The Impact of Ram Pressure Stripping on Star Formation both Inside and Outside of Galaxies

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Environment & galaxy morphology

Density-Morphology relation (Oemler 1974, Dressler 1976)

Butcher-Oemler effect (Butcher & Oemler 1978)

Evolution of Spirals to S0s (Dressler et al. 1997)

Galaxy Cluster MS1054-03 APOD July 22, 1999 **HST • WFPC**

PRC99-28 • STScI OPO • P. van Dokkum (University of Groningen), ESA and NASA

How do you make an S0 from a Spiral?

1) Redden the spiral

> Remove gas (passive spirals e.g. Moran et al. 2007; Poggianti et al. 1999)

2) Smooth out the spiral arms

> Remove gas (Bekki et al. 2002 find spiral arms lost 3.5 Gyr after gas removal)

3) Increase the Bulge/Disk ratio

> Dim the disk

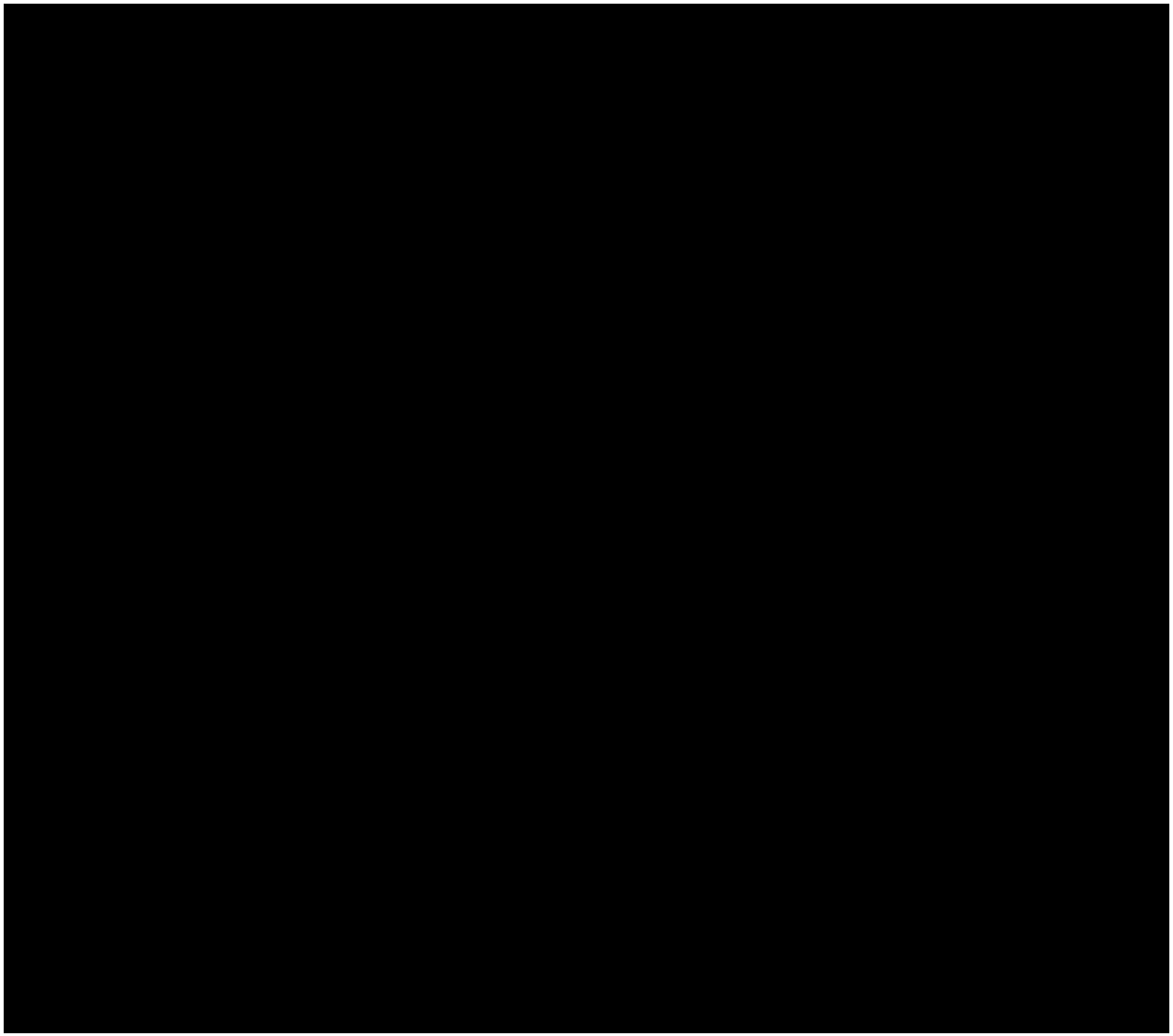
> Grow the bulge

A history of discussion, e.g.: Solanes et al. (1989); Burstein et al. (2005); Christlein & Zabludoff (2004)

Ram Pressure Stripping

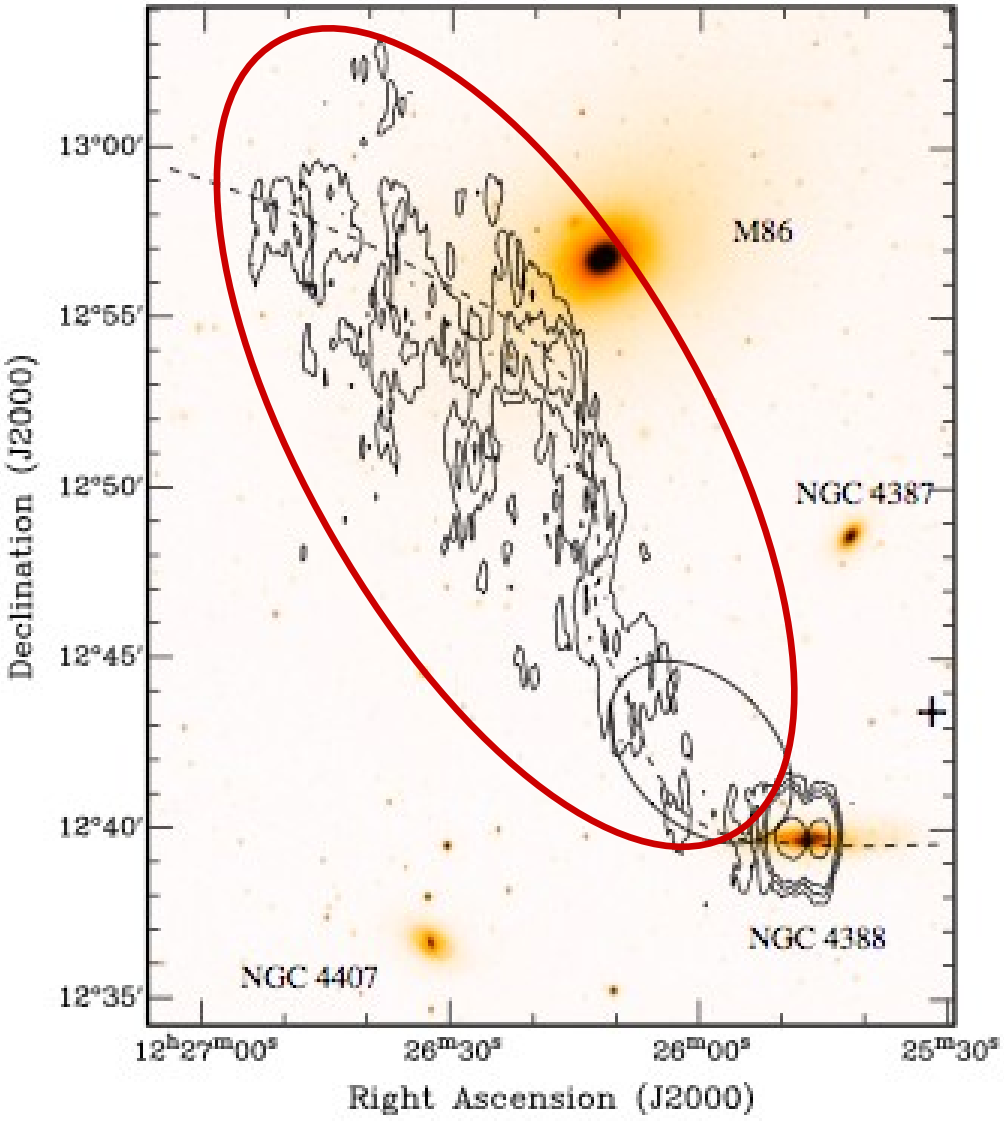
$P = \rho v^2$
(Gunn and Gott 1972)

