Modelling cosmic void statistics

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in collaboration with
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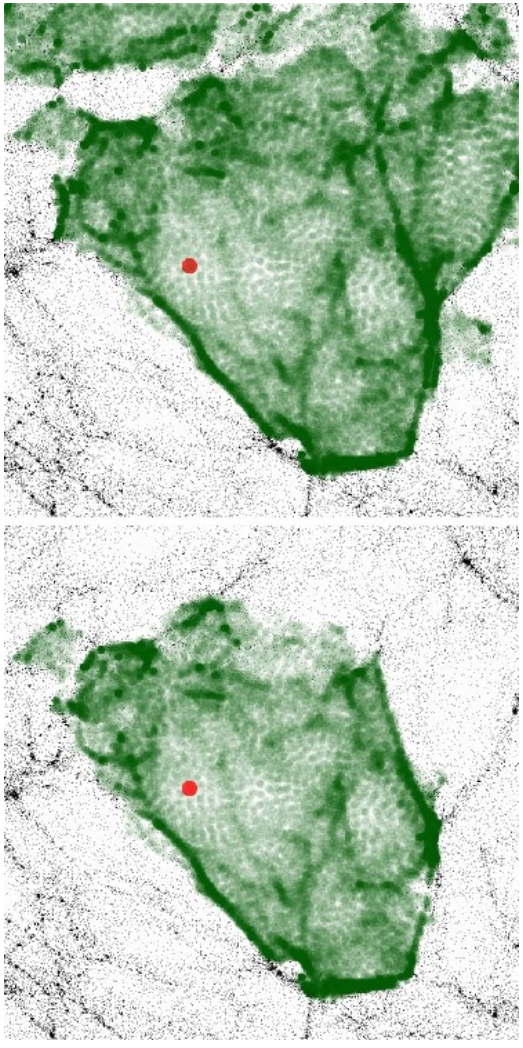
Alice Pisani, Florent Leclercq, Jens Jasche, Michael Warren

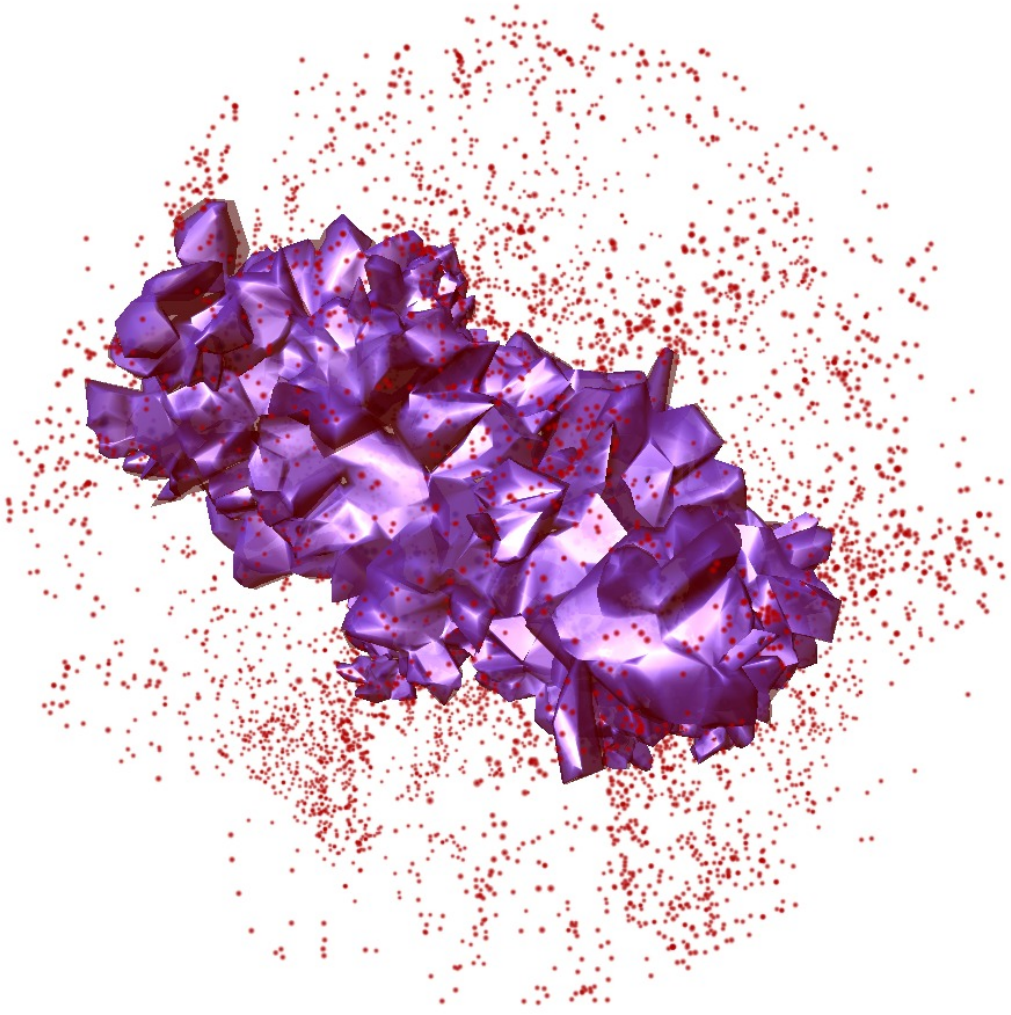
IAU Symposium 308 – The Zeldovich Universe Tallinn, June 27, 2014

1. Introduction
2. Density profile [arXiv:1309.5087, arXiv:1403.5499]
3. 2-point statistics in redshift space [in prep.]
4. Outlook

Voids in the cosmic web

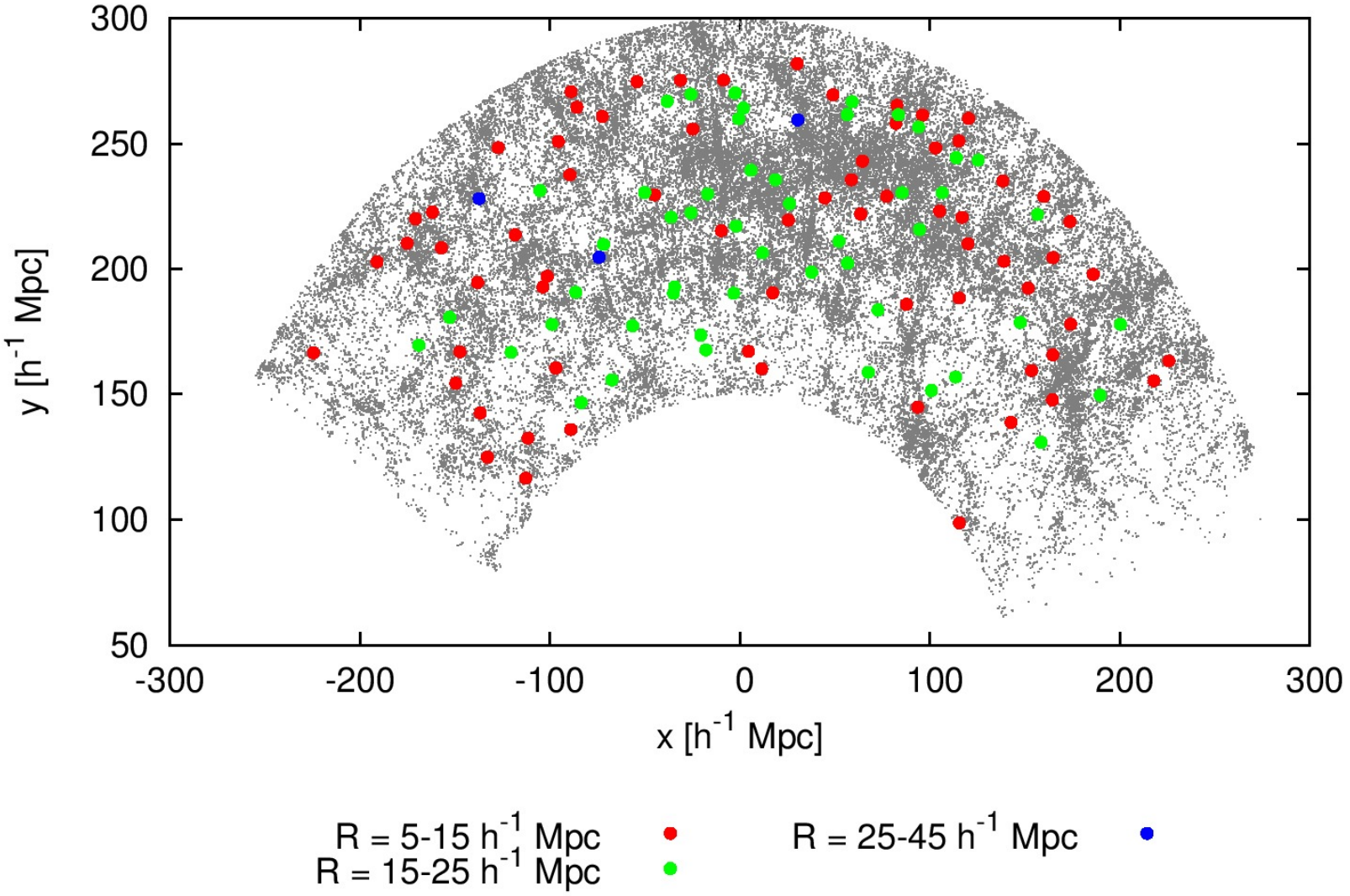


Zobov: Neyrinck (2008)



Sutter, Lavaux, Wandelt, Weinberg (2012)

SDSS voids



Sutter et al. (2012)

Void profile

Estimate density profile by “stacking” tracer particles around void centers

$$\rho_{\mathrm{v}}(r) = \frac{3}{4\pi} \sum_i \frac{m_i(\boldsymbol{r}_i)}{(r+\delta r)^3 - (r-\delta r)^3}$$

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Estimator for velocity profile

$$v_{\mathrm{v}}(r) = \frac{1}{N(r)} \sum_i \boldsymbol{v}_i(\boldsymbol{r}_i) \cdot \frac{\boldsymbol{r}_i}{r_i} \, V_c(\boldsymbol{r}_i)$$

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With linear theory

$$v_{\mathrm{v}}(r) = -\frac{1}{3}\Omega_{\mathrm{m}}^{\gamma} H r \Delta(r) \qquad \Delta(r) = \frac{3}{r^3} \int_0^r \left(\frac{\rho_{\mathrm{v}}(q)}{\bar{\rho}} - 1 \right) q^2 \mathrm{d}q$$

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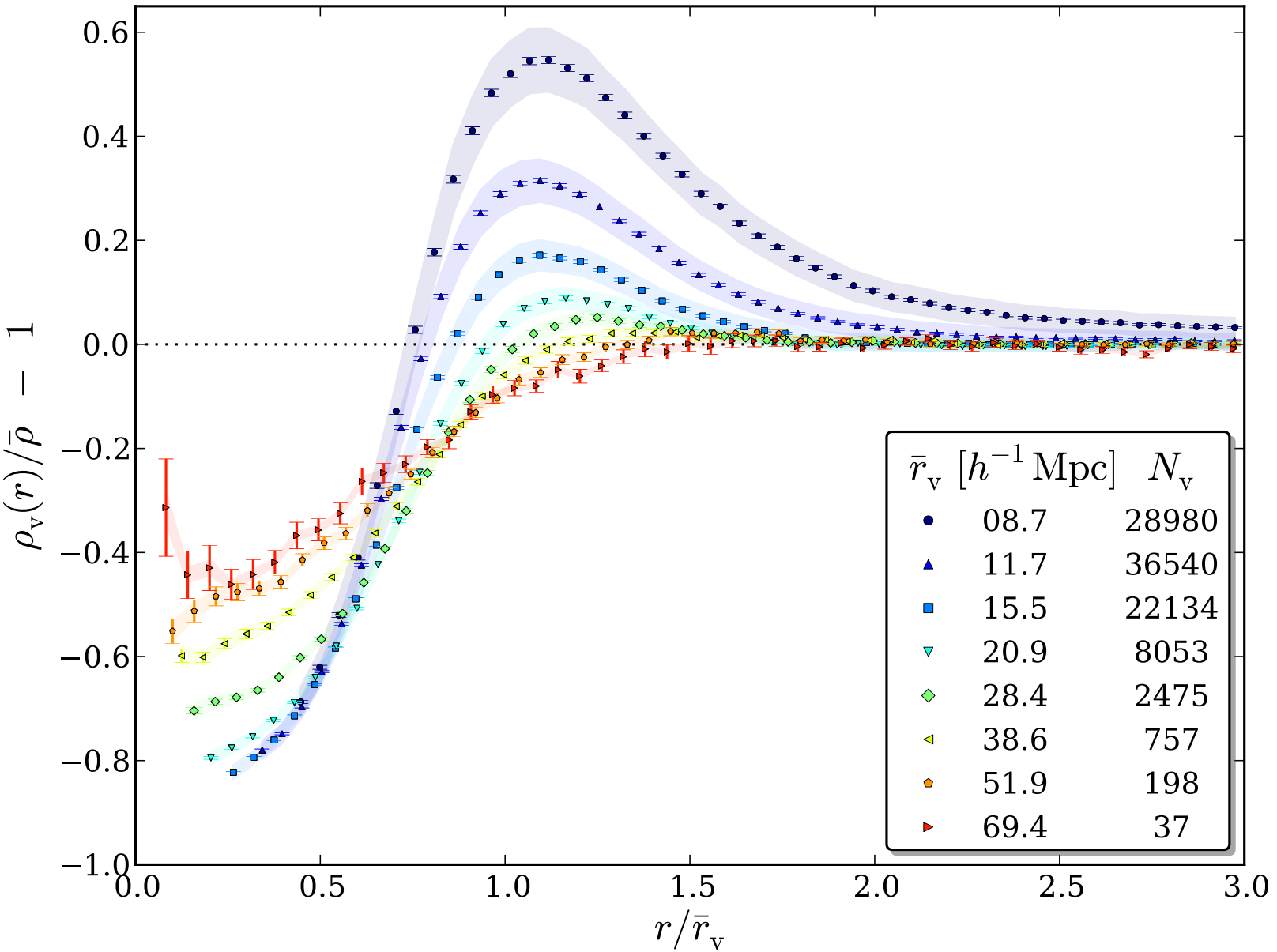
Empirical best-fit model (4 parameters)

$$\frac{\rho_{\mathrm{v}}(r)}{\bar{\rho}} - 1 = \delta_c \frac{1 - (r/r_s)^{\alpha}}{1 + (r/r_{\mathrm{v}})^{\beta}}$$

