Predicting future duration from present age: 
Revisiting a critical assessment of Gott’s rule

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Abstract

Gott has promulgated a rule for making probabilistic predictions of the future duration of 
a phenomenon based on the phenomenon’s present age [Nature 363, 315 (1993)]. I show that 
the two usual methods for deriving Gott’s rule are flawed. Nothing licenses indiscriminate use 
of Gott’s rule as a predictor of future duration. It should only be used when the phenomenon 
in question has no identifiable time scales.

1 Introduction

In an article1 published in Nature in 1993 and in subsequent publications2–5 and the concluding 
chapter of a book,6 J. Richard Gott III has promulgated a formula for making probabilistic predictions 
of the future duration of a phenomenon based on the phenomenon’s present age. When you 
observe that a phenomenon has lasted a time \(t_p\), Gott instructs you to predict that the phenomenon 
will last an additional time \(t_f \geq Y t_p\) with probability

\[
G(t_f \geq Y t_p) = \frac{1}{1+Y} .
\]

For example, Gott’s rule predicts that a phenomenon has a probability of 1/2 to survive an addi-
tional time at least as long as its past \((Y = 1)\) and, by the same token, a probability of 1/2 to end 
before reaching twice its present age.

In applying his rule to a host of phenomena, Gott usually couches his predictions in terms of 
a particular 95% confidence interval, 95% confidence being his standard for a scientific prediction. 
According to his rule, the probability that a phenomenon’s future duration, \(t_f\), will be between 
1/39 and 39 times its present age, \(t_p\), is \(G(t_f \geq t_p/39) - G(t_f \geq 39t_p) = 39/40 - 1/40 = 0.95.\) The
flip side of this prediction is that the phenomenon has a 2.5% chance to end before reaching 1/39 of its present age and a 2.5% chance of lasting longer than 39 times its present age.

Gott bases his formula on a temporal version of the Copernican principle: when you observe the phenomenon’s present age, your observation does not occur at a special time. Here I show, distilling the essence of a previous critical analysis of Gott’s work, that although the Copernican principle does lead directly to a version of Gott’s rule, this version is essentially meaningless and, in particular, does not authorize his predictions for future longevity based on present age.

In published papers and his book, Gott is on record as applying his rule to himself, Christianity, the former Soviet Union, the United States, Canada, world leaders, Stonehenge, the Seven Wonders of the Ancient World, the Pantheon, the Great Wall of China, Nature, the Wall Street Journal, The New York Times, the Berlin Wall, the Astronomical Society of the Pacific, the 44 Broadway and off-Broadway plays open and running on 27 May 1993, the Thatcher-Major Conservative government in the UK, Manhattan (New York City), the New York Stock Exchange, Oxford University, the internet, Microsoft, General Motors, the human spaceflight program, and homo sapiens. In all these cases—even the New York plays—Gott uses his rule to make probabilistic predictions for the survival of individual phenomena whose present age is known. For example, given Nature’s 123 years of publishing in 1993, Gott predicted that Nature had a 95% chance to continue publishing for a period between 3.15 years (already exceeded) and 4,800 years. Most notably, Gott has used the 200,000-year present age of homo sapiens to predict that we have a 95% chance to go extinct sometime between 5,100 years and 7.8 million years from now. Although Gott issues occasional cautionary statements about the applicability of his rule, the list of phenomena to which he has applied the rule indicates that these cautions don’t cramp his style much.

Gott’s predictions have received attention in the popular media, including a favorable piece by Timothy Ferris in The New Yorker, which highlighted Gott’s predictions for human survival (and which motivated me to write my original paper), and a recent article by John Tierney in The New York Times, which focused on the implications for space colonization. My late 1999 posting of the paper that eventually appeared in Contemporary Physics prompted a sympathetic article in The New York Times by James Glanz.

Glanz, as a long-suffering fan of the Chicago White Sox, was particularly interested in Gott’s prediction, issued in 1996, for the Sox’s World Series prospects. Gott opined that the Sox, having not won a World Series title since 1917, would, with 95% confidence, win a Series sometime between 1999 and 5077. In his 2000 article, Glanz noted that the Sox hadn’t yet succeeded, but he was clearly dismayed by the long wait evoked by the mere mention of 5077. Happily for him and other Sox fans, they did win the Series in 2005. In 1996 Gott would have predicted a World Series title in 2005 or before with probability 0.10, considerably less than the probability, $1 - \left(\frac{29}{30}\right)^9 = 0.26$, that comes from assuming that the Sox had the same chance each year as the other 30 major-league ball clubs.

