Observational Constraints on the Great Filter

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Abstract

The search for spectroscopic biosignatures with the next-generation of space telescopes could provide observational constraints on the abundance of exoplanets with signs of life. An extension of this spectroscopic characterization of exoplanets is the search for observational evidence of technology, known as technosignatures. Searching for technosignatures alongside biosignatures would provide important knowledge about the future of our civilization. If planets with technosignatures are abundant, then we can increase our confidence that the hardest step in planetary evolution—the Great Filter—is probably in our past. But if we find that life is commonplace while technosignatures are absent, then this would increase the likelihood that the Great Filter awaits to challenge us in the future.

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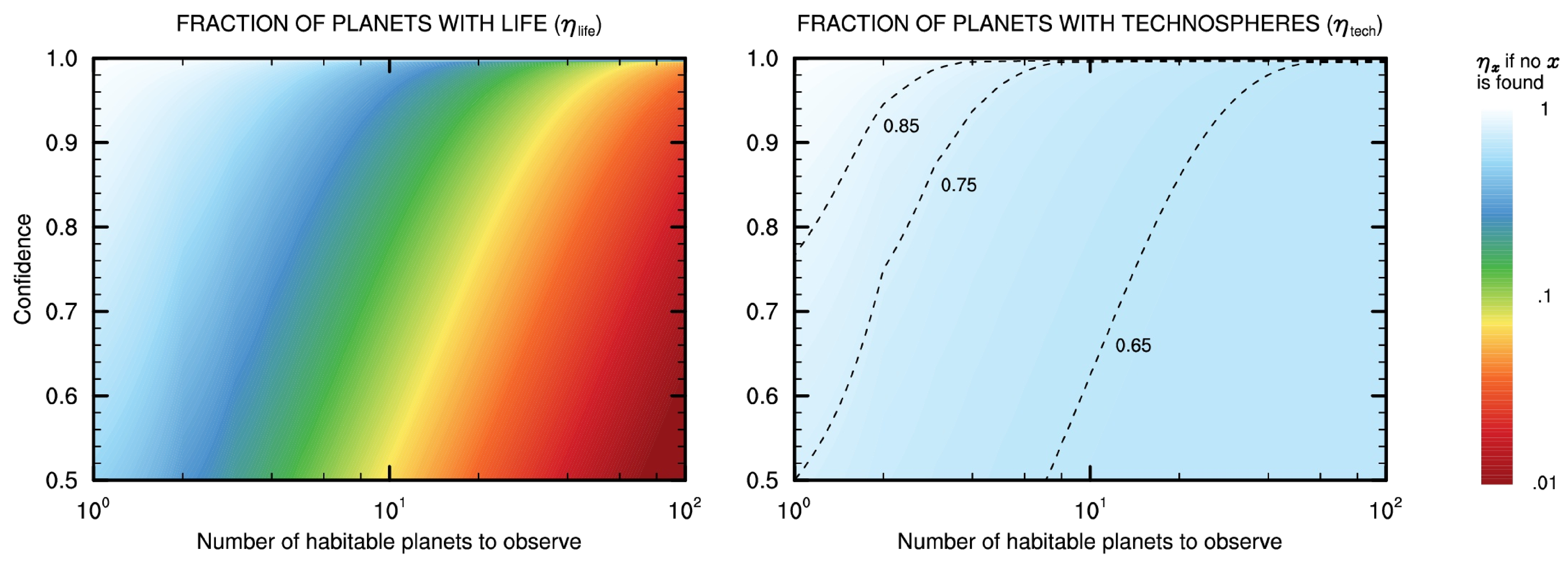
The search for spectroscopic biosignatures with the next-generation of space telescopes could provide observational constraints on the abundance of exoplanets with signs of life. An extension of this spectroscopic characterization of exoplanets is the search for observational evidence of technology, known as *technosignatures*. Searching for technosignatures alongside biosignatures would provide important knowledge about the future of our civilization. If planets with technosignatures are abundant, then we can increase our confidence that the hardest step in planetary evolution—the Great Filter—is probably in our past. But if we find that life is commonplace while technosignatures are absent, then this would increase the likelihood that the Great Filter awaits to challenge us in the future.

Suppose that a mission like LUVOIR (Large Ultraviolet Optical Infrared Surveyor) characterizes a statistically significant sample of planets during its lifetime. In order to constrain the frequency of a planetary property, η_x, LUVOIR must observe a number of exoplanet candidates, N_{ec}, that reveal evidence of feature *x*. The expression for N_{ec} assumes a binomial distribution for the probability of observing feature *x* on a given exoplanet and a high-efficiency detector.

