The Baryon Cycle on FIRE

Tracing Cosmic Inflows, Galactic Outflows, and Gas Recycling in Realistic Environments

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The interplay between local and global processes in galaxies
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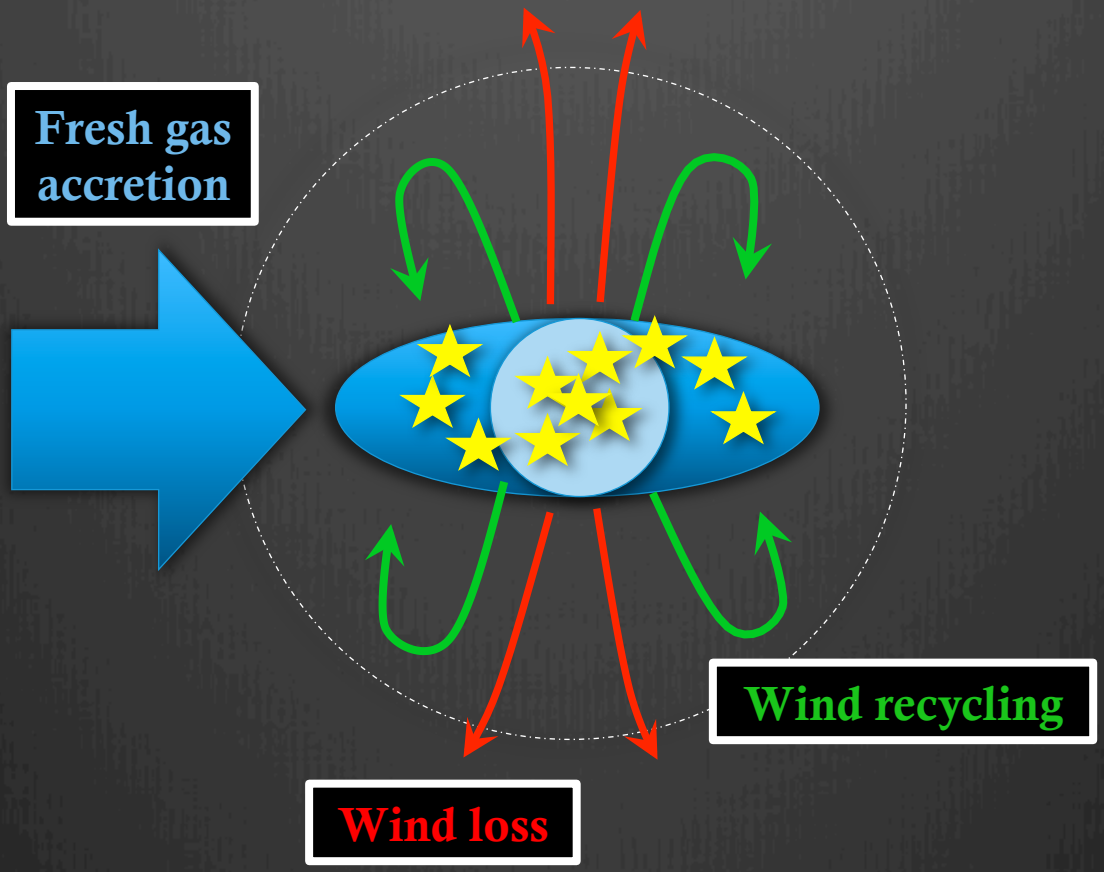
The Baryon Cycle in Galaxy Evolution

...Martin+2005, Erb 2008, Weiner+2009, Steidel+2010, Kornei+2012, Genzel+2011, Dekel+09, Oppenheimer+10, Davé+11,12, Lilly+13, Anglés-Alcázar+14, Shen+14, Muratov+15, Christensen+15,...



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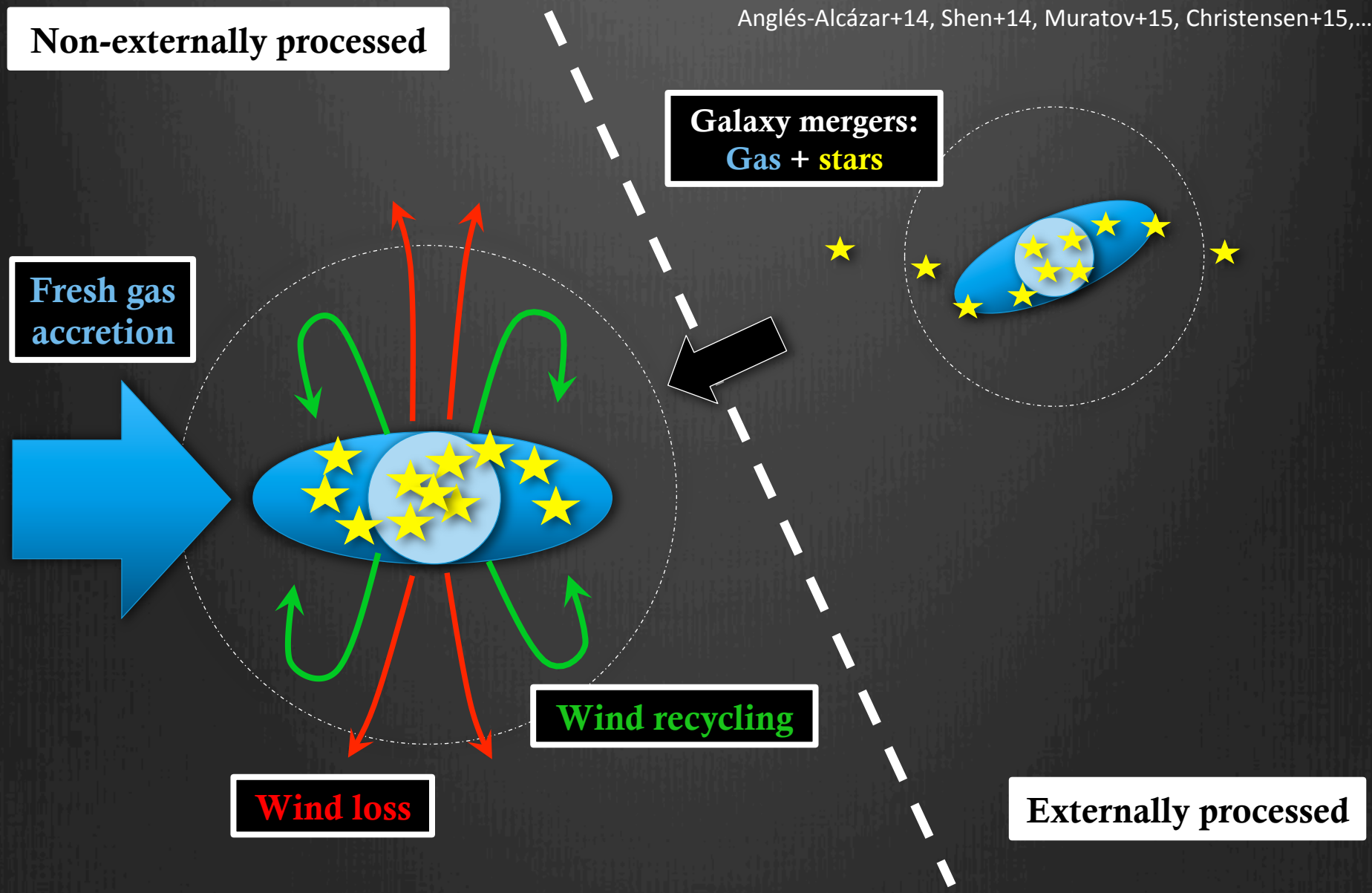

