Non-spherical voids: the best alternative to dark energy?

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Cosmology On The Beach
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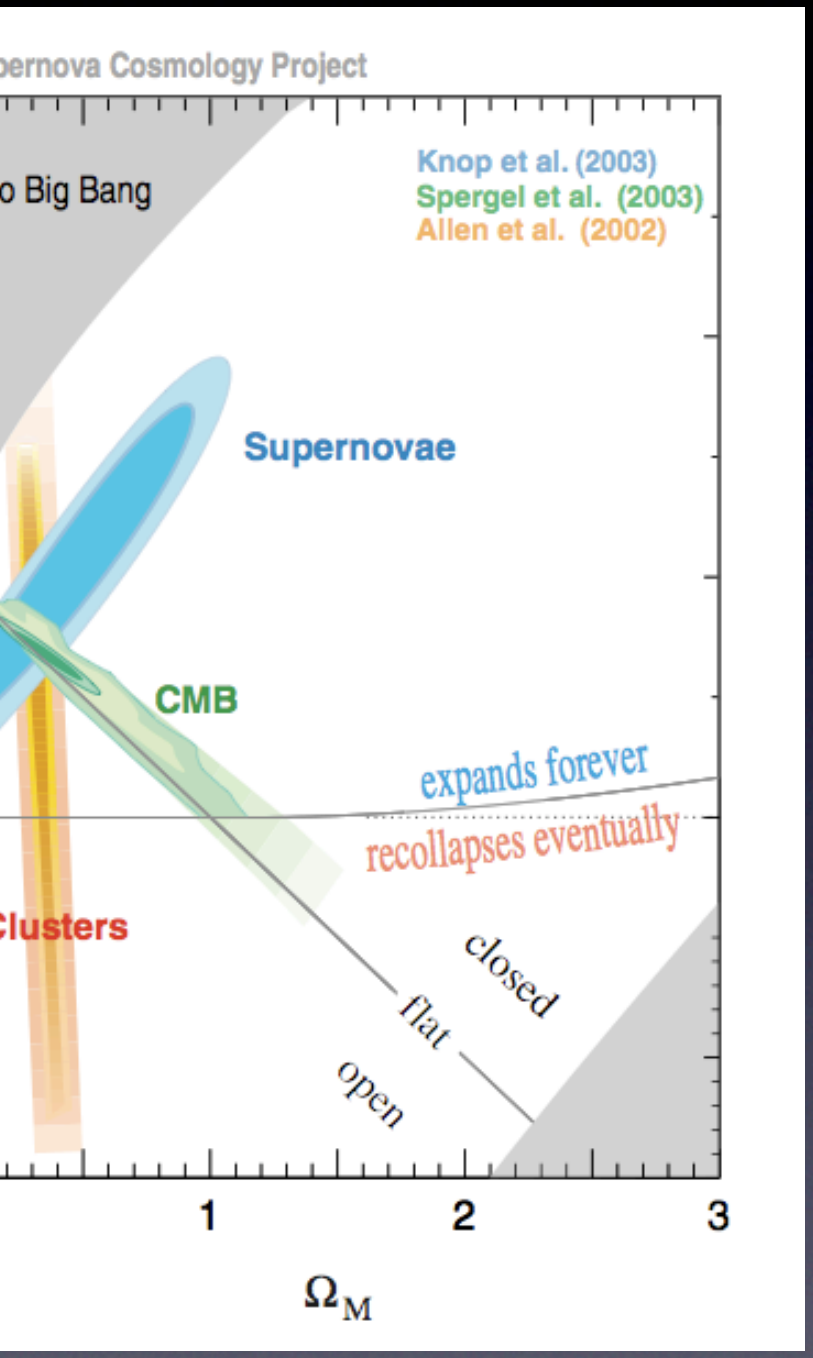
Cancún, QR, México

Lambda-CDM model !!!!!



It provides an excellent fit to cosmic observations

but

Homogeneity & isotropy (FLRW) is assumed at scales > 30-50 Mpc to obtain these fittings

Under this assumption, it is unavoidable to introduce dark energy (or: Lambda > 0)

should we explore other assumptions ??

servations so well, then why her looking for alternatives ?

ecause "dark energy" is a very elusive "black box"
d theoretical models to explain it (quintessence,
c) lack any observational support.

ecause what we have is just

+ linear perturbations
fferent variants of DE → Observations are well fit

converse of this implication is NOT (necessarily) true:
g observations DOES NOT IMPLY the ΛCDM model

servations can be fit by other models …

ternatives within General Relativity, such that

There is CDM

but

There is NO dark energy nor Lambda

echnical Disadvantage:

ve have to deal with full non-linearity of GR

onceptual Advantage:

ve only have to deal with the less "exotic"

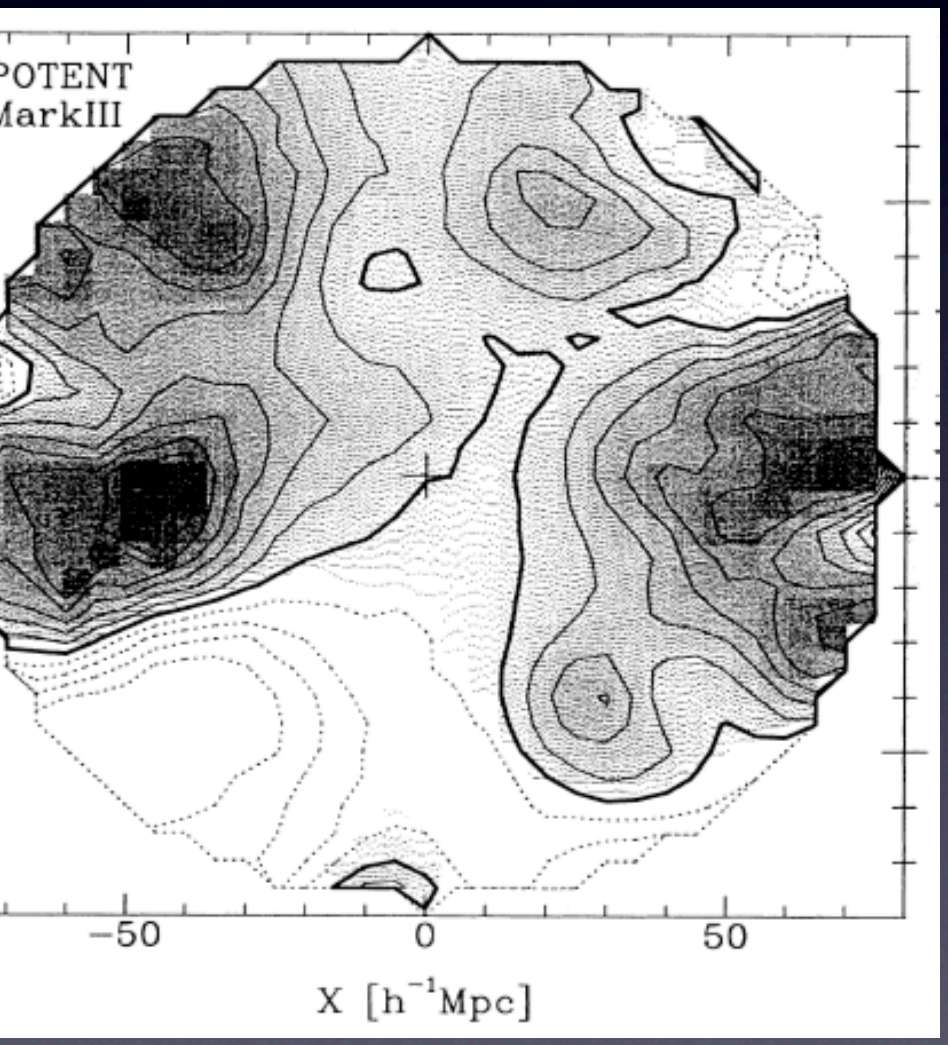
ark source (no dark energy)

