Gamma-ray emission from young supernova remnants indense circumstellar environments

Robert Brose[1,2], Jonathan Mackey[1], and I. Sushch[3,4]

1. Dublin Institute for Advanced Studies31 Fitzwilliam Place, Dublin 2, Ireland
2. Institute of Physics and Astronomy, University of Potsdam14476 Potsdam, Germany
3. Centre for Space Research, North-West University, 2520 Potchefstroom, South Africa
4. Astronomical Observatory of Ivan Franko National University of Lviv, Kyryla i Methodia 8,79005 Lviv, Ukraine

Supernova remnants are known to accelerate cosmic rays on account of their non-thermal emission of radio waves, X-rays, and gamma rays. However, the ability to accelerate cosmic rays 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 our 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.

We obtain that the maximum achievable CR energy is 100-200 TeV with reasonable assumptions, reached within one month after explosion. The peak luminosity for a LBV progenitor is 10^{43} erg s^{-1} (10^{42} erg s^{-1}) at GeV (TeV) energies and, for a RSG progenitor, 10^{41} erg s^{-1} (10^{40} erg s^{-1}). All calculated SNe reach their peak gamma-ray luminosity after <1 month and then fade at a rate $\sim t^{-1}$, as long as the SN shock remains in the freely expanding wind of the progenitor. We find that some bright type IIn SNe could be detectable with Fermi-LAT during their phase of peak luminosity, and potentially also at TeV energies.

Preliminary investigations of supernovae interacting with dense circumstellar shells show that late-time rebrightening after a months to years is possible, with an enhancement of up to 10x in gamma-ray luminosity possible at GeV and TeV energies.