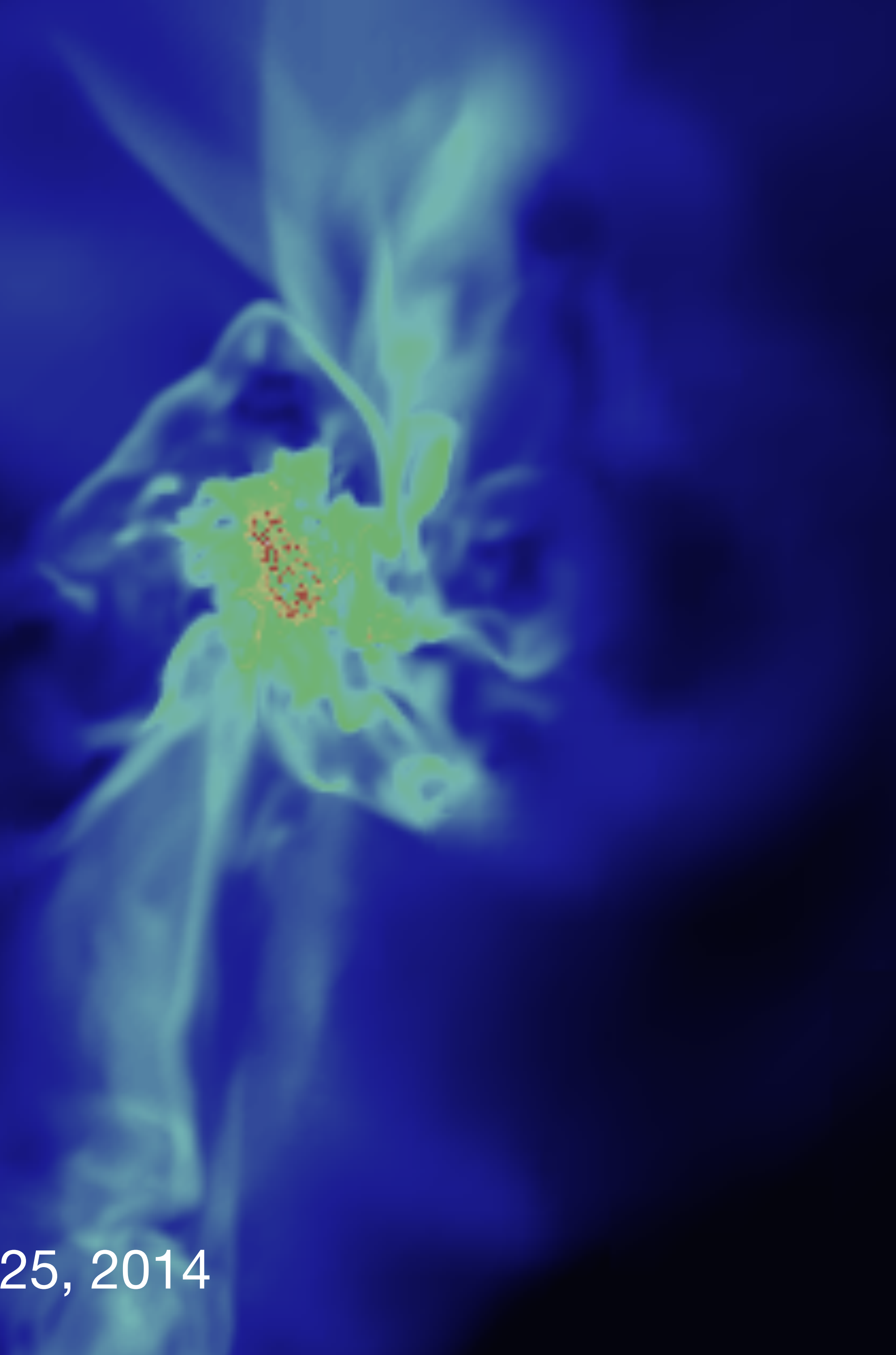
stellar feedback in the smallest galaxies in the universe

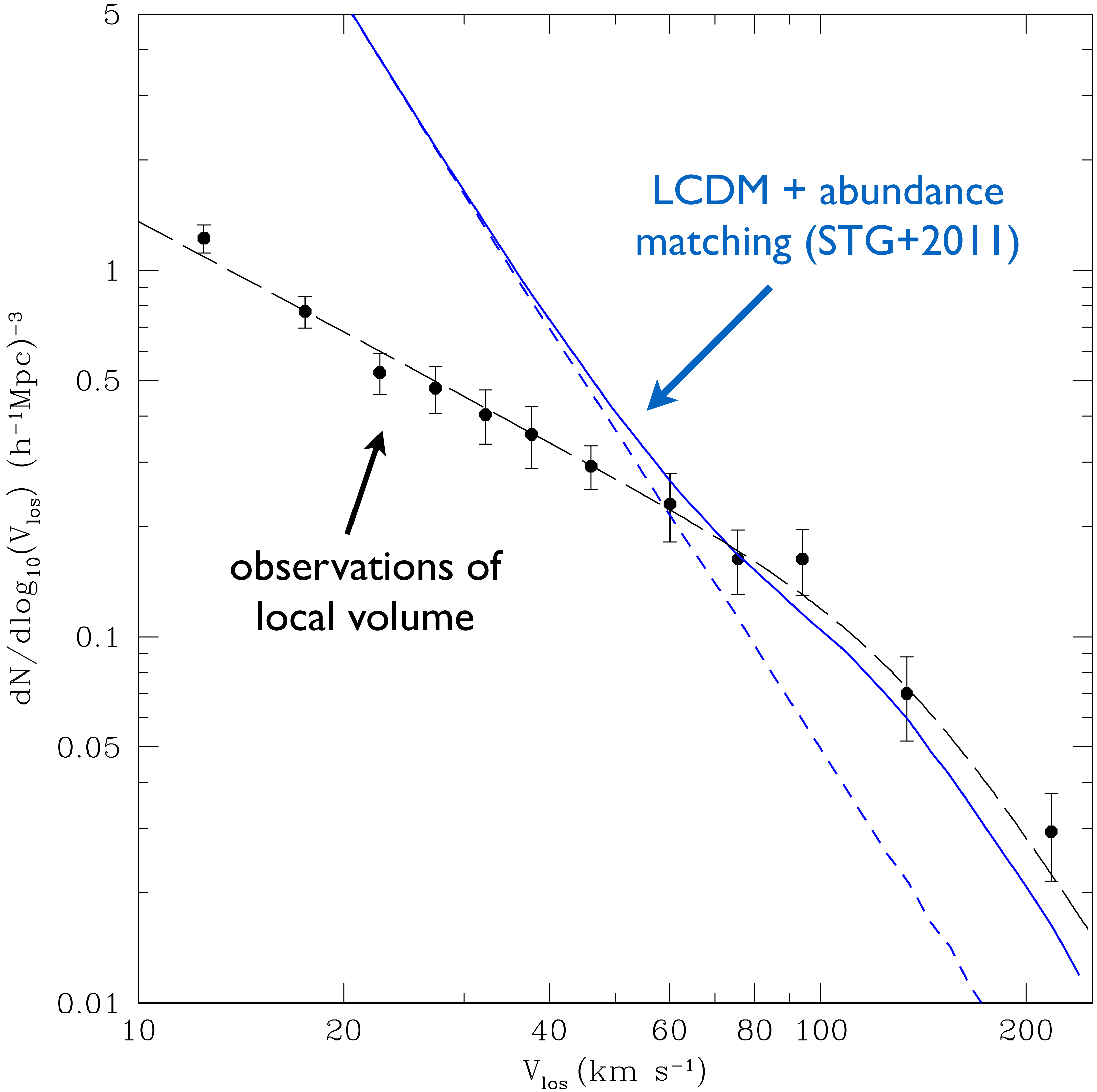
Sebastian Trujillo-Gomez
University of Zurich

in collaboration with:
A. Klypin, K. Arraki, P. Colin, D. Ceverino, J. Primack



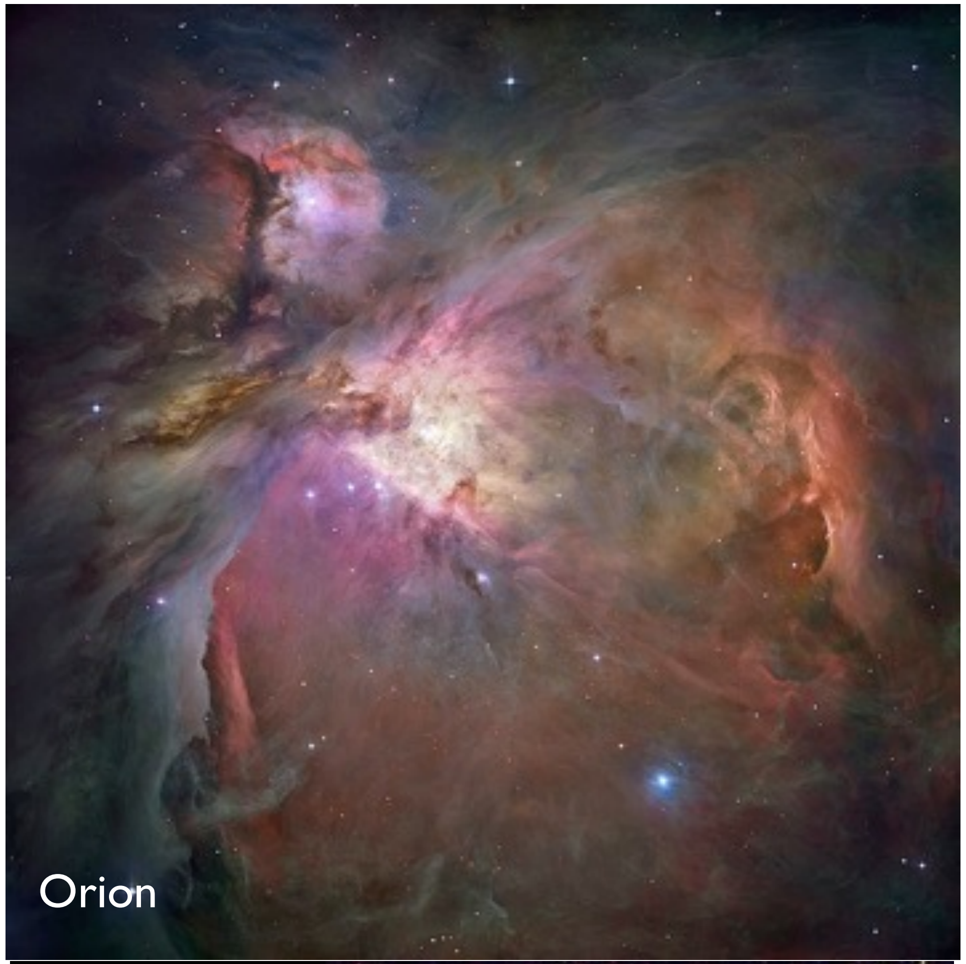
Potsdam Thinkshop - Potsdam, August 25, 2014

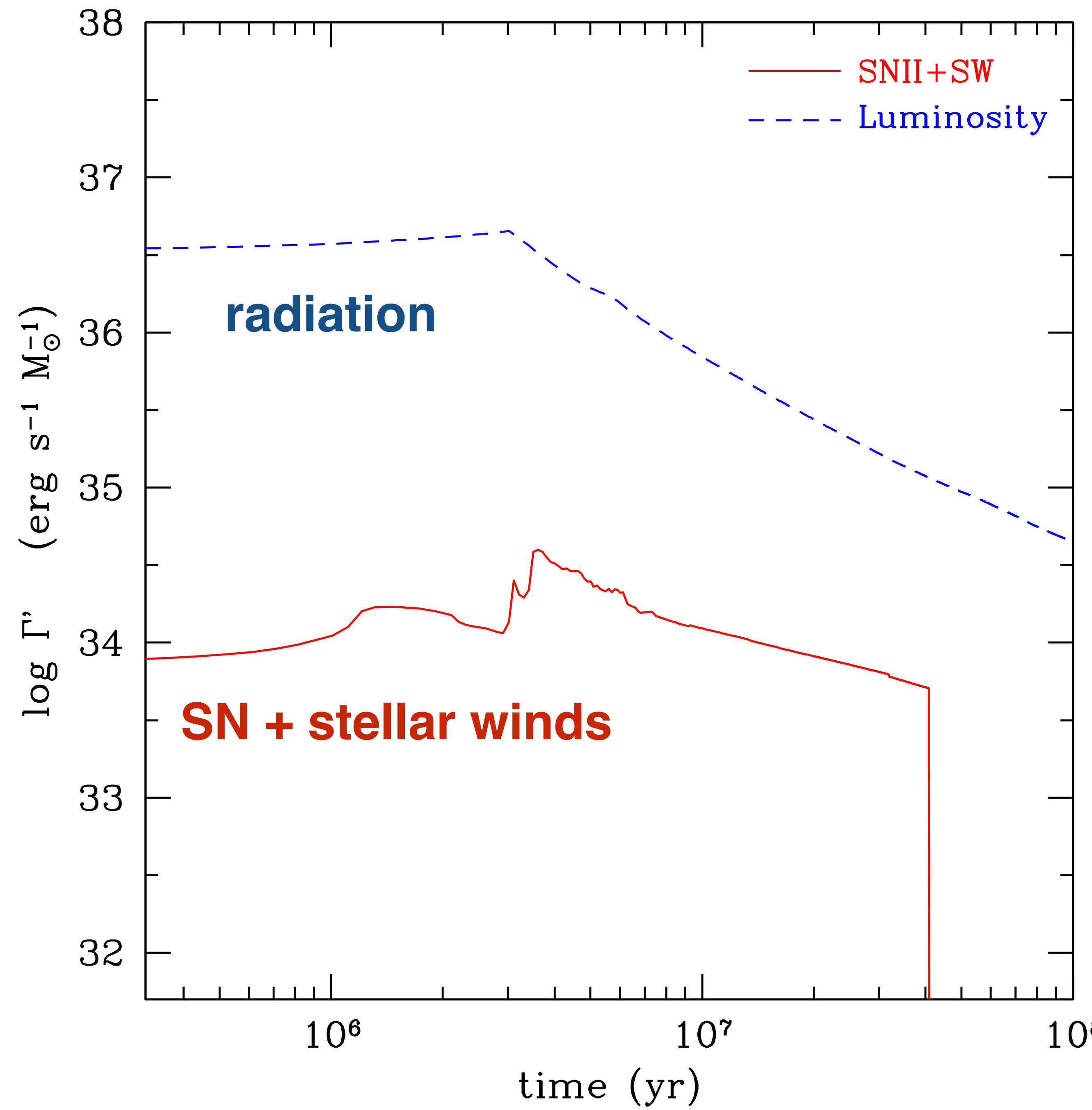
The abundance of the smallest galaxies (not just satellites)



