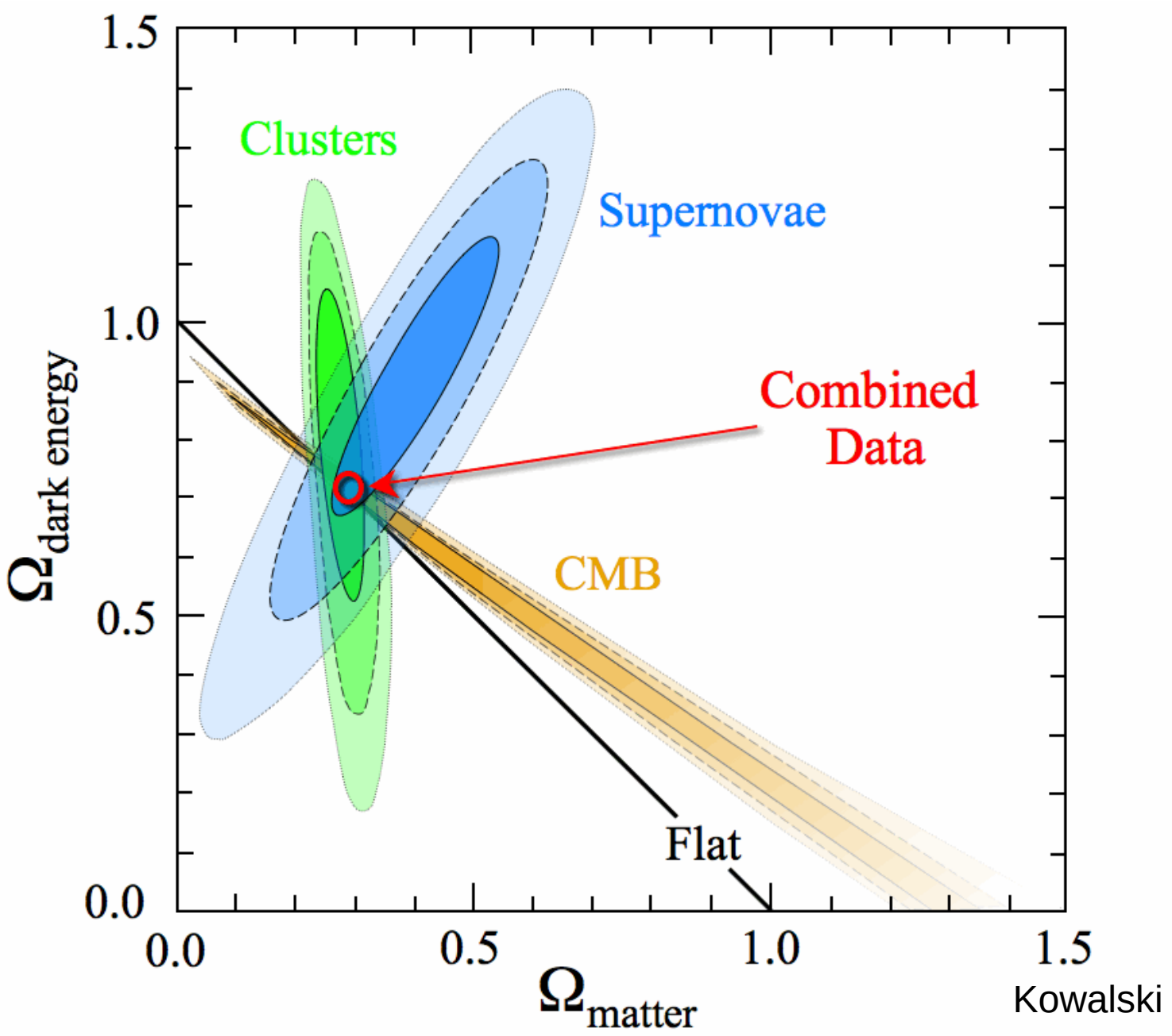
Colloque national Dark Energy
11-13 octobre 2017

The power of probe combination : cosmology with LSS and CMB

Stéphane Ilić
(IRAP/CEICO)

Why combining data ?



Kowalski et al. 2008

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“Categories” of probes :

	“Background evolution” (i.e. expansion)	**“Perturbed sector” (i.e. linear growth of structures)**
Early Universe		
Late Universe		

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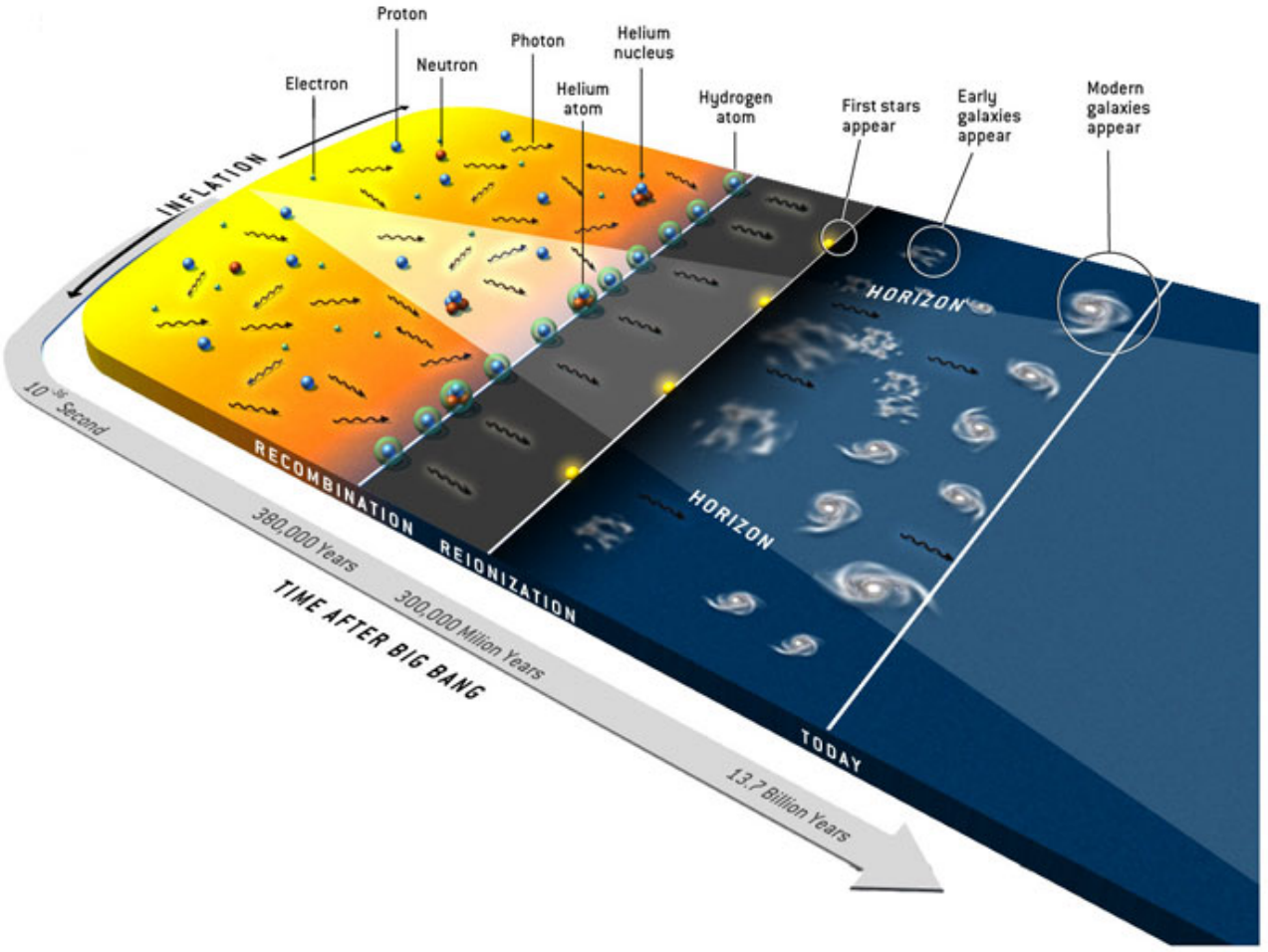

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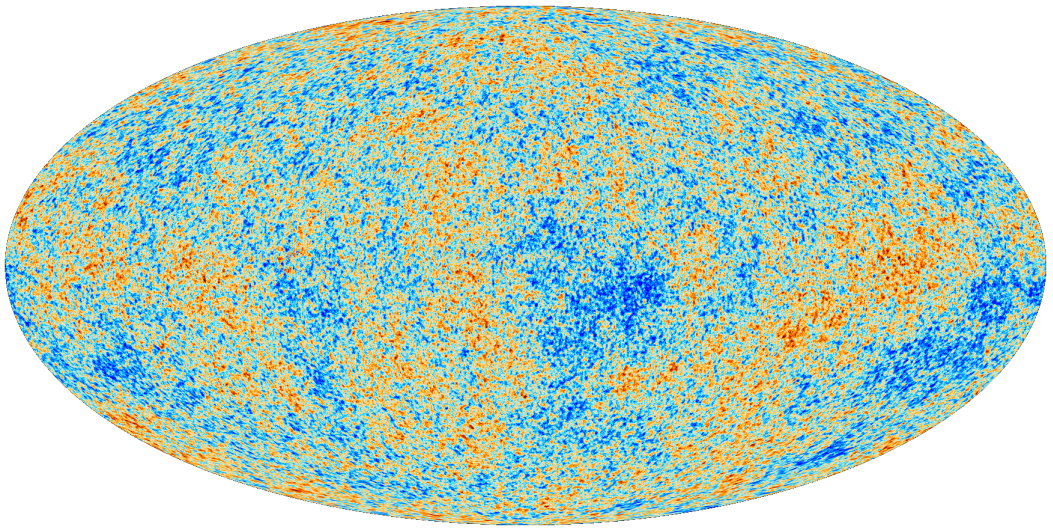
(e.g.  planck +  euclid)

I – Combining CMB & LSS data

How to combine datasets ?



