Theoretical Physics MSc & Euromasters

Queen Mary University of London

This is an unofficial guide to the programmes, put together by Dr David Vegh (d.vegh@qmul.ac.uk)

Why study physics at QMUL?

When selecting a degree programme, it's vital to consider future career prospects. Pursuing a physics or astronomy degree not only involves learning mathematics, programming, and physics but also emphasizes problem-solving skills. Graduates are highly valued by employers for their technical proficiency, adaptability, and problem-solving abilities, making them sought-after across various industries. Moreover, studying physics offers immense satisfaction as it delves into understanding the Universe, from minuscule to enormous scales. Through research projects, students not only gain knowledge but also learn to expand it, offering exceptional career prospects.

We take great pride in the attributes our graduates acquire during their degree, which open doors to diverse and exceptional careers. These span research and development in various industries, as well as roles in software engineering, artificial intelligence, machine learning, finance, management, education, and academia.

Our MSc programmes are situated at Mile End Campus in East London, which boasts a range of facilities including libraries, workspaces, computing facilities, social hubs, creating a vibrant atmosphere. On-site, we offer state-of-the-art computing and teaching labs, including our recently refurbished telescope. Students can also engage with various societies, such as the physics society "PsiStar," which organizes social events, field trips, and special research talks. Additionally, there are numerous other societies catering to different cultural, artistic, and recreational interests.

