

THE SIXTH ZEL'DOVICH MEETING

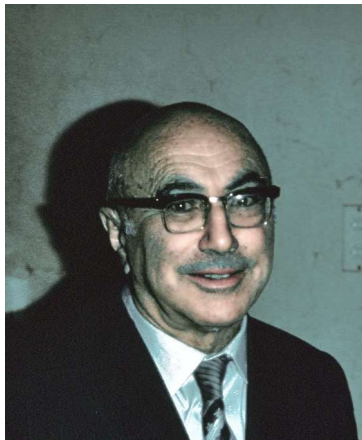


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천문학전공

Constraining Inflation Models with spinning voids

GeonWoo Kang, Jounghun Lee

[arxiv 2601.06589](#)



Yakov Borisovich
Zel'dovich



Sergei Fedorovich
Shandarin



Jounghun Lee



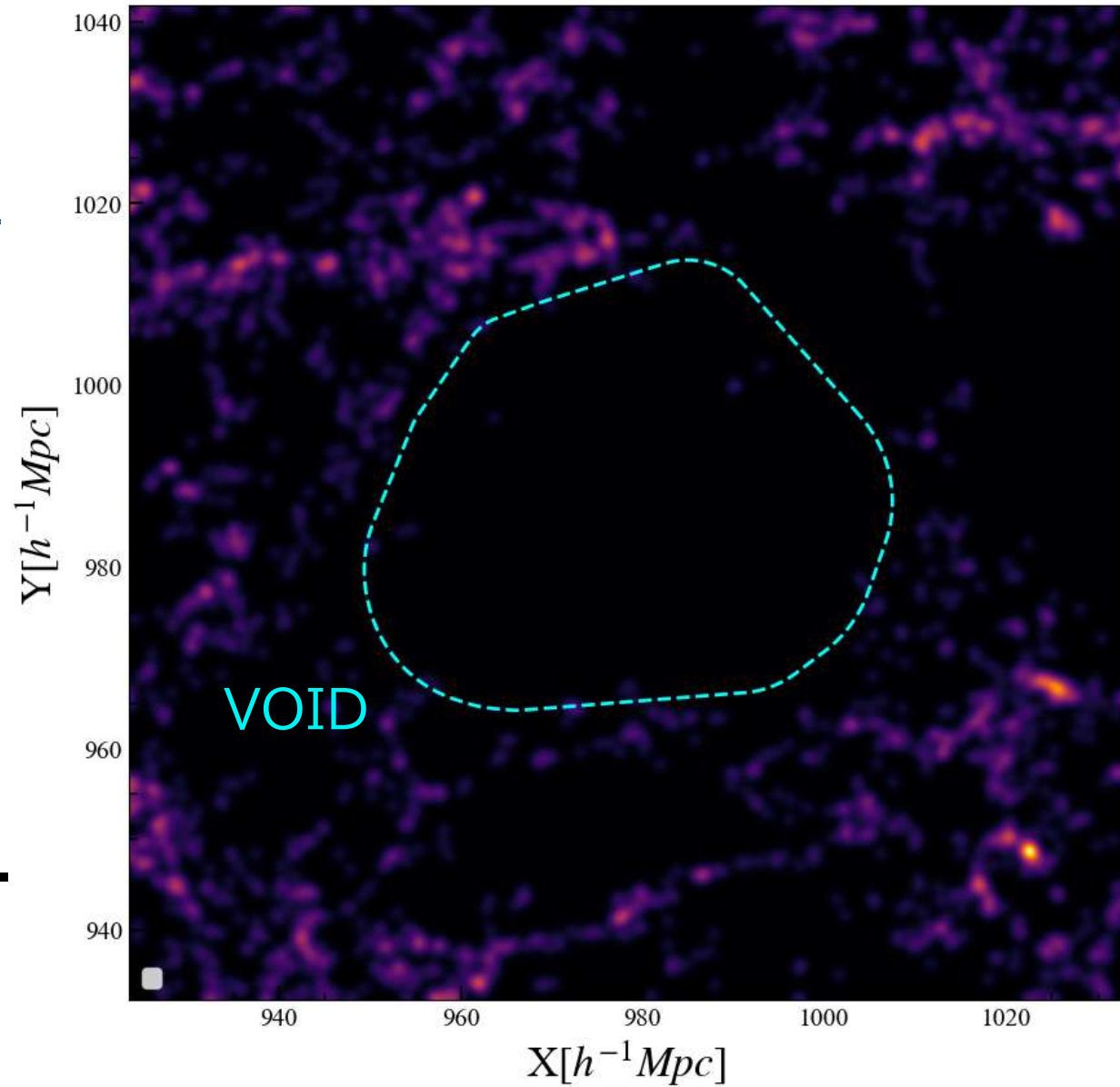
Geonwoo Kang

authors

Voids?

Largest, extremely underdense regions surrounded by filaments and sheets,

Ideal for probing initial conditions and cosmological parameters.



A Void from AbacusSummit c000 By Kang

Running of the scalar spectral index α_s

$$\alpha_s = \frac{dn_s}{d \ln k}$$

$$\alpha_s < 0$$

eBOSS Lyman-alpha forest constraint

$$\alpha_s = -0.0108 \pm 0.0022$$

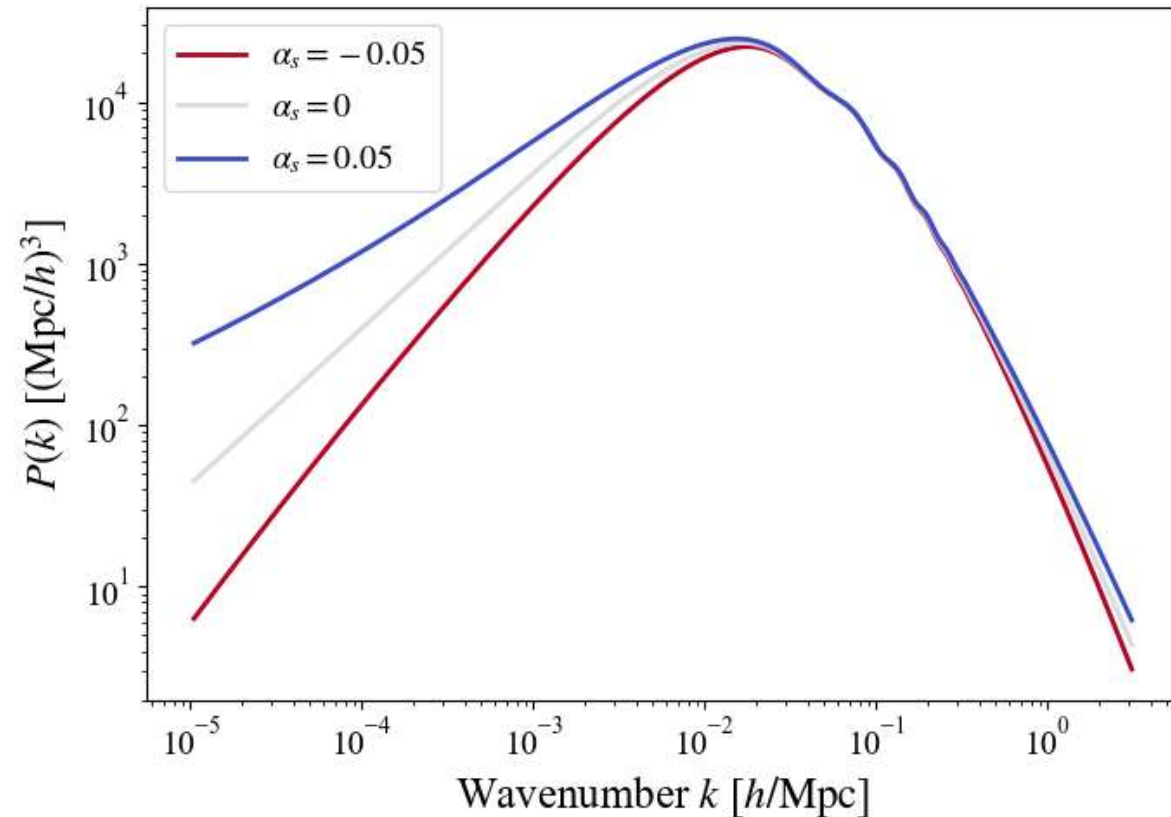
Rogers & Poulin (2025)

$$\alpha_s > 0$$

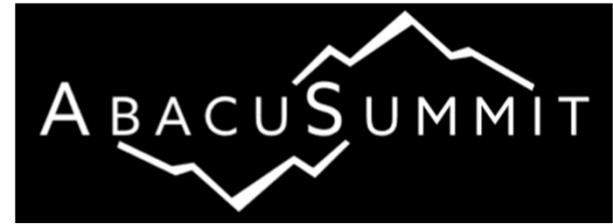
ACT DR6 CMB power spectra constraint

$$\begin{aligned} dn_s/d \ln k &= 0.0060 \pm 0.0055 \quad (68\%, \text{P-ACT}), \\ &= 0.0062 \pm 0.0052 \quad (68\%, \text{P-ACT-LB}). \quad (2) \end{aligned}$$

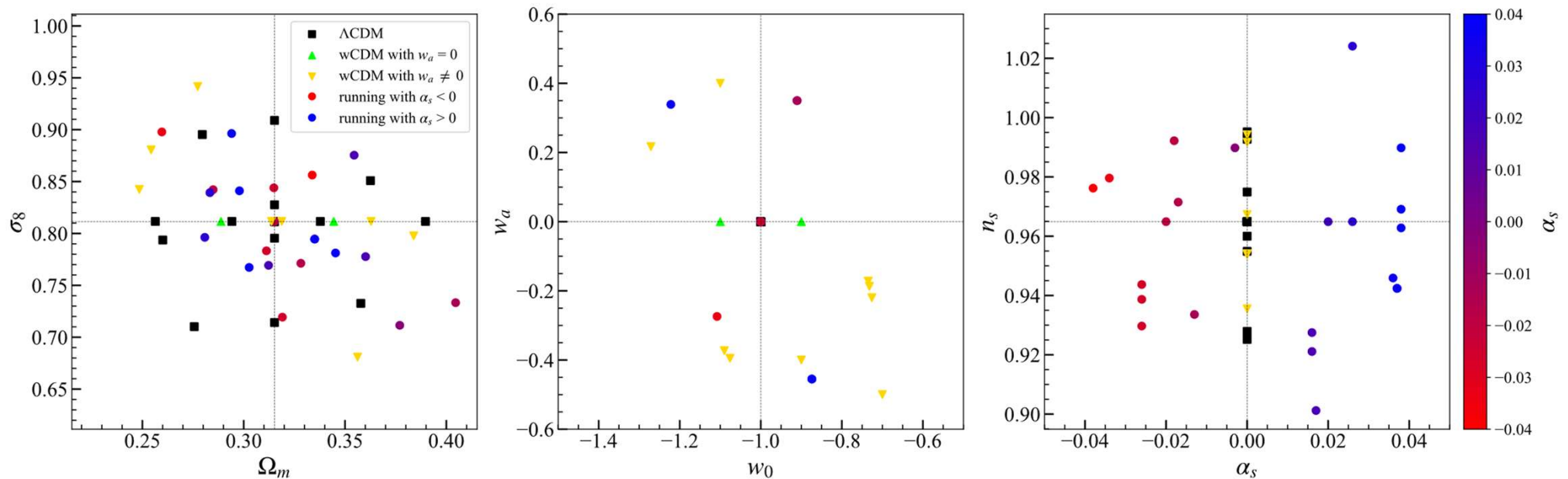
Calabrese et al. (2025)



Raw data - AbacusSummit



We choose **49 cosmologies** including Planck 2018
In total of 16 LCDM, 11 wCDM, 22 running model.



