Dipolar Quantum Gases

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Center for Ultracold Atoms and Quantum Gases, IExP and IQOQI, Innsbruck

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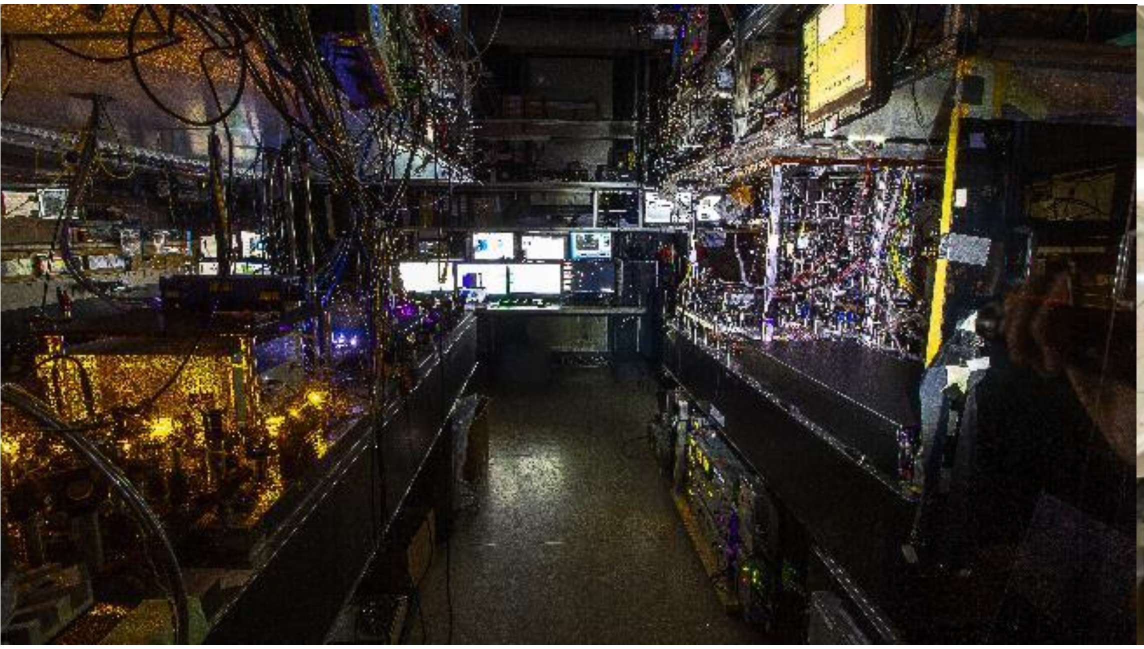

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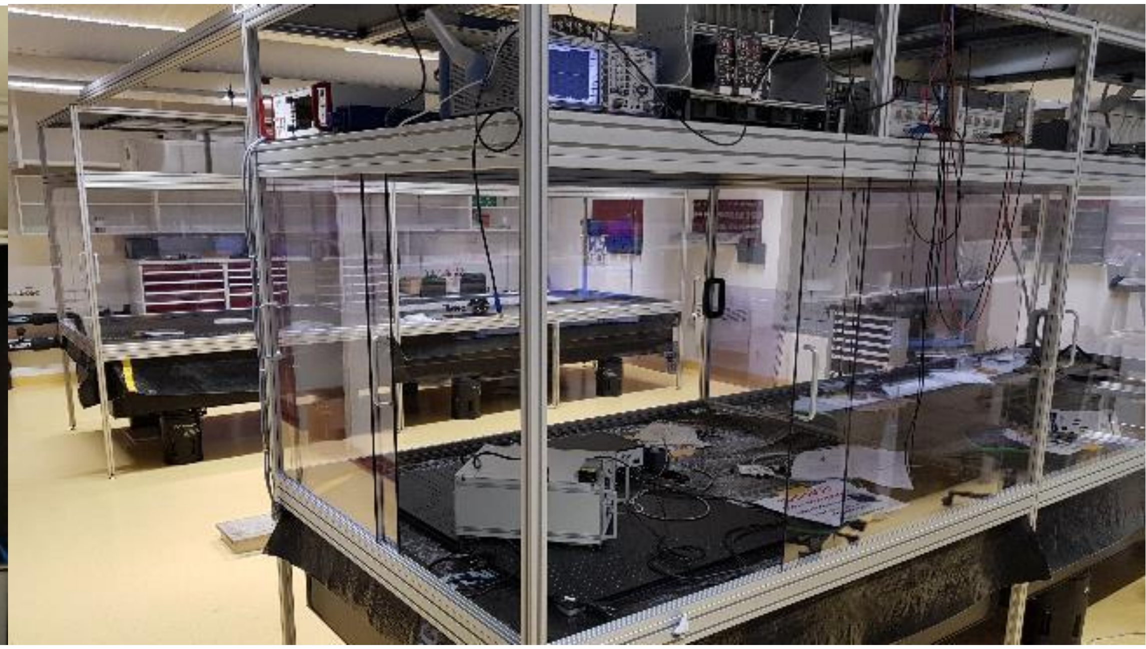
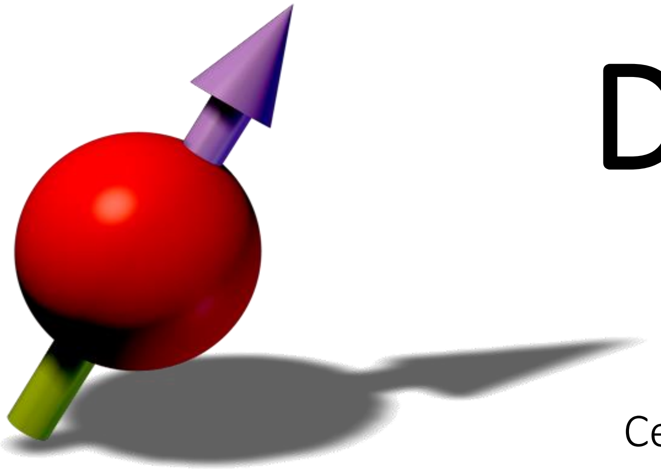


PI: Prof. Francesca Ferlaino

2 Post-Docs
10 PhD-Students
4 Master-students

YOU?

