The Mystery of the Cosmic Gamma-Ray Zaps

Bursts of gamma rays are seen by satellites. Nobody knows what or where they're from.

by Dietrick E. Thomsen

Bzzt! Bzzt! Like bursts of dental X-rays whomping into your jaw they hit the gamma-ray detectors on the Vela satellites. They are sudden bright bursts of soft gamma rays coming from somewhere in the cosmos. They last from tenths to tens of seconds and can have a complicated structure. They happen a few times a year.

The energy they deliver, if translated to light, would strike your eye like the planet Venus flashing on and off. This may not seem like much, but it is tremendous compared with the steady background flux of X-rays, which is extremely small compared with the background flux of light at night. If the flash-to-background ratio is translated into terms of light, it would be as if sudden bright flashes lit up the whole night sky.

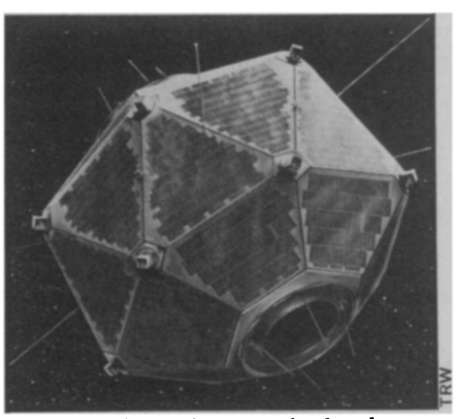
These gamma-ray bursts are a good example of astronomical serendipity. They were discovered by accident, almost unbelievingly, one might say. When observers became convinced of their existence, they immediately took their place on the rather lengthy list of outstanding cosmic mysteries that astrophysicists now have to contemplate. In the year or so since the discovery was publicly announced, a number of hypotheses about where they come from have arisen, all of them ingenious, some perhaps too ingenious for their own good.

The tale begins with the satellites of project Vela. Vela is one of the Spanish words for "watchman," and the satellites are part of a scheme to monitor compliance with the nuclear test ban treaty. They are in a high orbit (around 100,000 miles out), and their purpose is to record evidence of nuclear tests above the surface of the earth and even—so Jules Vernian is the military imagination these days—behind the moon. The importance of the Velas for this story is that they carry gamma-ray sensors and that there are several of them aloft in different locations at any time.

Having several satellites with the same sensing equipment in orbit at the same time means that when a gamma-ray pulse arrives in the neighborhood of the earth two or more sensors record a signal of the same shape at the same time. Such a multiple record was necessary to make observers believe in the reality of the pulses. OGO and OSO spacecraft had reported events in which their gamma-ray sensors suddenly went off scale, but the size of the flash made it seem incredible as a true observation, and people monitoring the data dismissed the events as glitches in the equipment. Multiple, simultaneous records began to change people's minds, and observers were driven to the conclusion that the bursts are indeed celestial phenomena. That conviction was announced about a year ago (SN: 6/19/73, p. 369).

In the years since 1969, 27 such bursts have been recorded by the Velas, according to R. W. Klebesadel of the Los Alamos Scientific Laboratory, who has been involved in the observing. Since the Vela orbit is large, there is a measurable time delay between the arrival of a given burst at one satellite and its arrival at another. Using these time delays and the locations of the satellites, the direction from which the signal came can be determined by a kind of triangulation. (The detectors themselves are not directional.) Directions have been determined for about nine of the events.

The determinations give a roughly even distribution of directions. The major members of the solar system are definitely ruled out as sources, says Klebesadel, but the isotropy leaves an ambiguity as to where else the sources may be. If they are within our galaxy, they must be quite near us, possibly in the Orion arm or in our own arm, says Klebesadel. Or they could be extragalactic. If they were generally distributed throughout our galaxy, the shape of the galaxy would show up in the distribution of directions, and it does not.



Vela satellites discovered the bursts.

Either way it is clear that high-energy events are involved. For sources inside the galaxy Klebesadel puts the energy output at the source as 10^{36} to 10^{40} ergs. For extragalactic sources the jolt may be as high as 10^{48} ergs, estimates Philip Morrison of the Massachusetts Institute of Technology. That, he says, equals 10 million years of the sun's emission.

A number of hypotheses about the sources have arisen. All of them are plausible, in Morrison's view; none can be ruled out, though some are more plausible than others. The truth of one does not necessarily exclude the others. There could be more than one kind of source.

Because of the short duration of the bursts and the energies involved the first candidate that leaped to a number of people's minds was supernovas. But checking the timing of the gamma-ray bursts against observed supernovas yielded a disappointment. There is no correlation. Since we are not sure that we observe all supernovas that happen, it could be that the bursts are coming from ones we don't see. What is obvious is that if supernovas are involved, not all supernovas produce such bursts. In fact only the ones that we don't see do.

This has led to a modification, the postulation of a bare supernova, one that we don't see because it does not throw off the large cloud of luminous matter that is what we see when we see a supernova. A bare supernova is the sudden implosion of a white dwarf to become a neutron star or a black hole. This could yield the gamma rays, but there are gravitational problems about whether the collapse could happen as envisioned.

Another theory has something falling onto a black hole or a neutron star and converting gravitational energy that it gains as it falls into gamma rays. One suggestion is comets falling onto a neutron star. But nobody has seen comets except around the sun, says Morrison. If there are comets around other stars, it is likely that the supernova explosions that turn ordinary stars into neutron stars blow the comets away along with the rest of the circumstellar matter.

A stellar superflare is another hypothesis. This would be similar to a solar flare but 10 billion times as big. There is no evidence that such superflares occur on other stars. To find it will require highly accurate monitoring of stars for events with a very short time scale. Up to now visual astronomy has not been programmed for this kind of work.

The most unusual suggestion so far is the relativistic BB. The other hypotheses all assume that the gamma rays come from some cataclysmic event that sends them out in all directions in a spherical front that expands across the universe. The Vela satellites get only a little bit of this total front. But the BB hypothesis suggests that what the Velas record is about all there is; the signal is highly directional and emitted in only a narrow cone.

The source that could supply such a cone is a small grain of iron moving at a speed near that of light, a relativistic BB. If the BB struck a photon of light from the sun, the gamma rays could be produced. But where do you get the BB's? Morrison asks. There would have to be a lot of them zipping around for the Velas to see only a few. And how do you energize them? An amount of energy equal to one-thousandth that of all starlight would have to be invested in BB's.

With so many open questions, the thing to do is keep looking at the phenomenon. Speaking at a symposium at the April meeting of the American Physical Society at which Klebesadel and Morrison also spoke, T. L. Kline of the Goddard Space Flight Center outlined some of the needs.

Better understanding of the spectral characteristics will be sought using sensors designed with the bursts in mind. Such equipment can be flown on balloons, and if quick answers are desired it may be piggybacked on satellites and probes already well along in their preparation. Another important point is precise and unambiguous determination of the directions from which the bursts come, determinations "to an arc second," says Kline. This can be done best if a triangulation point at some distance from the earth is provided. Putting a sensor on the upcoming Venus orbiter is one of Kline's suggestions. Another is the planned Helios B solar probe.

For the moment everything is still up in the air—or better up above the air. If astronomers have learned one thing in the last decade or two, it is that the cosmos is still full of surprises. What manner of beast these observations will add to the taxonomy of astrophysics remains to be seen. □