Review Article

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Modality in format of harmonics of synergetic processes and cycles of nature

Abstract

Modality in the format of harmonics of synergetic processes and cycles of nature is based, firstly, on the synergetics of processes in complex open systems (physical, biological, social, etc.). Secondly, on the exchange of energy/substance/information with the external environment. Thirdly, on the variability of development paths described by nonlinear equations. Fourthly, on the self-organization of new structures and orders. Fifthly, on bifurcation - a branching point where the system chooses one of the possible development paths. Sixthly, on the stable state to which the system strives. Seventhly, on harmonics - periodic components of a complex process described by trigonometric functions. Modality in a broad context means a mode of existence or manifestation of something. In synergetics, modality is interpreted as a set of possible states of a system; types of behavior near a stable state; qualitative modes of functioning. Cycles of nature are recurring processes with characteristic time scales: daily and seasonal cycles; biological rhythms (metabolism, reproduction); geophysical cycles (climatic, tectonic); astrophysical cycles (solar activity, orbital changes).

Keywords: modality, harmonics, synergy, natural processes, cycles

Volume 12 Issue 1 - 2026

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Received: February 28, 2026 | **Published:** April 1, 2026

Introduction

Synergistic processes in nature often have a **cyclical nature** and can be decomposed into harmonics:

* Population fluctuations (the "predator-prey" model) are described by nonlinear differential equations with periodic solutions.

* Climate changes contain harmonics of varying durations (Milankovitch cycles: ~ 20, 40, 100 thousand years).

* Biochemical oscillations (e.g., glycolysis) exhibit autowave processes.

Modality in this context manifests itself as:

* The existence of multiple stable regimes (attractors): for example, "drought" and "wet periods" in climate;

* Switching between regimes at bifurcation points (abrupt climate shifts);

* Hierarchy of time scales: fast harmonics (diurnal) modulate slow harmonics (seasonal).

Synergetic process with harmonics can be described by a system of nonlinear equations:

$$\frac{dx_i}{dt} = F_i(x_1, \dots, x_n) + \sum_{k} G_{ik} \sin(\omega_k t + \phi_k),$$ where:

* x_i — system state variables (temperature, concentration, abundance);

* F_i — nonlinear functions describing internal interactions;

* G_{ik} — amplitudes of external influences;

* ω_k — frequencies of natural cycles;

* ϕ_k — phases.

Example: climate model with the harmonic effect of solar activity:

$$\frac{dT}{dt} = -\alpha (T - T_0) + \beta \sin(\omega t),$$

where T is the temperature, T_0 is the equilibrium value, and α and β are the feedback parameters.

Examples in Nature

1. Biorhythms: Circadian rhythms (24-hour harmonics) interact with seasonal cycles (365 days), creating an "active/restful" modality.

2. Climate Oscillations: El Niño (ENSO, 2-7 years) modulates global weather patterns.

3. Ecosystems: Species abundance fluctuations (Lotka-Volterra cycles) with harmonics of different frequencies.

4. Geodynamics: Tectonic cycles (hundreds of millions of years) are superimposed on erosional processes (thousands of years).

Modality in the format of harmonics of synergistic processes" means:

* the existence of **several stable regimes** (modalities) of the system;

* their **periodic variability**, described by a set of harmonics;

* **nonlinear interaction** between harmonics of different scales (e.g., the influence of solar activity on climate);

* **transitions between modalities** at bifurcation points under the influence of fluctuations or external cycles.

This approach allows us to analyze natural systems as synergy of interconnected oscillators, where modality defines the alphabet of possible states, and harmonics define the "grammar" of their change over time.[1–8]

Synergy of natural processes

Synergy of natural processes is the coordinated interaction of these processes, leading to the emergence of new qualities, structures, or systems. It manifests itself at various scales—from the cellular level to ecosystems and the biosphere as a whole. This interconnectedness ensures the dynamics, stability, and evolution of living and nonliving systems. Synergy in the context of natural processes means that the result of their combined action is not equal to the sum of their individual effects. This creates new properties of the system that cannot be predicted based solely on an analysis of individual components. In ecosystems, the constant renewal of populations and the disappearance of older individuals maintains biodiversity and community stability.

1. **In biology and ecology**:

* **Succession** is the sequential replacement of communities of organisms in an ecosystem. The death of older individuals or the destruction of part of the ecosystem (for example, after a fire or deforestation) creates conditions for the emergence of new species. Pioneer species prepare the environment for subsequent, more complex communities, which ultimately leads to the formation of a climax biocenosis—the most stable state.

* **Predator-prey dynamics**. An increase in prey numbers leads to an increase in the number of predators, which, in turn, decreases the prey population. This cyclical interaction maintains balance in the ecosystem and prevents the dominance of a single species.

