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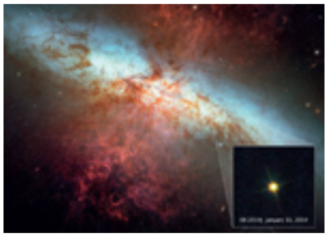
INTEGRAL catches radioactivity of a supernova


(http://images.iop.org/objects/ccr/cern/54/8/15/CCast1_08_14.jpg)

Supernova SN 2014J (http://images.iop.org/objects/ccr/cern/54/8/15/CCast1_08_14.jpg)

ESA's INTEGRAL satellite has detected gamma-ray lines from the radioactive decay of nickel and cobalt in a nearby supernova of type Ia. This unprecedented result confirms that the intense light of the supernova comes from the radioactive decay of these elements, which were formed by the thermonuclear explosion of a white-dwarf star.

There are basically two main classes of supernova explosions. Type II supernovae result from the collapse of the core of a massive star, whereas those of type Ia are thought to be the thermonuclear disruption of a white-dwarf star. According to the theory of such explosions, the carbon and oxygen found in a white dwarf should be fused into radioactive nickel (^{56}Ni) during the explosion. The ^{56}Ni should decay quickly into radioactive cobalt (^{56}Co), which itself subsequently decays, on a somewhat longer timescale, into stable iron (^{56}Fe). The ignition should arise when the white dwarf's mass exceeds a critical mass of about 1.4 times the mass of the Sun. This can result from mass transfer from a companion star or by the merger of two white dwarfs.

It is this uniform process among all type-Ia supernovae that makes them "standard candles" for cosmology, which were used to measure the acceleration of the expansion of the universe (*CERN Courier* November 2011 p5 (http://cerncourier.com/cws/article/cern/47484)). Type Ia supernovae are also less frequent than type IIs, and it is only by coincidence that two relatively nearby events appeared recently: SN 2011fe in the Pinwheel Galaxy (*CERN Courier* January/February 2012 p13 (http://cerncourier.com/cws/article/cern/48338)) and now SN 2014J in Messier 82 (Picture of the month *CERN Courier* March 2014 p12 (http://cerncourier.com/cws/article/cern/56220)). At a distance of 11.5-million light-years from Earth, SN 2014J is the closest of its type since 1972. Its appearance offered a unique opportunity to use the SPI gamma-ray spectrometer aboard INTEGRAL to try to detect the emission lines from the decays of ^{56}Ni and ^{56}Co. All other scheduled observations of INTEGRAL were delayed, but it paid off.

Eugene Churazov, from the Space Research Institute in Moscow and the Max Planck Institute for Astrophysics in Germany, and collaborators, report the detection of two emission lines at 847 and 1238 keV from the radioactive decay of ^{56}Co between 50 and 100 days after the ignition. They also find a weak signal at 511 keV from the electron–positron annihilation following the decay $^{56}\mathrm{Co} \rightarrow {}^{56}\mathrm{Fe} + e^+$ and associated emission in the 200–400 keV band. By fitting a three-parameter model to the observations, they calculate that about 0.6 solar masses of ^{56}Ni have been produced by the thermonuclear explosion. The observed broadening of the lines suggests a typical expansion velocity of about 10,000 km/s.

Another team, led by Roland Diehl from the Max Planck Institute for Extraterrestrial Physics, reports the detection of ^{56}Ni already 15 to 20 days after the explosion. This came as a surprise, and suggests that about 10% of the nickel is not produced at the centre of the star – from where the radiation could not escape – but must have been produced outside it. The researchers propose that a belt of helium accreted from the companion star could have detonated first, forming the observed nickel and then triggering the internal explosion that became the supernova.

Regardless of the fine details, these results represent a new breakthrough for the 12-year-old INTEGRAL spacecraft, which has previously detected the radioactive signal of ^{44}Ti from the bright type-II SN 1987A in the Large Magellanic Cloud (*CERN Courier* December 2012 p11 (http://cerncourier.com/cws/article/cern/51546)). The new results provide direct evidence that type-Ia supernovae are indeed thermonuclear explosions of white-dwarf stars.

About the author

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Further reading

E Churazov *et al*. 2014 *Nature* **512** 406.
R Diehl *et al*. 2014 *Science Express* DOI:10.1126/science.1254738.