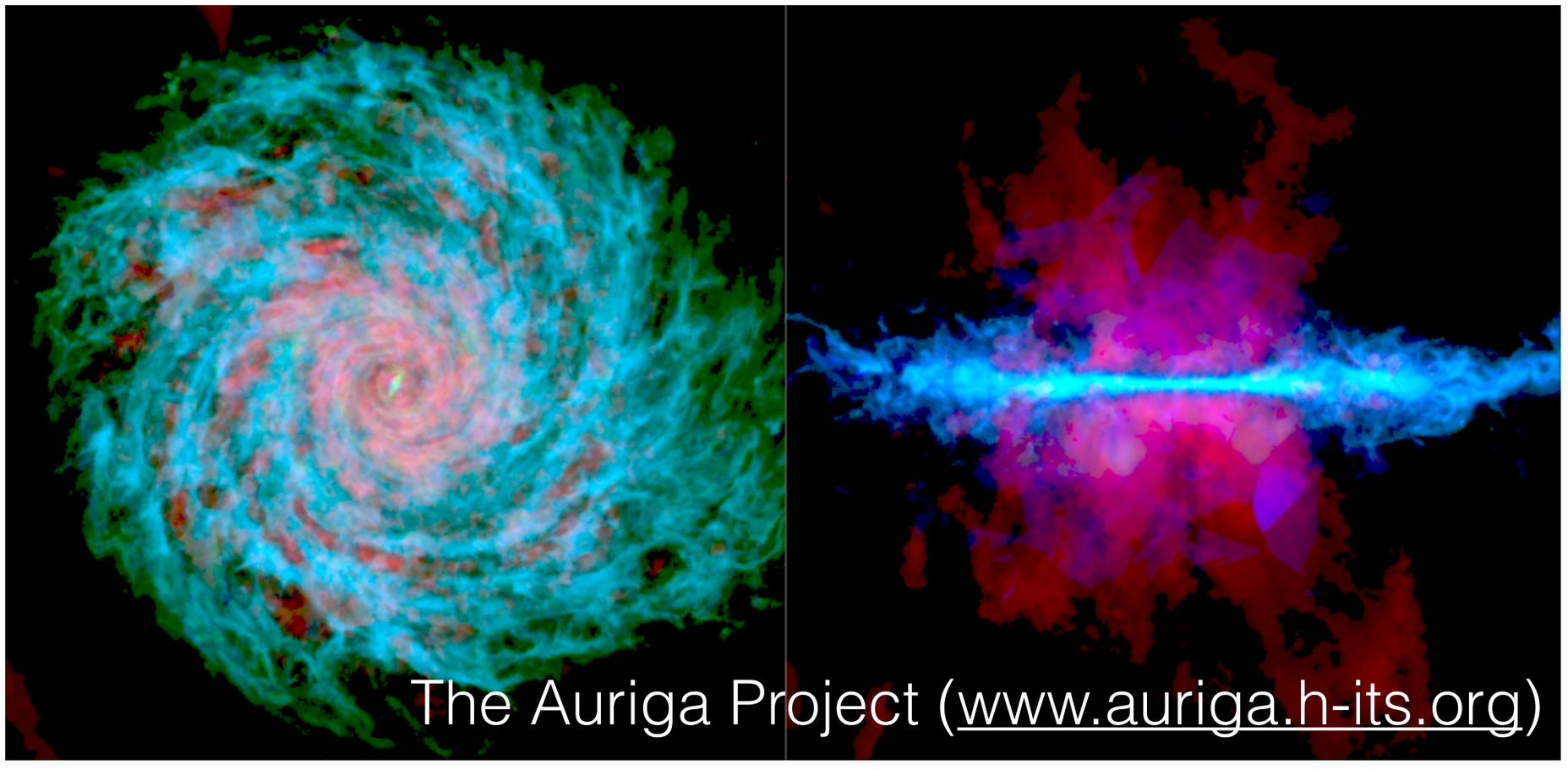
Feedback-driven fountain flows in Milky Way cosmological zoom-simulations: angular momentum and metallicity



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in collaboration with

Volker **Springel** (HITS, MPA), Rüdiger **Pakmor** (HITS), Facundo **Gomez** (La Serena), Federico **Marinacci** (MIT), Christine **Simpson** (HITS), Sebastian **Bustamante** (HITS), Dave Campbell, Adrian **Jenkins** (Durham), Carlos **Frenk** (Durham), Simon **White** (MPA), Hans-Walter **Rix** (MPIA)

The Auriga Project: Suite of Cosmological zoom MW mass halo simulations

(Grand+ 2017)

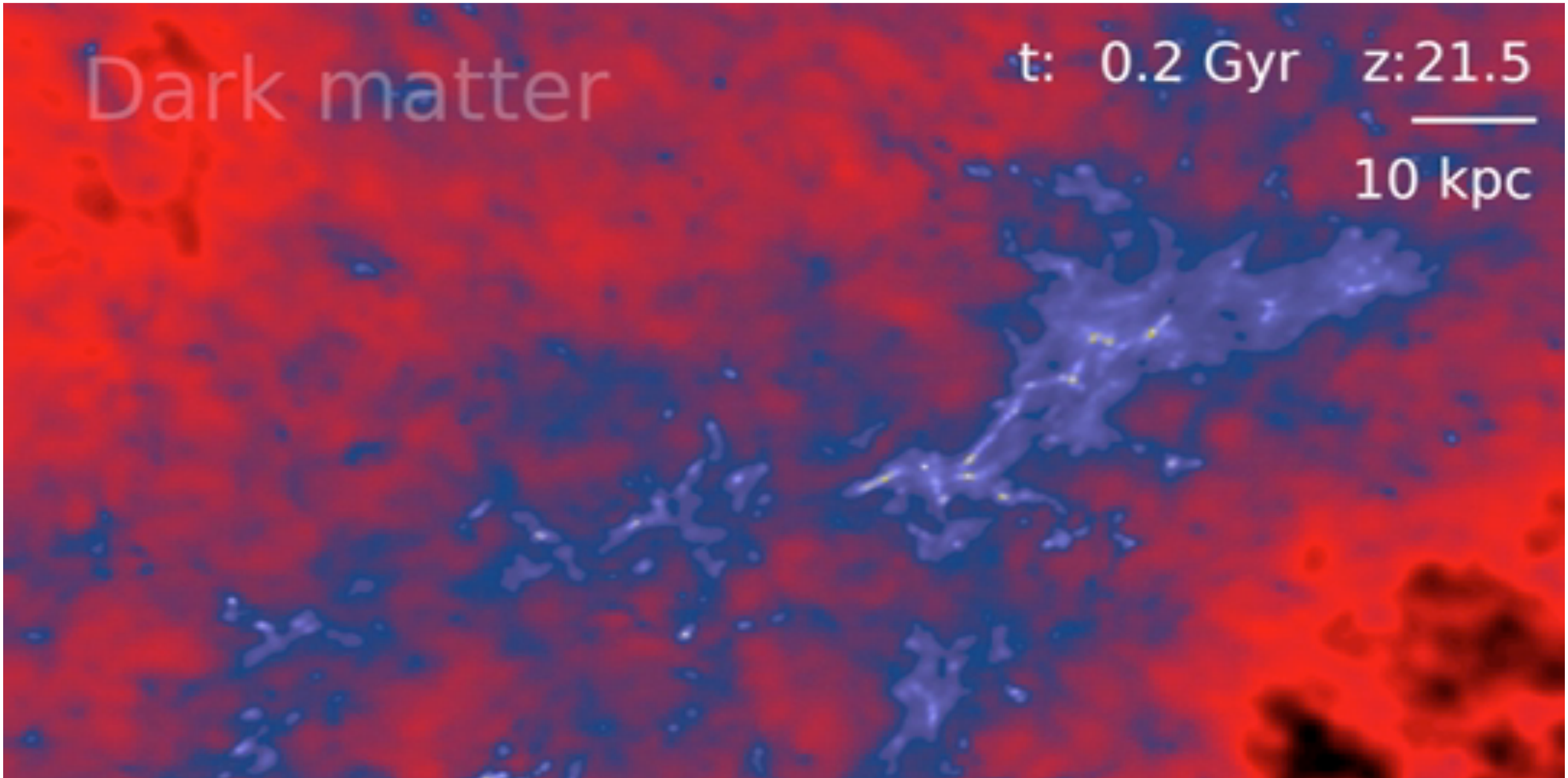
Haloes selected from EAGLE (Shaye+14) 100 Mpc DMO box:

- $5 \times 10^{11} < M_{vir}(z=0) < 2 \times 10^{12}$
- weak isolation criterion

40 sims with ~10^4 Msun; 8 with ~10^3 Msun

AREPO - moving mesh MHD code (Springel 2010)

- *Star formation*
- *Reioinisation (z=6)*
- *Metal line cooling*
- *Mass & metal enrich. (Type Ia & AGB)*
- *SNII feedback*
- *Black hole growth*
- *Radio & quasar AGN feedback*
- *Magnetic fields*



