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SIGRAV School in Cosmology

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in collaboration with Rocky Kolb and Sabino Matarrese

Cosmological background solutions and cosmological backreactions

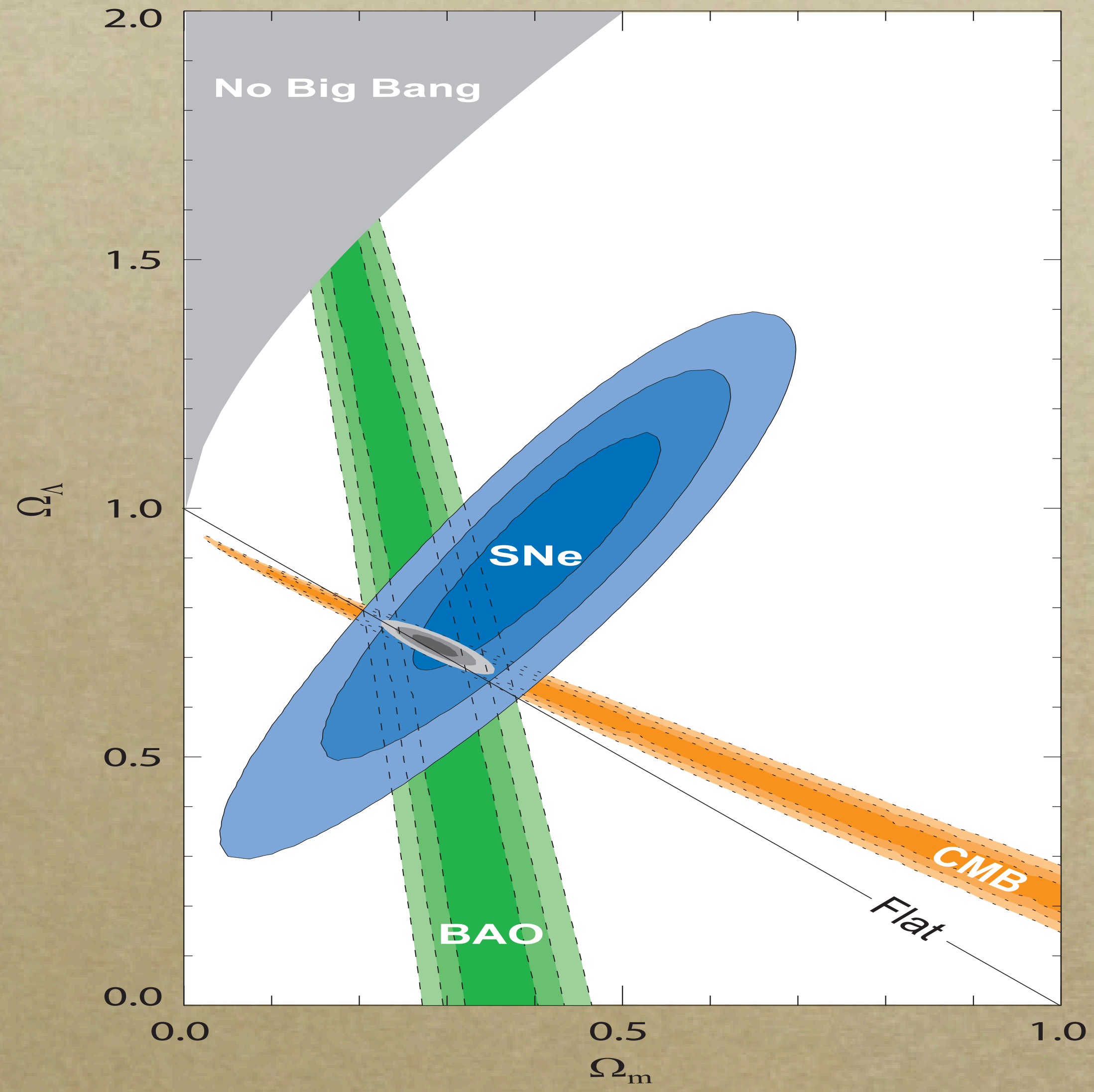
V. Marra, E. W. Kolb, S. Matarrese, A. Riotto
On cosmological observables in a swiss-cheese universe.
Phys. Rev. D 76, 123004 (2007)

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

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
A back-reaction approach to dark energy.
Padua@research ID588; arXiv:0803.3152

The cosmic concordance model



Kowalski et al. 08

$$\Omega_M \simeq 0.25$$
$$\Omega_{DE} \simeq 0.75$$
$$w_{DE} \simeq -1$$

successful, but..

- *coincidence problem*
- *origin problem*

A point of view

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?

