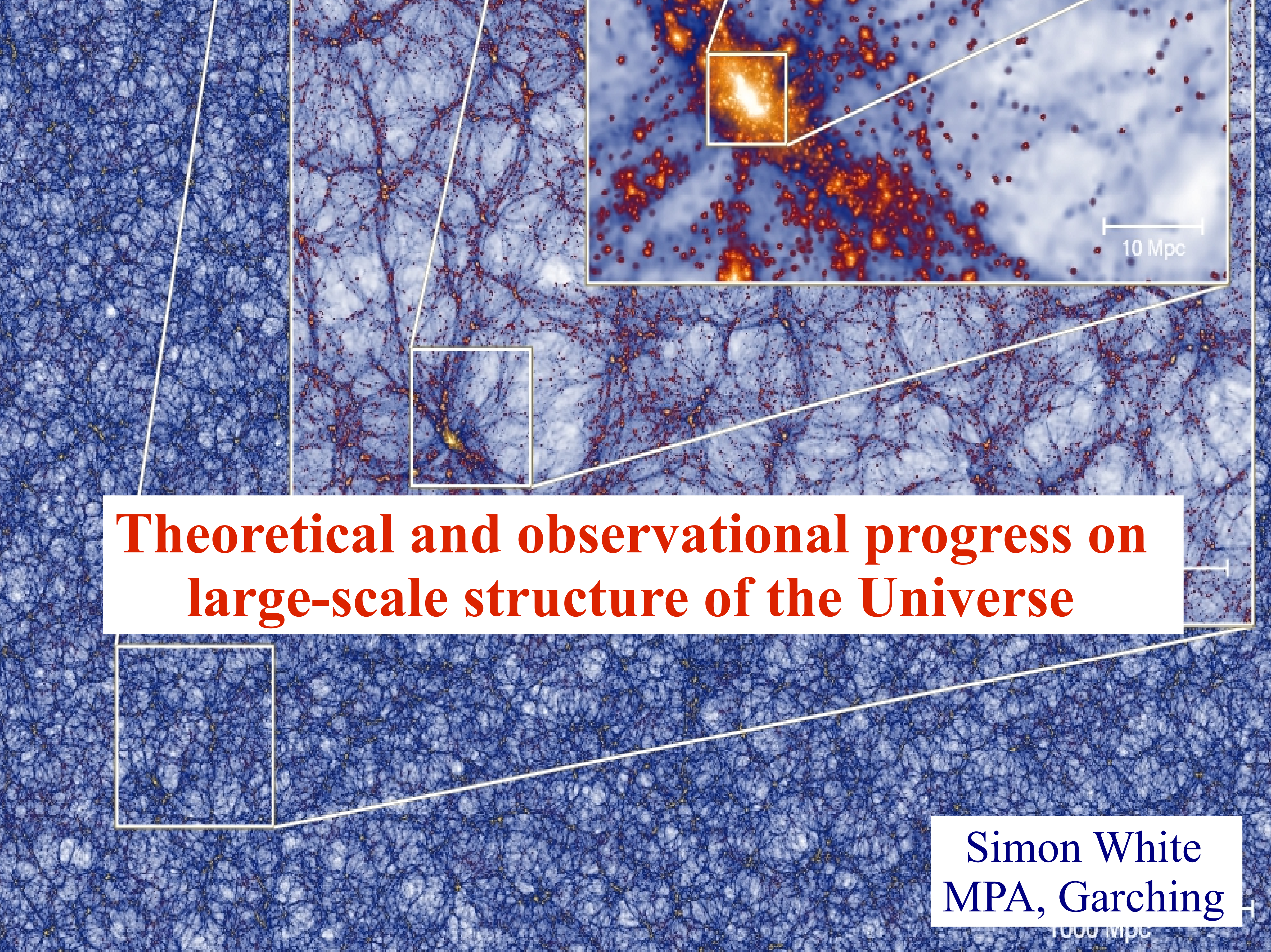
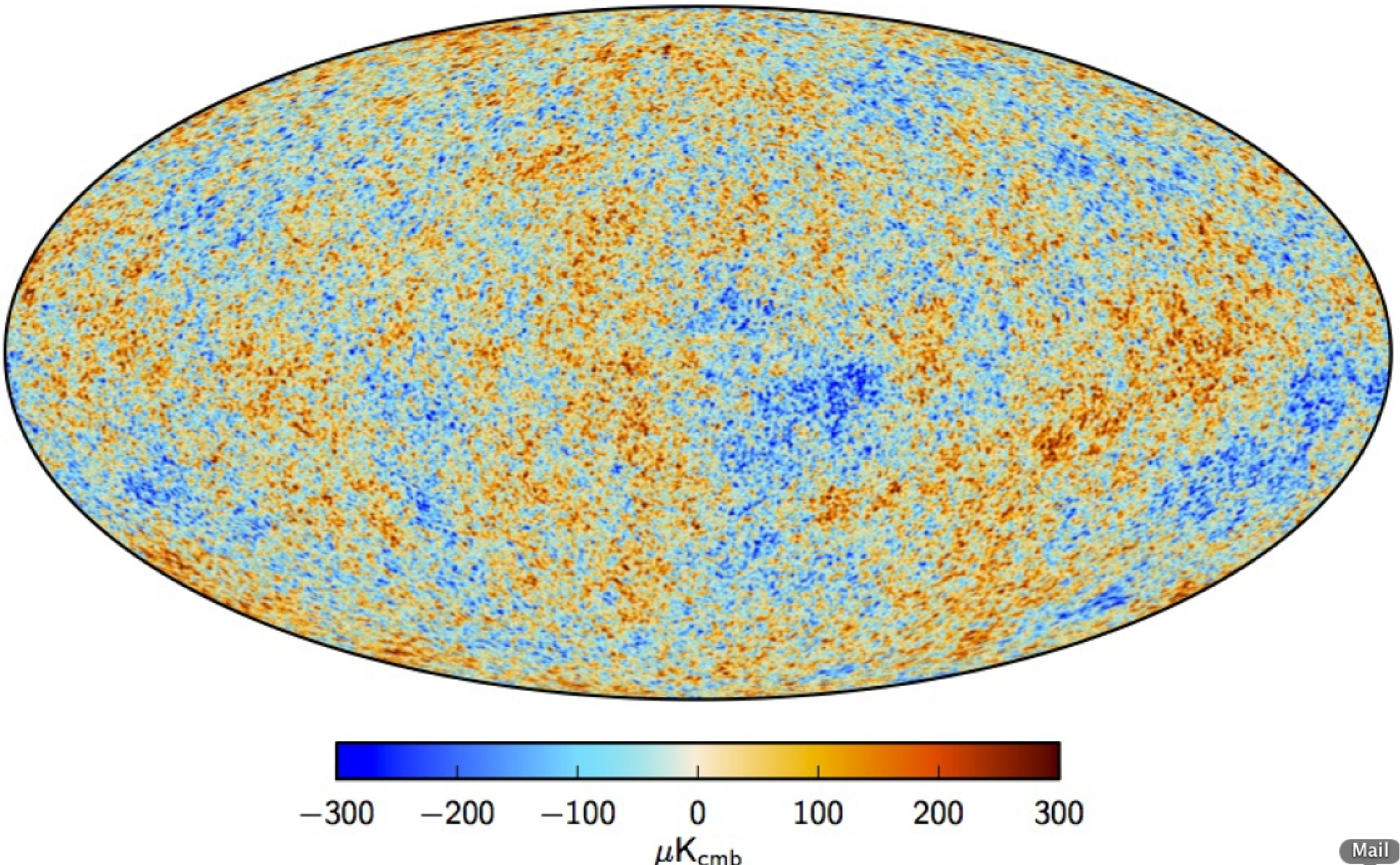


