Last years witnessed a few spectacular astrophysical observations, making headlines and excitement all over the world, also in out-of-science journals, newspapers and public media. These were – the gravitational wave (GW) detection and, quite recently, the black hole photo. The registered GW signals originated first from binary black hole mergers, then later on – also from binary compact (neutron) star mergers. Both objects, compact star and black hole, emerge from the final evolution of aging massive stars – supergiants with masses starting from eight times the mass of our sun ($M_\odot$) upwards and a radius even exceeding 1000 solar radii. They are in equilibrium as long as fusion processes in their cores create enough pressure to balance gravity of their mantles. When in its cooling core gravity takes over, a supergiant begins to collapse. The event features densities of nuclear matter which are inaccessible at any terrestrial experimental facilities. Then the core cannot be compressed further and bounces back. This leads to the ejection of the stellar mantle, known as core-collapse supernova explosion (CCSN). They are the most energetic outbursts in the universe, with a neutron star being left behind as compact remnant. If explosion fails a black hole is formed.

CCSN and binary neutron star mergers (BNSM) are known as the astrophysical sites for the formation of such hot and superdense nuclear matter, which eventually undergoes a so called deconfinement phase transition to a plasma of the fundamental constituents of nuclear matter - a quark-gluon plasma (QGP). Recently, it has been shown that this phase transition, when it is of 1st order, provides the central engine to explain observed phenomenon of supernova explosions of very massive stars of 50 $M_\odot$, which has long been a puzzle to the supernova-modeling community.

Since the nature of phase transitions at high baryon density remains yet almost entirely unknown it is the key objective of this project to identify of the viability of this suggested CCSN explosion scenario in dependence on details of the hadron-quark phase transition and for a wide range of stellar models. We will investigate the explodability of massive stars as an astrophysical criterion for the location of the transition region. Furthermore, the extension towards heavier, strange quarks is required in order to explore the hypothesis of absolutely stable strange matter in the context of compact star phenomenology. This has to be done consistently with underlying hadronic states where the presence of strange hadrons can be expected already at density slightly in excess of normal nuclear matter density.

Within this proposal, a new class of hadron-quark hybrid equation of state (EoS) which has recently been constructed to contain a dynamical quark confinement mechanism, will be further developed. Special focus is thereby devoted to constraints from nuclear physics and astrophysics, when in this project the properties of the hadron-quark hybrid EoS are studied systematically. The project has the potential of contributing to the yet incompletely solved missing red supergiant problem: The proposed failure of CCSN explosions of stars with zero-age main sequence masses in the mass range of 25 ± 5 $M_\odot$, associated with the window of most stellar core compactness, may be explained by the fact that in this mass range the traditional neutrino-heating mechanism for CCSN does no longer lead to explosions while the explosions triggered by the hadron-quark transition operate at higher stellar masses. If confirmed by future observations, parts of the current understanding of the evolution of the cosmos will have to be revisited. It will be a part of our research project to check whether the transition to the quark-gluon plasma need to be of 1st order for making the new explosion engine work or whether also a crossover transition as an alternative could do the job. This or the other way, the planned investigations will provide new insights into the yet-incomplete picture of the state of matter at extreme conditions.