



# Euclid and the Low Density Universe

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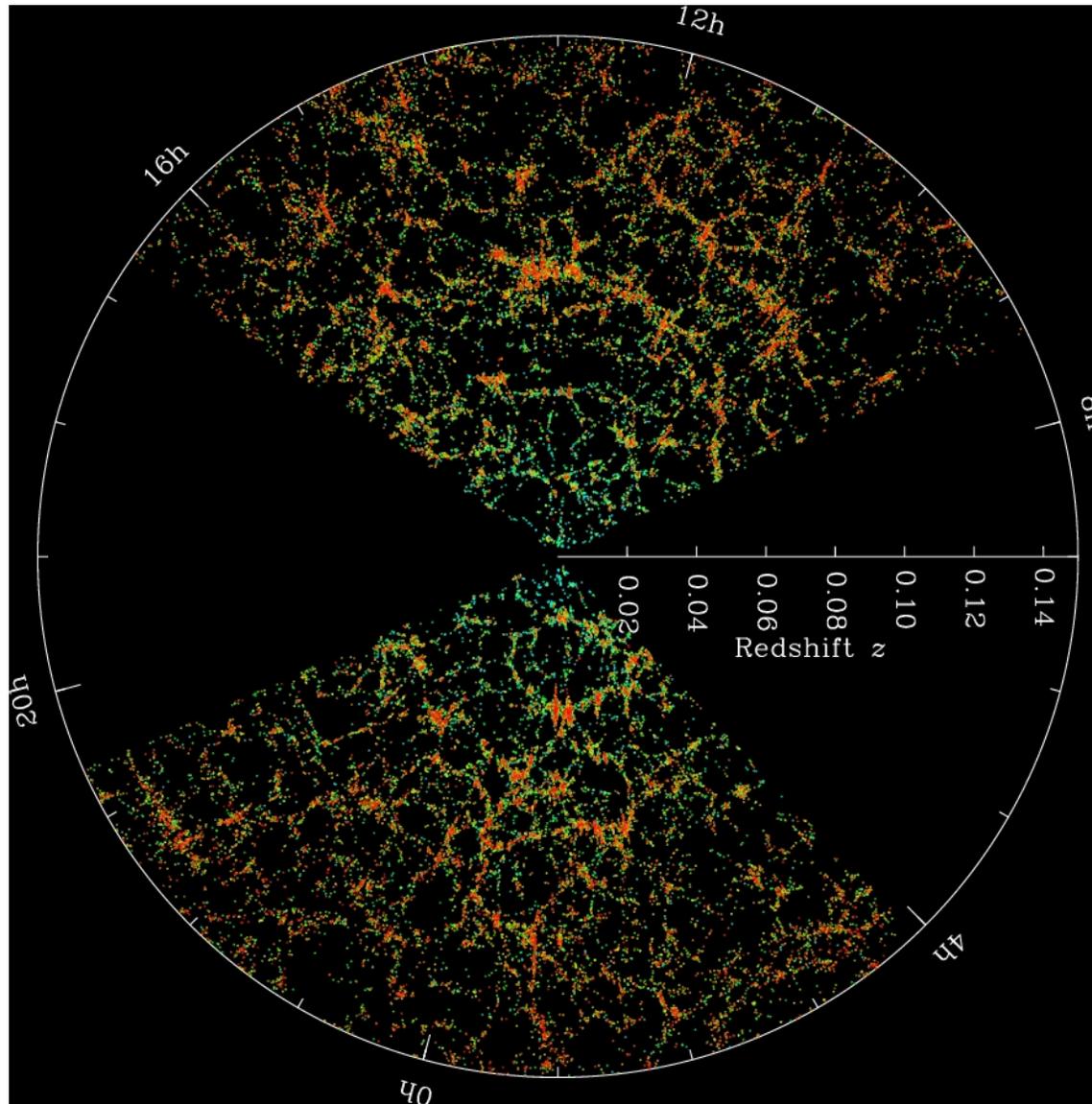
Sorbonne Université

Unique capability of Euclid:  
spectroscopic, low shot-noise survey.  
unlocks small scales at moderate  
redshifts ( $z \sim 1-2$ )

Bad news for cosmologists:  
Strong non-linear evolution collapses  
all matter into halos

Good news for cosmologist:  
Non-linear evolution of large scale  
structure creates structure of  
underdense regions, ie voids,  
separated by filaments and walls

