Bulgarian Academy of Sciences. Space Research and Technology Institute.
Aerospace Research in Bulgaria. 38, 2026, Sofia

DOI: https://doi.org/10.3897/arb.v38.e03

THERMODYNAMIC HYPOTHESIS IN COSMOLOGY

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Key words: *cosmology; thermodynamics; time evolution*

Abstract

SUMMARY: We summarise the principles of thermodynamics. We present a new way of describing time in physics – we consider time as a main manifold. We analyse its behaviour as a basic state in spacetime thermodynamics. We develop the cascading concept in the thermodynamic interpretation of the cosmological development of time and the spatial-temporal manifolds originating in it, considering them as new thermodynamic states.

We discuss how the behaviour of entropy as a leading parameter is reflected in the complicating evolutionary picture.

Introduction

There is no reason in the laws of physics that time moves only in one direction. Most processes and interactions are symmetrical in a time reversal. The only exceptions are the irreversible processes. They require a relaxation time until the previous state is restored. This is the reason, although in principle, both direct and reverse phenomena are permissible, they differ in the frequency with which they happen. In reality, reverse phenomena occur so rarely that we can postulate/to summarize, as time does not turn back and time has no closed curves anywhere. The relaxation time in practice requires an additional path until the exact event is restored. Therefore, one can never reach one's own past, only a neighbouring solution.

We will propose a thermodynamic interpretation that does not impose a cosmic caesura in the cosmology, but predicts/suggests a priority direction in the naturally universe/s development.

Thermodynamics (TD) considers the reversible and irreversible processes that occur as a result of the energy change – the exchange, the connections, and their transformation into other forms. At this time, the thermodynamics conceptually unites quantum and relativistic physics. They have contact points in the field of thermodynamics, and their mathematical physics manages, if not to unite them completely, but to adequately fit them together for an appropriate description of the natural processes and laws.

Formulations of the TD-principles for a temperatureless medium

1. The Zero Principle – generalisation of the TD-Spacetime (TDST)

If two thermodynamic systems are in a (energetic) equilibrium separately, with a third system, then they is also in equilibrium between them. All systems, which are in TD-equilibrium with each other, have the same energetic characteristics.

2. The First Principle – generalisation of the TD-Spacetime

The internal energy of a closed system is conserved.

The internal energy of an open system depends on additional factors, one of which is the number change of the subsystems.

3. The Second Principle – generalisation of the TD-Spacetime

The entropy of an isolated thermodynamic system can only increase or remain the same. Boltzmann gives a suitable summary: Nature moves from states of lower probability to states of higher probability.

4. The Third Principle – generalisation of the TD-Spacetime

The entropy of a system tends to a constant value when the system state tends to the (absolute) minimum energy level. The constant value is called the residual entropy of the system. It/Entropy relates to the number of possible eigenstates and may not be zero.

A more general form of the law exists for with more than one minimum energy level: Example – the universe onto instanton-tor has at least two absolute minimum energy levels!

The third law of thermodynamics applies only to equilibrium states.

Based on the second law, the minimum entropy can be determined only to within an arbitrary constant. The third law of thermodynamics allows the determination of the unknown constant, and thus the exact determination of the minimum entropy.

Central hypothesis

Postulate 1. *In a thermodynamic interpretation, we propose Time as a basic fundamental TD-state [1]. In such quality, the Time represents an active medium with its own energy and an unlimited number of dimensions, which has nonlocal properties and spontaneous flexibility, does not obey rotational symmetries (has no closed time curves anywhere and never), and can interact with the objects within itself, if any.*

1. Time as a thermodynamic object. Dual nature

Theoretical studies [2–4] and available observations indicate that the light speed constant undergoes centuries-long variation over cosmological epochs. If the light speed varies, then time precedes the birth of our (and other) space-time manifolds, is older than the Universe, and will remain after it.

- Then Time can be considered as a background, but also as a basic (minimum) thermodynamic state – an analogue of absolute (true) vacuum*.

