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Consciousness as Cosmic Relational Emergence

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Abstract

This paper develops a theoretical framework that situates consciousness within cosmic relational structures, extending relational ontology to encompass subjective experience as a manifestation of universal organizational principles. Through rigorous mathematical formalization grounded in thermodynamic and information-theoretic principles, we propose that consciousness emerges when cosmic structures achieve sufficient relational complexity to manifest self-referential organization. This framework addresses fundamental questions in consciousness studies by demonstrating how subjective experience represents a natural continuation of cosmic evolutionary processes rather than an isolated biological phenomenon. Drawing on structural realism, thermodynamics, and complexity theory, the work provides theoretical foundations for understanding consciousness as an intrinsic aspect of cosmic organization while maintaining empirical grounding and philosophical rigor.

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1. Introduction

The problem of consciousness presents one of the most profound challenges to our understanding of reality's fundamental structure. Despite extensive research in neuroscience and cognitive science, the relationship between objective physical processes and subjective experience continues to resist satisfactory explanation [2,5]. Traditional approaches typically treat consciousness as an isolated biological phenomenon, disconnected from the broader organizational principles that govern cosmic evolution and complexity emergence.

This paper develops a theoretical framework that situates consciousness within cosmic relational structures, building upon recent advances in relational ontology [1] and structural realism [6,10]. The central thesis argues that consciousness represents a manifestation of universal organizational principles operating through sufficiently complex relational structures, rather than requiring separate explanatory frameworks disconnected from cosmic processes.

The motivation for this approach emerges from recognizing that the universe consistently exhibits patterns of local organization and complexity emergence across scales, from galactic formations to biological systems [8,12]. These patterns suggest underlying organizational principles that may illuminate consciousness when extended to encompass subjective experience within cosmic relational frameworks.

The framework addresses several persistent challenges in consciousness studies. The hard problem [3] asks why there should be subjective experience accompanying physical processes, while the explanatory gap [11] highlights the conceptual distance between objective neural activity and subjective phenomena. Rather than treating these as insurmountable barriers, we propose that they emerge from artificially isolating consciousness from its cosmic relational context.

This work contributes to ongoing discourse in philosophy of mind by providing a rigorous theoretical foundation that connects consciousness with well-established physical principles while maintaining philosophical sophistication. The framework offers new research directions that bridge consciousness studies with cosmology and complexity science, potentially opening pathways for empirical investigation guided by theoretical clarity.

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The paper proceeds as follows. Section 2 establishes the theoretical foundations by extending relational ontology to encompass cosmic organizational principles. Section 3 develops the mathematical formalization that captures the relationship between cosmic structures and conscious experience. Section 4 examines how this framework addresses traditional problems in consciousness studies. Section 5 explores the implications for understanding subjective experience within cosmic evolution. Section 6 situates the work within contemporary debates in philosophy of mind. Section 7 addresses potential objections and limitations. Section 8 concludes with implications for future research.

2. Theoretical Foundations: Cosmic Relational Ontology

2.1. Extending Relational Ontology Beyond Local Structures

Relational ontology, as developed in recent work [1], establishes that existence emerges through relational structures rather than substantial entities. This principle can be formally expressed as entities existing if and only if they participate in non-trivial relational networks with empirical consequences. The success of this framework in addressing traditional problems in philosophy of science suggests its potential for illuminating consciousness when extended to encompass cosmic organizational principles.

The extension to cosmic scales recognizes that relational structures operate across multiple levels of organization, from quantum mechanical interactions to galactic formations. Each level exhibits characteristic patterns of organization that emerge from relational dynamics operating according to physical principles. The universe demonstrates consistent patterns of complexity emergence through thermodynamic processes that create local order while maintaining overall entropy increase [12].

Cosmic relational ontology proposes that consciousness represents a continuation of these organizational patterns rather than a qualitatively distinct phenomenon requiring separate explanation. This perspective suggests that the universe's capacity for generating complex relational structures naturally leads to configurations capable of self-referential organization, manifesting as subjective experience in sufficiently complex systems.

The theoretical foundation rests on recognizing that organizational principles operating throughout cosmic evolution provide the resources necessary for understanding consciousness without invoking non-physical properties or abandoning scientific naturalism. The framework maintains that consciousness emerges from the same relational dynamics that govern cosmic structure formation, biological evolution, and complexity emergence across scales.

