The **S**antiago-**H**arvard-**E**dinburgh-**D**urham void comparison project: SHEDding light on modified gravity

Enrique Paillas
Instituto de Astrofísica
Pontificia Universidad Católica de Chile

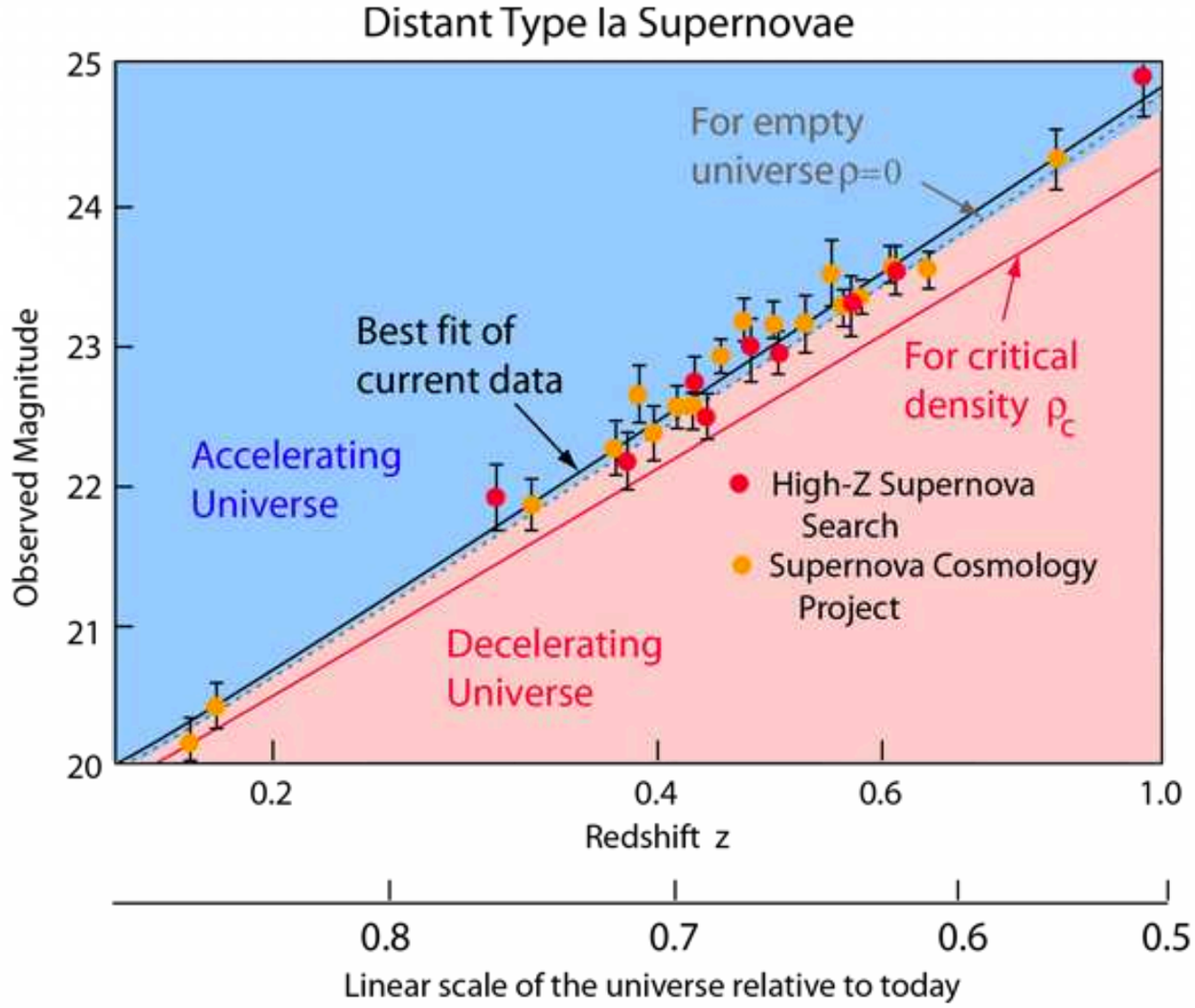
In collaboration with: Nelson Padilla (PUC), Yan-Chuan Cai (ROE), Joaquín Armijo (Durham), Marius Cautun (Durham), Baojiu Li (Durham), Sownak Bose (CfA)

A LONGSTANDING PROBLEM...

How to explain cosmic acceleration?

Invoke dark energy?

Modify theory of gravity?

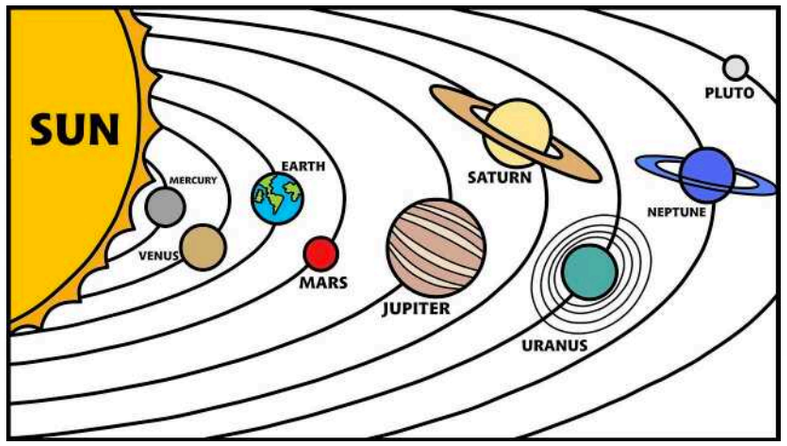


THE FIFTH FORCE

"The zoo of modified gravity theories is both vast and diverse..." (Burrage & Sakstein 2018)

Modifications to gravity involve additional degrees of freedom, generally of scalar type. These new scalar fields mediate an extra "**fifth force**"

SCREENING IN MG THEORIES



Gravity is very precisely measured within the Solar System, which strongly **constrains** the fifth force

MG theories incorporate **screening mechanisms** to suppress scalar interactions on solar-system scales.