Gott has given two main derivations of his rule: the argument from the Copernican principle, which he calls the delta-t argument, and a Bayesian analysis, which he adopted from criticism due to Buch. Both of these derivations are flawed. Here I begin in Sec. with an analysis of the delta-t argument, because it led Gott to his rule and because he consistently portrays it as the chief justification for his predictions. I show that the delta-t argument does not lead to any prediction of future duration based on present age. I then turn in Sec. to the usual Bayesian derivation of Gott’s rule, which has greater appeal to most other contributors to the literature on the subject. I demonstrate that this derivation is simply wrong and sketch the correct Bayesian
analysis. A concluding Sec. 4 considers the assumptions that are required to get Gott’s predictions.

It should be emphasized at the outset that we will not conclude that Gott’s rule is “wrong,” but rather that its two primary derivations are wrong. In science flawed justifications are as bad as—perhaps worse than—being obviously wrong, because they are more pernicious. They can mislead you into using methods that don’t apply in your situation and can get you into trouble when you export those methods to other contexts. Determining the assumptions that underlie whatever you are doing in science is essential, so that you know when to abandon what you are doing in favor of something else. The purpose of this article is thus to debunk the two primary derivations of Gott’s rule and to identify the assumptions that underlie Gott’s rule in its predictive form, so that you will know what you are doing should you choose to use it.

The discussion in this paper is couched mainly in terms of a simple graphical representation, which is equivalent to the more formal, Bayesian analysis given in Ref. 7. Section 2 on the delta-\( t \) argument is phrased almost entirely in terms of the graphical representation. The results of the Bayesian analysis in Sec. 3 can be understood by referring to the graphical representation, but the Bayesian equations are included for those who prefer to see the details.

The evidence from papers\(^ {13-17} \) that cite Ref. 7 is that its argument and conclusions have not been appreciated and understood. The goal of the present paper, with its graphical mode of presentation, is to rectify that situation.

## 2 Copernican ensembles and the delta-\( t \) argument

The delta-\( t \) argument is short and sweet. It starts from the premise that if your observation does not occur at a special time—that is the temporal Copernican principle—then it is equally likely to occur at any time within the total duration \( T = t_p + t_f \). This means that the probability that the present age \( t_p \) is less than or equal to \( XT \), where \( X \) is between 0 and 1 inclusive, is \( G(t_p \leq XT) = X \). This being the same as the probability that the future duration \( t_f \) is not smaller than \((1 - X)T\), i.e., not smaller than \((X^{-1} - 1)t_p\), one obtains Gott’s rule \(^ {11} \) by letting \( Y = X^{-1} - 1 \).

The alluring simplicity of the delta-\( t \) argument means that we need an equally simple way of investigating its validity and interpretation. In any probabilistic analysis, you start with a prior probability density, in this case a distribution \( w(T) \), which gives the probability \( w(T)\,dT \) that the phenomenon’s total duration lies in the interval between \( T \) and \( T + dT \). This prior probability density is based on whatever information or data you have about the phenomenon before observing it. To formulate the problem in terms of the temporal Copernican principle, the description in terms of duration \( T \) must be supplemented by introducing an additional temporal variable. In doing so, it is convenient to set the arbitrary zero of time at the present, i.e., at the time you observe the phenomenon, and to let \( t_0 \) denote the time when the phenomenon starts. With these choices, the present age is \( t_p = -t_0 \), and the future duration is \( t_f = T + t_0 \). The phenomenon is now characterized by two variables, either \( t_0 \) and \( T \) or \( t_p \) and \( t_f \).

The temporal Copernican principle—that you are not at a special time relative to the phenomenon—is implemented by saying that all starting times are equally likely, independent of duration \( T \). More precisely, one requires that the joint probability density be invariant under time translations,\(^ {18} \) which yields the unique probability density

\[
p(t_p, t_f) = p(t_0, T) = \gamma w(T) ,
\]

where \( \gamma \) is a constant, describing a uniform distribution for the starting time. That this distribution
cannot be normalized turns out not to be a problem, but it can be dealt with at this stage, if desired, by cutting off the distribution at very large negative and positive values of $t_0$.

