Institute for Computational Cosmology

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# Shedding light on modified gravity theories using voids

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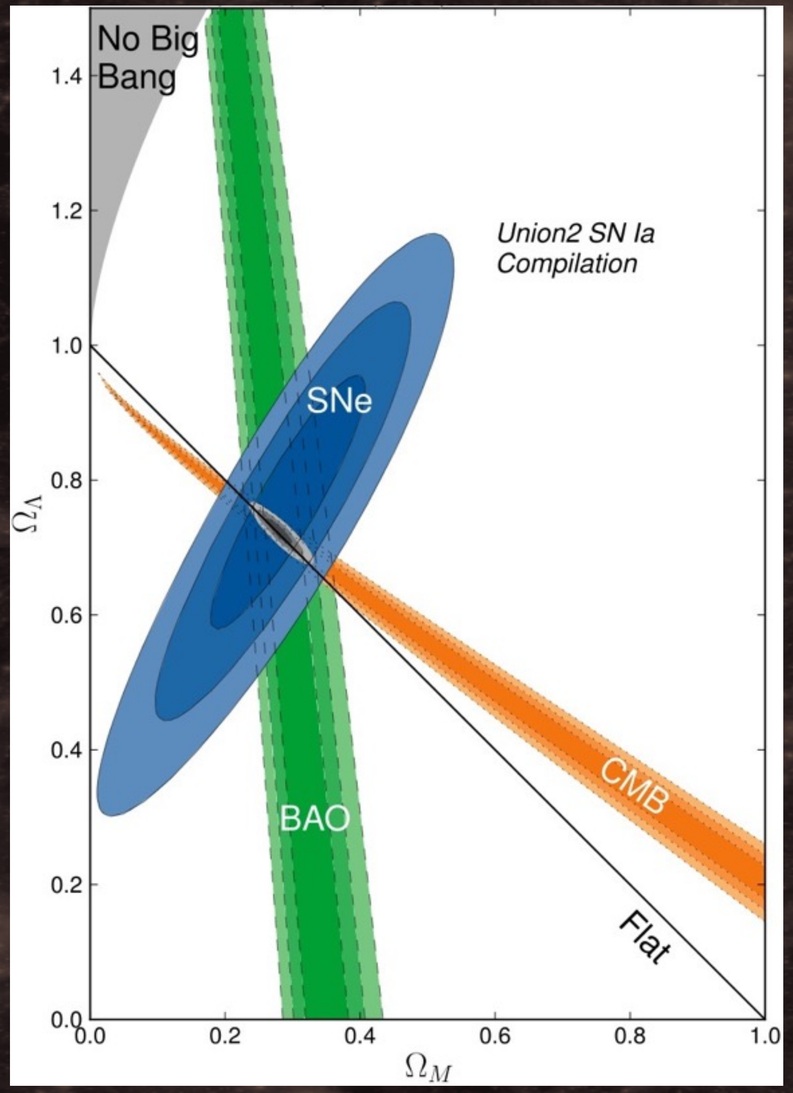
Cosmology 2018
Dubrovnik, Croatia
22 October 2018

MC+, MNRAS 476, 2018
Davies, MC+, MNRAS 480, 2018
Paillas, MC+, arXiv:1810.02864

# Overview




Amanullah+ (2010)

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = -8\pi G T_{\mu\nu}$$

General Relativity + dark energy:

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = -8\pi G T_{\mu\nu} + \Lambda g_{\mu\nu}$$

Modify General Relativity:

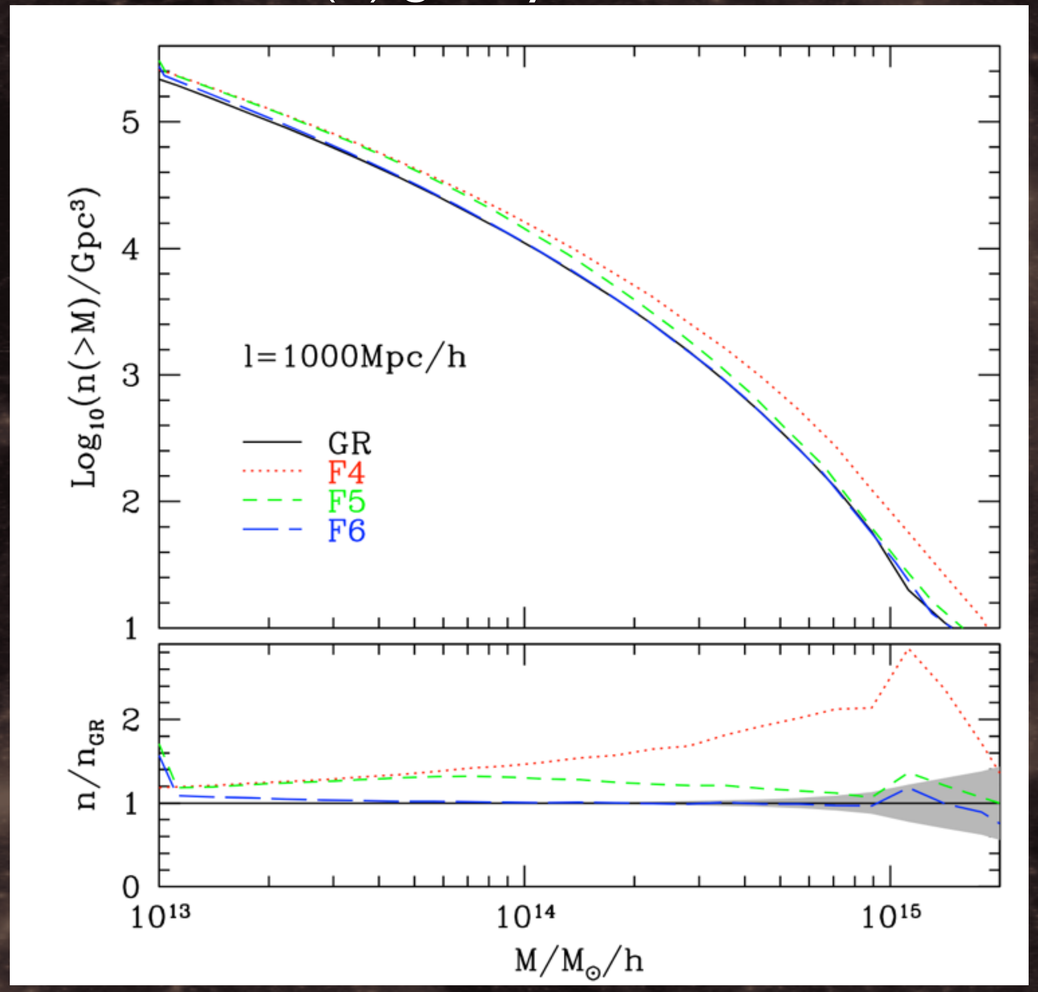
$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} - \Lambda g_{\mu\nu} = -8\pi G T_{\mu\nu}$$

# Voids as probes of modified gravity models

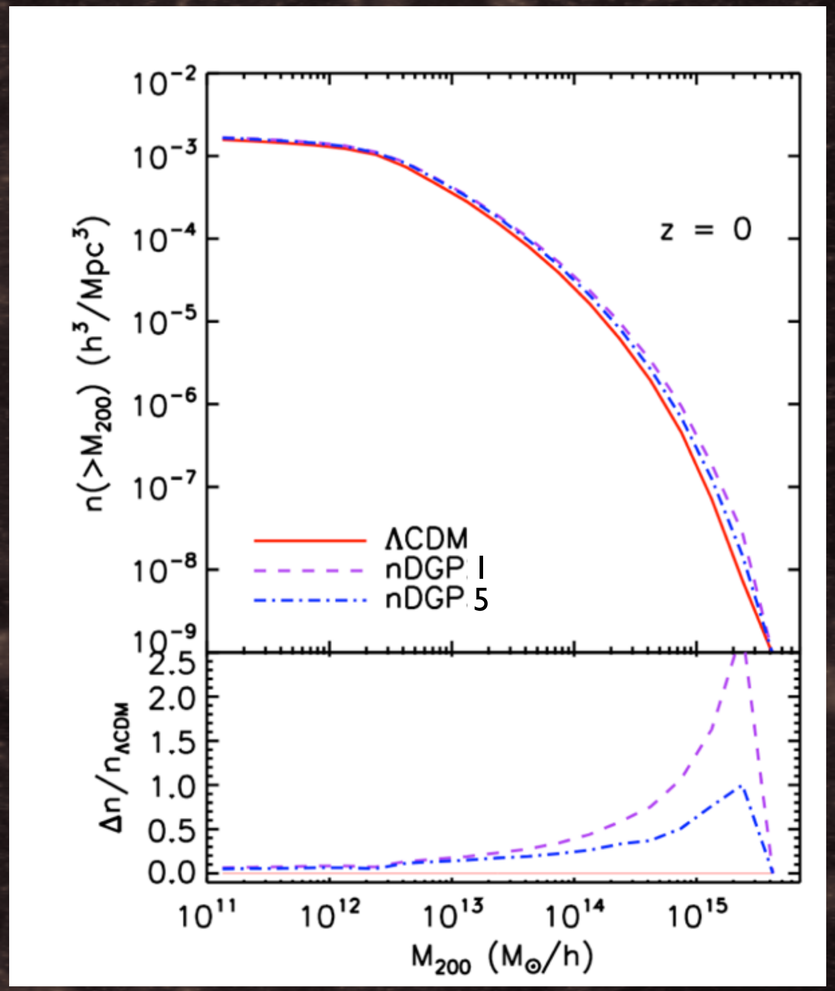
- The accelerated expansion of the Universe can be explained by modifying General Relativity, i.e. Modified Gravity (MG) models
- Such theories have additional degrees of freedom (e.g. scalar fields) that give rise to fifth forces
- Due to stringent solar system constraints, such forces must vanish in high density regions (*screening mechanisms*)
- These fifth forces can attain maximum values in low density regions, i.e. voids
- Many models have similar phenomenology, so I will focus on two such models: f(R) (Hu & Sawicki 2007) and nDGP (Dvali+ 2000)

# Halo mass function in MG models

f(R) gravity models




nDGP gravity models




Cai+ (2015);

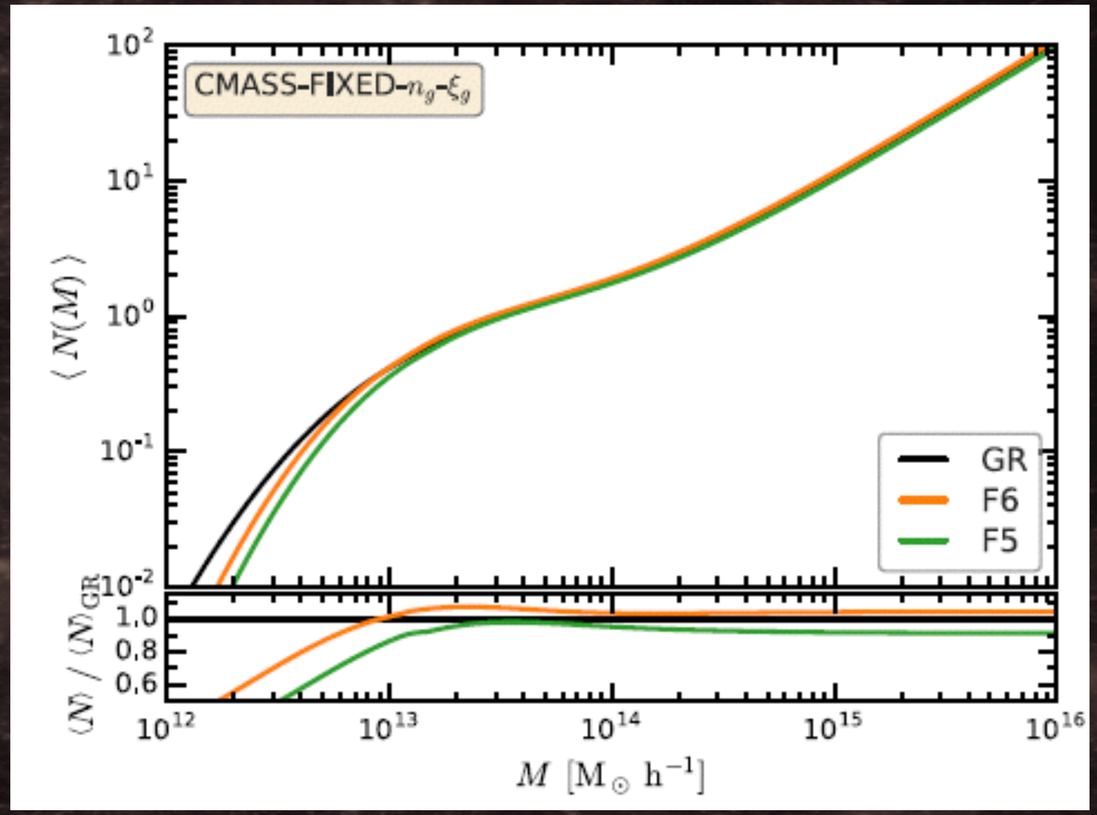
Falck+ (2018)