* **Microevolution and speciation**. The death of individuals unadapted to changing conditions and the birth of new, more adapted ones underlies natural selection and the evolution of species.

2. **In physics and chemistry**:

* **Nuclear reactions**. The creation of new elements and particles as a result of nuclear fission is accompanied by the "death" of the original atoms. This creates chain reactions that can maintain the stability of stars or lead to supernova explosions.

* **Cycle of substances**. The decomposition of organic matter (death) provides nutrients for new organisms (birth). For example, the activity of decomposers (fungi, bacteria) converts dead organic matter into mineral compounds, which are absorbed by plants.

3. **In the biosphere**:

* **Oxygen balance**. Photosynthesis (the process of "birth" of oxygen) and respiration of living organisms, as well as the decomposition of organic matter (processes associated with "death"), are in dynamic equilibrium. In a mature ecosystem, these processes are balanced, maintaining a stable oxygen concentration in the atmosphere.

* **Mortmass and living biomass**. The predominance of synthesis over the decomposition of organic matter indicates the development of the biosphere. An increase in mortmass (the stock of dead organic matter) indicates that the rate of biosynthesis has exceeded the rate of decomposition throughout the history of the biosphere.

Mathematical models:

* **Birth-Death Model (BD Model)**. Describes population dynamics, where the key parameters are the speciation rate (births) and the extinction rate. The net diversification rate (S - E, where S is the speciation rate, E is the extinction rate) determines whether the system will evolve, remain stable, or decline.

* **Logistic Equation**. Takes into account resource limitations and intraspecific competition. Initially, when the population size is small, exponential growth is observed, then growth slows due to competition for resources, and the system reaches a constant level (the carrying capacity of the ecological niche).

Lotka-Volterra Model ("Predator-Prey"). Describes the cyclical dynamics of interacting species, where an increase in prey abundance stimulates an increase in the number of predators, which subsequently reduces the prey population.

Synergy ensures:

* **System stability**. Continuous renewal and removal of obsolete elements prevents stagnation and collapse. * **Evolution**. Natural selection, based on the death of the unadapted and the birth of the adapted, leads to the development of new life forms.

* **Cyclicity and rhythm**. The alternation of phases of growth, maturity, and decay creates rhythms that are observed at all levels—from the cellular cycle to seasonal changes in ecosystems.

Thus, synergy is a fundamental principle of nature's organization, underpinning its dynamics, evolution, and stability.

The formation of natural cycles by processes of various entities

The formation of natural cycles by processes of various entities is a fundamental mechanism for maintaining balance in the biosphere and geosystems. These cycles ensure the continuity of life, the redistribution of energy and substances, and the evolutionary development of systems. They manifest themselves at various levels—from the individual life cycle of organisms to global biogeochemical and geological cycles.

Life cycles of organisms

A life cycle is the sequence of all stages of an organism's individual development from its inception to natural death or new division. The biological significance of such a cycle is to ensure the continued existence of the species. At the heart of any life cycle is the alternation of nuclear phases, which determines key moments in development—from the formation of reproductive cells to the emergence of offspring. Life cycles are divided into **simple** and **complex**:

* **Simple**—the new generation is similar to the parent and develops without intermediate stages. For example, in freshwater hydras, planarians, and earthworms.

Complex — include the alternation of different generations or developmental phases. For example, in plants, there is a regular alternation of sporophyte and gametophyte, while in insects, there is metamorphosis (egg → larva → pupa → imago). The death of an individual in the life cycle does not mean the end of the cycle — it ends with reproduction, after which the process is repeated in a new generation.

Succession and ecosystem dynamics

Succession is the sequential replacement of one community of organisms by another in a given area of the environment. It can be caused by both natural (climate change, pest outbreaks) and anthropogenic factors. Successions are classified as:

* **Primary** — begin on a substrate virtually unaltered by the activity of organisms (rocks, sand, cliffs).

* **Secondary** — the sequential replacement of one community by another on a pre-existing substrate. [

An example of succession is the overgrowing of a lake with plants from the shores to the center, which can ultimately lead to the lake's transformation into a peat bog.

Periodic disturbances of allogenic factors (e.g., catastrophes) can cause **cyclical successions**, in which the ecosystem recovers after a disturbance using accumulated reserves of organic matter.

Biogeochemical cycles

Biogeochemical cycles are the circulatory movement of chemical elements between the abiotic environment and living organisms. Mineral elements penetrate the tissues of plants and animals and, after their death, return to the environment, where they are redistributed and transformed.

Key cycles:

* **Carbon cycle**. Carbon dioxide is absorbed by plants during photosynthesis, converting it into organic compounds. During respiration and decomposition of organisms, carbon is returned to the atmosphere. Some carbon accumulates in fossil fuels, limestone, and other forms.