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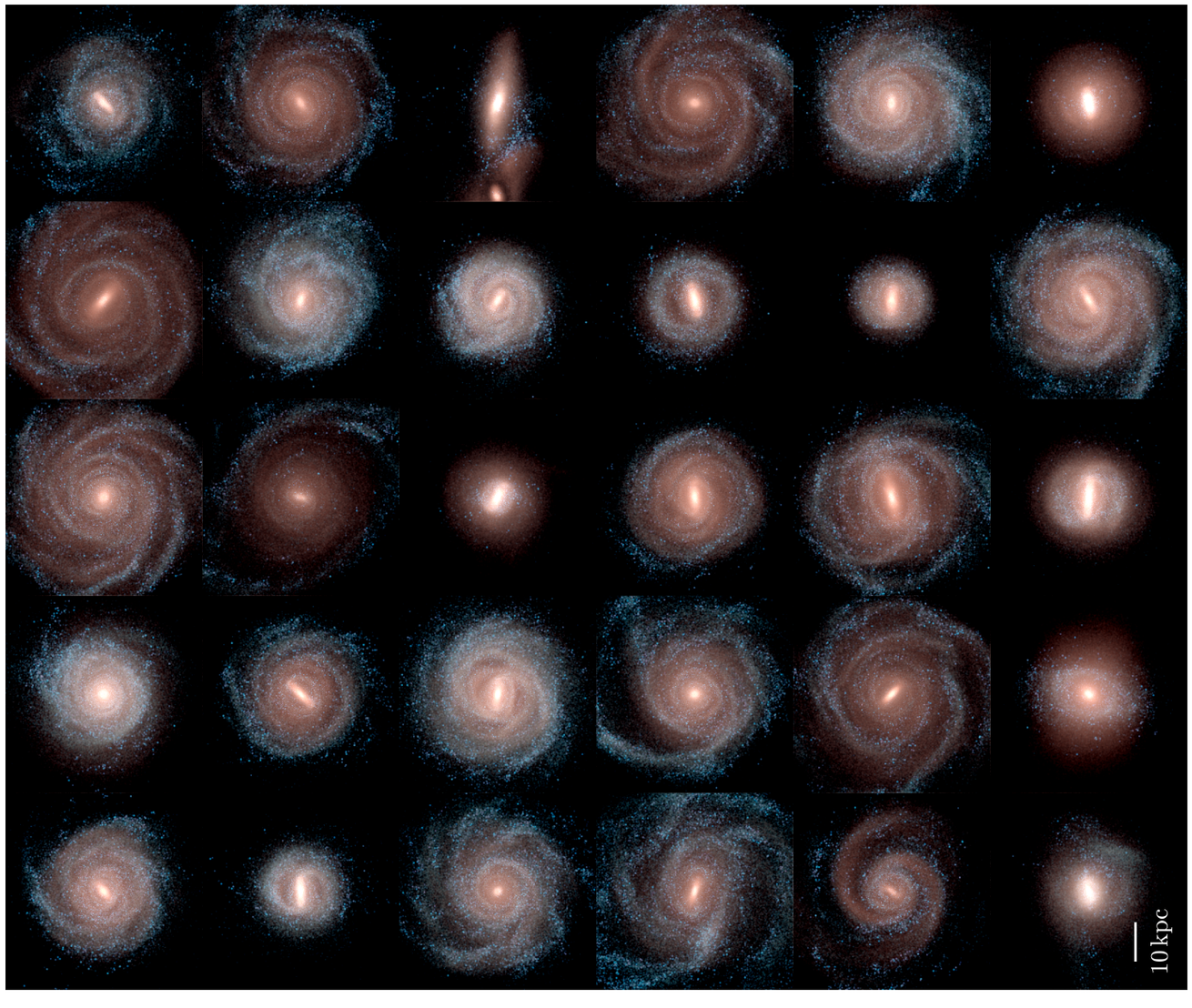
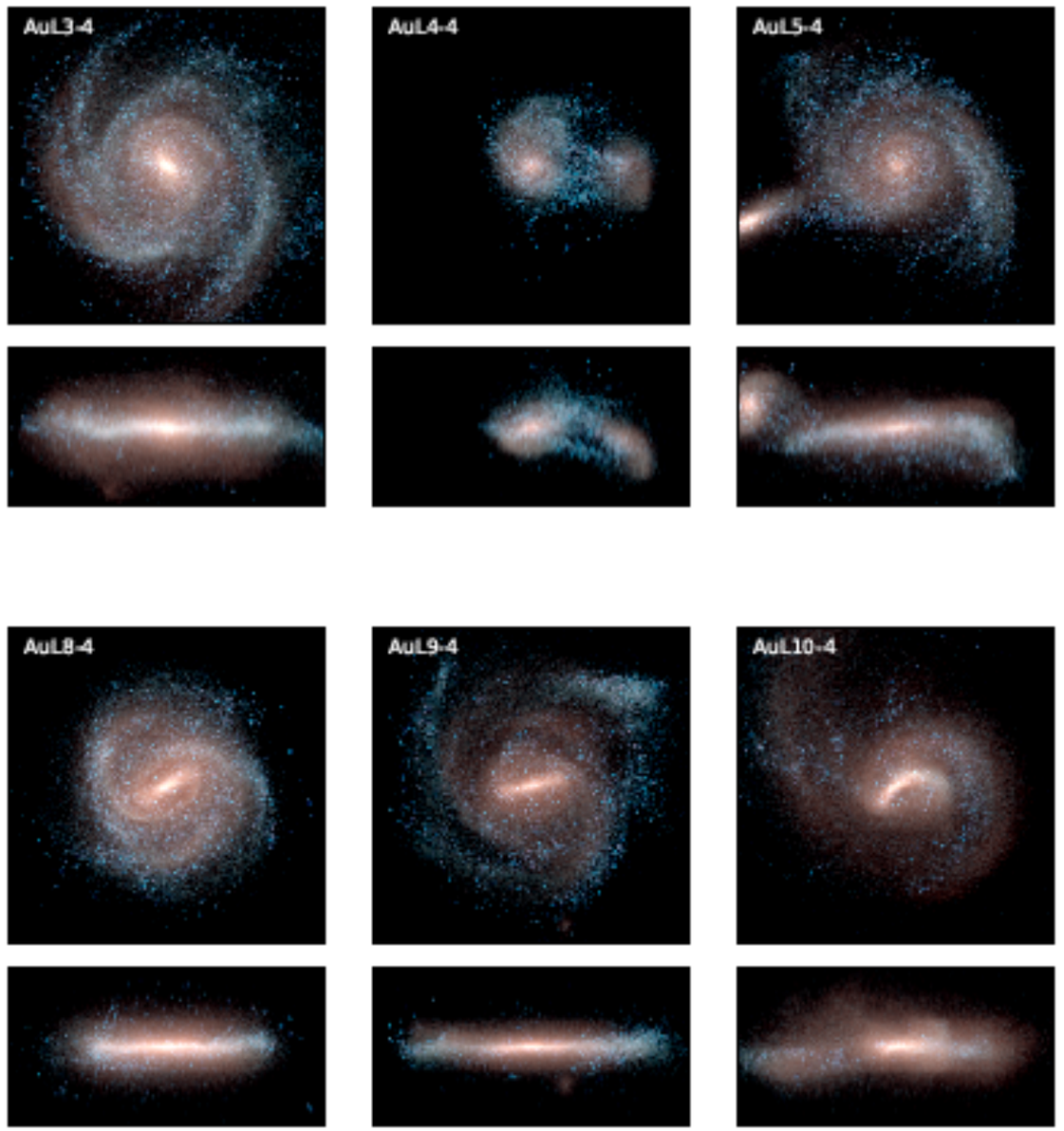
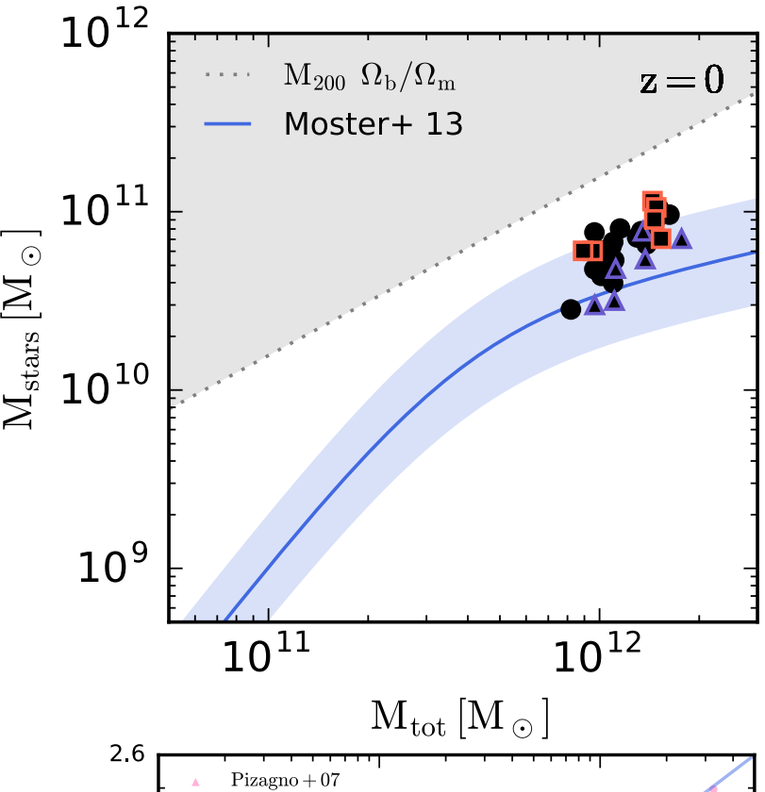
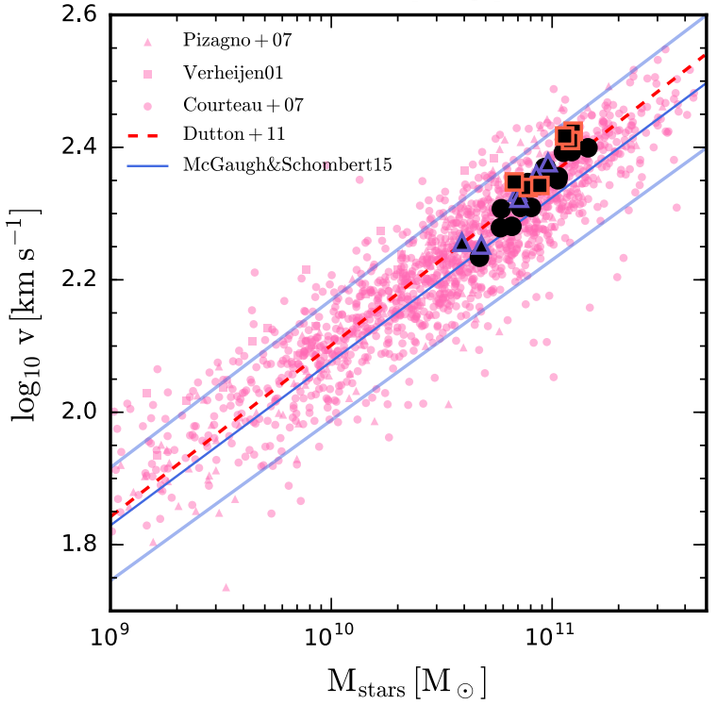
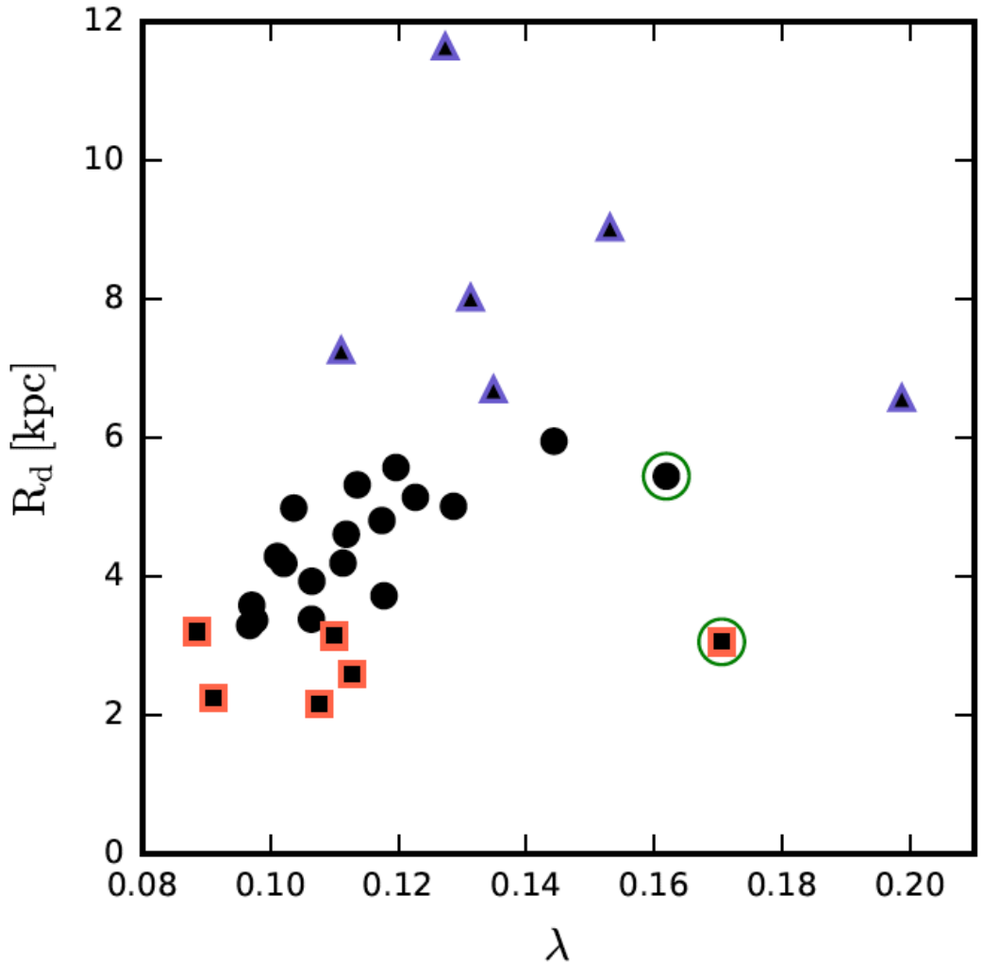




