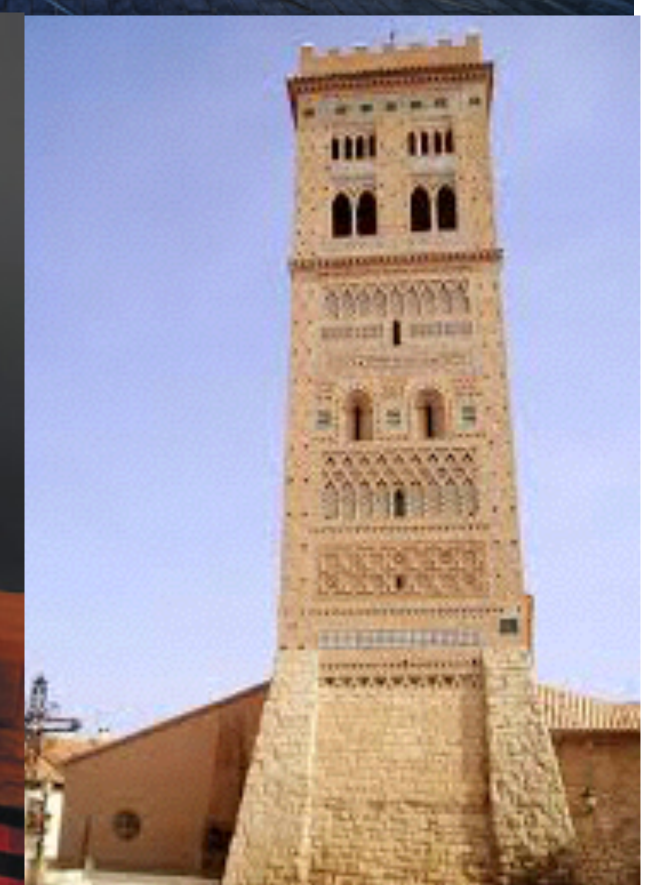
The impact of galaxy formation on redshift- space distortions

Álvaro Orsi
Raúl Angulo

Teruel



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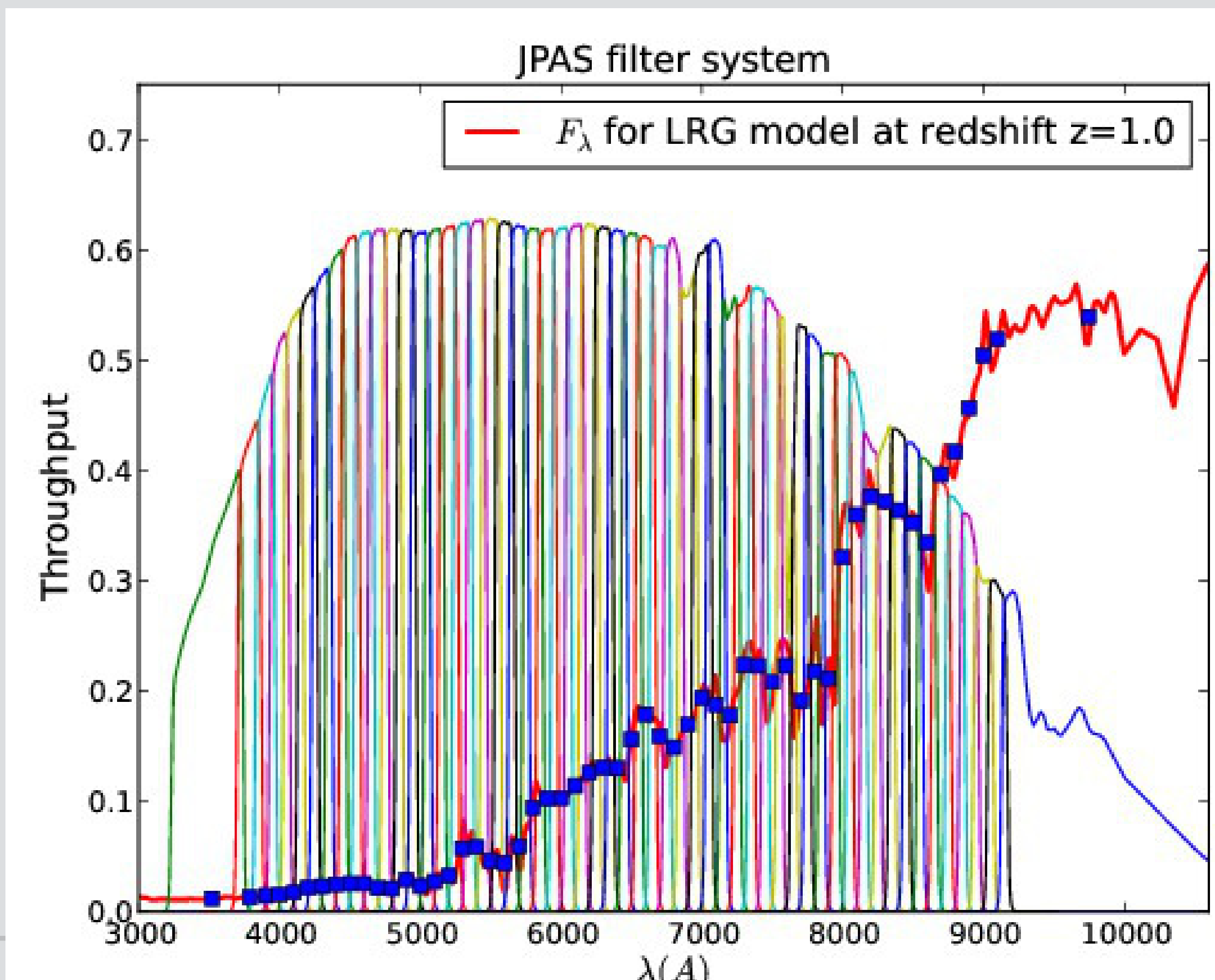
J-PAS

Javalambre Physics of the Accelerating Universe Astrophysical Survey

- J-PAS will image **8.5-10k deg^2** of Northern Sky using **59 filters** in the optical range with an spatial resolution of **0.23 arcsec/pix** reaching **magAB~22.3** (5 sigma, Ø3'').



J-PAS: *low-resolution spectra of the sky with narrow-band imaging*

Dedicated 2.55m telescope
photo-z precision
sigma_z ~0.003(1+z)
~90M LRGs and ELGs <1.2

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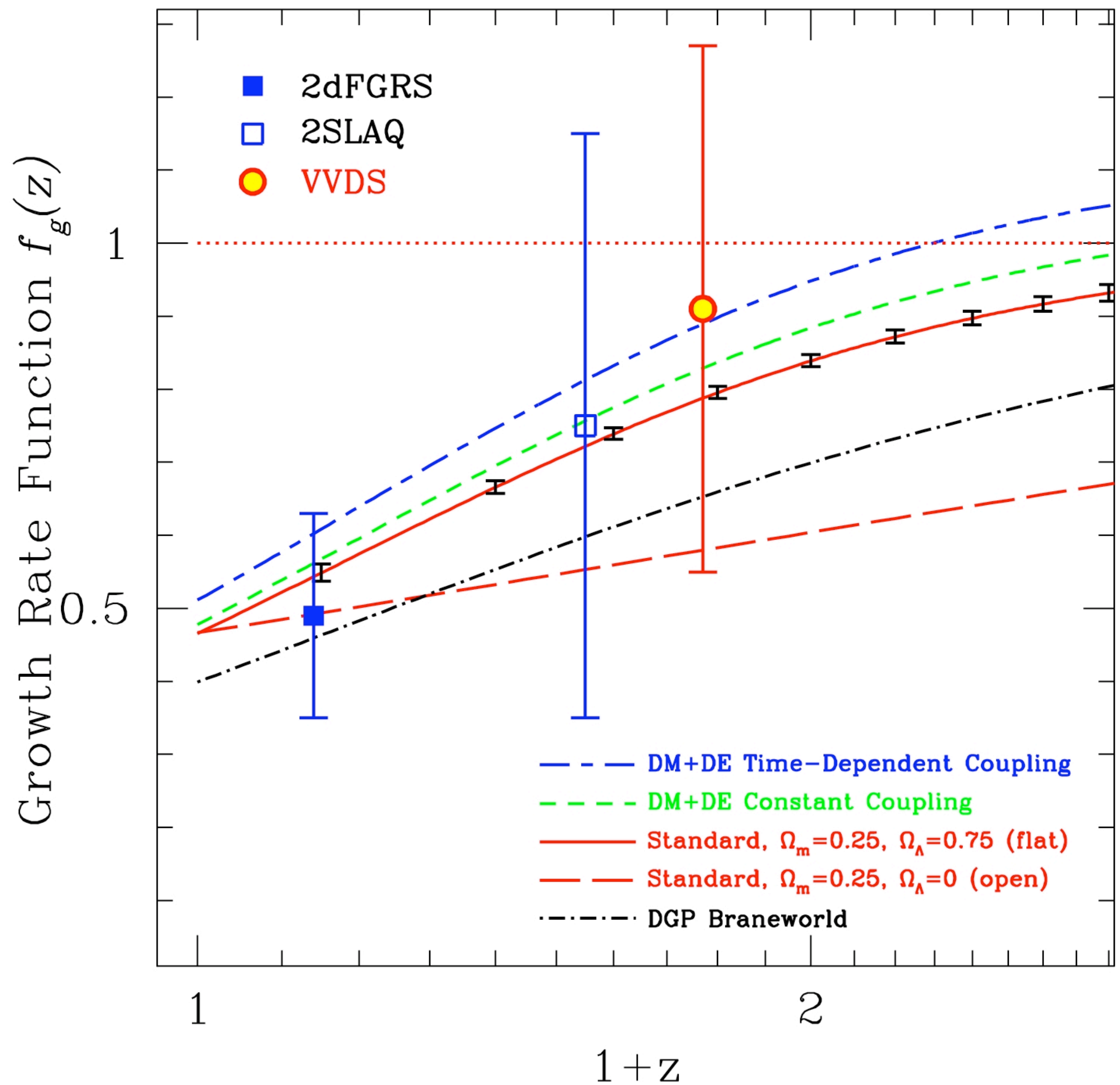
A tool to test the law of gravity

- Promising for modified gravity
- Based on galaxy clustering measurements

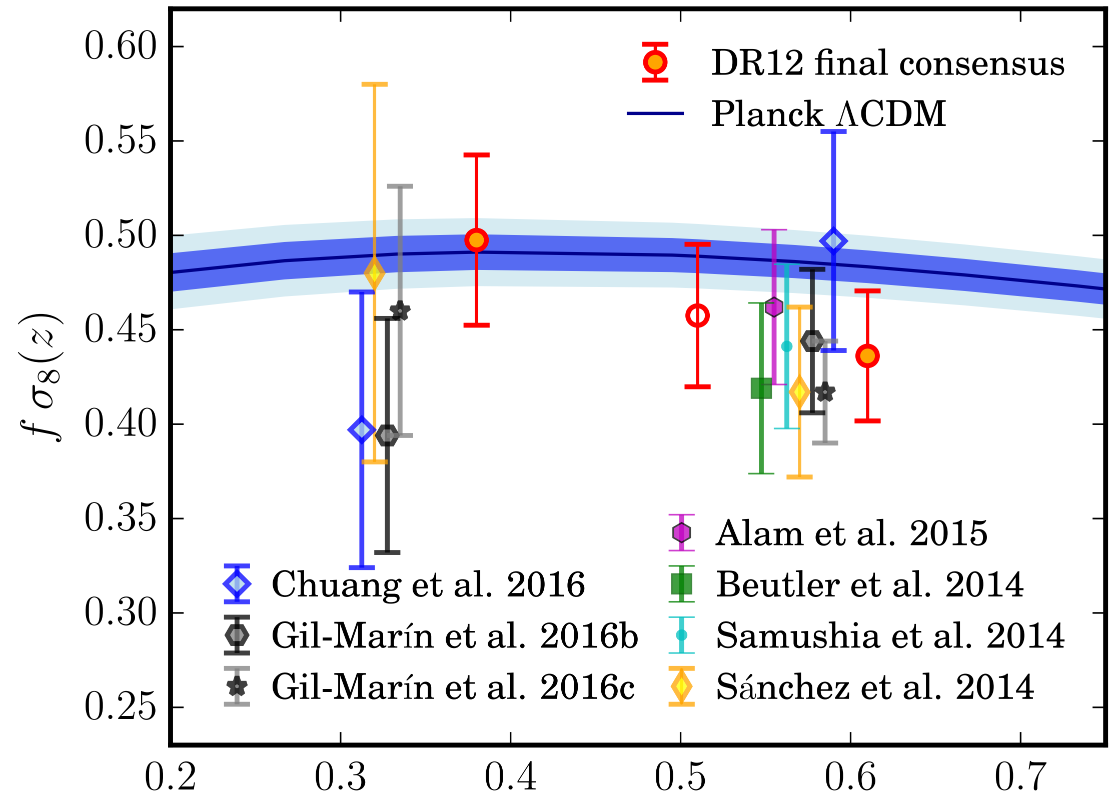
$$f = \frac{\mathrm{d}\ln D}{\mathrm{d}\ln a}$$

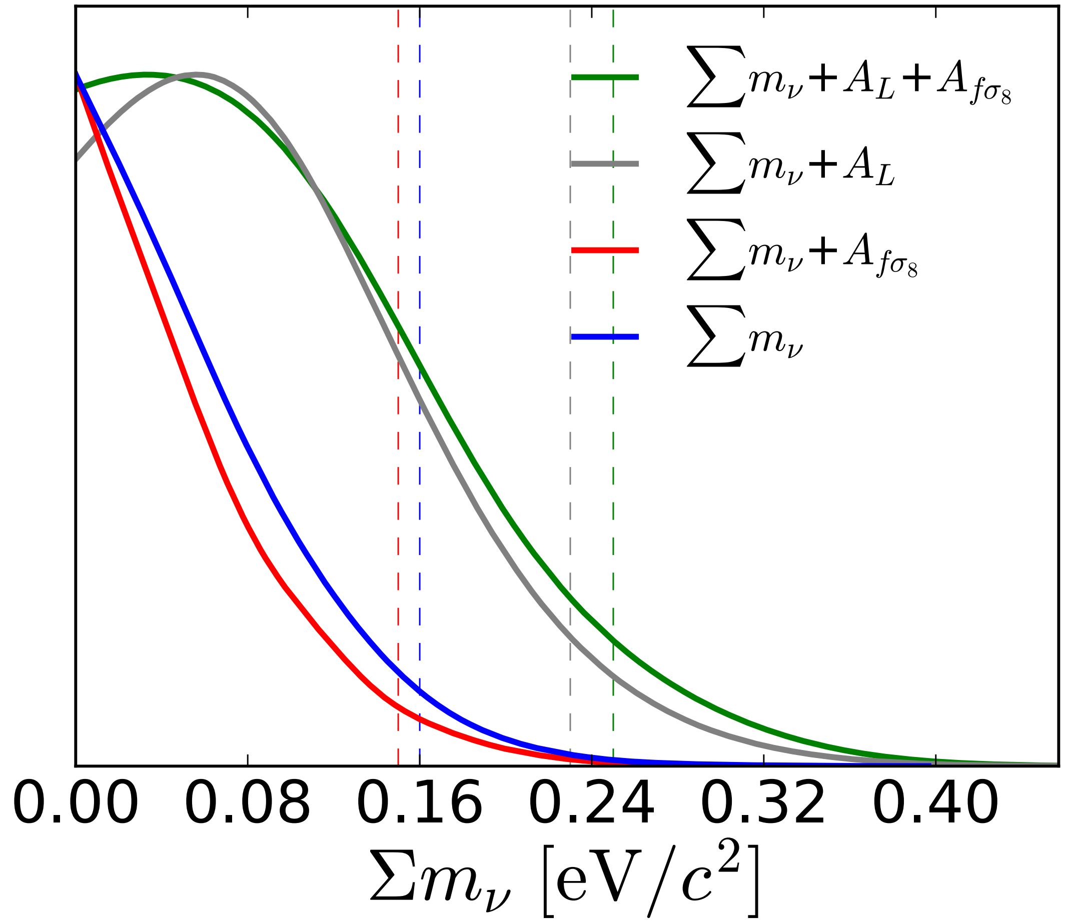
$$\approx \Omega_m(z)^\gamma$$



Guzzo et al. (2008)

