Physics of Core-collapse Supernovae

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Supernovae are nature's grandest explosions and an astrophysical laboratory in which unique conditions exist that are not achievable on Earth. The colossal explosion of massive stars (type II supernovae) is one of the most violent events occurring in the Universe.

Core-collapse supernovae (CCSN) are among the most fascinating phenomena in astrophysics and provide a formidable challenge for theoretical investigation. They mark the spectacular end of the lives of massive stars and, in an explosive eruption, release as much energy as the sun produces during its whole life. They are also the furnaces in which most of the elements heavier than carbon have been forged. The CCSN affects many aspects of astrophysics, ejecting many of the elements heavier than beryllium into their host galaxies, producing neutron stars and black holes, and powering some of the brightest transient outbursts in the universe. As such, multi-messenger diagnostics have been used to understand supernovae better:

- Electromagnetic emission probes a range of supernova engine and progenitor properties.
- Gamma-rays from radioactive decay and dust grains probe the production of elements (and through this production, the explosion energy).
- High-energy gamma-rays, cosmic rays, and high-energy neutrinos have the potential to probe the shock properties.
- Thermal neutrinos and gravitational waves (GWs) each probe different properties of the central engine powering the supernova.

Scientists have argued for decades about the physical mechanism responsible for these explosions. Determining the mechanism of supernovae explosion has been a half-century journey of great numerical and physical complexity.

This study will also be an attempt to assist in the SKA science because we will be addressing some of the questions that the SKA will be probing e.g. the strong-field tests of gravity using pulsars and black holes.

Under this topic, projects will involve:

i. The study and understanding of the sequences of stages of core-collapse events and the general properties of progenitors.
ii. Deriving equations to describe processes in the stages of Core-collapse.
iii. Applying kinetic theory, fluid dynamics, and magneto-hydrodynamics for relevant stages of the Core-collapse.