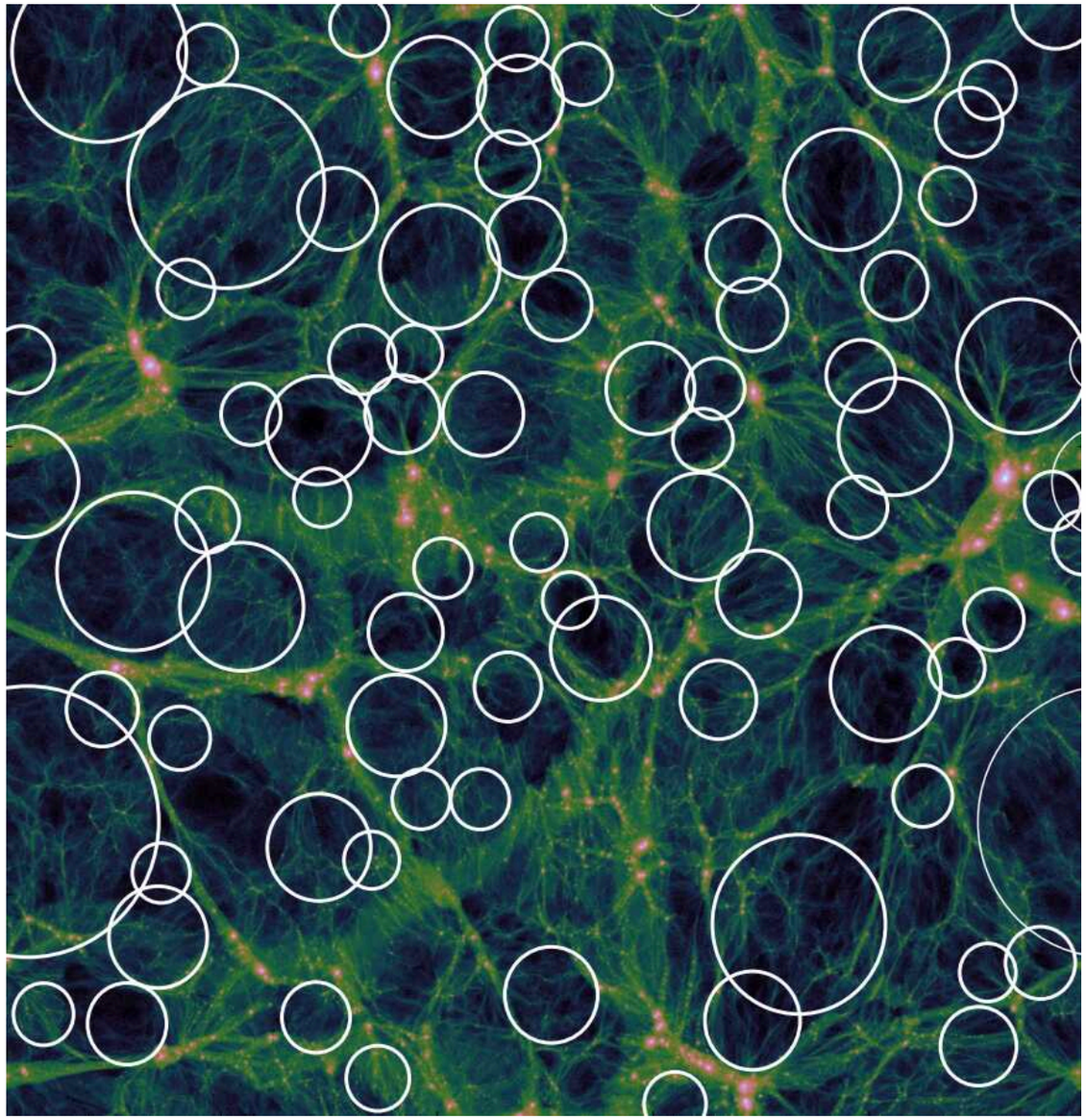
The nature of this screening depends on the scalar field interactions.

Examples include **chameleon, Vainshtein**, symmetron, dilaton, K-muflage mechanisms...

WHY COSMIC VOIDS?

Cosmic voids are a potentially powerful probe to test MG. The fifth force is expected to be unscreened within and around them.

Voids are the most subdense regions of the **large-scale structure** of the Universe. Their mass densities can be as low as 10 per cent of the cosmic mean.



