 

**Noname manuscript No.**
(will be inserted by the editor)

# Copernican Reasoning About Intelligent Extraterrestrials

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https://doi.org/10.1007/s10838-019-09465-7

Received: date / Accepted: date

**Abstract** Copernican reasoning involves considering ourselves, in the absence of other information, to be randomly selected members of a reference class. Consider the reference class *intelligent observers*. If there are extraterrestrial intelligences (ETIs), taking ourselves to be randomly selected intelligent observers leads to the conclusion that it is likely the Earth has a larger population size than the typical planet inhabited by intelligent life, for the same reason that a randomly selected human is likely to come from a more populous country. The astrophysicist Fergus Simpson contends that this reasoning supports the claims that the typical planet inhabited by ETIs is smaller than Earth (radius ≈ 5,000km; cf. Earth's radius = 6,371km) and that the typical ETI is significantly larger than us (≈ 314kg, the size of an adult male grizzly bear). Simpson's applications of Copernican reasoning are novel and exciting. They should be of interest to philosophers concerned with Richard Gott's delta t argument, the N=1 problem in astrobiology, limited principles of indifference, and probabilistic epistemology in general. While we agree with Simpson about the qualitative direction of his conclusions, we take issue with his presentation of precise quantitative results because his methods (1) display bias, (2) ignore other variables contributing to population size, (3) commit an equivocation, and (4) conceal their dependence on arbitrary assumptions.

**Keywords** Copernican Principle · intelligent extraterrestrials · aliens · Richard Gott · Fergus Simpson

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## 1 Introduction

We can make some inferences about the properties of extraterrestrial intelligences (ETIs)—should they exist—based on our scientific understanding of self-replicating and self-conscious life forms, as well as cautious generalizations from features of life on Earth. In addition to our scientific understanding of the boundary conditions of intelligent life, there is a further possible sort of evidence about ETIs: the Copernican Principle (CP). CP tells us to consider ourselves, in the absence of other information, to be randomly selected members of a reference class. By taking ourselves to be random selections from the reference class *intelligent observers*, we can make inferences about some distributions of characteristics and environments across intelligent species based on our observation of our own characteristics and environment.

The astrophysicist Fergus Simpson [15] has used CP to support the claim that the typical planet inhabited by ETIs is smaller than Earth (radius $\approx$ 5,000km; cf. Earth's radius $.5r_{\oplus}$ = 6,371km) and that the typical ETI is significantly larger than us ($\approx$ 314kg, the size of an adult male grizzly bear). Simpson's applications of Copernican reasoning are novel and exciting. They should be of interest to philosophers concerned with Richard Gott's delta t argument [3] [4] [5] [6], the N=1 problem in astrobiology, limited principles of indifference, and probabilistic epistemology in general. While we agree with Simpson about the qualitative direction of his conclusions, we take issue with his presentation of precise quantitative results because his methods (1) display bias, (2) ignore other variables contributing to population size, (3) commit an equivocation, and (4) conceal their dependence on arbitrary assumptions.

## 2 Gott's Copernican Principle

CP holds that, in the absence of other information, we should treat our observations of a phenomenon as random. This gives us the ability to derive probabilities regarding likely minimum and maximum values along a dimension from a single data point: our own observed value. The physicist Richard Gott [3] [4] [5] [6] has defended CP and applied it to a variety of circumstances, including the fall of the Berlin Wall and the run time of Broadway musicals. Most of Gott's examples are temporal and relate to the remaining length of time in an ongoing process, most famously, the length of time humans will continue to exist. Gott argues that by CP, we should regard ourselves as randomly located in the lifespan of humanity. There is a 50% chance that we are in the middle 50% of the duration of the human species, and a 95% chance that we are in the middle 95%. This means there is a 95% chance that our observed value of the longevity of humanity, 200,000 years, is between the 2.5 percentile and 97.5 percentile of the total longevity of humanity. If it is at the 2.5 percentile, we have 7.8 million years remaining; if the 97.5 percentile, 5,128 years. Gott concludes that we can have 95% confidence that humans will last between 5,128 and 7.8 million years.

In addition to temporal applications, Gott applies CP to a number of non-temporal dimensions. For example, he argues that you have a 95% chance of being in the middle 95% of the population on a test for a newly discovered enzyme, and that there is a 95% chance that at least 2.5% of the inhabitants of the country in which you were born live to the west of your birthplace and at least 2.5% to the east [5].

