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

Simon White
MPA, Garching
CMB map after the full Planck mission
“Precision” cosmology

Extraordinary precision, but “no surprises”?
Neutrino Rest Mass from Cosmology

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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 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

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ABSTRACT

The best candidate for the dark matter is a massive collisionless non-baryonic relic of the early universe.
Neutrino Rest Mass from Cosmology

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Department of Astronomy
Received January 27

Summary. In standard cosmological models, the mass density of neutrinos is observed to be less than the expected value, leading to a deceleration parameter that is lower than expected. This lower mass density could be due to a neutrino mass of 0.01 eV. Density fluctuations in the early universe are related to the formation of clusters of galaxies.

The best candidate for the dark matter component of the universe is the relic of the early universe.

TH

Astronomy

Theoretical Physics Center,
Excluding massive neutrinos as the Dark Matter
mock catalogues in 1985
Forward modelling of galaxy formation in the Millennium simulation...

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

\[ \Sigma m < 0.14 \text{ eV (at 95\% confidence)} \]
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?
“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.
“Theory”

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The halo model is the workhorse – do we need to move up to a more modern vehicle?
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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?
Reconstructing the structure and history of real LSS with new tests (e.g. kSZ).

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; $Z, \rho, p$ 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?