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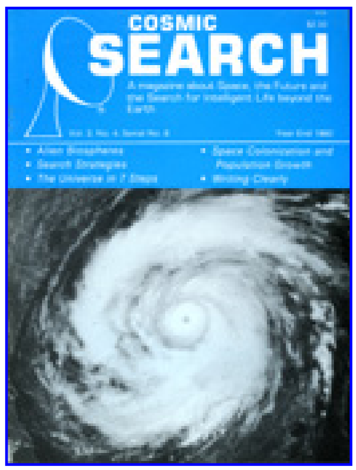

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The SEnTInel

By: Robert S. Dixon

What Caused the Dinosaur's Extinction?

Many reasons have been suggested in the past to explain why the dinosaurs suddenly became extinct about 65 million years ago. Among these are a sudden climate change, a reversal of Earth's magnetic field, and a nearby supernova. Actually the dinosaur extinction is only the most recent in a series of great extinctions that have occurred five times since the time of the oldest fossils, or about once every 100 million years. During these extinctions entire groups of plants and animals disappeared completely, yet others survived. For example, during the dinosaur extinction most of the water-living reptiles, all of the flying and large land reptiles, and many kinds of sea plants died out. But mammals, amphibious reptiles (like crocodiles), snakes and land plants survived. Any theory which successfully explains these events should explain not just one extinction but all of them, and should explain why some life forms died out while others lived on.

Recently acquired geological evidence now points strongly toward the hypothesis that the extinctions were caused by asteroids colliding with the earth. Luis Alverez, Walter Alverez, Frank Asaro and Helen Michel of the University of California at Berkeley explained their findings in the June 6, 1980 issue of *Science*.

Astronomers calculate that an asteroid of 10 km diameter or larger will collide with the earth about once every 100 million years, in good agreement with the frequency of the great extinctions. A 10 km diameter asteroid collision would make a crater about 200 km across. Three known craters exist on the Earth today that could have been caused by such impacts. The dust clouds thrown up by such an impact would quickly enter the stratosphere and be distributed by the wind to completely encircle the earth. This would effectively block out most of the sunlight and cause photosynthesis in plants to stop. As the plants died out, so would the animals that eat the plants, including most of the dinosaurs. As these animals died out, so would those who prey on them (the meat-eating dinosaurs).

The only survivors would be those who could temporarily exist on other food sources. The only mammals of that era were small, rodent-like creatures that could eat roots, nuts, seeds and other non-perishable food. Thus, they survived. Also in turn those animals that preyed on the small mammals (snakes and crocodiles) could survive. After several years the dust clouds would settle back to earth and the sun would reappear. Then the land plants which had lapsed into dormancy could spring up again from seeds or by sending forth new shoots from their roots.

It is useful to extrapolate the effect of an asteroid collision from the effects of the largest explosion in modern history; that of Krakatoa. Krakatoa is an island volcano in Indonesia that exploded with extreme violence in 1883. Although far smaller in its effects than an asteroid collision, Krakatoa did in fact throw up clouds of dust that encircled the earth. Brilliant sunsets caused by the dust occurred worldwide soon after the explosion. The sunsets lasted several years, and then stopped, indicating that the dust had settled back down to the earth. Thus, it may be reasonable to believe that an asteroid collision would cause effects similar to those required to cause the great extinctions.

Reasonable as this scenario may seem, it does not prove that an asteroid collision did in fact occur 65 million years ago, just at the time of the last great extinction. It is to this point that the Alverez group directed most of their effort. They studied the rock layers that were deposited at that time, in an effort to learn if they differed in any significant way from their neighboring older and newer layers. To eliminate local variations, they studied those layers at widely separated outcroppings in Italy, Denmark and New Zealand.

As the Earth originally formed and cooled from its molten beginning, certain groups of chemical elements migrated toward the center, leaving the outer crust relatively depleted in these elements, compared to that of the solar system as a whole. For example, the rare metal iridium is much less common in the Earth's outer crust than it is in asteroids, meteorites and interplanetary dust. The Alverez group reasoned that if an asteroid struck the earth, the dust it threw up would contain more iridium, relatively speaking, than is found in the average soil on Earth. As the dust settled, it would enrich the rock layers currently being deposited at the bottom of the ocean, so that there would later be a narrow layer of rock that contained an anomalously high concentration of iridium.

