Tackling Universe's fundamental questions with cosmic voids

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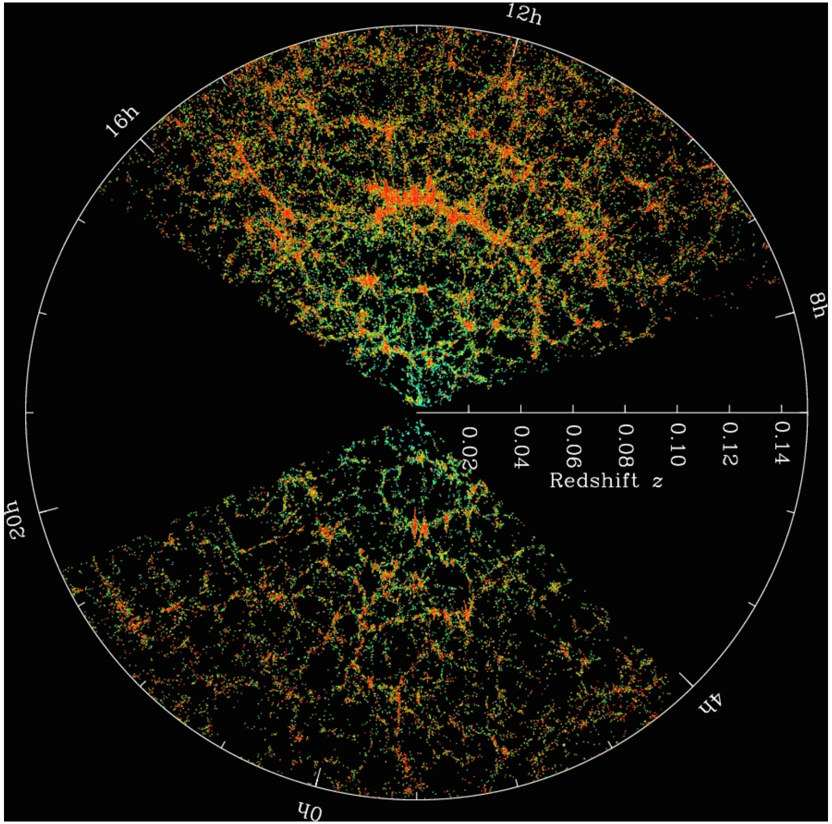
& Euclid Voids members

Marco Baldi, Carlo Giocoli, Alfonso Veropalumbo

Cosmology from Home 2021

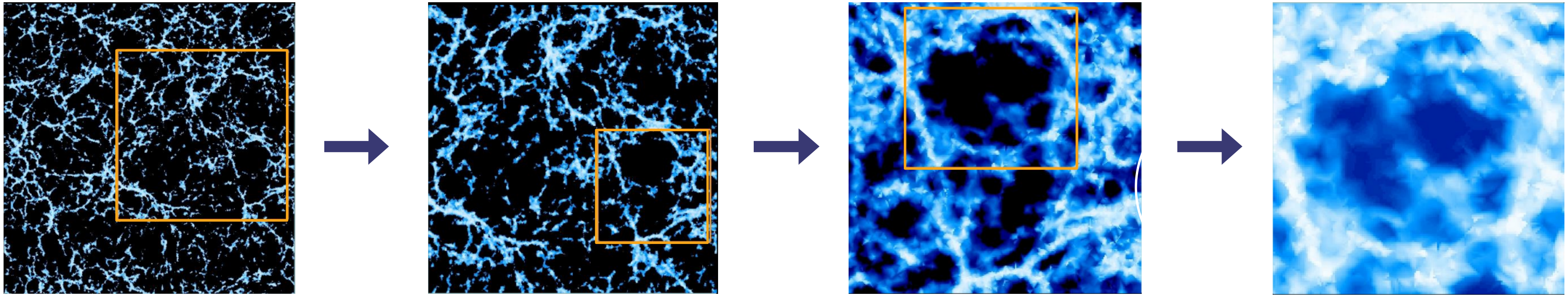
About cosmic voids



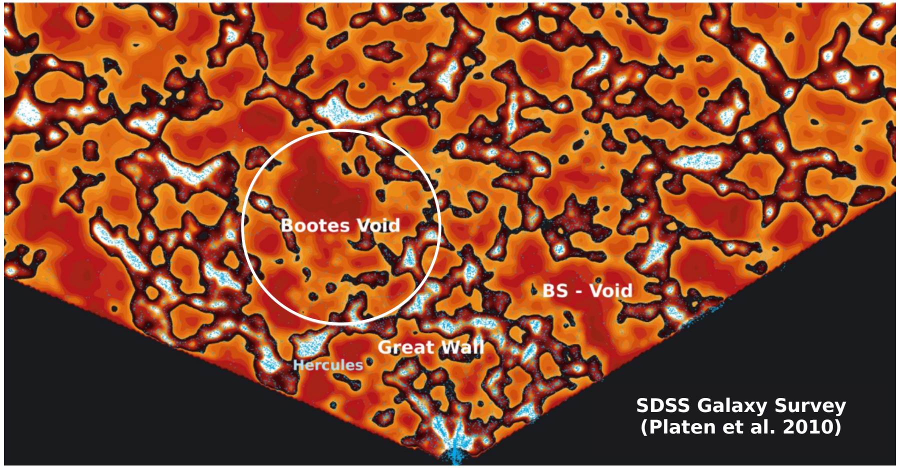
Credit: M. Blanton and the Sloan Digital Sky Survey

- **Ubiquity** and **prominence** of voids in the cosmic galaxy distribution
- Surrounded by elongated **filaments,** sheetlike **walls** and **clusters**
- **Major component** in terms of **volume**

About cosmic voids



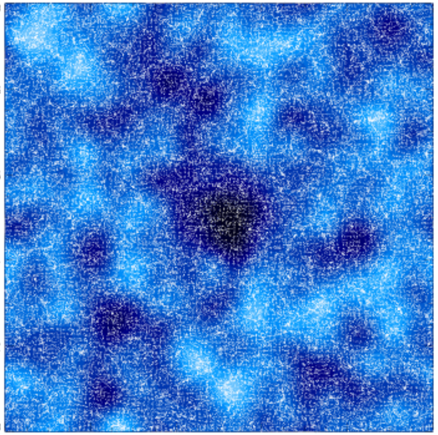
Credit: R. van de Weygaert



- Practically **devoid** of any **galaxy**
- Usually **roundish** in shape
- Very **large sizes** (10-100 Mpc/h)

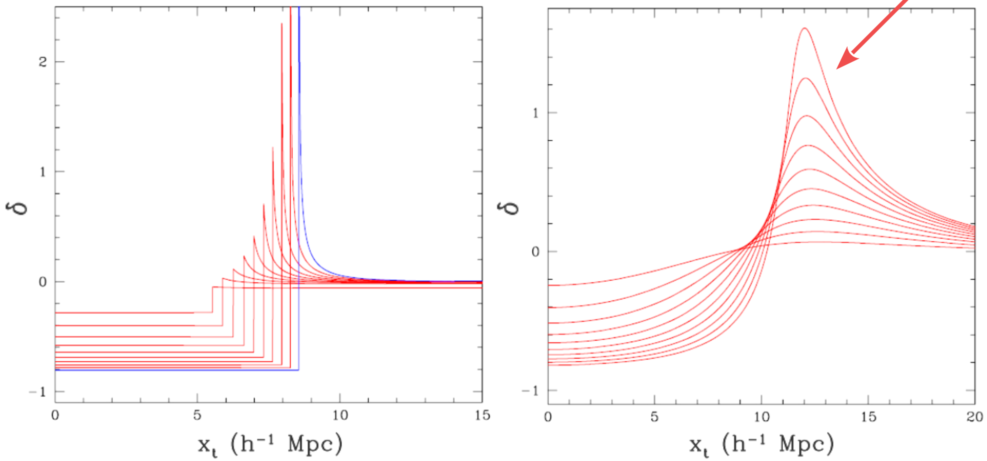
Formation and evolution of voids

- Voids originate from the evolution of **underdensities** in the primordial matter density field
- Isolated voids tend to become **more spherical** as they evolve, remaining **mildly non-linear** objects



Credit: Erwin Platen

Sheth & van de Weygaert (2004)



- **Shell-crossing** event (for steep initial profiles): interior shells of matter take over the initially external ones

$$\delta_{\rm v}^{\rm L} = -2.81$$

Formation and evolution of voids

- Hierarchical structure formation: **excursion set approach**
- **Two-barrier** problem: δ_v and δ_c (asymmetry between halo and void formation)
- **Merger** of voids (*void-in-void*) and **collapse** within larger overdensities (*void-in-cloud*)

