spot. Where it shines on dye, a fluorescing spot appears whose intensity is calibrated by the computer. After destroying the dye in one of a pair of adjacent cells, the researchers watch to see whether the dye in the other cell diffuses back into the first.

Tests headed by James Trosko showed that the dye won't move between cells that have been exposed to a cancer promoter — indicating damage to the gap junction, according to Holland. None of the dozens of non-cancer-promoting chemicals tested caused a similar breakdown.

If the association between tumor promoters and a communications shutdown proves universal and reliable, the scientists say, many carcinogen-screening studies presently using animals may be replaced by these much simpler, quicker, less costly and more easily interpreted cell-culture studies. "This test could reduce by a factor of 100 the number of animals needed" to identify new cancer promoters, says Holland.

Moreover, he says, data collected in the past few weeks by Trosko suggest that tumor promoters fall into discrete classes of potency — classes that appear to be differentiated by their mechanism in disrupting cell communications. — *J. Raloff*

Neutrino physics after the supernova

Neutrinos from supernova 1987A are beginning to change some of physicists' ideas about those elusive but important particles. The latest aspect of this is the attempt to determine whether the neutrino has mass by calculating from the time of flight between the Large Magellanic Cloud and the earth. What seems to be the first such calculation to be published — by John N. Bahcall of the Institute for Advanced Study in Princeton, N.J., and Sheldon L. Glashow of Harvard University — appears in the April 2 NATURE. When they first appeared in physics, neutrinos were not thought to have mass. More recently some theories have wanted them to have it. Now, from the supernova, it seems the original idea may have been right.

Supernova neutrinos may also help change astrophysicists' ideas of what happens in a supernova explosion. The usual theories propose that the core of the exploding star collapses — once — to become an ultradense object, either a neutron star or a black hole. At the recent Heavenly Accelerators workshop, held at Johns Hopkins University in Baltimore, Alvaro De Rújula of Boston University proposed that instead of just one collapse there might be a series of such collapses in a single supernova, each leading to a denser state than the previous one.

The first observation of neutrinos from the supernova to be reported, which came from a European collaboration working with the NUSEX detector under Mt. Blanc on the French-Swiss border, seems not to fit the standing theory — the neutrinos appear much more energetic than they ought to be. The other two observations, simultaneous determinations by the Kamiokande detector at Kamioka, Japan, and the IMB detector at Fairhaven, Ohio, seem closer to theoretical expectations. Some commentators have suggested that the Mt. Blanc observation is mistaken; these neutrinos were not from the supernova. De Rújula supposes the Mt. Blanc observation is real and combines it with the two others to see what the combination might tell about what happens in a supernova.

The Mt. Blanc detector saw five pulses of neutrinos in 7 seconds, and it saw them 4 hours 43 minutes before the simultaneous observations of Kamiokande and IMB. De Rújula makes a statistical argument to support the idea that Mt. Blanc saw something real, but then he has to explain why Kamiokande saw nothing at the time of the Mt. Blanc events. He can accomplish this by assuming that the energy of the neutrinos was somewhat less than observers have generally been postulating. Then, taking account of the characteristics of the detectors, he can make the different experiments compatible with one another. Thus he comes to the conclusion that there were two bursts of neutrinos from the supernova, 4 hours 43 minutes apart, and that leads to his suggestion of a double collapse.

Theory supposes that the collapse of the core of a star initiates a supernova explosion. During a star's life, heat produced by thermonuclear fusion processes holds it up, preventing it from collapsing under its own gravity. When a supernova begins, that support somehow fails and the core of the star collapses, producing either a neutron star or a black hole. An outward flying flux of neutrinos is a by-product of the collapse.

The core collapse also triggers a shock wave that propagates outward, blowing away the outer layers of the star. De Rújula calculates that it would take about 10 hours for the shock to cover the distance to the outermost layers of the star, and he proposes that — at least in the case of supernova 1987A — the shock didn't get all the way to the surface. A fizzling-out of the shock would have caused a second collapse of the core. The first collapse would have made a neutron star; the second would have made a denser object, a black hole. The experiments on earth would have received bursts of neutrinos from both collapses, separated by the 4 hours 43 minutes.

If this is really what happened, and a black hole is now there, De Rújula says, there should now be a steady flux of neutrinos from matter accreting around the black hole drawn by its tremendous gravity. He pleads that the detectors be kept on to look for this steady flux. Unfortunately, Kamiokande has already been shut down for maintenance and improvements.

Neutrinos from the supernova should come to us at the speed of light so long as they have no rest mass. Edward Kolb of Fermi National Accelerator Laboratory in Batavia, Ill., speaking at the Heavenly Accelerators workshop, calculated the duration of the flight at about 5 trillion seconds ($5.36 \pm 0.52 \times 10^{12}$ seconds). If the neutrinos have a small rest mass, they cannot come quite at the speed of light. The flight time of a given neutrino will be a little longer than that, and those with higher energy will come fastest. The duration of the pulses as they arrive at earth will depend on the amount of this supposed neutrino rest mass.

When the existence of neutrinos was first postulated, they were supposed to have exactly zero rest mass, and most experiments have been consistent with zero rest mass. The exceptions have been some experiments in the Soviet Union that persist in showing a neutrino rest mass of 30 or 40 electron-volts (eV). Some of the recent theories that are trying to unite all of particle physics in a single framework need to have neutrinos with a small rest mass, and these theories have spurred both the Russian and other attempts to find one. In addition, if neutrinos have a small rest mass, cosmologists can say that large gangs of them floating through the universe would constitute the majority of the matter in the universe and would provide enough unseen matter to make the universe close on itself, a condition that many cosmological theories need to have.

Unfortunately for these people, Bahcall and Glashow state that their analysis of the supernova data shows that neutrinos probably have no rest mass, or at least no more than 11 eV. This limit on the rest mass, they say, is stronger than any that has been achieved in 50 years of terrestrial experiments. The exact limit that one can set on a possible neutrino rest mass depends on certain assumptions about the relation of the duration of the neutrino pulses at earth to their duration at the source. Kolb, reviewing several yet-unpublished papers on the subject, says they set various limits from 5 eV to 25 eV.

If the supernova data are showing that neutrinos have zero rest mass, that, as De Rújula comments, "in 2 seconds would have destroyed 20 years of work by the Russians." It would also drive a nail into the coffin of some of the proposed unified theories of particle physics, and, to quote Bahcall and Glashow, "confirms the view that electron neutrinos do not constitute the major component of the matter density of the universe." — *D. E. Thomsen*