The Day of the Neutron Star

March 5, 1979. Some astrophysical events can be dated to the day, the hour, even the second. The transient bursts of gamma rays that come from various parts of the sky are like that. The March 5, 1979, one lasted little more than a tenth of a second (0.15 sec). Of the 100 gamma ray bursts recorded since they were first reported in 1973 from data taken by the Vela satellites, this one was the quickest and the most energetic (100 times as strong as the strongest previous one), according to W. Doyle Evans of the Los Alamos Scientific Laboratory.

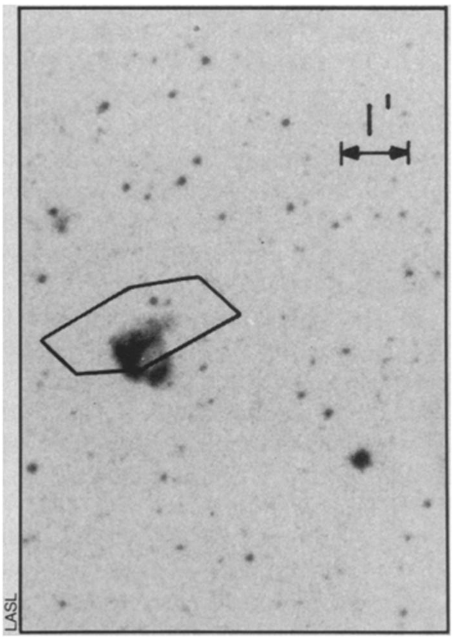
More than being perhaps unique, the March 5, 1979, burst may be giving the clue to what causes these bursts. In part that is because it is the first to be found to coincide with a visibly identifiable object, a supernova remnant in the Large Magellanic Cloud. From that, a chain of reasoning leads to a vibrating neutron star as the plausible source. This hypothesis was presented to the meeting in Washington this week of the American Physical Society by Reuven Ramaty, Thomas L. Cline, U. Desai, Richard Mushotzky and B. Teegarden of NASA's Goddard Space Flight Center in Greenbelt, Md.; Evans, R. Klebesadel, and J. Laros of Los Alamos; K. Hurley, M. Niel, and G. Vedrenne of the European Center for Space Research in Toulouse, France; and I.V. Estuline, A. Kuznetsov and V. Zenchenko of the Institute for Space Research in Moscow. Ramaty delivered the talk.

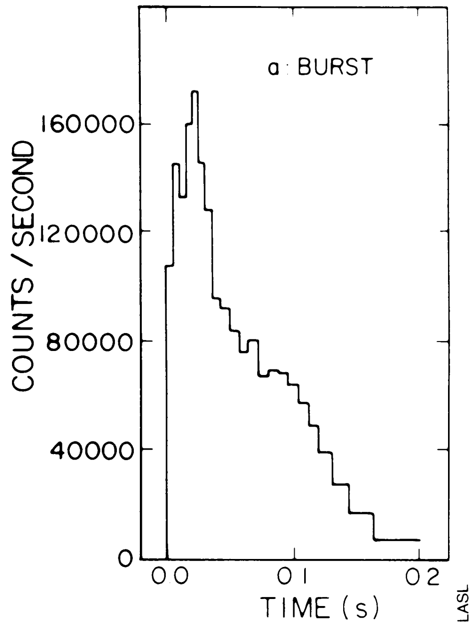
Locating the source of an unexplained astrophysical phenomenon can go a long way toward explaining it. In the case of the transient bursts, gamma ray observers were hindered because gamma ray sensors do not give good directional information. The bursts are also unpredictable. As Evans says, there is no way to know when or from what direction one will come. When one had come, the differences in its arrival time at different satellites could give a way of triangulating its direction more or less.

