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The Onset of Cosmic Ray Acceleration at Supernovae: From Shock Breakout to the First Decades

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We investigate the beginning of cosmic ray (CR) acceleration at supernovae, from the first day to the first few decades following the explosion. We show that supernovae occuring in dense winds should accelerate CR protons to energies E > PeV. We present a detailed study of the maximum CR energy, magnetic field amplification at the shock, and compute fluxes of secondary gamma-rays and neutrinos.

We also demonstrate, for the first time, that CR acceleration can start significantly before shock breakout for some supernovae surrounded with optically thick winds. Diffusive shock acceleration notably requires the presence of a collisionless shock (CS). It is usually thought that the shock is initially radiation-dominated, and that the CS only forms in the optically THIN layers of the wind. However, we show analytically and numerically, that a CS forms deep inside the THICK layers of the wind for some astrophysically-relevant progenitors, such as possibly SN 2008D.

An observational consequence is that secondary TeV neutrinos can reach the observer up to $\sim$ 10 hours before the first photons from shock breakout, enabling one to study the otherwise inaccessible optically thick layers of such winds.

Collaboration

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