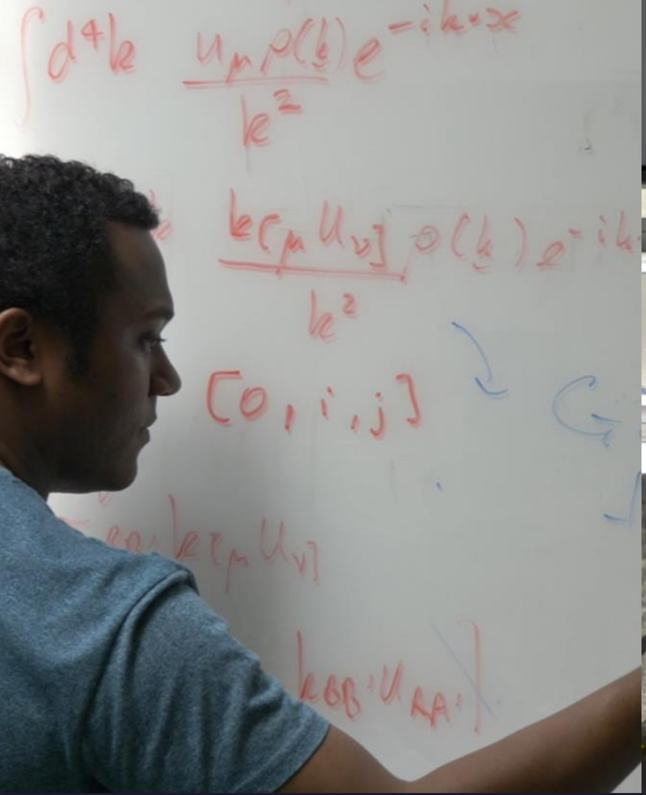
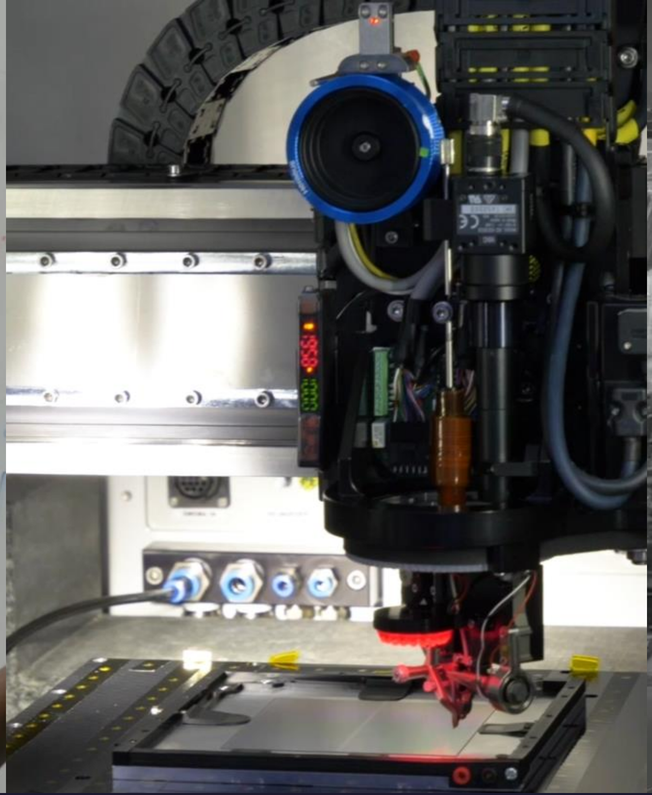
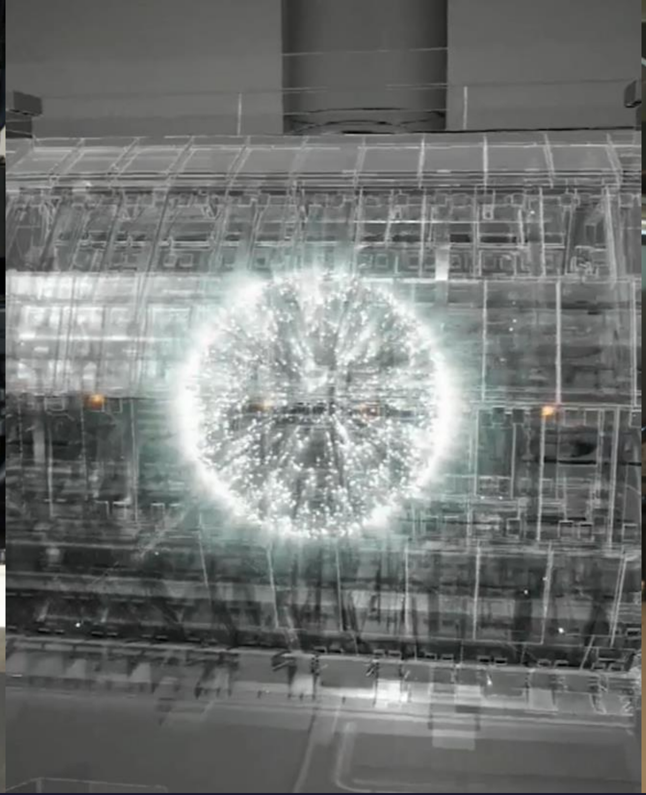
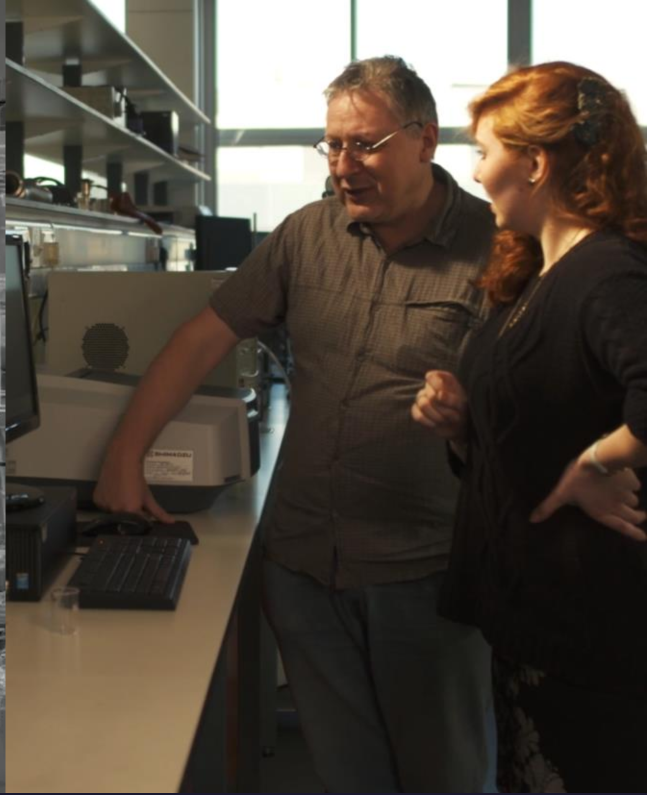
QMUL stands out as the most diverse university of its kind. The university has students from over 170 countries, representing diverse socio-economic backgrounds. Recognised for its efforts in improving social mobility, QMUL fosters a culturally rich community that offers a rewarding collegiate experience.

