

GMO-CLONES for an APC*

*Genetically **MO**dified - **C**onstrained **LO**cal & **N**esting **E**nvironment **S**imulations
for an **A**ccurate **P**recision **C**osmology



Jenny Sorce

Centre de Recherche Astrophysique de Lyon - Leibniz-Institut fuer Astrophysik, Potsdam

Astrosim - October, 9th 2018 - Lyon

Motivations

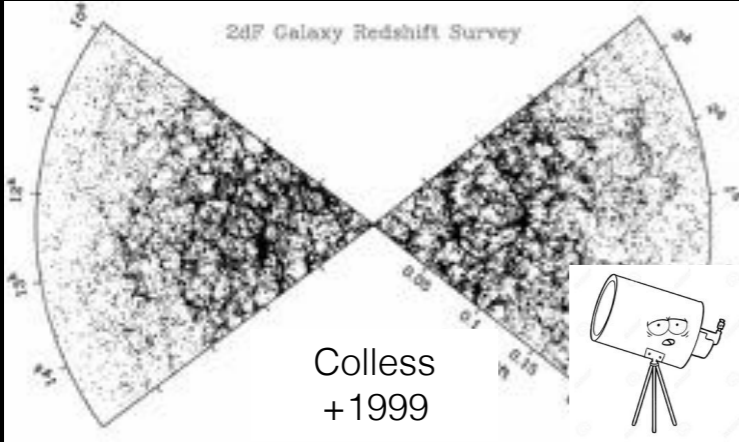
Simulations vs. observations: more precision is required



Overall: Λ CDM




Precision Era:
1-2% precision

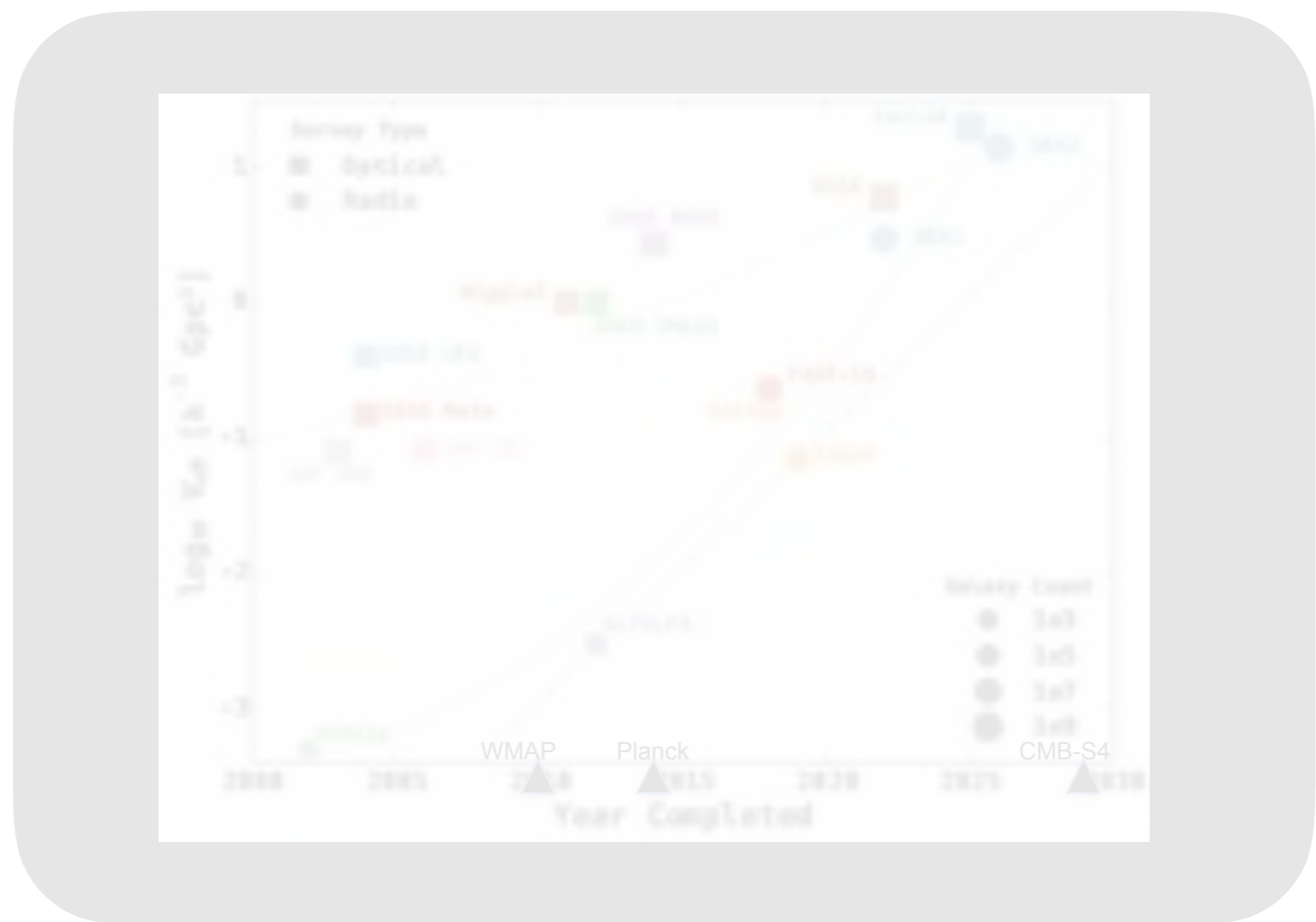

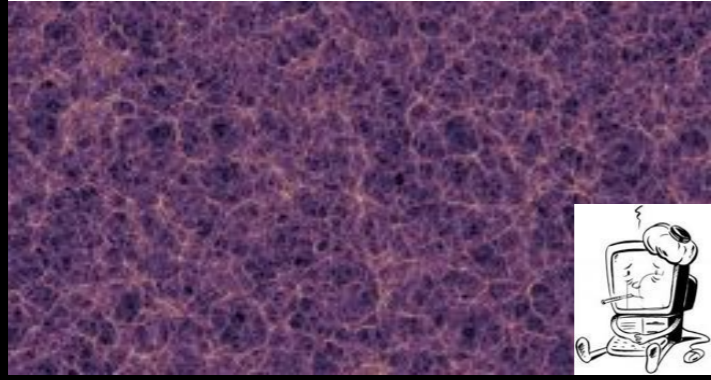


2dF Galaxy Redshift Survey

Colless +1999



Springel+2005,2008, Dubois+2016, etc



Motivations

Simulations vs. observations: more precision is required



Overall: Λ CDM



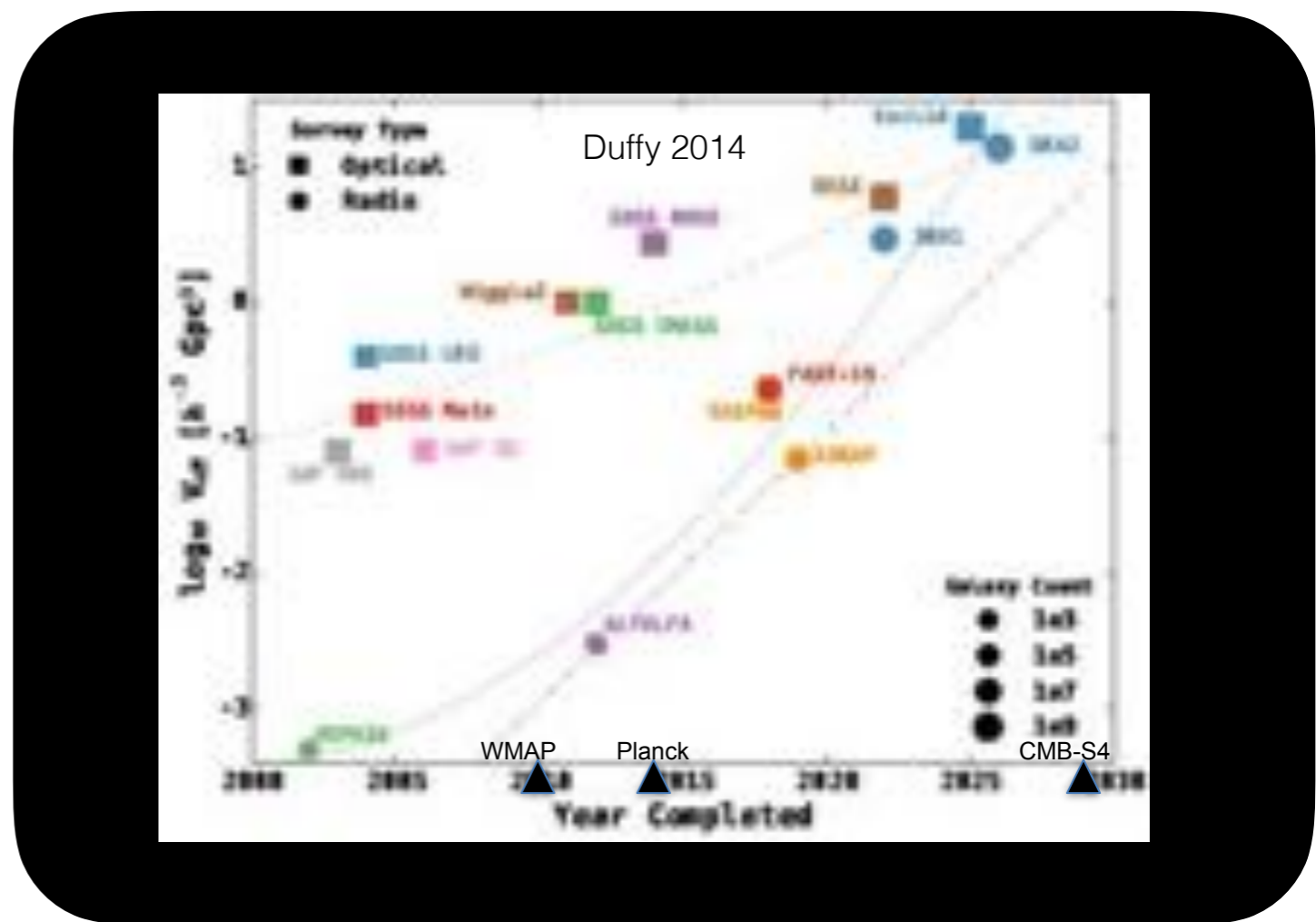
Precision Era:
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2dF Galaxy Redshift Survey

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This block contains two images. The top image is a wedge-shaped map of galaxy positions from the 2dF Galaxy Redshift Survey, with axes labeled in degrees and minutes. Below it is a cartoon of a person with a telescope. The bottom image is a simulation of the cosmic web, showing a dense network of purple and blue filaments. Below it is a cartoon of a person sitting at a computer monitor.



Motivations

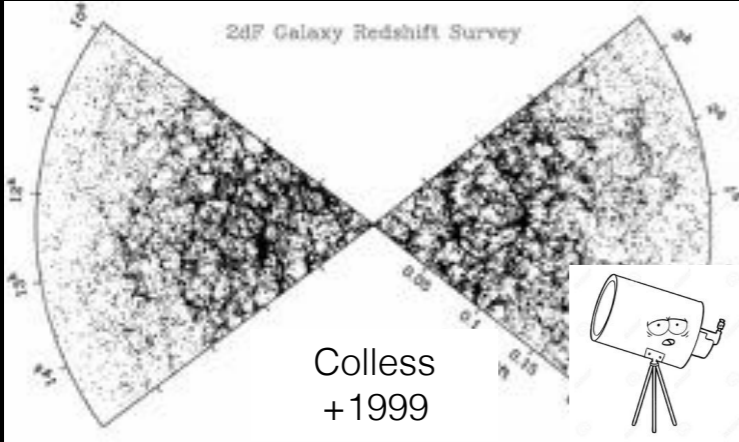
but with more precision come some tensions !



Overall: Λ CDM




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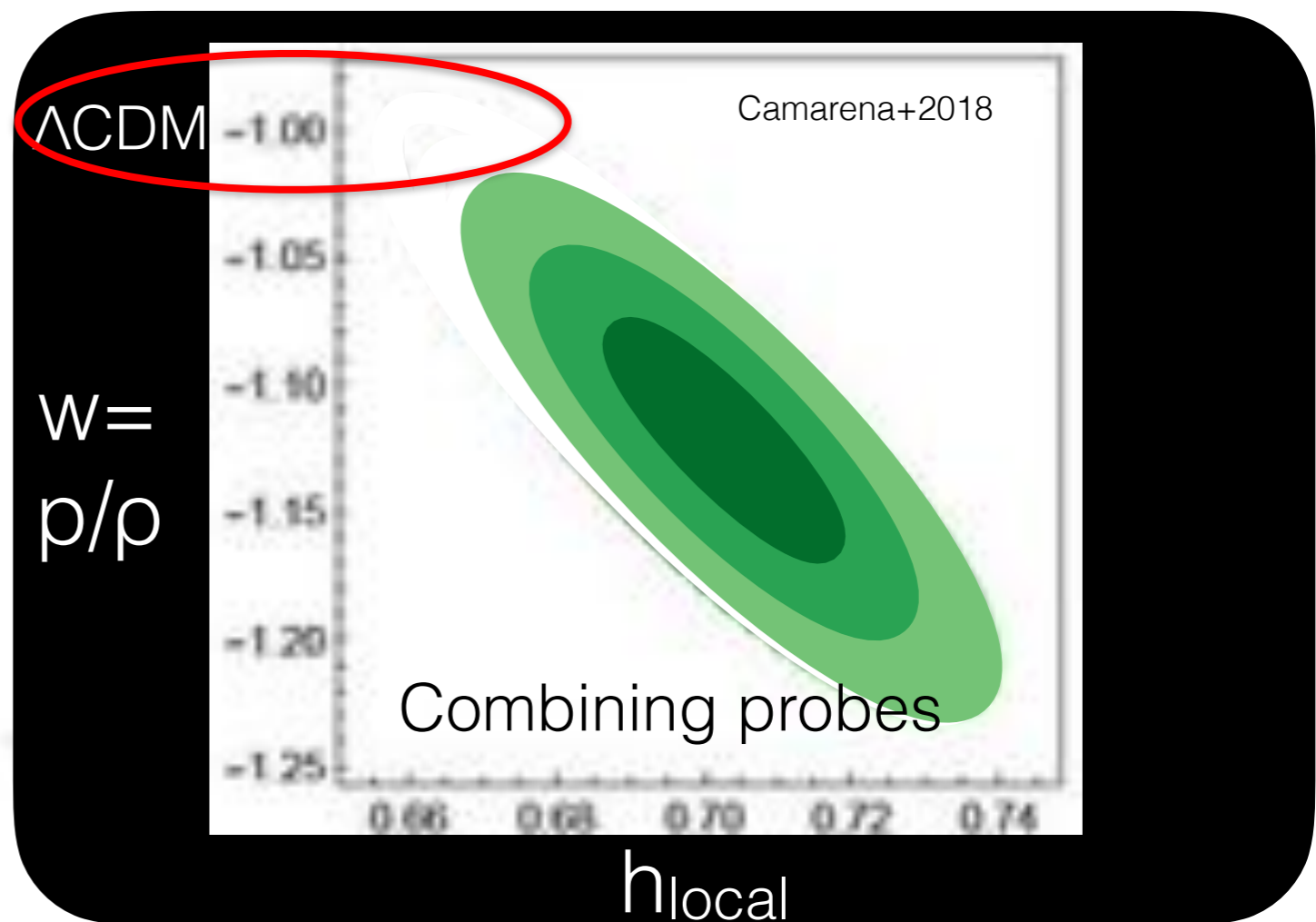