Alam et al. (2016)





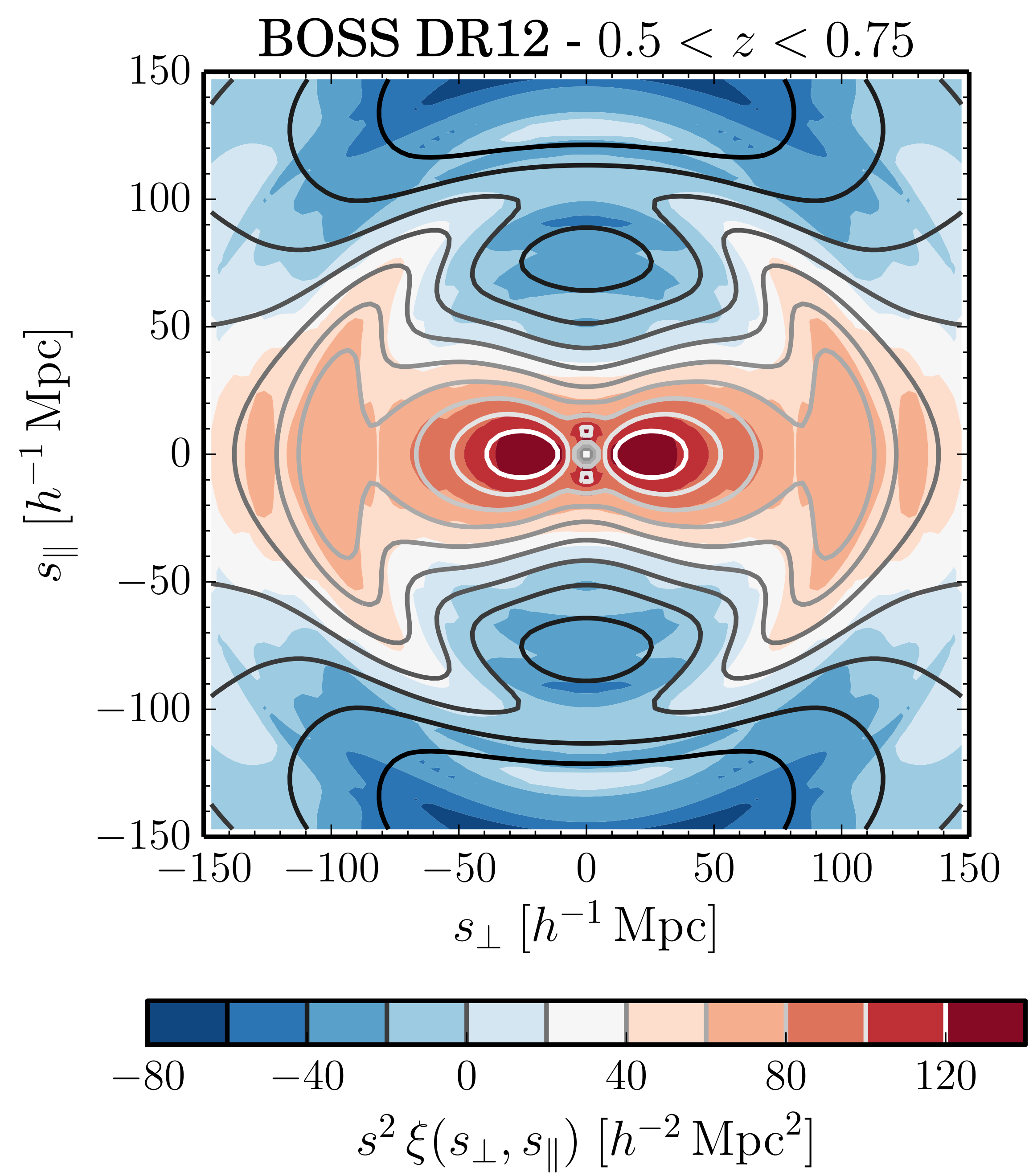
A tool to test the law of gravity

- BOSS DR12: A variety of different approaches to measure $f\sigma_8$
- Neutrino mass constraints
- *Less precise* than expansion history measurements

Measuring redshift space distortions

Alam et al. (2016)

- Anisotropic 2D correlation function
- Distorted by peculiar velocities
- Coherent: bulk motions on large scales
- Random: Cluster-scales, gives rise to Finger-of-god features

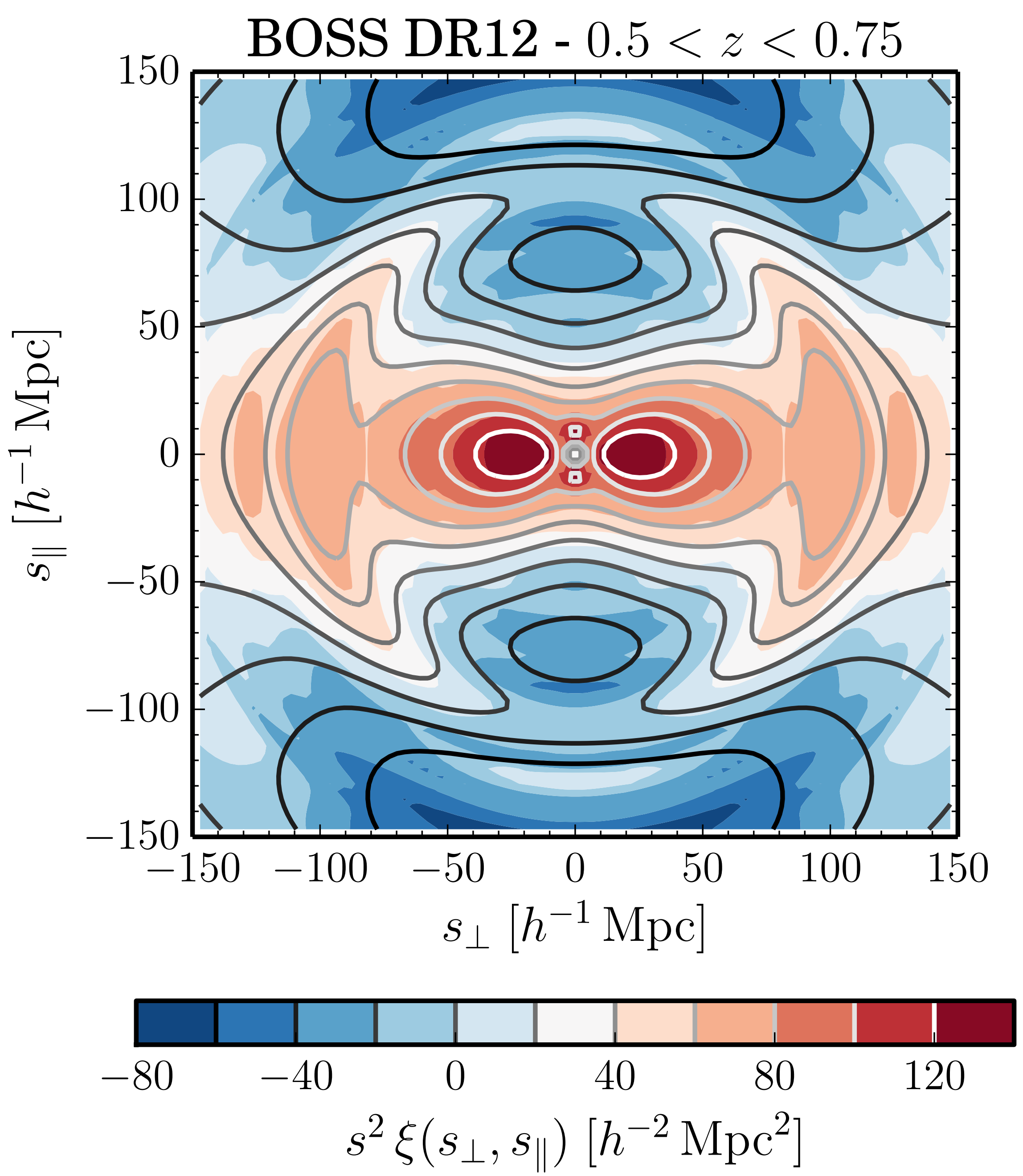


Measuring redshift space distortions

- Kaiser (1987)

$$P^s(k,\mu) = (1+\beta^2\mu^2)^2 P_g^r(k)$$

$$\beta = \frac{f}{b}$$



Alam et al. (2016)

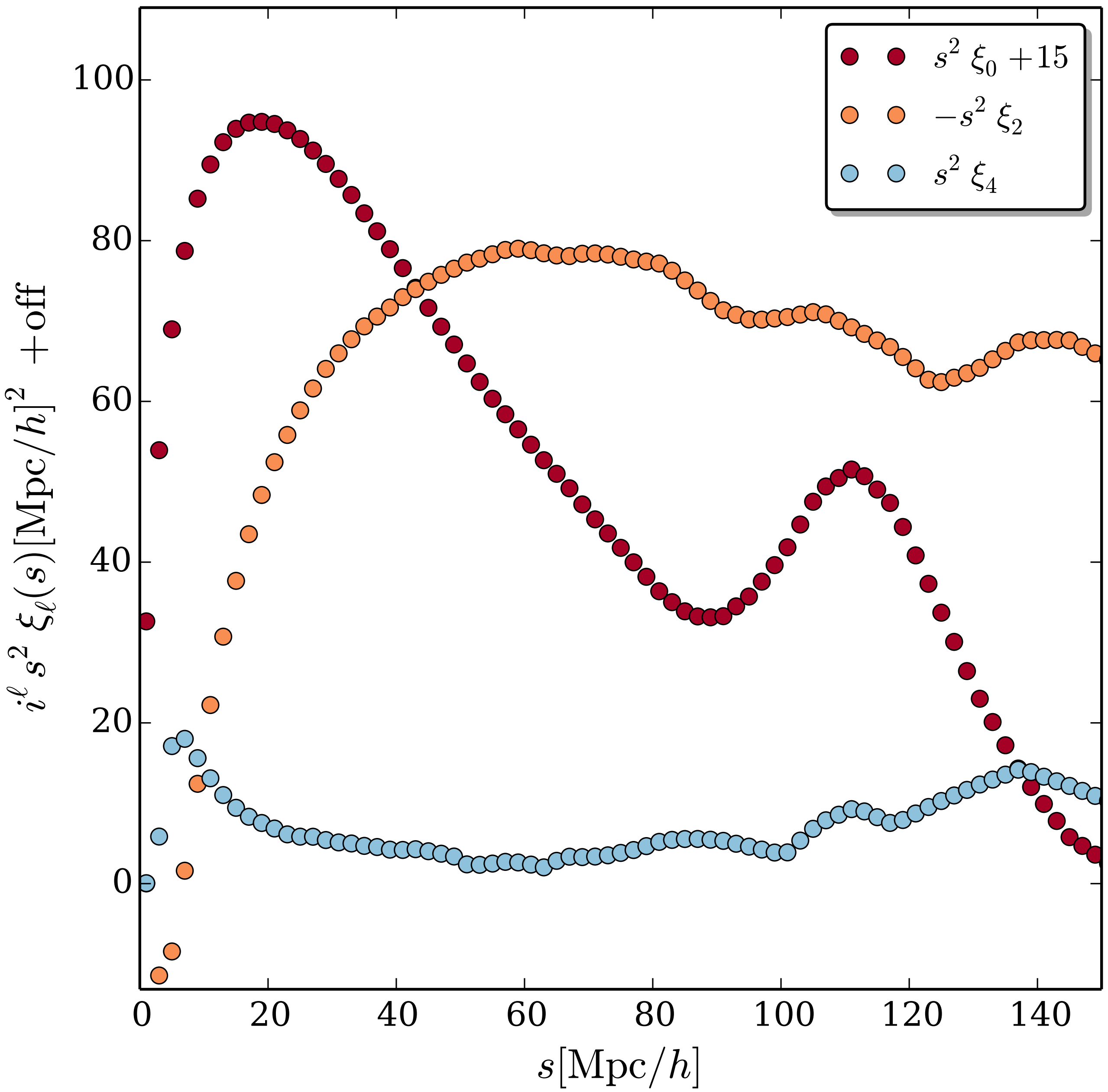
Measuring redshift space distortions

- Kaiser (1987)

$$P^s(k,\mu) = (1+\beta^2\mu^2)^2 P_g^r(k)$$

$$\beta = \frac{f}{b}$$

$$\xi_\ell(s) \equiv \frac{2\ell+1}{2}\int_{-1}^{1} L_\ell(\mu)\xi(\mu,s)\mathrm{d}\mu$$



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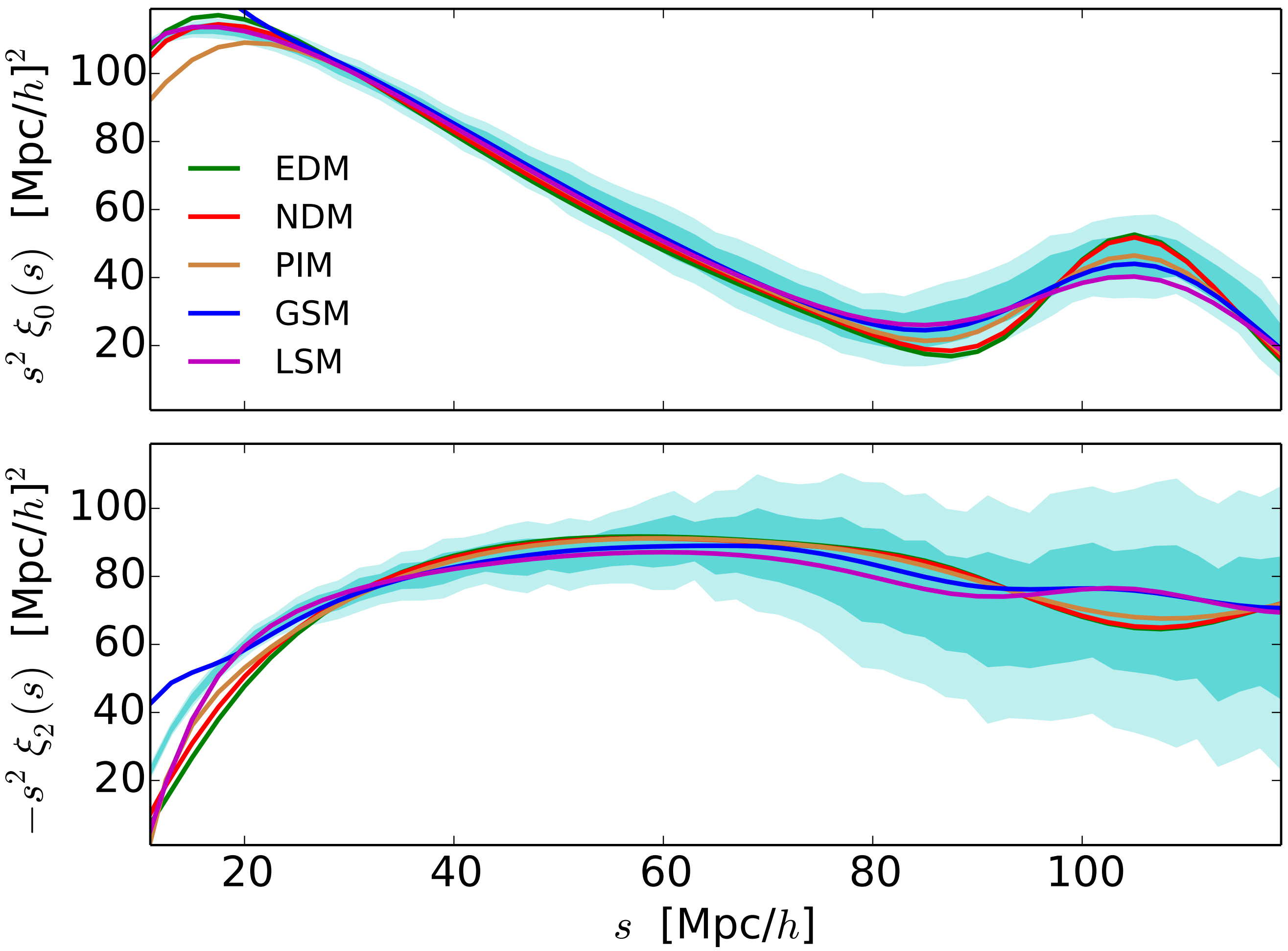
Modelling RSDs