# Tracer field

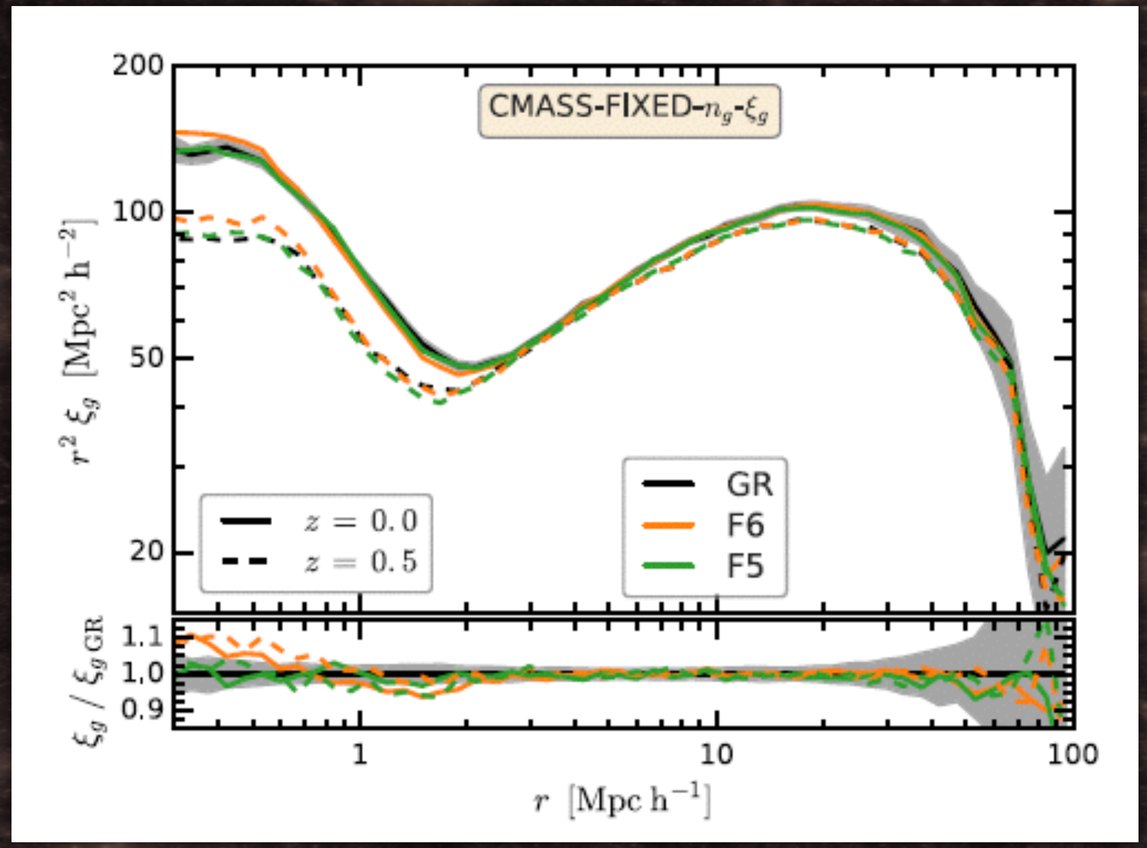
Distribution of galaxies as realistic as possible:

- HOD galaxies with number density and 2-pt correlation function as in SDSS CMASS sample.

- Match the 2-pt correlation function of galaxies in GR and MG models.



# Same galaxy clustering

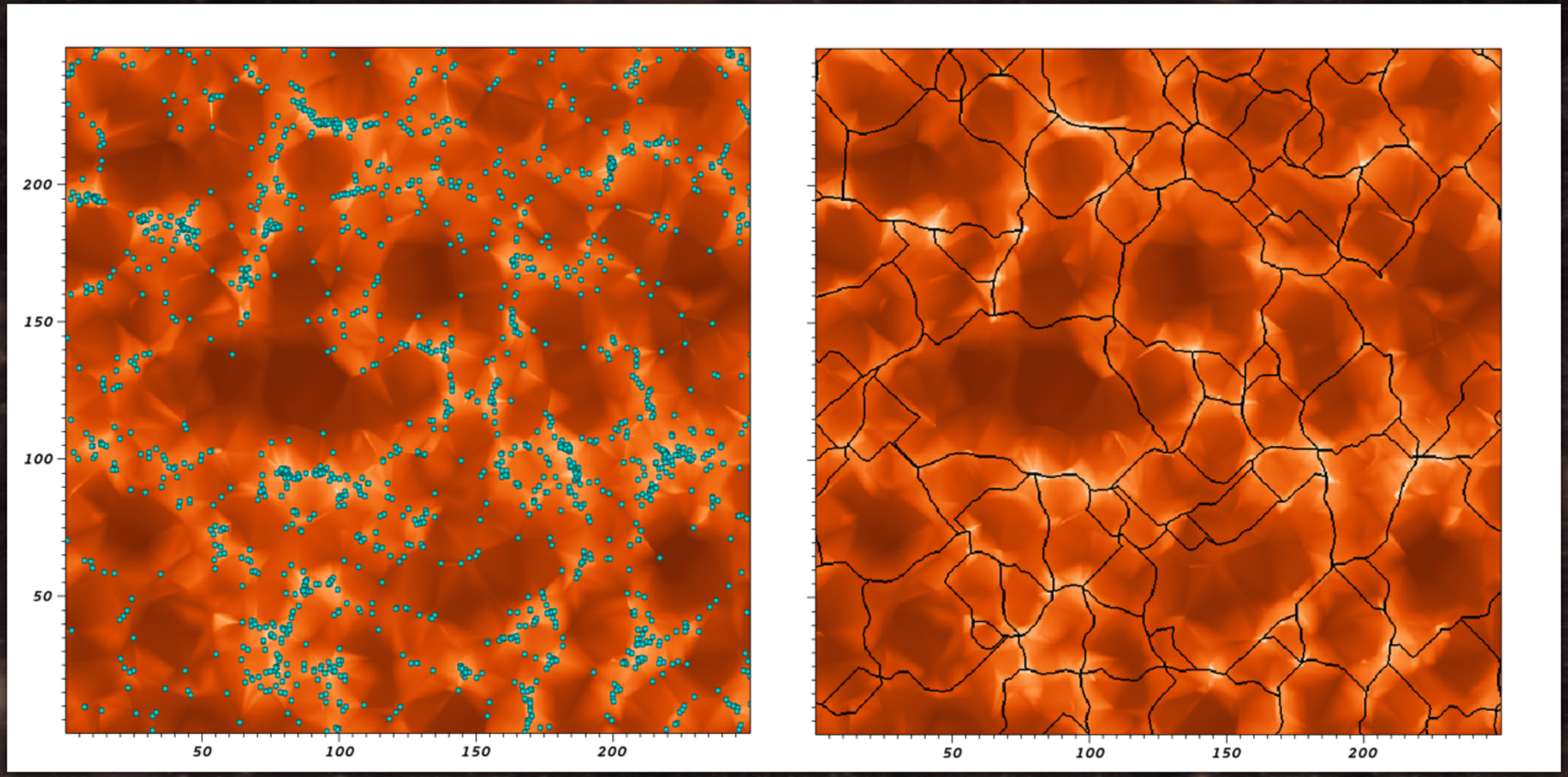



MC+(2018)

# Void identification

Distribution of **galaxies**

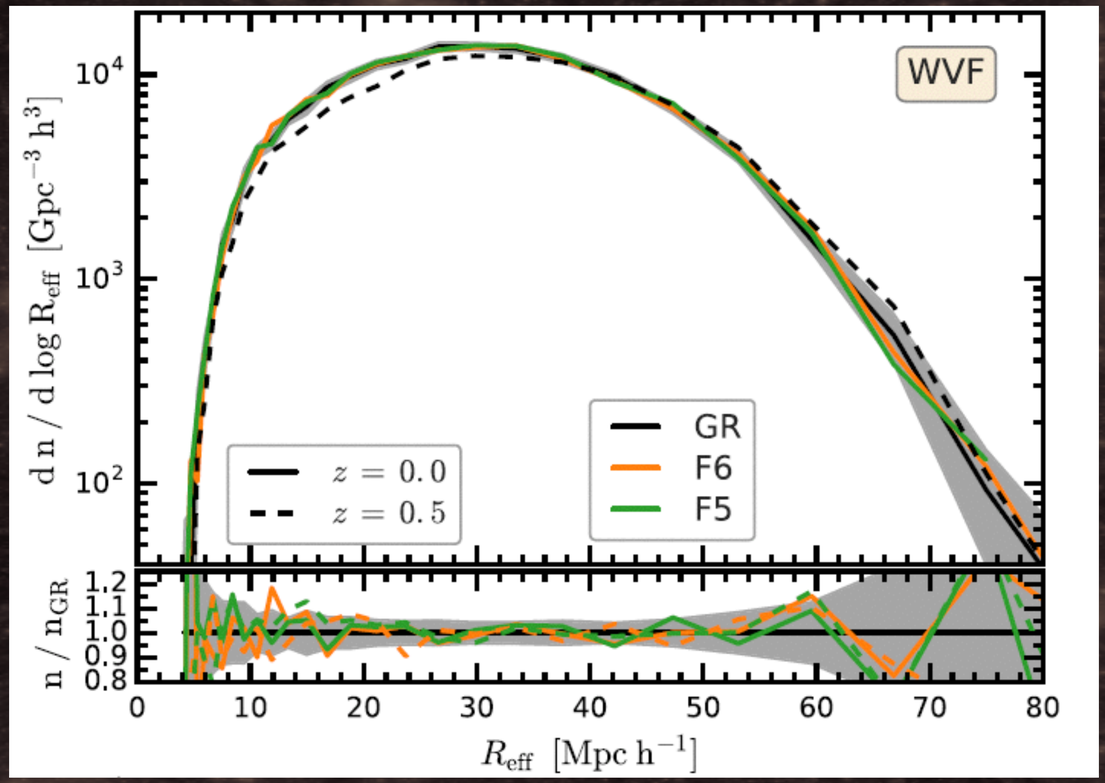
Distribution of **voids**




Watershed void finder (Platen + 2007)