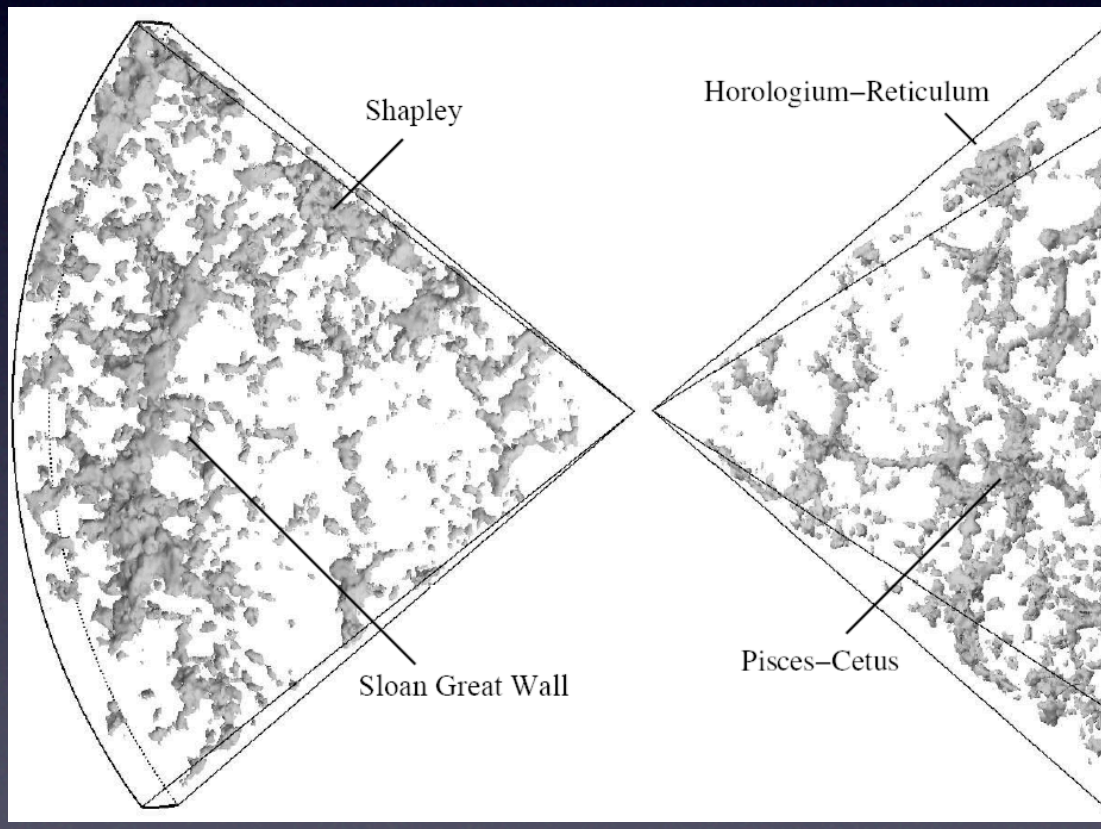
ntific controversy:

MEXICO
CALZA
CANA

homogeneous even at scales ~ 300 Mpc

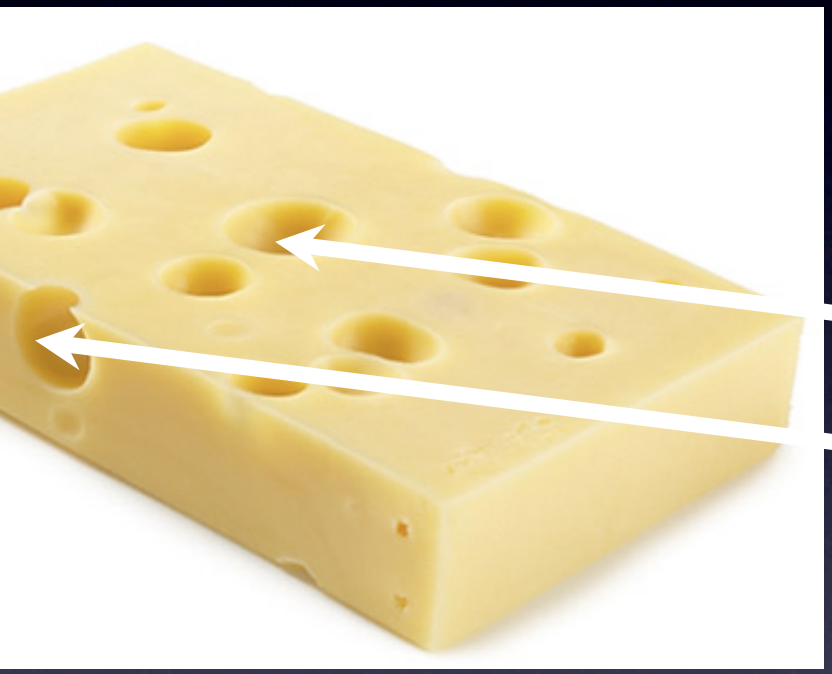
"Homogeneity scale" is still an open issue

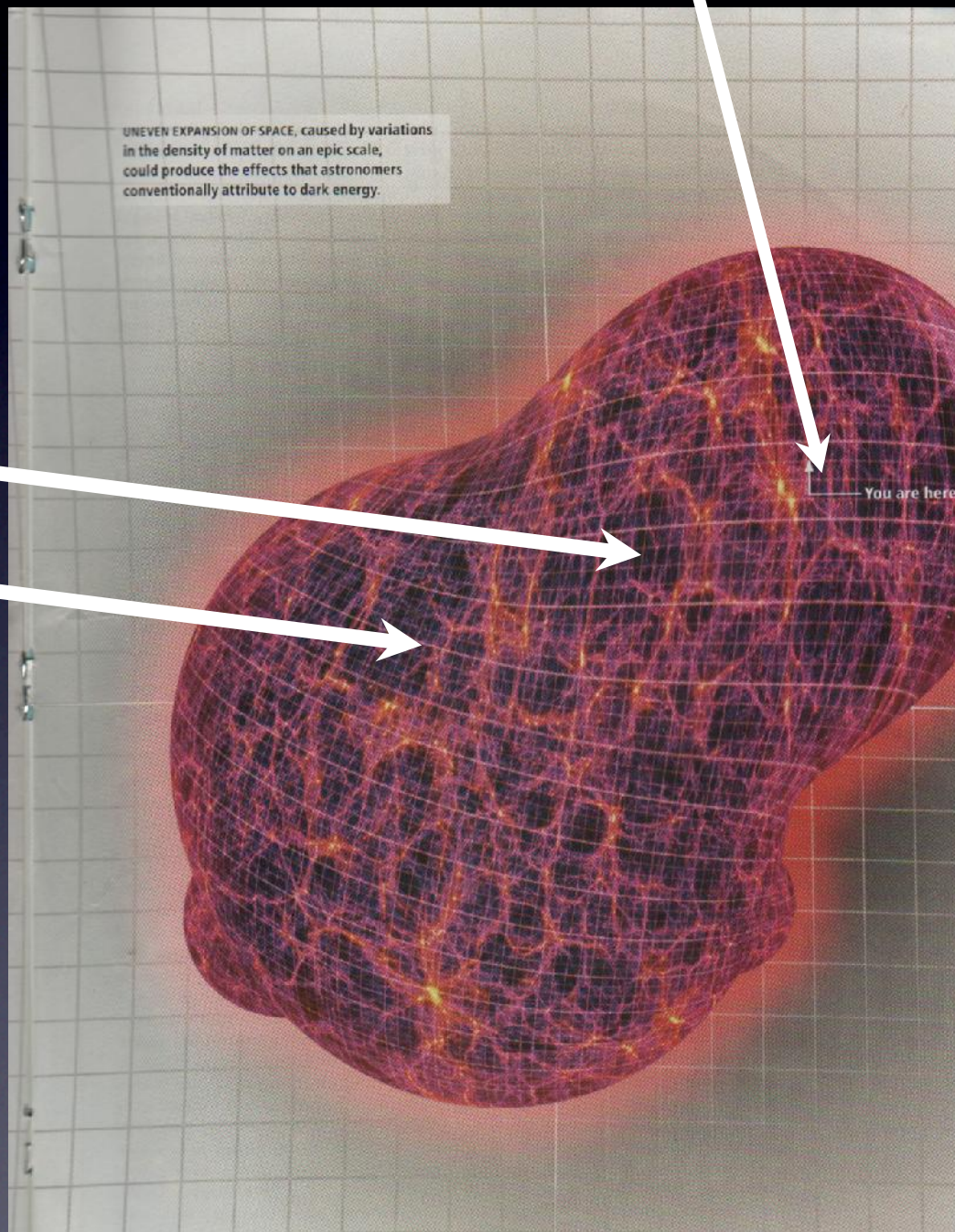




der the Universe as a "Swiss Cheese"

We could be inside of
of these void region





The cheese holes are the
void regions

esent this

[THE BIG PICTURE]