Theoretical and observational progress on large-scale structure of the Universe

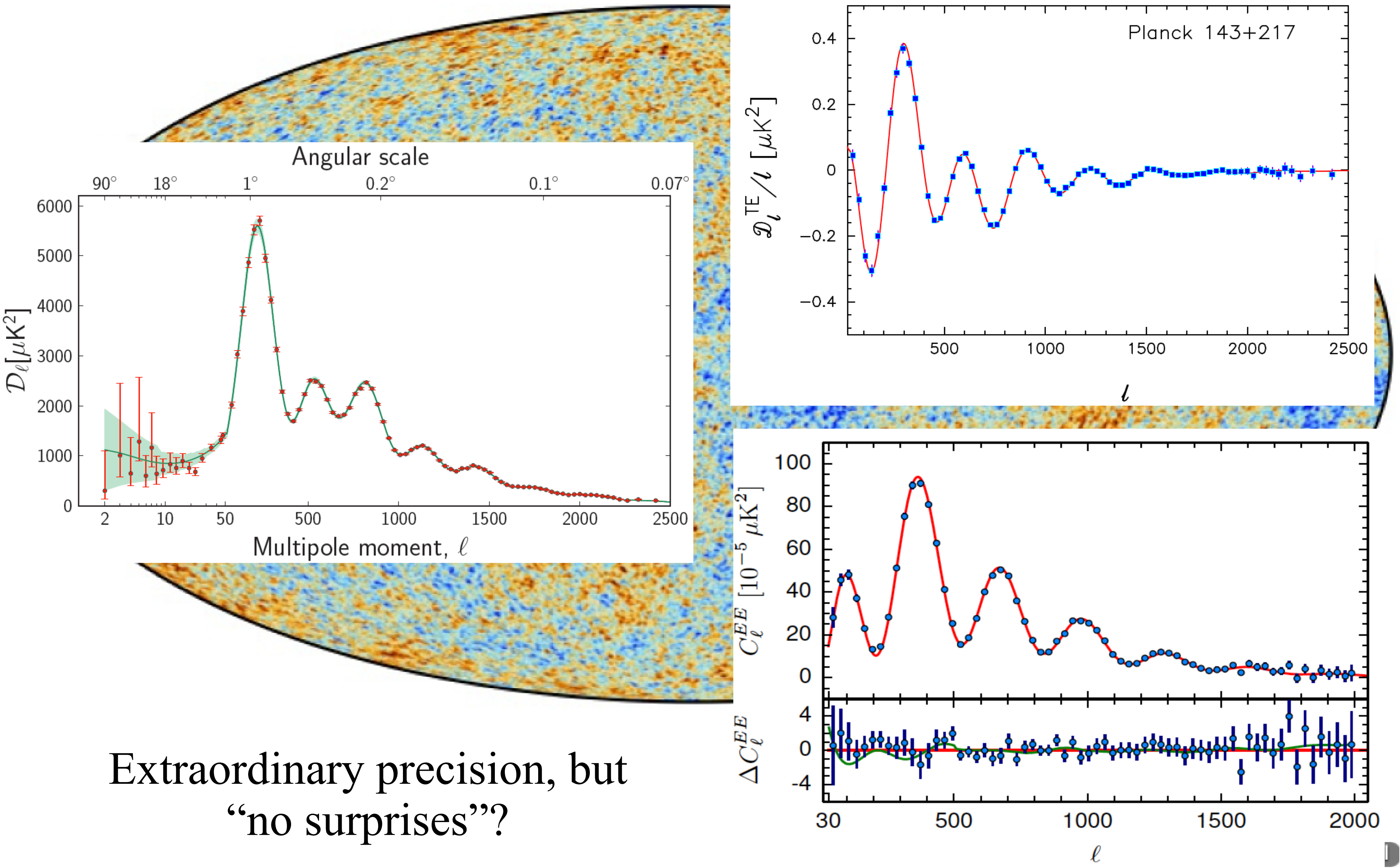
Simon White
MPA, Garching

CMB map after the full Planck mission



Mail

"Precision" cosmology



Extraordinary precision, but
"no surprises"?

Neutrino Rest Mass from Cosmology

A. S. Szalay and G. Marx
Department of Atomic Physics, Roland Eötvös University, Budapest

Received January 27, 1975

Summary. In standard cosmological models, the overall mass density of the Universe can be calculated from the observed value of the Hubble constant H_0 and the deceleration parameter q_0. Their most recent values The upper limit on the neutrino and neutretto rest mass obtained in this way is $m = 13.5$ eV. Density fluctuations in the primordial neutrino gas at the temperature $kT = mc^2$ may initiate the formation of clusters

THE COLLISIONLESS DAMPING OF DENSITY FLUCTUATIONS IN AN EXPANDING UNIVERSE

J. R. BOND
Institute of Theoretical Physics, Department of Physics, Stanford University

AND

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Astronomy Department, University of California, Berkeley; and Astronomy and Astrophysics Center, The University of Chicago

Received 1982 July 26; accepted 1983 February 10

ABSTRACT

The best candidate for the dark matter is a massive collisionless non-baryonic relic of the early universe.