Paillas et al. 2017

MODIFIED GRAVITY SIMULATIONS

3 different sets of DM-only simulations

Run with ECOSMOG (modified RAMSES, Li et al. 2012)

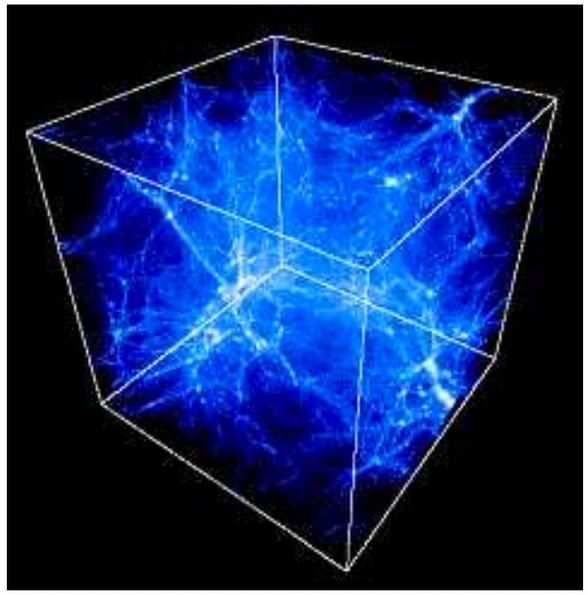
1024 Mpc/h on a side
1024^3 particles

General Relativity (LCDM)

Hu-Sawicki f(R) gravity - representative of MG with chameleon screening

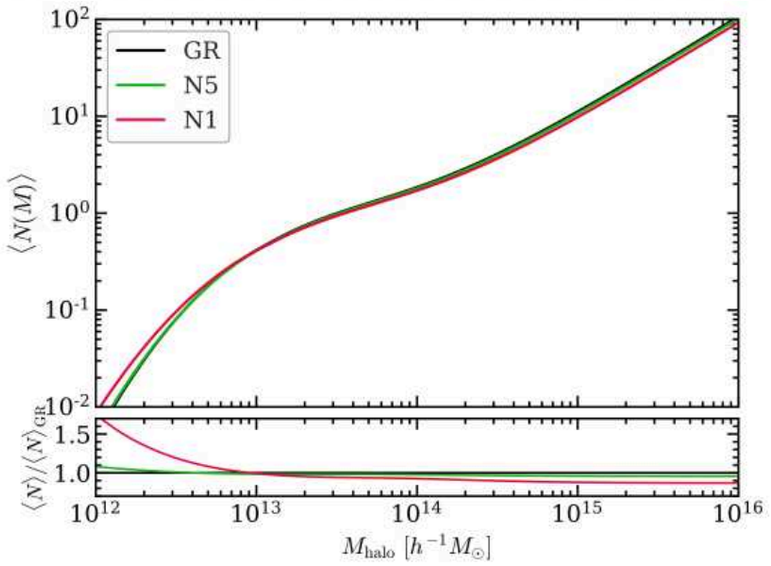
nDGP braneworld cosmology - representative of MG with Vainshtein screening

MOCK GALAXY CATALOGUES



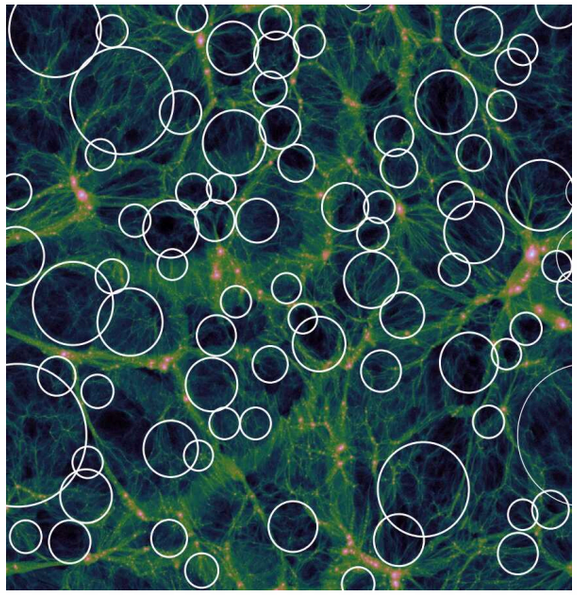
Start from DM simulation

All simulations share the same initial conditions



Populate DM haloes using HOD

HOD is calibrated so that all mock catalogues have roughly same number density and projected 2PCF

