

Local Temporal Degree of Freedom:Theory of Time Emergence Based on System Intrinsic Recursion and Environmental Coupling(Series Paper Part III)

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Abstract: General relativity explains time dilation via geometric curvature of spacetime, but it fails to distinguish differences in material system structures and cannot derive mathematically self-consistent extreme time dilation in extreme physical scenarios. Breaking away from the traditional framework of spacetime geometry, this paper starts from the essence of **system information interaction**, and proposes a theoretical model that determines the objective time flow rate jointly by the environmental coupling coefficient α and the effective intrinsic recursion intensity β , with the core formula $\xi = 1 - (1 - \alpha)\beta$, and strictly limits $0 \leq \alpha \leq 1$ and $0 \leq \beta \leq 1$. The model clarifies that time flow rate is essentially the result of the emergence of internal information recursion efficiency and inter-system information exchange smoothness of systems. Gravity and velocity regulate α and β simultaneously by interfering with the internal and external information transmission of systems, which can self-consistently explain the timing offset of GPS satellite atomic clocks, time dilation effects in high-speed and strong gravitational fields, and distinguish the temporal response differences between complex living systems, quantum timing systems and macroscopic structureless matter. It solves the logical defects of single-variable theories in extreme scenarios and provides a brand-new information theory perspective for the study of spacetime physics.

Keywords: Time Emergence; Environmental Coupling; Intrinsic Recursion; Information Exchange; Time Dilation; Spacetime Physics

1. Introduction

General relativity constructs the correlation system between gravity and spacetime curvature, and successfully explains the time offset phenomenon on the macroscopic celestial scale, but it has core theoretical limitations: first, it assumes that the time response of all matter is consistent, ignoring the differences in system structure complexity and information evolution; second, it only explains time changes from the dimension of spacetime geometry, lacking the underlying physical causal mechanism; third, in extreme scenarios such as near-light-speed motion and strong black hole gravity, a single spacetime variable cannot realize mathematically self-consistent infinite time dilation derivation; fourth, all existing experiments rely on microscopic quantum recursive systems, without direct observation support from macroscopic structureless matter.

In response to the above problems, this paper returns to the essence of physics, defines time flow rate as the emergent result of **system information interaction**, clarifies the physical connotation of environmental coupling and intrinsic recursion and the dual-variable

cooperative regulation mechanism, improves the adaptability of the theory in conventional and extreme scenarios, and forms a theory of time emergence with logical closed-loop and explanatory power for full-scenario spacetime phenomena.

2. Definition and Essential Connotation of Core Physical Quantities

2.1 Environmental Coupling Coefficient α

The environmental coupling coefficient α is essentially the **smoothness and synchronous binding degree of information exchange between the system and the overall spacetime field where it is located**, with a value range of $0 \leq \alpha \leq 1$. The closer α is to 1, the more unimpeded the information transmission between the system and the surrounding spacetime field and the more complete the synchronous coupling; the smaller α is, the more blocked the information exchange between the system and the environment and the lower the synchronization, until $\alpha \rightarrow 0$, the system is completely isolated from the external spacetime field and achieves complete decoupling.

The core of α regulation is **information exchange obstruction**: the system leaving the dense environment, distortion of gravitational field, and intensification of relative motion will all interfere with the information transmission between the system and the spacetime field, directly leading to the decrease of α ; on the contrary, the smoother and less disturbed the environment is, the closer α is to 1.

2.2 Effective Intrinsic Recursion Intensity β

The effective intrinsic recursion intensity β is essentially the **operation efficiency of internal information iteration and causal evolution of the system**, constrained by physical rules, and its value range is **strictly limited to $0 \leq \beta \leq 1$** , and $\beta=1$ represents that the internal information recursion of the system reaches the physical limit efficiency.

Based on the complexity of material structure, β presents hierarchical characteristics: macroscopic structureless matter (rocks, rigid bodies) has no internal information iteration, $\beta \approx 0$; atomic clocks and microscopic particles have basic quantum information oscillation recursion, and β is a low constant value; complex living systems have multi-level physiological and conscious information recursion, naturally in a high β range. At the same time, external forces regulate β by restricting internal information iteration efficiency: the greater the gravity and the faster the motion speed, the more constrained the internal information recursion of the system, the closer the efficiency approaches the limit, and β increases; the weaker the gravity and the smoother the motion, the more relaxed the internal recursion constraint, and β decreases.

2.3 Objective Time Flow Rate ξ

Objective time flow rate is not an inherent attribute of spacetime, but a physical quantity emerging from the internal and external information interaction of the system, jointly determined by α and β , with the core formula:

$$\xi = 1 - (1 - \alpha)\beta$$

The larger the value of ξ , the more efficient the internal and external information interaction of the system and the faster the time elapses; the smaller the value of ξ , the slower the information interaction and the slower the time flow; when $\xi \rightarrow 0$, the information interaction is almost stagnant and the time tends to be static.