Description of the spacetime

Cosmological Principle

FLRW Assumption:
GBS=ABS=PBS

No-go theorem by
Ishibashi and Wald, 2006

FLRW models

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 $\psi \ll 1$

GBS describes the spacetime

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 → observations do not see big departures from the *observed* Hubble flow

- Global Peculiar Velocities → **to be relaxed** → otherwise we assume that - *as a starting point* - the GBS describes the spacetime

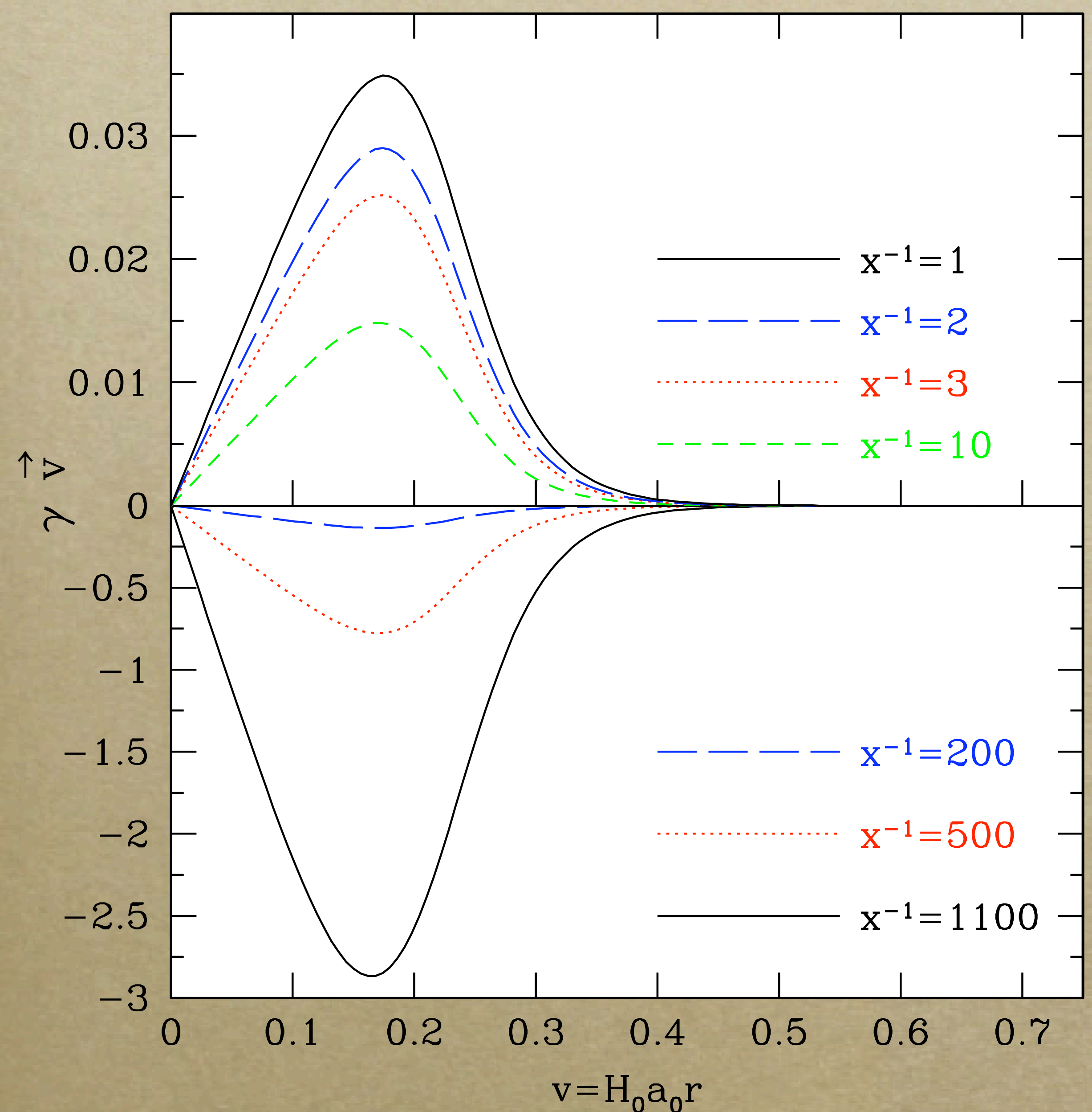
↓

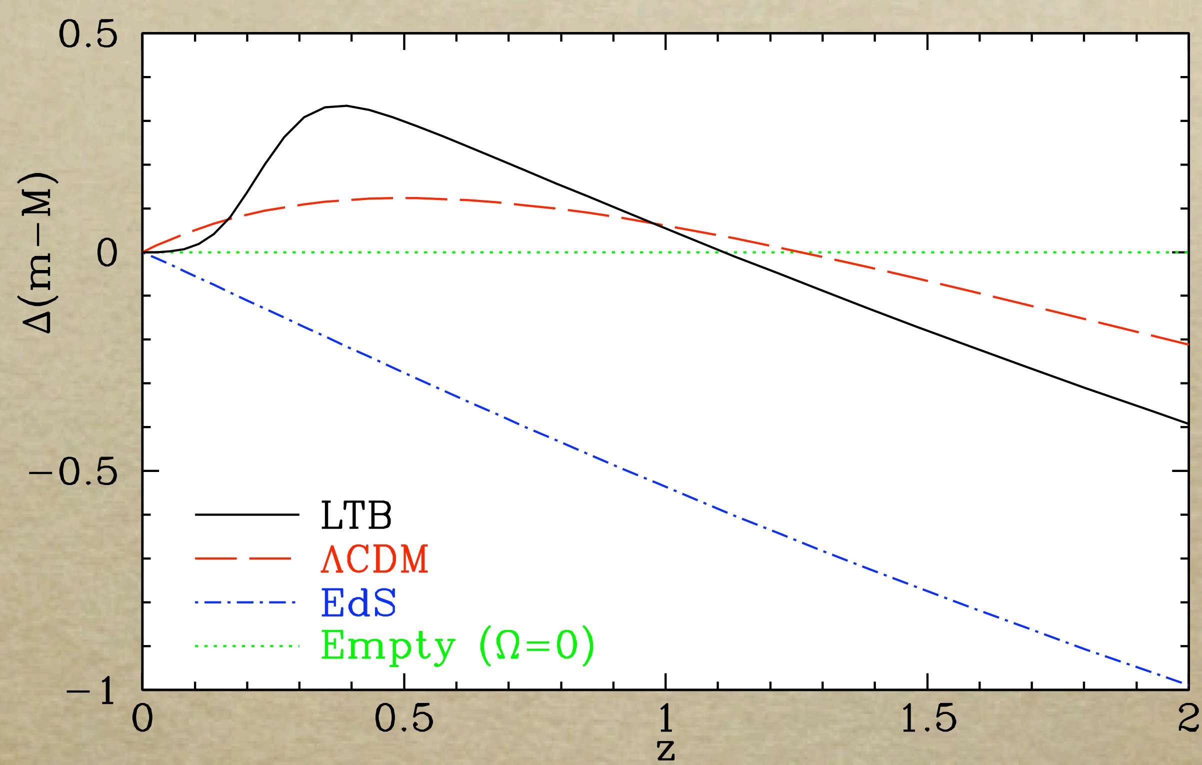
small GPV are a restriction on the dynamics of the inhomogeneities

↓

If inhomogeneities alone explain the concordance model, then there will be big GPV wrt EdS-GBS

Big Global Peculiar Velocities





The GBS does not describe the spacetime:
hint for Strong Backreaction

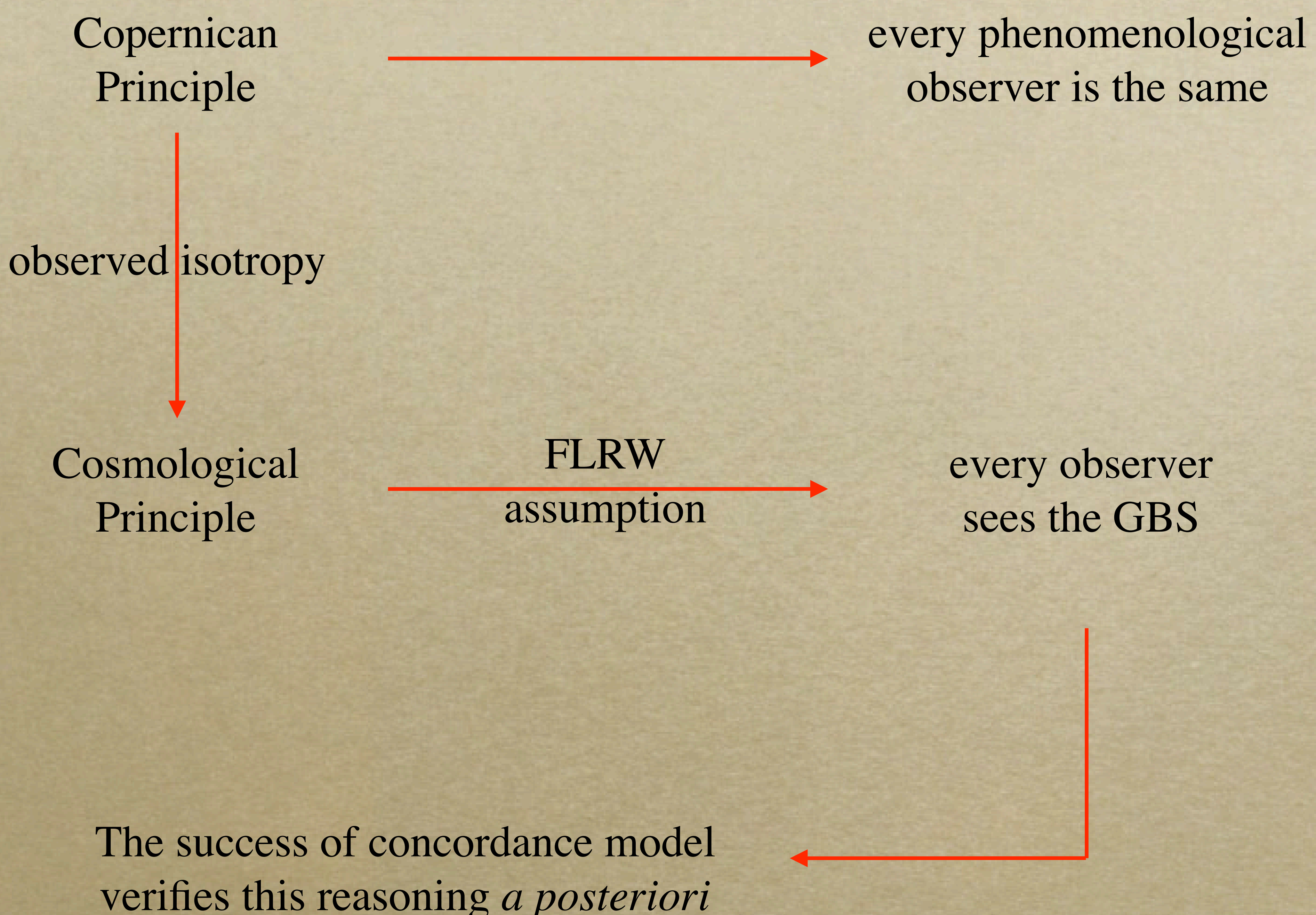
E. W. Kolb, V. Marra, S. Matarrese
Phys. Rev. D 78, 103002 (2008)

