integral

→ A DECADE REVEALING THE HIGH-ENERGY SKY

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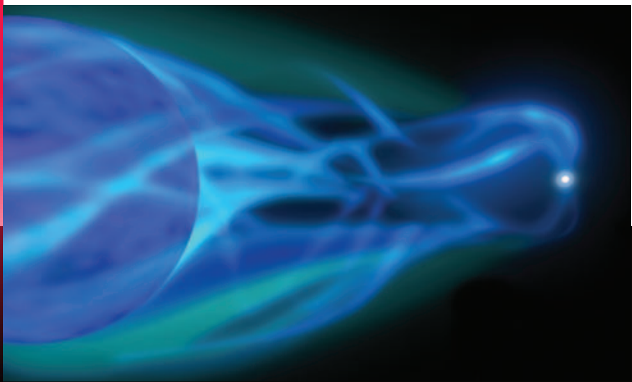
European Space Agency

A NEW CLASS OF BINARY STAR

Integral is well equipped to discover faint or short-lived phenomena and has found more than 60 new high-mass X-ray binary stars – an entirely new class of compact stellar objects named 'strongly-absorbed X-ray binaries'. These compact objects are very faint because they are deeply embedded in material streaming off their companion supergiant star. Only Integral can see them at higher energy wavelengths.

Integral is also carrying out extensive studies of supergiant fast X-ray transients – high-mass X-ray binaries that display X-ray and gamma-ray outbursts typically lasting only a fe w tens of minutes to hours. These objects comprise a neutron star most likely grabbing material from the clumpy wind emitted by its supergiant stellar neighbour.



FORGING NEW ELEMENTS

Stars are like nuclear furnaces, continuously fusing hydrogen and helium into heavier elements, from carbon to iron. These elements can then be distributed through the Universe if a star explodes in a supernova. Such explosive events also produce elements heavier than iron, along with radioactive elements. When these radioactive elements naturally decay, they emit gamma rays at characteristic energies.

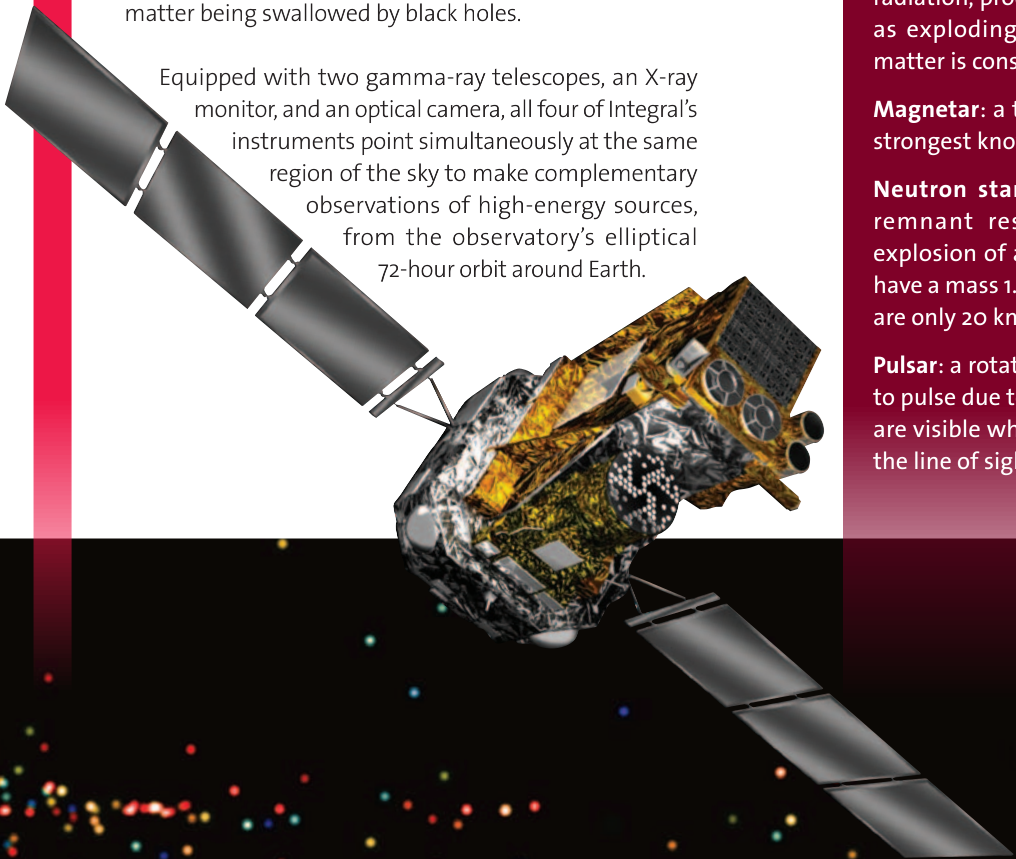
Integral has detected gamma-ray emission from an isotope of aluminium – aluminium-26 – all along the plane of our home Galaxy, proving its wide origin and leading to the estimate that a supernova explodes roughly once every 50 years somewhere in the Milky Way.

