The Potential for Life on Tidally-Locked Planets

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How many Red Dwarf Star (RDS) planets in the Milky Way Galaxy are candidates for Life?

Number of stars in Milky Way ~ 200 billion
Of these ~75% are Red Dwarfs (RDS)

Main characteristics of RDS (with respect to life on planets):-

Great Longevity (much longer than the age of the universe)

Planets of RDs may have life clement conditions for a wide range of atmospheric properties (Wandel, this meeting).

Much lower luminosity than our Sun; radiate at longer wavelengths.

In the Habitable Zone of RDs, planets are close and tidally locked.

Conclusion: Potential for life bearing planets in Milky Way, is **very** large, BUT -

Life on Trappist-1 and many other Red Dwarf star planets, may be exposed to High XUV radiation

XUV from Trappist-1, is many times that incident on Earth. Radiation often in spates of intense flaring. Even so, given a thick initial atmosphere and a magnetosphere (deflecting particulate radiation) water and oceans may survive.

Life evolving in water below a depth of 10cm would be protected by the absorption of XUV. However, water transmits little NIR; only a low level of PAR would be available for Oxygenic Photosynthesis.

Red Dwarf stars have longevity many times that of Sun-like G-type stars. Only in their early evolutionary stages do they have strong XUV flares. (Age of Trappist-1, 5-7Gy).

Habitability of RD planets, e.g. the Trappist-1 system

Trappist -1 is small – 0.12 Rsun (about the size of Jupiter); 8% mass of Sun.
Radiation flux – 0.05% of Sun.

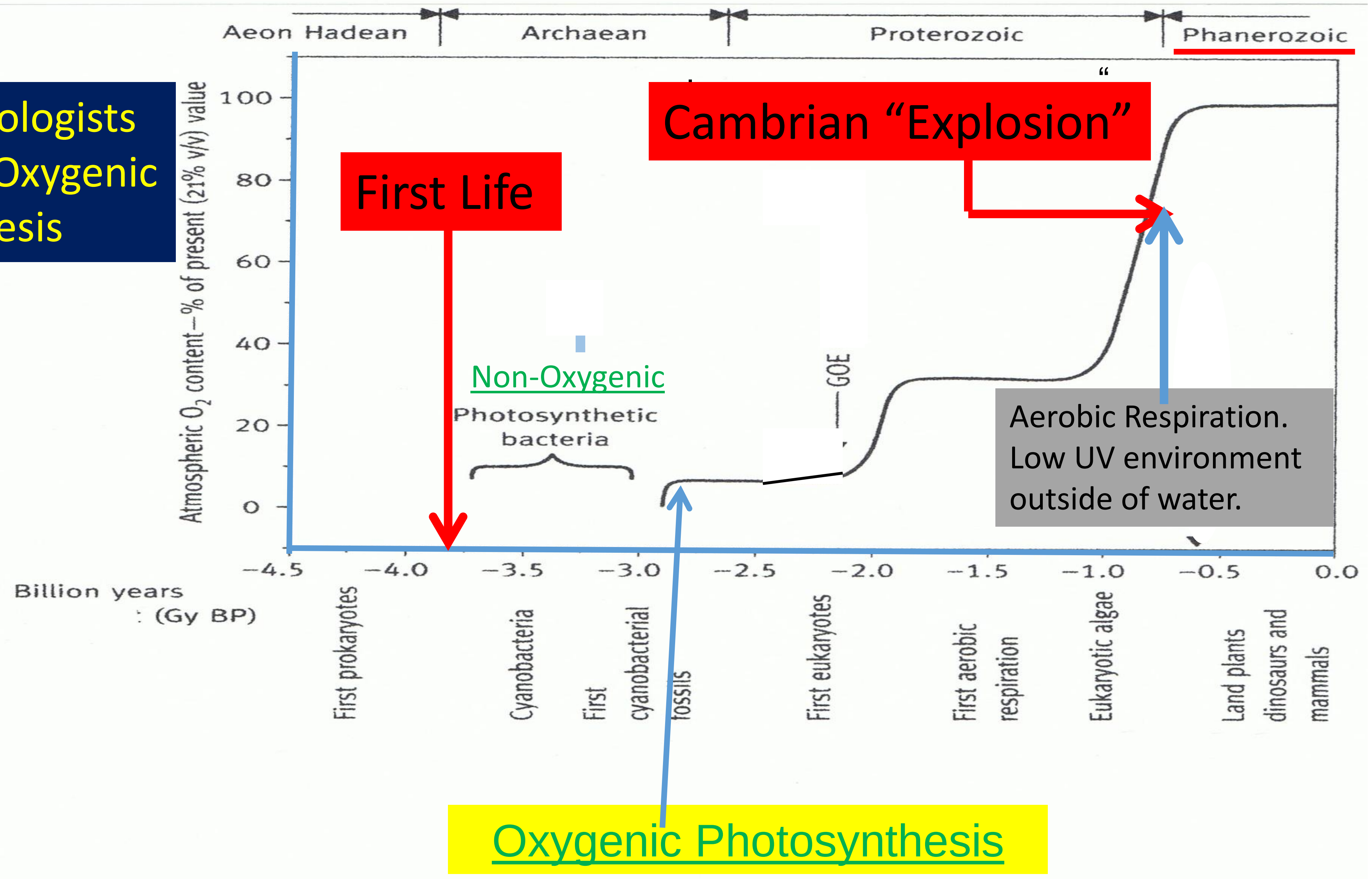
Age: 5- 7Gy.

