Dark-to-luminous mass fraction of Early-Type galaxies

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Galaxy Evolution & Environment – Milano 9 november 2011

sponsored by:

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G. Covone	Univ. Naples
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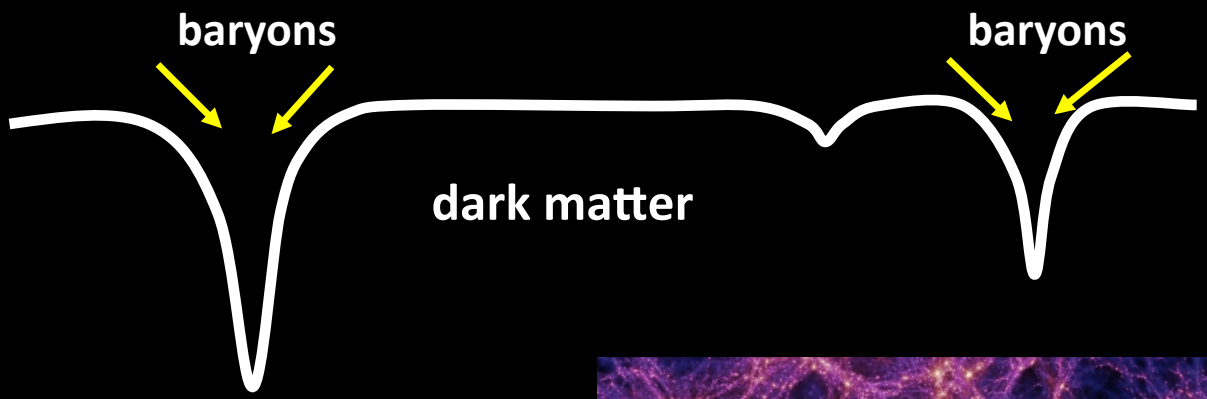
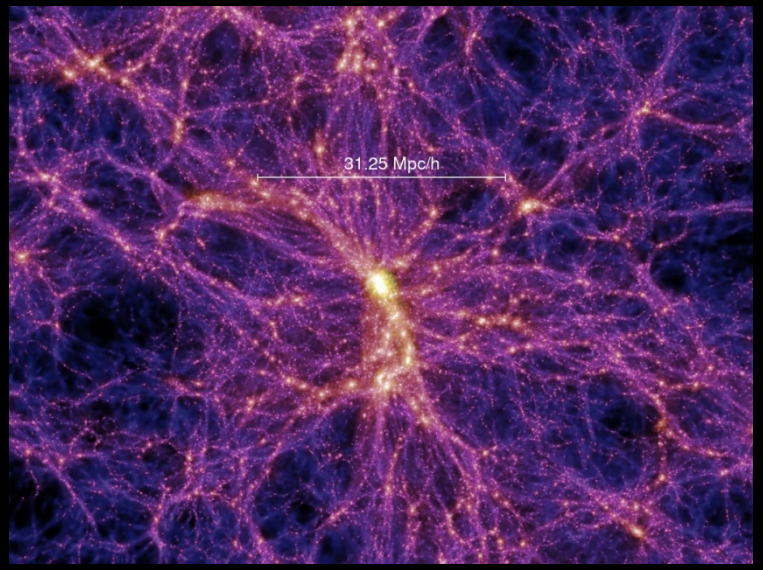
A. Romeo	Univ. E. Bello Santiago (Chile)

Outline

- a quick inventory of questions we want to address
- the central regions of ETGs: stellar populations and DM fractions
- new scaling relations of the central DM in ETGs (Reff, Age)
- environment
- conclusions

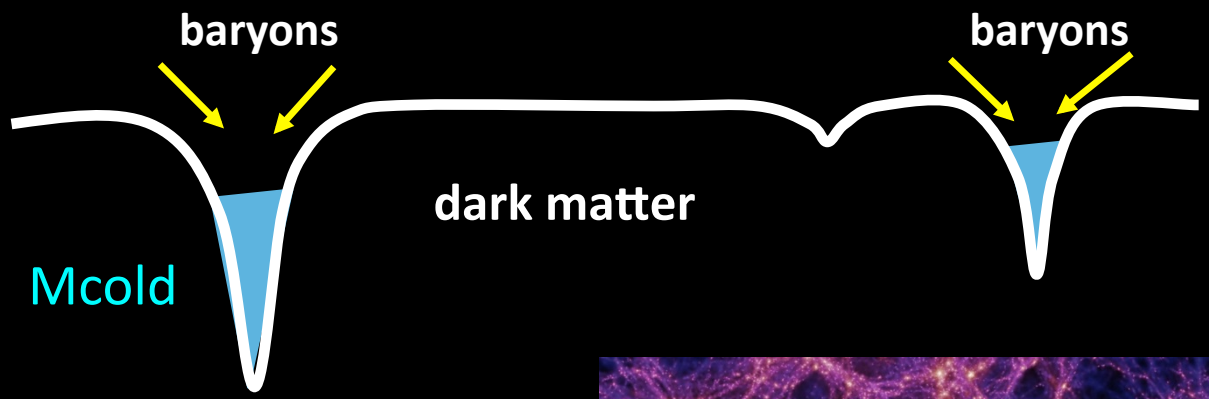
Background





Millennium Simulation

Background



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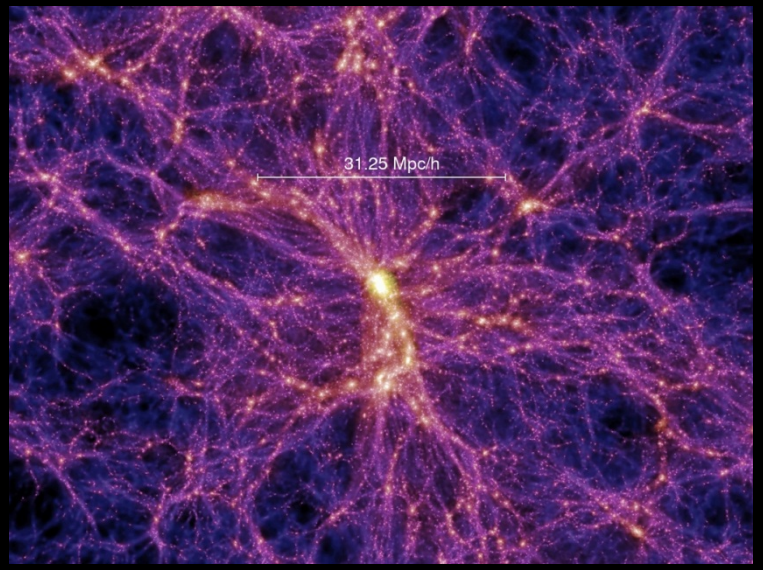

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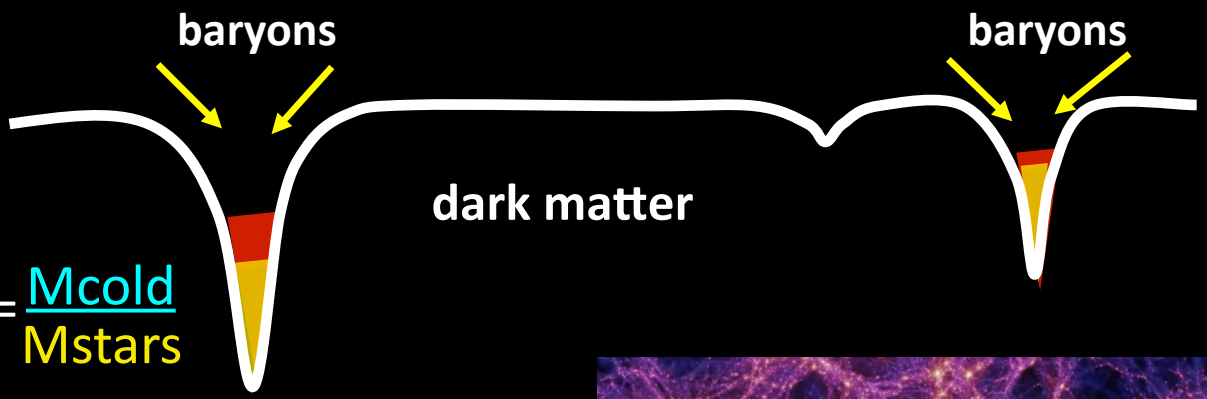
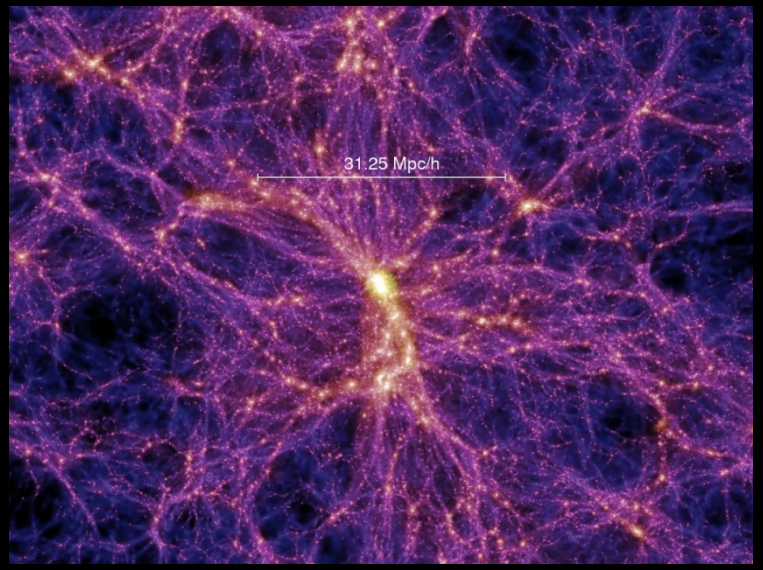


$(\text{SF efficiency})^{-1} = \frac{\text{Mcold}}{\text{Mstars}}$



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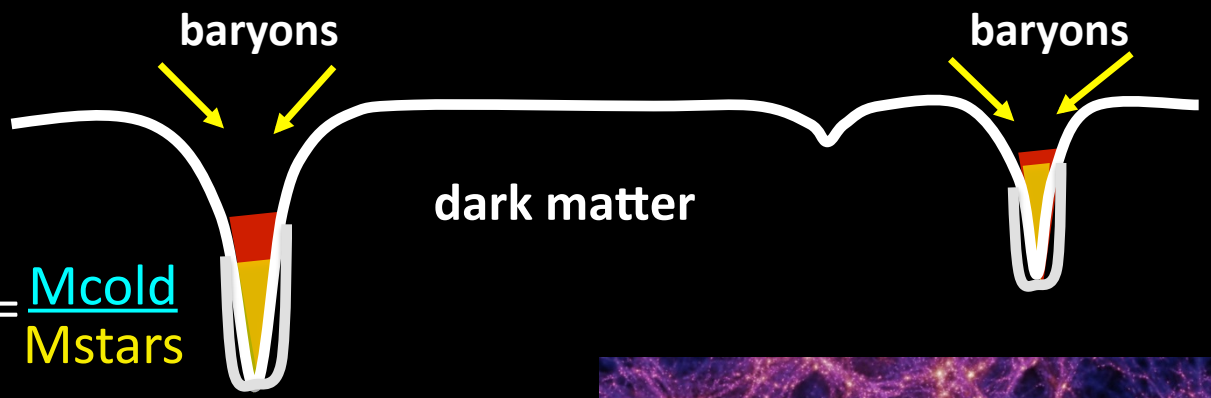
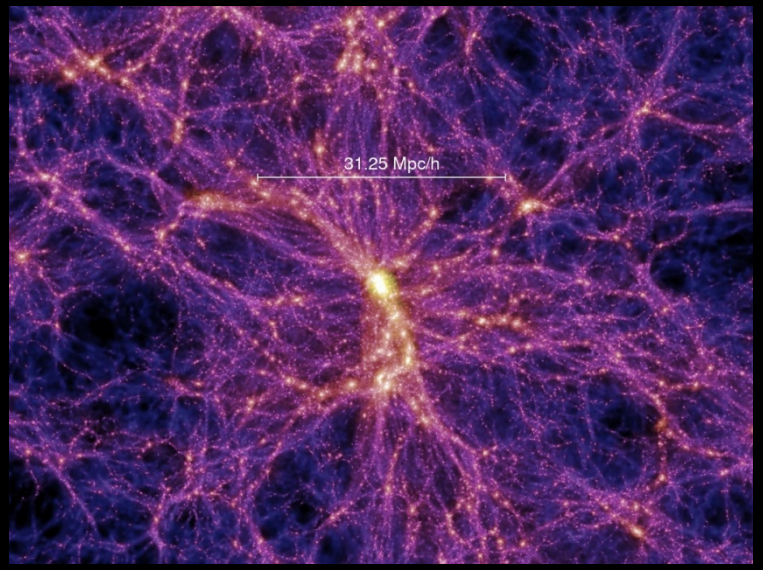


$(\text{SF efficiency})^{-1} = \frac{M_{cold}}{M_{stars}}$

Adiabatic Contraction



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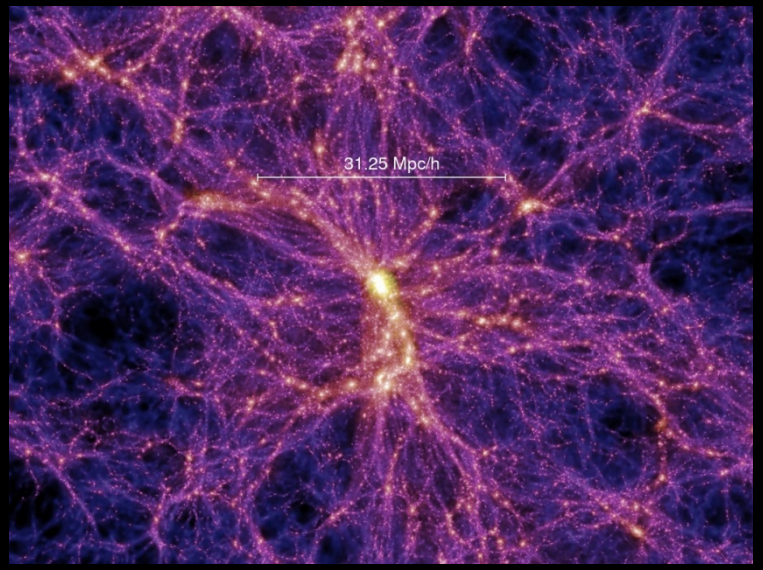

