Gregory Horndeski, 'Horndeski Scalar Theory, Past, Present and Future'

Towards Precision Cosmology With Void-Lensing:

I. How To Optimize Void-Lensing Measurements

II. How To Interpret the Measurement (in Collab With R. Voivodic)

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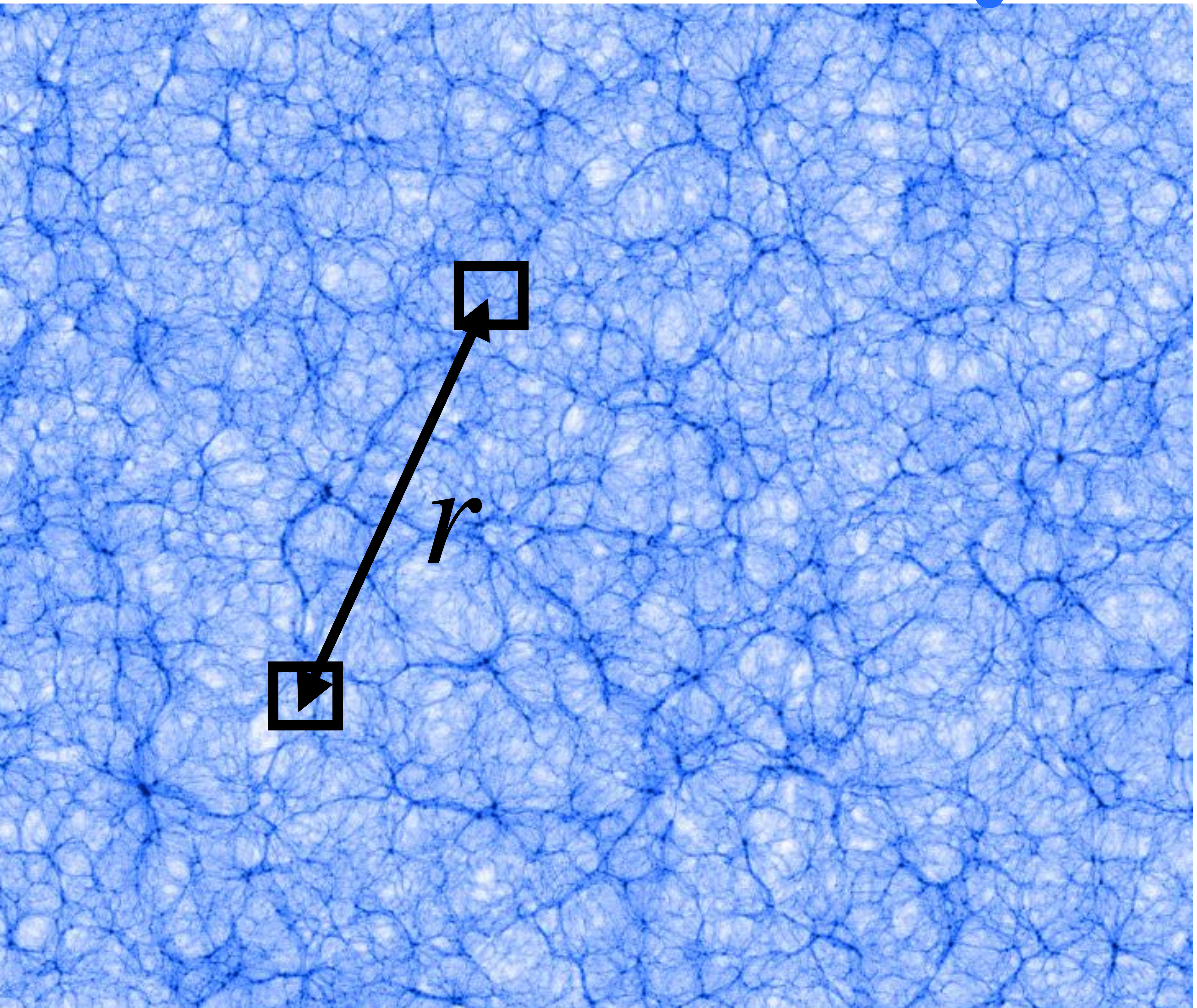
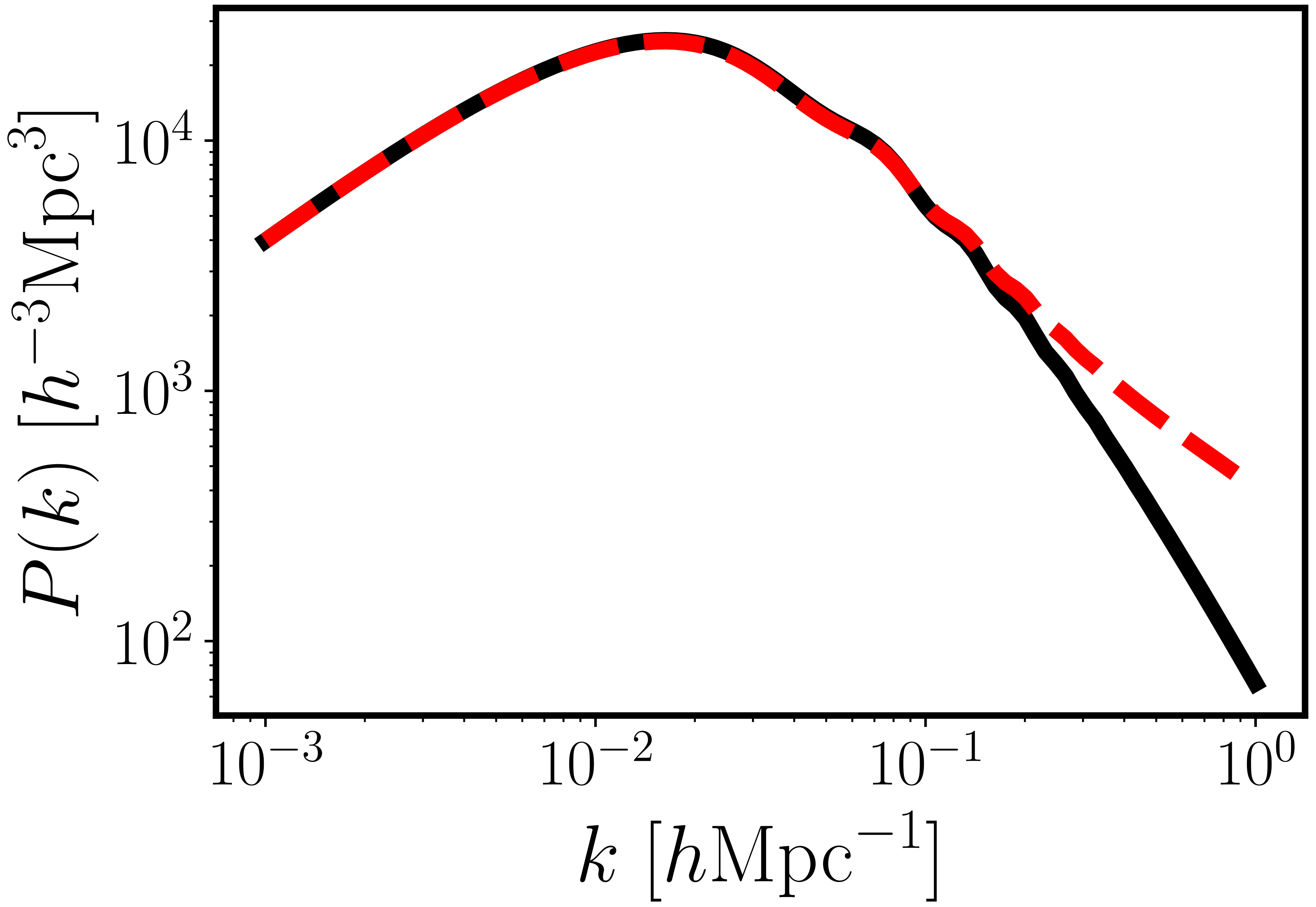
Aix-Marseille université Initiative d'excellence

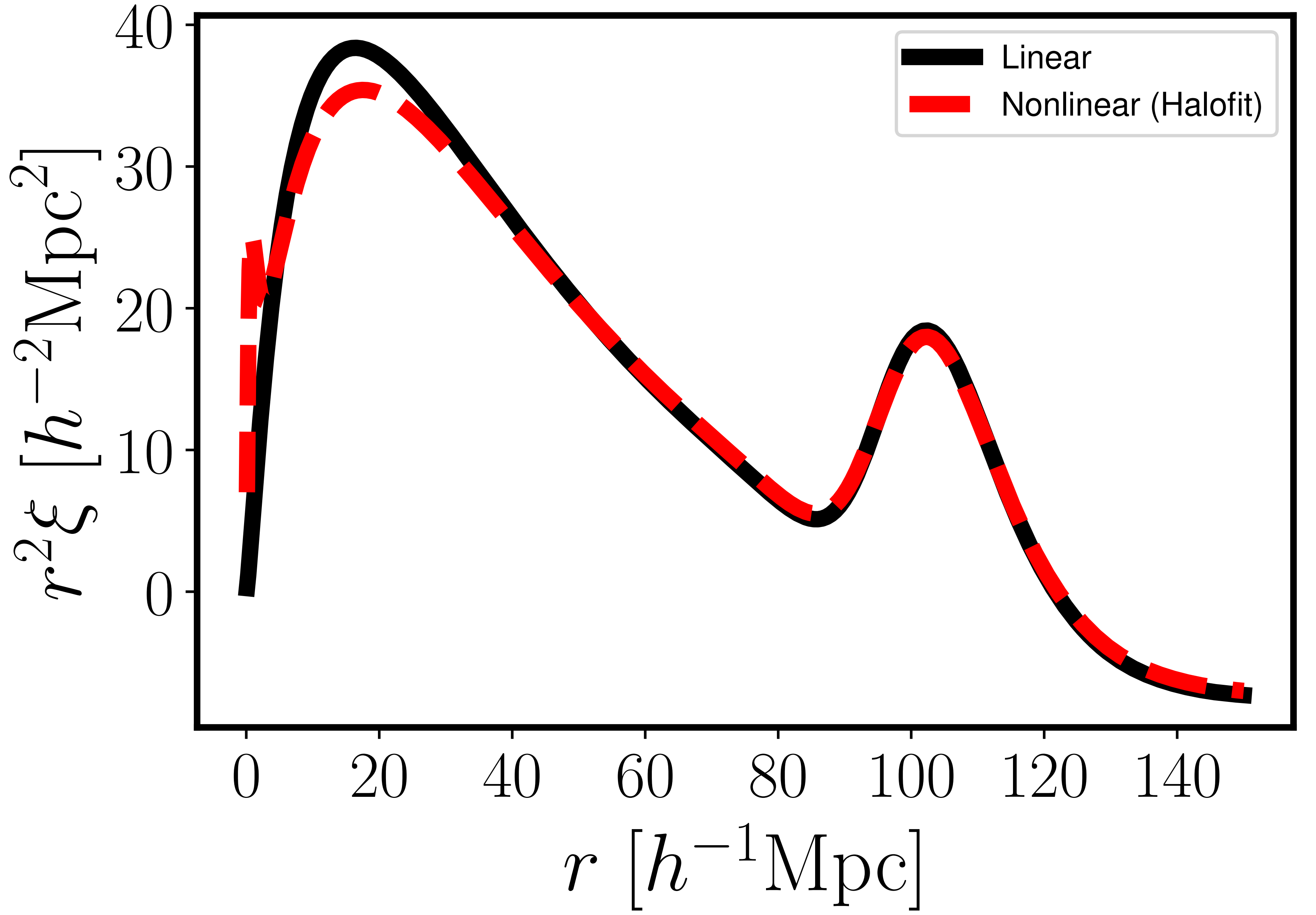
CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE CPPM

LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

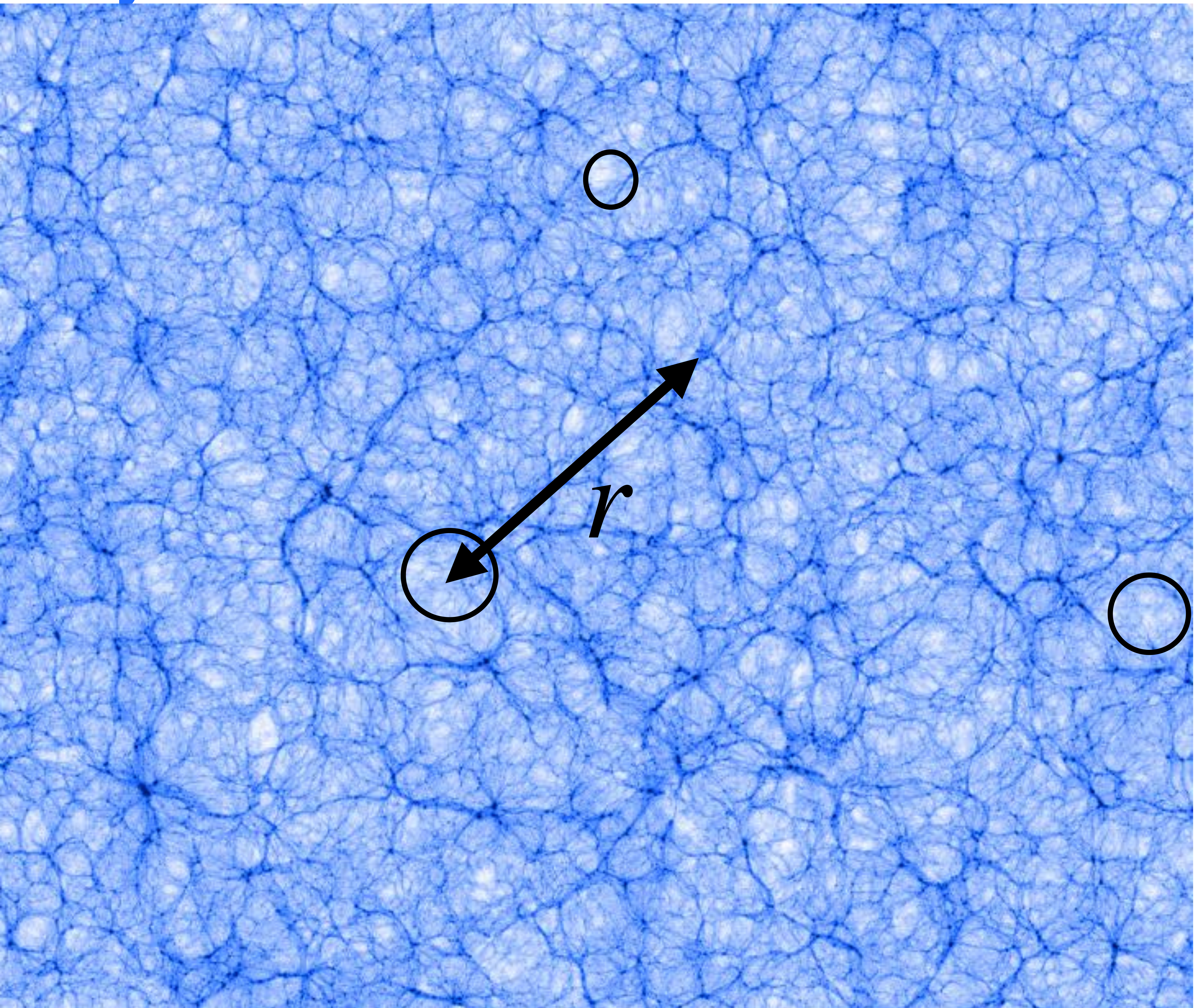
How To Extract Information From Large Scale Structure?