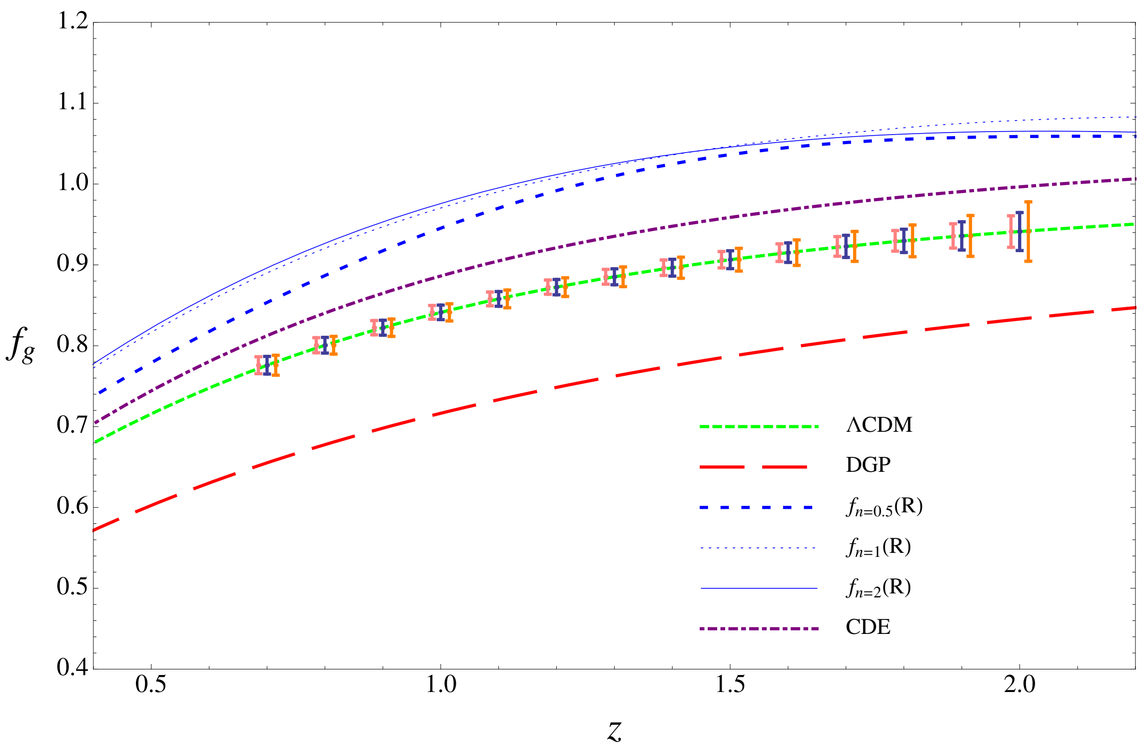
- Velocity field becomes non-linear on *large* scales
- But non-linear scales are measured with great accuracy
- Perturbation-theory descriptions of the mildly non-linear regime
- Galaxies are biased tracers of the underlying density/velocity field
- Other issues: Fingers-of-god effect
    - Unbiased results only for s > 30 Mpc/h with state-of-the-art models



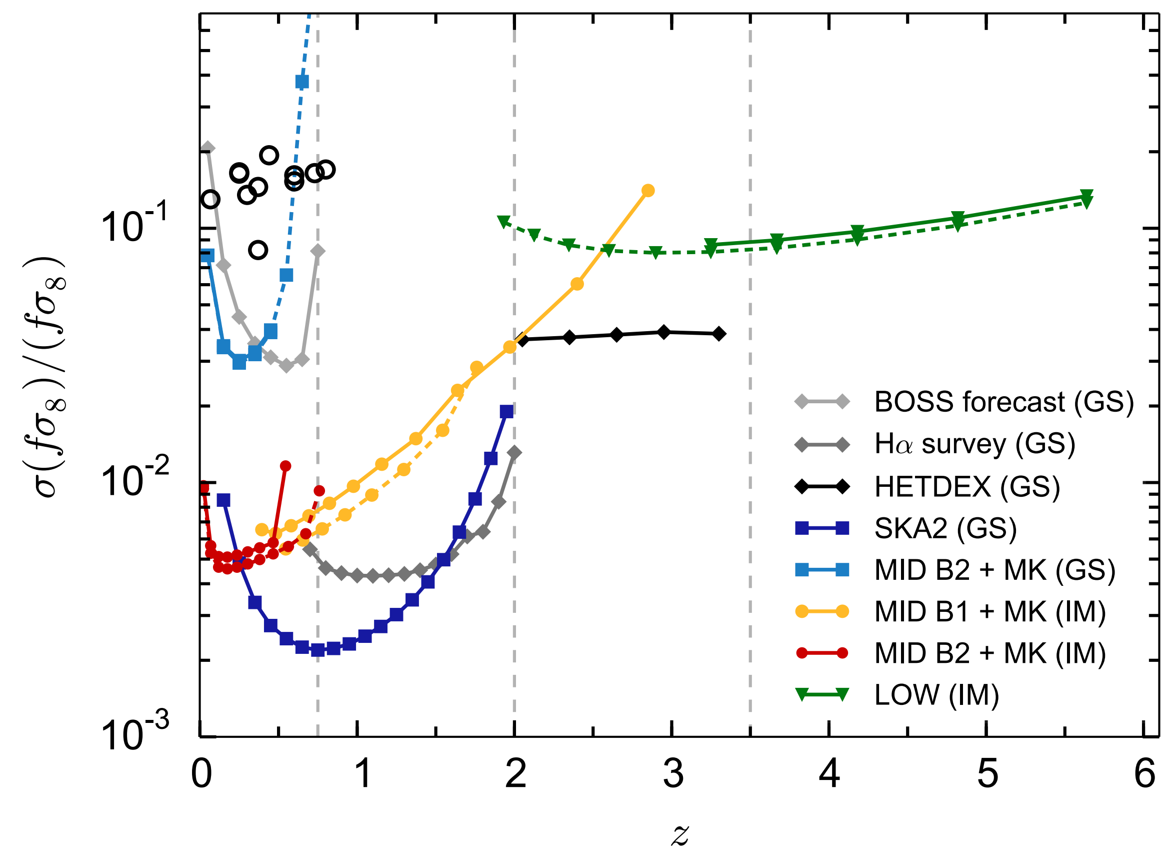
White et al. 2015

Future probes

Euclid



Amendola et al. (2016)



Bull, 2016

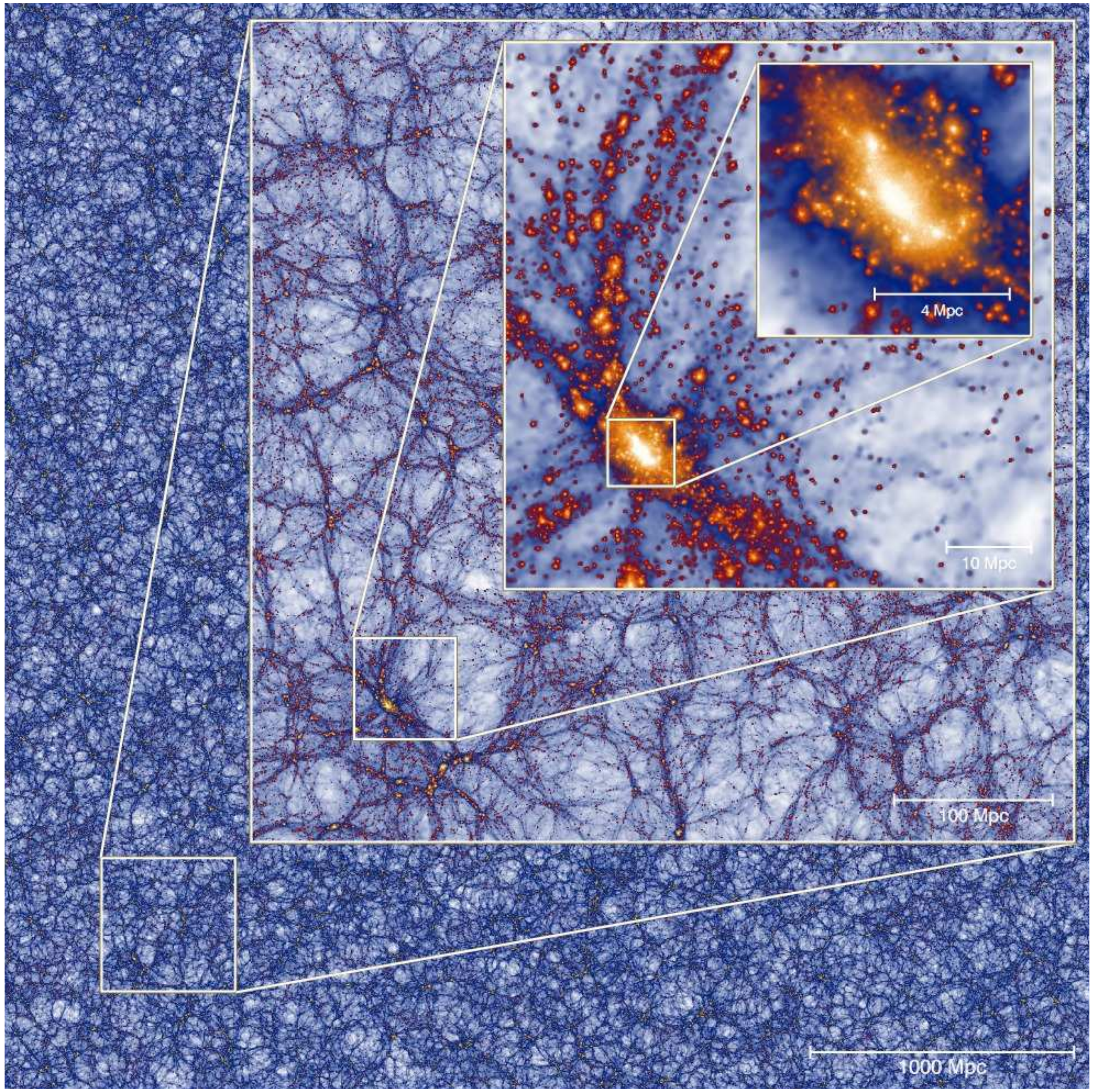
Data sets are becoming more accurate than model descriptions

Exploring the impact of galaxy formation on a large simulation

- Millennium-XXL:
  - 3 [Gpc/h]^3
  - SAM of Guo+11

$$M_{halo}^{min} = 1.22 \times 10^{10} h^{-1} M_{\odot}$$

  - extended merger trees matching Mill. sim.



Angulo et al. (2012)

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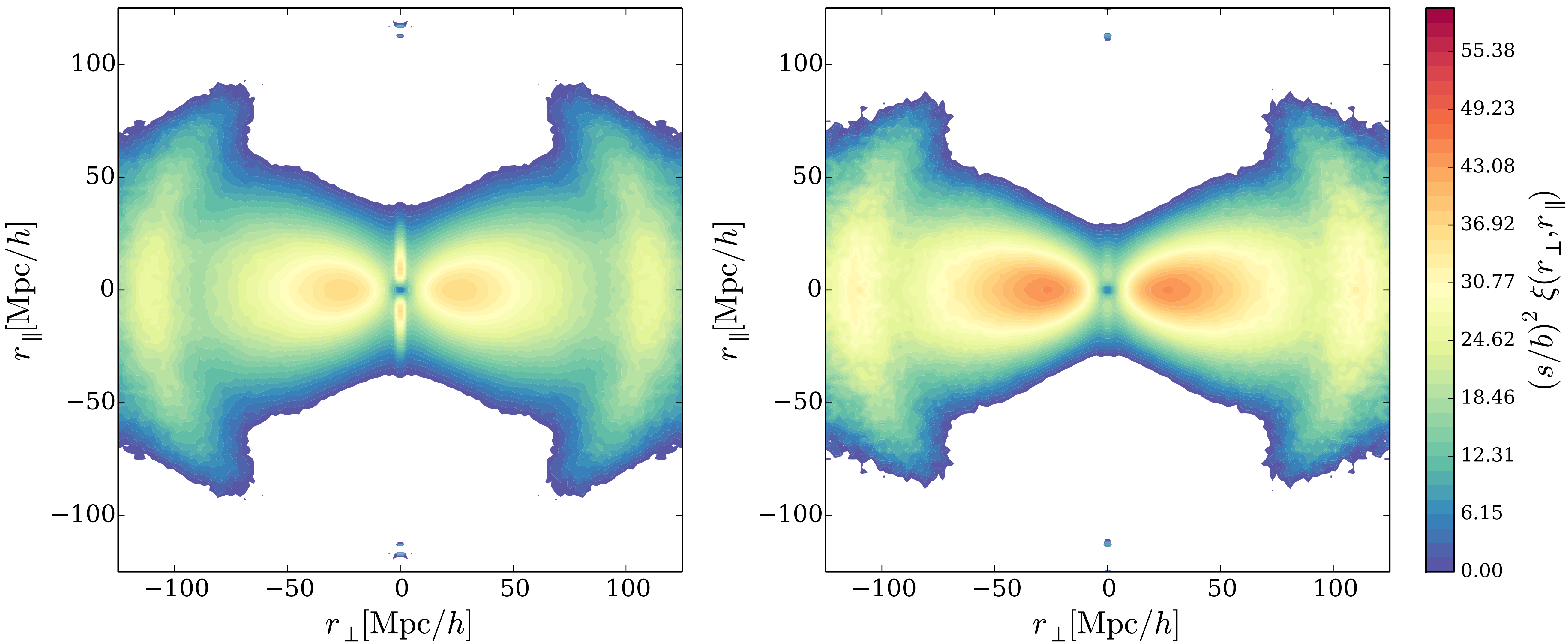
RSDs in different galaxy selections



