Using galaxy pairs as cosmological tracers

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Work in collaboration with:
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Phys. Rev. D 86, 023530, arXiv:1204.5761v2

10th of August 2012
Benasque 2012

Introduction: the AP effect and peculiar velocities

When analysed with correct geometry → Structure statistically isotropic

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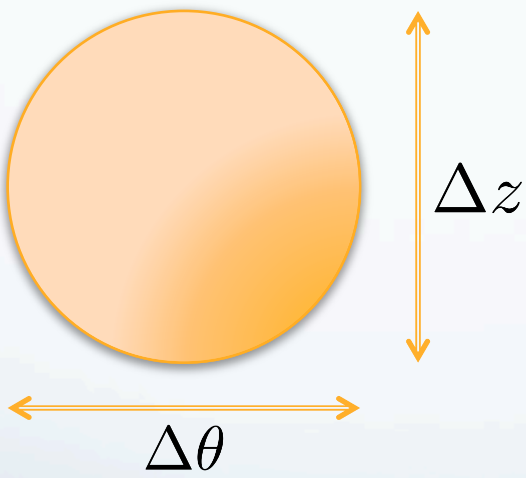

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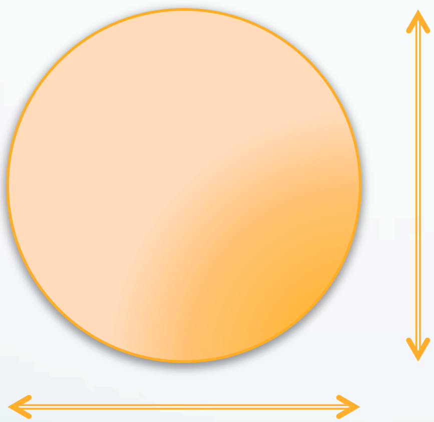

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$$d_1 = d_A(z)\Delta\theta$$

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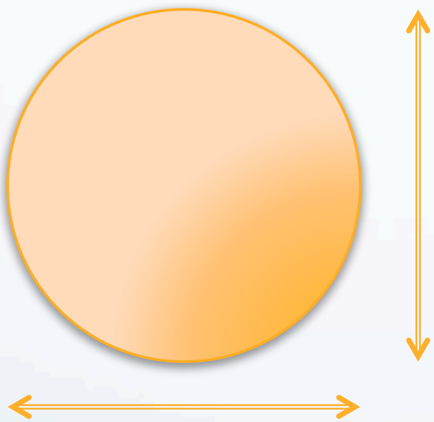

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$$H(z)d_A(z) = \frac{\Delta z}{(1+z)\Delta\theta}$$

$$d_1 = d_A(z)\Delta\theta$$

C. Alcock & B. Paczynski, Nature 281, 358, 1979

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→ Add to observed redshifts (RSD)

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AP measurements limited by peculiar velocities

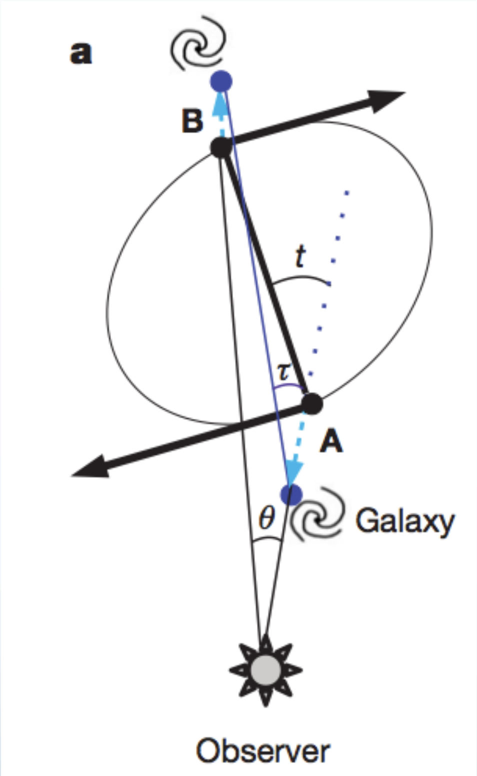
→ Add to observed redshifts (RSD)

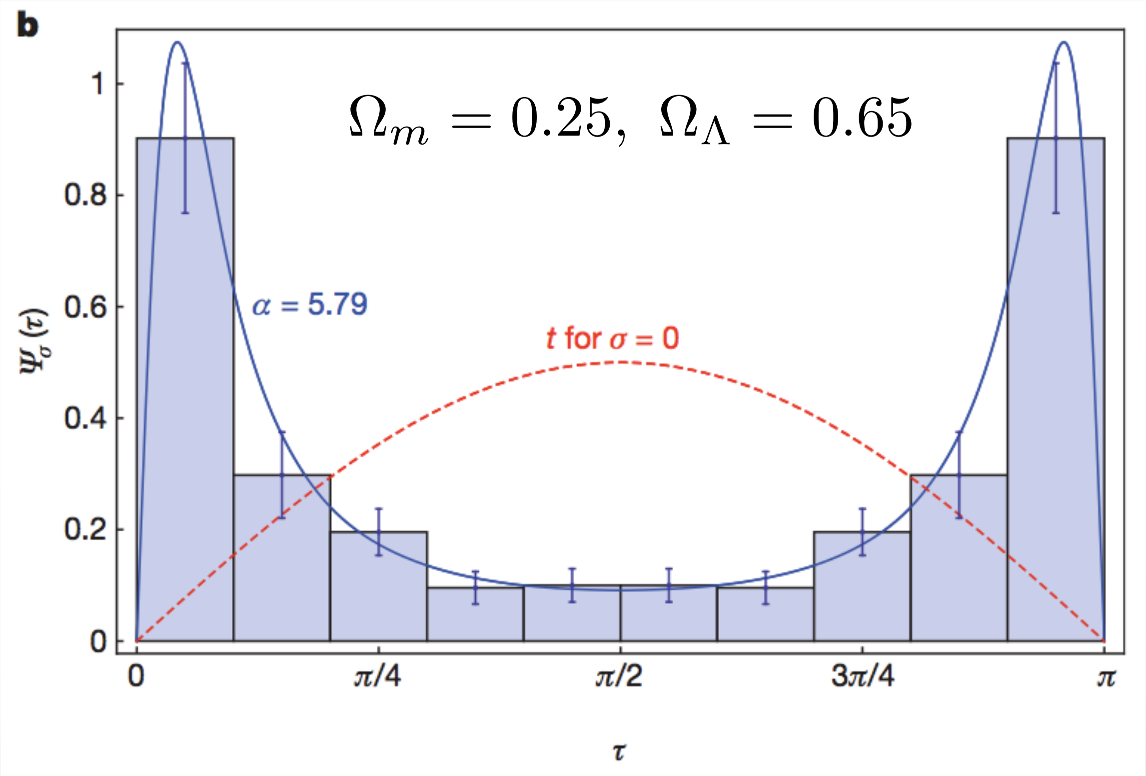
→ RSD are degenerate with the AP effect

REMOVE SIGNAL!!!

Galaxy pairs and the AP effect

Marinoni & Buzzi suggested using randomly oriented isolated galaxy pairs





C. Marinoni & A. Buzzi, Nature 468, 539, 2010

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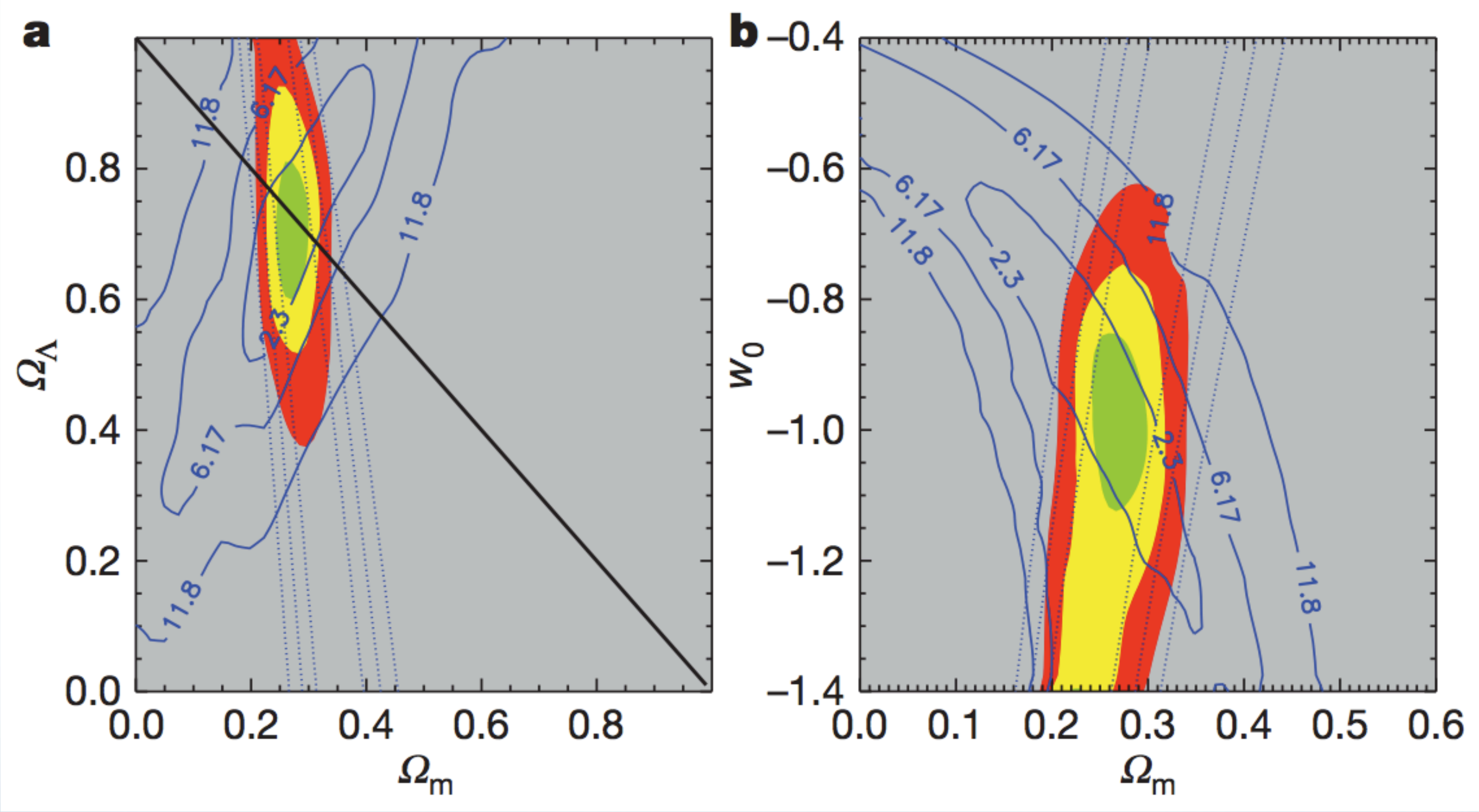

