Constraining the dark side with future large-scale structure surveys

DSU Conference

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Kigali

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In The Beginning...

Image: unsplash.com

The First Science

Image:Google

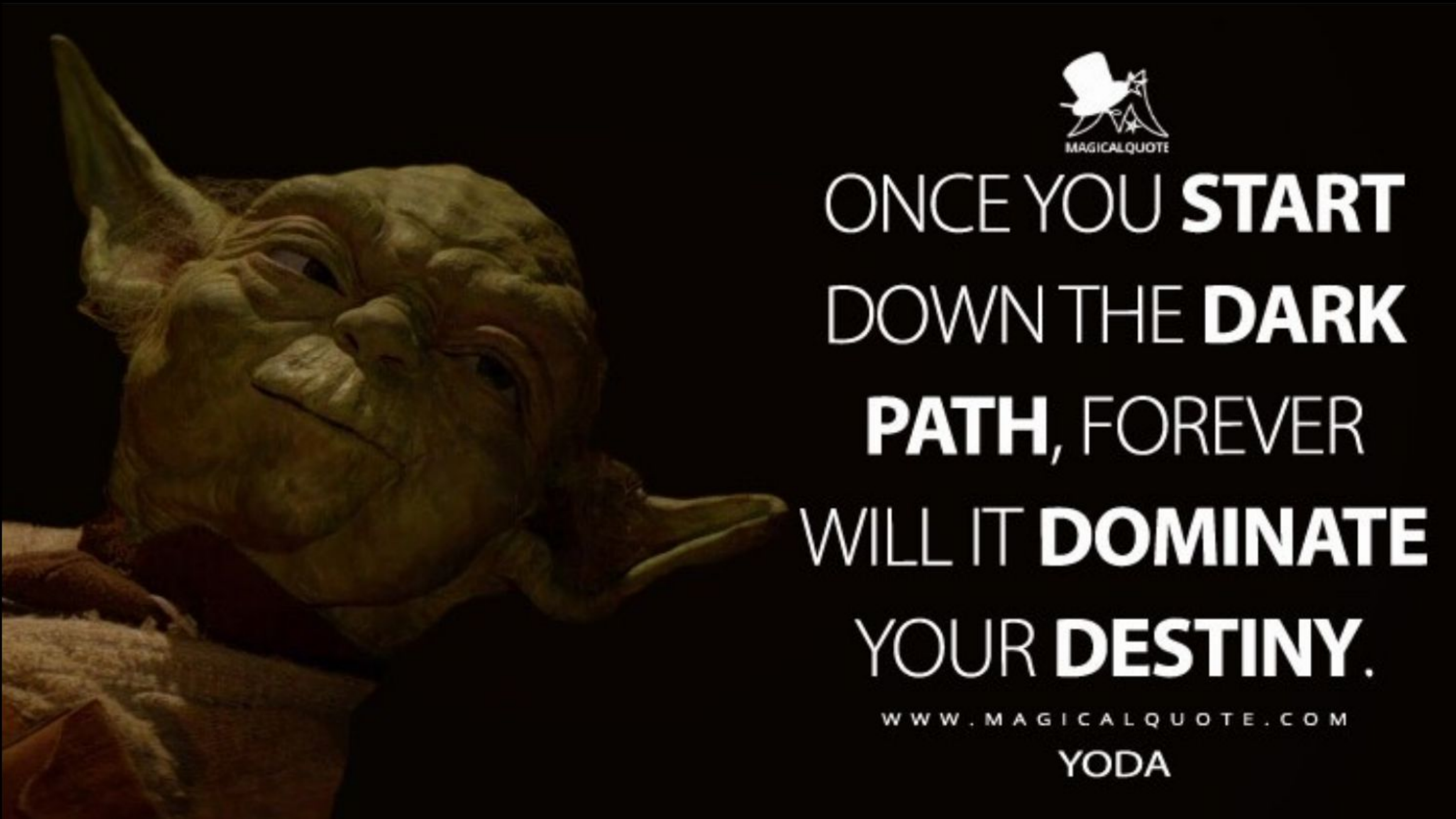
The First Science

Image:Google

Nabta Playa is the oldest 'Calendar Circle' in the world. It was found in the Nubian Desert dated to be built about 7500 BC.

- We now know that we don't know!
- About 95% of the contents of our universe remains a dark secret.

"We do not know the power of the dark side!!!"