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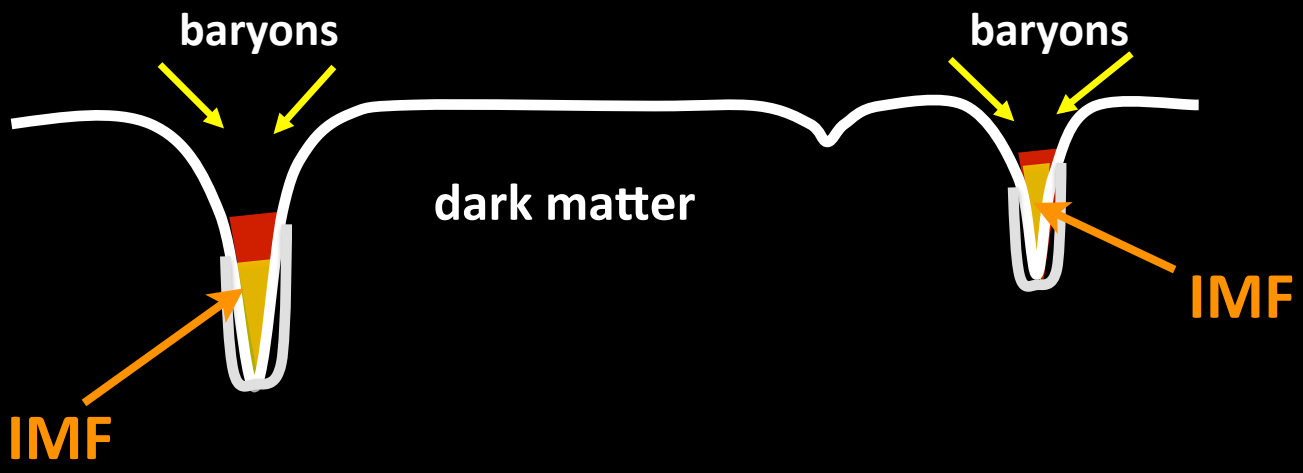
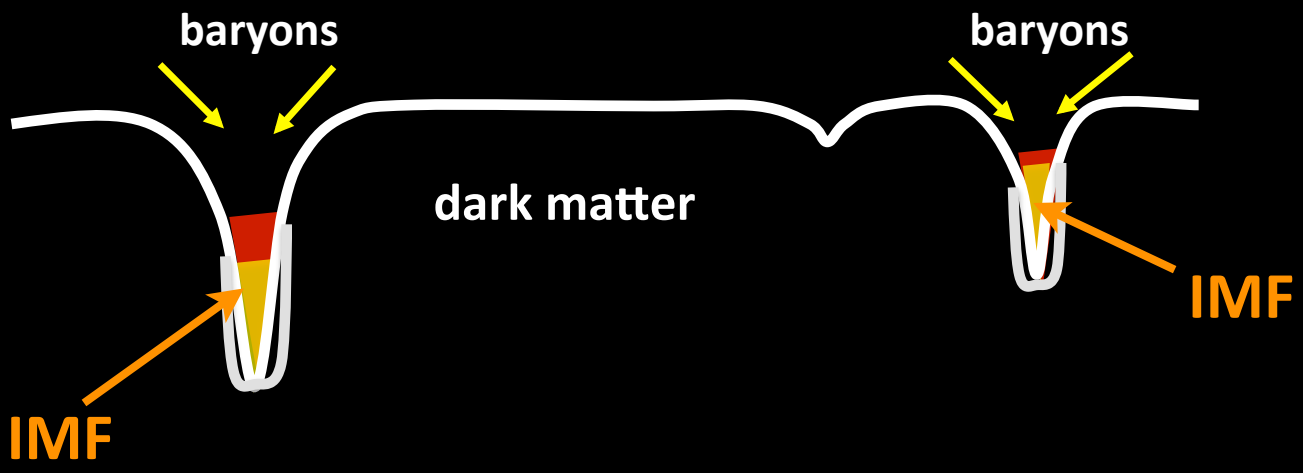


$$f_{DM} = \frac{M_{\rm DM}}{M_{\rm tot}} = \frac{M_{\rm DM}}{M_* + M_{\rm DM}}$$

Background



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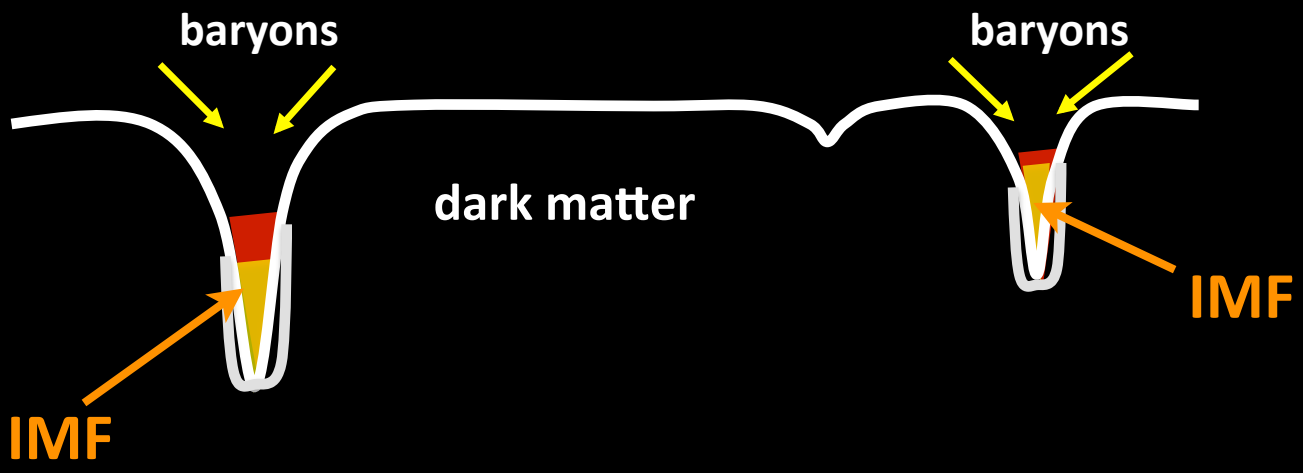
IMF

Background



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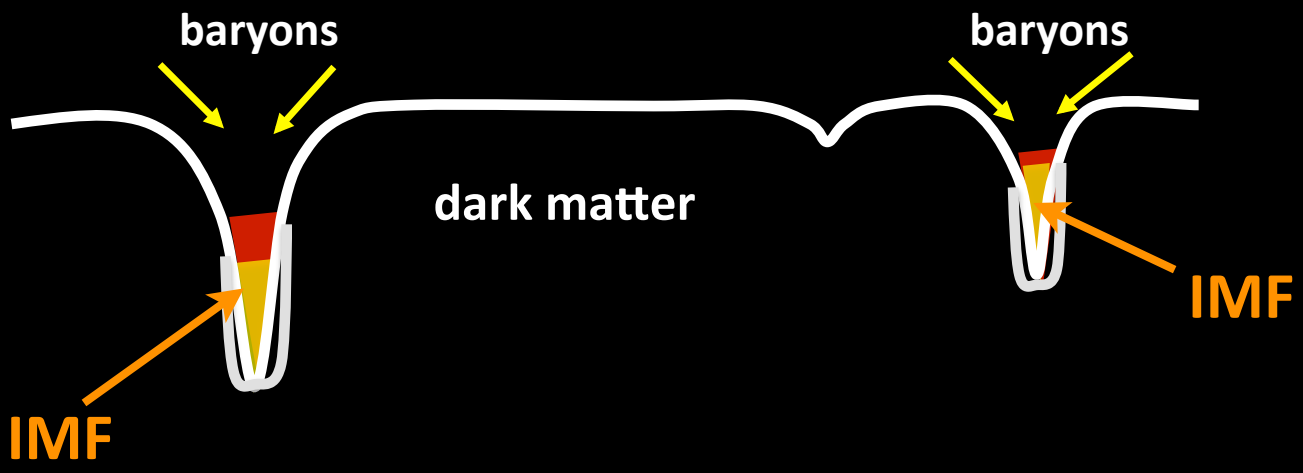


$$f_{\rm DM}^{\rm vir} = 1 - \epsilon_{\rm SF} \frac{M_{\rm bar}}{M_{\rm tot}} \sim 1 - 0.17\,\epsilon_{\rm SF}$$

star formation efficiency

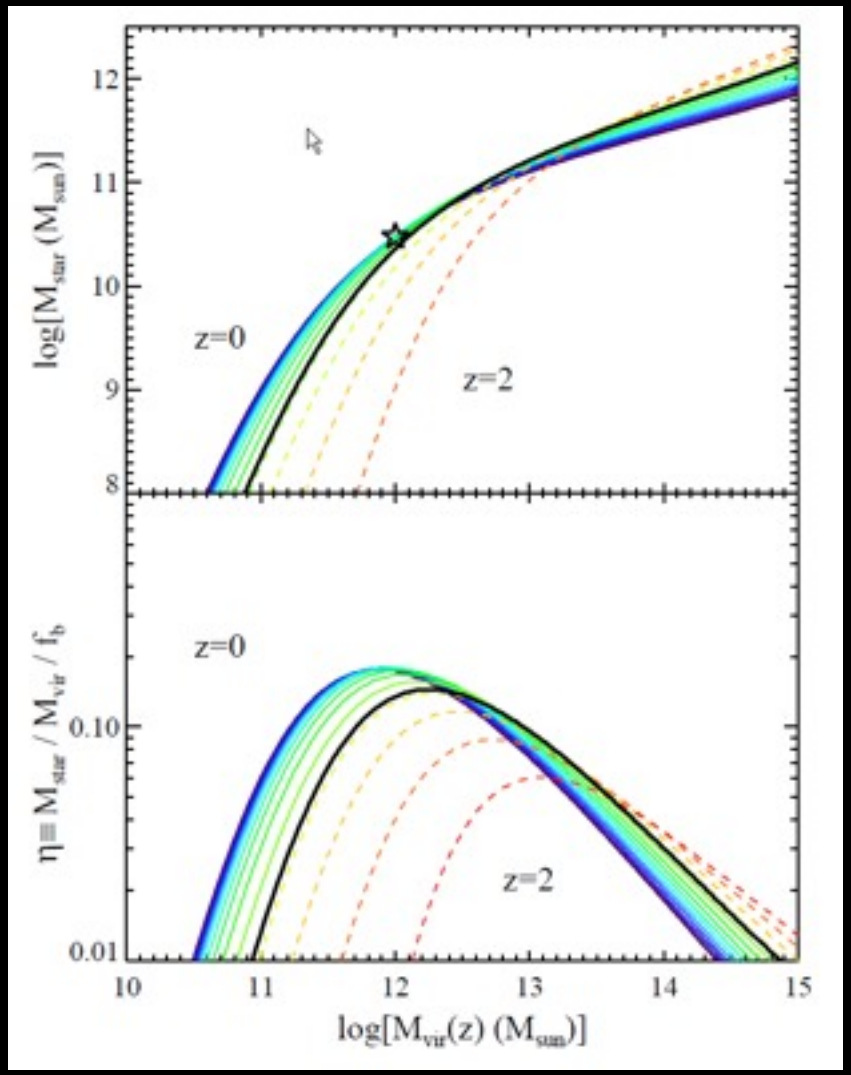
The galaxy formation picture

The cumulative effect is different at different mass scales: the star formation efficiency

Abundance matching:
observed spatial abundance of galaxies to the expected spatial abundance of halos at multiple epochs

ε_{SF} = fraction of baryon mass turned into stars

Conroy & Wechsler 2009



Why central dark matter fraction of early-type galaxies?

M/L_*

IMF

halo contraction

Why central dark matter fraction of early-type galaxies?

fundamental plane

$$r_e \sim \sigma_o^A I_e^B$$

$$(M/L) \sim \sigma^{2-A} I^{-1-B}$$

$$M/L \sim M^{\gamma}$$

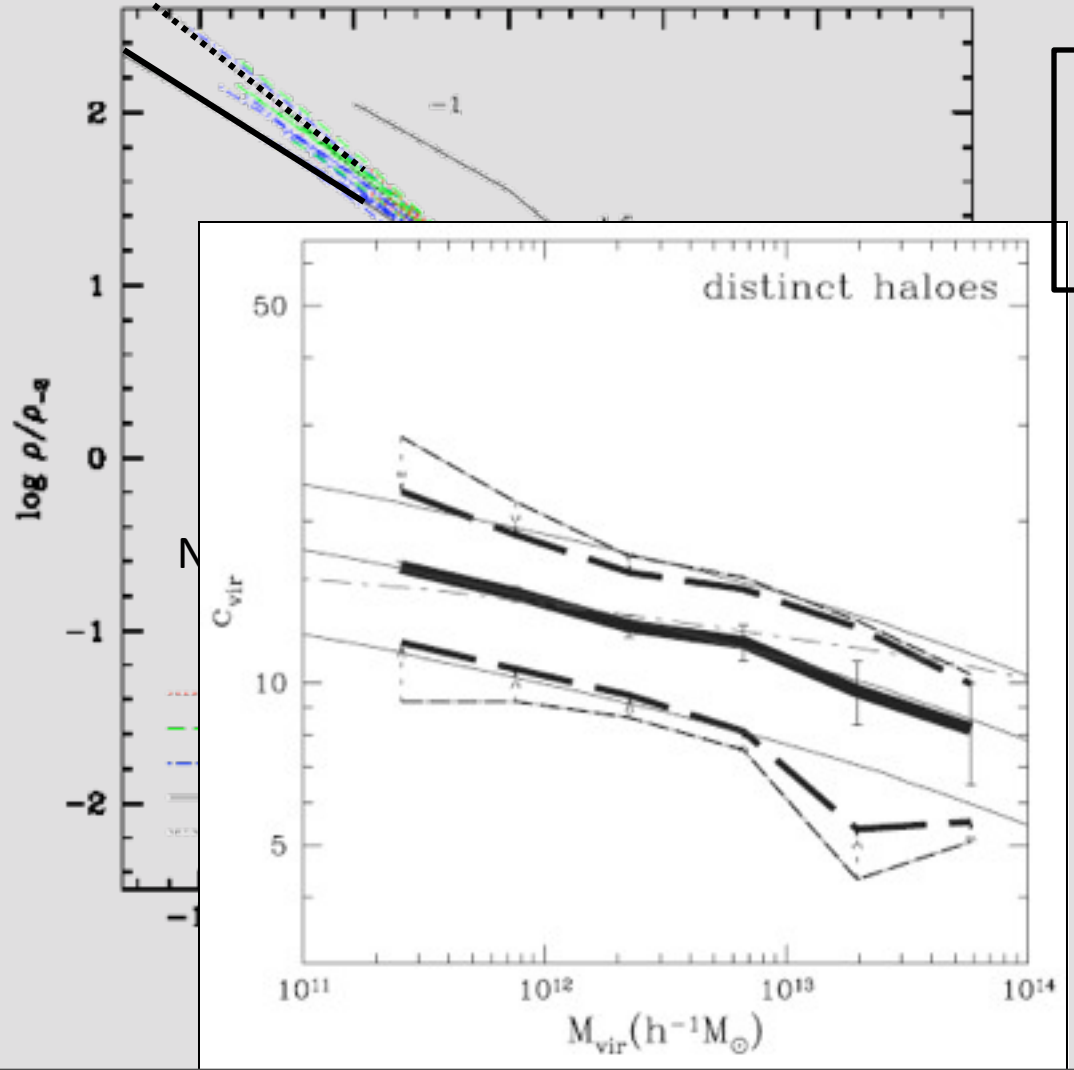
Why central dark matter fraction of early-type galaxies?

fundamental plane

$$f_{DM} = 1 - \frac{M/L_*}{M/L_{\rm dyn}}$$

DM haloes in the LCDM cosmology

(Cossisionless) Simulations say that DM halos are cuspy!



