Pairwise velocities and the halo model

COSMO 05

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Introduction

- This talk is about correlation function of galaxies in red-shift space as a function of galaxy luminosity.
- Work done in collaboration with Uroš Seljak (Princeton, ICTP) and Iro Tasitsiomi (Chicago)
- **`astro-ph/0507203`**, to be replaced with a revised version soon
- Motivation:
  - to investigate the possiblity of measuring halo dynamics without preselection
  - to investigate Jing & Börner 2005 result

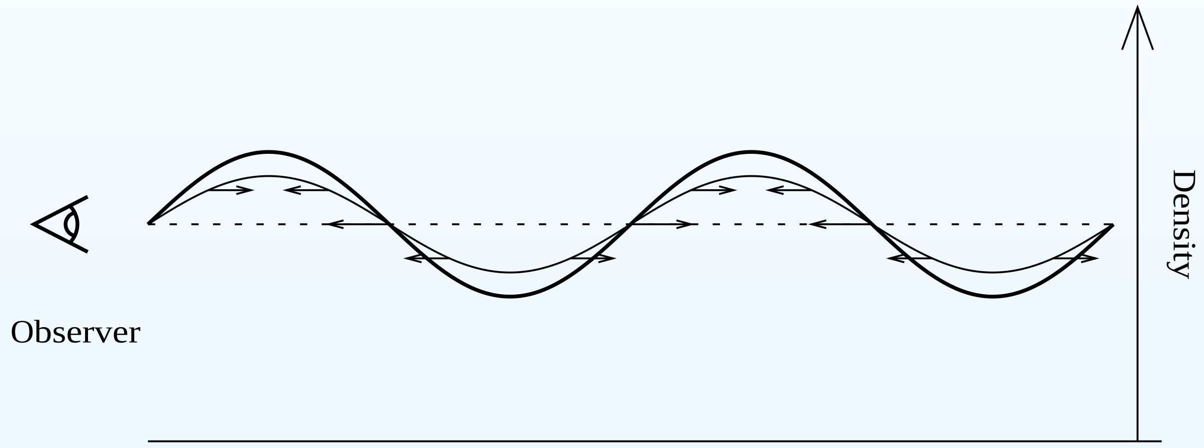
Background

Redshift-space distortions introduce anisotropy into the 2-point correlation function of galaxies:

- On large scales the overall infall squashes the correlation function along the line of sight – measure cosmology
- On small scales the peculiar velocities of virialised systems elongates the correlation functions along the line of sight – measure virialised behaviour
- Theory of squashing developed by Kaiser (1987), later extended with the exponential dispersion model
- Criticised by Scoccimarro (2004)

Kaiser compression

Linear growth is accompanied by the flow of matter into more dense regions:



(Taken from Hamilton, 1997)

In linear theory each Fourier mode is amplified by $1 + \beta\mu^2$ where $\mu = \cos\theta$ and $\beta \sim \Omega_m^{0.6}/b$ so:

$$P(k) \rightarrow P(k)(1 + \beta\mu^2)^2$$

Fingers of God

On small scales virialised system spread the galaxies along the line of sight:

$$(\sigma, \pi) \rightarrow \left(\sigma, \pi + \frac{v}{H_0}\right)$$

and so

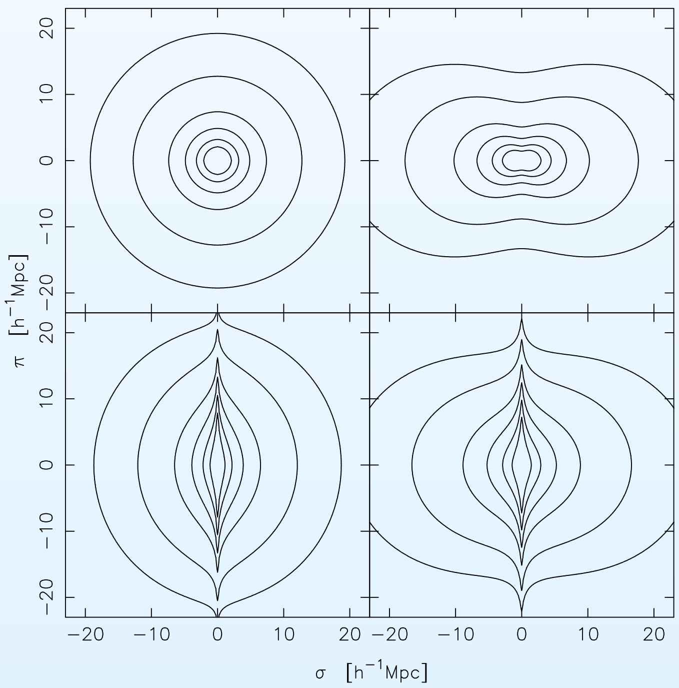
$$1 + \xi(\sigma, \pi) \rightarrow \int \left(1 + \xi\left(\sigma, \pi - \frac{v}{H_0}\right)\right) p(v) \mathrm{d}v \tag{1}$$

