EPSC Abstracts
Vol. 9, EPSC2014-864, 2014
European Planetary Science Congress 2014

A Road Map to the New Frontier: finding ETI

J.L. Bertaux
LATMOS - UVSQ/CNRS/IPSL, 11 boulevard d' Alembert, 78280 Guyancourt, France

Abstract

An obvious New Frontier for humanity is to locate our nearest neighbors technically advanced (ETI, extra-terrestrial intelligence). This quest can be achieved with three steps. 1. find the nearest exoplanets in the habitable zone (HZ) 2. find bio-signatures in their spectra 3. find signs of advance technology. We argue that steps 2 and 3 will require space telescopes that need to be oriented to targets already identified in step 1 as hosting exoplanets of Earth or super Earth size in the habitable zone. We show that non-transiting planets in HZ are 3 to 9 times nearer the sun than transiting planets, the gain factor being a function of star temperature. The requirement for step 1 is within the reach of a network of 2.5 m diameter ground-based automated telescopes associated with HARPS-type spectrometers.

1. Introduction

It is easy to show that the probability of transit for an exoplanet is sin α = R*/D, where α is the angle subtended by the stellar radius R* from the distance D of the exoplanet to its host star. Let us consider the family of all exoplanets having the same α value, transiting or non-transiting. Let N(α) being their number in a volume V centered on the sun. The volume V_t required to have the same number N(α) of transiting planet is:

$$V_t = V/\sin \alpha \qquad (1)$$

Therefore, we can state that, on average, a transiting exoplanet is at a distance from the sun larger than a non-transiting one by a gain factor F_g:

$$F_g = Q_t/Q = (\sin \alpha)^{-1/3} \qquad (2)$$

A non-transiting planet is brighter than its transiting counterpart by a factor F_g^2.The host star also is brighter by the same factor, and the signal/noise ratio is larger by the factor F_g (assuming the noise is the random fluctuation of the star signal). A telescope with a diameter larger by a factor F_g is needed to get the same S/N ratio for a transiting planet for the same exposure time.

2. The case for the Habitable Zone.

Mass, luminosity and radius R* of a main sequence star are linked to its spectral type quantified by its effective temperature T_{eff}. The distance of the HZ depends also of T_{eff}. The equilibrium temperature of a planet of albedo A without green-house at distance D form the host star can be computed easily and it comes:

$$T_p = T_{eff}\,(R^*/2D)^{1/2}(1-A)^{1/4} \qquad (3)$$

For the HZ the value of sin α = R*/D can be derived simply from equation (3):

$$\sin \alpha = R^*/D = 2\,(T_p/T_{eff})^2(1-A)^{-1/2} \quad (4)$$

The gain factor defined in section (2), $F_g = (\sin \alpha)^{-1/3}$ can therefore be expressed as:

$$F_g = 2^{-1/3}\,(T_p/T_{eff})^{-2/3}(1-A)^{1/6} \quad (5)$$

From this expression we see that the gain factor is weakly dependent on the albedo, and dependent on the stellar type (T_{eff}) and the equilibrium temperature of the planet T_p. On Figure 1 is plotted the gain factor F_g defined in (5) as a function of the star's effective temperature T_{eff} for various planet equilibrium temperatures: 195 and 285 K which define the boundaries of the habitable zone, and 258 K which represent the case of the Earth, for A=0.3. We have also plotted the gain factor for the middle of the habitable zone for 100 stars of the Cantrell et al. [1] sample of stars within 10 pc from the sun. For this sample the gain factor varies with T_{eff} from 3.2 to 9, with a middle value of 6. We may summarize these findings by stating that transiting exoplanets in the habitable zone of nearby stars are in average at a distance 3.2 to 9 times further out from the sun than non-transiting exoplanets, the gain factor depending on the stellar type.