It is instructive to think about the joint probability density in terms of an ensemble made up of many instances of the same phenomenon. We can picture this ensemble, which I call an unrestricted Copernican ensemble, as a population distributed in a plane whose horizontal axis is labeled by $t_p$ and whose vertical axis is labeled by $t_f$. The population density is proportional to the probability density $p(t_p, t_f) = \gamma w(t_p + t_f)$. The Copernican plane is depicted in Fig. 1.

The duration $T = t_p + t_f$ labels an axis that points symmetrically into the first quadrant. The constraint of nonnegative durations means that the ensemble occupies the upper right half-plane, which splits naturally into three regions:

1. The upper left wedge ($t_p = -t_0 < 0$), in which the phenomenon has not yet begun.
2. The lower right wedge ($t_f < 0$), in which the phenomenon is over.
3. The first quadrant ($t_p \geq 0, t_f \geq 0$), in which the phenomenon is in progress.

There are two instructive ways of dividing the unrestricted Copernican ensemble into subensembles. First, for each starting time $t_0 = -t_p$, the population along the associated vertical line is the subensemble of durations for a phenomenon that starts at $t_0$. The translational symmetry of the Copernican ensemble means that all these unrestricted vertical subensembles describe the same
Figure 2: First quadrant, on which resides the (truncated) Copernican ensemble, which applies to a phenomenon in progress. The truncated Copernican ensemble is obtained by lopping off Regions 1 and 2 of the unrestricted Copernican ensemble. The Copernican ensemble is an idealized sample of phenomena with uniformly random starting times $t_0$ (or present ages $t_p = -t_0$) and with duration distributed along each vertical subensemble according to the prior density $w(T)$. Since the starting time is uniformly random, population is distributed uniformly along each diagonal subensemble. Gott’s delta-$t$ argument is that the fraction of population with $t_f \geq Y t_p$ within each diagonal subensemble is, by the elementary geometry illustrated in the figure, $1/(1 + Y)$. This fraction being the same for each diagonal subensemble, it also applies to the entire Copernican ensemble, giving Gott’s rule (1). The content of Gott’s rule is the trivial statement that a fraction $X$ of the members in the Copernican ensemble have an age less than a fraction $X$ of their eventual duration. This trivial statement does not authorize any prediction of future duration based on present age because the present age is unknown. Once the present age is known, predictions of future duration are made within the vertical subensemble corresponding to the observed age and thus are governed by the prior density $w(T)$, but with those durations ruled out by the observed age discarded.

distribution of durations, given by the prior density $w(T)$. Second, population is distributed uniformly along the diagonal lines of constant duration $T$, each of which can be called an unrestricted diagonal subensemble.

To discuss your observation requires taking into account that you are only interested in the situation, denoted by $I$, where you find the phenomenon to be in progress. Imposing this condition requires you to lop off the regions of the unrestricted Copernican ensemble that correspond to the phenomenon not having begun or having finished [Regions 1 and 2 of Fig. 1]. This leaves the (truncated) Copernican ensemble depicted in Fig. 2 which occupies the first quadrant of the $t_p$-$t_f$ plane. The probability density for the truncated Copernican ensemble is given by

$$p(t_p, t_f | I) = \frac{w(t_p + t_f)}{T}, \quad t_p \geq 0, \quad t_f \geq 0,$$

(3)

where $T$ is a normalization constant equal to the mean value of the total duration with respect
to \(w(T)\). Truncating the unrestricted Copernican ensemble also truncates the unrestricted diagonal and vertical subensembles. In the following, the designation “truncated” is often omitted; an undesignated ensemble is always the truncated one.

A **diagonal subensemble** lives on a diagonal line of constant \(T\). Along the diagonal line, population is distributed uniformly, and the total population is weighted by \(Tw(T)\). The Copernican principle is the statement that the population within each diagonal subensemble is distributed uniformly, with no bias toward the past or the future, as is expressed by the fact that the joint density \((3)\) depends only on \(T\). A **vertical subensemble** lives on a line of constant \(t_p\); it has the same population density as the corresponding unrestricted vertical ensemble, except that durations that correspond to the phenomenon’s having already finished, \(T < t_p (t_f < 0)\), are not part of the ensemble and have no population. The Copernican ensemble is an idealization of a sample of phenomena in progress, with random starting times and durations distributed according to the prior density \(w(T)\).

