Axiomatic Energy Balance in Spacetime and Quantum Path Analysis

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Abstract

This document introduces an axiomatic framework describing the energetic structure of the universe, founded on spatial-temporal symmetry and conservation. It proceeds with theoretical derivations related to quantum particles such as photons and electrons, exploring how deviations from global energy balance can manifest as local information or path dependencies, and how entangled particles may serve as probes for universal local and temporal asymmetries. These considerations might lead to a method of measuring the structure of the universe on basis of the current influence of the total interacting universe onto the local space-time.

1 Axiomatic Structure of Universal Energy Symmetry

This section introduces three foundational axioms which define the energetic balance of the universe through space and time. The formulation is both mathematical and philosophical, reflecting an interpretation of reality as a temporally and spatially symmetric continuum. As a starting point we give some views on the practical limits of dynamic field integration calculations with the methods of classical physics.

1.1 Limitations of Classical Field Modeling

Classical field theory often assumes static energy fields and well-defined spatial paths. However, this idealization becomes problematic when applied to dynamic or quantum contexts.

1. Closed Line Integrals in Static Fields

Consider a closed spatial loop C of finite length evaluated at a fixed time $t = 0$ within a completely static energy density field $\rho(\vec{r})$:

$$\oint_C \nabla\rho(\vec{r}) \cdot d\vec{r} = 0 \tag{1}$$

Limitation: This identity initially holds only under the assumption of a perfectly time-invariant field. The time dimension is neglected ($\Delta t = 0$), which is an unrealistic simplification for real-world scenarios. This is identical to the assumption, that the state of a field is known along the path at the exact same point in time. As this can not be measured in practice we nevertheless use this concept to represent ideas and views which can be expressed with such formulas.

2. Temporal Integrals at a Fixed Location

Similarly, we can define a time-integral of the gradient field at a fixed point in space:

$$\int_{t_0}^{t_1} \nabla\rho(\vec{r}_0, t)\, dt \tag{2}$$

Limitation: There is no truly fixed location in space — not even relatively. Due to both relativistic and quantum effects, no particle can remain exactly at $\vec{r}_0$ over time. Thus, even this integral becomes a useful abstraction rather than a physical reality.

3. The Illusion of Closed Paths in Spacetime

In dynamic energy fields, every segment $\Delta\vec{r}$ and every moment Δt modifies the energy structure experienced by the particle. Therefore, a closed spacetime loop — returning to the same energy conditions — does not exist in practice.

Observation: After traversing a full loop, the object is always at a new spacetime coordinate — either in space, time, or both. The result of the integral reflects not cancellation, but the difference in energy potential between the start and end states:

$$\int_{\Gamma} \nabla\rho(\vec{r}(t), t) \cdot d\vec{r} \neq 0 \tag{3}$$

4. Comparison of Multiple Paths Between Two Events

Let two paths Γ_1 and Γ_2 connect the same spacetime events $pt_1 \to pt_2$. In classical field theory:

$$\int_{\Gamma_1} \nabla\rho(\vec{r}, t) \cdot d\vec{r} = \int_{\Gamma_2} \nabla\rho(\vec{r}, t) \cdot d\vec{r} \tag{4}$$

But in a dynamic field: Path-dependent energy accumulation becomes relevant. If an electron spirals around a heavy nucleus while another travels a direct route, their respective field interactions differ significantly. Even if both arrive at the same potential at the same time, quantum uncertainty makes perfect spatial-temporal identity impossible.

5. Quantum Perspective: Photon Entanglement as a Probe

In the case of photons, two entangled particles from a beam splitter or frequency halver can be guided through different spacetime routes. If successfully recombined at the same spacetime point, their interference patterns can reveal differences in their energetic history:

$$\Delta E = \int_{\Gamma_1} \nabla\rho_1 \cdot d\vec{r} - \int_{\Gamma_2} \nabla\rho_2 \cdot d\vec{r} \tag{5}$$

Such a result does not necessarily indicate a classical potential difference, but rather the influence of the underlying energetic texture of the universe on each path.