It will be useful to outline two points about Gott's use of Copernican reasoning. First, as Bradley Monton and Brian Kierland [10] and Gott himself [4] observe, Gott's standard formulation of CP can be characterized as a Bayesian inference using the Jeffreys prior. The Jeffreys prior is a non-informative prior which claims that the probability that a given value along a dimension is the maximum value is inversely proportional to that value [10]. The Jeffreys prior is location- and scale-invariant, which means, for example, in temporal cases, it applies to observations in units of millennia as much as milliseconds, and it applies no matter the magnitude of the observed value. When we have observed a single data point—for example, the length of time that humans have existed—we normalize and update, arriving at the same probability function as the method outlined above.

Second, Copernican reasoning only applies when we have no empirical information about the dimension under consideration. Often, we should not use an entirely uninformative prior because we have information about the shape of the distribution or the maximum values along certain dimensions. Instead, we truncate values that are inconsistent with our information, spreading the probability freed up proportionally to the remaining parts of the dimension. However, the resulting probability function will still display the results of Copernican reasoning, with a "Gott-like shift" [10] representing that, ceteris paribus, a higher observed value along a dimension increases the likelihood of a larger maximum value along that dimension, and a lower observed value along a dimension increases the likelihood of a smaller maximum value along that dimension.

## 3 Simpson's Use of Copernican Reasoning

Despite not having been peer-reviewed, a self-archived paper by Fergus Simpson [14] received substantial worldwide media attention in April 2015 (e.g., [9]) due to the evocative conclusion that typical ETI species are approximately the size of adult male grizzly bears (average mass of adult $\approx$ 314kg). Simpson's paper has been subsequently peer-reviewed, revised, and published [15]; its published version is our main target in this paper.

Simpson takes inspiration from Gott's observation that individual humans are more likely to find themselves in more populous countries. There are more than 200 countries, but half of humanity lives in one of six (China, India, United States, Indonesia, Brazil, Pakistan). There is a 95% chance that a randomly selected human was born in a country with a population greater than 5.8 million [5]. Since the median population of a country is 5.2 million, it is very unlikely that a typical human will find herself living in a typical country. If a sheltered geography student doesn't know which country she lives in, she should infer she is most likely in a country that is more populated than typical.

Simpson extends this reasoning to the population of Earth relative to the populations of other planets. First, he contends that Gott's reasoning should apply equally to the case where humans have colonised other planets: we should expect to find ourselves in larger rather than smaller groups of humans. He then supposes that it is irrelevant to this result whether the planets are inhabited by humans or ETIs—specifically, ETIs who belong to *advanced civilisations*: "a population of observers which has (a) colonised most of its host planet/moon and (b) developed sufficient intelligence to contemplate the existence of other inhabited planets" [15]. Unlike the case of countries on Earth, we do not know the demographics of other planets. However, since most population distributions over planets yield the result that the typical observer in an advanced civilisation does not live on a typical planet with an advanced civilisation, an analogue to the inference of the sheltered geography student is available: on the assumption that ETIs exist, we should expect to find ourselves on a planet with a greater population than the typical inhabited planet. (For brevity, I will use 'inhabited planet' to mean a planet that hosts an advanced civilisation.)

If our civilisation on Earth is more populated than advanced civilisations on extrasolar planets, we should expect it to have characteristics correlated with a higher population. Simpson looks in particular at three characteristics of advanced civilisations: the radius of the planet inhabited [15], and the body mass [15] and habitat [17] of the constituting species. Simpson makes qualitative inferences about these characteristics, as well as quantitative inferences about the first two. Qualitatively, he infers that Earth is larger than the typical inhabited planet because this characteristic is correlated with higher populations. He infers that typical ETIs are likely land dwellers based on the fact that it is unlikely that the number of land dwellers and the number of ocean dwellers in the universe are of the same order of magnitude. One of these groups is likely much bigger than the other. On a planet with only two countries, one of which is much more populated than the other, a sheltered geography student should infer that she is most likely in the more populated country. Similarly, since we find ourselves to be land dwellers, "it is highly probable that we are vastly more numerous than any water-based counterparts" [17]. Finally, he infers that typical ETIs are larger than humans. This inference relies on the inverse correlation found on Earth between population density and body mass. Since our population density is likely higher than that of a typical advanced civilisation, we should expect our body mass to be lower than that of the residents of such a civilisation.

