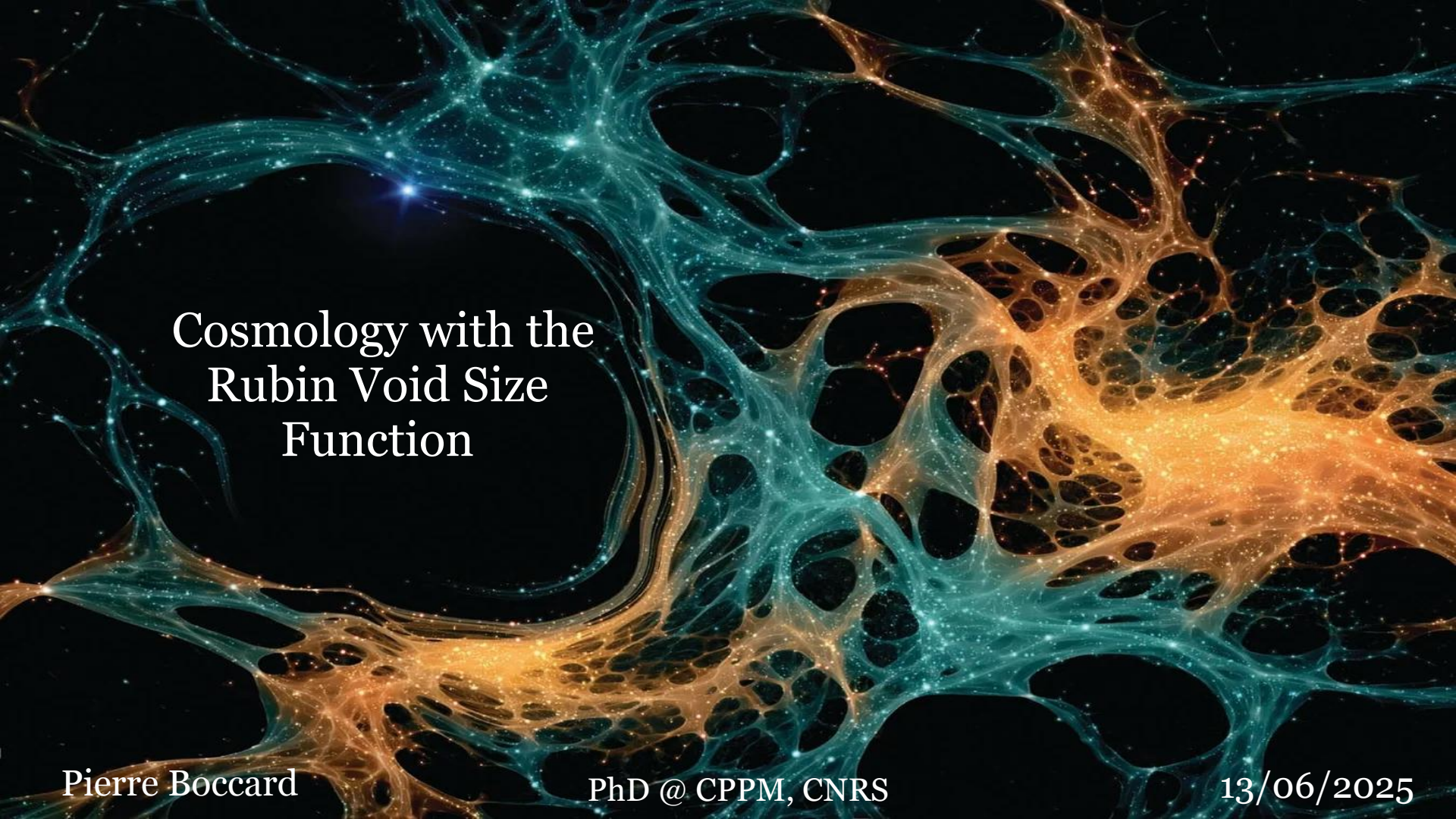

Cosmology with the Rubin Void Size Function

Pierre Boccard

PhD @ CPPM, CNRS

13/06/2025

PhD supervised by Alice Pisani

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE
CPPM

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VERA C. RUBIN OBSERVATORY

NSF U.S. National Science Foundation

U.S. Department of ENERGY | Office of Science

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Stéphanie Escoffier
Senior Researcher

Cosmic voids

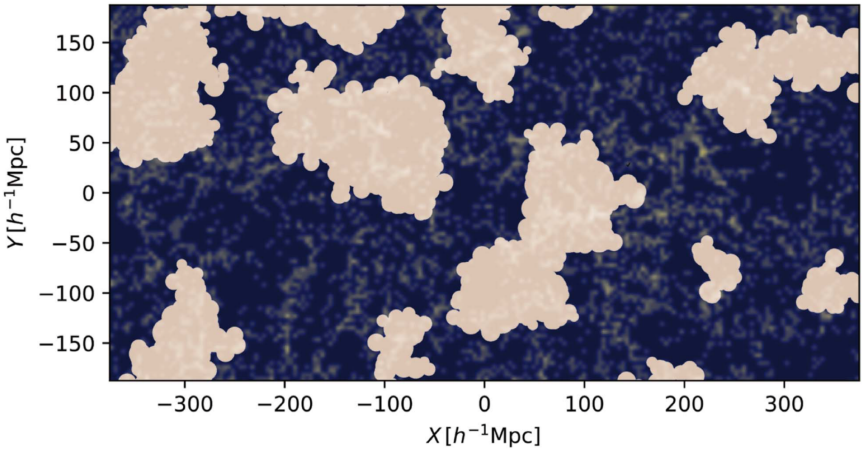
Underdense regions spanning from tens to hundreds of Mpc