Senior Scientist: Dr. Manfred Mark



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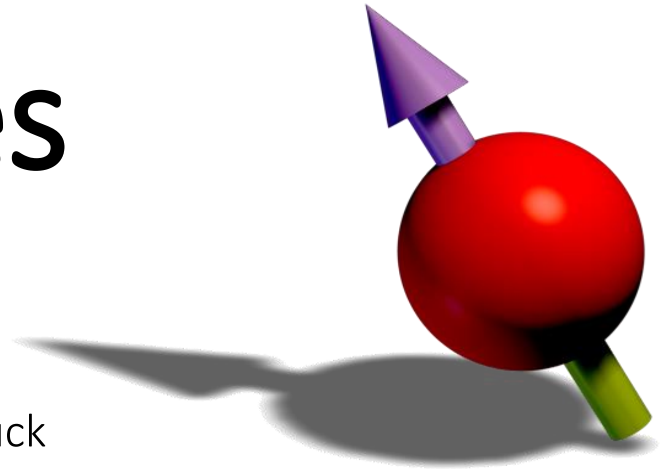

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PHYSICAL REVIEW RESEARCH

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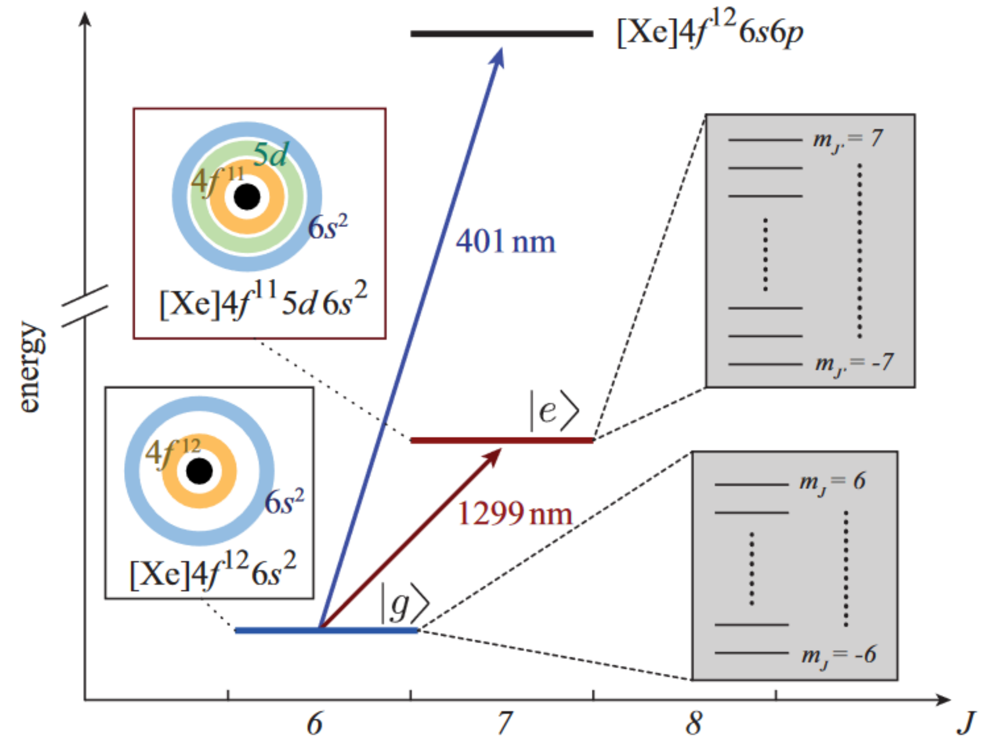
Observation of a narrow inner-shell orbital transition in atomic erbium at 1299 nm