Void profile: density



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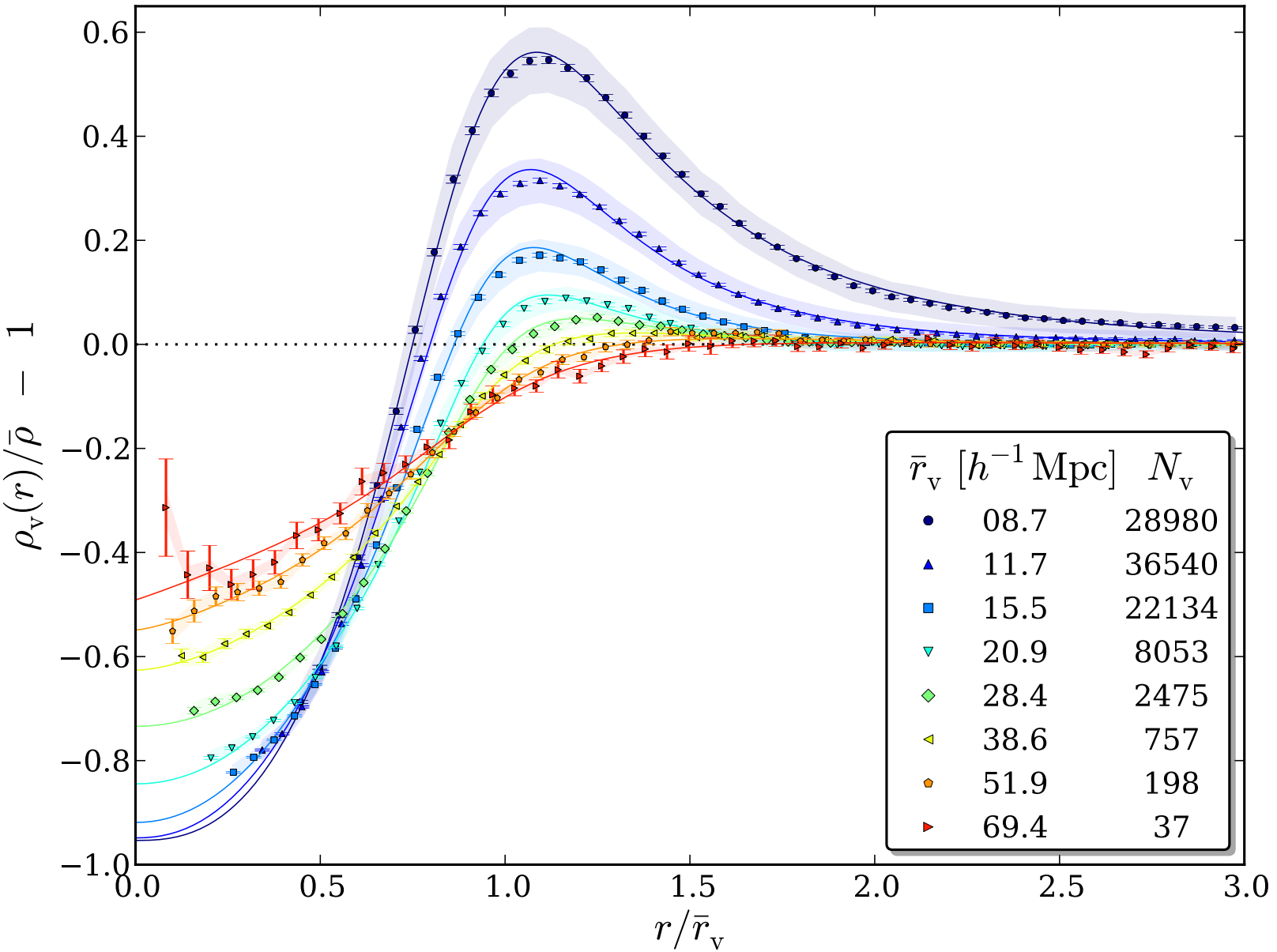
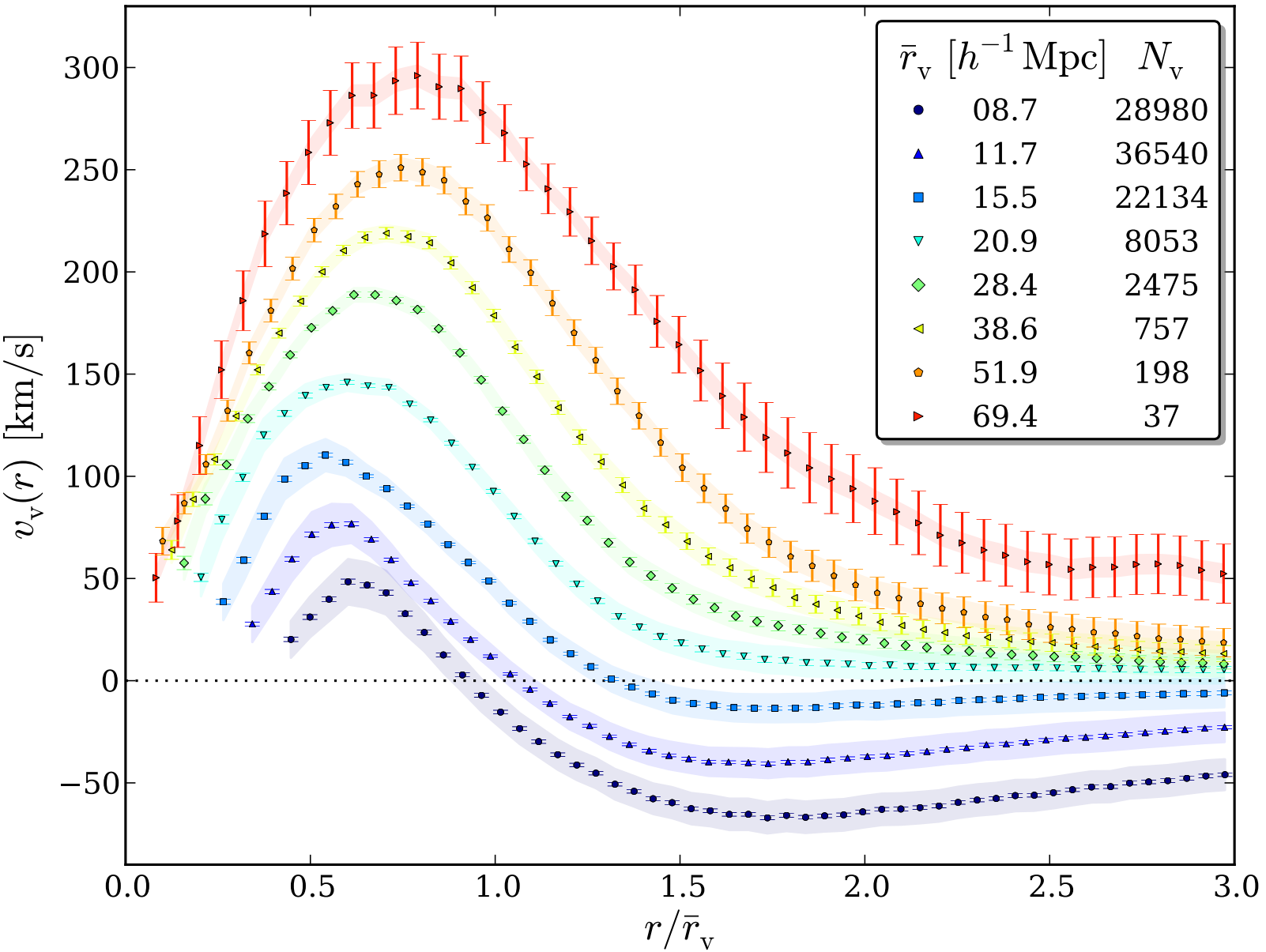


Void profile: velocity



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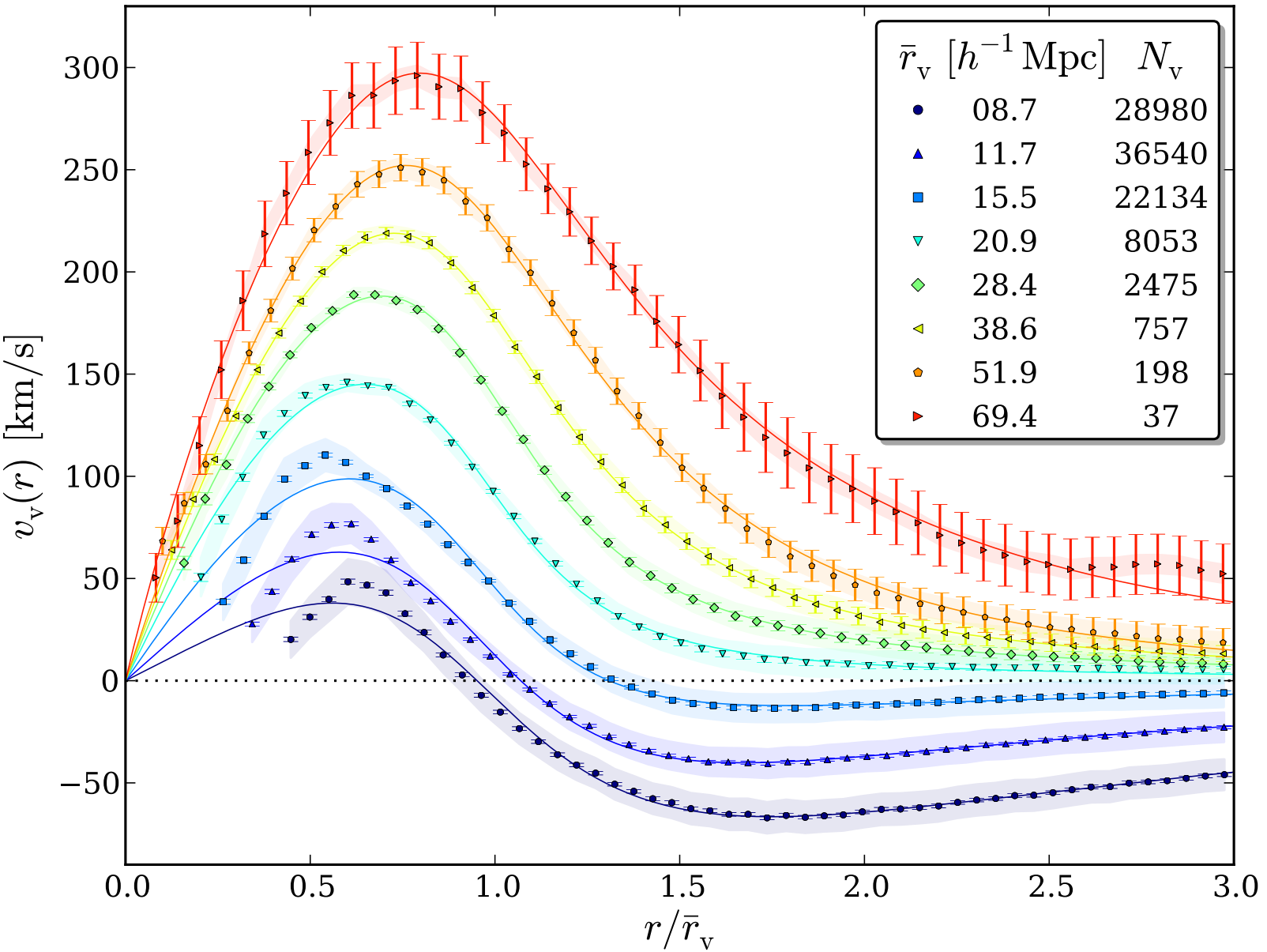

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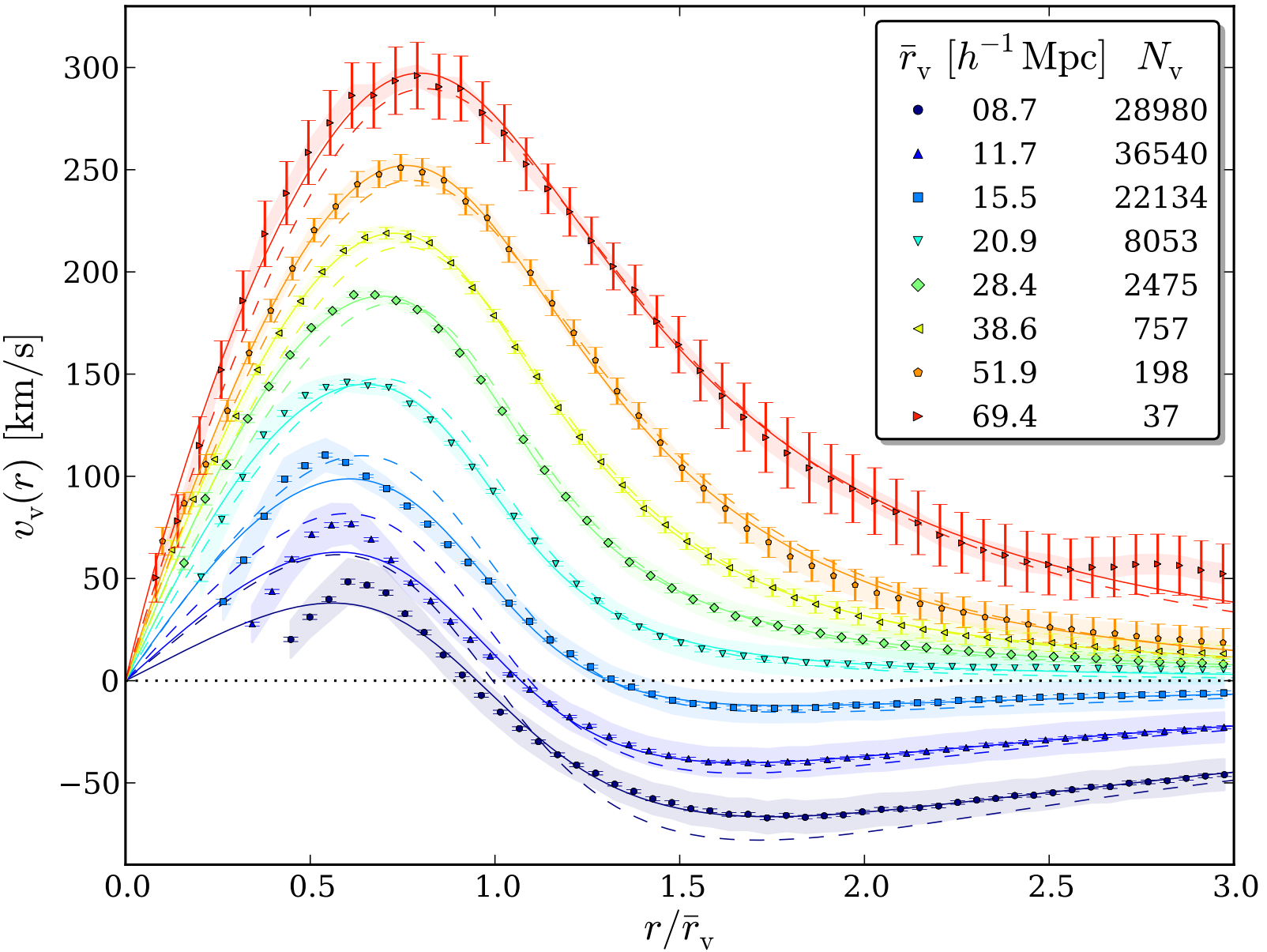
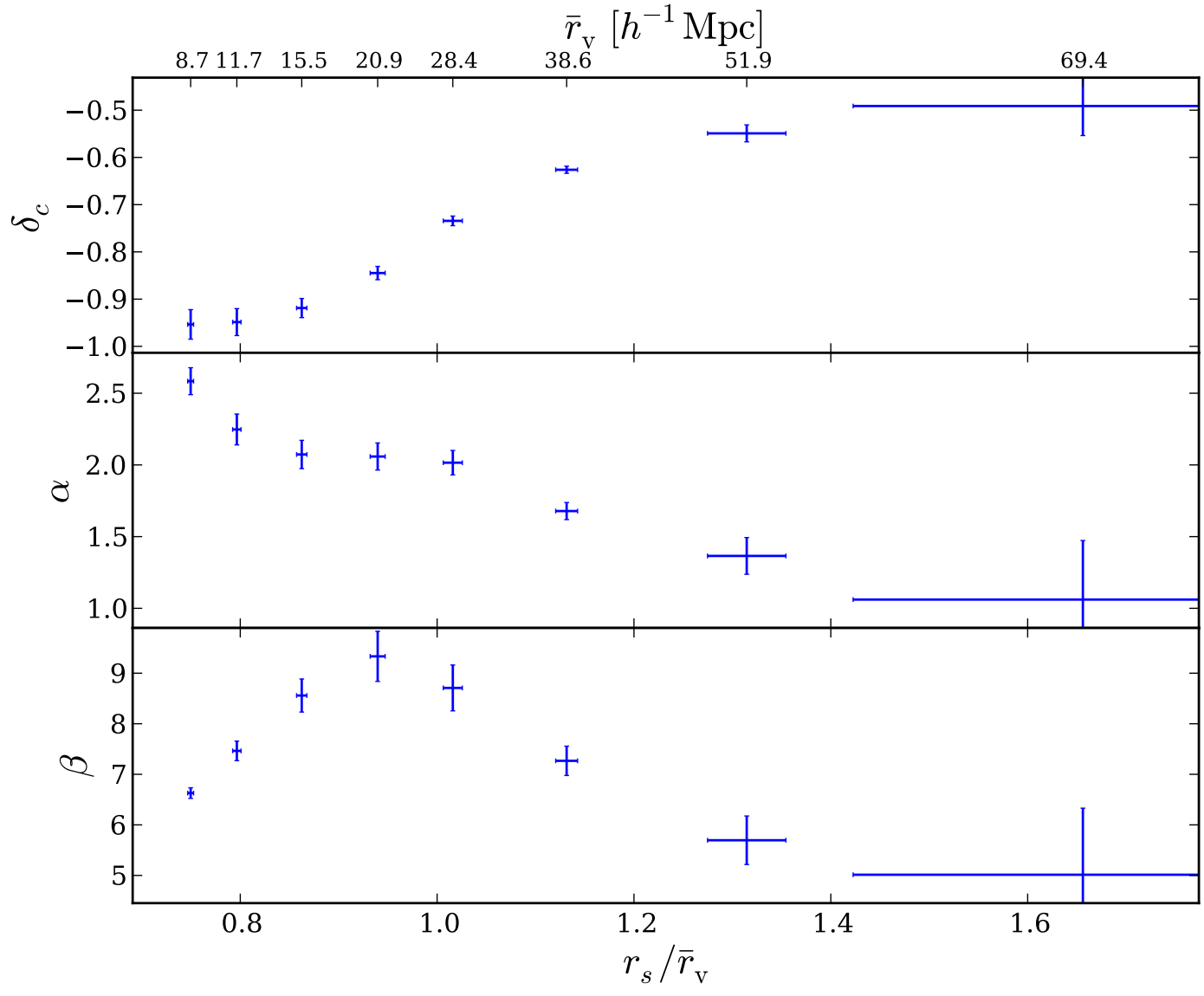