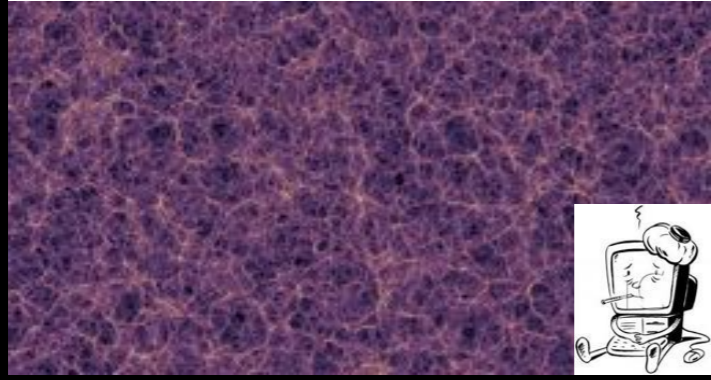


2dF Galaxy Redshift Survey

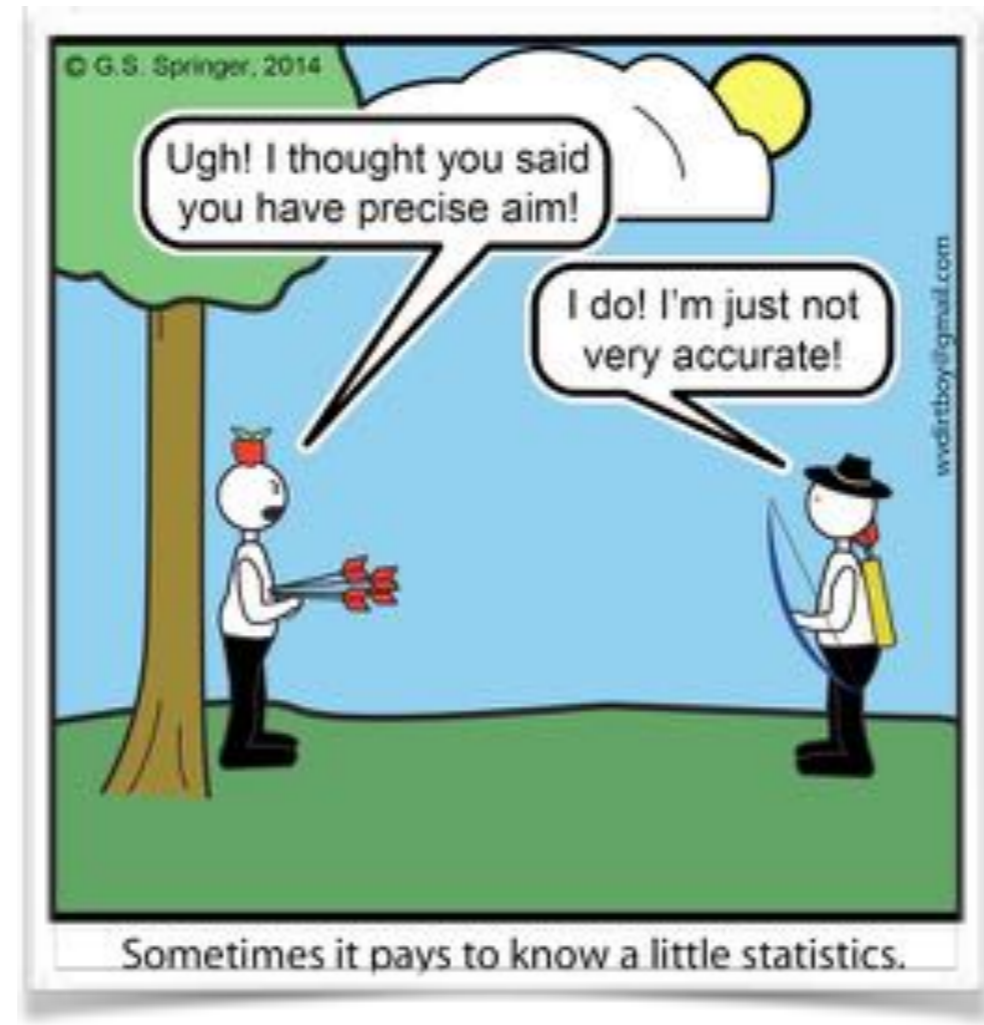
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Precision is not accuracy !

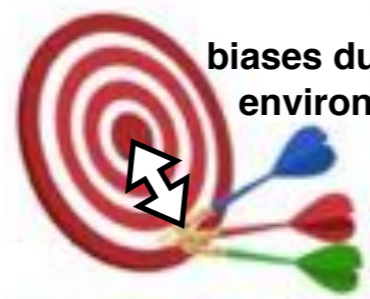


Motivations

Precision is not accuracy: environmental biases?



Overall: Λ CDM



Precision Era:
1-2% precision

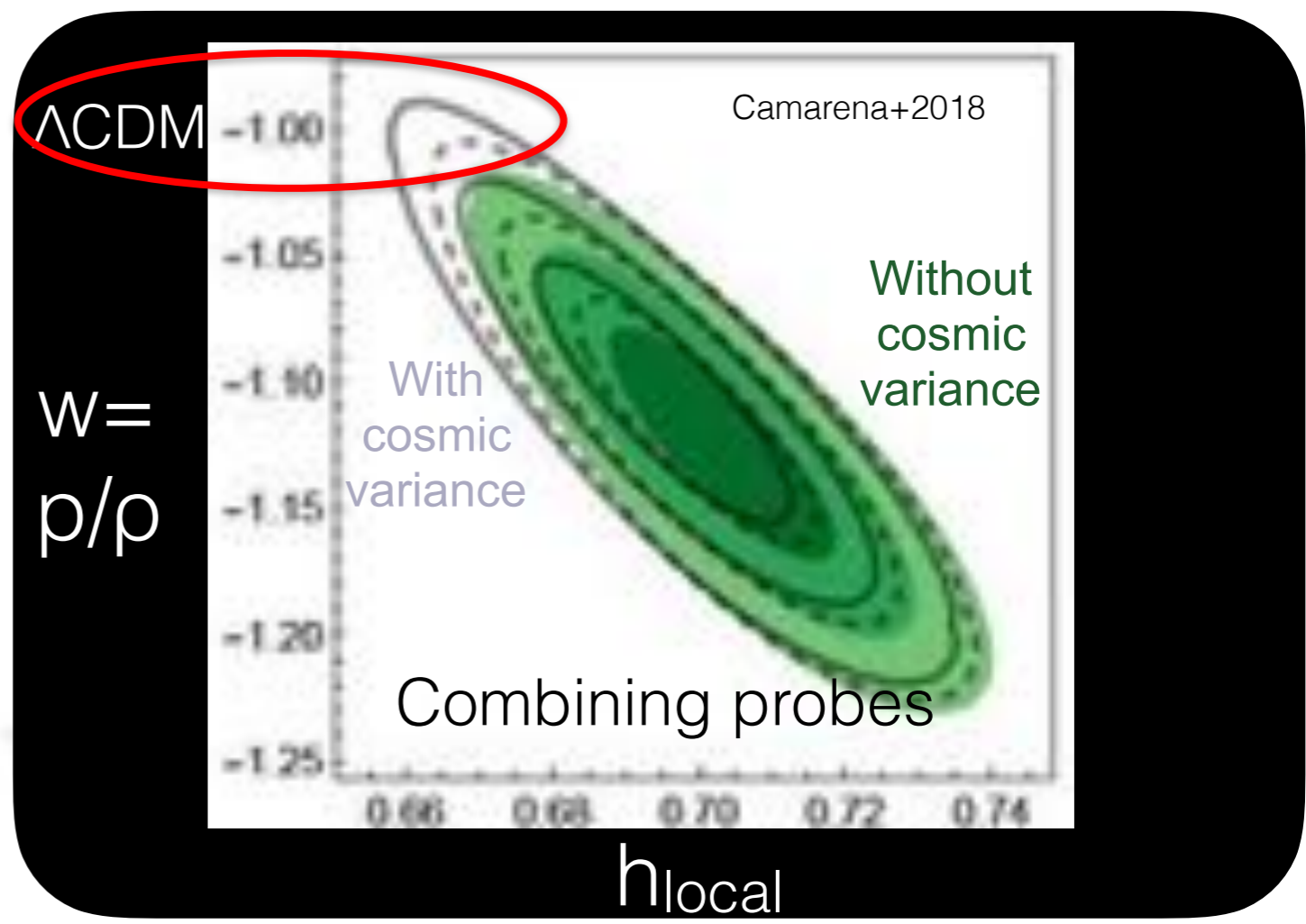


Accuracy:
1% bias non-negligible

2dF Galaxy Redshift Survey

Colless +1999

Springel+2005,2008, Dubois+2016, etc



Motivations

Need both Precision & Accuracy



Overall: Λ CDM



Precision Era:
1-2% precision

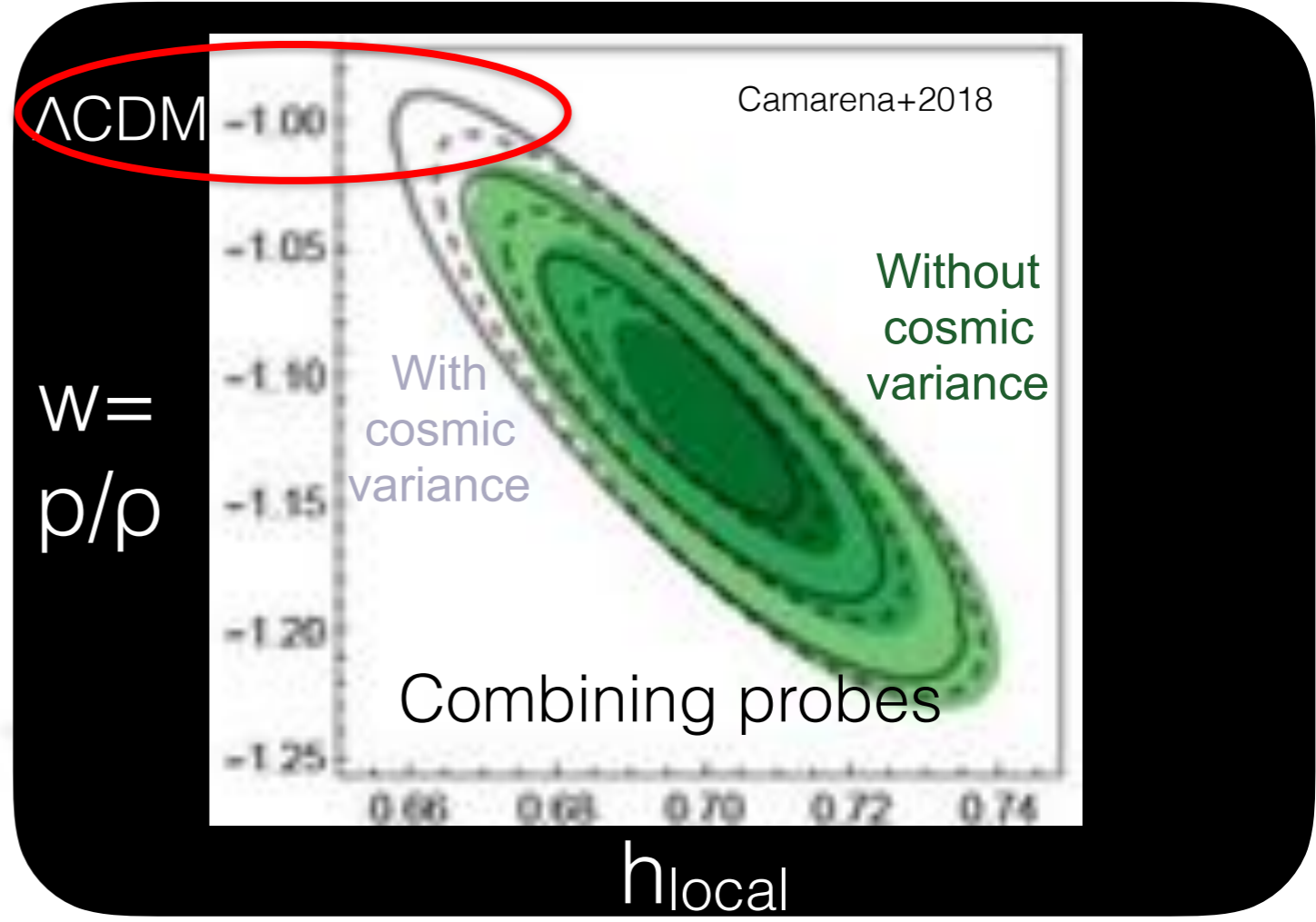


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When observations challenge Λ CDM