Klypin+2014

using stellar evolution models and observations we obtain a realistic feedback model





there is a vast energy reservoir in the radiation from O & B stars using stellar evolution and observations we obtain a realistic feedback model

time →

source:	photoionization heating in HII regions	momentum from radiation scattering	SNII energy
evolution:	high pressure for initial ~100 kyr	1% of photoheating pressure for initial ~3 Myr	1e51 ergs per massive star for 3 < t < 40 Myr
based on:	HII region observations	stellar evolution models	observations of ejecta

radiation important early when cloud is dense,
SNe important at later stages when bubbles develop

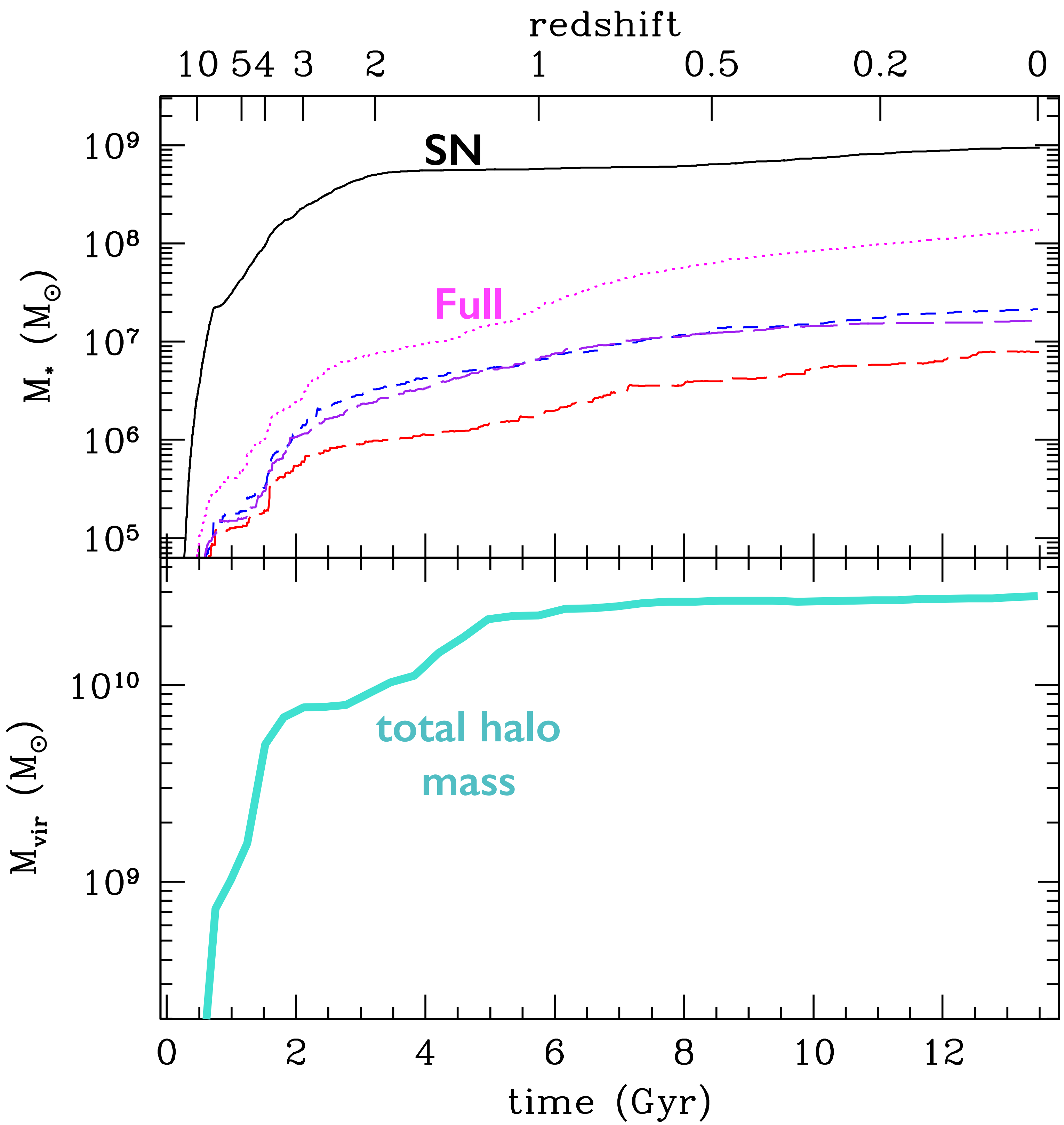
The experiments

run	*redshift*	*halo mass*	*R (proper)*	*resolution (proper)*	*local SF efficiency*	*stellar feedback*
dwarf_SN	z=0	~3x10	~80 kpc	38 pc/h	2%	SN
dwarf_ALL					5%	SN+RP+PH
spiral_SN	z~0.5	~2x10	~80 kpc	76 pc/h	2%	SN
spiral_ALL						SN+RP+PH

SN = supernovae only
Full = SN + radiation pressure + photoheating

-> we are testing the effect of feedback without fine tuning to produce realistic galaxies

