A bird's-eye view on the habitability of exoplanets via statistical learning techniques

Project for the exam: Machine learning, statistical learning, deep learning and artificial intelligence

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"Listen to me again. Just outside the Galaxy are the Magellanic Clouds, where no human ship has ever penetrated. Beyond that are other small galaxies, and not very far away is the giant Andromeda Galaxy, larger than our own. Beyond that are galaxies by the billions. Our own Galaxy has developed only one species of an intelligence great enough to develop a technological society, but what do we know of the other galaxies? Ours may be atypical. In some of the others-perhaps even in all-there may be many competing intelligent species, struggling with each other, and each incomprehensible to us. Perhaps it is their mutual struggle that preoccupies them, but what if, in some galaxy, one species gains domination over the rest and then has time to consider the possibility of penetrating other galaxies" (I.Asimov, Foundation and Earth)

ABSTRACT

Among the different tools that are considered by scholars to challenge the physical science issues, the statistical learning techniques seems to provide a promising approach to challenge them [1]. This approach can be used to tackle, one of the oldest problem of physical sciences: the habitability of exoplanets and the possibility of the presence of life on them [2]. This approach was previously used by scholars [3]: here a group of statistical learning techniques (Decision Tree, Random Forest, Support-vector machines and Quadratic Discriminat analysis) were applied to a selected set of 500 planets. The performances of the different methods were also compared and using the confusion matrix and the ROC curve.

CONTENTS

1 INTRODUCTION

The possibility of other form of life on other planets represent an issue that involved scientists as well as philosophers from different millennia of documented human history [6]. During the XX century, due to the technological progress, such question moved from a pure speculative approach, as it was previously for Lucretius, Muhammad al-Baqir or Iordanus Brunus, to a more quantitative and scientific method.Furthermore it is interesting to point out that this research was undertaken when the exploration of the Earth was almost completed [7]. The exploration of space, and the investigation of other planets was largely boosted with the use of telescopes that measure the radiation also outside the visible spectrum and later with the space telescopes such as the NASA's Kepler. As requested by all form of life in the Earth an habitable planet needs that liquid water can be present [2, 8, 9][1]. This feature is given, at first glance, by the radiation intensity I that is bounded to the power radiation (P) produced by the star that host the planet and the respective distance r. Indeed by approximating a star as a point or a perfect sphere, a radiation with a spherical symmetry is produced; thus the integral that gives the power produced P:

$$P = \int \mathbf{I} \cdot d\boldsymbol{A} \tag{1}$$

can be simplified as

$$P = |I| \cdot A_{surf} = 4\pi r^2 \tag{2}$$

and so [2]

$$|I| = \frac{P}{4\pi r^2} \tag{3}$$

Such relation establish an interval for the distance r where the stellar radiation is not too hot so that the water is the gas phase, and not to low so only the solid state phase is allowed. In the literature this interval is usually called habitable-zone [11]. However this represents a too simplified model since no atmospheric effect is taken in to account: indeed the surface temperature is also influenced by the greenhouse gases that allows to the host radiation to enter inside the planet but limits its escape [2, 14]. Basically this is due to the fact that the greenhouse molecules (CO_2,vapour, methane...) are excited by the infra-red radiation produced by the planet and remit it in all

1 Astrobiologist scholars also proposed that other form of life can come up without liquid water (see for instance [12]) however, for simplicity, here only planets that allows liquid water are considered habitable

2 Further details about this solution and the formalism by which it is obtained from the Maxwell equations can be found in Ref. [10].

directions. As consequence the radiation that is emitted by the planet is reduced, and so the temperature is increased. It is worth nothing that in principle the greenhouse is not negative since it allows to the planet to keep part of the heath received from the host star. However this can be a problem if the effect so large that the temperature of the planet abruptly increase: this was probably the fate of Venus that lost his oceans [15, 16, 2].

