Life on Other Stars

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In former times there was no question about life on other stars. The common belief followed a literal interpretation of the teachings of the Bible. Our earth was thought to be the center of the universe, the only place inhabited by living beings. At the time of creation all the plants and animals had come into existence as they are now, according to one well-conceived master plan. No change occurred—no development, no expansion. The natural sciences, too much in their infancy, and too strictly limited to a selected few, did not provide enough cogent evidence to the contrary to make a modification of this common belief necessary.

Some few hundred years ago, the human mind entered into a new phase of its evolution. It developed an inquisitive curiosity to know more about the world. Today our earth is no longer accepted as the perfect masterpiece of one six-day creation. It is recognized as a small planet among billions.

Figure 1. Relative sizes of the planets as seen from the earth.
and billions of stars in a boundless universe. Evolution, not perfection, sets the grandiose stage on which we are the actors and the spectators as well. We came to realize that the human mind has the capability of learning and, to a certain degree, of understanding how this world came into being, how it is built, and how it develops. To the visible world around us which was accessible to our forefathers, modern scientists have added new worlds: the world of the atoms, and the world of the stars. We have found that there are universal laws of nature valid equally in these three worlds which help us to understand their interrelations and some of their mysteries. The natural sciences today offer us the foundation for a concept of the world which is not only more correct, but also much greater, and far more magnificent, than any concept our forefathers could develop in their times.

Life on other stars? It would have been a profanity in medieval times to believe that it might have existed. Today this question is one of the most challenging problems of science. There is hardly one great scholar who does not give it his attention, and many of them are rewarded by brilliant new ideas. The remarkable fact is that every branch of natural science bears upon this problem—astronomy, physics, chemistry, biology, geology, meteorology, and all the others. Once we have the answer, its impact will be felt even by sciences as sublime as philosophy and theology.

The question of whether life exists outside the bounds of our earth cannot be answered by a plain yes or no today. If the answer should be positive, it may well be that we will have it as soon as a manned satellite around the earth offers a platform for observations. We certainly will know when our first interplanetary space ship takes us to Mars; and this may possibly happen before the end of our century.

It is another thing if we ask what the probability is that life exists on other celestial bodies. We know the external conditions under which life was able to develop and subsist on earth. We know much about the environmental conditions which prevail on other planets in our solar system, and even on other fixed stars. Comparing the necessary conditions for life with the exist-
ing conditions on stars, we can conclude with a high degree of probability whether life should be expected there, and into what forms it may have developed.

This way of reasoning may seem rather bold. However, countless observations on this earth have shown that whenever the conditions for a certain development are favorable, nature does not hesitate to start this development. Scientists are confident that this rule, so often confirmed on earth, may still be applied when the development is that of living organisms, and when the place is not confined to this earth.

Our original question about the existence of life outside the earth, therefore, reduces to the question of environmental conditions on other stars and of necessary conditions for the development of life. These questions can be answered to a considerable degree today, partially from direct observations and experiments, partially from extrapolations and logical deductions.

Although we usually think of planets only when we discuss the chances of finding life on other celestial bodies, we should not overlook the possibility of life developing also on the "dark" component of a double star, where light and heat would be available from the "bright" component. In the present article we restrict our considerations to planet-like bodies which are much smaller than the central star that gives them light and heat.

We will divide our subject from here on into three parts: The astronomical aspects, the physical conditions, and the biological problem. The present article will deal with the astronomical aspects of life on other stars.

When we think of life on other celestial bodies, we are inclined to associate its possible existence with environmental conditions as we have them on our earth. The average temperature should not be above 60 °C to 80 °C, and not much below the freezing point of water; there should be an atmosphere with at least some oxygen or carbon dioxide; there should be water; and there should be occasional sunshine, or an equivalent starshine. As we will see later, these conditions are mandatory.

That such an accumulation of conditions may well occur in planetary systems is proven by our own earth. The question is then: What is the probability that a planetary system like the solar family occurs among the fixed stars? Before answering this question, we take a short look at the structure and the history of the solar system, of our galaxy, and of the stellar universe.

Figure 3. Relative distances of the planets from the sun.