Neutrino Rest Mass from Cosmology

A. S. Szalay and
Department of Atom

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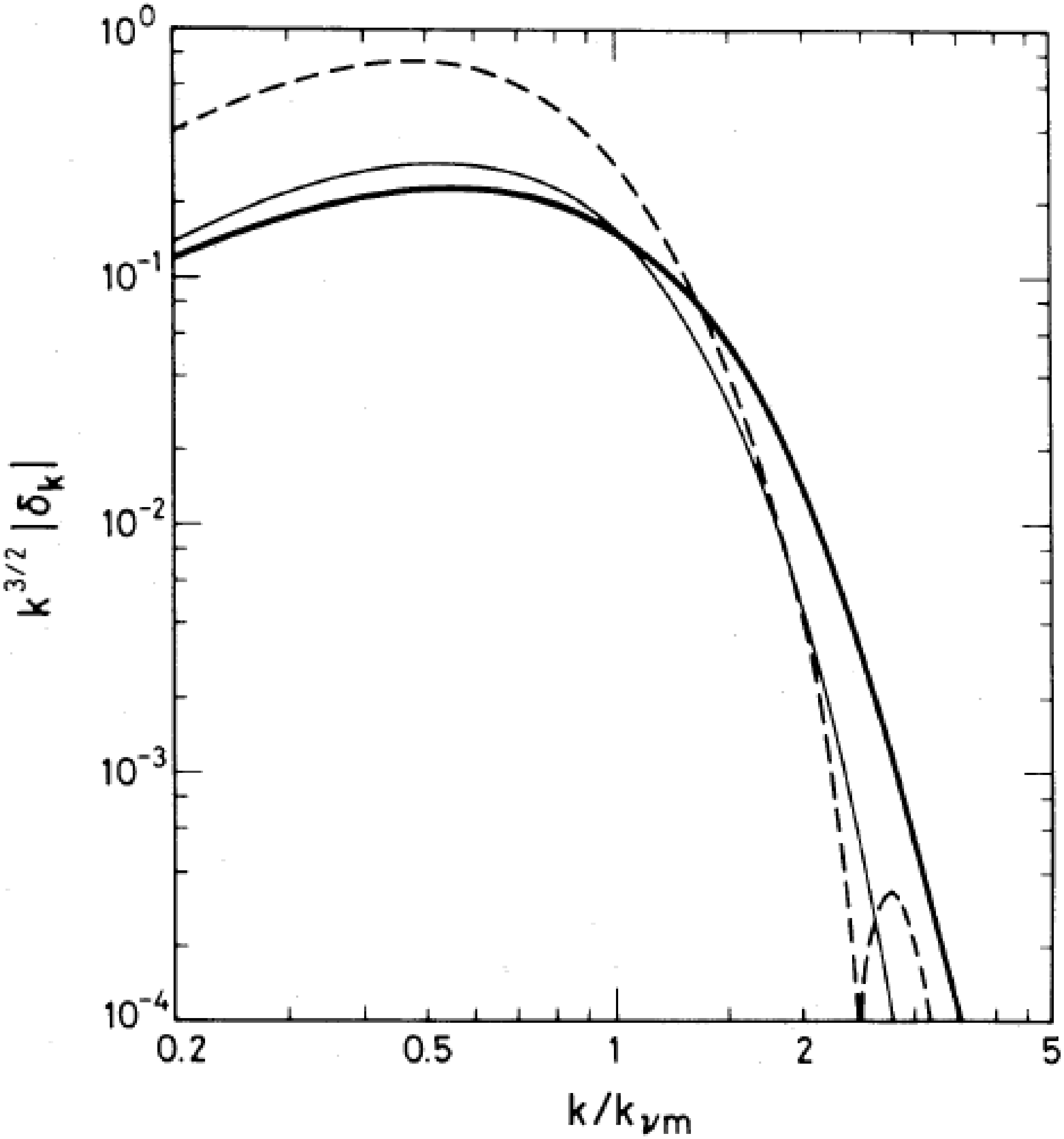

Summary. In sta … o and neutretto rest mass
mass density of t … 5 eV. Density fluctuations
observed value … gas at the temperature
deceleration pa … ormation of clusters

