D01:
Ultimate Physics Analysis

Eiichiro Komatsu
(Max-Planck-Institut für Astrophysik)
"*Cosmic Acceleration*" Kick-off Meeting
September 21, 2015

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(笑)

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Odeonsplatz


Theatinerkirche


Rathaus


Augstiner am Dom

We are hiring!

can start immediately

- **Munich is a nice place to live and work**
- **Interested in computing, coding, developing tools and softwares?**
- **We want you!**
- **Will issue an announcement soon, but talk to me or send me an email at komatsu@mpa-garching.mpg.de**

Ultimate Physics Analysis (D01)

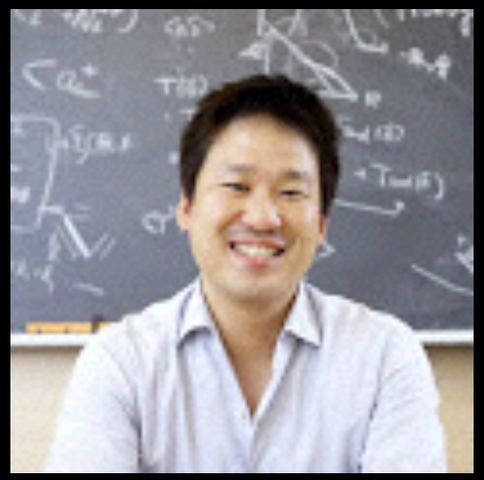
- The keyword is **“Cross-correlation”**

