stellar feedback and observational signatures of accretion and outflows

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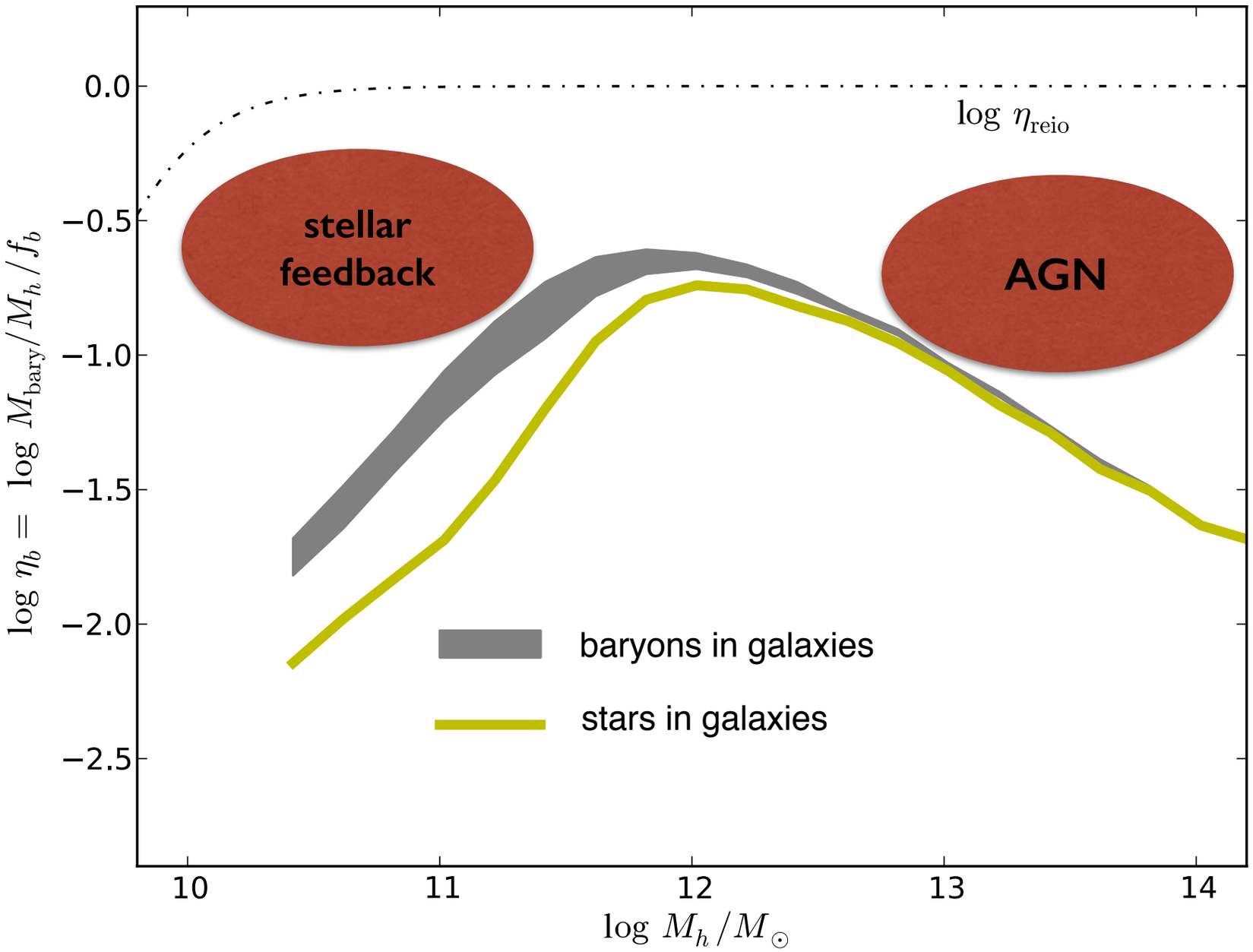
with
A. Klypin, D. Ceverino, K. Arraki, P. Colin, J. Primack, E. Klimek, C. Churchill, J. Vander Vliet

STG et al. (in prep.)
Churchill, Vander Vliet, STG+2015, ApJ, 802, 10
STG+2015, MNRAS, 446, 1140
Ceverino, Klypin, Klimek, STG+2014, MNRAS, 442, 1545

IGM@50 - Spineto, June 2015

the observed baryon content of haloes in CDM

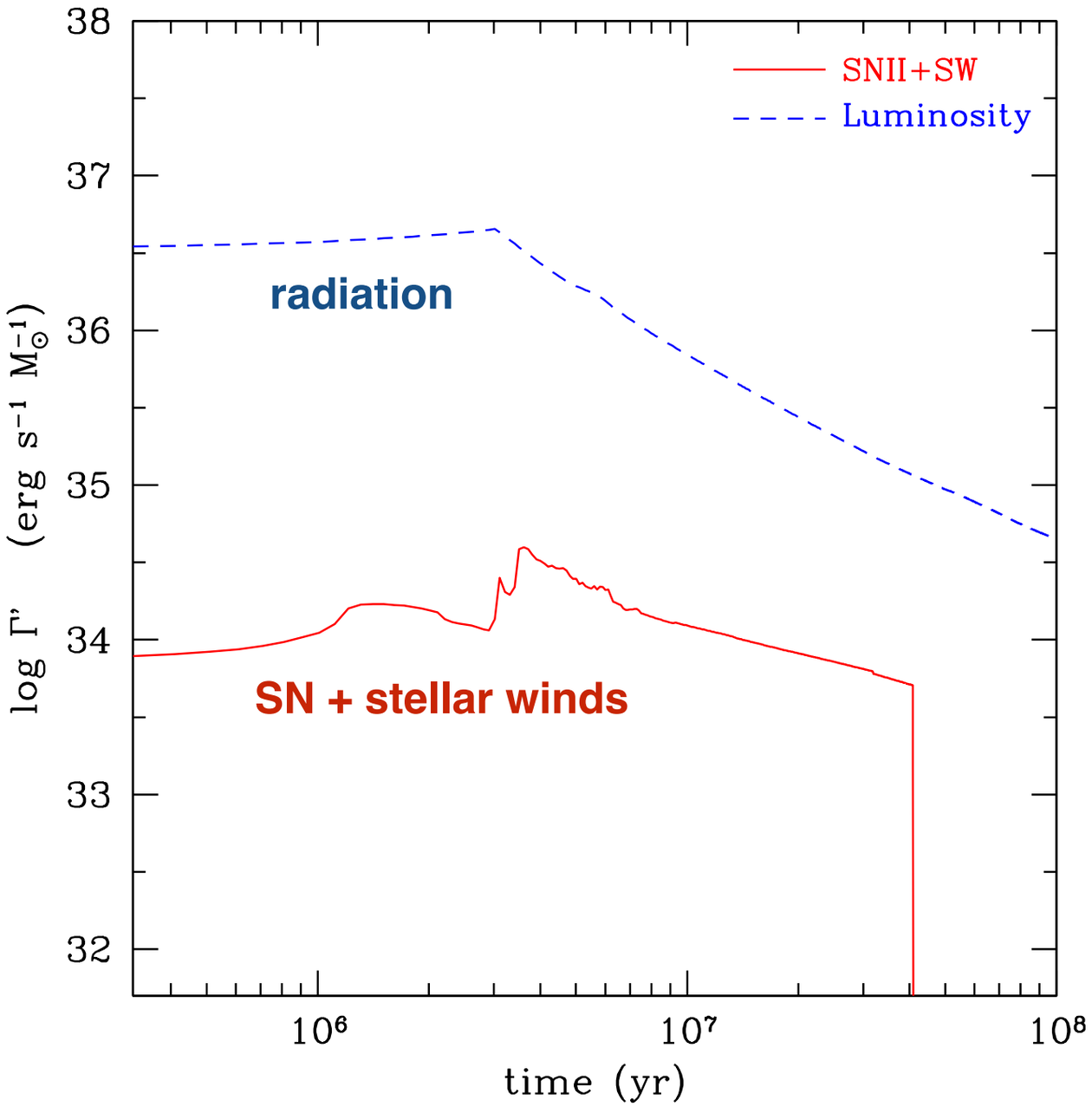


Papastergis+2012

if feedback regulates galaxy growth, does it produce the outflows we observe in real galaxies?

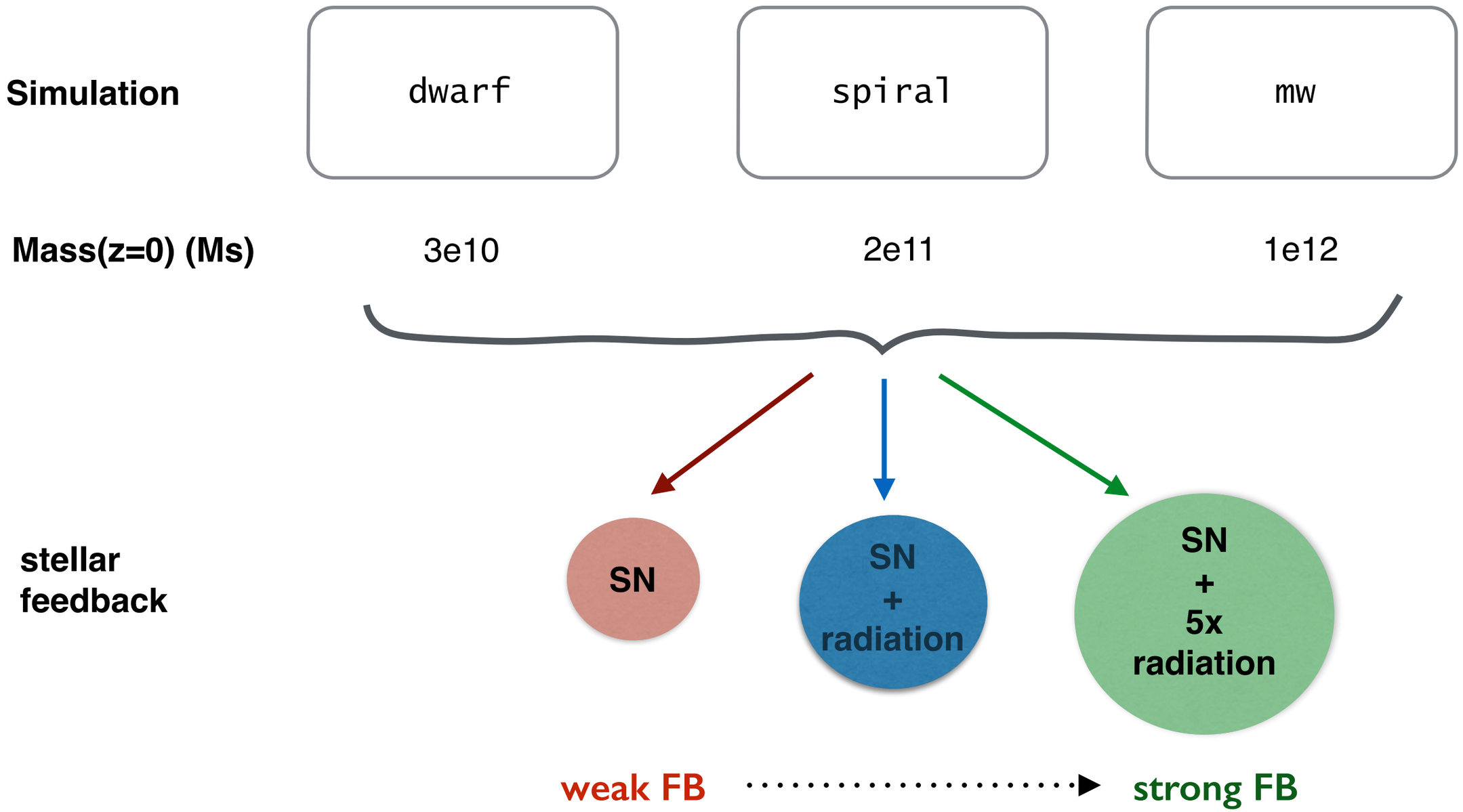
which effects of stellar feedback are robust?

