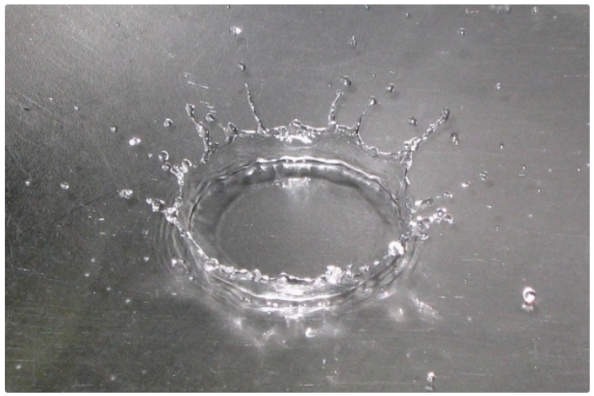
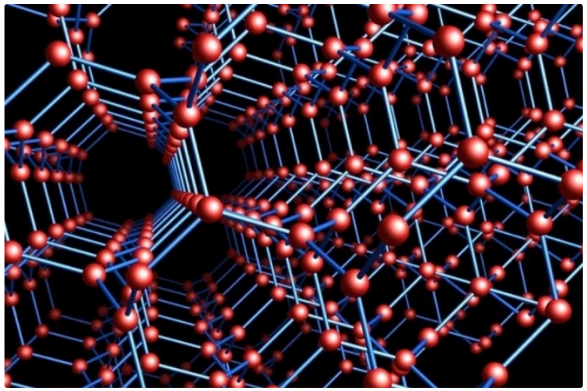
# Institute for Theoretical Physics UvA



## Soft Matter

Soft materials have exceptional mechanical, optical or functional properties and find applications in industrial sectors and society.

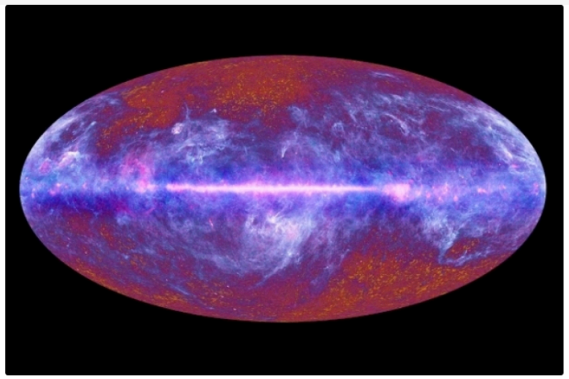


## Condensed Matter Theory

The research of the Condensed Matter Theory group focuses on collective effects in quantum and classical many-body systems.

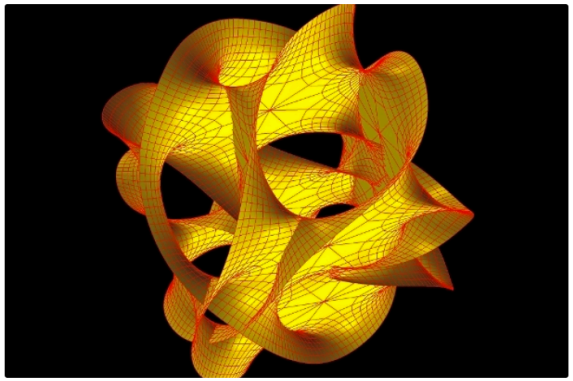
## History of Physics

The main focus of the History of Physics group, led by Prof. Jeroen van Dongen, is on the history of modern physics.



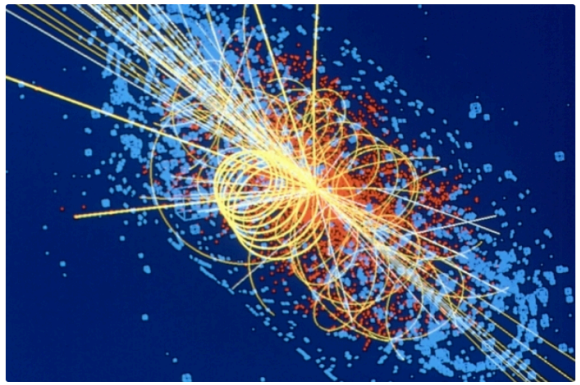
## GRAPPA

At GRAPPA, physicists tackle profound and challenging questions in astroparticle physics with advanced and innovative methods.