The time origin as a fundamental manifold without spatial dimensions is a purely theoretical problem of abstract mathematics. Therefore, we will refer to Gödel's First and Second Incompleteness Theorems, and we will accept that the mathematical fundamentals are unprovable and leave this question open. We will limit ourselves to a TD interpretation.

As a TD-object, Time can exist in two possible pure states, which belong as regions to the general manifold:

- Ordered time – the dimensions in these sections are orthogonal and linearly independent of each other; or
- Chaotic time where dimensions are randomly interwoven.

It is assumed that spatial manifolds arise only in the first type of time.

As a basic TD-state, time has a dual nature:

- ✓ it can be considered as a quantum environment with energetic info-structures without a causal relationship;
- ✓ but also as a continuous medium – an energy background, whose info-structures freely pass through each other, and information is rearranged in them without causing TD-recoil: E~(*)~information. Since info-structures are open systems, they can be shifted in different degrees, in different directions of Time, moving through each other without creating disturbances in the basic manifold.

The Time system is a two-sided open TD system: above to infinity, and below to indeterminacy – each finite interval of time can be divided into countless infinitely small intervals.

- In such an infinite-dimensional environment, any recoilless rearrangement of information in the main manifold can create a new timeline (it is not an arrow, has no cause-and-effect relationships), i.e., to release a new time dimension and thus increase its infinity. Each newly emerged dimension appears but cannot disappear. Because even if the timeline in question is erased, in the manifold, instructions remain (information/energy is not lost), how to restore it again (hidden dimensions).

2. *Transition theory*

As a basic state, time is in equilibrium. However, there is no reason to consider this equilibrium sustainable. Time is very flexible. Time dimensions are elastic, and most natural disturbances are smoothing out. However, there is a possibility that a given disturbance is effective enough to cause self-intersection in some time component. Then time transmutes – an instanton is born. This is a particular solution of a standing wave in time and represents a region of purely/only time dimensions covered with a spatial envelope (similar around the black hole horizon/ergosphere [5, 6]). Spatial dimensions are plastic. Plastic deformation, unlike elastic deformation, is irreversible and leads to an irreversible phase transition. Thus, through a phase transition in the thermodynamics of space-time, a primary multiverse (local multiverse) arises – a new Universe.

- Every space-time system is bounded (or closed) below by the primary instanton radius R_{in0}. (The initial scale function of the manifold coincides with the time scale at the moment of closure (here $R_{in0} = 10^{-43}$ cm ≡ $t_{pl} \rightarrow 10^{-43}$ s). Subsequently, the lag/lead G-function [7] regulates centuries-long variation in the light speed. The G-function acts in such a way that no rupture occurs in the manifold.
- Local multiverses are self-contained systems that do not depend (have no causal relationships) but interact with the environment. Resemble quantum structures (particles in a vacuum) in time. Similar to the type I and type II populations of galaxies, which are interpenetrating systems, independent of each other, but they interact gravitationally.

Time does not obey rotational symmetries, and this is the reason for forming instantons upon self-intersection [8, 9]. In the sense of the TDST second principle, the probability of the transition of pure time into space-time is infinitely large since this is a transition from a state with zero entropy (absent) to increasing entropy, and the entropy gradient is always positive. The entropy from the self-intersection (the entanglement of freedom degrees [10–12]) can argue a basic mechanism for the emergence of space-time. The loss of symmetry in the Time-manifold leads to the emergence of classical connected space-times.

The time arrow direction in the manifold coincides with the direction of the outer instanton normal at each moment of the expansion.

Surface gravity is constant throughout the instanton at the moment of formation. This fact reflects the TDST Zero Law, which states that a system in equilibrium has uniformly distributed energy characteristics.

The formation of instanton(s) through an irreversible phase transition changes the configuration from the main state to a new TD-state in which the first entropies arise. When an instanton is born, the surface itself is an entropy, and its birth is an irreversible transition in the sense of the generalisation of the TDST Second Law.