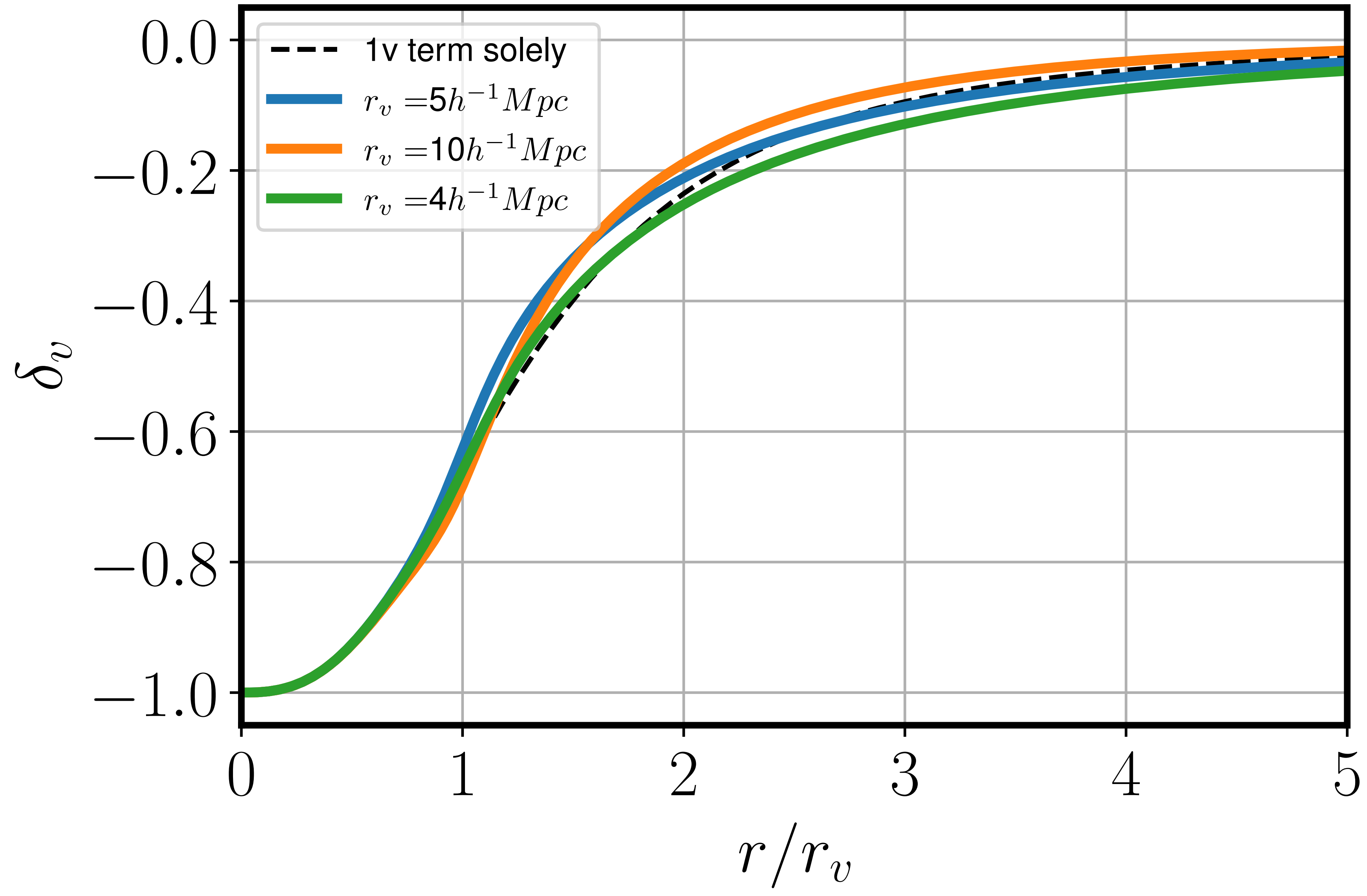


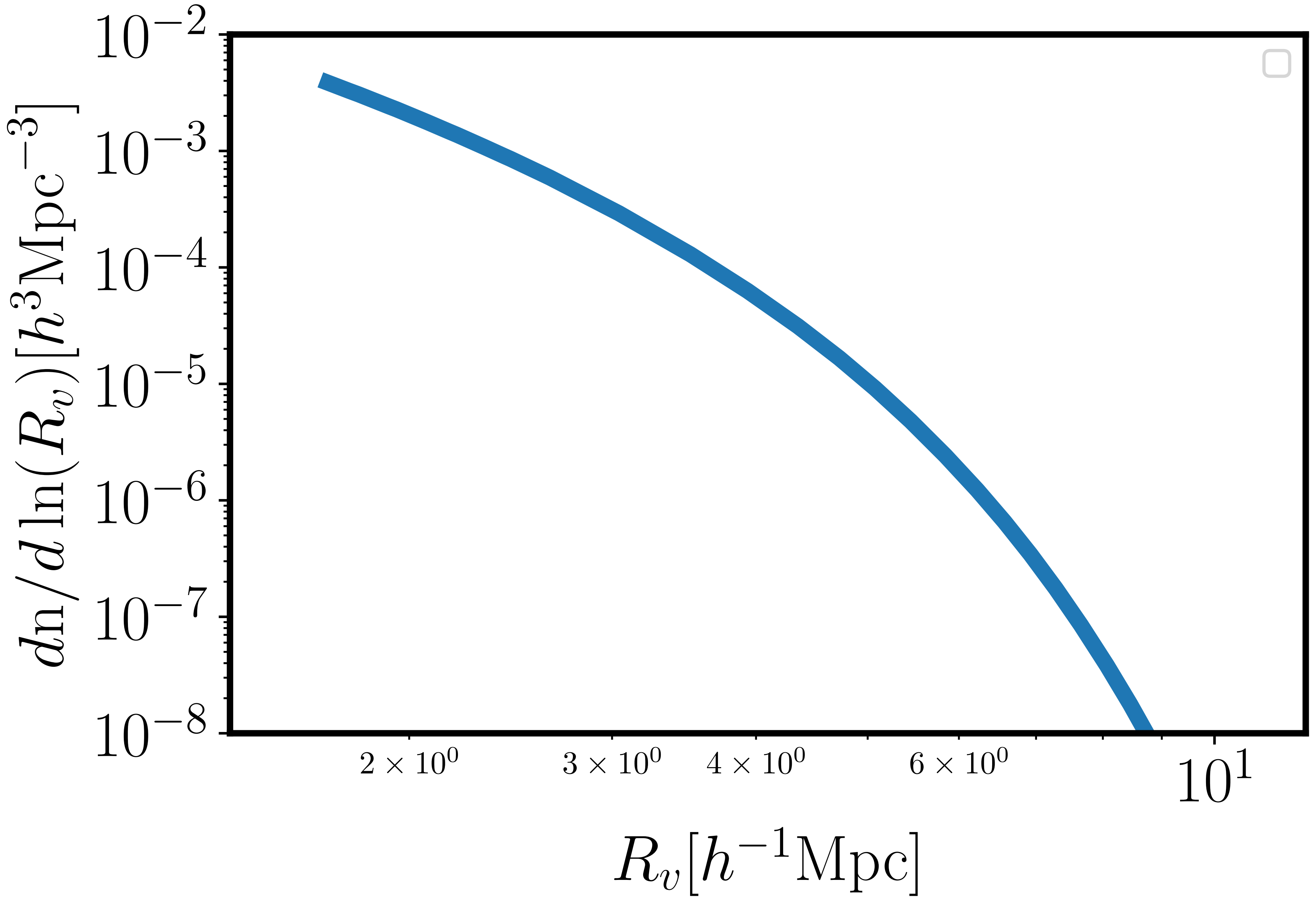




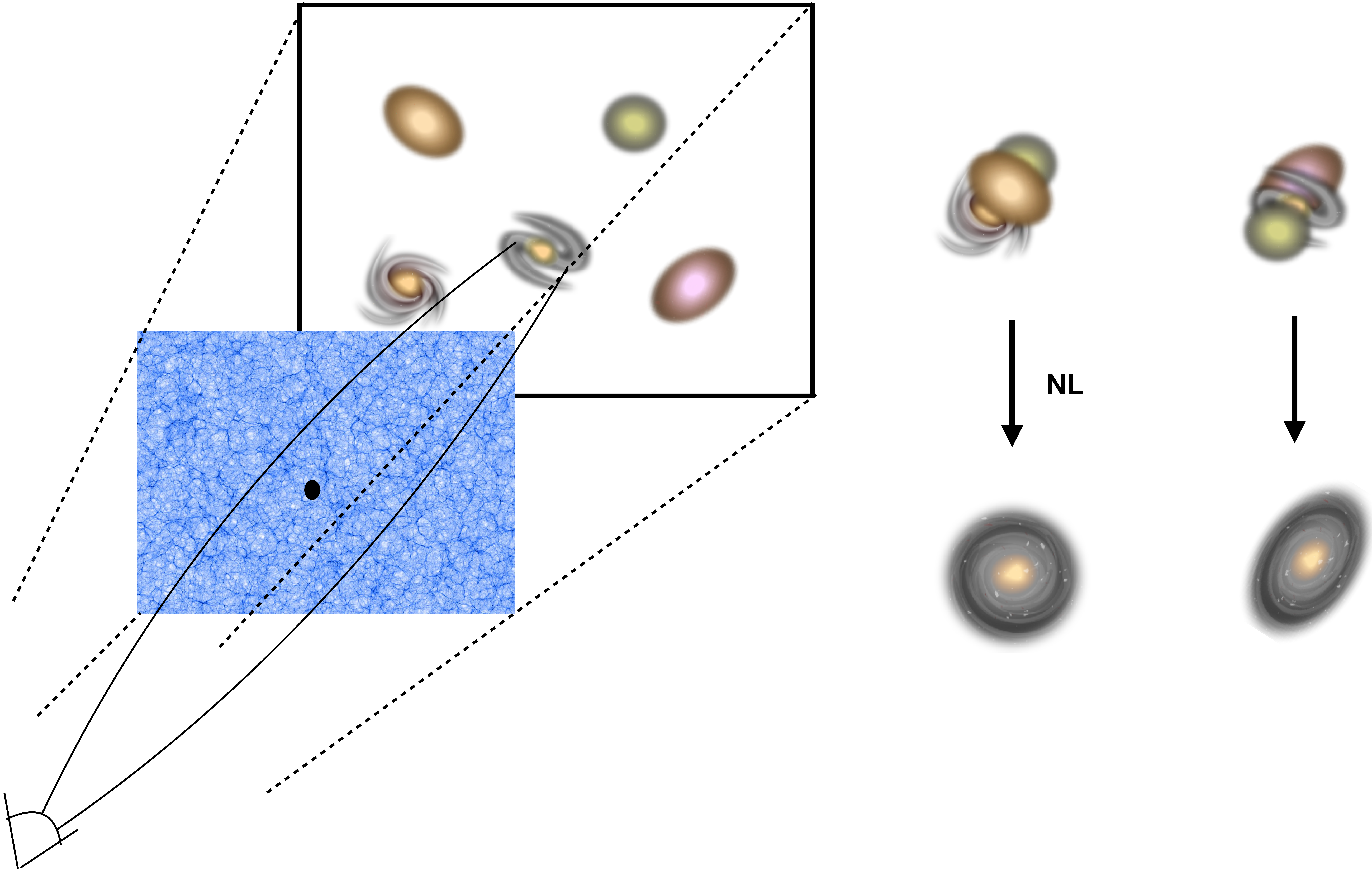
Why Voids?


r

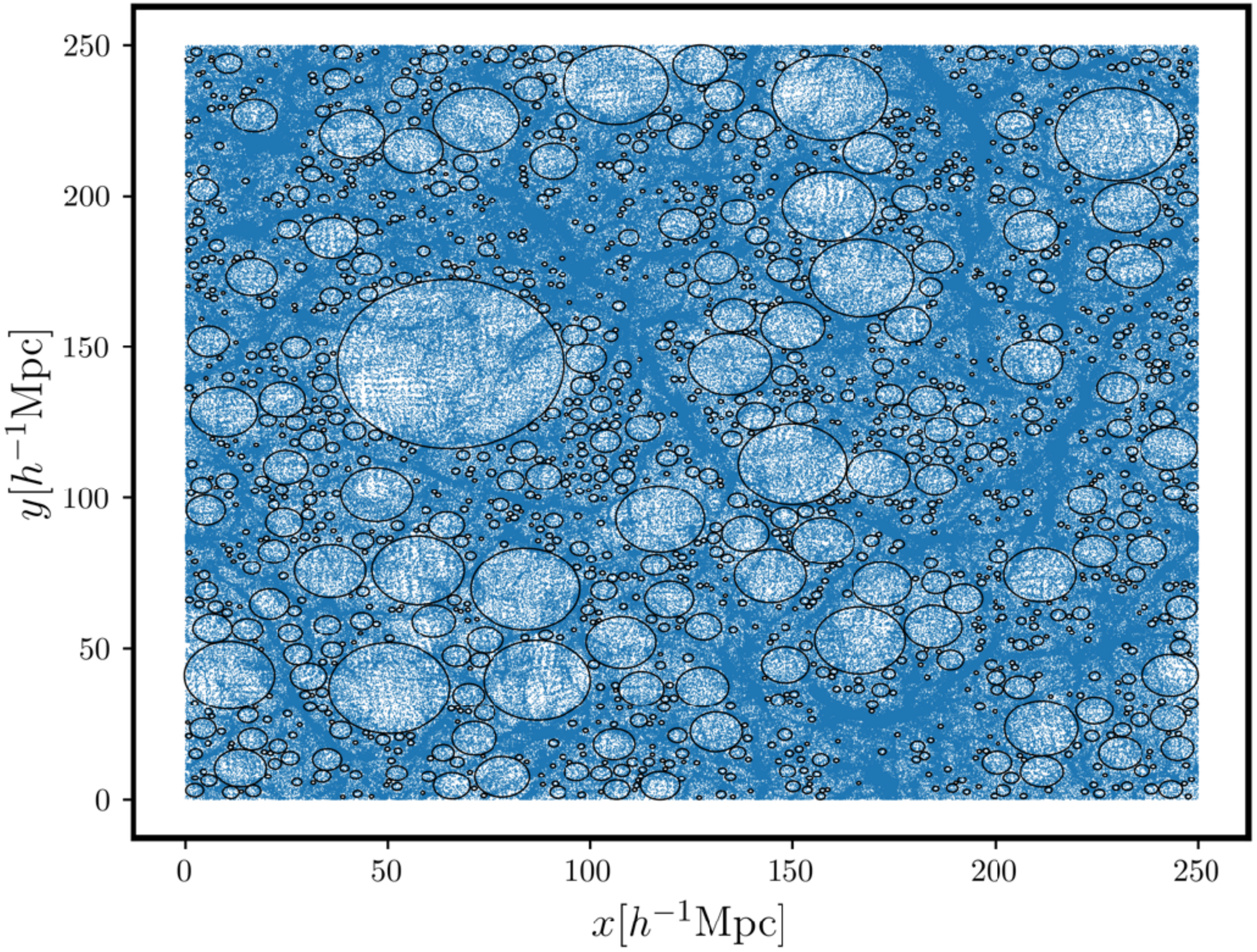

1v term solely
r_v =5$h^{-1}Mpc$
r_v =10$h^{-1}Mpc$
r_v =4$h^{-1}Mpc$
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
δ_v
0
1
2
3
4
5
r/r_v

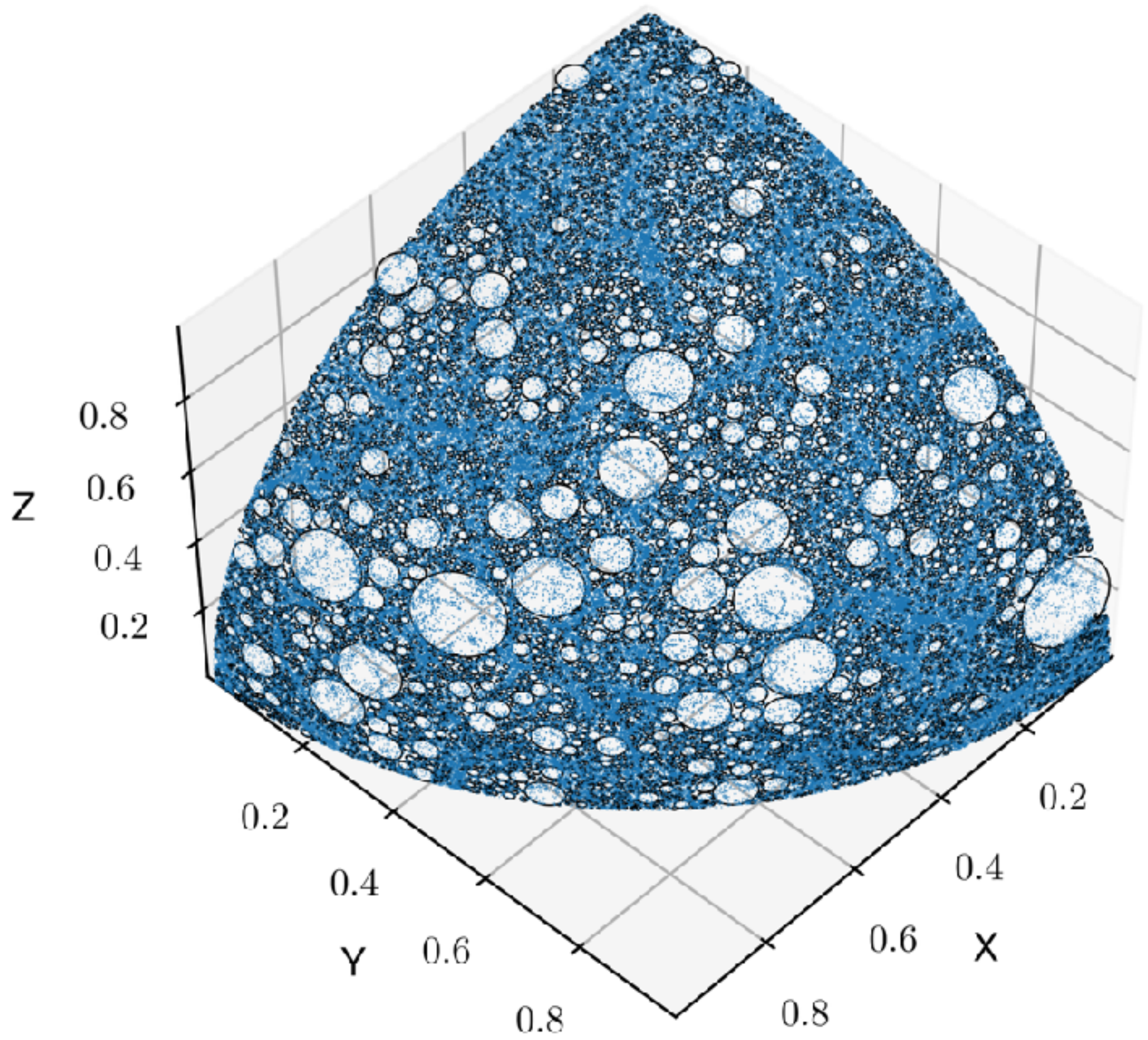

10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
$d\mathrm{n}/d\ln(R_v)[h^3\mathrm{Mpc}^{-3}]$
2×10^0
3×10^0
4×10^0
6×10^0
10^1
$R_v[h^{-1}\mathrm{Mpc}]$

Why Weak Lensing?