Research Excellence

Queen Mary has played a pivotal role in many of the greatest discoveries. It hosts world leading researchers who have made contributions to many areas in both theoretical and experimental physics, from spurring some of the superstring revolutions of the last few decades to actively participating in the discovery of the Higgs boson at the Large Hadron Collider.

In the MSc programme, students have the opportunity to work with leaders in diverse fields, spanning from theoretical to experimental subjects, such as quantum computation, machine learning, and more formal aspects such as the AdS/CFT correspondence. In many instances, students will have the chance to publish and work at the forefront of research.

Additionally, all students are assigned an academic advisor. This relationship is designed to provide support throughout the degree, offer guidance on module selections, serve as a point of contact for any issues, and assist in pursuing future career aspirations.

Introduction to the programmes

Physics MSc / Euromasters:

- 4 modules in the first semester
- 4 modules in the second semester
- Summer research project (Physics MSc)
  Full year research project (Euromasters)

Timeline (Theoretical Physics MSc)

- One compulsory module and seven elective taught modules are included in the curriculum, with four modules scheduled for the first semester and four for the second.
- The research project entails conducting an in-depth and independent investigation into a topic directly aligned with your interests and career objectives. This project is carried out during the spring and summer terms.

Timeline (Euromasters)

- Eight elective taught modules are offered, divided into four modules for the 1st semester and four for the 2nd semester.
- Research project: This component takes place during the second year of the programme.

If you choose to leave the MSc at the end of your first year without completing a research project, you may be awarded a Physics (Euromasters) PGDip.

Timeline

Research supervised by QMUL academic

4 modules

1st semester | 2nd semester | Summer project

4 modules

Physics MSc

vs.

Euromasters

4 modules

1st semester | 2nd semester | Full year research project

4 modules

Research supervised by QMUL academic

The modules

(a selection from a larger list)

Relativistic Waves & Quantum Fields

The module introduces quantum field theory, which explains the laws of Nature at the microscopic level.

The module starts by reviewing spacetime and its symmetries and the axioms of Einstein's special relativity. Lorentz transformations, generators of the Lorentz group and the Poincaré group are discussed in detail.

Klein-Gordon theory and its quantisation is discussed, along with symmetries and conservation laws via the example of the complex scalar field.

Further topics: Green's functions, propagators, T-products. Dirac equation and the quantisation of the Dirac field. Non-relativistic limit of the Dirac equation.

S-matrix, the Dyson expansion, and simple examples of Feynman diagrams.

