FUTURE EXOPLANET DETECTIONS FROM SPACE, AND DRAKES FORMULA: DISCUSSION ON DIFFERENT PARAMETERS. IMPLICATIONS ON FURTHER SPACE RESEARCH AND SETI?

A. Labèque, A.Léger, C.Valette, F.Brachet and B.Chazelas

Institut d'Astrophysique Spatiale, Bâtiment 121, Université de Paris-Sud, 91405 ORSAY Cedex, France

Abstract

After a brief reminder of Drake's formula, its different parameters will be discussed, and particularly those which should be better estimated after COROT, KEPLER, DARWIN and TPF-I missions. As the two first will give us first statistics about existence of terrestrial planets, space interferometers will give data about habitable and inhabited planets. In case of positive detections, our drastically changed conception of life should lead astronomers and governments to a significant increase of research potential in this field, to enlarge the research area, and get more detailed spectra. As soon as it will be technically feasible with science and techniques progresses, probes should be sent to the nearest of these worlds. Search for Extra-Terrestrial Intelligence should also be encouraged by positive results, and some new ways envisaged.

Key words: Exoplanets, Drake's equation

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1. Drake's formula

This formula was written by Frank Drake around 1960. As everybody knows, it is an attempt to estimate the number of civilizations in our galaxy able to communicate through large space distances. One of the common ways to write it is as following:

$N = N^* . f_{tp} . f_{hab} . f_{inh} . f_{tc} . t_{tc} / t^*$

where:
N : number of such civilizations
N^* : number of stars in the galaxy
t^* : mean lifetime of stars
f_{tp} : fraction of the stars with terrestrial planets
f_{hab} : fraction of these planets able to host life
f_{inh} : fraction of habitable planets where life evolved
f_{tc} : fraction of inhabited planets where technical civilizations appeared
t_{tc} : mean lifetime of such civilizations

Among these parameters, only N^* and t^* are known with reasonable accuracies. This situation may drastically change within the two next decades, and it is now time to think about what we will get from future exoplanet detection missions to better estimate parameters of Drake's formula.

2. Future missions and Drake's formula

2.1. The transit missions

Main next discoveries of terrestrial planets will very probably be done by transit detections made by the COROT and KEPLER observatories. Both will operate surveys of large fields, and detect transits of planets on the line of sight of their star by photometric variation. The CNES-ESA COROT mission (Fig. 1) should be launched in 2006, will observe 60 000 stars during 150 days, and will be able to detect ”hot big earths” (Rouan et al. 1999).

Figure 1. Artists view of COROT mission.

The NASA mission KEPLER should be launched in 2008, will observe about 100 000 stars during several years and will be able to detect planets down to earth size (Borucki et al. 2003). Both missions will give data allowing to considerably increasing accuracy of f_{tp} estimation, by a simple statistic on the star populations which will be studied.

2.2. Direct terrestrial planet detection missions

First direct terrestrial planet detections will probably be done by the NASA TPF-C mission (launch 2014?), and then help to refine estimation of f_{tp} and give a first estimate of f_{hab}.
A few years later, DARWIN (2014 ?) and TPF-I (2020 ?) will observe hundreds of stellar systems and give a good estimate of the terms f_{hab} and f_{inh} by detection of bio-markers in the studied planets (Fridlund et al. 2000, Beichman et al. 1999). At the moment, as the telescope diameter of these missions is not frozen, and as we have no accurate estimation of f_{tp}, we cannot know how accurate the estimation of this product will be.
The number of expected detection for Darwin is shown, depending on these parameters, in Figure 2.

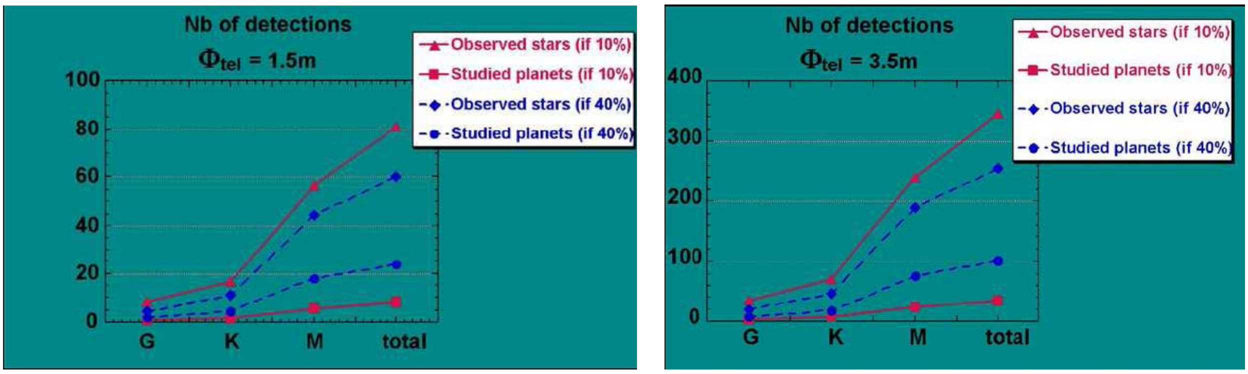

Figure 2. DARWIN expected detection of terrestrial planets.

2.3. Observation of biomarkers on young planets

Relatively young systems (1 to 1.5 Gyr) will be also studied with Darwin. If life is detected, it will reinforce the hypothesis of a fast and then frequent apparition of life and then allow giving a narrower error margin to f_{inh}. If we consider the case of Earth, life appeared rather soon, before 3.5 Gyr, that means less than 0.6 Gyr after the condensation of water (Westall et al. 2001), implying the presence of detectable ozone from 3 Gyr (Fig. 3).