A Special Place for Us

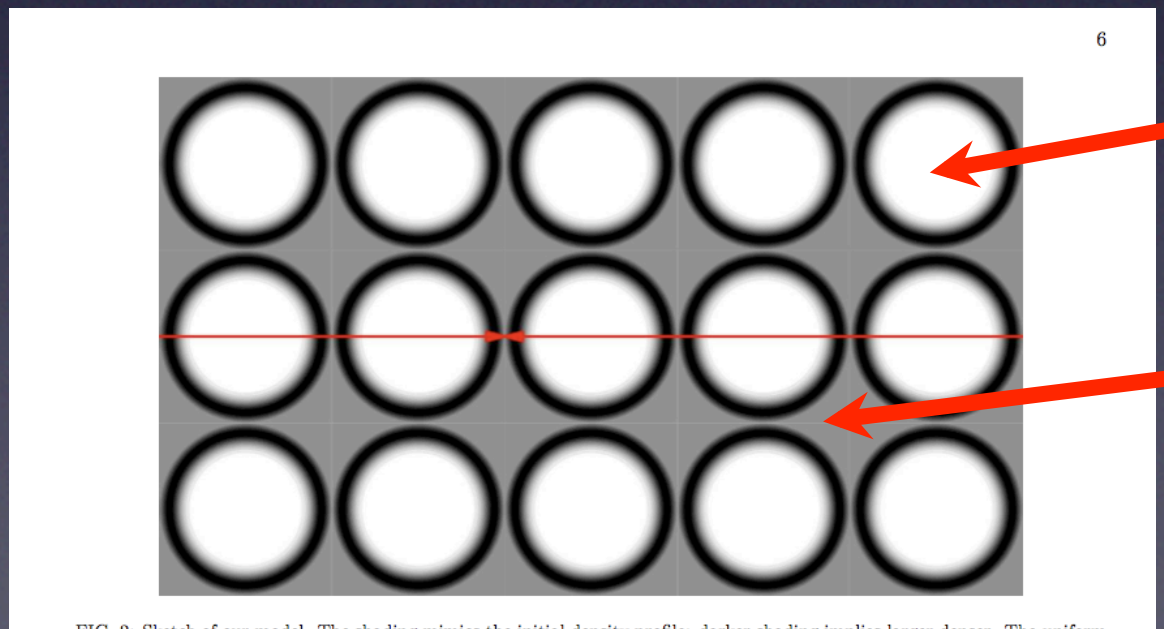
In his *Hitchhiker's Guide to the Galaxy* series of novels, Douglas Adams imagines a torture device that drives people insane by showing them the utter insignificance of their place in the universe. One would-be victim emerges unscathed when it turns out that the universe does, in fact, revolve around him. In a case of life imitating art, many cosmologists are investigating whether our planet indeed has a special place within the grand scheme of things.

HOMOGENEOUS UNIVERSE: OUR LOCATION IS TYPICAL
In the standard view, galaxies are lined up in a spidery pattern, but overall space looks much the same everywhere, and Earth's position is nothing special.

INHOMOGENEOUS UNIVERSE: OUR LOCATION IS SPECIAL
Alternatively, the density of matter could vary on large scales, and Earth may lie at or near the center of a relatively less dense region, or void.

Copern
principle
large
homoge
scal

simple model



Sph
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The "c
homoge
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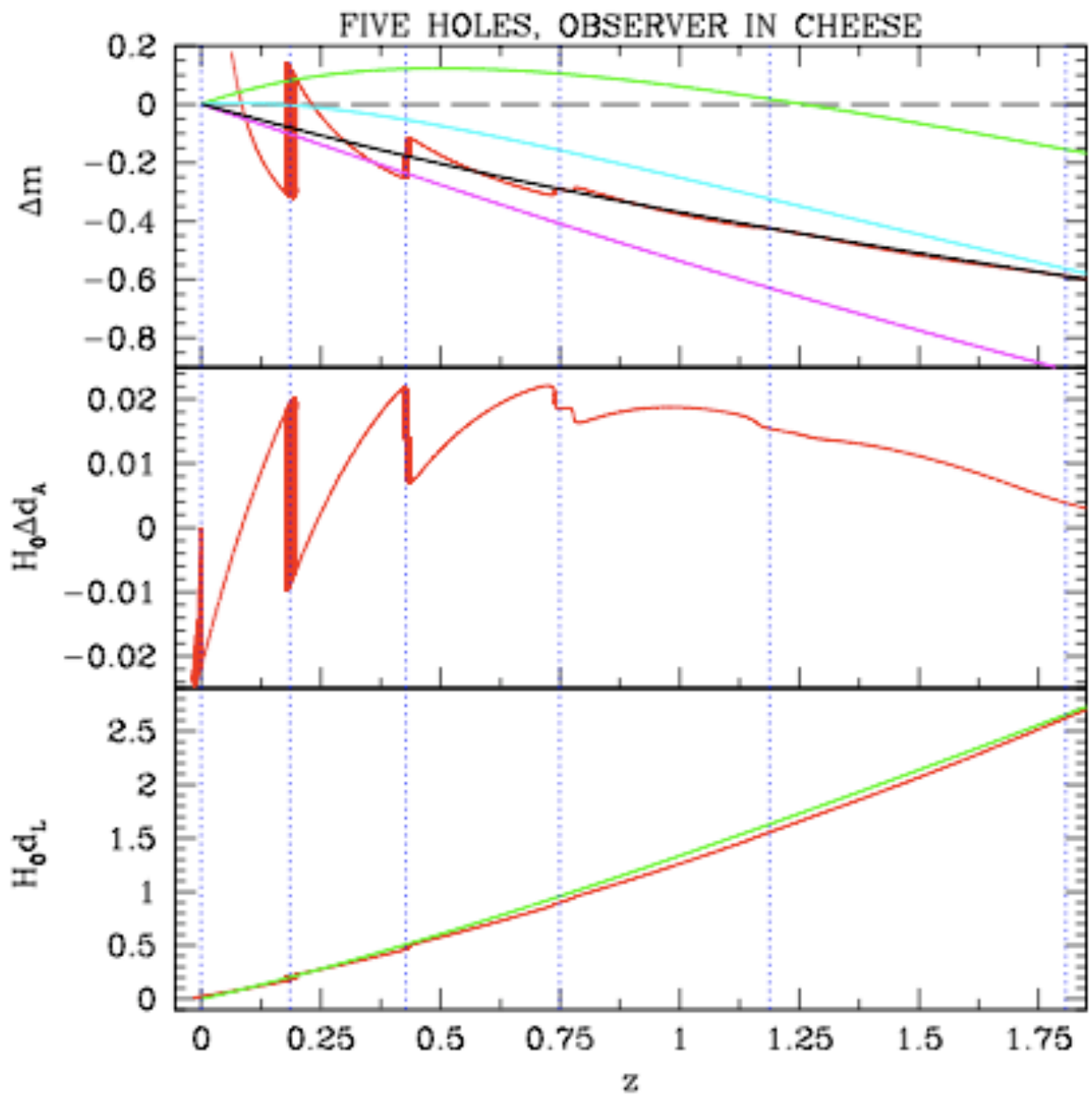
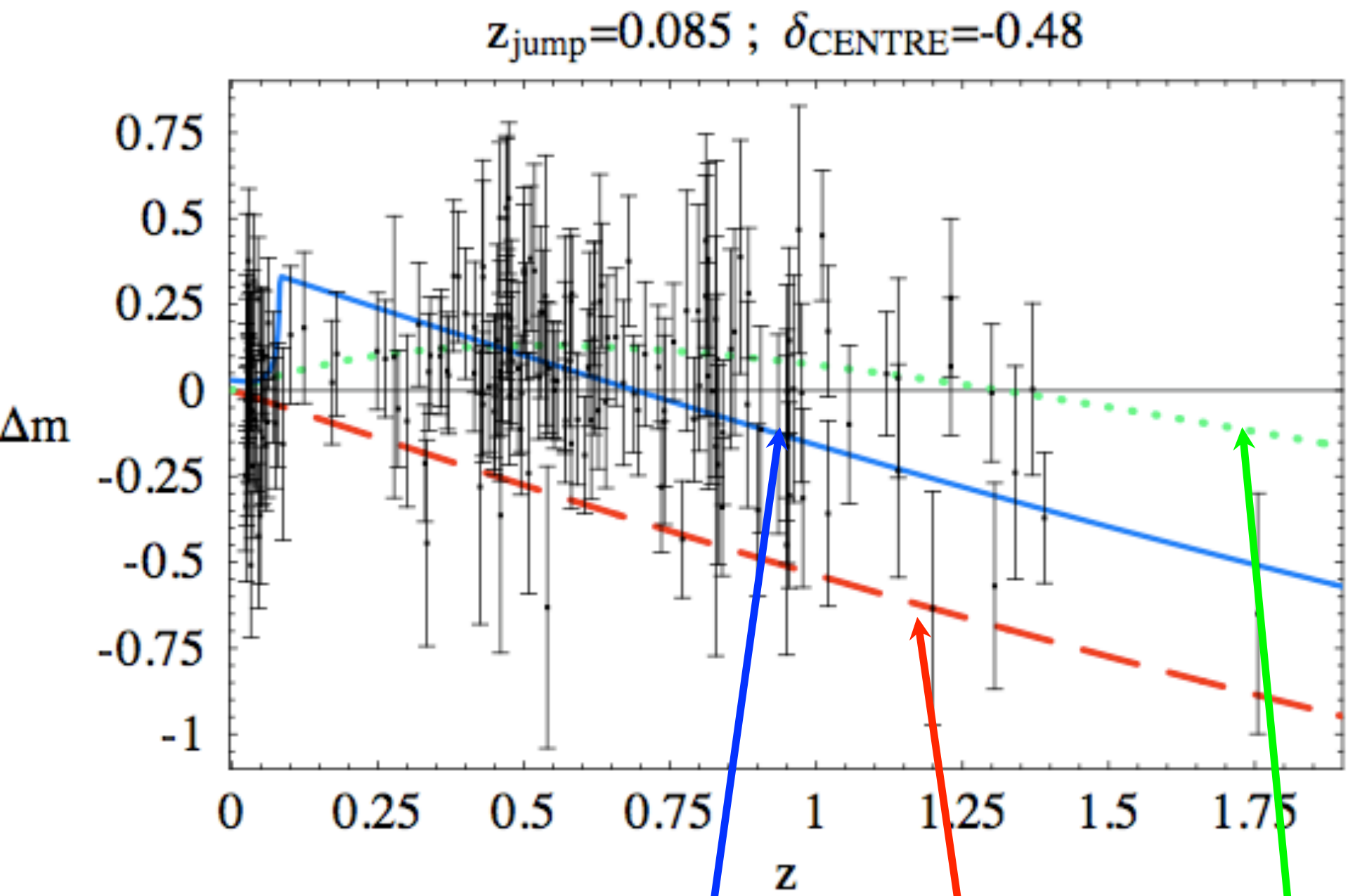
ds NATURALLY introduce a Reese Sciama effect
ost important void is the void where we are located
ost important factor in void optics is size of voids