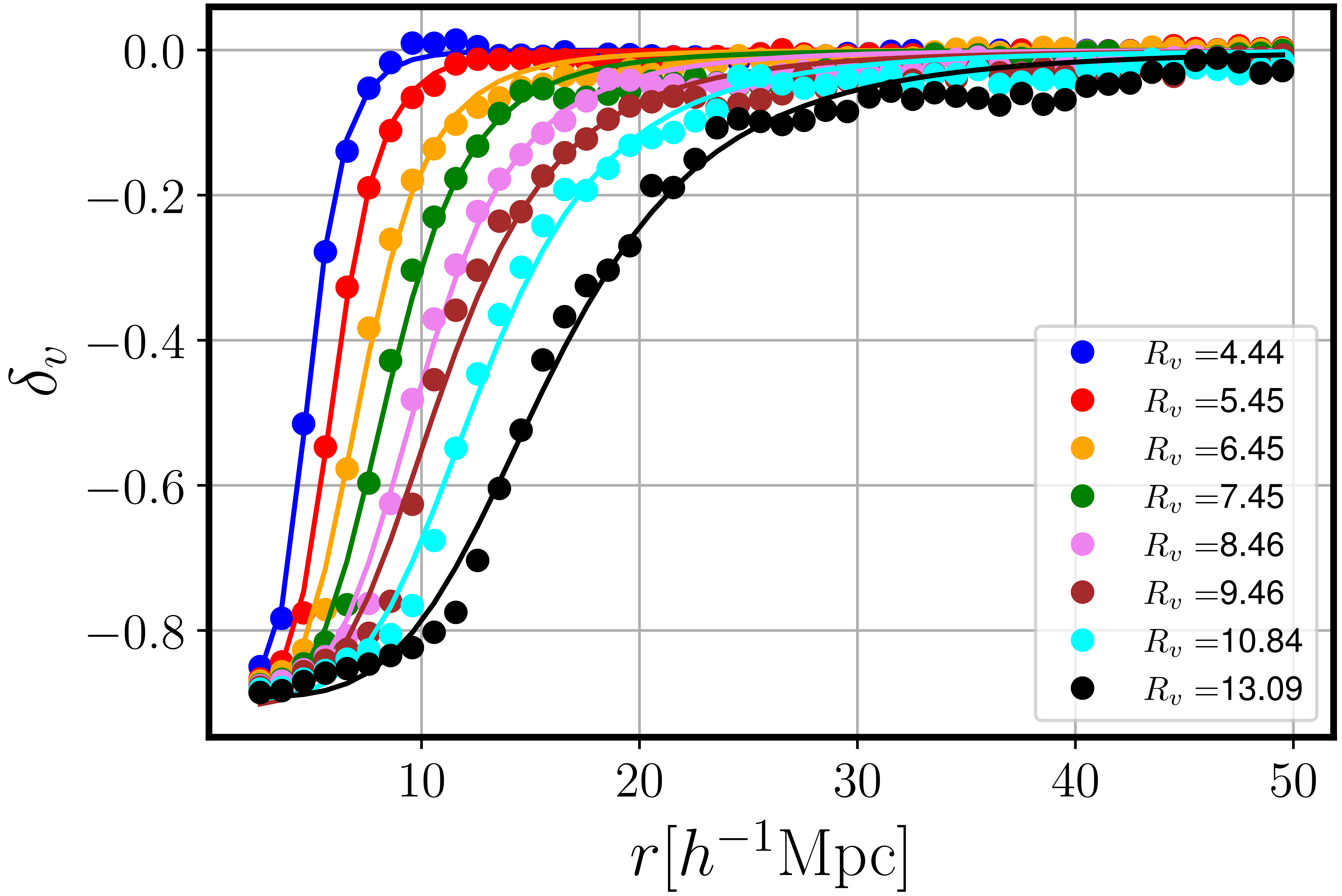
Optimum Centering Void Finder



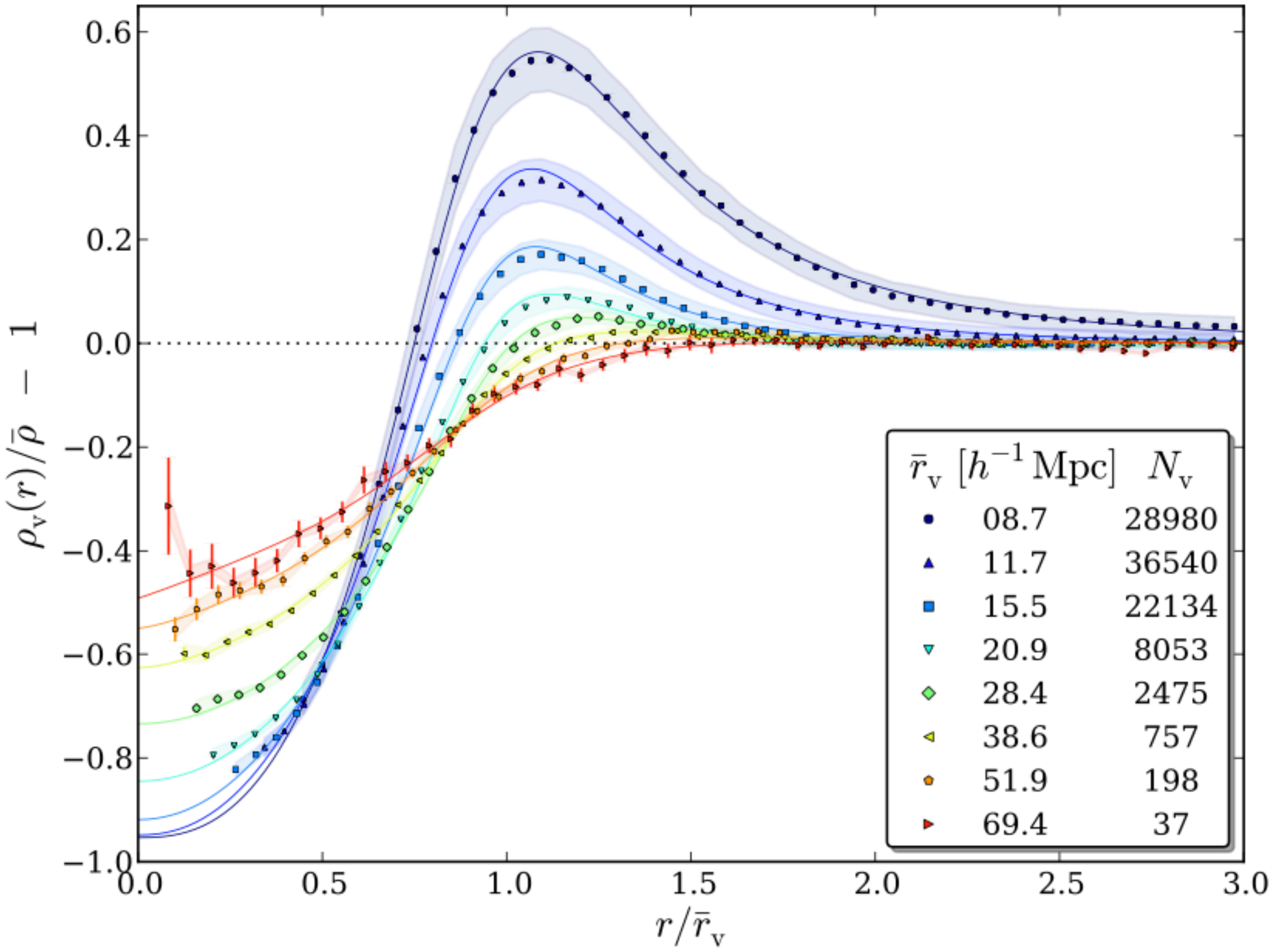


Comparison With Literature

OCVF

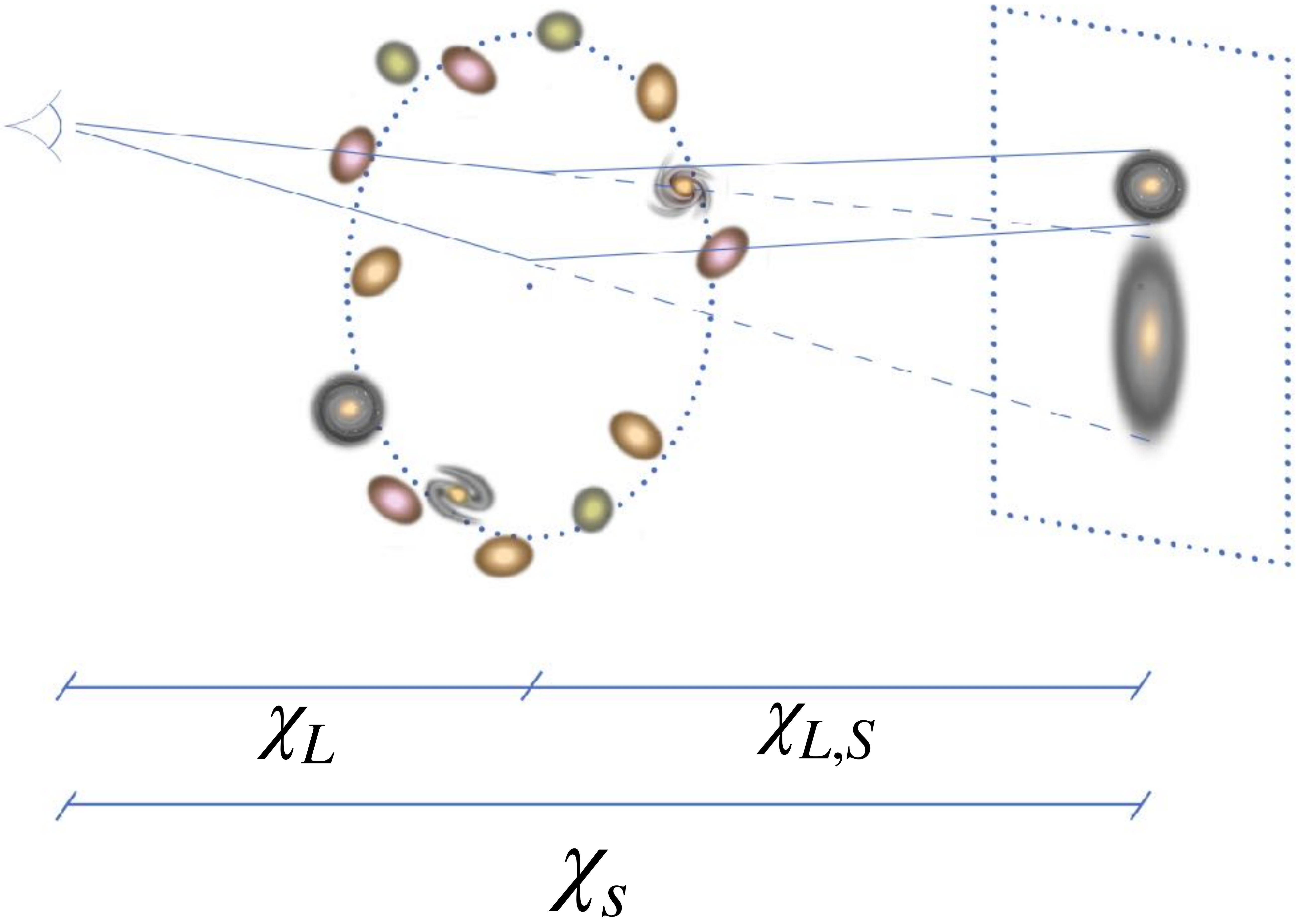


ZOBOV



Hamaus et al (2014)

