GALILEAN SCHOOL COURSES CATALOG

CLASS OF NATURAL SCIENCES

ACADEMIC YEAR 2020-2021

Calculus

Teacher: Daniela Tonon– UniPd – daniela.tonon@math.unipd.it

Motivations :
The course introduces tools of mathematical analysis for optimization and control. The goal is to be able to understand and solve simple problems of optimal control in Economics and Life sciences.

Targeted audience: Students in Economics and Life sciences.

Prerequisites: Basic notions of Mathematical Analysis

Syllabus: Optimization with constraints, Lagrange multipliers, Kuhn Tucker theorem, Ordinary differential equations, Calculus of Variations, Optimal Control, Pontryagin maximum principle, Dynamic Programming

Teacher CV:
2011 Ph.D. in Mathematical Analysis at SISSA Trieste, Italy.
2011-2012 Post-doc Fellowship on kinetic theory, ICERM, Brown University, Providence US.
2012-2013 Post-doc Fellowship on optimal control, SADCO Marie-Curie Action, Université Pierre et Marie Curie, Paris, France and Imperial College London, UK.
2013-2020 Maître de conférences Université Paris Dauphine, Paris, France.
Since December 2020 Associate Professor in Mathematical Analysis at University of Padova.
Research interests: Partial differential equations, Mean field games, Optimal control theory and Kinetic theory.

Textbooks/bibliography:
Weber, Optimal control theory with applications in Economics, the MIT press 2011
Seierstad Sydsaeter, Optimal control theory with economic applications, North Holland
Anita, Arnautu, Capasso, An Introduction to Optimal Control Problems in Life Sciences and Economics, Birkhauser

Complements of Analysis

Teacher: Davide Vittone - UniPD - vittone@math.unipd.it

Motivations. This course takes place in the first trimester of the first year; it requires only a minimal mathematical background. The aim is to cover topics that are related to (but not usually treated in) the standard first-year courses in Analysis.

Targeted audience. First year students in Sciences or Engineering.

Syllabus. Elementary set theory: Zermelo-Fraenkel axioms, cardinality, well-orderings, Zorn's lemma, ordinals and cardinals. Complements of Analysis: inequalities (elementary and not: weighted means, Holder, Minkowski, Jensen...), convex functions (definition, derivatives, fine properties), elements of Lipschitz and BV functions. Some topics in Number Theory, to be chosen among: Stirling formula, Wallis formula, Euler–Mascheroni constant, irrationality of pi, transcendence of e, Tchebychev theorem on distributions of primes, some arithmetic functions and their properties.

Teacher CV. Born in 1980. 1999-2003 Student at the University of Pisa with fellowship from Scuola Normale Superiore 2004-2006 PhD student at Scuola Normale Superiore 2007 Postdoc, University of Trento 2007-2014 Ricercatore (Assistant Professor) in Mathematical Analysis, University of Padova 2015-present Associate Professor in Mathematical Analysis, University of Padova Research interests: Geometric Measure Theory and sub-Riemannian Geometry.

Textbooks/bibliography T. J. Jech, Set Theory C. Mantegazza, Problemi di Analisi I dal Corso del I Anno alla Scuola Normale Superiore di Pisa G. H. Hardy, J. E. Littlewood, G. Pólya, Inequalities E. Giusti, Esercizi e Complementi di Analisi Matematica G. Travaglini, Appunti su teoria dei numeri, analisi di Fourier e distribuzione di punti

Introduction to probability models

Teacher: Alessandra Bianchi – UniPd – alessandra.bianchi@unipd.it

Motivations.
The aim of the course is to provide an introduction to elementary probability theory and its application to sciences.
The typical environment will be that of discrete probability spaces, that will be introduced in the first lectures together with some
basic probability tools. By the construction and the analysis of suitable models, it will be shown how probability can be applied
to the study of phenomena in physics, computer science, engineering and social sciences.
In turn, this will lead to the discussion of some open problems of the field.

Targeted audience. The course will be self-consistent and no specific mathematical knowledge is required.
Logic and a scientific attitude are always helpful.

