ADOLF GRÜNBAUM ON THE STEADY-STATE THEORY AND *CREATIO CONTINUA* OF MATTER OUT OF NOTHING

by Mirsaeid Mousavi Karimi

Abstract. The ideas of *creatio ex nihilo* of the universe and *creatio continua* of new matter out of nothing entered the arena of natural science with the advent of the Big Bang and the steady-state theories in the mid-twentieth century. Adolf Grünbaum has tried to interpret the steady-state theory in such a way, to show that the continuous formation of new matter out of nothing in this theory can be explained purely physically. In this paper, however, it will be shown that Grünbaum's interpretation encounters at least three problems: not distinguishing between material and efficient causes, inconsistency, and misconceiving the law of density conservation.

Keywords: *creatio continua*; *creatio ex nihilo*; density-conservation; Grünbaum; steady-state theory

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The ideas of *creatio ex nihilo* and *creatio continua* entered the arena of natural science with the advent of the theories of modern cosmology in the mid-twentieth century. The once popular idea of "continuous creation" of matter "out of nothing" was the outcome of the deceased steady-state theory. Also, the idea of the creation of the universe out of nothing seems to be a consequence of the widely accepted Big Bang theory that, at least in its initial version, implies the temporal finitude of the world.

Adolf Grünbaum (1989, 1991, 1993, 1998, 2004, 2009) in a series of papers claims that many writers have confused the genuine question of the "temporal" or "natural" origin of the universe (in the Big Bang theory) or of new matter (in the steady-state theory) with the pseudoproblem of the "creation" of the universe or of the new matter by an "external cause." According to Grünbaum (2004, 588), "It was . . . quite misleading that . . . Bondi . . . equated the problem of the origin of the universe with the alleged 'problem of creation.' Similarly, 'Narlikar is instructively articulate in his confusion of the question of the origin of the universe with the pseudo-problem of its creation.'" (Grünbaum 1989, 374) Likewise, claims Grünbaum (1998), Alfred Charles Bernard Lovell makes the same mistake

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when he "uses the theologically-tinged causal term 'creation,' instead of the neutral descriptive term 'accretion.'"

At present, the steady-state theory has few adherents among physical scientists, and the initial version of the Big Bang theory has been modified by theories such as the "inflationary early expansion," "grand unified theories," and "quantum cosmology." However, "the philosophical issues have remained essentially the same, although the technical details have changed considerably" (Grünbaum 1989, 376). In effect, Grünbaum claims that even the earlier versions of two rival cosmological theories, that is, the Big Bang theory and the steady-state theory, leave no room for divine creation, and that "none of these models pose any sort of challenge to atheism" (Grünbaum 1991, 236).

In this paper, I shall focus only on Grünbaum's claims concerning the steady-state theory. Grünbaum (1989, 1998) has tried to interpret this theory in such a way to show that the continuous formation of matter in this theory is not a case of *creatio continua* of matter out of nothing *by an external cause*; rather it is a physical phenomenon, which can be explained scientifically by appealing to the laws of nature. I start the paper by explaining briefly the steady-state theory. Then Grünbaum's interpretation of this theory is discussed. Finally, it will be shown that Grünbaum's interpretation of the steady-state theory is inconclusive, and his physical explanation of *creatio continua* of matter out of nothing encounters at least three problems: not distinguishing between material and efficient causes, inconsistency, and misconceiving the law of density conservation.

The Steady-State Model

In 1948, Hermann Bondi, Thomas Gold, and Fred Hoyle (Bondi and Gold 1948; Hoyle 1948) compiled a theory called the steady-state model to explain the cosmological phenomena and the process of the world's evolution. Assuming the world's perpetual stability, Bondi and Gold generalized the hypothesis entitled the "Perfect Cosmological Principle" which reads like this: "Not only is the world isotropic in every direction and homogeneous from every observer's angle but it has always been the same" (Silk 1980, 2). As a result, the properties of isotropy and homogeneity are generalized to the temporal dimension of the universe too.[1] Therefore, according to the steady-state model, the universe has always existed in the same state.

Contrary to the Big Bang model, which proposes the emergence of the whole universe at $t = 0$, the steady-state theory holds that the expanding universe might not be the result of the Big Bang and a singularity. This theory endorses the constancy of all parameters and Hubble's constant in the universe at all times. In order to explain the permanent identity of the expanding universe, the theory claims that new matter comes into existence in the interstices of space, which are created by moving away galaxies from each other.

