Superbubble Driven Galactic Winds: Realistic Galaxies from moderate Feedback Energy

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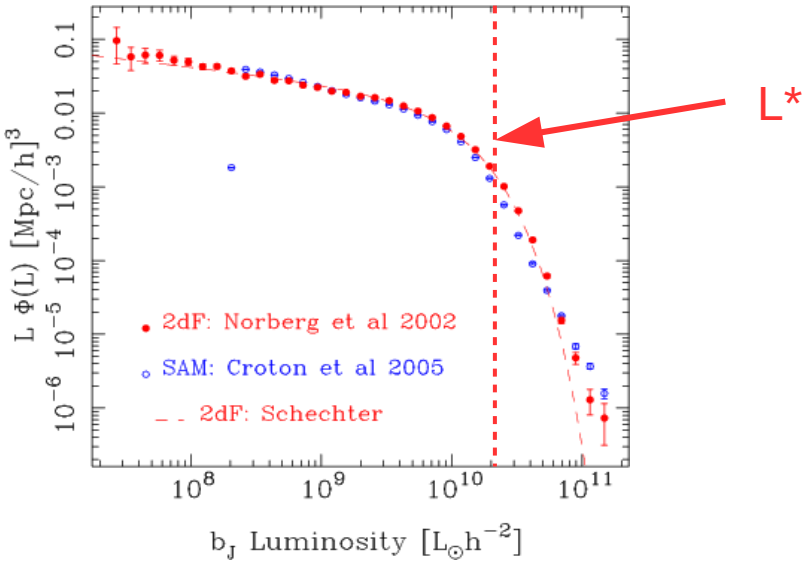
Keller, Wadsley & Couchman 2015

McMaster University

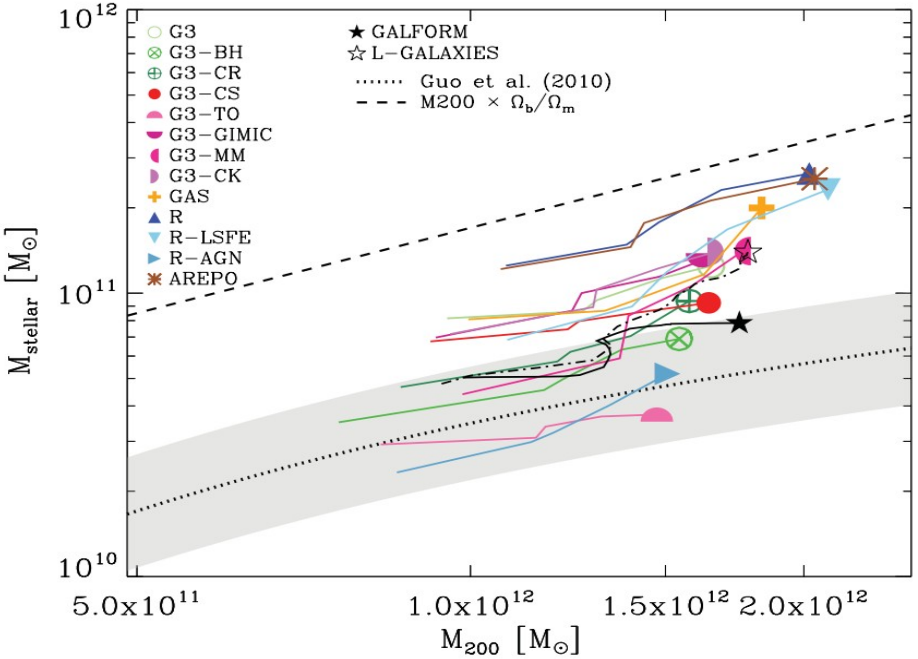
L* Galaxies: Star formation Engines

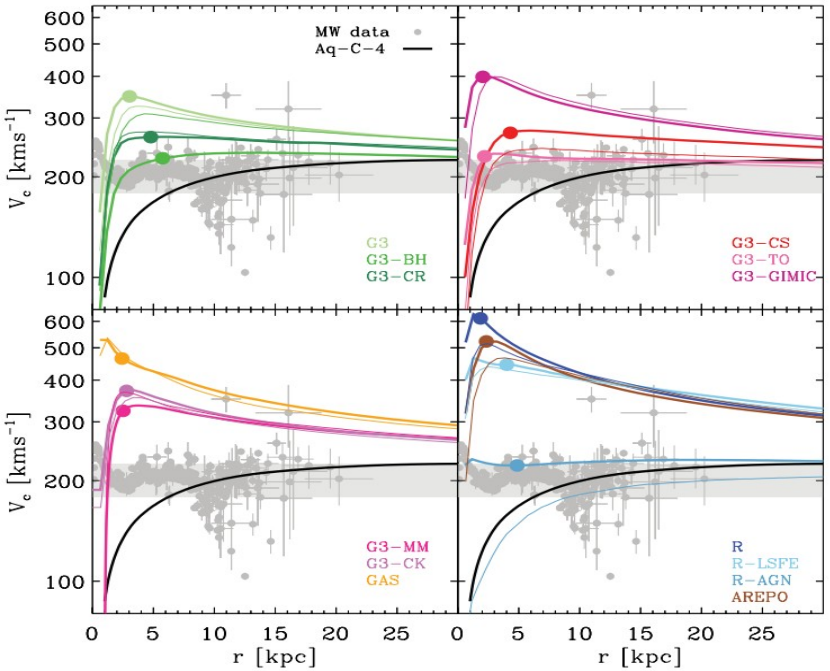
- Most efficient star formers
- Stellar Mass/Halo Mass 3-5%, lowest M/L ratio
- Common! (We live in one)
- Disk Dominated
- Young Stellar Population
- Halo Mass ~10^{12} $M_{\odot}$



M31 Image: GALEX NASA

Tension between Theory & Observations





- Aquila comparison (Scannapieco+2012)
  - Compared feedback models & simulation codes on same cosmological initial conditions
  - Most produced too many stars, too large bulge/disk ratios
  - None had both reasonable stellar mass fraction and small bulge.

Missing feature: Baryon expulsion!