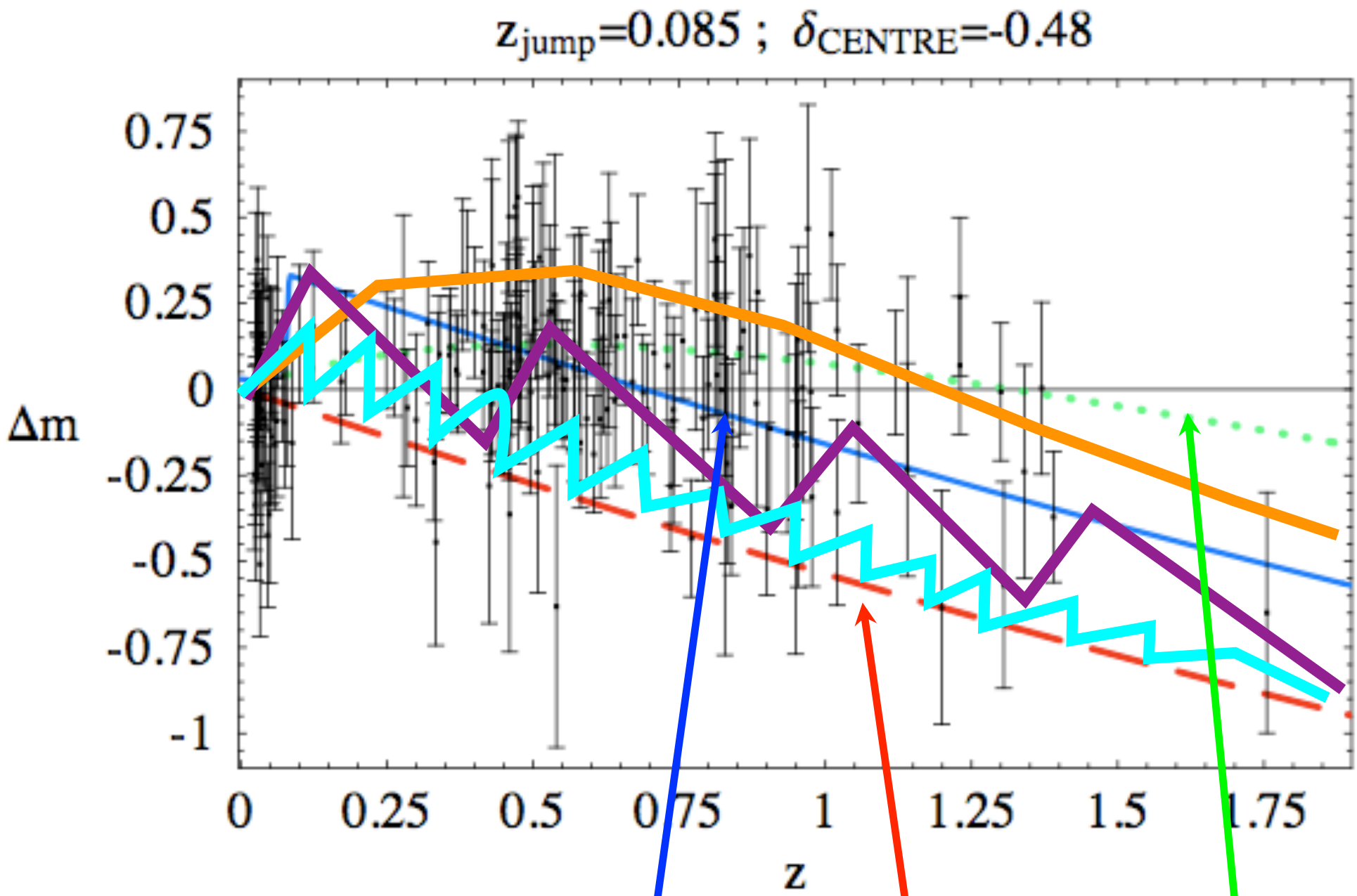


5: On the bottom the luminosity distance $d_L(z)$ in the five-hole model (jagged curve) and the ΛCDM solution with

From Ko
Matarese a
Marra


z_{jump}=0.085 ; δ_{CENTRE}=-0.48
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
Δm
0
0.25
0.5
0.75
1
1.25
1.5
1.75
z

Single 300



pc void

00 Mpc Swiss Cheese

Single 300 Mpc void

EDS

LCDM

CMB fitting: Look carefully at boundary conditions in the space & time directions:

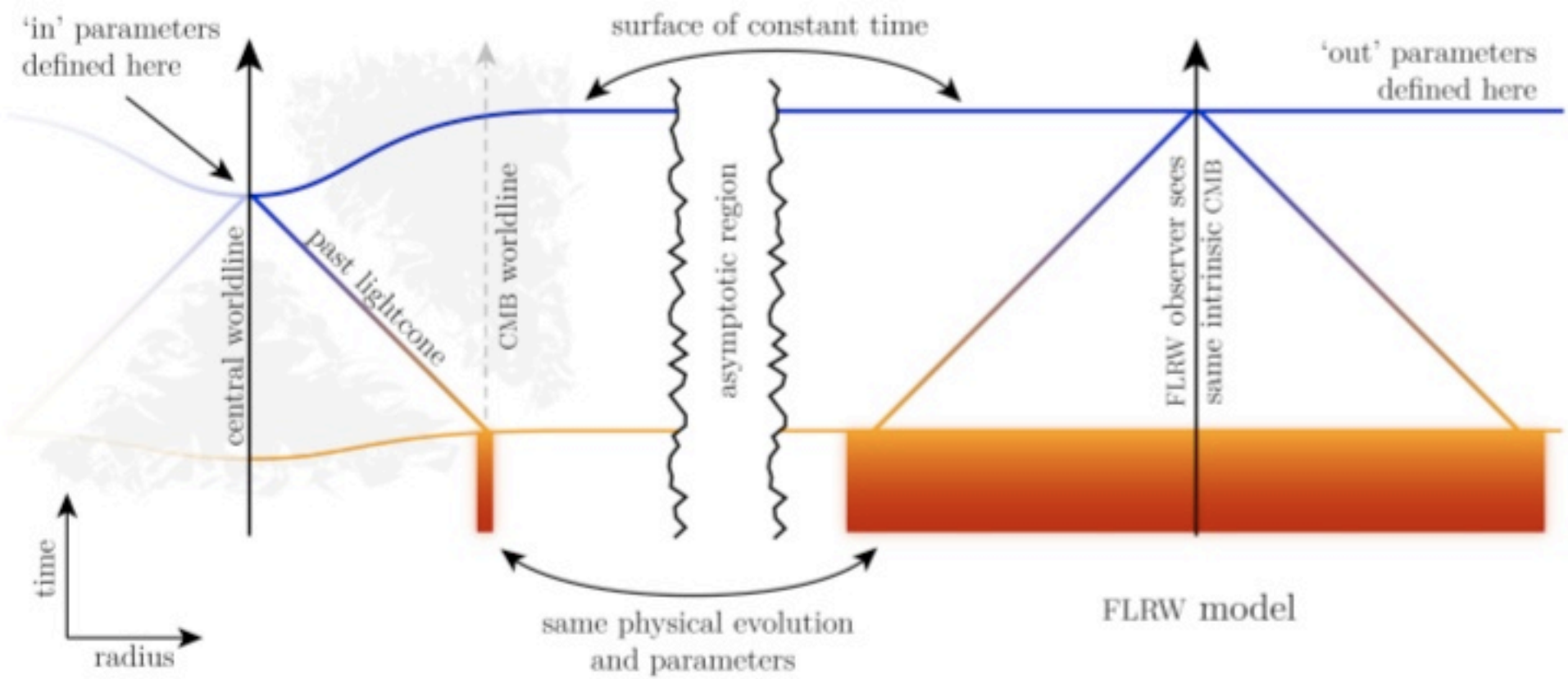
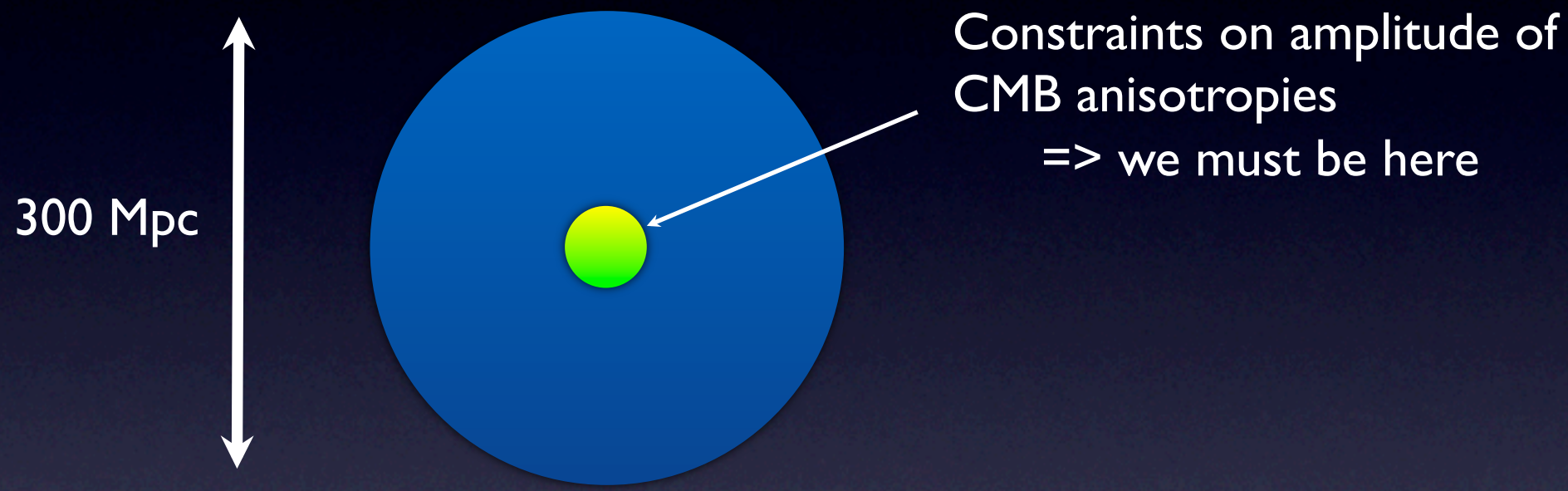


