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Leptonic non-thermal emission from supernova remnants evolving in the circumstellar magnetic field

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The very-high-energy (VHE; E>100 GeV) gamma-ray emission observed from a number of Supernova remnants (SNRs) suggests that particles are accelerated to high energies at the shock of the remnants. However, it is extremely difficult to determine which particles are responsible for this emission as both protons (through hadronic interactions and subsequent pion decay) and electrons (through inverse Compton scatter- ing on ambient photon fields) can potentially generate gamma-ray photons. Recent detection of the abrupt cut-off at lower energies in the gamma-ray spectra of several SNRs with the Fermi-LAT has been interpreted as a characteristic pion-decay feature, indicating emission from cosmic-ray protons. However, a similar spectral feature may possibly arise also in the leptonic scenario as a result of spatial or temporal variability of the ambient medium. SNRs created in core-collapse explosions expand inside the stellar wind bubble blown up by a progenitor star. In the free wind, the circumstellar magnetic field decreases as $B \propto 1/r$ with the distance from the star with high values at the stellar surface, e.g. 1-10 G for red supergiants, which is followed by the transition to the shocked wind medium accompanied by abrupt changes in the magnetic field strength. An interaction with such a magnetic-field distribution might result in strong modifications of the electron and subsequently radiation spectrum. In certain phases of the SNR evolution the gamma-ray spectrum resulting from the inverse Compton scattering of accelerated electrons might strongly reassemble the one expected from hadronic interactions. Moreover, the evolution of the SNR inside the stellar wind bubble might leave substantial imprints on the temporal evolution of the non-thermal radiation as well as its observable morphology impacting the whole range of the electromagnetic spectrum from radio to VHE gamma-rays. In this work, we conduct a detailed study of the impact of the circumstellar magnetic field on the resulting non-thermal emission from SNRs through numerical simulations with the RATPaC code, designed for the time- and spatially dependent treatment of the particle acceleration at the shocks of SNRs.

Abstract field

Author: SUSHCH, Iurii (North-West University)

Co-authors: PLOTKO, Pavlo (DESY); BROSE, Robert (Dublin Institute for Advanced Studies); DAS, Samata (DESY, 15738 Zeuthen, Germany); POHL, martin

Presenter: SUSHCH, Iurii (North-West University)

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