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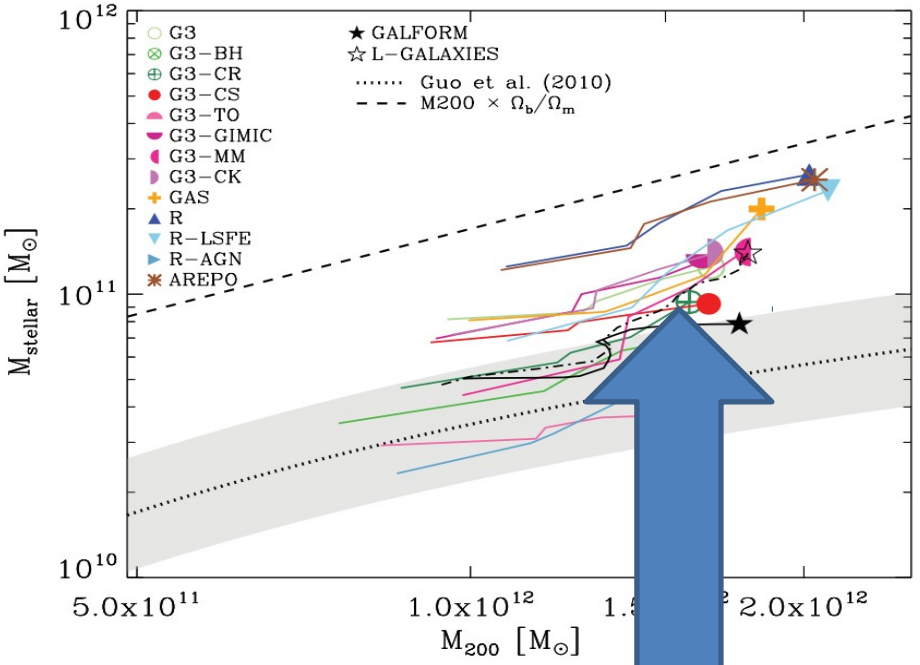

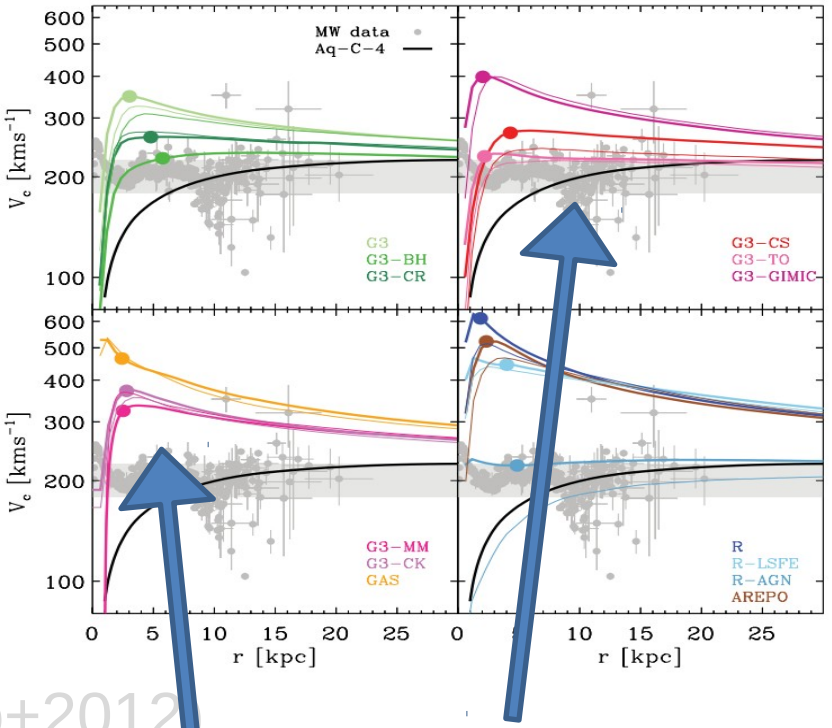

Too Many Stars!

Massive Bulge = Peaked Rotation Curves

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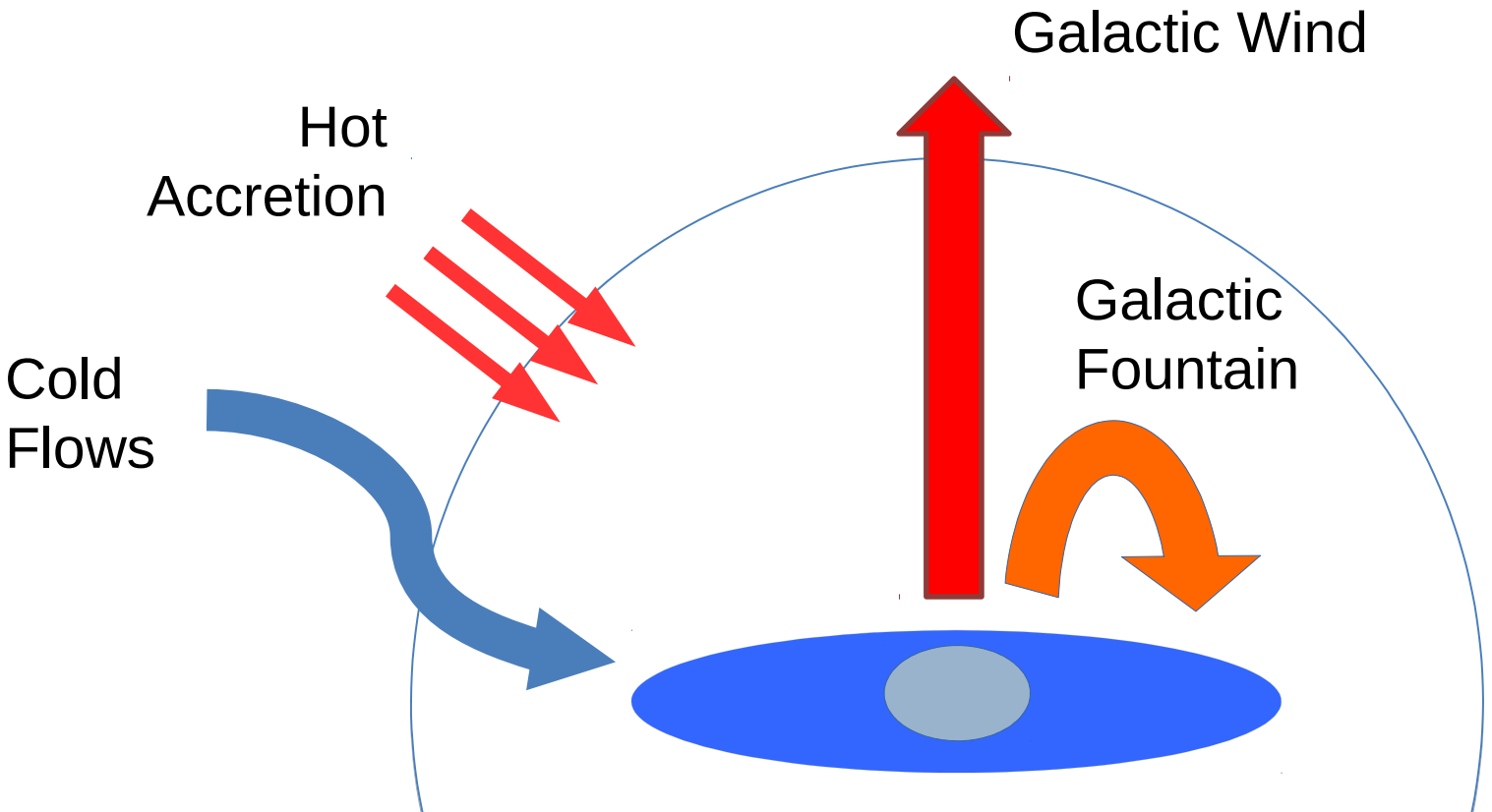
How Galaxies Get Gas