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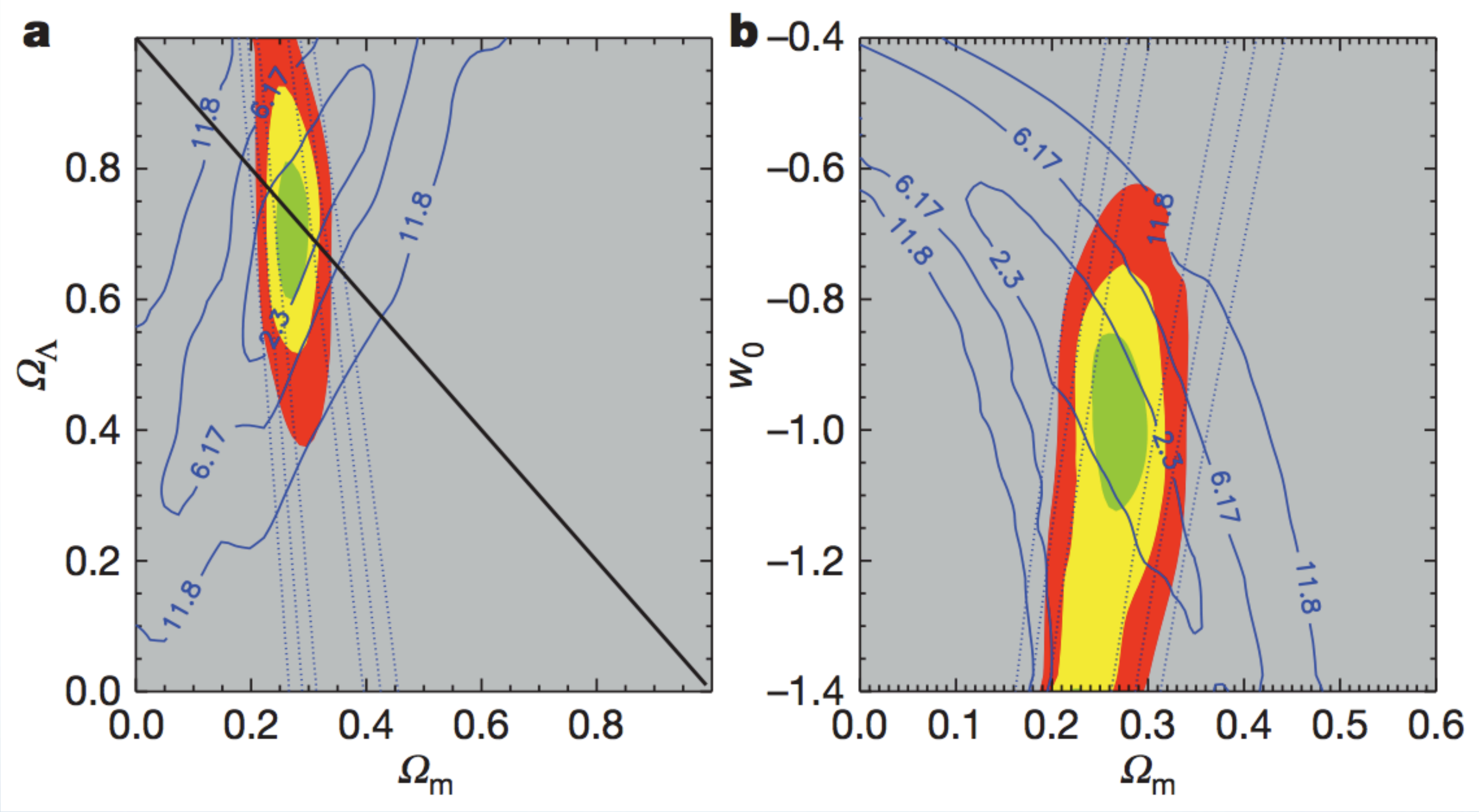
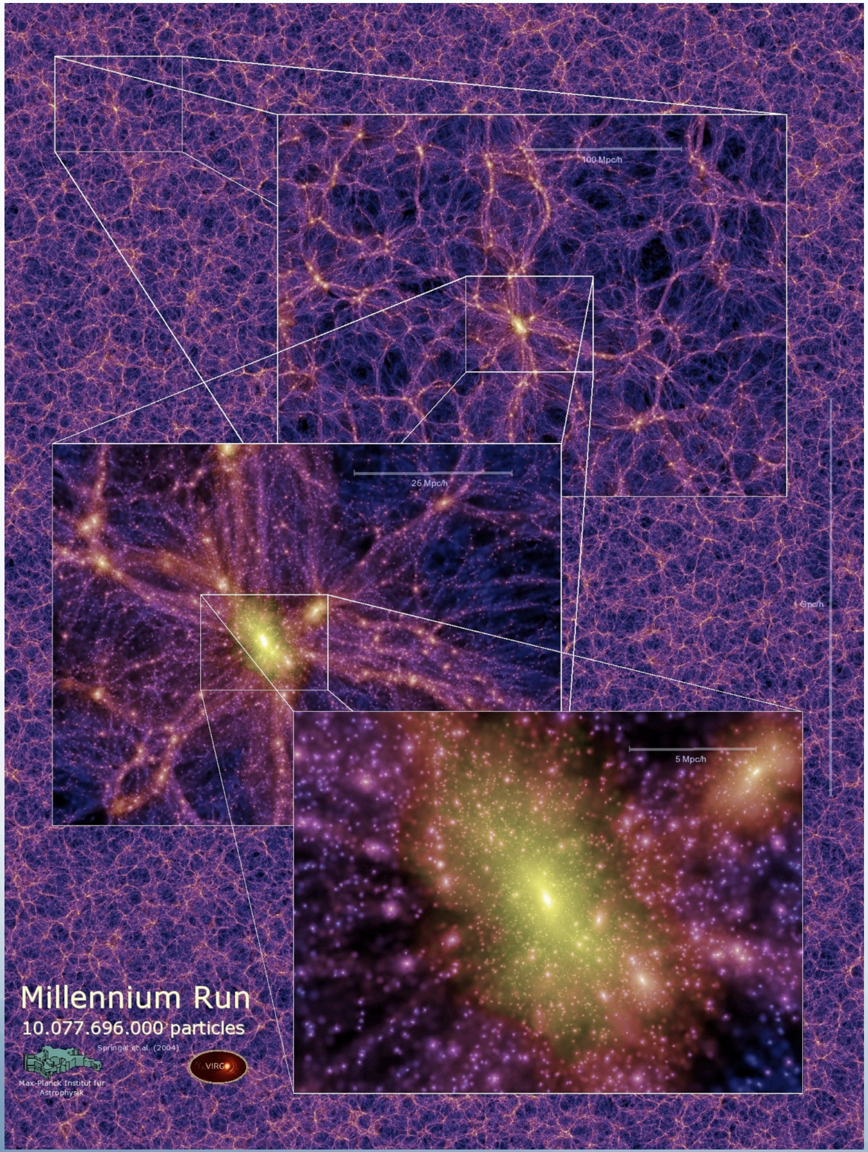


Jennings *et al.* further developed idea using N-body simulations

C. Marinoni & A. Buzzi, Nature 468, 539, 2010

E. Jennings *et al.*, MNRAS 420, 1079, 2012

The Millennium Simulation



2160^3 dark matter particles
Mass = 1.18×10^9 $M_\odot$
z = 0 – 127
Size = 500 Mpc/h

ΛCDM cosmology

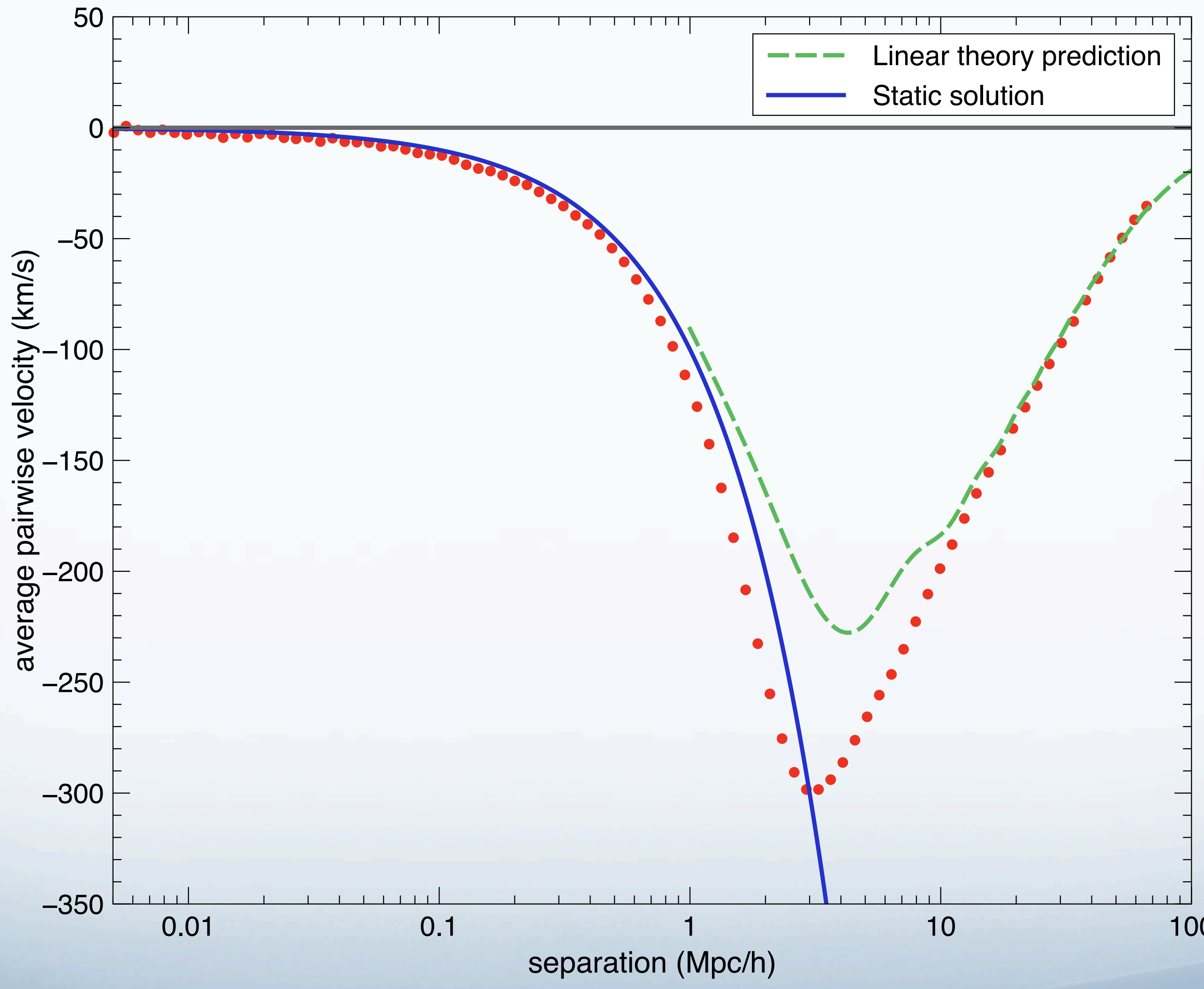
$$\Omega_m = 0.25, \quad \Omega_b = 0.045, \quad \Omega_\Lambda = 0.75,$$
$$n = 1, \quad \sigma_8 = 0.9, \quad H_0 = 73 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

Semi-analytic models:

- Guo *et al.*, MNRAS 413, 101, 2011
- Font *et al.*, MNRAS 389, 1619, 2008

Springel *et al.*, Nature 435, 629, 2005

Results: all galaxy pairs at z=0



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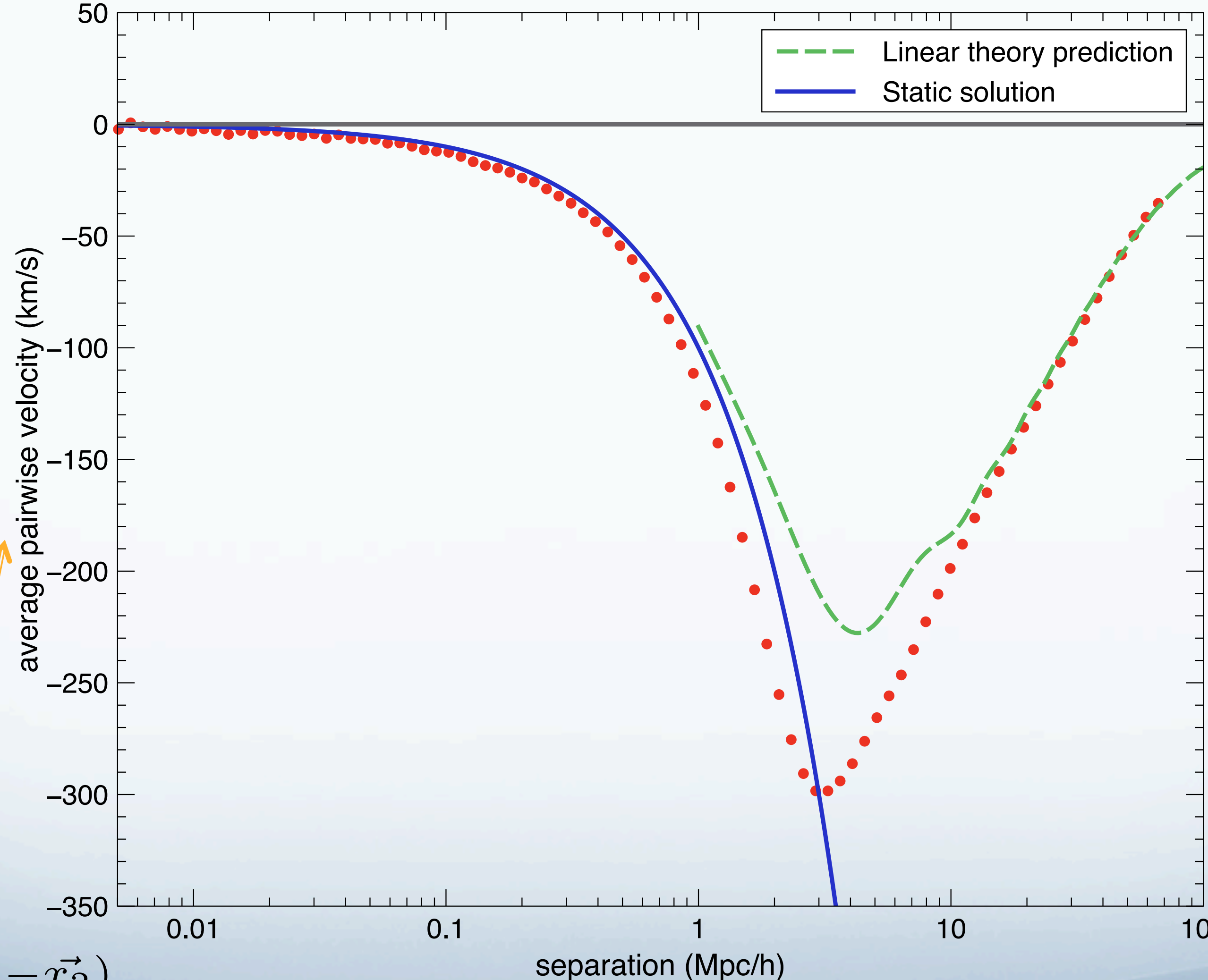

