Halo masses from the Dark Energy Survey and Spectroscopic Surveys

Anna Cabre, Bhuvnesh Jain, Marcos Lima

University of Pennsylvania, Philadelphia

18-23 July 2010, Edinburgh

Galaxy and Cluster Mass estimation

- A. r~10 kpc: Einstein Rings + Stellar velocity dispersion
- B. r~100 kpc: Galaxy-galaxy lensing + Satellite dynamics
- C. r~1-10 Mpc: Cluster-galaxy lensing + Dynamics
- D. r~1 Mpc: Individual cluster masses from dynamics and weak lensing

Statistical Measurement

Mass estimation methods

Cluster scales

- ***Lensing:*** Einstein Rings, Shear, Magnification:

Measures $(\phi+\psi)$. Relation to mass involves Poisson equation

- *Dynamics*: Velocity dispersion, Rotation, Infall:

Measures Newtonian potential ψ

$M_{lensing} = (1+\gamma)/(2\gamma)\, M_{dynamics}$, $\gamma = \psi/\phi$

- Both masses are equal in standard gravity. Modified gravity would show a difference between them.

At large scales general relativity can be tested:

Reyes et al 2010: combine
- galaxy-galaxy lensing
- galaxy clustering
- galaxy velocities derived from galaxy clustering in redshift space

Dynamics basics

Virial Theorem   2T=W

Virial scaling between:

Velocity dispersion inside virial radius and mass enclosed (statistically)

Tight relation for a huge range of masses!
Slope = 1/3

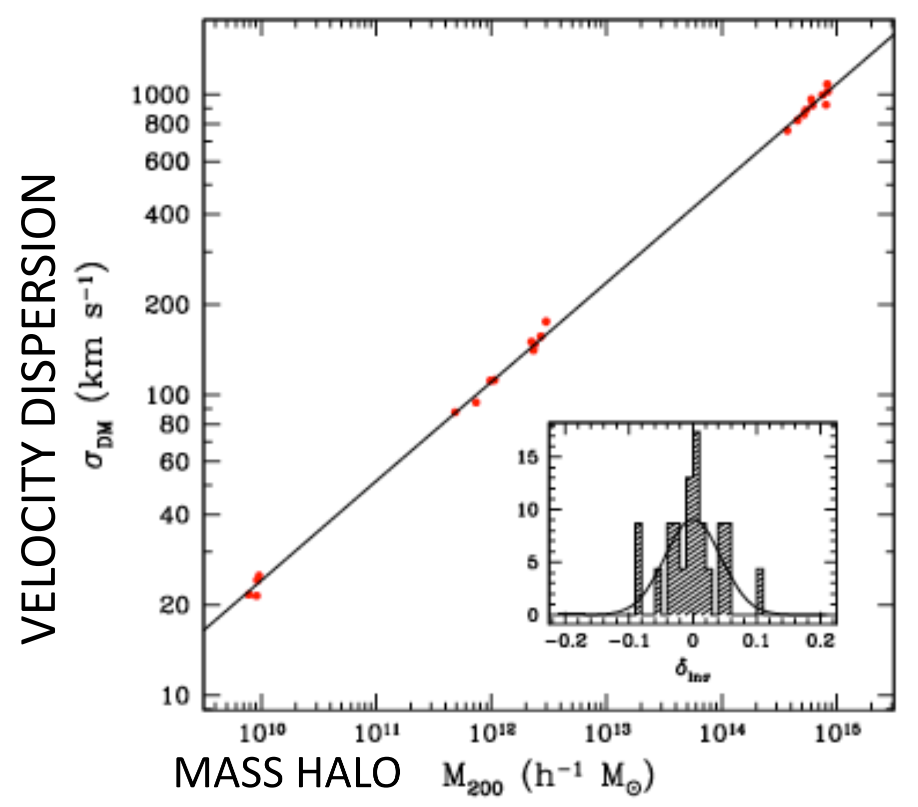
T prop to M σ^2
W prop to M^2/R

σ = A M ^(1/3)

$$M_{200} \equiv M(r_{200}) = 200\ \rho_c(z)\ \frac{4}{3}\ \pi\ r_{200}^3$$

Evrard et al give a relation between M_{200} and σ_{200}

$$log(\sigma_v(1D)) = log(1082.9) + 0.3361 log(h(z)M\sqrt{\Delta_c/200}/10^{15})$$



Coyote simulations

Jeans equation (r<r virial)

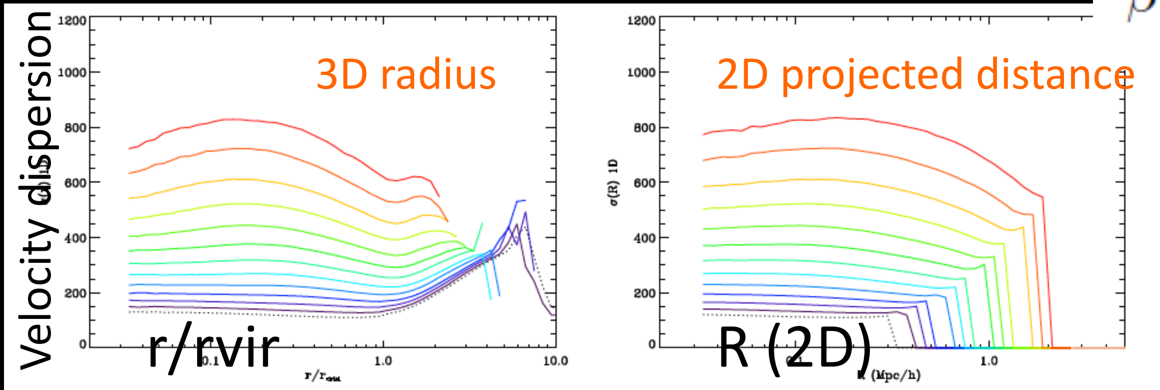
Jeans equation relates the orbits information and velocity with the mass.

