In Search of Earth-Like Planets

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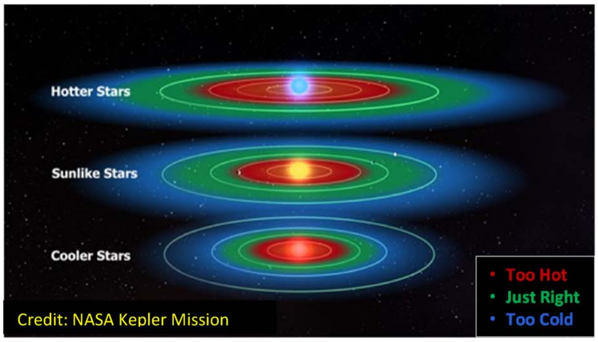

Fig. 1. Habitual zone concept.

The goal of detecting habitable planets requires finding those planets with masses between about one-half to ten Earth masses, assuming a similar density and composition for terrestrial planets, about 0.7 to 2.0 Earth radii.

I think the question "are we alone in the Universe?" has more of a philosophical flavor than pure science. First, its underlying concept may be too complex to approach only scientifically. Nevertheless, in this article, I concern myself with the scientific aspect of the question and examine recent science-based findings.

Scientific logic and intuition suggest that we are not alone. There are billions of galaxies in the known universe with each galaxy containing billions of solar systems. Therefore, it is reasonable to assume that some fraction of these solar systems may be suitable for life, considering that the only solar system for which we have detailed knowledge has life.

Now I have to define what is meant by "life!" As I warned in the first paragraph, it is difficult to keep philosophy out of this discussion; and again, I am focusing only on science. Life, as we know it, is carbon based. Carbon is uniquely suited for creating complex molecules that are necessary for sustaining life. Scientific literature offers a definition of life that includes self-replication and the ability for evolution [1]. Reproduction requires the passing of large amounts of information to the next generation. Only carbon-based complex molecules are capable of holding large amounts of information. (It has been suggested that silicon may also be another candidate for developing large molecules necessary for life. However, for this article, I will ignore the silicon possibility and focus on carbon-based life.)

It can be reasoned that development of carbon-based life may take place in conditions similar to our world. For example, carbon-based life can only exist within temperature ranges that are more or less what we find on Earth. This argument leads us to the following hypothesis that to find life outside our solar system we should look for conditions similar to what we find on Earth. This hypothesis places constraints on the physical features of a candidate planet, such as temperature and mass, and requires the presence of atmosphere. Hence, we should limit our search for extraterrestrial life to "habitable zones" similar to the habitable zone in our own solar system (Fig. 1). What this means is the following: look for exoplanets that are roughly the mass of Earth and lie a suitable distance from their sun, not to be too hot or too cold. In our solar system, the habitable zone is the region between the orbits of Venus and Mars. As a side note, life may also be possible outside the habitable zone under certain conditions. For example, the ocean beneath Europa's icy surface has been suggested as a reasonable candidate for developing and sustaining life. (Europa is a moon of Jupiter lying outside our sun's habitable zone, but tidal forces probably generate enough heat to maintain water as liquid beneath the surface.)

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Until 1995, the main issue was whether there are other solar systems (suns with planets) in our galaxy. Then, in 1995, for the first time, two Swiss astronomers detected an exoplanet using a ground-based telescope. However, the discovered planet was too close to its sun (too hot) and too massive to support life. Although ground-based observations have continued to discover exoplanets, it soon became clear that space-based observations are better

Digital Object Identifier: 10.1109/JPROC.2014.2314771

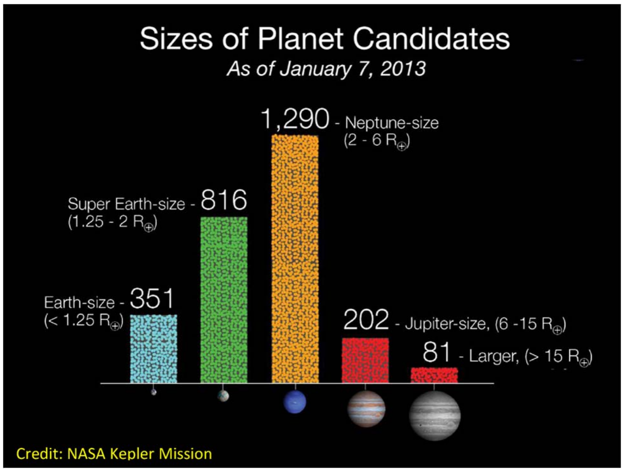

Fig. 2. Kepler Findings as of January 2013.

suited for the task. The first space-based observatory for finding Earth-like planets was NASA's Kepler spacecraft, which operated for three years from 2010 to 2013 (the Kepler exoplanet observation ceased in May 2013 because of the failure of two of its reaction wheels used for pointing the spacecraft). With Kepler, the pace of finding exoplanets was drastically accelerated. The main instrument on Kepler was a telescope with an aperture of about 1 m and a large field of view, about 100 square degrees. Kepler was pointed at, and it recorded data from, just a single group of 100 000 stars for the duration of the mission. Data from the individual pixels that make up each star of the 100 000 were recorded continuously and simultaneously. Its photometer (sensor) was composed of one instrument, which was an array of charge-coupled devices (CCDs) containing about one hundred million pixels.

