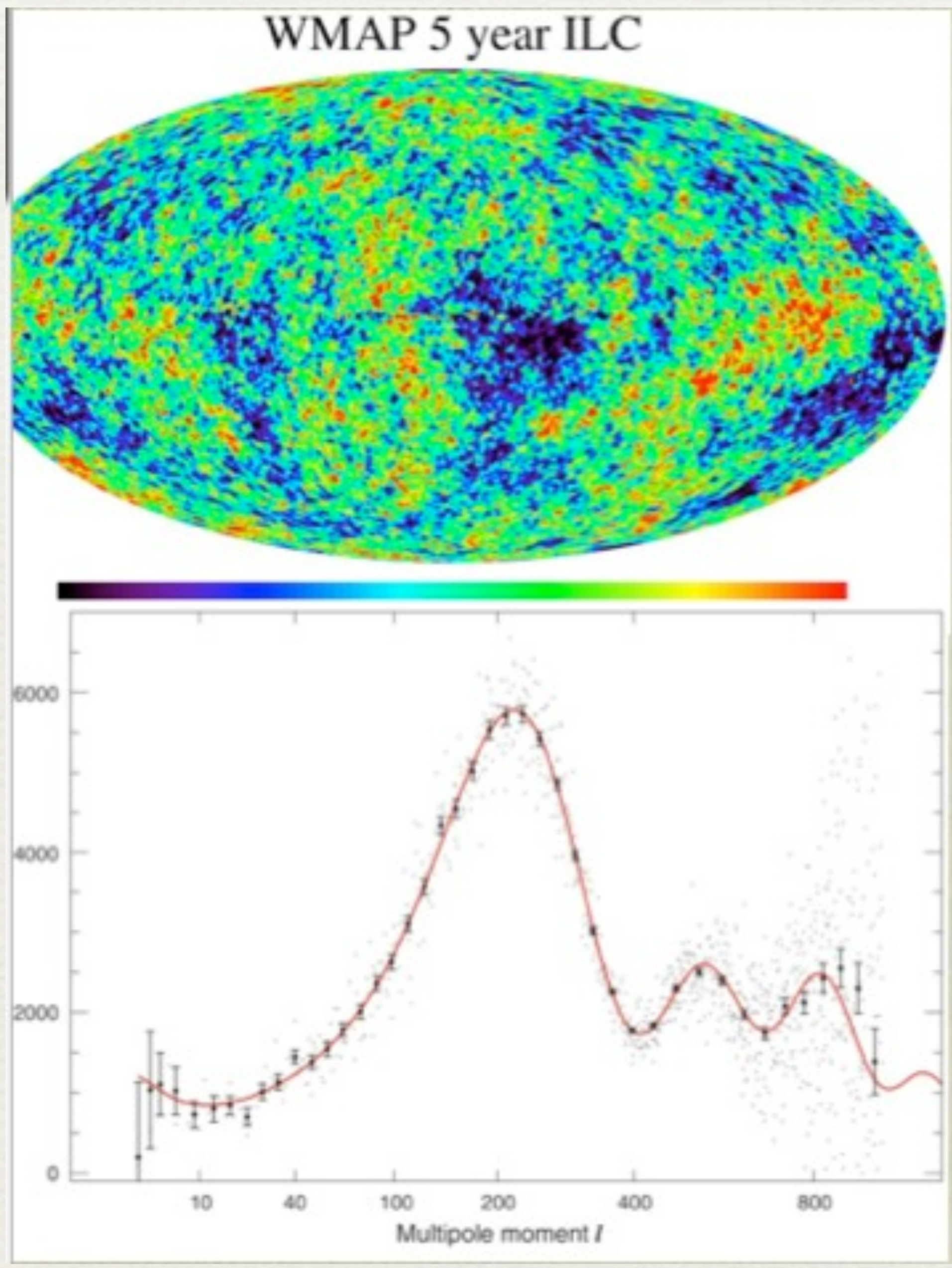
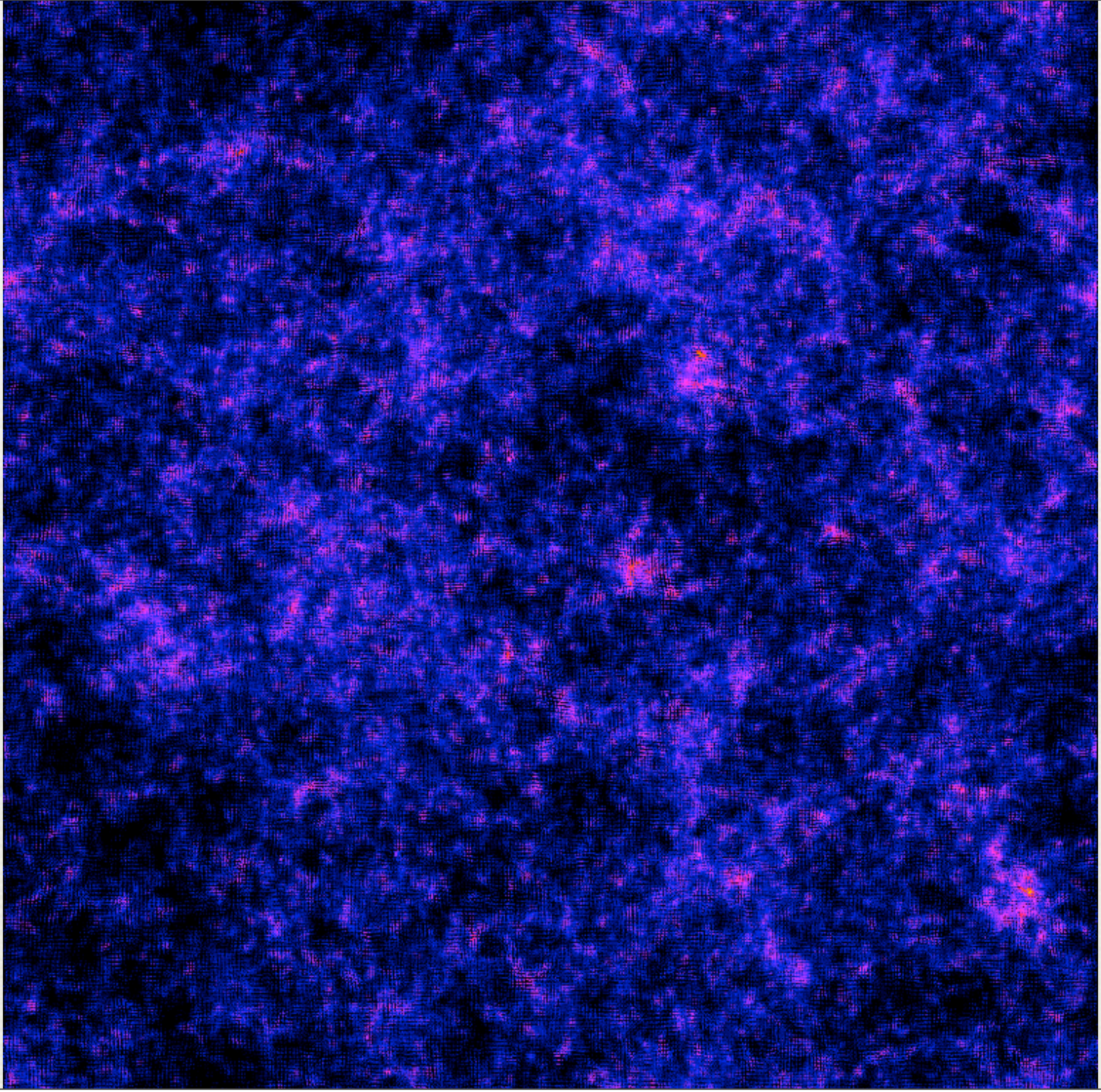
MAKING GALAXIES IN A COSMOLOGICAL CONTEXT (MAGICC)

