The missing dwarfs: a challenge for CDM?

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in collaboration with:

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E. Papastergis (Groningen)
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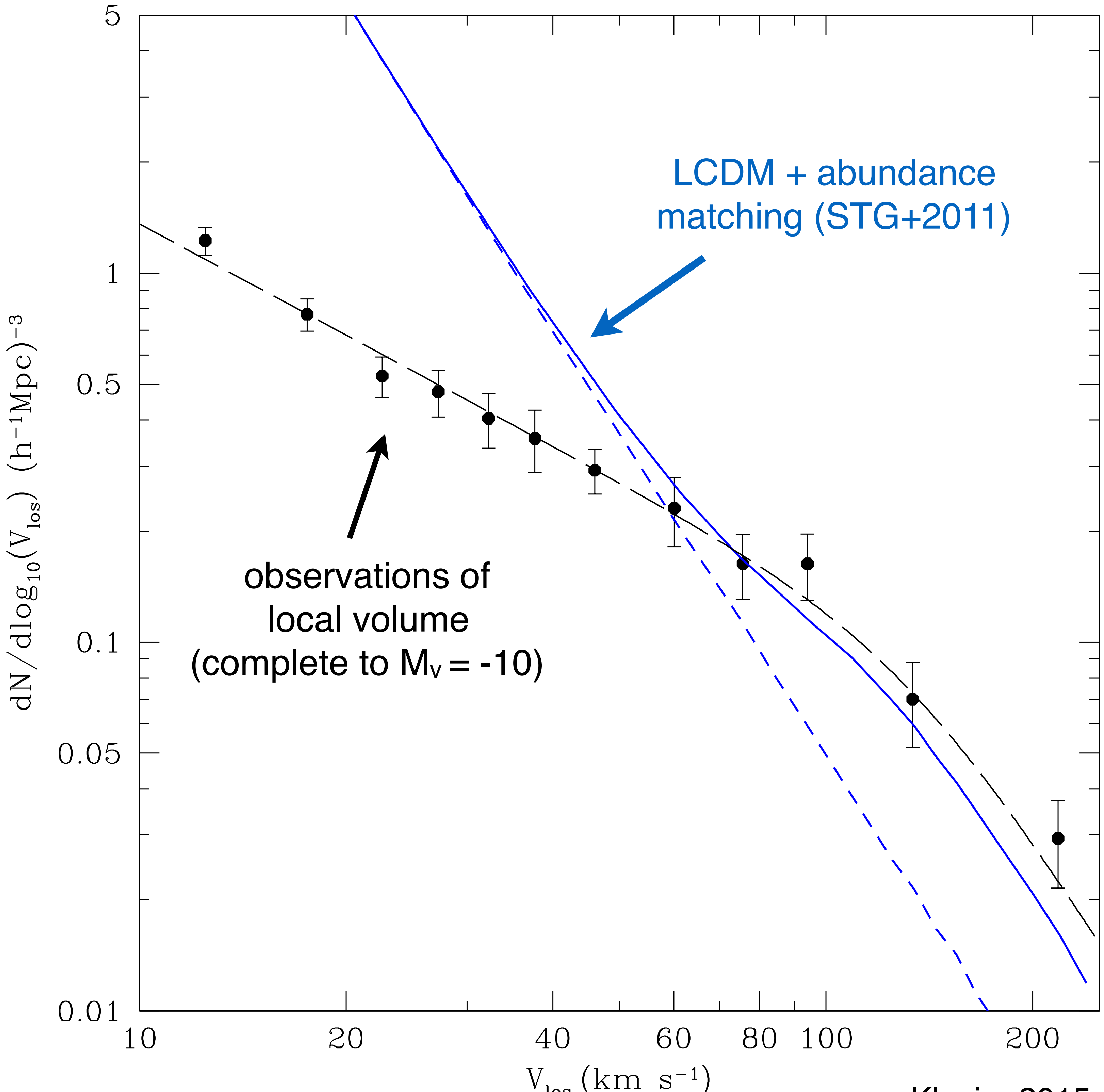
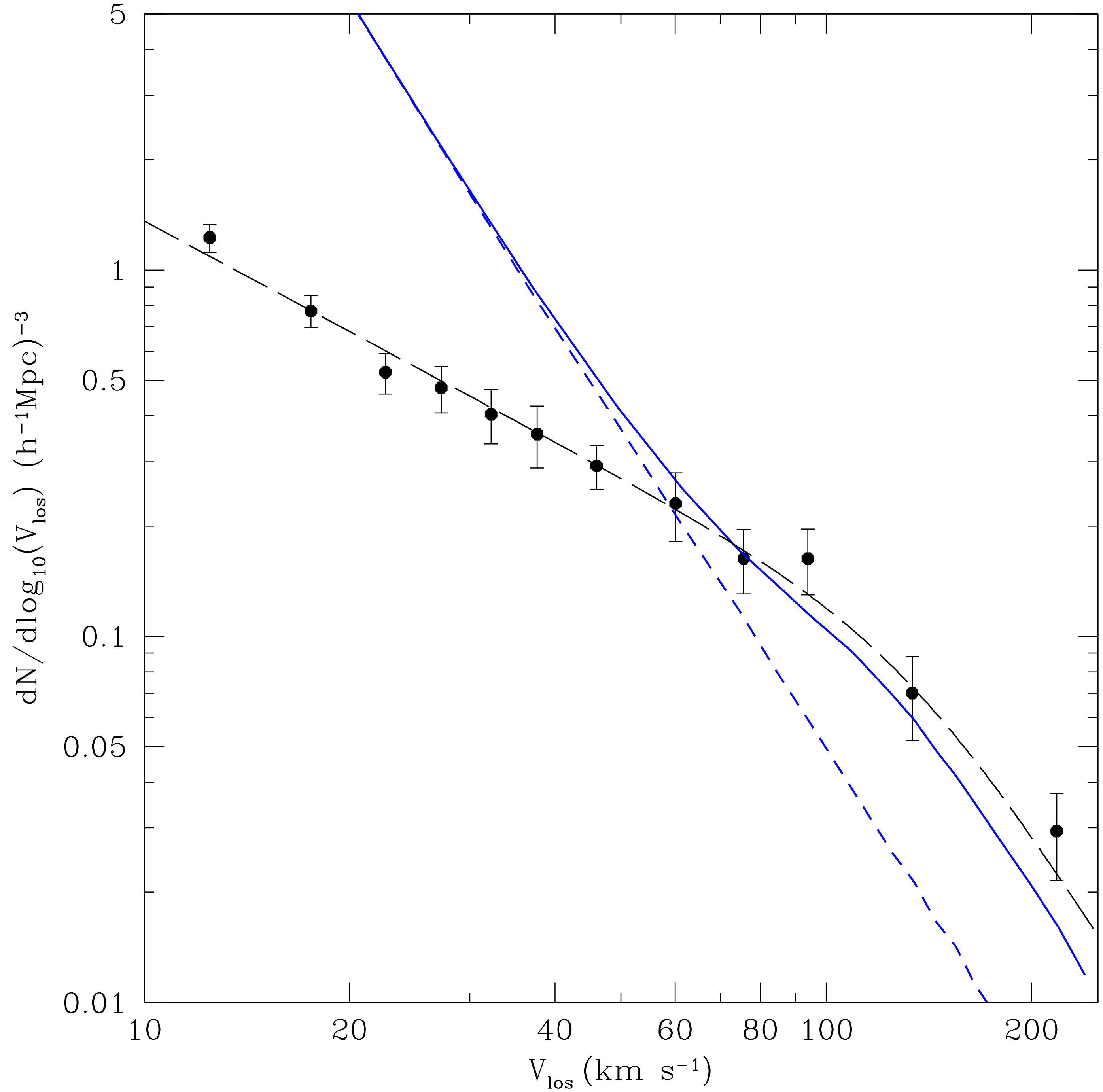
The abundance of the faintest galaxies



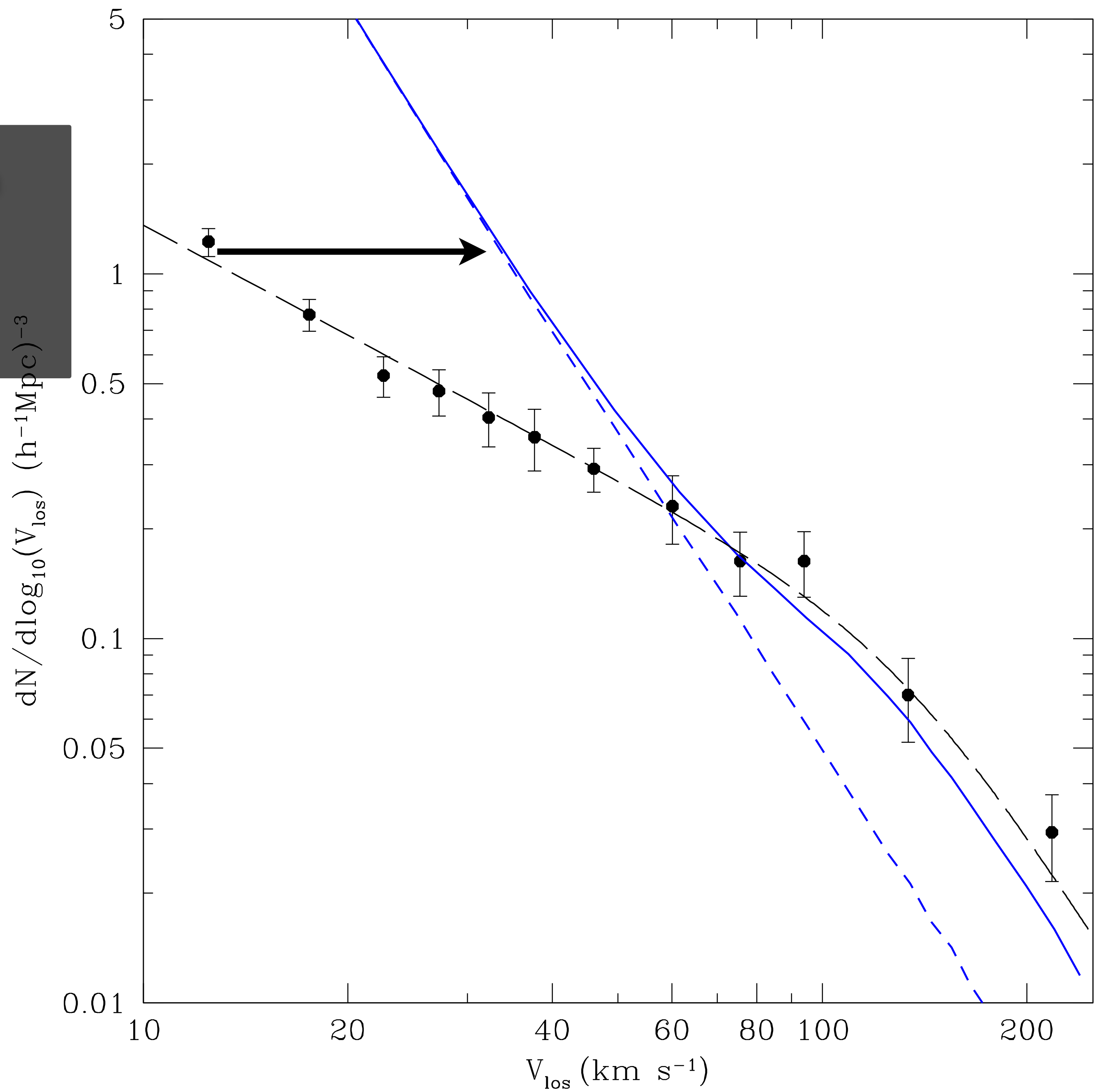
Klypin+2015, also Papastergis+2011, STG+2011, Zavala+2009

Solutions within CDM?



Solutions within CDM?

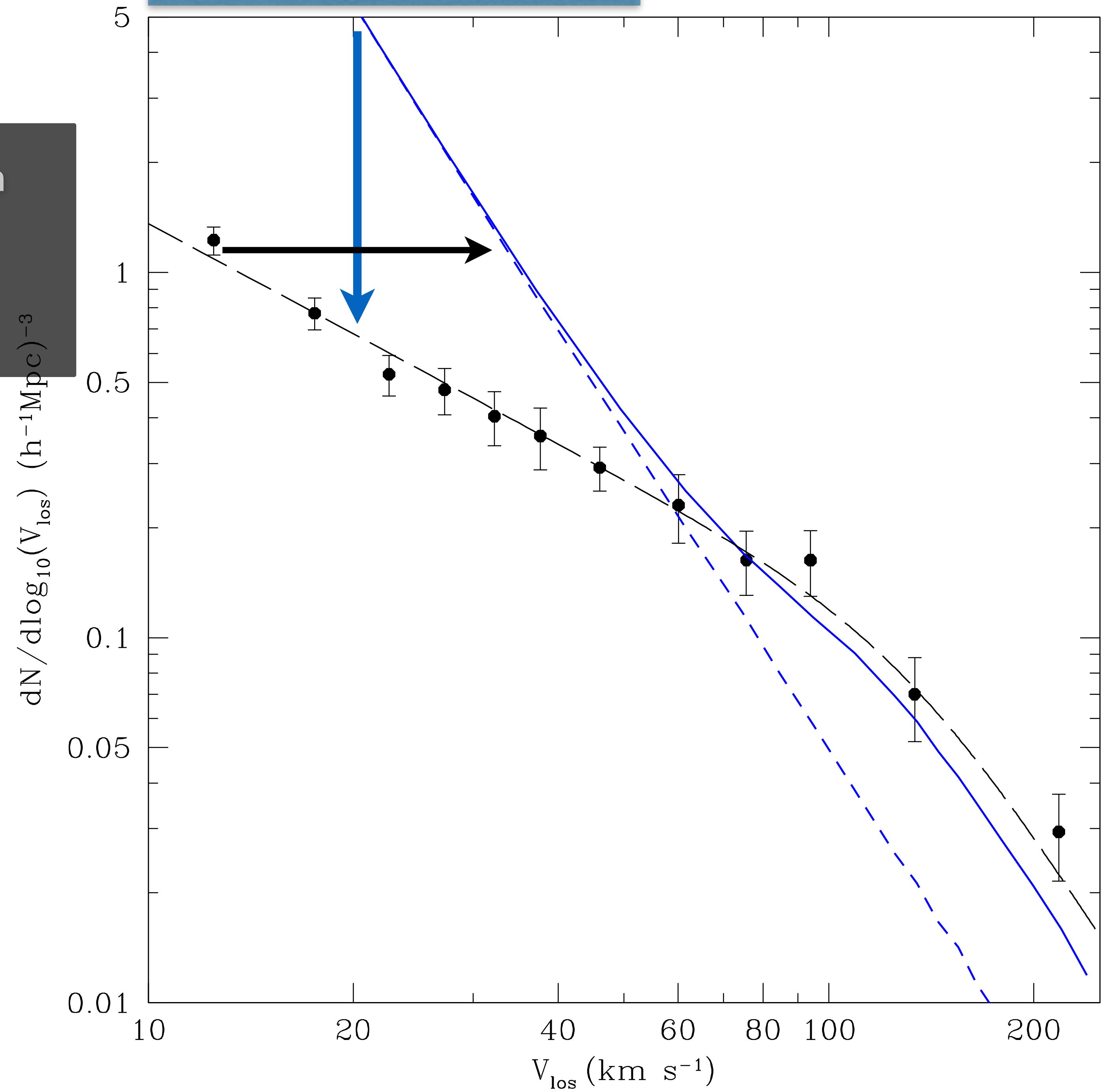
place faint dwarfs in massive halos (observational systematics)



Solutions within CDM?

reduce the abundance of halos that host galaxies (baryon physics)

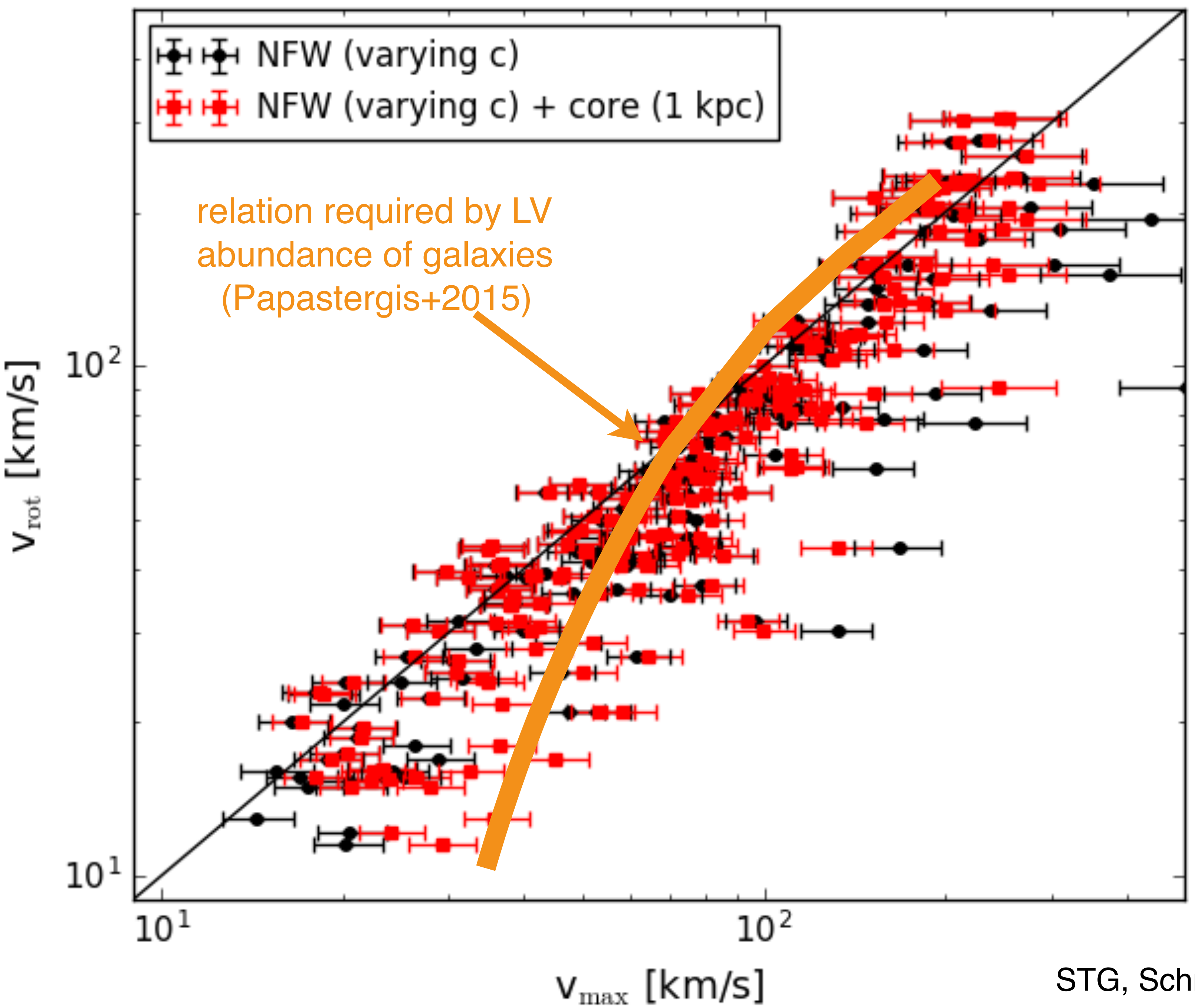
place faint dwarfs in massive halos (observational systematics)



