Feedback’s Role in the Growth of Galaxy Centers

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$M_{\text{halo}} \sim 10^{12} \, M_\odot$

$M_{\text{halo}} \sim 10^{11} \, M_\odot$

$M_{\text{halo}} < 10^{10} \, M_\odot$
CURRENT SUCCESSES: DWARFS

$M_{\text{star}} \sim 10^8 M_\odot$
CURRENT SUCCESSES: DWARFS

Christensen et al. 2014a
THE CHALLENGE FOR THEORISTS

- Challenge 1: Bulgeless L* galaxies
- Challenge 1b: B/T ratios
- Challenge 2: Classical/PseudoBulge Mix

Fisher & Drory 2011
Reproduce bulge scaling relations for first time

B/T overall still too large
Simulated MW Bulges are Generally Too Large
How to Match Everything, Including the High z $M_{\text{star}}-M_{\text{halo}}$ Relation

More feedback, please
USING THE FULL RANGE OF AVAILABLE FEEDBACK

- Supernovae — the go to since the dawn of feedback, but massive stars don’t go SNe until ~4Myr after the star particle is born

- Stellar winds — momentum injection from winds of massive stars (up to 1000 km/s)

- UV ionization — formation of HII regions

- Radiation pressure — momentum injection from scattering off dust grains (highly debated)
THE DEVIL IS IN THE DETAILS

Simulated MW-mass galaxies show too much outer disk growth, not enough central mass growth compared to observations.

Aumer et al. (2014), data from van Dokkum et al. (2013)
YOUNG STAR FEEDBACK CAN’T MAKE THIN DISKS

SN only

Simulated Young Stars

MW Young Stars

$k = 30$

Roskar et al. (2014)
A Possible Clue: Mergers Don’t Do What You Think They Do

- In dwarf galaxies, mergers prevent bulge formation!
- In L* galaxies, mergers do what you expect, and they do it too well
- Except in new feedback model….

Brooks & Christensen 2015; arXiv:1511.04095
What If We’re Missing This Process in L* Galaxies?
A POSSIBLE CLUE: Mergers Don’t Do What You Think They Do

- In dwarf galaxies, mergers prevent bulge formation!
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- Except in new feedback model....
Needed: observational tests of these models
Simulations are producing realistic dwarfs, but more massive galaxies remain a challenge (despite PR to the contrary).

Challenge: *simultaneously* reproduce B/T, classical/pseudo-bulge mix, central growth in concert with outer disk growth, and galactic wind/CGM properties. **Observations can constrain!**

Open question: What is the mix of physics that resolves these issues? (SF prescription, SNe, young stars, AGN?) How do we know?