Cornell University

ALFALFA

The galaxy-halo connection: insights from ALFALFA

'near field cosmology' with the ALFALFA HI survey

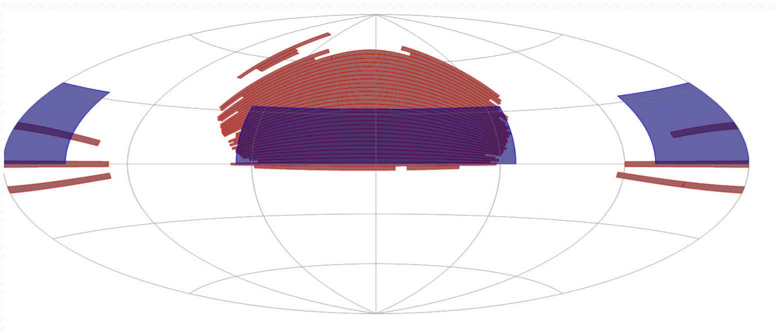
Manolis Papastergis, Cornell University, USA

Chalonge Meudon Workshop 2012
7 June 2012

the ALFALFA survey

http://egg.astro.cornell.edu/alfalfa/

- ALFALFA is a blind, wide area 21-cm line survey done with the Arecibo telescope.
- Presently available catalog:
  - ~3,000 deg^2 of sky
  - ~11,000 'Code 1' detections.
- ALFALFA has produced the *largest HI-selected sample to date*.

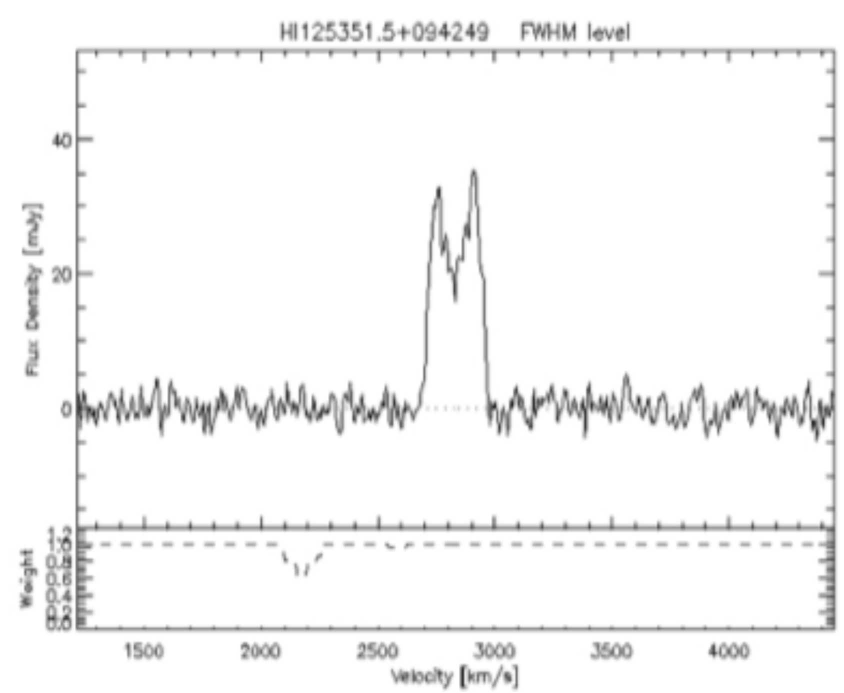


the ALFALFA survey

http://egg.astro.cornell.edu/alfalfa/

- ALFALFA directly measures three galactic properties:
  - redshift
  - integrated flux
  - velocity width
  - (HI mass)

$$M_{HI}(M_{\odot}) = 2.35\ 10^5 \text{ x } D^2 \text{ (Mpc) x } S_{int} \text{ (Jy kmsec}^{-1}\text{)}$$



- ALFALFA *cannot* measure any spatially-resolved property:
  - size
  - inclination
  - shape

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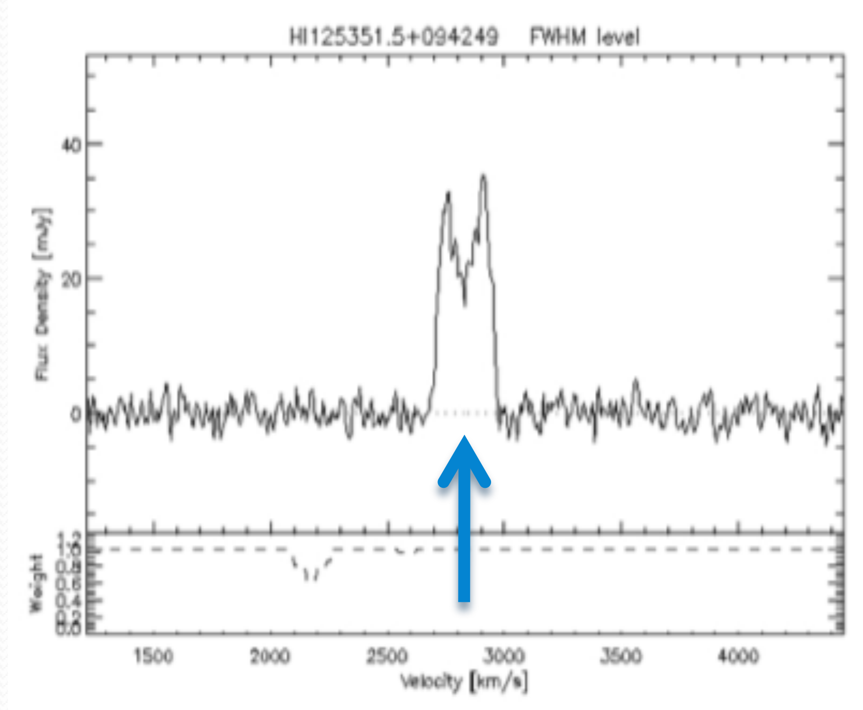

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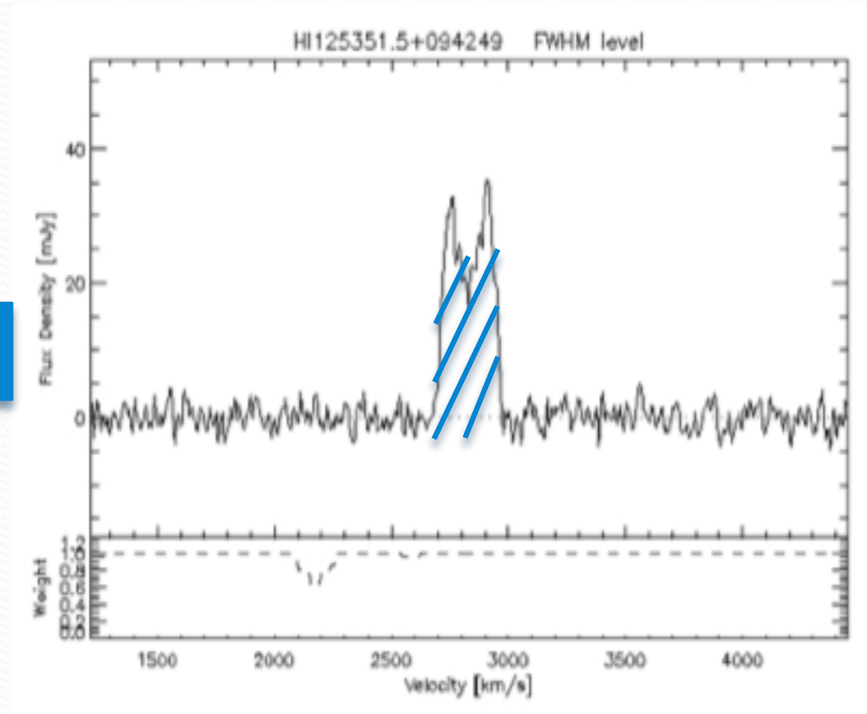

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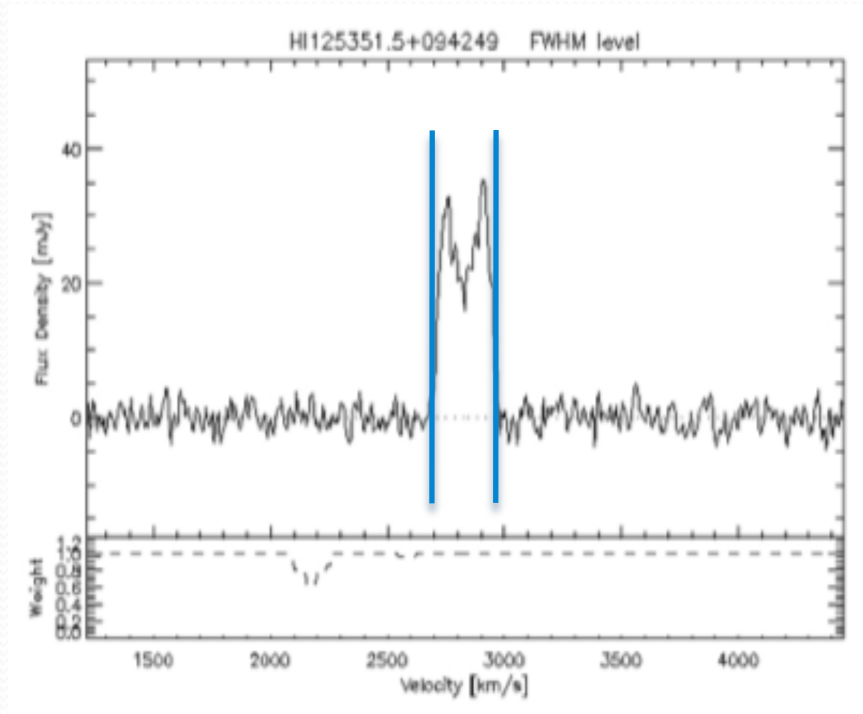

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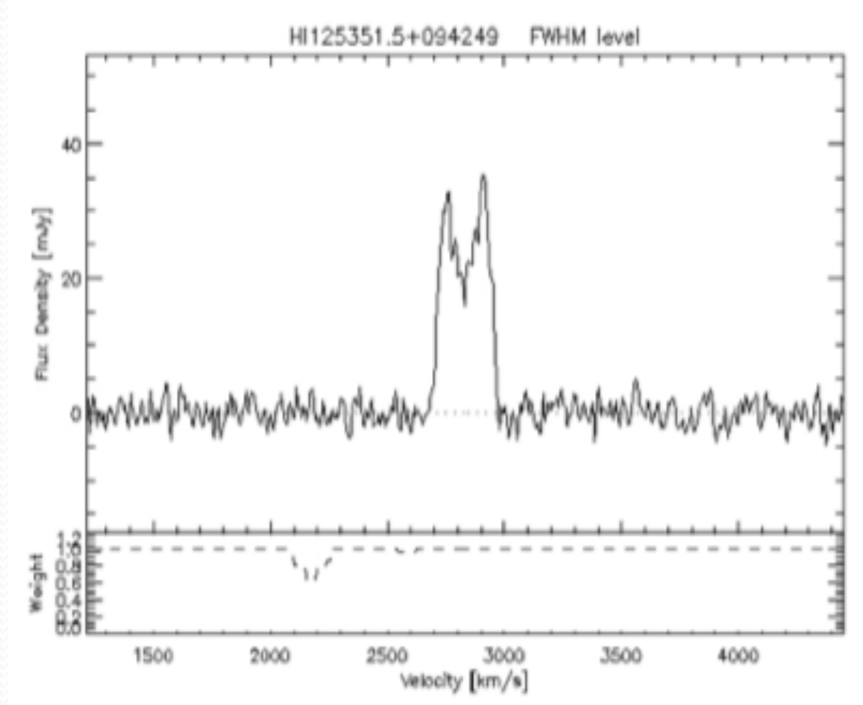

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the ALFALFA baryonic mass function

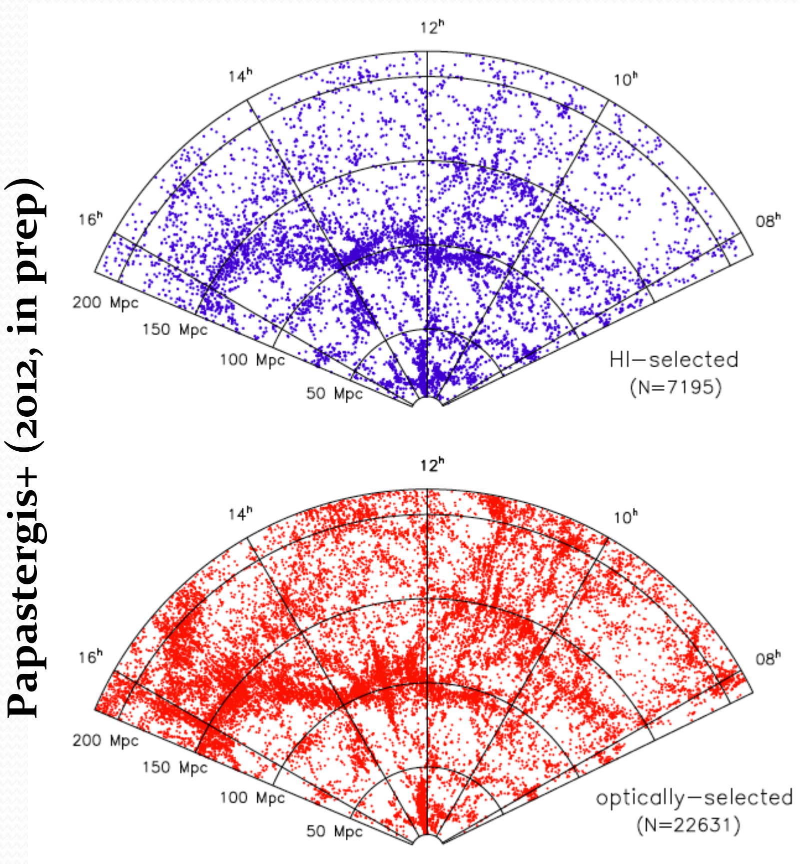
"A direct measurement of the Baryonic Mass Function of galaxies & implications for the galactic baryon fraction"

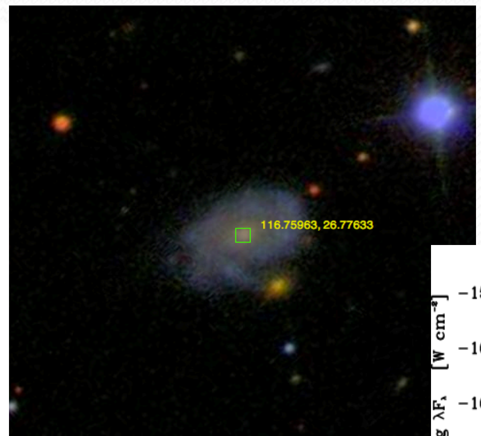
Papastergis E., *Cattaneo A., Huang S., Giovanelli R., Haynes M.P.*
(in prep)

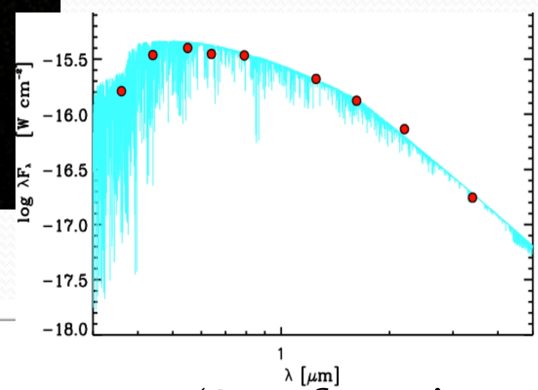
the ALFALFA baryonic mass function

- HI mass from ALFALFA, stellar mass from SDSS

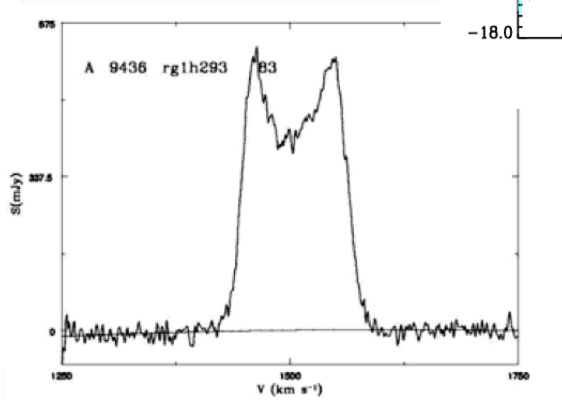
Papastergis+ (2012, in prep)







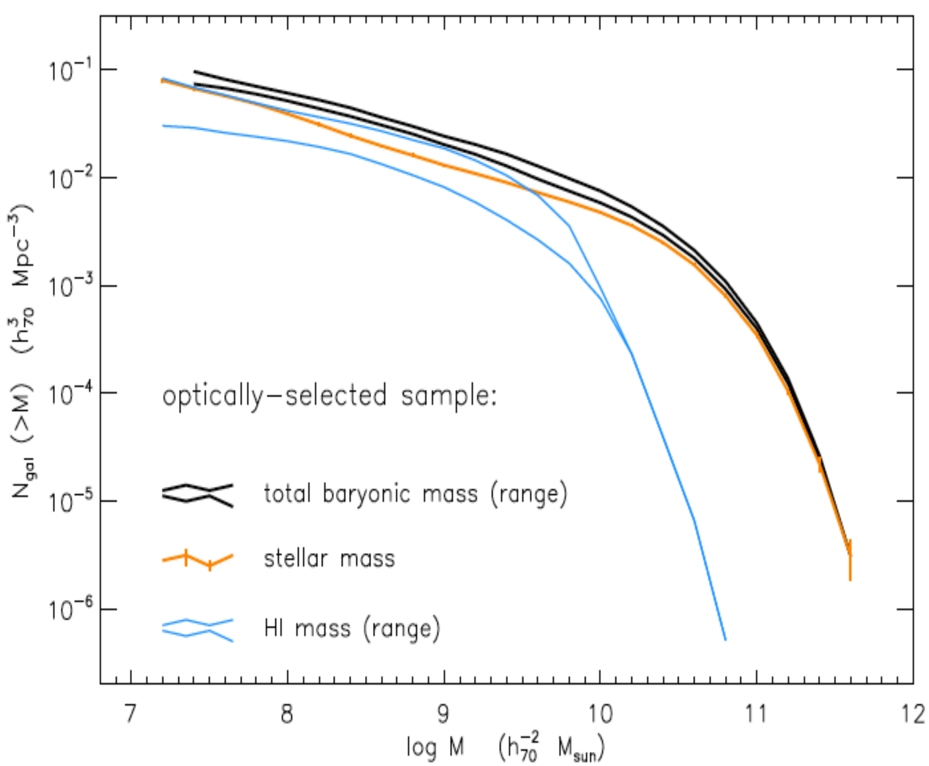
‘SED fitting’

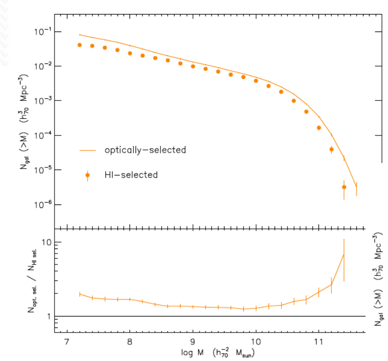


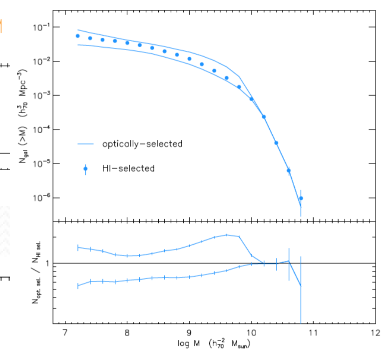
the ALFALFA baryonic mass function

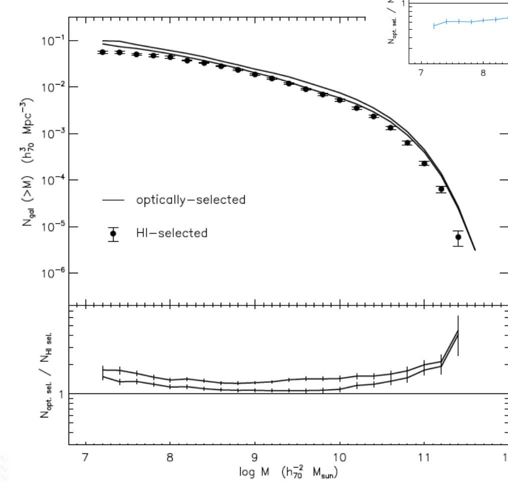
- stellar mass from SDSS, HI mass limits from ALFALFA

Papastergis+ (2012, in prep)