MAGICALQUOTE
ONCE YOU START DOWN THE DARK PATH, FOREVER WILL IT DOMINATE YOUR DESTINY.
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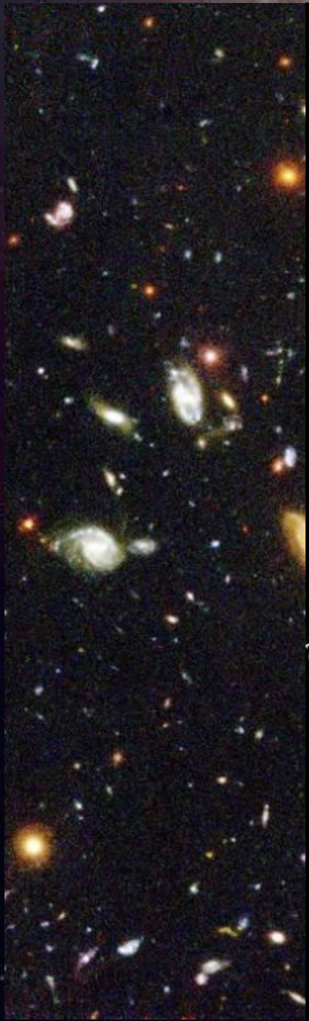
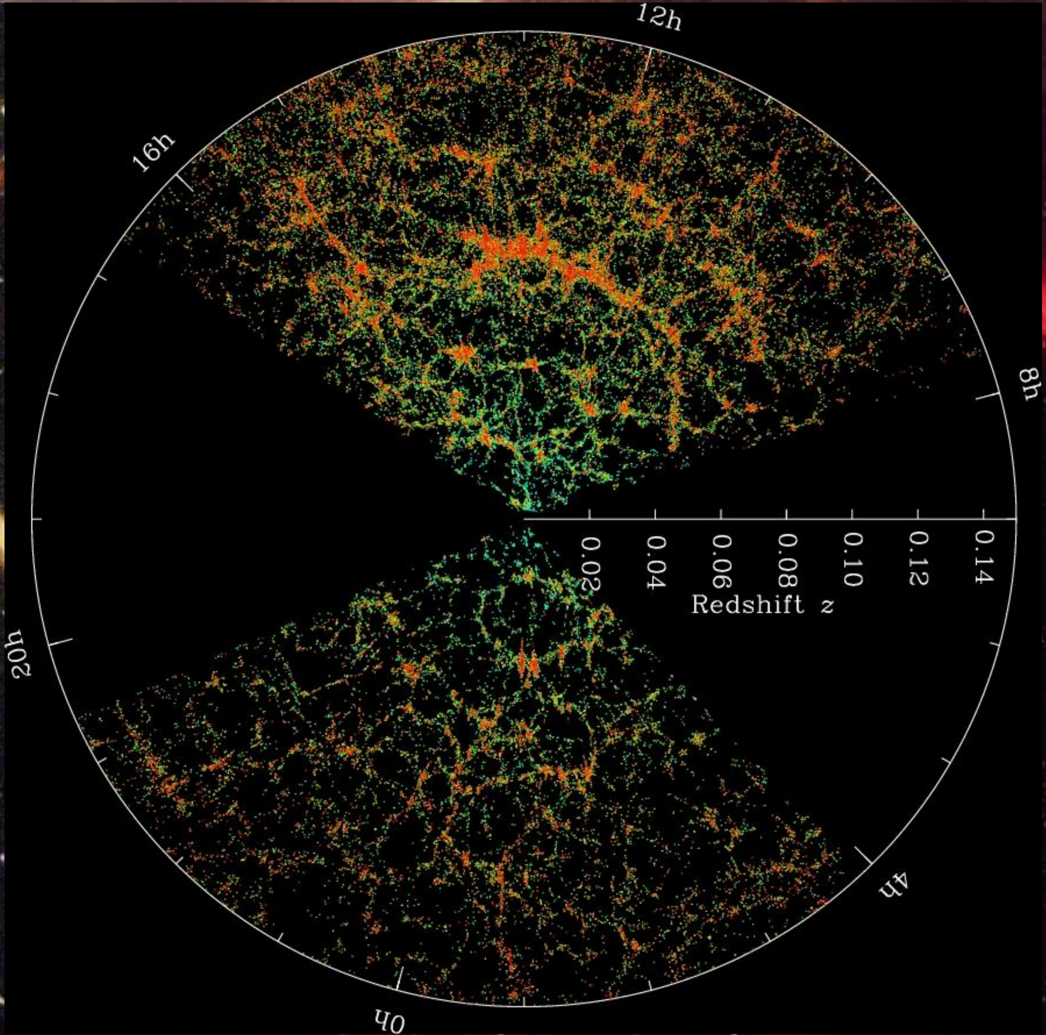
INTRODUCTION

- Observational probes of the large scale structure distribution of our universe has already provided a wealth of information on the cosmological model.

- Upcoming experiments with significantly better precision is an exciting prospect for constraining the theoretical modeling of our universe.

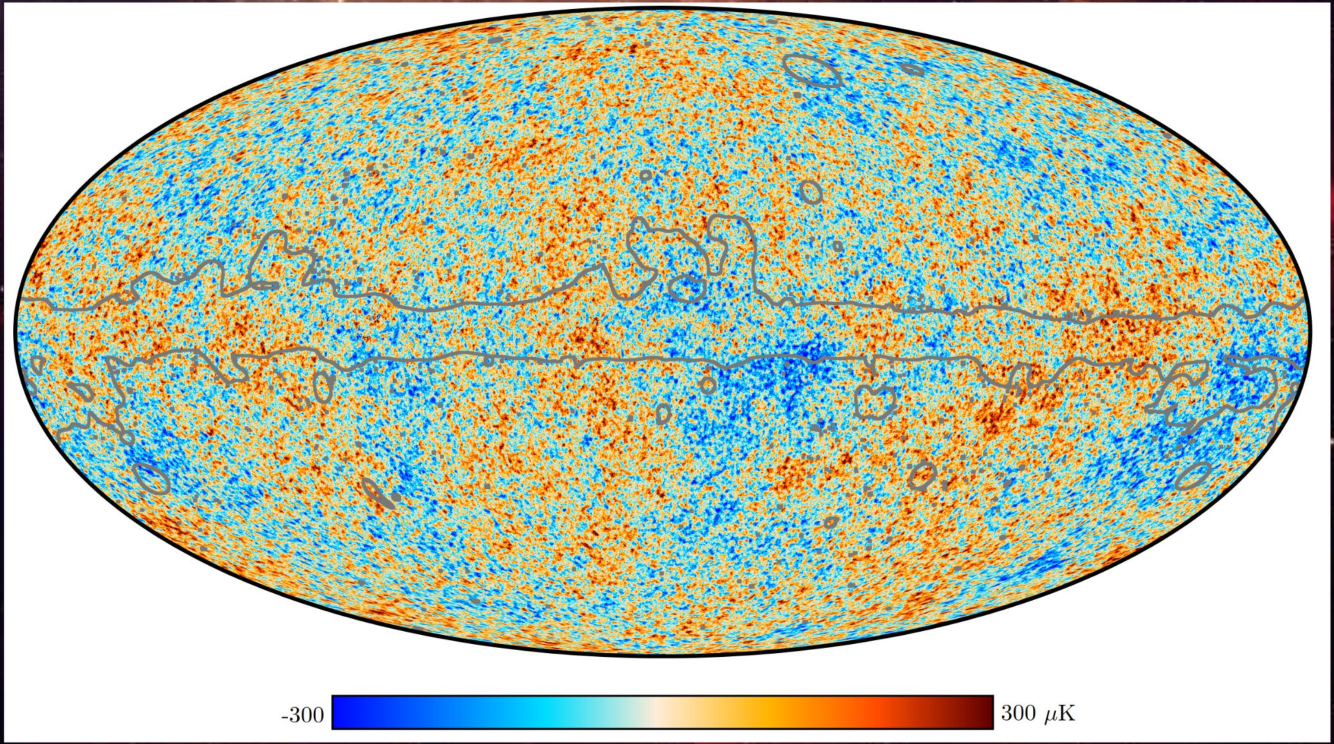
- Here we briefly examine the methodology of constraining the theoretical parameter set using observational measurements.