Stellar mass selected sample

Star-formation selected sample

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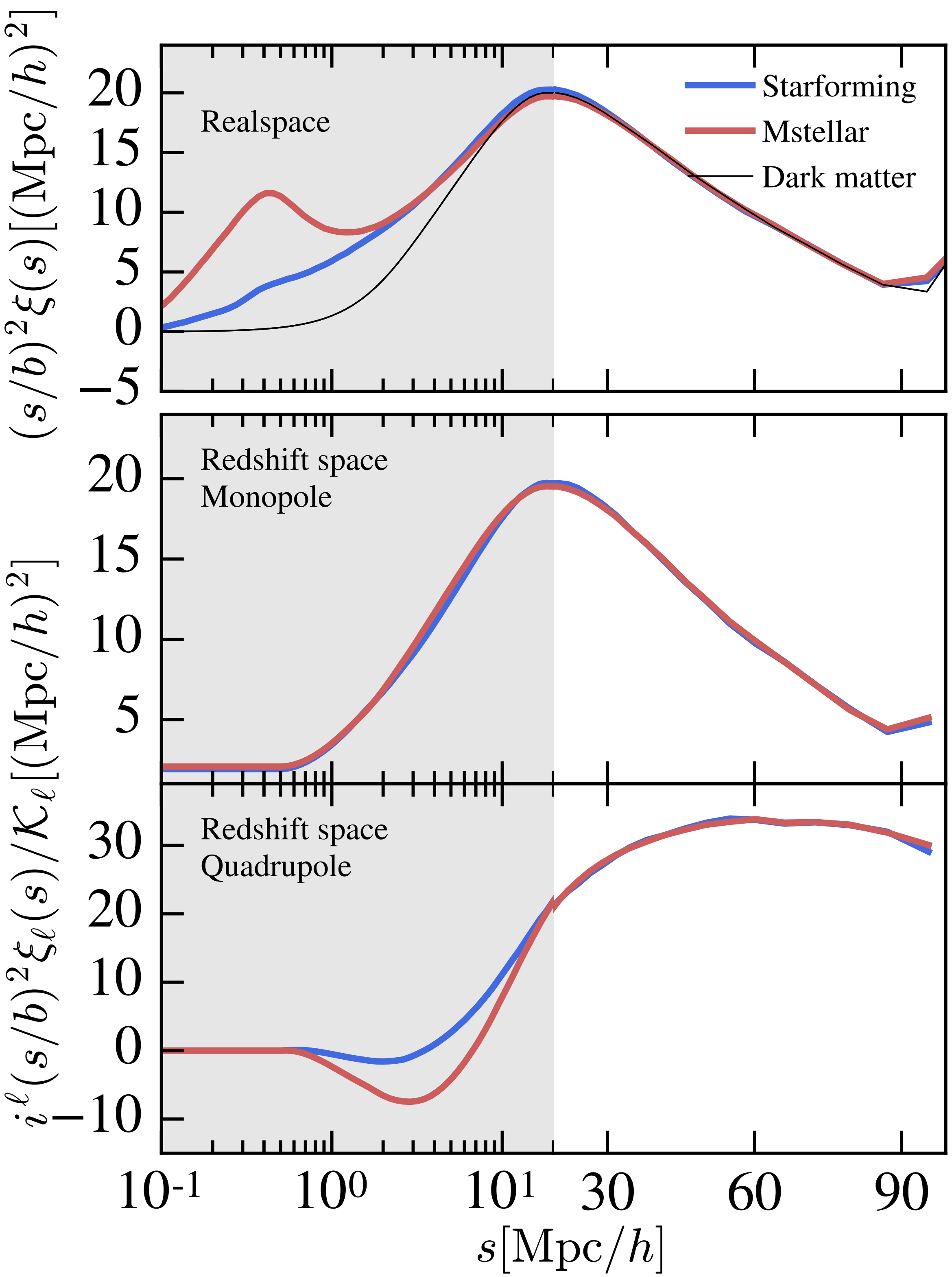
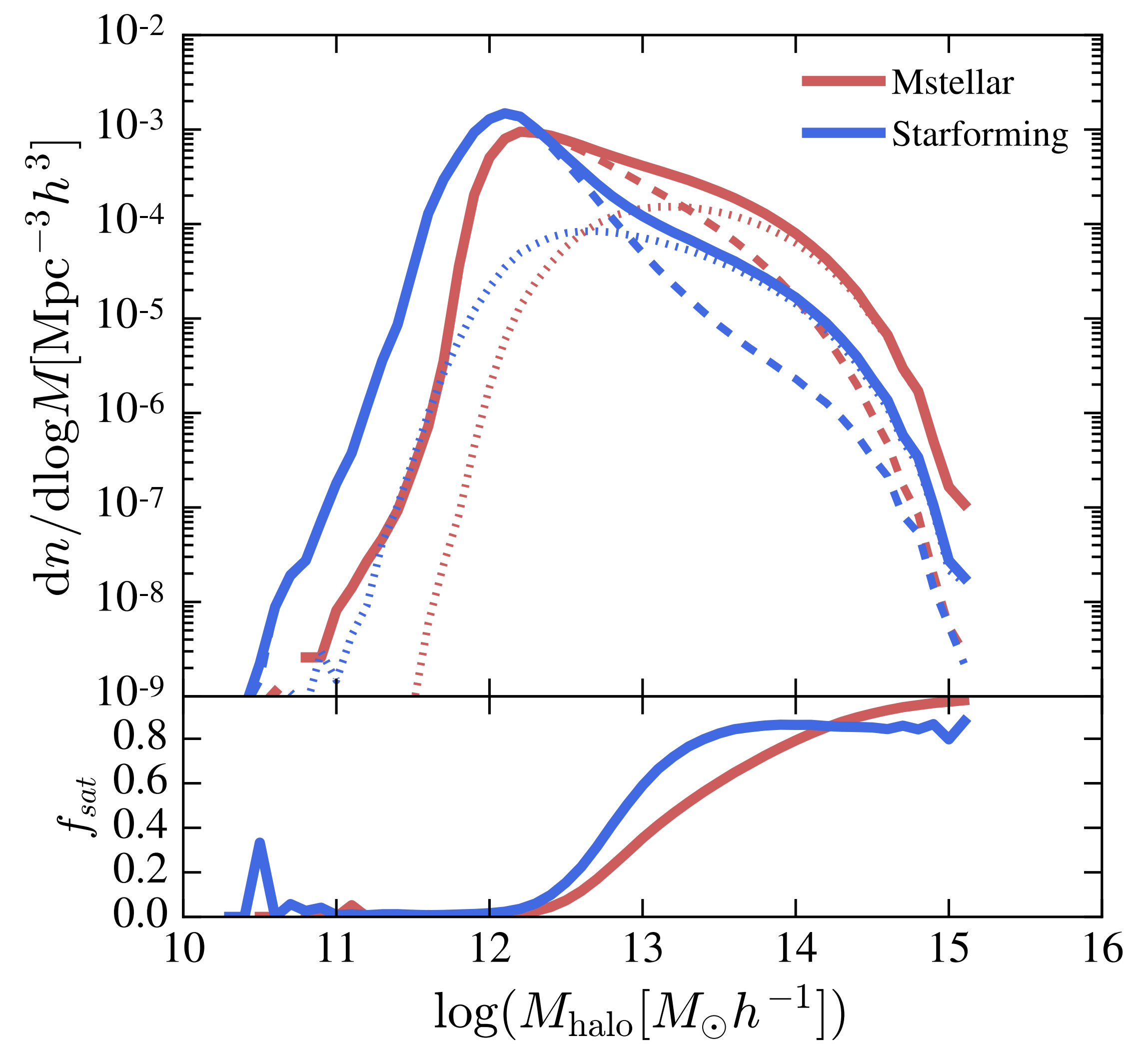
RSDs in different galaxy selections





The impact of the HOD on clustering at small scales

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From haloes to galaxies

Dispersion model
(e.g. Marulli et al. 2012)

$$\xi(s_\perp, s_\parallel) = \int_{-\infty}^{\infty} \mathrm{d}v f(v) \xi\left(s_\perp, s_\parallel - \frac{v(1+z)}{H(z)}\right)_{\mathrm{lin}}$$

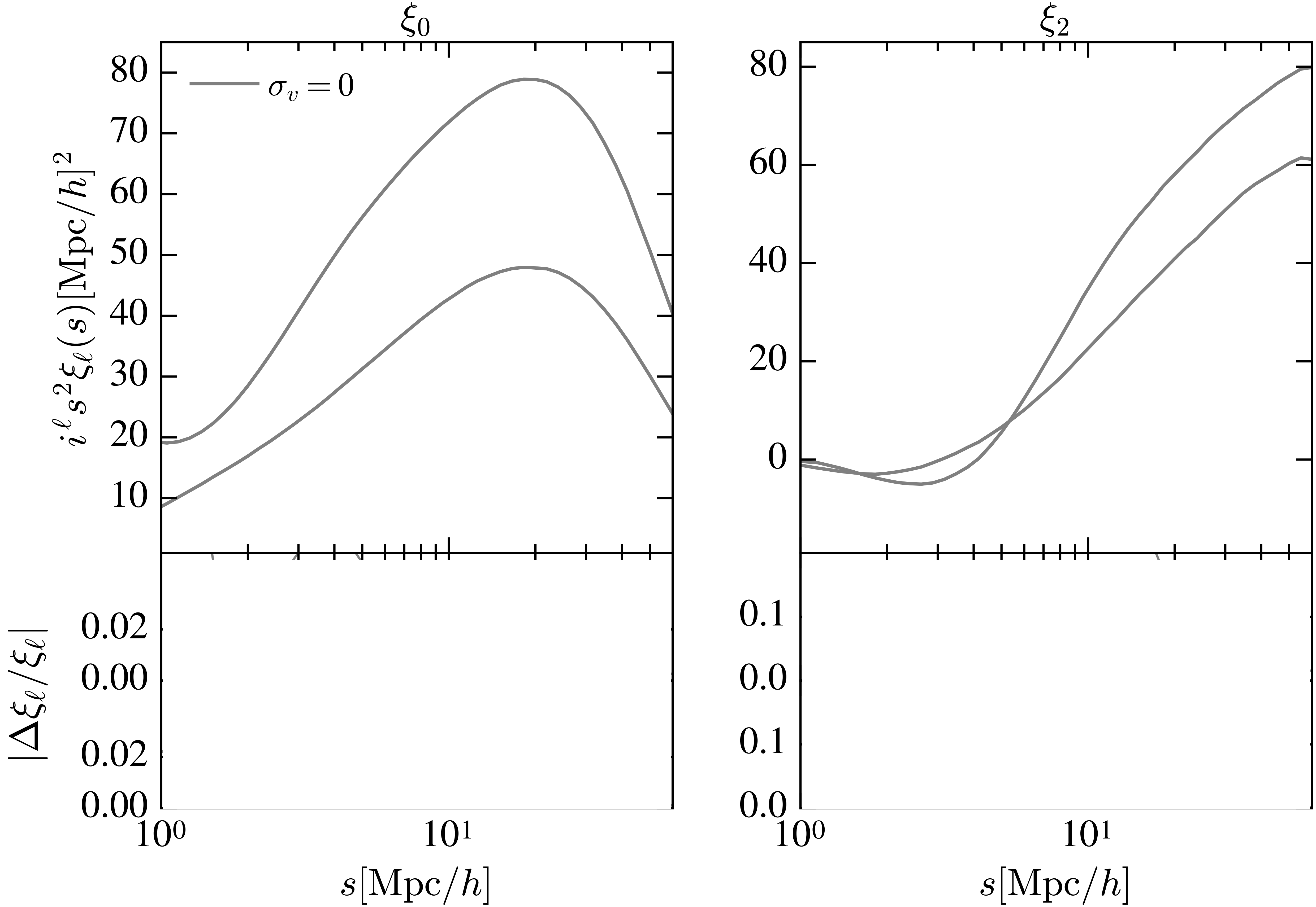
$$f(v) = \frac{1}{\sigma_{12}\sqrt{\pi}} \exp\left(-\frac{v^2}{\sigma_{12}^2}\right)$$

Intra-halo velocity dispersion as a nuisance parameter

Gaussian streaming model
(e.g. Reid et al. 2012,
Satpathy et al. 2016)

$$1 + \xi_g^s(r_\sigma, r_\pi) = \int \left[1 + \xi_g^r(r)\right] e^{-[r_\pi - y - \mu v_{12}(r)]^2 / 2\sigma_g^2(r,\mu)} \frac{\mathrm{d}y}{\sqrt{2\pi\sigma_g^2(r,\mu)}}$$

$$\sigma_g^2(r,\mu) = \sigma_{12}^2(r,\mu) + \sigma_{FoG}^2$$



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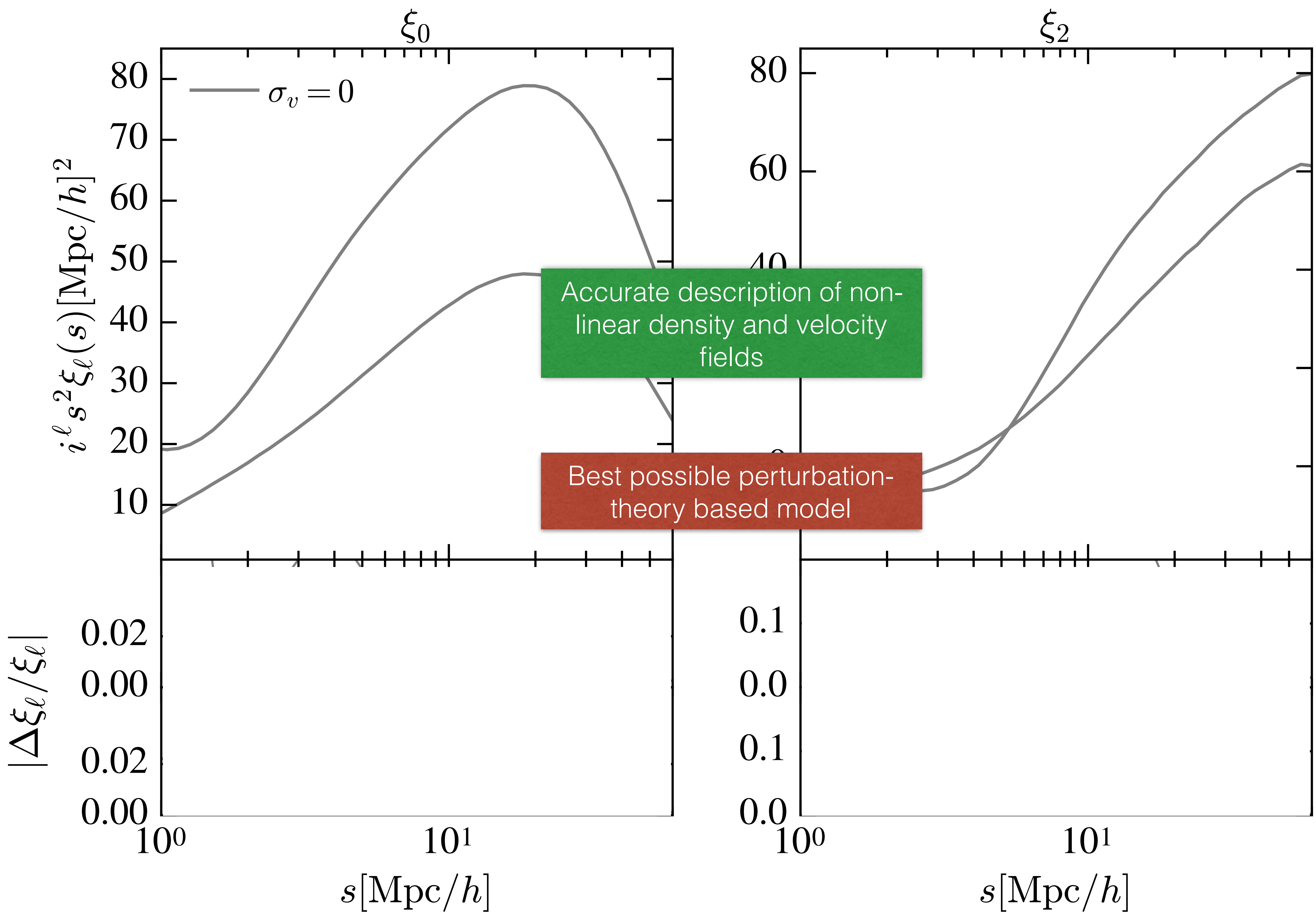