$$\frac{(\vec{v_1} - \vec{v_2}) \cdot (\vec{x_1} - \vec{x_2})}{d}$$

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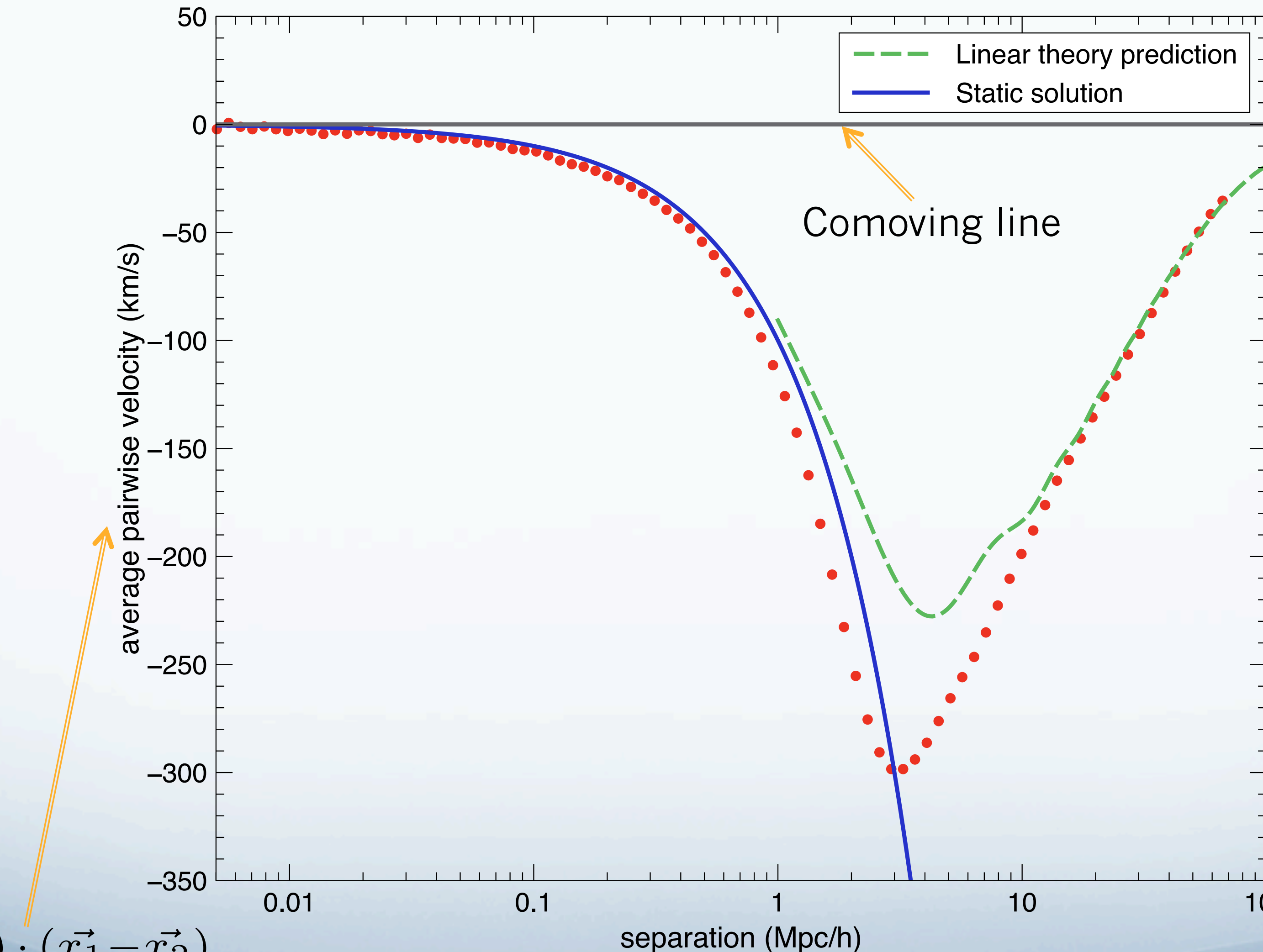

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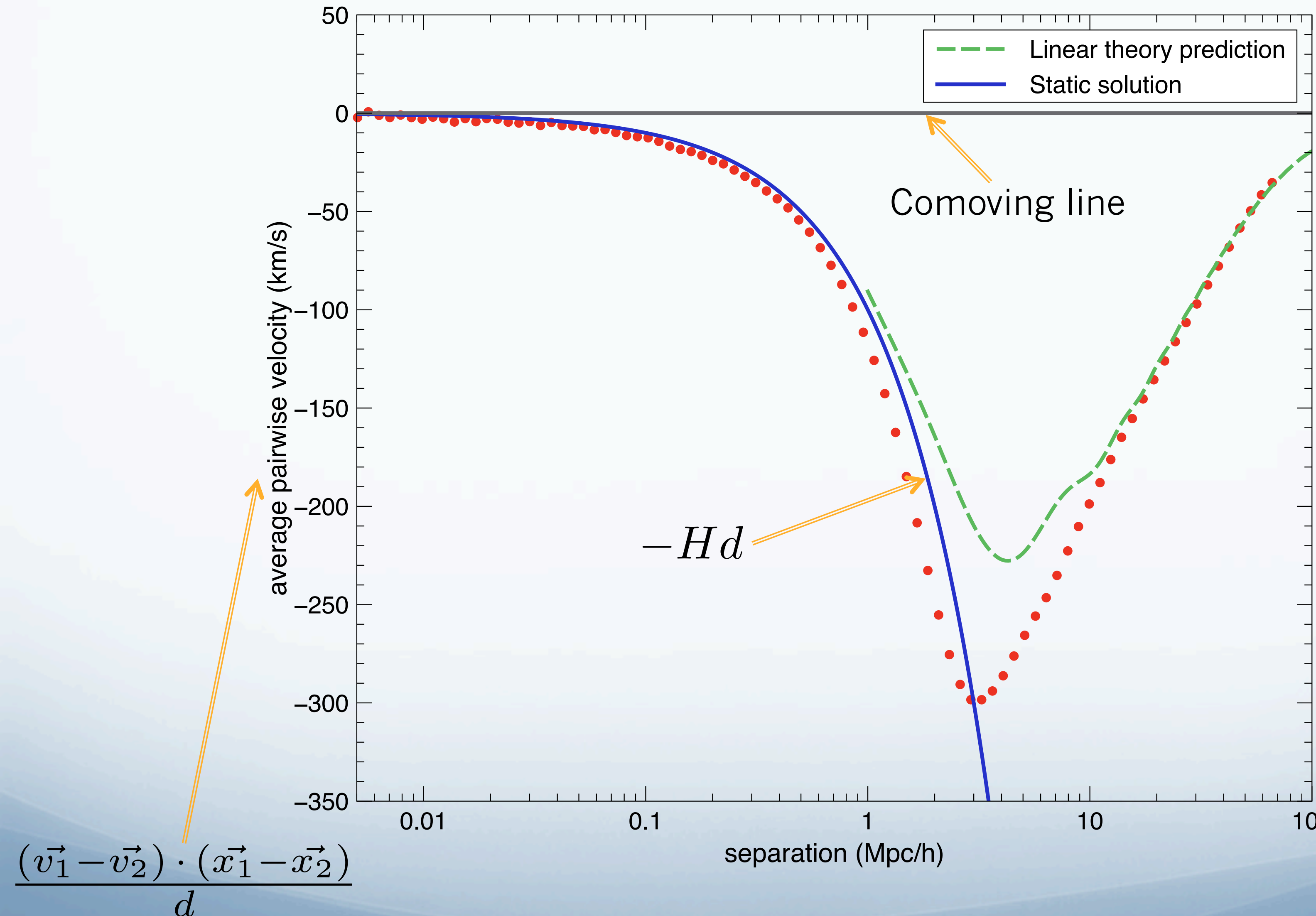

