mass of a star is that it should be in a binary system. Newton's laws of gravitation will yield equations that can be used to find the mass provided the star is in a close gravitational relation with another, and a star standing alone is not.

About half the stars in the sky are in binary or multiple systems, but X-ray emitters are a rare breed, and their statistics are not so cozy. About 100 stellar X-ray emitters have been found in our galaxy, but among them are only eight known binary systems. Each of these appears to consist of a collapsed star (the X-ray emitter) and a more or less normal optical star orbiting around each other.

The second requirement for determining mass is that there be some way of finding out the star's orbital motion. Luckily Vela X-1 emits X-rays in pulses. As the star moves in its orbit, alternately receding from the earth and advancing toward it, the frequency of the pulses will undergo an apparent change, a Doppler shift. From the Doppler shift the astrophysicists could tell the X-ray source's speed in orbit, and that datum allows them to set up a relation between the masses of the two bodies.

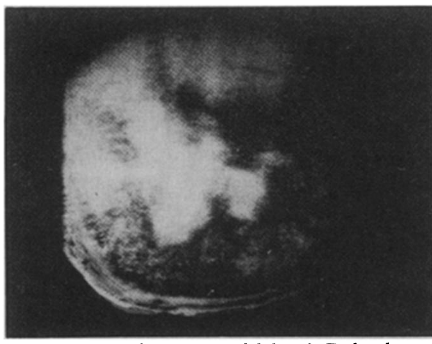
That, however, as any student of Algebra I knows, is not enough. To solve for two unknowns, the two masses, you need two equations. By a third piece of good fortune, the second equation became available. It proved possible to measure the Doppler shift in the light of the X-ray star's companion and make an independent determination of its orbital motion. With the two equations the two unknowns could be determined.

The X-ray source turns out to be a highly compacted, ultradense body, which has 1.7 times the sun's mass though it is only about 16 kilometers in diameter. The density of such a thing, the MIT astrophysicists calculate, is comparable to that of a pea that weighs a billion tons. The visible companion star has about 20 solar masses and 30 times the sun's diameter.

The determined mass for the neutron star is at or slightly above the upper limit that most theories assign for neutron stars (which would be about 1.65) almost into the range proper to black holes. Yet the pulsations indicate that Vela X-1 is not a black hole; theory knows no way for a black hole to pulse.

"The mere fact that you have a neutron star as massive as this places constraints on the physics of these objects," Joss says. Theorists suggest that much of the energy of the sea of particles in a neutron star is converted into new particles. This behavior would lower the interparticle repulsive forces and lead to lower mass estimates than it seems Vela X-1 has. Still, as Joss points out: "At densities greater than that of an atomic nucleus there is no direct information about how matter behaves." So the theorists have a number of options to go back to the drawing board with. ☐

Opto-sonic hologram: 3-D views of organs


Baum and Stroke/Science

Hologram of cyst would be 3-D by laser.

Medical researchers have long sought new ways of examining interior structures of the body, both healthy and abnormal, particularly in view of the potential dangers of X-ray exposure. One of the most widely used of these tools has been ultrasonography, a technique for creating images from reflected high-frequency sound waves (SN: 12/25/71, p. 424). But, like an X-ray, a sonogram is a two-dimensional image. The problem has been to find a way of creating such images in three dimensions, so that an investigator can measure the extent of, for example, a cyst in all directions.

Such a technique has now been reported by two New York researchers, Gilbert Baum of the Albert Einstein College of Medicine in the Bronx and George W. Stroke of the State University of New York at Stony Brook, in the Sept. 19 SCIENCE. Not too surprisingly, the key is holography, a method for creating three-dimensional images on a flat piece of film using diffraction patterns created and viewed with a coherent, or directionally aligned, beam of energy. The technique, however, is less obvious.

Clear three-dimensional "sound images" have heretofore been made largely by putting two-dimensional sonograms from parallel planes of the organ under study onto glass plates, and looking through the resultant "sandwich." The opaque sections of each plate, however, cast shadows on the plates beneath, so that a sandwich of more than a few plates becomes uselessly murky. Another approach is acoustic holography, but, says Stroke, it suffers from blurring caused by depth scattering when sound waves are reflected from soft tissue.

The method of Baum and Stroke combines both sonic and optical techniques, beginning with a series of conventional, two-dimensional sonograms made of adjacent planes. Since these do not depend on coherent energy, they can each resolve a plane as little as a half-millimeter thick. Then a conventional, optical hologram is made of the first sonogram on a piece of film. Next the first sonogram is replaced in the holograph's laser beam with the second, displaced by the same distance as the separation of the planes of the original sonograms. It is photographed on the same piece of film, which has been displaced by the same distance. This procedure is repeated for all the sonograms, which then appear simultaneously, with their original separation, when the film is viewed by laser light, and without the shadows of the glass sandwich.

Stroke says further research is necessary to determine the technique's range of applications, which might extend beyond medicine to such areas as metallurgy. ☐

Has a heavy lepton been discovered?

Lepton means something light in weight (from the Greek *leptos*), and the particles called leptons are the lightest known to physics: the electron, the muon and the neutrino associated with each of them. Heavy leptons would seem to be a logical contradiction, but their existence is predicted in some of the latest theories of particle physics, the unified field theories that link electromagnetism and the weak subatomic interaction in a single framework. In the Sept. 8 PHYSICAL REVIEW LETTERS, three theorists from Harvard University, A. De Rújula, Howard Georgi and S.L. Glashow propose that such things have been discovered, although the experimenters involved think not.

The experiment was done in a mine in India by M.R. Krishnaswamy and collaborators from the Tata Institute of Fundamental Research in Bombay. They were looking for neutrino interactions, but they found a significant number of events that yielded double tracks quite uncharacteristic of neutrino processes. Krishnaswamy and his group proposed that the double tracks come from the decay of a new heavy particle produced in the rock around the mine by neutrinos.

The Harvard theorists do not accept this. They say the double tracks are produced by decay of neutral heavy leptons. The neutral heavy leptons are produced in the upper atmosphere by decay of charged heavy leptons (plus or minus), which in their turn are produced by the cosmic rays. The neutrals last long enough to reach the mine, incidentally, because they decay under the governance of an interaction weaker than the usual weak interaction, possibly the super-weak force that has been proposed to account for certain other leptonic anomalies.

The proposed heavy leptons would have masses about two billion electron-volts. This is 20 times the mass of the heaviest known leptons (muons at 106 million electron-volts) and a little more than twice that of a proton. The heaviest known elementary particles of any class now run to about four billion electron-volts. ☐