stellar evolution models and observations *constrain* feedback



standard stellar evolution models ***provide the maximum*** energy and momentum that could couple to ISM

The experiments



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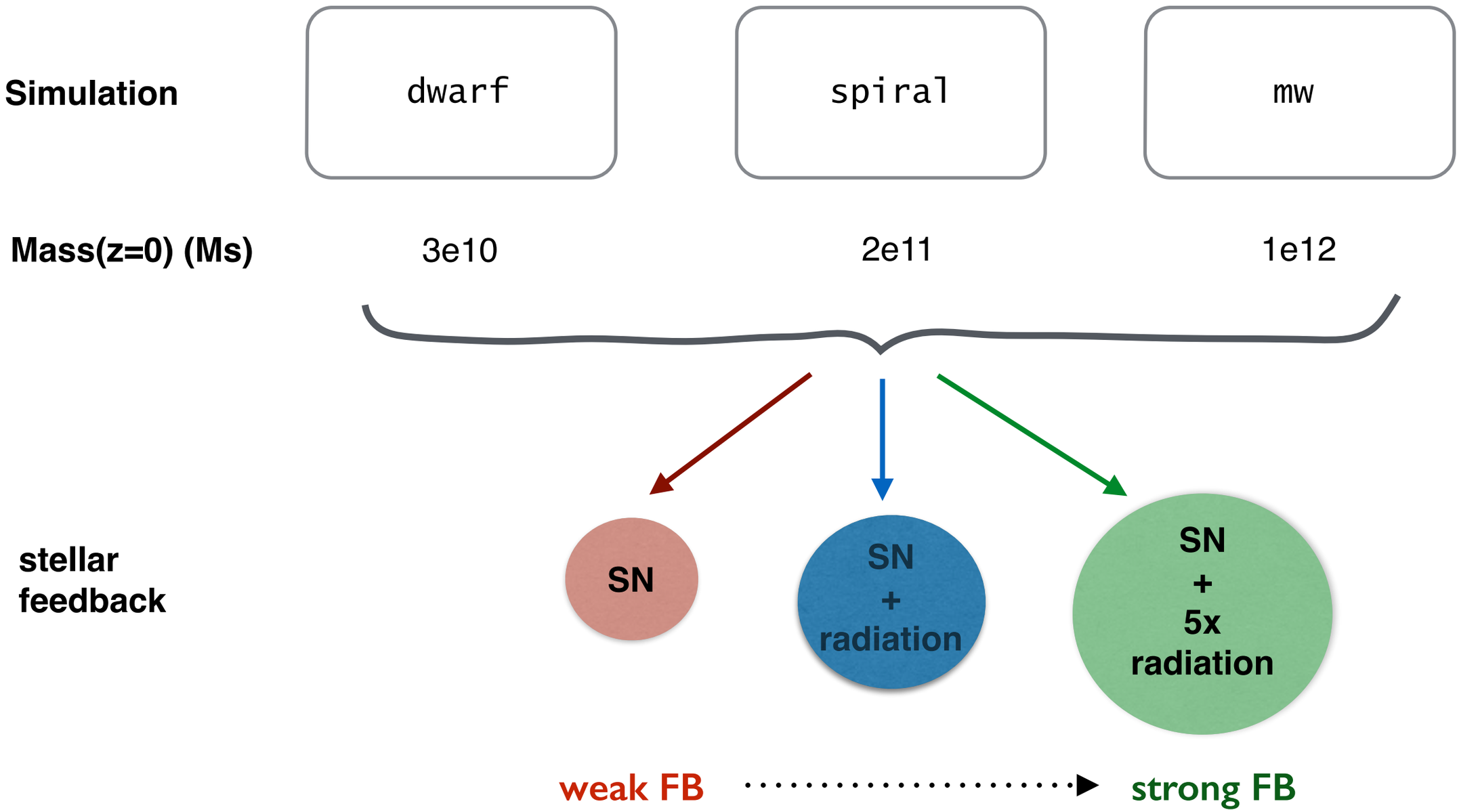
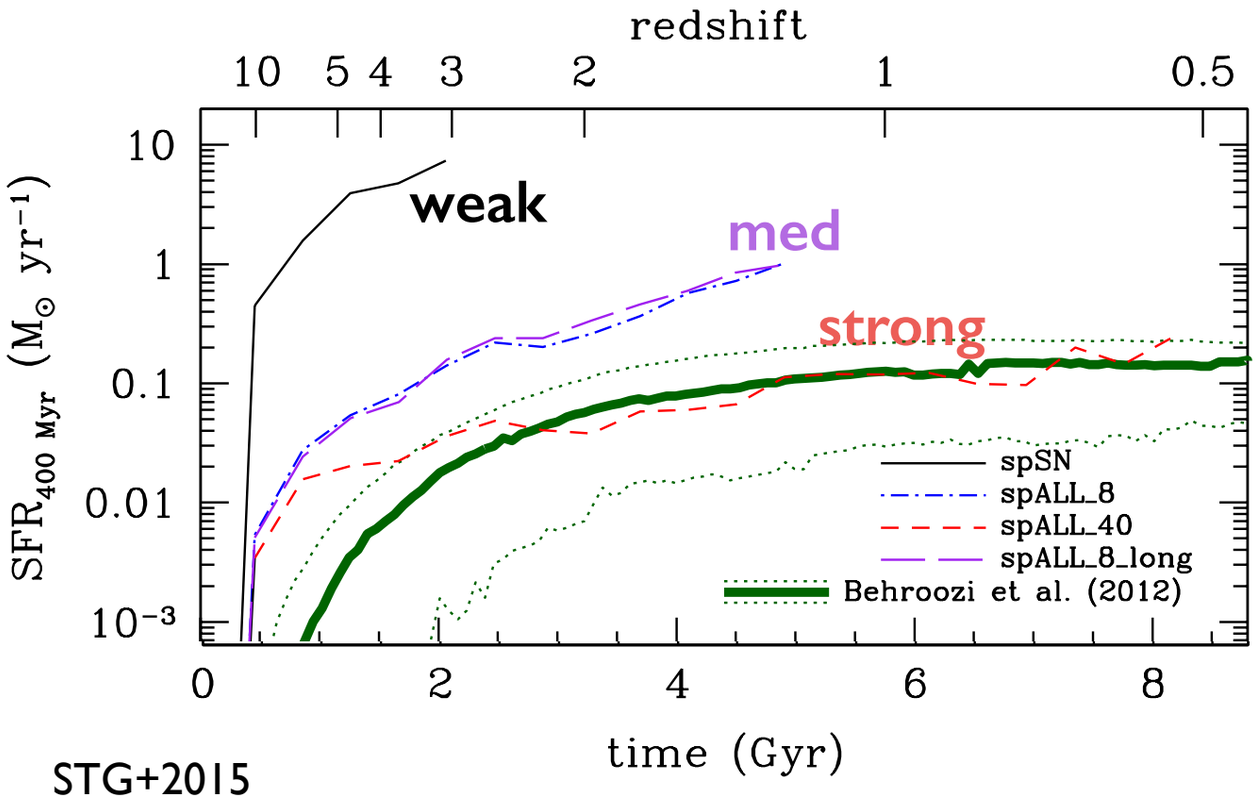


NO fine-tuning to produce realistic galaxies

The goal is to explore the effect of various feedback models on galactic winds

SN+radiation reduces SFR and prevents bulge

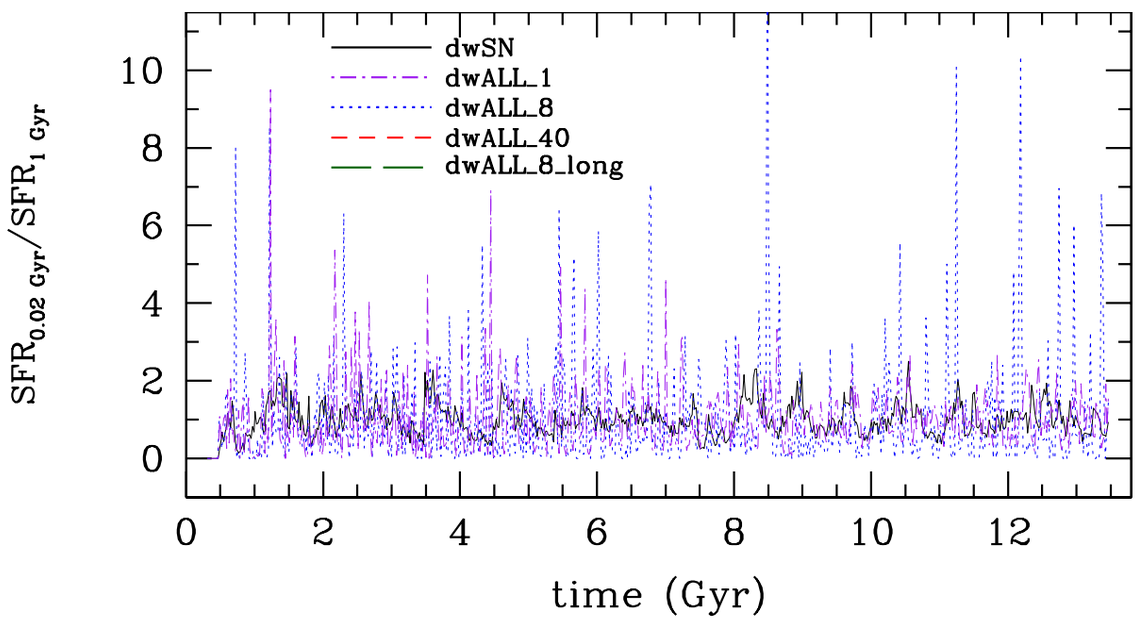
(Trujillo-Gomez+2015, MNRAS, 446, 1140)