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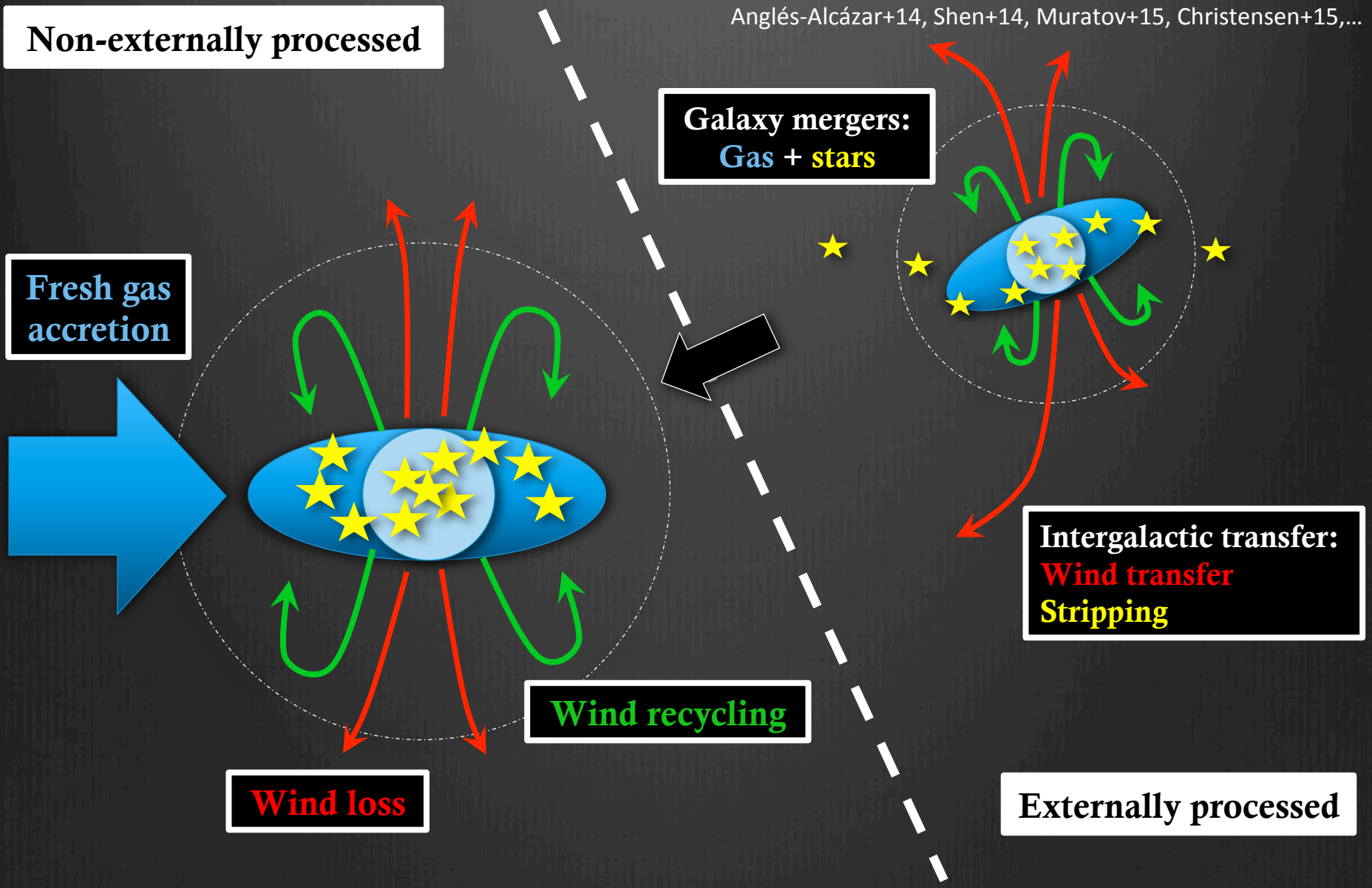
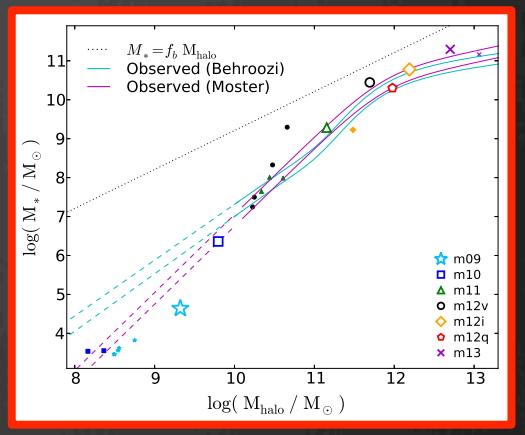


FIRE simulations

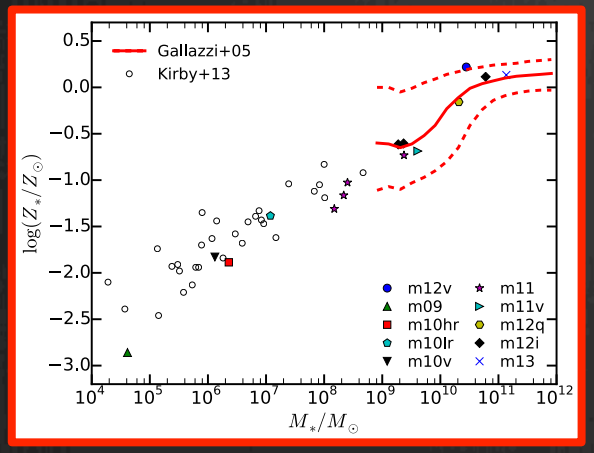
Connecting local and global processes in galaxies

High resolution cosmological zoom simulations with mass, momentum, energy, and metal feedback from stellar population synthesis models

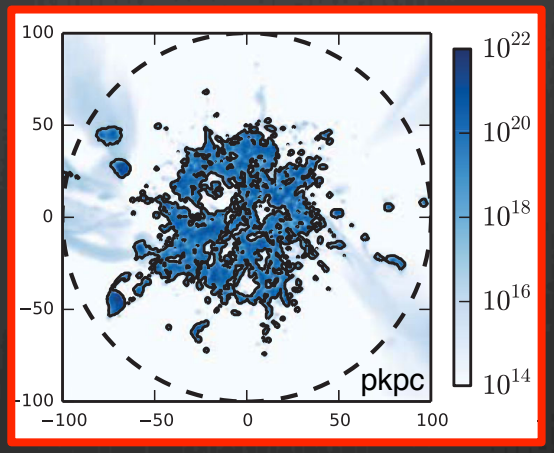
M_{STAR} – M_{HALO} relation: Hopkins+14