- Gas accreted and removed over galaxy's history
- Cold flows dominate early (Woods+ 2014)
- Fountains fuel low z star formation (Marasco+ 2012)

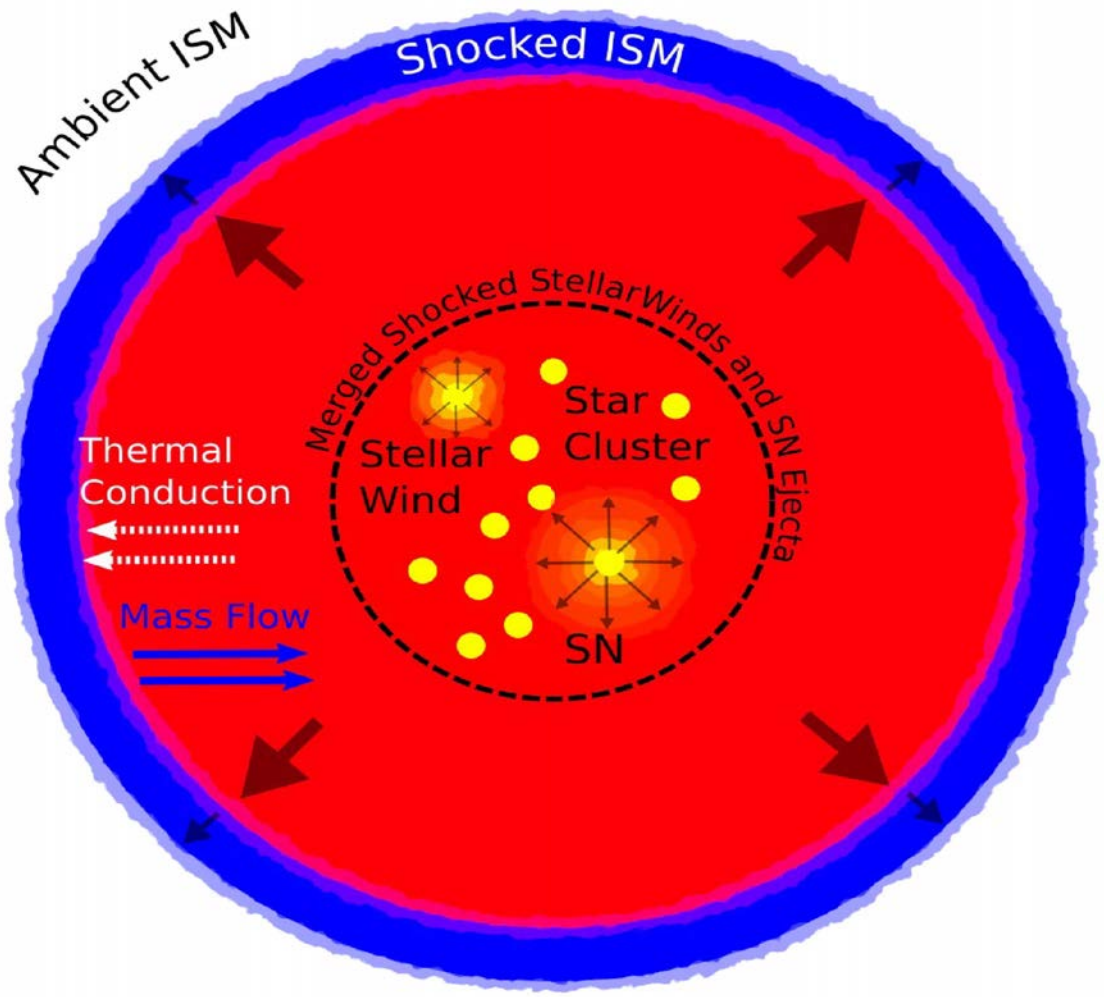
But: What powers outflows?



Superbubble Feedback

- Natural consequence of clustered star formation
- Key physical component is *Thermal Conduction*

$$\frac{\partial M_B}{\partial T} = \frac{4\pi\mu}{25 k_B} \kappa_0 T^{5/2} A_B$$

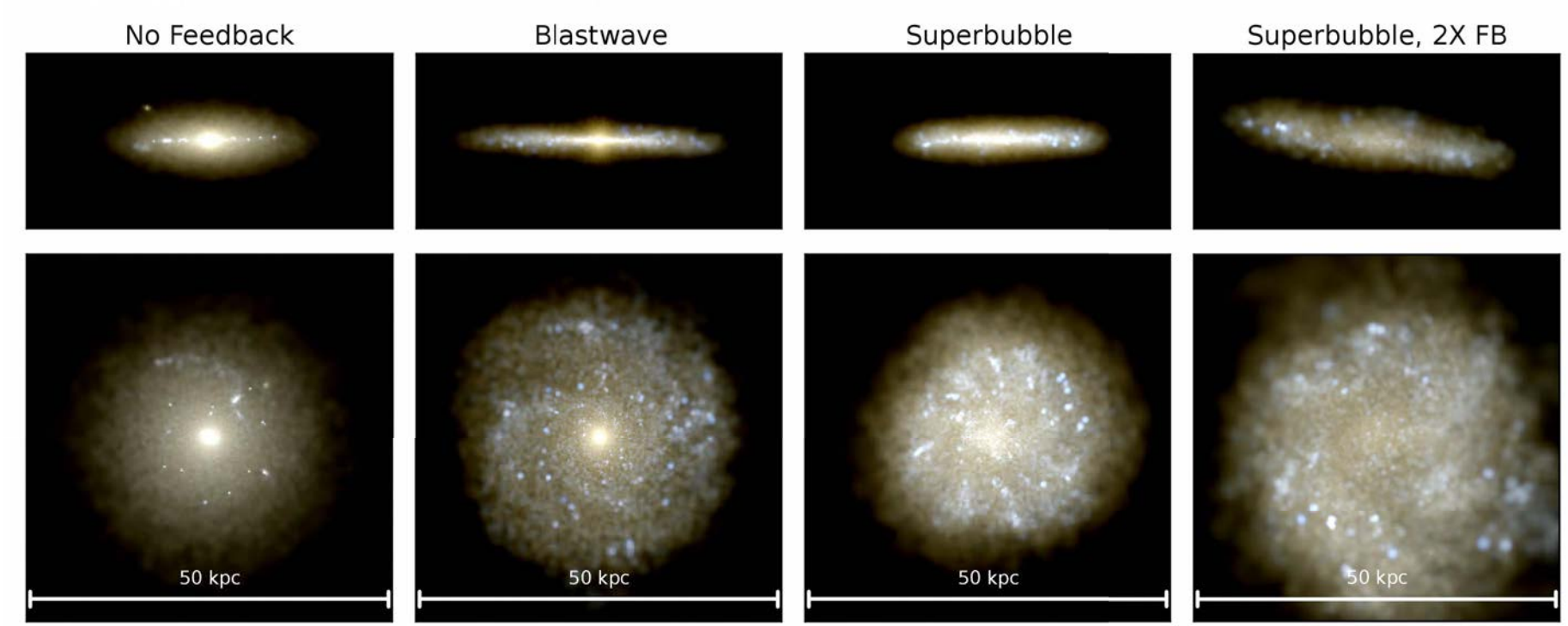


- Keller+ 2014 developed model based on these physical processes
  - Low resolution sensitivity
  - Highly effective in isolated galaxies