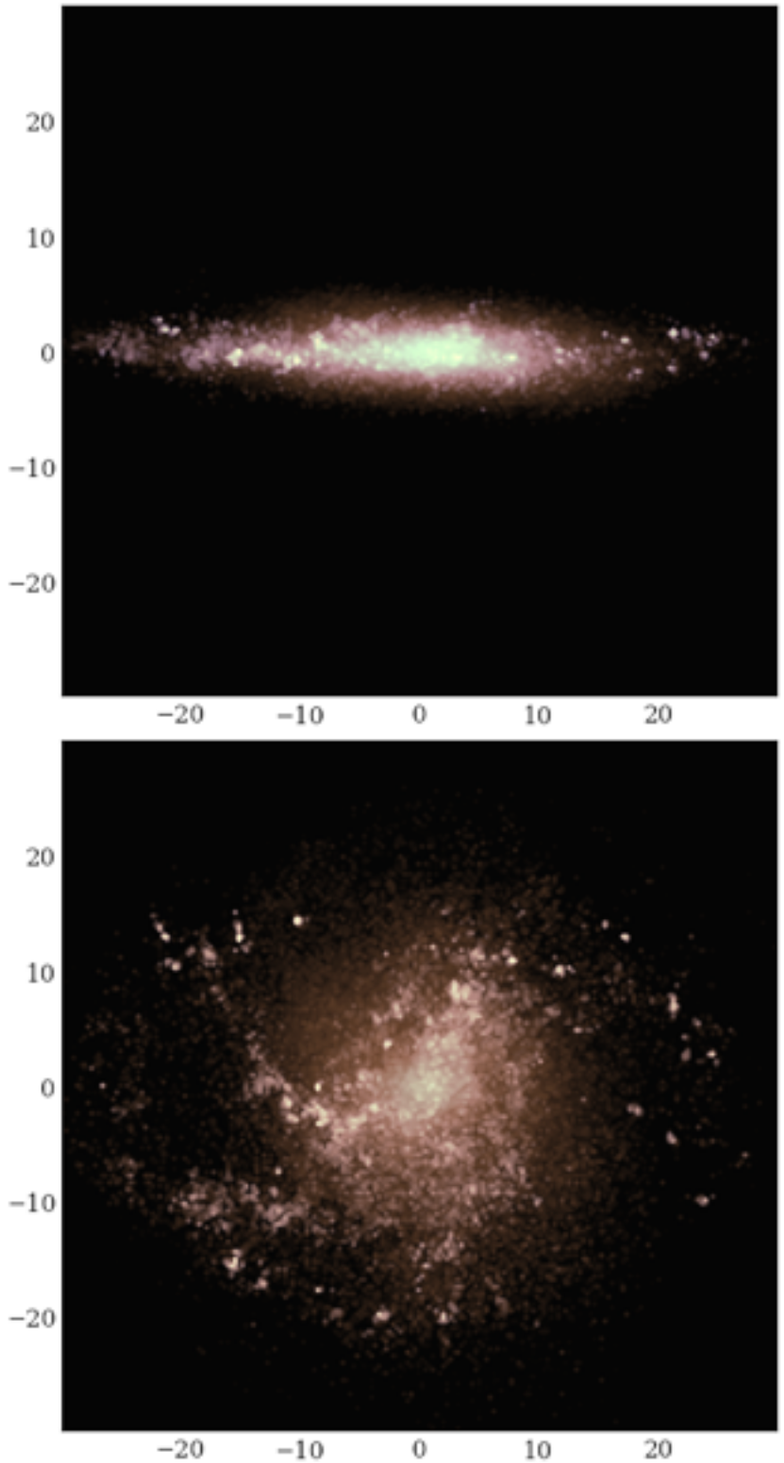
STG+2015

SF history brackets observational constraints

bursty SF arises from regulation due to strong feedback

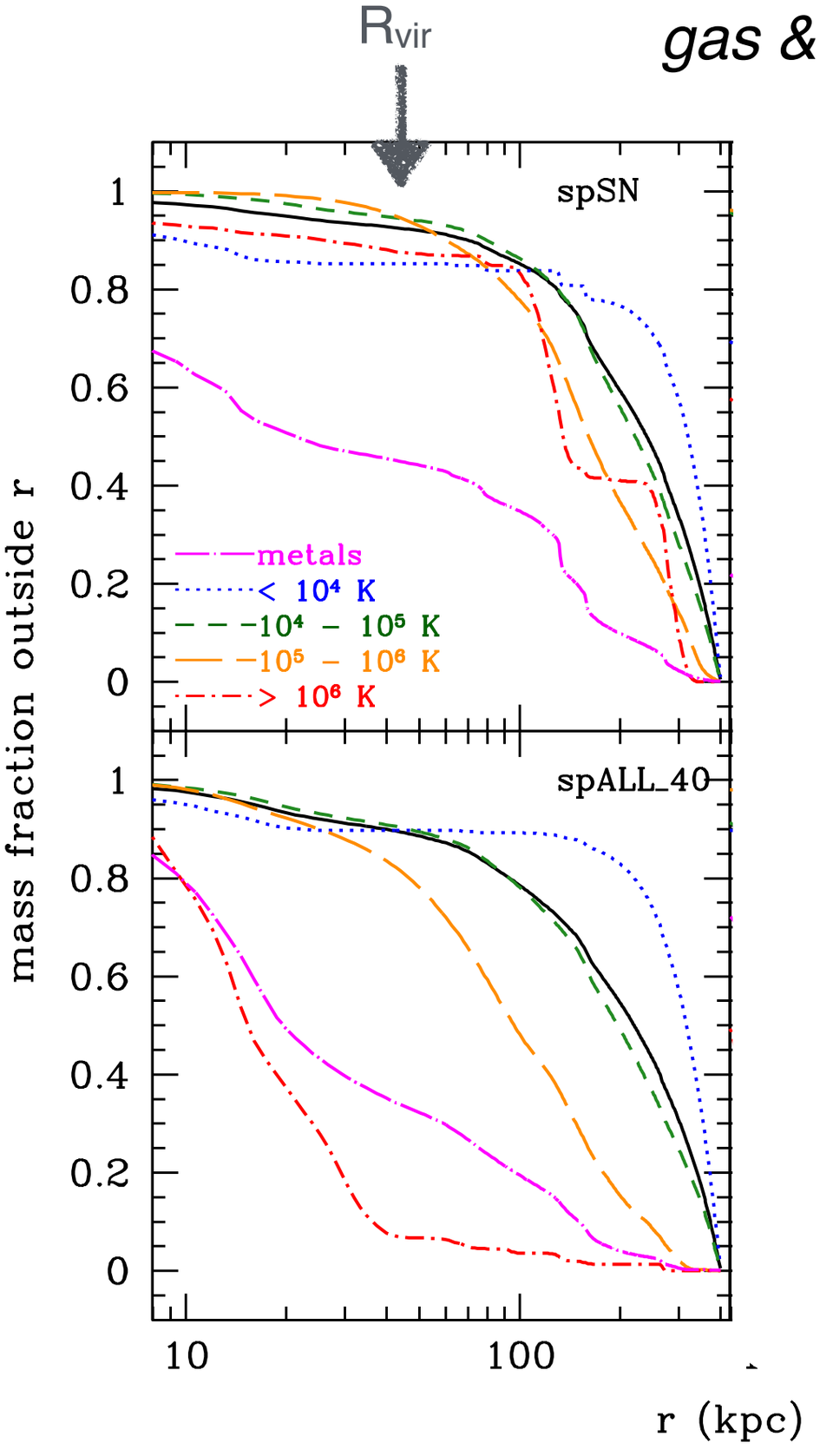


strong FB: ***bulgeless LSB spiral***



STG+2015

gas & metals in the halo



weak FB

strong FB

gas profile is robust to feedback variations but hot and warm gas are more abundant near the galaxy

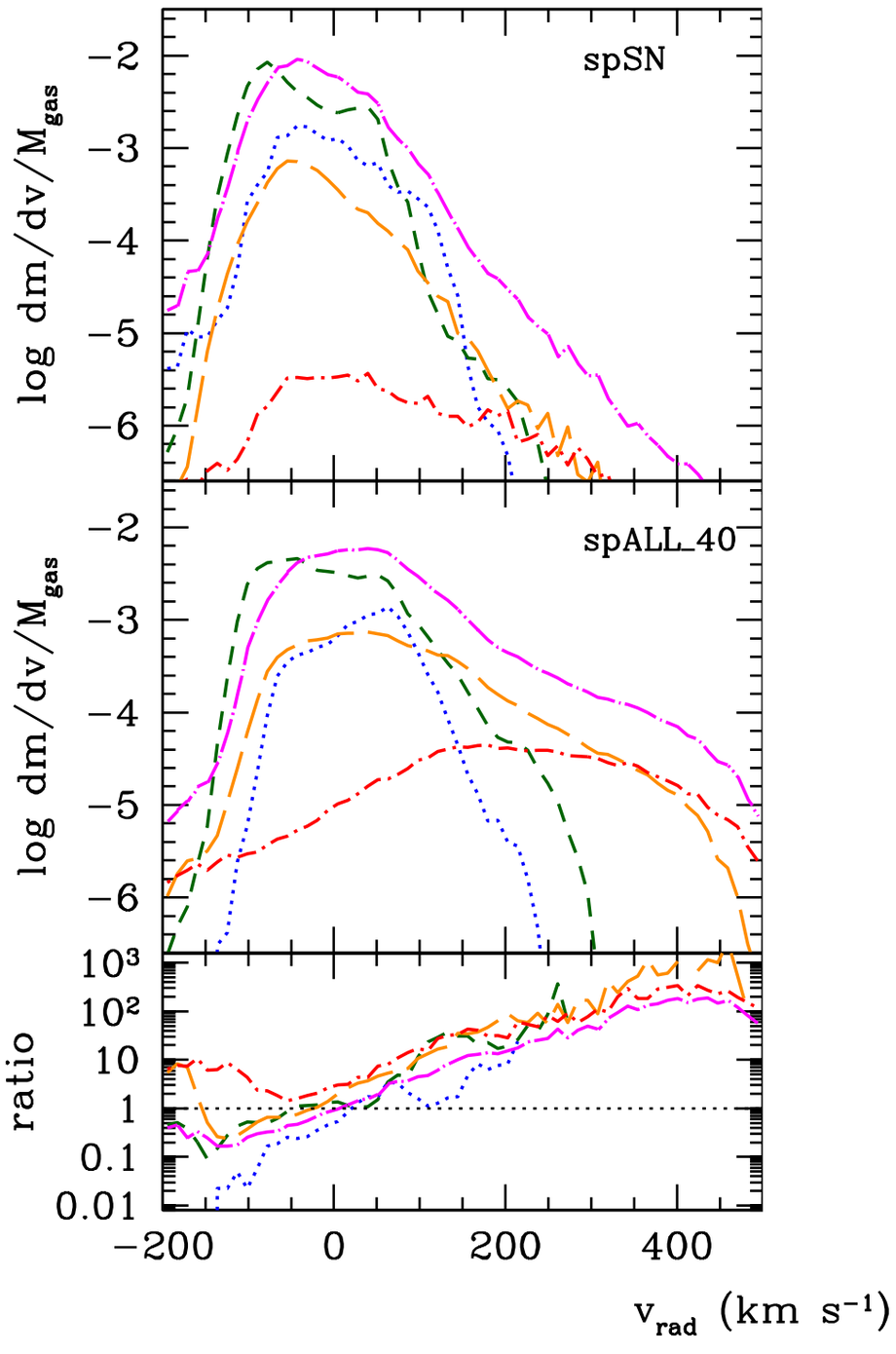
what is the halo gas doing?

