# EUROPEAN SCIENCE FOUNDATION

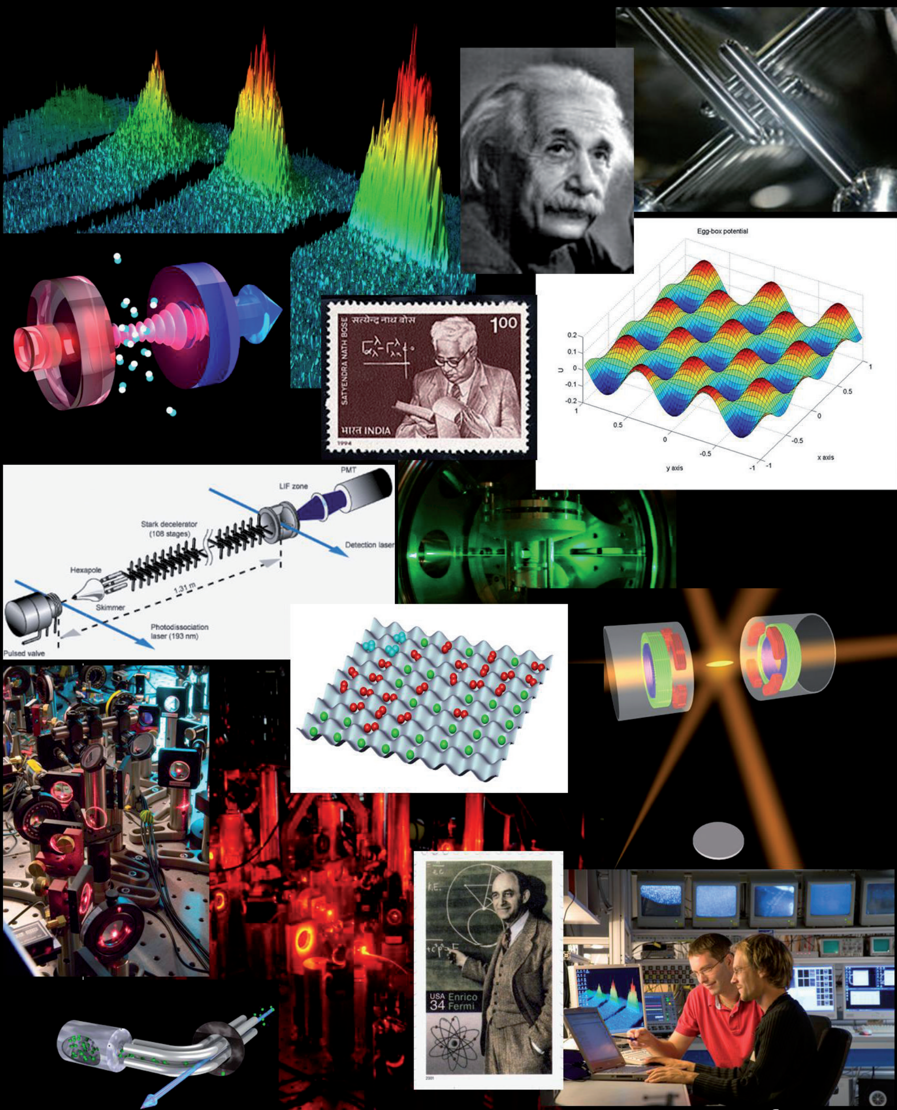
SETTING SCIENCE AGENDAS FOR EUROPE

## EUROCORES Programme

European Collaborative Research

# EuroQUAM

## Cold Quantum Matter

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# Cold Quantum Matter (EuroQUAM)

The field of quantum matter is complex and draws on atomic and optical physics, chemical physics and physical chemistry, plasma physics, statistical physics, solid-state physics and quantum chemistry. Although the field is driven by rapid advances in experimental capabilities, theoretical work is essential to guide experiments and explain their results. The EuroQUAM programme provides vital opportunities for scientists from different disciplines and countries to collaborate, with particular attention to collaborations between experiment and theory.

In Quantum Matter all the constituent atoms and molecules are in a single quantum state and behave coherently as a single quantum object. It typically exists at temperatures less than one millionth of a degree above absolute zero. In the long term, quantum matter is expected to have applications in diverse areas ranging from high-precision measurement to quantum information.

The first form of quantum matter to be produced were Bose-Einstein condensates (BEC), which were created in dilute atomic gases in 1995. Since then, there have been enormous advances in our ability to produce and manipulate quantum matter. Many completely new physical phenomena have emerged, and the first applications (such as atomic interferometry and improved atomic clocks) have been established. The interest in quantum matter is now spreading to other areas, and new phases of matter are emerging in molecular systems and plasmas.