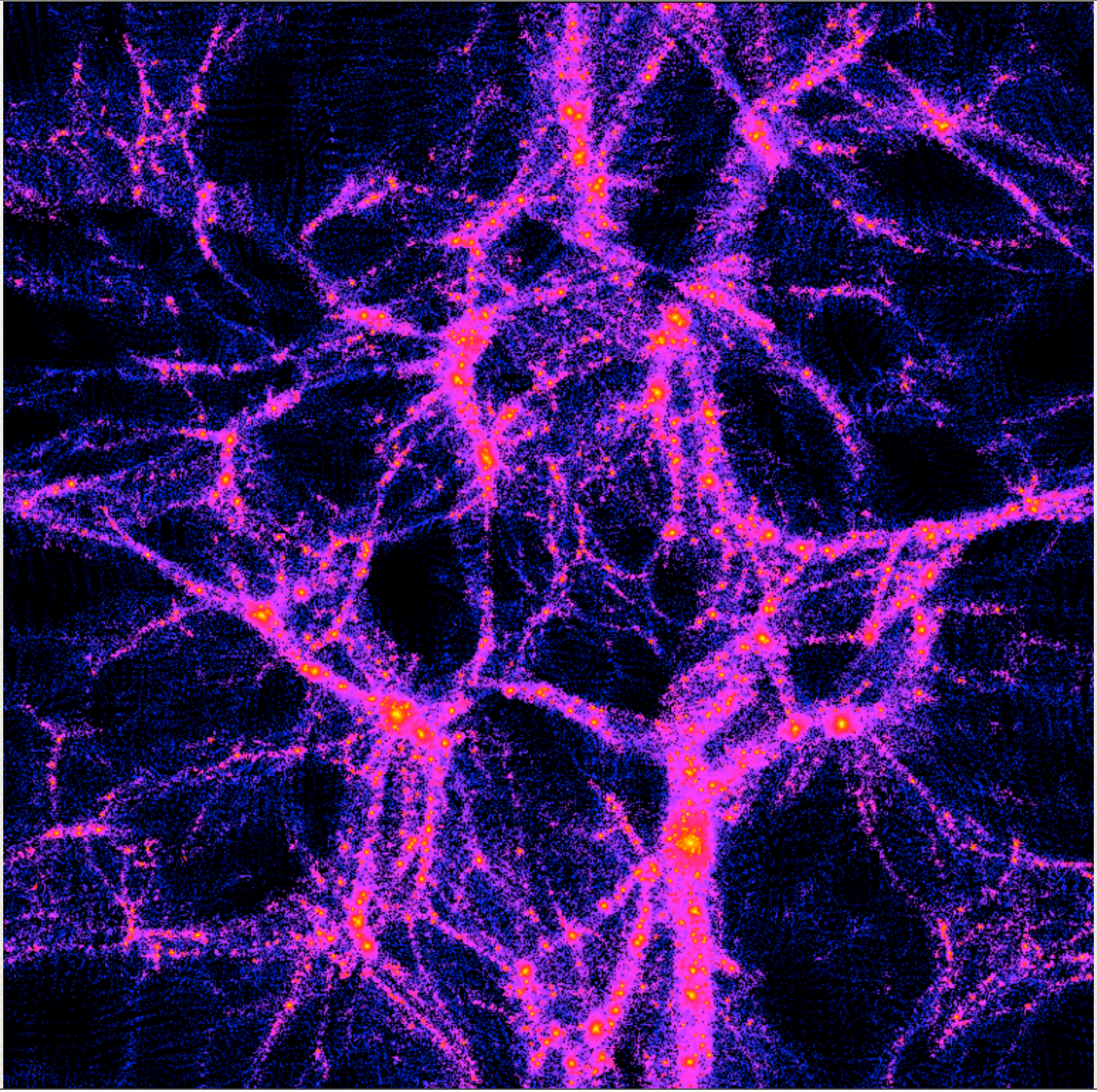
Greg Stinson
MPIA
Chris Brook (Madrid)