NFW

$$\rho(r) = \frac{\rho_s}{r/r_s(1+r/r_s)^2}$$

Moore et al. 1999

$$\rho_M(r) = \frac{\rho_M}{(r/r_M)^{1.5}\left[1+(r/r_M)^{1.5}\right]}$$

Bullock et al. 2001

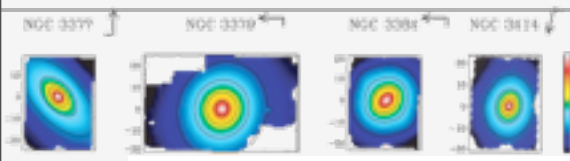
$$c = \frac{9}{1+z}\left(\frac{M_{vir}}{1.5\times10^{13}}\right)^{-0.14}$$

Central dark matter fraction of early-type galaxies

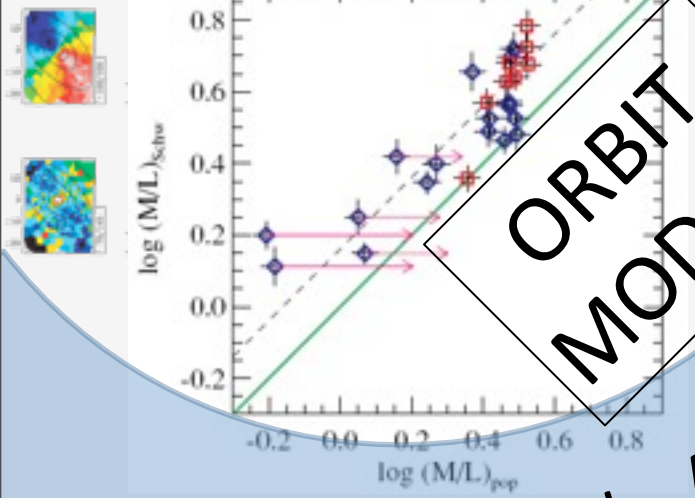
stellar mass

dynamical mass

Central mass content of early-type galaxies



SAURON
Cappellari et al. 2006

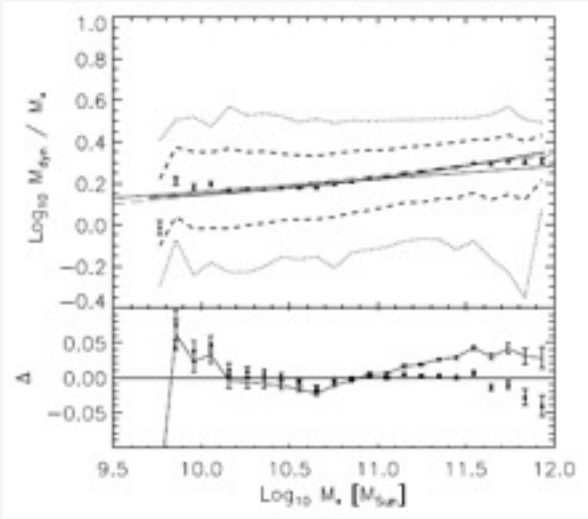


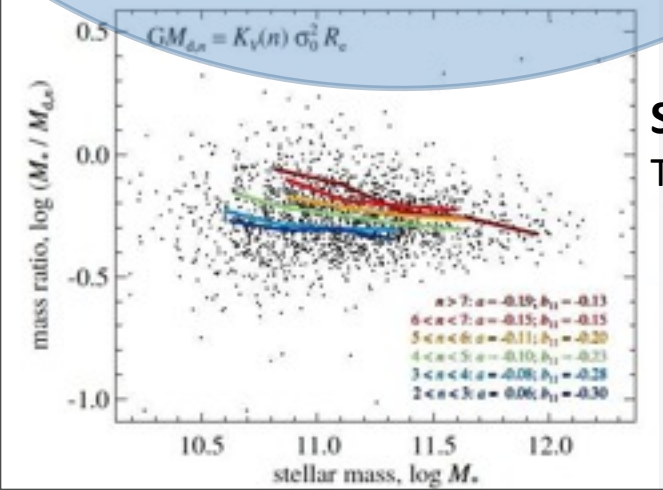
ORBIT MODELS

D Y N A M I C S

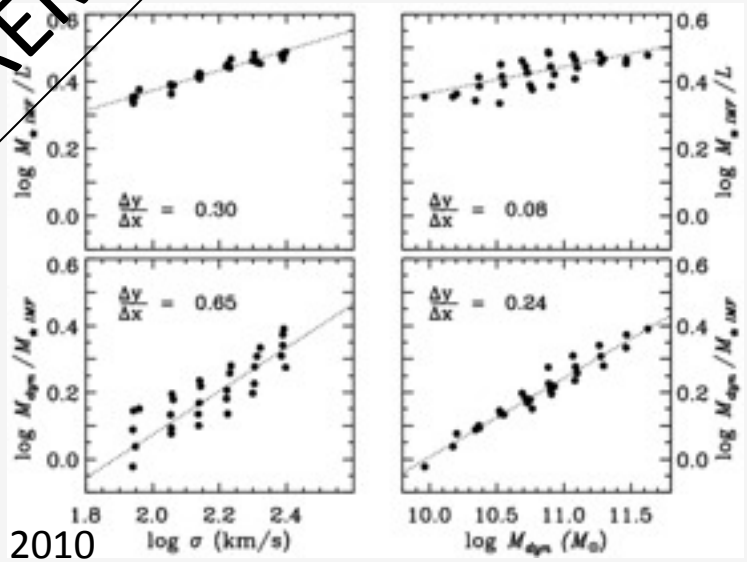
VIRIAL THEOREM

SDSS/DR4 (~50000 gal)
Hyde & Bernardi 2009





SDSS/DR7
Taylor et al. 2010



SDSS/DR6
(~16000 gal)
Graves et al. 2010

Central M_{DM}/M_* of early-type galaxies

We have started a pilot program on a limited sample of ~330 galaxies from Prugniel & Simien 1997:

1) Multiband photometry
2) Structural parameters (Re, Sersic index)
3) Aperture dispersion and rotation measurement
4) **Overlap with literature studies with more sophisticated analysis**

Central M_{DM}/M_* of early-type galaxies

Dynamical methods

Spherical Jeans analysis

isotropic models

stellar mass from Sersic

total mass isothermal

galaxy rotation

$$\frac{\mathrm{d}(j_*\sigma_r^2)}{\mathrm{d}r} + 2\,\frac{\beta(r)}{r}\,j_*\sigma_r^2 = -j_*(r)\,\frac{GM(r)}{r^2}$$

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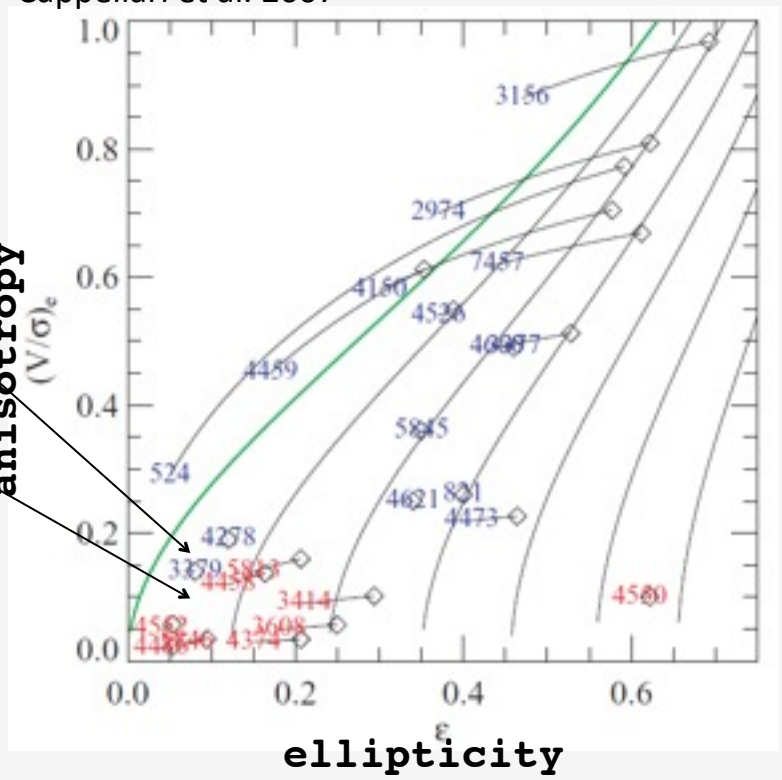
Cappellari et al. 2007



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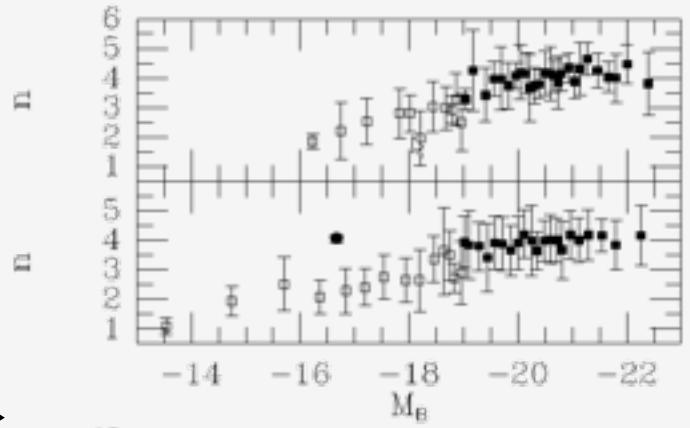
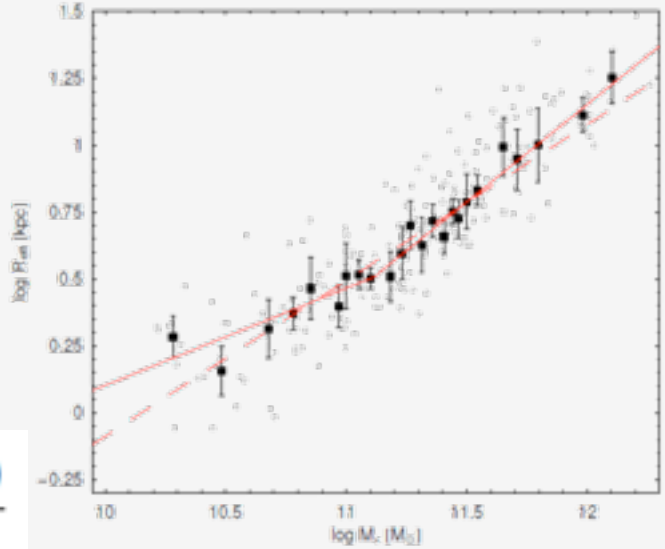
Prugniel & Simien 1997





Tortora et al. 2009

Central M_{DM}/M_* of early-type galaxies

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Spherical Jeans analysis

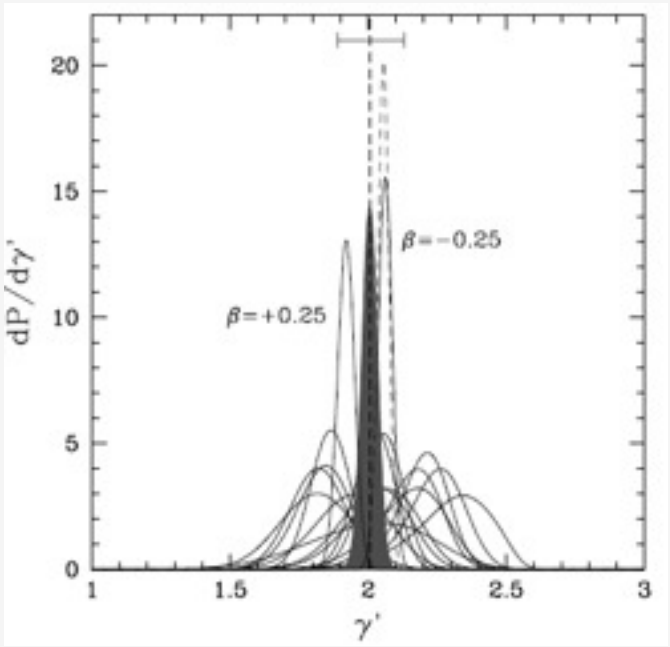
isotropic models

stellar mass from Sersic

total mass isothermal ⟶

galaxy rotation

Koopmans et al. 2006



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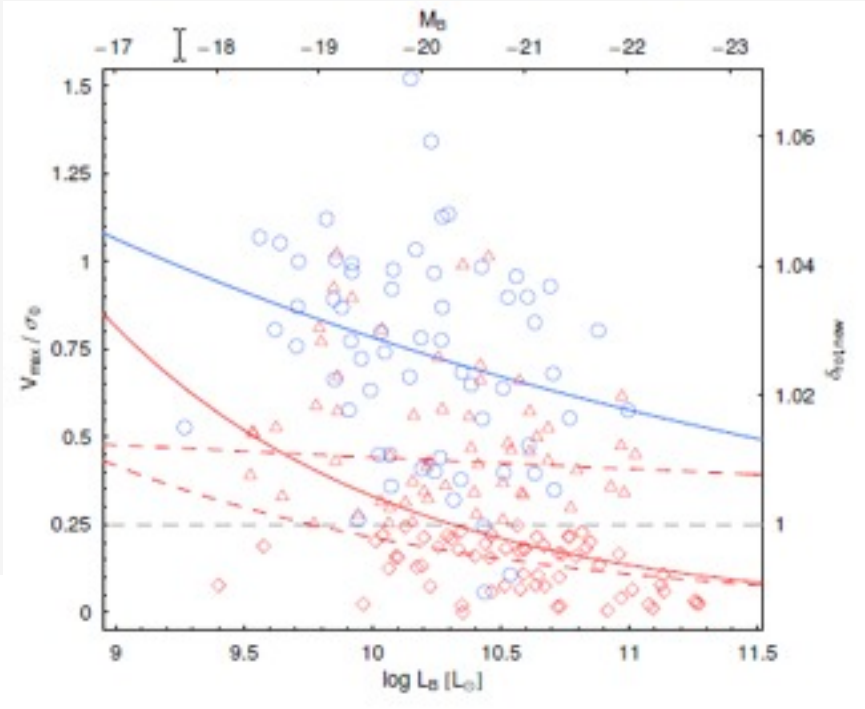

