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Cosmological background solutions and cosmological backreactions

V. Marra, E. W. Kolb, S. Matarrese, A. Riotto
On cosmological observables in a swiss-cheese universe.
Phys. Rev. D 76, 123004 (2007)

E. W. Kolb, V. Marra, S. Matarrese
Description of our cosmological spacetime as a perturbed conformal Newtonian metric and implications for the backreaction proposal for the accelerating universe.
Phys. Rev. D 78, 103002 (2008)

V. Marra, E. W. Kolb, S. Matarrese
Light-cone averages in a swiss-cheese universe.
Phys. Rev. D 77, 023003 (2008)

V. Marra
A back-reaction approach to dark energy.
Padua@research ID588; arXiv:0803.3152
The cosmic concordance model

\[ \Omega_M \lesssim 0.25 \]
\[ \Omega_{DE} \lesssim 0.75 \]
\[ w_{DE} \lesssim -1 \]

successful, but..

• coincidence problem
• origin problem

Kowalski et al. 08
The “safe” consequence of the success of the concordance model is that the isotropic and homogeneous LCDM model is a good observational fit to the real inhomogeneous universe.
Cosmological backgrounds

- Global Background Solution (GBS)
  \[ \rho_{GBS} = \langle \rho \rangle_H \]
  \[ 3\mathcal{R}_{GBS} = \langle 3\mathcal{R} \rangle_H \]
  + local equation of state

- Average Background Solution (ABS)
  [Buchert’s background]
  \[ a_H(t) \propto V_H(t)^{1/3} \]
  \[ \rho_{ABS} \neq \langle \rho \rangle_H \]
  \[ 3\mathcal{R}_{ABS} \neq \langle 3\mathcal{R} \rangle_H \]
  “averaged” equation of state:
  no local energy conditions

- Phenomenological Background Solution (PBS)
  \[ d_L(z) \]
  \[ \rho_{PBS} \neq \langle \rho \rangle_H \]
  \[ 3\mathcal{R}_{PBS} \neq \langle 3\mathcal{R} \rangle_H \]
Backreactions

Description of the spacetime: GBS, ABS, none? [perturbatively]

Description of the observer: on what does the PBS depend? are all the PBSs the same?
Cosmological Principle

FLRW models

FLRW Assumption:
GBS=ABS=PBS

No-go theorem by
Ishibashi and Wald, 2006

even with \( \delta \gg 1 \):

\[
ds^2 = a^2(\tau) \left[ - (1 + 2\psi) d\tau^2 + (1 - 2\psi) \gamma_{ij} dx^i dx^j \right]
\]

with \( \psi \ll 1 \)
Description of the spacetime

No-go theorems are made by assumptions

reconsider the assumption

“with velocity much smaller than light relative to the Hubble flow”
Ishibashi and Wald, 2006
**Description of the spacetime**

- Phenomenological Peculiar Velocities: small
- Global Peculiar Velocities: to be relaxed

observations do not see big departures from the observed Hubble flow

otherwise we assume that - as a starting point - the GBS describes the spacetime

small GPV are a restriction on the dynamics of the inhomogeneities

If inhomogeneities alone explain the concordance model, then there will be big GPV wrt EdS-GBS
The GBS does not describe the spacetime: hint for Strong Backreaction
Description of the observer

- Global Observer
  - observer comoving with the GBS/ABS Hubble flow

- Phenomenological Observer
  - observer comoving with the PBS Hubble flow
Description of the observer

- Copernican Principle
  - observed isotropy
  - Cosmological Principle
    - FLRW assumption
    - every observer sees the GBS
- The success of concordance model verifies this reasoning \textit{a posteriori}
Bare principles

- Bare Cosmological Principle → homogeneity and isotropy on a large enough scale → the ABS (not necessarily the GBS!) describes the universe: insensitive to the scale of averaging

- Bare Copernican Principle → observed isotropy, success of LCDM → the PBS (not necessarily the GBS/ABS!) describes observations for every observer, even though not necessarily the same
EdS cheese with LTB holes:

$$\frac{\dot{a}^2(r, t)}{a^2(r, t)} = \frac{8\pi G}{3} \hat{\rho}(r, t) - \frac{k(r)}{a^2(r, t)}$$

by construction: $\text{ABS} = \text{EdS}$

wrong model to study GBS vs ABS
**PBS ≠ GBS**

**concordance model:** \( \Lambda CDM \) with \( \Omega_M = 0.3, \Omega_{DE} = 0.7 \)
\[ q_0 = \Omega_M / 2 - \Omega_{DE} = -0.55 \]

**reference model:** \( \Lambda CDM \) with \( \Omega_M = 0.6, \Omega_{DE} = 0.4 \)
\[ q_0 = \Omega_M / 2 - \Omega_{DE} = -0.1 \]

**EdS model:** \( \Lambda CDM \) with \( \Omega_M = 1, \Omega_{DE} = 0 \)
\[ q_0 = \Omega_M / 2 - \Omega_{DE} = 0.5 \]

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V. Marra, E. W. Kolb, S. Matarrese, A. Riotto
*Phys. Rev. D 77, 023003 (2008)*

V. Marra, E. W. Kolb, S. Matarrese
*Phys. Rev. D 76, 123004 (2007)*
“Hubble bubble” scenario

Far from the center, cosmological principle holds.

Variance in $H_r$ too big:
- global observer $\neq$ phenomenological observer

The GBS describes the spacetime but not the PBSs of the phenomenological observers: Weak Backreaction
**Observable backreaction**

The PBS is the only one that matters from an observational point of view.

The distinction between strong and weak backreaction is indeed good to lay a framework, but it might be illusory and unphysical.

Only the “end result” matters

**Observable Backreaction:**
the evolution of inhomogeneities leads the PBS to have an energy content and curvature different from the corresponding local quantities
THANKS