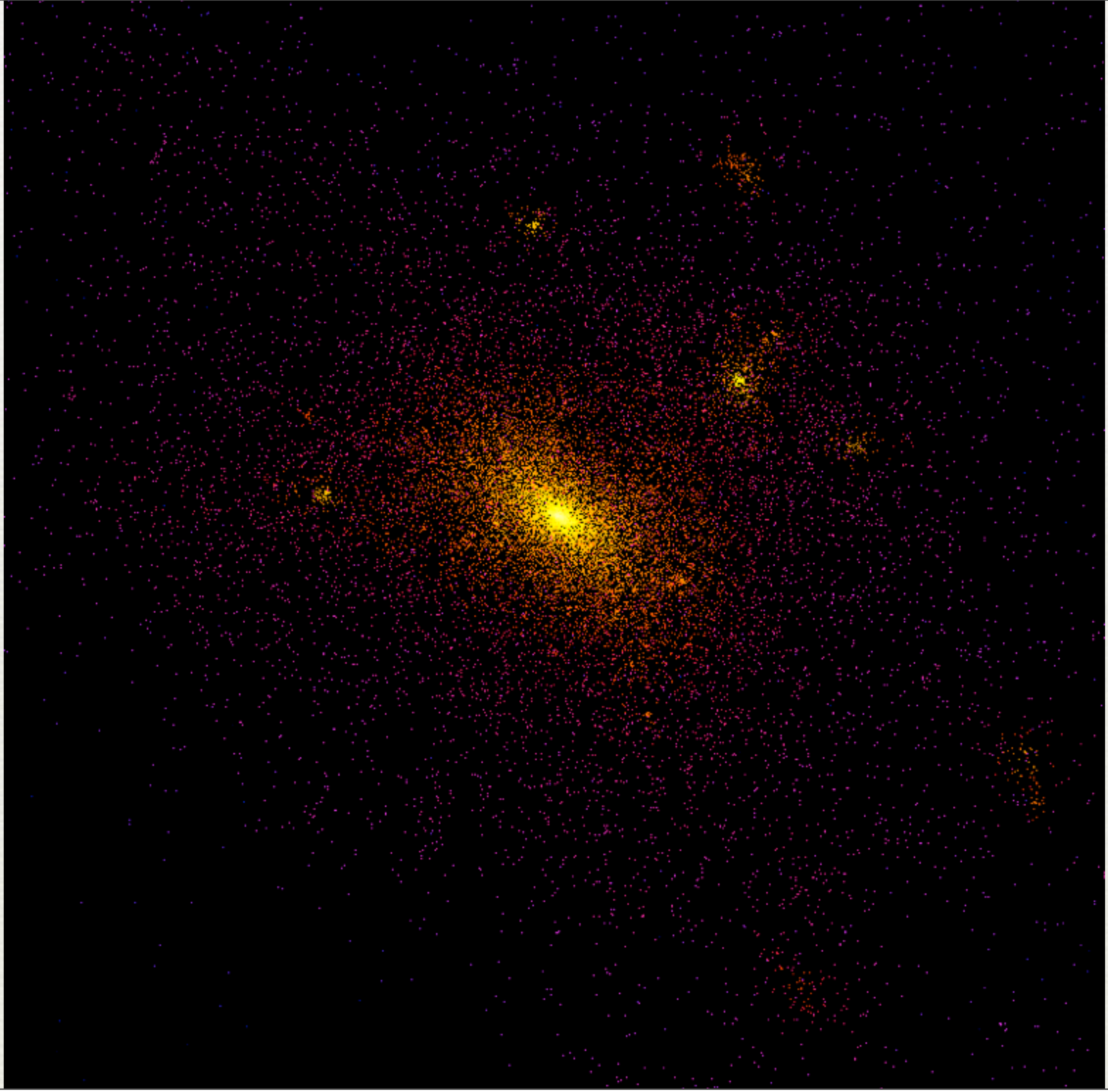
The goal

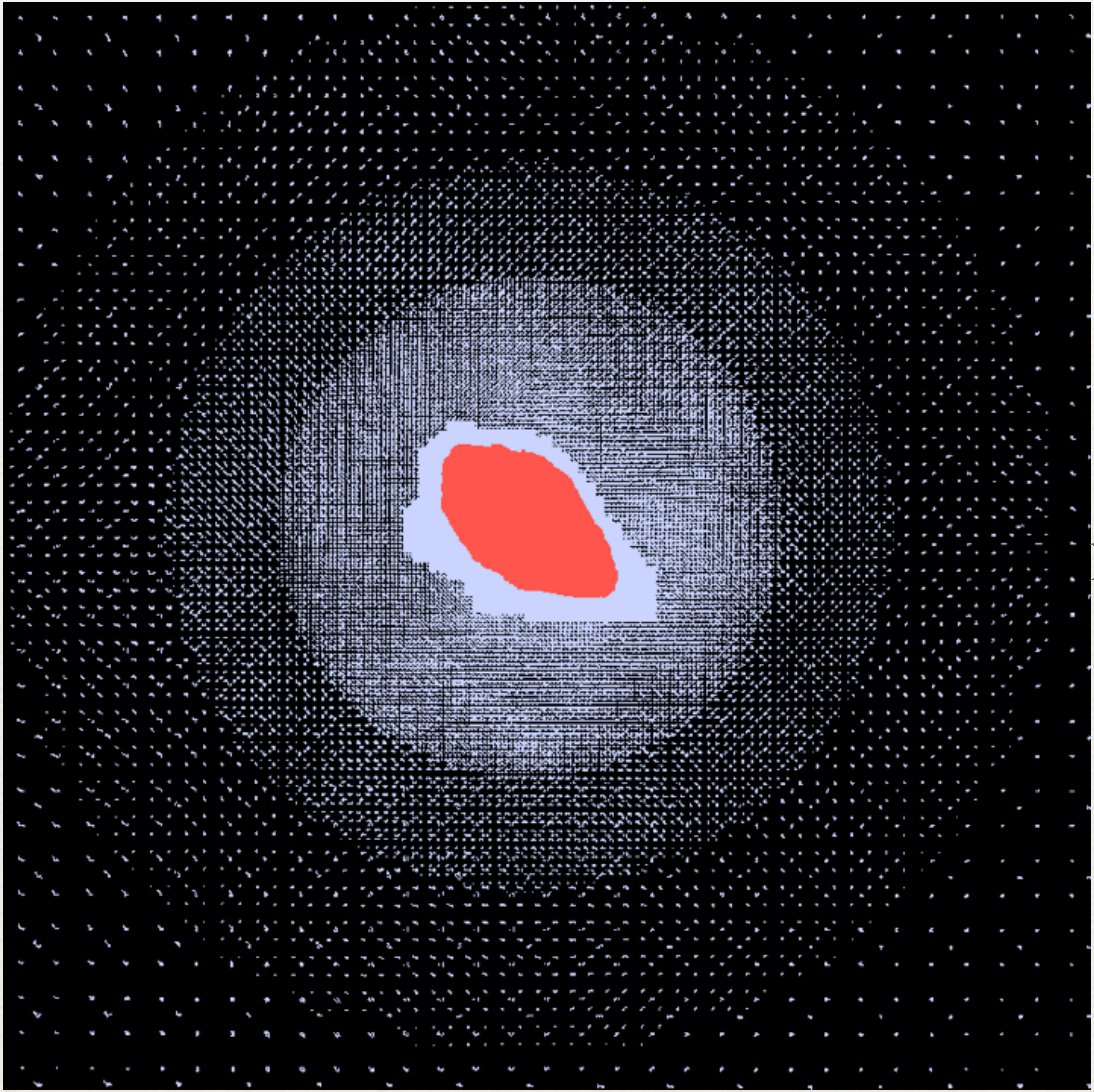


Create a sample of simulated galaxies









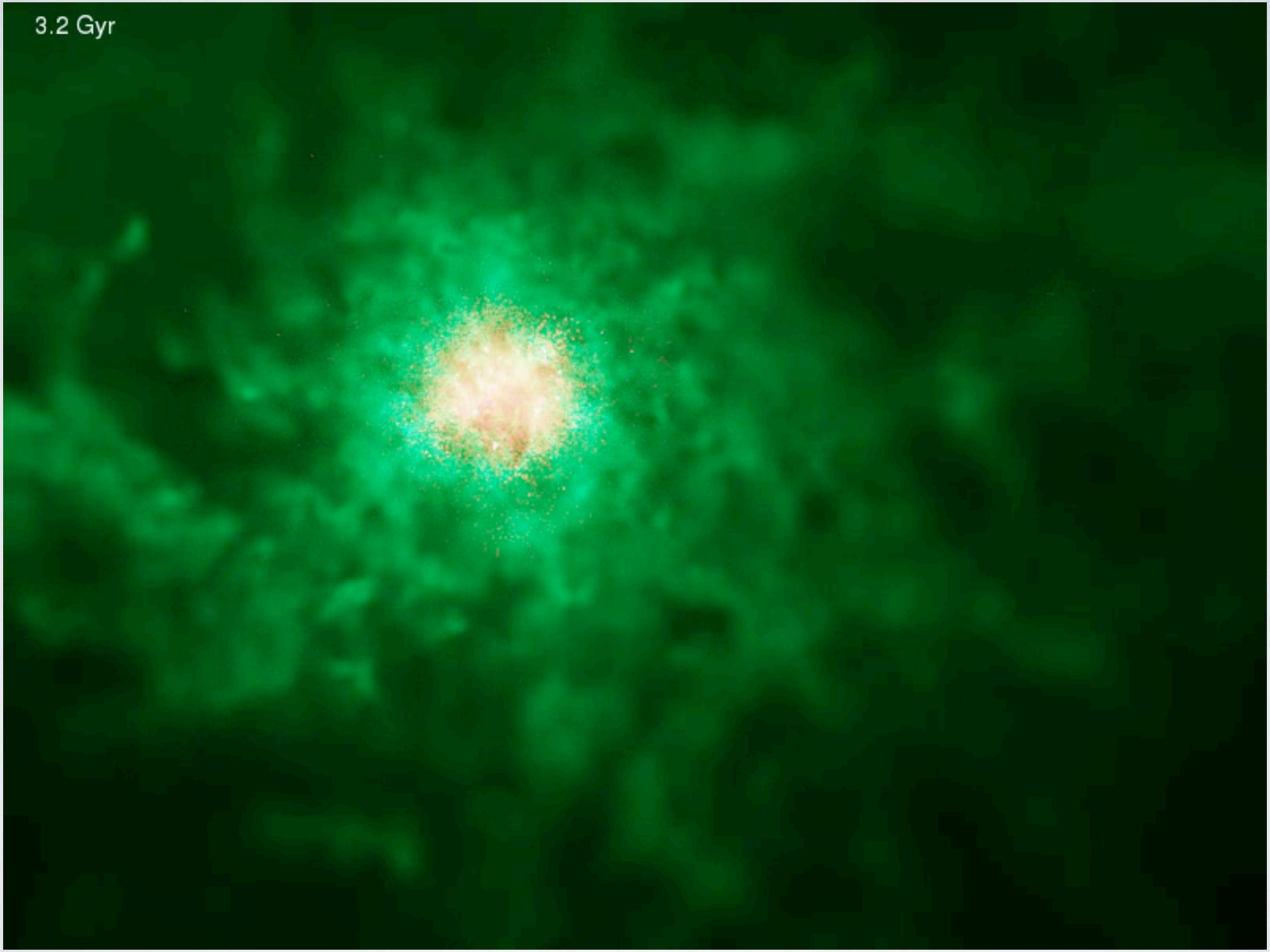
10^6 gas particles in r_{vir}

Gasoline

Wadsley et al (2004)

- Smoothed Particle Hydrodynamics (SPH)
- New low temperature and metal cooling (Shen 2010)
- UV heating (Haardt + Madau 1996)
- Metal Diffusion (Wadsley et al 2008)
- Star Formation (GS et al 2006)
- Stellar Feedback