12h
16h
8h
20h
4h
0h
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Redshift z

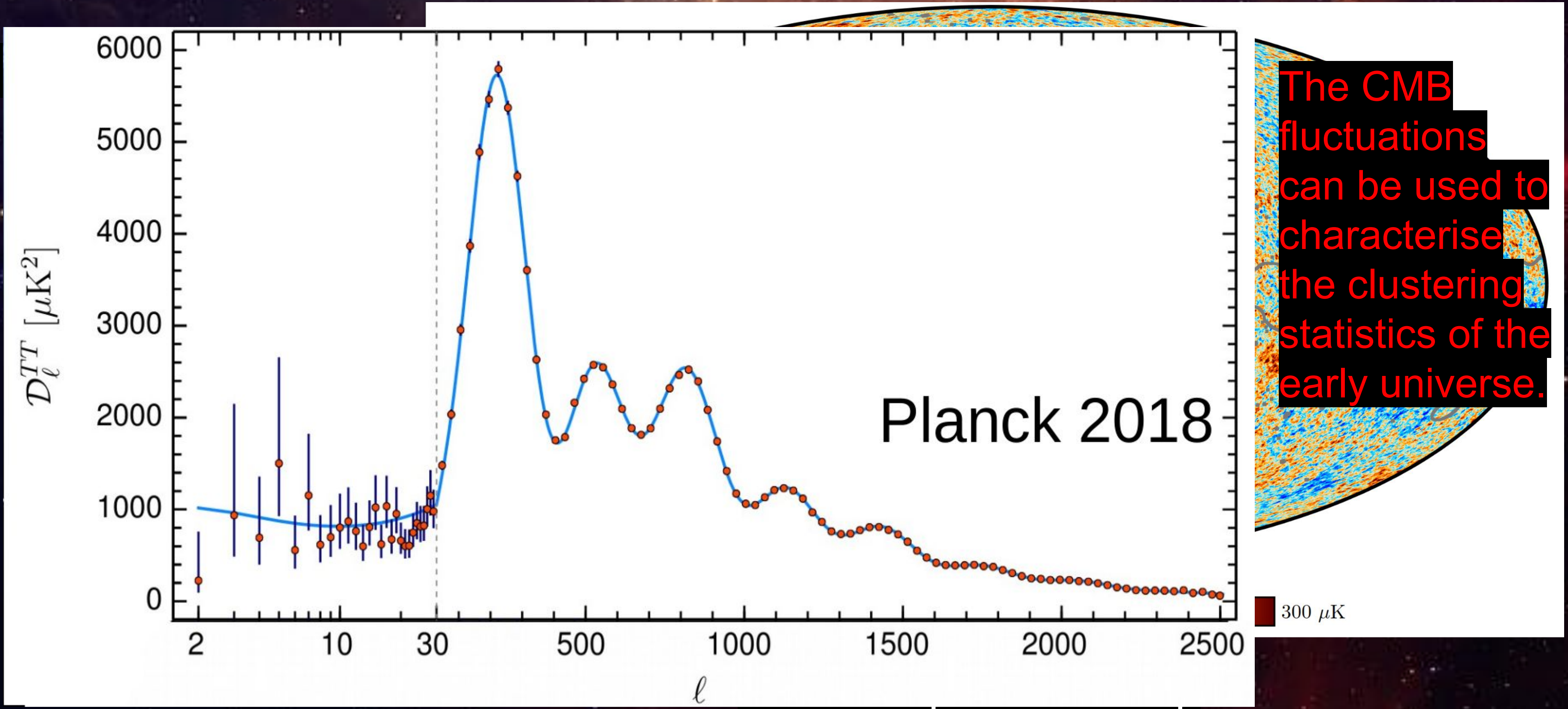
THE CMB MAP

- CMB anisotropies reveal thermal fluctuations in the early universe.



CMB temperature map

THE CMB MAP

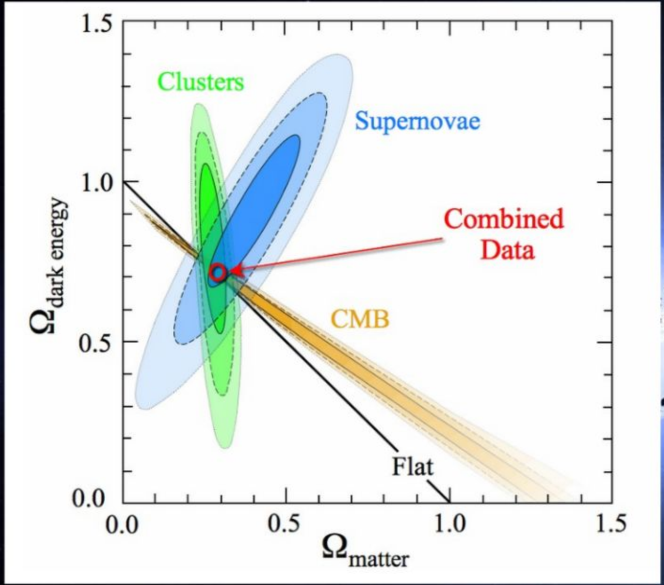


The CMB fluctuations can be used to characterise the clustering statistics of the early universe.