stellar mass assembly

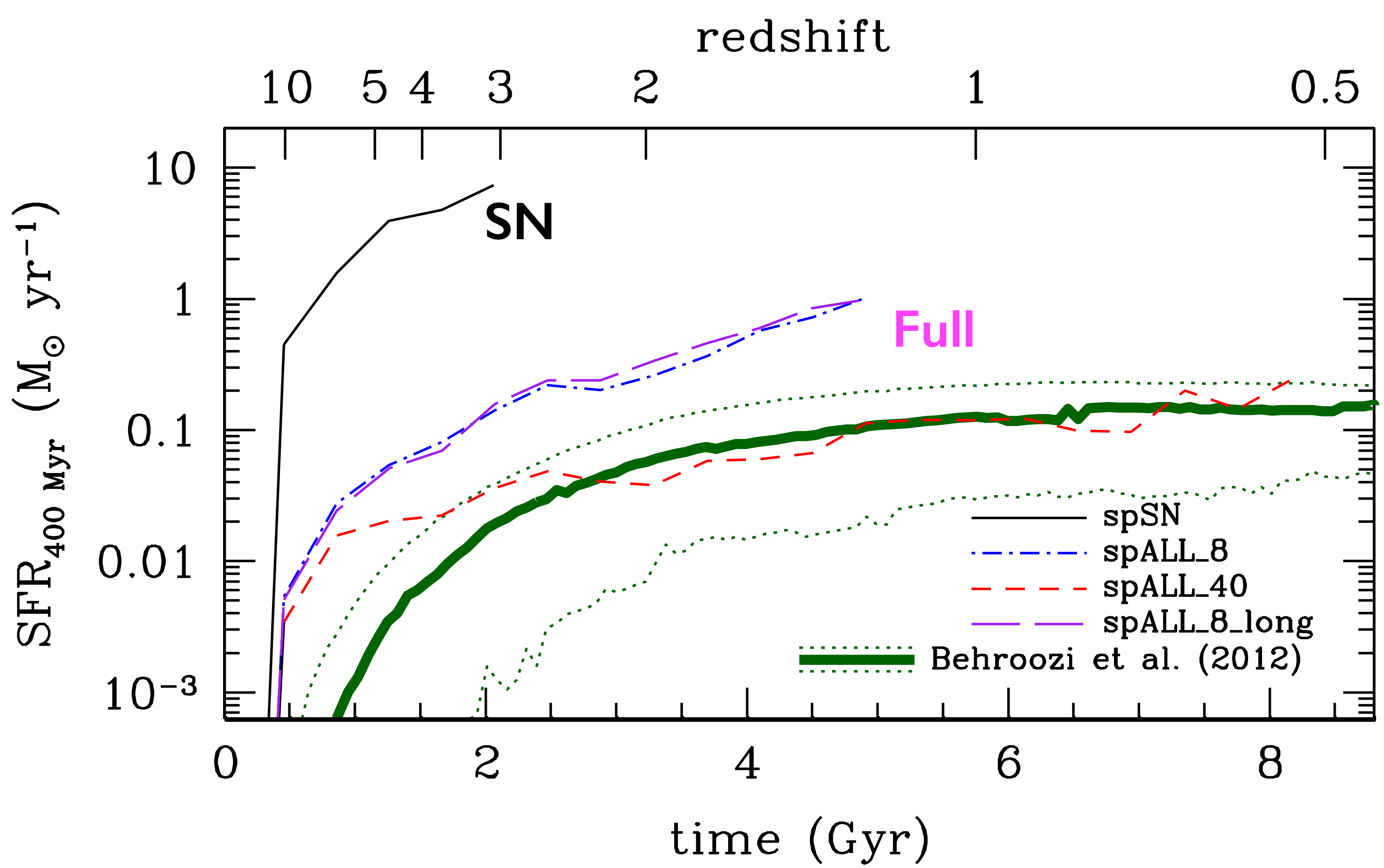


STG+2013

SN: ~80% of stellar mass assembled before z=2

Full feedback: >60% of stellar mass assembled after z=1

the star formation history of a spiral

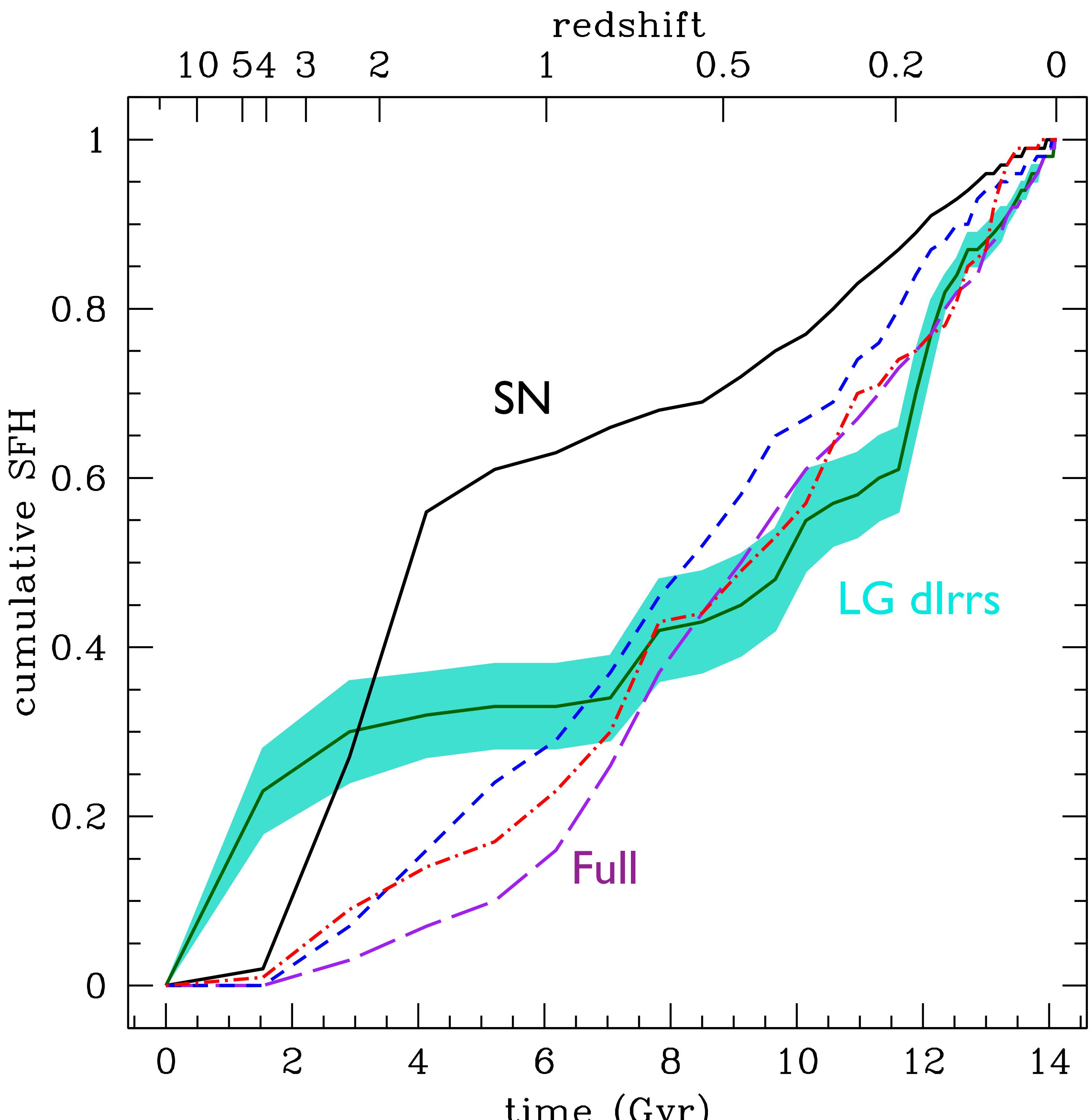


SF history matches observational constraints

STG+2013

the star formation histories of dwarfs

Weisz+2014: resolved star formation histories of LG dIrrs using HST

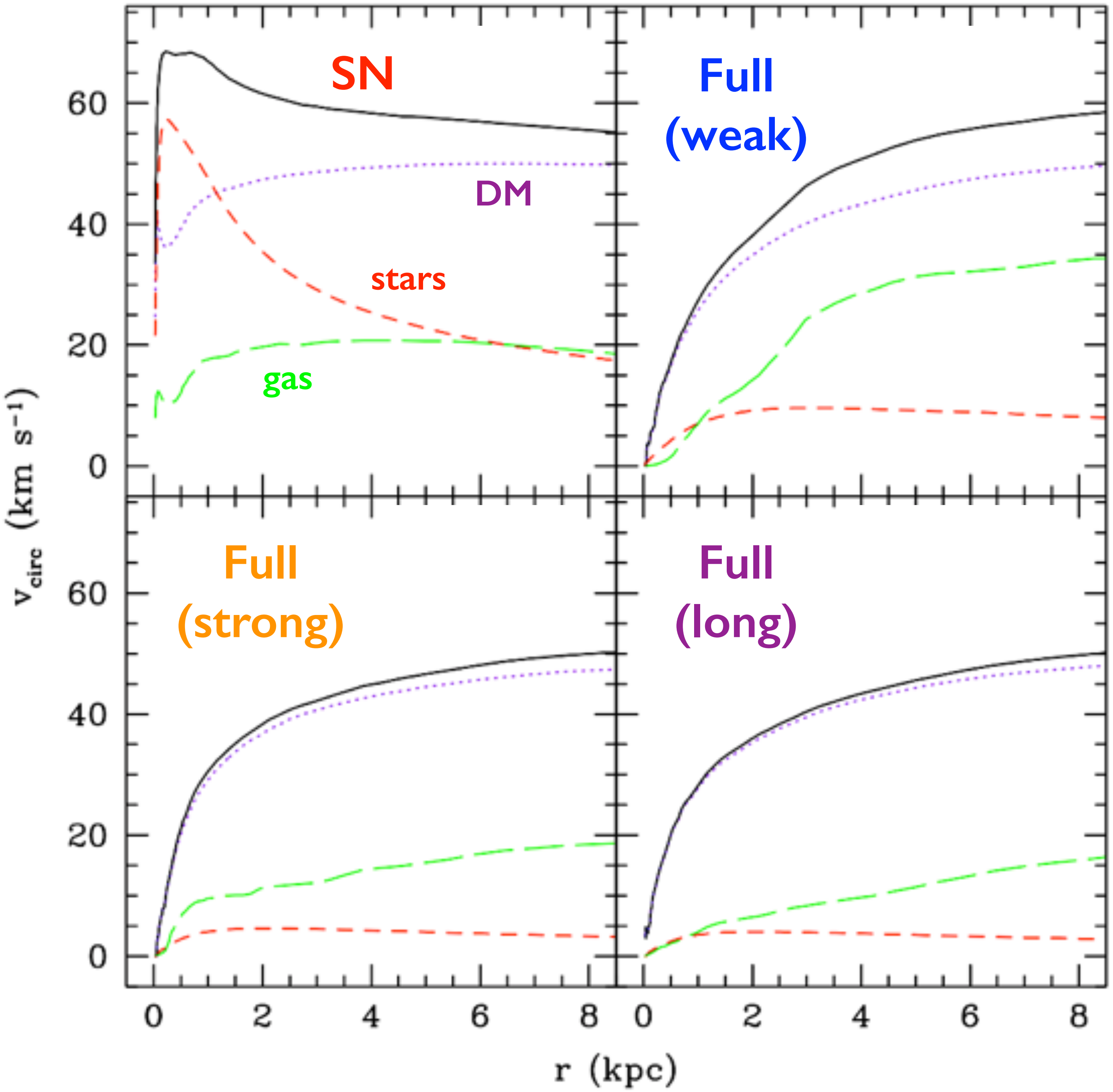


Weisz+2014

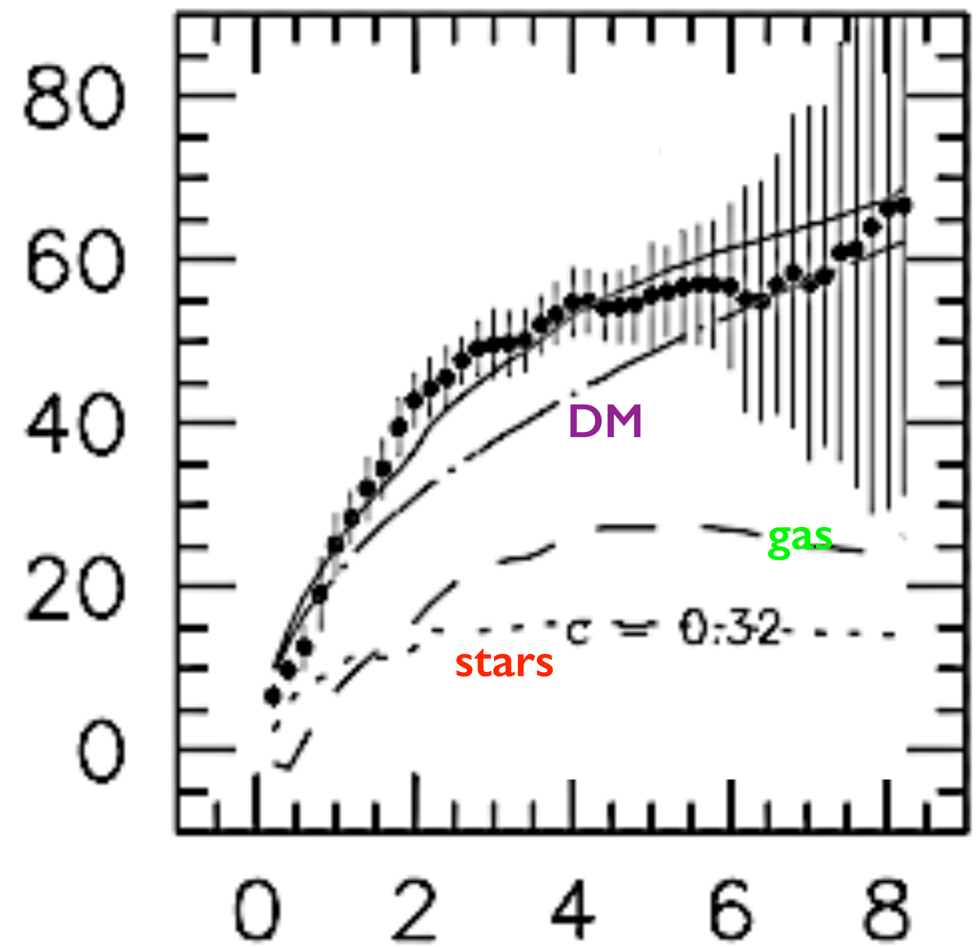
also consistent with SFHs of SDSS galaxies from spectra (Leitner+2013)