Tensions

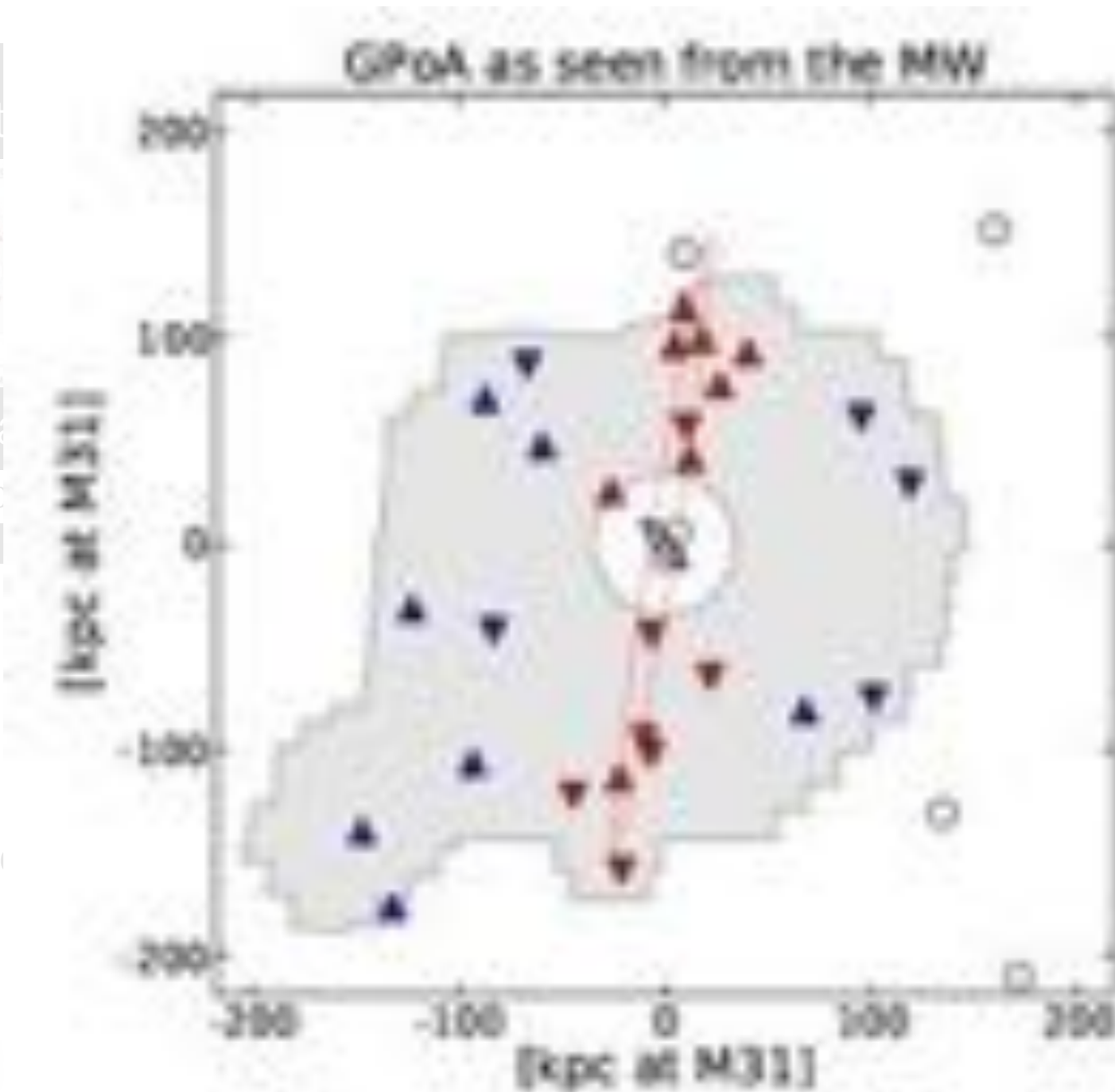

on all scales, some examples: I. small scales

small scales

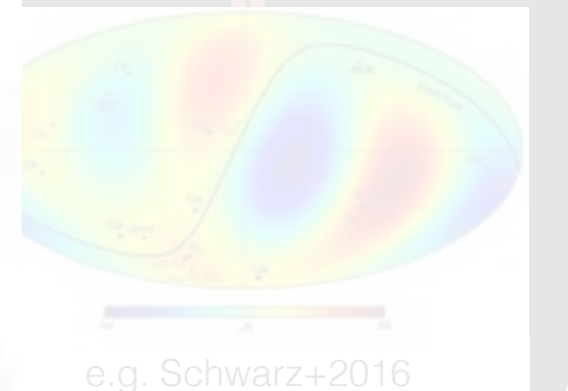
local/global cosmological parameters

large scales

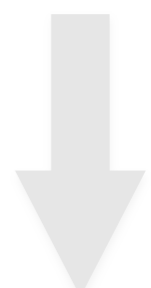
Planes of satellite
no
planes
 Λ CDM local
Famaey+2013, Bullock+20



north/south power
asymmetry



e.g. Schwarz+2016



Only local detail
observations

rol of foregrounds to a
few % level



Local specificities?

Our observation site?

Foreground effect?

Tensions

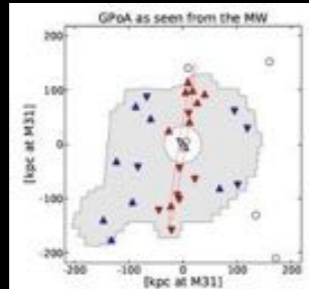
on all scales, some examples: I. small scales

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no
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Λ CDM

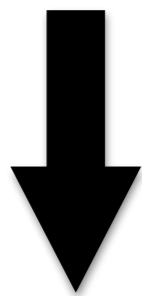
local

Famaey+2013, Bullock+2017

H_0



north/south power
asymmetry



**Only local detailed
observations**

It looks like Λ CDM does not model
both CMB and local Universe!

Control of foregrounds to a
few % level



Local specificities?



Our observation site?



Foreground effect?

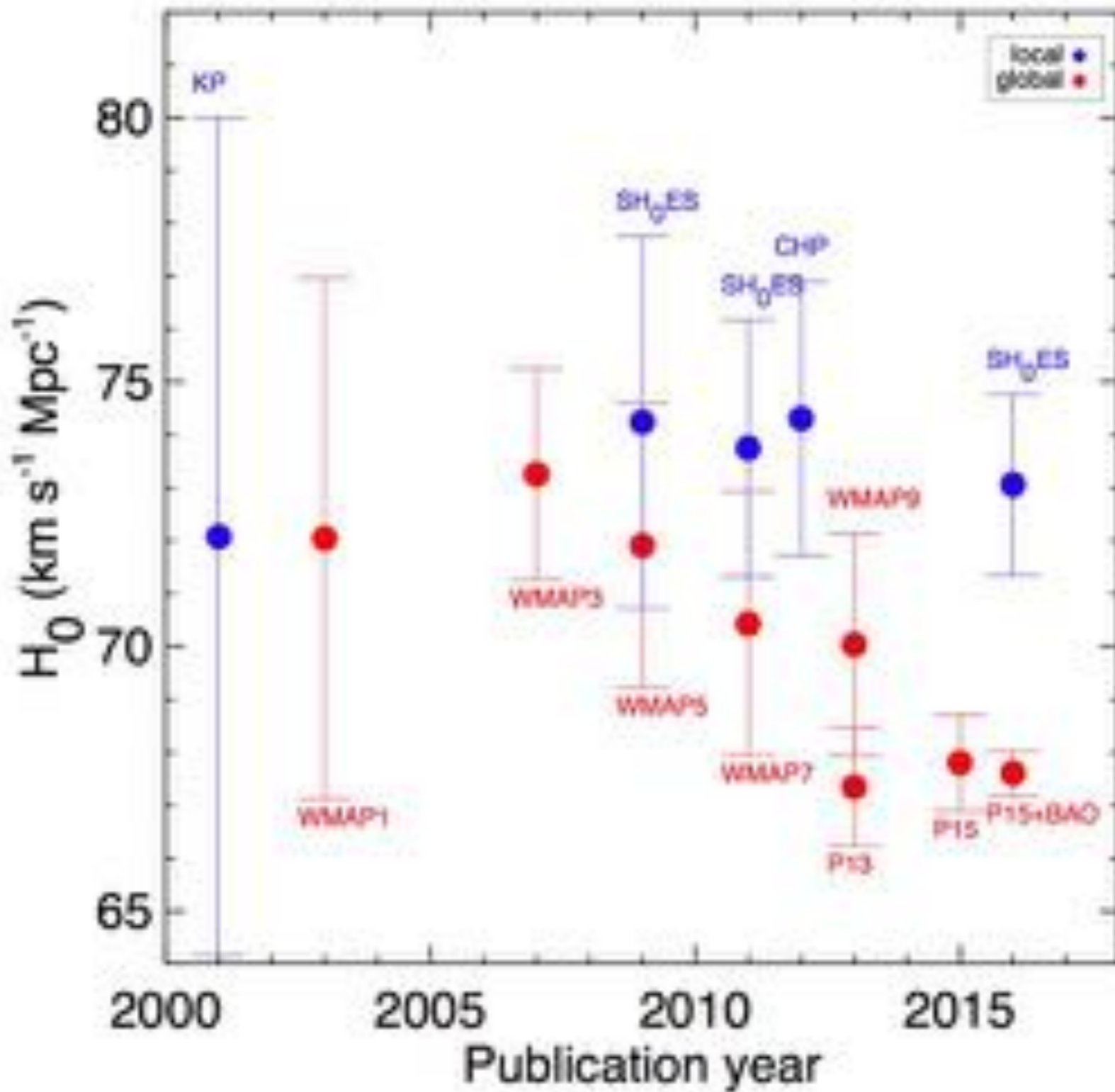
Tensions

on all scales, some examples: II. local/global

small scales

large scales

Planes of satellites
no planes
 Λ CDM
Famaey+2013, Bullock



North/south power asymmetry
e.g. Schwarz+2016

Only local deobservatic

of foregrounds to a few % level



Local specificities:

Our observation site?

Foreground effect?

Tensions

on all scales, some examples: II. local/global

small scales

local/global cosmological parameters

large scales

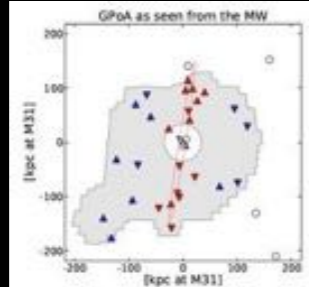
Planes of satellites

no
planes

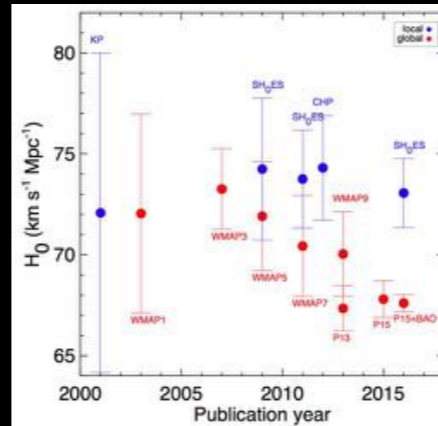
Λ CDM

local

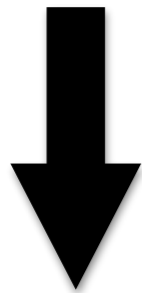
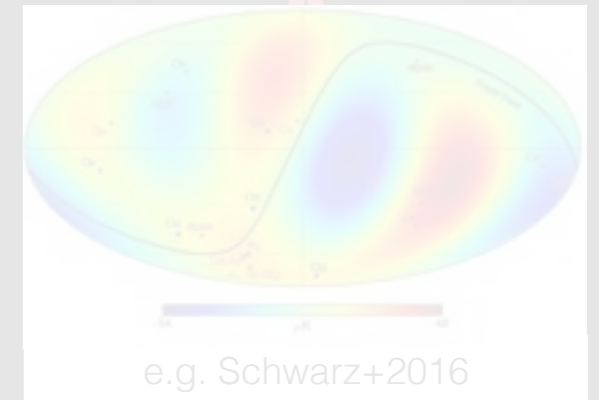
Famaey+2013, Bullock+2017



H_0



north/south power
asymmetry



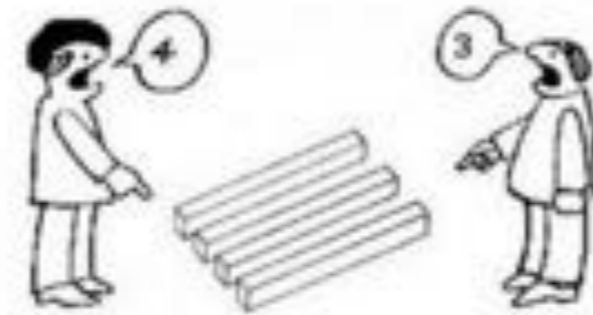
Only local detailed
observations



Local specificities?



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Our observation site?



Control of foregrounds to a
few % level



Foreground effect?

