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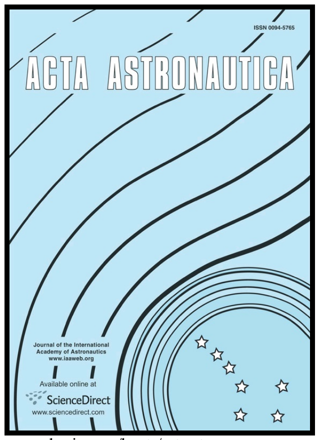

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How far are Extraterrestrial Life and Intelligence after Kepler ?

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Abstract

The Kepler mission has shown that a significant fraction of all stars may have an Earth-size habitable planet. A dramatic support was the recent detection of Proxima Centauri b. Using a Drake-equation like formalism I derive an equation for the abundance of biotic planets as a function of the relatively modest uncertainty in the astronomical data and of the (yet unknown) probability for the evolution of biotic life, F_b. I suggest that F_b may be estimated by future spectral observations of exoplanet biomarkers. It follows that if F_b is not very small, then a biotic planet may be expected within about 10 light years from Earth. Extending this analyses to advanced life, I derive expressions for the distance to putative civilizations in terms of two additional Drake parameters - the probability for evolution of a civilization, F_c, and its average longevity. Assuming "optimistic" values for the Drake parameters, (F_b~F_c~1), and a broadcasting duration of a few thousand years, the likely distance to the nearest civilizations detectable by SETI is of the order of a few thousand light years. Finally I calculate the distance and probability of detecting intelligent signals with present and future radio telescopes such as Arecibo and SKA and how it could constrain the Drake parameters.

Keywords: Kepler mission – exoplanets – biotic planets – SETI – Drake equation - SKA

1. Introduction

An important yet until recently poorly known factor, required for estimating the abundance of extraterrestrial life is the fraction of stars with planets, in particular Earth-like planets within the Habitable Zone. In the past decade planets have been discovered around hundreds of nearby stars, yet most of them were Jupiter-like gas giants, and too close to their host star to permit liquid water on their surface (e.g. Fridlund *et al*. 2010). In the last four years, the Kepler mission yielded over 5000 exoplanet candidates, most of them with sizes smaller than Neptune and down to Earth-sized planets (~1-2 Earth radii)**.** Such small planets have been shown to constitute the majority of exoplanets (Buchhave et al., 2012; Batalha et al., 2013; Dressing and Charbonneau, 2015). Further work has demonstrated that such planets are often found within the Habitable Zone of their host star. Recent analyses of the Kepler data showed (Petigura *et al.,* 2013) that about 20% of all solar-type stars have small, approximately Earth-sized planets orbiting within their Habitable Zone. Observational uncertainties and false-positive detections (Foreman-Mackey, Hogg and Morton, 2014; Farr, Mandel and Stroud, 2014) may significantly reduce this figure (down to 2-4%, however with a large uncertainty), yet it still implies a significant fraction and a huge number of stars with Earth-size habitable planets. Similar results have been obtained by different methods. The HARPS team (using the Doppler method) estimated that more than 50% of solar-type stars harbor at least one planet, with the mass distribution increasing toward the lower mass end (<15 Earth masses) (Mayor *et al*., 2011). HARPS also detected Super Earths in the Habitable Zone (Lo Curto *et al*., 2013). These findings demonstrate that "Earthlike" planets (in the sense of Earth-size planets in the Habitable Zone) are probably quite common, enhancing the probability of finding planets with conditions appropriate for the evolution of biological life as we know it.

Another conceptual break-through has been the recognition that life need not be limited to planets orbiting solar-type stars, which are only a small fraction of all stars in the Galaxy. Especially Red Dwarf (RD) or M-type stars (the lowest-mass stars, 0.08-0.6 M_{Sun}, less luminous and cooler than the Sun), are of great interest, as RDs are the type most common in the Galaxy, constituting about 75% of