early rise at z>1 poorly constrained

dwarf: mass distribution

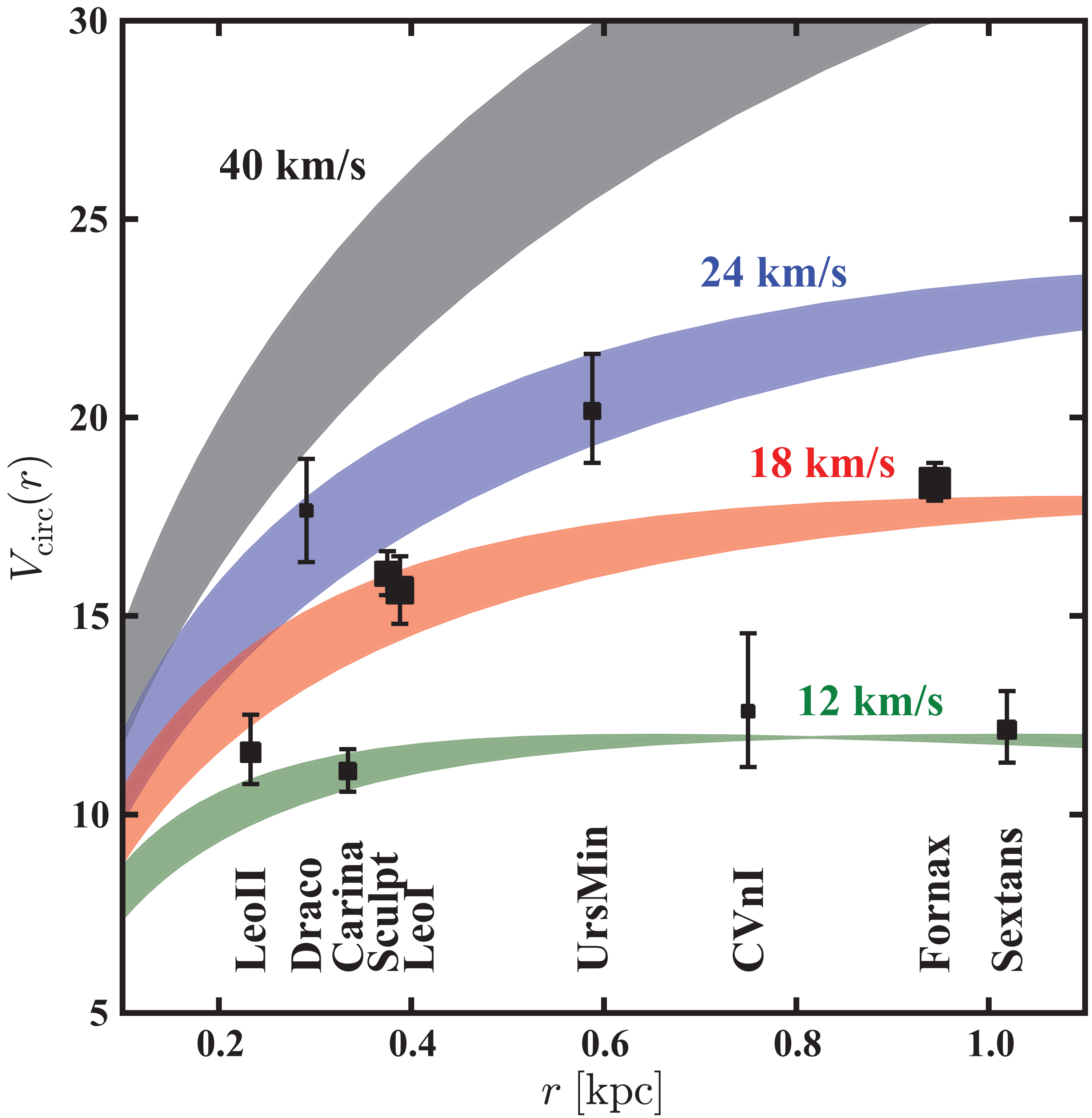


STG+2013



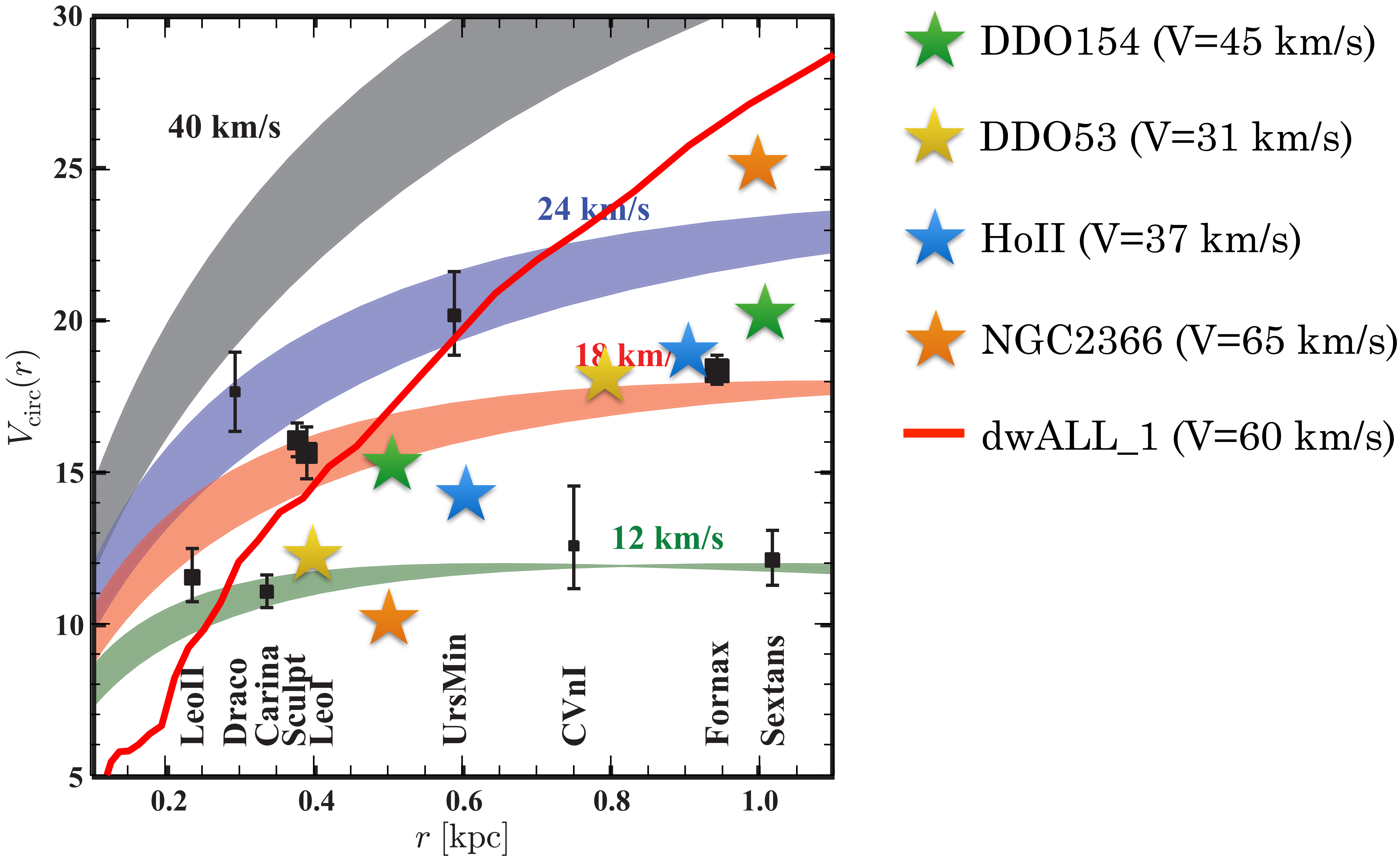
NGC2366 (Oh+2011)

