

Life in the galactic danger zone

Do we live in a realm of the Milky Way Galaxy that is conducive to forming habitable planets and even life? **Gemma Lavender** grabs a bird's eye view of our Galaxy to find out.

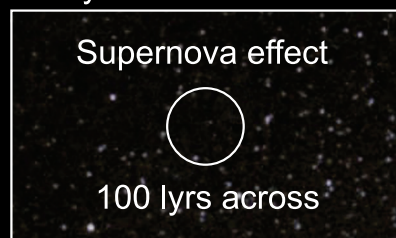
At an average distance of 149.6 million kilometres from the Sun, the snug conditions on our planet are just right for the existence of life. Our world is a temperature-perfect blue orb that floats through space, maintaining the liquid water that flows in the rivers and oceans and is crucial for our survival. Our very presence on this blue planet is made possible thanks, in part, to the strip of space in which our world spins and orbits the Sun around; a panel of perfection called the habitable, or goldilocks, zone.

The bigger picture

If we were able to step back from our home planet to a position where we could see our entire Solar System, the positioning of the habitable zone would become immediately obvious; parked between the orbits of a sweltering hot Venus and chilly Mars. However, if we were to take an even bigger step back from our Solar System to a point that gave us a bird's eye view of our Galaxy, identifying the best region for life to thrive is trickier. Located in the crook of the Orion Arm – a spur of stars

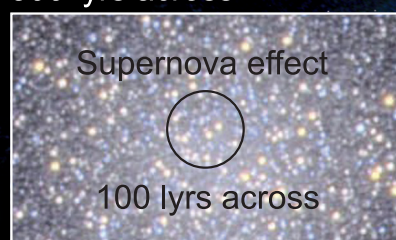
▼ Different models of the GHZ, with decreasing metallicity with radius and the number of stars affected by supernovae near the galactic centre and out in the spiral arms. In Gowanlock's model, 50 percent of habitable planets lie between 8,000 light years and 14,000 light years. AN graphic by Greg Smye–Rumsby.