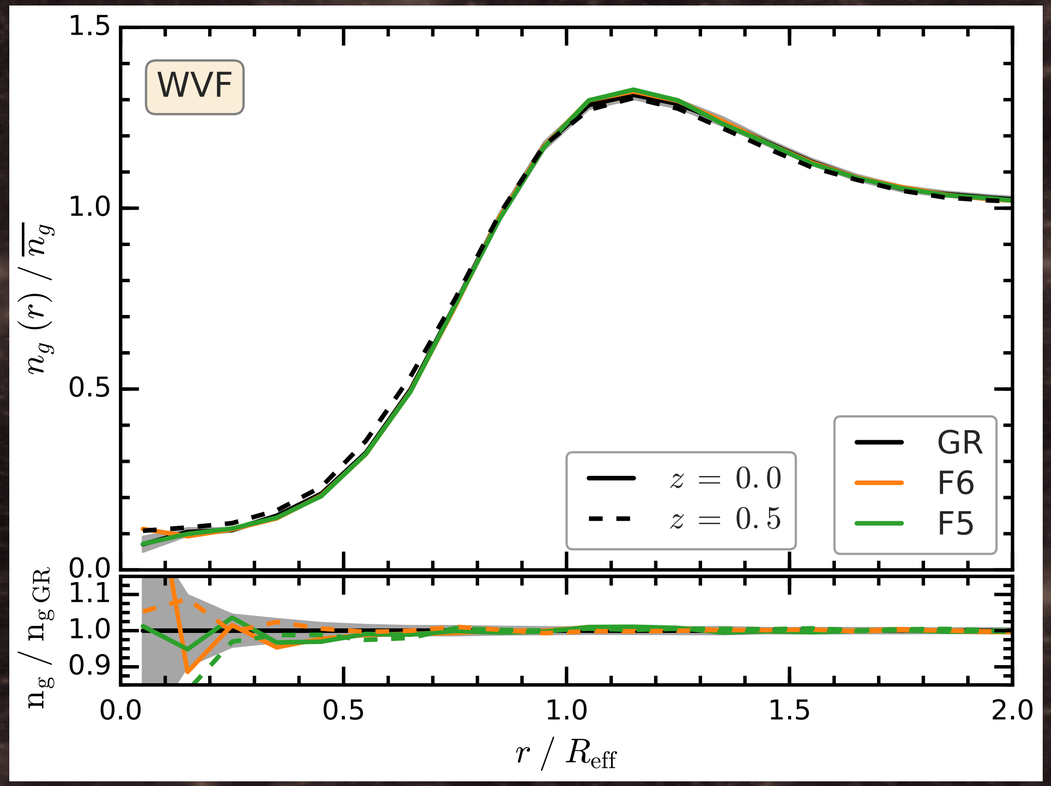
MC+(2018)

# Distribution of void sizes



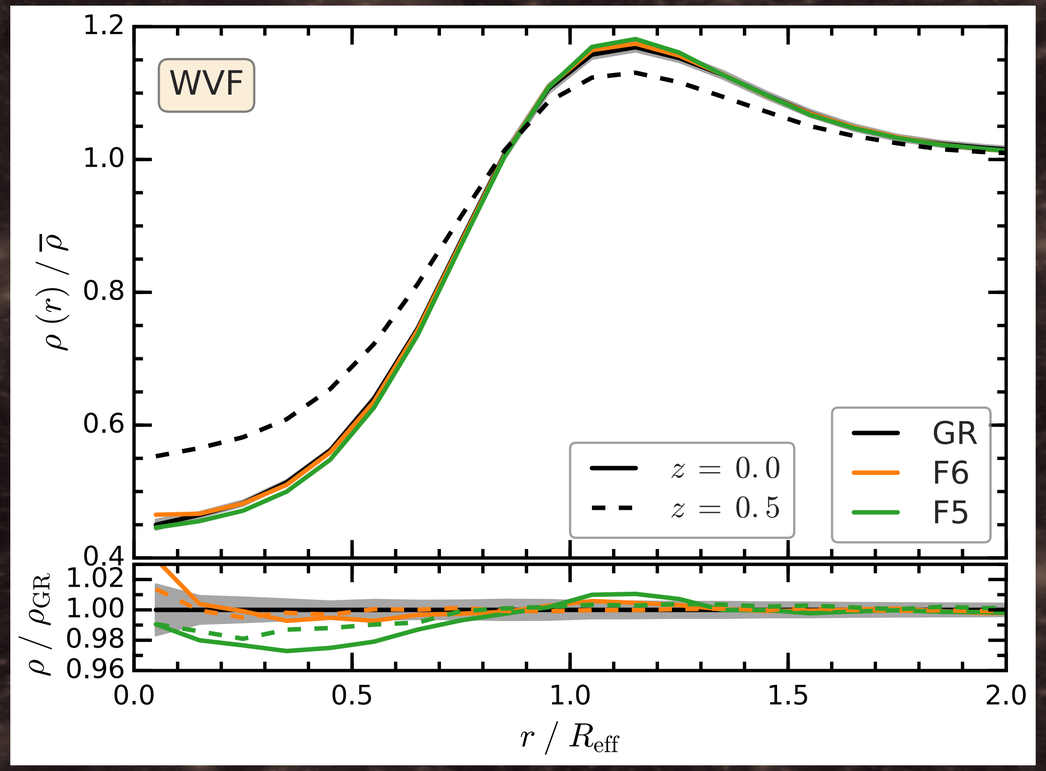

MC+(2018)

# Galaxy density profiles



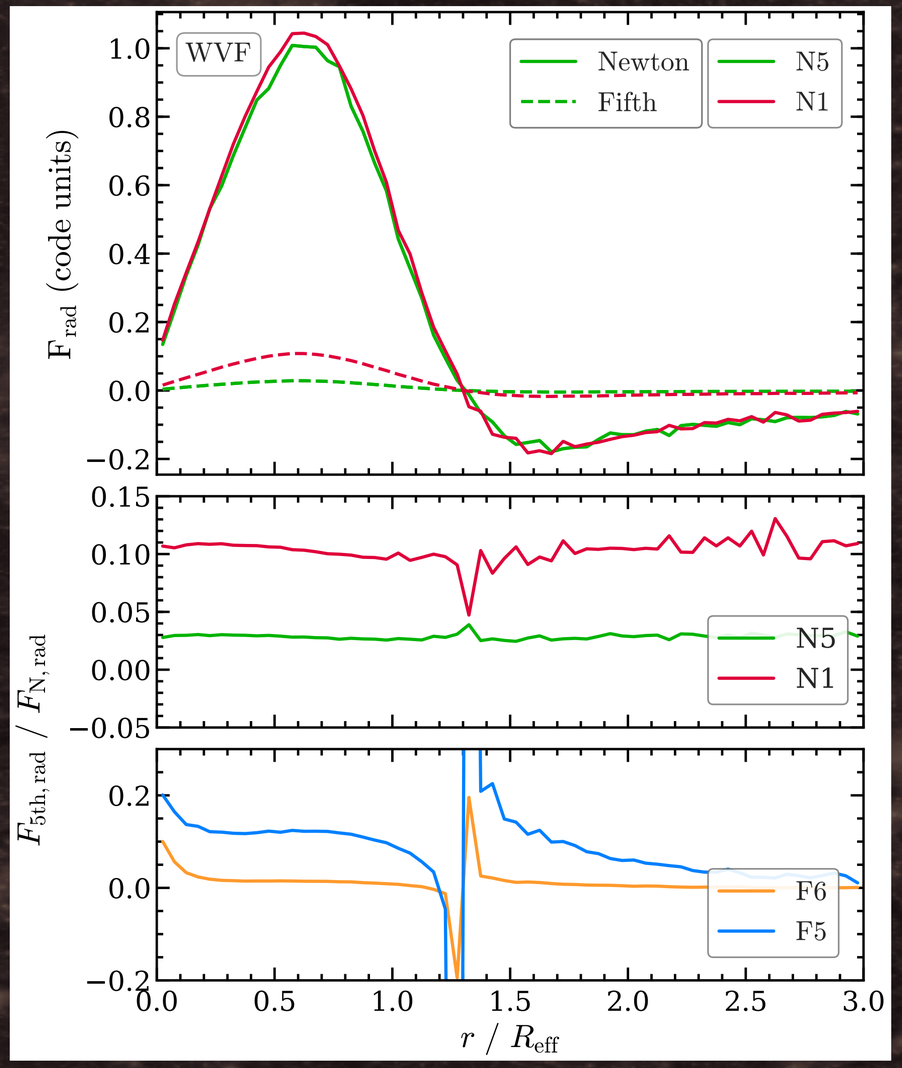

MC+(2018)

# Mass density profiles



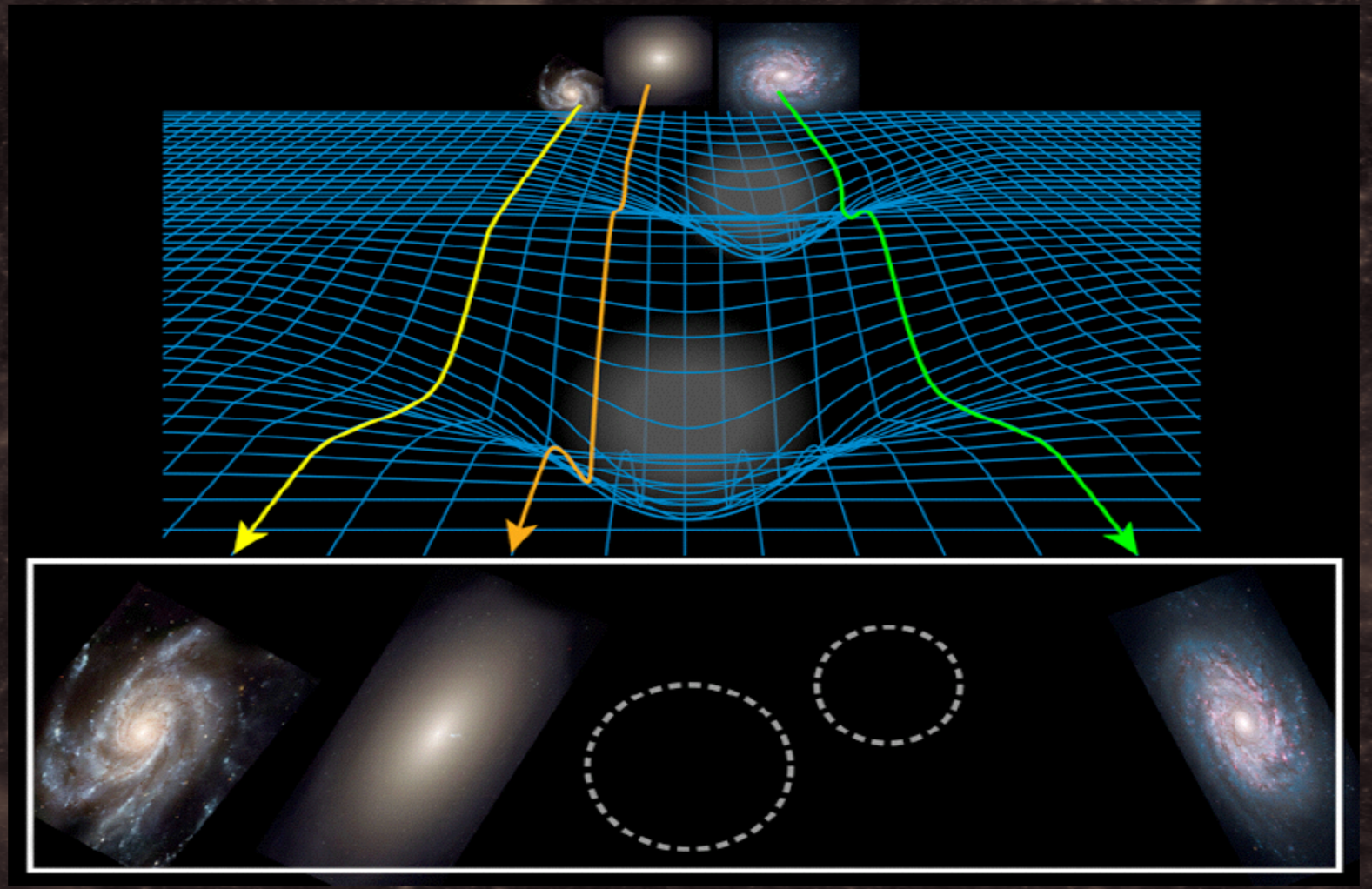

MC+(2018)

# Why more underdone voids?




Paillas + (2018)