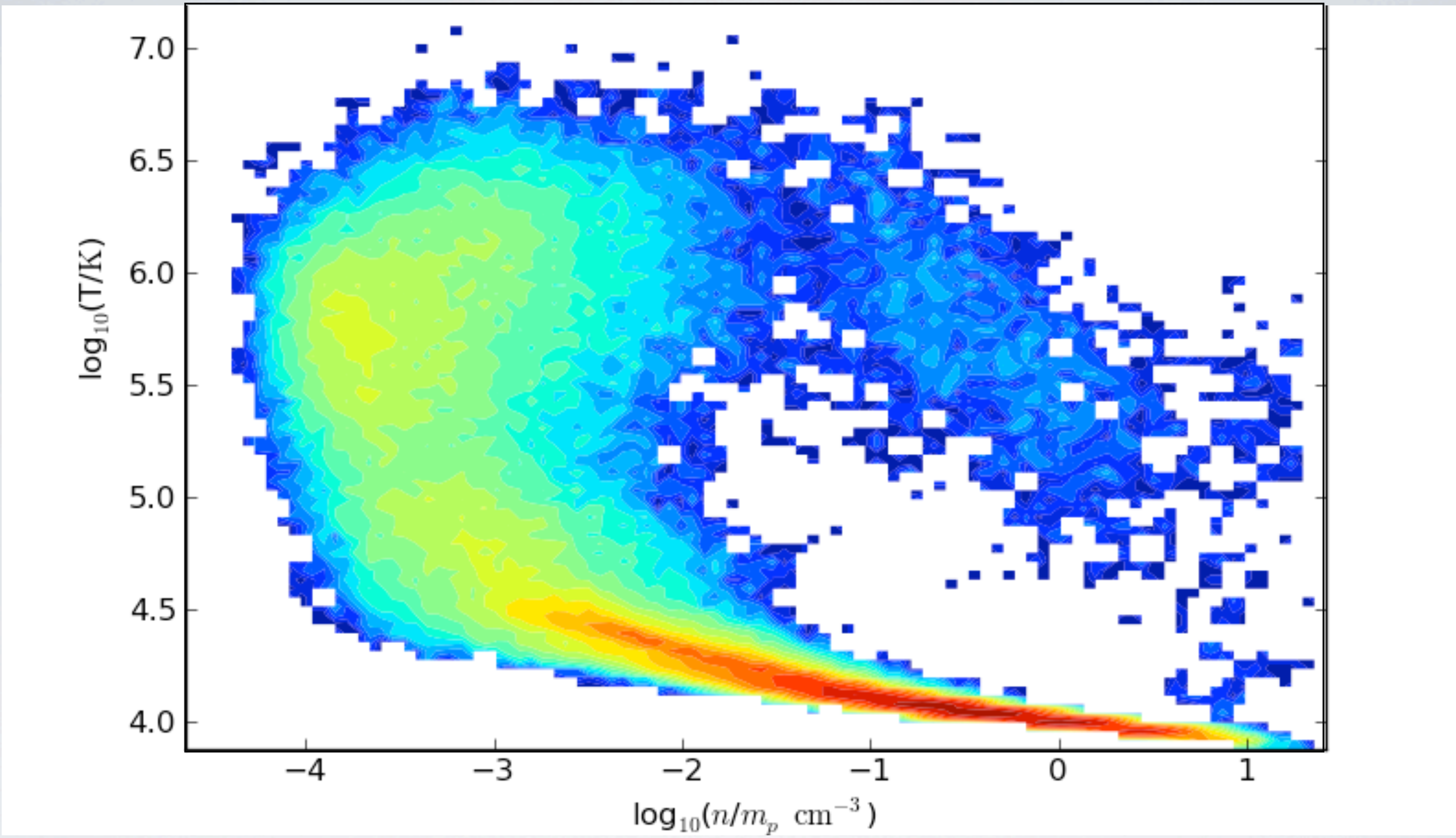
100 kpc



Gas

Young Stars

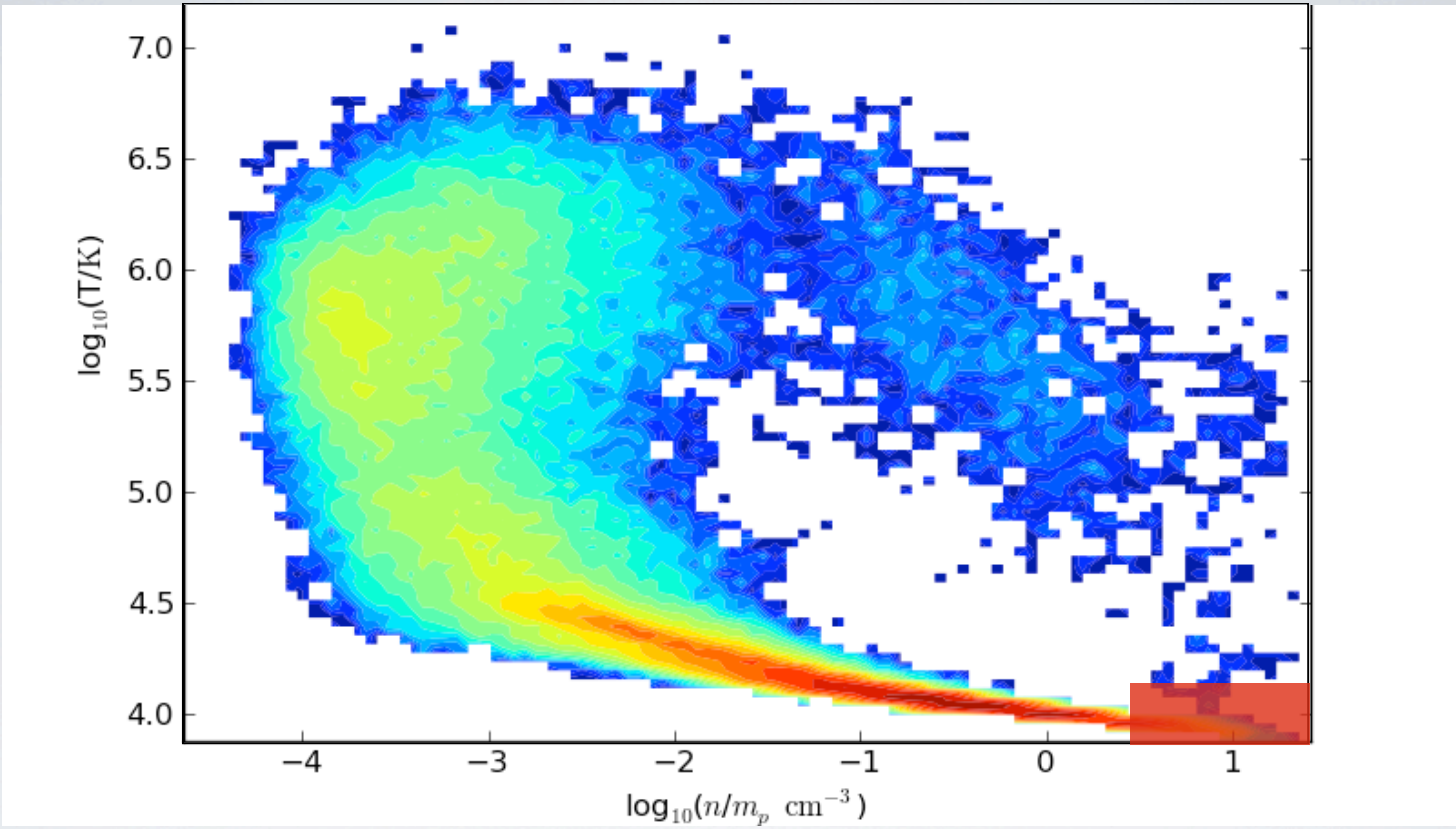
Old Stars



COOL, DENSE GAS FORMS STARS

T_{max} = 15000 K; n_{min} = 10 cm-3 (resolved density)

Follow Schmidt Law: $dM^*/dt = c^* M_{gas}/t_{dyn}$



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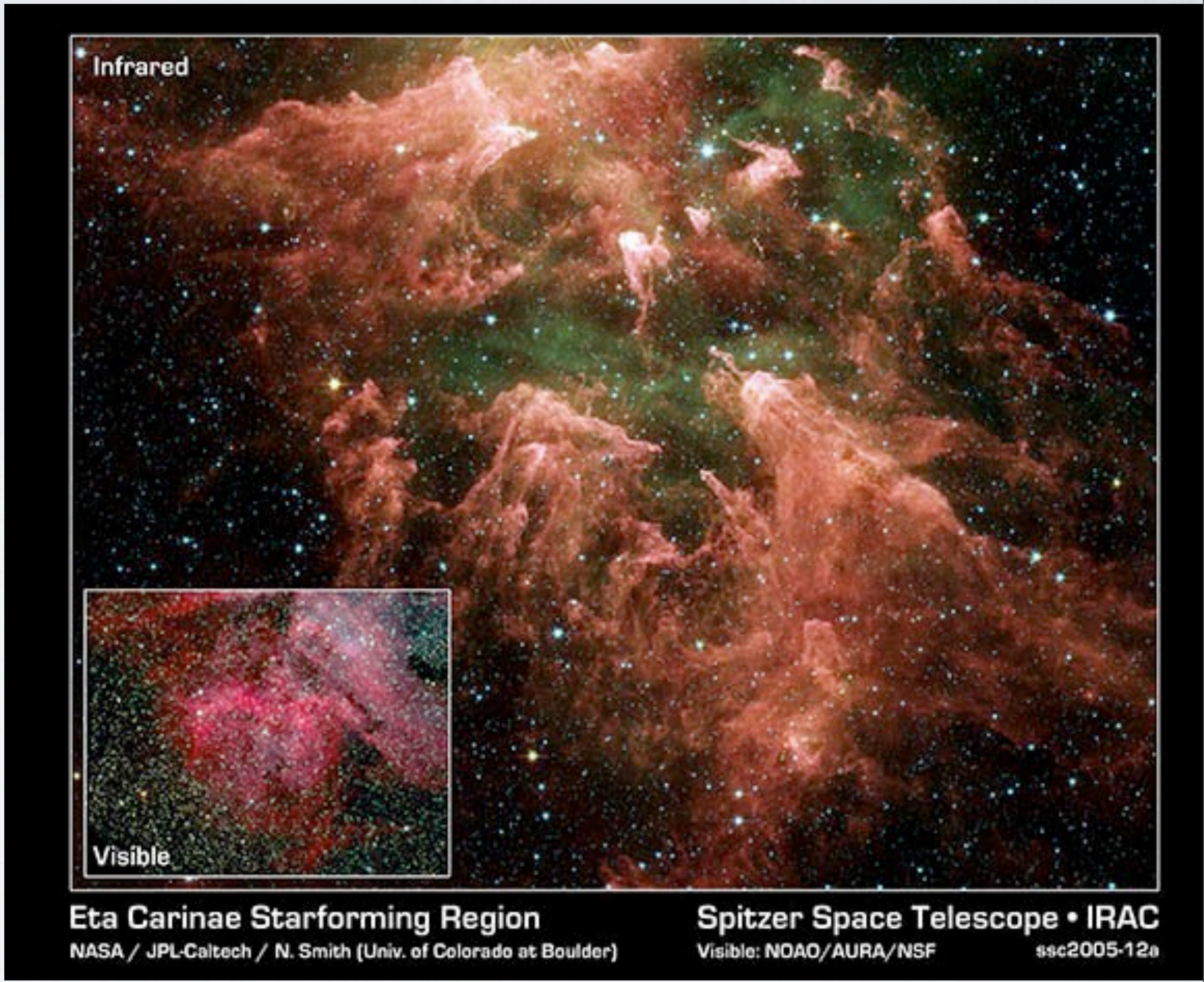
STELLAR FEEDBACK

- Ideally, stellar feedback should do 3 things
  - Limit star formation
  - Provide pressure support for the disk
  - drive outflows



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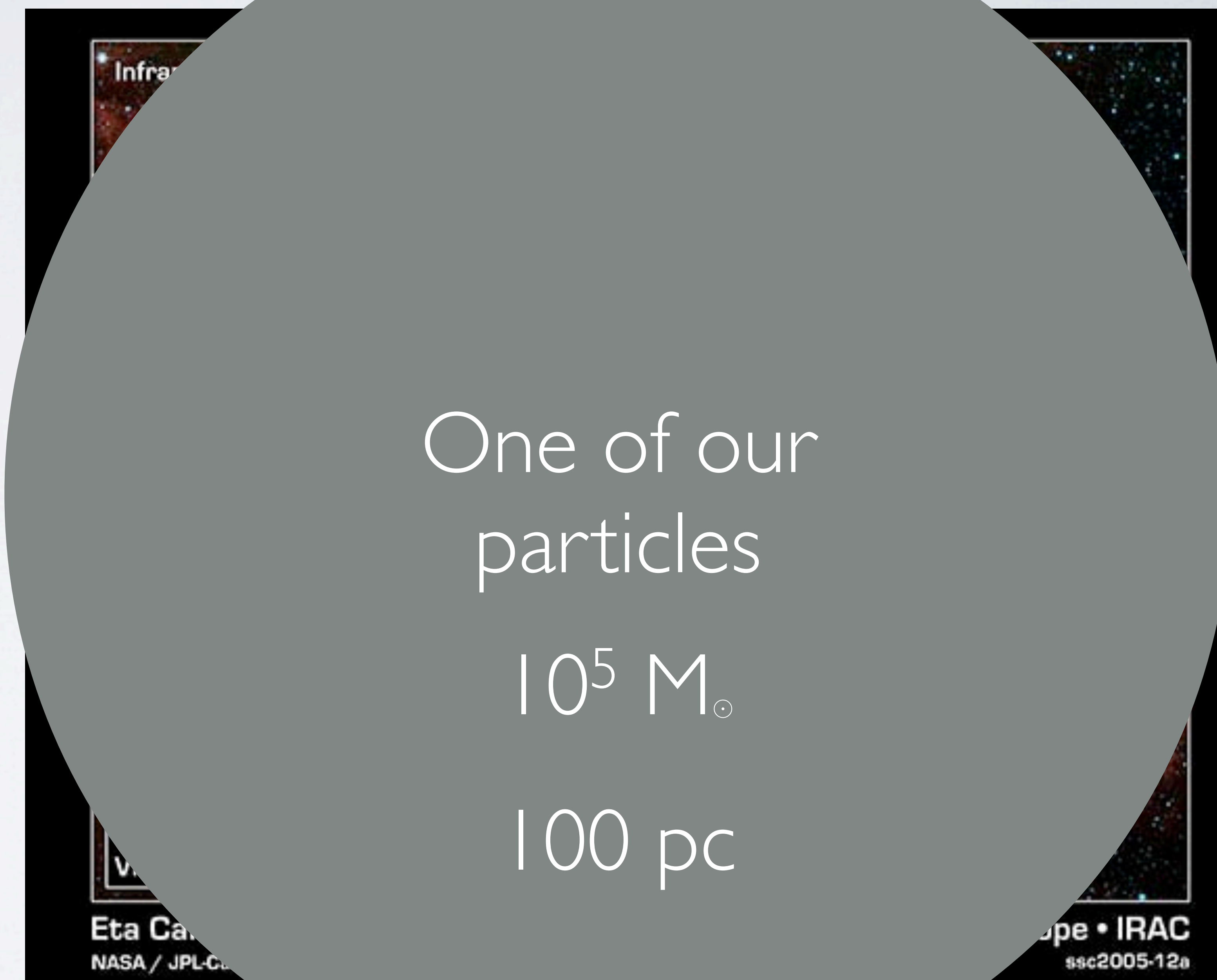


