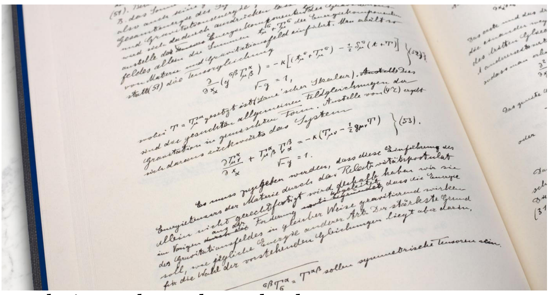
Relativistic Gravitation and Astrophysics



SUMMARY.
Geometric gravity theories: General Relativity (GR) and alternatives ...
... their tools and methods ...
... and applications to astrophysics and cosmology.

OBJECTIVES

Improving your knowledge in GR and in some related astrophysical applications.

It mainly consists in the acquisition of the skills required in geometric gravity and relativistic astrophysics. This includes mastering the mathematical tools required to be conversant in these fields. Special attention will be payed to exact GR solutions.

PREREQUISITES

☒ S2. Gravity & relativity

CARE: it is of first importance the student not to be scared by the formal issues involved in this course (tensor calculous, Riemannian geometry, ...).

THEORY

by Bertrand Chauvineau

- **Mathematics**

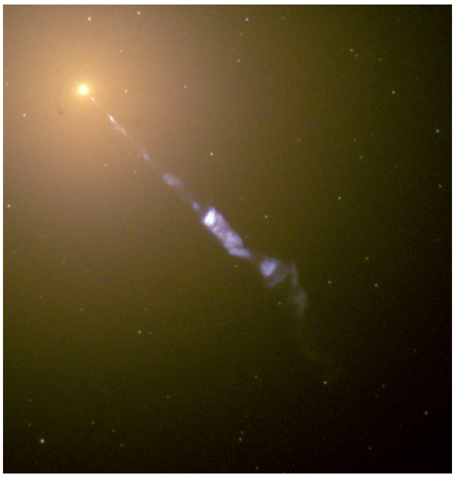
Tensor calculous
Riemannian geometries: metrics, geodesic curves, covariant derivatives, curvature.
Advanced topics (Killing vectors, ...).

- **Gravitation theories**

GR, scalar-tensor gravity, ...
Lagrangian formalism, matter description, stress tensor.
Linearized theory, gravitational waves.
Conservation laws.
Exact solutions: Schwarzschild, Reissner-Nordström, de Sitter (& Schwarzschild-de Sitter), Robertson-Walker, Kasner, axial symmetry, Kerr, ...

- **Relativistic Astrophysics**

Perfect fluids in astrophysics, examples of relativistic stars.
Black holes and their environment (dynamics, optics).
Gravitational radiation.
Backgrounds on cosmology.



APPLICATIONS

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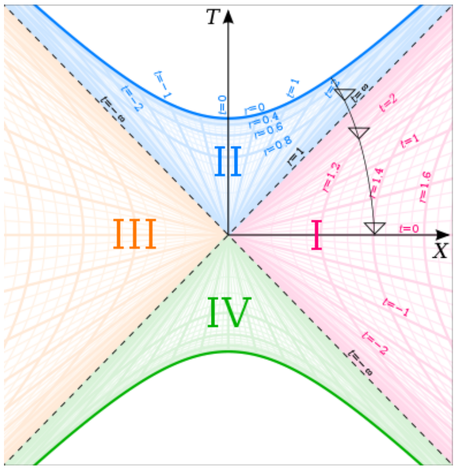
For the "project part" of the METEOR, the student will choose a part of the lectures, or a specific topic related to them, and make a presentation that shows his mastering of its different aspects, including technical issues.

MAIN PROGRESSION STEPS

- Whole period
  theoretical courses and exercises (about 60h, planified on 3/4 sessions a week).
  Reading of some review and/or pedagogical papers.
- Last 2/3 weeks
  Some specific points (courses and exercices, more specifically related to the project).
  Focus on a specific topic and preparation of the oral presentation (project part).



EVALUATION

- `Theory grade [30%]` Written exam.
- `Practice grade [30%]` Student's investment during the whole period.
- `Defense grade [40%]`
  - Oral and slides quality
  - Context
  - Project / Personal work
  - Answers to questions

— BIBLIOGRAPHY & RESOURCES —

Any GR book/online course designed for undergraduate and/or graduate students is welcome.

More specifically, let me suggest (plenty of books ... Dozens new books every year! Hard to choose ...):

C.W. Misner, K.S. Thorne, J.A. Wheeler, "Gravitation" (San Francisco, Freeman, 1973).
> THE reference in the field, even if a bit old. Different levels of reading. An about 1000 pages book!

R.M. Wald, "General Relativity" (The University of Chicago Press, 1984).
> In two parts: 1. Fundamentals (about 150 pages), 2. advanced topics (about 300 pages).

H. Stephani, "General Relativity" (Cambridge University Press).
> Different editions. I like the second one (1990).

L. Landau, E. Lifchitz, "Field theory" (Mir Editions, 1970).
> Of course, the 2cd volume of their renowned course of physics! The second part (of this 2cd volume) is devoted to GR.

S. Weinberg, "Gravitation and Cosmology" (John Wiley & Sons, 1972).
> Another (old) reference book. Maybe easier to understand than Wald's book for the introduction to tensors.

H.C. Ohanian, "Gravitation and spacetime" (W. W. Norton & Company, 1976).
> Basics + a bit more.

E. Schrödinger, "Spacetime structure" (Cambridge University Press, 1950).
> I like so much this little book !!! (By the way, he is THE Erwin S., the guy you know as one of the creators of the quantum theory.) He introduces the concepts from nothing, all seems very natural. However, he first defines affinely connected spaces (ie the theory of spaces endowed by an affine connexion), and only later introduces metrics. So maybe not the most directly useful for your need ... and clearly, astrophysics is not his concern: not a single word about the Schwarzschild metric, black holes, planetary motions and so on. Just interested in field equations ... but so splendidly! Just amazing !!!

All of these books present relativity and gravitation from scratch, sometime going up to an advanced level. They all first thing (or after a short introduction, as I do in my lectures) present the required formalism. Many of these books are not recent, but are still references nevertheless.

Let me also suggest some french books:

P. Tourrenc, "Relativité et gravitation" (Armand Colin, 1997).
> A very pedagogical book.

H. Andrillat, "Introduction à l'étude des cosmologies" (Armand Colin, 1970).
> A very pedagogical introduction to GR, cosmology (in those times ... but ok for understanding the basics nevertheless) and to tensor calculous. (Henri Andrillat introduced GR in the French university teaching. With specific attention to pedagogy, as I said ...)

D. Gialis, F.-X. Désert, "Relativité Générale et Astrophysique" (EDP Sciences, 2015).
> mainly compilations of exercises, with corrections.

A. Barrau, J. Grain, "Relativité Générale" (Dunod, 2016).
> mainly compilations of exercises, with corrections.

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