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Cosmic-ray acceleration and escape from post-adiabatic Supernova remnants

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Supernova remnants are known to accelerate cosmic rays on account of their non-thermal emission observed at radio, X-ray and gamma-ray energies. Although there are many models for the acceleration of cosmic rays in Supernova remnants, the escape of cosmic rays from these sources is yet understudied.

We use our time-dependent acceleration code RATPaC to study the acceleration of cosmic rays and their escape in post-adiabatic Supernova remnants and calculate the subsequent gamma-ray emission.

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. Our simulations span 100,000 years, thus covering the free-expansion, the Sedov-Taylor, and the beginning of the post-adiabatic phase of the remnant's evolution.

At later stages of evolution a considerable amount of cosmic rays with a wide range of energis can reside outside of the remnant. This leads to spectra softer than predicted by standard diffusive shock acceleration which feature breaks in the 10 - 100 GeV range. The total spectrum of cosmic rays released into the interstellar medium has a spectral index of s˜2.4 above roughly 10 GeV which is close to that required by Galactic propagation models. We further find the gamma-ray luminosity to peak around an age of 4,000 years for inverse-Compton-dominated high-energy emission. Remnants expanding in low-density media reach higher inverse-Compton peak-luminosities matching the fact that the brightest known supernova remnants - RCW86, Vela Jr, HESSJ1721-347 and RXJ1713.7-3946 - are all expanding in low density environments.

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