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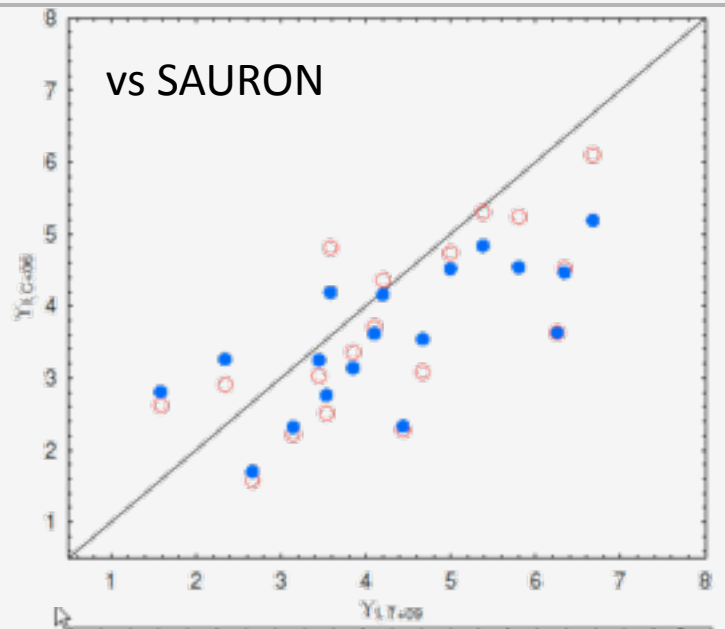
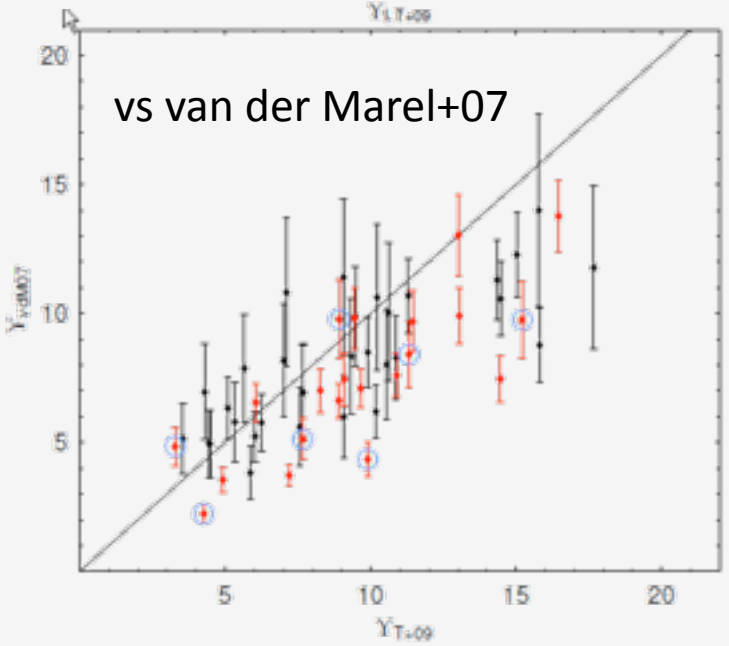




Central M_{DM}/M_* of early-type galaxies

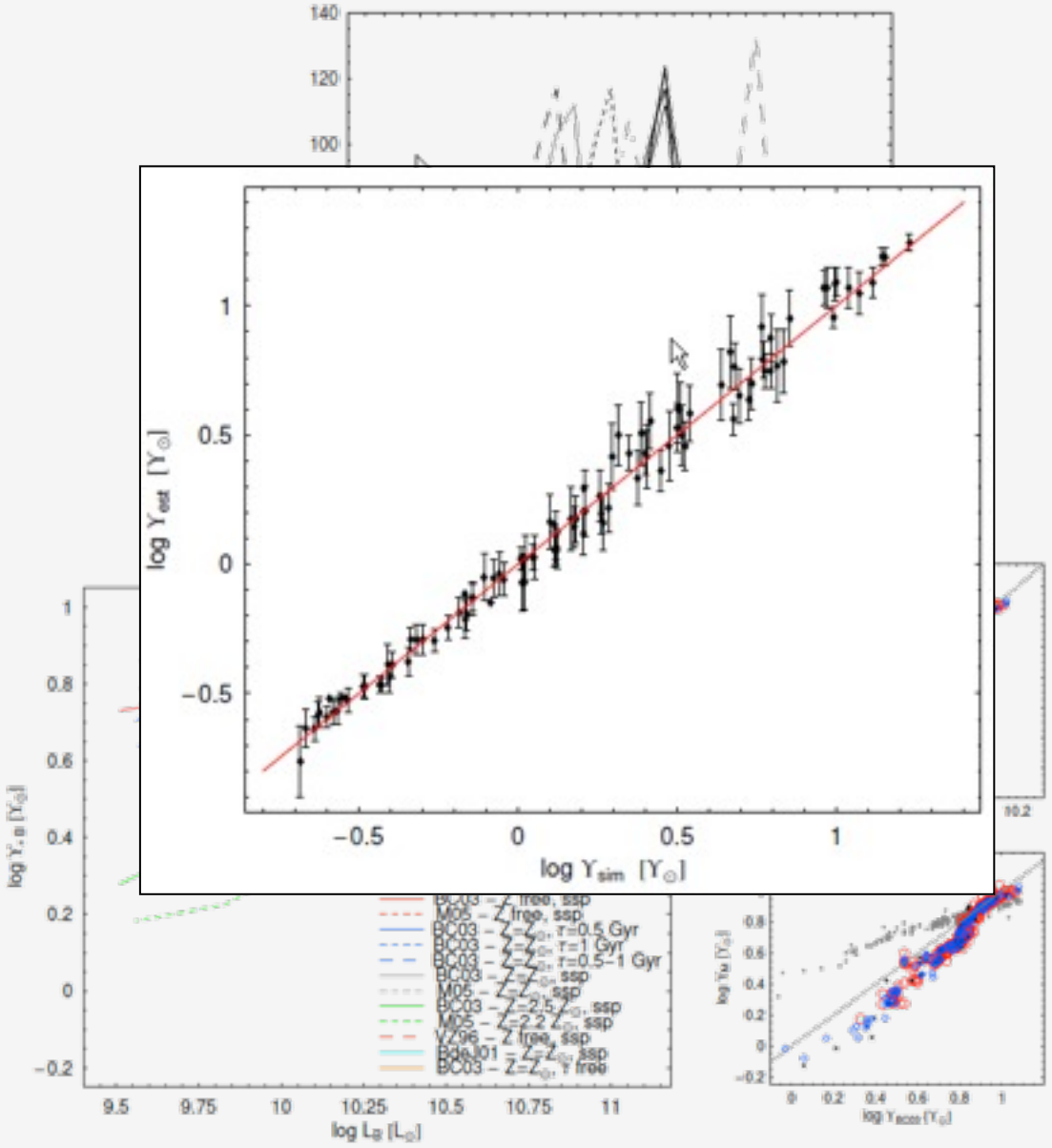
Stellar populations

Bruzual & Charlot 2003
Charlot & Bruzual 2007
Maraston 2005

Simple Stellar population
Exponentially decaying SFR

Salpeter IMF
(Kroupa IMF)
Chabrier IMF

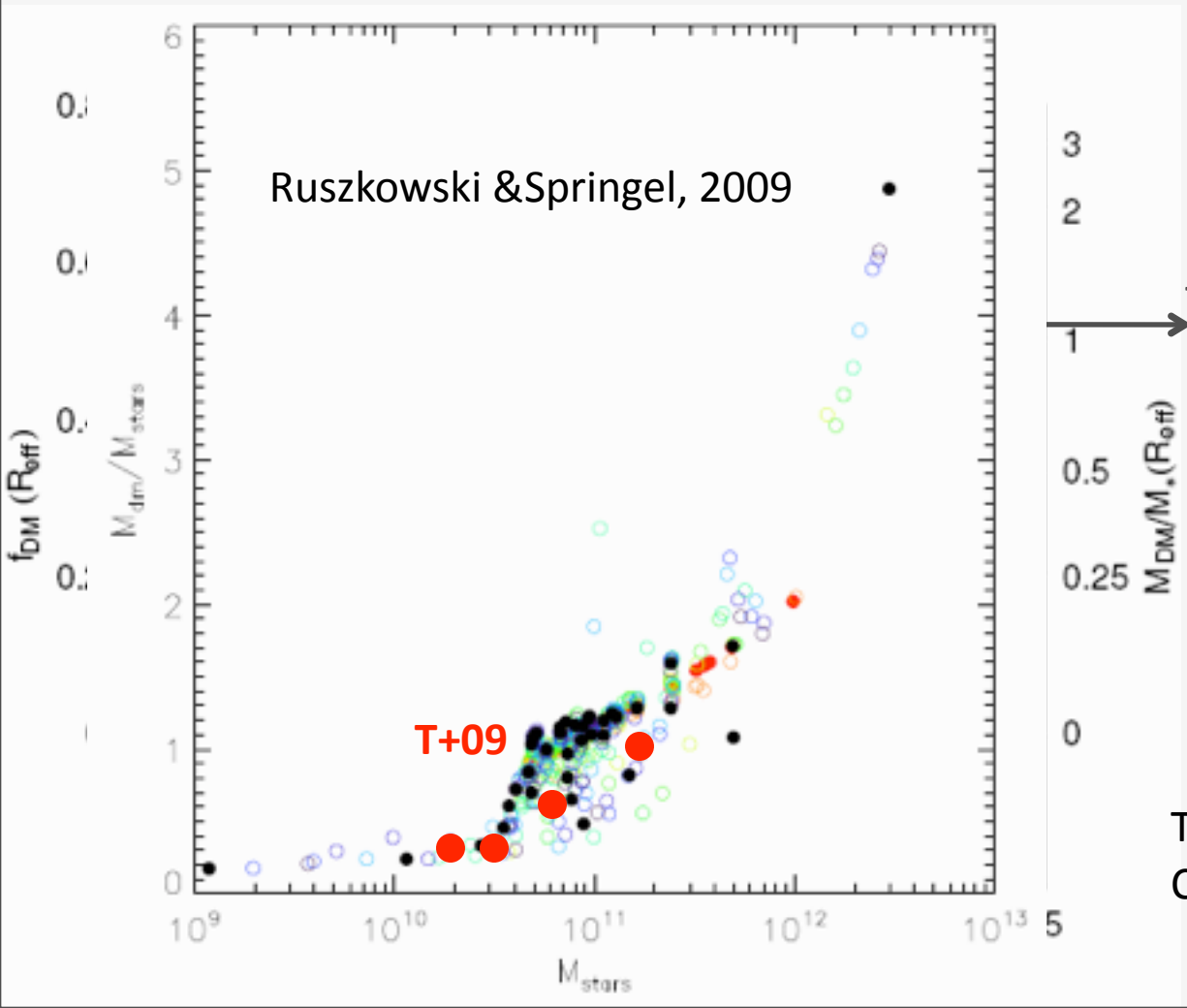
Z, Age, τ free parameters



Central M_{DM}/M_* of early-type galaxies

DM fraction depends on galaxy luminosity, mass and R_{eff}

$f_{DM} = M_{DM}/M_{tot} = (1+M_*/M_{DM})^{-1}$



ellipticals

lenticulars

Tilt of the Fundamental Plane

$M/L \sim L^{0.2}$

20 to 50% dark matter within 1 effective radius

Tortora, Napolitano, Romanowsky, Capaccioli, Covone (2009)