Tensions

on all scales, some examples: III. large scales

small scales

local/global cosmological parameters

large scales

Planes of satellites

no
planes

Λ CDM

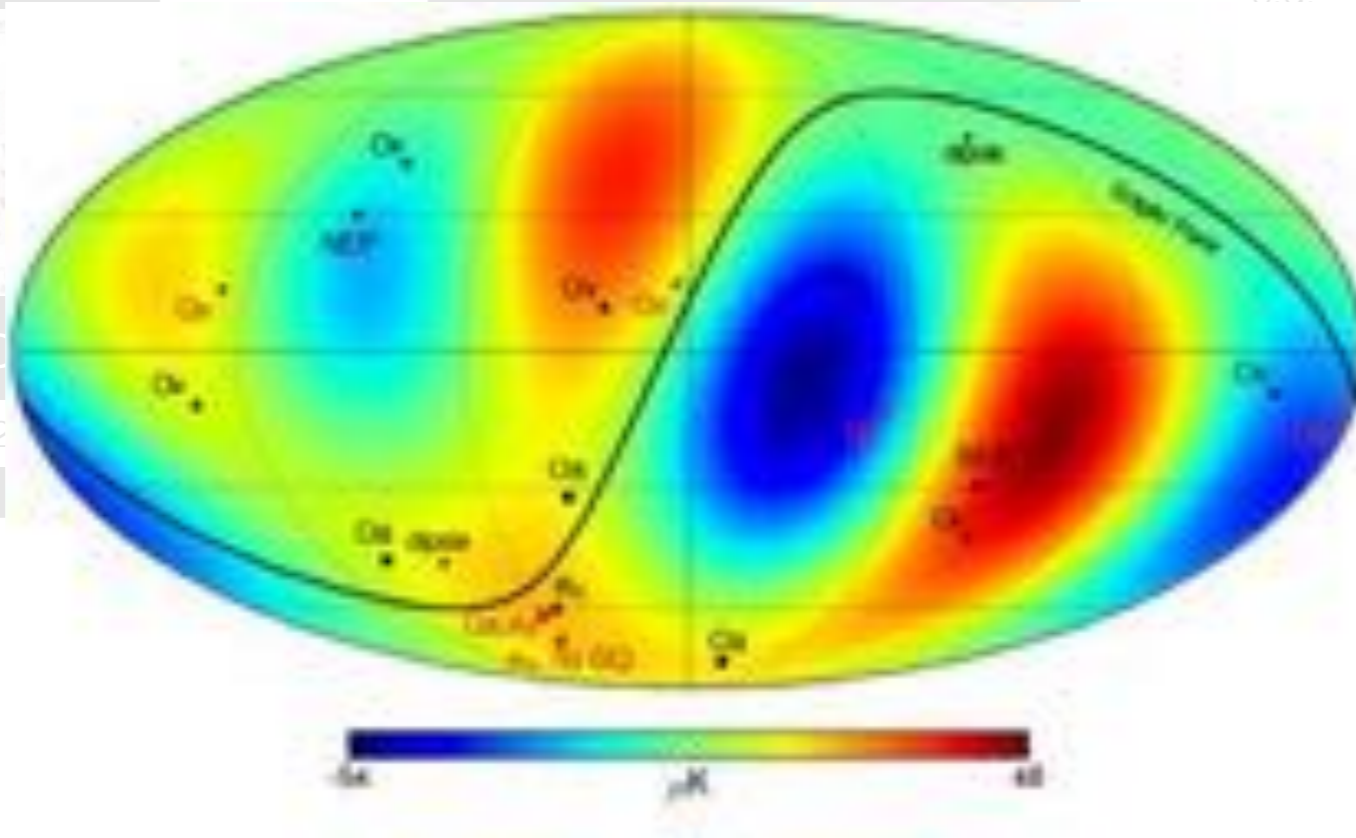
loc

Famaey+2013, Bullock+2



H_0

e.g.



north/south power
asymmetry



e.g. Schwarz+2016



Only local detailed
observations

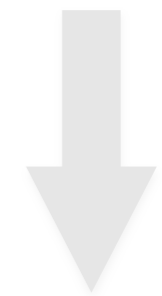


Local specificities?

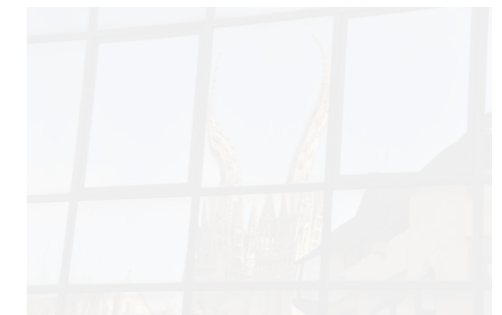
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Our observation site?



Control of foregrounds to a
few % level



Foreground effect?

Tensions

on all scales, some examples: III. large scales

small scales

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large scales

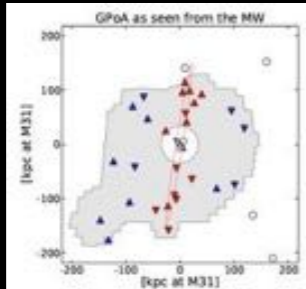
Planes of satellites

no
planes

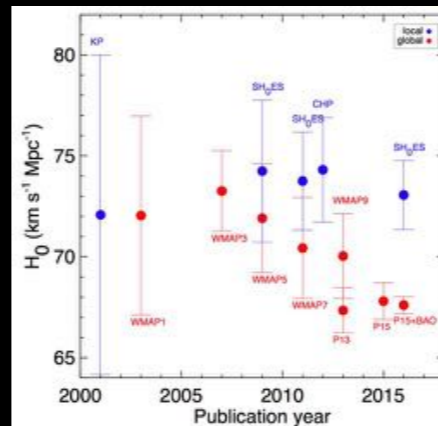
Λ CDM

local

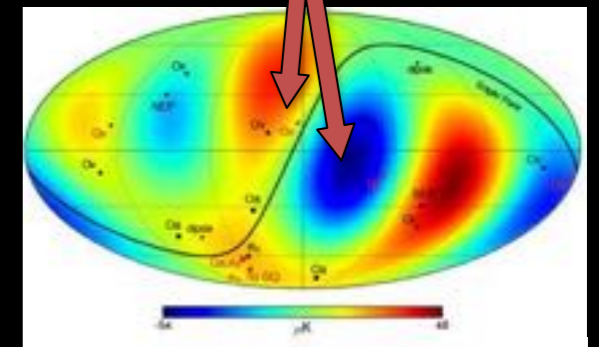
Famaey+2013, Bullock+2017



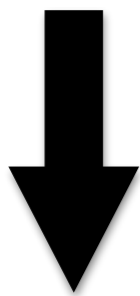
H_0



north/south power
asymmetry



e.g. Schwarz+2016



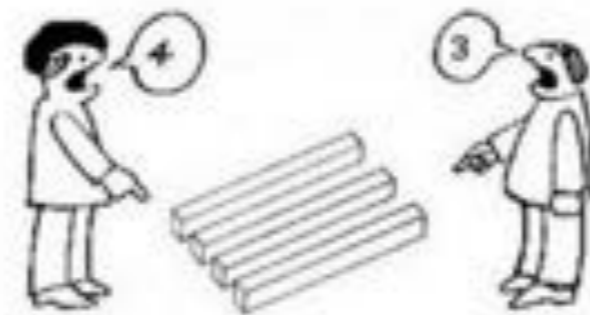
Only local detailed
observations



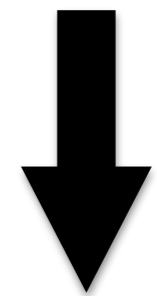
Local specificities?



It looks like Λ CDM does not model
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Our observation site?



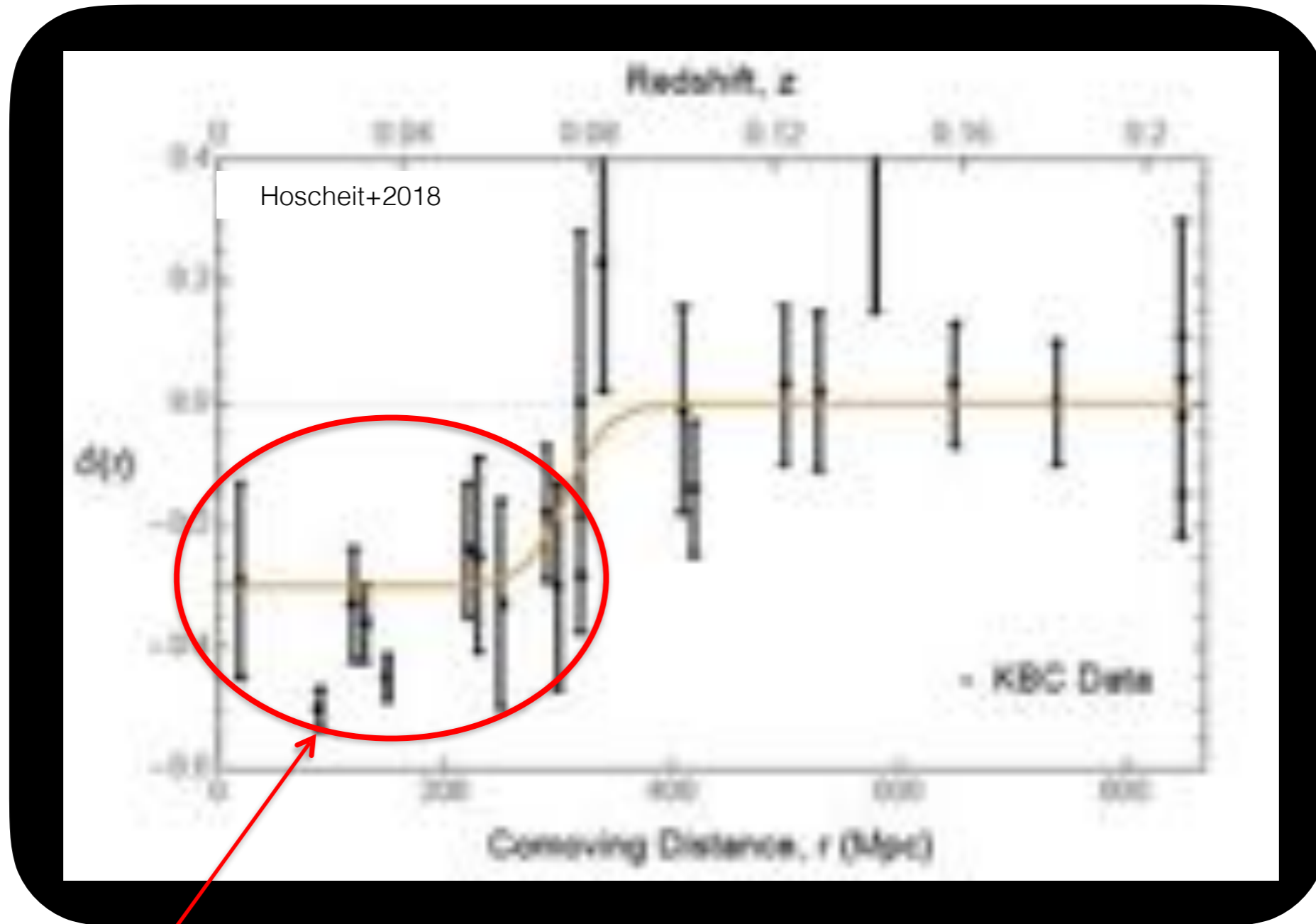
Control of foregrounds to a
few % level



Foreground effect?

What can be the biases? What effects can they have? Anyway, remember, we want to be both precise and **accurate** = we need to take it into account whatever happens !





An example: Hint at
a local underdensity
up to $z=0.07$

Keenan+2014

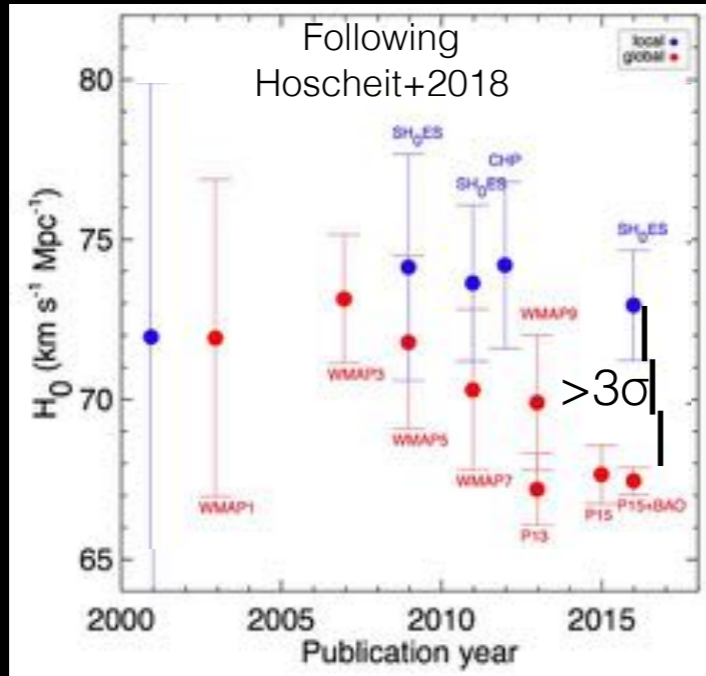
Tensions

Effect of the distribution of matter, some examples

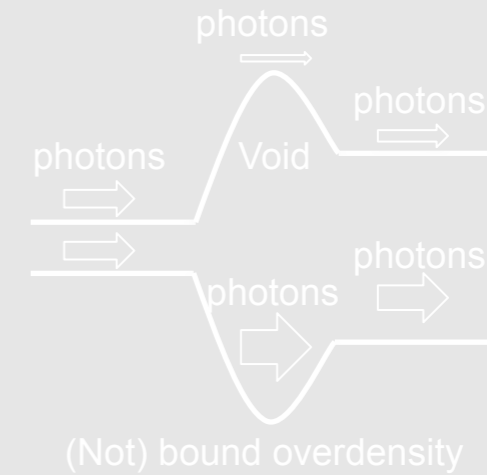
local/global cosmological parameters

large scales

Simple void model (Λ CDM + KBC void)



Gravitational redshift:
linear (Integrated Sachs-Wolfe)

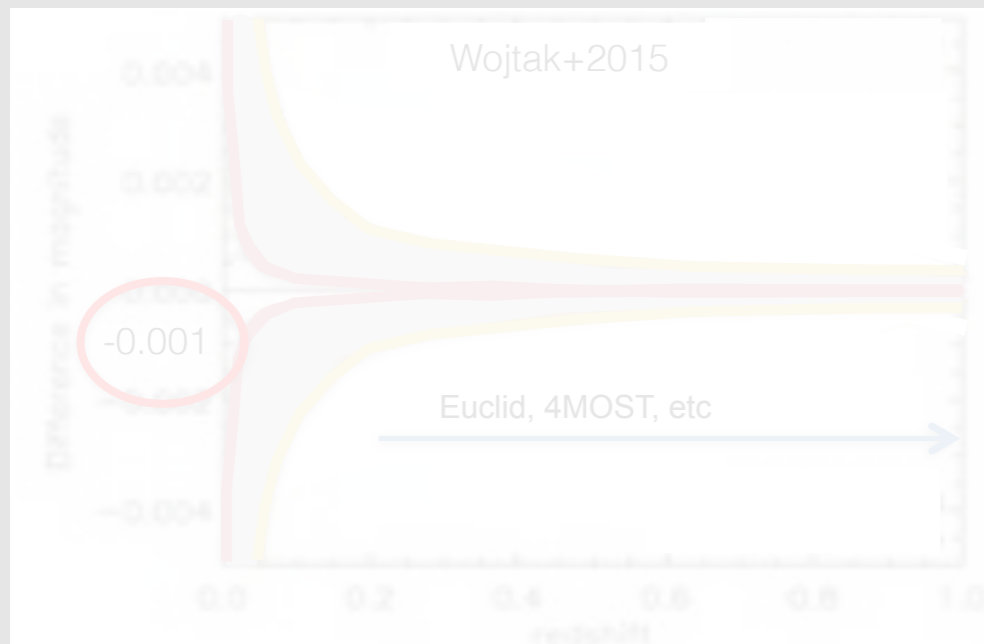


Simple luminosity - density model



large scales

Average void: Impact on z of 10^{-3} !