Directly affects only gas



Kenney et al. (2004)

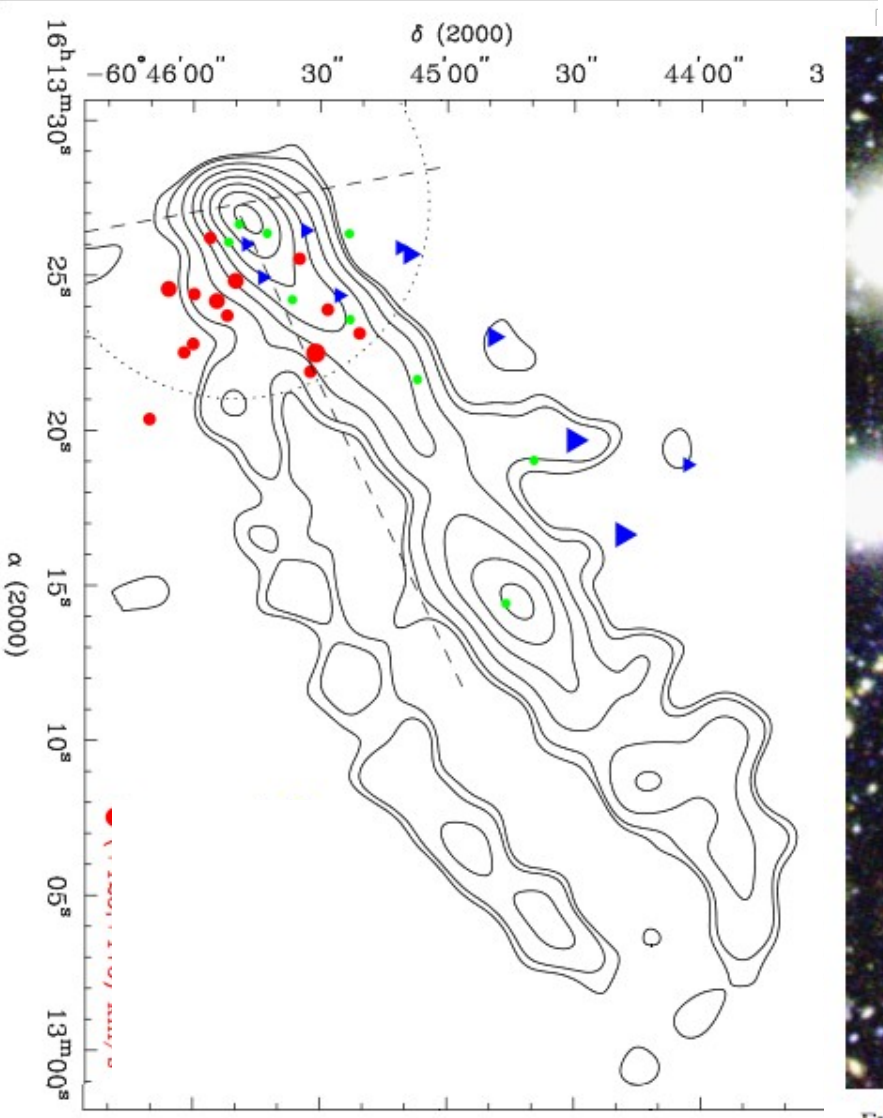
Long tails have been observed in HI, X-rays, and Hα



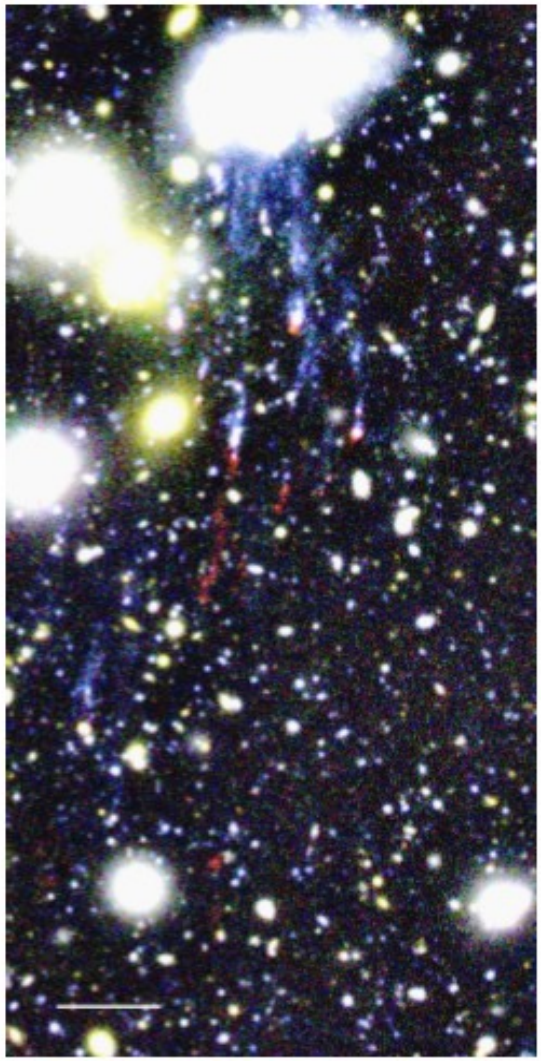
~110 kpc tail

Oosterloo & van Gorkom 2005

Star Formation in Stripped Tails



Sun et al. (2009)



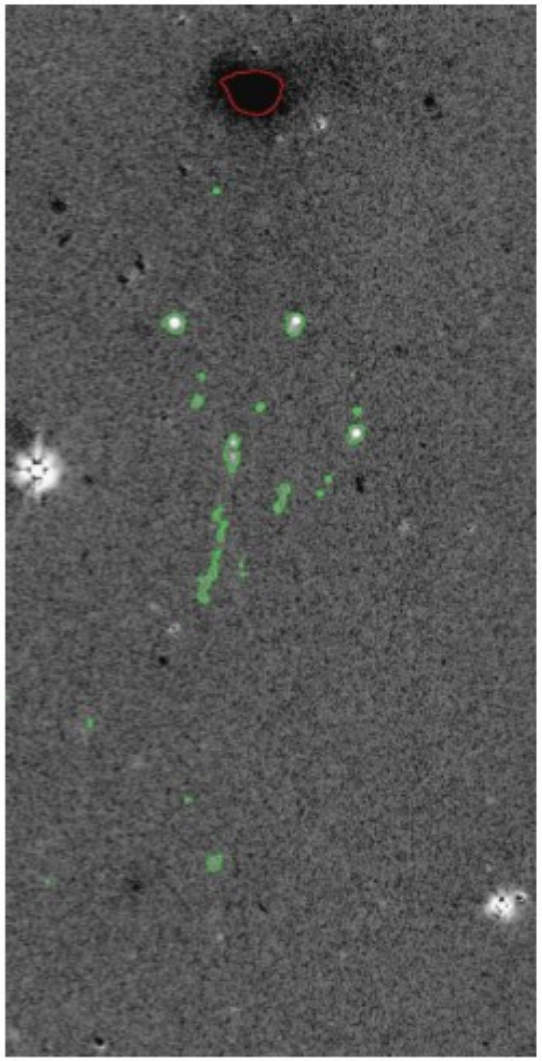


FIG. 4L.— Same as Figure 4A but of GMP4060.