Reproduce the low-matter density condition produced by the Λ-led accelerated expansion

Dark energy dominates voids earlier than any structure : sensitive to its effect

Existence of different theoretical models and void finders

Kreisch et al. 2020



Motivations

- Surveys of large volumes covering large range of redshifts

- Surveys of large volumes covering large range of redshifts

HACC haloes simulation

↓

SkySim5000

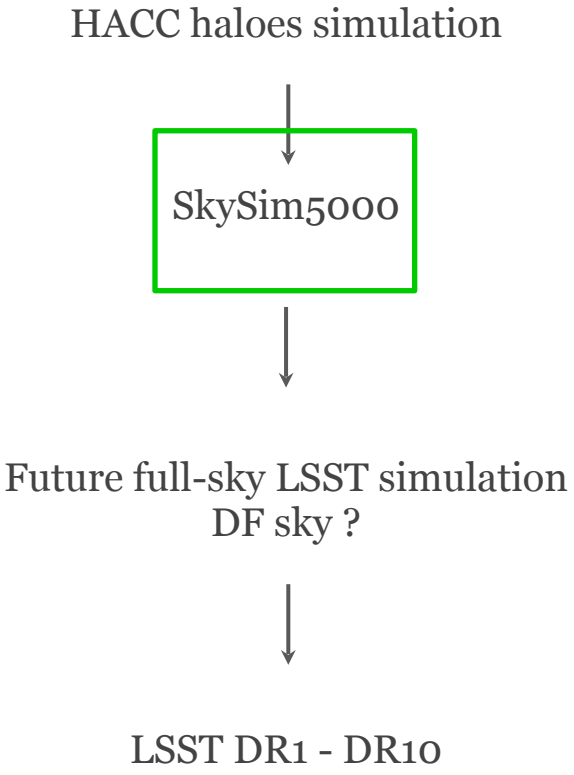
↓

Future full-sky LSST simulation
DF sky ?

↓

LSST DR1 - DR10

- Surveys of large volumes covering large range of redshifts



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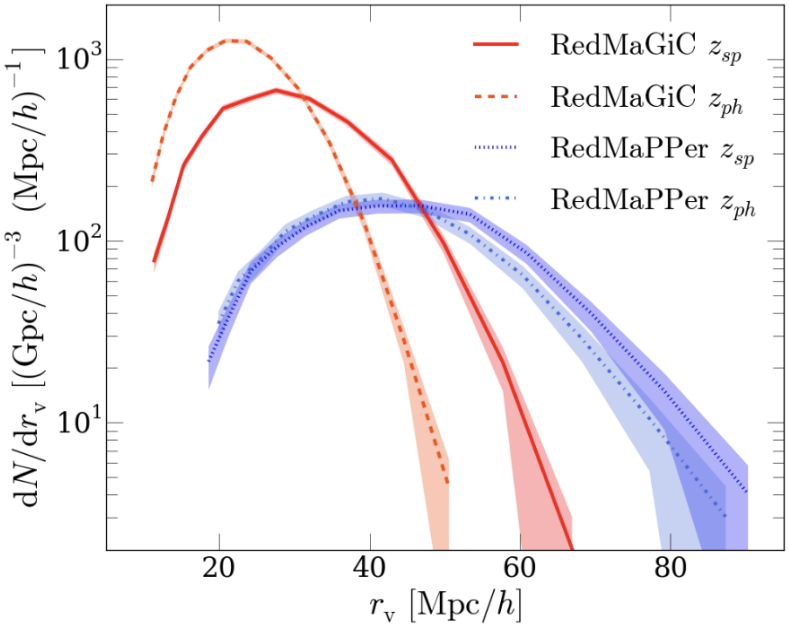
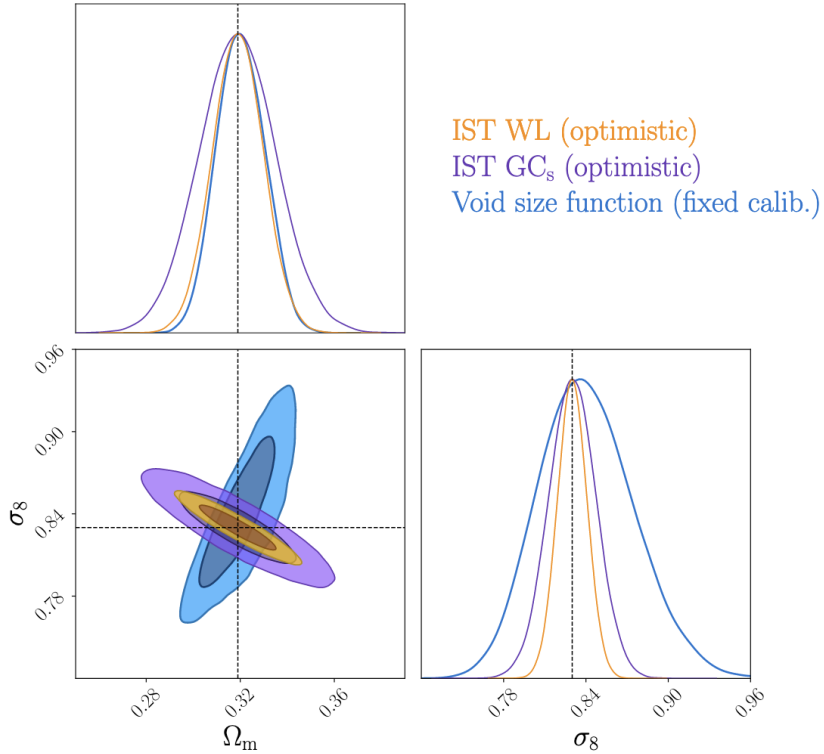
Pollina et al. 2018