Void profile: parameters



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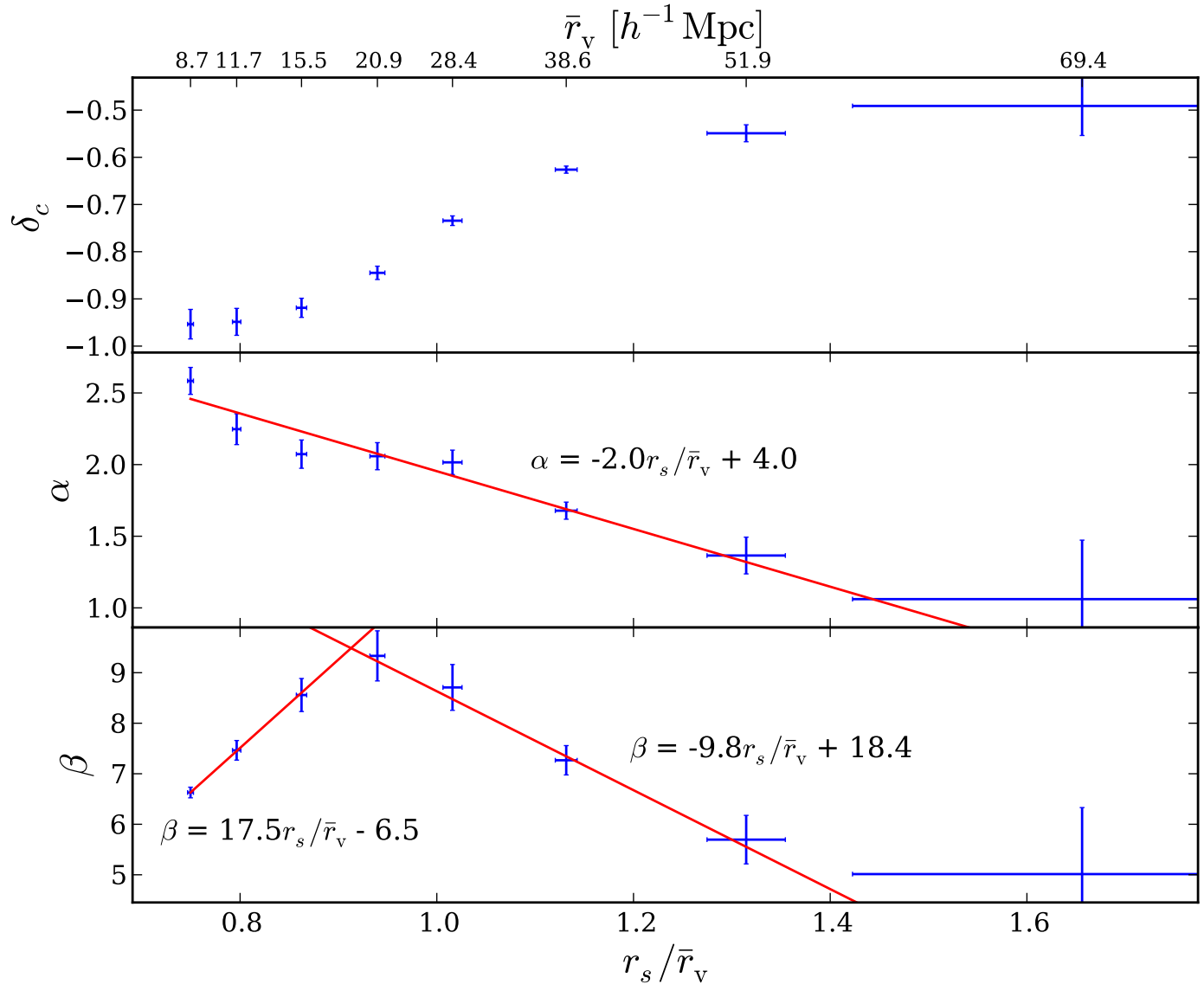

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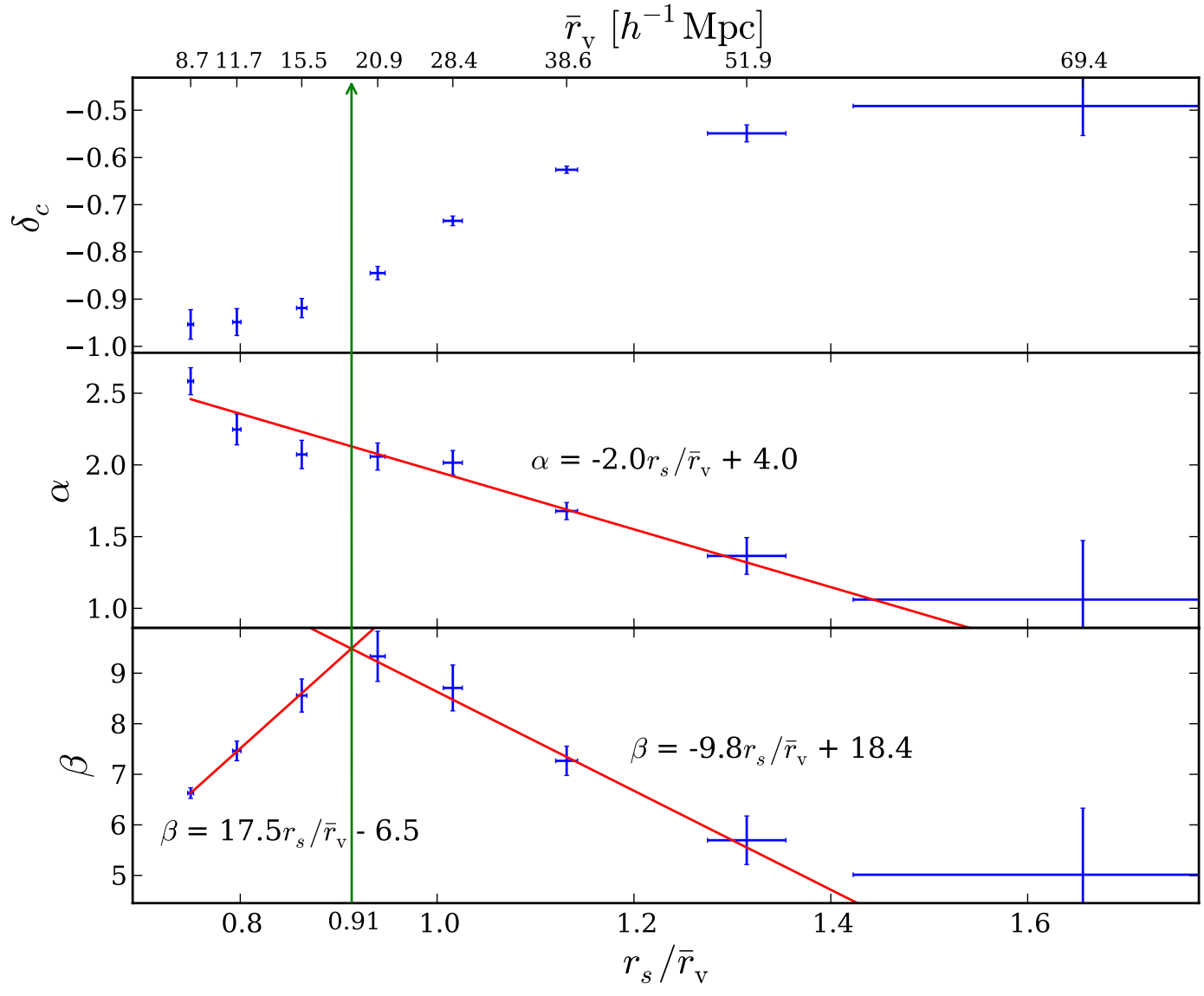
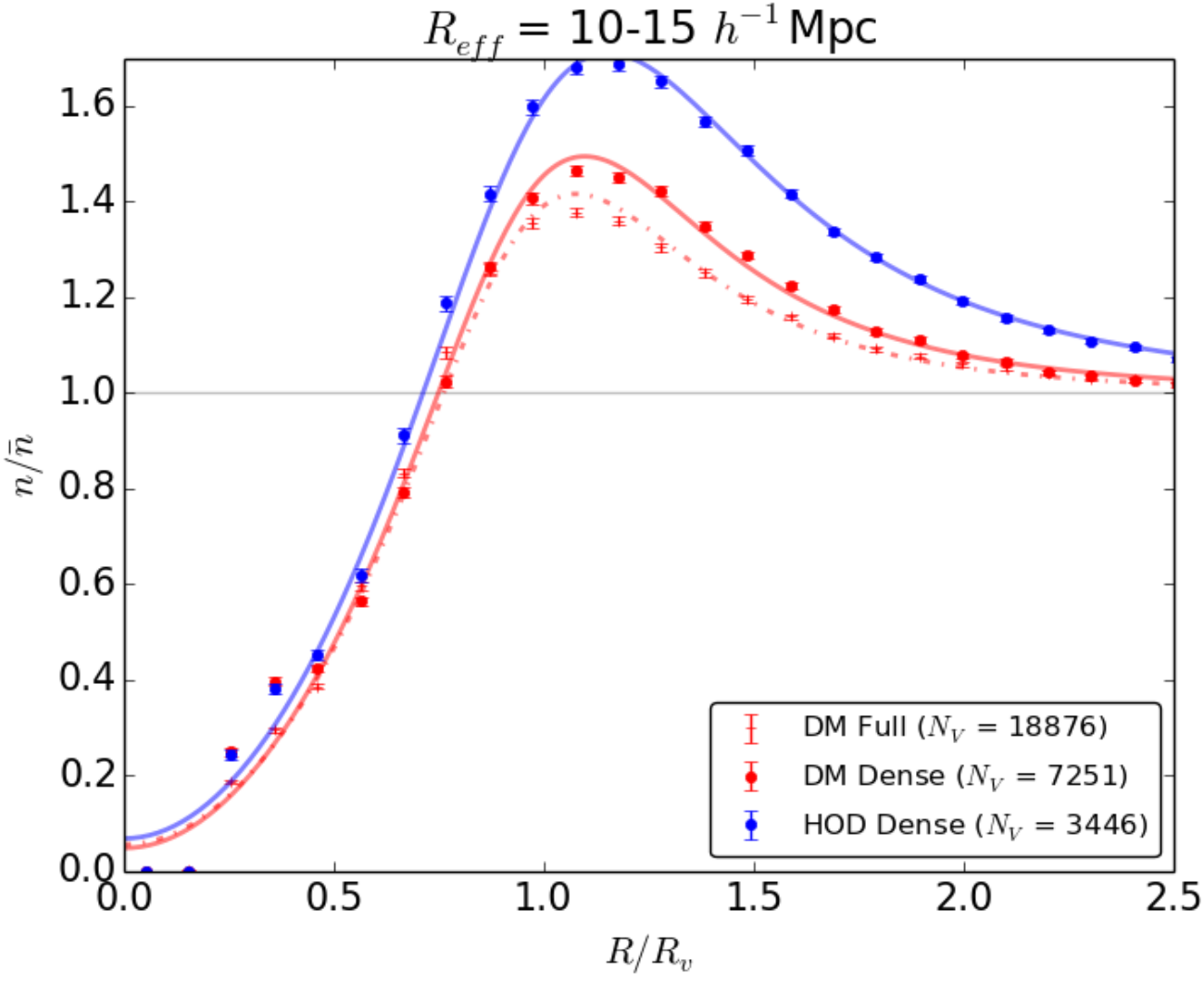


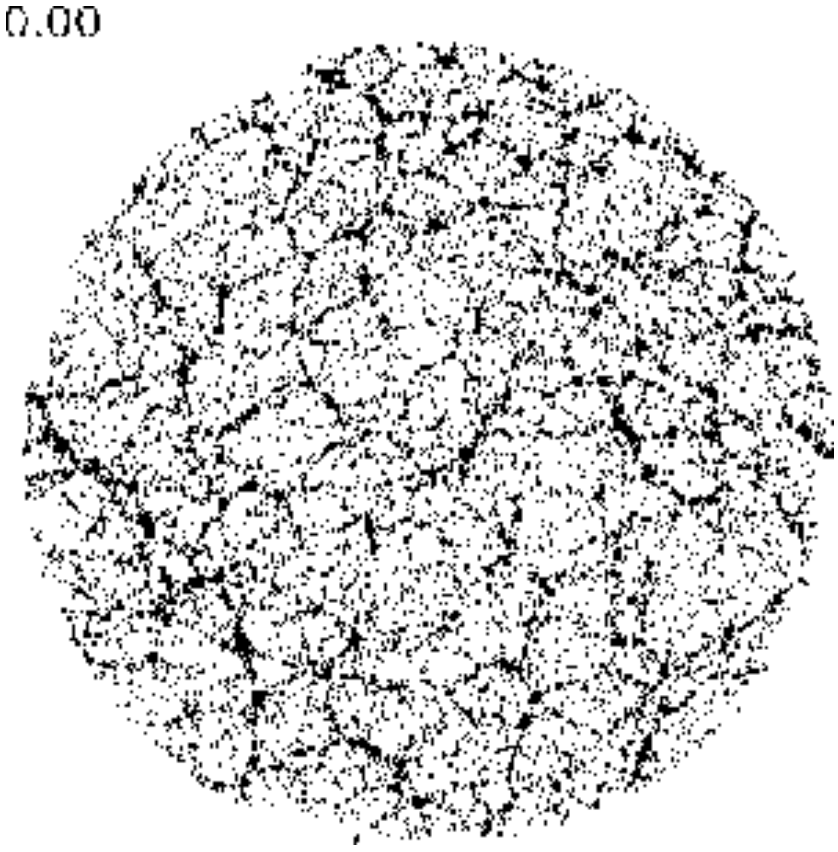
Void profile: universality



Voids in redshift space

Peculiar motions of galaxies cause redshift-space distortions:

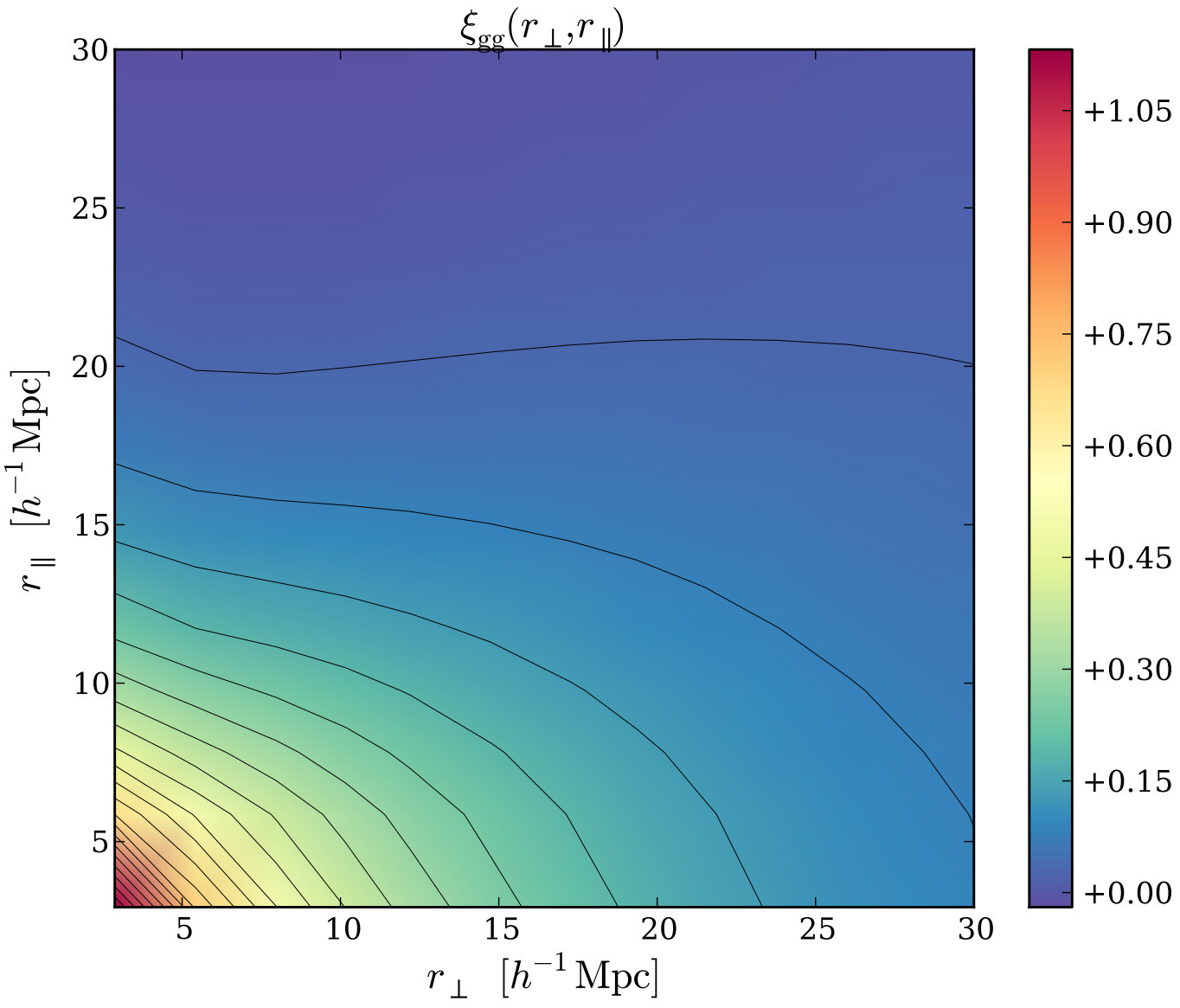
$$\mathbf{r}_s = \mathbf{r} + \mathbf{v}_{\parallel} H^{-1}(z)$$



Melott et al. (1998)

- $\perp$ to line of sight:
  Pancakes of God from linear growth
- $\parallel$ to line of sight:
  Fingers of God from nonlinear collapse
- Galaxy power spectrum no longer isotropic, what about void power spectrum?

Voids in redshift space: 2D correlation function



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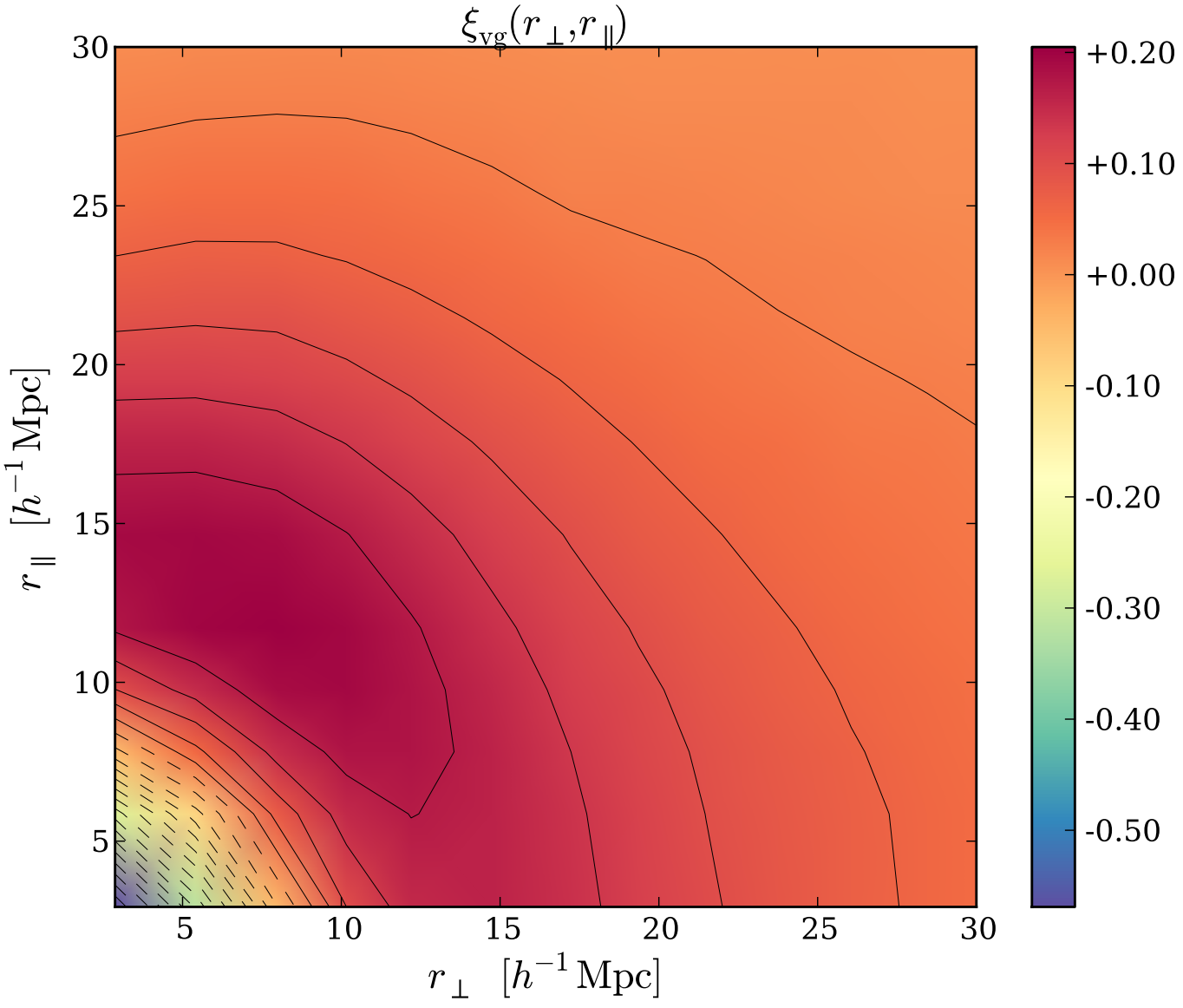

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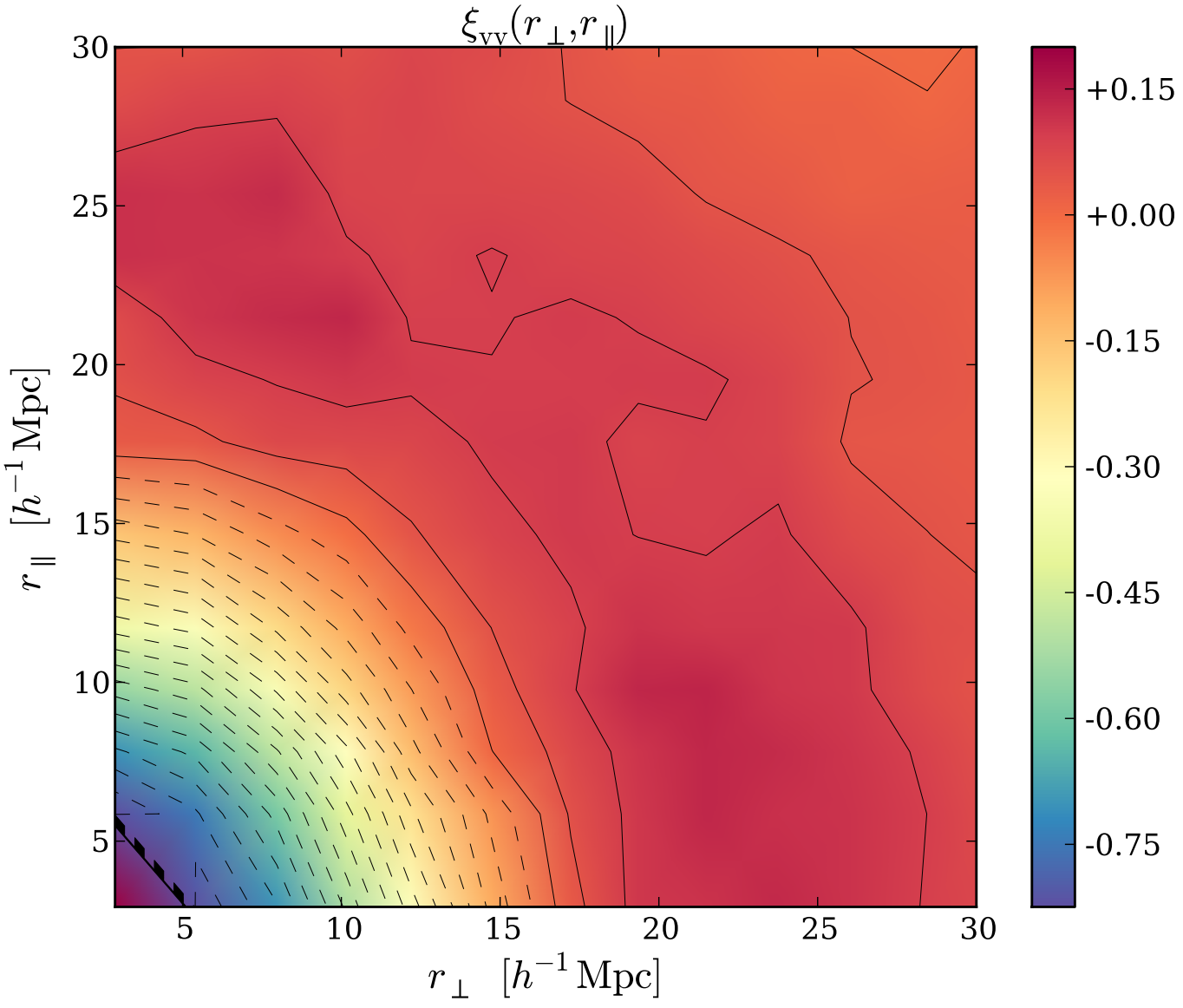
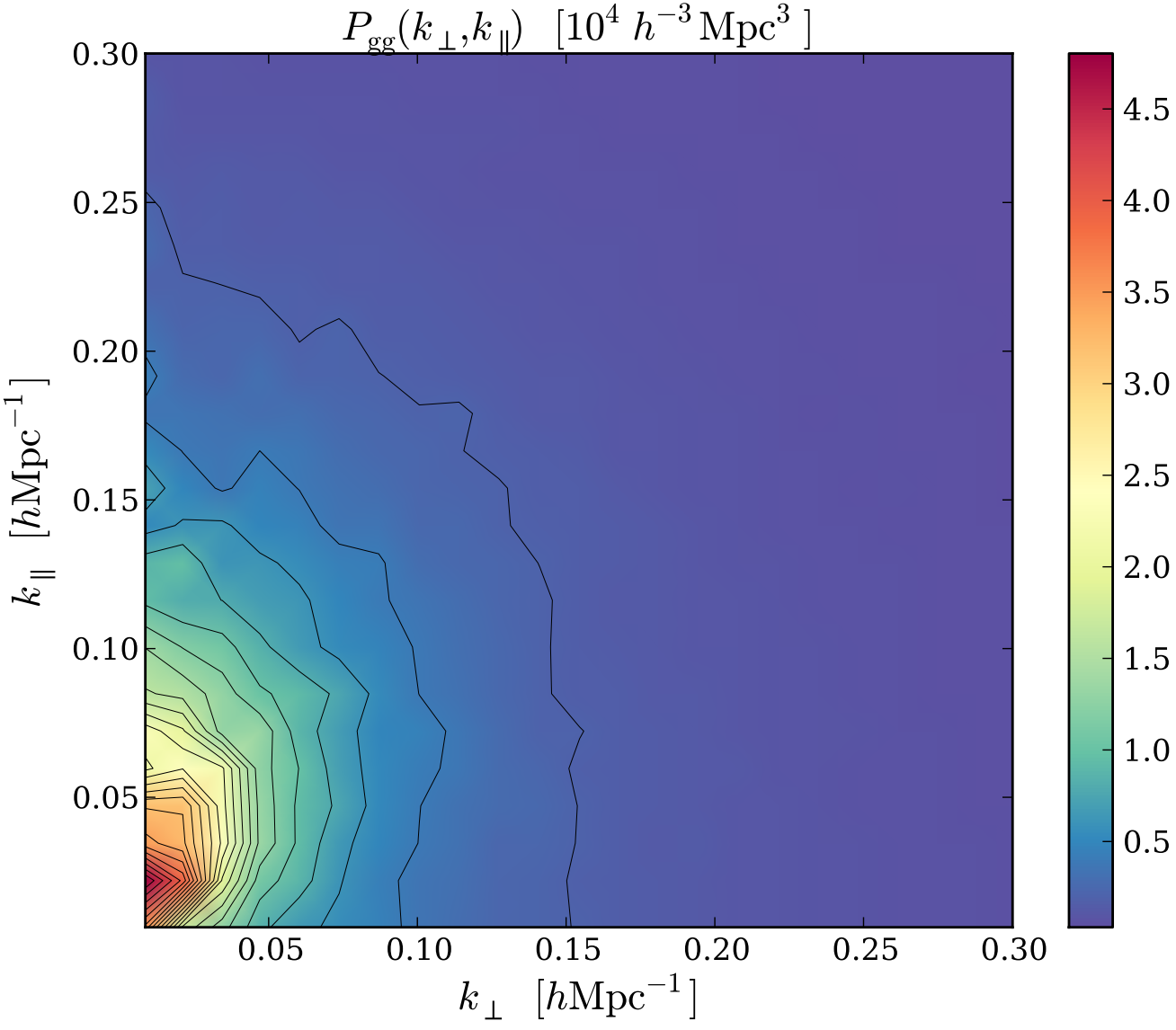