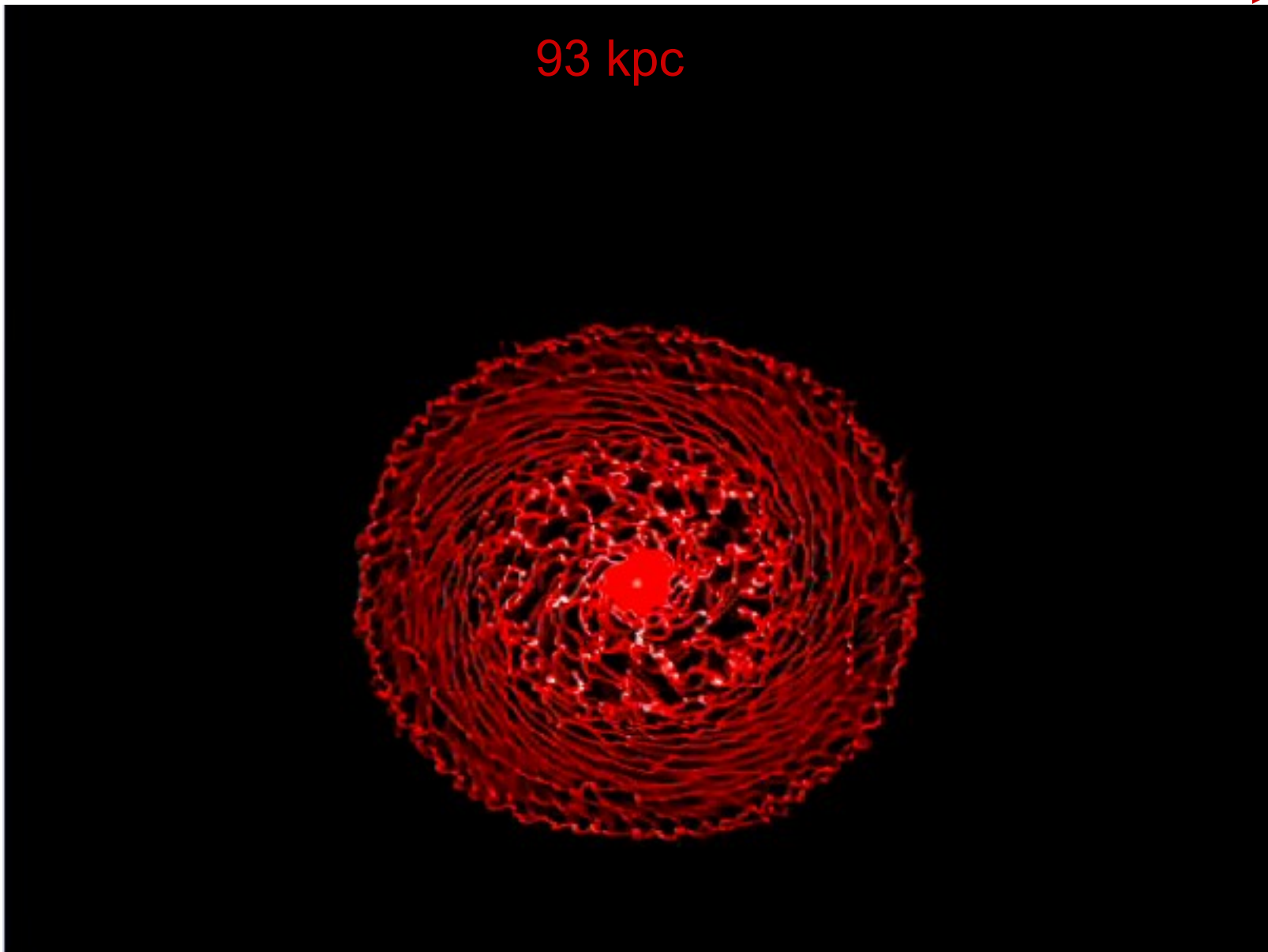
Yagi et al. (2010)

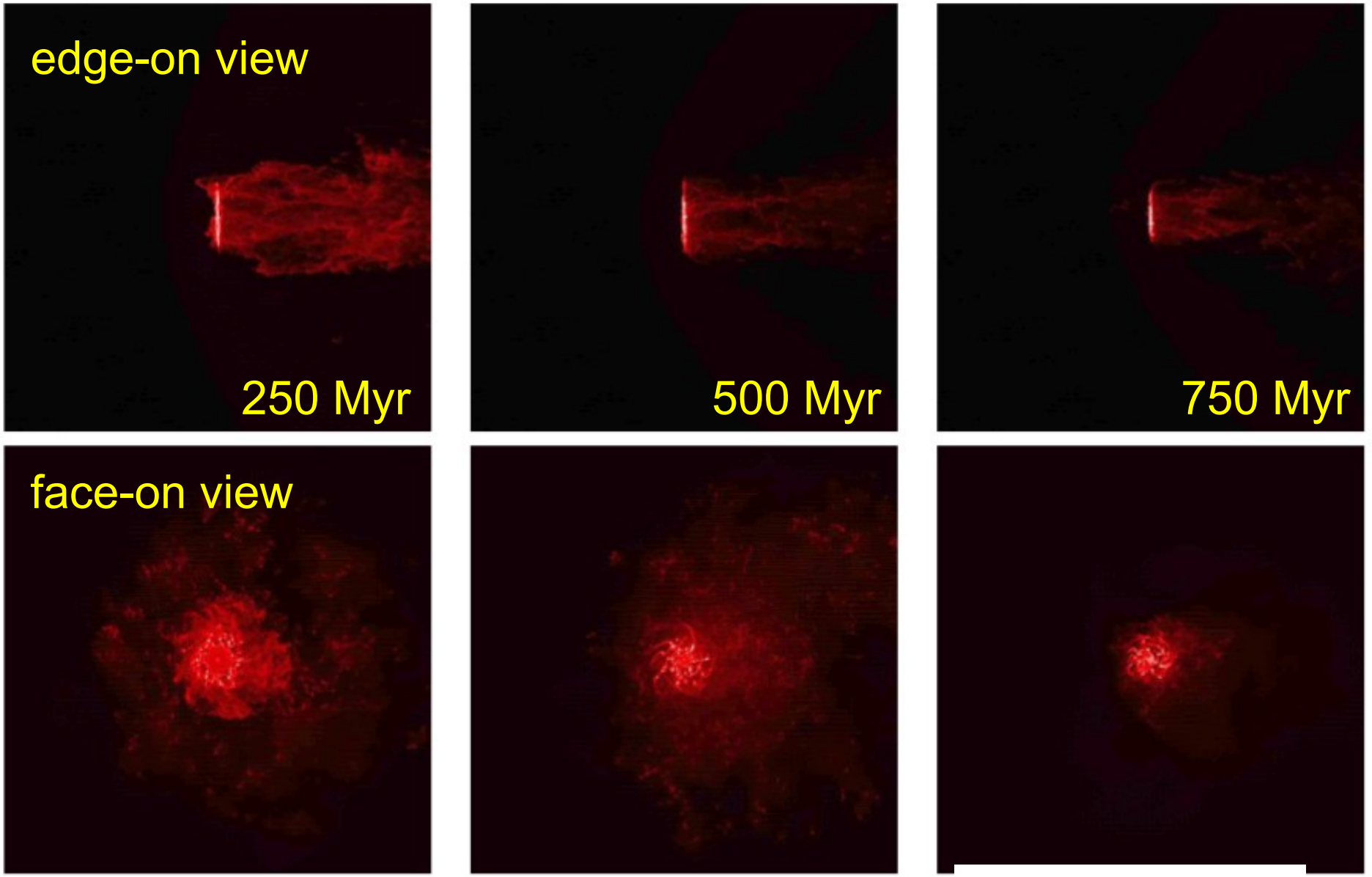
Zooming in to Highly Resolved Simulations of Ram Pressure Stripping

Enzo
(AMR)