radiation feedback produces DM cores



Boylan-Kolchin+12

radiation feedback produces DM cores

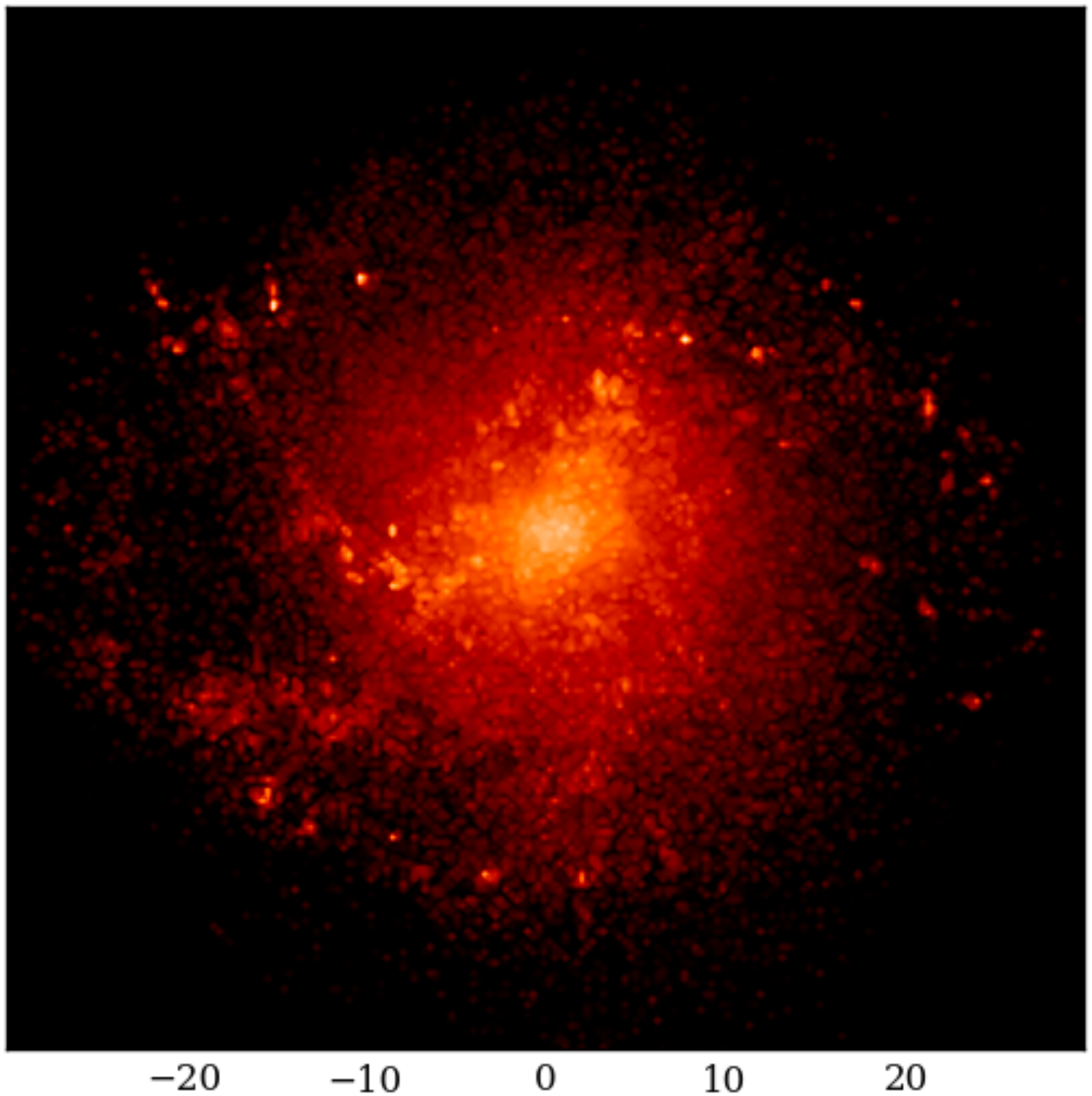


Boylan-Kolchin+12

The effect of feedback on morphology

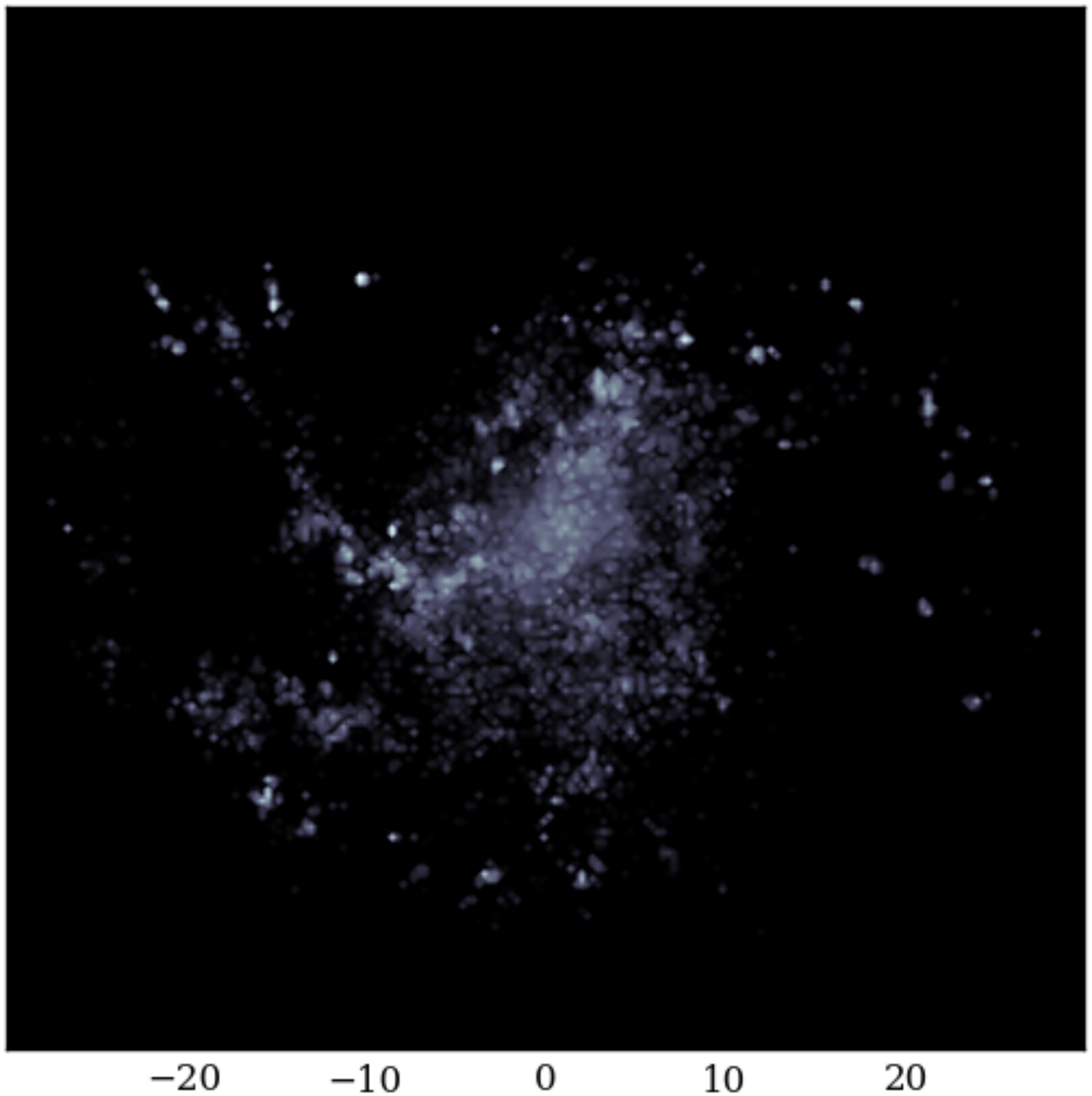
STG+2013

The effect of feedback on morphology



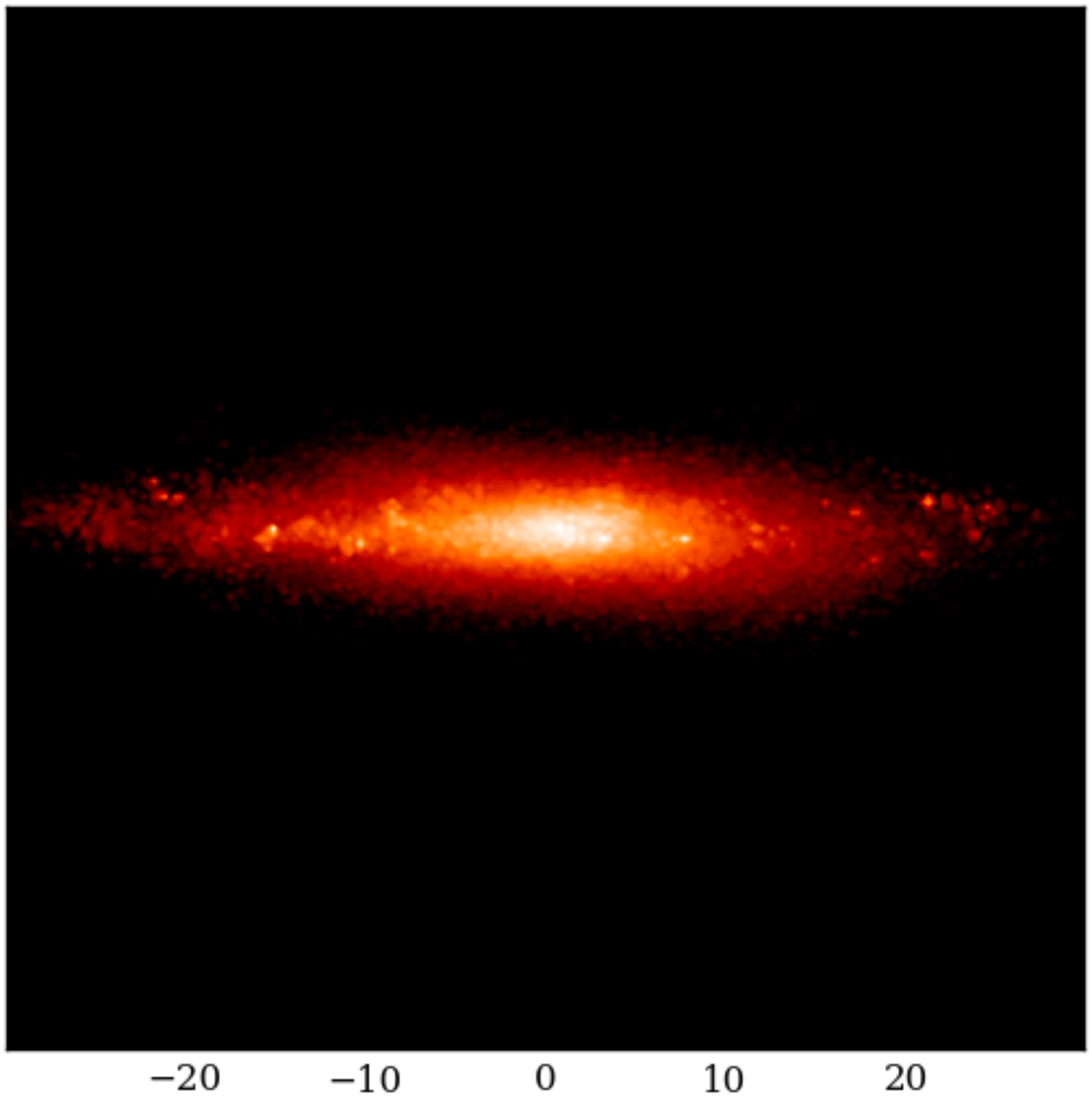
STG+2013

The effect of feedback on morphology



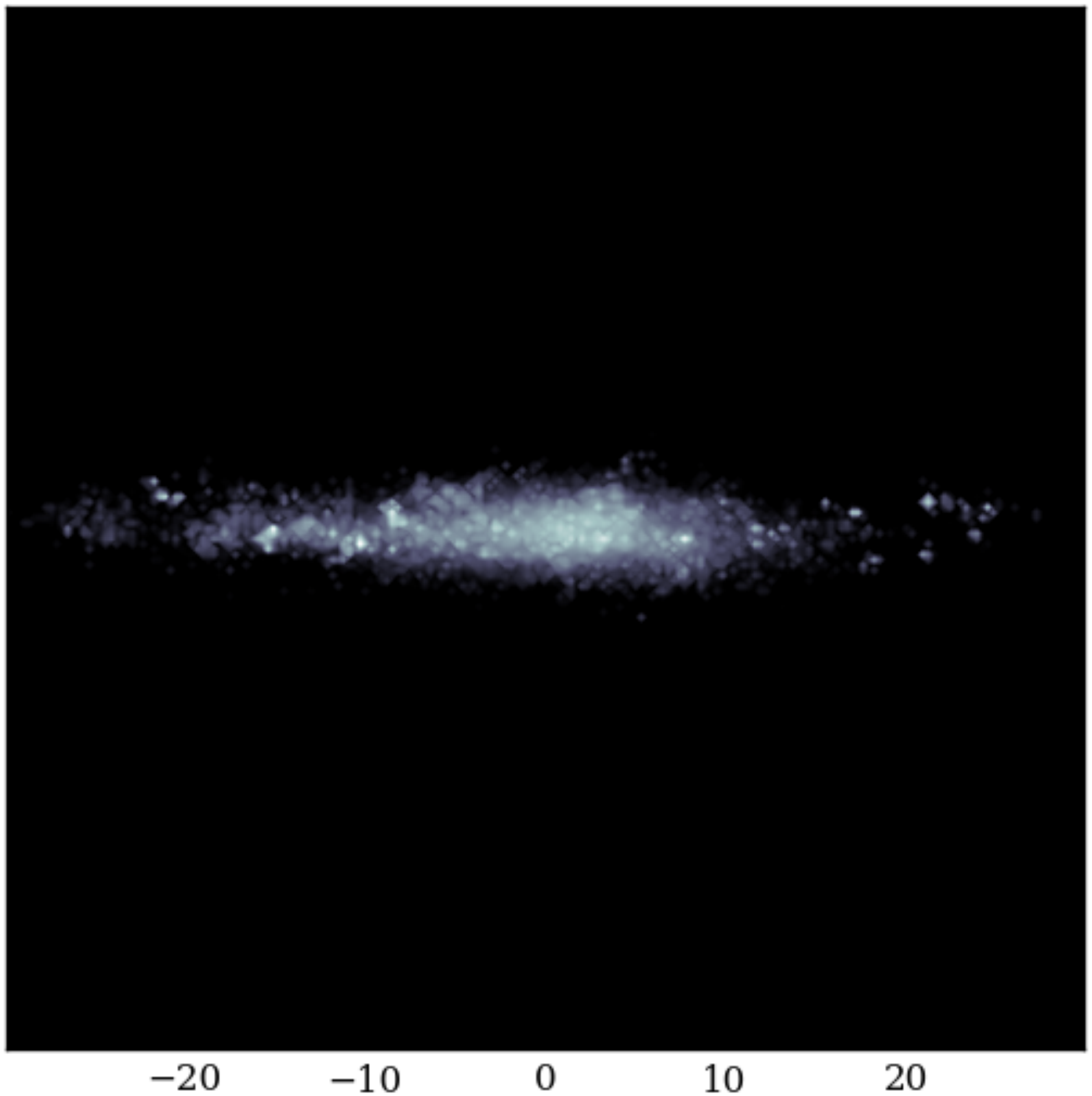
STG+2013

The effect of feedback on morphology



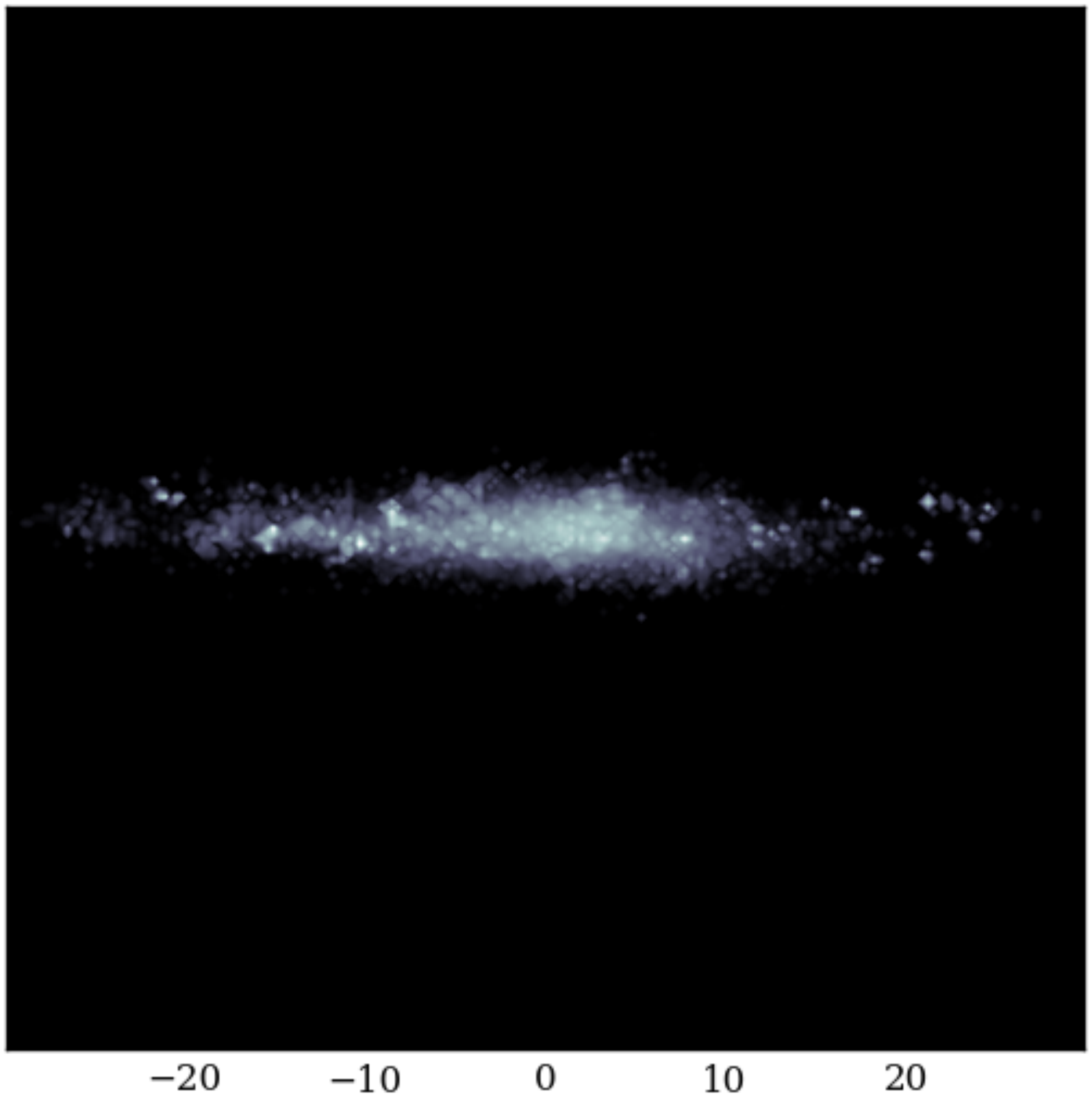
STG+2013

The effect of feedback on morphology

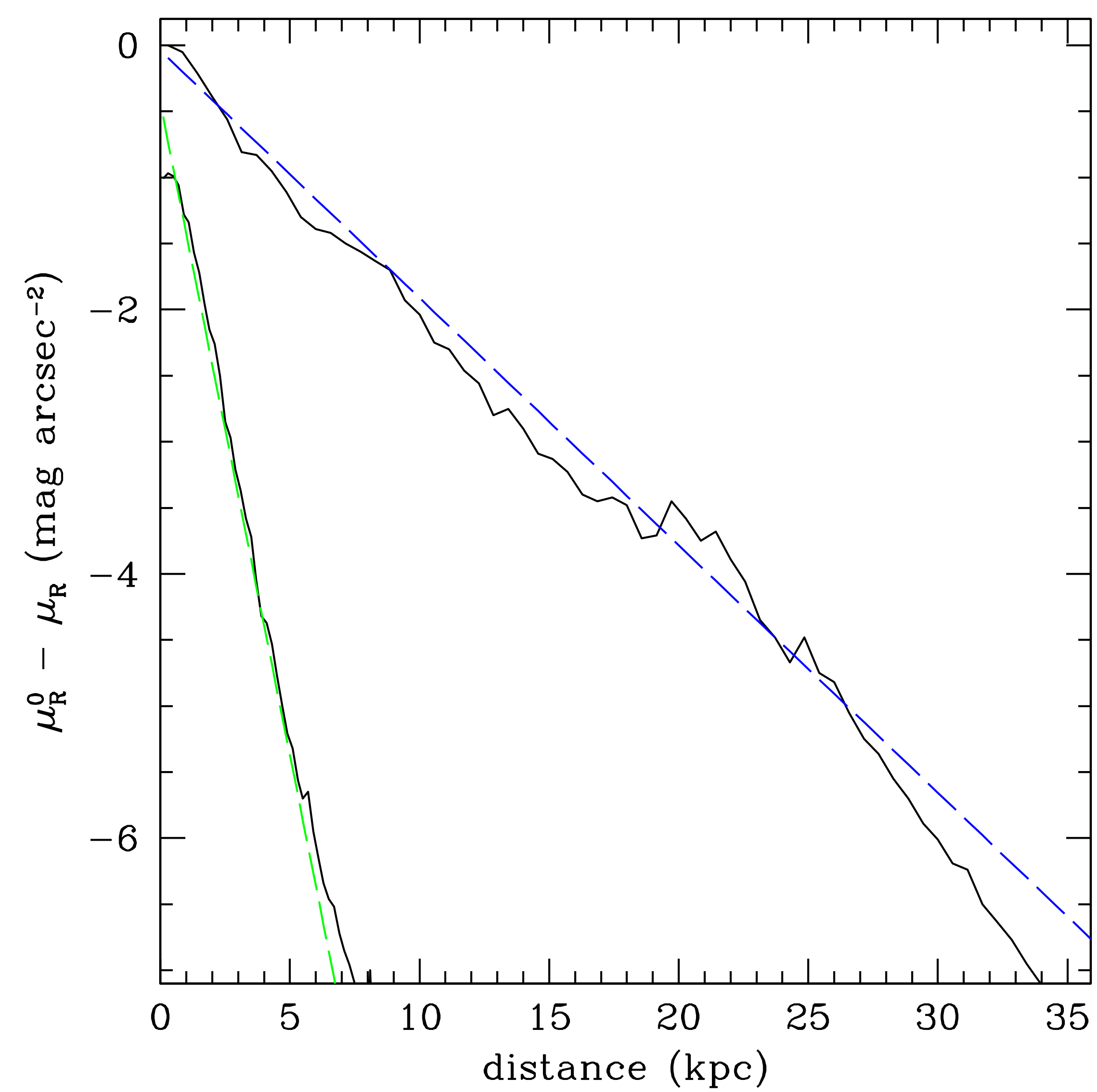


STG+2013

The effect of feedback on morphology



R-band light profile



STG+2013

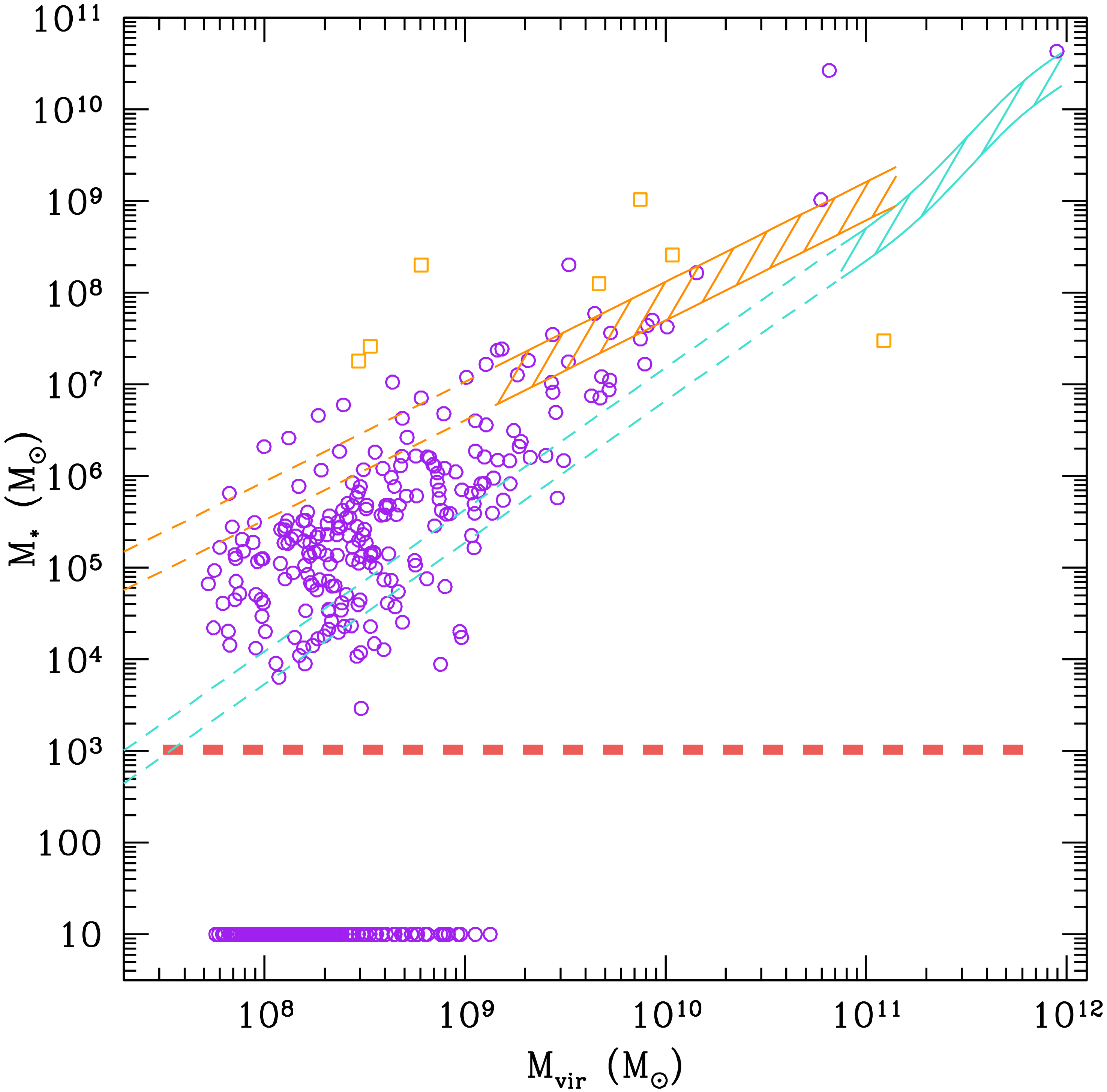
the formation of the smallest galaxies in high-res zoom-in mesh simulations

- suite of hydro cosmological simulations of central galaxies with L ~ 0.3-1.0M_{MW} and resolution 10-50 pc/h (Ceverino+13, Trujillo-Gomez+13)