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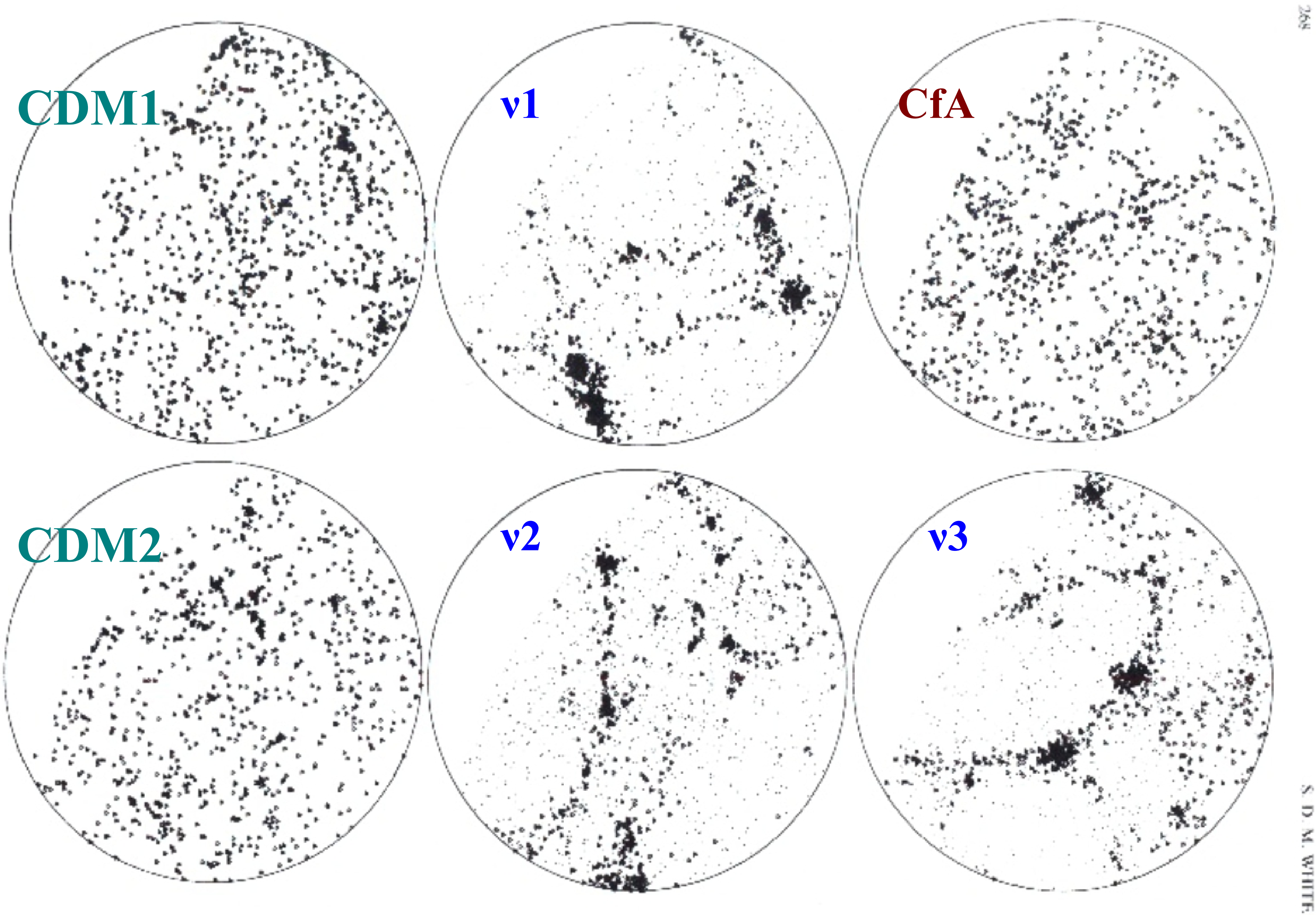
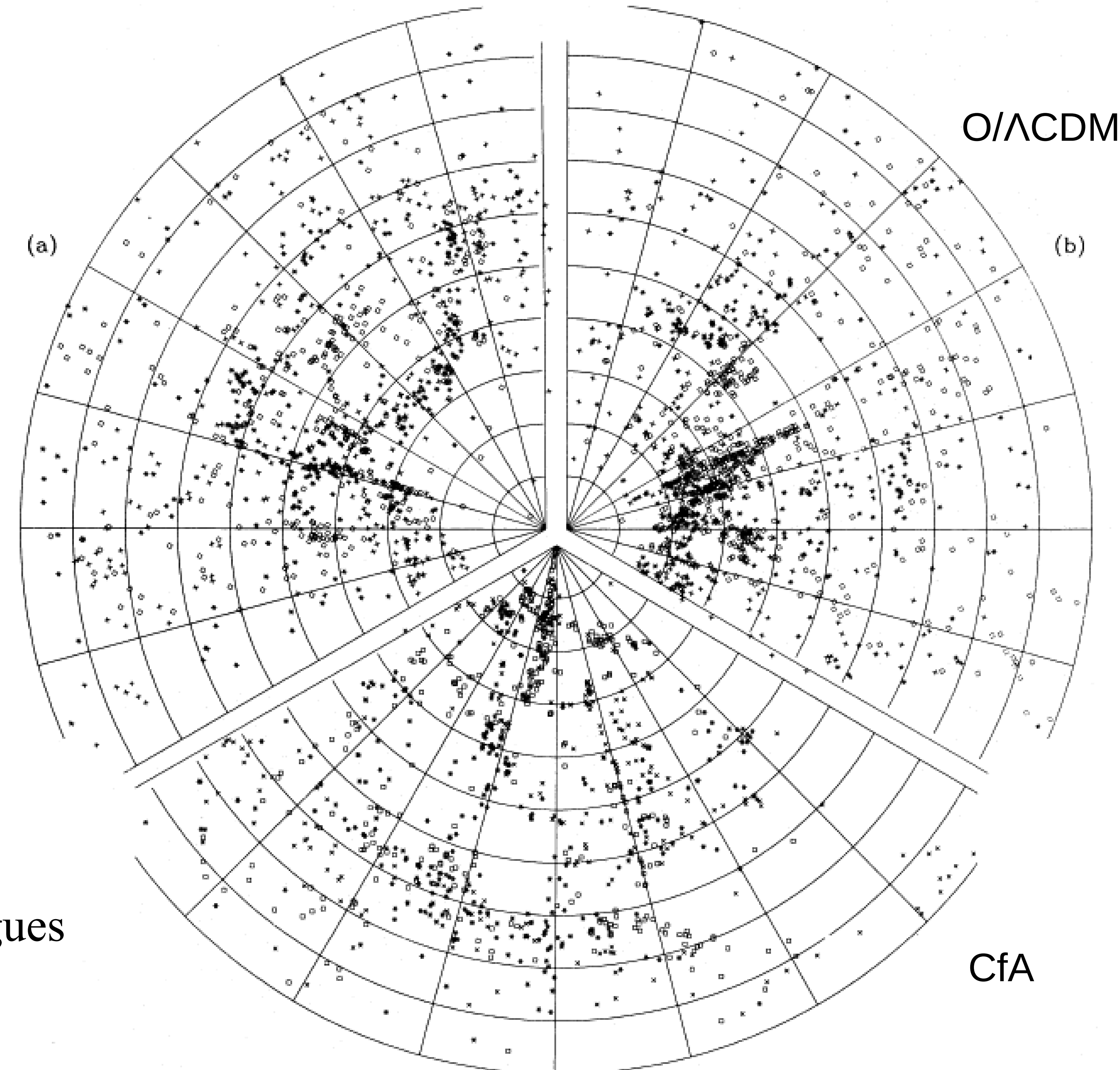
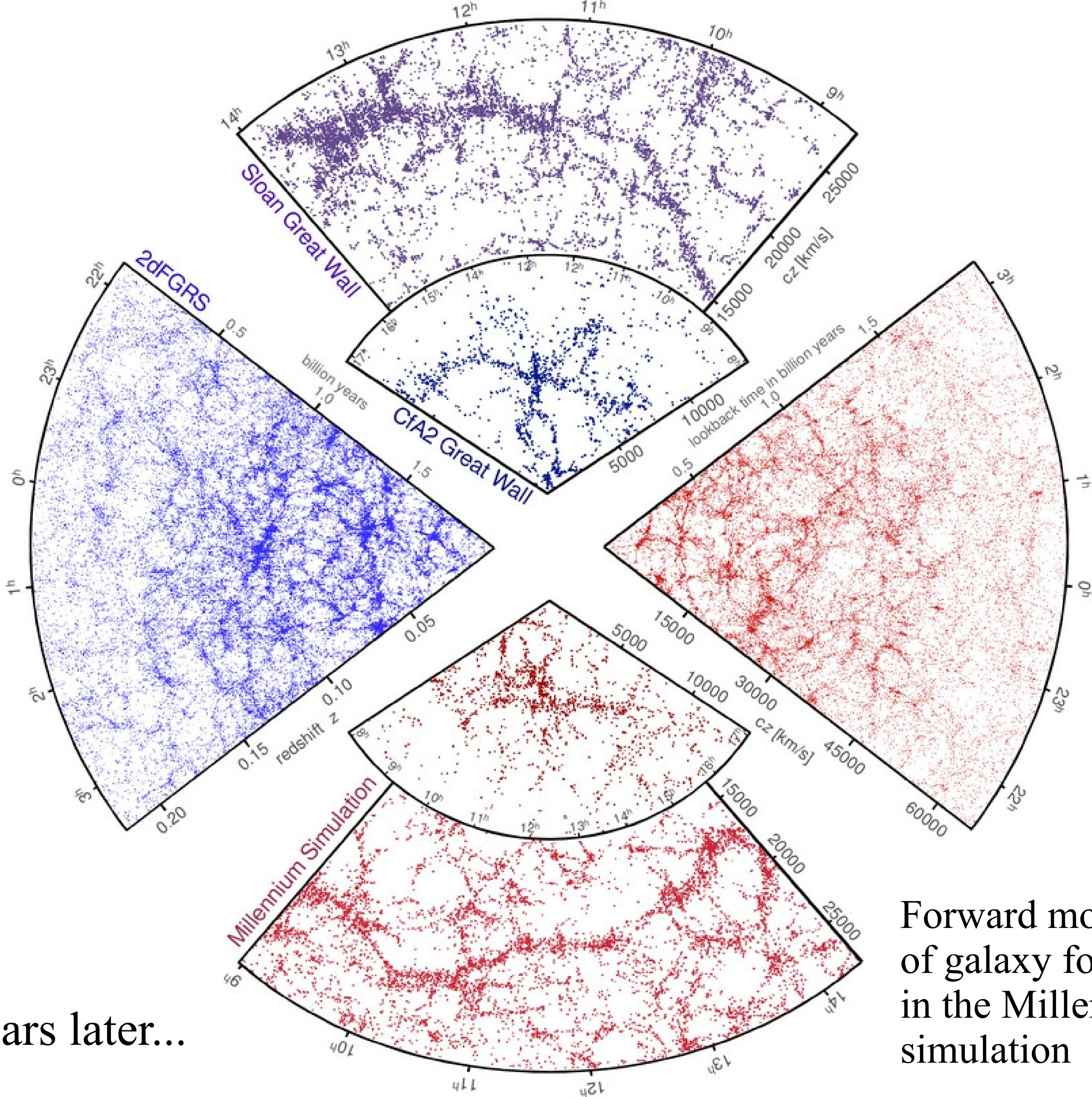
The best ca … onic relic of the early universe.

Excluding massive neutrinos as the Dark Matter





mock catalogues
in 1985



...20 years later...

Forward modelling of galaxy formation in the Millennium simulation

Whither LSS in the precision era? (or how to beat the CMB and defeat the 6/7/8-parameter tyranny?)