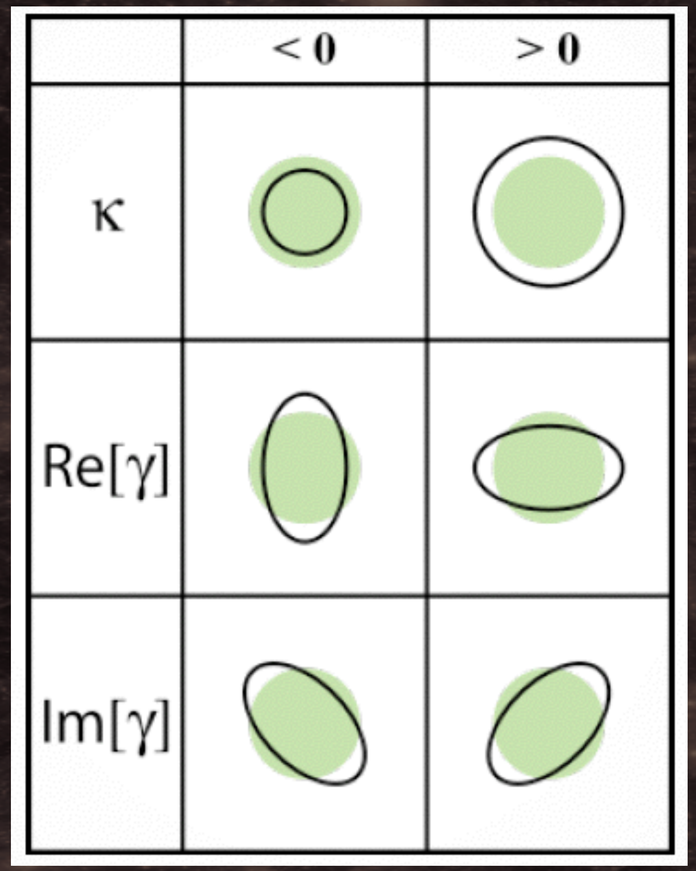
# Gravitational lensing



# Gravitational lensing

Convergence

Shear



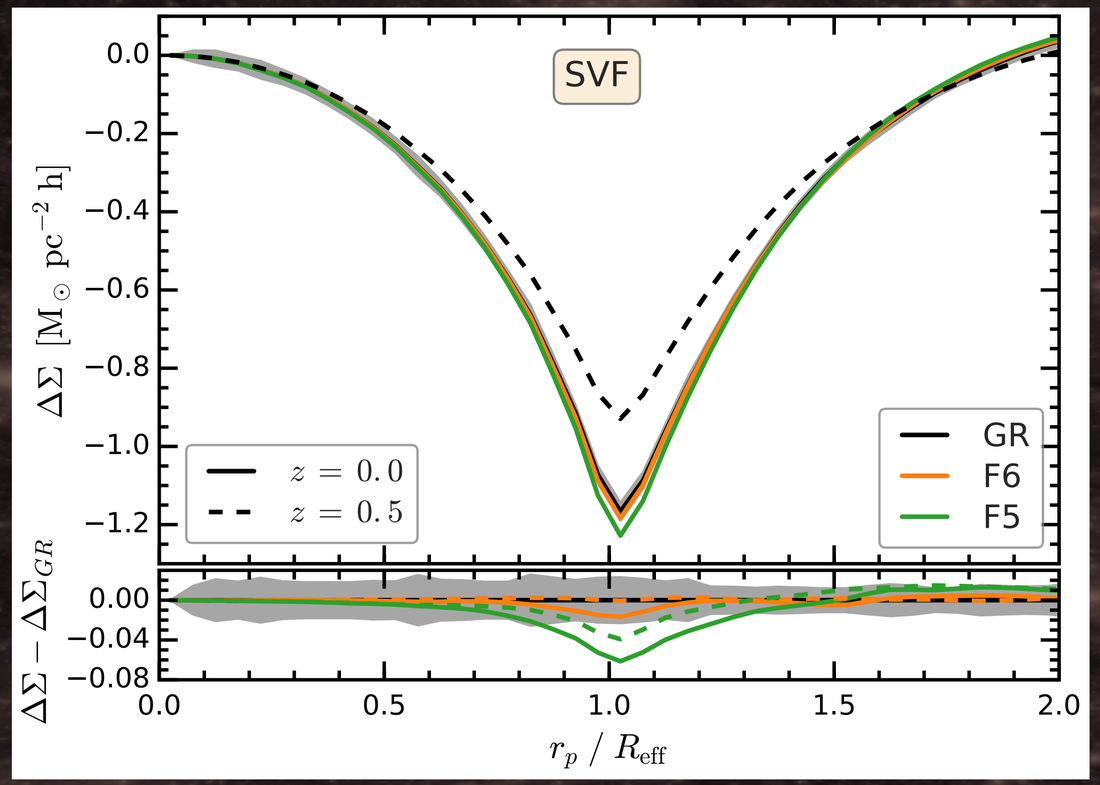

- magnification of background galaxies
- proportional to the line-of-sight projected density

- change in the shape of background galaxies
- proportional to the line-of-sight projected density

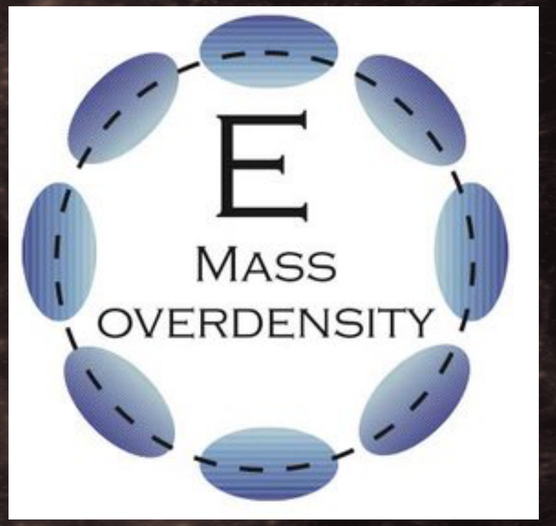
$$\gamma_t = \overline{\kappa}(<r) - \kappa(r)$$

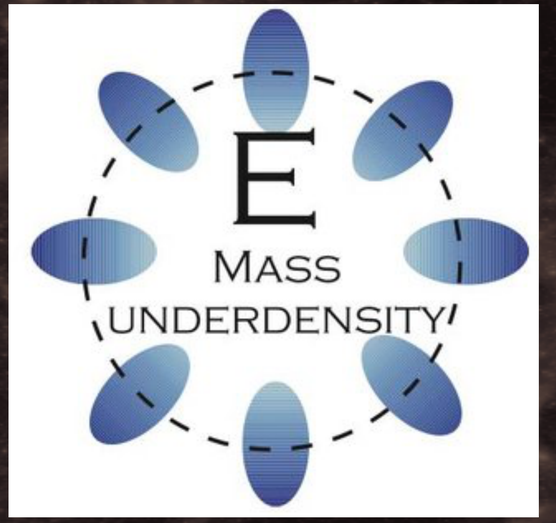
# Tangential shear profiles

$$\gamma_t(r) = \frac{\Delta\Sigma(r)}{\Sigma_c}$$




MC+(2018)

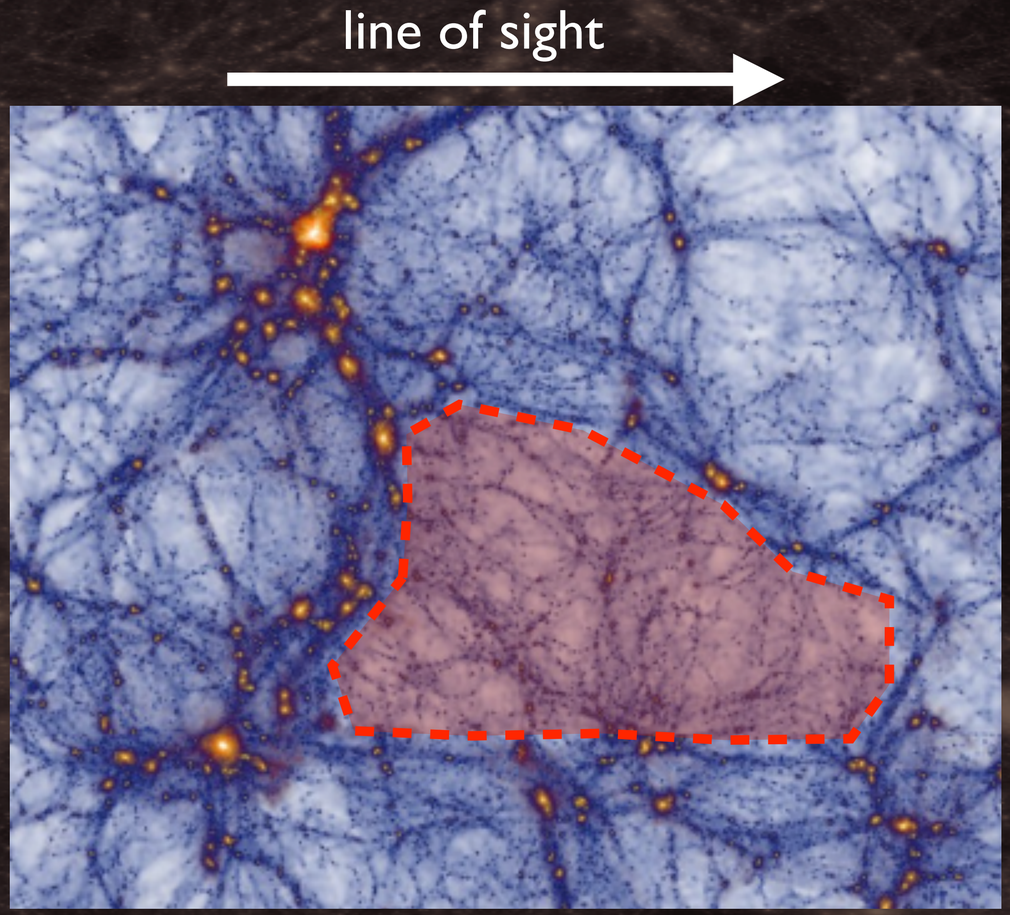


# Why is weak lensing by voids so *weak*?

$$\gamma_t(r) = \frac{\Delta\Sigma(r)}{\Sigma_c} = \frac{\overline{\Sigma}(<r) - \Sigma(r)}{\Sigma_c}$$

- The lensing signal depends on the projected line-of-sight density



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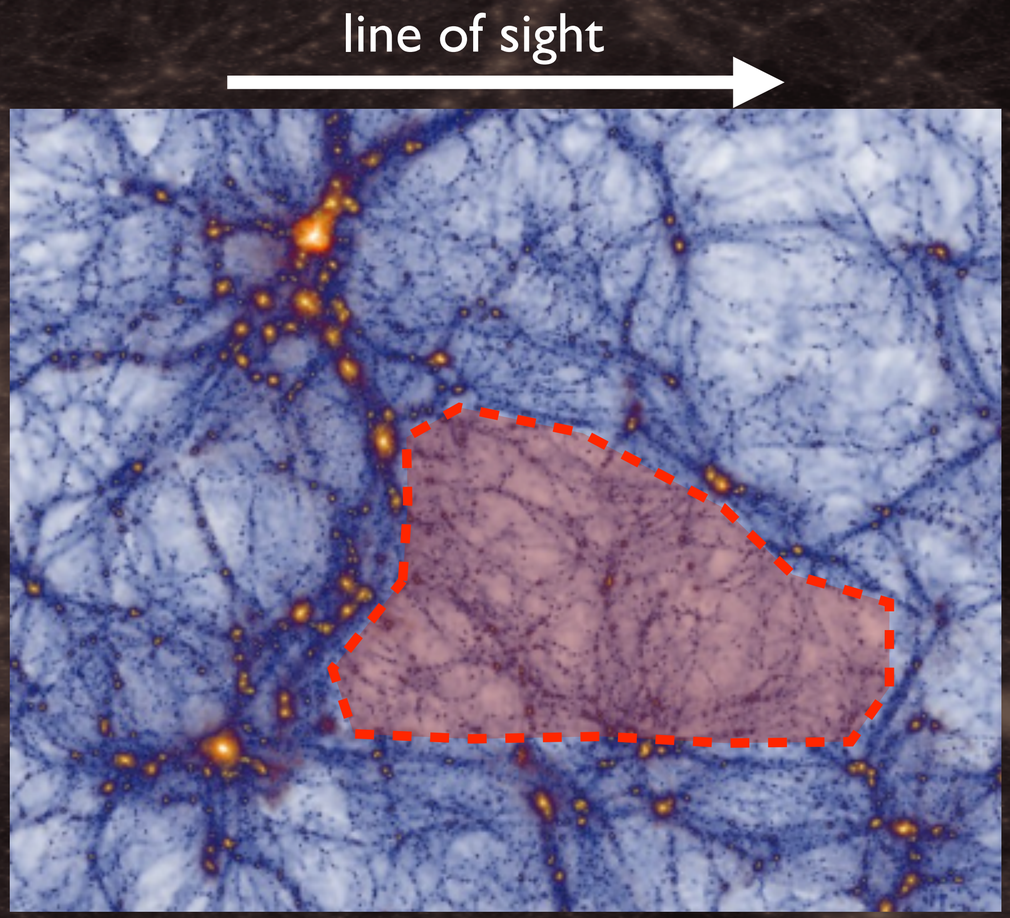
- High density regions on the void edge and also along the line of sight partially compensate the emptiness of the void



