Contribution ID: **29** Type: **not specified**

Gamma-ray emission from young supernova remnants in dense environments

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 $\gamma\gamma$-absorption attenuates the observable signal. Here, we investigate to which extend the interaction of SNR-shocks with dense structures in the medium around luminous blue variable (LBV) stars can boost the gamma-ray emission months 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 LBV stars and added dense structures that arise from episodes of highly-enhanced mass-loss of the progenitors. The results are compared to calculation of smooth, unstructured winds.

We find that the interactions with the dense structures happens typically after a few months for LBV progenitors. During the interaction stage, the $\gamma\gamma$-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. As a consequence, the observable flux can be considerably higher compared to the signal expected shortly after the explosion where $\gamma\gamma$-absorption is important and where most gamma-ray observatories search for transient signals from these Supernovae. Further, the change of the shock-speed during the shock-shell interaction boosts the achievable maximum energy beyond a PeV, where early interactions yield higher peak-energies.

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Session Classification: PeV Accelerators: The traditional paradigm - SNRs as PeVatrons