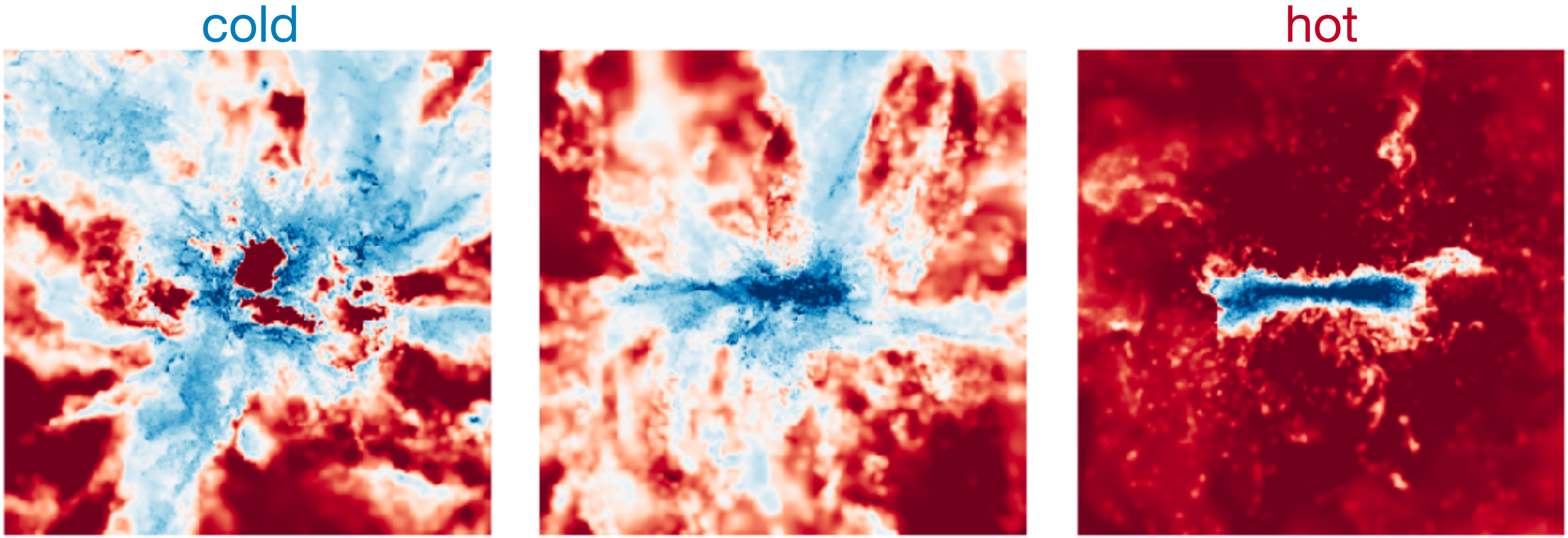
Inner CGM virialization and its implications for disk galaxies, star formation and galactic winds

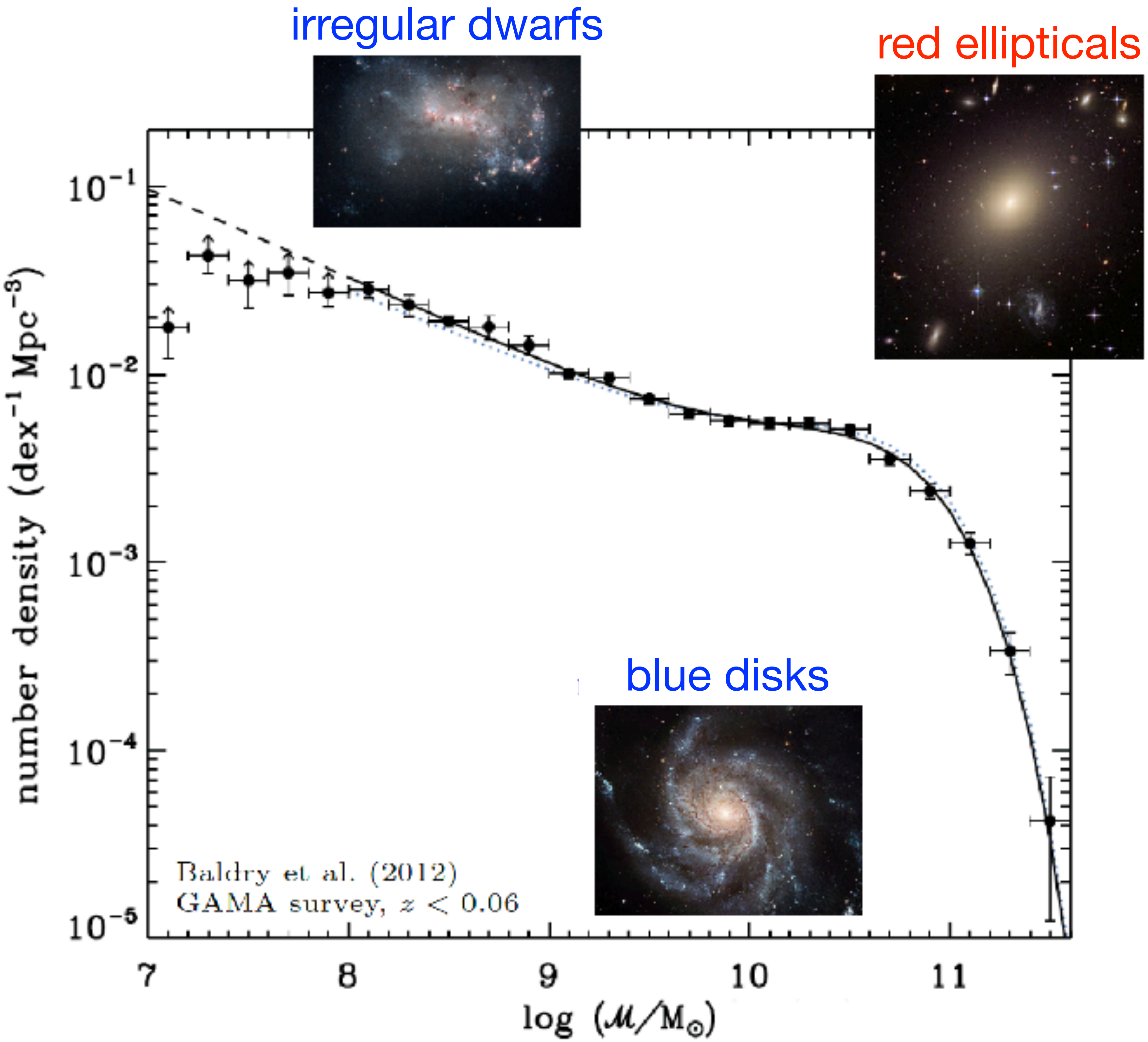
"ICV"



Claude-André Faucher-Giguère
Northwestern | CIERA

Jonathan Stern (see poster!), Drummond Fielding, Daniel Anglés-Alcázar, Sarah Wellons, Mike Grudić,
Alex Richings, Alex Gurvich, Lindsey Byrne, Zach Hafen, José Flores, Megan Tillman,
Phil Hopkins, Dusan Kereš, Eliot Quataert, Norm Murray + FIRE team

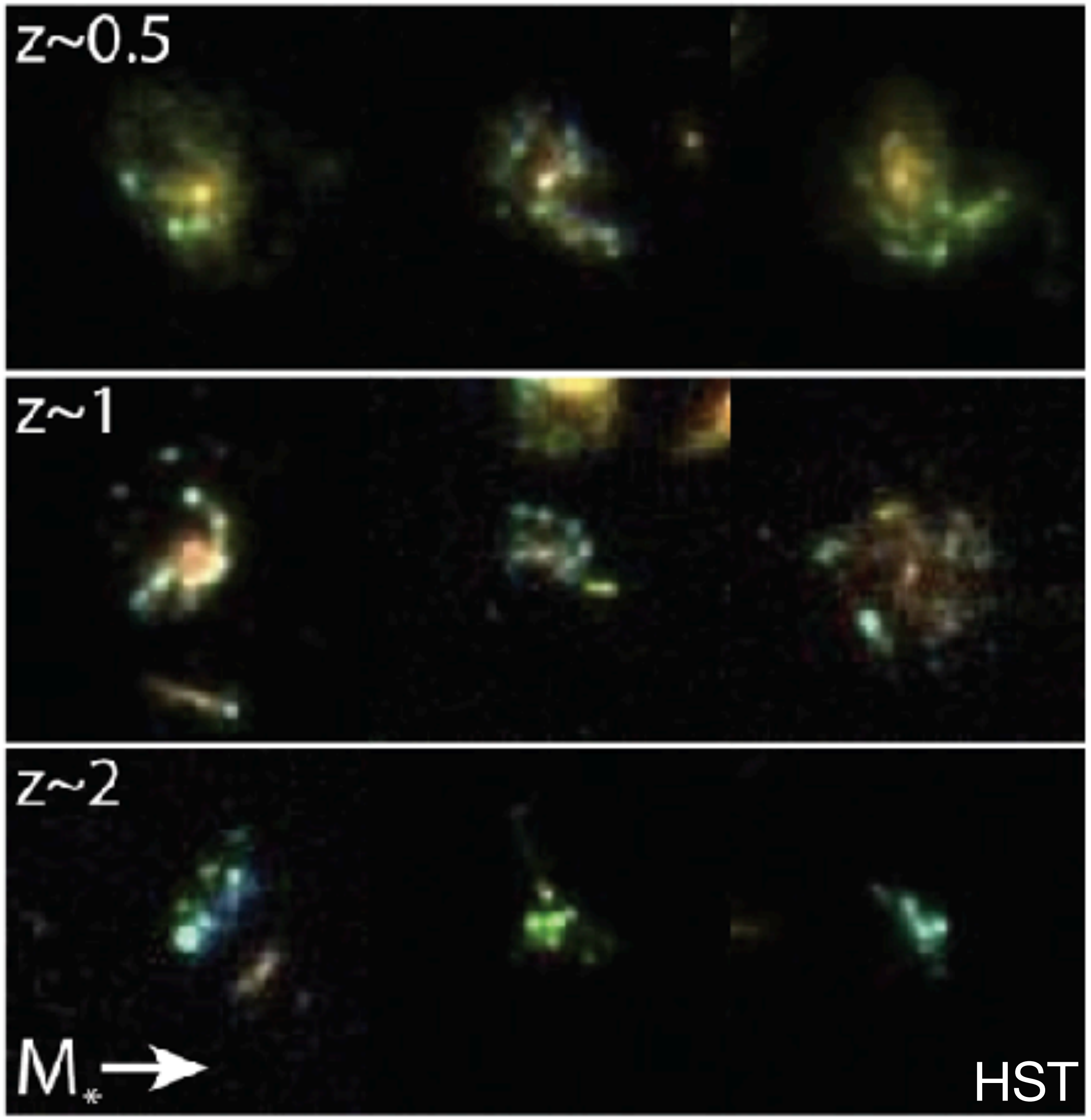
When do galaxies have large disks, and why?