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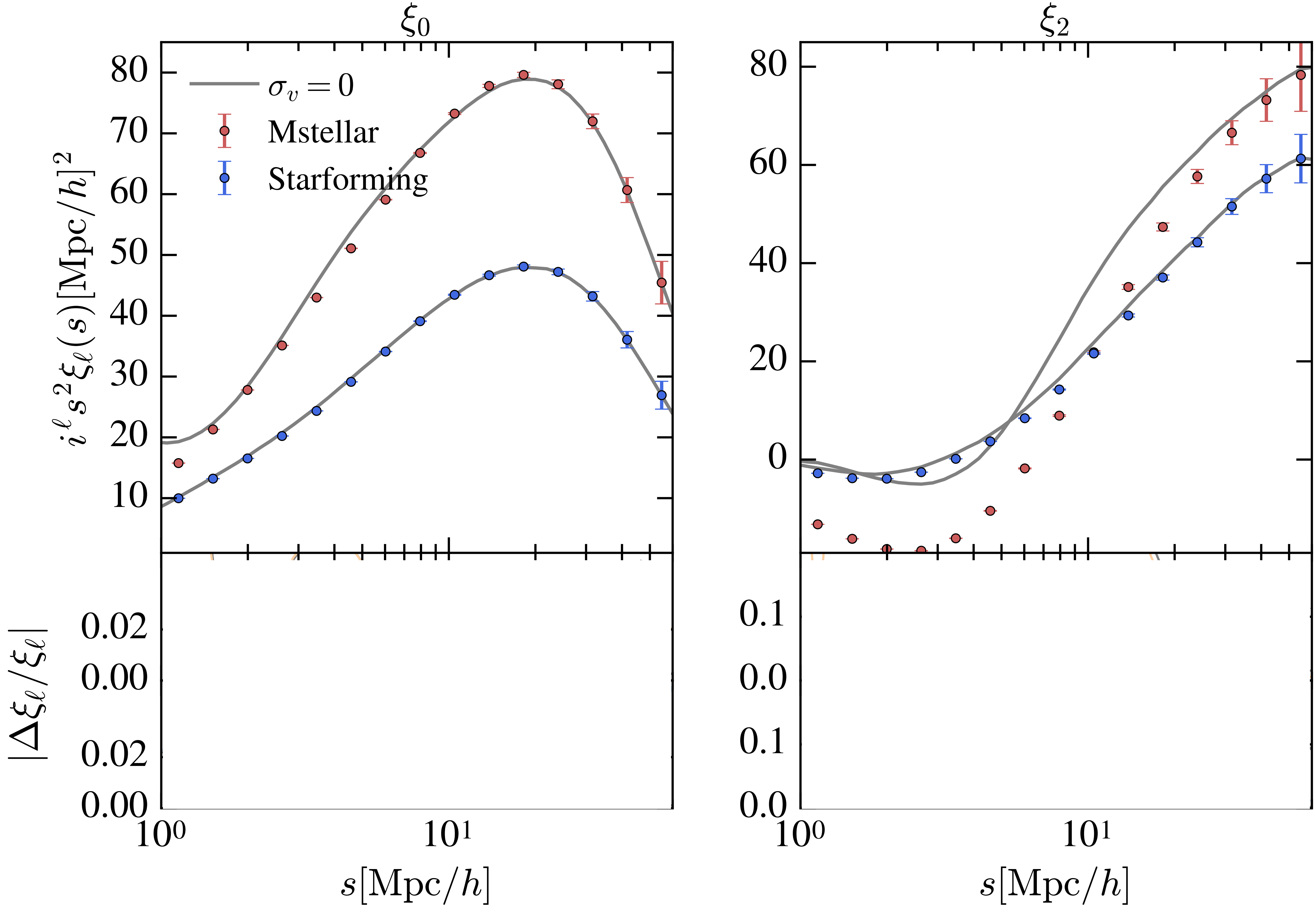
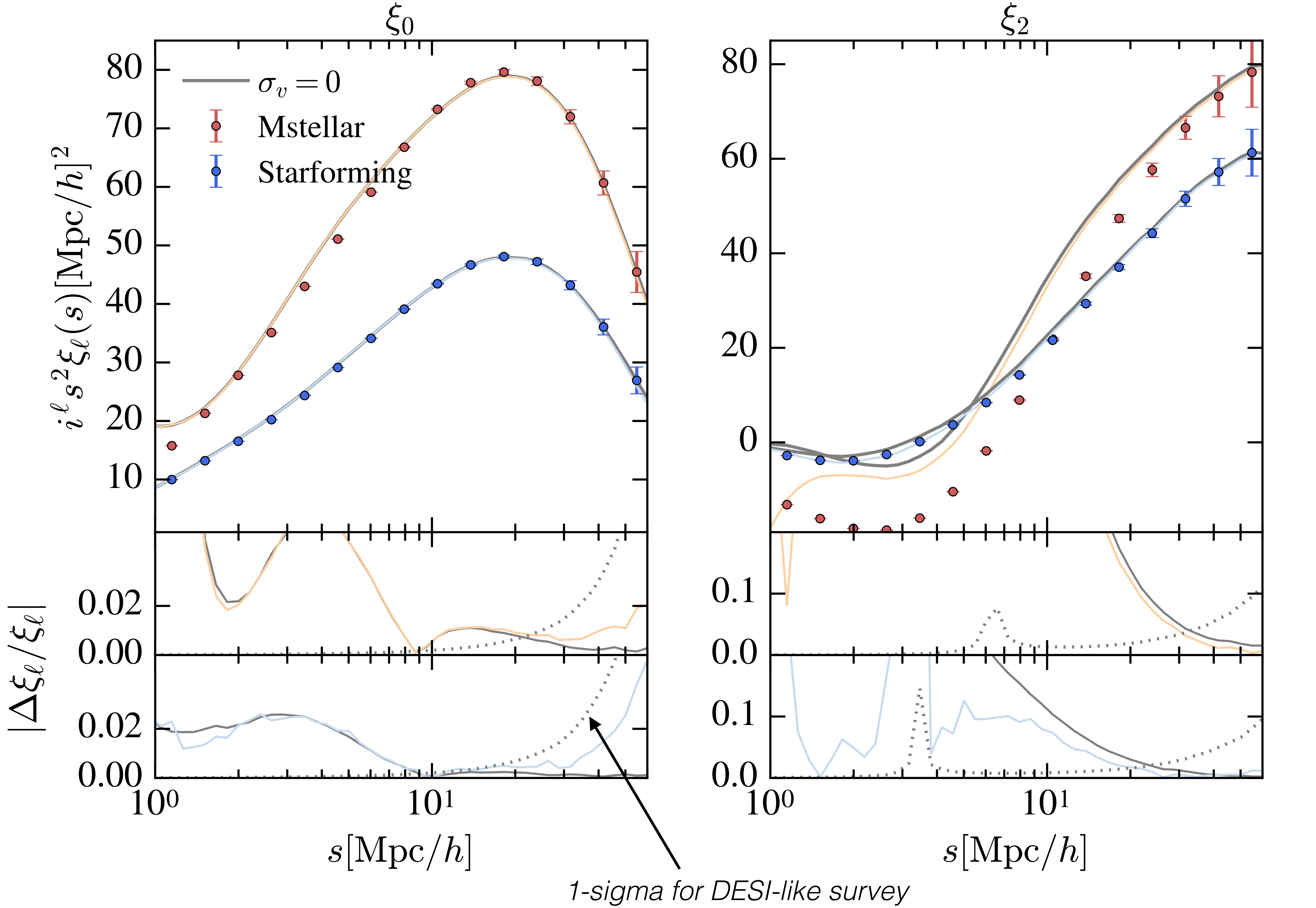

ξ_0
ξ_2
$\sigma_v = 0$
Mstellar
Starforming
$i^\ell s^2 \xi_\ell(s) [\mathrm{Mpc}/h]^2$
$|\Delta\xi_\ell / \xi_\ell|$
$s[\mathrm{Mpc}/h]$
$s[\mathrm{Mpc}/h]$



ξ_0
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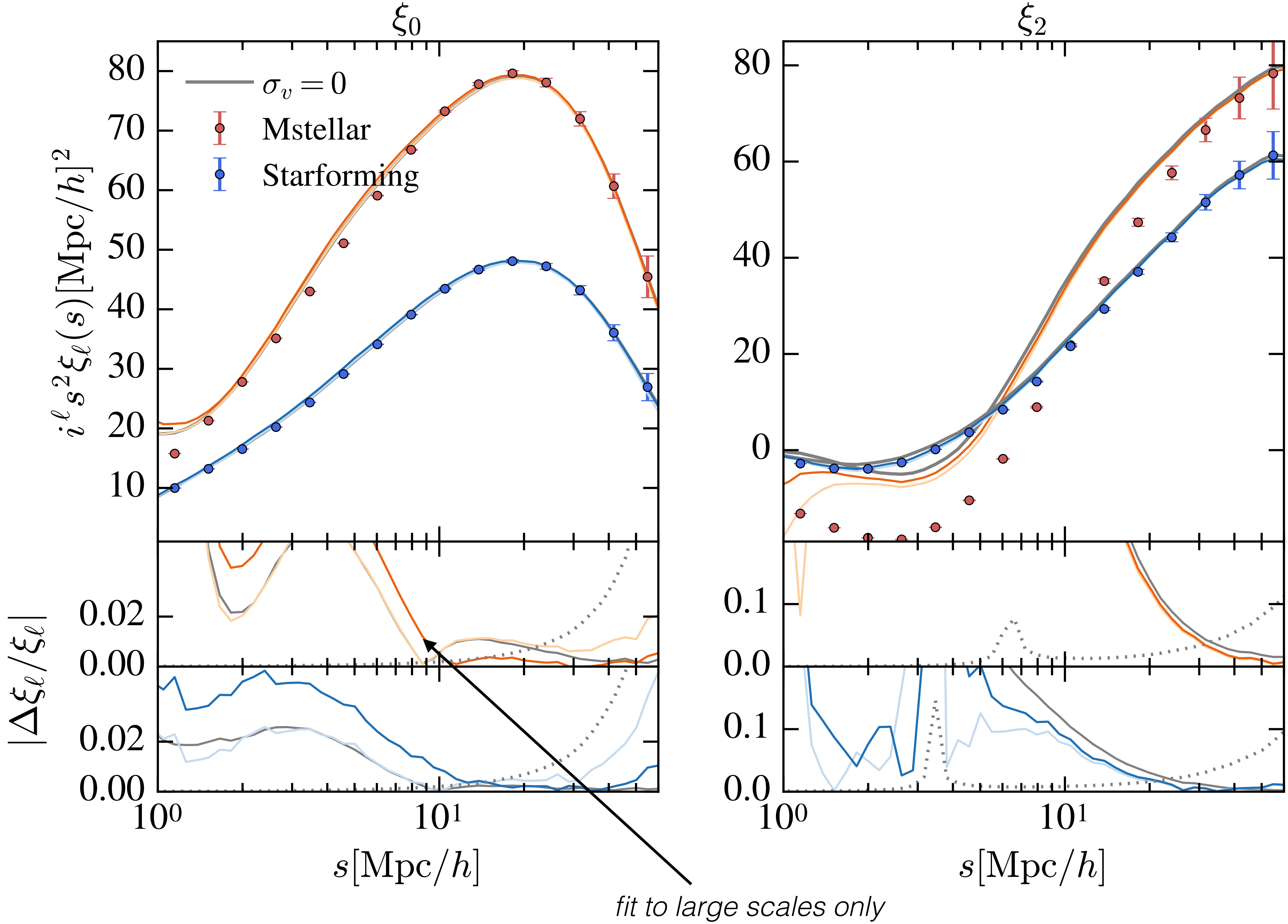
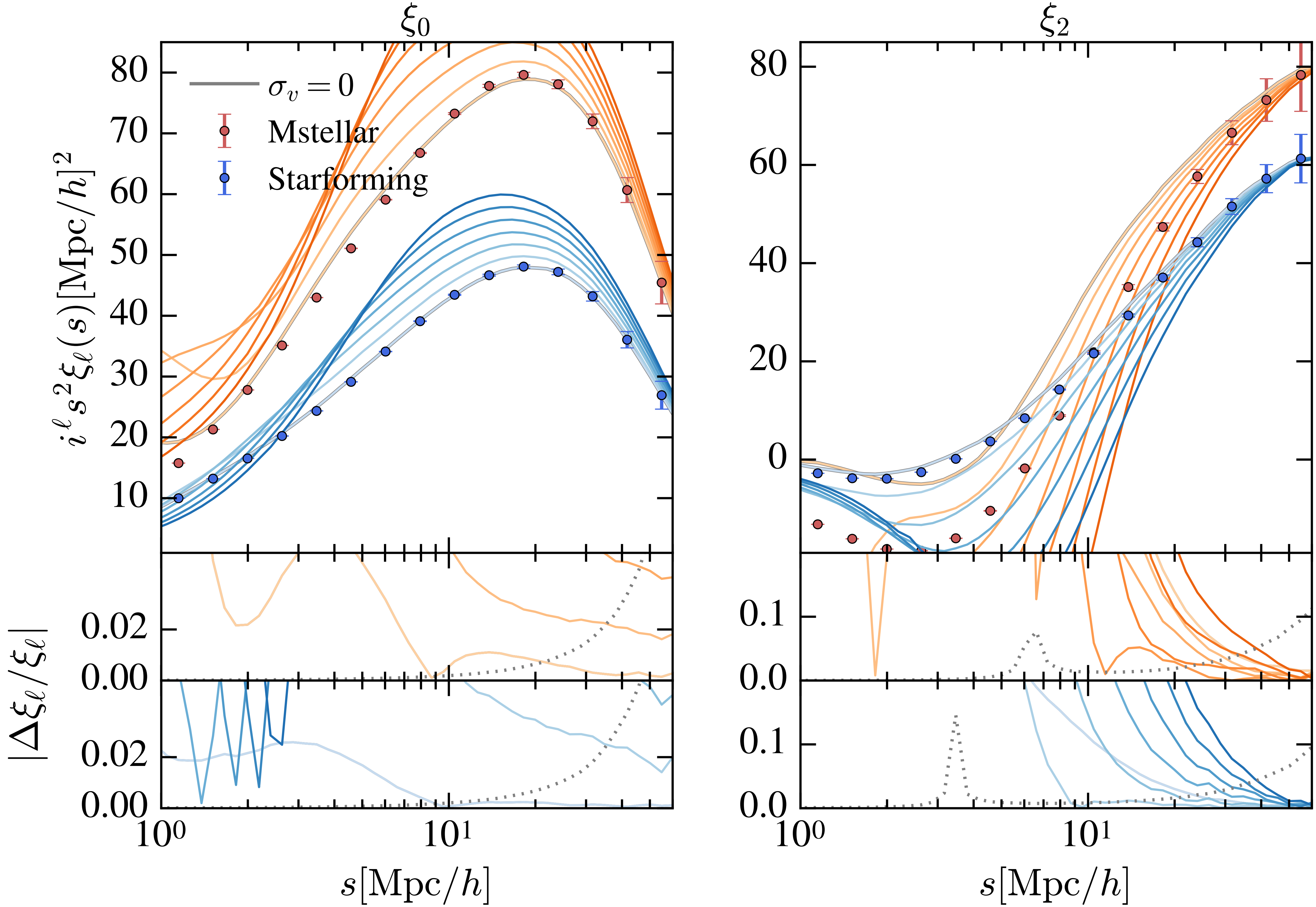
$|\Delta\xi_\ell/\xi_\ell|$
$s[\mathrm{Mpc}/h]$
$s[\mathrm{Mpc}/h]$
1-sigma for DESI-like survey



ξ_0
ξ_2
$\sigma_v = 0$
Mstellar
Starforming
$i^\ell s^2 \xi_\ell(s) [\mathrm{Mpc}/h]^2$
$|\Delta\xi_\ell/\xi_\ell|$
$s[\mathrm{Mpc}/h]$
$s[\mathrm{Mpc}/h]$
fit to large scales only