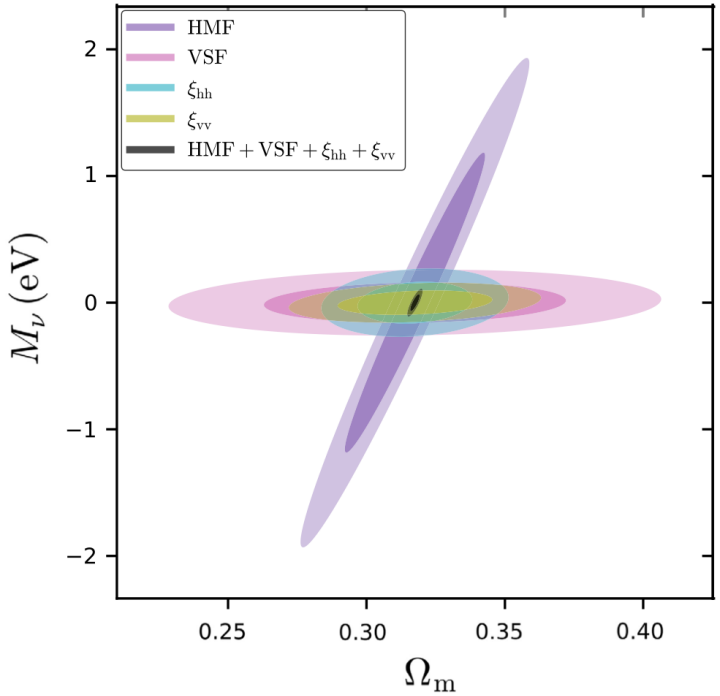
- Surveys of large volumes covering large range of redshifts
- Few studies on VSF in photo-z data
- Cluster-VSF is not significantly affected by photo-z uncertainty
- Complementary to other classical probes

Contarini et al. 2022



- Surveys of large volumes covering large range of redshifts
- Few studies on VSF in photo-z data
- Cluster-VSF is not significantly affected by photo-z uncertainty
- Complementary to other classical probes
- Powerful tool for physics beyond standard model : modified gravity and the sum of neutrinos masses

Kreisch et al. 2020



Theory

- VIDE voids are topological voids (Zobov, watershed)

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- Post-process to have a fixed value in the mean density contrast and compare to theory

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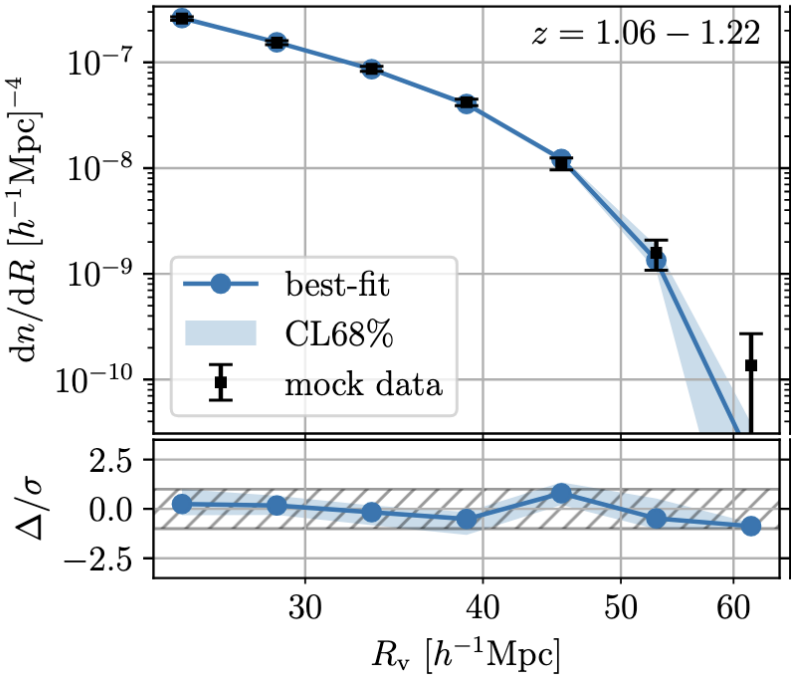
Verza et al. 2024



- VIDE voids are topological voids (Zobov, watershed)

