Large-scale structure and the intrinsic alignment of galaxies

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IAU 308 - Tallinn

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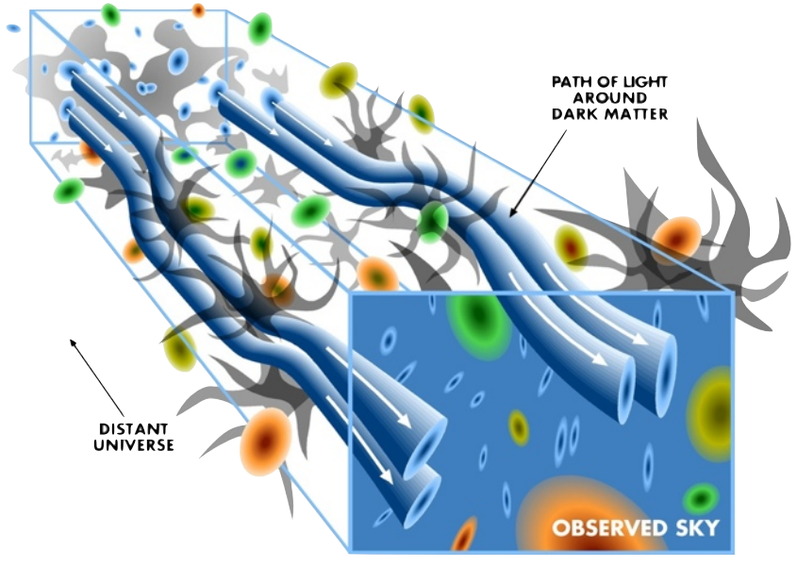
image: Bolshoi

Overview

- Weak lensing and intrinsic alignments (IA)
- Measuring IA in observations
- Modeling IA
  - Tidal (linear) alignment
  - IA as a probe of structure and galaxy/halo physics

IA and weak lensing



$$\gamma^{obs} = \gamma^I + \gamma^G$$

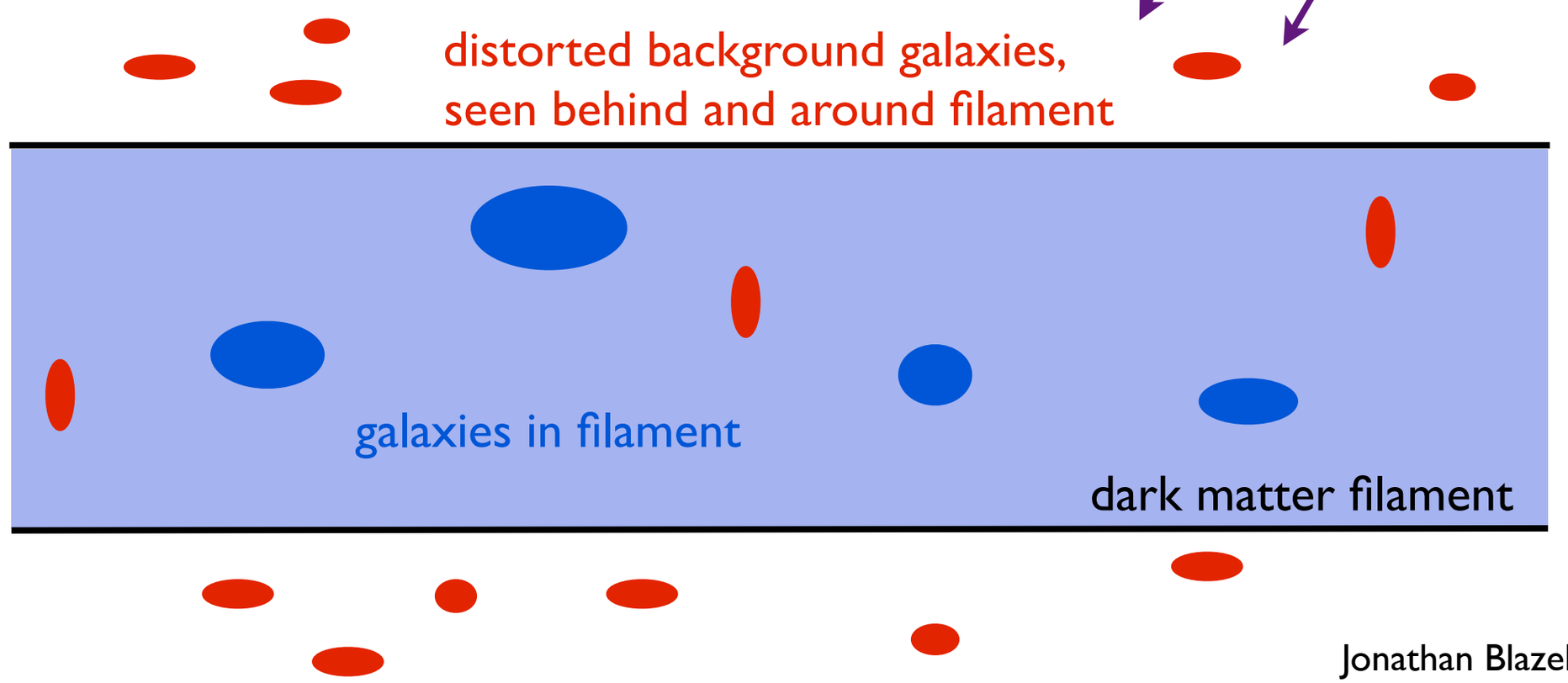
IA auto-correlation

$$\langle \gamma_i^{obs} \gamma_j^{obs} \rangle = \langle \gamma_i^G \gamma_j^G \rangle + \langle \gamma_i^I \gamma_j^G \rangle + \langle \gamma_i^G \gamma_j^I \rangle + \langle \gamma_i^I \gamma_j^I \rangle$$

lensing signal

IA-lensing cross-correlation
*harder to remove

(Hirata & Seljak 2004)