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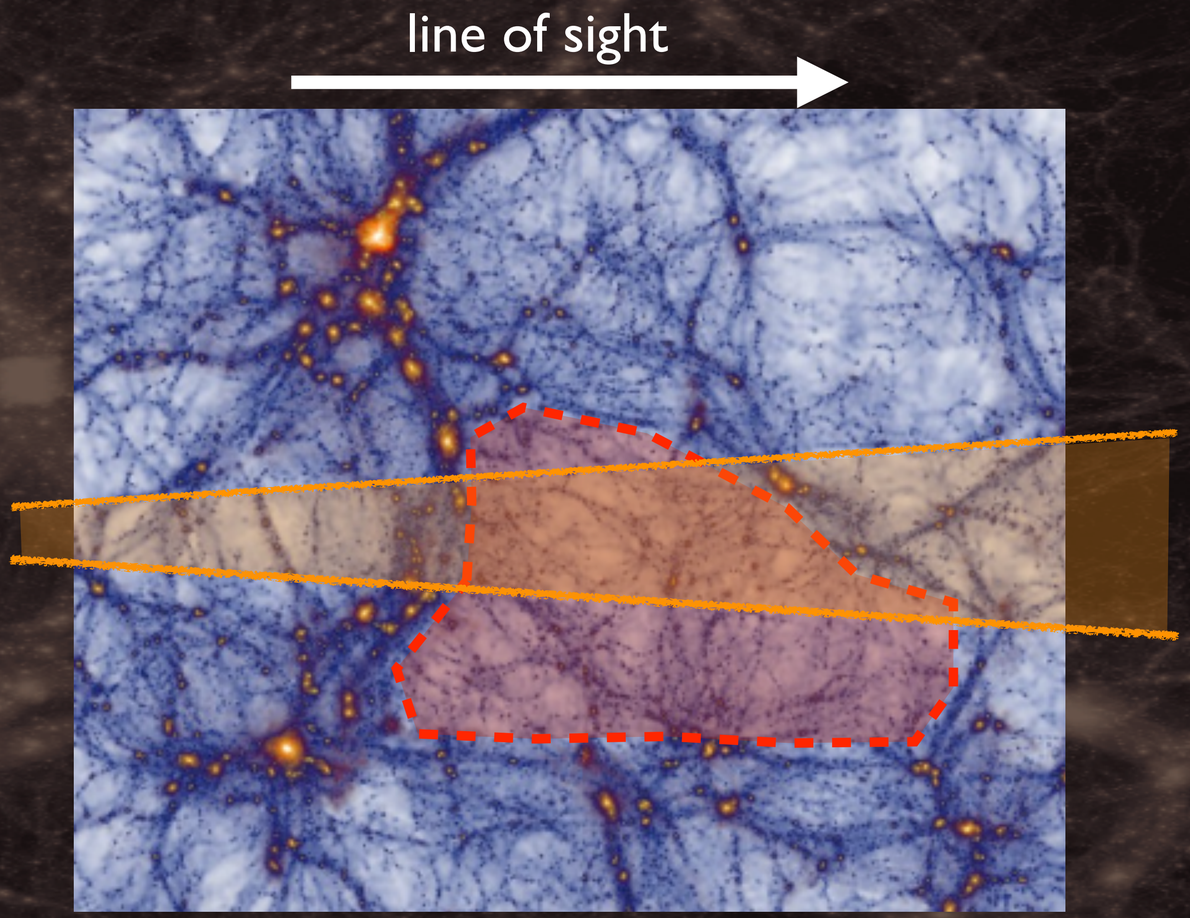
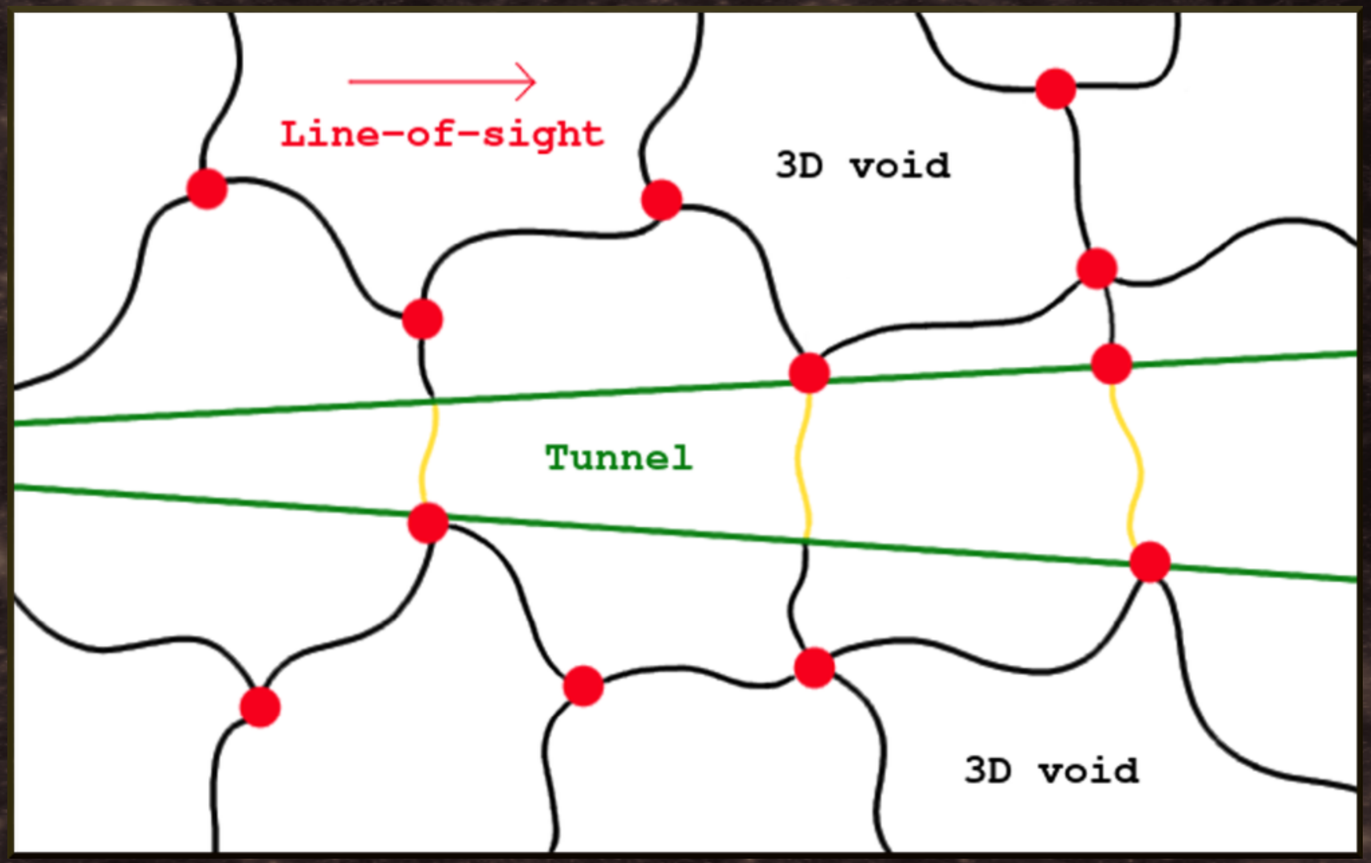
- The lensing signal depends on the projected line-of-sight density
- High density regions on the void edge and also along the line of sight partially compensate the emptiness of the void
- Choose line of sights through voids that do not overlap with high density regions —> line-of-sight under densities

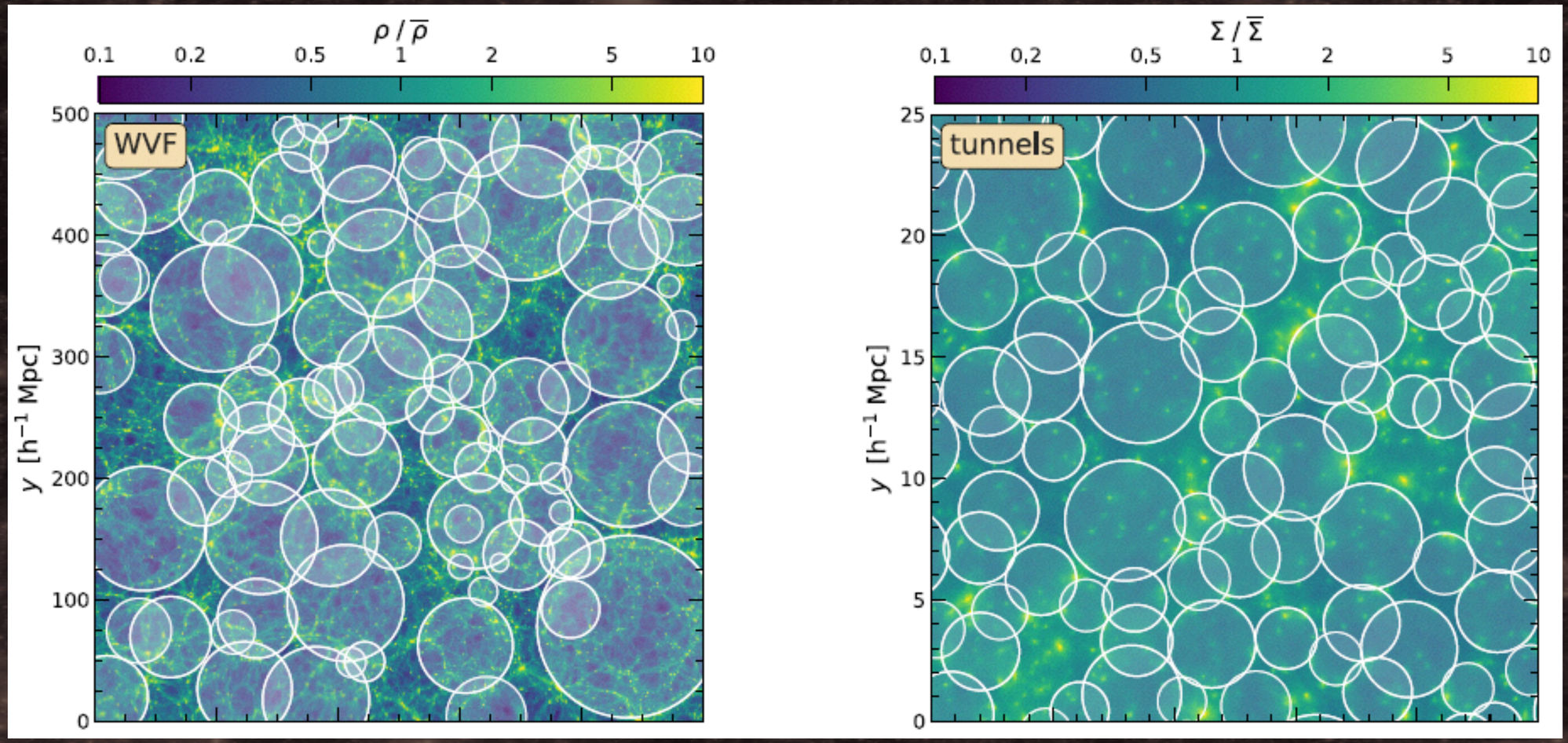


# Voids in the projected galaxy distribution

Tunnels
(MC + 2018)