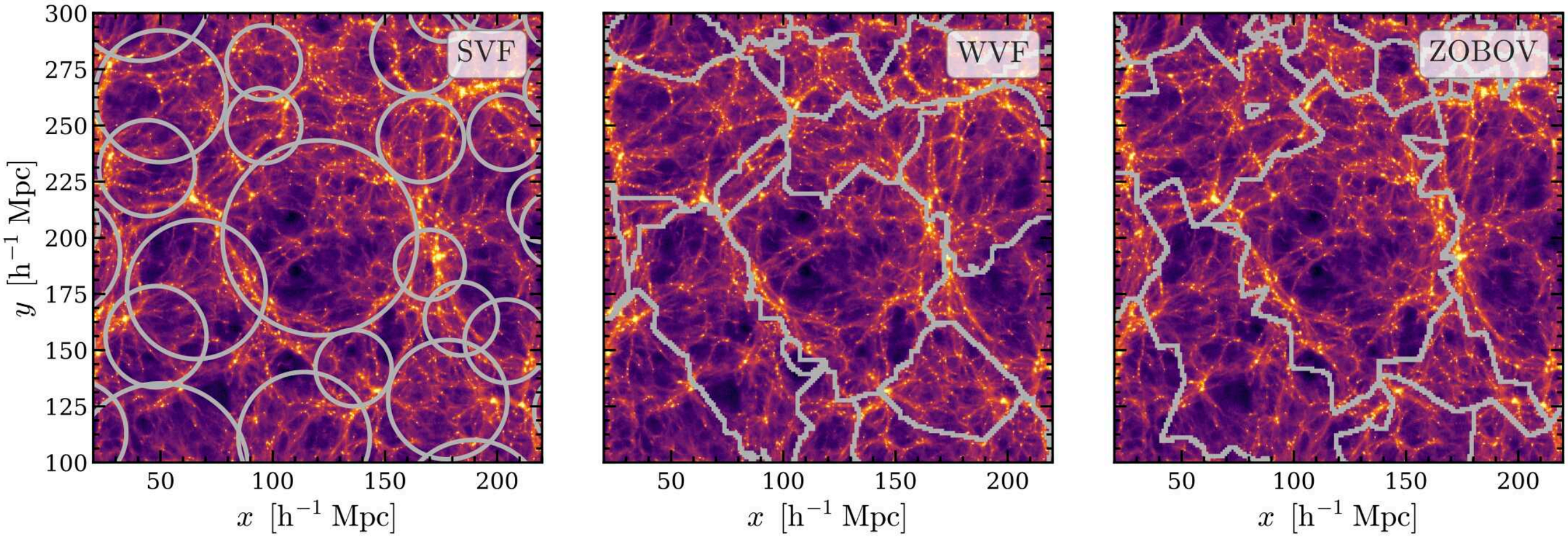


Run void finder on mock catalogues

We use 6 different void finding algorithms: three of them are 3D, the rest are 2D

3D VOID FINDERS

Paillas et al. 2018



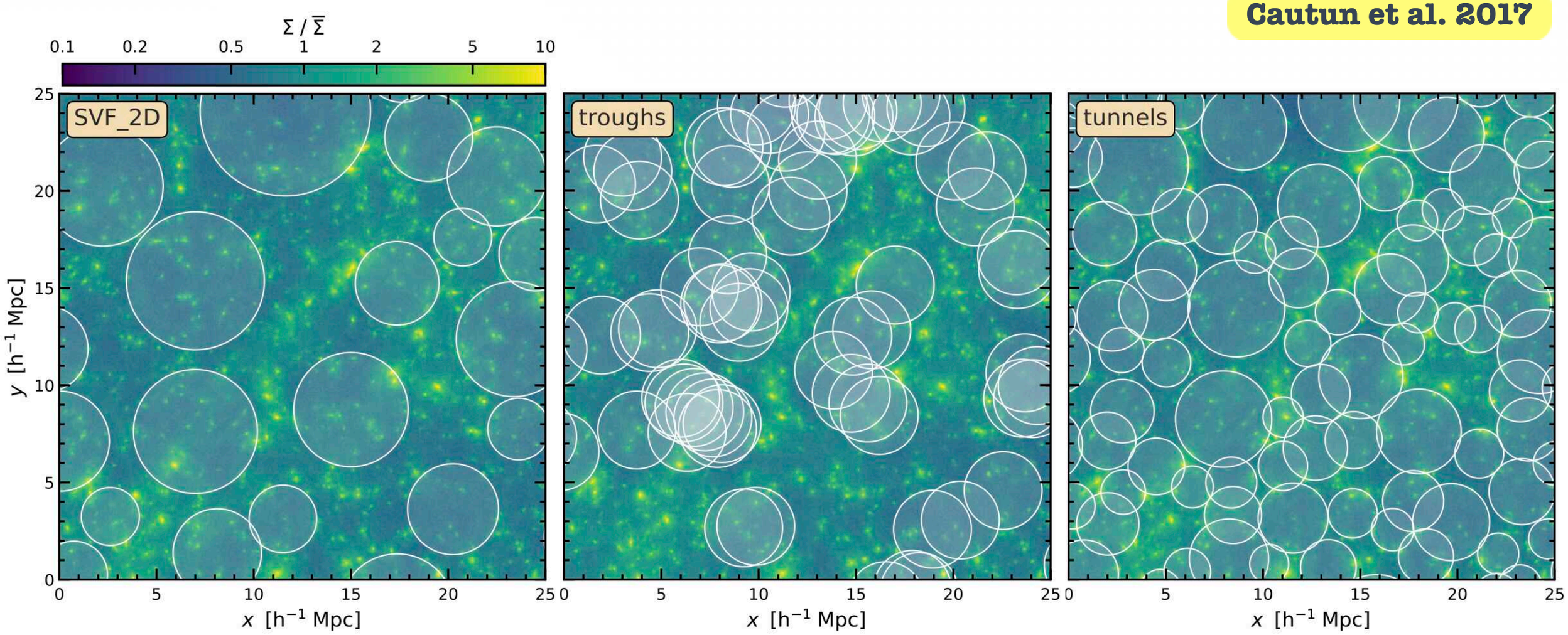
Spherical Void Finder (SVF, Padilla 2005, Paillas et al. 2017)

Watershed Void Finder (WVF, Platen et al. 2006)

ZOBOV (Neyrinck 2008)