Asymmetry

Broken asymmetry

Francis+2010

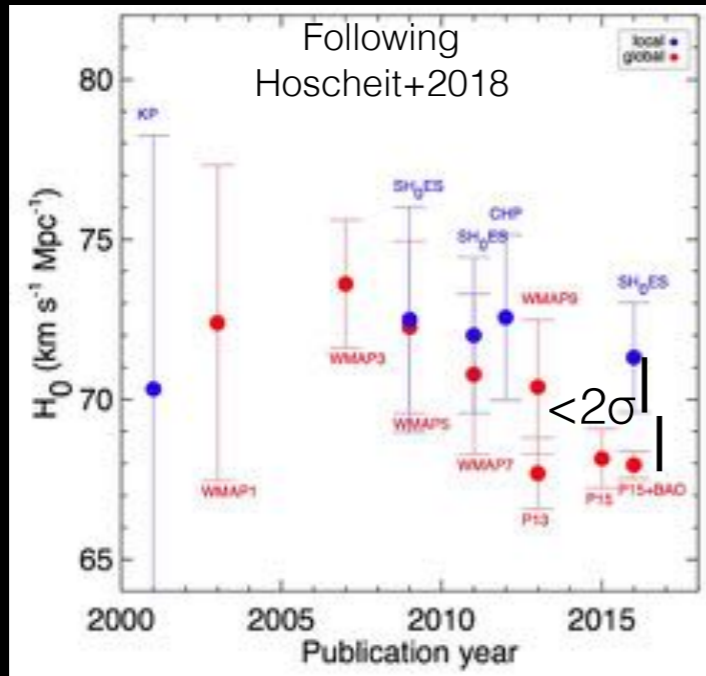
Tensions

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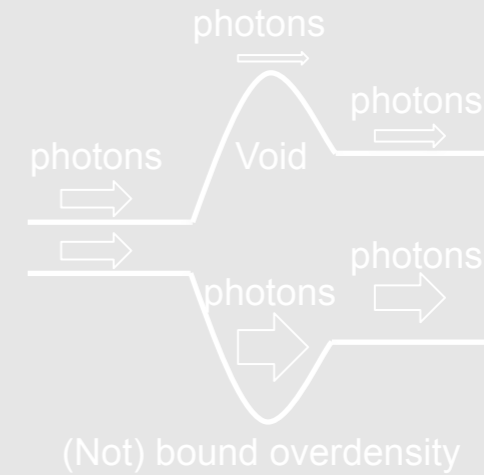
local/global cosmological parameters

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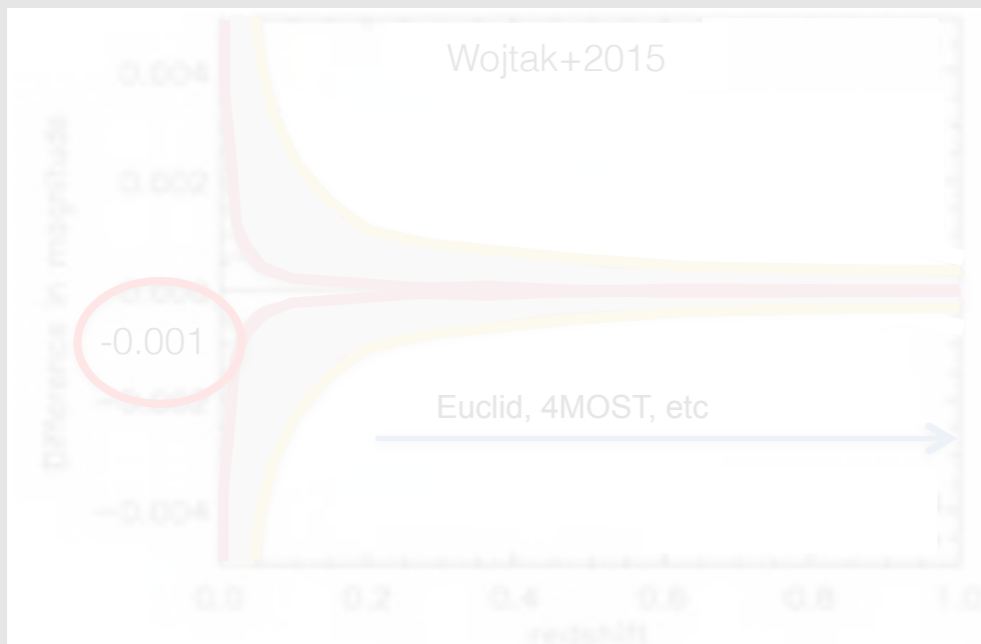


Simple luminosity - density model



large scales

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Asymmetry

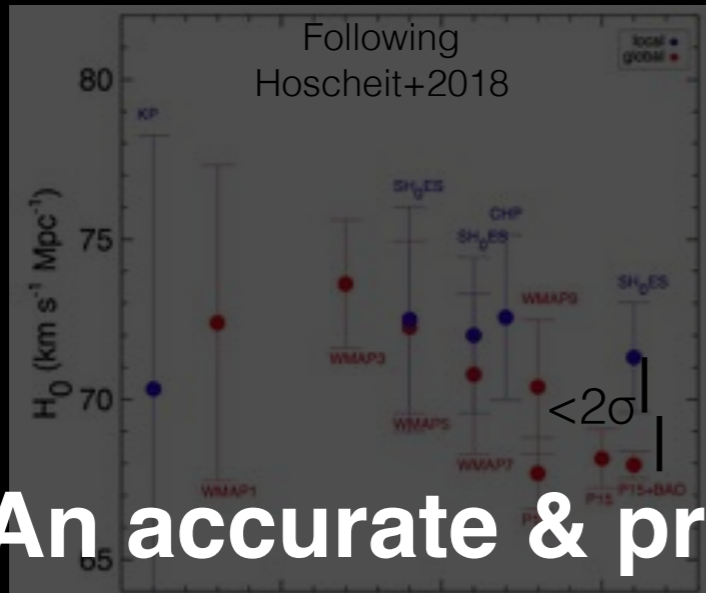
Broken asymmetry

Francis+2010

local/global cosmological parameters

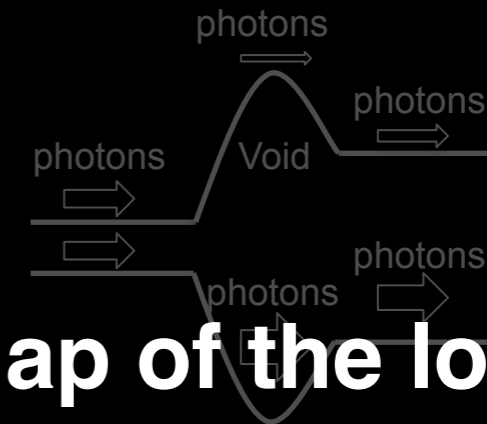
large scales

Simple void model (Λ CDM + KBC void)

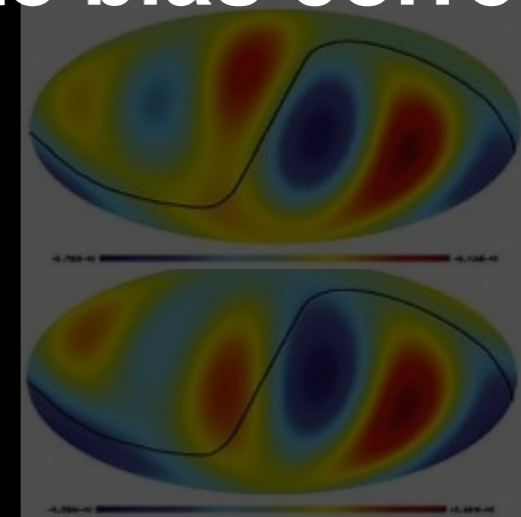


An accurate & precise non-linear map of the local distribution of matter is required to provide an apple to apple comparison & an accurate bias correction !

Gravitational redshift: linear (Integrated Sachs-Wolfe)

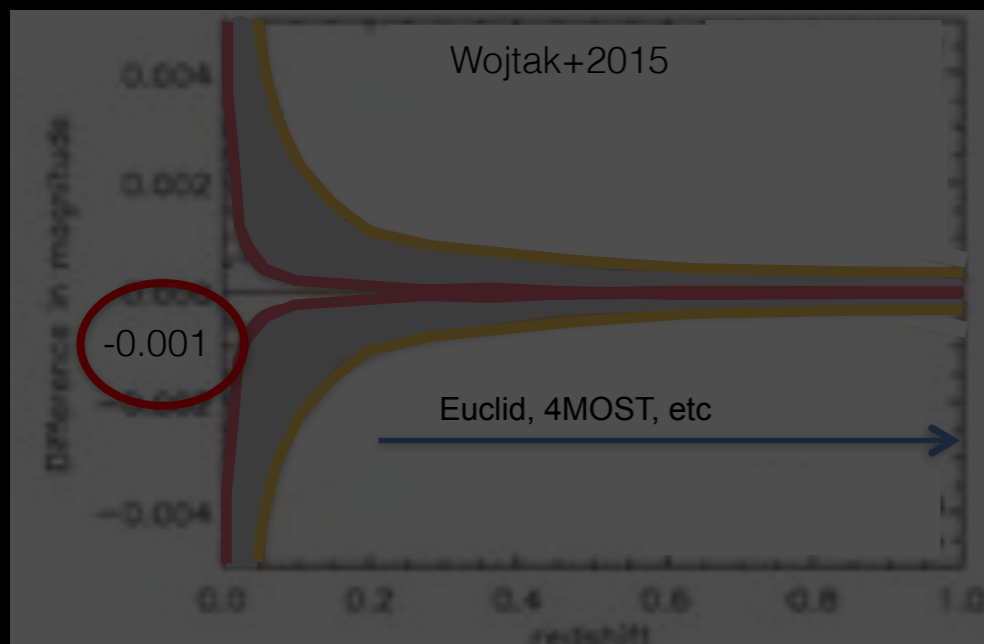


(Not) model overdensity
Simple density model

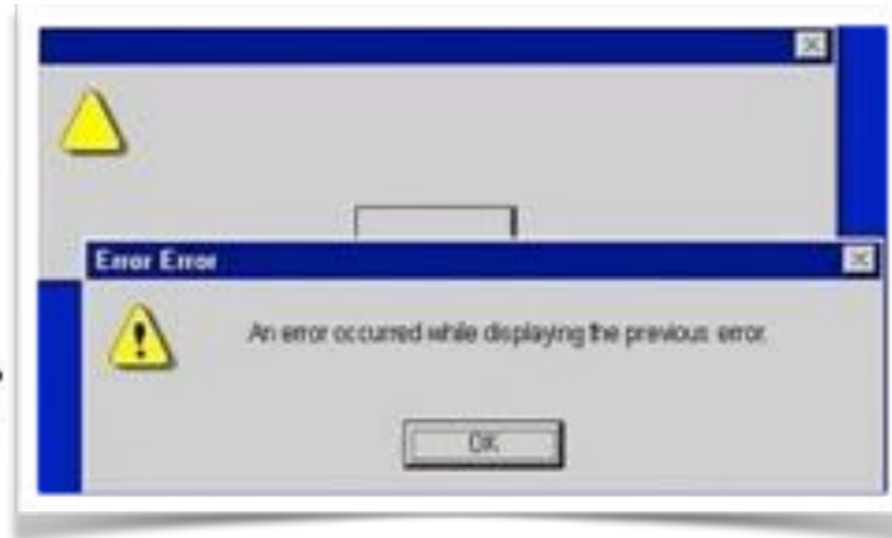


Francis+2010

Average void: Impact on z of 10^{-3} !



