Are we alone?

3 March 2016

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Earth viewed from space resembles a blue marble with white clouds swirling over a blue ocean (NASA Goddard Space Flight Center Image by Reto Stöckli).

Earth could be considered rarefied if it belongs to a small, esoteric and exclusive group of planets that are rocky, orbit within the habitable zone of their stars and support life. NASA's Kepler space observatory has now confirmed the existence of at least 2000 planets beyond our solar system (exoplanets). Considering that Kepler has searched within a very small patch of the sky, it is probable that exoplanets are out there in abundance. Some, like the exoplanets Kepler 542b and 186f, appear to be Earth-like: rocky planets up to two times bigger than Earth that orbit within the habitable zone of their star. But whether any of these Earth-like exoplanets also support life remains unknown.

The discovery of these distant rocky exoplanets, along with our Sun's four inner rocky planets Mercury, Venus, Earth and Mars, suggests that rocky planets are not rare. However, they tend to be small and difficult to detect. Rocky planets are unusual in that they concentrate all the heavies, those elements heavier than the two lightest elements hydrogen (H) and helium (He). Most of the atoms in our solar system, as well as our universe as a whole, consist of H and He, with H making up 73% and He

25% of all atoms. All the other elements known on the periodic table make up the remaining 2%. These heavies were forged from H and He within large stars or during the explosion of large stars (supernovas) since the big bang 13.7 billion years ago. Because large stars are relatively rare, not much of the original H and He that formed at the time of the big bang have managed to be forged into the heavier elements.

H and He are great for making stars but it is difficult to imagine how they could ever form the building blocks of life. Life as we know it requires elements such as carbon, oxygen, nitrogen, phosphorus, sulfur and a whole host of trace metals and other elements. So, the key initial step in making a living planet is making one that, like the rocky planets, concentrates the heavies. But all we need to do is look at our rocky planet neighbours to realise that the other critical factor for life is that the planet orbits within the habitable zone. Venus is too hot and Mars is too cold, but Earth is 'just right' – neither too hot nor too cold for liquid water to exist in abundance. Earth, the 'blue marble' planet (see image above), is unique among our solar system's rocky planets, with our big blue ocean and swirling white clouds indicating that we orbit within our Sun's habitable or just right 'Goldilocks' zone. There have been recent discoveries of planets from other solar systems that appear to orbit within their star's habitable zone, but whether they too are blue marble planets is more difficult to discern (see image below).

The ideal rocky exoplanet, one that may support life, would be the same size or up to twice as big as Earth and orbit a star similar to our Sun as does the best candidate, Kepler 542b. Size matters because a planet needs to be big enough to retain an atmosphere of gases heavier than H and He. Like a child's helium balloon, Earth's initial H and He gases floated off into space, eventually joining up with their multitudinous kin residing in our Sun. However, the heavier gases, including water vapour, were retained and once conditions had cooled enough this water vapour rained out to form the oceans. And it was soon after the oceans formed that life was established on Earth. It is the presence of life that may or may not be the most rarefied aspect of our planet. Besides extraterrestrial visitors or communiqués from outer space, how might we detect life on other planets? What features could we look for uniquely associated with life?

Earth can also be thought of as rarefied in terms of its outermost layer, its atmosphere. While iron sank to the core, the lightest elements buoyantly made their way to the surface to form Earth's atmosphere - its most elevated and lofty, least dense layer composed of a thin mix of gases. Earth's atmosphere initially had no oxygen gas (O_2), but today oxygen gas is abundant making up 21% by volume. The oxygen gas content increased as a by-product of photosynthesis, the process by which algae and plants use sunlight energy to combine carbon dioxide (CO_2) and water to grow. It is thought that it was the rise in oxygen gas to threshold levels, for example, that allowed for the rapid evolution of animals during the Cambrian explosion 541 million years ago. And life as we know it, based on carbon and photosynthesis, seems the most likely for other rocky worlds given that their chemistry would be similar to ours and life arose here so soon after it was possible.

Currently we are unable to see potential Earth-like exoplanets well enough to know if they are blue marbles having oxygen-rich atmospheres. However, far more powerful space telescopes are in the works and these might be able to provide the first solid evidence for life elsewhere. If we could find evidence for life on just one other planet the implication would be that Earth is not rarefied after all. In that case, the equation: 'chemistry (of a rocky planet) plus energy (from its star) plus time equals life' just may apply, and we would be only one of many, many living worlds in our universe. Given how science has humbled our rarefied views of our place in the universe in the past (for example, Earth is not the centre of the solar system; we are not separate from but are in fact related to all other organisms on Earth), it should not come as too big a surprise to learn that we are not alone. Of course, Earth is special and its particular life forms are undoubtedly unique in many respects, but it seems likely that there are many other worlds out there, equally alive and special.

An artist's interpretation of a 'blue-marble' exoplanet (Kepler 186f) (NASA Ames/JPL-Caltech/T. Pyle).