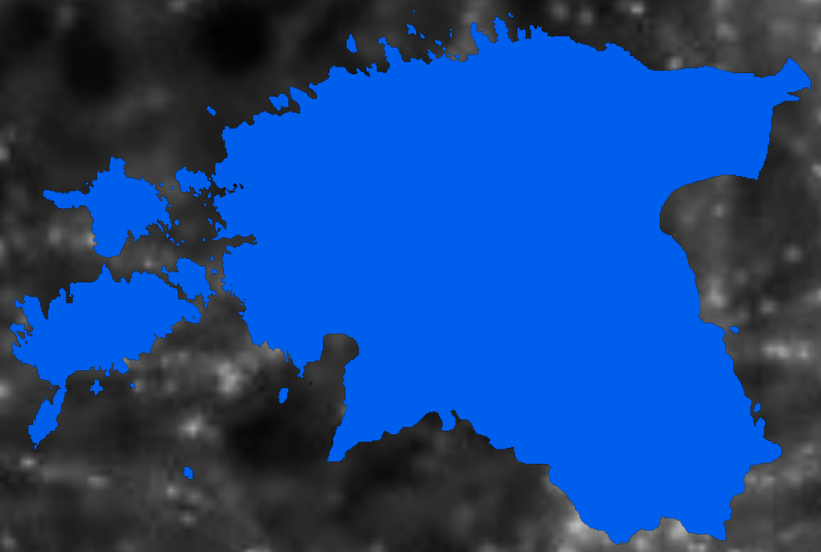
Real-space density profile reconstruction of stacked voids

IAU Symposium 308 The Zeldovich Universe

Genesis and Growth of the Cosmic Web



Alice Pisani
In collaboration with:
B. Wandelt, P. Sutter, G. Lavaux, N. Hamaus
Institut d'Astrophysique de Paris (France)

Eesti
Tallinn
27/06/2014

Credit: Millennium simulation

Voids are great !

(Rien van de Weygaert's review)

Cosmological probes (AP…)
(Yan-Chuan Cai's and Paul Sutter's talks)

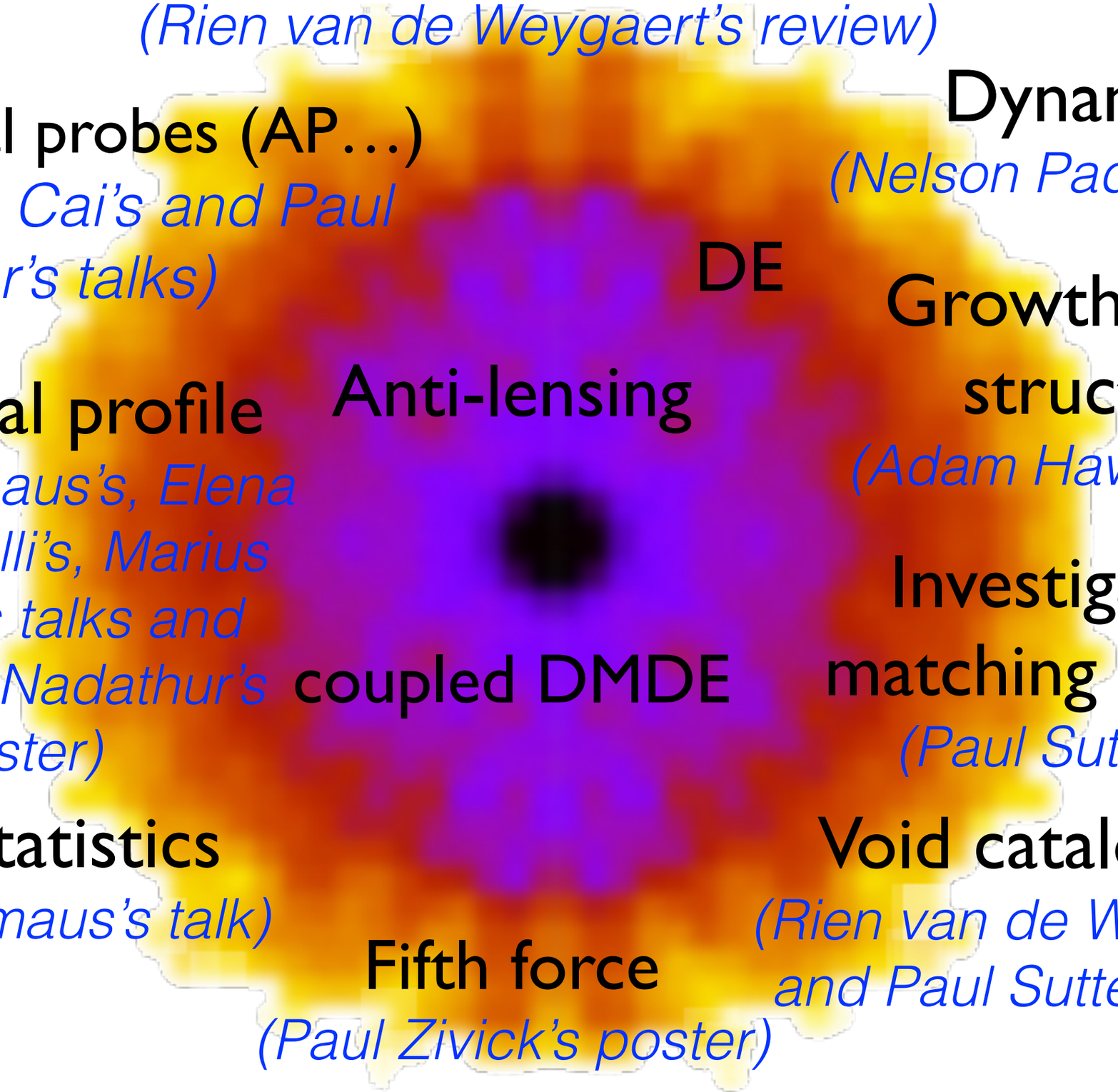
Dynamics
(Nelson Padilla's talk)

DE

Growth rate of structures
(Adam Hawken's talk)

Universal profile
(Nico Hamaus's, Elena Ricciardelli's, Marius Cautun's talks and Seshadri Nadathur's poster)

Anti-lensing



coupled DMDE

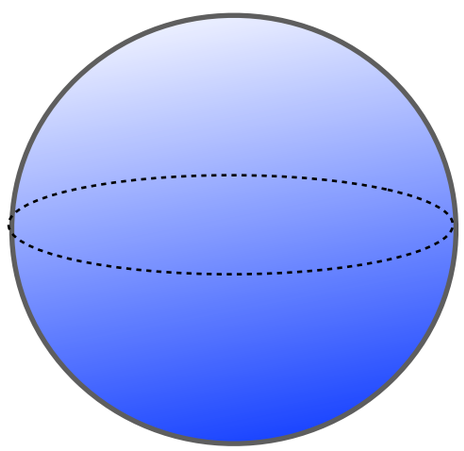
Investigate bias matching DM voids
(Paul Sutter's talk)

Void statistics
(Nico Hamaus's talk)

Void catalogues
(Rien van de Weygaert's and Paul Sutter's talks)

Fifth force
(Paul Zivick's poster)

What do we know about voids?



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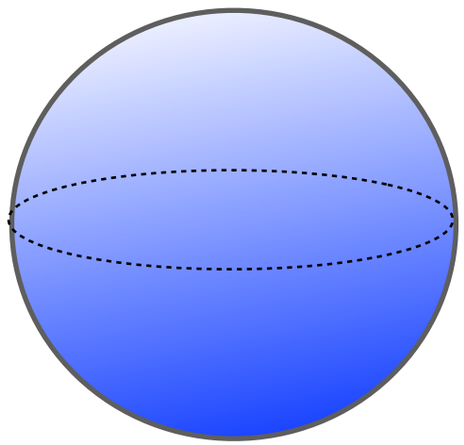
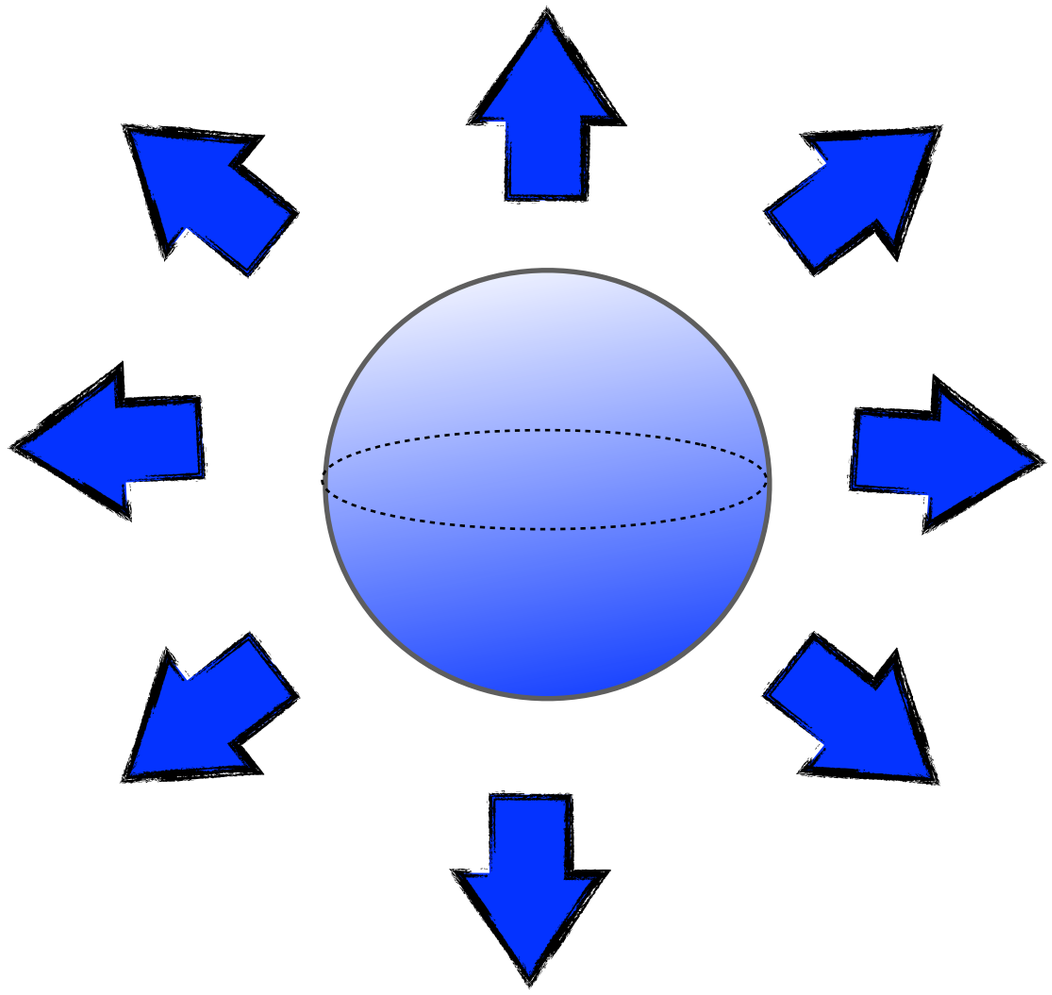
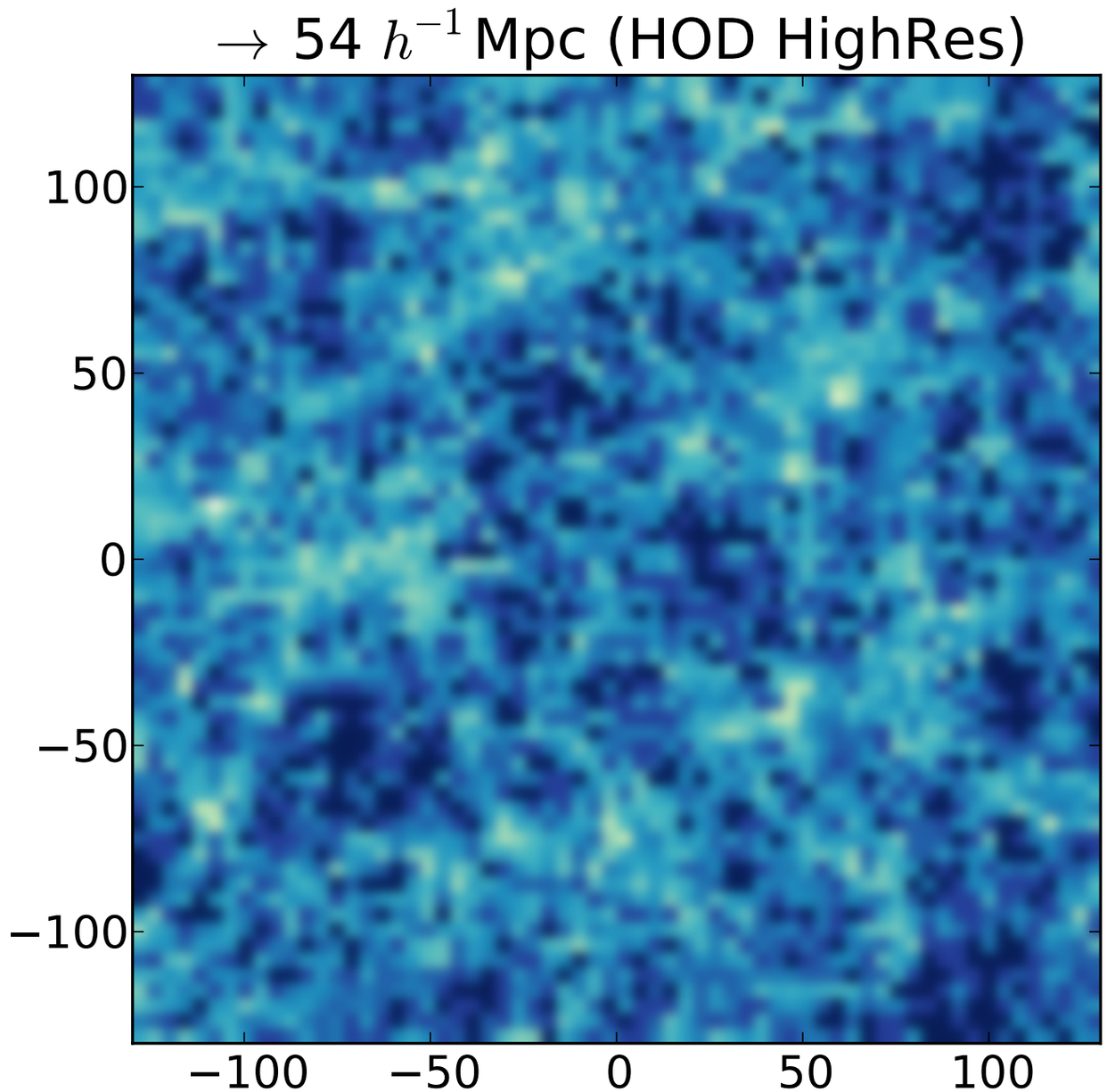


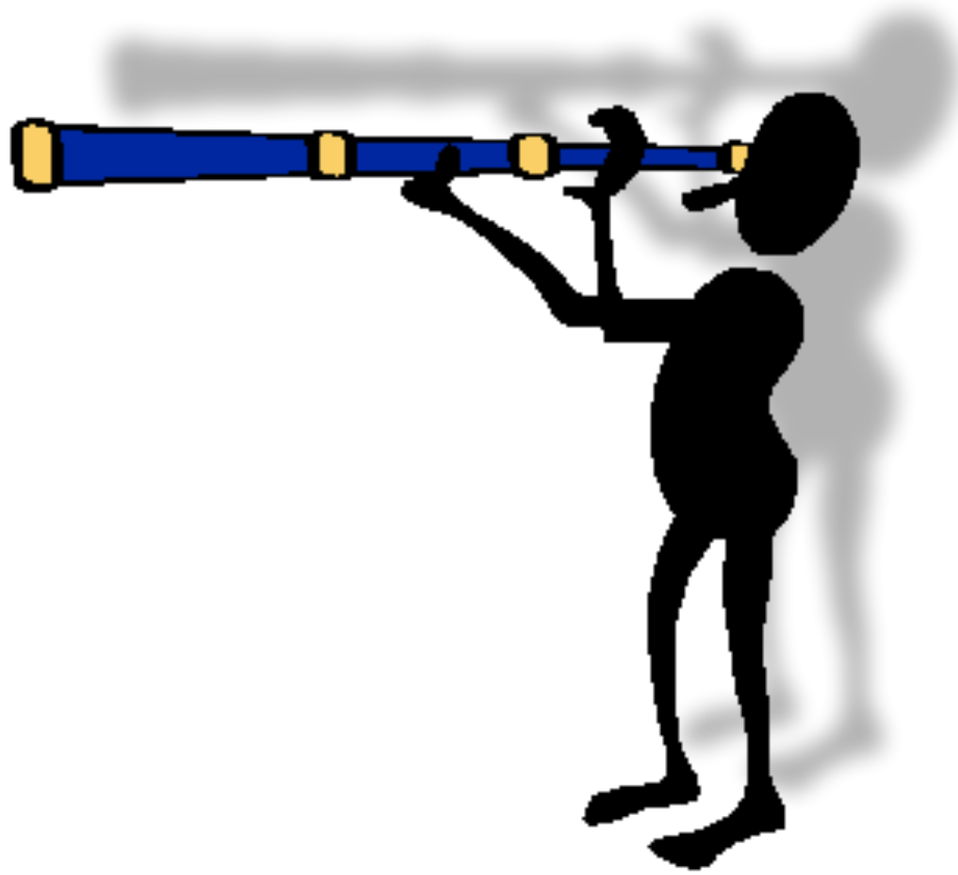
STATIC????



DYNAMICS ????

