Requiem for an observatory

One of NASA's most productive satellites is about to meet a fiery end. Henry Bortman assesses the achievements of the Compton Gamma-Ray Observatory, and considers the missions that will follow in its footsteps.

Early in the morning of 4 June, a swath of the central Pacific Ocean some 4,000 kilometres southeast of Hawaii will be kept clear of shipping and aircraft — and for good reason. If all goes to plan, 17 tonnes of satellite will come hurtling out of orbit, disintegrate in the atmosphere, and rain down as a series of fireballs over a belt roughly 1,500 kilometres long by 25 kilometres wide.

It will be a sad day for science. The Compton Gamma-Ray Observatory (CGRO), which is being scuttled by NASA to avoid the remote possibility that it might make an uncontrolled descent over an inhabited area, has been a stellar performer. In the nine years since it was put in orbit by the Space Shuttle Atlantis, the CGRO has transformed astronomers' understanding of some of the most intriguing objects in the Universe.

And although other, more powerful gamma-ray instruments will be launched over the next few years, Compton's loss will leave gamma-ray astronomers helpless should an important high-energy astrophysical event occur during the hiatus. "For a few years we'll be just blind," says Isabelle Grenier of the University of Paris VII.

CARL W. AKERLOF, UNI. OF MICHIGAN & NASA/SPL

Vision on: launched nine years ago, the Compton Observatory (main picture) has allowed Earth-bound instruments such as ROTSE (inset) to study stellar gamma-ray bursts with new accuracy.

Great expectations

The CGRO's demise also marks a turning point in NASA's philosophy. Compton is one of the four 'Great Observatories' — astronomical satellites of unprecedented size and performance designed to study the sky across a range of wavelengths from infrared to gamma-rays. The group also includes the Hubble Space Telescope, which recently celebrated its tenth anniversary in space; the Chandra X-Ray Observatory, launched last July; and the Space Infrared Telescope Facility (SIRTF), scheduled for launch in December 2001.

The plan was to overlap the operation phases of each satellite to let astronomers use different wavelengths simultaneously to observe objects, allowing them to gain insights that would be impossible to achieve using just a narrow wavelength band. But each observatory has suffered a series of delays — the programme's schedule was thrown into disarray from the start after NASA's shuttles were grounded following the 1986 Challenger disaster. And in losing the CGRO after Chandra has been in orbit for less than a year, and before SIRTF has even left the ground, the goal of overlapping observations at all wavelengths has clearly been missed.

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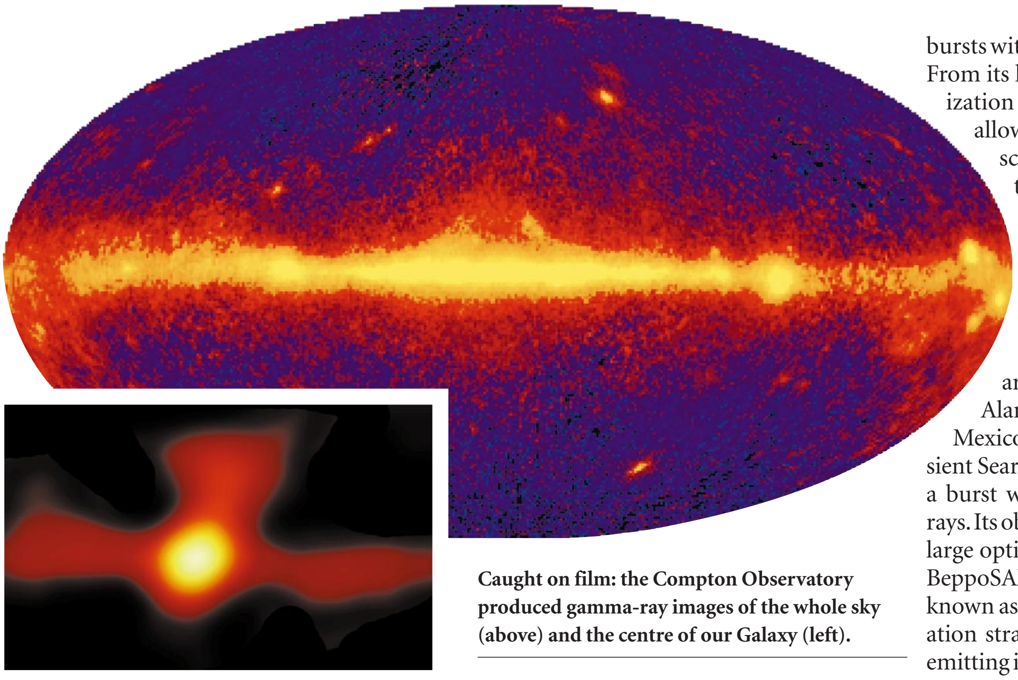
Now they have got their hands on the data that the CGRO has amassed, however, most astronomers aren't too concerned. They are still committed to the idea of studying objects at various wavelengths simultaneously. But, with the exception of near-infrared astronomy, where plans for the $1 billion Next Generation Space Telescope to succeed Hubble are well advanced, the consensus is that this will in future be best done using smaller satellites focused on particular scientific goals.