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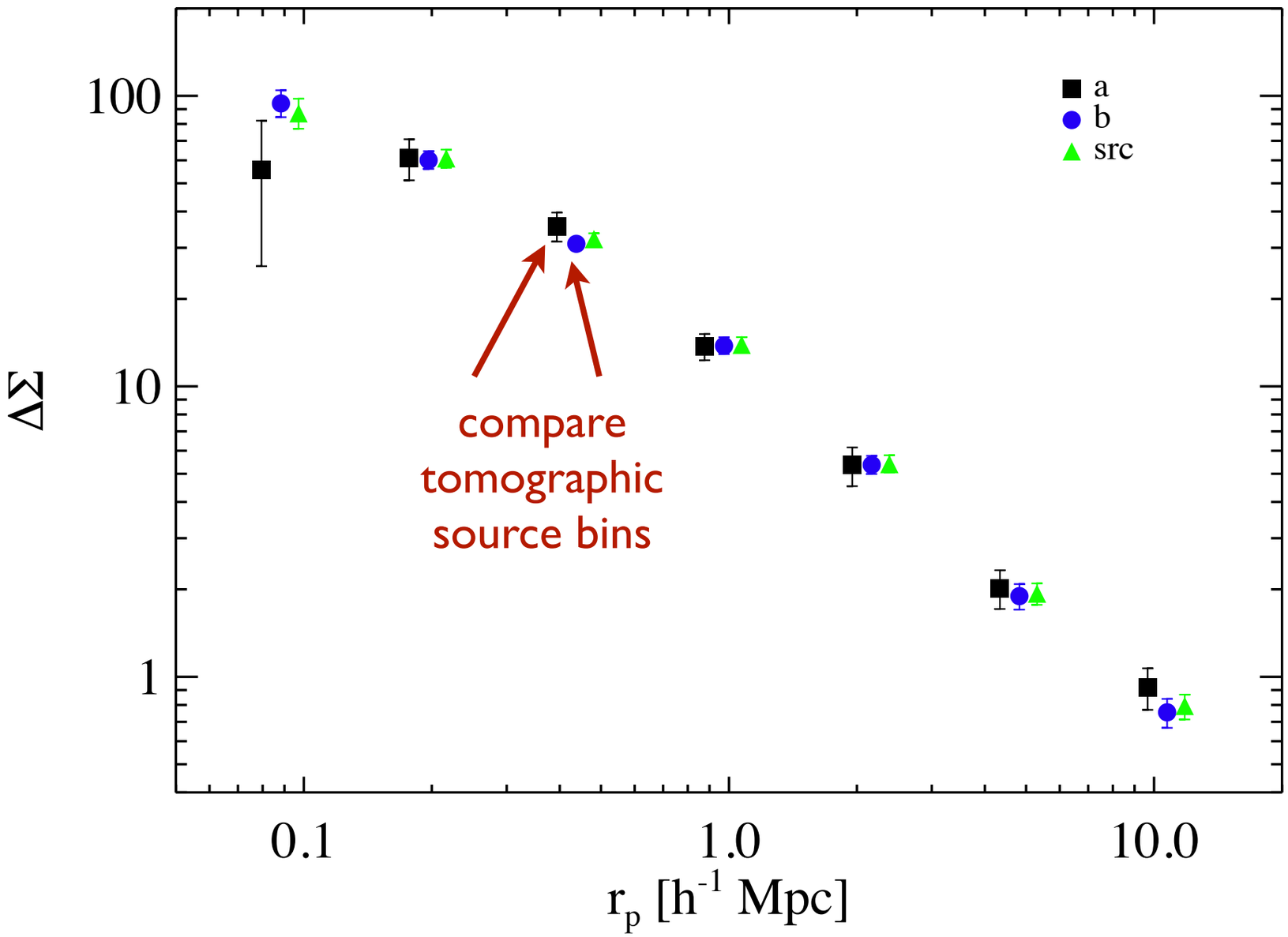
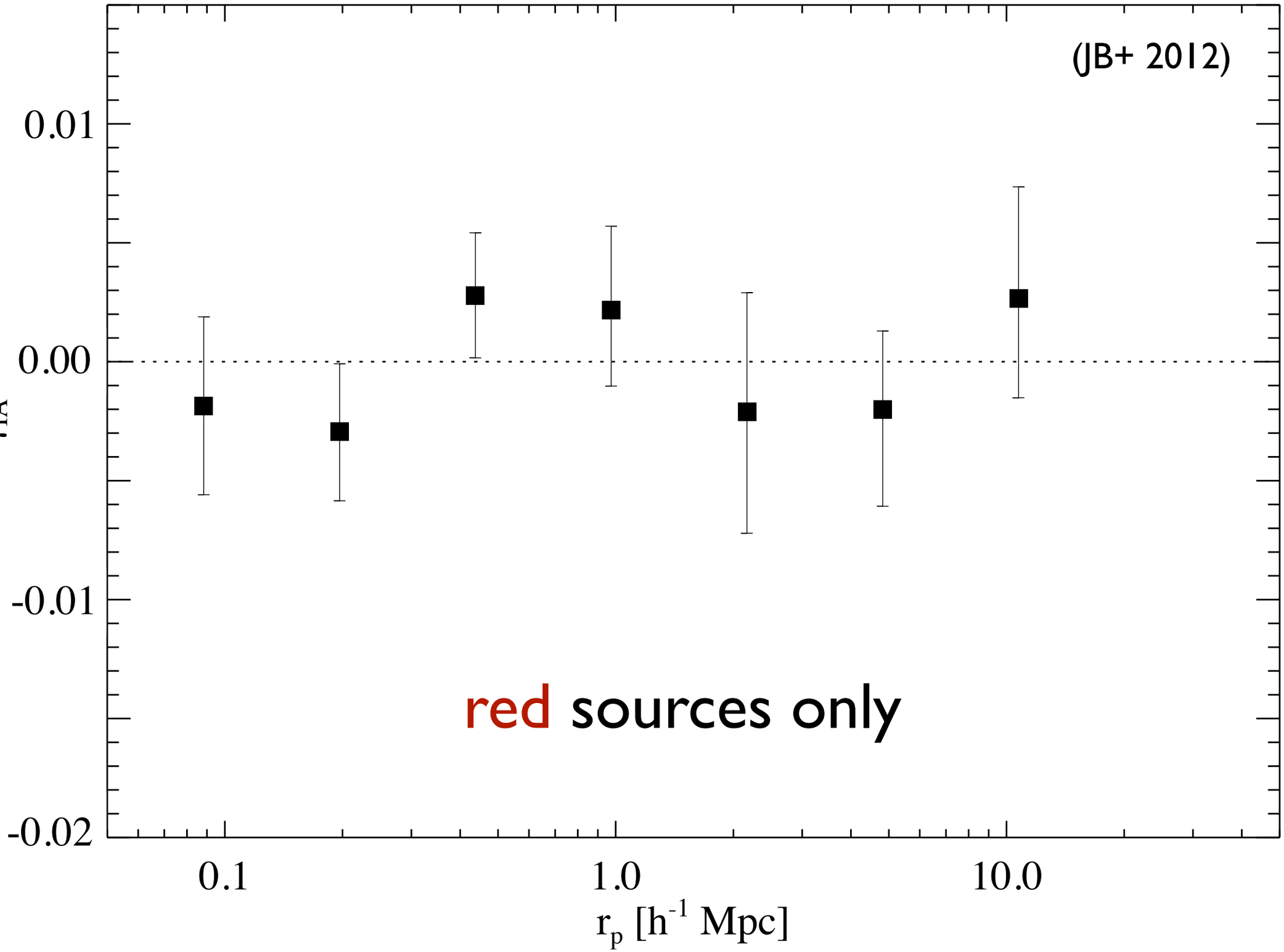
Separating IA and lensing signals