Syllabus. First elements of probability theory: Discrete probability spaces; Combinatorics; Conditional probability; The Ising model in statistical mechanics: Definition and properties; Analysis of phase transitions in dimension 1 and 2; Discrete random variables: Discrete distributions, mean value, independence; Binomial and geometric distribution; Moments generating function; Applications to two common problems: The coupon collector problem; Shuffling a deck of cards; The symmetric random walk in one and higher dimensions: Definition and properties; Reflection principle and return probability at 0; Analysis of transience and recurrence; Random walk on general graphs; Application to the gambler's ruin problem: probability of loss and win in a gambling game; Markov chains (theory): Definition and classification of Markov chains in finite space; Stationary distribution and ergodic theorem; Markov chains (examples and applications): Eherenfest model; Bernoulli-Laplace model; GaltonWatson branching process; Elements of Monte Carlo method: Definition of Monte Carlo Markov Chain (MCMC); examples and application to optimization problems.

Teacher CV. Born on 31/12/1977 Education and positions - July 2003 degree in Mathematics - University of Bologna - April 2007 PhD degree in Mathematics - University of Roma Tre - 2007-2009 postdoc fellow at the WIAS of Berlin (Germany) - 2010- 2012 postdoc fellow at the Mathematics Dep. of Bologna - Since May 2012 Assistant Professor ("Ricercatore") of Probability and Statistics at the Mathematics Dep. of Padova. Research interests: probability and Statistical Mechanics, Metastability in Markovian processes, Stochastic dynamics and relaxation time, Interacting particle systems on random structures.

Introduction to Thermodynamics

Teacher: Fulvio Baldovin – UniPd – fulvio.baldovin@unipd.it

Motivations.
Thermodynamics is a basic interdisciplinary subject which bridges over different areas of science, including physics, mathematics, chemistry, engineering, biology, and medicine. Although common to many bachelor curricula, time constraints and needs of focusing on practical application in the specific field tend to hinder the presentation of the simple, symmetric structure which underlies Thermodynamics. As a consequence, students may turn out to be confused about the meaning and use of different thermodynamic potentials and response functions.
Goal of the present course is to introduce the thermodynamics of simple systems. While keeping mathematical aspects at a level suitable for first-year undergraduate students, emphasis will be given to the equivalence of the entropy and energy representations, which through Legendre transformations generate all other potentials. Exemplifications and case of study from different fields will help the comprehension and application the formal structure.

Targeted audience.
The course targets the Natural Science Class of the Galilean School of the University of Padova, including students in physics, mathematics, chemistry, engineering, biology, and medicine. The ideal audience has supposedly been exposed to an introductory course of mathematical analysis in one variable, while a practical knowledge of partial derivatives and Legendre transformations will be offered within the course's lectures.

Syllabus.
- The temporal nature of macroscopic measurements
- The spatial nature of macroscopic measurements
- Summary of thermodynamic parameters
- The postulate of thermodynamic equilibrium
- Walls and constraints
- Measurability of the energy
- Quantitative definition of heat
- The basic problem of equilibrium thermodynamics
- The entropy postulates
- Partial derivatives and differentials
- Intensive parameters and equations of state
- Thermal, mechanical, and chemical equilibrium
- The Euler equation
- The Gibbs-Duhem relation
- Fundamental relation and equations of state
- The simple ideal gas
- The van der Waals ideal fluid
- The electromagnetic radiation
- The “rubber band”
- Second derivatives of the fundamental relation
- Possible, impossible, quasi-static, and reversible processes
- The maximum work theorem
- Engine, refrigerator, and heat pump performance
- The Carnot cycle
- Insight: thermal conductance and conductivity
- Power output and endoreversible engines
- The energy minimum principle
- Legendre transformations
- Thermodynamic potentials
- Massieu functions
- The minimum principles for the potentials
- The Helmholtz potential and the Laplace equation
- The Gibbs potential and chemical reactions
- Maxwell relations
- Reduction of derivatives
- Reconstruction of a fundamental equation from response functions

- Thermodynamic stability in the entropy representation
- Thermodynamic stability for the potentials
- Introduction to phase transitions
- The Clapeyron equation
- Unstable isotherms and first-order transitions
- General attributes of first-order phase transitions
- Thermodynamics in the neighborhood of the critical point

Teacher CV.
Fulvio Baldovin is Assistant Professor in Physics at the Physics and Astronomy Department of the University of Padova. He is author of about 45 original research articles in international journals. He has been teaching Statistical Mechanics for the Ph.D. degree in Physics, and Biological Physics for the Bachelor degree in Molecular Biology. He has been tutor in Theoretical Physics for the Galilean School of the University of Padova. He actively collaborates with complex systems groups at the Weizmann Institute in Israel and at the Universidad Nacional Autonoma de Mexico (UNAM).

