Tensorul Energie–Impuls în Modelul Barbu–Ilie

Covariant Stress–Energy Structure of a Fundamental Continuum Defined by Pressure and Density Fields

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Abstract

We present an extended covariant formulation of the stress–energy tensor associated with the Barbu–Ilie Model, a theoretical framework in which the physical universe is described as a fundamental continuum governed by two primordial scalar fields:

$$
P(x^\mu)
$$

representing internal pressure / active tension,

and

$$
\rho(x^\mu)
$$

representing local density / inertia / geometric condensation.

Within this framework, matter, energy, gravitation, and cosmological dynamics emerge as secondary manifestations of the coupled evolution of these two fields. A fully covariant stress–energy tensor is derived from an invariant action principle and shown to couple naturally to Einstein geometry.

The resulting structure provides a unified language for describing local condensation, momentum transport, large-scale curvature, and cosmological expansion.

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1. Introduction

Modern theoretical physics relies on the principle that geometry and matter are dynamically linked. In General Relativity, this relation is encoded through:

$$
G_{\mu\nu}=\frac{8\pi G}{c^4}T_{\mu\nu}
$$

where:

* (G_{\mu\nu}) is the Einstein curvature tensor,
* (T_{\mu\nu}) is the stress–energy tensor.

The Barbu–Ilie Model proposes a deeper ontological layer: conventional matter is not fundamental, but emerges from a substrate continuum possessing two primitive degrees of freedom:

1. pressure field (P),
2. density field (\rho).

The objective of this paper is to derive the covariant tensor governing such a continuum.

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2. Fundamental Variables

Let spacetime coordinates be:

$$
x^\mu=(ct,x,y,z)
$$

Define two real scalar fields:

$$
P=P(x^\mu), \qquad \rho=\rho(x^\mu)
$$

with physical interpretation:

2.1 Pressure Field (P)

Encodes:

* internal active stress,
* propagation capacity,
* elastic response,
* expansion-driving tendency.

2.2 Density Field (\rho)

Encodes:

* local condensation,
* inertial loading,
* structural persistence,
* matter-generating potential.

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3. Covariant Action Principle

We postulate the invariant action:

$$
S=\int d^4x\sqrt{-g},\mathcal L
$$

with Lagrangian density:

$$
\mathcal L=
\frac12 g^{\mu\nu}\partial_\mu P\partial_\nu P
+
\frac12 g^{\mu\nu}\partial_\mu \rho\partial_\nu \rho

U(P,\rho)
$$

where:

* kinetic terms describe propagation of the two fields,
* (U(P,\rho)) is an interaction / self-organization potential.

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4. Stress–Energy Tensor Definition

The tensor is obtained variationally:

$$
T_{\mu\nu}
==========

-\frac{2}{\sqrt{-g}}
\frac{\delta S}{\delta g^{\mu\nu}}
$$

yielding:

$$
T_{\mu\nu}^{BI}
===============

\partial_\mu P\partial_\nu P
+
\partial_\mu \rho\partial_\nu \rho
----

g_{\mu\nu}\mathcal L
$$

Hence:

$$
\boxed{
T_{\mu\nu}^{BI}
===============

\partial_\mu P\partial_\nu P
+
\partial_\mu \rho\partial_\nu \rho
----

g_{\mu\nu}
\left[
\frac12(\partial P)^2
+
\frac12(\partial \rho)^2

U(P,\rho)
\right]
}
$$

with:

$$
(\partial P)^2=g^{\alpha\beta}\partial_\alpha P\partial_\beta P
$$

$$
(\partial \rho)^2=g^{\alpha\beta}\partial_\alpha \rho\partial_\beta \rho
$$

---

5. Physical Interpretation of Tensor Components

5.1 Energy Density

The (00) component in locally flat coordinates becomes:

$$
T_{00}
======

\frac12\dot P^2
+
\frac12|\nabla P|^2
+
\frac12\dot\rho^2
+
\frac12|\nabla\rho|^2
+
U(P,\rho)
$$

This corresponds to total local energy density.

