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Entropy Principle for the Evolution of the Universe

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Abstract

The universe began with Big Bang and is expanding, and the expansion is accelerating at present. Entropy of the universe becomes larger and larger, hence the Second Law of Thermodynamics is valid in this process. The acceleration of the expansion of the universe is considered due to "dark energy". The amount (density) of dark energy decreases when some amount of dark energy changes to matter. Energy is equivalent to matter: Einstein formula $E=mc^2$, which is shown to be valid for the conversion of matter to energy, and also for the conversion of energy to matter. When the large amount of dark energy decreases by the change to matter, the decrease of dark energy induces the change of the dynamics of the universe from expansion to shrinking, and the universe shrinks smaller and smaller. According to the Second Law of Thermodynamics (Entropy Principle), the randomness of the state of the universe becomes larger with time in this shrinking process. Finally, the universe shrinks to a point with very large randomness in the state and vanishes (Big Crunch): the end of the universe. Thus, the Second Law of Thermodynamics describes all processes of the evolution of the universe from the beginning to the end. The validity of the Second Law of Thermodynamics (Entropy Principle) in the universe has been established in this article, for the first time. The assertion of Clausius in 1865 has been shown to be valid for the first time here, after a long time since his assertion.

Keywords: The universe; Entropy; Dark energy; The expanding universe; The shrinking universe; The end (death) of the universe

1. Introduction

Thermodynamics (Clausius, Lord Kelvin) was one of the three props of classical physics in 19th century, with the classical mechanics (Newton) and the electromagnetic theory (Faraday, Maxwell). In 20th century, the revolutions (relativity, quantum) occurred and the latter two disciplines have changed to completely new paradigms. Only thermodynamics is not so fragile and has been valid until now and may be so in future, as in the Einstein's quote [1]: "----lt (classical thermodynamics) is the only physical theory of universal content concerning which I am convinced that ----it will never be overthrown".

Hutchinson (ecology, limnology) pointed out that the studies of complex systems like lake ecosystems consist of two different approaches: *"hololological"* (holos=whole) and *"metrological"* (meros=part) [2]. In *"hololological"* approaches, complex systems are treated as black boxes without scrutinizing the internal components and their interactions within systems, and the attentions are focused on input and output to/from systems. On the other hand, in *"merological"* approaches,

components of systems and their interactions are studied in detail and detail, and then integrated into whole systems, if possible. The methodology of thermodynamics is *"hololological"*: the only one in contrast to other fields of physics *(merological)*. Thermodynamics is the best tool to treat complex and macroscopic systems, each as a whole, the usefulness of which is already shown by the arguments of Aoki [3] on the Entropy Principle for the development of biotic systems.

The term "entropy" was coined by Clausius [4], who was the founder of the Second Law of Thermodynamics, with Lord Kelvin. Clausius [4], asserted that the essence of the Second Law of Thermodynamics is "Die Entropie der Welt strebt einem Maximum zu (The entropy of the universe tends to a maximum; translated by J. Tyndall)".

Thermodynamics in chemistry (Chemical Thermodynamics) has been completed by Prigogine and others [5]. The Second Law of Thermodynamics (Entropy Principle) in all biotic systems in the universe (Biological Thermodynamics) has been established to be true by Aoki in 2018 [6].

The concept of entropy in cosmology was already extensively discussed by Tolman in 1931 [7], and has been argued by many researchers until now, e.g., Tolman [8], Prigogine [9], Lineweaver [10], and Aoki [6], as roughly cited. Since the time of Tolman's work in 1931, many theoretical, experimental and observational evidences have been accumulated, and it is possible to specify the entropy principle for the evolution of the universe, just at present, and the validity of the assertion of Clausius as shown above has been established to be valid for the first time, after a long time since the assertion of Clausius in 1865 [4].

The standpoint of the present article is that any theories and laws etc. should be accepted to be true after verifications by solid calculations, experiments and/or observations.

The present article completely establishes the entropy principle for the universe from the beginning to the end with the solid evidences and discussions, for the first time. The *hololological* method is adopted here to discuss the entropy principle for the evolution of the universe, i.e. the present article does not scrutinize fine detailed structures and processes within the universe; "coarse graining" (this is essential in thermodynamics).

As it is well-known, the universe was born by Big Bang [11-13], and is expanding [14], and the expansion is accelerating [15,16]. These are the scientific facts verified by the observations. However, note that the expansion rate of the universe has not yet been precisely determined at present (2020), see, e.g., Jee et al. [17].

Friedmann shows that the universe continues to expand eternally or to shrink to a point and vanishes (Big Crunch) [18]. These results have been deduced by the calculation by use of the theory of general relativity of Einstein, which is true at present.