Cool – 2,550^{o}K – Most radiation in NIR; peaking at ~1µm.

Planets in Habitable Zone are close to star (0.1 – 0.35AU), which makes them **Tidally locked.**

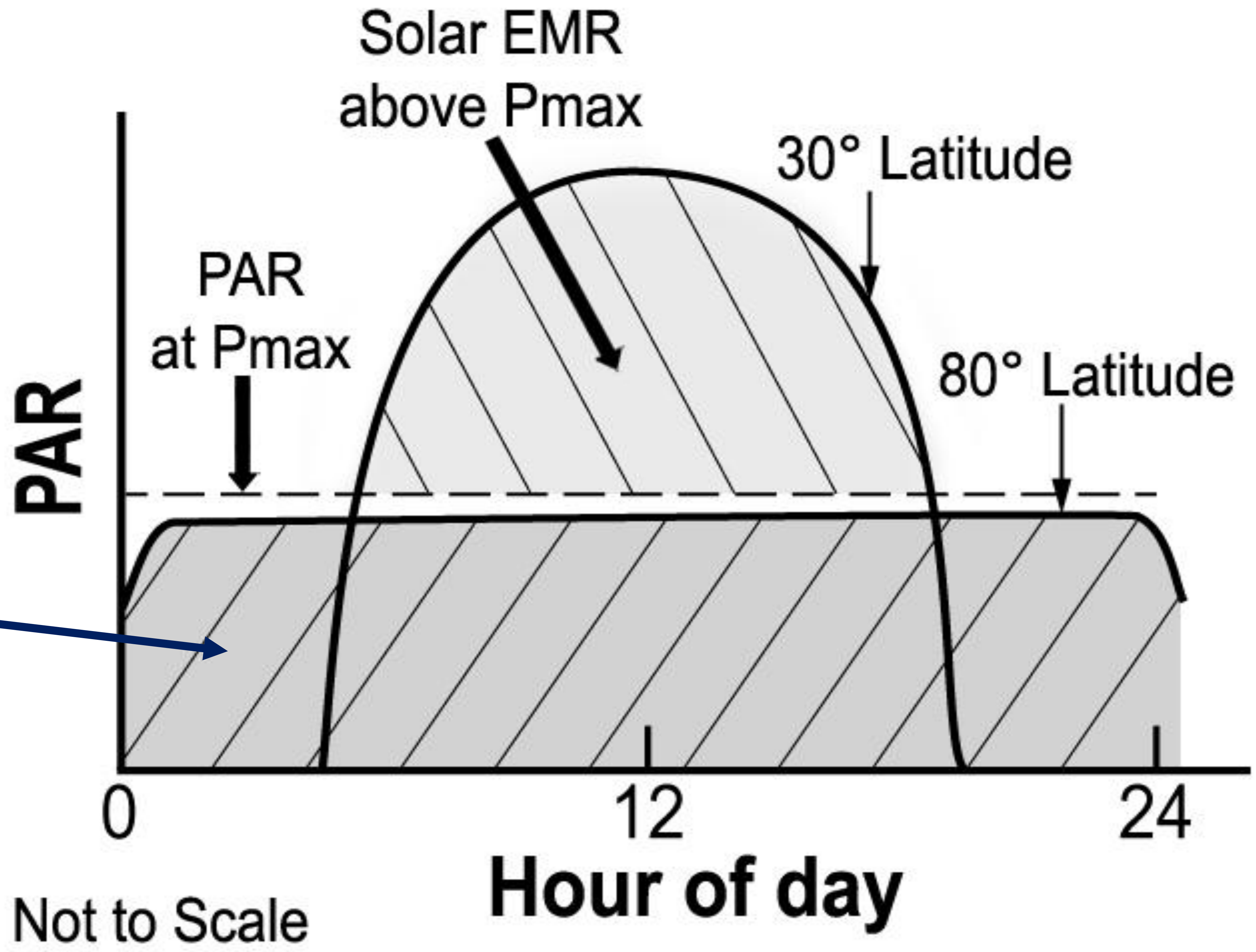
At Sub-Stellar point, Planets receive 0.25 – 4.0 of the EMR flux incident on Earth. Of this, only ~ 10% is within the Photosynthetically Active Radiation (PAR) waveband (400-700nm) vs 30% of EM radiation on Earth.

