Death Star

NASA

Some scientists believe that a mysterious companion star to our sun periodically hurls lethal comets at the Earth, snuffing out many living things

By CHERYL SIMON

A group of 25 or so scientists from a medley of disciplines gathered in California recently to consider an astonishing idea: That periodically the earth is pelted by comets jarred into the inner solar system by a companion star to the sun. The idea has turned the gazes of many scientists, who normally study the rocks beneath our feet, toward the heavens. Suddenly they must consider the possibility that throughout earth history not one or two, but many mass extinctions were tied to impacts with asteroids or comets, and that the extinctions were not random in time. Instead, it appears, extinctions and impacts take place in cycles, every 26 or 28 million years.

This unexpected twist in thinking came about only a few months ago, after two paleontologists, David Raup and John Sepkoski of the University of Chicago, discovered a pattern in mass extinctions (SN: 10/1/83, p. 212). In 1977 Alfred Fischer and Michael Arthur, both of Princeton University in Princeton, N.J., suggested that 32 million years elapsed between mass extinctions, but the idea received little attention. Nearly everyone continued to view extinctions as random events. Then, Raup and Sepkoski examined the records of times during the last 250 million years when 3,500 families of marine organisms vanished from the fossil record. To their surprise, an unmistakable pattern emerged against the background of extinctions that occur in the normal course of life. A range of statistical tests yielded the same, inexplicable signal: The mass extinctions rose to a stark peak roughly every 26 million years. No earthly physical or biological process is known to occur on a cycle of that length. The answer, Raup and Sepkoski suggest in the February Proceedings of the National Academy of Sciences, must lie outside the earth, in the solar system or galaxy or beyond.

With this tantalizing gauntlet tossed their way, several teams of astronomers and physicists rose to the challenge, quickly producing a round of possible explanations for the extinction cycles. Their curiosity had long been piqued by a bold and testable hypothesis advanced in 1980 by Luis Alvarez of Lawrence Berkeley Laboratory (LBL) in Berkeley, Calif., Walter Alvarez of the University of California at Berkeley, and Frank Asaro and Helen Michel, also at LBL.

Sixty-five million years ago, they said, at the end of the Cretaceous period, an asteroid or comet hit the earth. They told of a collision that sent huge quantities of dust into the stratosphere, cloaking the world in darkness and affecting the earth's climate and environment so drastically that many forms of life could not survive. The record of this calamity is written in the thin clay layer that separates the Cretaceous from the next period, the Tertiary. The clay, it happens, contains vast concentrations of the metal iridium, which is rare on the earth's surface but abundant in extraterrestrial bodies.

Acting on an informed and pivotal hunch, Luis Alvarez deduced that the clay embodied the debris of a tremendous explosion that followed the impact. The event and the boundary are important because at that time, more than 75 percent of species on earth disappeared forever. It was one of the largest mass extinctions the earth has ever seen, and certainly the most famous, for the dinosaurs apparently were among the victims.

In the ensuing years the hypothesis has been variously cheered, jeered at, challenged and upheld. It has revitalized the study of extinction, raising new questions about its dynamics and importance in evolution. High iridium concentrations have been found at more than 50 locations in rocks spanning the boundary, and in rocks formed both from ocean and freshwater sediment. Some scientists have scrutinized cores of mud extracted from the sea floor to learn if other time periods and mass extinctions coincide with iridium anomalies. Other scientists are studying the physical effects of impacts on the earth, and still others are trying to assess how much energy would be required to vault sufficient material into the atmosphere to cause the alleged climate effects.

And now, with an apparent cycle in mass extinctions, the notion that impacts with extraterrestrial bodies can affect earth history has taken yet another turn. It may be that at regular intervals, some force outside terrestrial biology perturbs the biological system, upsetting it so powerfully that the course of evolution is changed forever.

With this panorama of ideas in mind, Luis Alvarez and David Raup recently invited a group of scientists to an informal workshop at LBL to explore the cycles in extinction, evidence for periodic cometary impacts, and the various explanations proposed.

Working independently and without knowledge of each other's efforts, two groups of scientists represented at the conference had come up with similar theories to explain the extinction cycles. Both suggest that the sun has a sister. Our sun, viewed as a solitary star, is unusual. Many stars travel in pairs, gravitationally linked in cosmic couplets known as binary systems. The two research teams are Daniel P. Whitmire of the University of Southwestern Louisiana in Lafayette, working with Albert A. Jackson IV of Computer Sciences Corp. in Houston; and Marc Davis and Richard Muller of the University of California at Berkeley, and Piet Hut of the Institute for Advanced Studies in Princeton, N.J. Their proposals, to be published in NATURE, differ mainly in estimates of the star's mass, brightness, and the eccentricity, or shape, of its orbit. "I really don't think there are any important differences between their paper and ours," Muller says. "We both came across what we believe is the only plausible model."