A large sample of hi-res, rotationally supported star-forming MW analogues (see also NIHAO (Wang+14, Buck+18), Aquarius (Marinacci+14), APOSTLE (Fattahi+16))





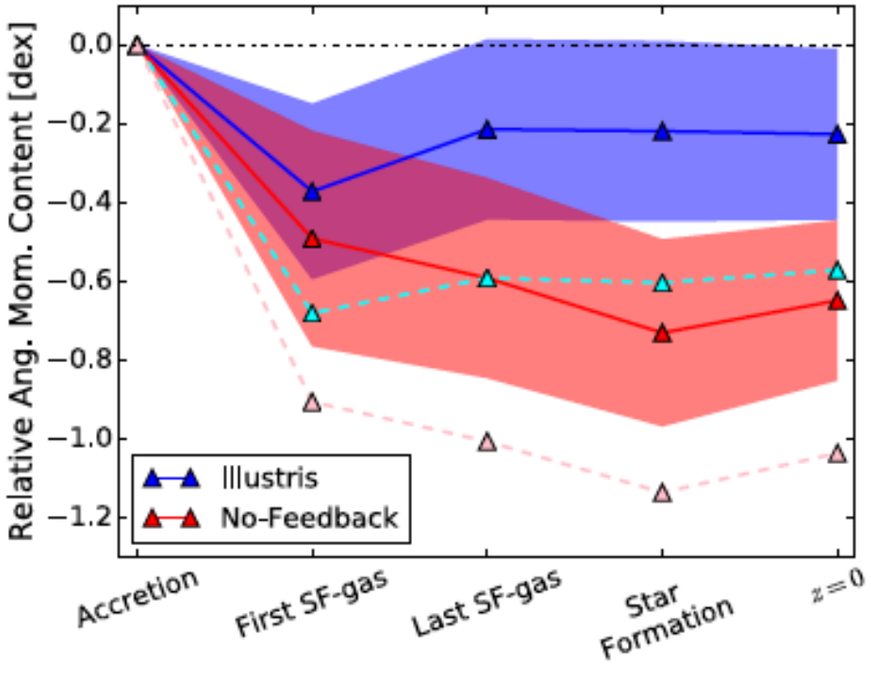


A wide range of sizes and spins -
bears out expectations of halo collapse models
(e.g., Peebles 69, Mo+ 98)

what role do fountain flows/winds play?

HITS

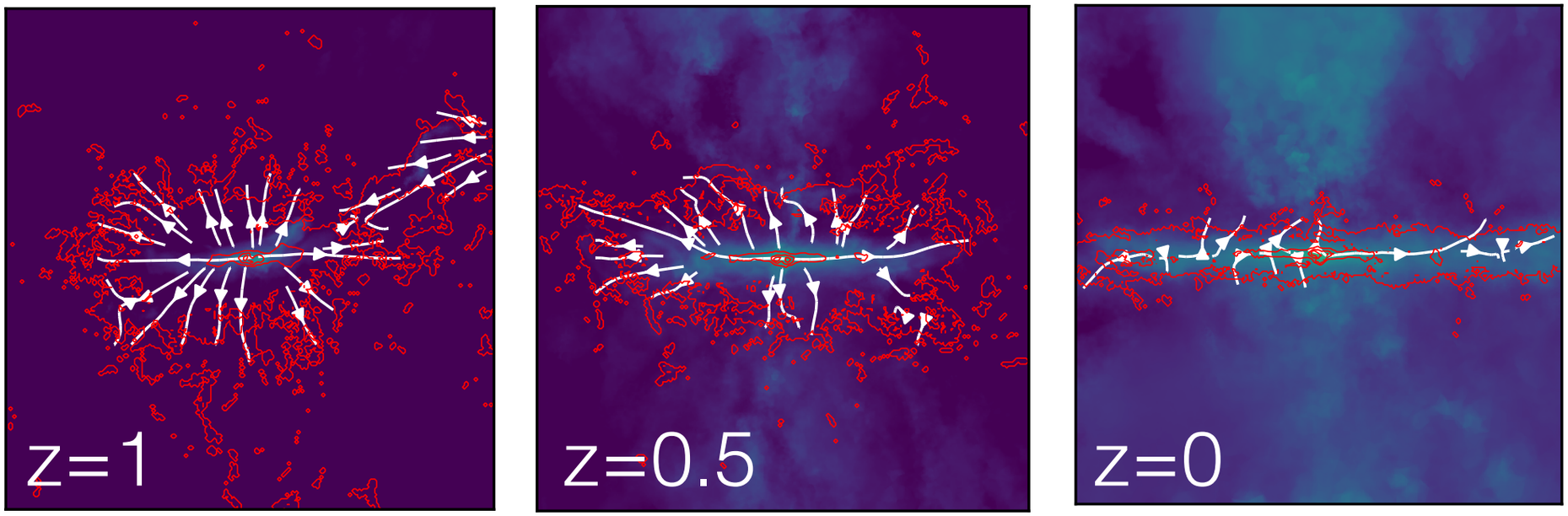
Winds play an important role in growing the disc



Cosmological hydro box simulations (Illustris) show that feedback helps increase angular momentum of galaxies (DeFelippis+ 2017)

feedback-driven fountains can mix with the CGM/ corona and drag material back into the disc (Fraternali's talk and refs therein)

We can imagine them helping grow the gas disc inside-out (and perhaps upside-down)