1.2 Reconsiderations for axiomatic modelling

Energy Conservation

Energetic Interpretation of Energy Density Integrals: The integrals over the energy density function considered here do not make any direct claim about the absolute magnitude of energy itself. The total energy may be arbitrarily large or small. Rather, these integrals indicate that the *energy level at the beginning and end of a path is identical* — either because the entire space is uniformly filled with a smooth energy field, or because the field converges into a single point of fixed potential.

The energy density also does not determine whether energy is positive or negative; it merely describes the *difference in energy* between two points in spacetime. A "negative valley" in the surface of the energy field relative to the initial and final potential still represents real, effective energy.

For the sake of clarity, we retain this visual interpretation even though the roton-model under consideration *does not rely on classical energy conservation.* In this framework, fundamental (not stable) waves in the underlying medium or in other words quantum fluctuations are also treated as a form of potential energy, and under certain obviously rare conditions, transitions between classical energy and quantum noise are permitted. And might - if they are not considered as part of the energy sum - lead to a potentially measured energy difference along some integration paths where energy (i.e. only photons in the roton-model) are created arbitrarily out of too high local quantum fluctuation intensity. Or vice-versa a photon might become destabilized and be drawn into a wave-pattern in the medium by a kind of temporal anti-photon at the same spacetime point as the photon.

1.3 Axiom I: Local Temporal Energy Balance

$$\forall \vec{r} \in \mathbb{R}^3 : \quad \int_{-\infty}^{+\infty} \nabla\rho(\vec{r}, t)\, dt = \vec{0} \tag{6}$$

Components:

- $\rho(\vec{r}, t)$: Energy density field at position $\vec{r}$ and time t
- $\nabla\rho$: Spatial gradient of the energy density
- $\vec{r} \in \mathbb{R}^3$: Any point in Euclidean space
- $t \in \mathbb{R}$: Time, treated as a continuous variable

Interpretation: At every location in space, the cumulative spatial tension (gradient) of energy density over the entire history of time sums to zero. This implies that each point experiences a complete energetic balance across all temporal states, with no lasting directional bias. This axiom implies not only, that the energy gradient cancels itself out *over the whole universe* but also for every single local point *over the whole time.* And as location only exists in a relative and not absolute view, this implies that the axiom holds for all chosen entangled paths across the universe.

Considerations: *Path integration* As stated before, there is no way to keep a tag at the same "spot in space" in the universe over any chosen time distance. So the integral of Axiom 1 actually integrates over any chosen continuous forward path of an infinitesimal point on its way from $-\infty$ to $+\infty$. This start and end formally described as infinity might be considered as actually being the same single point in space and time where everything started and everything ends. So we might consider $pt_{-\infty} = pt_{+\infty}$ either as a calculative simplification or a philosophical statement. So this basically summarizes to a statement regarding the energy potential $\phi()$ at the starting and ending point of the universe.

$$\phi(\vec{r}_0, -\infty) = \phi(\vec{r}_0, +\infty) \tag{7}$$

Wondering why the starting and ending point are the same ($\vec{r}_0 = \vec{r}_\infty$)? Well as this is the only location left there can not be any spacial difference between them.

Model variation - source gradient: Now wait, what about this:

$$\phi(\vec{r}_0, -\infty) = -\phi(\vec{r}_0, +\infty) \tag{8}$$

Not having anything to compare with, the difference of the potential is arbitrary and somewhere between 0 and inf

This model expresses, that there is a certain gradient between the starting and ending spot. So all stable waves and particles are simply more efficient transport vessels for energy through spacetime. So the higher the energy density the higher the efficiency of the universe and the faster the time flows. Or in short: no energy, no time. So any space with an energy gradient of zero should not experience any time. This does not mean that the space does not exist it just hangs in time until it experiences further changes in the energy gradient. Only energy and an energy-gradient starts to give time to a specific location (which might indeed not have existed before). We could consider any particle is a tube through the universe from the starting pod to the end pod transferring energy. Every rearrangement or transformation of energy and sub-particles is a mesh of tubes exchanging and balancing energy levels.