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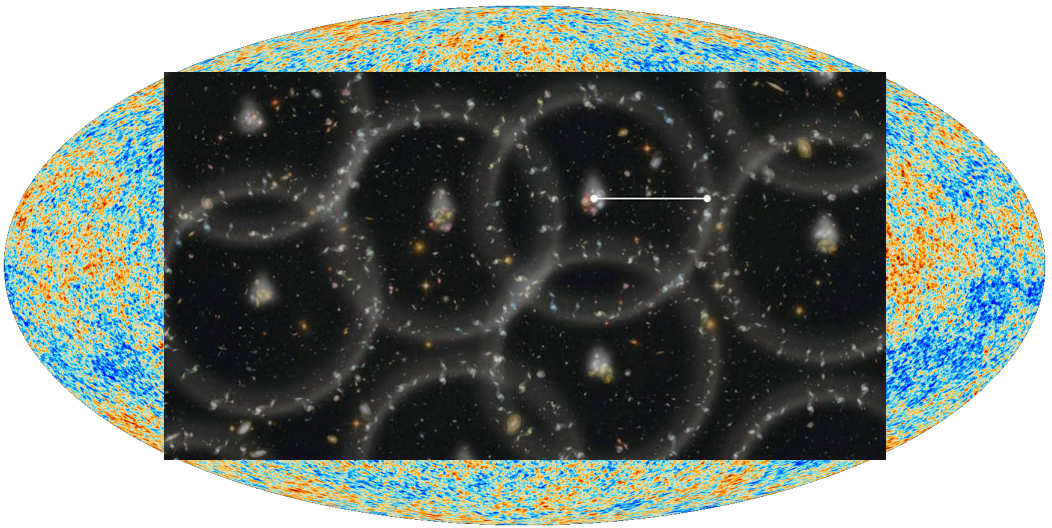

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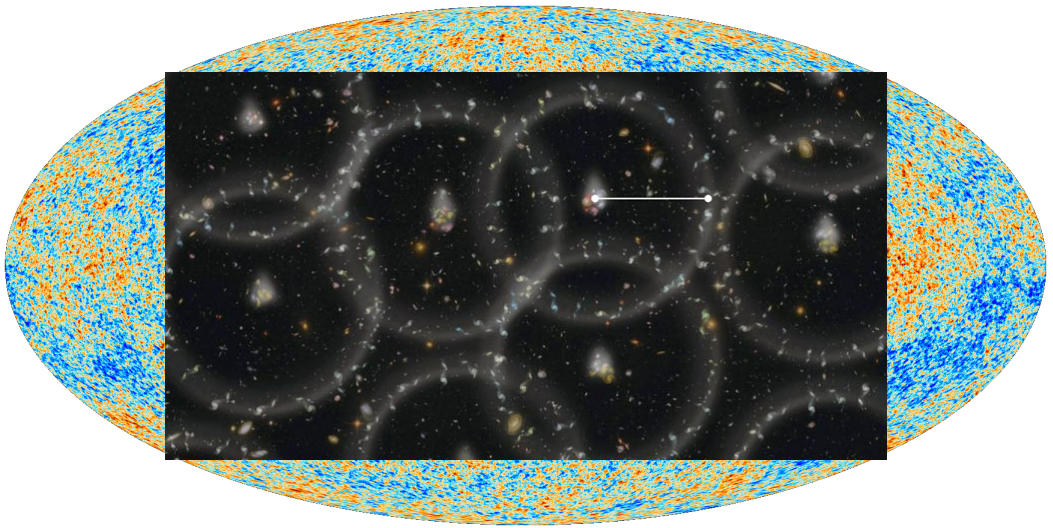

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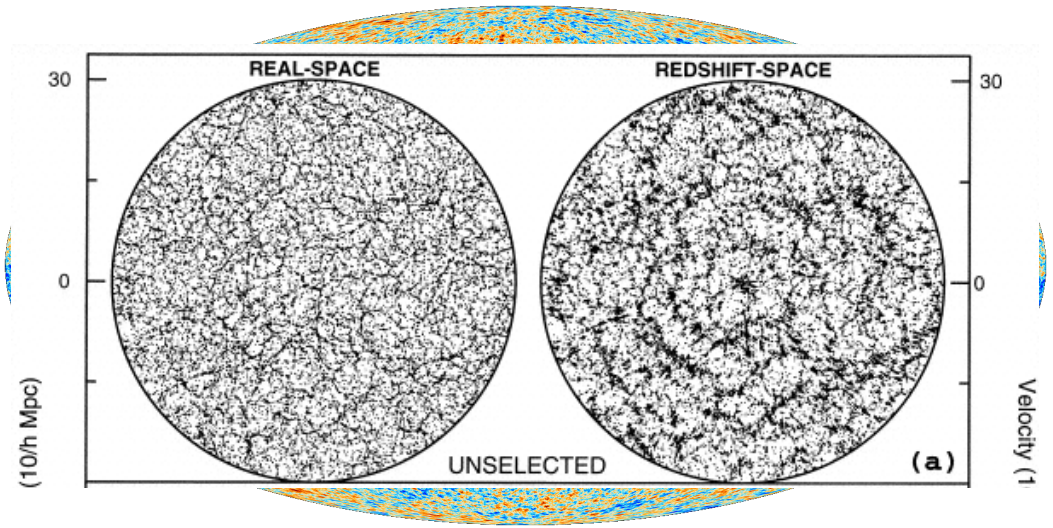

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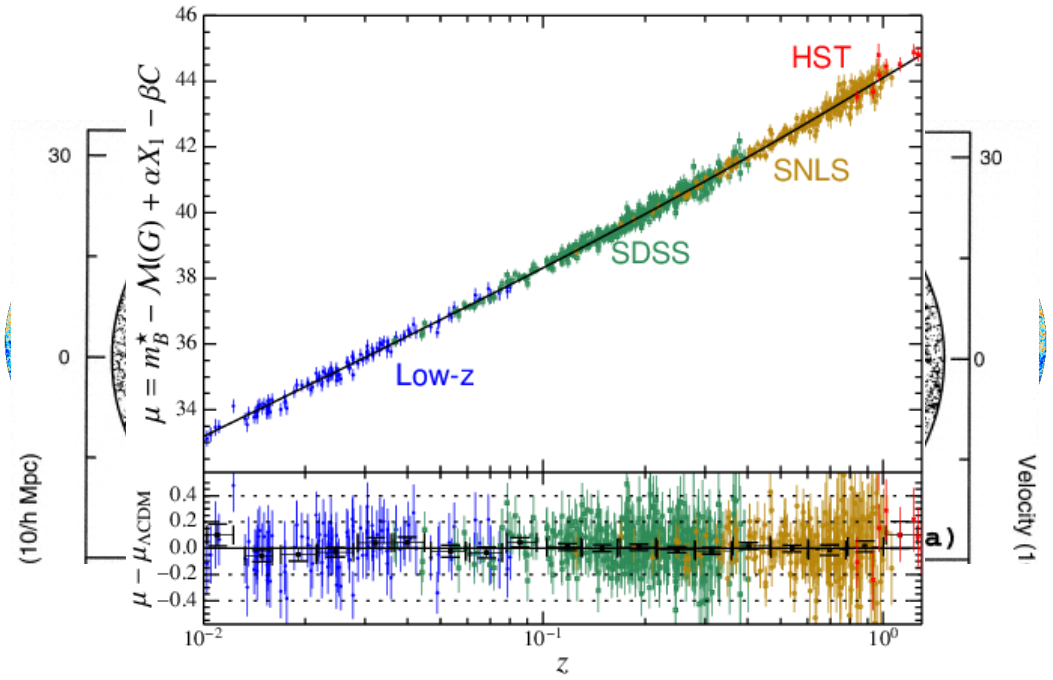

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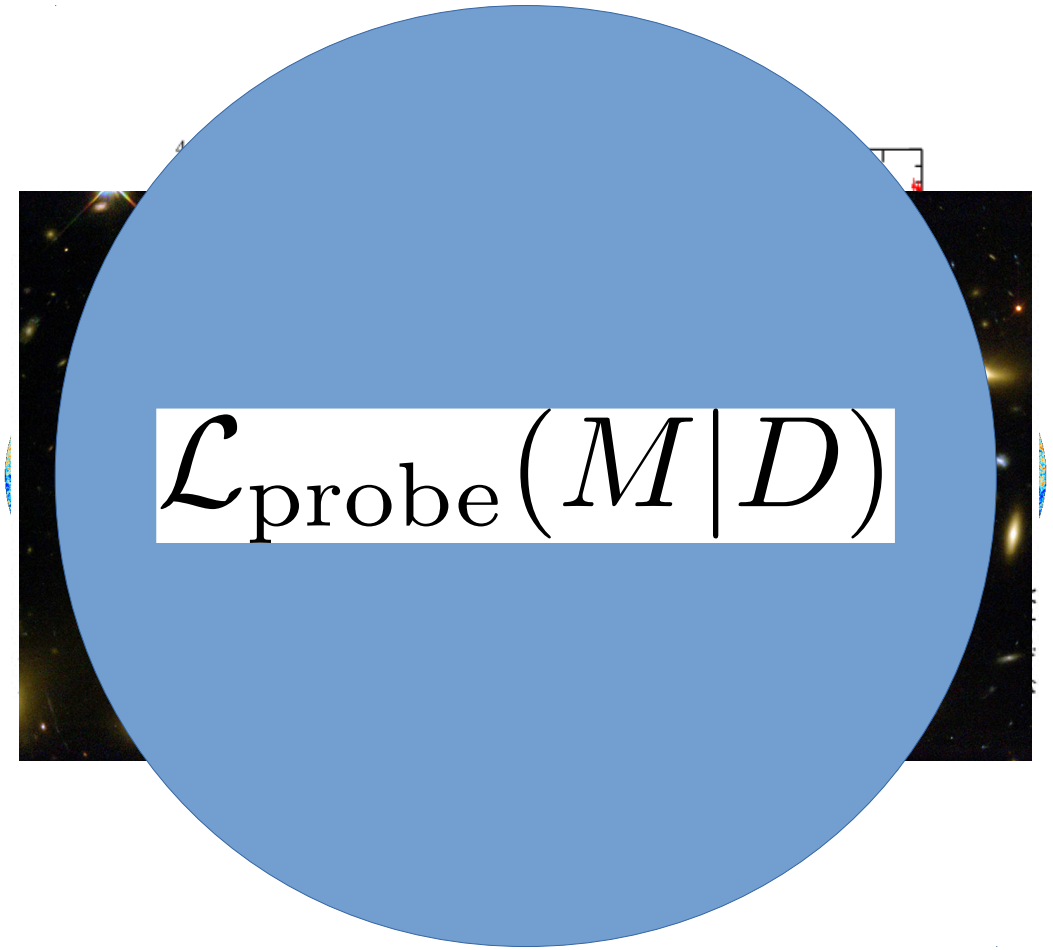

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(correlations ~ 0)

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Fisher formalism :

- Choice of “fiducial” model : $\boldsymbol{\Theta}_{\rm fid} = \{\theta_{1,\rm fid}, \theta_{2,\rm fid}, \theta_{3,\rm fid}, \cdots\}$
- Assumption : likelihood ~ Gaussian :

$$\mathcal{L} \propto \exp\left[-\frac{1}{2}(\boldsymbol{\Theta} - \boldsymbol{\Theta}_{\rm fid})^T \mathcal{F}\ (\boldsymbol{\Theta} - \boldsymbol{\Theta}_{\rm fid})\right]$$

- Fisher matrix :

$$\mathcal{F} = \begin{pmatrix} -\frac{\partial^2 \ln \mathcal{L}}{\partial \theta_1^2}\Big|_{\rm fid} & -\frac{\partial^2 \ln \mathcal{L}}{\partial \theta_1 \partial \theta_2}\Big|_{\rm fid} & \cdots \\ -\frac{\partial^2 \ln \mathcal{L}}{\partial \theta_1 \partial \theta_2}\Big|_{\rm fid} & -\frac{\partial^2 \ln \mathcal{L}}{\partial \theta_2^2}\Big|_{\rm fid} & \\ \vdots & & \ddots \end{pmatrix} = \mathbf{C}^{-1}$$

Forecasted errors on parameters

- Then...

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- Then...

$$\mathcal{L}_{\rm probe1+probe2} = \mathcal{L}_{\rm probe1} \times \mathcal{L}_{\rm probe2}$$
$$\mathcal{F}_{\rm probe1+probe2} = \mathcal{F}_{\rm probe1} + \mathcal{F}_{\rm probe2}$$

Current + “future” datasets ?

Question : how to make forecasts for next-gen LSS surveys + CMB ?