Let's give a look to a void…





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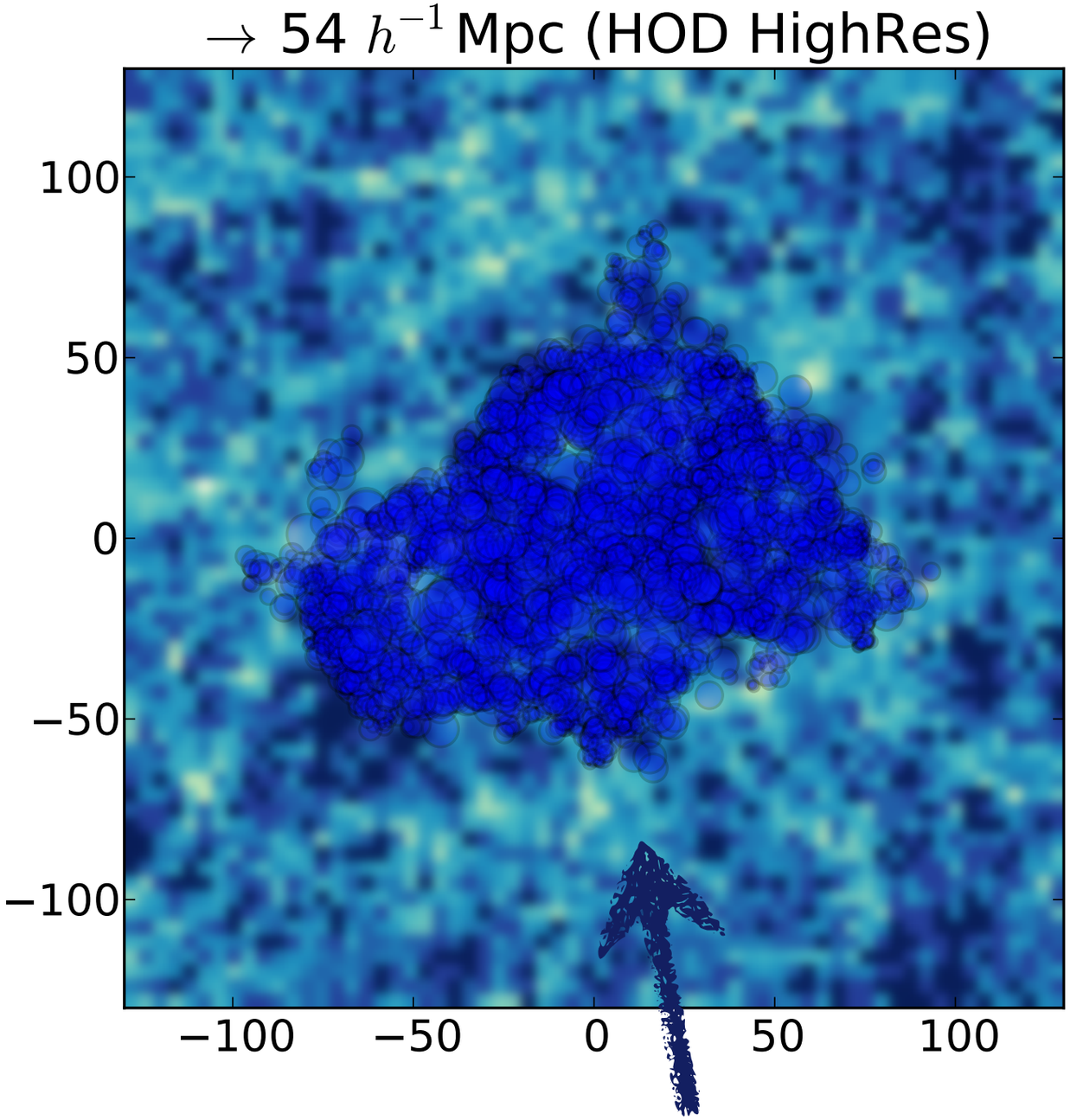

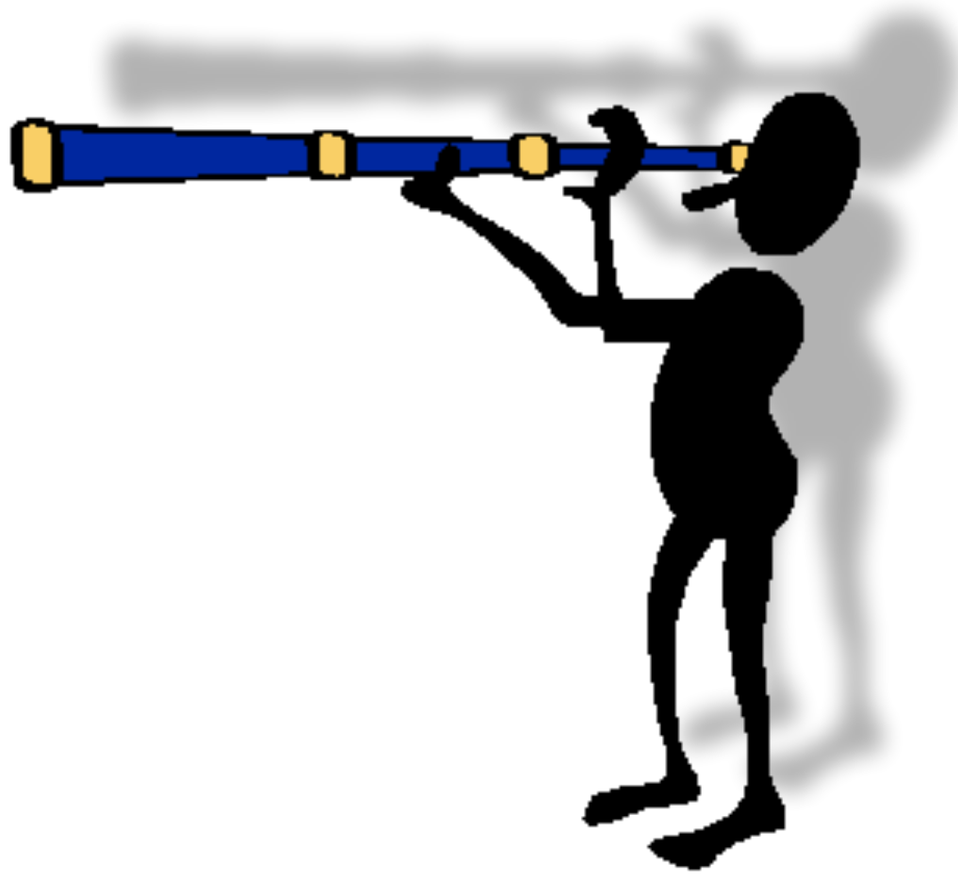

No PV

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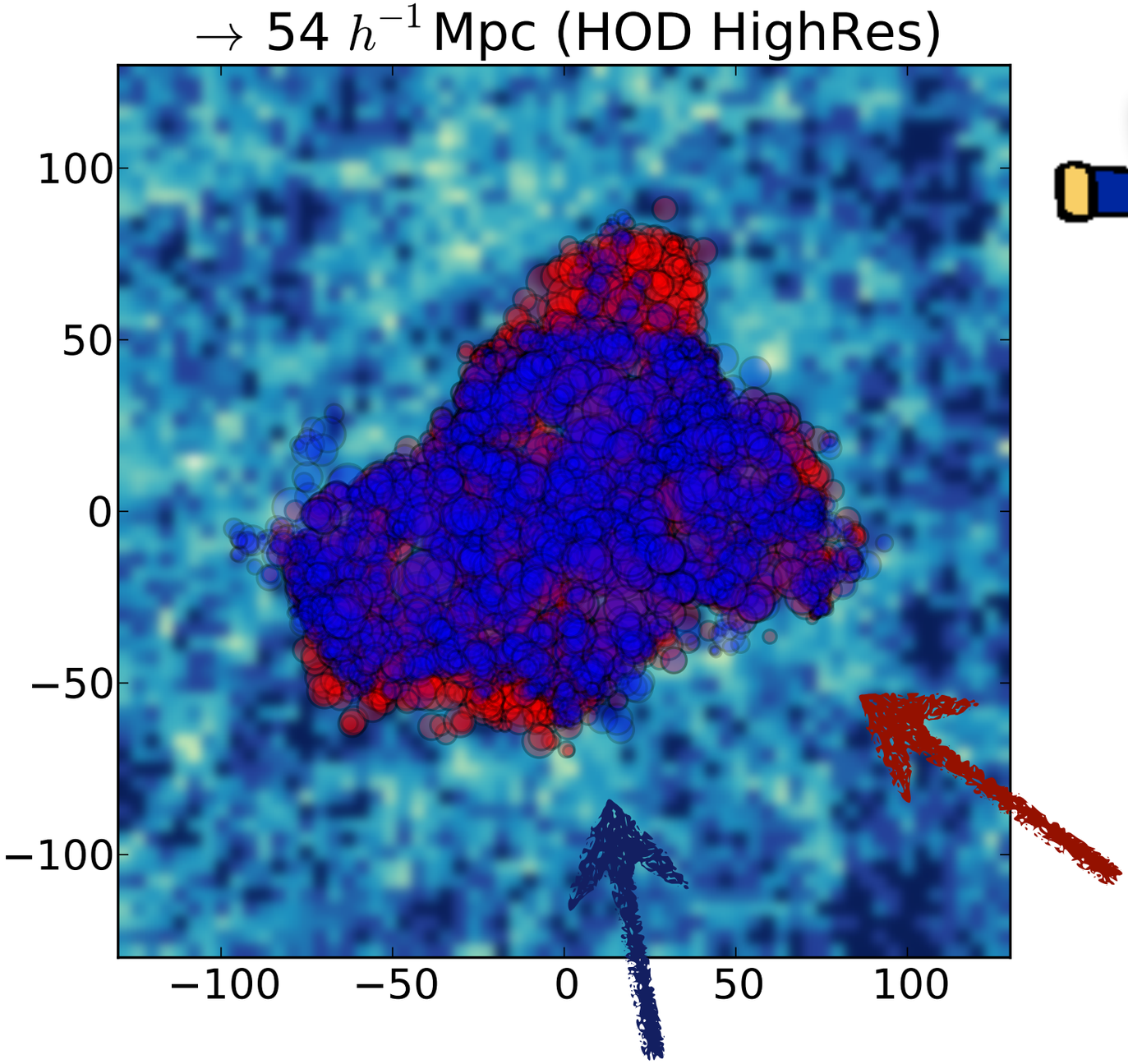
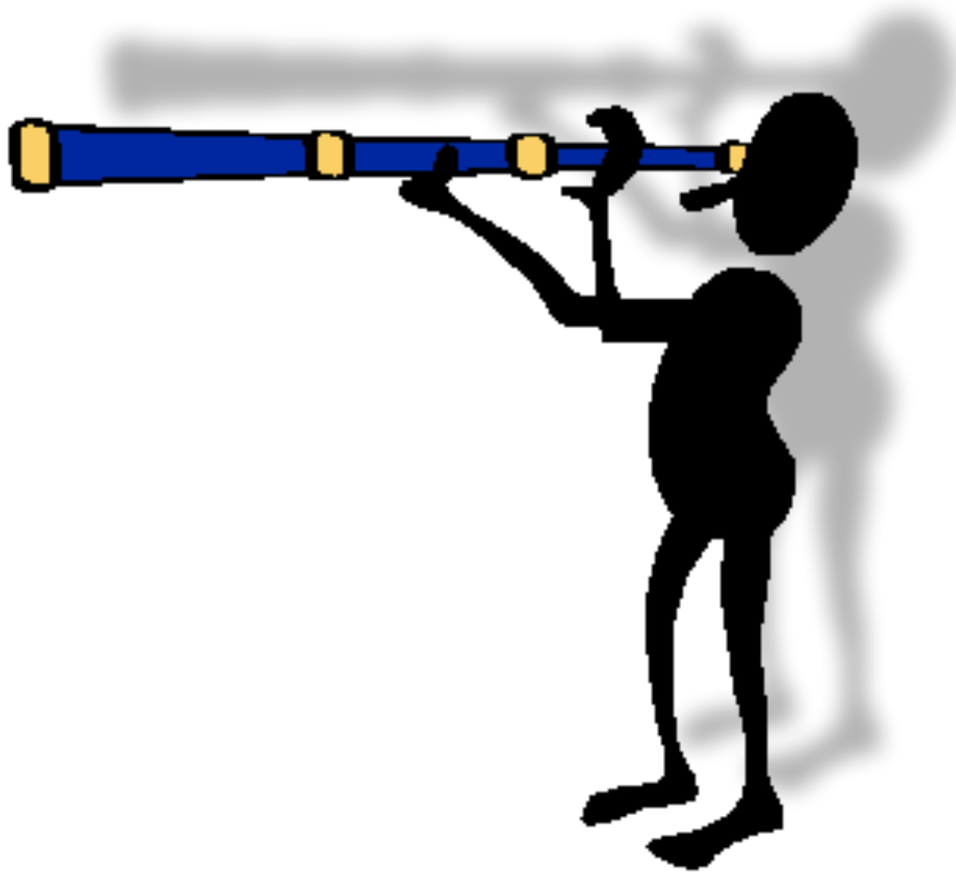
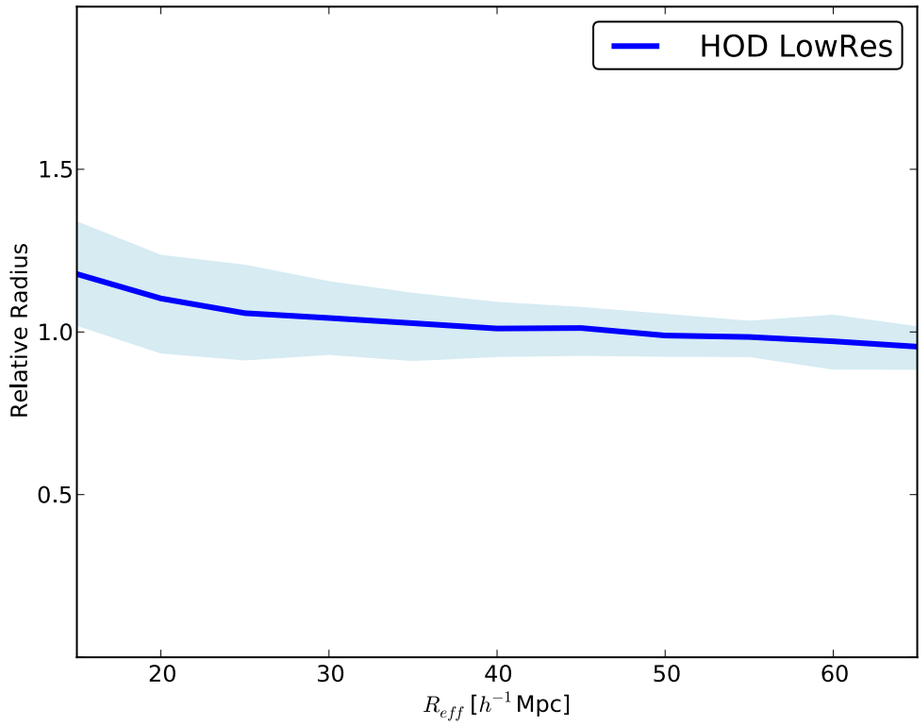


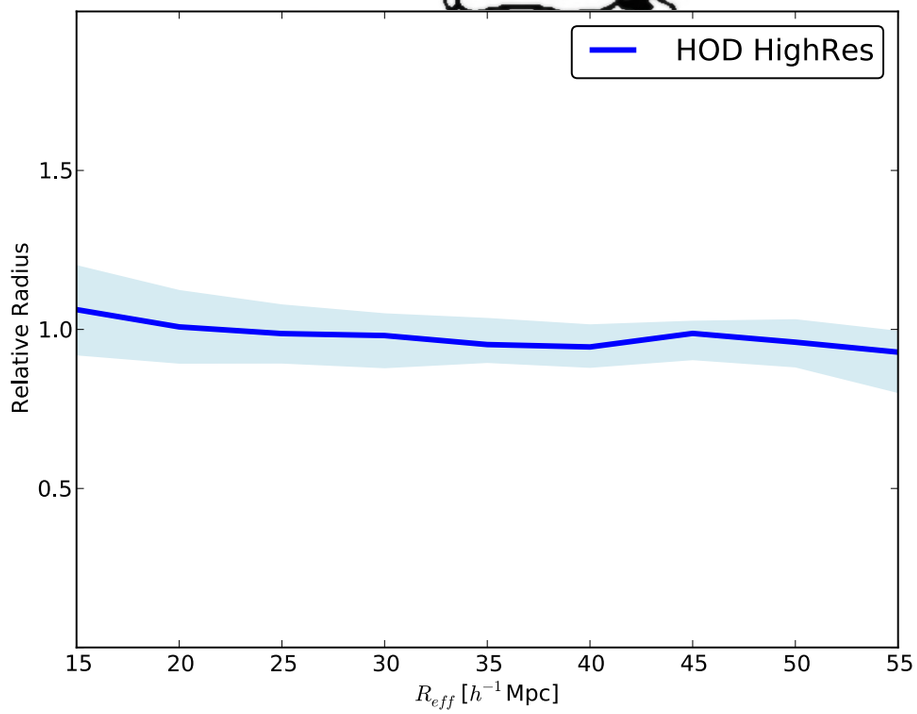


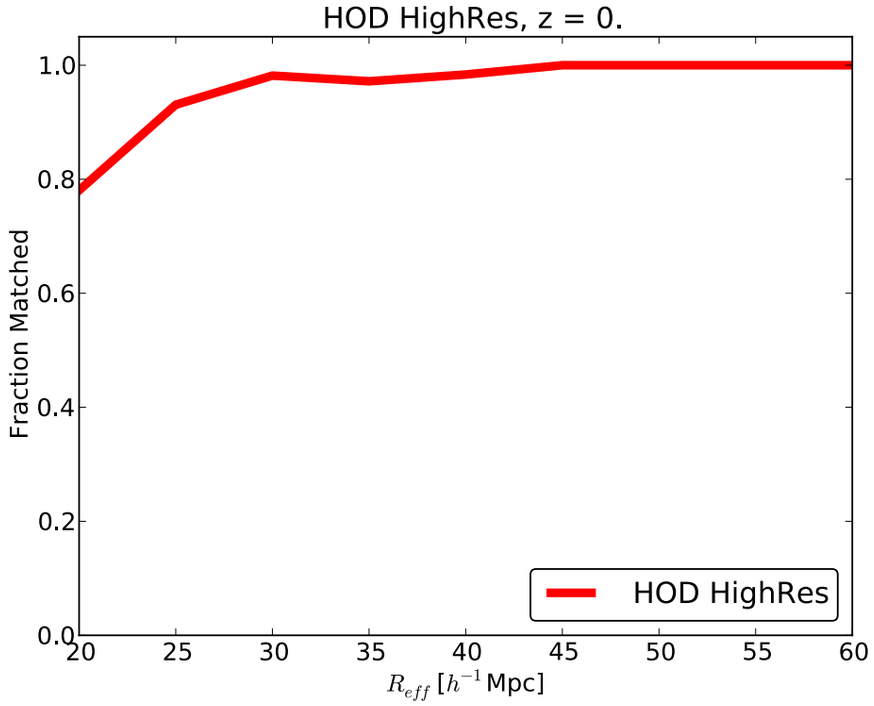
No PV

PV

Velocity effect ?