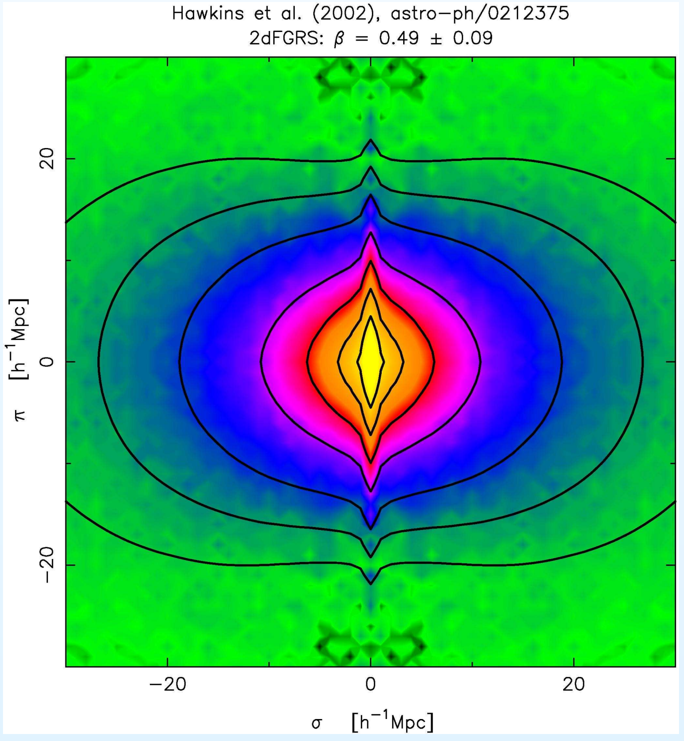
Convolution in real spaces $\rightarrow$ multiplication in Fourier space: pretty much just smoothing.

Exponential dispersion model

For an exponential distribution of velocities the two effects can be combined into (Hawkins et al 2002)

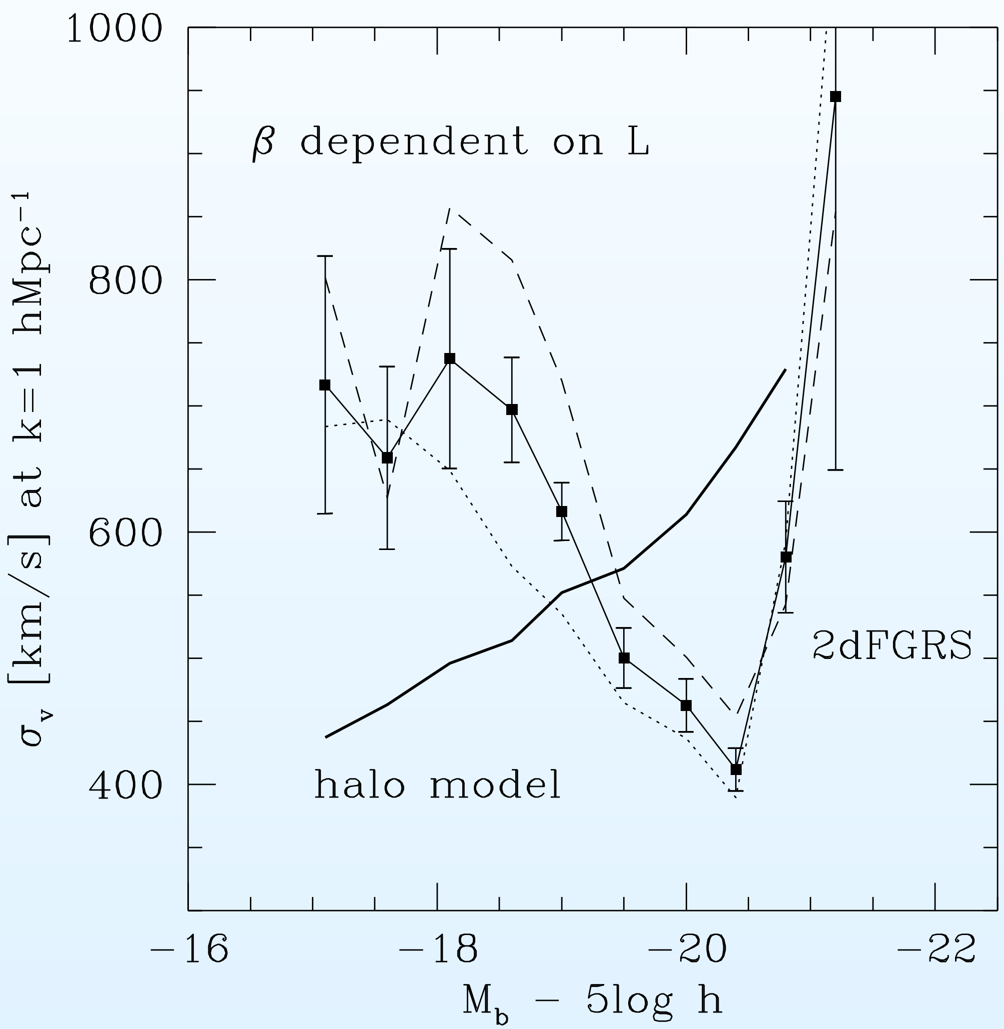
$$P^s(k) = P(k)\frac{(1+\beta\mu^2)^2}{1+\frac{1}{2}k^2\mu^2\sigma_{12}(k)^2}$$