CGM (10kpc < r < R_{vir}) at z=2

weak FB

strong FB

weak/strong



distribution is not peaked at v=0 ->
gas is permanently infalling (not supported)

strong feedback increases mass in the high velocity tail of the halo

RF ejects more cold gas & reduces the accretion of cold gas and metals at any epoch (recycling)

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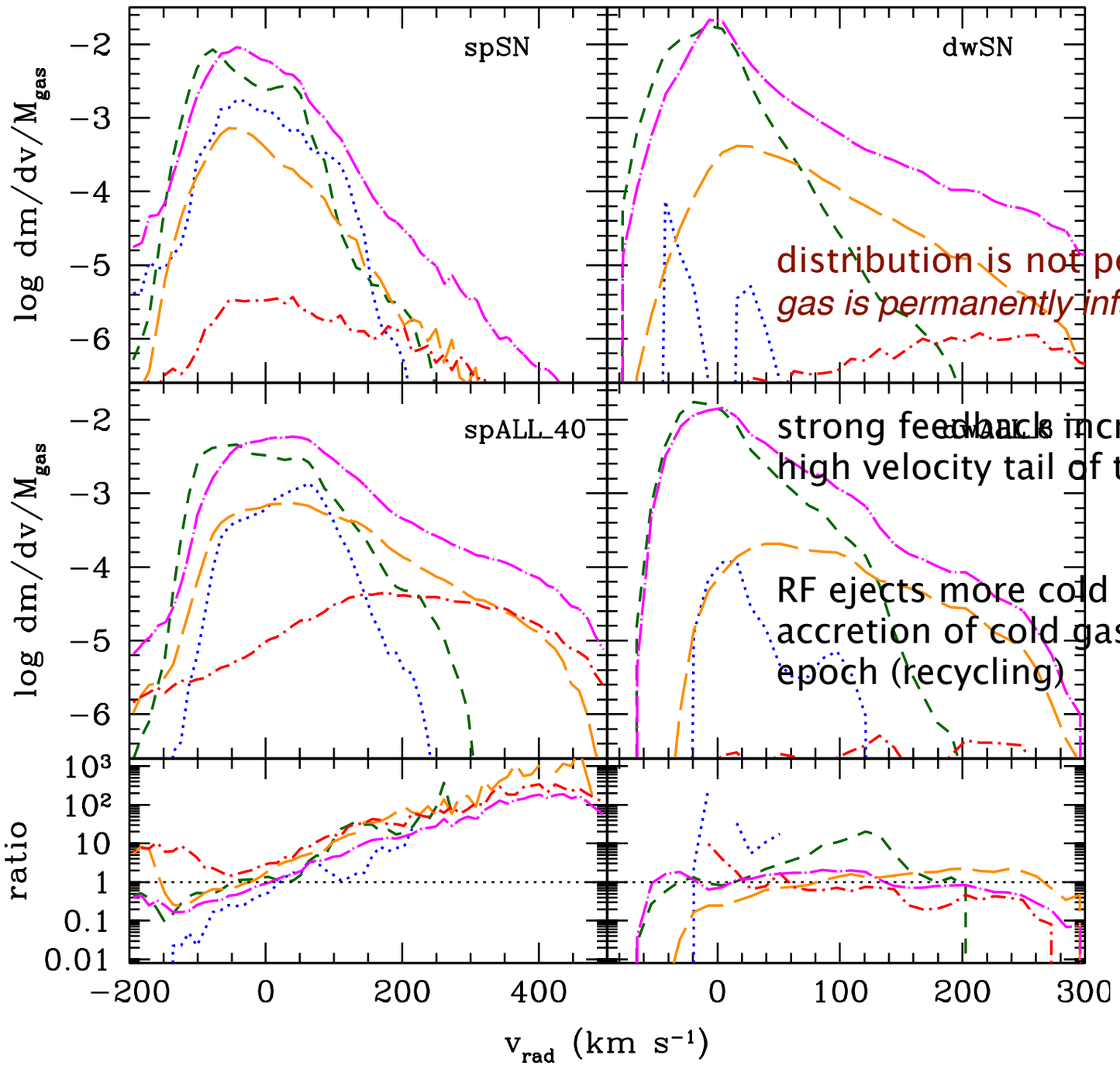

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how efficient are galactic winds?

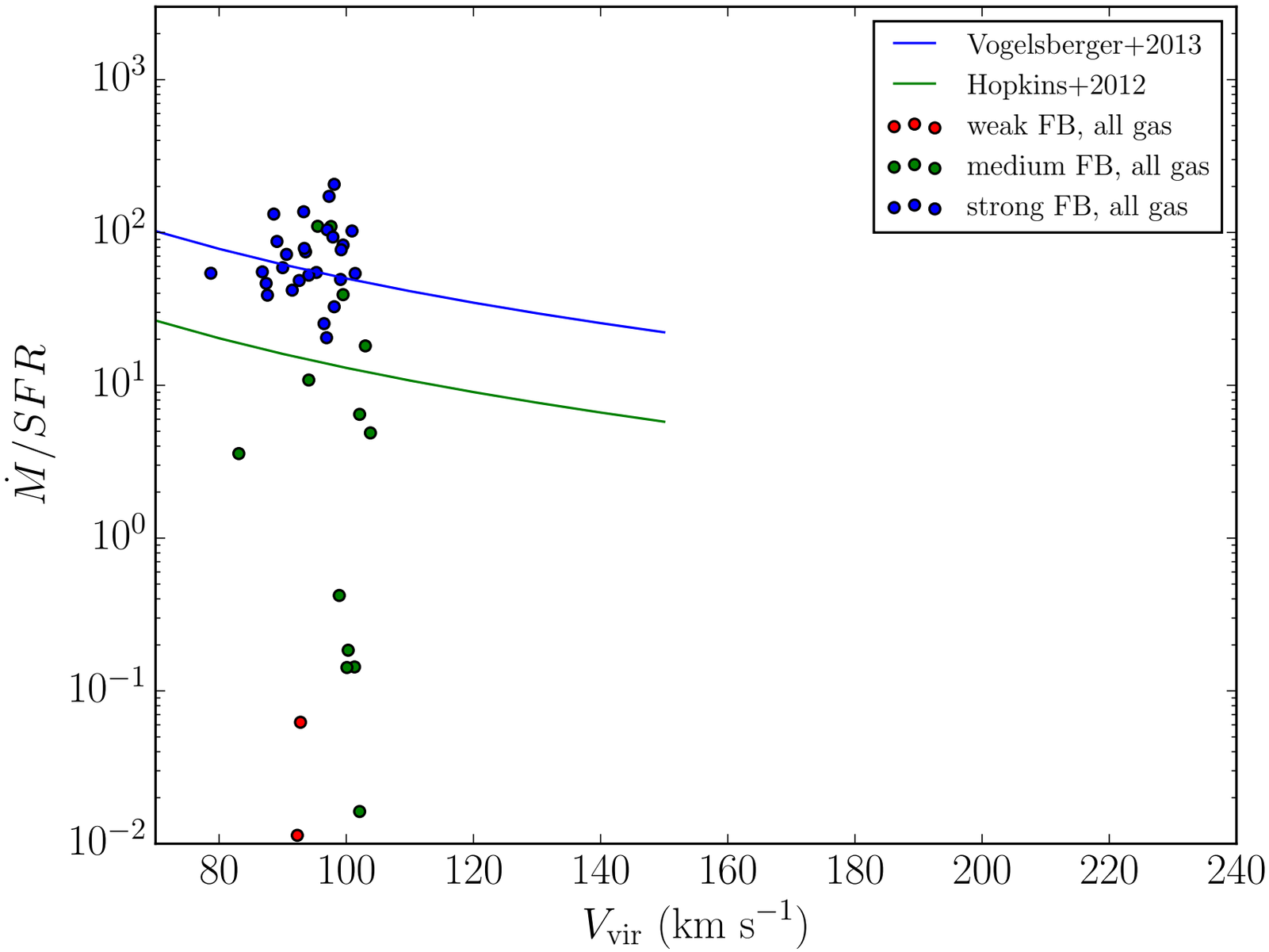
the "Bouche plot"

mass-loading: outflow mass/SFR

weak FB

med FB

strong FB



regulation of SFR results in mass-loaded winds
consistent with other simulations

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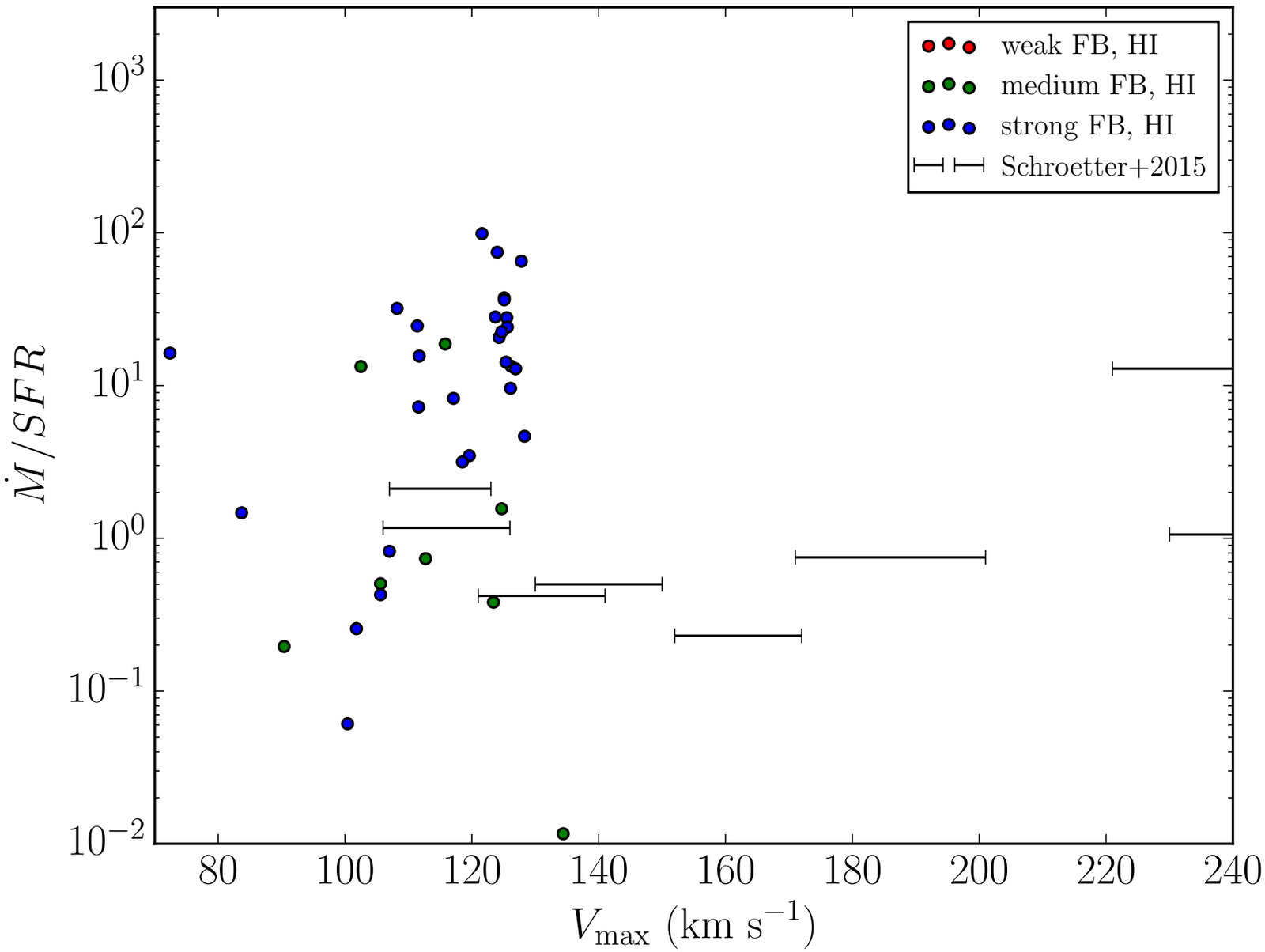