Pisani, Sutter, Wandelt 2014 (in prep.)

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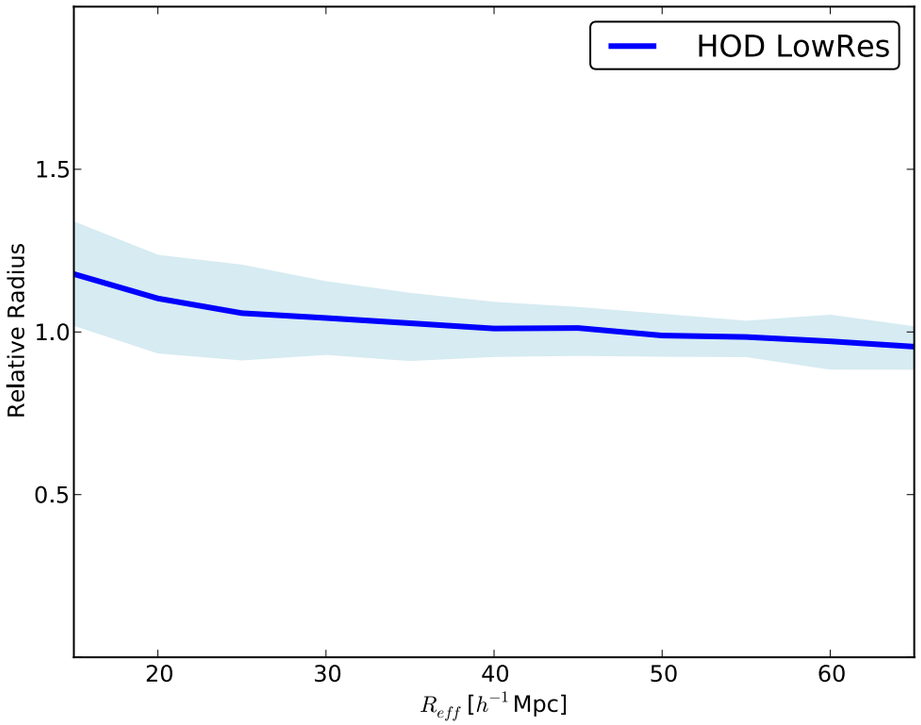

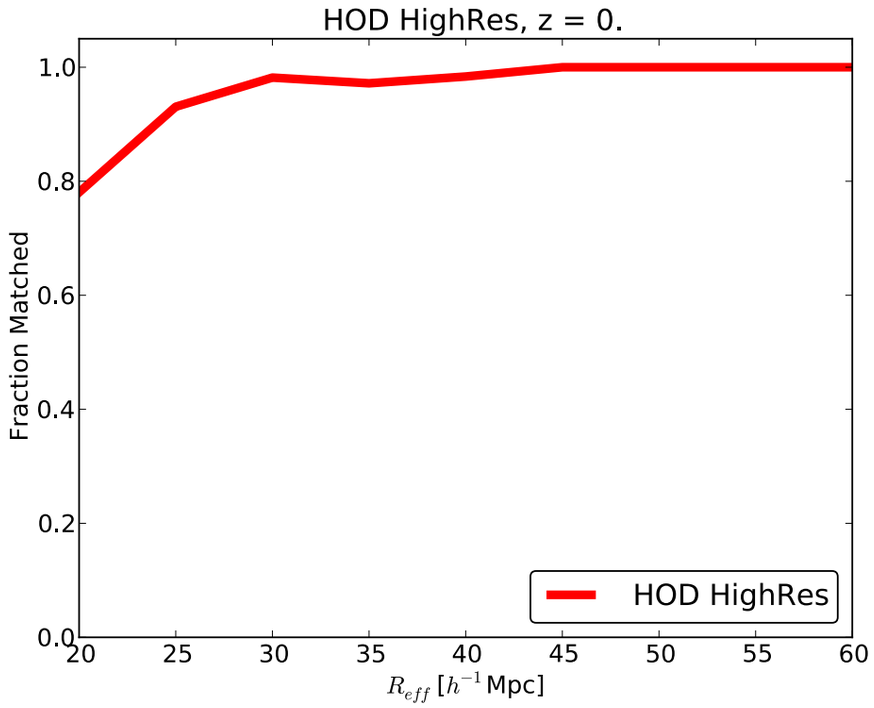

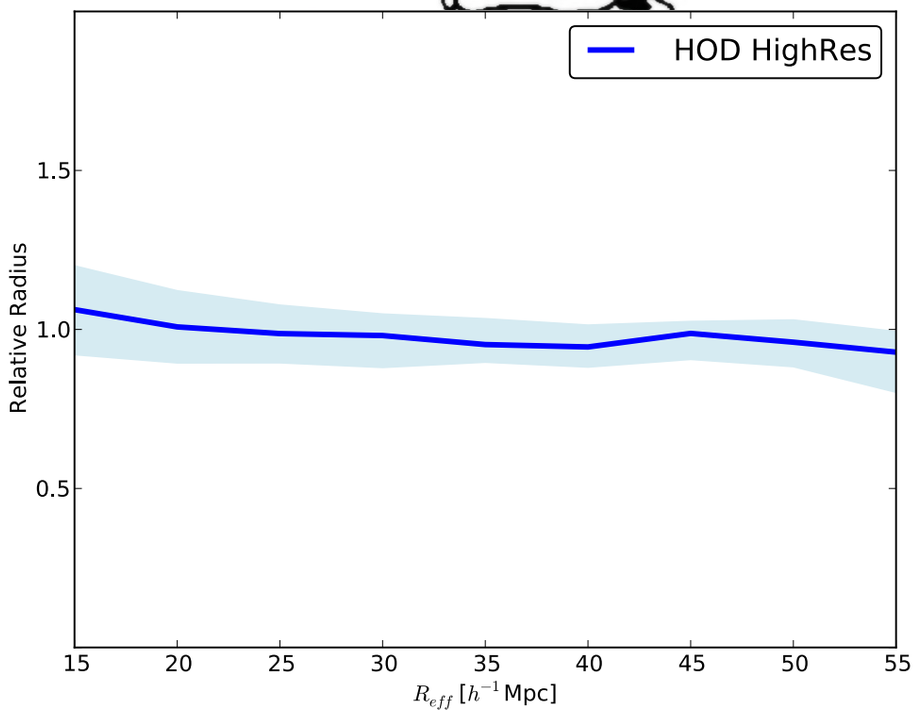

Pisani, Sutter, Wandelt 2014 (in prep.)

We see voids in redshift space!

Features might be *distorted!*

If something is going to respond to components such as neutrinos or Dark Energy it's void features!

To use voids as cosmology laboratories we need the real space shape of stacked voids...

Real space shape can:

shed light into modified gravity

Graviton could become massive, which would introduce a new scalar field.

The equation of state could be DENSITY and SCALE DEPENDENT

In lower density zones the effect of MG should be different!

Spolyar et al. (ArXiv: 1304.5239)

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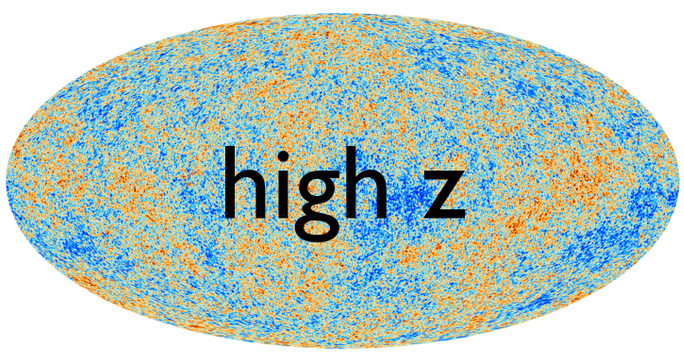
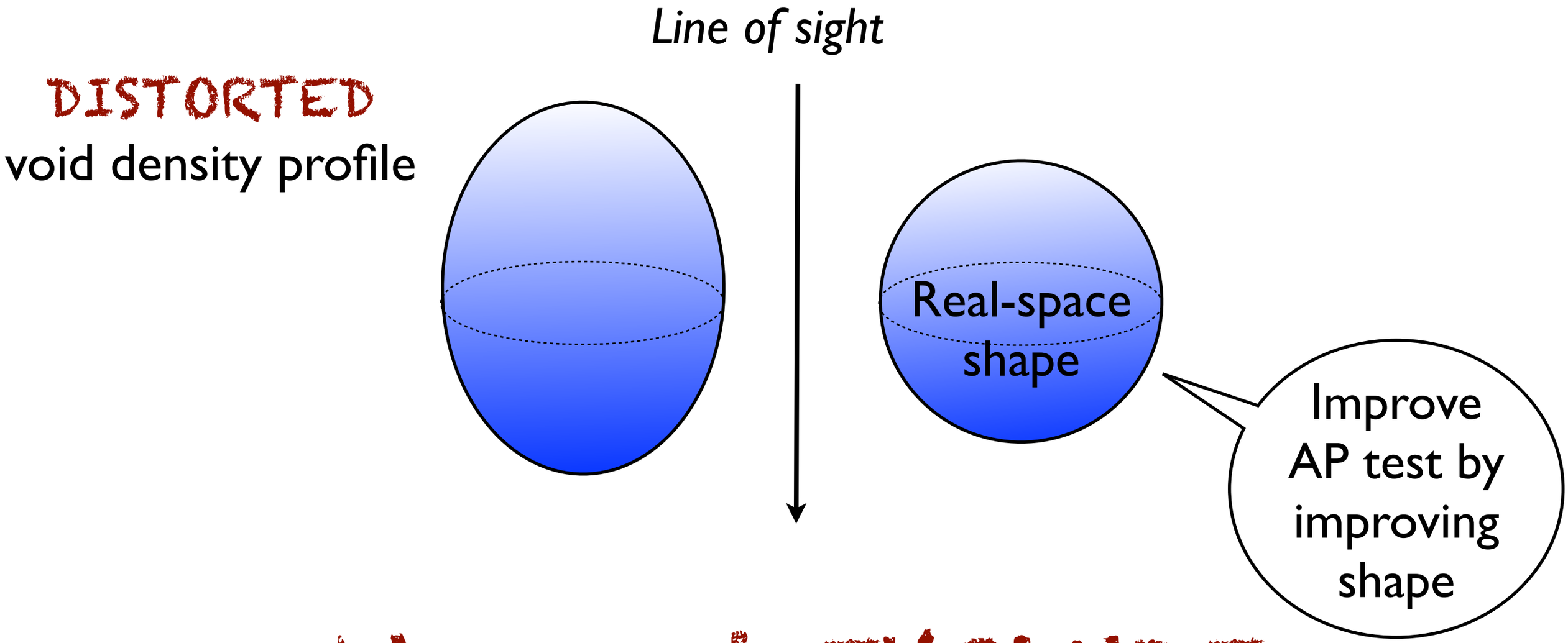
→ give a low z measure of the Hubble parameter



How to determine the real-space density profile?



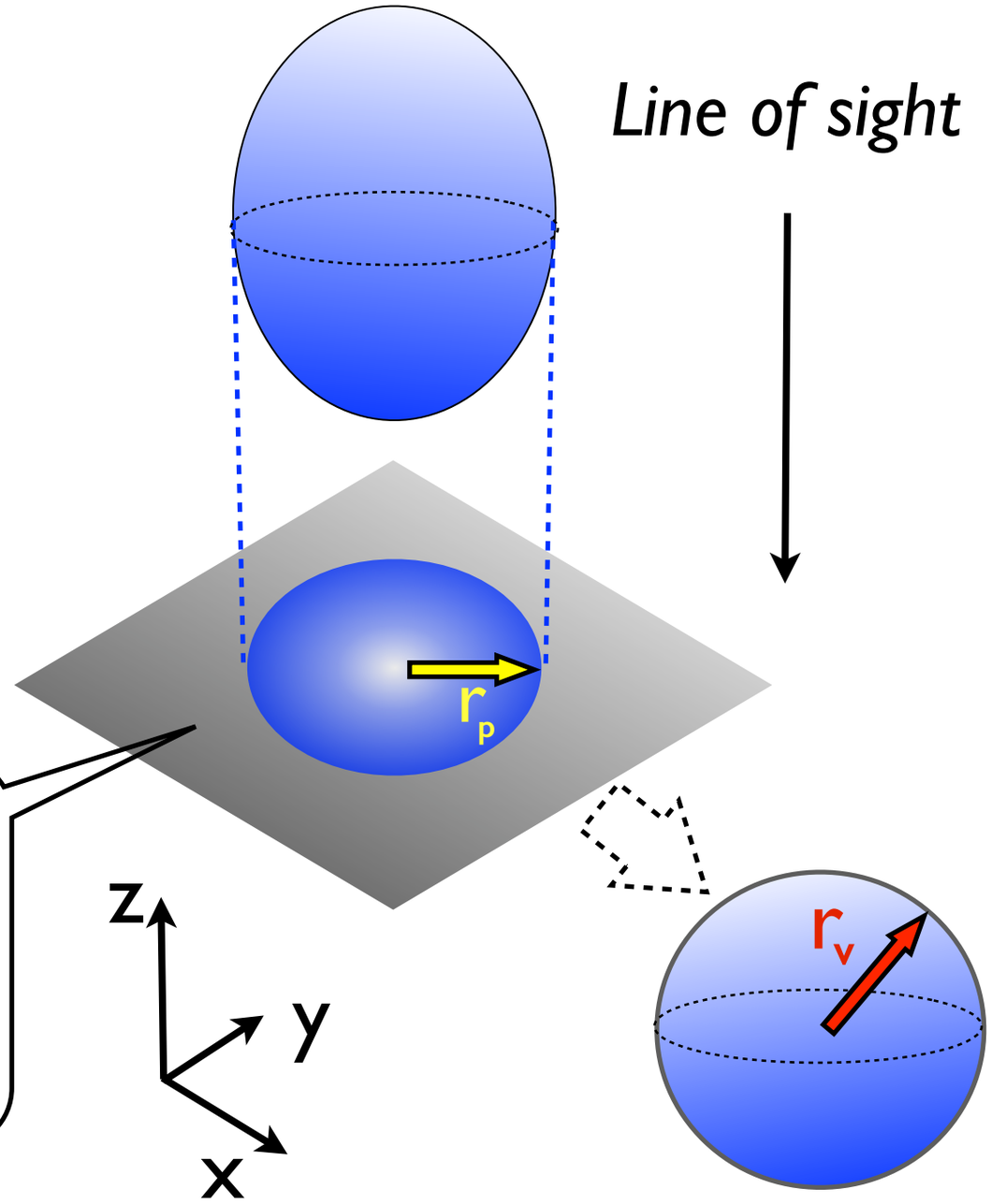
We must EXCLUDE distortion!

The method to get the spherical profile

Key idea

Projecting the 3D distribution along the line of sight, the contribution of peculiar velocities disappears.

From this projection we reconstruct a 3D profile without the contribution of peculiar velocities.