Assuming spherical symmetry and stationary system, the Jeans equation:

$$v_{c,eq}^2 = -\sigma_r^2[dln(\rho\sigma_r^2)/dlnr + 2\beta] = v_c^2$$

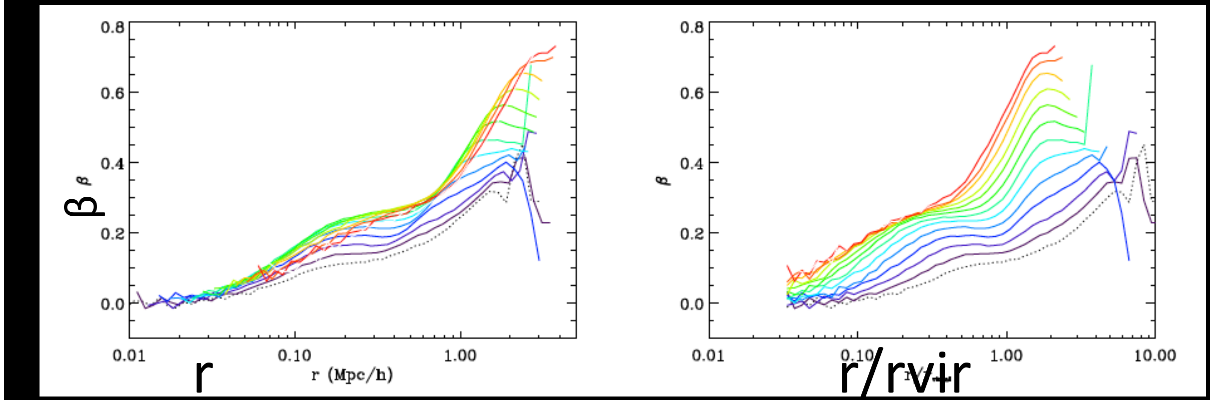
$$v_c^2 = GM(<R)/r$$

$$\beta = 1 - \sigma_t^2/(2\sigma_r^2)$$



1D (LOS) velocity dispersion for different masses

Mass higher → dispersion higher



Velocity anisotropy: beta

Orbits are more radial than tangential

Procedure for statistical dynamics

- Select clusters, host+satellite galaxies (problems: redshift space)

- Calculate velocity differences between host and satellite (we only have LOS direction)

- Stack the velocities depending on a mass dependent property (richness, host luminosity)

- Deal with interlopers, and other observational and theoretical effects

-Relate the velocity dispersion to an estimation of mass , for different radius!

Lensing and dynamics comparison

carefully, using exactly the same selection and taking into account the S/N at different radius.

Dynamics in real DATA: problems

Need to find clusters: host and satellite galaxies

- BCG's? (*Becker et al 2007*)
- condition in host-satellite luminosity, velocity difference, aperture (host is assumed to be the brighter one) *Yang et al 2008, More et al 2008*

We must correct by:

- Are brightest galaxies central galaxies? NOT ALWAYS *Skibba et al 2010*

- Fake hosts

- Hosts that are not well centered, or have velocity different from the center of mass of the halo