Resolution
38 pc

Cooling to
300 K

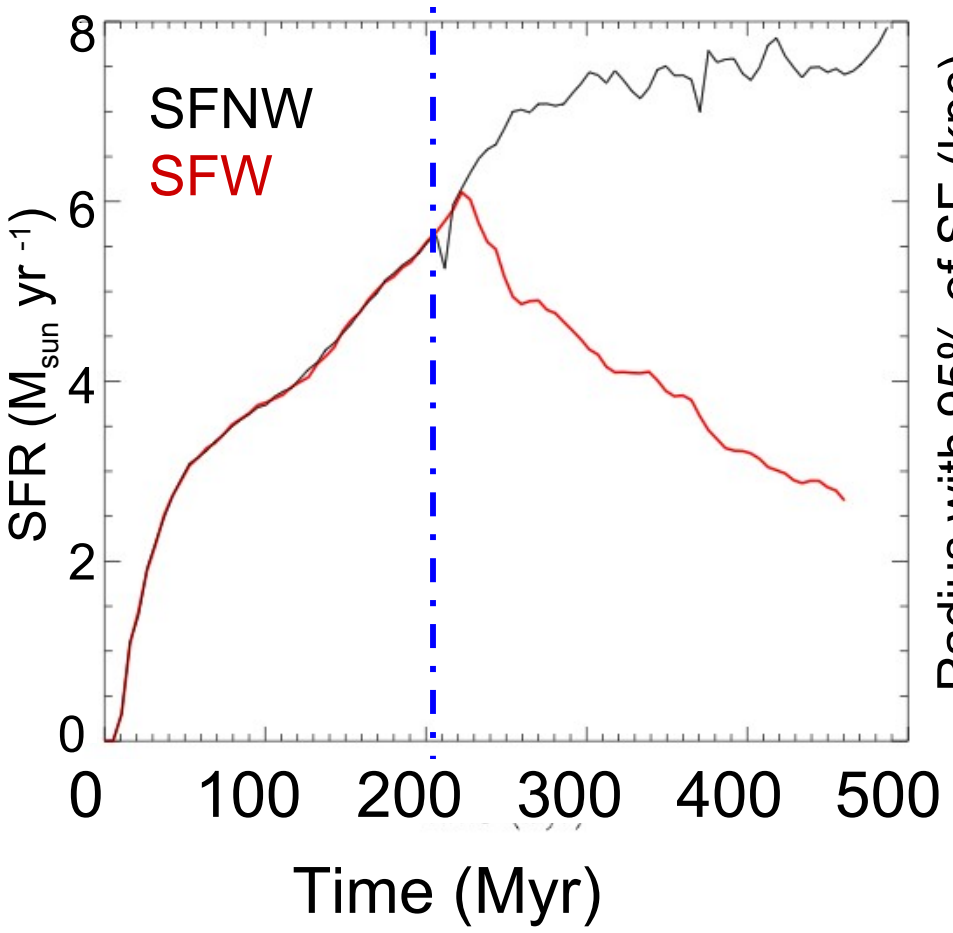


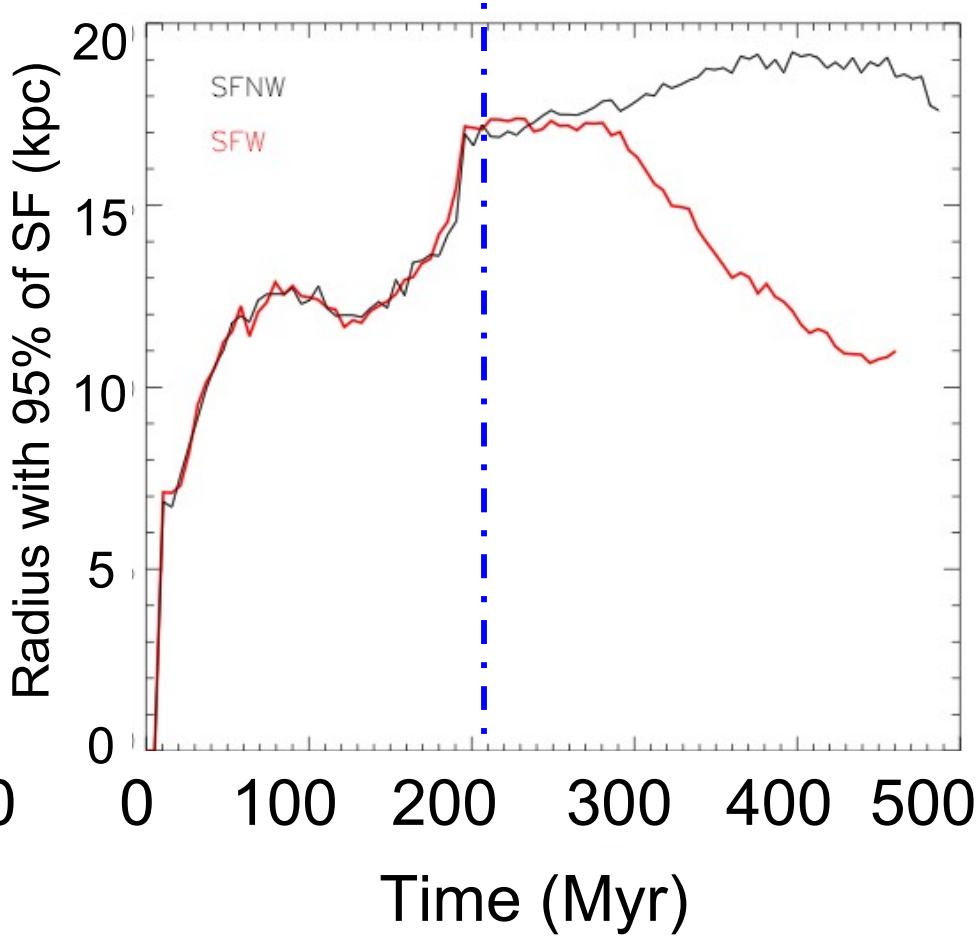


$P_{ram} = 6.4 \times 10^{-12}$ dyn cm^{-2}
$n = 3 \times 10^{-4}$ cm^{-3}
$v = 1413$ km s^{-1}

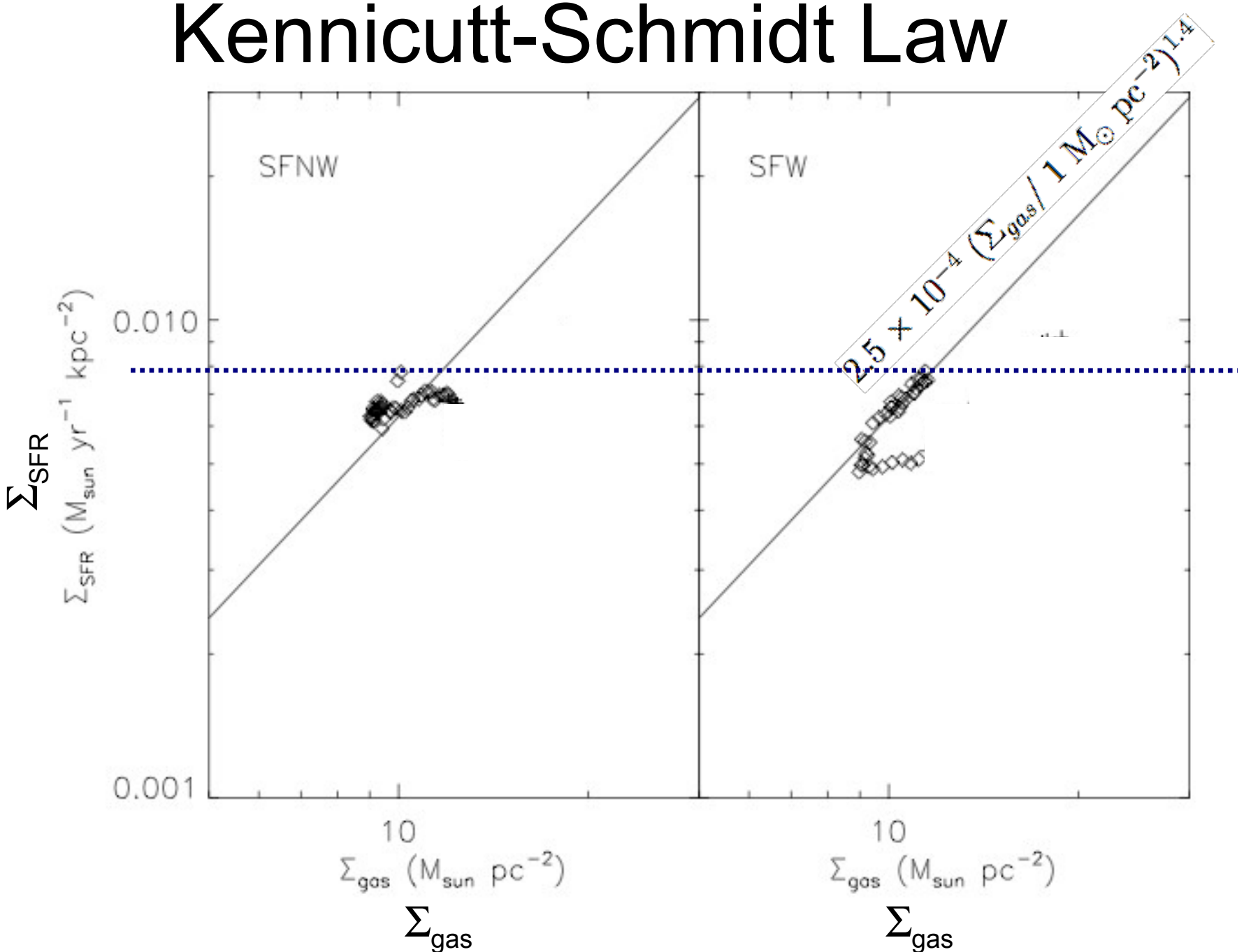
The ram pressure experienced at about the virial radius of a cluster with $M = 6 \times 10^{14}$ M_{sun} (Tonnesen, Bryan & van Gorkom 2007)