* **Nitrogen cycle**. Atmospheric nitrogen is fixed by microorganisms (e.g., root nodule bacteria) and converted into forms available to plants (nitrates, ammonium). Plants use these compounds to synthesize proteins, which are decomposed by decomposers after the death of the organisms. Denitrifying bacteria return the nitrogen to the atmosphere.

* **Phosphorus cycle**. Phosphorus is found in phosphate rocks. When they are destroyed or washed away, phosphates enter the soil or water, are used by plants, and after the death of the organisms, can be re-entered into the cycle.

These cycles are not completely closed—some elements are removed from them and accumulated in a "reserve fund" (for example, carbon in coal).

Sedimentogenesis is the totality of processes that form and alter geological sediments through the reworking of pre-existing rocks. It includes three stages:

1. Mobilization of material in the weathering crust.

2. Transport of material by water, wind, ice, or gravity.

3. Sedimentation of material in final bodies of water or on land.

The sediment is then gradually transformed into sedimentary rock through diagenesis.

Interconnected processes

The birth and death of organisms, successions, biogeochemical, and geological cycles are interconnected. For example:

* The decomposition of dead organic matter (mortimass) supplies nutrients to the soil, nourishing new generations of plants.

* Mass die-offs of species in an ecosystem can lead to population booms of other species and changes in community structure.

* Geological processes (e.g., volcanic activity) influence the composition of the atmosphere and, consequently, biogeochemical cycles.

Thus, the processes of birth and death ensure a dynamic equilibrium in nature, allowing systems to adapt to change and evolve.

Dynamic resilience of natural cycles

Dynamic resilience is the ability of a system to maintain functioning and return to equilibrium after being impacted by disturbances, without becoming static, but by adapting through internal changes. In the context of natural cycles, this means that ecosystems can withstand external influences and recover through internal self-regulation mechanisms.

Key Mechanisms of Dynamic Resilience

1. **Homeostasis** — the ability of a system to maintain a stable state through feedback. For example, the regulation of body temperature in mammals or the maintenance of pH balance in water bodies.

2. **Biogeochemical cycles** (carbon, nitrogen, water, etc.) — ensure the circulation of substances, allowing ecosystems to process waste and renew resources.

3. **Biodiversity** — the higher the diversity of species, the more likely a system will find a way to compensate for impacts (for example, replacing one pollinator with another when it disappears). 4. Le Chatelier-Brown principle: when exposed to external influences, the system shifts in a direction that weakens the effect of that influence. For example, increased photosynthesis with increasing atmospheric CO2 concentrations.

5. Hierarchical organization: the interaction of subsystems of different scales (from microorganisms to biomes) creates multi-level protection against failures.

6. Cyclicity of processes: natural fluctuations (seasonal, long-term) provide a "safety margin," allowing the system to adapt to periodic stresses.

Examples of natural cycles and their resilience

1. Carbon cycle:

* Resilience: forests and oceans absorb up to 60% of anthropogenic CO_2 emissions.

* Disturbance: deforestation and burning fossil fuels disrupt the balance, leading to the greenhouse effect.

2. **Water Cycle**:

* **Resilience**: Evaporation, condensation, and precipitation maintain freshwater distribution.

* **Disturbance**: Drainage of wetlands (85% loss of wetlands over 300 years) reduces the ability of ecosystems to store water and carbon.

3. **Nitrogen and Phosphorus Cycles**:

* **Resilience**: Microorganisms fix atmospheric nitrogen, making it available to plants.

* **Disturbance**: Excess fertilizer leads to eutrophication of water bodies (only 9% of nitrogen and 13% of phosphorus are recycled).

4. **Biodiversity Cycle**:

* **Resilience**: Mutualistic relationships (pollinators and plants) ensure the reproduction of species. * **Disruption**: Pollinator decline threatens food security (the market for pollination-dependent crops is $235–$577 billion).

Citation: Bryndin E. Modality in format of harmonics of synergetic processes and cycles of nature. *Int Rob Auto J.* 2026;12(1):54‒62.
DOI: 10.15406/iratj.2026.12.00317

Factors threating dynamic resilience

* **Anthropogenic Impact**:

* Resource extraction beyond the resilience of ecosystems;

* Chemical pollution (350,000 compounds in circulation, 70,000 of which have been registered in the last decade);

* Landscape changes (urbanization, agriculture).

* **Climate Change**: Shifting seasonal cycles, extreme events (droughts, floods).

* **Invasive Species**: Displacement of native species disrupts established ecosystem connections.

####To describe dynamic stability, the following are used:

* **Differential equations** (e.g., Lotka-Volterra models for predator-prey):

* **Response functions** (sine/cosine functions for cyclic processes):

* **Quadratic functions** for assessing tipping points:

Pathways to restoring stability

1. **Regenerative Economy**: implementing closed cycles (e.g., recycling waste into resources).