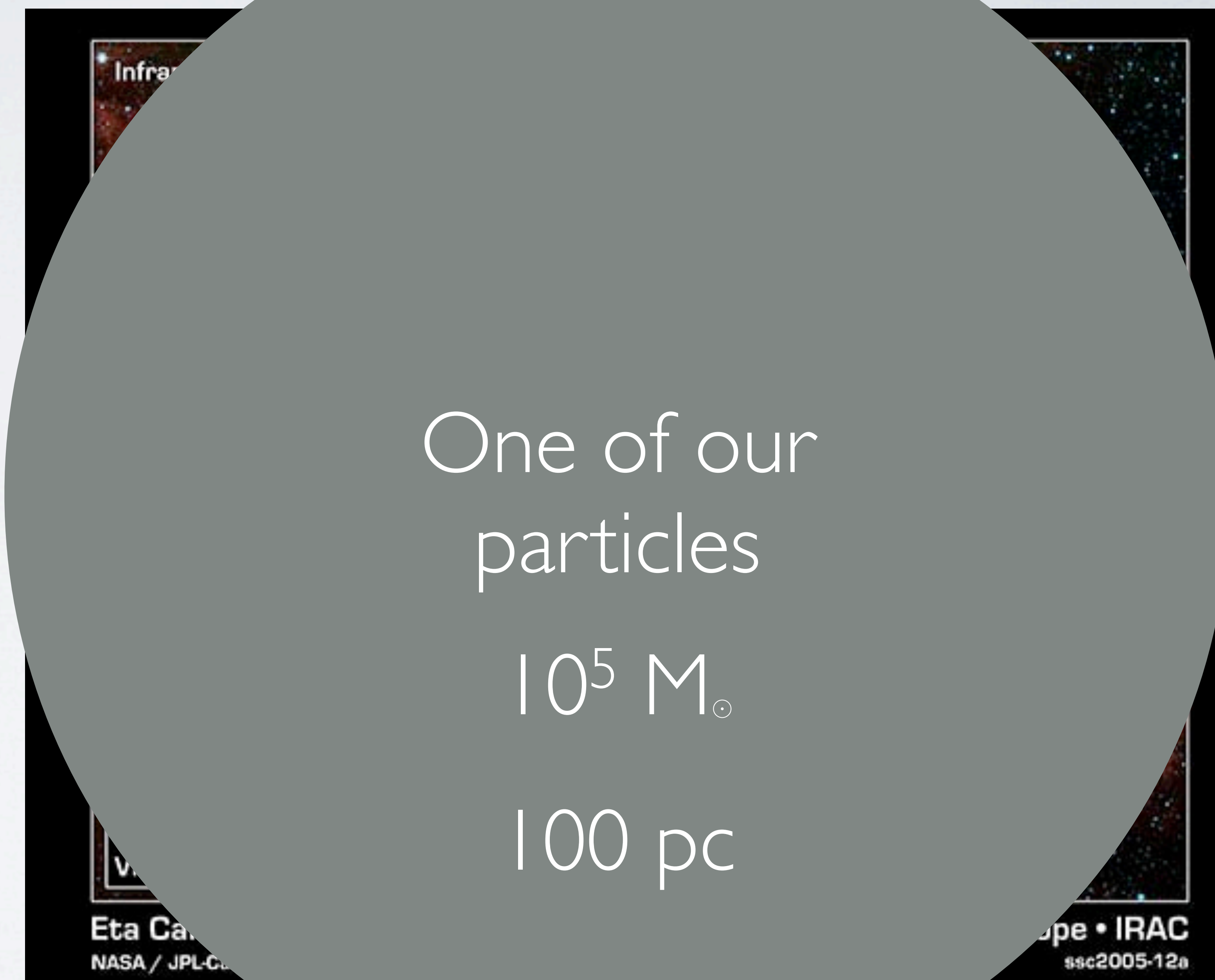
One of our particles

$10^5\ M_\odot$

100 pc

STELLAR FEEDBACK

- Problems
  - Dense gas cools fast ($t_{cool} < t_{dyn}$)
  - Small amounts of gas have a large impact
  - How do you drive observed outflows?