Textbooks/bibliography.
H.B. Callen, *Thermodynamics and an introduction to Thermostatistics – Second Edition*, Wiley.
A number of problems and examples will be explicitly solved at the blackboard.

Measure theory

Name of the teachers: Pier Domenico Lamberti

Motivations. This lecture course is an introduction to a number of modern techniques in real analysis with focus on measure theory and the theory of integration. The material will be presented in an abstract setting including as a special case the Lebesgue theory of integration in the n-dimensional Euclidean space. This case will be discussed in detail and will serve as a source of examples and motivations. The Lebesgue integral is a standard tool in contemporary scientific literature and it is a matter of folklore to say that it is a flexible integral allowing the proof of powerful theorems such as the celebrated Dominated convergence Theorem. In fact, the main reason for its success is much deeper and is related to the completeness of the corresponding Lp-spaces, a fact of fundamental importance in mathematical analysis and its applications. For example, the completeness of those spaces allows to prove the existence of solutions for important partial differential equations from Mathematical Physics.

Targeted audience. This lecture course is particularly directed to students in Mathematics, Physics and Engineering. However, students from other scientific disciplines may take advantage of a rigorous presentation of fundamental notions from measure theory which are often assumed to be known without providing a proof. A basic course in calculus would cover all necessary prerequisites.

Syllabus.

Measures and σ-algebras; Measurable sets and Caratheodory's Theorem; Borel measures on the real line. Remarkable examples: Cantor-Volterra-type sets, Vitali set, a Lebesgue measurable set which is not a Borel set. Measurable functions and definition of integrals for real or complex-valued functions defined on a general measure space. Main theorems for taking the limit under the integral sign: Monotone convergence Theorem, Fatou's Lemma, Dominated convergence Theorem and integration of series, differentiation under integral sign. Product Measures and the Lebesgue measure in the n-dimensional Euclidean space. Fubini-Tonelli Theorem and change of variables in integrals. Spaces of integrable functions: Lp-spaces and Sobolev spaces. Applications to the proof of existence of solutions to important partial differential equations from Mathematical Physics.

Teacher CV.

Pier Domenico Lamberti is Associate Professor in Mathematical Analysis at the Department of Mathematics of the University of Padova since 2006. He got his PhD in Mathematics from the University of Padova in 2003 and the National Scientific Habilitation to Full Professor in Mathematical Analysis in 2019. His scientific interests are mainly in spectral perturbation problems for partial differential operators of elliptic type and include real and functional analysis, theory of function spaces, linear and non-linear spectral theory and calculus of variations. He is also interested in didactics of mathematical analysis. He is the author of more than fifty publications in international journals, some of which have been jointly written with his students. He has been visiting a number of mathematical institutions in several countries and he has participated into many international conferences. Three students have already defended their PhD thesis under his supervision and he is currently supervising a fourth one.

Textbooks/bibliography Folland, Gerald B. Real analysis. Modern techniques and their applications. 2nd ed. Pure and Applied Mathematics. A Wiley-Interscience Series of Texts, Monographs, and Tracts. New York, NY: Wiley. (1999)

Fluidynamics

Teacher: Roberto Turolla – UniPD - turolla@pd.infn.it

Motivations
Fluids and their motions play a central role in many areas of physics, engineering, biology and physiology, from the scale of living cells to astronomical ones. Fluids are complex systems, the dynamics of which was (partly) understood only during the last century. The course aims at providing the basics of fluid mechanics, i.e. the dynamics of liquids, presenting at the same time a number of examples and applications.

Targeted audience
Second year students in physics, mathematics, chemistry and engineering. The course is suited also for students in life sciences with a sufficient mathematical background (only elementary notions of calculus and vector analysis are required).