DM halos have invariant AM profiles ⇒ something other than AM conservation must be important (cf. Fall & Efstathiou 80; MMW98, …)

What drives observed redshift evolution?

High-z galaxies



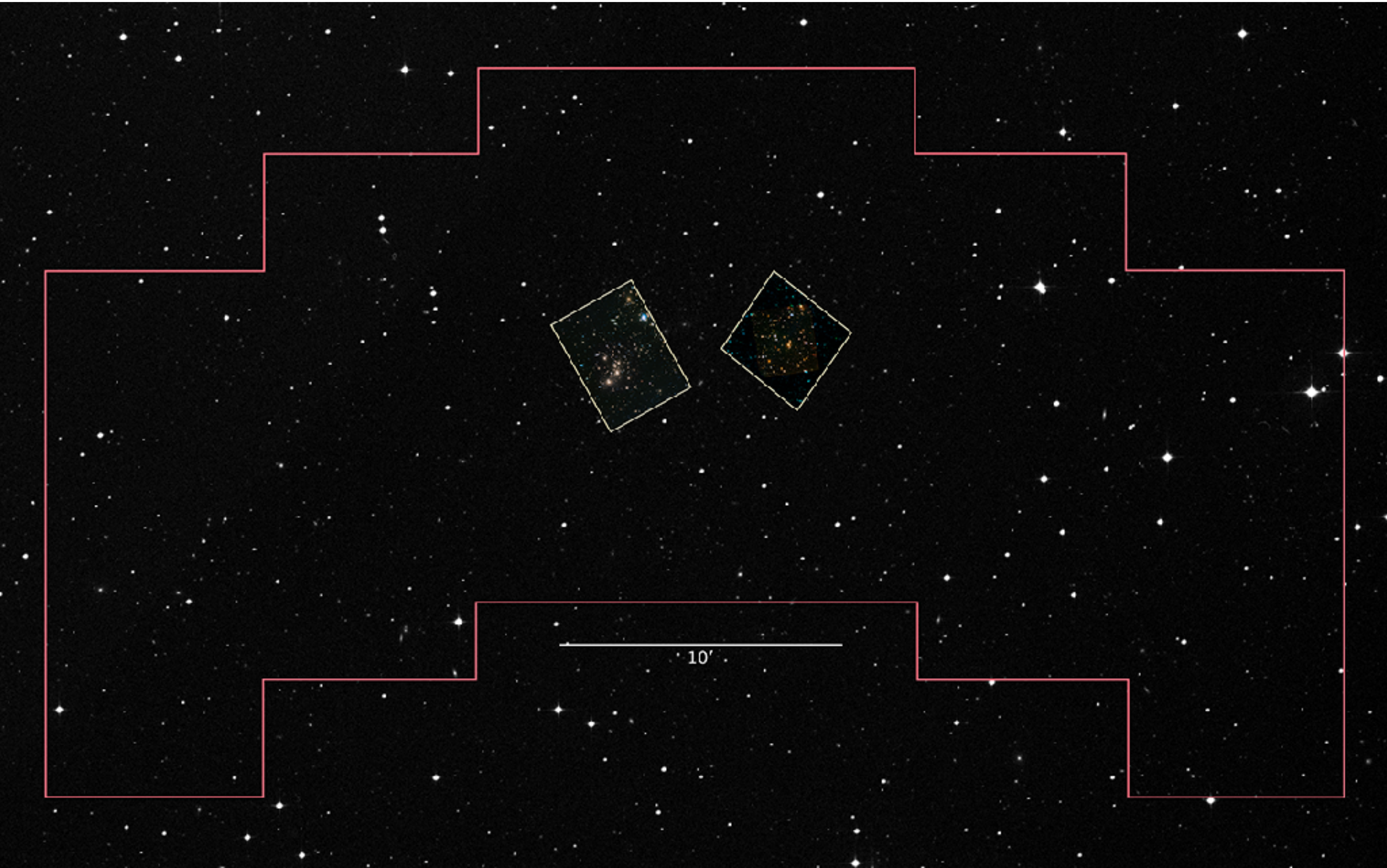
Local disk galaxy (M63)

disks increasingly common with decreasing *z*

Guo+15; R. Gendler

Roman: HST resolution but 100x FoV

→ greatly improved ability to test disk formation models, especially at high redshift



FIRE: Feedback in Realistic Environments

- Cosmological “zoom-ins" resolving GMCs

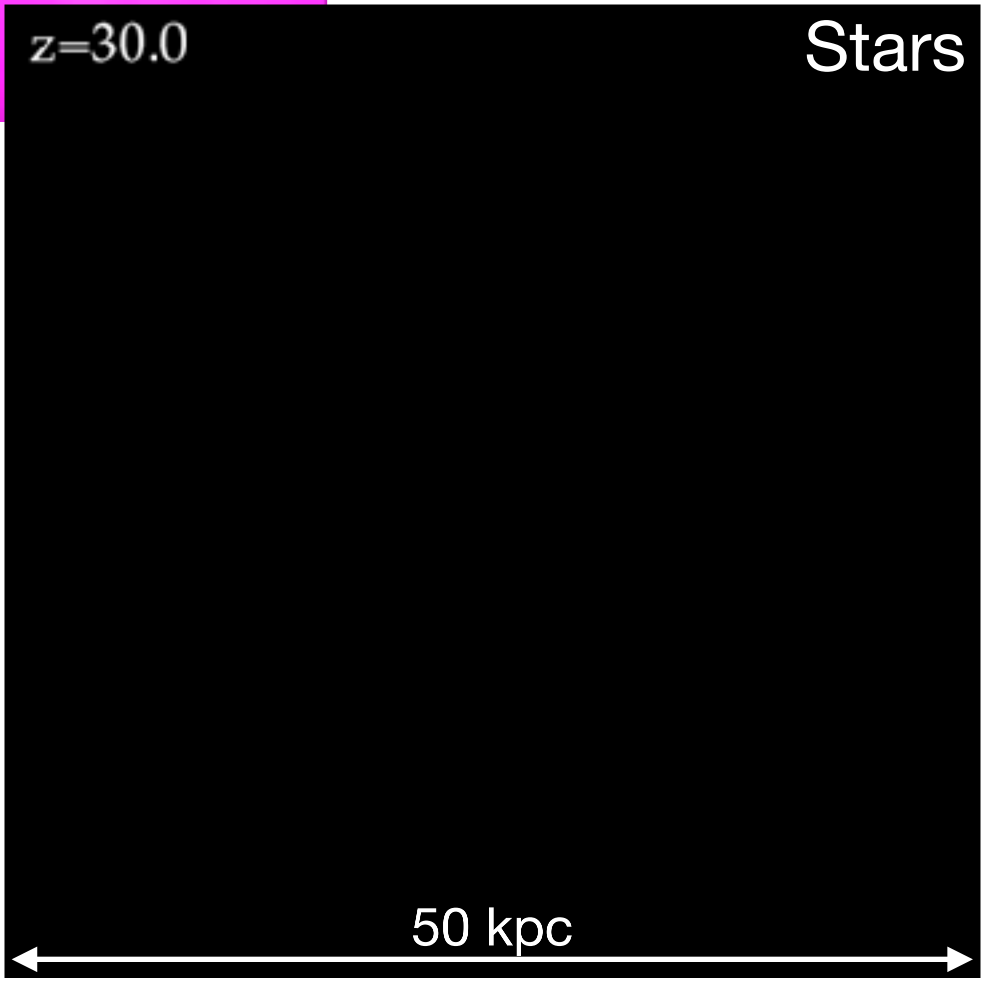
- Metal and molecular cooling to $T\sim10$ K; SF in dense, self-grav. gas

- Stellar feedback (SNe II&Ia, stellar winds, radiation) based on STARBURST99

- ISM properties, SF regulation, outflows, etc. emerge from energy injection on the scale of star-forming regions

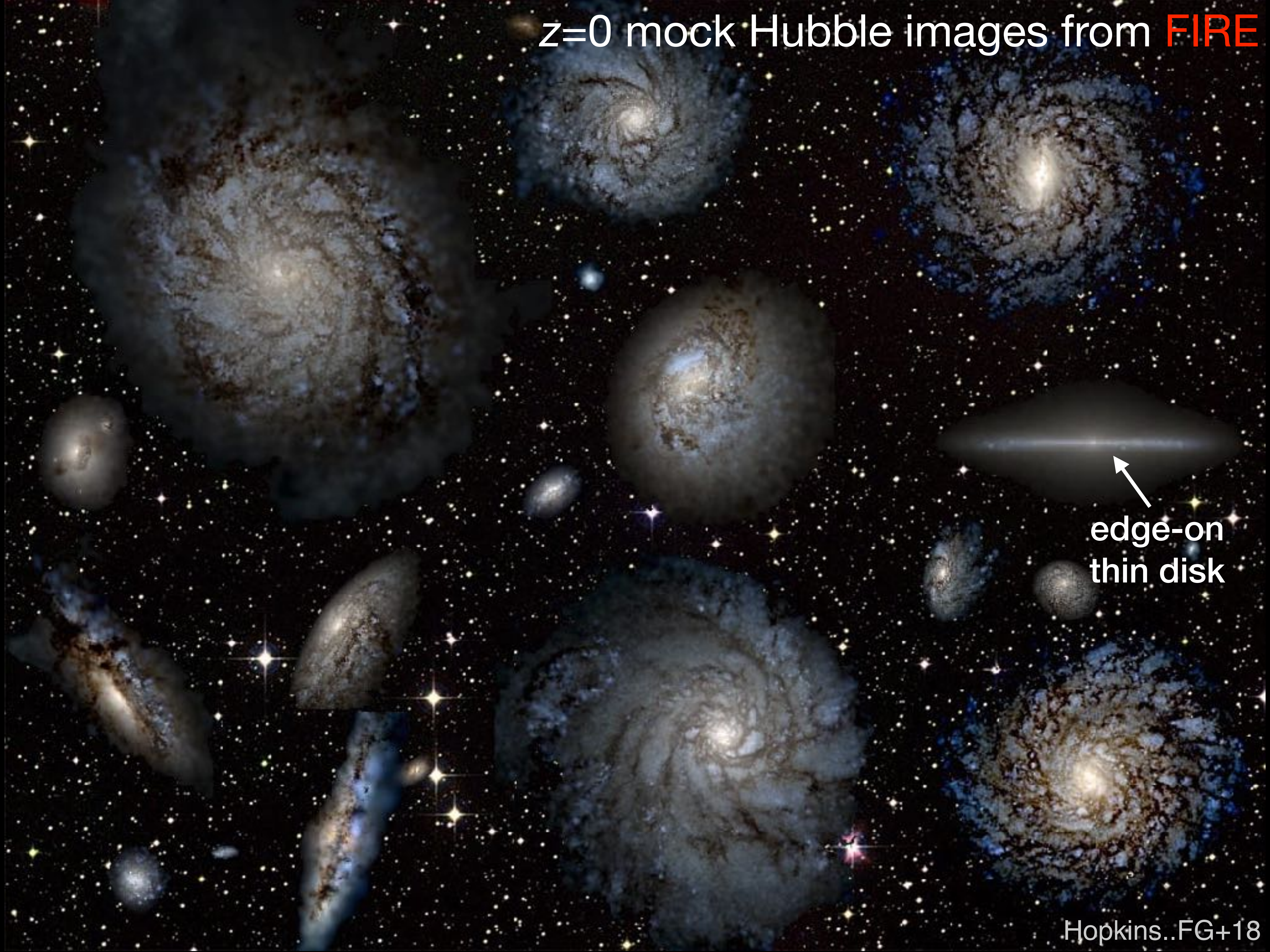
Res. (dwarfs to >L^*): $30\text{-}3\times10^4$ M_{sun}, 0.1-10 pc