In addition to these qualitative conclusions, Simpson calculates probability distributions for planet radius and body mass for a randomly selected advanced civilisation. In some cases, he arrives at specific expectation values. Simpson's quantitative conclusions are based on the difference between two methods of random sampling. The first method is sampling by making a random spatiotemporal selection of an advanced civilisation: our closest neighbouring civilisation today [15]. (Spatial and temporal proximity would not generally be a random method of selection on Earth, but Simpson is making the plausible assumption that characteristics of a civilisation do not depend on the location of its host star or the time of its development.) The second method is sampling by random observer. According to the Copernican Principle, this is the selection we make when we observe our own particular location in the universe. Since more populous civilisations are more likely to be observed by randomly selected observers, characteristics associated with higher populations are more likely when sampling is done by individual than by spatiotemporal location. We find ourselves observing the characteristics of our civilisation on Earth, and so we can make inferences about the probability distributions for characteristics of the nearest advanced civilisation—namely, that it is more likely to have characteristics associated with lower populations.

Simpson's quantitative characterisation of the bias resulting from our sampling by individual observer begins with an observation about how to calculate the mean population size of a civilisation ($x$) in terms of that civilisation's total number of observers ($N$), average individual longevity ($R$), and overall longevity ($L$). The mean population size is the number of observer-years divided by the lifespan of the civilisation:

$$x = \frac{NR}{L} \tag{1}$$

Since our Copernican expectation is that our civilisation has a greater-than-typical number of total observers, Simpson solves for $N$:

$$N = \frac{xL}{R} \tag{2}$$

[15]. Since $N \propto \frac{x}{R}$, we are more likely to observe characteristics of inhabited planets that increase $\frac{x}{R}$.

Let $\theta$ be a characteristic of a civilisation, such as $x$, $L$, $R$, planet radius, or average body mass. The probability distribution $p(\theta|T)$ is a function from each value of $\theta$ to the probability that this value will be exemplified by our closest neighbour today. $p(\theta|I)$ is a function from each value of $\theta$ to the probability that this value will be exemplified by the advanced civilisation observed by a random individual. Simpson uses Bayes' Theorem to conclude that

$$p(\theta|I) \propto p(\theta|T)E(\frac{x}{R}|\theta, T) \tag{3}$$

$E(\frac{x}{R}|\theta, T)$ is the expectation value of $\frac{x}{R}$ conditional on a particular value of $\theta$ when the civilisation is sampled by location. It is calculated by:

$$\int\int \frac{x}{R} p(x, R|\theta, T)\, dx\, dR \tag{4}$$

Simpson states that his key result is equation (3). If the expectation value of $\frac{x}{R}$ is not constant for all $\theta$, then $p(\theta|I)$ and $p(\theta|T)$ must differ, creating a bias when sampling is done by observer rather than by spatiotemporal location. For example, if a given value of $\theta$ positively affects the ratio $\frac{x}{R}$, the expectation value given in (4) becomes larger. When this expectation value becomes larger, (3) entails that $p(\theta|I)$ becomes larger relative to $p(\theta|T)$. This means that the probability of a value of $\theta$ that positively affects the ratio $\frac{x}{R}$ will be higher for a civilisation sampled by observer than for a civilisation sampled randomly (e.g., by spatiotemporal location) [14].

While this conforms to the direction of Simpson's qualitative inferences, it appears completely unhelpful for calculation. We do not know, e.g., the probability distribution for planet radius over the ensemble of inhabited planets. However, Simpson is able to proceed by calculating an expectation from all distributions of a certain functional form. He states that the exact functional form does not matter [15]; he chooses a set of lognormal Gaussian distributions. The result is a double integral over the mean and variance (the square of the standard deviation) of the distributions. For example, in the case of planet radius $r$, Simpson assumes that inhabited planets do not include those with very small and very large radii, and that they form a normal distribution. He then calculates probability functions for a narrower ($.05 < \sigma r < .2$) and broader ($.2 < \sigma r < .8$) range of standard deviations, as well as a version of the broader range which is truncated at $.5r_{\oplus}$ (the Earth's radius) to represent the hypothesis that life cannot exist on planets with gravity insufficient for an atmospheric water cycle. He concludes: "The extent to which the Earth overestimates the radii of other inhabited planets strongly depends on the choice of prior. However the conclusion that larger radii are disfavoured is robust to the choice of prior on $\sigma r$" [15]. Assuming a specific standard deviation (.4) and mean radius (1), Simpson calculates that the typical advanced civilisation is composed of 15 million individuals on a planet about half the volume of earth (radius $\approx$ 5,000 km).