LSS = Large-scale Structure; CMB = Cosmic Microwave Background

D01: The Team

I. Kayo
Tokyo Univ. of Tech

- **LSS**
- **Lensing**



E. Komatsu
MPA

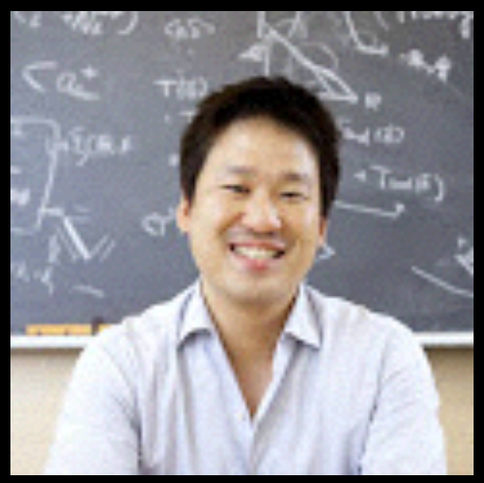
- **LSS**
- **CMB**

K. Takahashi
Kumamoto Univ.

- **LSS**
- **21cm**

LSS = Large-scale Structure; CMB = Cosmic Microwave Background

D01: The Team



I. Kayo
Tokyo Univ. of Tech

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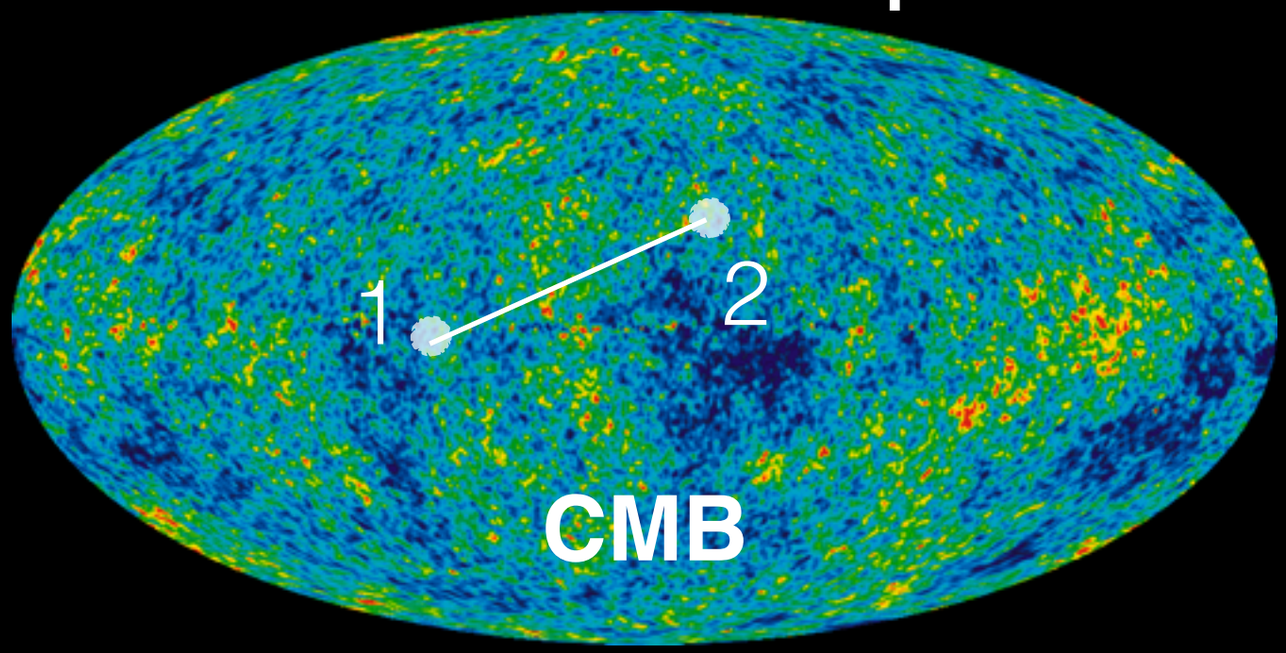
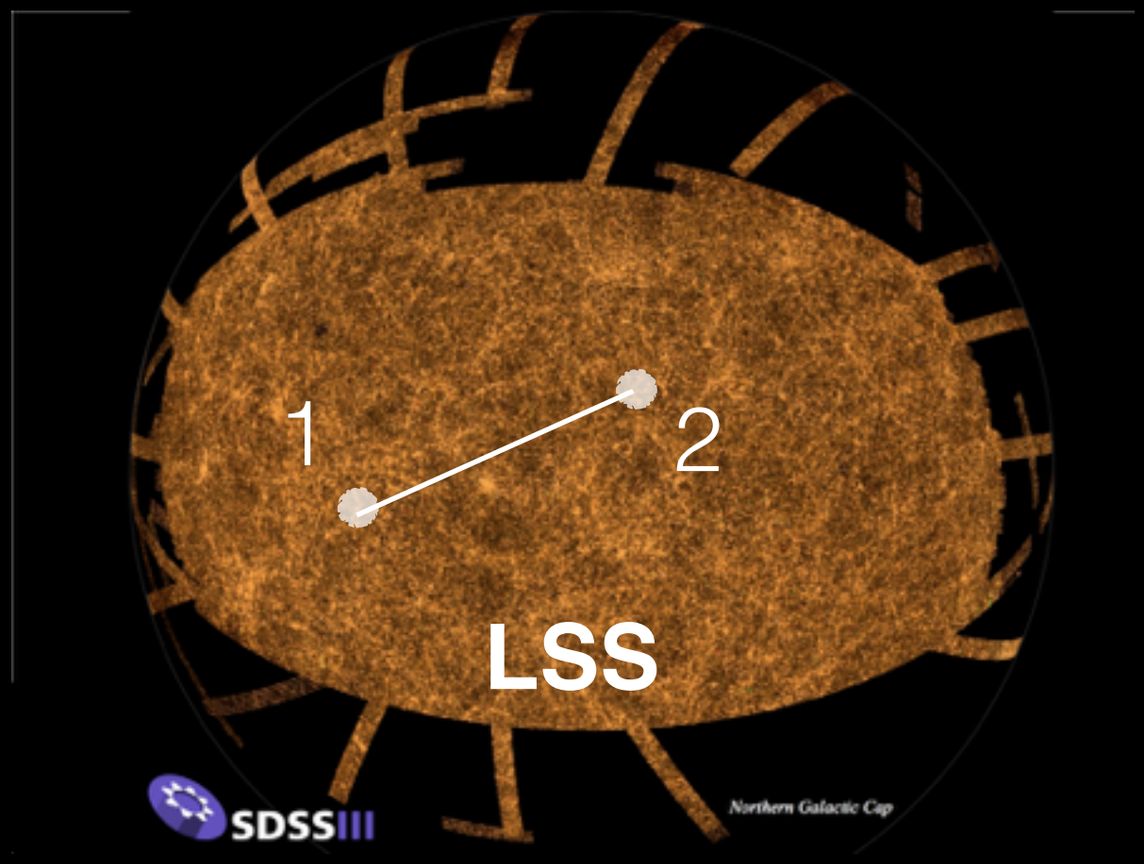
I. Kayo	E. Komatsu	K. Takahashi
• **LSS**	• **LSS**	• **LSS**
• **Lensing**	• **CMB**	• **21cm**