– Concentrate on late-time effects (e.g. dark energy, modified gravity, neutrino modulation of growth)

– Identify intrinsically nonlinear effects (interacting DM)

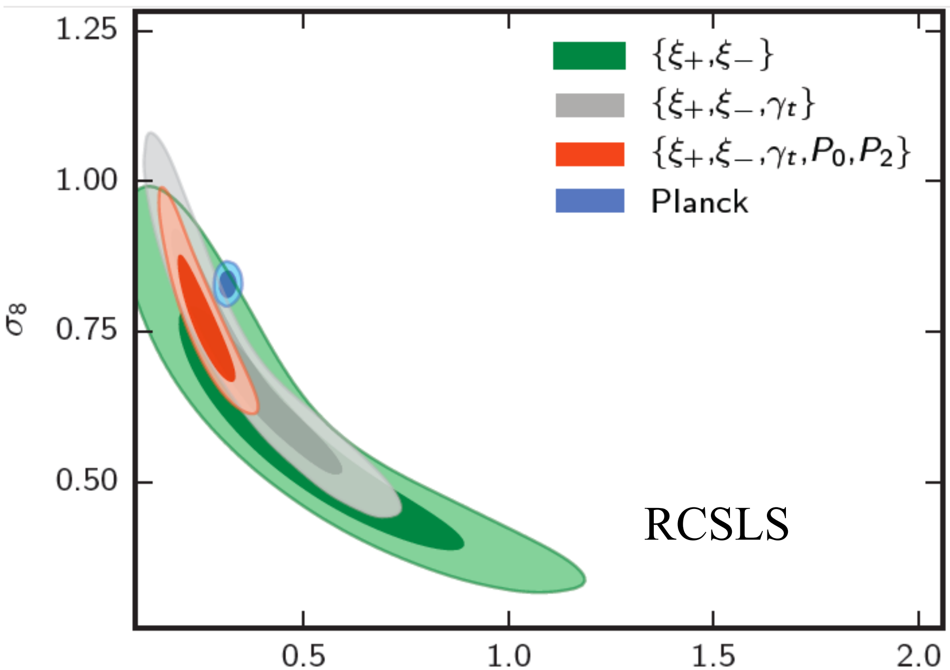
– Find new tracers (lensing, Ly-alpha forest, 21cm at high z) and new ways to analyse well studied tracers (peaks/troughs; clusters, filaments and voids)

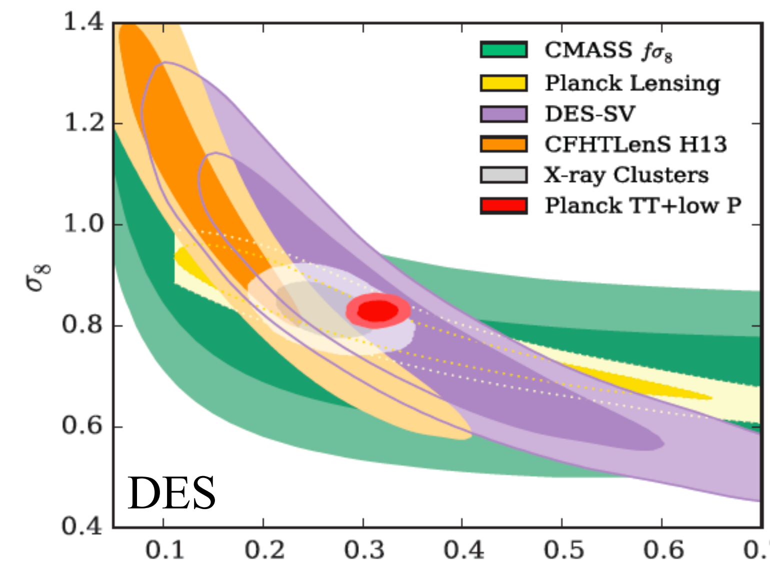
– Move away from fundamentalist problems (back towards astrophysics of galaxies/clusters/IGM...)

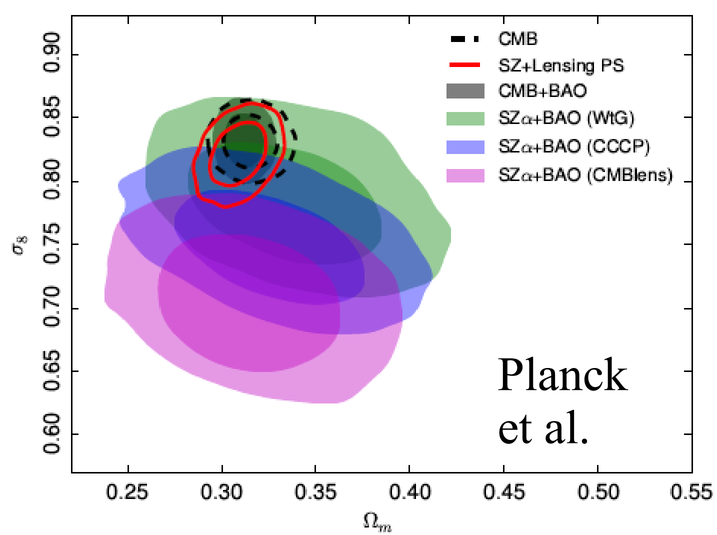
– Concentrate on things that seem NOT to work

Data1 + Data2

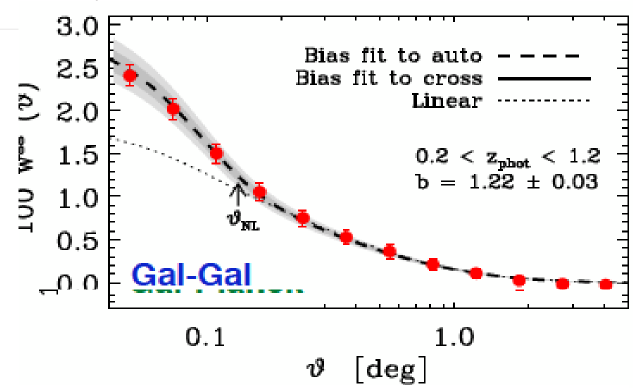
Improved BAO/RSD data are mostly consistent with Planck “standard” model and tighten constraints, but tensions with lensing.

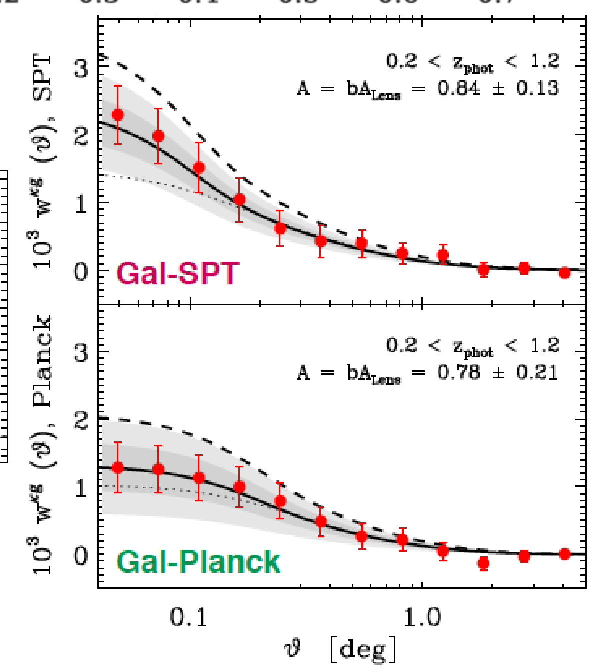






Planck et al.