2. **Biodiversity Conservation**: creating nature reserves, restoring habitats.

3. **Sustainable Land Use**: agroforestry, organic agriculture.

4. **International Agreements**: adhering to planetary boundaries (carbon budgets, limiting chemical pollution).

5. **Monitoring and Forecasting**: using models to assess risks (e.g., quasi-attractor analysis in biosystems).

Conclusion: The dynamic stability of natural cycles is the result of a complex interaction of self-regulation mechanisms. Maintaining this stability requires reducing anthropogenic pressure and transitioning to development models that take into account the natural limitations of the biosphere.

Harmonic cycles of natural processes

Harmonic cycles of natural processes are associated with periodic oscillations that can be described using harmonic functions (sine, cosine). Harmonic oscillations are processes in which a physical quantity changes over time according to the sine or cosine law. In nature, such oscillations often occur in simplified or modified forms, while real-world processes often represent a superposition of several harmonic oscillations or contain additional components.

Mathematical Basis

Harmonic oscillations are described by an equation of the form:

x = A \cos(\omega t + \phi),

where:

*x is the deviation from the equilibrium position;

*A is the amplitude (maximum deviation);

*omega is the angular frequency;

*t is the time;

*phi is the initial phase.

For a system in which energy is not dissipated, the differential equation for the free oscillations of a harmonic oscillator is:

x + \omega_0^2 x = 0,

where x is a variable describing the state of the system (displacement, charge, etc.), and omega is the natural frequency of oscillation.

Examples of harmonic processes in nature

1. **Pendulum oscillations** are a classic example of harmonic oscillations. For small deviations from the equilibrium position, the pendulum's motion obeys the harmonic law.

2. **Sound waves** propagate in a medium as harmonic pressure oscillations.

3. **Electromagnetic oscillations**: in an oscillatory circuit (for example, in an LC circuit), the charge on the capacitor and the current in the coil vary harmonically. [

4. **Tides** — periodic fluctuations in sea level caused by the gravitational influence of the Moon and Sun — can be approximately considered harmonic.

5. **Biological rhythms** — some biological processes (e.g., circadian rhythms) are periodic and can be modeled using harmonic functions.

Using harmonics in the analysis of natural cycles

Many natural processes are not strictly harmonic, but they can be decomposed into a sum of harmonic oscillations using the **Fourier series**. This mathematical tool allows one to represent a periodic signal as the sum of sine and cosine functions with different frequencies, amplitudes, and phases.

Harmonic analysis is used to study:

* **Climate cycles** — fluctuations in temperature, precipitation, and solar activity. For example, cycles of 7-11 years, 20-47 years (Brickner cycles), and secular fluctuations (60-90 years) have been identified.

* **Geological processes** — tectonic movements, volcanic activity, sea level fluctuations. These are believed to be linked to cosmic factors, such as the influence of planets in the solar system.

* **Biological populations** — fluctuations in species abundance. The Lotka-Volterra model, which describes the interaction of predators and prey, leads to periodic fluctuations that can be associated with harmonic oscillations.

* **System complexity** — many natural processes are multidimensional and require consideration of multiple interrelated parameters. Therefore, scientific research often uses more complex models that include nonlinear equations, stochastic (random) components, and numerical modeling methods.

Harmonic processes form the basis for their mathematical description and analysis. This allows us to identify periodicities, predict changes, and better understand the dynamics of complex systems.

Describing natural processes with harmonic-based formulas

Let's consider the theoretical basis for describing natural processes with harmonic-based formulas, focusing on the mathematical apparatus and practical steps.

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Theoretical Basis: Fourier Series

Harmonic analysis is based on the **Fourier series**—the expansion of a periodic function f(t) with period T into a sum of harmonic oscillations (sines and cosines):

f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \left(a_n \cos(n \omega t) + b_n \sin(n \omega t) \right), where:

* omega = \frac{2\pi}{T} is the fundamental angular frequency;

* a_0 is the constant component (the average value of the function over the period);

* a_n, b_n are the Fourier coefficients for the nth harmonic.

Calculating fourier coefficients

The coefficients are calculated using the following formulas:

1. DC component:

a_0 = \frac{2}{T} \int_{0}^{T} f(t) \, dt.

2. Coefficients for cosine harmonics:

a_n = \frac{2}{T} \int_{0}^{T} f(t) \cos(n \omega t) \, dt.

3. Coefficients for sine harmonics:

b_n = \frac{2}{T} \int_{0}^{T} f(t) \sin(n \omega t) \, dt.

Complex form of fourier series

It is more convenient to work with the complex form using Euler's formula e^{i\theta} = \cos \theta + i \sin \theta:

f(t) = \sum_{n=-\infty}^{\infty} c_n e^{i n \omega t},

where the complex coefficients are:

c_n = \frac{1}{T} \int_{0}^{T} f(t) e^{-i n \omega t} \, dt.