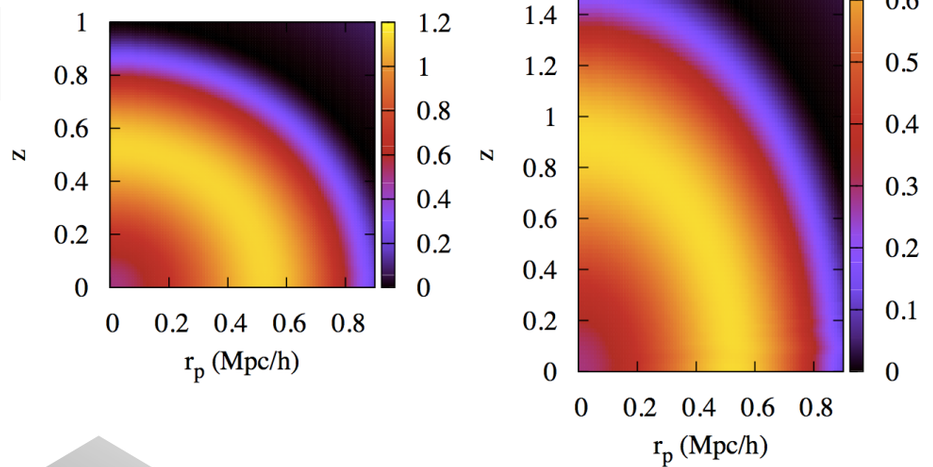


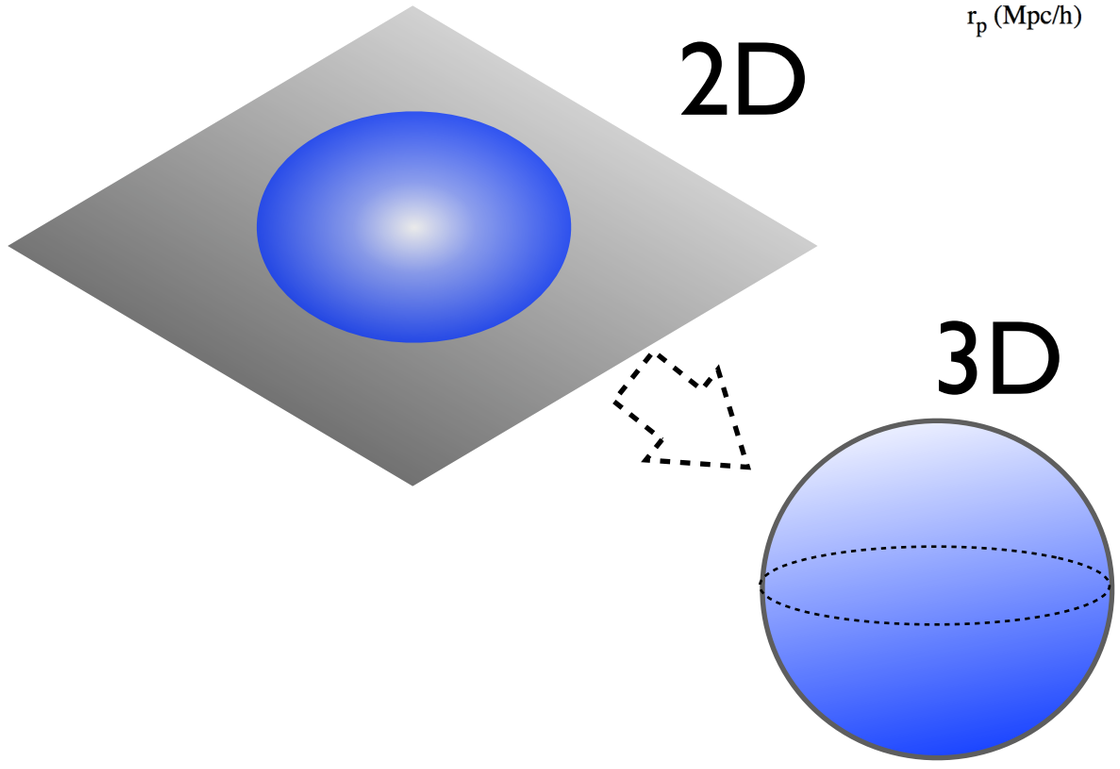
We can obtain the SPHERICAL density profile of stacked voids in real space.

Result I

The toy model

$$g(r) = -\frac{1}{\pi}\int_r^1 \frac{I'(y)}{\sqrt{y^2 - r^2}}dy$$





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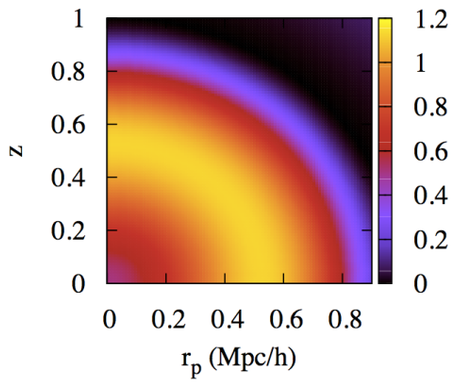
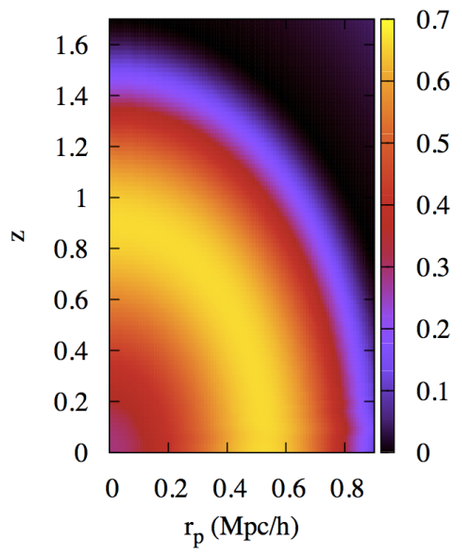
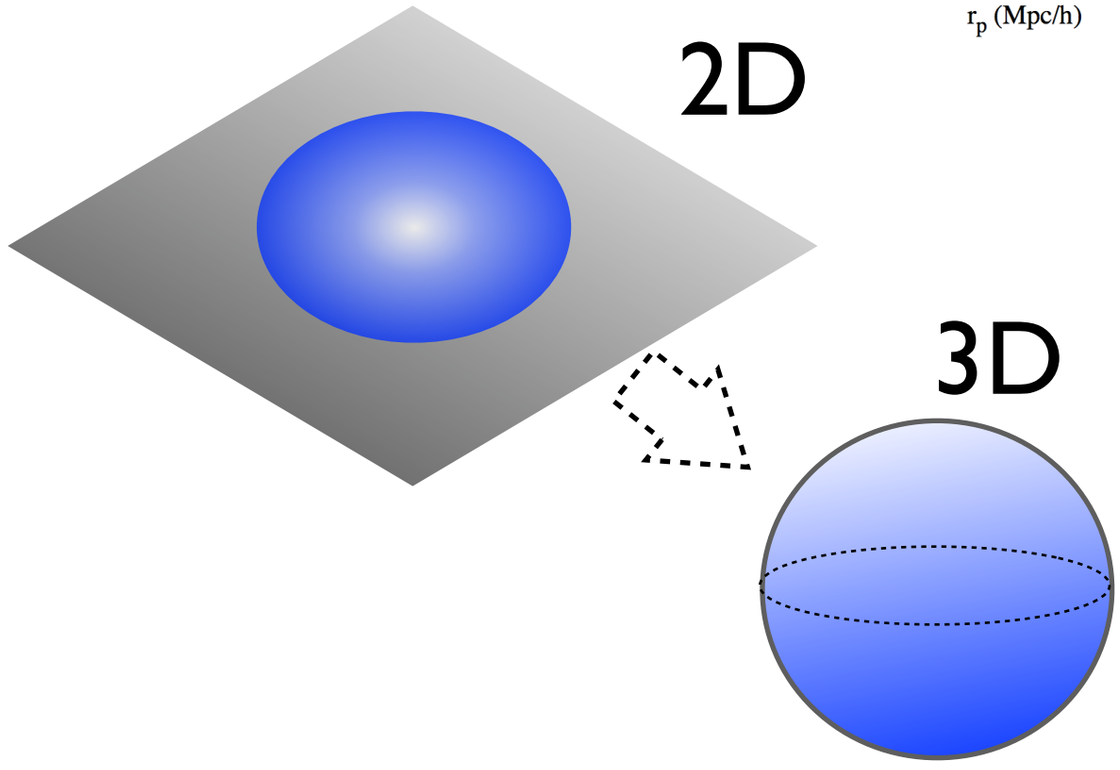




$$g(r) = -\frac{1}{\pi}\int_r^1 \frac{I'(y)}{\sqrt{y^2 - r^2}}dy$$

Abel inverse transform:
mathematically well-defined
but ill-conditioned!



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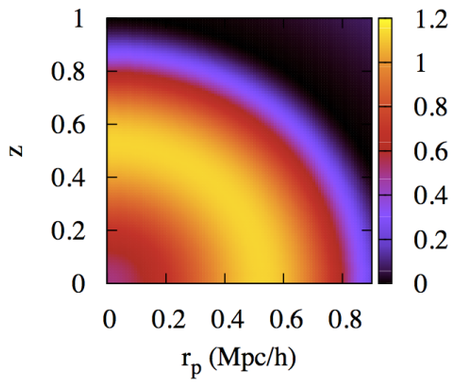

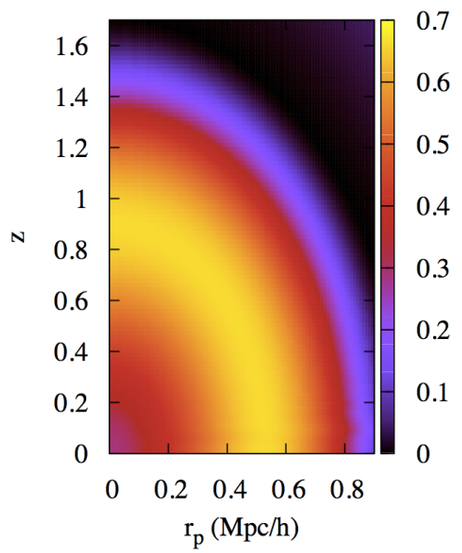

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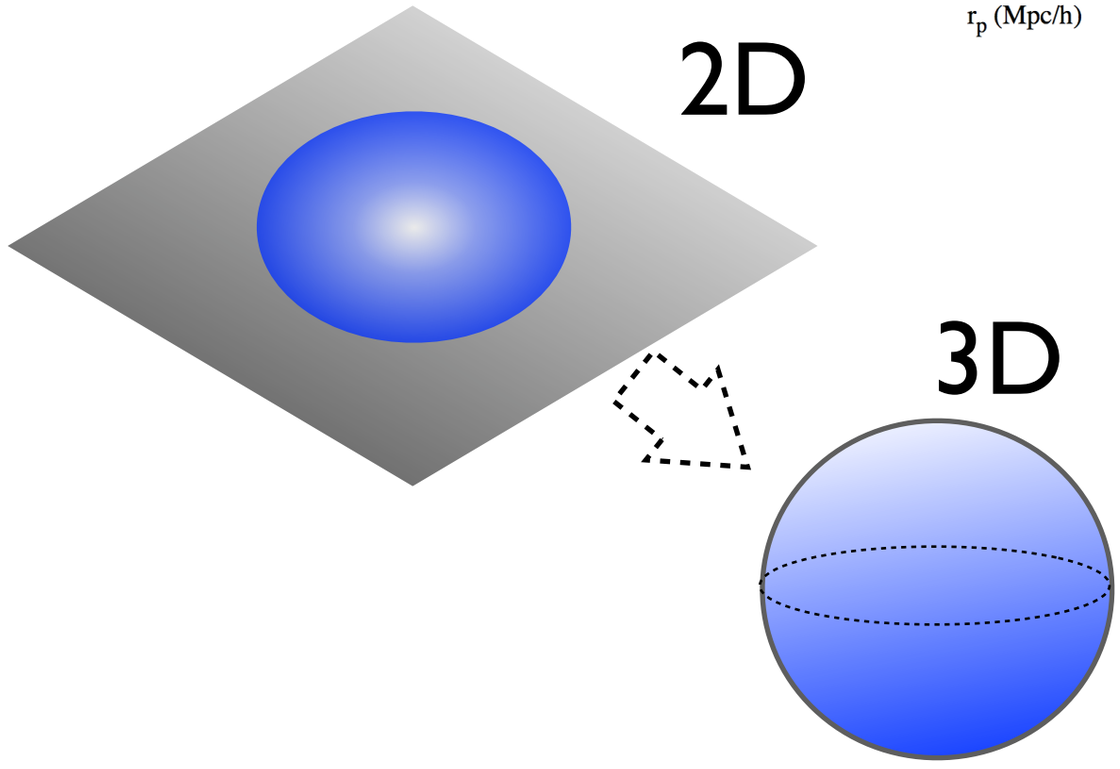

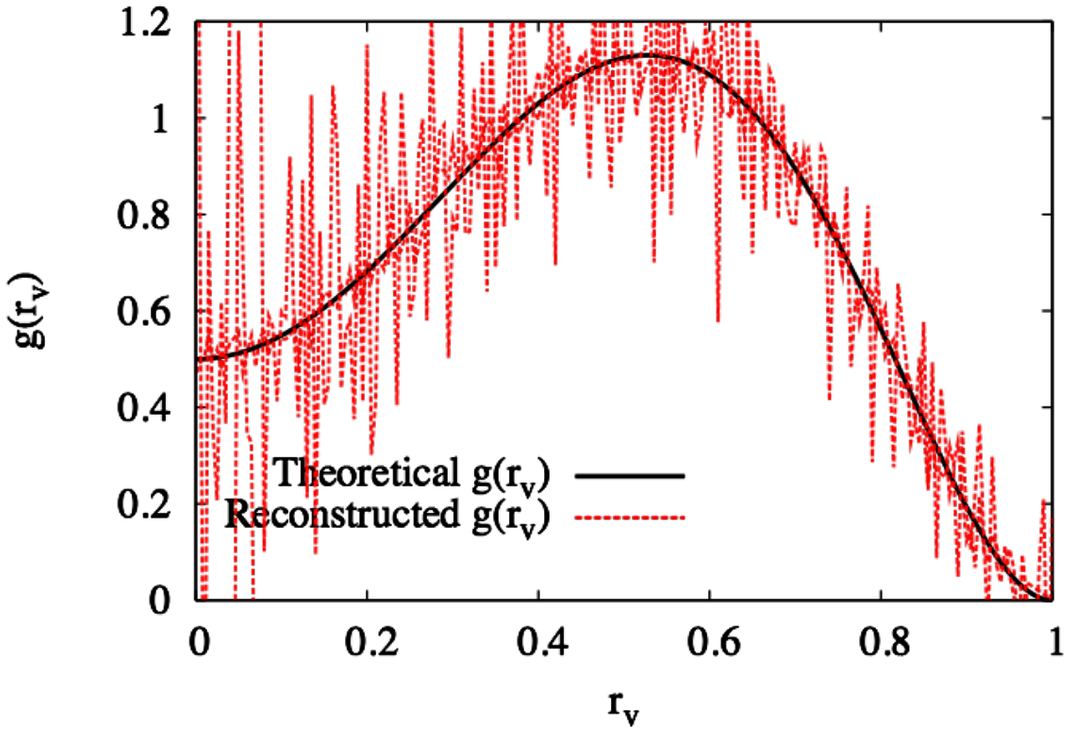

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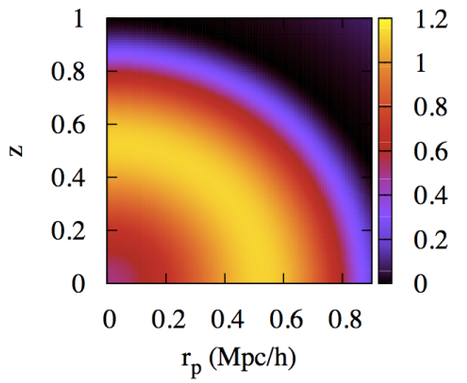