## String Theory

String theory aims to unify all particles and forces in nature, including gravity, in a way consistent with quantum mechanics and relativity.



## Particle Physics, Cosmology, Gauge Theory

This theoretical physics research group is led by prof. Eric Laenen. Research in this theme also takes place at the Nikhef theory group.

contact: Theo M. Nieuwenhuizen

Institute for Theoretical Physics

University of Amsterdam

# Fluids and Cosmology

Jácome Armas

Cosmological solutions for the evolution of the universe usually require the introduction of different fields such as scalars or the cosmological constant in order to describe inflation.

Modern hydrodynamics includes responses to curvature and by modelling matter as a fluid it is possible to find simple cosmological solutions that do not require exotic ingredients.

The idea of the project is to review some of the classical solutions and understand how these new methods can provide an equivalent description.

Based on arxiv:1907.04976 ; arxiv:1907.02974

# Lensing by Kerr black holes

Jácome Armas

The Kerr black hole is the basic model for black holes in astrophysics.

This project consists in studying how light rays bend around the horizon of the black hole (lensing) and how photon-rings are created.

In order to do so, one must understand and study null geodesics around the Kerr black hole, that is, one must study the paths followed by light rays that reach distant observers.

Based on arxiv:1910.12881; arxiv:1910.12873; arxiv:1906.00873

# Instabilities of spinning higher-dimensional black holes

Jácome Armas

Black holes in higher-dimensions both in Einstein gravity and in string theory behave in many ways like fluids or elastic membranes.

Fluids and elastic materials when slightly perturbed propagate sound waves and the way they propagate can give hints towards their stability.

This project deals with the hydrodynamic/elastic description of spinning black holes and how to derive the propagation of these waves.

Based on: https://arxiv.org/abs/1901.09369

# Topologie in mechanische metamaterialen

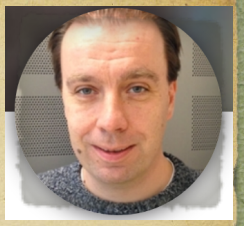
Jasper
van Wezel

Naast symmetrie is topologie de afgelopen 20 jaar naar voren gekomen als een manier om nieuwe fases van materialen en fase-overgangen tussen verschillende fases te bewerkstelligen.

Recent is gebleken dat veel van dit soort nieuwe fases ook (of zelfs gemakkelijker) voorkomt in zogenaamde metamaterialen, die zijn opgebouwd uit macroscopische blokken in plaats van atomen.

In dit project bestuderen we theoretisch de eigenschappen van zo'n topologisch metamateriaal.

# Phases of matrix models



Marcel Vonk

Matrix models (also known as matrix integrals) are interesting toy models for quantum field theories. The eigenvalues of the matrices behave like fermionic particles in a potential that can be arbitrarily chosen.

For the Mexican hat ("Higgs") potential, it is known that the model has an interesting phase structure where 'cuts' of eigenvalues can join, separate, or even form tree-like structures. However, other potentials have not been studied much.

In this mathematical physics project, we will investigate whether similar (and/or other) phase transitions occur in matrix models with other potentials.

The project involves analytic work as well as Mathematica computations.

# Finite-size scaling analysis of 2D classical spin systems using tensor networks

Philippe Corboz

The partition function of a 2D classical spin system on a square lattice can be represented as a tensor network made of rank-4 tensors. Thermodynamics quantities can be computed directly by a contraction of this network.

The goal of this project is to develop an efficient scheme for finite 2D periodic lattices and apply this approach to study 2D critical phenomena using a finite-size scaling analysis.