Solution 1:

Faint dwarfs are hosted by very massive DM halos

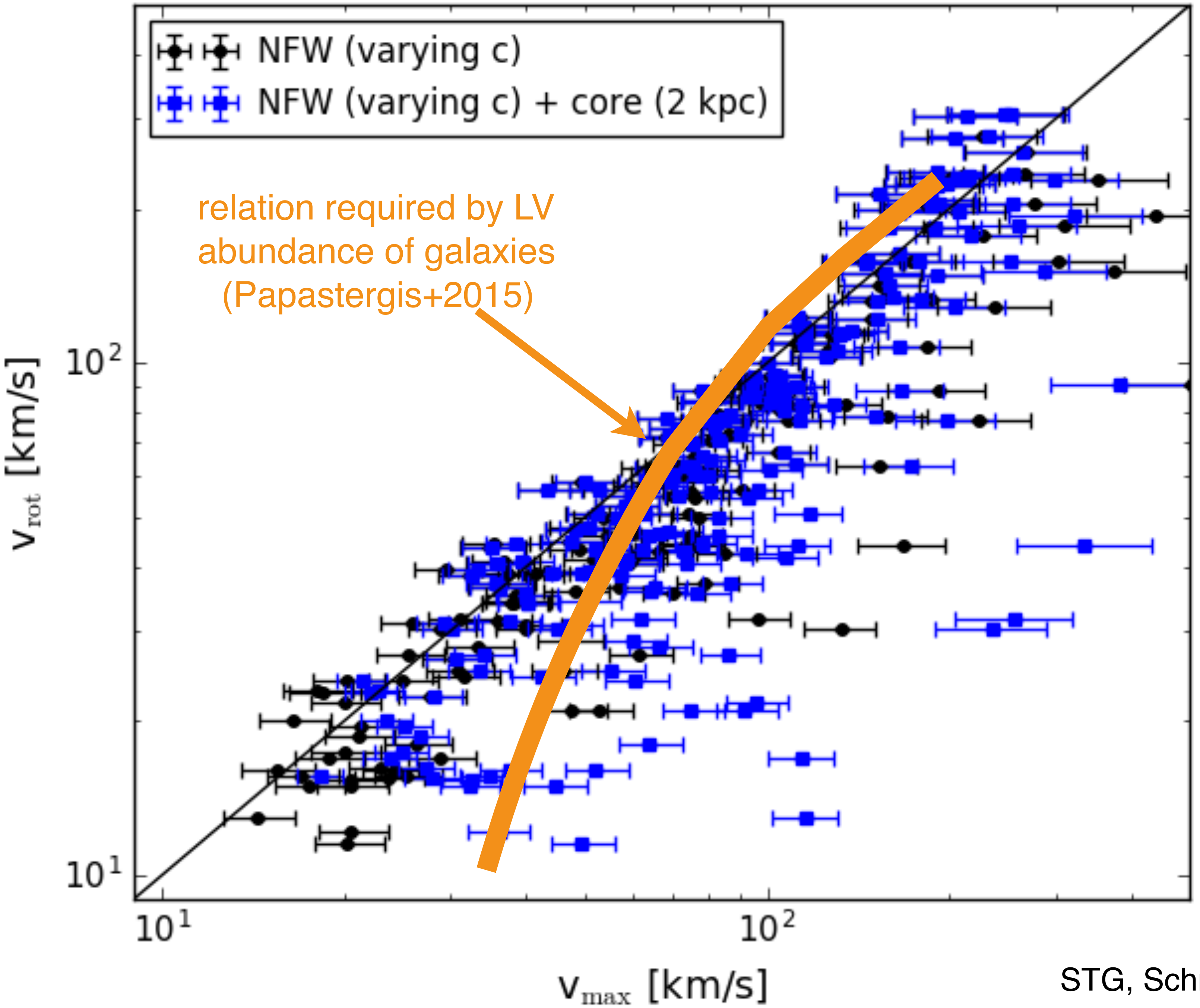
Solution 1: Faint dwarfs are hosted by massive DM halos



STG, Schneider & Papastergis (in prep.)

not all rotation observations allow for a "DM core" solution to the abundance problem

Solution 1: Faint dwarfs are hosted by massive DM halos



STG, Schneider & Papastergis (in prep.)

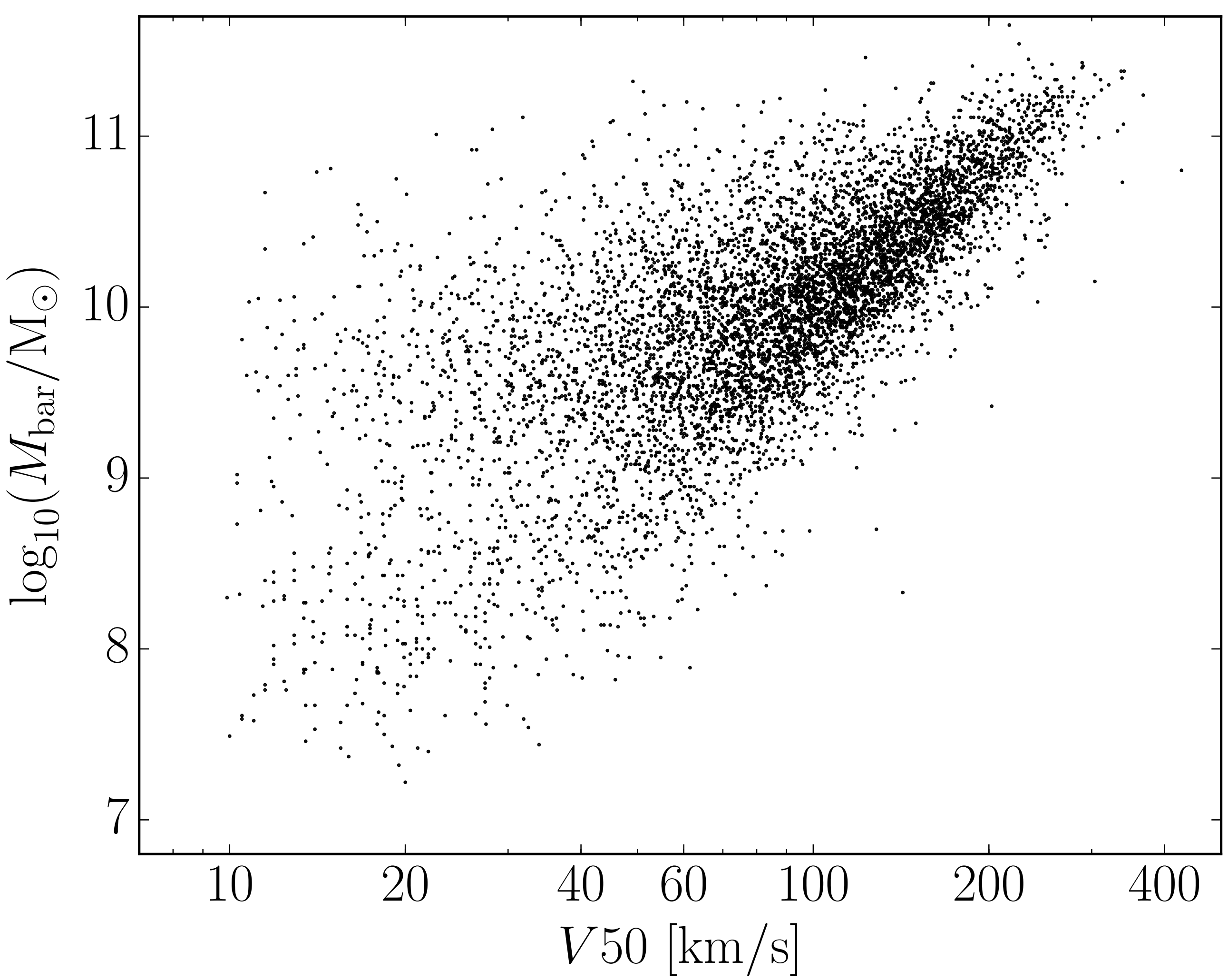
not all rotation observations allow for a “DM core” solution to the abundance problem

Is galaxy rotation a good probe of the maximum circular velocity of the DM halo?

Solution 1: rotation velocity underestimated in unresolved kinematic data?

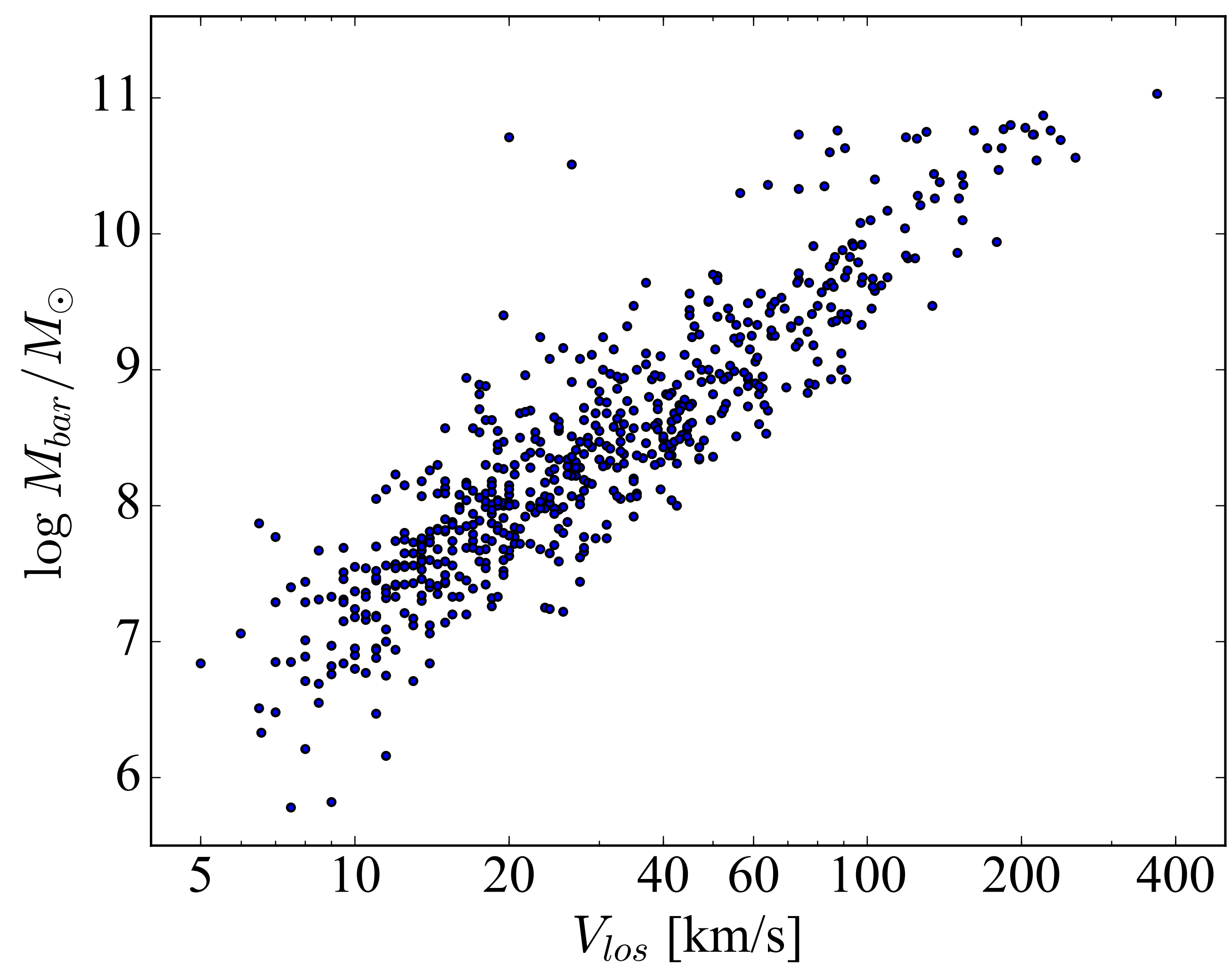
The ALFALFA blind HI survey

~10000 galaxies (brightness limited)

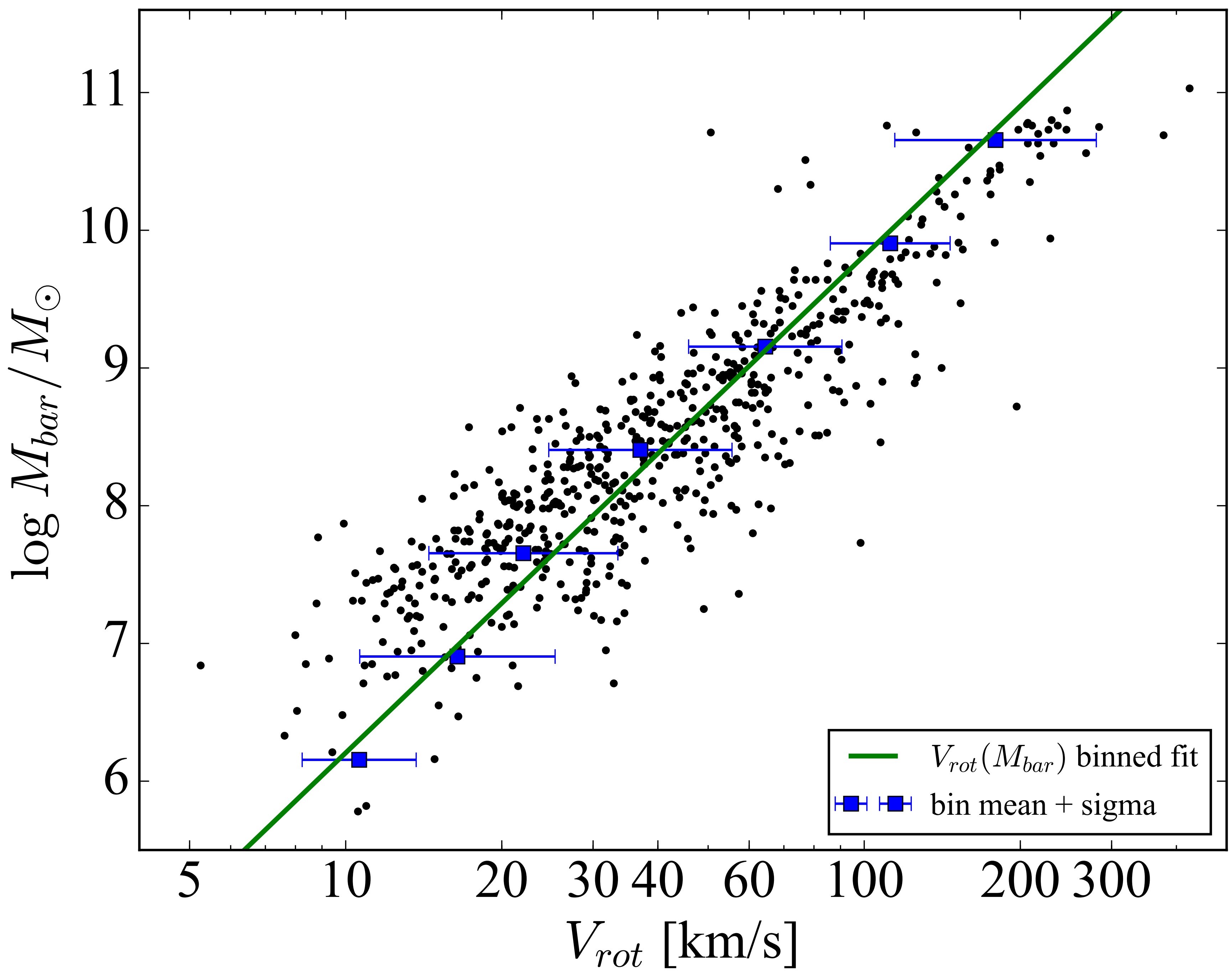


The Local Volume catalog

~900 galaxies (volume limited)