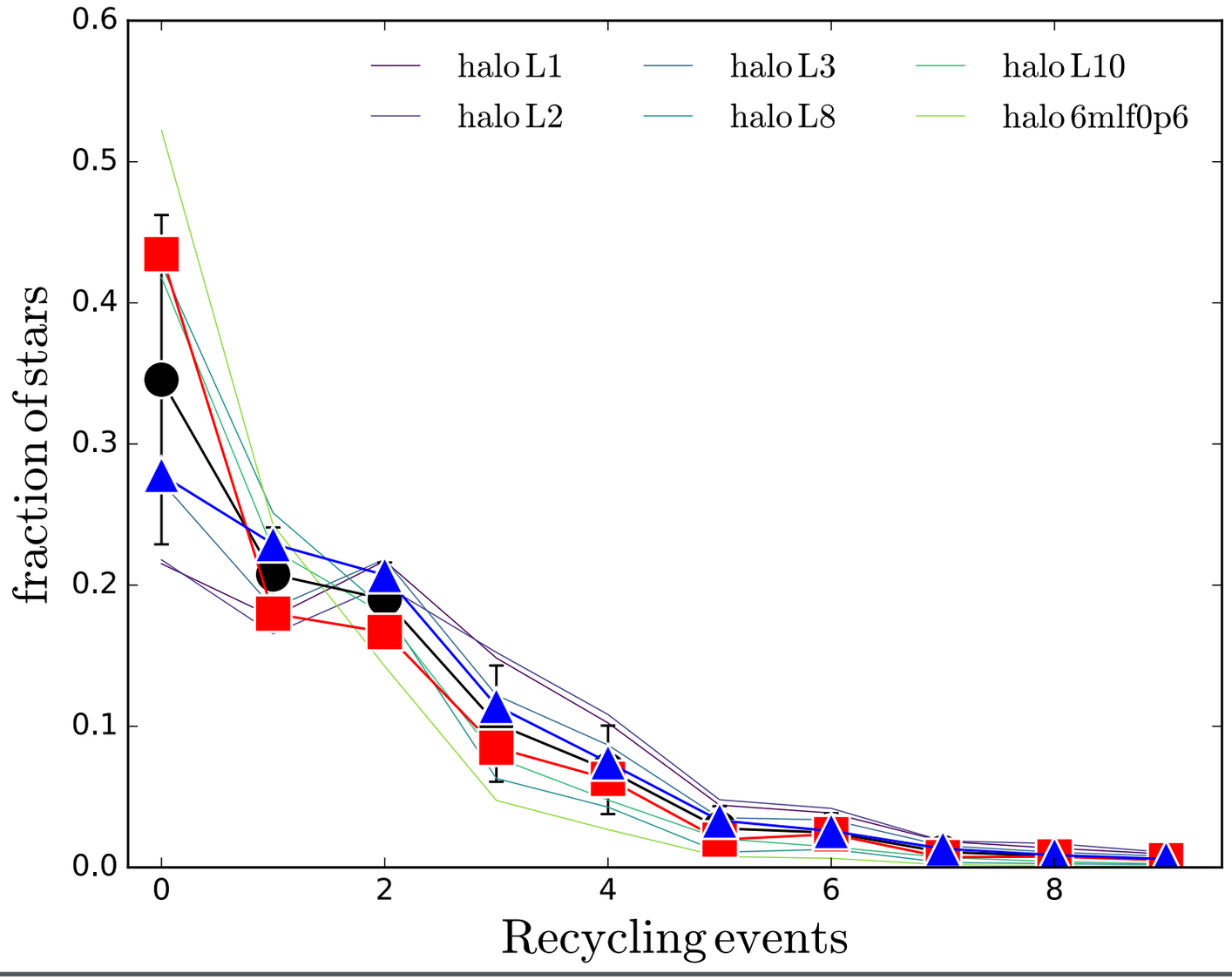


- how does this fit in with the large range of spin values in Auriga?
- relative importance compared to formation histories? e.g. mergers?
- how does it affect the metal distribution?

HITS

Wind recycling: how much recycling happened for stars today?

Method: Identify all stars at redshift zero and quantify the gas recycling events using MC tracer technique (Genel+ 2014)



- More than half of **all** stars have gone through at least **1** recycling event
- About half of **outer disc** stars have gone through at least **2** recycling events

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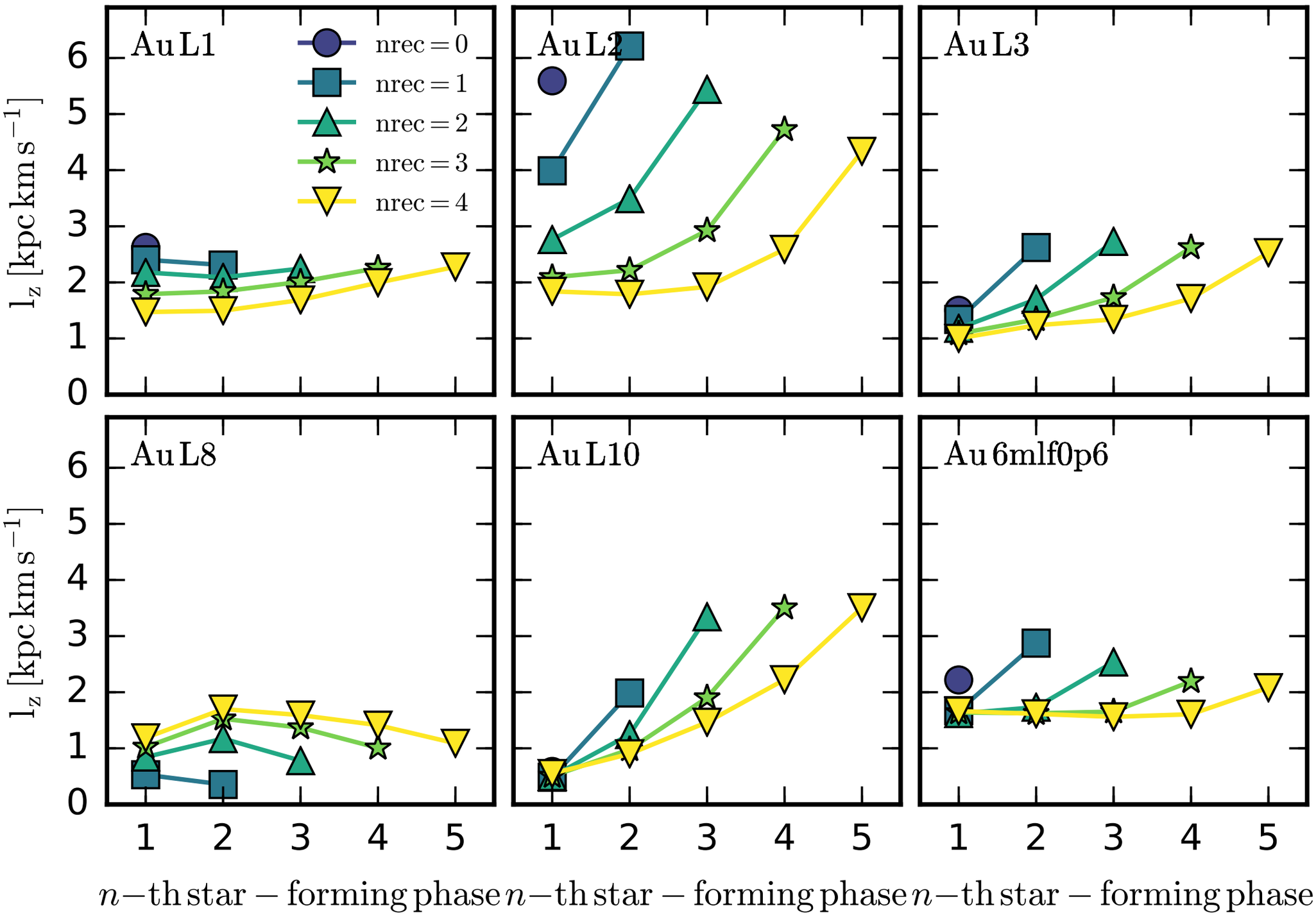
Wind recycling: quantifying the disc growth



- Winds generally increase any. mom. with each recycling event…
- … but a range of trends can be seen

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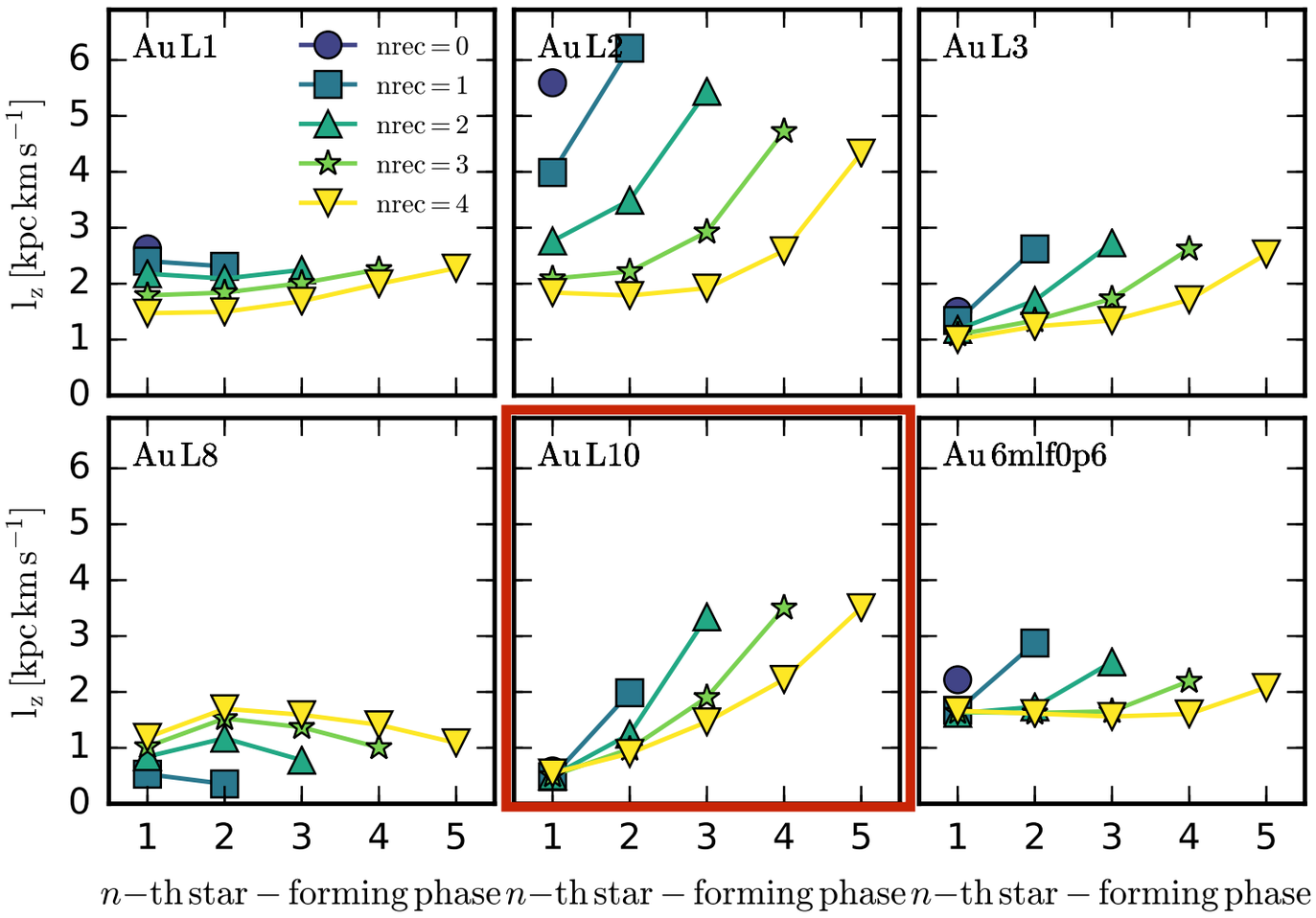