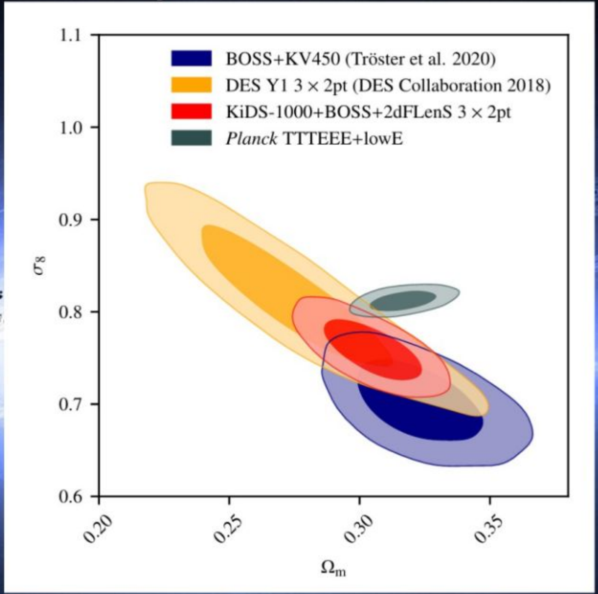
CMB power spectrum

Joint Constraints

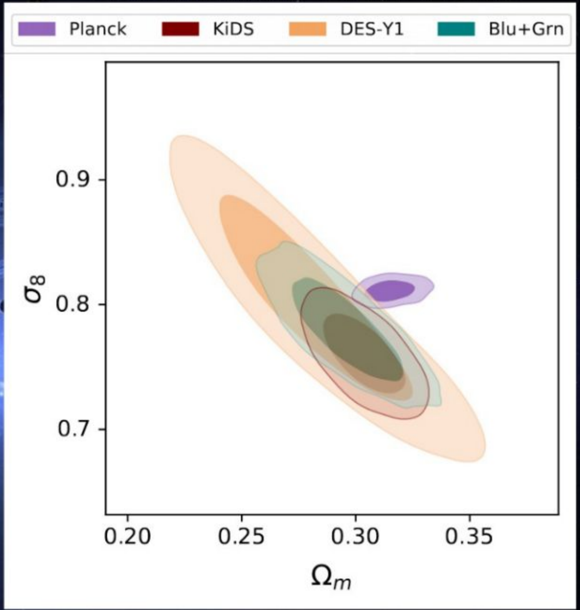
Einasto et al 2009



Heymans et al. 2020



Krowlewski et al. 2021



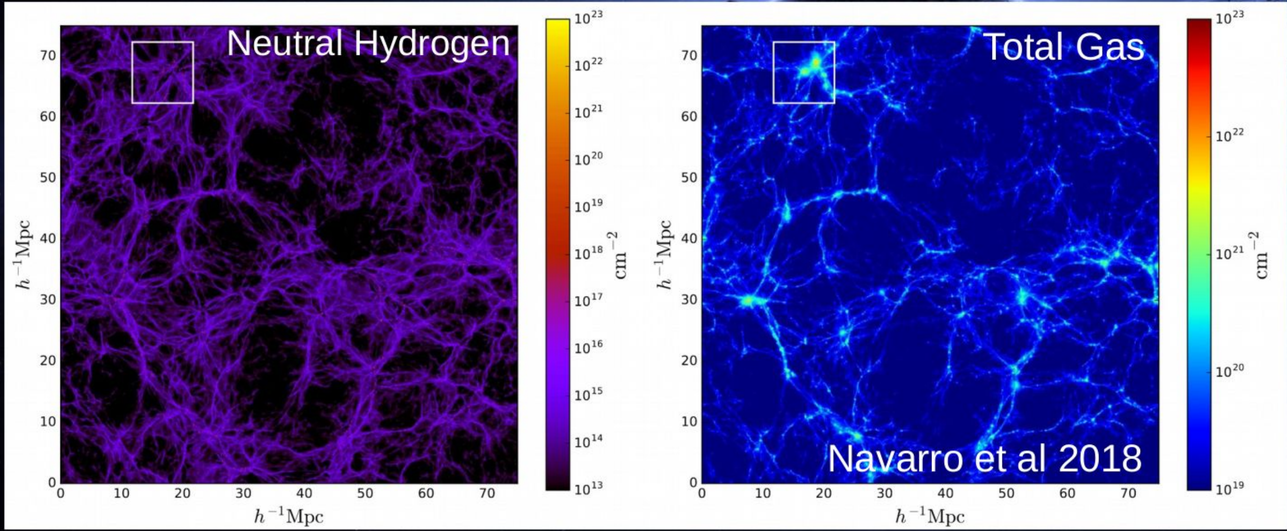
Combined survey constraints on the cosmological density parameters.

Combined galaxy and Planck constraints on the matter density and σ_8.

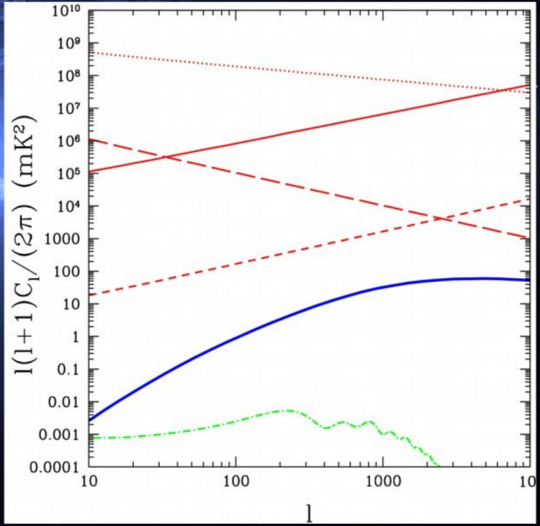
Image: Pavbca.com

HI Intensity Mapping

- The 21cm line emission of hydrogen can be used to map the large scale distribution of the universe.
- One of the main challenges facing HI experiments is the foreground contamination.