WL Voids



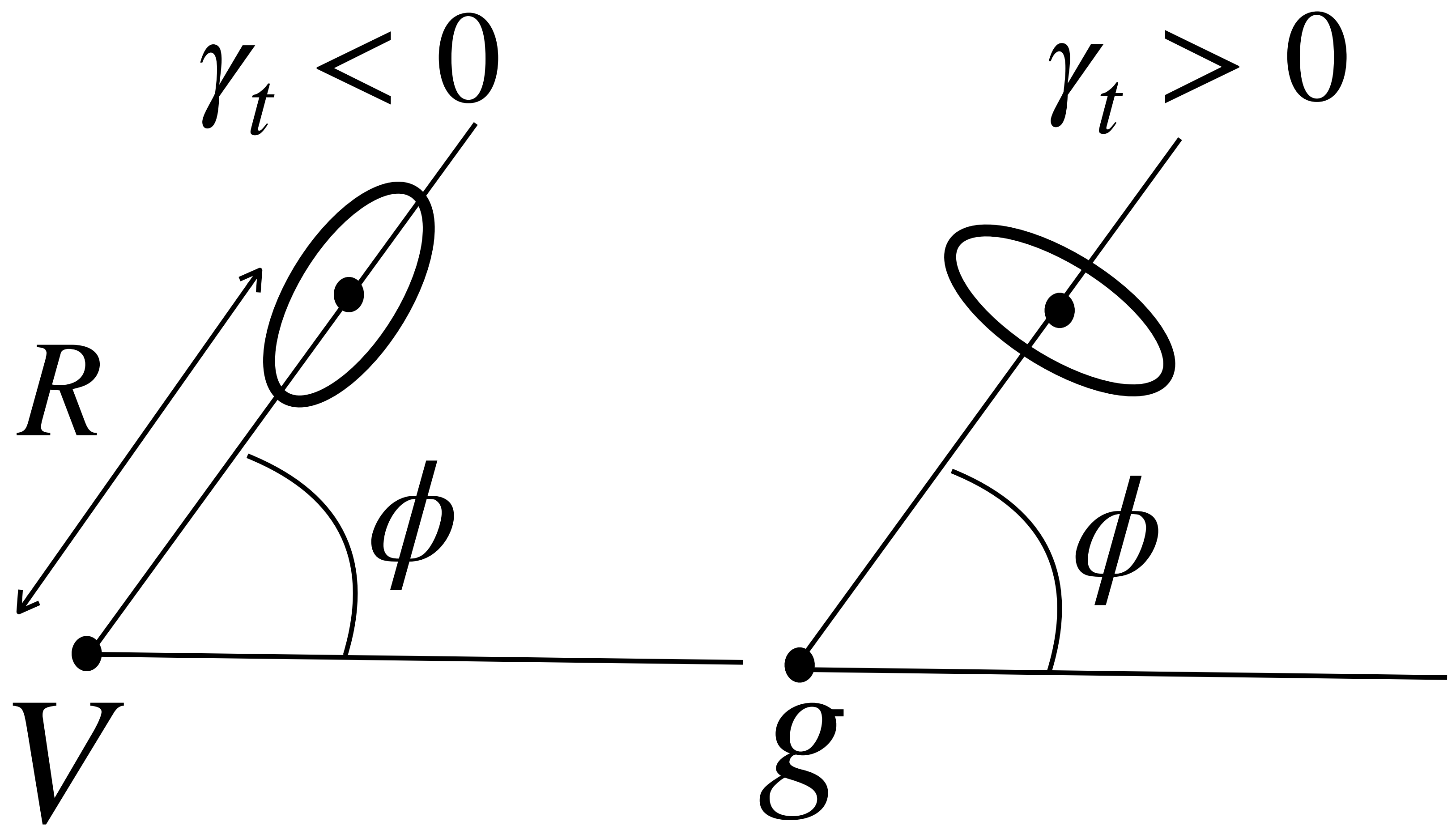
Differential surface mass density:

$$\Delta\Sigma(R, z_L) = \Sigma_{crit}(\bar{\kappa}(< R) - \kappa(R))$$

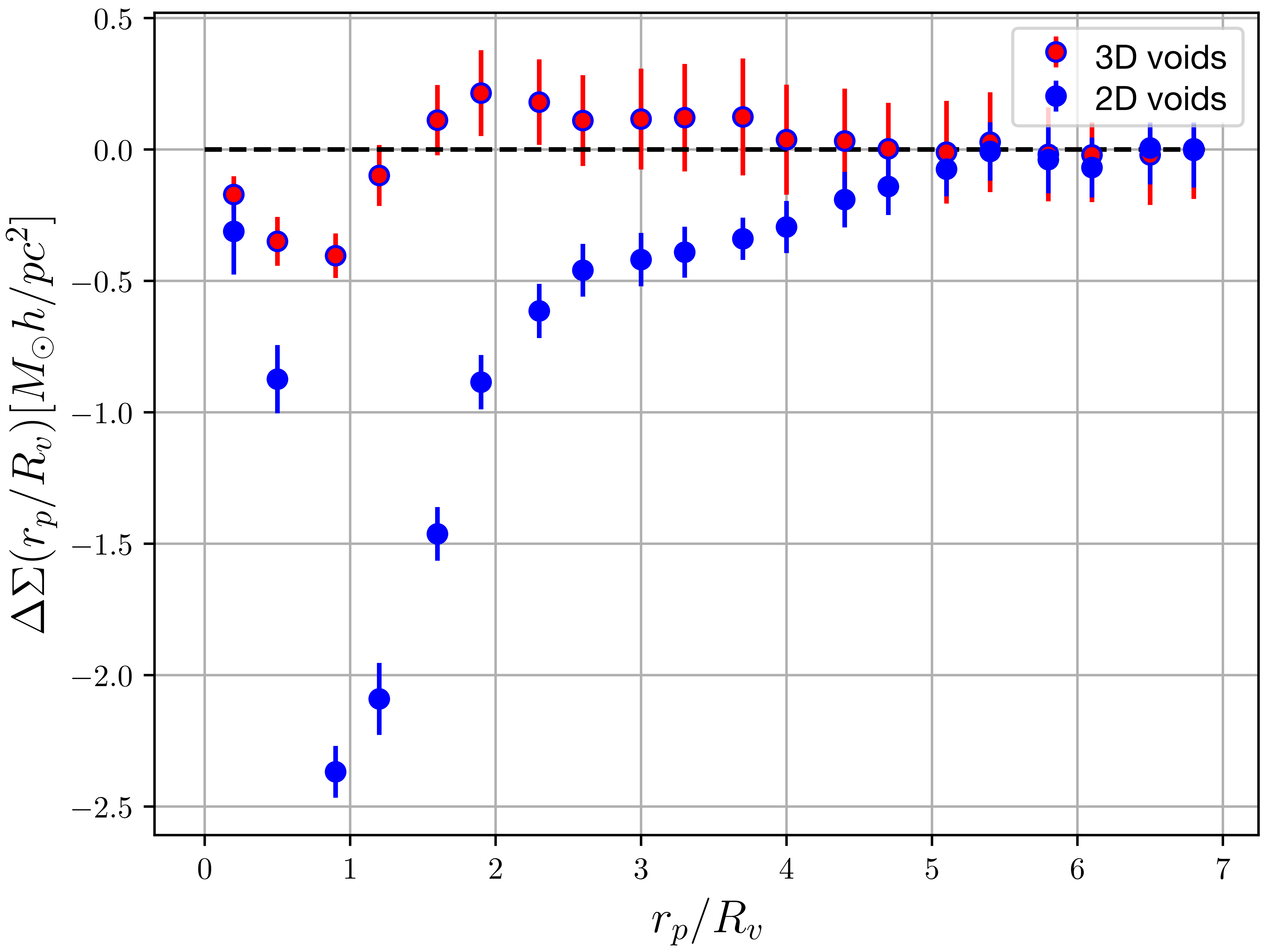
$$= \Sigma_{crit} \times \gamma_t(R)$$

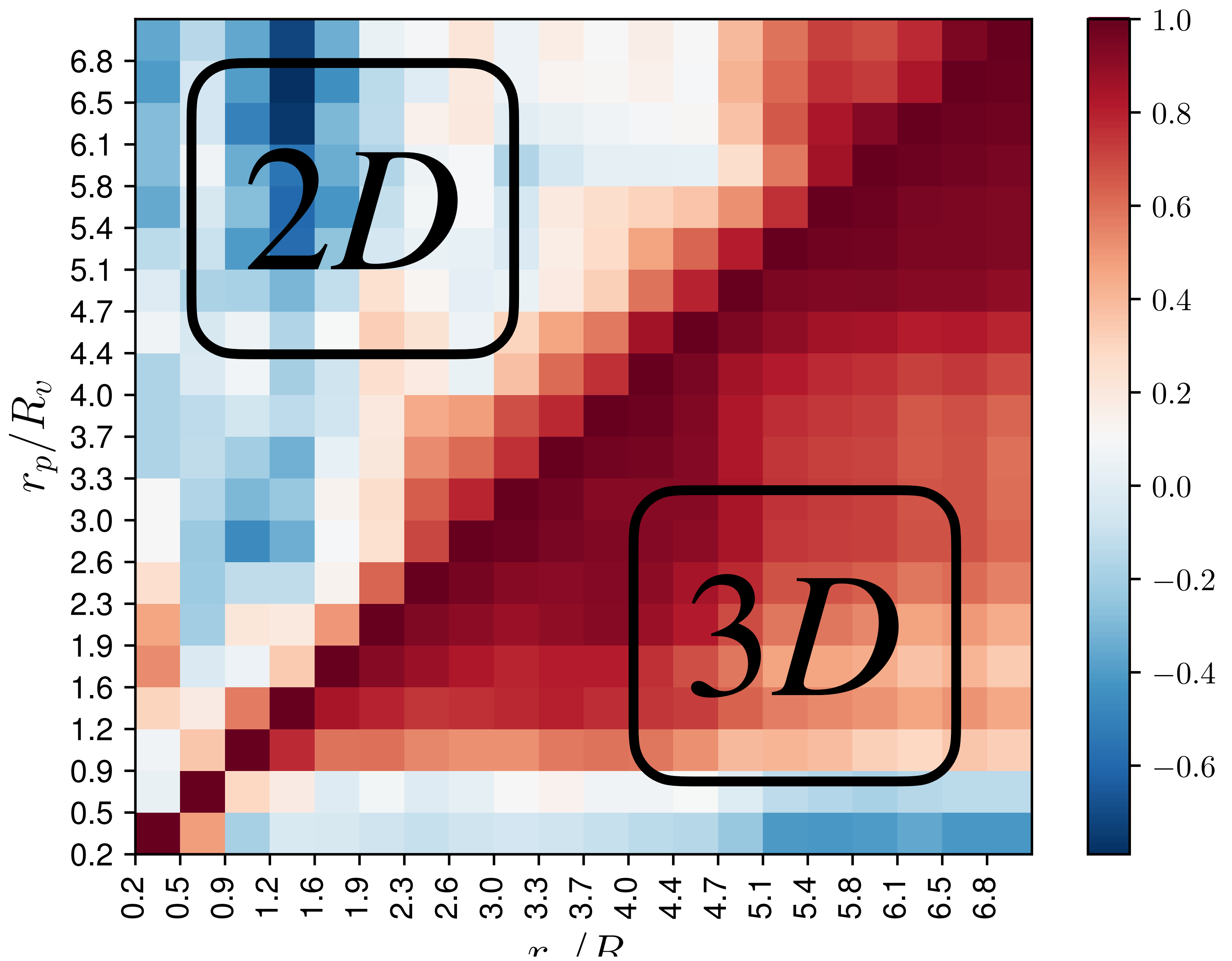
$$\kappa(R) = \int d\chi \Sigma_{crit}^{-1} \bar{\rho} \delta(\chi, R) \equiv \Sigma_{crit}^{-1} \Sigma(R)$$