- steady growth with quiet merger history

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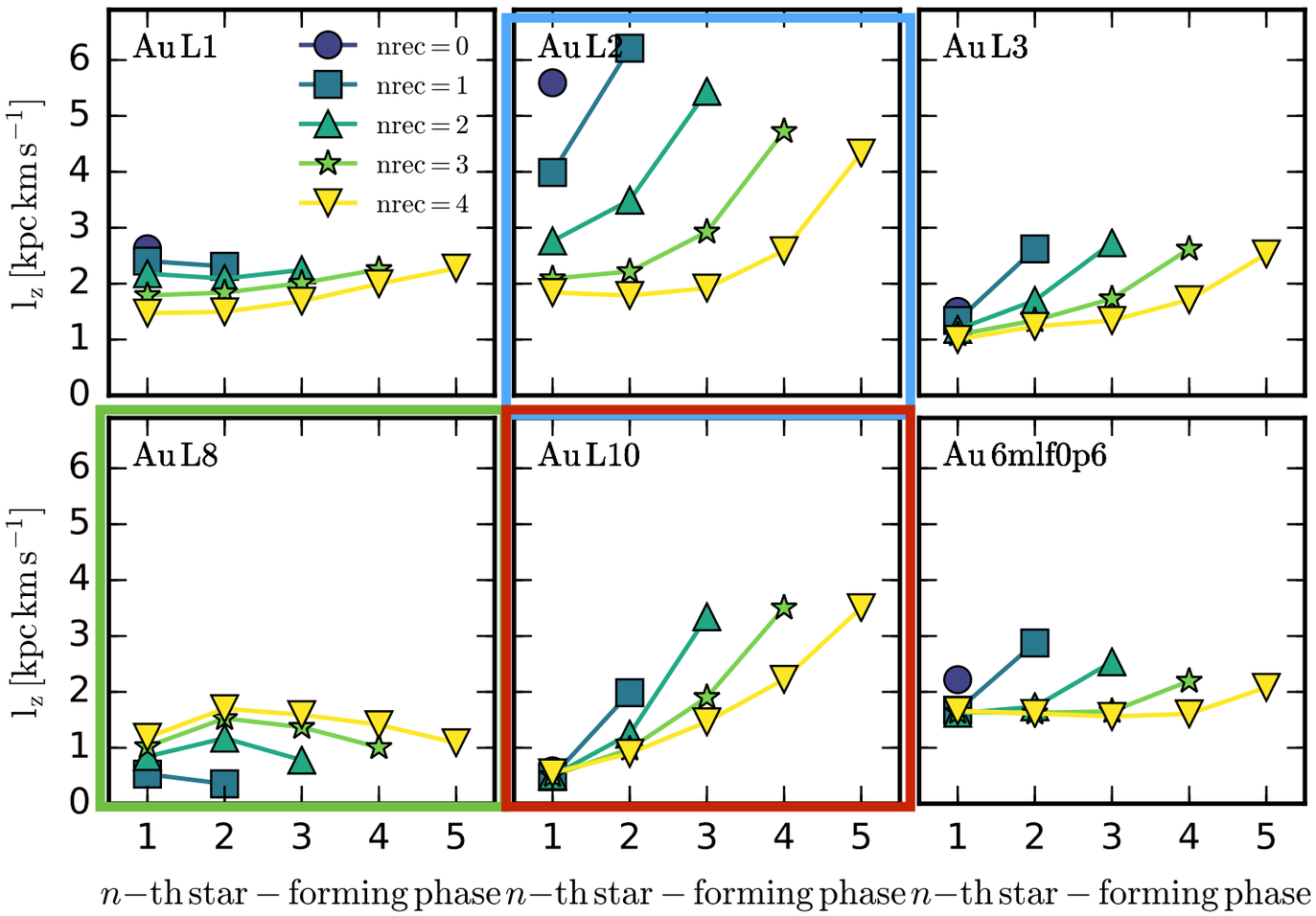
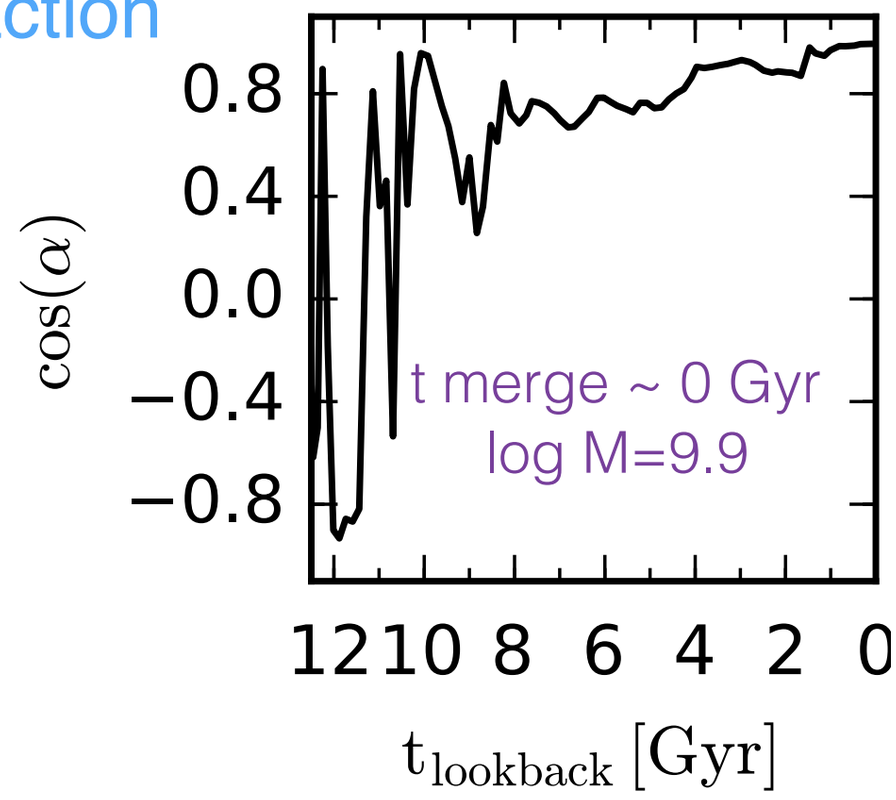
Wind recycling: the importance of mergers