Davis, Hut and Muller call the star "Nemesis," an allusion to the Greek goddess who persecutes the "excessively rich, proud and powerful." Other participants at the meeting called it more informally, "the death star." Both groups believe that the elusive star travels an elongated orbit that every 26 million years brings it closest to the sun. At this point the companion would enter the Oort cloud, a sparse halo of comets on the fringes of the solar system that is the source of the comets that have been observed.

Many astronomers believe that within the Oort cloud exists an inner cloud of comets, still unobserved. This hypothetical cloud is 10 times as massive as the Oort cloud, and in fact, supplies the Oort cloud's comets. When the companion star enters the inner cloud, the theory goes, some of the comets are shaken loose, causing comet showers that last as long as a million years. During the shower, more than a billion comets could flash through the solar system. To an earthbound viewer, this would provide a light spectacle of unimagined splendor. That is, until one of the icy bodies hit the earth. During the course of the shower, the authors report, about two dozen such collisions might occur.

The researchers draw heavily from a 1981 paper by Jack G. Hills of Los Alamos National Laboratory in New Mexico, that explores the effect a random, non-companion star passing the solar system would have on the comets in the Oort cloud. These passages, within 3,000 astronomical units (A.U.) of the sun, or 3,000 times the distance between the earth and the sun, should occur perhaps every 500 million years. Davis, Hut and Muller calculate that at its closest point, the companion star could still be up to 10 times as far from the sun as such a random star. But because it would move much more slowly, the companion could be in position long enough to send the same number of comets into the inner solar system. Whitmire and Jackson propose a black or brown "dwarf," a star so small that its core never ignited. They say that the invisible star passes closer to the sun, to within 2,000 to 9,000 A.U., to bring a similar number of comets toward the earth.

Both groups of researchers believe that the solar companion still may exist, and that it formed about 4.5 billion years ago

John C. Brandt & Robert D. Chapman, *Introduction to Comets*, Cambridge Univ. Press 1981

along with the sun and the planets. But most binary stars are much closer to each other than the sun and her proposed sister. There is a chance, the researchers concede, that the star — by varying estimates from one-third to one-twentieth as massive as the sun — has been stripped from the solar system. Kepler's laws dictate that the speed of the star would decrease progressively as it follows its orbit away from the sun; thus, the companion would spend most of its time at the point where its gravitational links with the sun are weakest.

At the meeting, several observers noted that this makes the distant star more vulnerable to tugs by passing stars which, while probably not strong enough to lure the companion away, could have disturbed the star's orbit during the last 4.5 billion years. A stronger, but less frequent influence would be the passage of the solar system through giant interstellar clouds of gas and dust. Both theories for the companion star say that such perturbations have lengthened the period of the star's orbit, and have increased the orbit's size. If the star in fact exists, the researchers agree, in another billion years or so its orbit will be so distorted that it will abandon the sun forever.

While the companion star theory was warmly received, some cautionary notes were sounded. Gene Shoemaker, of the United States Geological Survey in Flagstaff, Ariz., and a respected authority on comets, quickly ran through some calculations to explain his conclusion that while the death star's existence theoretically is possible, the probability is less than 1 percent.

He derives this low figure from a complex series of conditions that a companion would have to meet. He says that the companion must have survived for 4.5 billion years, its orbit has had to remain stable for at least the last 250 million years, and the shape of its orbit is such that the star's close passage to the sun would disturb the comets, but would not rip the comet cloud, and the solar system, apart.

"The main problem is that there are so many uncertainties," Hut told SCIENCE NEWS. "We don't know how the comet cloud is filled up in the first place, or how it originally was built up and how much of that was lost. If it turns out that it is difficult to get enough comets to the earth — so that if you set up 100 solar systems, only one will give you the right cratering — still you cannot say you've ruled out a theory. It may be a little less probable, but it might be that for every 100 solar systems, only one gets comets hitting a planet. And that may be the planet where life evolves."

Whitmire too acknowledges a chance that the companion no longer exists, if it ever did. However, he adds, "What those probability arguments ignore is the evidence." He was referring to the peaks in the record of mass extinctions, and to a subsequent finding that the cratering record on earth also falls neatly into peaks that match the fossil record.

This correlation came about after Muller told Walter Alvarez about the binary star theory. To test the prediction, they looked for evidence that the craters on earth also formed in cycles. Using a list of 88 craters compiled by Richard Grieve of Brown University in Providence, R.I., Muller and Alvarez limited their analysis to the craters within the time frame used by Raup and Sepkoski — between five million and 250 million years ago. They further culled the craters by including only those larger than 10 kilometers in diameter, and those accurately dated.

Using a variety of statistical approaches, Muller and Alvarez came up with a period of 28.4 million years. To their delight, the phase of the impact cycles closely mirrors the cycles in extinctions.

A year ago, when the extinction pattern first was discerned, Raup and Shoemaker too looked for a matching cycle in the formation of impact craters. They did not perceive one because they included craters with poorly known ages. Recently Raup repeated his analysis, using different methods than Muller and Alvarez, and another way of sorting the craters. His result? About 28.5 million years.