***Joint analysis*, fully taking into account the mutual cross-correlation**

Traditional Method: Auto 2-point Correlation





$T_{CMB}(1) \times T_{CMB}(2)$

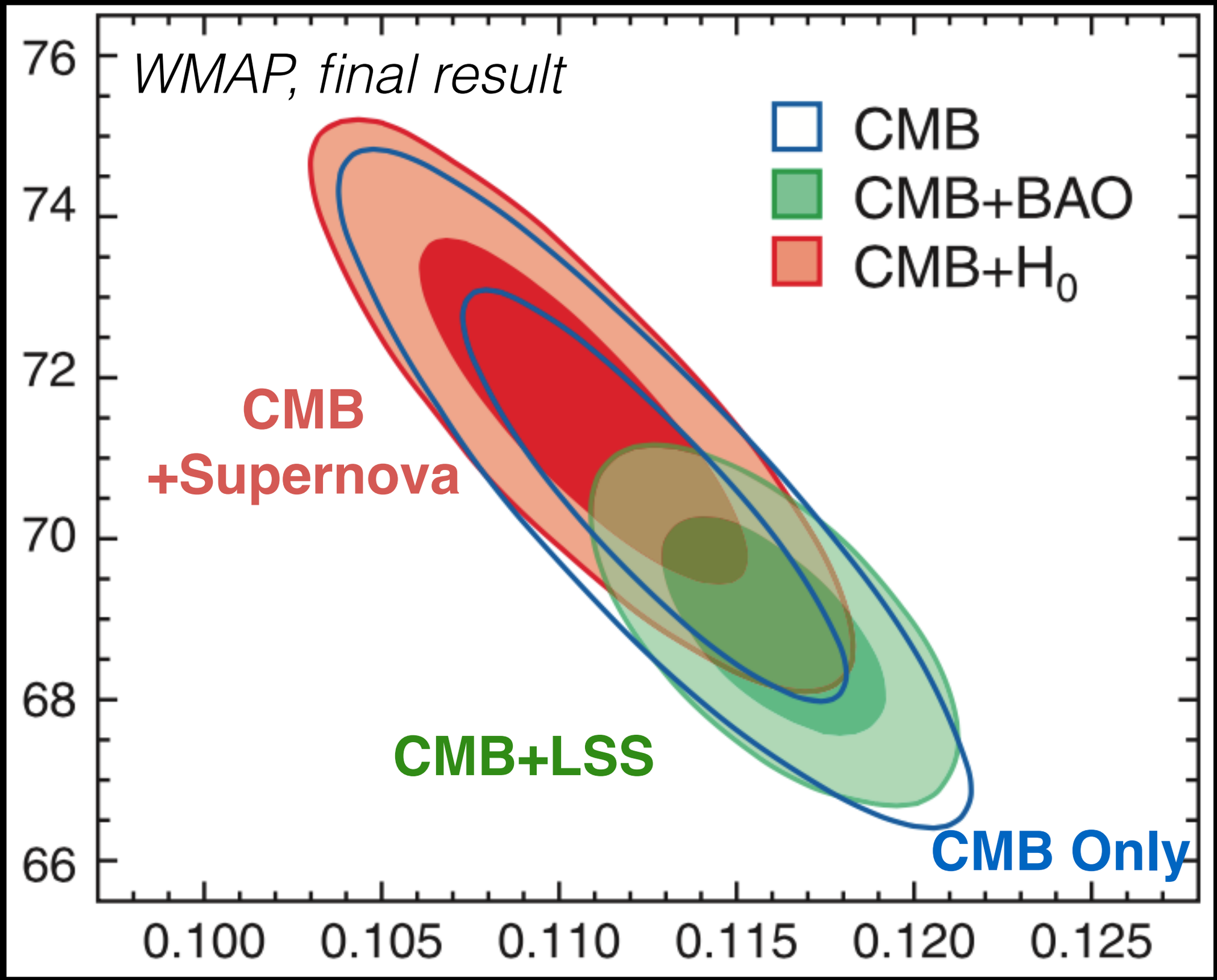
Cosmology

Joint Constraints

Cosmology

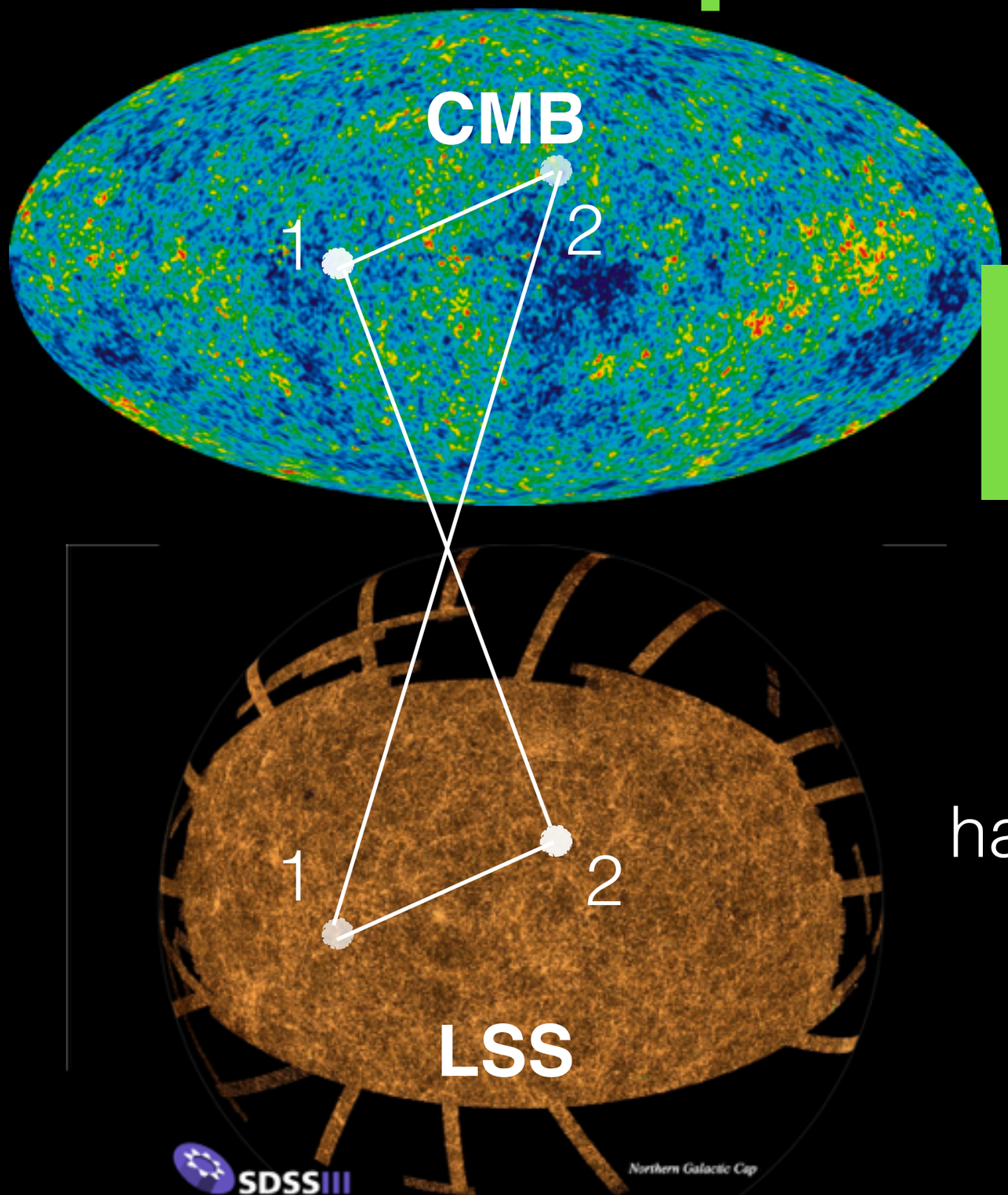
$n_{gal}(1) \times n_{gal}(2)$

Hubble const. H_0 [km/s/Mpc]



Dark Matter Density, $\Omega_c h^2$

Our Approach:
Cross 2-point Correlation



$T_{CMB}(1) \times T_{CMB}(2)$

$T_{CMB}(1) \times n_{gal}(2)$

$n_{gal}(1) \times T_{CMB}(2)$

$n_{gal}(1) \times n_{gal}(2)$

Some cross-correlations
have been considered partially
in the previous study,
but **never systematically**

Bayesian Joint Analysis

- **Joint analysis including all the cross-correlations** between CMB, spectroscopic LSS, and imaging LSS

- let us write the conditional probability of cosmological parameters, given the data X, as **P(parameters|X)**

- Conventional method：P(parameters) =

  P_1(parameters|**CMB**) x P_2(parameters|**specLSS**) x P_3(parameters|**imagingLSS**)

- Our approach：**P(parameters)**

  = P(parameters | CMB, specLSS, imagingLSS)

What creates cross-correlations?