Syllabus
Basic properties of fluids: pressure, density, viscosity. Newtonian and non-Newtonian fluids (interlude: how it is possible to walk on a liquid).
Conservation laws and equations of motion. The control volume and the Reynolds transport equation. The conservation of mass, the equations of momentum and energy. The Euler and Bernoulli equations.
Dimensional analysis and the similarity principle. The basic adimensional groups in fluidynamics: force and pressure coefficients, the Reynolds, Froude, Rossby and Mach numbers. Adimensional form of the equations of motion and the role of "numbers" in their analysis.
Ideal flows. Two-dimensional inviscid flow. Stream function and streamlines. The velocity potential and Laplace equation. Superposition principle. Circulation. Ideal flow past a cylinder. Magnus effect. Lift: why do planes fly ?
The stress tensor. Stresses in an incompressible fluid. The Navier-Stokes equations. Applications to one-dimensional flows: Poiseuille flow, fluid sheet on an inclined plane. Internal laminar flows. Flow in a conduct: critical Reynolds number and the entrance length, Poiseuille law. Flow between two plane-parallel plates: the Couette flow. Two dimensional viscous flows: Stokes flow.

The boundary layer for a plane surface, Blasius solution. The boundary layer for a curved surface.
Geostrophic flows and the Ekman boudary layer.

Teacher CV
Roberto Turolla earned his Master degree in Physics at the University of Padova, attended a PhD programme at the International School for Advanced Studies in Trieste and is presently full professor at the Department of Physics and Astronomy, University of Padova. Since 2007 he holds a Honorary Professorship at Mullard Space Science Laboratory, University College London (UK).
Research interstests: astrophysics of compact objects (black holes and neutron stars). In particular, his expertise is in astrophysical radiative transfer under strong field (gravitational and magnetic) conditions and in the interpretation of X-ray/optical/radio data from collapsed stars in terms of physical models. Such an activity is sustained by several international collaborations with different institutions, both in Europe and the US. He published more than 200 papers on international refereed journals. He teaches General Physics for the bachelor degree in Astronomy and Relativistic Astrophysics for the master degree in Physics.

Textbooks/bibliography
J.F. Kreider *Principles of Fluid Mechanics, Allyn & Bacon*
Notes of the lectures (in pdf format)

Fundamentals on Drugs Action and Their Psychotropic Effects

Teacher: Alessandro Angrilli - UniPD - alessandro.angrilli@unipd.it Motivation The course provides an overview of the mechanisms of drugs action, their psychotropic effects along with side effects, and in some interesting cases, their potential use for pharmacological treatment of neurological and psychiatric disorders. Targeted audience The course is especially directed to students in Medicine, Biology, Psychology, Chemistry, Neuroscience. However, students from other scientific disciplines may take advantage of the principles in drug action. Pre- requisite are basics on cell biology, chemistry, neuroscience and neurophysiology.

Syllabus

1) Principles of action of drugs, pharmacokinetic, pharmacodynamics and toxicity [4h]
2) Drugs that inhibit the central nervous system, benzodiazepines, GHB, abuse inhalants, and alcohol [7 h]
3) Psychostimulant drugs, cocaine, amphetamine, caffeine, and nicotine [7 h]
4) Oppioids, stupefying drugs (morphine, heroin, oxycodon, methadone, etc.) [4 h]
5) Psychedelic drugs, ketamine, LSD, psyclocibin, ecstasy, addiction and psychopharmacological use [4h]
6) Marijuana and cannabinoids, addiction and psychopharmacological use [4h]

Teacher CV

Master degree in Biology. PhD in Experimental Psychology with a thesis entitled "Psychophysiology of emotions". In 1995 spent one year in the Institute of Medical Psychology and Behavioral Neurobiology of Tübingen directed by Prof. Niels Birbaumer. In 1997-1998, Marie-Curie post-doc grant at the University of Konstanz, laboratories of Prof. Thomas Elbert with a project on cortical plasticity of language in aphasic patients after recovery. Since 2015, Full professor of Psychobiology, Department of General Psychology, University of Padova. In 2011-2013 he was coordinator of the PhD Course of Psychobiology. Since 2003, head of the Microgravity and Brain Plasticity Lab. Since 2013, head of the Psychophysiology Research Labs of his department including the Sleep Psychophysiology Lab. Department delegate for all the laboratories of his department. Associated Editor of the Journals: Biological Psychology, Scientific Reports, BMC Neuroscience.