Requirements: Knowledge in statistical physics and programming skills

# CP violation in the Standard Model

Wouter
Waalewijn

The breaking of the combined charge conjugation-parity (CP) symmetry was observed in kaons a long time ago (Nobel prize 1980).
While CP violation was controversial at that time, it is actually essential for observed the matter-antimatter asymmetry in our universe.

It was realized that CP violation in the Standard Model requires three generations of fermions (Nobel prize 2008), before this third generation was discovered.

Goals of this project: study these important results, investigate CP violation in mesons, and the strong CP problem.

# Perturbation theory to all orders!

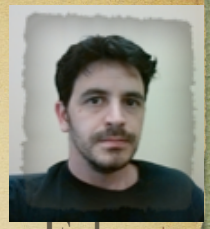
Wouter Waalewijn

The emission of photons by an electrically-charged particle is enhanced when the emitted photon has low energy (soft) or is moving almost parallel to the particle (collinear).
Because the perturbative corrections are large in these limits, it is insufficient to work to some fixed order in the coupling.

Interestingly, one can capture the dominant effect of these emissions to all orders in perturbation theory, by showing that the matrix elements and phase-space integrals of soft and collinear emissions factorize from the matrix element and phase space for the rest of the process.

Goals of this project: study this factorization for quantum electrodynamics and quantum chromodynamics, and use it to perform an all-orders calculation for a specific observable.

# The mechanics of gels



Edan Lerner

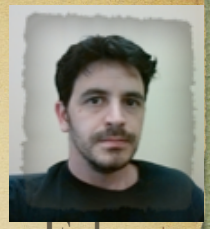
The mechanics of gels: in this project we will study an interesting model colloidal system that forms an **equilibrium gel** upon cooling.

We will investigate how the gel's structure evolves upon cooling, and study this system's elastic and rheological properties.

**Solid programming experience is essential for this project.**

Reference: F. Sciortino, P. Tartaglia, and E. Zaccarelli,
*One-Dimensional Cluster Growth and Branching Gels in Colloidal Systems with Short-Range Depletion Attraction and Screened Electrostatic Repulsion*,
J. Phys. Chem. B 109, 21942 (2005)

# Two-dimensional glasses under hexagonal periodic boundary conditions



Edan Lerner

In this project we will investigate the possible effect of box geometry on the vibrational properties of various amorphous solids.

In particular, we will ask whether box shape can induce an anisotropy in **micromechanical** observables.

**Solid programming experience is essential for this project.**

# Qubitization

Kareljan
Schoutens

Eén van de taken die een quantumcomputer snel kan uitvoeren is het bepalen van de eigenwaarde van een unitaire operator op een gegeven eigenvector  (“quantum phase estimation”).

Als die operator de evolutie-operator U is voor een gegeven Hamiltoniaan, dan is het nodig U middels een quantumcircuit te genereren. Hiervoor is door Low en Chuang een techniek voorgesteld met als naam *qubitization*.

In dit project bestuderen we deze techniek, en een aantal recente extensies, en passen die toe op een eenvoudige modellen voor gecorreleerde elektronen.

# Dynamics of quantum measurement and the measurement problem

Theo Nieuwenhuizen

In textbooks quantum measurement is treated by postulates, but in the reality of a laboratory it deals with the dynamical interaction of the tested system and the macroscopic apparatus.

A rich but treatable model exists, which exhibits 3 dynamical regimes: disappearance of off-diagonal terms; registration; stabilisation of sub-ensembles.

This approach allows to solve the *quantum measurement problem*, that is, to describe individual measurements within the quantum formalism.

It is based on arXiv:1107.2138; arXiv:1303.7257

# Heating of dark matter by baryons

Theo
Nieuwenhuizen

A model has been proposed in which baryons heat the dark matter in galaxies.
This allows to explain observed properties of their rotation curves.

It offers a dynamical connection to the so-called Modified Newtonian Dynamics.
In that theory, the Newton force falls off only as $1/r$ at large $r$,
which works well in practice.

based on arXiv:1912.07626