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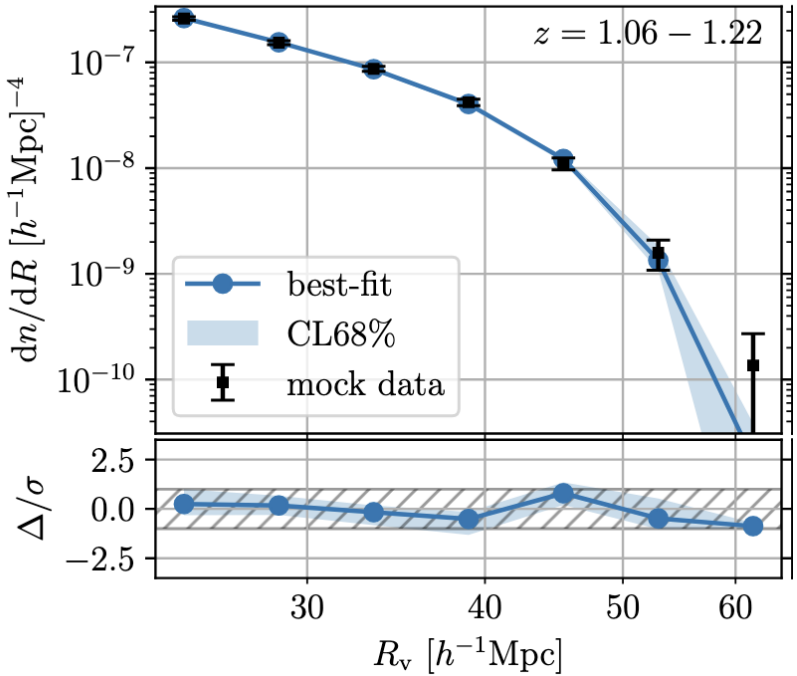
- VSF is directly related to DM power spectrum :

Void abundance : $n_V(R)dR = \frac{d}{dR}\left[f_V(\delta_v, S)\right]\frac{dS}{dR}$

Density field variance : $S(R) = \int_0^\infty \frac{dk}{k}\frac{k^3 P(k)}{2\pi^2} W^2(kR$

Verza et al. 2024



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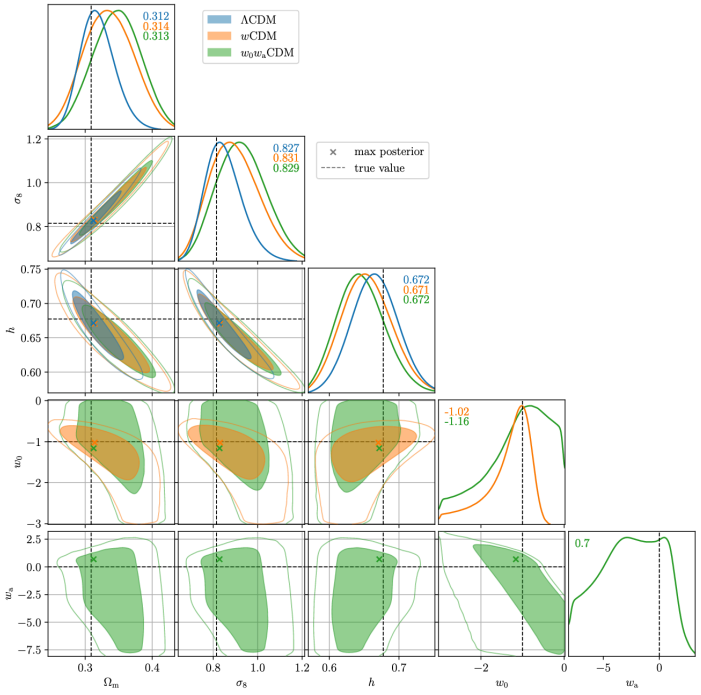
Infer cosmological parameters

