quency of binaries is just as high as among all stars."

Moreover, young binary systems appear to have properties very similar to those of older systems. "Everything seems to fit together pretty well," says Alan P. Boss of the Carnegie Institution of Washington, D.C.

The growing catalog of young-star binaries provides valuable clues for theorists trying to determine how binary star systems form. Are they created through a process of cloud collapse and fragmentation? Or do they result from the splitting, or fission, of rapidly rotating objects? The evidence now points toward collapse and fragmentation as the preferred mechanism for the formation of close, low-mass binaries.

The new observations and computer simulations have forced a major shift in the way astronomers picture the formation of binaries. For decades, astronomers thought fission was the more likely possibility for producing close binaries: a large glob of stellar material – a protostar – spinning so rapidly that it breaks up into two pieces. "The problem is that it doesn't work," says Boss.

Recent computer simulations show that when a spinning glob begins breaking up, it kicks out streams of material that form graceful spiral arms. The gravitational force exerted by the spiral arms on the incipient binary robs the binary of the spin it needs to keep on forming. The result is not a low-mass binary but a single, rapidly rotating object surrounded by a disk or ring.

Furthermore, no one has detected the protostars needed for the fission scenario. Binaries are present among even the youngest stars observed, indicating that breakup probably occurs before the formation of a large central object, or protostar.

That leaves cloud collapse and fragmentation as the more promising theoretical model. Theorists suspect that for a cloud to contract and form any star, it must go through a very rapid collapse. Such a process, in which the density of matter increases dramatically by 20 orders of magnitude, inevitably leads to the breakup of the cloud. "People who have studied fragmentation have found that it is actually almost hard to find clouds that will not fragment," Boss says.

Computer calculations show that fragmentation, depending on the cloud's initial geometry and motion, can lead to binary systems with a wide range of separations between the partners. In some cases, binaries start to form but don't quite make it. They end up merging together again to form a single star. In other instances, the newborn pair of stars survives as a binary.

Fragmentation may also occur several times during cloud collapse. The contracting cloud breaks into two pieces, then those two pieces break up further, and so on. Boss' calculations show that fragmentation appears to stop when the fragments are smaller than one-hundredth the mass of the sun.

The mass limit on cloud breakup suggests that the fragmentation scenario is an unlikely source of planetary systems, in which planets have masses much less than one-hundredth a solar mass. "As you go to a smaller and smaller mass, it's harder and harder to get the cloud to break up," Boss says.

Theorists still have a long way to go to explain the birth of binary stars. "This is a very young field," says Joel Tohline of Louisiana State University in Baton Rouge. "We are just beginning to understand qualitatively how the process can take place in nature."

"At this point, theorists are dealing primarily with the issue of how you get two stars bound together," Mathieu says. "So far, they haven't really made many specific predictions about what the system will look like after they're made. What will the orbital periods be? What will the eccentricities be? How do the systems evolve to what we see? We need to have predictions by which to test what the theorists are saying." ☐

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Nobels awarded for physics, chemistry

Electrons, photons, neutrinos and mesons – these subatomic particles form the background for the Nobel prizes this year in physics and chemistry.

In contrast to last year's Nobel prize in physics, awarded for very recent work on superconductivity, the Royal Swedish Academy of Sciences reached back to work done nearly three decades ago to select the 1988 physics prize winners. Three Americans – Leon Lederman, director of the Fermi National Accelerator Laboratory in Batavia, Ill., Melvin Schwartz of Digital Pathways Inc. in Mountain View, Calif., and Jack Steinberger, now at the European physics research center CERN in Geneva, Switzerland – won the prize for work they did in 1960 to 1962 while at Columbia University in New York City.

During that time, they became the first researchers to devise a way to produce a stream of neutrinos in the laboratory. When they did so, the trio found a new type of neutrino, a discovery that helped lead to the creation of the current family tree showing the relationships among all subatomic particles.

The neutrino is a neutral particle with little or no mass and very little interaction with other particles. It is so noninteractive that billions of neutrinos pass unimpeded through each square centimeter of the Earth every second. Until Schwartz suggested a method, no one knew how to create a stream of neutrinos to study in the laboratory.

To produce neutrinos the group used high-energy protons from a particle accelerator to bombard a beryllium target, producing a shower of protons, neutrons and the smaller pi-mesons (pions). As the pions traveled away from the target they disintegrated into mu-mesons (muons) and neutrinos. The researchers filtered out all particles but the neutrinos by passing the beam through a 44-foot-thick barrier of steel. The neutrinos then entered a 10-ton aluminum detection chamber, where a few neutrinos out of the hundreds of billions passing through interacted enough with the aluminum atoms to be detected.

From previous research the scientists knew neutrinos could create either electrons or muons as they interacted with matter. But in the detector the neutrinos from pion disintegration created only muons, indicating there must be two types of neutrinos – one for muons and one for electrons. The academy awarded the 1988 Nobel prize to the three not only for the discovery of the muon neutrino, but also for the method for producing high-energy neutrino streams.

The Nobel prize in chemistry went to three West Germans – Johann Deisenhofer, now working at the Howard Hughes Medical Institute in Dallas, Robert Huber of the Max-Planck Institute for Biochemistry in Martinsried, West Germany, and Hartmut Michel of the Max-Planck Institute for Biophysics in Frankfurt am Main, West Germany – for determining the structure of a bacterial protein that performs simple photosynthesis. The cytochrome protein, which sits astride the bacterial membrane with one part inside the cell and one part outside, uses a specialized molecular architecture to absorb photons of light and uses that light energy to transfer electrons and hydrogen ions across the membrane.

Bacteria use the resulting difference in the concentrations of hydrogen ions (pH) and electrons (voltage) inside and outside the cell to make one of life's most basic chemical energy sources, adenosine triphosphate. This type of photosynthesis is simpler than that in plants, but the German trio's discovery contributes to the understanding of the mechanisms of photosynthesis in general.

Michel solved the biggest technical difficulty of the project in 1982 when he discovered how to purify and crystallize the membrane-bound protein. Deisenhofer and Huber then joined Michel to perform X-ray crystallographic measurements on the purified protein, which allowed the team to elucidate its structure in 1985. *– C. Vaughan*