"We're not doing Great Observatories any more, because it puts too many eggs in one basket, frankly," says Alan Bunner, director of NASA's Structure and Evolution of the Universe programme. "What's needed next in this field of astrophysics are more specialized missions that focus on a particular capability or a particular problem and go after that with a vengeance."

Bursting on the scene

Although astronomers are excited by the possibilities offered by the missions on the drawing-board, they view the CGRO's demise with regret. The observatory may not have achieved the fame of Hubble, but that has little to do with its scientific significance. Compton isn't a household name simply because its instruments couldn't provide stunning pictures that could be splashed across the world's newspapers. But with the observatory facing its doom, astronomers are keen to sing its praises.

"Probably the most important discovery had to do with gamma-ray bursts," says Neil Gehrels, project scientist for the CGRO, based at NASA's Goddard Space Flight Center in Greenbelt, Maryland. These flashes of radiation last from a few milliseconds to a few minutes, and were first recorded in the 1960s by spy satellites searching for evidence of nuclear weapons tests. Prior to the Compton observatory, there was not much information on the bursts. "But what little there was had convinced the community completely — I



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Caught on film: the Compton Observatory produced gamma-ray images of the whole sky (above) and the centre of our Galaxy (left).

mean almost to a person — that since they're such bright flashes of gamma-rays, they must be something occurring in our own region of the Milky Way," says Gehrels.

Within months of its launch, however, Compton was overturning that view. One of its main instruments is the Burst and Transient Source Experiment (BATSE). This allowed astronomers to monitor the distribution of the gamma-ray bursts across the sky, and soon showed that they come at a rate of about one per day from all directions[1]. The fact that the bursts aren't concentrated in the plane of our Milky Way Galaxy suggested that they come from great distances away — which in turn indicated that their sources must be the most energetic explosions in the Universe. "This changed the subject of gamma-ray bursts from a little exotic side topic to a major discipline in astronomy," says Gehrels.

The CGRO also pioneered studies of a class of objects dubbed 'blazars'. These are quasars, or distant active galaxies, from which huge jets of matter stream out at almost the speed of light. "Even before the CGRO, looking at radio data and some optical data, there was this odd set of quasars that seemed to have different properties," says Gehrels. "Instead of being steady objects, the light coming out of them would vary from day to day fairly rapidly."

Web links

CGRO ▸ **http://cossc.gsfc.nasa.gov**
Great Observatories ▸ **http://sirtf.jpl.nasa.gov/sirtf/Mission/Family/greatobs.html**
HETE-2 ▸ **http://international.gsfc.nasa.gov/International/Missions/Hete_2/Hete_2.html**
Swift ▸ **http://swift.sonoma.edu**
GLAST ▸ **http://www-glast.stanford.edu**
INTEGRAL ▸ **http://astro.estro.estec.esa.nl/SA-general/Projects/Integral/integral.html**

The nature of these quasars was clarified by an instrument aboard Compton called the Energetic Gamma-Ray Experiment Telescope (EGRET), which revealed that they were also emitting gamma-rays[2–4]. Because astrophysicists know that high-energy gamma-rays are generated when particles are accelerated to very high speeds, explains Gehrels, "we were able to show in a solid way that these were really coming from jets flowing out".

Puzzling evidence

Some of Compton's discoveries, however, have provided more questions than they have answers. Using EGRET, astronomers have documented around 170 point sources of gamma-rays that defy explanation[5,6]. These appear in the plane of our Milky Way, and so are thought to lie in the main disk of our Galaxy, a kiloparsec or more away.

Earlier this year, a team led by Gehrels reported the existence of a smaller group of fainter sources lying in a nearby star-forming zone called the Gould Belt, 100–400 parsecs from our Solar System[7]. The nature of both classes of sources remains a mystery. "We don't have a clue what they are," admits Bunner. "They don't show up — at least no one has been able to find the counterparts — at other wavelengths."