Integral all-sky map of high-energy X-ray sources

AN INTEGRAL VIEW OF THE HIGH-ENERGY SKY

Integral, the International Gamma-Ray Astrophysics Laboratory, is the most sensitive gamma-ray observatory ever launched. Gamma rays are a million times more energetic than visible light and are produced in cataclysmic astronomical events, including exploding stars, colliding neutron stars, particles trapped in magnetic fields and matter being swallowed by black holes.

Equipped with two gamma-ray telescopes, an X-ray monitor, and an optical camera, all four of Integral's instruments point simultaneously at the same region of the sky to make complementary observations of high-energy sources, from the observatory's elliptical 72-hour orbit around Earth.



JARGON

Active Galactic Nucleus (AGN): a luminous compact region at the centre of a galaxy that emits an excess of light, thought to be a result of accretion of mass by a supermassive black hole at its centre.

Gamma-ray burst: a burst of high-energy radiation, produced in extreme events such as exploding or colliding stars, or when matter is consumed by massive black holes.

Magnetar: a type of neutron star with the strongest known magnetic field.

Neutron star: a compact, dense stellar remnant resulting from a supernova explosion of a massive star. Neutron stars have a mass 1.4–2 times that of our Sun, but are only 20 km in diameter.

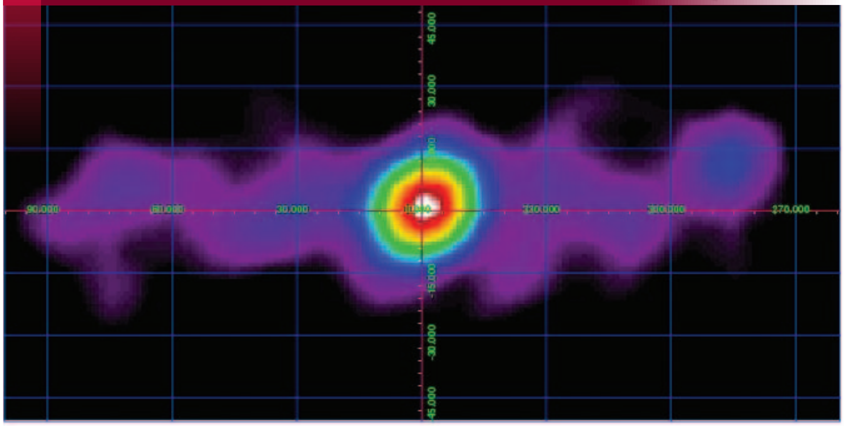
Pulsar: a rotating neutron star that appears to pulse due to its rapid rotation. The pulses are visible when beams of light rotate into the line of sight from Earth.

ANNIHILATING ELEMENTARY PARTICLES

Integral has for the first time mapped the entire sky at the specific energy produced by the annihilation of electrons with their positron anti-particles. The collisions release gamma rays at an energy corresponding to the mass of both particles according to Einstein's famous equation $E = mc^2$.

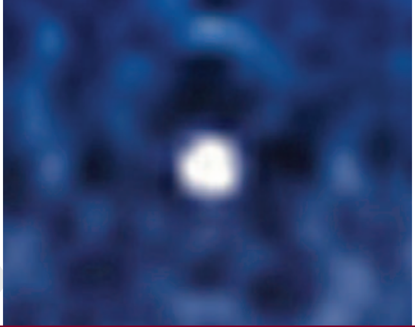
According to the emission seen by Integral, some 15 million trillion trillion trillion pairs of positrons and electrons – that's 15 followed by 42 zeros – are being annihilated every second near the Galactic centre. The power released corresponds to more than six thousand times the luminosity of our Sun. While electrons are ubiquitous, it is unknown what produces this huge number of their antimatter counterparts. Likely candidates are supernovas, accreting binary stars, massive stars and pulsars, but exotic sources such as our Galaxy's supermassive black hole, gamma-ray bursts or dark matter particles could also be contributing.