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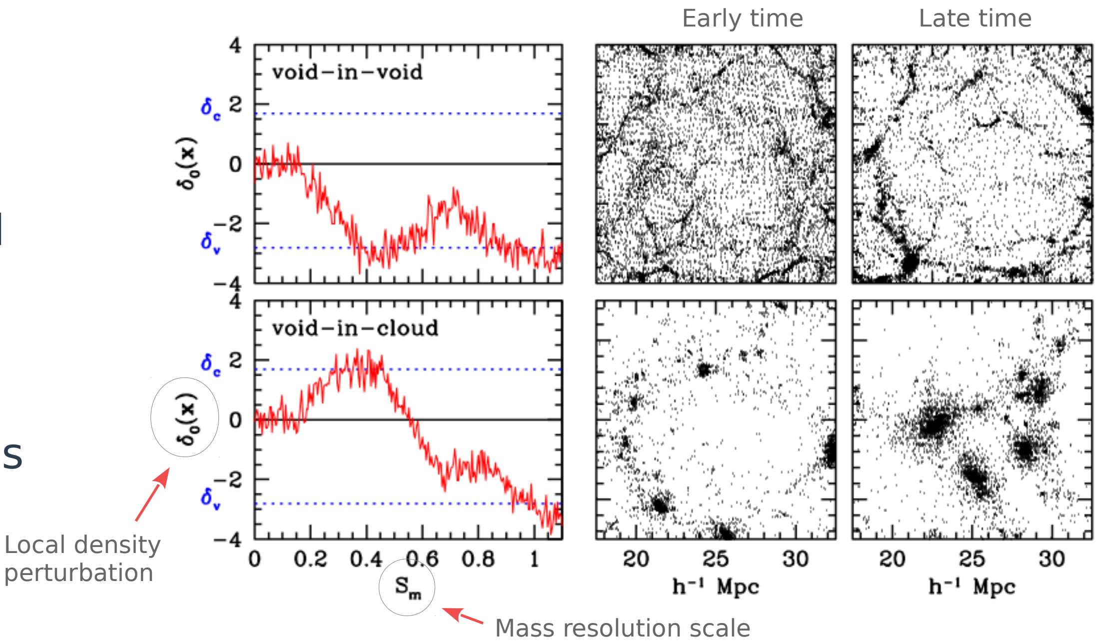

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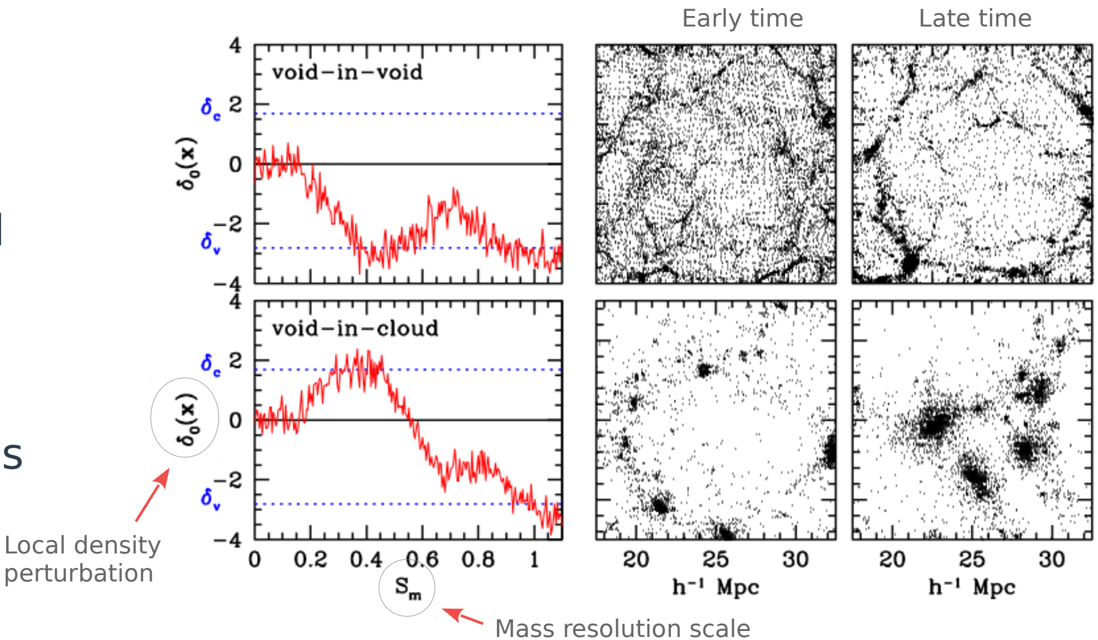
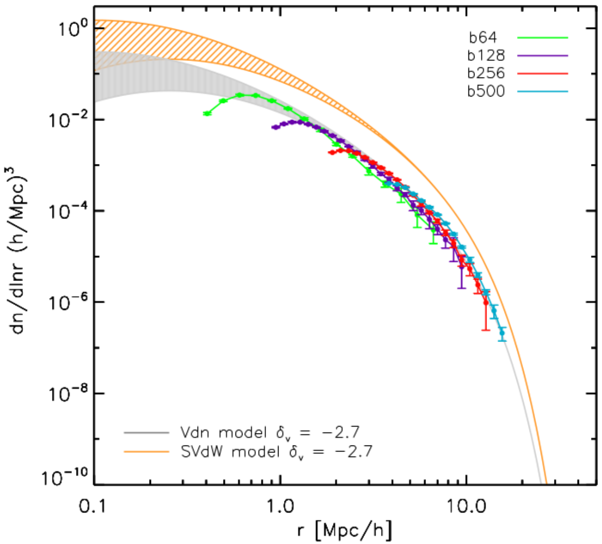


Fraction of random walks that first cross δ_v at S and not cross δ_c at any S'<S → **void size function**

Sheth & van de Weygaert (2004)
Jennings et al. (2013)

Void statistics



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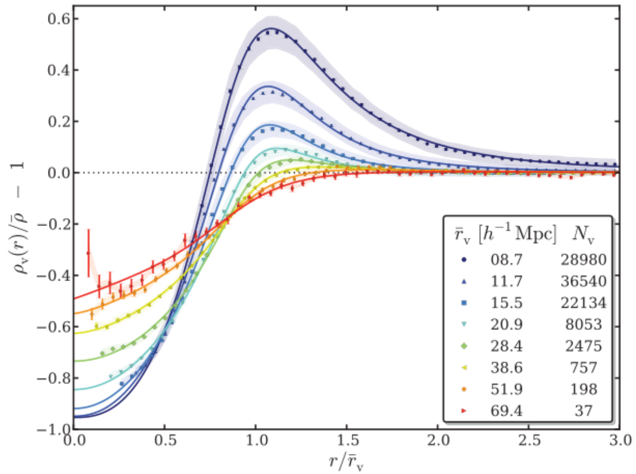
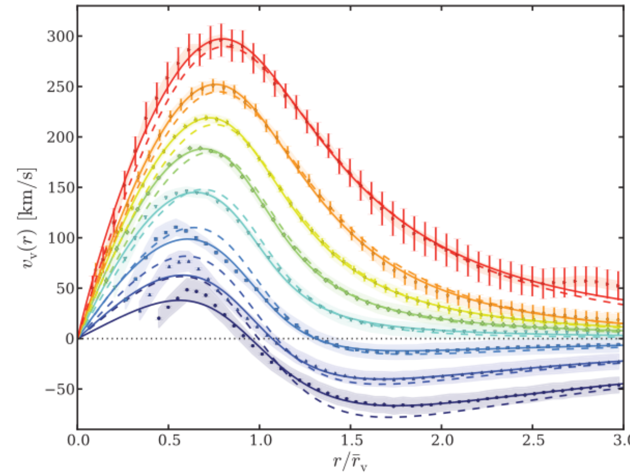
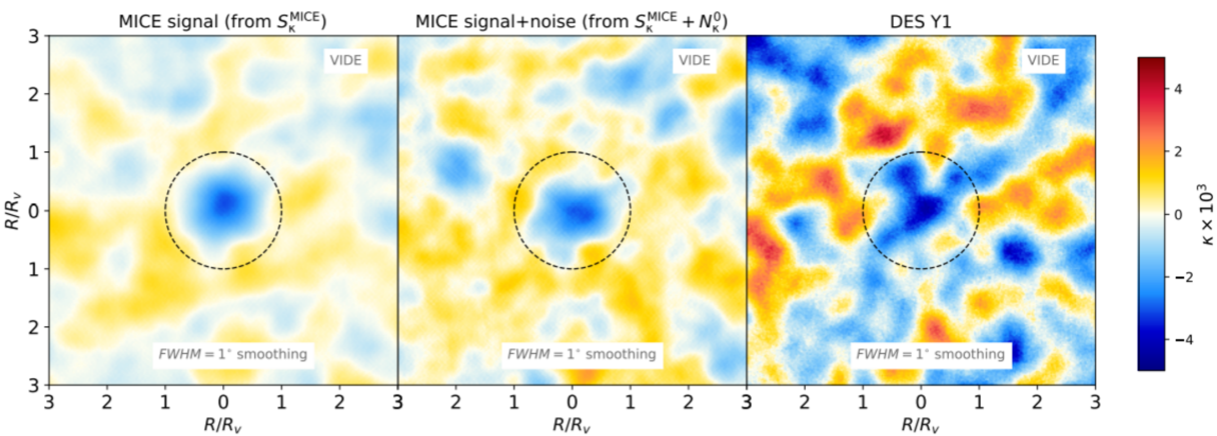
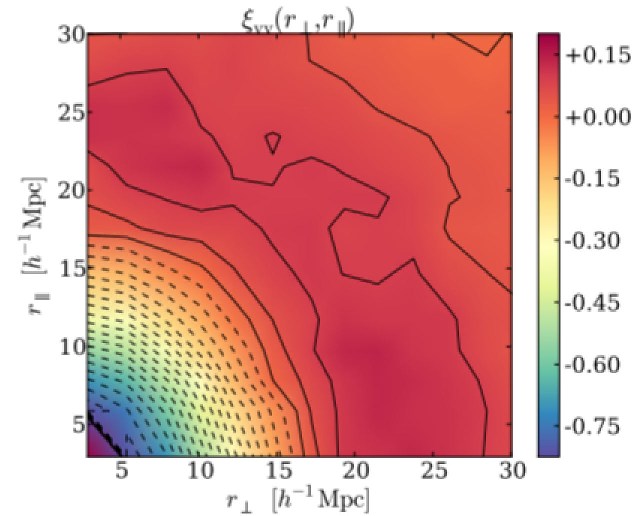