Relationship between the coefficients:

* c_0 = \frac{a_0}{2};

* c_n = \frac{a_n - i b_n}{2} for n > 0;

* c_{-n} = \frac{a_n + i b_n}{2.

Practical steps for developing formulas

Step 1. Defining the function and period

Specify the function f(t) to be expanded and its period T.

Step 2. Calculating the coefficients

Calculate a_0, a_n, b_n (or c_n) using the formulas above. For complex functions, numerical integration is used.

Step 3. Selecting the number of harmonics

In reality, the series is truncated to N harmonics:

f_{\text{approx}}(t) \approx \frac{a_0}{2} + \sum_{n=1}^{N} \left(a_n \cos(n \omega t) + b_n \sin(n \omega t) \right).

The larger N, the more accurate the approximation, but the more complex the formula.

Step 4. Converting to an amplitude-phase form

It is often more convenient to represent the result in terms of the amplitudes A_n and phases \varphi_n:

f(t) \approx \frac{a_0}{2} + \sum_{n=1}^{N} A_n \cos(n \omega t + \varphi_n), where:

* amplitude of the n-th harmonic: A_n = \sqrt{a_n^2 + b_n^2};

* phase of the n-th harmonic: \varphi_n = -\arctan\left(\frac{b_n}{a_n}\right).

Step 5. Checking Accuracy

We estimate the approximation error, for example, using the standard deviation:

\sigma = \sqrt{\frac{1}{T} \int_{0}^{T} \left[f(t) - f_{\text{approx}}(t) \right]^2 dt}.

If sigma is too large, increase N.

Calculation tools

* **Analytical**: in computer algebra systems (Mathematica, Maple).

* **Numerical**:

* MATLAB/Octave: `fft` (fast Fourier transform), `ifft` functions;

* Python: `numpy.fft` library;

* Excel: Analysis Package (Fourier analysis).

* **Non-periodic signals**: use the **Fourier integral** or windowed Fourier transform.

* **Discrete data**: use **Discrete Fourier Transform (DFT)** or **Fast Fourier Transform (FFT)**.

Spectral modality in AGI

Spectral modality in AGI is a blend of concepts from different fields. Let's take a closer look.

1. **Spectral Data Analysis** in AGI:

* signal processing using the Fourier transform ($\mathcal{F}$), wavelet analysis ($\psi(t)$), and other spectral methods;

* frequency component extraction in audio, video, and sensory data;

* noise filtering using spectral filters.

2. **Spectral-enhanced Multimodality**:

* integration of a larger number of modalities (text, sound, image, tactile data, biosignals);

* smooth transitions between modalities—like a spectrum from one to another;

* weighting the contribution of modalities using spectral-like activation functions.

3. **Spectrum of AGI cognitive functions**:

* distribution of computational resources among tasks (as a spectral energy distribution);

* dynamic switching between thinking modes: logic, intuition, creativity, planning;

* scaling the depth of reasoning: from shallow analysis to deep causal models.

4. **Spectral architecture of neural networks**:

* use of graph spectral convolutions;

* analysis of eigenvalues (λ_i) and eigenvectors (v_i) of attention matrices to assess model stability;

* spectral normalization of network weights to improve convergence and robustness.

Key components for implementation

To implement spectral modality, an AGI system must include:

* **Multimodal Encoder** — a unified mechanism for encoding different types of data (text, audio, video, tactile signals) into a common semantic space.

* **Dynamic Modality Router** — a module that:

* evaluates the relevance of each modality for the current task;

* allocates computing resources (e.g., activates "experts" in the Mixture of Experts architecture);

* adapts modality weights in real time.

* **Spectral Attention Mechanisms** — modifications of the Attention mechanism with:

* frequency analysis of queries/keys;

* filtering out irrelevant spectral components;

* highlighting dominant patterns in the data. * **Crossmodal learning** — models that:

* transfer knowledge across modalities (e.g., visual concepts into text);

* form a unified picture of the world based on heterogeneous data.

* **Adaptive architecture** — the ability to:

* add new modalities without complete retraining;

* scale processing depth (shallow/deep analysis);

* dynamically change network topology to suit the task.