Now suppose you ask for the probability that \(t_f \geq Y t_p\) for a phenomenon selected from the truncated Copernican ensemble. Within each diagonal subensemble this probability is given by the fraction of the length of the diagonal line that lies above the line \(t_f = Y t_p\) shown in Fig. 2. This ratio, from elementary geometry, is \(1/(1 + Y)\), and this ratio is the delta-\(t\) argument. Since this fraction is the same for all the diagonal subensembles, it gives the probability that \(t_f \geq Y t_p\) within the entire truncated Copernican ensemble. The result is Gott’s rule \((1)\), written here as

\[
P(t_f \geq Y t_p | I) = \frac{1}{1 + Y}.
\]

Notice that this probability is independent of the prior density \(w(T)\); it is wholly determined by the time-translation symmetry of the Copernican ensemble. The rule is particularly easy to understand for the case \(Y = 1\): half the members of the Copernican ensemble lie above (below) the line \(t_f = t_p\) and thus have a future duration that is greater than (less than) their present age. We conclude that Gott’s rule is a universal expression of the Copernican principle for a phenomenon drawn from the entire Copernican ensemble, i.e., for a phenomenon known to be in progress, but whose present age is unknown.

Gott’s rule as a universal expression of the Copernican principle has precisely the content that a fraction \(X\) of the members in the Copernican ensemble have an age less than a fraction \(X\) of their eventual duration. This trivial conclusion is what the Copernican principle tells you: you know a phenomenon is in progress, but you know neither when it started nor when it will end, so you judge yourself equally likely to be at any point in the phenomenon's life. This trivial conclusion is of very little interest, because the present age being unknown, the rule has no predictive power. What attracts attention to Gott’s work is that he repeatedly uses his rule in a different way, to make probabilistic predictions of the future longevity of particular phenomena whose present age is known.

We thus need to determine what you can say when you discover the present age. Your probabilistic predictions are then determined by the distribution of population within the vertical subensemble whose members have the observed present age. It is clear from Fig. 2 that the probability density for future duration within this subensemble—this is the conditional probability density for \(t_f\) given \(t_p\)—is proportional to \(w(t_p + t_f)\). Properly normalized, this conditional density becomes

\[
p(t_f | t_p, I) = w(t_p + t_f)/\Pi(t_p), \quad t_f \geq 0,
\]

\(6\)
Figure 3: (a) Unrestricted vertical subensemble, in which population is distributed according to the prior density \( w(T) \). (b) Unrestricted Copernican ensemble, created from many copies of the unrestricted vertical ensemble (fifteen copies, including the vertical axis, are shown), each corresponding to a different starting time \( t_0 = -t_p \). Gott’s Copernican principle is the statement that all starting times are equally likely. (c) (Truncated) Copernican ensemble, which describes phenomena in progress. It is created by removing from the unrestricted Copernican ensemble the regions that correspond to phenomena not yet begun and already completed (Regions 1 and 2 of Fig. 1). In particular, each vertical subensemble is truncated by removing the part with \( T < t_p \) (\( t_f < 0 \)). Population is distributed uniformly along the diagonal subensembles of constant total duration \( T \), one of which is shown. (d) Vertical subensemble chosen by an observation of present age \( t_p \). Predictions within this vertical subensemble are governed by a renormalized prior density, \( w(T)/\Pi(t_p) \), with durations ruled out by the observed age omitted. Steps (b) and (c) of this process can be short-circuited by going directly from (a) to (d). Imagining many copies of the unrestricted vertical ensemble, as is done in implementing the temporal Copernican principle and thus constructing the Copernican ensemble, or even having an approximation to the Copernican ensemble available cannot increase your power to predict the future duration of a phenomenon with a particular present age. This is particularly clear in the special case of a phenomenon whose total duration \( T \) is known in advance, so that only one diagonal subensemble is populated, say, the one shown in (c). At the stage of the truncated Copernican ensemble in (c), the present age and future duration are strictly correlated, but randomly distributed within the interval \( [0, T] \), thus giving Gott’s delta-\( t \) argument. Once you observe the present age, however, the future duration is known and is certainly not governed by Gott’s rule.
where the normalization constant,