$$\widetilde{\Delta\Sigma} \sim \left\langle \tilde{\Sigma}_{\rm c} \tilde{\gamma}_{\rm t} \right\rangle = \left\langle \tilde{\Sigma}_{\rm c} \left(\Delta\Sigma {\Sigma_{\rm c}}^{-1} + \gamma_{\rm t,IA} \right) \right\rangle$$

observed signal — lensing signal — IA contamination



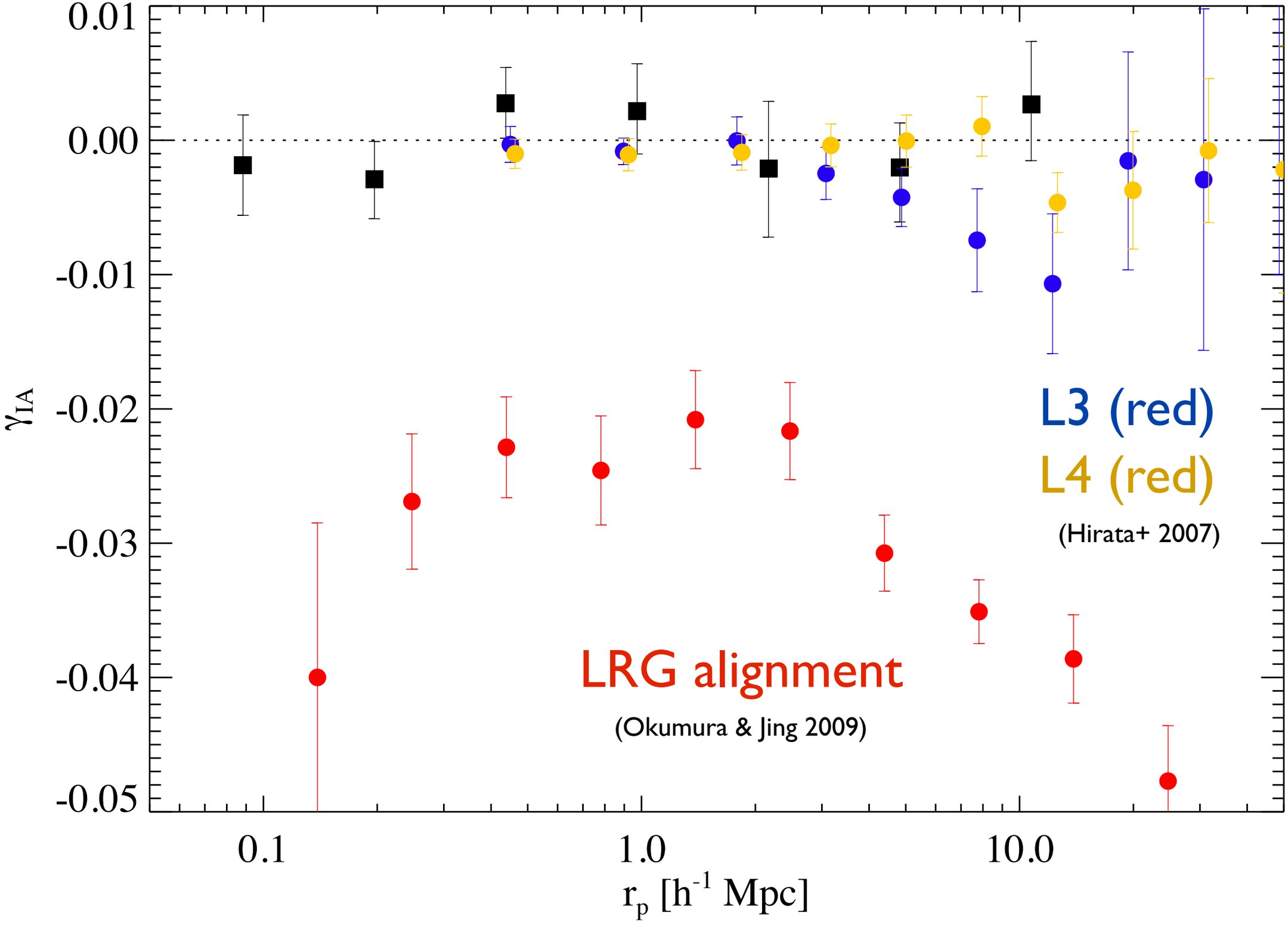
IA per excess lens-source pair



red sources only

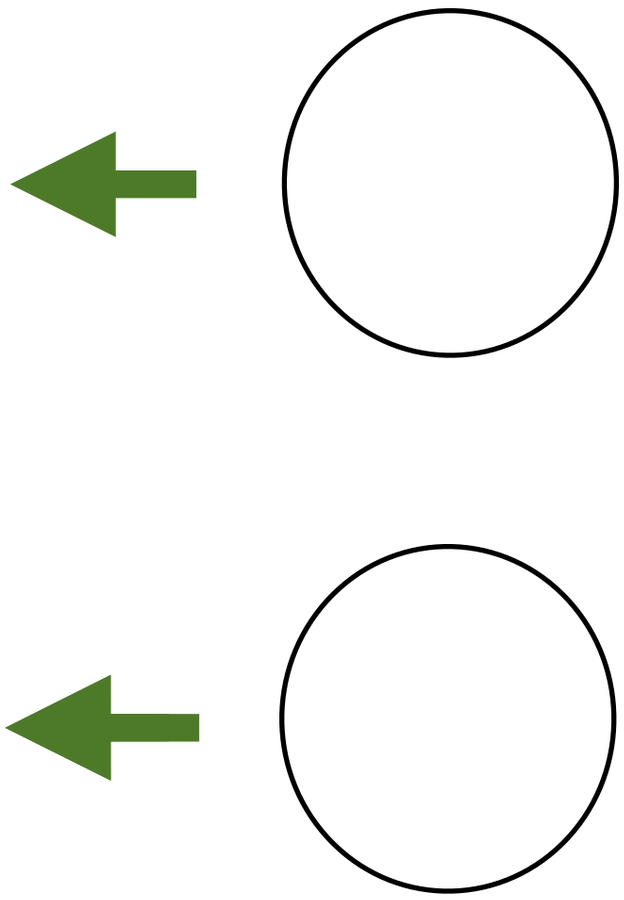
SDSS DR7 LRG lenses (~62k) at z=0.16-0.36

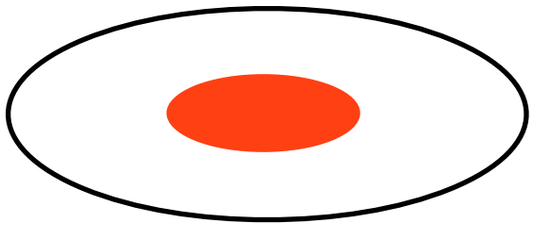
IA per excess lens-source pair



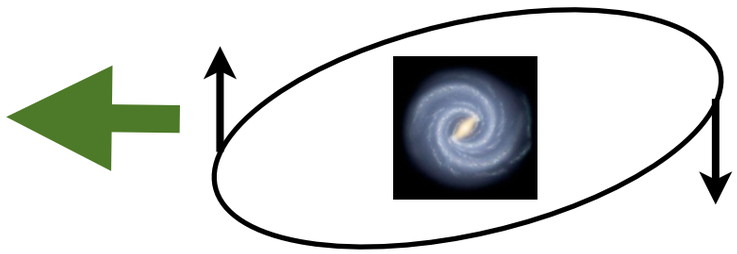