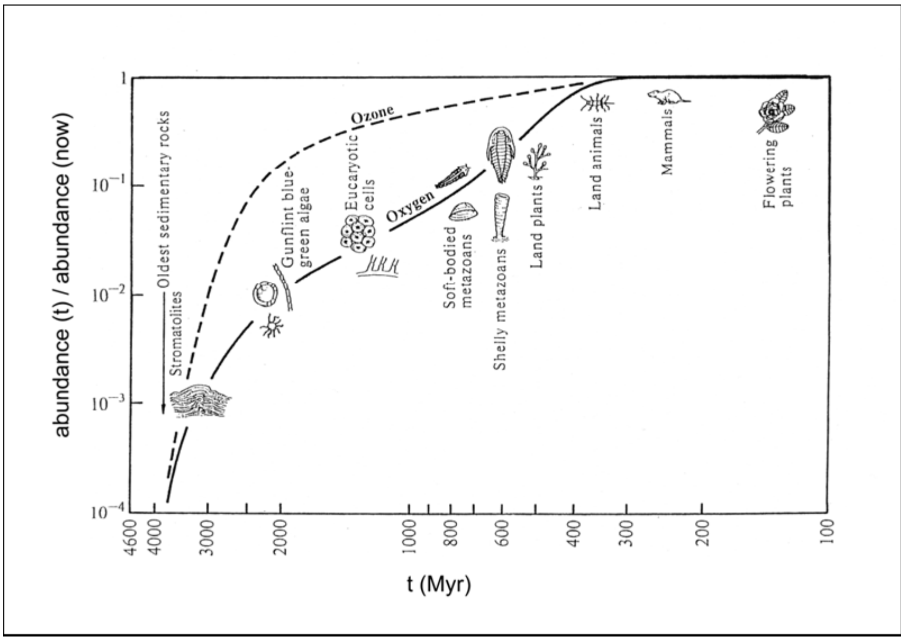

Figure 3. A possible history of O_2 and O_3 in Earth atmosphere.

3. Drake's formula and Fermi paradox

Different cases are to be considered, according to the results of these missions:

– COROT and KEPLER show that terrestrial planets are rare and Darwin/TPF-I gives no positive detection: N is probably very low, maybe N=1, and Fermi paradox is almost solved!

– COROT and KEPLER show that terrestrial planets are not rare and Darwin/TPF-I gives no positive detection: life apparition is rare, and it leads to the same conclusion, with a little uncertainty because we don't know f_{tc}.

– COROT and KEPLER show that terrestrial planets are rare and Darwin/TPF-I gives positive detections (rather improbable, but possible): earths are rare, life apparition is not rare, and it leads to big uncertainty on evaluation of N.

– COROT and KEPLER show that terrestrial planets are not rare and Darwin/TPF-I give positive detections: N remains unknown, its value depends only on the product $f_{tc} . t_{tc}$ but can be high. Search for direct or indirect detection of extra terrestrial intelligence should be strongly encouraged by these results, but should be envisaged in radically new ways.

4. Which mission after DARWIN/TPF-I ?

Whatever the result of these missions, the impact on mankind will be huge: in the two first cases of preceding paragraph, loneliness feeling will be big, and this is not the subject of a scientific paper...
In the third and of course, the fourth case, which is our favourite, scientific community will have to face to one of the most important intellectual challenge of history, comparable to the just pre-Colombian times: there are other earths, like there were other continents What should the space science community do in these cases?

– construction of a Super Darwin and a Super TPF-I to increase the statistics and to refine spectrometric measurements? (attempt to detect technical activity through non natural gases detection, etc). This will be technically feasible and will require only money and intelligence. It should be the following step on the way of discovery these new worlds, has to be done, and will bring a lot of information on them. However, technical activity can easily be missed by these very far remote sensing.

– if technology improvement allows it, send interstellar probes towards these systems, even if the travel lasts centuries? This is much more difficult, because unusual technologies have to be developed, like projects Orion (Dyson 2002) and Daedalus (Bond et al. 1978) to reach reasonable fraction (0.1) of light celerity. Anyway, this seems to be done as a second step, may be not during the 21_{th} century, but in the following centuries.

– carefully look in our solar system for such extra-terrestrial probes potentially observing the Earth?
This can be done within a few decades, and should be done: the reason is that if N can be rather high, and we haven't detected anything with previous SETI researches, other hypothesis on extraterrestrial intelligences have to be investigated: if "they" exist and we don't see them, it is probably because they don't want to communicate. We have then to seriously envisage at least a soft version of "Zoo hypothesis", of "watchers" which look to the Earth with engines which are difficult to detect.
What could be the places for such probes? A good candidate is L1 Lagrange point, and it should probably be rather easy to detect artificial objects (other than human satellites...) at this point. Other good candidates are orbits which are out of ecliptic, internal to Earth's orbit, and synchronous with it, so that the probe has two fly-by a year, at a reasonable distance, difficult to detect in the Sun's direction. This kind of probe is not easy to detect: a way to do it could be to try to illuminate it with spinning large orbital plane mirror, reflecting sunlight. If a kind of cat's eye effect could work on the optics of the probe, it could be a manner to see it when its line of sight is not too near of the Sun.

5. Conclusion

Of course, we cannot exclude the fact that mankind is the first technical civilisation in the galaxy, but, at this moment of our history, our knowledge is insufficient to claim it, unless to put ourselves in a classical anthropocentric point of view. History of sciences shows a lot of examples of the inefficiency of this attitude.
COROT, KEPLER, DARWIN and TPF-I missions will give data which may completely change our conceptions about terrestrial planets and about life. If these observations give us good reasons to think that life is widely spread in the galaxy, then mankind has to face a new challenge: try to detect existence of extraterrestrial intelligences, even if these ones do the maximum to remain undetected.

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