$$\Pi(t_p) = \int_0^{\infty} dt_w(t_p + t_f) = \int_{t_p}^{\infty} dT w(T),$$

(6)
is the survival probability, i.e., the probability for the phenomenon to survive at least a time \(t_p\).
The conditional probability density \([5]\) gives the probabilities you should use for making predictions of future duration based on present age. It has a very simple interpretation: once you determine the present age, you rule out total durations shorter than the observed age, and you use the prior density, suitably renormalized, for total durations longer than the observed age. This is what you would have done had you not bothered to introduce the Copernican ensemble, but rather worked directly within an unrestricted vertical ensemble.\(^7\)

The process of constructing an unrestricted Copernican ensemble, truncating to take account that the phenomenon is in progress, and observing the present age is depicted in Fig. 3.

One way to construct the vertical subensemble for present age \(t_p\) is to select, from each diagonal subensemble with \(T \geq t_p\), the subpopulation that has age \(t_p\). That population is distributed uniformly within the rest of each diagonal subensemble is irrelevant to the statistics of a phenomenon drawn from a vertical subensemble. This is why the Copernican principle has no bearing on predictions of future duration based on present age. Indeed, once you discover the present age, the probability that \(t_f \geq Yt_p\) is

$$P(t_f \geq Yt_p|t_p, I) = \int_{Yt_p}^{\infty} dt_p p(t_f|t_p, I) = \frac{\Pi\left((1 + Y)t_p\right)}{\Pi(t_p)}. \quad (7)$$

This is the predictive form of the desired probability, predictive because it is conditioned on the present age. It is determined completely by the prior density and coincides with Gott’s rule \([1]\) only for a special choice of prior density, which is identified in Sec. 3 and discussed further in Sec. 4. We conclude that Gott’s rule should not be used indiscriminately to make probabilistic predictions of future duration based on present age.

All your prior information about a phenomenon’s total duration is incorporated in the prior density \(w(T)\). Often you can improve your predictions of future longevity by studying a phenomenon as it progresses, gathering information about its particular history. In the absence of gathering additional information, however, all predictions about future longevity must arise from the prior density. That Gott’s rule, as it comes from the delta-t argument, is independent of the prior density is a dead give-away that it has no predictive power. Since any prior density can be embedded in a Copernican ensemble, it is clear that the Copernican principle does not restrict the prior density in any way and thus is irrelevant to predicting future longevity.

### 3 Bayesian analysis of Gott’s rule

Gott has endorsed\(^{11}\) a Bayesian derivation of his rule, which was introduced by Buch\(^{12}\) in the only technical comment Nature has published on Gott’s original article. The input to Buch’s analysis is the prior density \(w(T)\) and the assertion that given the duration \(T\), present age \(t_p\) is uniformly distributed within the interval \([0, T]\):

$$q(t_p|T) = \begin{cases} 1/T, & 0 \leq t_p \leq T, \\ 0, & t_p > T. \end{cases} \quad (8)$$
A simple application of Bayes’s rule gives

\[ q(T|t_p) = \frac{q(t_p|T)w(T)}{q(t_p)} = \begin{cases} w(T)/Tq(t_p), & T \geq t_p, \\ 0, & T < t_p, \end{cases} \] (9)

where

\[ q(t_p) = \int_t^\infty dT \frac{w(T)}{T} \] (10)

is the unconditioned probability density for present age \( t_p \). The conditional probability that \( t_f \geq Yt_p \), given \( t_p \), takes the form

\[ Q(t_f \geq Yt_p|t_p) = \int_{(1+Y)t_p}^\infty dT q(T|t_p) = \frac{q\left((1 + Y)t_p\right)}{q(t_p)}. \] (11)

If you use the (unnormalizable) prior density \( w(T) = 1/T \), this result reduces to Gott’s rule, in a predictive form:

\[ Q(t_f \geq Yt_p|t_p) = \frac{1}{1+Y}. \] (12)

The prior \( w(T) = 1/T \), called the Jeffreys prior, has the unique status of being the only distribution on the interval \([0, \infty]\) that is invariant under scale changes. Thus this Bayesian derivation concludes with the appealing result that Gott’s rule, as a genuinely predictive rule for future duration given present age, follows from assuming a prior that has no built-in time scales.

