

trons in the counter. Thus the detectors responded isotropically.

Properties. The bursts show integrated photon fluxes ranging from 10^{-5} erg/cm² to about 5×10^{-4} erg/cm², with a maximum flux intensity up to around 4×10^{-4} erg/cm² sec. Each event consists of a rapid flux increase—attaining its peak in less than 1/10 sec—followed by a slower decay over a period of several seconds. Multiple peaks often occur in the first tenth of a second or so, and the peak width at half height is usually around 1 or 2 sec for the whole event. The energy spectra fit a power law with an intensity going as $1/E$ approximately in the range 10 keV–100 keV, and, between 100 keV and 1 MeV, all six events seen by IMP-6 are consistent with exponential spectra.

Many attempts have been made to correlate these gamma-ray bursts in time and space with other astronomical events and objects. First, because of the Colgate prediction, the Los Alamos group working with Vela data compared the gamma-burst occurrences with supernova observations. There was no correlation; in fact the result was rather an anticorrelation in the sense that no gamma-ray burst accompanied the largest supernova in the period, NGC 5253.

Cline and Desai reported at the Denver conference that they had searched for time correlations with galactic radio-noise spikes, with rapid atmospheric fluorescence increases, with the Cygnus X-3 radio flare, and even with Joseph Weber's published times for gravitational radiation events, with no success.

The direction from which the gamma-ray bursts come gives no clue to their origin either. The event with the best position coordinates, that of 14 May 1972 observed by OSO-7, was not near any known x-ray source, supernova or flare star. None of the Vela events correlated with the positions of known supernovae. The arrival directions appear to be isotropic, although the statistics are as yet too low to be significant. As Klaus Pinkau (Max Planck Institute, Munich) cautiously said when summarizing the known facts for the Denver conference, the data "are consistent with isotropy." Certainly terrestrial and solar-system origins have been ruled out.

Conjectures. As might be expected, theoretical astronomers have had a field day trying to explain these observations, with no general agreement yet. Many theoretical models were aired at the Los Alamos conference; Colgate's view of the explanations put forward so far is that "most of them have an equal probability of being correct." His own model involves supernovae, but the Type II kind found to occur in the rela-

tively young stars of the spiral arms of galaxies rather than Type I supernovae of the older stars on which his earlier predictions had been modeled. He thinks the bursts originate when a shock wave rises to the surface of the star.

One problem with any "supernova" explanation is the lack of correlation with optical observations. The difficulty can be avoided by postulating that the supernovae in question radiate relatively weakly in the visible wavelengths, a theory first put forward by Philip Morrison (MIT); such events are known to observers as "theoretician's supernovae." Colgate acknowledges the variable time structure to be a much more difficult obstacle. Strong suggested that, as half-a-dozen bursts detected by Vela were extremely brief (all much less than 0.5 sec), these might be the best candidates for supernovae.

Reuven Ramaty (Goddard) and Jeffrey Cohen (University of Pennsylvania), and, independently, Remo Ruffini (Princeton), suggest that in a gamma burst we are seeing a "quiet" collapse of a white-dwarf star to become a neutron star without a supernova stage. At Los Alamos, Ramaty suggested that the very hot neutron star cools by radiating as a black body, and the roughly ten-second gamma bursts represent an integration of the black-body radiation during the fast cooling process. If the neutron star "bounces," (collapses, expands and collapses again) this model could account for the multiple-spike structure often observed near the onset of a burst.

Floyd Stecker and Kenneth Frost (Goddard) believe⁴ that the gamma bursts show many of the same properties as do solar x-ray bursts, and therefore suggest that we are seeing evidence of stellar "superflares" from certain high-magnetic-field stars. The high field could have the effect of changing the ratio of x-ray to optical emission, so explaining the lack of correlation with known objects. Obvious candidates for such stars, Stecker told us, are white dwarfs, which are very faint anyway. Not everyone agrees with the premise that gamma bursts and solar x-ray bursts are similar; the energy spectra seem to be somewhat different.

A stellar flare model is also the choice of Philip Morrison and Kenneth Brecher (MIT), but rather than following Stecker and Frost's analogy with solar flares they prefer an approach from fundamentals.

Martin Harwit and Edwin Salpeter (Cornell) reported at the Los Alamos meeting on their model of gamma-burst emission by comet capture. Suppose, they say, that comets are about ten times more abundant around

other stars than they are in the solar system. Suppose further that a comet survives the supernova stage in a star's evolution if it happens to be in a distant part of its orbit at the time. Then occasionally a comet may suffer an orbit perturbation that brings it within a few hundred kilometers of a neutron star. The comet may not be captured straight away; it may swing out again, being broken up into fragments as it goes. The debris would then rain down upon the star the next time the comet comes round, the pieces all reaching the surface within a few seconds producing x rays and gamma rays upon impact. The structures seen in many of the gamma bursts could be the result of individual comet fragments impacting separately.

This comet-and-neutron-star model is one of a more general class of accretion models that have been considered by David Pines and Donald and Fred Lamb (University of Illinois), which Donald Lamb presented at the Los Alamos conference.

These are only a few of the many conjectures currently being discussed. Theoretical astronomers have never been at a loss to invent models when a new kind of data comes along (remember the first pulsars?), and with gamma-ray bursts they appear to have cataclysmic events that provide them with plenty of scope. —JTS

References

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Canadian role confirmed for 144-inch telescope

The implementation of a joint project to build a 144-inch reflecting telescope on Mauna Kea, Hawaii is closer with the confirmation of Canadian participation by the Canadian government. Also involved in the program is the Centre National de la Recherche Scientifique, which is awaiting French government approval, and the University of Hawaii, which will provide the site, access roads and support facilities.

The site, which is 13 800 feet above sea level, is expected to afford 2800 hours per year of clear viewing. The telescope, which has a primary mirror made out of Cervit, will join an 88-inch reflecting telescope that the University of Hawaii already maintains on the site. □