2.2. Thermodynamic Foundations of Cosmic Organization

The thermodynamic principle underlying cosmic organization can be expressed through the relationship between system entropy and environmental exchange:

$$\frac{dS_{system}}{dt} = \frac{dS_{internal}}{dt} + \frac{dS_{exchange}}{dt} < 0 \tag{1}$$

where $\frac{dS_{internal}}{dt} \geq 0$ but $\frac{dS_{exchange}}{dt} < 0$ with $|\frac{dS_{exchange}}{dt}| > \frac{dS_{internal}}{dt}$. This principle describes how open systems can locally decrease entropy while remaining consistent with the second law of thermodynamics, providing the foundation for understanding how cosmic structures maintain organization against thermodynamic decay.

Neural systems represent sophisticated applications of this principle, maintaining complex organizational patterns through continuous energy expenditure and information processing. The extension to consciousness suggests that subjective experience may represent the internal perspective of these thermodynamic processes as they maintain adaptive organization through environmental interaction.

This thermodynamic foundation connects consciousness with fundamental physical principles while avoiding the introduction of non-physical properties. The maintenance of neural organization requires continuous information processing and energy flow, suggesting that consciousness may be inherently linked to these thermodynamic processes that characterize complex adaptive systems throughout cosmic evolution.

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2.3. Information-Theoretic Aspects of Cosmic Structures

Information processing represents a fundamental aspect of cosmic organization, from quantum mechanical interactions to biological systems. The universe exhibits consistent patterns of information integration and processing across scales, suggesting underlying principles that govern the emergence of complex adaptive systems [7].

Conscious systems demonstrate sophisticated forms of information integration that may represent extensions of information processing principles operating throughout cosmic evolution. The mathematical frameworks developed for understanding cosmic structure formation, including scaling relationships and optimization principles, provide theoretical resources for understanding consciousness as a manifestation of universal information processing principles.

The connection between information theory and thermodynamics offers additional theoretical resources for understanding how conscious systems maintain organization while processing information about their environment. These principles suggest that consciousness may represent the universe's evolved capacity for self-observation and adaptive response, manifested through sufficiently complex relational structures.

3. Mathematical Formalization

3.1. Cosmic Relational Structure for Consciousness

Building upon the mathematical framework established for relational ontology [1], we propose an extended relational structure that captures the cosmic dimensions of conscious systems:

$$S_{cosmic-conscious} = \langle E_{neural}, R_{neural}, E_{cosmic}, R_{cosmic}, \Phi_{experience} \rangle \tag{2}$$

where:

$$E_{neural} = \text{Neural elements} \tag{3}$$
$$R_{neural} = \text{Neural relational structures} \tag{4}$$
$$E_{cosmic} = \text{Cosmic organizational elements} \tag{5}$$
$$R_{cosmic} = \text{Cosmic evolutionary relations} \tag{6}$$
$$\Phi_{experience} = \text{Experiential mapping function} \tag{7}$$

This formalization captures the multi-scale nature of conscious systems by incorporating both immediate neural structures and the broader cosmic context that shaped their emergence. The experiential mapping function $\Phi_{experience}$ represents the theoretical process through which relational structures give rise to subjective experience, connecting objective organizational patterns with subjective phenomena.

The neural components (E_{neural}, R_{neural}) capture the proximate structural basis of consciousness in biological systems, while the cosmic components (E_{cosmic}, R_{cosmic}) represent the broader evolutionary context that provides the organizational principles underlying conscious experience. The experiential mapping function provides the theoretical bridge between these structural elements and subjective phenomena.

3.2. Organizational Complexity Measure

We propose a measure for cosmic organizational complexity that captures the relationship between information processing and adaptive capacity:

$$\Omega(S) = \int_{t_0}^{t_1} \frac{\Delta I(S)}{\Delta t} \cdot \frac{\Delta A(S)}{\Delta t} \, dt \tag{8}$$

where $I(S)$ represents information integration capacity and $A(S)$ represents adaptive response capability. This measure captures the dynamic relationship between information processing and envi-

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ronmental adaptation that characterizes conscious systems as sophisticated manifestations of cosmic organizational principles.