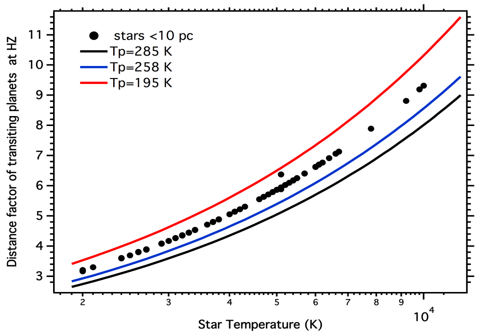

Figure 1. Distance factor (or gain factor Fg) of transiting planets in the HZ as a function of stellar temperature for 3 planet temperatures (258K is the case of Earth). The dots are for the stars within 10 pc from a sample [1].

3. Radial Velocity search

It is our contention that sophisticated observatories capable of characterizing the atmospheres, and search for intelligent life, must not spend their precious time in trying to find the existence of an exoplanet around a star. It would be much more efficient to target them towards stars where the presence of a planet is already know, as well as the distance to the star and its period and phase. One potential promising space system [2], the external occulter (to decrease the light of the central star) is a good example of a system which is not easily "pointed" from one star to the other, a change of target requiring somewhat lengthy operations. JWST could observe Gaia spacecraft used as an external occulter to explore in-flight performances of an external occulter, both spacecraft being around L2 point.

Now we discuss the capabilities of the radial velocity search of exoplanets in their habitable zone. We concentrate on planets of the size of the Earth and larger, up to 2.8 Earth Radii (Re). The reason is that the Kepler mission, observing 60,000 stars simultaneously, has provided a tremendous progress in the statistics of existing planets. The observed transit allows measuring the radius of the planet. Petigura et al. [2] have shown that the distribution of planetary radii decrease abruptly above 2.8 Er, while it is about constant for the three smallest bins 1 to 1.41, 1.41 to 2, 2 to 2.8 (geometric progression of sqrt(2)). From their analysis [3], they conclude that 45% of all stars possess one planet with an orbital period between 5 and 100 days.

We note that the gravity increase like the radius (for a constant density) and therefore the gravity for the biggest Earth considered here is not outrageous, at 2.8 g (surely not comfortable for us, but possibly manageable by some forms of life, even out of the sea, on the ground).

On figure 2 is represented the period of a planet in the middle of the habitable zone for the stars of the Cantrell et al. [1] sample of nearby stars, as a function of the star mass, derived form a typical relationship between the mass and T_{eff}. The reflex motion of an Earth or super Earth is also shown.

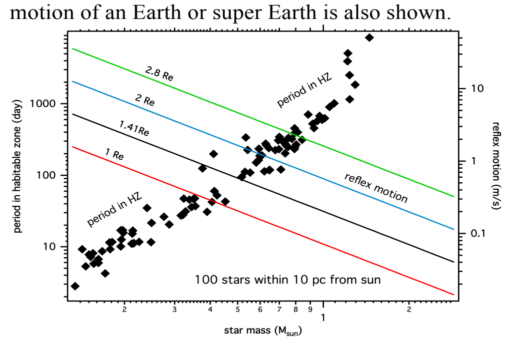

Figure 2. Period of planets in the HZ for a sample of 100 stars within 10 pc [1] as a function of star mass (black diamonds, left scale). Right scale: reflex motion induced by exoplanets of various masses.

The actual performance of HARPS is around 0.5-1 m/s. Some improvements (i.e., telluric line correction) may be achieved. However, for one single measurement the "jitter" linked to the star activity is rather the limit, which can be overcome only with long series of observations to average out this jitter. This new strategy calls for the implementation of a network of automated telescopes with HARPS type spectrometers.

References

[1] Cantrell, R., et al., The Astronomical Journal, 146:99 (20pp), 2013

[2] Cash,W., Nature, vol.442, p.51-53, 2006

[3] Petigura, E.A., et al., PNAS, vol. 110 , no. 48 | pp 19273–19278 ,2013