Bondi and Gold proposed no mechanism for the creation of matter required by the steady-state theory, but Hoyle postulated the existence of what he dubbed the "creation field," or just the "C-field." The C-field has negative pressure, which enables it to drive the steady expansion of the universe, and produces the creation of new matter, keeping the large-scale matter density approximately constant. In this model, the rate of the formation of new matter is very slow: one hydrogen atom per cubic meter per 10^{10} year (Gribbin 1979, 509). One could accordingly see that it is technically almost impossible to put this claim to test.

Ever since this model was first proposed in 1948, in spite of several revisions by Hoyle (1975, 657–94; 1992, 177–93), it has never been very convincing.[2] According to Stanley L. Jaki (1974, 347), this theory never secured "a single piece of experimental verification." Problems with the steady-state theory began to emerge in the mid-1960s, when observations showed that quasars and radio galaxies were found only at large distances, whereas the steady-state theory predicted that such objects would be found everywhere, including close to our own galaxy. Moreover, the galactic red-shift plus the cosmogonic nucleosynthesis of the light elements were strong evidence against the theory (Craig 1999).

However, the decisive refutation of the steady-state theory came with the discovery of the 3 K microwave background radiation in 1965 by Penzias and Wilson. This showed that the early universe was hotter than the present universe. As a result, the steady-state model has been banished from cosmology, and models based on Big Bang have replaced it (Brush 1992, 40). However, there is another reason that invites us to discuss the theory: whether *creatio continua* of new matter out of nothing in the steady-state theory, as Grünbaum considers and interprets the theory, can be explained *physically* or not.

The Steady-State Model and *Creatio Continua* of New Matter out of Nothing

In order to justify the eternity of the universe and the constancy of its density through time Bondi (1961, 42) wrote: " . . . we have no choice but to postulate that there is going on everywhere and all times a continual creation of matter, the appearance of atoms of hydrogen out of nothing"; and, "It should be clearly understood that the creation here discussed is the formation of matter not out of radiation but out of nothing" (Bondi 1960, 144). Bondi and Gold (1948), however, could not explain how and why the process happens. This was beyond what can be concluded from "The Perfect Cosmological Principle."

Hoyle, on the other hand, claimed that the C-field, if it ever existed, could provide an explanation for the creation of new matter. He assumed that this imaginary field has extended throughout the universe, and in certain locations, the field is said to build up to greater intensity, and then new matter comes into existence. With regard to the question of the source of the new matter, Hoyle (1955, 342) replied that this query is "meaningless and unprofitable." He asserted that it is not fair to pose this question only to the steady-state theory, since in the Big Bang model all the matter is created at $t = 0$, and no explanation is given regarding why and how (Hoyle & Narlikar 1980, 459–60). According to Jayant V. Narlikar (1977, 136–37), "[t]he most fundamental question in cosmology is, 'Where did the matter we see around us originate in the first place?' This point has never been dealt with in the big bang cosmologies in which, at $t = 0$, there occurs a sudden and fantastic violation of the law of conservation of matter and energy. After $t = 0$ there is no such violation. By ignoring the primary creation event most cosmologists turn a blind eye to the above question."

So, as Lovell (1961, 118–19) sees it, "the major issue" between the competing steady-state and Big Bang models of the universe is "whether creation is occurring now and throughout all time in the past and in the future, or whether the fundamental material of the universe was created in its entirety some billions of years ago." Lovell (1961, 124) argues that the "steady-state theory has no solution to the problem of creation of [new] matter."

Grünbaum on the Steady-State Theory

Adolf Grünbaum, in a series of papers (1989, 1991, 1993, 1998, 2004, 2009), aims to show that formation of new matter out of nothing in the steady-state theory, even in its original version of 1948, can be explained physically. Although in the Hoyle-Narlikar C-field cosmology there was strict conservation of energy and momentum, Grünbaum (1991, 1994, 1998, 2000, 2004), without discussing the differences between Bondi, Gold, and Hoyle's ideas in detail, emphasizes that his interpretation of the steady-state theory can be extended even over the original version of the theory in which the theory features a *violation* of matter-energy conservation: "But for my philosophical purposes here, which pertain to attempted *theological appropriations* of physical cosmology, I need to focus on the simplest of the 1948 versions" (Grünbaum 1998).