# Data example: the SDSS survey



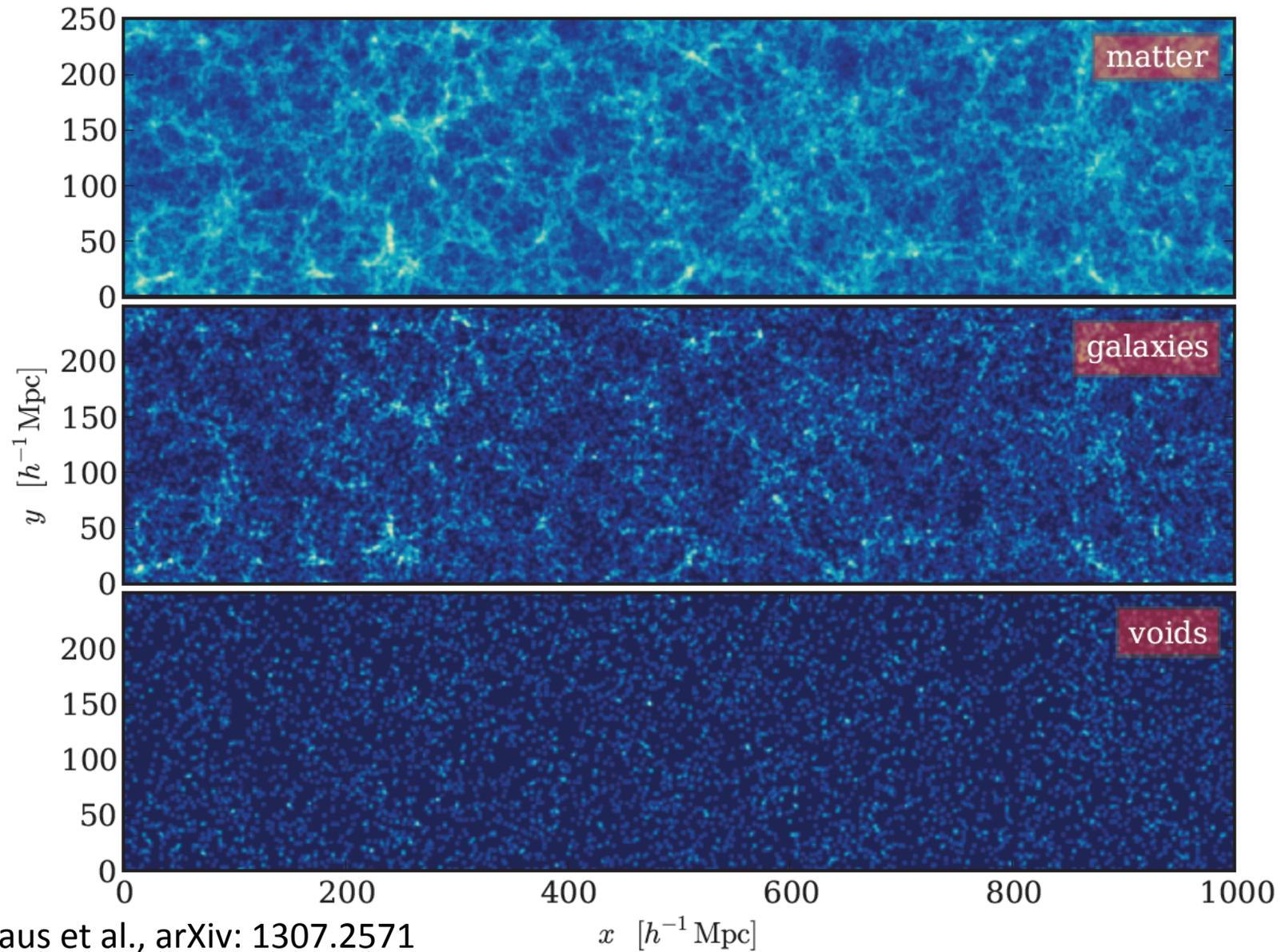
M. Blanton  
and SDSS

# Voids...

- ... fill most of the cosmic volume
- ... are the first dark-energy dominated objects
- ... are the places where neutrinos have the
- ... are well-described by semi-analytics

Euclid will be a fantastic void machine:  
~10,000 voids per  $\text{Gpc}^3$ .