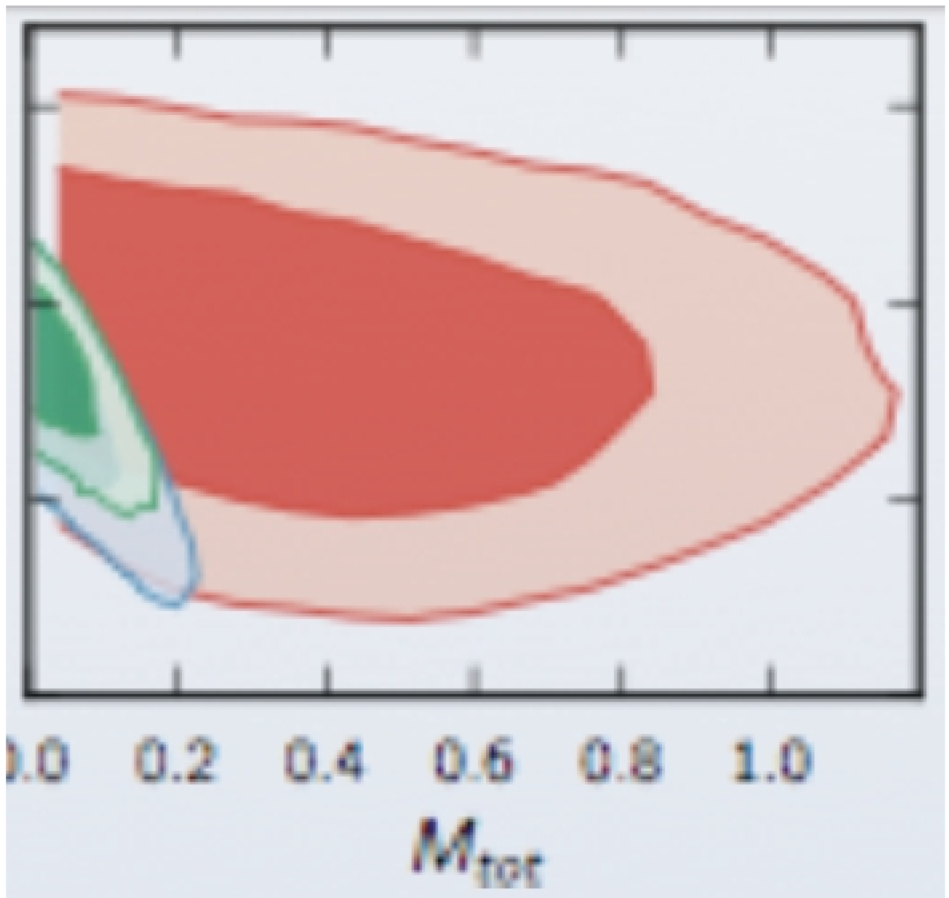




DES

Data1 + Data2

Ly alpha forest amplitude tightens constraint on sum of neutrino masses beyond CMB + BAO alone. Only a factor of two to the particle physics lower limit!



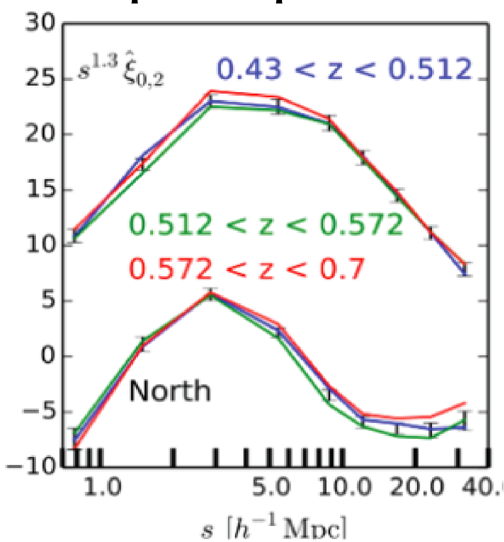
Σ m < 0.14 eV (at 95% confidence)

Data1 + Data2

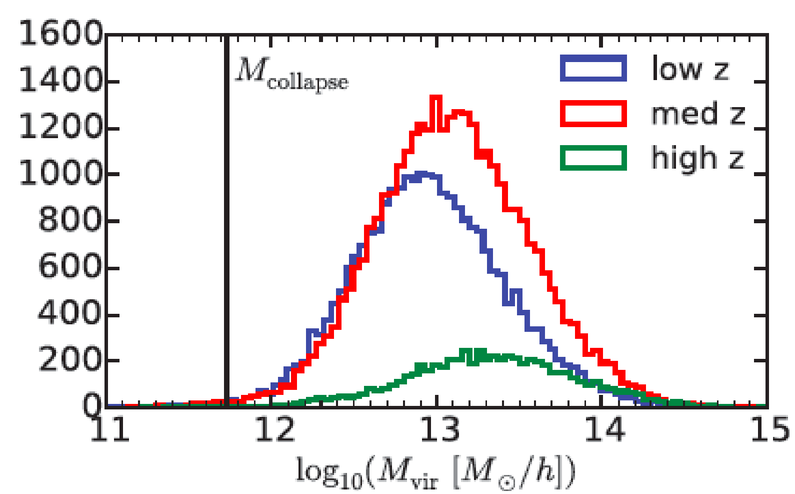
As data get more precise (SDSS-main, BOSS, VIPERS, DES....) matching abundances-colours-clustering-lensing distributions requires ever more detailed/complex modelling:

- – Assembly bias
- – Conformity
- – Evolution
- – Baryon modification of overall mass distribution

How to avoid/manage proliferation of parameters?
How to impose prior of consistent evolution in LCDM-like universe?



BOSS
-CMASS



“Theory”

What is the right approach to calculate structure to smaller scales?

Do much smaller scales contain “useful” information (e.g. DM nature, baryon effects)?

The halo model is the workhorse for modelling nonlinear effects.

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How do we find a better way to calculate/model covariance matrices?

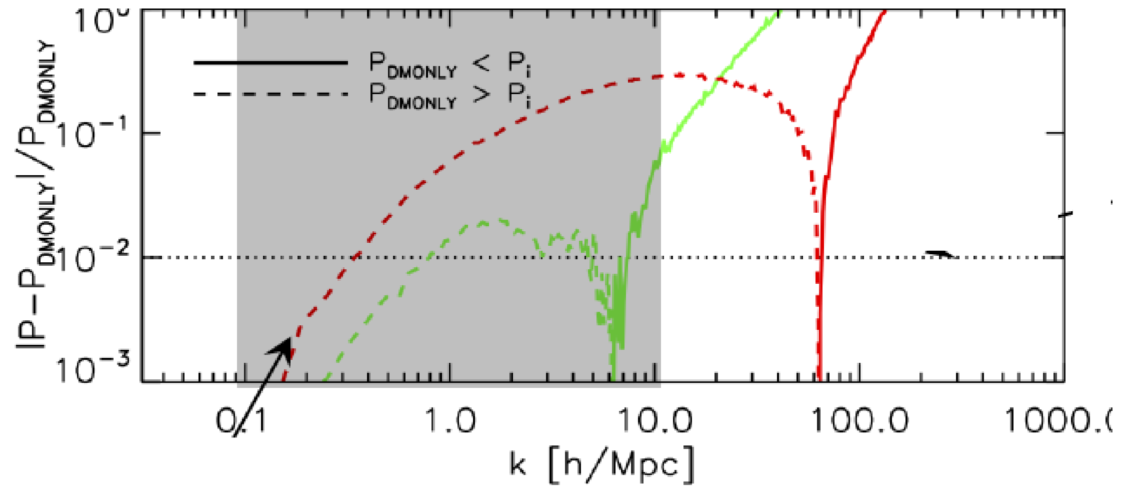
Where do we look for clustering fossils? Do we need 21cm cosmology to get enough modes?