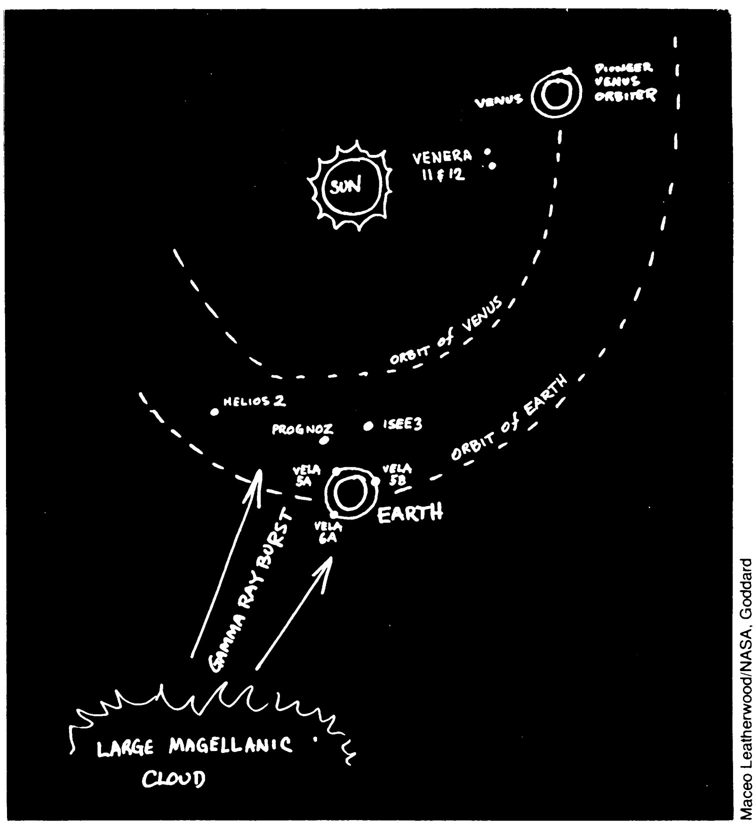
The Velas themselves were not far enough apart to do a very precise job of this. In 1979 an international group of nine spacecraft located in various parts of the solar system were set up to do it. They are in orbit around the earth (Vela 5A, 5B, 6A), Venus (Pioneer Venus orbiter) and the sun (Helios 2, ISEE 3, Prognoz, Venera 11 and 12). It is this group that recorded the March 5 burst, and gave its direction quite precisely: toward the supernova remnant called N49 in the Large Magellanic Cloud, a galaxy that is a satellite of our own, and about 150,000 light years away.

Under the assumption that the gamma ray burst came in fact from N49 and not some place nearer or farther — and to astronomers the assumption is reasonable — a lot of things begin to fall into place. The first thing, says Ramaty, is that the amount of energy in the burst can be calculated from the known distance and the observed intensity of the burst. It comes to 10^{44} ergs. To produce that kind of energy in so short a time requires a dynamic system that is very dense in energy. The answer Ramaty and the others propose is a vibrating neutron star.

The neutron star was not chosen out of







A sudden, sharp burst of astrophysical gamma rays (graph) was recorded by an international, interplanetary consortium of observing satellites (map), which determined that it came from a small area in and near N49 in the Large Magellanic Cloud (photo).

the Sears and Roebuck catalog. In a sense it was there waiting in the supernova remnant. According to a quite independent theory, when a star explodes as a supernova, it leaves behind this huge cloud of glowing gas, the supernova remnant and its own core, crushed into a neutron star. So in a sense the neutron star is the obvious candidate.

To justify the proposal that a vibration of a neutron star, a neutron starquake, could flick off 10^{44} ergs in gamma rays Ramaty kept telling a press conference that it is a "small amount" (compared to the 10^{46} to 10^{51} erg that such a vibration would have available). This provoked Evans to intervene: "Reuven keeps saying 10^{44} is small. It's enormous. 10^{44} ergs in a tenth of a second is 10^{45} ergs per second. That exceeds the luminosity of the whole Milky Way galaxy."

Another argument for the neutron star comes from studies of the spectrum of the gamma ray burst by the Russian observer E.P. Mazets. Mazets found a sharp enhancement, a spectral line, that is, at 400 kilo-electron-volts. The only thing likely to cause a gamma ray line in that range is the annihilation of electrons and positrons. The annihilation line is normally found at 511 kilo-electron-volts. If the difference is taken to be a redshift, it has to be a redshift due to the gravitational field of the source. There is no cosmological redshift between us and the LMC. The redshift gives the ratio of mass to radius of the source. Picking a neutron star of one solar mass (a plausible figure) the radius comes to 10 kilometers (also plausible).

The whole hypothetical sequence goes like this: Something happens in the interior of the neutron star. "I cannot be precise about what that is," says Ramaty. A vibration propagates outward to the surface carrying energy. The vibration shakes the star's magnetosphere, an atmosphere composed of electrically charged particles bound in magnetic fields. The vibrating magnetosphere accelerates the particles, and that produces the gamma rays, both the annihilation line and the continuous part of the spectrum.

There is a plus. The vibrating mass of the star generates gravitational waves. These carry off a sizable part of the energy. This damps the vibration, rendering the phenomenon transient. The damping time that theory calculates for a neutron star that would produce the observed redshift in the gamma ray line (0.25) is 0.15 seconds. That compares well with the length of the main outburst pulse.