3. Consequences

By analogy with the event horizon of black holes, an instanton is also formed, but here the environmental conditions create formation peculiarities. This is a different type of instanton that arose not by nonlinearity in the space-time fabric, but as a consequence of the transmutation of one type of dimension into another. By analogy with the elements synthesis – the transformation of pure time into space-time during the transition from the basic to the next TD-state, encapsulates the remainder of the "energy of transmutation" in the new structure.

Consequence 1: *The encapsulated energy has a small non-zero value: It represents the locked-in instanton shell (minimal rotational surface [13]) spatial fabric, which is essentially the dark matter [9] (DM) and corresponds to the minimal entropy at the moment of its closure. Unlike ordinary matter, DM does not obey rotational symmetries – DM-particles in the manifold walls do not have spin.*

Consequence 2: *As a consequence of the closure at about one [Planck] time, gravity separates, and dark energy (DE) arises as a primary thermodynamic recoil – the own dynamics of the manifold:*

(1) a f (Λ),

(2) a = const (Λ), (in our Universe); [8]

In [14], early dark energy is considered as a cosmological constant. Moreover, [15] suggests that the scalar field potential that drives inflation would act as a cosmological constant that decreases with time.

In our considerations, dark energy is a thermodynamic recoil, an inertia, a consequence of the emergence. It represents its own manifold dynamics and, as such, is assumed to be constant and corresponds to the cosmological constant in general, and not only at the beginning. DE is a very small constant, and therefore, in the early epochs, its action is negligible. In the following epochs, the particles' materialisation (birth-annihilation) releases spatial density and illuminates it in the manifold. The manifold surface tension weakens [16] and becomes more and more difficult to resist the emergence of inertia. Therefore, although the dark energy is constant, the expansion is accelerating (the Hubble constant undergoes a centuries-long variation). The agreement of the processes with what we observe (in our Universe) leads to the conclusion that the expansion is stable, $a_{\Lambda} = const$, and the expansion rate has a nearly parabolic growth function, with a very small correction in the degree, far beyond the decimal point.

When the instanton is formed, it has m-number of unfolded spatial dimensions, n-number of broken/compactified * and ∞-number of time dimensions (inside and outside). In the local multiverse, the folding fractal is characteristic (Kaluza-Klein solutions [17]), and n is a finite number. The number of unfolded dimensions m (= 3 here) is constant, since they belong to the spatial envelope of the instanton formed in the transition.

Cascading construction of new TD-states

1. Primary and secondary manifolds

Primary manifolds arise through a phase transition in the TD-Space-time, when a time component self-intersects and breaks the symmetry in the main manifold. The born instantons (space-like manifolds) generate secondary manifolds in the process of their evolution.

A necessary condition for the emergence of a primary manifold is that it does not rotate, because time dimensions do not obey rotational symmetries, but this is not enough of a condition.

If a manifold tunnels to an absolute (true) vacuum, then it has no basic spatial state. This statement is a possible candidate for a sufficient condition for a given manifold to be primary.

Secondary manifolds are the result of a critical nonlinearity in some dimension in a primary manifold. Then a pole appears in the primary manifold, which is an embryo that forms an instanton [18]. A black hole (BH) is a formed pole in the space-time manifold.

When a Universe rotates, it is a sufficient condition to conclude that it belongs to a secondary manifold – a generated Universe.

2. Type of the manifold – Dynamic classification

According to whether and how the topology and spectra of the inner and outer derivatives change at a fixed point of the local manifold, the manifold and its structures can be classified into the following dynamical classes:

- Stationary manifold with static metric.
- A stationary manifold with a non-stationary metric is a contradiction. A non-stationary metric implies dynamics in some time dimension. In addition, even if it is external (oscillations of the horizon/surface of the instanton) to the manifold, there is no way that the spectres of the derivatives can remain unchanged to keep the manifold stationary.
- Dynamically flexible manifold with "static" topology and quasi-stationary metric * – soft Swiss cheese (here).
- Dynamic manifold with non-stationary metric – (the only basic manifold – Time).