Voids in redshift space: 2D power spectrum



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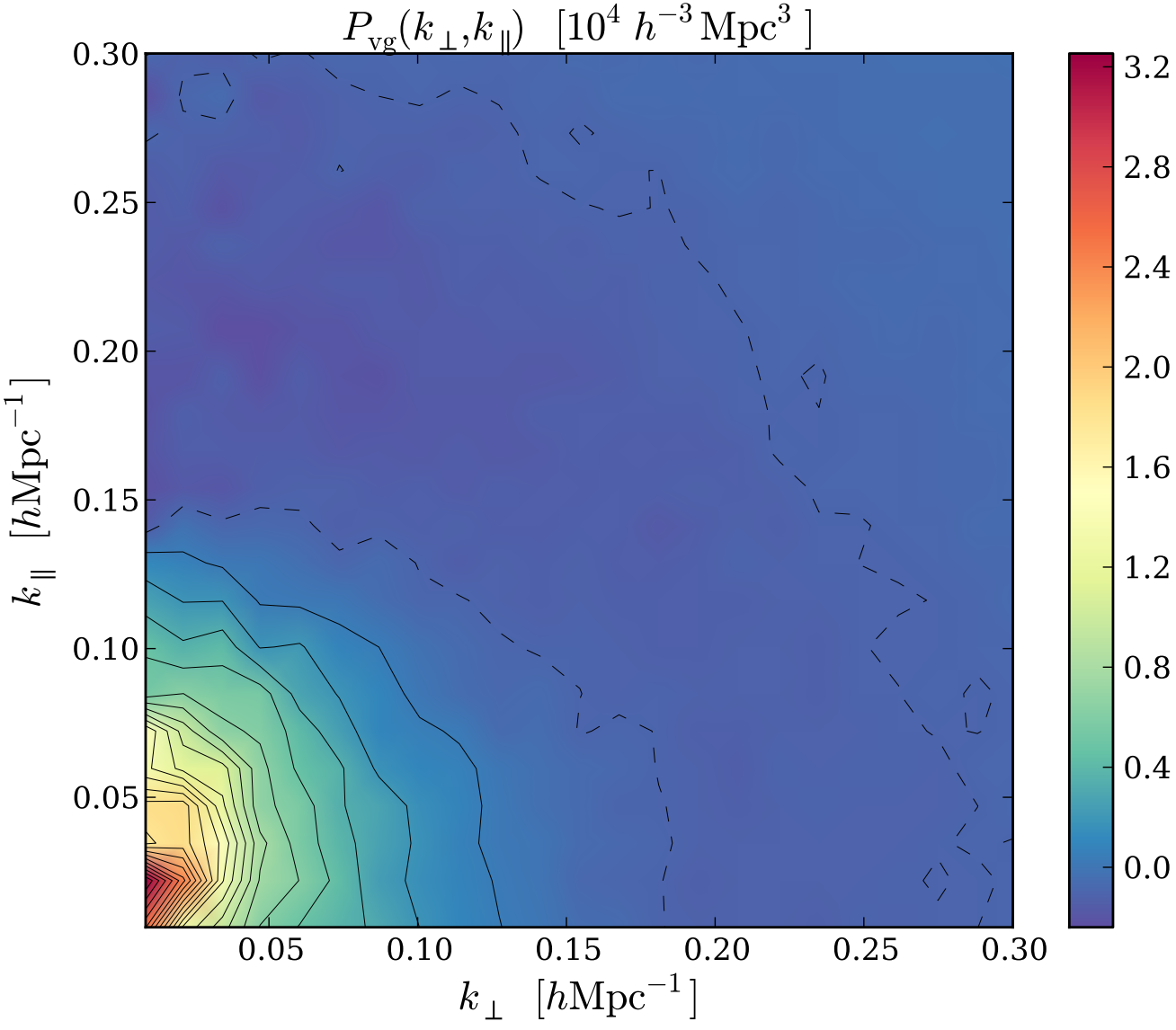

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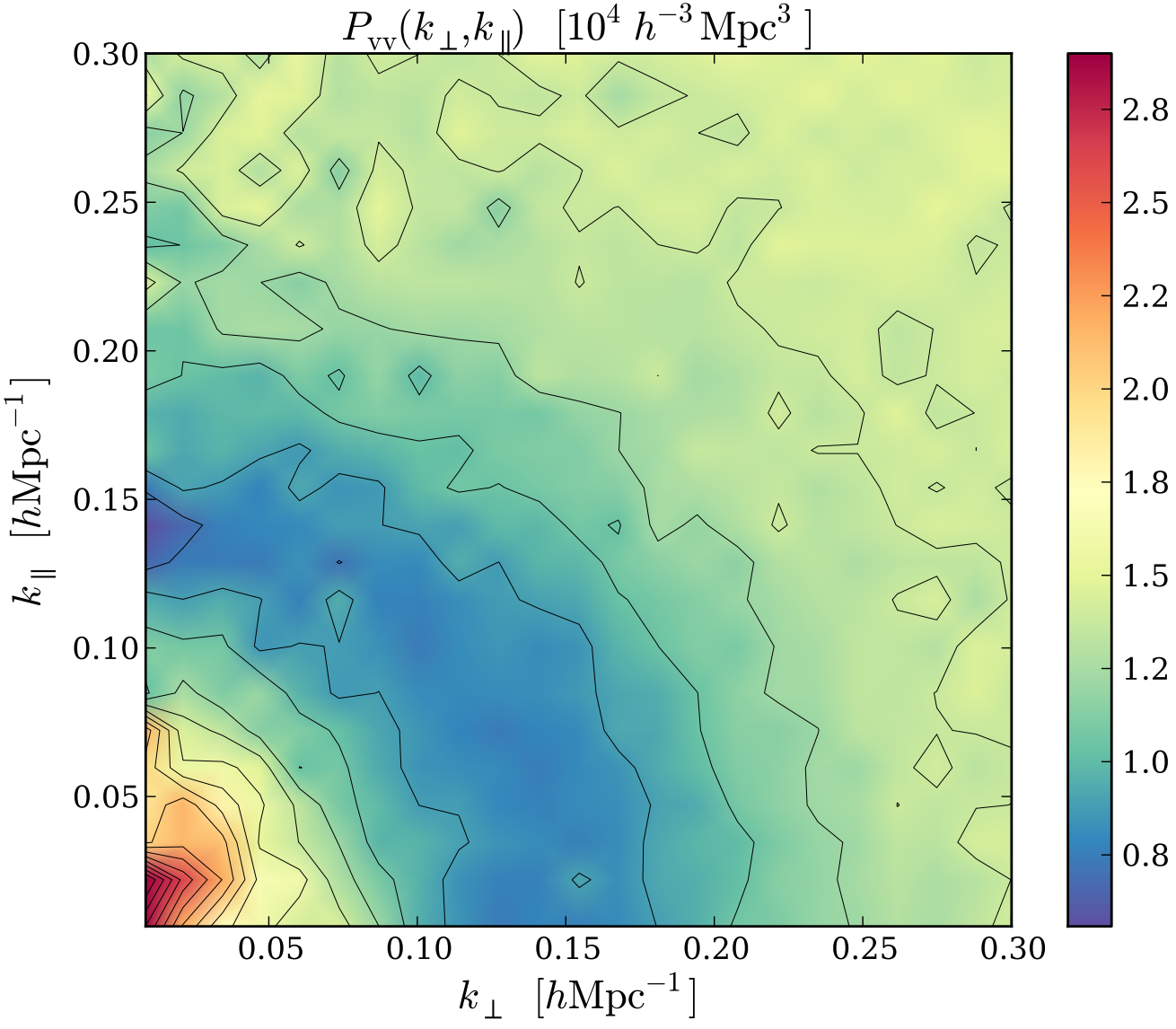

Voids in redshift space: Alcock-Paczynski test

Perform *Alcock-Paczynski test* to constrain cosmological parameters:

- Angular separation $\delta r_\perp = D_A(z)\,\delta\Theta$
- Radial separation $\delta r_\parallel = cH^{-1}(z)\,\delta z$

Angular diameter distance & Hubble rate

$$D_A(z) = c\int_0^z H^{-1}(z')\,\mathrm{d}z' \quad , \quad H(z) = H_0\sqrt{\Omega_\mathrm{m}(1+z)^3+\Omega_\Lambda}$$

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Any deviation from the fiducial cosmology causes geometric distortions. $\Rightarrow$ Measure ellipticity of power spectrum:

$$\epsilon(k_i) \equiv \int_{\Delta k_i} k_\parallel^2 P(\mathbf{k})\mathrm{d}^3k \Big/ \int_{\Delta k_i} k_\perp^2 P(\mathbf{k})\mathrm{d}^3k$$

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Problem: degeneracy with redshift-space distortions

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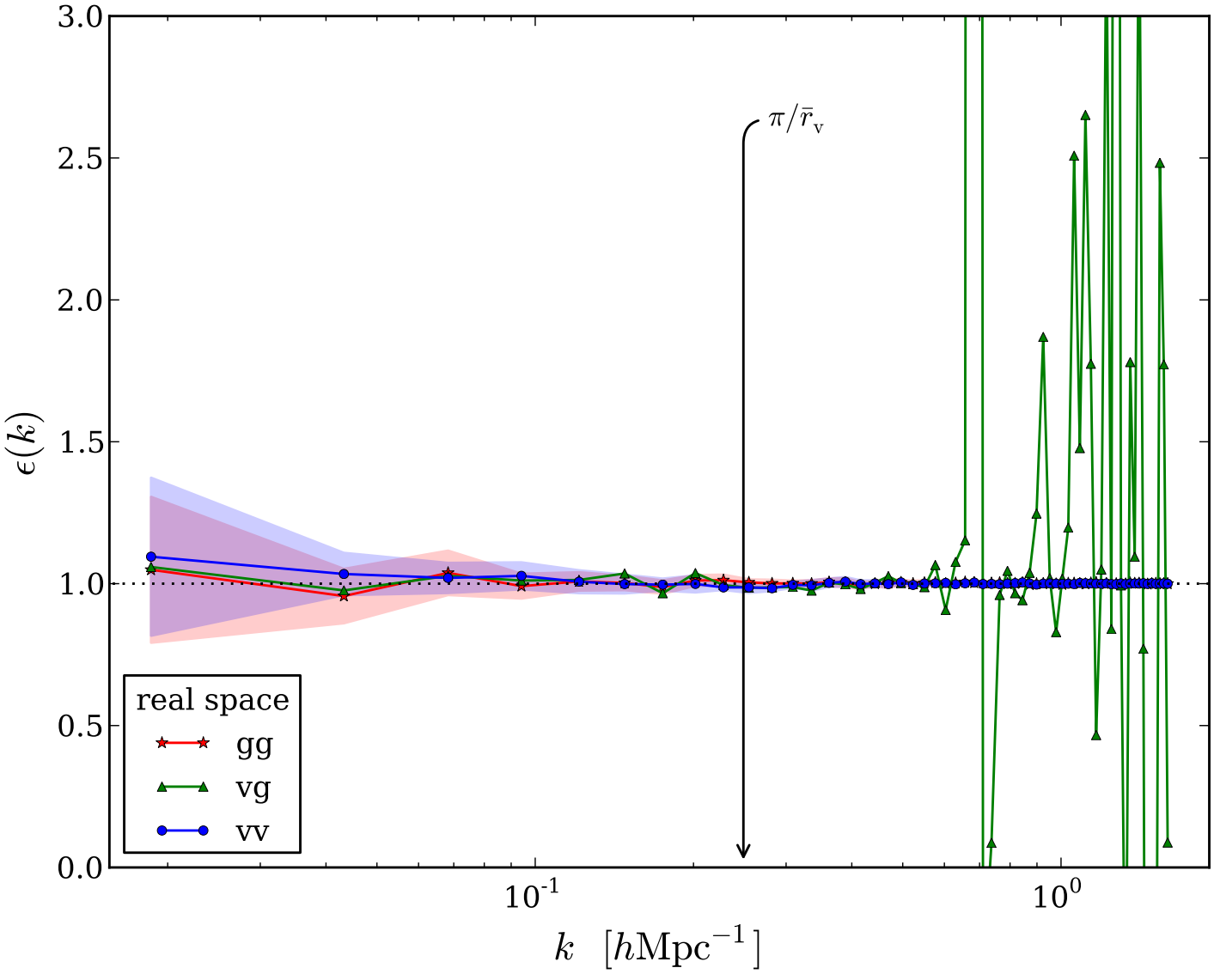

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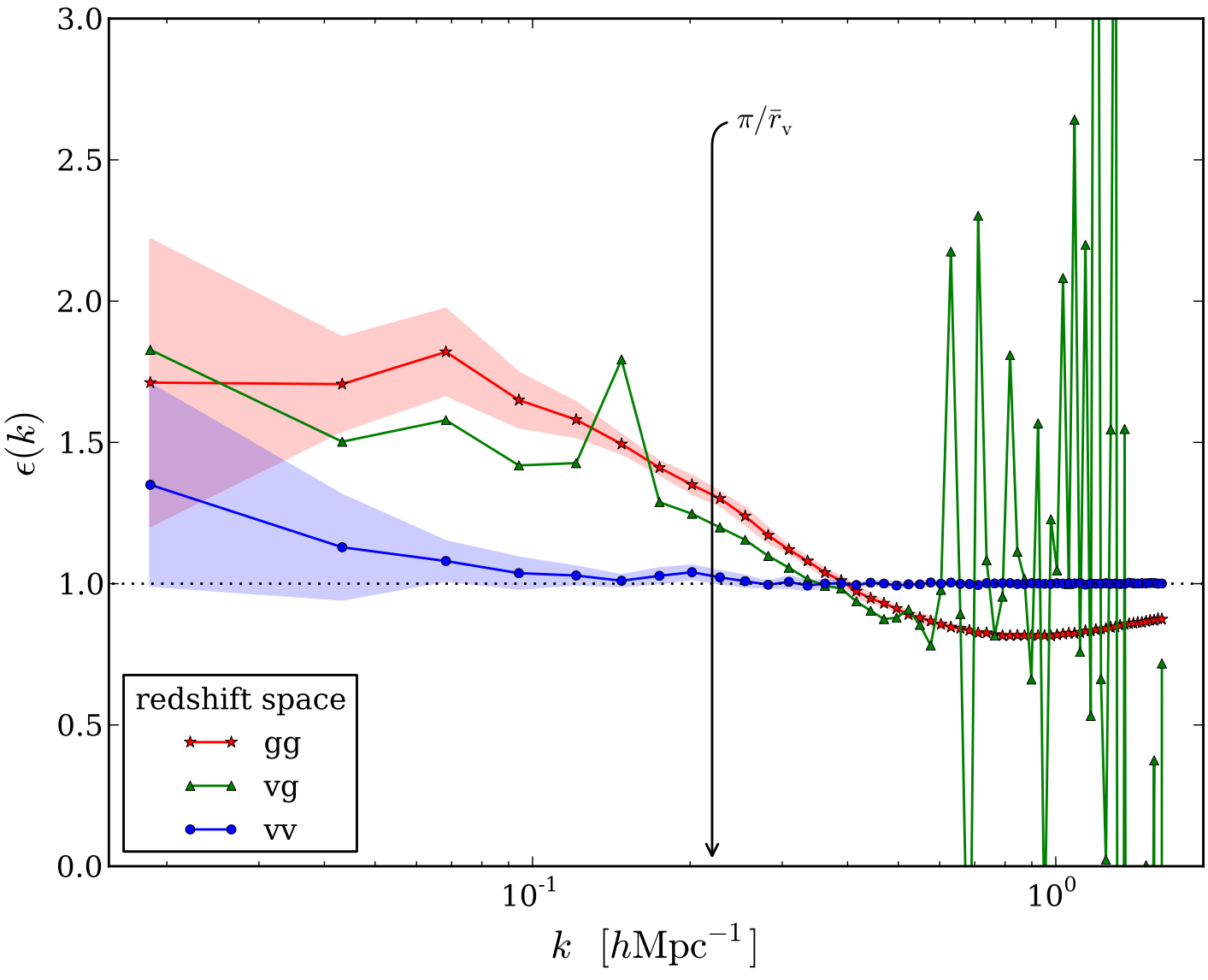