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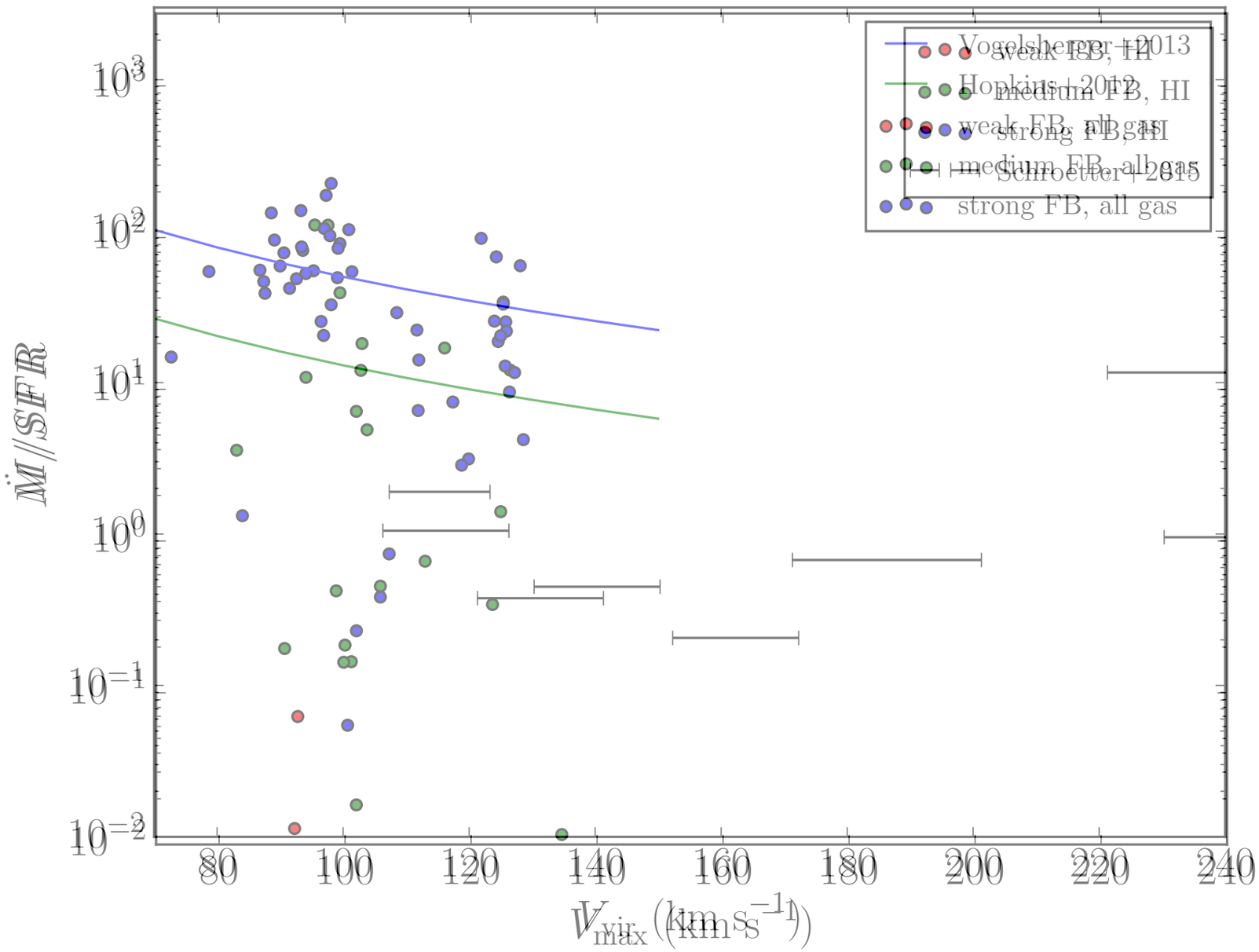

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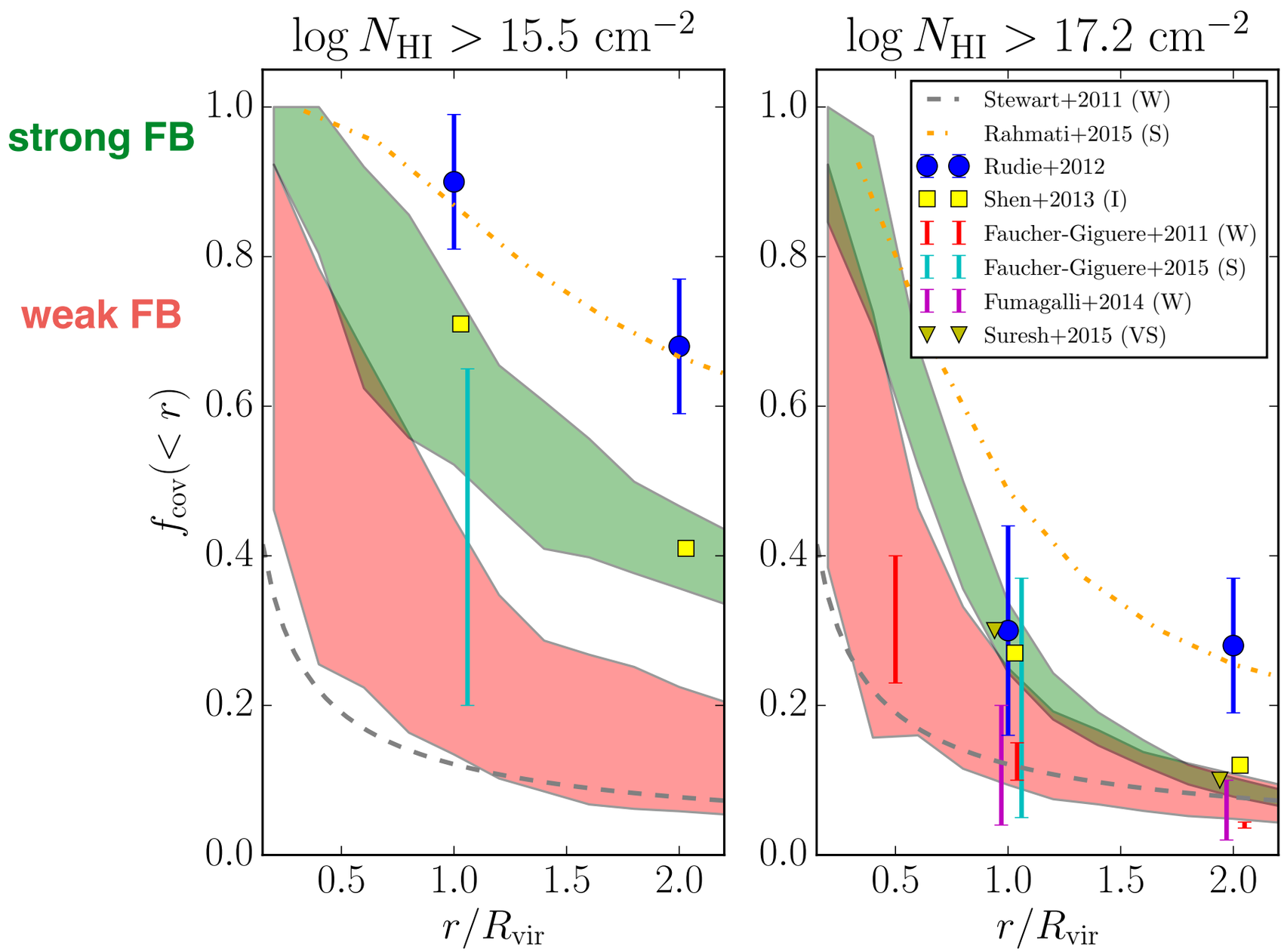
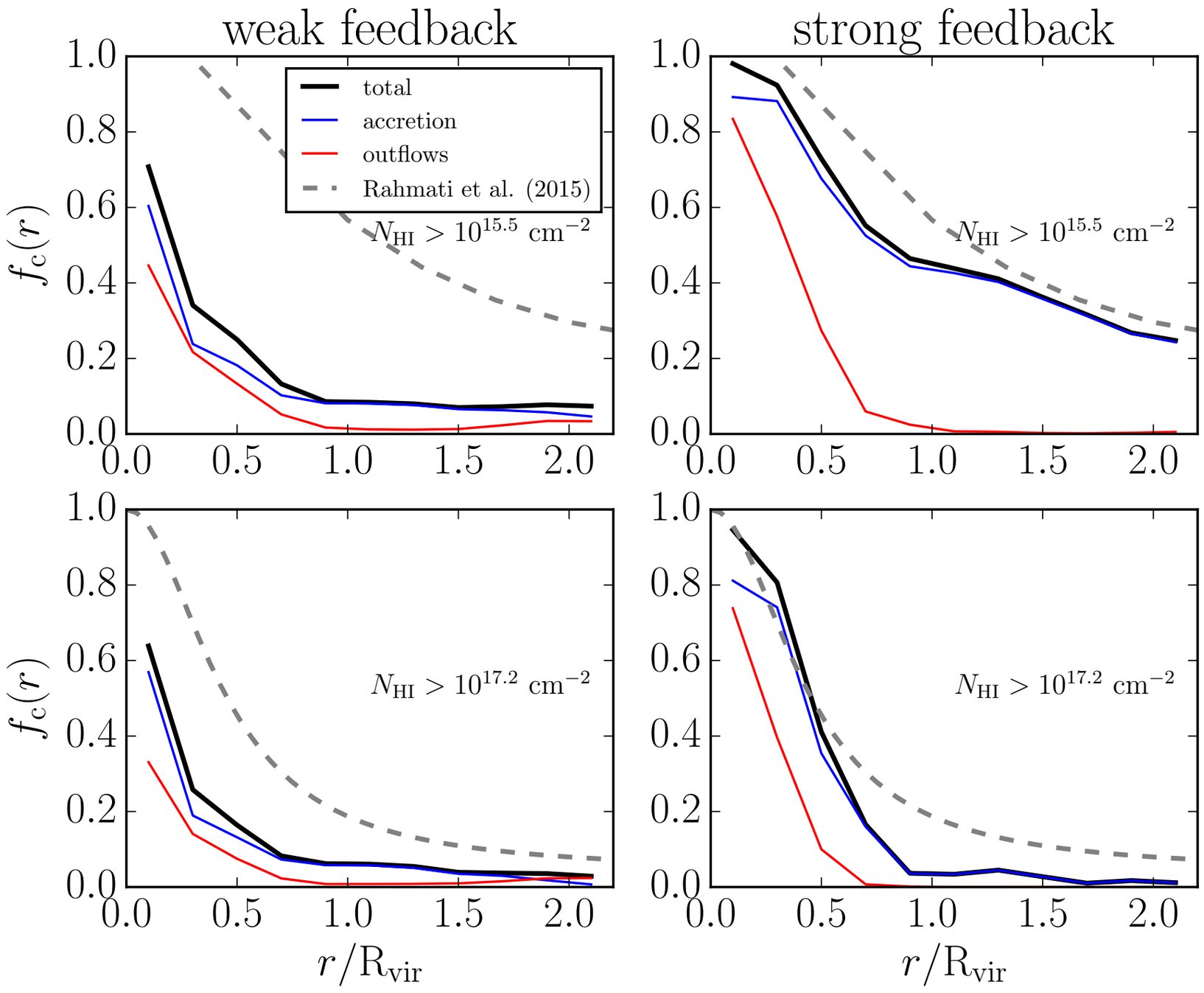
abundance of neutral hydrogen around galaxies