$$iS_F(k) = i\frac{\not{k} + m}{k^2 - m^2 + i\varepsilon}$$

Advanced Quantum Field Theory

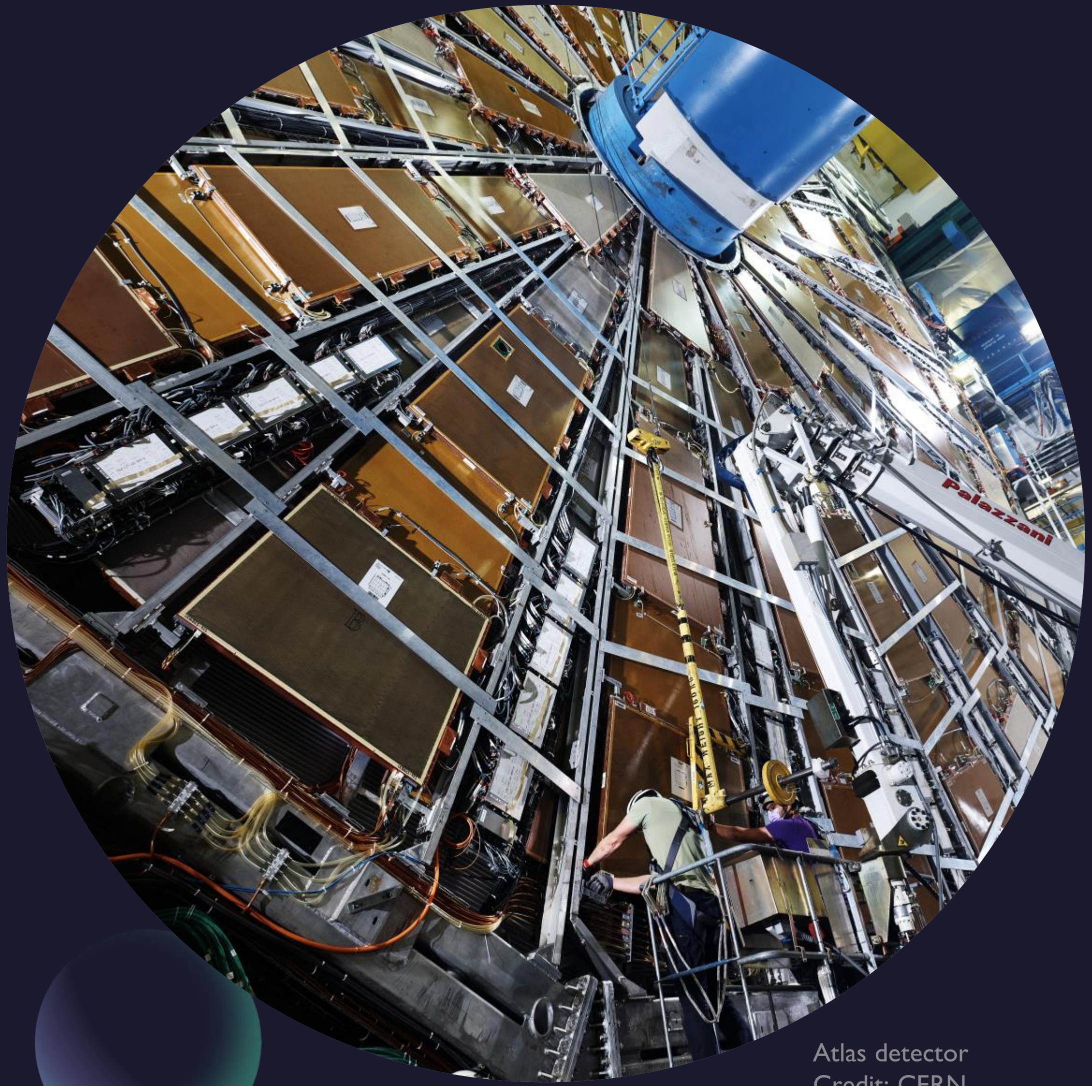
Building on the fundamental concepts of Quantum Field Theory introduced in Relativistic Waves and Quantum Fields, this course will cover the following topics:

Classical field theory and Noether's theorem, quantisation of free spin 0, 1/2 and 1 fields.

Perturbation Theory and Feynman diagrams:
Dyson formula and the S-matrix, in and out states, evaluation of S-matrix elements using Wick's theorem and LSZ reduction formula, formulation in terms of Feynman diagrams (part revision)

Quantum electrodynamics, Feynman diagrams for QED, simple scattering processes at tree level, cross sections, spin sums

Renormalisation of QED at one-loop level, regularisation (dimensional and Pauli-Villars), running coupling, corrections to electron anomalous moment.