Obtaining an accurate & precise non-linear map of the local Universe



PATH INTEGRAL METHODS FOR PRIMORDIAL DENSITY PERTURBATIONS: SAMPLING OF CONSTRAINED GAUSSIAN RANDOM FIELDS

EDMUND **BERTSCHINGER**

Center for Theoretical Physics, Center for Space Research, and Department of Physics, Massachusetts Institute of Technology

Received 1987 August 17; accepted 1987 September 10

ABSTRACT

Path integrals may be used to describe the statistical properties of a random field such as the primordial density perturbation field. In this framework the probability distribution is given for a Gaussian random field subjected to constraints such as the presence of a protovoid or supercluster at a specific location in the initial

Work	Constraints	Redshift surveys	peculiar velocities + density	peculiar velocities
Kitaura2008,2012,2013 Hess+2013		☑		
Lavaux2010, Jasche+2013-tdy		☑		
Wang+2014-tdy		☑		
Klypin+2003			☑	
Sorce+2014-tdy				☑



"This identical twin of yours... Can you describe him?"

no luminosity bias

$$V_{\text{radial pec}} = v_{\text{obs}} - H_0 \times d$$

Sorce & Tempel 2017,2018

Wiener1942

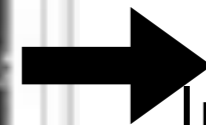
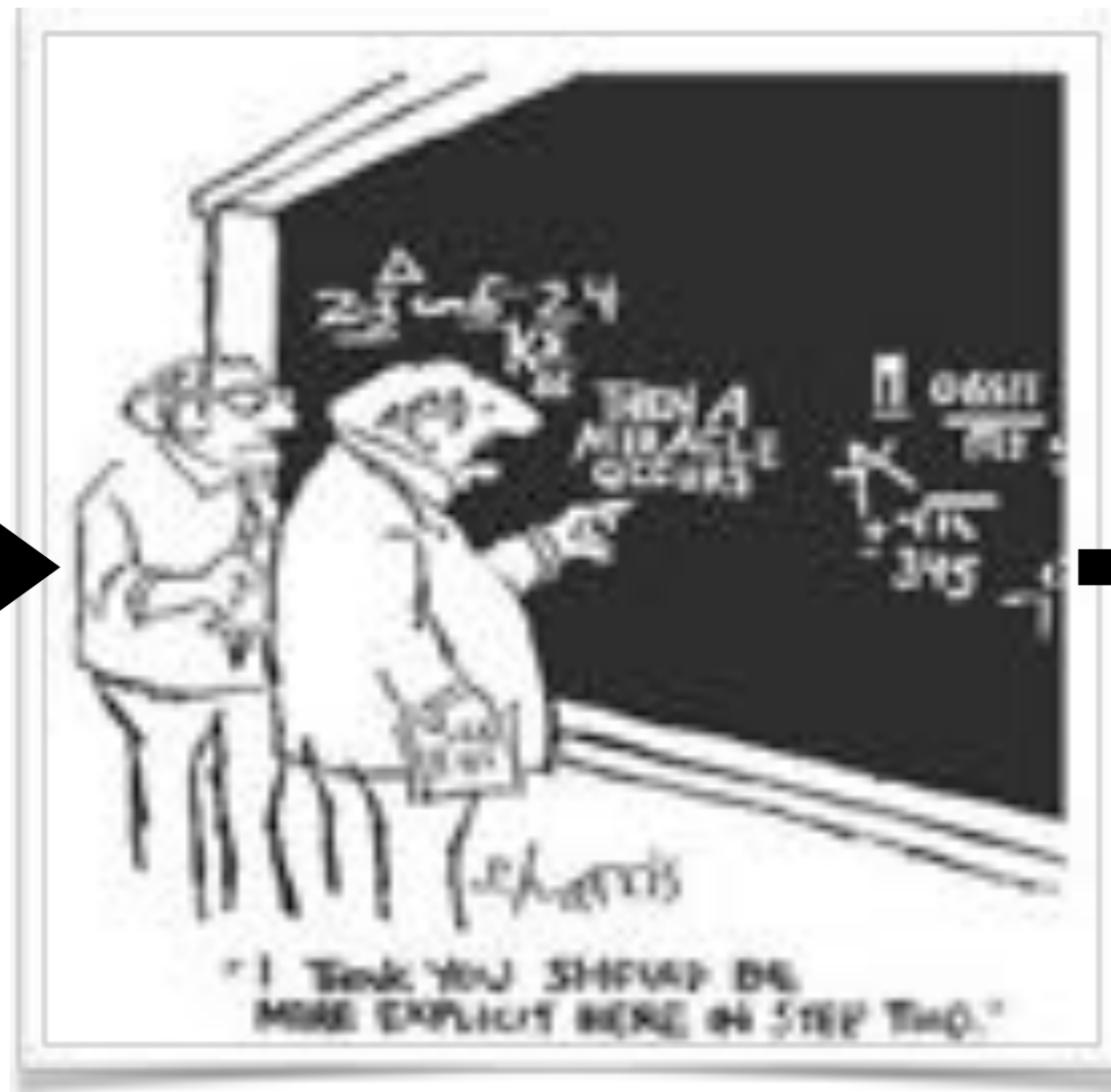
Hoffman & Ribak 1991

