(T) For every $x$, for every time $t_1$, for every time $t_2$, $Fx$ at $t_1$ at $t_2$ if and only if $Fx$ at $t_1$.

Consider (R) and (T) as special cases of the following more fundamental principle governing alethic indices in general, and we have uncovered a common basis for the two arguments against (E):

(I) For every $x$, for every index kind $k$, for every index $i_1$ of kind $k$, for every index $i_2$ of kind $k$, $Fx$ at $i_1$ at $i_2$ if and only if $Fx$ at $i_1$.[2]

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[2] 'Gore lost at time $t$ at @' is not equivalent to 'Gore lost at time $t$.' The redundancy holds only when the iterated indices belong to the same kind. Hence the need for $k$.

# *Anthropic reasoning does not conflict with observation*

DIEN HO AND BRADLEY MONTON

*1.* Ken Olum (2004) argues that anthropic reasoning conflicts with observation; we will show that he is mistaken. Olum's argument is as follows. Observation suggests (via inflationary theory) that the universe is spatially

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infinite, with an infinite number of observers currently existing, most of whom are presumably in large civilizations (where many galaxies have been colonized). Observation also suggests that we are currently in a small civilization. Anthropic reasoning, on the other hand, suggests that one should reason as if one were a random sample from the set of all presently existing observers. Since no more than one in a billion observers are in small civilizations, according to Olum, then anthropic reasoning suggests we should find ourselves in a large civilization. Olum (2004: 3) then appeals to the following principle: 'when the predictions of a theory are violated at the level of one in a billion, the theory must be rejected.' He concludes that anthropic reasoning or inflationary theory (or some other product of observation) must be rejected.

*2.* As a first step in seeing that Olum's argument is mistaken, we will present an application of his line of reasoning where it is more evident that his argument structure is faulty. Consider Barb, who is bored one day and decides to precisely measure the square footage of her living space. She observes that her living space is 917.354 628 square feet (to the nearest 1/1,000,000th of a square foot). She calculates that less than one in a billion observers live in that size living space. Anthropic reasoning thus suggests that she should not find herself in that size living space. Since she does find herself in that size living space, she concludes that anthropic reasoning conflicts with observation.

There is nothing wrong with anthropic reasoning in this example, as long as anthropic reasoning is properly understood. Anthropic reasoning does yield the result that, before Barb measures her living space, she should not expect to get the result of 917.354 628 square feet. But when she does get that result, that does not show that anthropic reasoning is mistaken. The reason is there are further inferences one can draw from anthropic reasoning, beyond the inference that she should not expect to get the result of 917.354 628 square feet. One such inference is that she should expect to get a result that was antecedently considered improbable, from the standpoint of anthropic reasoning. The reason is that *any* observer who measured the square footage of her living space would get a result that was antecedently considered improbable. Thus, anthropic reasoning suggests that Barb should be one of those observers. It follows that anthropic reasoning is compatible with observation; Barb's conclusion is mistaken.

*3.* This reply to Barb's reasoning carries over to Olum's reasoning. It is true that anthropic reasoning yields the result that we should not expect to be in a small civilization. However, regardless of what civilization one finds oneself in, one can use anthropic reasoning to get the result that one

should not expect to be in that sort of civilization. For example, consider an observer, Blaine, in a large civilization, which has colonized exactly 17,000 galaxies. Using anthropic reasoning, Blaine can conclude that less than one in a billion observers would find themselves in a civilization that has colonized exactly 17,000 galaxies. But Blaine should not conclude that anthropic reasoning conflicts with observation, because he should recognize that any observer could engage in the sort of reasoning he has, regardless of their civilization size.

Olum's argument relies on a particular partitioning of civilizations: the partition between small and large civilizations. Olum picks the partition in such a way that we find ourselves in an esoteric class: most observers belong to the other side of the partition. But, for any observer, one can pick a partition such that that observer finds herself in an esoteric class. Thus, the fact that we find ourselves in an esoteric class, given a particular partition, should not lead us to reject anthropic reasoning or observation.

*4.* Note that we are not disputing Olum's claim that (given inflationary theory) it is antecedently very improbable that we would find ourselves in a small civilization; we are just arguing that this should not lead us to reject anthropic reasoning or observation. But what about the general principle that Olum appeals to: 'when the predictions of a theory are violated at the level of one in a billion, the theory must be rejected'? We will show that this principle is false.

Consider for example a radioactive atom which according to quantum mechanics has a less than one in one billion chance of decaying in the next five minutes. Suppose that in fact it decays after three minutes. Must this observation lead us to reject quantum mechanics? The answer is clearly *no*. Regardless of when the atom decays, it decays in a five-minute interval that has less than a one in one billion chance of being the interval in which the atom decays. The event of the atom decaying is an improbable event, but every time such an atom decays, regardless of when it decays, the event is equally improbable.

This does not mean that it is impossible to reject quantum mechanics on the basis of such evidence. If a large number of such atoms were all observed to decay in the first five minutes, this would be strong evidence against quantum mechanics. In fact, even a single decay *can* constitute evidence against quantum mechanics – what we have made clear in the previous paragraph is that it *need* not. Consider a hypothetical rival to quantum mechanics, Theory X, which makes many of the same predictions as quantum mechanics but predicts that the radioactive atoms in question are all guaranteed to decay within five minutes. A particular atom decaying in the first five minutes can lead to a probability shift in favour of Theory X, thus providing evidence for Theory X. (We are following a

standard probabilistic practice of saying that $E$ provides evidence for $H$ just in case $P(H|E) > P(H)$.) Whether one's resulting credence in the theory of quantum mechanics would be so low that one would reject quantum mechanics would depend on details like one's prior probability for Theory X. Even with a probability shift in favour of Theory X, one's credences could still be such that quantum mechanics is judged vastly more probable than Theory X.

Just as the observation of the decay can provide evidence for Theory X and against quantum mechanics, the observation that we are in a small civilization can provide evidence for or against various physical theories. For example, consider Theory Y, which predicts that all civilizations are small. The fact that our civilization is small could constitute evidence in favour of Theory Y and against inflationary theory. But depending on such factors as one's prior probability for Theory Y, one's credences could still be such that inflationary theory is judged vastly more probable than Theory Y. Thus, that our civilization is small could lead one to decrease one's credence in inflationary theory, but nevertheless that credence could still be high.

The issue we are discussing in the previous paragraph is a general issue about theory comparison in science; if that is the core of Olum's paper then there is nothing surprising here. It would be surprising if there were a conflict between anthropic reasoning and observation, but Olum's argument fails to show that this is the case.

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# *Does Frege have too many thoughts? A Cantorian problem revisited*

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In two recent papers in this journal, Adam Rieger (2002) and Nicholas Denyer (2003) discuss a problem with Frege's ontology. According to

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