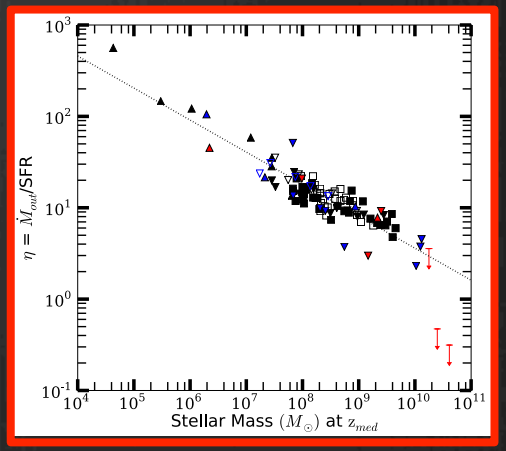
Mass–Metallicity relation: Ma+15



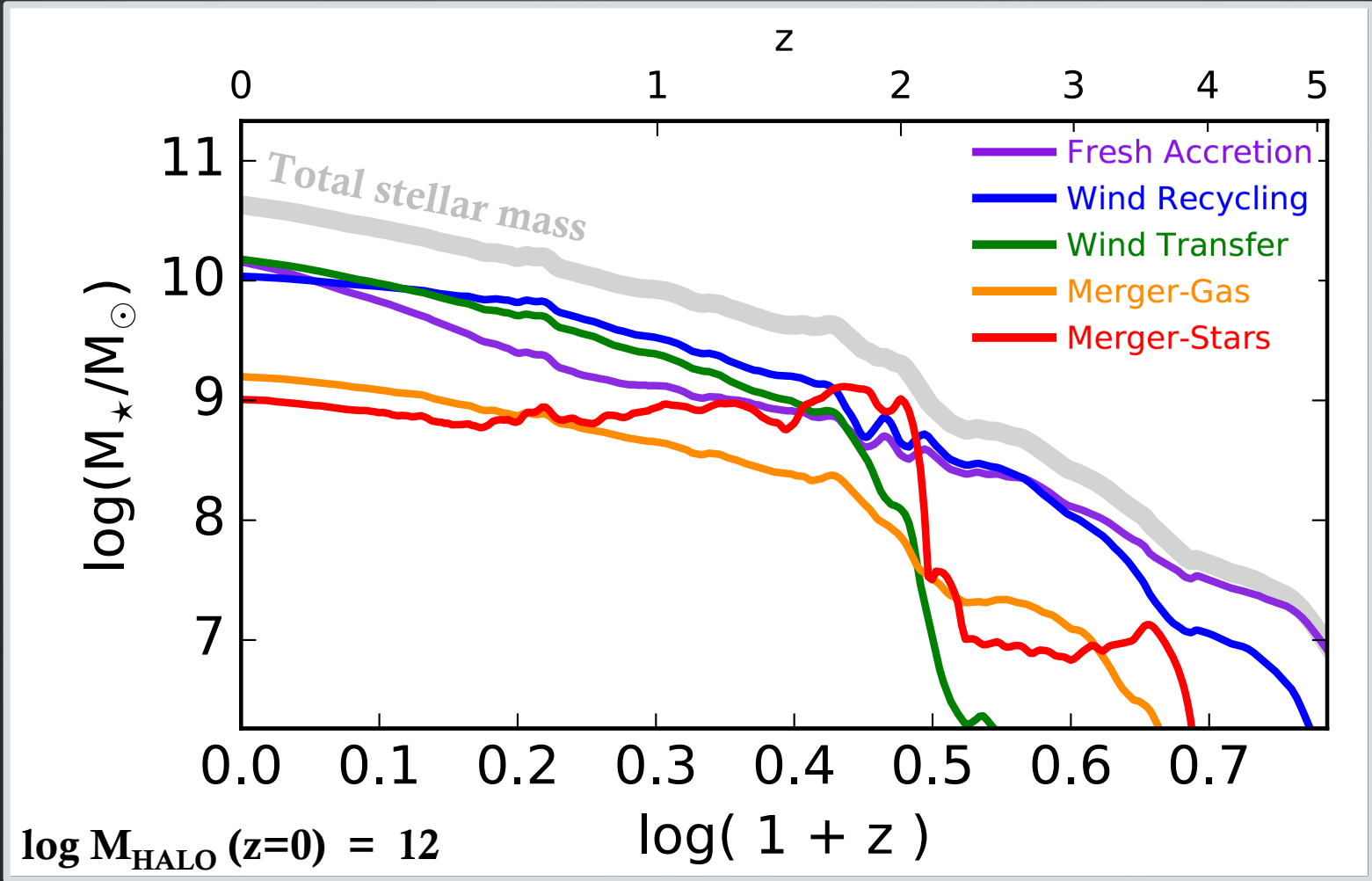
HI in z=2 CGM: Faucher-Giguère+15



Powerful outflows: Muratov+15



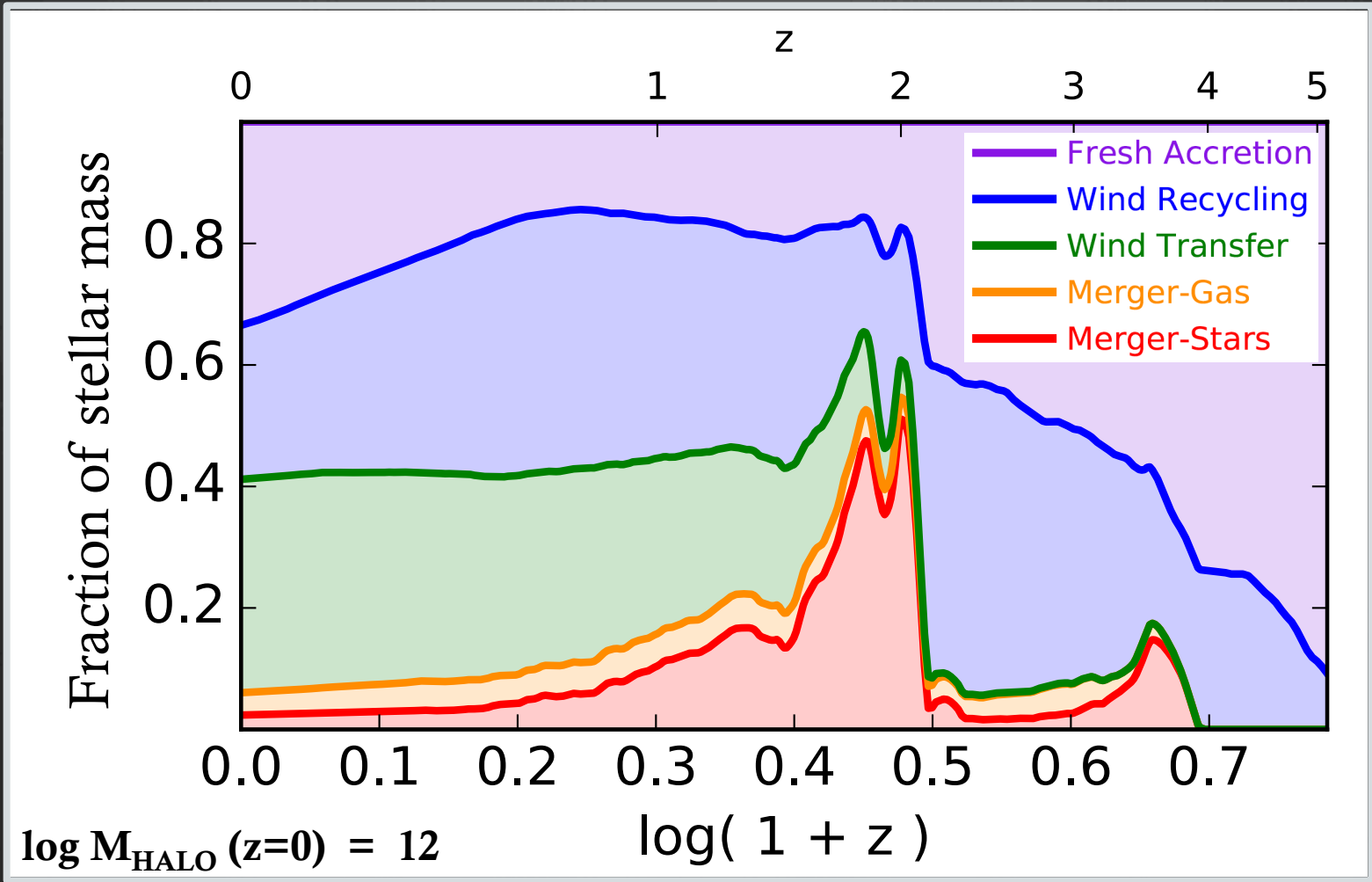
Origin of stellar content of galaxies