The only problem with this neat conclusion is that this Bayesian derivation is dead wrong. This is evident from the posterior (9), which is not just the original prior with excluded durations given zero probability, as in the process of lopping off the already completed phenomena from the unrestricted ensembles to get the truncated ensembles. The analysis gets right that the posterior probability is zero for durations \( T < t_p \) that are ruled out by the observation of present age \( t_p \), but it doesn’t use a renormalized version of the prior density for the durations that are still allowed, i.e., for \( T \geq t_p \). This must be wrong because your prior density \( w(T) \) already contains your entire judgment about the future duration of the phenomenon should it survive to age \( t_p \). In the absence of getting additional information, there is nothing to justify changing your judgment about future duration when you learn that the phenomenon has indeed survived to age \( t_p \).

The question then is where this apparently innocuous Bayesian analysis goes wrong. It is not hard to determine that. The error lies in using the uniform conditional probability density \( q(t_p|T) \) of Eq. (8) in conjunction with the prior density \( w(T) \). Within the unrestricted Copernican ensemble, where it is correct to use \( w(T) \), learning the duration \( T \) tells you nothing about the present age, as is evident from considering the unrestricted diagonal subensemble in Fig. 1. This is confirmed by a trivial application of Bayes’s rule to the uncorrelated variables \( t_p \) and \( T \): \( p(t_p|T) = p(t_p,T)/w(T) = \gamma \). It is simply not consistent with the unrestricted Copernican ensemble to use the uniform conditional probability density (8).

The natural thing then is to try the truncated Copernican ensemble of Fig. 2, which applies once you know the phenomenon is in progress. Then it is correct to use a uniform conditional density for \( t_p \), i.e.,

\[ p(t_p|T,I) = \begin{cases} 1/T, & 0 \leq t_p \leq T, \\ 0, & t_p > T. \end{cases} \] (13)

as is evident from considering the truncated diagonal subensemble in Fig. 2 but it is not correct to use the prior density \( w(T) \). Once you know the phenomenon is in progress, you must weight \( w(T) \)
by a factor of $T$, which comes from the “lengths” of the truncated diagonal subensembles being proportional to $T$. Formally, one has

$$p(T|I) = \int dt_p \, dt_f \, p(t_p, t_f|I) \delta(T - t_p - t_f) = \frac{T w(T)}{T}.$$  \hspace{1cm} (14)

The factor of $T$ here is not optional. It is required once you have decided to describe the phenomenon in terms of two temporal variables and to impose the time-translation symmetry of the Copernican principle on the joint probability density. To put it more succinctly, it is required once you decide to use an ensemble of phenomena with random starting times.

Once one realizes that the factor of $T$ is present in $p(T|I)$, the Bayesian inference of Eq. (9) is replaced by

$$p(T|t_p, I) = \frac{p(t_p|T, I)p(T|I)}{p(t_p|I)} = \begin{cases} \frac{w(T)}{\Pi(t_p)}, & T \geq t_p, \\ 0, & T < t_p, \end{cases}$$  \hspace{1cm} (15)

since the probability density of $t_p$ is given by

$$p(t_p|I) = \int_0^\infty dt_f \, p(t_p, t_f|I) = \frac{\Pi(t_p)}{T}.$$  \hspace{1cm} (16)

This correct Bayesian analysis is thus in accord with the obvious inference of truncating the unrestricted vertical ensemble to get the conditional probability density for $T$, given $t_p$.

Because of the additional factor of $T$ in this correct analysis, the (unnormalizable) prior density that gives a predictive version of Gott’s rule turns out to be $w(T) = 1/T^2$. This prior density plays a special role in this problem because it is the unique distribution on the first quadrant of the $t_p$-$t_f$ plane that is (i) constant on lines of constant $T$ and (ii) invariant under simultaneous scale changes of $t_p$ and $t_f$. Formally, with this prior, we can write [see Eq. (7)]

$$P(t_f \geq Y t_p|t_p, I) = \frac{1}{1+Y},$$  \hspace{1cm} (17)

since $\Pi(t_p) = 1/t_p$. Thus Gott’s rule, in a predictive form, emerges from a prior $w(T) = 1/T^2$ that has no time scales into the past or future; alternatively, one can say that this predictive form of Gott’s rule arises when the probability density for $T$ within the truncated Copernican ensemble, i.e., $p(T|I)$ of Eq. (14), is the Jeffreys prior.