Annihilation emission



Galactic latitude

Galactic longitude



ESA/SPI Team/ECF

GRB021125, the first gamma-ray burst imaged by Integral

STELLAR DEATH CRIES

Roughly once a day, a burst of gamma rays washes through the Solar System, marking the death cry of a massive star somewhere in the Universe that has burned up its fuel supply and collapsed in on itself. Gamma-ray bursts (GRBs) can also be sparked by the collision of neutron stars and black holes, and last from just a few hundredths of a second to hundreds of seconds.

Integral's analysis of GRB 031203 found it to be one of the closest and faintest gamma-ray bursts on record, defying the classic assumption that the fainter an object the further its distance and suggesting that a entire population of weak GRBs had been going unnoticed.

At the other end of the scale, on 27 December 2004, Integral was hit by one of the strongest flood of gamma rays ever measured by a satellite. More powerful than any radiation burst from the Sun, the blast came from a 'magnetar' on the other side of the Milky Way, some 50 000 light-years distant. Magnetars are extremely magnetised pulsars and Integral's observations are providing new constraints on the geometry and physics of the strongest magnetic fields in the Universe.

COSMIC ACCELERATORS

Rapidly spinning neutron stars – pulsars – are known to accelerate particles to enormous energies, typically a hundred times more than the most powerful man-made particle accelerators on Earth, like CERN's Large Hadron Collider. Until Integral began studying this breed of star, it was uncertain exactly how these cosmic accelerators operate.

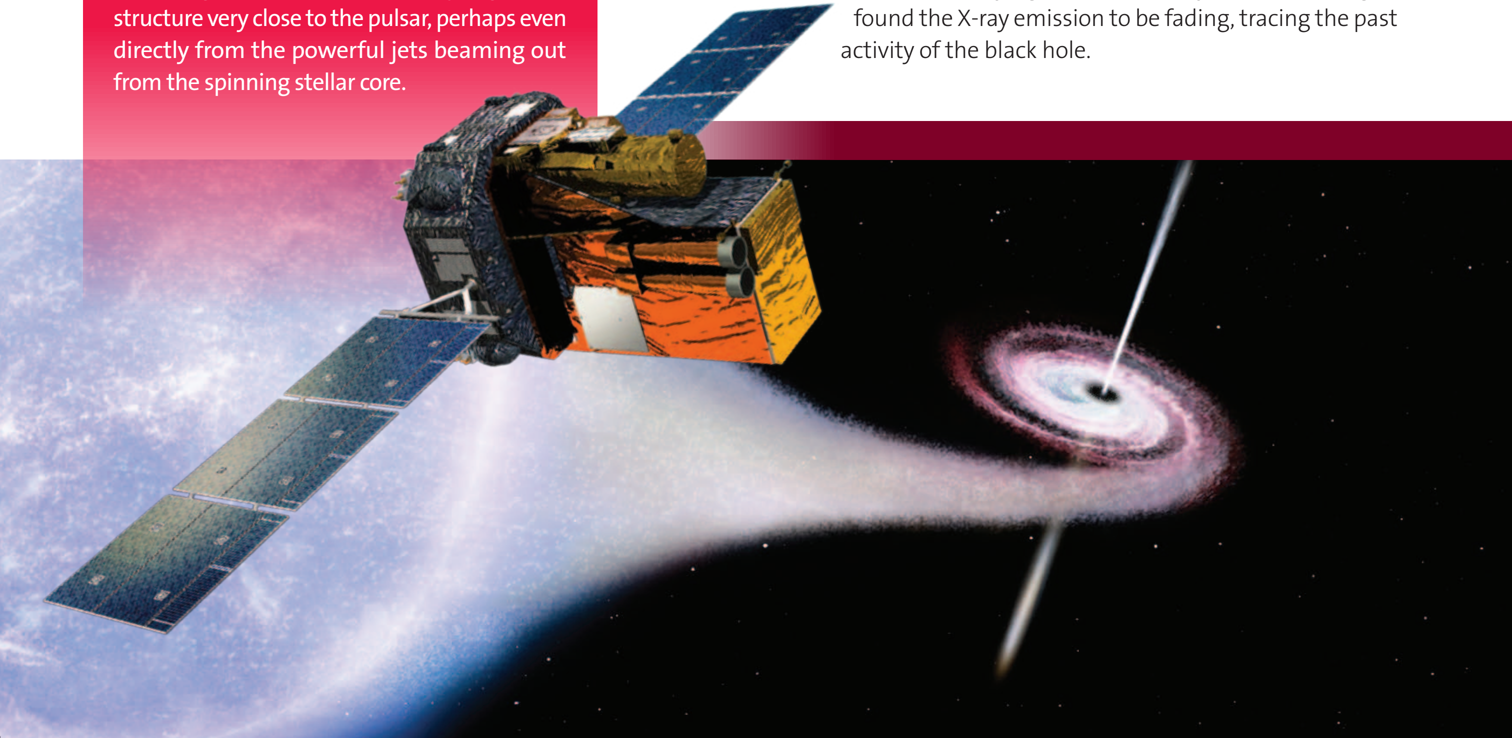
The Crab Nebula, the remains of a supernova explosion seen from Earth in 1054, hosts a pulsar at its heart. By studying the polarisation – alignment – of the waves of high-energy radiation originating from the Crab Nebula, Integral found that the radiation is strongly aligned with the rotation axis of the pulsar. This implies that a significant fraction of the particles generating the intense radiation must originate from an extremely organised structure very close to the pulsar, perhaps even directly from the powerful jets beaming out from the spinning stellar core.