Why is this variation not much different from the original? Well as we consider it as being 0 or ∞ or having an arbitrary incomparable value anyway. So all the following consideration might hold in the same way for any local partition of the universe, where an actual linear energy gradient is present over longer distances and time.

Energy pressure differences This intermediate model might suggest, that adjacent energy levels might take several paths through spacetime to the next energy pod/level. Might this lead to a certain energy flow competition where energy preferably takes the biggest or steepest tube? This is not confirmed with "Communicating vessels" concepts.

Mutual Influence of Parallel Energy Paths In classical static fields, the gradient along a given energy path is determined solely by the field configuration and remains unaffected by the presence of alternative paths. However, in dynamic or reactive energy fields—where the flow of energy modifies the underlying field structure—this independence no longer holds.

If two spatially distinct paths connect the same energy reservoirs, and energy is allowed to flow through both, the activity along one path can alter the local energy landscape experienced by the other. This occurs through field deformation, energy pressure redistribution, or dynamic feedback effects. As a result, the gradient along the first path becomes a function of the total energy flow in the system, including contributions from parallel or competing routes.

In such systems, energy density is not a passive backdrop but an active participant, reshaped by the flow it hosts. Therefore, energy paths are no longer isolated; they are coupled through the field that binds them.

Path-Dependent Integrals in Dynamic Energy Fields As many people re-invent different wheels all the time the author realizes, that these thoughts of course have already been made in quantum physics.

In a classical, conservative field, the integral of the energy density gradient between two points is path-independent. That is, for any two paths Γ_1 and Γ_2 connecting the same endpoints:

$$\int_{\Gamma_1} \nabla\rho(\vec{r}) \cdot d\vec{r} = \int_{\Gamma_2} \nabla\rho(\vec{r}) \cdot d\vec{r}$$

This holds because the field is static, and energy flow does not influence the field itself.

However, in dynamic or reactive systems—where energy flow modifies the field structure—the situation changes fundamentally. If two distinct energy "channels" (paths or conduits) allow flow from a common source to a common sink, then usage of one channel can alter the energetic configuration experienced by the other. The gradients become time-dependent, and potentially even non-conservative.

Let:

$$I_1 = \int_{\Gamma_1} \nabla\rho_1(\vec{r}, t) \cdot d\vec{r}, \qquad I_2 = \int_{\Gamma_2} \nabla\rho_2(\vec{r}, t) \cdot d\vec{r}$$

In general, $I_1 \neq I_2$, even if the initial and final potentials are nominally identical. The difference encodes the history of local field deformation, back-reaction, or interference effects—concepts that resonate with field-coupling theories in quantum electrodynamics and general relativity.

This path dependence implies that energy transport is not merely a passive reading of a static field, but a process that actively reshapes the landscape it traverses. In such contexts, integrals over multiple routes serve not just as measurements of difference—but as witnesses to the structure and memory of the field itself.

Related Concepts: This behavior reflects ideas from:

- **Quantum field theory:** where particle interactions alter field vacuum states
- **Nonlinear electrodynamics:** where charge flow modifies the local field
- **Gravitational back-reaction:** in which moving masses distort the curvature they traverse

Predictions: This view might give some predictions regarding the behaviour of two entangled (therefore mostly identical) photons taking a different path over different energy gradients from one common point to another common point.

The Energy-Tube Model: Photon Lifepaths in the Energy Potential Landscape.

Einführung To visualize how a photon interacts with the structure of energy in spacetime, we consider the energy potential landscape as traversed by a single photon. We define the photon's path as an isolated *energy tube* — a one-dimensional conduit embedded in the larger field, connecting two local energy potential points. In the absence of interactions, the photon travels this tube without deviation, preserving its wave function in a confined energetic context.