And used only $\log m_h > 11.5$ halos

Void identification

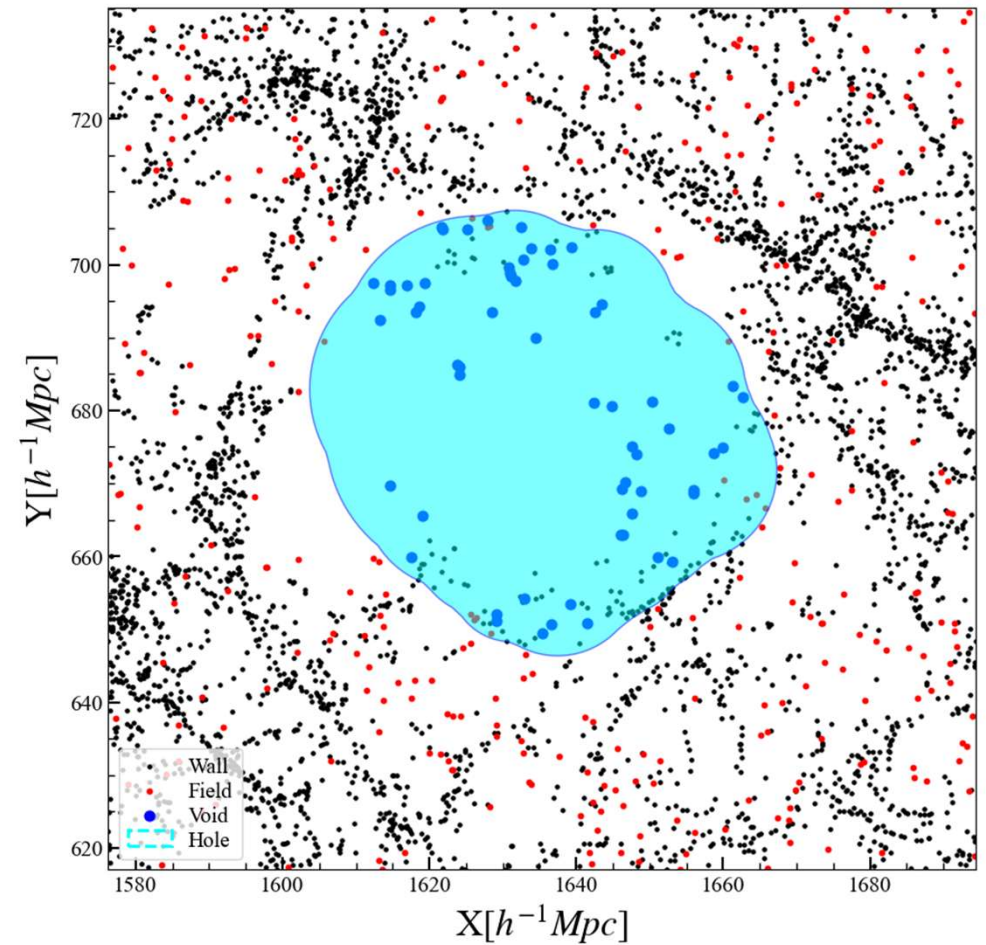
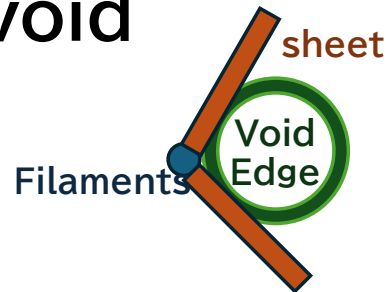
Hoyle & Vogeley (2002)

Voidfinder algorithm

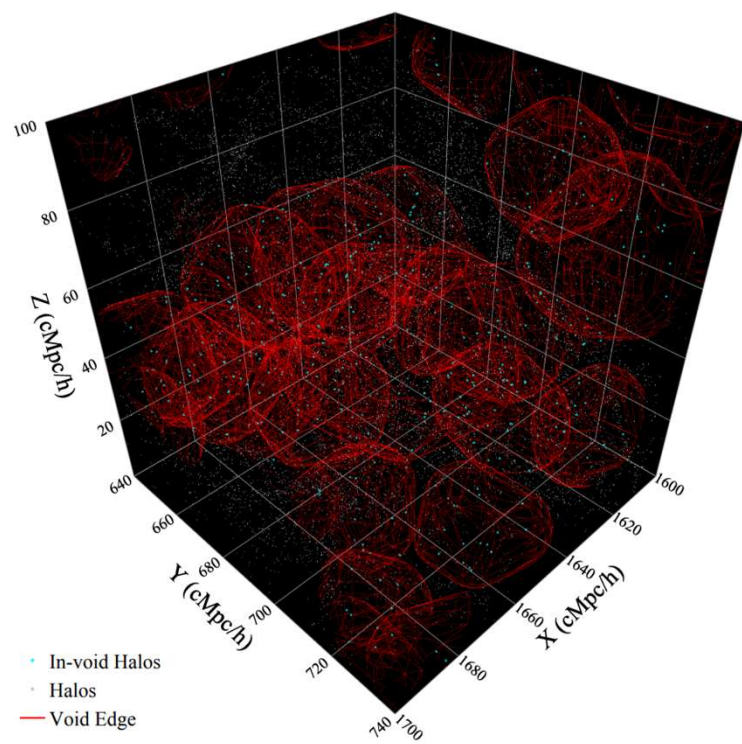
Precise underdense criteria

Works well on **observational**
data

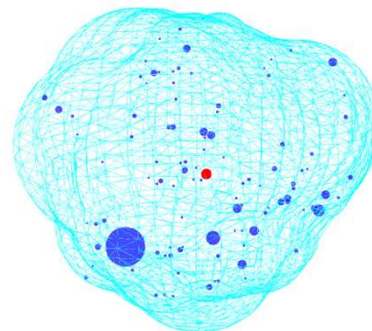
Reveals **complex void**
structures



VoidFinder Algorithm, by Kang

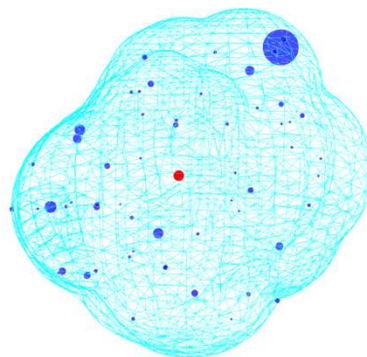


$R_{\text{eff}} = 30.32 \text{ h}^{-1} \text{ Mpc}$
 $n_h = 108$
 $\delta_v = -0.92$



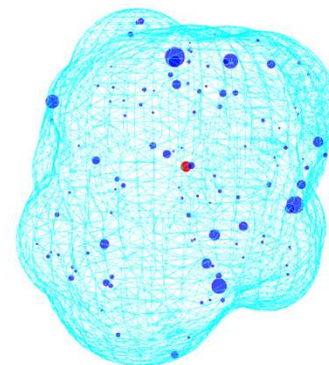
• Void Center
• Halos in Void
— Void Outline

$R_{\text{eff}} = 22.67 \text{ h}^{-1} \text{ Mpc}$
 $n_h = 58$
 $\delta_v = -0.90$



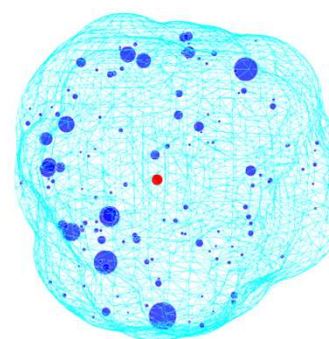
• Void Center
• Halos in Void
— Void Outline

$R_{\text{eff}} = 27.92 \text{ h}^{-1} \text{ Mpc}$
 $n_h = 114$
 $\delta_v = -0.90$



• Void Center
• Halos in Void
— Void Outline

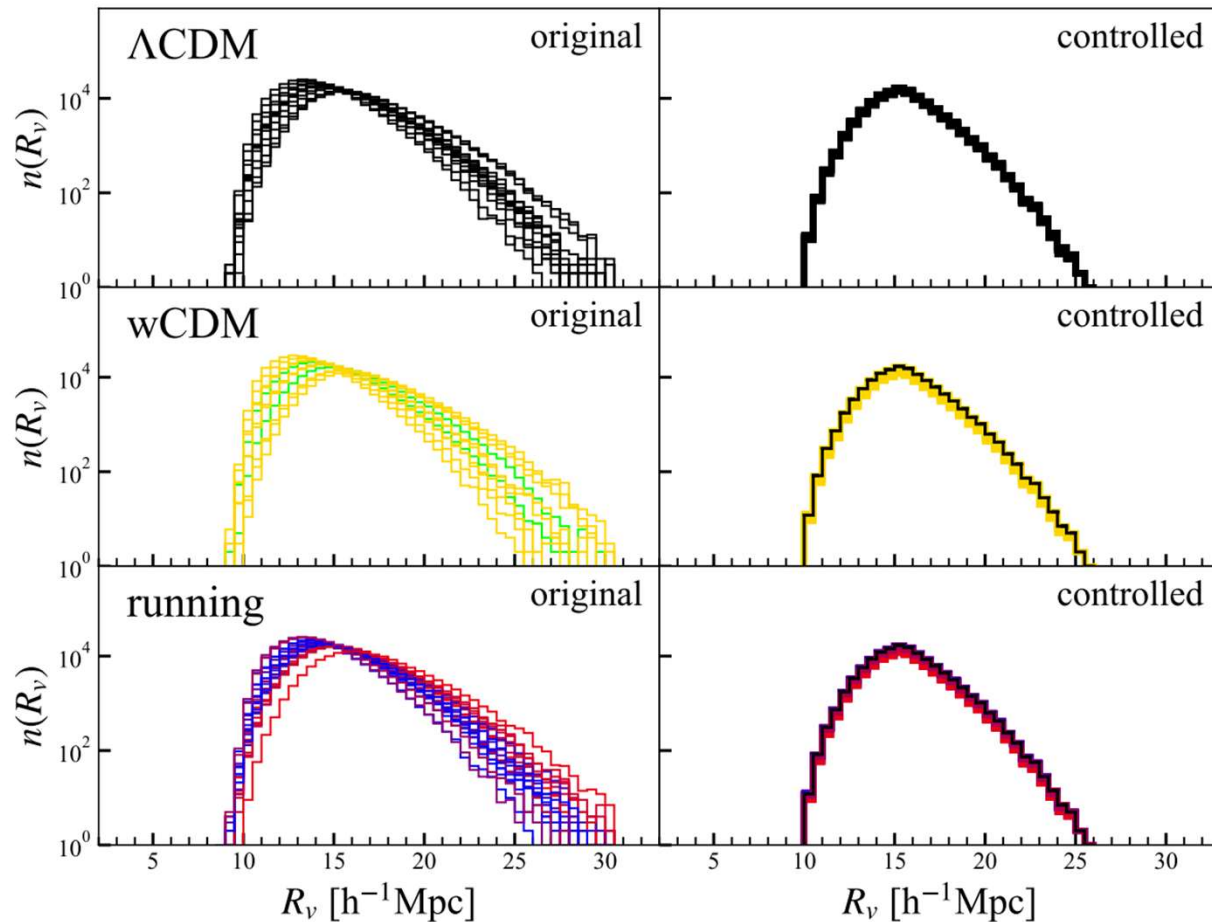
$R_{\text{eff}} = 32.05 \text{ h}^{-1} \text{ Mpc}$
 $n_h = 136$
 $\delta_v = -0.92$