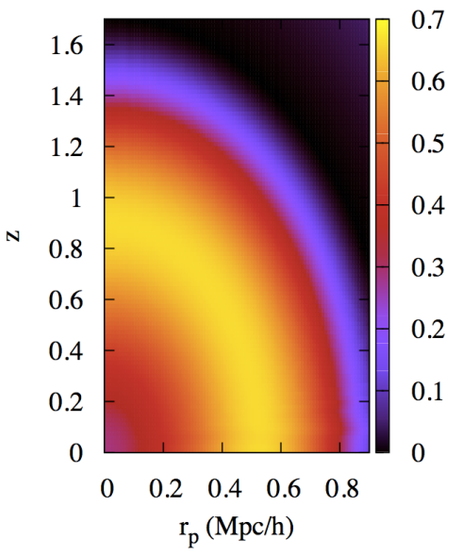

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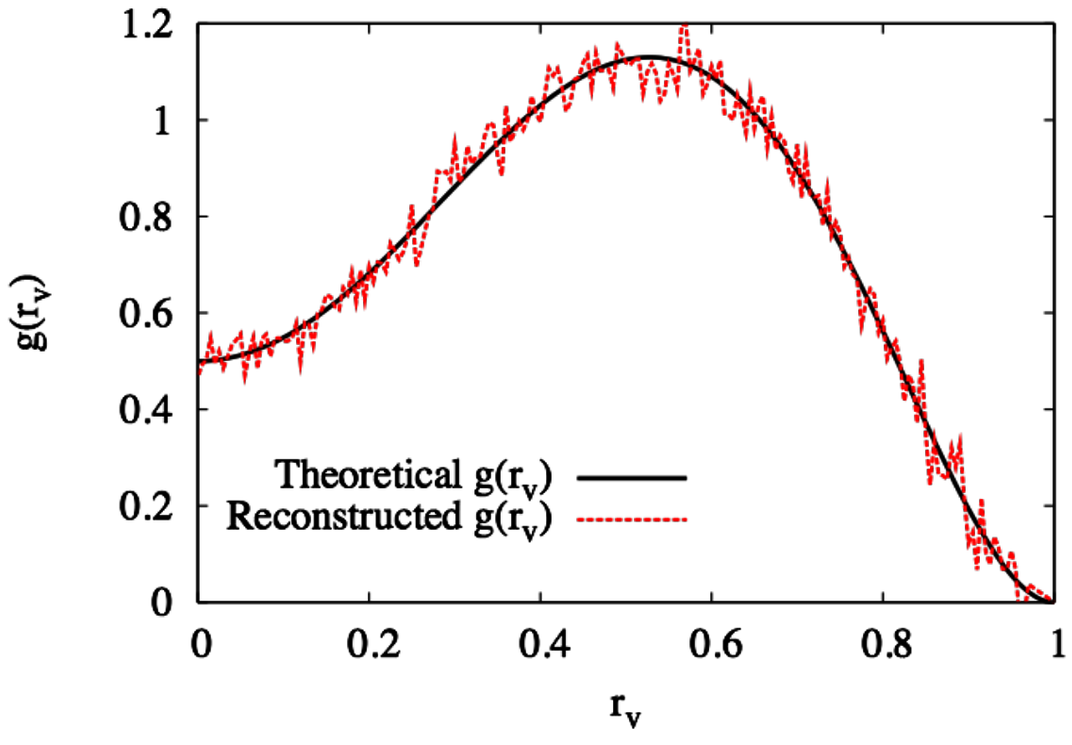
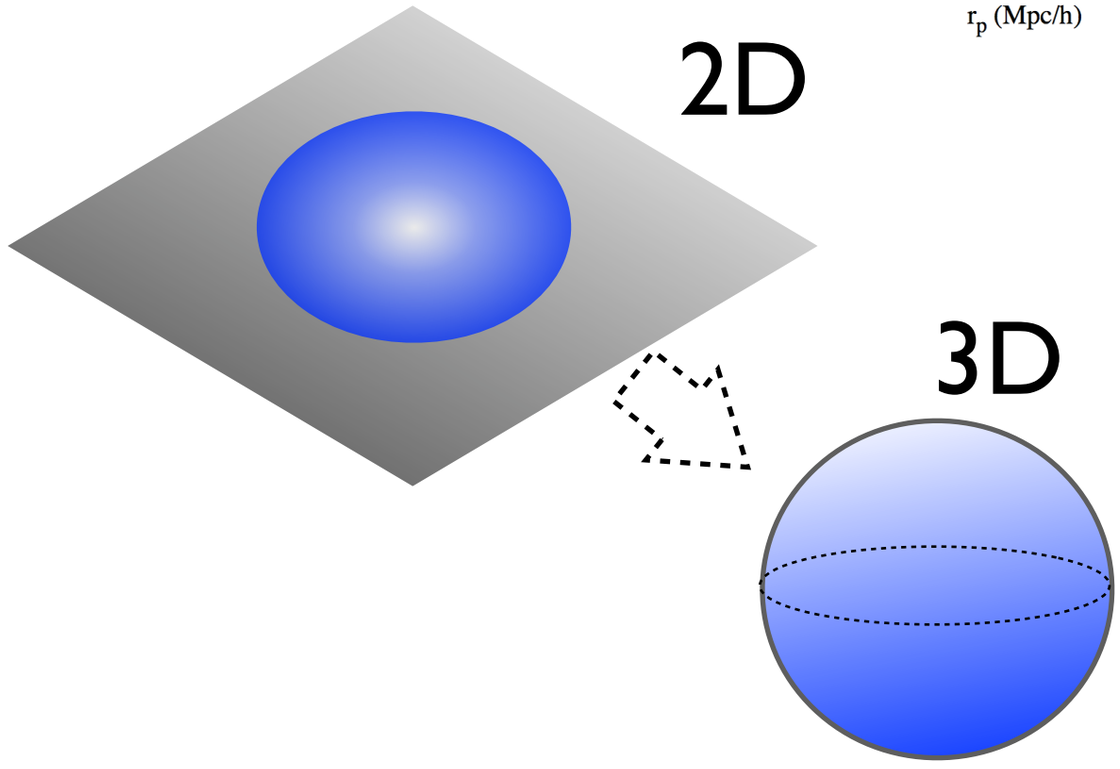
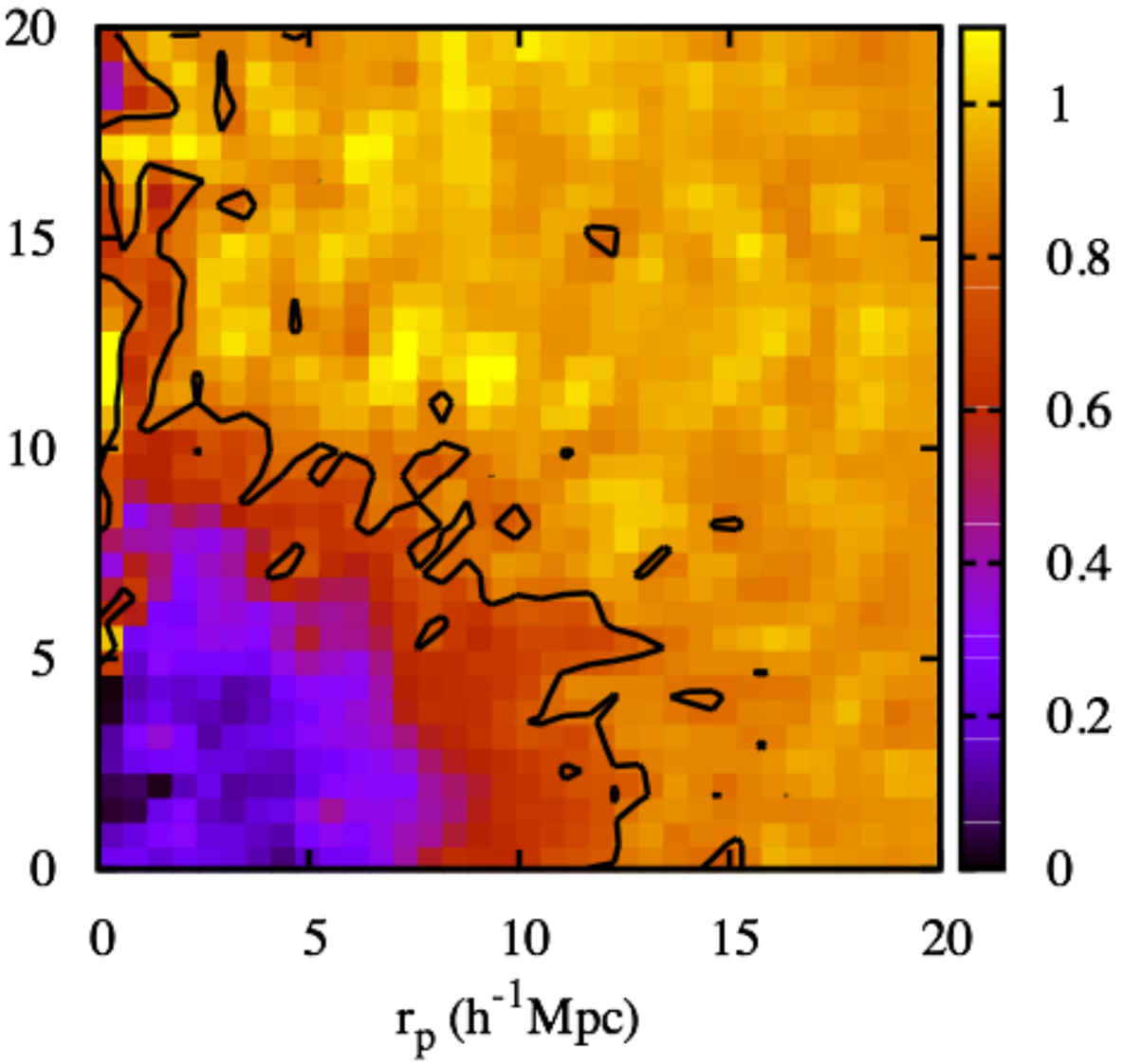


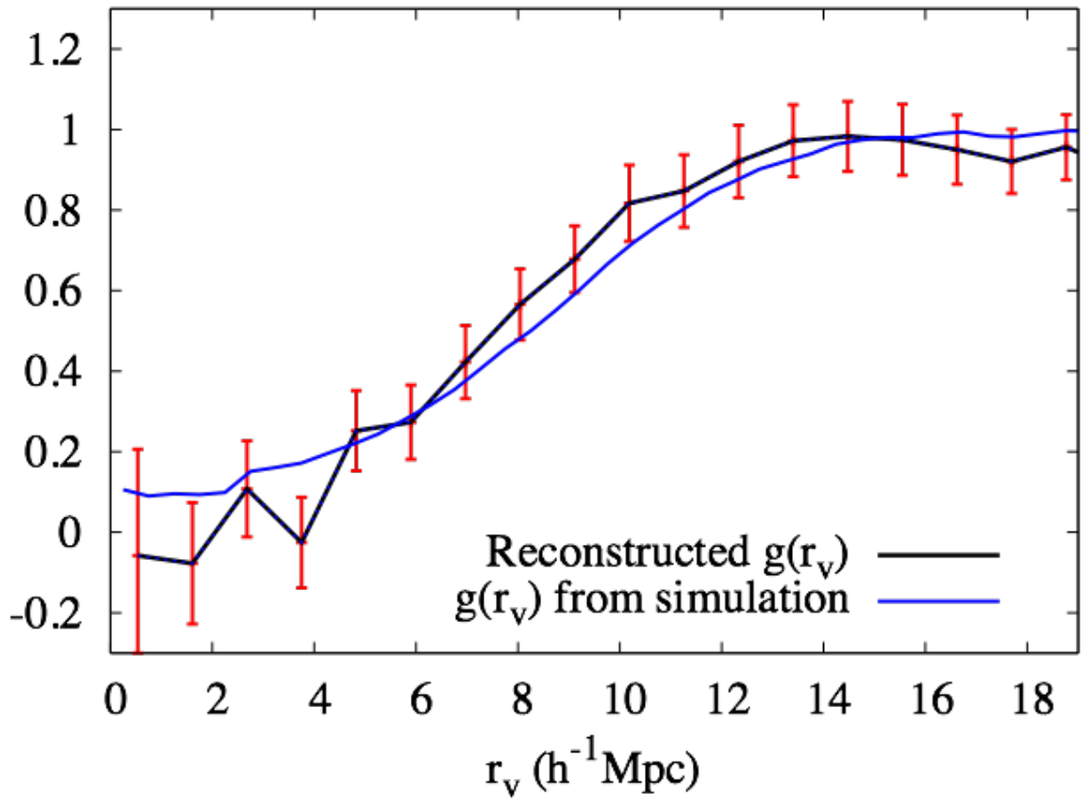


RESULT:
Very good
reconstruction!

Result II

The full simulated stacked void





Stacking from 10 to 12 Mpc/h

Simulated void from G. Lavaux

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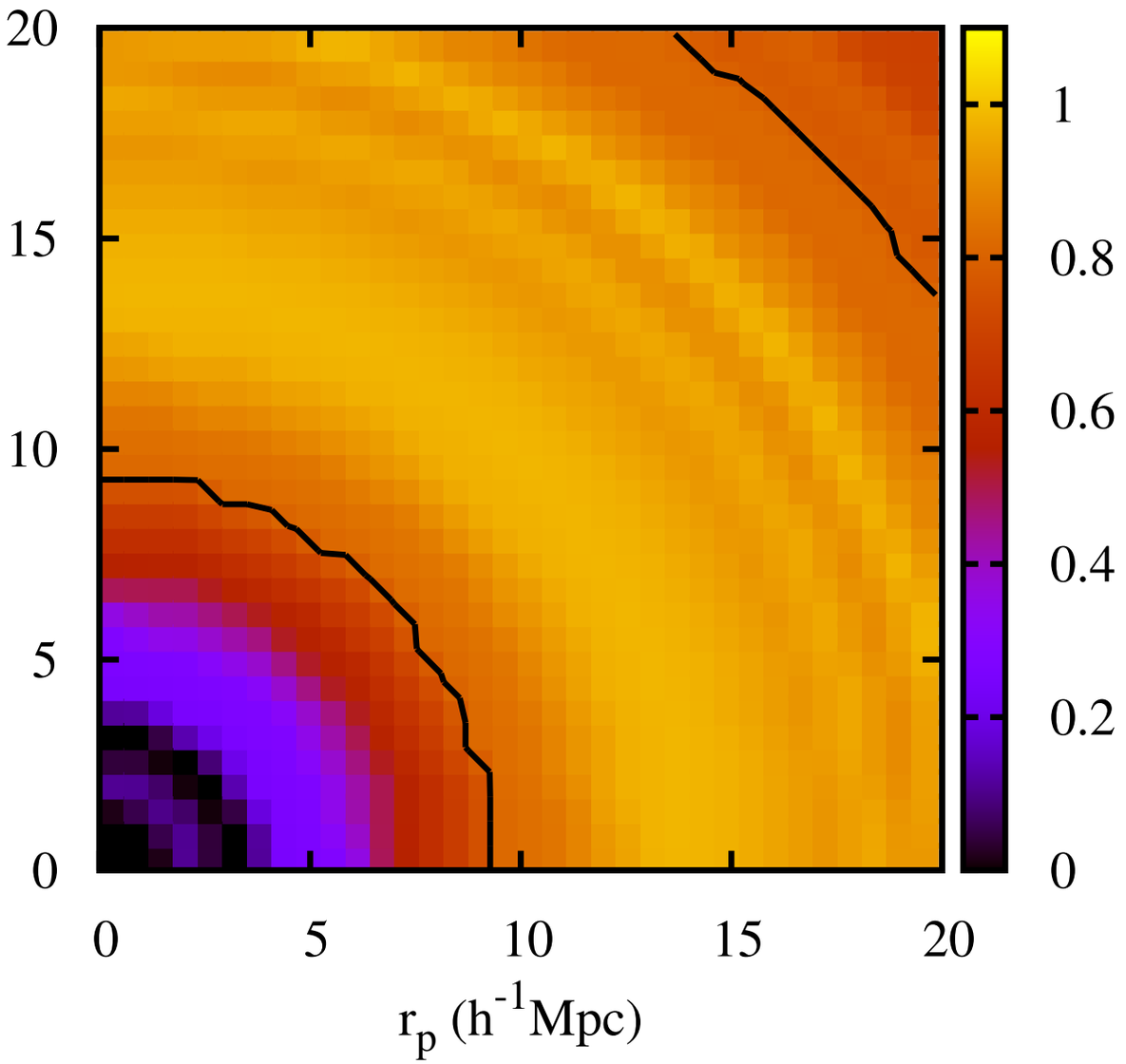

