

# Density functional theory for a unified description of quark-hadron matter

Description for the general public

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*Quarks* are known to be the most elementary components of matter and thus represent the main subject of nuclear physics. Even though almost every ordinary matter consists of quarks, we can not directly see or detect them. They always appear in bound states, so-called *hadrons* (e.g., protons, neutrons ...) and can not exist free. The phenomenon of quarks being trapped inside hadrons is called *confinement*. However, it is believed that quarks were free during the most early stages of our Universe, as well as in the most extreme conditions of matter. Such conditions can occur only within vanishing time fractions of the most powerful collision experiment (e.g., at the world-wide known LHC collider) or in powerful astronomical events like supernovae, where an entire star, much more massive than our Sun, blows up and releases more energy than anything the world has ever seen. Unfortunately, even though the quark model was introduced half a century ago, their character remains an open question for modern theoretical and experimental physics. The renowned *quantum chromodynamics* (QCD) theory is used to describe such matter, but regardless of it being widespread, this theory is astonishingly complicated and its nature is insufficiently understood. To be more specific, there is no acknowledged model, which would describe hadrons as composites of quarks.

With this in mind, the primary goal of this research project is to develop a consistent model for the description of quark-hadron matter. It should overcome the common caveat of treating quarks separately of hadrons and be capable of doing predictions for actual questions, which tried to be explored in modern experiments. Due to the complexity of QCD theory, we use effective models, which are not of first principle, but should capture all important characteristics. This can be achieved by creating a new generation of models, based on the sophisticated description of quantum statistics, the theory of many-particle systems. The project aims to collect all knowledge, which humanity has about matter in such extreme conditions and utilise it to fix unknown parameters.

What we plan to achieve is a fundamental theory of strongly interacting matter, which will be instrumental for disentangling the remaining uncertainties in the understanding of the nature of QCD and bridge the gap between quarks and hadrons. The greatest contribution of this approach would be the unified description of two currently separate fields of particle physics – astrophysics, which deals with most powerful galactic events, and heavy-ion physics, which aims for the description of collision experiments.

All in all, the project aims to create a new generation of models, capable to become a most basic foundation for all the future research, connected with finding the unity between microscopic and macroscopic worlds.