2D VOID FINDERS

Cautun et al. 2017



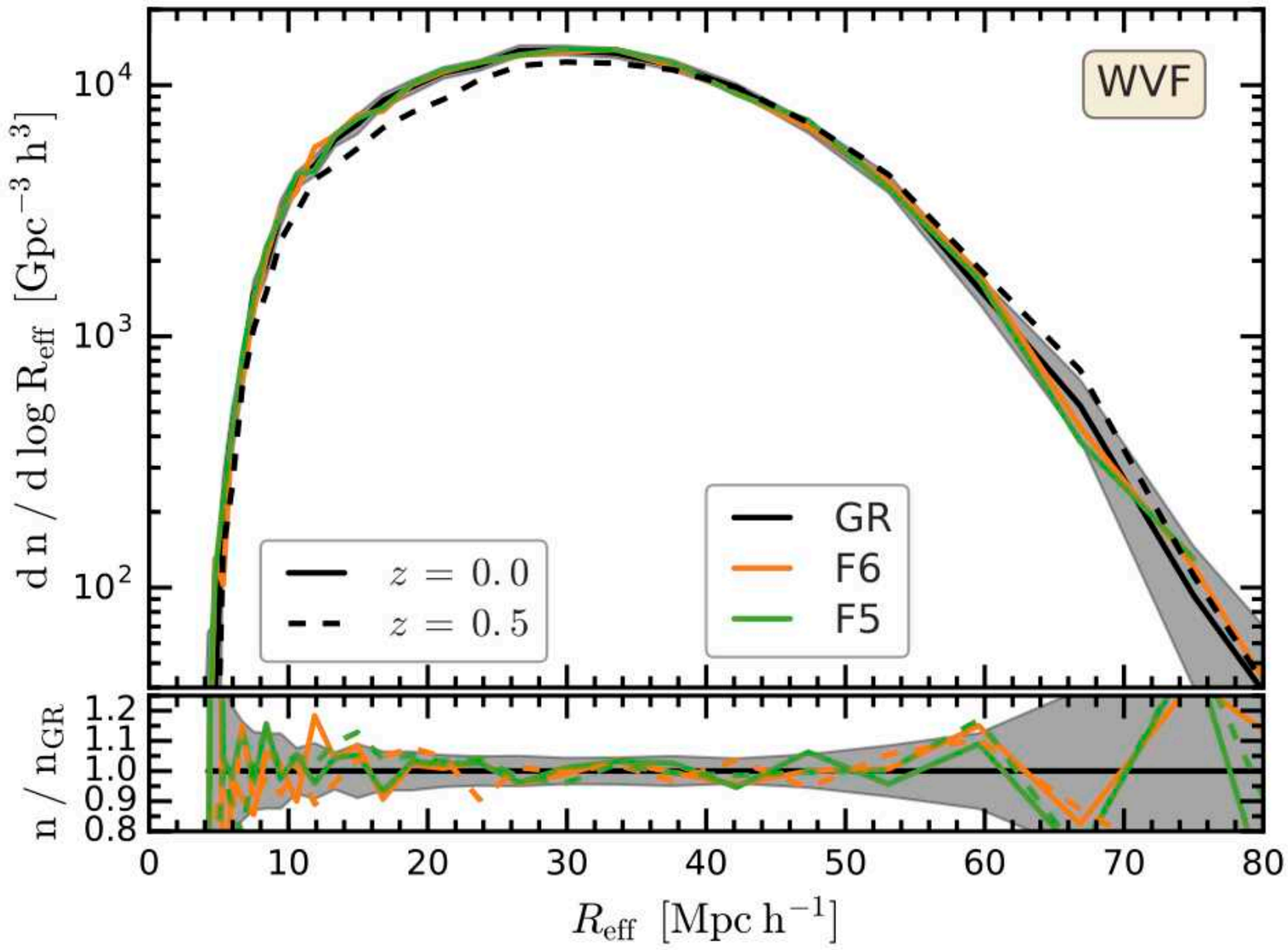
2D Spherical Void Finder (SVF_2D, Cautun et al. 2017)

Troughs (Gruen et al. 2015)

Tunnels (Cautun et al. 2017)

VOID NUMBER COUNTS

The **void number counts** alone do not constitute a good test for MG, once the number density and clustering of mock galaxy catalogue are fixed.