Grünbaum (1994, 1998, 2004), without explaining the role of the C-field in different versions of the steady-state theory, asserts that formation of new matter in this theory is indeed a kind of popping into existence of mater *ex nihilo*. In other words, he makes an equation between "*non*-conservative matter-accretion" and "popping into existence *ex nihilo*"

(Grünbaum 1998). Hence, in the steady-state world "the *accretion or formation of new matter . . . is ex nihilo*, [although] it is clearly not 'creation' by an external agency" (Grünbaum 2004, 587, italics added).[3]

Grünbaum (1989), accusing philosophers and scientists of confusing the question of the origin of the universe with the pseudoproblem of its creation, argues that demands for an *external* cause of the origination of matter in the steady-state theory are illegitimate. For, in that theory the origination of matter out of nothing is *natural*, such that it can be explained by appealing to *internal* causes.

Grünbaum (1991, 248) states that "the hypothesized matter-increase in a steady-state universe is turned into a divine miracle only by the gratuitous, dogmatic insistence on matter conservation as *cosmically* the natural state*, no matter what the empirical evidence*." He argues that in the steady-state theory, the matter conservation is replaced by *density*-constancy as *a matter of natural law* so that "while the galaxies are receding from each other everywhere in the universe, the matter-*density* nonetheless ubiquitously *remains constant* through time" (Grünbaum 1998, italics in original). Bondi and Gold's theory, therefore, assumes the *conservation* of *density*, *not* of matter.

According to Grünbaum (2009, 16, italics in original), "[t]he conjunction of this constancy of the density with Hubble's mutual recession of the galaxies from one another then entails a *counter-intuitive* consequence: Throughout space-time, and *without any matter-generating agency, new matter (in the form of hydrogen) pops into existence completely naturally in violation of matter-energy conservation*." Therefore, there is no need for an external cause of the coming into existence of the new hydrogen atoms in the steady-state universe. Grünbaum (1989, 375) calls this phenomenon "the spontaneous, natural, unperturbed behavior of the physical world!" He emphasizes that "Equally crucial is the fact that, *without* this cosmic expansion, density-conservation *alone* would *not* issue in matter-accretion" (Grünbaum 1998).

It is true that the consequences of the steady-state theory seem to be counterintuitive, but it should be noted that "Bondi and Gold rejected matter-conservation on the huge cosmological scale as the inevitable natural career of externally undisturbed physical systems" (Grünbaum 1991, 247). This theory, therefore, provides a "*physical*, rather than supernatural, creative cause for the coming into being of its new matter" (Grünbaum 1994). It is indeed merely a matter of *empirical* fact that "in the steady-state world, *the expansion of the universe amid nomic density-conservation is the creative cause* of the popping into existence of new matter *ex nihilo*" (Grünbaum 1994, italics added). Grünbaum (1998, italics in original) emphasizes that "in conjunction with that law of density conservation, the so-called expansion of the universe or mutual galactic recession is *causally sufficient* for the *completely natural* coming into existence *ex nihilo* (out of nowhere) of new matter!" Hence, it begs the question if one asks for the energy-source or transformative cause of the new hydrogen atoms[4] (Grünbaum 1998). In sum, "[a]pparently, if the steady-state world were actual, it would impugn the ontology of the medieval Latin epigram 'Ex nihilo, nihil fit' . . . Thus, in the hypothesized Bondi and Gold world, *the spontaneous accretion of matter would be explained deductively as entirely natural by the conjunction of two of its fundamental physical postulates* [i.e., the conjunction of *density-conservation and cosmic expansion*]" (Grünbaum 2004, 587–88, italics added).

Grünbaum (1991, 248, italics in original) concludes that: "Lovell, the theist, and Dingle, the atheist, made identically the same mistake of thinking that the matter-increase would be miraculous . . . [and they both] overlook the following key point: *Just as a theory postulating matter-conservation does not require God to prevent the conserved matter from being annihilated, so also the steady-state theory has no need at all for a divine agency to cause its new hydrogen to come into being!*"

The Problems of Grünbaum's Thesis

At a first glance, Grünbaum's interpretation of the steady-state theory seems to be persuasive. Grünbaum (1998) reports that even Lovell, who is a theist, at a meeting conceded his point. In what follows, however, I put forward three arguments in order to show that Grünbaum's thesis is inconclusive.