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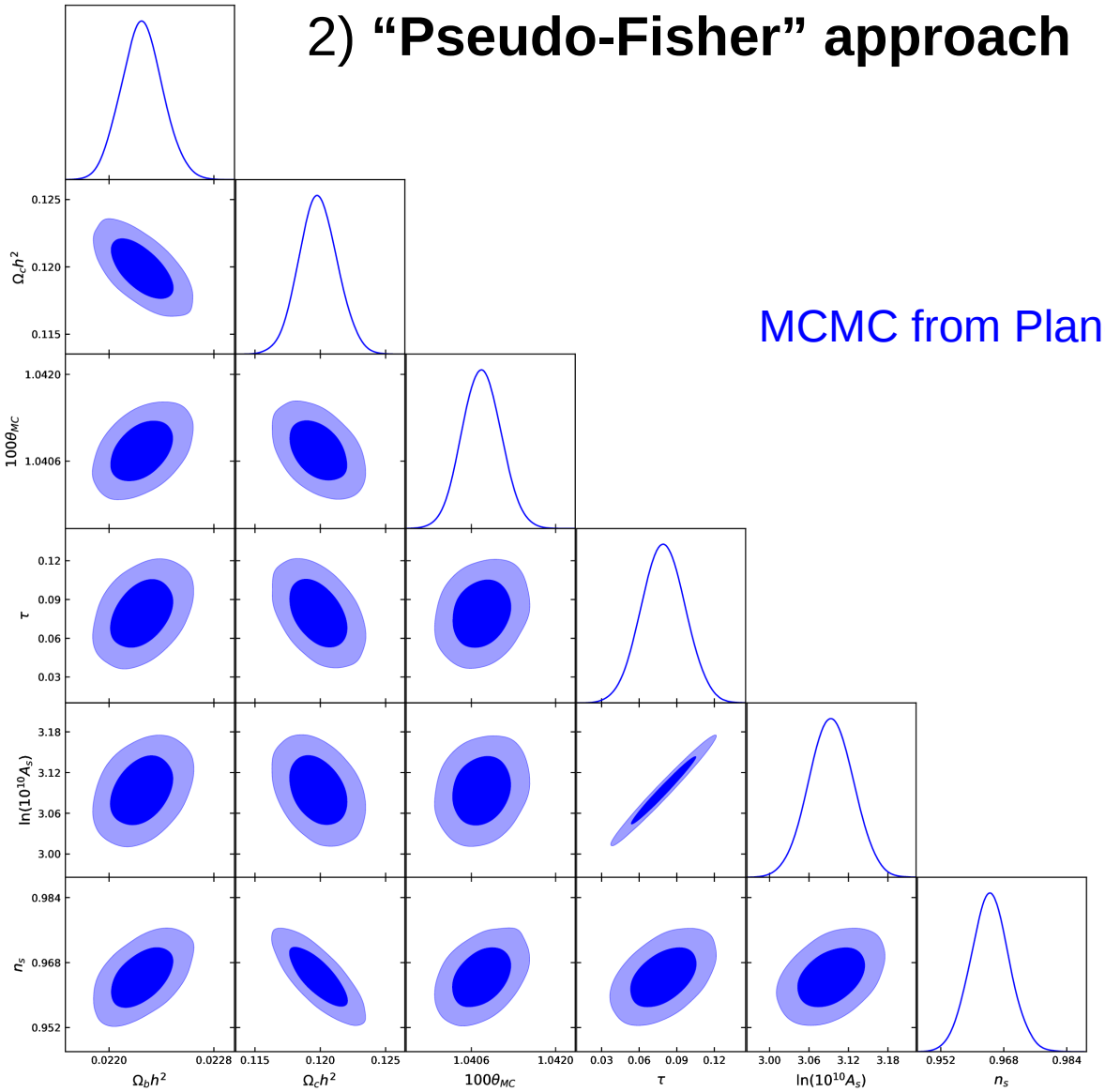
1) Choose a fiducial, compute a “fake Planck” Fisher
→ but : ignores the actual data (and fiducial !)

Current + “future” datasets ?

Question : how to make forecasts for next-gen LSS surveys + CMB ?

2) **“Pseudo-Fisher” approach**



MCMC from Planck data

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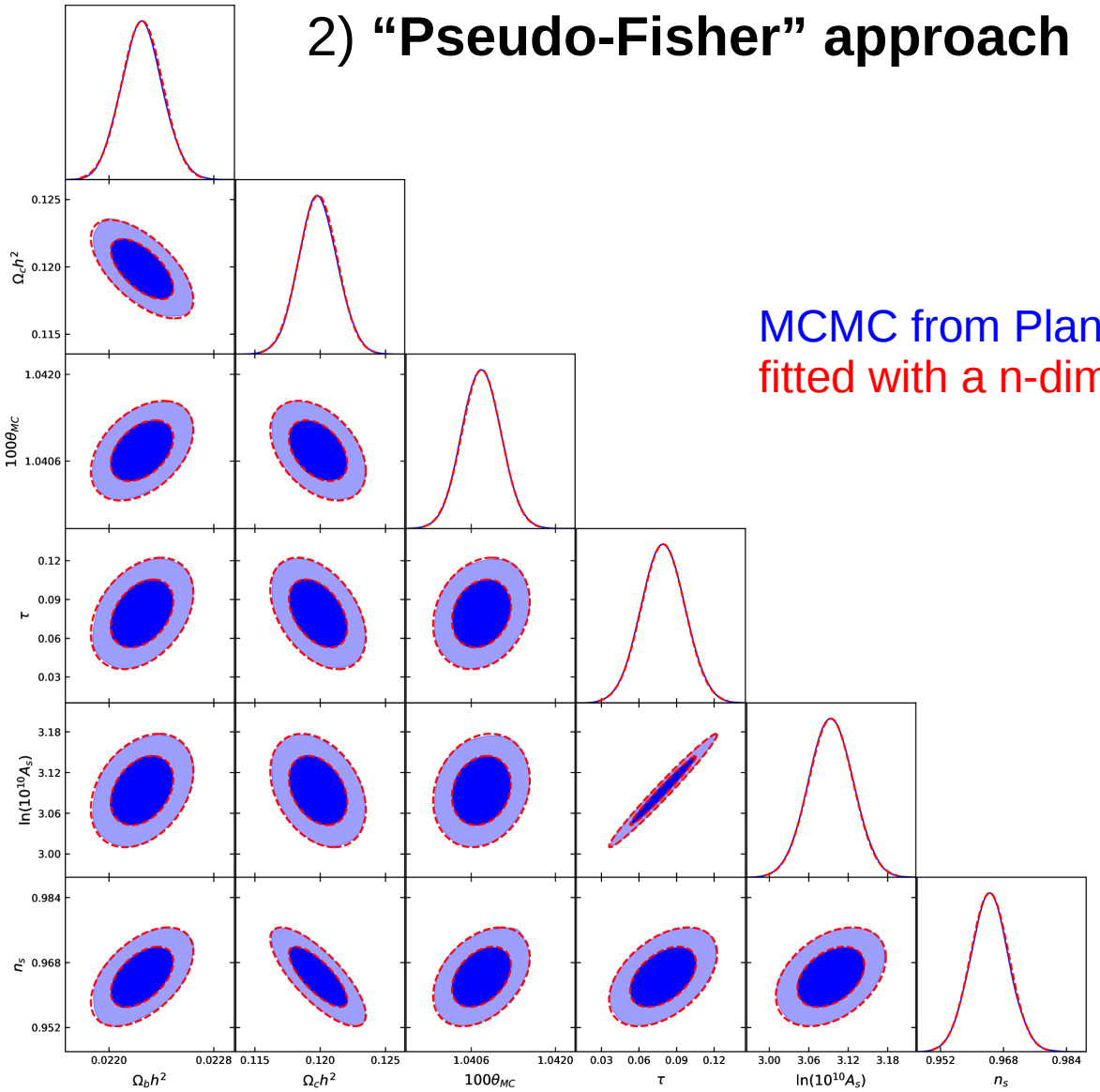

MCMC from Planck data
fitted with a n-dimensional Gaussian

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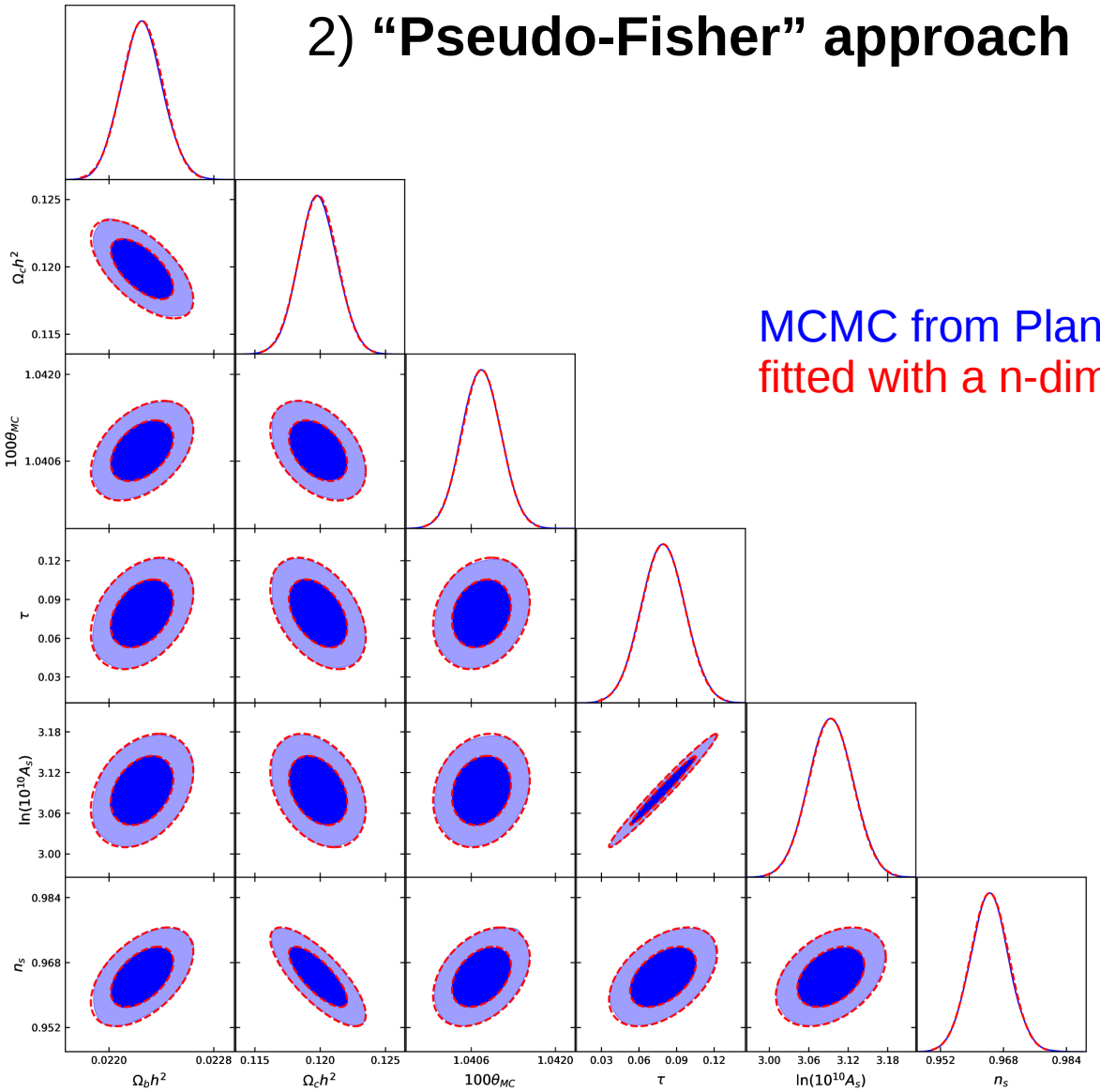