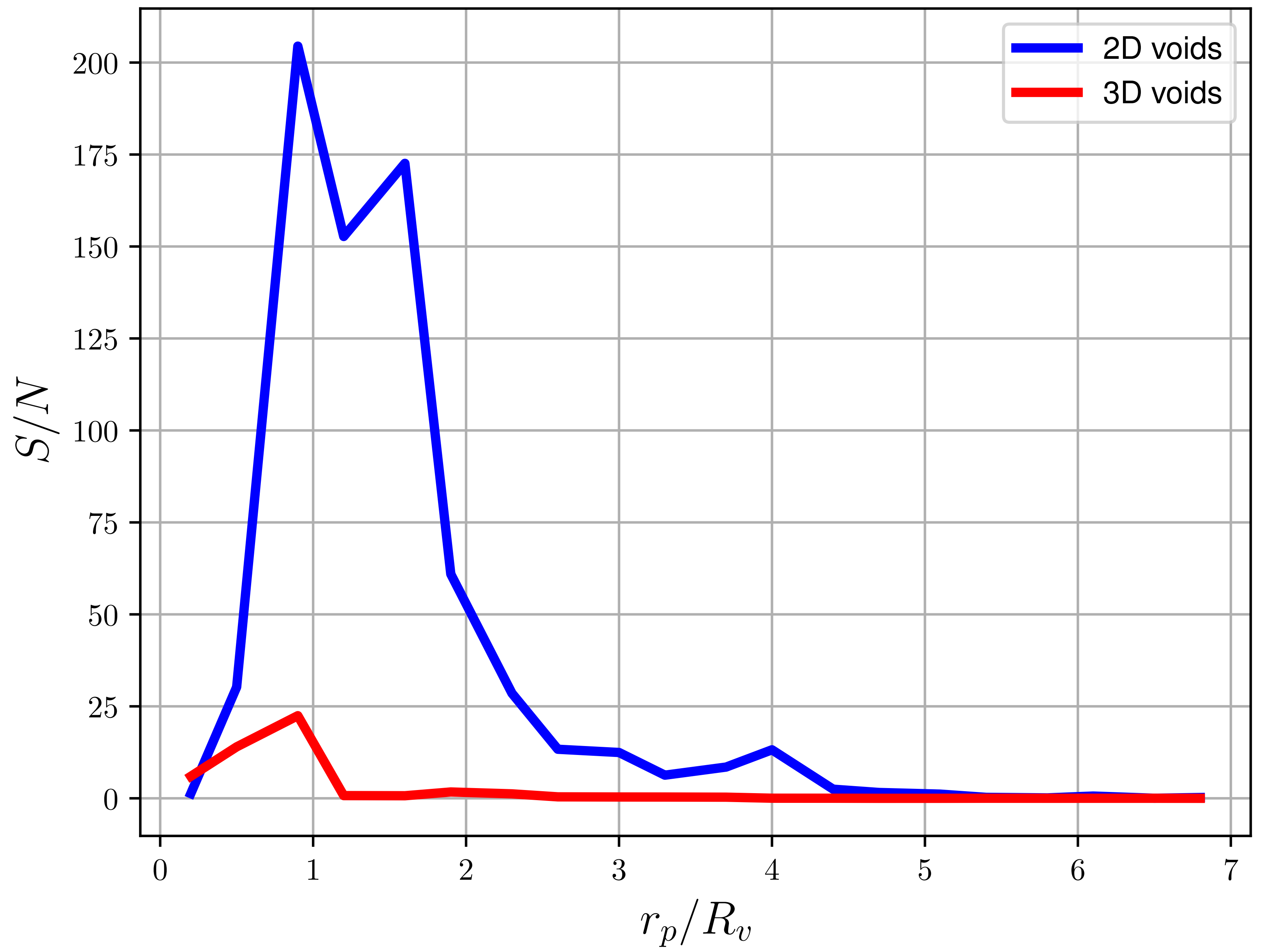
$$\Rightarrow \Delta\Sigma(R) = \bar{\Sigma}(< R) - \Sigma(R)$$



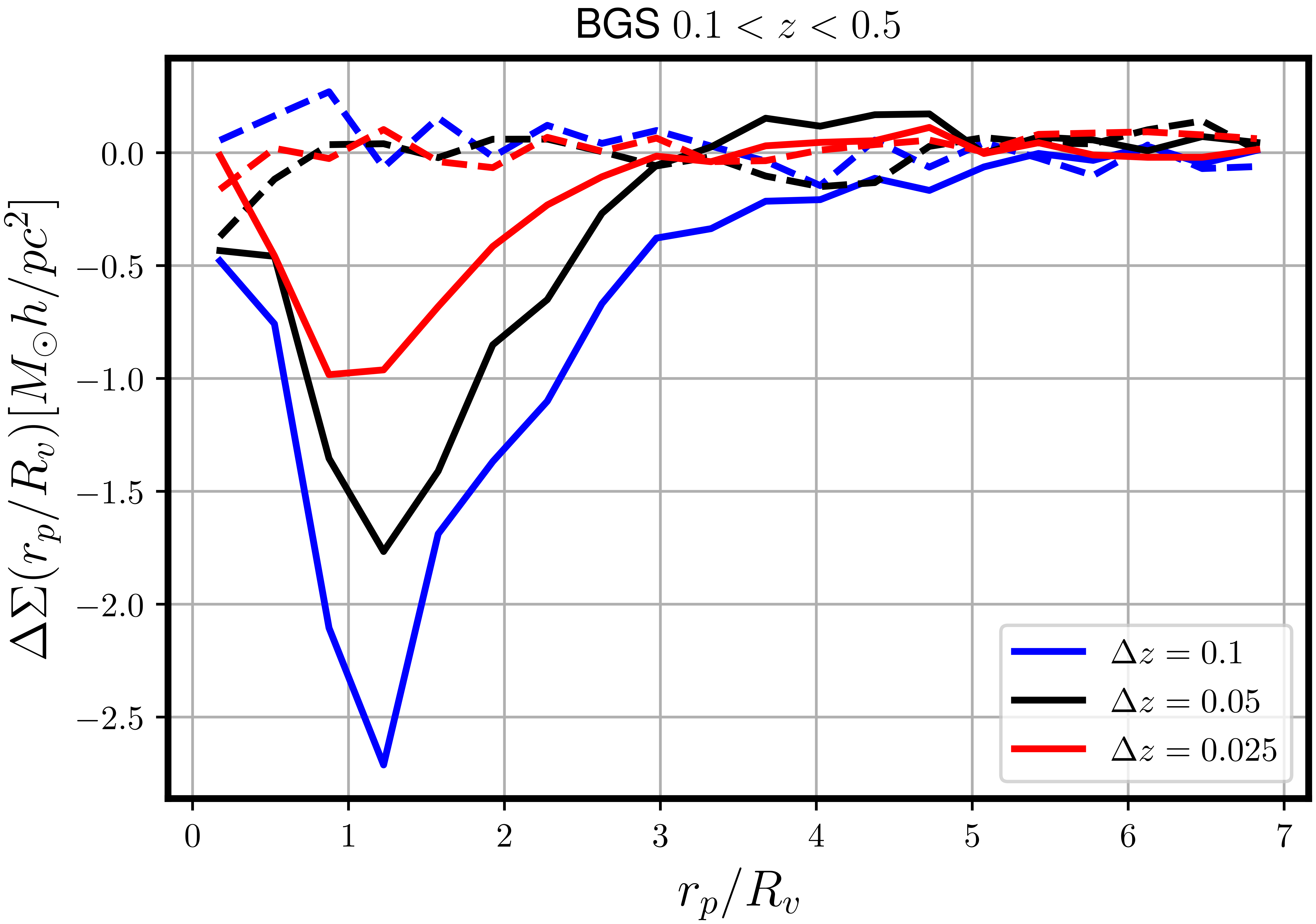
How To Optimize VL Measurement?



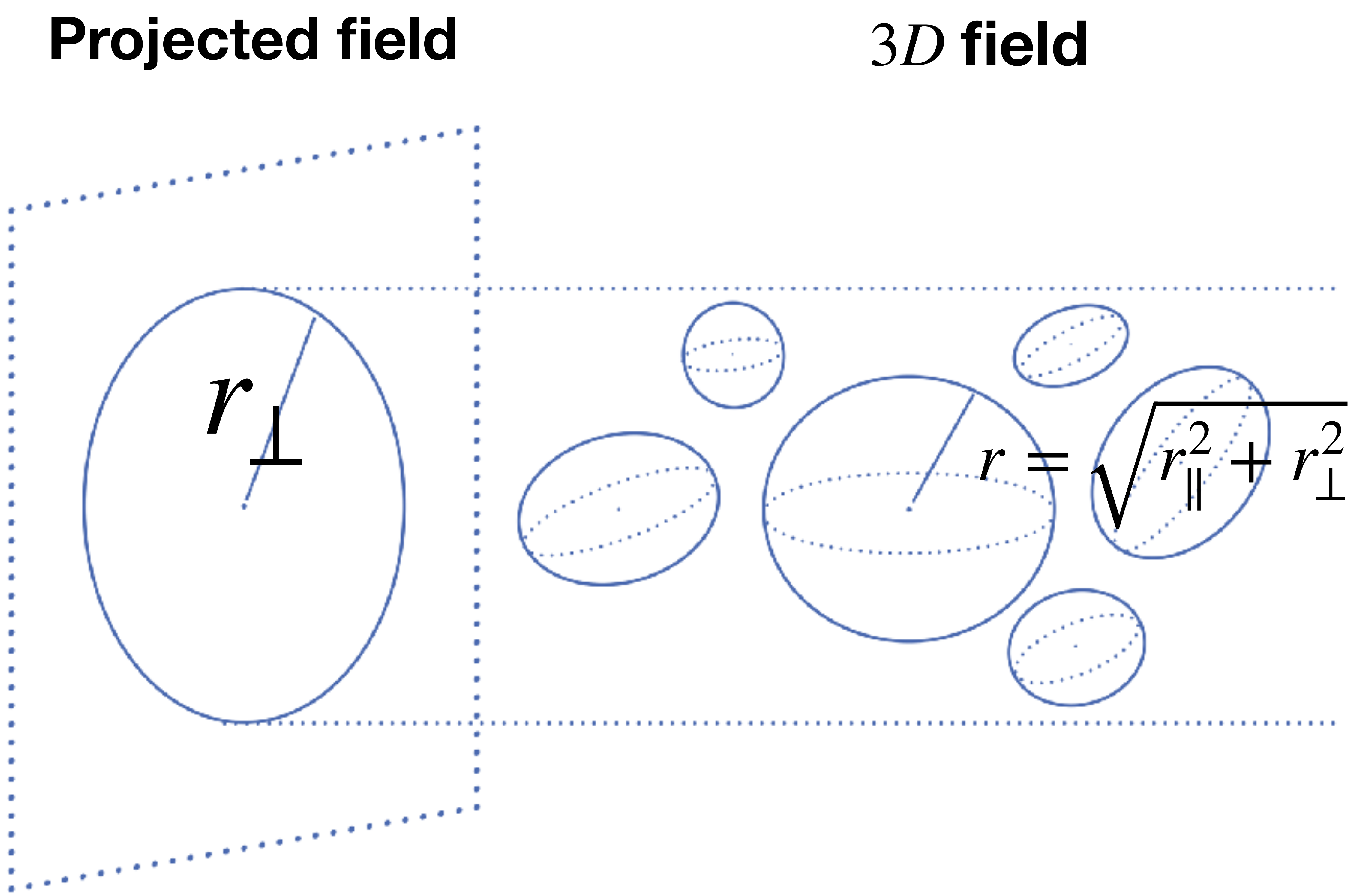




The Role of Bin Size



The Void-Lensing Model



$$\delta_{2D}(r_\perp \,|\, R_{2D}, \Delta_{2D}) = \int dR_{3D} \frac{dn_v}{dR_{3D}}(R_{3D} \,|\, \Delta_{3D}) \int dx_\perp dx_\parallel d\alpha P(x_\perp, x_\parallel, \alpha \,|\, R_{3D}, R_{2D}, \Delta_{3D}, \Delta_{2D}) \int dr_\parallel \, \delta_{3D}(r_\perp - x_\perp, r_\parallel - x_\parallel \,|\, \alpha, R_{3D}, \Delta_{3D})$$