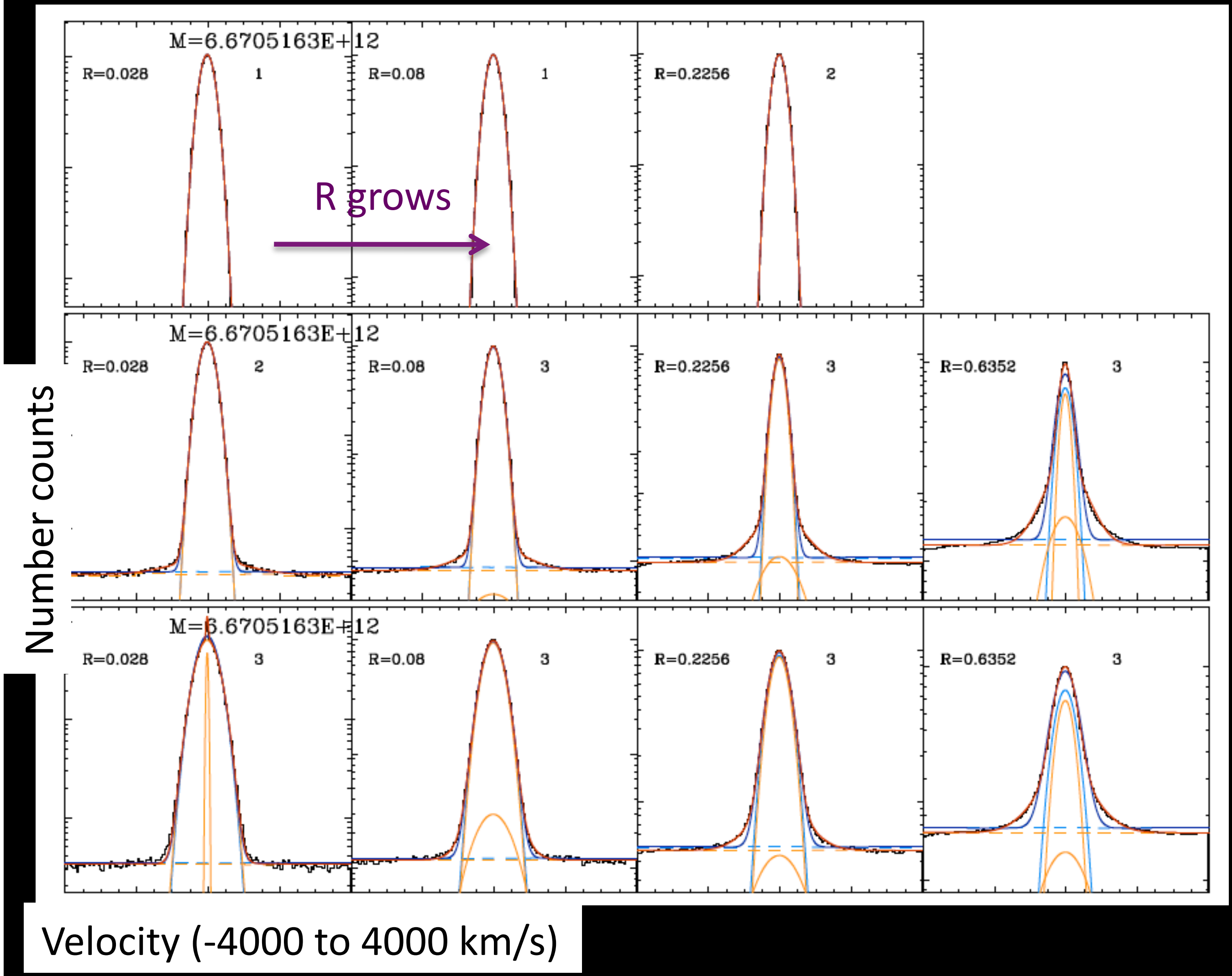
- INTERLOPERS: Fake satellites: happen to be on the LOS but not correlated with the halo (constant contribution + infalling contribution)

-Define halo to be able to convert velocities to mass

Mass mixing, clusters selected by luminosity or richness, not directly mass
Velocity bias, relation between galaxies and dark matter, no way to know right now

Some histograms (interloper and host problem)