- steady growth with quiet merger history

- prograde late-time merger + SF = high Lz unrecycled fraction

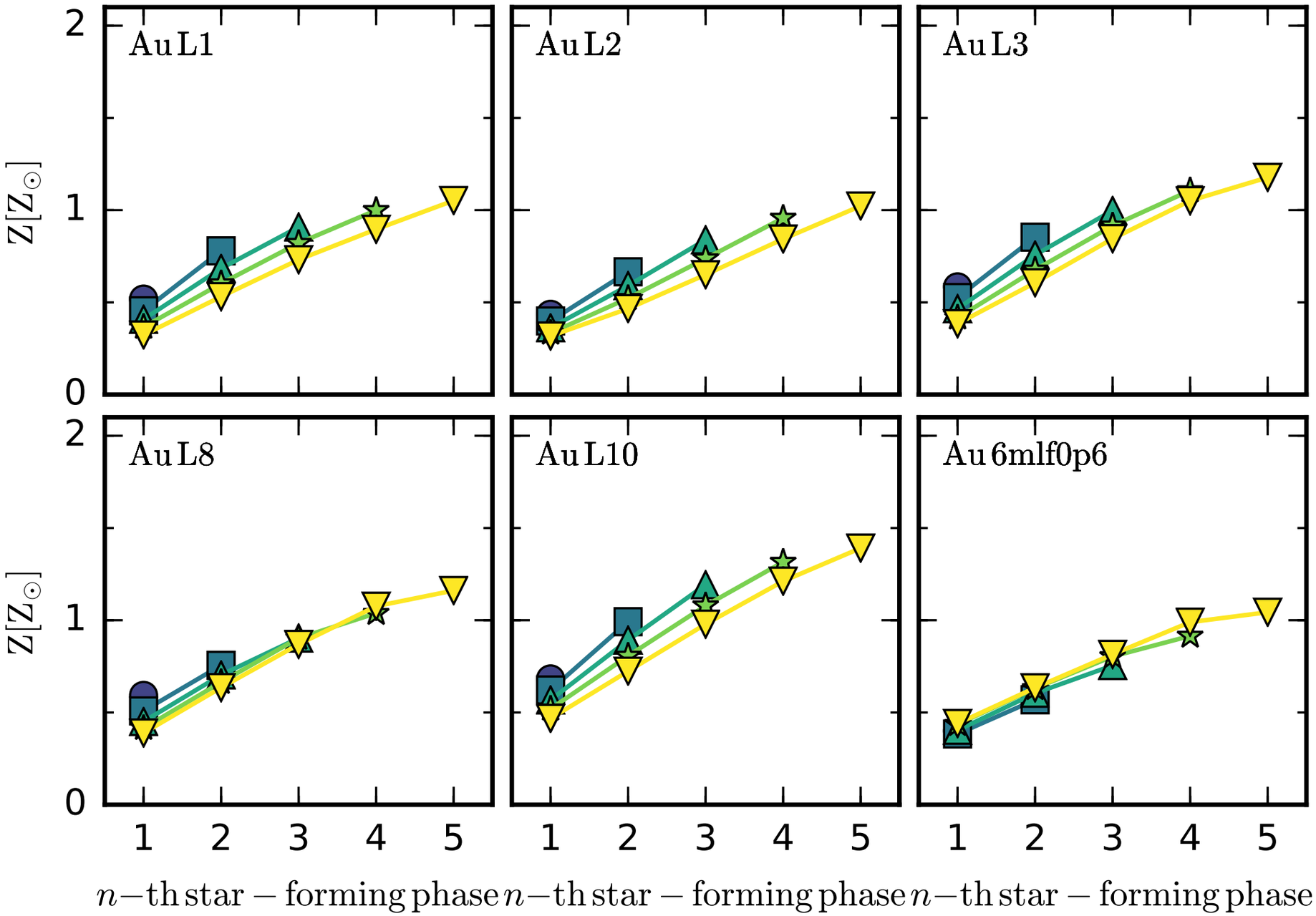


- massive retrograde merger - negative trends

- details likely depend on: the time gas entered SF phase relative to merger; fraction of fresh gas brought in etc.

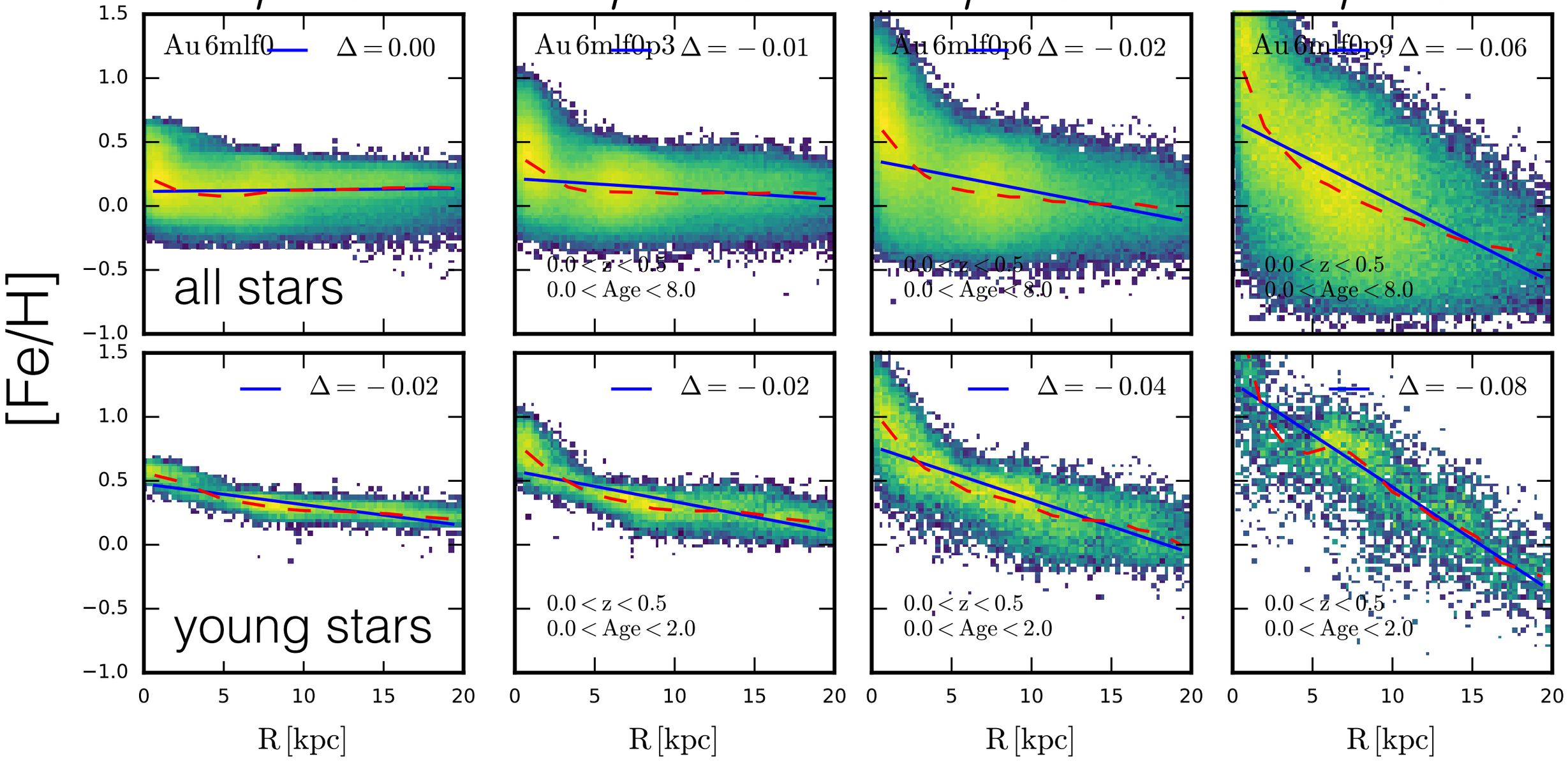
Wind recycling: a key for setting metallicity gradients

For each SNII event, winds are loaded with $1 - \eta = 0.4$ of the metals of the particle, where eta is fraction left behind



- metal enrichment scales almost monotonically with recycling events

Metal loaded-Fountain flows critically affect metallicity distribution



- fully loaded winds lead to flat [Fe/H] gradients and small dispersion
- gradients (dispersion) becomes steeper (broader) for metal poorer winds
  —> more efficient metal mixing in CGM? (van de Voort's talk)

This highlights the importance of fountain flows for the formation of discs

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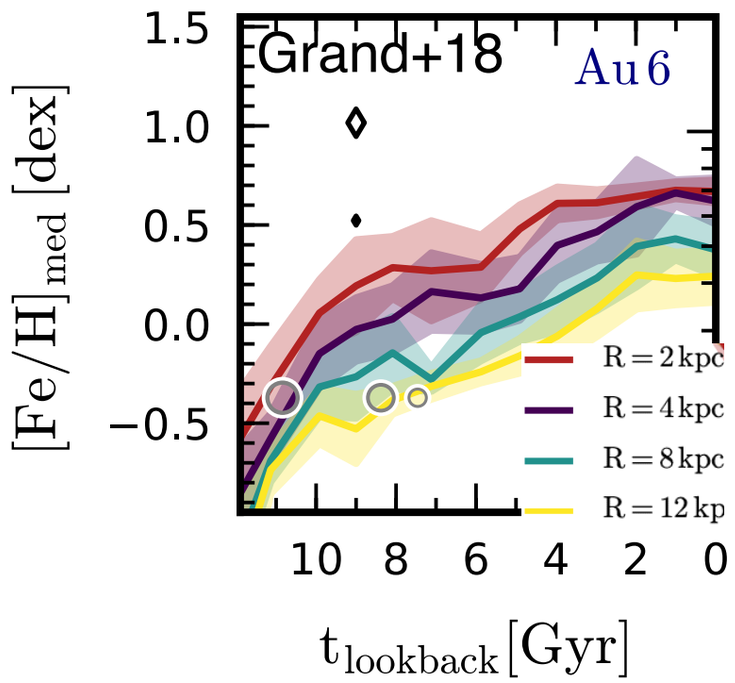
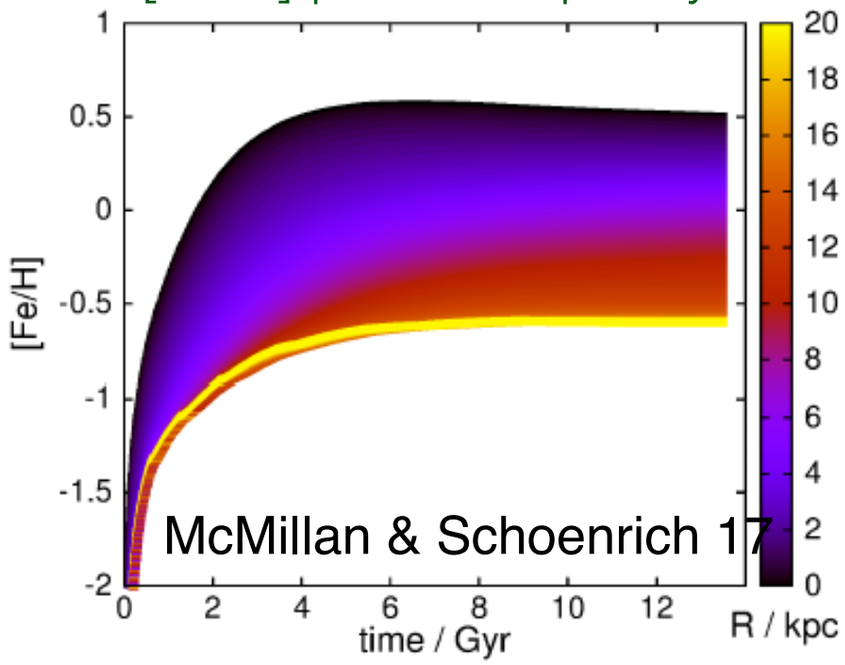
Fountain flows continually enrich gas metallicity:- A problem for chemical evolution models?