Can we get accurate enough measures to see relativistic effects?

"Simulation"

Gas dynamics and feedback affect LSS statistics

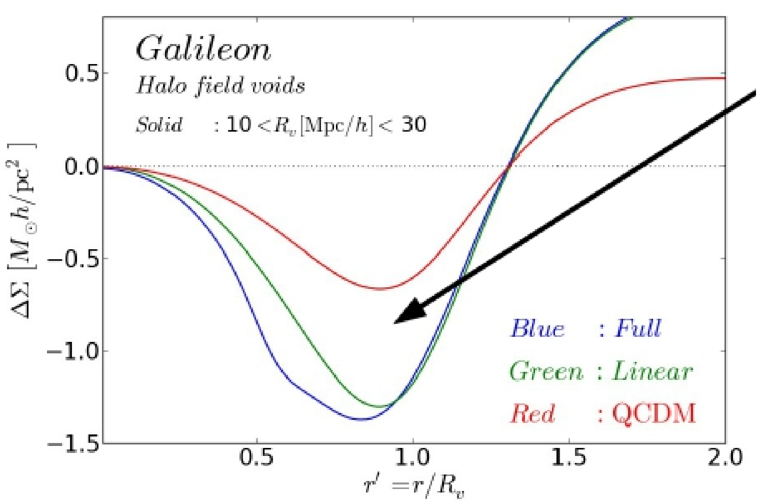
Simulation techniques for large surveys need further development



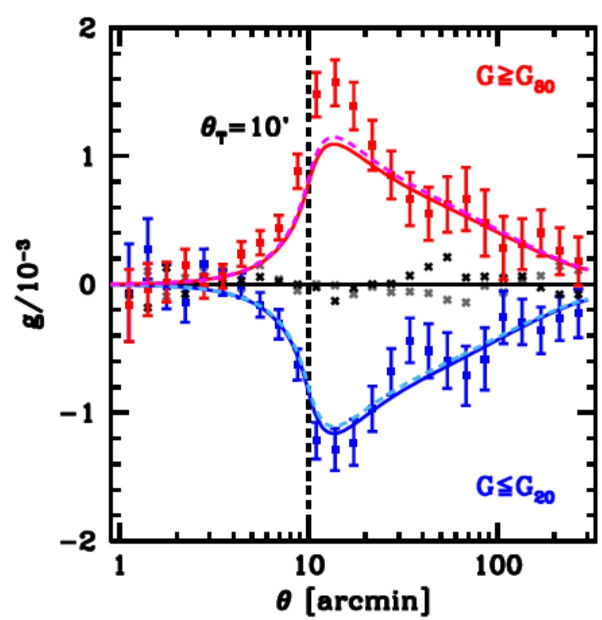
"prefer physical over nuisance parameters – validation over marginalisation"

Codes for modelling a variety of modified gravity theories have now been written and tested against each other.

The dynamics of voids is hot – modified gravity?



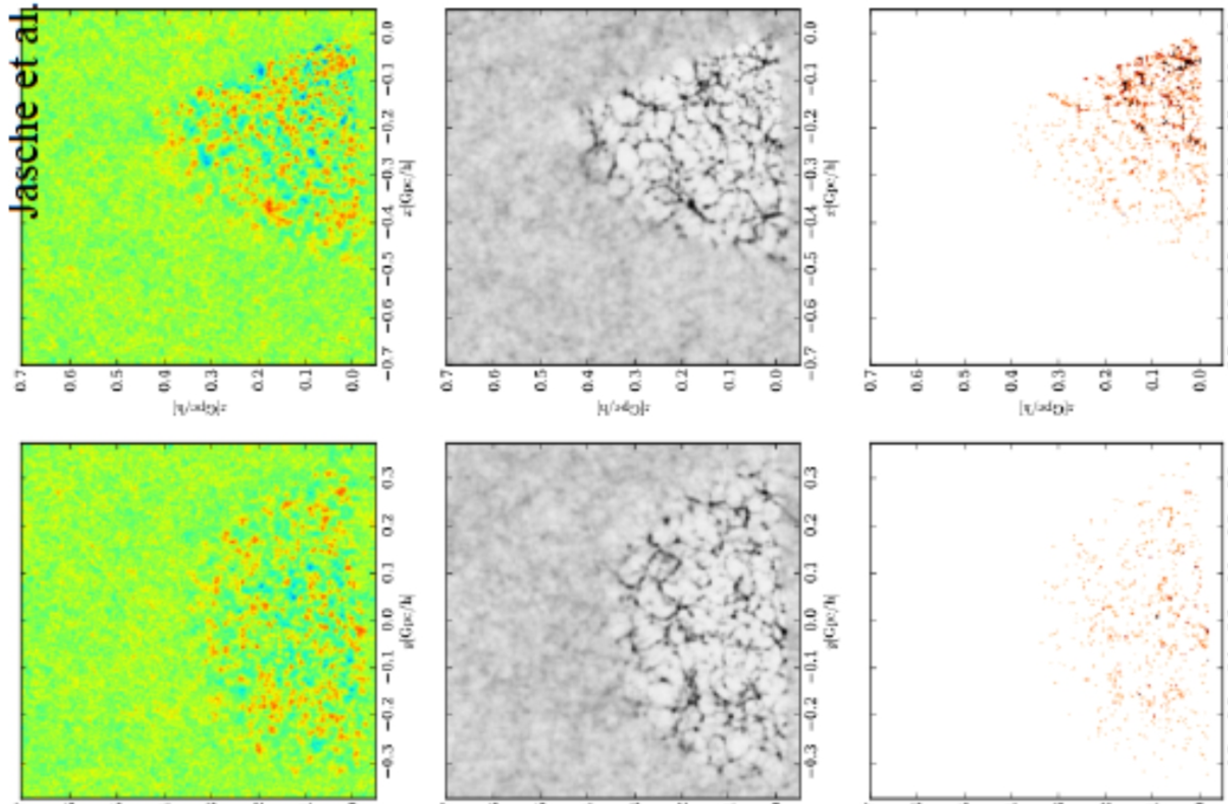
Asymmetry not seen?