Not Distinguishing between Two Kinds of Causation: Efficient and Material. In assuming the expansion of the universe plus its density conservation as the *sufficient* cause of the formation of new hydrogen atoms, it seems that Grünbaum does not separate two kinds of causal relationship.[5] The point can be expressed more precisely in terms of Aristotle's (1996) distinction between *material* and *efficient causes*.[6]

To explain the issue, consider, for example, the production of an artifact like a wooden chair. The wood, as the "material cause" of this process, is the material out of which the chair is made. It is also the subject of change, that is, the thing that undergoes the change and results in a chair. The "efficient cause" or the "source of change" is the source of the process that brought the chair into being. This can be the art of carpentry (shaping the wood to make a chair), or the person (a carpenter) who made the chair, or the combination of these two factors.

Now, returning to Grünbaum's thesis, consider the following question: why, according to the steady-state theory, are atoms of hydrogen created or formed? This question can be interpreted in two different ways. According to the first interpretation, the question is seeking to find the *efficient* cause of the formation of hydrogen atoms. Grünbaum's answer is "the law of density-conservation plus the expansion of the universe." The second interpretation, however, is to seek the *source* or the *material* cause of the atoms of hydrogen. It is clear that "the law of density-conservation plus the expansion of the universe" *cannot* be the *material* cause of the existence of the created hydrogen atoms. Therefore, they cannot explain the material source, which produces the new matter.

Grünbaum might reply that seeking the material cause of new matter is indeed based on assuming the matter conservation as a law of nature. By denying this law there would be no need to any kind of material cause. In other words, since the steady-state theory explicitly *denies* the energy-conservation and the matter-conservation laws on the huge cosmic scale, it would be question begging if one asked for the matter source, or "the energy-source or transformative cause of the new hydrogen" (Grünbaum 1998). This means something can *naturally* come into existence out of absolutely nothing without any matter-generating agency.

However, even if this metaphysically odd idea is accepted, there is a problem in Grünbaum's response. To explain the issue, consider the following equation:

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O.$$

If it is asked what amount of matter we will have on the right-hand side of the equation if we have, say, 100 g on the left-hand side, the answer, according to the law of mass conservation would be 100 g. But this law does not explain why in the right-hand side we should have Na_2SO_4 and $2H_2O$, and not, for example, 100 g of $CaCl_2$ and $MgCO_3$. Indeed, the law would still be held even if we had 100 g of meat or anything else as the products of the reaction. However, we can have only Na_2SO_4 and $2H_2O$ on the right-hand side as the products since the *materials* of the left-hand side of the reaction, as the part of *material cause*, determine *what kind* of materials can be produced on the right-hand side of the reaction. Even in nuclear reactions or nuclear decays the initial particles, as the part of material causes, provide the background for determining *the kind* of the produced particles or energy.

Likewise, in the steady-state theory, even if "spontaneous popping into existence follows deductively from the conjunction of the theory's postulated matter-*density*-conservation with the Hubble law of the expansion of the universe" (Grünbaum 2000, 6), it does not explain *what* is the *source* and *material* cause of the new particles; that is, it is unclear *why* the new matter are atoms of *hydrogen*, and not something else. If hydrogen atoms can come into existence out of nothing, why could it not be assumed that every time something different from the previous one could be created out of nothing? It would satisfy Grünbaum's interpretation of the steady-state theory if suddenly a rabbit springs into existence in a very far planet to save the law of density conservation. Since there is no previous causal connection between *the matter* of the assumed rabbit and of other entities of the universe, therefore nothing can prohibit it to be created.

It might be claimed that the new created matter should be hydrogen, since, to the best of our knowledge, there is no other element in the universe whose properties can save the law of density conservation. This response, however, is inconclusive. For, first, the only physical property of the new matter, which is related to the law of density conservation, is the amount of its *mass* (which occupies a specific volume of space). So, we can imagine the new matter as an element whose mass is exactly equal to hydrogen's mass while its other physical properties are completely different. Second, and more importantly, our *epistemic* restrictions do not justify it to infer that *ontologically* the new matter *cannot* be an unknown element. Similarly, it would obviously be question begging if it is said that the new matter should be hydrogen because almost 70–75% of cosmic mass has been made of hydrogen.

