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DEBRIS FROM STELLAR EXPLOSIONS IN THE GALAXY'S FAST LANE

19 November 2013

Astronomers looking at the radioactive afterglow of supernovae with ESA's INTEGRAL mission have revealed that the remains of stellar explosions move through the Milky Way much faster, on average, than stars and most of the Galaxy's gas. This stellar debris is most likely ejected by winds and supernova explosions in large groups of massive stars located primarily on the leading edges of the Galaxy's spiral arms.

While the night sky delivers a peaceful and almost immutable cosmic view, the picture belies a Universe alive with ceaseless motion from the smallest to the largest scales. All structures in the Milky Way, both the stars and the diffuse interstellar medium, swirl around the centre of the Galaxy at velocities as high as hundreds of kilometres per second, taking about one hundred million years to complete a revolution.

By studying how these objects move, astronomers can figure out the structure of the Milky Way at large and, in particular, of the spiral arms – a prominent characteristic of our Galaxy. These investigations are key in the challenge of understanding the history of the Milky Way's evolution.

Artist's impression of our Galaxy. *Credit: ESA - C. Carreau*

Using data from ESA's INTEGRAL mission, a team of astronomers has mapped out galactic motions, exploiting a new tracer that follows stellar debris both through space and time. With this new method, they revealed that the remains of stellar explosions move, on average, much faster than stars and most of the gas in the Milky Way.

"*The stellar winds blown by a massive star, and the supernova explosions at the end of its life, are powerful agents. They release large amounts of matter and energy into interstellar space, and we managed to trace some of this matter during its very long journey,*" explains Karsten Kretschmer from the Laboratoire APC in Paris, France. Kretschmer is the lead author of the paper reporting on the new results, published in Astronomy & Astrophysics.

The astronomers traced the path of the supernova debris by tracking its velocity relative to us through the Galaxy. They sought the light emitted at a specific gamma-ray wavelength by the radioactive decay of aluminium-26 (^{26}Al), an isotope produced in the supernova explosions. Matter ejected by a supernova is richer in heavy elements than the raw material from which the parent star formed, because many new atomic nuclei are created in the star's interior as well as during the explosion.

Part of the ejected material is in the form of nuclei of radioactive isotopes, and the majority of them decay over short timescales – ranging between a few days and several years. But not ^{26}Al. With a half-life of about 700 000 years, ^{26}Al nuclei can travel very long distances before they decay. When they do so, astronomers can exploit the gamma rays emitted during the decay to trace the long-term reach of stellar explosions.

"*Looking at the radioactive afterglow of supernovae about a million years after the explosions, we followed how their debris has spread across the Galaxy. This is not possible with observations at other wavelengths, which only show the remnants of more recent supernovae,*" adds Kretschmer.

Kretschmer and his collaborators used the SPectrometer on INTEGRAL (SPI) instrument to search for the emission from the radioactive decay of ^{26}Al. With these data, they could map the distribution and velocity of this isotope across the Milky Way.

"*Surprisingly, during the first million years of their journey, the ejecta from supernovae seem to move, on average, twice as fast as stars and the diffuse gas we see at other wavelengths in the Galaxy,*" comments co-author Roland Diehl from the Max-Planck Institut für Extraterrestrische Physik in Munich, Germany.

"*We expected such high velocities in the initial phase after the explosion, but not after a million years. Our measurements are unique as they can detect the motion of the debris on such a long time scale, but still before it is slowed down as it ploughs through the surrounding gas that moves with the general flow.*"

The astronomers also found that supernovae tend to be more abundant in the inner parts of the Milky Way, where the spiral arms stem from the central regions of the Galaxy, rather than at the periphery.

"*We conclude that the ejecta from supernovae are mainly concentrated towards the leading edges of the arms, while most of the gas and dust from which stars take shape are located in the core of the arms,*" he adds.

This offset in velocity and location between the cradles of star formation and the graveyard of stellar remains suggests the existence of strong asymmetries in the outflows from massive stars and supernovae within the Galaxy.

Stars form deep within the spiral arms, but may migrate outwards during their lifetime. The most massive of them blow intense winds during their lifetime and eventually die as supernovae. The material ejected during these events proceeds faster towards the regions of the Milky Way between the arms, creating gigantic bubbles that expand more easily in those directions where interstellar material is less dense.

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"[illegible] already suggested that massive stars and supernovae may be preferentially located on the edges of spiral arms. Now, we have obtained direct proof," says Kretschmer.