Central M_{DM}/M_* of early-type galaxies

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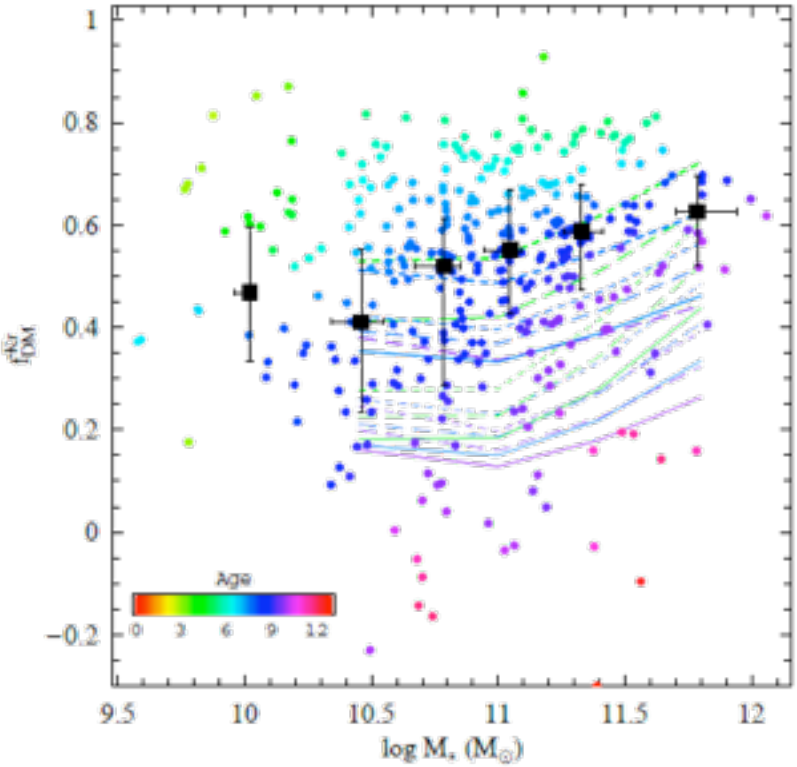
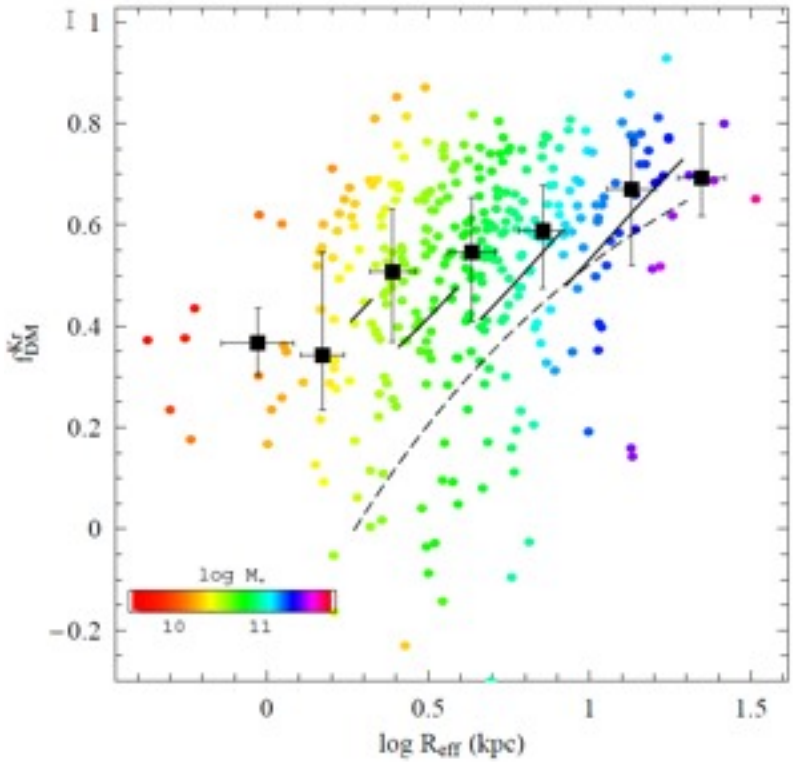
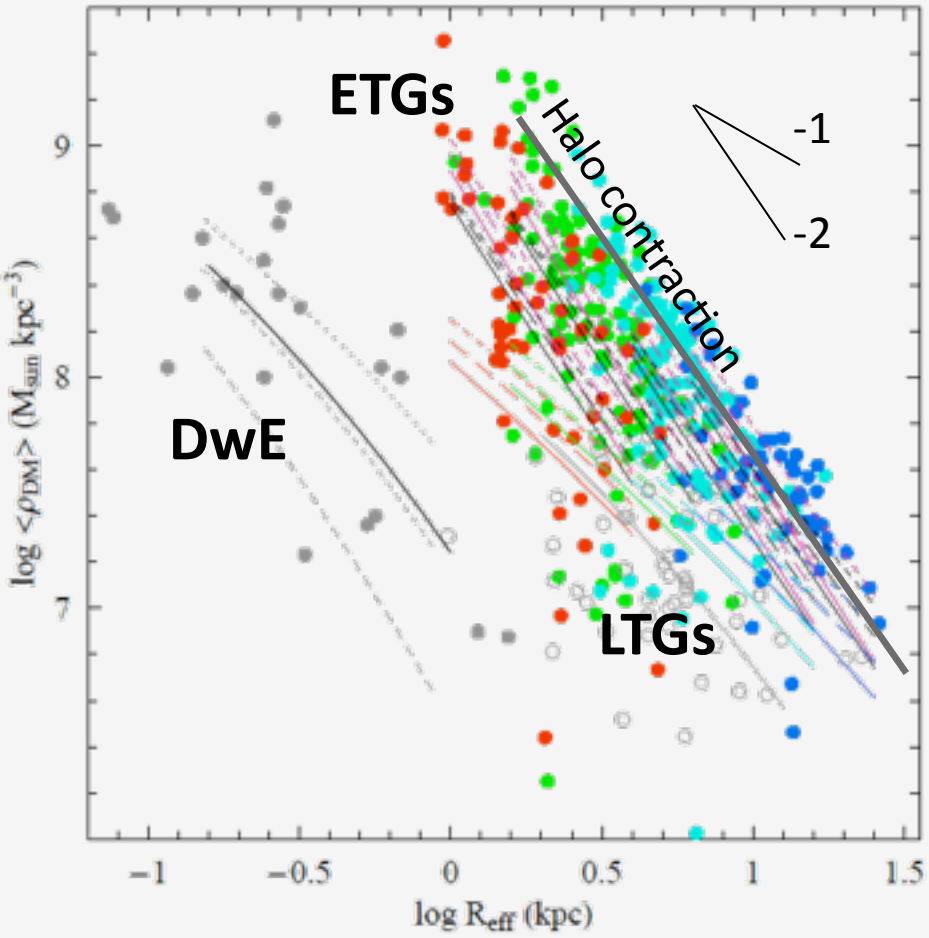




Napolitano Tortora & Romanowsky (2009)

Central DM density of early-type galaxies



$<\rho_{DM}> \sim R_{eff}^{-2}$ **for a cuspy (contracted) halo!!!**

Why a contracted cuspy halo

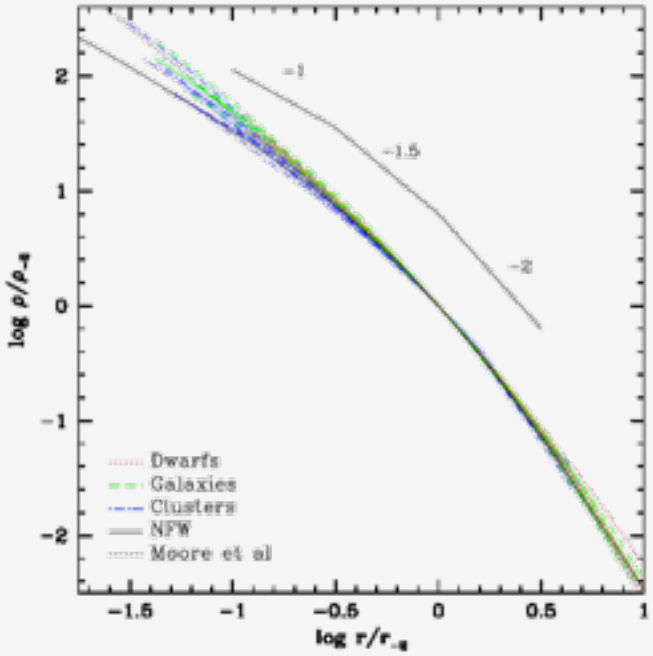
If $\rho(r) \sim r^{-\alpha}$ $\alpha<3$

$M(r) \sim r^{3-\alpha}$

$<\rho(R_{eff})> \sim R_{eff}^{-3} M(R_{eff}) \sim R_{eff}^{-\alpha}$

For a non contracted NFW $\alpha \sim 1.3$ @ R_{eff}

For a contracted halo α =1.6-1.9 @ R_{eff}



Napolitano Romanowsky & Tortora 2010

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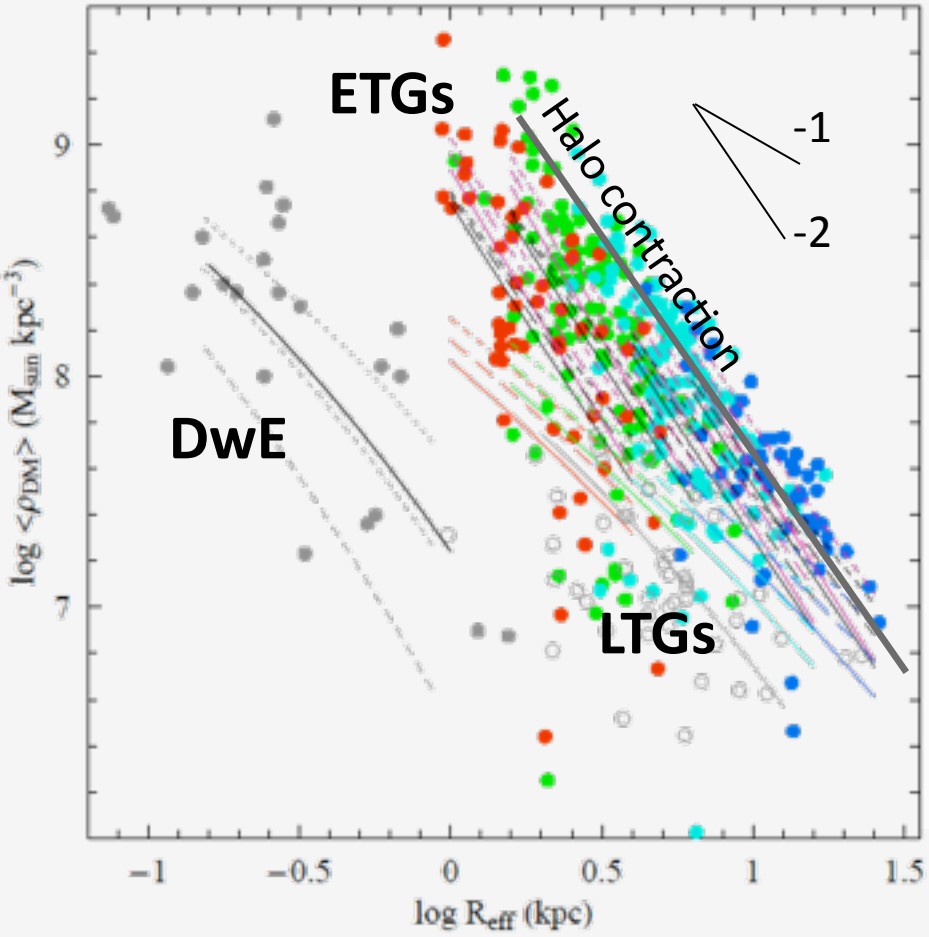
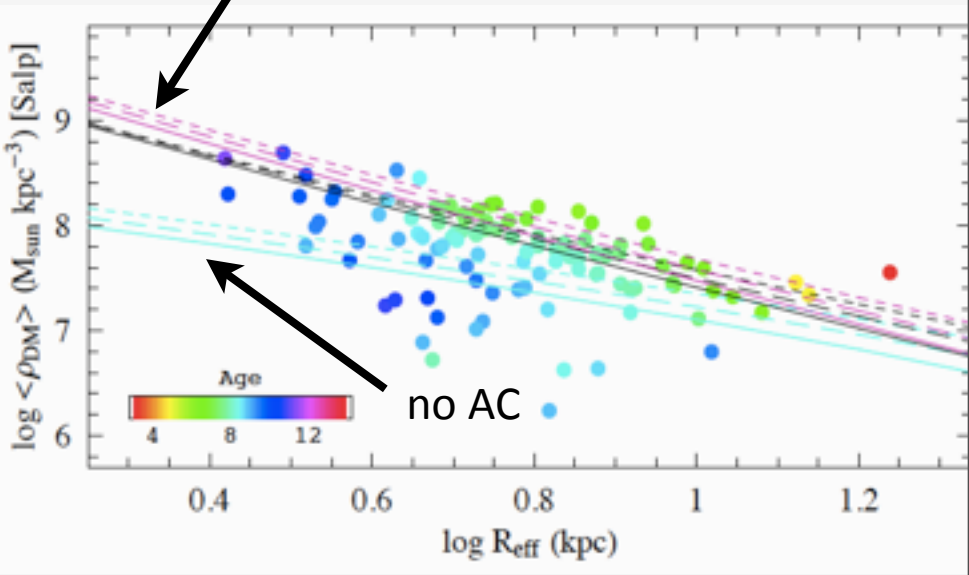


LCDM predictions with AC



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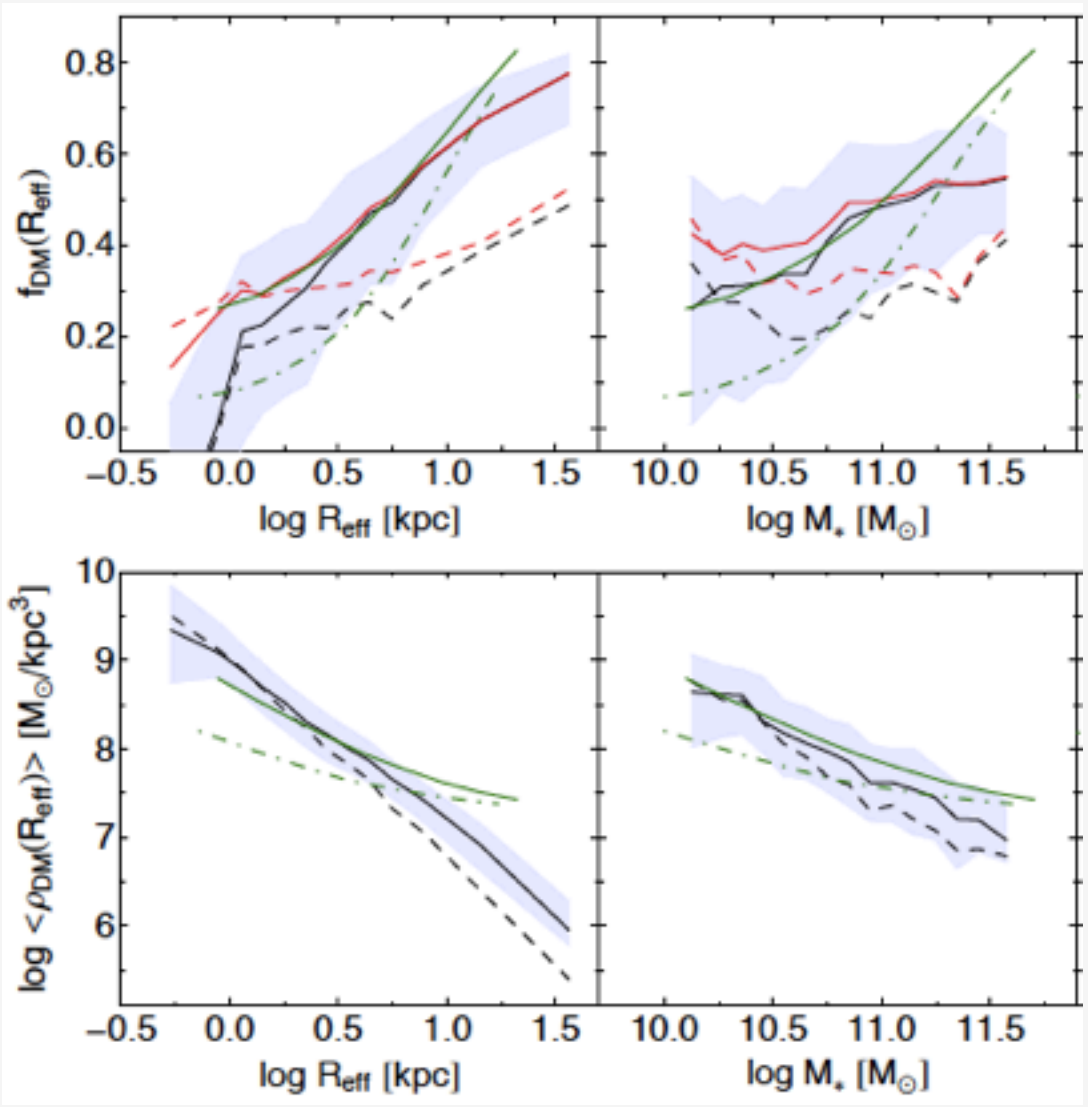
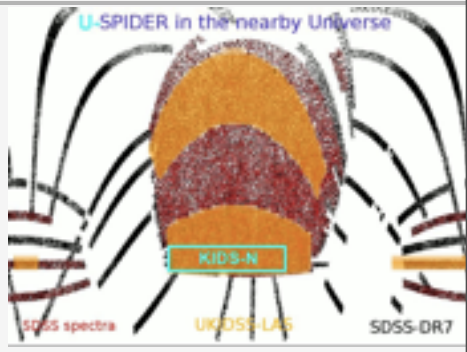
Napolitano Romanowsky & Tortora 2010

Central DM with the Spider sample



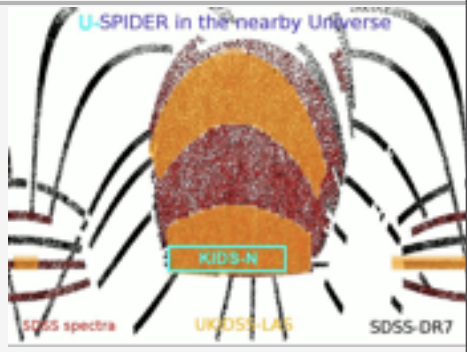


La Barbera et al.