IA modeling

tidal field: T

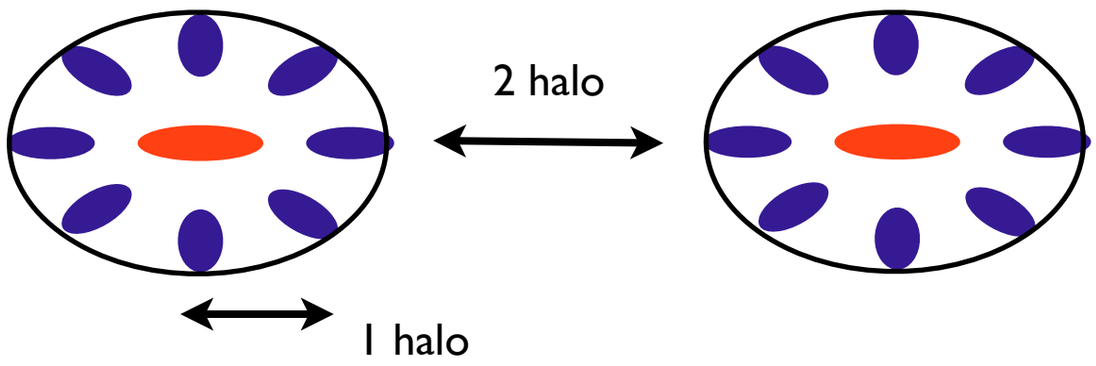




tidal alignment:
linear in T
(Catelan+ 2001)



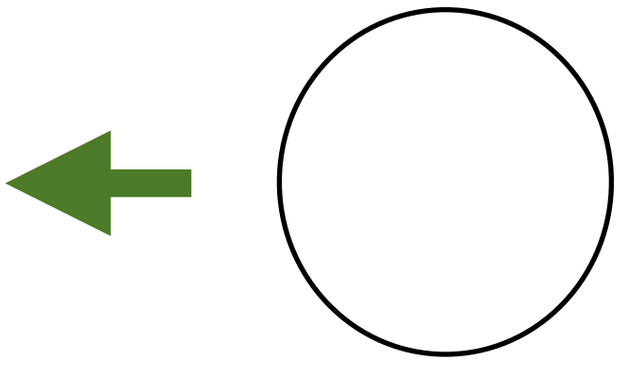
tidal torquing:
quadratic in T
(Talks by Lee, Codis, Pichon)

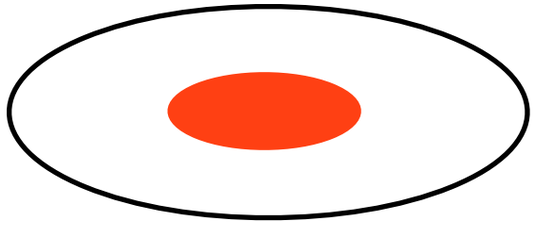


hybrid halo model
(e.g. Schneider&Bridle 2009)

IA modeling

tidal field: T





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hybrid halo model
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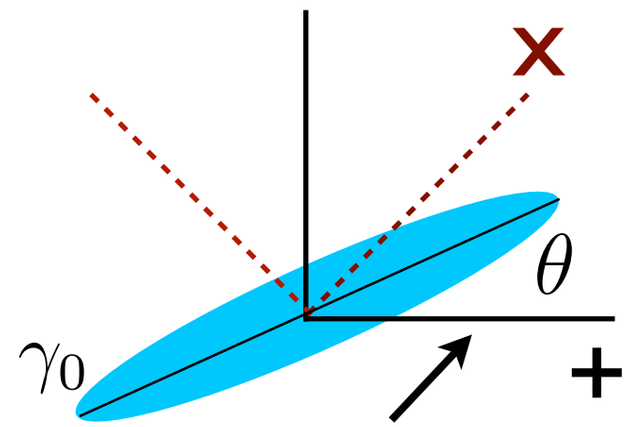
Tidal alignment model

