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# Cosmic rays, explosions and galaxy formation: the deposition of momentum in the ISM and their influence in star formation

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## Abstract

The cataclysmic explosions of massive stars as supernovae (SNe) are fundamental in the paradigm of galaxy formation. However, their current implementation as SNe feedback in galaxy formation simulations still requires taking into account additional important physics, such as magnetic fields and cosmic rays (CRs). In order to understand the effects that cosmic rays have on the evolution of SNe, as well as to advise future SN feedback models in galaxy simulations, I will present in this talk our study of the evolution of individual supernova remnants (SNRs) in the context of CR magneto-hydrodynamics (CRMHD). We generate our simulations using an anisotropic diffusion and streaming CR implementation in RAMSES. Our vast suite of 3D simulations samples the parameter space spanned by ambient density, magnetic field strength and initial CRs energy of the SN.

We find CRMHD runs to follow the canonical SN evolution up to the end of the Sedov-Taylor phase. However, the dominance of CR energy inside the SNR drives an extra phase of additional momentum growth. Furthermore, we find that the strongly anisotropic diffusion of CRs in an aligned magnetic field configuration drives the formation of extended outflows near the magnetic poles, influencing the morphology of the shock. We also explore a more realistic setup by means of a turbulent initial magnetic configuration. This results in a quasi-isotropic diffusion of CRs and a more significant acceleration of ambient gas in terms of momentum deposition compared to the aligned configuration. Overall, our results show that the effect of CRs using 10% of the SNe energy results in an increase of  $\sim 50\%$  of the final momentum. Finally, I will present our SN feedback sub-grid model that accounts for this additional momentum deposition, and compare its effects with that of including CRs in the zoom cosmological simulation of the NUT galaxy.

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