Coordinating Compton's observations with those at other wavelengths has proved invaluable in identifying other gamma-ray sources, including the transient bursts. Within seconds of detecting a burst, the CGRO can transmit its coordinates — admittedly not very well localized — to other space- and ground-based observatories.

This approach really came into its own when Compton was teamed up with the Italian–Dutch satellite BeppoSAX. This craft observes at gamma-ray and X-ray wavelengths, and can pinpoint the origin of the bursts with greater precision than Compton. From its launch in 1996, BeppoSAX's localization of bursts recorded by Compton allowed astronomers to train their telescopes on the area of sky from which the bursts came, and so watch their afterglow[8,9]. Measurements of the redshift of the optical counterparts of the bursts confirmed that they were coming from distant galaxies[9].

Most significantly, on 23 January 1999, an instrument at the Los Alamos National Laboratory in New Mexico, called the Robotic Optical Transient Search Experiment (ROTSE), observed a burst while it was still emitting gamma-rays. Its observations[10], together with those of large optical telescopes guided by data from BeppoSAX[11–15], suggested that the source, known as GRB990123, was beaming its radiation straight in our direction, rather than emitting it in all directions.

The hole story

If this pattern is typical of gamma-ray bursts, it means that the total energy of the explosions responsible need not be as high as astrophysicists thought. This fits with the theory that at least some of the bursts are caused when a supermassive star goes supernova. According to this 'collapsar' model, material blown away by the explosion will collapse back onto the black hole left behind, and then be emitted as highly energetic jets from its poles. "The follow-up at all wavelengths has been the key to cracking this problem," says Stan Woosley of the University of California at Santa Cruz, one of the proponents of the collapsar model.

The same argument applies to other gamma-ray sources. "Once it's been possible to look at objects across the whole spectrum, it's become pretty blindingly obvious that that was the way to study them," says Ken Pounds, a high-energy astrophysicist at the University of Leicester, and formerly chief executive of Britain's Particle Physics and Astronomy Research Council. "If you take something like the nucleus of an active galaxy, then you will find that it puts out pretty much equal amounts of power in all

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Sunblind: the Compton Observatory's early demise will hamper studies of solar flares.

parts of the spectrum: radio, infrared, optical, ultraviolet, X-rays and even gamma-rays. To understand these objects, you really do have to look at them in all these different ways. Otherwise, it would be like trying to draw a picture of a human being by only looking at an arm or a leg."

Given this, you might expect that astronomers working on the Great Observatories programme would be distraught at losing the CGRO before Chandra has really hit its stride, and with SIRTF still waiting in the wings. But most are relatively sanguine. "It would have been nice to have Chandra and the CGRO up together for longer," says Gehrels. "Chandra is following up, making observations of gamma-ray bursts, studying the X-ray afterglow in a way that we've never been able to before. But if you look at the overall science programme of Chandra, it's a fairly small fraction."