The Astrobiologists fixation on Oxygenic Photosynthesis



An Earth Analog for Radiation on a Tidally Locked Planet

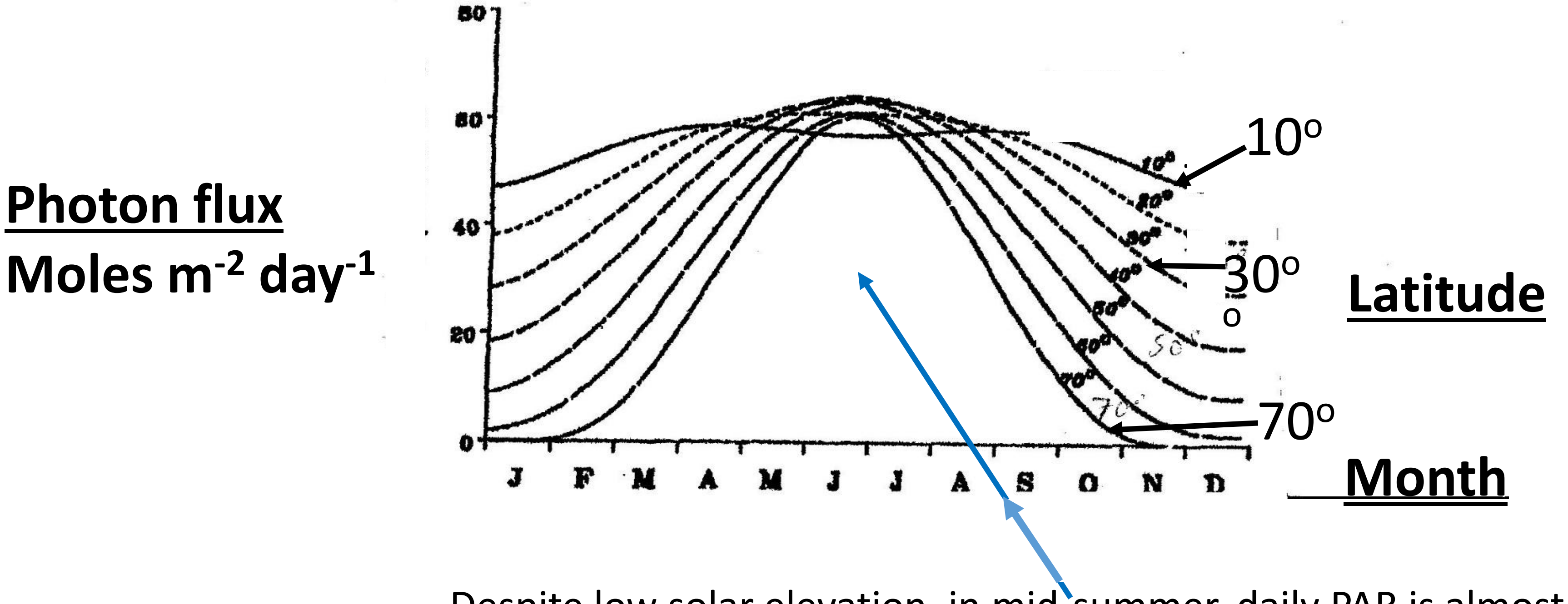
24 h radiation on Earth, at Mid and High Latitudes, in mid-summer.