Sorce 2015, 2018

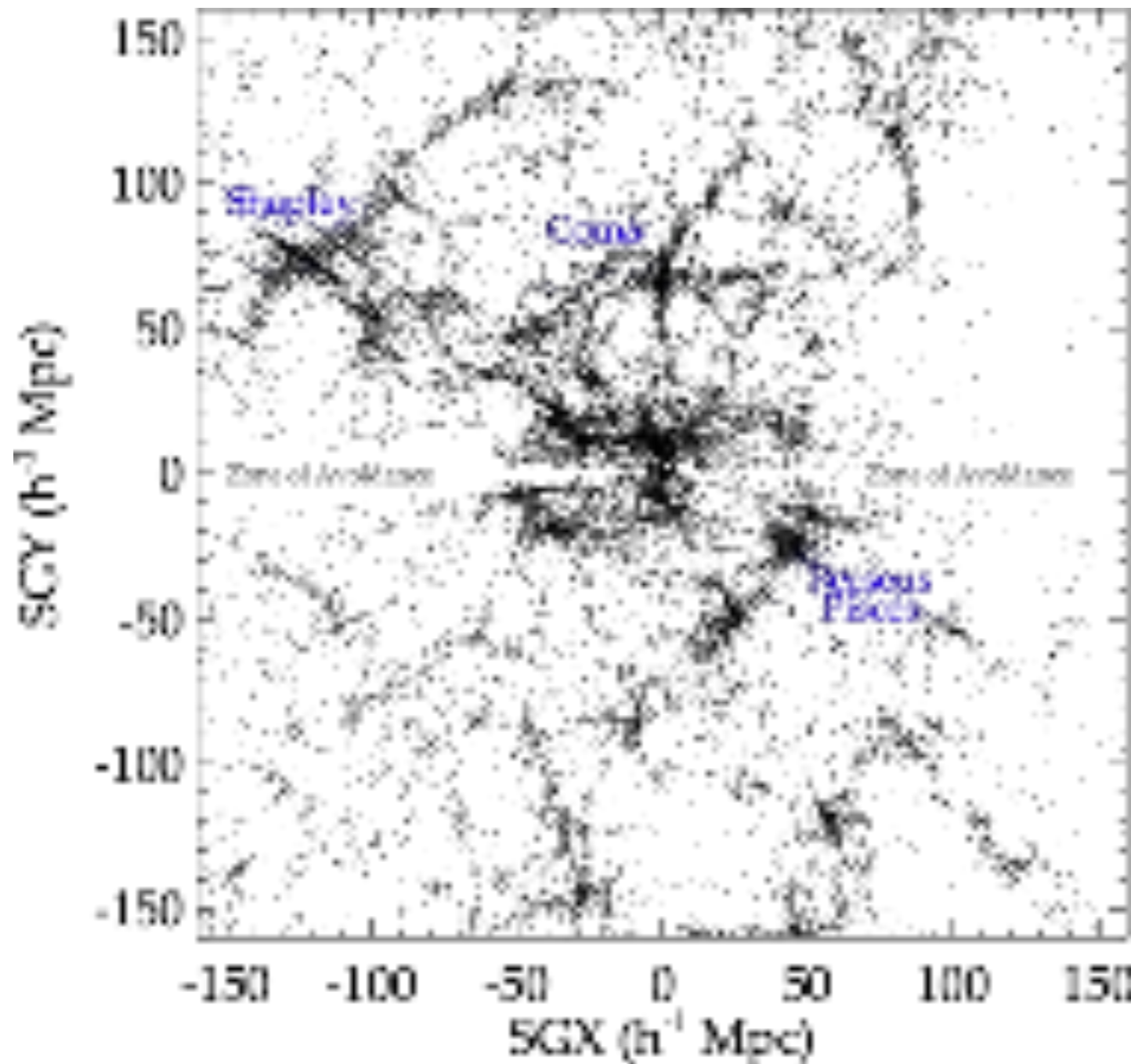
Doumler+2013

Sorce+2014

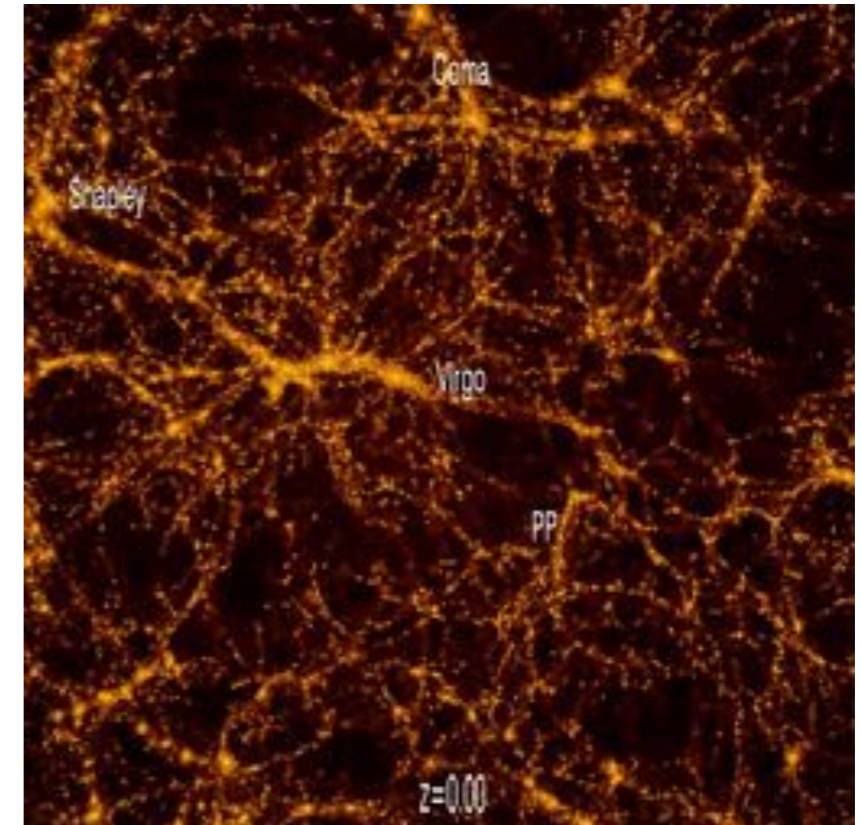
Observational local
Constraints



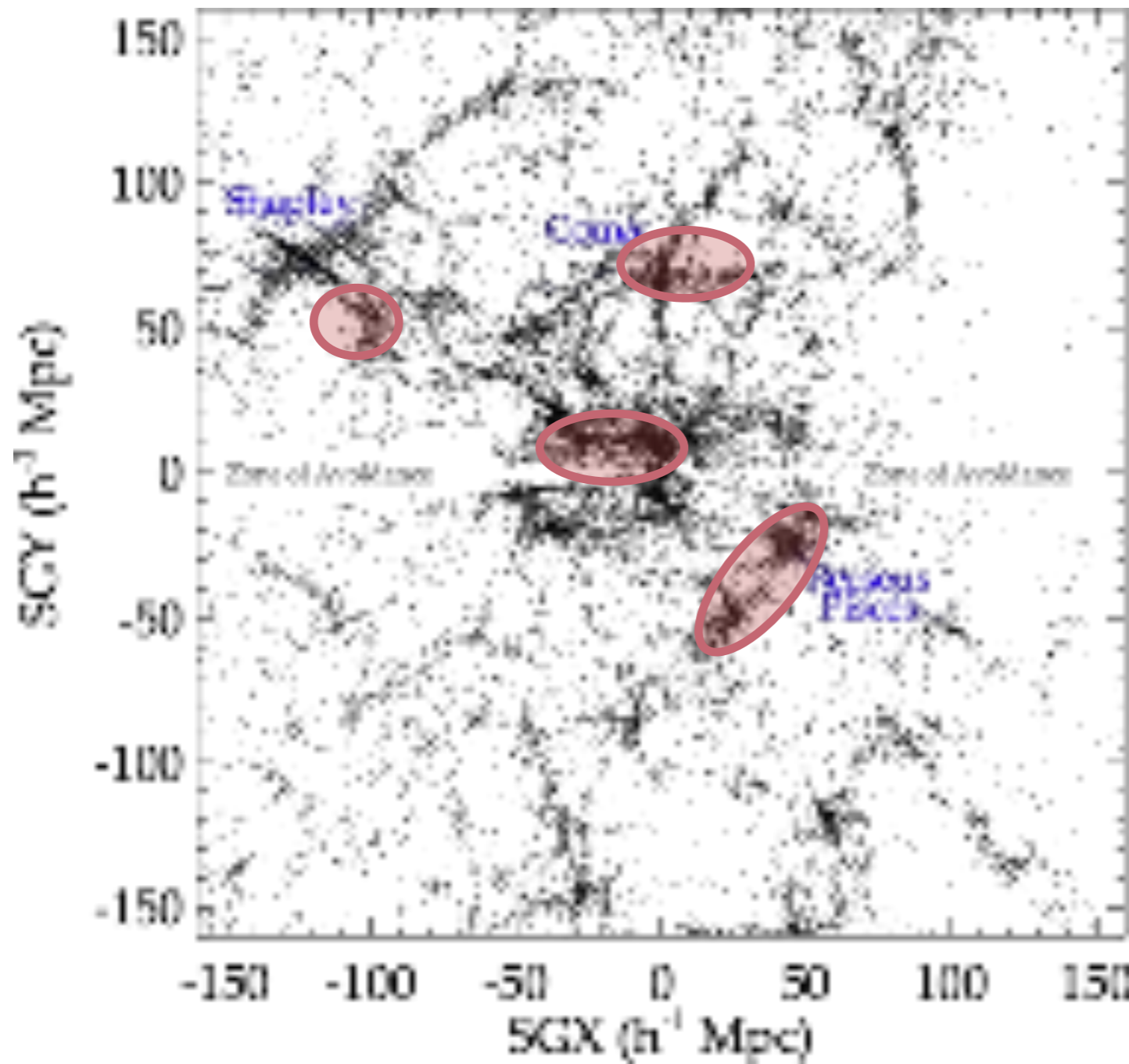
Constrained
Initial Conditions



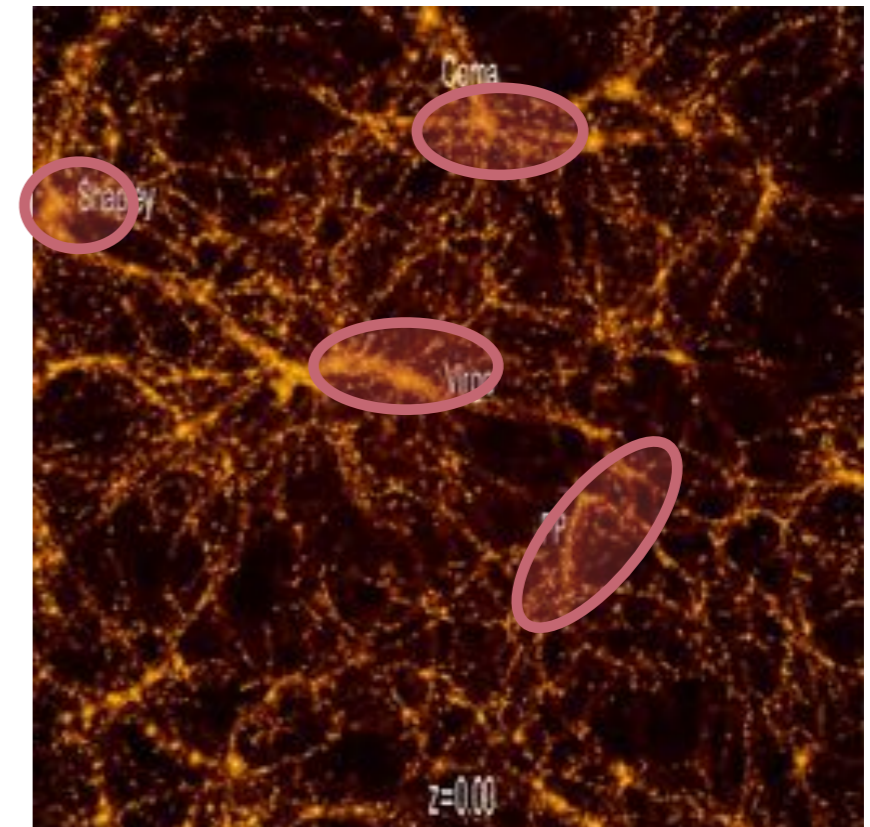
Note the fingers of gods



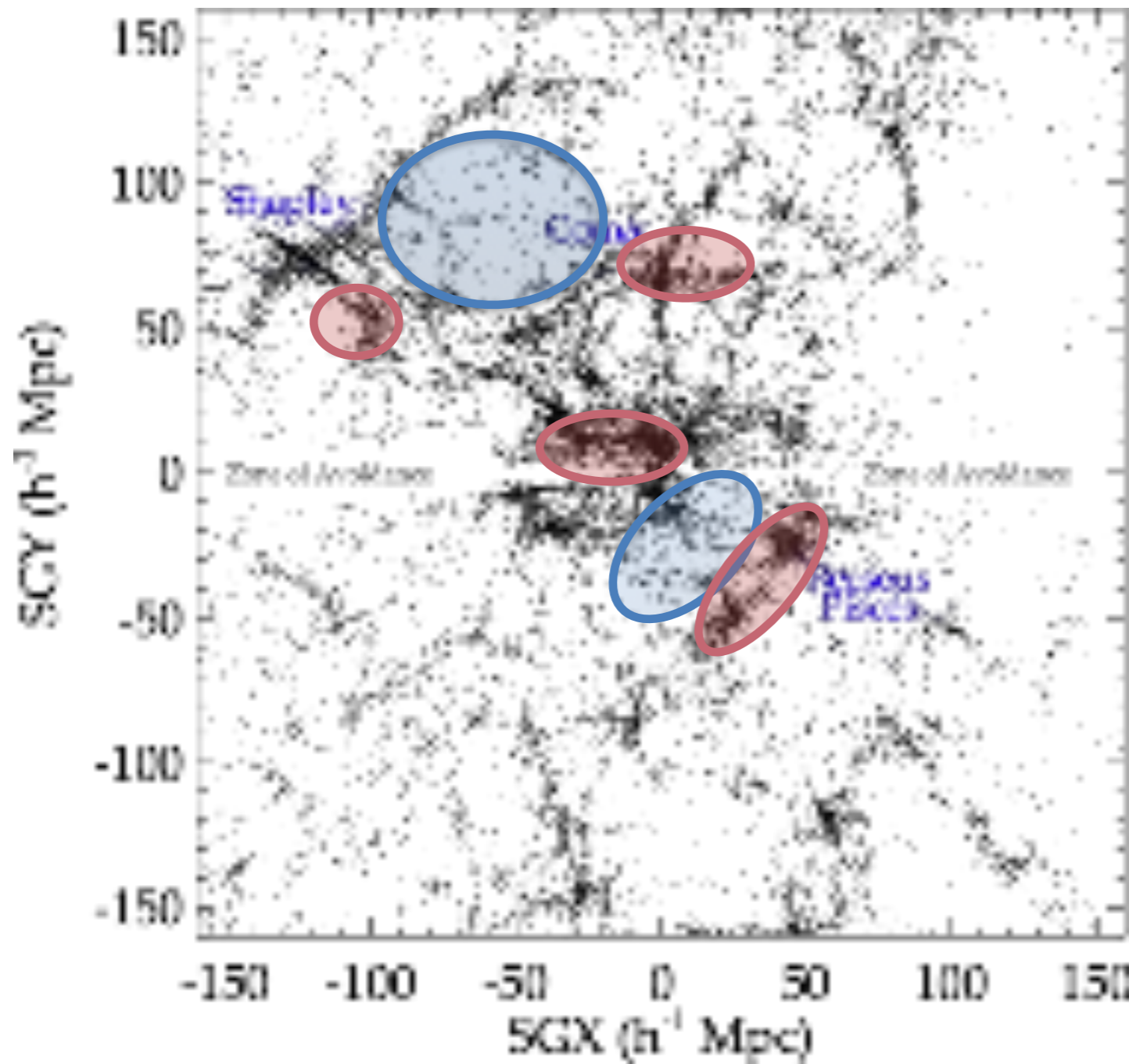
500 Mpc/h, 1024^3 particles,
DM only, Planck cosmology



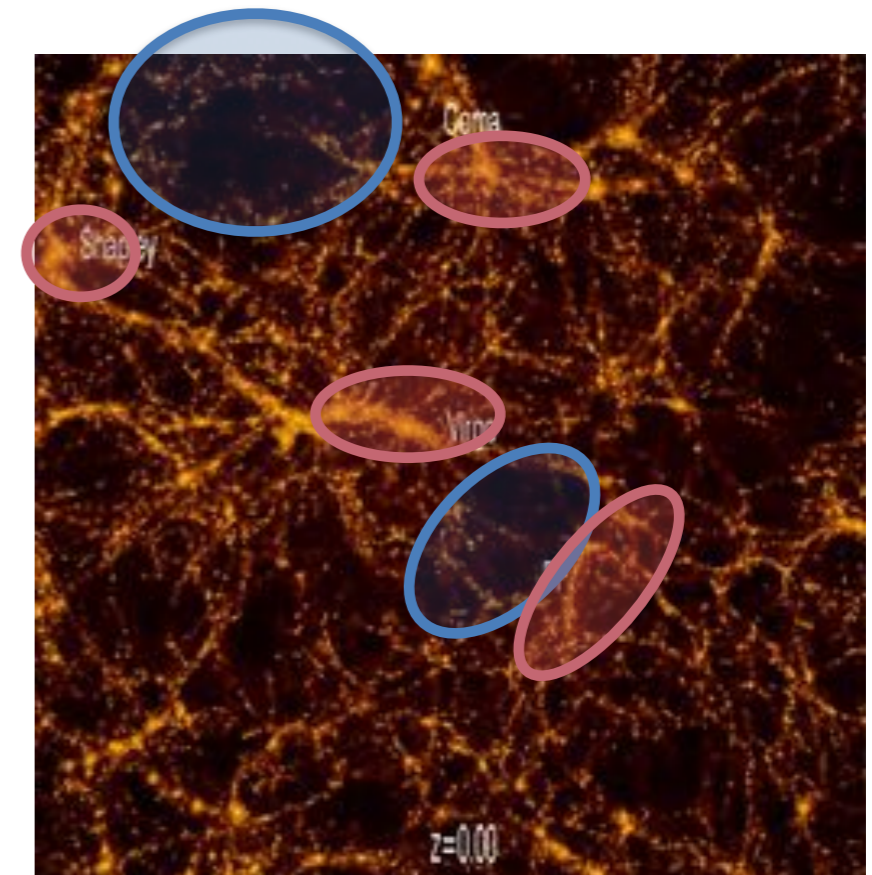
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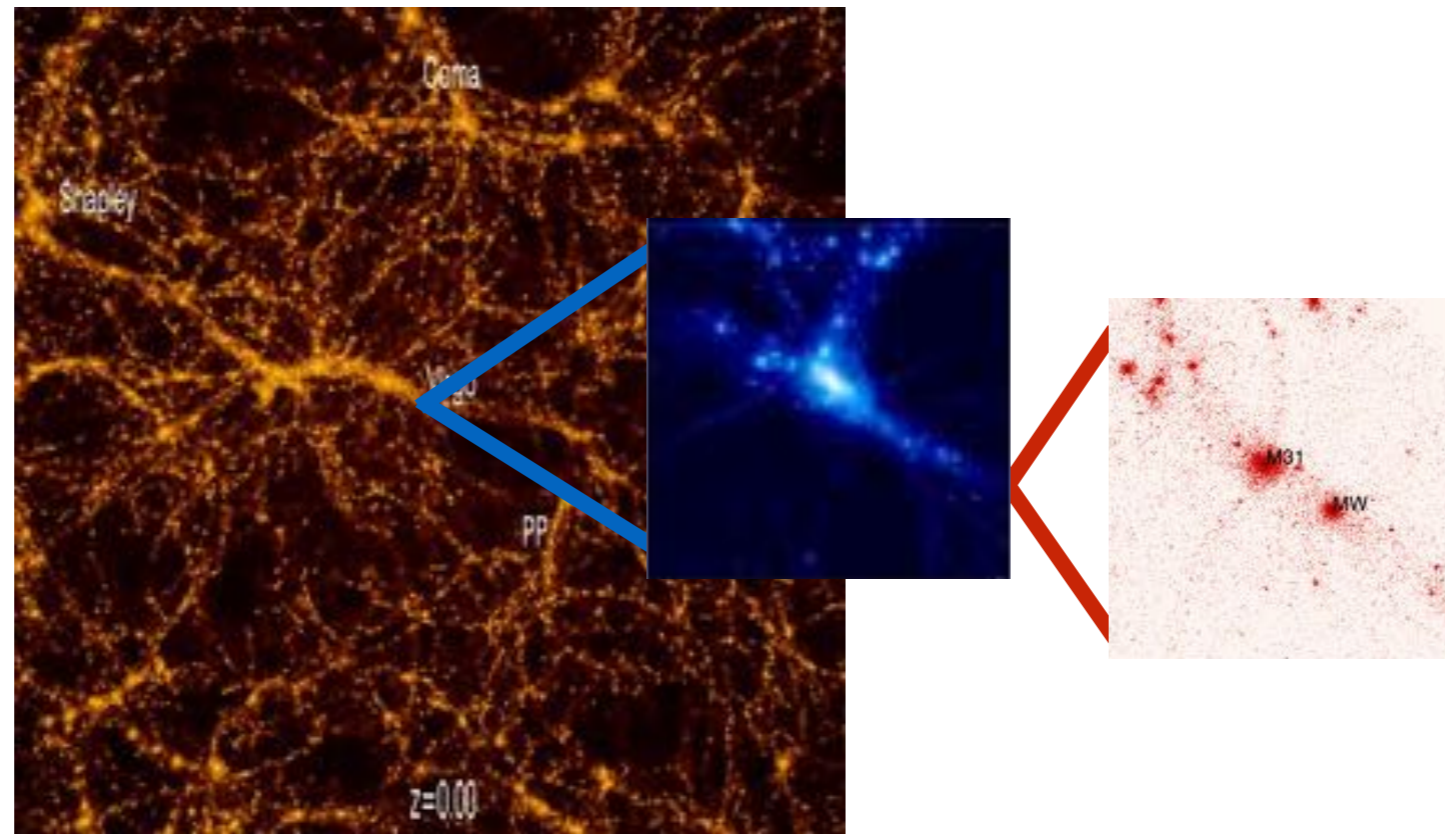
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Note the fingers of gods