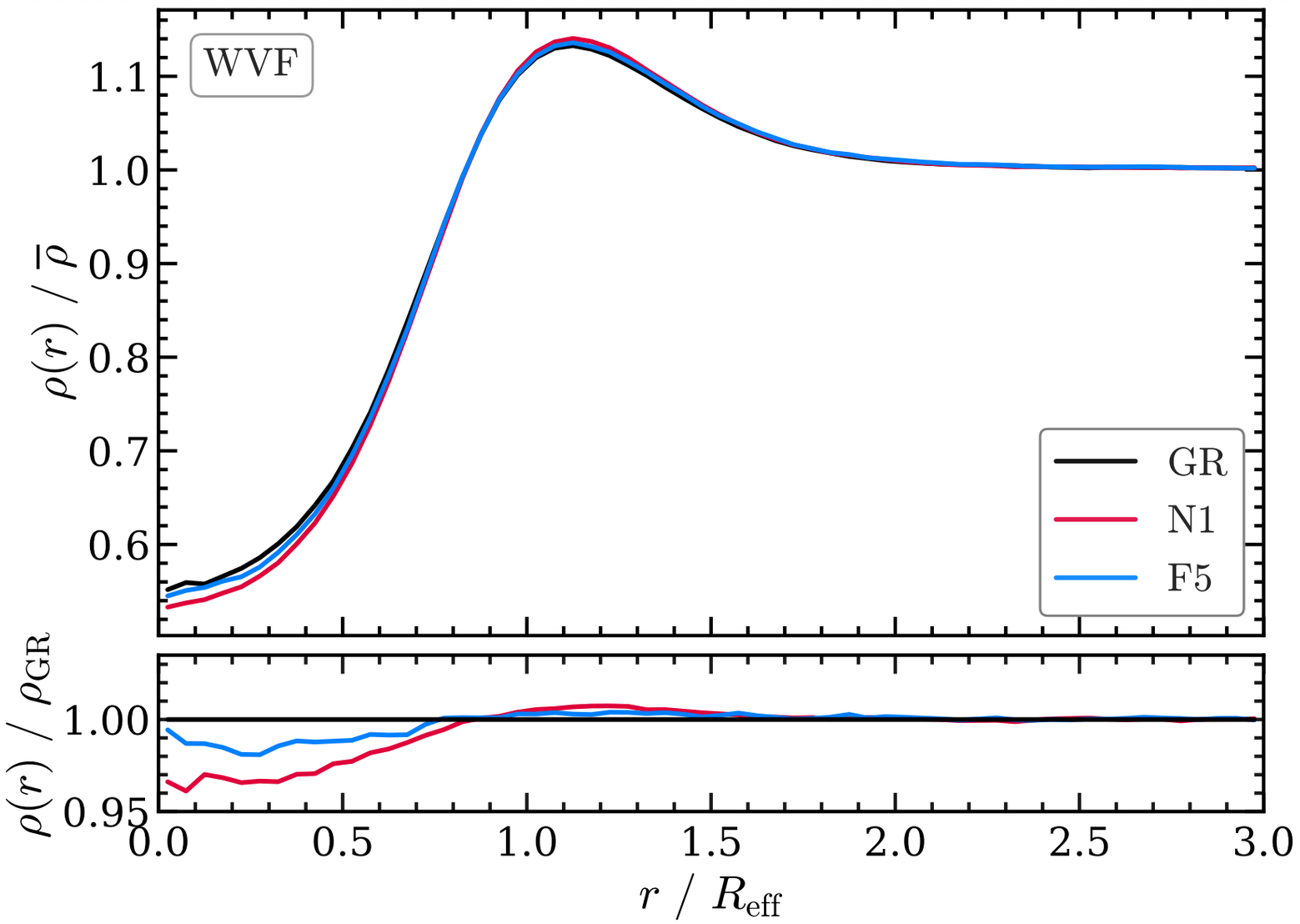
Cautun et al. 2017

VOID DENSITY PROFILES

The **matter density profile** around voids, however, encapsulates valuable information.

Voids in MG appear more underdense in their interiors, and more overdense at the void walls.

This is due to the **fifth force** aiding the evacuation of matter from voids.



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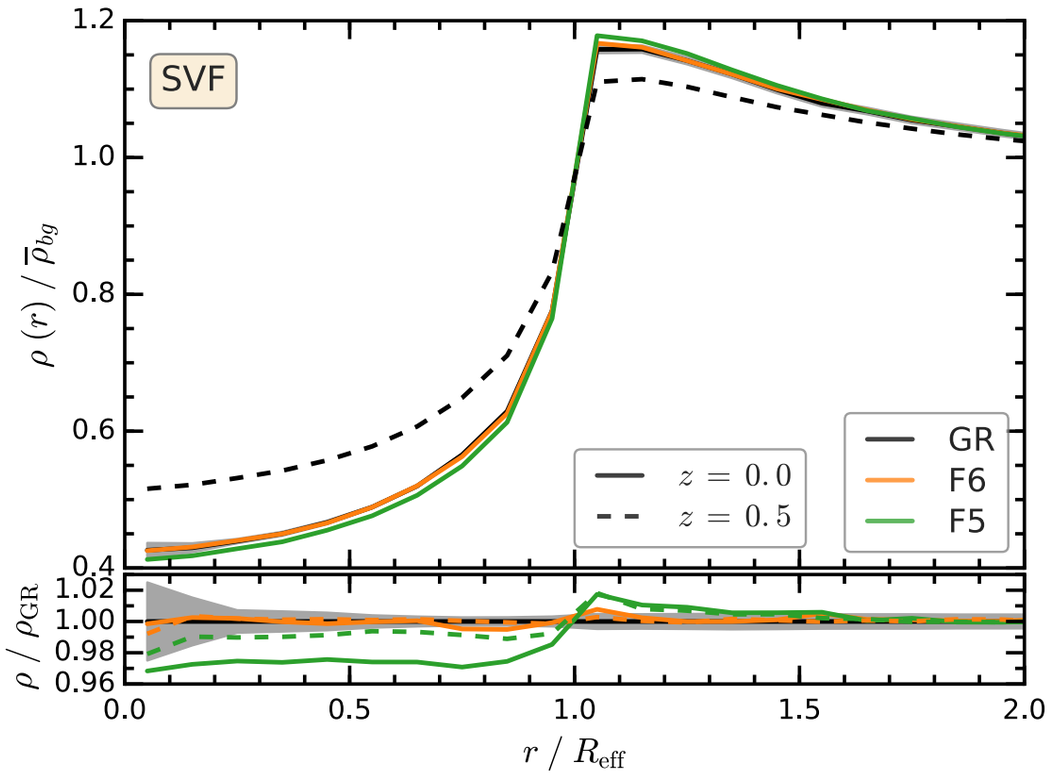
WEAK LENSING BY VOIDS