←MW-mass by z=0



Project web site: http://fire.northwestern.edu

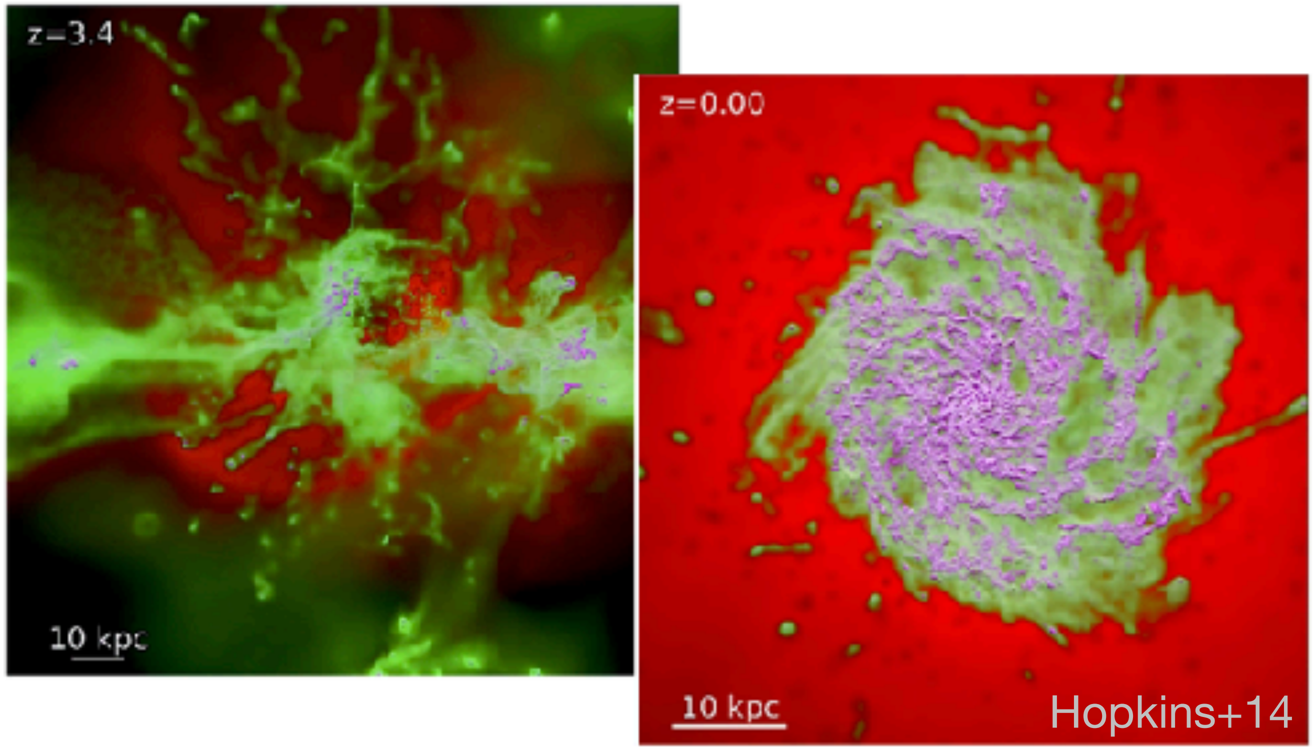
$z=0$ mock Hubble images from FIRE



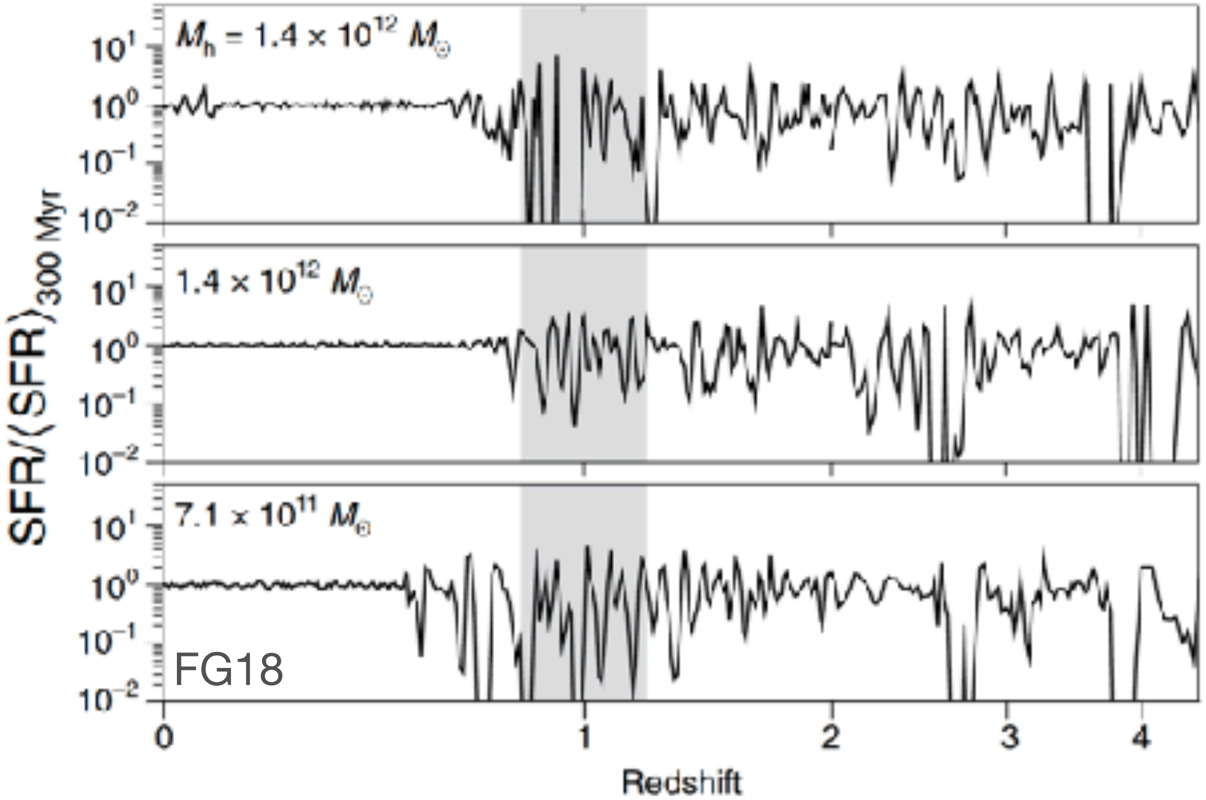
Hopkins..FG+18

Multiple transitions occur at the same time, at ~*L**

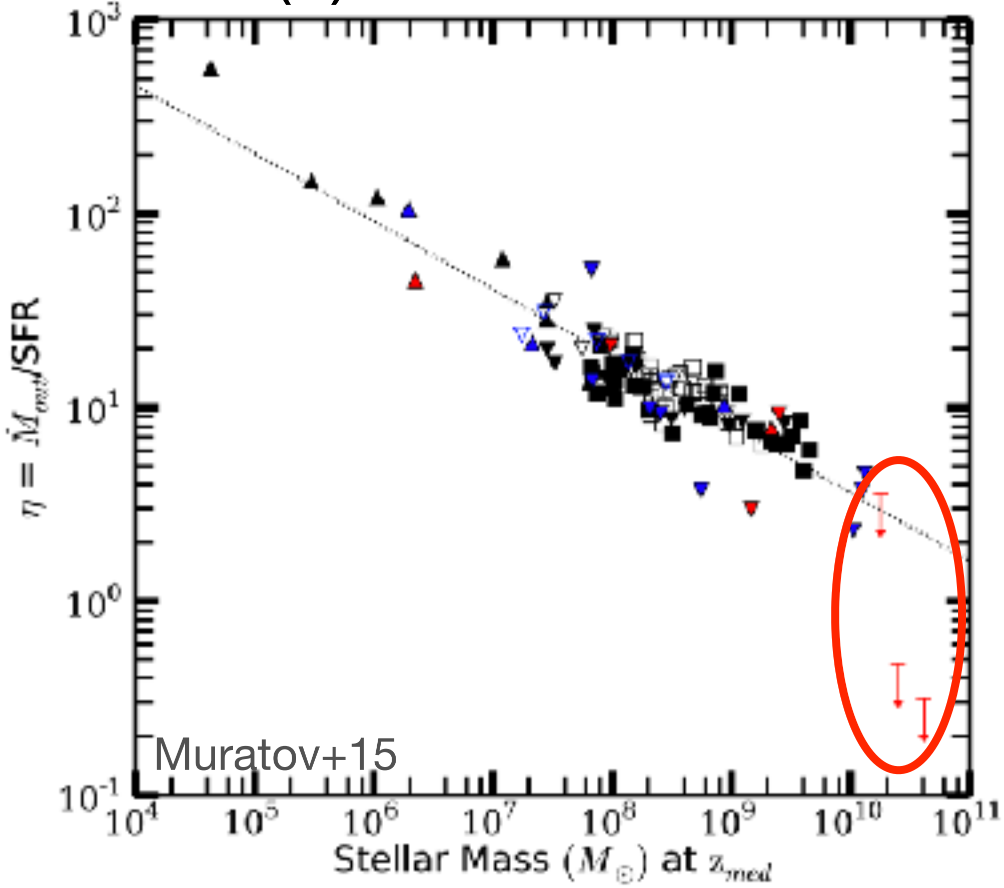
(1) **Morphology**



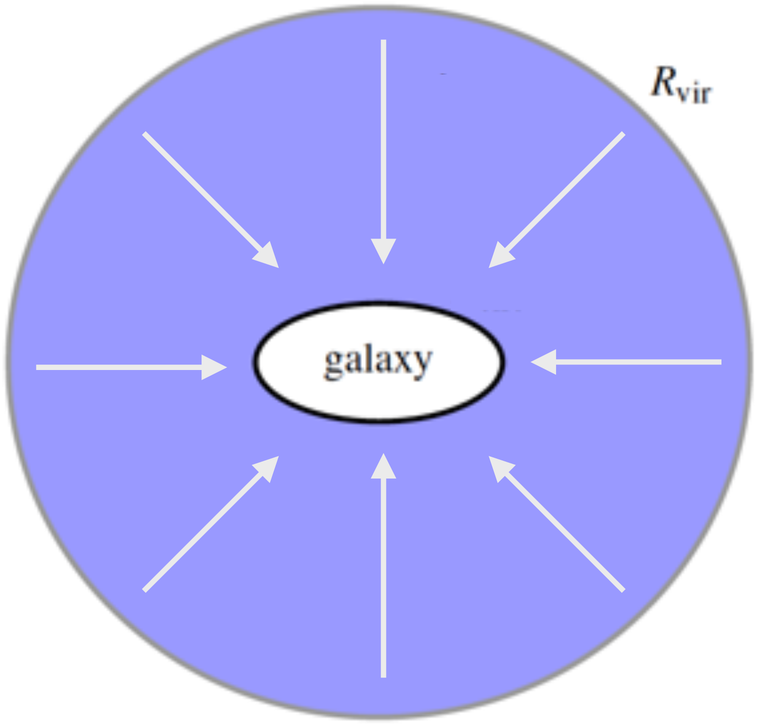
(2) **SFR variability**



(3) Galactic winds



Three circumgalactic medium (CGM) regimes



high gas density

rapid cooling ($t_{\rm cool}<t_{\rm ff}$) everywhere
("free fall")

accreting gas crashes supersonically onto galaxy