~4000 ETGs
SDSS+UKIRT
SDSS spectra

Tortora et al. 2011, (almost) submitted

Central DM with the Spider sample



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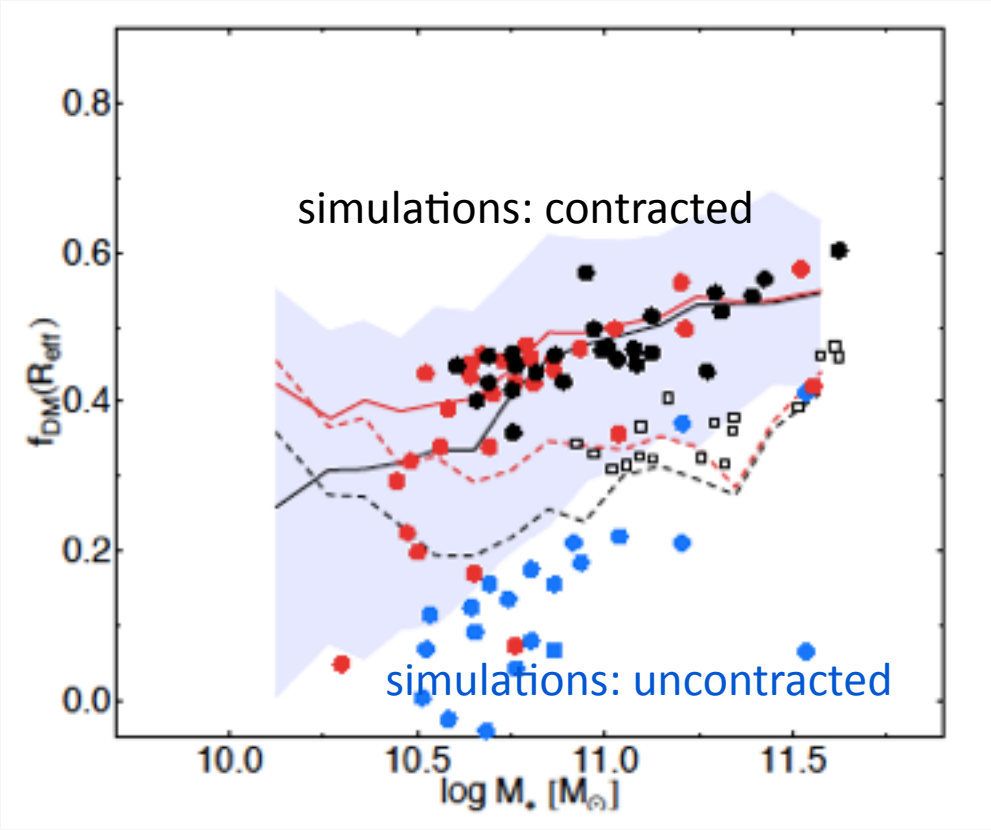

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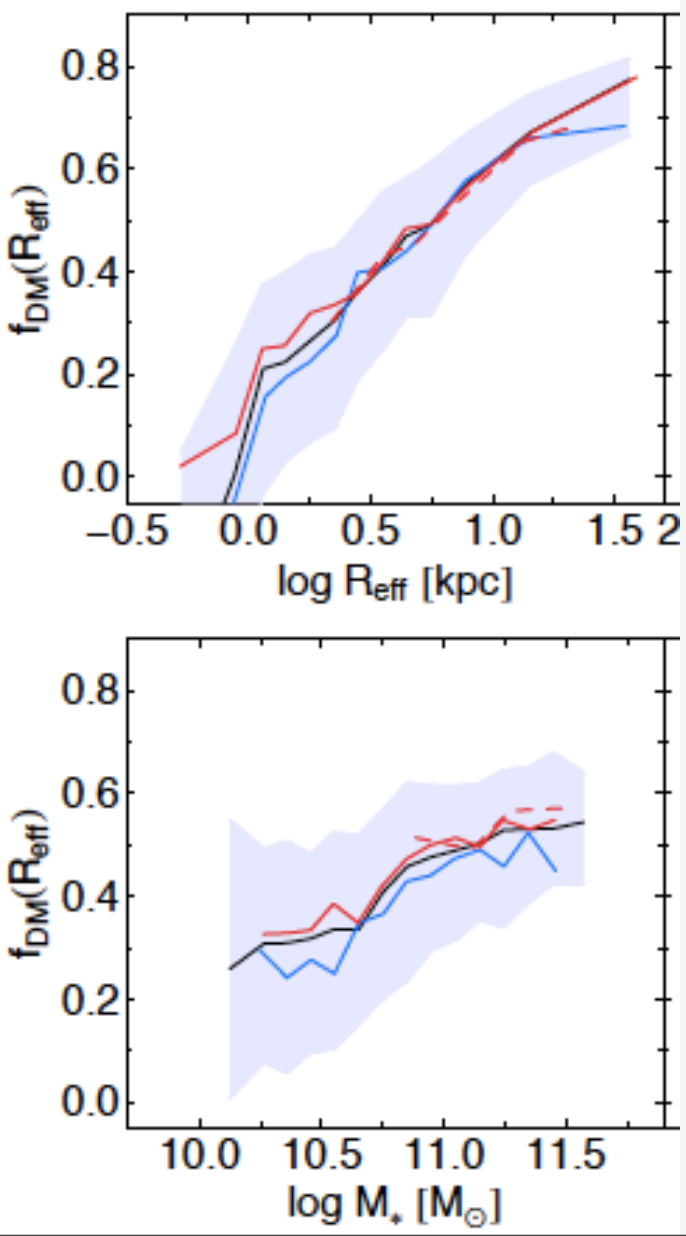
Central DM with the Spider sample

ENVIRONMENT

FIELD

SATELLITES

CENTRALS



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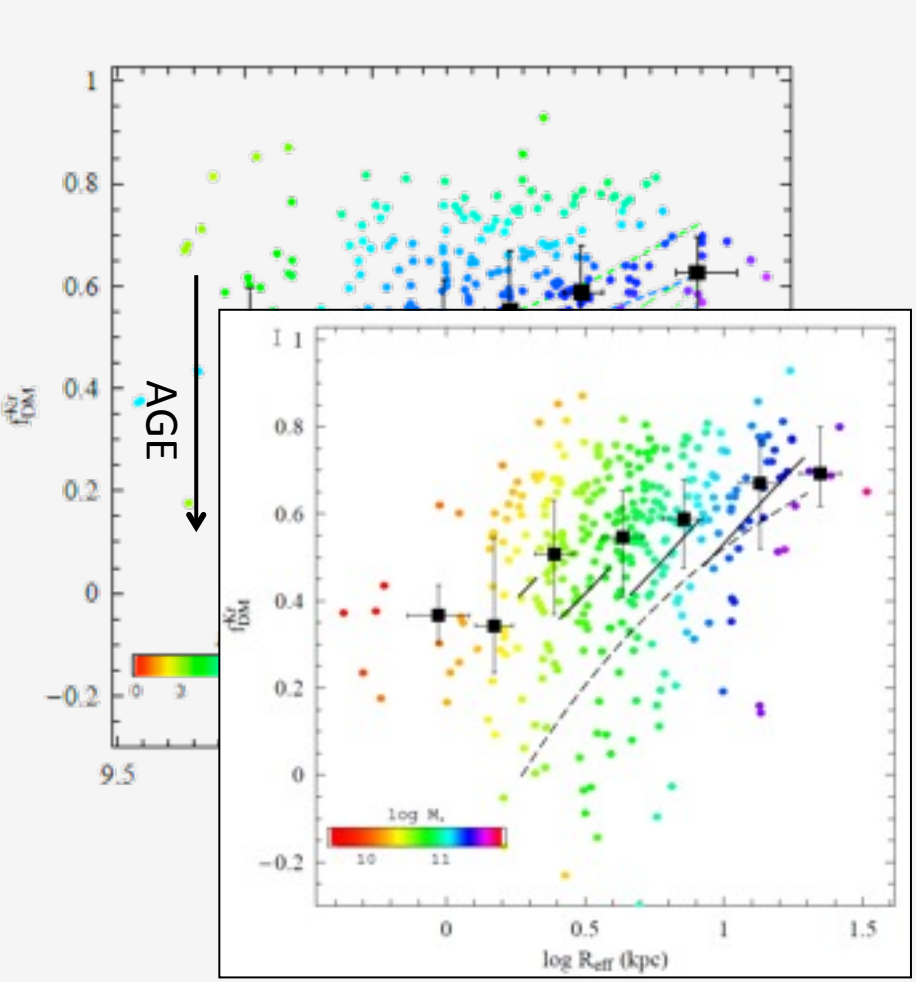
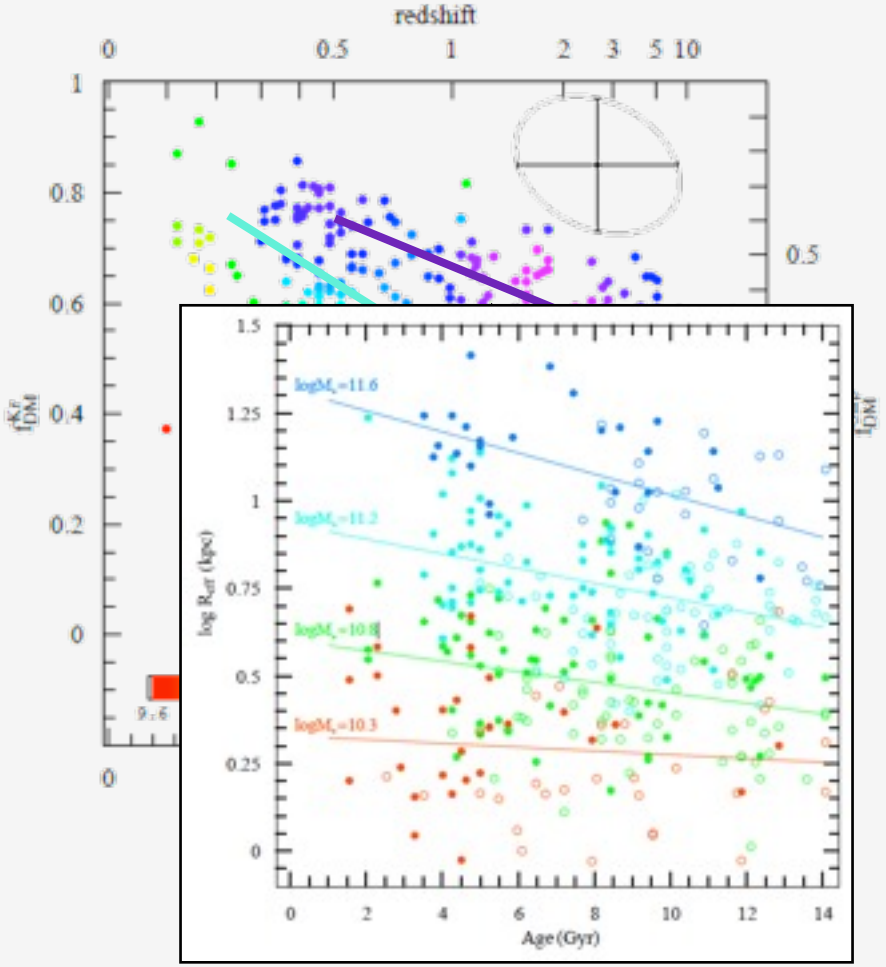
Central M_{DM}/M_* and connections with SFH

DM fraction depends on Age





Napolitano Tortora & Romanowsky (2009)

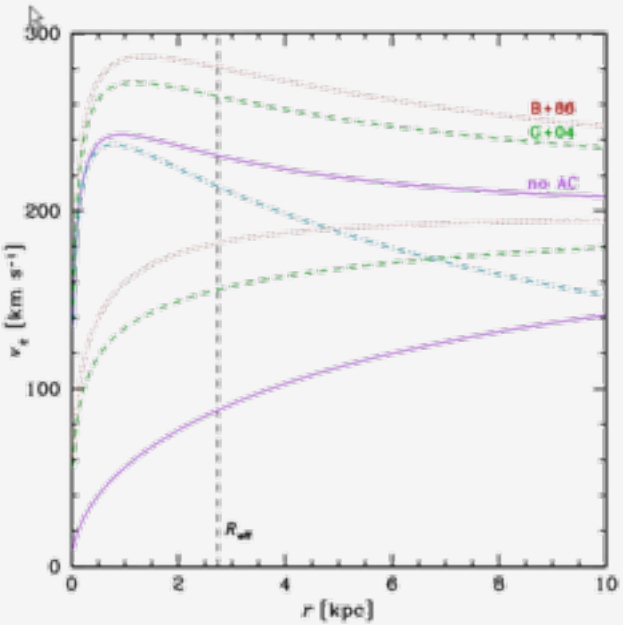
Central M_{DM}/M_* and connections with SFH