data (Rudie+2012)

all simulations with strong feedback reproduce observed abundance of cold gas out to 2Rvir

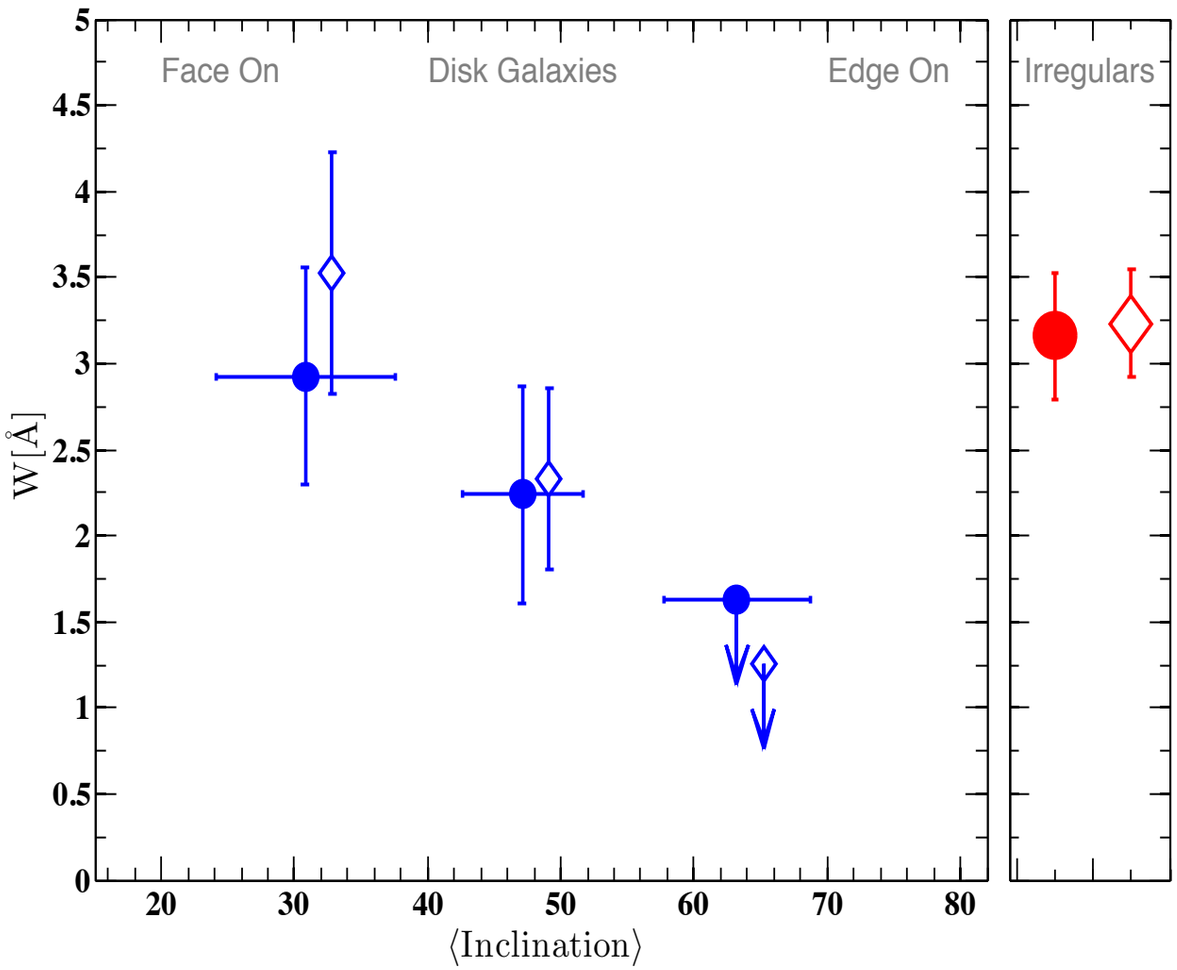
neutral fraction calculated using Rahmati+2013 radiative transfer fit and Haardt & Madau 2012 UV background.



population and orientation scatter is larger than discrepancy between various simulations

increase comes from the halo fountain: diffuse outflows cool and return to the galaxy as dense neutral gas

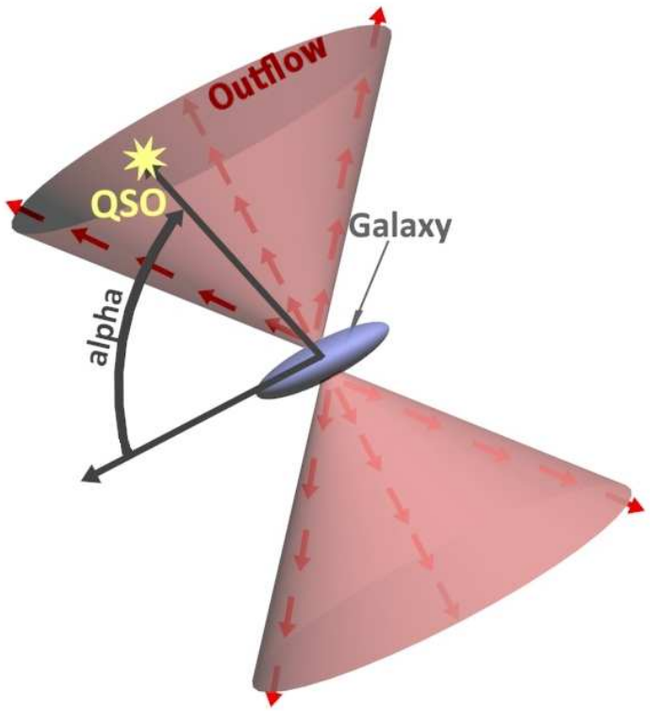
can we detect accretion and winds?



winds are detected in individual galaxies and statistically along minor axis in low ionisation absorption

(Chen+2010, Bordoloi+2011, Kacprzak +2011, Bouche+2012, Bordoloi+2014, Rubin+2014, Schroetter+2015)

detection of cold accretion and winds in a spiral galaxy at 0 < z < 1



N. Lehner will confirm this for HI

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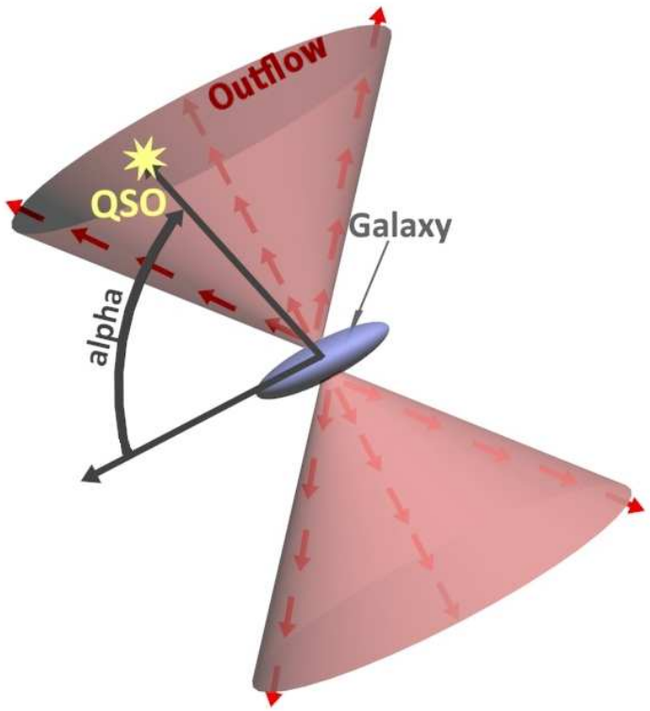