→ **Fresh gas** accretion dominates first but **wind recycling** takes over

→ **Stars** + **gas** from galaxy merger at z=2, but **wind transfer** dominates

Origin of stellar content of galaxies



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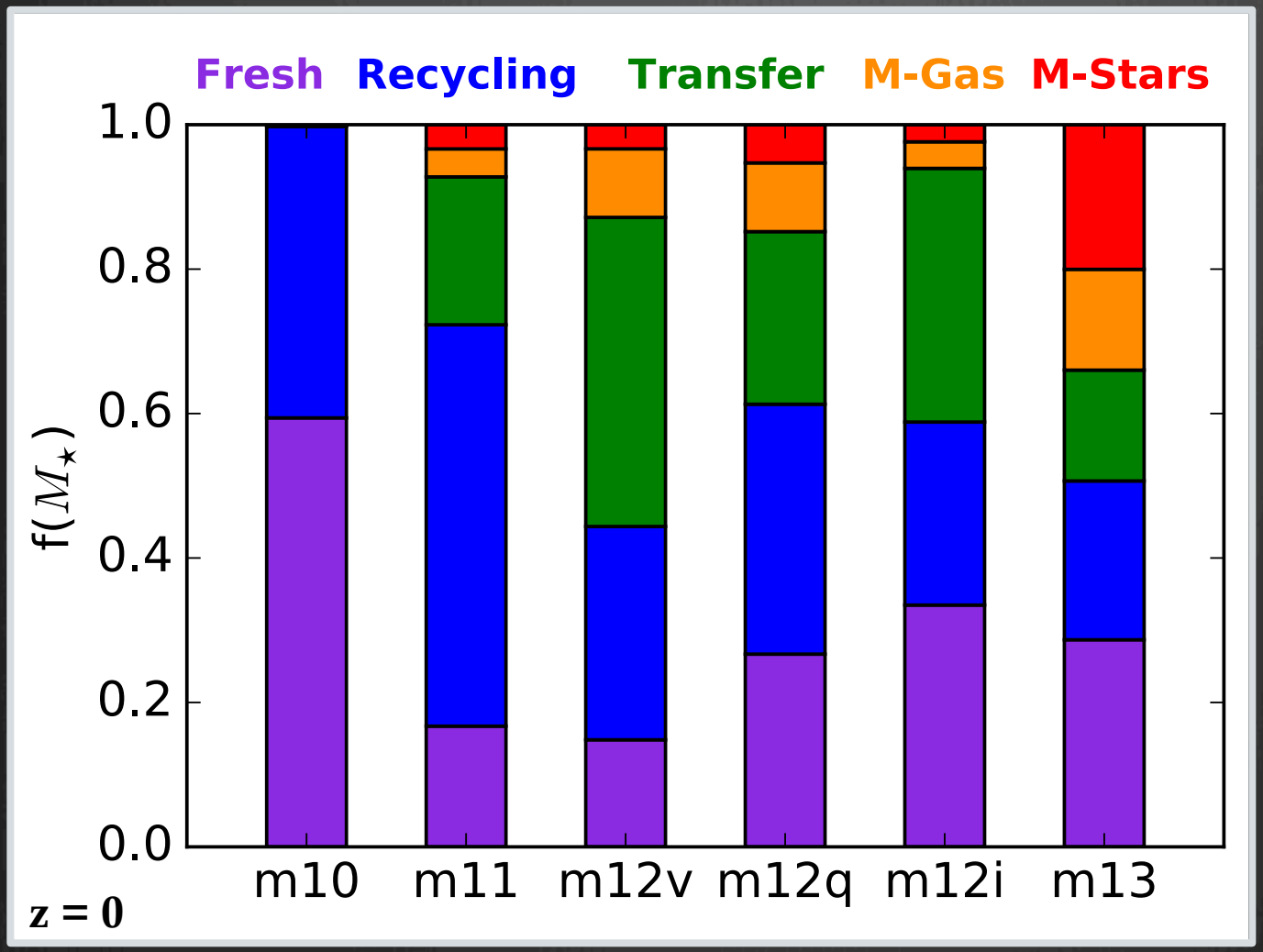
Fraction of z = 0 M_{STAR}