SpecLSS

3D galaxy map
Velocity fields

CMB

Lensed CMB
ISW
Thermal SZ
Kinetic SZ

ImagingLSS

Matter density map

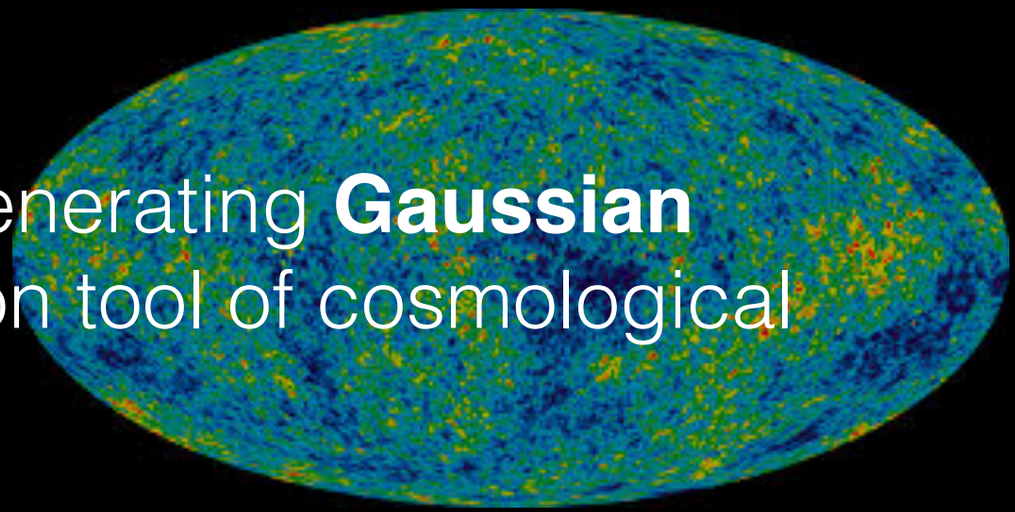
$P(\text{param.}) = P_1(\text{param.}|\text{CMB}) \times P_2(\text{param.}|\text{specLSS}) \times P_3(\text{param.}|\text{imagingLSS})$

P(param.) = P(param. I CMB, specLSS, imagingLSS)

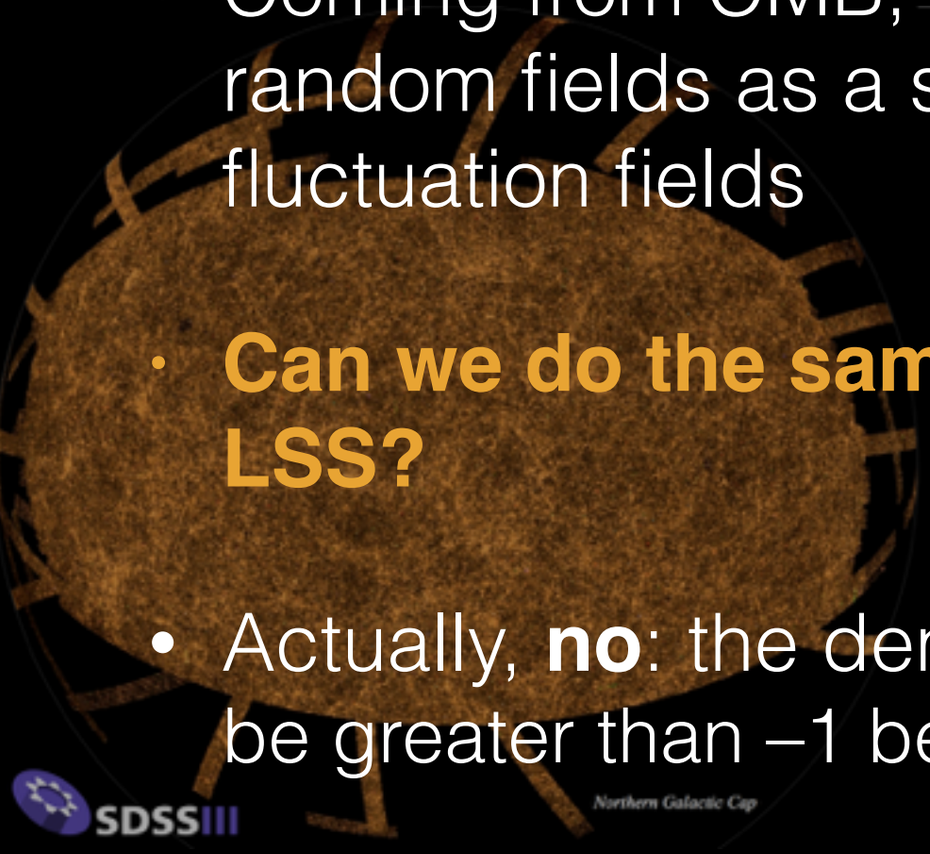
Tool: Log-normal Simulation

- The goal of D01 is to develop tools to determine the cosmological parameters, given the data, including all the cross-correlations
- To do this, we need simulations that we understand completely