Coyote dark matter simulations

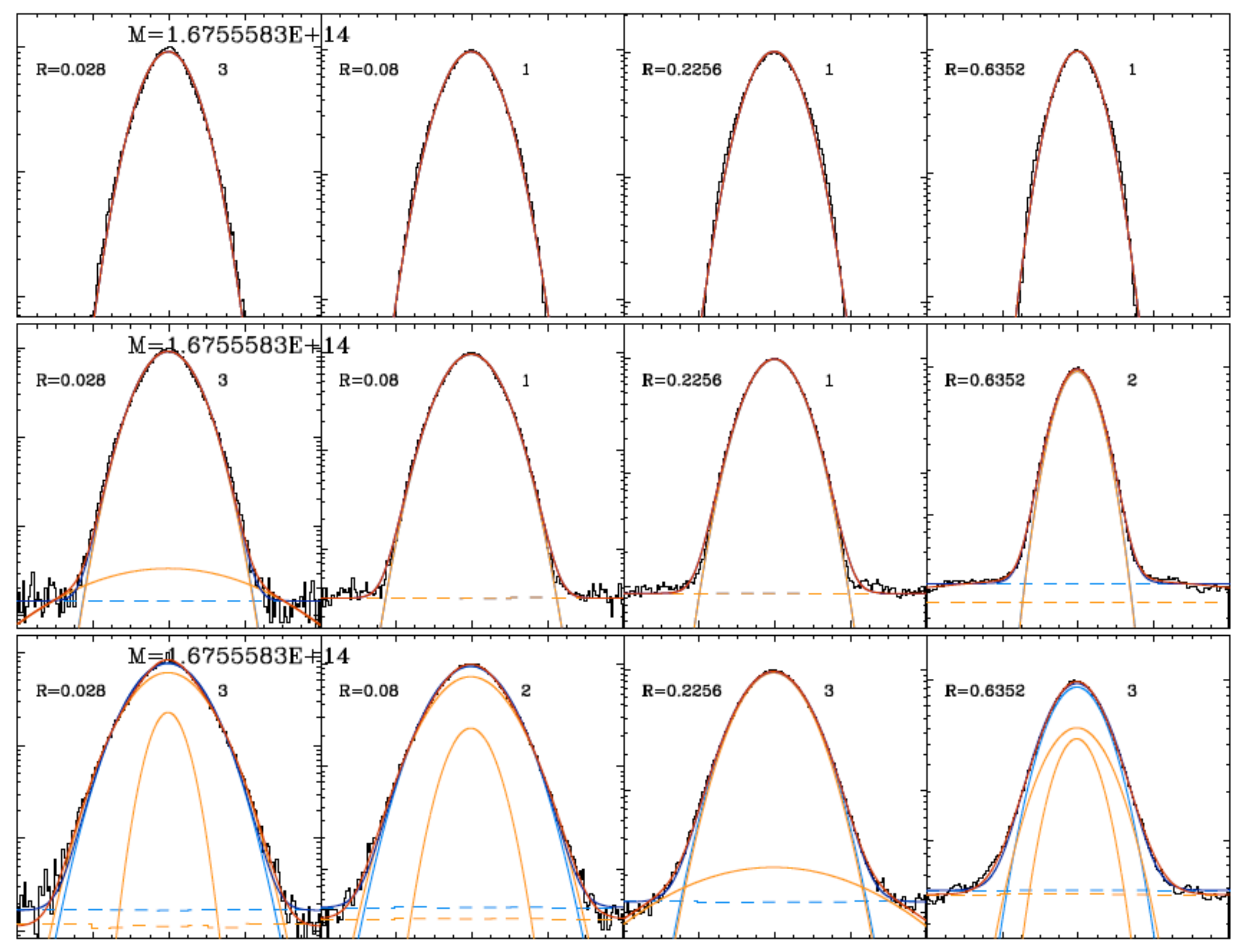


Halo defined as sphere
with overdensity=200
with center
the most bound particle
GAUSSIAN!

Halo selected with a
velocity cut of 4000km/s
INTERLOPER= gaussian+
infalling gaussian+ flat

Take wrong velocity as
the host velocity
DISPERSION GROWS
HIGHER ESTIMATED MASS

Higher mass → higher velocity dispersion

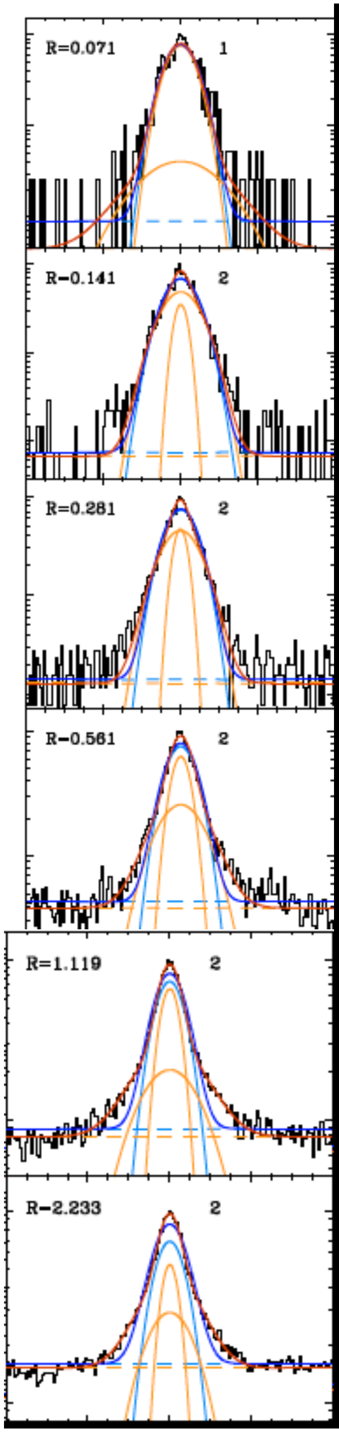


SDSS DR7: REAL DATA! (larger spectroscopic survey)

$M=-22.25,\ \log(L)=10.8$

red galaxies

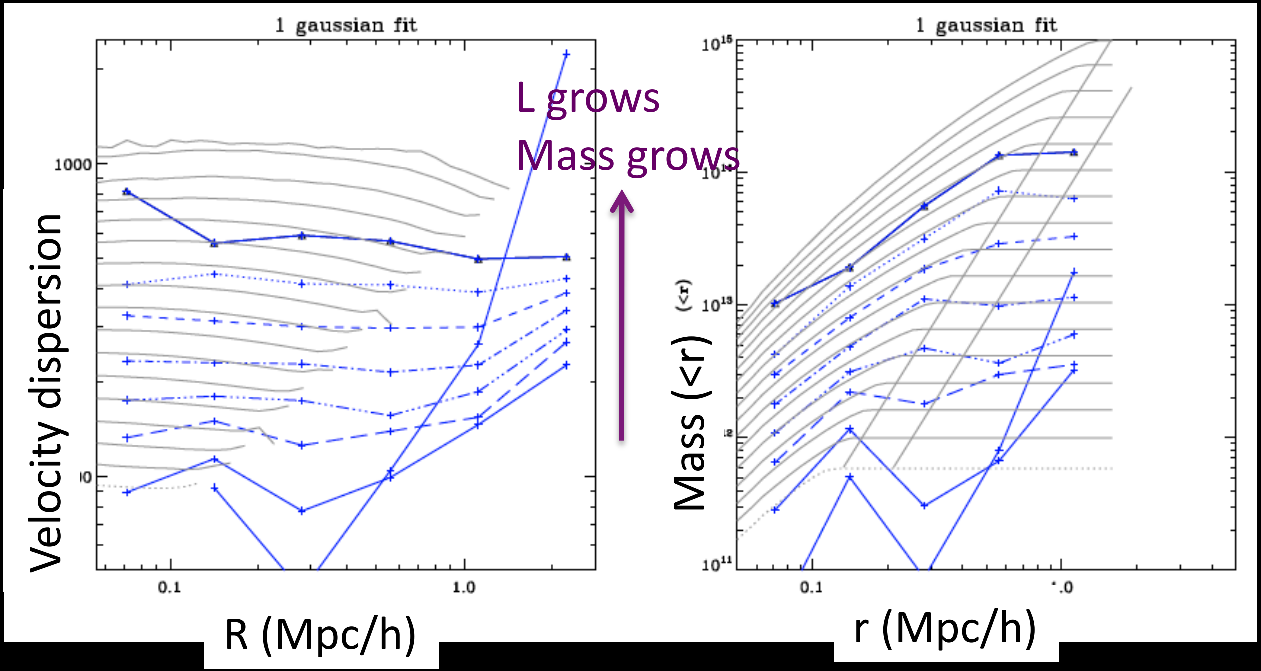
$z=0.01-0.2,\ \text{Mhostmin}=-19,\ \Delta v_{host} = 2400 km/s,\ \Delta v_{sat} = 2000 km/s,$
$R_{host} = 1.5 Mpc,\ R_{sat} = 0.5 Mpc,\ f_{host} = 1.1,\ f_{sat} = 1.1$