Verza et al. 2024



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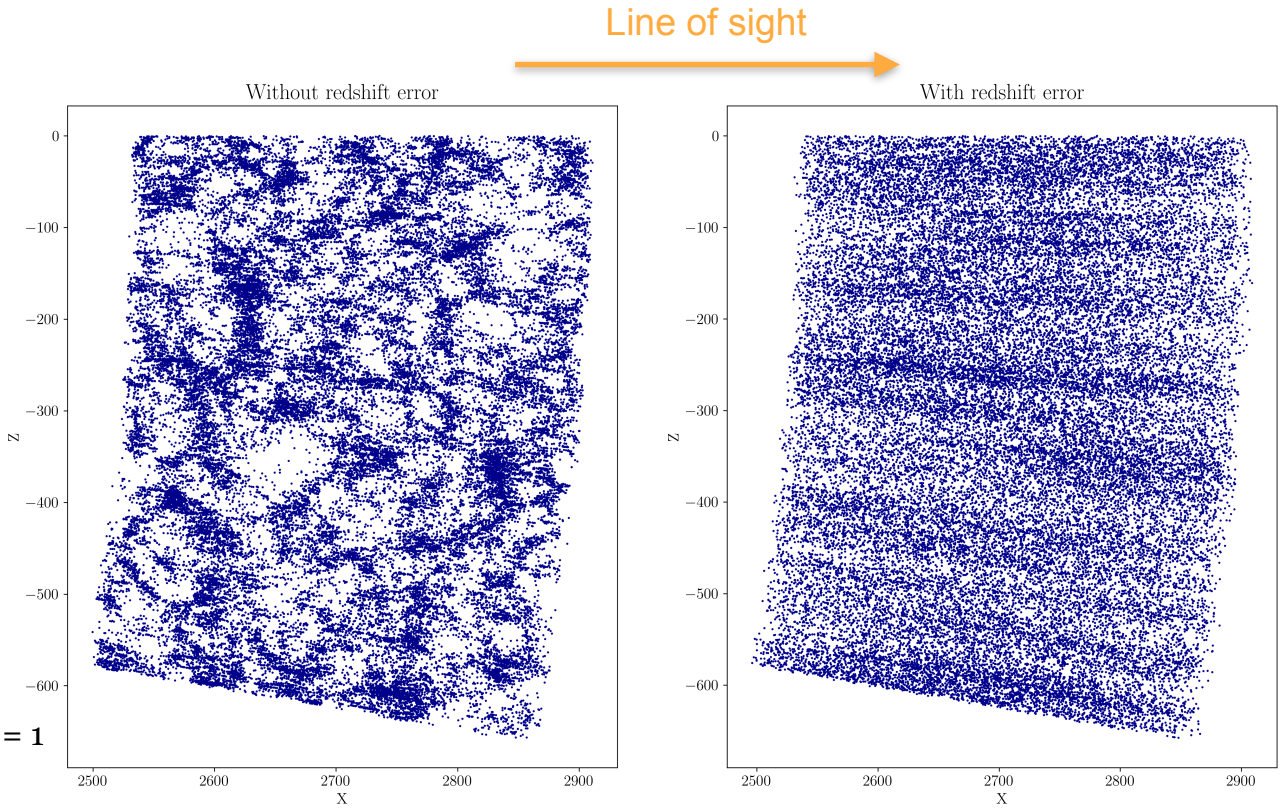
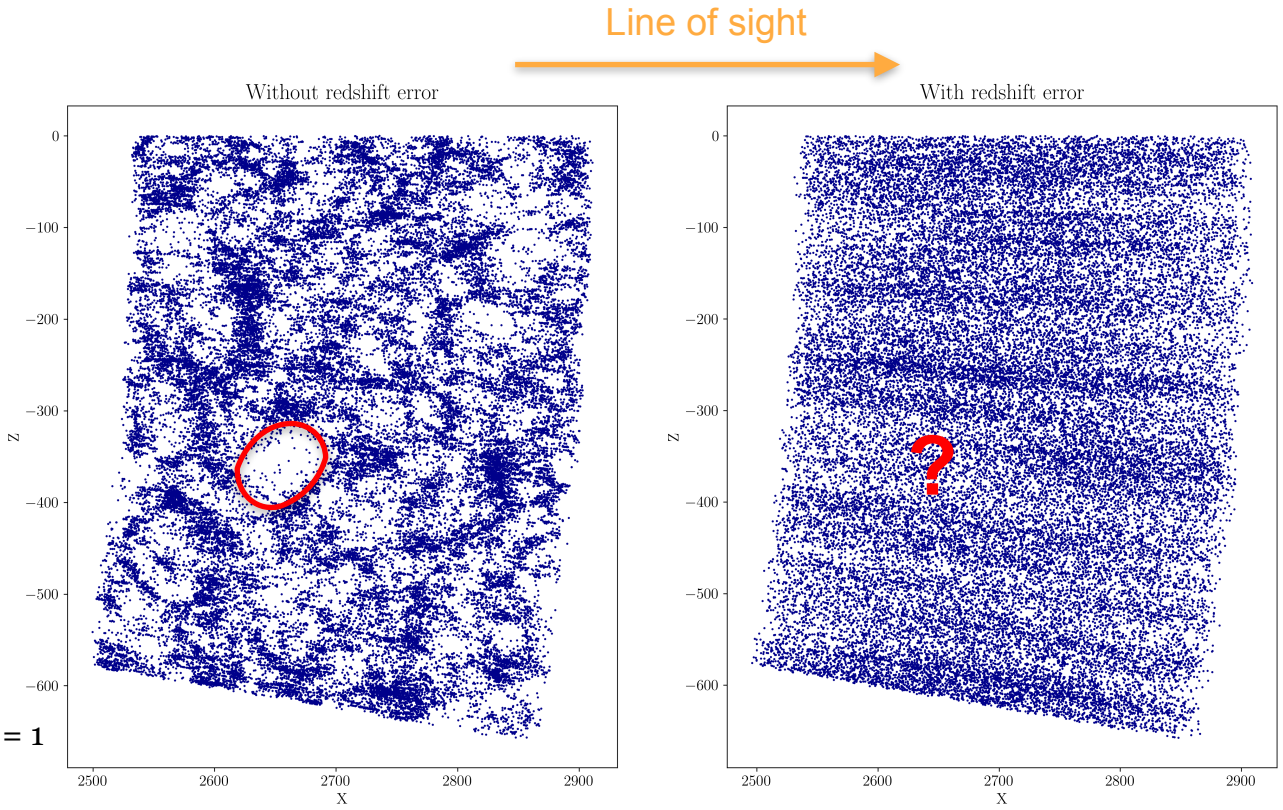