3. The complexity Levels – structuring and self-organisation

Time – basic level – infinite-dimensional dual manifold without spatial dimensions.

I. Primary manifold – through a phase transition, by the transmutation of time into space-time, a local multiverse is born. Every dynamic manifold evolves and can stratify:

- The primary cleavage upon closure in rotationally mobile branches (universes families) is a Secondary TD-recoil of the second type; Parallel are those branches of the stratification whose external invariants do not change from point to point [19].

The branches are not connected spatially-continuously along the orthogonal timeline (may be tunnels between them, but they are rotationally mobile and not glued together), so there is no violation of the stability condition of the manifold for two or more time directions.

– Each branch is copied into specific realities -> quantum cloning in layer-alternatives (the Universes) – each primary branch is a kind of complex of subspace trestles with its own spectrum of bifurcation points.

II. Secondary manifolds – offshoots from the local multiverse – generated Universes.

III. Swarming – detachment from the Mother Universe.

4. The TD-recoils

The formation rearrangement and the secondary manifolds displacement lead to TD-recoil in the main/primary manifold:

Primary TD-recoil is long-lasting, in the multiverse's own lifetime ~1 Planck time, the instanton is born, and dark energy arises as a reaction to the closure of the instanton. The gravity separated.

Secondary TD-recoil of the first type is short-term. That is the inflation and the χ-boson appearance.

10^{-35}–10^{-32} s – interrupts the cord with the mother universe and the wormhole closes; follows a secondary TD-recoil of the inflation. The strong interaction separated;

10^{-10} s – the χ-boson breaks away from the manifold walls, and the particles acquire mass. The last splitting in the force so far occurs: the weak and electromagnetic interactions separated.

Secondary TD-recoil of the second type is caused by internal-structural shifts in the local multiverse, such as:

The primary branches split upon closure, and

The rearrangement in the frequencies of a momentary reality*.

Entropy

In the sense of the II principle of the TDST, the transition probability from the main state to a state with non-zero to increasing entropy is always different from zero [1].

In the new state, each subsystem space-time bounded (or closed) below by the primary instanton radius. We will consider trees of space-time manifolds as individual quantum objects. Each has its own dynamic "arrow of time"*. The energy is grouped at another level through an irreversible transition – the new structures are discrete, and they lose the properties of a continuum.

The loss of symmetry in the basic manifold is an irreversible process. Irreversibility always reduces the amount of free energy. When an instanton is born, part of it is encapsulated in the new structure, and the “transmutation energy” will not be restored until the end of the local multiverse. An irreversible process that changes the configuration from the main state. The attenuation of the interaction in a particle system is an irreversible process. Entanglement is also a form of attenuation, i.e., irreversibility. The entropy of a self-intersection [8–9] (the entanglement of freedom degrees [10–12]) is only a primary result in the thermodynamic evolution of time. The irreversibility of the processes in the next levels is mainly associated with two aspects:

In the local manifold, the emergence and displacement of the bifurcation points relative to their initial location, due to the mobility of the space-time fabric, is caused by the inherent dynamics (expansion) of a manifold.

Swarming from the universe's mothers leads to TD-recoil, but also expands the population of the main manifold with secondary manifolds. In an open system, such as time, which depends on the number of changes of its subsystems, this is essential due to the following important circumstances:

The secondary manifolds can rotate. Primary manifolds are rotationally mobile, but their momentum is zero because they arise from pure time, and time dimensions do not obey rotational symmetries;

Also possible for them to be born together, observing certain symmetries between each other, or

Too quickly die, if the primary TD recoil is so powerful, i.e., DE has too high a value and the expansion is exponential:

(3) $a = f(\Lambda) \neq \text{const},$

Time as an open system should be able to self-structure itself in such a way that entropy decreases. This raises the question: how much the entropy increase in cascades is regulated by the number of short-lived local multiverses, whose demise restores some of the lost symmetries in the main manifold. Also, can the regions' chaotic time provide a buffer mechanism for regulating entropy in the orderly time regions?