Grünbaum, by (1) assuming creative causation out of nothing, (2) rejecting transformative causation, and (3) denying the existence of any external cause to determine the kind of creation and creatures, indeed allows formation of *everything* out of nothing. His interpretation then might be formulated as follows: "to explain the eternal isotropy and homogeneity of the universe in the steady-state theory, it is assumed that the universe expansion plus its density-constancy are the sufficient cause for formation of *X* out of nothing; *X* can be anything whose mass is, say, *a* grams." This is not, however, the kind of formulation that the laws of nature have.

The problem remains unsolved unless the steady-state theory can formulate a causal relationship which explains *how* and *why* the conjunction of the law of density conservation plus the expansion of the universe are the sufficient cause for producing that *kind of particles*, that is, hydrogen atoms, which are created.[7] In this case, however, it would be the formation of something from *something*, and *not* something out of nothing.

The Inconsistency of Grünbaum's Thesis. To see how the problem of inconsistency occurs, let φ be the most fundamental particle being created as the effect of density-conservation law plus expansion of the universe. φs of course can be assumed as divisible particles. That is to say, φs might have spatial parts, or as perdurantists believe temporal parts. However, it is highly unlikely that the formation of a new φ is such that a part of it, say φ_i, is created at time t_i, then its next part, i.e., φ_{i+1}, is created at t_{i+1}, and so on. Rather, it is plausible to assume that the creation, or the emergence, of a new φ is an instantaneous event.[8] That is to say, each new

φ as a rigid particle, in its entirety, is created, or formed, at each point of time instantaneously, so that φ_1 emerges at t_1, φ_2 at t_2, and so on.[9] δt $(= t_{n+1} - t_n)$ is indeed the shortest possible interval of time between the creation, or the emergence, of two successive particles φ_n and φ_{n+1}.

On the other hand, time itself has a continuous nature, which can be divided ad infinitum. That is to say, for time t_{n+1} after time t_n, however small δt (i.e., the difference between them) is assumed, there is a t_m such that $t_n < t_m < t_{n+1}$. Also, it is plausible to assume that the expansion of the universe is not a discrete and quantized process, but rather a continuous process. In other words, even if quantized jumps in the values of some physical parameters in the subatomic scale are possible, it would be highly implausible to presume on this basis that the universe, in such incredibly large scale, jumps from volume V_n to volume V_{n+1} without taking the all-intermediate magnitudes between V_n and V_{n+1}. This would mean that the volume of the universe expands in a nonquantized continuous manner.[10]

Given the above-mentioned points, let ρ_n, V_n, and ME_n denote, respectively, the density, the volume, and the total mass (plus energy) of the universe at time t_n, and let ρ_{n+1}, V_{n+1}, and ME_{n+1} denote, respectively, the same parameters of the universe at time t_{n+1}. According to the steady-state theory: (a) $\rho_{n+1} = \rho_n$, whereas (b) $V_{n+1} > V_n$, and (c) $ME_{n+1} > ME_n$. The difference between ME_{n+1} and ME_n is only one particle φ, and since the emergence of φ is an instantaneous event, there is no amount of ME such that it can possibly be less than ME_{n+1} and more than ME_n; that is, it cannot be the case that ME takes an amount such that $ME_{n+1} > ME > ME_n$. Therefore (d) $\neg\ (ME_{n+1} > ME > ME_n)$, for all possible amounts of ME.

Now, consider time t_m such that $t_n < t_m < t_{n+1}$. Let ρ_m, V_m, and ME_m be the density, the volume, and the total amount of the mass (plus energy) of the universe at t_m, respectively. It is clear that, according to the steady-state theory: (e) $\rho_n = \rho_m = \rho_{n+1}$. The continuous expansion of the universe, however, implies that (f) $V_n < V_m < V_{n+1}$. Since $\rho = ME/V$, (e) and (f) give (g) $ME_{n+1} > ME_m > ME_n$. In other words, it cannot be the case that ME_m is equal to ME_{n+1}, since *ex hypothesis*, ME_{n+1} has one more new particle, that is, φ_{n+1}. ME_m cannot also be equal to ME_n since in this case, in which $V_m > V_n$, we would have $\rho_m < \rho_n$, which contradicts our initial assumption of density constancy.[11] We, therefore, have no option other than to accept inequality (g). This inequality, however, is in direct contradiction to another result of Grünbaum's thesis, that is, (d).