# Matter, galaxies, voids in simulation

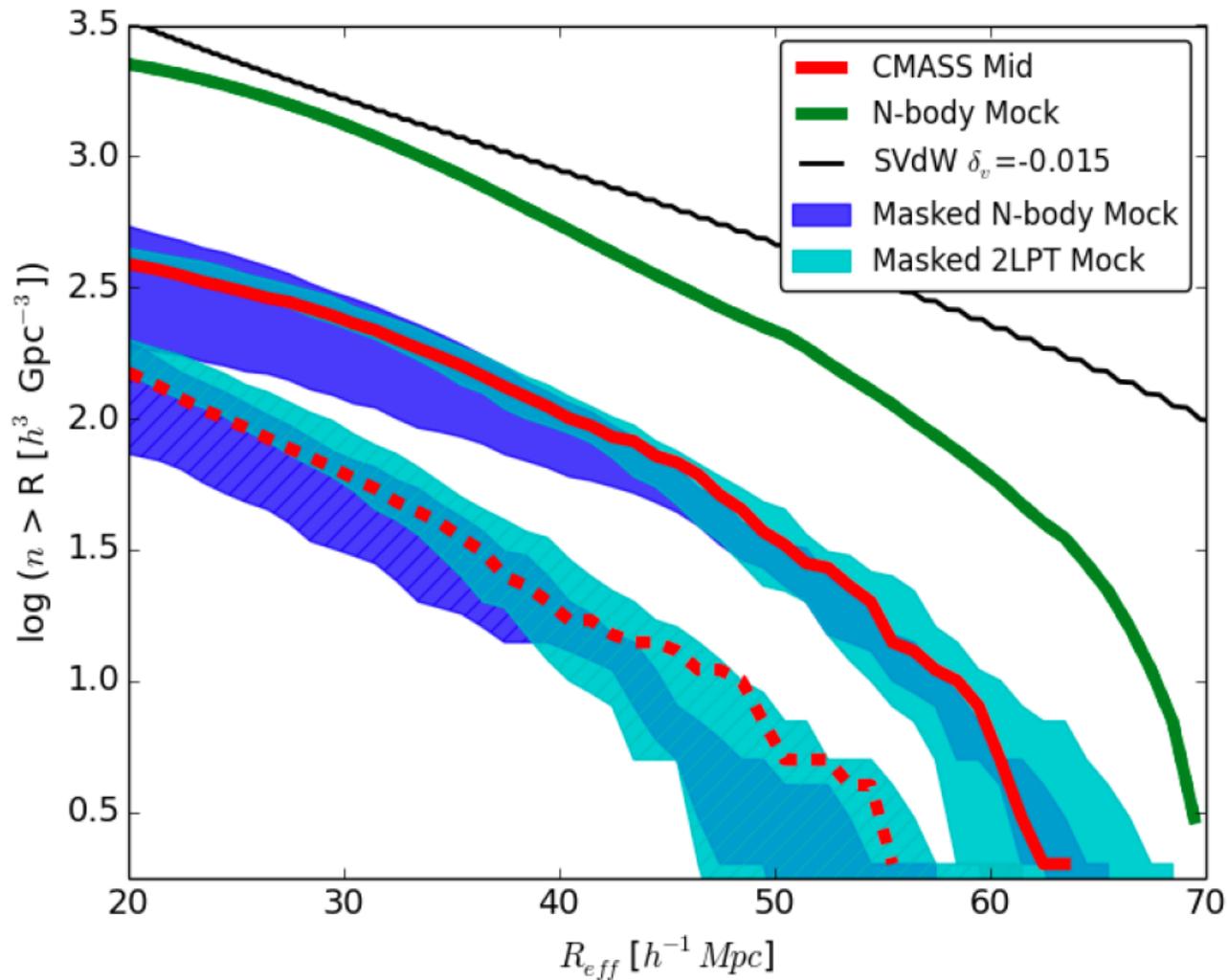


# Void observables – recent progress

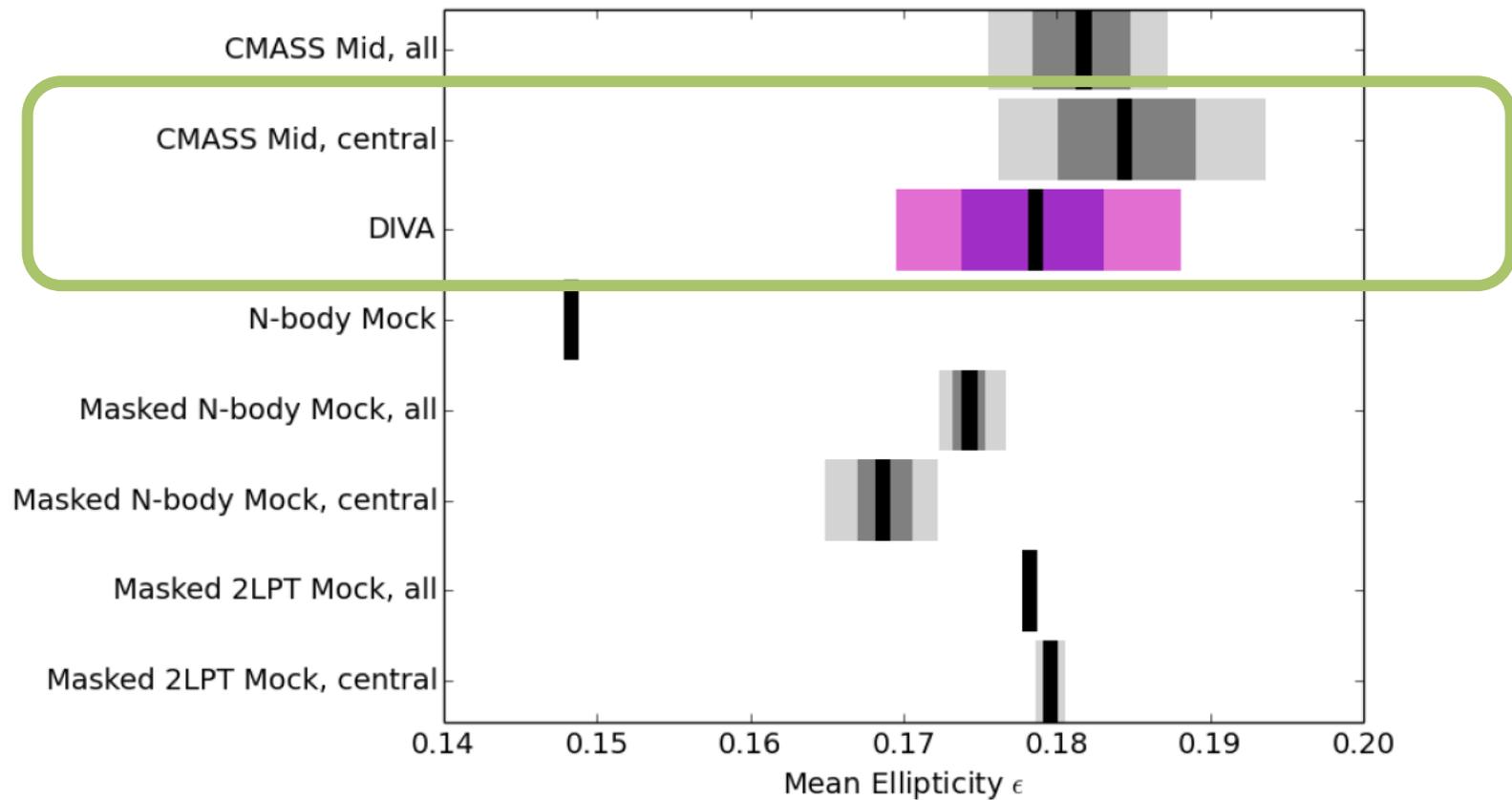
- **Voids definition in surveys**
  - E.g. voids in the SDSS DR9: Sutter et al., arXiv:1310.7155
- **Their properties can be characterized**
  - Effect of sparse sampling and bias on voids: Sutter et al., arXiv: 1309.5087
- **Voids are related to dark matter**
  - Dark matter in galaxy voids: Sutter et al., arXiv: 1311.3301
- **They can be used as LSS tracers**
  - Void-galaxy cross-correlations, Hamaus et al., arXiv: 1307.2571
- **Voids lens background galaxies**
  - Gravitational lensing of voids in SDSS: Melchior et al., arXiv: 1309.2045
- **Voids can be stacked to get real space information**
  - Real-space profile reconstruction: Pisani et al., arXiv: 1306.3052
- **Voids can be used to define new cosmological observables**
  - Alcock-Paczinsky, standard ruler, galaxy bias etc.