Star Formation in the Disk

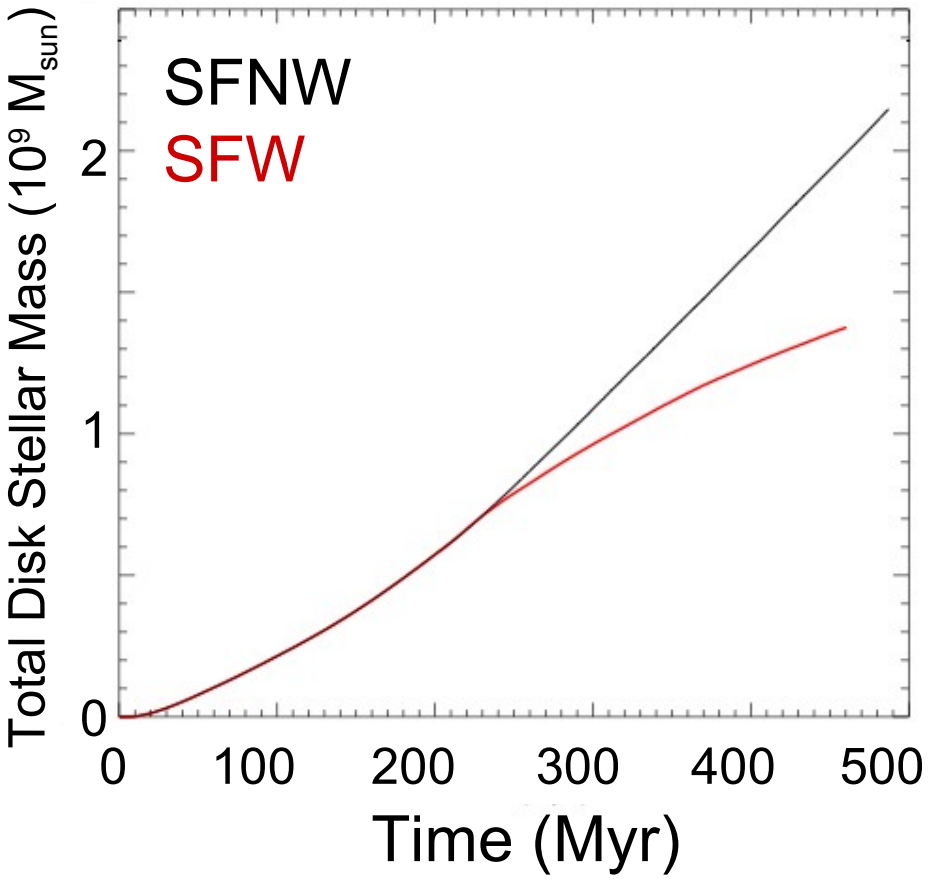


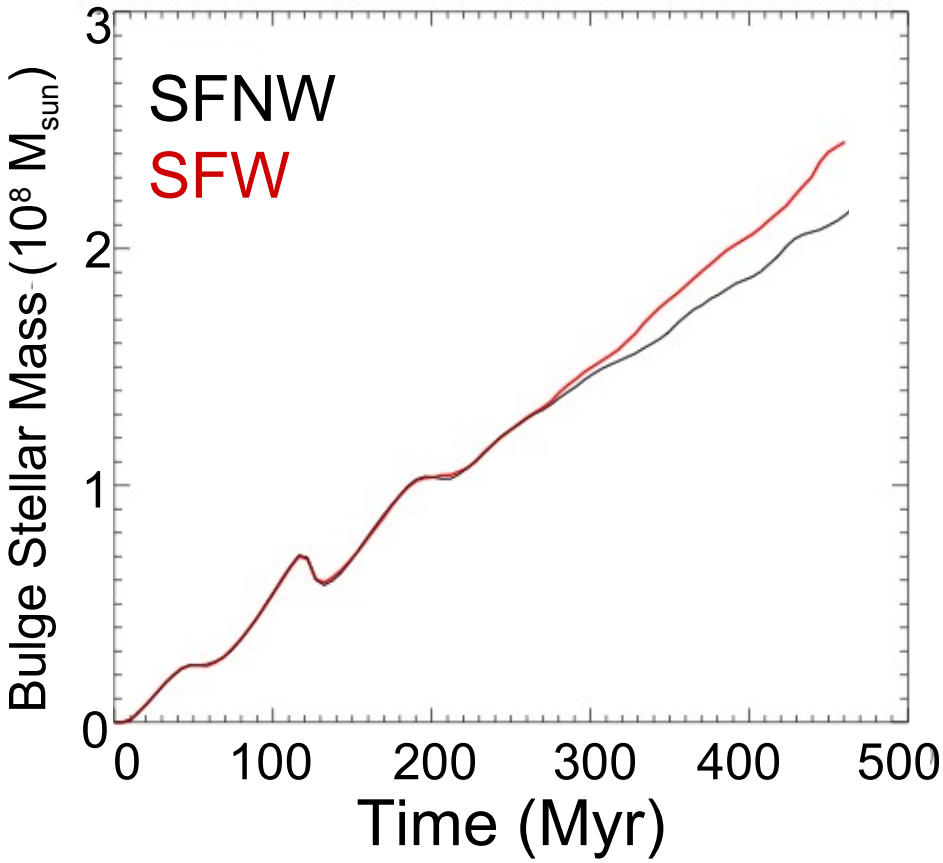


Kennicutt-Schmidt Law



Stellar Mass in the Disk and Bulge
Does RPS grow the bulge?

