Moving fast – How “runaway stars” shape the landscape of galactic supernova remnants

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Photo: X-ray: NASA/CXC/Dublin Inst. Advanced Studies/S. Green et al.; Infrared: NASA/JPL/Spitzer

The massive runaway star Zeta Ophiuchi moving with a velocity of 24 km/s, seen in infrared by the Spitzer instrument. Such objects influence the distribution of supernova remnants in the Galaxy.

Considering the star movement is an important, yet hitherto neglected ingredient for the study of the supernova-remnant population at very-high-energy gamma rays. Scientists from the University of Potsdam and the Institute for Space Science in Barcelona now succeeded in determining the fraction of moving massive “runaway” stars in the Milky Way. Their finding appeared in the journal Astronomy & Astrophysics.

Massive stars frequently move with high velocities through interstellar space. Their movement can be measured directly from changes in the spectrum. At the end of their lives, such massive stars explode in a giant supernova, leaving behind a remnant that is known to accelerate cosmic rays to very high energies. However, the emission of these supernova remnants does not allow any conclusions to be drawn about the velocity of their progenitors.

A team of scientists from the University of Potsdam and the Institute for Space Science in Barcelona has now for the first time used the positions of supernova remnants to investigate the effects of the star movement. They indirectly determined the fraction of massive “runaway” stars that are moving, rather than being stationary, from very-high-energy gamma-ray data.

In order to do so, they had to simulate the spatial distribution of the birthplaces of massive stars, take into account their movement, their lifetime, and also include the type and evolution of the supernova remnant. The simulations were done using supercomputing resources at the National High Performance Computing System “Lise” at Zuse Institute Berlin. They found that a fraction of 33 percent of massive stars being “runaways” are needed to explain observations - a value that is in remarkable agreement with the canonical value obtained since decades by direct observation of massive stars.

“Our studies demonstrate that the motion of supernova progenitors plays a crucial role in the detectability of supernova remnants at very high energies,” says Rowan Batzofin, PhD student at Potsdam University and first author of the study. “We must take this motion into account when studying the Galactic population of supernova remnants and comparing observational data with simulations.”

“These findings open a wide research avenue, at the border of high-energy astroparticles and the physics of massive stars that we are thrilled to explore in the near future, particularly within the context of the gamma-ray observatories CTAO (Cherenkov Telescope Array Observatory) and LHAASO (Large High Altitude Air Shower Observatory)”, adds Dominique Meyer from the Institute for Space Science in Barcelona.

Link to Publication: R. Batzofin, K. Egberts, D. M.-A. Meyer, and C. Steppa: Runaway stars and the Galactic supernova remnant landscape: Non-thermal emission and observational evidence, Astronomy&Astrophysics, 701, L4 (2025), **https://doi.org/10.1051/0004-6361/202555665**

Image: The massive runaway star Zeta Ophiuchi moving with a velocity of 24 km/s, seen in infrared by the Spitzer instrument. Such objects influence the distribution of supernova remnants in the Galaxy. Image: X-ray: NASA/CXC/Dublin Inst. Advanced Studies/S. Green et al.; Infrared: NASA/JPL/Spitzer

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