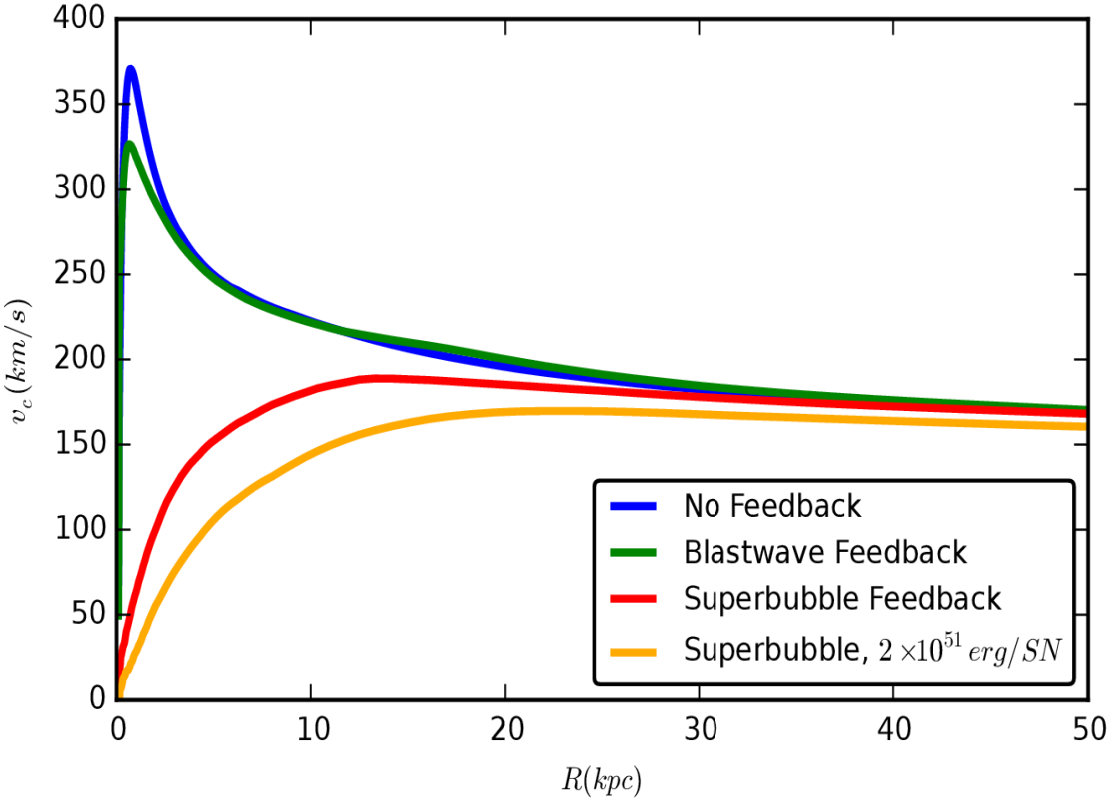
MacLow & McCray 1988, Weaver+ 1977, Silich+ 1996

Simulations

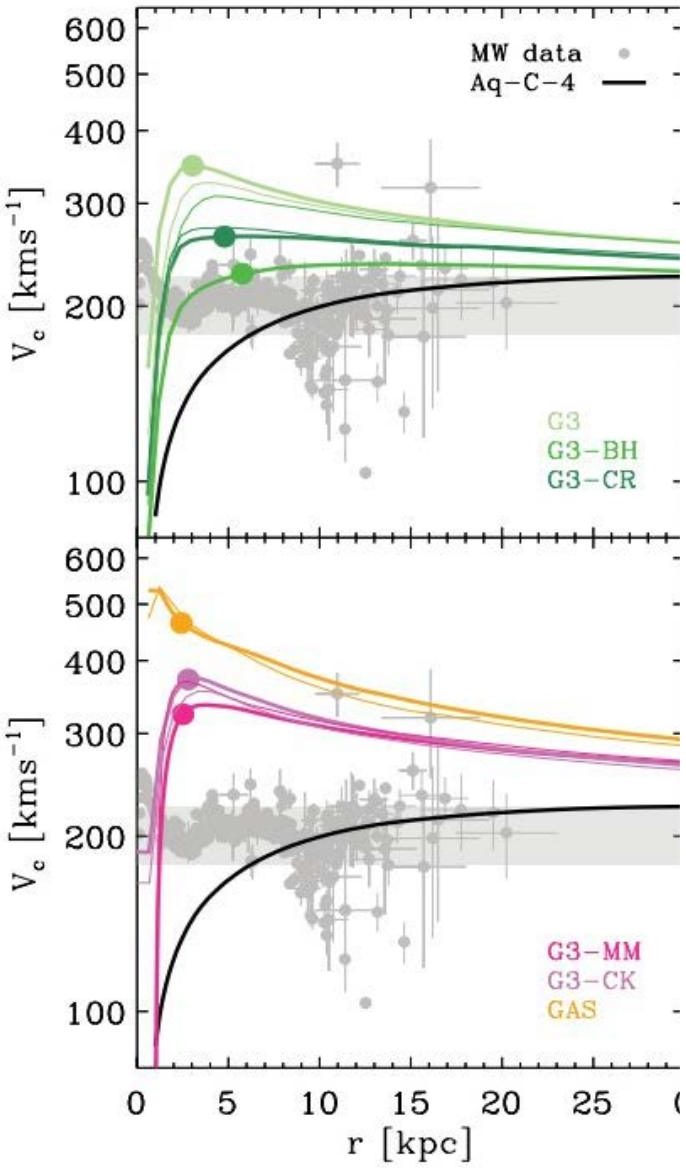
- 4 test cases:
  - No Feedback
  - Blastwave (old Feedback)
  - Superbubble Feedback
    $E=10^{51}$erg/SN
  - Superbubble Feedback E x 2
- Initial Conditions
  - 8 x $10^{11}M_{sun}$ halo
  - Cosmological zoom-in
  - Last major merger at z=2.9