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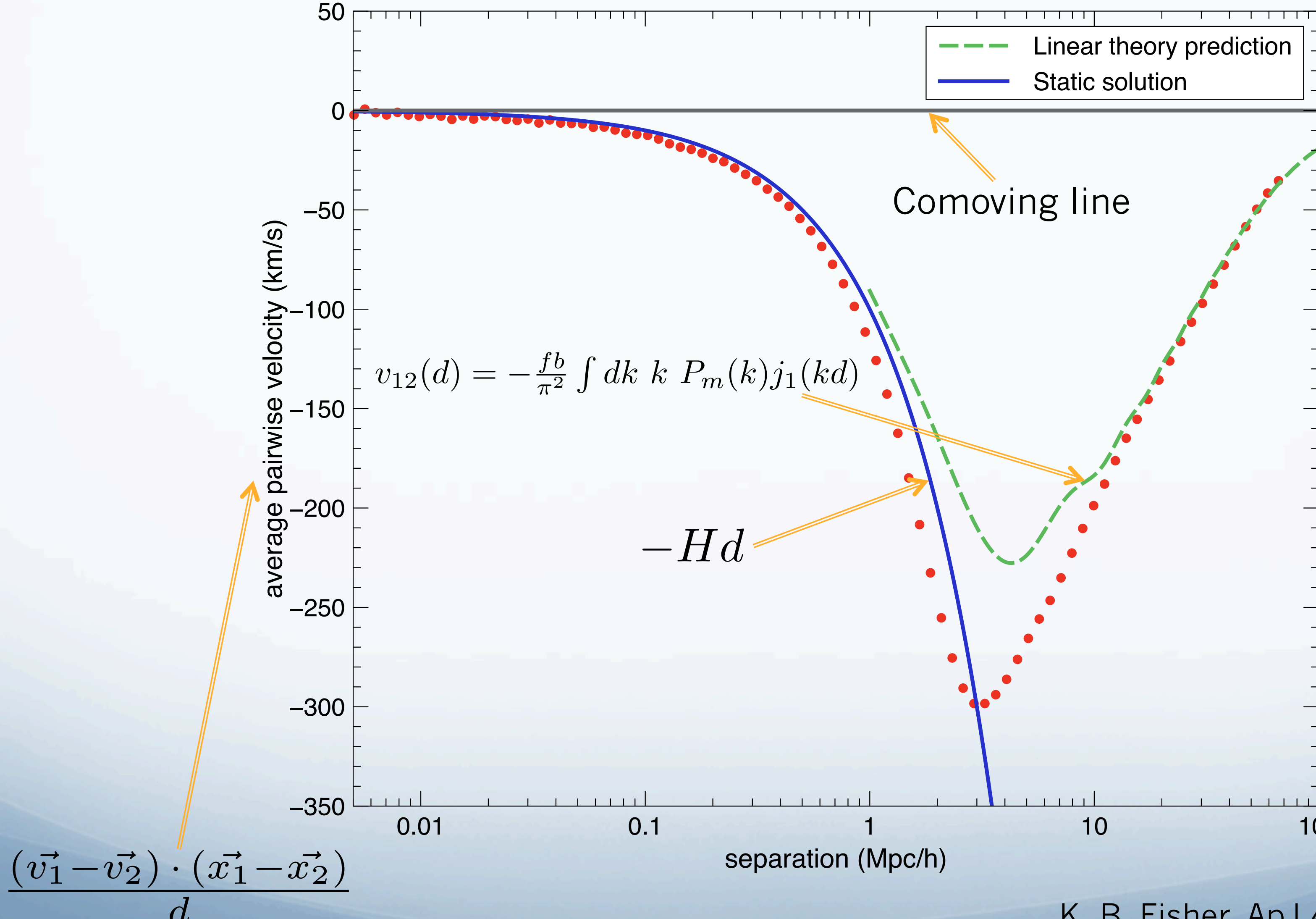
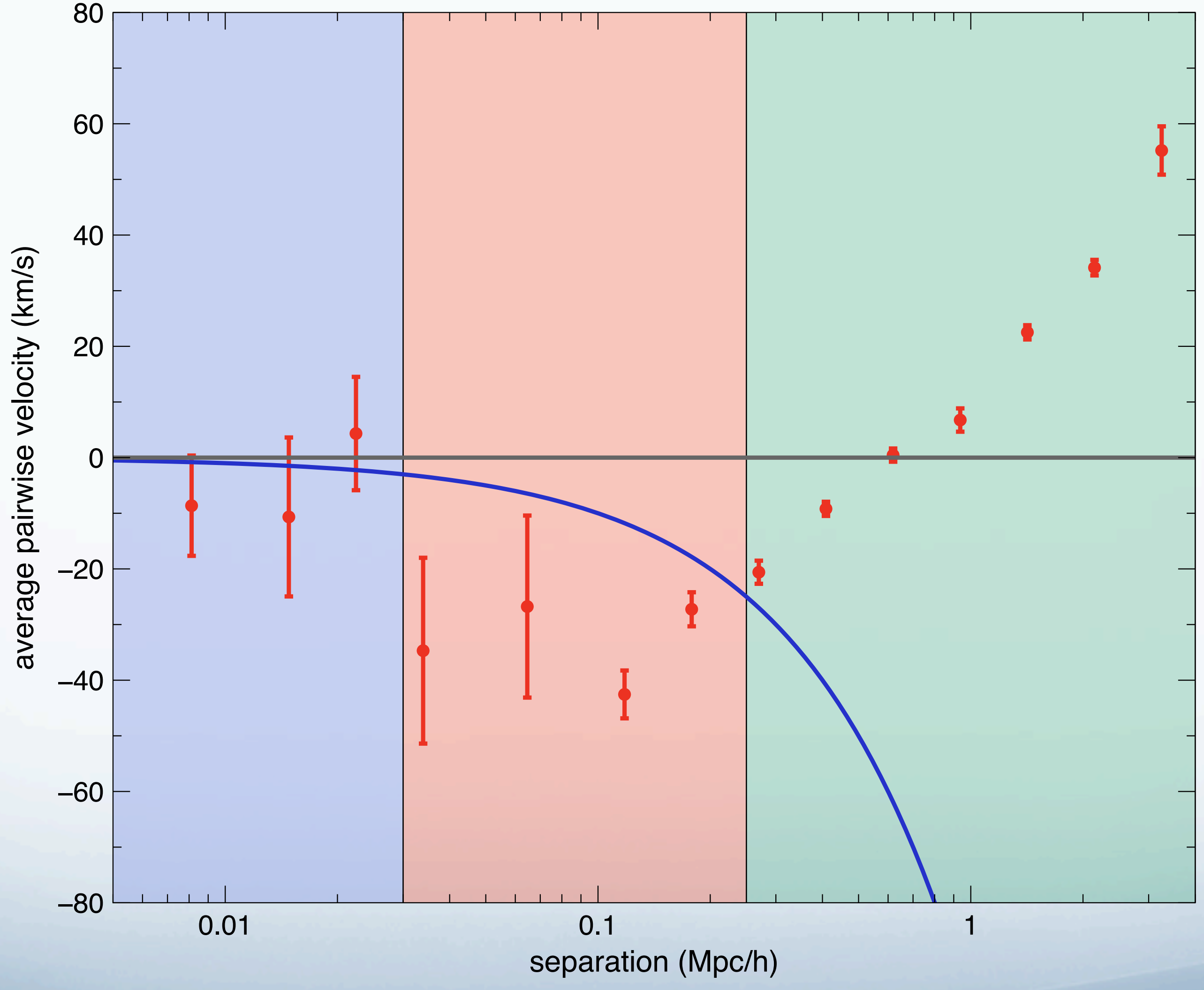


K. B. Fisher, ApJ 448, 494, 1995

Results: isolated pairs at z=0



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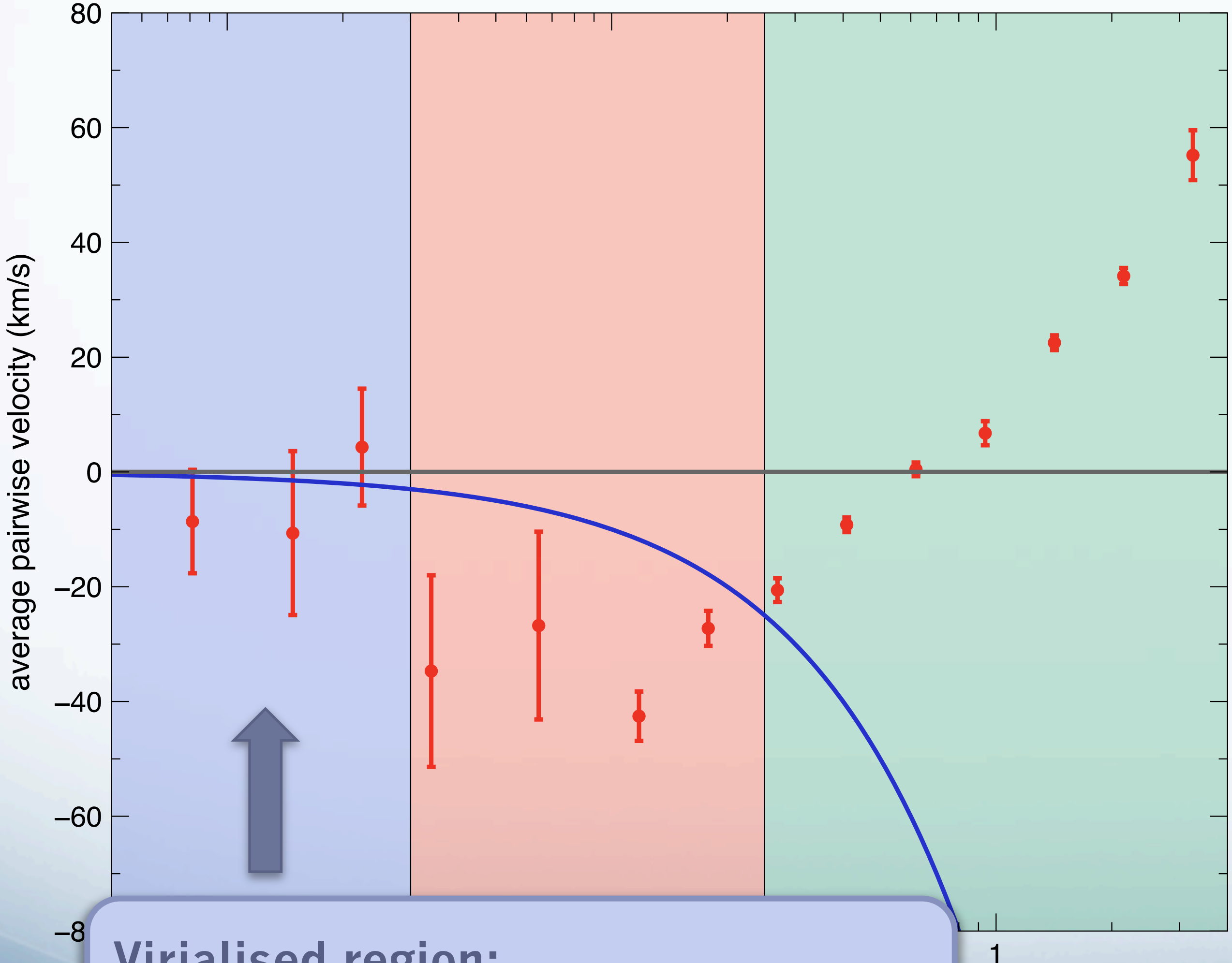
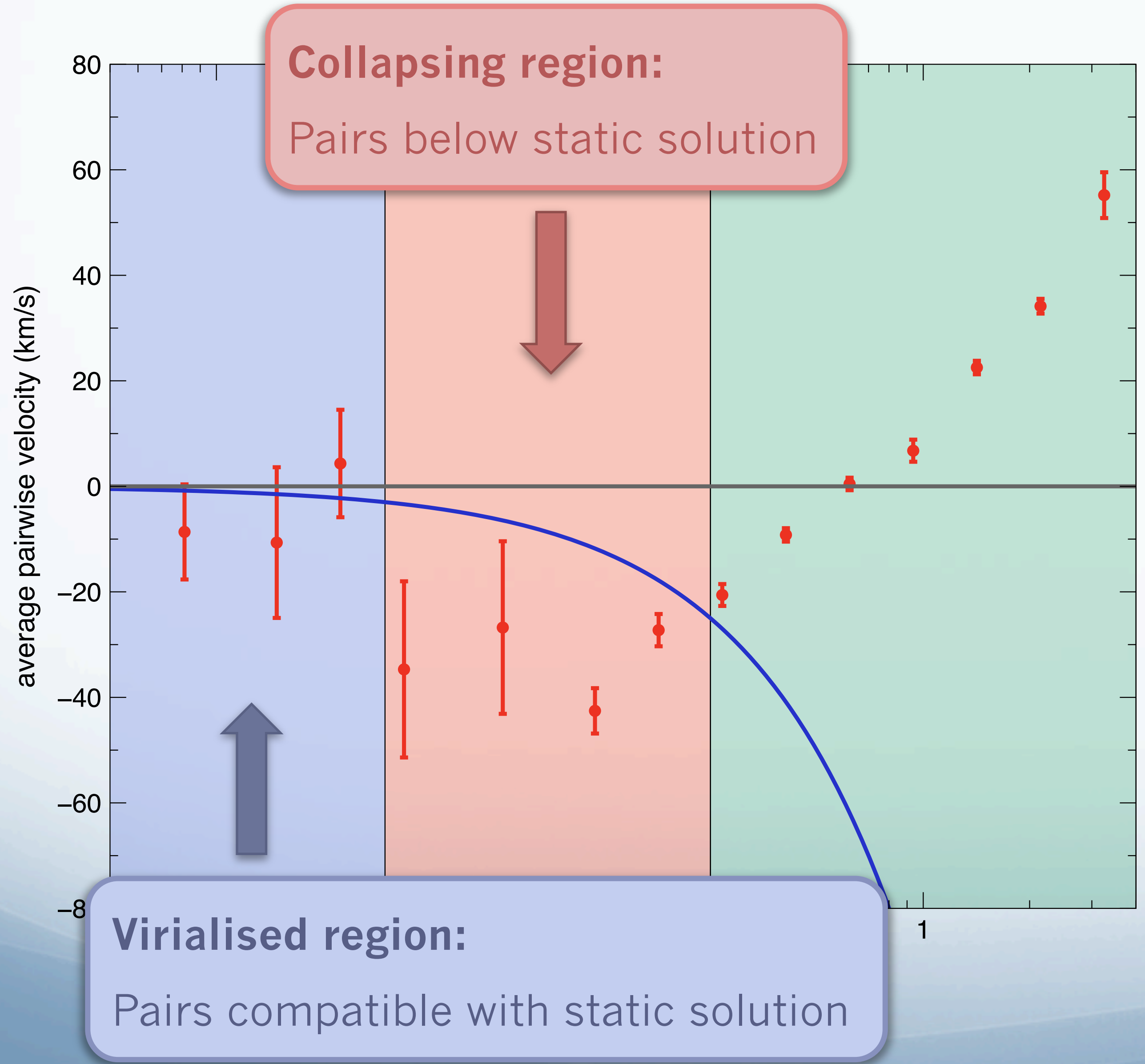


Virialised region:

Pairs compatible with static solution

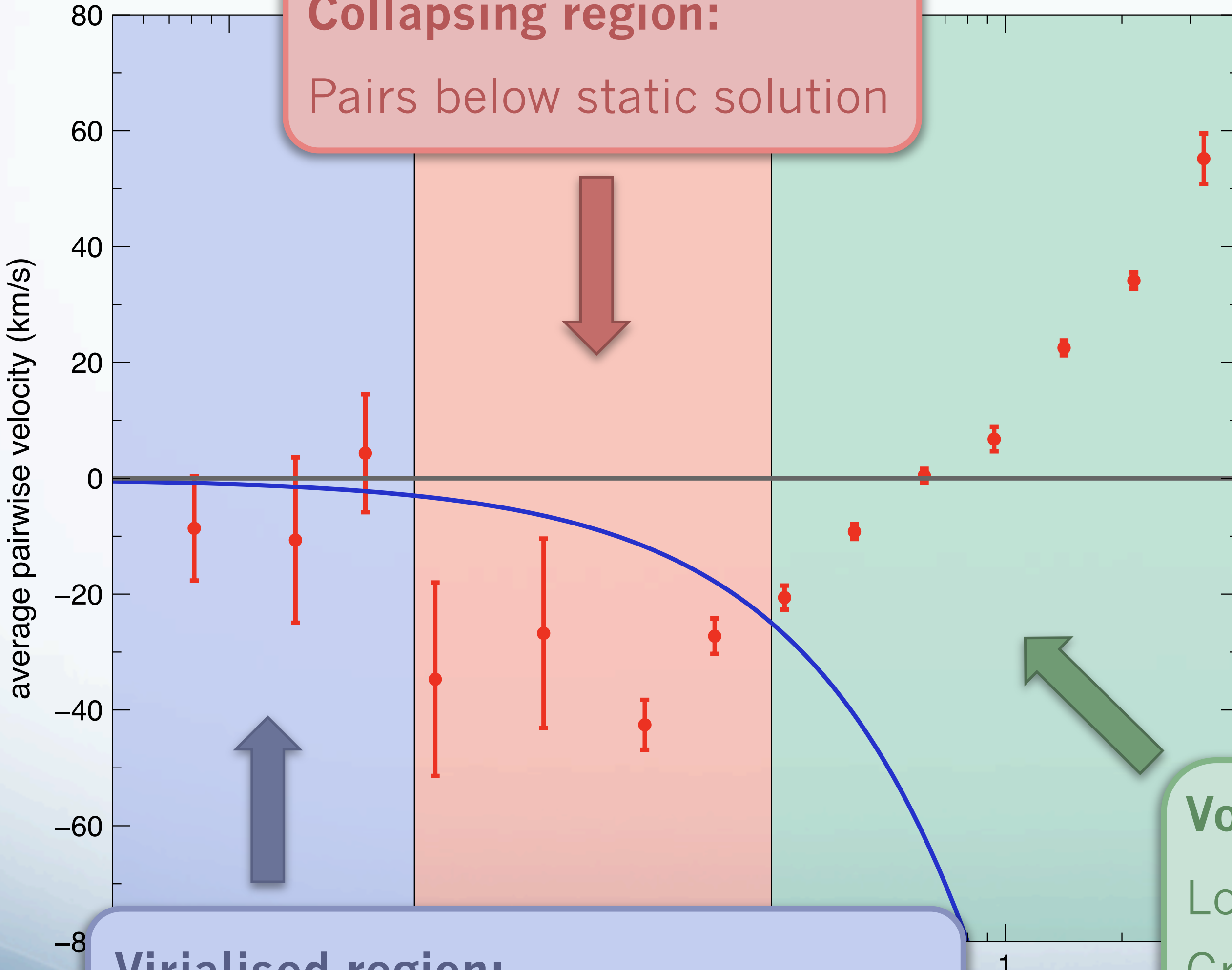
Results: isolated pairs at z=0



Results: isolated pairs at z=0

Collapsing region:

Pairs below static solution



Void effect:

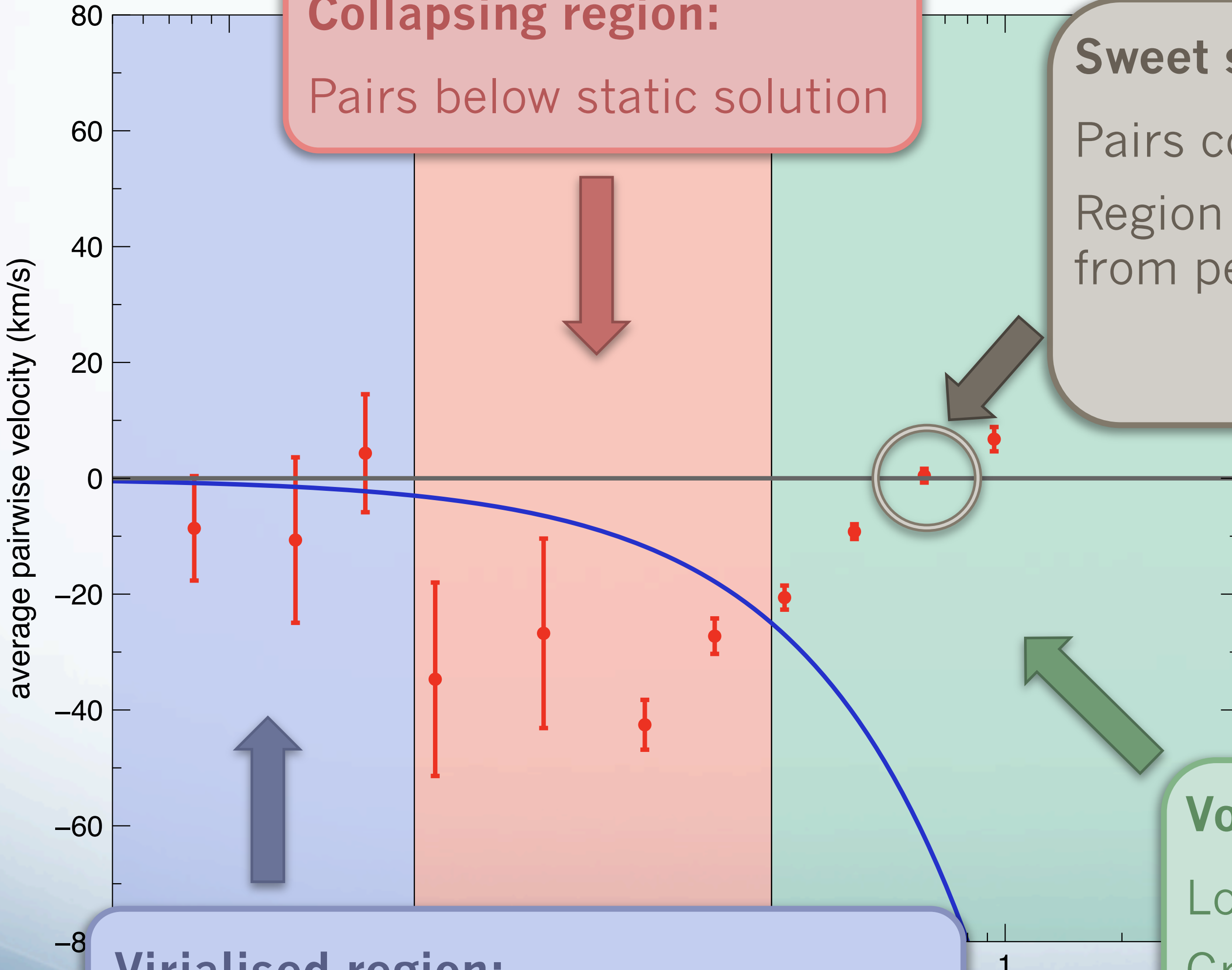
Logarithmic growth of v_{12}

Gravitional pull of galaxies outside pair

Virialised region:

Pairs compatible with static solution

Results: isolated pairs at z=0



Collapsing region:

Pairs below static solution

Sweet spot d_0:

Pairs comoving with background

Region with least corrections from peculiar velocities

$$\frac{v_{12}}{|Hd|} \ll 1$$

Void effect:

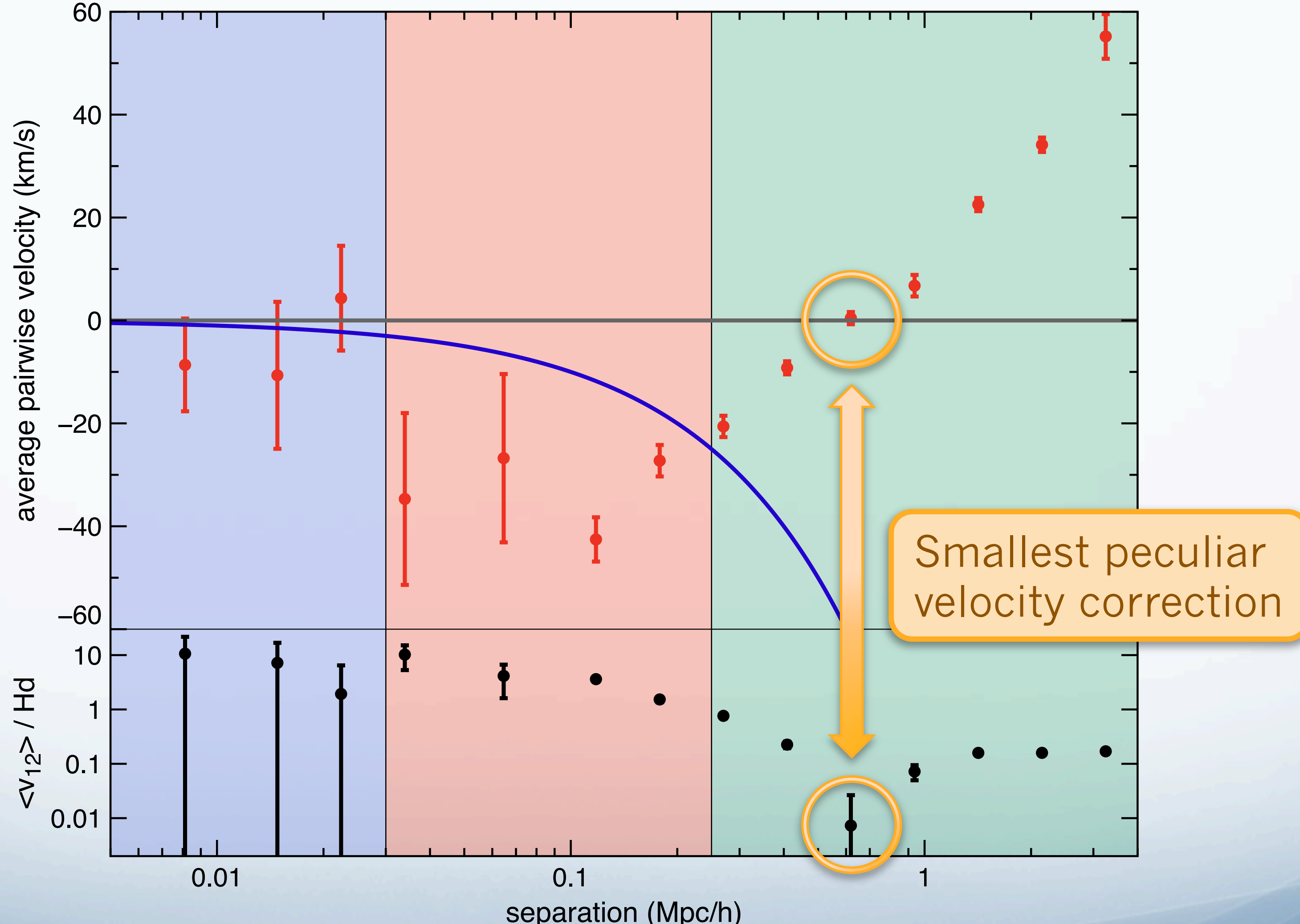
Logarithmic growth of v_{12}

Gravitional pull of galaxies outside pair

Virialised region:

Pairs compatible with static solution

Results: isolated pairs at z=0



Varying galaxy properties

We have found a regime where isolated galaxies may be used as cosmological tracers

In "real life" surveys are flux limited → Need to explore dependence with galaxy properties