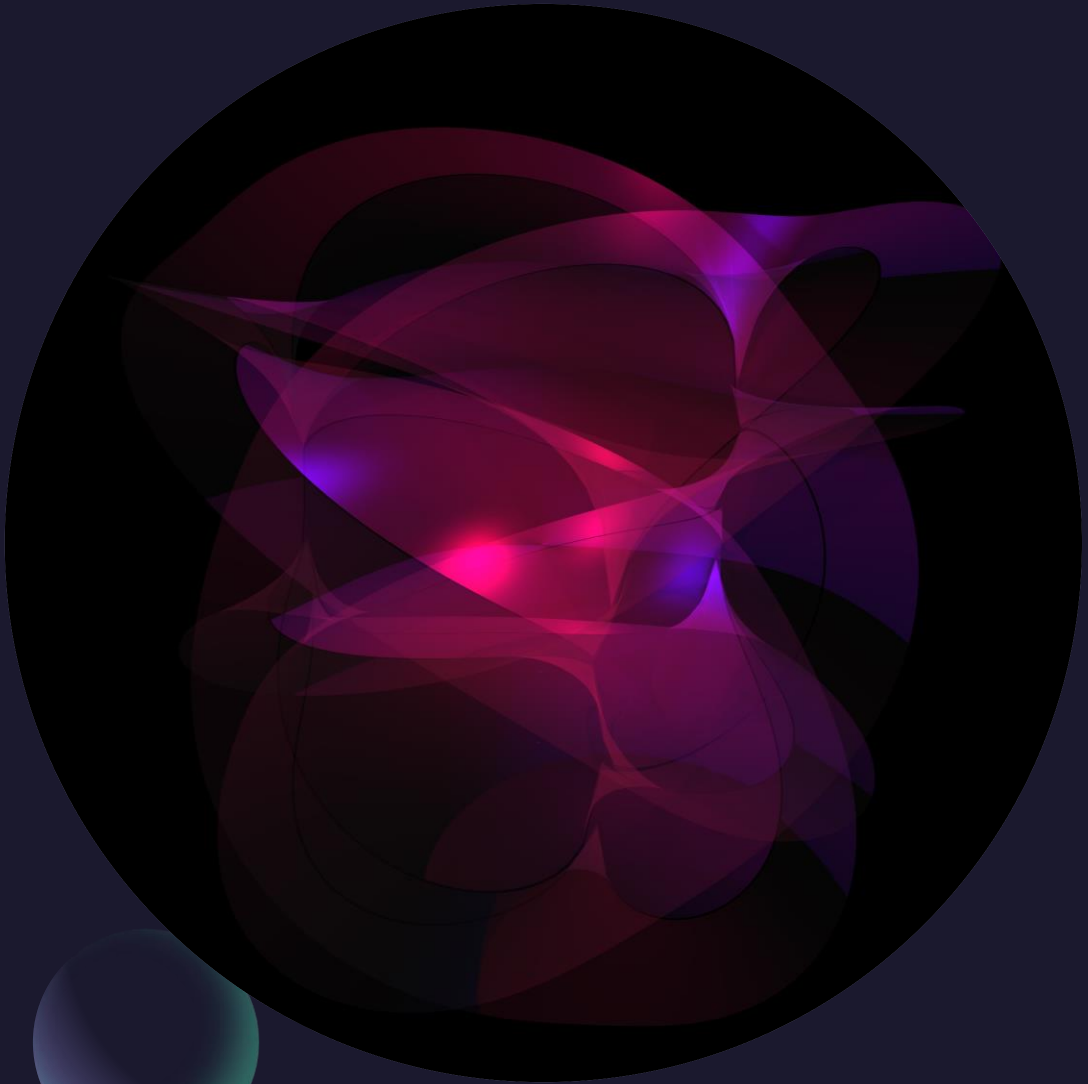
Atlas detector
Credit: CERN

Introduction to Strings & Branes

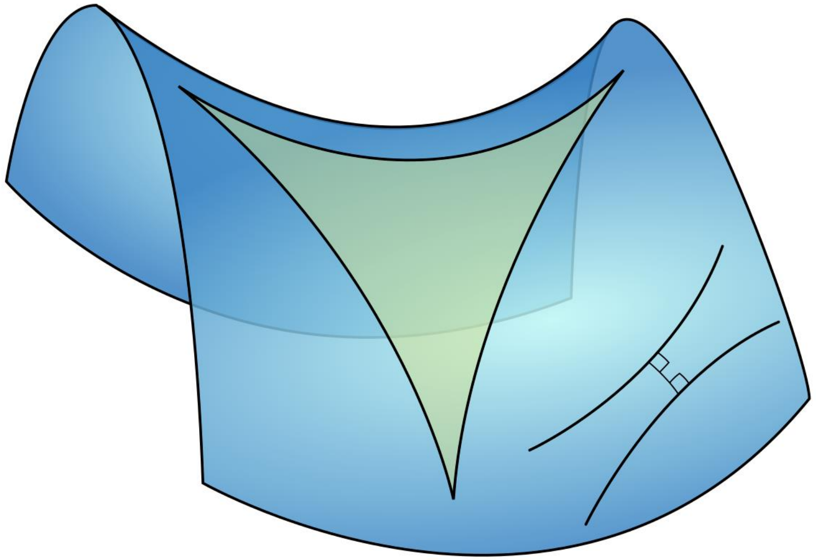
The module introduces the classical and quantum dynamics of point particles and strings in spacetime. It discusses bosonic string theory, the GSO projection, Type I and II superstrings. Higher dimensional objects e.g. D-branes are also described.