Jing & Börner

Jing & Börner, 2004, fit the exponential dispersion model to 2dF galaxies in *luminosity subsamples*:



Less bright galaxies appear to move faster!

Why is this problematic?

- Standard model of structure formation assumes that galaxies form in dark-matter halos
- More massive halos have more massive and hence brighter galaxies
- More massive halos have larger circular velocities
- A fairly robust prediction is to expect brighter galaxies to move faster

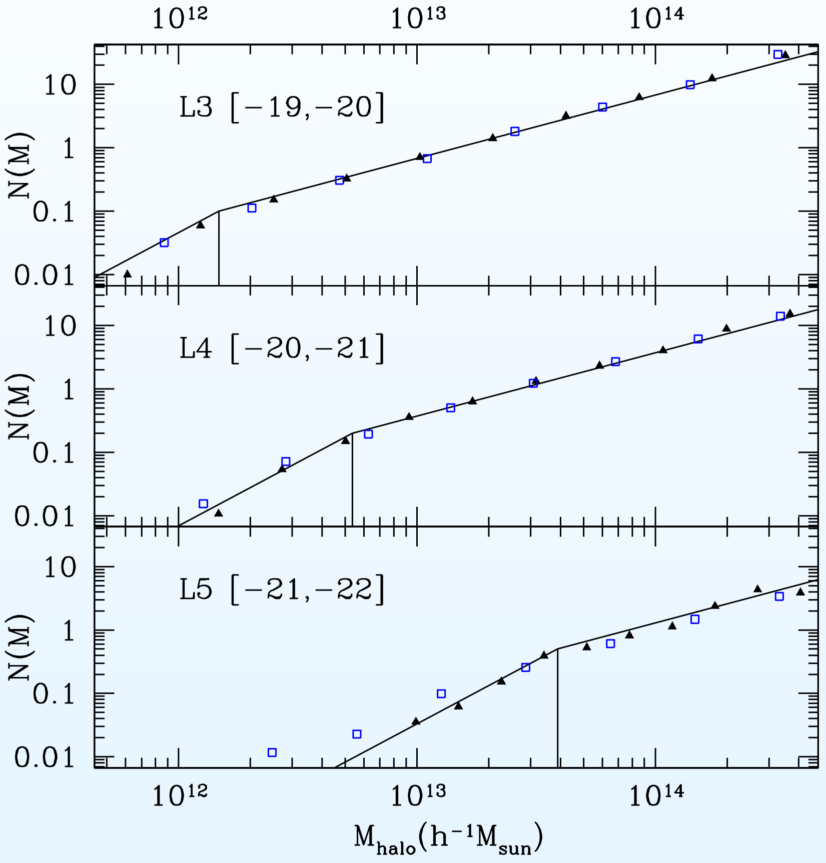
Avoiding preselection

- Many authors (Brainerd et al, Prada et al, etc.) considered *isolated* halo systems.
- Typical recipes include one bright galaxy with not much around plus a few fainter satelites
- Are isolated halos representative?
- Rather poor yield, a few thousand systems per SDSS or 2dF
- Nevertheless some nice results...
- Could we get the same info from cross-correlating galaxies of different luminosities?

Halo model

Ingredients:

- Dark matter halos have number-counts from simulations (slightly better than PS) and are clustered according to the *linear theory*
- If a halo is massive enough it has a central galaxy
- Even more massive halos can have one or more satellite galaxies