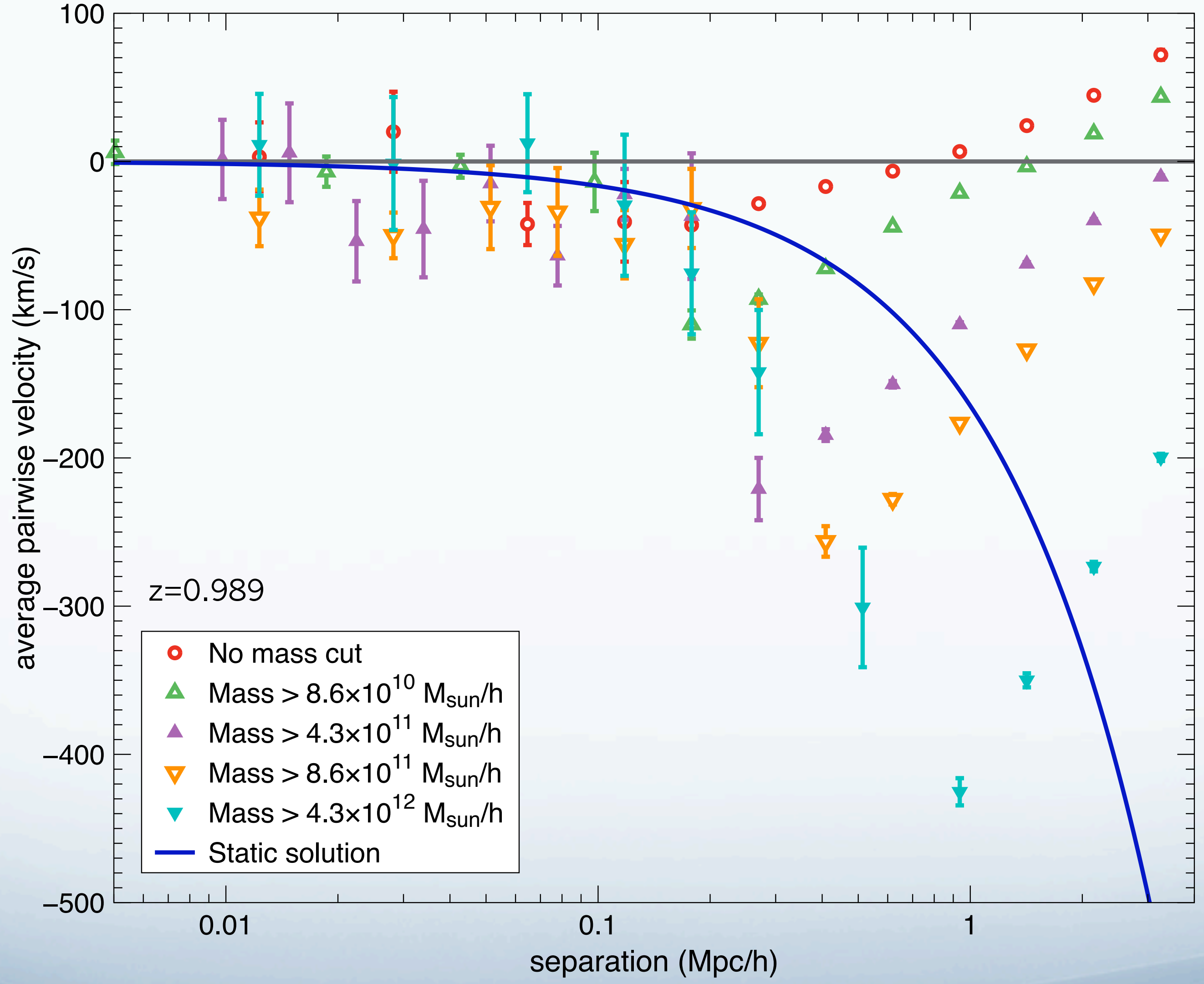
We explored subsamples according to:

- Subhalo mass
- Stellar mass
- Rest frame r-band magnitude from SDSS
- Semi-analytic model

We studied the redshift dependence:

- z = 0, z = 0.5085, z = 0.989, z = 1.504

Results: isolated pairs, n_p cuts



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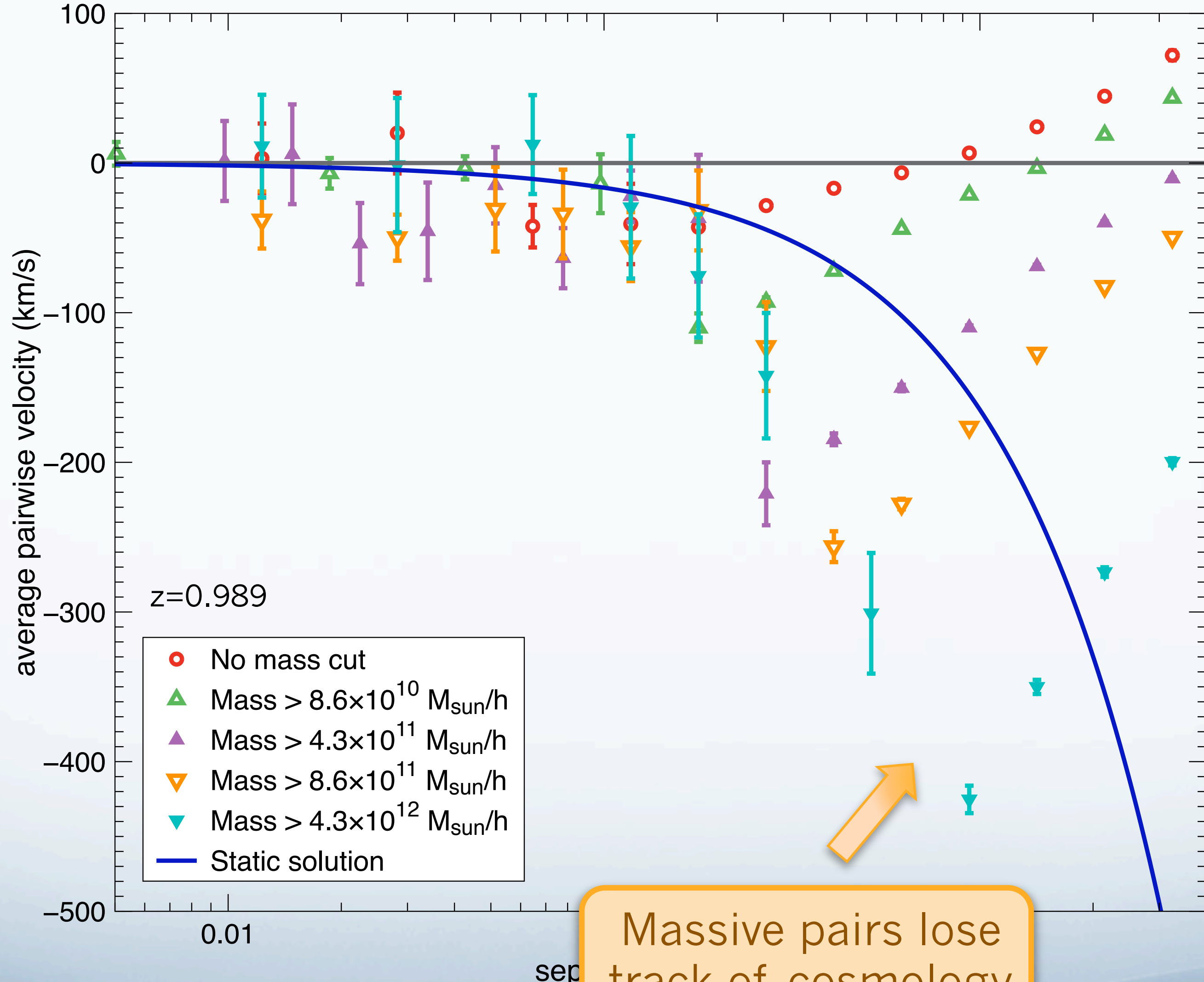
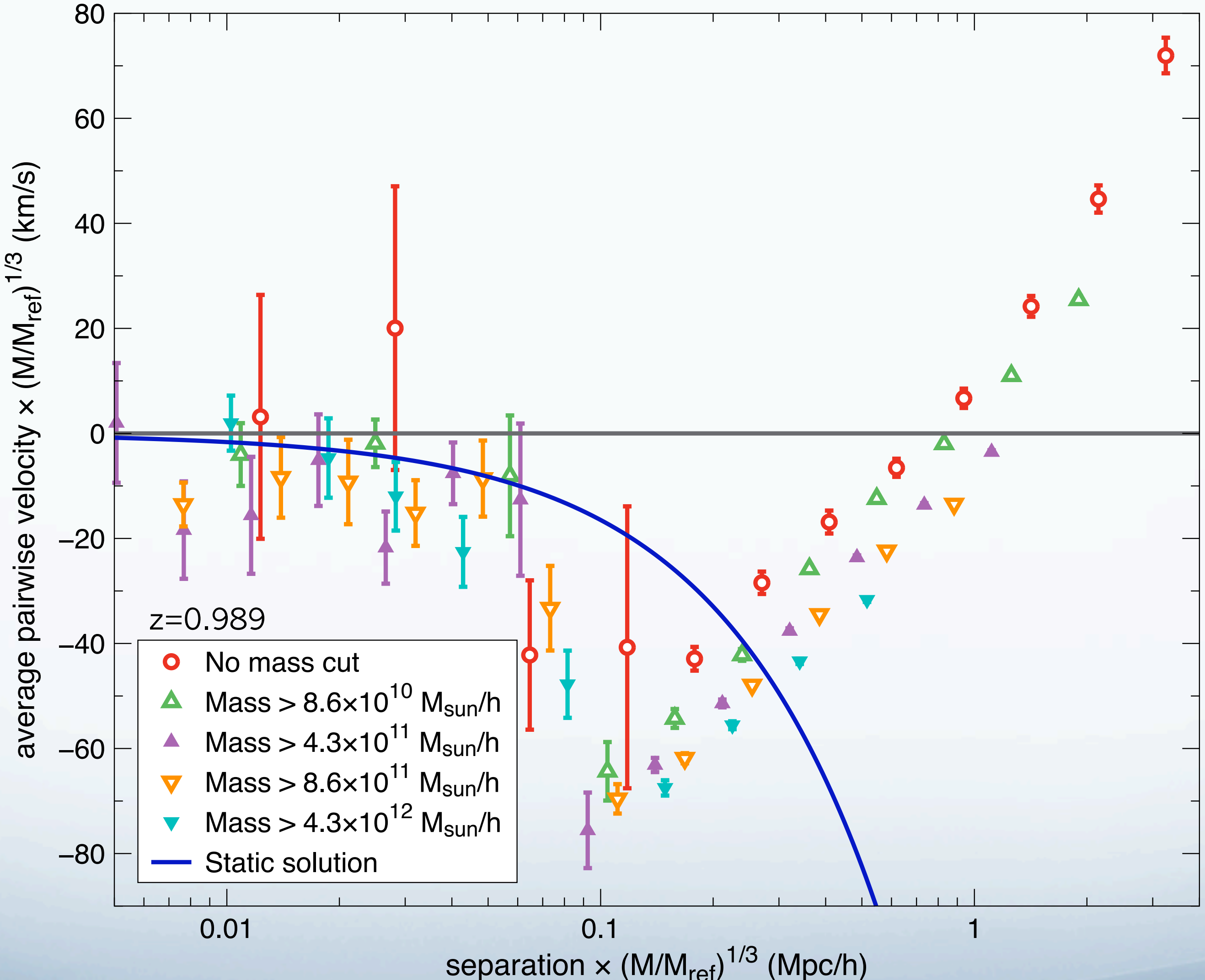