Tool: Log-normal Simulation



- Coming from CMB, I am used to generating **Gaussian** random fields as a simple simulation tool of cosmological fluctuation fields

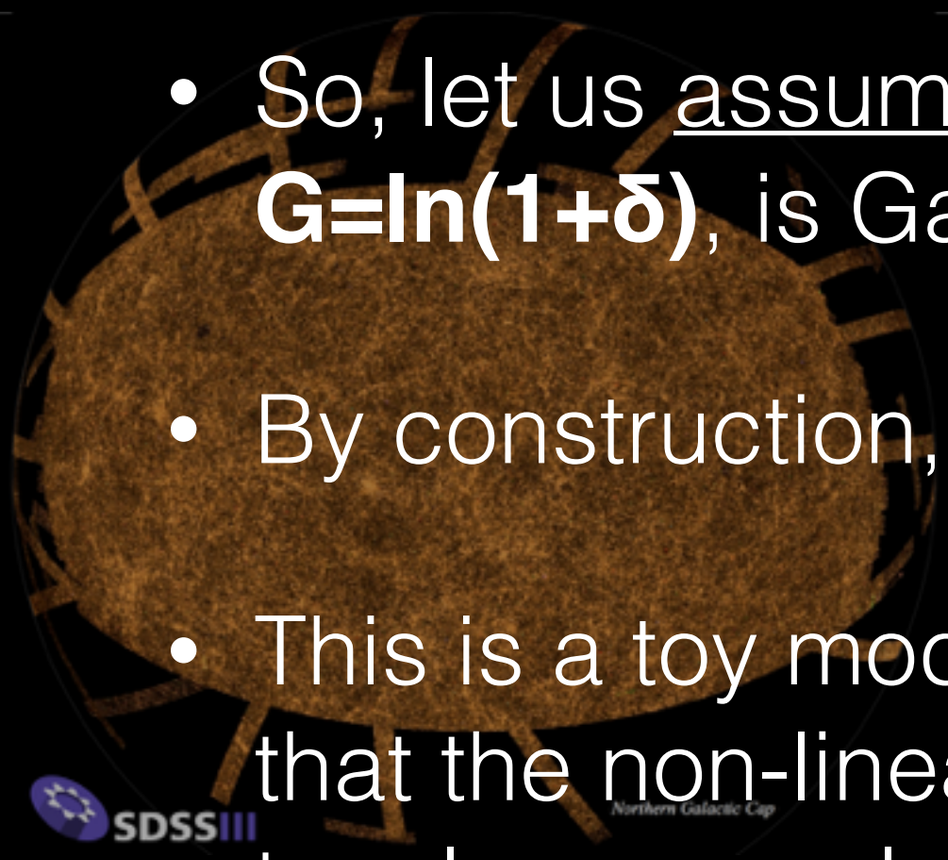


- **Can we do the same for generating density fields of LSS?**

- Actually, **no**: the density fluctuation field, $\delta=\rho/\rho_{mean}-1$, must be greater than -1 because the density, ρ, must be positive

- For LSS, the variance of δ is of order unity or greater. Therefore, a Gaussian distribution gives regions with $\delta<-1$, which is unphysical