A. Patscheider, B. Yang, G. Natale, D. Petter, L. Chomaz, M. J. Mark, G. Hovhannesyan, M. Lepers, and F. Ferlaino

Phys. Rev. Research **3**, 033256 – Published 17 September 2021

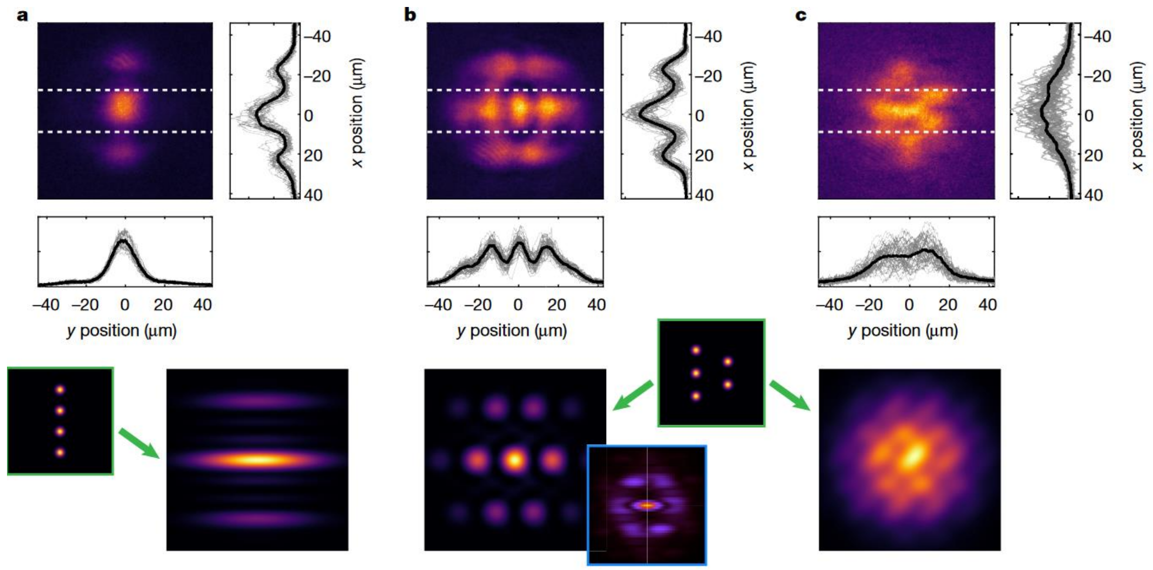


nature

Article | Published: 18 August 2021

Two-dimensional supersolidity in a dipolar quantum gas

Matthew A. Norcia, Claudia Politi, Lauritz Klaus, Elena