It might be argued that the passage of time is not continuous. For, according to some quantum physicists, at a fundamental level, space-time can be discrete. In this case, time cannot be physically divided ad infinitum; rather, there would be a smallest unit of time that would be physically meaningful. Therefore, for time t_{n+1} after time t_n, there would not be a t_m

between them. Accordingly, we no longer have equations (e), (f), and (g), and there would be no contradiction in Grünbaum's thesis.

This counterargument, however, does not work. For, first, the idea of the discontinuity of time is not a majority view among physicists. Second, Grünbaum's thesis still leads to inconsistency even if discontinuity of time is assumed. To show this, suppose that we have discrete times $\ldots t_1, t_2, t_3, \ldots, tn, t_{n+1} \ldots$ without having any instant of time between them. Accordingly, we have discrete volumes $\ldots V_1, V_2, V_3, \ldots, V_n, V_{n+1} \ldots$, discrete densities $\ldots \rho_1, \rho_2, \rho_3, \ldots, \rho_n, \rho_{n+1} \ldots$, and discrete total amounts of the mass (plus energy) of the universe $\ldots ME_1, ME_2, ME_3, \ldots, ME_n, ME_{n+1} \ldots$ correlated with the discrete times. It is clear that, according to the steady-state theory: (a′) $\ldots \rho_1 = \rho_2 = \rho_3 = \cdots = \rho_n = \rho_{n+1} \ldots$. The (discrete and yet constant) expansion of the universe, however, implies that (b) $\ldots V_1 < V_2 < V_3 < \cdots < V_n < V_{n+1} \ldots$. Since $\rho = ME/V$, (a′) and (b′) give (c′) $\ldots ME_{n+1} > ME_n > \cdots > ME_3 > ME_2 > ME_1 \ldots$ (for all possible amounts of ME).

It is clear that, at the quantum level, the interval between each pair of t_n and t_{n+1} is incredibly small. In other words, the number of t_ns is infinitely large. On the other hand, as we mentioned already, the rate of the formation of new matter in the steady-state theory is very slow. This means that there can be imagined infinite discrete times in which no formation of matter happens. Now, consider times t_m and t_z such that t_m is before t_n and very close to it whereas t_z is after t_n and very far from it. So, it would be totally plausible if it is assumed that at times t_n and t_z new matter is formed, while there is no formation of new matter from t_m to t_n. This implies that: (d′) $\ldots ME_z \ldots > ME_n = \cdots = ME_m \ldots$, which is in direct contradiction to (c′).

Moreover, even if discontinuity of time in the subatomic scale is accepted, it would be highly implausible to presume on this basis that the universe, in such incredibly large scale, jumps from time t_n to time t_{n+1} without taking the all intermediate magnitudes between t_n and t_{n+1}. In addition to all these, Grünbaum (1994) claims that there is no first state of the universe since for any state t_i after the initial time t_0 there is another t_k such that $t_0 < t_k < t_i$ even though the universe is nevertheless temporally finite. This means that he explicitly believes that time is continuous.

In effect, the problem of Grünbaum's thesis is that it is based on the law of density conservation. In this law, contrary to the laws of matter conservation and energy conservation, we deal with *two kinds* of variables: mass increasing, which is a quantized variable, which increases very slowly, and volume increasing, which is a nonquantized continuous (or probably a quantized) variable, which increases much faster than mass increasing. That is, there can be imagined infinite times in which the volume of the universe increases while its mass remains fixed, and consequently, the density of the universe decreases. Then, by coming into existence of new hydrogen atoms the density of the universe increases to its initial amount. That is, there are infinite moments in which the law of density conservation is violated.

Moreover, the above scenario shows that, if there is any causal power for the laws of nature, then it is not the density constancy, but rather it is the density change, which might play a causal role. In other words, as far as the density of the universe has not changed, the universe, in its totality, is as if in a physically and thermodynamically stable state in which nothing happens. However, the formation of new atoms happens when the density changes; that is, in the cases that the law of density conservation is violated. Grünbaum, of course, can assume that the law of density conservation is always true, whether the density of the universe changes or remains fixed. But, this means he needs to consider the laws of nature as entities, which are independent of the states of material content of the world. However, as it will be explained in the next section, this is a view that Grünbaum explicitly rejects.