Hamaus et al. (2014) a

Vielzeuf et al. (2021)





Hamaus et al. (2014) b

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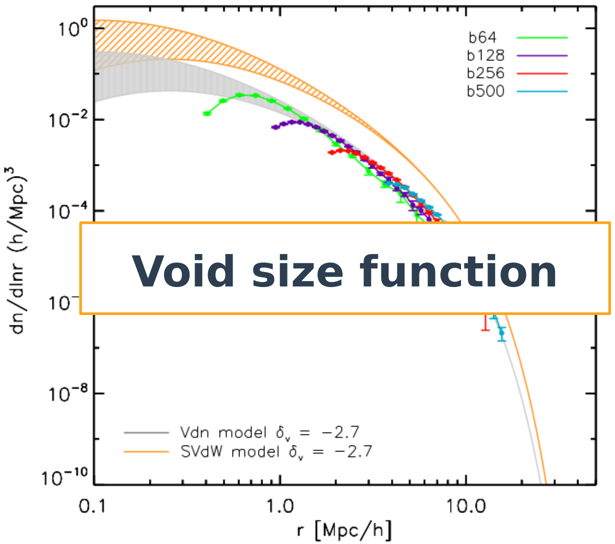
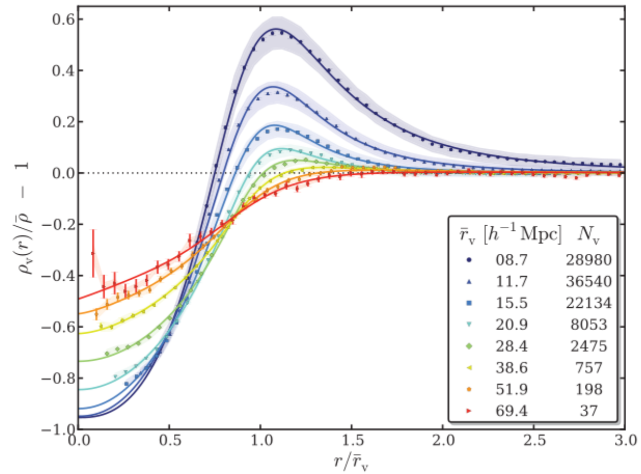
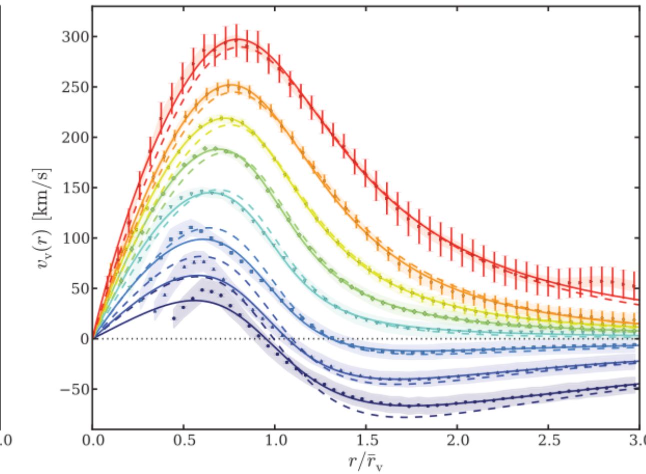


Void size function

Jennings et al. (2013)





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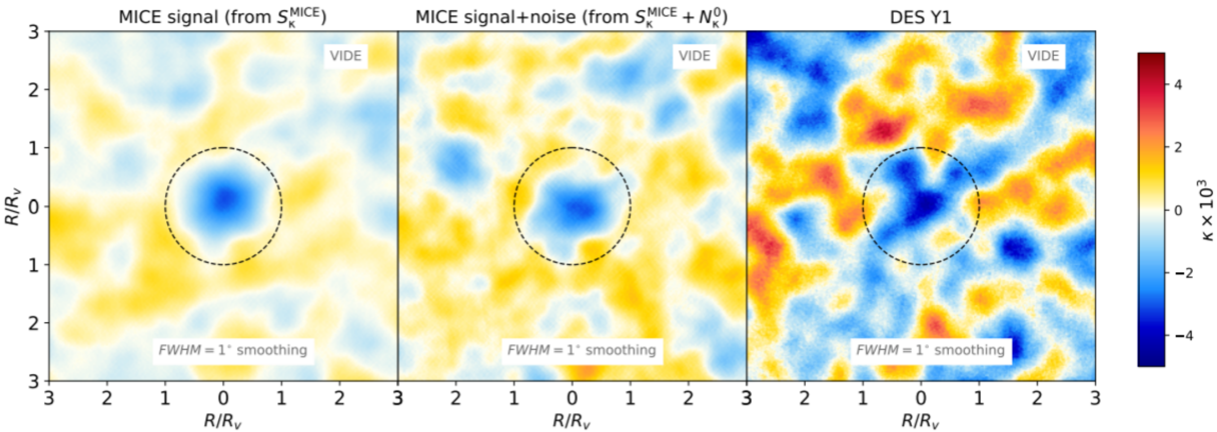

