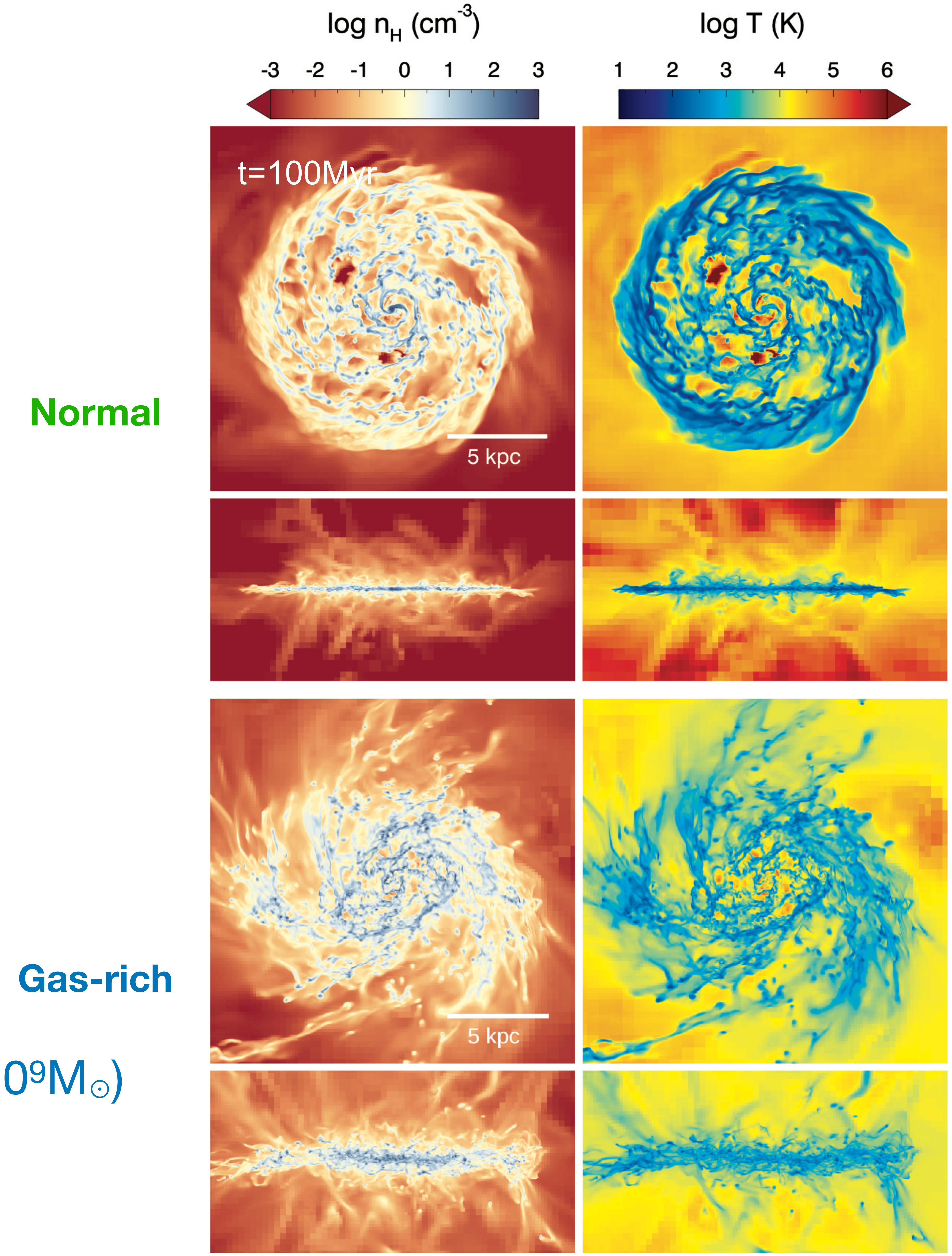
- Simulation setup - galaxies
  - Idealized wind-tunnel experiments
  - IC (G9) generated by Rosdahl+15 using MakeDisk (Springel+05)
  - Box size: 300kpc on a side
  - $M_{halo} \sim 10^{11} M_\odot$, R_{vir}=89 kpc
  - $M_\star \sim 2.1 \times 10^9 M_\odot$ ($R_{1/2} \sim 2.4$kpc), $Z_\star = 0.75 Z_\odot$
  - Gas content
    - Normal gas fraction : $M_{HI}/M_\star \sim 0.54$ ($1.1 \times 10^9 M_\odot$)
    - High gas fraction (5x of normal) : $M_{HI}/M_\star \sim 2.6$ ($5.4 \times 10^9 M_\odot$)
  - Cell resolution down to 18pc



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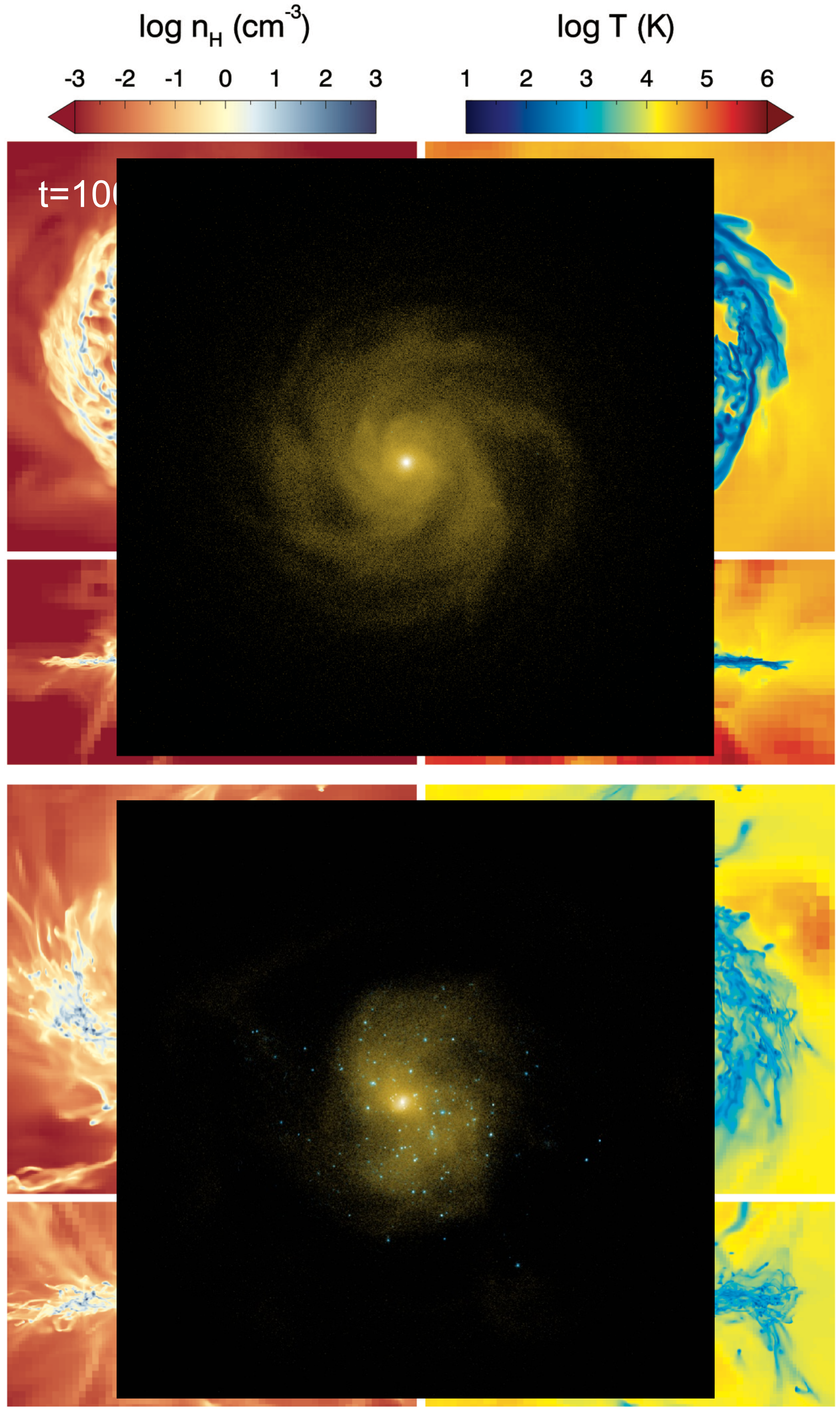
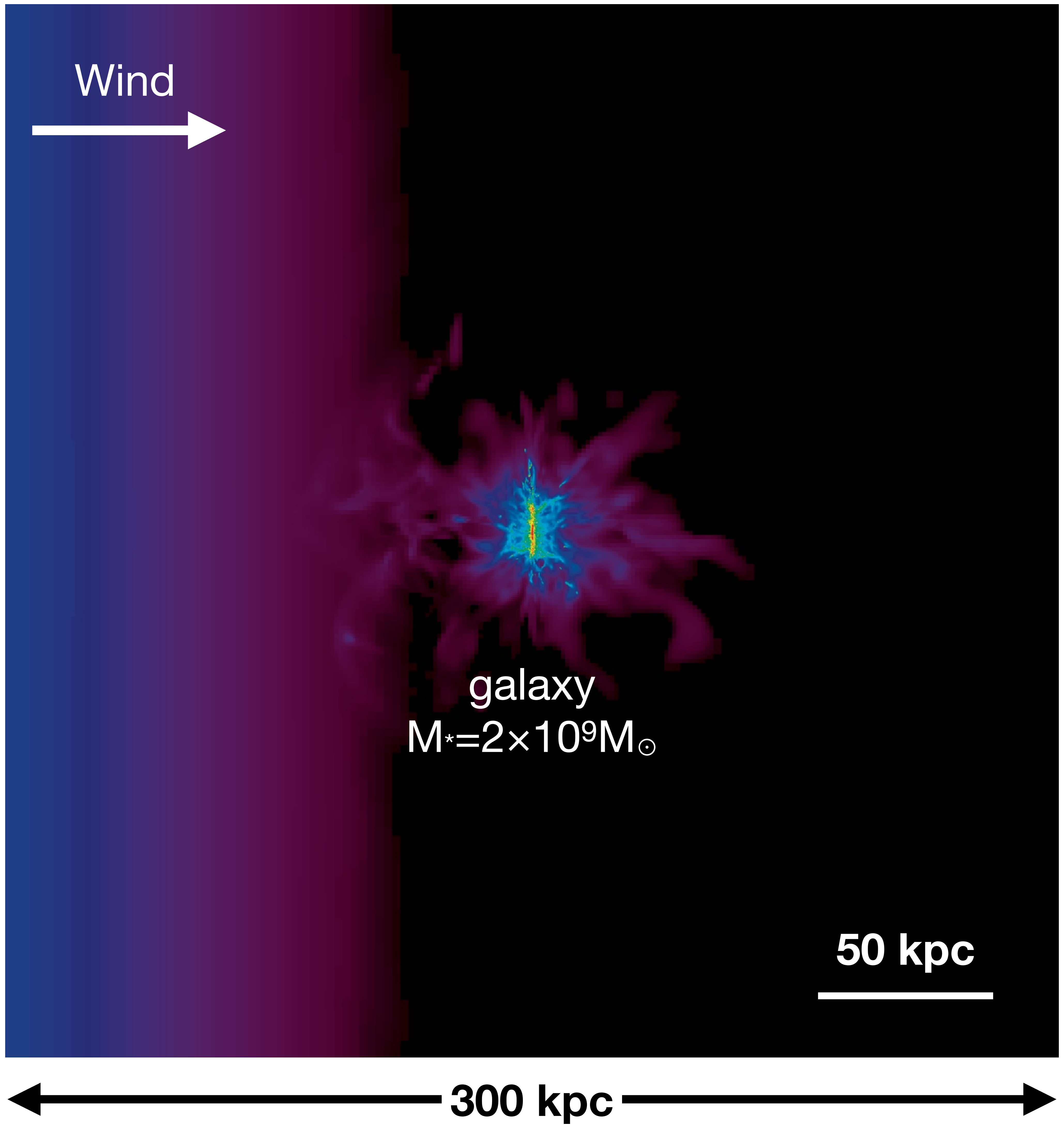
Normal

