

## Radioactive iron provides a window into stars

**ESA's orbiting gamma-ray observatory INTEGRAL has made the first unequivocal discovery of radioactive iron in the galaxy. Even though it has been found drifting in space, the isotope known as iron 60, can give astronomers a powerful insight into the workings of the massive stars that pervade and shape the galaxy.**

Radioactive iron has been a long-sought chemical in space. There have been reported sightings of it in the past but all have been subject to interpretation and controversy. Now, however, INTEGRAL has provided unequivocal evidence.

Since late 2002, INTEGRAL has been collecting data from across the Galaxy. It shows an enhancement of gamma rays at two characteristic energies, 1173 and 1333 keV. These are produced as the iron 60 radioactively decays into cobalt 60.

Roland Diehl, Max-Planck-Institut für extraterrestrische Physik, headed the work and believes that this is a major step forward. "There has been some disputed detection of these gamma ray lines before. INTEGRAL is the only instrument capable of doing this work and now we know that iron 60 does exist in interstellar space of our Galaxy," he says.

Its presence is more than a curiosity. It opens a new door into the very heart of the most massive stars in the cosmos. The vast majority of chemical elements are built inside stars from the raw ingredients present when the star formed out of an interstellar gas cloud. In addition to hydrogen and helium, which themselves were produced in the big bang, this gas contained some enrichments, known to astronomers as 'metals', from previous generations of stars and their nuclear burnings.

Until this detection of iron 60, astronomers only had one radioactive chemical with which to probe the current build-up of chemical elements in stars and their distribution towards future star formation. That was the radioactive isotope aluminium 26, first discovered in 1978. As a result, "The study of aluminium 26 has developed into its own branch of astronomy," says Diehl.

Iron 60 gives astronomers a valuable new insight because, although it is produced in the same stars as aluminium 26, its production differs markedly. Iron 60 is synthesised both later in a star's life and deeper inside.

As massive stars age, they develop a layered structure in which different chemical elements are fused together. Whereas aluminium 26 is one rung on the ladder of a star's nuclear reactions, iron 60 is produced from the pre-existing stable iron isotopes by a process called neutron capture in the layers where helium and carbon atoms are fusing together, respectively.

"The iron 60 detection is our entry in studying neutron capture in stars through contemporaneous radioactivity," says Diehl. It has also prompted a number of particle accelerators to begin more detailed studies of how easy it is for iron to capture neutrons.

Unlike, aluminium 26, iron 60 is only thrown out into space when the star explodes at the end of its life. It then decays with a half-life of 1.5 million years, producing the gamma rays that INTEGRAL has detected.

The new data pins down the ratio of iron 60 to aluminium 26, which decays with a half-life of 740,000 years. Previous predictions have fallen anywhere between 10 and 100 percent. INTEGRAL shows it to be 15 percent. Thankfully, that agrees well with the current estimates predicted by theoreticians. But theoreticians and nuclear-reaction physicists have been stimulated by INTEGRAL's results to strive for better precisions of their predictions.