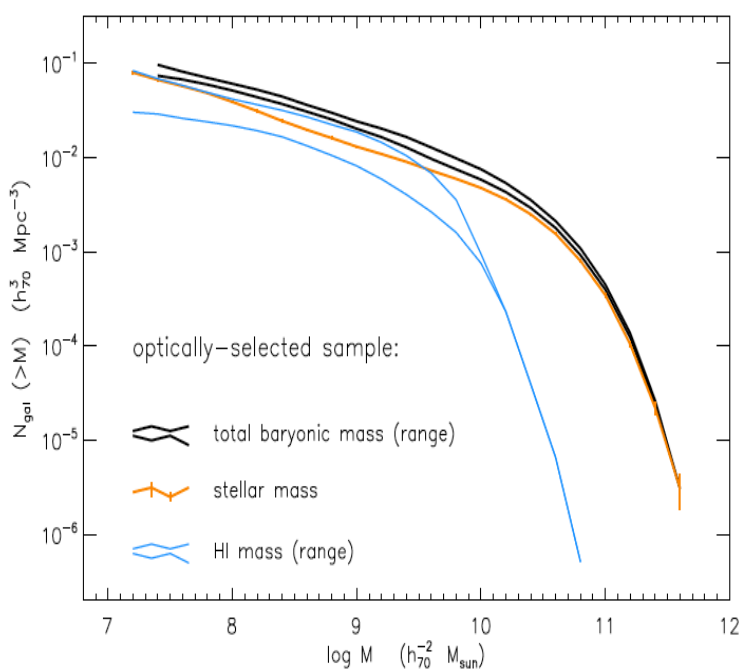




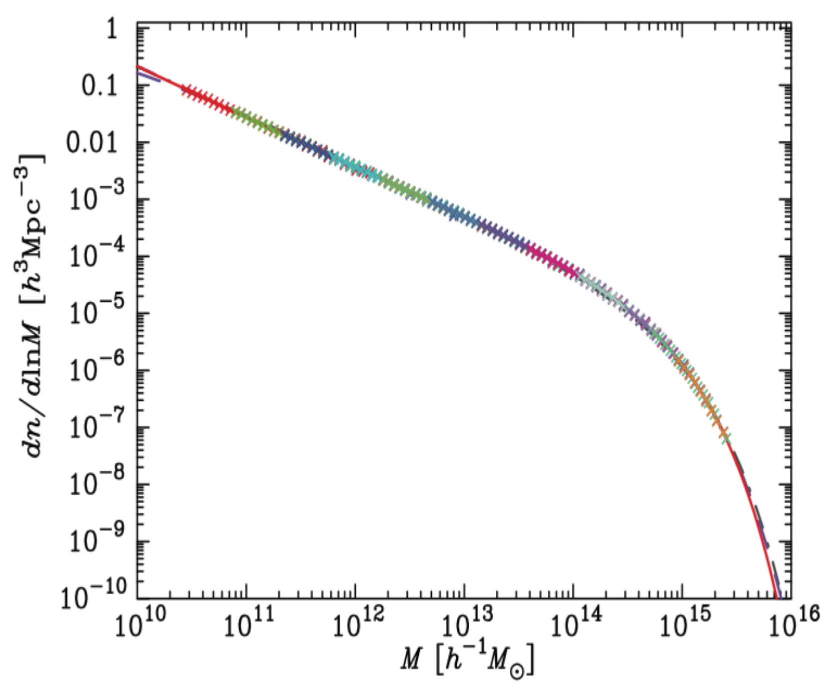


the ALFALFA baryonic mass function

- connecting galaxies with halos: 'abundance matching'



Papastergis+ (2012, in prep)



Warren+ (2006)

the ALFALFA baryonic mass function

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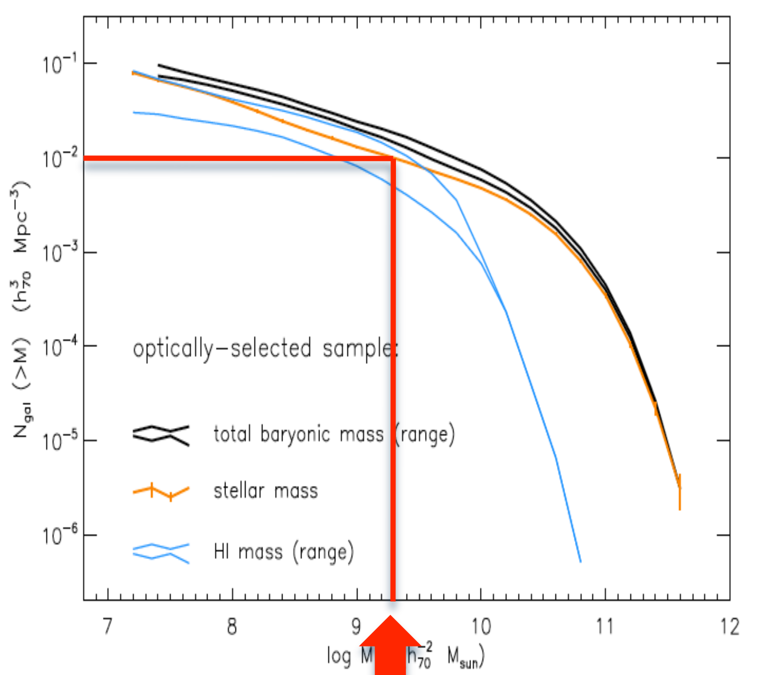

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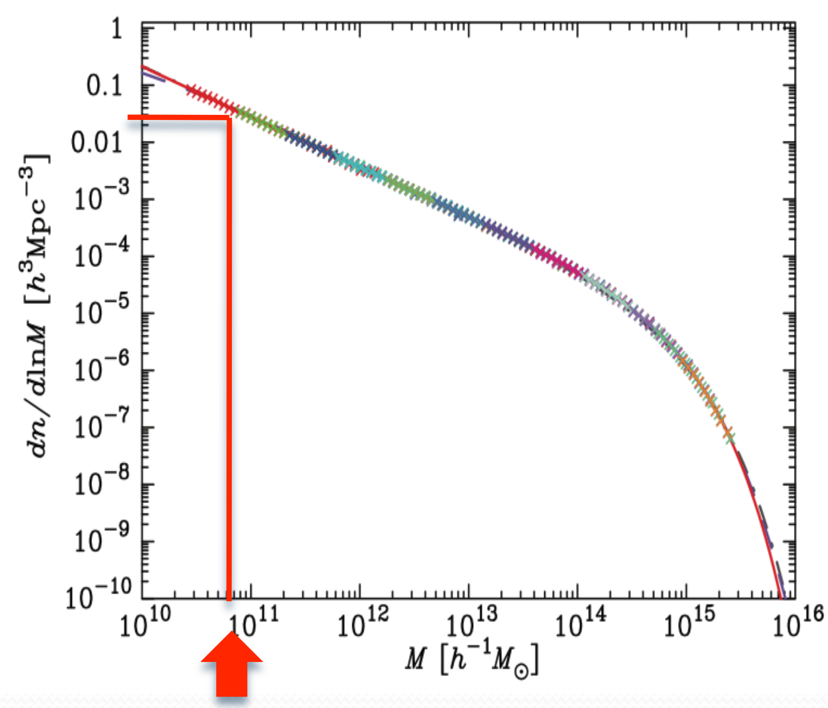
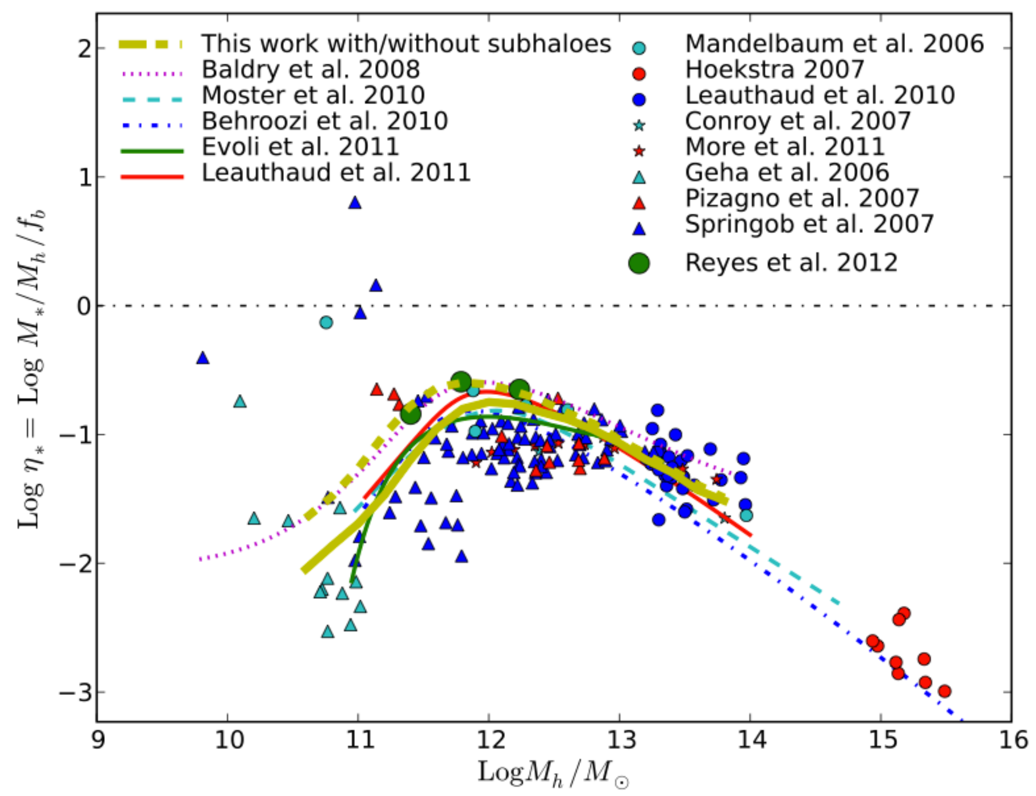


Warren+ (2006)

the ALFALFA baryonic mass function

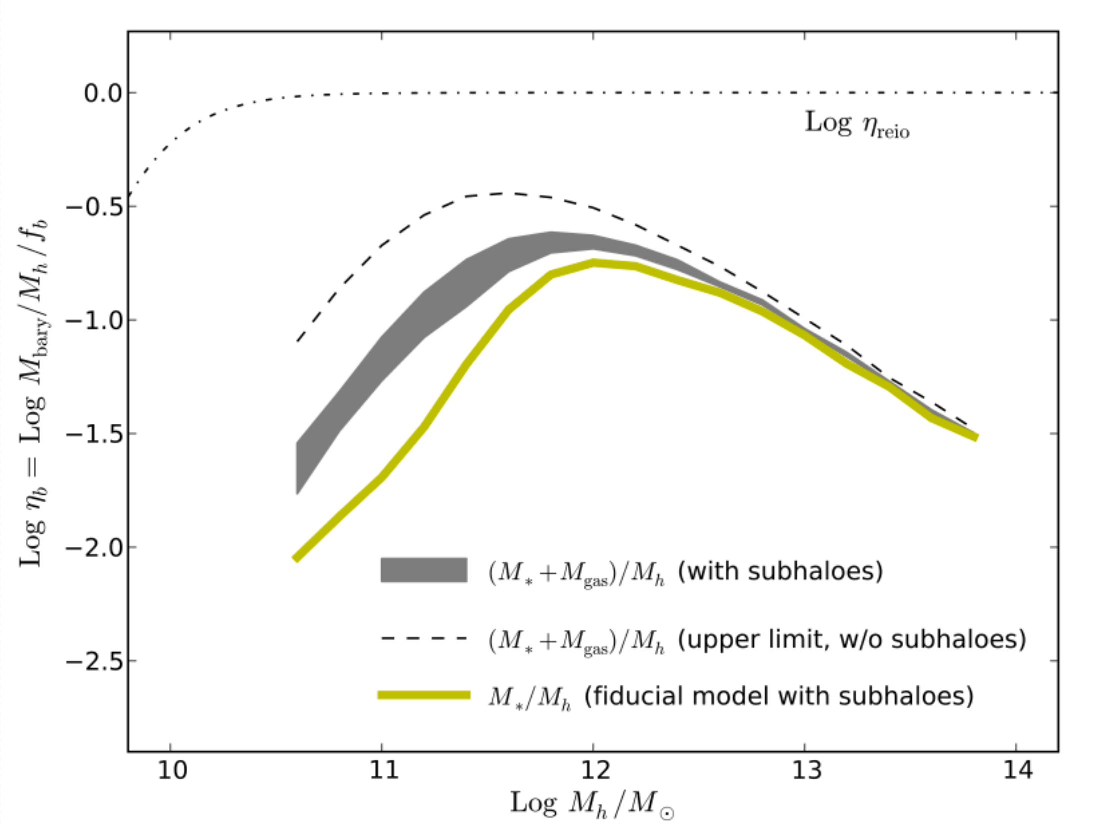
- low "stellar conversion efficiency", $\eta_* = (M_*/M_h) / f_b$



Papastergis+ (2012, in prep)

the ALFALFA baryonic mass function

- "baryon retention fraction" also low, $\eta_b = (M_b/M_h) / f_b$



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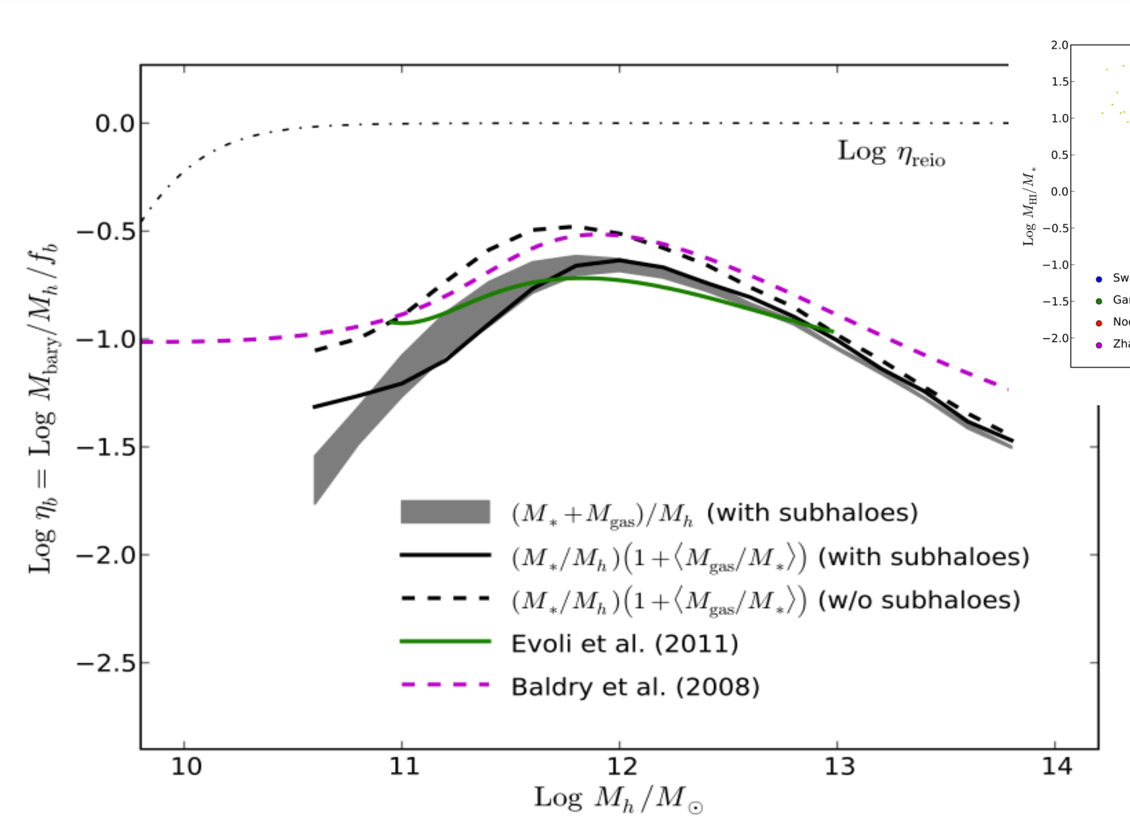
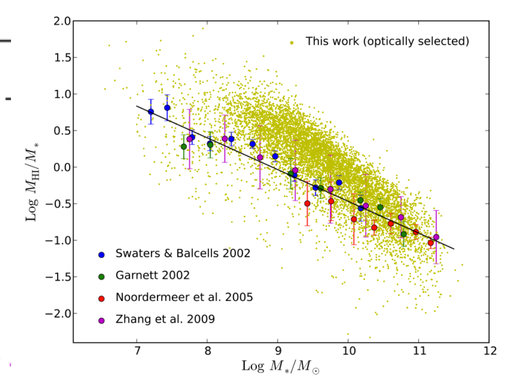
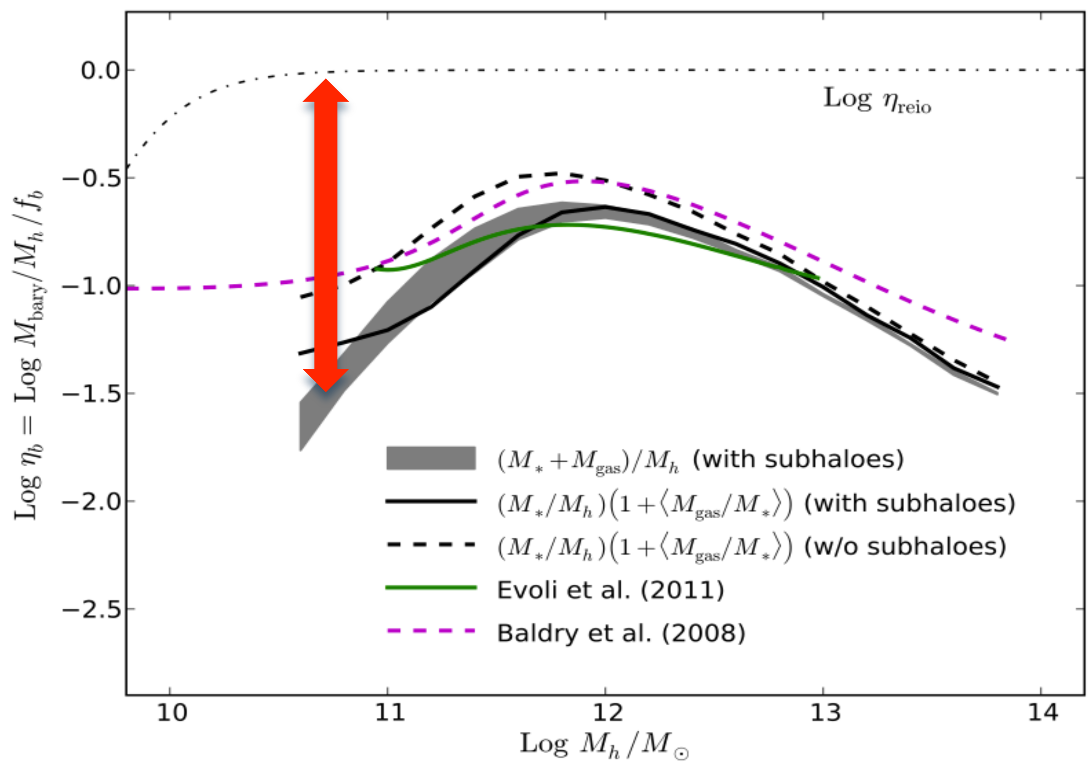