Now consider the existence of *two* such energy tubes between the same potential points. The only known physical realization of parallel photon pathways is in the form of quantum entanglement. Two entangled photons may take distinct energetic paths to or from the same spatial-temporal coordinates. Because the photon is fundamentally a wave, the mere presence of two possible tubes alters the boundary conditions of its propagation. The wave function is shaped by the tube topology itself. This is the first key aspect: the photon does not merely traverse space, but co-defines the energetic geometry it travels through.

The second aspect concerns the photon's temporal nature. From the photon's own frame of reference — moving at the speed of light — time does not progress. It exists entirely at $t = 0$, stretched across space, but not across time. This implies that any change in the field configuration along the tube — even one occurring "in the future" — can retroactively affect the state of the photon as it emerges. In this sense, the photon's worldline is not a sequence, but a singular energetic identity. It is both the emission and the absorption event, simultaneously.

If, during propagation, the field geometry permits a bifurcation — a phenomenon we may call *tube splitting* — or a redefinition of the active energetic pathway — *re-tubing* — then the entire system enters a higher-order coupling state. The photon begins to interfere with its own alternatives across spacetime. This nonlocal entanglement persists as long as the system remains closed and no measurement or leakage collapses the wave function. Once collapse occurs, the energy system resolves, and the "lifecircle" of the photon — the closed energetic loop — is complete.

The Energy-Tube Model - SEINS and meins ergänzt An **energy tube** is defined as an energetically isolated path through spacetime connecting two points p_0 and p_1. Energetic isolation can be seen as adhering to the energy conservation principle while there is no interaction or exchange of energy with any other part of the system. The photon still travels through the energy potential field energetically (mostly) unaffected. A **coupled energy tube** is a second such path that begins and/or ends at the exact same spacetime coordinates, but potentially follows a distinct trajectory through the energy potential landscape.

These tubes can serve as a conceptual framework for understanding the behavior of photons — particularly entangled photons — in relation to their surrounding energy field.

Key Realization

The behavior of a photon - represented by one energy tube - may highly depend on whether a second coupled energy tube exists with an entangled photon. The coupled photons now share the same energy state along their whole tube-system and the behavior of both photons depends on which paths their tubes take through spacetime and where they start and end. The mere presence of an alternative, energetically valid path can influence the system as a whole — even in the absence of direct interaction.

Implications of Entangled Energy Tubes A starting and ending point is marked by any event, where energy is exchanged. And the energy state of the whole tube-system highly depends on the locations of these points within the energy potential field. The tube system might either have the shape of a tree or paths might also re-combine building some loops. Both topologies come with their own fascinating insights.

When two entangled photons propagate along different energy tubes and are eventually recombined, their interference behavior depends not only on their final meeting point, but on the history of their traversal. If one tube remains energetically isolated while the other suffers a "leak" no real loop remains as the recombined photons do not share the same energy level anymore. In general quantum physics such a situation is also called a collapse of the wavefuntion due to measurement or environmental disturbance — the entanglement is broken. This decoherence affects the wave behavior of the remaining photon, regardless of whether the two photons meet again in space-time. If they meet with different energy states this might be detected with a change in the interference behavior. This analogy describes the basis of quantum-cryptography where we can identify whether any of the photon has been measured on its way which will show a leak in the energy tube.

Leak-less joining Now we consider the situation where two coupled tube paths re-join with no leaks. This builds a real loop where photons sharing the same energy state recombine. According the quantum physic experiments this situation might lead to a distinct and distinguishable interference pattern.

The interesting part starts now if we try to compare these photons after having returned from two different paths through the energy field. Will there be a measurable difference in their behavior? Might a slight difference in phase, frequency or rotation axis be measurable? Is there any method to detect phase differences without adding a measurement leak to one path before re-combining the photons?

Key Conclusion:
Once entangled energy tubes are created, the collapse or leaks along one path (e.g., via measurement) modifies the energetic conditions experienced by the other. This change manifests independently of any spatial proximity between the two paths and may underlie what is commonly referred to as ”instantaneous”entanglement effects in quantum mechanics.