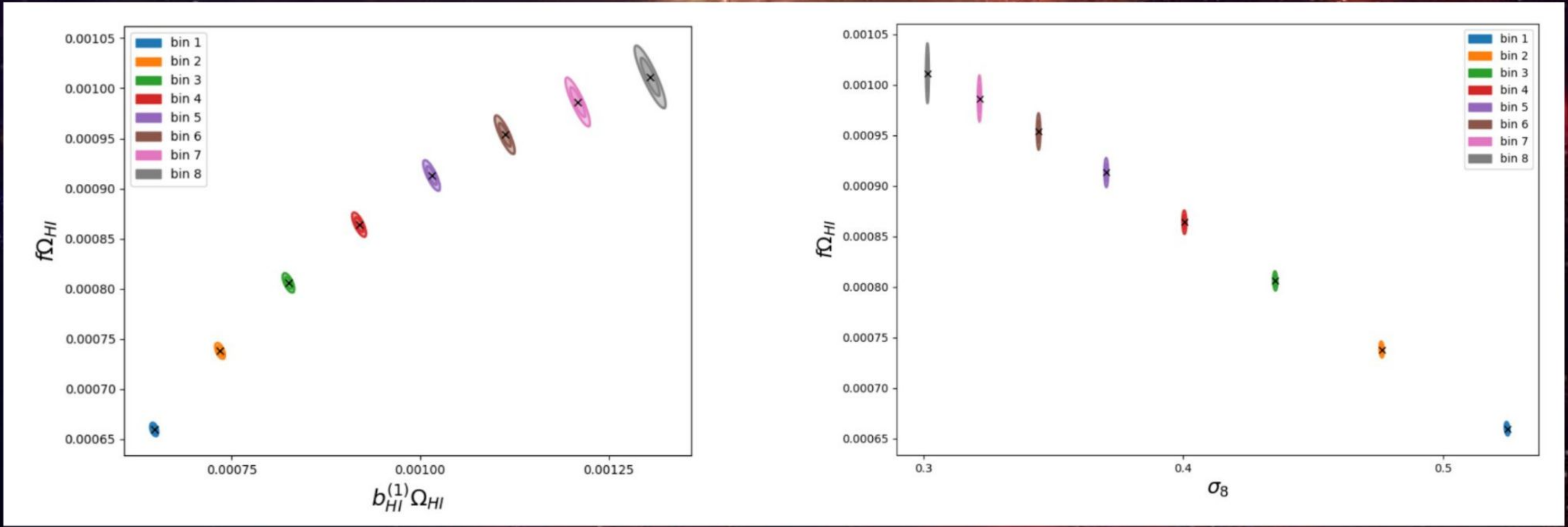
Large scale structure simulation of the HI distribution