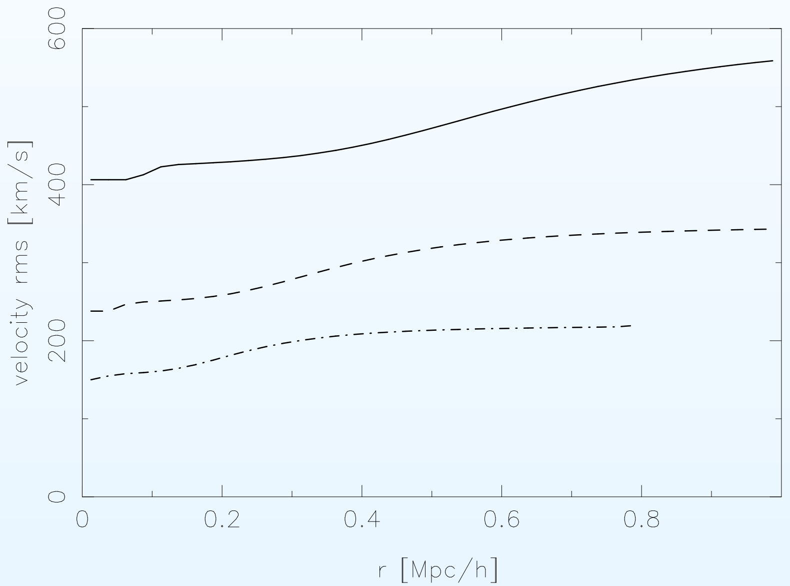


Halo model

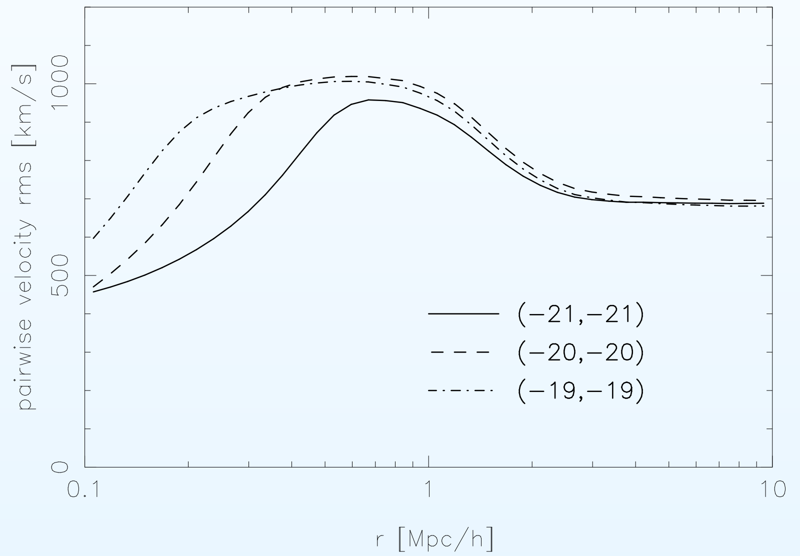
Ingredients:

- Galaxies are distributed in halos according to NFW (cut at r_{vir})
- We keep NFW concentration fixed at c=2
- Galaxies have random velocities; distribution is Maxwellian and isotropic
- Velocity dispersion is constant throughout the halo
- Velocity dispersion is $\propto M^{1/3}$