• Void Center
• Halos in Void
— Void Outline

Void distribution and shape from AbacusSummit c000, by Kang

Void size distribution control



To isolate the pure cosmological signal without size dependence we generated **R_v -controlled** void samples

This guarantees that any observed differences are driven entirely by the **background cosmology**, not by **variations in void size distributions**.

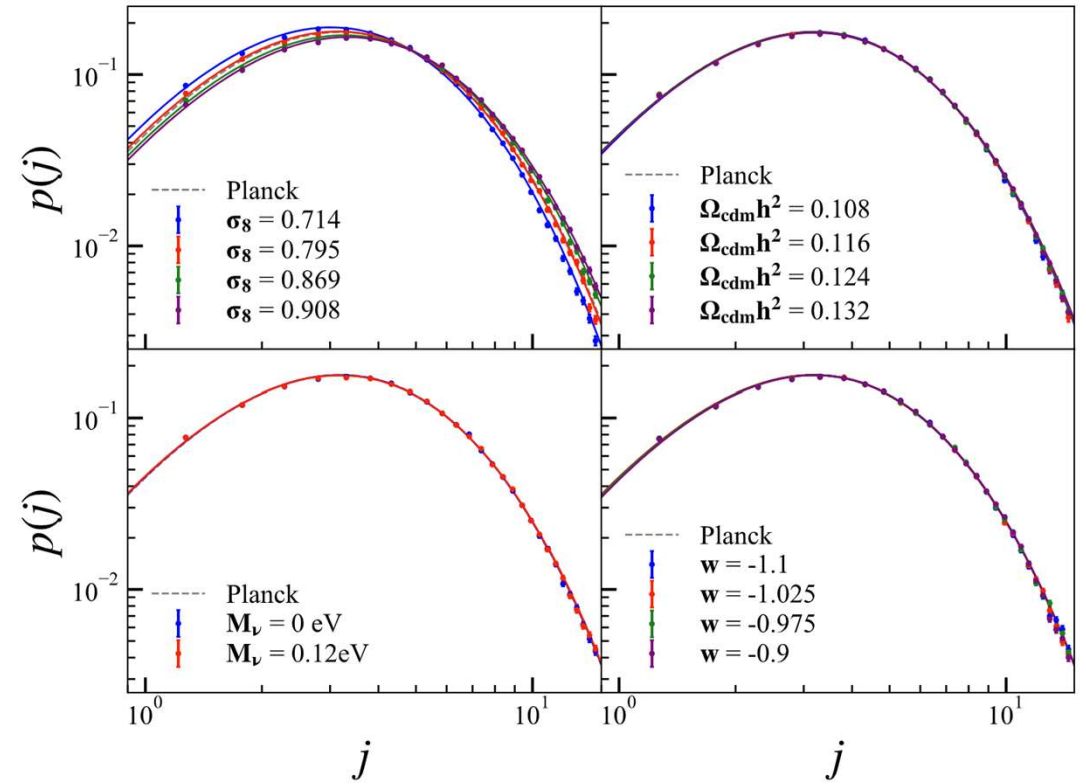
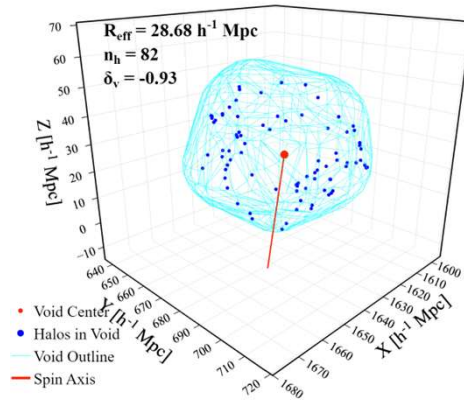
Void spin

$$\mathbf{j} \equiv \frac{1}{\sqrt{2}(V_v R_{eff})} \sum_{i=1}^{n_h} (\mathbf{x}_i - \mathbf{x}_c) \times (\mathbf{v}_i - \mathbf{v}_c) ,$$

$$p(j) = \frac{(j)^{k-1}}{2\Gamma(2k)\theta^k} \exp \left[- \left(\frac{j}{\theta} \right)^{\frac{1}{2}} \right]$$



Arxiv 2501.09476

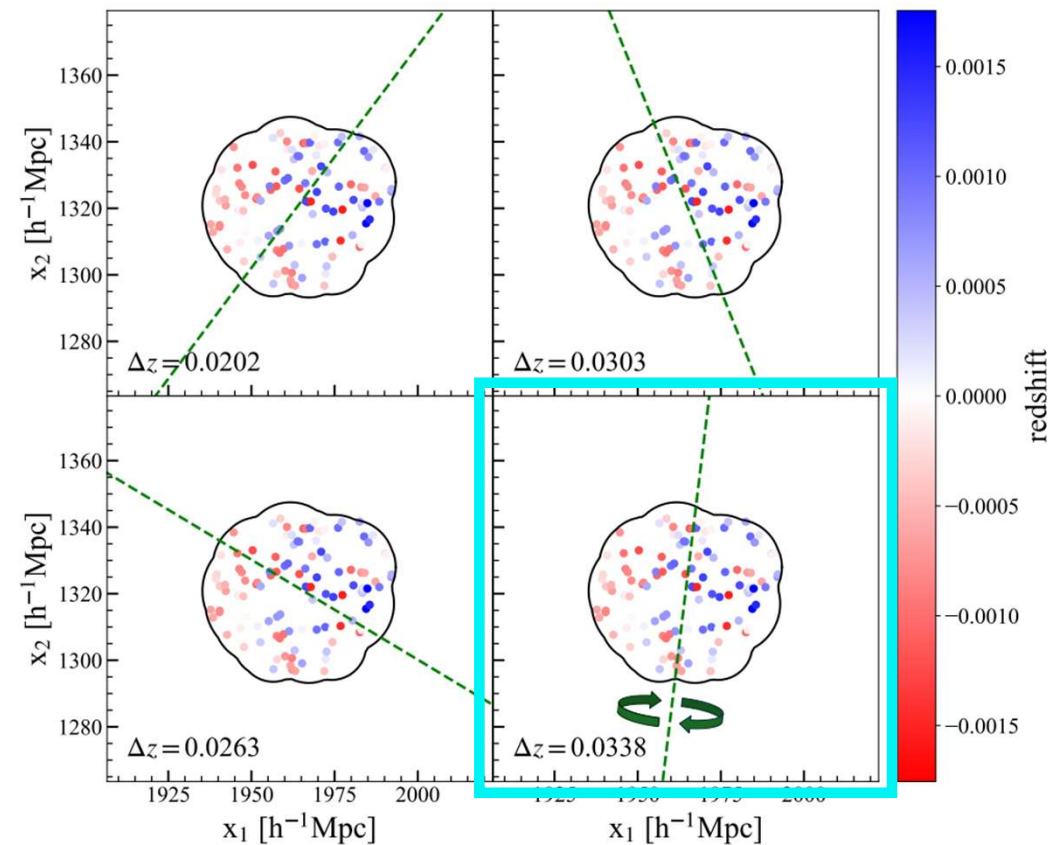


Kang&Lee(JCAP, 2025)

Redshift asymmetry Δz_{max}

$$\Delta z = \frac{1}{2} \left| \sum_{\beta=1}^N \sigma_{\beta} v_{\beta} \right|$$