(Catelan+ 2001)

$$\gamma^I_{(+,\times)} = -\frac{C_1}{4\pi G}(\nabla^2_x - \nabla^2_y, 2\nabla_x\nabla_y)S[\Psi_P]$$

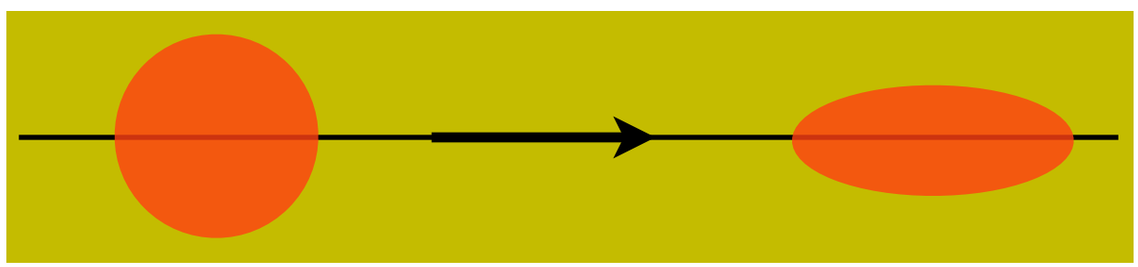


- Ellipticity aligns with tidal field
- Should dominate on large scales: ~ P(k)

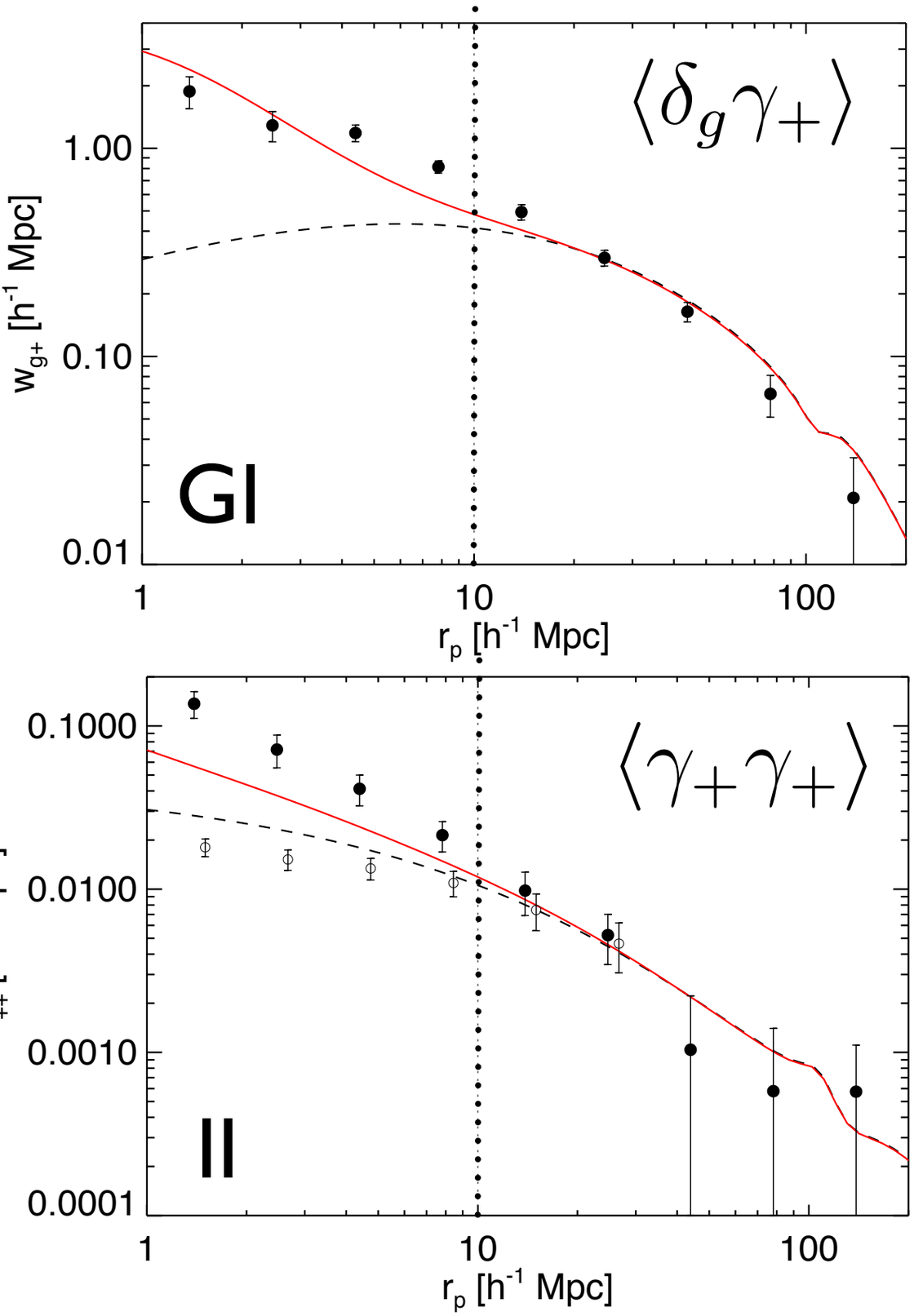
$$\gamma_+ = \gamma_0 \cos 2\theta$$

$$\gamma_\times = \gamma_0 \sin 2\theta$$

tidal field



The model works!