In sum, Grünbaum's thesis implies inconsistent consequences. Moreover, contrary to what Grünbaum assumes, in the steady-state universe there are infinite moments in which the law of density conservation is violated. Furthermore, Grünbaum's thesis faces a dilemma: Grünbaum should either accept that the density constancy of the universe is the result of the emergence of new matter, and not vice versa, or he should admit that the law of density conservation (as a physical or abstract entity) exists independent of objects of the world. In the next section, it is shown that both options for Grünbaum's thesis are problematic.

Misconceiving the Law of Density Conservation as a (part of a) Cause. Grünbaum (1989, 1991, 1998, 2009) claims that the density-conservation law is (a part of) the creative cause of the formation of new matter. It seems by saying this Grünbaum considers the laws of nature as entities (physical or abstract), which are partly responsible for bringing new matter into existence continuously. At a first glance, however, this seems to be absurd. For, "the laws of physics do not themselves cause or constrain anything" (Craig 1991; 95). Indeed, some believe that the laws of nature are merely "descriptive statements of what occurs in nature" (Carroll 1988, 67). However, it seems by the laws of nature Grünbaum does *not* mean merely mathematical formulas, statements, or descriptions; rather he means *that which instantiates* the laws which have ontological power such that they can bring into existence new hydrogen atoms.

Now, considering the laws of nature as such entities, suppose there is the law of density conservation (*Ld*), which can (partly) explain the formation of new matter (*NM*) out of nothing. The relationships between *Ld* and *NM* would be one of the following possibilities:

(1) *Ld* is ontologically prior to *NM*, such that *NM* comes after *Ld*.

(2) *NM* is ontologically prior to *Ld*, such that *Ld* comes after *NM*.

Option (1) assumes that *Ld* precedes *NM* as if *Ld* is imposed "from above" upon *NM*. This option can be compatible with the Armstrong (1978, 1983) Dretske-Tooley's (1977) theory, according to which the laws of nature are objective relations, not between objects, but between properties or universals they instantiate. Option (1) can also be compatible with the view of those philosophers like Bigelow, Ellis, and Lierse (1992); Ellis and Lierse (1994); and Ellis (2001), who believe that the laws of nature are facts about dispositional nomic properties, essentially possessed by natural kinds of objects. Likewise, Bird (2007, 201) seems to agree with option (1) when he says that "[t]he laws of a domain are the fundamental, general explanatory relationships between kinds, quantities, and qualities of that domain, that supervene upon the essential nature of those things"; and that "the existence of salt depends on Coulomb's law. If Coulomb's law is false then salt cannot exist" (Bird 2002, 257). Whether *Ld* is contingently imposed upon *NM* or necessarily, the crucial point is that if *Ld* exists prior to, and independent of, *NM* then it can be assumed that *Ld* is partially the cause of bringing *NM* into existence.

Option (1), however, seems to consider laws as some abstract entities which exist independently of objects. Some physicists who try to explain the emergence of the whole universe in the Big Bang theory at $t = 0$ by appealing to the laws of nature have such a view about laws. For example, Paul Davies (1983, 217) says: "They [laws] have to be 'there' to start with so that the universe can come into being. Quantum physics has to exist (in some sense) so that a quantum transition can generate the cosmos in the first place." This is, however, not the view with which Grünbaum agrees. He explicitly says that, "the laws [of nature] do not hover over the universe, as it were, in some separate realm ... 'Talk about laws of nature is really only talk about the power and liabilities of bodies.' In short, the laws are inextricably intertwined with the material content of the universe" (Grünbaum 2004, 598).

This phrase shows Grünbaum's implicit agreement with option (2). The upshot of our discussion in the previous section also showed that option (2) is the inevitable consequence of Grünbaum's thesis. According to this option, *Ld* is derived and emerged from *NM*. *Ld* is none other than facts about the properties of *NM* or the relations among those properties. *Ld* of course can be considered ontologically independent of *NM*, or supervenient on it. Also, as positivists believed, *Ld* can be a kind of unrestricted regularity that exists between some aspects of *NM*.

However, the important point is that, *ontologically*, *NM* comes first and *Ld* comes next so that the former serves as the ontological ground for the latter. It is true that, in this case, the properties of *NM* constitute truthmakers for *Ld* describing the behavior of *NM* in the circumstances of its emergence. *Ld*, however, cannot be the sufficient or the partial cause of the existence of *NM*, and can never explain *why* and *how NM* comes into existence if *NM* is the ontological origin of *Ld*. This means not only the material content of the universe at each moment is ontologically and causally prior to the law of density conservation, but also the new matter which is going to come into existence is ontologically and causally prior to the density constancy of the universe.

