einstein equations. The Einstein-Hilbert action. |

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| | The linearized theory and the Newtonian limit. Gravitational waves in the linearized theory. The Schwarzschild solution: derivation and properties. Test particles in Schwarzschild spacetime. Perihelion shift and deflection of light rays. The Schwarzschild radius. Singularities. Maximal extension of a spacetime. Rindler spacetime. The event horizon. Maximal extension of the Schwarzschild solution and Kruskal spacetime. Event horizons and Black Holes. Conformal compactification and Penrose diagrams. Casual properties of an asymptotically flat spacetime and the characterization of Black Holes. Kerr solution and its properties. Ergosphere and supperradiance. Black hole dynamics. General relativity as a dynamical system. The Arnowitt-Deser-Misner formalism. The Einstein constraints and hyperbolic evolution. Mass and four-momentum of an isolated system. Open problems in mathematical general relativity. Relativistic cosmology. Friedmann equations and cosmological models. |
| **Teaching methods** | Lectures are going the way of the blackboard.<br>I think that a projector lecturing is unsuitable for mathematics and physics. As a teacher I am not just conveying information, I teach to think mathematically, by example. Calculations are inevitable in our discipline, and it is crucially important to let students feel the subtle play of rhythms, and to highlight recursion and reduction to simpler cases. |
| **Reccomended or required readings** | Robert M. Wald, General Relativity, The University of Chicago Press.<br>W. Rindler: "Relativity, Special, General and Cosmological" Oxford University Press.<br>Selected chapers from:<br>(1) C. Misner, K. Thorne, J. A. Wheeler: "Garvitation", Freeman<br>(2) J. Jost: “Riemannian Geometry and Geometric Analysis”, Springer<br>(3) S.W. Hawking & G.F.R. Ellis:" The large scale structure of space-time", Cambridge Univ. Press;<br>(4) Y. Choquet-Bruhat, C. DeWitt-Morette, M. Dillard-Bleick: “Analysis, Manifolds and Physics” (Rev. Edit.) North-Holland<br>(5) M. Berger: “A Panoramic View of Riemannian Geometry”, Springer<br>(6) D. Christodoulou: “Mathematical Problems of General Relativity I”, Europ. Math. Soc.<br>(7) Y. Choquet-Bruhat: “General Relativity and Einstein Equations”, Oxford Univ. Press |
| **Assessment methods** | Oral examination.<br>The final oral examination is aimed to find out what students have understood of the topics of the course rather than just what they know and can recite. The exam will assess the acquired knowledge of General Relativity, the ability to express and communicate as well as the ability to analyze the question posed during the examination, break it down into the relevant key points and work through to provide an acceptable answer. All of these will help me in assessing the success of the student in transitioning from a “knowledge-acquirer” to a practicing physicist who can synthesize and attack complex problems as well create new knowledge by carrying out original research. |
| **Further information** | This is an English-friendly course. Hence, upon request (even by a minority of the students attending the lectures) lectures will be delivered |

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| | in English |
| **Sustainable development goals - Agenda 2030** | $lbl_legenda_sviluppo_sostenibile |