Popular Science

Stars more massive than about 8 times the mass of our sun are huge clouds composed of gas. In our solar system they would extent up to the orbit of the planet Jupiter. Such massive stars produce enormous amounts of energy at their interior from various nuclear processes, similar as at the interior of our sun, most of which is carried away by radiation. The associated pressure generated at the star's core balances gravity. However, when all the nuclear fuel is exhausted in the core and the thermal pressure drops accordingly, gravity wins and the stellar core starts to contract. This is a generic feature that all massive stars suffer from at the end of their lifes. Eventually, the initial stellar implosion reverses into an explosion when very high densities are reached and matter is no further compressible. It leads to the ejection of the stellar mantle. These events are the most energetic outbursts in the universe, known as gravitational-collapse supernovae. A neutron star is left behind as remnant in case of a “successful” explosion, otherwise a black is hole formed in the case of a “failed” explosion.

Supernovae are frequent events at the sky, several hundred per year. Unfortunately, no direct view into the central supernova happenings is possible, because a thick layer of material prevents light from escaping freely. The light which reaches us at Earth from supernovae stems form the decay of radioactive elements, e.g., nickel and titanium. Moreover, all currently observed supernovae are of extra-galactic origin and too far to be seen with the pure eye. A close-by supernova within our galaxy is required to reveal insights into the supernova engine, i.e. the yet-unknown mechanism that drives the explosion. A particular puzzle is thereby the origin of observed supernova explosions associated with the most massive stars, on the order of 40 times the mass of our sun and more.

For this class of stars, in this proposal a new idea is being brought forward for the supernova explosion mechanism. It relates to one of the greatest puzzles of modern physics: the state of matter at extreme conditions found at stellar interiors, that cannot be probed in experiments on Earth even in the most advanced particle accelerator facilities. Therefore, this proposal challenges the existence of an exotic state of matter by means of performing large-scale computer simulations of massive star explosions where the transition from ordinary matter to quarks and gluons – the currently known fundamental constituents of ordinary matter – takes place. This proposal investigates possible observable signatures associated with this phase transition in the neutrino and gravitational wave signals emitted, with the intriguing perspective of becoming observable at Earth for the next galactic event. The advantage thereby is that, unlike light, both sources of radiation are emitted directly form the supernova interior and hence carry information that is otherwise inaccessible.

With this proposal, the first milestones will be set to a deeper understanding of the global picture of gravitational-collapse supernovae of very massive stars. If the here proposed scenario will be confirmed by future observations, parts of the current understanding of the evolution of the cosmos will have to be reviewed. Even if not confirmed by observations, it will shed light onto the yet incomplete picture of the state of matter at extreme conditions.