PUSHING THE LIMITS FOR ALIEN WORLDS HUNTING

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ABSTRACT

After the pioneering phase of the space era we are, again, looking for worlds outside of our solar system. We do with a variety of space and ground based mission and we note that most of the predictions, both on the scientific than on the technological capabilities to do so, have proved wrong. Some alien world is maybe looking toward us with the same kind of approach and it is likely we will not know of each other in this way. But the race to push away our border of knowledge is just started.

1 FOREWORD

In the middle of the age of enlightenment it was normal to see drawings where stars in the night sky are depicted surrounded by a number of other planets, and occasionally even by other kind of objects like comets. With the work, that nowadays we could label as iconic, of Bernard le Bovier de Fontenelle, [1] become normal in artistic and popular representation of the starry night to add circling planets of different shape and distances. This depiction basically vanished in the short century [2] and I speculate one of the concourse being that the objects in our own solar system become "at hand", first in science fiction and later in reality, pushing these worlds in a forgotten realm for the general public and leaving exoplanets well outside the zeitgeist of the whole space-age.

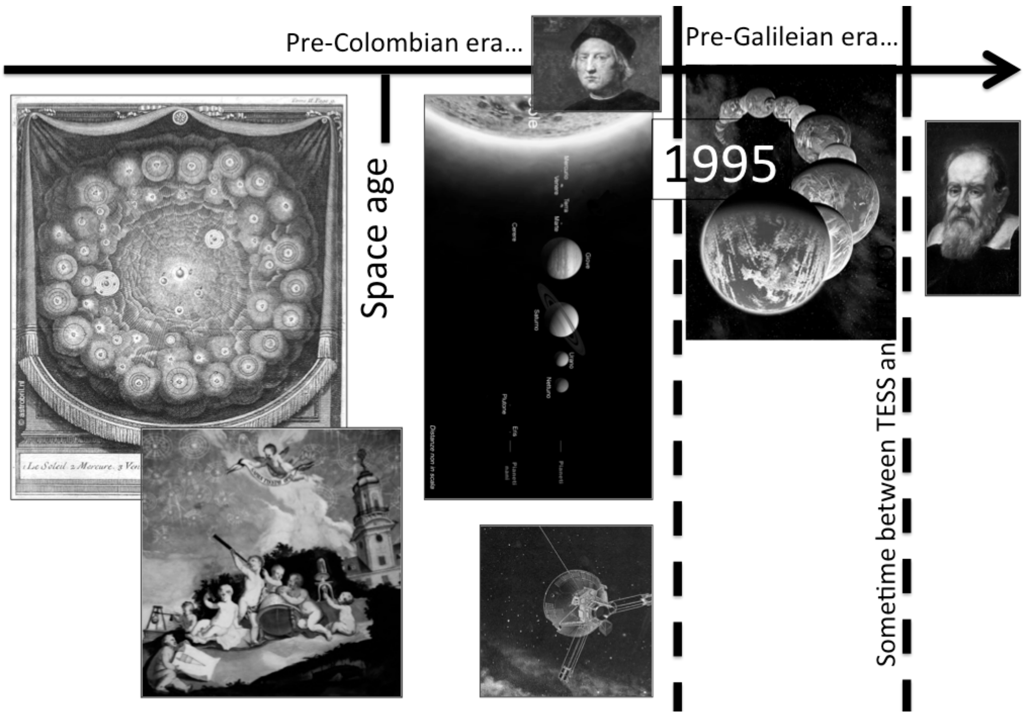

Figure 1. The arrow of time depicting the Colombian and the Galileian eras in exoplanets hunting.

Still at the moment of writing this piece, and 23 years after the discovery of the first genuine exoplanet [3], the number of confirmed ones remains in the realm of a few thousands, somehow below the number of stars visible to the naked eye. By analogy with the discovery of the Galileian telescope we could say that we are living in the transition between a pre-Colombian era (where no exoplanet was actually known) and an imminent Galileian epoch that will occur as soon, very likely with the TESS findings [4,5] and surely with the PLATO ones [6,7], as the number of known exoplanets will exceeds the number of naked eye stars.