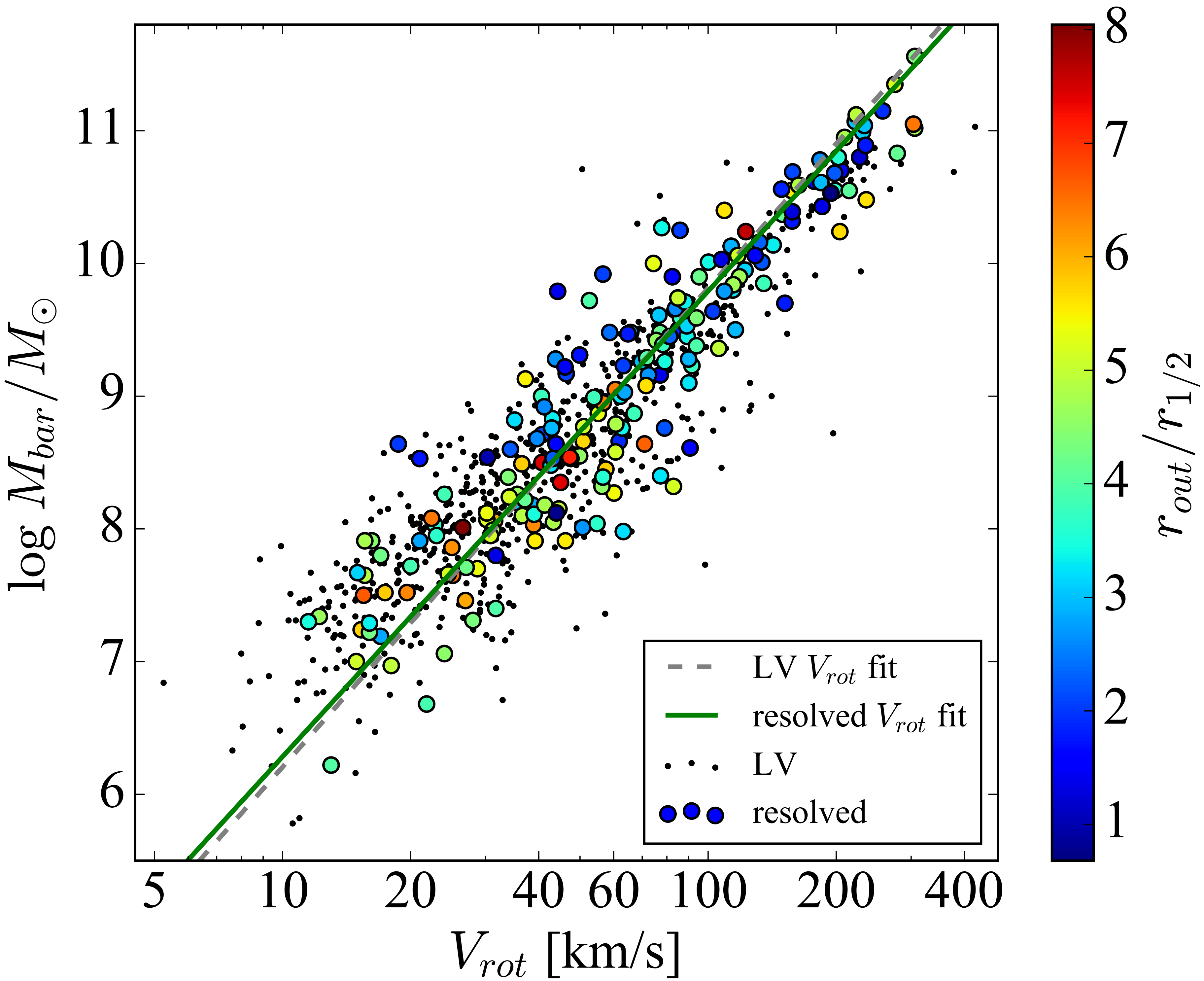


Solution 1: rotation velocity underestimated in unresolved kinematic data?



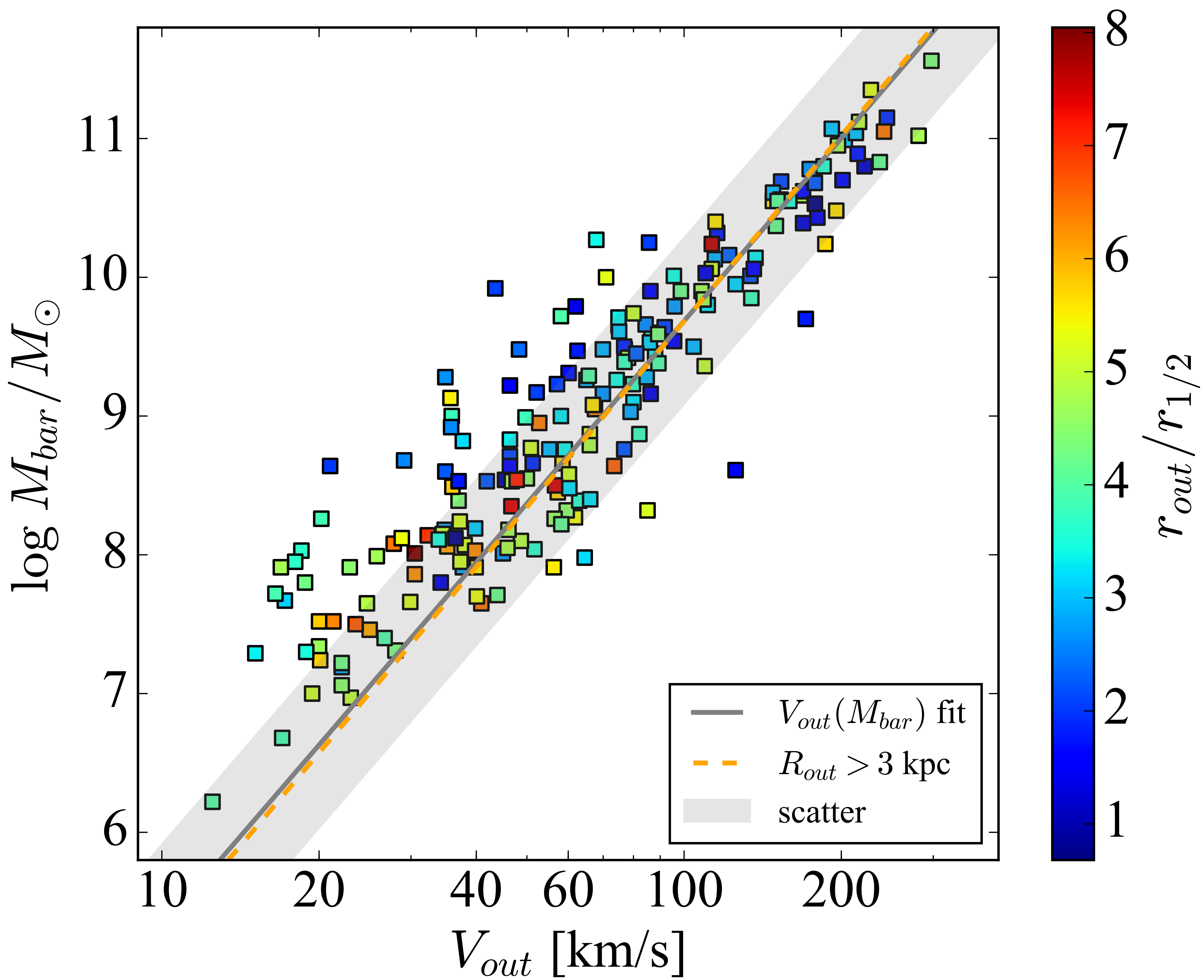
STG, Schneider & Papastergis (in prep.)

Solution 1: unresolved vs. resolved kinematic HI data



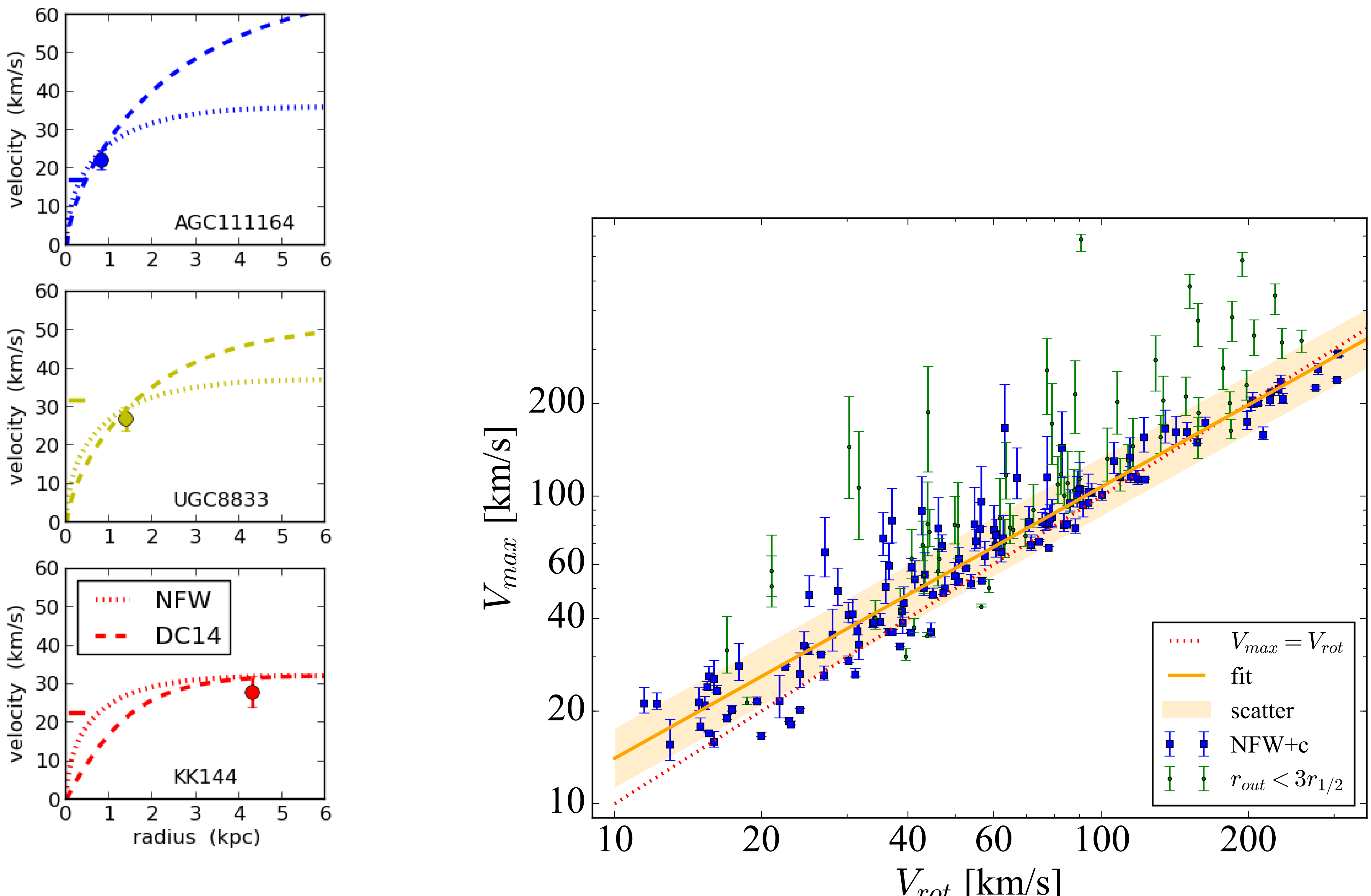
STG, Schneider & Papastergis (in prep.)

Solution 1: connecting profile widths to rotation curves



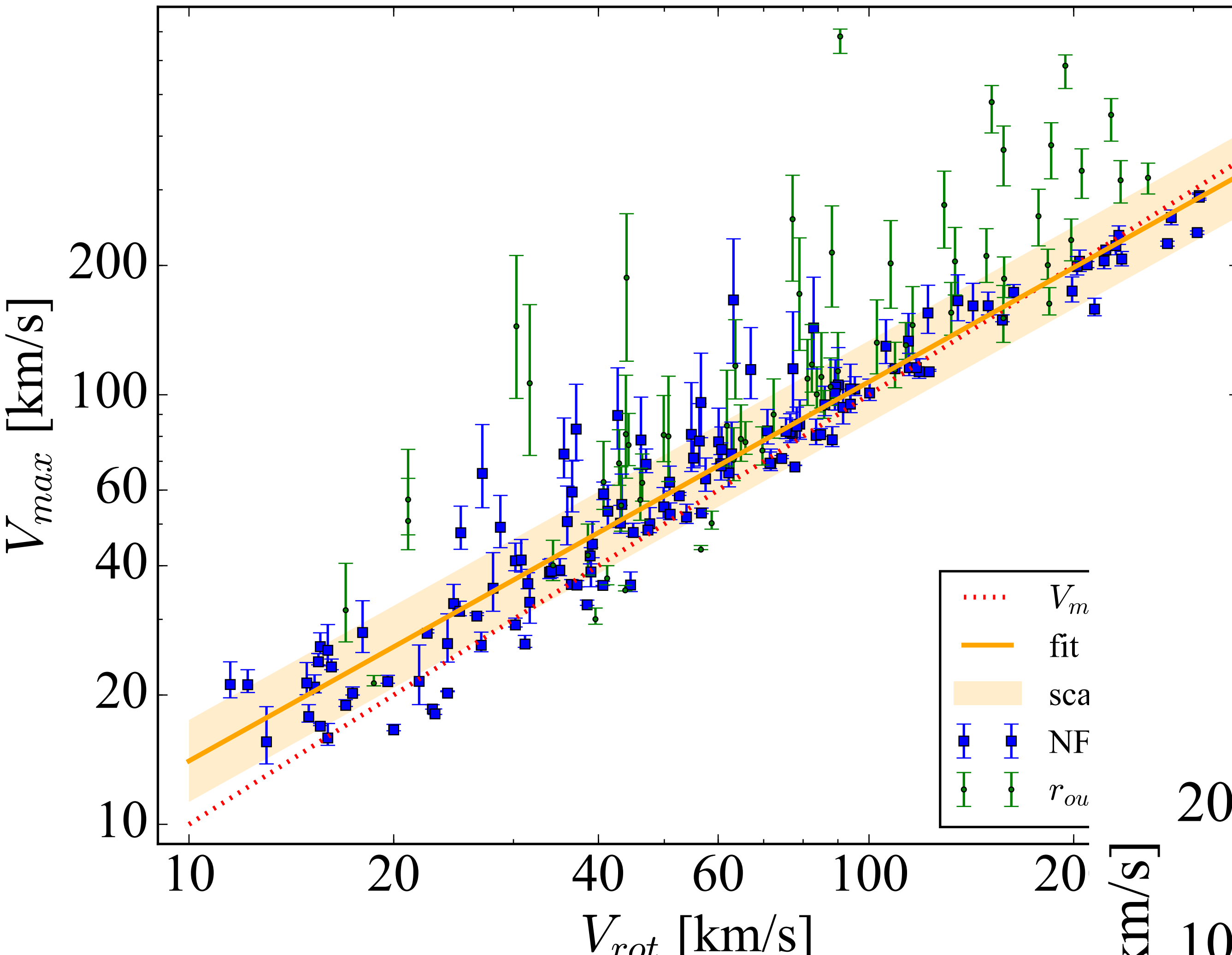
STG, Schneider & Papastergis (in prep.)

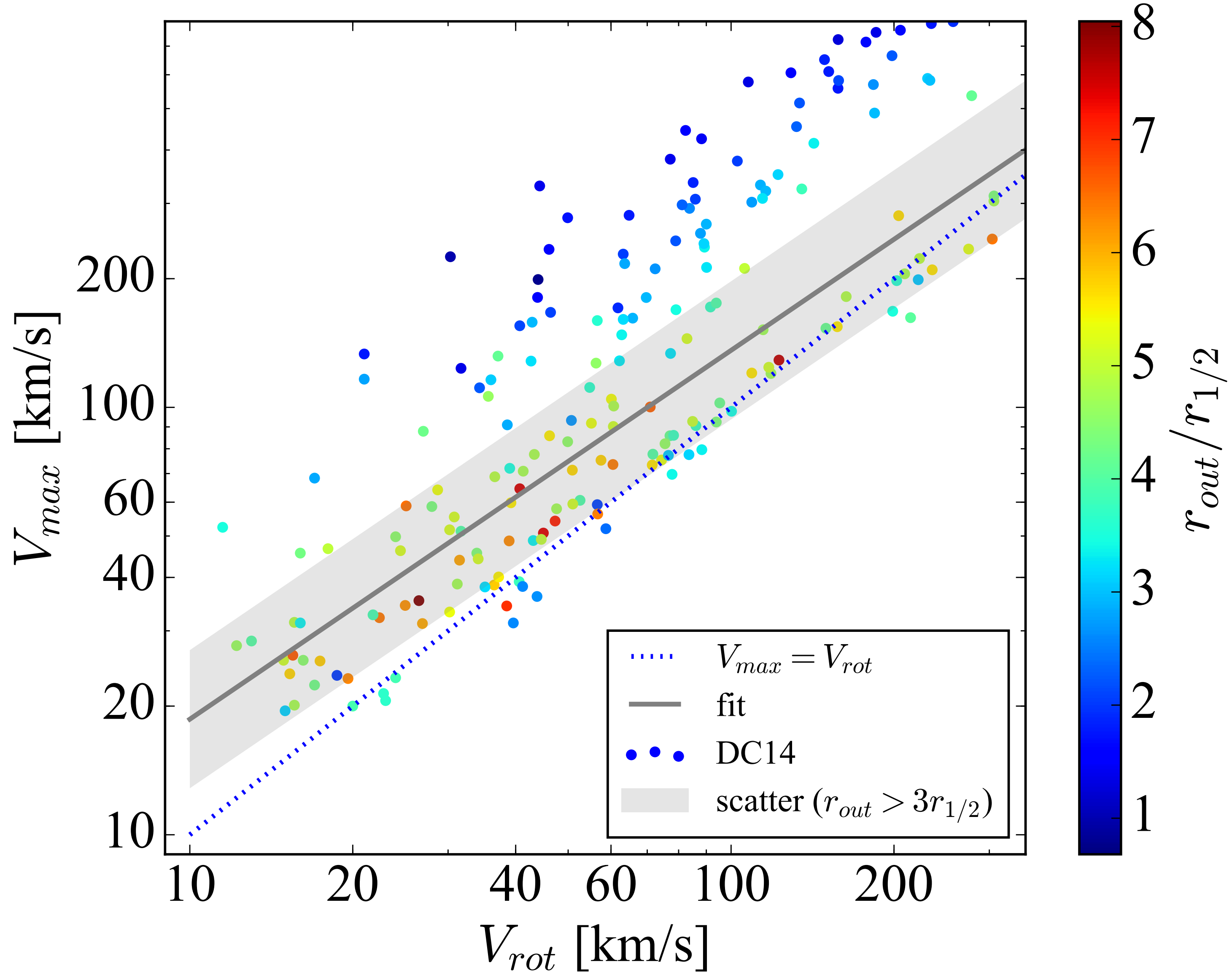
Solution 1: Connecting rotation curves with halo V_{max}