Papastergis+ (2012, in prep)

the ALFALFA baryonic mass function

- requires: expelled mass ≈ 100 x stellar mass



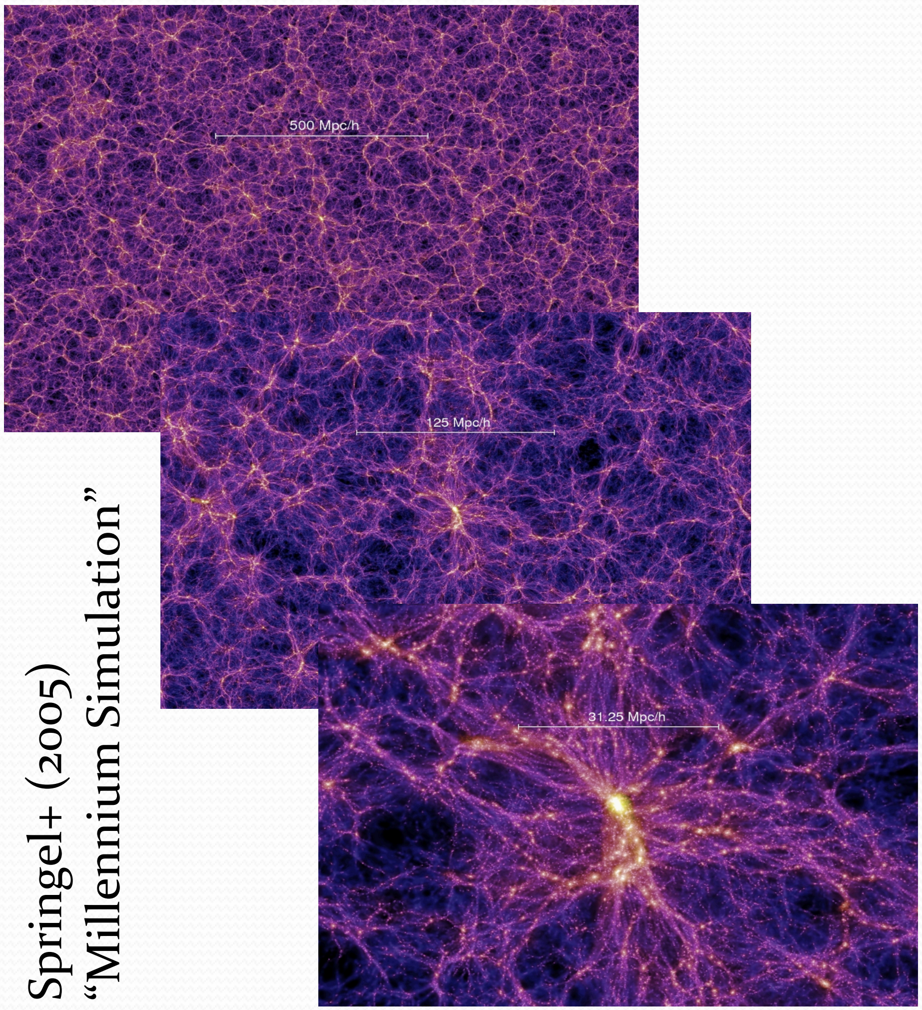
Papastergis+ (2012, in prep)

the ALFALFA velocity width function

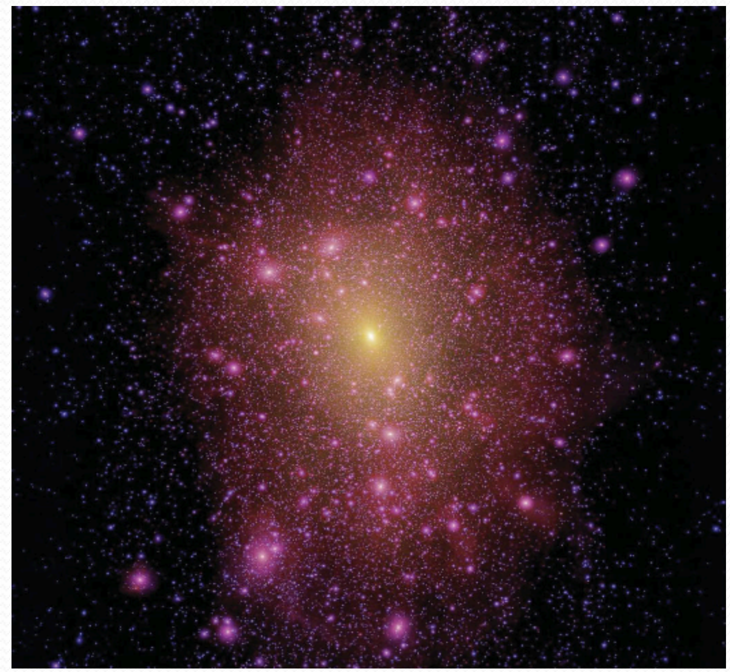
"The Velocity Width Function of Galaxies from the 40% ALFALFA Survey: Shedding Light on the Cold Dark Matter Overabundance Problem"

Papastergis E., *Martin A.M., Giovanelli R., Haynes M.P.*
ApJ, 739, 38 (2011)

the Cold Dark Matter paradigm

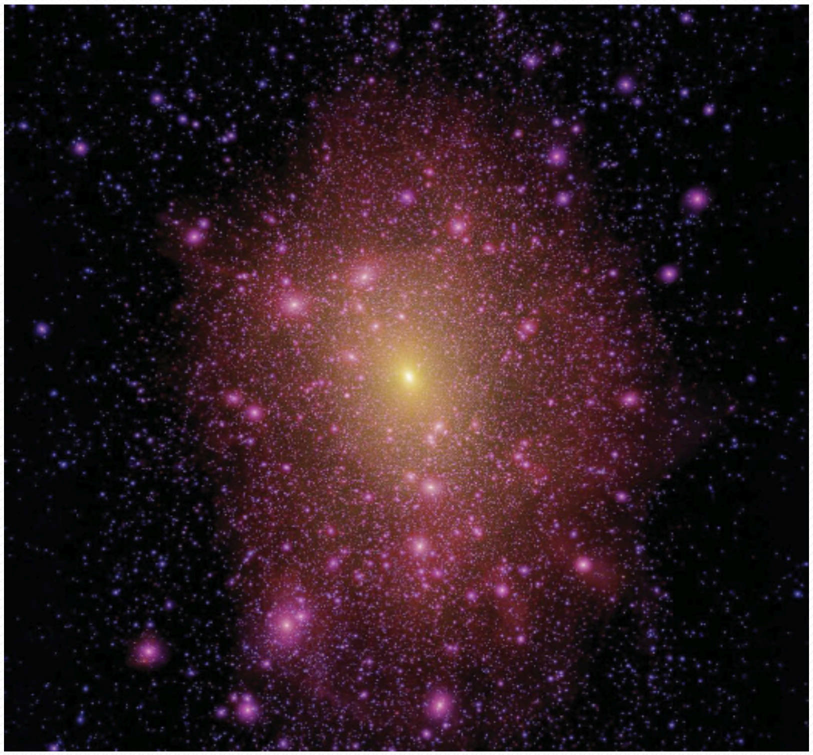


Springel+ (2005)
"Millennium Simulation"



Lovell+ (2012)

the Cold Dark Matter paradigm



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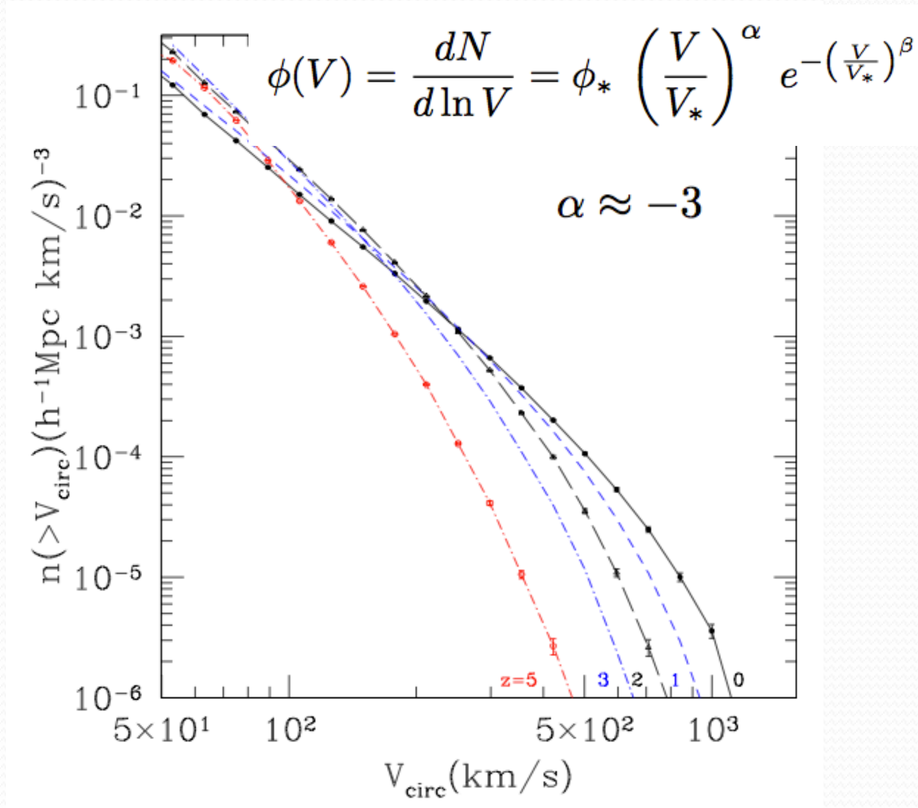
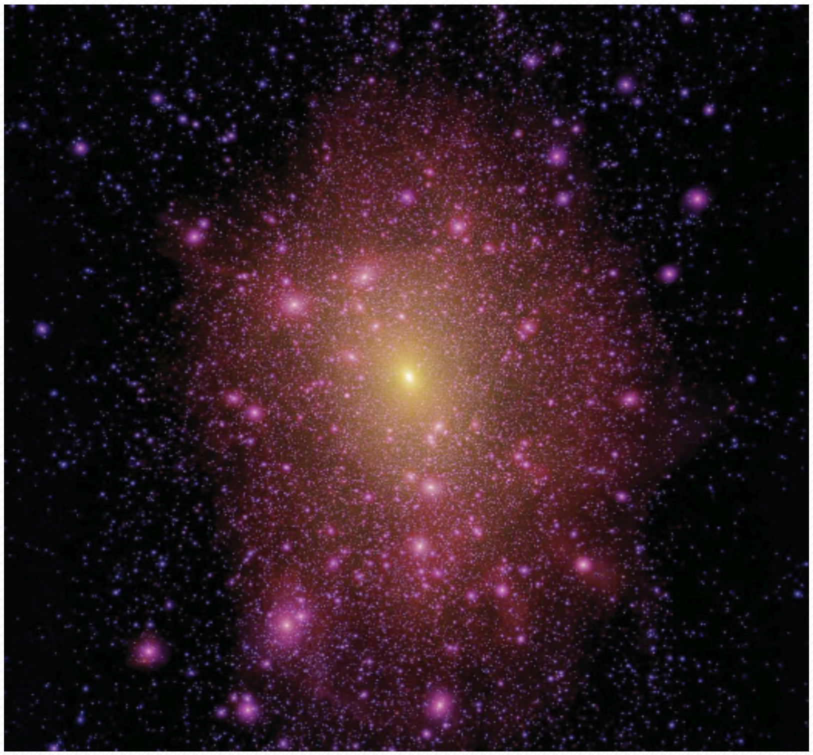
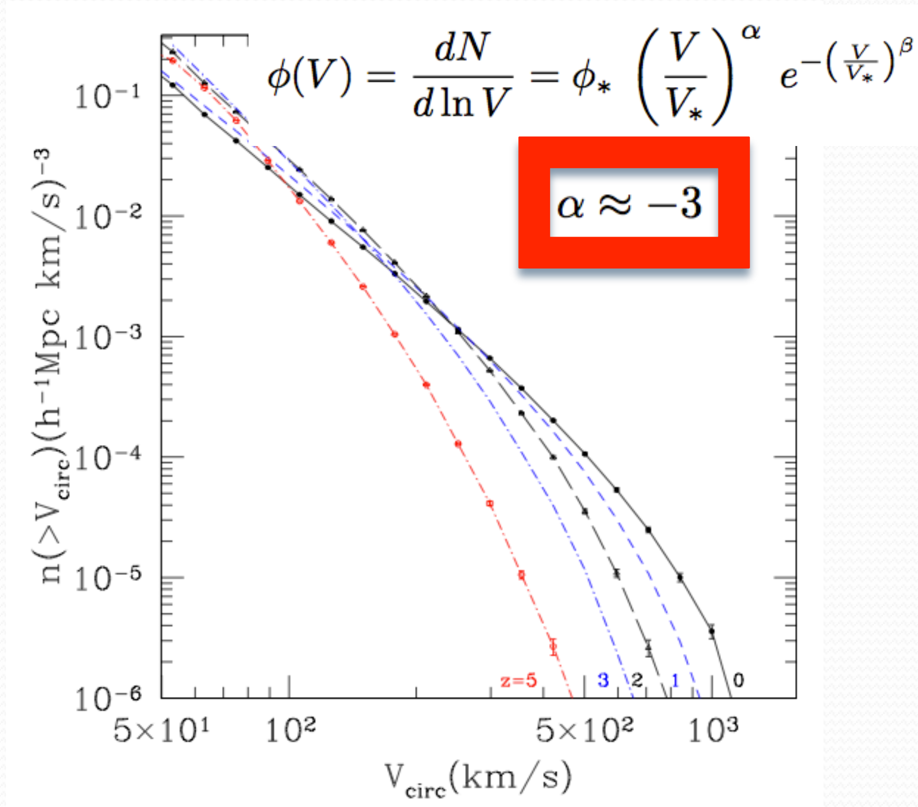


Klypin+ (2011) “Bolshoi simulation”

the Cold Dark Matter paradigm



Lovell+ (2012)



Klypin+ (2011) “Bolshoi simulation”

the ALFALFA survey

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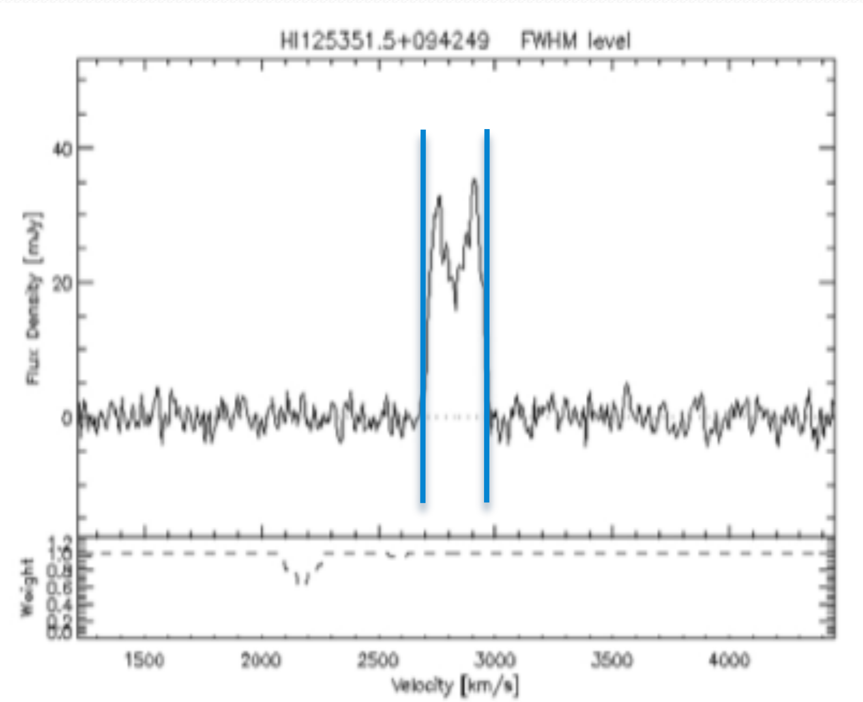
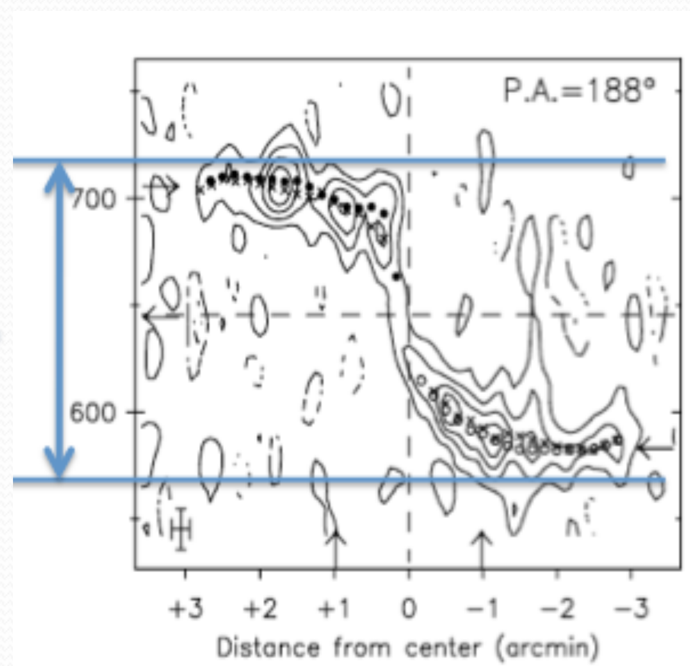
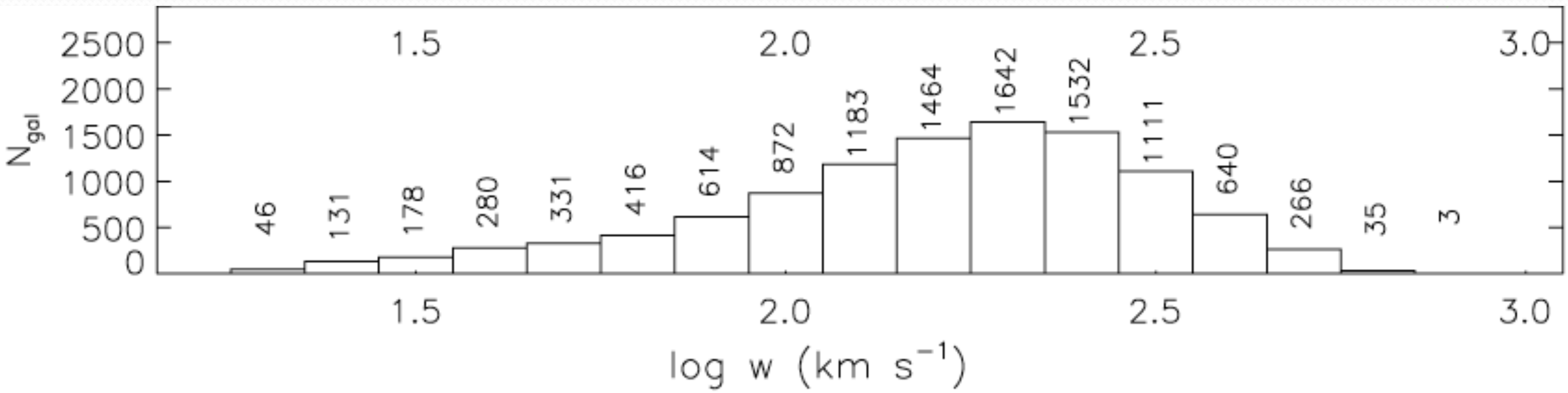
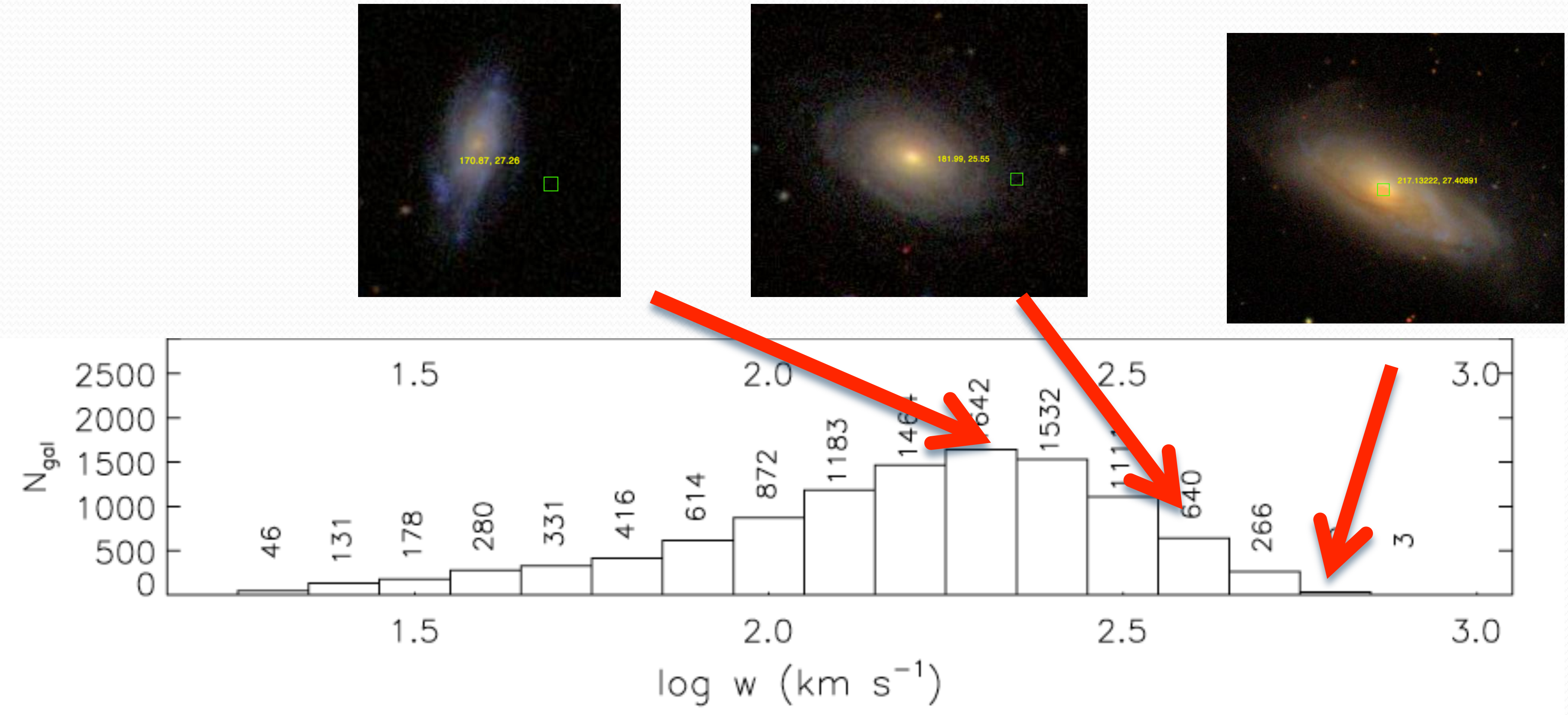
- The velocity width of a galaxy is ~twice its maximum circular velocity (projected on the line-of-sight)
- Direct indicator of *dynamical mass*