2 LEARNING FROM ERRORS

In this early beginning of the 21st century, with the discovery of Bellerophon, one should not forget what was the current understanding of the alien world's hunting, in order to avoid to make again the same mistakes, but at least to make new ones. At the time everyone was aware that our Solar System was the only example at all and that extrapolation could translates into some sort of misjudgement. However accretion from planetesima was the winning theory and this was driving a number of expectations in the realm of exoplanets, finding. Furthermore, there was doubt that planetary system was a common situation in our Galaxy, and one should see at the way developments of the searching techniques have been developed, with a certain respect. In practice, although the final results span a relatively large number of spectrum in the mass vs. distance from the host star plane, there was a general consensus that rocky planets, possibly upper bounded by a mass close to the one of our Earth, would lie in the vicinity of the star, while giant gaseous planets would stay at a significantly larger distance [8,9]. It is interesting that treating giant gaseous planets as objects that missed the nuclear ignition and failed to become stars, by analogy with the well known realm of double stars, the prediction of what are nowadays called "hot Jupiter" have been made in advance of almost half a century. We know today that hot Jupiter, although not common, are not a rare phenomenon (they encompass about 10% of normal stars, although the actual figure should be revised once the observational bias will be removed without the unavoidable uncertainties that today dominates the arena) and their formation, prohibited to happen closer to the host star by the so-called snowline (in our Solar System located at about 5AUs) and how they eventually later reached their current orbit, is still a controversial subject. This failure in predicting the much wider variety of planetary formation around stars other than our one, translated into pushing resources into technological developments that were aiming to copies of our Solar System, missing the actual discoveries. This should be kept in mind when, sometime maybe driven by non scientific aims, we look avidly for bio signatures, based again on the only kind of life we know on this planet (associating it, for example, to the possible existence of liquid water). Interesting enough, life appearance remains a process with several unknown, while accretion of gaseous spheres or aggregation of silicate are by orders of magnitude simpler and better known process (although still with several question marks).
The analogies could easily continue, and let me make some sort of practical examples, where I suggest a sort of figuring out a "what if" should be used to adjust our adjustment in the direction where to look for alien worlds. Here they are:

- A civilization living in a rocky planet co-rotating around an M-star could rapidly conclude that this is the only condition where the absence of the shocks of a night and day variations are key to their existence in a temperate strip close to the local terminator.
- A civilization living on a planet orbiting a very active star could conclude that the flares played a key role in the perturbation of their –likely complex- genetically mechanism, leading to what we would called an accelerated evolution.

- As about half of the stars in our Milky Way are double stars, a civilization living around such a kind of multiple system could easily conclude that the presence of two source of energy is essential to avoid lack of heating,.

All the three cases could be dragged to believe that looking for planets around a quiet G0V single star would be a total waste of resources in order to find the “proper” (from their viewpoint) evidence of extra-local life.

On the more pragmatic and less philosophical side of the story, at the dawn of the first exoplanet discovery the quest for the technological development in order to find out what was thought to be the expected population of planetary systems is well described in a document by the NRC [11] where astrometry and direct imaging has been ranked much higher than anything else in the list of the most effective way to find exoplanets. Radial velocity and photometry (through transits) is cited, but –not surprisingly given the kind of the expected signals- they are classified as interesting means but likely of little statistical relevance. On one hand one should recall that the signal, both for transits and radial velocities, is paramount much larger if giant gaseous planets at orbits much closer than the Mercury ones are considered, an option that was evidently not in the radar’s range of most of the astronomical instrumentation builder at the time. Ironically an handful (but rather important) of exoplanets has been discovered by direct imaging and basically none by astrometry so far. At the same time a huge progress in conceiving new techniques to achieve direct imaging has been developed (including my own personal contribution [12], later recognized as the best way to achieve wavefront sensing in order to compensate from the ground the atmosphere aberrations and isolate the light from circumstellar objects [13]) while the vast collection of confirmed exoplanets comes from transit, and specifically from a single space mission, namely KEPLER [14,15], although with the important precursor of COROT [16]. Small apertures are viable as well [17].

It is evident from the considerations made so far that prediction remain a very risky business and that even in the development of existing instrumentation, without the introduction of new paradigms, the risk of missing important contributions is evident. Coronography remains an area, however, where there is no evidence that the fundamental limits have been reached and some important surprise, even with relatively small or ground based telescopes could be at hand. Inspection of the literature findings could be less useful than usual, because the regime here optical telescope works nowadays is much different than the one of a few years ago, reaching Strehl ratios very close to the ultimate limit much often, and hence allowing for techniques that was simply unaffordable just a decade ago.

3 MAPPING OUR NEIGHBOROUDS

On one point, however, the study previously pointed out [11] was in fact totally right: there is no fundamental limitation in the discovery space for astrometry and direct imaging, in contrast with radial velocity and especially transits. While the latter proved to play a fundamental role, once corrected for the observational bias, and encompassing a large enough sample of stars, the only way to map our neighbourhoods is likely through astrometry and in fact the recent proposals of NEAT, THEIA and TOLIMAN are all along this line.

Technique	*Scaling with distance*	*Favoured periods*	*Effect of the orbit inclination*
Transit	No	Short	Strong, preventing detection
Imaging	Yes	Long	Mild, with no blind spot
Radial velocity	No	Short	Mild, with a blind spot
Astrometry	Yes	Long	None

Table 1. Various exoplanets detection techniques compared in the way they are biased by the orbital inclination, by the distance of the star from the observer and on the nature of the exoplanet’s orbit.

Transits will probably remain for one or two decades one of the main sources of statistical information on the distribution of the exoplanets population, but will surely fail to assess a definitive census in our backyard. Exoplanets discovered by transits offers furthermore unique opportunities to detect atmosphere signature and, once time resolved spectroscopy of high enough precision, maybe with JWST, will be routinely available, one can probe atmosphere at different altitudes and provide some first stratiphication profiles. Direct imaging from ground and from space are evolving as well and the big change of paradigm is going to occurs as soon as spectroscopic analysing the exoplanet light isolated from the host star will become an high SNR exercise.
A curious feature of transit exoplanets detection rely on the fact that to avoid the scattered light from our own Sun long period search are confined to region of the sky distant enough from the ecliptic plane. The net result is that we are not looking for one-year period exoplanets (or basically of twins of our own system) in the region of the sky where we are detectable from others civilizations using the same method. Of course this does not rule out the possibility of detection by other means, including the transit itself through Time Transit Variations.