This could be the continuous radiation regime on a Tidally Locked Planet

Mid-summer radiation on Earth, an analog for the radiation regime on Tidally Locked planets

Diurnal, Photosynthetically Active Radiation (PAR) as a function of Latitude (cloudless sky)



Despite low solar elevation, in mid-summer, daily PAR is almost the same at high as at low latitudes.

After Campbell and Aarup, 1989

Comparison of potential productivity of algae, under radiation incident on Earth and on planet Proxima C.- b.

(from Ritchie et al, 2017, Table 10)

Potential Primary Productivity- g C m^{-2} h^{-1}

(calculated from PAR values of star's radiation, and algae photosynthesis measured under laboratory conditions)

Algae	on Earth	on Proxima C. b
Synechoccocus	0.82	0.155
Chlorella	0.813	0.104

However: Assuming cloudless skies, the number of hours of Sunlight per year on Earth, at mid-latitudes is ~ 2,000, while, at the sub-stellar point on Proxima C.- b, starlight shines continuously for 8,760h over the same Earth year.

This could increase estimated Primary Productivity by a factor of ~4.

Potential for Oxygenic Photosynthesis of Plants which have invaded Dry Land

Continuous daylight results in a “yearlong” dose of PAR photons at a level at least as high, and possibly higher than experienced by mid-latitude Earth vegetation.

Not being screened by water, such Dry Land plants would receive the full NIR radiation from the RDS. E.g., about 15-20% of the incident radiation of Trappist-1 is within this waveband.

It has been suggested that Oxygenic Photosynthesis could evolve pigments using NIR between 700-1,000nm.

<u>Conclusion:</u> vs Earth – Plentiful radiation for Oxygenic Photosynthesis.

Would Life evolving on Tidally Locked Planets be the same as life on Earth?

The Genetic Code conundrum

On “Goldilocks” planet Earth, only **One** basic life form survived (and perhaps, only one appeared). On Earth all life uses almost the same amino acids and always the same genetic code.

Why?

- There are Alternative explanations for there being only one genetic code of Life on Earth.

<u>But</u>

Although possible, there is no certainty, that other life forms would use the same genetic code.

There is no way to predict what other codes would produce.

Some consequences of life on Tidally Locked Planets

Plants:

Continuous light (and photosynthesis) would require a different balance of anabolic/catabolic enzymes.
Many Earth species suffer when exposed to such an environment – others rapidly adjust.

Earth plants are adapted to circadian and seasonal rhythms. E.g. seasonally changing night length determines leafing/flowering/bulb filling etc., optimizing adjustment to the environment.

Dry land plants may evolve photosynthetic pigments which can utilize the NIR of radiation, below 1000nm, of RDS'.

Animal Life:

Earth life - adapts to seasonal changes e.g. hibernation and estivation.

Earth life suffers daily light/dark cycles. E.g. a third of human life is spent in suspended animation (sleep) which evolved to conserve resources, (todays necessity of sleep is probably a secondary adaptation).

Do you suffer from Jet Lag? Move to a tidally locked planet. Is the 24h day too short for you? Wait a million or so years, it will be longer.

Conclusions on the likelihood for Life supporting conditions on Tidally Locked planets

Life and Oxygenic photosynthesis could evolve.

The evolution of Complex Life in a high Oxygen environment is possible (but not necessary) .

Such life could be very different to that on Earth.

The product of the above and the huge number of such planets, results in a very strong probability of there being other abodes of Life and even Complex Life in the Milky Way Galaxy.

Intelligent Life??

(back to the Fermi Paradox- Where is everybody?)