So Ramaty remarks, "We have for the second time indirect evidence for gravitational waves." He proposes that a good confirmation of this theory would be the detection of a burst of gravitational waves coincident with a gamma ray burst. For the moment that's beyond the capability of gravity wave detectors. Maybe when there's a stronger burst or more sensitive detectors. □

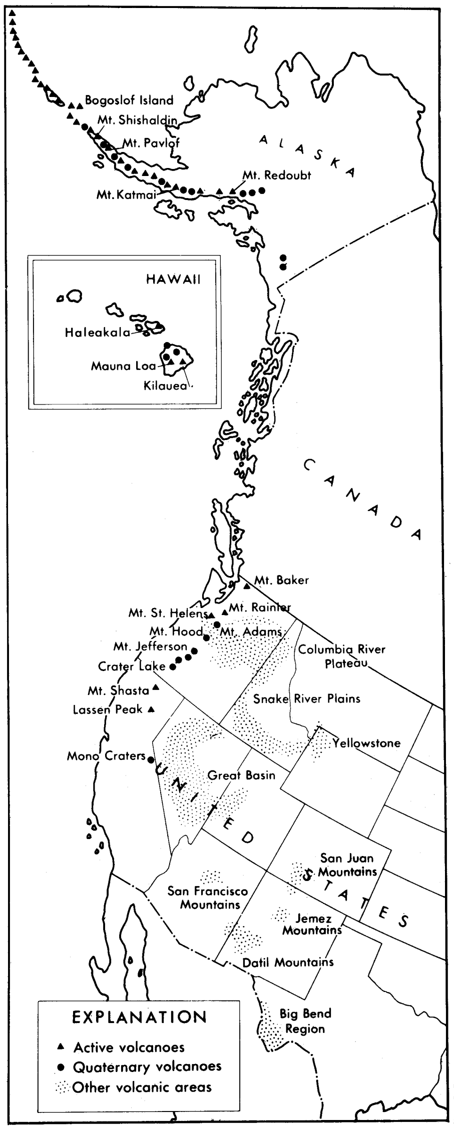
The life and times of Mt. St. Helens

The story of Mt. St. Helens is truly beginning to resemble a soap opera: With nearly theatrical timing, the volcano smolders, fumes and spits, always threatening, but never quite building to a climax. With each episode it promises its geological viewers, "Wait one more day."

The latest crisis in the life of the only erupting volcano in the continental United States is a bulge on its northern flank. Recently taken aerial photographs show that the mountain "underwent large bodily displacements" since the first eruption March 27 (SN: 4/5/80, p. 213). By April 30, the USGS determined that a one-half-square-mile area on the north slope below the volcano's crater had risen at least 80 feet since August 1979. Certain points within the region appear to have bulged considerably more: A pinnacle on the north rim of the now 2,000-foot-wide crater measures about 250 feet higher than it did before the first eruption, according to the USGS. From April 24 to 28, the swelling increased "at an impressive rate" by as much as 20 ft. in the Goat Rocks area at the 7,500-foot level of the 9,677-foot mountain. The bulge "represents the most serious potential hazard yet posed by the volcano" due to the threat of avalanches of rock, ice and mud.

Just what the swelling means is unclear. The movement of magma may be forcing the rock outward, says USGS volcanologist Robert I. Tilling, or gravitational forces may be causing a "slumping" that appears as a bulge in the aerial photographs. Tiltmeters, designed to measure the volcano's swelling or inflation, have been in place at lower levels, but until recently did not show a consistent trend of inflation or deflation, Tilling says. The most recent tilt measurements show "some tilt, not much, but at least compatible with the [photographically detected] bulge." Observers are waiting for precise measurements before making more definite statements. Mappers are redrawing contours of the area, Tilling says, and targets for precise horizontal and vertical measurements are being chosen. "Qualitatively we know something is happening to the north flank. Now we're waiting for something quantitative to tell us what, where and how much."

High in the sky, atmospheric chemists are also getting a quantitative picture of Mt. St. Helens. Richard D. Cadle of the National Center for Atmospheric Research in Boulder, Colo., directed a series of sampling flights through the thick of some of the volcano's most spectacular explosions. Flying in a specially equipped Beechcraft Queen Air, Cadle and coworkers obtained "superb samples" on April 7 and 8 when "we got in such thick ash we had trouble seeing out the windshield in order to land." In a week's



Washington State's Mt. St. Helens is one of the "Ring of Fire" volcanoes that encircle the Pacific Ocean. Such volcanoes occur at the junction of two tectonic plates.

total of five plume-crossing flights, the scientists analyzed the gas content of the eruptions; measured the size, weight and composition of the particles; sampled the water in the cloud to determine its origin; and took time-lapse films of the eruptions.

Though much analysis remains, Cadle says his results suggest that the volcano probably will not have a long-term effect on weather or climate. Major volcanic eruptions such as Krakatoa in 1883 can fling volcanic particles into the stratosphere, which scatter solar radiation and produce cooler global temperatures. In order to produce such effects a volcano must kick out very fine ash particles and large amounts of sulfur compounds, says Cadle, but Mt. St. Helens meets neither requirement. "Our results suggest even if the explosions did reach the stratosphere — which they did not — one would not expect an effect on weather because the particles are so large they fall out immediately and not enough sulfur is present."