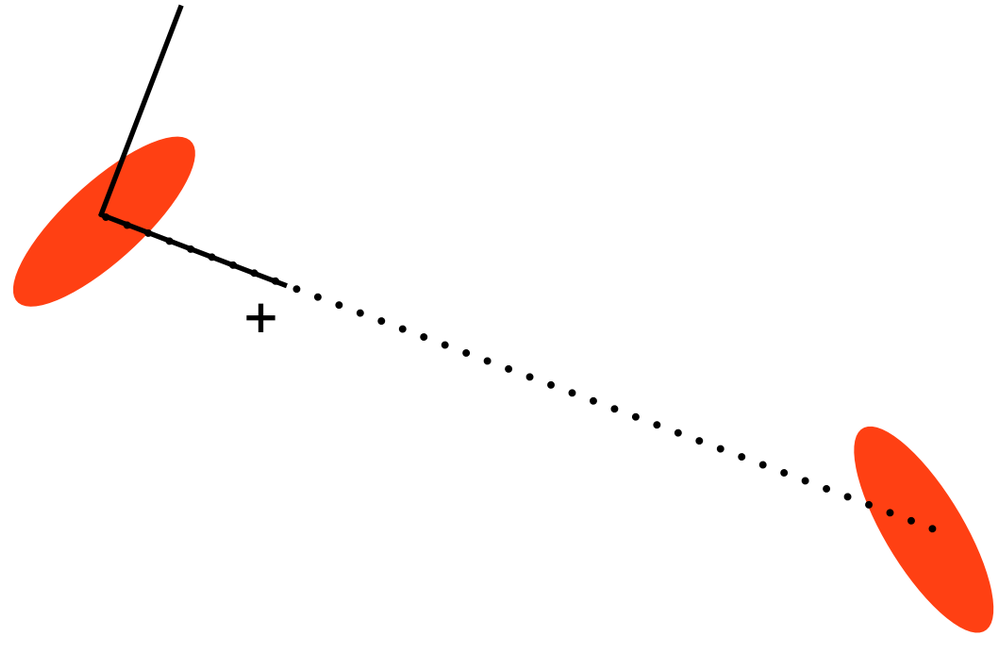


Luminous red galaxies (LRGs) from SDSS DR7
0.16<z<0.47 (Okumura+ 2009; Okumura & Jing 2009)

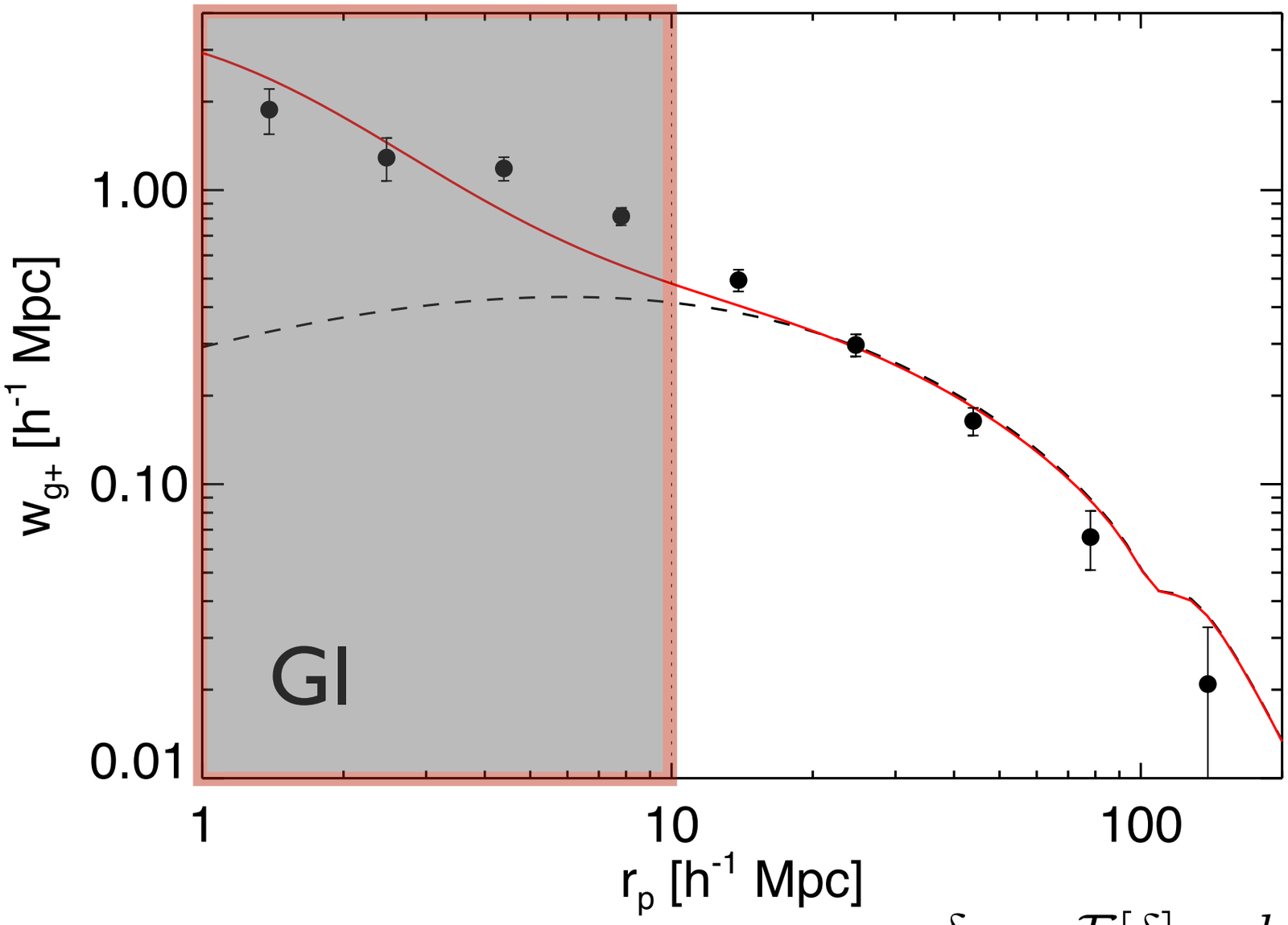
(JB+ 2011)

Test	$C_1 \rho_{\rm crit}$
w_{g+}	0.125 ± 0.007
w_{++}	0.123 ± 0.014

(c.f. Joachimi, Mandelbaum+ 2011)