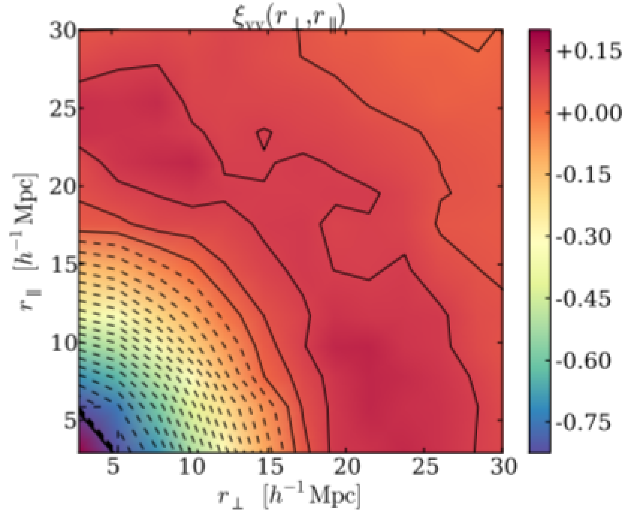

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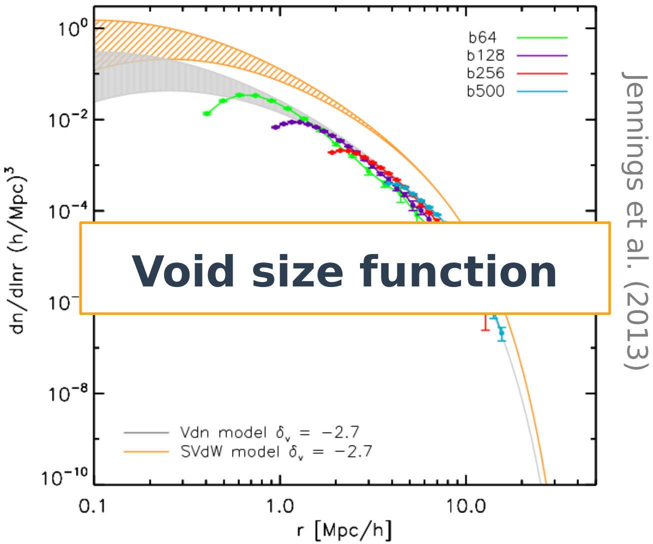
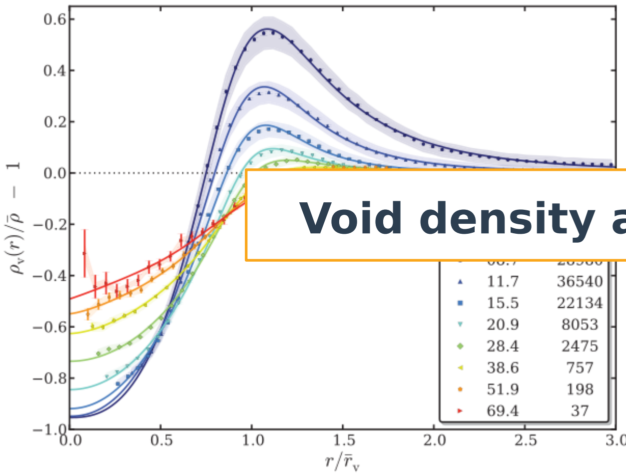
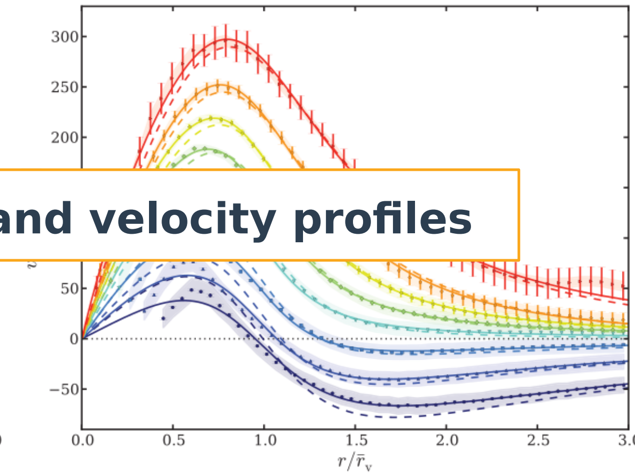


Jennings et al. (2013)

Void density and velocity profiles





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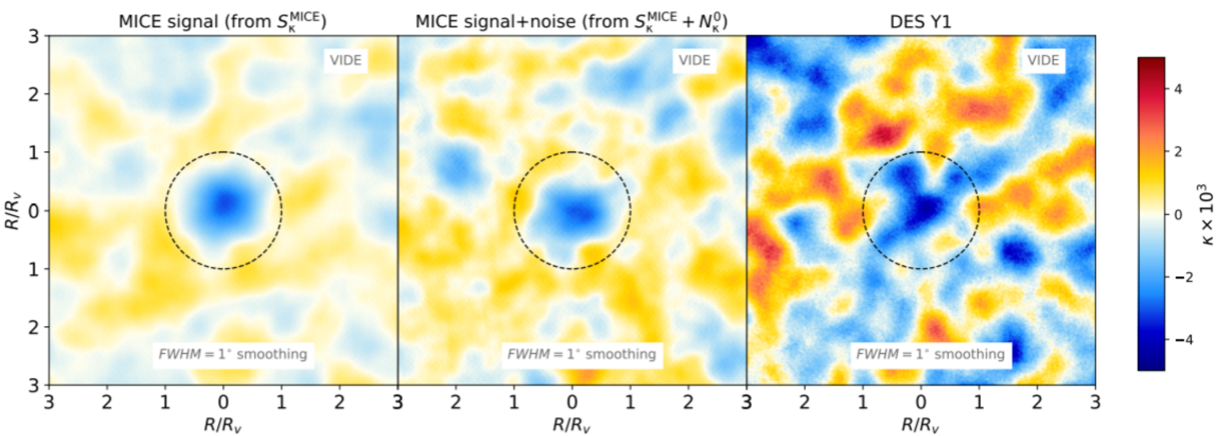

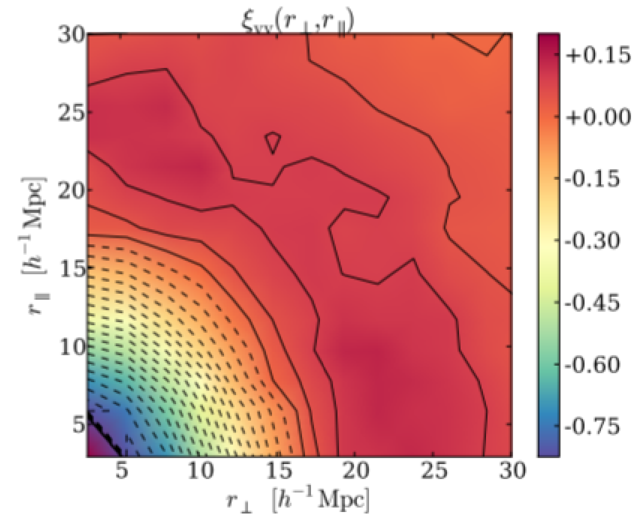

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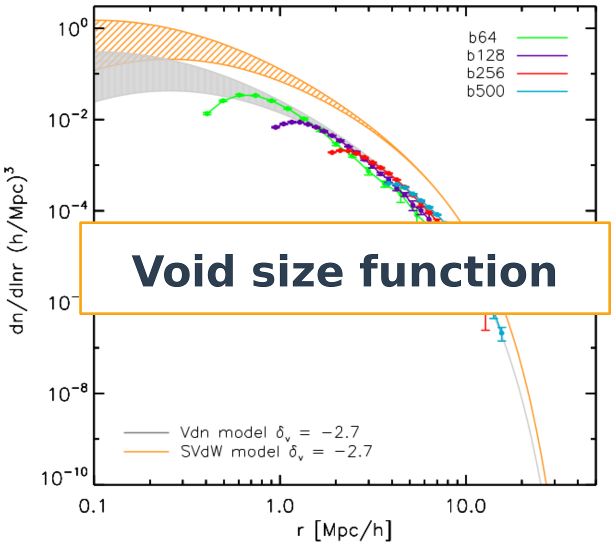

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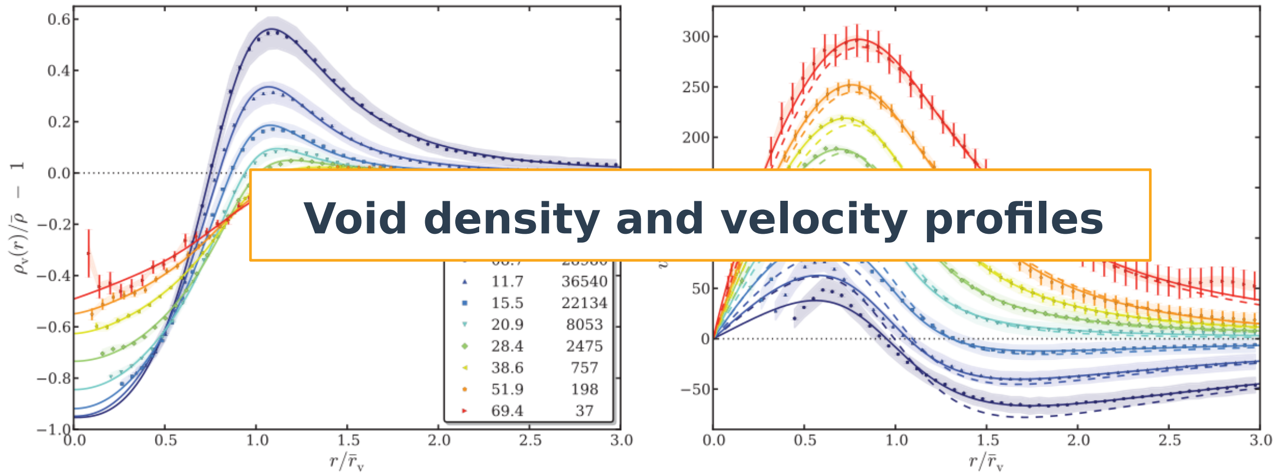