Papastergis & Shankar (2016)

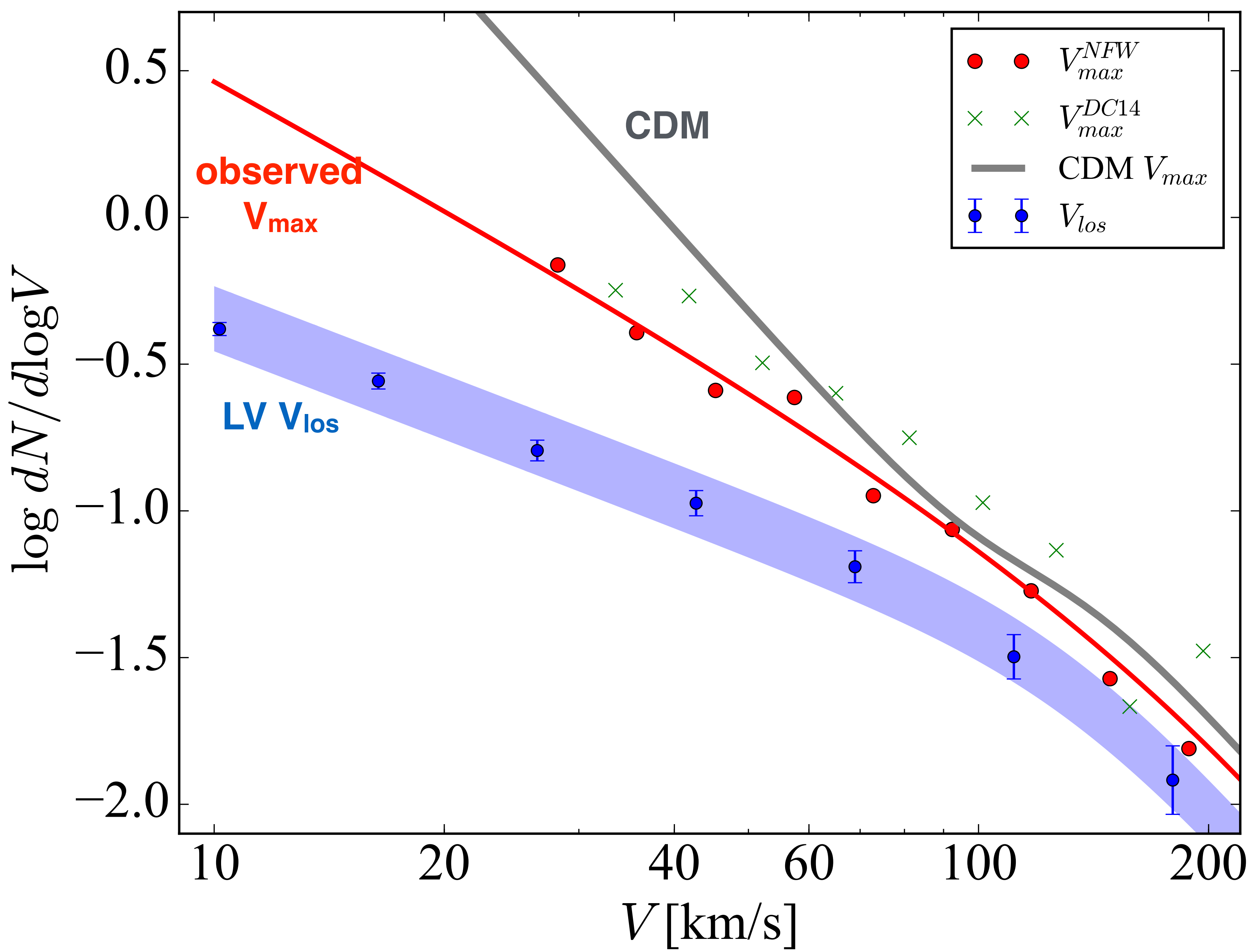
Solution 1: Including a large correction due to baryon-induced DM cores





STG, Schneider & Papastergis (in prep.)

Solution 1: The V_{max} Velocity Function of galaxies vs. CDM haloes



STG, Schneider & Papastergis (in prep.)

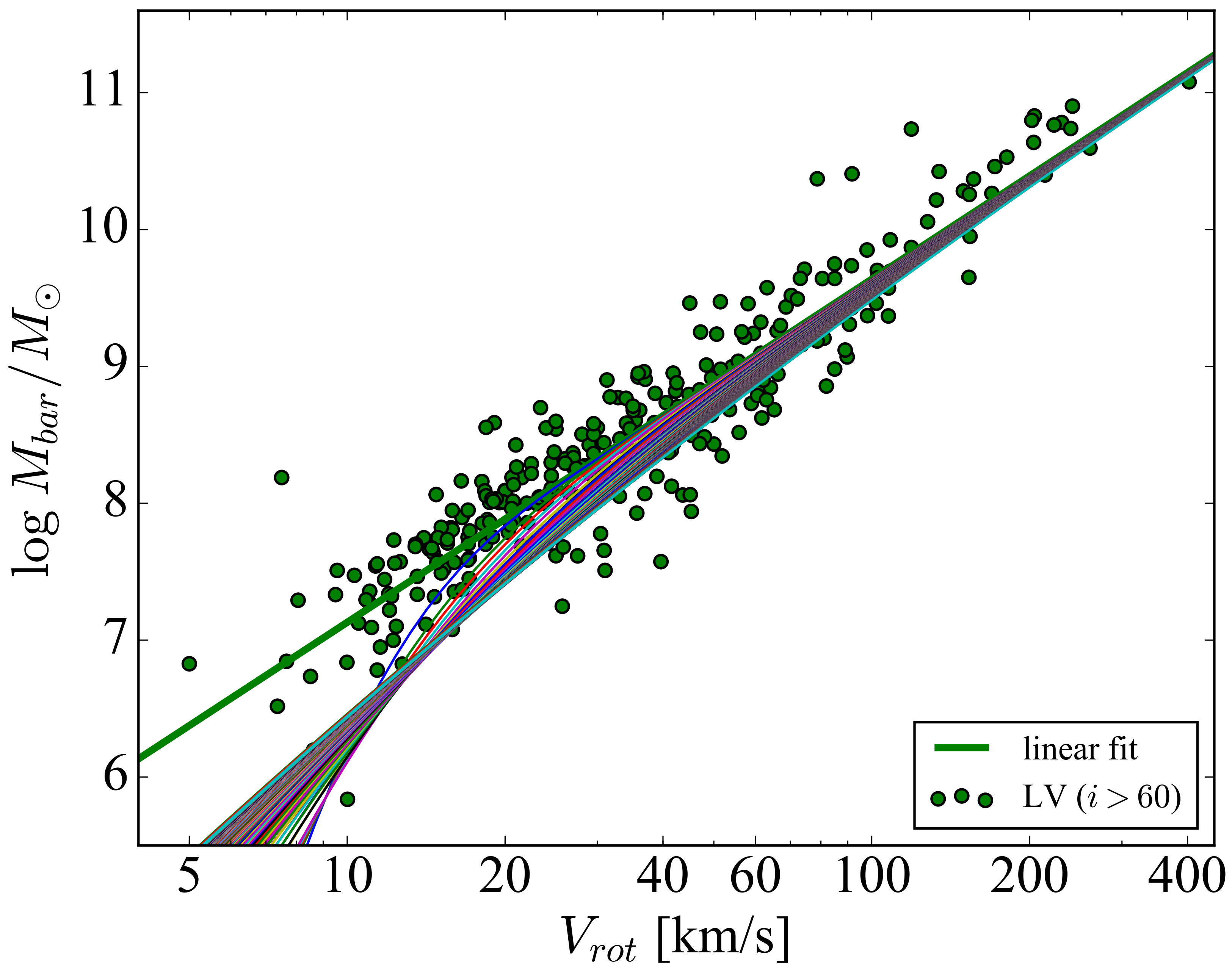
Solution 2:

Due to baryon physics, very few dwarf DM halos host galaxies

Solution 2: photo-evaporation due to ionising background

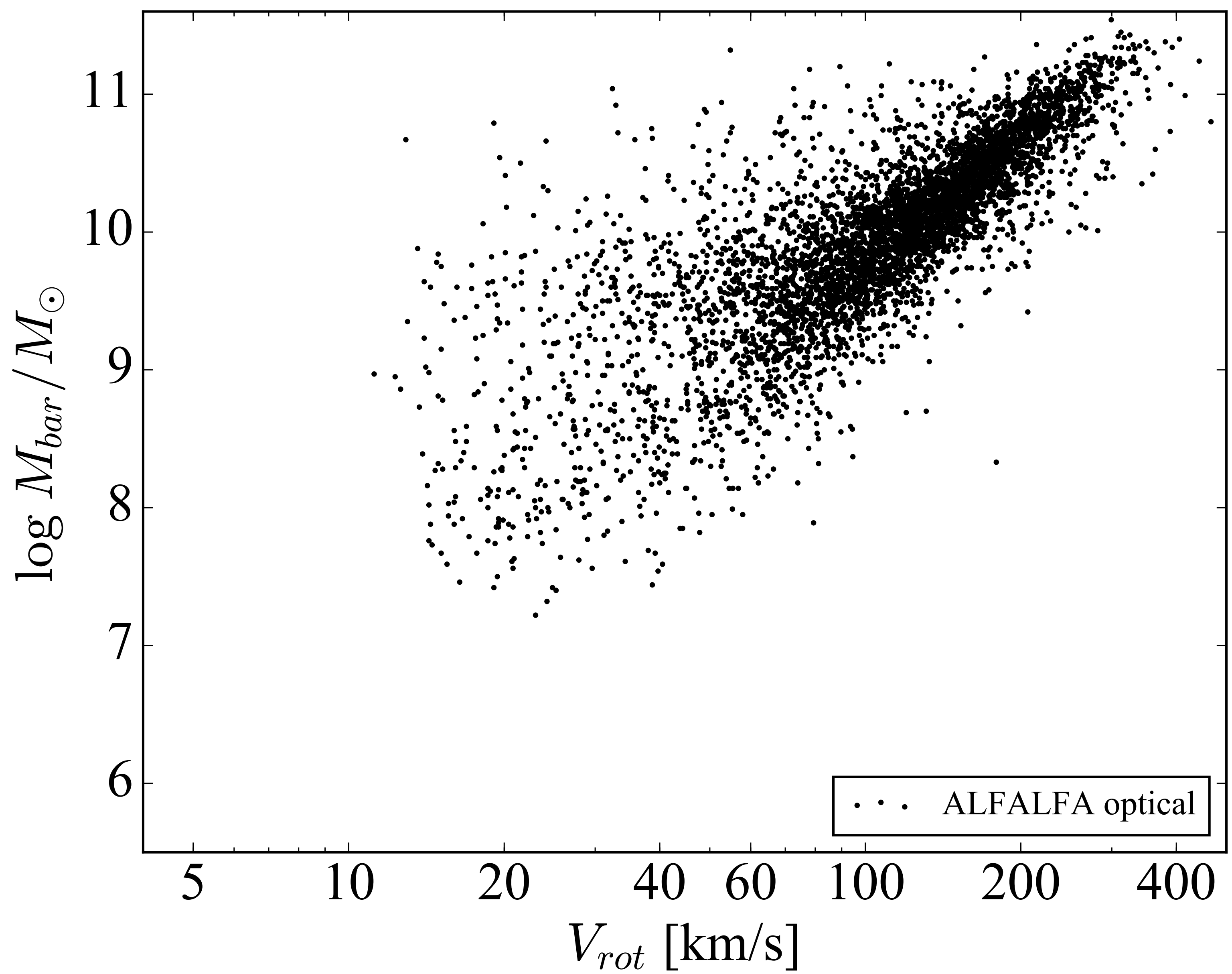
reionisation of the Universe at z=10 heats IGM to 10^4 K

this should prevent the formation of galaxies in DM halos with shallow potential wells



Baryonic Effects: photo-evaporation due to ionising background

ALFALFA optical



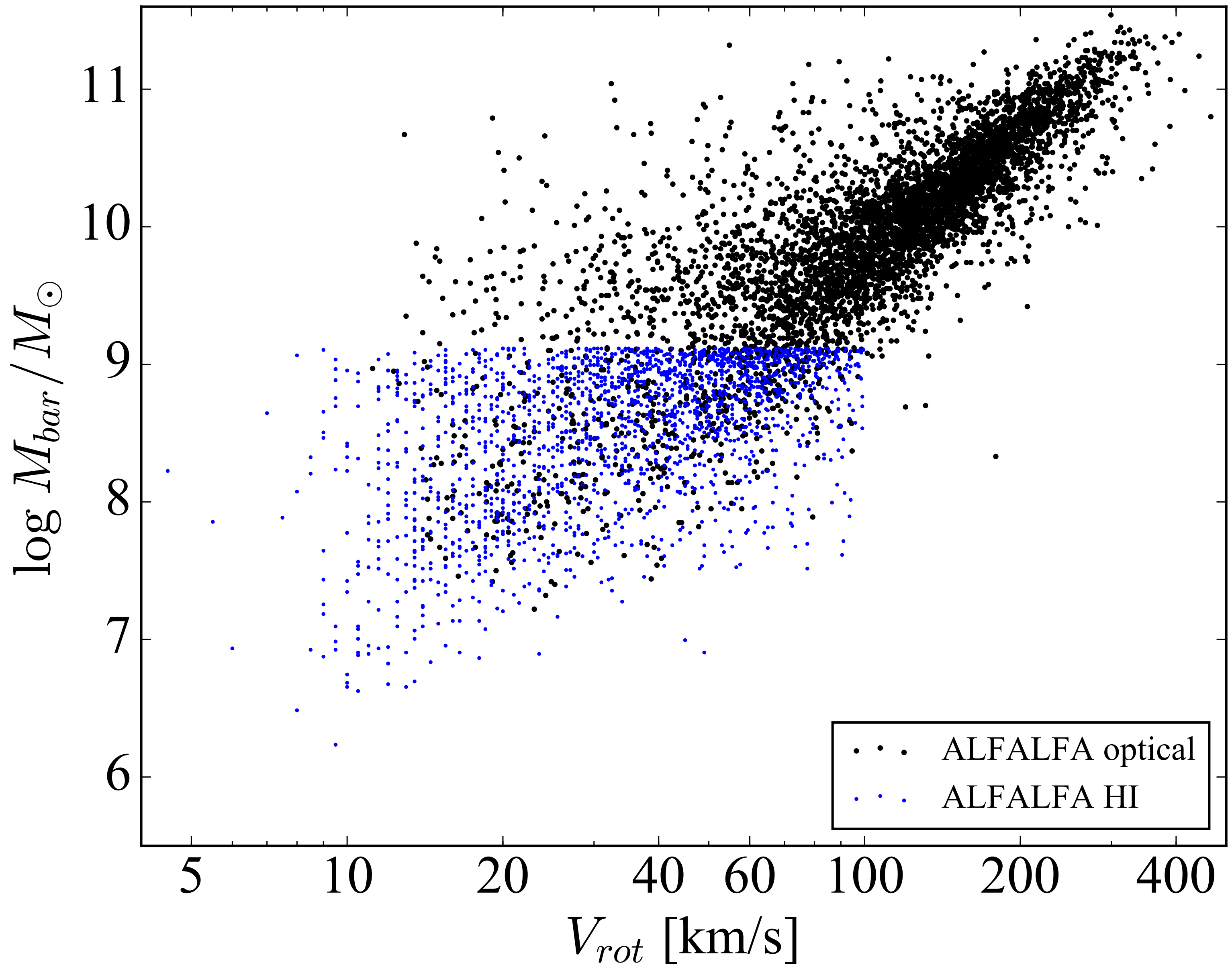
STG, Schneider & Papastergis (in prep.)

Baryonic Effects: photo-evaporation due to ionising background

ALFALFA optical

+

ALFALFA HI



STG, Schneider & Papastergis (in prep.)

