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Asymmetric ashes

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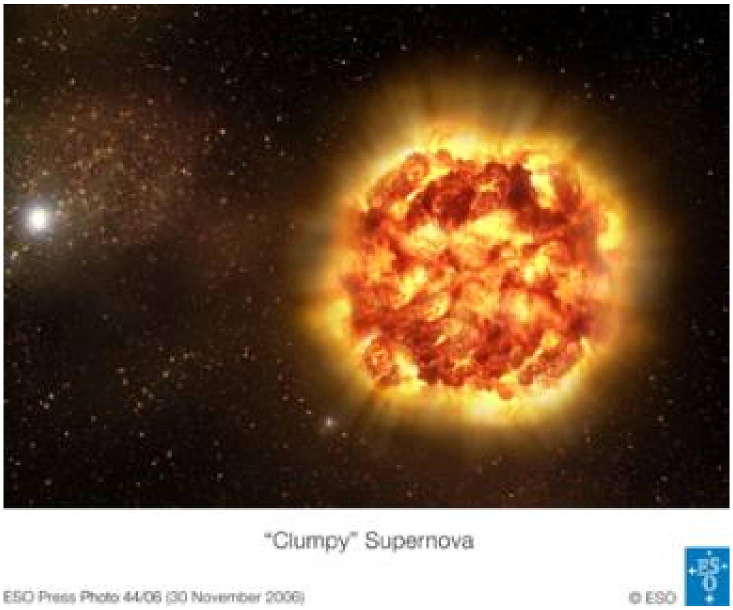

Artist's impression of how Type Ia supernovae may look like as revealed by the spectr-polarimetry observations. The outer regions of the blast cloud is asymmetric, with different materials found in 'clumps', while the inner regions are smooth. Credit: ESO

Astronomers are reporting remarkable new findings that shed light on a decade-long debate about one kind of supernovae, the explosions that mark a star's final demise: does the star die in a slow burn or with a fast bang" From their observations, the scientists find that the matter ejected by the explosion shows significant peripheral asymmetry but a nearly spherical interior, most likely implying that the explosion finally propagates at supersonic speed.

These results are reported today in Science Express, the online version of the research journal Science, by Lifan Wang, Texas A&M University (USA), and colleagues Dietrich Baade and Ferdinando Patat from ESO.

"Our results strongly suggest a two-stage explosion process in this type of supernova," comments Wang. "This is an important finding with potential implications in cosmology."

Using observations of 17 supernovae made over more than 10 years with ESO's Very Large Telescope and the McDonald Observatory's Otto Struve Telescope, astronomers inferred the shape and structure of the debris cloud thrown out from Type Ia supernovae. Such supernovae are thought to be the result of the explosion of a small and dense star - a white dwarf - inside a binary system. As its companion continuously spills matter onto the white dwarf, the white dwarf reaches a critical mass, leading to a fatal instability and the supernova. But what sparks the initial explosion, and how the blast travels through the star have long been thorny issues.

The supernovae Wang and his colleagues observed occurred in distant galaxies, and because of the vast cosmic distances could not be studied in detail using conventional imaging techniques, including interferometry. Instead, the team determined the shape of the exploding cocoons by recording the polarisation of the light from the dying stars.

Polarimetry relies on the fact that light is composed of electromagnetic waves that oscillate in certain directions. Reflection or scattering of light favours certain orientations of the electric and magnetic fields over others. This is why polarising sunglasses can filter out the glint of sunlight reflected off a pond. When light scatters through the expanding debris of a supernova, it retains information about the orientation of the scattering layers. If the supernova is spherically symmetric, all orientations will be present equally and will average out, so there will be no net polarisation. If, however, the gas shell is not round, a slight net polarisation will be imprinted on the light.

"This study was possible because polarimetry could unfold its full strength thanks to the light-collecting power of the Very Large Telescope and the very precise calibration of the FORS instrument," says Dietrich Baade.

"Our study reveals that explosions of Type Ia supernovae are really three-dimensional phenomena," he adds. "The outer regions of the blast cloud is asymmetric, with different materials found in 'clumps', while the inner regions are smooth."

The research team first spotted this asymmetry in 2003, as part of the same observational campaign. The new, more extensive results show that the degree of polarisation and, hence, the asphericity, correlates with the intrinsic brightness of the explosion. The brighter the supernova, the smoother, or less clumpy, it is.

"This has some impact on the use of Type Ia supernovae as standard candles," says Ferdinando Patat. "This kind of supernovae is used to measure the rate of acceleration of the expansion of the Universe, assuming these objects behave in a uniform way. But asymmetries can introduce dispersions in the quantities observed."

"Our discovery puts strong constraints on any successful models of thermonuclear supernova explosions," adds Wang.

Models have suggested that the clumpiness is caused by a slow-burn process, called 'deflagration', and leaves an irregular trail of ashes. The smoothness of the inner regions of the exploding star implies that at a given stage, the deflagration gives way to a more violent process, a 'detonation', which travels at supersonic speeds - so fast that it erases all the asymmetries in the ashes left behind by the slower burning of the first stage, resulting in a smoother, more homogeneous residue.

The results presented here are reported in "Spectropolarimetric diagnostics of thermonuclear explosions", by Lifan Wang, Dietrich Baade and Ferdinando Patat, *Science Express*, 30 November 2006.

Source: European Southern Observatory (ESO)

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