During its three-year operating life, Kepler collected enormous amounts of data. Scientists continue to analyze Kepler observations, and they continue to make new discoveries. The analysis of data collected by Kepler is expected to continue for some time in the future. For obvious reasons, it is easier to find large planets (roughly the size of Neptune or larger) than small planets (Earth size). Fig. 2 shows Kepler discoveries as of January 2013. Clearly, Kepler discoveries are dominated by large planets. However, this does not mean that Earth-size planets are rare. It only means that detecting Earth-size planets is more difficult than detecting larger planets. Moreover, it is easier to find planets that are close to their suns. In general, observing Earth-size planets in the habitable zone of a star is a challenging task.[1] In spite of all this, as of the writing of this article, Kepler has already found one Earth-size planet in the habitable zone of a sun similar to ours, and this planet is considered to be a good candidate for sustaining life. The following is a brief description of the finding as was announced by NASA in 2013, "Kepler-62f is a remarkably Earth-like planet about 1200 light-years from our planet. The world is only 1.4 times bigger than Earth and is in orbit around a star that is somewhat dimmer and smaller than the sun. It orbits in what is believed to be the habitable region of its star."

What are we going to do with the discoveries of Earth-like planets by Kepler and other observatories, past and future? Such discoveries will certainly increase our knowledge and will add credence to the argument that we are not alone in the Universe. But, will it help us to contact potential life forms in other solar systems? Is there hope to visit such planets?

Fig. 3 gives us an outlook regarding such ponderings. This figure shows our galaxy and points to the section of the galaxy that Kepler observed. Indeed, Kepler only sampled a tiny region of the galaxy. Its maximum range was merely 3000 light years. It is reasonable to assume

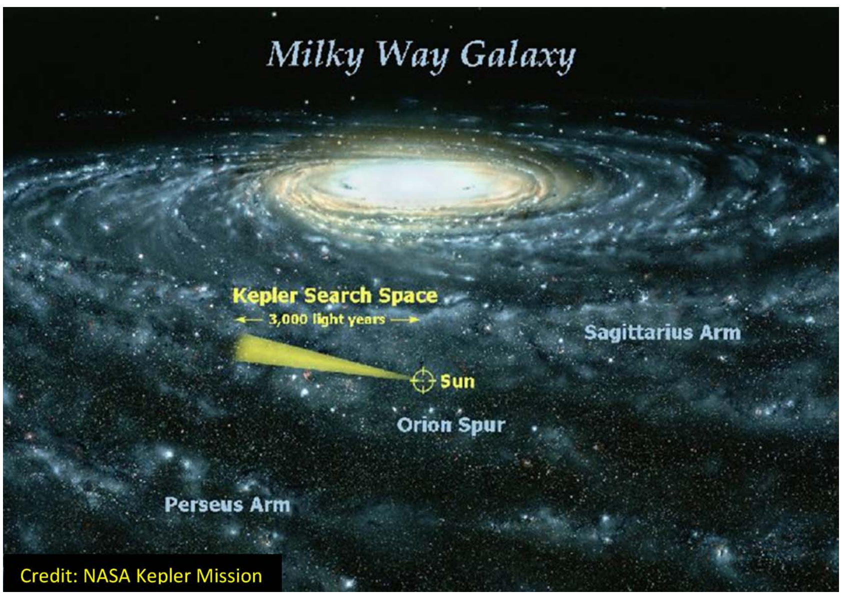

Fig. 3. The Milky Way Galaxy and Kepler Coverage Area.

[1] I have been reminded by a colleague that a large size (Saturn or Jupiter size) planet in the habitable zone with a moon about the size of Earth may also be a good candidate to support life.

that Earth-like planet discoveries from Kepler and other observation sources are likely to be hundreds of light years (or more) distant from us. What does it really mean to say "hundreds of light years?" Last year, NASA announced that Voyager 1 spacecraft, a marvel of human ingenuity, has entered the interstellar region after a journey of more than 35 years at astonishing speeds. After all this time, Voyager 1 is only 17 light hours (hours not years!) from us.

I cannot even begin to appreciate the vastness of the Universe. I am clearly astonished, bewildered, and amazed by it. I am unable to comprehend and digest the immensity of outer space. Not even science can help me in this regard. Perhaps this is the right moment to quote the master of philosophy, Socrates, who said, "I know nothing!" ■

REFERENCES

[1] N. Pace, "The universal nature of biochemistry," *Proc. Nat. Acad. Sci. USA* vol. 98, no. 3, pp. 805–808, Jan. 2001.