The Void-Lensing Model

$$\delta_{2D}(r_\perp | R_{2D}, \Delta_{2D}) = \int dR_{3D} \frac{dn_v}{dR_{3D}}(R_{3D} | \Delta_{3D}) \int dx_\perp dx_\parallel d\alpha P(x_\perp, x_\parallel, \alpha | R_{3D}, R_{2D}, \Delta_{3D}, \Delta_{2D}) \int dr_\parallel\, \delta_{3D}(r_\perp - x_\perp, r_\parallel - x_\parallel | \alpha, R_{3D}, \Delta_{3D})$$

$$\simeq$$

$$\delta_{2D}(r_\perp | M_{2D}) = \int d\ln R_{3D} \frac{dn_v}{d\ln R_{3D}} \int dx_\perp (1 + \xi(x_\perp)) \int dr_\parallel\, \delta_{3D}(r_\perp, r_\parallel | \alpha, R_{3D})$$

$$= \int dr_\parallel \delta^{eff}(r_\perp, r_\parallel | \alpha, R_{3D})$$

$$\Rightarrow \Delta\Sigma(r_\perp) = \bar{\delta}_{2D}(< r_\perp) - \delta_{2D}(r_\perp)$$

The Void-Lensing Model

$$\delta_{2D}(r_\perp | R_{2D}, \Delta_{2D}) = \int dR_{3D} \frac{dn_v}{dR_{3D}}(R_{3D} | \Delta_{3D}) \int dx_\perp dx_\parallel d\alpha P(x_\perp, x_\parallel, \alpha | R_{3D}, R_{2D}, \Delta_{3D}, \Delta_{2D}) \int dr_\parallel\, \delta_{3D}(r_\perp - x_\perp, r_\parallel - x_\parallel | \alpha, R_{3D}, \Delta_{3D})$$

$$\simeq$$

$$\delta_{2D}(r_\perp | M_{2D}) = \int d\ln R_{3D} \boxed{\frac{dn_v}{d\ln R_{3D}}} \int dx_\perp (1 + \xi(x_\perp)) \int dr_\parallel\, \delta_{3D}(r_\perp, r_\parallel | \alpha, R_{3D})$$

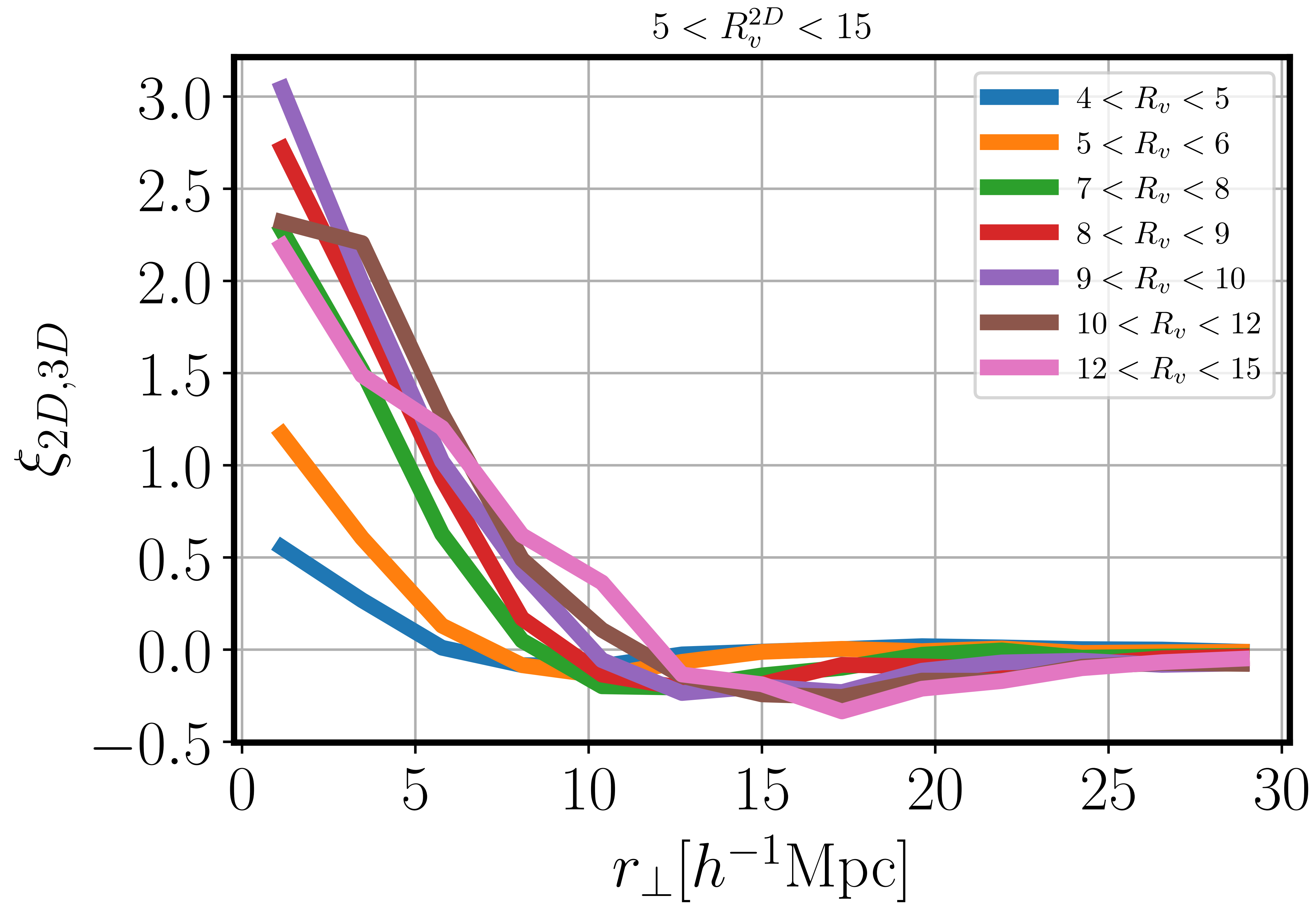
$$\frac{dn_v}{d\ln R} = \frac{f(\sigma)}{V(R)} \frac{d\ln\sigma^{-1}}{d\ln R}$$, **where** $$\sigma^2(R) \equiv \int \frac{dk}{2\pi^2} k^2 P^L_{mm}(k) |\tilde{W}(k \mid R)|^2$$

The Void-Lensing Model

$$\delta_{2D}(r_\perp | R_{2D}, \Delta_{2D}) = \int dR_{3D} \frac{dn_v}{dR_{3D}}(R_{3D} | \Delta_{3D}) \int dx_\perp dx_\parallel d\alpha P(x_\perp, x_\parallel, \alpha | R_{3D}, R_{2D}, \Delta_{3D}, \Delta_{2D}) \int dr_\parallel \rho_{3D}(r_\perp - x_\perp, r_\parallel - x_\parallel | \alpha, R_{3D}, \Delta_{3D})$$

$$\simeq$$

$$\delta_{2D}(r_\perp | M_{2D}) = \int d\ln R_{3D} \frac{dn_v}{d\ln R_{3D}} \int dx_\perp \boxed{(1 + \xi(x_\perp))} \int dr_\parallel \delta_{3D}(r_\perp, r_\parallel | \alpha, R_{3D})$$

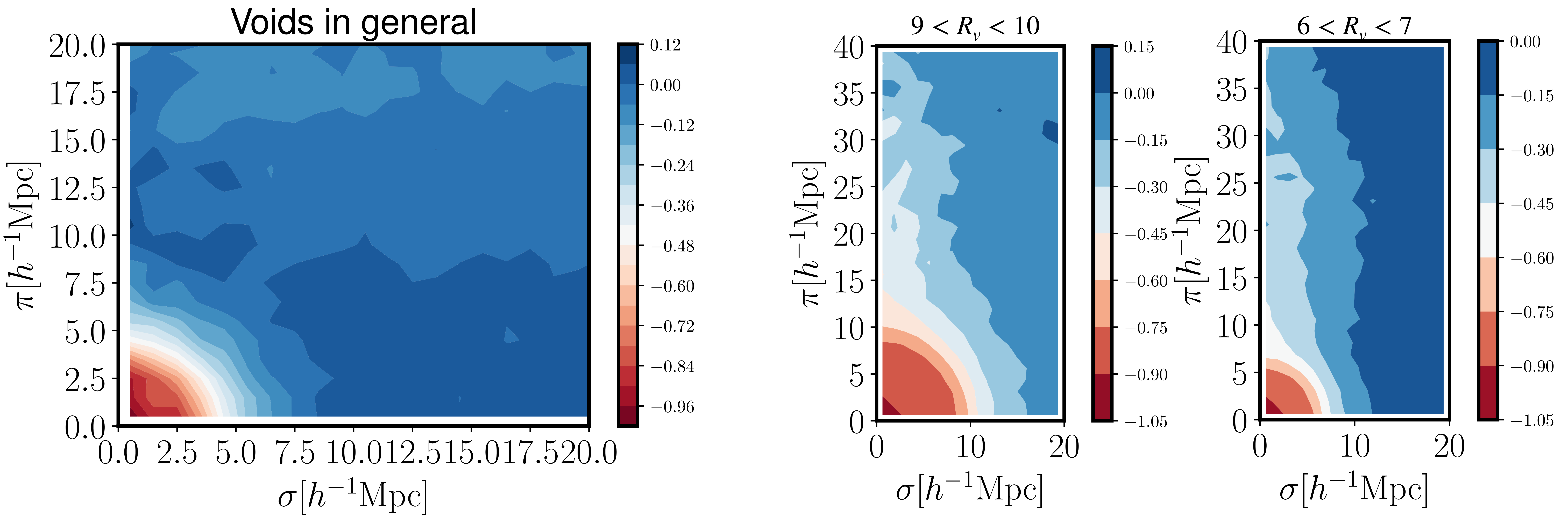


The Void-Lensing Model

$$\delta_{2D}(r_\perp | R_{2D}, \Delta_{2D}) = \int dR_{3D} \frac{dn_v}{dR_{3D}}(R_{3D}|\Delta_{3D}) \int dx_\perp dx_\parallel d\alpha P(x_\perp, x_\parallel, \alpha | R_{3D}, R_{2D}, \Delta_{3D}, \Delta_{2D}) \int dr_\parallel \, \delta_{3D}(r_\perp - x_\perp, r_\parallel - x_\parallel | \alpha, R_{3D}, \Delta_{3D})$$

$$\simeq$$

$$\delta_{2D}(r_\perp | M_{2D}) = \int d\ln R_{3D} \frac{dn_v}{d\ln R_{3D}} \int dx_\perp (1 + \xi(x_\perp)) \int dr_\parallel \boxed{\delta_{3D}(r_\perp, r_\parallel | \alpha, R_{3D})}$$