Find $\hat{d}$ that
Maximize Δz



Redshift asymmetry distribution

Redshift asymmetry

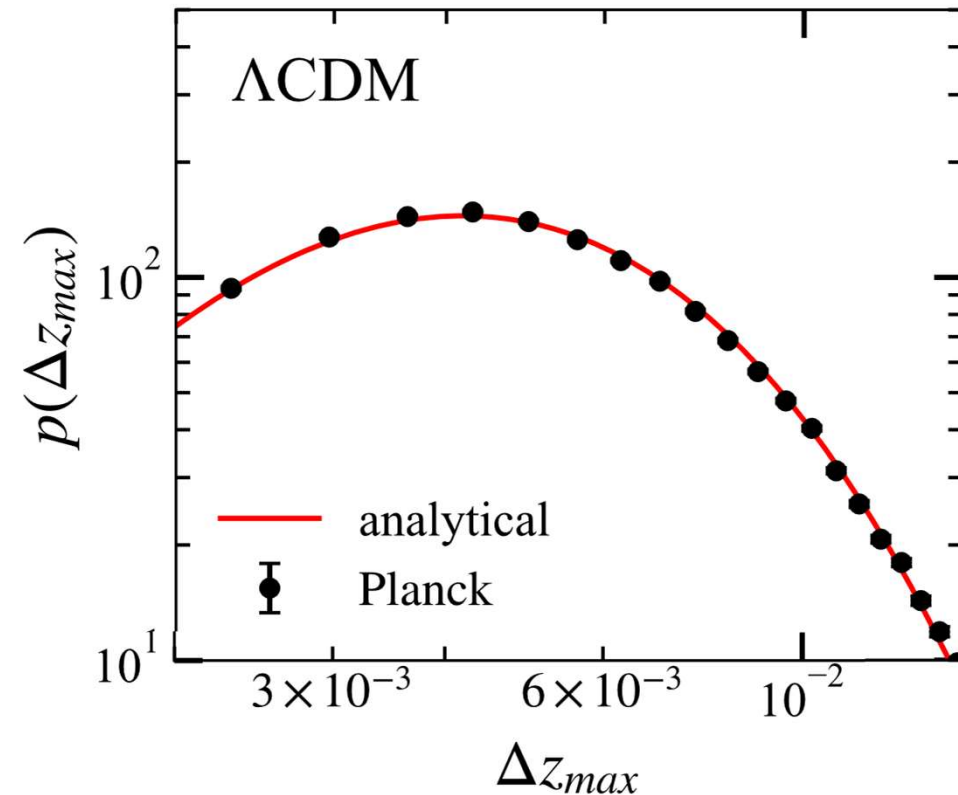
with

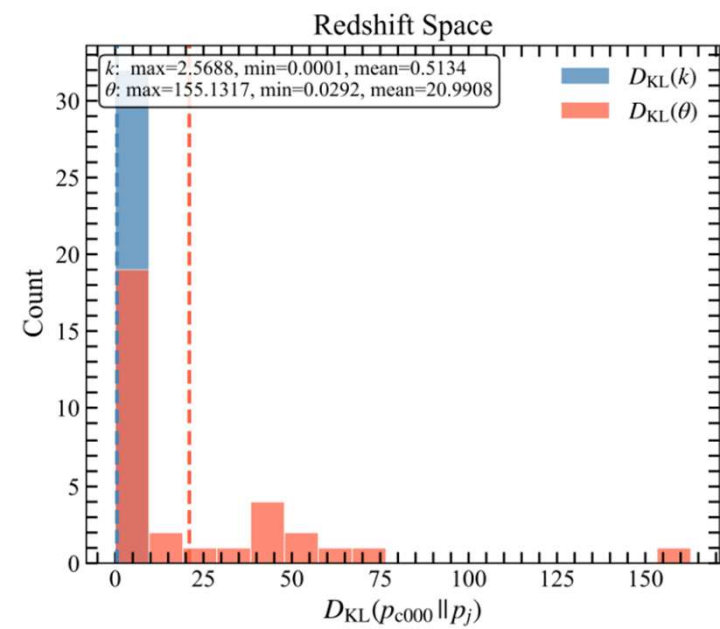
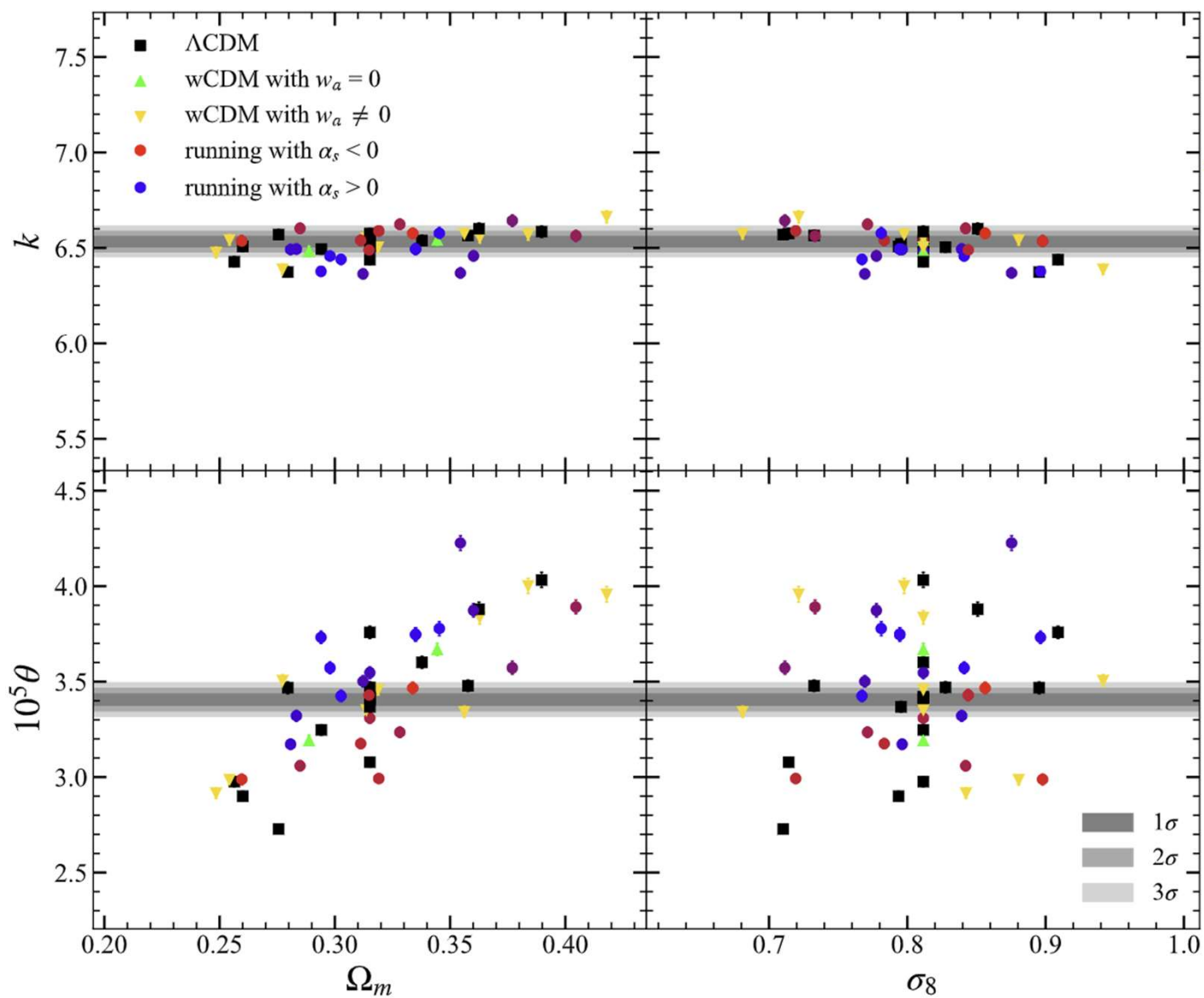
Generalized gamma distribution

With two parameters $\{k, \theta\}$

$$p(\Delta z_{\max}) = \frac{(\Delta z_{\max})^{k-1}}{2\Gamma(2k)\theta^k} \exp\left[-\left(\frac{\Delta z_{\max}}{\theta}\right)^{\frac{1}{2}}\right]$$

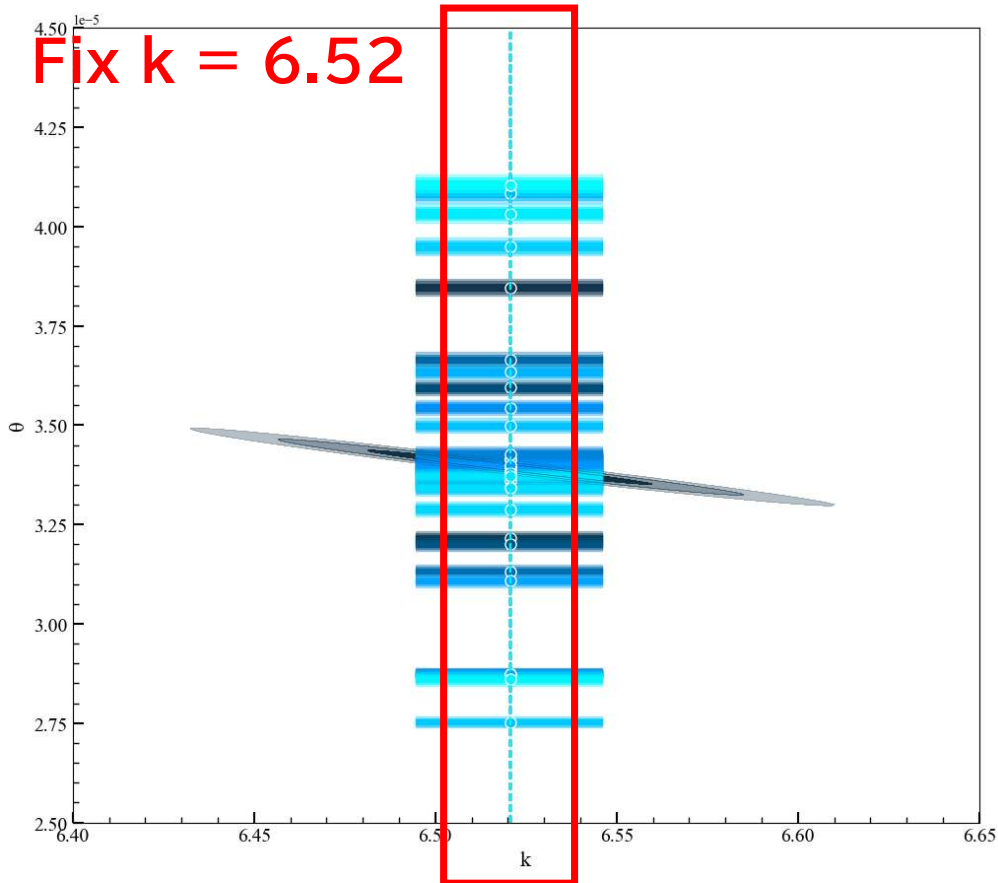
$$\Gamma(2k) \equiv \int_0^\infty dt t^{2k-1} e^{-t}$$



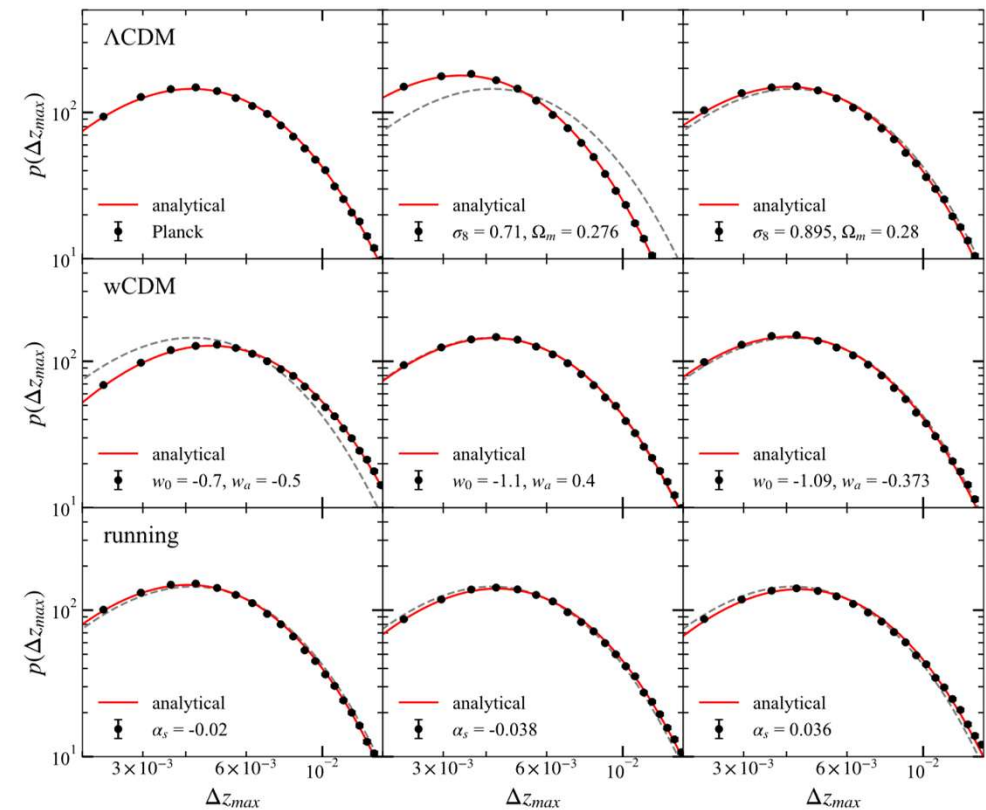


Now, We have
Single-parameter model
 for redshift asymmetry

$$p(\Delta z_{\max}) = \frac{\Delta z_{\max}^{5.53}}{1.13 \times 10^9 \theta^{6.53}} \exp \left[- \left(\frac{\Delta z_{\max}}{\theta} \right)^{\frac{1}{2}} \right]$$