FIG. 2: Schematic of our model and assumptions. The central observer sees a small patch of the last scattering surface, which we assume evolves as in the asymptotic part of the model which is FLRW. The shaded regions are not required to be fixed for the calculation of the small scale CMB, but are constrained a posteriori.

blem: CMB fitting requires being "near" the
ter of a spherical void.



at next ???

arture from spherical symmetry suggests that
nter problem" can be removed (or made less

pherical void models that comply with several observations:

SN Ia

CMB amplitude & multipoles & BAO

nitial conditions (LSS) compatible with inflation

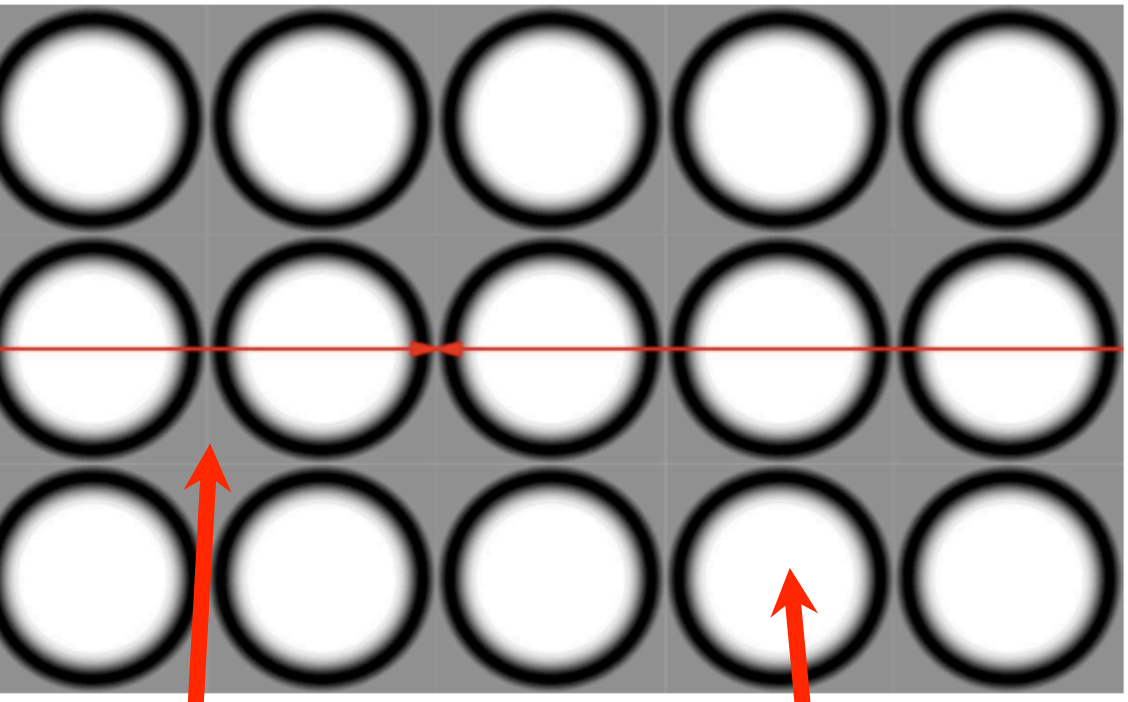
age constraints & H0 measurement

kinematic S-Z

Not Possi

LTB mod are too simple They la dynamic freedo

o, what are we proposing ?



6

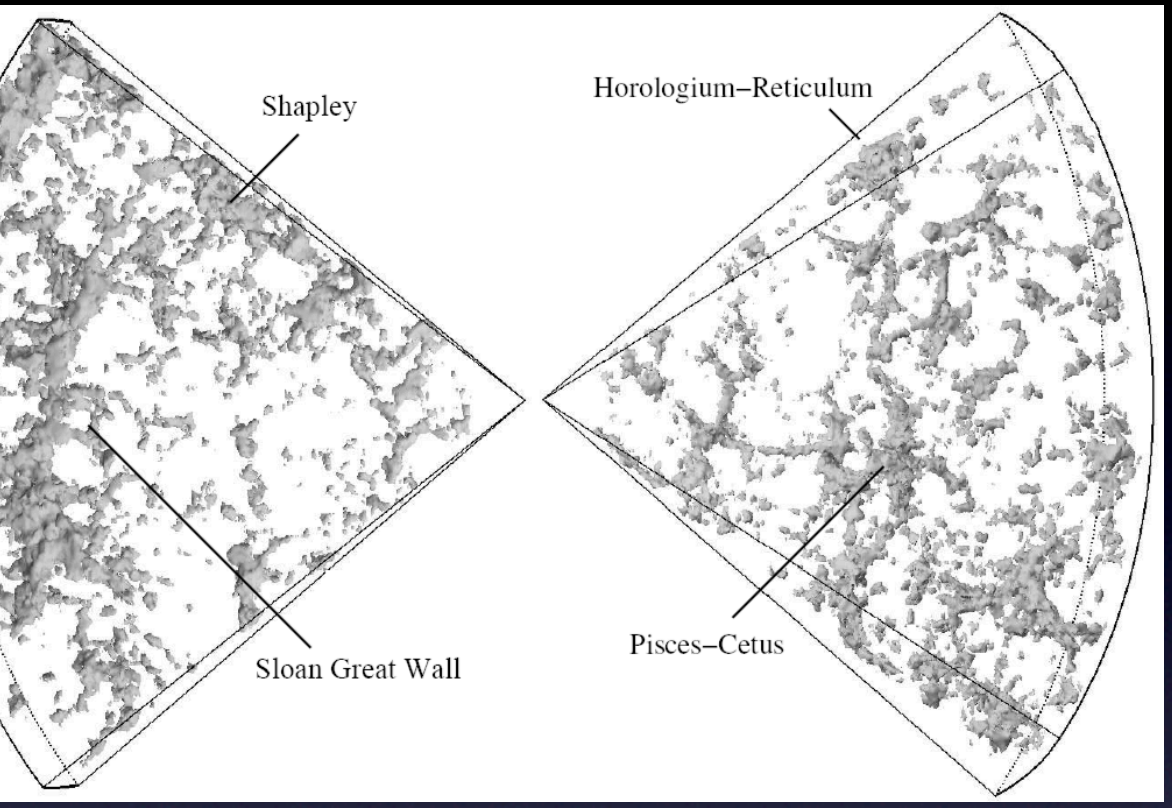
ch of our model. The shading mimics the initial density profile: darker shading implies larger denser. The uniform FRW cheese. The photons pass through the holes as shown by the arrows and are revealed by the observer placed e.