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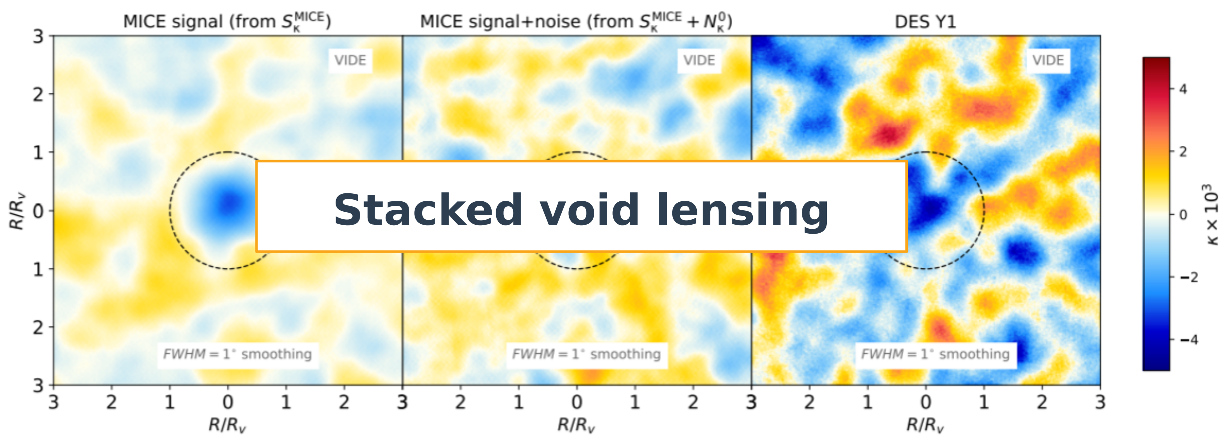

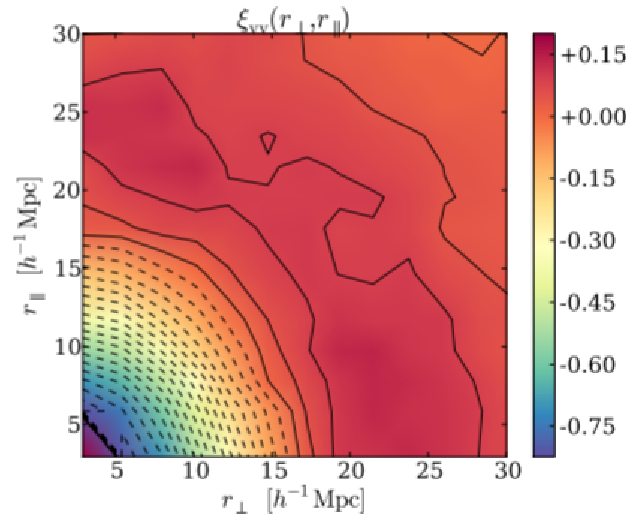

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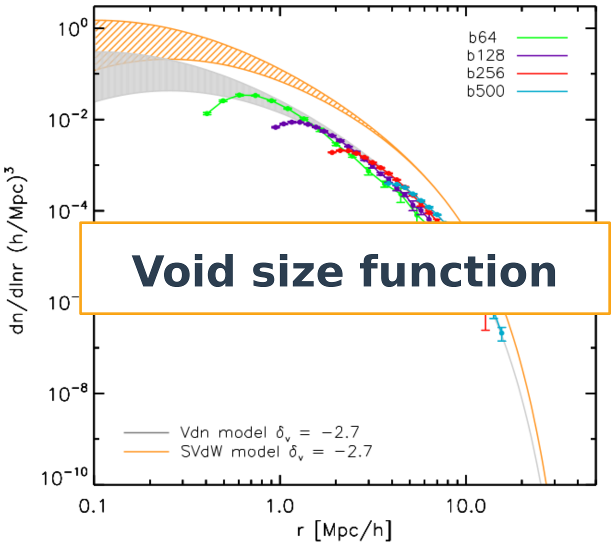

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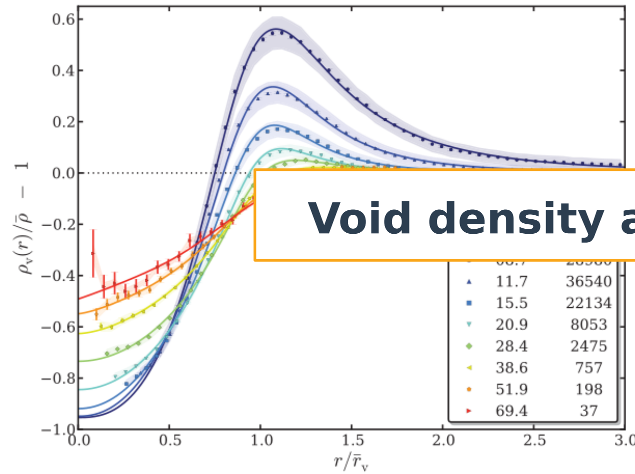

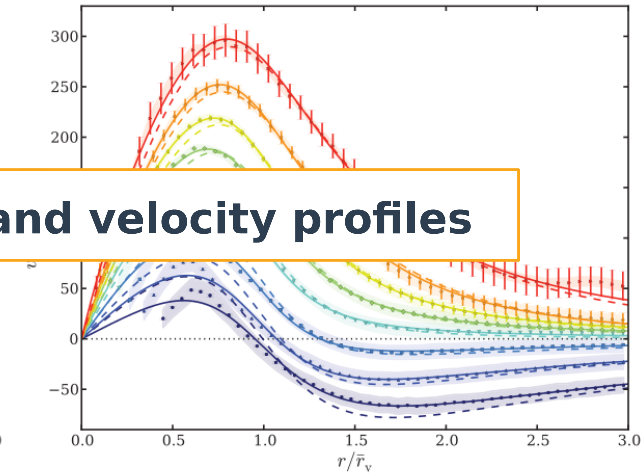

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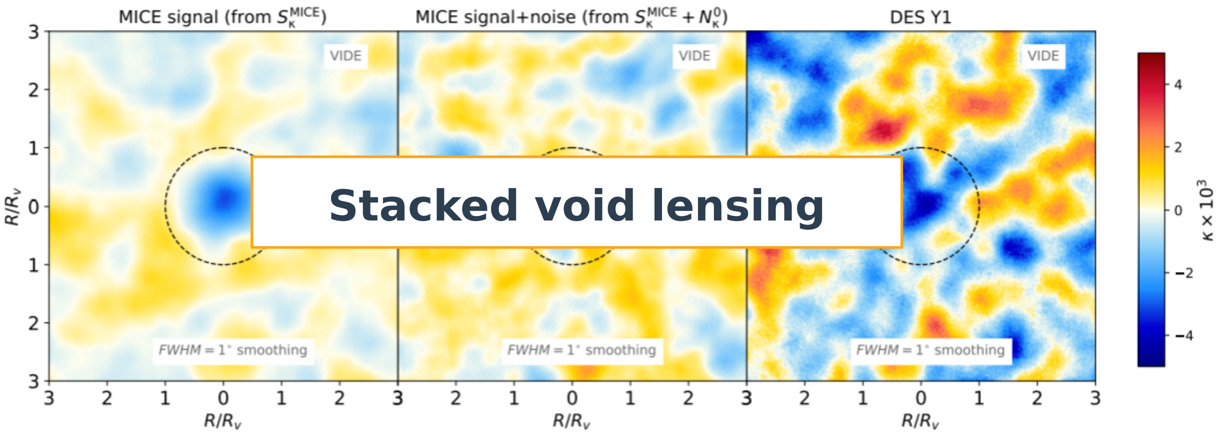
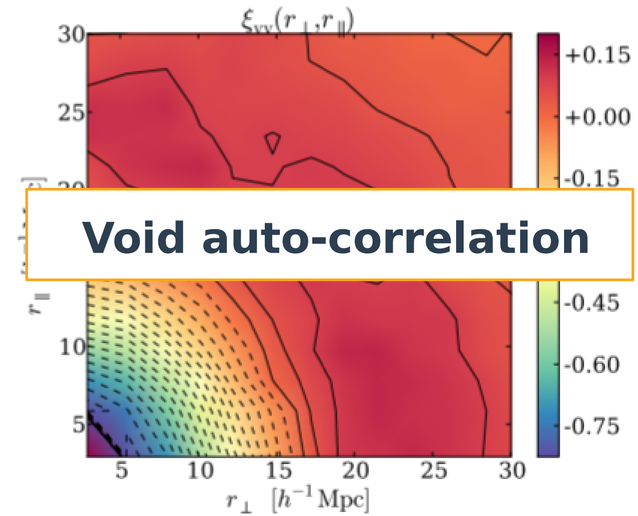


Stacked void lensing



Void auto-correlation

Hamaus et al. (2014) b

Voids as cosmological probes

Some advantageous aspects of cosmic voids:

- Only **mildly nonlinear** objects
- Easy modelling of **redshift-space distortions**
- Average **spherical symmetry** (standard spheres)
- High **complementary** with other cosmological probes

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Ideal environment to test a variety of cosmological parameters:

- **Growth rate** and **primordial non-Gaussianities**
- **Dark energy** and **neutrino mass**
- **Modified gravity** models