Simpson's most attention-getting conclusion relates to body size. He gives a lower-bound estimate of the relationship between population size and body mass ($m$) based on the biological literature: $E(x|m, T) \propto m^{-3/4}$. Larger body mass is associated with a longer life span, so he combines this with an expectation for $R$ to conclude that $E(\frac{x}{R}|m, T) \propto m^{-1}$. Since we have reason to expect that the ratio $\frac{x}{R}$ is overrepresented on Earth, and since larger body size is associated with both fewer observers and longer life spans, we can expect that we are smaller than typical ETIs [15].

To derive a numerical prediction, Simpson stipulates a prior range of standard deviations from .5 (that exhibited by body size in great apes) to 3 (a relatively arbitrary factor "so as not to greatly exceed terrestrial variance," [15]). Taking 70kg as the mean mass of an adult human, Simpson calculates the mass of a typical ETI as 314kg, roughly the size of a large adult male grizzly. (Actually, Simpson says polar bear, but he is wrong about how big polar bears are. Adult females are smaller than 314kg; males are much larger; the average of males and females is significantly larger.)

In related work, Simpson makes qualitative and quantitative inferences about the position of the Earth among the ensemble of habitable planets in regard to ratio of land area to total surface area [17] and length of habitable period [16]. The details of these inferences are different than those already outlined because they do not rely upon the claim that the Earth has a higher population than a typical inhabited planet. Rather, the comparison made is to other habitable planets—those which have liquid water on the surface—whether they have intelligent life on them or not. Simpson relies upon the principle that when a normal distribution is truncated, such that there are no observations of the majority of the distribution, a random selection on the remaining portion of the distribution will likely be close to the truncation point. In other words, if we slice a normal distribution on the left tail and sample randomly from what remains of the left tail, we will probably select something near the slice. But if we slice a normal distribution on the right tail and sample randomly from what remains, it is less likely that we will select something near the slice. It follows from these likelihoods that if we find ourselves near the slice, we should infer that the slice is likely on the left tail. Thus, if we observe ourselves near a truncation point beyond which we do not expect there to be observers, it is likely that the majority of the probability distribution lies beyond that truncation point.

Simpson argues that in cases of both ocean coverage and habitable period, Earth is near a truncation point beyond which we do not expect observers. In regards to the former, it is unlikely that a planet's water and basin capacity would be within the same order of magnitude, making most habitable planets desert worlds or waterworlds (greater than 99.7% ocean coverage). Neither of these situations is conducive to intelligent observers. (Recall his argument that the vast majority of observers are land-based.) The surface of Earth is 71% water, which is close to the waterworld limit. Simpson concludes that we can infer it is likely that most habitable planets are waterworlds [17]. In regards to the latter, the habitable period of a planet is the length of time that it has liquid water on its surface. Simpson claims that intelligent observers need to have a mass of at least 1kg, which requires an increase in size of at least 15 orders of magnitude from the earliest life. Looking at rates of size increase in species like the blue whale, Simpson calculates that it is unlikely that intelligent life would emerge much earlier than it has on Earth. Again, we are near a truncation point beyond which it is unlikely that there would be any observers. We should infer that it is likely that the majority of the probability distribution lies beyond this point, i.e., that most habitable planets have habitable periods shorter than Earth's, and shorter than the length of time required to develop intelligent observers [16].

## 4 Four Objections to Simpson

We find Simpson's creative use of the Copernican Principle novel and exciting. We endorse in principle his application of Copernican reasoning to characteristics of ETIs. In particular, we think he is right about the direction this reasoning pushes us: a typical civilisation composed of ETIs will likely have a lower population than our own, and will likely have characteristics associated with lower populations. However, we disagree with some of the details of Simpson's use of Copernican reasoning to calculate an expected value for a single civilisation characteristic, and disagree in particular with his quantitative conclusions about planet radius and body size. Simpson is correct that a typical ETI civilisation will inhabit a planet smaller than Earth and be composed of individuals that are larger than humans, but his numerical estimates (1) display some bias, (2) ignore other variables contributing to population size, (3) commit an equivocation, and (4) conceal their dependence on arbitrary assumptions.

Our first critique is that Simpson's definition of advanced civilisations introduces a bias towards civilisations that are less populous. Simpson's method of randomly selecting an advanced civilisation may not succeed because a civilisation may span multiple planets and star systems. Several civilisations may be overlapping. The method needs to be altered so as to select one civilisation—perhaps something like "the civilisation whose furthest part from us is closest to us." However, science fiction provides us with many cases where the boundary of a civilisation is indeterminate. If we exclude civilisations with indeterminate boundaries, we introduce bias towards less populous civilisations.