R grows

Velocity dispersion
for growing luminosity cuts

Mass unclosed estimated

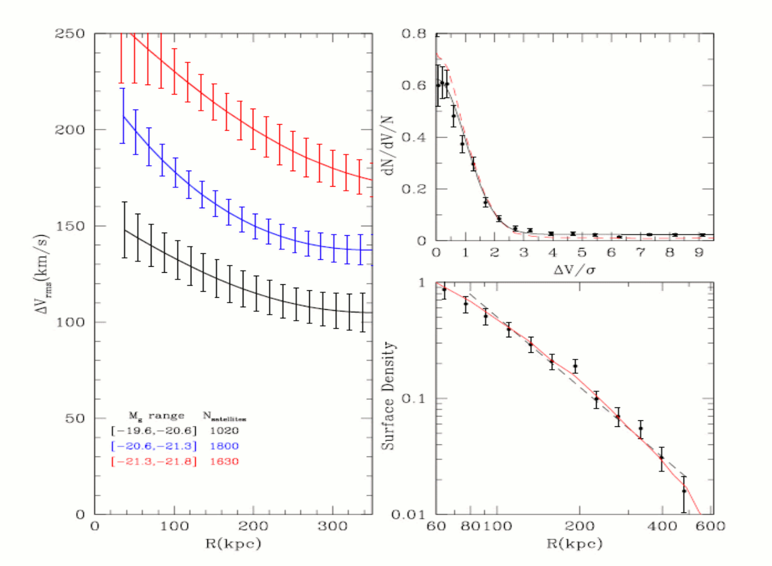


L grows
Mass grows

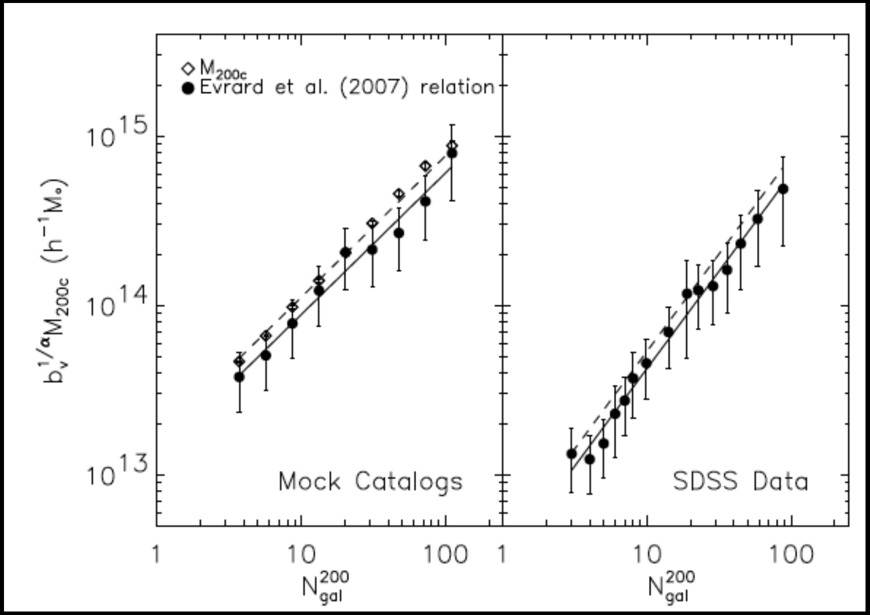
Future? No big spectroscopic survey like SDSS
But lots of multi-fiber (>100 fibers) spectrographs on wide field imagers (~1 sq deg). People are collecting data on 10s of clusters (big), in principle possible to get a sample of 100s of smaller clusters.

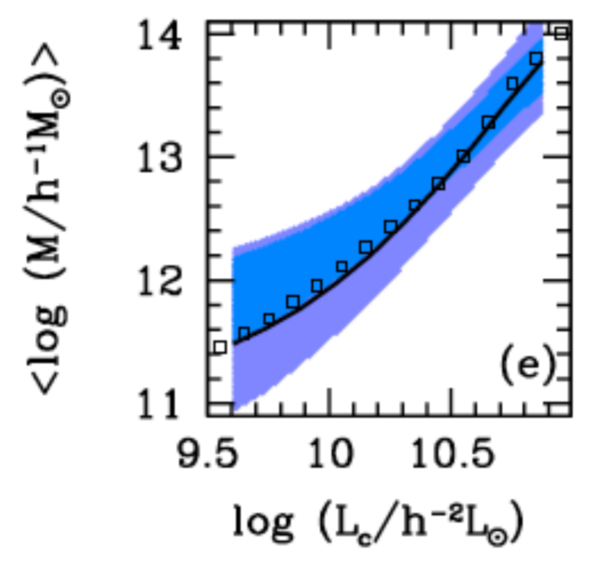
Literature, **B/C. Galaxies: dynamics at r~100 kpc**