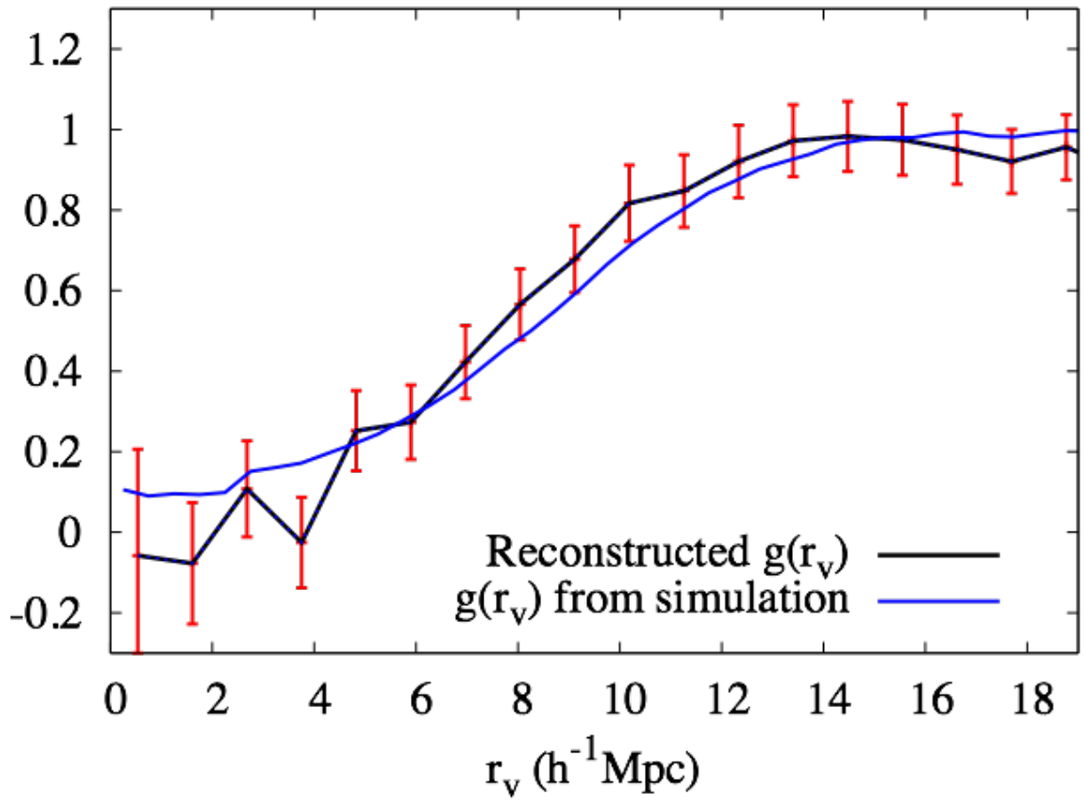

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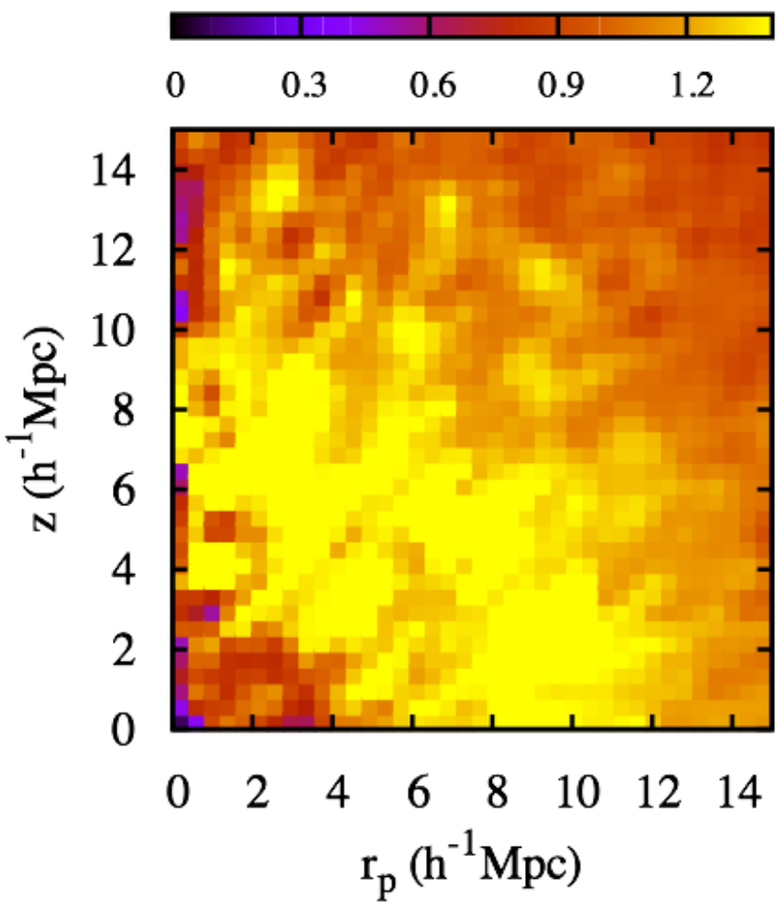
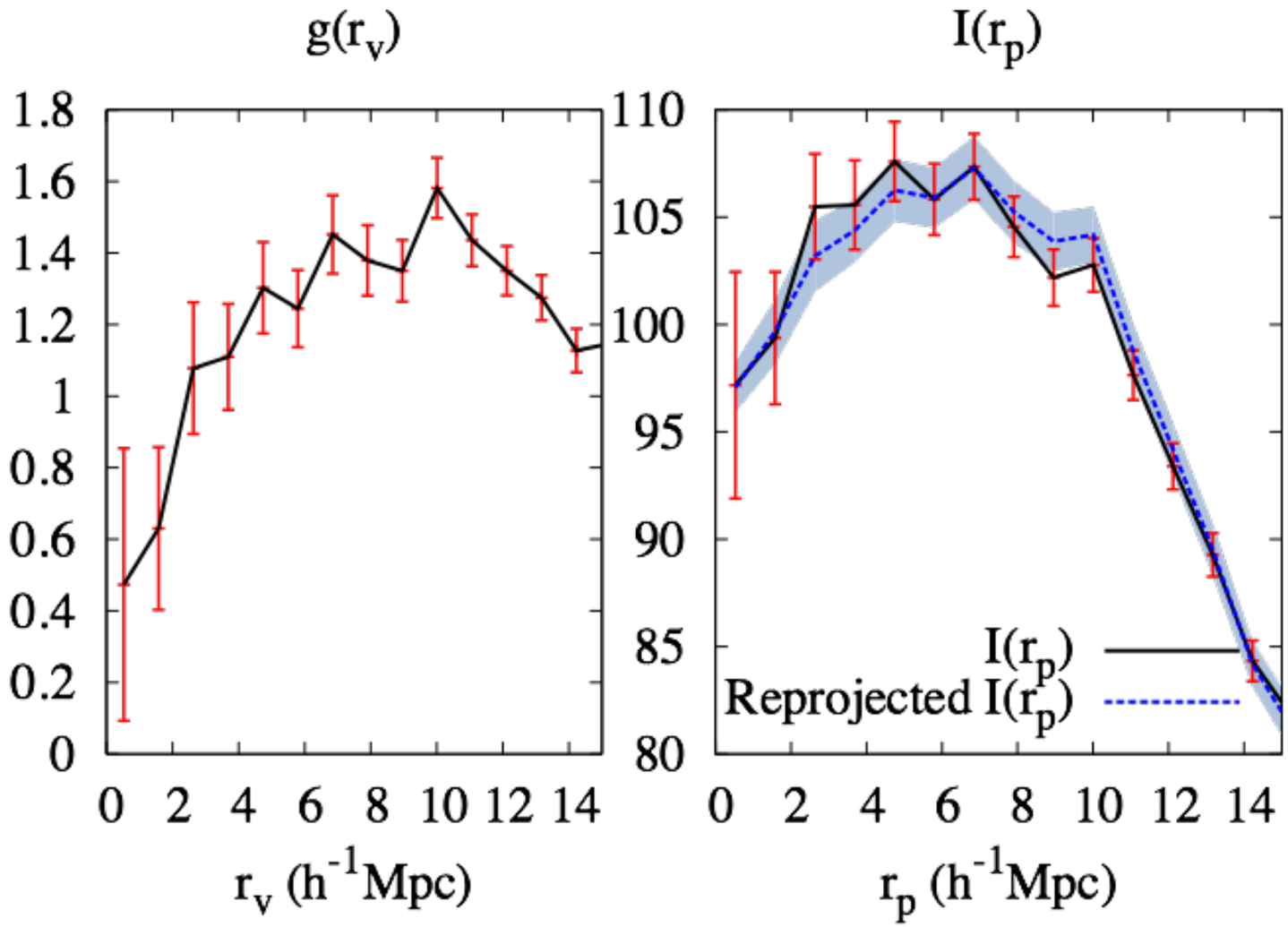
Result III

REAL DATA from SDSS!!!





Dim 2 (5-15 Mpc/h)

arXiv:1306.3052 (A. Pisani, G.Lavaux, P. M. Sutter, B. D.Wandelt 2013)

Back to the future: betting on LSS! upcoming surveys & telescopes

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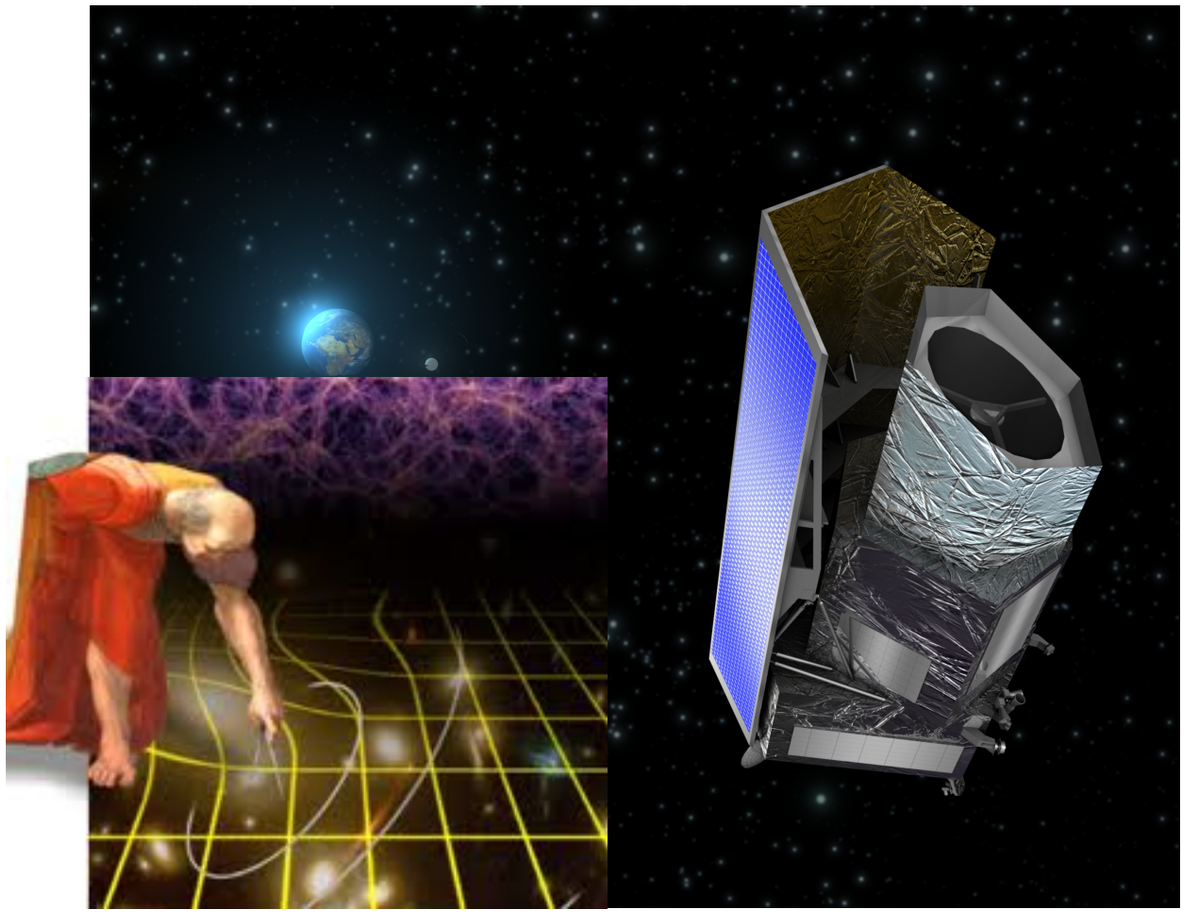

EUCLID

$5.0 \cdot 10^7$ galaxies $z \simeq 1.5$

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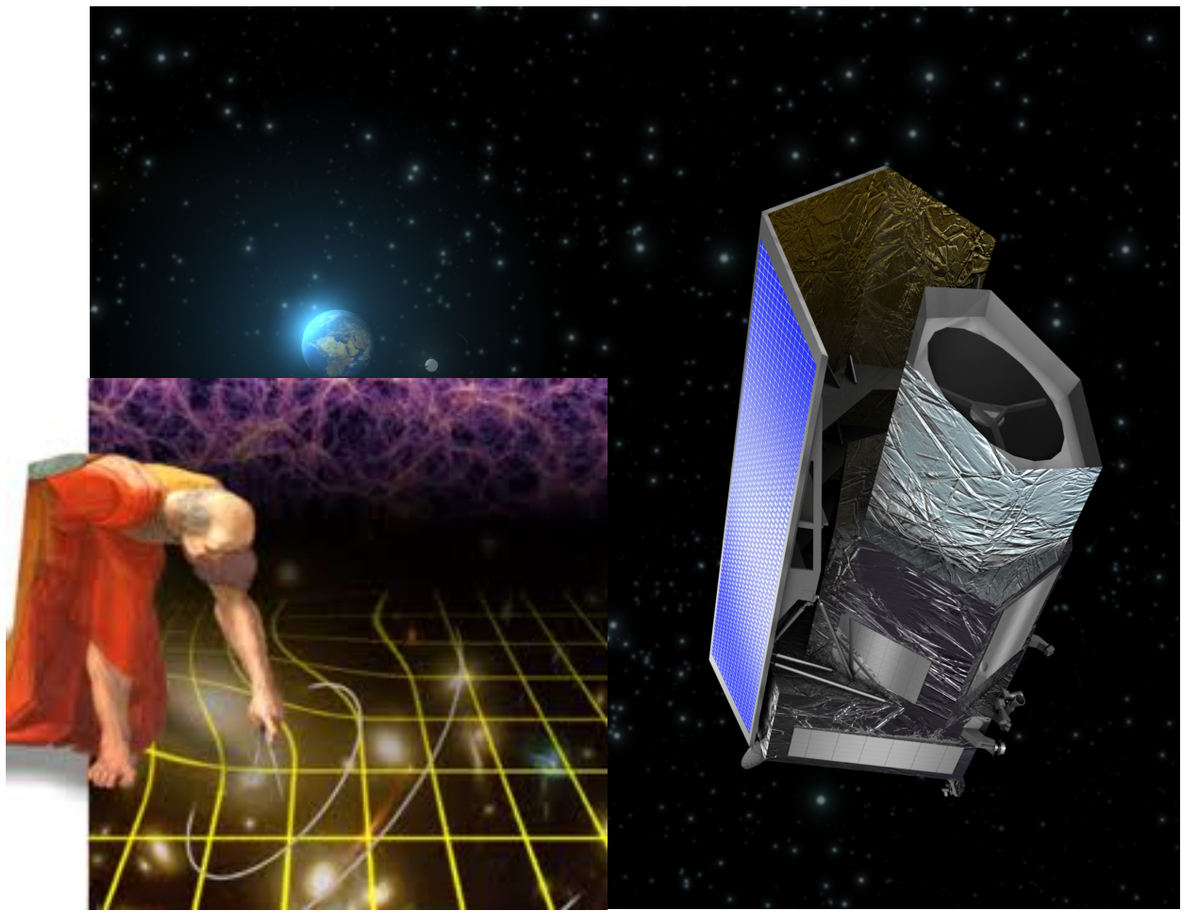

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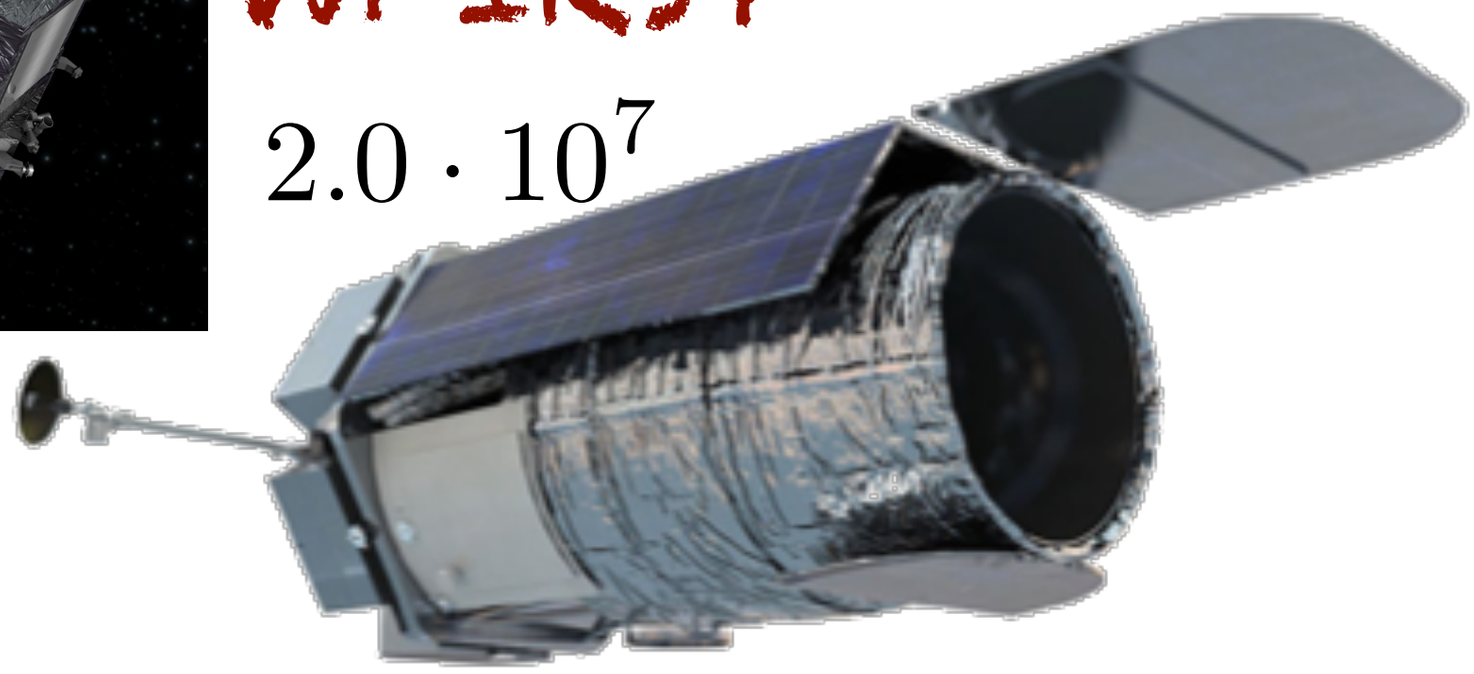

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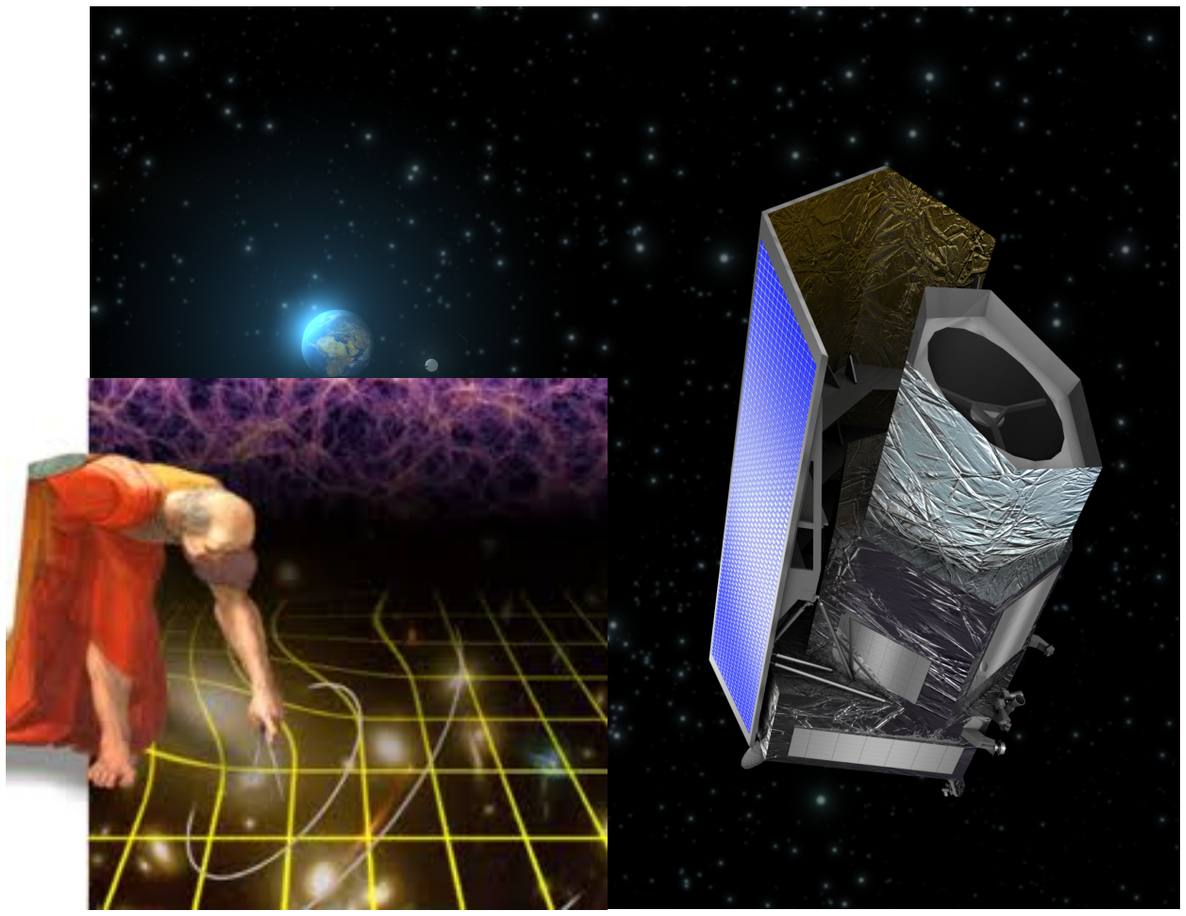