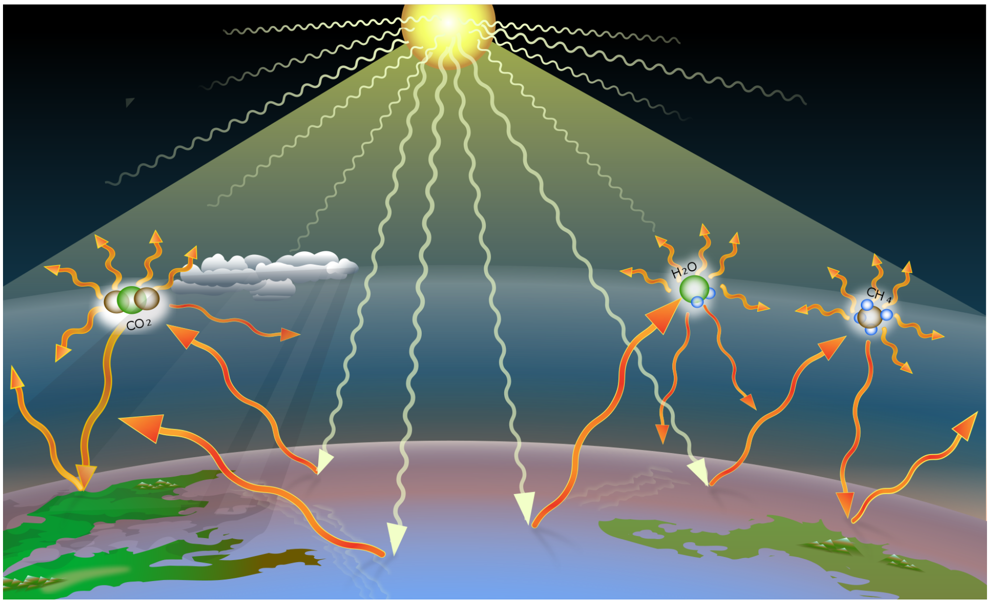

Figure 1: The greenhouse effect: the radiation of the host star is captured by the planet and than remitted: this process is limited by the greenhouse molecules of the athomosphere that absorb and re-emit the radiation in all directions. Image taken from [2]

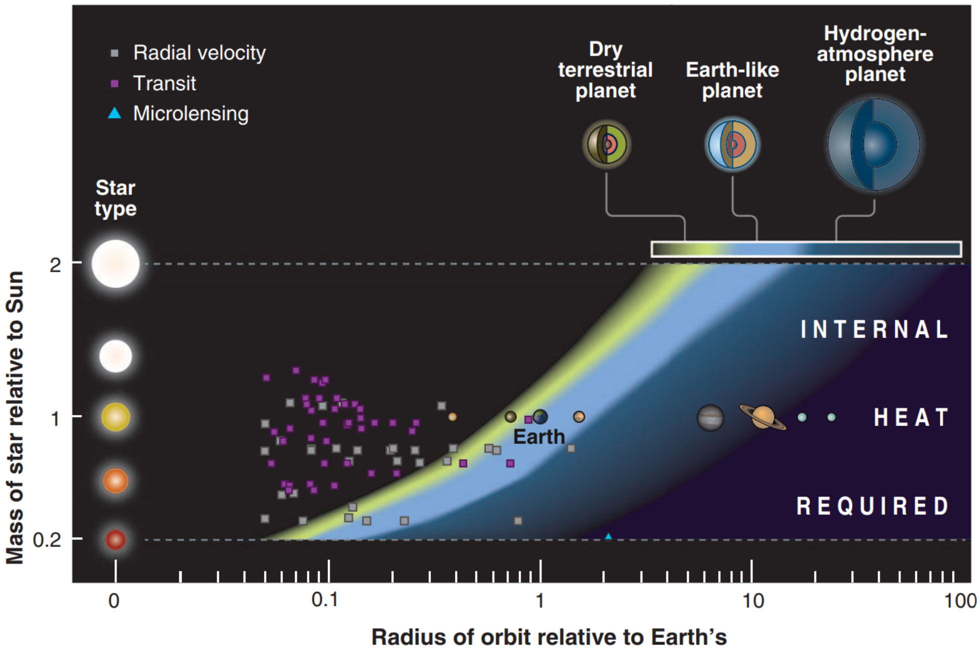

Figure 2: Seager representation of planet habitability as function of star type (that determinates the stellar activity) and planet distance. Image taken from [2]

2 R CODE

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