Klypin et al 2007 Jeans equation, variation in R



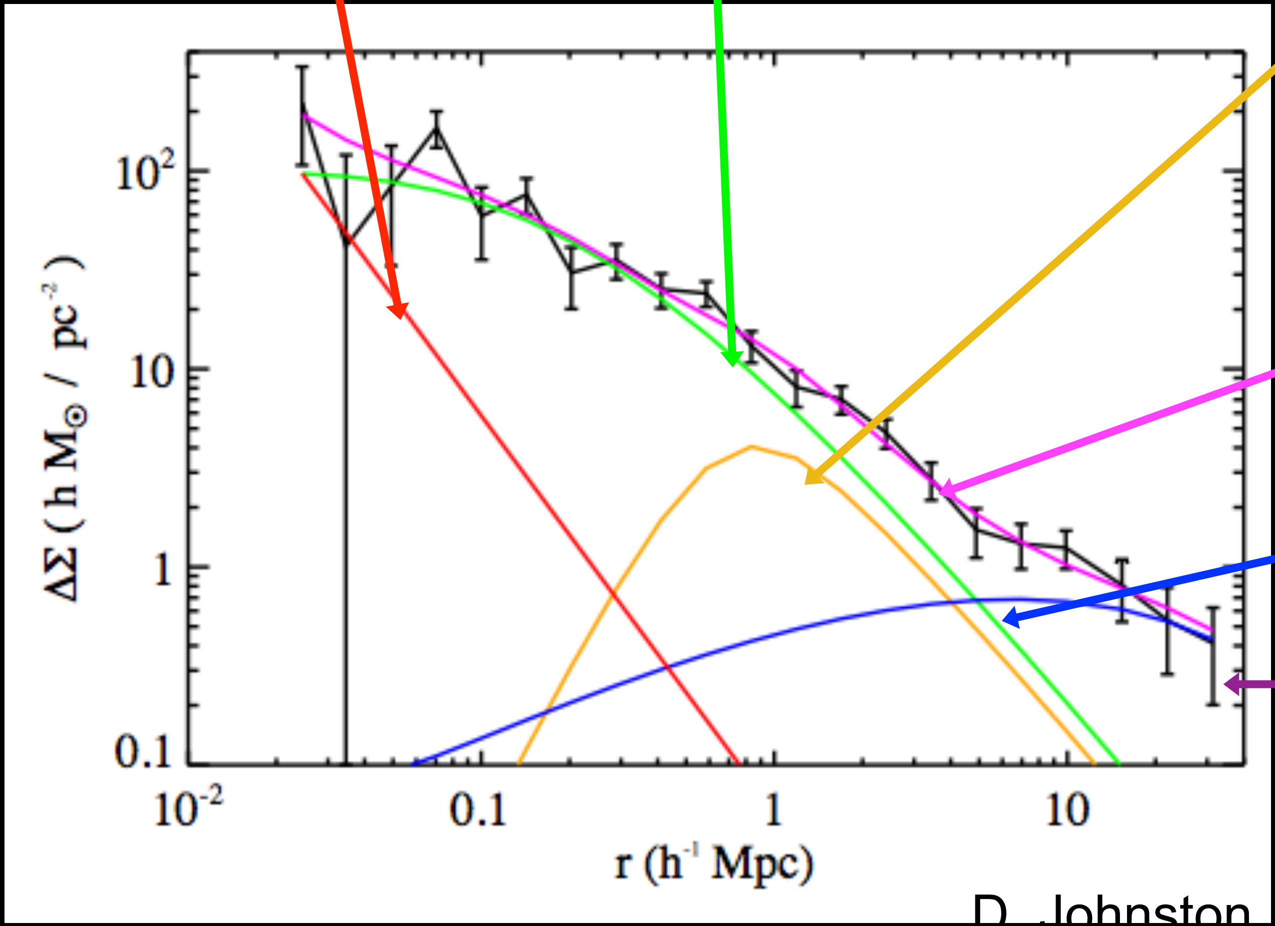
Becker et al 2007 BCG+virial scaling.
M-richness relation