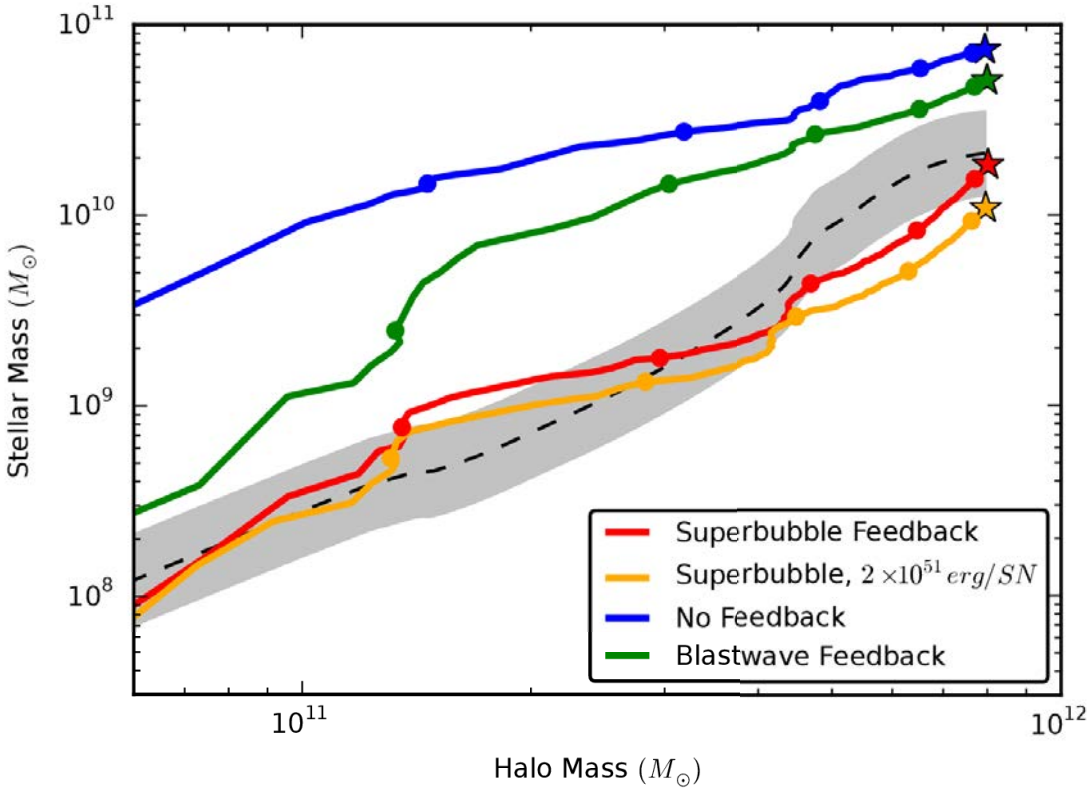
Flat Rotation Curves

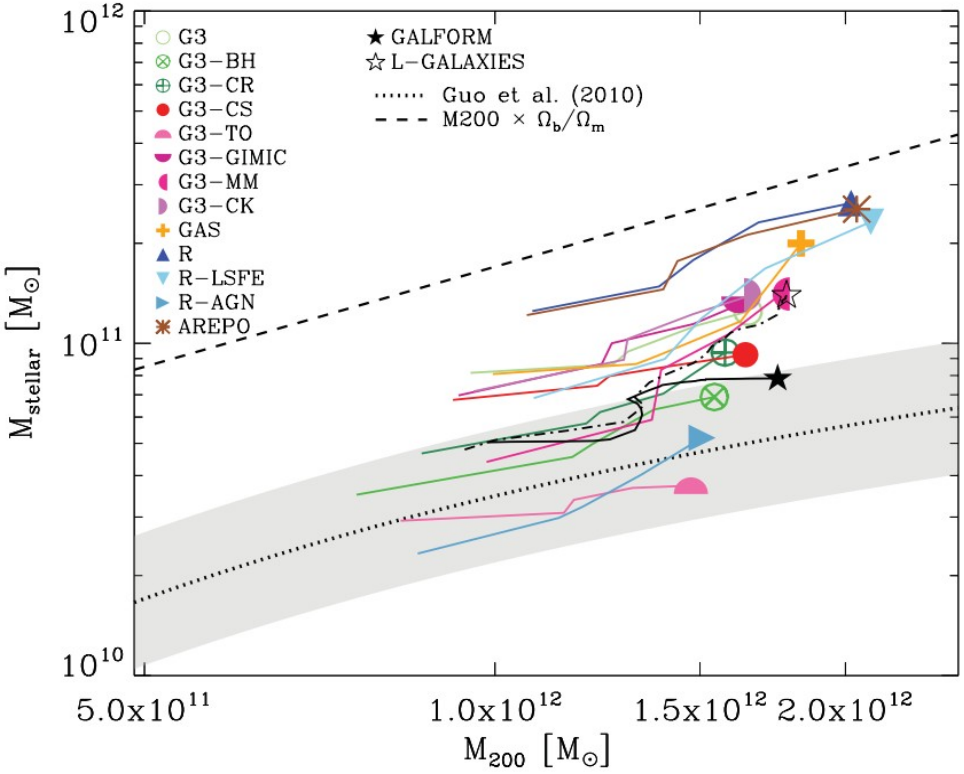


Flat rotation curves with SN only!
(c.f. Aquila, Scannapieco+ 2012)