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



Bare principles

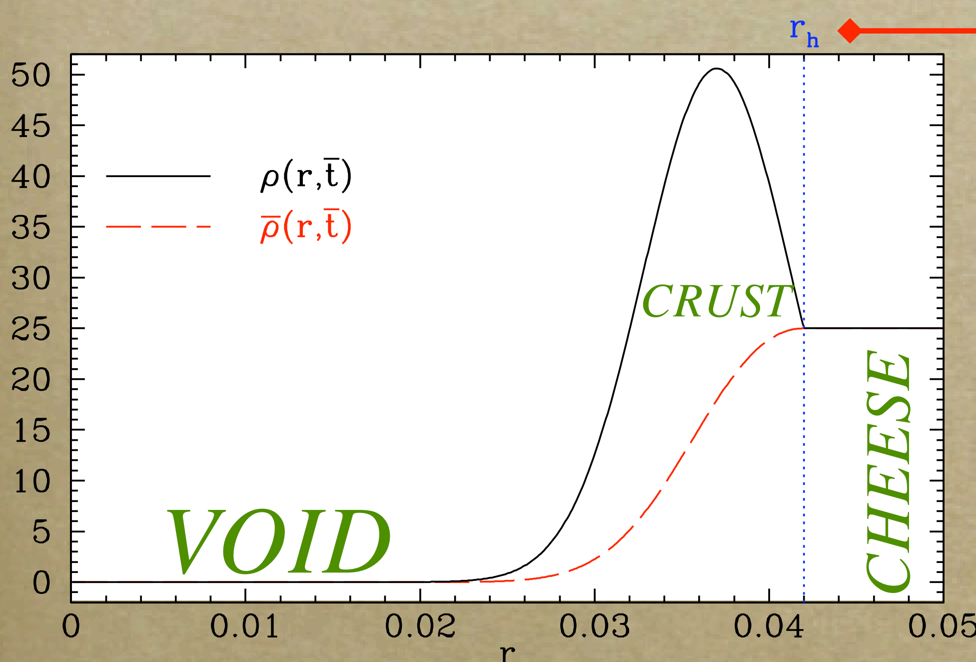
- Bare Cosmological Principle → homogeneity and isotropy on a large enough scale → the ABS (not necessarily the GBS!) describes the universe: insensitive to the scale of averaging