500 lyrs across



Outer star population

500 lyrs across



Inner star population

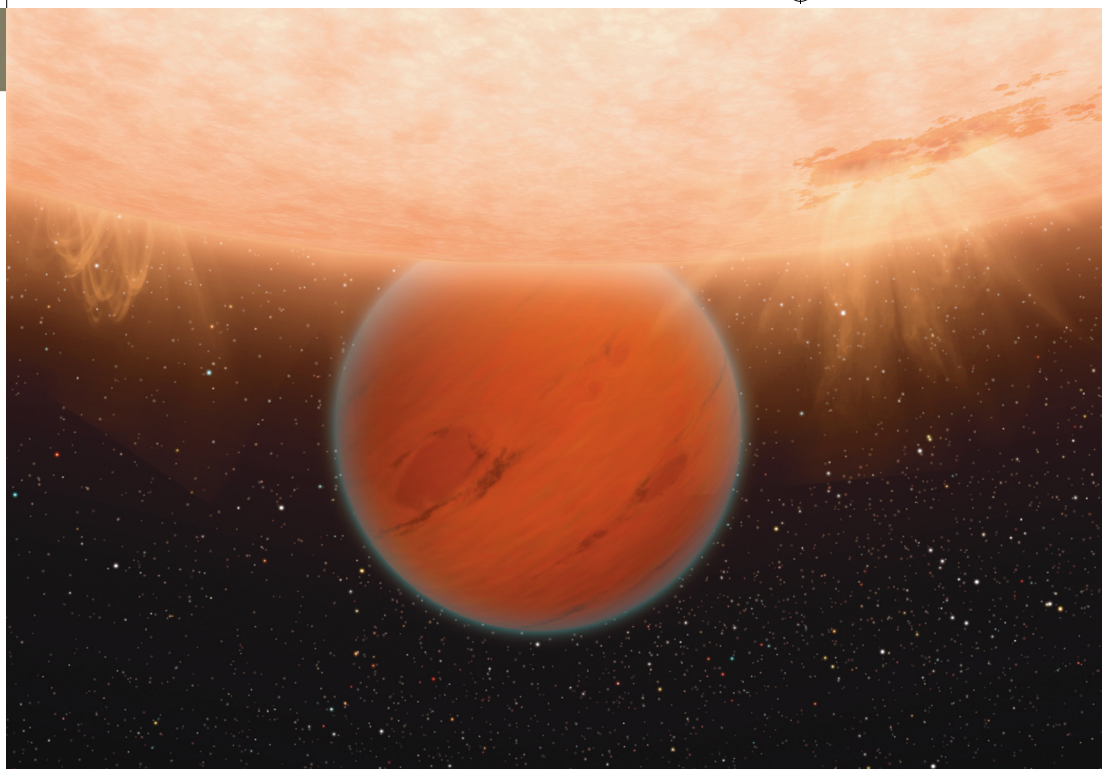
Lineweaver's GHZ

Gowanlock's GHZ

The Sun

26,000 lyrs from galactic centre





▲ Do hot jupiters barrel through their planetary systems, migrating closer to their star, at the expense of terrestrial worlds? Image: NASA/JPL-Caltech/R Hurt (SSC/Caltech).

and gas that rests between the arms of Sagittarius and Perseus – life exists on Earth around 26,400 light years from the glowing galactic centre. But where else? Up to this moment in time, we have found no conclusive evidence for life anywhere else in our Galaxy, so what is so special about our neck of the stellar woods?

In order to answer these questions, astronomer Guillermo Gonzalez of Iowa State University, along with Donald Brownlee and Peter Ward of the University of Washington in Seattle, introduced in 1991 a concept dubbed as the galactic habitable zone (GHZ), referring to the location in our Galaxy that is most favourable to the development of life. Just as several factors influence the existence of life on our home planet and on the scale of the Solar System, there are conditions that must be met in order for life to exist widespread on a much larger galactic scale.

Galactic ingredients

Many astronomers endorse the concept of the GHZ, including Charles Lineweaver of the Planetary Science Institute at Mount Stromlo Observatory in Australia and Michael Gowanlock of NASA's Astrobiology Institute, who have independently conducted contrasting research that outlines the parameters behind the GHZ. The factors that come into play in order for us to exist in the Milky Way Galaxy, let alone around one of its approximately 200 billion stars, tell a story of carefully mixed interstellar

ingredients that define the location of the GHZ.

The galactic centre is teeming with elements heavier than hydrogen and helium. We describe an area like this as having high metallicity. These constituents favour the creation of rocky terrestrial planets and, without these elements, we would not have the solid ground underneath our feet, let alone the basis of complex molecules from which we formed. While a planetary system must lie close enough to the galactic centre, within reach of heavy elements, being too close could spell disaster. The powerful radiation that shoots out of the heart of our Galaxy could damage the habitability of any world. However, that is not all; too high a metallicity has its dangers, especially for planets with a mass comparable to that of Earth.

"The highest metallicity stars are the most likely to have hot jupiters; massive planets close to their host stars," says Lineweaver, who details this drawback in his 2004 paper *The Galactic Habitable Zone and the Age Distribution of Complex Life in the Milky Way* published in the journal *Science*. "The massive planets could not have formed so close to their host stars so they must have migrated [or been scattered] into smaller orbits. When this happens, it is likely that they would destroy any terrestrial planets in the circumstellar habitable zone." Consequently, Lineweaver believes that any planetary systems with hot jupiters are unlikely to leave any terrestrial planets in situ for life to evolve on. "So far I have not

been convinced by claims that a Jupiter [or larger] mass planet could pass through the circumstellar habitable zone without gravitationally sweeping up small debris such as Earth-mass planets," he says.