From dwarfs to elliptical galaxies

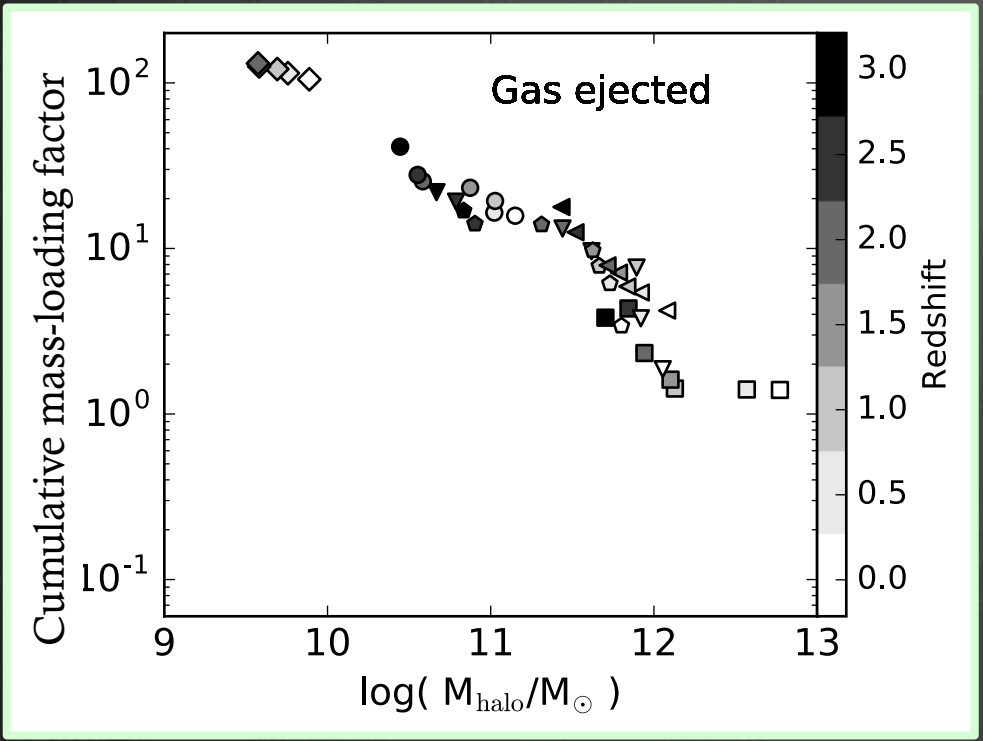


Externally processed

Non-externally processed

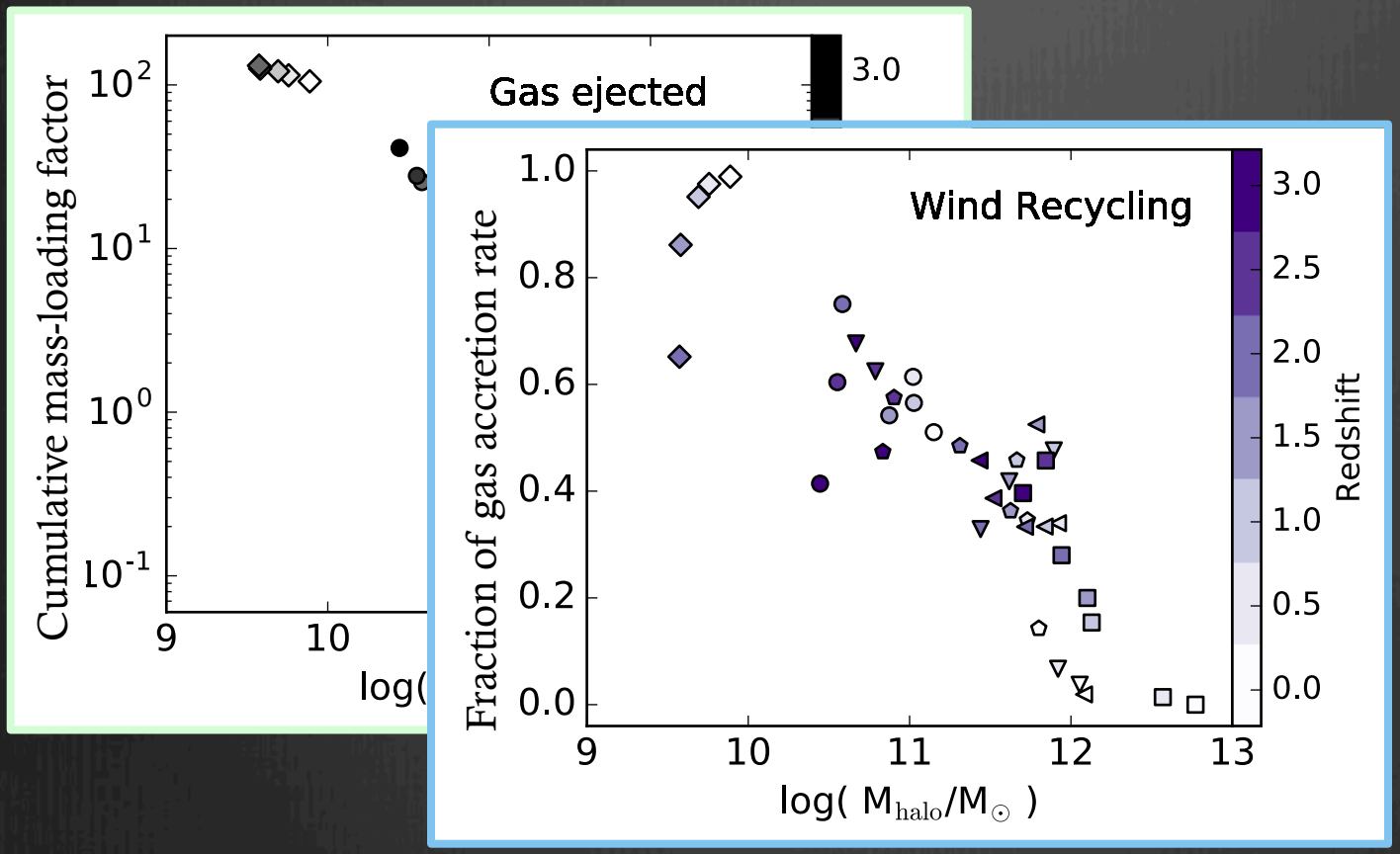
Increasing halo mass: $\log M_{HALO} = 10 \rightarrow 13$

Trends with halo mass



→ **Mass-loading factor larger for low mass galaxies (Muratov+15)**

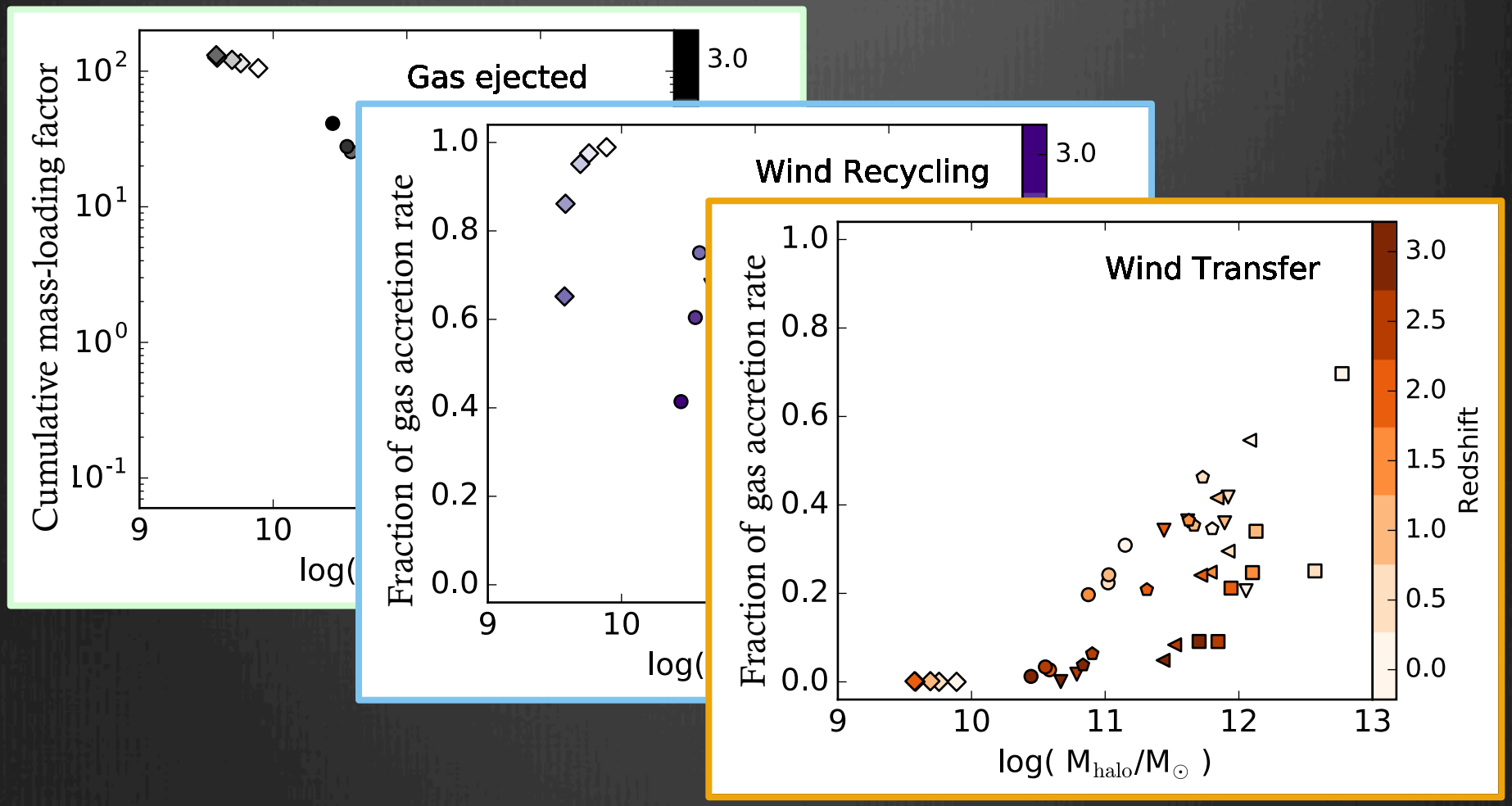
Trends with halo mass



→ Mass-loading factor larger for low mass galaxies (Muratov+15)