→ [www.cosmicvoids.net](http://www.cosmicvoids.net)

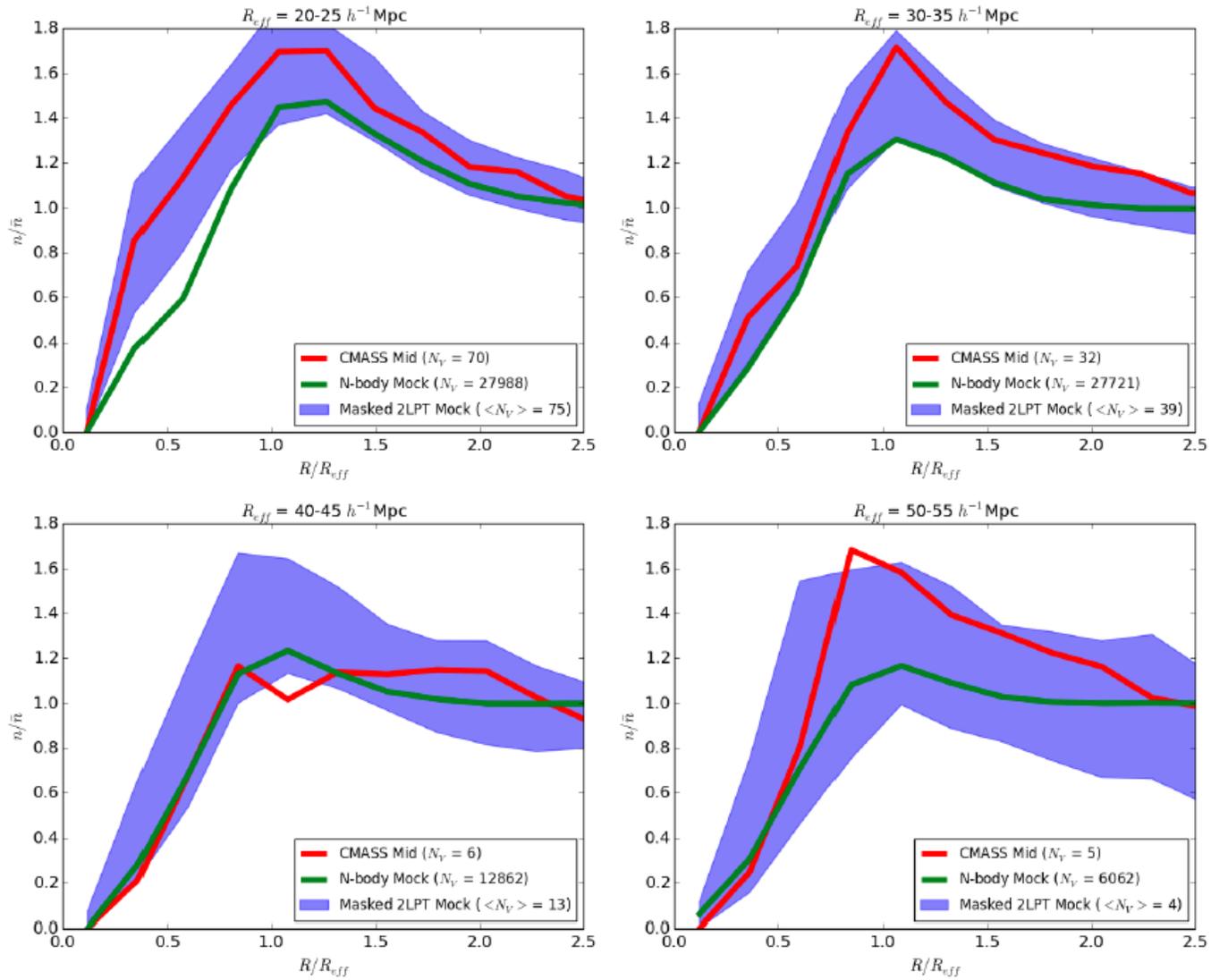
# Void number functions in BOSS-CMASS match mock surveys