Baryonic Effects: photo-evaporation due to ionising background

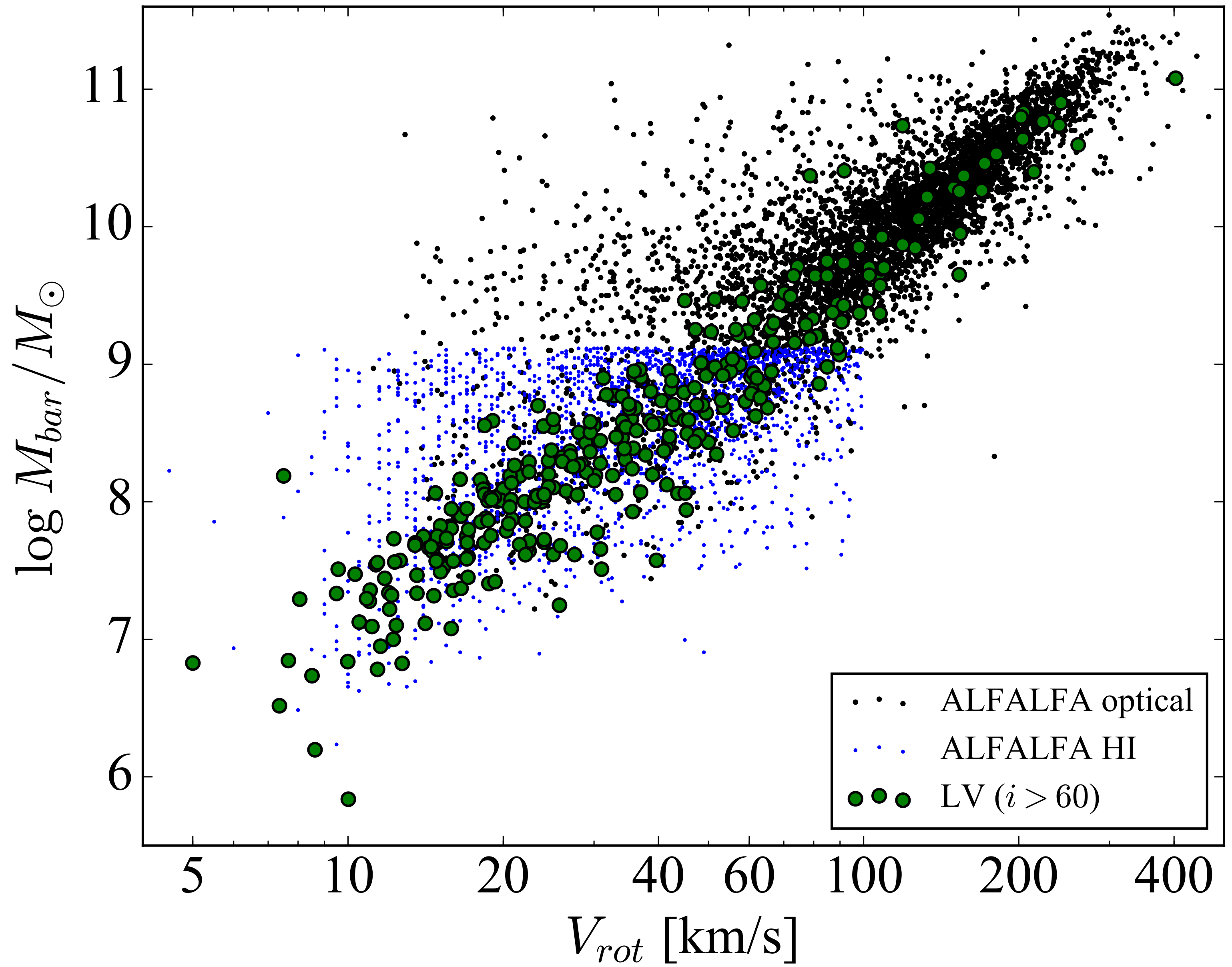
ALFALFA optical

+

ALFALFA HI

+

Local Volume optical



STG, Schneider & Papastergis (in prep.)

Baryonic Effects: photo-evaporation due to ionising background

ALFALFA optical

+

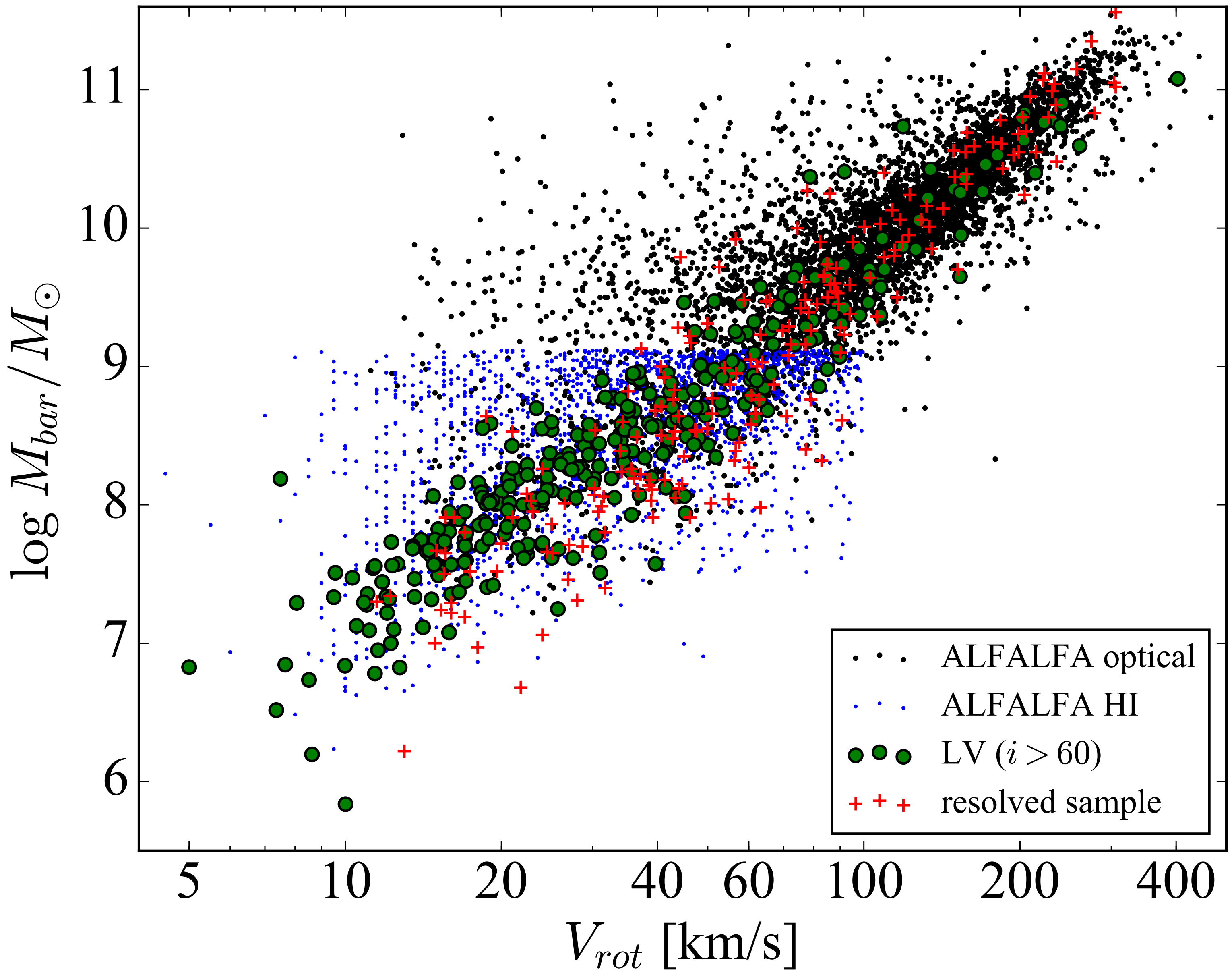
ALFALFA HI

+

Local Volume optical

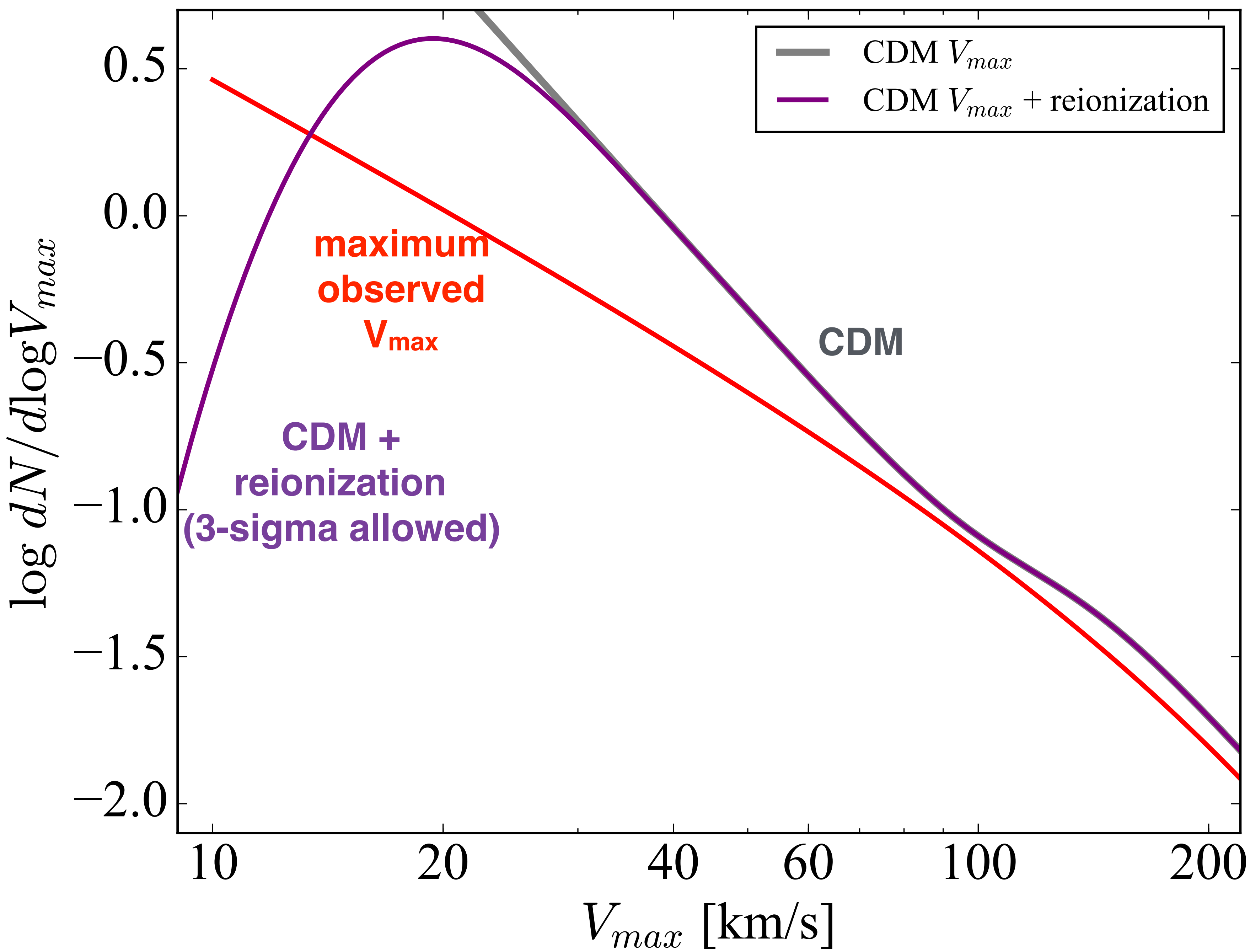
+

resolved rotation curves



STG, Schneider & Papastergis (in prep.)

Solution 1: Recovering the halo V_{max} from HI profile widths



STG, Schneider & Papastergis (in prep.)

The missing dwarfs: a challenge for CDM?

1. YES, but disagreement is smaller than in raw survey data
2. Systematic underestimation of rotation velocity due to extent of HI profile
3. Rotation curves allow for correction from galaxy rotation to halo V_{max}
4. Discrepancy may be reconciled using baryonic feedback
5. BTF and satellite luminosity function rule out most solutions

thank you

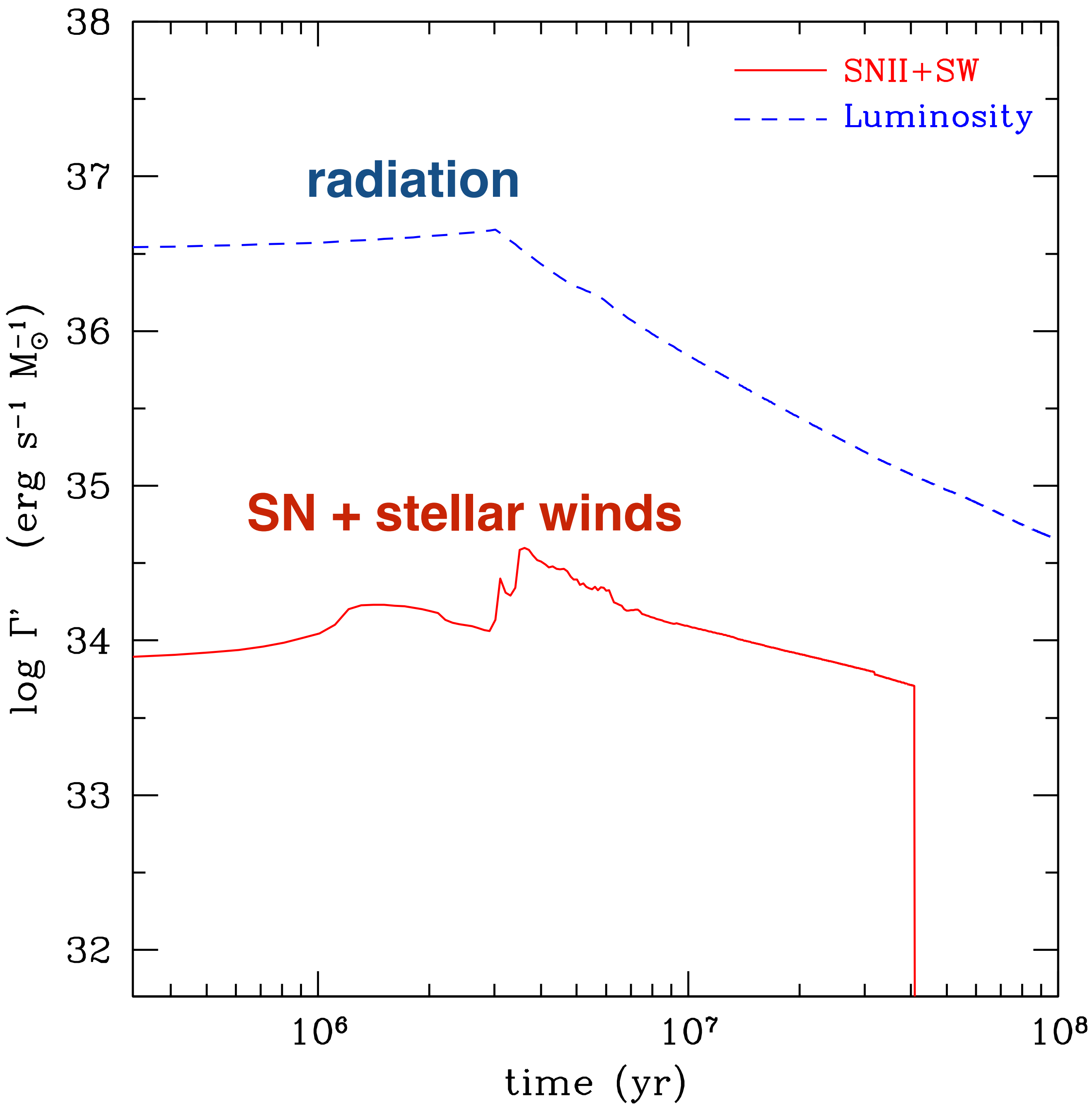
Solution 2: Due to baryon physics, very few DM halos host galaxies

simple predictions are difficult due to complex physics of baryons: need for numerical experiments

- suite of hydro cosmological simulations of MW-like haloes (Ceverino+ 2013, Trujillo-Gomez+ 2015).
- resolution ~17 pc, min. star particle mass ~600 M_{sun}
- dwarf galaxies "resolved" down to $M_{vir} \sim 10^7 M_{sun}$, $V_{max} \sim 7$ km/s (well below the reionization suppression scale)
- probe volumes ~ Mpc^3 around each large halo
- sample of > 2000 dwarf galaxies (field and satellites) for each run
- first statistical sample of high-resolution simulated dwarfs
- uncertainties in reionization & stellar feedback dominate

Uncertainties in stellar feedback modelling

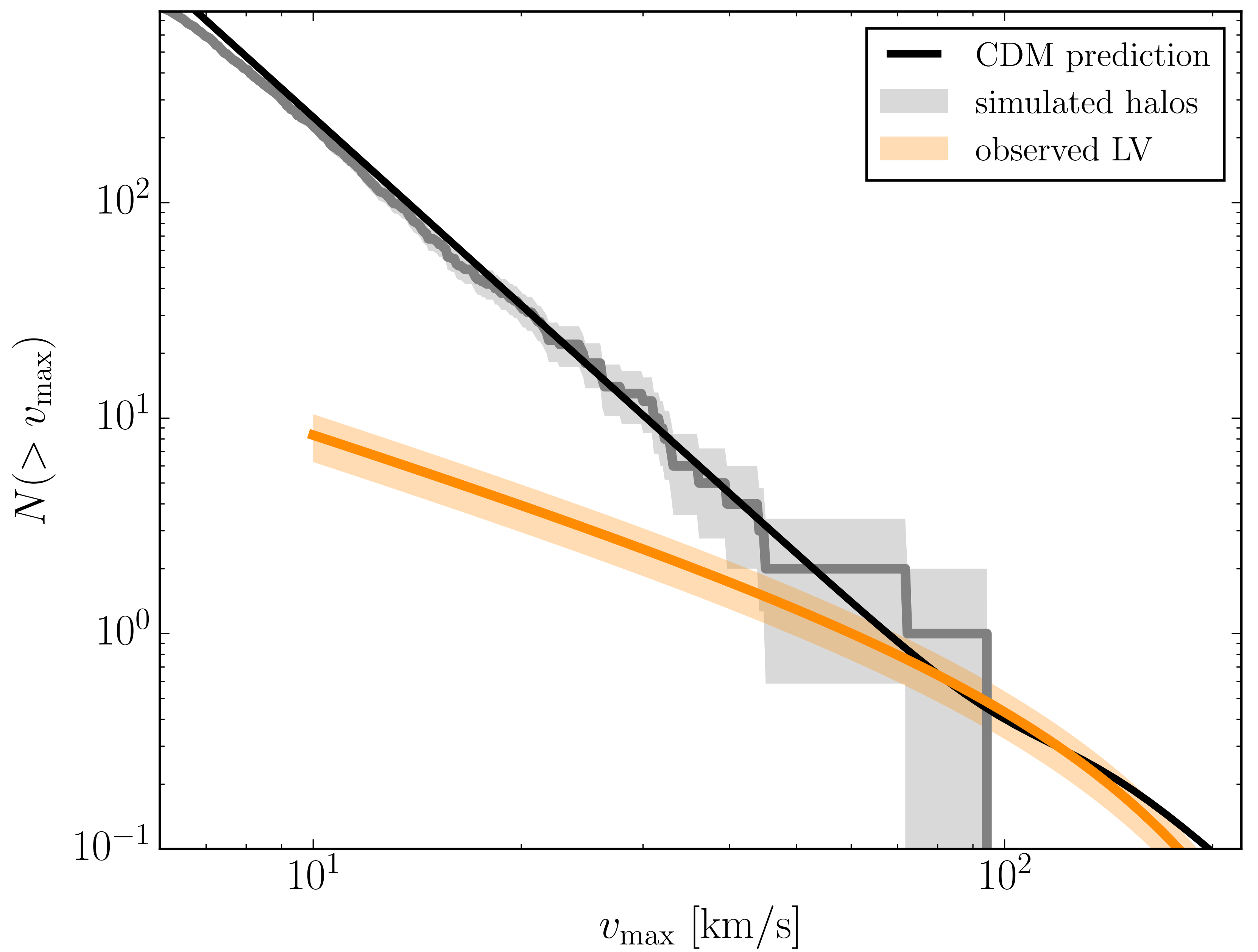
stellar energy and momentum output known but coupling to galactic scales highly uncertain