Velocity dispersions

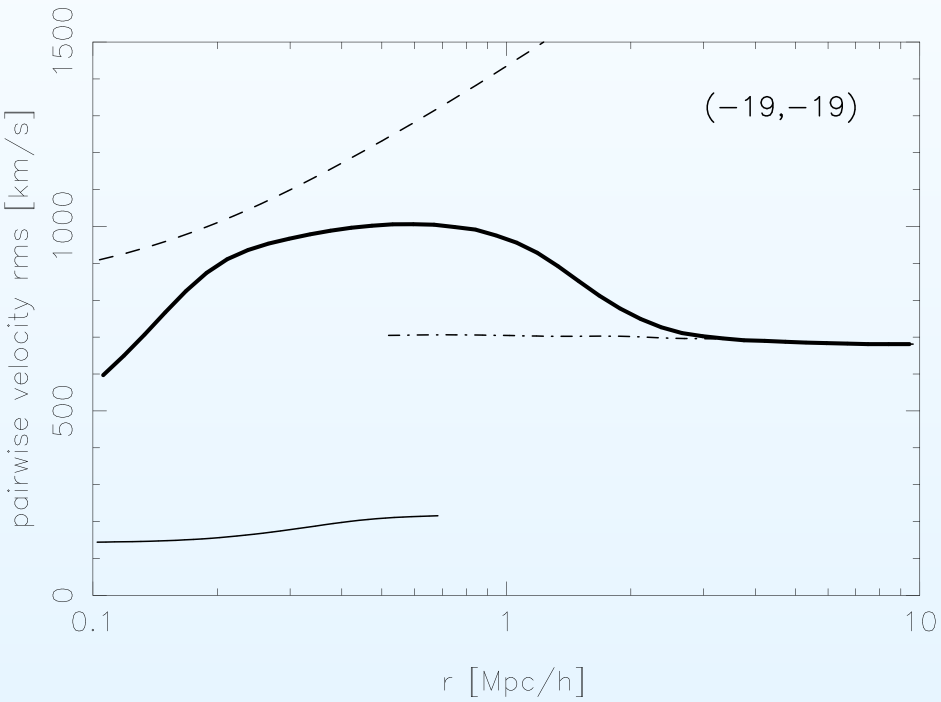


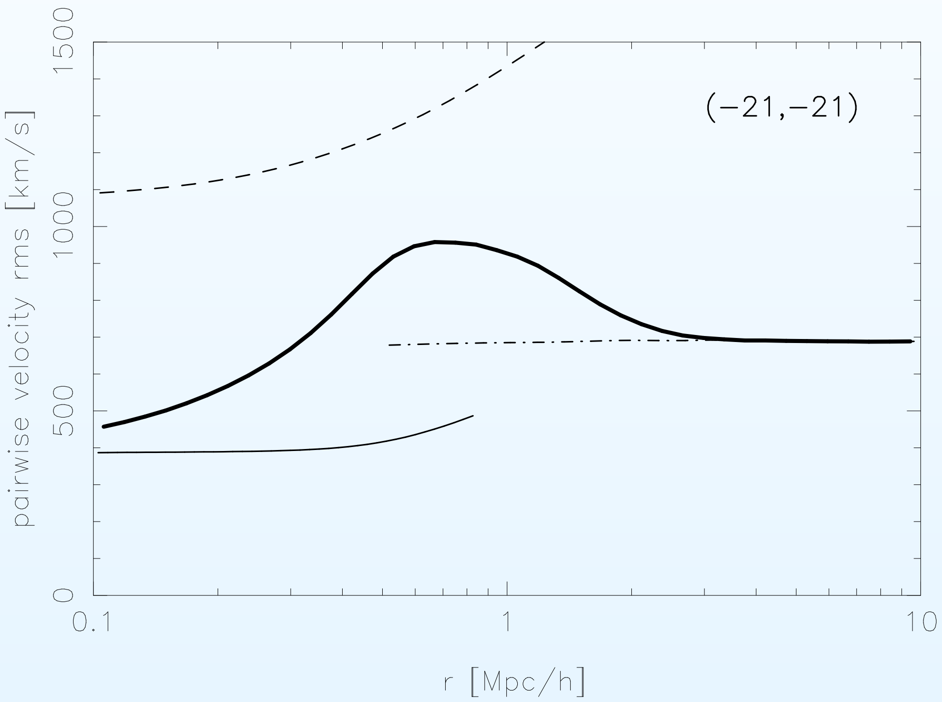
1-point wrt to halo center



2-point

How do we get faster -19 galaxies?





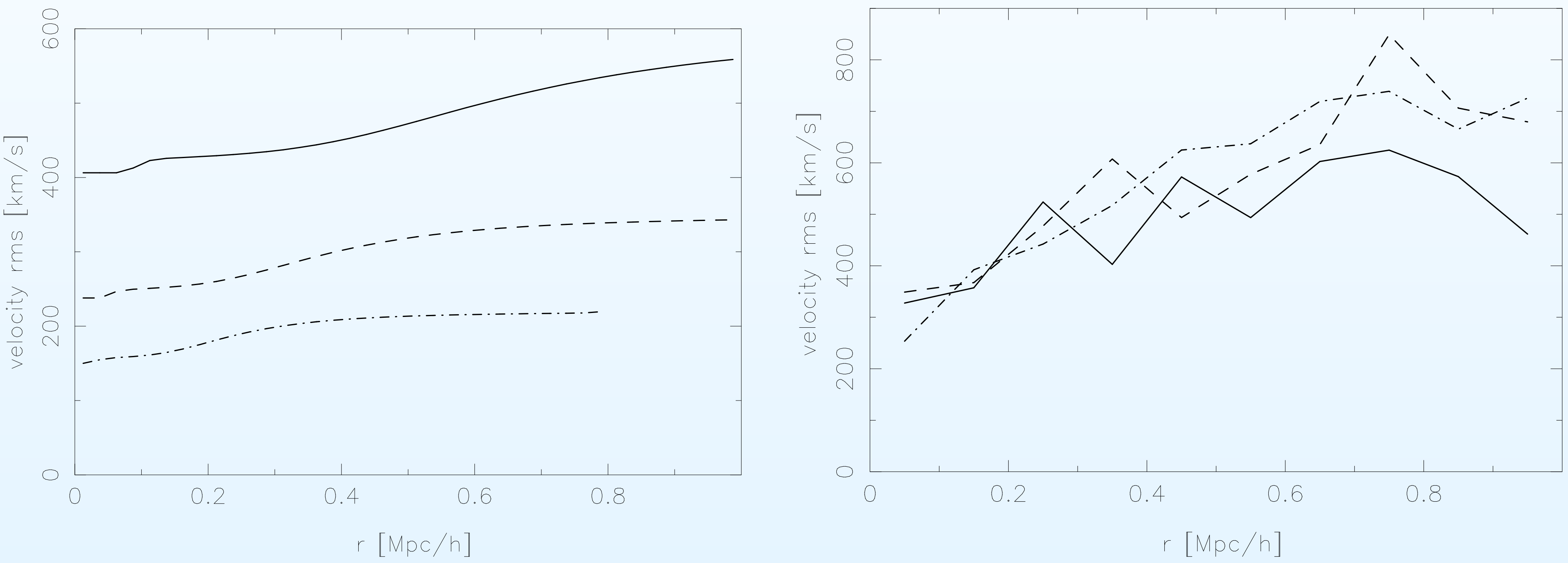
N-body simulation

We compare this against an N-body simulation:

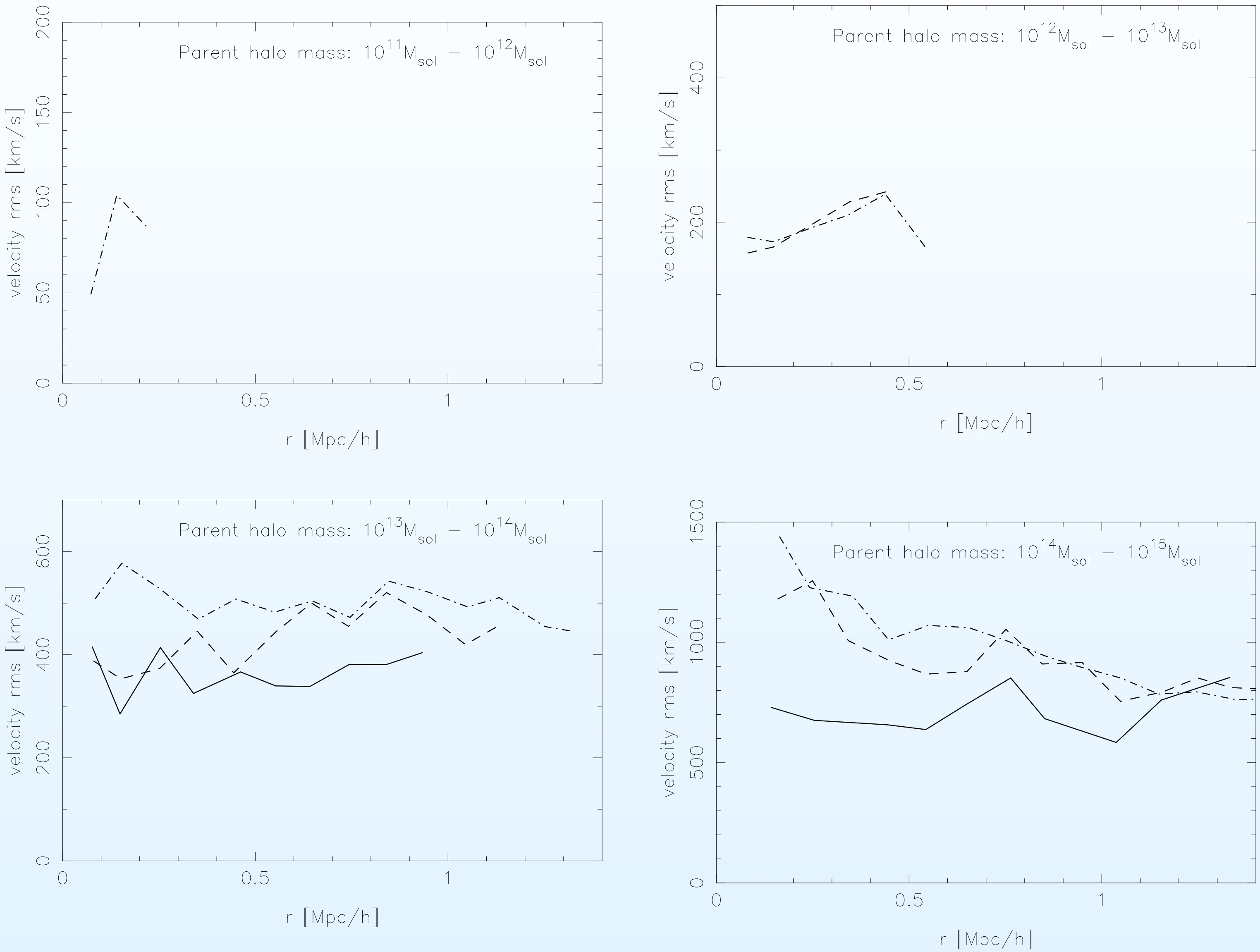
- 120 h^{-1} Mpc, 512^3 particles, DM only
- Tasitsiomi et al (Kravstov group in Chicago)
- Only haloes heavier than $10^{11} h^{-1} M_\odot$ can be used
- The maximum circular velocity is used as a proxy for halo mass
- Luminosities are assigned to each halo by matching the cumulative velocity function $n(> V_{\rm max})$ to the observed r-band cumulative luminosity function of SDSS. $\leftarrow$ good SDSS mock

Comparison with simulations

1D velocity dispersion: A luminosity dependent velocity bias?