A galactic danger zone

With these factors in mind, along with an estimate for biological evolution, Lineweaver and his colleagues have identified what they believe to be the GHZ, between about 22,800 light years and 29,400 light years from the galactic centre and, according to their model, it is continuing to widen with time.

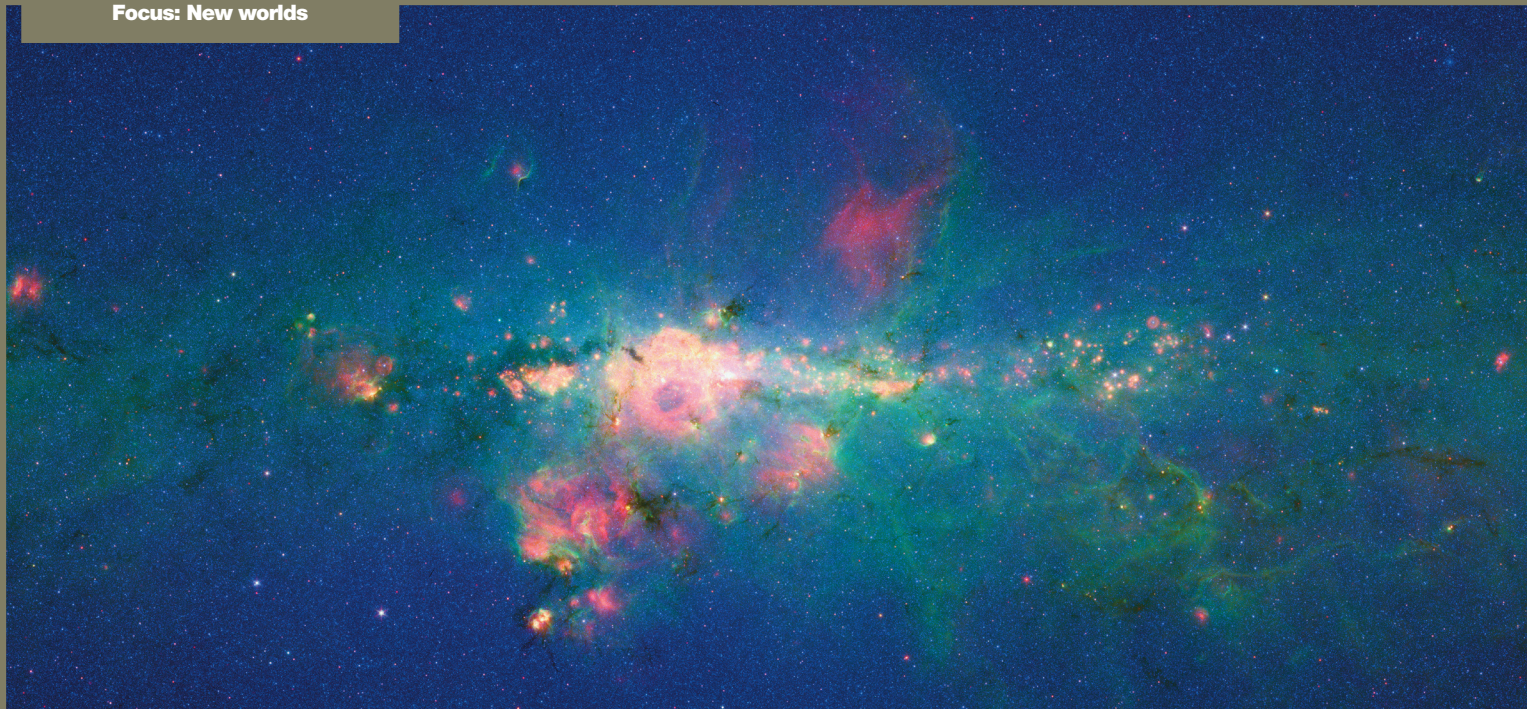
"There are two reasons why the galactic habitable zone expands with time," says Lineweaver. "The metallicities of regions far from the galactic centre increase into the conducive metallicity region [where the 'Earth Habouring probability' is high]. Another reason is that the danger factor close to the galactic centre decreases with time [because the star formation rate at the centre decreases with time, leading to less supernovae] thus regions closer to the galactic centre become more conducive to life, widening the galactic habitable zone."