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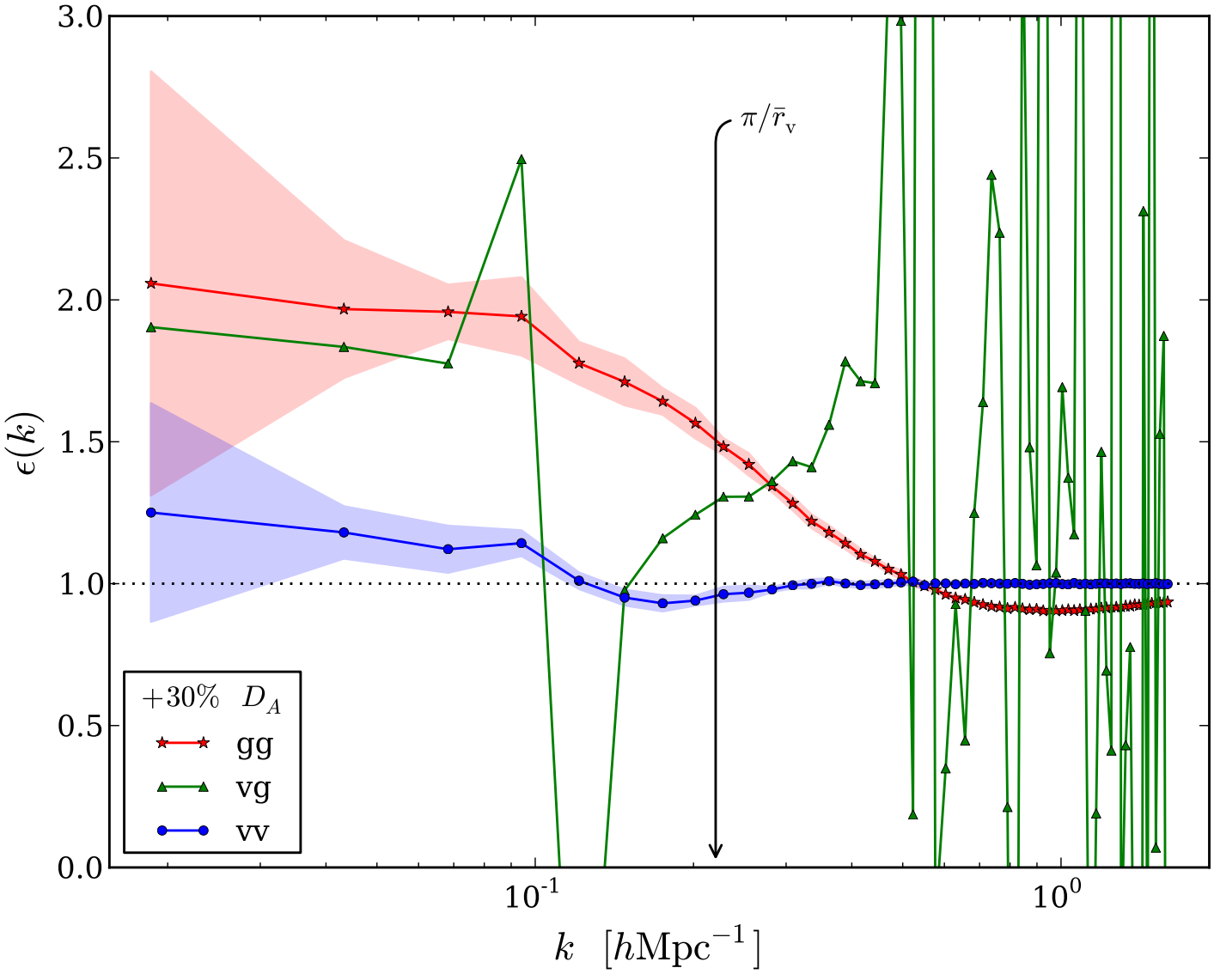

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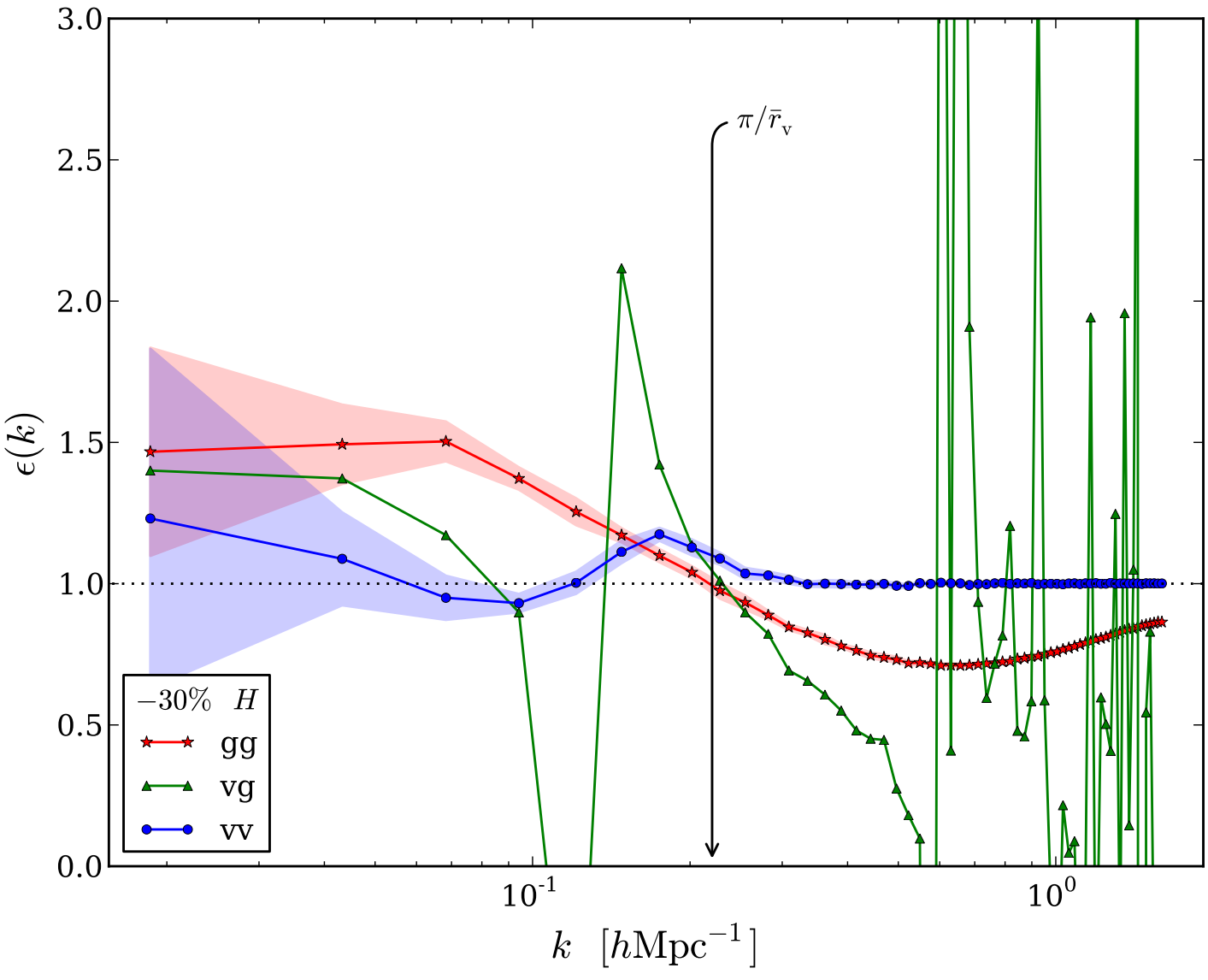

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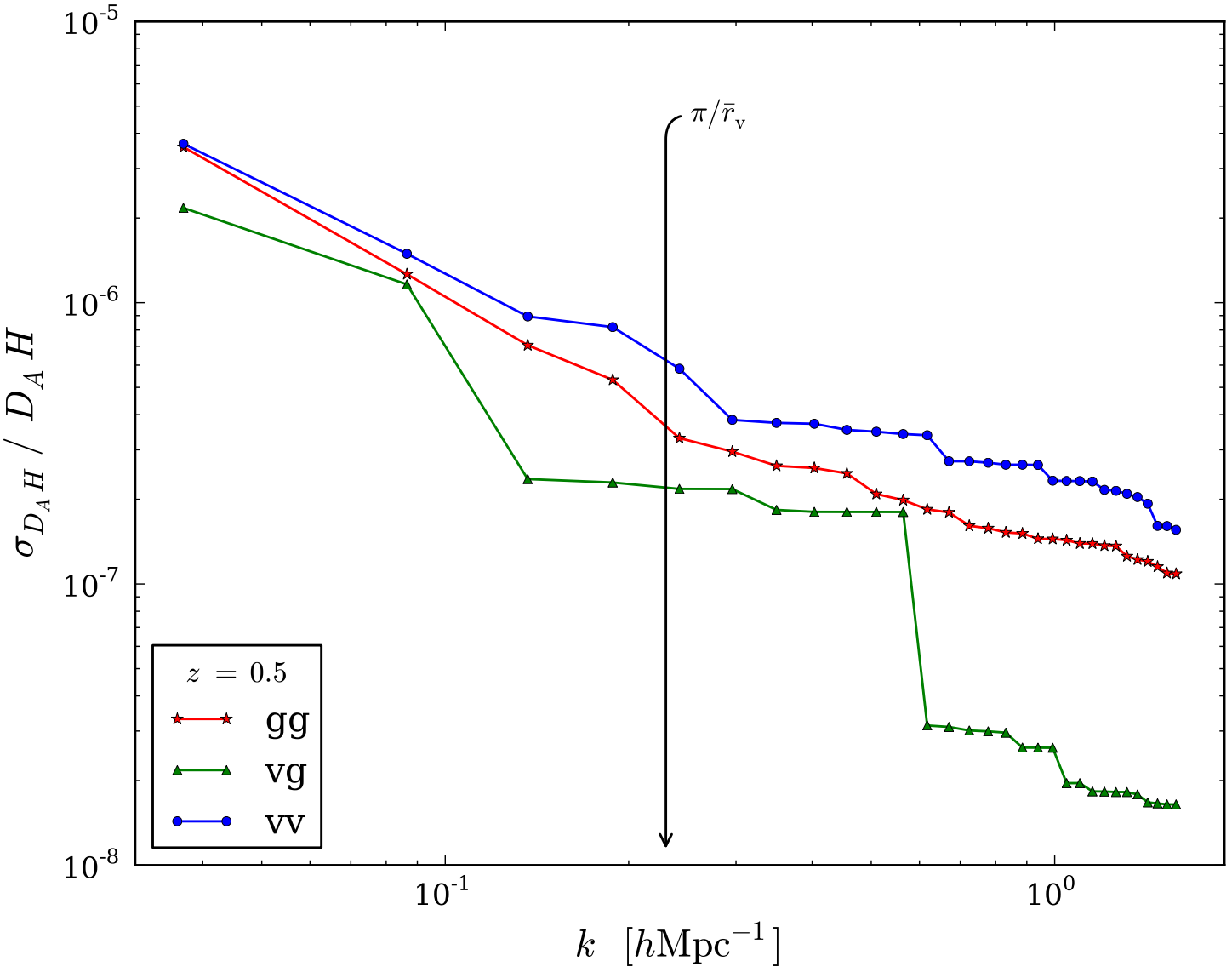

Outlook

- Universal void density- and velocity profiles emerge from self-similarity / fractal nature of large-scale structure?
- Void auto-correlations provide pristine Alcock-Paczynski test?

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Questions ? Thank you !

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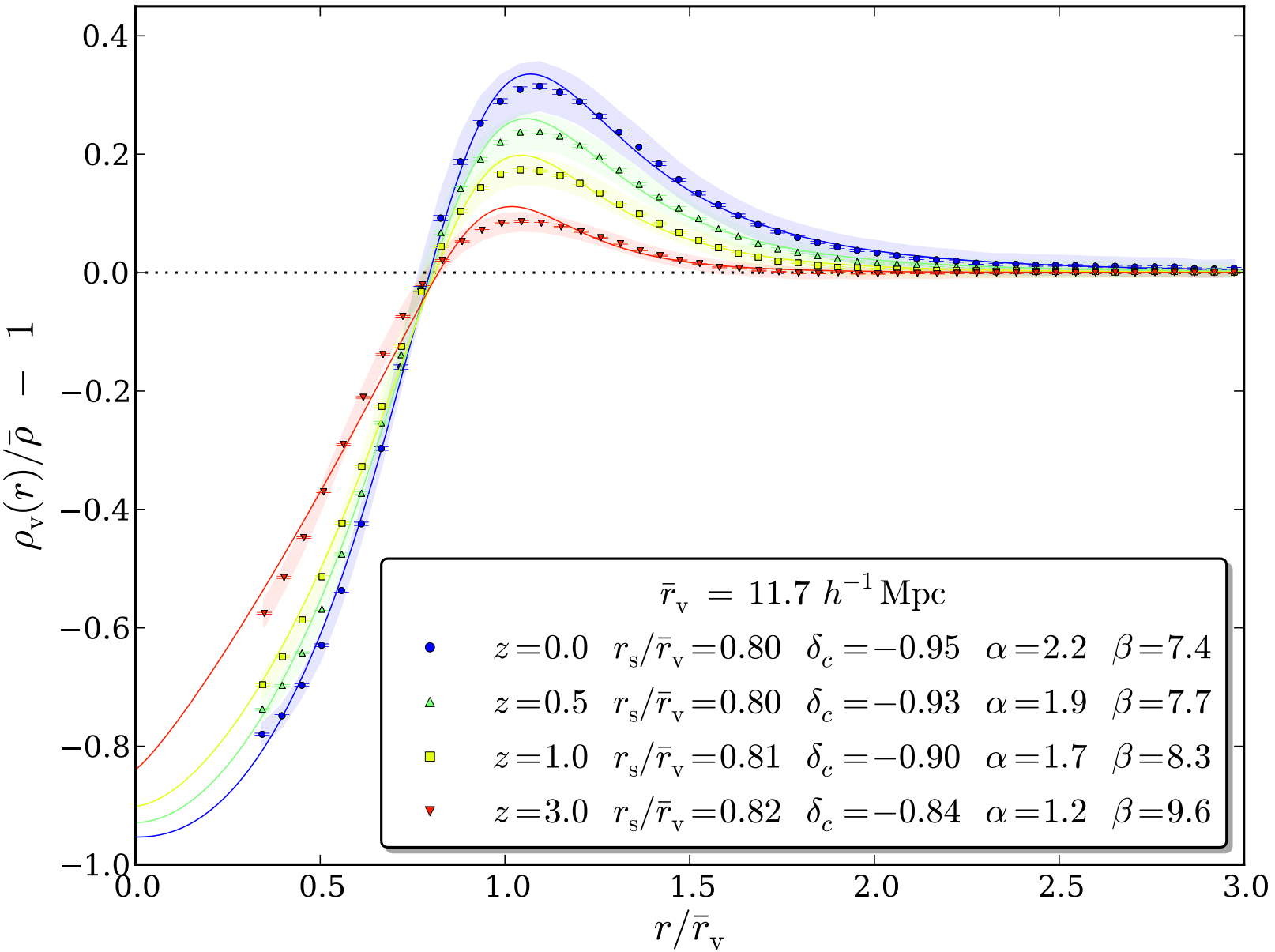

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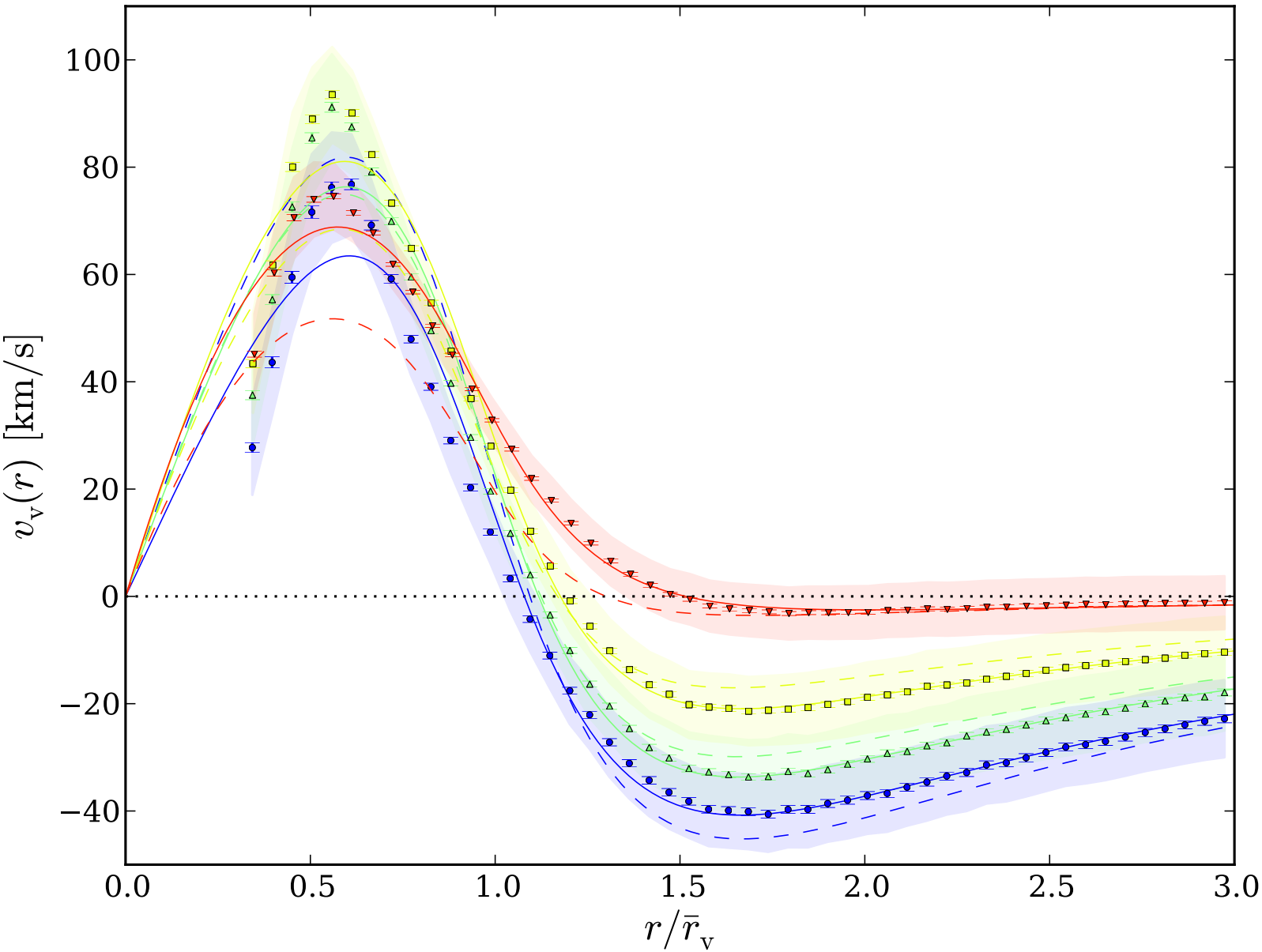

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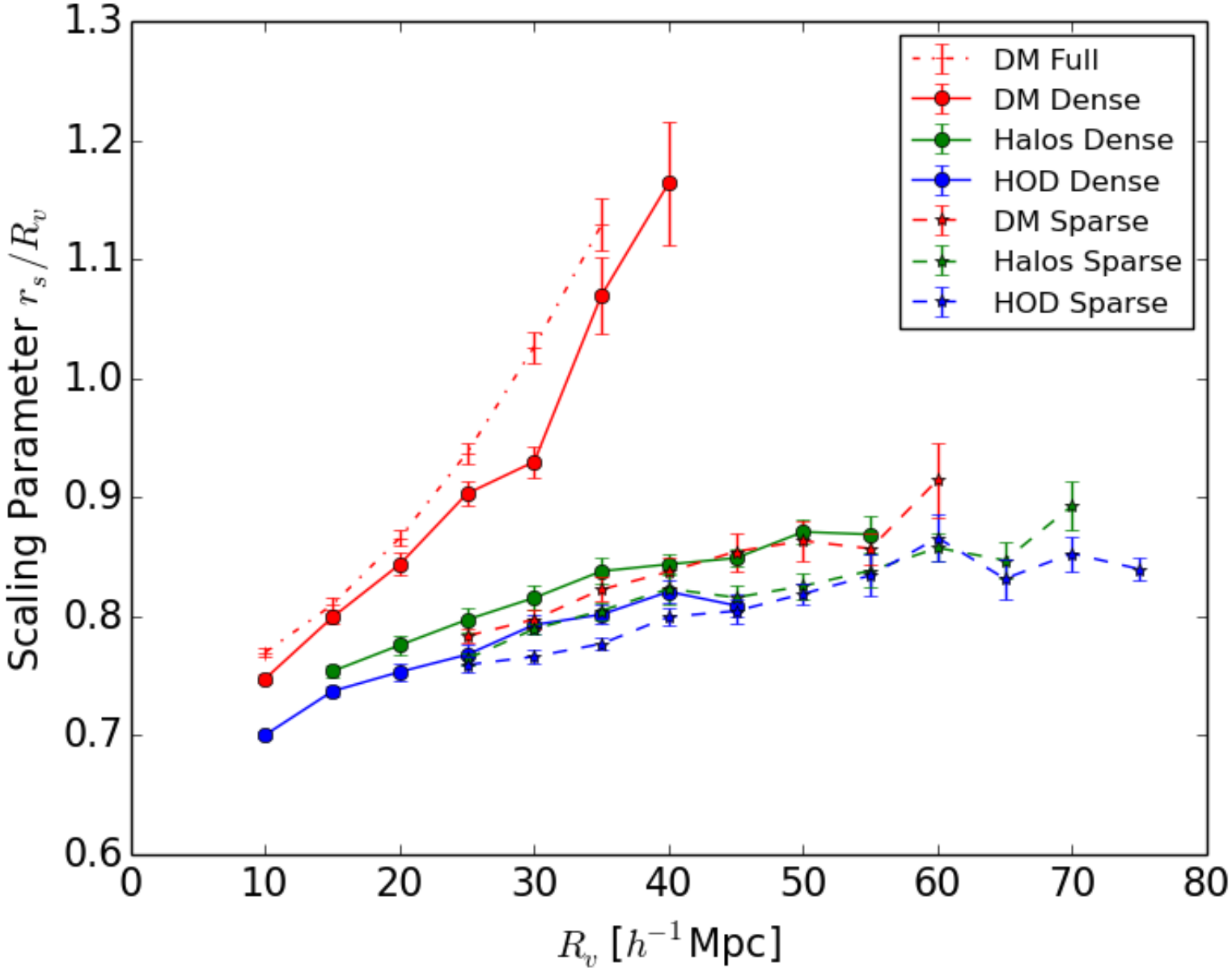

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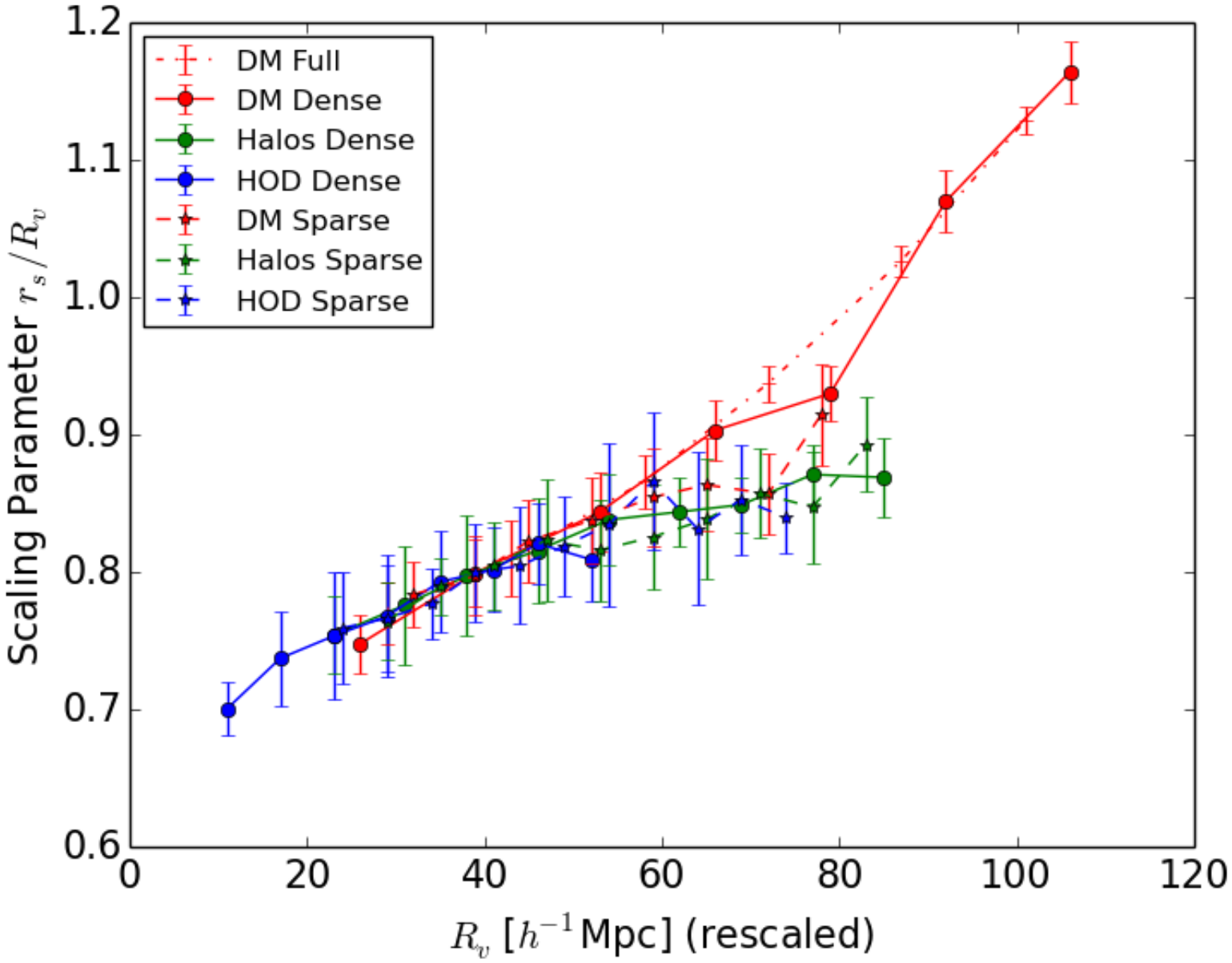

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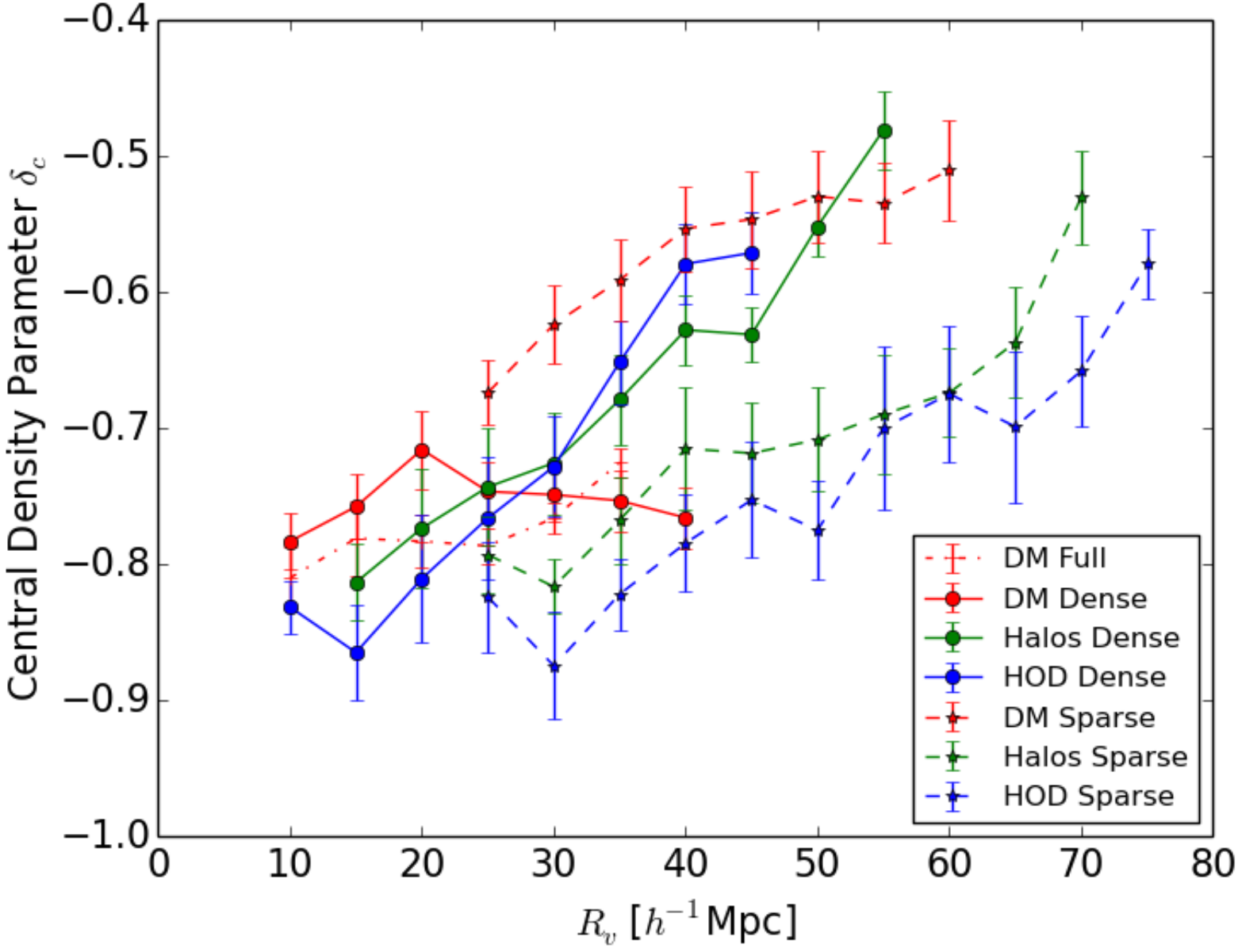

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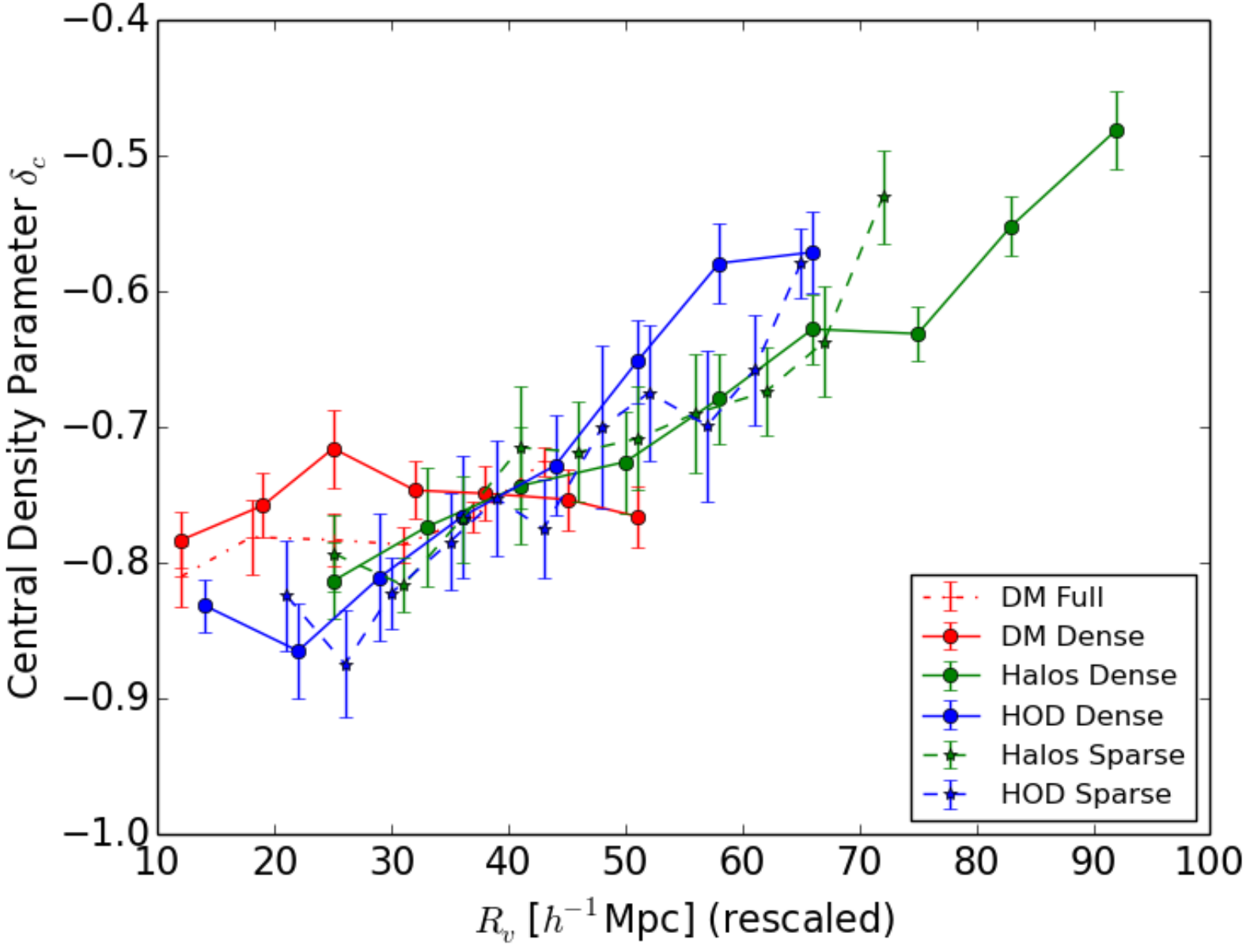