“Simulation”

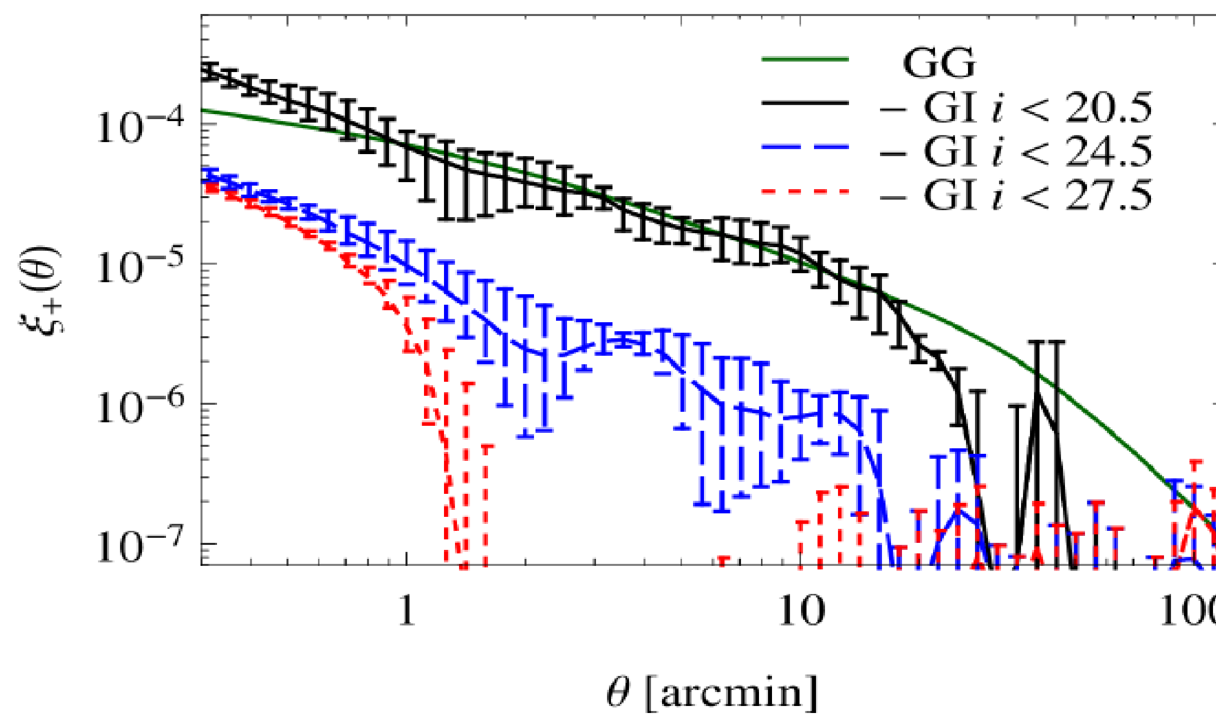
Reconstructing the structure and history of real LSS

→ new tests (e.g. kSZ)



$z = 0.6$ x $z = 1.0$

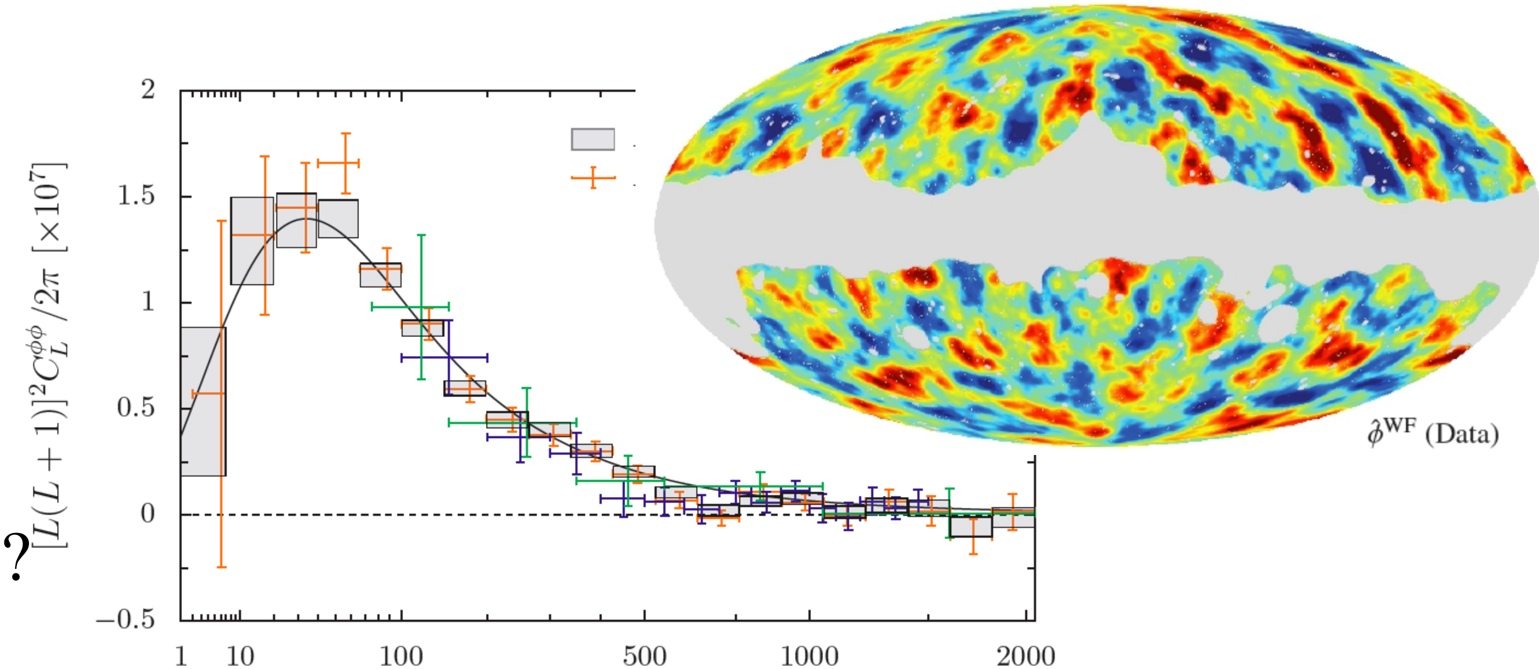
Intrinsic alignment is ~10% contaminant to cosmic shear



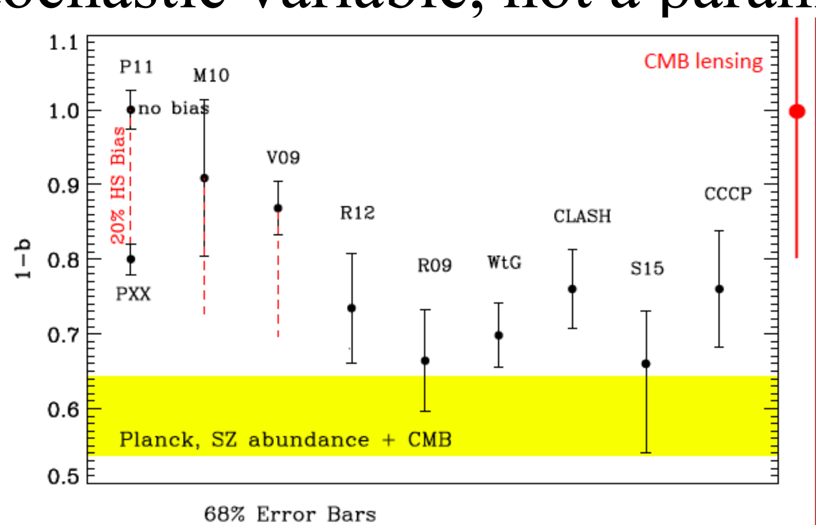
Lens/cluster;

CMB lensing –
new kid on block

Lensing still not
"precision-ready"?



Cluster catalogues can now be large and systematic (e.g. redMapper)
Issues: mass calibration
sample selection biases
cluster structure (CR; turbulence; Z, ρ, p fluct's, irregularity)
(1 – b) is a stochastic variable, not a parameter



Precision measurements require precision analysis

Systematics identification/mitigation is critical

Pay particular attention to anomalies

Use independent routes/new angles to assess their significance

Prefer physical to purely statistical models

Don't dismiss crazy theories!

Follow your own hobbies, while supporting the larger efforts!

Thanks for a great conference Eiichiro!

Now where's the beer?