N_gal
2500
2000
1500
1000
500
0
1.5
2.0
2.5
3.0
46
131
178
280
331
416
614
872
1183
1464
1642
1532
1111
640
266
35
3
log w (km s⁻¹)


170.87, 27.26
181.99, 25.55
217.13222, 27.40891
N_{gal}
2500
2000
1500
1000
500
0
1.5
2.0
2.5
3.0
46
131
178
280
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416
614
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1532
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266
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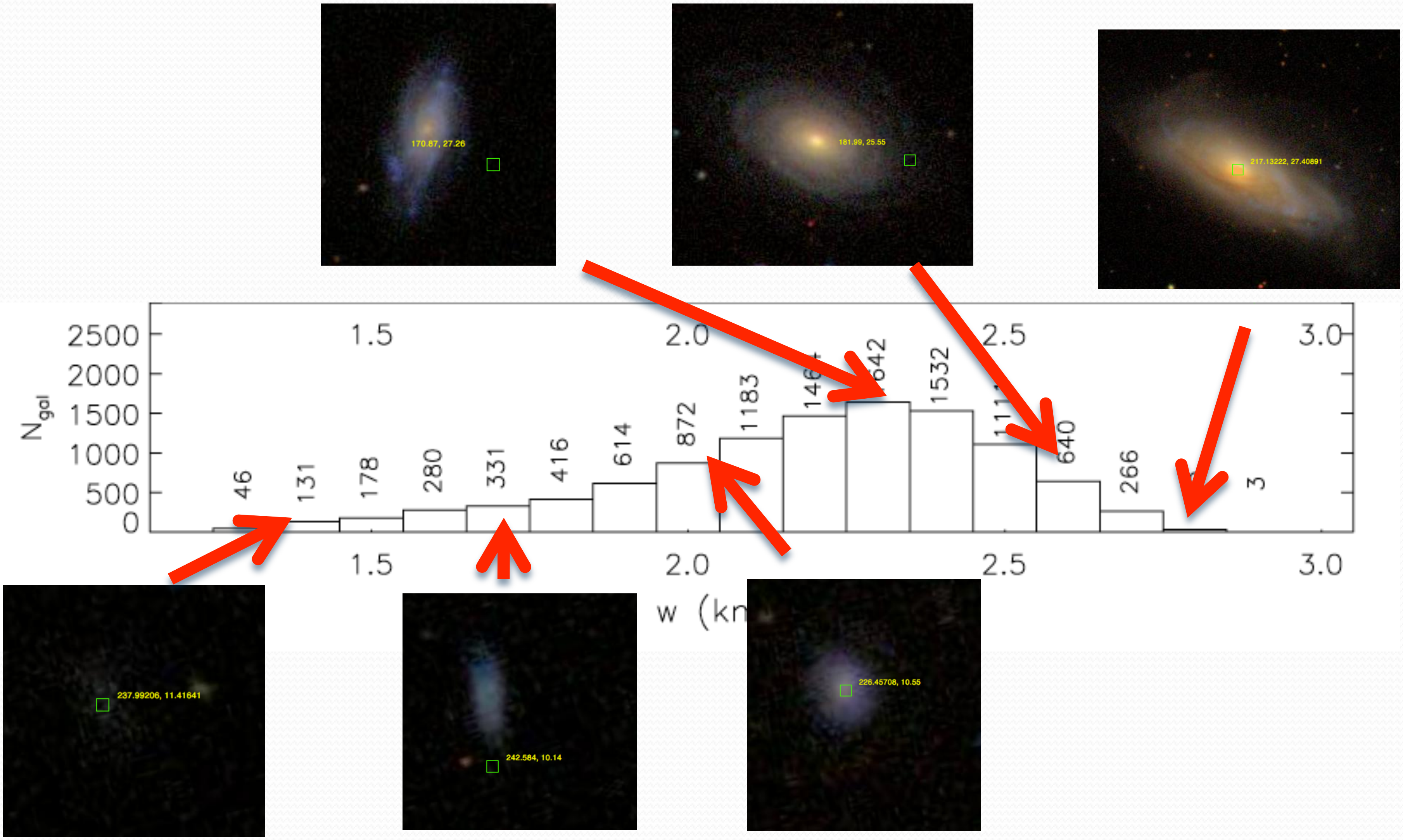
log w (km s^{-1})



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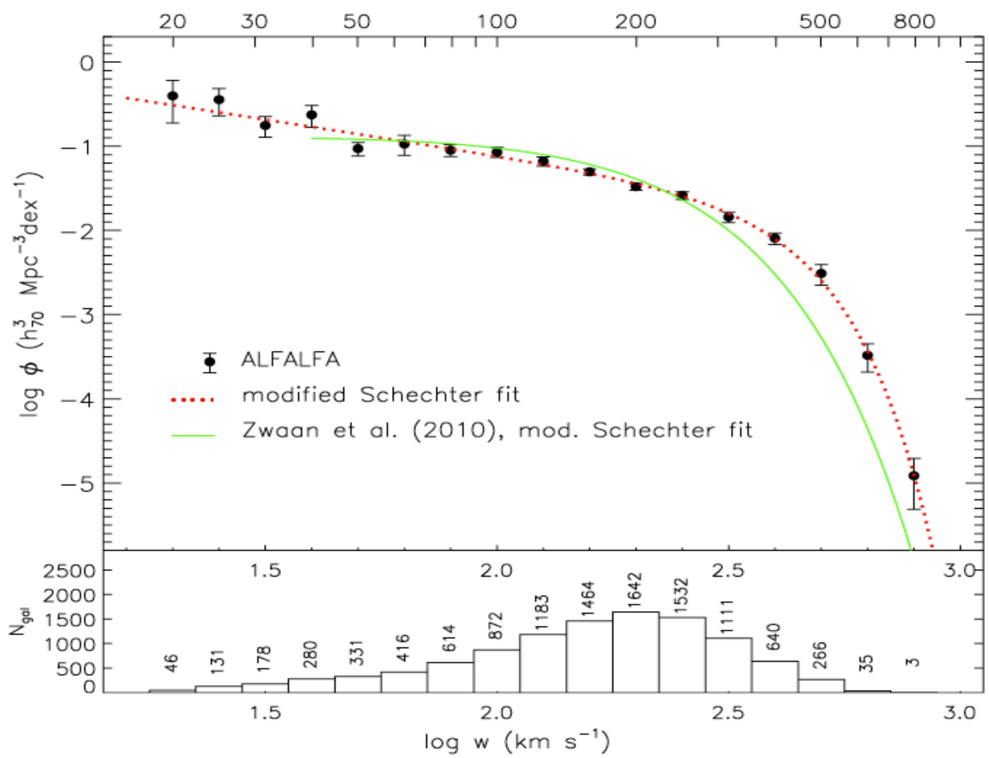
3.0
46
131
178
280
331
416
614
872
1183
1532
640
266
3
237.99206, 11.41641
242.584, 10.14
226.45708, 10.55

the ALFALFA velocity width function

- abundance of galaxies as a function of their velocity width
- modified Schechter function with a "shallow" measured slope of α = -0.85, down to w = 20 km/s

Papastergis+ (2011)



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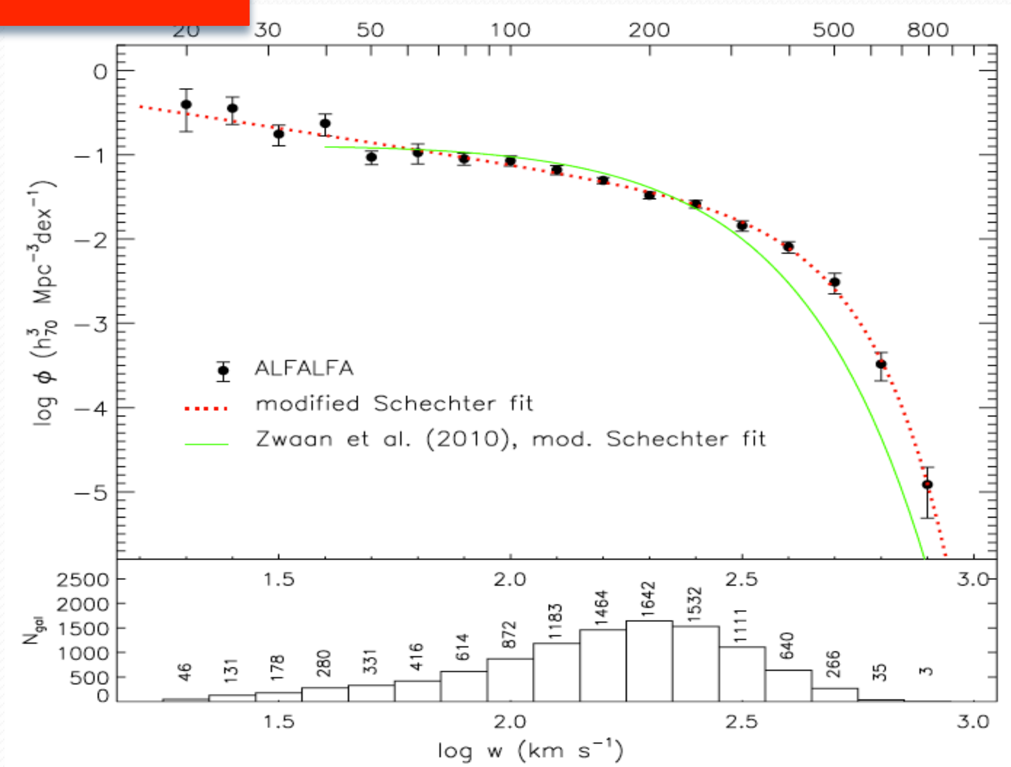
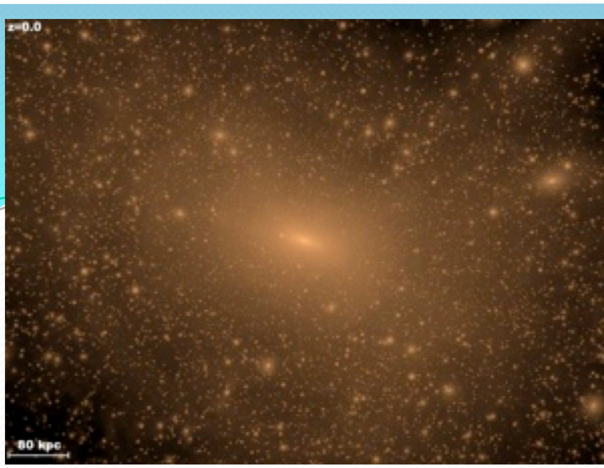




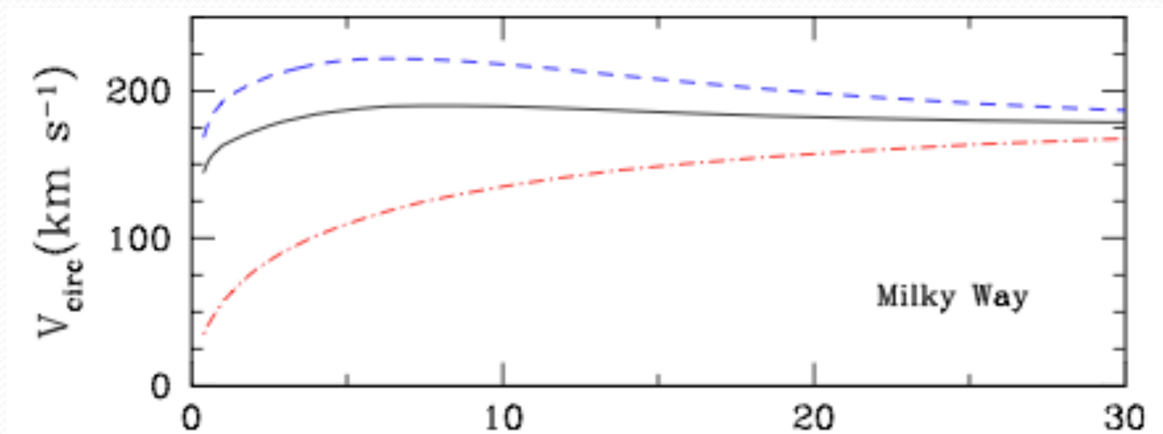
add baryons

does the halo host a single galaxy ?

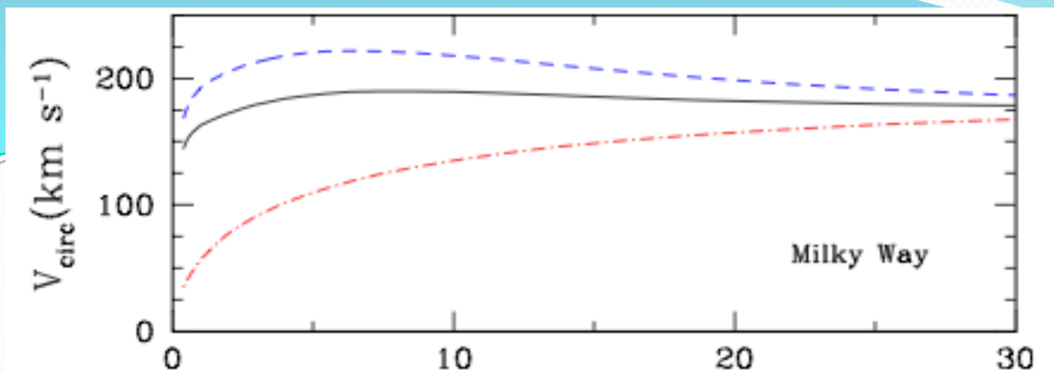
what is the stellar mass of the galaxy ?

what is the gas mass of the galaxy ?

is the DM halo distorted under the influence of the baryons ?



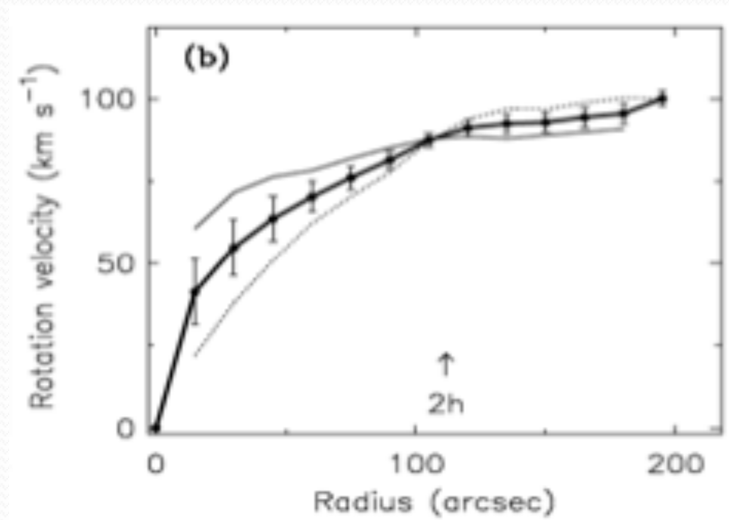
Trujillo-Gomez+ (2011)

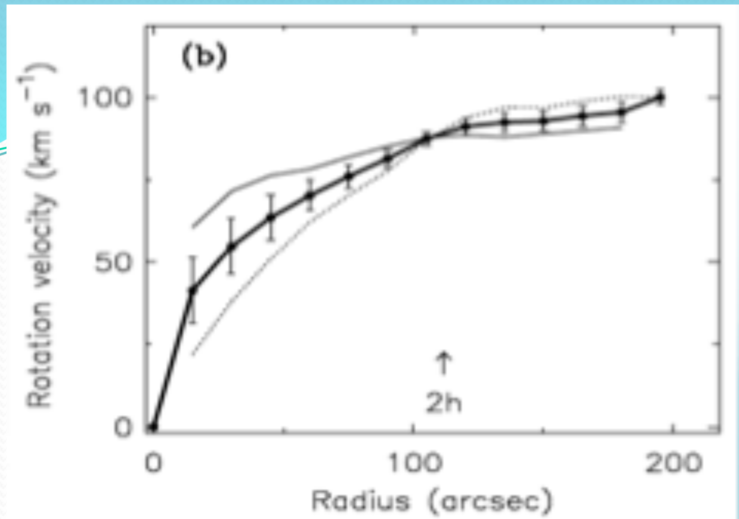


Trujillo-Gomez+ (2011)

add the tracer (HI)

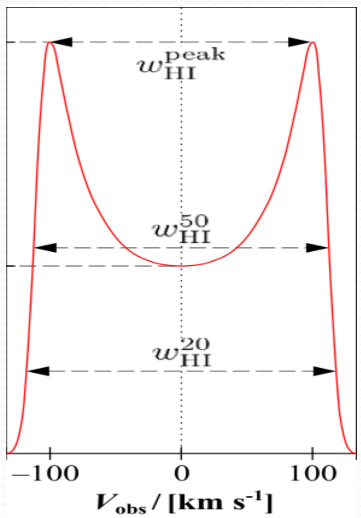
how extended is the HI disk ?





+ thermal broadening

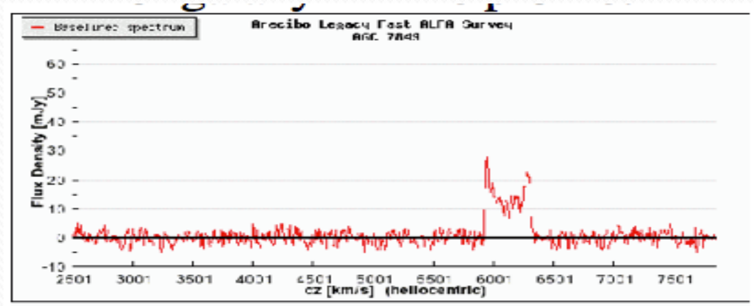
+ spatial integration



+ projection on line-of-sight

+ Doppler & instrumental broadening

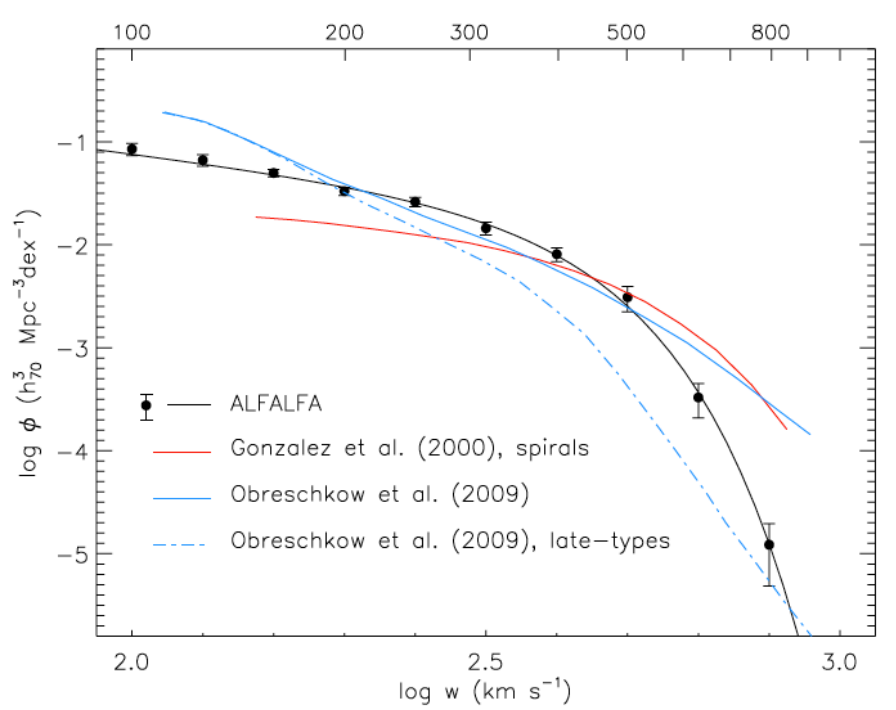
+ noise



observation vs. theory

- the ALFALFA WF is in fair agreement with theoretical predictions for massive galaxies.