4 Conclusion

The best way to test belief in probabilistic predictions is to offer a bet based on those predictions. For that purpose, I sent an e-mail on 1999 October 21 and again on 1999 December 2 to my department’s most comprehensive e-mail alias, which included faculty, staff, and graduate students, requesting information on pet dogs. The responses were compiled and checked for accuracy on 1999 December 6; a notarized list of the 24 dogs, including each dog’s name, date of birth, breed, and caretaker, was deposited in my departmental personnel file on 1999 December 21. In accordance with his practice for other phenomena, Gott would have made a prediction for each dog’s future prospects based on its age. In particular, he would have predicted that each dog would survive beyond twice its age with probability 1/2.

For the youngest and oldest dogs on the list, Gott’s predictions offered favorable opportunities for betting. I chose to focus on the oldest dogs, and for each of the six dogs above ten years old
on the list, I offered to bet Gott $1,000 US that the dog would not survive to twice its age on 1999 December 3. To sweeten the pot, I offered Gott 2:1 odds in his favor. Gott refused to bet on the grounds that “I don’t do bets.” If he had believed his own predictions, his expected gain would have been $3,000 US, and the probability that he would have been a net loser on the six bets was 7/64 = 0.11. I contacted the caretakers during May and June of 2008 and verified that all six dogs have died. Thus, as I fully expected, I would have won all the bets and been $6,000 US richer. Even with the current reduced state of the US dollar, that would have been enough to buy a very nice piece of Australian aboriginal art.

More revealing than Gott’s blanket refusal to bet was his excuse that his rule only applies to a random dog chosen from my sample, which is another way of saying that his rule applies to a sample of dogs drawn from the truncated Copernican ensemble, i.e., a sample selected without regard to present age. In discussions of the 44 New York plays and of his own longevity, Gott has also suggested that a fair test of the Copernican hypothesis should involve a large sample selected without regard to present age. As we have seen, Gott is quite right on this score: his rule does apply to a phenomenon whose present age is unknown. If this were all Gott claimed, however, no one would pay attention, because the universal form of his rule, applicable when the present age is unknown, has no predictive power. What grabs attention is that in case after case, Gott uses his rule to make predictions of the future longevity of individual phenomena whose present age is known. In the language of this paper, Gott makes predictions for the vertical subensembles, but only wants to bet on the entire Copernican ensemble.

It is obvious that in a large sample of dogs selected without regard to age, roughly half the dogs, within the inevitable statistical fluctuations, will be in the first half of their lives, with the rest in the second half. This is the trivial content of Gott’s Copernican principle. It is equally obvious that having a sample in which half the dogs are in the first half of their lives does not imply that any particular dog in the sample has a probability of 1/2 to survive beyond twice its present age. Yet the elementary error of making this implication underlies all of Gott’s predictions.

We have seen, at the end of Sec. 3, that there is a particular (unnormalizable) prior density, \( w(T) = 1/T^2 \), which does give Gott’s rule in a predictive form. Although the prior density \( 1/T^2 \) does not appear in any of Gott’s publications, it has a special status in that it is the unique prior density that makes the Copernican probability \( p(t_p, t_f | I) \) invariant under simultaneous rescaling of the past and the future. Use of this prior is the only license for Gott’s predictions. When you can’t identify any time scales, Gott’s rule is your best bet for making predictions of future duration based on present age.

For most phenomena, including many that Gott discusses, especially those involving human institutions and creations, it is easy to identify important time scales. Although it is often difficult to incorporate these time scales into a prior probability, it is always a good idea to try. This having been said, it is usually the case that formulating prior information precisely is of less value than observing a phenomenon as it progresses, since readily available current information is more cogent than prior information for predicting the future.

Although there is little love lost between White Sox fans and fans of the Chicago Cubs, I like to think that New York Times writer Jim Glanz, having experienced a Sox World Series win in his lifetime, sympathizes with the plight of Cubs fans, who haven’t seen a World Series title since 1908. Gott would predict, with 95% confidence, that they won’t win a Series in the next three years, but will win one before 5868. Perhaps more to the point, he would predict with probability 1/2 that they won’t bring home a title in the next 99 years. We are immediately skeptical of Gott’s prediction. For example, giving each of the 30 clubs an equal chance each year sets the probability
of a 99-year drought at \((29/30)^{99} = 0.035\). It’s not that this is the “right” way to calculate the probability, but it does show that a reasonable assumption gives quite a different answer from Gott’s rule.