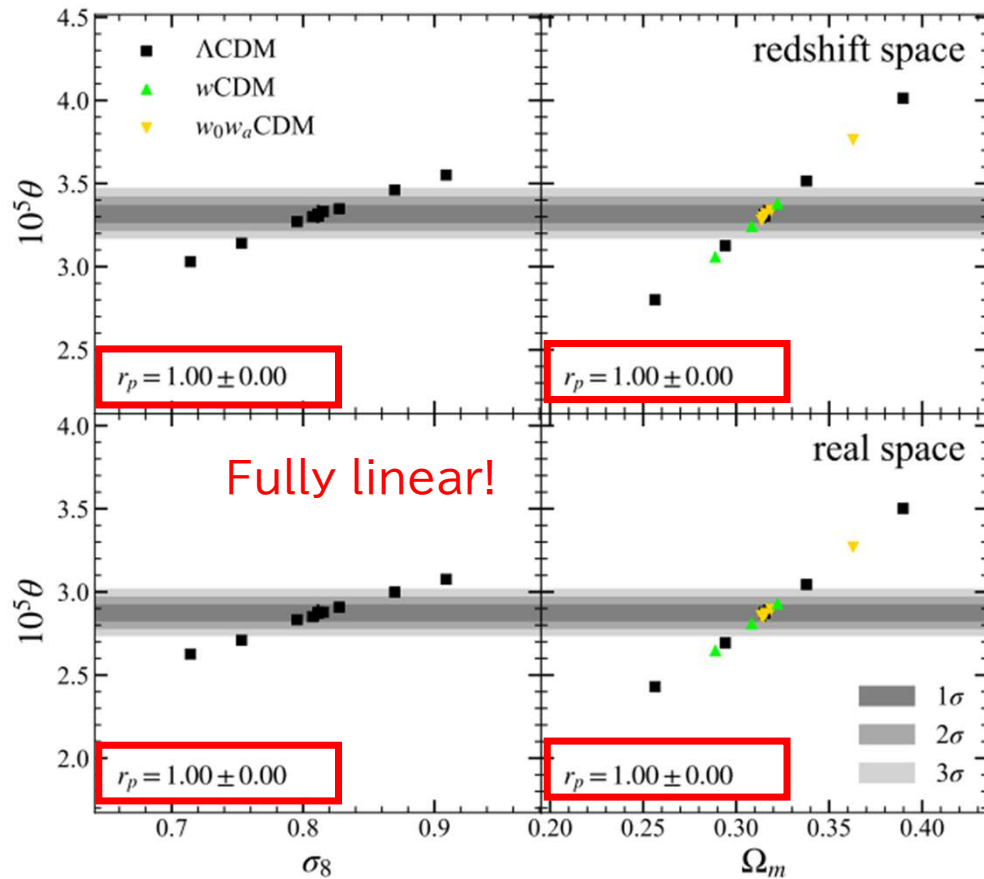
Which could **universally fit** various models
 with **high precision**



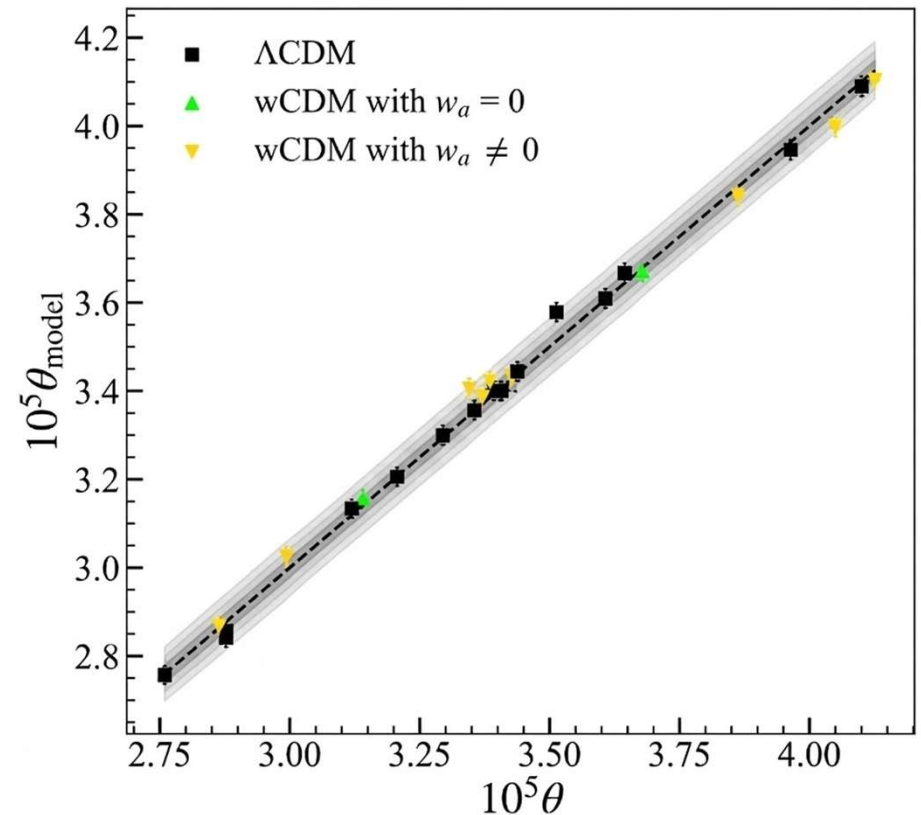
Making bilinear model

Depending on Ω_m and σ_8

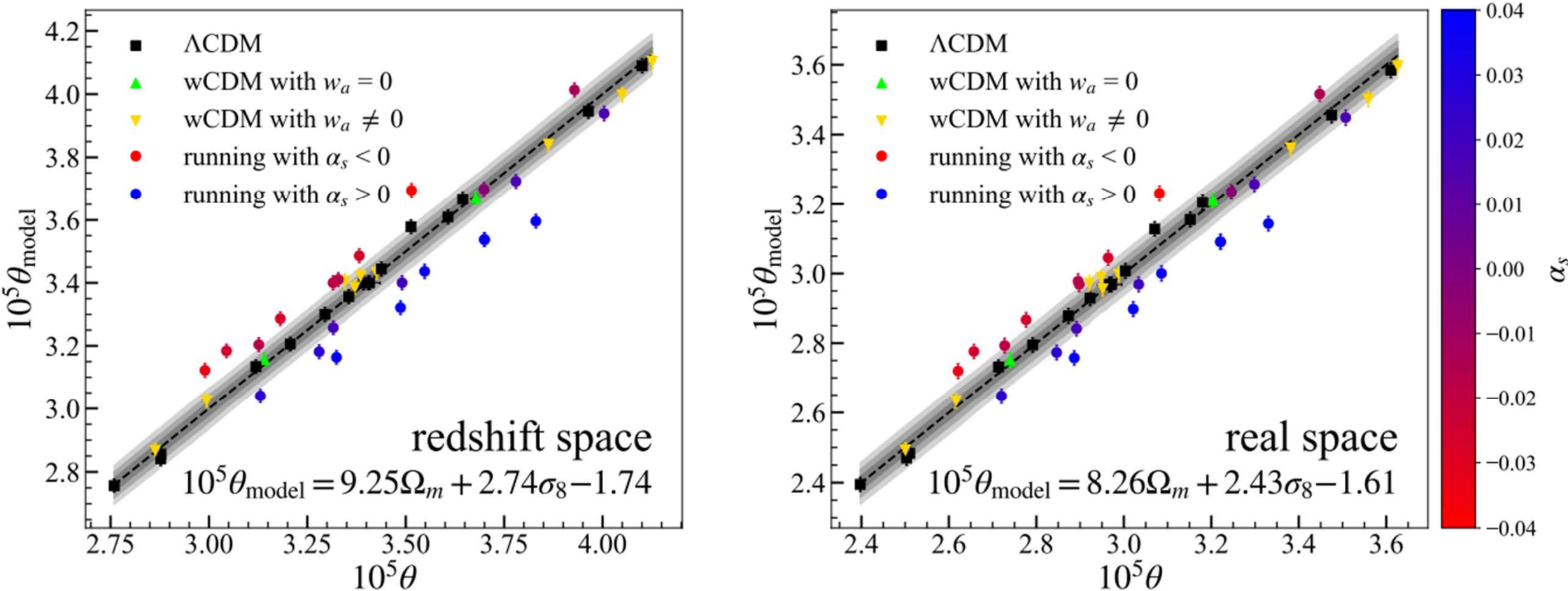
$$p(\Delta z_{\max}) = \frac{\Delta z_{\max}^{5.53}}{1.13 \times 10^9 \theta^{6.53}} \exp \left[- \left(\frac{\Delta z_{\max}}{\theta} \right)^{\frac{1}{2}} \right]$$