Stern+20a, building on classic theory by Rees, White, Ostriker, Silk, Binney, Dekel, Birnboim, …

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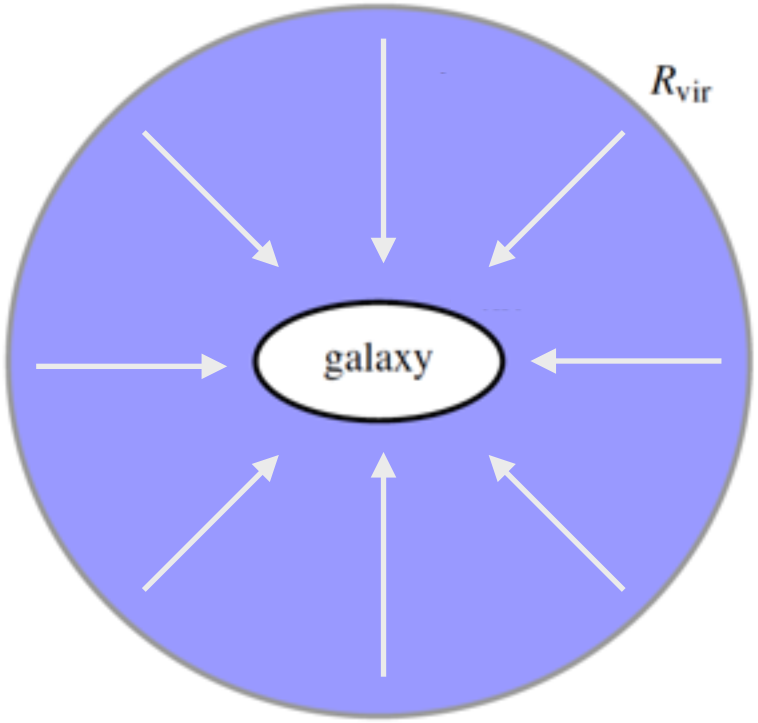

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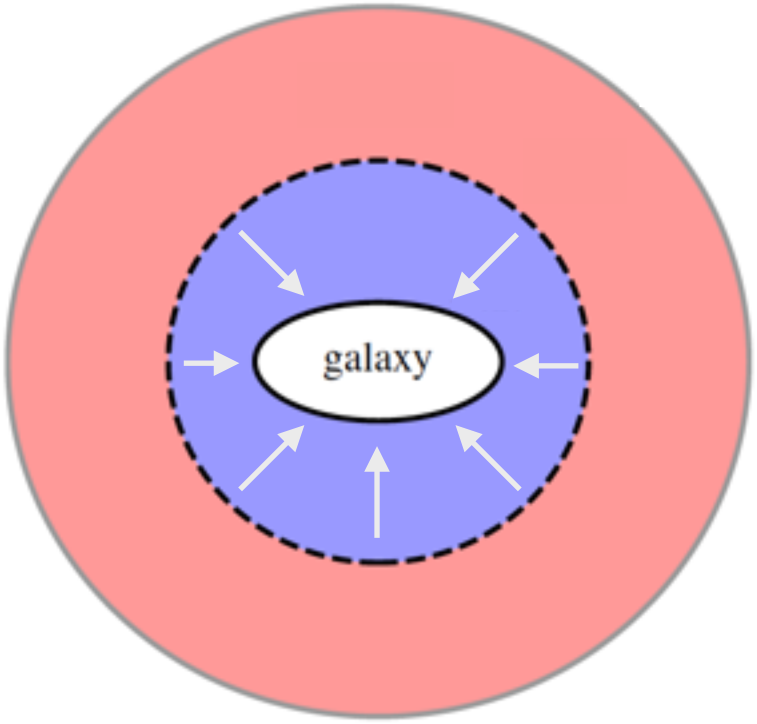

intermediate

slow cooling in outer halo,
rapid in inner halo
("transonic")

still crashes
supersonically

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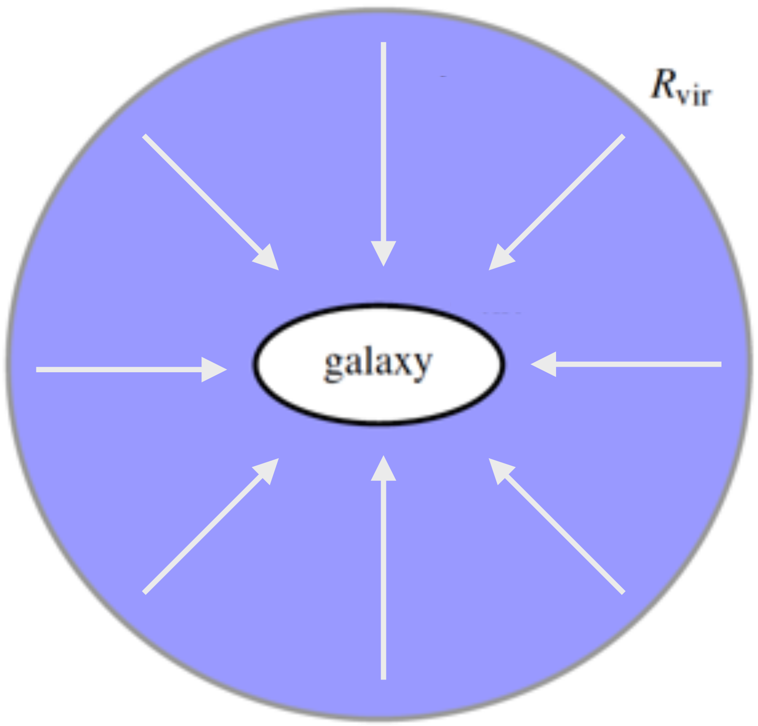

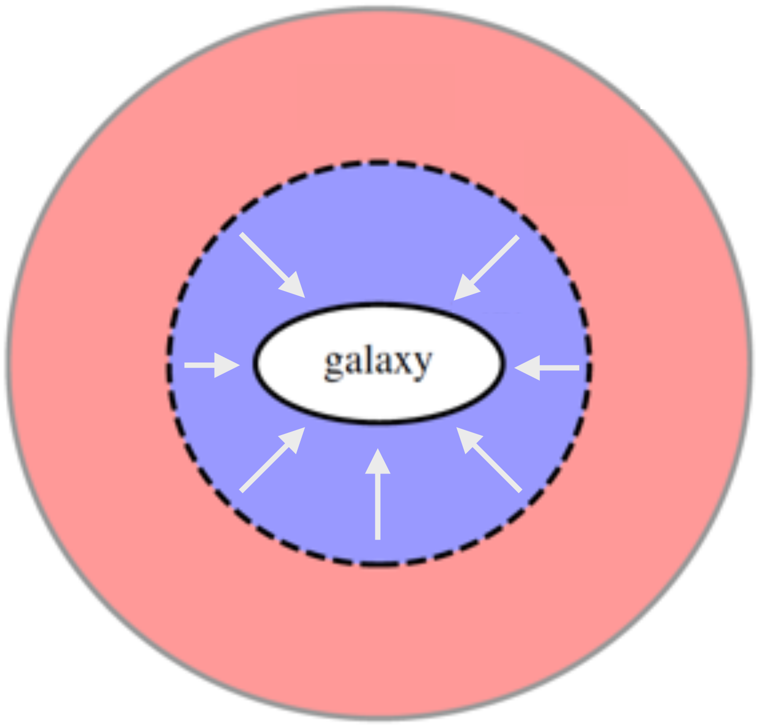

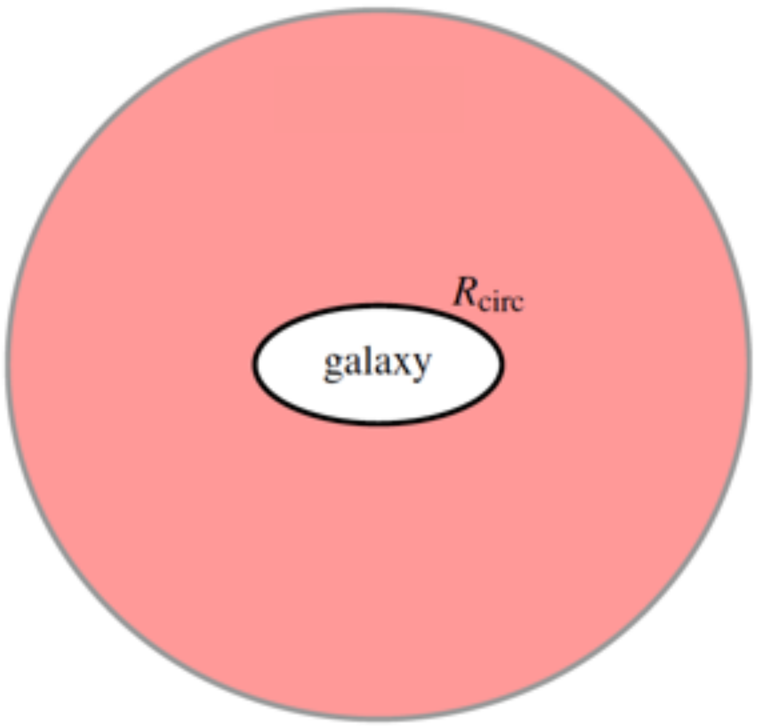

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all the way galaxy
(“cooling flow”)

