APC colloquium

Wednesday, September 24th at 11am

Room Luc Valentin, 454A

Matteo Bugli

CNRS — IAP

The modeling of extreme stellar explosions: How to connect the central engine to multi-messenger observations

Credit: Soheb Mandhai

The gravitational collapse of massive stars can lead to extreme stellar explosions when both fast rotation and strong magnetic fields are present during the onset of the supernova. This scenario is particularly important when it comes to exceptional sources such as hypernovae and long gamma-ray bursts, whose very high energy release can only be explained by progenitors with the most extreme physical conditions.

A detailed understanding of how magnetic fields extract angular momentum from the central proto-neutron star is crucial to produce quantitative predictions with respect to not only the explosion dynamics, but also the associated multi-messenger emission of gravitational waves, neutrinos, and ultimately the electromagnetic signal associated to the stellar collapse. Numerical simulations are one of the most important tools at our disposal to characterize the properties of the so-called "magneto-rotational supernovae". However, the extreme scale separation between the site of the central engine and the external regions where the non-thermal electromagnetic transient is produced remains one of the most difficult challenges to address for numerical models.

In this talk I will present the results obtained in recent years in the ab-initio modeling of extreme core-collapse explosions and the associated relativistic jets that lead to long gamma-ray bursts. I will show the intimate connection between the engine's activity with the emission of gravitational waves and neutrinos, along with the conditions most favorable for the launching of a relativistic outflow. I will also showcase the importance of accurately capturing the dissipation of magnetic fields through magnetic reconnection, which is one of the main mechanisms invoked for accelerating particles and thus dissipate the jet's energy. Finally, I will discuss the future prospects of connecting the central engine's activity to the modeling of actual GRB lightcurves and spectra.