Are we alone in the Universe? Habitable planets

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A revolution has occurred in the last two decades in the world of astrophysics. It all started in the mid '90s with the first discovery of new worlds around other stars. The term "Extrasolar planet" (or Exoplanet) became widely used to identify planets orbiting a star other than the Sun. A planet is a celestial body massive enough to be bounded by its self gravity (unlike a rock or an asteroid, that are kept together by electromagnetic forces), but not massive enough to produce energy through nuclear fusion (as stars do).

Planetary scientists have confirmed the existence of more than 1500 exoplanets and have identified a few thousand exoplanet candidates that require more investigation before they can join the planet club (see exoplanets.org for the most recent figures). The most remarkable discoveries came only in the last couple of years thanks to the Kepler space telescope. This amazing instrument has been patiently looking for the extremely tiny dimming induced by the passage of a planet in front of its host star.

The wealth of data provided by Kepler has revealed an astonishing fact: "When you wish upon a star, you are wishing upon a star with planets" (W. Borucki). There is on average **one planet orbiting every star in the Universe** (Cassan et al., 2012; Swift et al., 2013). Just in our Galaxy this means we have 100 billion planets. Since we have about 100 billion galaxies in the Universe, there are about 10,000,000,000,000,000,000,000 = 10^{22} planets out there.

This is fascinating, but still it does not tell much about the likelihood of extraterrestrial life. Planets like Jupiter or Mercury are not expected to host life due to their extreme surface conditions. This could well be the rule in the Universe, with Earth being just a lucky shot of nature. The question is then how common

are planets that can likely support biological life. A possible requirement is having a rocky planet in the so called Goldilocks or habitable zone, a range of distances from the host star where surface temperatures are just about right for liquid water to be present. This might well be a restrictive definition of habitability, as life forms might thrive in very different environments from what we are used to. But one has to start somewhere, and liquid water seems to have played a decisive role as a catalyst for biological life on Earth.
And here is where it gets very interesting, as just recently we learned that Earth-like planets are indeed very common. Statistically speaking at least 1 in 5 planets around Sun-like stars could potentially support life Petigura, Howard, and Marcy (2013). And Sun-like stars are extremely common, resulting in about **20 billion habitable planets just in the Galaxy**, with the closest possibly "just" 12 light years away.
Given the stellar density in the solar neighborhood (~ 0.14 pc^{-3}, where 1 pc equals 3.26 light years) and $\sim$80 years of TV broadcasting this implies human-made electromagnetic signals have reached $\sim$1700 planets potentially suitable for life. The rumor is out we are here (and have some terrible tv channels).

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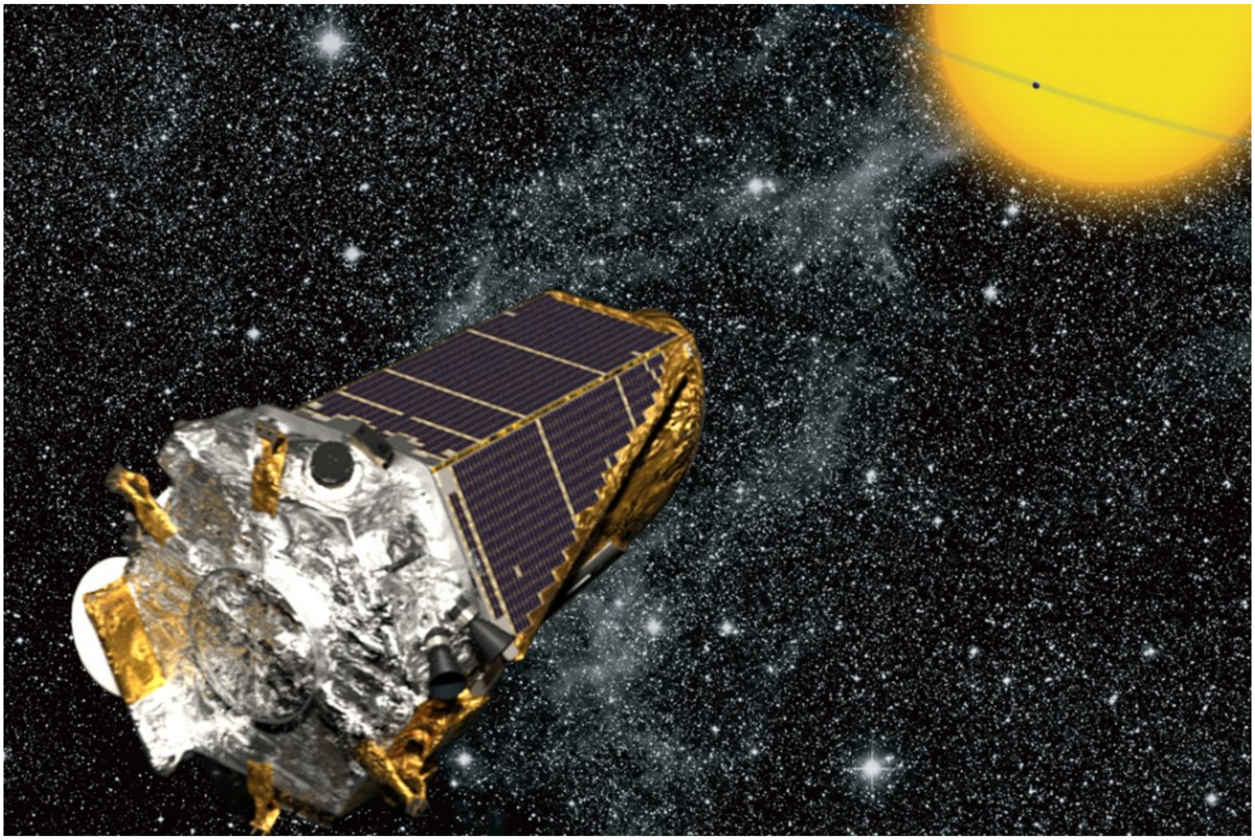