Foreground to signal comparison
Santos et al. 2015

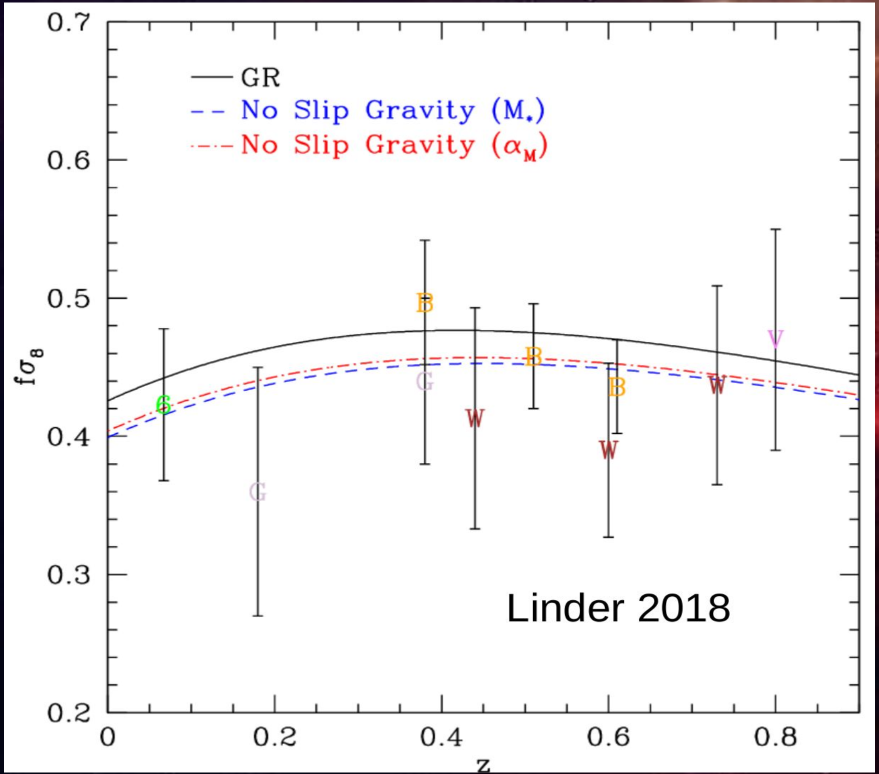
Image: Pavbca.com

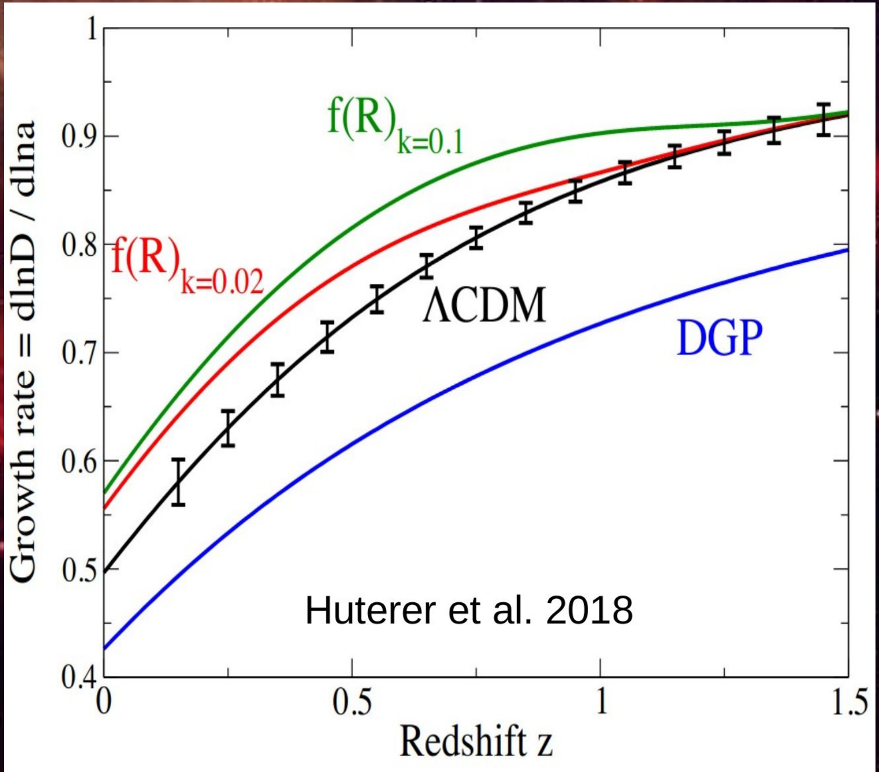
Parameter Constraints



Constraints on redshift evolution functions

Modified Gravity





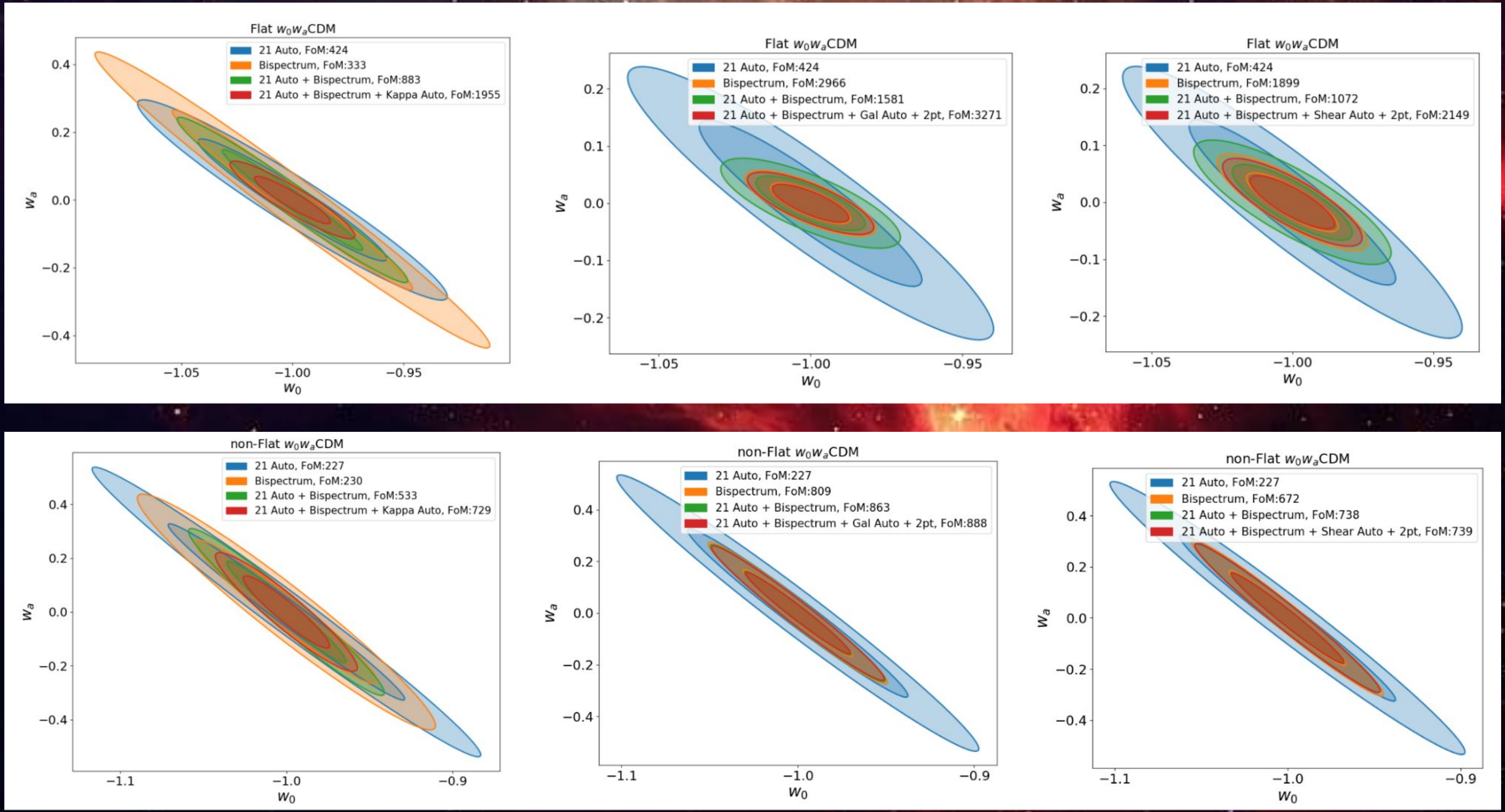
Constraining gravity models with structure growth.