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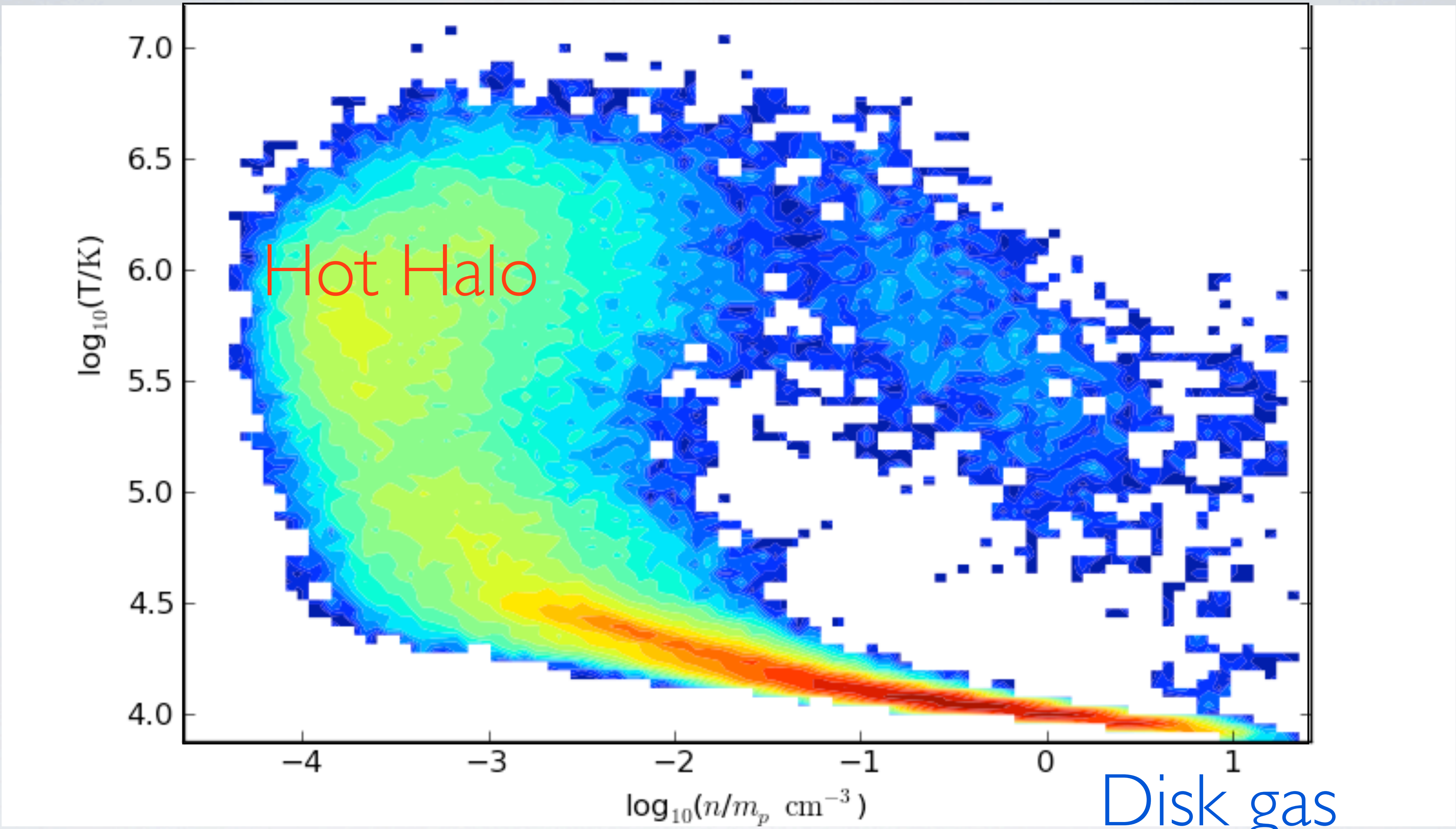
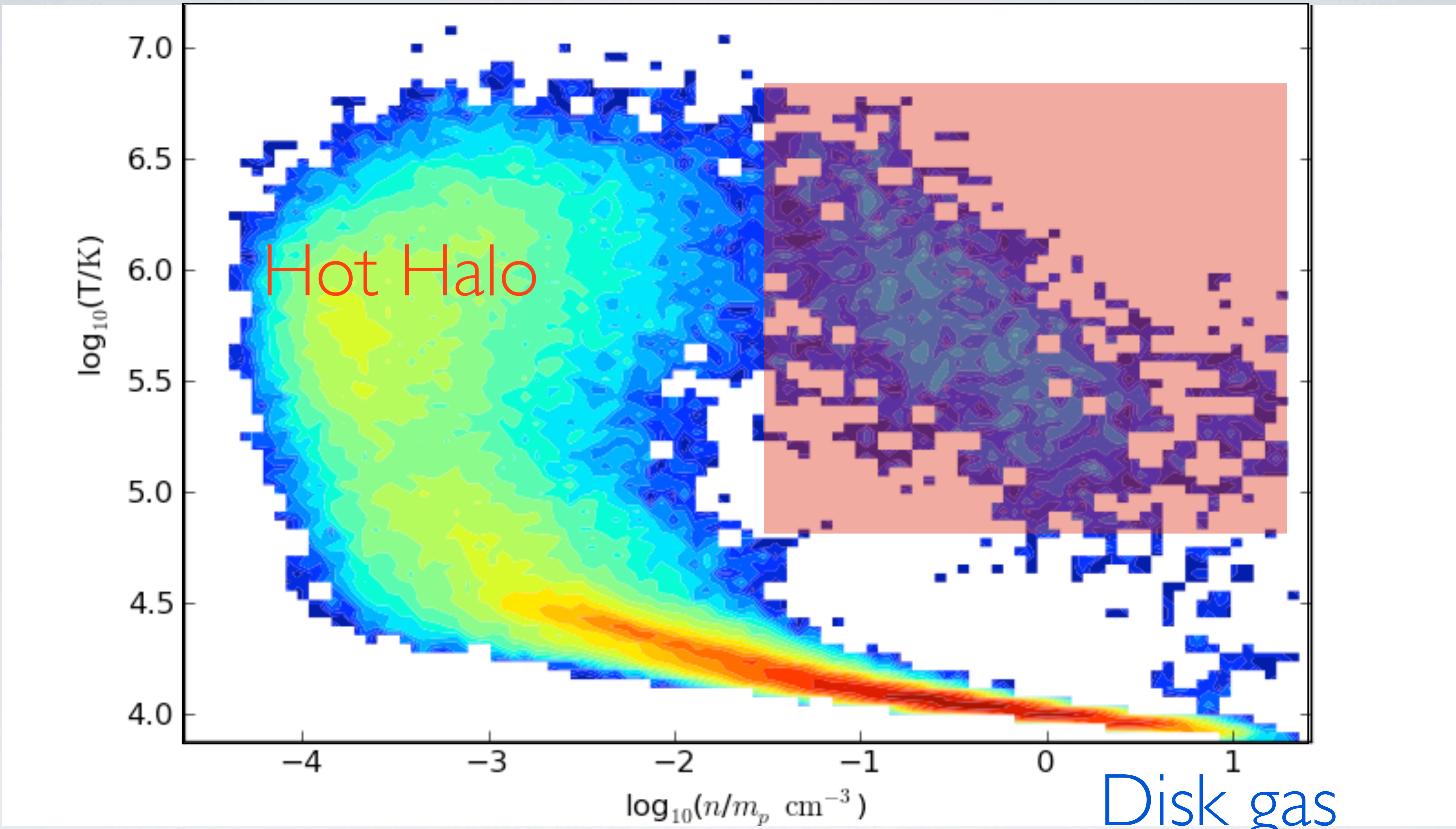


FEEDBACK GAS IN PHASE SIMULATION DIAGRAM

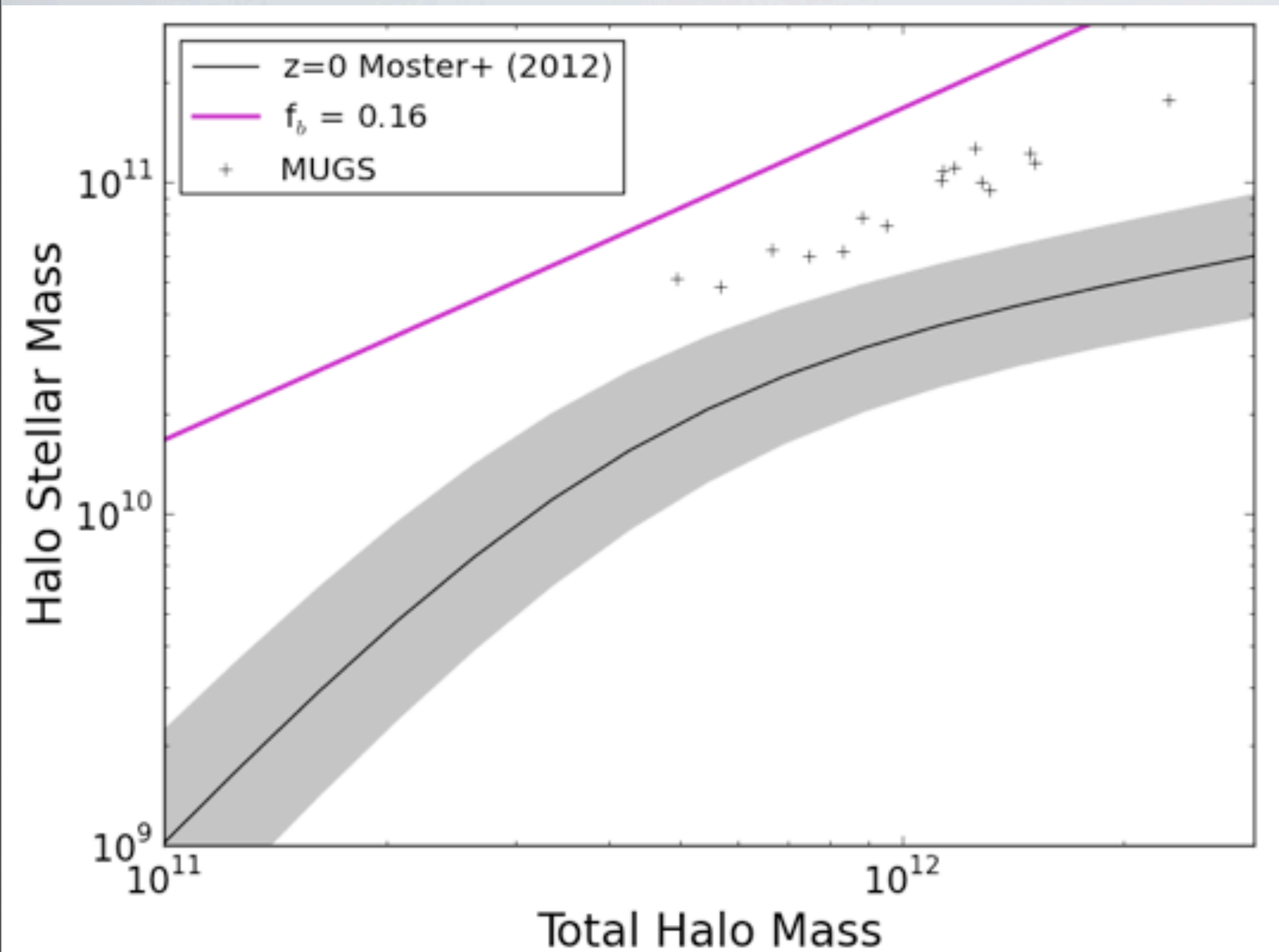
delay cooling based on blastwave equations (Stinson+ 2006)