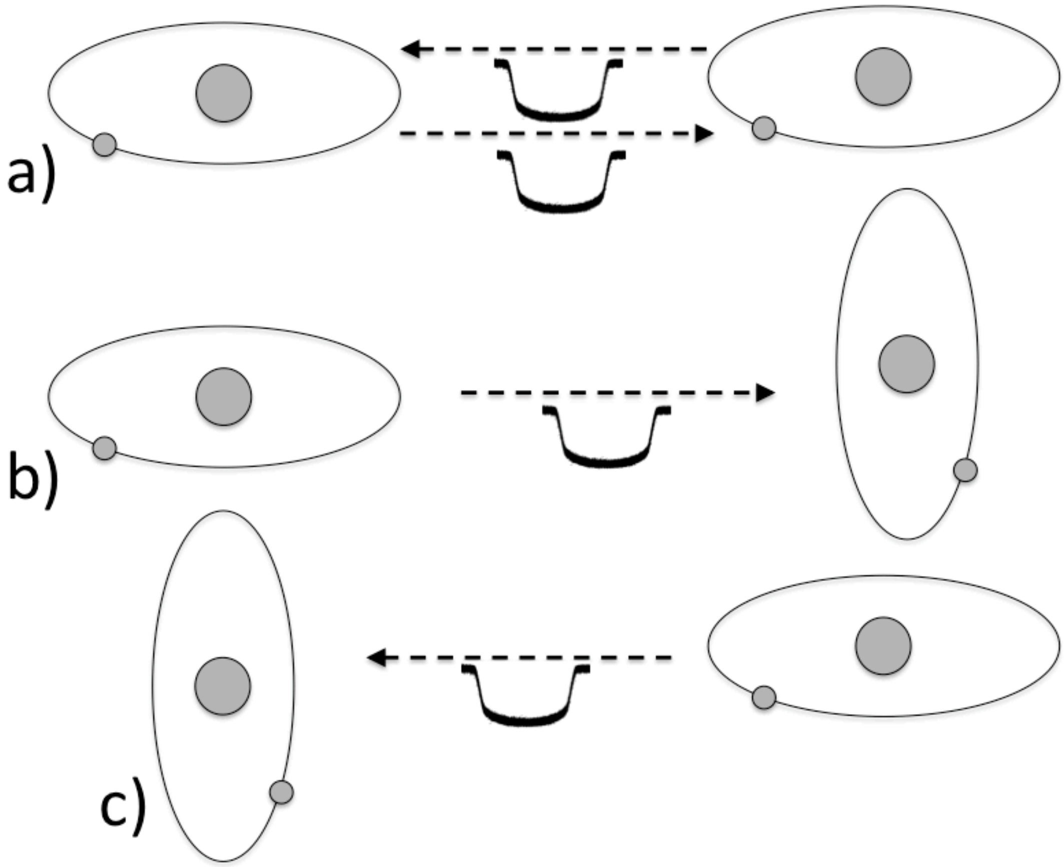

Figure 2. Looking for twins of a Sun-Earth system through transits will lead to a mutual discovery, as depicted in a) as a very unlikely situation, not only because of the product of the plane alignment probabilities (each amounting to about 1% making the composite one out of 10^4, a non impossible configuration in our Milky Way) but because searching for transits with a one year periods will lead to a disturbance by the local star with the same cadence. Options b) (we are seen) or c) (we can see) are much likely to happen. Interstellar wars with close twins based upon transit detection technology are unlikely.

It is interesting that out of five of the closest stars, including the Alpha Centaurus double, most of the remaining stars exhibits a continuum into the astrometric precision needed in order to detect an exoplanet in what we today call the Habitable Zone. With a given exoplanet population distribution this means that once we will break the technology limit of detecting exoplanets at the one parsec level we have to expect to detect a plethora of objects in our vicinity.

4 CONCLUSIONS

We have seen huge surprises in the last couple of decades and prediction proven wrong in all areas, from the purely scientific ones to the area where technology development would make a significant leap. Although the two are interconnected some of the failures are genuine and we should be extremely cautious when getting into the realm of exoplanets spectroscopy or astrobiology. It is relatively easy, given the past experience, to expect the unexpected and to be ready to change direction in the development of astronomical instrumentation from ground and from space to keep track of the new findings. There is now a planned "armada" of spacecraft that are going in the next decade to scrutinize for transits a large number of stars with their exoplanets, that we now know will be surely extremely numerous. Imaging and coronography, could still leave ample space for new conceptual solutions to provide novel kind of observations. As it has been in stellar astrophysics from the first phenomenological classification of star's spectra to the most sophisticated reverberation mapping available today, allowing to map surfaces of the stars, we have to expect a complete new class of instrumentation and of methodologies for spectral mapping and analysis of exoplanets in a timescale of the order of one or two decade.

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