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Cosmic ray transport near particle accelerators

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The observational progress from radio to gamma-ray observations reveals more and more morphological features that need to be accounted for when modeling the emission from particle accelerators in the Galaxy. It was recently realised that the cosmic-ray flux outside of such an accelerator cannot be modelled independently of the flux and spectrum of cosmic rays in the interior of the object. Using the time-dependent acceleration code RATPaC that simultaneously solves the transport equations for cosmic rays, magnetic turbulence, and the hydrodynamical flow of the thermal plasma, we can study the formation of extended gamma-ray halos around supernova remnants and the morphological implications that arise when the high-energetic particles start to escape from the SNRs.The simulations span 25,000 years, thus covering the free-expansion and the Sedov-Taylor phase of the SNR's evolution. The morphology of the gamma-ray emission from SNRs at later stages is different for the two main emission processes. At early times, both the inverse-Compton and the pion-decay morphology are shell-like. However, as soon as the maximum-energy of the freshly accelerated particles starts to fall, the inverse-Compton morphology starts to become center-filled, whereas the pion-decay morphology keeps its shell-like structure. Escaping high-energy electrons start to form an emission halo around the SNR at this time. There are good prospects for detecting this spectrally hard emission with the future Cerenkov Telescope Array, as there are for detecting variations in the gamma-ray spectral index across the interior of the SNR. Further, we find a constantly decreasing nonthermal X-ray flux that makes a detection of X-ray unlikely after the first few thousand years of the SNR's evolution. The radio flux is increasing throughout the SNR's lifetime and changes from a shell-like to a more center-filled morphology later on. We discuss the findings in the context of single-source contributions to the cosmic-ray flux at Earth and gamma-ray haloes around other objects.

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