→ Wind recycling more important in low mass galaxies

Trends with halo mass

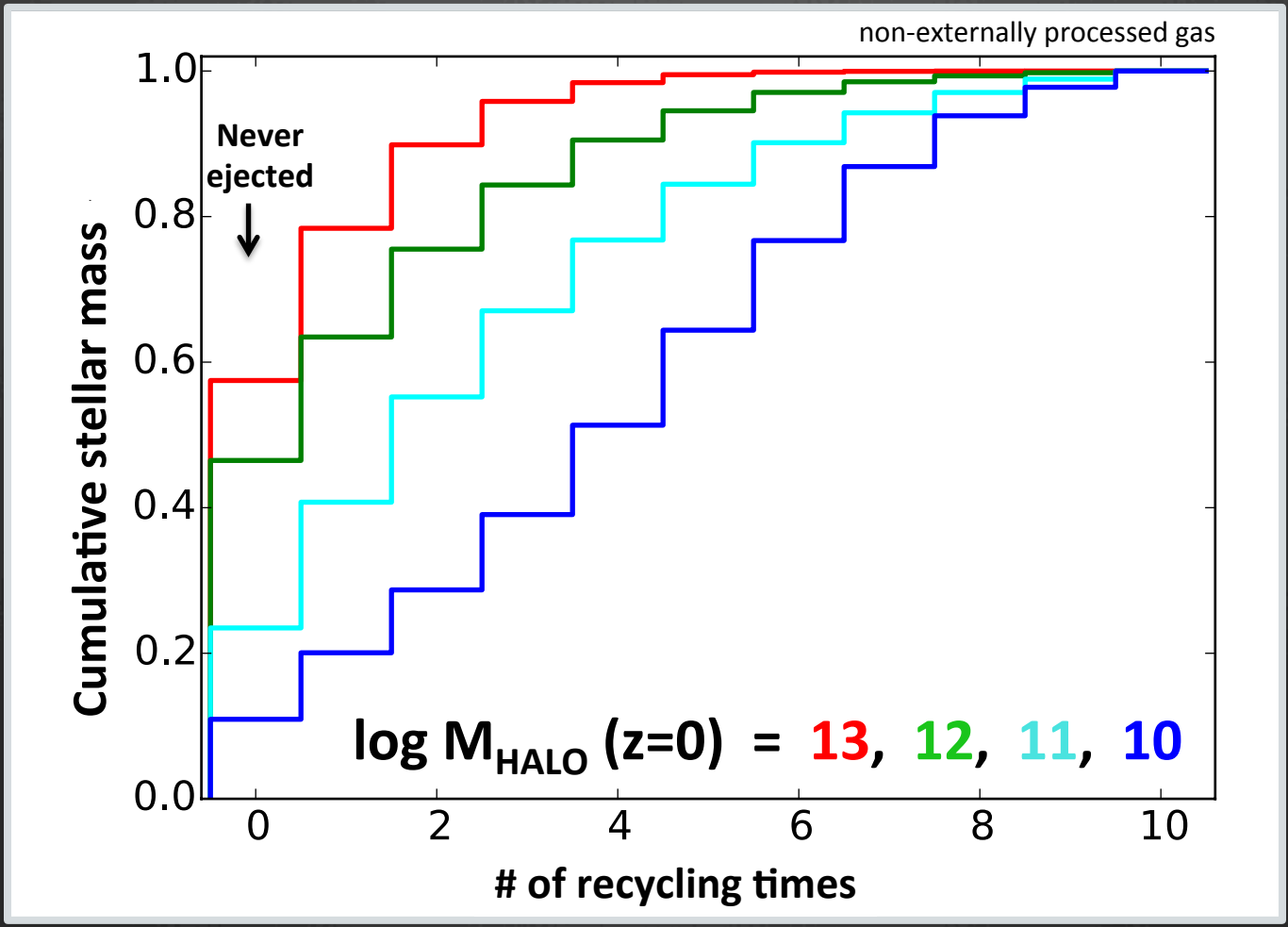


→ Mass-loading factor larger for low mass galaxies (Muratov+15)