Papastergis+ (2011)

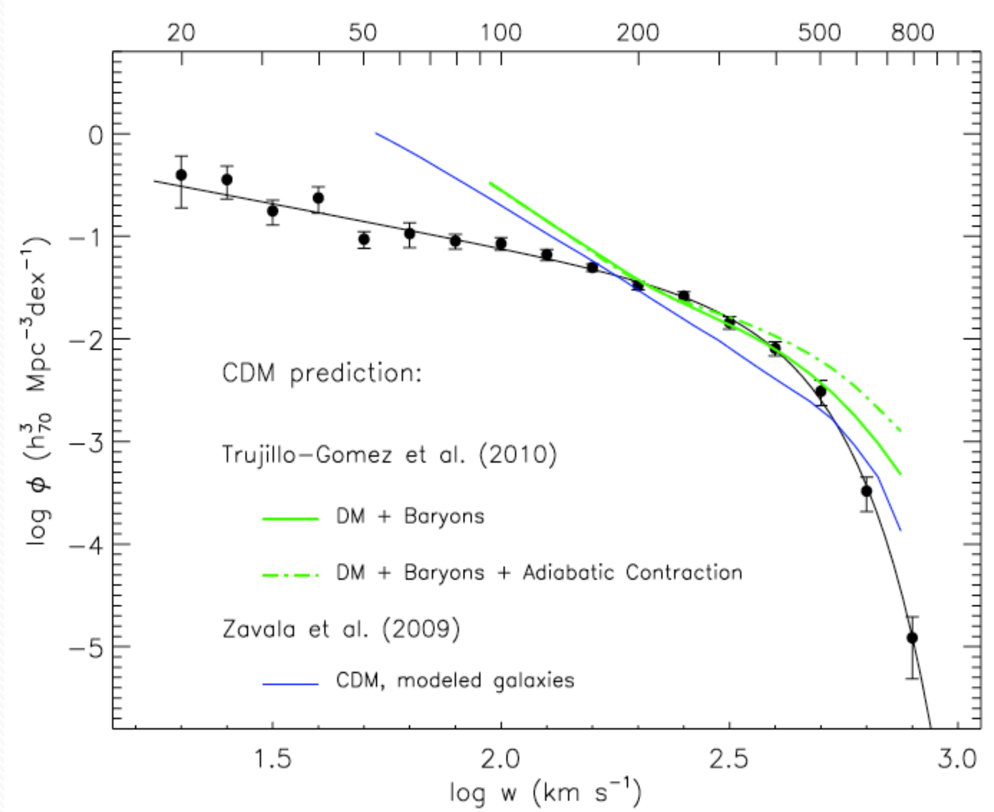


modeling: Obreschkow+ (2009)

observation vs. theory

- at low widths (w < 150 km/sec) the observational and theoretical distributions disagree.

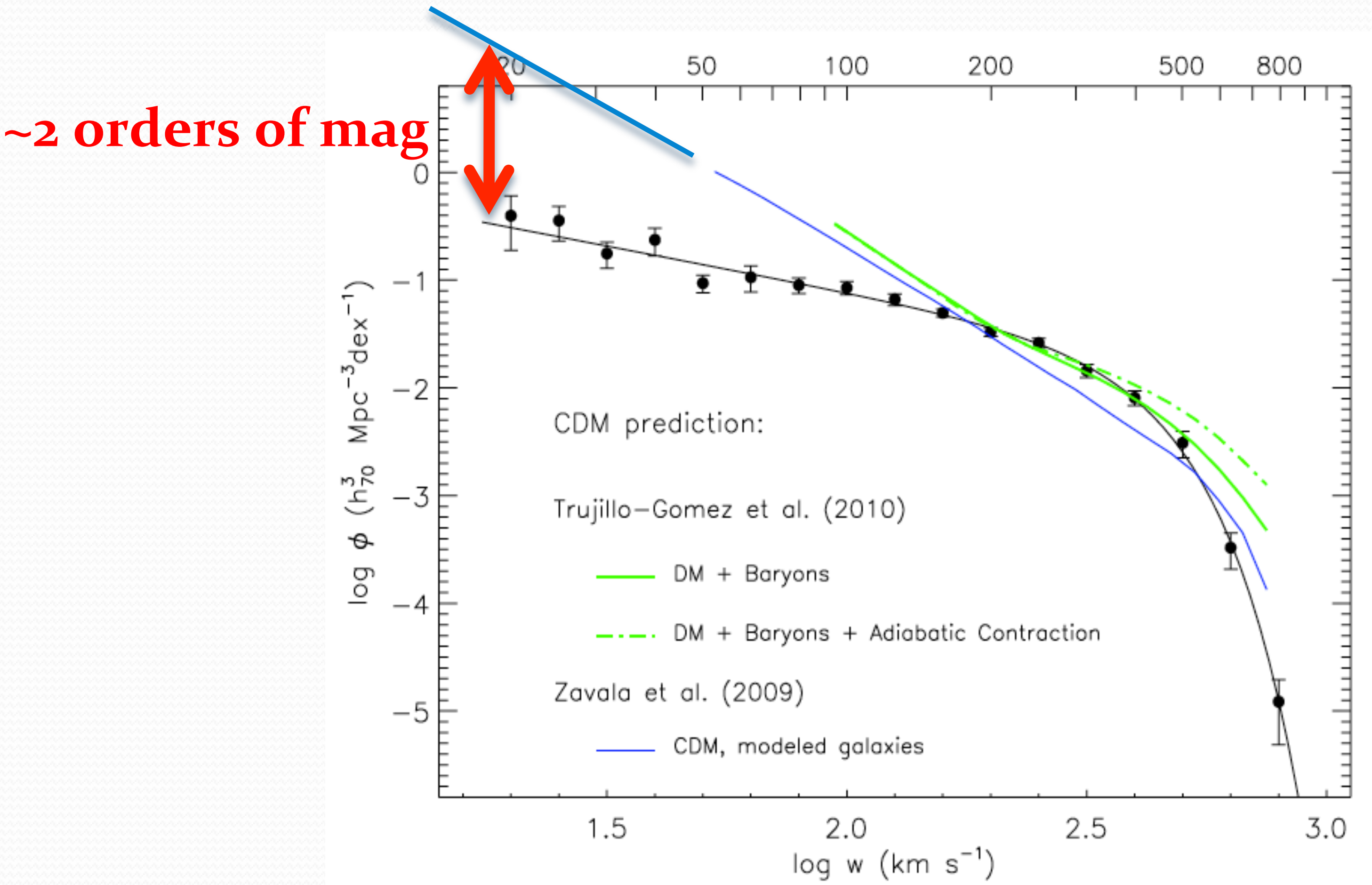
$$w = 2v_{\rm rot} \sin i + w_{\rm eff}$$



Papastergis+ (2011)

modeling: Trujillo-Gomez+ (2011), Zavala+ (2009)

observation vs. theory



Papastergis+ (2011)

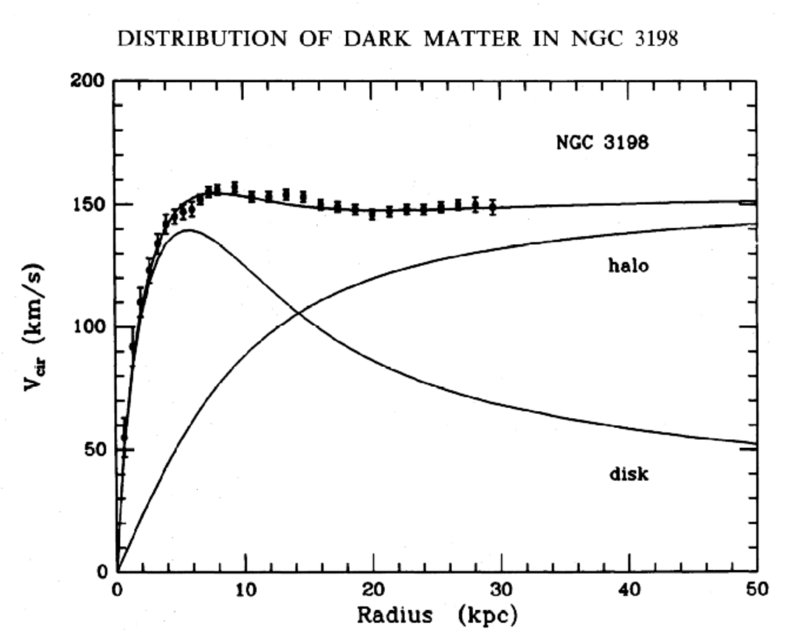
The “overabundance” problem of CDM

- “missing satellites” problem
- “void phenomenon”
- sizes of mini-voids in local volume
- flatness of stellar & H mass functions

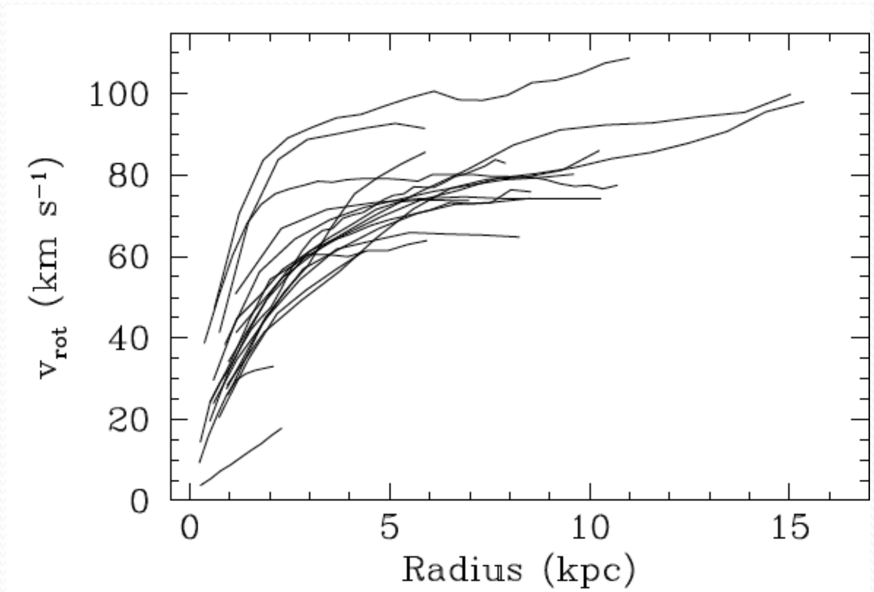
Possible solutions ?

extent of HI disk

- HI disks in dwarf galaxies are often rising to the last measured point.



'flat' rotation curve



'rising' rotation curves

Swaters+ (2009)

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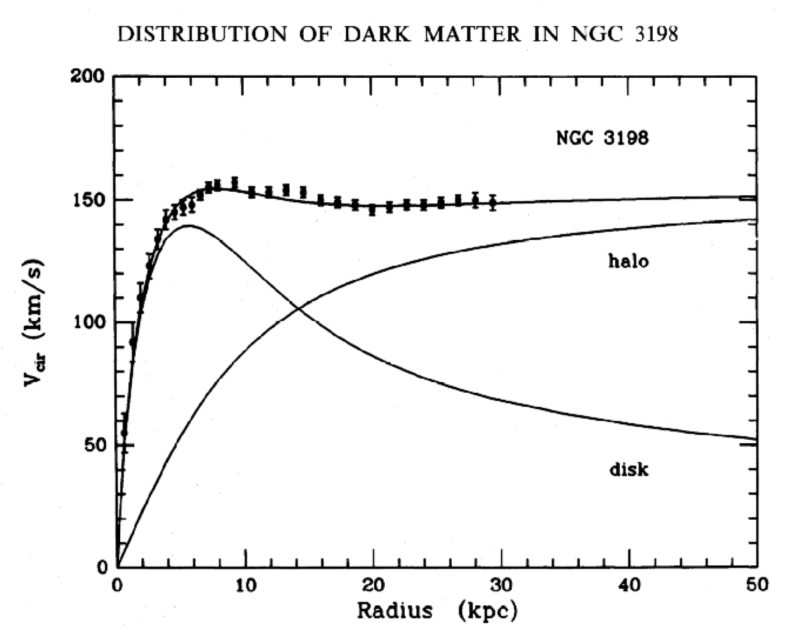

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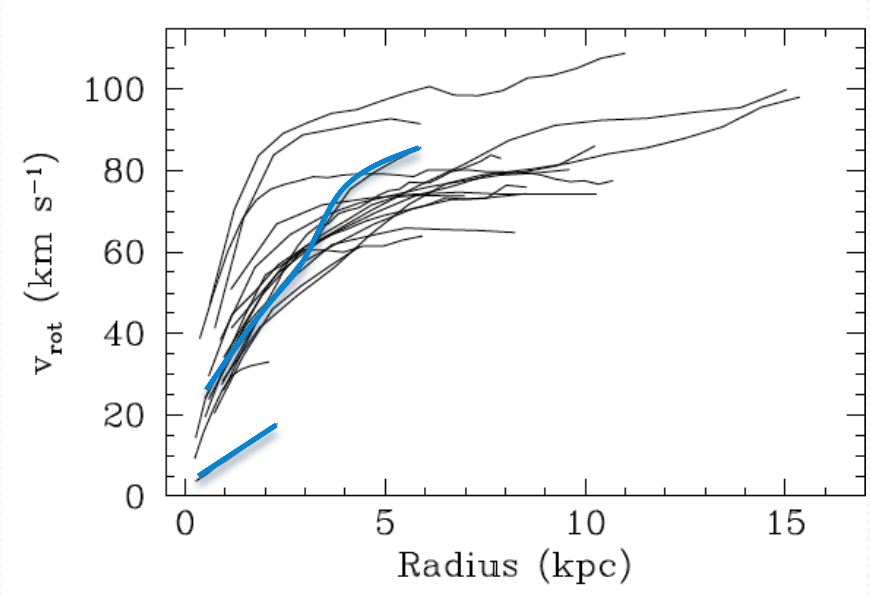

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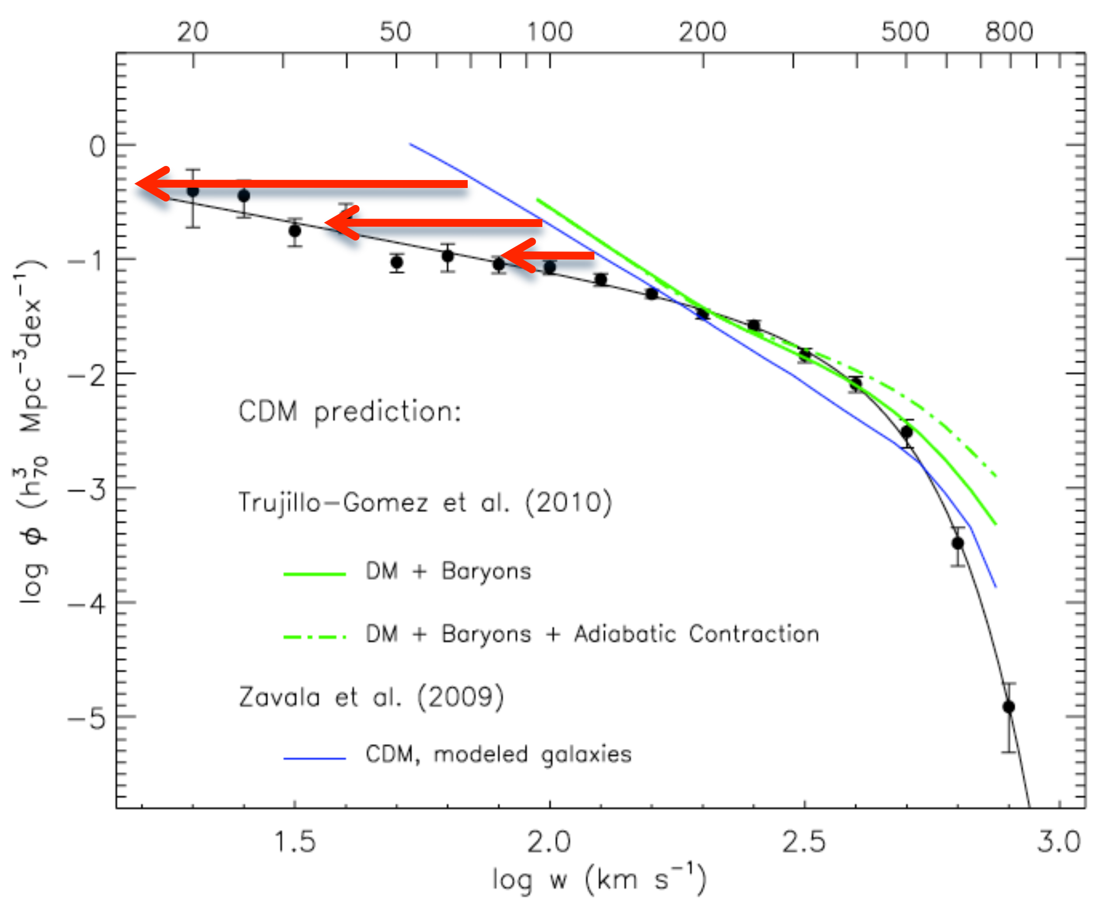
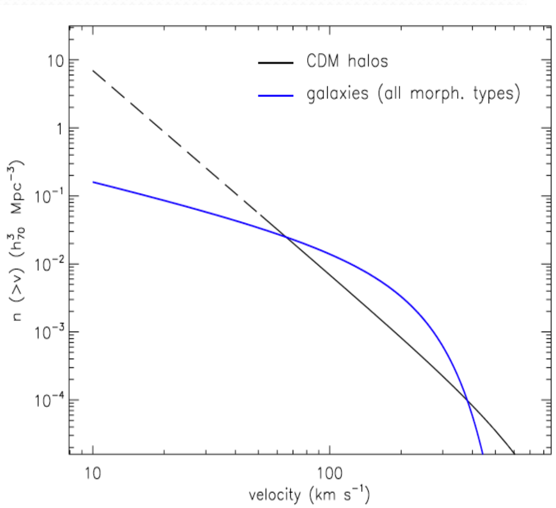
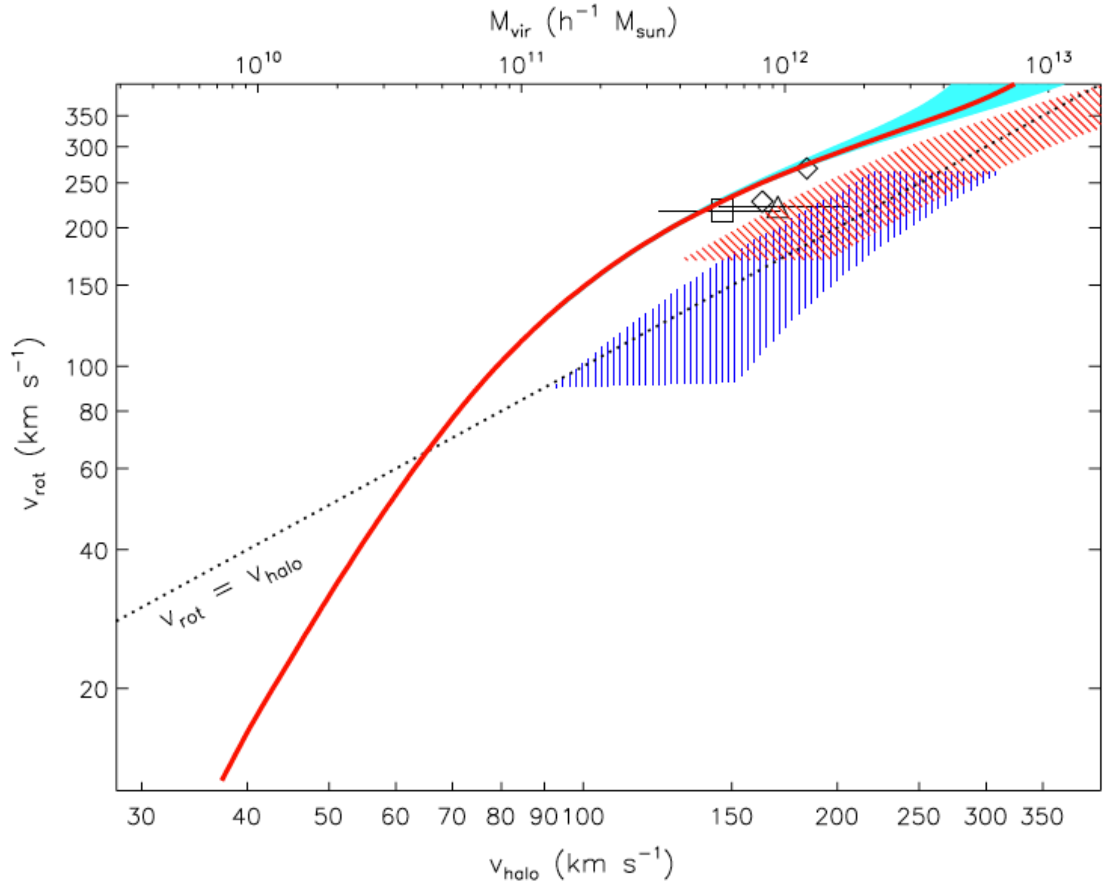


$v_{rot} - v_{halo}$ relation in CDM universe



'abundance matching'

