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

Supernova remnants are known to accelerate cosmic rays (CRs) from the detection of non-thermal emission of radio waves, X-rays, and gamma rays. However, the ability to accelerate CRs up to PeV-energies has yet to be demonstrated. The presence of cut-offs in the gamma-ray spectra of several young SNRs led to the idea that PeV energies might only be achieved during the very initial stages of a remnant's evolution.

We use the time-dependent acceleration code RATPaC to study the acceleration of cosmic rays in supernovae expanding into dense environments around massive stars, where the plentiful target material might offer a path to the detection of gamma-rays by current and future experiments. 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 red supergiant (RSG) and luminous blue variable (LBV) stars and accounted for the strong $\gamma\gamma$ absorption in the first days after explosion.

The maximum achievable energy is limited to below 600 TeV despite the strong magnetic and high mass-loss rates that we are considering. The maximum energy is not expected to surpass $\approx$ 200 TeV and $\approx$ 70 TeV for LBVs and RSG that experience moderate mass-loss prior to the explosion. We find gamma-ray peak-luminosities consistent with current upper limit and evaluated that current-generation instruments are able to detect the gamma-rays from Type-IIP explosions at distances up to $\approx$ 100 kpc and Type-IIn explosions up to $\approx$ 1.5 Mpc. We also find a good agreement between the thermal X-ray and radio synchrotron emission predicted by our models with a range of observations.

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