LOS slice of the SkySim light cone at z = 1

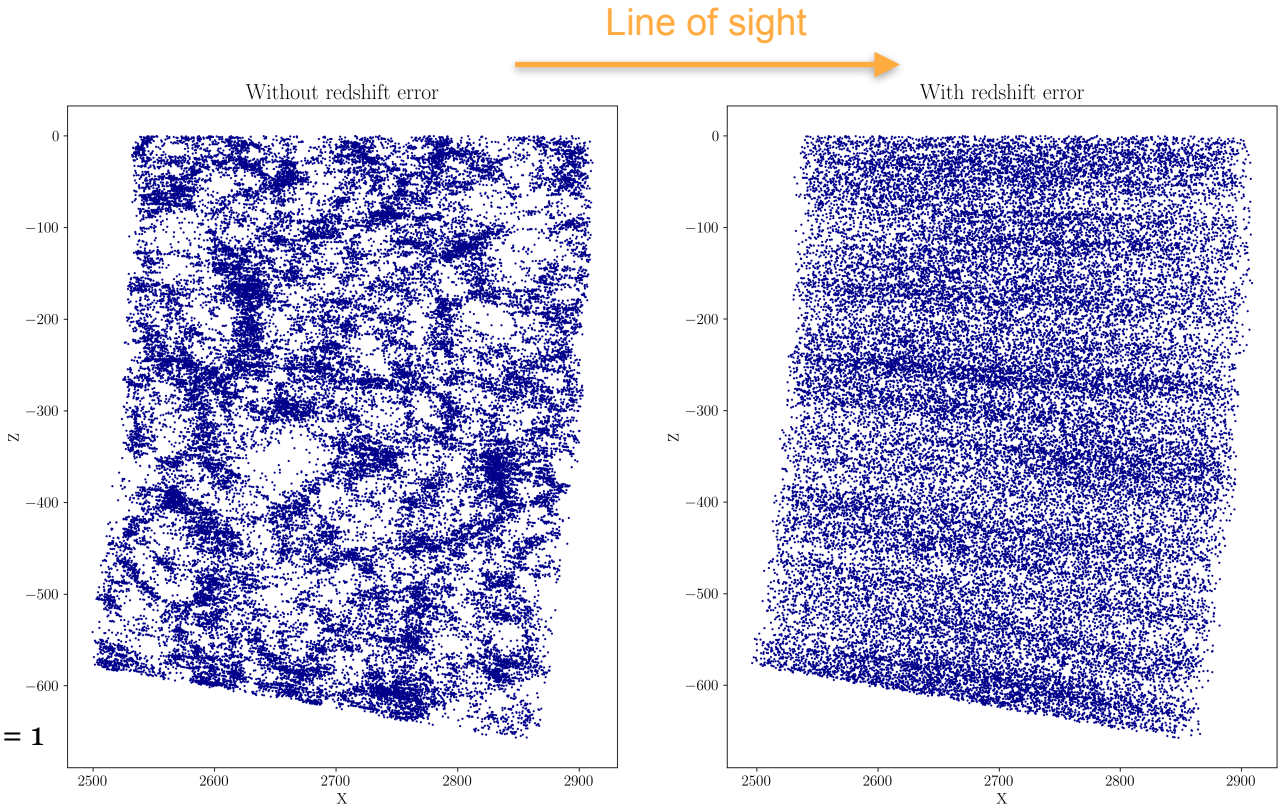
- Expected redshift uncertainty in LSST : $\sigma_z/(1+z) \simeq 0.02$

- Makes void identification with VIDE very complicated



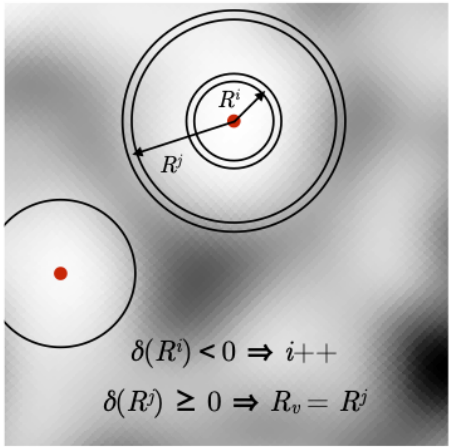
LOS slice of the SkySim light cone at z = 1

- Expected redshift uncertainty in LSST : $\sigma_z/(1+z) \simeq 0.02$
- Makes void identification with VIDE very complicated
- Need to use 2D void finders



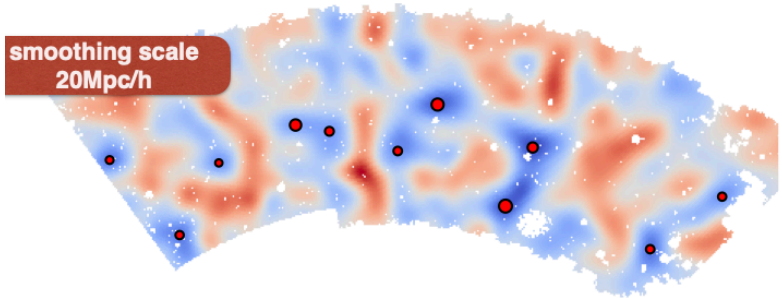
LOS slice of the SkySim light cone at z = 1