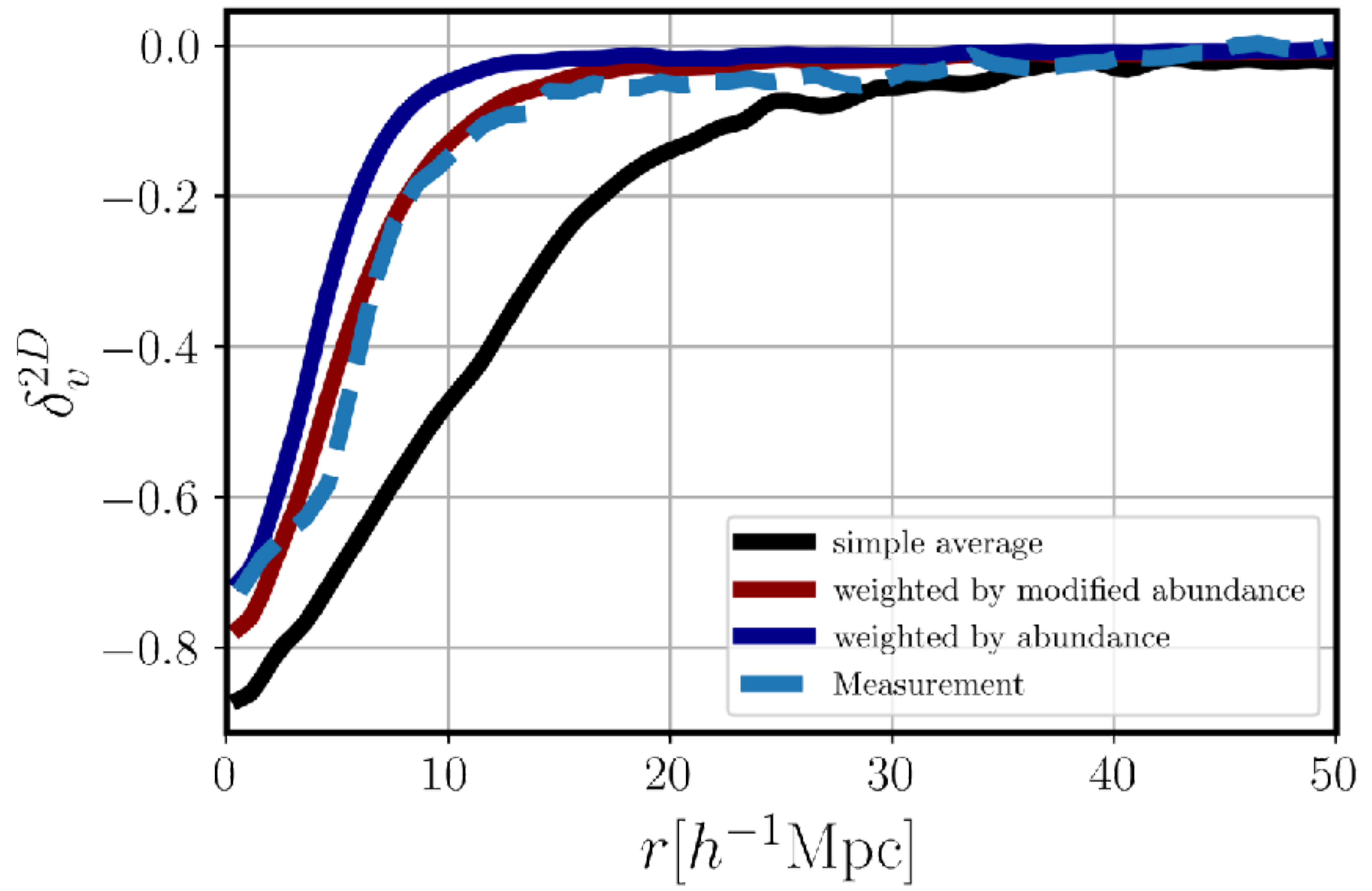


Preliminary Result

$$\delta_{2D}(r_\perp \,|\, R_{2D}, \Delta_{2D}) = \int dR_{3D} \frac{dn_v}{dR_{3D}}(R_{3D} \,|\, \Delta_{3D}) \int dx_\perp dx_\parallel d\alpha P(x_\perp, x_\parallel, \alpha \,|\, R_{3D}, R_{2D}, \Delta_{3D}, \Delta_{2D}) \int dr_\parallel \, \delta_{3D}(r_\perp - x_\perp, r_\parallel - x_\parallel \,|\, \alpha, R_{3D}, \Delta_{3D})$$

$$\simeq$$

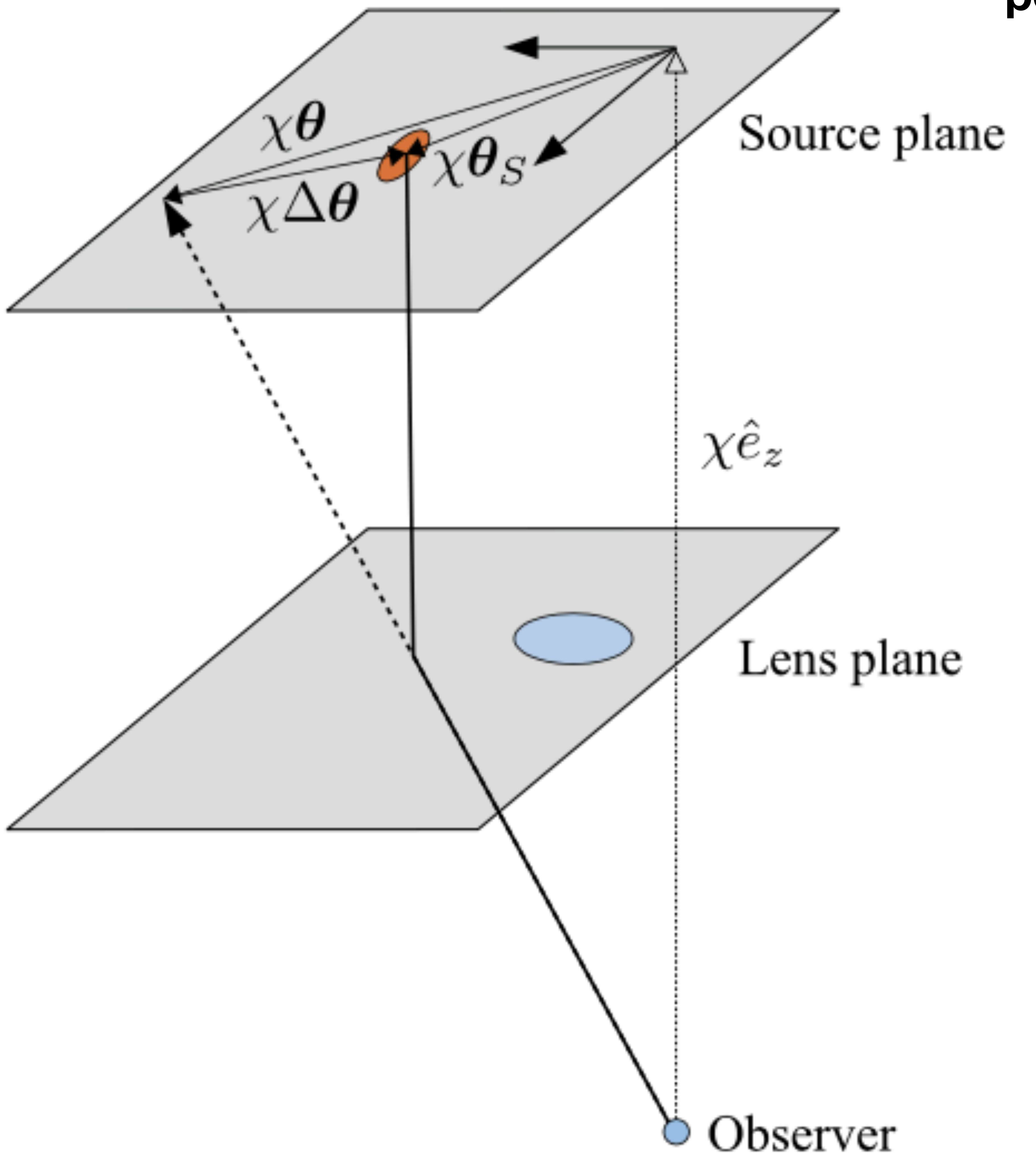
$$\delta_{2D}(r_\perp \,|\, M_{2D}) = \int d\ln R_{3D} \frac{dn_v}{d\ln R_{3D}} \int dx_\perp (1 + \xi(x_\perp)) \int dr_\parallel \, \delta_{3D}(r_\perp, r_\parallel \,|\, \alpha, R_{3D})$$



Conclusions and Prospects

- Our method is capable of measuring $\Delta\Sigma$ with high S/N
- Apply this method to real DESI data
- Promising results in relating 3D and 2D underdensities
- Open questions: (i) How much we can reconstruct from the DM field using 2D underdensities? (ii) Is the Void intrinsic alignment sensitive to cosmology, modifications to gravity or neutrinos?
- Future: Apply the pipe line to the real data and perform cosmological analysis for the first time

WL



Dodelson and Schmidt (2021)

Geodesic equation + scalar perturbations $\Rightarrow$

$$\theta^i = \theta^i_s + \Delta\theta^i$$

$$\Delta\theta^i(\boldsymbol{\theta}) = \frac{2}{c^2}\int_0^{\chi} d\chi' \Phi_{,i}\left(\boldsymbol{x}\left(\boldsymbol{\theta},\chi'\right)\right)\chi'\left(1-\frac{\chi'}{\chi}\right)$$

$$\psi_{ij} \equiv \frac{\partial \Delta\theta^i}{\partial\theta^j} = \frac{\partial^2}{\partial\theta^i\partial\theta^j}\phi_{\rm L}(\boldsymbol{\theta}) = \frac{2}{c^2}\int_0^{\chi} d\chi' \Phi_{,ij}\left(\boldsymbol{x}\left(\boldsymbol{\theta},\chi'\right)\right)\chi'\left(1-\frac{\chi'}{\chi}\right)$$

$$A_{ij} \equiv \frac{\partial\theta^i_S}{\partial\theta^j} = \begin{pmatrix} 1-\kappa-\gamma_1 & -\gamma_2 \\ -\gamma_2 & 1-\kappa+\gamma_1 \end{pmatrix}$$

$$A_{ij} = \delta_{ij} + \psi_{ij}$$

$$\kappa = \psi_{11} + \psi_{22} = \frac{2}{c^2}\int_0^{\chi} d\chi' \nabla^2\Phi\left(\boldsymbol{x}\left(\boldsymbol{\theta},\chi'\right)\right)\chi'\left(1-\frac{\chi'}{\chi}\right)$$

$$\gamma_1 = -\frac{\psi_{11}-\psi_{22}}{2} \qquad \gamma_2 = -\psi_{12}$$