More et al 2008
host luminosity selection M-L relation

Galaxy-galaxy lensing



Point mass term

NFW correctly centered

Miscentered halo

Sum of all

Two-halo term

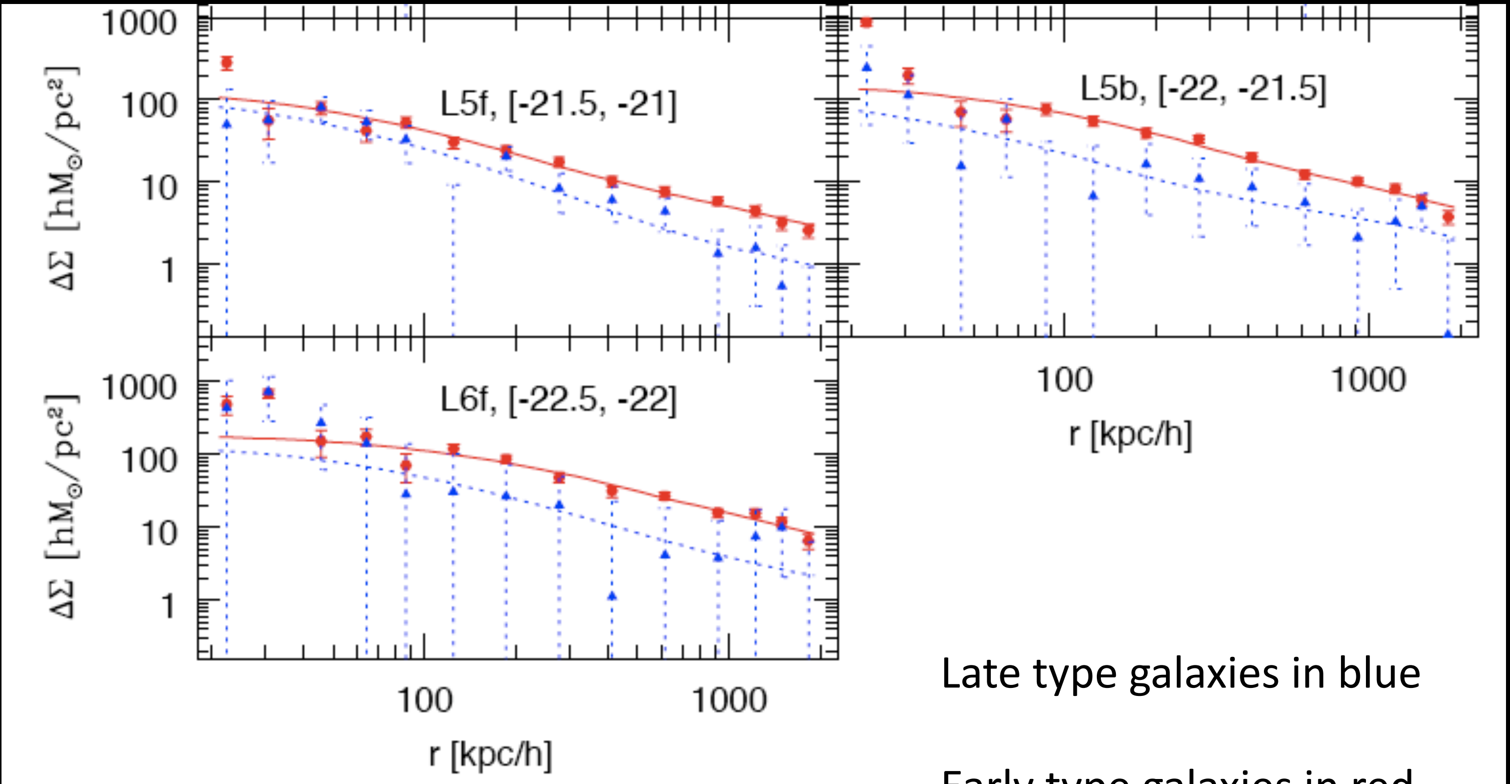
Shear value $\sim 10^{-4}$!

D. Johnston

Modeling is always needed! This shows the effect of observational error (halo center) plus theoretical error (1 halo vs 2 halo).

The nature of the 2 halo is quite different in the dynamical part, what we call “correlated interloper”

B. Galaxy-galaxy lensing



Late type galaxies in blue

Early type galaxies in red

- •Projected mass profile in three luminosity bins *Mandelbaum et al 2006*
- •Statistical errors on lensing/dynamical comparison at 100-400 kpc: ~20%
- •Systematic errors are comparable or larger.
- •Errors in lensing are quite small, compared to dynamics errors, and they can still improve more

Galaxy-galaxy lensing future surveys

$$\gamma_T \Sigma_{\rm crit} = \bar{\Sigma}(< R) - \bar{\Sigma}(R) \equiv \Delta\Sigma$$

$$\Sigma_{\rm crit}^{-1} = \frac{4\pi G D_{LS} D_L}{c^2 D_S}$$

zl (SDSS) = 0.2   zl (DES) = 0.4
zs (SDSS) = 0.4   zs (DES) = 0.7

Nl (SDSS) = 10^5   Ns (SDSS) = 30 10^6
Nl (DES) = 10^6   Ns (DES) = 100 10^6

nlense(DES) / nlense(SDSS) = 5-10
nsource(DES) / nsource(SDSS) = 3

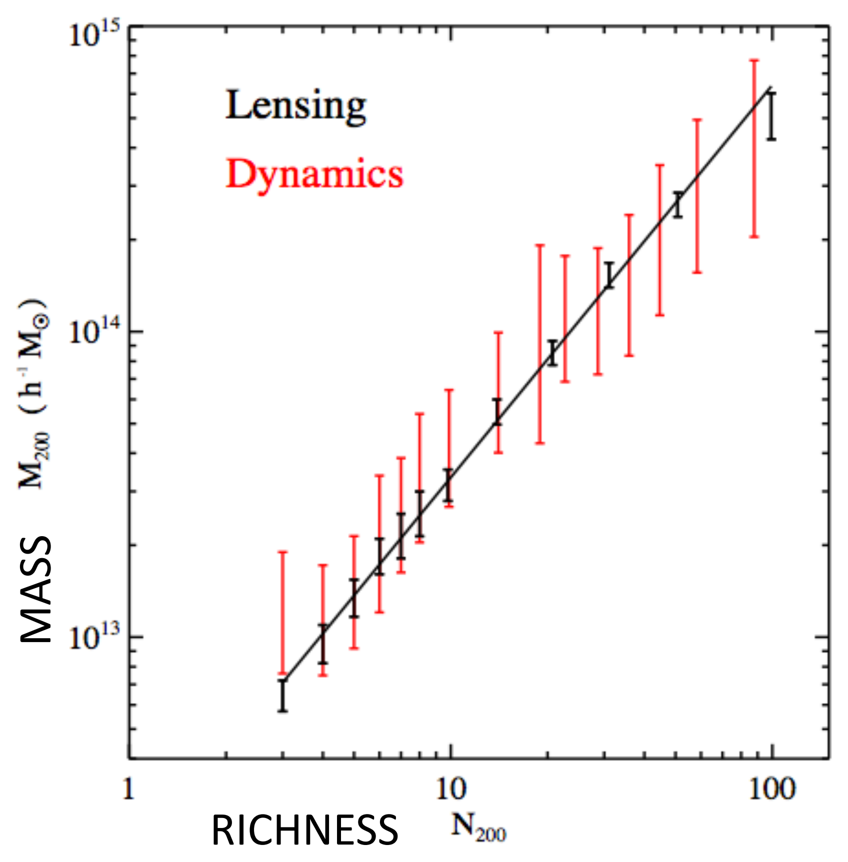
Err= sqrt{ (Nl_DES x ns_DES) / (Nl_SDSS x ns_SDSS) }

