Conférence ELBERETH des doctorants en astronomie et astrophysique en Ile de France

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Signature of instabilities in the multi-messenger signal of core-collapse supernovae

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The final step of the life of a massive star is its collapse and explosion creating a supernova. During the collapse phase, several phenomena happen in the core of the star before the observed explosion. One of these phenomena is the development of instabilities. The collapse creates a shock wave that becomes stationary ~150 km away from the surface of the proto-neutron star (PNS). All the instabilities developing between the shock and the core of the PNS modulate the signal emitted in gravitational waves (GW) and neutrinos. The aim of my PhD thesis is to study the convection instability evolving within the sphere delimited by the shock. The matter immediately under the shock interacts with the neutrinos emitted by the neutrinosphere. The neutrinos heat up the matter and trigger convection due to the Rayleigh-Taylor instability. This instability plays a crucial role in pushing the shock outward closer to the explosion threshold, producing GW and modulating the emission of neutrinos. To decipher whether the convection will develop or not, we use a criterion that combine several physical parameters. It prevents us from doing expensive simulations varying each parameter, one by one. In this case, the criterion is the ratio between buoyancy and advection time scales in the heating region. Indeed, the Rayleigh-Taylor instability competes with the advection that tends to stabilise the process. As a result, the Ledoux criterion is not enough to predict the evolution of the system. In addition, several length scales must be considered because of the compressibility and the neutrino-heating/cooling. Foglizzo et al. (2006)1 suggested that, if the ratio of the two timescales is less than ~3, then the advection stabilises the convection. I take a new look at the current stability criterion χ established in 2006 where only one length scale was used: H. However,
by distinguishing several length scales: the size of the unstable domain limited by the shock position Hg (or H), the size of the most buoyant region HS and the density scale-height Hρ, we prove that this criterion needs to be updated.

I study toy models to improve the understanding of the phenomena and the relevant parameters that need to be taken into account to define a convection criterion. To do that, I do analytical calculations and confront them to numerical calculations.

Field

Compact objects (supernovae, black holes, neutron stars)

Day constaints

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