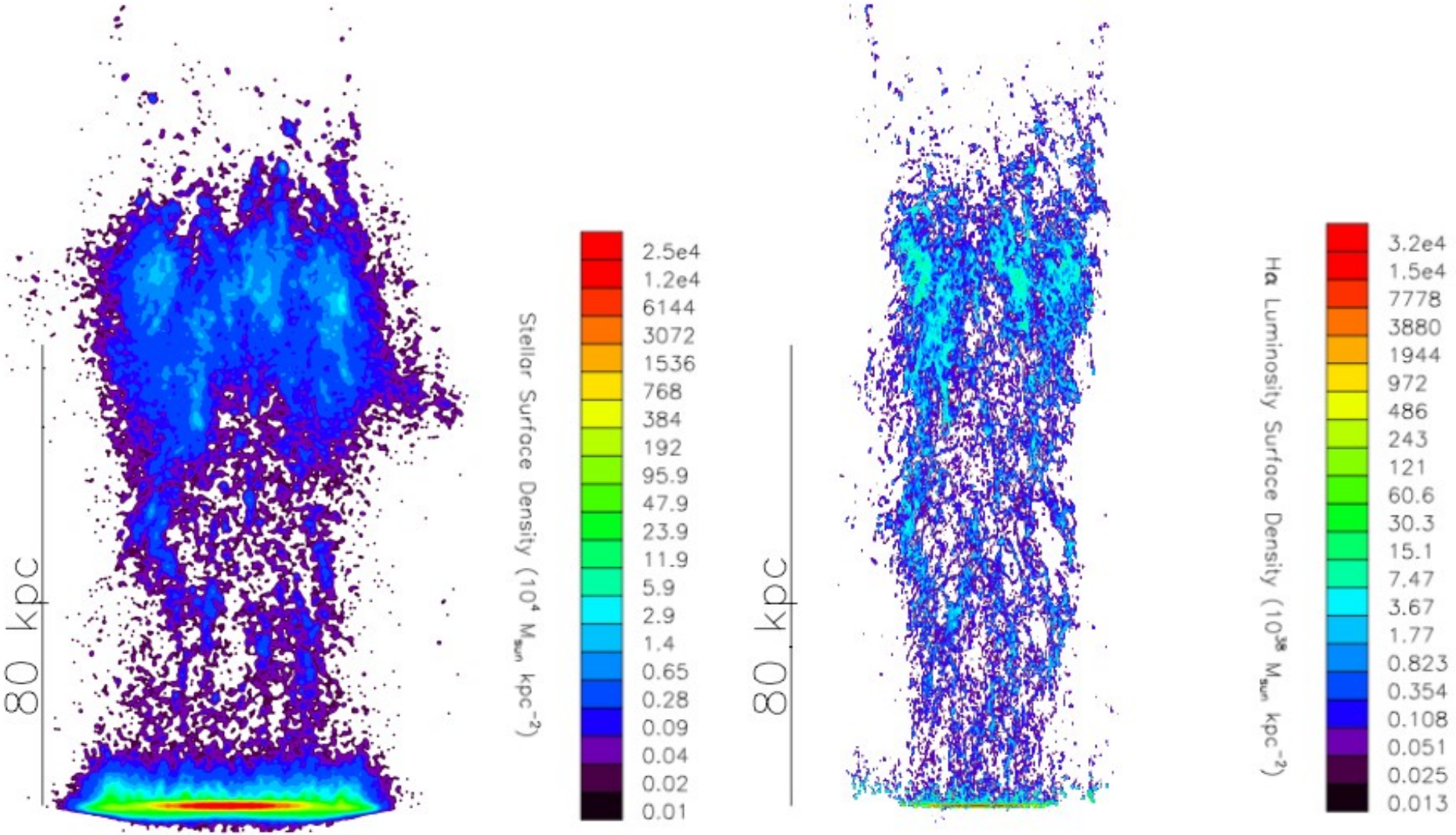




B/T (M_{new*}): SFNW ~ 0.1 SFW ~ 0.2

BUT, the galaxy began with
$M_* = 10^{11}$ and $M_{bulge} = 10^{10}$

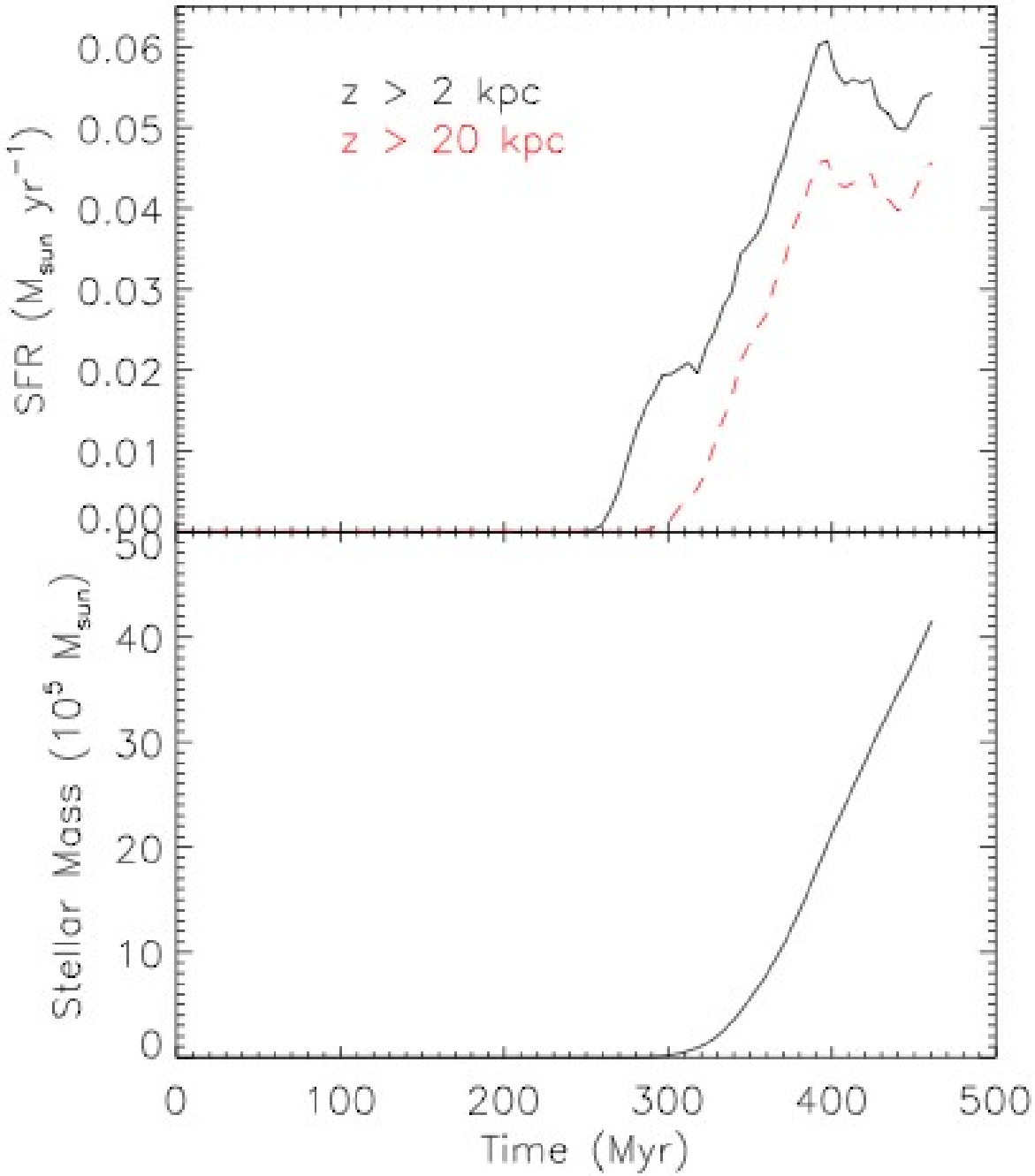
The Stellar Tail



Does this add to the ICL?

Less than 1% of the mass of stripped gas turns into stars

The stellar mass formed in the tail is less than 10% of the mass of new stars in the disk



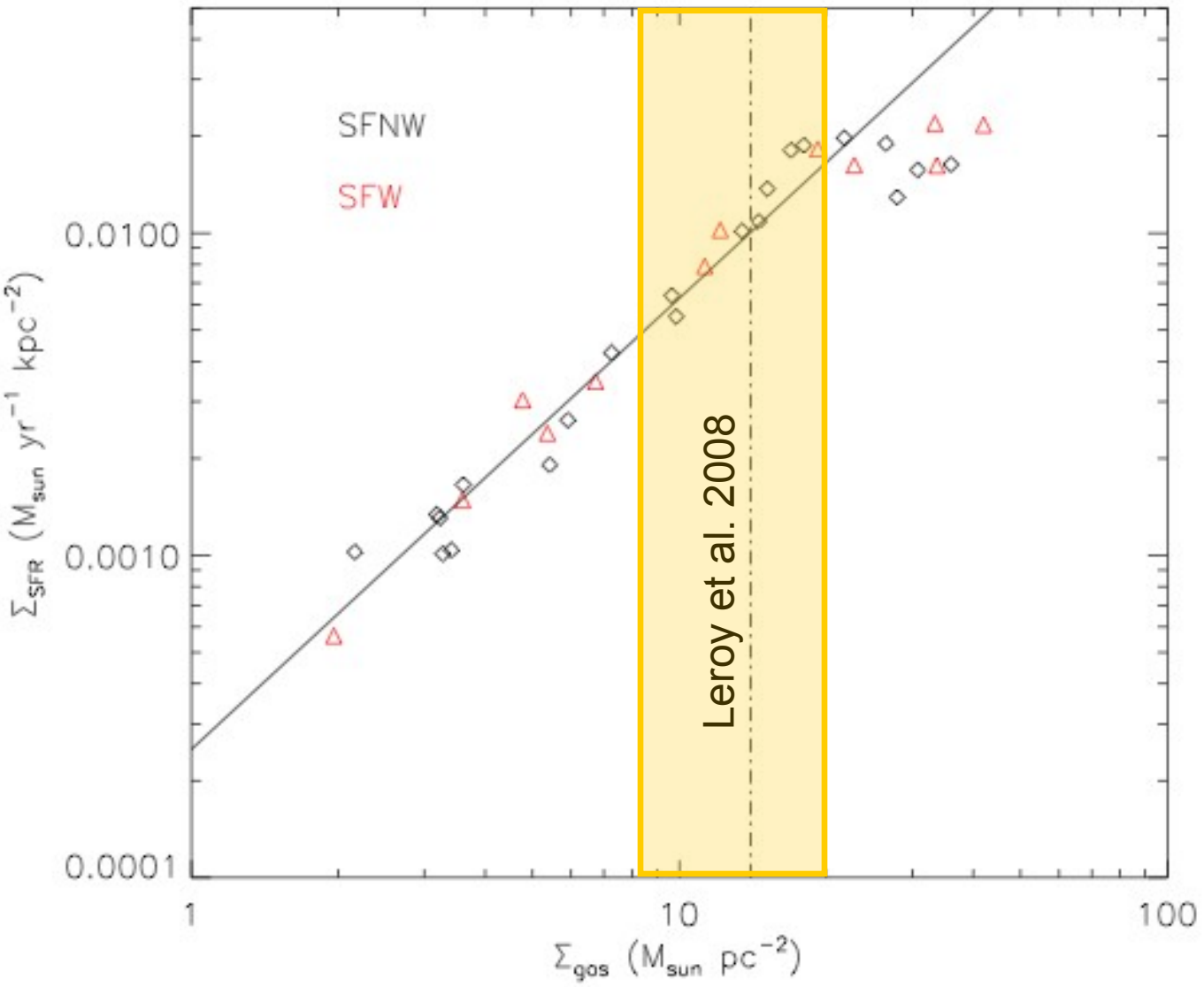
Conclusions

- RPS does not increase the total SFR inside a galaxy, either through the increase of the surrounding ICM pressure or through a shock
- RPS does not affect the relationship between Σ_{gas} and Σ_{SFR}
- RPS increased the bulge stellar mass relative to a galaxy with no ICM wind
- RPS does add a small and seemingly insignificant amount of stellar mass to the ICL

