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Gamma-ray emission from young supernova remnants in dense, structured circumstellar environments

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Supernova remnants are known to accelerate cosmic rays from the detection of non-thermal emission of radio waves, X-rays, and gamma rays. The presence of cut-offs in the gamma-ray spectra of several young SNRs led to the idea that the highest energies might only be achieved during the very initial stages of a remnant's evolution. Unfortunately, the gamma-ray luminosity is assumed to peak in the first weeks after the Supernova explosion where strong γγ absorption attenuates the observable signal. Here, we investigate to which extend the interaction of SNR-shocks with dense structures in the medium around red supergiant (RSG) and luminous blue variable (LBV) stars can boost the gamma-ray emission moths to years after the explosion.

We use the time-dependent acceleration code RATPaC to study the acceleration of cosmic rays in supernovae expanding into dense environments around massive stars. We performed spherically symmetric 1-D simulations in which we simultaneously solve the transport equations for cosmic rays, magnetic turbulence, and the hydrodynamical flow of the thermal plasma in the test-particle limit.

We investigated typical parameters of the circumstellar medium (CSM) in the freely expanding winds around RSG and LBV stars and added dense structures that arise from episodes of highly-enhanced mass-loss in case of LBV or photoionization-shells in the case of RSG progenitors.

We find that the interactions with the dense structures happens typically after a few months for LBV progenitors and a few years for RSG progenitors. During the interaction stage, the γγ absorption by photons emitted from the Supernova's photosphere became negligible. The gamma-ray luminosity of the interacting SNRs can surpass the internal/unabsorbed peak-luminosity that arises shortly after the explosion by a factor of up to 10 for the parameters that we explored. As a consequence, the observable flux can be 100 times higher compared to the signal expected shortly after the explosion where γγ absorption is important and where most gamma-ray observatories search for transient signals from these Supernovae.

Collaboration name

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