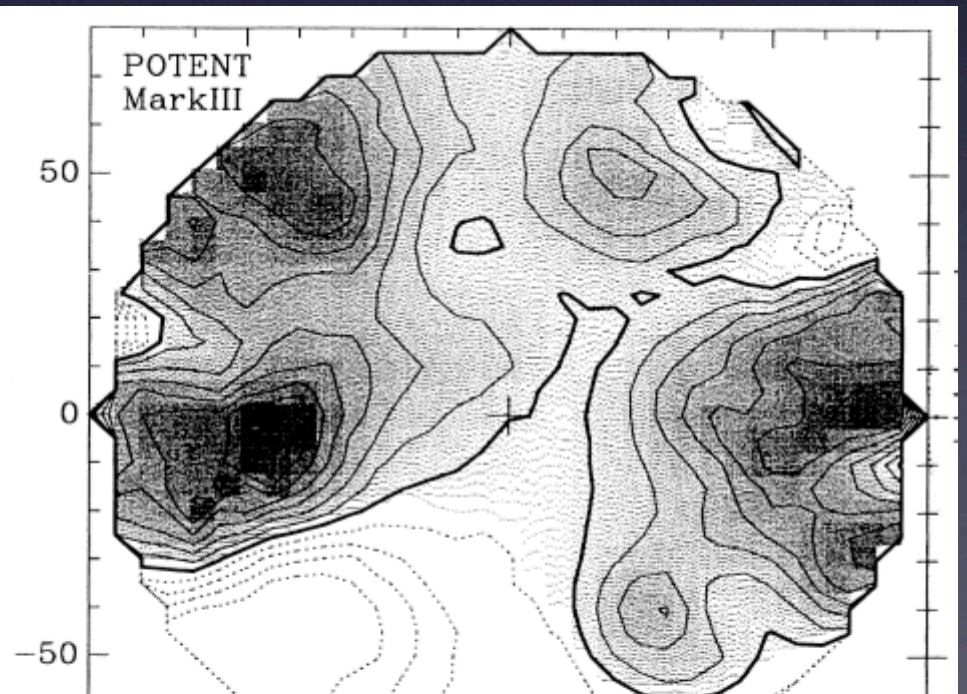
A Swiss cheese model, but the "inside" of the holes is no long spherically symmetric

The "cheese" is omogeneous dust (FLRW)

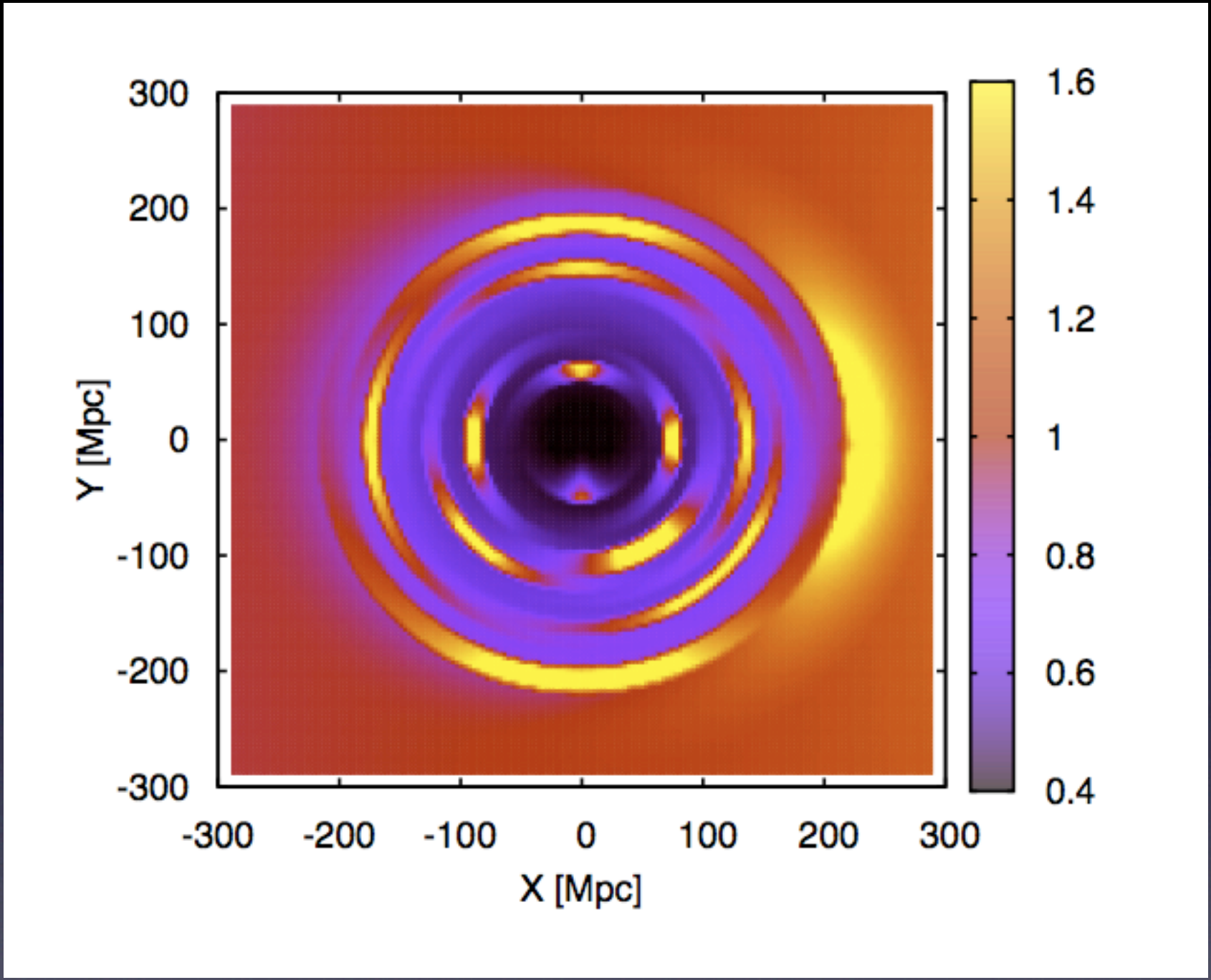
Dust underdensities (voids) that are NOT spherically symmetric (Szekeres)

Spherically symmetric ...