→ Wind recycling more important in low mass galaxies

→ Wind transfer increases with halo mass

Tracking # of recycling times

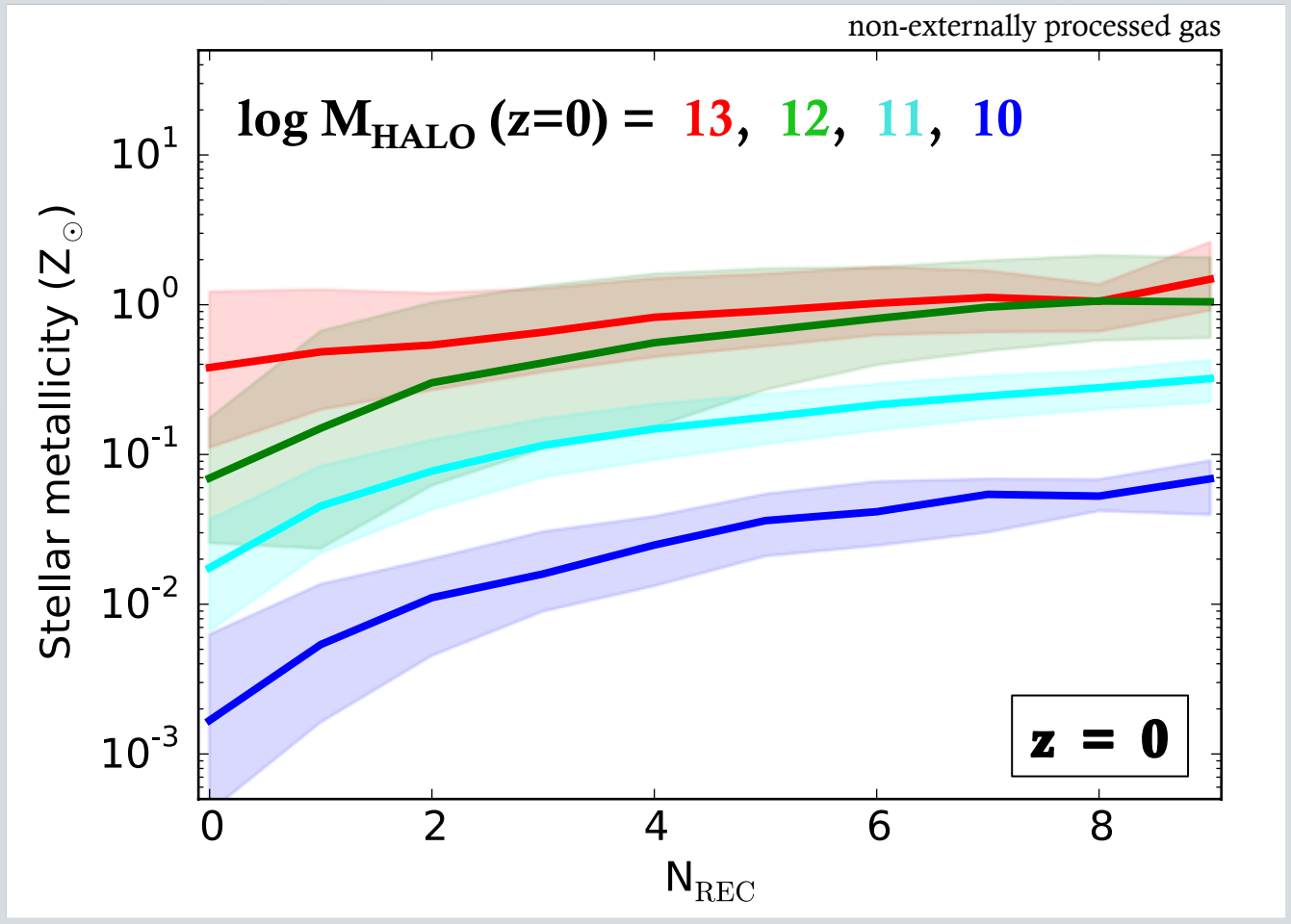


→ Gas is recycled more in lower mass halos prior to forming stars

→ 50% of mass recycled more than [1, 2, 3, 6] times in log M_{HALO} = [13, 12, 11, 10]

Metallicity implications

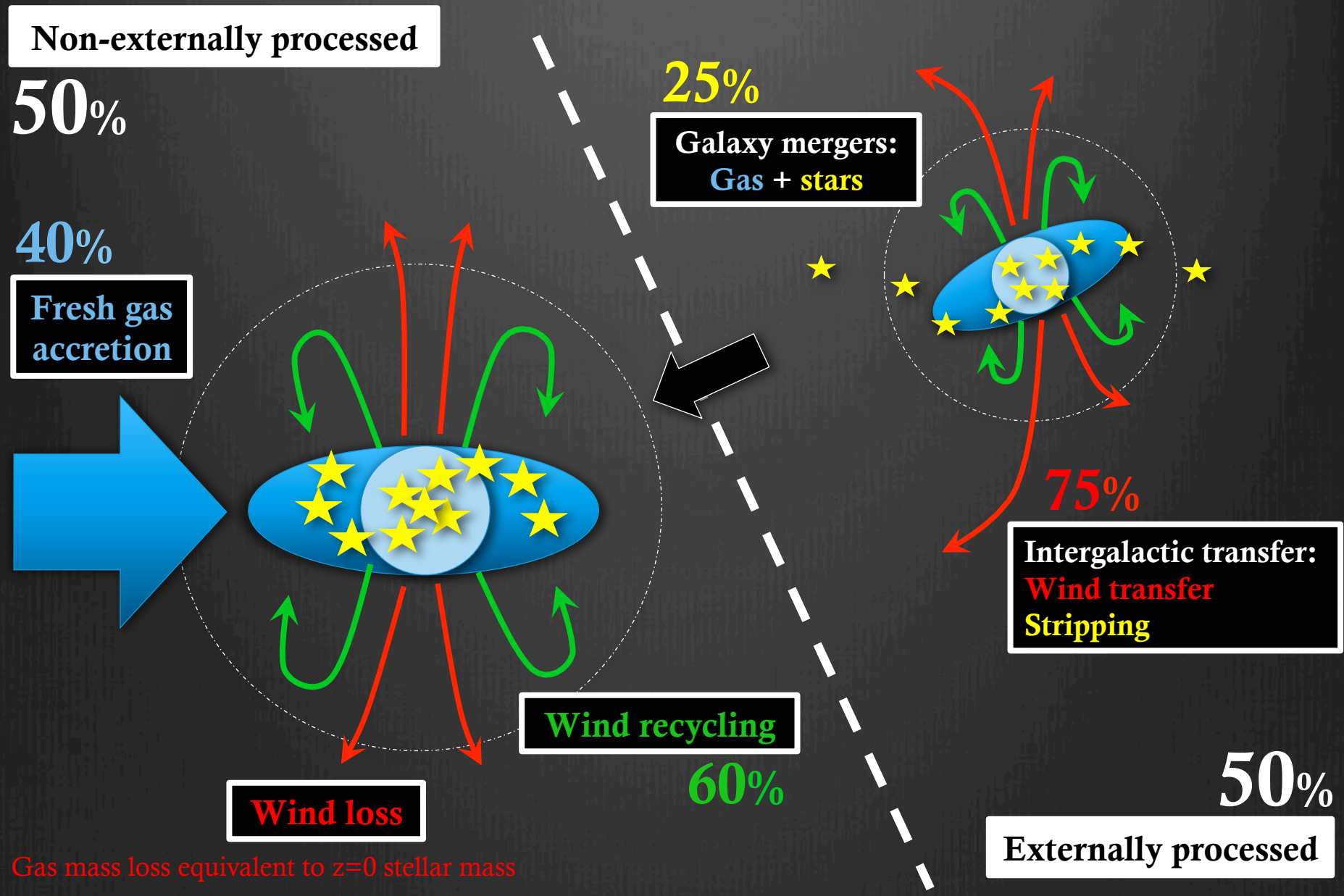
→ Track number of times ejected gas cycles through the galaxy



→ Gas increasingly enriched as it cycles through the galaxy

The Baryon Cycle in MW-mass galaxies

% stellar mass at z=0 averaging 3 MW-mass galaxies



Tracing baryons in the FIRE simulations

1) On-going particle tracking analysis of FIRE zoom-in simulations to quantify the cycling of baryons in galaxy evolution