Technical approaches and tools

| Component | Technologies and Methods | Objective |

| Modality Processing | Transformers (ViT, Whisper, BERT), Convolutional Networks (CNN), Recurrent Networks (RNN) | Unified Data Representation |

| Spectral Methods | Fourier Transform ($\mathcal{F}\{x(t)\}$), Wavelet Transforms ($\psi_{a,b}(t)$), Spectral Clustering | Frequency Response Analysis, Pattern Extraction |

| Architecture | Mixture of Experts (MoE), Dynamic Networks, Graph Neural Networks (GNN) | Flexible Resource Allocation, Task Adaptation |

| Training | Multi-task Learning, Meta-Learning, Reinforcement Learning (RL) | Knowledge Transfer, Rapid Adaptation |

| Evaluation | Cross-modal benchmarks (VQA, NLVR2), consistency metrics (CC, SIM) | Quality control of modality integration |

Practical application scenarios

1. **Autonomous Explorer**:

* Analyzes reflected light spectra to identify minerals;

* Compares acoustic signals with visual data for navigation;

* Makes decisions based on multimodal hypotheses.

2. **AGI Medical Assistant**:

* Combines MRI data (visual), ECG (time series), blood tests (structured data), and patient complaints (text);

* Identifies spectral markers of diseases (e.g., abnormal frequencies in ECG);

* Offers personalized treatment plans.

3. **Scientific Discovery System**:

* Processes scientific articles (text), experimental data (signals), and simulations (video);

* Reveals hidden patterns through spectral analysis of big data;

* Generates hypotheses for testing.

Challenges

* **Computational complexity** — spectral methods require significant resources (FFT: $O(N \log N)$, SVD: $O(N^3)$).

* **Modal synchronization** — aligning data with different sampling rates and semantics.

* **Interpretability** — it is difficult to explain how spectral components influence the solution.

* **Learning with a small number of examples** — the need to generalize based on limited multimodal experience.

* **Ethics and security** — risks of misuse of multimodal AGI (e.g., real-time biometric analysis).

Conclusion

"Spectral modality in AGI for:

Flexible integration of multiple modalities;

Use of spectral data analysis methods;

Dynamic allocation of cognitive resources.

Implementation will require the synthesis of:

Multimodal architectures (transformers, MoE);

Spectral algorithms (FFT, wavelets, spectral clustering);

Adaptive learning methods (meta-learning, RL).

Spectral modality of the Universe representation by ASI systems

The spectral modality of the Universe representation by ASI systems relies on and connects key concepts.

1. Spectral Representation

In mathematics and physics, a **spectral representation** (or spectral decomposition) is a way of describing complex objects through a set of basic elements. A classic example is the **Fourier series**: any periodic signal $f(t)$ can be represented as a sum of sinusoidal oscillations of different frequencies:

f(t) = \frac{A_0}{2} + \sum_{n=1}^{\infty} A_n \cos(n \omega_1 t + \phi_n), where:

* A_n is the amplitude of the nth harmonic (amplitude spectrum);

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* \phi_n is the initial phase of the nth harmonic (phase spectrum);

* \omega_1 — the fundamental frequency.

Key characteristics of the spectral approach:

* decomposition of the complex into the simple;

* use of orthogonal basis functions (sines, cosines, wavelets, etc.);

* the ability to reconstruct the original object from the spectrum.

Modality

1. In logic and philosophy - the attitude of the statement to the reality

2. In ASI - the type of data (visual, audial, textual modality).

3. In physics - the type of oscillations or waves in the system (for example, modes of a resonator).

Spectral modality unites these meanings: different "modes" (types) of the spectral description of the Universe.

3. ASI systems can represent the Universe spectrally.

Intelligent ASI cognitive architectures can use spectral methods to model and analyze the universe at different levels:

3.1 Levels of spectral representation

Physical level:

* spectral analysis of electromagnetic radiation (from radio waves to gamma quanta);

* acoustic modes in the early universe (baryon acoustic oscillations);

* gravitational waves as a "spectrum" of space-time curvature.

Mathematical level:

* decomposition of the space-time metric into spherical harmonics (for example, analysis of the anisotropy of the relic radiation);

* Wavelet analysis of the large-scale structure of the universe;

* Operator spectra in quantum cosmology.

Cognitive level (how AI "understands" the universe):

* Graph spectral embeddings for modeling physical laws;

* Spectral methods in reinforcement learning (analysis of event frequencies);

* Multimodal spectral representations (combining visual, textual, and numerical data).

Spectral modality ASI

Spectral Modality ASI is a **way of representing and interpreting the Universe through different spectral decompositions, where each "mode" corresponds to:

* a specific physical scale (quantum, astronomical, cosmological);

* a type of data (electromagnetic spectrum, gravitational waves, neutrinos);

* a mathematical basis (Fourier, wavelets, spherical harmonics);

* a level of abstraction (empirical observations, theoretical models, simulations).

Properties of this modality:

* **multi-layered**: different spectra complement each other (for example, optical and radio data);

* **hierarchical**: low-frequency modes describe global properties, while high-frequency modes describe details;

* **adaptive**: intelligent systems can choose the optimal basis for a given task;

* **predictive**: analyzing spectral changes over time allows for predicting the evolution of systems.