When the Alverez group analyzed the rock layer that was created at the time of the dinosaur's extinction, they found that the concentration of iridium was 50 times greater than in any neighboring rock layers. This is strong evidence that the earth had a sudden inflow of extraterrestrial material, that lasted only a short time, and occurred at the same time the dinosaurs became extinct. An asteroid collision seems to best explain all the observed facts.

The wider implications of all this on the evolution of life in the universe are unclear. It seems likely that the extinction of the dinosaurs left the surviving mammals with fewer competitors and predators, thereby allowing them to more rapidly expand their habitats and evolve to occupy more ecological niches. On the other hand, this might have occurred eventually anyhow. If occasional great extinctions caused by asteroid collisions are a necessary condition for intelligent life to evolve, then the frequency of intelligent life is dependent on the frequency of available asteroids. We do not know if our solar system is unusual in having an asteroid belt, so we can only speculate as to whether the work of the Alverez group increases or decreases our estimates of the frequency of intelligent life in the universe.

Faster-Than-Light Motions Observed in Radio Sources

In recent years it has become possible to record radio signals of a celestial object simultaneously at a number of different radio telescopes located in various places on the earth, and then later combine the data from all the telescopes to simulate what would have been observed with one huge radio telescope that is nearly as large as the Earth. This observing technique is known as a very long baseline interferometry, or VLBI. It can provide angular resolution of 1/1000 of a second of arc, which is significantly better than can be achieved with conventional optical telescopes.

This extreme resolving power has been used to study objects whose angular diameter is very small, indicating that the objects are either very small in size, very far away, or both. The most exciting discovery made thus far using this technique came about from a program that monitored the finely-detailed structure of about 10 such objects over a period of several years. This effort was summarized by Alan Marscher of the University of California at San Diego and John Scott of the University of Arizona, in the April, 1980 issue of the *Publications of the Astronomical Society of the Pacific*. Most radio sources never change their observable shape, but amazingly enough, *half* of the compact objects studied do change, and in a most dramatic way. Several components of these objects appear to be moving at speeds greater than that of light, with respect to one another (such motions are called *superluminal*). Their speeds are not just marginally faster than light, but range up to twenty times that of light!

Clearly something is wrong here, since Einstein's Theory of Relativity says that nothing can move faster than the speed of light. But we have to be careful here and point out that "nothing" means "no thing that has mass." It is quite possible for some kind of an *effect* to move faster than the speed of light. In fact it is fairly easy to create an effect that moves faster than light. Suppose you shine a flashlight on the wall and rapidly change the direction in which you point it. The spot of light on the wall will move very quickly. By a mere flick of the wrist you can move the spot 100 kilometers per hour or more, right in your own room. The important thing to note here is that the spot itself has no mass; it is not a material "thing"; it is only an observable "effect". It's fairly easy to see that to achieve higher spot speed, all we have to do is put the wall further away or move the flashlight faster. To reach the speed of light, we only have to fasten the flashlight to the shaft of a common electric motor (this will spin the spot in a circle 3,600 times a minute) and shine it on a mountain range or cloud bank 800 kilometers away. Of course, this simple experiment has some practical difficulties, but it serves to illustrate the point.

Using this concept of "effect" motion, astrophysicists have developed several different explanations of why the radio source components seem to be moving so fast. So far, no one is really sure which explanation is correct, and only by continual monitoring or these objects over a period of several more years will astrophysicists be able to decide on the correct explanation.

The Universe as a Black Hole* (*Contributed by David Raub)

In the previous issue of **COSMIC SEARCH** (Summer, 1980), two different kinds of black holes were discussed in an article appearing in the SEnTInel column. One of these, "classical" black holes, is formed by the gravitational collapse of dying stars at least three times as massive as our sun. These black holes can be very large and are the kind usually referred to in today's popular science literature.

The other type of black hole, "primordial" black holes, is postulated to have formed during the early moments of the Big Bang.