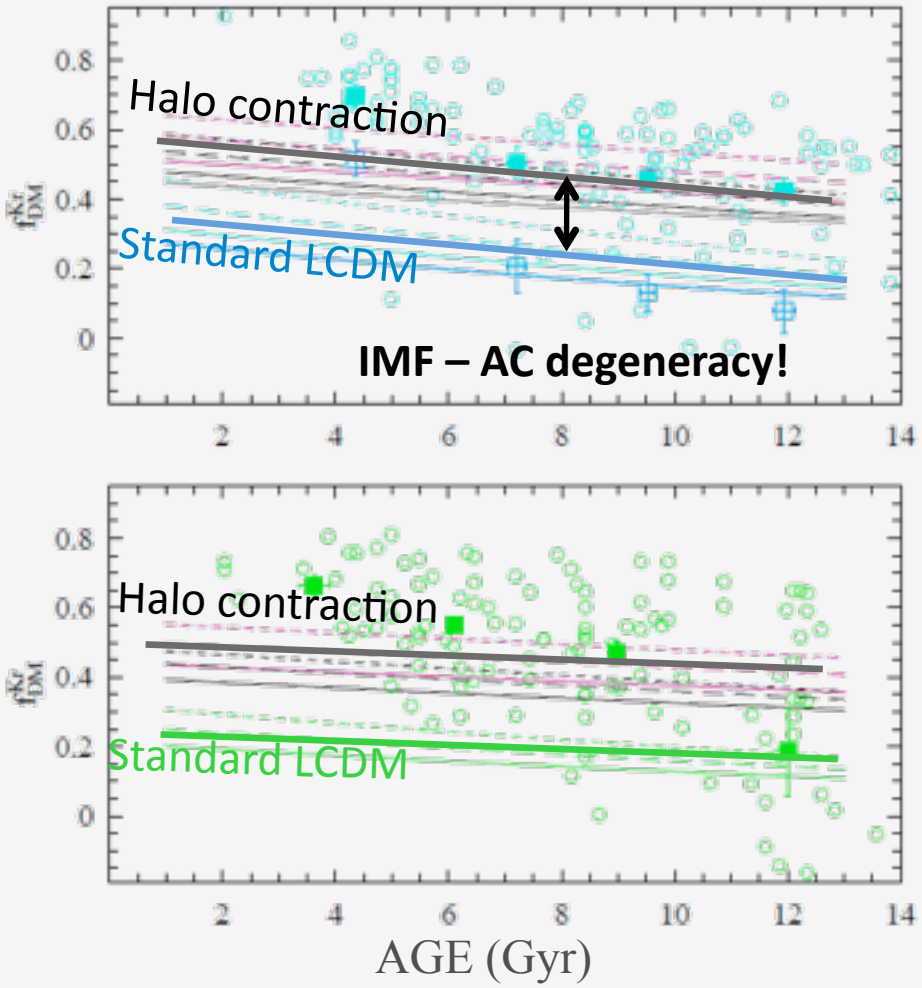
Kroupa IMF

LCDM predictions

1) Assume a normal NFW halo
2) Assume a Sersic profile for the stars
3) Compute the f_{DM} for different ε_{SF}

4) Add some adiabatic contraction





Napolitano Romanowsky & Tortora 2010

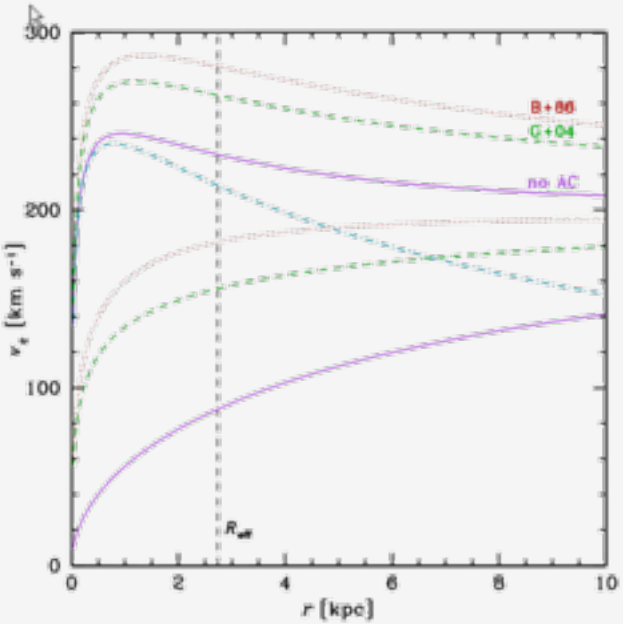
Central M_{DM}/M_* and connections with SFH

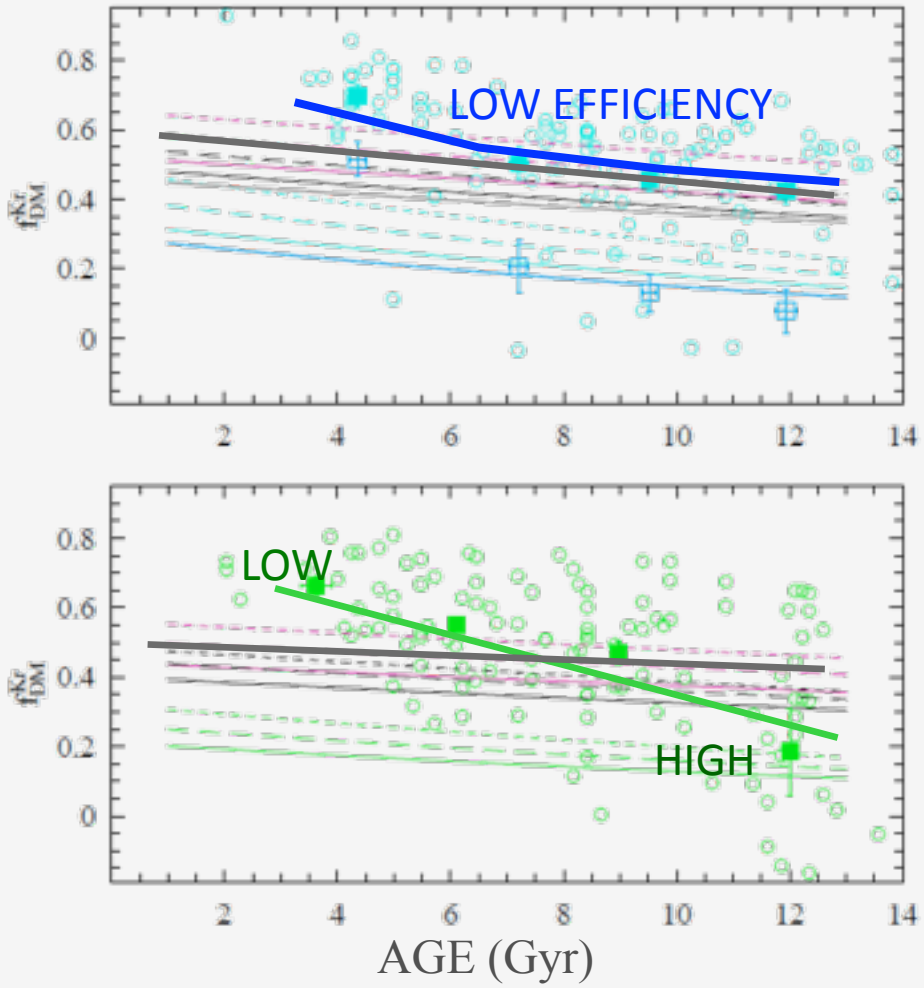
Kroupa IMF

LCDM predictions

1) Assume a normal NFW halo
2) Assume a Sersic profile for the stars
3) Compute the f_{DM} for different ε_{SF}

4) Add some adiabatic contraction





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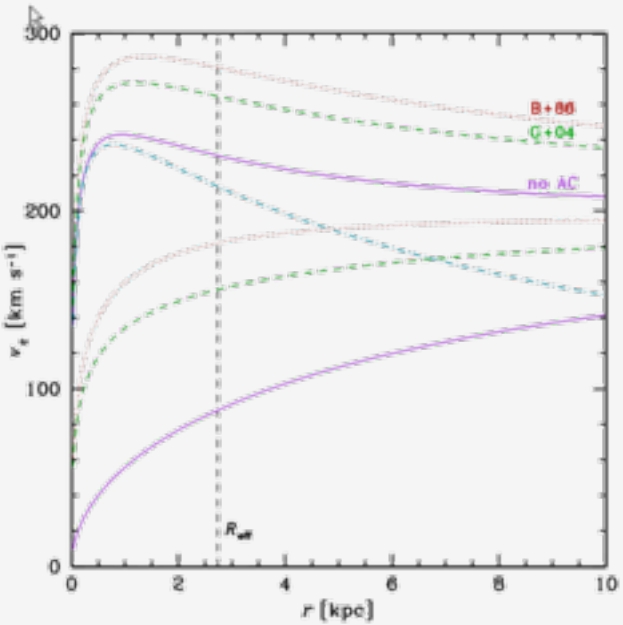
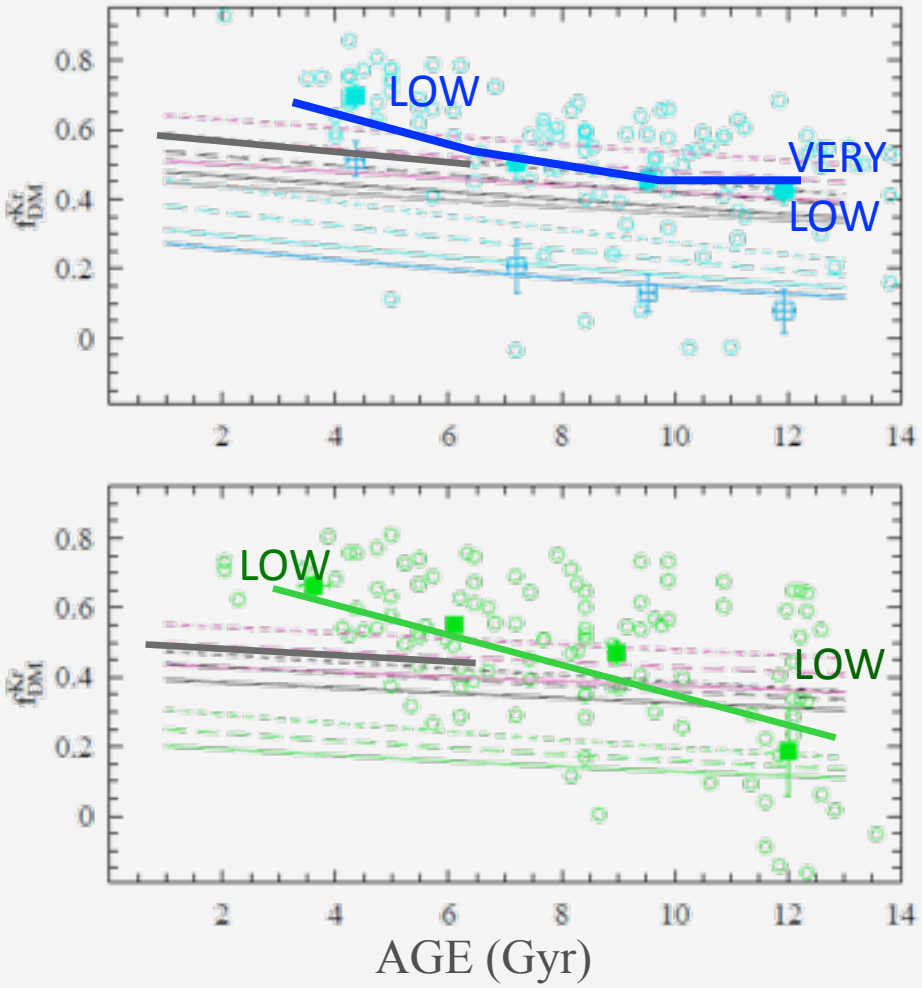


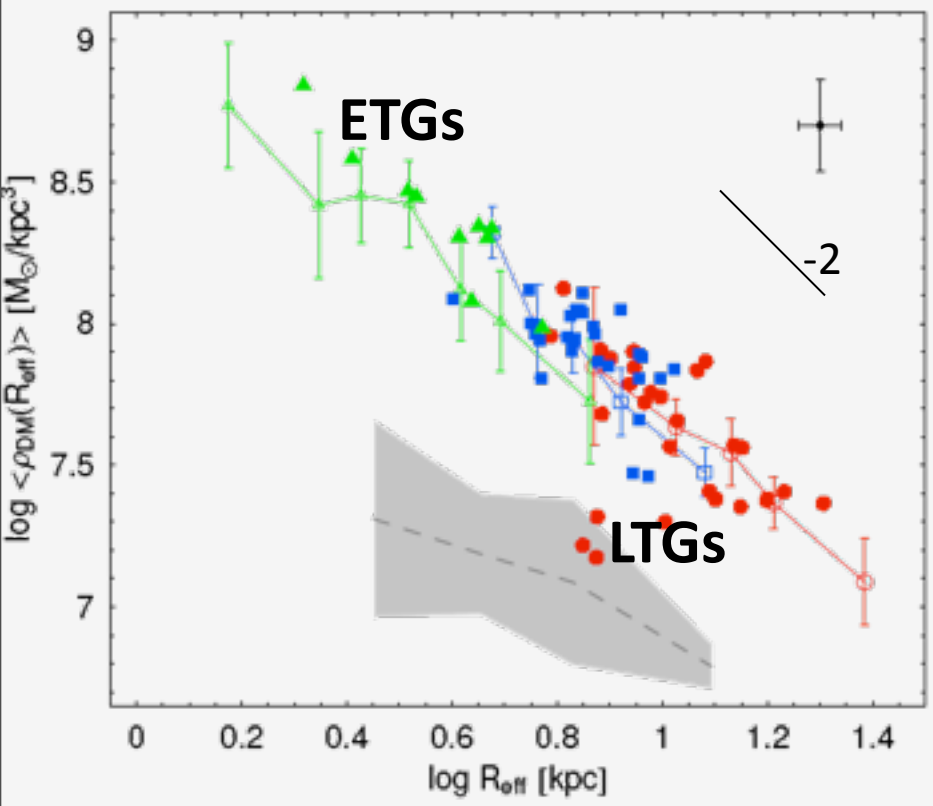


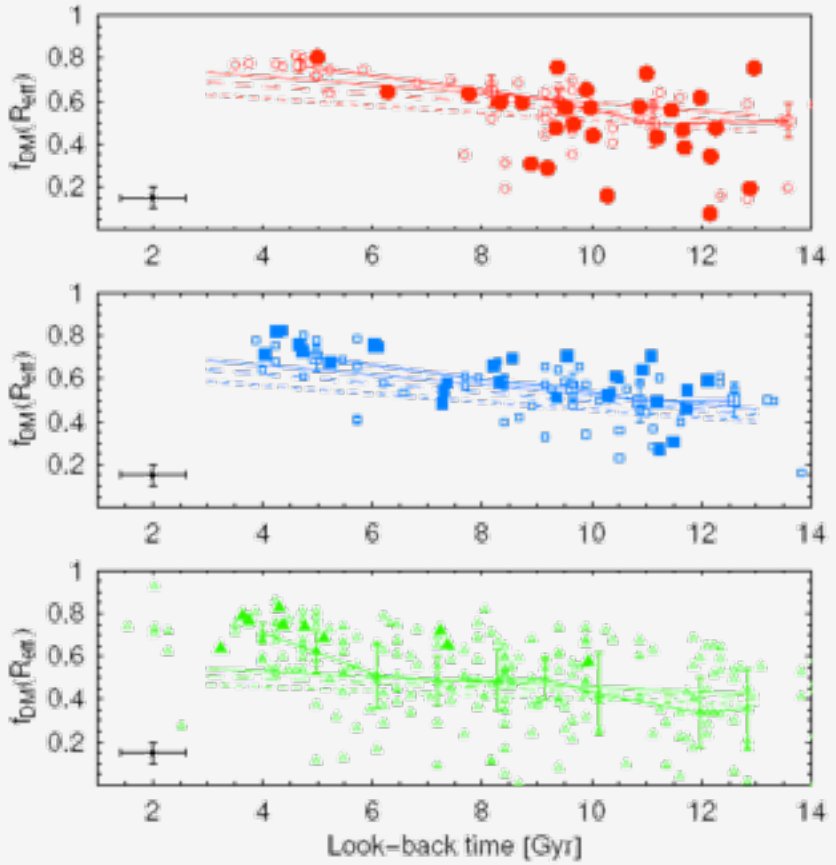
Napolitano Romanowsky & Tortora 2010

Strong lensing, dynamics and stellar populations

NRT10 confirmed by ~70 SLACS gravitational lenses @ z~0.3 (~3Gyr)