The Temporal Identity of Photons A photon, being a wave, can be thought of as a coherent energetic structure stretched across space — but with no passage of time from its own perspective. In its rest frame (which is undefined in relativity, but conceptually helpful), the photon exists entirely at $\Delta t = 0$. Thus, any change in the energy field along its path — even one occurring ”in the future” — is reflected instantly in its entire wave identity. So a superposed energy wave which emerges as a photon at some point along its lifespan is only aware of it’s energy exchanging processes during interaction with other particles (energy states) - as these processes seem to take some time for energy exchange and reforming (e.g. on level of electrons).

Extended Conclusion:
A photon remains energetically and temporally consistent across its isolated tube. As such, its creation and absorption events are not temporally separated, but part of a single extended structure. If its future path changes (e.g., via tube splitting or re-routing), the creation process itself is retroactively influenced. This forms the conceptual basis for entanglement in quantum physics: the photon’s identity is not bounded in time, and thus reacts as a whole to changes anywhere along its energy-preserving path.

1.4 Axiom II: Global Spacetime Energy Cancellation

$$\int_{\mathbb{R}^3} \left(\int_{-\infty}^{+\infty} \nabla \rho(\vec{r}, t)\, dt \right) d^3\vec{r} = \vec{0} \tag{9}$$

Interpretation: The total net energy-gradient vector across all space and time vanishes. This expresses the idea that while local fluctuations and tensions may exist, the universe as a whole is perfectly self-balancing. In view of Axiom (1) this might sound trivial as an integral over 0 seems to remain 0. This does not necessarily hold for superposed integrations though.

As a visualization, we may imagine the universe as an elastic membrane on which waves propagate. The underlying axiom implies that the boundaries of this membrane are fixed and held at the same reference level — for instance, zero. The mean energy potential of all oscillations across the surface remains balanced, centered around this baseline — i.e., zero.

1.5 Axiom III: Spacetime Integration Symmetry

$$\int_{\mathbb{R}^3} \left(\int_{-\infty}^{+\infty} f(\vec{r}, t)\, dt \right) d^3\vec{r} = \int_{-\infty}^{+\infty} \left(\int_{\mathbb{R}^3} f(\vec{r}, t)\, d^3\vec{r} \right) dt \tag{10}$$

Interpretation: The order of integration over space and time does not affect the result. This asserts a fundamental symmetry between space and time within the universe. Therefore we can either integrate the same spot over time or integrate the same time-period over different paths. The integration over the space-time as a whole remains 0.

2 Derivations: Energy Interaction and Quantum Particles

2.1 Fundamental Postulate: Temporal Integration Over a Non-Interacting linear Path

As an example we take the lifetime of a photon during a none-interacting path where no energy is exchanged with the surrounding.

$$\int_{\gamma(t)} \left(\int_{t_0}^{t_1} \nabla \rho(\vec{r}(t), t)\, dt \right) d\ell = \vec{0} \tag{11}$$

Interpretation: Along an idealized, interaction-free path, the local energy tension over time cancels. The photon's spacetime existence does not imprint or disturb the universal balance. This corresponds to a loop in time where the photon (experiencing a lifetime of 0 ns) during an undisturbed path and loop in time. This only holds if there is no interaction with any other form of energy along the given path. In practise the equation holds as long as the start and endpoint of the photon have the exact same energy level. This is a trivial fundamental equation holding for all physical fields.

2.2 Fundamental Postulate: Integration over a local loop

As an example we take the local path of an electron coming back to its "original" relative location during a local undisturbed rotation or loop with no energy exchange with its surrounding (presuming this would be possible). A local loop or path is regarded to (theoretically) match this equation, if the particle returns to any location in space time with the exact same energy level. This might seem as a trivial fundamental equation holding for all ideal physical fields, presuming the energy field is known at all positions in space-time.

$$\vec{\Delta E} = \int_{t_0}^{t_1} \nabla \rho(\vec{r}_0, t)\, dt = \vec{0} \tag{12}$$