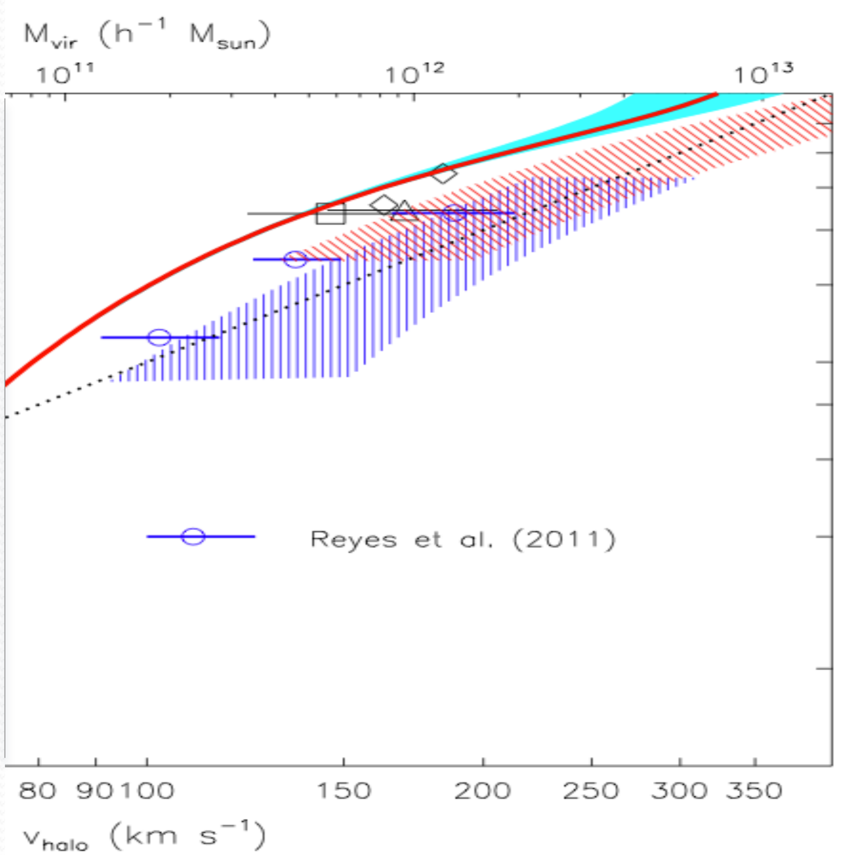


Papastergis+ (2011)

$v_{rot} - v_{halo}$ relation in CDM universe

- $v_{rot} \approx 1.5\ v_{halo}$ for MW-sized galaxies

Papastergis+ (2011)



<u>external datasets:</u>

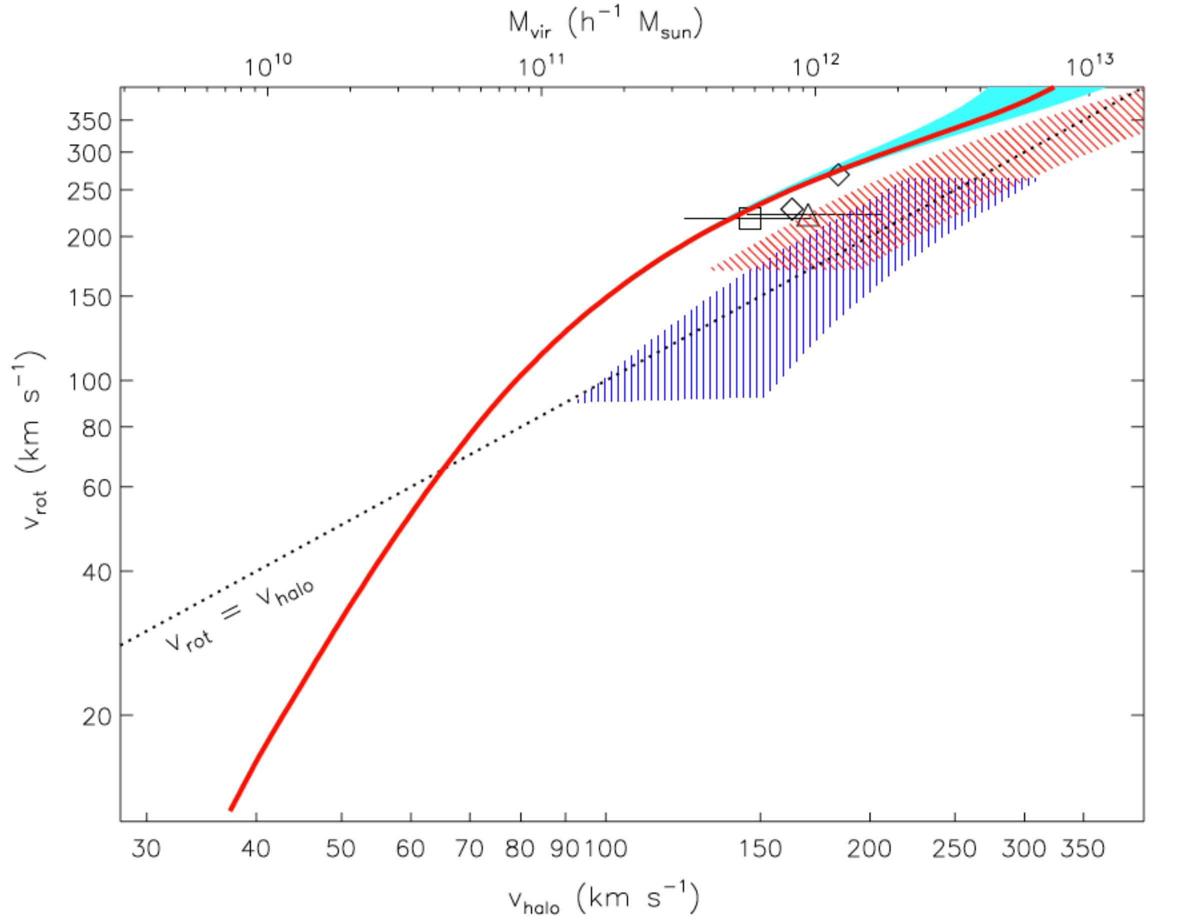
MW mass:
Klypin+ (2002), Xue+ (2008), Smith+ (2007)

Andromeda mass:
Klypin+ (2002)

stacked weak lensing & satellite kinematics:
Dutton+ (2010), Reyes+ (2012)

v_{rot} – v_{halo} relation in CDM universe

- In CDM, HI rotational velocities *must* underestimate the true halo mass.
- The underestimate is **a factor of ~2** at **v_{rot} = 20 km/sec**.



Papastergis+ (2011)

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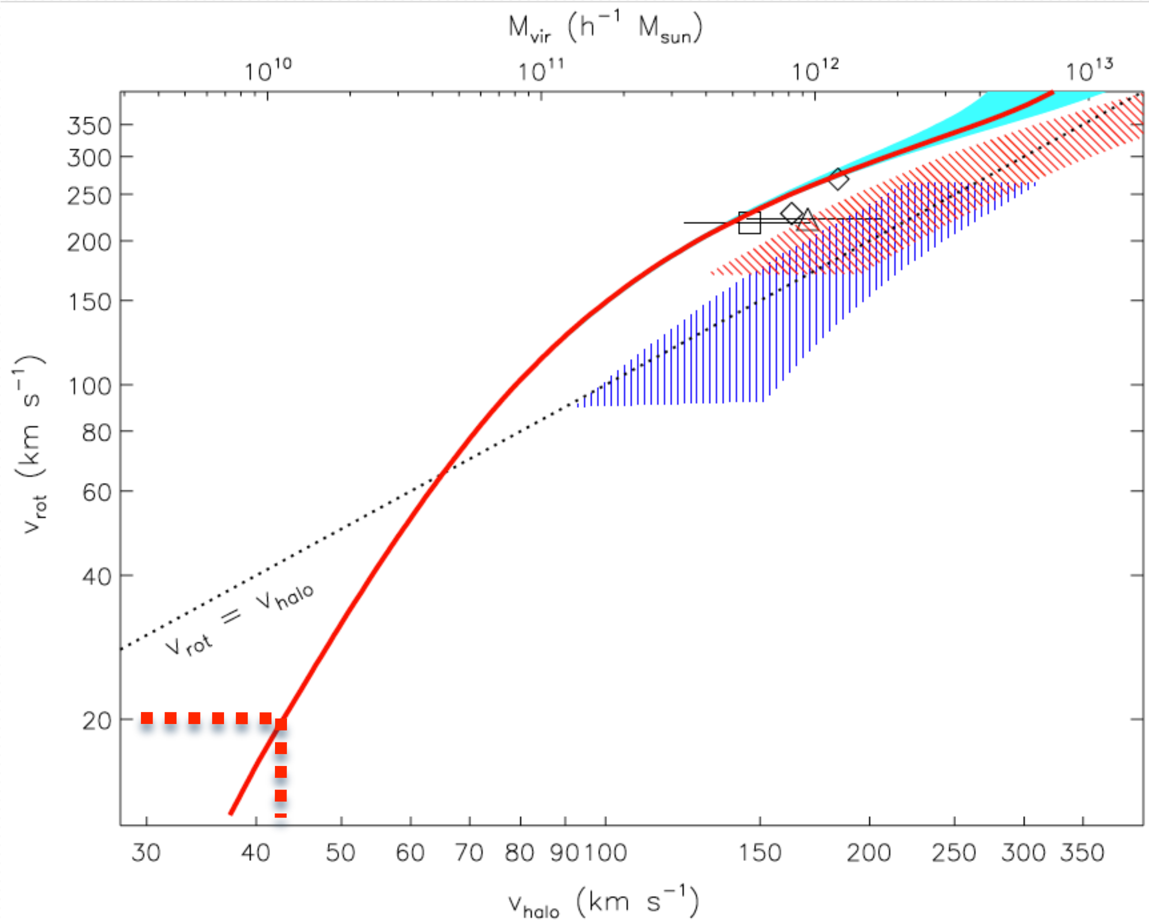
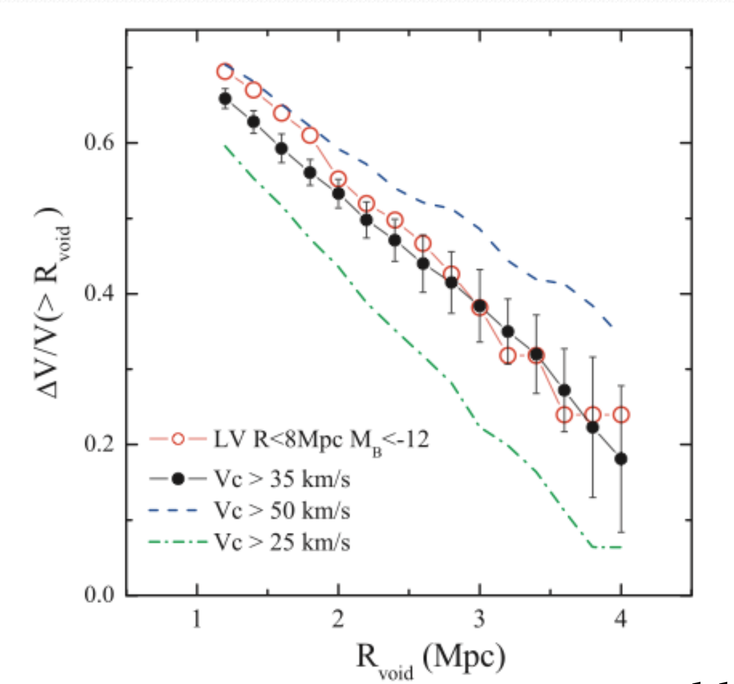


Papastergis+ (2011)

the “mini-void” size problem

- Galaxies brighter then M_B = -12 should be hosted by halos with v_{max} > 35 km/sec.



Name	M_B	Axial ratio	W_{50}	V_{rot}
E349-031,SDIG	−12.10	0.82	20.0	17.5
KKH5	−12.27	0.62	37.0	23.6
KKH6	−12.38	0.60	31.0	19.4
KK16	−12.65	0.37	24.0	12.9
KKH18	−12.39	0.57	34.0	20.7
KKH34,Mai13	−12.30	0.56	24.0	14.5
E489-56,KK54	−13.07	0.53	33.8	19.9
KKH46	−11.93	0.86	25.0	24.5
U5186	−12.98	0.23	42.0	21.6
E321-014	−12.70	0.43	39.8	22.0
KK144	−12.59	0.33	44.0	23.3
E443-09,KK170	−12.03	0.75	29.0	21.9
KK182,Cen6	−11.89	0.60	16.0	10.0
DDO181,U8651	−12.97	0.57	42	23.7
DDO183,U8760	−13.13	0.32	30.0	15.8
HIPASS1351-47	−11.88	0.60	38.8	24.2

Tikhonov & Klypin (2009)

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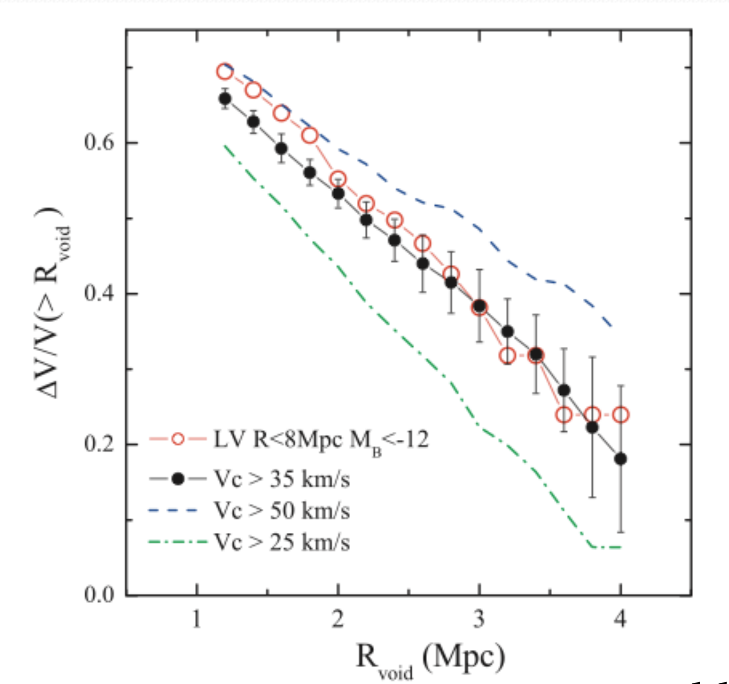

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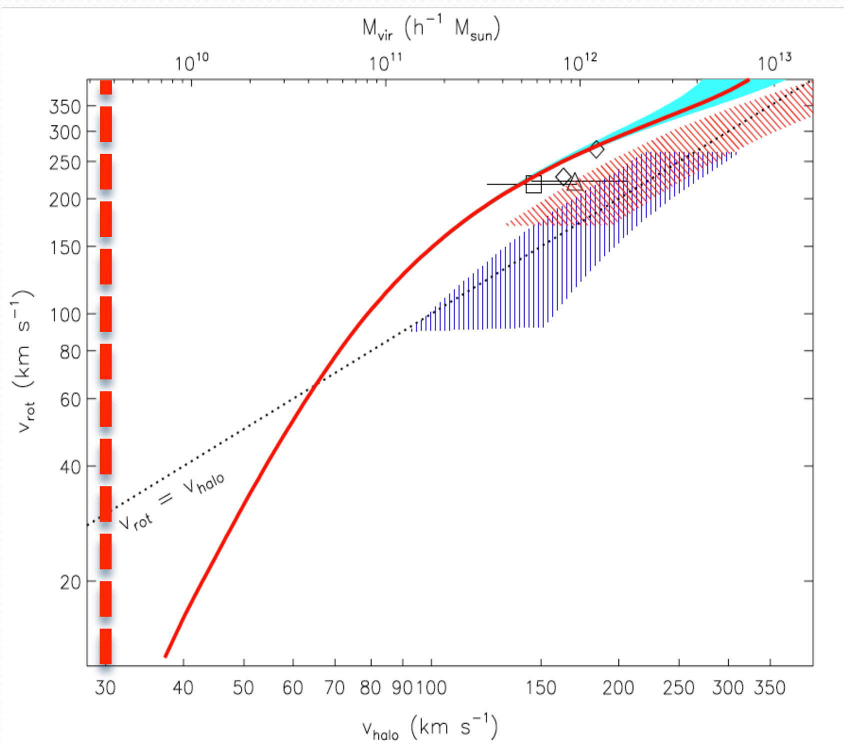
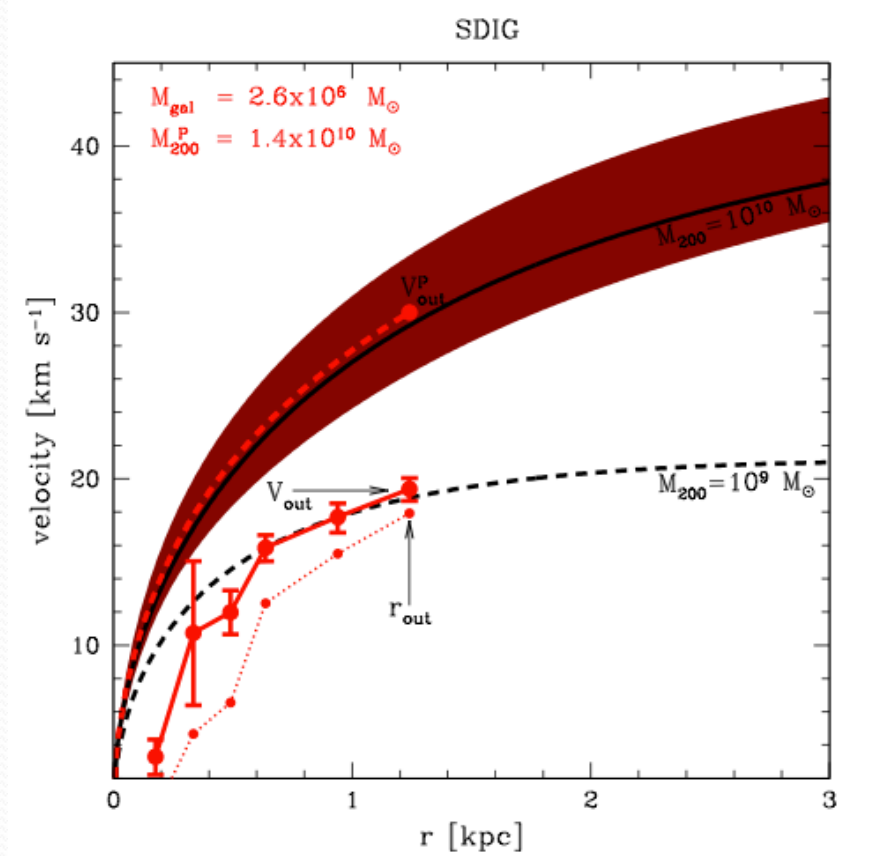
Tikhonov & Klypin (2009)

dwarf galaxy rotation curves



Papastergis+ (2011)



Ferrero+ (2011)