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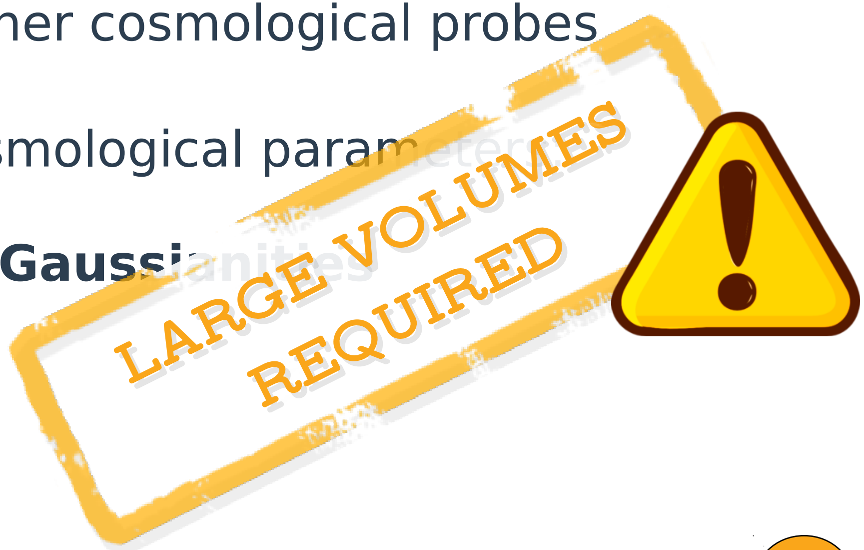
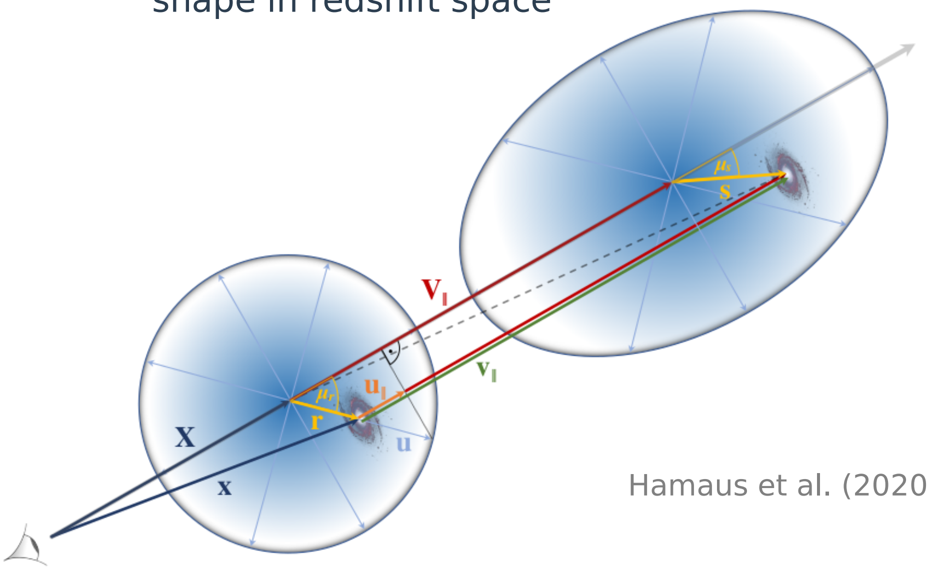


Precision cosmology with voids

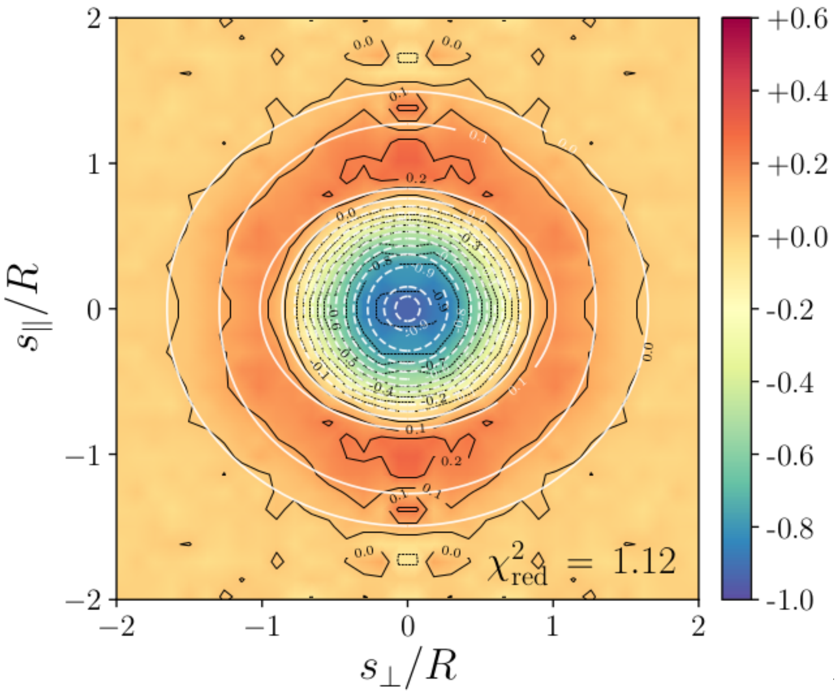
Modelling of the **dynamic** (redshift-space) and **geometric** (Alcock–Paczynski) **distortions** of average void shapes

Apparent elongation on voids shape in redshift space



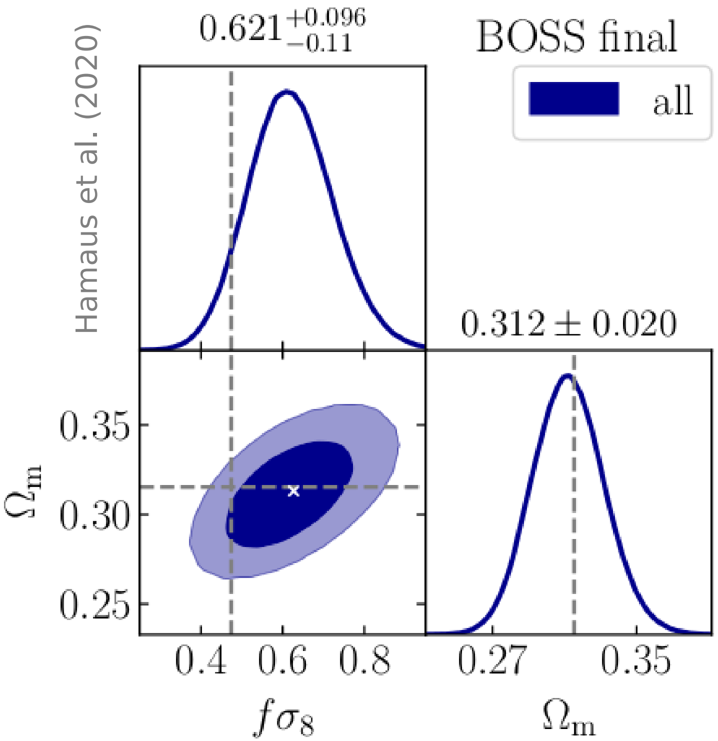
Hamaus et al. (2020)

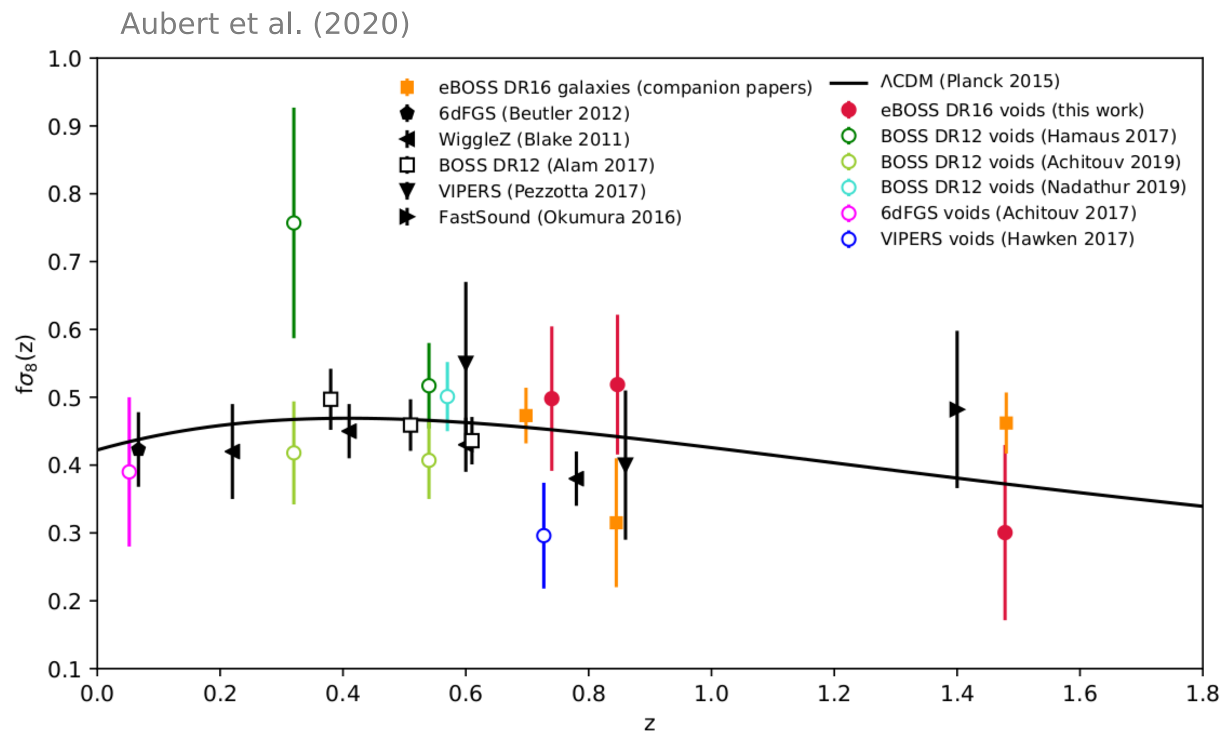
Void-galaxy cross-correlation function in redshift space