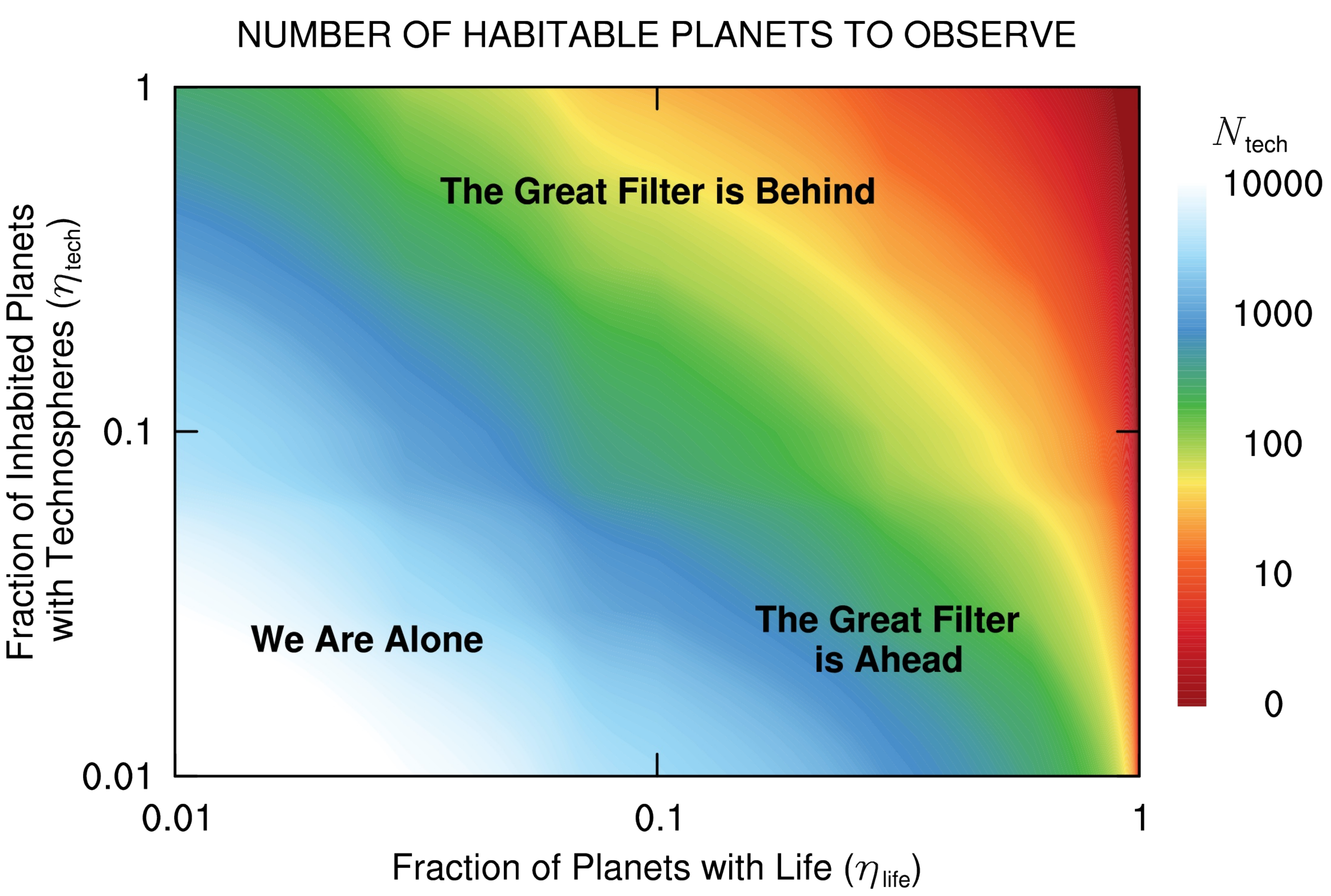
$$N_{ec} = \frac{\log(1-c)}{\log(1-\eta_x)}$$

Suppose that a second mission is designed with the intention of searching known exoplanet candidates for technosignatures, referred to as TSIG (TechnoSIGnature Surveyor). The quantity η_{tech} is defined as the fraction of inhabited planets that show observable technospheres (Class V planets), so TSIG must observe N_{tech} planets in order to determine the prevalence of technology.

$$N_{tech} = \frac{\log(1-c)}{\eta_{life}\log(1-\eta_{tech})}$$



A mission such as LUVOIR that observes N_{ec} habitable planets and finds no biosignatures on any of them will place an upper limit on the fraction of planets with life (η_{life}), given a confidence (left). Similarly, a comprehensive search for technosignatures with TSIG that finds none will place an upper limit on the fraction of inhabited planets with observable technospheres (η_{tech}), given a confidence (right). For example, a search with N_{ec} = 60 at c = 95% confidence that finds no biosignatures or technosignatures would place limits of $\eta_{life} \leq 0.05$ and $\eta_{tech} \leq 0.64$.



The number of habitable planet observations required to constrain the Great Filter (with 95% confidence) depends on the fraction of planets with life (η_{life}) and the fraction of inhabited planets with observable technospheres (η_{tech}). A mission such as LUVOIR may able to constrain the value of η life, but subsequent searches for technosignatures will be required to determine whether the Great Filter is in our past ($\eta_{tech} \geq \eta_{life}$) or future ($\eta_{tech} < \eta_{life}$).