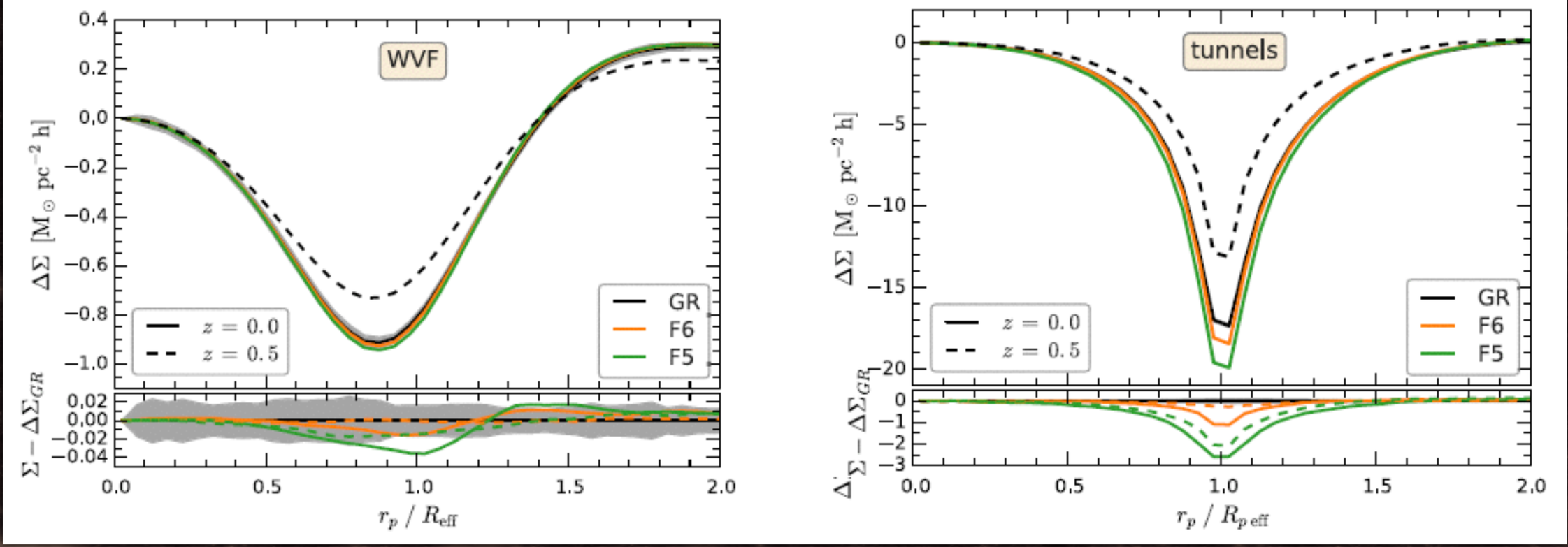


# 3D versus 2D void finders




MC+(2018)

# Void lensing profiles



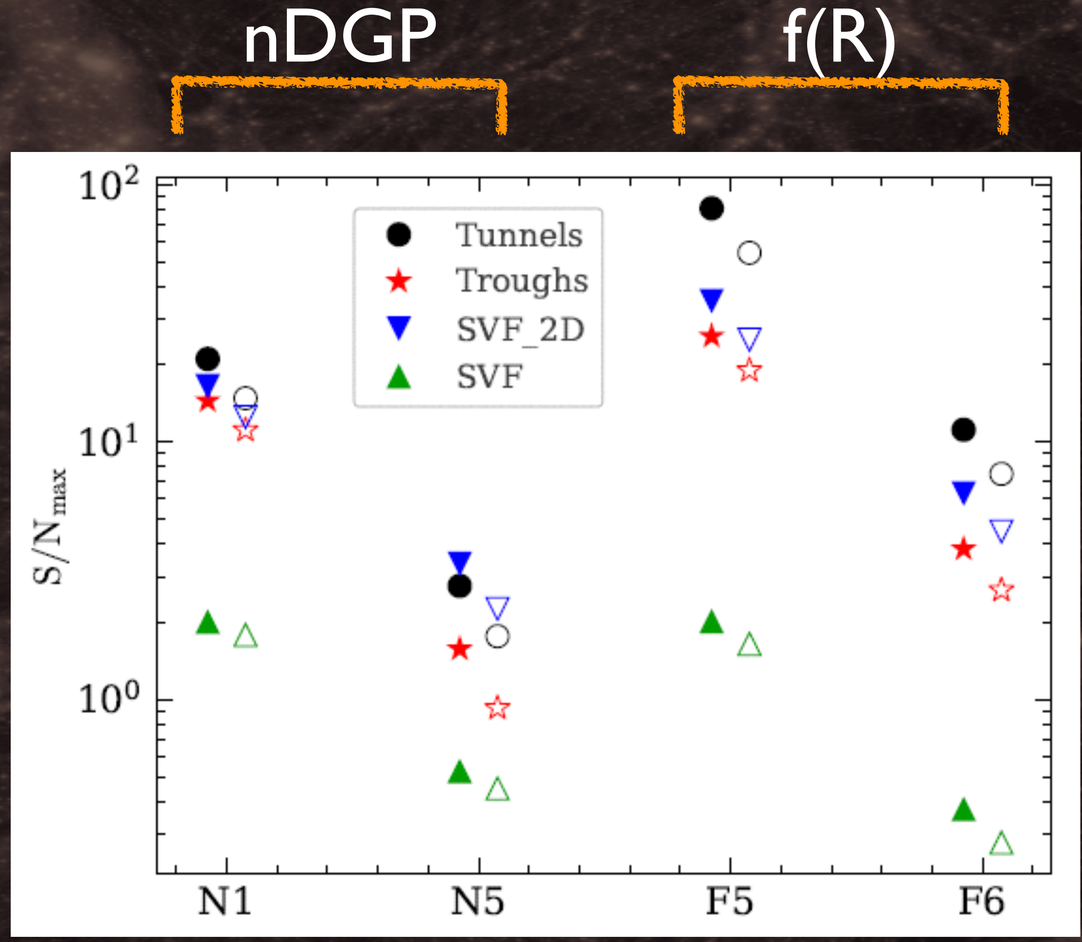

MC+(2018)

# S/N for distinguishing models

Predictions for future surveys including shape noise:

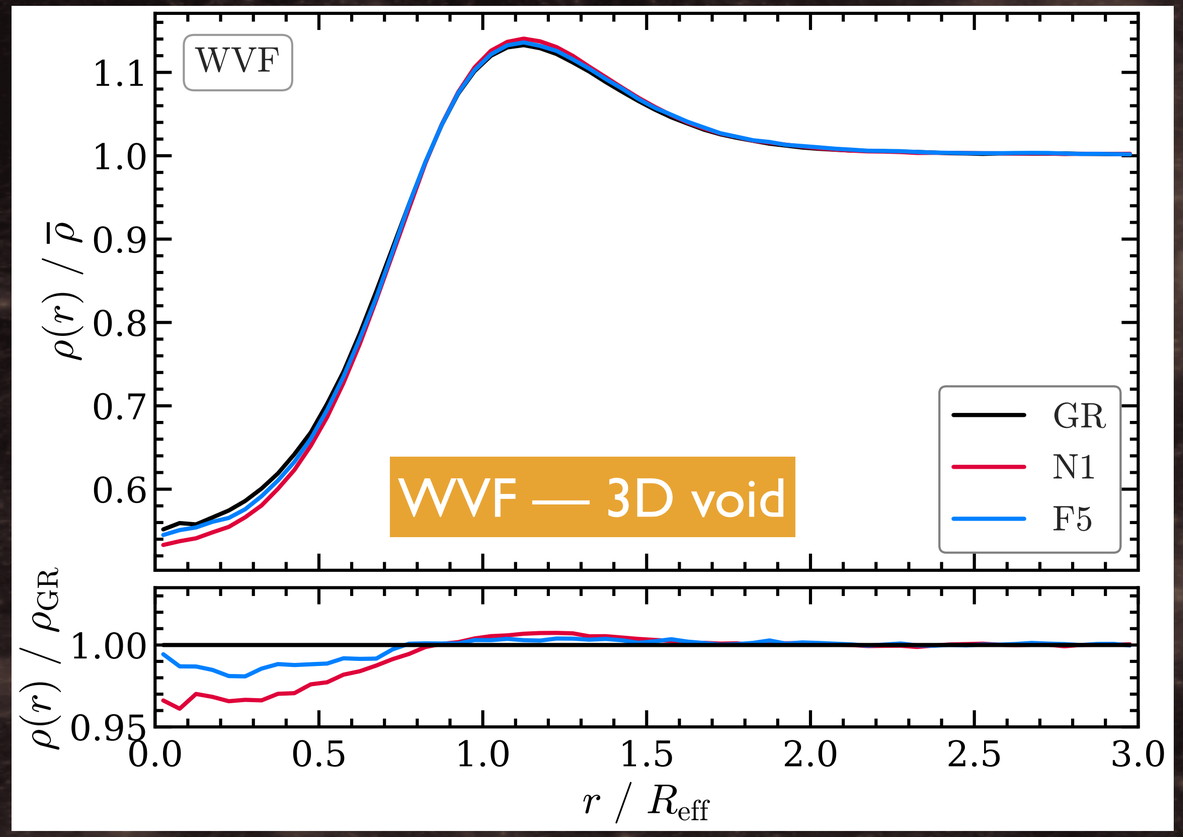
LSST (filled symbols)

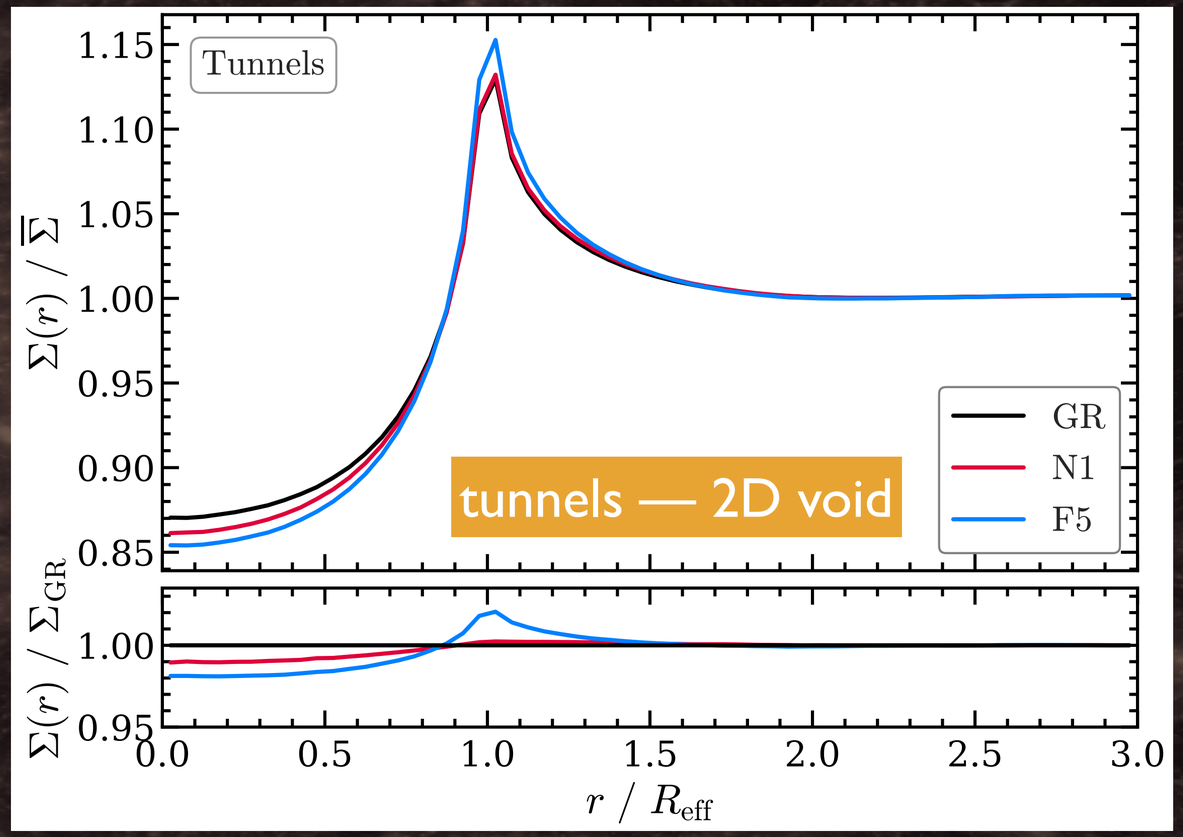
Euclid (empty symbols)