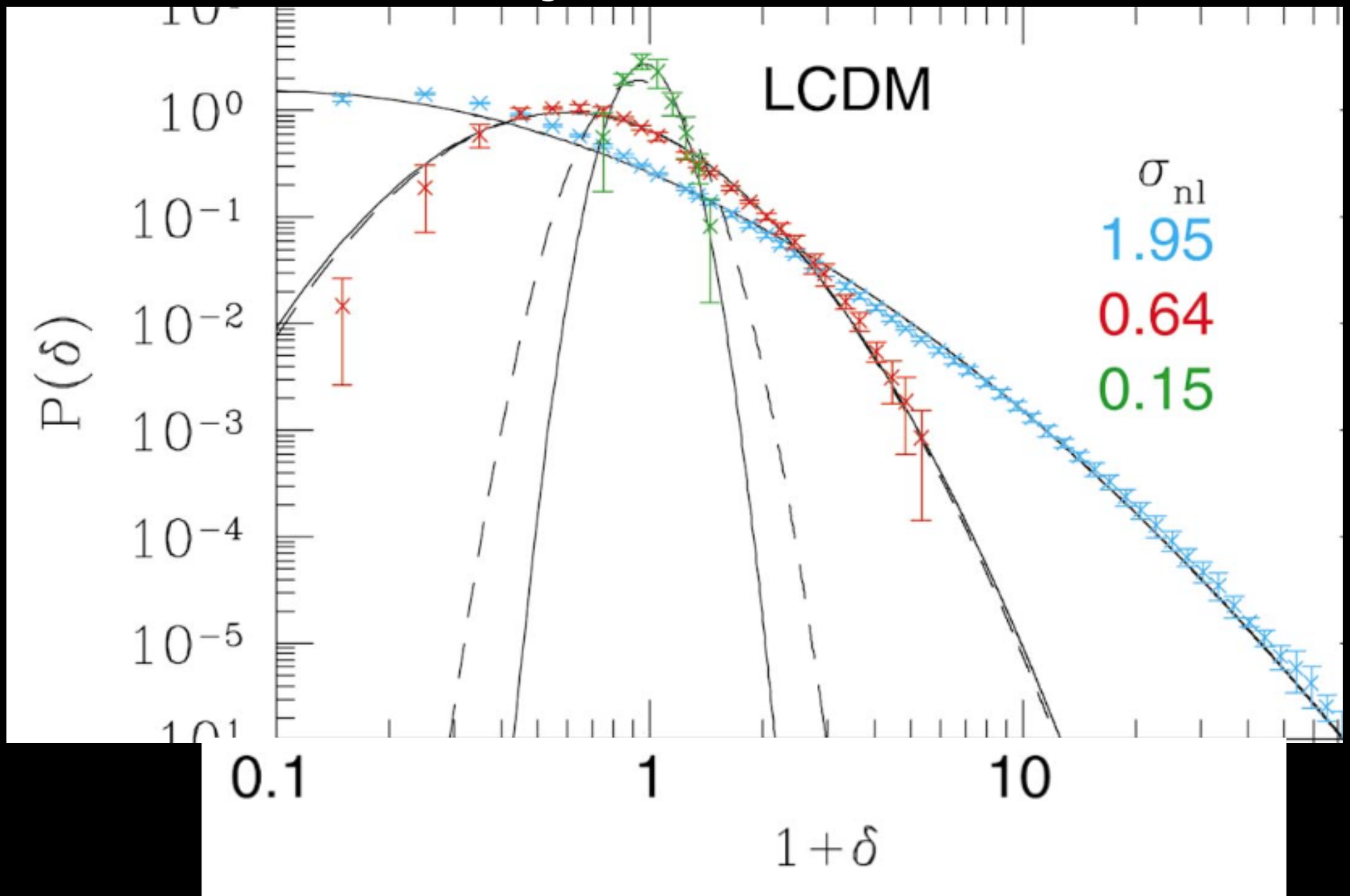
Tool: Log-normal Simulation



- So, let us <u>assume</u> that a logarithm of δ, **G=ln(1+δ)**, is Gaussian, instead of δ itself
- By construction, **δ=exp(G)–1≧–1** is satisfied
- This is a toy model, but N-body simulations show that the non-linear, evolved density field is close to a log-normal distribution, as shown by **Kayo, Taruya and Suto (2001)**

Kayo, Taruya & Suto (2001)

Log-normal Distribution from N-body Simulation



Log-normal Simulation?

- Everyone is running N-body and/or hydro simulations. Why log-normal simulation now?