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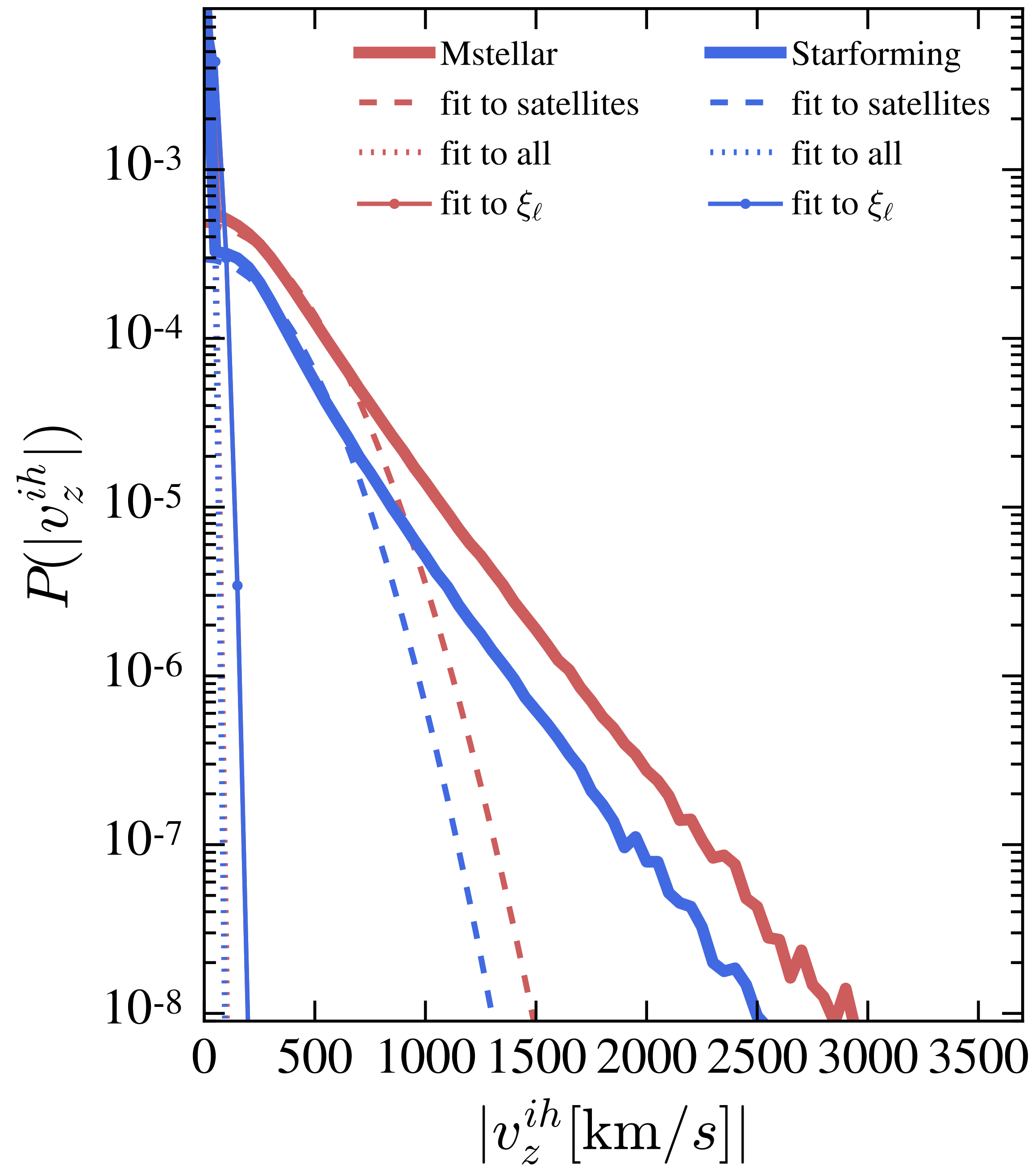
Intra-halo velocities in detail…

1. Intra-halo velocities are not Gaussian distributed



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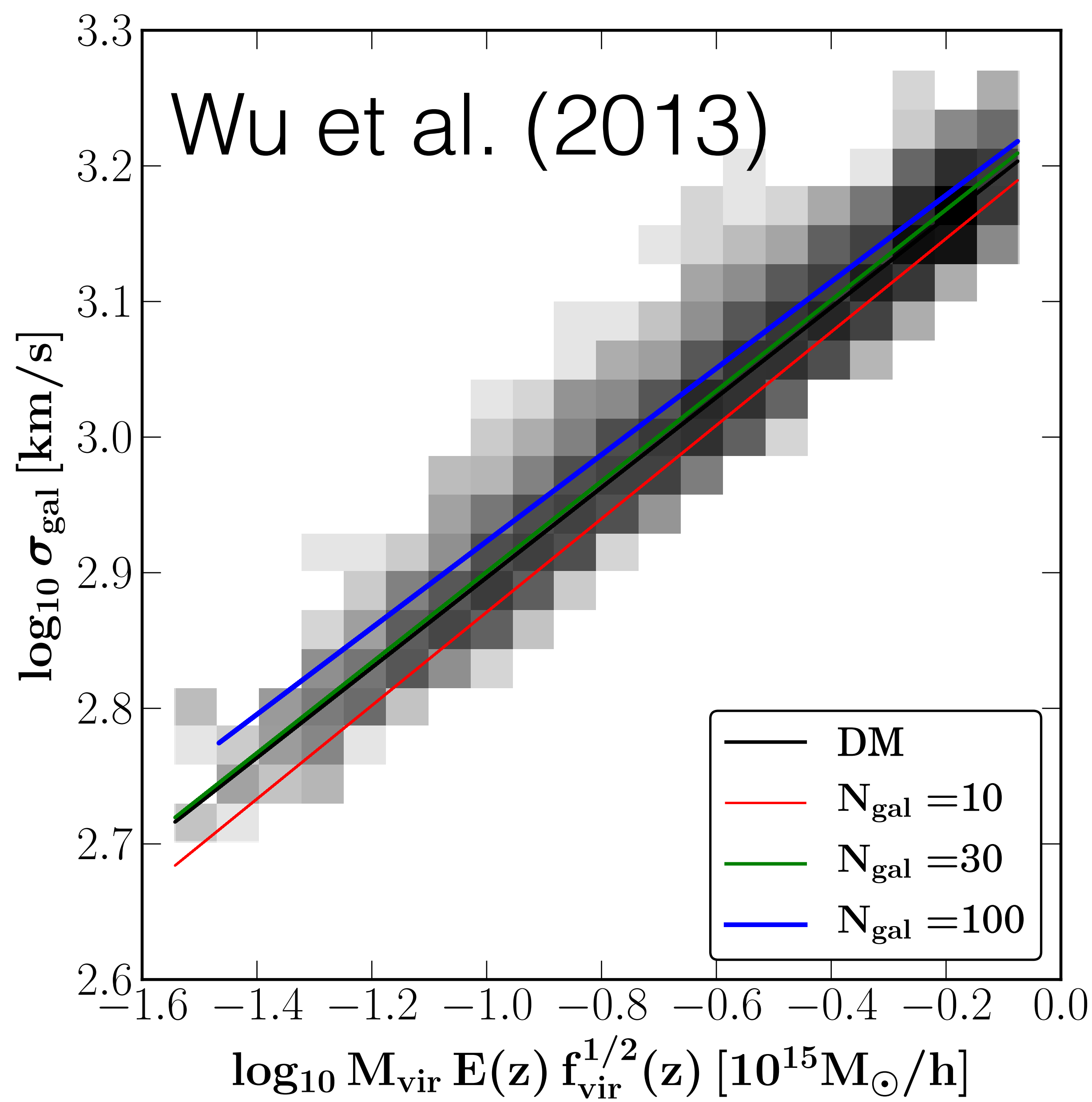
Intra-halo velocities in detail…

1. Intra-halo velocities are not Gaussian distributed

2. Velocity dispersion correlates strongly with halo mass



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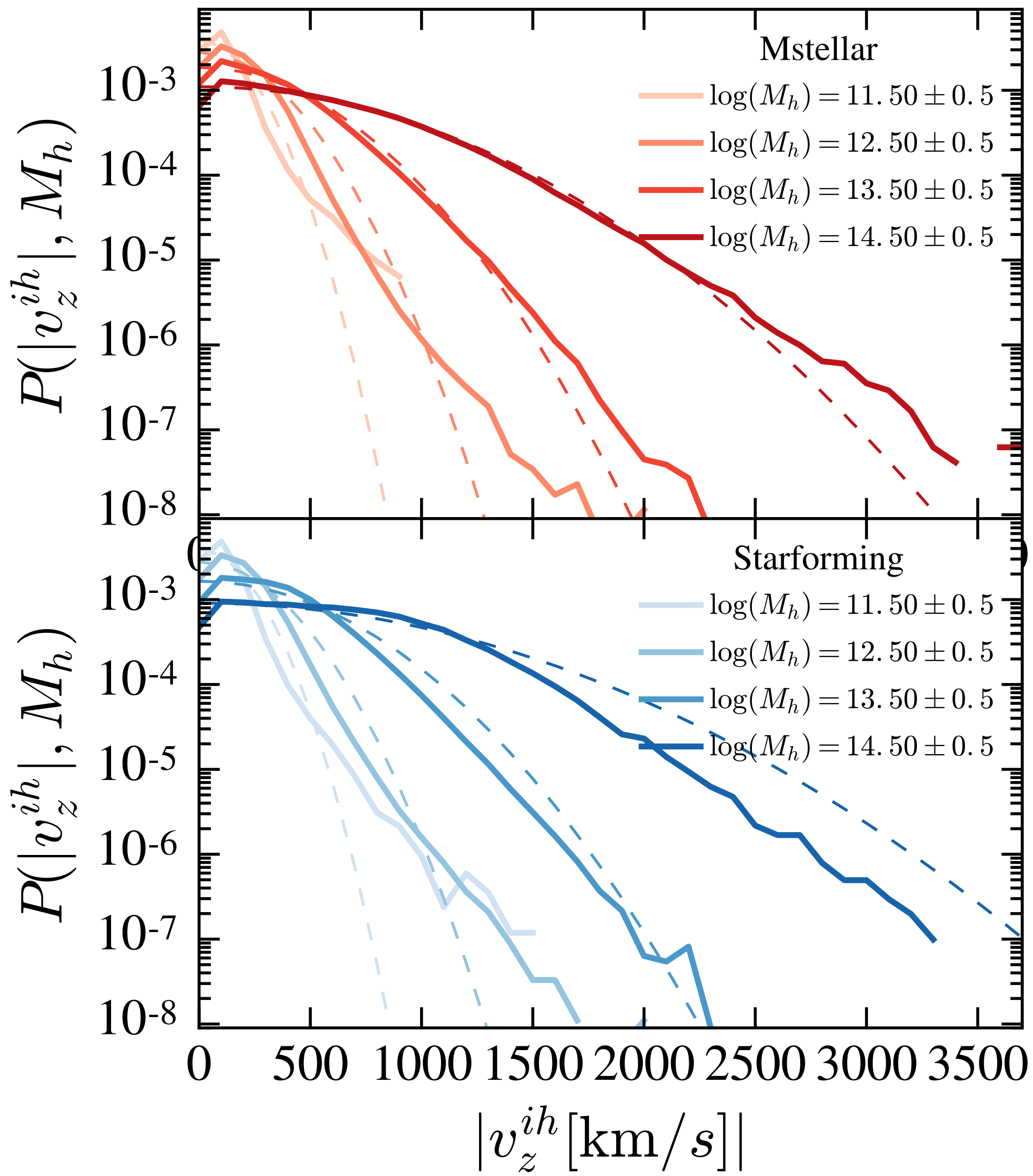

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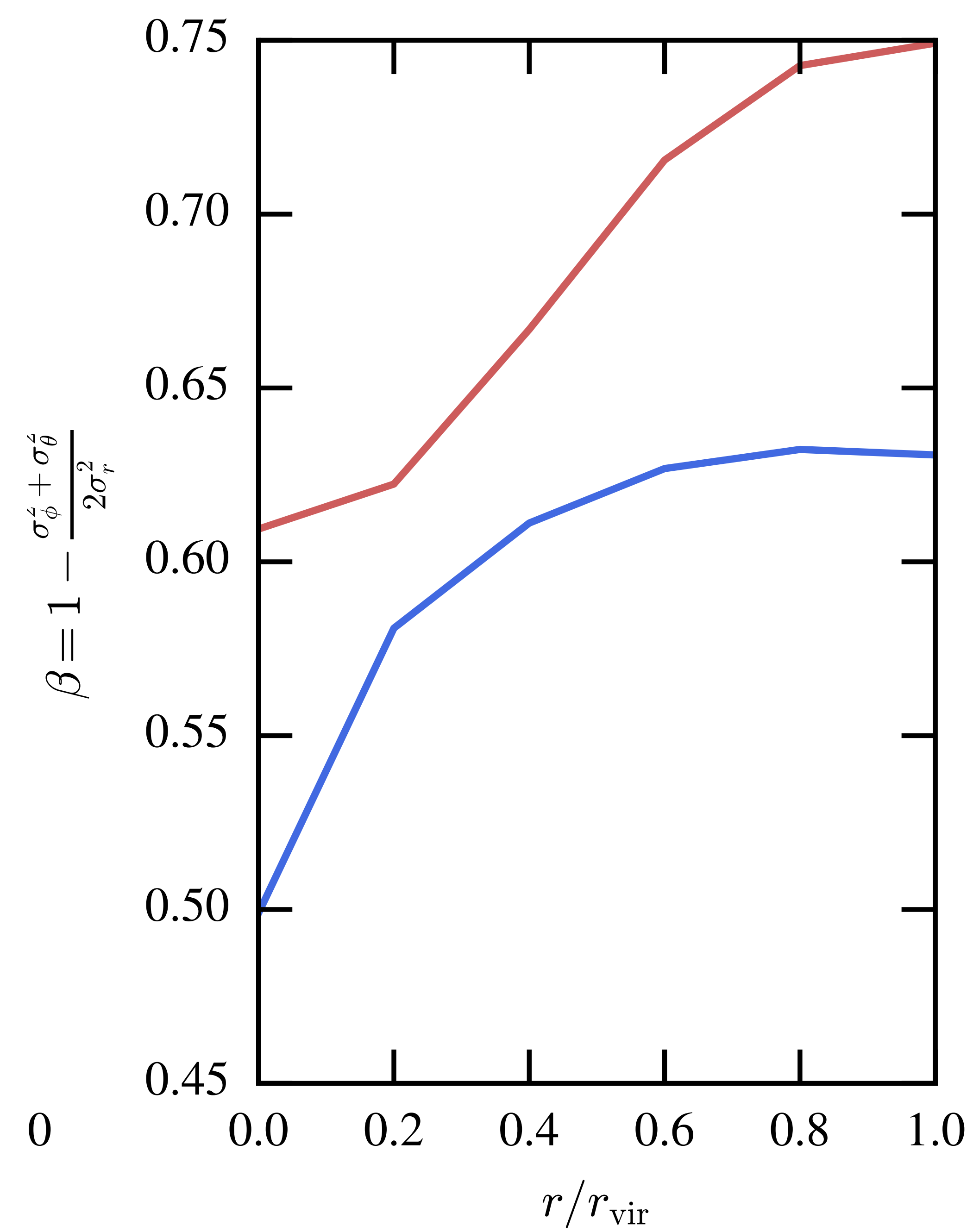
Intra-halo velocities in detail…

1. Intra-halo velocities are not Gaussian distributed

2. Velocity dispersion correlates strongly with halo mass

3. Velocity dispersion is anisotropic and this depends on the galaxy sample



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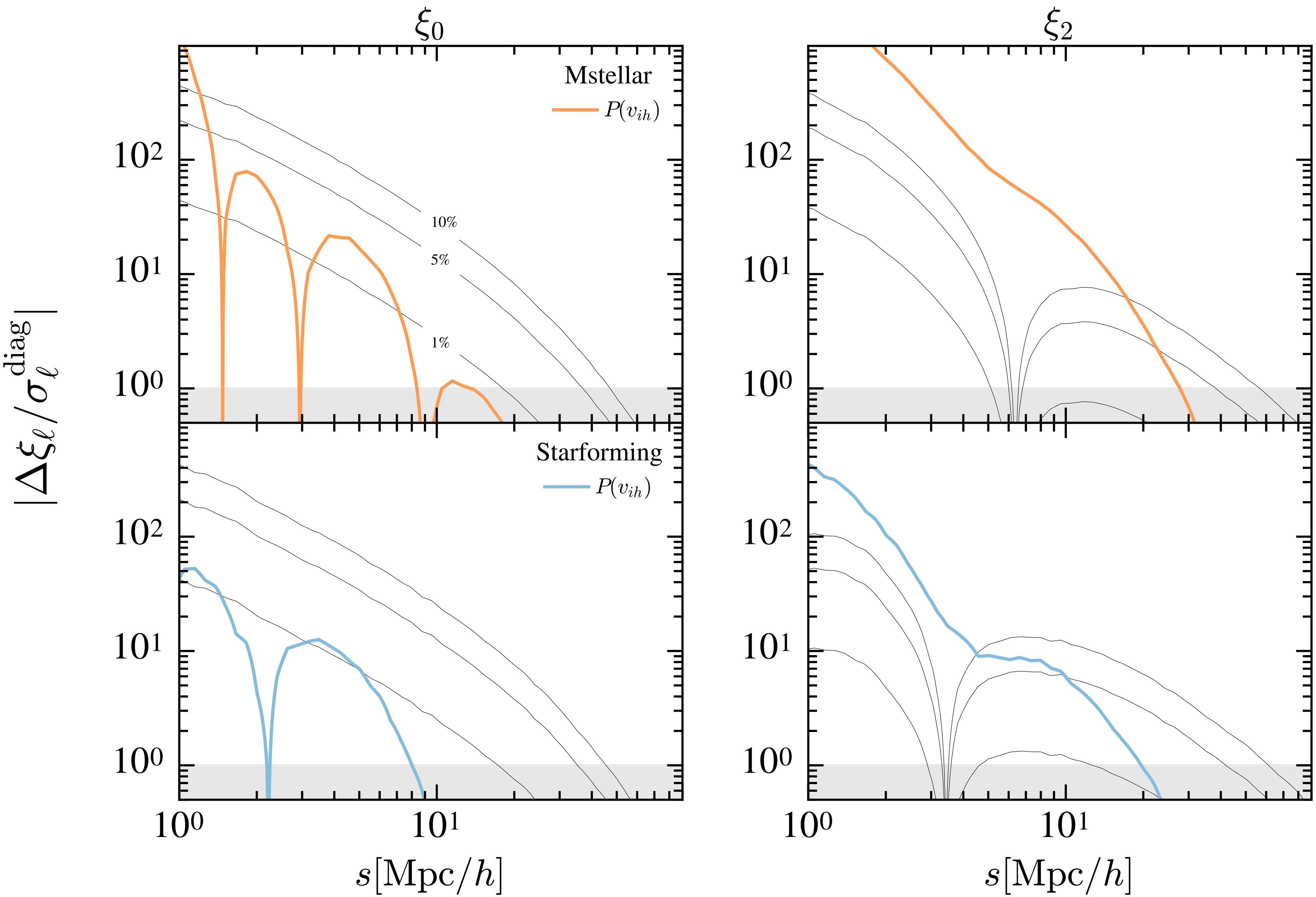
Implementing more accurate velocities