- 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

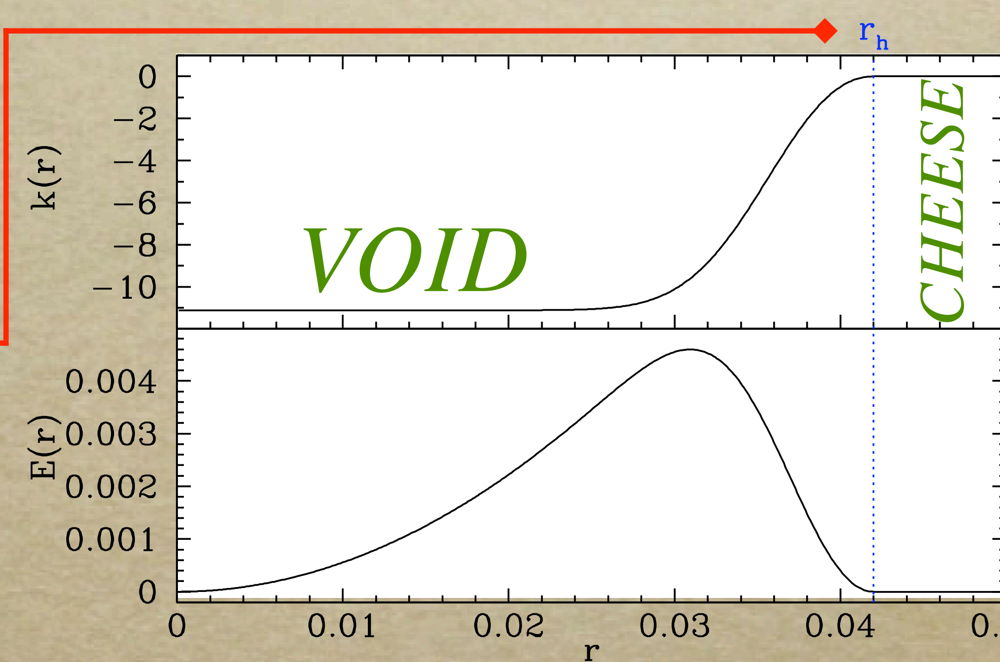
Swiss cheese

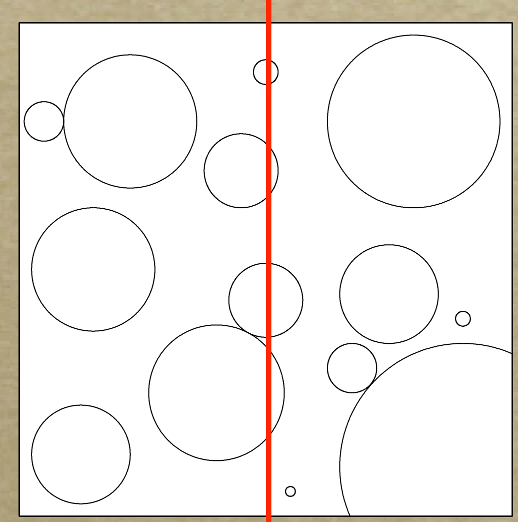
EdS cheese with LTB holes:

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



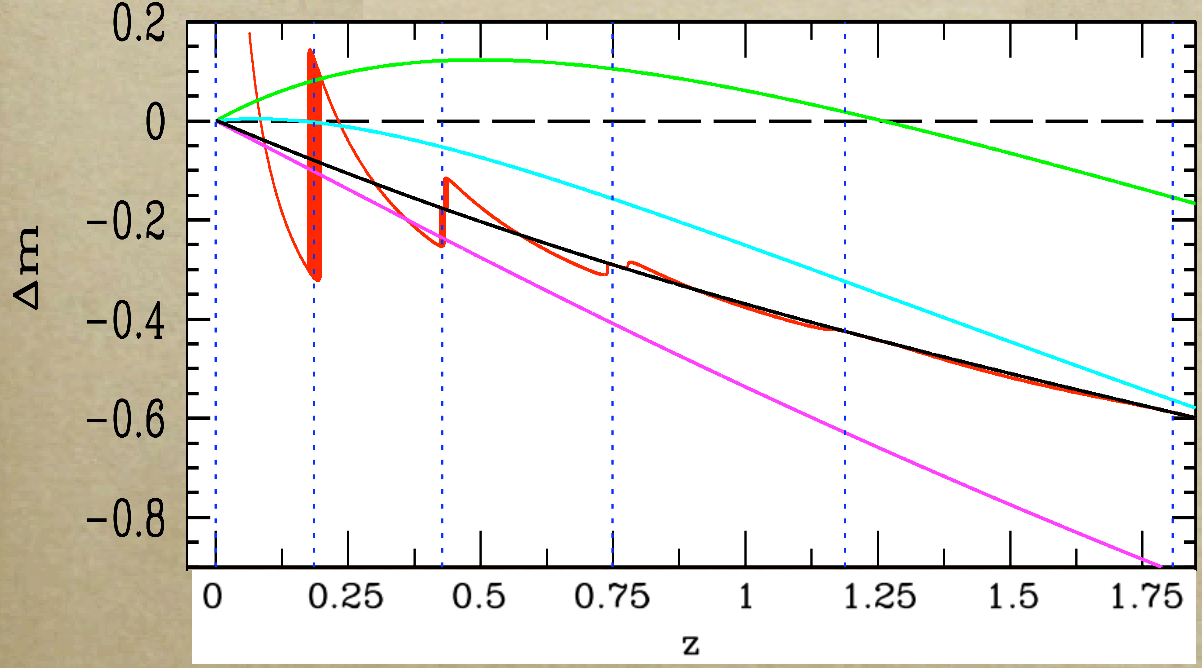
matching at r_h

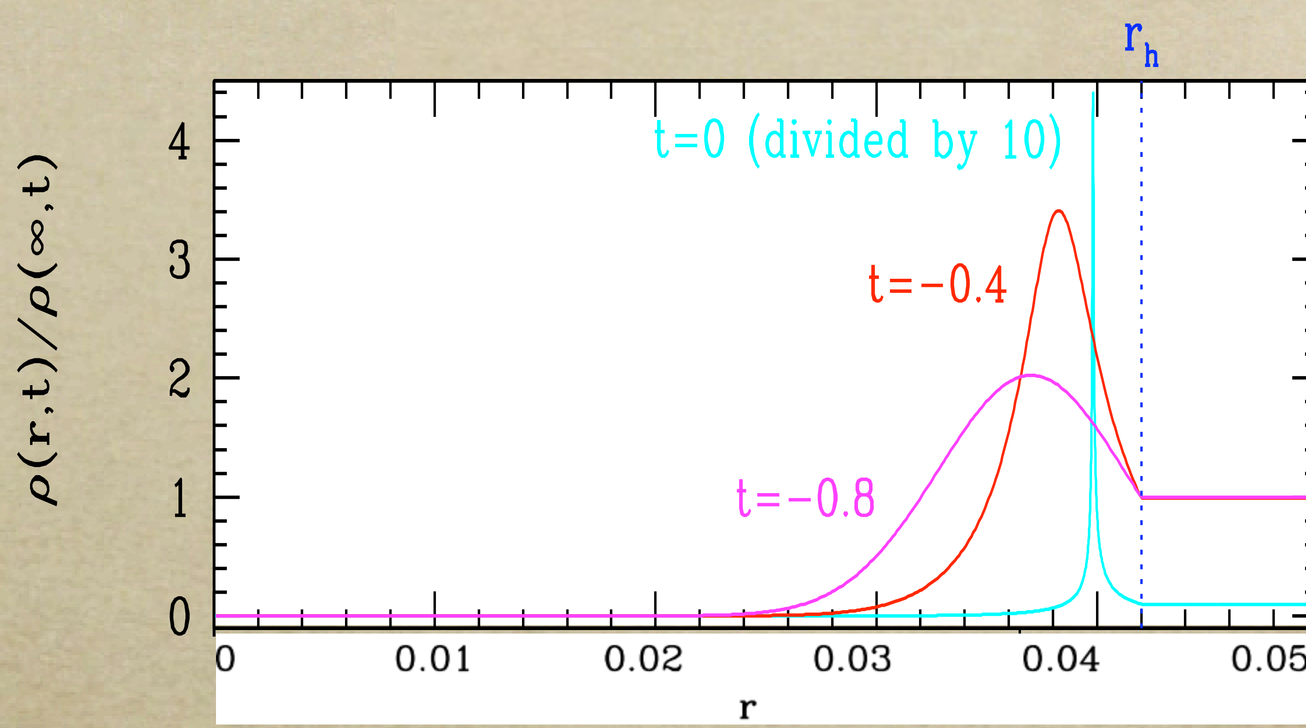




by construction: ABS = EdS → wrong model to study GBS vs ABS

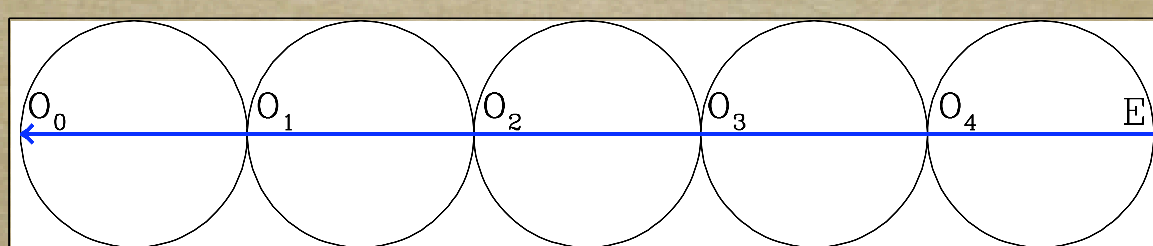
$PBS \neq GBS$





concordance model: ΛCDM with $\Omega_M = 0.3$, $\Omega_{DE} = 0.7$

$q_0 = \Omega_M/2 - \Omega_{DE} = -0.55$