Precision cosmology with voids

Comparison with the **constraints** on the **growth rate** of cosmic structures obtained with conventional clustering measurements



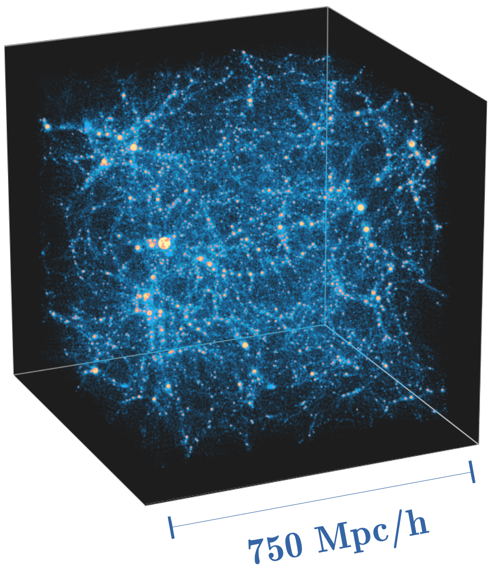


Voids in MG models with massive neutrinos

Cosmic voids in modified gravity models with massive neutrinos

S. Contarini, F. Marulli, L. Moscardini et al. (arXiv:2009.03309, MNRAS 504, 5021)

→ Disentangling the degeneracies coming from a proper combination of **modified gravity** and **neutrino mass**



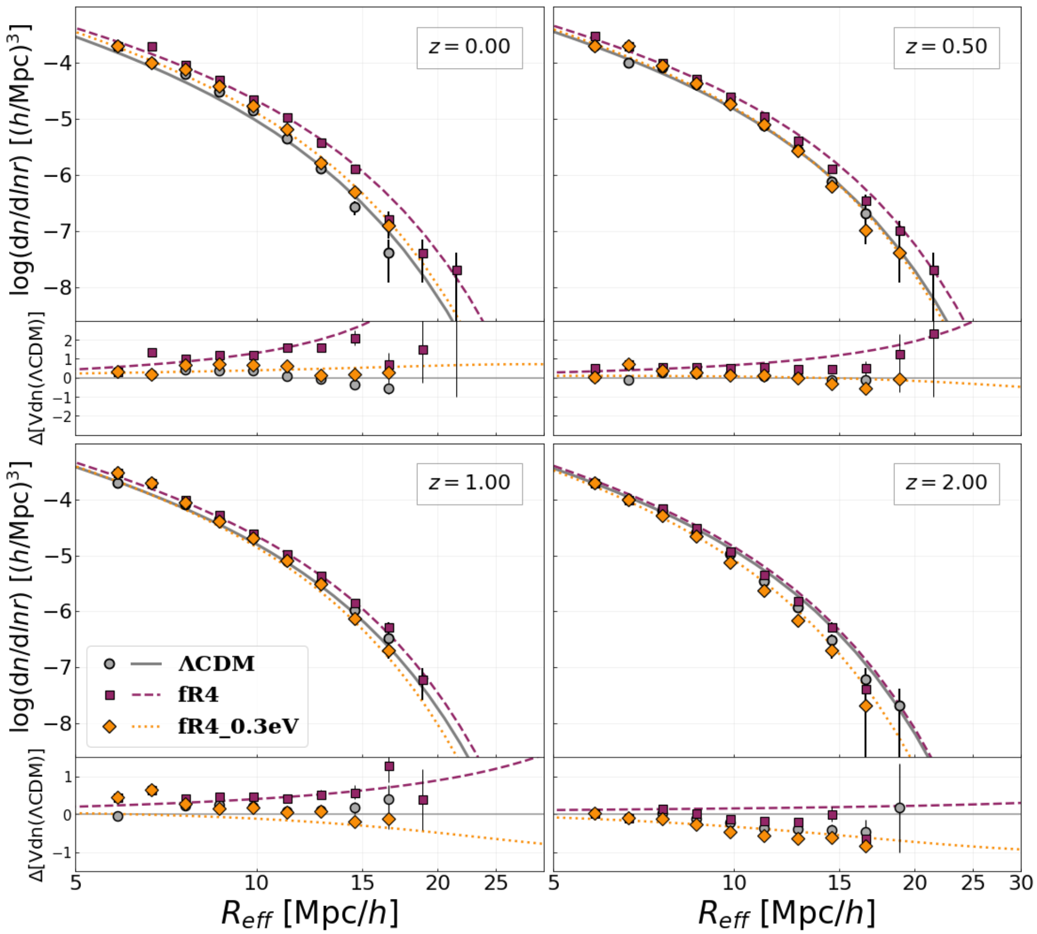
Voids in **DM particle** and **halo distributions** of the DUSTGRAIN-*pathfinder* simulations

Simulation name	Gravity model	f_{R0}	m_ν [eV]	Ω_ν	σ_8
ΛCDM	GR	–	0	0	0.842
fR4	$f(R)$	-1×10^{-4}	0	0	0.963
fR4_0.3eV	$f(R)$	-1×10^{-4}	0.3	0.00715	0.887

MG only (most extreme)

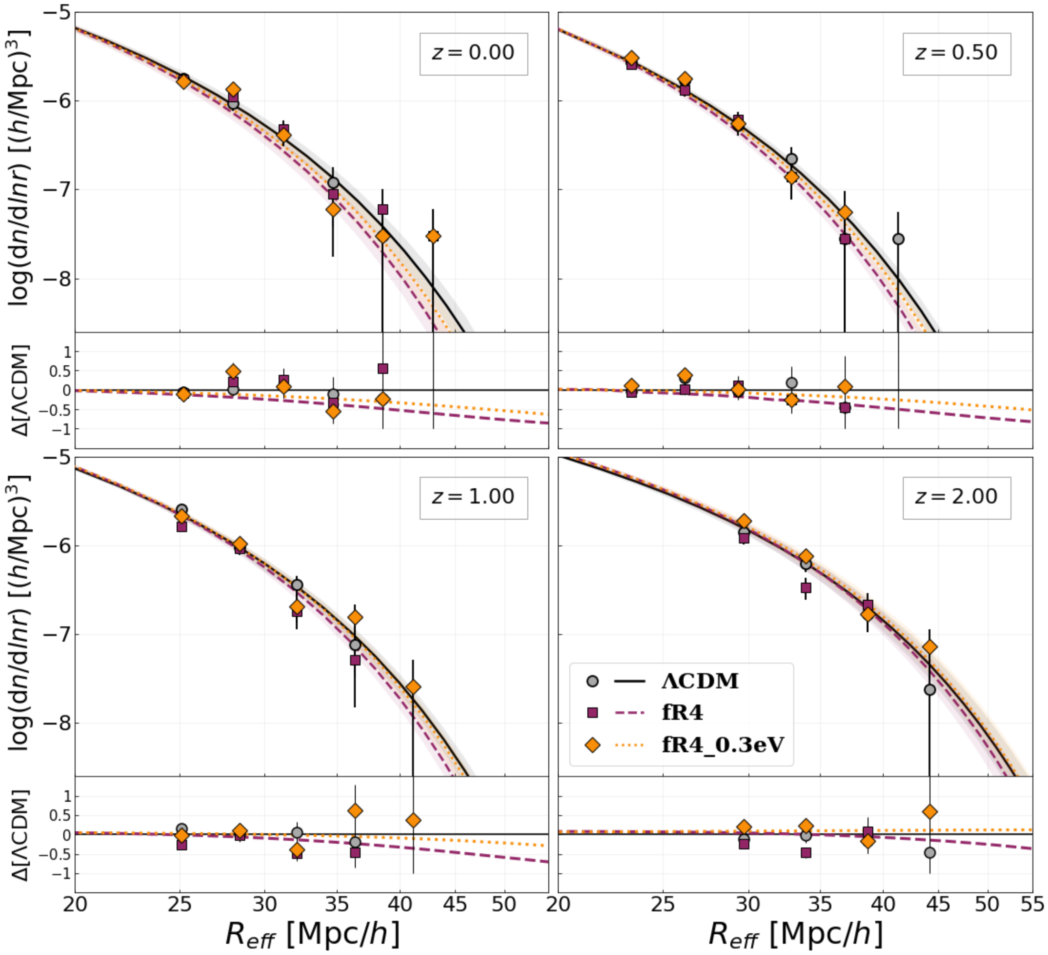
MG and massive neutrinos → degenerate with ΛCDM