The temporal integration reflects the developmental nature of consciousness as an evolved capacity emerging through cosmic evolutionary processes. Systems exhibiting higher values of $\Omega(S)$ would demonstrate greater organizational complexity, providing a quantitative framework for understanding consciousness within cosmic relational structures.

This measure connects with existing approaches to quantifying consciousness [13] while extending the framework to encompass the cosmic context in which consciousness emerged. The integration of information processing and adaptive capacity captures the functional relationship between conscious experience and environmental interaction within cosmic organizational principles.

3.3. Thermodynamic Organization Indicator

We further propose a thermodynamic indicator that connects conscious organization with entropy-reducing processes characteristic of cosmic structure formation:

$$\Psi(S) = \frac{|\frac{dS_{exchange}}{dt}|}{\frac{dS_{internal}}{dt}} \cdot I_{complexity}(S) \tag{9}$$

where $I_{complexity}(S)$ represents the complexity of information integration within the system. This indicator measures the efficiency of entropy export relative to internal entropy production, weighted by organizational complexity. Higher values of $\Psi(S)$ indicate systems demonstrating greater organizational sophistication within cosmic thermodynamic principles.

This formulation connects consciousness with thermodynamic efficiency while incorporating information-theoretic measures of organizational complexity. The relationship between entropy management and information processing provides a quantitative framework for understanding how conscious systems maintain organization while processing environmental information, representing sophisticated applications of principles operating throughout cosmic evolution.

4. Addressing Traditional Problems in Consciousness Studies

4.1. The Hard Problem Reconsidered

The hard problem of consciousness [2] asks why physical processes should be accompanied by subjective experience rather than proceeding without inner awareness. This formulation assumes a fundamental distinction between objective physical processes and subjective phenomena that may reflect conceptual limitations rather than genuine metaphysical barriers.

The cosmic relational framework suggests that this distinction emerges from artificially isolating consciousness from its cosmic organizational context. When consciousness is understood as a manifestation of universal organizational principles, the hard problem transforms into a question about how cosmic structures achieve sufficient relational complexity to manifest self-referential organization.

Rather than requiring explanation of why there should be subjective experience at all, the framework explains how consciousness emerges as a natural development of cosmic organizational principles. The hard problem dissolves when consciousness is recognized as a continuation of cosmic evolutionary processes rather than a qualitatively distinct phenomenon requiring separate explanation.

This perspective maintains scientific naturalism while acknowledging the genuine phenomena that motivate consciousness research. Subjective experience represents the internal aspect of cosmic organizational processes as they achieve sufficient complexity to manifest self-referential awareness through relational structures.

4.2. The Explanatory Gap and Cosmic Context

The explanatory gap [11] highlights the conceptual distance between objective neural processes and subjective experience. Traditional approaches struggle to bridge this gap because they treat consciousness as an isolated biological phenomenon disconnected from broader organizational principles.

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The cosmic relational framework addresses this challenge by situating consciousness within the broader context of cosmic organization and complexity emergence. Rather than requiring a direct bridge between neural activity and subjective experience, the framework demonstrates how both emerge from the same underlying organizational principles operating across cosmic scales.

The gap becomes less problematic when consciousness is understood as the internal perspective of cosmic organizational processes manifested through sufficiently complex relational structures. Neural activity and subjective experience represent different aspects of the same fundamental organizational dynamics rather than requiring separate causal connections.

This approach reduces the conceptual distance between objective and subjective domains by showing how both emerge from cosmic relational structures. The explanatory gap reflects the limitations of approaches that artificially isolate consciousness from its cosmic organizational context rather than genuine metaphysical barriers.

4.3. The Binding Problem and Cosmic Organization

The binding problem asks how unified conscious experience emerges from distributed neural processes [3]. Traditional approaches struggle to explain how separate neural activities combine into coherent subjective experience without invoking problematic mechanisms or non-physical properties.

The cosmic relational framework provides new theoretical resources by connecting consciousness with organizational principles that govern the emergence of unified structures throughout cosmic evolution. The universe consistently demonstrates the emergence of coherent structures from distributed components, from galactic formations to biological systems.