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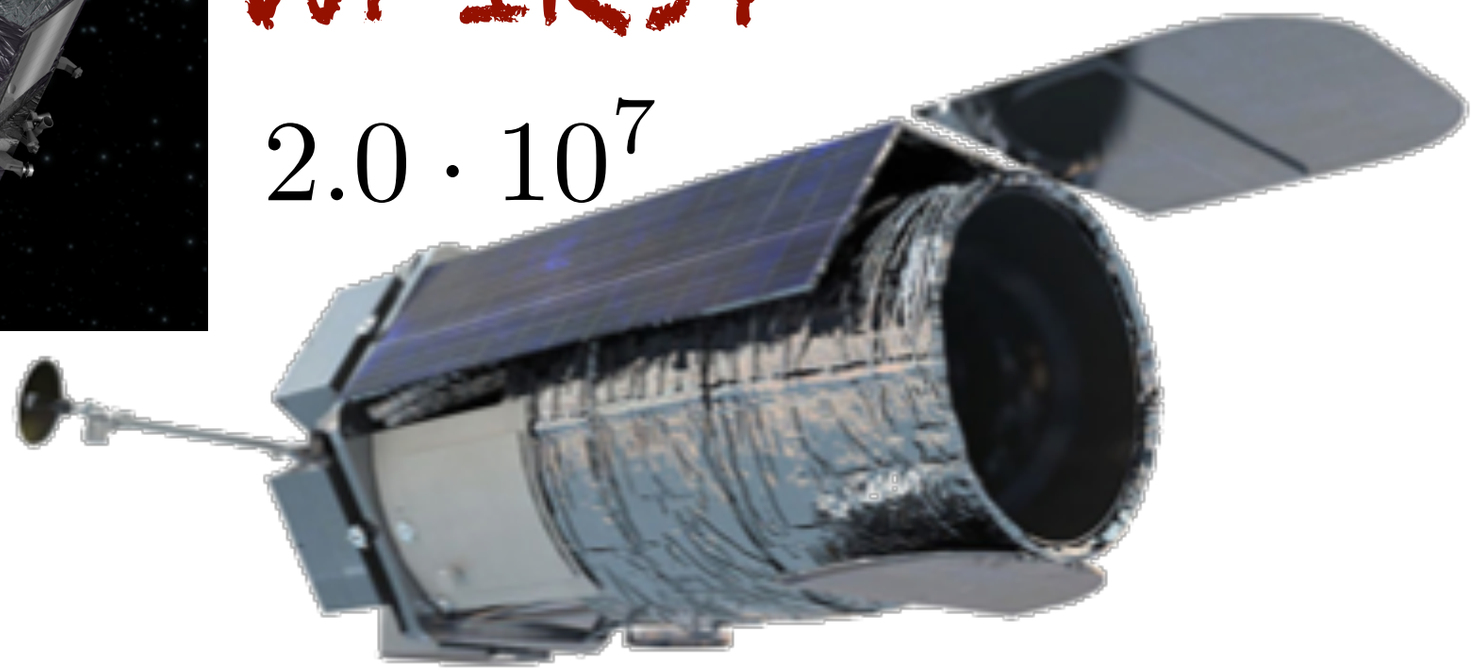

SDSS DR7 $1.5 \cdot 10^6$

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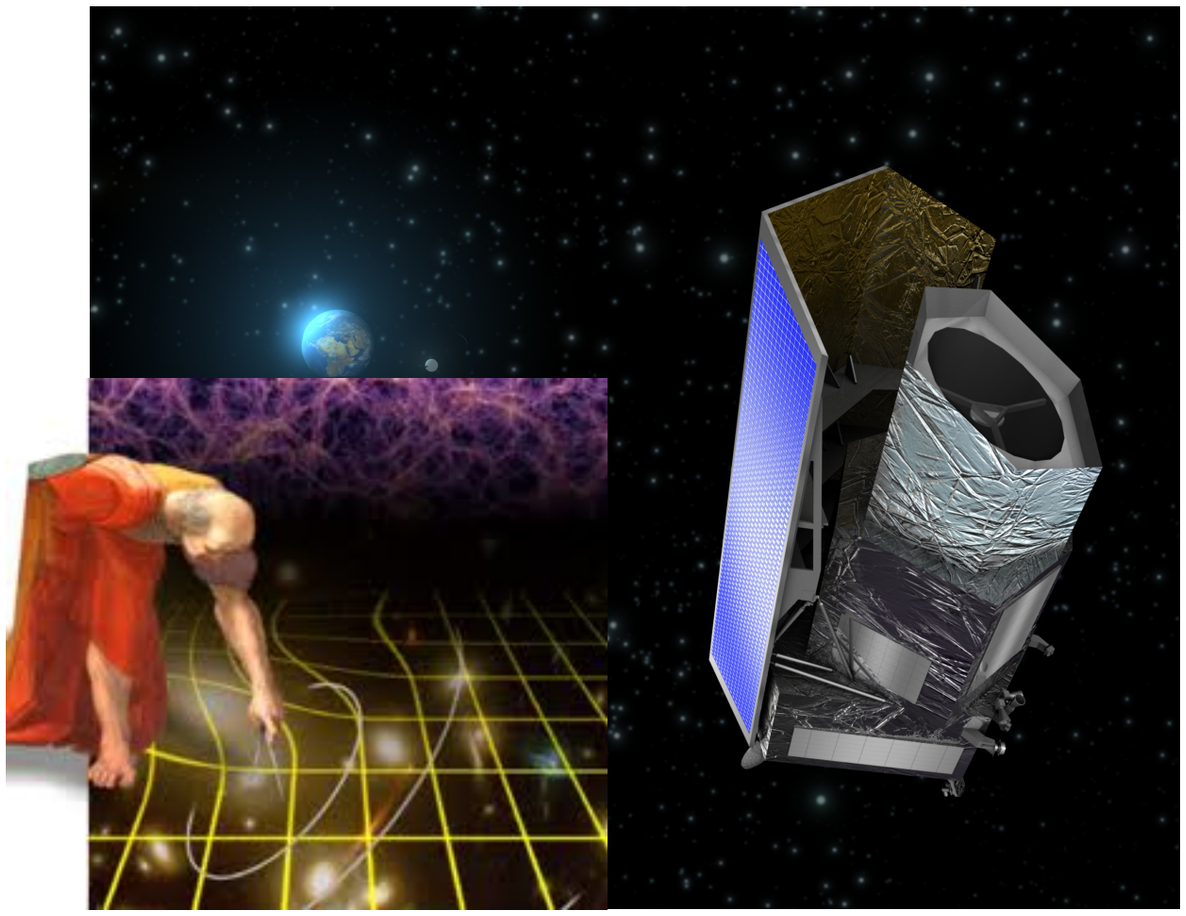

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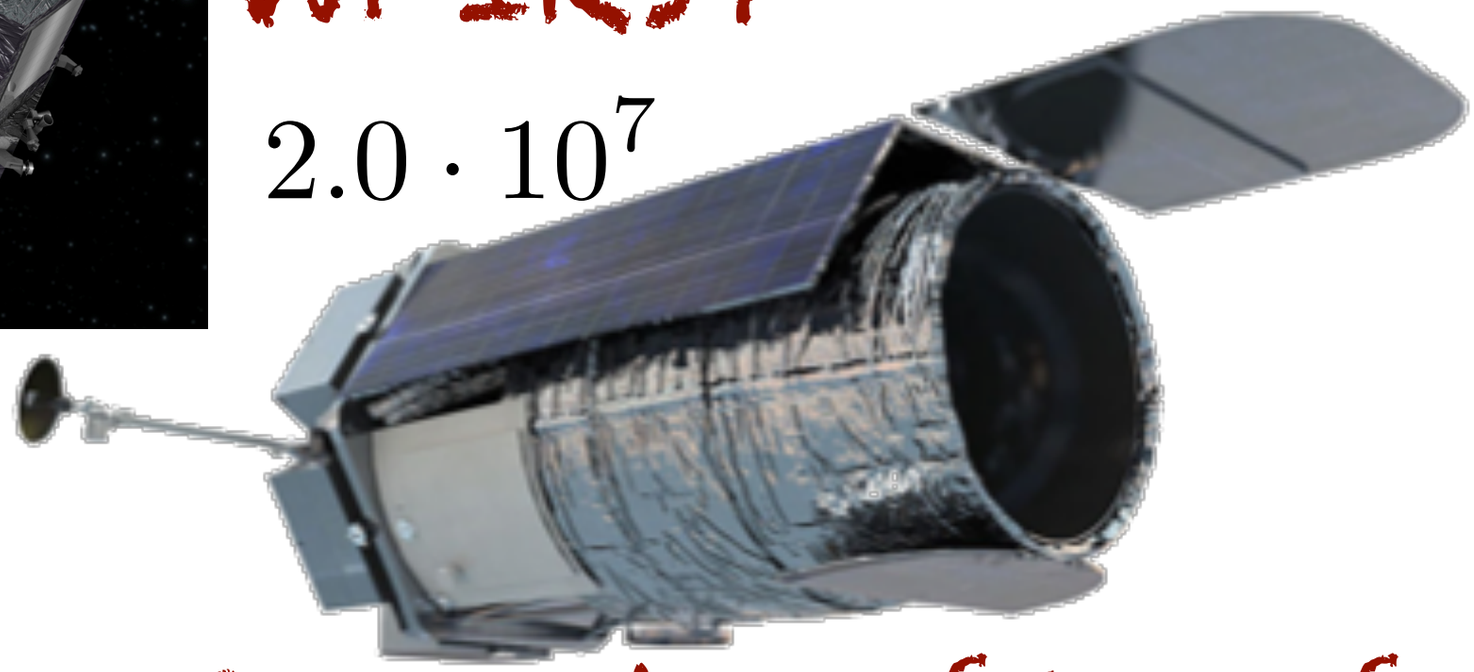


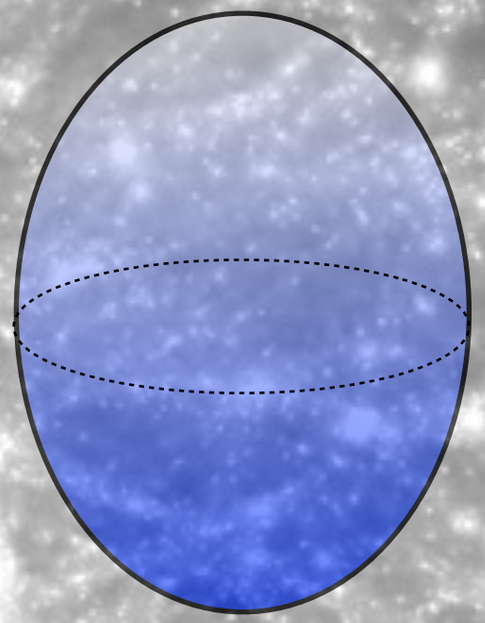
SDSS DR7 $1.5 \cdot 10^6$

Real-space density void profiles of increased precision!

Conclusion

Algorithm for density profile reconstruction:

- ➡ Tested on simple benchmark, simulations.
- ➡ Successfully applied on real voids, first density profiles in real space!



Density reconstruction:

- ➡ Instrumental for Alcock-Paczyński test improvement
- ➡ Constraining modified gravity and DE models

Velocity effects on voids

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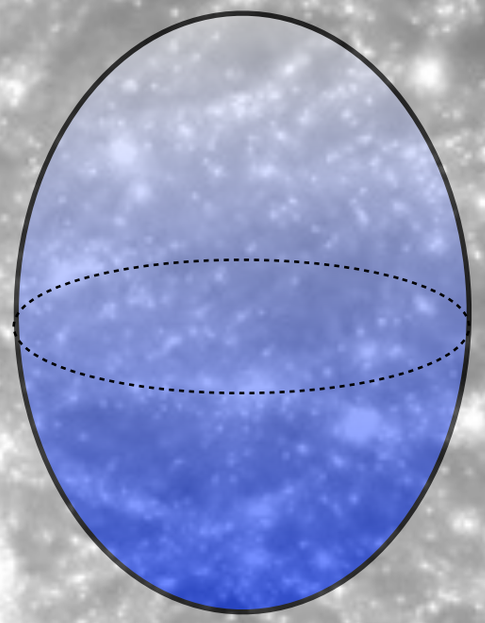