olution



ross section (tessellation) of the Szekeres

rse-graining cosmic structure by
keres solutions

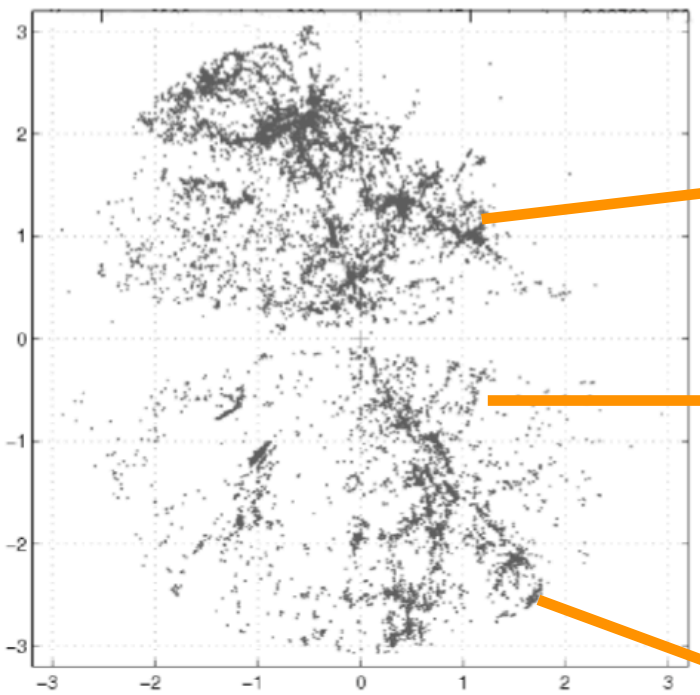
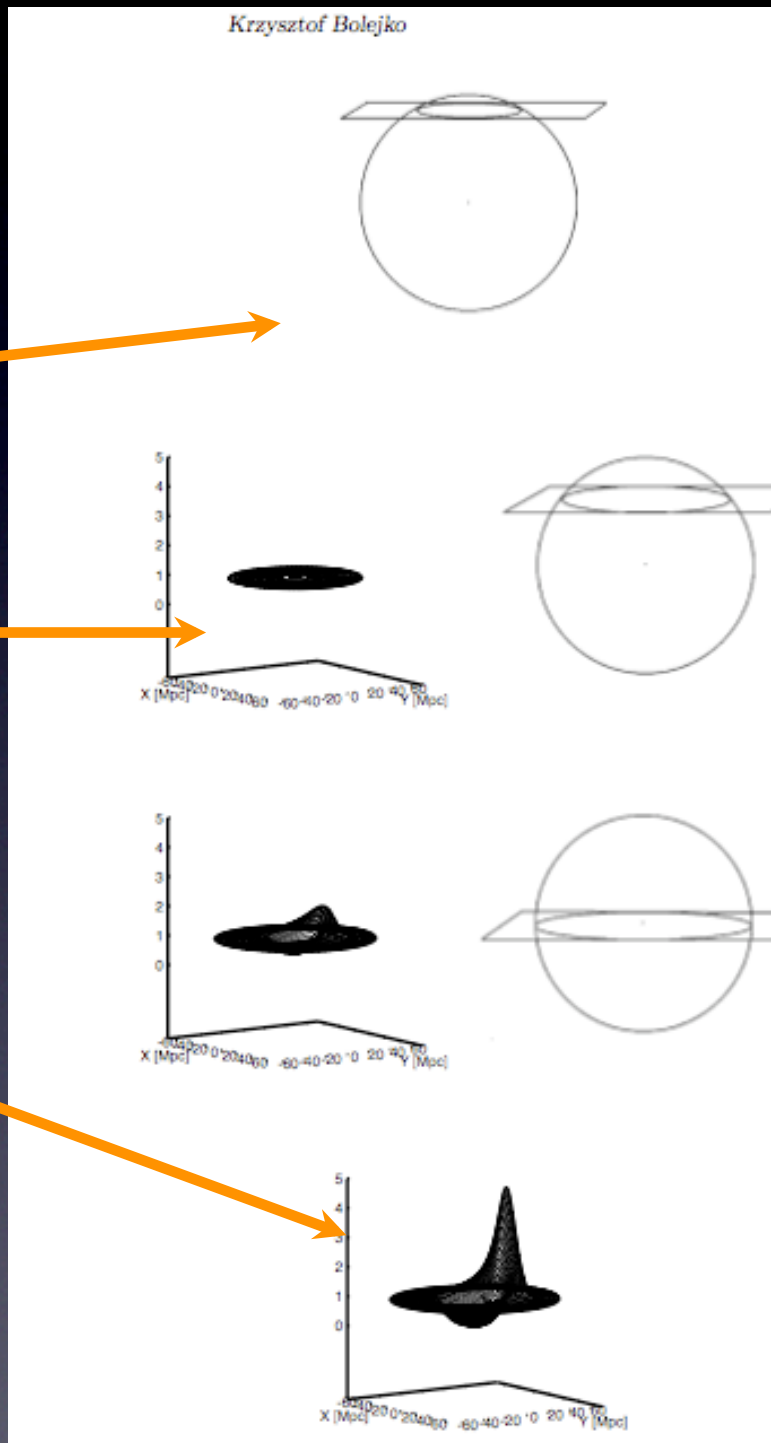
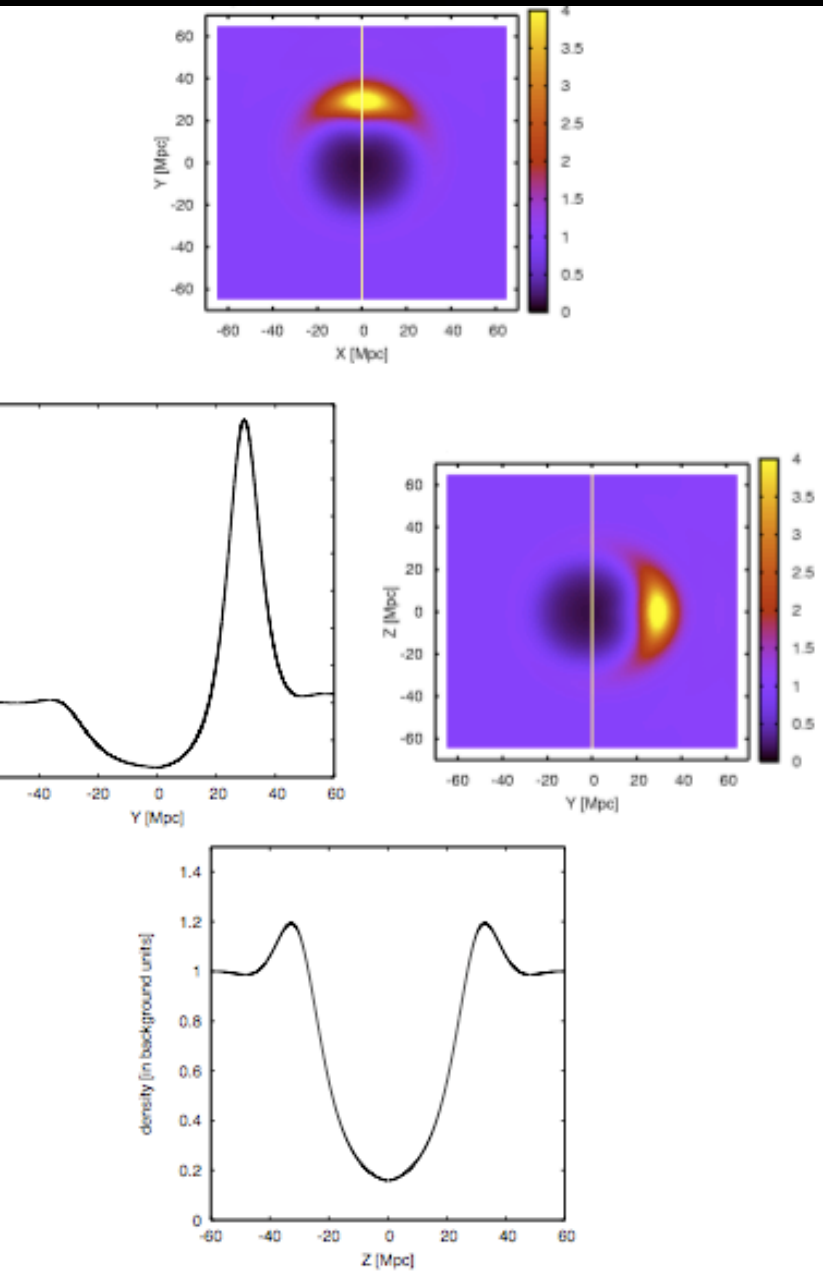


Figure 1. The galaxy distribution in a slice 1600 km/s thick and 32000 km/s square. The Zone of Avoidance is clearly visible in the middle of the picture. Since the data are from different redshift surveys, some structures are well mapped, while other regions are not. Still there are regions from which there is no data at all.





4. Density distribution in the considered structure. Upper
nel presents colour coded density distribution of the equatorial
ection (see Fig. 3, bottom panels). Lower left panel presents the
cross–section of $X = 0$, through the considered model. The
lines correspond to the density profiles, which are presented on