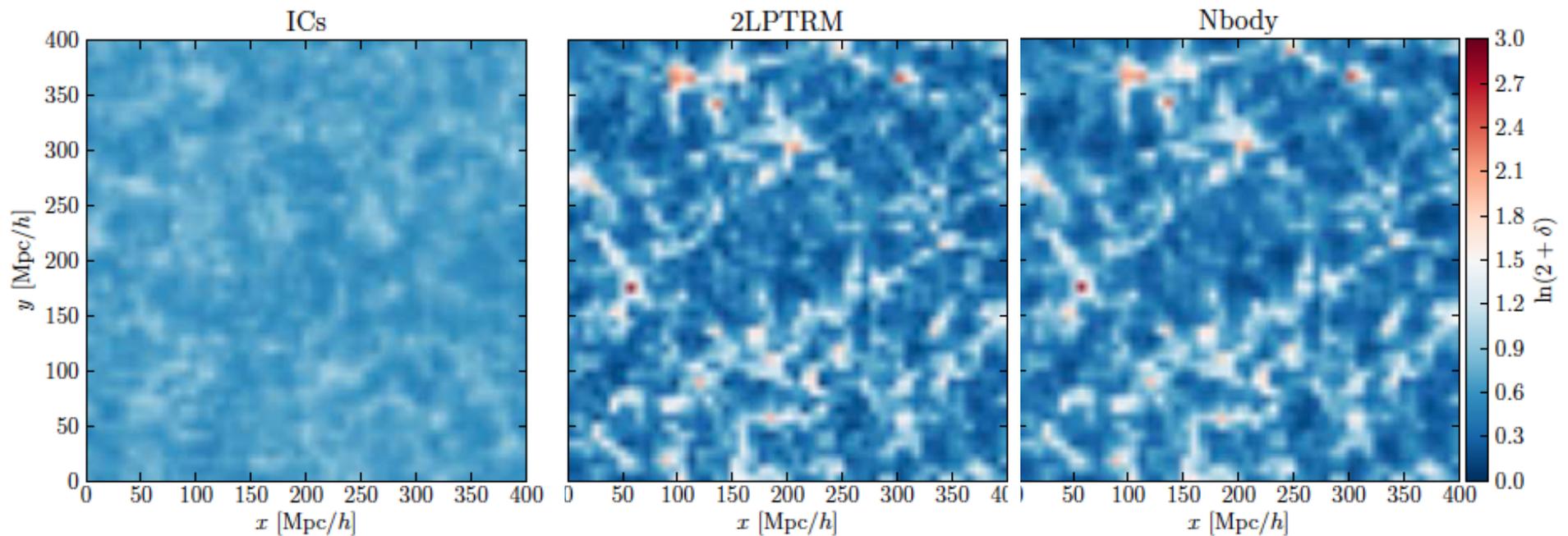
# Void ellipticities – semi-analytic theory matches data