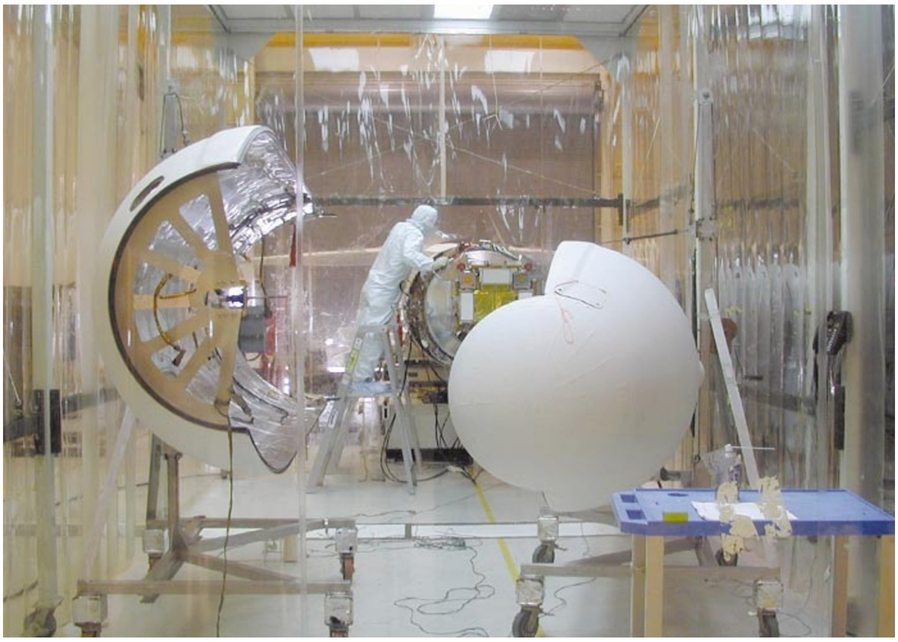
Sharpshooting satellites

Indeed, most astronomers are now looking forward to a series of smaller, more specialized gamma-ray missions that should fill in the details of the broad-brush picture painted by Compton. The High Energy Transient Explorer-2 (HETE-2), for instance, is a gamma-ray burst detector set for launch by a NASA-led international team in July. Although less sensitive than Compton's BATSE instrument, HETE-2 will be far better at pinpointing the location of the bursts it does detect, making it easier to coordinate observations at other wavelengths.

"I'm absolutely sure that, when HETE-2 goes up, you'll see a huge revitalization of the gamma-ray burst field," says Shri Kulkarni, an astrophysicist at the California Institute of Technology in Pasadena. HETE-2 should be followed in 2003 by Swift, a NASA mission that will combine a good ability to pinpoint the bursts with instruments that are five times as sensitive as Compton's.

The Gamma-ray Large Area Space Telescope (GLAST) is scheduled for launch by NASA in 2005. It will focus on studying the highest-energy end of the gamma-ray spectrum. With 30 times Compton's sensitivity for gamma-rays with energies in the giga-electron-volt range, and 10 times the angular resolution, GLAST should help to unlock the secrets of gamma-ray objects whose sources have not yet been identified. The European Space Agency is also getting in on the act with its International Gamma-Ray Astrophysics Laboratory (INTEGRAL). This mission, which should reach orbit in April 2002, will provide spectra for gamma-ray sources within our own Galaxy.

Despite the general feeling that these focused missions are the way of the future, some researchers are upset about NASA's decision to sacrifice Compton. Jim Ryan of the University of New Hampshire in Durham is co-principal investigator for an instrument called COMPTEL, or the Imaging Compton Telescope. He has been circulating a letter among astrophysicists urging the US Congress to suspend NASA's de-orbiting plan and to start an independent investigation of the safety risks.


Ray of hope: when it's launched this July, HETE-2 (the High Energy Transient Explorer-2), here undergoing testing, will be able to pinpoint the locations of elusive gamma-ray bursts.

DAVE BRESLAU/HETE

In-between days

NASA decided to bring the craft down after a gyroscope failure last December put it one more gyro malfunction away from a possible uncontrolled re-entry. Given that some sections of the huge satellite are bound to reach the Earth's surface, this carries a one in a thousand risk of causing human casualties. However, alternative control techniques that don't rely on gyroscopes might reduce that chance to one in 4 million — a risk some astronomers feel is worth taking. "I bet you a nickel to a dime that there's more risk to the public in the launch of a shuttle than there is in bringing down the CGRO," says Ryan.

Ryan is particularly frustrated about lost opportunities to observe gamma-ray emissions from the Sun. "We're in the maximum of solar activity right now, and we've just begun to start acquiring some terrific solar flare data for which we've been waiting 10 years," he says. NASA's High Energy Solar Spectroscopic Imager (HESSI) mission, designed to observe solar flares at X-ray and gamma-ray wavelengths, was supposed to have been launched in July, and could have taken over solar observations from Compton. But it was damaged in March during bungled vibration tests, and is now unlikely to fly before January 2001.

Bunner is sympathetic to Ryan's concerns. "People hate the thought of turning off any observatory, especially one that's still functioning," he says. But, according to the safety framework within which NASA has to operate, Bunner says that the agency had little choice but to bring Compton down. NASA officials did consider sending a shuttle mission to repair the ailing spacecraft, but that was deemed too expensive — and too dangerous for the astronauts who would have to perform the spacewalks.

Most astronomers seem willing to accept this logic, although they're aware that Compton's demise means that the lights are about to go out for a while on the gamma-ray sky. "I think that we'll get by with a two- or three-year gap, provided there isn't an extremely rare event that needs a gamma-ray mission to follow it properly," says Pounds. "For instance, if there were to be a supernova explosion in our Galaxy — a once-in-a-hundred-year event — and we missed seeing it in part of the spectrum where it was probably going to be very interesting, then that would be a considerable loss." From 4 June, high-energy astrophysicists will just have to keep their fingers crossed. ■

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