Current research programmes include the following:

Western Cape Node (University of Stellenbosch)

Cold Atomic Quantum Gases

Systems of ultracold atomic gases are an extraordinary tool to simulate different regimes and phases of other matters which cannot be studied experimentally. The main advantage of systems of cold atomic gases is the possibility to change the interaction between particles and so to search for new phases and regimes of matter. Thus nowadays, matter is substance to be synthesized, organized, and exploited for broader purposes, both at the level of basic research and for numerous technological applications. In general any matter from semiconductors to nuclear, neutron or QCD matter can be emulated and scaled by means of controllable cold atoms.

The unprecedented ability to control interparticle interactions, as well as to engineer artificial, but matter-like environments in cold atomic gases, requires a deep theoretical understanding of such control and the light-matter interaction. The Western Cape node of NITheP focuses on this through three closely related, but different subjects:

- **Control and manipulations of collisions of cold polar molecules in different variations of external fields:**

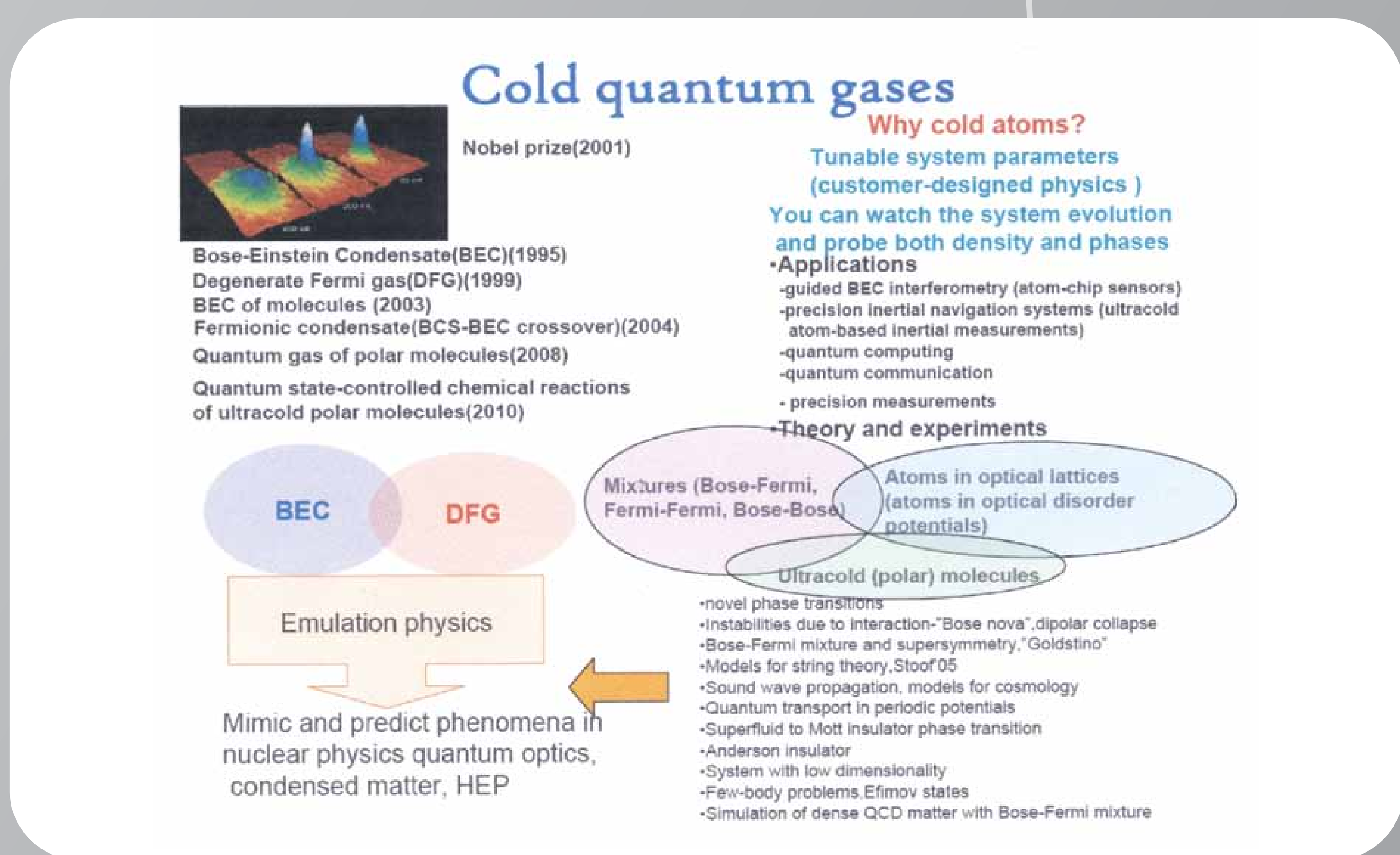
This focuses on the collision dynamics of cold polar molecules in a variation of external fields such as a microwave field, electrostatic fields, electrostatic and magnetostatic fields and all three together. The aim of these studies is to find more effective control mechanisms.

- **The development and applications of efficient and physically rigorous theoretical and computational methods for simulations of quantum processes in cold quantum gases under "extreme" conditions:**

The main goal is to elaborate a theoretical approach that allows one to describe the trapped Bose-Fermi (BF) mixture with a tuneable interspecies interaction in the vicinity of a magnetic field Feshbach resonance (FR). The theory should describe the BF mixture not only near the FR, but for both the atomic and the molecular limits. Such a controllable interaction allows both weakly- and strongly interacting systems and thus the control of the macroscopically different phases of a BF mixture. In order to explore such a rich and sensitive phenomenon requires the development of many-body techniques that go beyond the mean-field level and the inclusion of two-body collisions in the many-body environment.

- **Mimicking nuclear and neutron matter with ultracold atomic gases:**

Some exotic phases and/or regimes of neutron and nuclear matter can be predicted and studied by means of simulations with trapped ultracold atoms. The main advantage of cold atomic gases is the extraordinary precision with which the interaction between particles can be controlled, which opens up the possibility of exploring new phases of matter.



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