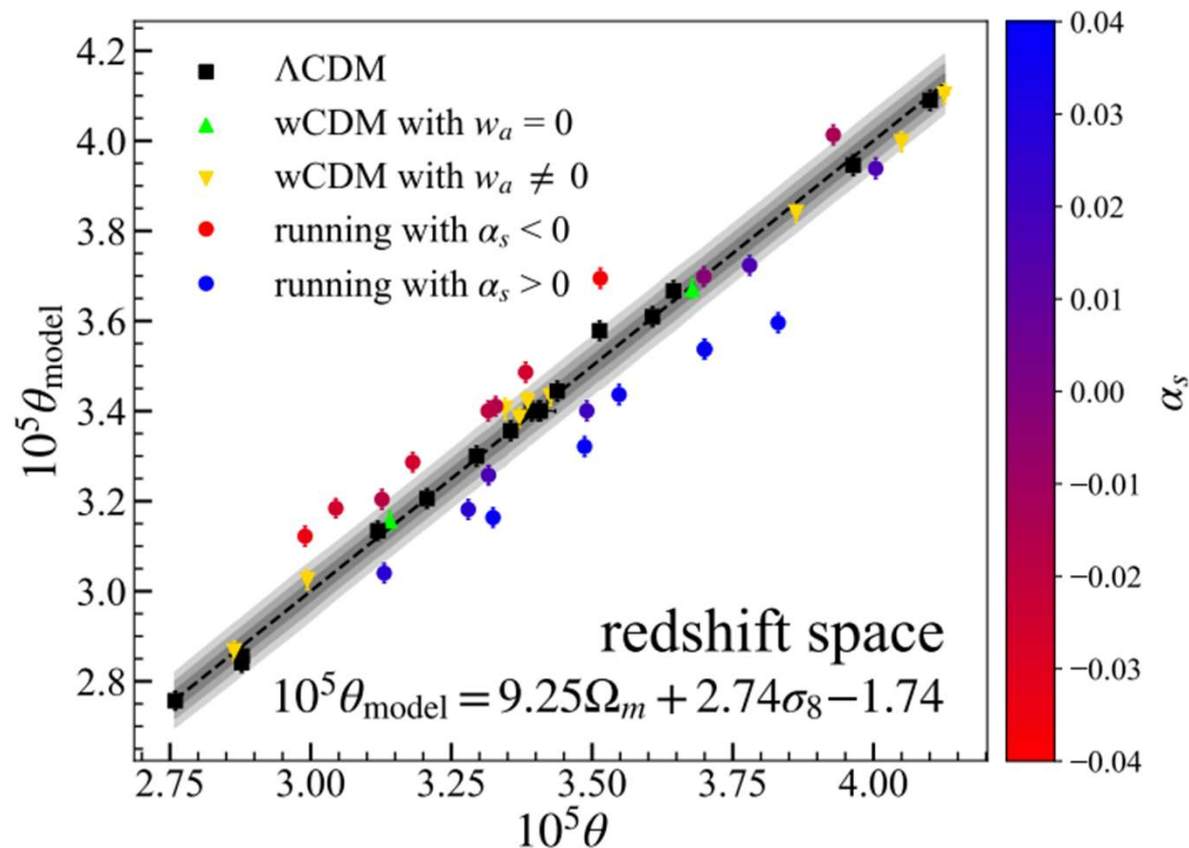
$$\theta_{\text{model}} = \eta_1 \Omega_m + \eta_2 \sigma_8 + \eta_3$$



As cosmological probe



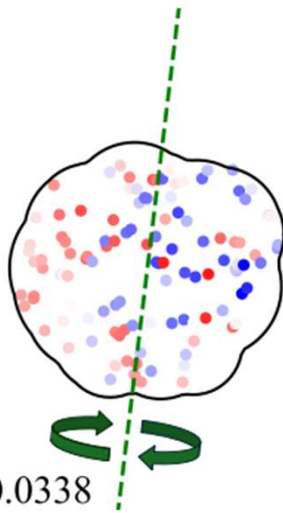
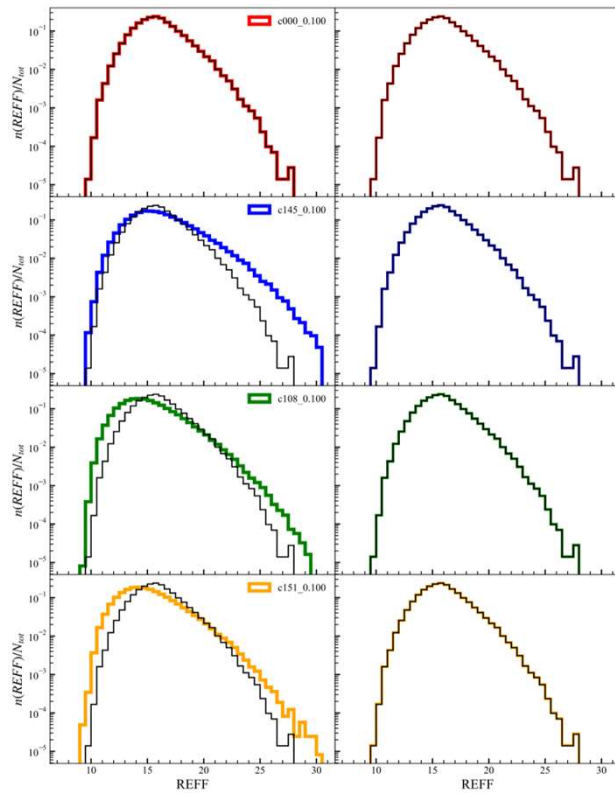
Why meaningful?



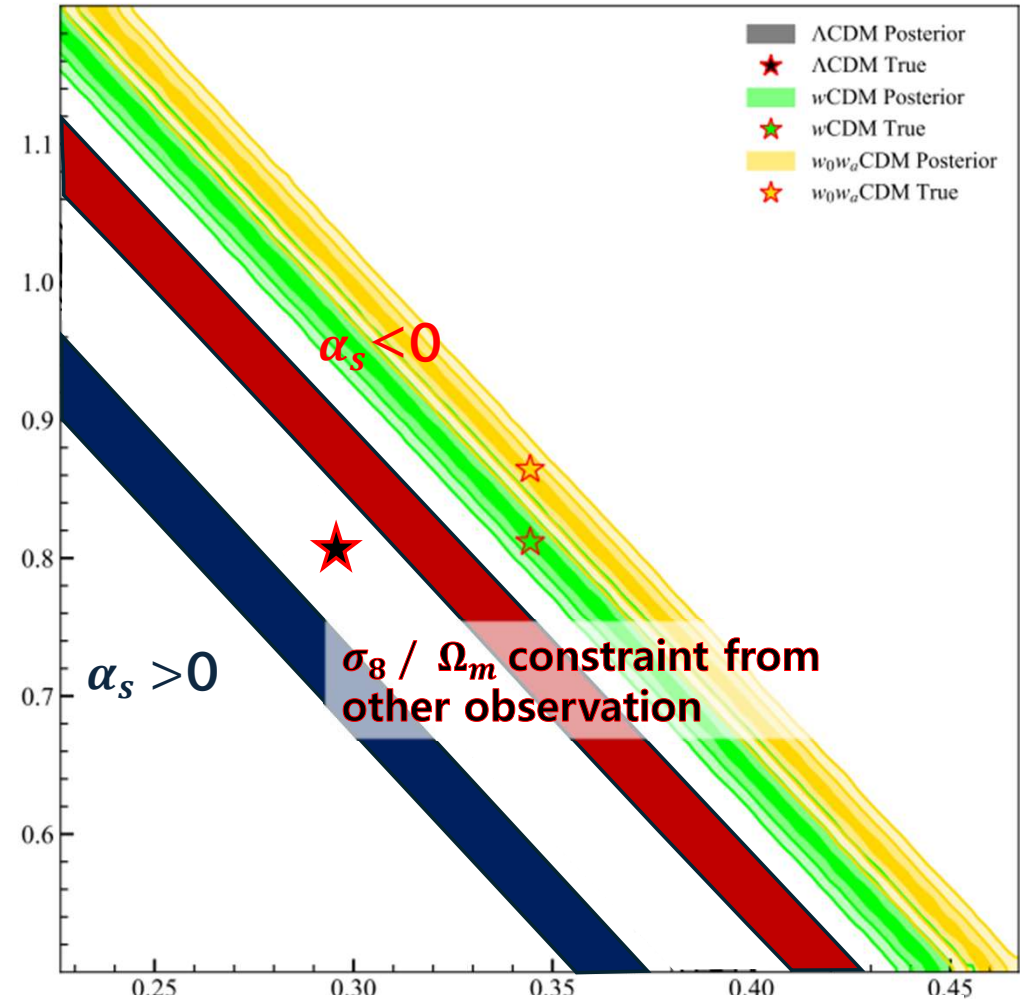
Void redshift asymmetry distributions follow a **universal, bilinear generalized Gamma model** on **large variety** of cosmologies + **no w_0, w_a dependencies** unlike other LSS based diagnostics

Deviations from this universality occur **only for non-zero α_s** making it possible for voids to **independently constrain** inflation models.

With observation?



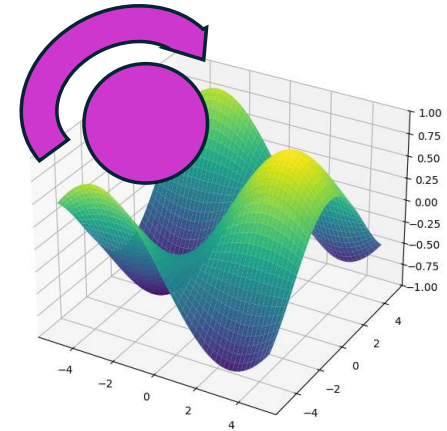
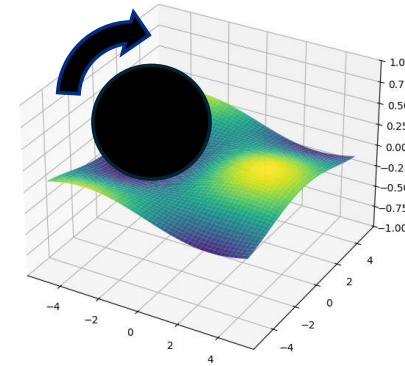
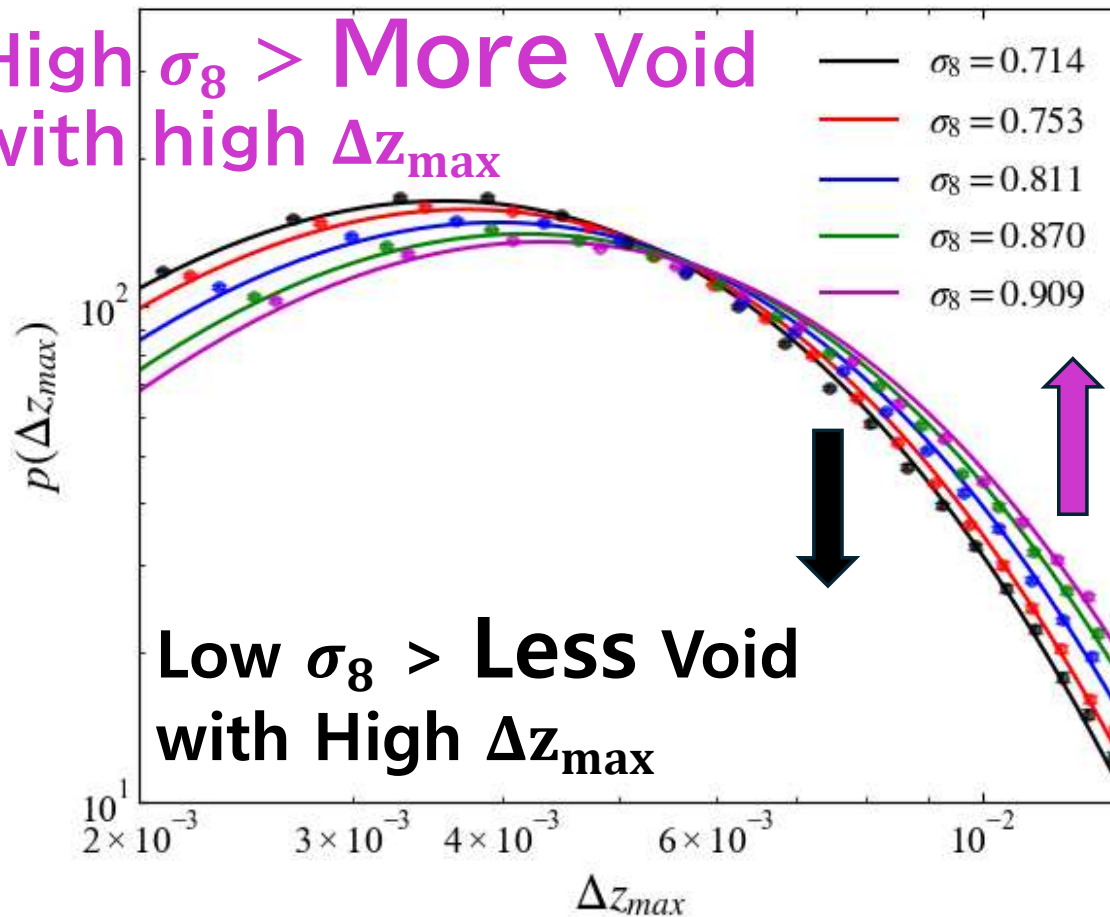
$$10^5 \theta_{\text{model}} = 9.25 \Omega_m + 2.74 \sigma_8 - 1.74$$