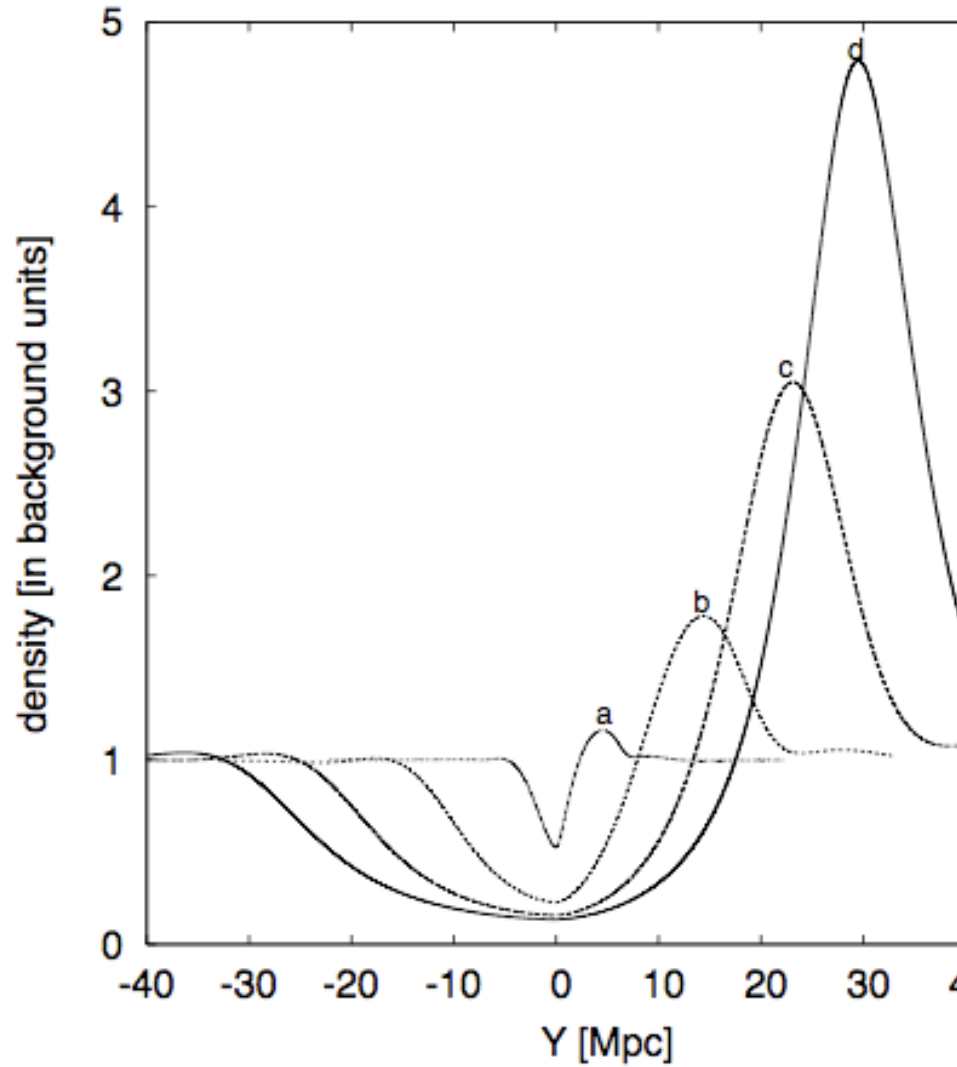
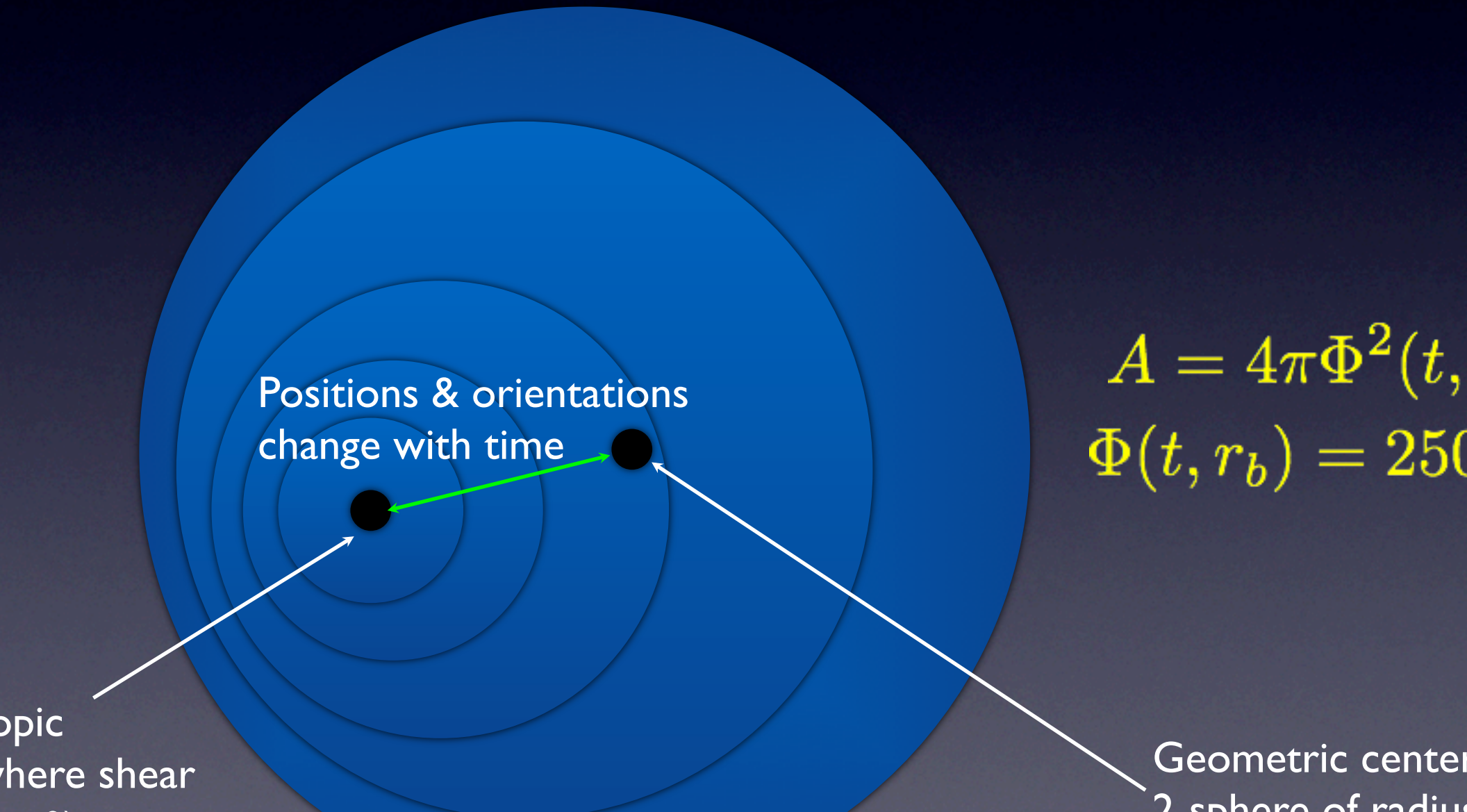


Figure 5. The density profile for diffrent time instants: a —
after the Big Bang, b — 5.5 Gy, c — 10 Gy, d — present insta

o longer unique --- NO need to do "fine-tunin

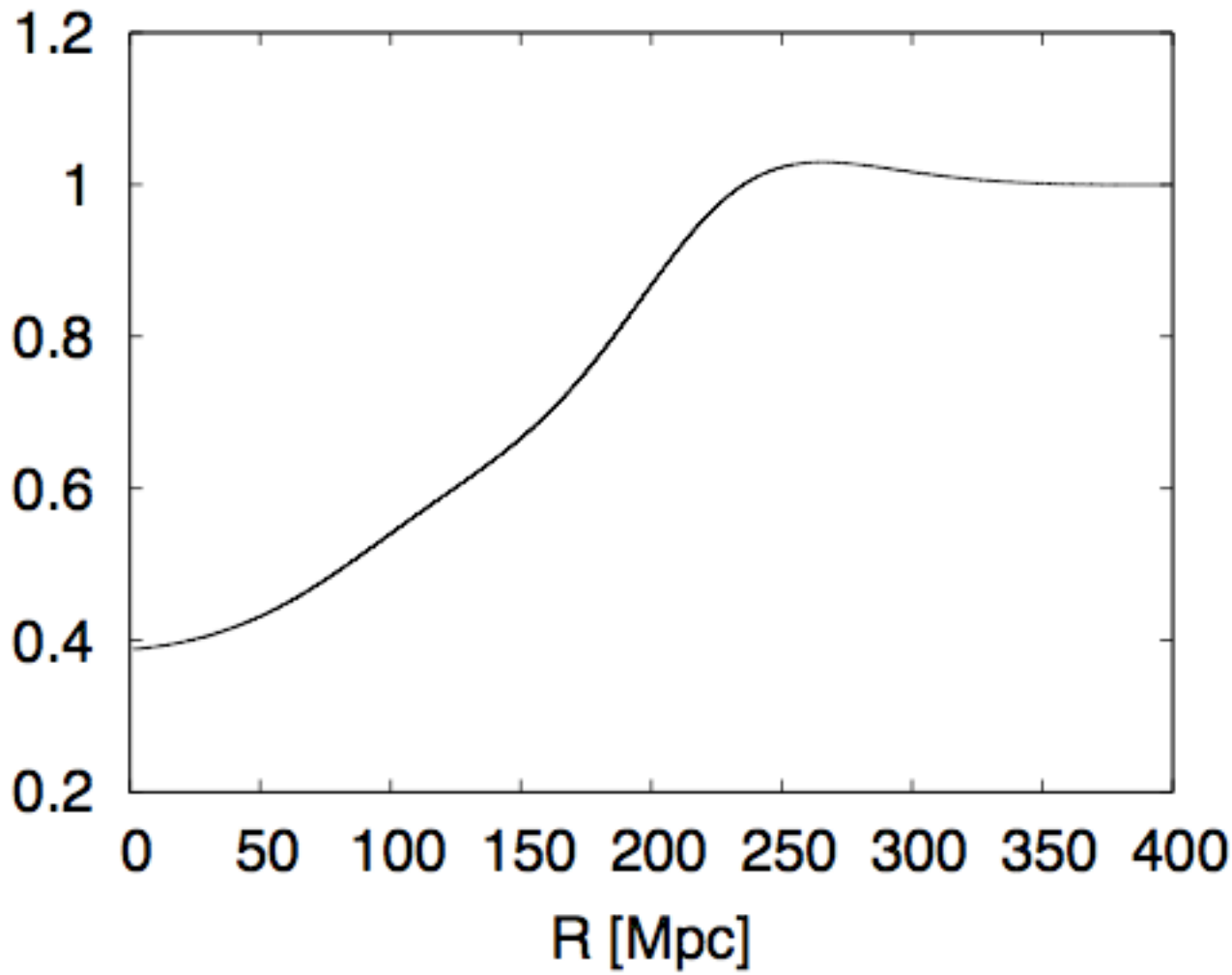
zekeres quasi-spherical geometry ---- 2 possible "cente
tions whose position & orientation changes with time:



$$A = 4\pi\Phi^2(t,$$

$$\Phi(t, r_b) = 250$$

distribution is fa
spherical, its ave
spherical !!!



Density profile after averaging $\langle\rho\rangle(r_{\mathcal{D}})/\rho_0$ (where ρ_0 is the back-
ensity). Since $\langle\rho\rangle(r_{\mathcal{D}})$ in (9) is independent of x and y, its dependence
the form of a cosmic void whose radius is approximately 250 Mpc
us to the spherical voids of reference [8]).

What needs to be done next ??

Integrate null geodesics for the Szekeres Swiss cheese, and verify the fitting of SN Ia & CMB data

Provide a better theoretical interpretation for the averaging

Try our luck with geometries more general than Szekeres (3d codes)

Wait for better observations (galactic

Big Void
DARK
ENERGY