- dwarf galaxies resolved down to M_{vir} ~ 10^7 M_{sun} (below the suppression scale)
- probe volumes ~ few Mpc^3 around each large galaxy
- sample of ~500-1000 dwarf galaxies (field and satellites) for each run
- *see Kenza's talk for more details*

is stellar feedback really unimportant for the smallest galaxies?

stellar mass vs. halo mass

weak feedback (SN+RP)



Behroozi+2013 (HAM)

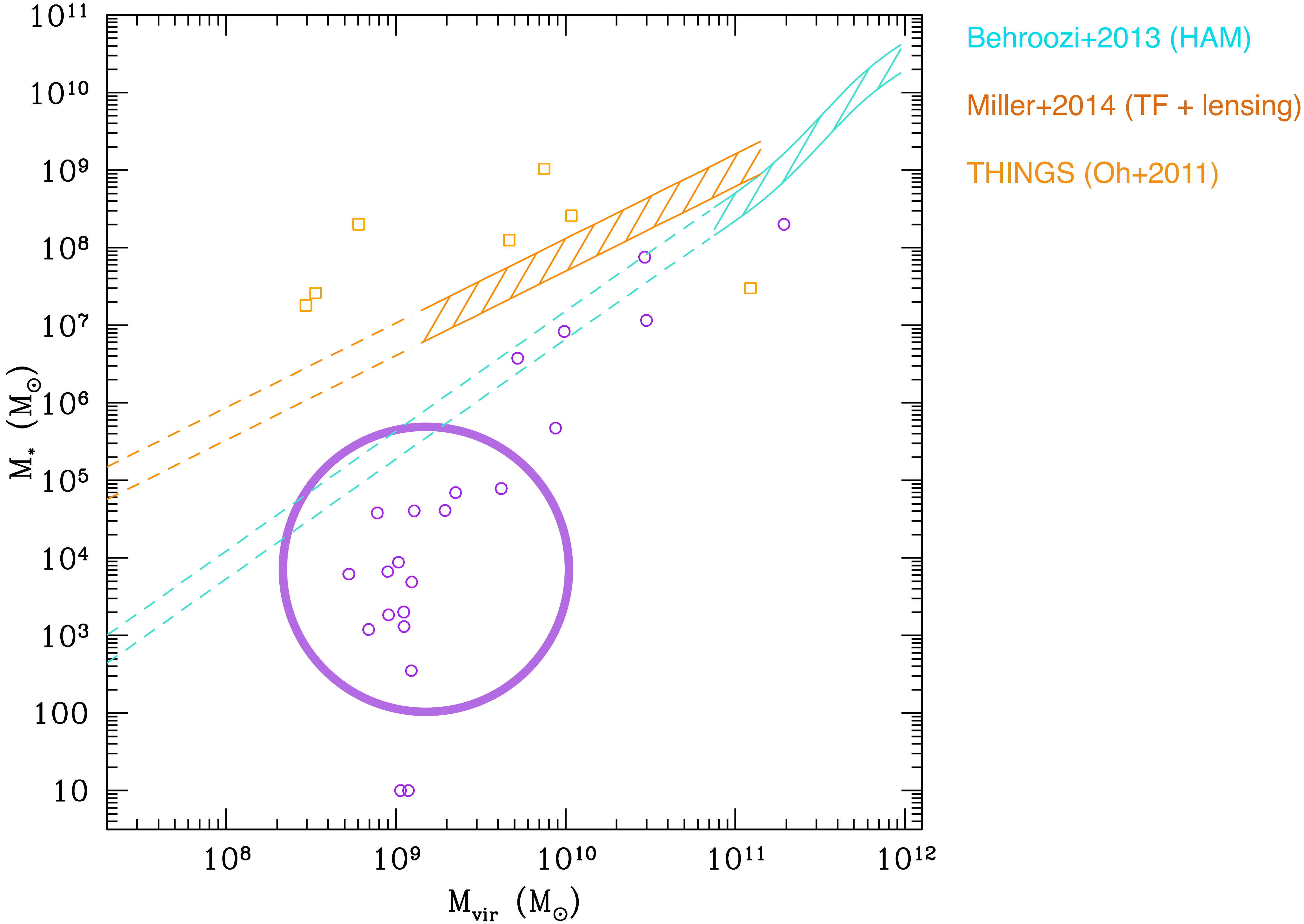
Miller+2014 (TF + lensing)

THINGS (Oh+2011)

no field galaxies with M < 1000 Msun*

stellar mass vs. halo mass

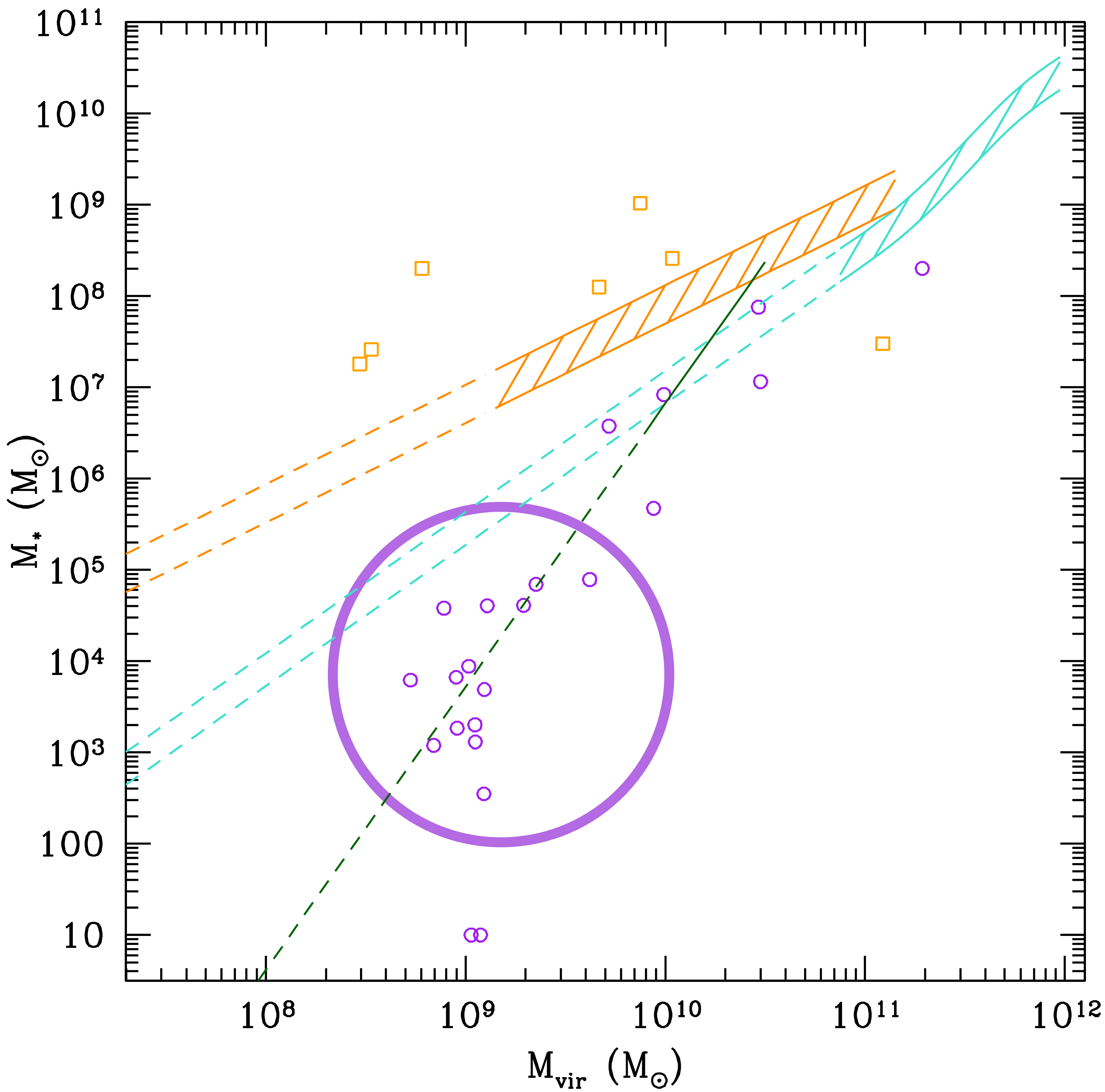
strong feedback (SN+RP +photoheating)



feedback is important even in smallest halos. at low masses, feedback is even more effective at lowering the stellar mass content

stellar mass vs. halo mass

strong feedback (SN+RP +photoheating)



Behroozi+2013 (HAM)

Miller+2014 (TF + lensing)

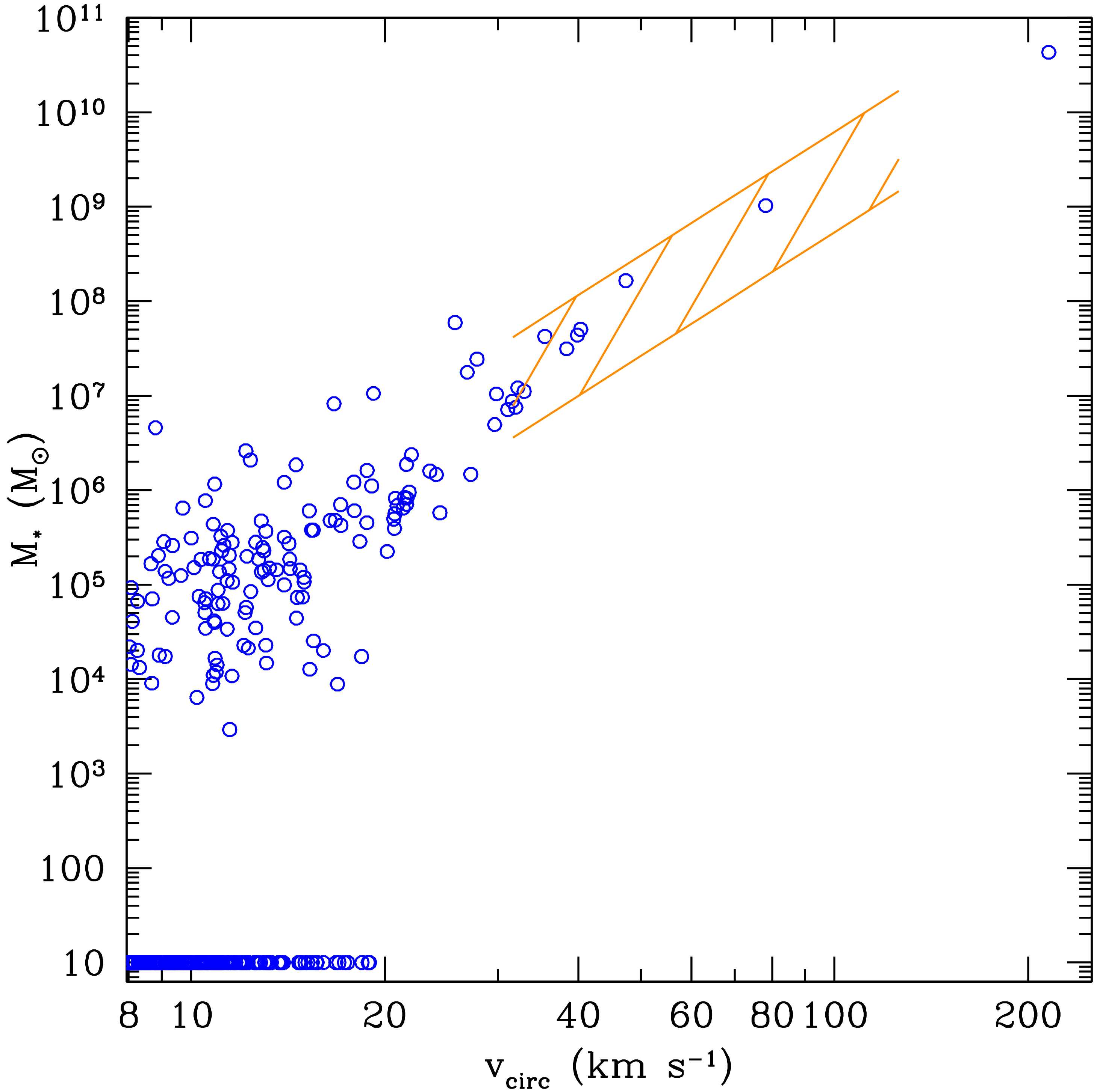
THINGS (Oh+2011)