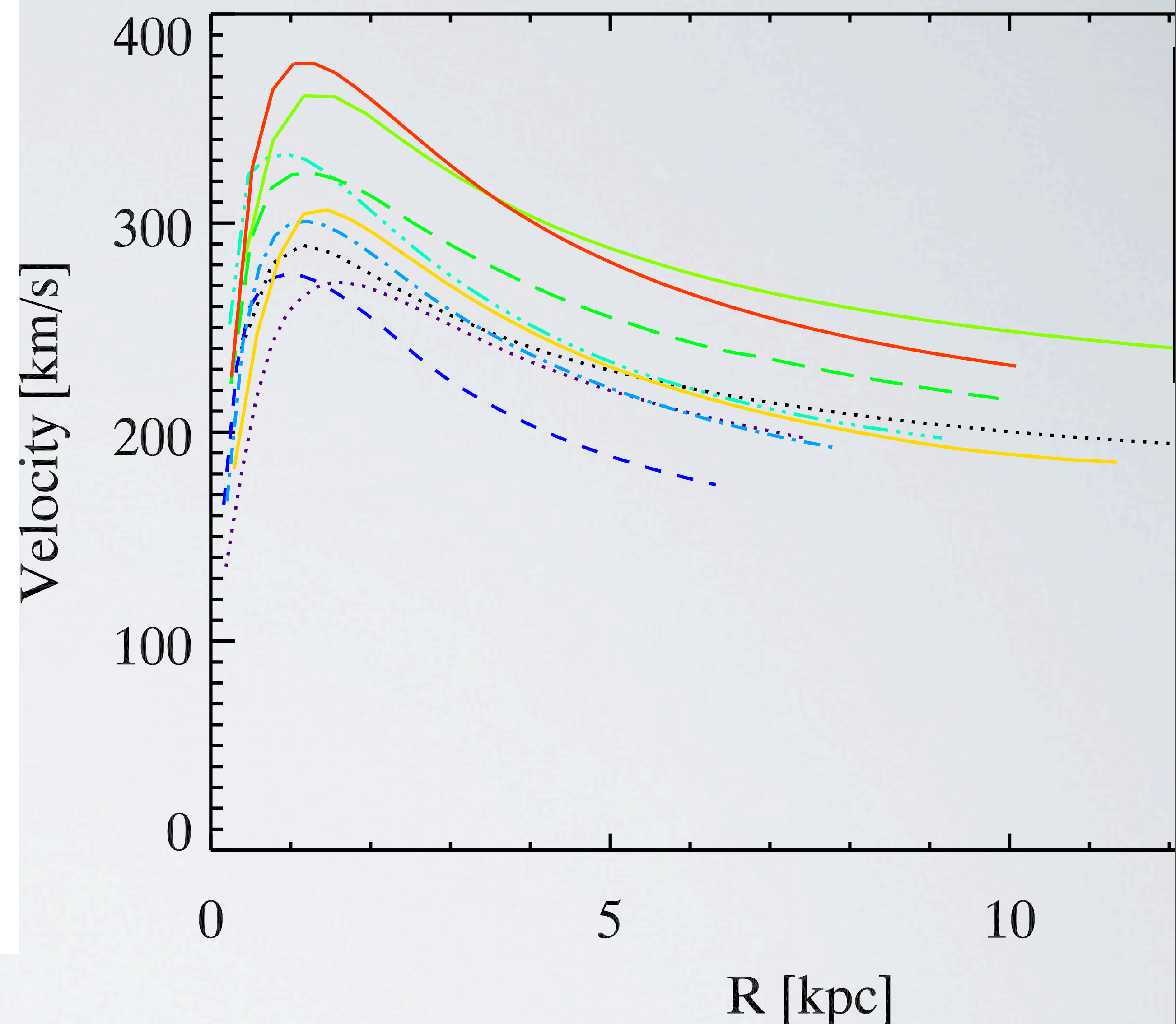
FEEDBACK GAS IN PHASE SIMULATION DIAGRAM

delay cooling based on blastwave equations (Stinson+ 2006)

Too many stars formed



primarily in the center



OVERCOOLING

Stinson et al (2010)

FROM MUGS TO MAGICC*

Increase SN feedback

* Making Galaxies in a Cosmological Context

FROM MUGS TO MAGICC*

Increase SN feedback

Kroupa + (1993) 10% Mass SN	→	Chabrier (2003) 20% Mass SN

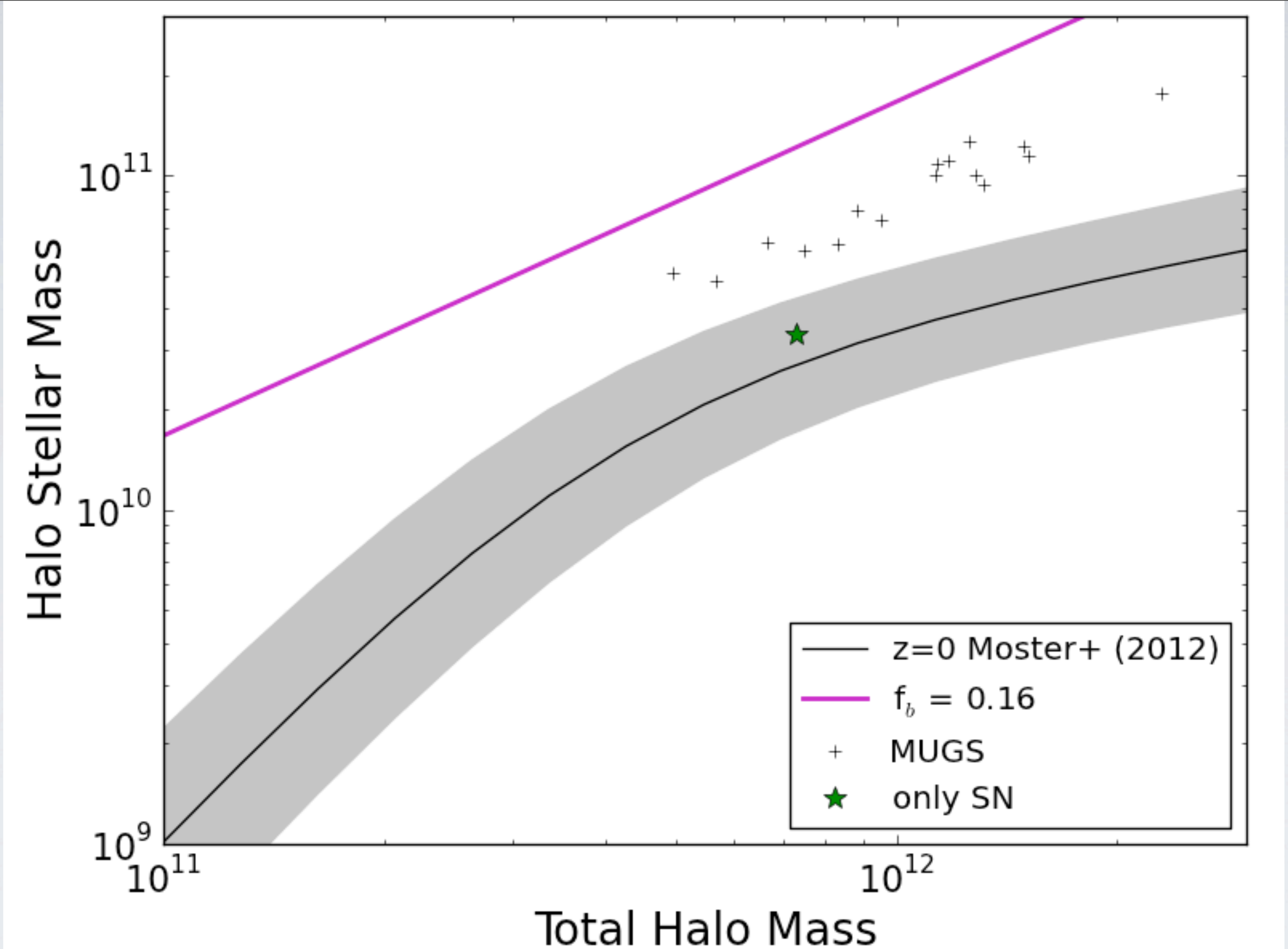
* Making Galaxies in a Cosmological Context

FROM MUGS TO MAGICC*

Increase SN feedback

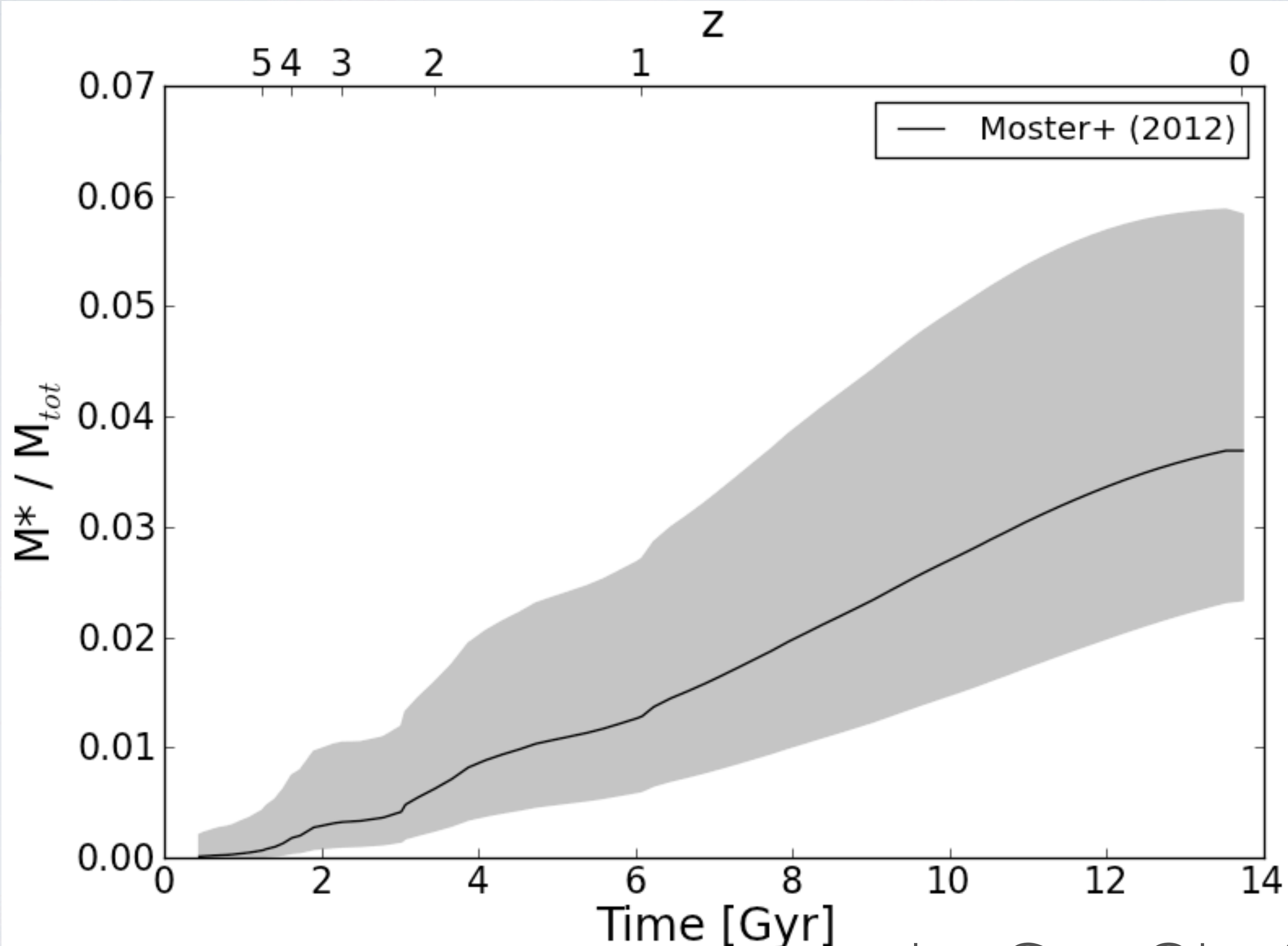
Kroupa + (1993) 10% Mass SN	→	Chabrier (2003) 20% Mass SN
$E_{SN} = 0.4\times10^{51}$ ergs / SN	→	$E_{SN} = 10^{51}$ ergs / SN