Textbooks/ Bibliography

Robert M. Julien, Claire Advokat, Joseph E. Comaty. Droghe e farmaci psicoattivi. Bologna: Zanichelli, 2012. (the course will focus only on the chapters describing addiction drugs). The English original version of the book has a more advanced edition, it is better to use the English 12th edition corresponding to the Italian edition. Robert M. Julien, Claire Advokat, Joseph E. Comaty, 2010. A Primer on Drug Action, 12th Edition

Algorithm Design

Teacher: Francesco Silvestri, DEI@UniPD, silvestri@dei.unipd.it

Motivations:
Algorithms are not only the heart of computer science, but represent a valuable method widely used in several scientific fields, for instance to extract information from data or to carry out scientific simulations. Algorithms are so pervasive that is quite likely that every scientist or engineer will face the development of an algorithm to cope with some application-specific computational problems. The goal of this course is to introduce to algorithm design, and in particular to study the most important design methods in the development of an algorithm.

Targeted audience
The course targets the Natural Science Class of the Galilean School of the University of Padova. The ideal audience has supposedly been exposed to some notions of programming in any language.

Syllabus:
Fundamental concepts: computational problem, algorithm, pseudocode.
Analysis and complexity of algorithms.
Greedy algorithms.
Dynamic programming.
Divide and conquer.
Approximate algorithms.
Randomized algorithms.
Algorithmic hardness.

Teacher CV:
I'm associate professor in Computer Engineering at the University of Padova. I enjoy teaching Big Data Computing and Computer Architecture in the master and bachelor programs in Computer Engineering. My unconditional love is doing research on algorithms and data structures, in particular for big data and parallel computing. In 2017-2019, I was assistant professor at the same university. Before (2014-2016), I was visiting scholar and postdoc at the IT University of Copenhagen, where I worked on high dimensional algorithms and learned how to cook smørrebrød. Going further back, I was a postdoc (2009-2014), a PhD student in Computer Engineering at the University of Padova (2005-2008), and a visiting scholar at the University of Texas at Austin (2007).

Textbooks/bibliography
Jon Kleinberg, Éva Tardos. Algorithm Design. Pearson 2006.

Introduction to Linear Algebraic Groups

Teacher: Giovanna Carnovale– UniPd – carnoval@math.unipd.it

Motivations.

Linear Algebraic Groups are a family of groups having also a compatible geometric structure. Examples include the general linear groups, the special linear groups, orthogonal and symplectic groups, the affine line and the multiplicative group of the base field. Their subgroups of rational points over a finite field are also crucial in the classification of finite simple groups. The course aims at providing an introduction to linear algebraic groups with a focus on the classification and the structure theory of (quasi)simple algebraic groups. If we have time, we can also explore the representation theory of quasisimple algebraic groups.

Targeted audience.

The targeted audience will be third year students in Mathematics or Physics. Other motivated students are certainly welcome, but they should be prepared to learn the prerequisites with the help of the teacher and/or the tutors.

Prerequisites. Basic notions of linear algebra (including Jordan normal form), ring theory and group theory. Non-mathematicians willing to take this class are invited to contact for advise on missing prerequisites. The necessary notions from Algebraic Geometry will be given in the course.

Syllabus. Basic notions of Linear algebraic groups, the structure of abelian and solvable algebraic groups, actions and quotients, Borel(=maximal solvable connected) subgroups. The Lie algebra of a linear algebraic group. Root space decomposition of the Lie algebra. Structure of reductive groups in terms of root subgroups. Chevalley's classification theorem.

It time permits: Basic notions of representation theory. Irreducible highest weight modules..The Bruhat decomposition and the flag variety. The Kazhdan-Lusztig's paradigm.

Teacher CV.

After graduating cum laude from La Sapienza I attended a Master Class in Algebraic Lie Theory and Hypergeometric Functions in The Netherlands. I earned my Ph.D. in Utrecht in june 1999. I have been post-doc at Cergy-Pontoise, Paris VI, Antwerp and Rome Tor Vergata, Since 2001 I have been working at the University of Padova, until 2015 as Ricercatore, and since then as Associate Professor.

My main research interests are in algebraic Lie theory and geometric methods in representation theory.

