

## Astrobiology News for July 2013: What Makes a Planet Habitable?

In May, we posed the question, how many stars have planets? It is becoming increasingly likely that the answer to this question may be virtually all of them! Think about this – on a clear night from the suburbs you can see maybe a few hundred stars, from the country, maybe a few thousand. This is a small fraction of the hundreds of billions of stars in our galaxy alone, not to mention the hundreds of billions of galaxies in the observable part of our Universe. If stars, on average, have just one planet each, then the number of planets in the observable Universe is an integer with 23 digits -- tens of trillions of planets for each of the 7 billion human beings on planet Earth -- more planets than all the grains of sand on all the beaches of the Earth... With all this opportunity, it's very difficult to imagine that Earth might be the sole abode of life! So, what makes a planet habitable?

Let's rephrase this question a bit: Are there any extraterrestrial environments that could or do support life as we know it on Earth? There's no reason to presuppose that life elsewhere in the Universe has to be similar to life on Earth, but it's also unclear how to go about searching for life-as-we-don't-know-it, so we begin with what we know. We know that liquid water is critical to the chemistry of all life on Earth, hence NASA's strategy to "Follow the Water" in designing robotic missions to search for present or past life in our Solar System and remote observations of the atmospheres of exoplanets. Of course, one might envision more exotic solvents on which life could depend, such as liquid methane, but again, we're starting with what we know!

Traditionally, the Habitable Zone (HZ) is defined as the region around a star marked by an inner and outer orbit within which there could be stable surface water on a planet (sometimes called the "Goldilocks Zone"). Closer to the star, the water boils; further away, it freezes. Simple, huh? Not exactly... For one thing, the requirement for surface water is motivated primarily by observational constraints – if the mass of the biosphere is on the surface of a planet, we have a better chance of detecting it. Life might exist in subsurface water under ice on worlds such as Europa, or subsurface aquifers on Mars. Satellites (moons) of large planets could be internally heated by tidal interactions with their planets, creating conditions conducive to life. Even on Earth, where microbes exist in all sorts of extreme environments, the mass of subsurface microbes might equal the mass of all life on Earth's surface!

More to the point, there are a variety of factors other than the distance of a planet from its star that affect habitability as we've defined it. Broadly, these factors depend upon properties of the planet, the planet's star, interactions of the planet with other nearby objects (such as moons), and changes in the planet's and star's properties over time. For the planet in question, the mass and pressure of its atmosphere, its gravity and its albedo (or reflectivity – how much of the star's energy is reflected rather than absorbed by the planet) are a few important considerations. Also, for most of Earth's history, Earth wasn't anything like it is today and there would be different signposts of life in Earth's atmosphere. For 13%

of its history, Earth was lifeless. Microbes populated the Earth for 74% of its history, plants and animals for 13% of its history, and intelligent species for only 0.1% of Earth's history.

Habitable Zones also change with time, due to changes in the brightness of stars over their lifetimes. For example, the Sun's brightness has increased by 30% since the formation of the Solar System. This means the HZ for a given planet moves outward in time, and in the case of Earth, complicates the problem of how the Earth broke out of a period known as *Snowball Earth* about 635 million years ago, when ice is thought to have covered the planet. Steady brightening of the Sun will eventually trigger a Moist Greenhouse Effect on Earth, in which most of the water in the atmosphere will be driven off into space. Of course, this process can be greatly accelerated through the effects of increasing CO<sub>2</sub> in Earth's atmosphere! You can't easily separate the habitability of a planet from its inhabitants -- there are many ways in which the interaction of life with its environment has been important in the history of life on Earth.

One of the most intriguing possibilities for life-sustaining planets is coming from the mounting evidence that Earth-sized and "super-Earth-sized" planets may be common in the HZ's of M-dwarfs. M-dwarfs are stars that are much cooler than the Sun, have longer lifetimes, and are more than ten times as ubiquitous. The contrast between the size and brightness of an M-dwarf and an orbiting planet is smaller than for larger, hotter stars, so planets tend to be easier to find. In the past, M-dwarfs weren't considered good candidates for harboring habitable planets since the stars themselves experience strong flares and HZ planets would have to orbit close enough to their stars to be "tidally locked" (meaning the same face of the planet would continuously face the star - like the same side of the Moon continuously faces the Earth). However, current thinking is that HZs may extend to greater distances from M-dwarfs than previously thought. Ice and snow are less reflective against long wavelengths, so icy planets around these reddish stars would absorb more light than around a "bluer" star like our Sun. There are about eight M-dwarfs within a "mere" 10 light-years of the Solar System, so the nearest potentially habitable planet could be relatively nearby!

Remember, you're all invited to join *Planethunters* ([www.planethunters.org](http://www.planethunters.org)) in the search for new worlds! Also, although this is a bit off-topic for Astrobiology News, the Zooniverse team has just launched a new "mini" project called *Galaxy Zoo Quench*. *Galaxy Zoo Quench* invites volunteers to take part in the entire scientific process - everything from classifying galaxies to analyzing results to collaborating with astronomers to writing a scientific article! So, if you'd like to get a good feel for how science is actually done in the real world, please consider signing up at [quench.galaxyzoo.org](http://quench.galaxyzoo.org)

Until next month,

Grace Wolf-Chase, Ph.D.

Suggested Resources:

- (1) The Planetary Habitability Laboratory at the University of Puerto Rico at Arecibo maintains The Habitable Exoplanets Catalog, a database of currently known exoplanets that might be considered potentially habitable. This website also provides a HZ calculator and more detailed information about HZ boundaries: <http://phl.upr.edu/projects/habitable-exoplanets-catalog>
- (2) Some astrobiologists talk about Galactic Habitable Zones, but this is still very controversial and speculative. You can find a brief introduction to some of the considerations regarding how habitability may depend upon location and time within a galaxy here:  
<http://astro.unl.edu/naap/habitablezones/ghz.html>