The lonely life of a double planet

We could be alone in the Galaxy because the Earth and the Moon make up a unique double planet. Rare, giant moons such as ours may be necessary for the emergence of life

Jerome Pearson

WHERE ARE the extraterrestrials? Why haven’t they landed in their flying saucers on the White House lawn to welcome humanity to the Galactic Club?” Enrico Fermi asked this most pertinent question back in 1939, long before the search for extraterrestrial intelligence (SETI) began. In the past few decades, Fermi’s question has taken on a new urgency as we have built powerful radio receivers and listened to tens of thousands of ever-silent stars, and even sent our own planned and unplanned signals to unresponding planets.

Fermi’s paradox arises from a chain of apparently sound logic, observations, and assumptions. The Milky Way is a pinwheel disc of stars, gas and dust about 100,000 light years across, rotating once every 200 million years. There are billions of stars in the Milky Way that are very much like the Sun, warm and long-lived. Many millions of these stars may be accompanied by planets, and hundreds or even millions of the planets may be suitable for life. If life arises naturally, then we might expect thousands of living planets and perhaps hundreds of civilisations in our Galaxy.

In the 1960s, Frank Drake, who was working at the National Radio Astronomy Observatory, West Virginia, created an equation to estimate the number of civilisations in the Galaxy. This was based on reasonable guesses about the proportion of suitable stars and planets, and the probability that life, intelligence and civilisation would develop. Any seemingly consistent set of numbers in Drake’s equation predicts a multitude of life in the Galaxy. Our Galaxy is between 10 and 15 billion years old, so if there are civilisations, some of them should be much older than ours. Traveling a mere 1 per cent of the speed of light, their spaceships could have covered the entire Galaxy in a few million years. Yet an ever-expanding SETI program has found no evidence of any intelligence. There are no signs that they visited us, are on the way, or even that they are communicating among their many settled worlds. Fermi’s paradox has become more of a mystery than ever.

What are the possible answers? Over the past decade, many scientists have considered the possibilities. Those who believe in the quest for extraterrestrial intelligence, led by Carl Sagan of Cornell University, imagine that interstellar travel is difficult or impossible, that spreading civilisation is a slow and painful process, and that societies destroy themselves before they can reach us. This leaves us with the possibility of using radio to communicate with isolated societies on other planets.

Other scientists, such as Anthony Martin and Alan Bond of the Culham Laboratory, the United Kingdom Atomic Energy Authority’s centre for fusion research near Oxford, see the lack of extraterrestrials as proof that we are alone in the Galaxy, if not in the Universe. Many of these scientists use biology to argue that the occurrence of life by chance is so remote as to be unthinkable. Other scientists believe that evolution is such a random walk that no two intelligent species developing on different planets could have enough in common even to recognise each other, much less to communicate intelligently.

Perched somewhat precariously are those who deny the very existence of the Fermi paradox and insist that the Galaxy is teeming with life, just as Drake’s equation predicts, and that extraterrestrials have visited us. They have not revealed themselves because they are studying us. An interstellar civilisation could know all there is to know about stars, planets and solar systems. The only unpredictable thing that could arouse their scientific curiosity would be the extraordinary variety of alien life forms, and therefore they have set us aside in a “zoo” (or “asylum”) for observation.

The time is ripe for a fresh look at these contradictory theories. Something is wrong either with our assumptions or with our logic. One basic assumption is that of ordinariness. We assume that the Earth and its life are typical, placed in a moderate location in a typical solar system around an average star. Yet the Earth is not typical at all—it is unique in our own Solar System, for several reasons.

The most obvious point is that the Earth and its Moon are more like a double planet than a primary and its satellite. The Moon is far larger compared with the Earth than any other satellite of a major planet in the Solar System. Our Moon is so large that it does not actually go around the Earth at all; its orbit is always concave toward the Sun. Jupiter and Saturn have 3.17 and 95 times the mass of the Earth, respectively. Even so, their largest moons are hardly bigger than our Moon. Only Pluto and Charon represent another such pair, and they are so small that they are more of a double asteroid than a major planet and its moon. They may be the remnants of an escaped moon of Neptune ruptured by the violent upheaval that tore it from that planet. Alternatively, they may be part of a second asteroid belt that shades into the distant, giant Oort Clouds of comets orbiting far beyond Neptune. Our large Moon has affected the Earth significantly. The ocean tides raised by the Moon had a profound effect on the evolution of crustaceans and amphibians. The emergence of tidewater zones, which alternate between flooding and drying out, perhaps even helped life to emerge on land.