Textbooks/bibliography

G. Malle, D. Testerman, Linear Algebraic Groups and Finite Groups of Lie Type, Cambridge Studies in advanced mathematics 133, Cambridge University Press, 2011.
T. A. Springer, Linear Algebraic Groups, Second Edition, Progress in Mathematics, 9. Birkhäuser, 1998.

Selected Topics in Non Equilibrium Statistical Mechanics

Teacher Davide Gabrielli – University of L'Aquila – davide.gabrielli@univaq.it

Motivations I will present a selection of topics in non equilibrium statistical mechanics. The final selection will depend on the interests of the audience. After an introduction to large deviations theory, I will discuss its application in some specific frameworks like interacting particle systems and flows on graphs. The course is located at the intersection of theoretical physics, mathematical physics and mathematics. Priority will be given to developing and illustrating ideas and constructions rather than formal proofs.

Target audience Master and PhD students

Prerequisites Elements of probability theory

Syllabus Introduction to large deviations and statistical mechanics; Markov chains, stochastic interacting particle systems; Long time behavior, stationary non equilibrium states; Large deviations for the current, dynamic phase transitions, flows on networks; Time periodic systems, thermodynamic uncertainty relations. Scaling limits, quasipotential, macroscopic fluctuation theory.

Teacher CV 1994: Degree in Physics, University La Sapienza. Roma 1998: PhD in Mathematical Physics, SISSA Trieste 1998-2001: Postdoc fellow at University of S˜ao Paulo and University of Wien from 2001: University of L'Aquila where he is now Full Professor in Mathematical Physics Scientific interests: Statistical Mechanics and Probability Theory.

Textbooks/Bibliography Rassoul-Agha, Firas; Seppalainen, Timo A course on large deviations with an introduction to Gibbs measures. Graduate Studies in Mathematics, 162. American Mathematical Society. Den Hollander, Frank Large deviations. Fields Institute Monographs, 14. American Mathematical Society. Bertini, Lorenzo; De Sole, Alberto; Gabrielli, Davide; Jona-Lasinio, Giovanni; Landim, Claudio Macroscopic fluctuation theory Rev. Modern Phys. 87 (2015), no. 2, 593–636. Gabrielli, Davide Notes of the course

Statistical (Mechanical) Methods for Quantitative Finance

Proff. Claudio Tebaldi Fabrizio Lillo

Statistical (Mechanical) Methods for Finance I

Teacher
Claudio Tebaldi claudio.tebaldi@unibocconi.it

Motivation
The course presents an introduction to the basic notions underlying asset and derivative valuation with an emphasis on the applicative implications of these quantitative models and on the open problems.

Syllabus
- An Introduction to State Contingent Pricing Arbitrage and State Prices.
Risk Neutral Probabilities. Equilibrium and Pareto Optimality. State Price Beta Models.
- State Prices and Option Markets Valuation by replication. Local Volatility Models
Breeden-Litzenberger Formula VIX, the fear index and its construction
- Volatility, its Aggregation Properties and Long-Term Risks
Variance Modeling and Estimation. Turbulence and Real Space Renormalization group methods. Long-Term Risks and their impact on household portfolio choice. Black Swans and the cost of long-term volatility insurance.

Prerequisites
Probability Theory, Linear Algebra, PDE basics. Basic knowledge of Stochastic Calculus in discrete and continuous time is useful but not required.

Teaching material
Part 1. Darrell Duffie. Dynamic Asset Pricing Theory Chapter 1
Part 2 and 3 Lecture Notes and Research Papers distributed by the Instructor.

Teacher's CV
C.T. holds a MPhil and a PhD in Statistical Mechanics from SISSA Trieste, a MSc in Economics and Finance from Venice International University. He is a tenured faculty member of the Department of Finance, L. Bocconi University Milano. Associate professor in the field of Quantitative Methods for Economics, Finance and Insurance since 2011, holds the National Qualification for Full Professorship since 2015.

Black Holes

Teachers: Davide Cassani — INFN - davide.cassani@pd.infn.it
Gianguido Dall'Agata — UniPd - gianguido.dallagata@pd.infn.it

Motivations
Black holes are predicted by Einstein's general relativity and are believed to populate our universe. Although until a few years ago their existence was based on indirect observations, the detection of gravitational waves generated by a black hole merger has opened a new era of direct black hole observations in astrophysics. Black holes also play a central role in theoretical physics: they pose a number of deep puzzles and their full description requires a theory of quantum gravity. The course aims at providing the basic theoretical tools for understanding the physics of these fascinating objects.