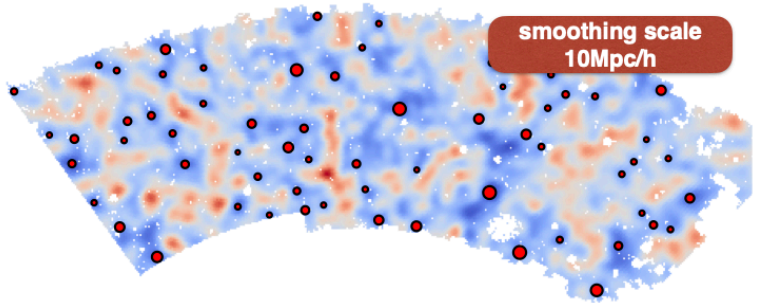
Sanchez et al. 2017



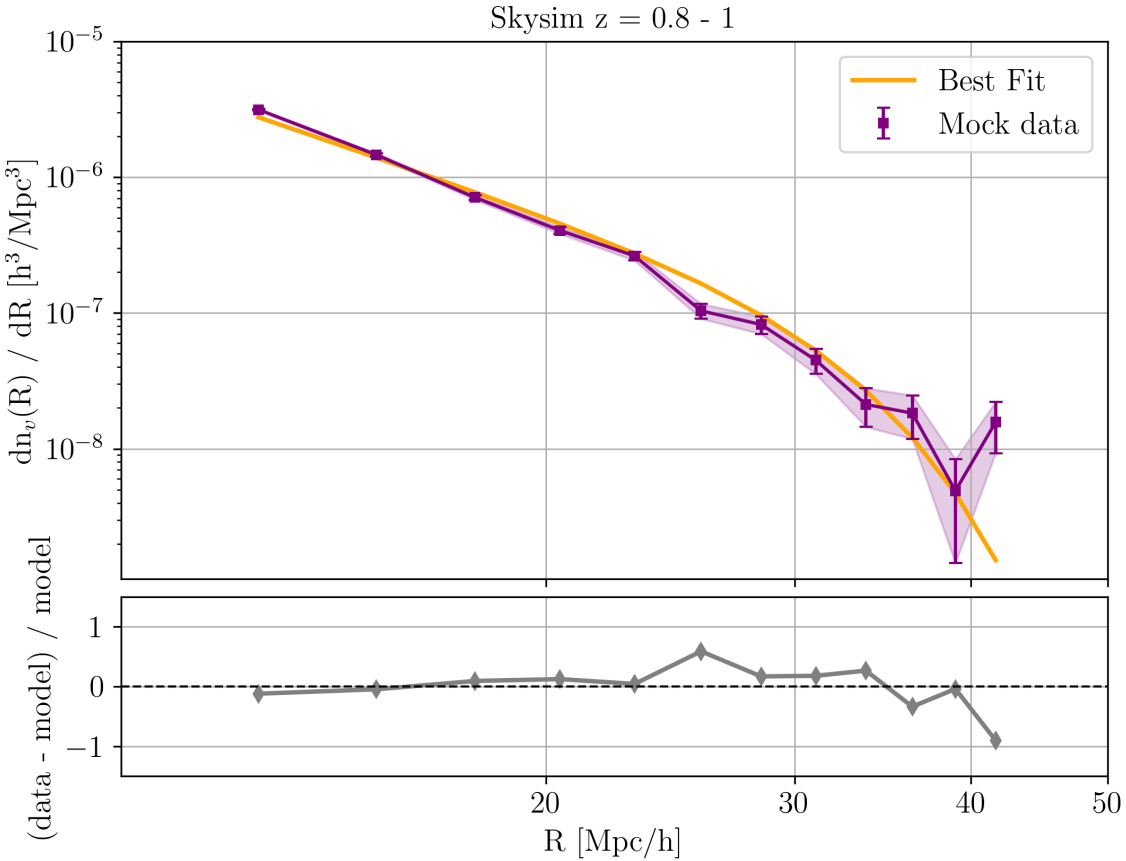
2D void finder

- Slice the sample in redshift bins of 100 Mpc/h.
- Compute the density field by counting galaxies per pixel and applying Gaussian smoothing
- Identify the most underdense pixel and grow a void until the mean density is reached
- Record the void, remove it from the map, and repeat the process





Early results


Skysim z = 0.8 - 1
Best Fit
Mock data
10^{-5}
10^{-6}
10^{-7}
10^{-8}
$dn_v(R)$ / dR [h^3/Mpc^3]
(data - model) / model
1
0
−1
20
30
40
50
R [Mpc/h]

Future steps of the project

New Slack Channel !

desc-voids

Feel free to join us

- Study VSF without errors on broader redshift range

- Add gaussian error ~ 0.02(1+z) to SkySim redshifts

- Impact of photo-z uncertainties on VSF and cosmological inferences

- Use more robust methodologies to select SkySim galaxies that are more consistent with LSST Data Releases

- Simulate DR1-DR10 with mocks to measure the evolution of the cosmological constraints