In sum, *ontologically* speaking, it is the new matter that comes first, and then, consequently, there is density conservation (if there is any). In other words, density conservation may *epistemologically* help us to assume the formation of new particles. But *ontologically*, contrary to what Grünbaum assumes, it is the formation of new particles, which is the *cause*, and the density conservation is its *effect*, and not vice versa. That is, since some new particles emerge, the density of the universe, as the effect of the phenomenon of matter origination in the steady-state model, remains fixed.[12] Therefore, we still need to find a causal explanation of the formation of new particles.

In short, the term "natural state," used by Grünbaum, does not help him to justify his interpretation. Grünbaum's interpretation is neither a scientific description nor a scientific explanation of new matter origination in the steady-state theory. Indeed, the *creatio continua* of new matter out of nothing, at least in the original version of this theory, contrary to what Grünbaum assumes, cannot be explained scientifically, since the theory does not introduce any internal creative cause of the new matter.

Notes

1. The properties of homogeneity and isotropy of the universe mean that the matter has been uniformly distributed in all spatial directions and at all points, resulting in a constant density for the universe as a whole in all its spatial directions.

2. In 1993, in an attempt to explain some of the evidence against the steady-state theory, Hoyle, Geoffrey Burbidge, and Jayant V. Narlikar presented a modified version called "quasi-steady-state cosmology" (QSSC). In QSSC, the C-field plays the crucial role of creating new matter without violating any conservation law. Although this theory has many similarities with "chaotic inflation theory," and especially with the model of "eternal inflation," the theory has no considerable proponent today.

3. In a forthcoming paper, after investigating different cosmological models, I argue in favor of an almost trivial point that no scientific explanation appealing to the laws of nature can possibly explain the phenomena of *creatio ex nihilo* and *creatio continua* of matter out of nothing. In effect, it can be shown that all cosmological models explain the creation of the universe (or of matter), not out of nothing, but from something. As John Polkinghorne (1988, 60) asserts, it would be "great abuse of language" if entities and phenomena such as fields, vacuum, quantum fluctuations, and so on are called "nothing." However, I will not discuss this issue here.

4. Surprisingly, Grünbaum here rejects the need for a transformative cause and accepts the creative cause while he (2004, 608) believes that "transformative causation is the only kind of causation for which we have evidence—be it agent-causation or event-causation—rather than creative causation *ex nihilo*."

5. Although Grünbaum continuously uses the concepts of cause and causation (and also concepts such as external cause, supernatural cause, agent causation, event causation, partial or

total cause, traditional first cause, creative cause, transformative cause, sufficient cause, physical causes, external dynamical cause, and so on), he does not define them clearly. The space of this paper does not allow us to discuss this issue in detail. At any rate, it would be enough for the purpose of this paper if "A causes B" means "if A had not occurred (existed), B would not have occurred (existed)."

6. According to Aristotle (*Physics* II3 and *Metaphysics* V2), four types of things that can be given in answer to a why question are material cause, formal cause, efficient cause, and final cause.

7. It should be noted that the postulated spontaneous new matter formation in the steady-state theory would presumably need to include not only hydrogen but also the observed abundance of deuterium, helium, and lithium.

8. Even if the creation of φ is assumed as a gradual process, we can rebuild our argument on the basis of the situation of particle φ_i, in which the creation, or the emergence, of this new particle is assumed an instantaneous event at time t_i.

9. In the steady-state theory, in which the new matter is hydrogen atoms, this is indeed a true assumption.

10. This point is also confirmed by the fact that Friedmann's equations, which explain the expansion (or the contraction) of the universe, are mathematically continuous functions at all amounts of R (i.e., the radius of the universe).

11. It is also obvious that the justification of the inequality of $ME_m > ME_n$ cannot rely on the emergence of the new particle φ_{n+1}, which will emerge at the later time t_{n+1}. For, in addition to the problem of backward causation, this means at time t_m something, which does not exist yet, and hence does not belong to the universe, and therefore is external to it, determines the density conservation of the universe. This problem destroys Grünbaum's thesis, which repeatedly insists that all causes of events of the universe are internal, and not external.

12. The same goes for the case of mass conservation. Since the same amounts of matters are consumed and produced in both sides of a reaction then the total mass remains constant and the mass-conservation law is saved, and not vice versa.

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