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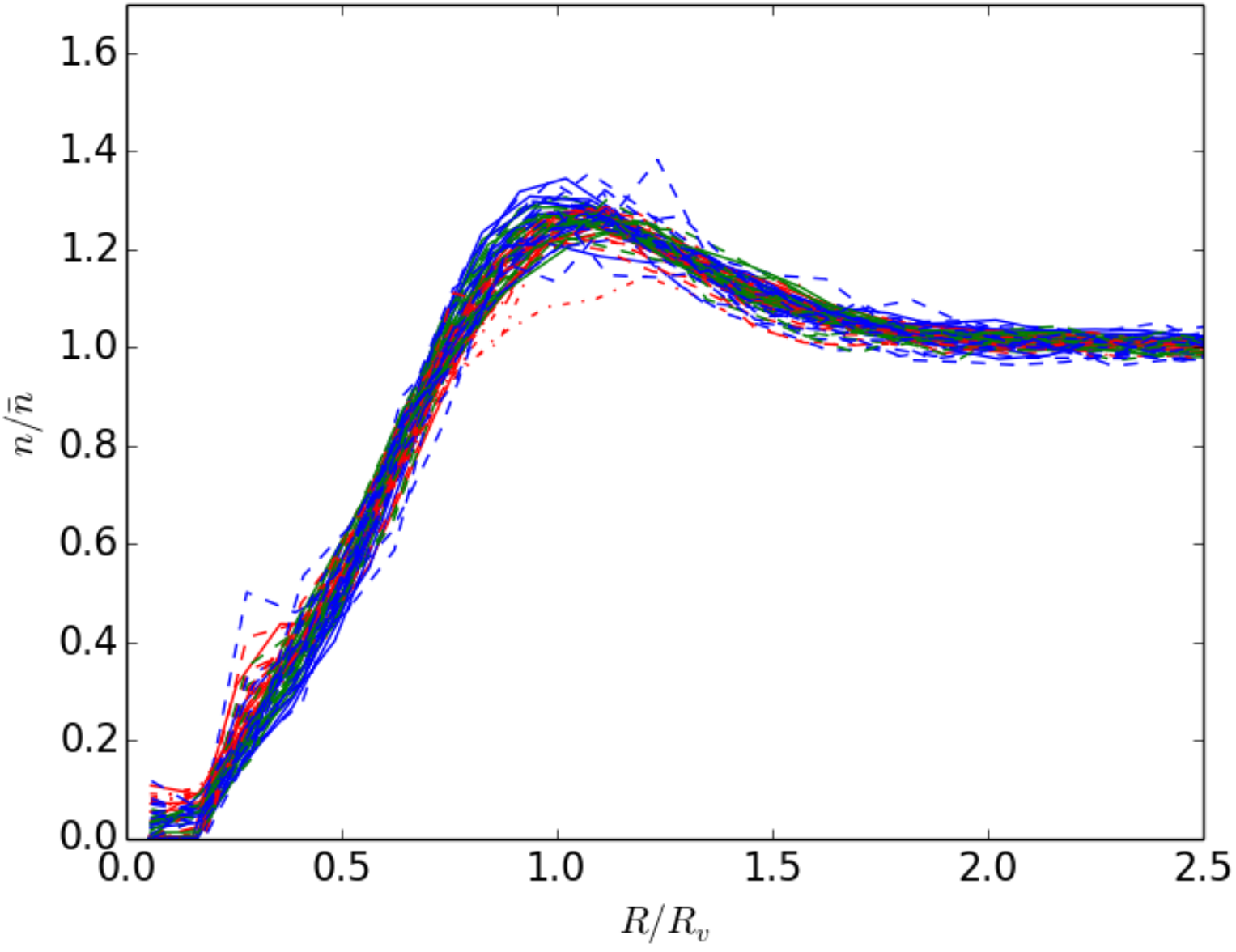
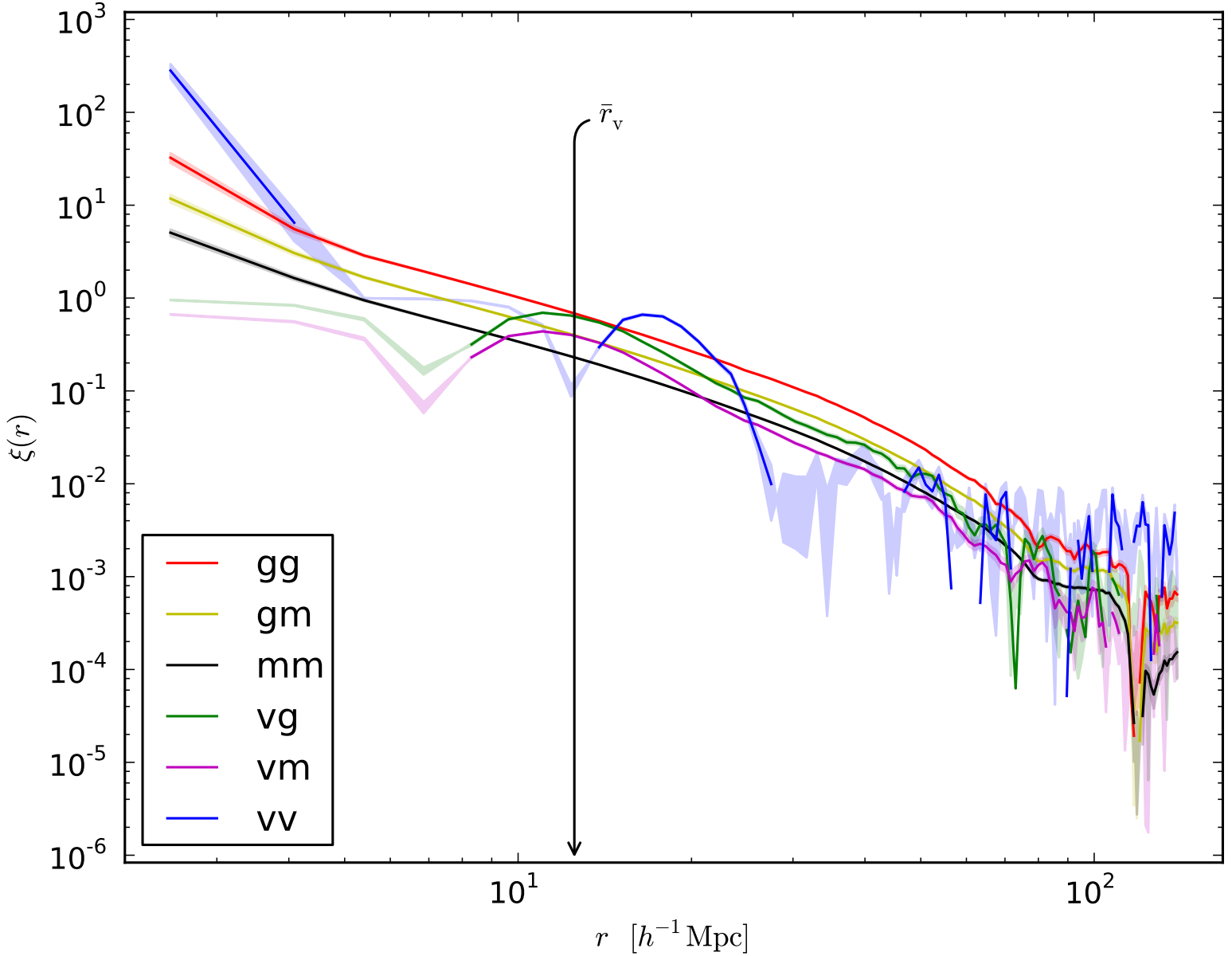
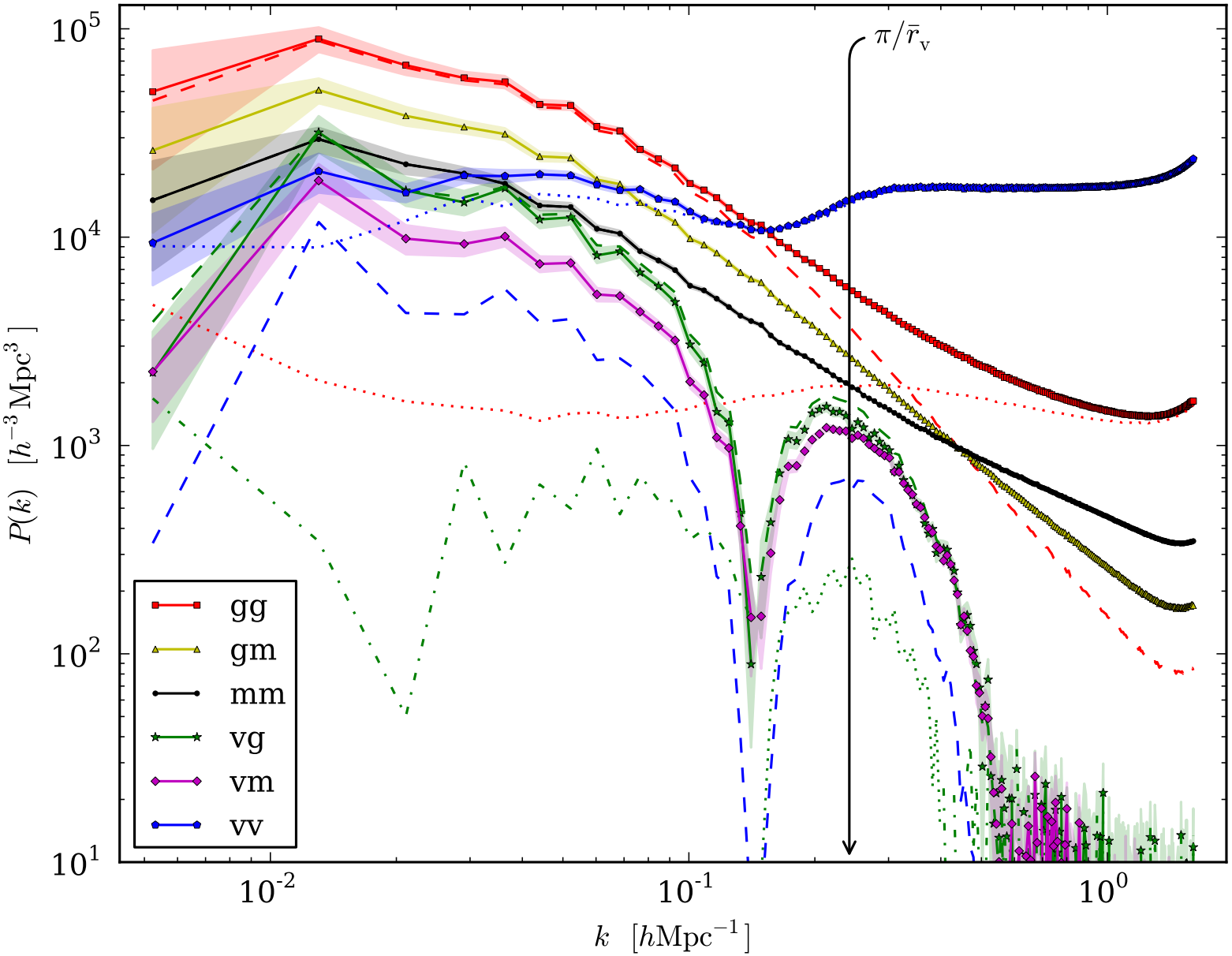
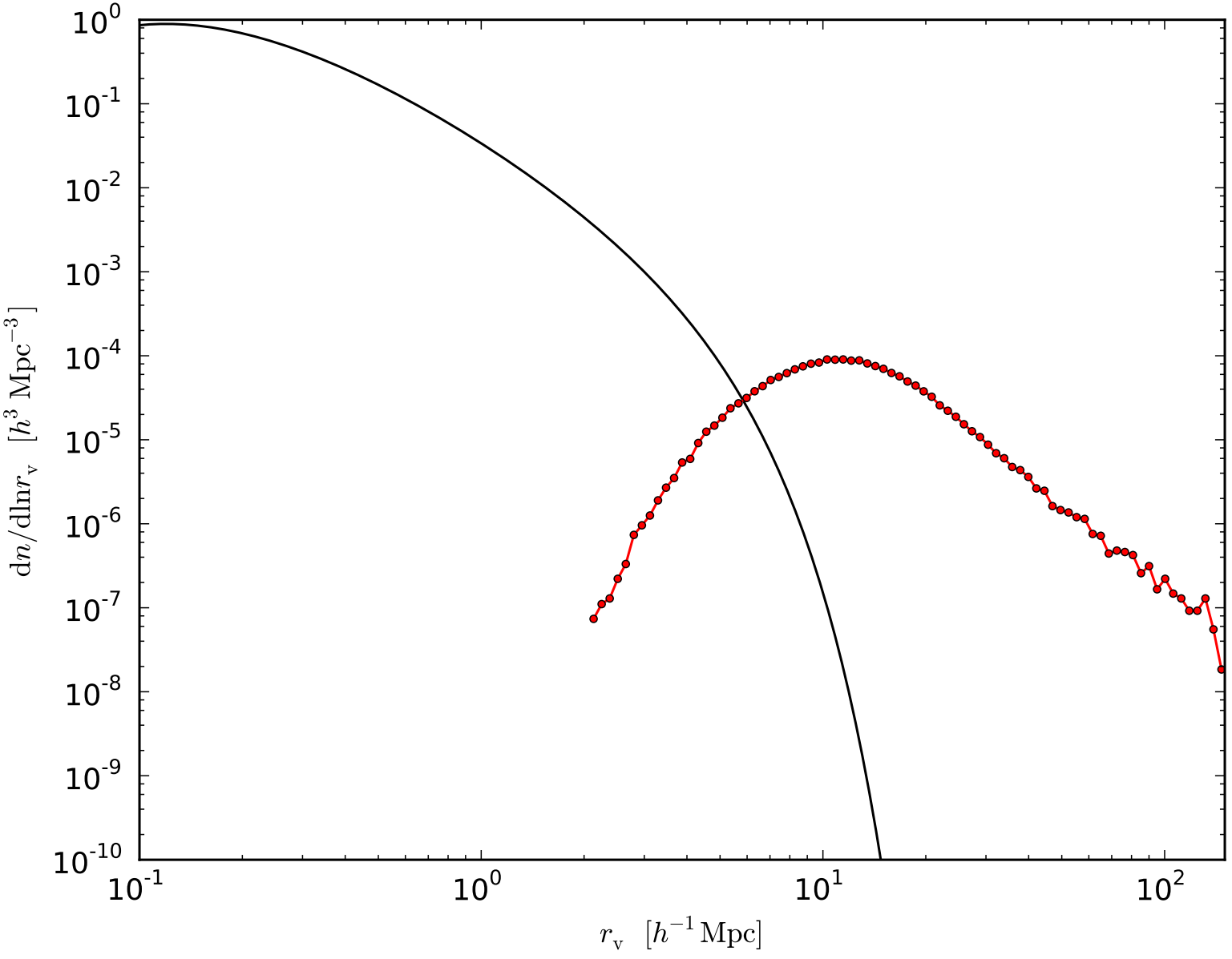


Voids in redshift space: 1D correlation function



Voids in redshift space: 1D power spectrum



Void number function