Massive pairs lose track of cosmology

Results: mass scaling



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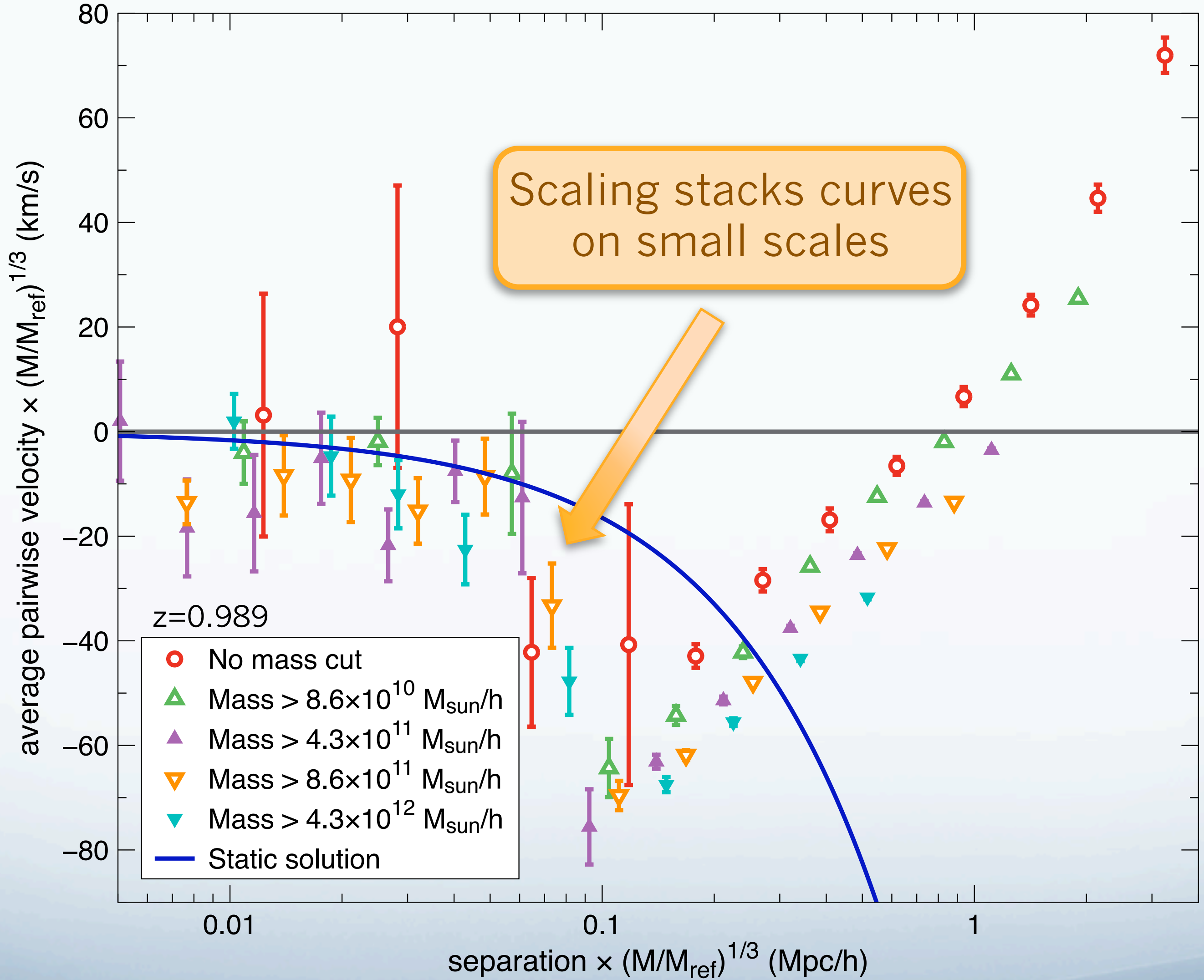
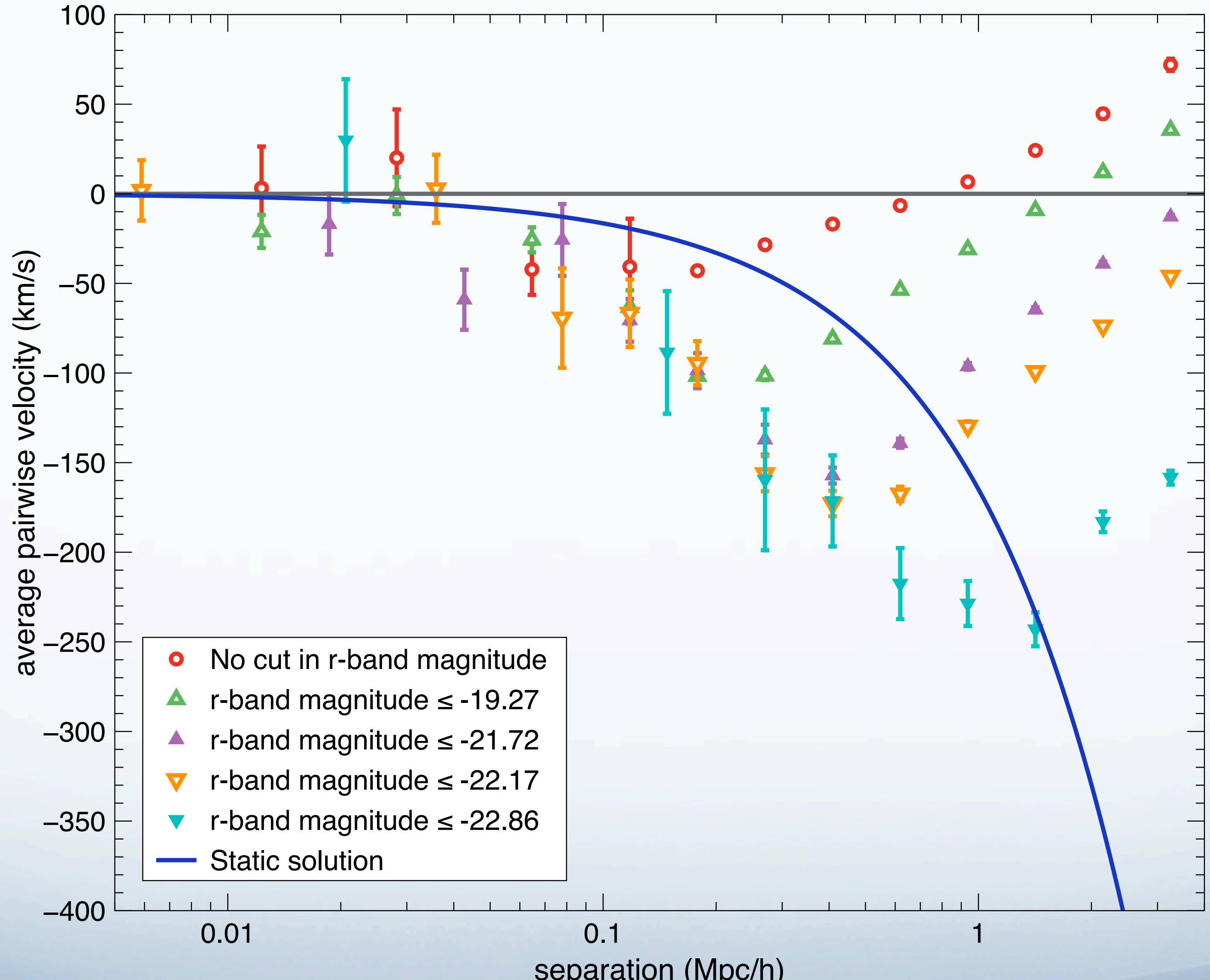


Results: r-band magnitude



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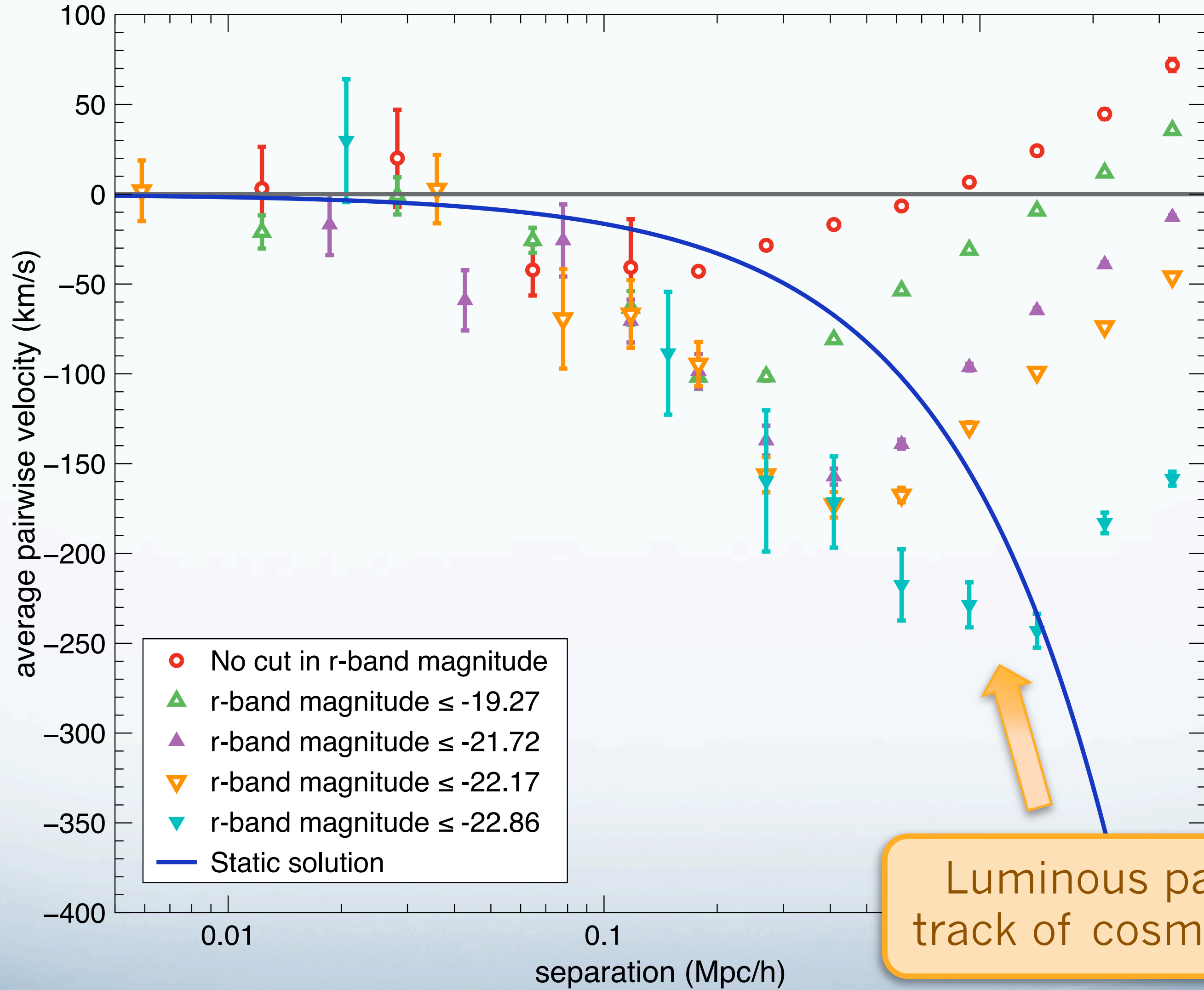
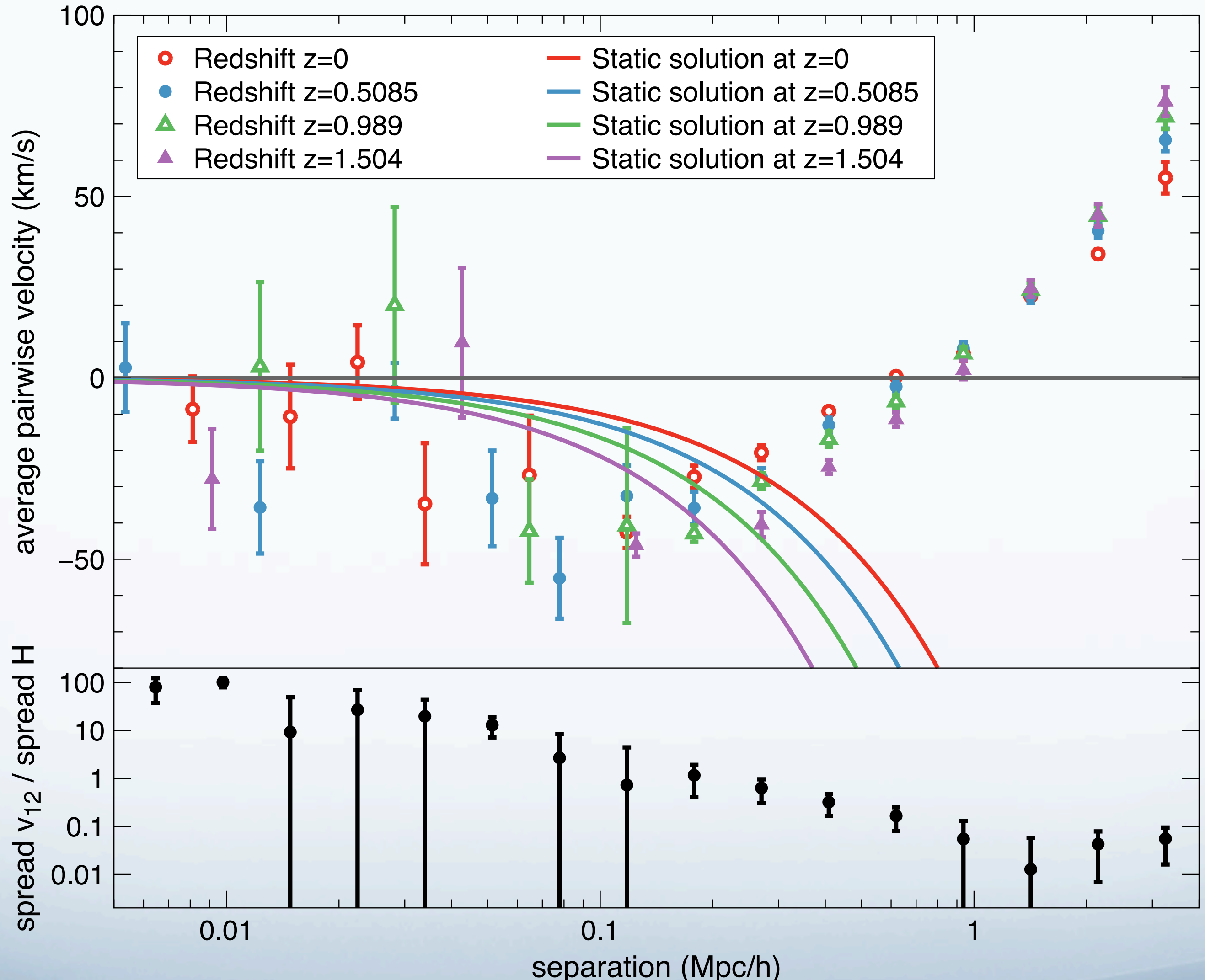