# List of funded Collaborative Research Projects (CRPs)

## Cavity-Mediated Molecular Cooling (CMMC)

(CSIC-MEC, DFG, EPSRC, FNU, FWF)

Cavity-mediated cooling has emerged as the only general technique with the potential to cool molecular species down to the microkelvin temperatures needed for quantum coherence and degeneracy. The CMMC projects bring together leading theoreticians and experimentalists, including the technique's inventors and experimental pioneers, to develop it into a truly practical technique. Four major experiments will explore a spectrum of complementary configurations, while a comprehensive theoretical programme examines the underlying mechanisms and identifies the best routes to practicality. By extending cavity-mediated cooling to molecules, we aim to enable new realms of quantum coherent molecular physics and chemistry.


**Project Leader:**

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## Collisions of Cold Polar Molecules (CoPoMol)

(EPSRC, DFG, MNII)

CoPoMol brings together leading experimental and theoretical groups to contribute to one of the key objectives of EuroQUAM, achieving quantum degeneracy for polar molecules. It is already possible to cool polar molecules to temperatures around 10 to 100 milliKelvin. However, quantum degeneracy requires considerably lower temperatures. Sympathetic cooling, in which the molecules are cooled by contact with ultracold atoms is a very promising approach for achieving the required sub-microKelvin temperatures. The CoPoMol project will investigate the use of sympathetic cooling for polar molecules and will explore collisions between pairs of polar molecules.

### Project Leader:

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## Controlled Interactions in Quantum Gases of Metastable Atoms (CIGMA)

(CNRS/IFRAF, CNR, DFG, MNII)

CIGMA focuses on 4 lines of research: the search for long-range correlation effects in Bose and Fermi gases; interaction of atoms in optical lattices and dipole traps; the search for new interaction effects such as Feshbach resonances in metastable gases and their control; and the metrology in ultracold metastable atoms. Two atomic species used (helium and neon) provide bosonic and fermionic isotopes as well as hetero-nuclear mixtures of different isotopes.

### Project Leader:

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## Fermionic Mixtures of Ultracold Atoms: Pairing, Superfluidity, and Quantum Phases (FerMix)

(AKA, CNR, CNRS, DFG, FWF, MEC)

Ultracold Fermi gases are at the heart of an emerging research field on strongly interacting quantum matter. FerMix focuses on these by combining strongly interconnected individual projects of leading European researchers with a balance of theoretical and experimental activities. The project has four main objectives (i) preparation of strongly interacting and strongly correlated systems, (ii) studies of new pairing and interaction phenomena, (iii) exploration of novel regimes of superfluidity, and (iv) studies of novel quantum phases in optical lattices.


### Project Leader:

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## Quantum-Degenerate Dipolar Gases of Bialkali Molecules (QUDIPMOL)

(CNR, CNRS, DFG, EPSRC, FWF, GAČR)

QUDIPMOL brings together five experimental and four theoretical groups with complementary expertise. The aim is the creation, understanding and control of a dipolar quantum gas formed by heteronuclear bialkali molecules. Ideally, molecules in the gas are characterized by single, identical rotational, vibrational and translational quantum state, achieved by synthesizing the molecules from atomic quantum gases using photoassociation and Feshbach linking. Various scattering methods will be investigated for the control of molecular collisions in a many-body system.


### Project Leader:

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## Quantum Simulation using Cold Atoms in Optical Lattices (DQS)

(CNR, DFG, EPSRC, FWF)

The aim of DQS is to engineer the properties of ultracold atoms, and molecules, in optical lattices and use these precisely controlled many-body systems to model important strongly-correlated systems from Condensed Matter Physics (CMP). Optical-lattice experiments thus function as 'analogue' quantum computers, and allow exploration of physical regimes inaccessible in CMP systems. The ultimate vision is to develop a complete 'toolbox' of methods for the direct quantum simulation of strongly-correlated systems.


**Project Leader:**

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The aim of the European Collaborative Research (EUROCORES) Scheme is to enable researchers in different European countries to develop collaboration and scientific synergy in areas where European scale and scope are required to reach the critical mass necessary for top class science in a global context.
The scheme provides a flexible framework which allows national basic research funding and performing organisations to join forces to support excellent European research in and across all scientific areas.
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**www.esf.org/eurocores**

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*Academy of Finland,* Finland

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*National Centre for Scientific Research,* France

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France

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Poland

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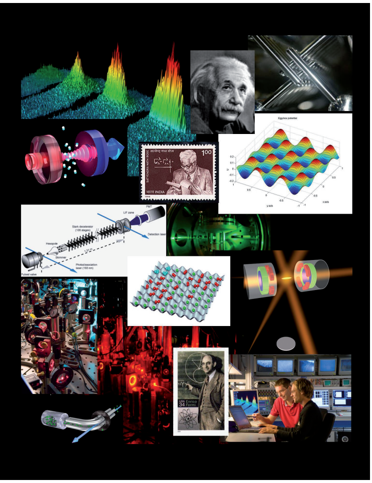

# EuroQUAM
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