Strong stellar feedback is required to fit the observed star formation histories and halo gas properties of simulated galaxies

However, strong feedback *fails* to produce thin stellar discs in large galaxies (Agertz+2015)

The abundance of DM haloes in hydro simulations

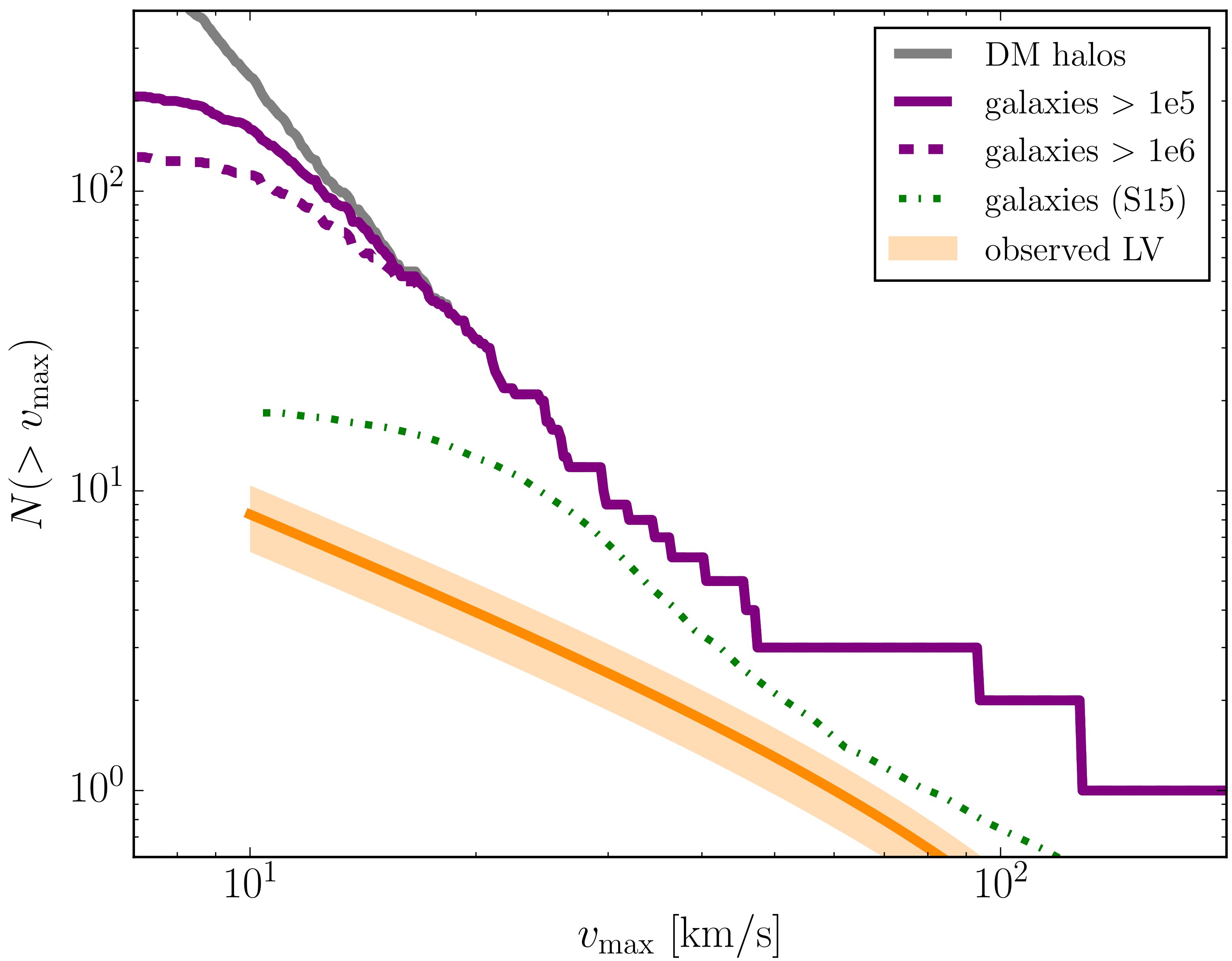


CDM prediction + HAM: STG+ 2011

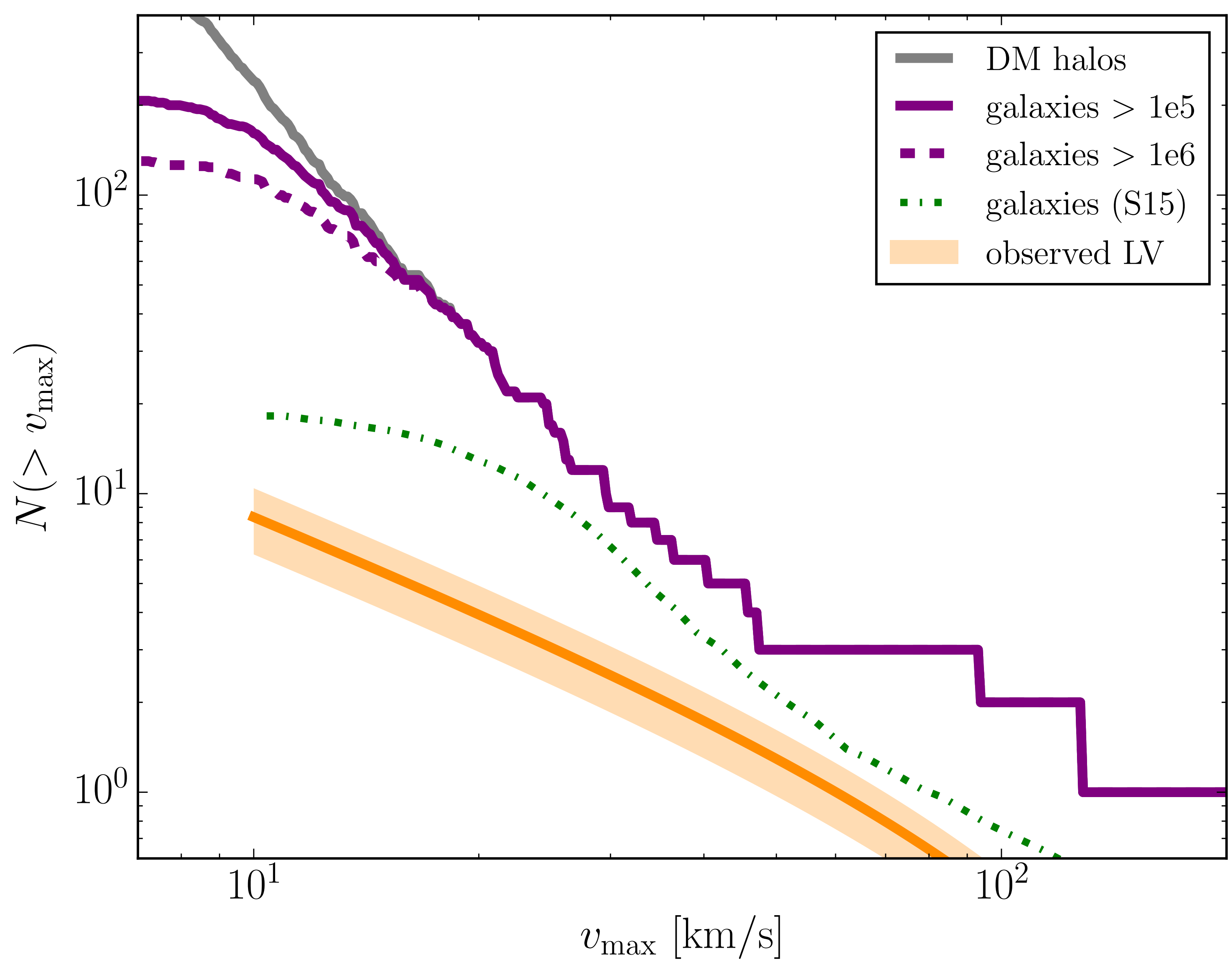
optical + ALFALFA surveys of Local Volume: Klypin+ 2015

The abundance of galaxies in hydro simulations

weak (SN) feedback + late reionization



The abundance of galaxies in hydro simulations



The abundance of galaxies in hydro simulations

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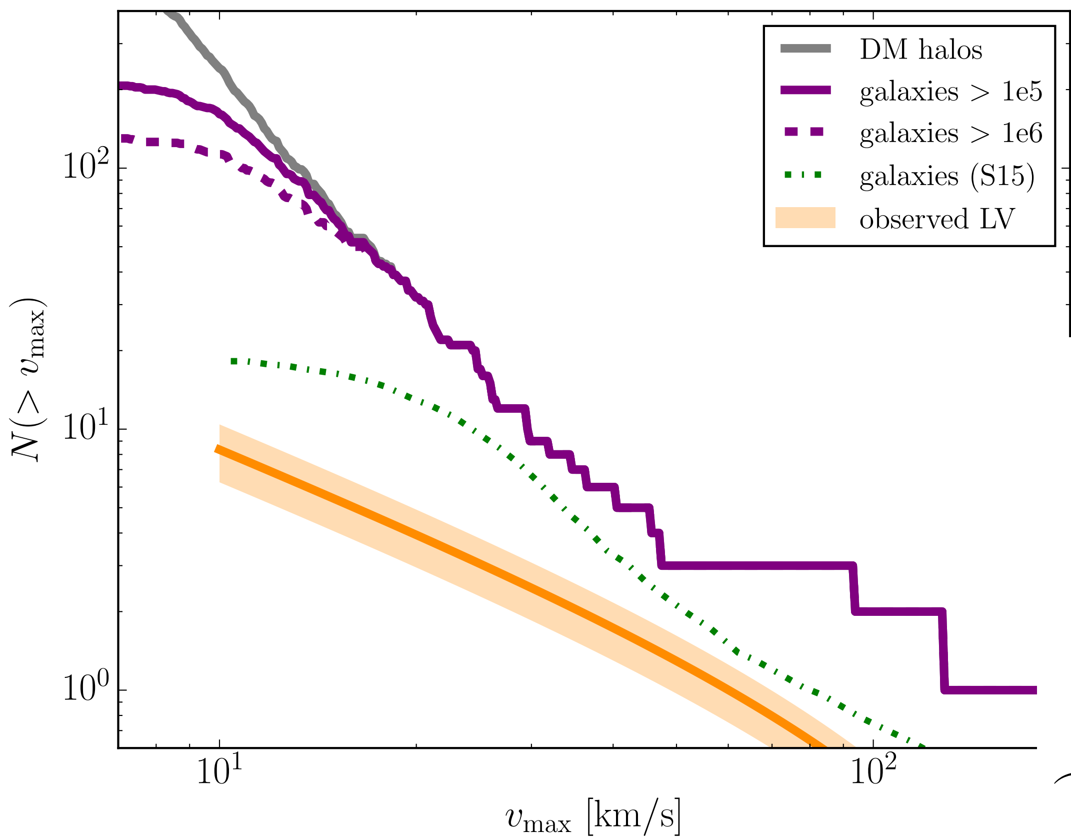
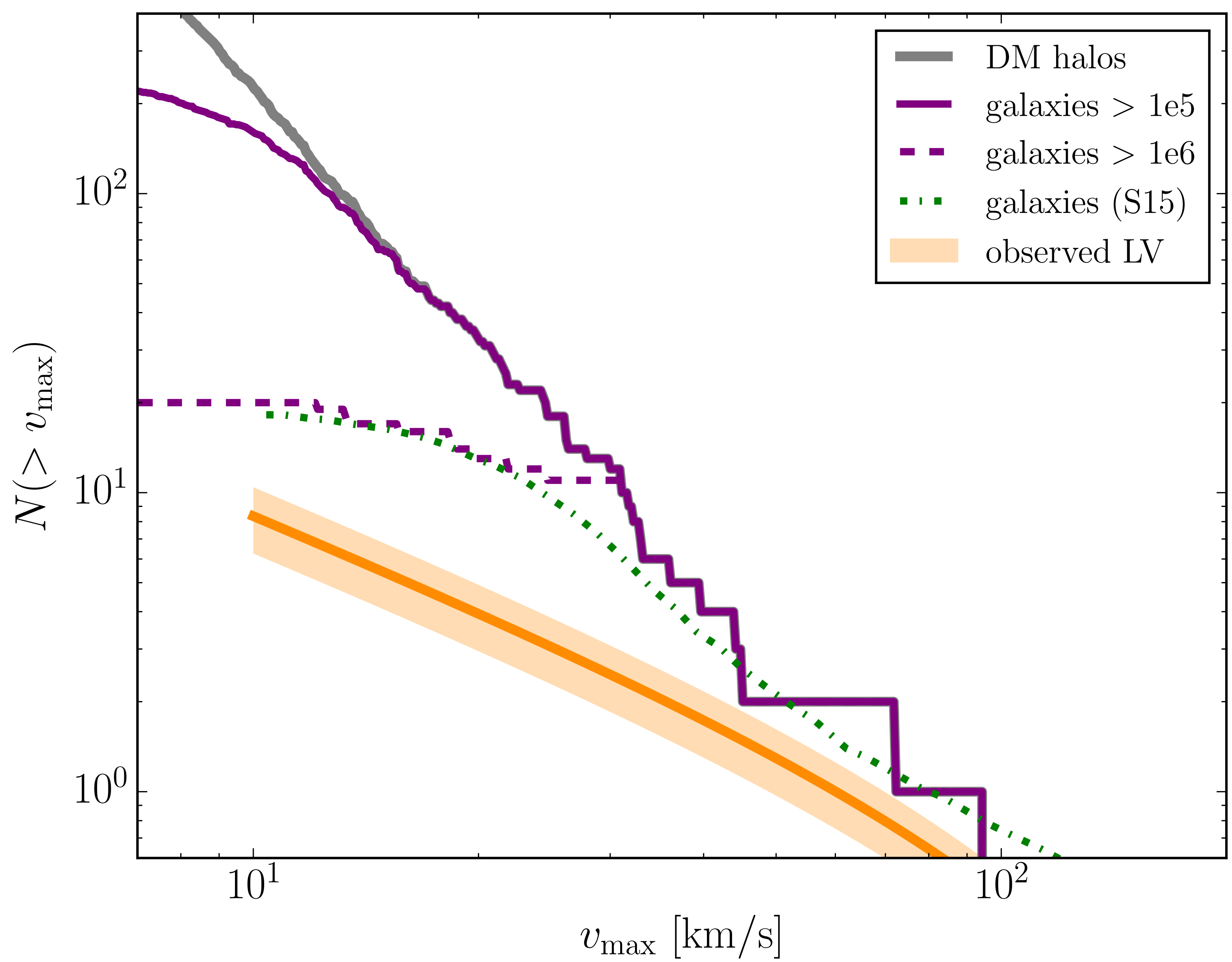
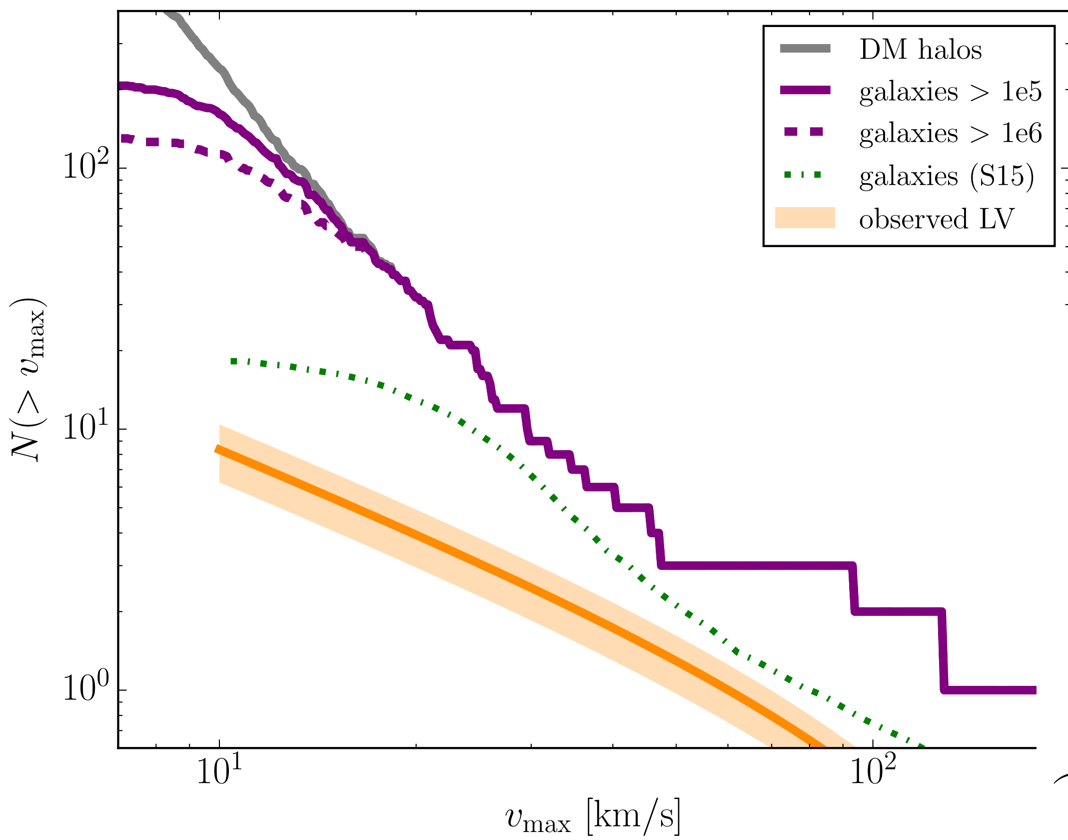