Important mathematics is introduced along the way, in addition to other tools, e.g. conformal field theories, which live on the worldsheet of the string and describe its embedding into spacetime.

Further topics include: bc ghosts, operator expansions and primary operators. String scattering amplitudes. T-duality.



Differential Geometry



The aim of this course is to provide the student with a number of advanced mathematical tools from differential geometry, essential for research in modern Theoretical Physics, and apply them to certain physical contexts.

The notation of differential forms will be introduced and the geometric aspects of gauge theory will be explored. Gravity will be interpreted as a gauge theory in this geometric setting. Manifolds will be introduced and studied, leading to the definition of fibre bundles.

Finally, we will explore the Dirac and 't Hooft-Polyakov monopoles and the Yang-Mills instanton, as well as their associated understanding in fibre bundle language.

Relativity & Gravitation

Einstein's theory of relativity is one of the pillars of modern physics and is currently enjoying a renaissance due to recent progress in cosmology and gravitational wave detection. This course is aimed at providing sufficient tools to understand the deep physics that underpins these advances, and to provide the foundational mathematics and physics required for more advanced study. This will begin with an introduction to differential geometry, before moving on to Einstein's gravitational field equations and their solutions. It will include the study of black hole physics and gravitational wave emission. In particular, you will be presented with:

An introduction to differential geometry. Einstein's theory of general relativity, including some exact solutions to the field equations of the theory. The formalism used for studying perturbative relativistic gravity, for use in the Solar System and for calculating the gravitational wave signals from inspiralling binaries. Some of the modern developments in general relativity, including the LIGO detection of gravitational waves.

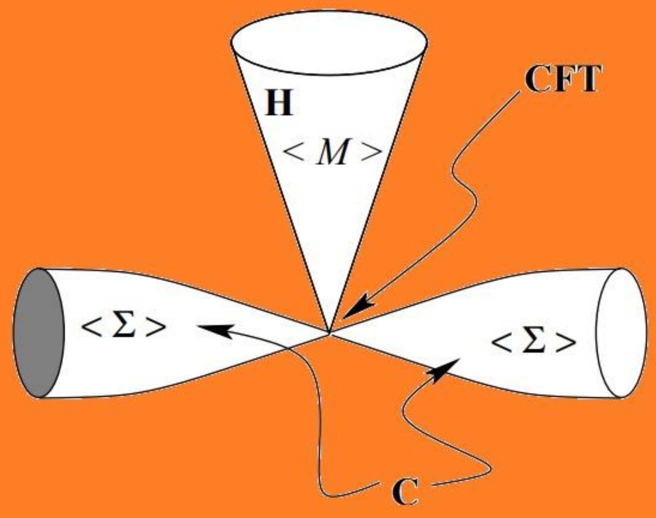
Supermassive black hole in galaxy M87
Credit: Event Horizon Telescope Collaboration 2019

Supersymmetric Methods

Starting with supersymmetric quantum mechanics as a toy model, the course covers the supersymmetry algebra, its representations, the Witten Index, and the resulting constraints on quantum dynamics.

We then move on to introduce supersymmetric field theories in three space-time dimensions consisting of scalars and fermions while giving a basic introduction to symmetry currents, the classical and quantum Wilsonian renormalisation group flow, moduli spaces, spurions, and non-renormalisation arguments.