Supernovae are the real scourge of habitability in the galaxy. These exploding stars trigger blast waves and release cosmic rays, gamma-rays and X-rays that can be fatal to life on any nearby Earth-like planets. However, without knowing precisely how robust organisms are to high doses of radiation and how much the surrounding interstellar dust can absorb the dangerous energy of the supernova, the researchers have had to roughly estimate a supernova danger factor.

Michael Gowanlock has a different view on the effects of supernovae. With an astronomer and computer scientist from Trent University, David Patton and Sabine McConnell, he recently published a paper, *A Model of habitability within the Milky Way Galaxy*, in *The Astrophysical Journal*, building on Lineweaver's research into the Milky Way's habitability but with some significant variations.

"The major difference between our methods is that we use a computational approach to model the galactic habitable zone, whereas

GHZ



▲ An infrared view of stars and dust in the galactic centre. According to one model this is a bad place to live, but another suggests that we're more likely to find habitable planets here. Image: NASA/JPL-Caltech.

the work by Lineweaver and his colleagues uses a statistical approach," says Gowanlock. "We model stars individually and select which stars will become supernovae from within this stellar population based on their stellar mass." In contrast Lineweaver's paper does not model supernovae individually, but places an upper limit for the supernova rate, which would be catastrophic for habitability, and a lower limit that is friendlier to life, reducing the possibility that a planet will be in the firing line of a torrent of harmful rays.

Gowanlock's logic is different. Yes, the galactic centre is subject to a large number of supernovae, and these can sterilise a larger number of worlds because the density of stars there is greater. However, he disagrees that high metallicity environments always allow hot jupiters to run rampant. "In contrast to Lineweaver, we used the results of radial velocity planet searches in combination with a model of planet formation in the literature to determine where habitable planets form and how often we expect giant planets to inhibit these terrestrial planets. The danger posed by high metallicity environments in the work of Lineweaver is higher than that of our work."

So, if you believe Gowanlock, the higher metallicity coupled with the high density of stars near the galactic centre means that although many will be sterilised by a supernova blast wave, there will be many more that survive long enough for complex life to emerge (which we take to be four billion years, based on Earth's experience, although Gowanlock recognises that this is perhaps not representative). In contrast, although farther out from the galactic centre is a much safer place, with fewer stars in the blast radius of a supernova, there are also fewer rocky planets because the metallicity out in the galactic suburbs is lower.

"Our work makes very different predictions than the work of Lineweaver," explains Gowanlock. "We find the inner Galaxy [up to 8,000 light years from the galactic centre] produces the greatest number of planets with the ability to host complex life, whereas Lineweaver finds the galactic habitable zone to be an annular region between 22,800 and 29,400 light years that widens with time."

Ironically our Solar System does not fall into Gowanlock's GHZ, although he doesn't claim that habitability is impossible beyond it, only that it is less common. Furthermore, the disparities between Gowanlock and Lineweaver imply that GHZ models still have some maturing to do as we understand the factors implicit within them better.

"This type of work depends upon numerous observational studies of supernovae, exoplanet searches, protoplanetary discs and the morphology of the Galaxy," says Gowanlock. "Advanced models of the chemical evolution of the Galaxy and dynamical simulations of planet formation among other models are also very important." The more we learn about each individual factor, the greater our overall picture will become.

▼ The youngest supernova in our Galaxy is believed to have exploded undetected in the galactic centre in the late nineteenth century, its remnant captured here at X-ray and radio wavelengths. Image: NASA/CXC/NCSU/S Reynolds et al./NSF/NRAO/VLA/Cambridge/D Green et al.