Void Finding > Radius matching > Redshift asymmetry calculating > Fitting

σ_8 on void spin

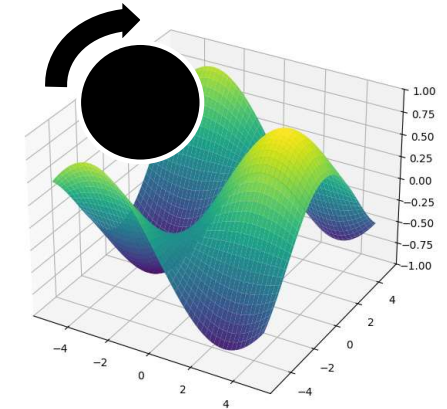
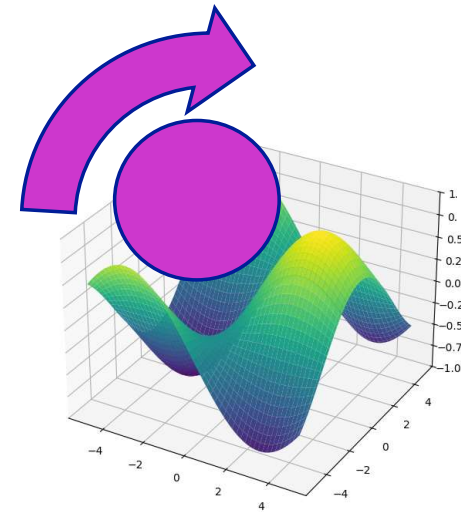
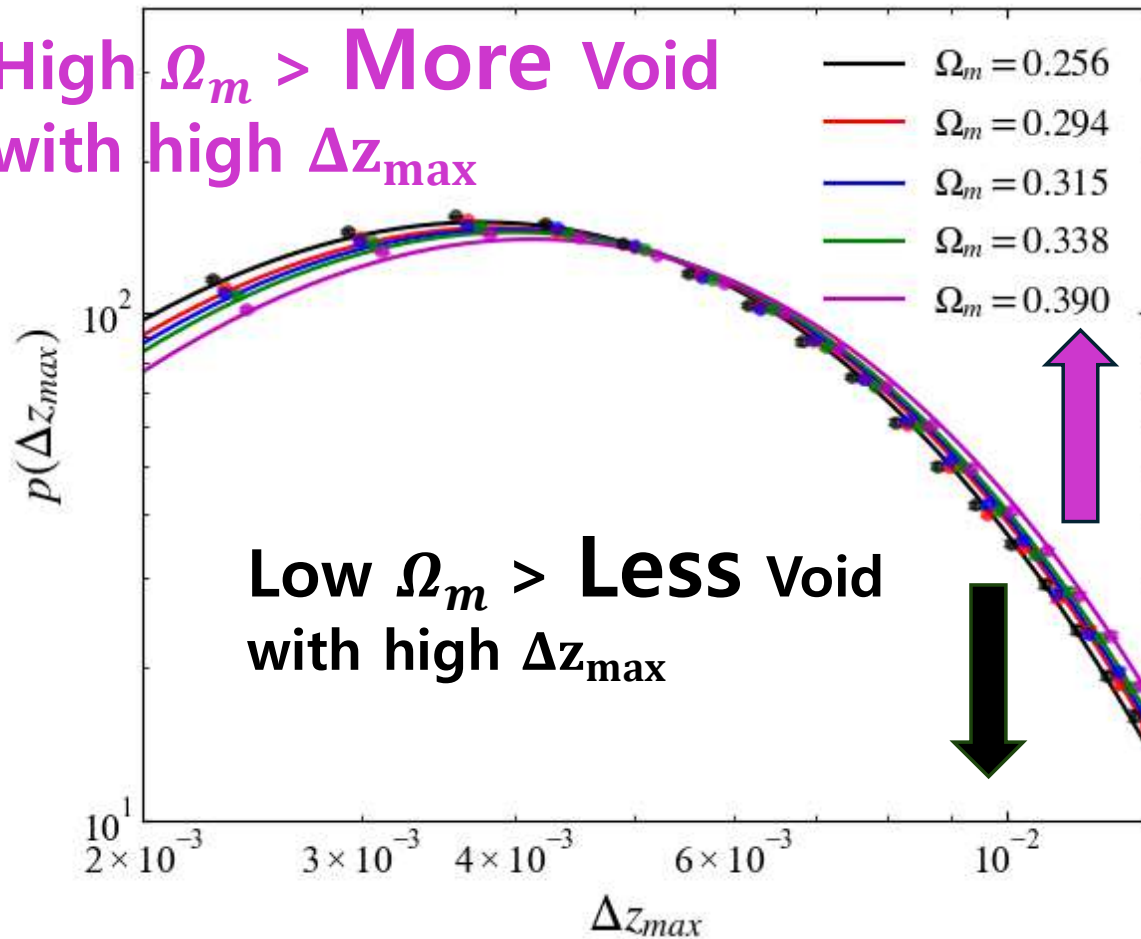
High $\sigma_8 >$ More Void
with high $\Delta z_{\max}$



Higher density fluctuation
due to High σ_8
Change the strength of large
scale tidal field
Resulting high redshift
asymmetry amplitude

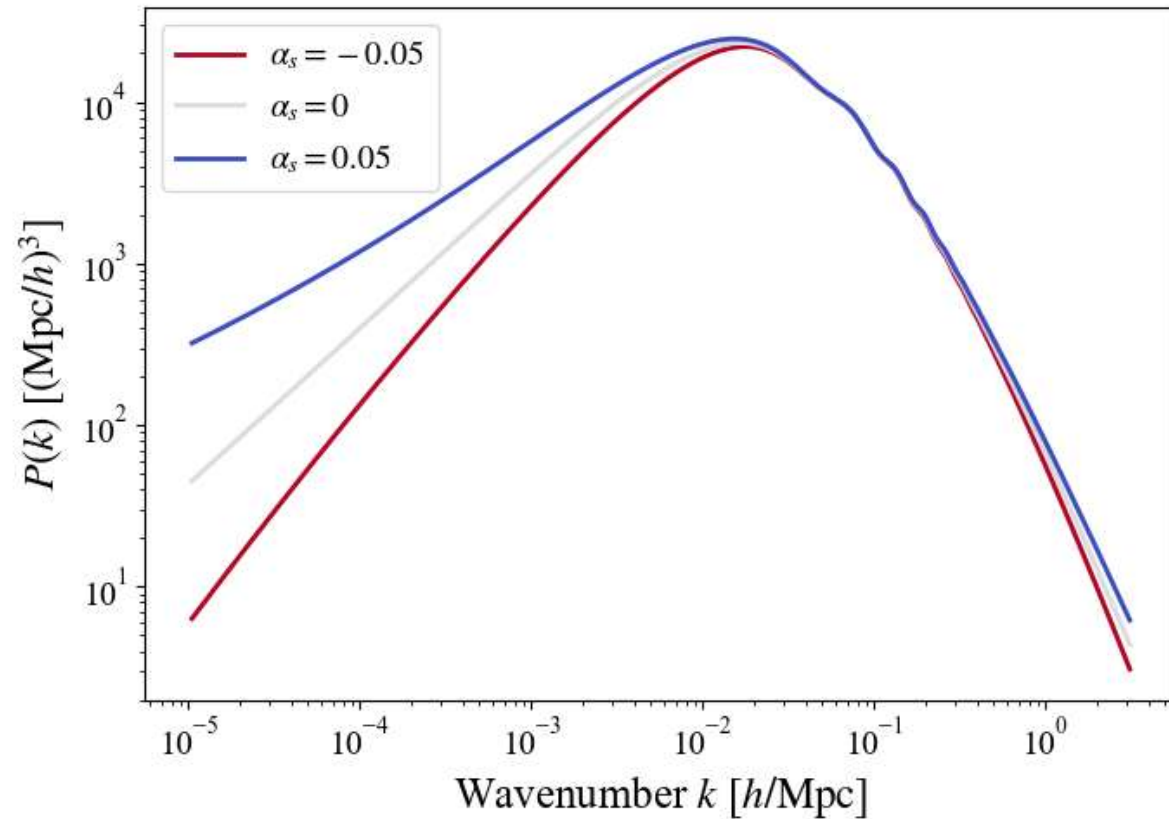
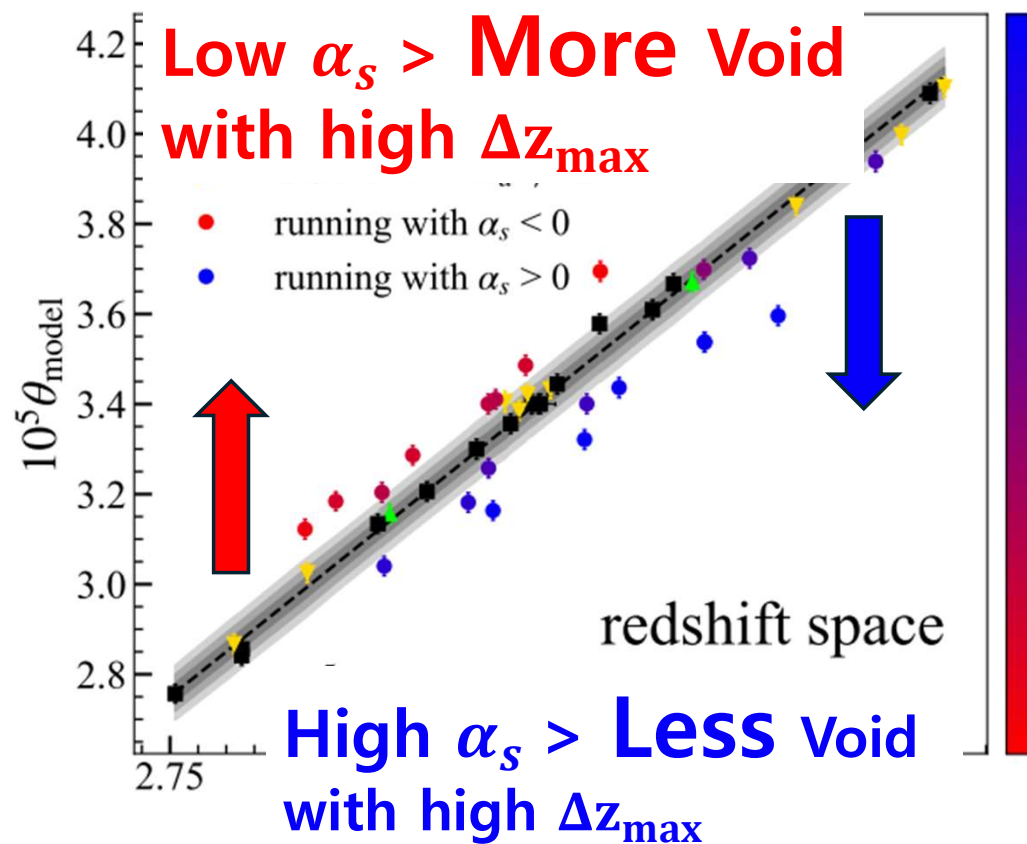
Ω_m on void spin