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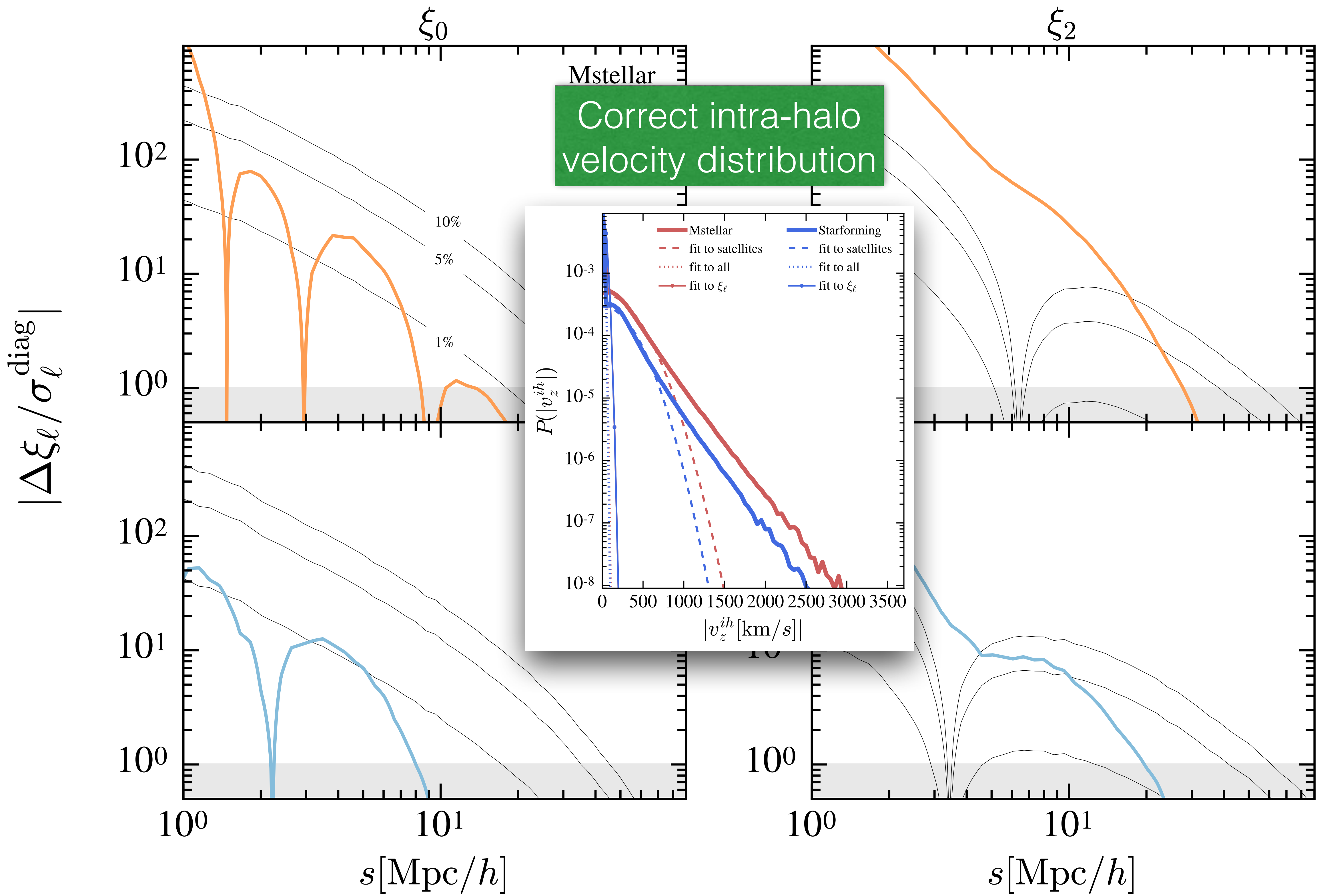

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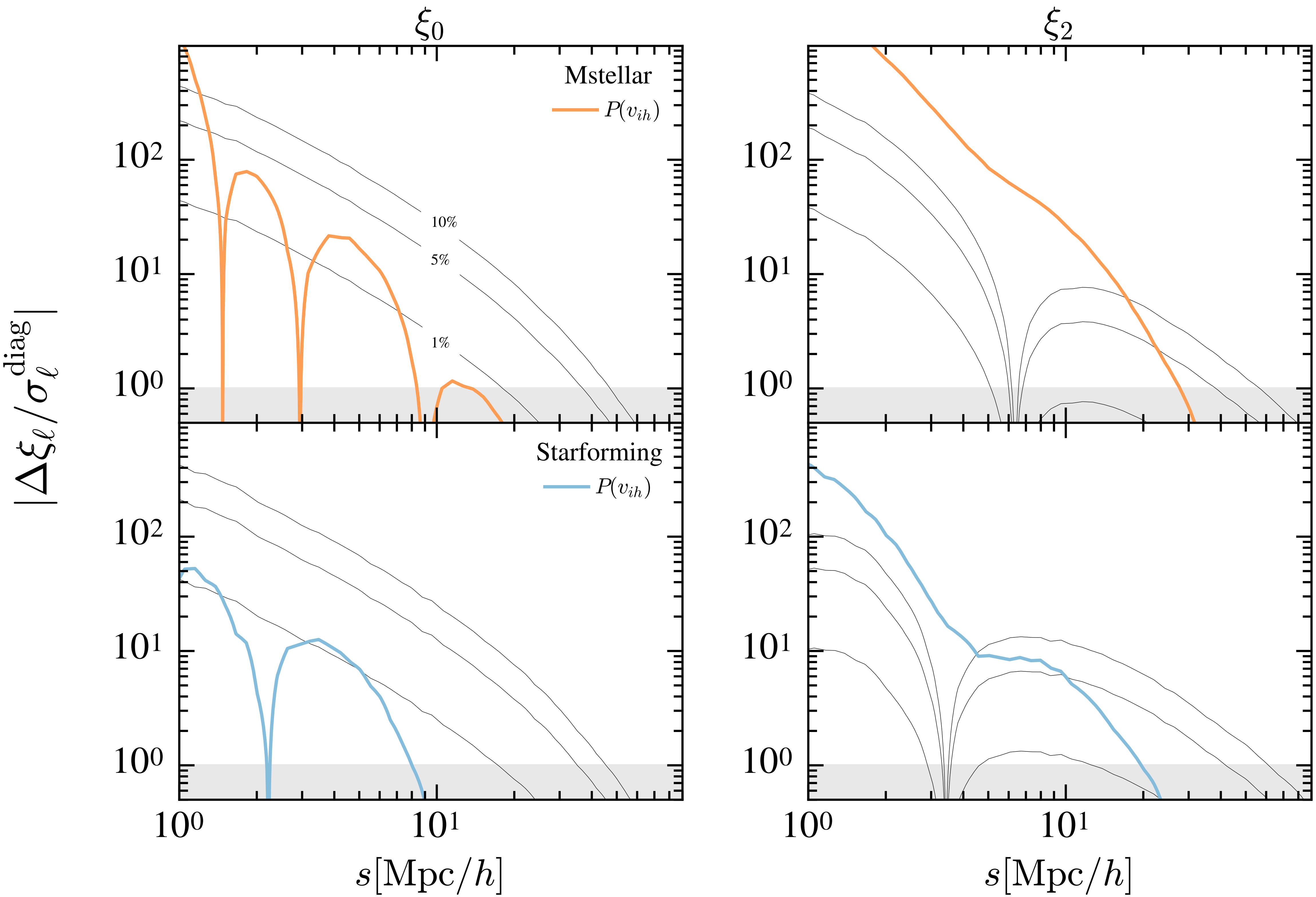

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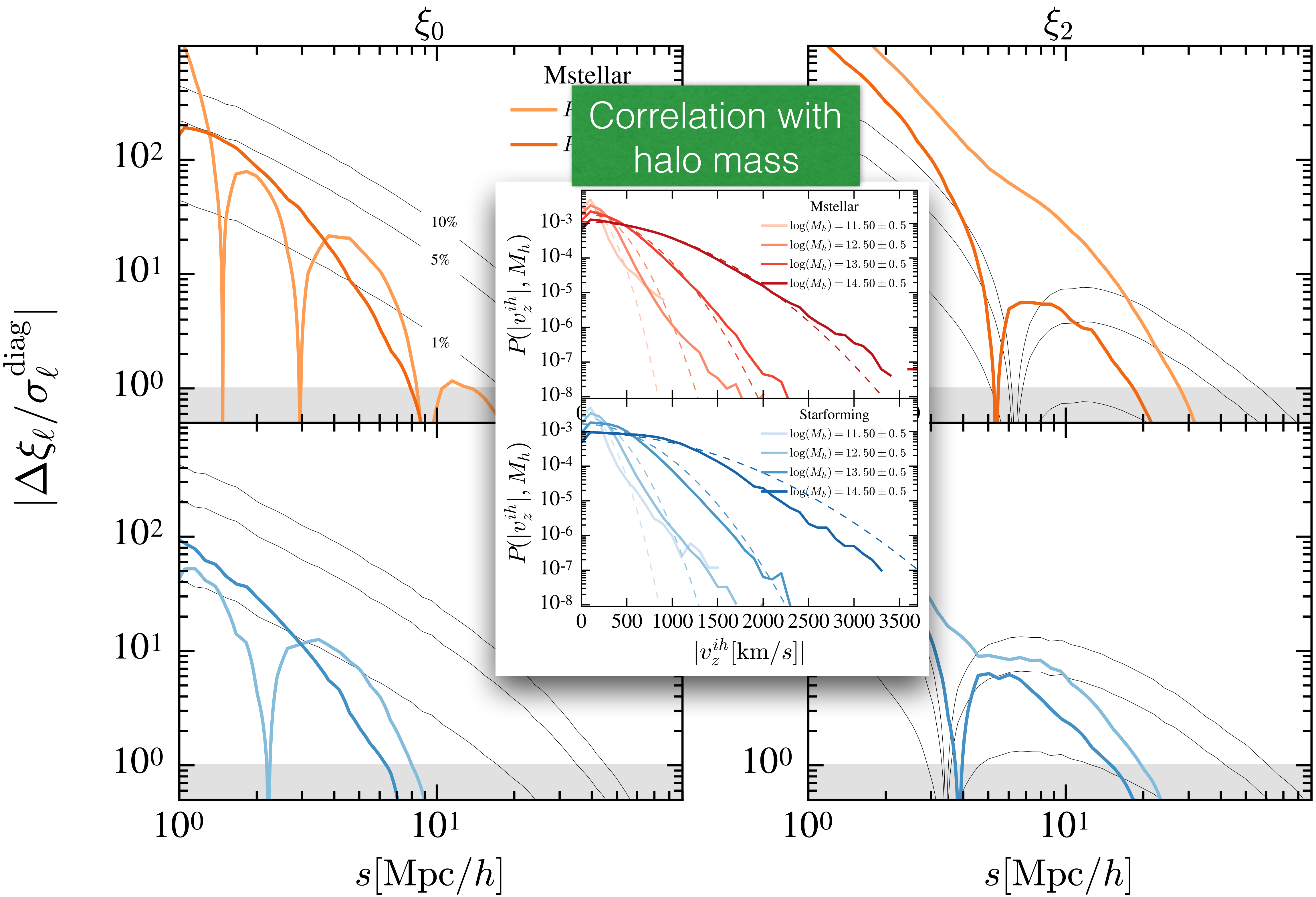

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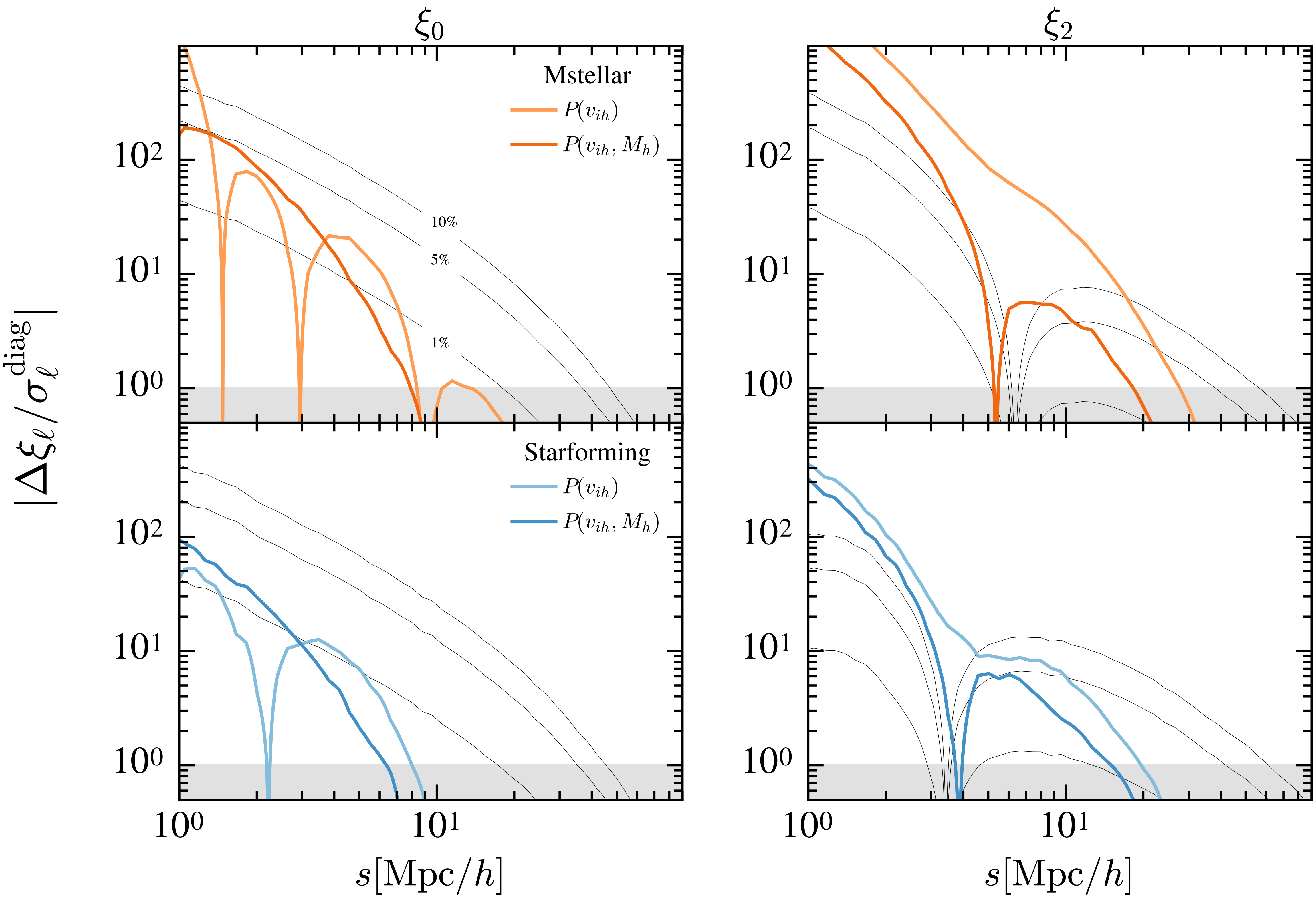