Practical application

* **Analysis of the relic radiation**: temperature fluctuations \Delta T(\theta, \phi) are expanded in spherical harmonics Y_{lm}(\theta, \phi):

\Delta T(\theta, \phi) = \sum_{l=2}^{\infty} \sum_{m=-l}^{l} a_{lm} Y_{lm}(\theta, \phi).

The power spectrum C_l = \langle |a_{lm}|^2 \rangle contains information about the geometry and composition of the universe.

* **Neural networks with spectral layers**: using Fourier or Laplace transforms within neural network architectures to analyze time series (e.g., predicting the evolution of cosmological parameters).

* **Spectral graph networks** (Spectral Graph Networks): modeling particle or galaxy interactions through graph Laplacian spectra.

ASI intelligent systems with spectral modality support can:

Automatically classify astronomical objects by their emission spectra;

*Reconstruct the history of the universe from data on the cosmic microwave background;

* To model quantum gravity through the spectra of geometric operators;

* To optimize the search for exoplanets through the analysis of star spectra.

Conclusion

Spectral modality of the Universe representation is a powerful approach that combines the mathematical apparatus of spectral analysis with the capabilities of intelligent systems. It allows us to:

* Structure information about the Universe at all scales;

* Identify hidden patterns through decomposition into basis functions;

* Create adaptive models that can learn from multimodal data.

This approach is particularly promising for cosmology, astrophysics, and fundamental physics, where processing vast amounts of data is required, taking into account their multi-scale nature.

Conclusion

Representing the living information of the entities of the Universe through harmonic modality provides a holistic picture of the Creator from self-organizing structures (from atoms to galaxies); feedback processes (evolution, homeostasis); and systems capable of transmitting and processing information (DNA, neural networks,

Citation: Bryndin E. Modality in format of harmonics of synergetic processes and cycles of nature. *Int Rob Auto J.* 2026;12(1):54‒62.
DOI: 10.15406/iratj.2026.12.00317

star clusters).[9–11] Harmonic modality uses harmonic oscillations as a descriptive language:

* each entity has a "frequency portrait"—a set of resonant frequencies;

* entities interact through harmonic resonance/interference;

* the hierarchy of structures corresponds to the hierarchy of harmonics (fundamental frequency + overtones).

The Universe exhibits harmonious patterns at all levels:

* **atomic level**: electrons in atoms have discrete energy levels corresponding to quantized radiation frequencies $E_n = h \nu_n$, where h is Planck's constant, ν_n is the frequency;

* **molecular level**: the vibrational spectra of molecules are described by harmonic oscillators with frequencies $\omega = \sqrt{\frac{k}{m}}$, where k is the bond stiffness and m is the reduced mass;

* **astronomical level**: orbital resonances of planets (e.g., the period ratio of Jupiter's satellites is 1:2:4), stellar pulsations;

* **cosmological level**: the cosmic microwave background radiation with its acoustic peaks in the power spectrum, reflecting primordial density fluctuations.

Any complex system can be expanded in a Fourier series in harmonics:

$f(t) = a_0 + \sum_{n=1}^{\infty} \left(a_n \cos(n \omega t) + b_n \sin(n \omega t) \right)$, where:

* a_0 is the mean value (constant);

* ω is the fundamental frequency;

* a_n, b_n are the harmonic amplitudes.

For spatial structures, the multidimensional Fourier transform is used:

$F(\mathbf{k}) = \int f(\mathbf{r}) e^{-i \mathbf{k} \cdot \mathbf{r}} \, d^3\mathbf{r}$,

where $\mathbf{k}$ is the wave vector characterizing the spatial frequency.

1. **Biological systems**:

* Neural activity of the brain (alpha, beta, and gamma rhythms with frequencies of 8–13 Hz, 13–30 Hz, 30–100 Hz);

* circadian rhythms (approx. 24 hours) as a biological clock;

* DNA as a "record" of genetic information in a nucleotide sequence, which can be represented as a frequency spectrum.

2. **Astrophysical Systems**:

* Pulsars — neutron stars emitting regular pulses with periods from milliseconds to seconds;

* Solar oscillations (helioseismology) with periods of ~ 5 minutes;

* Spiral arms of galaxies formed by density waves with characteristic spatial harmonics.

3. **Quantum Systems**:

* Energy levels of atoms and molecules described by quantum numbers and corresponding transition frequencies;

* Phonons in crystals — quantized lattice vibrations with the dispersion relation $\omega(k)$.