# Void profiles well-modeled using 2LPT mocks!

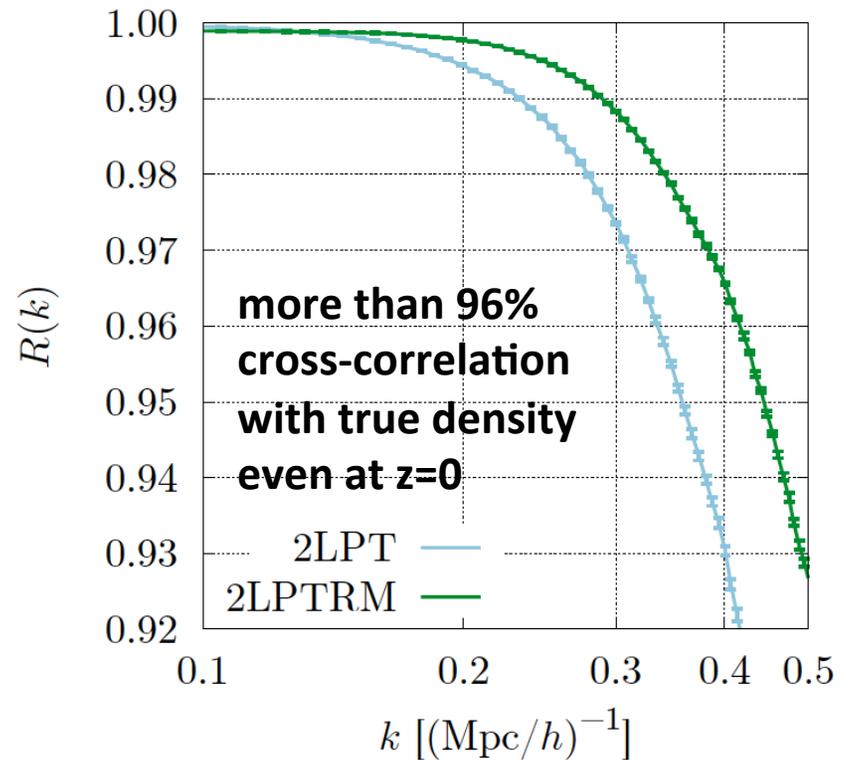
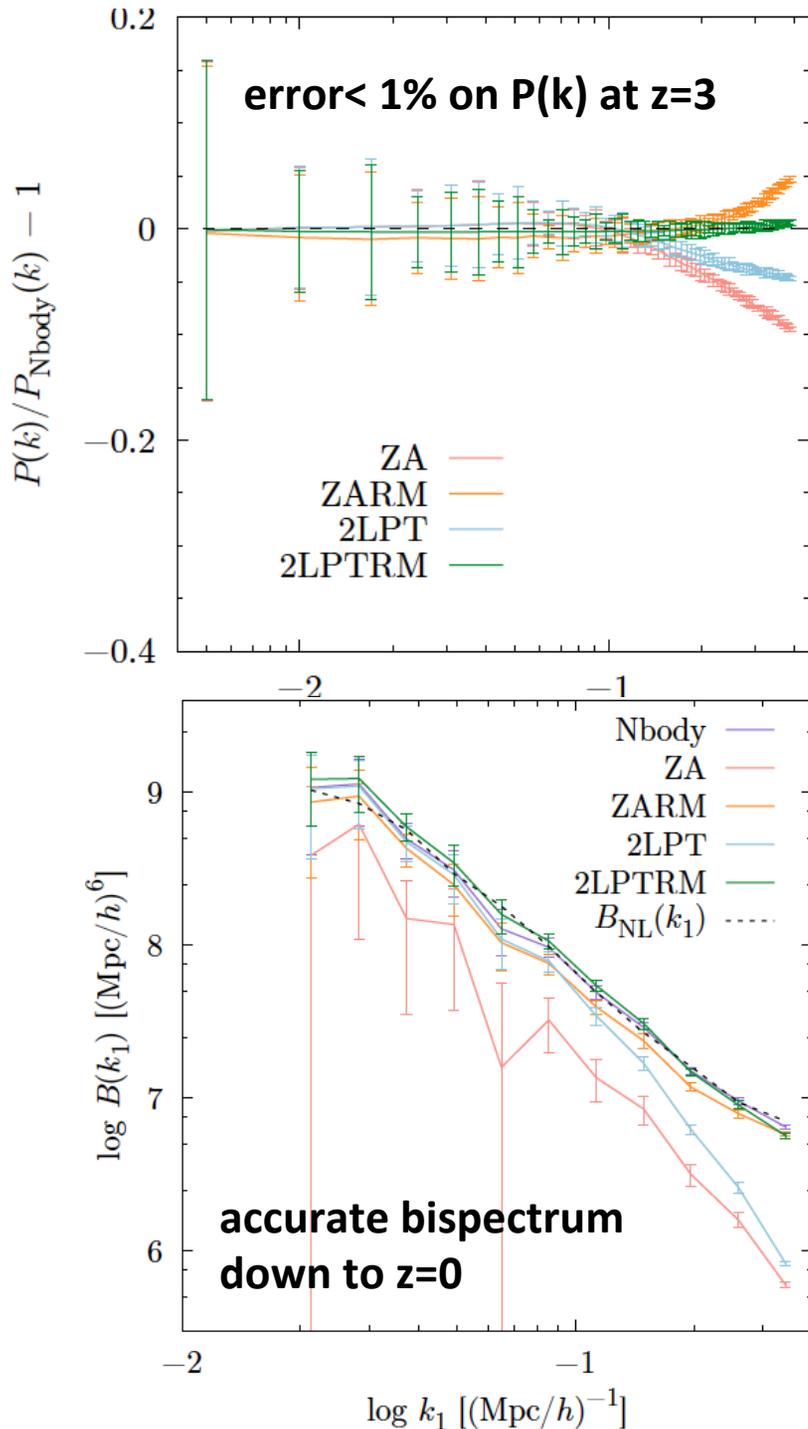


# 2LPT+remapping: superfast model of mildly non-linear density field



# 2LPTRM: Quantitative agreement of 2&3-point functions down to $k \sim 0.4 \text{ h/Mpc}$

Leclercq, Jasche, Gil-Marín, BDW 2013



"Joint probes:" what if we could just fit  
the entire survey?