Poli, Maximilian Sohmen, Manfred J. Mark, Russell N. Bisset, Luis Santos & Francesca Ferlaino



PHYSICAL REVIEW RESEARCH

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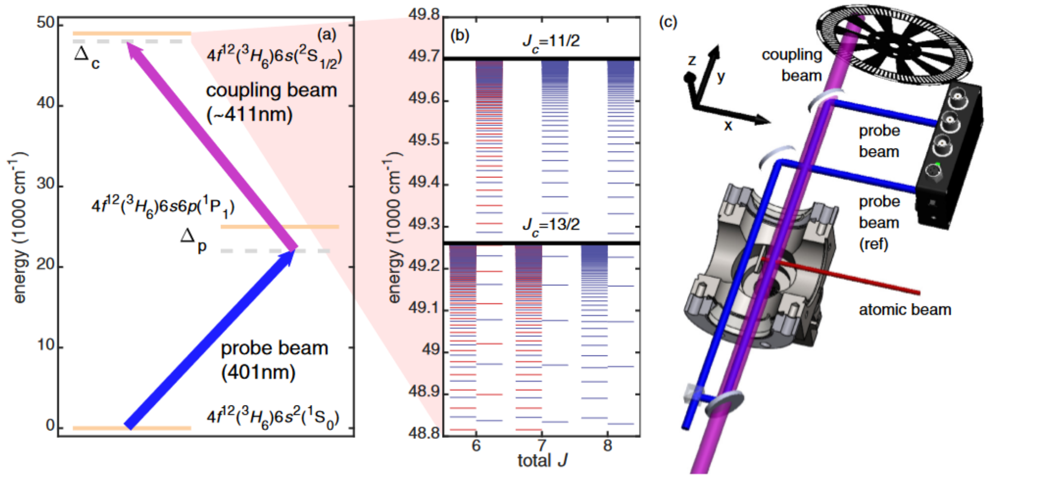
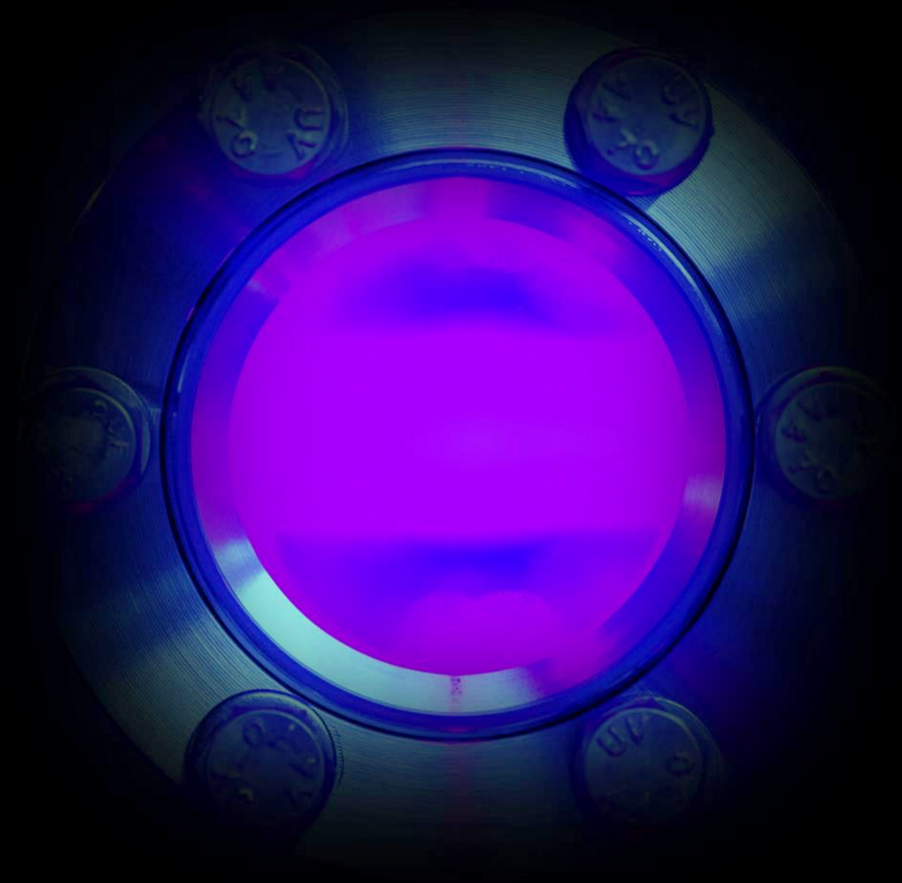
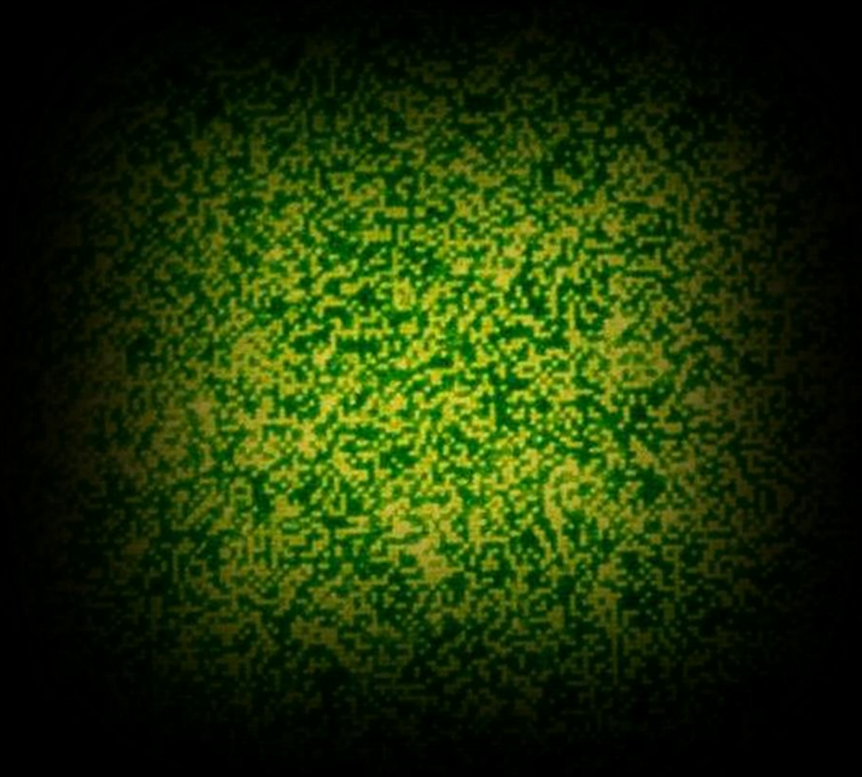
Spectroscopy of Rydberg states in erbium using electromagnetically induced transparency