5.2 Momentum Flux

Mixed components:

$$
T_{0i}
======

\dot P,\partial_iP
+
\dot\rho,\partial_i\rho
$$

describe transport of momentum and internal energy.

5.3 Spatial Stress Tensor

The spatial block:

$$
T_{ij}
$$

describes:

* compression,
* shear,
* directional tension,
* structural equilibrium.

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6. Coupling to Gravitation

The continuum curves spacetime according to:

$$
G_{\mu\nu}
==========

\frac{8\pi G}{c^4}T_{\mu\nu}^{BI}
$$

Thus gravitation is interpreted as geometric response to the internal organization of pressure and density fields.

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7. Cosmological Reduction

For homogeneous fields:

$$
P=P(t),\qquad \rho=\rho(t)
$$

the tensor reduces to perfect-fluid form:

$$
T_{\mu\nu}
==========

(\epsilon+p)u_\mu u_\nu + p g_{\mu\nu}
$$

where effective quantities are:

$$
\epsilon=
\frac12\dot P^2+\frac12\dot\rho^2+U(P,\rho)
$$

$$
p=
\frac12\dot P^2+\frac12\dot\rho^2-U(P,\rho)
$$

This enables direct insertion into FLRW cosmology.

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8. Matter as Local Density Condensation

The Barbu–Ilie interpretation identifies matter as localized stable enhancement of (\rho):

$$
\rho(x^\mu)=\rho_0+\delta\rho(x^\mu)
$$

Massive bodies induce pressure deficits:

$$
P(x)=P_0-\delta P(x)
$$

leading to effective attraction through gradients:

$$
\vec g \sim -\nabla P
$$

This offers an emergent route toward Newtonian gravity.

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9. Critical Elastic Relation

A central relation proposed in the model is:

$$
\frac{P}{\rho}=c^2
$$

interpreted as:

* universal elastic ratio,
* conversion scale between active and inert sectors,
* propagation invariant.

This parallels the mass–energy relation:

$$
E=mc^2
$$

with pressure and density treated as deeper primitives.

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10. Stability and Phase Transitions

Matter formation may correspond to critical transitions where density can no longer track pressure-driven expansion:

$$
\dot P > \lambda \dot\rho
$$

for some threshold (\lambda).

Then the continuum reorganizes into stable localized structures satisfying:

$$
\frac{\delta P}{\delta \rho}\to c^2
$$

This mechanism may be interpreted as primordial condensation.

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11. Predictions and Testable Directions

The model suggests possible observable signatures:

1. deviations from standard dark-energy equation of state,
2. density-pressure coupling corrections in early cosmology,
3. emergent gravity deviations at weak accelerations,
4. nontrivial vacuum elastic modes,
5. modified compact-object interiors.

These remain subjects for future quantitative development.

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12. Advantages of the Framework

1. Fully covariant formulation.
2. Two-field unified substrate.
3. Natural link between matter and geometry.

4. Cosmological compatibility.
5. Potential bridge between continuum and particle emergence.

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13. Open Mathematical Problems

Further work requires:

1. explicit form of (U(P,\rho)),
2. perturbative stability analysis,
3. quantization scheme,
4. observational parameter fitting,
5. exact Newtonian limit derivation.

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14. Conclusion

We have derived the stress–energy tensor of the Barbu–Ilie Model:

$$
T_{\mu\nu}^{BI}
===============

\partial_\mu P\partial_\nu P
+
\partial_\mu \rho\partial_\nu \rho
----

g_{\mu\nu}
\left[
\frac12(\partial P)^2
+
\frac12(\partial \rho)^2

U(P,\rho)
\right]
$$

Within this framework:

* mass is density condensation,
* energy is active pressure manifestation,
* momentum is organized flux,
* gravity is geometric reaction of spacetime.

The model offers a novel continuum-based route toward unification of matter, dynamics, and geometry.

Acknowledgment

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Formal mathematical presentation assisted by AI.

Signature

Barbu Ilie
AI Mathematical Drafting

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