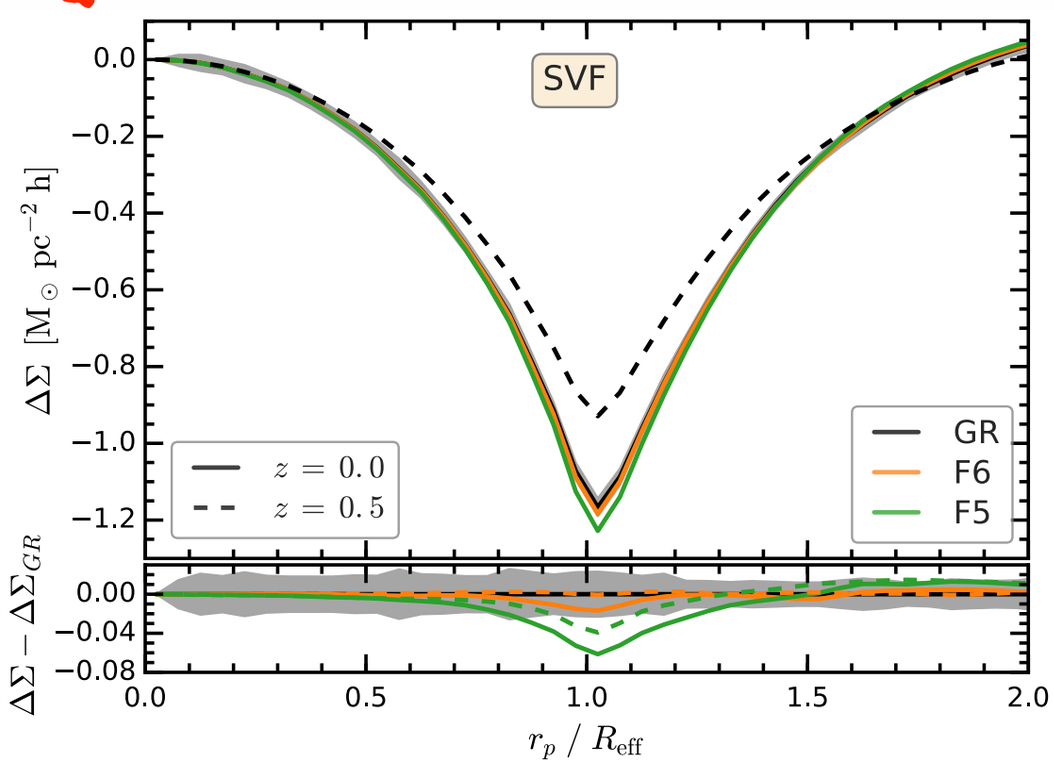


We can calculate the weak lensing **tangential shear** that would be produced by the matter around each void

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

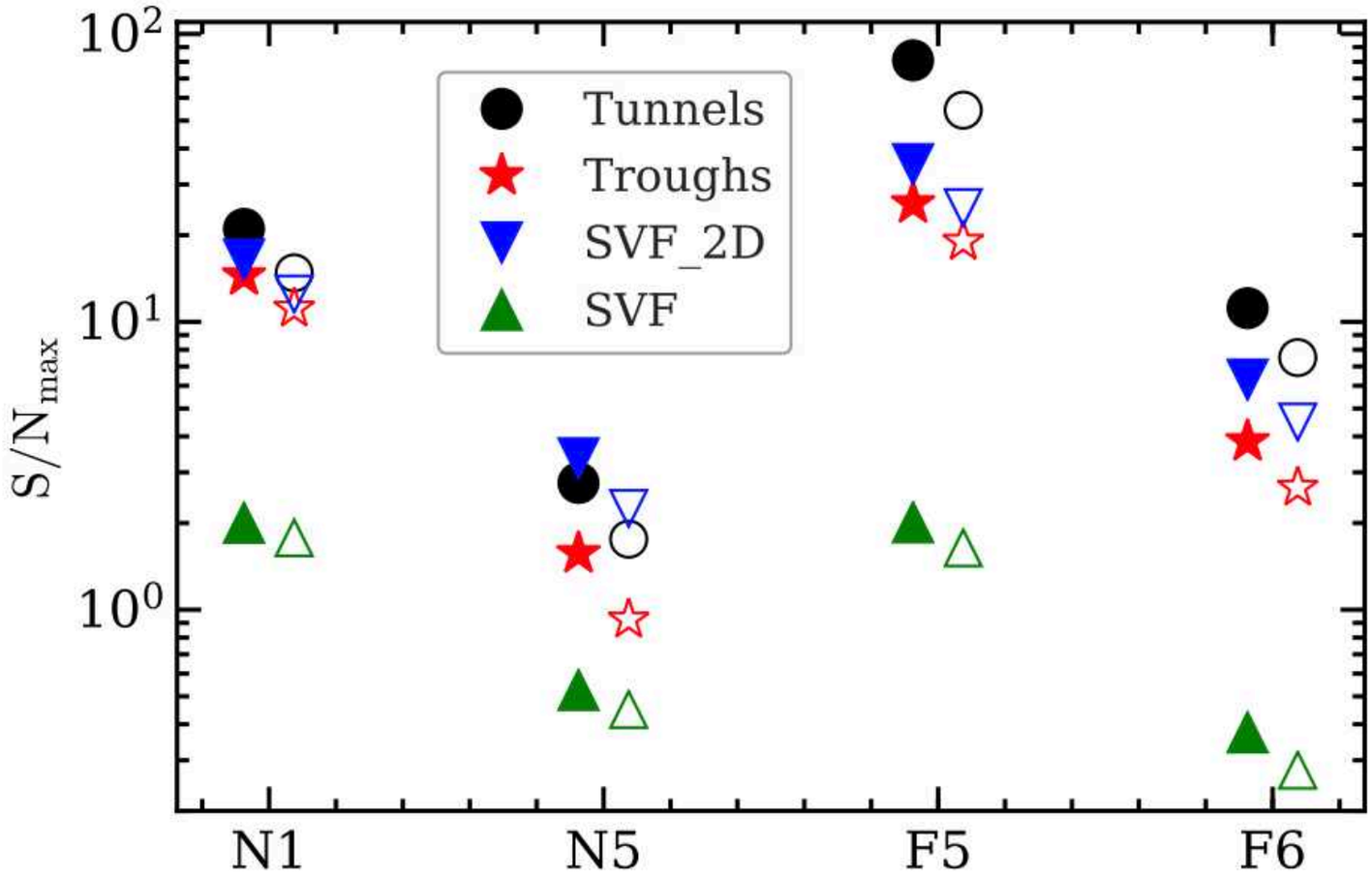
MG leaves an **imprint** on the stacked weak lensing signal around voids