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$$C^{-1} = \mathcal{F}$$

Added to LSS Fisher

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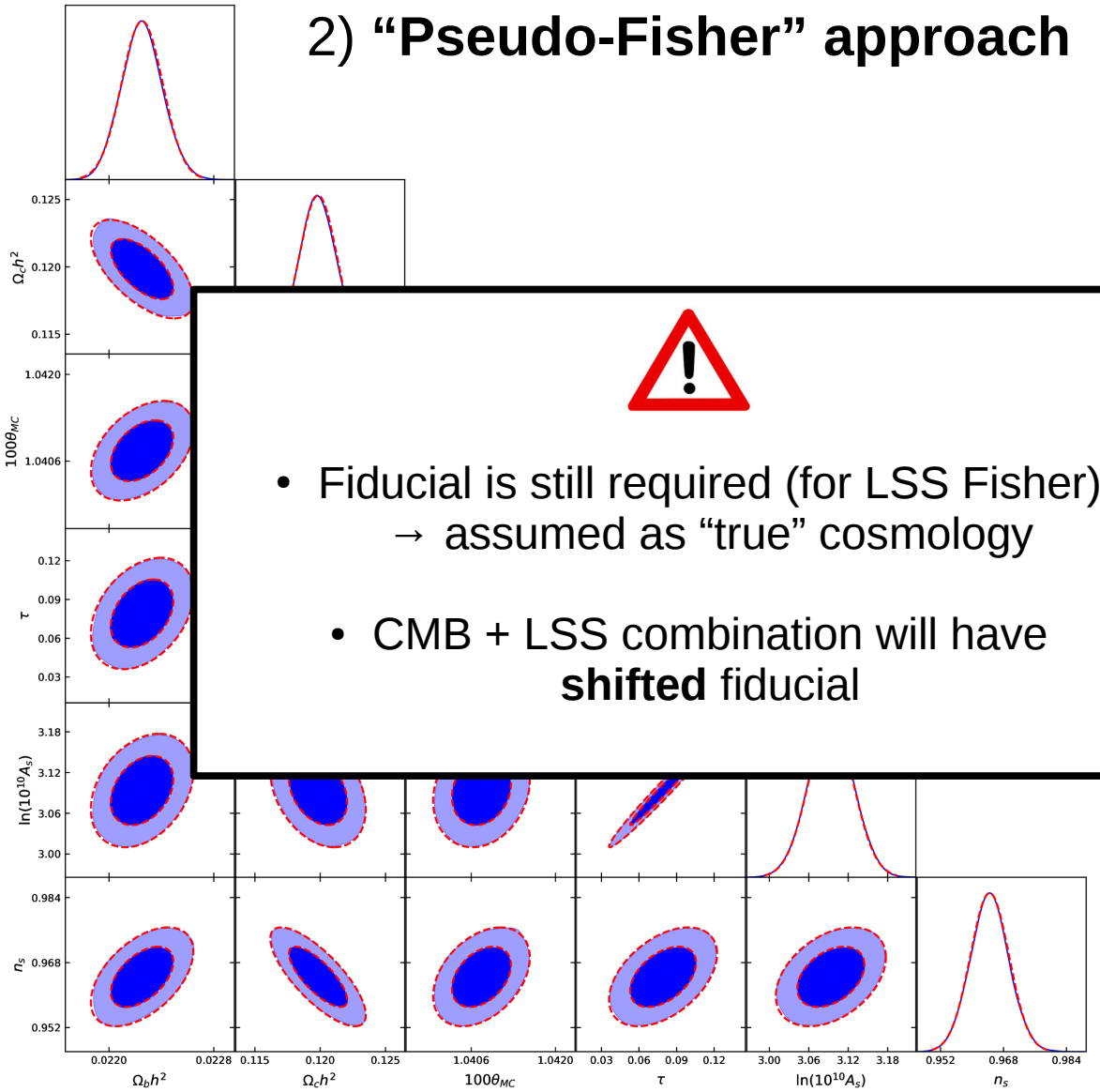

- Fiducial is still required (for LSS Fisher)
  → assumed as “true” cosmology
- CMB + LSS combination will have **shifted** fiducial

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ional Gaussian

$$C^{-1} = \mathcal{F}$$

ed to LSS Fisher

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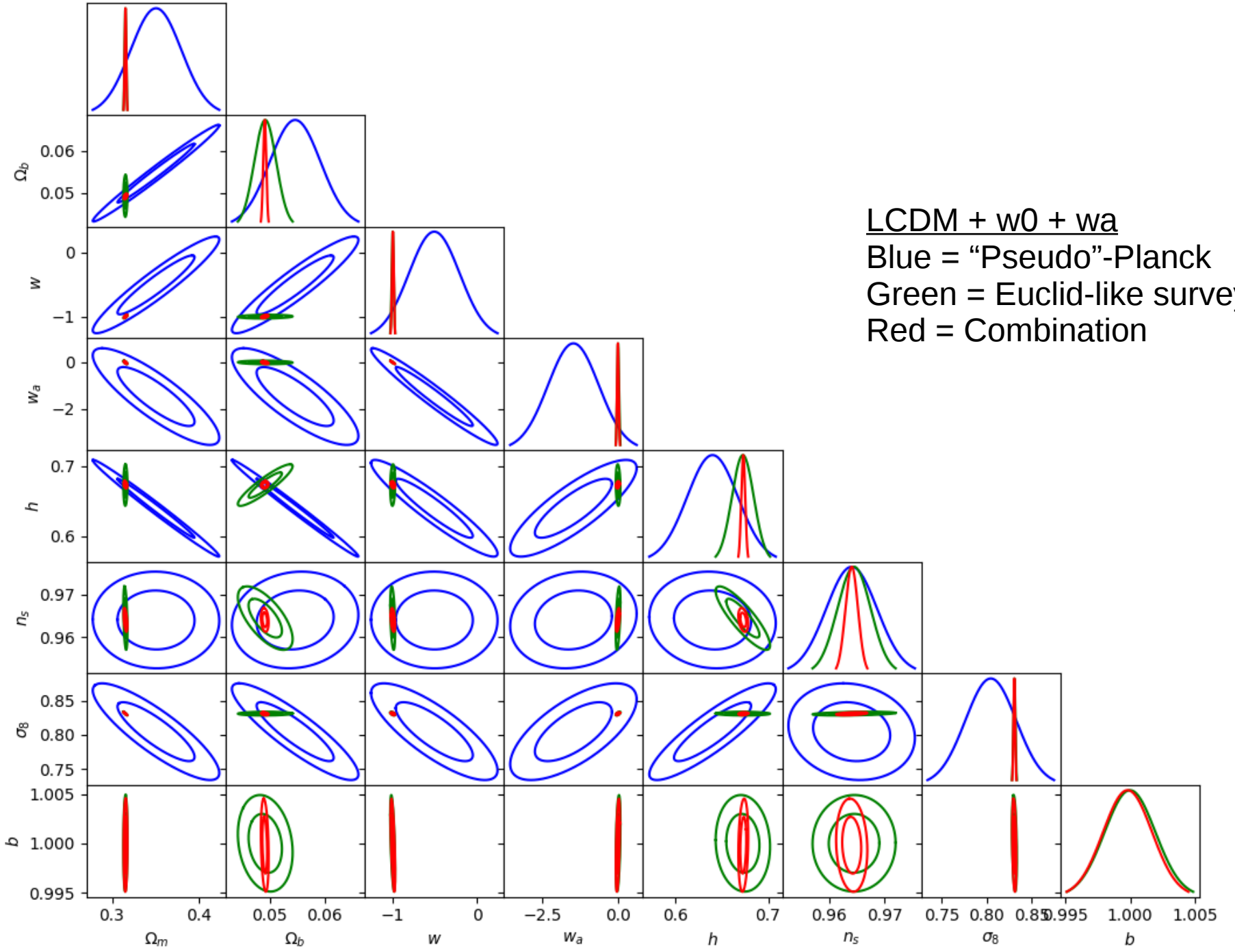
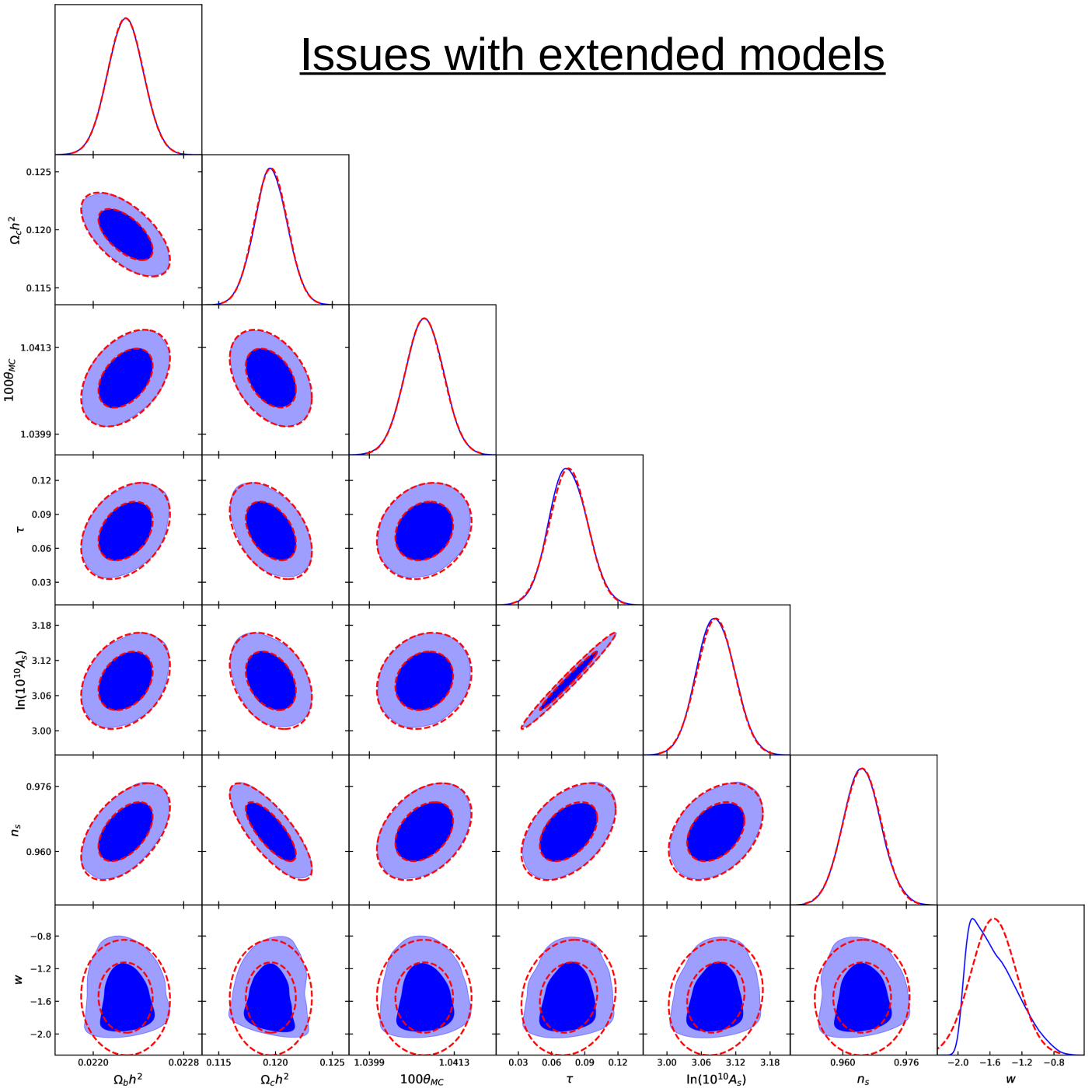


<u>LCDM + w0 + wa</u>
Blue = “Pseudo”-Planck
Green = Euclid-like survey
Red = Combination

Current + “future” datasets ?