No equilibrium between pristine gas infall and chemical enrichment *(contrary to assumptions of analytic Chemical Evolution models)*

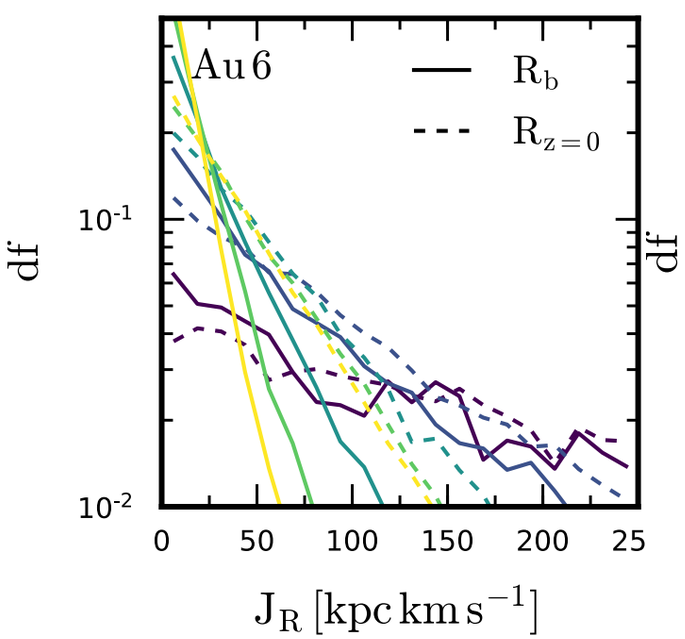
[Fe/H] increases



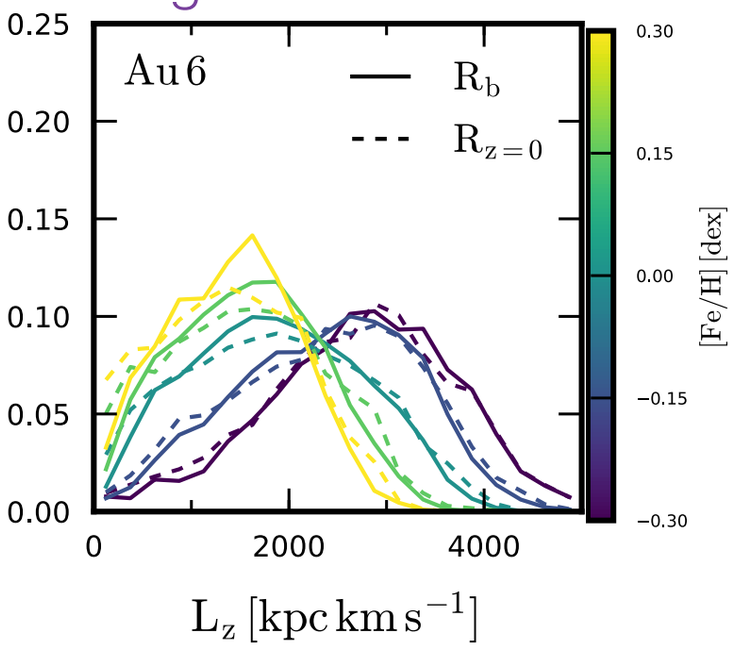
[Fe/H] plateaus quickly



Radial action



Angular momentum



Critical for interpreting the phase space distribution of coeval/mono-abundance stellar populations from surveys like *Gaia* and APOGEE

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And now for something completely different….

