LIFE AROUND A RED DWARF (dM) STAR WITH SPECIAL EMPHASIS ON GLIESE 581. D. Schulze-Makuch[1] and E. F. Guinan[2], [1]School of Earth and Environmental Sciences, Washington State University, Pullman, WA, 99164, USA, dirksm@wsu.edu [2]Dept. of Astronomy, Villanova University, Villanova, PA, USA

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 [1] elevating M star systems as prime targets for Earth-like planets [2].

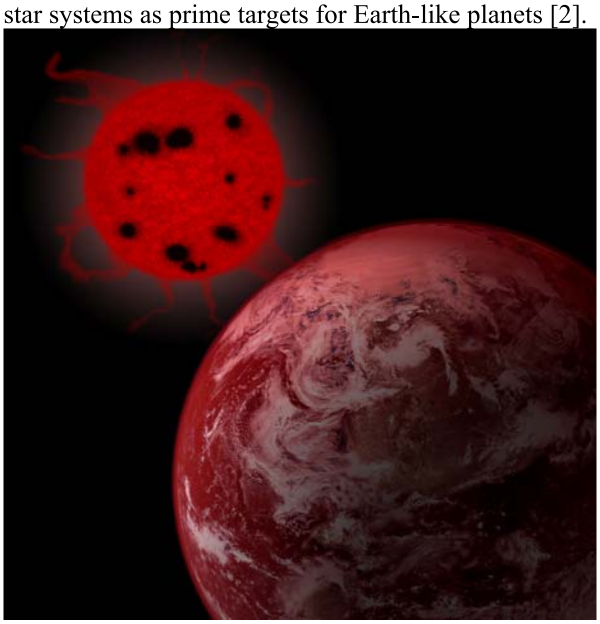

Fig. 1. Red dwarf star (M-star) with a planet. Credit to Scott Engle, "Living with a Red Dwarf Program", Villanova University.

Life on a M-star? 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.

The Gliese 581 System: The Gliese 581 planetary system is at a distance of 20.3 lightyears 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 [3]. 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 [4]

On the inside edge of the habitable zone away from its parent star lies Gliese 581d, a planet about 7-13 Earth masses and probably at least close to twice Earth's radius. If Mars would be that size in our Solar System, Mars would likely still be a habitable planet in a tradiotinal sense (stability of liquid water on its surface). The same could be true for Gliese 581d. In our view it is the most promising candidate of the extrasolar planets detected so far to support life.

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.

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

References: [1] Selsis, F. et al. (2007) *Astronomy & Astrophysics,* 476, 1373-1387. [2] Tarter, J.C. et al. (2007) *Astrobiology,* 7, 30-65. [3] von Bloh, W. et al. (2007) *Astronomy & Astrophysics* 476, 1365-1371. [4] Udry, S. et al. (2007) *Astronomy & Astrophysics*, 469, 43-47. [5] Schulze-Makuch, D. & Irwin, L.N. (2008) Life in the Universe: Expectations and Constraints. Springer.

Table 1. Properties of Red Dwarfs (dM) stars and their relationship to planetary habitability

M star property	Astrobiology Assessment	Comments
Nearly constant luminosities of dM stars over time scales of tens of billions of years results in fixed HZs	Beneficial for life in general	This provides a stable environment for life to form and evolve on a possible dM star HZ planet
dM stars are ubiquitous, comprising >75% of stars	Beneficial for life in general	High chance for at least some habitable planets
Long life times (> 50 Gyr)	Beneficial for life in general	Especially beneficial for advanced/ intelligent life
There are many old dM stars (> 5 Gyr) in our galaxy.	Detrimental for life for planets hosted by very old (metal poor) dM stars. But life on younger (ages ~ 2 - 8 Gyr) & metal rich dM stars is possible.	This could mean that life on a HZ planet around a dM star could be much more evolved and more advanced than us at 4.6 Gyr. However, very old, metal poor, Pop II dM stars were likely not able to form rocky planets because of the paucity of metals. A low metal environment would also be problematic for the development of life.
Theoretical studies indicate that "Super Earths" can easily form in the proto-planetary disks of dM stars. In fact many have been found.	Beneficial for life in general	Planets hosted by dM stars should be at least as common as those hosted by solar-type stars. Even without much effort, several dM stars have been found to host planets.
dM stars have HZs located very close to the host star at <0.1AU - 0.4AU	Possibly detrimental to life from flares and coronal mass ejections.	The planet can become easily tidally locked, thus global habitability would be impossible
Unlike solar-type stars, dM stars have essentially no photospheric continua in the UV (<2500Å), because of their low temperatures	Beneficial for life once it is established. Ozone blocking of NUV radiation not necessarily needed.	While UV irradiation is generally harmful to organisms, it is a powerful ingredient for evolutionary adaptations and might also have played a role in the origin of life. But UV flares could help.
dM stars have very efficient magnetic dynamos resulting in strong coronal X-ray, transition region FUV & chromospheric FUV-UV emissions	Harmful for life in general but even a thin atmosphere screens out all FUV radiation < 220 nm.	Harmful, but these types of radiation are easily filtered out by planetary atmospheres and may be beneficial for evolutionary adaptations
Coronal mass ejections from dM stars can easily erode the entire atmosphere of its dM star planet(s)	Harmful for life in general	The effect is mitigated if the planet has a magnetic shield. Larger planets would more likely generate stronger magnetic moments and higher gravitational acceleration to counter atmospheric erosion and escape
dM stars flare frequently and emit impulsive XUV energies	Both harmful and beneficial to life	Even a thin atmosphere, such as that of Mars, does not allow any incoming FUV/X-ray radiation with wavelengths <2000Å to reach the surface. Some impulsive bursts of radiation could aid evolutionary adaptation through mutations in the genetic material though.