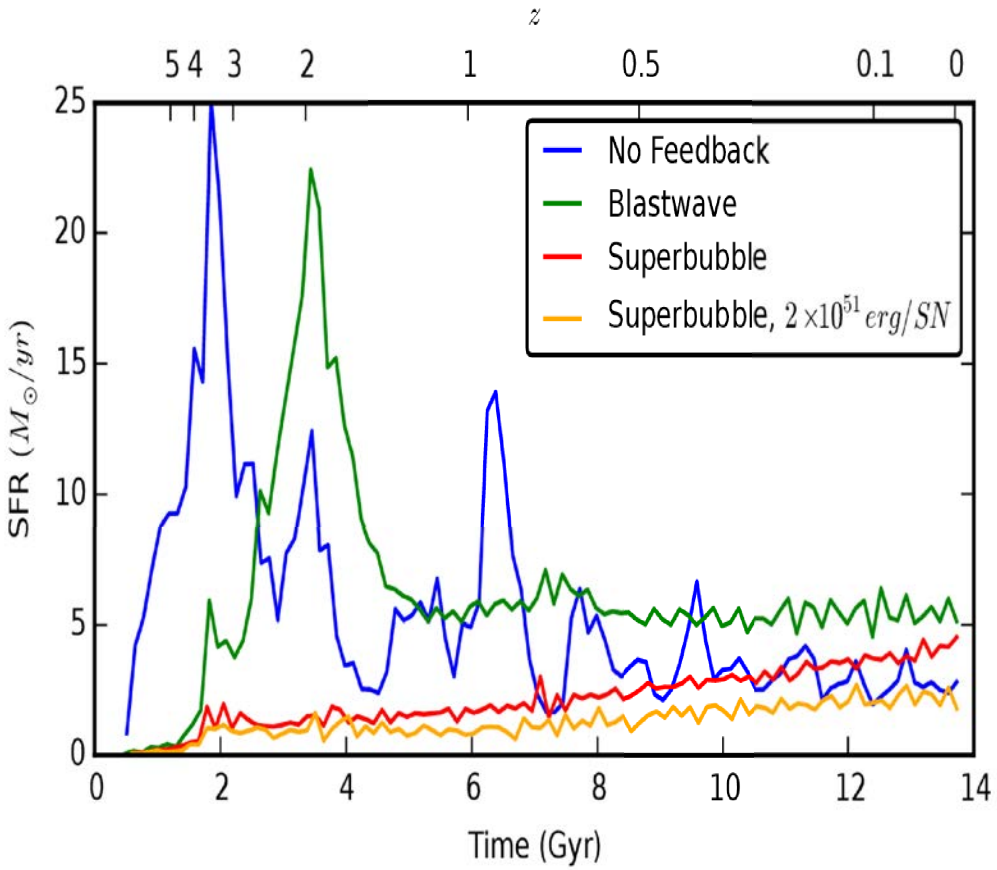
Correct Stellar Mass Fraction





Abundance Matched Stellar Mass History: Behroozi+ 2013

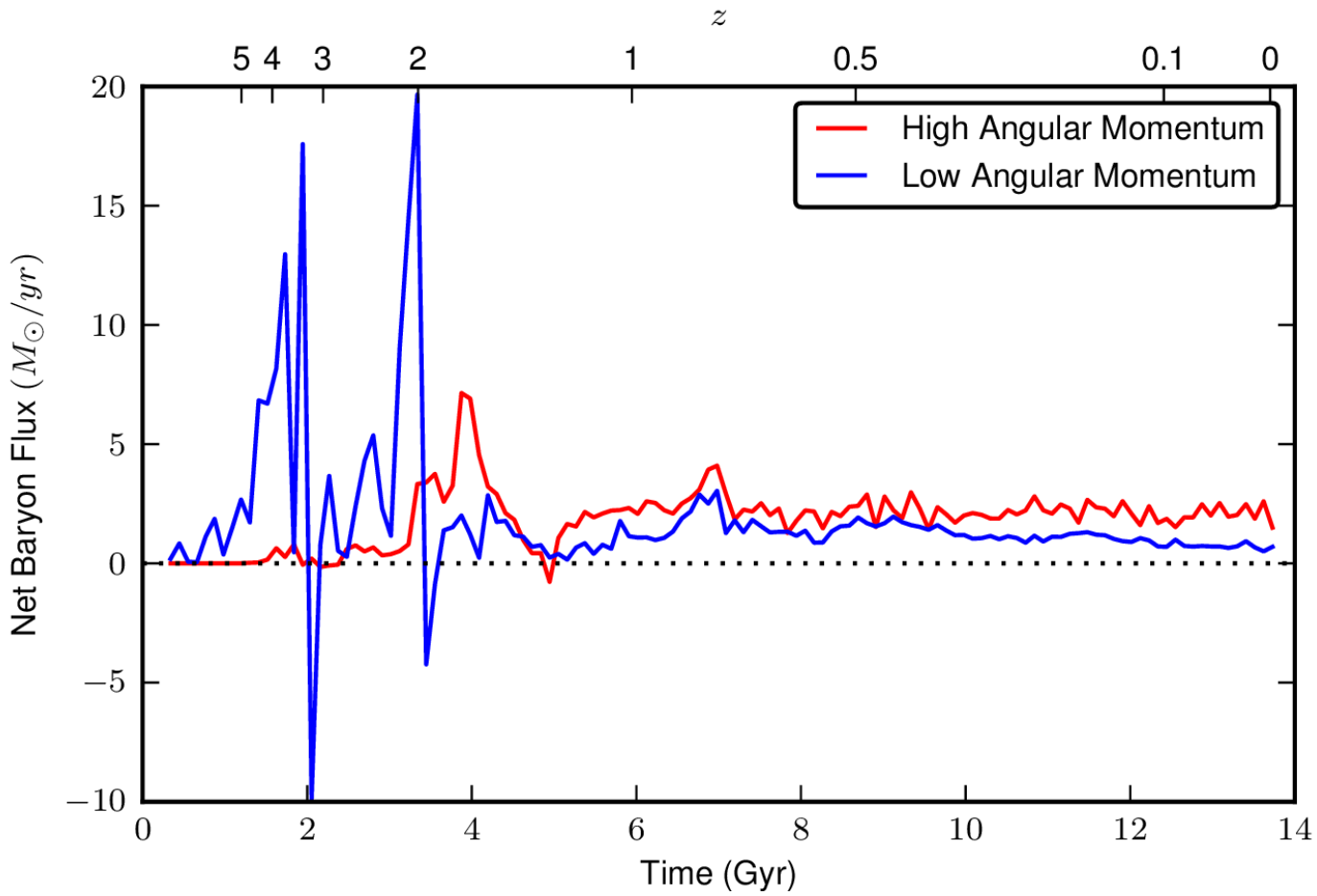
Star formation Rates



- L* galaxies form ~90% of their stars after z=2.5
- Older stars tend to live in bulge, halo

Could low angular momentum material be accreted early?

