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Facts are difficult to overcome: Capabilities of Affordable Instruments Searching for Biosignatures vs η_{earth}

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Abstract

A simple analytic model is described that allows estimating the capabilities of affordable space missions searching for biosignatures by direct imaging and spectroscopy. Explicit relations between performance and relevant parameters, such as the mirror diameter, distance and radius of planets, are obtained. Two main types of instruments are considered: coronagraphs working in the visible, and nulling interferometers working in thermal IR. Instrument specifications that are considered as affordable in the mid-term future are: 2.4 m mirror coronagraphs with an Inner Working Angle of 2.5 λ/Φ, and interferometers with four 0.75 m collecting mirrors and bases from a few decameters to a few hectometres in Formation Flying configuration.

The numbers of accessible planets is calculated as a function of η_{earth}, the mean number of earth analogues and Super-earths, in the Habitable Zone of stars. The model is used to estimate the potential of these instruments, when *Kepler* will give its best value for η_{earth}. For low values of η_{earth}, e.g. 10% for solar type stars, and 50% for M stars, the coronagraph could study ~ 1.5 planets with radius 1.5 R_{earth}, and the

interferometer ~ 8 planets in the same conditions.

In both cases, a prior detection of the planets with a combination of ultra high precision astrometry mission, as Neat or/and Step, and Doppler observations during a 20 yr period, could save the valuable time of the spectroscopic mission(s), avoiding the study of stars without relevant planet. Even more important, it would provide the actual mass of the planets, an important parameter for any exobiology assertion.

The two instruments are not equally equipped to face a low value of η_{Earth}. If η_{Earth} = 10%, the 2.4 m coronagraph could study only a very limited sample of telluric planets in the HZ, 1.5 as a mean value, which would probably be prohibitive for a dedicated mission unless we are lucky. However, a mission with other astrophysical goals could be worth. The capabilities of an affordable interferometer (0.75 m mirrors) would remain significant. For η_{Earth} = 10% the number of planets that can be studied in spectroscopy is 4 to 12, according to their radius, 1.0 to 2.0 R_{earth}. If all are 1.5 Earth radius planets, they would be 8. Even with the risks of small number statistics, several planets of very high scientific significance could be investigated, which would legitimate a dedicated mission.

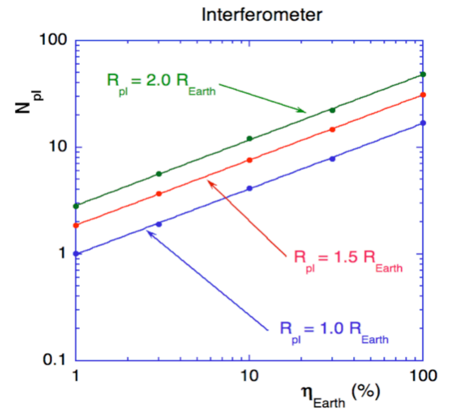

Figure 3: Total number of planets located in the habitable zone of stars that can be studied in spectroscopy in the thermal IR, at resolution λ/Δλ = 20, with a nulling interferometer equipped with four 0.75 m mirrors, spending 4 yrs on FGK stars and 1 yr on M stars, as a function of η_{earth}, and different values of the planetary radius. Calculated data points are well aligned on power laws, which would be the case in absence of quantization.

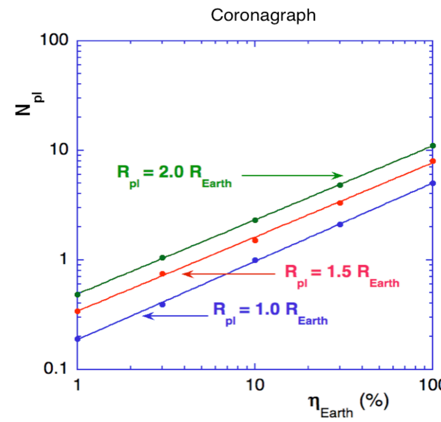

Figure 2: Number of planets located in the habitable zone that can be studied in spectroscopy in the visual (λ/Δλ ~ 70), with a IWA = 2.5 λ/Φ coronagraph on a 2.4 m telescope, as a function of η_{earth}, for different values of the planetary radius