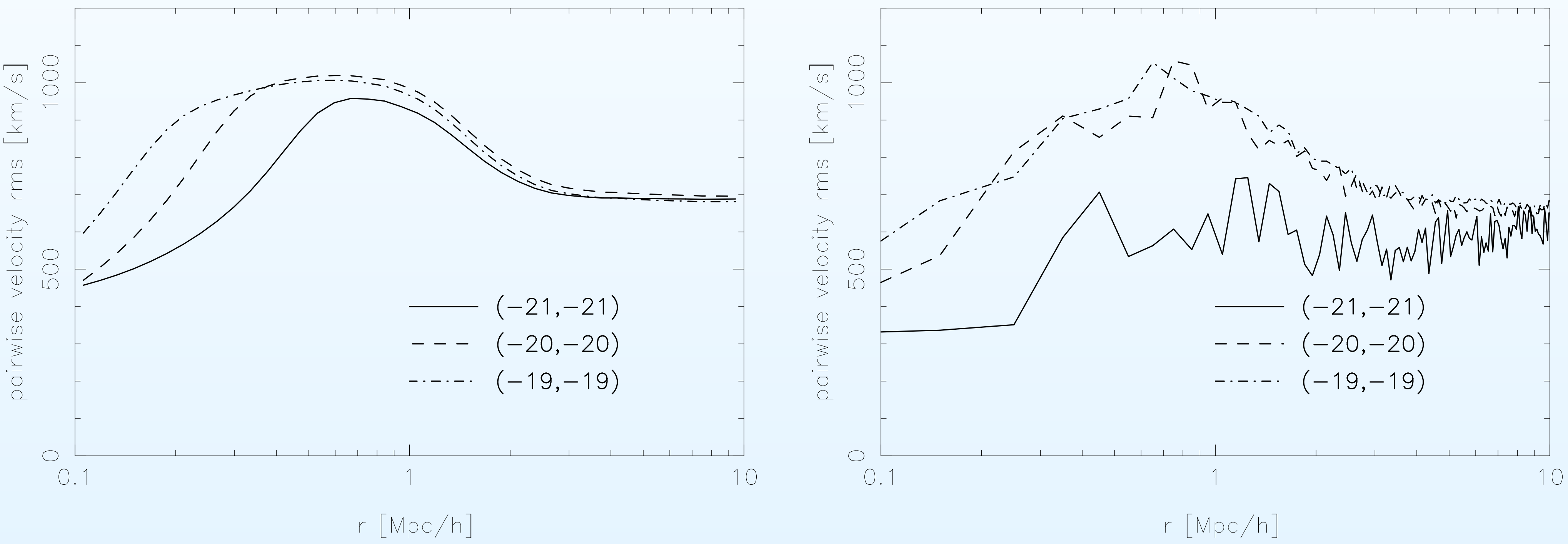


Velocities in simulations



Comparison with simulations

2D velocity dispersion; luminosity bin (-x,-x)

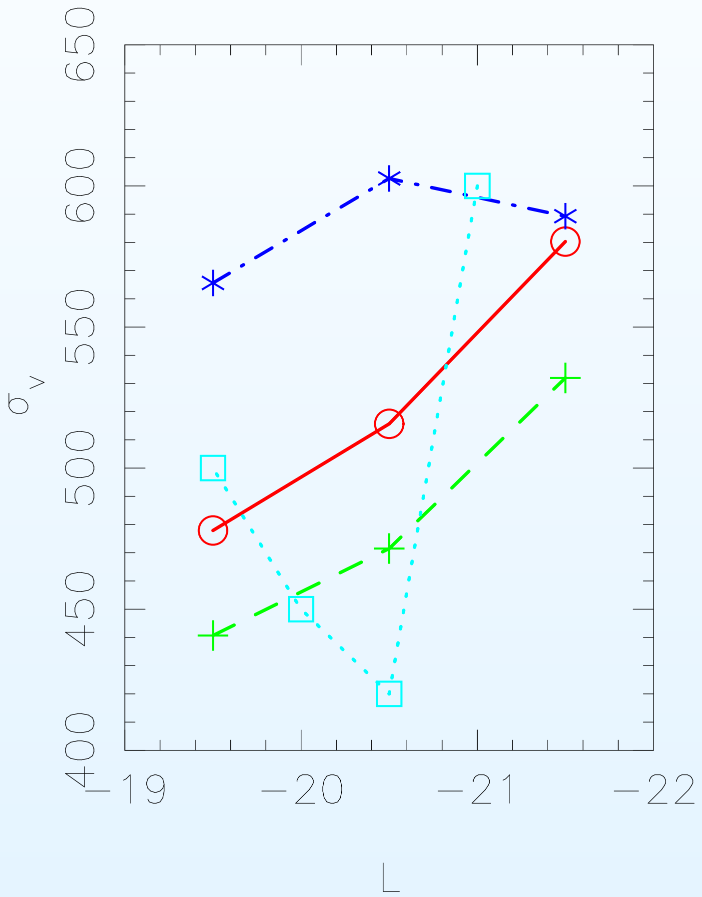


Can we explain Jing & Börner?