Paillas + (2018)

# f(R) versus nDGP gravity

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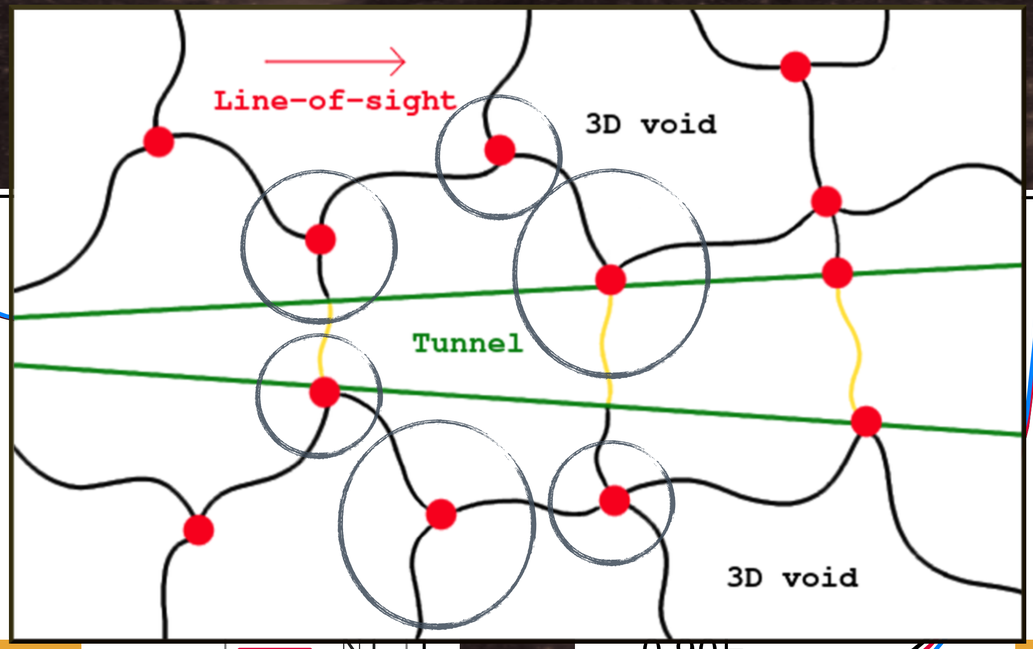
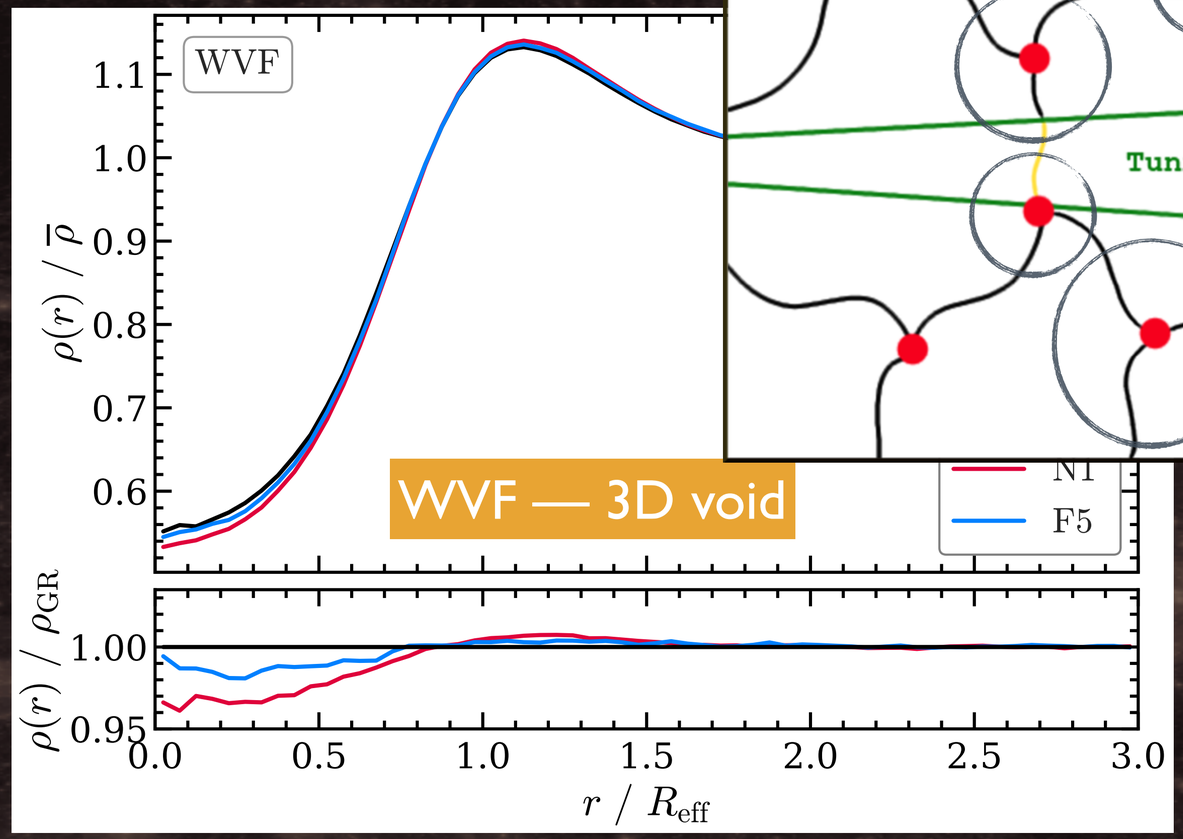
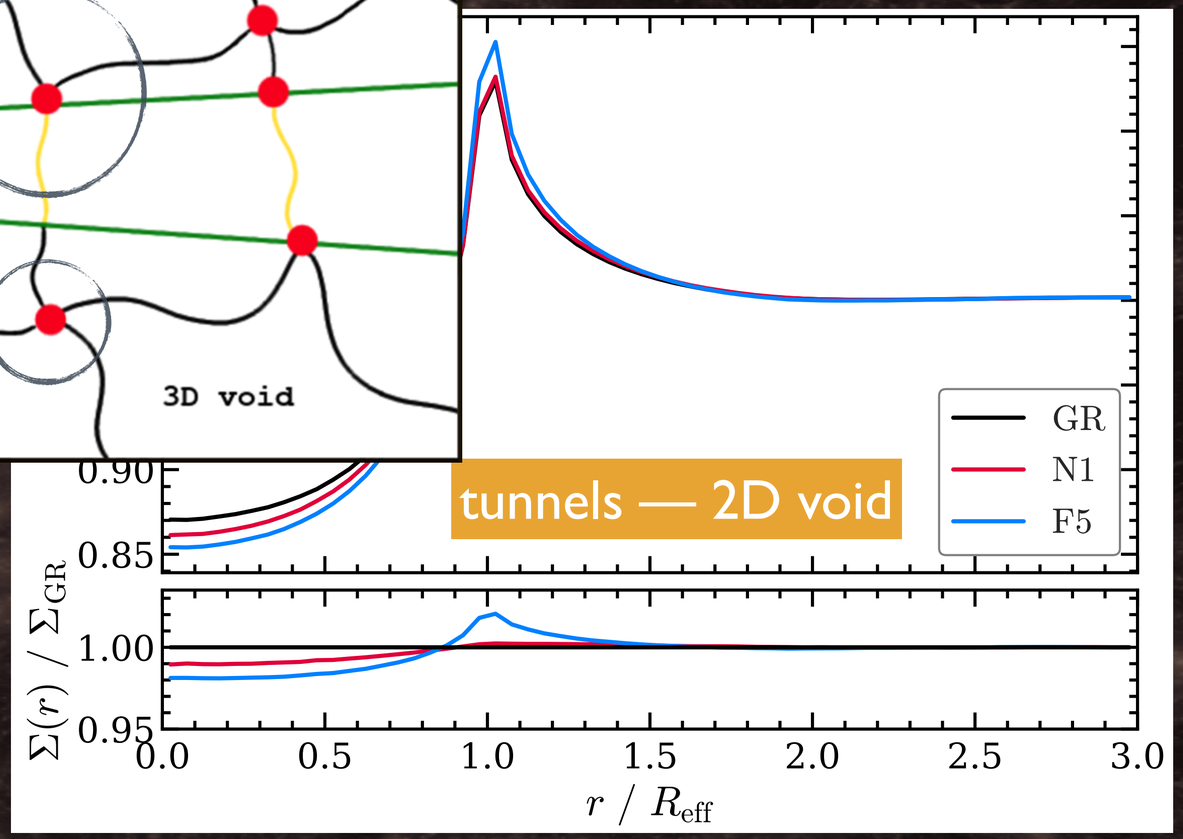


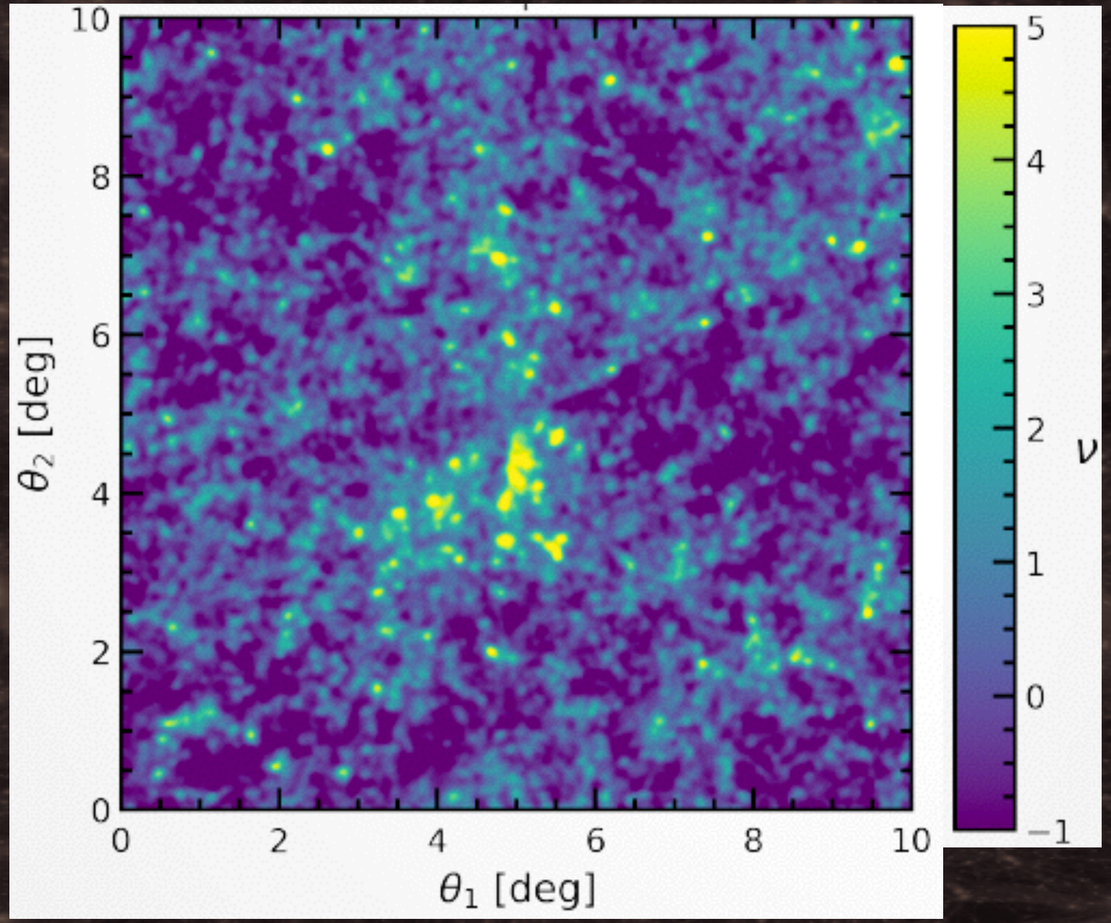




Paillas + (2018)