Conclusions and Discussion

In conclusion, we will note that the TD-hypothesis does not impose any restrictions on m and n (except for being finite), the fractal shape, and its compactification radius in the local manifold. Therefore, in this way, the TDPV second principle guarantees the diversity of local multiverses, since the probability that the unfolded dimensions are the same number or are arranged in the same way $\rightarrow 0$! Moreover, the folding fractal in compactified volumes is different.

We will also note that it is extremely important to acquire the appropriate tools and measurable physical quantities that allow adequate testing of the theory.

Spectra bifurcation points related to the universe's fundamental constants. Types of symmetries are broken at bifurcation points. In different universes, they are broken in different ways.

Spectra Frequencies of a momentary reality could be cosmological sources of the gravitational waves included in the background cosmic noise. It has long been theorised that it consists of individual signals that are too weak to be detected, but combined create a static background noise [20].

Information transferred through special points (regions) between the manifolds is preserved, but has no memory of the initial state and therefore does not impose a restriction on the initial conditions of the generated Universes. The irretrievable loss of information contradicts one of the basic postulates of quantum mechanics. According to the Schrödinger equation, physical systems that change in time cannot create or destroy information – a property known as unitary. However, the Laws are not violated because only the reflected information (Hawking radiation) has degraded, and the direct information to the daughter manifold has the potential to preserve its memory of the IC, albeit in an incomplete form (distorted/deformed, but in a precisely defined way – a modulation from whose signature additional concretisations about previous states can be extracted).

All of these tools are subjective, related to a local manifold, and can be predicted theoretically within the framework of the mathematics developed for the corresponding geometry of the local manifold.

The general mathematical framework of the basic manifold will require continuous adaptation in relation to the fact that time is the fourth type by the dynamic classification, and its geometry changes with the diversity of the subsystems arising in the gradation of the levels.

Appendix

(*) – Without spatial dimensions, there is no mass expression for the energy.

Absolute (true) vacuum – complete lack of space and spatial dimensions.

Compactified dimensions begin the transmutation (they are no longer time dimensions), but they fail to complete it. They remain enclosed within themselves (ordered structures in fractals) – the Kaluza-Klein solutions [https://arxiv.org/pdf/hep-th/9906064].

Dynamic time arrow – the arrow direction coincides with the direction of the instanton normal at each moment of the expansion.

Frequency of a momentary reality – the location, shape, and oscillations of the brane-alternative compared to the other structures in the local multiverse, at a particular moment in the expansion.

Quasi-stationary metric – the metric undergoes negligible changes, the accumulation of which leads to noticeable physical effects that can no longer be ignored.

