Blowing in the stellar wind: Scientists reduce the chances of life on exoplanets in so-called habitable zones

November 30 2017, by John Greenwald

Image of starlight on exoplanet, courtesy of NASA/JPL-Caltech.

Is there life beyond Earth in the cosmos? Astronomers looking for signs have found that our Milky Way galaxy teems with exoplanets, some with conditions that could be right for extraterrestrial life. Such worlds orbit stars in so-called "habitable zones," regions where planets could hold liquid water that is necessary for life as we know it.

However, the question of habitability is highly complex. Researchers led by space physicist Chuanfei Dong of the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) and Princeton University have recently raised doubts about water on—and thus potential habitability of—frequently cited exoplanets that orbit red dwarfs, the most common stars in the Milky Way.

Impact of stellar wind

In two papers in The *Astrophysical Journal Letters*, the scientists develop models showing that the stellar wind—the constant outpouring of charged particles that sweep out into space—could severely deplete the atmosphere of such planets over hundreds of millions of years, rendering them unable to host surface-based life as we know it.

"Traditional definition and climate models of the habitable zone consider only the surface temperature," Dong said. "But the stellar wind can significantly contribute to the long-term erosion and atmospheric loss of many exoplanets, so the climate models tell only part of the story."

To broaden the picture, the first paper looks at the timescale of atmospheric retention on Proxima Centauri b (PCb), which orbits the nearest star to our solar system, some 4 light years away. The second paper questions how long oceans could survive on "water worlds"—planets thought to have seas that could be hundreds of miles deep.

Two-fold effect

The research simulates the photo-chemical impact of starlight and the electromagnetic erosion of stellar wind on the atmosphere of the exoplanets. These effects are two-fold: The photons in starlight ionize the atoms and molecules in the atmosphere into charged particles, allowing pressure and electromagnetic forces from the stellar wind to sweep them into space. This process could cause severe atmospheric losses that would prevent the water that evaporates from exoplanets from raining back onto them, leaving the surface of the planet to dry up.

On Proxima Centauri b, the model indicates that high stellar wind pressure would cause the atmosphere to escape and prevent atmosphere from lasting long enough to give rise to surface-based life as we know it. "The evolution of life takes billions of years," Dong noted. "Our results indicate that PCb and similar exoplanets are generally not capable of supporting an atmosphere over sufficiently long timescales when the stellar wind pressure is high."

"It is only if the pressure is sufficiently low," he said, "and if the exoplanet has a reasonably strong magnetic shield like that of the Earth's magnetosphere, that the exoplanet can retain an atmosphere and has the potential for habitability."

Evolution of habitable zone

Complicating matters is the fact that the habitable zone circling red stars could evolve over time. So high stellar wind pressure early on could increase the rate of atmospheric escape. Thus, the atmosphere could have eroded too soon, even if the exoplanet was protected by a strong magnetic field like the magnetosphere surrounding Earth, Dong said. "In addition, such close-in planets could also be tidally locked like our moon, with one side always exposed to the star. The resultant weak global magnetic field and the constant bombardment of stellar wind would serve to intensify losses of atmosphere on the star-facing side."

Turning to water worlds, the researchers explored three different conditions for the stellar wind. These ranged from:

- Winds that strike the Earth's magnetosphere today.
- Ancient stellar winds flowing from young, Sun-like stars that were just a toddler-like 0.6 billion years old compared with the 4.6 billion year age of the Sun.
- The impact on exoplanets of a massive stellar storm like the Carrington event, which knocked out telegraph service and produced auroras around the world in 1859.

The simulations illustrated that ancient stellar wind could cause the rate of atmospheric escape to be far greater than losses produced by the current solar wind that reaches the magnetosphere of Earth. Moreover, the rate of loss for Carrington-type events, which are thought to occur frequently in young Sun-like stars, was found to be greater still.

"Our analysis suggests that such space weather events may prove to be a key driver of atmospheric losses for exoplanets orbiting an active young Sun-like star," the authors write.

High probability of dried-up oceans

Given the increased activity of red stars and the close-in location of planets in habitable zones, these results indicate the high probability of dried-up surfaces on planets that orbit red stars that might once have held oceans that could give birth to life. The findings could also modify the famed Drake equation, which estimates the number of civilizations in the Milky Way, by lowering the estimate for the average number of planets per star that can support life.

Authors of the PCb paper note that predicting the habitability of planets located light years from Earth is of course filled with uncertainties. Future missions like the James Webb Space Telescope, which NASA will launch in 2019 to peer into the early history of the universe, will therefore "be essential for getting more information on stellar winds and exoplanet atmospheres," the authors say, "thereby paving the way for more accurate estimations of stellar-wind induced atmospheric losses."

Scientists spot potentially habitable worlds with regularity. Recently, a newly discovered Earth-sized planet orbiting Ross 128, a red dwarf star that is smaller and cooler than the sun located some 11 light years from Earth, was cited as a water candidate. Scientists noted that the star appears to be quiescent and well-behaved, not throwing off flares and eruptions that could undo conditions favorable to life.

Collaborating with Dong on the PCb paper were physicists from Harvard University, the Harvard-Smithsonian Center for Astrophysics, the University of California, Los Angeles, and the University of Massachusetts.

More information: Chuanfei Dong et al. Is Proxima Centauri b Habitable? A Study of Atmospheric Loss, *The Astrophysical Journal* (2017). DOI: 10.3847/2041-8213/aa6438 arxiv.org/abs/1702.04089

Chuanfei Dong et al. The Dehydration of Water Worlds via Atmospheric Losses, *The Astrophysical Journal* (2017). DOI: 10.3847/2041-8213/aa8a60 arxiv.org/abs/1709.01219

Provided by Princeton University