Accretion separated into high and low angular momentum gas



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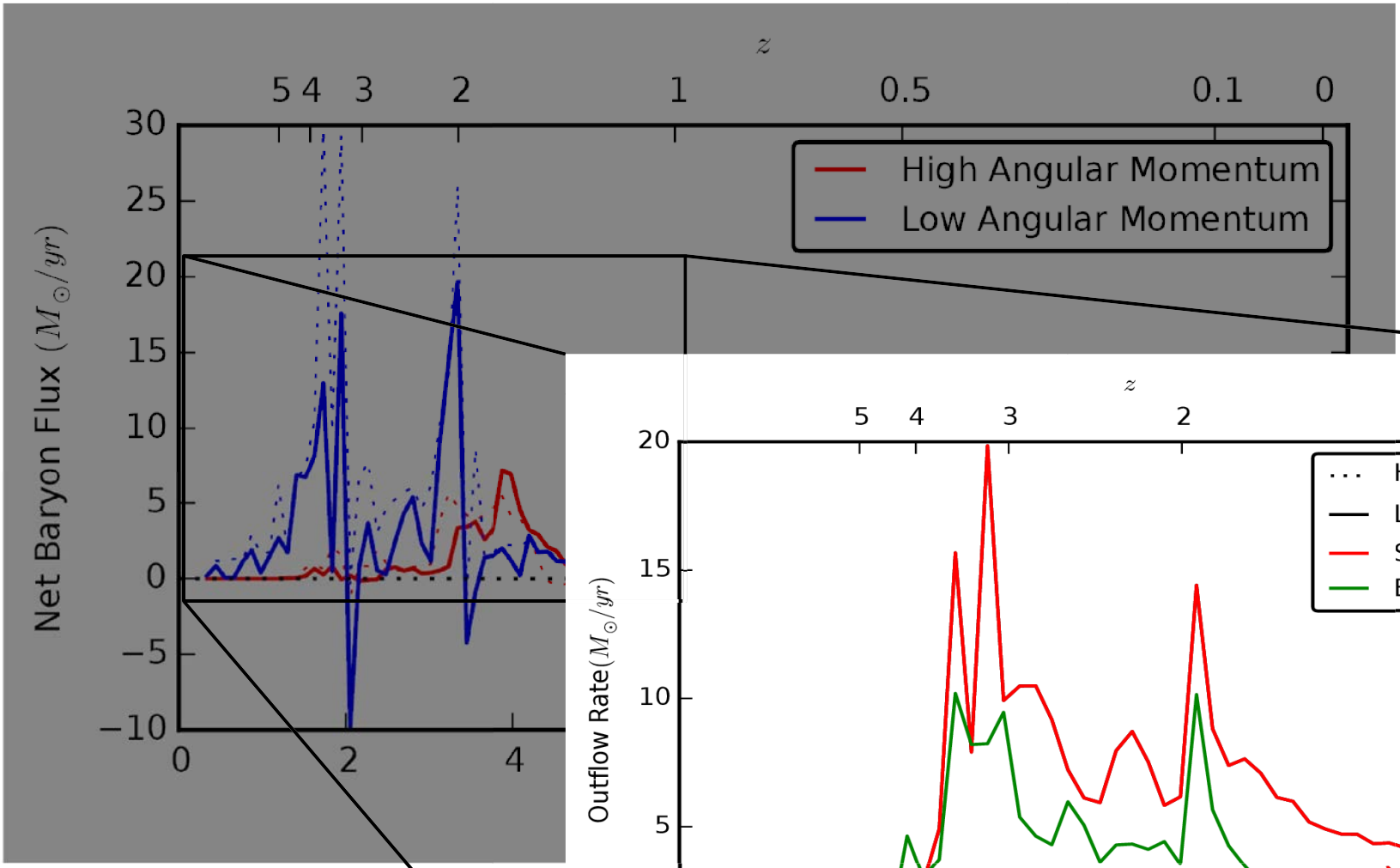

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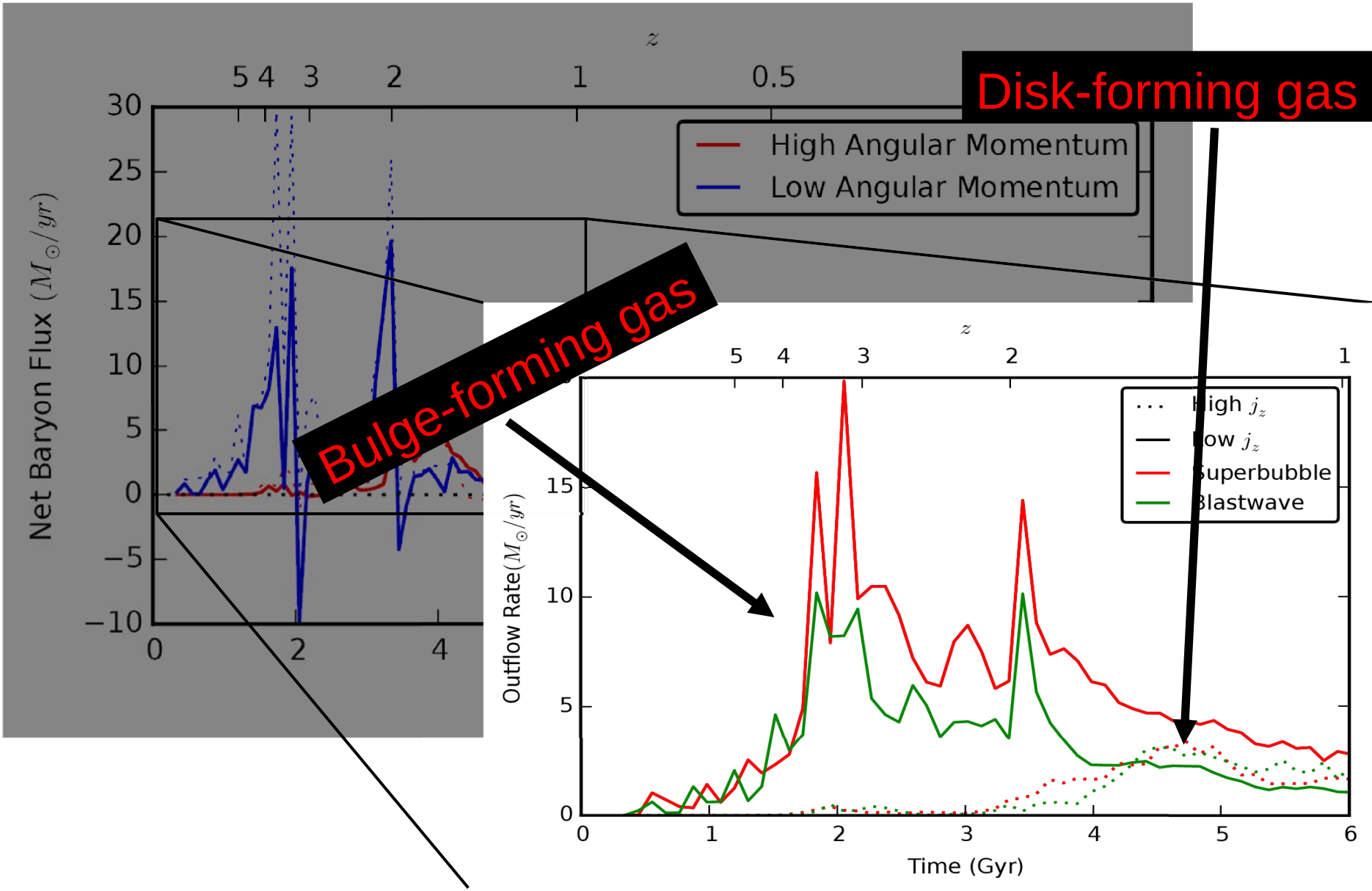
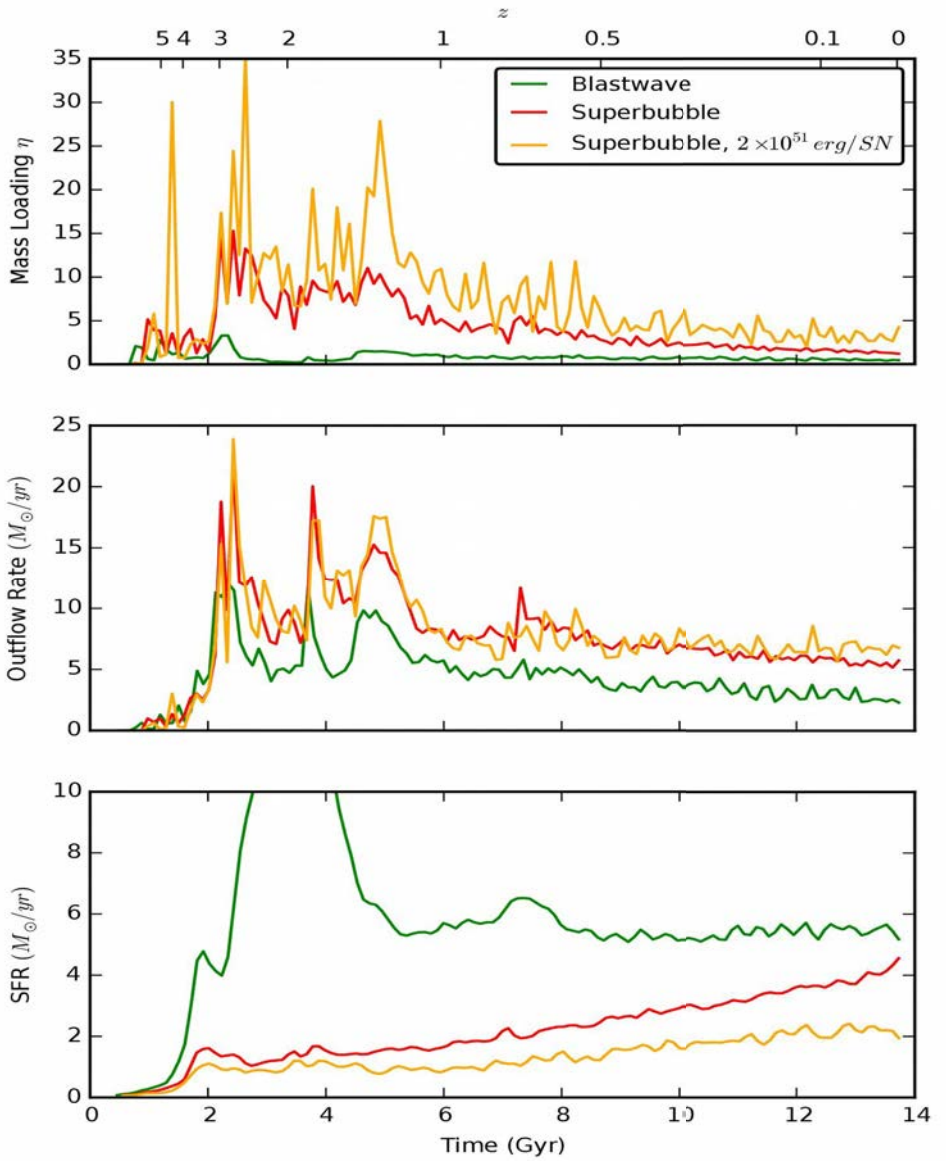