Targeted audience
Students of "Laurea magistrale". Some basic notions of general relativity and quantum field theory are required.

Syllabus

The course is divided in two parts.

FIRST PART (G. Dall'Agata)
Introduction; Komar integrals; Schwarzschild black hole and gravitational collapse; Eddington-Finkelstein and Kruskal-Szekeres coordinates; surface gravity; Penrose diagrams; charged black hole; the extremal case; multi-centre solutions; imaging the shadow of a black hole; quasi-normal modes and GR tests from gravity waves.

SECOND PART (D. Cassani)
Kerr and Kerr-Newman black holes; Penrose process for energy extraction; the laws of black hole mechanics; Beckenstein-Hawking entropy; Hawking radiation and black hole evaporation; Euclidean approach to black hole thermodynamics; Hawking-Page phase transition; microstate counting (time permitting).

Teachers CV

Gianguido Dall'Agata — PhD. in Theoretical Physics in Turin (2000), then EU and DFG fellow at Humboldt Uni., Berlin, CERN fellow, CNRS associated researcher at ENS and Ecole Polytechnique Paris. Professor of Theoretical Physics in Padova since 2016. Sigrav Prize for Classical and Quantum Gravity 2008.

Davide Cassani — Degree in Physics at University of Pavia; PhD at Laboratoire de Physique Théorique de l'Ecole Normale Supérieure, Paris; postdoctoral positions at University of Padova and King's College London; Marie Curie and Lagrange fellow at LPTHE, Université Paris Sorbonne; researcher at Istituto Nazionale di Fisica Nucleare, sezione di Padova, Italy.

Textbooks/Bibliography

S. Carroll, "Spacetime and Geometry. An Introduction to General Relativity", Pearson 2013.
P. Townsend, "Black Holes" lecture notes, gr-qc/9707012.
Additional material provided during the course.

Signaling roles of metabolites

Teacher: Luca Scorrano – UniPD – luca.scorrano@unipd.it

Motivations

Organic molecules are used by living organisms to harness energy used by the cells (catabolism) or as building blocks for macromolecules that constitute the cellular frameworks (anabolism). Recently, we understood that their function extends to the ability to instruct cells on how to respond to the surrounding environment in a process termed “signaling”. This area is at the forefront of modern biomedical research and it intertwines with advanced analytical chemistry, offering a fresh perspective to understand disease pathogenesis and to identify new disease biomarkers.

Targeted audience

The course targets students of the class of Natural Science. The course asks for some very basic prerequisites in organic chemistry, analytical chemistry, biology that are in principle high school level. The teacher will develop the basic concepts of biochemistry, signaling and pathology during the course and tailor it to the a priori knowledge of the participating students.

Syllabus

The signaling molecules; their metabolic origin; how to measure them; their signaling effect; their role in disease: the example of cancer biology (from Warburg effect to pseudohypoxia); their potential use as biomarkers

Teacher CV

1996 MD, 2000 PhD, University of Padua. 2000-2003 HFSP postdoctoral fellow, DFCI-Harvard Medical School (Boston, MA, USA); 2003-2006 Assistant Telethon Scientist, Dulbecco-Telethon Institute at VIMM, Padua; 2006-2013 Full Professor, Dept. of Cell Physiology and Metabolism, University of Geneva Medical School (Switzerland). 2013-now, “Chiara Fama” Full Professor of Biochemistry, Dept. of Biology, University of Padua. Elected EMBO Member in 2011 and Academia Europaea Member in 2019. He proudly trained 97 exceptional postdoctoral fellows and PhD students, and received >13M€ of competitive grants from Italian, Swiss, US and European agencies. He published >150 papers, mostly on mitochondrial dynamics and interorganellar contact sites, his current research interests.

Textbooks/bibliography. N. Chandel “Navigating Metabolism” CSHL Press Reviews/papers distributed during lectures, ad hoc seminars by leading experts in the field

Knot Theory

Teachers: Domenico Fiorenza and Paolo Papi, Sapienza Università di Roma, fiorenza@mat.uniroma1.it, papi@mat.uniroma1.it

Motivations.