A second anomaly is the presence of Earth’s atmosphere and oceans, which are unique in the Solar System. The amount of oxygen in the Earth’s atmosphere is far too much for chemical equilibrium. This unstable condition is maintained by the constant action of living plants; without life, the oxygen would react with the materials on the surface and produce carbon dioxide. The excess carbon is tied up in enormous beds of limestone and rocks containing other
carbonates that were laid down millions of years ago. The oxygen not only supplies animals with energy so they can move and reproduce, but also creates and maintains the ozone layer that protects life from deadly ultraviolet radiation from the Sun.

James Lovelock of the Coombe Mill Experimental Station in Cornwall developed the idea that life tries to moderate its local environment, creating a feedback mechanism that keeps the Earth habitable. His hypothesis envisaged the planet as a giant living organism which he called “Gaia”. This concept regards the Earth as a self-organising, self-regulating system that maintains enough oxygen for the animals and enough carbon dioxide for the plants. The Gaia mechanism keeps the ocean and the atmosphere at a moderate temperature by a controlled greenhouse effect, and by regulating the recycling of materials needed for life—oxygen, water, soil and rock. It is not perfect, however, because the Earth still swings between warm periods and ice ages.

The magnetic effect of the Moon

The Earth also has a very powerful magnetic field. This field is much larger in proportion to its mass and the angular momentum caused by the Earth rotating than that in any other planet. Angular momentum is a measure of the rotational inertia of a body; it is greater if the body is large, massive, and rotates faster. If you could attach a giant lever to the centre of the Earth and push on the end to stop the Earth rotating, then the angular momentum tells you how large a force you would need and how long a time you would have to push to stop it.

The distances of the planets from the Sun are related by Bode’s law, formulated in the 17th century. It depends on manipulating a sequence of numbers that double each step after the first. The strengths of the magnetic field of the planets are related to their rotation by a magnetic version of Bode’s law. Figure 1 shows this relationship for all the planets (not drawn to scale) out to Uranus, based on information gained during the Voyager 2 flyby in January 1986. It shows that the Earth is far above the nominal line encompassing Jupiter, Saturn, Uranus, Venus and Mars. The excess heating caused by the gravity of the Sun explains why Mercury is above the line. The Earth, however, has a field 100 times stronger than expected. Existing theories cannot explain this, even when we take into account the heating caused by the tidal action of the Sun and the Moon (at the Moon’s present distance from Earth).

Another unusual aspect of the Earth is its active, molten core. The energy of this core drives the tectonic plates, recycles new crust from the interior, and releases the same kind of gases from inside the Earth as those that produced the present atmosphere. This molten core is responsible for all the volcanoes and mountain ranges, for the opening and closing of ocean basins, and for the separation of the continents, which has isolated gene pools and speeded up evolution. The Indian researcher U. R. Rao, of the Satellite Centre in Bangalore, has noted that a magnetic field is vital in maintaining the ozone layer to protect life from ultraviolet radiation. Geologists have also discovered that many species become extinct during the times when the Earth’s magnetic field reverses and its strength temporarily goes to zero.

All these unusual characteristics of the Earth may be due to the presence of our large Moon. According to a recent theory championed by Australian geologist Stuart Ross Taylor, the Moon is large because it is a remnant of the second largest planetesimal (the small bodies that coalesced to form the planets) in the cloud of debris that formed the young Earth. Normally, the larger planets grow at the expense of the smaller ones by collisions and by collecting debris from nearby orbits. The Moon may have been “captured” by the Earth during an unusual collision in which the Moon “grazed” the Earth. Such double planets are likely to be very rare because the overwhelming majority of “orbital encounters” result in either the complete shattering or merging of the two bodies after a collision, or a simple flyby after a miss.

For a billion years after its bizarre capture, the Moon was very close to the Earth; this proximity raised enormous tides on both bodies and heated their cores far above what would be normal for their rates of rotation. This prolonged heating continued until the action of the tides pushed the Moon to nearly its present distance, and slowed down the rotation of the Earth from about 4 hours to 24 hours. The Earth does not follow the magnetic version of Bode’s law because it was heated in the process of slowing down.