Also, when considering the body size of ETIs, Simpson implicitly assumes that advanced civilisations will be comprised of one species. But it is possible that an advanced civilisation may be composed of multiple species, as *homo* culture may have been at one time. Indeed, for all we know, some advanced civilisations may contain observers who are not biological beings. Simpson can avoid these complexities by stipulating that his result is about advanced civilisations composed of a single species of biological creatures. However, this again introduces a bias towards less populous civilisations. For these reasons, we think Simpson would be better off working with the reference class *intelligent observers* rather than *intelligent observers in advanced civilisations*.

Our second critique is founded on the observation that Simpson's method has the potential to be applied to a large number of characteristics of advanced civilisations associated with population size or longevity. Other characteristics that we would expect to correlate with large populations are: the availability of domesticable crops, the development of agriculture and industrial agriculture, the percentage of planetary surface area that is habitable, the inability to engage in effective collective long-term planning about resource conservation, the development of antibiotics, vegetarian or vegan diet, the ability to create artificial intelligences, the availability of other habitable planets in the star system, and the development of space colonisation. (Admittedly, some of these characteristics are also associated with longer lifespans, but in our own case at least, the development of antibiotics and industrial agriculture has resulted in a sharp increase of the ratio of $\frac{x}{R}$ over time.)

A little reflection suggests that some of these characteristics may make a much more significant contribution to $\frac{x}{R}$ than planet radius or body size. For example, less than 15% of the Earth's surface area is habitable by humans. An increase of 5% in percentage of surface area that is habitable would lead to a bigger increase in habitable surface area than a 5% increase in planetary radius. The ability to colonise space or construct artificial observers could lead to a significant increase in population. A recent study has found that converting our agriculture away from biofuels and meat products would allow the Earth to feed 4 billion more humans without expansion of existing cropland [1]. And our development of industrial agriculture and antibiotics have made large contributions to our current high population.

We conclude there are many ways that ETI civilisations can fall short of the current human population without being so massive in body size. Their diets could contain a larger portion of animal protein, they could not have invented antibiotics, or a smaller percentage of their home planet could be habitable. Most crucially, they could have failed to develop large-scale agriculture. Human populations before the development of large-scale agriculture had colonised a great majority of Earth and were able to contemplate the existence of life on other worlds, and in fact match Simpson's population estimates for the typical advanced civilisation (estimates for world population at 12,000 ybp (years before present) range from 1 to 15 million; Simpson's specific prediction for a typical advanced civilisation is 15 million).

Simpson would agree with us that his method can be applied to a number of different characteristics of advanced civilisations. His method allows him to look at one characteristic at a time by using the method of marginalisation, which allows us to derive an expectation value for a single parameter while ignoring all other parameters. The results from this method "are insensitive ... to the numerous variables which influence population size, provided they remain uncorrelated with planet size" [15]. However, there is at least one variable influencing population size that is correlated with planet size. The development of large-scale agriculture capable of substantially increasing population sizes is not inevitable, and in fact depends on the resources available for domestication of crops and animals. These resources on Earth are not evenly distributed, and there are some continents on which there just aren't useful animals capable of being domesticated [2]. Jared Diamond [2] argues that another contributing feature to the development and spread of large-scale agriculture is the orientation of continents (east-west being preferable to north-south), or we might say more generally, the connectedness of similar habitats to allow for cultural spread of agricultural practices. All of these factors may be expected to vary with planetary radius: bigger planets will have more chances at the evolution of domesticable animals and crops and the existence of large, connected habitable areas. This means that there is a variable, the development of agriculture, strongly associated with mean population size that is correlated with planet size, undermining Simpson's numerical results concerning the size of inhabited planets and the dependent calculations about body mass.

Our third critique of Simpson concerns his derivation of a specific expectation value for body mass of the typical ETI. His calculation depends on the relationship established by biologists between population density and body mass. Humans conform to this relationship only by virtue of our ancestral population. But Simpson's calculation of the population size of a typical planet inhabited by ETIs is based on our modern population. It is much higher than it would be if it were based on our ancestral population. The result is an equivocation. The human population size relevant to the relationship between body mass and population density is our ancestral population, but our modern population size is used to calculate the expected number of individuals in a typical ETI civilisation, and consequently their average body mass.