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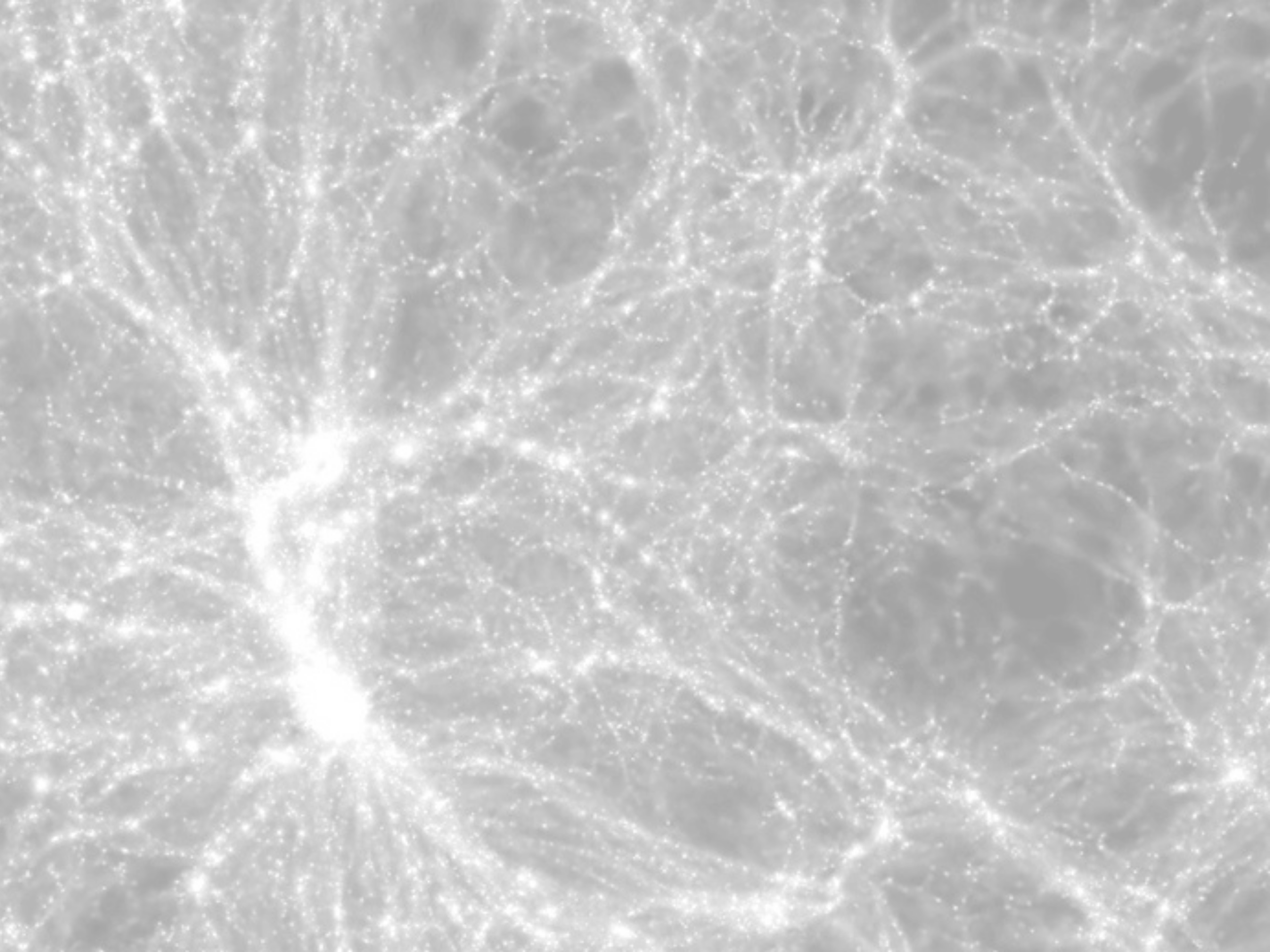
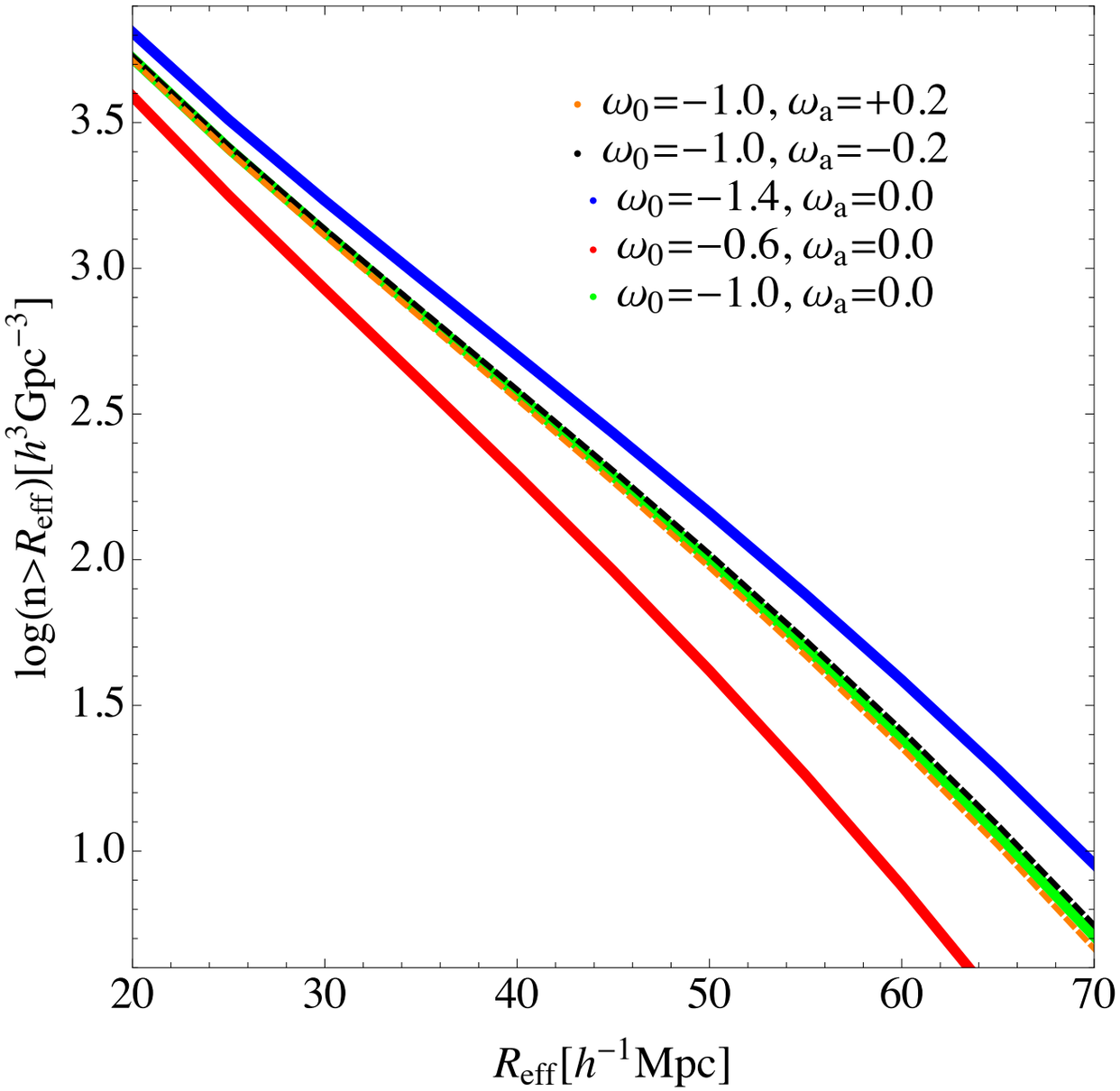
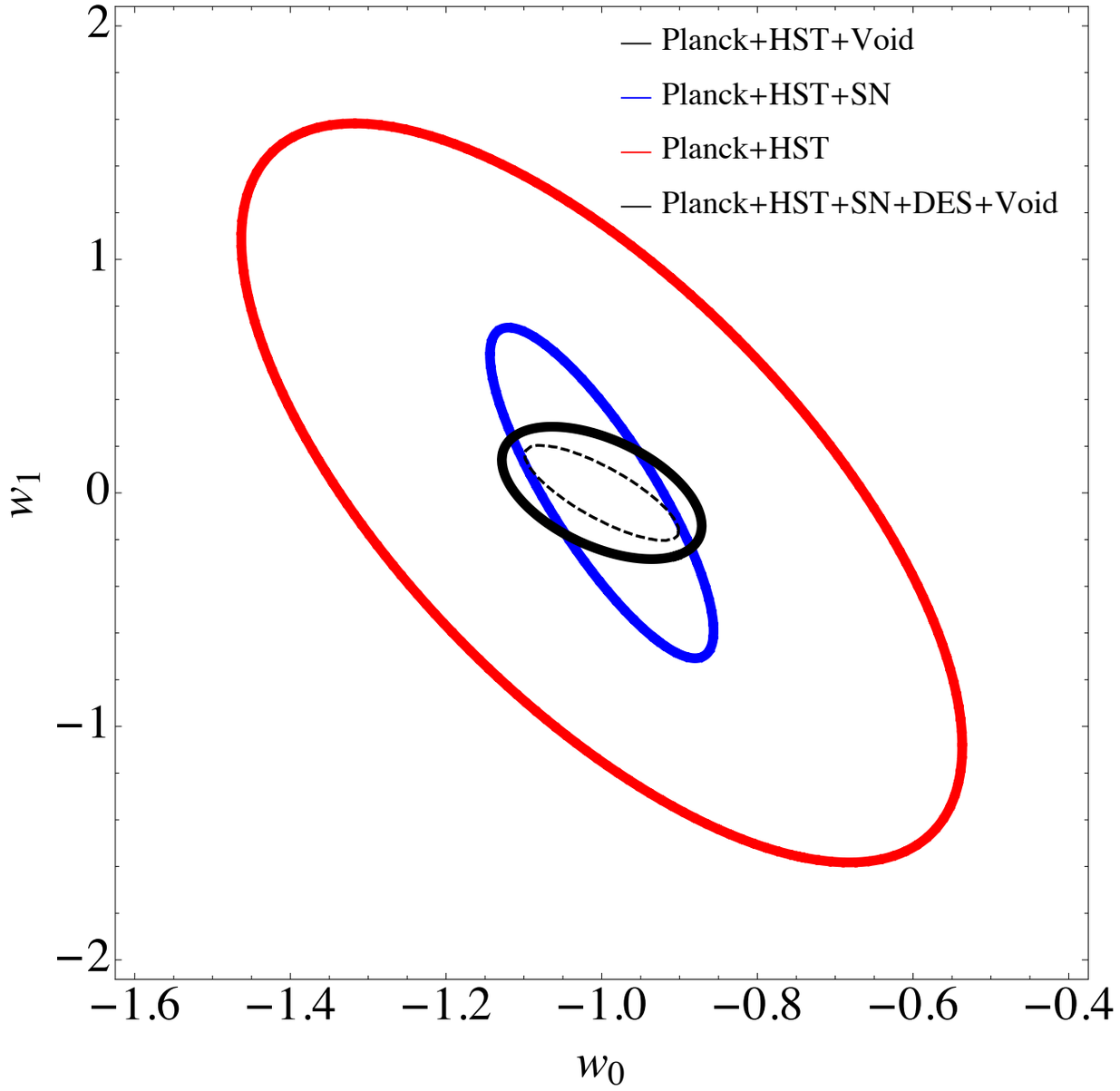


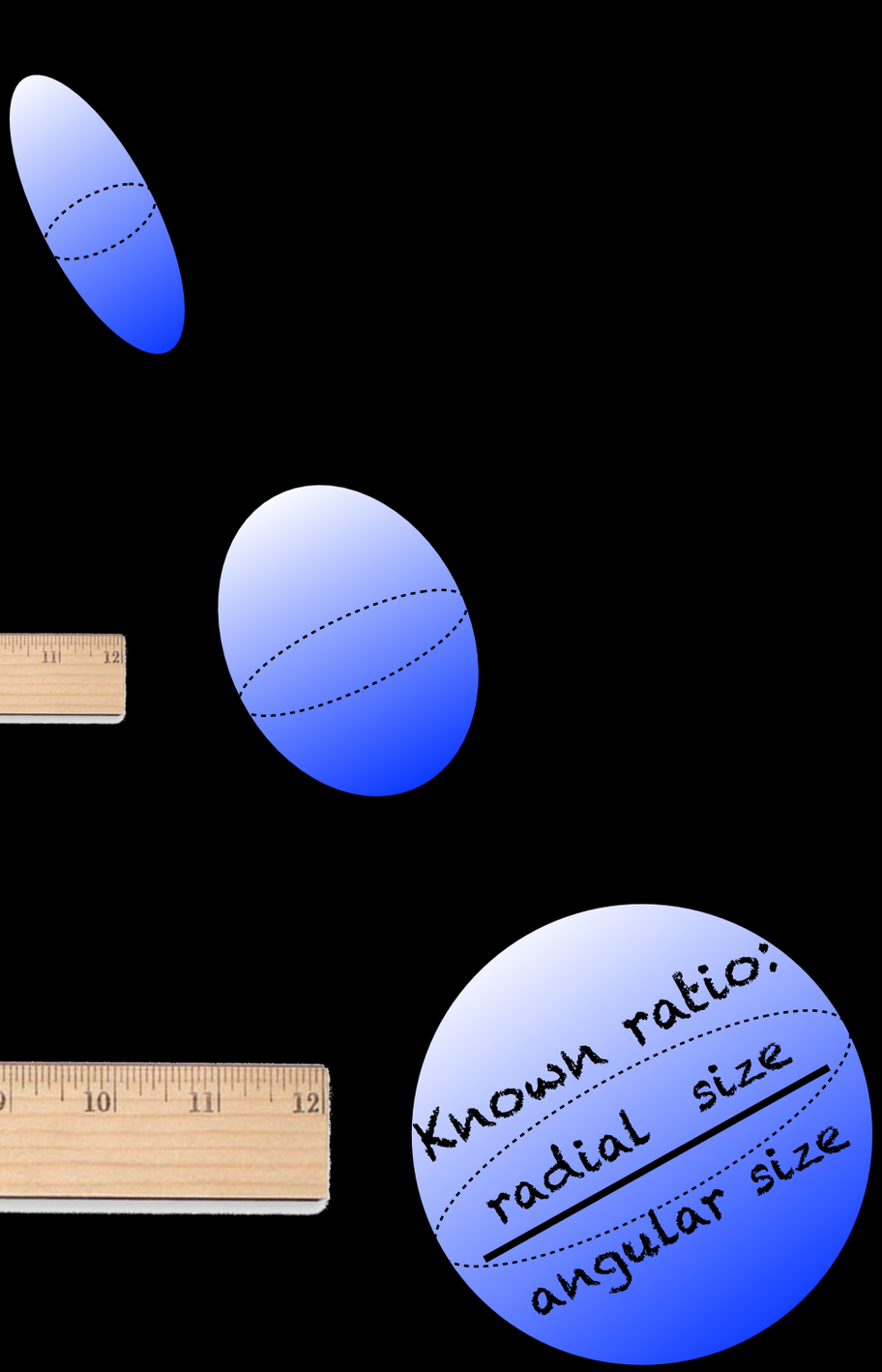
Supplementary slides

A window on abundances





The test uses the apparent stretching of spheres in the redshift space coordinates to estimate the local geometry of expansion by comparing the angular size to the radial/redshift size that is affected by cosmology.



VIDE, a void finder (… yes there are others)

Based on Zobov (Neyrinck 2008)

galaxy survey or simulation → Voronoi tessellation → Watershed transform → Voids

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Voronoi what?

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All points closer to the seed than to any other point

$$\rho_{local} = \frac{1}{V_{cell}}$$

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Cells merged into basins, which center is the cell only surrounded by higher density cells (local minima).

Void IDentification and Examination

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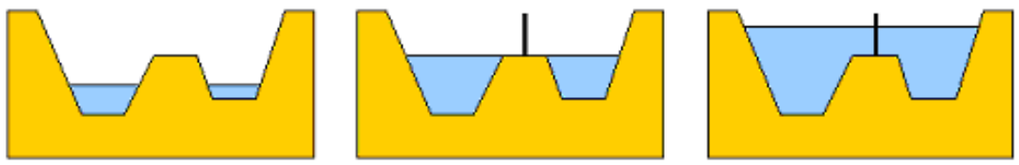
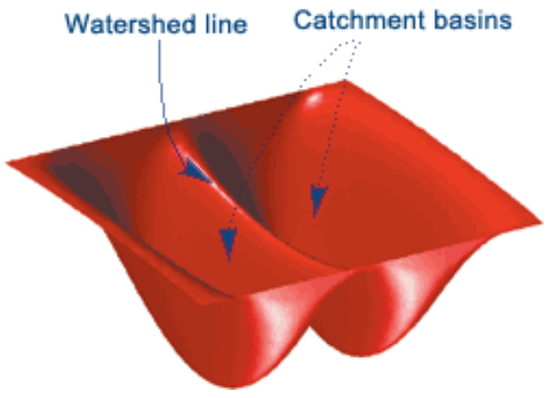


Each basin is a sub-void, 2 basins are merged in one void if, looking at the density along all their borders, the border with lower density (compared to other borders, not to the center of the basin) is common.



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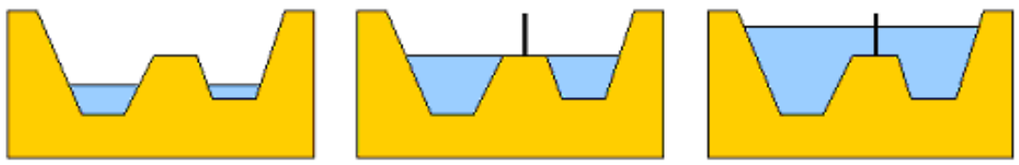

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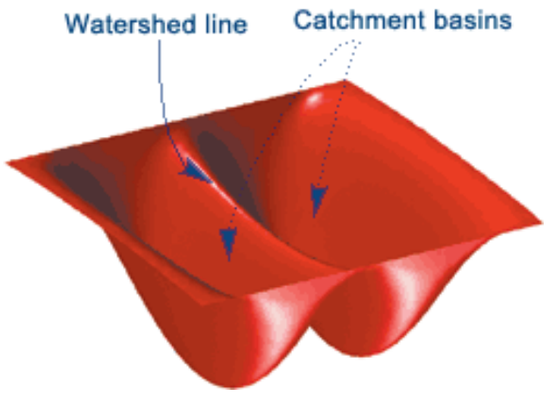

Density cuts:
1)all cells mean density <-0.8
2)density in Reff/4<-0.8

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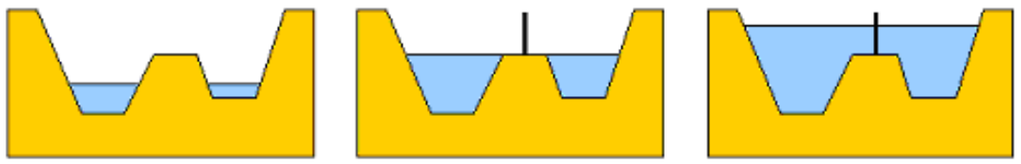

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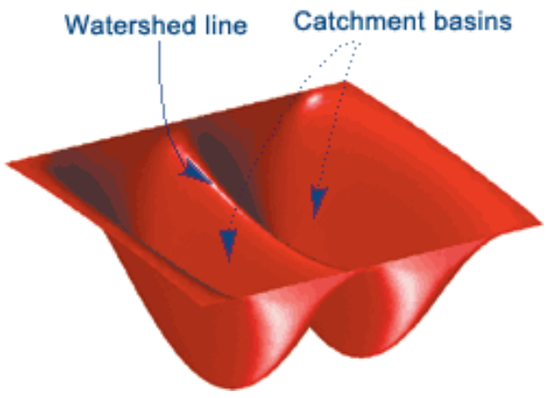

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2)density in Reff/4<-0.8

ANY SHAPE

Credit: Sutter et al. 2012

+ it takes into account survey boundaries and masks

BOX: 1 h^-1Gpc side

1024^3 particles

Mass resolution:
7.36 × 10^11 h^−1 M⊙

Rockstar halo finder
(Behroozi et al. 2013)

Dense: halos above 1.47 × 10^12 h^−1 M⊙

Sparse: 1.2 × 10^13 h^−1 M⊙

HOD modeling=>mock catalog
WMAP 7-year cosmological parameters

Simulation: 2HOT code, adaptive treecode
N-body method,standard symplectic integrator (Quinn et al. 1997)

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The deviations from fiducial cosmology cause geometrical distortions.

Alcock-Paczyński test with voids… we use stretch…

$$E(z) = \frac{H(z)}{H_0}$$

$$\frac{\delta z}{\delta d} = \left(\frac{H_0}{c}\right)^2 \frac{D_A(z)E(z)}{z} = \left(\frac{H_0}{c}\right)^2 \frac{D_A(z)H(z)}{zH_0}$$

$$\frac{\delta z}{\delta d} = \frac{H_0}{c}\frac{H_0}{c}\frac{D_A(z)E(z)}{z} = \frac{H_0}{c}e_v(z) \longleftarrow \text{this is stretch…}$$

$$e_v(z) = \frac{c}{H_0}\frac{\delta z}{\delta d}$$

Alcock-Paczyński test

The deviations from fiducial cosmology cause geometrical distortions.

$\delta r_\perp = D_A(z)\delta\Theta$ comoving line of sight distance

$\delta r_\parallel = cH^{-1}(z)\delta z$ projected angular extent

where

$$D_A = c\int_0^z H^{-1}(z')dz' \qquad H(z) = H_0\sqrt{\Omega_m(1+z)^3+\Omega_\Lambda}$$