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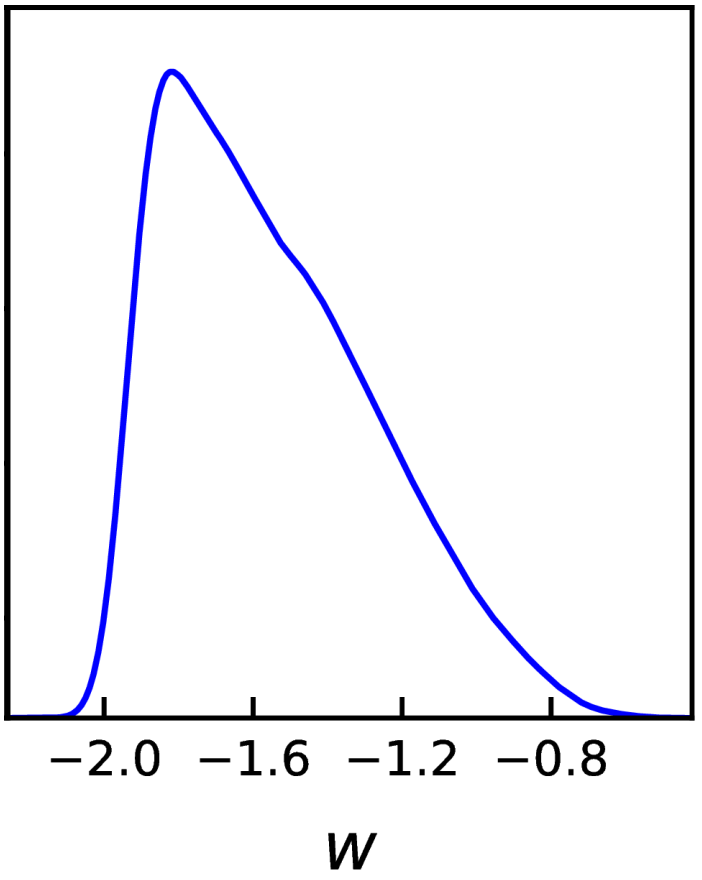
Solution :



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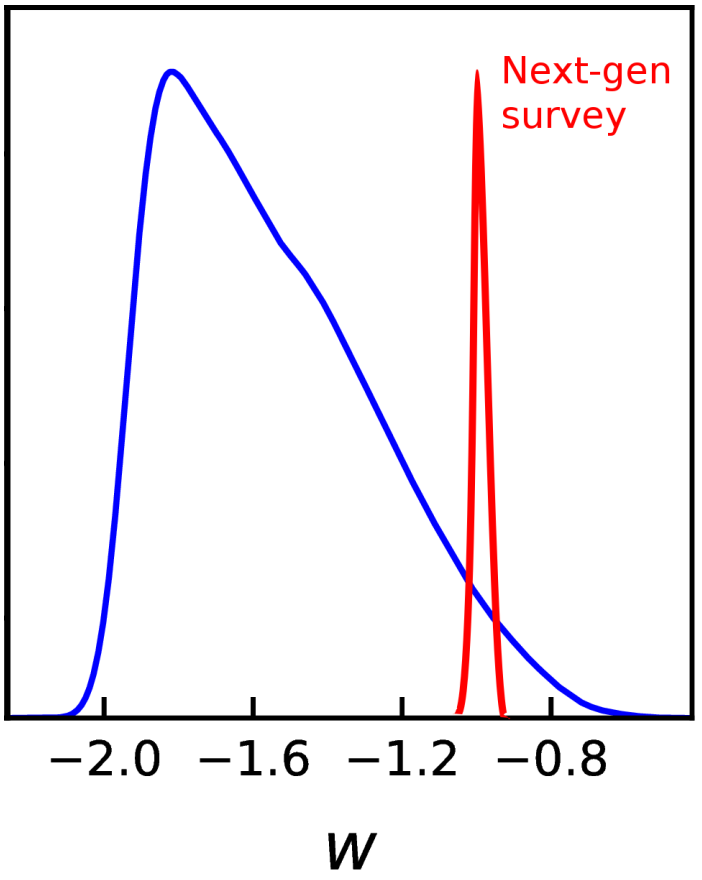

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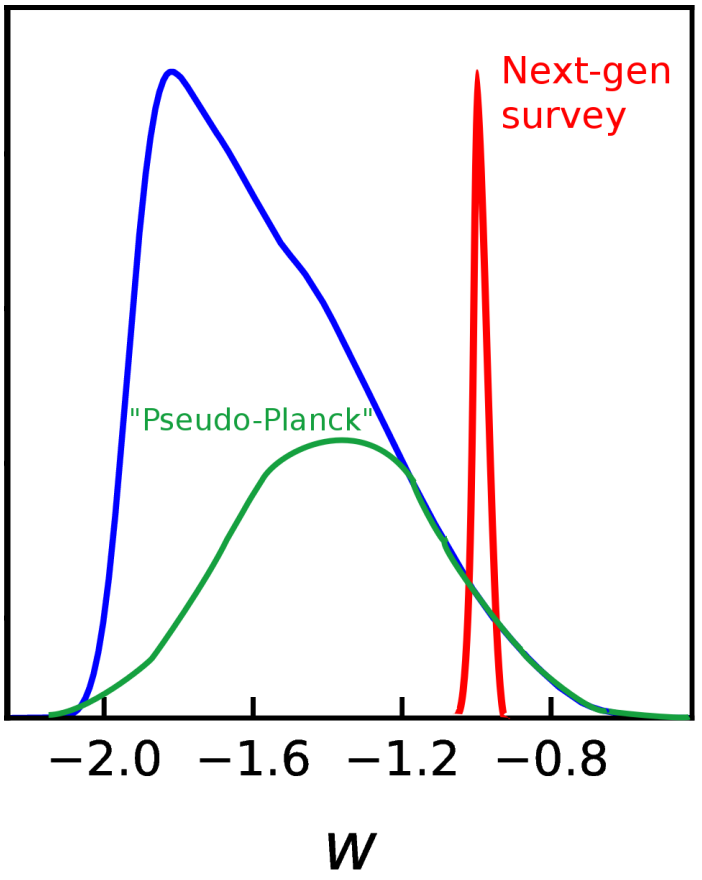
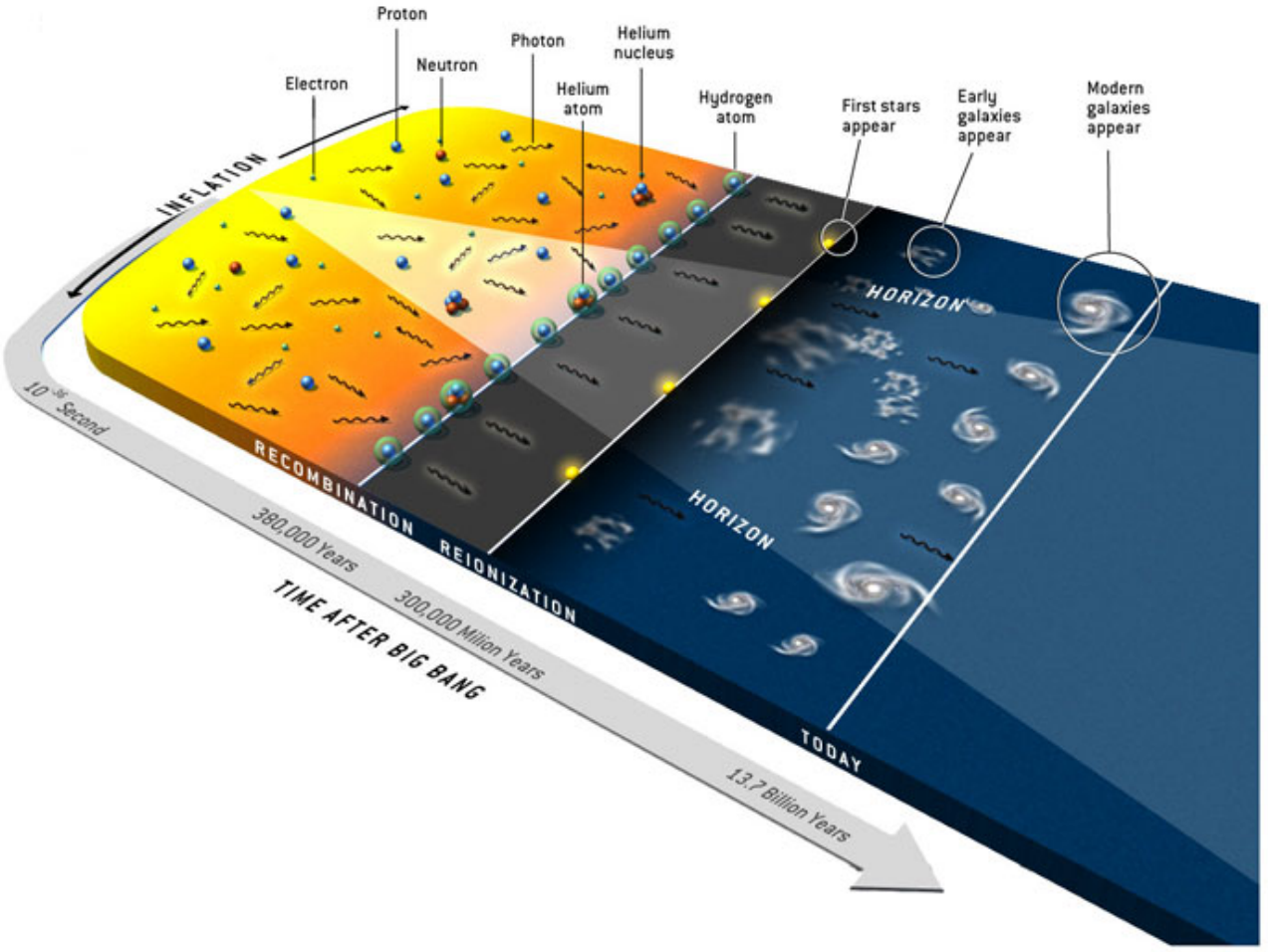


II – Cross-correlating CMB & LSS data

Why cross-correlating ?