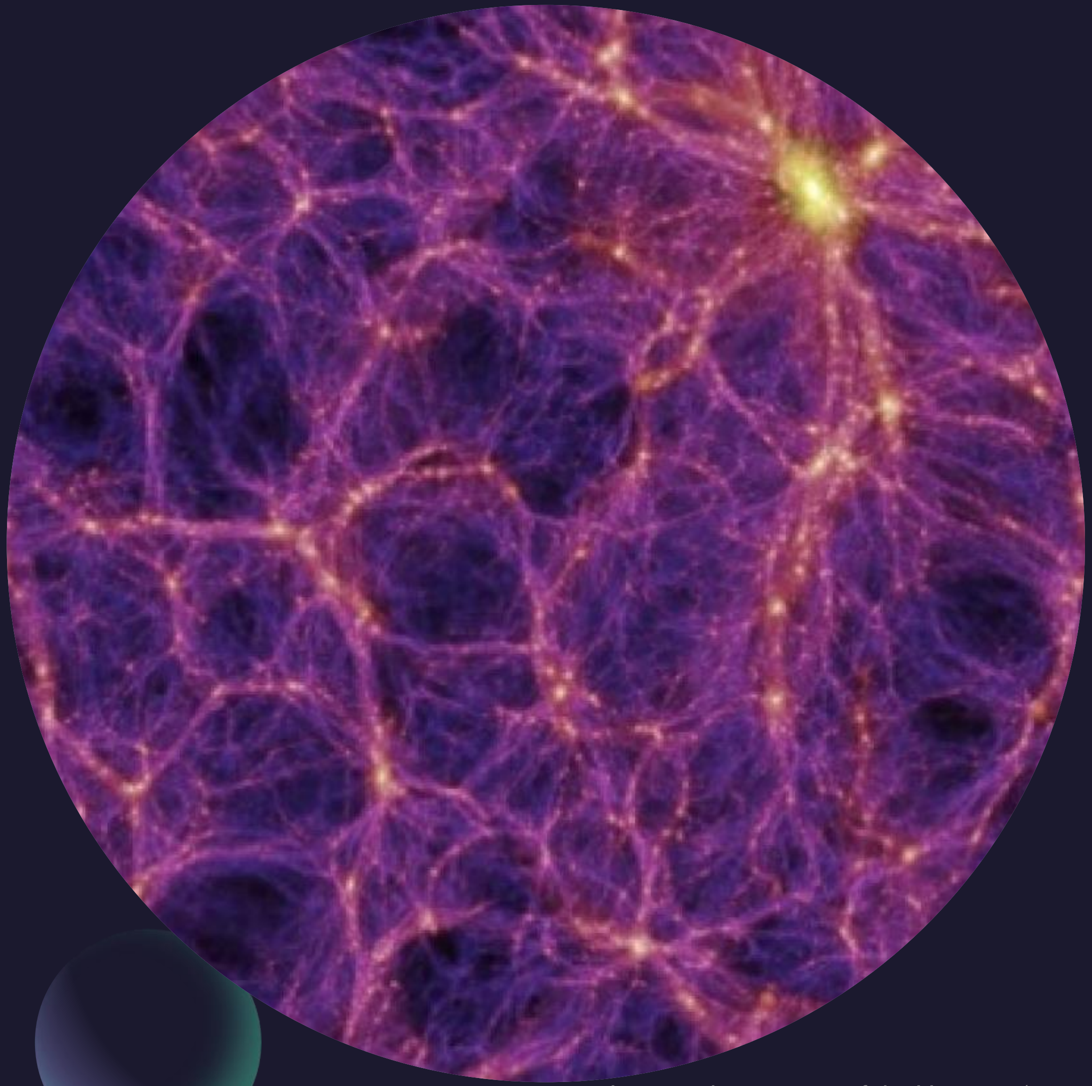
The course is designed to culminate with a study of dualities in three-dimensional supersymmetric abelian gauge theories. However, if time permits, we may also discuss basic aspects of dualities with broken supersymmetry, explicit applications of superspace techniques to condensed matter systems, or embeddings of some of our dualities in string theory.



Advanced Cosmology

Cosmological perturbation theory is an essential tool to understand the physics of the universe. Gravity is non-linear and each order in perturbation theory reveals different but complementary aspects of the underlying fully non-linear theory. Using linear, or first order, theory allows us, for example, to model the large-scale structure of the Universe.

Higher order theory can then be used to calculate higher order effects such as the generation of vorticity and primordial magnetic fields. The course provides an introduction to cosmological perturbation theory.



Large-scale structure of the Universe (part of a bigger image).
Credit: Volker Springel / Max Planck Institute For Astrophysics

Further questions?

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