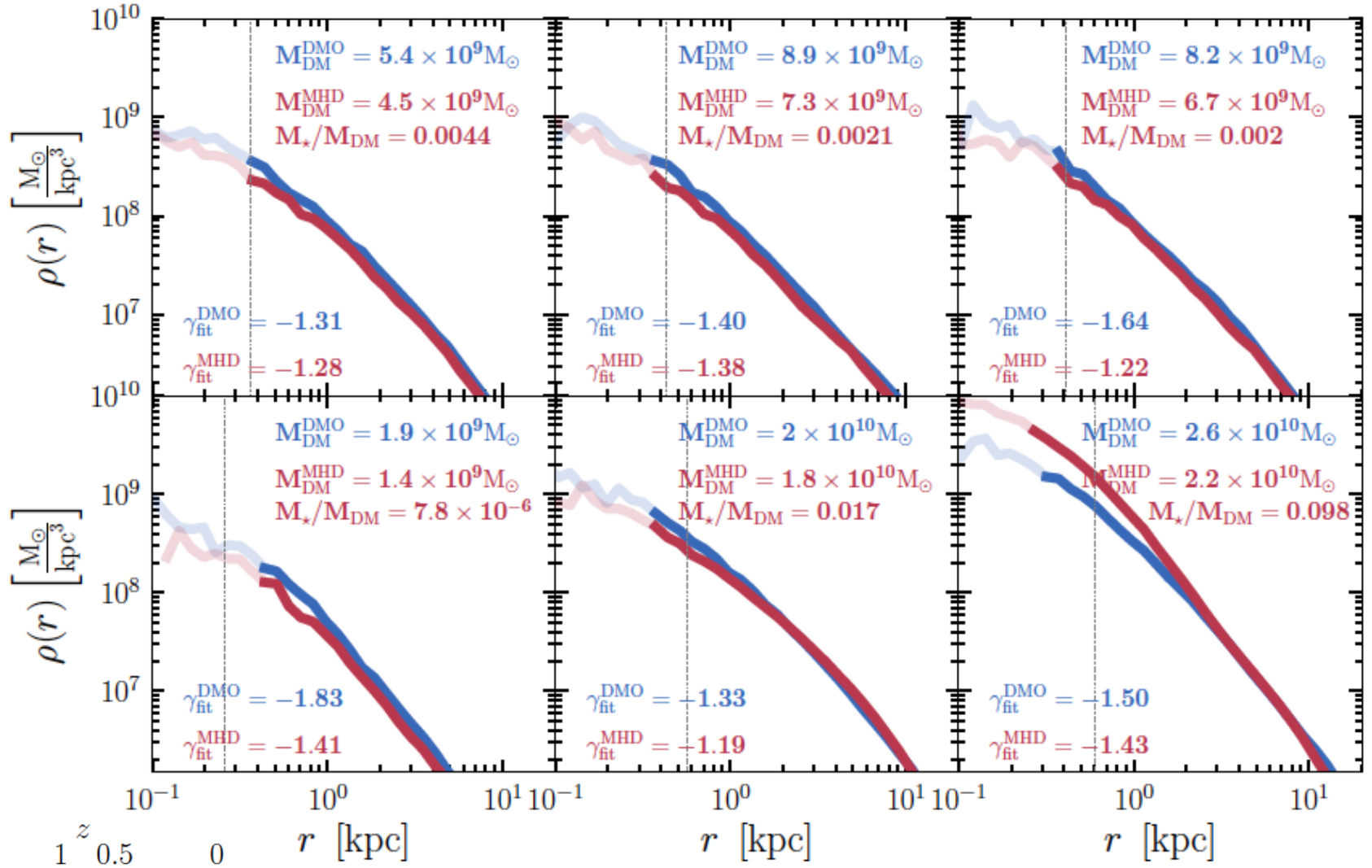
Dark Matter Cores/Cusps

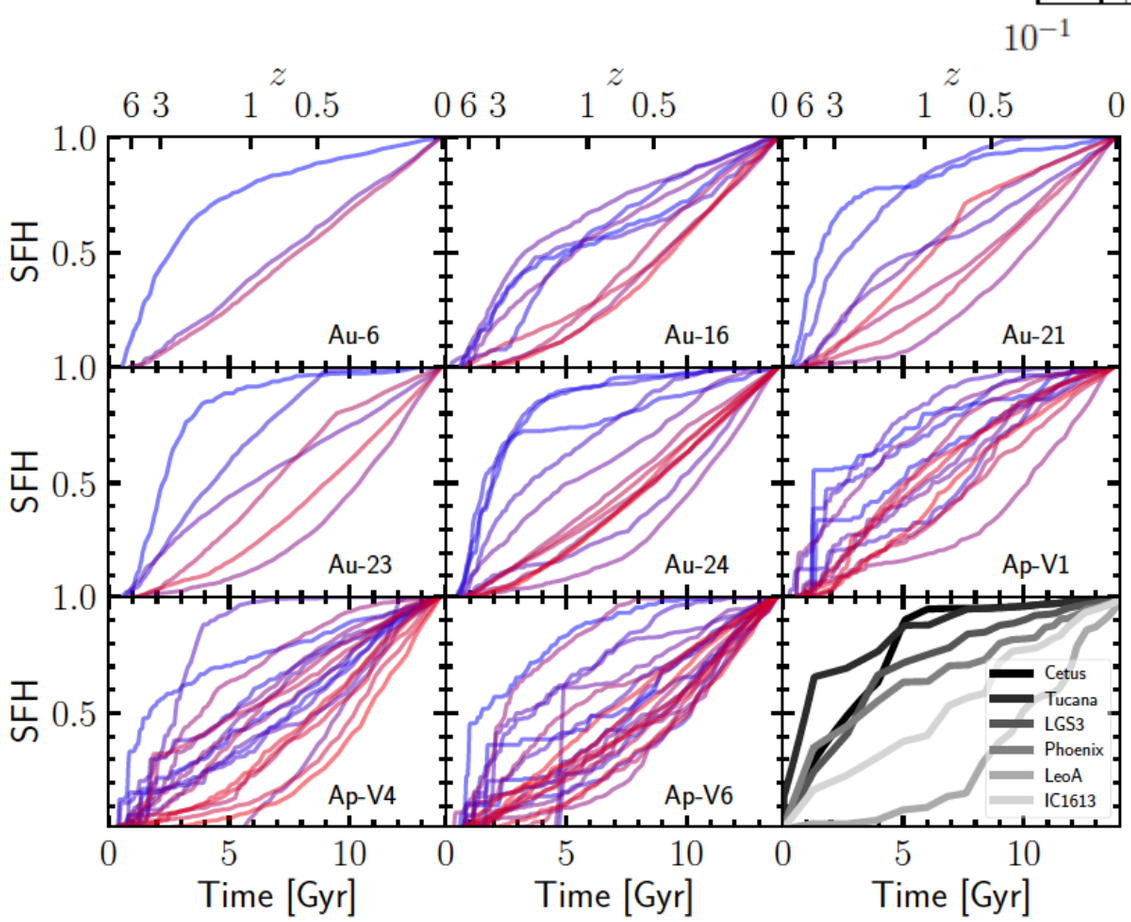
HITS

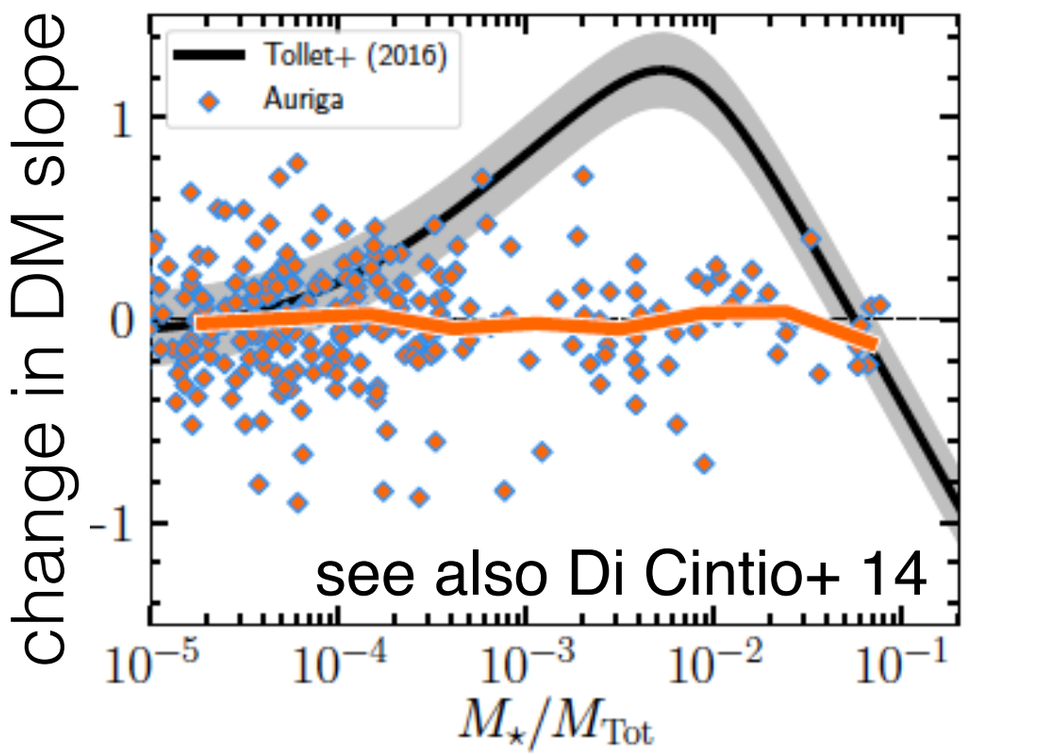
No cores to see here

(Bose, RG+ in prep)

Neither Auriga nor APOSTLE (Fattahi+16) show a single dwarf with a DM core (despite a range of SFHs including bursty ones)







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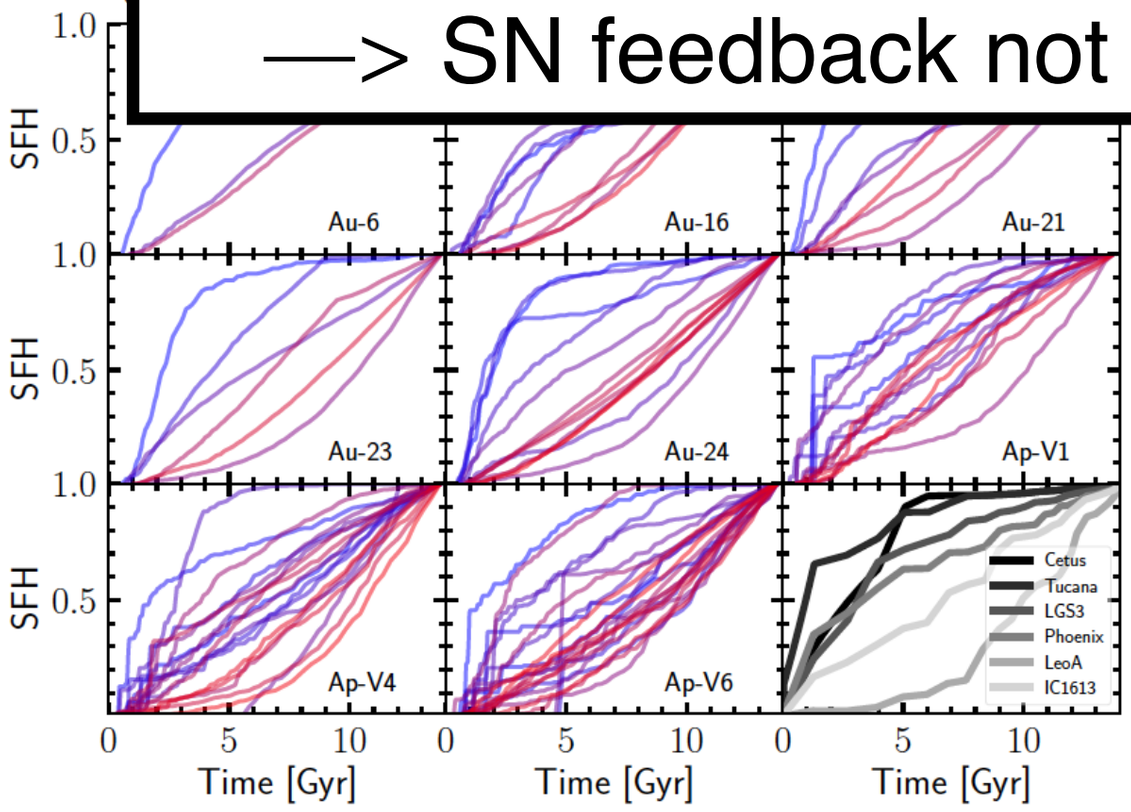
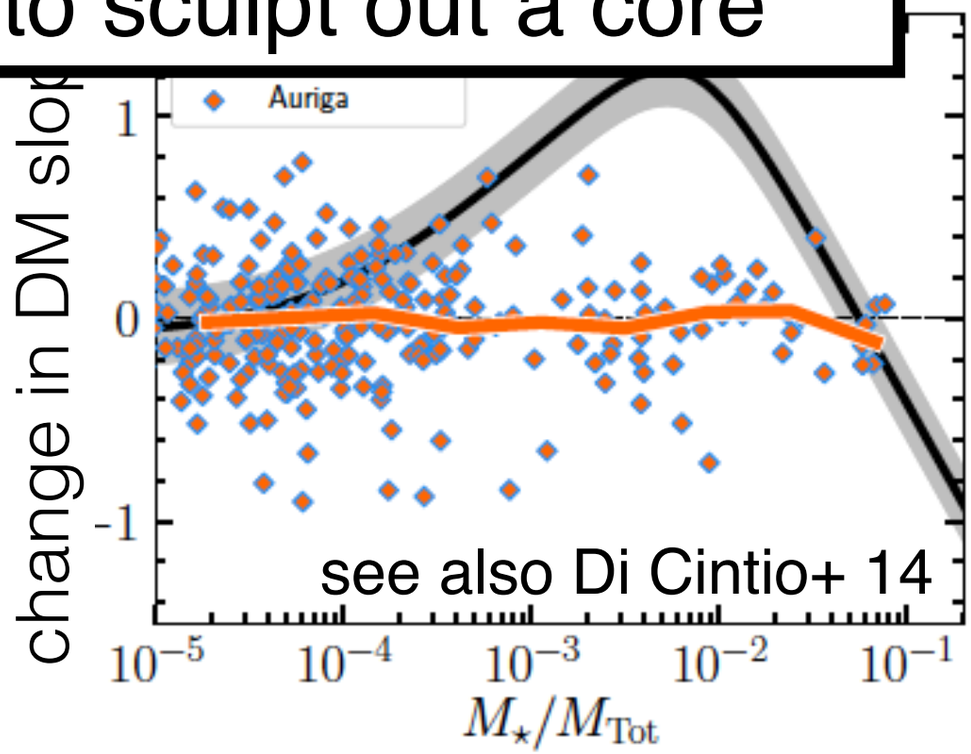
Upshot: relatively low SF density threshold too low to allow gas to build up and dominate central potential

—> SN feedback not effective to sculpt out a core





Summary

Feedback-driven fountain flows are in operation and generally:

- increase aid inside-out growth…
  … but mergers and late-time accretion of fresh gas can dramatically affect trends

- play a major role in setting the gas (and star) metallicity distribution
  depends heavily on metal loading and therefore gas dynamics/mixing on the small scales

HITS