4. Representation Schema

| Level of the Universe | Essence | Fundamental Harmonic | Overtones (Higher Harmonics)

| Quantum | Electron in an Atom | Transition Frequency $1s \to 2p$ | Lyman, Balmer Series |

| Molecular | C–H Bond Vibrations | ~ 3000 cm^{-1} | Combination tones |

| Cellular | Membrane potential | ~ 100 mV (pulse) | Ion currents Na^+, K^+ || Body | Heart rate | 1 Hz (60 bpm) | Heart rate variability |

| Planetary | Earth's rotation | 24 hours | Tides ($12{.}4$ hours) |

| Stellar | Cepheid pulsations | 1–100 days | Brightness harmonics |

| Galactic | Arm rotation | ~ 200 million years | Spiral structure |

5. Principles of information encoding by harmonics

1. **Frequency separation**: different types of information are transmitted at different frequencies (like radio waves).

2. **Phase synchronization**: phase coherence between harmonics encodes complex patterns (e.g., coherent states in the brain).

3. **Amplitude modulation**: changing the amplitude of a harmonic carries information (as in AM radio).

4. **Nonlinear interactions**: frequency combinations ($\omega_1 \pm \omega_2$) create new information channels.

Representing living information through harmonic modality offers a universal language for describing the Universe—from quantum fluctuations to galactic structures. Each entity has a unique "frequency passport" determined by:

* fundamental resonant frequency;

* overtone spectrum;

* phase relationships between harmonics;

* modulation dynamics over time.

This approach unites physics, biology, and computer science, allowing us to see the Universe as a gigantic symphony orchestra, where every particle, cell, and star plays its part in the overall harmony.

The essence of the Universe can be represented as harmonics. The spectral form of harmonics is described by Fourier functions. By transforming the Fourier functions, a hologram of the spectral form can be obtained. The hologram can be digitized using a large data set displaying the interrelationships of harmonics. AGI, by analyzing large volumes of data, will be able to predict future processes and phenomena on a cosmic scale.

The harmonic modality allows us to represent living information from various entities of the Universe in AGI and ASI systems at the micro and macro levels of natural processes, and to create super-intelligent research models capable of finding solutions to complex scientific and technical problems.[12–16]

Acknowledgments

None.

Conflicts of interest

Author declares there is no conflicts of interest.

References

1. Kröger B. Hermann Haken: from the laser to synergetics: a scientific biography of the early years. Cham: Springer, 2015.
2. Konyukhov NI. Cosmic energies and humanity: cycles, bifurcation points, development / N. I. Bamkon Scientific Center. – Moscow; 2019. 369 p.
3. Chernavsky SD. Synergetics and information. Dynamic information theory. Publishing stereotype. 2021. 304 p.
4. Evgeny Bryndin. Formation and development of scientific knowledge and research to the use of natural technologies. *Journal of Advanced Research in Education.* 2023;2(4):1–5.
5. Tsiolkovsky K. E. The Will of the Universe. EKSMO. 2024. 576 p.
6. Evgeny Bryndin. Noospheric technology of interpersonal communication using AI. *Journal of Progress in Engineering and Physical Science*. 2025;4(2):11–15.
7. Evgeny Bryndin. Formation and manifestations of natural human intelligence under the influence of the Universe. *American Journal of Neural Networks and Applications*. 2025;11(2):51–57.
8. Evgeny Bryndin. Towards Continuous Changes through Interacting Processes with Synergetic Self–Regulation according to the Law of Harmony. *ShodhSamajik: Journal of Social Studies*. India. 2025. p. 29–38.
9. Evgeny Bryndin. Modeling of creative and professional activities by ensembles of intellectual agents based on live information. *International Journal of Artificial Intelligence and Mechatronics (IJAIM).* 2022;10(4):44–50.
10. Evgenii Brindin. Synergy of clear consciousness, quantum brain, and spatial extrasensory soul as research toolkit. *Studies in Psychological Science*. 2026;4:1.
11. Evgeny Bryndin. Living information of the creator in the control of change and movement of entities of the Universe for the science of the future. *Journal of Modern Classical Physics & Quantum Neuroscience*. 2026;2(2).
12. Evgeny Bryndin. Automated Analytics by Models of Brain based on Big Information and Artificial Intelligence. *Journal of Artificial Intelligence and Emerging Technologies*. 2025;2(120):7–16.
13. Tsaregorodtseva RE, Vazhdaeva KV, Martyasheva VA. Automated control systems for natural processes and phenomena through the prism of cognitive modeling. *Alternative Energy and Ecology (ISJAEE)*. 2025;7:142–159.
14. Raymond John Uzwyshyn. Harnessing AI for research: 2025 GenAI large language model introduction: AGI and reasoning models, multimodal models and deep research with autonomous agents. Conference: University of California Riverside, Orbach Science Library AI Series. 2025.
15. Evgeny Bryndin. Neural network axiomatic solver coaching AGI method for solving scientific and practical problems. *International Robotics & Automation Journal*. 2025;11(2):60–69.
16. Evgeny Bryndin. Spatial generative multimodal dynamic AGI as model of consciousness. *International Robotics and Automation Journal*. 2026;12(1):6–16.