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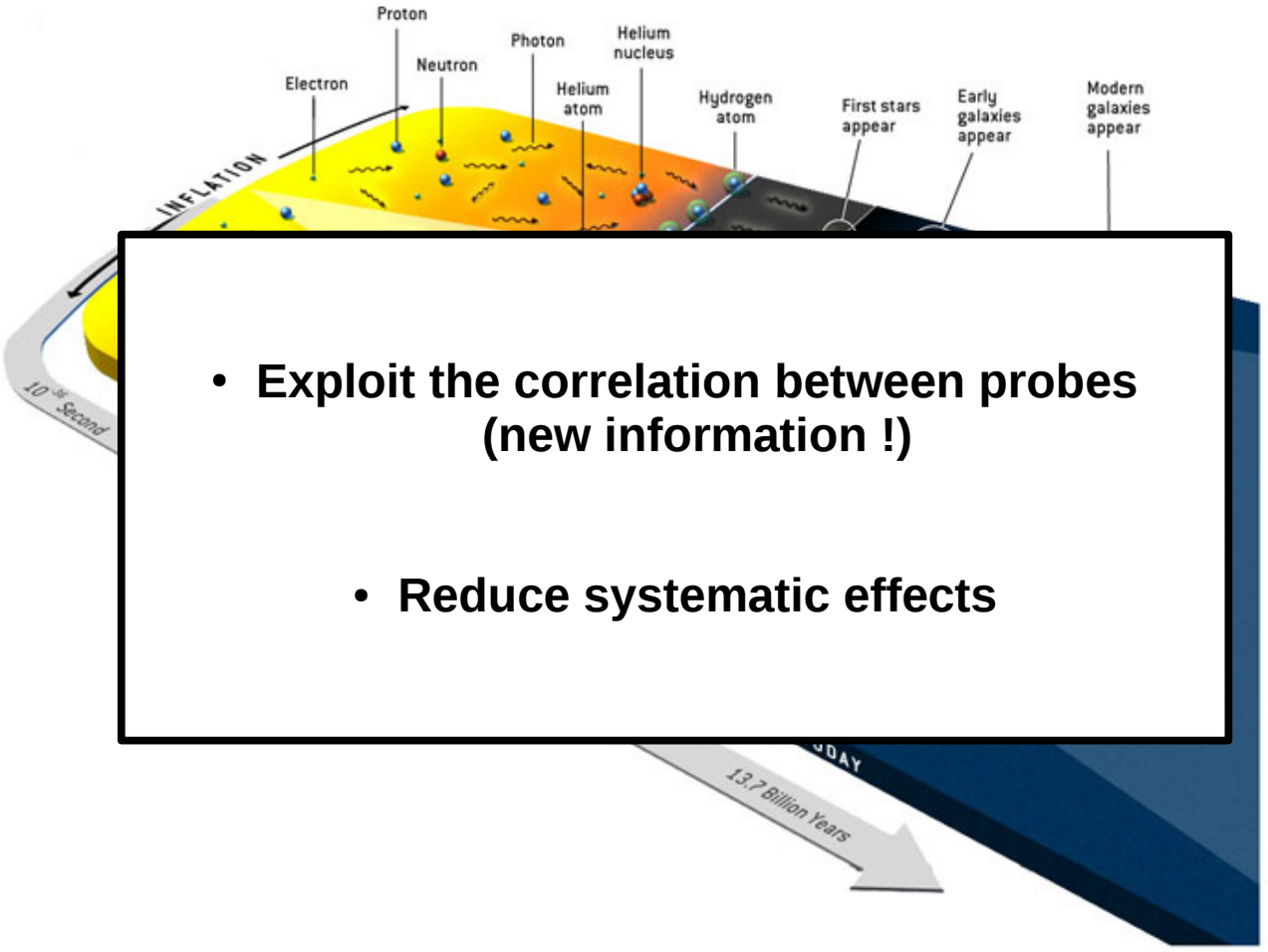
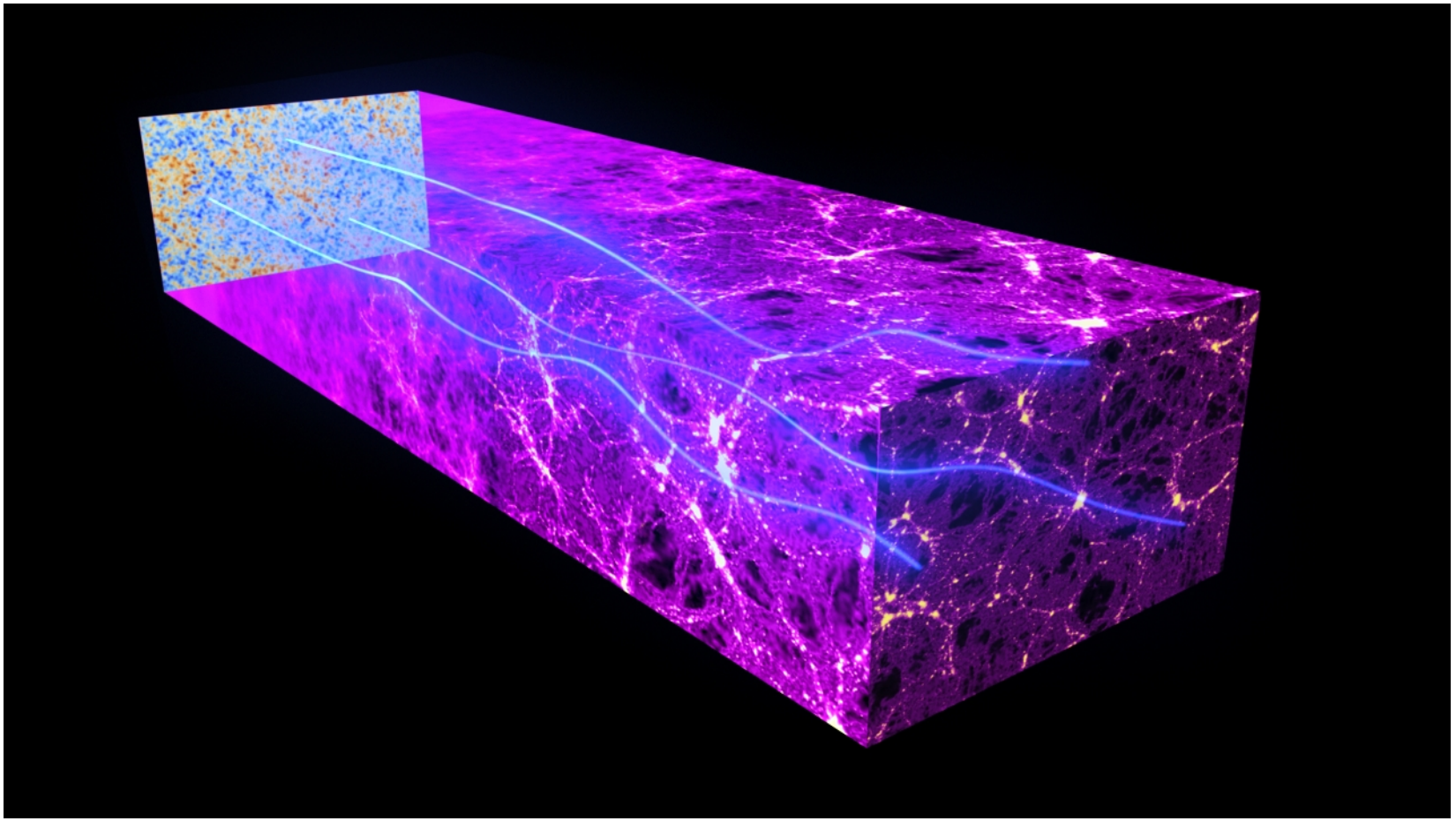


- **Exploit the correlation between probes (new information !)**
- **Reduce systematic effects**

CMB lensing



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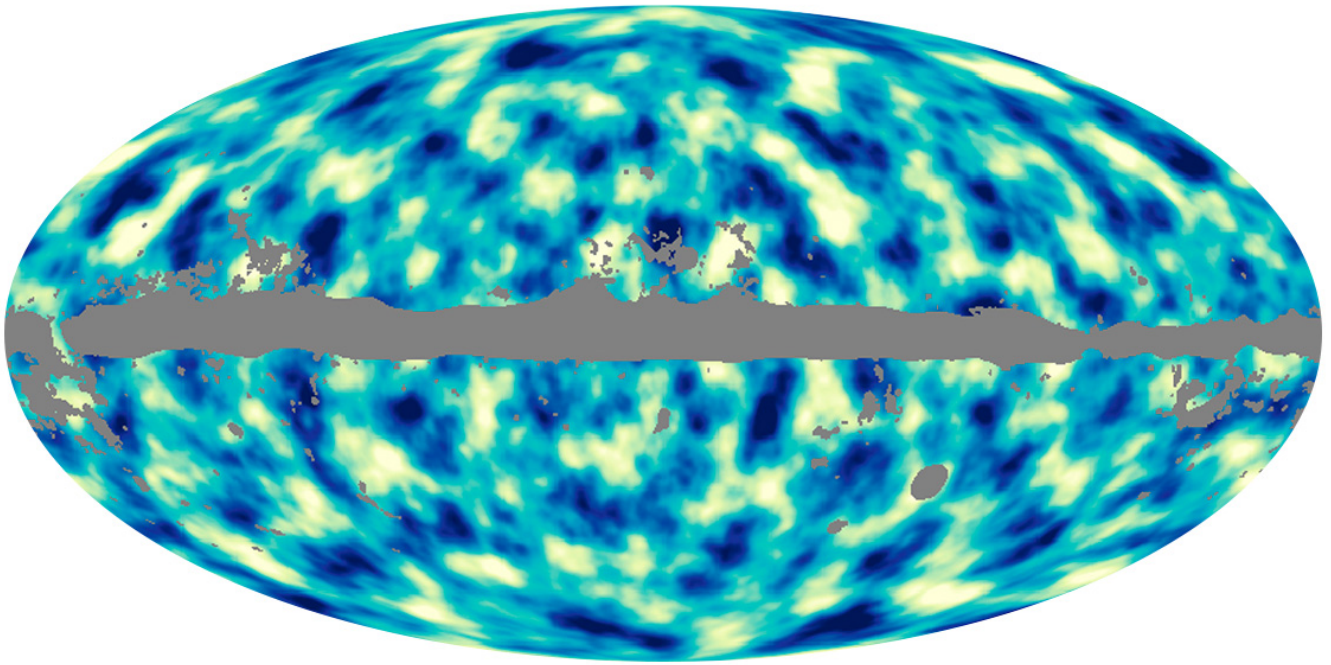
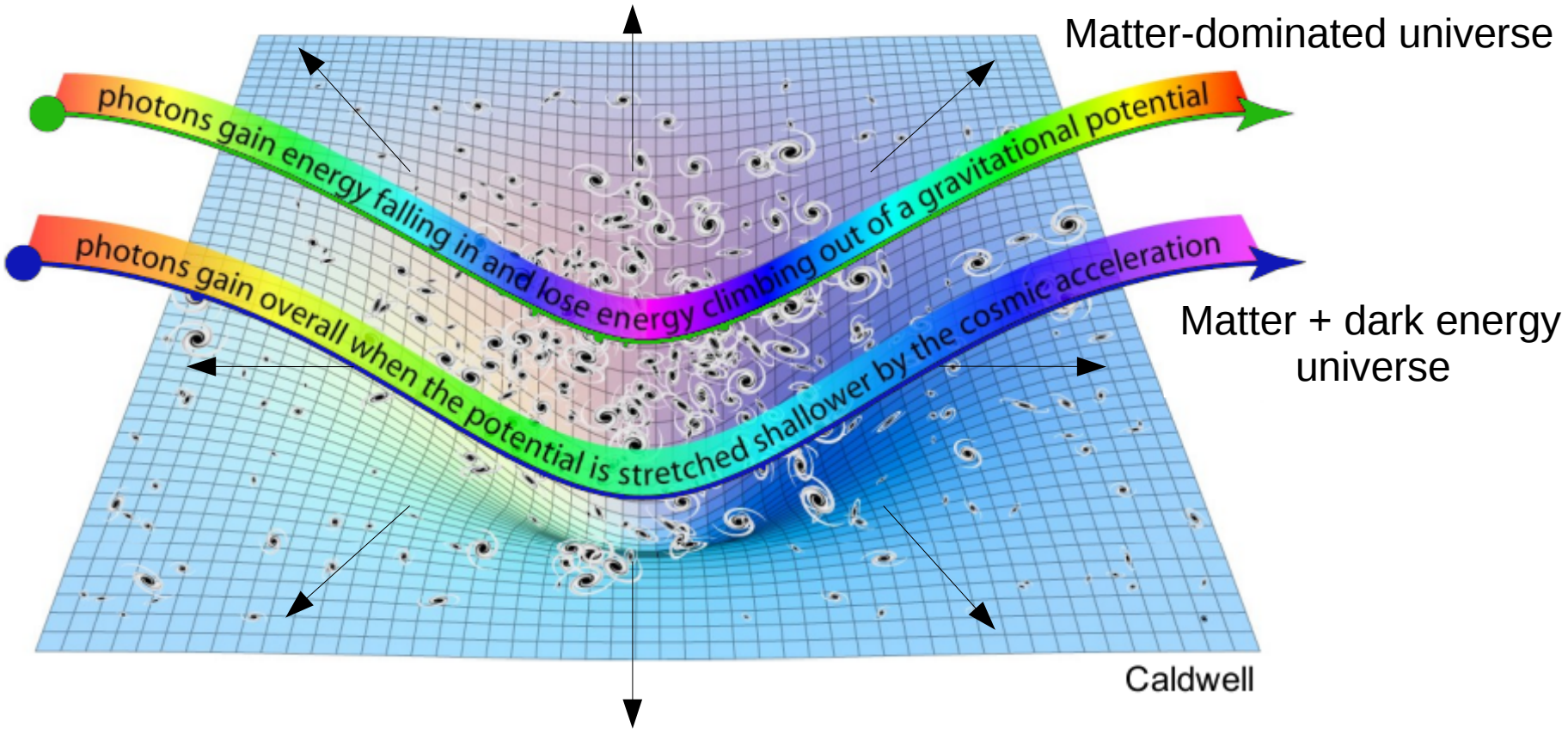