A. Trautmann, M. J. Mark, P. Ilzhöfer, H. Edri, A. El Arrach, J. G. Maloberti, C. H. Greene, F. Robicheaux, and F. Ferlaino

Phys. Rev. Research **3**, 033165 – Published 19 August 2021







Bachelor Projects

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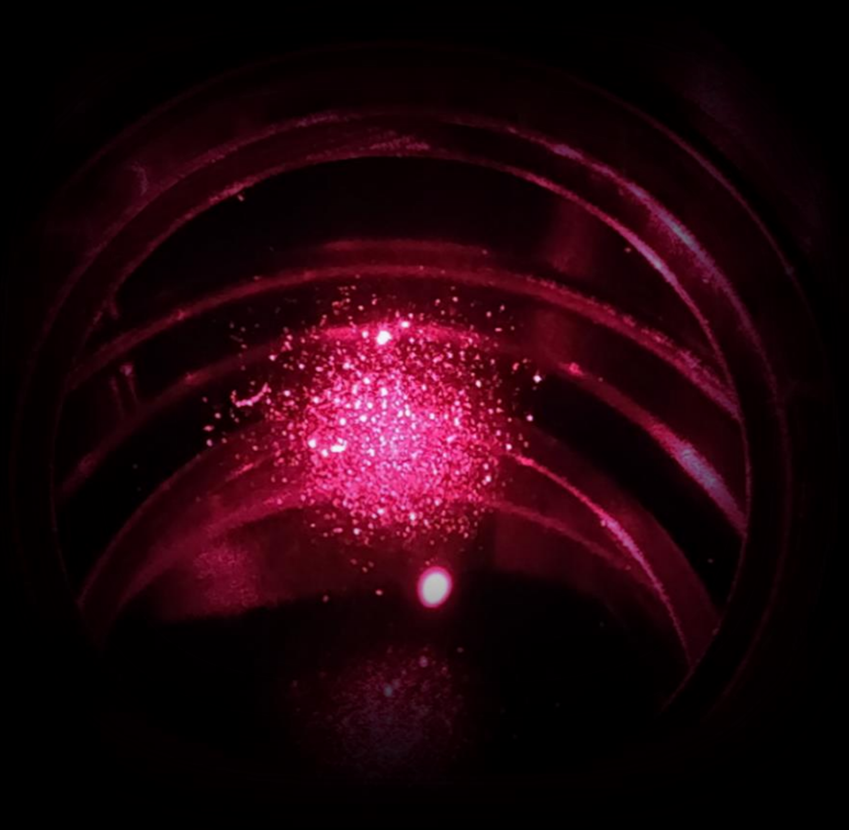
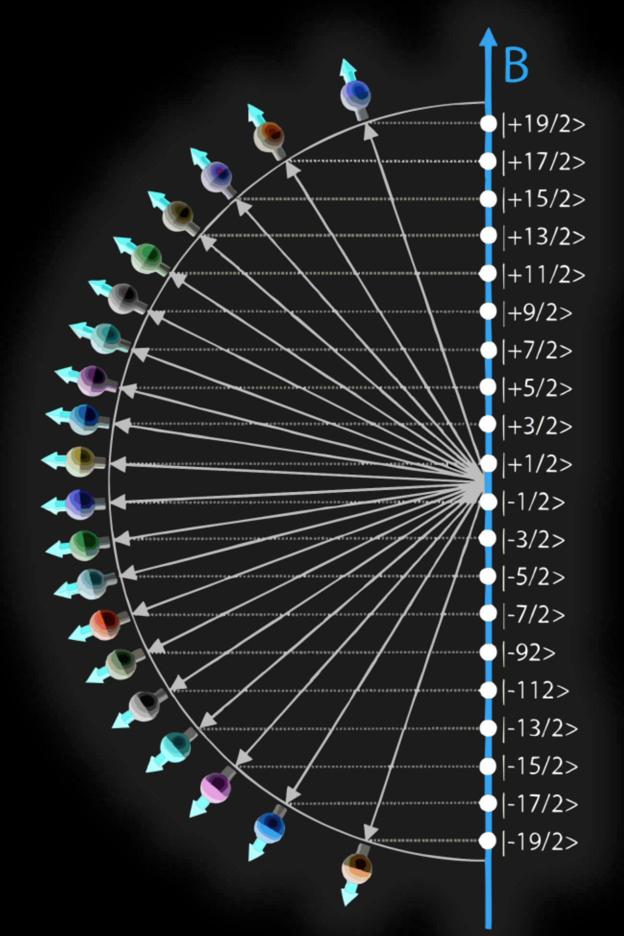