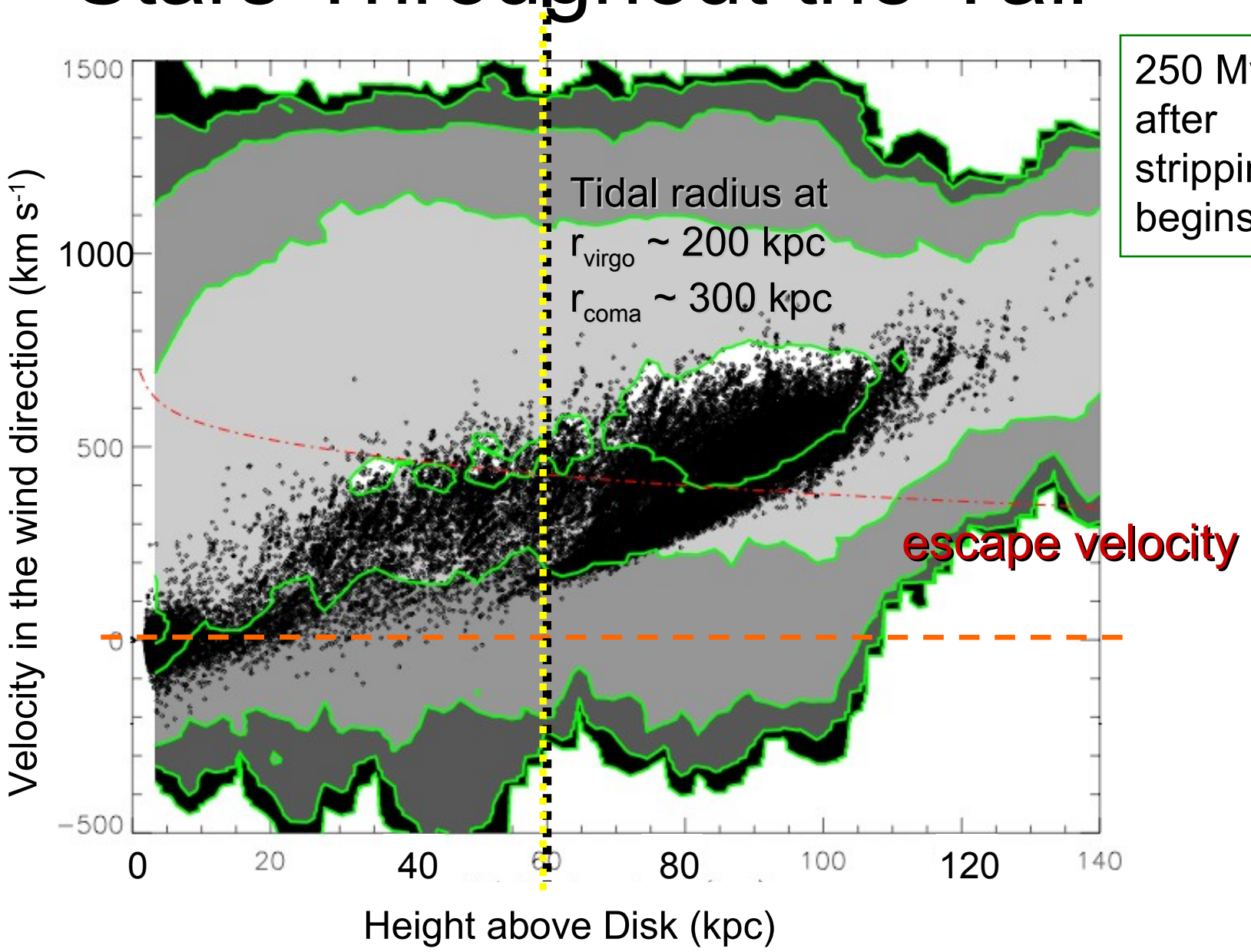
The Local Schmidt Law

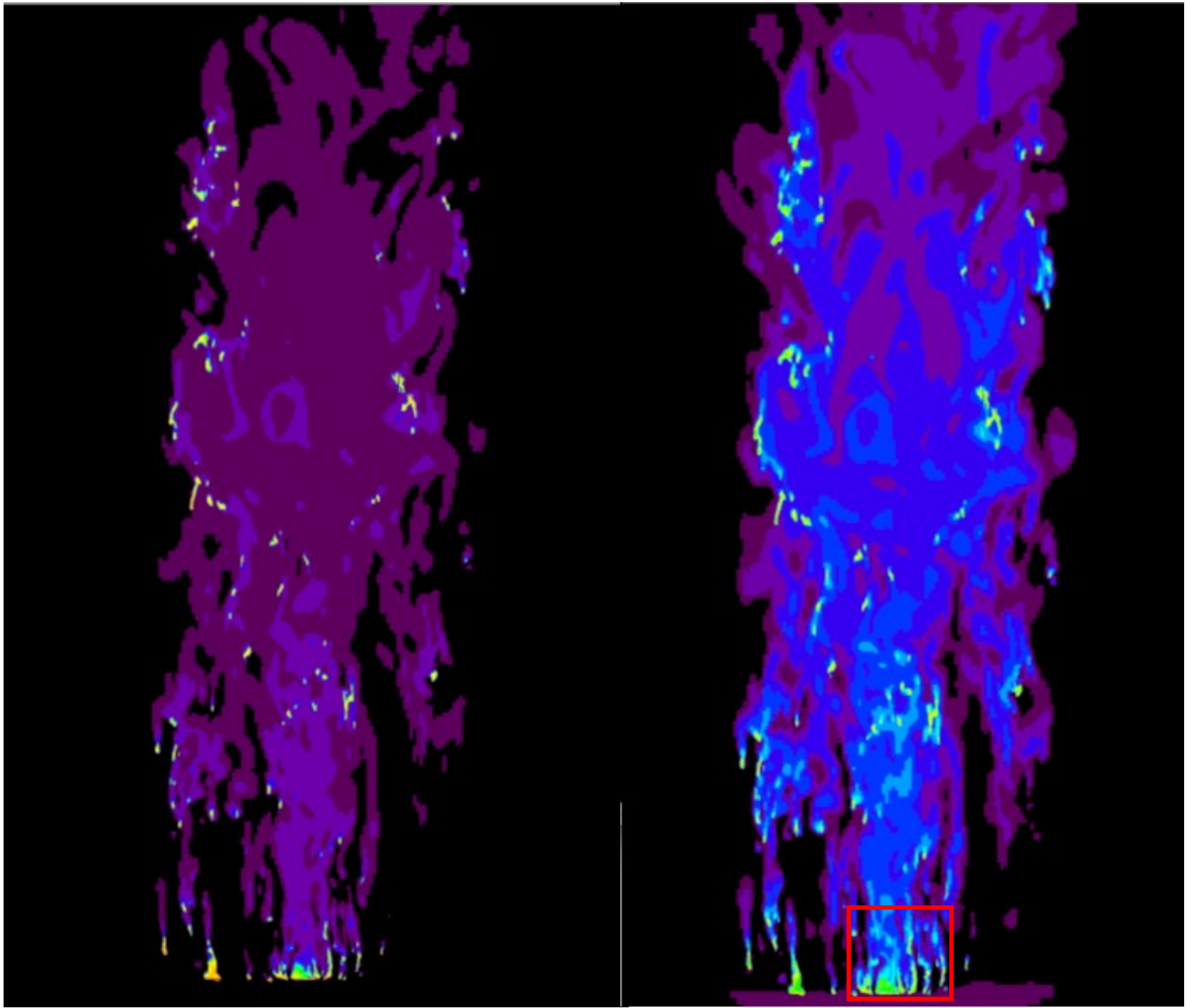
Whether or not wind is included, the galaxies fall along the same relationship between Σ_{SFR} and Σ_{gas}.