The Earth and the Moon are obviously a rare case, but how rare? It is difficult to predict the likelihood of such double planets occurring, although there are some computer simu-
lations that we could usefully modify to examine the problem. On the other hand, there is some evidence in the Solar System for the existence of double planets. This evidence consists of miniature solar systems, represented by the satellites of the giant planets, and the remnant planetesimals, represented by the asteroids.

Several moons are either locked into interweaving orbits with a twin body or with a ring of debris. In the jovian system, 1 out of 14 satellites shows such effects; in the saturnian system, 3 out of 13 show such a connection; and in the uranian system, 1 out of 14 is affected. So far, little is known about Neptune's moons, but Voyager 2 may change that situation when it flies past in September next year.

Some of the thousands of known asteroids vary in brightness during the time it takes them to rotate. This variation might have been interpreted as closely orbiting bodies, but further analysis has shown that these objects are asteroids with complex shapes, like the asteroidal moons of Mars. These shapes were probably produced when the asteroids collided with other bodies or were bombarded by planetesimals. There are as yet no confirmed double asteroids. Recent observations by Luke Flynn of the University of Hawaii showed that none of the 17 most likely candidates, including Ceres, Pallas and Vesta, had any companions. Nor was there any evidence of dust clouds around these asteroids.

Collisions and close encounters during orbits have been common among these satellites and asteroids, as their cracked, scarred, and pitted surfaces show. However, not one of the many interactions has formed a double satellite comparable to the Earth/Moon system. All of them produced either rings of debris or interacting bodies that keep their distance. About one-tenth of the satellites have been affected; if these grazing collisions between satellites and asteroids are rare, then perhaps only one in a hundred or one in a thousand planets will be part of a double act.

This result alone reduces the expected number of habitable planets in the Galaxy to far below the millions foreseen by Drake. There is another factor that could lower the number further. Studies of the Earth's climate show that even a small change in our average distance from the Sun could have turned the Earth into a runaway greenhouse or a cold, dry desert. The range of orbits where life is possible—the habitable zone—is small. A little closer to the Sun and we would fry; a little farther away and we would freeze (see Figure 2). It may be that the habitable zone is far smaller than astronomers thought, or even that there is no permanently habitable zone at all.

The requirements for life can be summarised as follows: a strong magnetic field is necessary so that the planet can become "active"; only an active planet offers protection from cosmic radiation, recycles crustal material, and produces oxygen by the release of gases from the interior. A single planet cannot develop such an internal field without being too massive or rotating too rapidly to be able to support life. Even a double planet must develop life very quickly in order to forestall the instabilities of greenhouse effect or glaciation. All habitable planets are double, therefore, and all single planets are uninhabitable.

This implies that there may be two types of terrestrial planets: the first type consists of double planets, with very strong magnetic fields, plate tectonics, life, and stable (or moderate) climates; the second type consists of single planets, with weak magnetic fields, incomplete plate tectonics, and unstable climates that are either too hot or too cold.

If this is correct, we may be alone, or one of a very few civilisations in the Milky Way. Any civilisation attempting to colonise the Galaxy will find that every suitable planet is inhabited, and that every uninhabited planet represents a major challenge to make it habitable. This would delay considerably the colonisation of the Galaxy, perhaps long enough to explain why no other civilisation has reached us so far.

This hypothesis, of course, has significant implications for the search for extraterrestrial intelligence. It will be a long, difficult task; if there are only a few civilisations in the Galaxy, the nearest one may be tens of thousands of light years away. SETI may be more successful in nearby galaxies, such as Messier 31 in the constellation Andromeda, which represents billions of possible targets.

The implications for humanity are that we may be alone—this Galaxy belongs to us. Our species may be the only opportunity for life to spread across this Galaxy.

The American Indians made a very wise choice when they selected the words for treaties meant to last forever:

As long as the moon shall rise,
As long as the rivers shall flow,
As long as the sun shall shine,
As long as the grass shall grow.

These words encapsulate the requirements for life—a double planet with a large moon, a temperate zone where water can flow, a warm and lasting sun, and a system like Gaia to keep it so.

Jerome Pearson is an aerospace engineer and consultant. He is now chief of the structural dynamics branch at the USAF Air Force Flight Dynamics Laboratory.