Modeling smaller scales

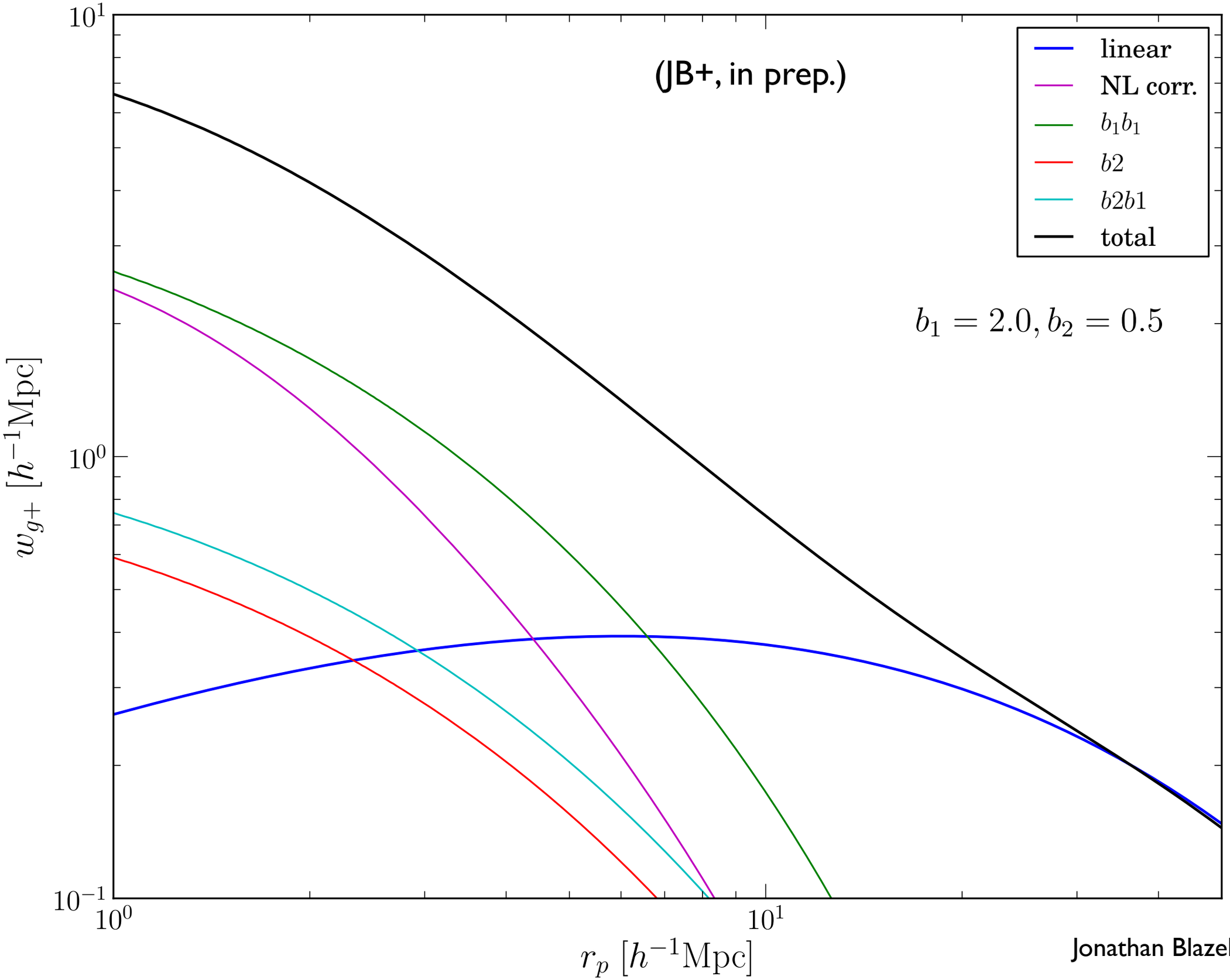


$$\delta_g = \mathcal{F}[\delta] \approx b_1\delta + b_2\delta^2 + \cdots$$

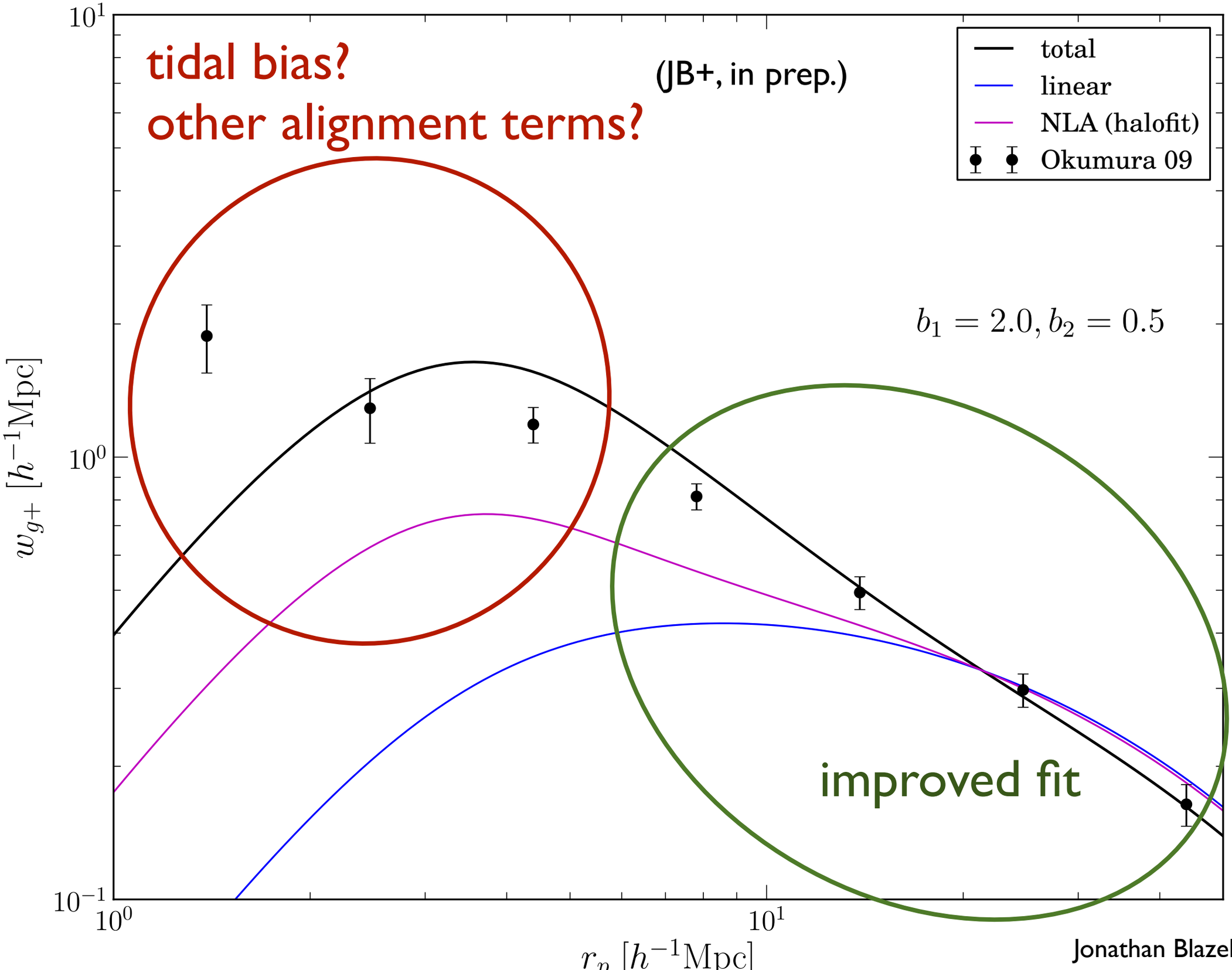
$$\langle \delta_g | (1+\delta_g)\gamma_+ \rangle = b_1\langle \delta|\gamma_+\rangle + b_2\langle \delta\delta|\gamma_+\rangle + b_1^2\langle \delta|\delta\gamma_+\rangle + b_2 b_1 \langle \delta\delta|\delta\gamma\rangle + \mathcal{O}(P_{\rm lin}^3)$$