Void size function in DM particle field



- Overall trend well reproduced by the theoretical model
- fR4 model predicts a **larger number of voids** with larger sizes at **low redshifts**
- **excessive reduction** in the void abundance as the effect of massive neutrinos at **high redshifts**

Void size function in biased tracer field



- **Re-parametrisation** of the Vdn model's threshold δ_v with a function of the **tracer bias** (Contarini et al. 2019)
- Measured abundances all **consistent** with the **ΛCDM** predictions
- Distinct trends predicted by the models, especially for **large voids**

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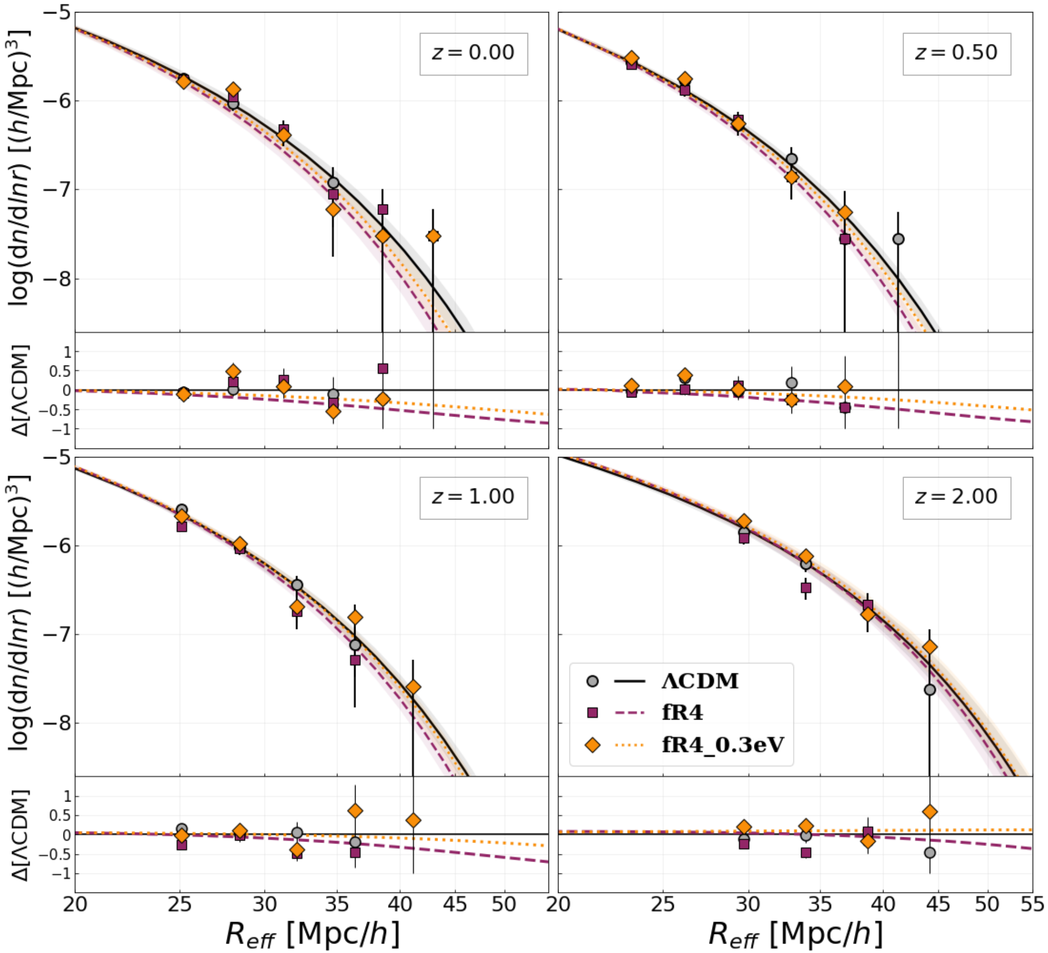

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Potentially high **disentangling power**, but larger void samples are required

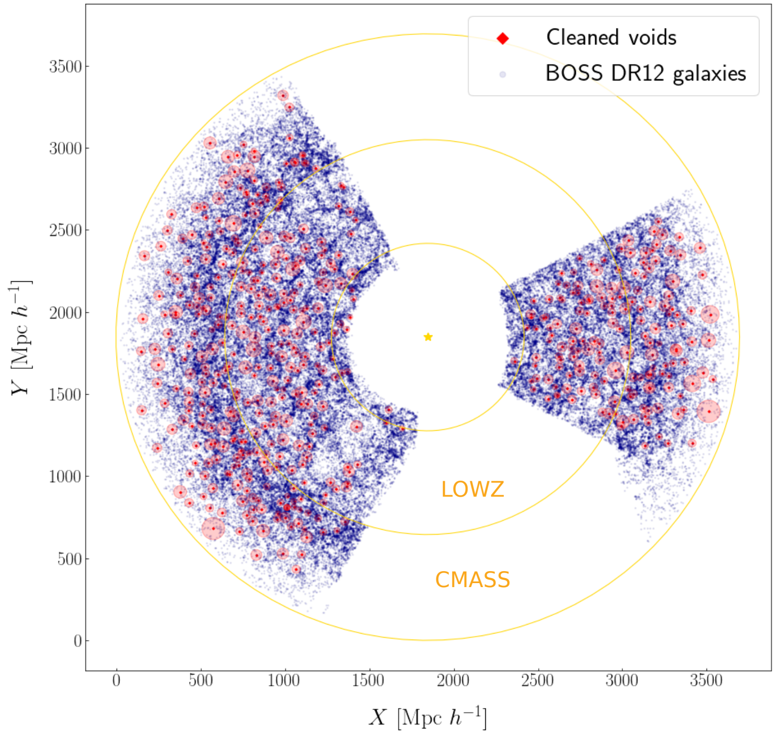
Future perspectives

- Investigate **different cosmological models** and calibrate the model using **large mock catalogues**

- Test the constraints on the **dark energy equation of state**, providing forecasts for the **Euclid** mission

- Derive cosmological constraints using the abundance of voids identified in **wide field galaxy surveys** (BOSS, eBOSS, DES, …)

- Exploit the powerful **combination** of voids with **other probes**



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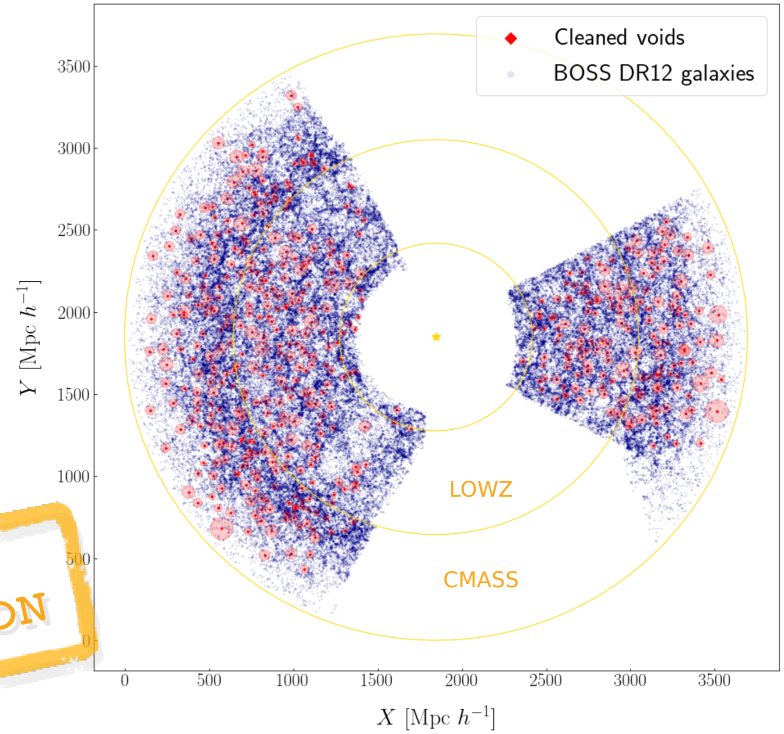

THANKS FOR YOUR ATTENTION

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