The reason Gott’s prediction for the Cubs is so unreasonable is that there are readily identifiable time scales—the length of a typical player’s career, the turnover in owners and management, etc.—that are well short of 99 years and suggest that the Cubs might get their act together much sooner. Indeed, as of June 21, they have the best record in North American baseball and are leading the National League Central division. Still, Cubs fans know to keep some pessimism in reserve.

Suppose a fan at a Cubs game at Wrigley Field in Chicago got up and announced to great fanfare that half the people at the game were in the first half of their life. Everyone would yawn (except perhaps the technically sophisticated, who might wonder about whether the attendees are a representative sample of all ages, although a ball game is probably not a bad sample in this regard).

Suppose, however, that the fan marched up to parents holding a one-month-old infant and proclaimed, “Gott says your baby has a 2.5% chance of dying before tomorrow’s game,” or informed the 60-year-old next to him, “Gott says you have a 50% chance of living to 120.” Both these predictions would garner attention, as applications of Gott’s rule often do. The parents would probably call security and ask that the fan be removed. The 60-year-old might reply, with the ingrained pessimism of Cubs fans, “God only knows, but maybe if I lived to 120, I could see the Cubs win a Series.” His seatmate would pour cold water on that: “Don’t get your hopes up. Gott gives, and Gott takes away. You might live to 120, but Gott says there’s only a 38% chance the Cubs will win the Series by then. There’s only a 50% chance they’ll win before you’re 160.”

Gott’s rule makes absurd predictions for human longevity and other human activities because there are readily identifiable time scales, the most obvious of which is the average human life span, that render application of his rule entirely inappropriate. If he continues to believe his rule makes nontrivial, universal predictions for the future duration of individual phenomena, it’s time he took some bets.

1 J. R. Gott III, “Implications of the Copernican principle for our future prospects,” Nature 363, 315 (1993).

2 J. R. Gott III, “Our future in the Universe,” in Clusters, Lensing, and the Future of the Universe, Astronomical Society of the Pacific Conference Series, Vol. 88, edited by V. Trimble and A. Reisenegger (Astronomical Society of the Pacific, San Francisco, 1996), p. 140.

3 J. R. Gott III, “A grim reckoning,” New Scientist 156 (No. 2108), 36 (1997 November 15).

4 J. R. Gott III, “The Copernican principle and human survivability,” in Human Survivability in the 21st Century, Transactions of the Royal Society of Canada, Series VI, Vol. IX, edited by D. M. Hayme (University of Toronto Press, Toronto, 1999), p. 131.

5 J. R. Gott III, “Colonies in space; Will we plant colonies beyond the Earth before it is too late?” New Scientist 195 (No. 2620), 51 (2007 September 8).

6 J. R. Gott III, Time Travel in Einstein’s Universe (Houghton Mifflin, Boston, 2001), Chap. 5.

7 C. M. Caves, “Predicting future duration from present age: A critical assessment,” Contemporary Physics 41, 143 (2000).
Author’s note: This paper was originally submitted to Nature on 2000 April 3 and was summarily rejected on the grounds that Nature had already published sufficient technical comment on Gott’s original paper. Then I forgot about it, though it’s not clear to me now why I didn’t post it to the preprint archive. That was probably just pique, to which I was more subject then than now. It’s just as well, because the current version is, I think, considerably improved. Three circumstances prompted me to revive the paper: (i) my 2007–08 sabbatical at the University of Queensland, which has given me the gift of time; (ii) John Tierney’s recent New York Times article,9 which showed that Gott’s predictions still have the power to fascinate; and (iii) a conversation with B. J. Brewer of the University of Sydney, which indicated that there would be interest in a simpler explanation of my Contemporary Physics article.7 In preparing the current version, I expanded the discussion of the delta-t argument with the aim of making it as simple and airtight as possible, incorporated a discussion of Bayesian derivations of Gott’s rule, updated the references, and gathered information about the six dogs’ ultimate fates.