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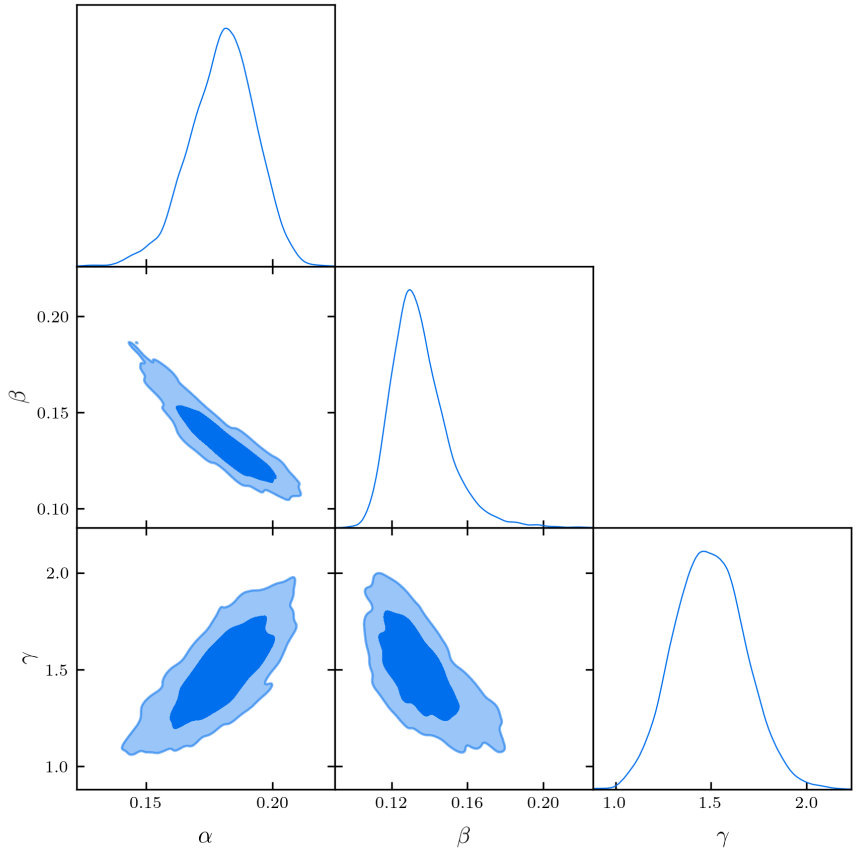
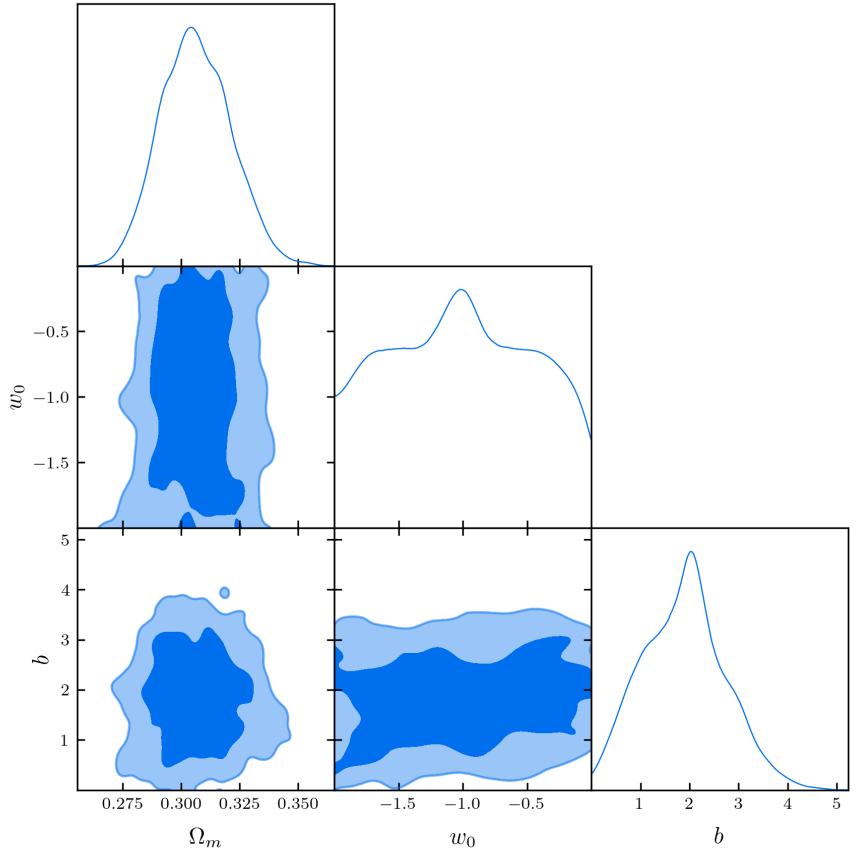
Thank you !

$$f(S) \simeq \frac{e^{-B_S^2/2S}}{\sqrt{2\pi S}} \left[\sqrt{\frac{\Gamma_{\delta\delta}}{2\pi S}} \exp\left(-\frac{S}{2\Gamma_{\delta\delta}} \left(\frac{B_S}{2S} - B'_S \right)^2 \right) + \frac{1}{2} \left(\frac{B_S}{2S} - B'_S \right) \left\{ \mathrm{erf}\left[\sqrt{\frac{S}{2\Gamma_{\delta\delta}}} \left(\frac{B_S}{2S} - B'_S \right) \right] + 1 \right\} \right]$$

$$B(S) = \alpha \left[1 + (\beta/S)^\gamma \right]$$


0.20
0.15
0.10
β
2.0
1.5
1.0
γ
0.15
0.20
0.12
0.16
0.20
1.0
1.5
2.0
α
β
γ


−0.5
−1.0
−1.5
w_0
5
4
3
2
1
b
0.275
0.300
0.325
0.350
−1.5
−1.0
−0.5
1
2
3
4
5
Ω_m
w_0
b