The course requires only a minimal mathematical background (linear algebra, basic analysis). The goal is to introduce the basic ideas of knot theory from a combinatorial point of view, with emphasis on the knot invariants mostly used in the applications to Physics and Chemistry.

Targeted audience: Second/Third year -year students in Mathematics, open also to students in Science (Physics, Biology, Chemistry).

Syllabus. Knots. Deformation. Polygonal and smooth knots. Torus knots. Topological symmetries. Links. Invariants. Pictures of links and projections. Diagrams. Some families of links. Crossing number. Invariants from oriented diagrams. Moves on diagrams. The classification problems. An introduction to the arithmetic of knots. Discovery of the Jones polynomial. The Kauffmann bracket. Properties of the bracket polynomial States of graphs and diagrams Adequate diagrams. Bounds on crossing number. Polynomial link invariants. The categorical approach: braided tensor categories, quantum groups, ribbon categories, invariants of 3-manifolds. Some optional arguments (depending on the background of the audience: spanning surfaces, matrix invariants, more on quantum groups).

Teacher CV.

Domenico Fiorenza is Associate Professor at Sapienza University of Rome from 2015. He got his Ph.D. degree in Mathematics at the University of Pisa in 2002. From 2002 to 2005 he has been PostDoc researcher in the University of Rome Tor Vergata and Sapienza; from 2005 to 2015 he has been Assistant Professor at Sapienza. His research is focused on the interactions between homotopical algebra, algebraic topology and theoretical physics. He is the author of 38 publications and has been presenting his research in several international conferences.

Paolo Papi is Full Professor at Sapienza University of Rome from 2017. He got his Ph.D. degree in Mathematics at the University of Pisa in 1994; from 1994 to 2000 he has been Assistant Professor at Sapienza and from 2000 to 2017 Associate Professor, again at Sapienza. His research interest regard Algebraic Combinatorics, with emphasis on roots systems, Invariant theory and representation theory of infinite dimensional Lie algebras, with emphasis on affine algebras and vertex algebras. He has supervised four Ph.D. students. He authored more than 55 publications, two volumes of proceedings and a monograph on knot theory.

Textbooks/bibliography.

C. Adams, The knot book.
B. Bakalov, A. Kirillov, Lectures on Tensor Categories and Modular Functors.
P. Cromwell, Knots and links.

Topics in sub-Riemannian geometry

Targeted audience. This lecture course is particularly directed to 4th and 5th year students in Mathematics and Physics and Engineering.

Teachers: Davide Barilari (1st part) Andrei Agrachev (2nd part)

Motivations : Sub-Riemannian geometry is the geometry of a world with nonholonomic constraints. In such a world, one can move, send and receive information only in certain admissible directions but eventually one can reach every position from any other. In the last two decades sub-Riemannian geometry has emerged as an independent research domain impacting on several areas of pure and applied mathematics, with applications to many areas such as quantum control, image reconstructions, robotics and PDEs.

Aim: Part 1: the first part of the course is mainly an introduction to the subject towards theory and motivating examples. We illustrate the relation with applications such as mechanics and image reconstruction. Part 2: The second part focuses on more advanced questions, providing students to recent progress in the field and some open questions.

Syllabus:

Part 1

Review of some differential geometry: Vector fields and differential equations, flows and Lie brackets. Theorems of Frobenius and Chow-Rashevskii. Applications to some problem in mechanics (e.g., problem of rolling spheres) and relation to some mathematical problems (e.g. isoperimetric problems) and physical ones (e.g. motion of a particle in a magnetic field). Sub-Riemannian distance. Metric completeness. Pontryagin extremals: description in terms of symplectic geometry and Hamiltonian formalism. Normal and abnormal extremals. Examples in dimension 3.

Part 2

The second part will focus on different questions around abnormal extremals, with discussions on more recent advances and open questions. Abnormal extremal trajectories are critical points of the endpoint map that sends an admissible trajectory to its endpoint. We will study the second variation of the endpoint map, characterize rigid and length-minimizing trajectories and discuss the structure of the sub-Riemannian distance near abnormal length-minimizer.

References

Agrachev, Barilari, Boscain, A Comprehensive Introduction to Sub-Riemannian geometry, Cambridge University Press 2019