2.3 Standard Integration over a Conservative Field

In standard field theory and computation retaining a energy conservation and symmetric field over space and time, this might sound trivial for all cases where the starting and end points are "the same". This is expressed in the formula (7) shown below. In a practical relativistic view though "the same place and time" is difficult to determine or measure. The only possible situation where this can be ensured is a photon which starts at a given place and time and after its life returns to the same path back in time to it's original location. This is expressed in other parts of the roton-model as the bi-temporal state of the photon.

$$\oint \nabla\rho \cdot d\vec{r} = 0 \tag{13}$$

2.4 Postulate: Rest Frame and Local Energy Imprint

Now lets come back to a real live situation observing an electron on its rotation around its nucleon e.g. in a H-Atom. This is a practical path where an electron return to its relative position with idealised no energy interaction with the bigger surrounding. Now in 4D space-time this corresponds to a spiral where the electron is not possible to return to its same space-time location. As the electron also rotates around the earth and in the universe it can not even return to its "absolute" same place. So even though the energy level might be assumed to be identical after one rotation, we are not exactly at the "same" position and might not be able to identify the energy level of this now position. So the former equation will result in a deviation from the postulated $\vec{0}$ vector. A deviation which might not be measurable though - having no measurable impact on local behaviour within an atom after this short time range.

$$\vec{\Delta E} = \int_{t_0}^{t_1} \nabla\rho(\vec{r}_0, t)\, dt \neq \vec{0} \tag{14}$$

Interpretation: The non-zero result indicates an energetic asymmetry: the electron interacts with its environment (e.g. the whole universe) and leaves a trace in the spacetime field structure.

2.5 Local Non-Commutativity: Path Dependence of Integration

Starting from Axiom 3 we look at the equation integrated over a limited path in space-time. Even if we return to the same relative or even absolute path are we sure the order of integration over space and time is symmetric?

$$\int_\Omega \left(\int_{t_0}^{t_1} \nabla\rho(\vec{r}, t)\, dt \right) d^3\vec{r} \neq \int_{t_0}^{t_1} \left(\int_\Omega \nabla\rho(\vec{r}, t)\, d^3\vec{r} \right) dt \tag{15}$$

Interpretation: This non-commutativity reflects a local asymmetry of energetic flux in spacetime — a "dynamical wrinkle" in the universal fabric.

2.6 Entanglement as a Spacetime Correlation Probe

$$\vec{I}_1 = \int_{\gamma_1} \left(\int_{t_0}^{t_1} \nabla\rho(\vec{r}_1(t), t)\, dt \right) d\ell, \quad \vec{I}_2 = \int_{\gamma_2} \left(\int_{t_0}^{t_1} \nabla\rho(\vec{r}_2(t), t)\, dt \right) d\ell \tag{16}$$

Interpretation: Differences in $\vec{I}_1$ and $\vec{I}_2$ may serve as witnesses of asymmetry, revealing the influence of the universe's energetic structure on seemingly isolated quantum events.

2.7 Connection to Path Integrals in Quantum Field Theory

In the path integral formalism of quantum field theory, the probability amplitude for a particle transitioning from x_i to x_f is given by:

$$\mathcal{A}(x_i \to x_f) = \int \mathcal{D}[x(t)]\, e^{\frac{i}{\hbar}S[x(t)]} \tag{17}$$

where $S[x(t)]$ is the action functional. If we introduce an energetic background field $\rho(\vec{r}, t)$, its influence can be embedded in the action:

$$S[x(t)] = \int_{t_0}^{t_1} \left(L(x, \dot{x}, t) + \lambda \nabla\rho(x(t), t) \cdot \dot{x}(t)\right) dt \tag{18}$$

This introduces a coupling between the particle's path and the energy field, allowing for measurement of deviation via interference effects.

References:

- Feynman & Hibbs: *Quantum Mechanics and Path Integrals*
- Peskin & Schroeder: *An Introduction to Quantum Field Theory*
- Sakurai: *Modern Quantum Mechanics*