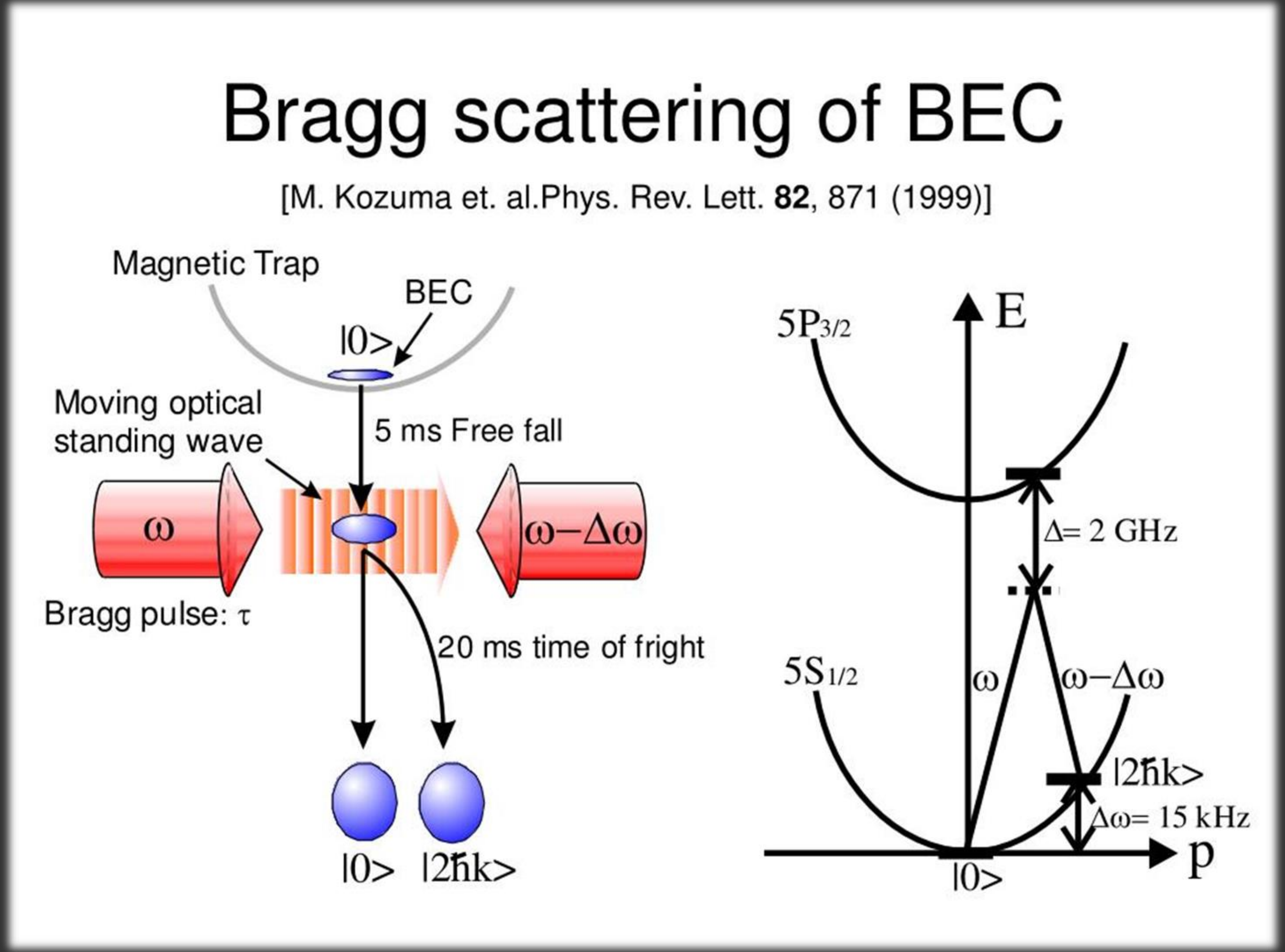


Bachelor Project

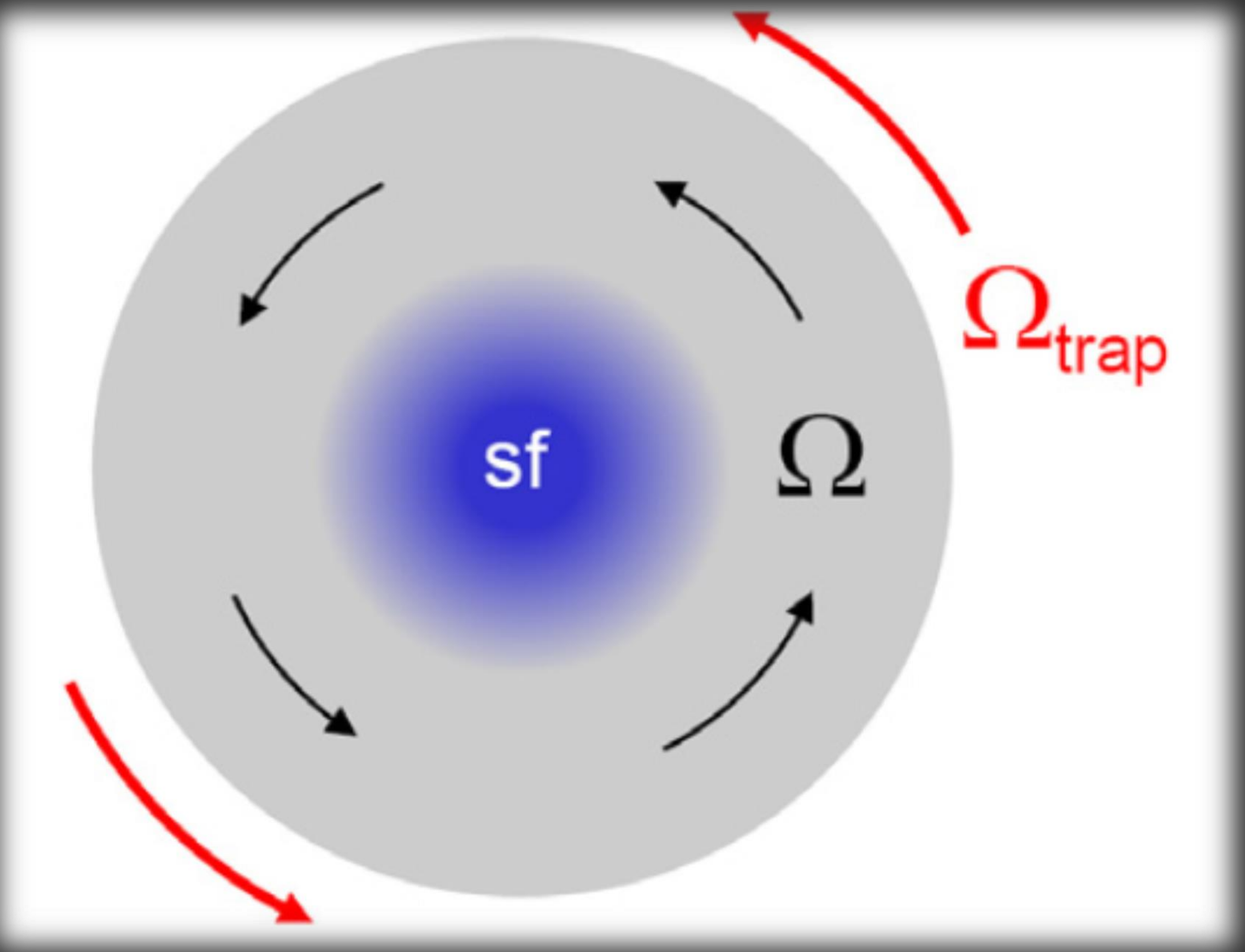
1. Elementary excitations : testing 1940's theory via photon Bragg scattering on gaseous Bose-Einstein condensates

Reaching ultralow temperatures, the quantum nature of a large assembly of particles becomes manifest macroscopically and a phase transition to a quantum degenerate state occurs. For bosonic particles, a Bose-Einstein condensate (BEC) is formed. While interparticle interactions are not needed for a BEC to form, they will lead to superfluidity. The understanding of these effects traces back to Landau's works in the 1940's on elementary excitations, i.e. intrinsic modes of oscillation on top of the quantum fluid. Landau's picture was substantiated by Bogoliubov. The advent of ultracold gases in experiments hence directly enables us to test Bogoliubov theory in a clean setting. A powerful technique to test Bogoliubov theory on quantum gases relies on Bragg scattering, using potentials created by light. Over the years, Bragg spectroscopy has been widely used in cold-atom experiments demonstrating effects predicted by Bogoliubov as well as others.

This bachelor thesis should work out the basic description of quantum Bose gases and their elementary excitation within the Bogoliubov theory, the concept of Bragg scattering excitation and its various implementations on ultracold atom experiments. In addition, software implementation of tunable Bragg spectroscopy laser beams using a Digital Micromirror Device can be performed within the framework of an optical laboratory internship.