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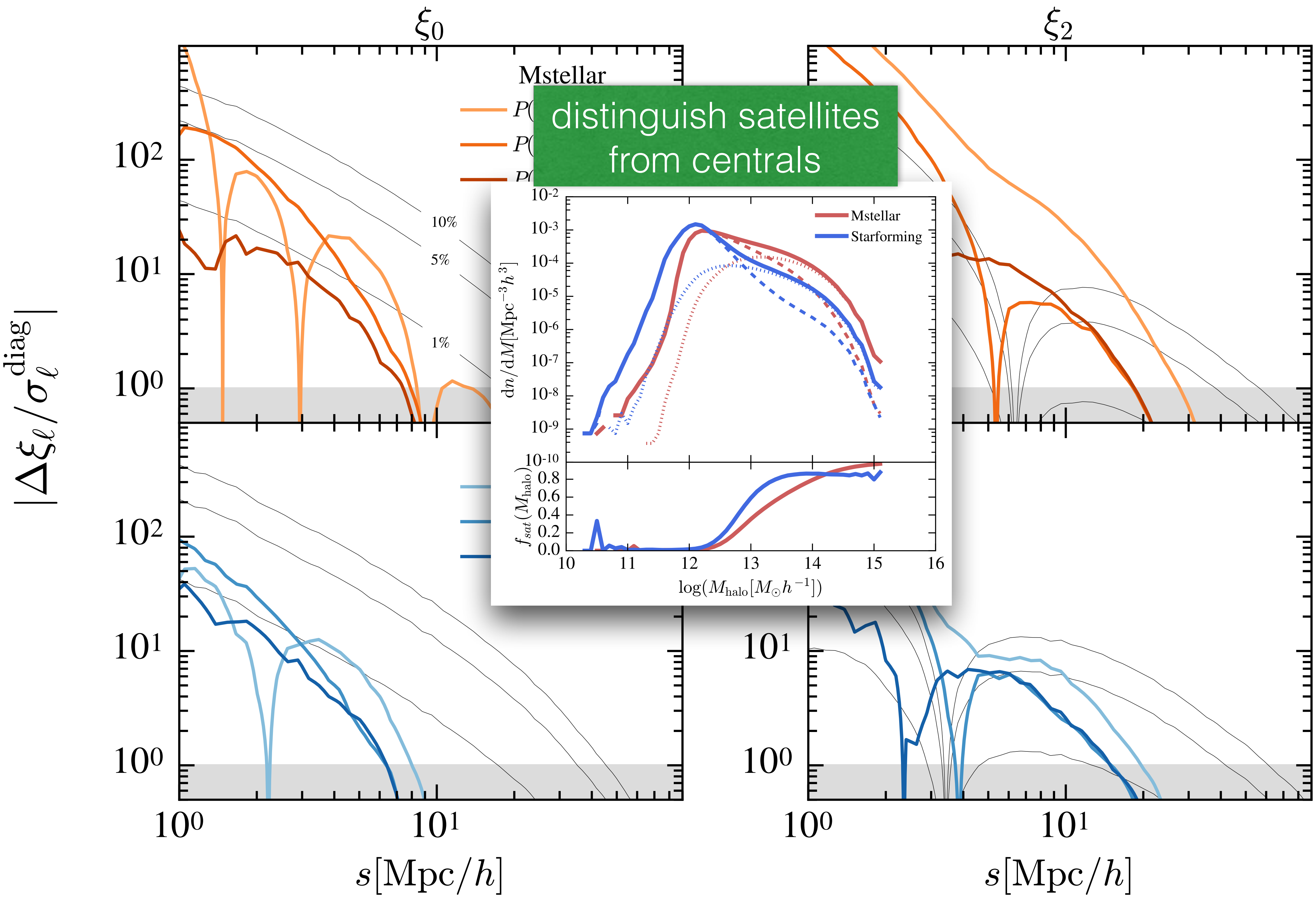

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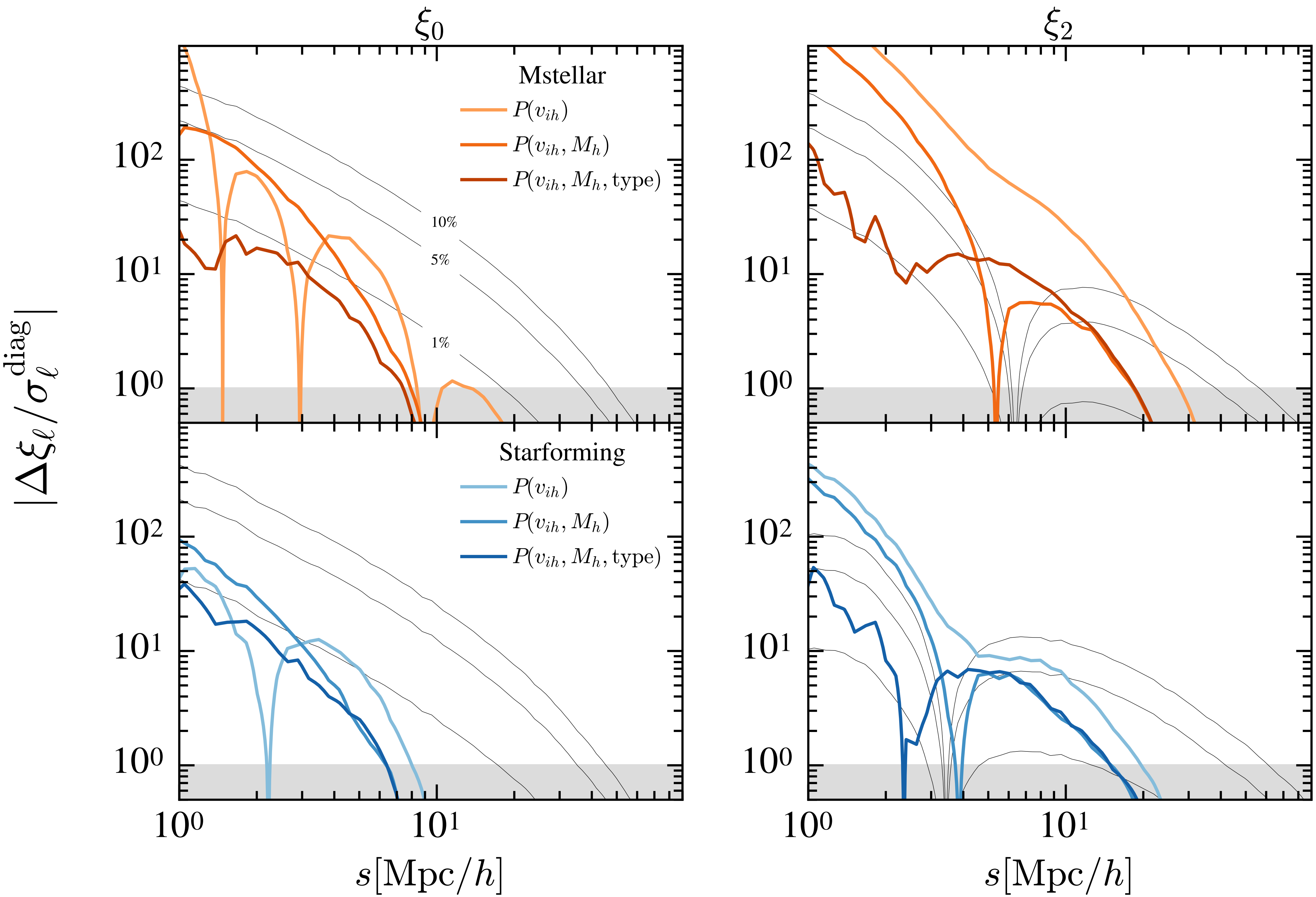

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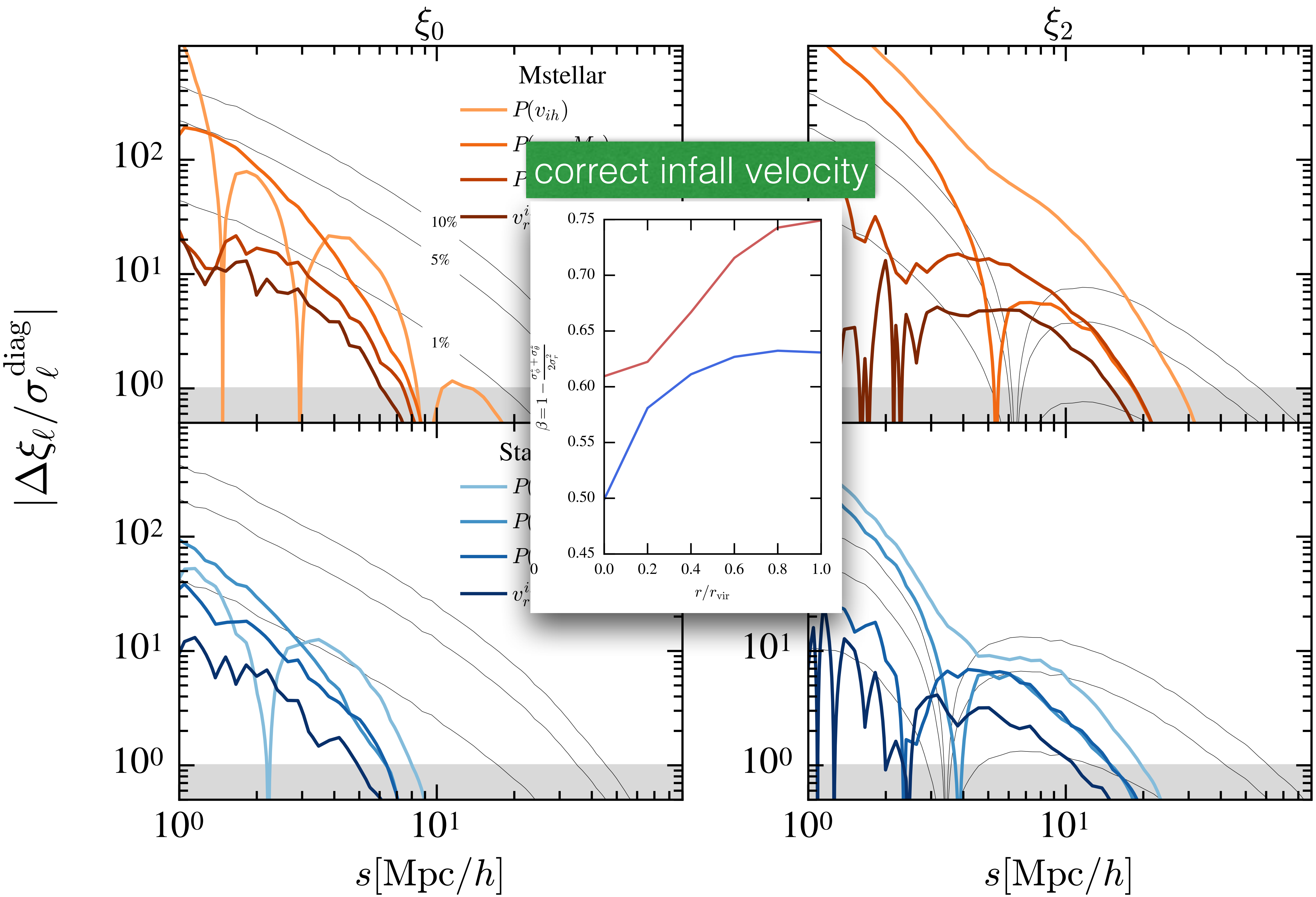

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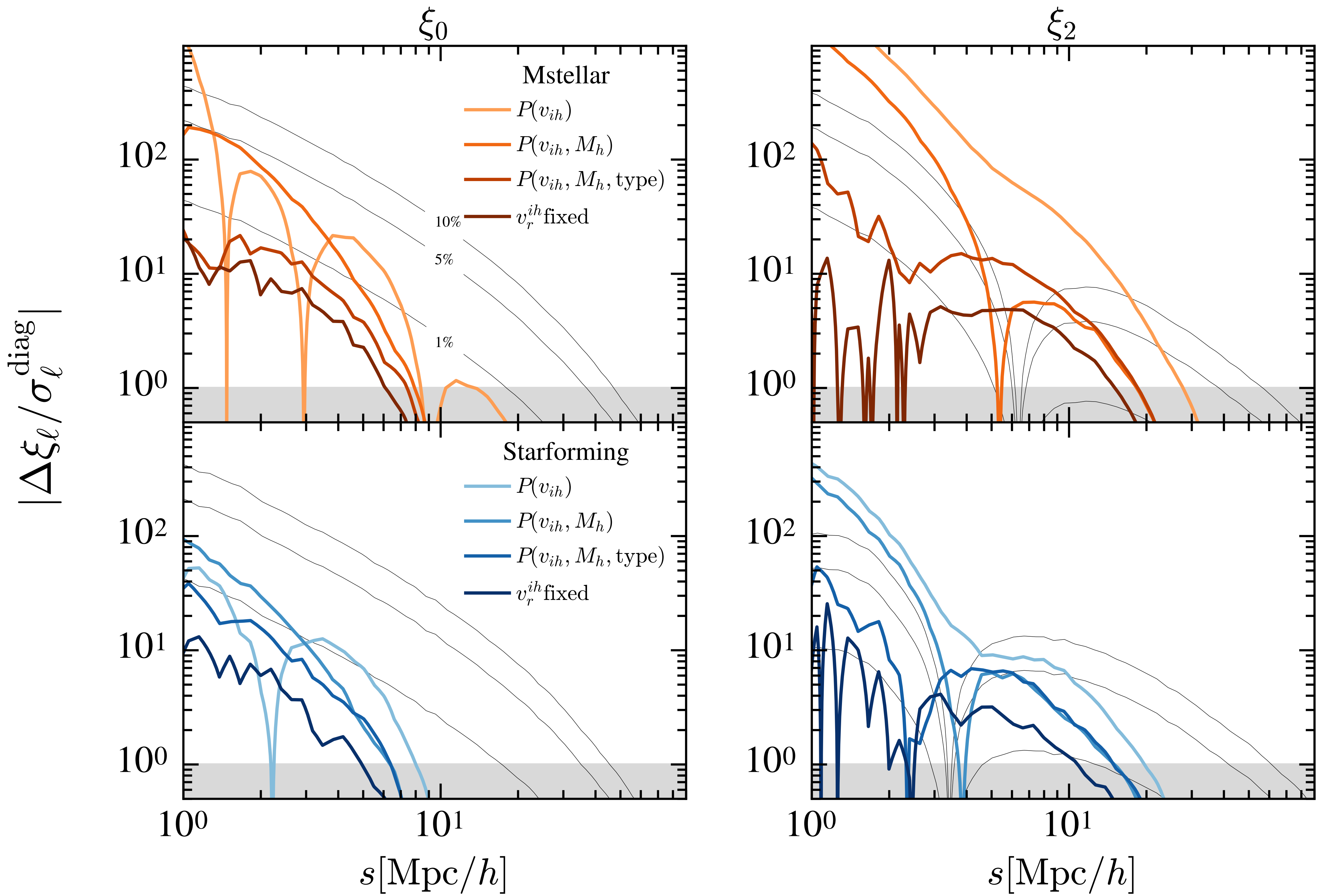

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Conclusions

- Different galaxy populations *behave differently* in redshift-space
- Intra-halo velocities (i.e. Fingers-of-god) currently **limits models accuracy**
  - Wasting most accurate measurements of xi, **sub-optimal cosmological exploitation of data**
- 3 problems: i) Velocity distribution is *not Gaussian*, ii) Correlates with *halo mass*, iii) *Anisotropic* velocity dispersion
- Taking *galaxy formation* into account makes descriptions accurate to scales of a **few Mpc/h**
  - ***Potential for improving current analysis of RSDs using galaxy formation models***