Figure 4. The Crab Nebula, a leftover of a supernova explosion in 1054 A.D.
One of the most impressive features of the solar system is the smallness of its components as compared to their distances. If we should build a model of the sun and its planets, and if we chose a sphere of three inches in diameter, for example, an orange for the sun, the planets would have the following diameters and distances: Mercury, 0.01 inches at 10 feet; Venus, 0.026 inches at 20 feet; earth, 0.027 inches at 27 feet; Mars, 0.015 inches at 40 feet; Jupiter, 0.3 inches at 135 feet; Saturn, 0.25 inches at 255 feet; Uranus, 0.12 inches at 525 feet; Neptune, 0.12 inches at 810 feet; Pluto, with an unknown diameter, at 1,060 feet (Figs. 1, 2 and 3.) In the same model, the nearest fixed star would have a distance of 1,000 miles from the sun, and the end of our galaxy would be 20 million miles away. Besides the nine planets, we find a belt of many small asteroids between the orbits of Mars and Jupiter; about 1,500 of them have been identified. The mass of the sun comprises about 99.8% of the total mass of the solar system; the planets only 0.2%. On the other hand, the combined angular momentum of the planets is about 98%, and that of the sun 2%, of the total angular momentum of the system. The sun consists of over 90% hydrogen; heavy elements are rare. On the earth, heavy elements are much more abundant. The composition of the planets, disregarding their atmospheres, is very probably similar to that of the earth.

The large angular momentum of the planets is a very strong proof against the assumption that the planets were in former times a part of the sun, or even that the sun and the planets were formed in one process out of a big diffuse nebula. A more satisfactory explanation is possible only if another star, in addition to the sun, is assumed to have participated in the planetogenic process. Theories by Chamberlin and Moulton, and in a very advanced and refined form by Jeans, succeeded in describing many of the detailed features of the solar systems by assuming the close approach of another star. Gravitational
forces would produce huge tidal waves and would even pull large amounts of matter out of the sun, in the form of a gigantic "filament." This filament would finally break up under its own gravitation and form a number of separate bodies which finally would move around the sun in planetary orbits. Their angular momentum would have been provided by the passing star. The same planet-forming process would also account for the moons of the planets. One conspicuous fact remains unexplained by this theory—the fast rotation of some of the planets. In order to make this rotation understandable, Jeffreys supposes a "grazing collision" between a star and the sun, instead of a close approach. Frictional forces, in addition to gravitational forces, could then account for the rotational motions of the planet.

With this assumption, the observed rotation and the total mass of the planets can be explained satisfactorily. However, the large angular momentum of the planets then remains a mystery.

A new idea was introduced by Russell and developed further by Lyttleton. They pointed out that many of the stars, almost one-half of them, are twin stars, revolving around each other at distances which may count from about a third of a light year down to less than the diameter of one of them. Polaris, our north star, is known to be a quintuplet; Castor is even composed of six individual stars, all orbiting around each other. Russell assumed that our sun had a twin, too, at about the distance of the major planets. This twin was hit and smashed to pieces by another star. Some of the fragments remained in solar orbits; they are our planets now.

This theory is able to explain the rotation, the angular momentum, the distances, and many other features of the planets. Its shortcoming is the extremely small probability for a direct hit between stars. To help this situation, Hoyle made the suggestion that the twin star may not have been hit by another star, but may have gone through the natural cycle of its evolution, which terminated in a catastrophic explosion. The heavy pieces of this explosion were hurled far out into space; a huge cloud of gases and dust remained in the solar gravitational field, but with the angular momentum which was left over from the twin star. This gas and dust cloud first spread out around the sun in a ring-shaped disk, but later it contracted into discrete blobs because of eddy currents and gravitational instabilities. Most of the mass contained in the gas and dust cloud was finally concentrated in the nine planets.

This theory of planetary origin is part of a comprehensive "New Cosmology" by Hoyle and Lyttleton. Although it is by no means free of controversies, it offers very intriguing descriptions of the life cycles of stars, of their energy balance, and of their compositions. The explosion of the sun's twin star, in the light of this theory, would be a "supernova," the last phase of one specific group of stars called supergiants. Three supernovae were observed within our galaxy in historic times: the first was seen in 1054 by the Chinese; the second in 1572 by Tycho Brahe; and the third in 1604 by Keppler. The first supernova left a gaseous mass, the well-known Crab Nebula (Fig. 4), which has been expanding during the past 900 years with a peripheral velocity of about 600 miles per second.