# VOLES — voids from weak lensing

Convergence map

= (weighted) line-of-sight projected density




Davies + (2018)

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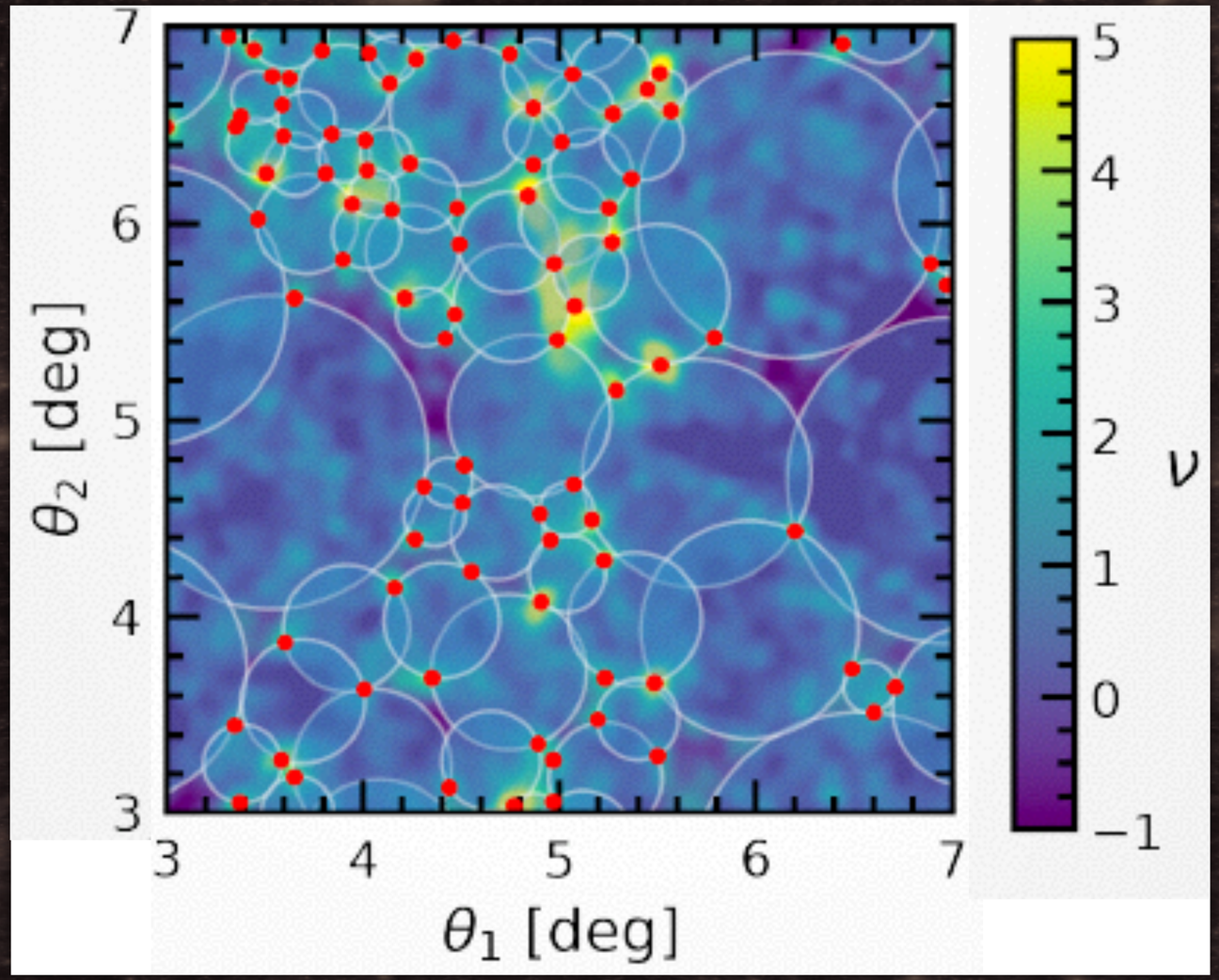
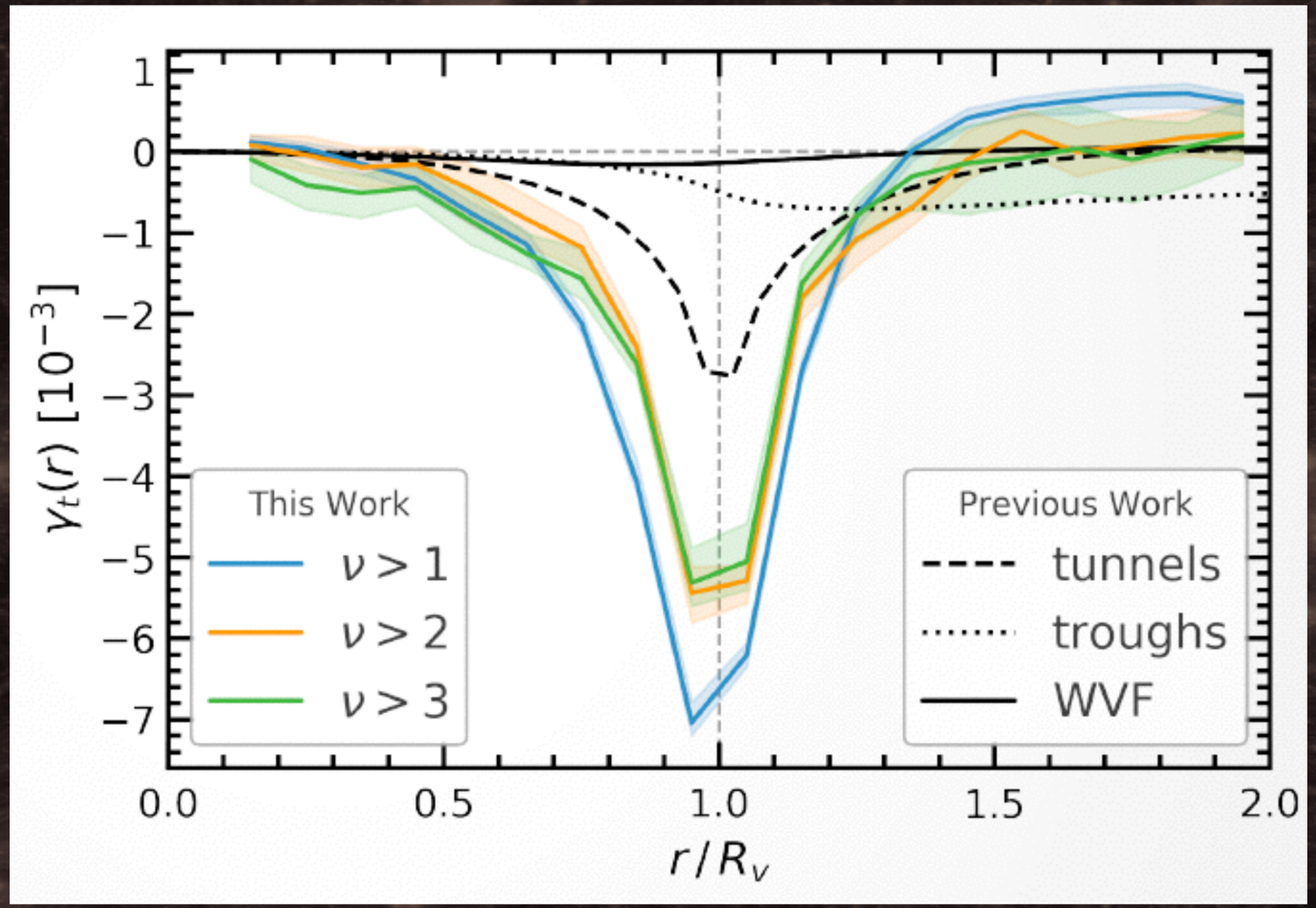


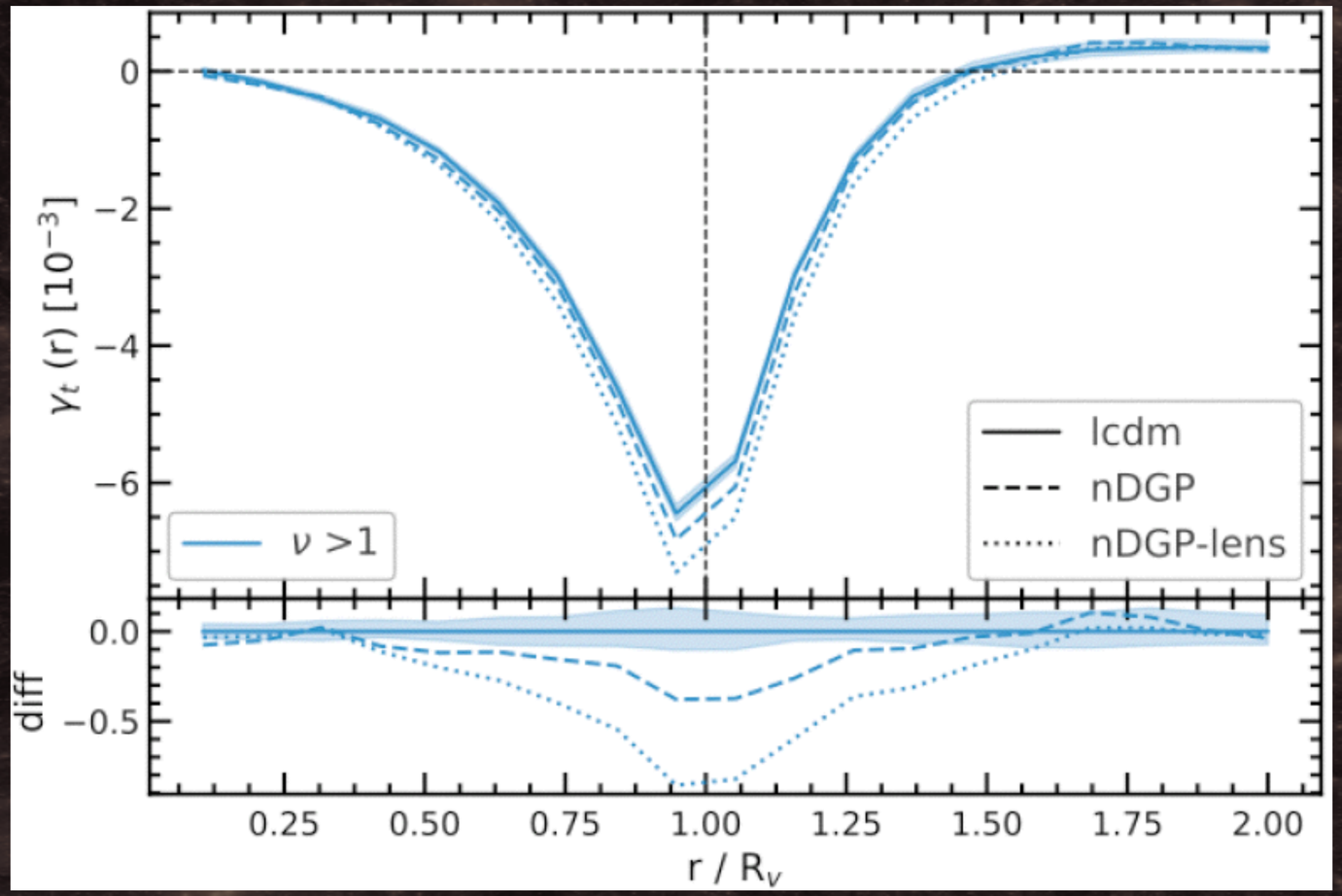

Davies + (2018)

# Shear profile of VOLES




Davies + (2018)

# Testing modified gravity theories using VOLES




Davies + in prep

# Conclusions

- Voids are ideal probes of modified gravity theories since usually the fifth force in these models is maximal inside voids.
- The fifth force enhances the evacuation of matter from voids -> emptier voids.
- When matching the tracer distribution between GR and MG models, void statistics are the same except for the matter density profile (and RSD), and hence weak lensing by void.
- Voids identified in the weak lensing maps (VOLES) represent a new method of selecting the most underdense (line-of-sight) regions of the Universe and hence opens a new avenue for cosmological tests.

# Thank you!