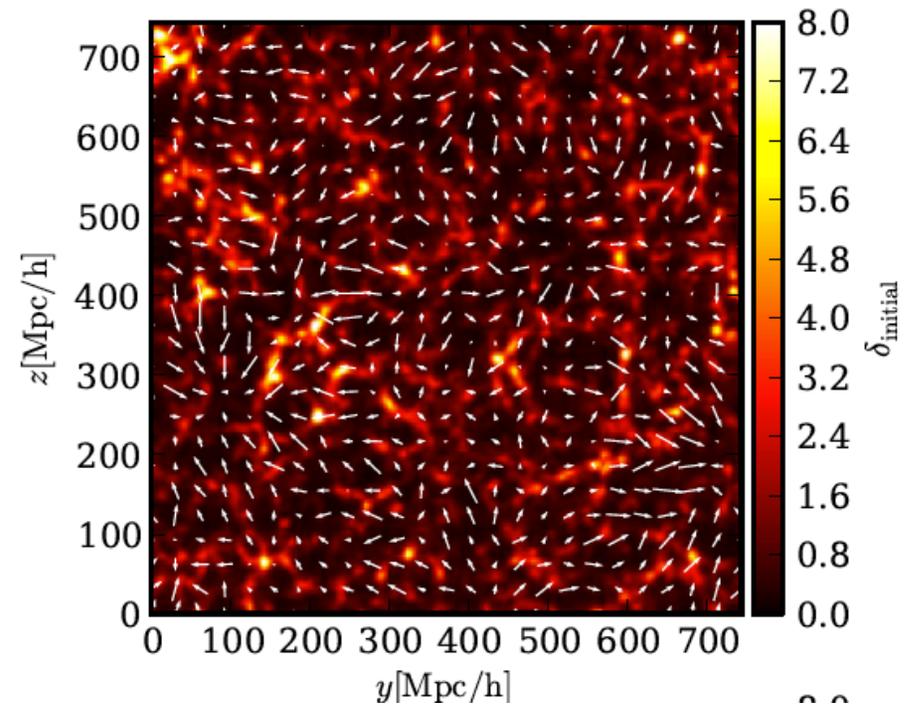
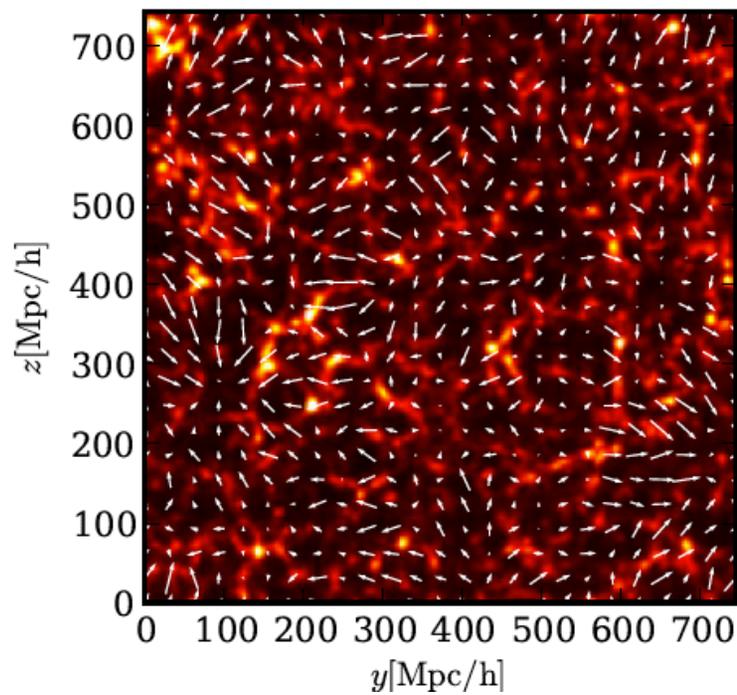
# Physical, modeling of large scale structure surveys

- Assume that the initial conditions are well-described as a (nearly) Gaussian random field
- Uses gravity for non-linear evolution and a bias model describing the statistics of galaxies from the non-linearly evolved field to match linear bias.

Jasche, Wandelt 2013

**=>MOVIES:**

# Dynamical reconstruction of the velocity field



# Conclusions

- “Voids” are a new, purely geometrical LSS observable, sensitive to dark energy properties, and easy to model semi-numerically
- Euclid will see  $\sim 10^6$  voids – a new science opportunity
- Super-fast generation of accurate mock density fields
- Major advances in non-linear, *physical* cosmological inference in 3D with  $\sim 10^7$  parameters – something to study with a view to joint analysis for Euclid