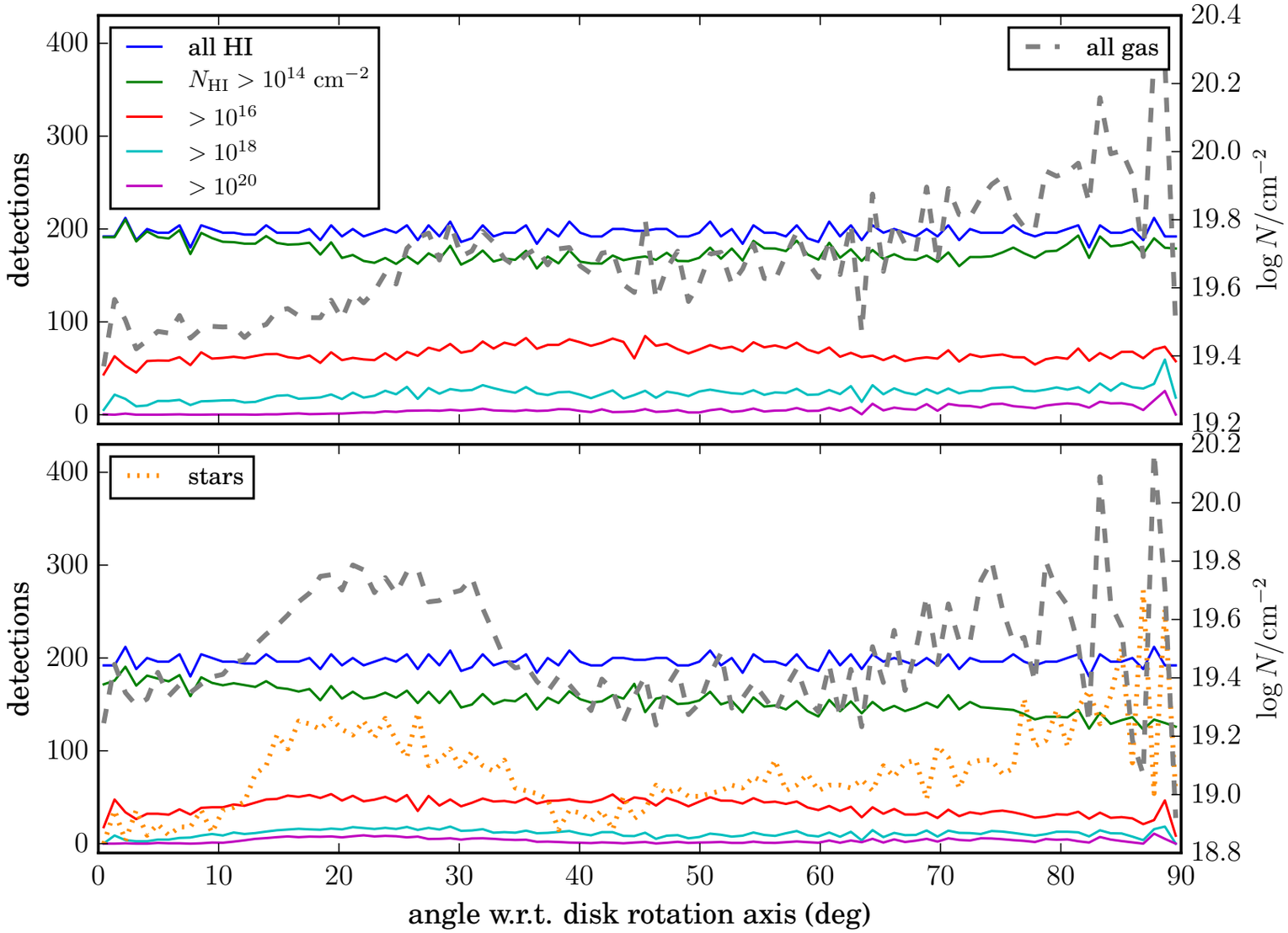

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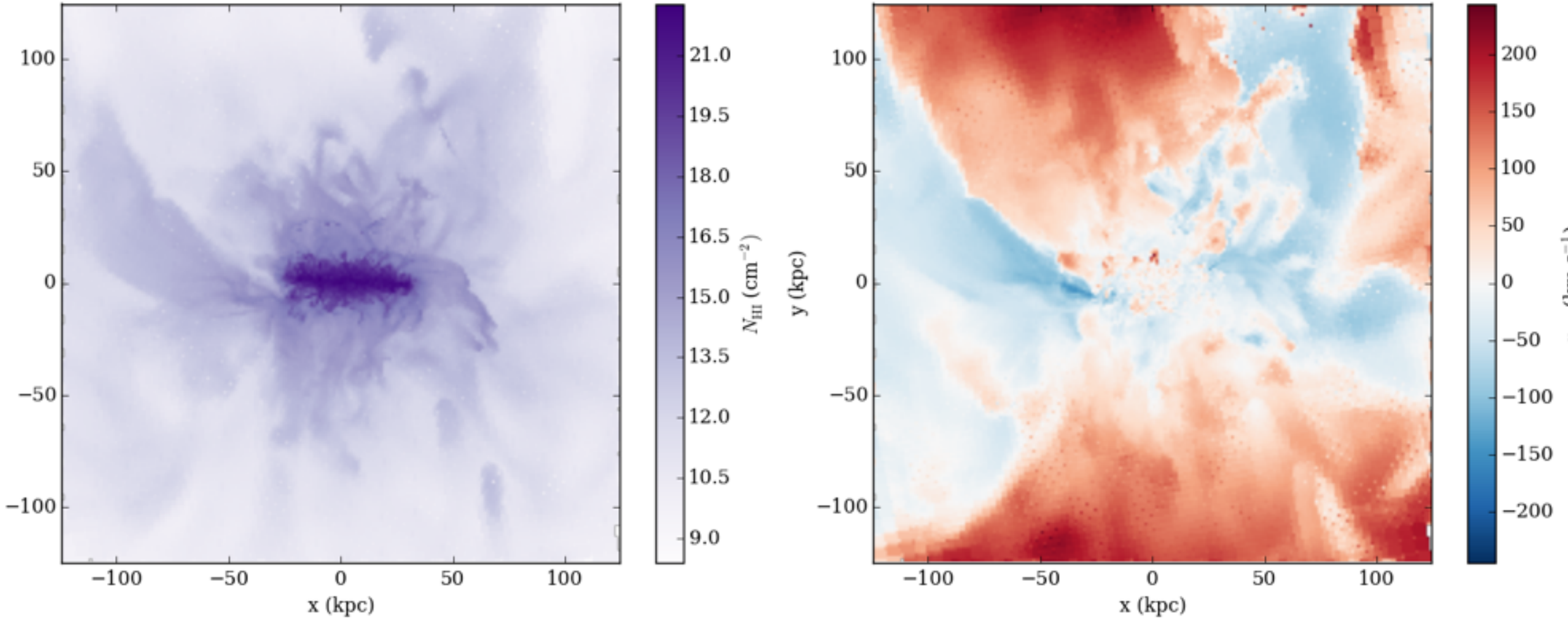
no azimuthal dependence of the detection of HI at any column density threshold within 100 kpc of the galaxy

neutral fraction calculated using Rahmati+2013 radiative transfer fit and Haardt & Madau 2012 UV background.



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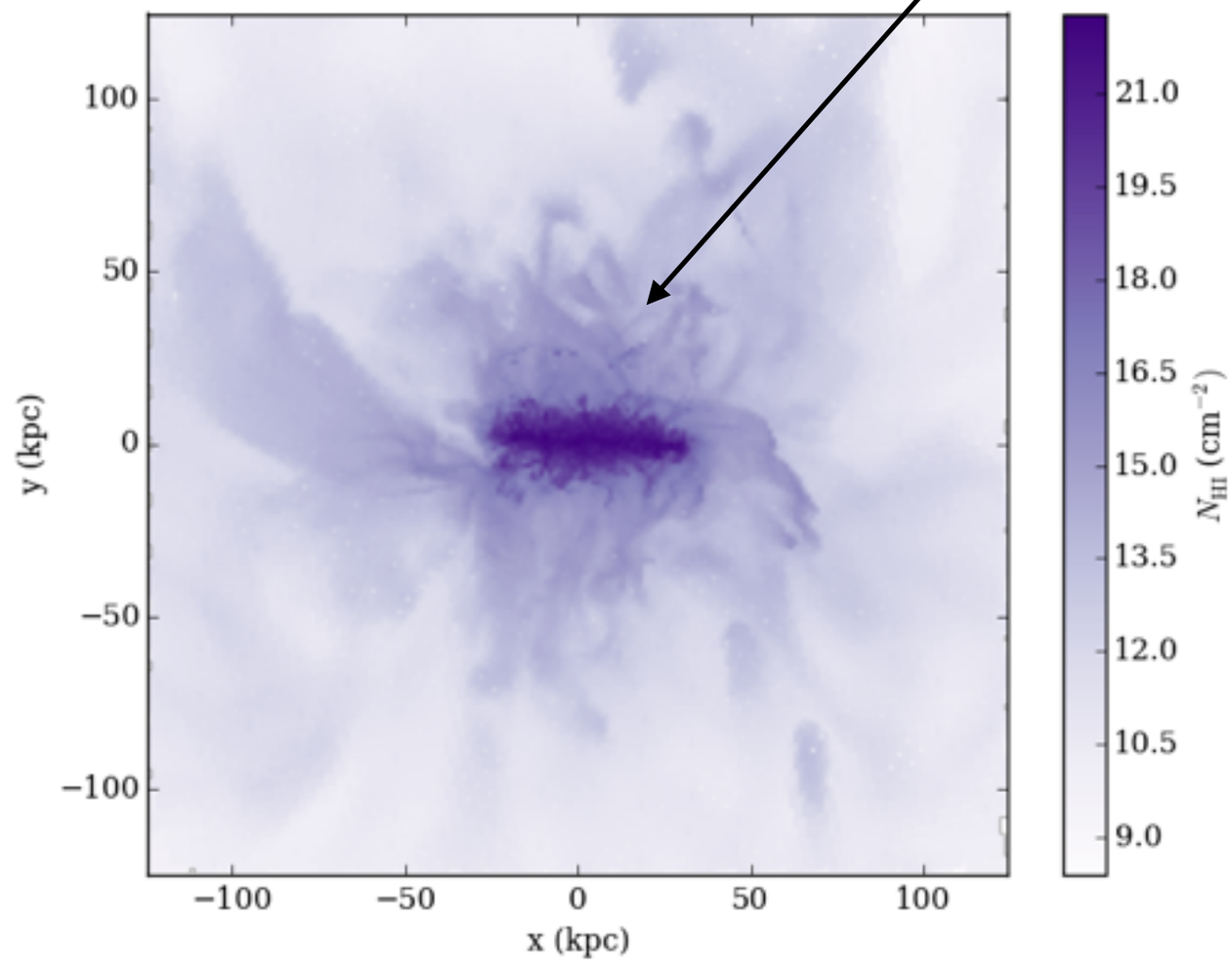
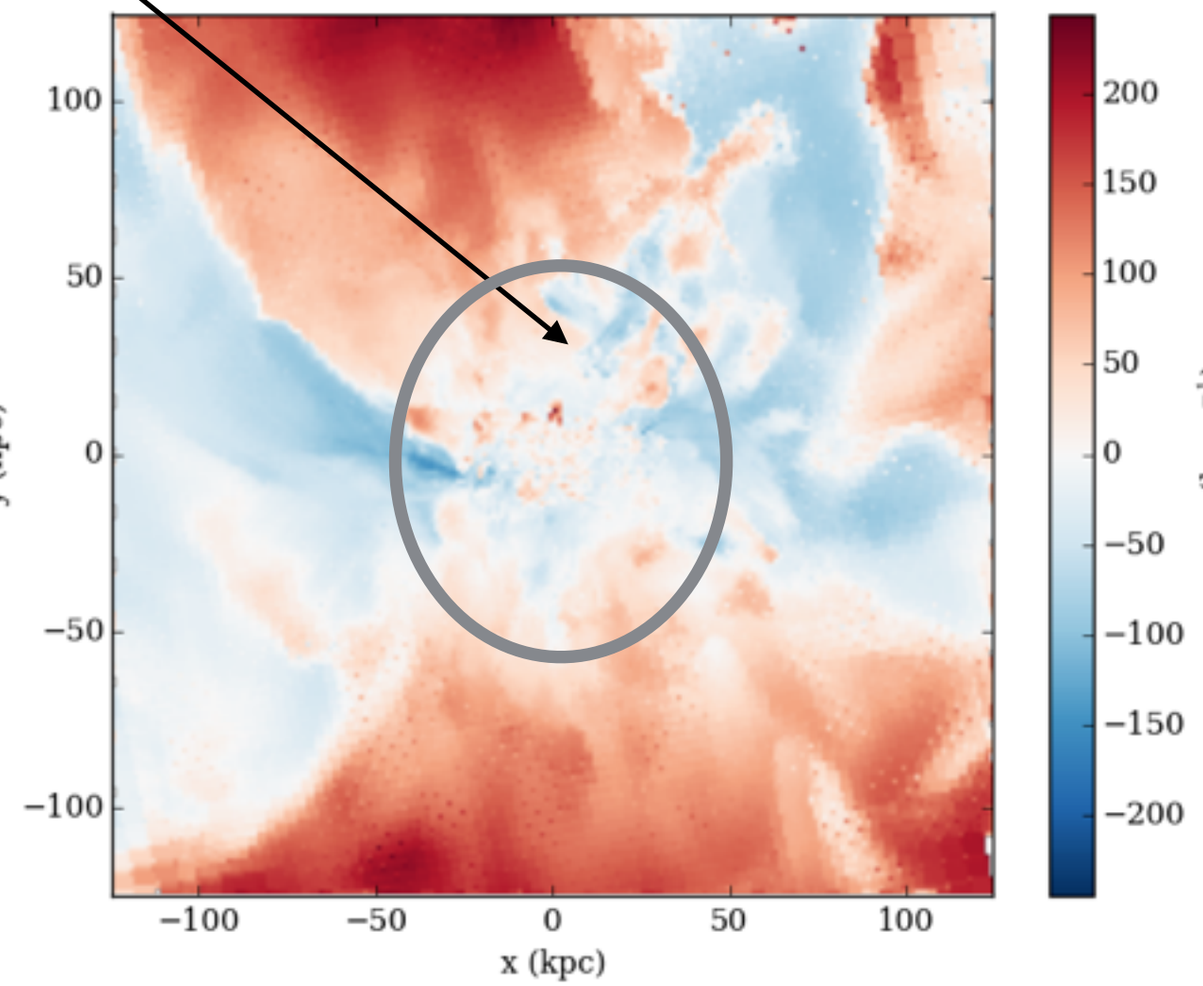
galaxy is surrounded by dense reaccreting material





