009 - CEDA MODEL CARD

A. Identification

Title: *On Average Properties of Inhomogeneous Fluids in General Relativity: I. Dust Cosmologies*
Author: Thomas Buchert
Year: 2000 (arXiv v2: 27 Dec 1999)
Source: arXiv: gr-qc/9906015
Framework Class: General Relativity (3+1 ADM formulation, scalar averaging)
Matter Content: Irrotational dust (+ optional Λ)
Scope of Paper: Formal derivation of averaged scalar Einstein equations on compact spatial domains; exploration of “backreaction” effects on effective expansion.

On Average Properties of

B. Declared Ontology & Degrees of Freedom

Fundamental degrees of freedom:

- Spacetime metric $g_{\mu\nu}$gμν
- Dust 4-velocity u_{μ}uμ
- Rest-mass density ϱρ

Derived / effective quantities:

- Domain-dependent scale factor $a_{\mathcal{D}}(t)$aD(t)
- Averaged expansion $\langle\theta\rangle_{\mathcal{D}}$⟨θ⟩D
- Averaged spatial Ricci scalar $\langle R\rangle_{\mathcal{D}}$⟨R⟩D
- Backreaction scalar $Q_{\mathcal{D}}$QD, constructed from variance of expansion and shear

New dynamical fields introduced?
❌ No new fundamental fields.

Effective variables introduced?
⚠️ Yes — $a_{\mathcal{D}}(t)$aD(t), $Q_{\mathcal{D}}(t)$QD(t), $\langle R\rangle_{\mathcal{D}}(t)$⟨R⟩D(t), all domain-dependent and not locally dynamical fields.

C. Kinematics, Dynamics, and Conservation

Underlying dynamics:

- Standard Einstein equations with dust stress–energy
- Local energy–momentum conservation enforced
- Raychaudhuri equation used explicitly

Averaging procedure:

- Spatial averaging of scalar quantities on compact, comoving domains
- Foliation: flow-orthogonal (irrotational dust, Gaussian normal slicing)

Key structural move:

- Non-commutativity of averaging and time evolution generates additional terms
- These terms are collected into a scalar quantity $\mathcal{Q}_D$QD

Conservation status:

- Local conservation: ✅ explicit and enforced
- Domain mass conservation: ✅ enforced
- Global conservation interpretation: ⚠️ domain-relative, slicing-dependent

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D. Claimed Physical Effect

Primary claim (formal):

- Spatially averaged Einstein equations for inhomogeneous dust differ from standard FRW equations by additional “backreaction” terms.
- These terms can modify the effective expansion of a spatial domain.

Secondary claim (interpretive):

- Inhomogeneities generically generate effective curvature and modify expansion, even if initial averaged curvature is zero.
- Standard FRW behavior is not guaranteed to emerge from averaging.

Does the paper explicitly claim accelerated expansion?
⚠️ Not universally. Acceleration is possible *for certain domains and assumptions*, but no generic late-time acceleration theorem is claimed.

E. Regime of Validity (as declared)

Matter regime: Pressureless dust
Vorticity: Zero
Perturbative assumptions: None (non-perturbative formalism)
Closure of equations: ❌ Not achieved without additional assumptions
Domain dependence: Explicit and central
Global limit behavior: Underspecified

The paper **explicitly states** that the system of averaged equations is *not closed* without extra assumptions relating $\mathcal{Q}_D$QD and $\langle \mathcal{R} \rangle_D$⟨R⟩D.

F. Role of Backreaction Term $\mathcal{Q}_D$QD

Definition:

$\mathcal{Q}_D := \frac{2}{3}\langle(\theta - \langle\theta\rangle_D)^2\rangle_D - 2\langle\sigma^2\rangle_D$QD:=32⟨(θ−⟨θ⟩D)2⟩D−2⟨σ2⟩D

Status:

- Not a fundamental stress–energy component
- Not associated with a new field
- Emerges from variance under averaging

Interpretive status in paper:

- Treated as a genuine source term in averaged equations
- Simultaneously acknowledged as dependent on:
    - choice of domain
    - foliation
    - closure assumptions

G. Explicit Non-Claims (important)

The paper explicitly does **not** claim:

- A closed dynamical mechanism for cosmic acceleration
- A replacement for inflation
- A generic prediction for late-time cosmology
- That backreaction must be large or dominant

- That averaging uniquely determines global dynamics

This restraint matters for the audit.

H. Initial CEDA Flags (non-verdict)

These are **review flags**, not failures:

- ⚠️ **Coarse-graining dependence is central**, not auxiliary
- ⚠️ **Effective dynamics depend on domain choice**
- ⚠️ **Closure requires extra assumptions**
- ⚠️ **Backreaction behaves functionally like a free scalar unless constrained**

No diagnostics applied yet. No verdict assigned.