High Redshift Outflows Are Key



- Potential well is shallow
- High mass loadings: correct stellar mass fraction

Preferentially remove low angular momentum gas!

High Redshift Outflows Are Key

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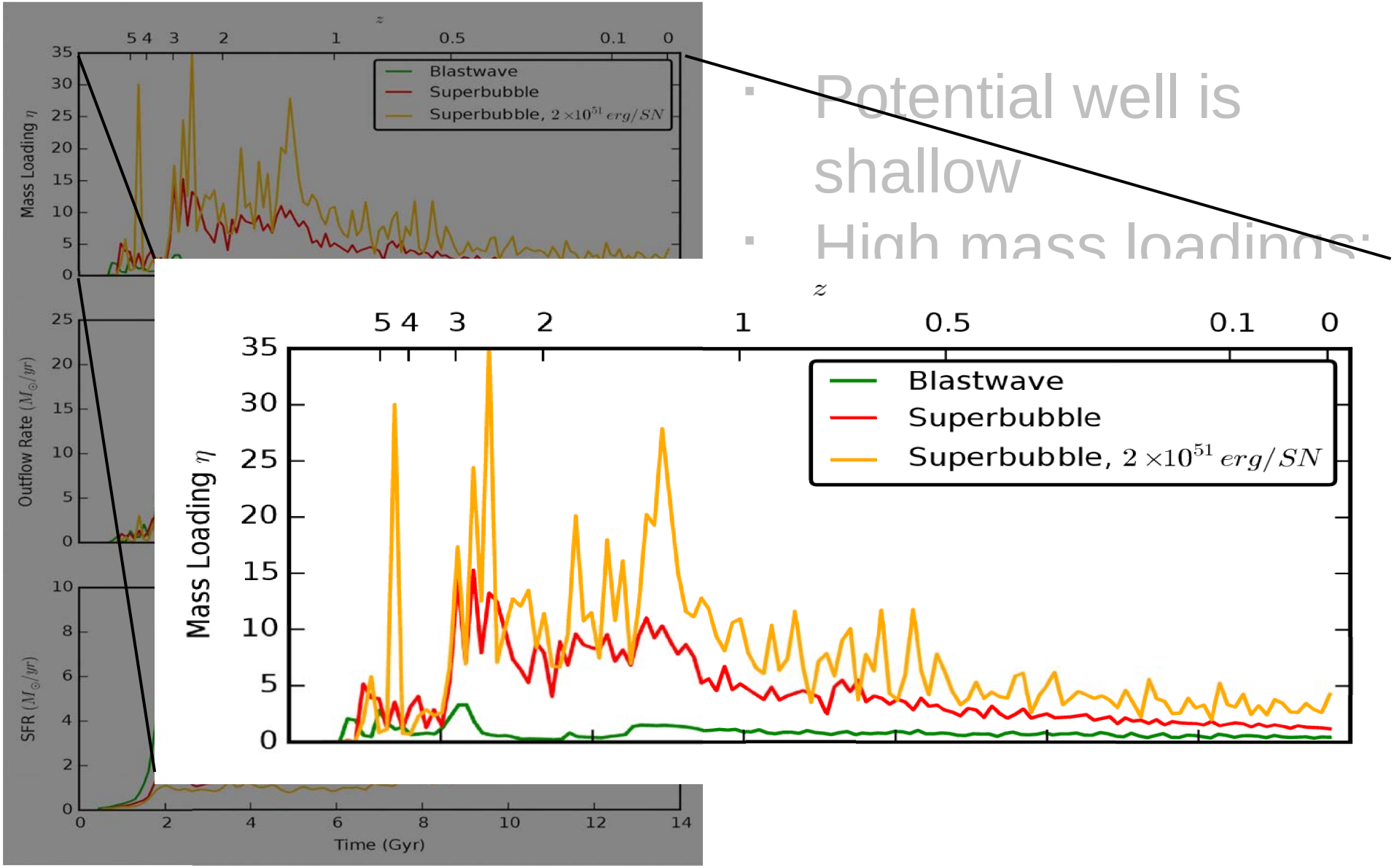

Conclusions

- Superbubble-driven outflows can give realistic L* galaxies in cosmological simulations
- These outflows can be powered by supernova feedback alone, with standard SN energies
- Evaporation naturally gives high mass loadings in superbubble outflows
- Outflows remove low angular momentum gas, preventing the formation of a massive bulge
- This gas removal also reduces the total star formation, giving realistic stellar mass fractions

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