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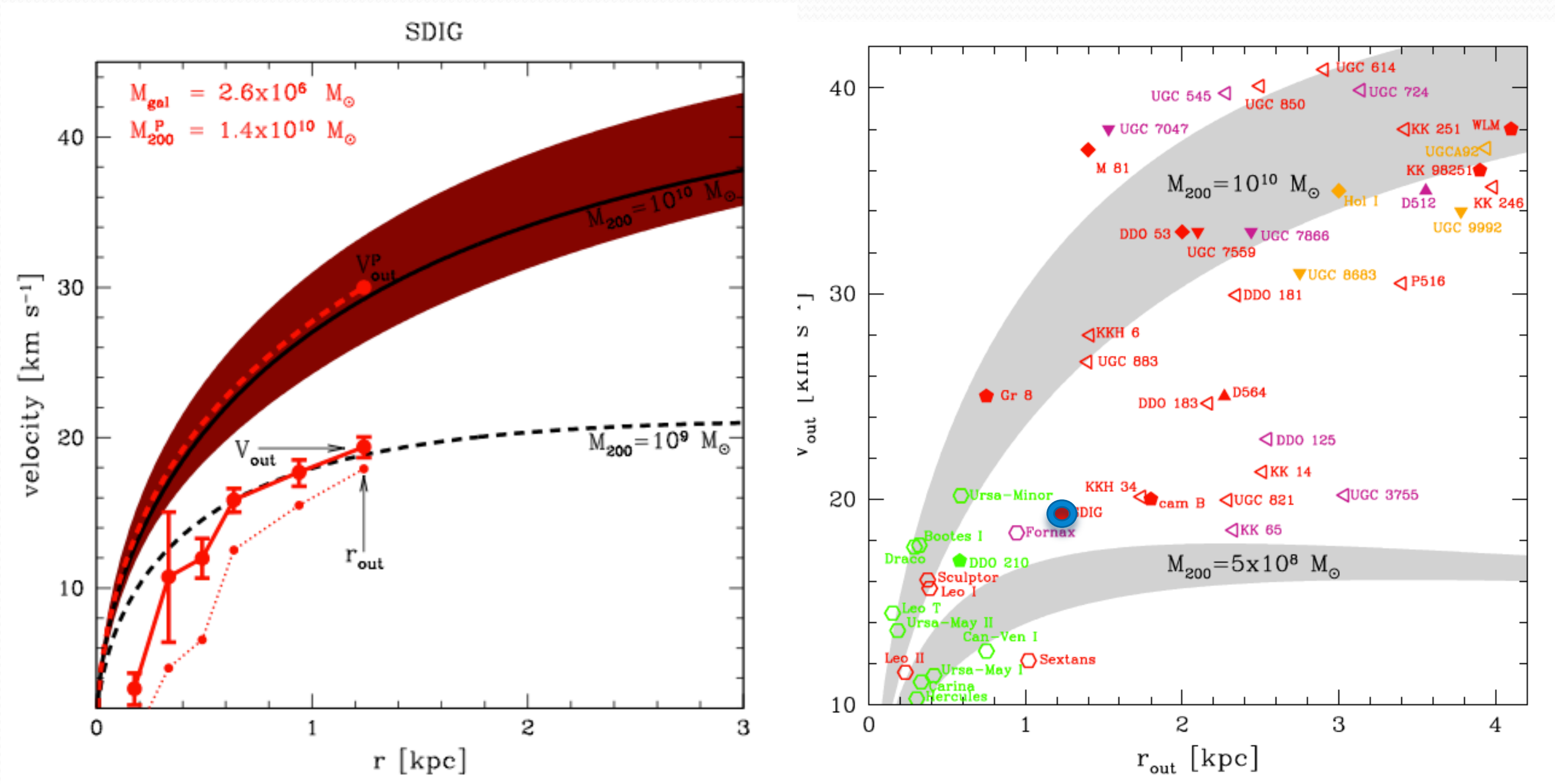
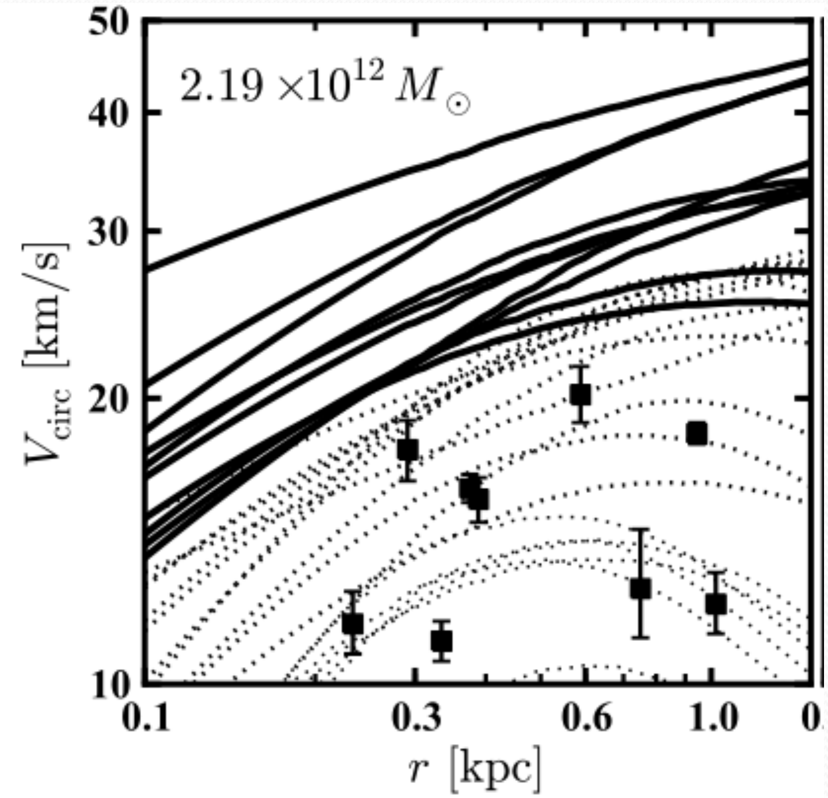


Ferrero+ (2011)

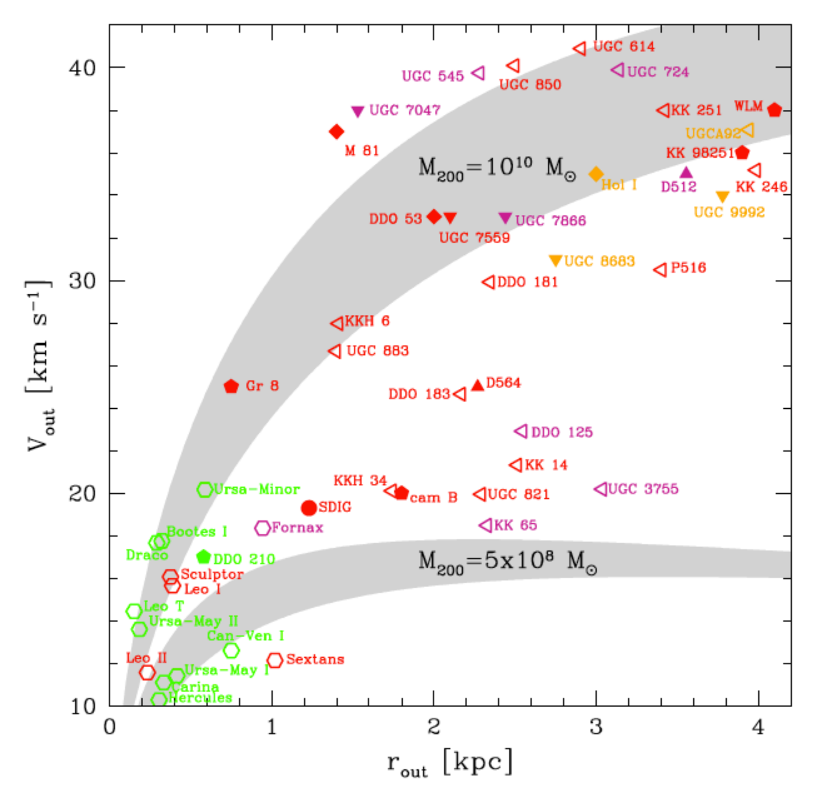
CDM challenges

MW satellites



Boylan-Kolchin+ (2012)

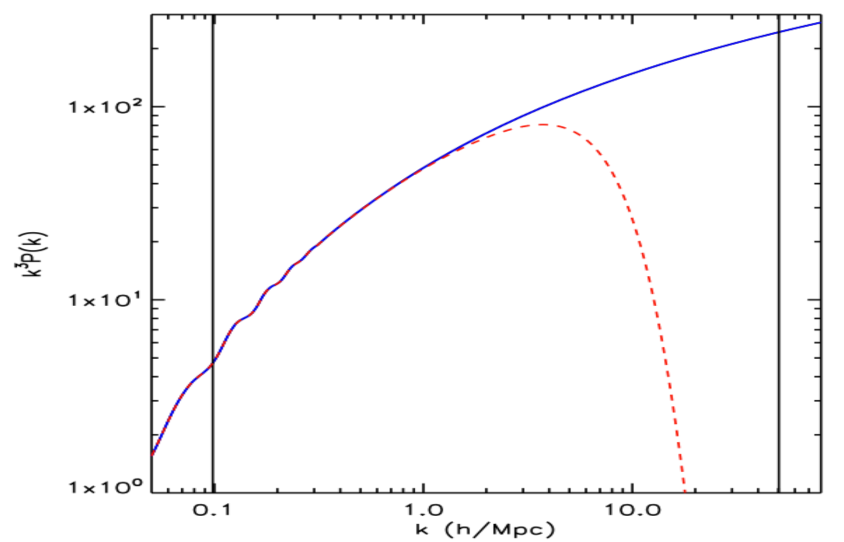
field dwarfs



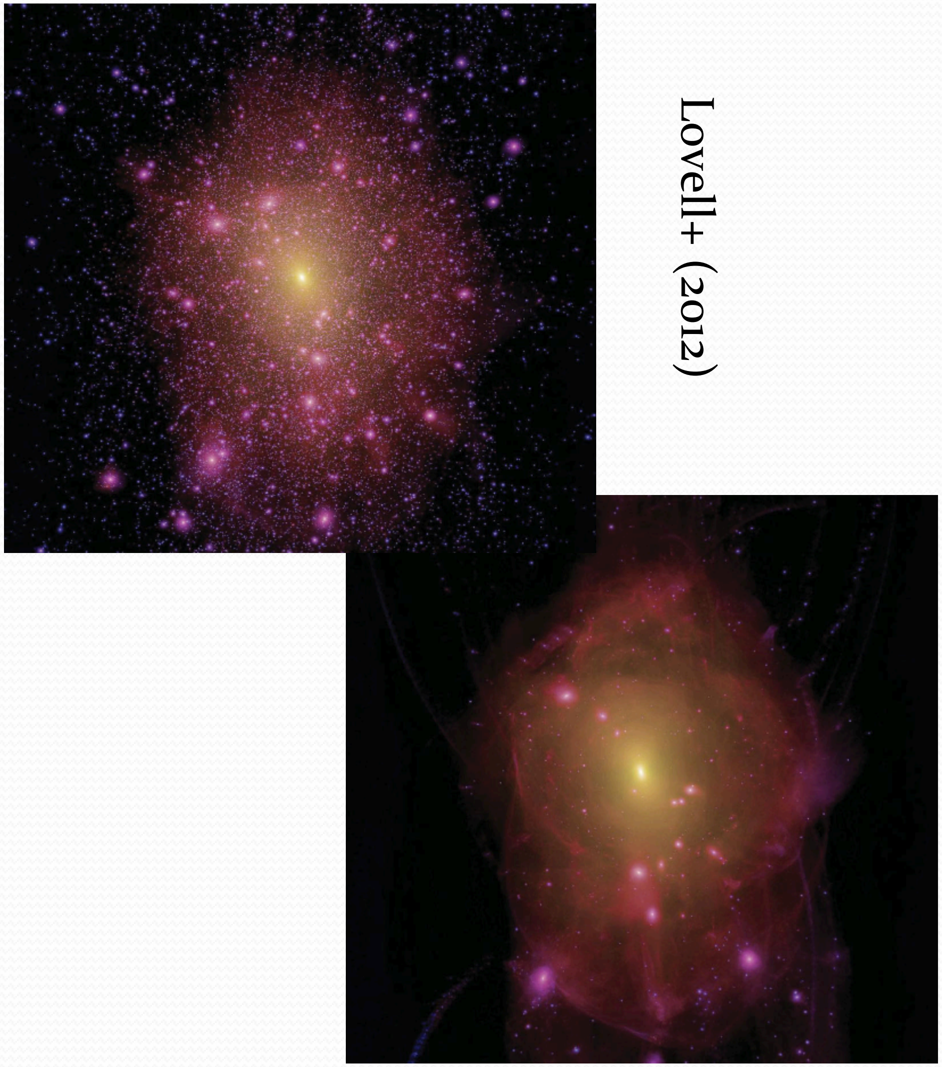
Ferrero+ (2011)

Warm Dark Matter (WDM)

- in a ~keV warm dark matter universe, low-mass halos would be far less numerous.

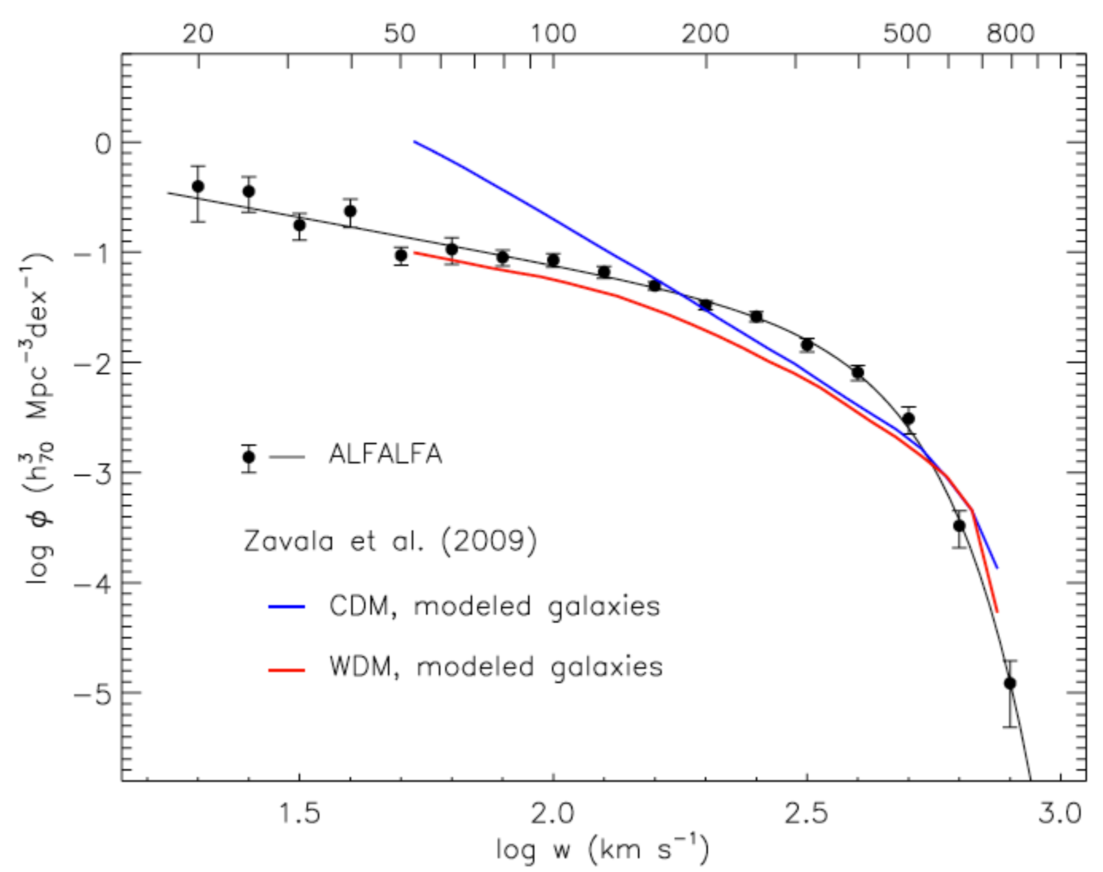


Zavala+ (2009)



Lovell+ (2012)

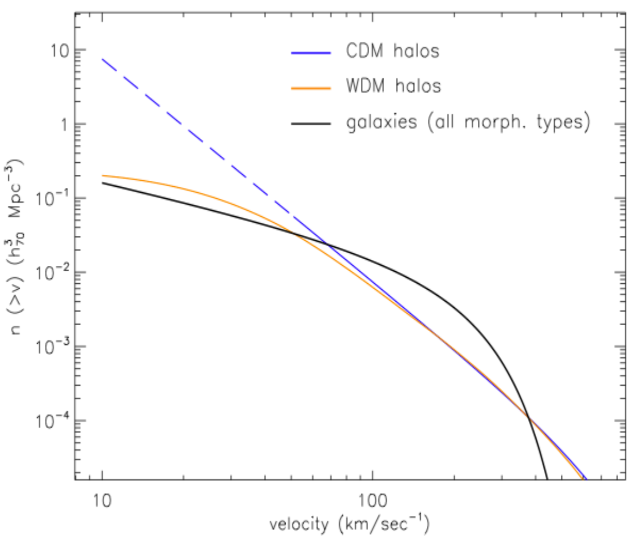
Warm Dark Matter (WDM)

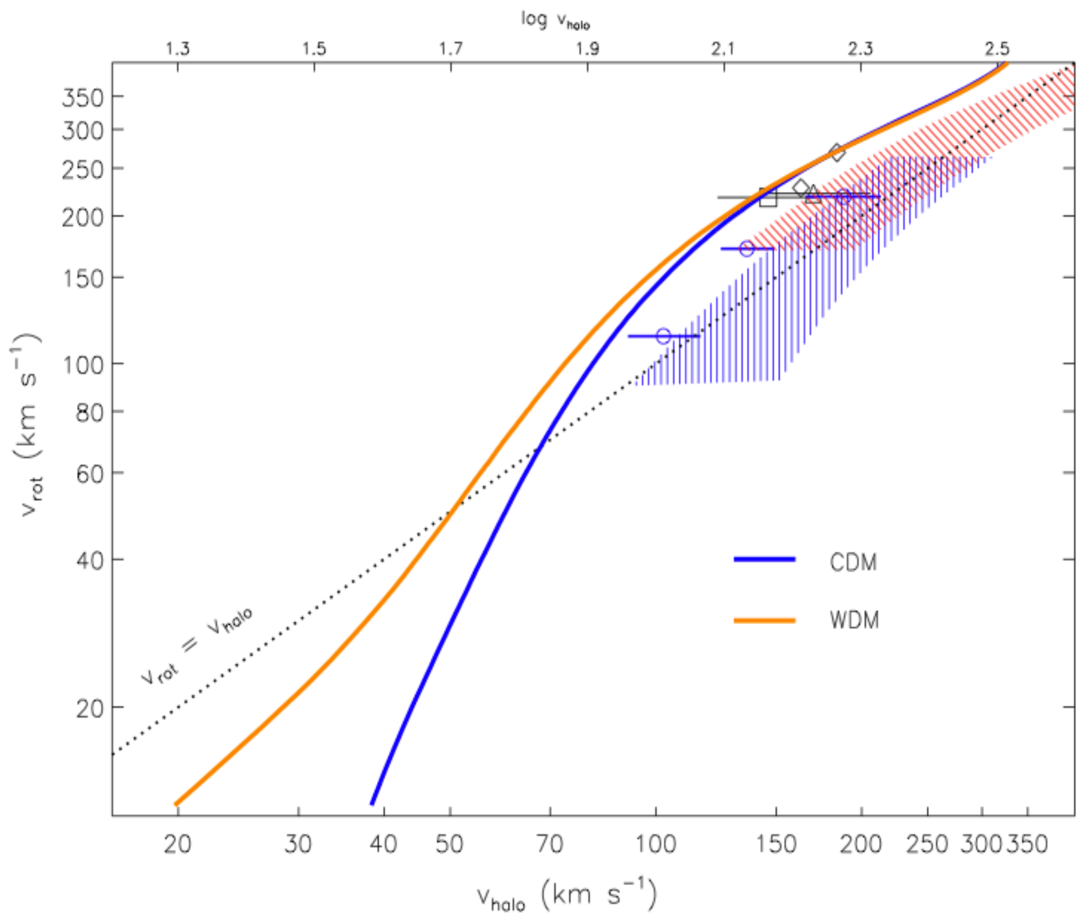


Papastergis+ (2011)

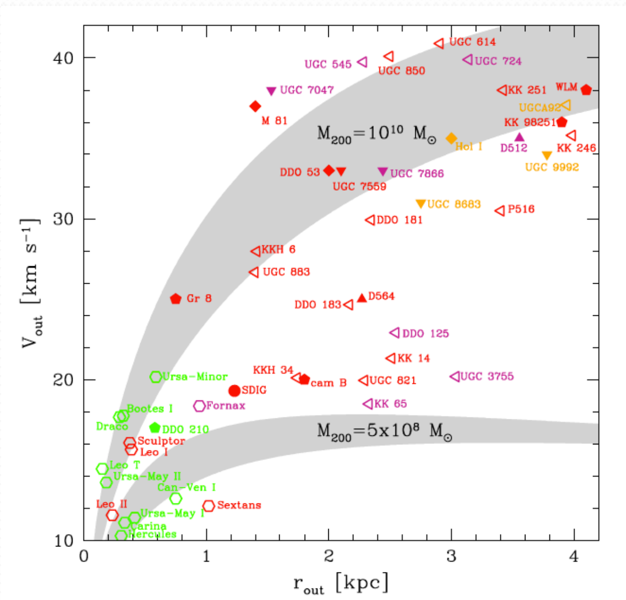
modeling: Zavala+ (2009)

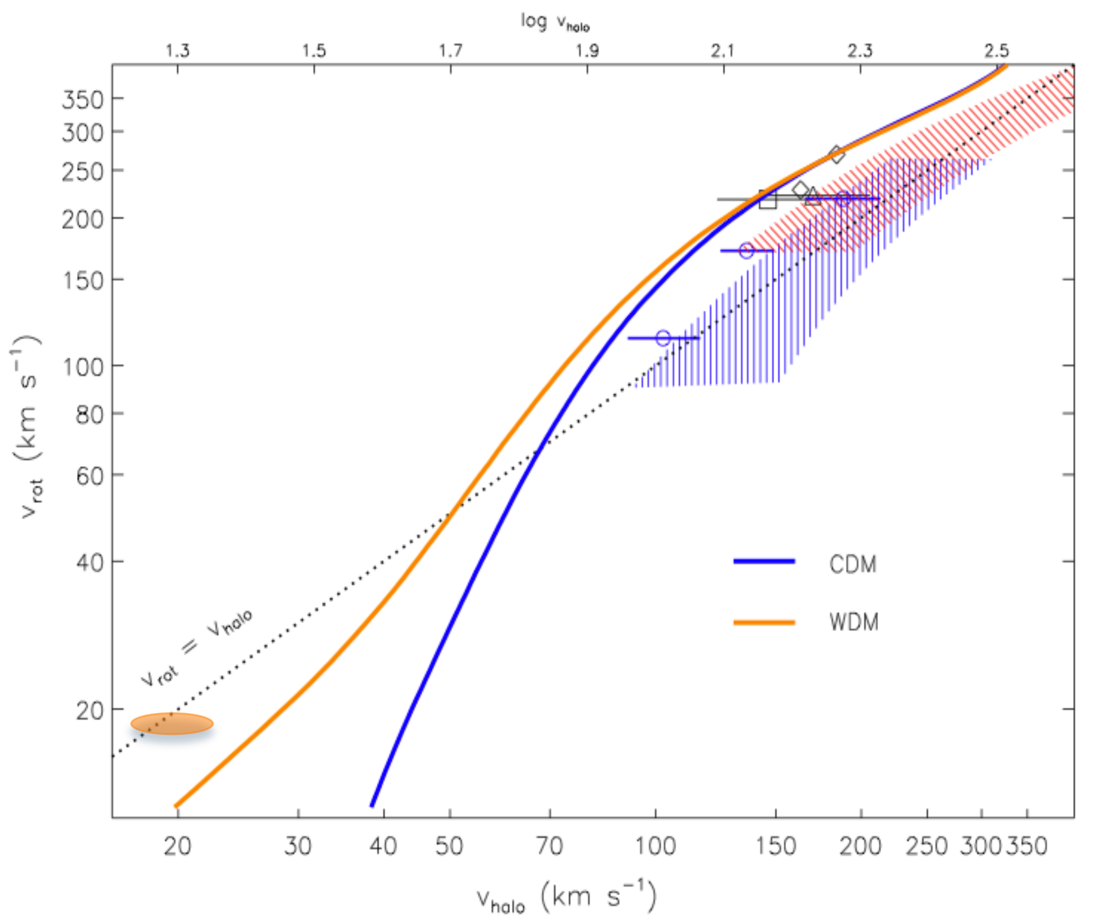
v_{rot} – v_{halo} relation in WDM universe





$v_{rot} - v_{halo}$ relation in WDM universe





merci pour votre attention!