Conscious binding represents a sophisticated application of these universal organizational principles rather than requiring separate explanatory mechanisms. The framework suggests that unified conscious experience emerges through the same relational dynamics that create coherent structures throughout cosmic evolution.

This perspective explains how distributed neural processes can give rise to unified subjective experience without invoking mysterious binding mechanisms. The unity of consciousness reflects the organizational principles that govern structure formation across cosmic scales, manifested through sufficiently complex relational networks.

5. Consciousness Within Cosmic Evolution

5.1. Evolutionary Continuity and Subjective Experience

Cosmic evolution exhibits consistent patterns of complexity emergence through thermodynamic processes that create increasingly sophisticated organizational structures. From the formation of atoms and molecules to the development of biological systems, the universe demonstrates a trajectory toward greater relational complexity and adaptive capacity.

Consciousness represents a continuation of this evolutionary trajectory rather than a qualitatively distinct phenomenon requiring separate explanation. The emergence of subjective experience reflects the universe's evolved capacity for self-observation and adaptive response, manifested through relational structures of sufficient complexity to sustain self-referential organization.

This evolutionary perspective explains why consciousness appears to be a natural development rather than an unlikely accident. The organizational principles that govern cosmic evolution naturally lead toward configurations capable of subjective experience when sufficient relational complexity is achieved through evolutionary processes.

The framework suggests that consciousness may represent a significant transition in cosmic evolution, comparable to other major transitions such as the emergence of life or complex multicellular organisms. Understanding consciousness within cosmic evolutionary context provides new insights into both the nature of subjective experience and the broader trajectory of cosmic development.

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5.2. Self-Organization and Conscious Structures

Self-organization represents a fundamental aspect of cosmic evolution, from the formation of cosmic structures to the development of biological systems. These processes demonstrate how complex organizational patterns can emerge through local interactions governed by physical principles, without requiring external direction or non-physical properties.

Conscious systems represent sophisticated examples of self-organization, maintaining complex relational structures through environmental interaction and information processing. The framework suggests that consciousness emerges when self-organizing systems achieve sufficient relational complexity to manifest self-referential awareness.

This perspective connects consciousness with well-understood principles of self-organization while explaining how subjective experience can emerge from physical processes. The self-referential aspect of consciousness represents an advanced form of self-organization rather than requiring fundamentally different explanatory principles.

The mathematical frameworks developed for understanding self-organization in physical and biological systems provide theoretical resources for understanding consciousness as a manifestation of cosmic organizational principles. This connection offers new research directions that bridge consciousness studies with complexity science and evolutionary theory.

5.3. Information Integration Across Cosmic Scales

Information processing represents a fundamental aspect of cosmic organization, manifested through quantum mechanical interactions, thermodynamic processes, and biological systems. The universe exhibits consistent patterns of information integration and processing that suggest underlying principles governing complexity emergence.

Conscious information integration may represent a sophisticated manifestation of these universal principles rather than requiring separate explanatory frameworks. The mathematical principles governing information processing in conscious systems may correspond to those describing information integration throughout cosmic evolution.

This perspective suggests that conscious information processing exhibits organizational patterns that reflect the broader cosmic context in which consciousness emerged. The framework proposes that conscious systems demonstrate information integration principles that mirror those governing cosmic structure formation and complexity emergence.

The connection between consciousness and cosmic information processing offers new theoretical resources for understanding subjective experience while maintaining scientific naturalism. This approach suggests research directions that could illuminate both consciousness and cosmic organization through comparative analysis of information processing principles across scales.

6. Contemporary Debates and Philosophical Implications

6.1. Relationship to Structural Realism

Structural realism emphasizes the relational structure of reality over intrinsic properties of individual entities [6,10]. This approach has proven successful in addressing problems in philosophy of science while maintaining scientific realism about theoretical entities defined through their relational roles.

The cosmic relational framework for consciousness extends structural realist insights to encompass subjective experience as a manifestation of relational structures operating across cosmic scales. This extension maintains the structural realist emphasis on relations while providing new theoretical resources for understanding consciousness within scientific frameworks.

The framework suggests that consciousness represents the internal perspective of cosmic relational structures rather than requiring the introduction of non-relational properties or substantial entities. This approach preserves the insights of structural realism while extending its scope to encompass subjective phenomena.