References

1. Yankova, Kr. Cascade principle in the cosmology. Complexity levels – structure-formation and self-organization, Proceedings SES 2023, ISSN 1313-3888, 91–93. (bg)
2. Albrecht, A., J. Magueijo. A time varying speed of light as a solution to cosmological puzzles. https://arxiv.org/pdf/astro-ph/9811018.pdf, Phys. Rev. D 1999, 59, 043516, https://doi.org/10.1103/PhysRevD.59.043516
3. Magueijo, J., Lee Smolin. Lorentz invariance with an invariant energy scale, https://arxiv.org/pdf/hepth/0112090.pdf, Phys.Rev.Lett. 2002, 88:190403. https://doi.org/10.1103/PhysRevLett.88.190403
4. Magueijo, J. New varying speed of light theories. https://arxiv.org/pdf/astro-ph/0305457.pdf, Rept.Prog.Phys. 2003, 66:2025. https://doi.org/10.1088/0034-4885/66/11/R04
5. Krauss, L.M., H. Liu. Quantum hair, instantons, and black hole thermodynamics: Some new results, Nucl.Phys.B 1997, 491, 365-386, DOI: 10.1016/S0550-3213(97)00053-9. https://inspirehep.net/literature/425529
6. Chen, Yu, Ed. Teo. Black holes on gravitational instantons, Nucl.Phys.B 2011, 850:253-272. https://doi.org/10.1016/j.nuclphysb.2011.04.019, https://arxiv.org/pdf/1011.6464
7. Giuseppe Frè P. Gravity, a Geometrical Course I, 2013.
8. Yankova, Kr. Advection into a multidimensional medium, Proceedings SES 2019, ISSN 1313-3888, 62–65. (bg)
9. Yankova, Kr. Advection and cosmology – connections and consequences, Proceedings SES 2020, ISSN 1313-3888, 81–83. (bg)
10. Hooft G.'t. The Holographic Principle, 2000. https://doi.org/10.48550/arXiv.hep-th/0003004, https://arxiv.org/pdf/hep-th/0003004.pdf
11. Raamsdonk, M. V. Building up spacetime with quantum entanglement, Gen. Rel. Grav. 2010, 42 2323. https://doi.org/10.1007/s10714-010-1034-0, https://arxiv.org/pdf/1005.3035.pdf
12. Susskind, L. The World as a Hologram, J. Math. Phys. 1995, 36, 6377–6396. https://doi.org/10.1063/1.531249, https://arxiv.org/pdf/hep-th/9409089.pdf
13. Aleksieva Ya. Lorentz surfaces in four-dimensional pseudo-Euclidean space with neutral metric, Aftoreferat 2017. (bg)
14. Poulin, V., T. Smith, T. Karwal, M. Kamionkowski. Early dark energy can resolve the Hubble tension, Phys. Rev. Lett. 2019, 122, 221301. https://doi.org/10.1103/PhysRevLett.122.221301
15. Peebles, P. J. E., B. Ratra. The cosmological constant and dark energy, Rev.Mod.Phys. 2003, 75:559-606. https://doi.org/10.1103/RevModPhys.75.559
16. Binétruy, P. How many dimensions to our Universe?, Europhysics News 2002, Vol. 33, No. 2, pp. 54–57. https://doi.org/10.1051/epn:2002205
17. Randall, L., R. Sundrum. An Alternative to Compactification, Phys.Rev.Lett. 1999, 83:4690-4693. https://doi.org/10.1103/PhysRevLett.83.4690, https://arxiv.org/pdf/hep-th/9906064
18. Belavina, A.A., A.M. Polyakova, A.S. Schwartza, Yu.S. Tyupkina. Pseudoparticle solutions of the Yang-Mills equations, Physics Letters B. 1975, Volume 59, Issue 1, Pages 85–87.

19. Chen,B.-Y. Black holes, marginally trapped surfaces and quasi-minimal surfaces. Tamkang J. Math. 2009, 40, no. 4, pp. 313–341. DOI: https://doi.org/10.5556/j.tkjm.40.2009.600
20. Wilkins, A. Gravitational waves produce a background hum across the whole universe, New Scientist 29 June 2023. https://www.newscientist.com/article/2380451-gravitational-waves-produce-a-background-hum-across-the-whole-universe/

ТЕРМОДИНАМИЧНА ХИПОТЕЗА В КОСМОЛОГИЯТА

К. Янкова

Резюме

Обобщаваме принципите на термодинамиката. Представяме нов начин за описание на времето във физиката – разглеждаме времето като основно многообразие. Анализираме поведението му като основно състояние в пространствено-времевата термодинамика. Развиваме каскадната концепция в термодинамичната интерпретация на космологичното развитие на времето и произлизащите от него пространствено-времеви многообразия, разглеждайки ги като нови термодинамични състояния.

Обсъждаме как поведението на ентропията като водещ параметър се отразява в усложняващата се еволюционна картина.