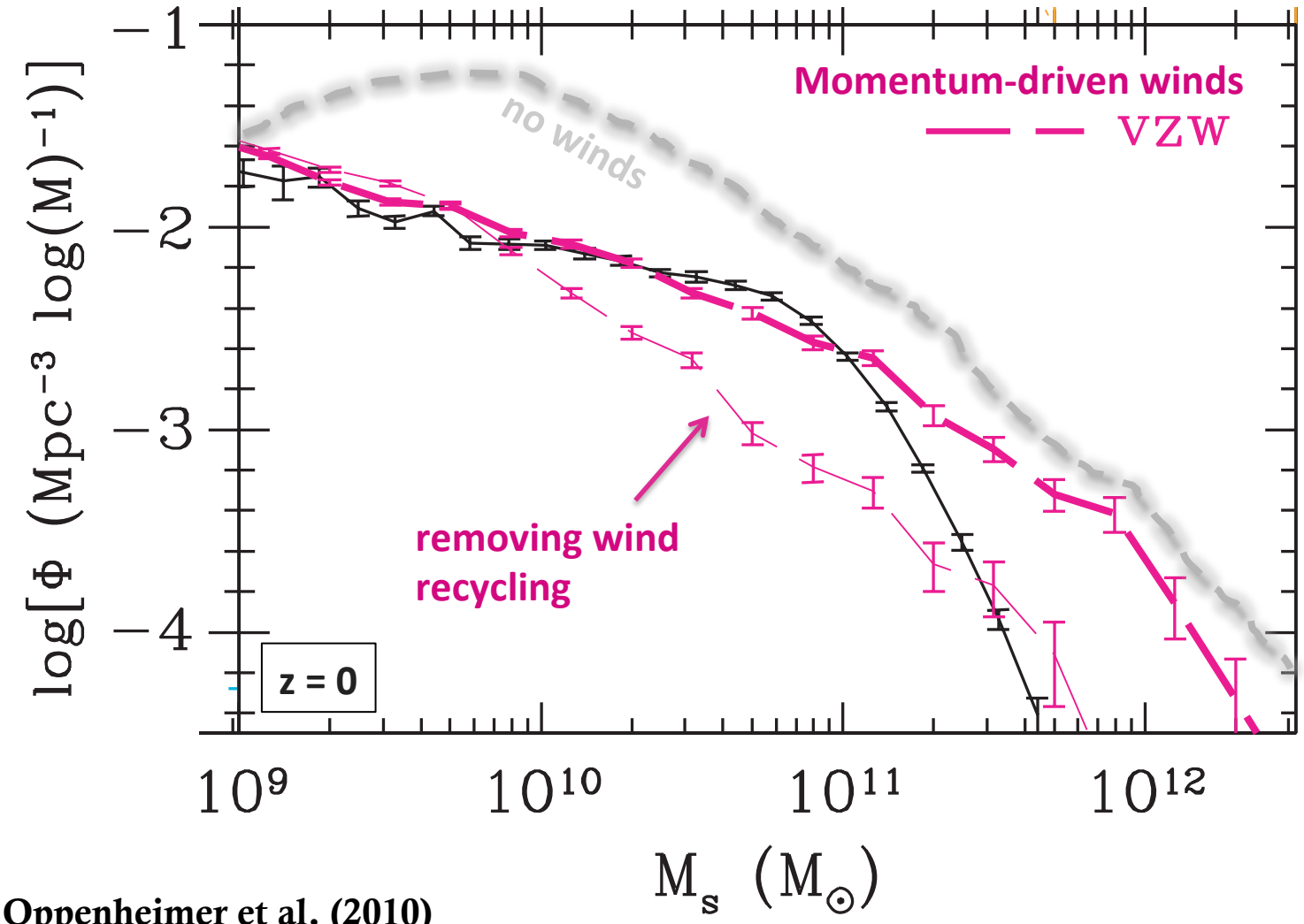
2) Recycling of galactic winds represents a significant contribution to galaxy growth, but also the transfer of gas between galaxies via winds!

3) Currently exploring the implications of fresh accretion, gas recycling, wind transfer, and mergers for chemical evolution and structural properties of galaxies

4) Develop observational diagnostics of the baryon cycle

Anglés-Alcázar et al. in preparation

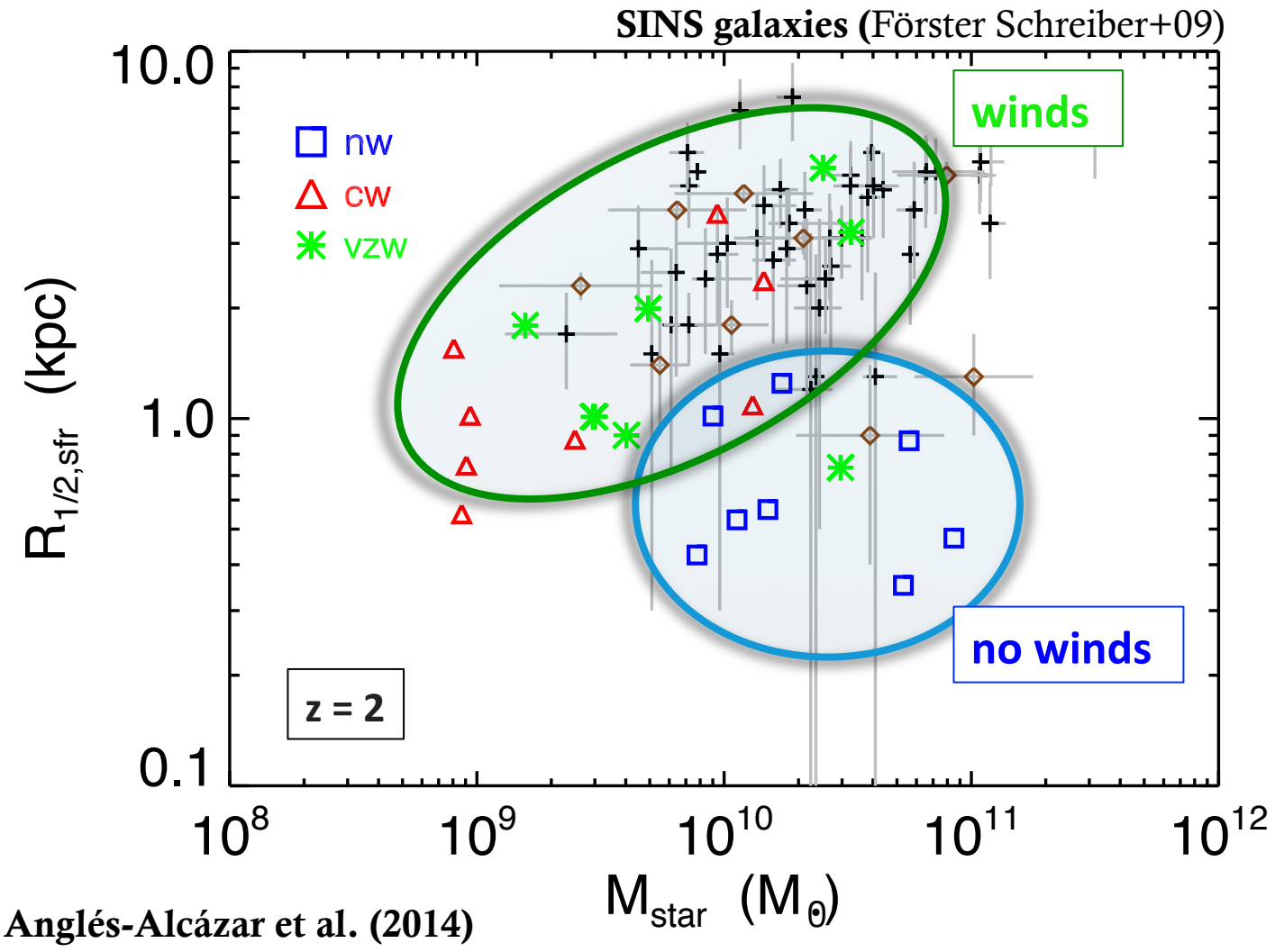
The baryon cycle in simulations



Oppenheimer et al. (2010)

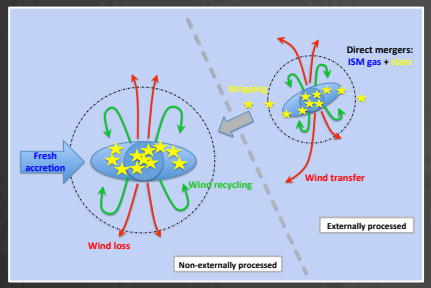
→Galactic winds required to match GSMF and wind recycling contributes a lot!

The baryon cycle in simulations



→Galactic winds required to match structural/kinematic properties of z=2 disks

Tracing stars back to the original gas source



Stellar content of Galaxy at z = 0

Externally processed

Mergers

Gas: ISM

Stars

Intergalactic transfer

Gas: wind transfer

Stars: stripping

Non-externally processed

Gas: wind recycling

Gas: fresh accretion

Tracing stars back to the original gas source

% mass from each mode for
log M_{HALO} = [13, 12, 11]