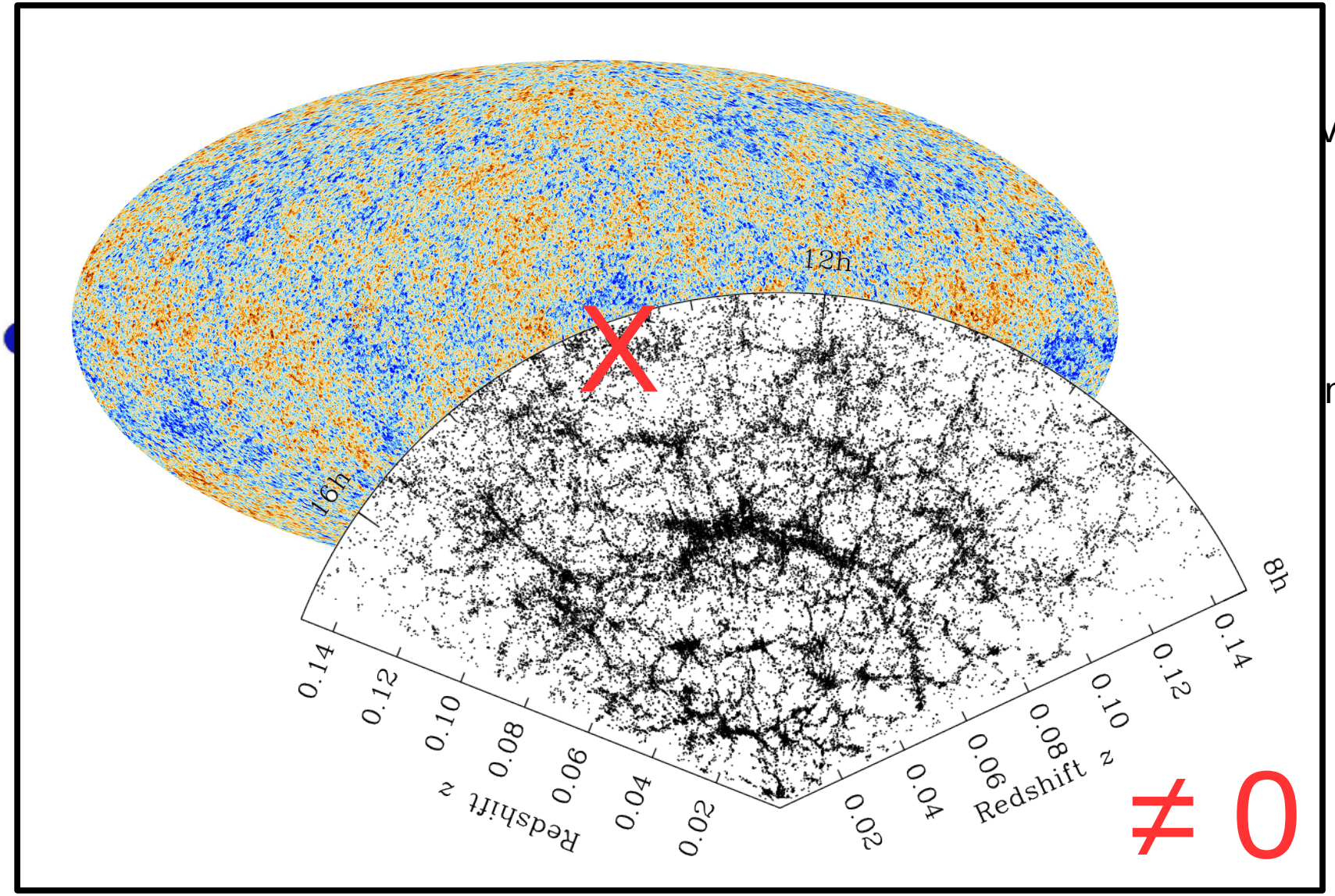
The integrated Sachs-Wolfe effect



The integrated Sachs-Wolfe effect

verse

nergy



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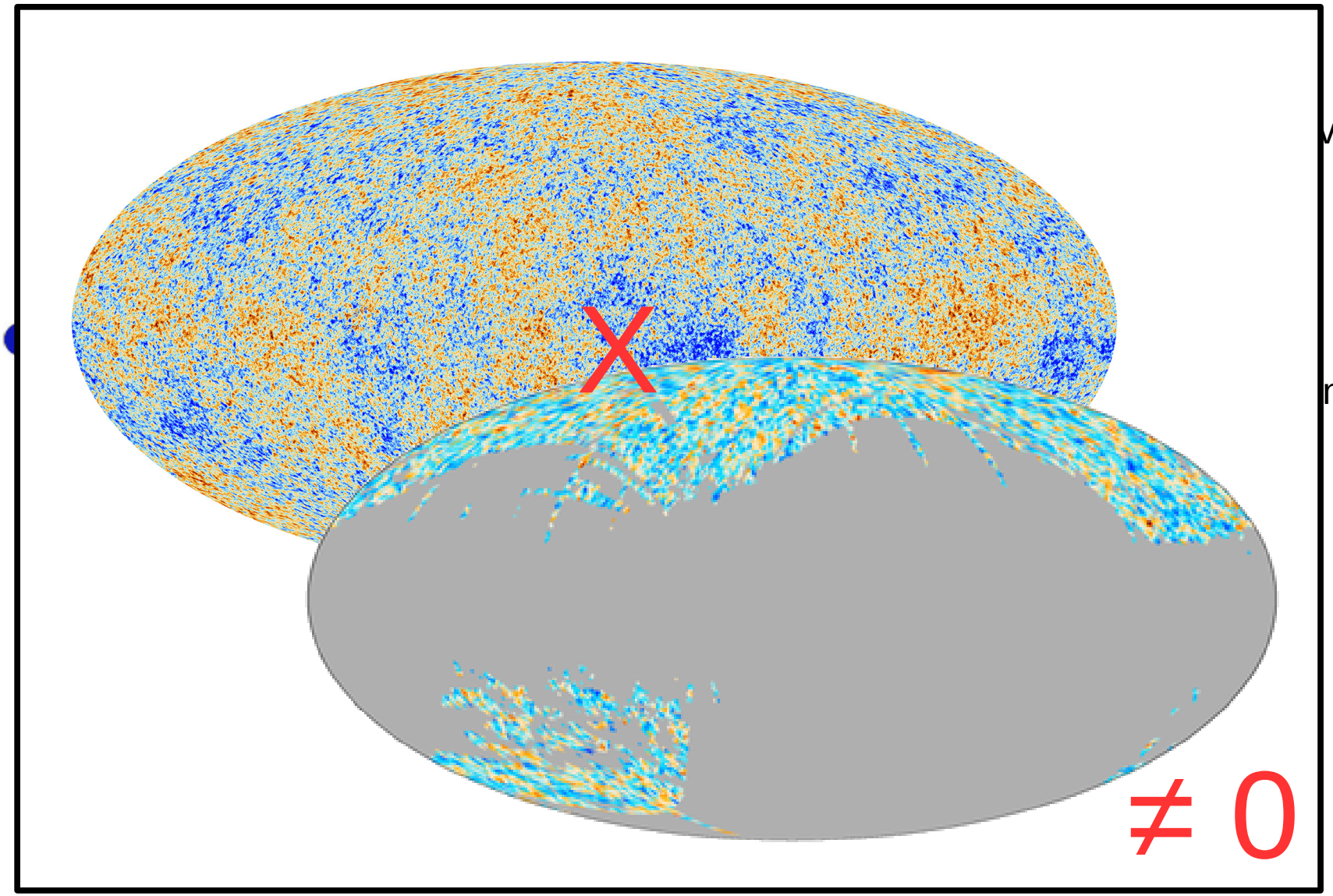