The uncertainties in dating rocks according to the fossils they contain are such that the difference between a 26-million year cycle and a 28-million year cycle is negligible, Sepkoski says. For the most recent 100 million years, the two cycles are in lockstep. The first extinction peak and crater both are dated to about 11 million to 13 million years ago. The next three peaks in the series — 38 million years, 65 million years and 91 million years before the present — also match up with the cratering dates. Beyond that, the fit is good but not superb. In part this is because the fossil record in such ancient rocks is so difficult to decipher.

As a further test of the pattern's strength, Raup and Sepkoski arbitrarily divided the extinction peaks into halves. Often with small collections of data, Raup explains, evidence of cycles disappears completely. Instead, the two halves show robust periodicities of 27 million and 29 million years, with confidence levels higher than 95 percent.

The cratering cycles are subject to some skepticism from other scientists familiar with the data. Richard Grieve, for instance, says that there may be spikes in the cratering record, but raises several questions about the cycles proposed and the methods used to identify them. First, he says, the craters included overlap those used to determine the rate at which asteroids strike the earth. Some of the craters have geochemical signatures that indicate that they were formed by stone and iron meteorites. If all of the craters that Alvarez and Muller are using were formed by periodic comet showers, he says, "where are all the big craters formed by the asteroids? You can't use the same craters to calculate two different things." He also doubts that the statistical method (Fourier transform analysis) used by the Berkeley scientists is useful in identifying patterns in such a small set of data — in this case, well-dated craters.

Another team of researchers, Michael Rampino and Richard Stothers of Goddard Institute for Space Studies in New York, also report a cycle in the cratering record, citing a period of about 31 million years between comet showers. In a paper also submitted to NATURE, they explain the cycles by the periodic movement of the solar system through the plane of the galaxy, the Milky Way. Each half of this vertical oscillation takes 33 million years, give or take three million years, and is the only known phenomenon with a period that conceivably could explain the extinction pattern. As the solar system penetrates the plane of the galaxy, the scientists believe, it could encounter large interstellar gas and dust clouds concentrated in this region. They write that this in turn could affect the earth's biology by polluting the earth's atmosphere with hydrogen gas, or by disturbing the gravity of comets in the inner cloud, launching them toward the earth.

An inherent question about the Milky Way hypothesis is that the last mass extinction in the Raup and Sepkoski data was about 13 million years ago, leaving another 13 to 15 million years or so until the next cataclysm, if the pattern continues. Rampino and Stothers, however, take a different view of the extinction data. In their own statistical analyses of the extinction peaks, they include only the nine largest extinction events, as opposed to the 12 used by Raup and Sepkoski. In this light, the period between extinctions is about 30 million years. In a letter to SCIENCE NEWS, the Goddard researchers, who elected not to attend the meeting, further explain the scatter in mass extinctions. They write: "At the present time, the solar system is passing through a 'hole' in the galactic plane, so that encounters with some of the larger clouds either in the recent past or in the near future are unlikely."

Other researchers, including the death star proponents, also considered the galactic plane idea but rejected it, deeming the cycle too far out of phase with the extinction record. "We're in a region of higher than normal star density right now," Shoemaker says. "Not only is the galactic plane passage out of phase with the present extinction cycle, it was out of phase for the last several cycles."

While the researchers debate the problem, even now some are combing the sky in search of the companion, looking through the catalogs of known stars, and scrutinizing the data from the Infrared Astronomy Satellite (IRAS), which might have observed the star in parts of the light spectrum invisible to the naked eye.

Muller, for instance, is using an automated telescope on the Berkeley campus to search the whole sky for a small visible star with a mass and orbit that could explain the extinction cycles. The star, if found, is expected to have a large parallax motion. This is the apparent change in a star's mean position against the backdrop of distant stars when measured from opposite sides of the earth's orbit. The closer the star, the larger the parallax. Among the prime candidates are the 3,000 known dim red stars, Muller says. These stars burn at relatively low temperatures, and their parallax motions might not have been measured. "We believe that if it's there, we can find it within a year," he says.

As some scientists focus on the heavens, some others who study fossils and earth history are beginning to speculate: What philosophical changes are implied if the idea that impacts and extinctions are both linked and periodic stands up to rigorous scientific testing? For instance, the idea that mass extinctions are extraterrestrially controlled means that in some ways, they may be random with respect to Darwinian adaptation. Or, as Raup puts it, "The system gets clobbered every once in a while without regard to fitness in the conventional sense."

Another outcome may be a unifying theory of extinction. Conventional wisdom holds that extinctions are complex and that they stem from a variety of causes. Over the years, reasons proposed for mass extinctions have included climate changes, glaciations, changes in sea level, and anoxic events, in which the oceans become devoid of oxygen, for reasons unknown. And finally, impacts of the earth with large extraterrestrial bodies. All of these events are documented in the geologic record, though not all necessarily occurred at every mass extinction.

It could turn out, Raup says, that large body impacts are triggering the other effects. "That's a large amount to swallow, but this would remove us from a situation where there have been several antagonistic ideas to explain extinction. It could just turn out that everyone was right." □