3. Core Regulation Mechanism and Explanation of Physical Phenomena

3.1 Cooperative Regulation of Dual Variables by Gravity and Velocity

Gravity and motion velocity essentially realize the simultaneous regulation of α and β by **interfering with the internal and external information exchange of the system**, which is completely in line with physical intuition:

1. The faster the speed, the system continuously breaks away from the local spacetime field, **the information exchange between the system and the environment is pulled and blocked**, leading to the decrease of α ; at the same time, the internal information iteration is constrained by motion, the recursion efficiency increases, and β rises.
2. The greater the gravity, the spacetime field structure is squeezed and distorted, **the information transmission channel between the system and the environment is twisted and congested**, the synchronization fails, and α decreases; at the same time, the internal information recursion is strongly squeezed, the efficiency approaches the physical limit, and β rises.

In short, both gravity and velocity realize the two-way regulation of **α decrease and β increase** by hindering the external information coupling of the system and compressing the internal information recursion efficiency, which is the core logic to explain the time effects in all scenarios.

3.2 Timing Acceleration of GPS Satellite Atomic Clocks

Satellites in Earth orbit are not completely separated from the constraint of Earth spacetime field. Only because they are far away from the dense material area on the Earth's surface, the interference of information exchange is reduced, and α is **slightly lower** than that on the Earth's surface; at the same time, the gravity in satellite orbit is weaker, the constraint of internal information recursion is greatly relaxed, and the β value of satellite atomic clocks decreases significantly. Substituting into the formula, the increase of time flow rate caused by the significant decrease of β is far greater than the influence of the slight decrease of α , and finally the time flow rate of satellite atomic clocks is faster than that on the Earth's surface, which is completely consistent with the actual GPS observation results.

3.3 Extreme Time Dilation in High-Speed Motion and Strong Gravitational Fields

In scenarios of near-light-speed motion and strong black hole gravity, the internal and external information exchange of the system is extremely interfered: the external information channel is completely blocked, and α sharply approaches 0; the internal information recursion reaches the physical limit efficiency, and β approaches 1. Substituting the extreme values into the formula:

$$\xi = 1 - (1 - 0) \times 1 = 0$$

It realizes mathematically self-consistent complete time stagnation, solves the problems of numerical divergence and logical contradiction of traditional theories in extreme scenarios, and conforms to the physical essence that time is meaningless when information interaction is stagnant.

3.4 Time Variation of Complex High-Recursion Systems

For complex living systems with high β represented by human beings, in a stable environment without gravity and high-speed disturbance, the isolated state will reduce external information exchange, only causing the decrease of α , while the system β remains constant. Due to the high base number of β of living systems, a small decrease of α can significantly reduce ξ , resulting in objectively slower physical time flow, which is a unique time effect of high-information recursion systems, essentially different from low-recursion systems.

3.5 Time Invariance of Macroscopic Structureless Matter

For macroscopic matter without internal information iteration such as rocks and rigid bodies, $\beta \approx 0$, and substituting into the formula, $\xi \equiv 1$. No matter how gravity and velocity change, and no matter how α fluctuates, such matter has no changes in information recursion and interaction, and the time flow rate is always constant without any time dilation effect. This inference is not in conflict with existing physical observations, and is different from the universal time dilation conclusion of general relativity.

4. Supplementary Note on Subjective Time Perception

In the conventional strong coupling environment on the Earth's surface ($\alpha \approx 1$), when the human body is under pressure and tension, the frequency of conscious information recursion increases briefly, but **the objective α and β of the whole system do not change substantially**, only subjective perception of time slowing down occurs, without objective physical time flow change. This phenomenon belongs to the category of conscious information perception and is not included in the core theoretical system of objective time evolution.

5. Theoretical Essence and Research Prospect

5.1 Theoretical Core Essence

This theory completely breaks away from the traditional framework of spacetime geometric curvature, and returns to the physical essence of **information interaction**: time is not an inherent attribute of spacetime, but a physical quantity emerging from the joint action of internal information recursion and inter-system information coupling of systems. Gravity and velocity do not directly change spacetime, but regulate the coupling coefficient and recursion efficiency by interfering with system information transmission, and finally reflect as time flow rate changes, with more intuitive logic, clearer causality, and no contradiction in full-scenario adaptation.

5.2 Future Research Directions

Subsequent research can further quantify the interference degree of gravity and velocity on system information exchange, construct quantitative functions of α , β with gravity and velocity; design targeted experiments to verify the core inferences such as time invariance of structureless matter and coupling deceleration of high-recursion systems; expand the theory to the quantum microscale to realize the unification of micro information evolution and macro spacetime effects.

References

- [1] Einstein A. The Foundation of the General Theory of Relativity[J]. Annalen der Physik, 1916, 49(7): 769-822.
- [2] Hafele J C, Keating R E. Around-the-World Atomic Clocks: Predicted Relativistic Time Gains[J]. Science, 1972, 177(4044): 166-168.
- [3] Qian X S. Systems Science and Philosophy[M]. Beijing: China Renmin University Press, 1986.
- [4] Zhao Z. Black Holes and Curved Spacetime[M]. Beijing: Beijing Normal University Press, 2018.