~hydrostatic

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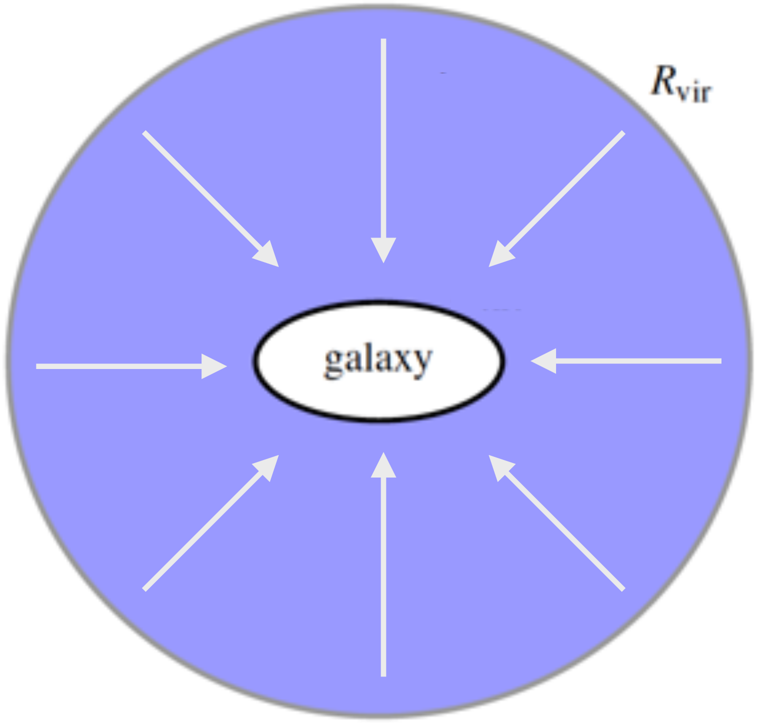

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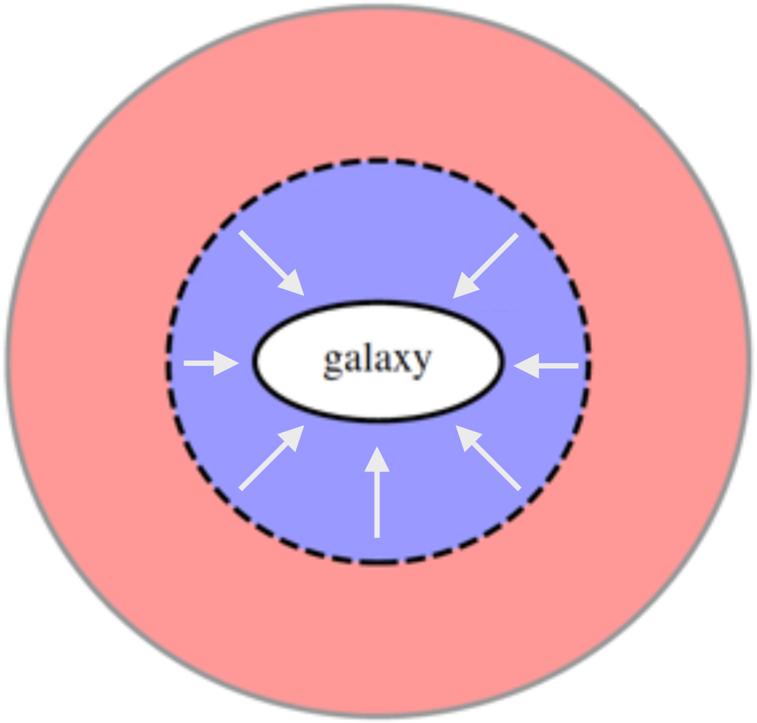

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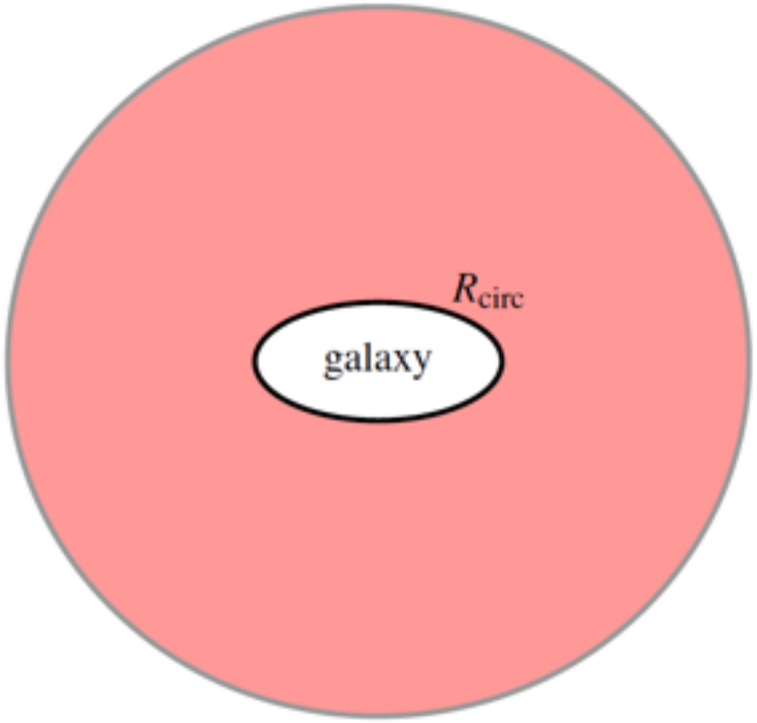

low gas density

slow cooling ($t_{\rm cool}>t_{\rm ff}$) all the way galaxy
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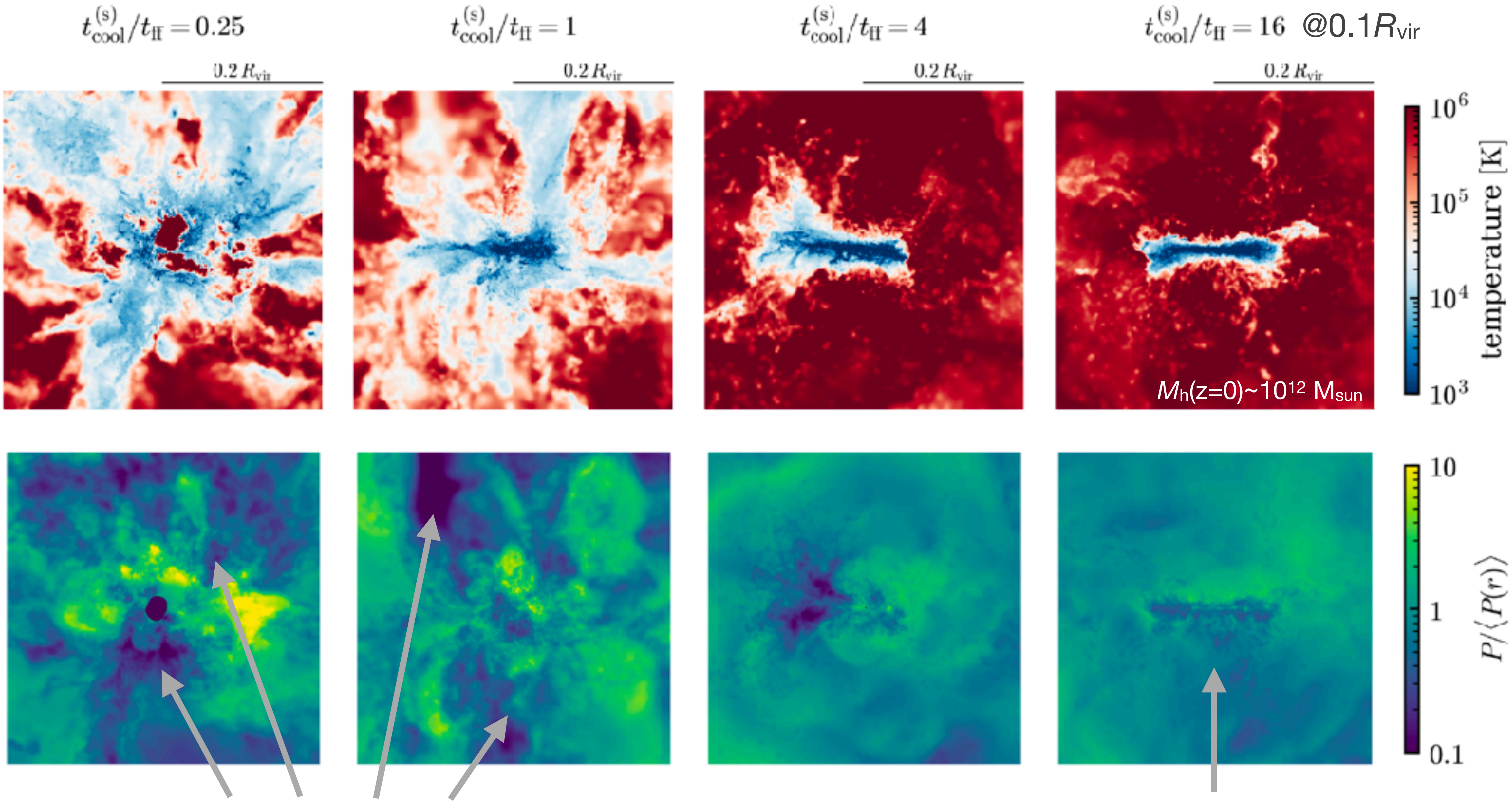
transition at ~10^{12} $M_{\rm sun}$, when $t_{\rm cool}/t_{\rm ff}$~1 at $0.1R_{\rm vir}$