Luminous pairs lose track of cosmology too

Results: redshift dependence



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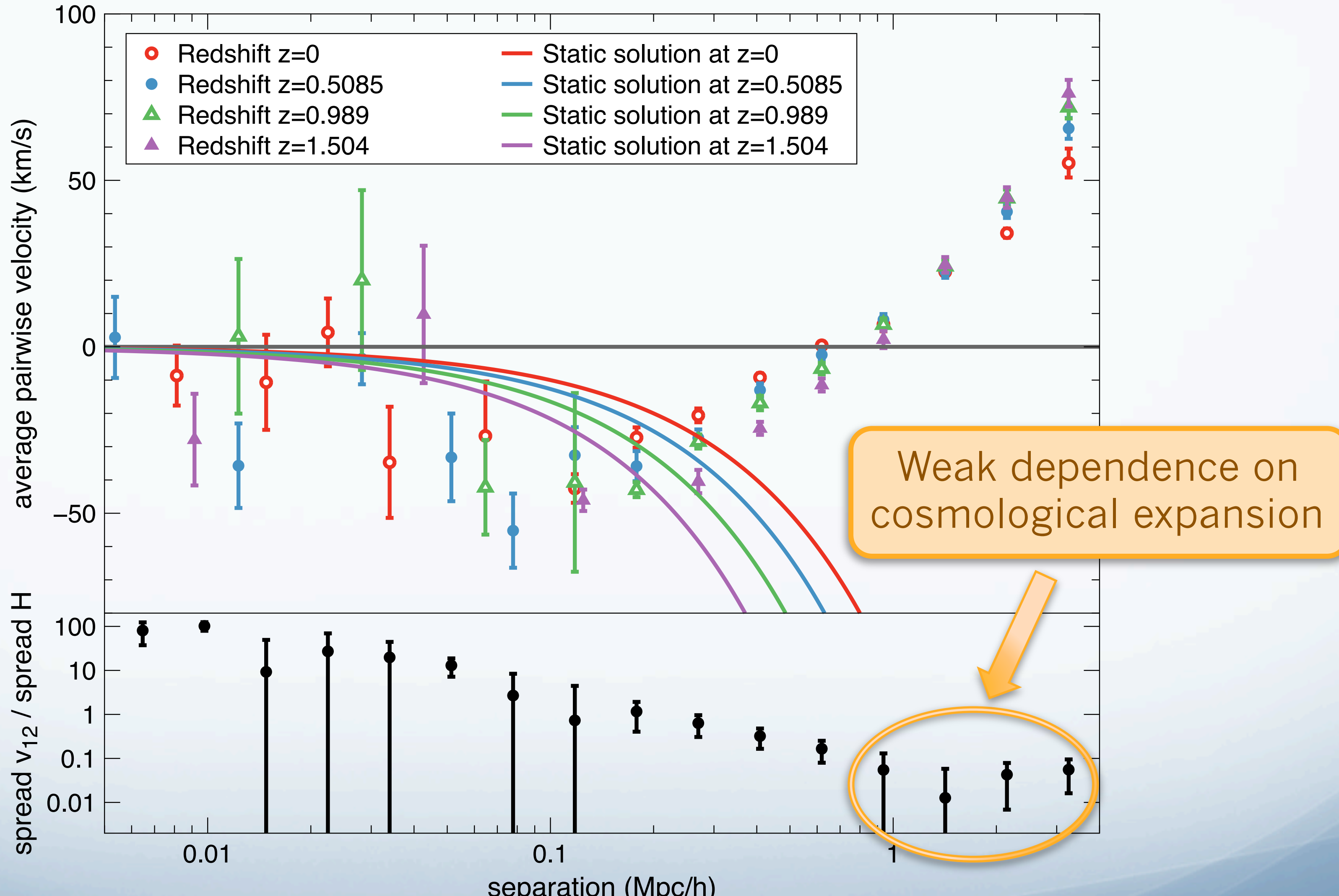
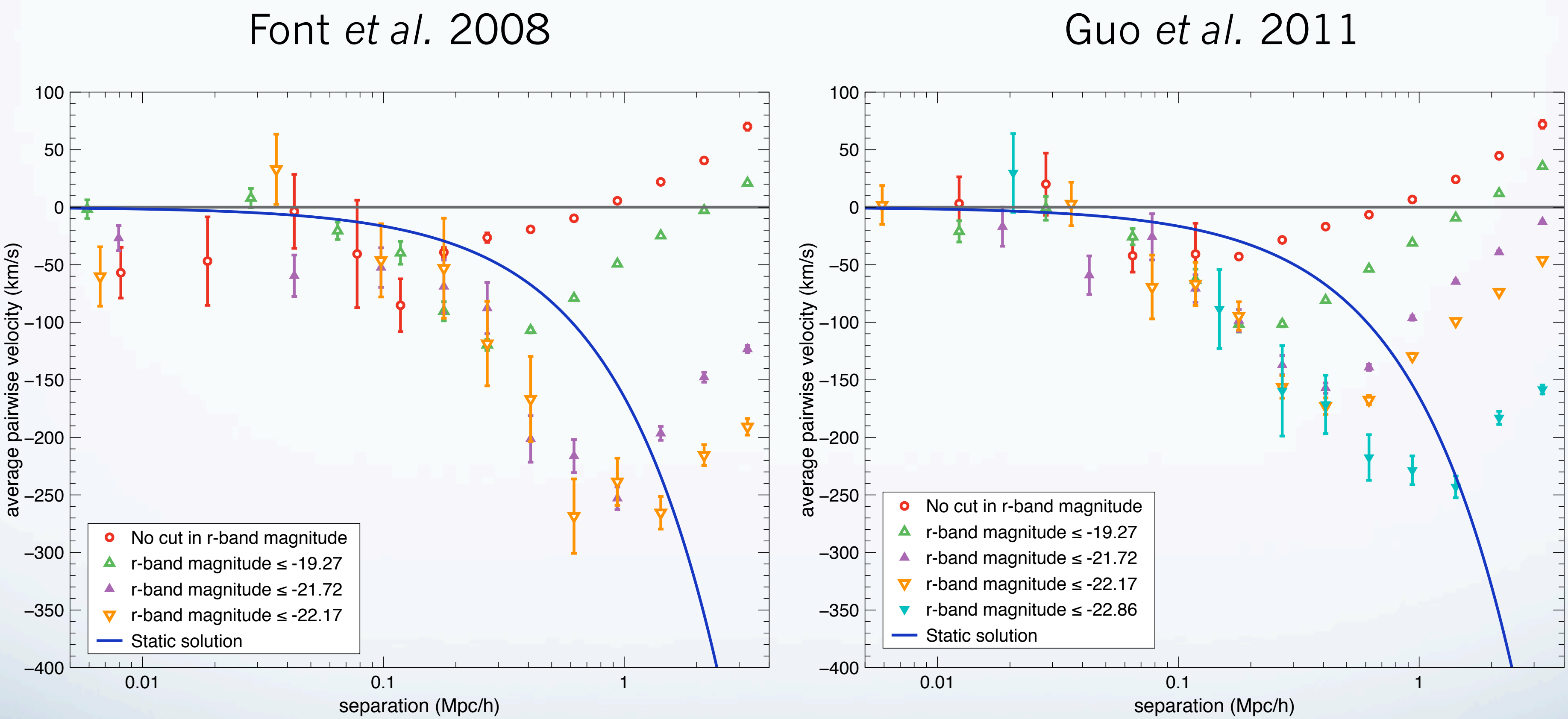
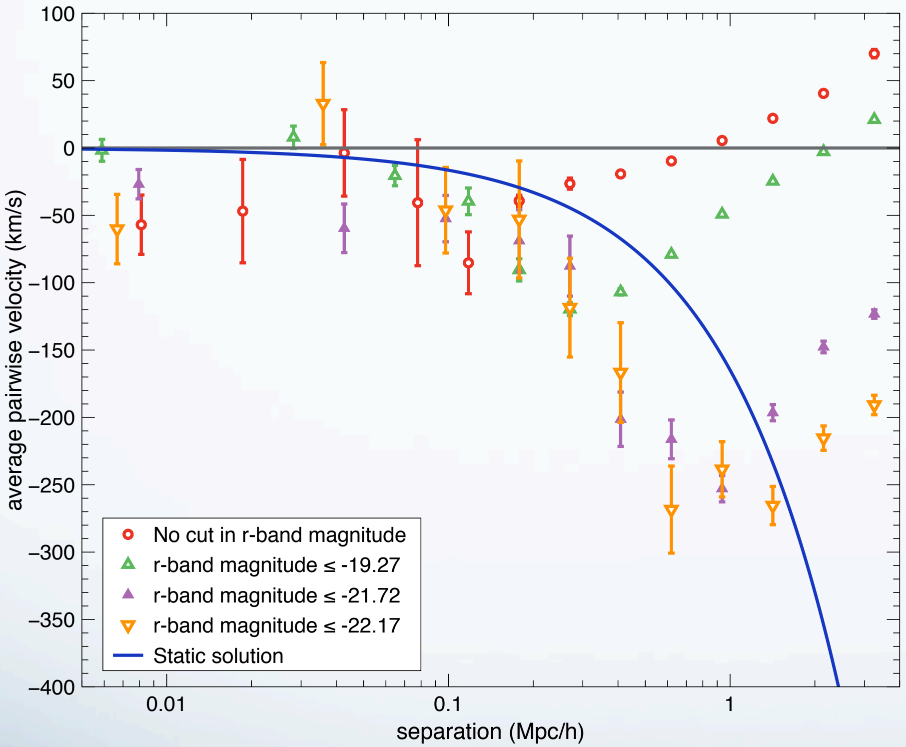


Results: catalogue comparison

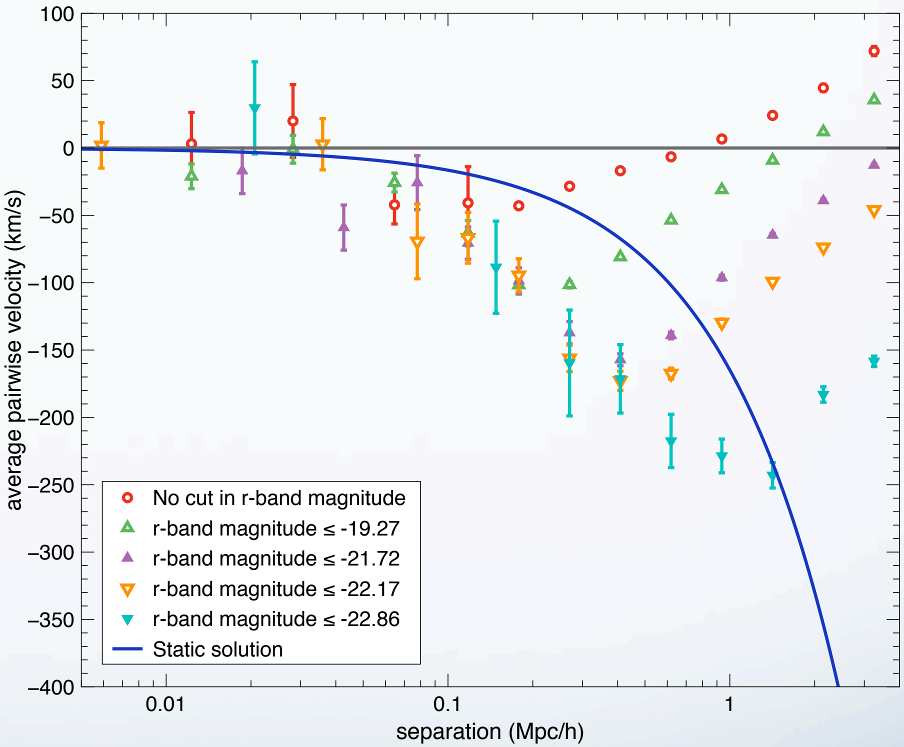


Results: catalogue comparison

Font *et al.* 2008



Guo *et al.* 2011



Different catalogues, same story

Conclusions

- It has been proposed that isolated galaxy pairs may be used as cosmological tracers (C. Marinoni & A. Buzzi, 2010)
- We have explored this idea using N-body simulations and studied the dependence on redshift, degree of isolation and galaxy properties
- We find that isolated galaxy pairs may trace expansion for $d \gtrsim 1\ \mathrm{Mpc/h}$ regardless of redshift
- Low mass pairs are best tracers, as d_0 increases with galaxy mass
- Regime of negligible peculiar velocities is reached for $m \lesssim 10^{11}\ \mathrm{M}_\odot/h$
- Promising technique, but modelling of the peculiar velocities is still required, specially on the scales probed by Marinoni and Buzzi