For more information, contact **Francesca Ferlaino** (francesca.ferlaino@uibk.ac.at)



Bachelor Project

2. Is it really superfluid? The challenge of testing superfluidity in ultracold quantum gases

For a long time, the only known superfluid in nature was Helium liquid. The fascinating ability of the helium superfluid to flow without any friction has stunned scientists all around the words. In 1995, scientists have produced in laboratory a new system: quantum gases of ultracold neutral atoms. Central to the understanding of the physics of ultracold gases are the concepts of Bose-Einstein condensation and superfluidity. The two concepts have been conceptually linked ever since the discovery of superfluidity in liquid helium in 1937, but they are nevertheless clearly distinct and their exact quantitative connection is often elusive or given for granted.

The Bachelorarbeit will focus on few experimental techniques employed to study superfluidity in Bose of ultracold atoms in search of unambiguous evidences of superfluidity. Particular emphasis will be given to superflow and non-classical moment of inertia.

For more information, contact **Francesca Ferlaino** (francesca.ferlaino@uibk.ac.at)

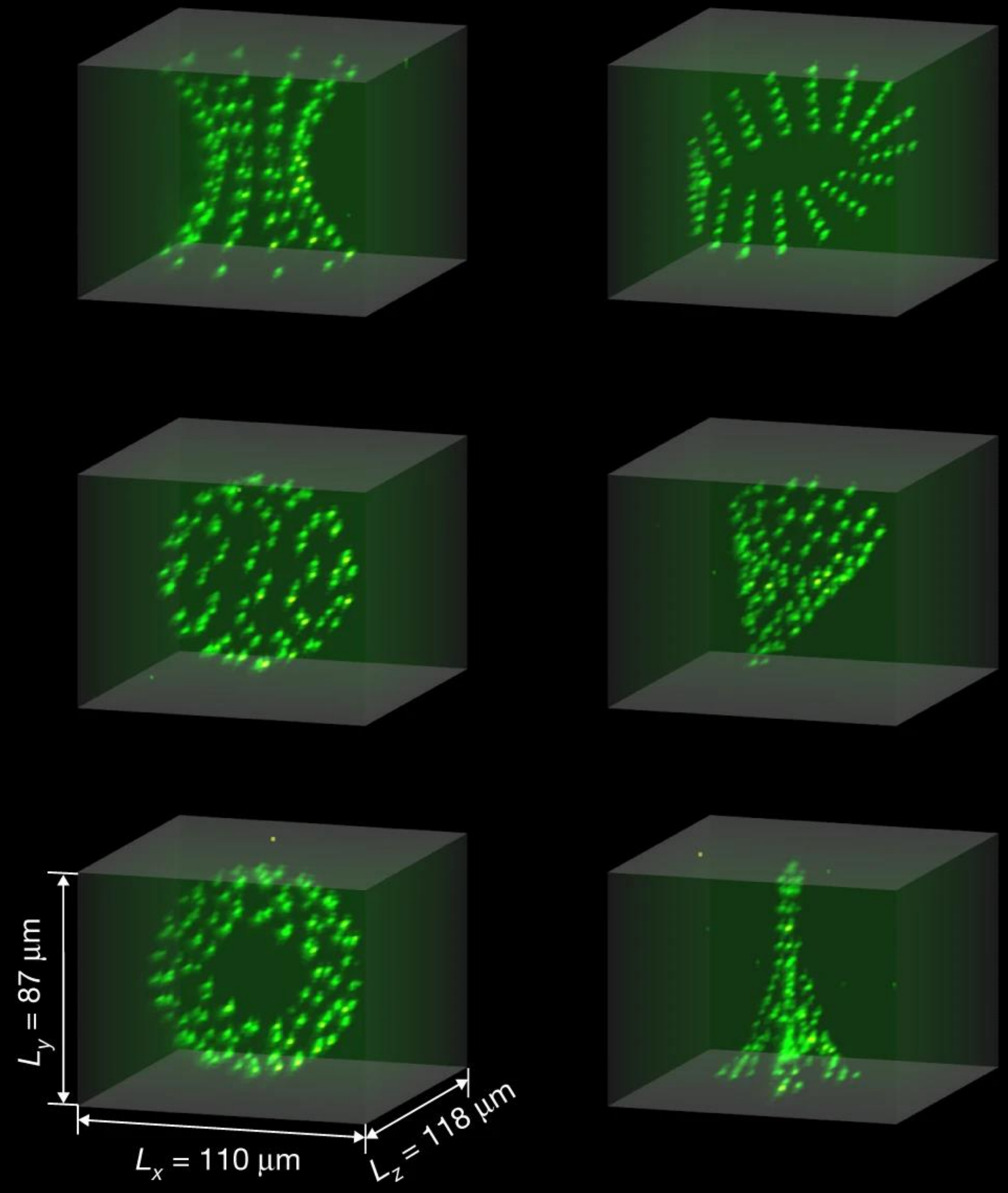
Bachelor Project

3. Quantum simulation with neutral atoms in optical tweezers

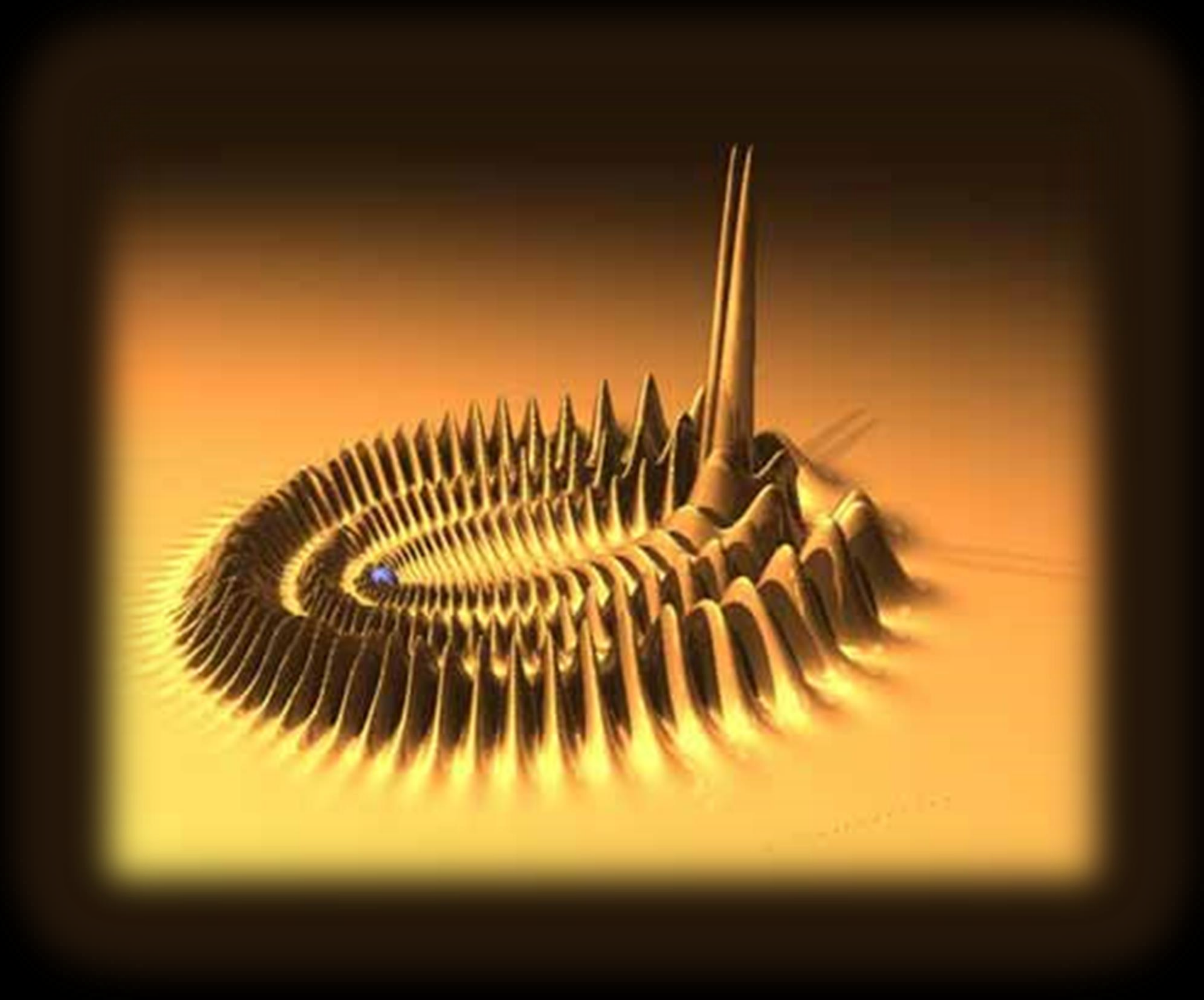
Simulating physics with computers has been a long standing challenge, the notion of a quantum computer or a quantum simulator was suggested in the 1980s and sparked an ongoing technological and theoretical effort to fulfill these aspirations. Simulating quantum systems is a formidable problem, Richard Feynman put it in memorable words: “Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical and by golly it's a wonderful problem, because it doesn't look so easy.”