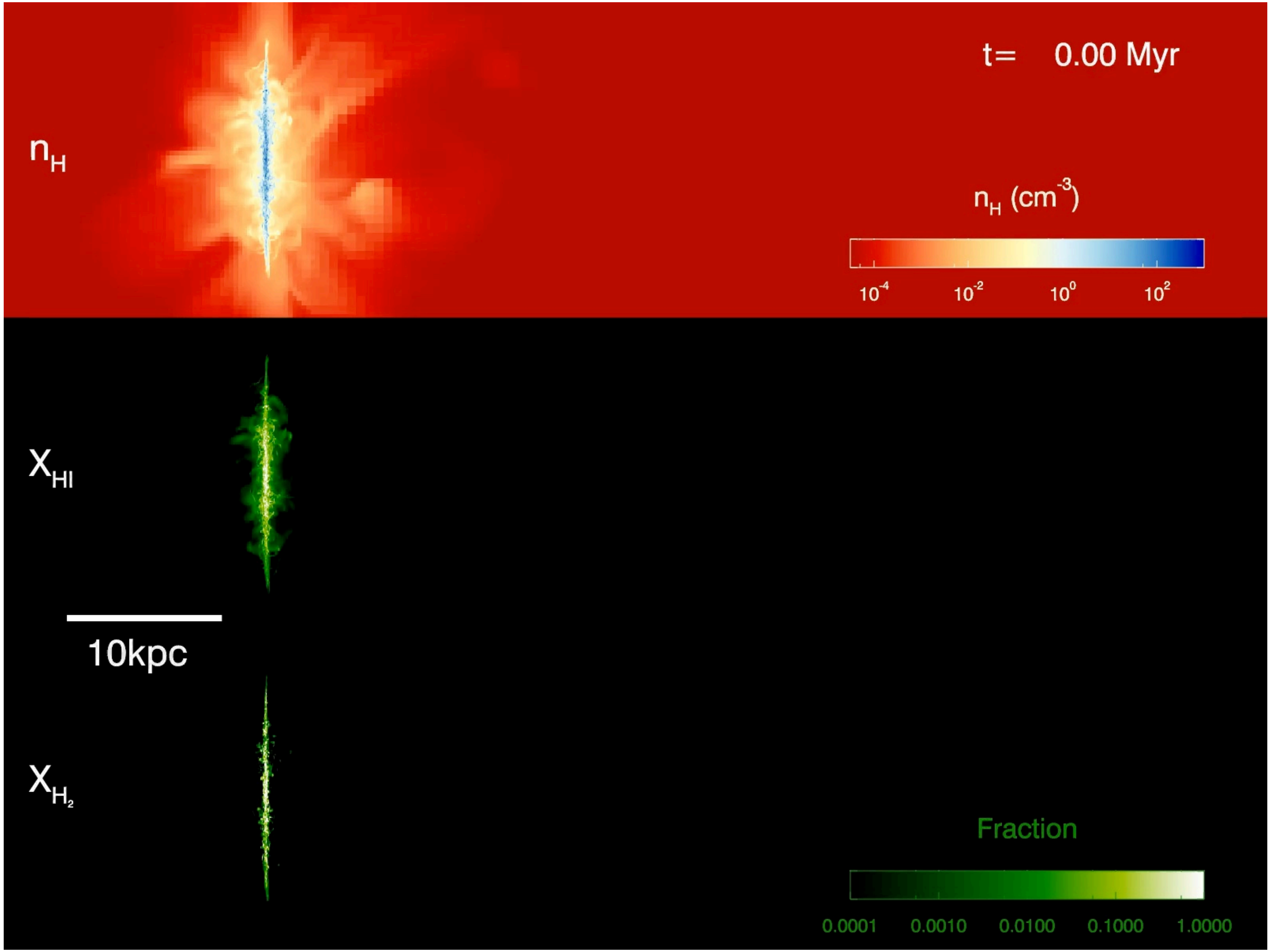
Gas-rich



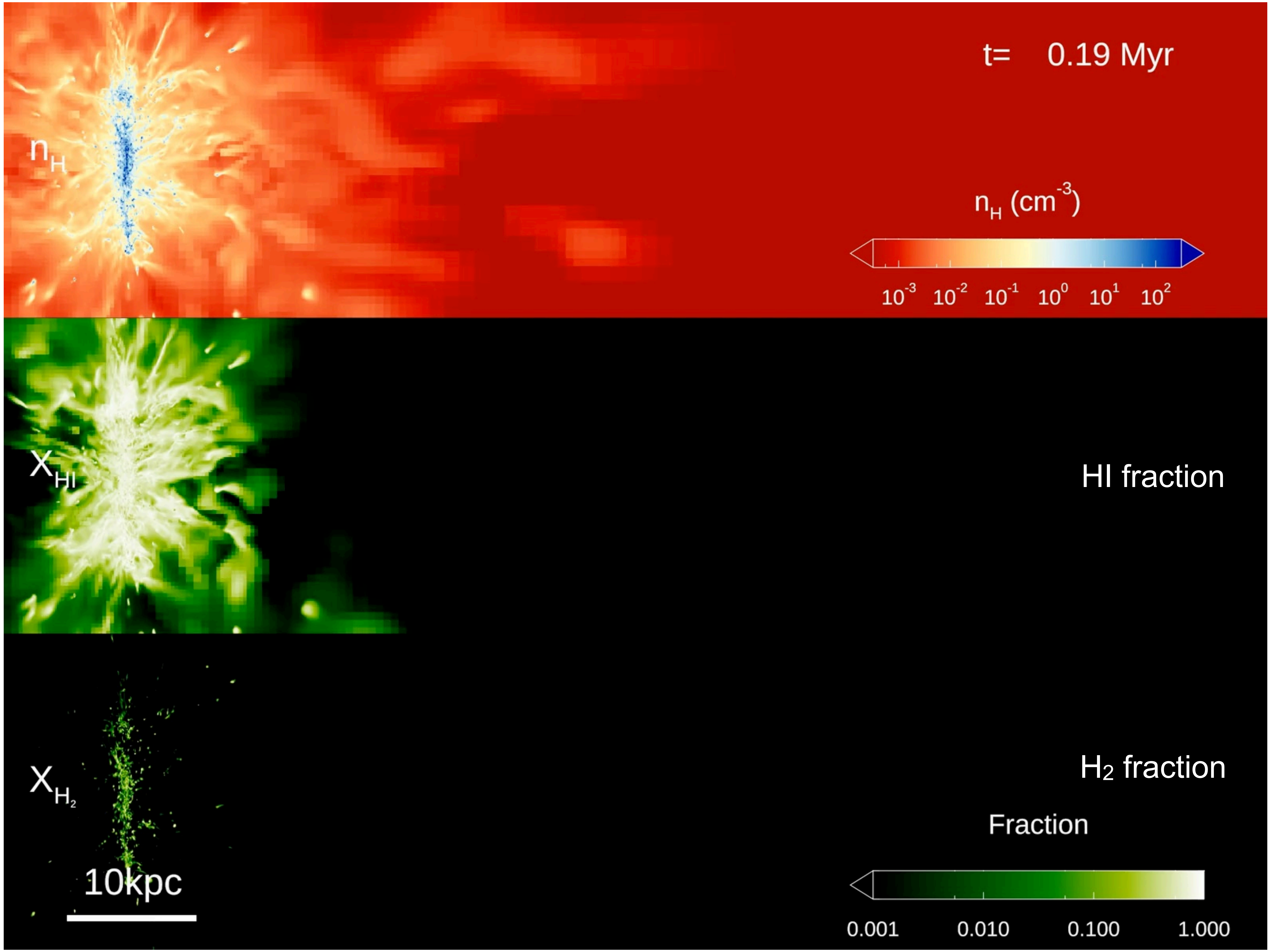
- Simulation setup
  - Isolated environment - no wind (control sample)
    - Gas-rich galaxy (NoWind_rich)
  - Strong face-on winds to mimic ram pressure at the cluster center (v_{wind}=1,000km s^{-1}, T_{ICM} ~10^7K, n_H=3×$10^{-3}$$cm^{-3}$, Z_{ICM}=0.3$Z_\odot$)
    - Gas-rich galaxy (FaceWind10_rich)
    - Normal galaxy (FaceWind10, adopted from the previous study)



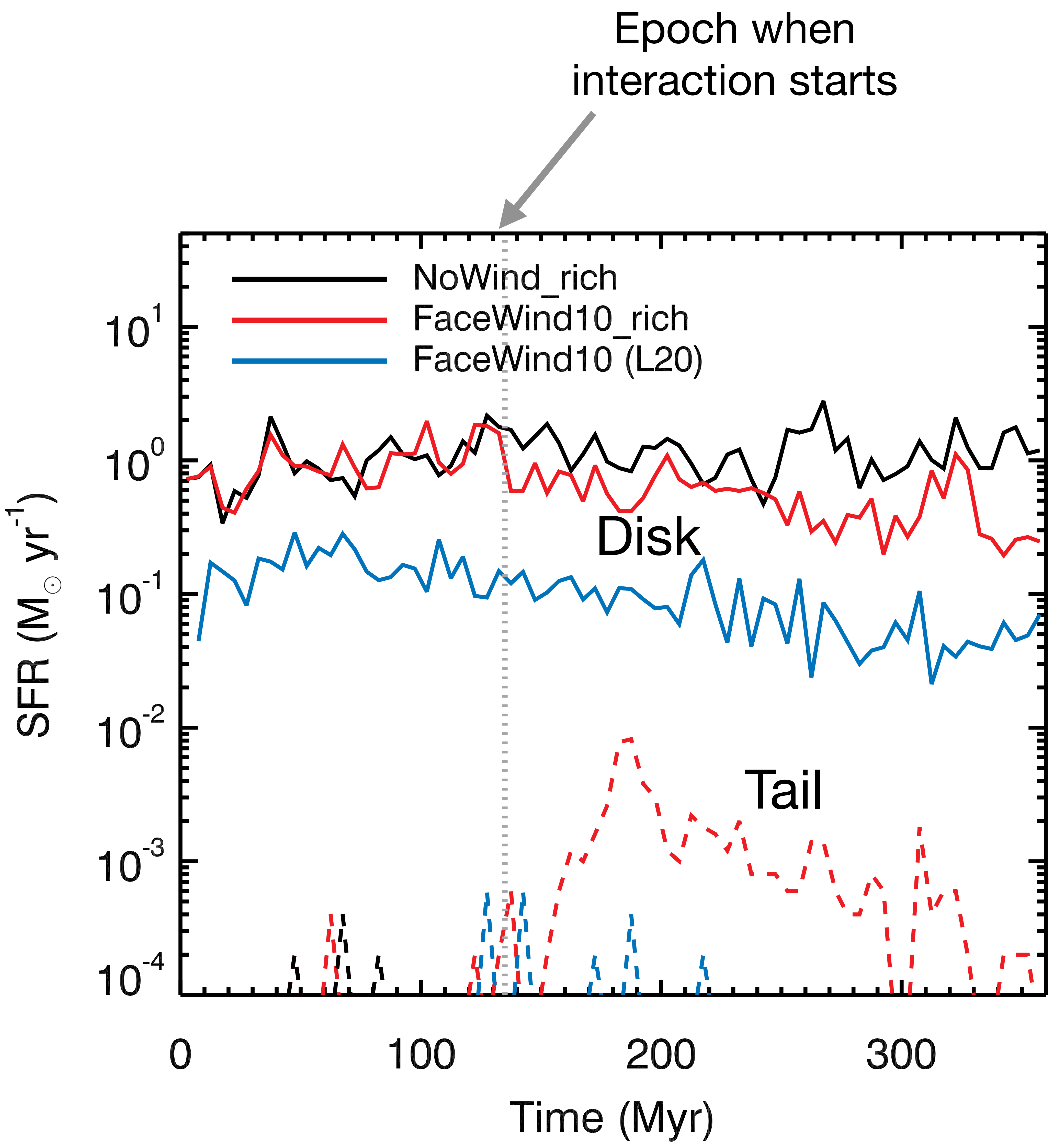
- FaceWind10 - a normal galaxy encountering a strong wind



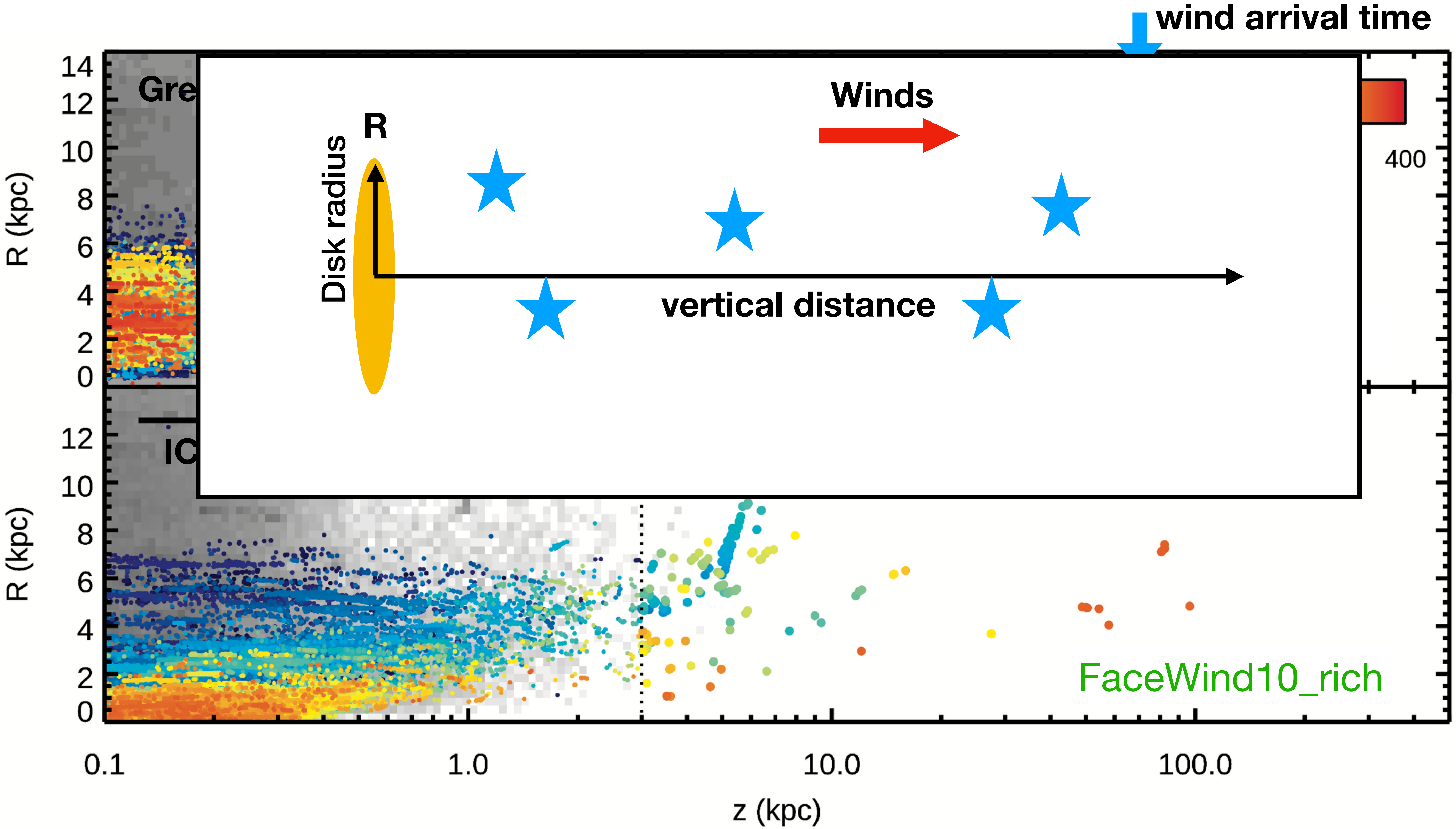
- FaceWind10_rich - gas-rich galaxy encountering a strong wind



- Star formation rate (SFR) evolution
  - Disk star formation (SF) is quenched over time after encountering the ICM winds
    - SFRs decrease in the normal and gas-rich galaxies with similar rates
    - SF is boosted at the center (r<<1kpc) due to gas compression by the ICM winds
  - Evident tail SF is observed in FaceWind10_rich
    - Tail SFR~10^{-3}-10^{-2} $M_{\odot}$/yr - comparable with observations (e.g. D100 in Coma)



- Birthplace of stars in the gas-rich galaxy as a function of time
  - No stars form in z>3kpc after t~100Myr in the NoWind_rich galaxy
  - Stars form in the tail of the FaceWind10_rich galaxy after encountering the wind (t>130Myr)



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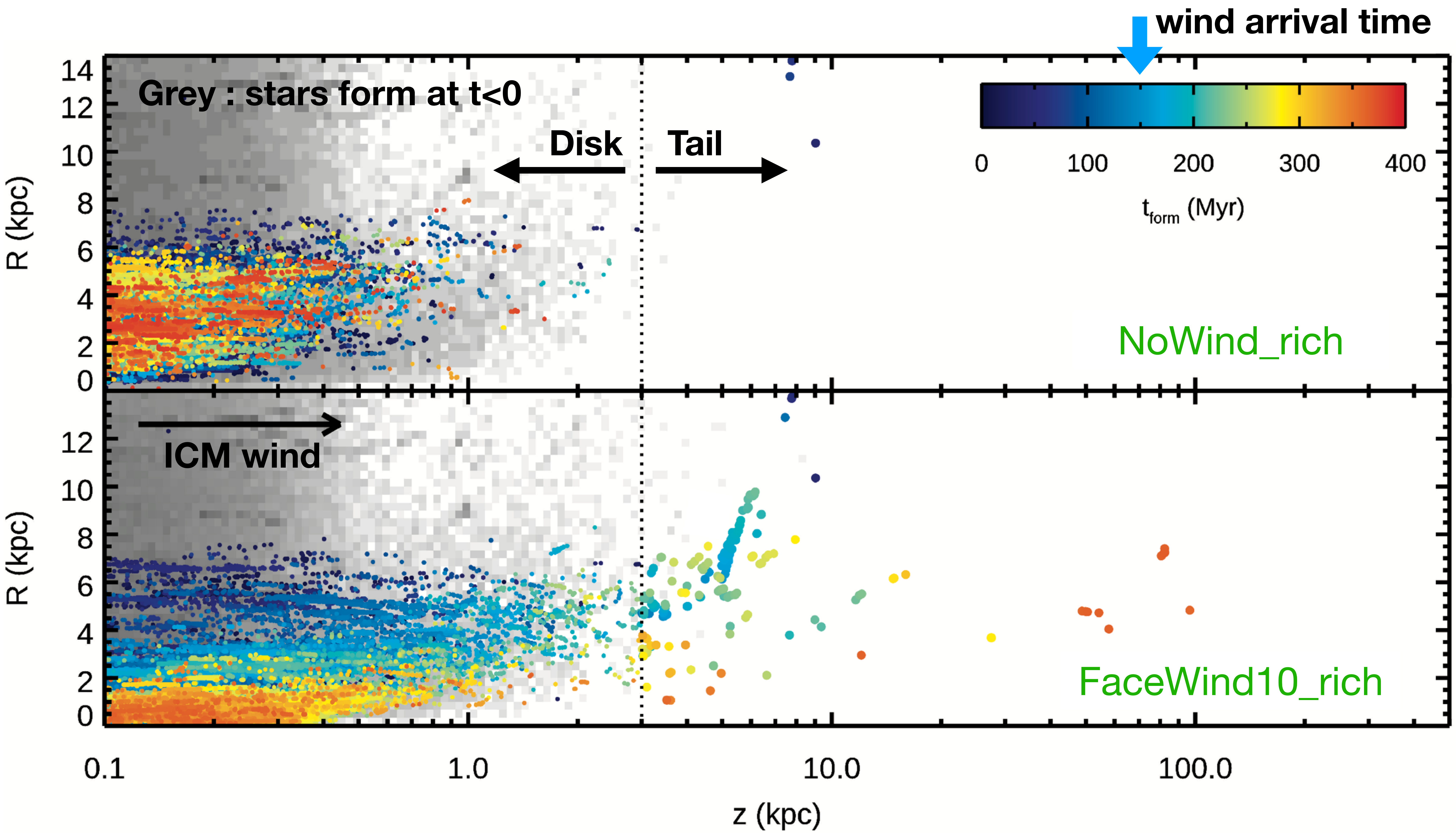
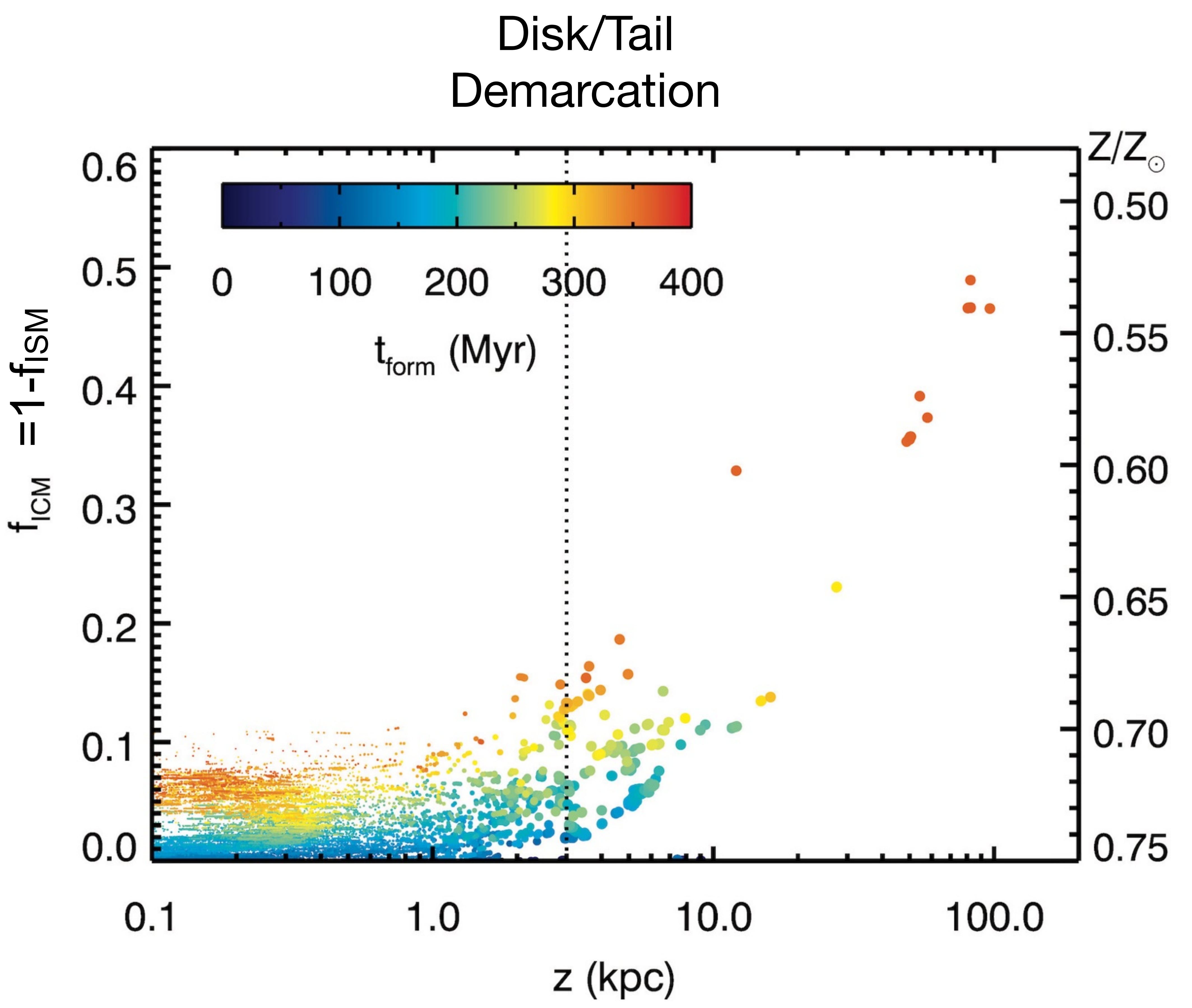


- Source of tail SF
  - Most (~90%) tail SF occurs in the near wake (z<10kpc) of the FaceWind10_rich galaxy
    - Their origin is mostly stripped ISM
  - Distant stars form in clouds that are mixed well with the ICM
    - Indicating the formation of molecular clumps in the RPS tail

※ Metallicity is not enriched by stars

$$f_{\rm ISM} = \frac{Z \quad - Z_{\rm ICM}}{Z_{\rm ISM} - Z_{\rm ICM}} \qquad (Z_{\rm ICM} = 0.3 Z_\odot,\ Z_{\rm ISM} = 0.75 Z_\odot)$$



- Origin of tail molecular clumps

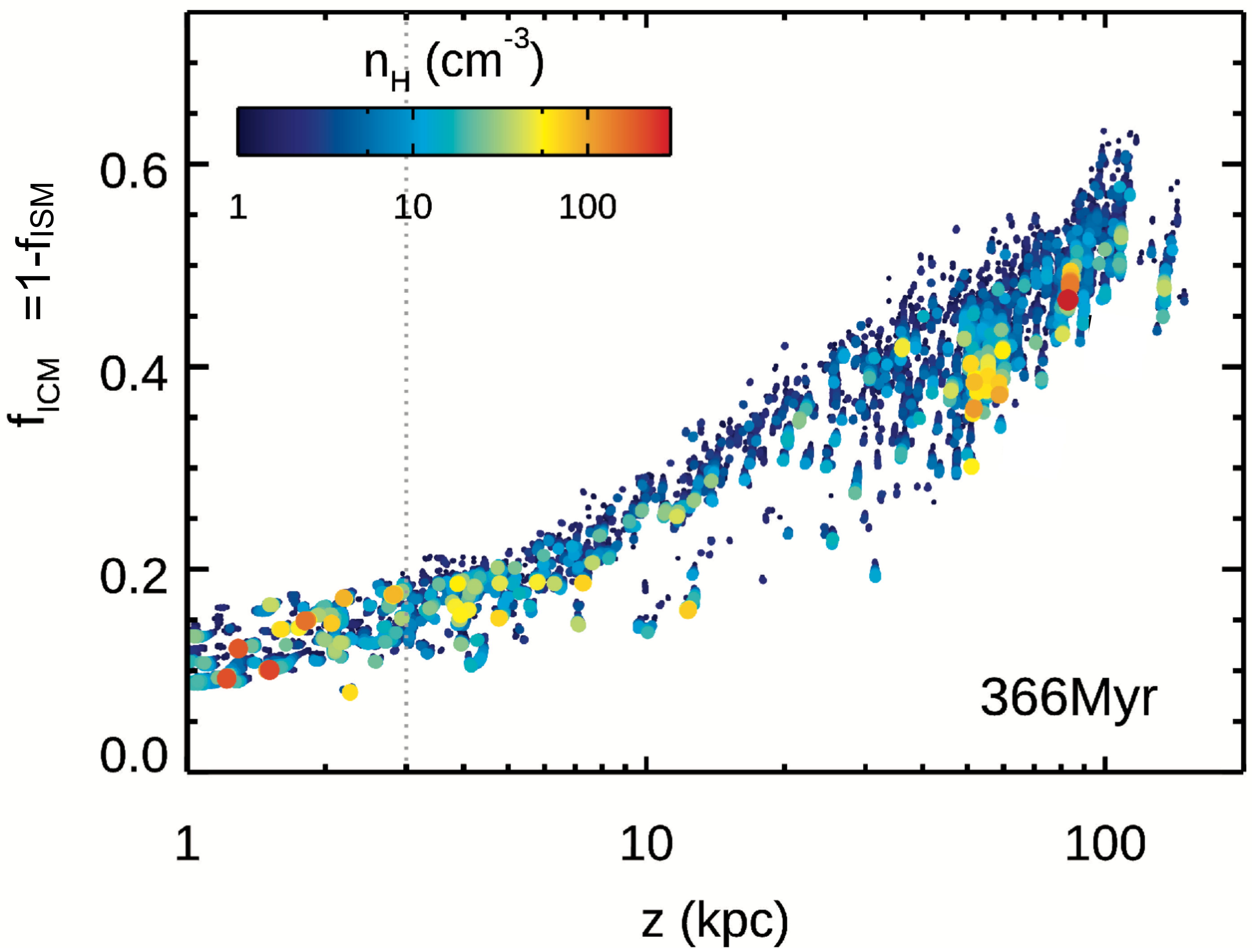
  - Molecular hydrogen clumps (n_H>100cm^{-3}) form far behind (z~60-80kpc) the galactic disk of the FaceWind10_rich galaxy

  - No dense clumps form in the tail of the FaceWind10 galaxy

  - Two galaxies have significantly different gas t_{cool} in their tails

    - FaceWind10 : poor ionized gas with short t_{cool}

    - FaceWind10_rich : plenty ionized gas with t_{cool}<1Myr that can collapse within ~100Myr



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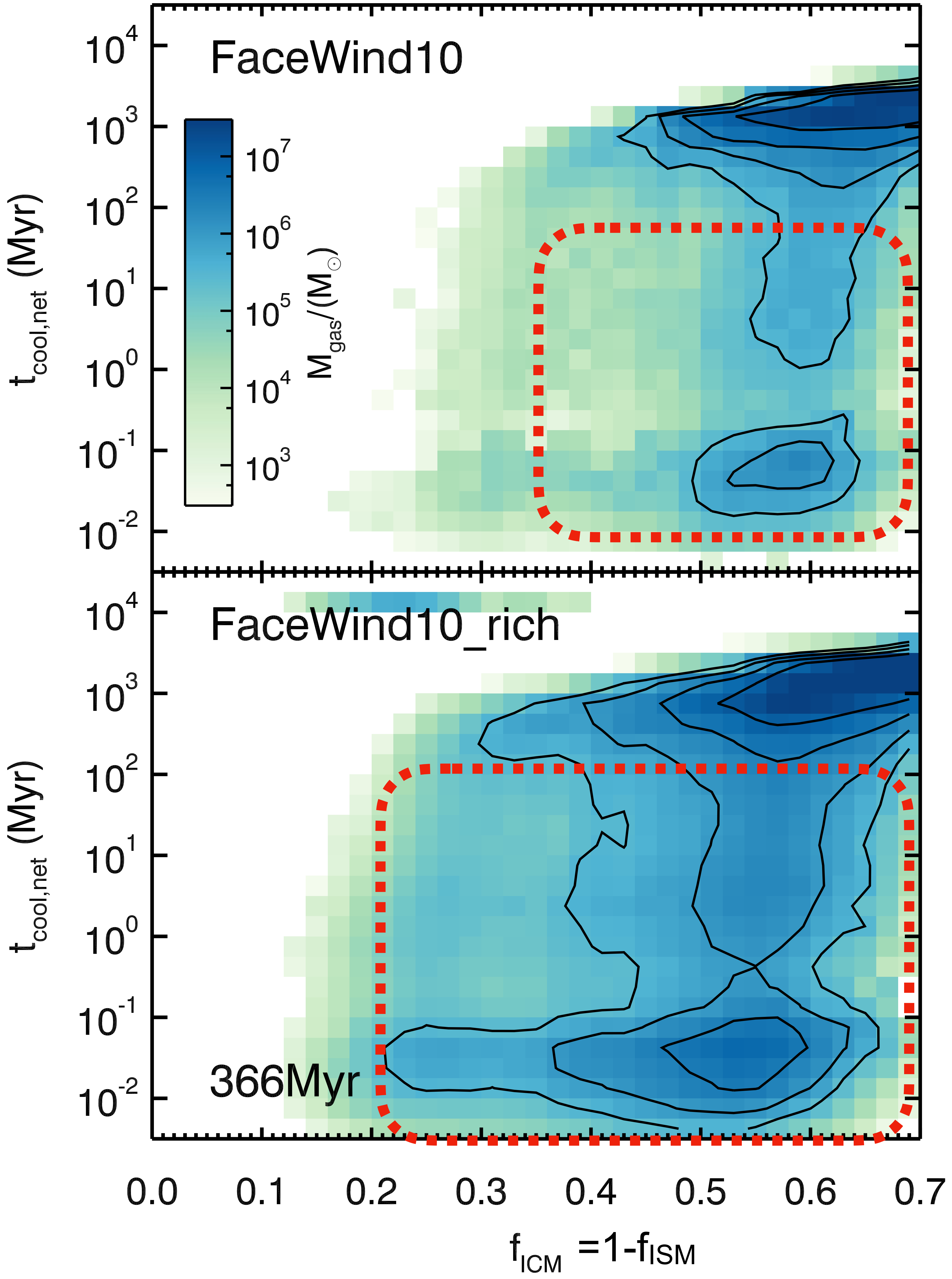

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  - Two galax in their tails
    - FaceWind10 : poor ionized gas with short t_{cool}
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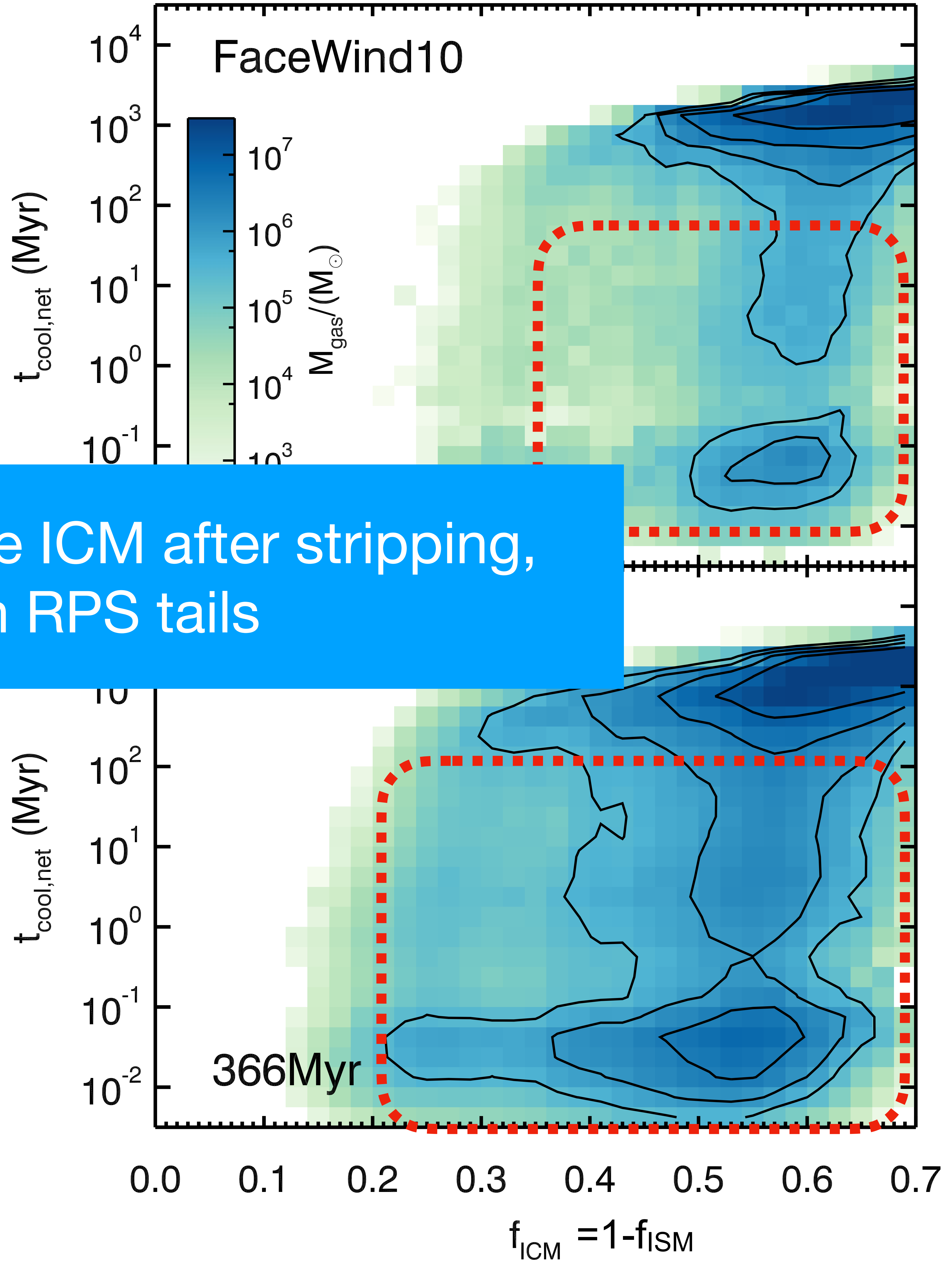
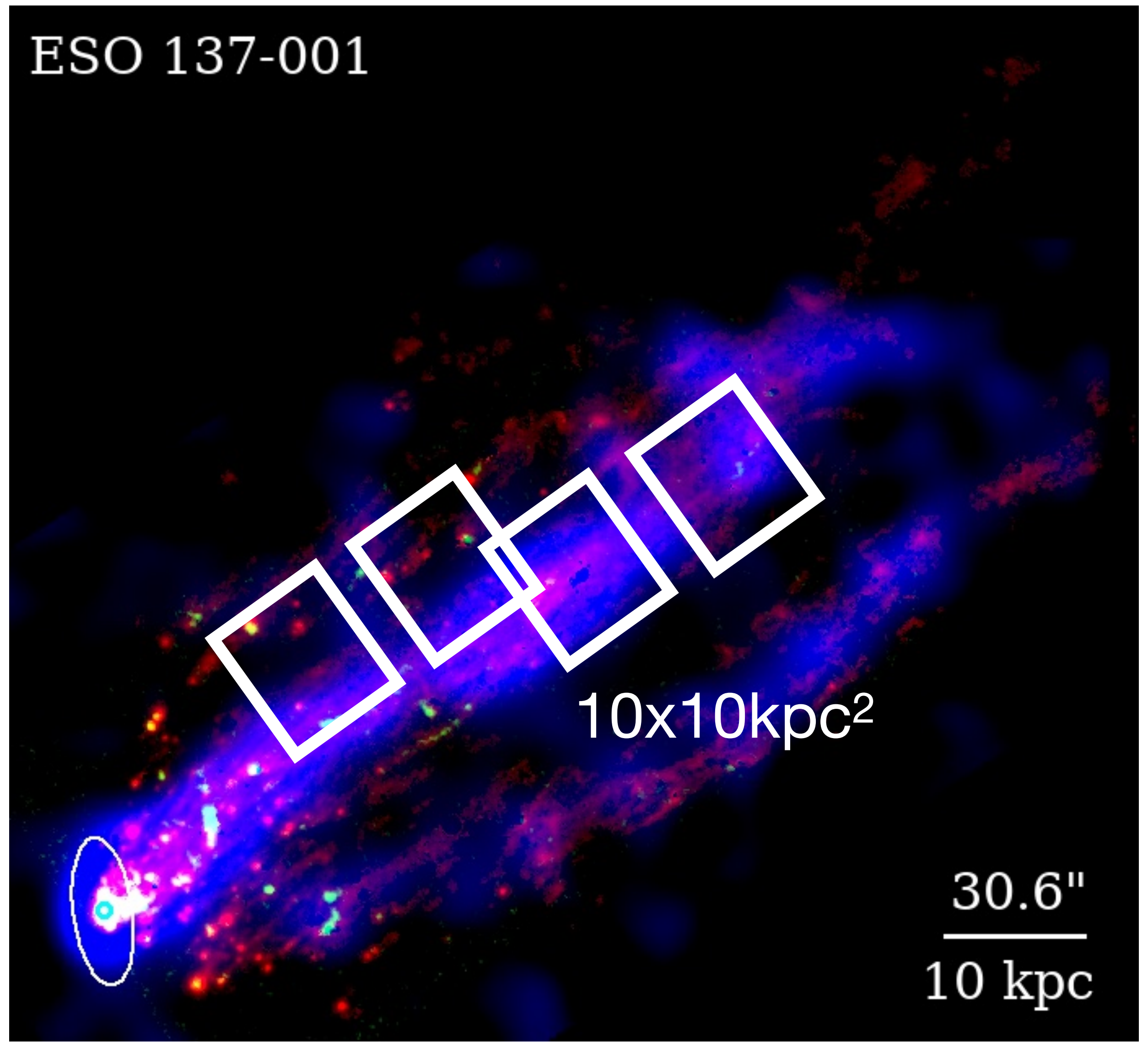
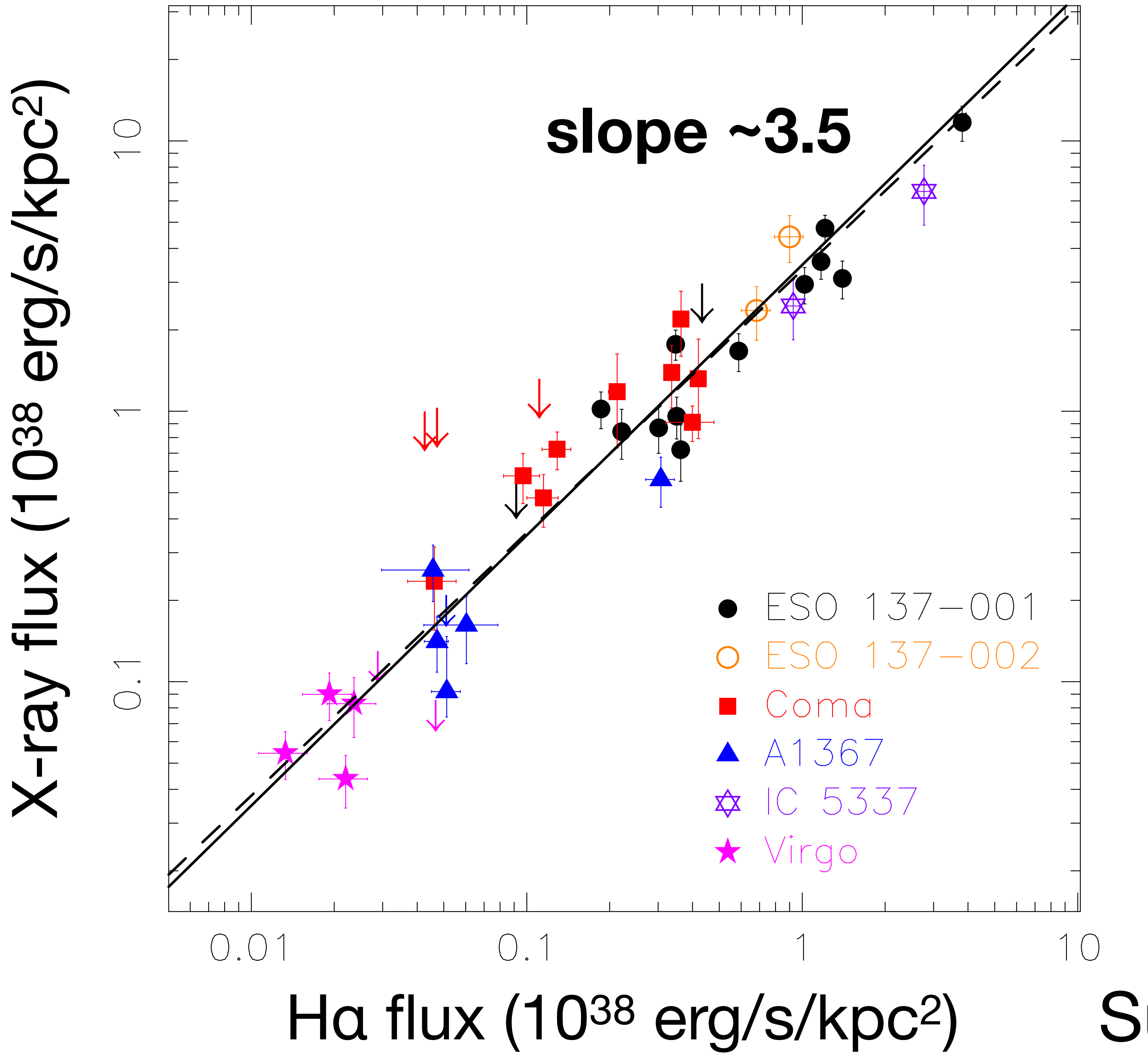
The abundant ISM is mixed with the ICM after stripping, facilitating gas cooling in RPS tails



- What is the evidence of mixing? - Hα-to-Xray flux correlation in the RPS tails
  - A strong correlation is reported by Sun+21
    - $F_X/F_{H\alpha}$~3.5 in RPS tails, on average
      - Measured on a scale of 10×10kpc^2
    - The source of the Hα and Xray photons are fundamentally different: T_{gas}~10^4K vs T_{gas}~10^7K
    - Strongly evidencing mixing between the ICM and stripped ISM in RPS tails?





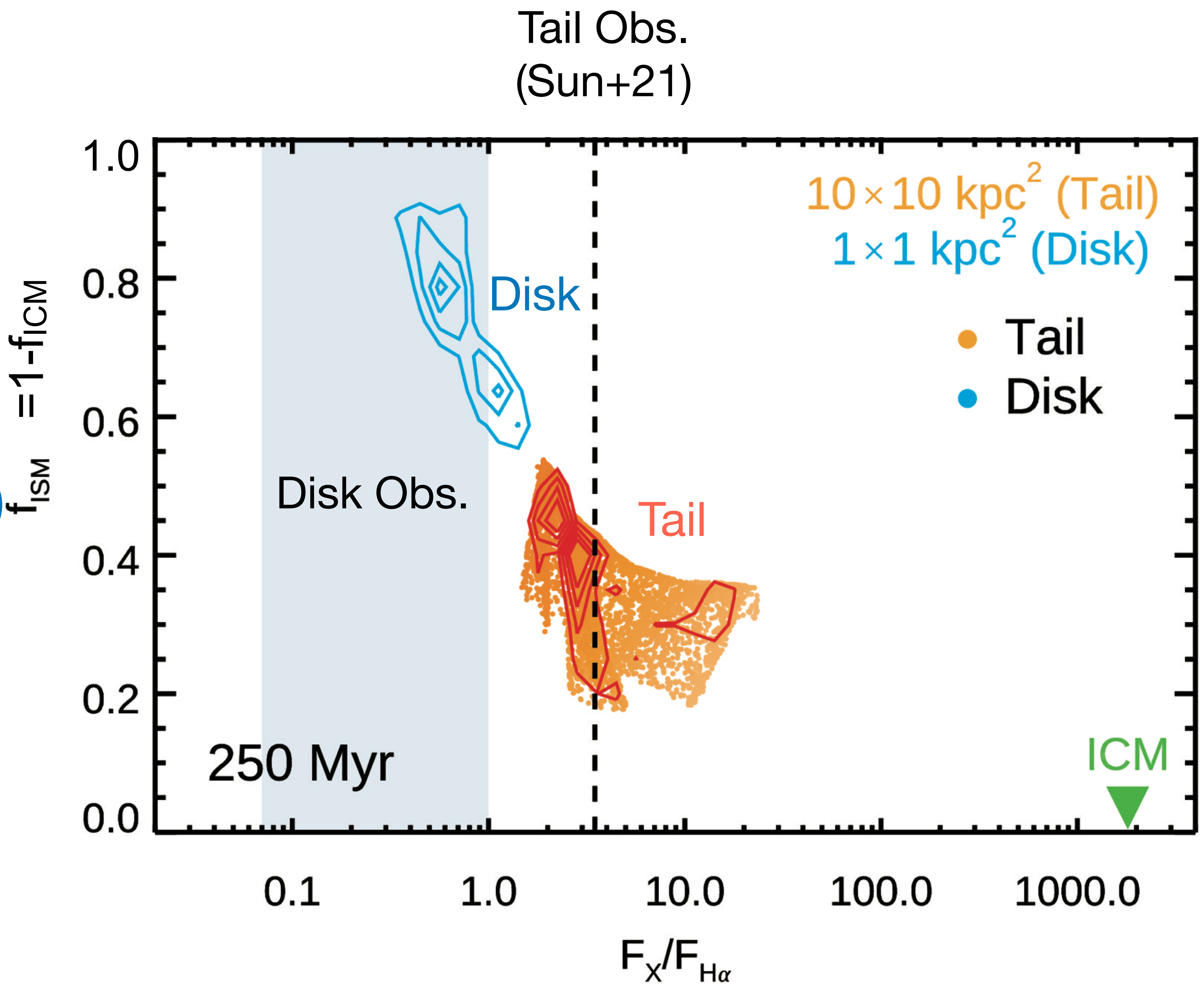
Sun+21

- Hα and X-ray emissivity of the FaceWind10_rich galaxy
  - Hα: computed for recombinative and collisional excitation processes
  - X-ray: computed using Astrophysical Plasma Emission Code (Smith+01)

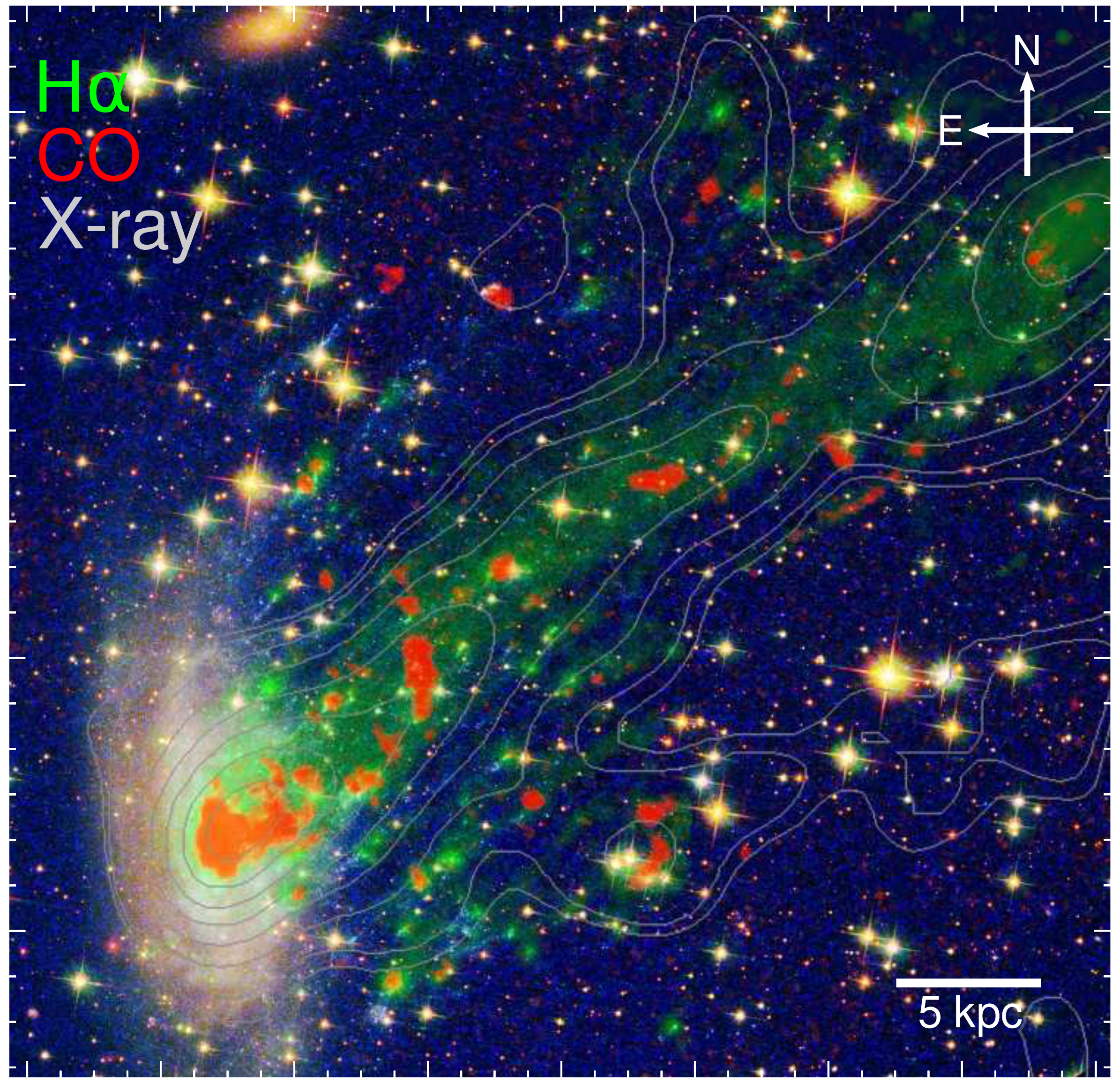
- Hα - Xray SB correlation in the RPS tail of the FaceWind10_rich galaxy
  - F_X measured in 0.4-7.5keV and converted into bolometric flux, following observations (Sun+21)
  - $F_X/F_{H\alpha}$~1800 in the ICM

    ~1.5-20 in the tail (c.f. $F_X/F_{H\alpha}$~3.5 in Sun+21)

    < 1.5 in the disk
  - F_{ISM} tightly correlates with $F_X/F_{H\alpha}$
    - $F_X/F_{H\alpha}$ increase with decreasing f_{ISM}

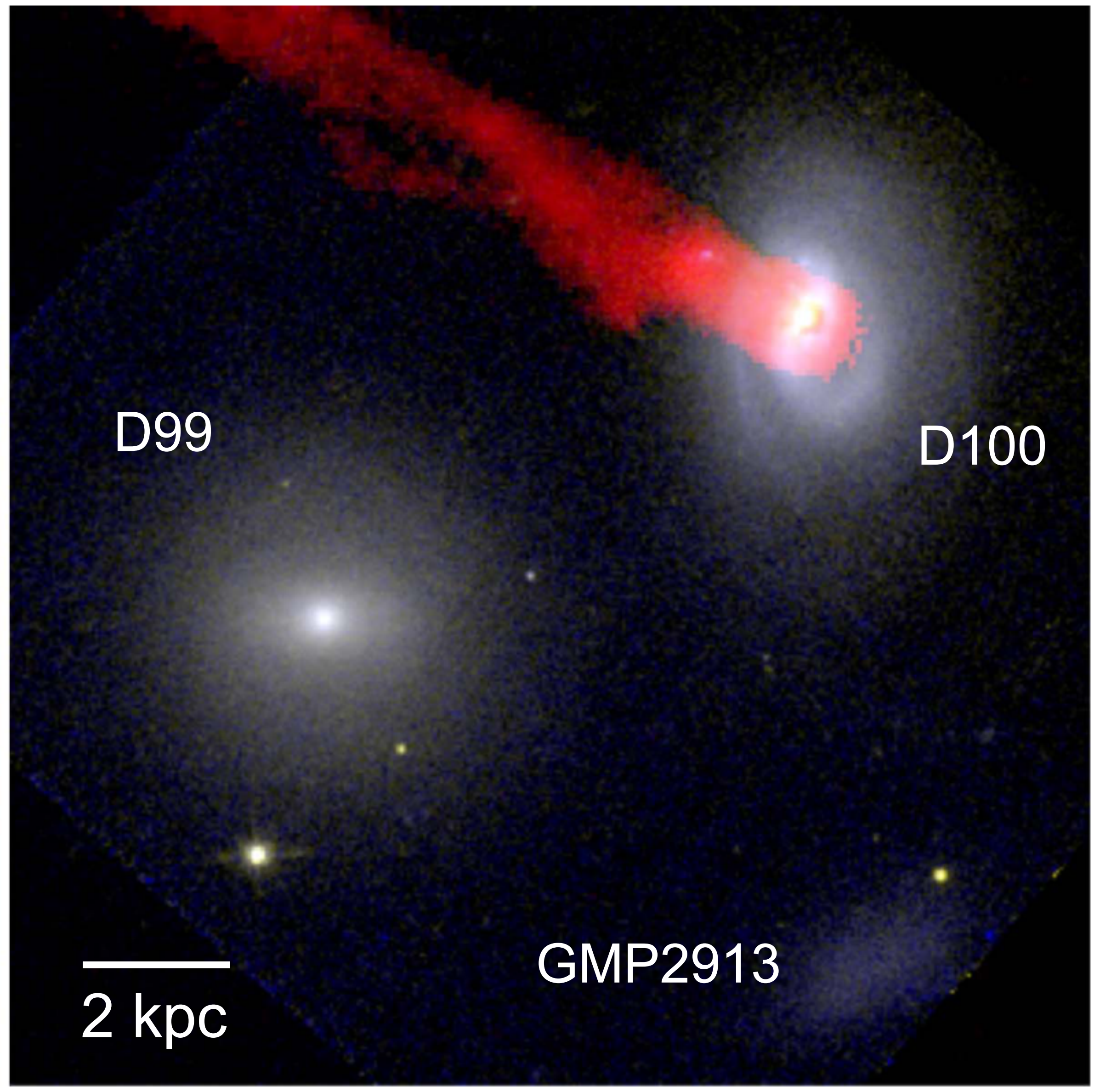


- Caveats
    - Missing physics - Magnetic fields, thermal conduction
    - Idealized setup - Tail features can be different in live haloes



ESO137-001 in the Norma cluster
Jachym+19

- Interesting scientific issues to be addressed
    - Some molecular-rich tails are weakly or not detected in HI (e.g. ESO137-001 and D100)
        - All cooled? preferentially ionized?