Another infelicity is that Simpson uses 70 kg as the average mass of humans. This is the average mass of modern Europeans. Worldwide, the current average mass is 62 kg, with a 34.7% obesity rate [18]. A proxy estimate of our average ancestral mass is 47 kg, the average mass of a member of the Hadza tribe, a group of hunter-gatherers [13]. If these more precise figures were to be used to calculate the expectation value of the body size of the typical ETI, this value would be significantly lower than 314kg, even ignoring the equivocation. (Figure 1 illustrates Simpson's equivocation using calculations with these more precise figures for body mass.)

Put another way, if we take the modern human population density and use the biological relationship between population density and body mass to estimate our mass, we would be off by two orders of magnitude (0.17173 kg). But this is exactly what Simpson is doing with ETIs: calculating their population size using our modern population, and then calculating their body mass with a relationship that applies only to our ancestral population and body mass.

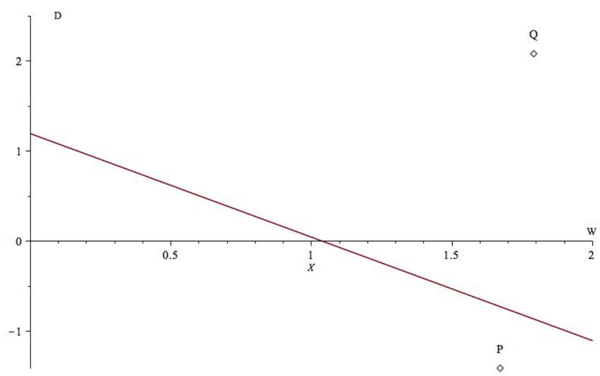


**Fig. 1** The relationship of ancestral (P) and modern (Q) human populations to an established relationship between body mass in $kg$ (W) and population density in $individuals/km^2$ (D) on a log10 scale. The line depicted is $D = 15.7W^{-1.15}$ [12]. We take the habitable land area on Earth to be $63,824,447km^2$, a commonly cited figure achieved by subtracting deserts and mountains from Earth's total land area. P depicts our ancestral (12,000 ybp) coordinates at a population of 2.43 million [11] and body mass of 47kg. Q depicts our modern coordinates at a population of 7.6 billion and body mass of 62kg. Note how much of an outlier Q is given that this is a log10 scale.

Our fourth and final critique of Simpson's specific calculation of a typical ETI's body mass is that the need of his method to make sometimes empirically-ungrounded assumptions about the range of standard deviations means that the exact numerical results may not be particularly meaningful. For example, the range of standard deviation he uses plays a large role in the determination of the value 314kg. The lower value of this range, ($\sigma = .5$), is fixed by the standard deviation among great apes, with no error range given. The upper bound ($\sigma = 3$) is less-empirically-grounded: it is chosen "so as not to greatly exceed the terrestrial variance" [15]. The choice of this upper bound has significant effects on the overall calculation, just as the choice of ranges of standard deviations in his calculation of planet radii has a marked impact: the range $.05 < \sigma r < .2$ yields a 95% confidence bound of $r < 1.2r_\oplus$, while the range $.2 < \sigma r < .8$ yields $r < .9r_\oplus$. This is a substantial difference based on an arbitrary choice. We have no issue with the direction of Simpson's inference, or even with his testing arbitrary ranges of standard deviations. However, we do find the advertisement of a specific expectation value for body mass of a typical ETI, which generated immense media attention, to be insufficiently transparent about the assumptions going into the calculation (e.g., "we conclude that most species are expected to exceed 300kg in body mass" [15]).

## 5 Conclusion

We agree with Simpson that, when a characteristic of our civilisation correlates with population size or longevity, we can infer that the magnitude we observe on Earth is biased in the direction of higher population and lower longevity. If well-grounded assumptions about standard deviations and means are available, we may even be able to calculate meaningful numerical expectations. However, those derived by Simpson are premature. Ungrounded assumptions, inaccurate data, and equivocation on terms results in a set of numerical outcomes that are exaggerated gestures in the direction of the more modest inferences we should be making, especially on the issue of body mass.

Yet Simpson's research is fascinating. It points to a number of important directions to explore. For example, there probably are not many species of ETIs who are vegan, space-faring, and very small—otherwise we would likely find ourselves to be one of them. Continued exploration of the feasibility and results of Simpson-style inferences is recommended. The current explosion in the detection of exoplanets and our incipient ability to obtain spectral analyses of their atmospheres make this more than a theoretical exercise.

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Copernican Reasoning about Intelligent Extraterrestrials: A Reply to Simpson

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