DES: 10 times smaller error bars than SDSS.

LSST, SNAP are at least 4 times smaller still!

Comparison lensing-dynamics

Johnston et al , BCG clusters



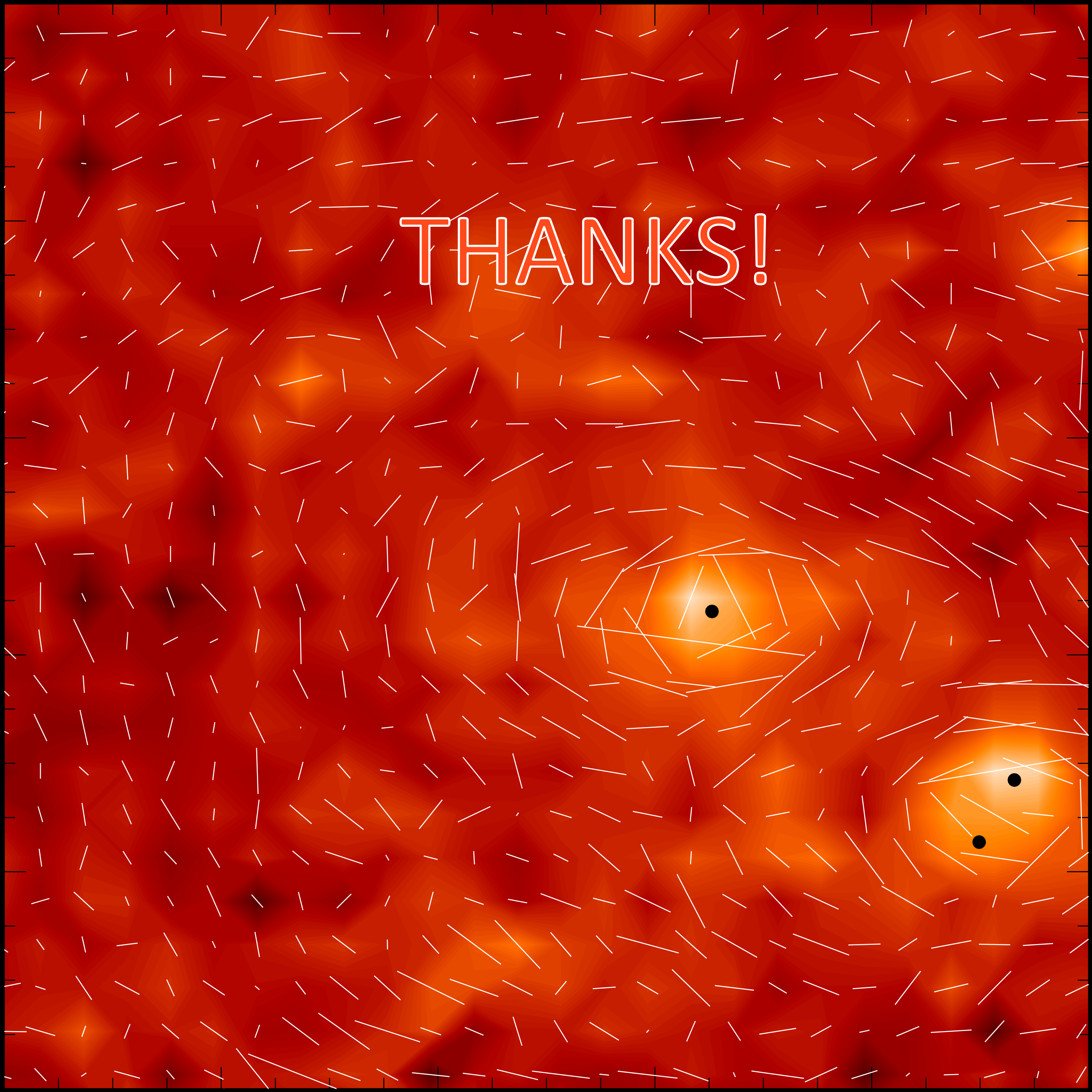
CONCLUSIONS AND FUTURE

Errors from dynamics higher than lensing

Dynamics have a lot of systematics and model assumptions, try to improve that.

Study in detail R variation

By comparing lensing and dynamics, we can know about modified gravity



THANKS!