"NLA model" nonlinear bias density weighting

Additional contributions

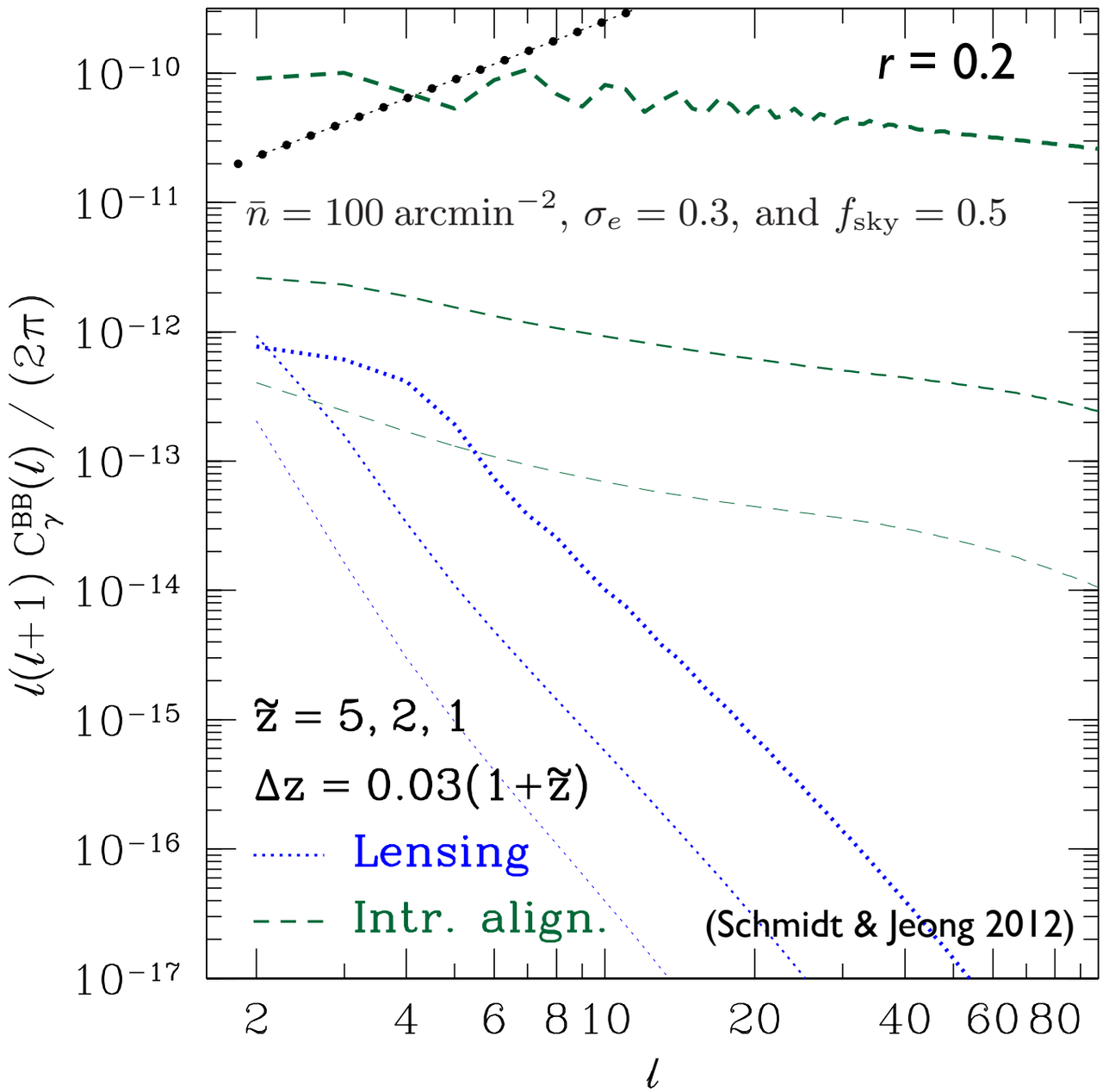


Fit to data


tidal bias?
other alignment terms?
(JB+, in prep.)
total
linear
NLA (halofit)
Okumura 09
$b_1 = 2.0, b_2 = 0.5$
improved fit
$w_{g+}\ [h^{-1}\mathrm{Mpc}]$
$r_p\ [h^{-1}\mathrm{Mpc}]$
10^1
10^0
10^{-1}
10^0
10^1

Intrinsic alignments as a signal

- halo and galaxy formation and evolution (e.g. JB+ 2011)
- additional tracer of LSS (e.g. Chisari & Dvorkin 2013)
- density field reconstruction (c.f. Lee & Pen 2000)
- nonlinear and tidal galaxy bias (JB+, in prep.)
- tidal field B-modes from primordial gravity waves (Schmidt & Jeong 2012; Chisari+ 2014)



Summary

- We have made a lot of progress in understanding IA - more is needed!

- Indirect measurement constraints IA contamination in SDSS to ~2% - apply method to new data sets

- Tidal alignment provides a good description for LRGs on large scales - nonlinear corrections improve the model on smaller scales

- Future/ongoing work:
  - Nonlinear alignment effects
  - Compare with N-body and hydro sims
  - IA measurements on new data sets, including DES

- See papers: JB+ 2011 (JCAP 5, 10); JB+ 2012 (JCAP 4, 41); JB+ in prep.