Parameter Constraints

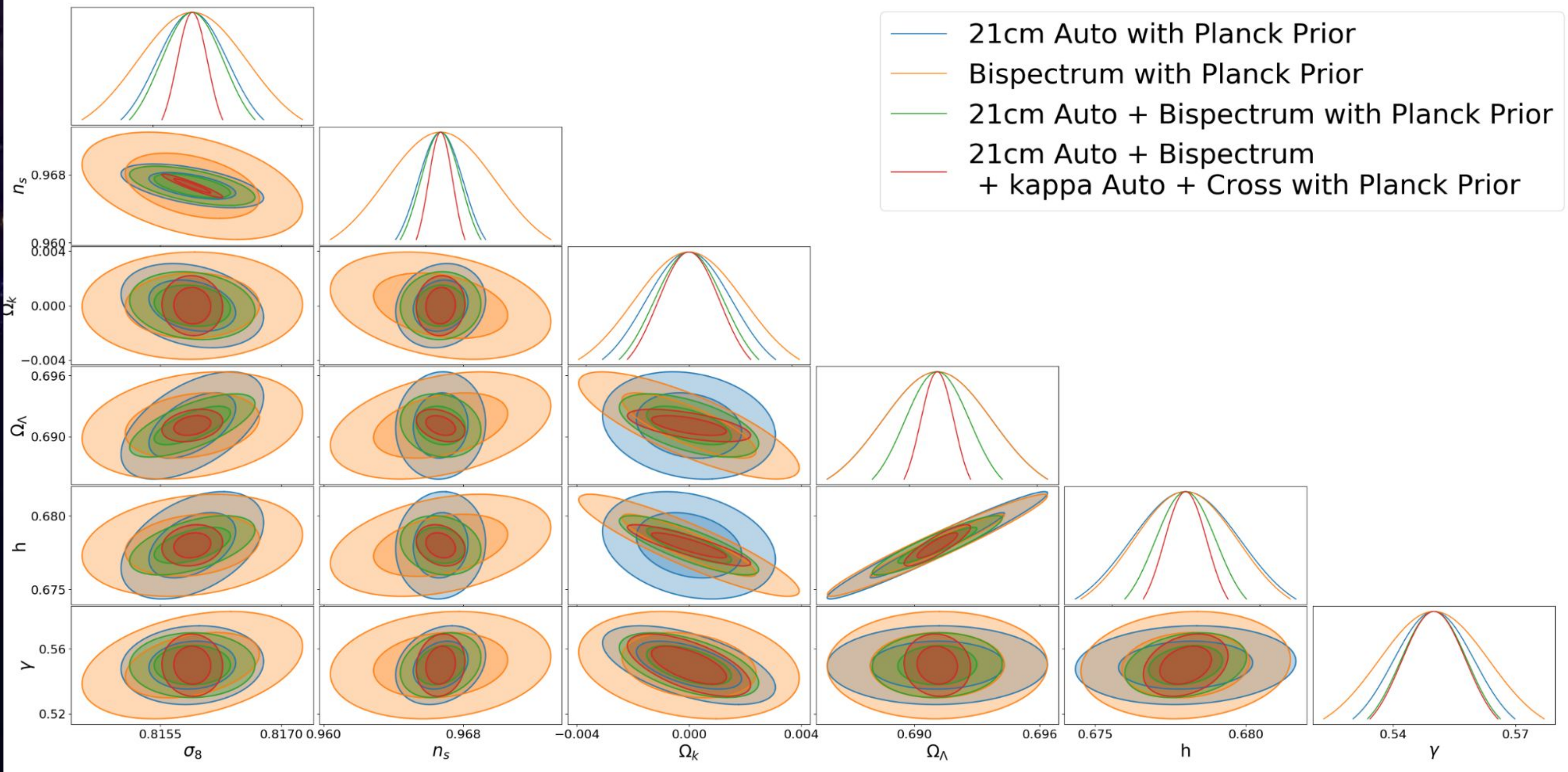
	Ω_m	σ_8	h	n_s	ω_b
Planck	0.0074	0.0060	0.0054	0.0042	0.00015
HIRAX + *Planck*	0.0041	0.00073	0.0031	0.0012	0.00012
HI-CMB lensing Combined + *Planck*	0.0022	0.00020	0.0017	0.00059	0.00011
HI-Gal Combined + *Planck*	0.00059	0.00012	0.00082	0.00081	0.00011
HI-Shear Combined + *Planck*	0.00099	0.00025	0.0010	0.0010	0.00011

Marginalized 68% ΛCDM parameter forecast constraints for the HIRAX experiment and in combination with the CMB lensing, galaxy density and cosmic shear autocorrelation, cross-correlation and cross-bispectrum.