500 Mpc/h, 1024^3 particles,
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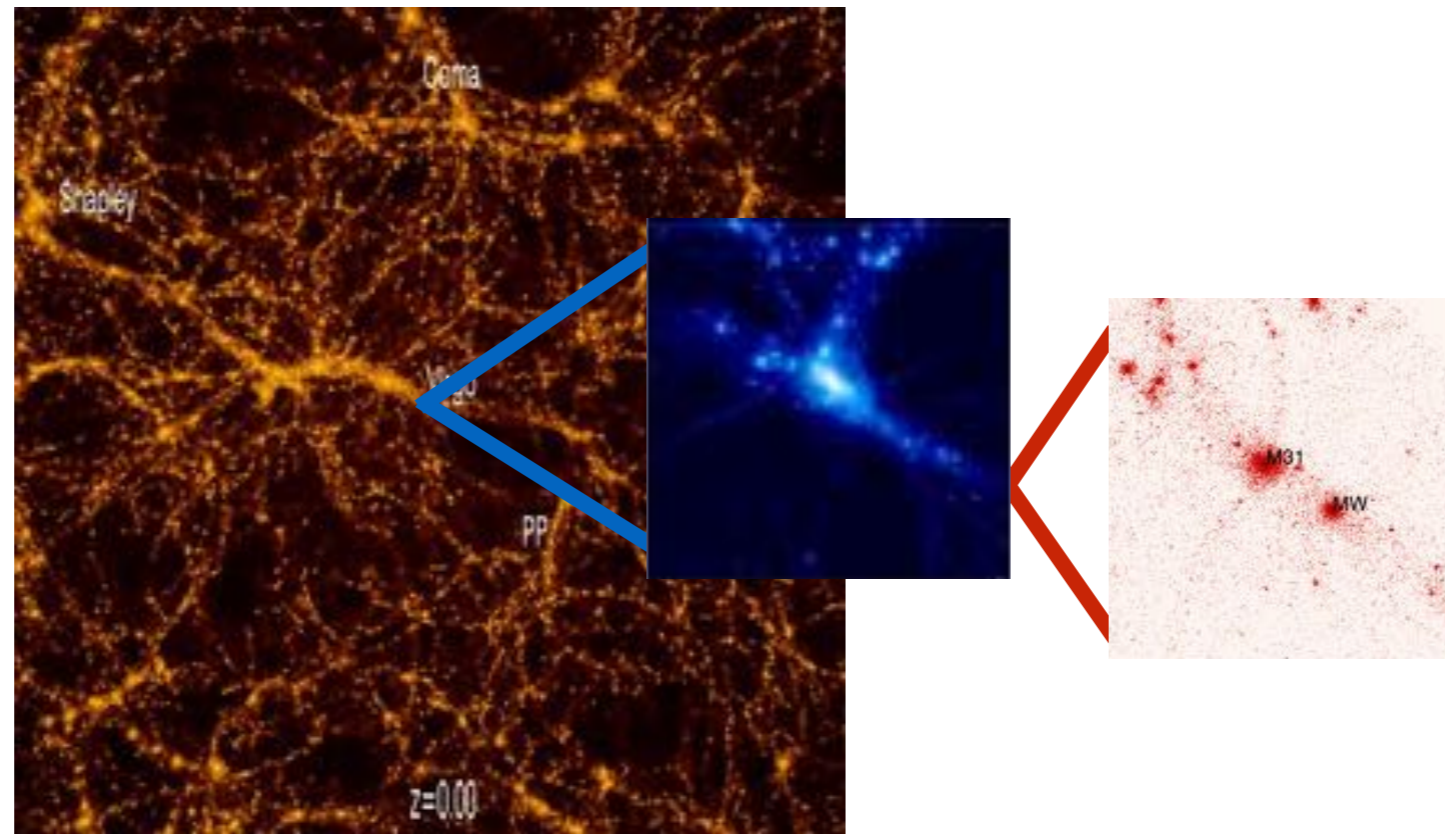


Work	Constraints	large scales	cluster scales	local group scales
Kitaura2008,2012,2013 Hess+2013		✓	✓ no statistics	
Lavaux2010, Jasche+2013-tdy		✓		
Wang+2014-tdy		✓	✓ not nearby, no statistics	
Klypin+2003		✓	✓ mass 'by hand'	✓ induced
Sorce+2014-tdy		✓	✓	✓ induced

} luminosity bias !

e.g. for the **Virgo cluster** Sorce+2016b, Sorce +in prep. including the past history!

e.g. Carlesi,Sorce+2016
Carlesi,Hoffman,Sorce+2016
Carlesi,Hoffman,Sorce+2017



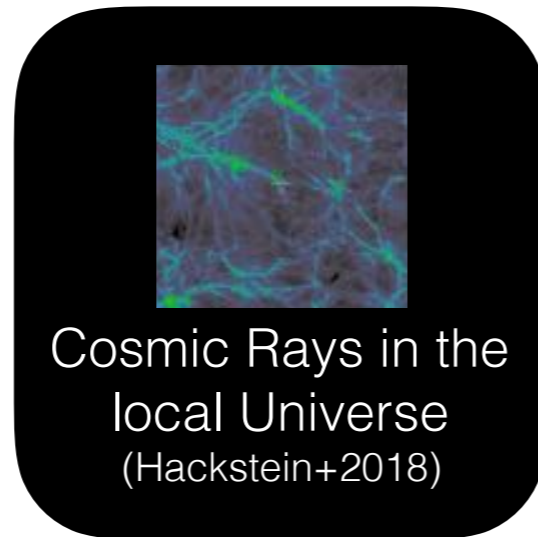
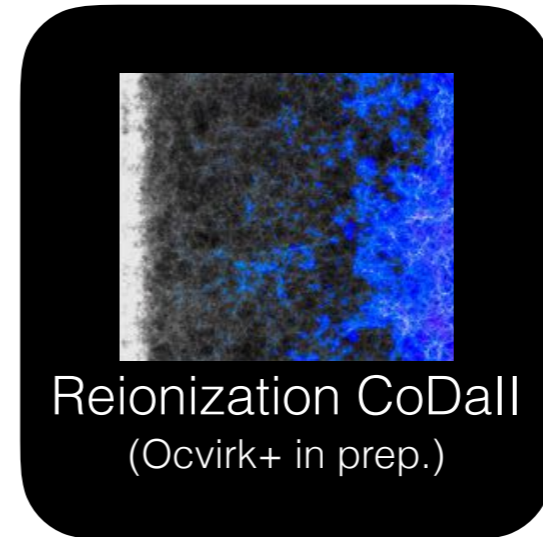
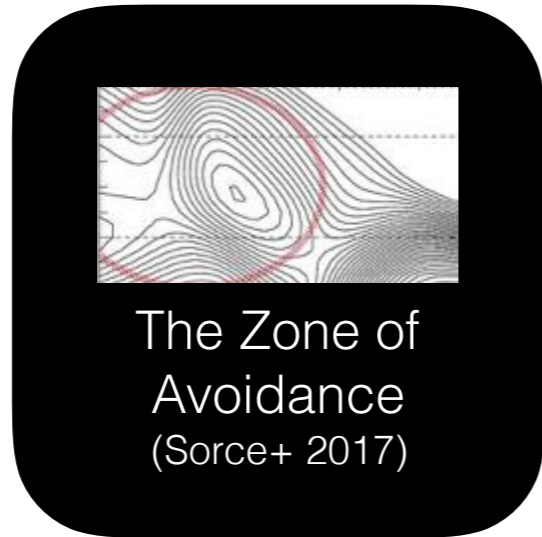
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Sorce+2014-tdy		✓	✓	✓ induced
GMO-CLONES		✓	✓	✓

} luminosity bias !

e.g. for the **Virgo cluster** Sorce+2016b, Sorce +in prep. including the past history!

on-going

e.g. Carlesi,Sorce+2016
Carlesi,Hoffman,Sorce+2016
Carlesi,Hoffman,Sorce+2017



Summary: where do we stand?
How far have we come?
Where are we going?

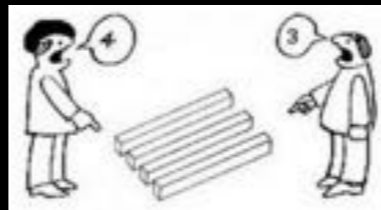


Ultimate goal: Λ CDM or else?

Galaxy formation
and evolution
(small scales)



Local cosmological
parameters (local)



Large cosmological
surveys & CMB
(global)



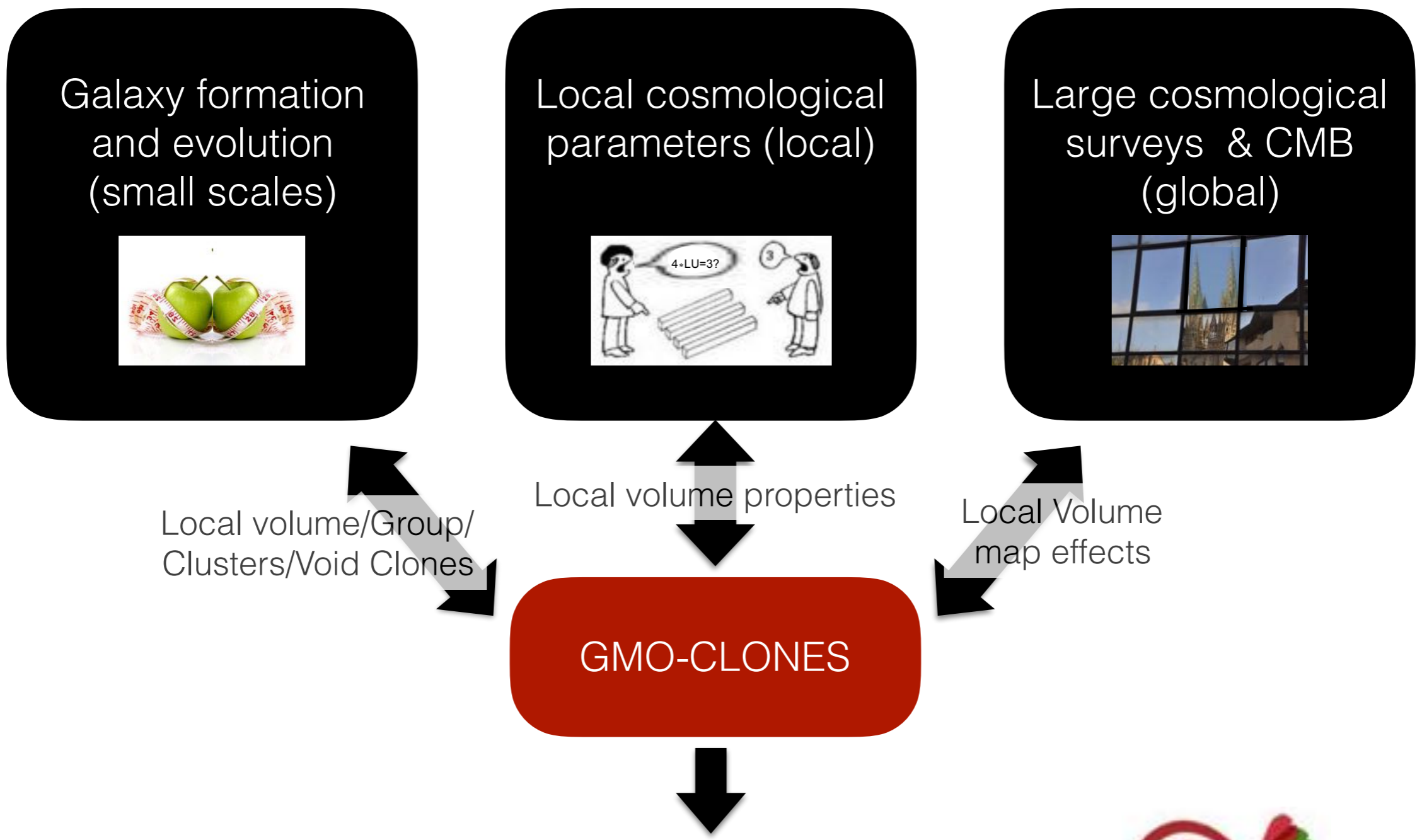
All of this is on-going via observations and simulations ✓



Biased precision cosmology



Ultimate goal: Λ CDM or else?

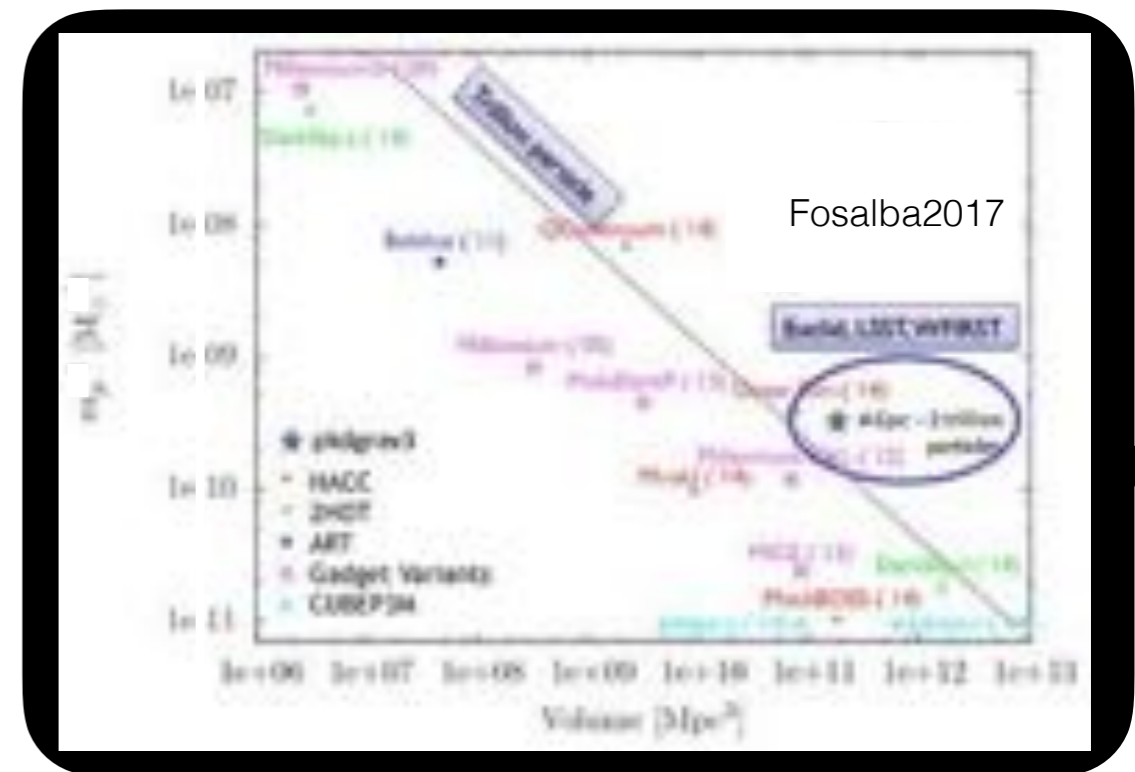


Accurate precision cosmology



Challenges & Increasing Problems

- Sharing initial conditions at high resolution required for local Group for instance
- Sharing/Saving the simulation outputs (**several TB**)
- The Large Scale Structure plays a major role in shaping the small scales. How do we combine both (**with hydrodynamics**)? (>a **trillion** particles)
- zoom-in not possible yet for some codes: cosmic rays propagation (CR-Propa), for reionization (ramses cudaton). Anyway only small regions, no stat., not the whole map
- how do we compare efficiently to observations?
- increasing queue time, even for test runs
- Problem of analyses (not enough memory, **long term saving/storage** for post-processing)



Thank you, Merci, Grazie,
Gracias, Danke, **спасі́бо**,
Mahalo, 谢谢, **ありがとう**,
תודה, Obrigada, Dank u,
Tak, Cảm ơn, Dziękuję,
Kiitos, Aitäh, ...*

* Missing your 'thanks' spelling? It means I did not get the chance yet to visit your country but I am looking forward to do so ! (**exceptions to the rule**)