very strong (SN+radiation) feedback + late reionization



The abundance of galaxies in hydro simulations



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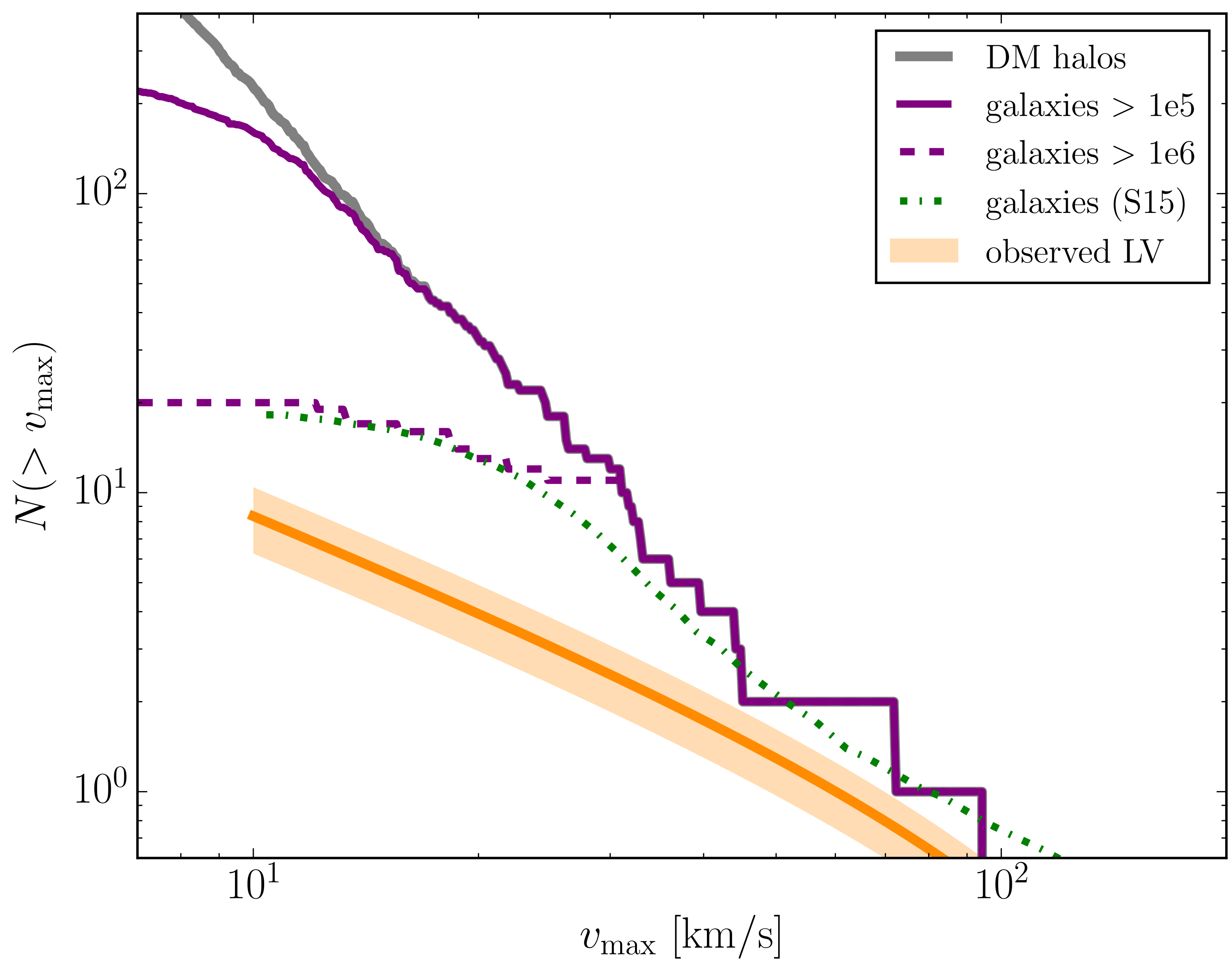

The abundance of galaxies in hydro simulations

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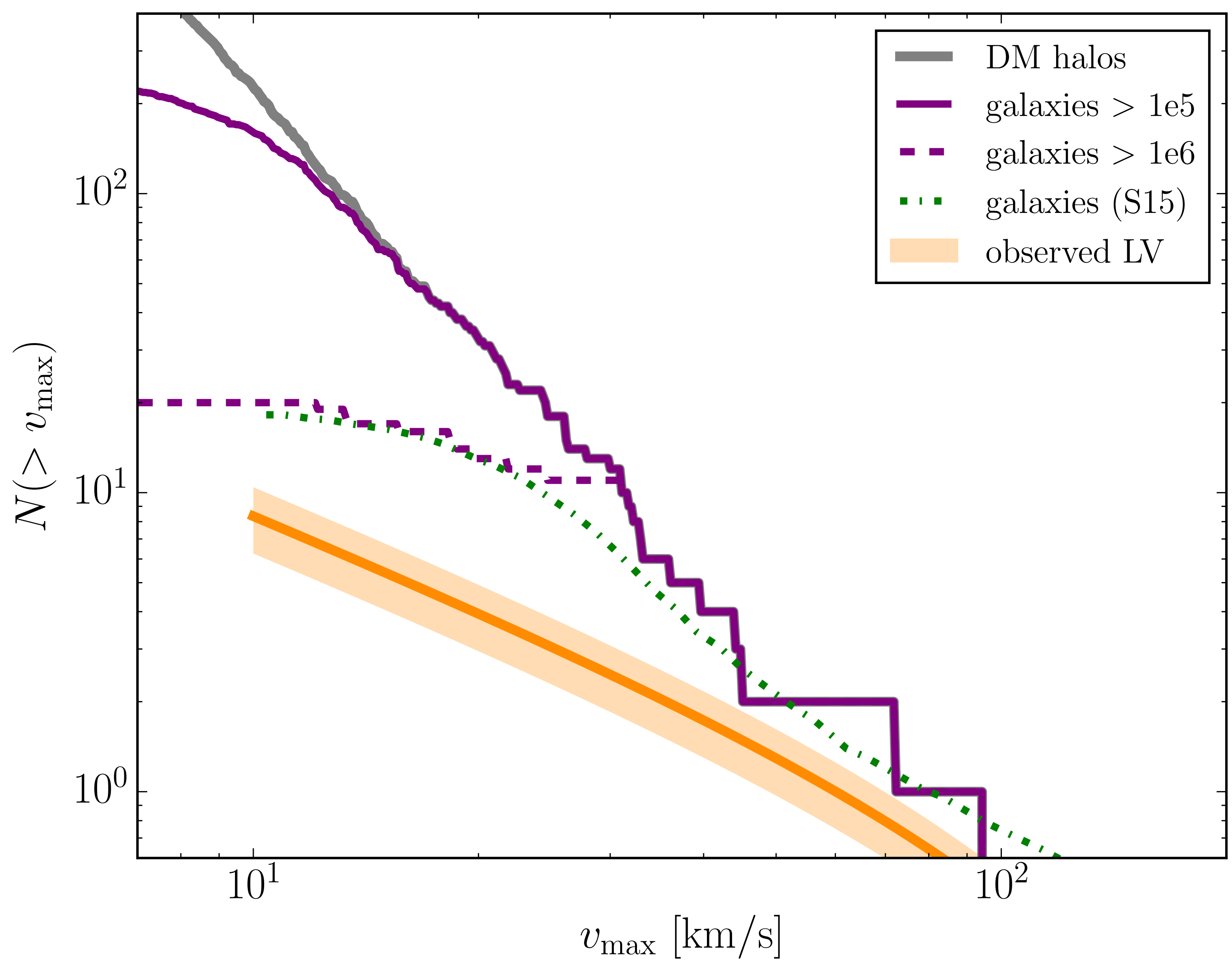

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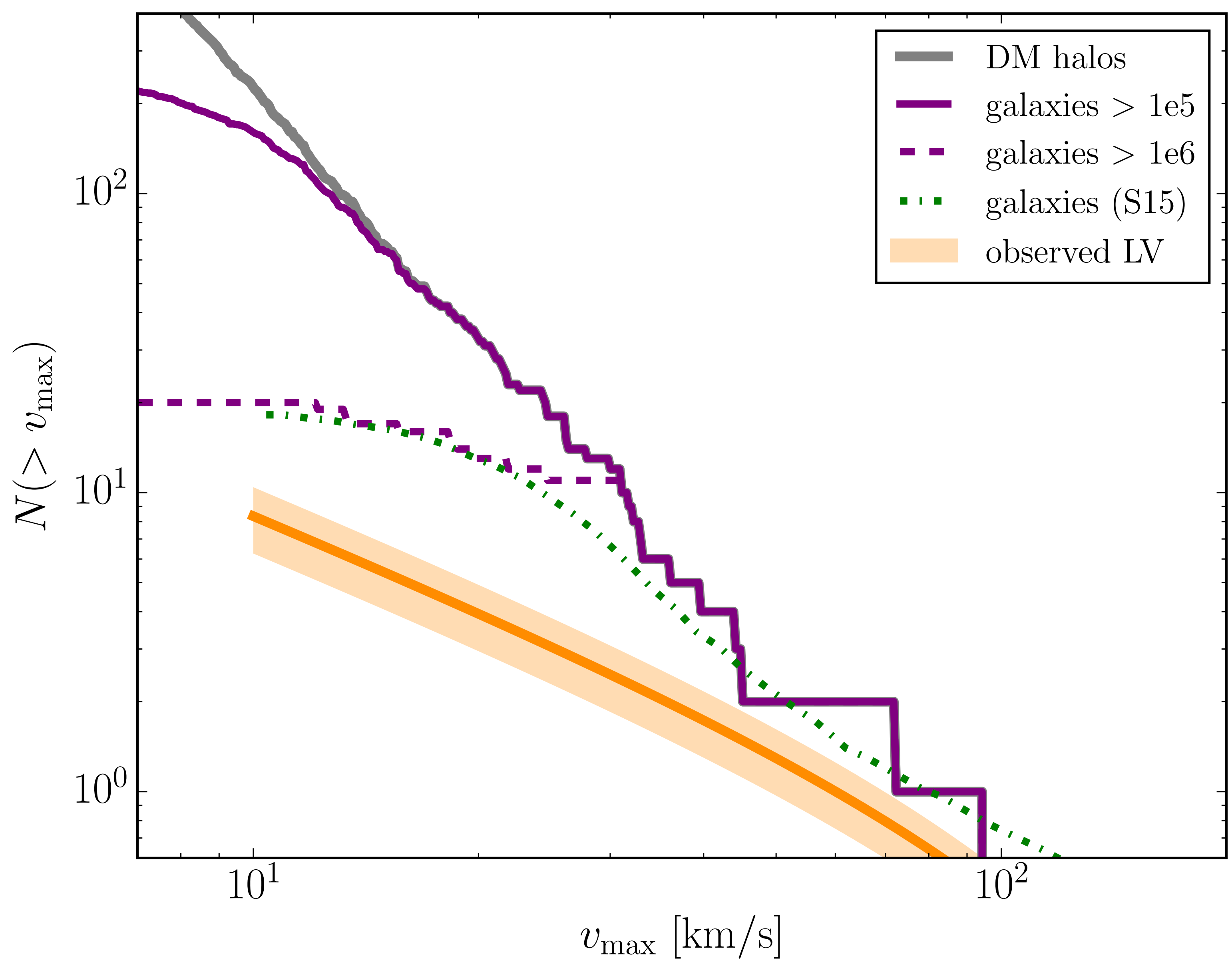
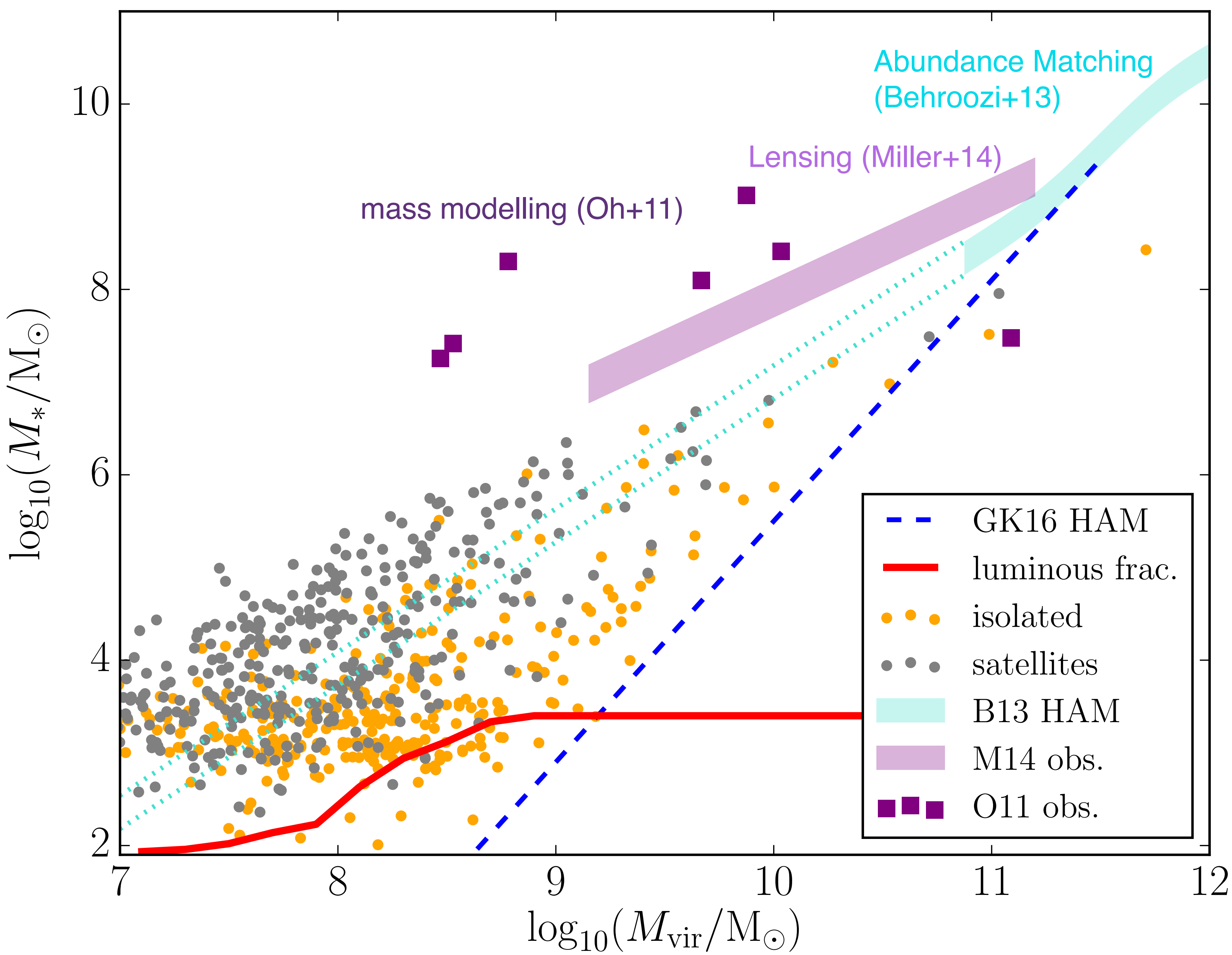