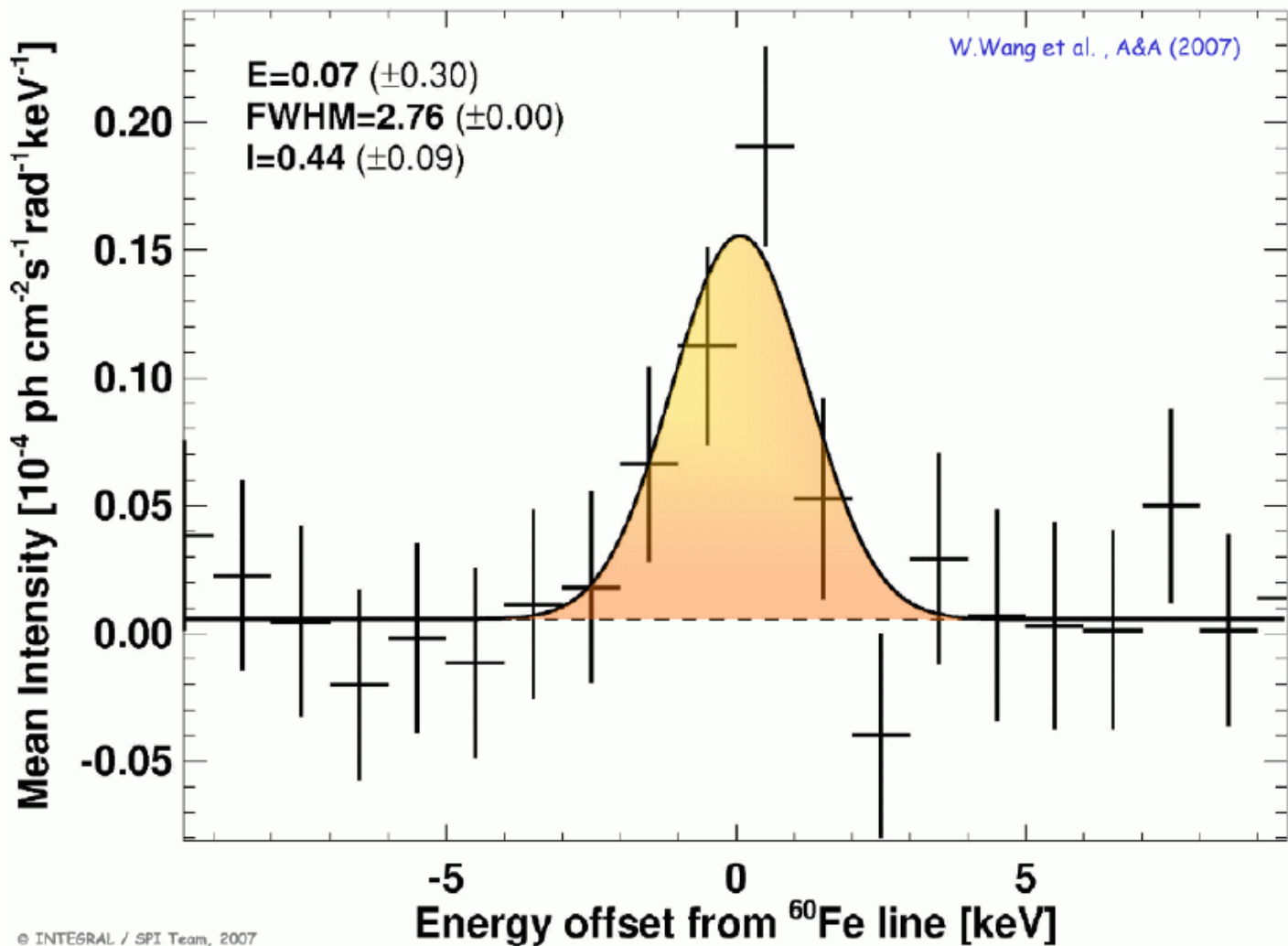
Although INTEGRAL clearly sees the telltale gamma rays, they are too faint for it to map out enhancements and paucities across the Galaxy. "Mapping the distribution of iron 60 is a job for the next generation of gamma-ray instruments," says Diehl.

Nevertheless, the team will continue observing with INTEGRAL for as long as they can, in the hopes that they can gain some coarse ideas about the iron's spread across the Galaxy.



## Picture of the Month

June 2007



### Diagnosing the trace of supermassive stars

$^{60}\text{Fe}$  is a radioactive isotope produced in convective shells of massive stars by neutron capture reactions. Theoretical predictions of  $^{60}\text{Fe}$  yields are quite uncertain, due to uncertainties in nuclear reaction rates and neutron sources and stellar structure. With a 2.2 My radioactive lifetime,  $^{60}\text{Fe}$  accumulates in the interstellar medium after it is ejected by the core-collapse supernova, which ends the massive-star's life shortly after  $^{60}\text{Fe}$  has been synthesized.

SPI on INTEGRAL measures the two gamma-ray lines resulting from the decay of  $^{60}\text{Fe}$  in interstellar space. This spectrum shows the superposition of both lines, resulting in the most-significant detection of this isotope to date, improving upon previous hints from RHESSI and earlier SPI measurements.

$^{60}\text{Fe}$  nucleosynthesis is a key diagnostic of the structure of massive stars in their late stages. In particular, the ratio of  $^{60}\text{Fe}$  to  $^{26}\text{Al}$  gamma-rays is a convenient relative diagnostic, if both isotopes indeed originate predominantly from massive stars. This ratio has been predicted to lie in the range 10-100%, and is now measured by SPI as 15%. Refinements of models are underway, in particular re-evaluating nuclear reaction cross sections and beta-decay lifetime.

Credits: The SPI Team and W. Wang et al. ([A&A in press, 2007](#)).

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