Stern+20a, building on classic theory by Rees, White, Ostriker, Silk, Binney, Dekel, Birnboim, …

Outside-in CGM virialization in FIRE

z=1 → z=0



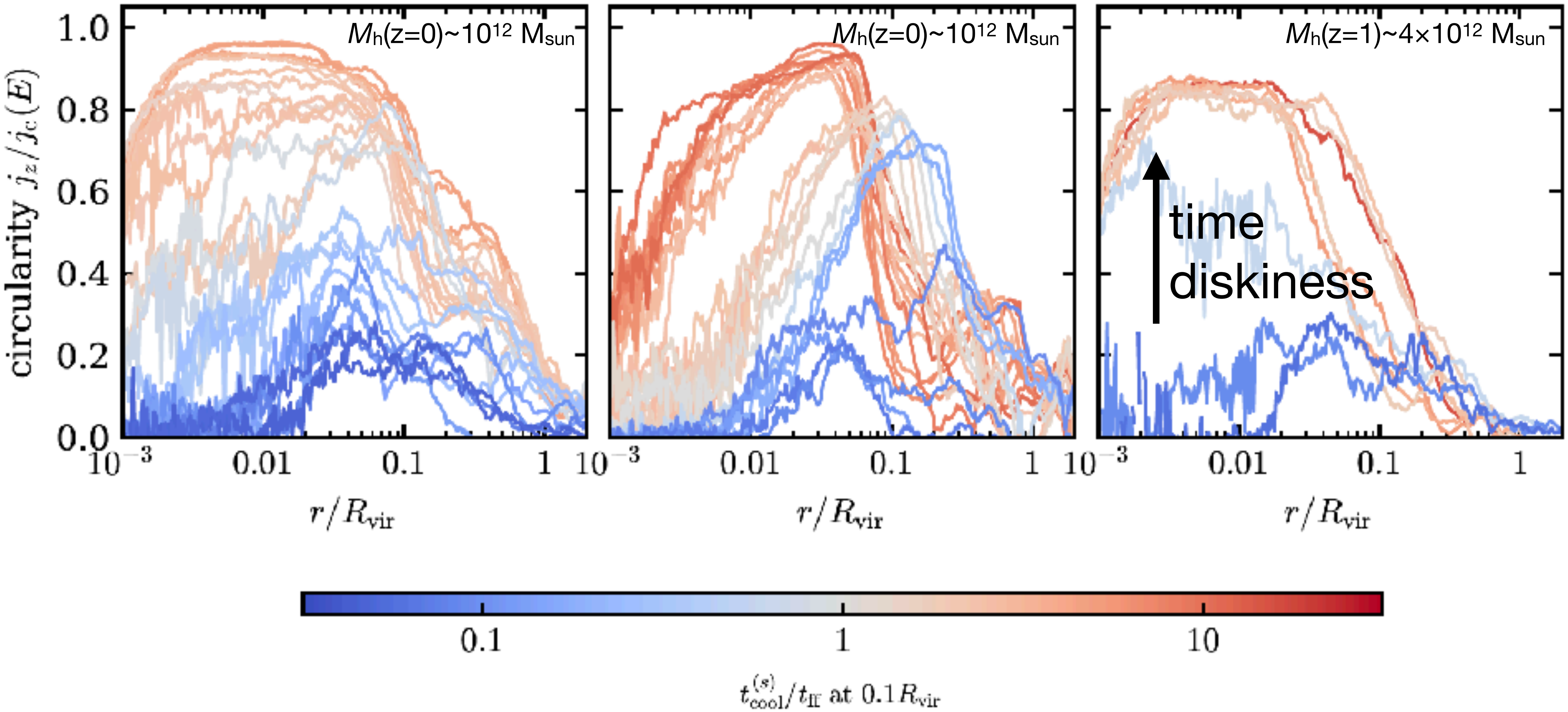
under-pressurized channels prior to ICV

disk well confined by inner CGM pressure

Stern, FG+20b

Inner CGM virialization (ICV) → disk formation

Stern+20b



Inner CGM virialization (ICV) → disk formation

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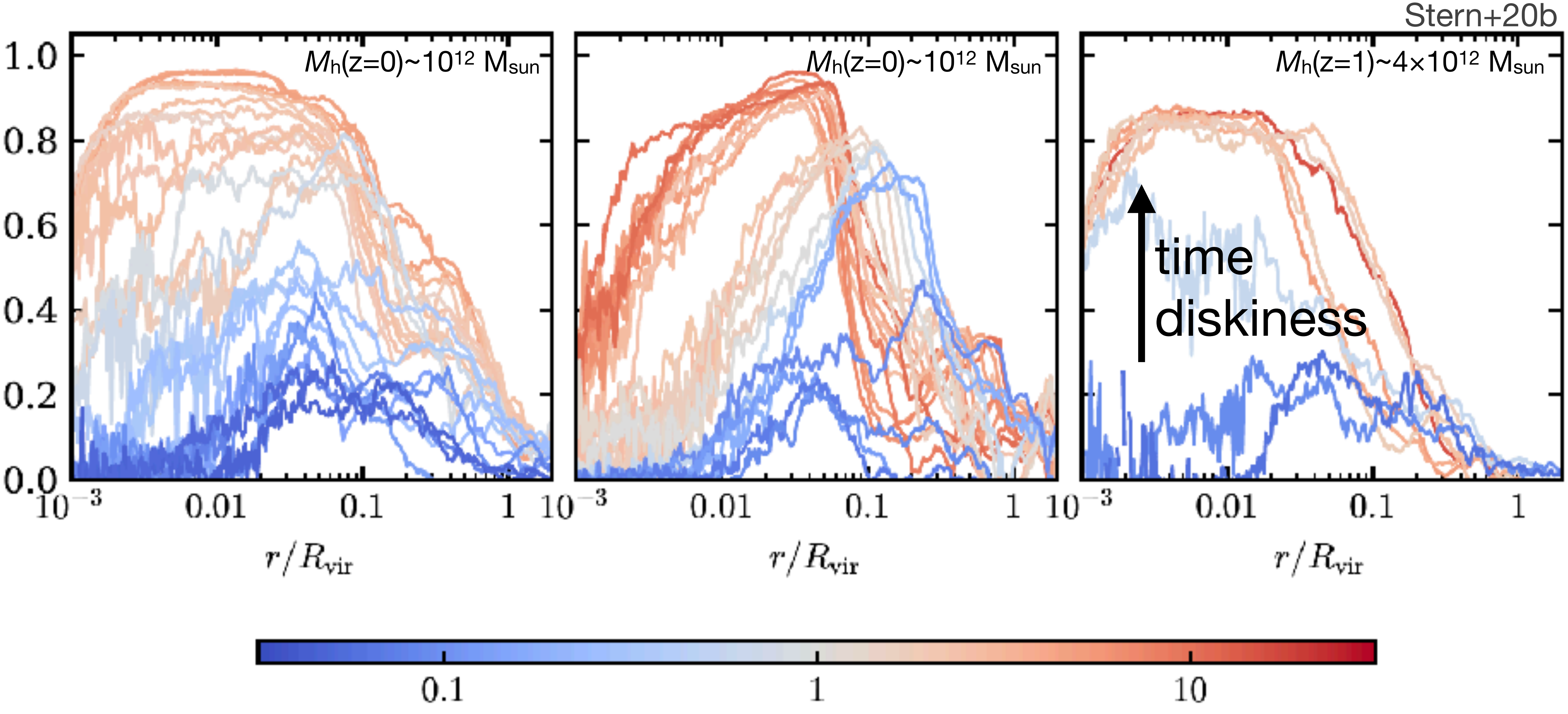
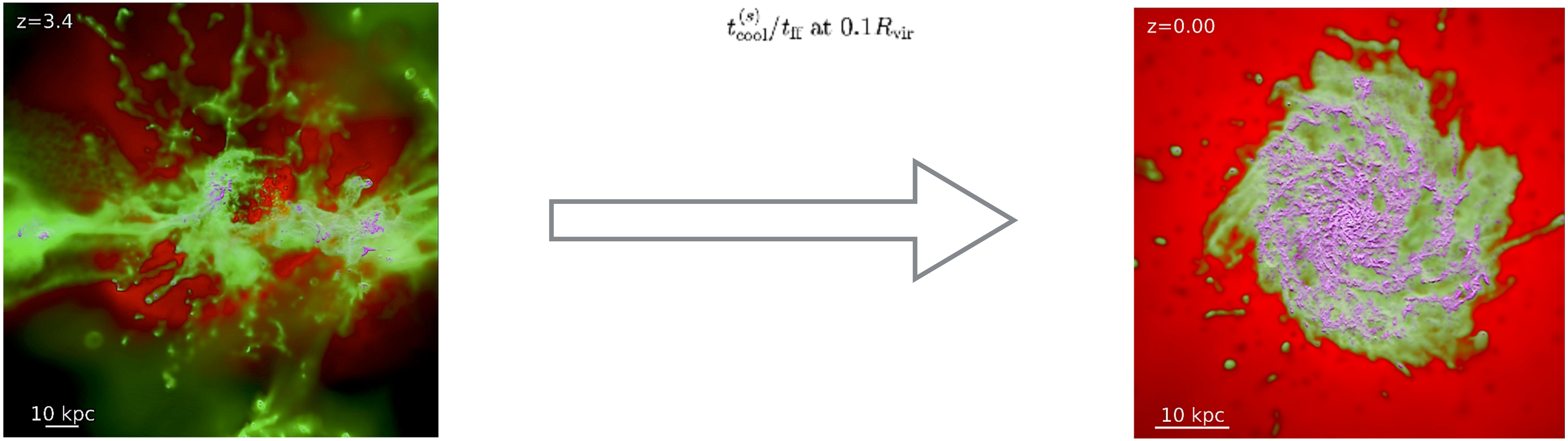
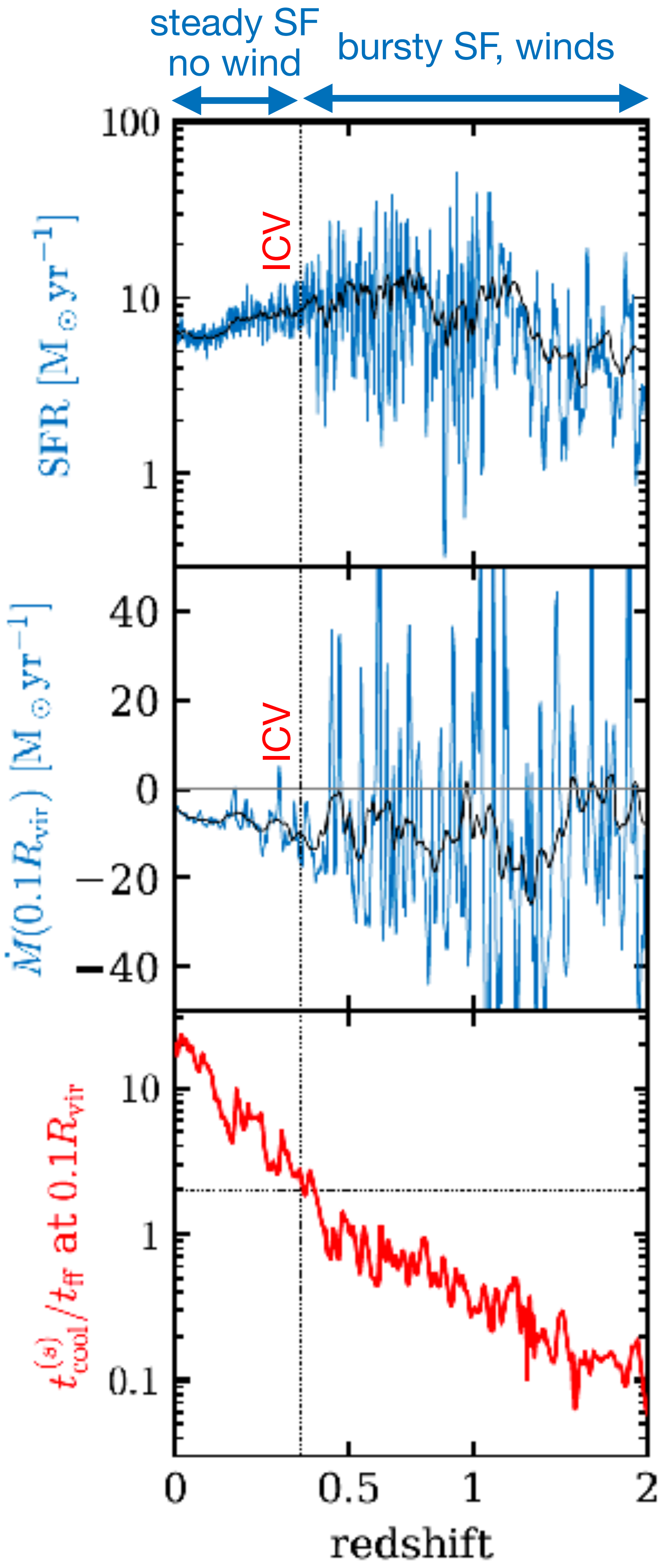