Brook+2014 (LV HAM)

feedback is important even in smallest halos. at low masses, feedback is even more effective at lowering the stellar mass content

observational constraints now reach smaller masses and higher redshifts

weak feedback
(SN+RP)

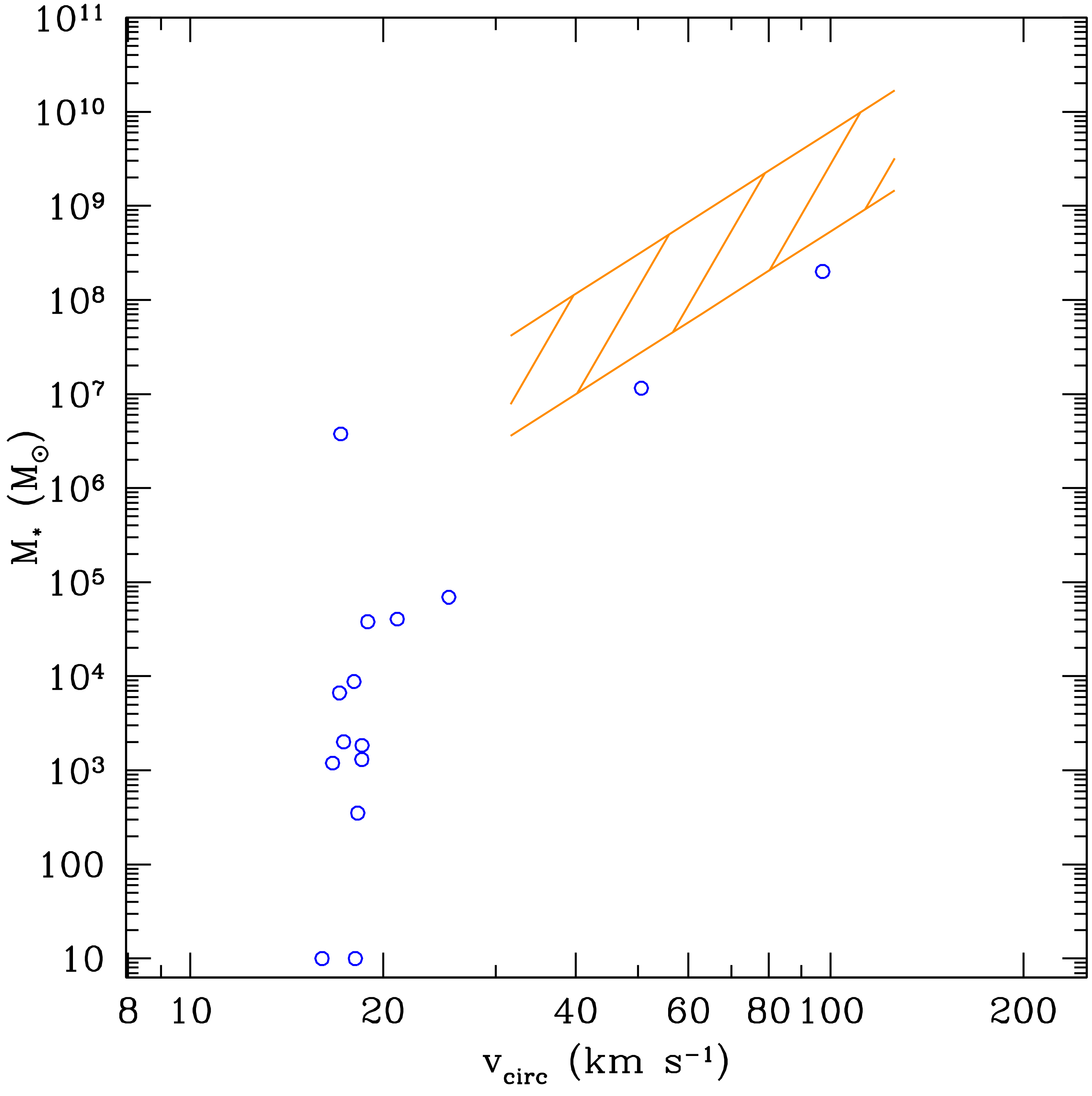


observations:

Miller+2014
(measured at $2.2r_s$)

including strong feedback from local photoheating

strong feedback
(SN+RP+photoheating)



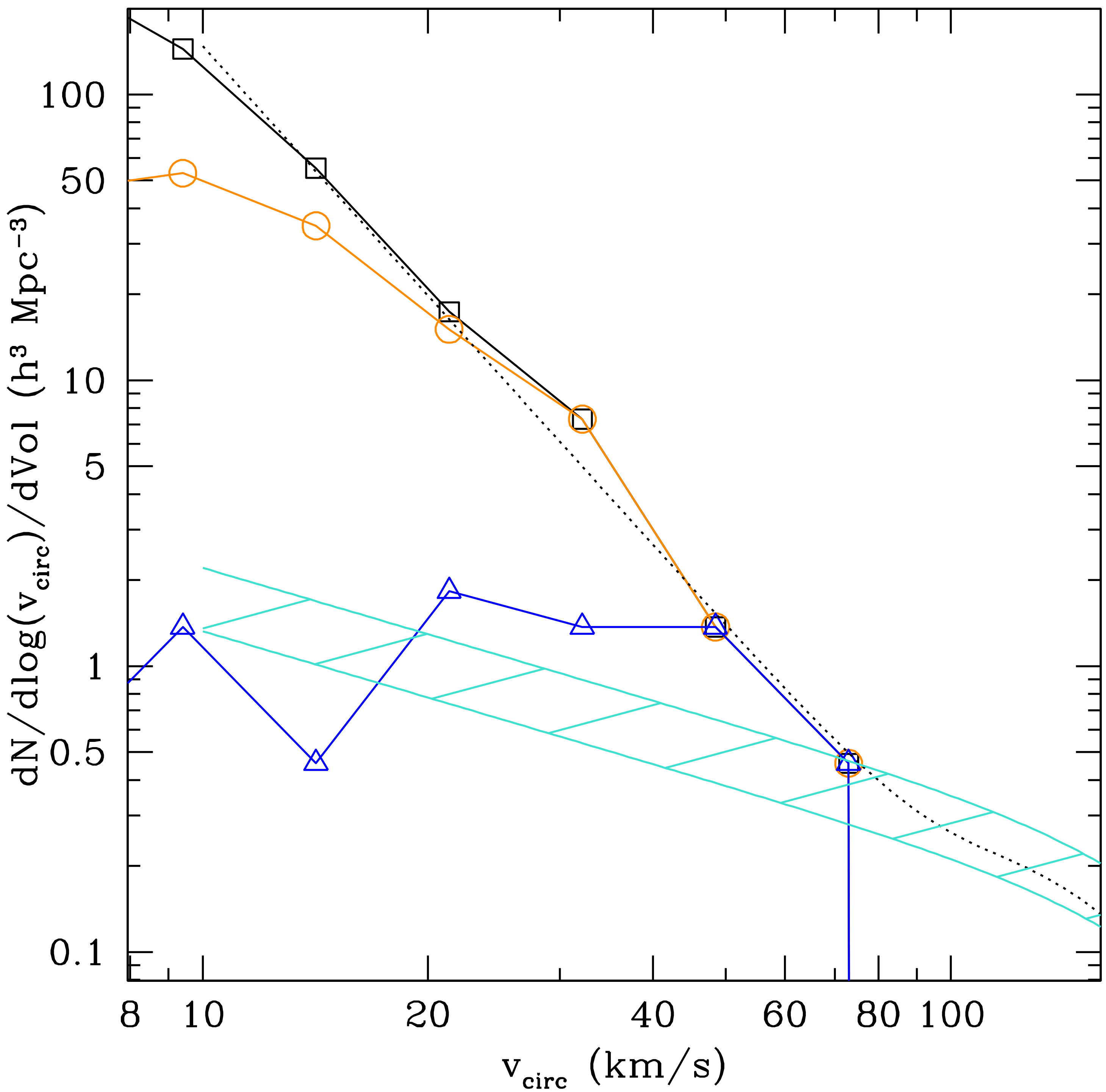
observations:

Miller+2014 (measured at $2.2r_s$)

the velocity function

weak feedback
(SN+RP):

squares = DM halos
circles = galaxies
triangles = wih cold gas



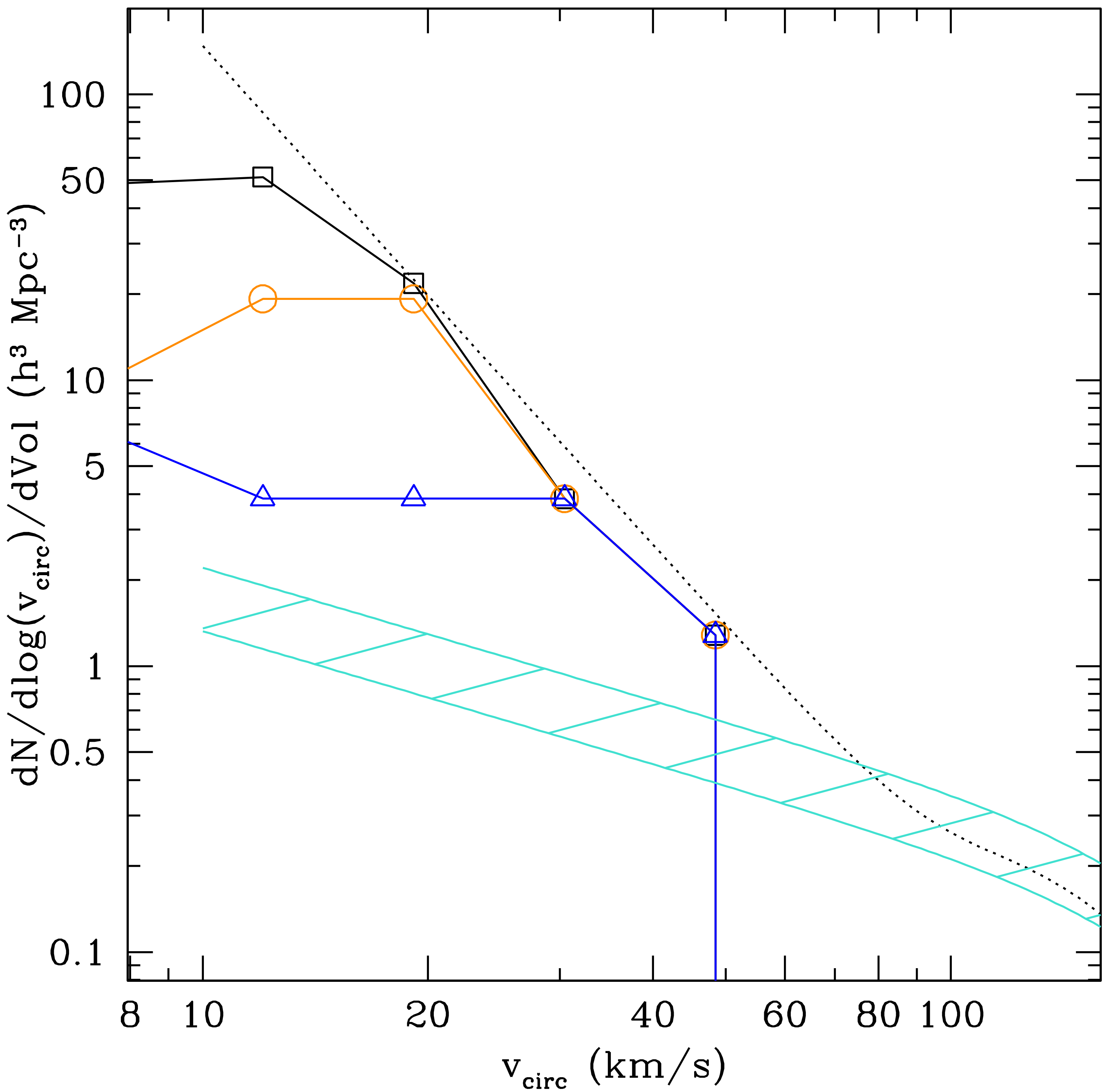
dotted line:
LCDM+HAM prediction
(STG+2011)