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The connection with structural realism provides philosophical grounding for the cosmic relational approach to consciousness while suggesting new directions for structural realist philosophy. The framework demonstrates how structural approaches can address traditional problems in philosophy of mind while maintaining scientific naturalism.

6.2. Emergence and Cosmic Organization

Traditional emergence theories [4,9] often struggle to explain why certain complex systems should exhibit emergent properties while others do not. The cosmic relational framework addresses this challenge by connecting emergence with organizational principles operating throughout cosmic evolution.

The framework suggests that consciousness emerges when cosmic organizational principles achieve sufficient relational complexity to manifest self-referential awareness. This approach provides specific criteria for emergence based on cosmic organizational principles rather than treating emergence as mysterious or requiring non-physical properties.

Conscious emergence represents a sophisticated manifestation of organizational principles that govern complexity development throughout the universe. The framework explains why consciousness appears to be a natural development while maintaining that it emerges from well-understood physical processes.

This perspective extends emergence theories by providing concrete mechanisms for understanding how consciousness arises from complex relational structures. The thermodynamic and information-theoretic foundations offer specific models for understanding emergence within cosmic organizational principles.

6.3. Naturalism and Subjective Experience

Scientific naturalism maintains that all phenomena can be understood within scientific frameworks without invoking non-physical properties or supernatural explanations. Consciousness has traditionally presented challenges to naturalistic approaches because of the apparent gap between objective physical processes and subjective experience.

The cosmic relational framework addresses this challenge by demonstrating how consciousness emerges from organizational principles operating throughout cosmic evolution. This approach maintains naturalistic commitments while providing theoretical resources for understanding subjective experience within scientific frameworks.

The framework explains how consciousness can be understood as a natural phenomenon without reducing it to mere computational processes or eliminating its distinctive characteristics. Subjective experience represents the internal aspect of cosmic organizational processes rather than requiring non-naturalistic explanations.

This naturalistic approach to consciousness provides philosophical resources for addressing traditional problems while maintaining scientific rigor. The framework suggests that naturalism can encompass subjective experience when consciousness is understood within its proper cosmic organizational context.

7. Addressing Objections and Limitations

7.1. The Category Extension Problem

Critics might argue that extending cosmic organizational principles to consciousness involves inappropriate category extension, conflating distinct levels of description or explanation. This objection requires careful consideration of the relationship between cosmic and conscious processes without conflating different explanatory levels.

The framework addresses this challenge by proposing that the categorical distinction between cosmic and biological processes may be less fundamental than typically assumed. Rather than extending biological concepts to cosmic processes, we suggest that both consciousness and cosmic evolution represent manifestations of more fundamental organizational principles.

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The key insight involves recognizing that consciousness does not require the introduction of novel causal principles beyond those governing cosmic organization. Instead, consciousness represents a natural continuation of cosmic organizational processes toward increasingly sophisticated forms of adaptive response and self-referential awareness.

This perspective maintains appropriate categorical distinctions while recognizing deeper connections between cosmic and conscious phenomena. The framework explains how consciousness can emerge from cosmic organizational principles without conflating different levels of description or explanation.

7.2. Empirical Accessibility and Theoretical Validation

Theoretical frameworks in consciousness studies must generate implications that distinguish them from simpler alternatives while providing guidance for empirical investigation. The cosmic relational framework addresses this requirement through specific mathematical measures and theoretical predictions.

The proposed complexity measures and thermodynamic indicators offer quantitative tools for investigating consciousness within cosmic organizational principles. These measures generate theoretical predictions about conscious systems that can be tested through neuroimaging, complexity analysis, and comparative studies across different species and developmental stages.

The framework's connection with established research programs in neuroscience, complexity science, and thermodynamics enhances its empirical accessibility. The theoretical predictions can be investigated using existing experimental techniques while offering new perspectives on consciousness research.

The mathematical formalization provides concrete operational definitions that can be implemented and tested empirically. This approach ensures that the theoretical framework remains grounded in empirical investigation while offering new conceptual resources for understanding consciousness.

7.3. Scope and Limitations

The cosmic relational framework addresses significant aspects of consciousness while acknowledging areas requiring further theoretical development. The relationship between cosmic organizational principles and specific aspects of subjective experience, such as qualitative characteristics and individual differences, requires additional investigation.