High $\Omega_m >$ More Void
with high $\Delta z_{\max}$

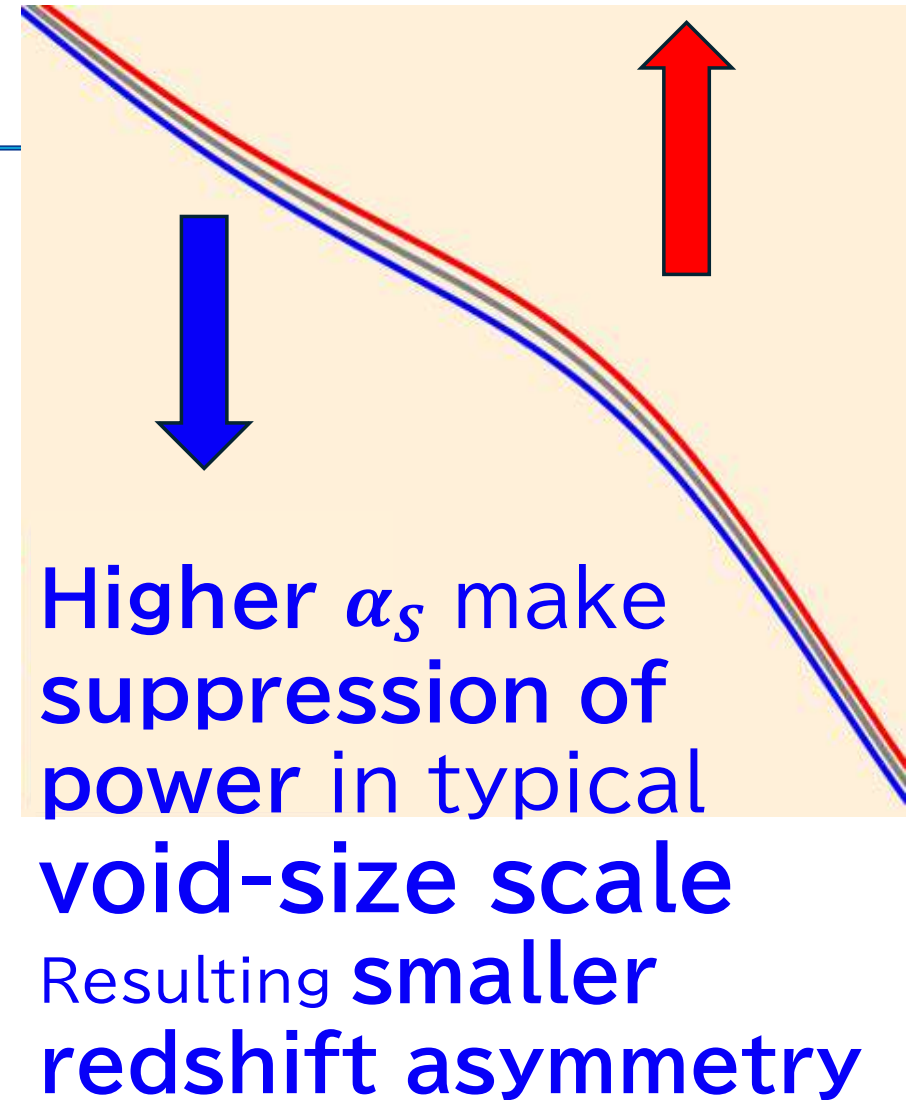
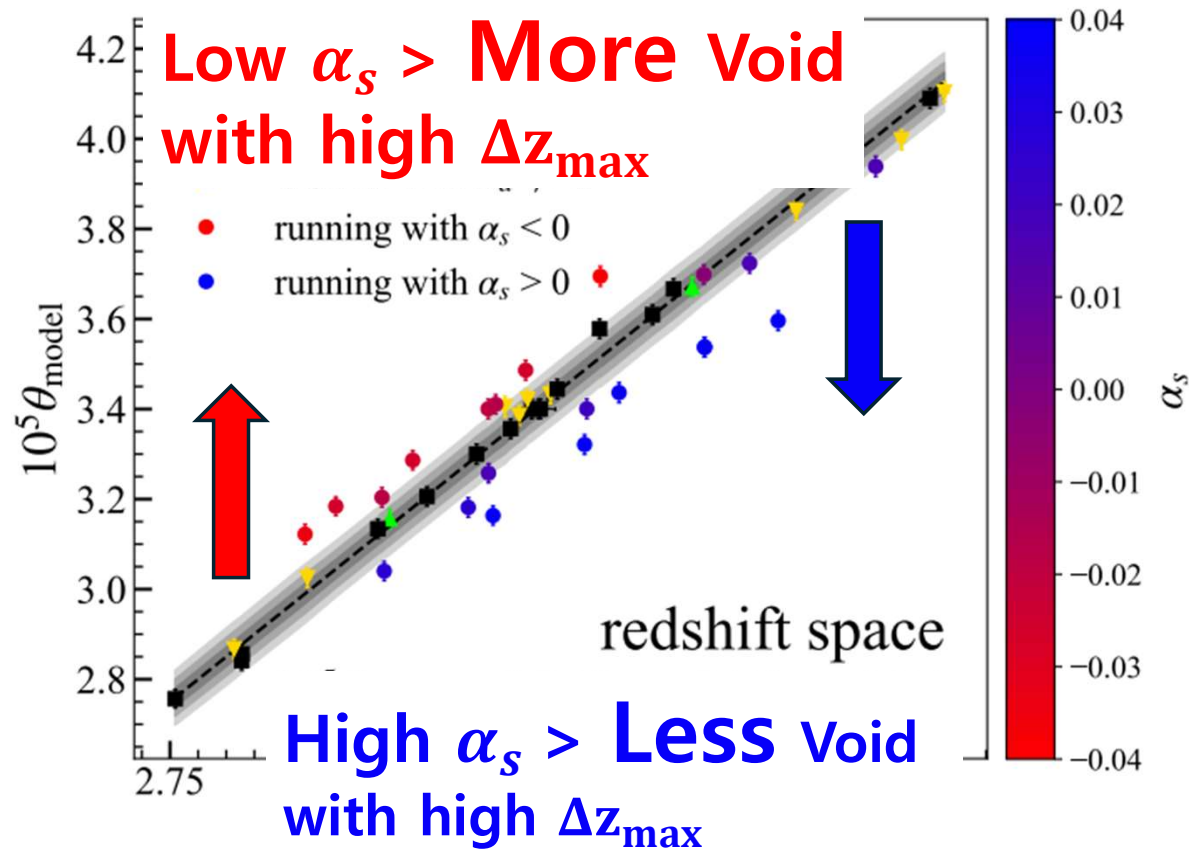


Faster formation of Large-Scale Structure due to High Ω_m
Make void rotating Faster
Resulting high redshift
asymmetry amplitude

α_s on void spin



α_s on void spin



Future works

Measuring Δz_{max} with **observed void**

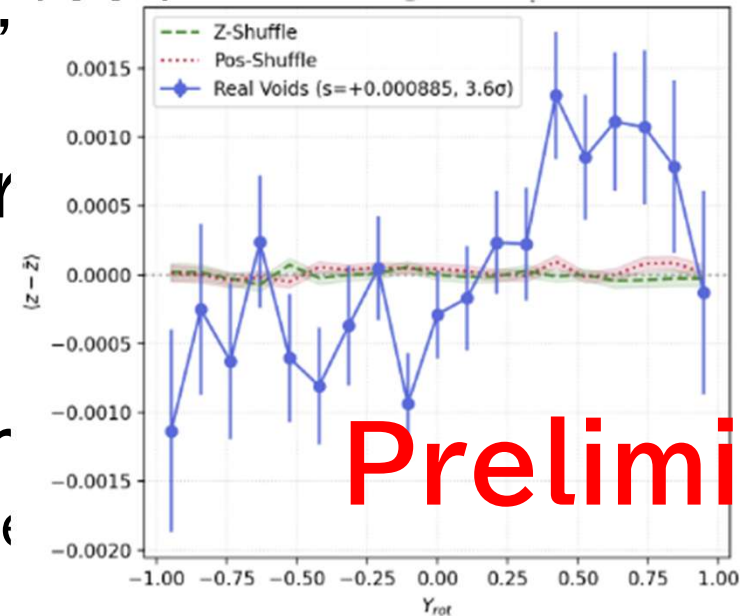
In DESI and SDSS catalog + Euclid, LSST

Develop **physical model** for

Strengthen theoretical foundation

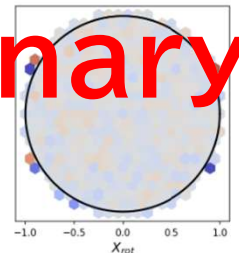
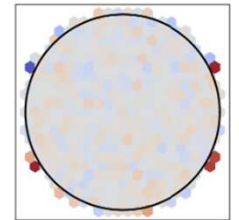
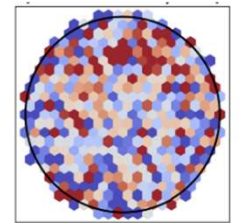
Testing redshift asymmetry in

Fully understand how void spin effects universe



Preliminary

Found **$>3\sigma$ spin evidence**
on real void



Summary | Q&A

Universally valid model that give constraint on α_s

We've numerically derived a **universally valid non-parametric model** for **redshift asymmetry** which is a good observational proxy for **void spin**. By discovering universality breaks down with **non-zero α_s** , we propose the possibility of **novel, independent** framework to test **early universe inflation model**.

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Arxiv here:

