Effects of Varying the FIRE Feedback Model on the ISM in a Self-regulating Disk Galaxy

Building Galaxies from Scratch, Vienna

February 21, 2024

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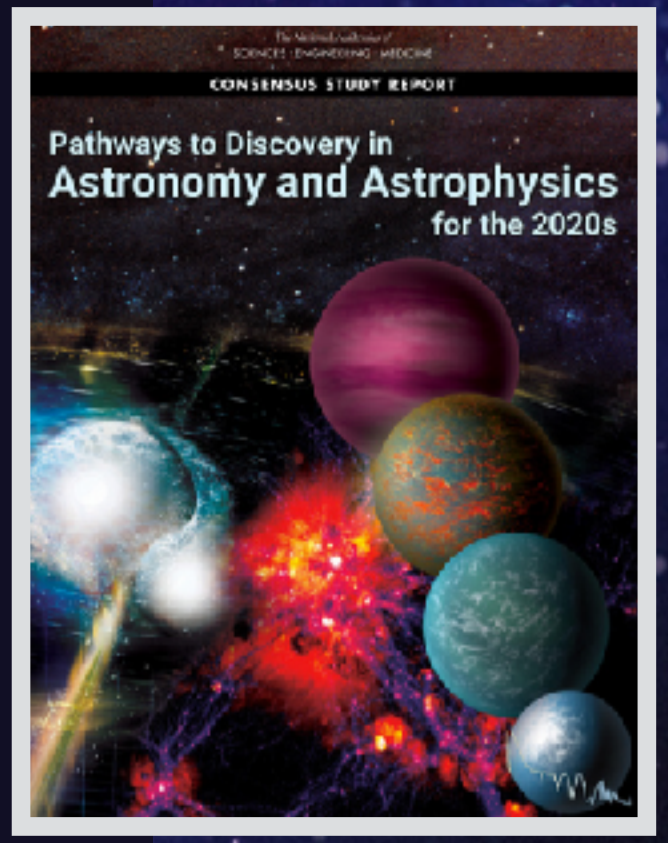
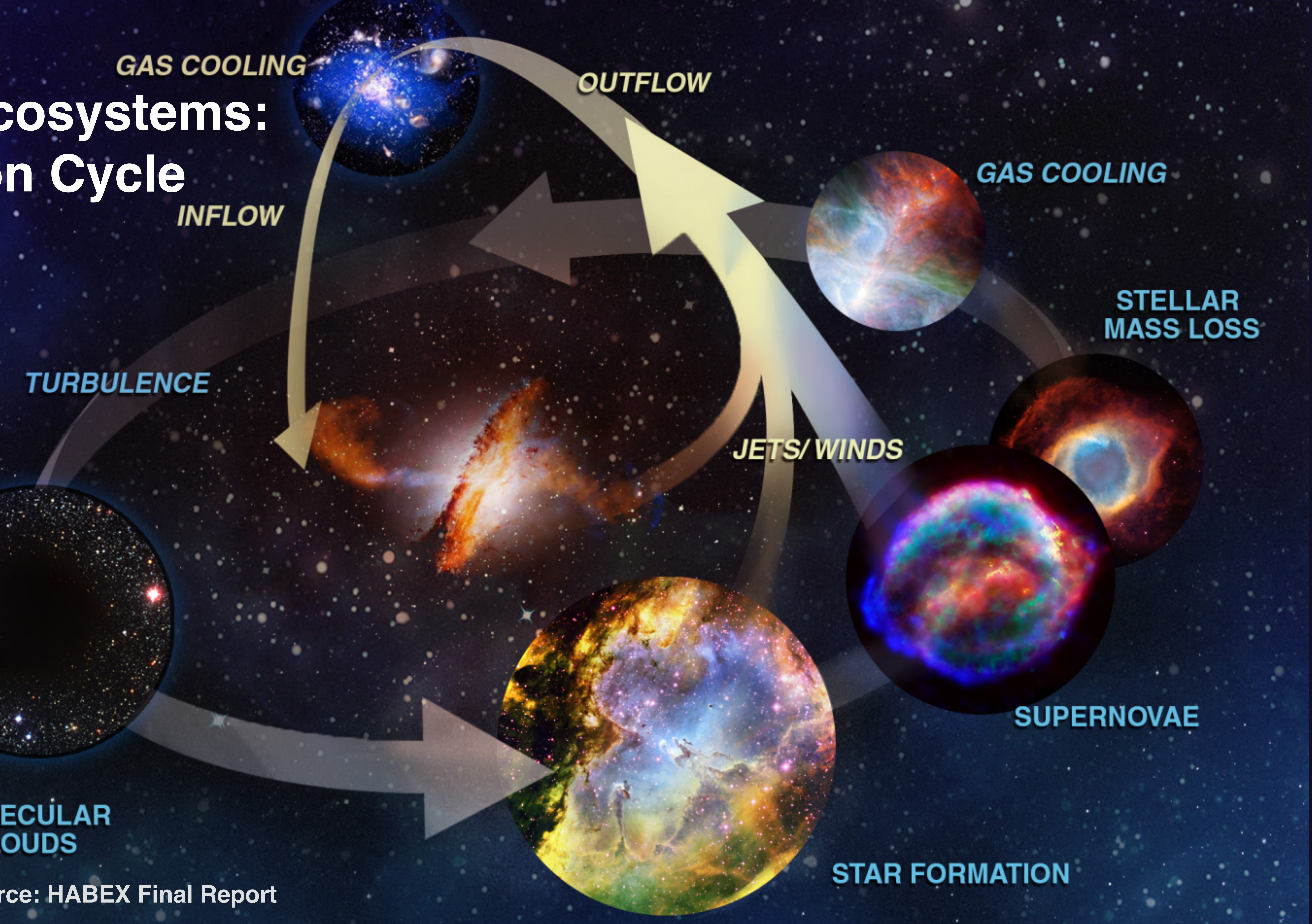
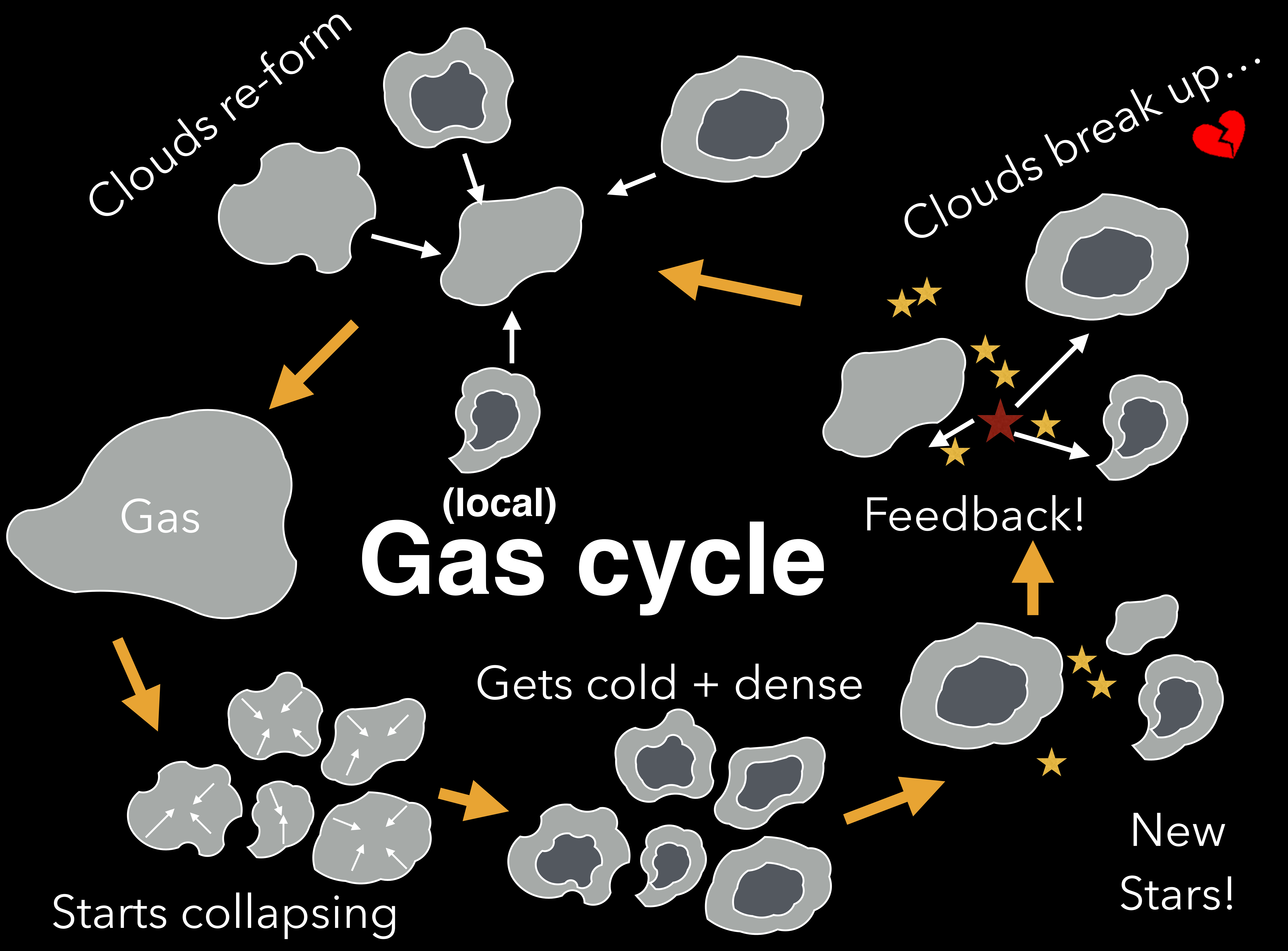
CCA | Flatiron Institute
Physics & Astronomy | Rutgers University

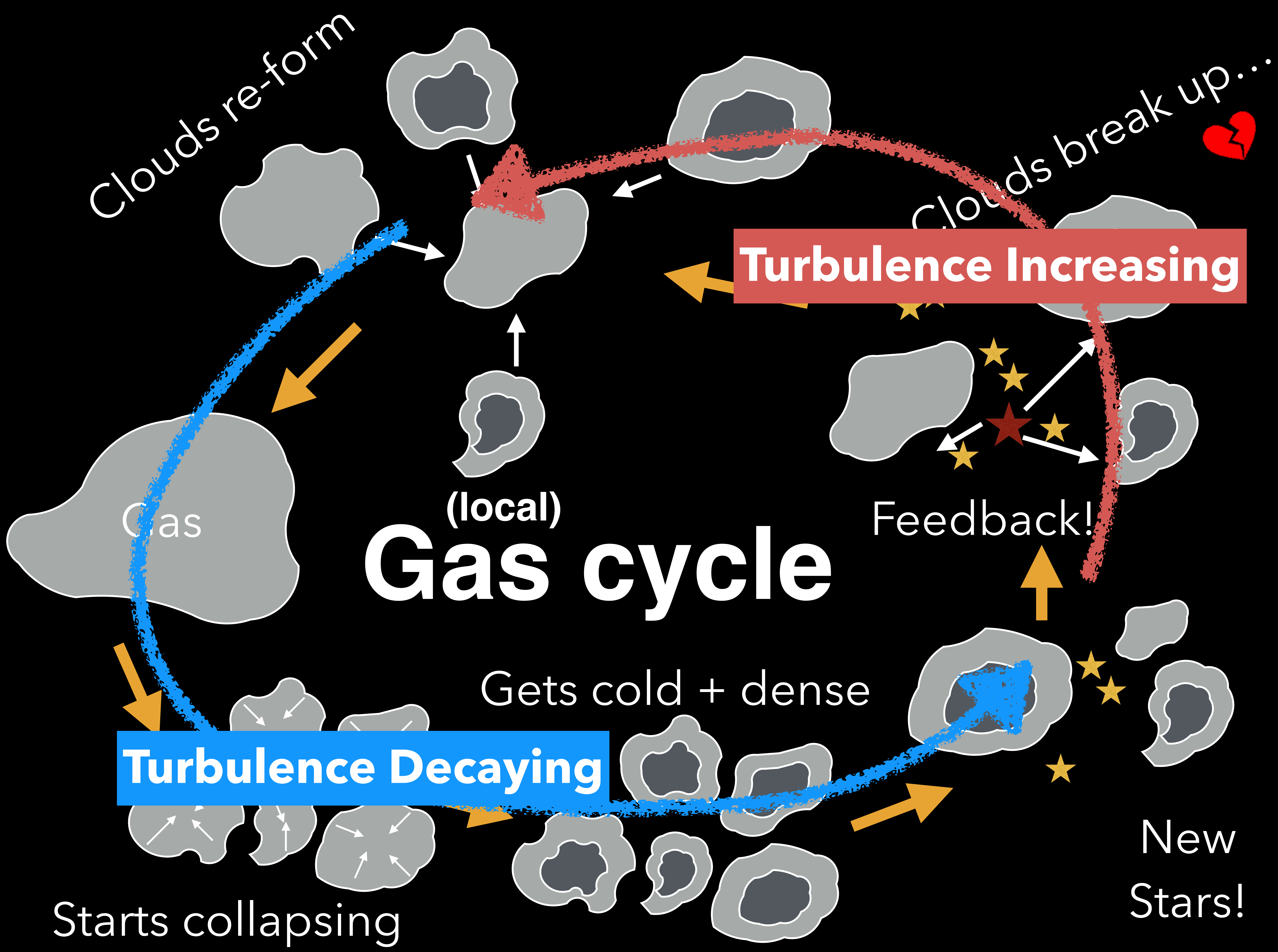
Cosmic Ecosystems: The Baryon Cycle

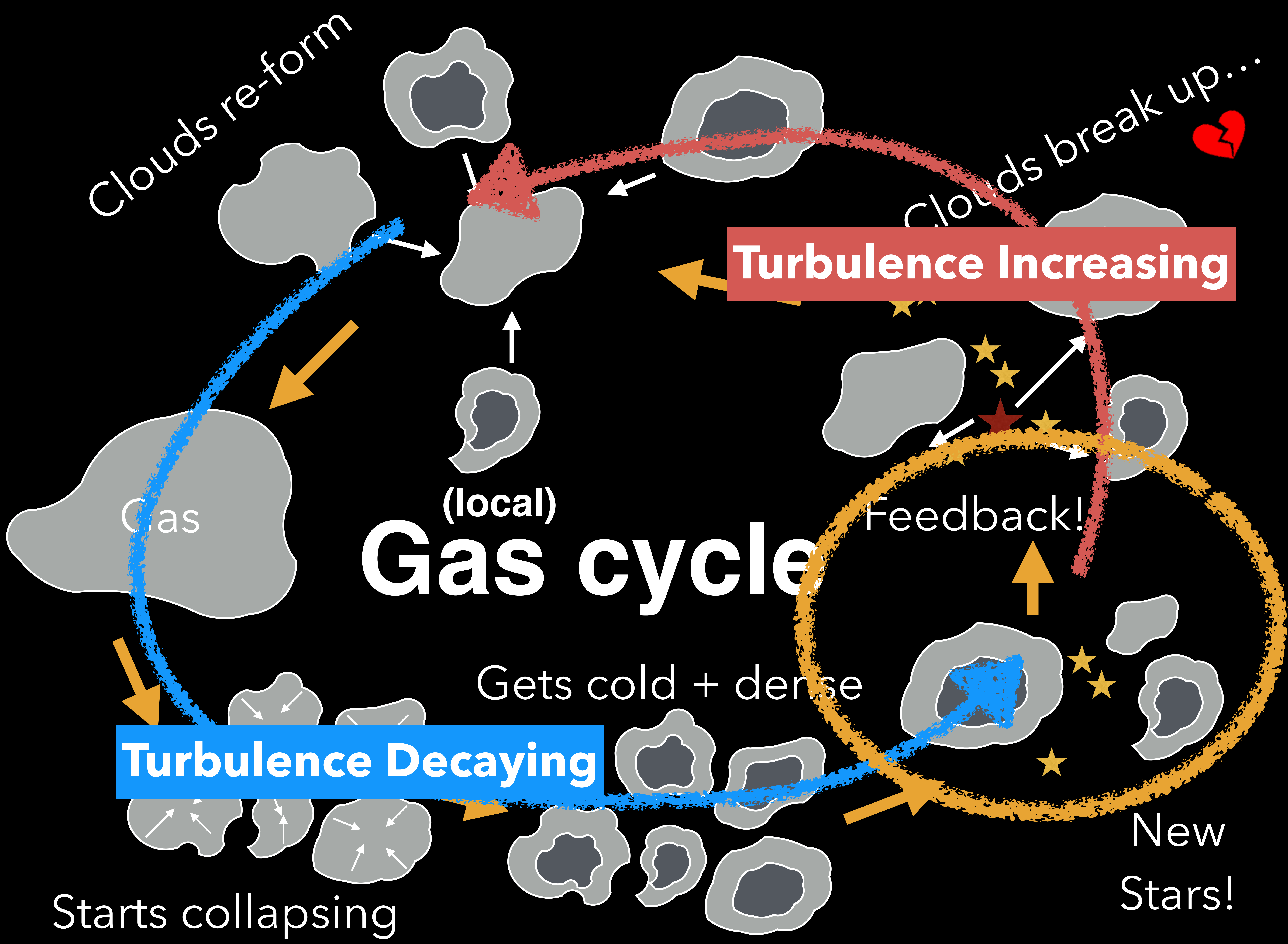




Source: HABEX Final Report


(local)
Gas cycle
Clouds re-form
Clouds break up...
Gas
Feedback!
Starts collapsing
Gets cold + dense
New Stars!


Clouds re-form
Clouds break up...
Turbulence Increasing
Gas
(local)
Gas cycle
Feedback!
Gets cold + dense
Turbulence Decaying
Starts collapsing
New Stars!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Gas
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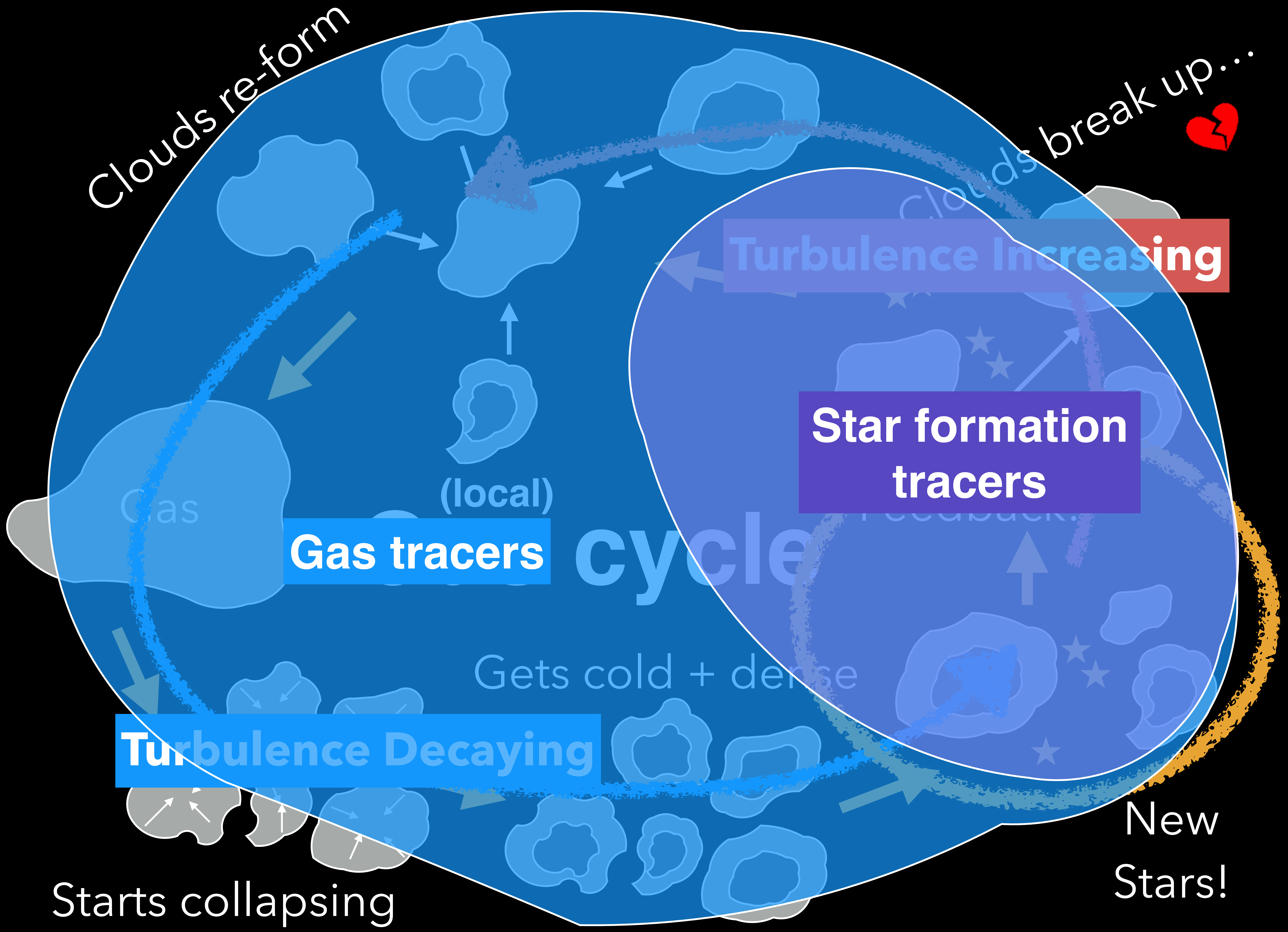
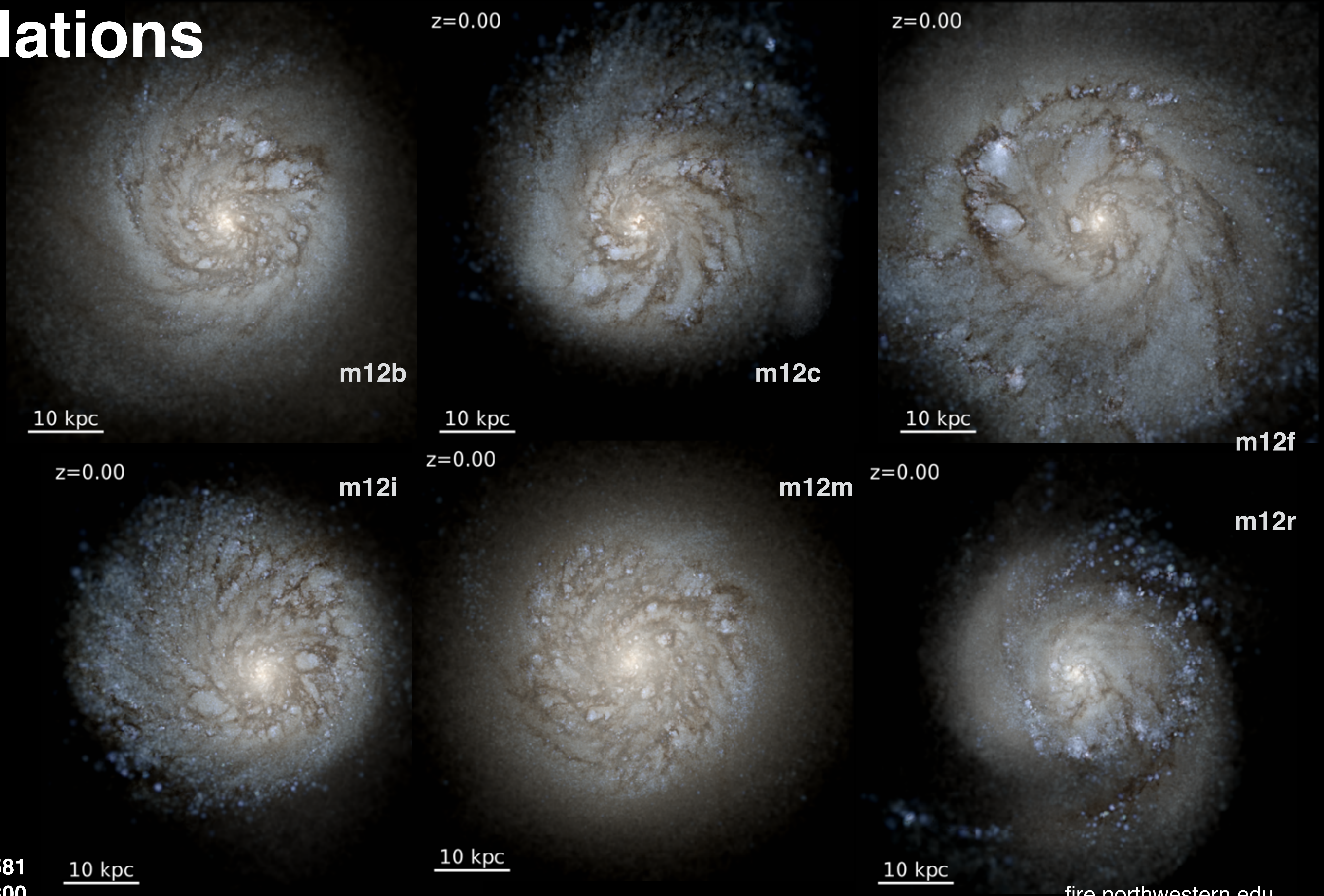

Clouds re-form
Clouds break up...
Turbulence Increasing
Star formation tracers
(local)
Gas tracers
cycle
Gas
Gets cold + dense
Turbulence Decaying
Starts collapsing
New Stars!

FIRE-2 Simulations

Cosmological zoom-in simulations are in a unique position to help resolve questions about star formation, feedback and enrichment within galaxies.



The FIRE-2 Simulations (Feedback In Realistic Environments)

FIRE-1: Hopkins+2014, MNRAS 445, 581
FIRE-2: Hopkins+2018, MNRAS 480, 800

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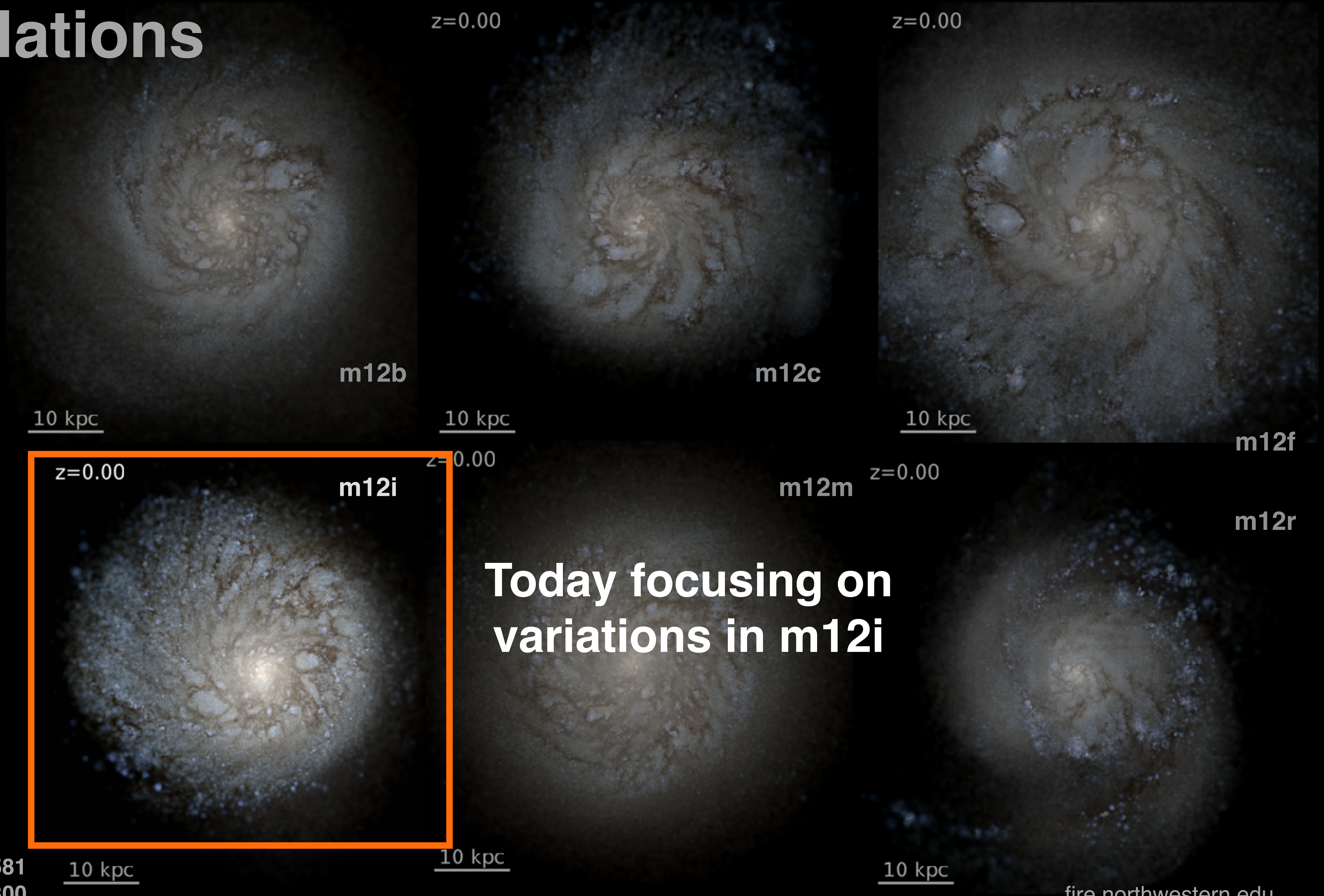

Today focusing on variations in m12i

FIRE-1: Hopkins+2014, MNRAS 445, 581
FIRE-2: Hopkins+2018, MNRAS 480, 800

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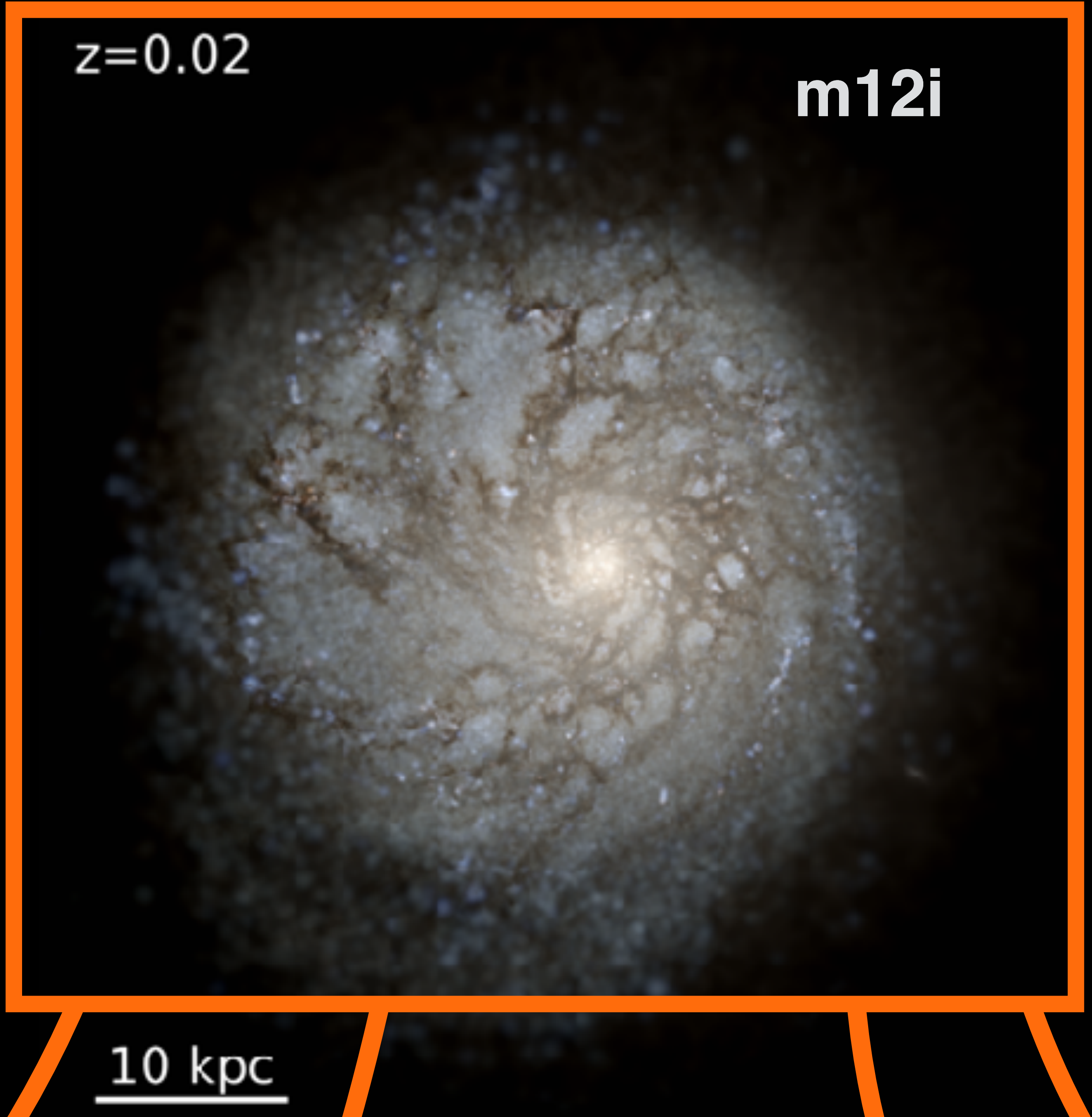
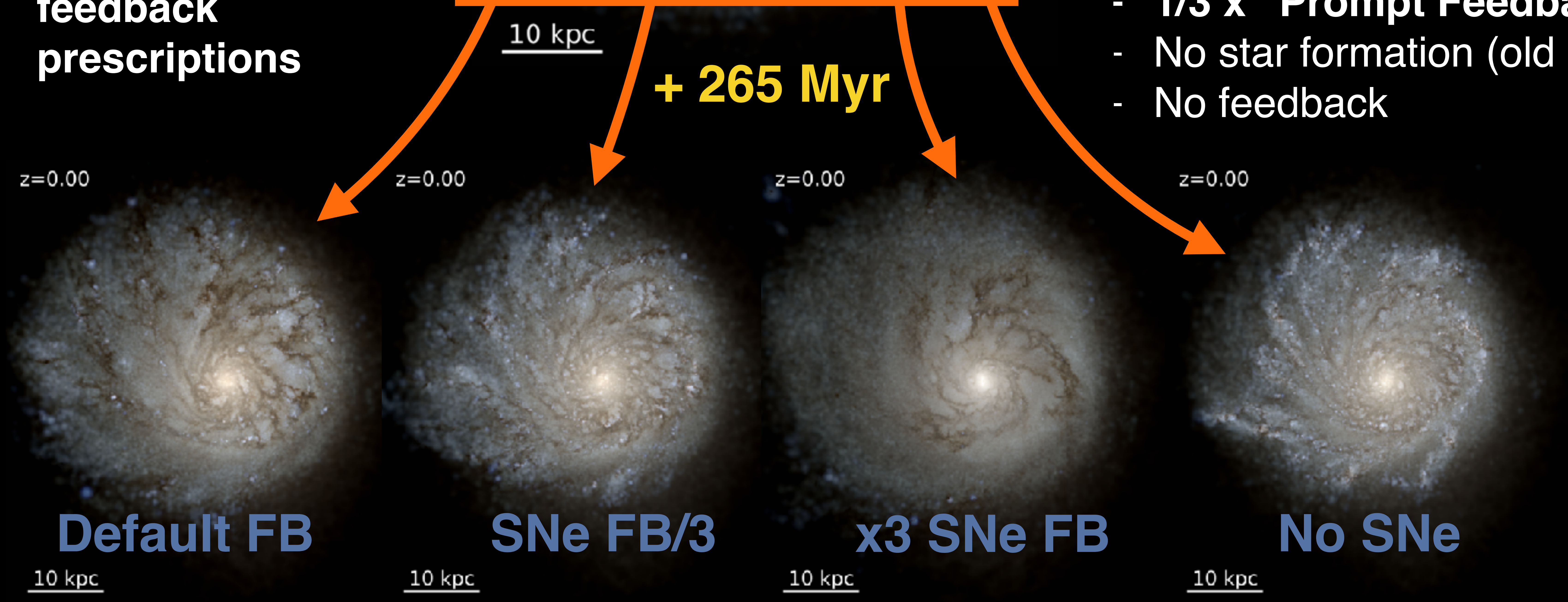
Simulation Set-up

Take z ~ 0.02 snapshot of m12i, at 7100 $M_{\odot}$ resolution with a fairly quiescent, star-forming disk, and evolve it for ~250 Myr with variations on the standard FIRE-2 feedback prescriptions





Runs include:

- **Default FIRE-2 Feedback Physics**
- **No core-collapse SN delay time**
- **Double core-collapse SN delay time (6.8 Myr)**
- **No core-collapse SN Feedback**
- **3 x Initial SN Energy**
- **1/3 x Initial SN Energy**
- **Only core-collapse SN Feedback**
- **3 x Photoionization + Radiation Pressure + Winds ("Prompt Feedback") Strength**
- **1/3 x "Prompt Feedback" Strength**
- No star formation (old stellar pop feedback ok)
- No feedback

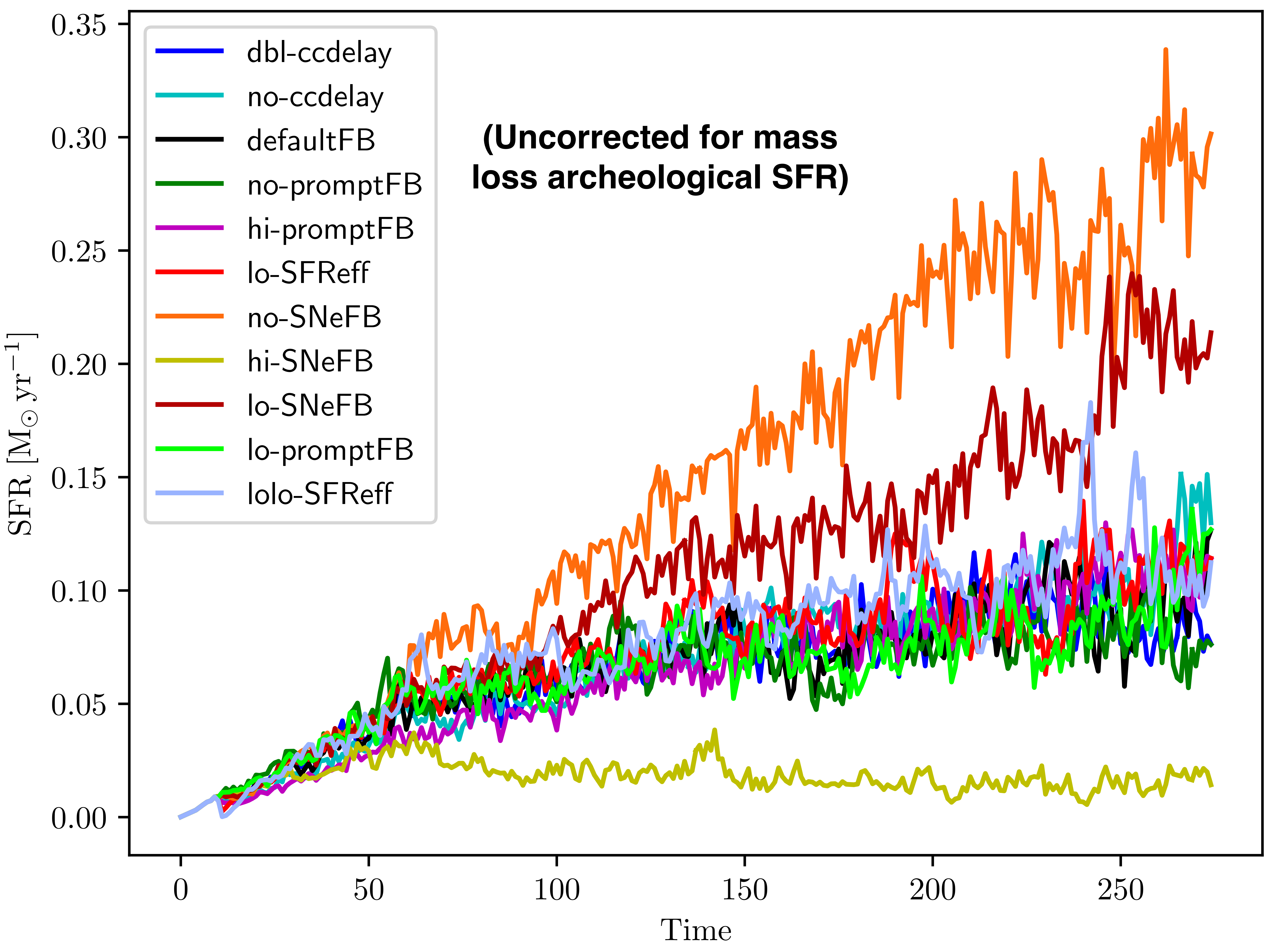
*Non-bolded **runs haven't finished yet. I.e., will include partial results in this talk**

At a glance, only the *no-supernovae* run looks visually distinct.

Have a look at the archaeological SFRs

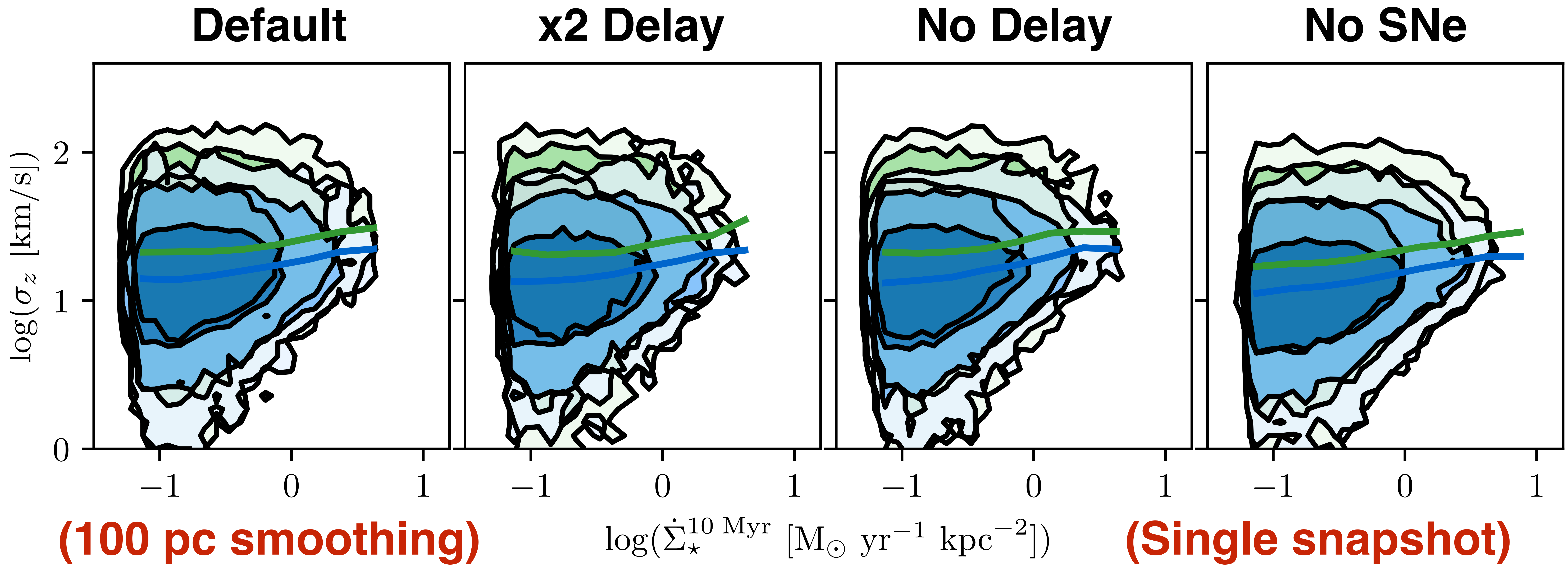
Varying the delay time before core-collapse supernova feedback begins, the small scale SF efficiency, strength of ‘prompt’ feedback does not meaningfully affect the overall large-scale energetics of the ISM… so of course the SFRs are largely unaffected.

Whereas, varying the strength of SN feedback dramatically affects the SFR



Gas Vertical Velocity Dispersion Responses

Blue: Cold & Dense gas
Green: Ionized Gas T~10^4 K



Keeping the SNe Energetics the same results in no statistically significant difference in the velocity dispersion distribution on 100 pc scales.

Removing SNe entirely results in ~0.1-0.2 dex lower vertical velocity dispersions:

other FB/dynamical processes still maintain rough disk vertical equilibrium

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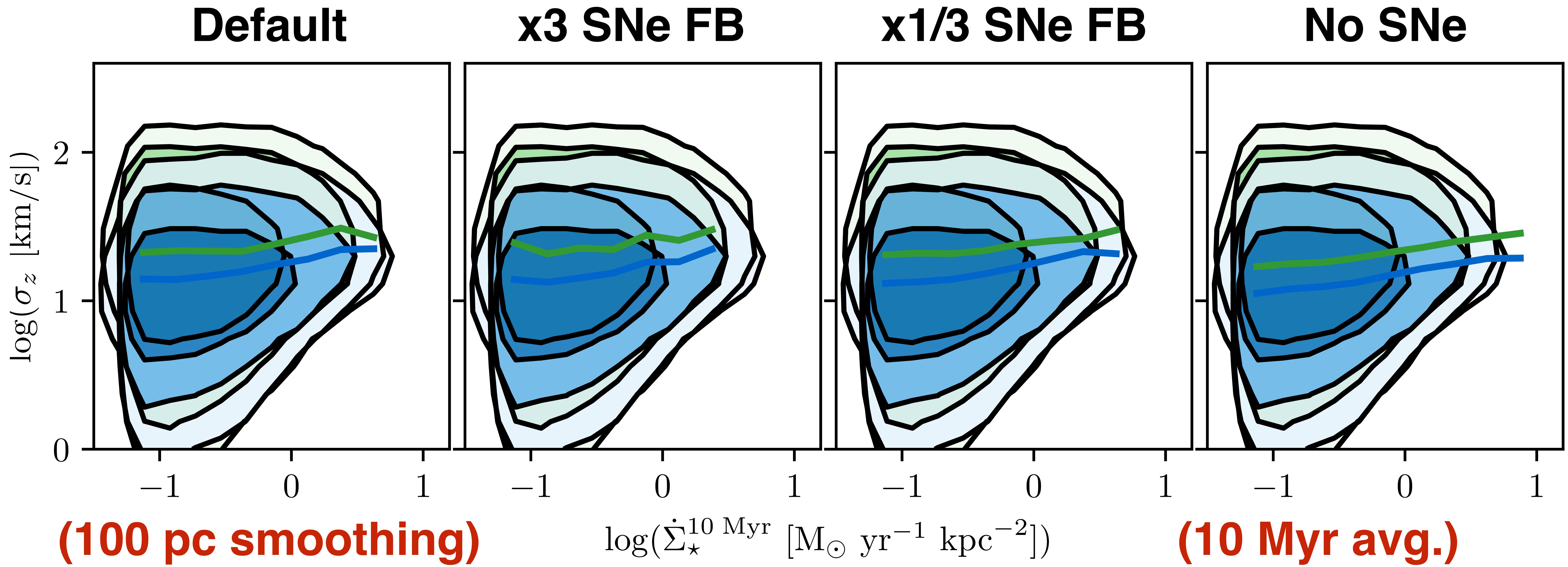
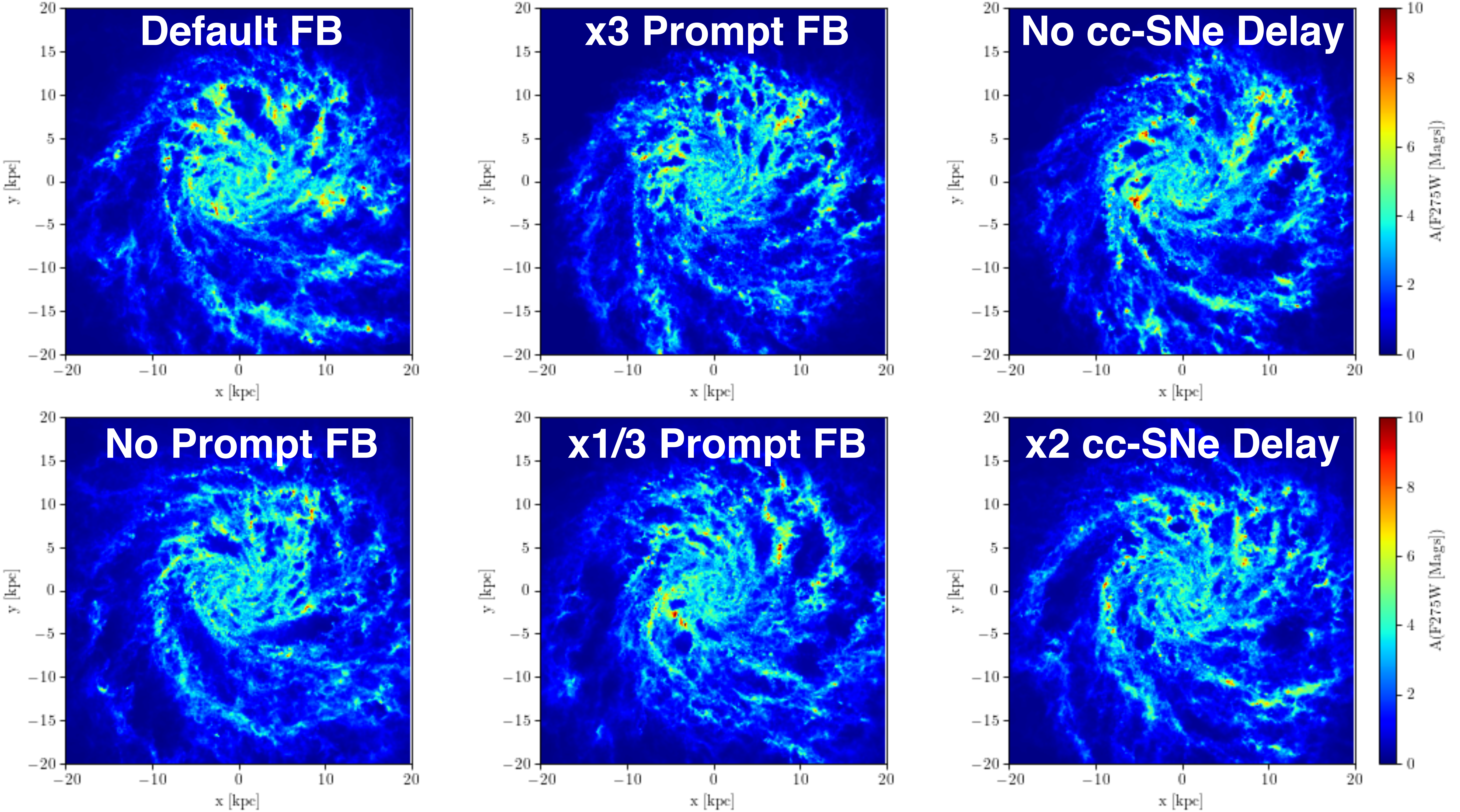


(100 pc smoothing) **(10 Myr avg.)**

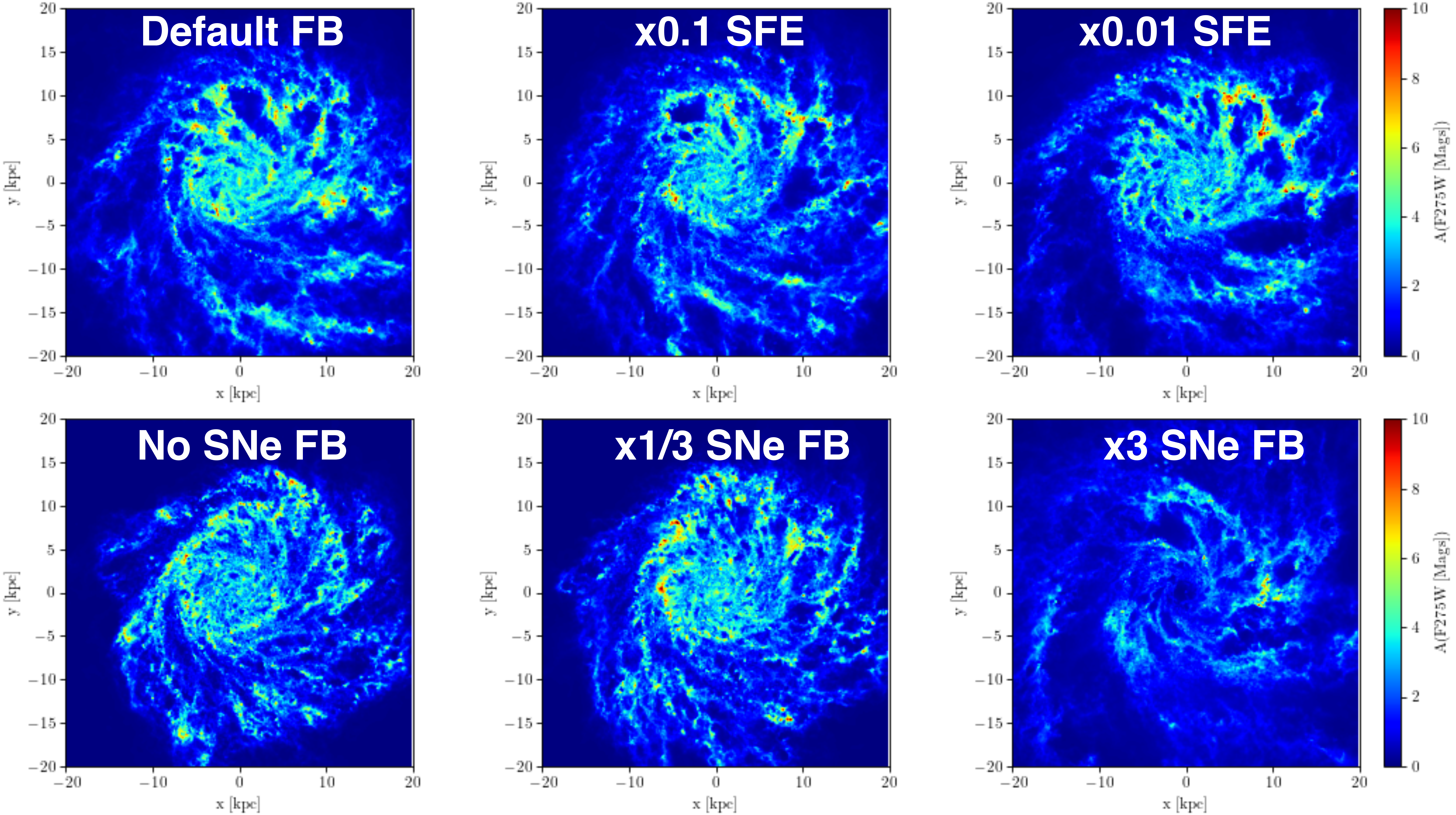
HOWEVER! Changing SNe Energy by ~dex does nothing to velocity dispersions!

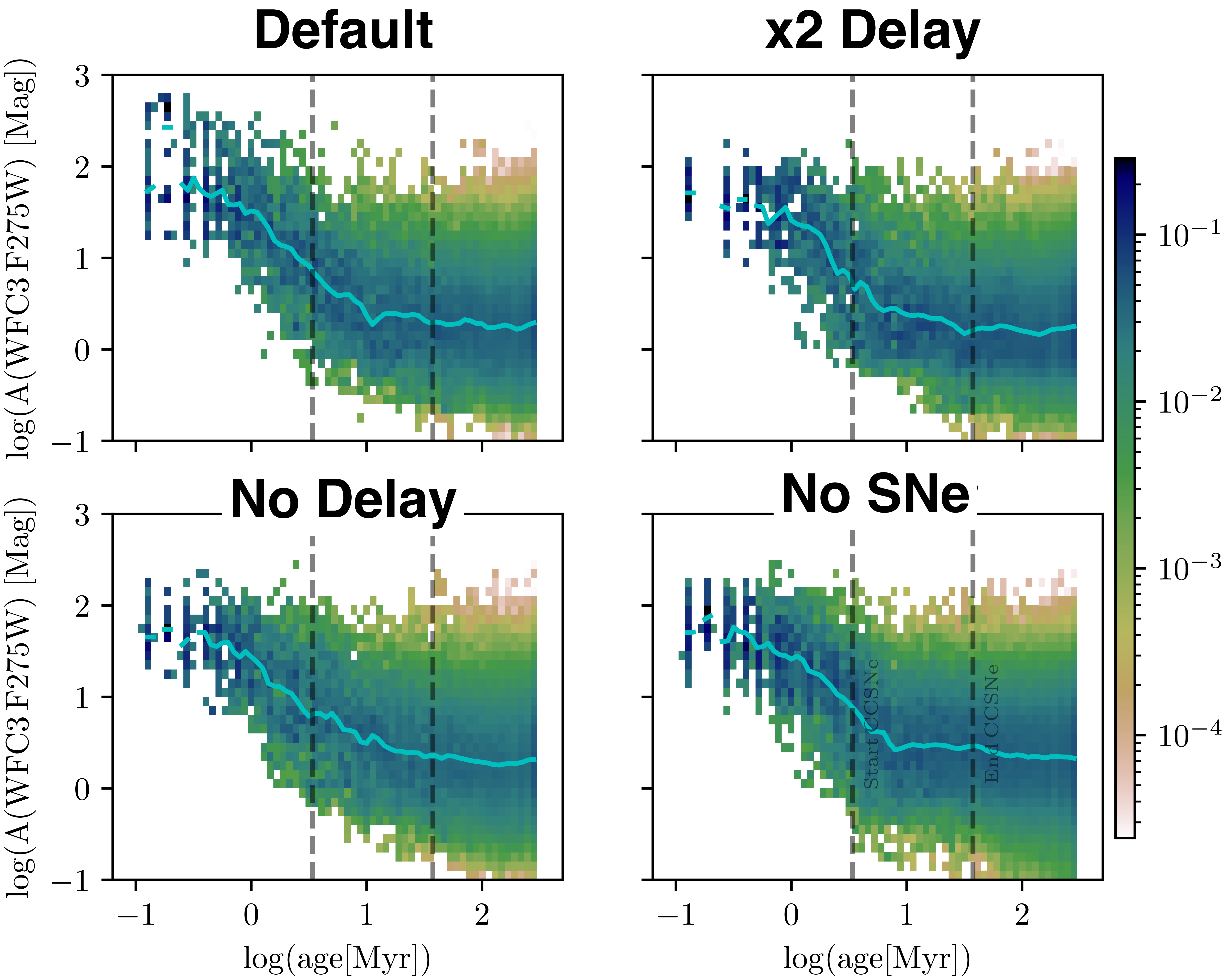
ONLY Removing SNe entirely results in ~0.1-0.2 dex lower vertical velocity dispersions: **other FB/dynamical processes still maintain rough disk vertical equilibrium**

Gas Surface Density Changes



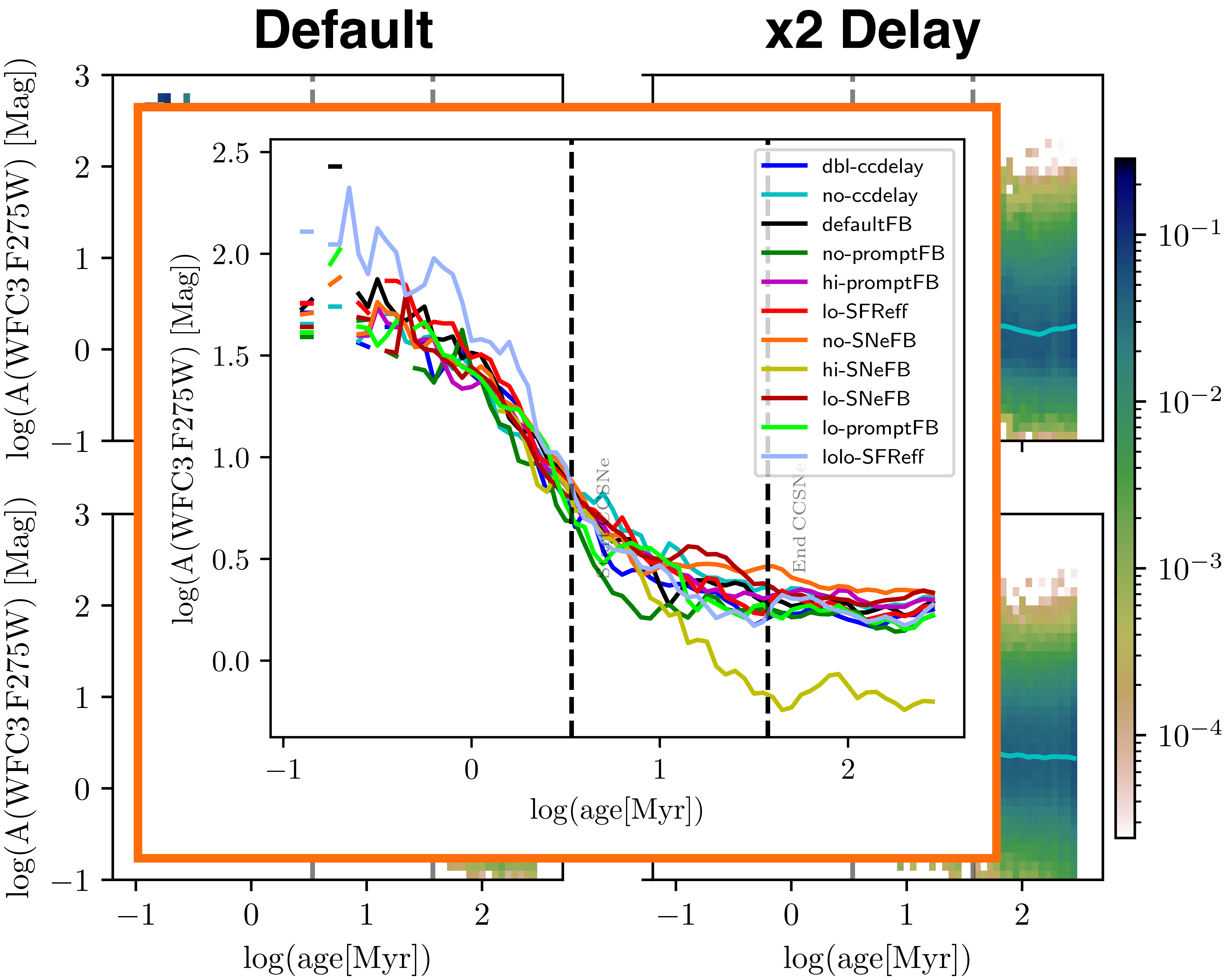
Gas Surface Density Changes





Changes to How Deeply Embedded Young(-ish) Stars are

Completed runs all have similar time evolution of the embeddedness of young stars- prompt feedback is unaffected and dominates the GMC evolution.



Changes to How Deeply Embedded Young(-ish) Stars are

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x3 SNe strength creates lower density environments

Low SF efficiency results in ISM is denser on-average

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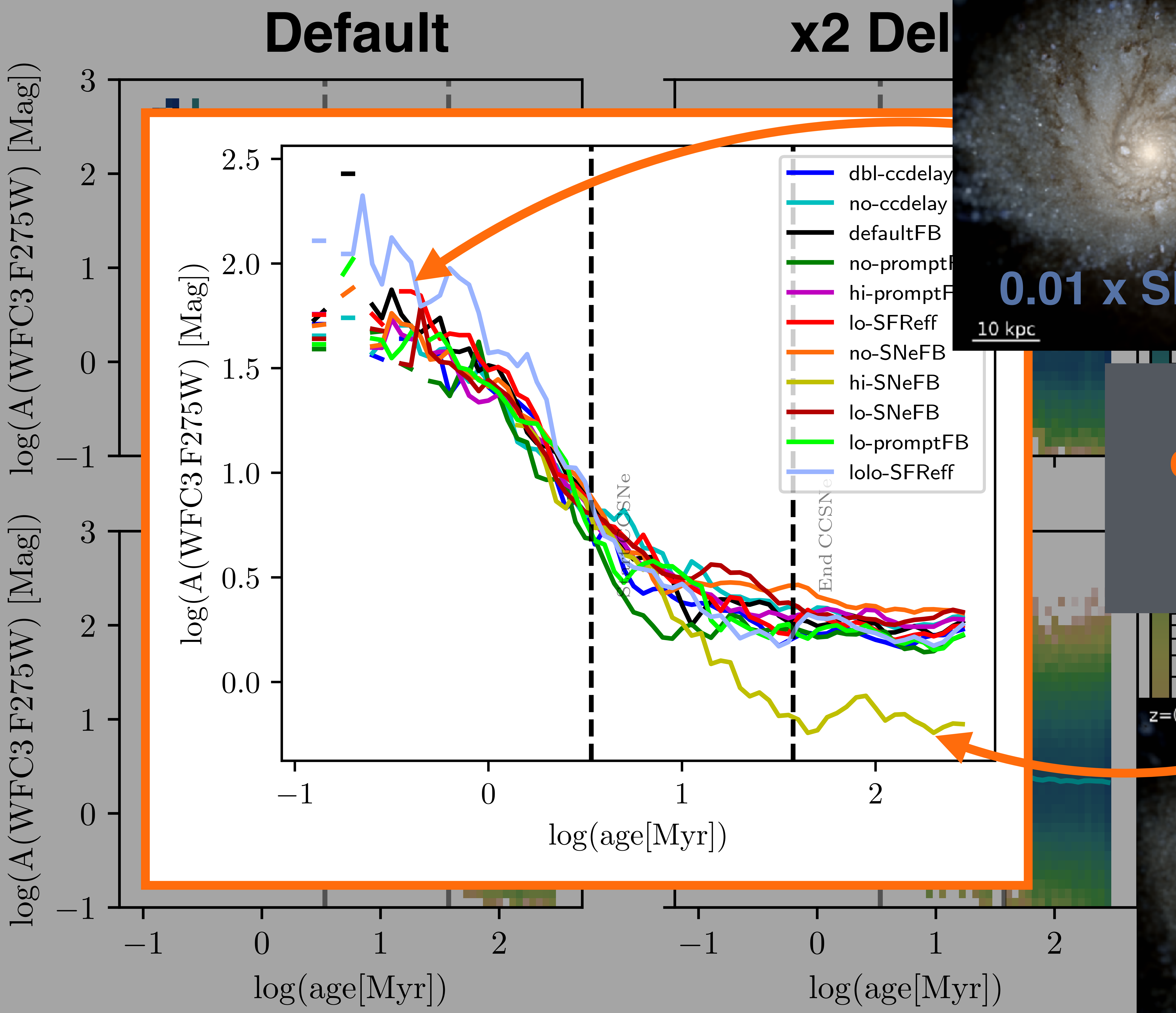

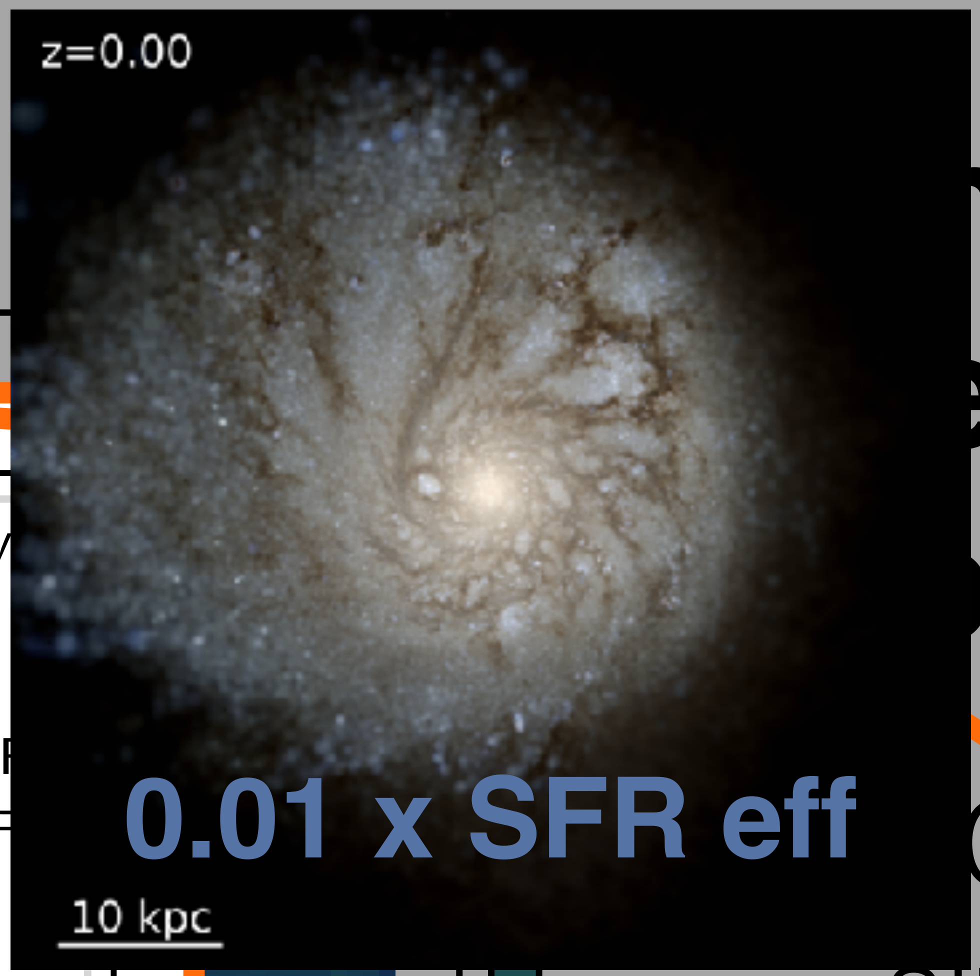

Completed runs all have
similar time evolution of the
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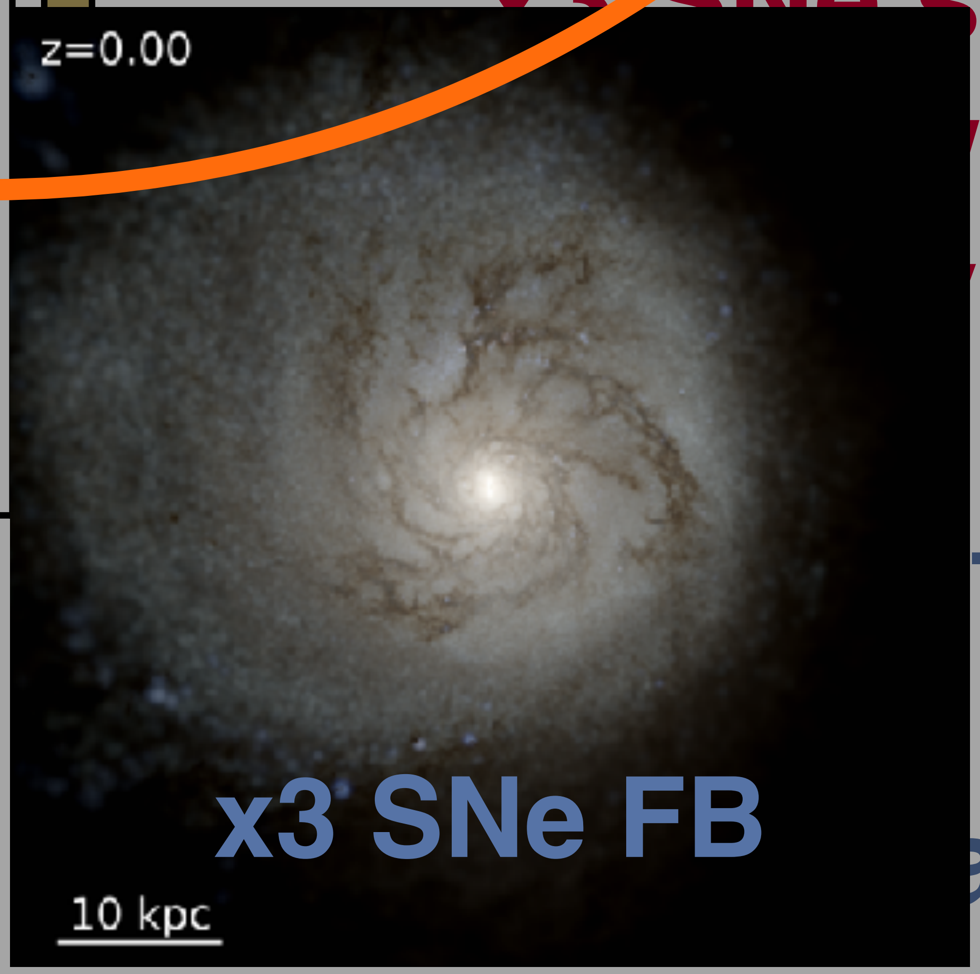
Largest changes gas columns seen in high SN strength and low SFR efficiency runs

x3 SNe strength creates
er density
ironments



fficiency results
is denser on-
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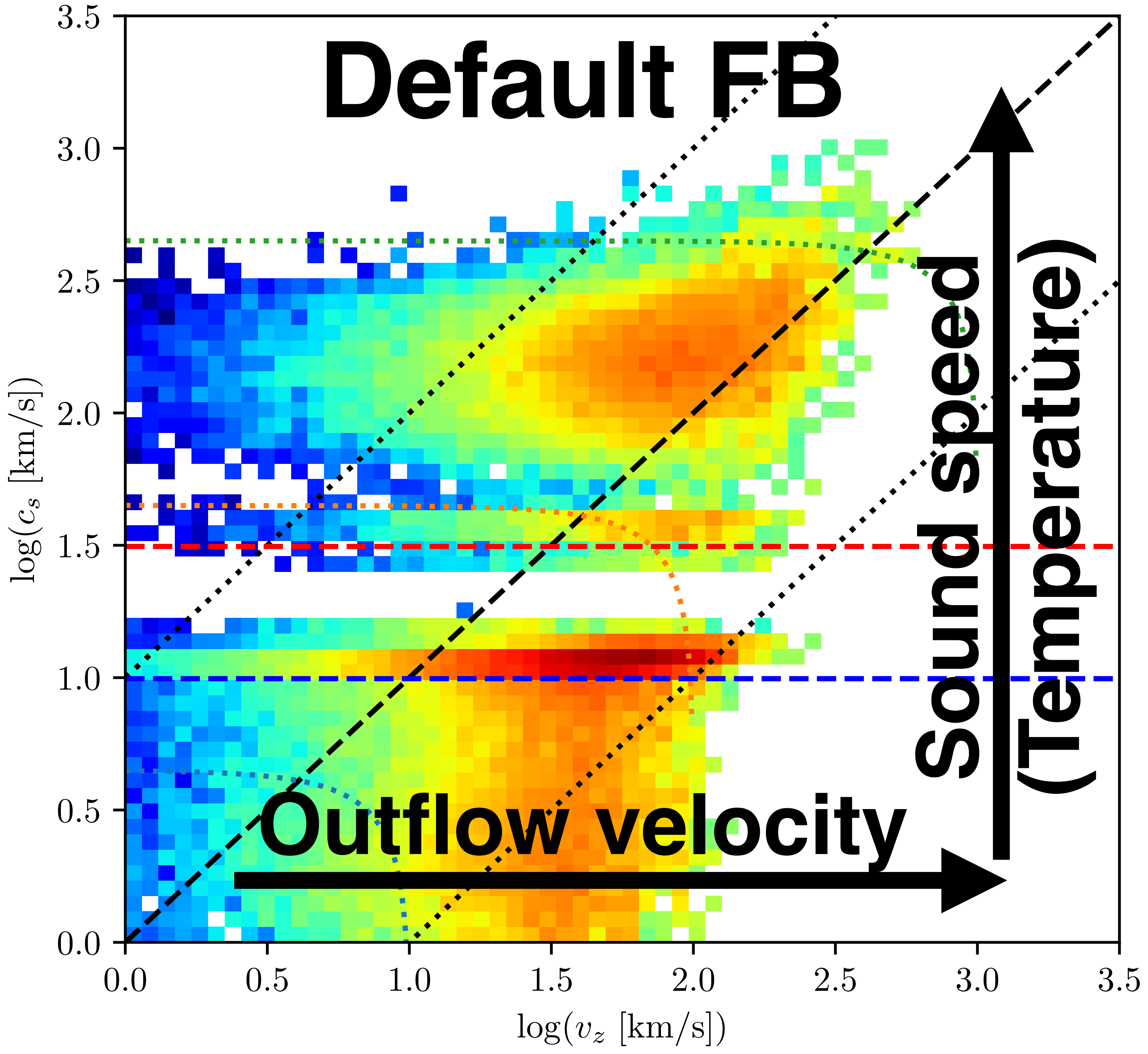
Gas Outflow Properties - Mass Flux



Gas Outflow Properties - Mass Flux
H = 2 kpc
Default FB
x3 Prompt FB
No cc-SNe Delay
No Prompt FB
x1/3 Prompt FB
x2 cc-SNe Delay
Outflow velocity
Sound speed (Temperature)
log(c_s [km/s])
log(v_z [km/s])
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
10^5
10^6
10^7
10^8
10^9

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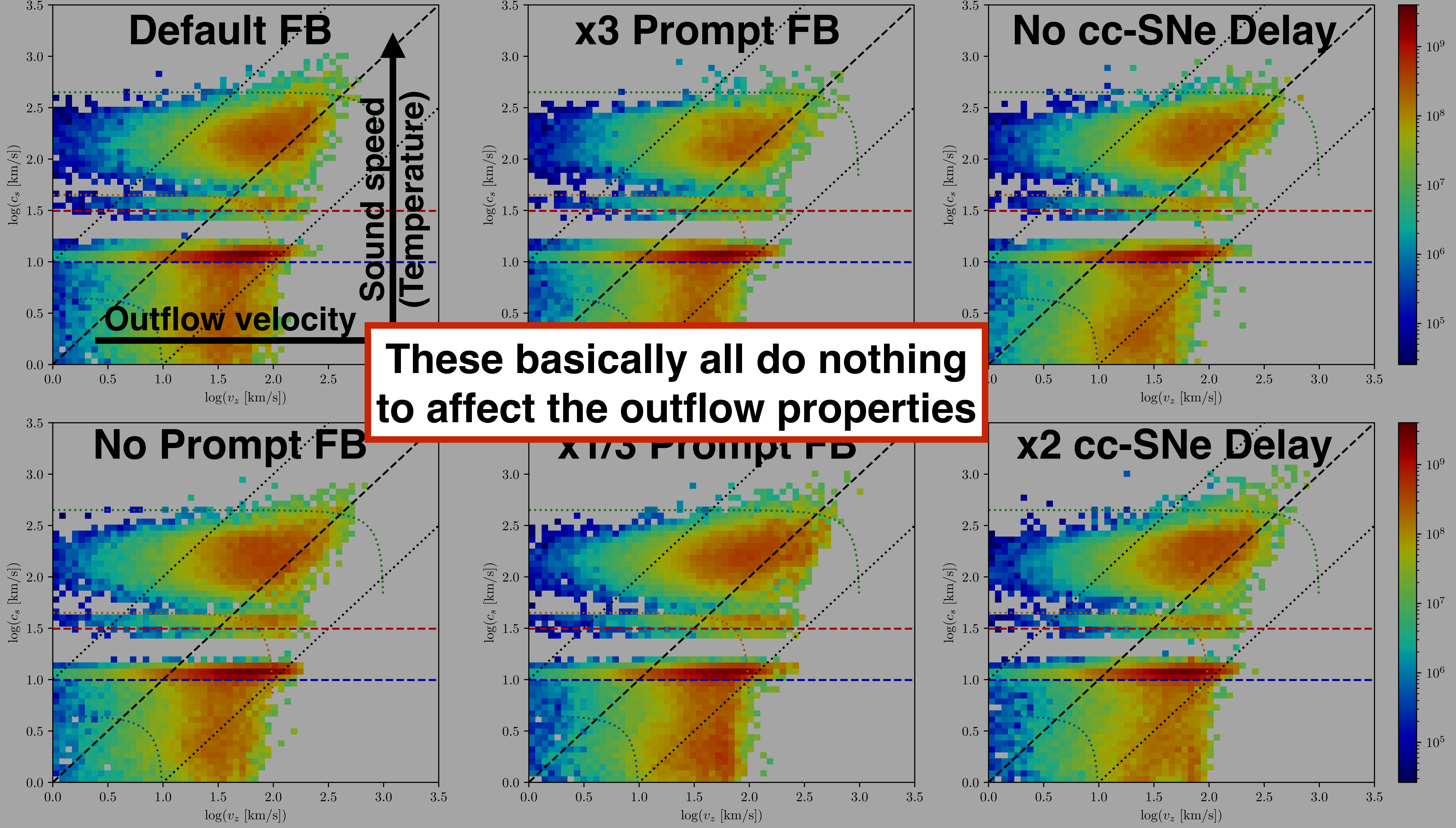

These basically all do nothing to affect the outflow properties

Gas Outflow Properties - Mass Flux
H = 2 kpc
Default FB
x0.1 SFE
x0.01 SFE
No SNe FB
x1/3 SNe FB
x3 SNe FB
Sound speed (Temperature)
Outflow velocity
$\log(c_s$ [km/s]$)$
$\log(v_z$ [km/s]$)$
0.0
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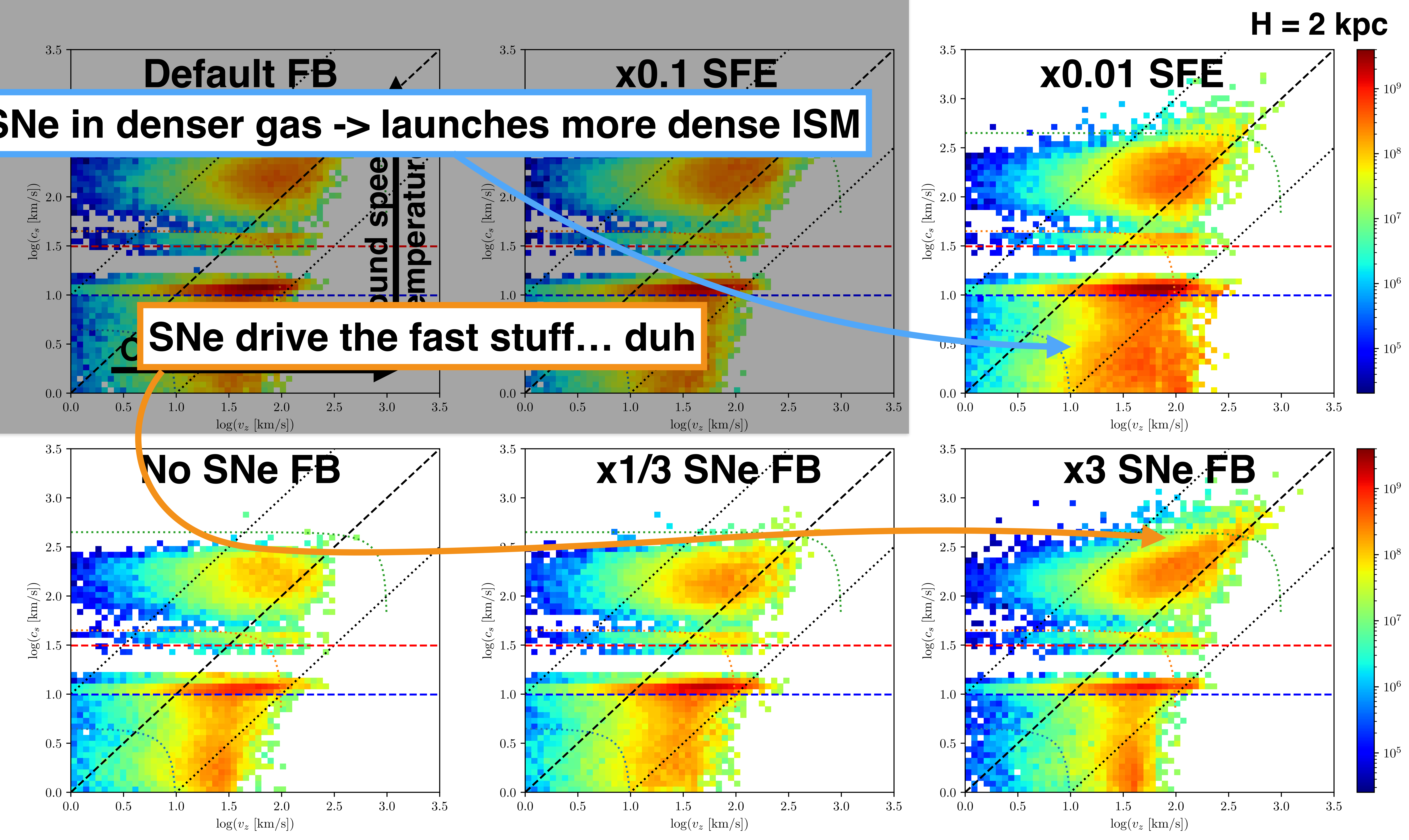
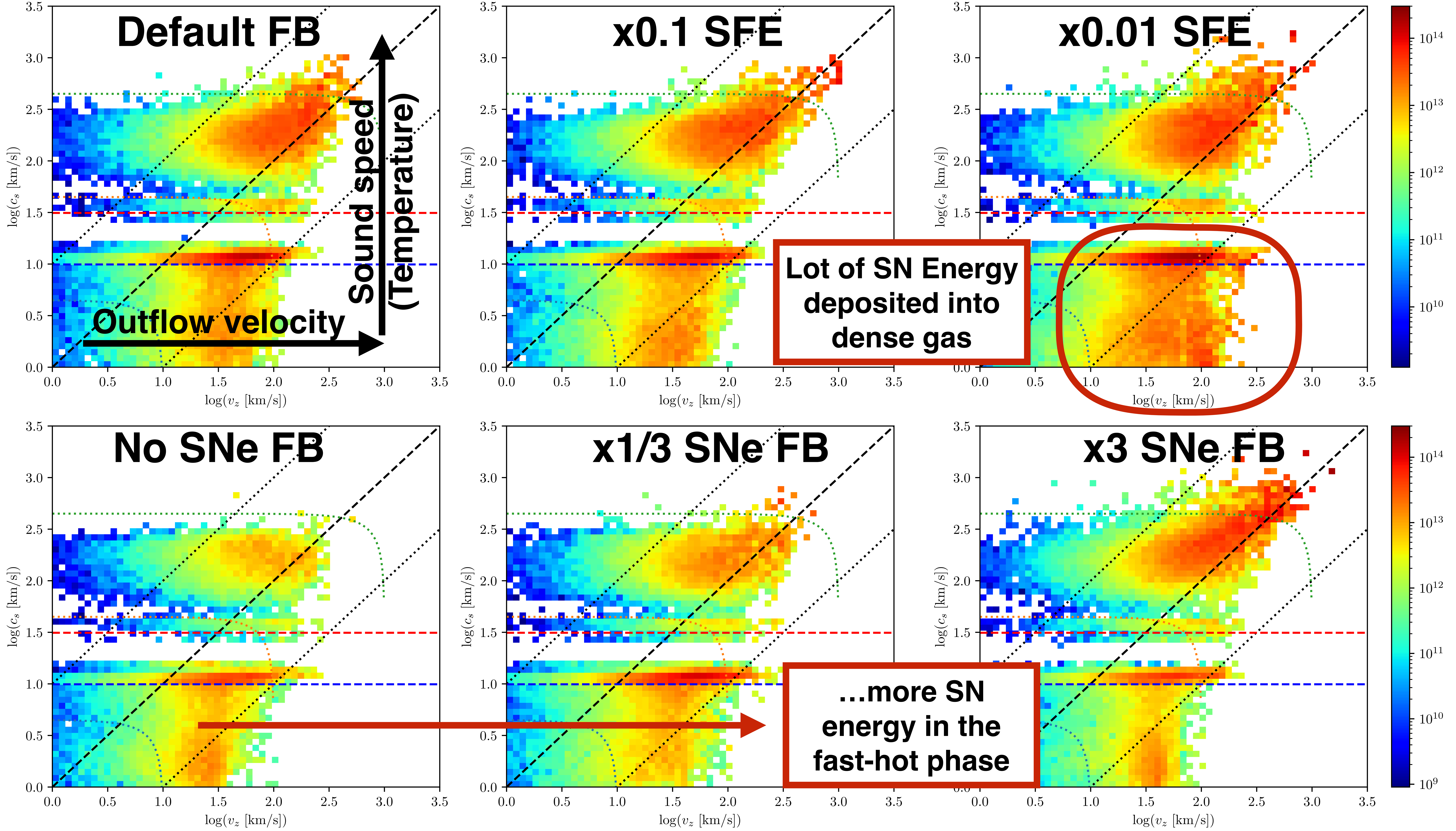
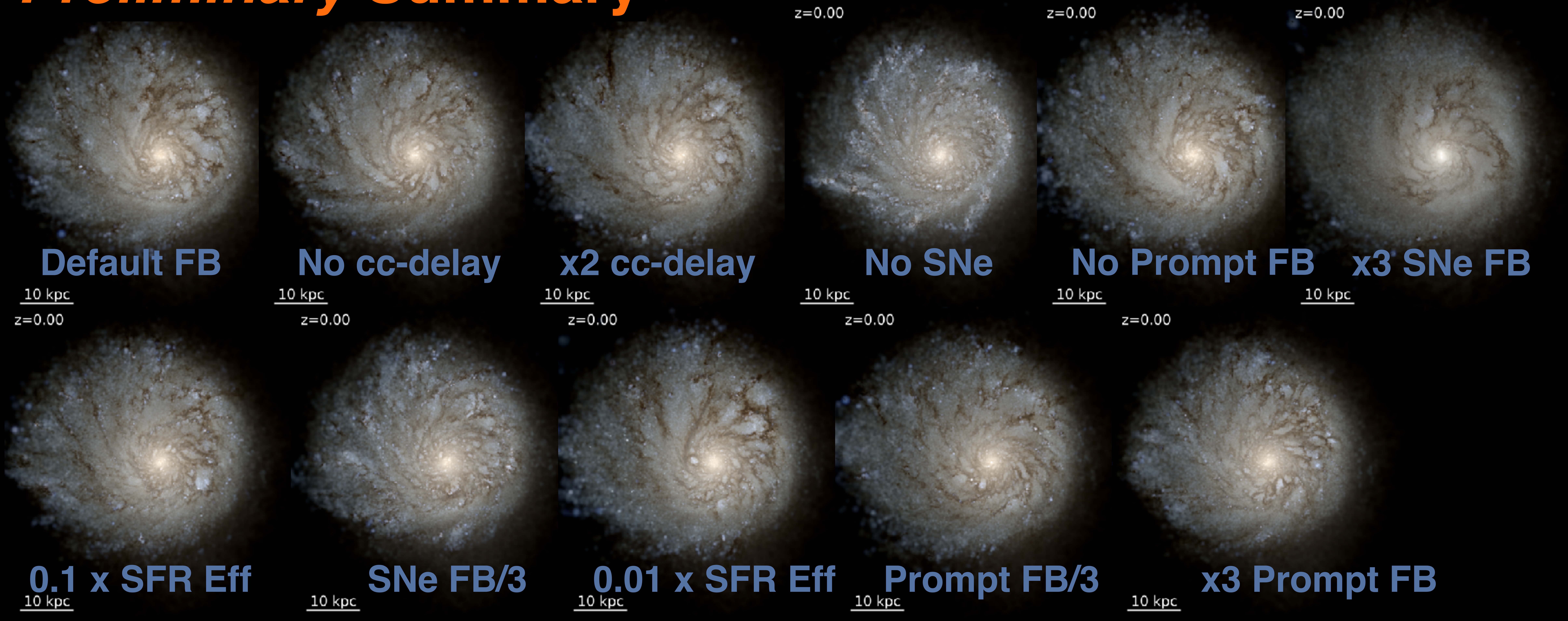


Gas Outflow Properties - Energy Flux

H = 2 kpc

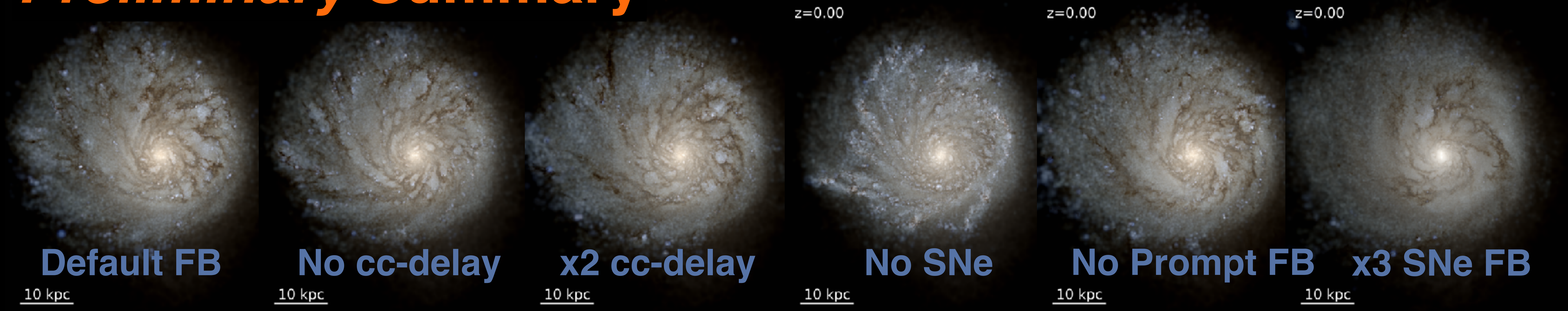


Preliminary Summary



Exploring the effects of varying FIRE feedback on the gas disk equilibrium of a spiral galaxy near z=0.

Preliminary Summary



+ more to come!

Exploring the effects of varying FIRE feedback on the gas disk equilibrium of a spiral galaxy near z=0.

- **Changing the delay time of cc-SNe, the strength of prompt feedback or small-scale SFE (to a point) has little effect** on gas velocity dispersions, star-forming region properties
- **Strong SNe** do affect inter-arm gas, sweeping out diffuse gas effectively
- Most dramatic effects appear **when SN FB is culled *entirely*: vertical velocity dispersions fall, gas is dense *on-average***
- ***Self-regulating disks are hard to affect in most 'observable' parameters!***
  Disk outflow properties provide a weak constraint

Plan to run CHIMES+RADMC3D synthetic observations pipeline on these physics tests to see how these choices affect observables like C+, CO, Halpha in more careful detail than the approximate treatment presented here.

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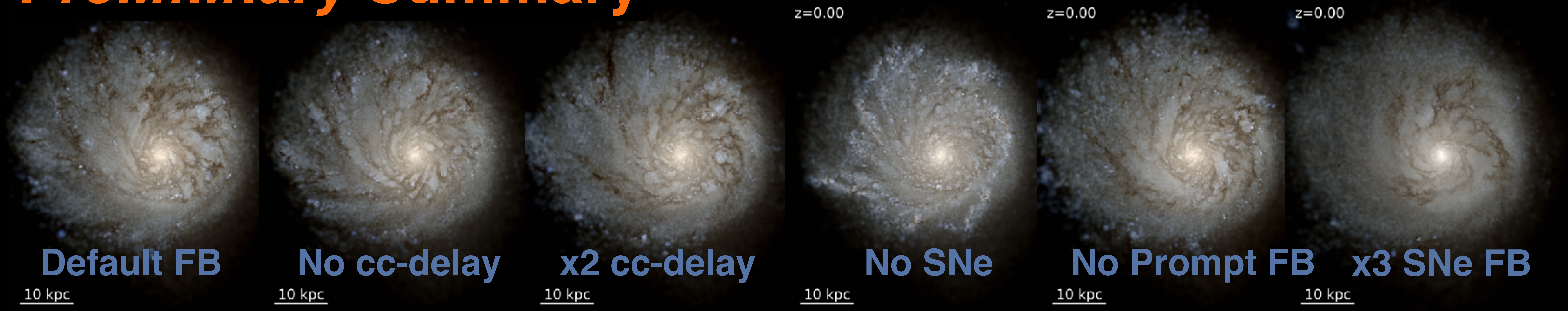

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Thanks!