One interesting attribute of both classical and primordial black holes is that they are not completely "black". Rather, they both emit thermal radiation at a rate inversely proportional to their size (the smaller the black hole, the higher the temperature). This thermal radiation is caused by quantum mechanical effects which result in spontaneous "particle creation" near the observational boundary of the black hole. These newly created particles occasionally tunnel out through this boundary and might be seen by observers like us as ordinary thermal radiation.

Recently Stephen Hawking of Cambridge University and an associate, G.W.

Gibbons of the Max Planck Institute for Theoretical Physics and Astrophysics, have extended the ideas of black hole thermal radiation and quantum particle creation to the universe as a whole. In the black holes discussed above the strong gravitational field produced by a collapsing mass is so strong that light emitted from the mass is dragged back and cannot be seen by observers outside the black hole. The boundary of this region of unobservability is referred to as the black hole "event horizon".

Event horizons of a different kind occur in certain cosmological models where the rate of expansion of the universe is so rapid that it greatly exceeds the strength of the gravitational field to cause collapse. The effect of this rapid expansion is that for each observer there are regions of the total universe from which light can never reach them. Hawking and Gibbons, writing in the May 15, 1977 issue of *Physical Review D* (Volume 15, Number 10), call this region the "cosmological event horizon of the observer". In a sense, Hawking and Gibbons are really discussing the event horizon associated with a third kind of black hole — the universe itself.

Such cosmological event horizons apparently have many formal similarities to ordinary black hole event horizons. One might therefore expect that with the existence of a cosmic black hole, particle creation with a corresponding thermal radiation would also occur near its event horizon. The authors' calculations show that this is indeed the case. Observers such as us would detect thermal radiation with a characteristic wavelength of the order of the Hubble radius (e.g., a wavelength which is the width of the entire observable universe). This would correspond to a temperature of less than 10^{-28} degrees kelvin so that it is not of much practical significance. However, it is important conceptually because it shows that black hole thermodynamical arguments can be applied to the entire universe.

Hawking and Gibbons regard the area of our cosmological event horizon as a measure of our lack of knowledge about the remainder of the universe beyond our observational limit. If one absorbs thermal radiation coming from this event horizon with a hypothetical particle detector, one gains energy and entropy at the expense of the unobservable regions of the universe beyond. Therefore, the area of the cosmological event horizon decreases. As the area of the horizon goes down, the temperature of the thermal radiation emitted by particle creation also decreases so the cosmological event horizon returns to a stable condition. However, if we choose not to activate our particle detector and subsequently do not disturb any radiation, there is no change in the temperature nor in the area of our cosmological event horizon. This astounding fact shows that particle creation and the back reaction associated with it seem not to be defined independently of the observer. Rather, we find that quantum particle creation and its subsequent thermal radiation are observer-dependent (e.g., they depend upon whether the observer chooses to activate his particle detector or not).

Hawking and Gibbons discuss the implications of this notion of observer-dependence at the end of their fascinating paper and conclude that one must adopt a seemingly bizarre interpretation of quantum mechanics called the Everett-Wheeler interpretation to account for these amazing facts. This interpretation views the universe as constantly splitting into a stupendous number of alternative parallel worlds, each world representing a possible course our world has taken as the result of physical interactions between the universe's many microscopic components in the past. In actuality all of these parallel worlds really exist, but we can only experience one of them.

To see what this "parallel world" concept implies, one need merely note that because every cause, however small or large, may ultimately affect the evolution of the entire universe, it follows that every quantum transition taking place on every star, in every galaxy, in every remote corner of our universe is constantly splitting our local world on earth into an infinity of copies (including copies of us as well!).

This novel interpretation of quantum mechanics is gaining increasing acceptability among scientists these days, especially among physicists engaged in research associated with the quantum mechanics of the whole universe.

Since the Search for Extraterrestrial Intelligence (SETI) is concerned with the detection of something which could indicate the existence of other intelligent life beyond the earth, experimental verification of the conclusions drawn by Hawking and Gibbons (and hence proof of the validity of the Everett-Wheeler interpretation of quantum mechanics as well) would mean that the lucky scientist making such a discovery would not only prove the existence of a single extraterrestrial civilization, but rather an infinity of civilizations existing in different parallel universes (even though he may never hope to communicate with any of them).

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