Quantum simulators, where synthetic systems are built and studied to gain insight into complicated, many-body real-world problems have been developing rapidly over the last two decades. Systems of individually controlled neutral atoms, interacting with each other when excited to Rydberg states, have emerged as a promising platform for quantum simulation, particularly for the simulation of spin systems.

The Bachelorarbeit will focus on the assembly and control of neutral atom arrays, Rydberg states and interactions between them and combining these two elements to simulate Ising spin models.



For more information, contact **Manfred Mark** (manfred.mark@uibk.ac.at) and **Hagai Edri** (hagai.edri@uibk.ac.at)



Bachelor Project

4. Ultralong-range Rydberg Molecules – From Trilobites to Butterflies

Rydberg atoms, i.e. electronically highly excited atoms, have brought new insights to the field of atomic physics since its origins. Their extreme properties make them very interesting as building blocks in recent efforts on quantum simulation and quantum computation.

This thesis will look at the basic properties of Rydberg atoms and then especially focus on the interactions between the Rydberg electron and neutral disturber atoms, leading to the possibility of forming giant molecules. Finally recent experimental progress on the detection and characterization of those molecular states will be discussed.

For more information, contact **Manfred Mark** (manfred.mark@uibk.ac.at)

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1. Elementary excitations : testing 1940’s theory via photon Bragg scattering on gaseous Bose-Einstein condensates (FF)
2. Is it really superfluid? The challenge of testing superfluidity in ultracold quantum gases (FF)
3. Quantum simulation with neutral atoms in optical tweezers (MM/HE)
4. Ultralong-range Rydberg Molecules: From Trilobites to Butterflies (MM)