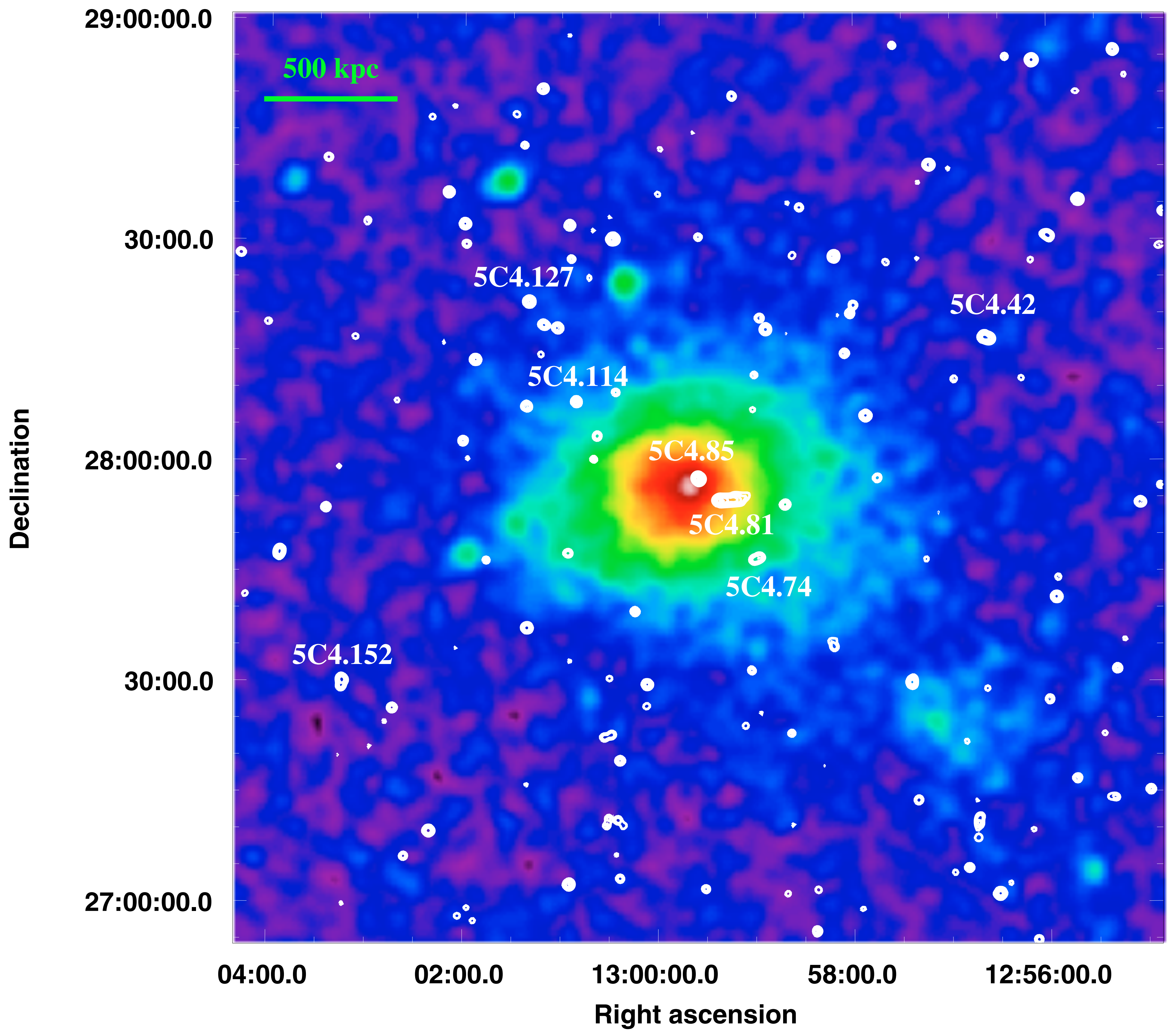
D100 in the Coma cluster
Jachym+17

- Summary
  - The abundant ISM stripped by strong ram pressure plays a critical role in the formation of jellyfish galaxies with distinct features
  - Strong ram pressure efficiently suppresses star formation in a gas-rich galaxy
  - Considerable amount of stars can form in the RPS tail of the gas-rich galaxy
  - Molecular clumps can form in-situ in the RPS tail from warm ionized gas produced by mixing between the ICM and ISM
    - The mixing results in the characteristic Xray-to-Halpha flux ratio in the RPS tails

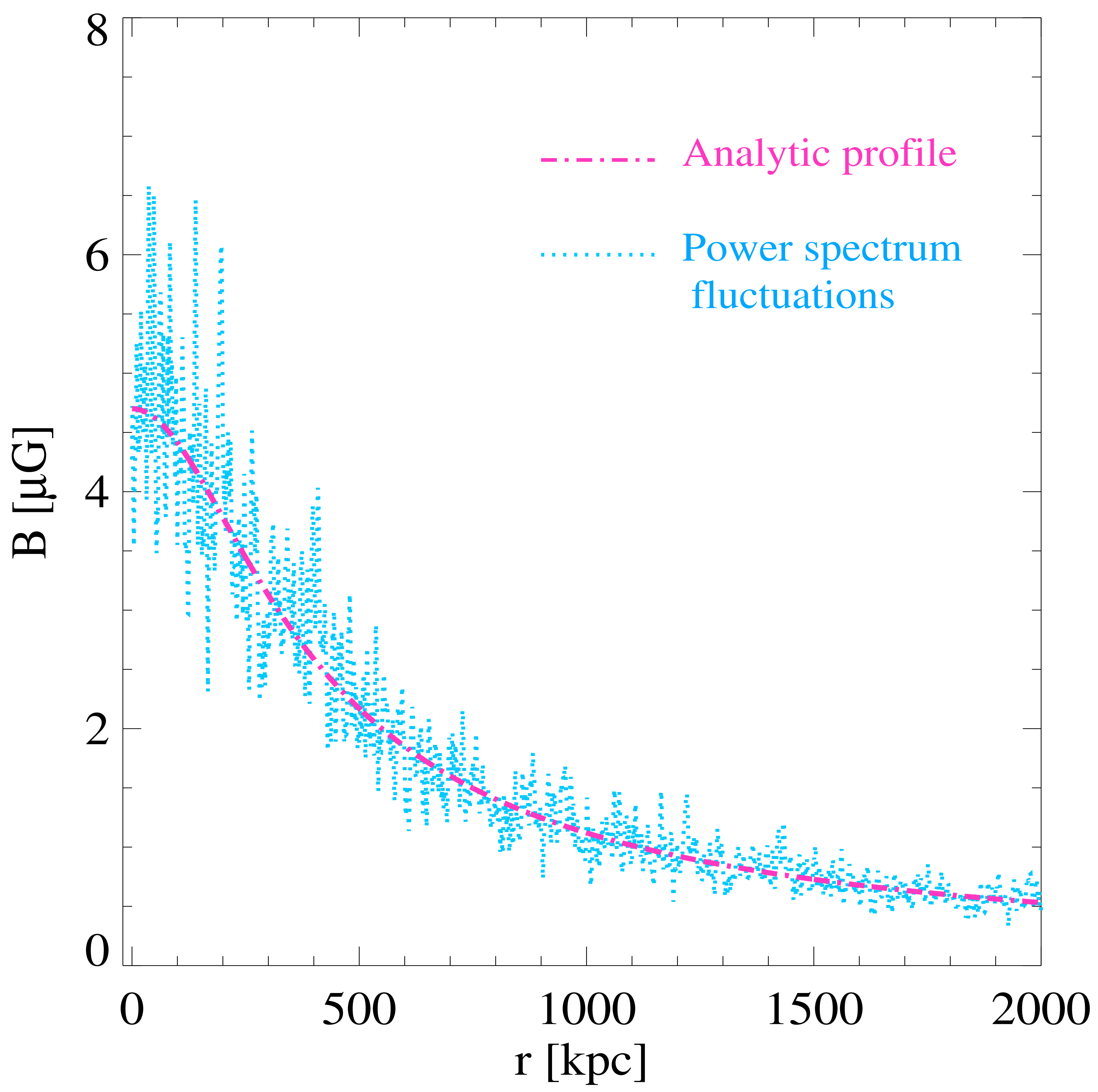

Jellyfish Galaxies in Magnetic Fields

- Magnetic fields in the ICM
  - Strong B-fields are observed in the ICM (typical |B|~1μG, e.g., Carilli & Taylor 02)
  - B-fields stabilize clouds and suppress the growth of instabilities between two flows

Coma X-ray+HI emission



Coma B-field profile



Bonafede+10