Dark Energy EoS



Modified Gravity Through Structure Growth

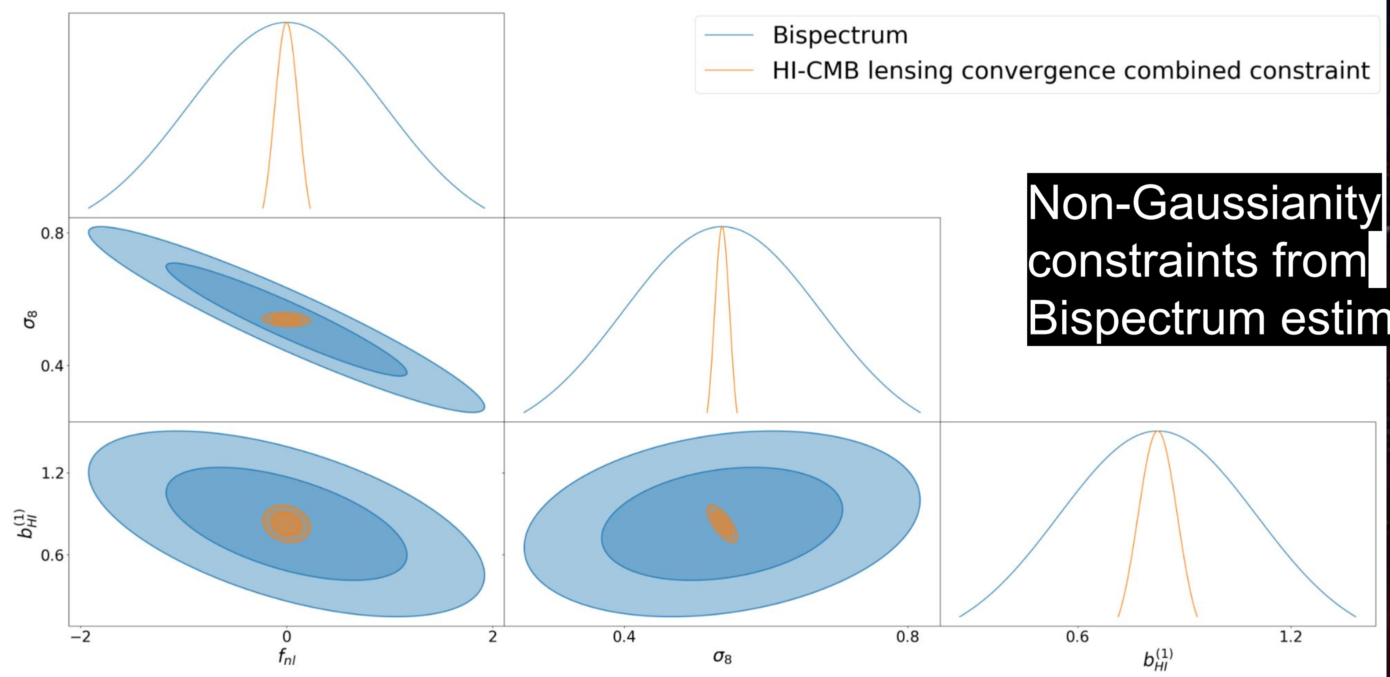


Inflation

- We can include the non-Gaussianity parameter into our analysis to probe deviations induced into structure formation by inflation.

$$\Phi_{\rm in}(\mathbf{x}) = \varphi_{\rm G}(\mathbf{x}) + f_{\rm NL}\left(\varphi_{\rm G}^2(\mathbf{x}) - \langle\varphi_{\rm G}^2\rangle\right)$$

State of the art -0.9 ± 5.1, Planck 2018



Non-Gaussianity constraints from Bispectrum estimator.

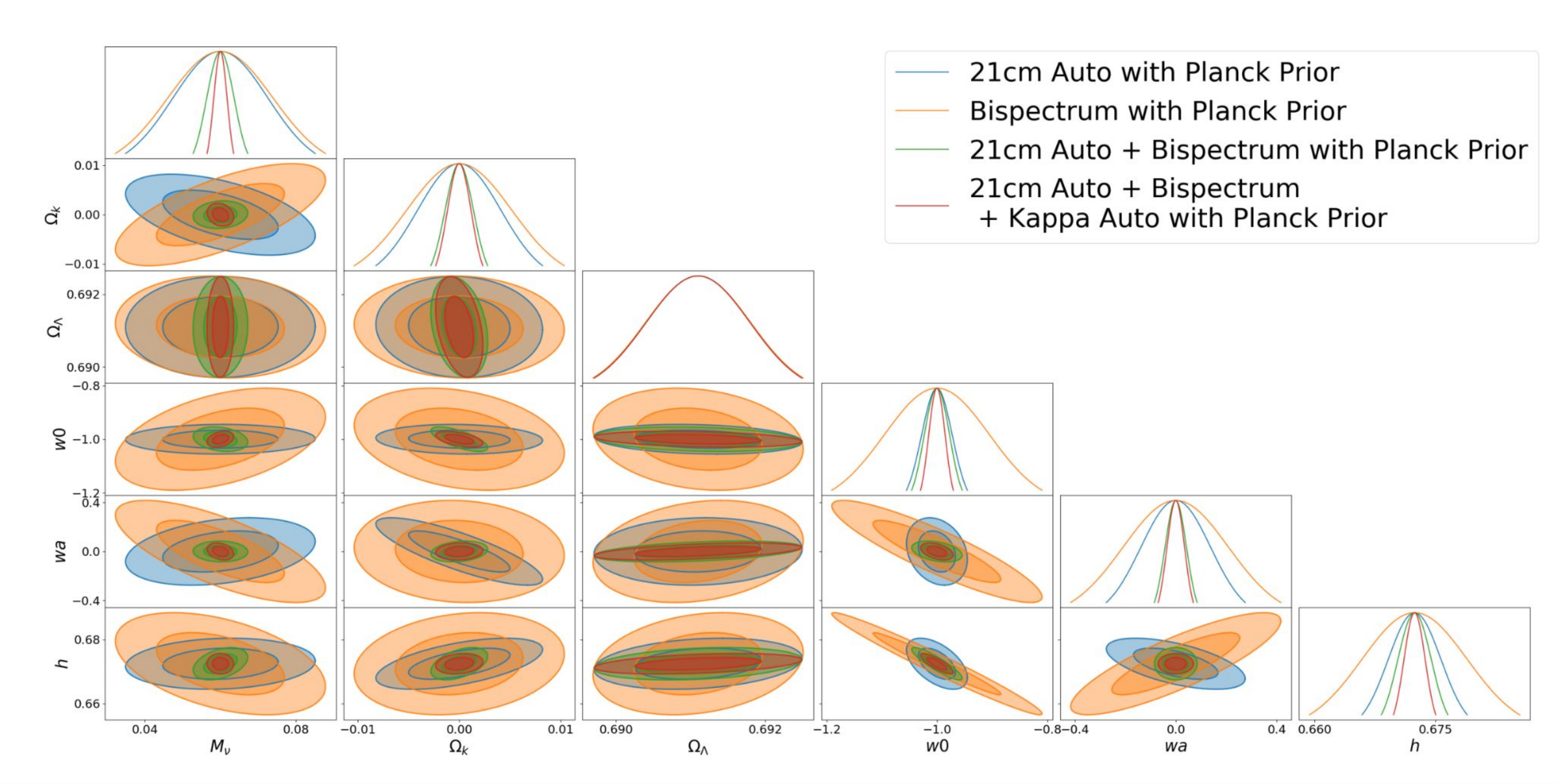
Neutrino Mass

- Cosmological surveys can also be used to constrain the neutrino mass.

$$\delta_m = \frac{\Omega_{bc}\delta_{bc} + \Omega_\nu \delta_\nu}{\Omega_m}$$

- Current best estimates of neutrino mass from Planck 2018 and BOSS 2017 place $M_v < 120$ mev

Neutrino Mass



Conclusion

- Observational probes of the large scale structure of the universe can place significant constraints on the theoretical models we put forward.
- Future experiments promise even tighter constraints on the existing models.
- Here we explored how we can use future experiment to obtain these constraints.