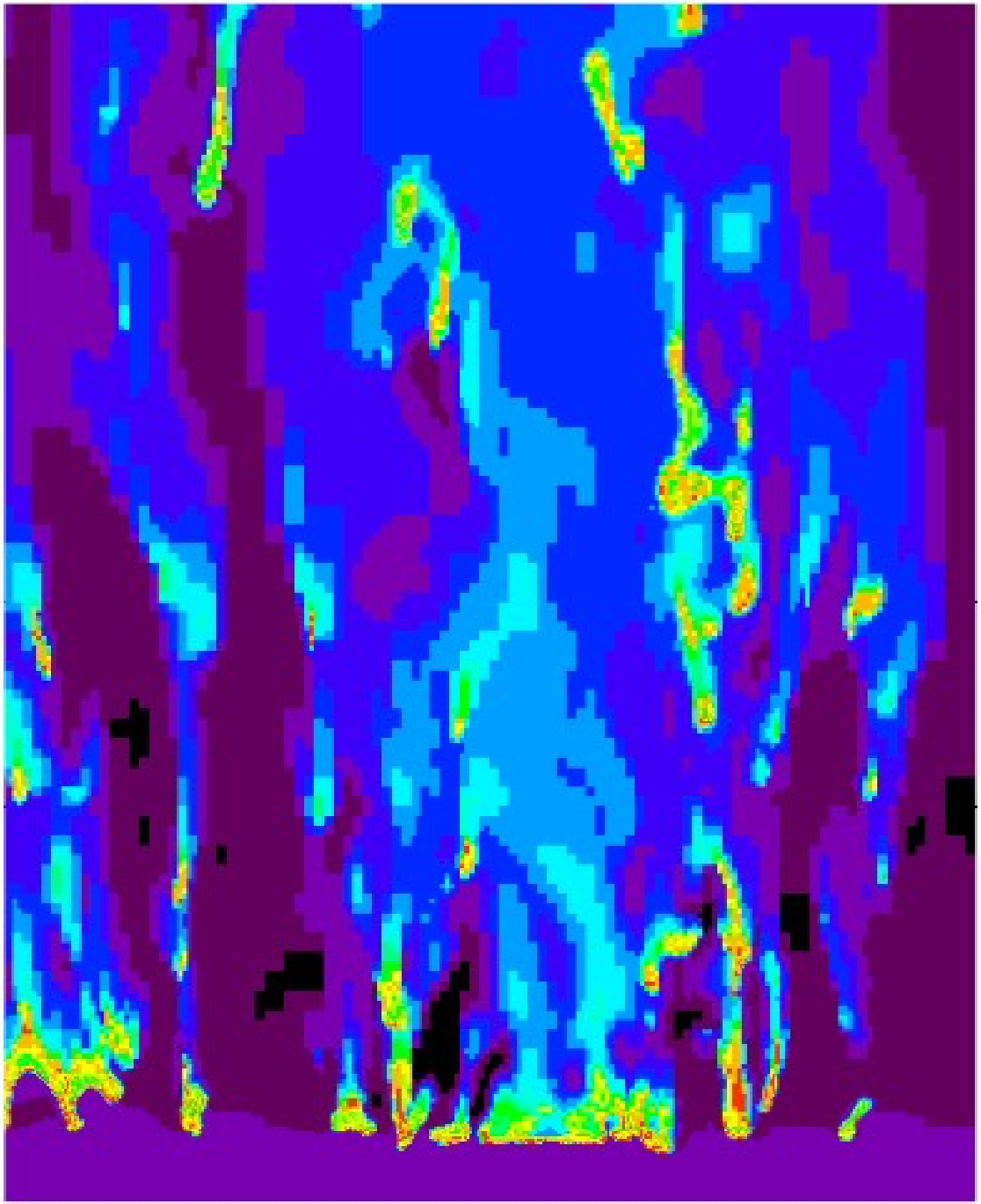
The Σ_{SFR} flattens at the same Σ_{gas} observationally found by Leroy+ (2008) (THINGS)



Stars Throughout the Tail







Clouds are marginally resolved and we do see mixing with the ICM.

Tonnesen vs Kapferer

AMR

cells in disk~5×10^7

Mass refinement: 4900 M_{sun}

cooling: 300 K

T_{SF}: 1.1×10^4 K

ρ_{SF}: 3.85×10^{-25} g cm^{-3}

SPH

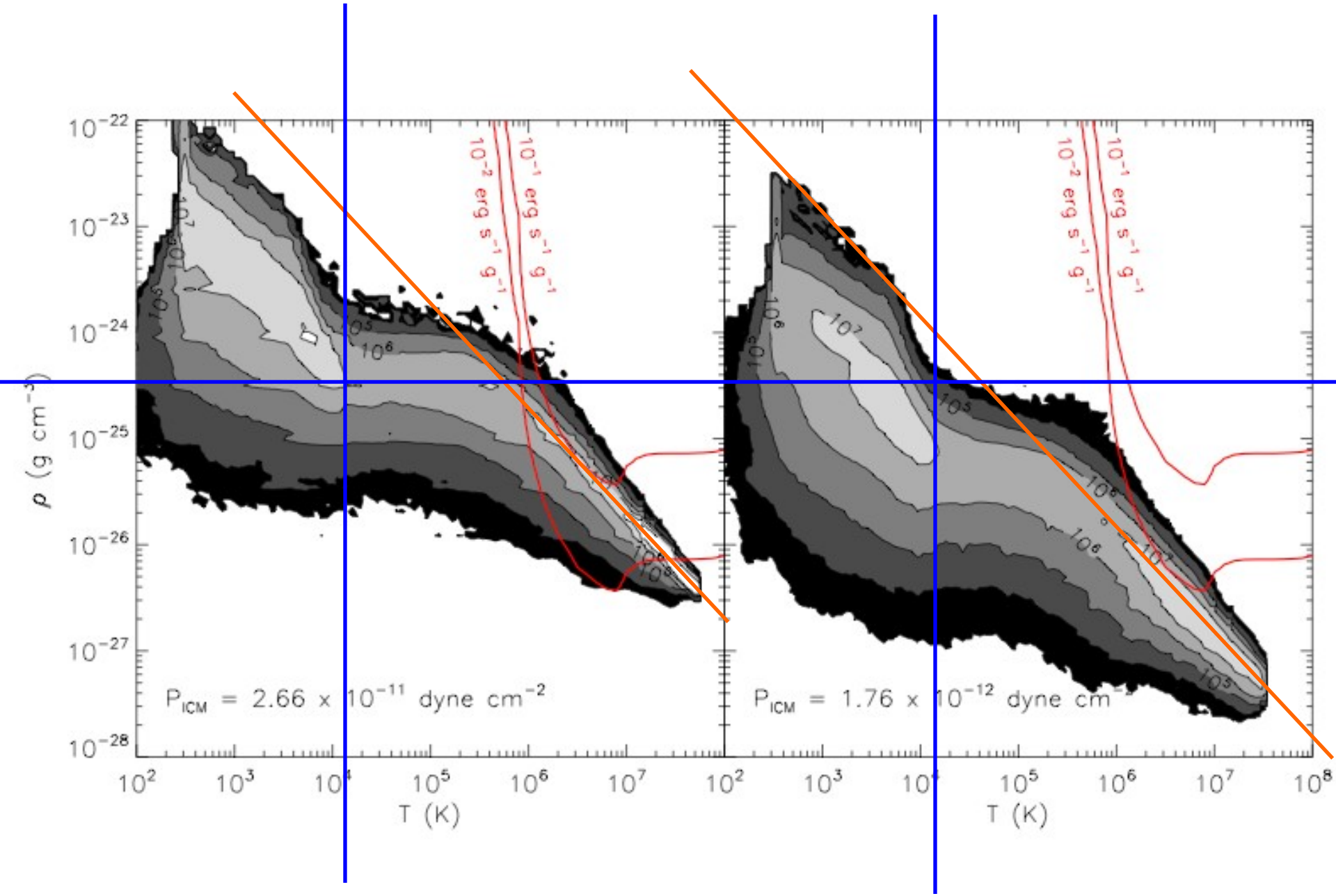
particles in disk: 2×10^5

particle Mass: 3.4×10^4 M_{sun}

cooling: 10^4 K

T_{SF}: 10^6 K

ρ_{SF}: ~7×10^{-26} g cm^{-3} (?)


10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10^{-28}
ρ (g cm^{-3})
10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8}
T (K)
10^{-2} erg s^{-1} g^{-1}
10^{-1} erg s^{-1} g^{-1}
P_{ICM} = 2.66 x 10^{-11} dyne cm^{-2}
P_{ICM} = 1.76 x 10^{-12} dyne cm^{-2}