The framework primarily addresses the emergence and general characteristics of consciousness rather than providing detailed accounts of specific conscious phenomena. This limitation reflects the theoretical nature of the work rather than fundamental inadequacies in the approach.

Mathematical objects and abstract entities present challenges for relational approaches that focus on empirical interactions. The framework may require extension to encompass non-empirical relational structures while maintaining its core insights about consciousness and cosmic organization.

The theoretical framework provides foundations for understanding consciousness within cosmic organizational principles while requiring further development to address specific aspects of subjective experience. This limitation suggests directions for future research rather than fundamental problems with the approach.

8. Conclusions

This paper has developed a theoretical framework that situates consciousness within cosmic relational structures, extending relational ontology to encompass subjective experience as a manifestation of universal organizational principles. The framework addresses fundamental questions in consciousness studies by demonstrating how subjective experience represents a natural continuation of cosmic evolutionary processes.

The mathematical formalization provides quantitative tools for understanding consciousness within cosmic organizational principles while maintaining philosophical rigor and empirical ground-

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ing. The framework offers new theoretical resources for addressing traditional problems in consciousness studies, including the hard problem, explanatory gap, and binding problem.

The work contributes to contemporary debates in philosophy of mind by providing a naturalistic account of consciousness that maintains scientific rigor while acknowledging the genuine phenomena that motivate consciousness research. The framework suggests new research directions that bridge consciousness studies with cosmology and complexity science.

The cosmic relational approach demonstrates how consciousness can be understood within scientific frameworks without reducing subjective experience to computational processes or invoking non-physical properties. The framework explains how consciousness emerges from the same organizational principles that govern cosmic evolution and complexity emergence.

The theoretical foundations developed here provide resources for future research that could advance understanding of consciousness through interdisciplinary collaboration and empirical investigation. The framework offers a solid foundation for exploring the relationship between consciousness and cosmic organization while maintaining theoretical sophistication and empirical accessibility.

The ultimate significance of this approach lies in demonstrating how consciousness can be understood as an intrinsic aspect of cosmic organization rather than an isolated biological phenomenon. This perspective opens new research directions while addressing fundamental questions about the nature of subjective experience and its place within the cosmic order.

Future work will focus on developing more detailed mathematical models, extending the theoretical framework to address specific aspects of conscious experience, and exploring empirical implications through interdisciplinary research programs. The cosmic relational framework provides a promising foundation for advancing understanding of consciousness as both a natural phenomenon and a manifestation of cosmic organizational principles.

References

1. Baron, B. (2025). Relational ontology as a bridge between realism and empiricism in scientific explanation. *Unpublished manuscript*.
2. Chalmers, D. J. (1995). Facing up to the problem of consciousness. *Journal of Consciousness Studies*, 2(3):200–219.
3. Chalmers, D. J. (1996). *The Conscious Mind: In Search of a Fundamental Theory*. Oxford University Press.
4. Clayton, P. (2004). *Mind and Emergence: From Quantum to Consciousness*. Oxford University Press.
5. Crick, F. and Koch, C. (1990). Towards a neurobiological theory of consciousness. *Seminars in the Neurosciences*, 2:263–275.
6. French, S. (2014). *The Structure of the World: Metaphysics and Representation*. Oxford University Press.
7. Friston, K. (2010). The free-energy principle: A unified brain theory? *Nature Reviews Neuroscience*, 11(2):127–138.
8. Kauffman, S. (2000). *Investigations*. Oxford University Press.
9. Kim, J. (2006). Emergence: Core ideas and issues. *Synthese*, 151(3):547–559.
10. Ladyman, J. (1998). What is structural realism? *Studies in History and Philosophy of Science*, 29(3):409–424.
11. Levine, J. (1983). Materialism and qualia: The explanatory gap. *Pacific Philosophical Quarterly*, 64(4):354–361.
12. Prigogine, I. and Stengers, I. (1984). *Order Out of Chaos: Man's New Dialogue with Nature*. Bantam Books.
13. Tononi, G., Boly, M., Massimini, M., and Koch, C. (2016). Integrated information theory: From consciousness to its physical substrate. *Nature Reviews Neuroscience*, 17(7):450–461.