ICV → bursty SF transition, wind suppression



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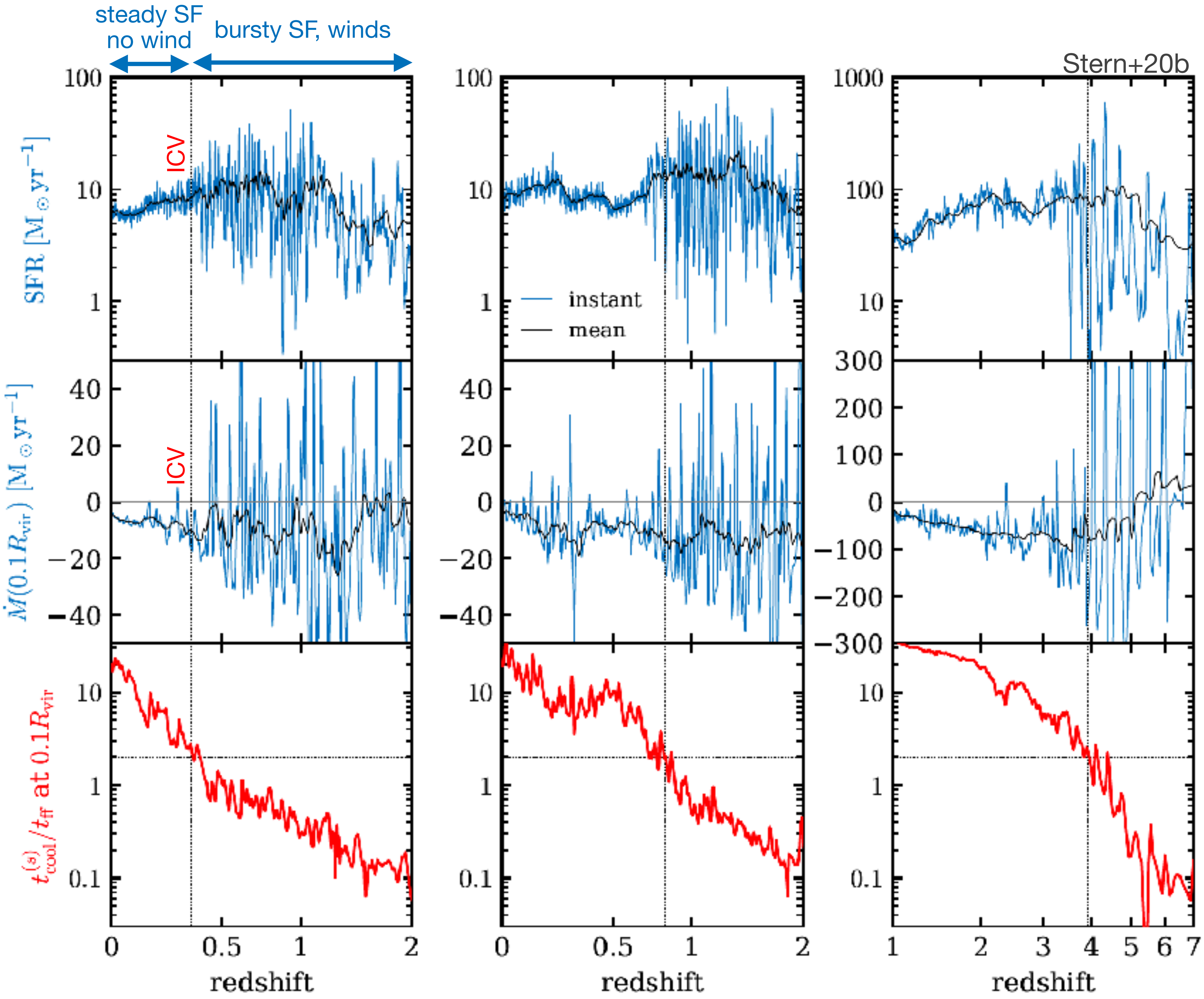
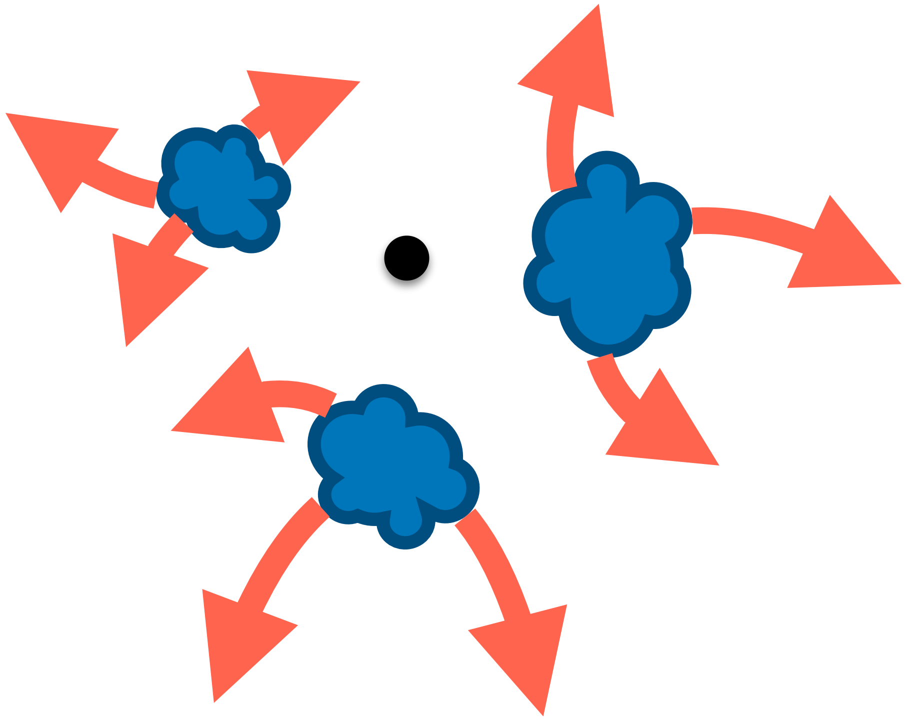


Stern+20b

Cartoon picture

<u>High *z*, low mass</u>

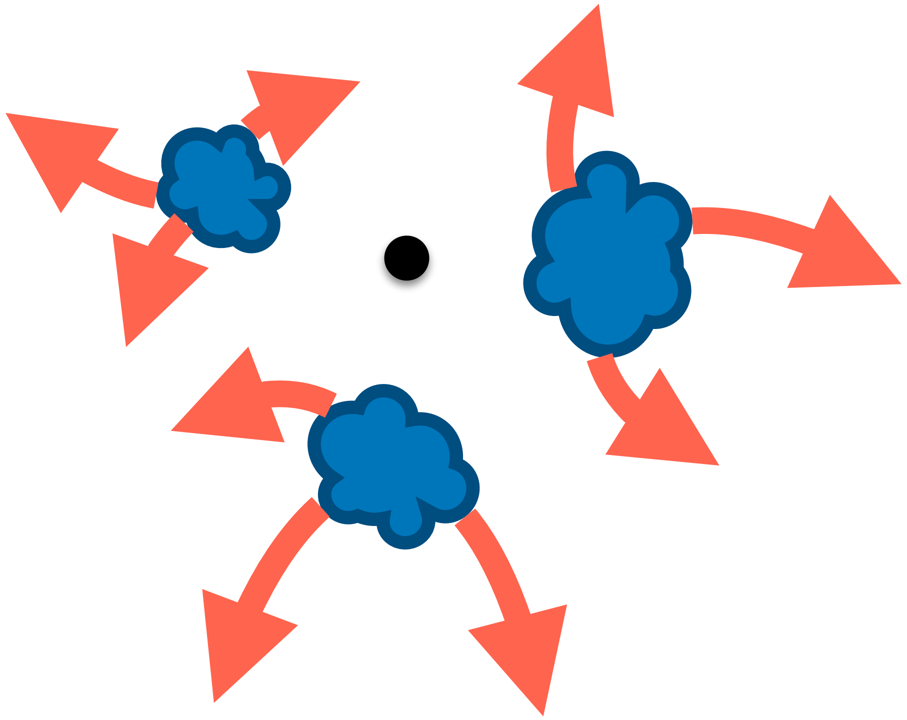


- free fall accretion + bursty feedback into low-pressure halo
- galaxy repeatedly blows itself apart in “inflow-SF-outflow" cycles

Stern+20b; Gurvich+ (in prep.)