verse

nergy

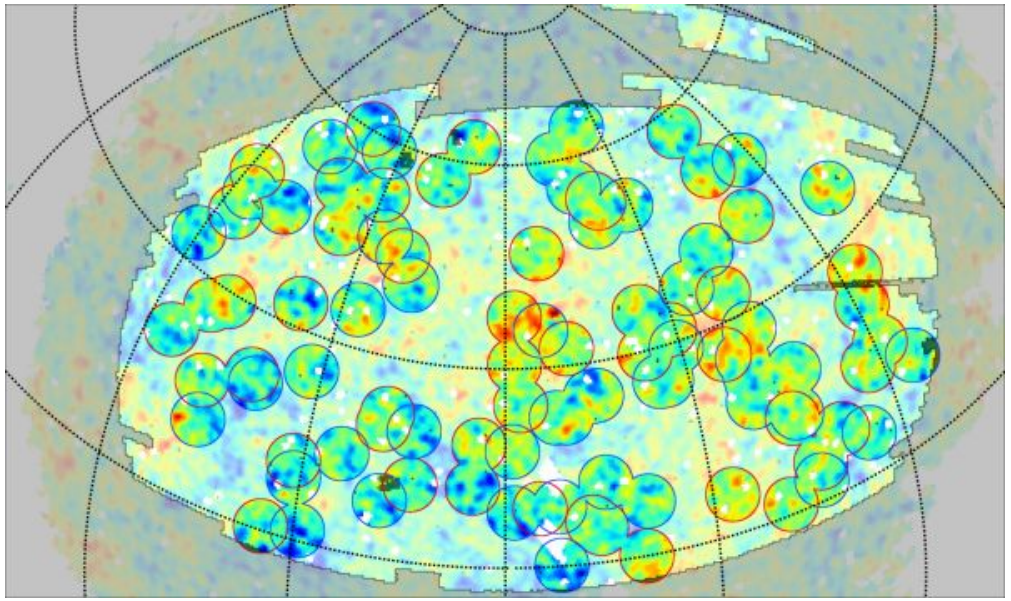
Strong probe of growth of strucutres

The integrated Sachs-Wolfe effect

From arXiv:1707.02263
Galileon Gravity in Light of ISW, CMB, BAO and H0 data

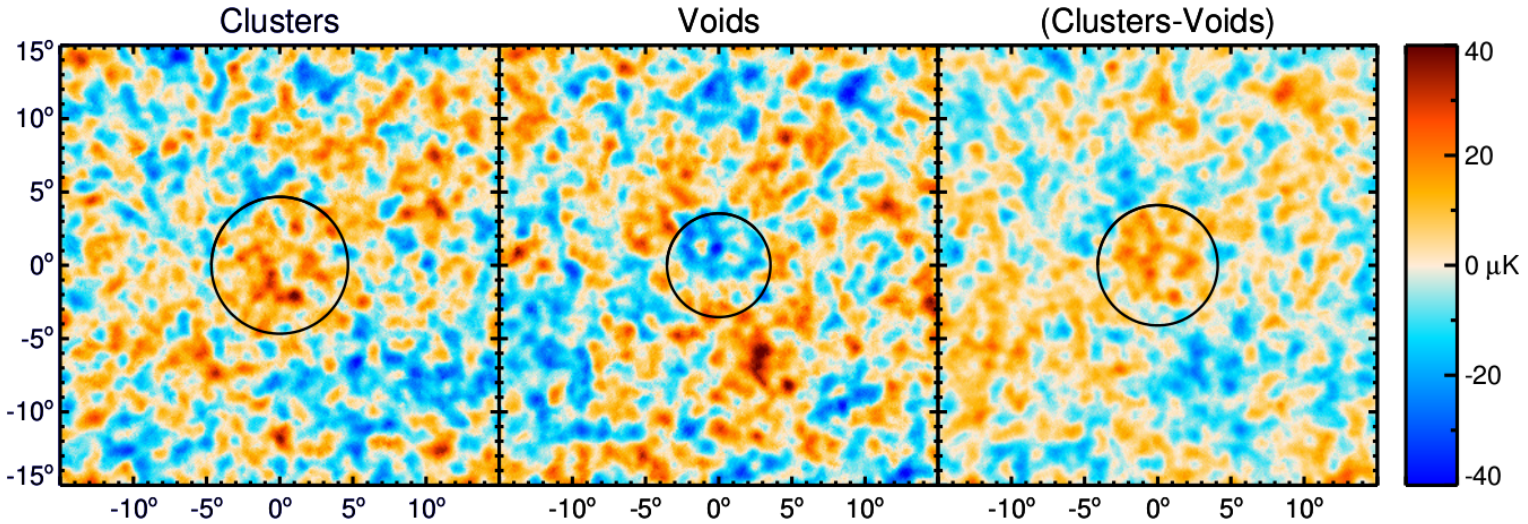
the galaxy sample. It is positive if the potential decays (like in ΛCDM), negative if it deepens. We constrain three subsets of Galileon gravity separately known as the Cubic, Quartic and Quintic Galileons. The cubic Galileon model predicts a negative C_ℓ^{Tg} and exhibits a 7.8σ tension with the data, which effectively rules it out. For the quartic and quintic models the ISW data also rule out a significant portion of the parameter space but permit regions where the goodness-of-fit is comparable to ΛCDM. The data prefers a non zero sum of the neutrino masses ($\sum m_\nu \approx 0.5$eV) with $\sim 5\sigma$ significance in these models. The best-fitting models have

The integrated Sachs-Wolfe effect



Stacking approach : ISW imprint of individual superstructures

- **(Planck 2013 & 2015, incl. Ilić)**
- Rigorous analysis of sample of 100 structures
- 3 - 4 sigmas signal
- Discrepancy with ΛCDM expectations



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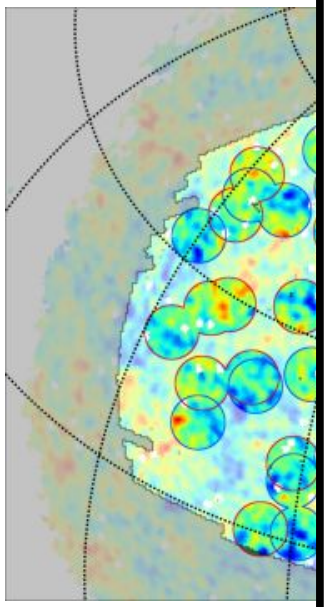
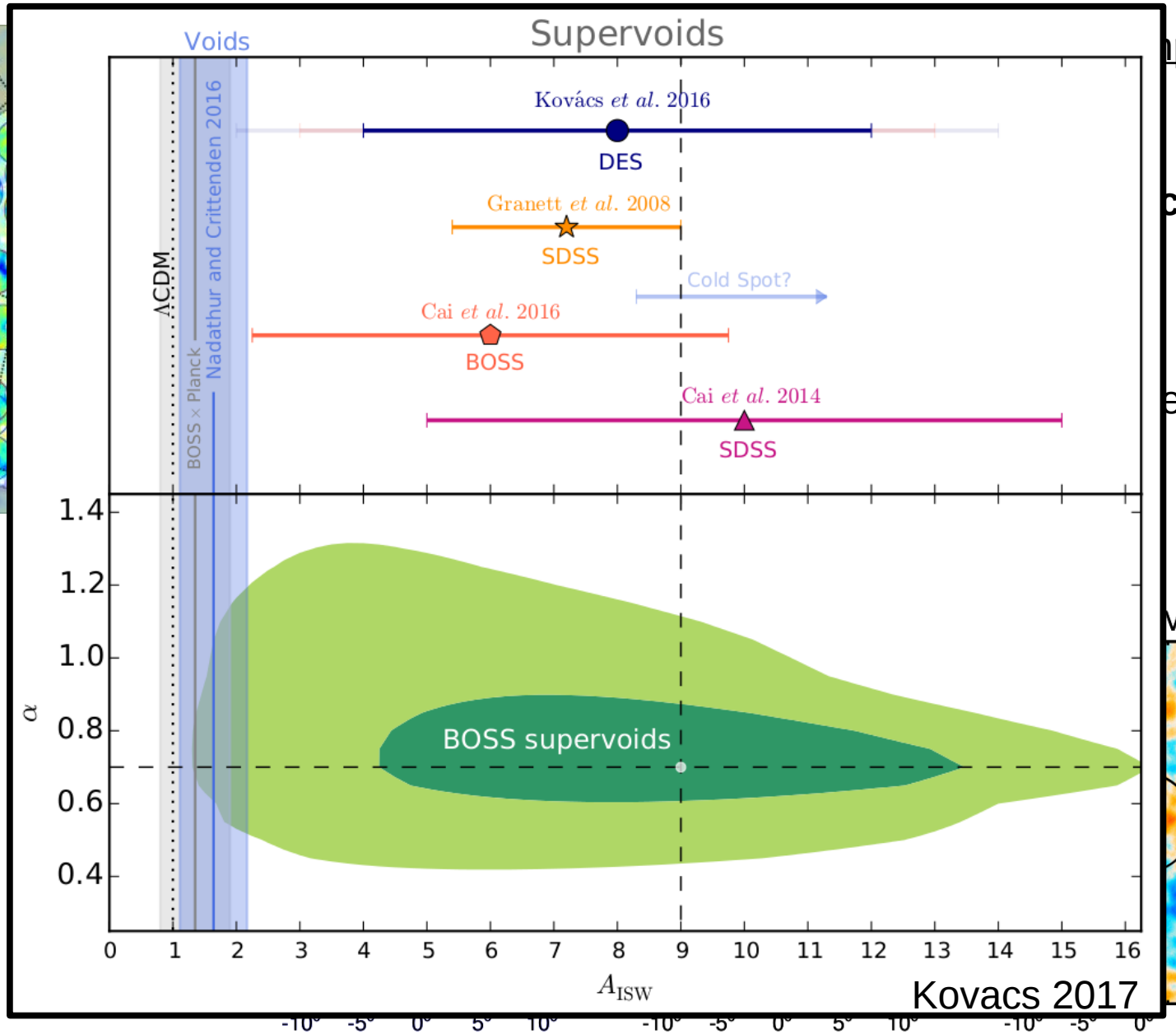
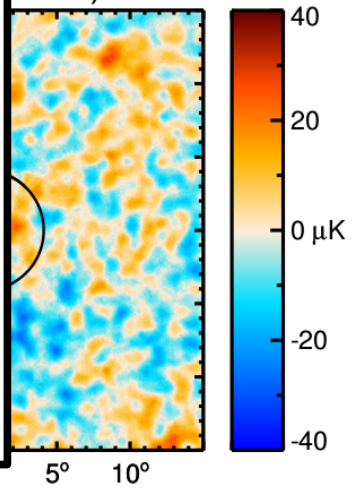
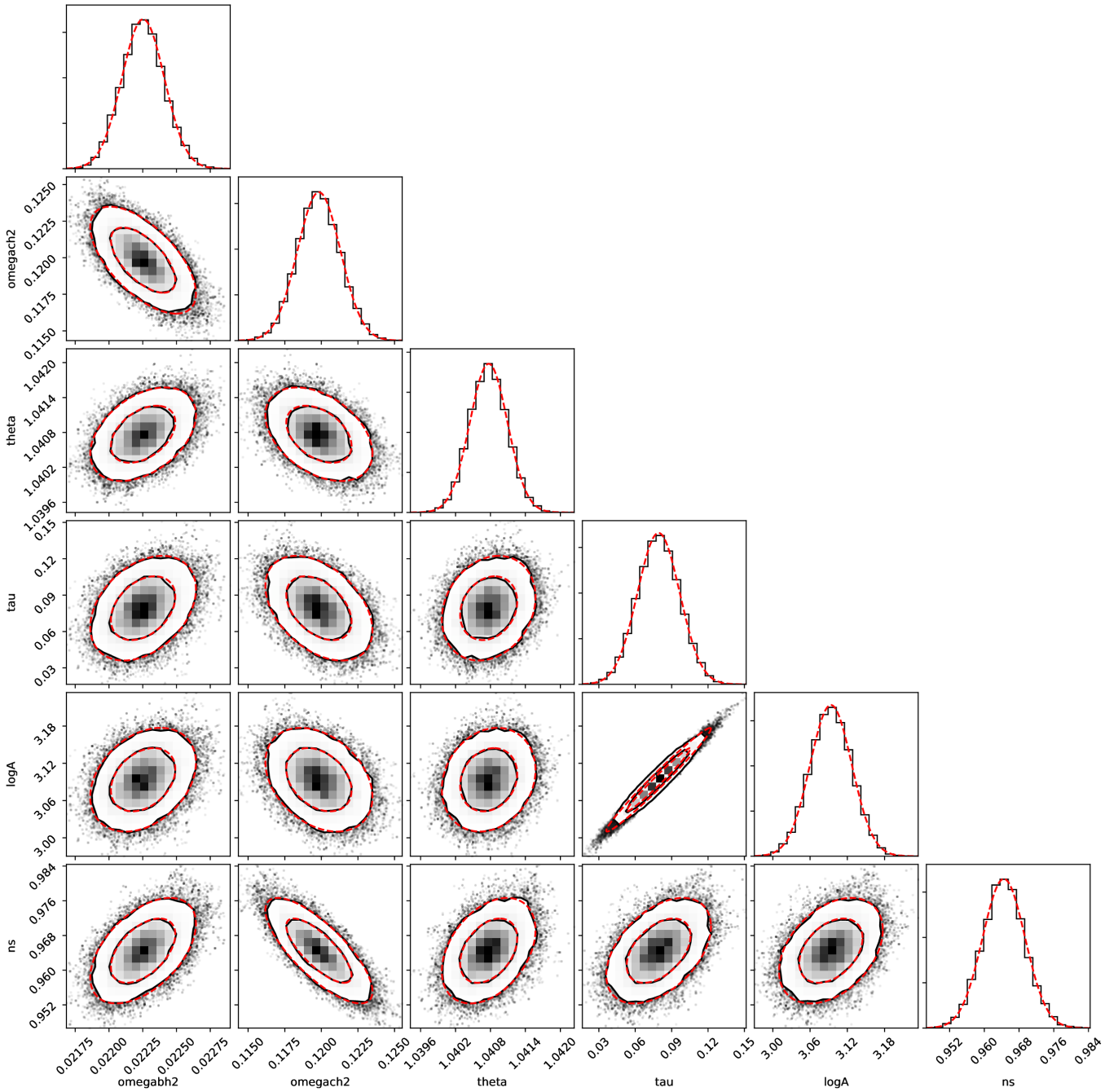






Thank you for your attention !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