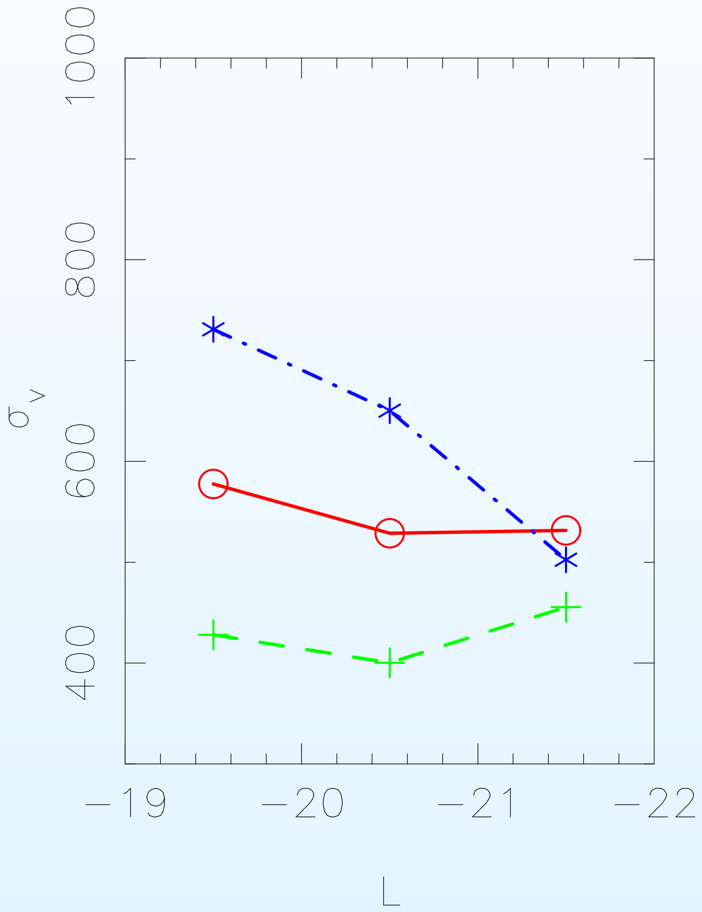
- Two options:
  - pair weighting
  - velocity dependent bias
- Jing and Börner work in k-space at $k = 1h/\mathrm{Mpc}$
- Does this corresponds to $1h^{-1}\mathrm{Mpc}$ or $2\pi h^{-1}\mathrm{Mpc}$?
- We calculate correlation function in real space, invert into Fourier space and fit dispersion model to it
- Tried:
  - original model
  - $r_{\mathrm{cut}} = 2r_{\mathrm{vir}}$
  - Introduced luminosity dependent velocity bias matched to simulations

Can we explain Jing & Börner?

Provisional:



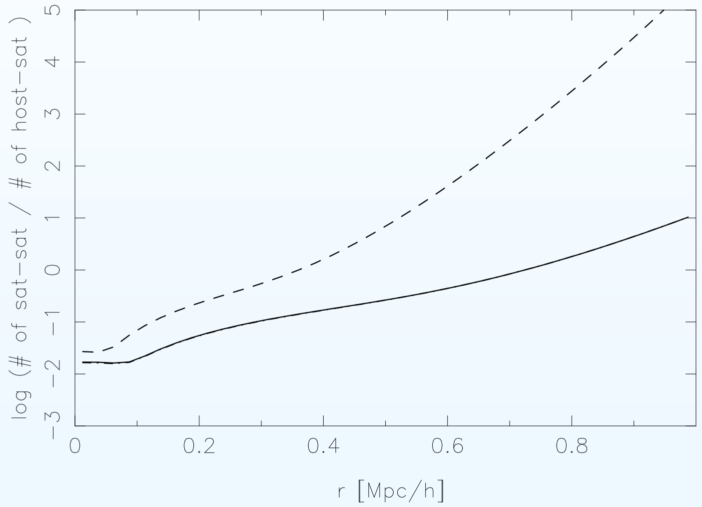
$k = 1h/\mathrm{Mpc}$



$k = 2.4h/\mathrm{Mpc}$

Avoiding preselection?

- Can try cross-correlating bright and non-bright galaxies:



- Need to select real close pairs...
- One option is to go for non-bright $\times$ non-bright and probe massive halos via sat-sat?
- However, “smoothing length” $\sim 10h^{-1}\,\mathrm{Mpc}$ - all contributions get mixed up...

Conclusions

- We can potentially explain Jing & Börner
- Not clear whether luminosity dependent velocity bias is crucial.
- Prospects for haly dynamics without preselection are dim: very difficult to disentangle different pairs