The unscreened **fifth force** in voids modifies the matter distribution, and this in turn affects the WL signal



PREDICTIONS FOR LSST/EUCLID

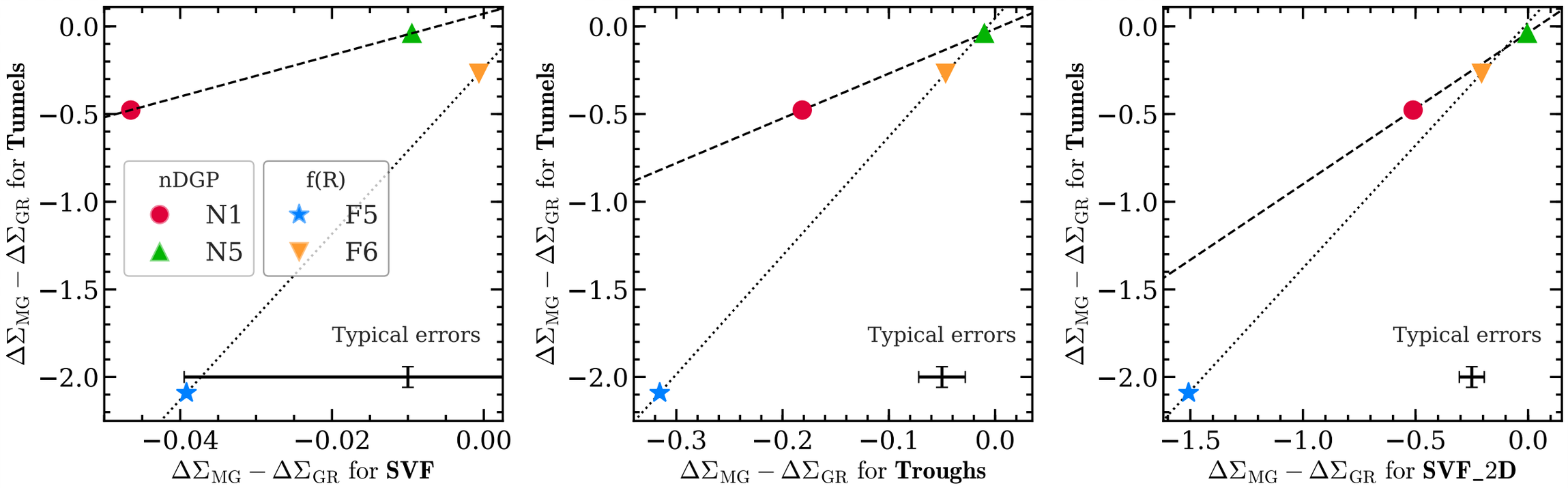
By how many sigmas will we be able to distinguish MG from GR using void lensing in a survey with the characteristics of **LSST** (filled) and **EUCLID** (open)?



Among all void finders tested here, **2D voids** seem to be the most promising.

Paillas et al. 2018

OK, BUT WHICH MG THEORY?



If a deviation from LCDM is found, we might be able to tell which MG theory is at work by **combining different void finders**

TAKE-AWAY MESSAGES

- Voids are powerful probes of modified gravity

- Voids are emptier in modified gravity due to the action of the fifth force

- We can access the imprint of modified gravity on void density profiles via weak lensing

- 2D void finders are especially promising to constrain modified gravity

1st SHED paper:
Cautun+2017
1710.01730

2nd SHED paper:
Paillas+2018
1810.02864