reference model: ΛCDM with $\Omega_M = 0.6$, $\Omega_{DE} = 0.4$

$q_0 = \Omega_M/2 - \Omega_{DE} = -0.1$

EdS model: ΛCDM with $\Omega_M = 1$, $\Omega_{DE} = 0$

$q_0 = \Omega_M/2 - \Omega_{DE} = 0.5$

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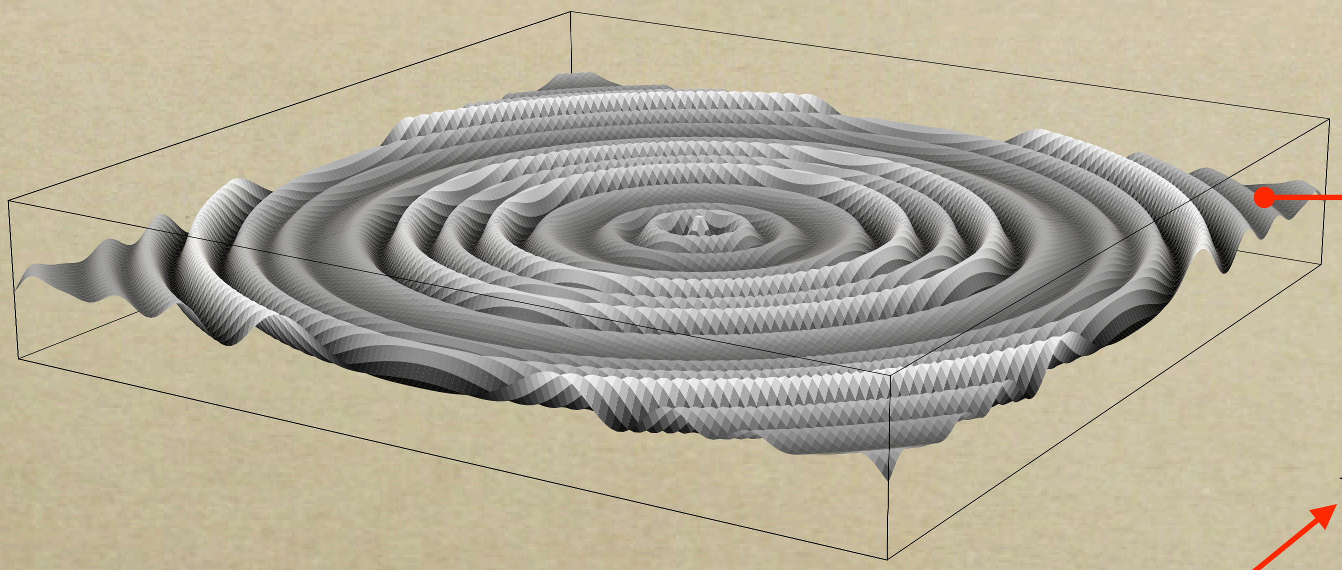
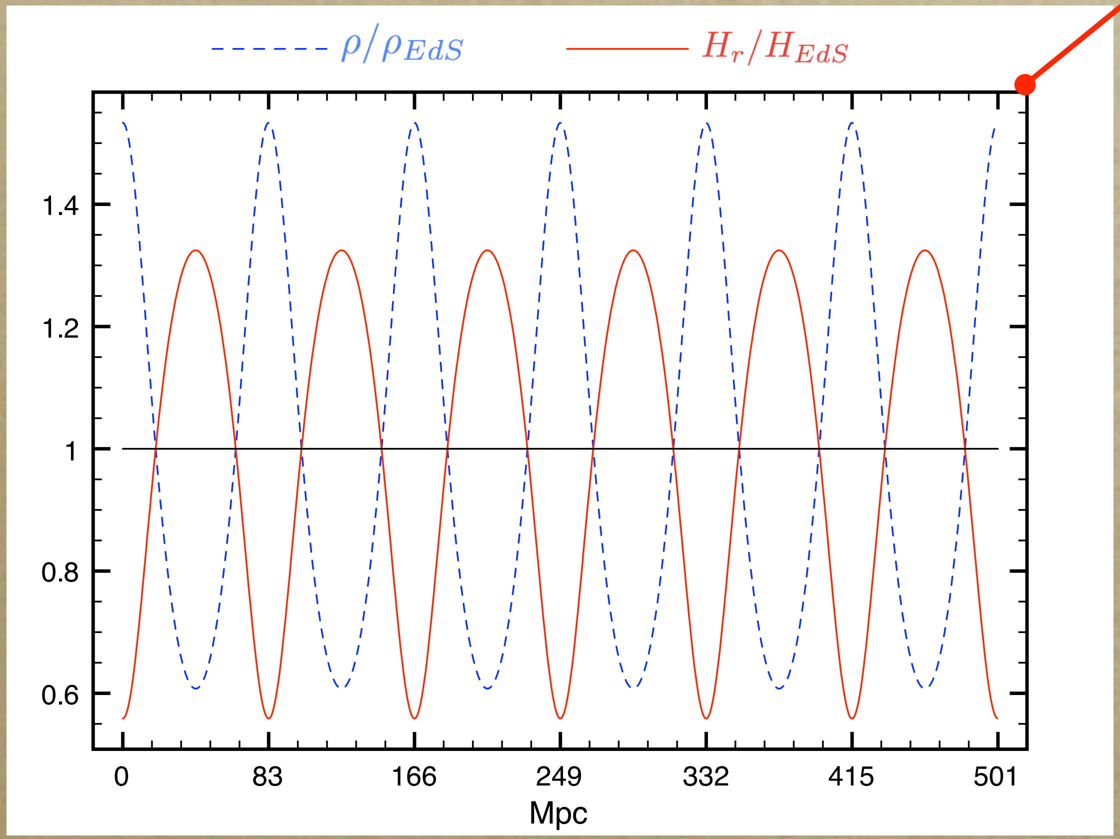
V. Marra, E. W. Kolb, S. Matarrese
Phys. Rev. D 77, 023003 (2008)