Supernova explosions are known from other galaxies. Their outburst of light is so tremendous that they can be observed from the earth. Although the final development stage of a supergiant which leads to a supernova may well extend over millions of years, the explosion itself lasts only for a few days. The frequency of supernova explosions, according to Baade and Zwicky, is about once in 400 or 500 years per galaxy, a figure which agrees well with the three supernovae observed within our galaxy during the last 900 years.
Hoyle's theory is well capable of explaining many of the outstanding features of our planetary system. It even explains why we find an abundance of heavy elements on the planets, but not on the sun; heavy nuclei are formed in energy-consuming nuclear processes during the collapsing phase of a supergiant, shortly before its explosion. During this same phase it is likely that a supergiant emits electromagnetic waves which are observed by radio astronomers on earth. The last phase of the entire process, the contraction of the gas and dust cloud into discrete planets, has been studied in great detail by von Weizsäcker. Expanding the laws of fluid dynamics to an astronomical scale, and applying them to the special case of a gas and dust cloud around the sun, he could derive many of the special properties which we observe in the planetary system.

It cannot be said today whether this concept of planetogenesis comes close to the truth. However, it seems to lead to less controversies than older theories, and we may well adopt it until better theories are available. The probabilities for all the individual steps of this planetary history can be estimated from observations and mathematical deductions; we finally can calculate how often a planetary system may have developed within our galaxy since its beginning.

This article is far too short to give an indication of the details of the various theories or of the methods of observation and reasoning which are applied by astronomers to obtain numerical results. The following numbers and figures are therefore only transmitted as facts without further arguments.

Figure 6. A star 'cloud' in Sagittarius. This is only a minute portion of the stars visible in one galaxy. Within the earth's range of observation there are about 100 million galaxies. Each galaxy may contain 100,000 self-sustaining planets.
Our galaxy has an age of about 4 billion years. With one supernova explosion every 400 years, about 10 million supernovae must have exploded during our galaxy’s life span. Every second one of them may have been one component of a twin star, giving rise to a circumstellar gas and dust cloud, and subsequently to a family of planets. Even if it may be too optimistic to assume that each of the resulting 5 million planetary systems contains at least one planet with conditions favorable for the development of life, it is certainly not unrealistic to expect that one planetary family out of 50 includes a member on which conditions similar to those on our earth prevailed at one time or another. *This means that we should expect that life in some form may have developed, during the last 4 billion years, on about 100,000 different planets within our galaxy.*

Our own galaxy shows the structure of a spiral nebula. Its size and shape resembles very closely one of its nearest neighbors in space, the beautiful spiral nebula in Andromeda (Fig. 5), which is “only” 1,500,000 light years away. The diameter of our own galaxy is about 60,000 light years. It contains between 10 and 100 billion stars. Comparing this tremendous number of stars within our galaxy with the 100,000 planets which may possibly bear life, we must conclude that life is, on an absolute scale, a frequent event within the galaxy. Relatively speaking, however, it is extremely rare. Only one in about a million stars is privileged to send its warming sunshine out to a satellite on which living organisms develop.

Our most powerful telescope on Mount Palomar is able to discern galaxies as far out as one billion light years. Within this observation range there are about 100 million galaxies (Fig. 6 and 7). Each of them may contain 100,000 life-sustaining planets, *which leads us to a total of ten thousand billion planets, within today’s observable universe, which may be inhabited by living beings.* The total number of stars in this volume is ten billion billions.

It is well to remember that this gigantic number is numerically equal to the number of molecules within one cubic centimeter of air.

How long will life continue to prosper on our earth? The heat balance of the earth depends almost entirely on the sun. Solar heat is constantly produced by the fusion of hydrogen nuclei into helium nuclei. This heat production will go on with a slowly increasing rate for about 50 billion years. While the hydrogen supply is gradually consumed, the sun will slowly heat up and, at the same time, swell to a diameter about as large as the orbit of Mars. From then on the sun will start to shrink. It will not explode like a supergiant, but very gradually cool off. At the end, the sun will be a black dwarf. Long before that, life on any of the solar planets will have become impossible because of the heat increase during the hydrogen-helium conversion. But there is a good chance that life will persist on earth for several billions of years—as far as the sun is concerned.

In the next edition of SPACE Journal we will discuss the varying physical conditions which are found on a planet in the course of its life cycle, and we will see in particular whether the earth is prepared to support life for some more billions of years.