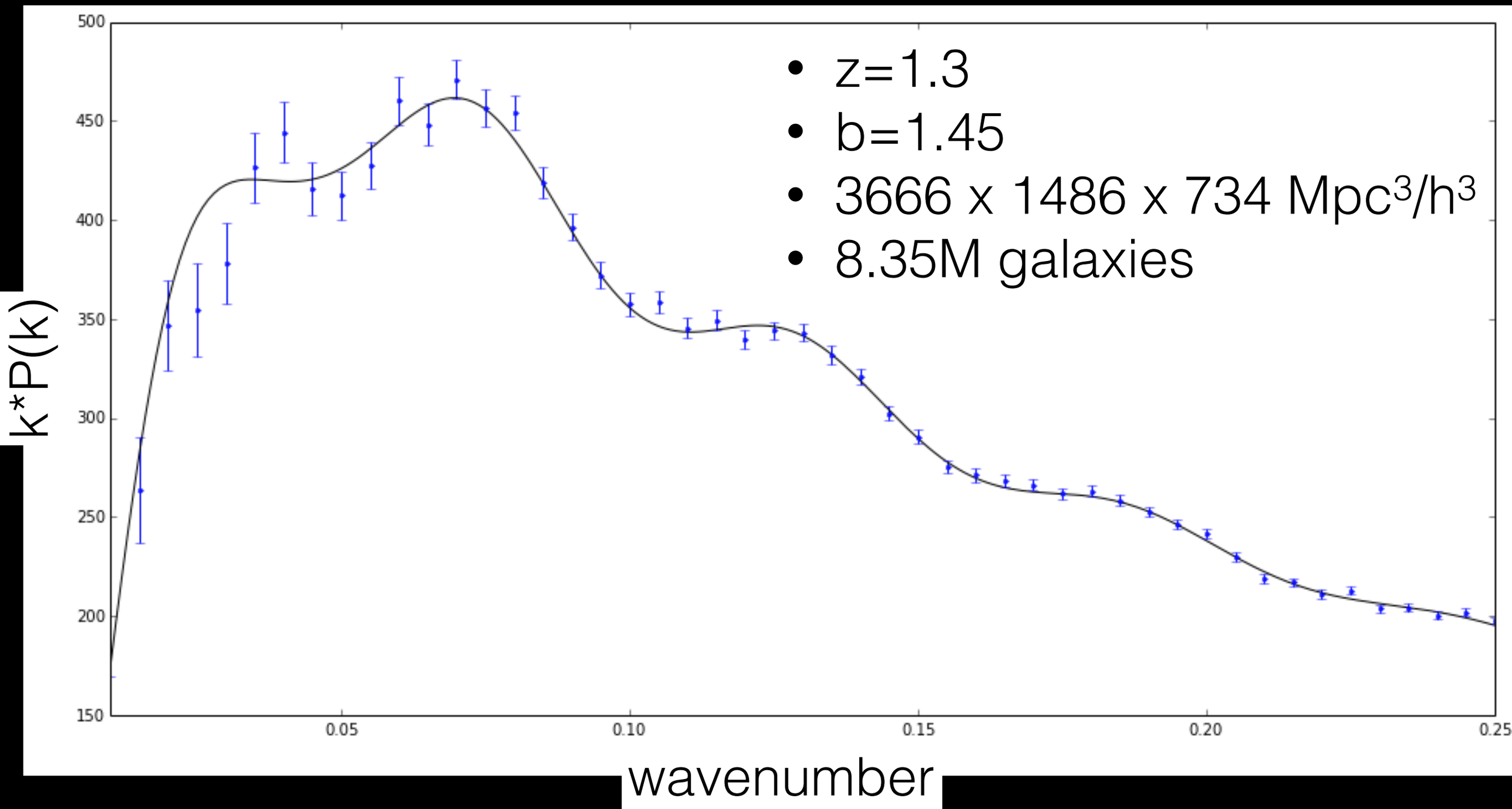
- The physics inputs to N-body/hydro sims are known, but the outcome is not known because of non-linearities

- This will be a problem when we develop tools to infer the parameters: lack of precision model to fit the data

Tool:Log-normal Simulation

- But, we know precisely what the outcome of log-normal simulation is. We can fit the log-normal simulation data with no model uncertainty
- Understanding the non-linear physics is of course important but it is a separate question, which will be addressed by the other group, e.g., Sugiyama-san's A03. **Complementarity**

Example



- z=1.3
- b=1.45
- 3666 x 1486 x 734 Mpc^3/h^3
- 8.35M galaxies

- Average of **500** realisations

Work Plan

Log-normal Simulation
(in hand)

Lensing map (Kayo)

Galaxy distribution (in hand)

CMB T&P (Komatsu)

21cm (Takahashi)

P(parameters) = P(parameters | all data)

(Komatsu, Kayo, Takahashi, and **YOU**)

Why should you apply for our advertised postdoc position?

- With this work, you can enhance skills for the software development, and analysis of many of the on-going and future observational data (not just one)

- 手に職 “Have a marketable skill”

- This is precisely the area in which the Japanese community has relative weakness. **You can fill the gap!**