Cartoon picture

High *z*, low mass



$M_{\rm h}$~10^{12} $M_{\rm sun}$ $\longrightarrow$

in detail, sensitive to galaxy size, $v_{\rm c}$ ($t_{\rm ff}$), inner CGM metallicity ($t_{\rm cool}$)

Low *z*, high mass

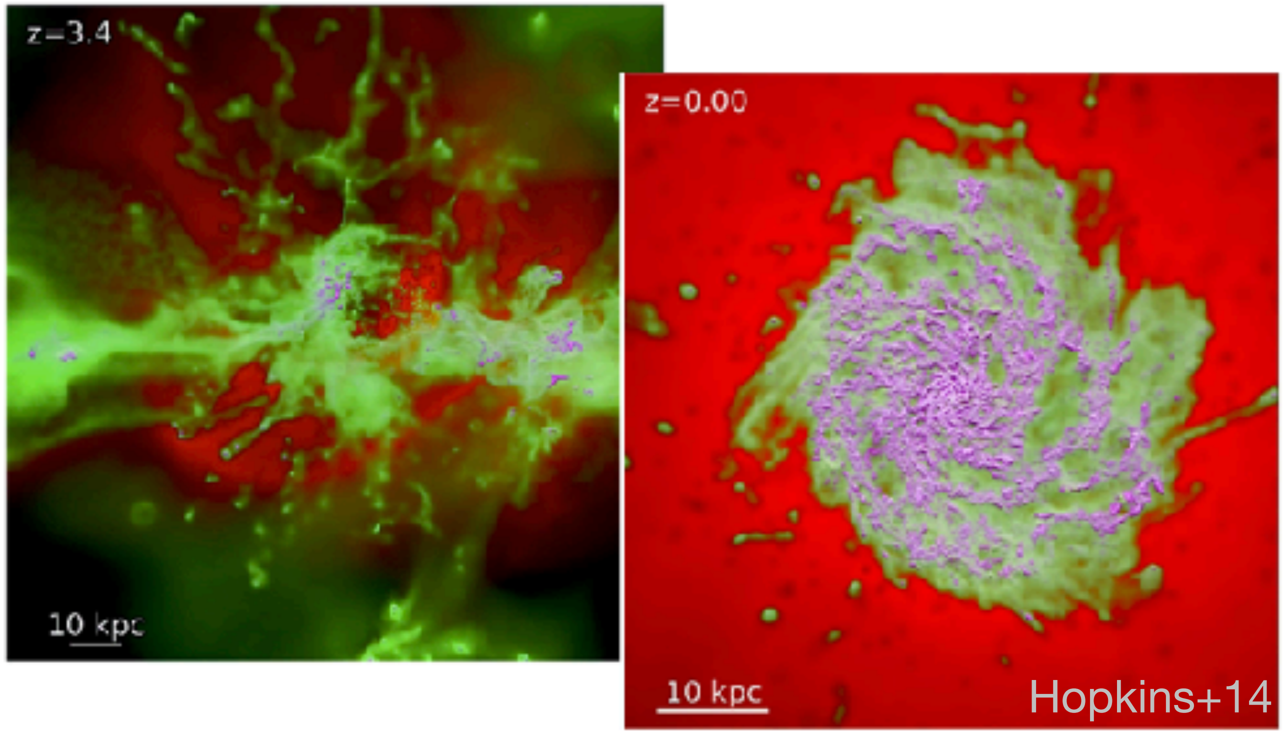
- free fall accretion + bursty feedback into low-pressure halo
- galaxy repeatedly blows itself apart in “inflow-SF-outflow" cycles

- disk stably confined by hot inner CGM
- galactic winds suppressed by halo gas pressure
- SFR regulated to steady state

Stern+20b; Gurvich+ (in prep.)

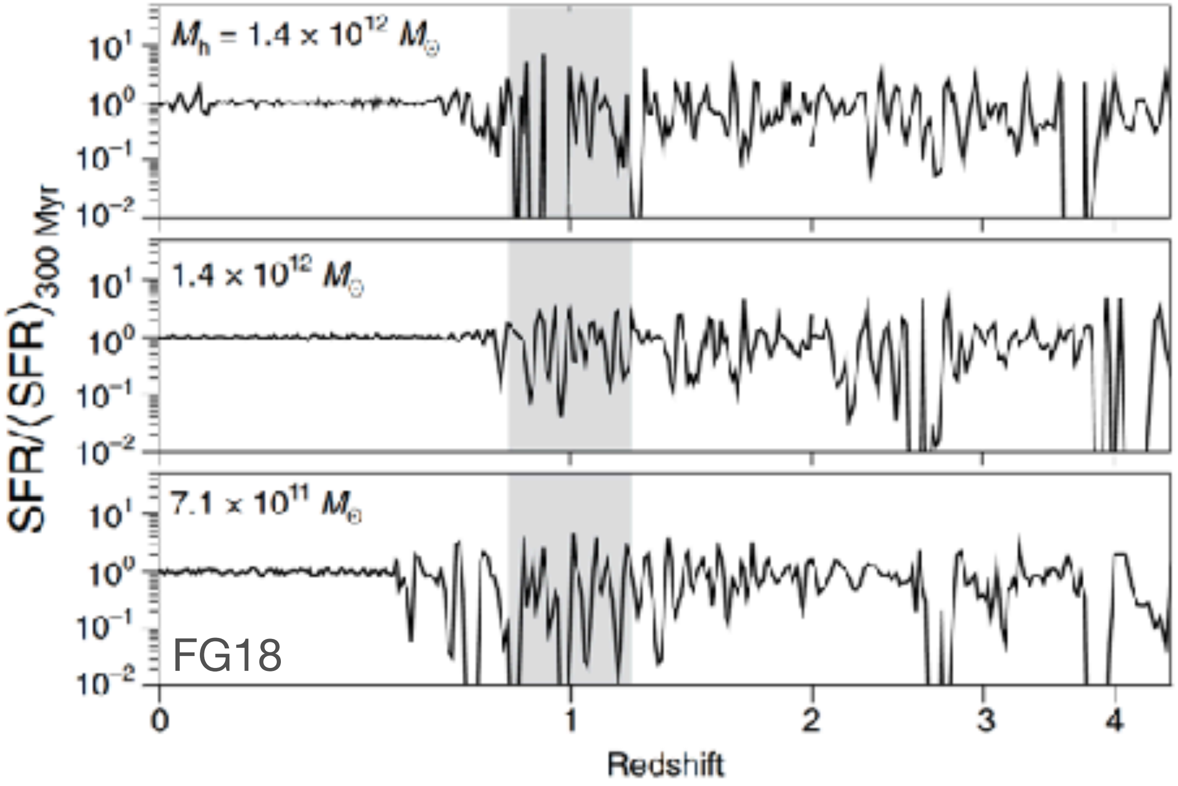
Summary: ICV explains multiple transitions at ~L^* in FIRE

(1) **Morphology**



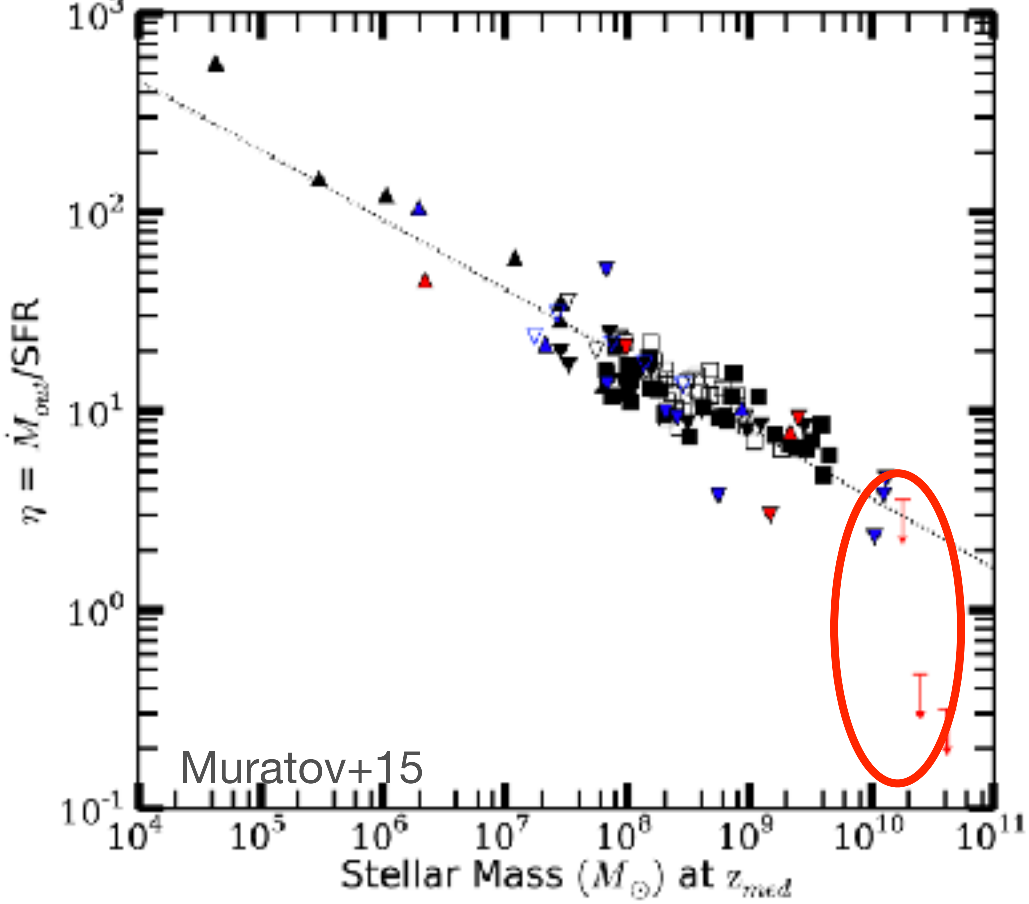
Hopkins+14

(2) **SFR variability**



FG18

(3) **Winds**



Muratov+15

Roman can test these predictions, especially at high *z*

In prep. on other ICV predictions:
Gal.-by-gal. diskiness, DLAs (Stern+ab); BHs (Byrne+, Tillman+)