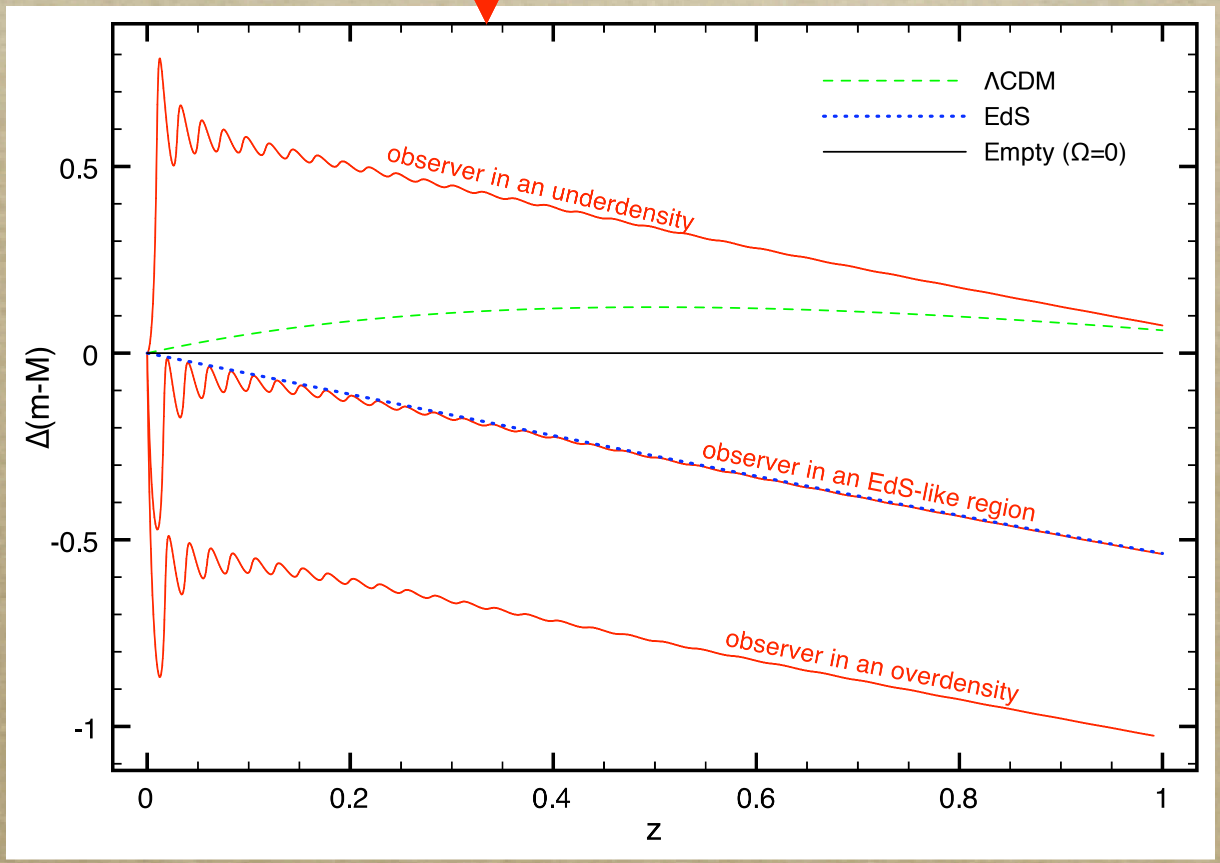
"Hubble bubble" scenario



Far from the center, cosmological principle holds.

Variance in H_r too big:
global observer ≠ 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