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Gliese 581d: A Possibly Habitable Planet around a Red Dwarf Star

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Abstract

Gliese 581d is a terrestrial super-earth planet, located on the inside edge of the habitable zone away from its parent star. If Mars would be that size in our Solar System, Mars would likely be a habitable planet in a traditional sense (stability of liquid water on its surface). The same is likely true for Gliese 581d, which makes it a promising candidate of the extrasolar planets detected so far to support life. Planets around red dwarf stars (dM) appear in principle at least as suitable for the development of life as planets around dG stars.

1. Introduction

Red dwarfs (dM) stars are the most common stars in the galaxy. In the solar neighborhood, these cool, faint, low mass stars comprise over 75% of the stellar population. Because of their low luminosities (~0.02% - 6% of the Sun's luminosity), the circumstellar habitable zones (HZs) of dM stars are located within ~ 0.05 - 0.4 AU of the host star. The first planetary system with possibly habitable temperatures has been detected around Gliese 581 [3] elevating M star systems as prime targets for Earth-like planets [5].

2. Life around Red Dwarf Stars

We consider the prospect of life on a planet, which is located in the habitable zone around a red dwarf (Fig. 1), as moderately high based on the longevity of these stars (>50 Gyr), their constant luminosities, and high space densities. However, young red dwarfs (ages < 2 Gyr) exhibit strong magnetic-dynamo generated coronal X-ray, transition region Far Ultraviolet (FUV) and chromospheric FUV-UV emissions, and frequent flares. But these types of radiation are easily filtered out by even a thin atmosphere and might be, at the level they would be experienced on a planetary surface, beneficial for evolutionary innovations. Moreover, because of their low temperatures (~2200 – 3800 K), dM stars (unlike hotter stars like our Sun at T ~5779 K) do not have significant photospheric Near UV (NUV) continuum radiation below about 3000A. A more serious concern is that many dM star HZ planets are likely to be tidally locked (with $P_{rot} = P_{orb}$), probably do not possess large moons, and many may be too old to be enriched enough in metals to form a terrestrial type planet. Nevertheless, planets around older, less magnetically-active dM stars should be considered a prime target for possible life, and may also serve as a refuge for advanced, intelligent civilizations when their host star becomes inhabitable due to stellar evolution as our Earth will be in a few billion years from now.

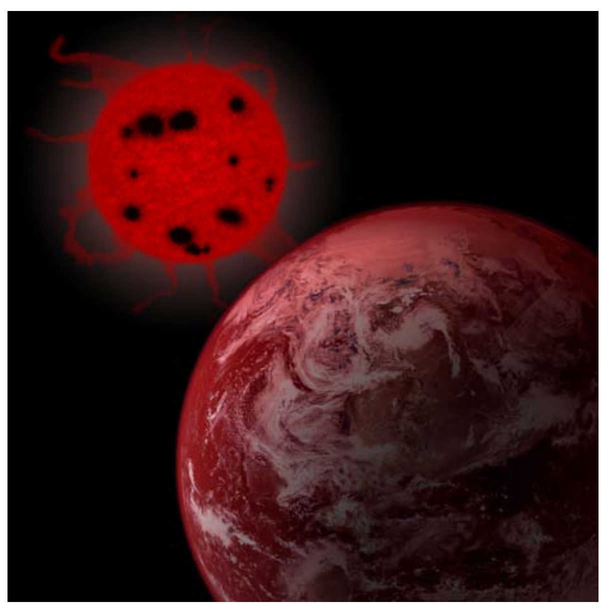

Fig. 1. Red dwarf star (M-star) with a planet. Credit to Scott Engle, "Living with a Red Dwarf Program", Villanova University.

3. The Gliese 581 System

The Gliese 581 planetary system is at a distance of 20.3 light years from Earth and hosted by a M3V star. Four planets have been detected in the Gliese 581 system of which two may lay inside the habitable zone. Gliese 581c is a planet with about five to ten times the mass of Earth, and probably at least 1.5 times its radius. It just orbits inside the inner edge of the habitable zone close to its parent star [6]. Gliese 581 c completes one orbit in only 13 days and may exhibit habitable conditions on its surface, though it more likely is subject to a runaway greenhouse effect as Venus is [7]

Well outside the habitable zone are Gliese 581e with an orbital period of 3.15 days and Gliese 581b with an orbital period of 5.4 days. Gliese 581e is the smallest planet of the system detected so far and has only a mass of about 1.9-3.1 Earth masses.

On the inside edge of the habitable zone away from its parent star lies Gliese 581d, the most promising candidate of the Gliese 581 system to be habitable.

4. Gliese 581d

Gliese 581d is a planet about 7-13 Earth masses and probably at least close to twice the radius of Earth. It is, like Mars, located at the edge of the habitable zone away from its parent star. Mars is considered to be just outside of the habitable zone of our Solar System, but if Mars would be much heavier and had a thicker atmosphere, liquid water would be stable on its surface and it would be considered habitable in a traditional sense. Given that Gliese 581d is about ten times the mass of Earth and assuming it has a similar composition to Earth or Mars we would expect continued volcanic activity and endogenic activity on this exoplanet, and with it the presence of a magnetic shield and protection from radiation, plus a much thicker atmosphere and with it the potential of surface oceans and possibly even life within these oceans. One of the next goals in explanet research should be to determine mean temperatures and pressures on Gliese 581d. This could be done by direct imaging and possibly by transit photometry via TPF (Terrestrial Planet Finder), JWST (James Webb Space Telescope), and Kepler, and inferred from orbital and physical measurements (mass, radius, obliquity) by direct imaging, radial velocity, transit photometry and gravitational microlensing via SIM (Space Interferometry Mission) Lite, Kepler, and Gaia. Ocean areas could possible be detected by direct imaging via TPF and JWST and atmospheric composition being determined by direct imaging by transit photometry via TPF and JWST.

5. Conclusions

The Gliese 581 system is the most intriguing extrasolar planetary system detected so far and shows astrobiological promise for at least one (Gliese 581d), if not two, of its orbiting planets. We expect that M-star planets can be habitable in principle [4,5], and thus detecting planetary systems and identifying habitable planets around M-stars should be one of the priorities in future astrobiological investigations [1,2].

References

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