Tensions with other probes of DM halo occupation - stellar vs. halo mass

very strong (SN+radiation) feedback + late UVB

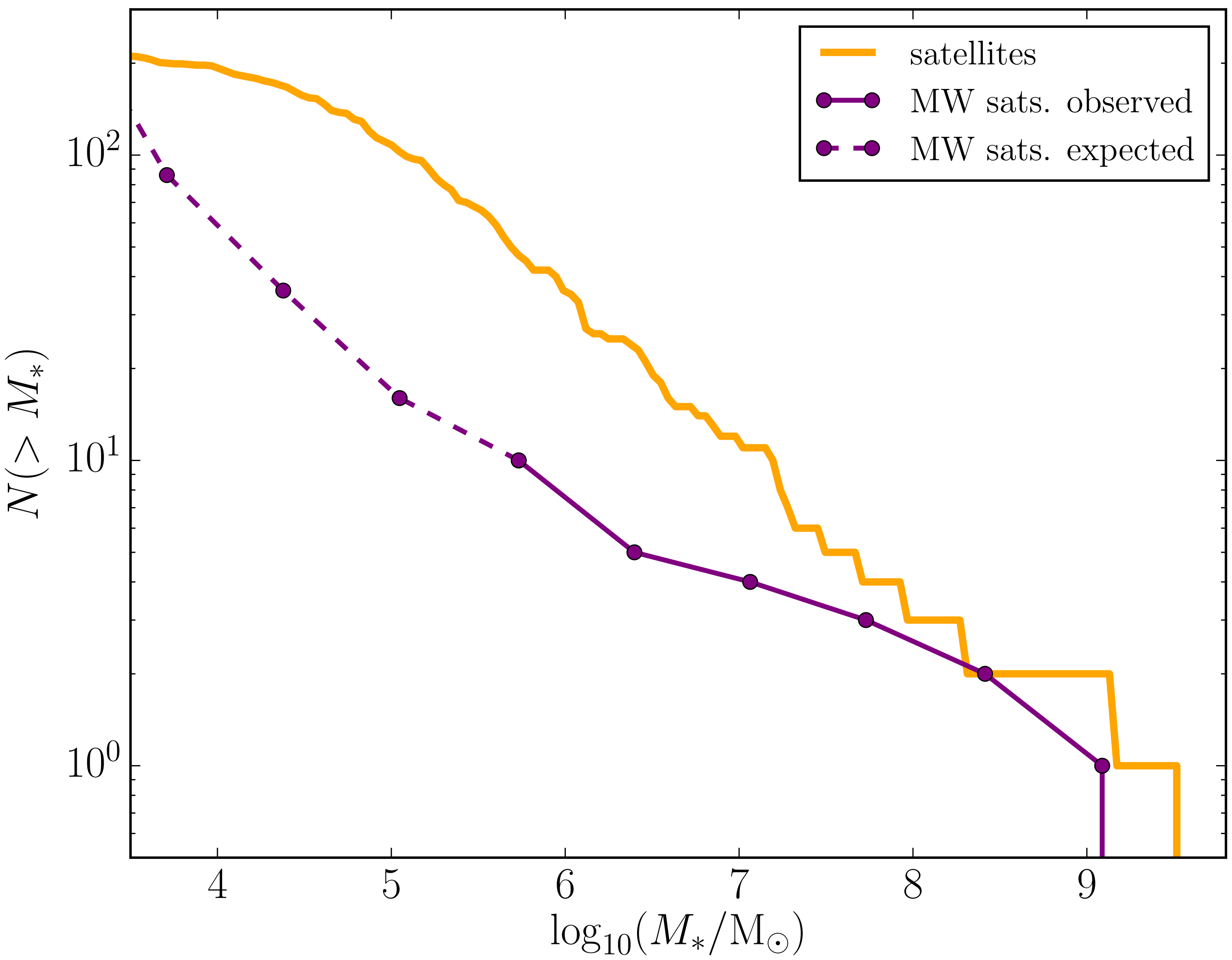


field

satellites

Growth of stellar mass in the MW satellite population

weak (SN) feedback + late reionization



Observed SDSS MW satellites + prediction from completeness (Tollerud+2012)

Growth of stellar mass in the MW satellite population

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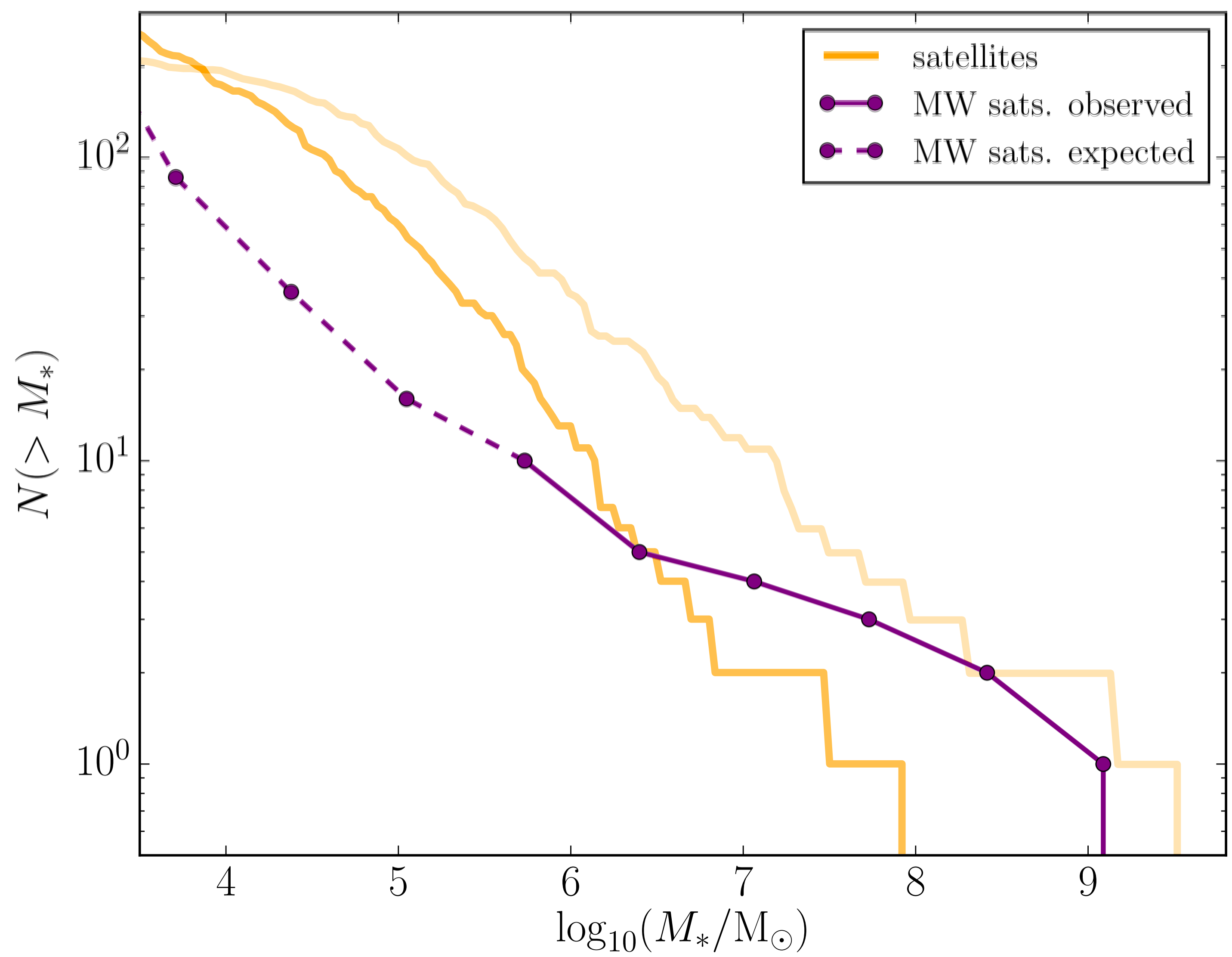

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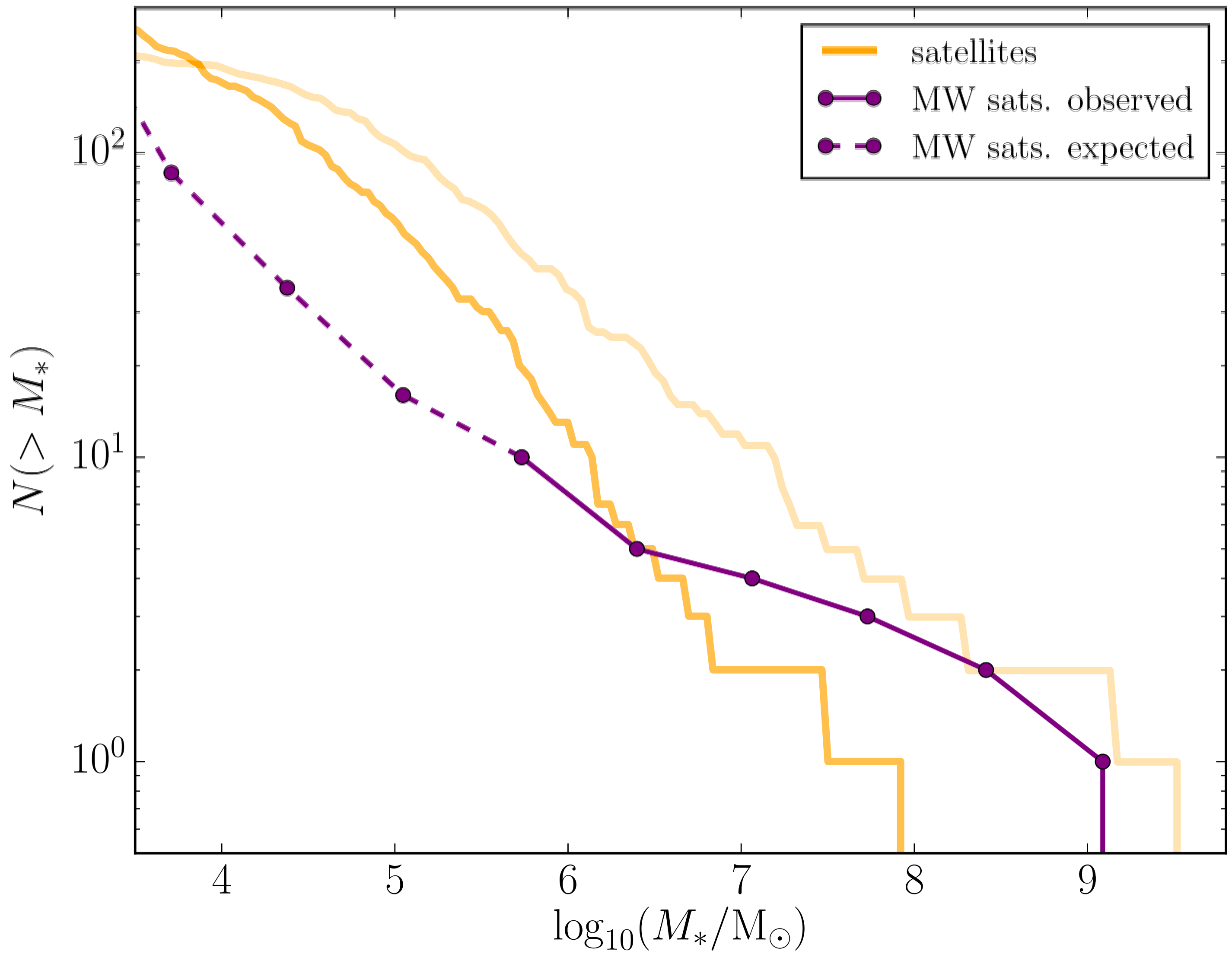

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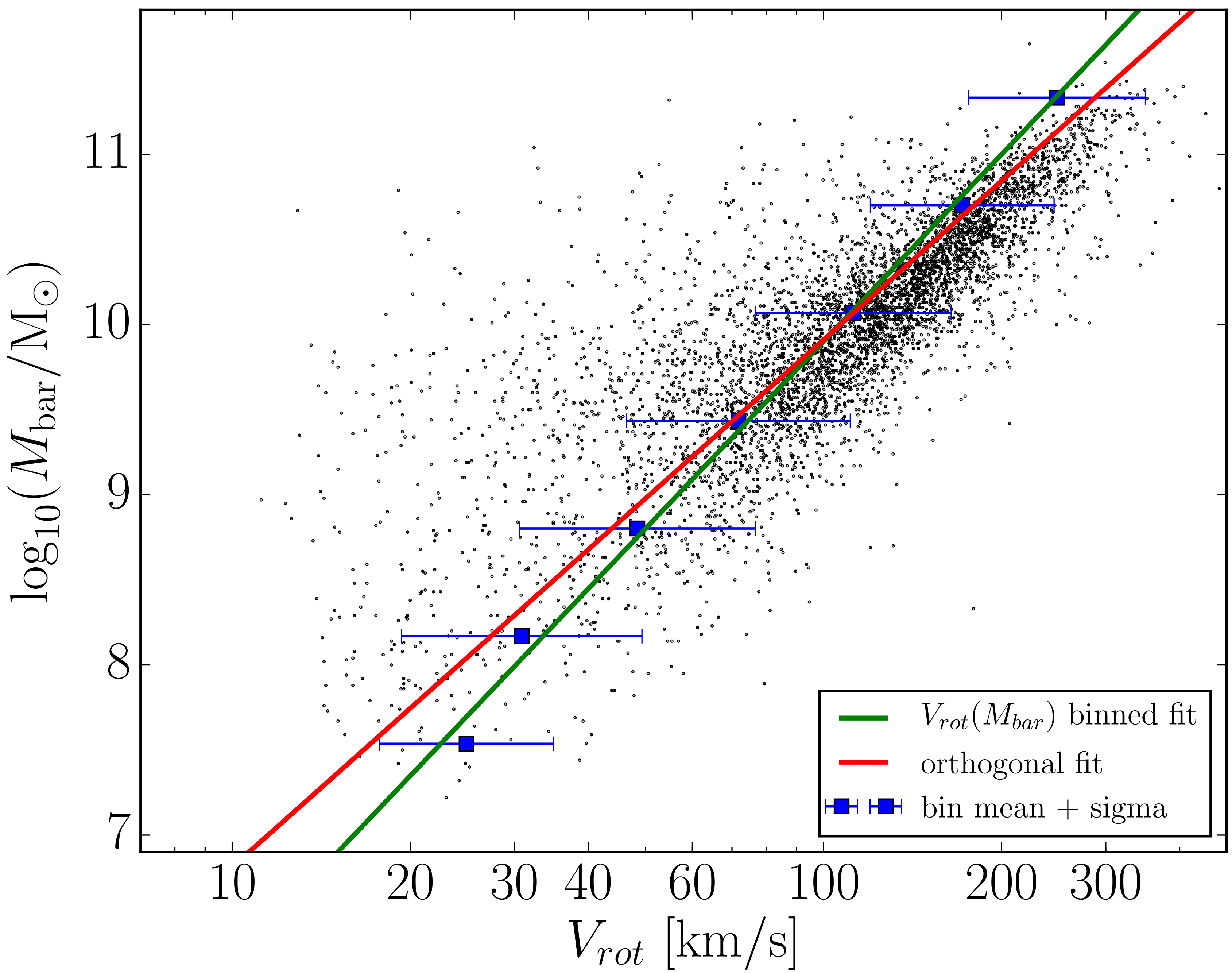
Solution 1: rotation velocity underestimated in unresolved kinematic data?



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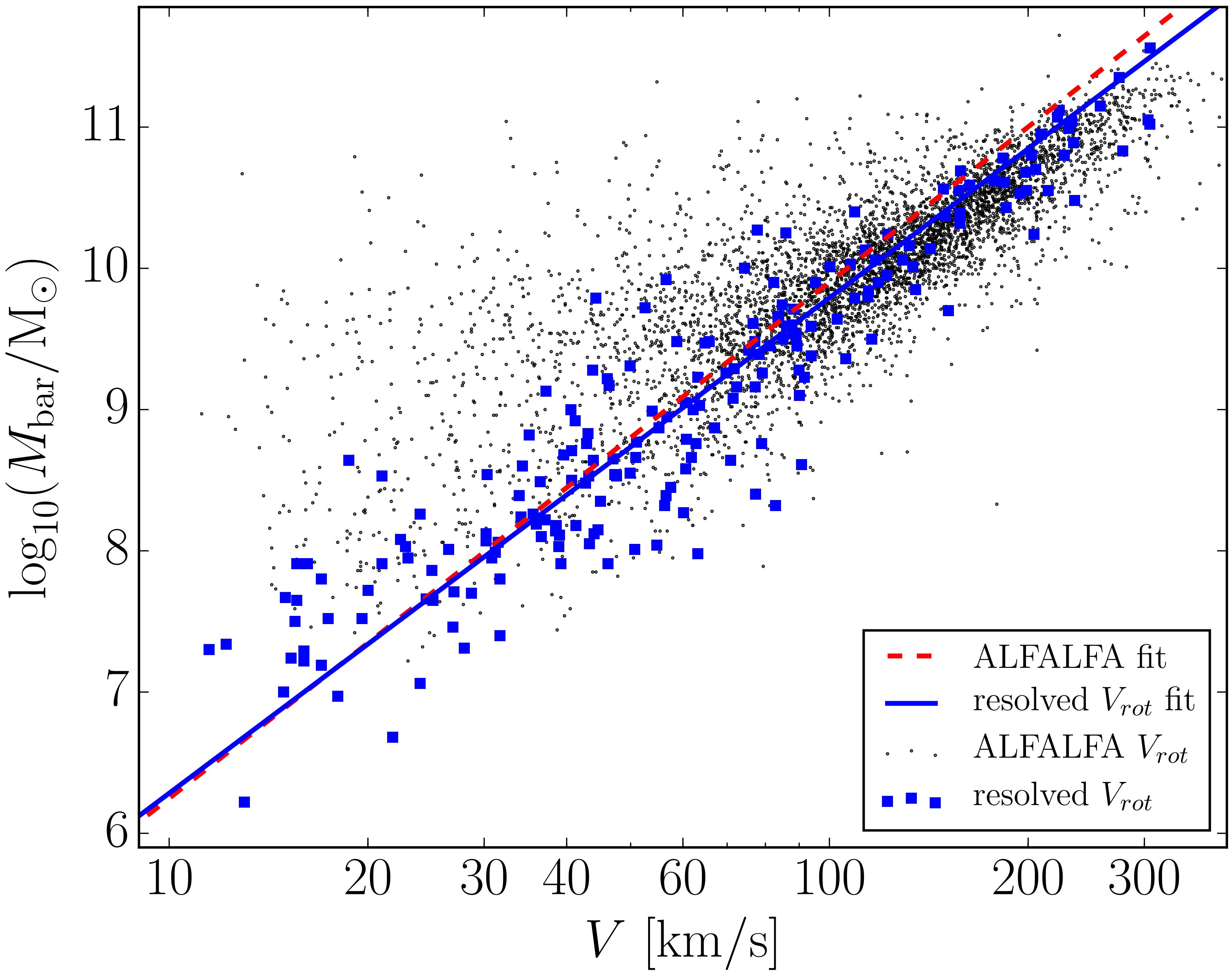
Solution 1: unresolved vs. resolved kinematic HI data



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