In the former stage (the universe is expanding), entropy of the universe tends to become larger with time (dispersion or diffusion is the process by which entropy increases with time), and the Second Law of Thermodynamics certainly holds (the

universe is an isolated system: nothing observed outside of the universe, **at present at least**). The description of the latter process (the universe is shrinking) is made in the following.

The shrink of the universe

The acceleration of the expansion of the universe is considered due to "dark energy". Nothing is known about dark energy except its ability to accelerate the expansion of the universe. The term "dark energy" is coined and first discussed by Turner [19]. In 2011, the five-year survey of 200,000 galaxies and spanning 7 billion years of cosmic time confirmed that "dark energy is driving our universe apart at accelerating speeds" [20,21]. Assume that dark energy is ordinary energy as we know, and remind that energy is equivalent to matter: the well-known formula of Einstein: $E=mc^2$ [22]. After some long time, some of dark energy may change to matter, and the enough (density) of dark energy may decrease, in which case the dynamics of the universe may change from expansion to shrinking, and the universe becomes smaller and smaller, and the randomness of the state of the universe becomes larger with time, and finally shrinks to a point with the very large randomness of the state, and vanishes (Big Crunch), as Friedmann shows [18]. The point is: the conversion of dark energy to matter is proved to be true by solid theories/observations/experiments.

The validity of $E=mc^2$

The validity of Einstein formula $E=mc^2$ was tested by the experiments by Cockcroft and Walton [23], and Rainville et al. [24], and shown to be valid for the conversion from matter to energy. To show the validity of $E=mc^2$ for the conversion from energy to matter, the calculations by use of Lattes quantum chromo dynamics have been made (the calculation based on Quantum Chromo Dynamics (QCD) is difficult, so instead lattes QCD was used). The first evidence is given by Dürr et al. [25] in 2008. Proton consists of quarks and gluons, and quarks are bound by gluons. Dürr et al. [25] show that mass of quarks is 5% of proton mass (mass of gluons is zero), the remaining 95% of mass comes from energy of movements and interactions of quarks and gluons inside of proton. This is the first evidence which shows that energy converts to matter. The Einstein formula $E=mc^2$ is validated for the conversion of energy to matter for the first time, after a long time since the proposal of Einstein in 1905 [22]. Later studies by Yang et al. [26] in 2018 show that proton mass comes from : quarks (9%), kinetic energy of quarks violently moving inside proton (32%), energy of gluons to hold quarks together (36%), and energy that quarks and gluons interact in complicated ways within proton (23%). The above two studies used the technique of lattes QCD as the method of calculation; lattes QCD is considered to be correct at present. The direct experimental verification of the conversion of energy to matter was already suggested by Breit and Wheeler in 1934 [27]; it is to observe the reaction: $\gamma\gamma' \rightarrow e^+e^-$. The experimental apparatus to detect this reaction was made at 2014 by Pike et al. [28] and is running until now, but there is no evident result at present (2020).

Big Crunch

The decrease of the amount (density) of dark energy occurs due to the conversion of a large amount of dark energy to matter, and the universe tends to convert to shrink from the expansion. This process is possible by the theory of Friedmann [18]. According to the Second Law of Thermodynamics, entropy of the universe is increasing, and the randomness of the state of the universe becomes larger with time, and the universe becomes to a point and disappears with the very large randomness

(Big Crunch): this is the end (death) of the universe. Note that there are other theories with different explanations about the end of the universe, e.g., Penrose [29].

The temperature of the universe

The temperature of the universe in the expanding stage becomes lower with time to the absolute zero degree because of the adiabatic expansion. In the shrinking stage, the temperature is randomly variable from high to low everywhere in the universe.

Conclusions and Discussions

This article has shown that the universe in the expanding stage and in the shrinking stage can be described by The Second Law of Thermodynamics. The present argument represents just the Entropy Principle for the evolution of the universe from the beginning to the end, together with the arguments in Aoki [6].

Also, entropy principle for the evolution of all biotic systems in the universe has been completely established in the sense of *macroscopic* and *holistic* viewpoint [6]. This viewpoint is essential in Thermodynamics, as shown in the beginning of this article.

Thus, Entropy Principle (the Second Law of Thermodynamics) has been established and shown to be valid in all biotic systems in the universe [6], and universe itself (the present article), i.e., all in the universe, for the first time in this article. The principle of evolution of all in the universe as a whole is simply deduced from the classical thermodynamics, as in the Einstein's quote [1]; other generalized, extended or modified versions of the classical thermodynamics are not necessary.

However, it is not known that dark energy is ordinary energy, or other new kind of energy (if any, but it may be possible). If dark energy is different to ordinary energy, it is not known whether the Einstein's formula ($E=mc^2$) can be applied to dark energy or not. Also, it is not known when the conversion of dark energy to matter occurs, and what triggers the conversion of dark energy to matter.

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