Figure 1: **The Kepler spacecraft** finds planets beyond our solar system by detecting changes in star brightness when a planet passes in front of a star. It has been monitoring over 100,000 stars simultaneously for about 4 years, pointed to a small section of the constellations Lyra and the Northern Cross (Cygnus). Credit: NASA/ Wendy Stenzel

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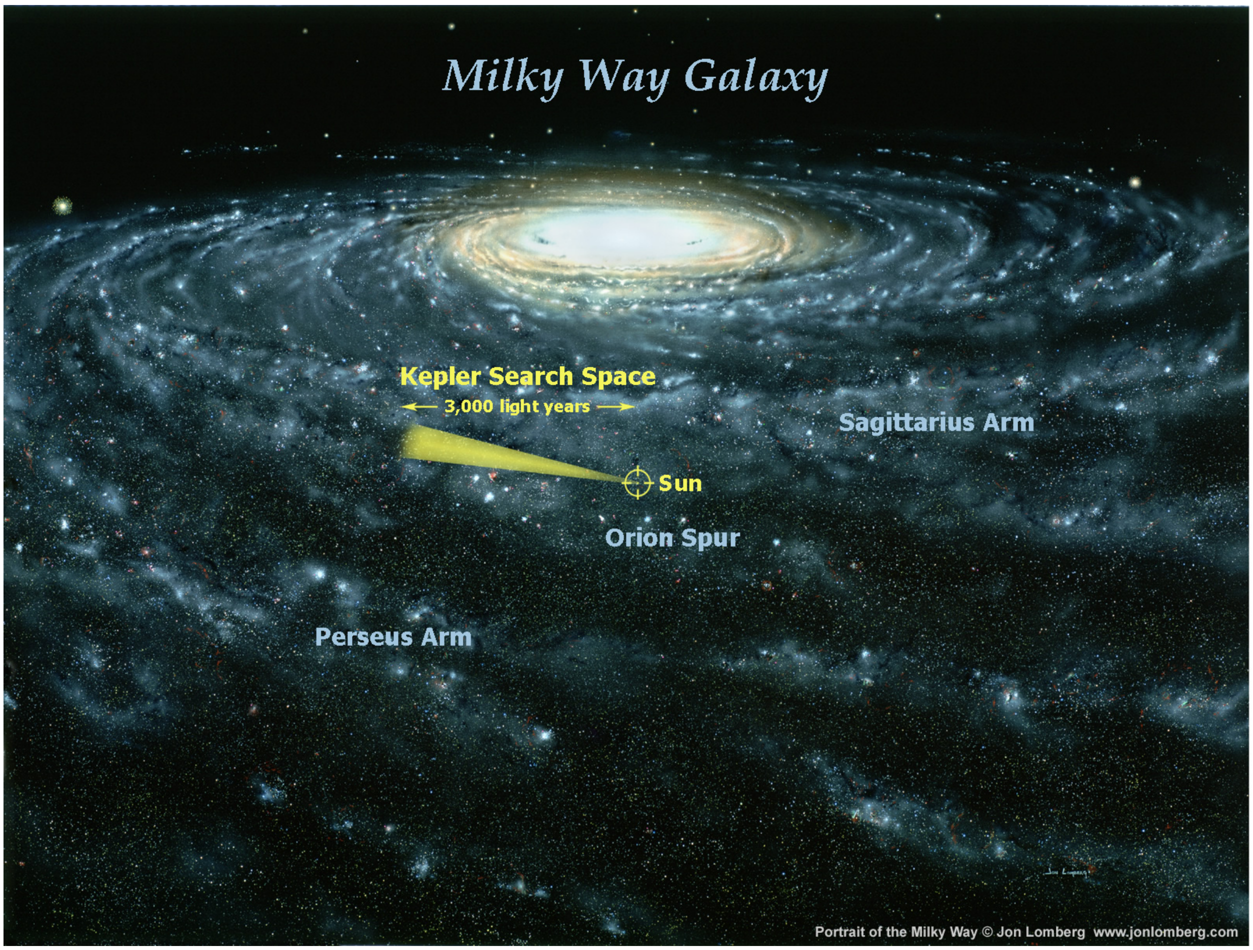

Figure 2: **Kepler search space**, a cone extending about 3000 light years in one of the Milky Way's spiral arms. While being a statistically significant sample, the 100,000 stars monitored by the spacecraft represent only 0.0001% of the 100 billion stars in the Galaxy. Credit: NASA

References

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