GALACTIC MONSTERS

Integral plays a key role in our understanding of supermassive black holes and active galactic nuclei, the active black holes found lurking in the bellies of most galaxies, as well as of stellar-mass black holes in our Galaxy.

The satellite has revealed the nearby black hole Cygnus X-1 in a new light. This black hole is in the process of ripping a companion star to pieces and gorging on its gas. Integral is able to study this extremely hot matter just a millisecond before it plunges into the jaws of the black hole, finding that some of it might be making a getaway thanks to highly structured magnetic field lines acting as an escape tunnel.

Integral also discovered persistent high-energy X-ray emission from the centre of our own Galaxy coming not from its central black hole Sagittarius A*, or Sgr A*, but rather from a nearby massive cloud of gas and dust known as Sgr B2. The observation is best interpreted as radiation emitted by Sgr A* being reflected or scattered by Sgr B2 about 100 years later. Integral found the X-ray emission to be fading, tracing the past activity of the black hole.



FACTS AND FIGURES

Launch vehicle	Proton/Block-DM
Launch site	Baikonur, Kazakhstan
Orbital location	Elliptical 72-hour orbit
Operational lifetime	10+ years
Payload	**Four science instruments:** SPI (Spectrometer on Integral) and IBIS (Imager onboard Integral) to measure and image gamma rays; JEM-X (Joint European X-Ray Monitor) to record X-ray emission; and OMC (Optical Monitoring Camera) to provide visible light images. Coded aperture masks for all high-energy instruments. Monitoring of the orbital radiation environment is provided by IREM (Integral Radiation Environment Monitor)
Launch mass	4 tonnes
Size	5 x 4 x 3.7 m; deployed solar panels span 16 m
Satellite control centre	European Space Operations Centre, Darmstadt, Germany
Science operations centre	European Space Astronomy Centre, Villanueva de la Cañada (Madrid), Spain
Ground station	Redu, Belgium

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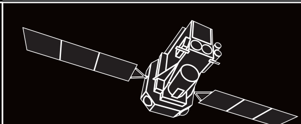

INTEGRAL'S FUTURE

Integral was launched on 17 October 2002 with an initial mission duration of two years. It continues to operate very successfully after ten years, however, and a further extension beyond 31 December 2014 is under consideration.

Integral is currently the only multi-purpose X-ray/gamma-ray observatory studying the most energetic phenomena in the Universe. Future science might include the characterisation of high-energy radiation from a supernova explosion within our Milky Way, an event that is long overdue.

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