Kroupa IMF





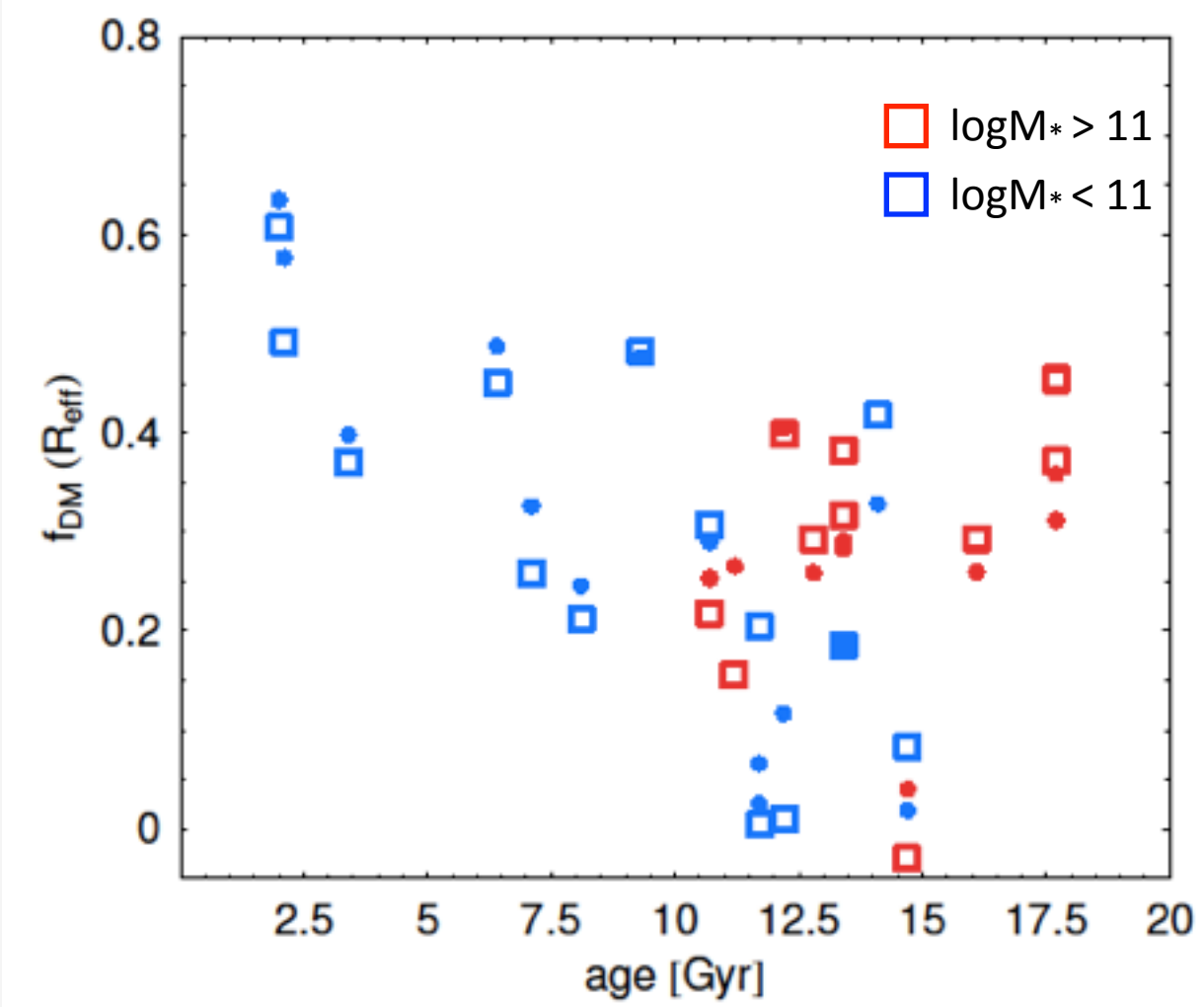
AGE (Gyr)

$<\rho_{DM}> \sim R_{eff}^{-2}$ for a cuspy (contracted) halo!!!

Tortora Napolitano Romanowsky & Jetzer 2010, ApJL

Strong lensing, dynamics and stellar populations

fDM-Age confirmed by the SAURON sample



Central M_{DM}/M_* and connections with SFH

Explaining the f_{DM} – Age

Central M_{DM}/M_* and connections with SFH

Explaining the f_{DM} – Age

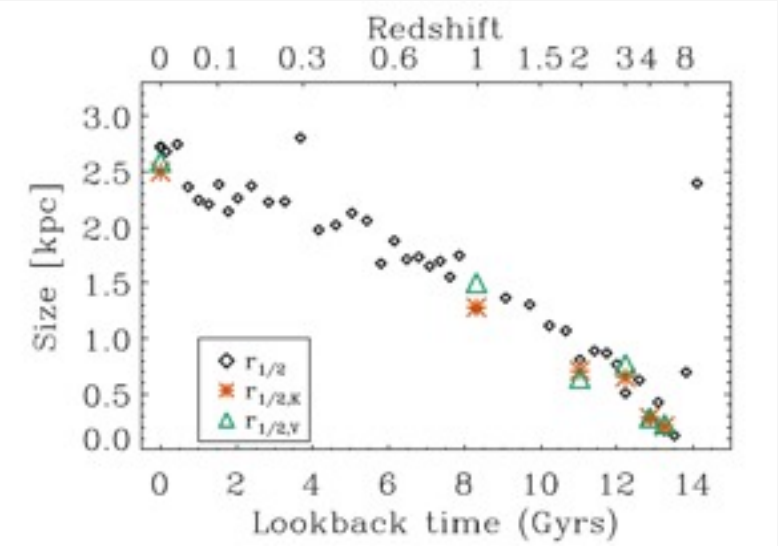
1) Reff – Age

Central M_{DM}/M_* and connections with SFH

Explaining the f_{DM} – Age

1) Reff – Age => compatible with size evolution with lookback time

(Naab et al. 2009)



Naab et al. 2009

Central M_{DM}/M_* and connections with SFH

Explaining the f_{DM} – Age

1) **Reff – Age** => compatible with size evolution with lookback time
2) **Some ε_{SF} variation** => compatible with early cold accretion (e.g. Dekel et al. 2009, Naab et al. 2009) -- overall qualitatively consistent with CW09

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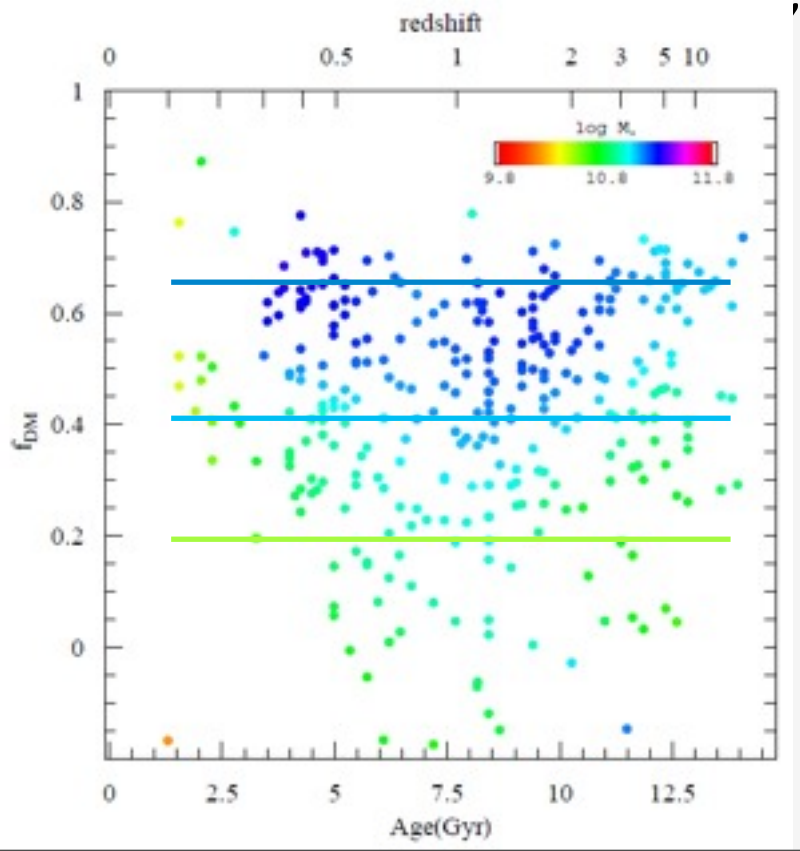

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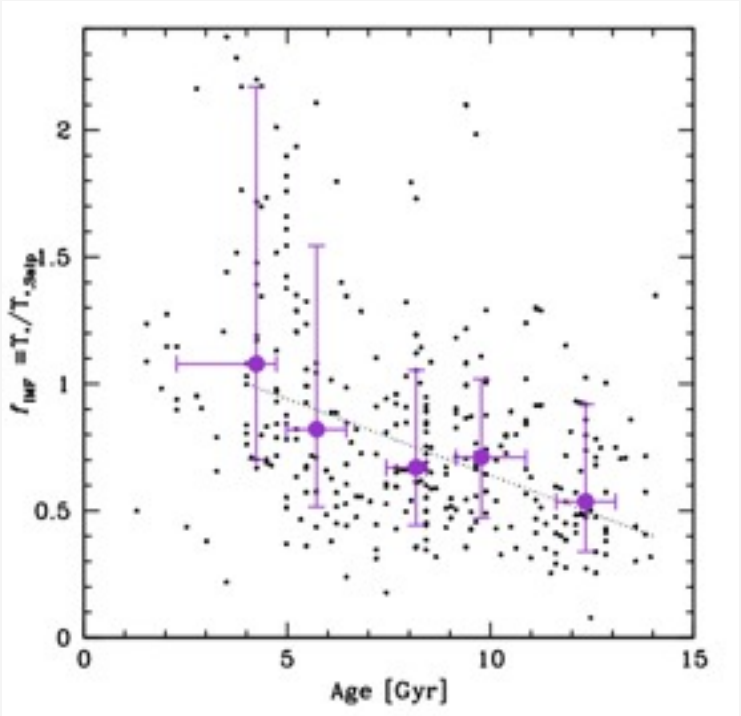

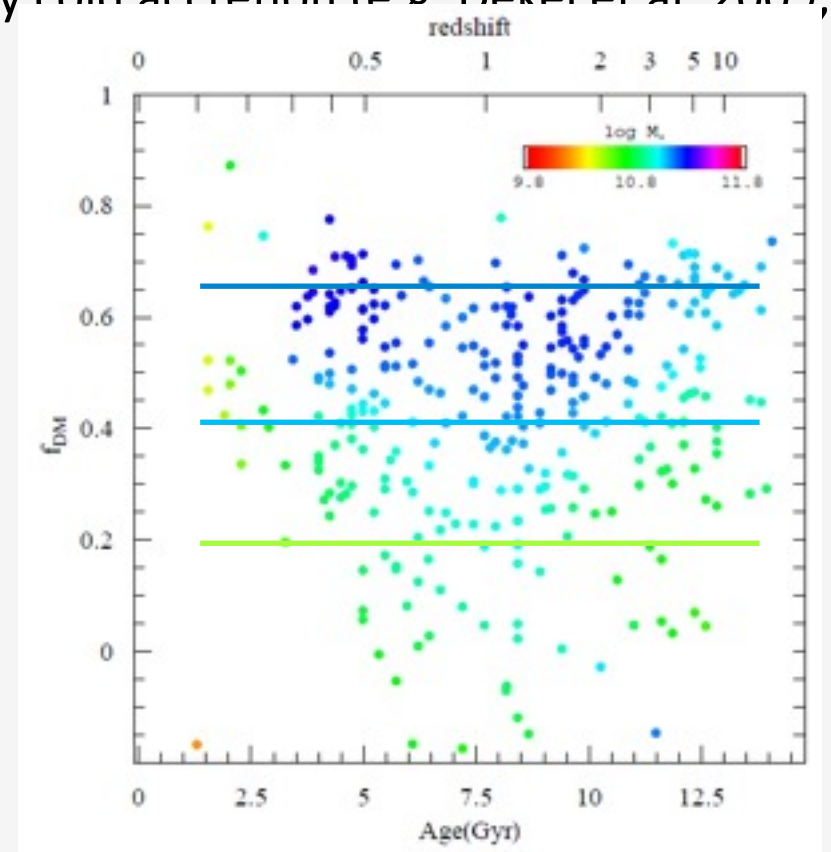

Conclusions

- fDM are mainly driven by Reff
- The Reff-Age (size-z evolution) is responsible of most of the fDM-Age relation
- the residual trend is possibly caused by the eSF-Age => younger systems have lower eSF. Older systems follow the CW09 eSF-M_*
- If there is a AC variation with time, younger systems show stronger AC
- IMF variation (?): younger galaxies have Salpeter IMF, older Chabrier IMF
- fDM seem not to have a significant dependence on the environment

The End

Today is a good day...