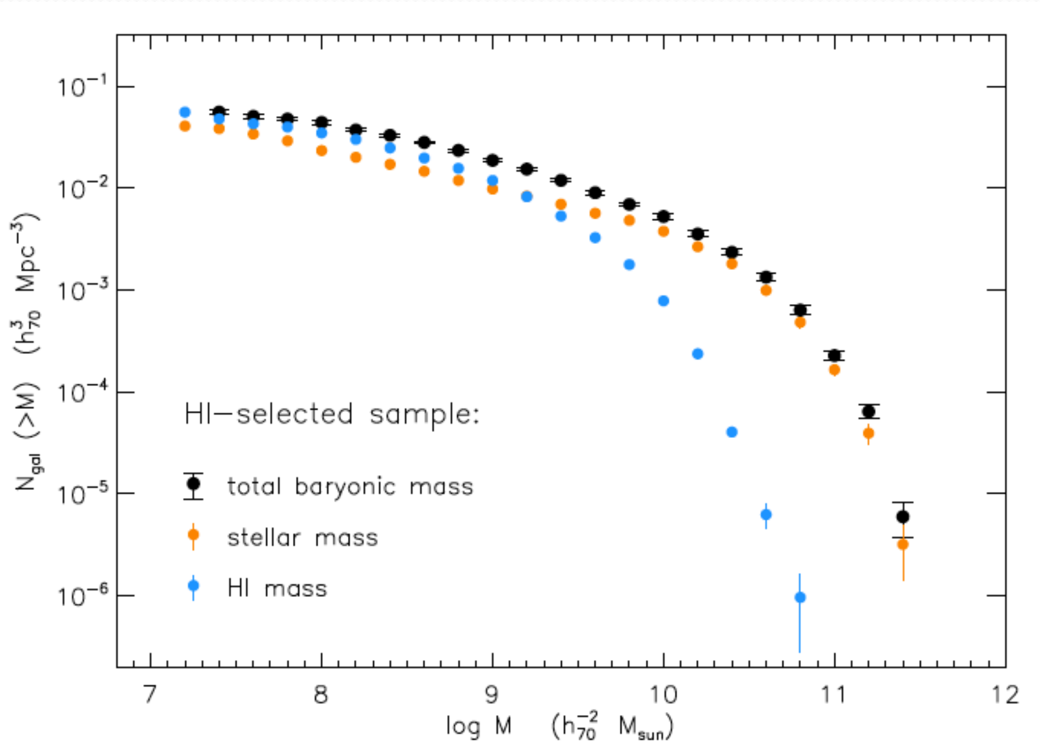
questions?

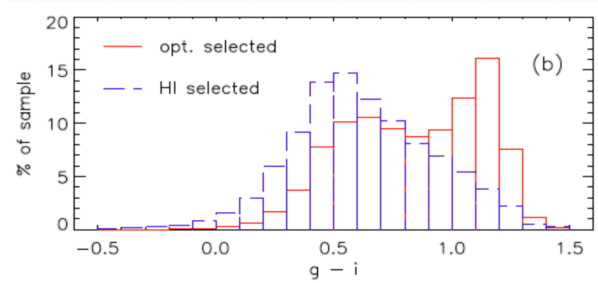
- the ALFALFA measurement of the velocity width function is in disagreement with CDM expectations, given current galaxy semi-analytical modeling.
- Two main solutions: WDM or the inaccurate modeling of the HI disk (dynamical tracer)
- Constrains from the observed WF and the inner structure of dwarf galaxies currently pose the strongest challenges on the CDM paradigm of structure formation.
- imperative to understand baryonic process, but feedback required may be difficult to obtain.

the ALFALFA baryonic mass function

- HI mass from ALFALFA, stellar mass from SDSS
  - HI-selected sample biased against red-sequence

Papastergis+ (2012, in prep)





the ALFALFA baryonic mass function

"A direct measurement of the Baryonic Mass Function of galaxies & implications for the galactic baryon fraction"

***Papastergis E.**, Cattaneo A., Huang S., Giovanelli R., Haynes M.P.*
(in prep)

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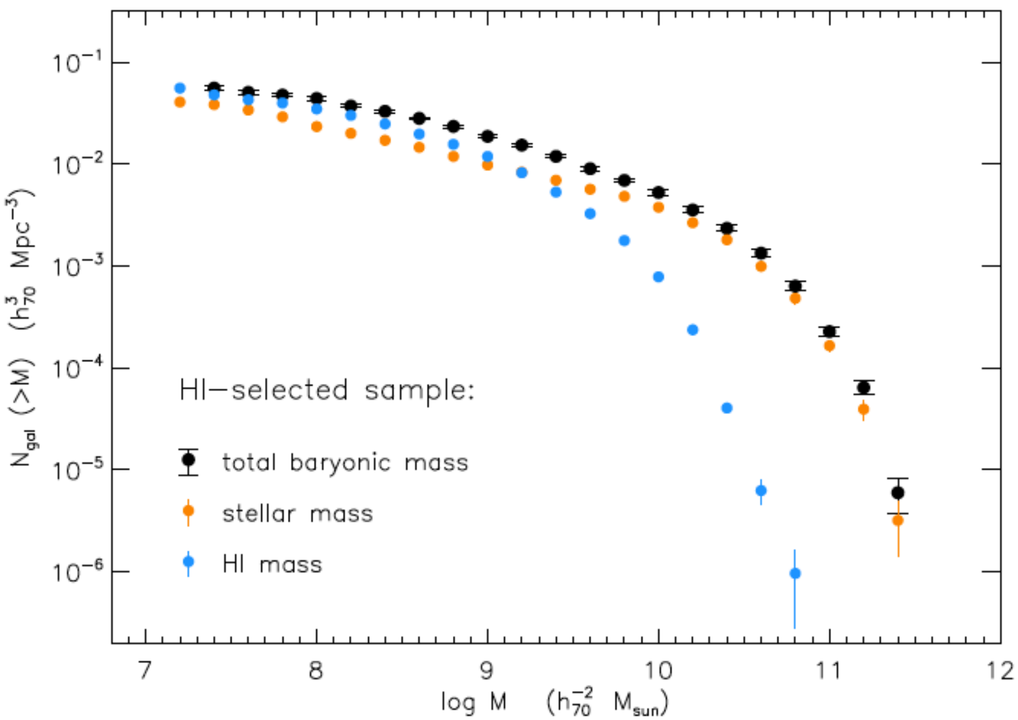
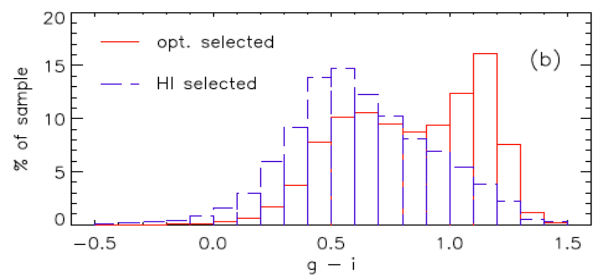
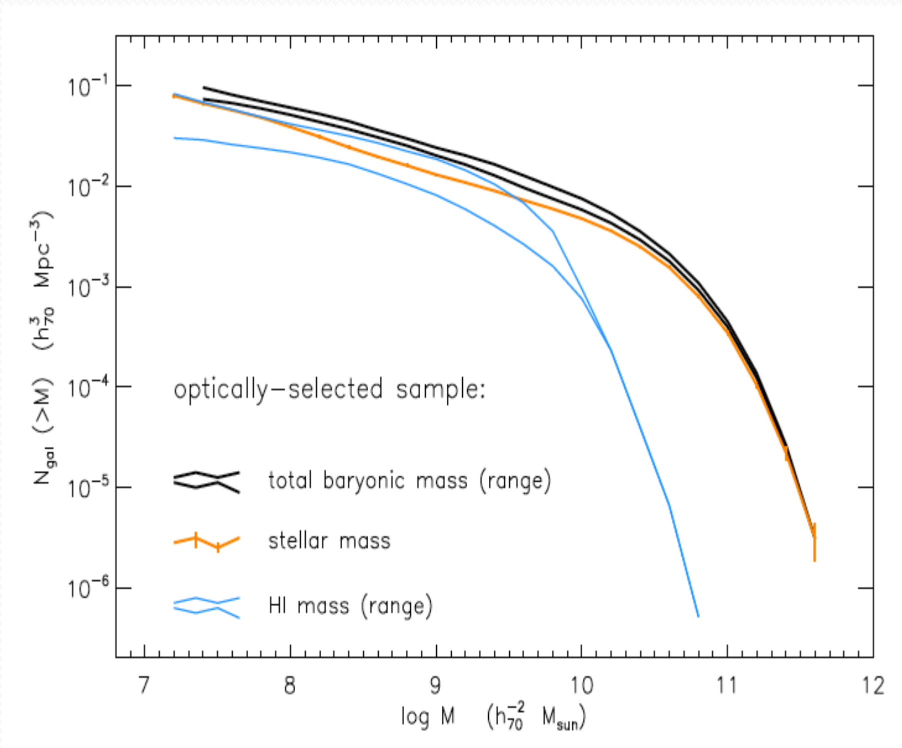


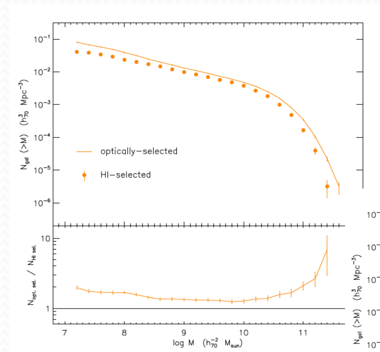


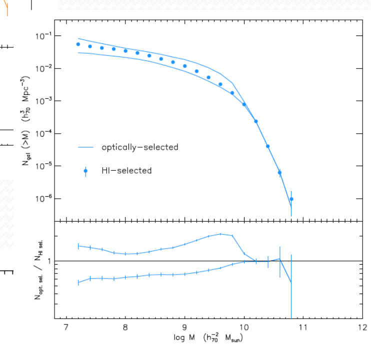
the ALFALFA baryonic mass function

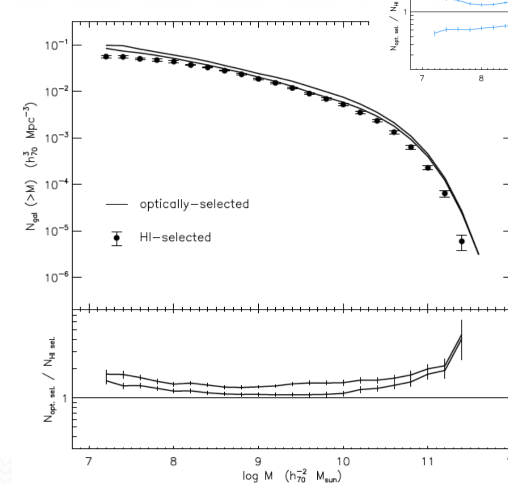
- stellar mass from SDSS, HI mass limits from ALFALFA

Papastergis+ (2012, in prep)



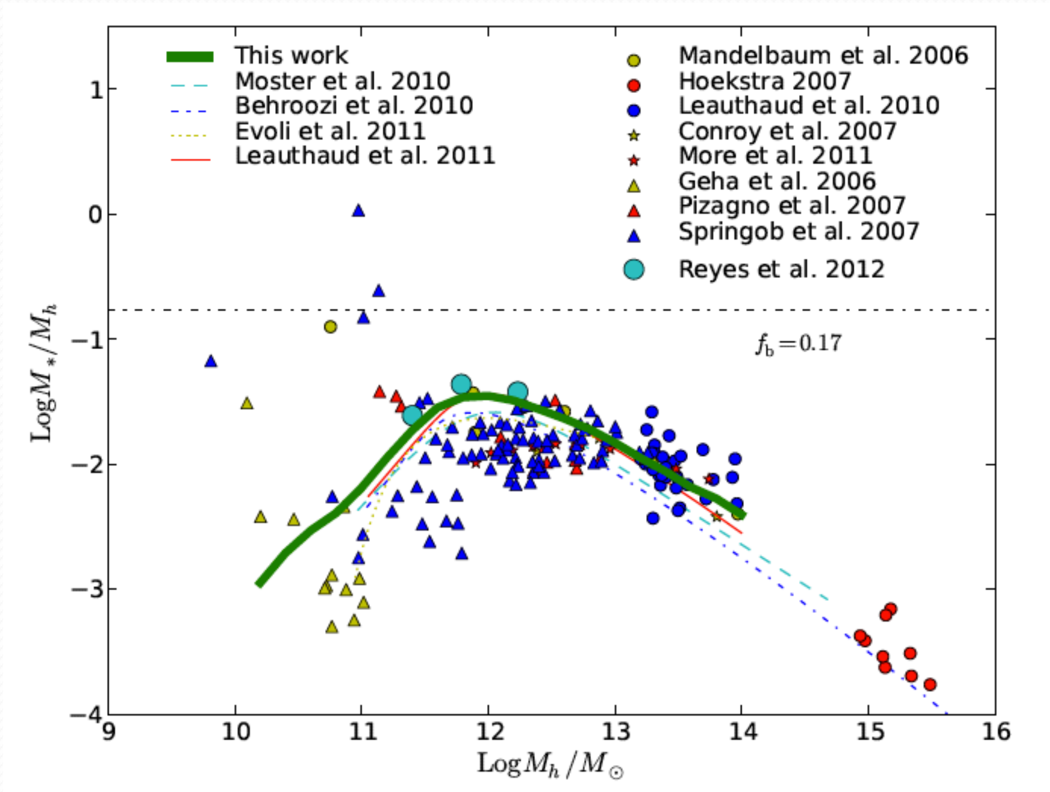






the ALFALFA baryonic mass function

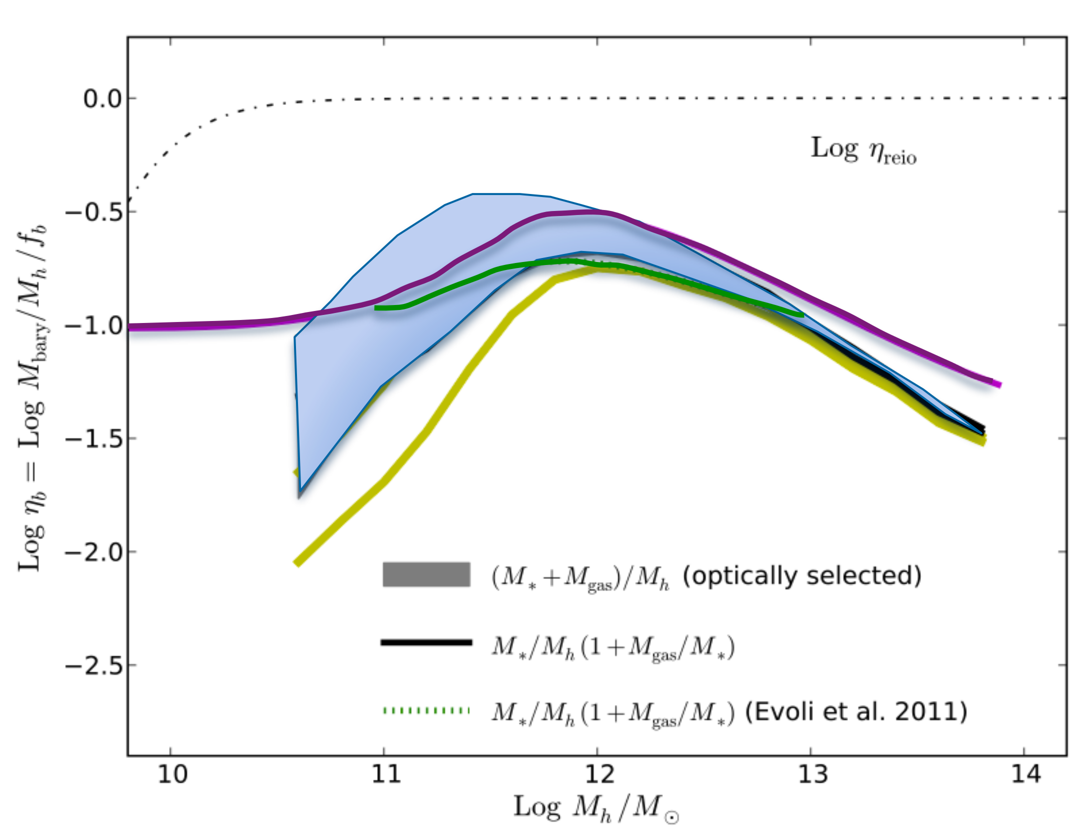
- low "stellar conversion efficiency", $\eta_* = (M_*/M_h) / f_b$



Papastergis+ (2012, in prep)

the ALFALFA baryonic mass function

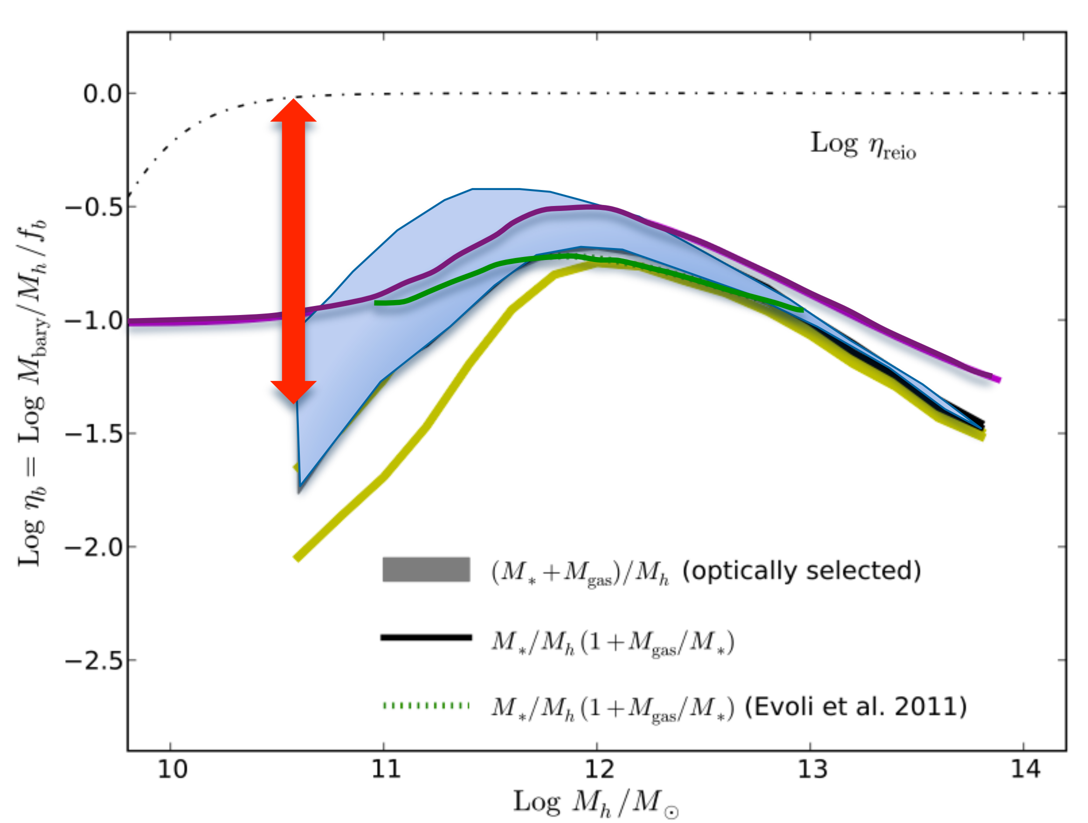
- "baryon retention fraction" also low, $\eta_b = (M_b/M_h) / f_b$



Papastergis+ (2012, in prep)

the ALFALFA baryonic mass function

- requires: expelled mass ≈ 100 x stellar mass



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