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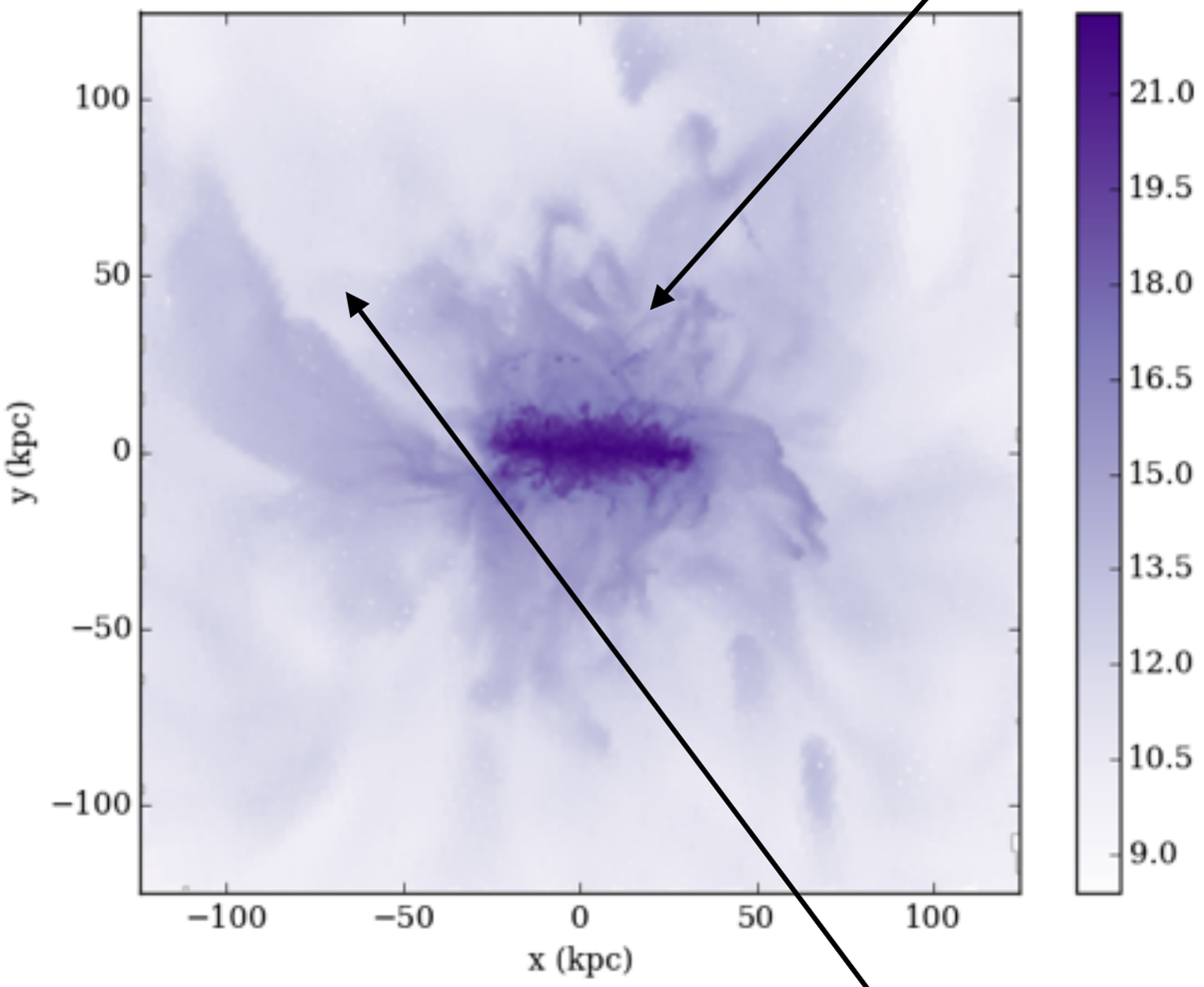

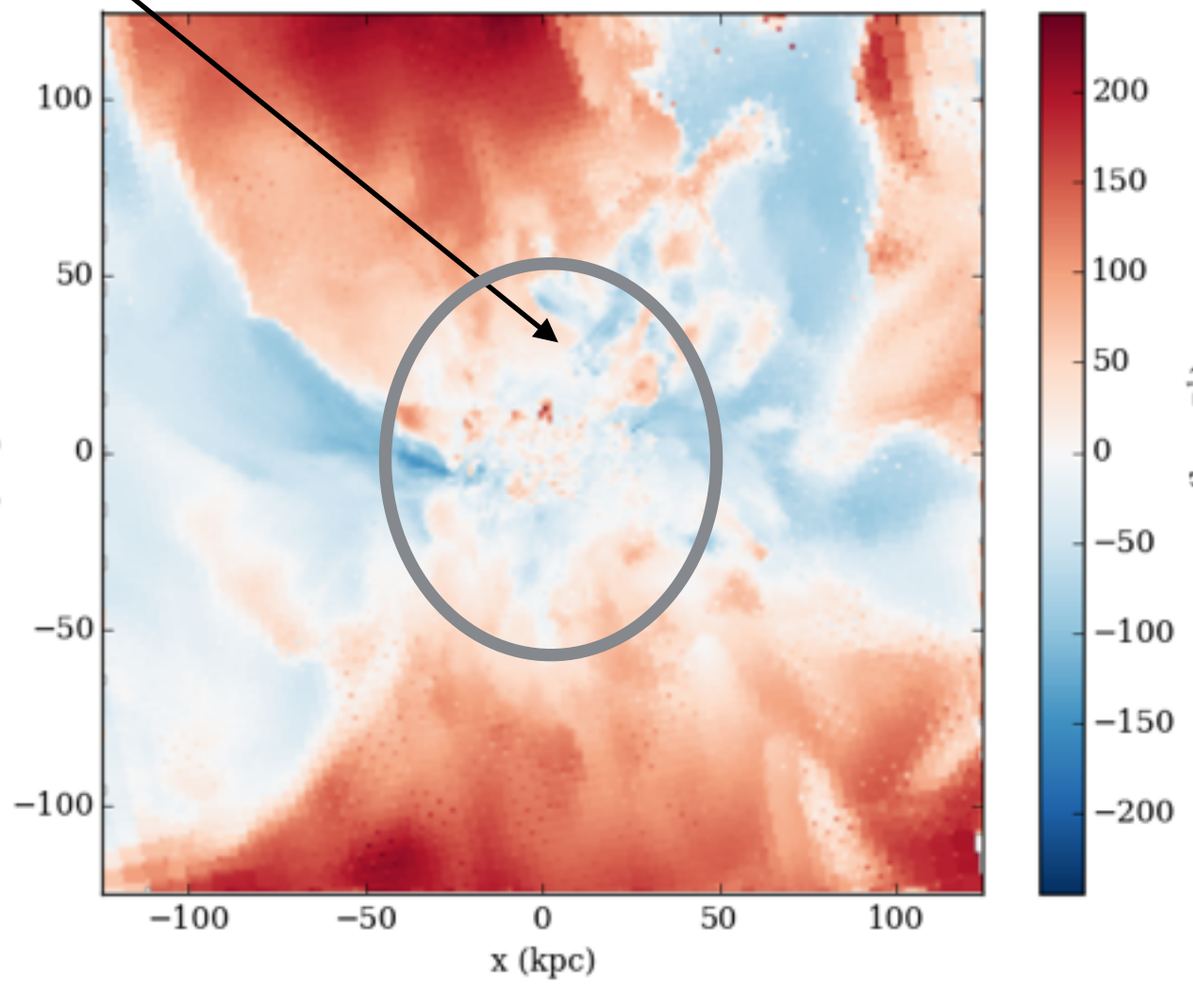

outflows have low column densities due to low density and temperature > 10^4 K

neutral fraction calculated using Rahmati+2013 radiative transfer fit and Haardt & Madau 2012 UV background.

Summary

hydro simulations can provide *robust* constrains on the role of feedback and cosmological accretion:

1. *for any feedback CGM is highly dynamic: gas is not supported*

2. *large energies necessary to regulate SFR at high z, launching massive winds*

3. *all simulations agree: need strong FB to account for HI abundance around galaxies - increase is due to reaccretion of old outflows*

4. *strong FB does not produce observed geometry of accretion/winds - outflows are too tenuous: not detectable in low-ionisation absorption such as HI, MgII, SiII*

Thank You