shaded area:
Local Volume optical +
ALFALFA HI (Klypin+2014)

the velocity function

strong feedback
(SN+RP+photoheating):

squares = DM halos
circles = galaxies
triangles = wih cold gas



dotted line:
LCDM+HAM prediction
(STG+2011)

shaded area:
Local Volume optical +
ALFALFA HI (Klypin+2014)

the *observed* velocity function

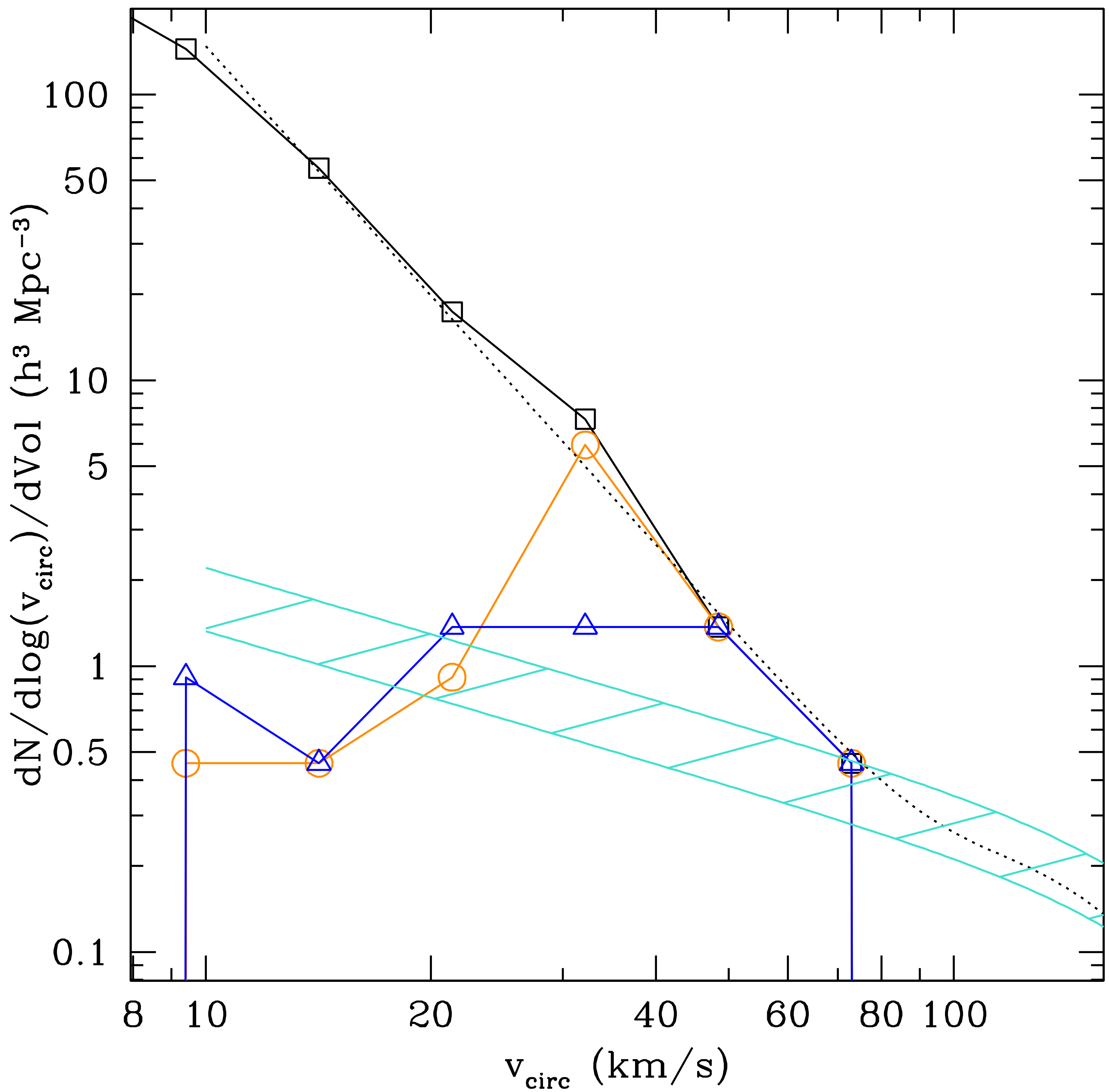
weak feedback (SN+RP):

squares = DM halos
circles = galaxies
triangles = wih cold gas

sensitivity of VF samples:

Klypin+2014: $M_V < -10$

ALFALFA: $M_{HI} > 10^6\ M_{sun}$



the *observed* velocity function

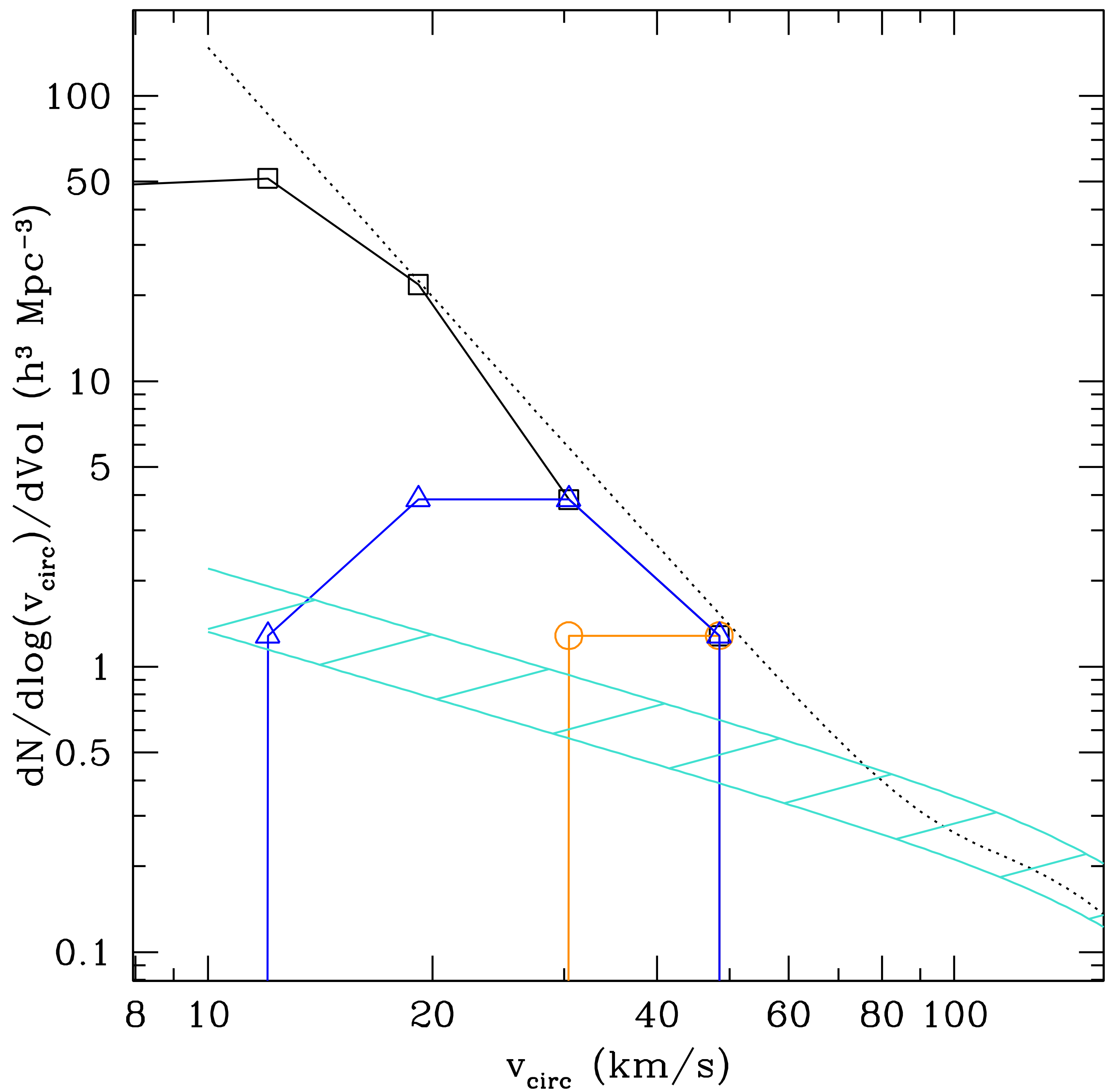
strong feedback (SN+RP+photoheating):

squares = DM halos
circles = galaxies
triangles = wih cold gas

sensitivity of VF samples:

Klypin+2014: $M_V < -10$

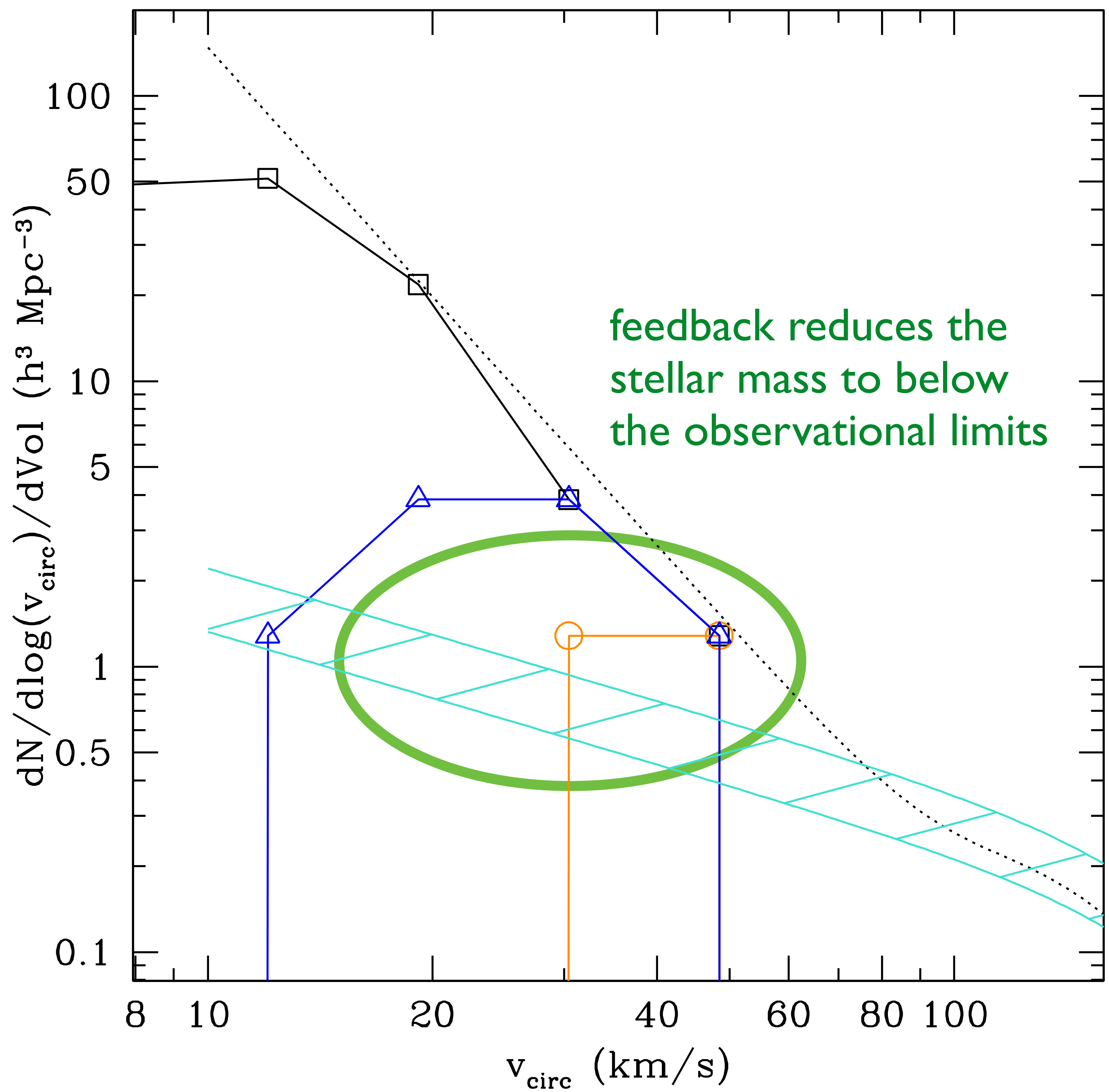
ALFALFA: $M_{HI} > 10^6\ M_{sun}$



the *observed* velocity function

strong feedback (SN+RP+photoheating):

squares = DM halos
circles = galaxies
triangles = wih cold gas



sensitivity of VF samples:

Klypin+2014: $M_V < -10$

ALFALFA: $M_{HI} > 10^6\ M_{sun}$

Conclusions

Stellar feedback *(constrained by ISM observations)* is essential in the evolution of the smallest galaxies:

1. *regulates galaxy SFR (especially at high z)*
2. *produces galaxies that match many observational constraints: SFH, rotation curve, central cores, bulgeless disks*
3. *stellar feedback controls assembly of the smallest galaxies ~ 10 km/s*
4. *feedback from stellar photo-heating reduces the "observed" abundance of 20-50 km/s dwarfs and may be key to solving field abundance problem*

need to move towards including baryons in simulations

&

towards "observations" of simulations

thank you