* Making Galaxies in a Cosmological Context

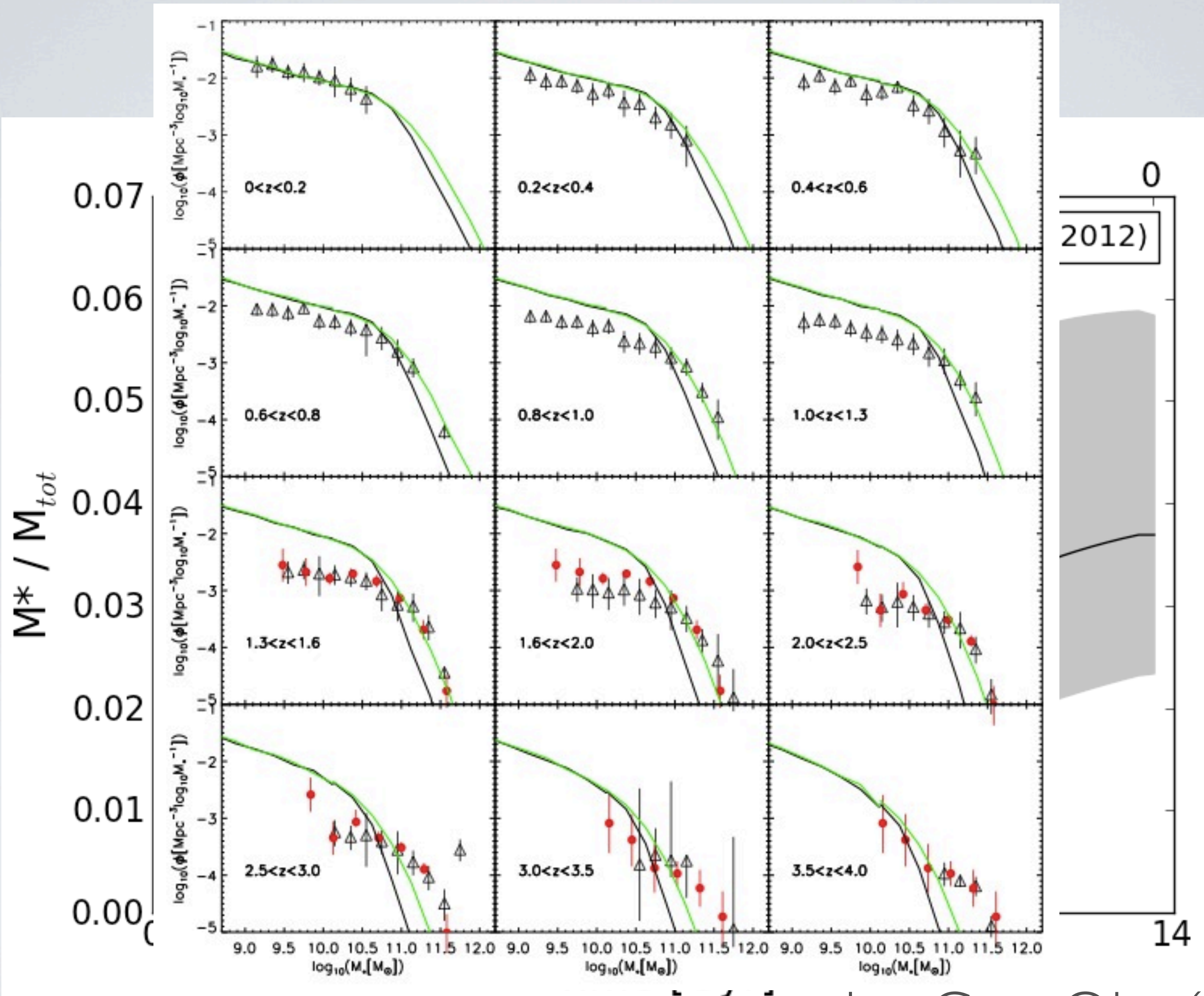


TURN UP FEEDBACK

100% Supernova Efficiency (10^{51} erg)



see also Guo, Qi+ (2011)
Behroozi+ (2012)



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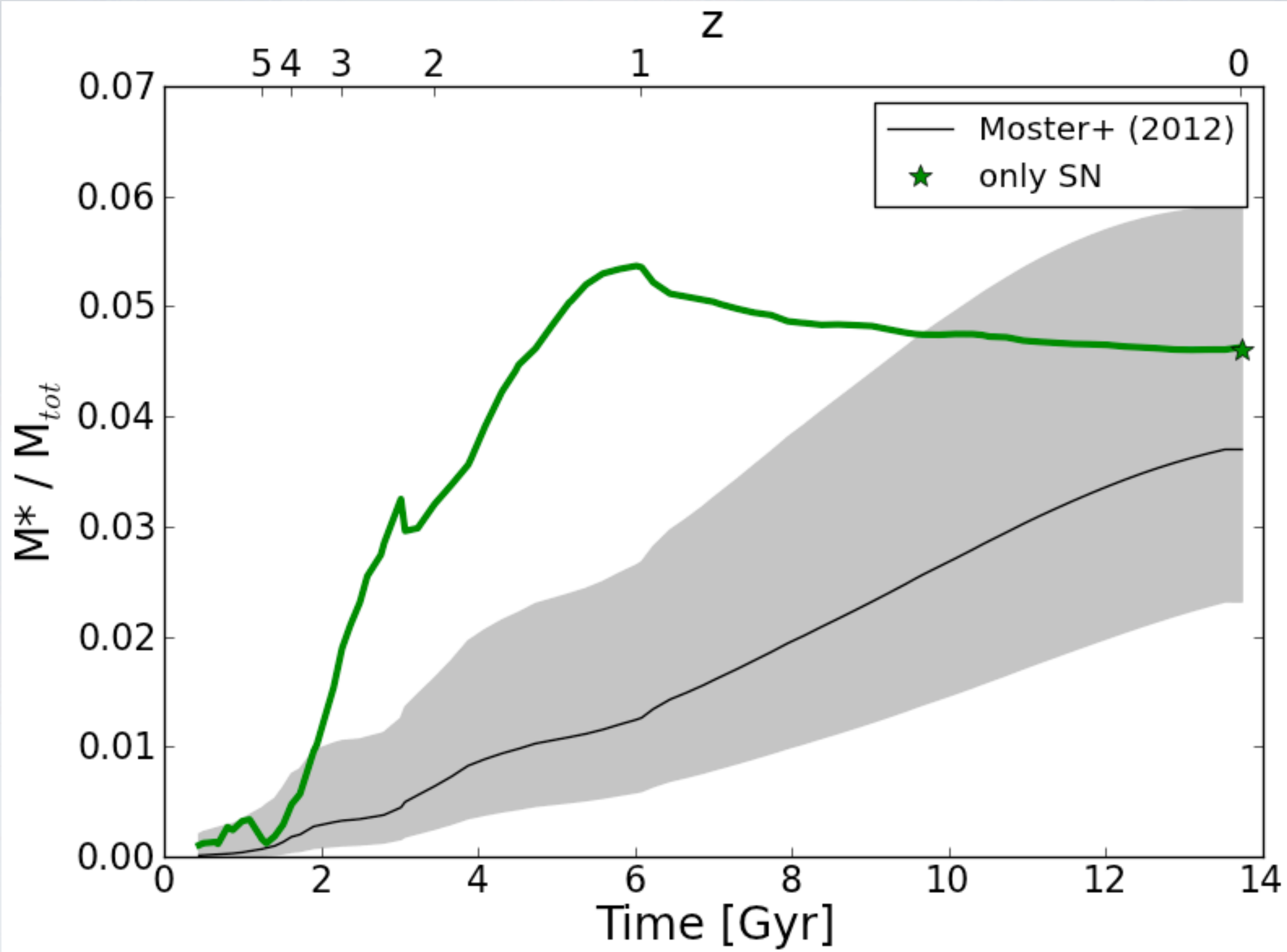

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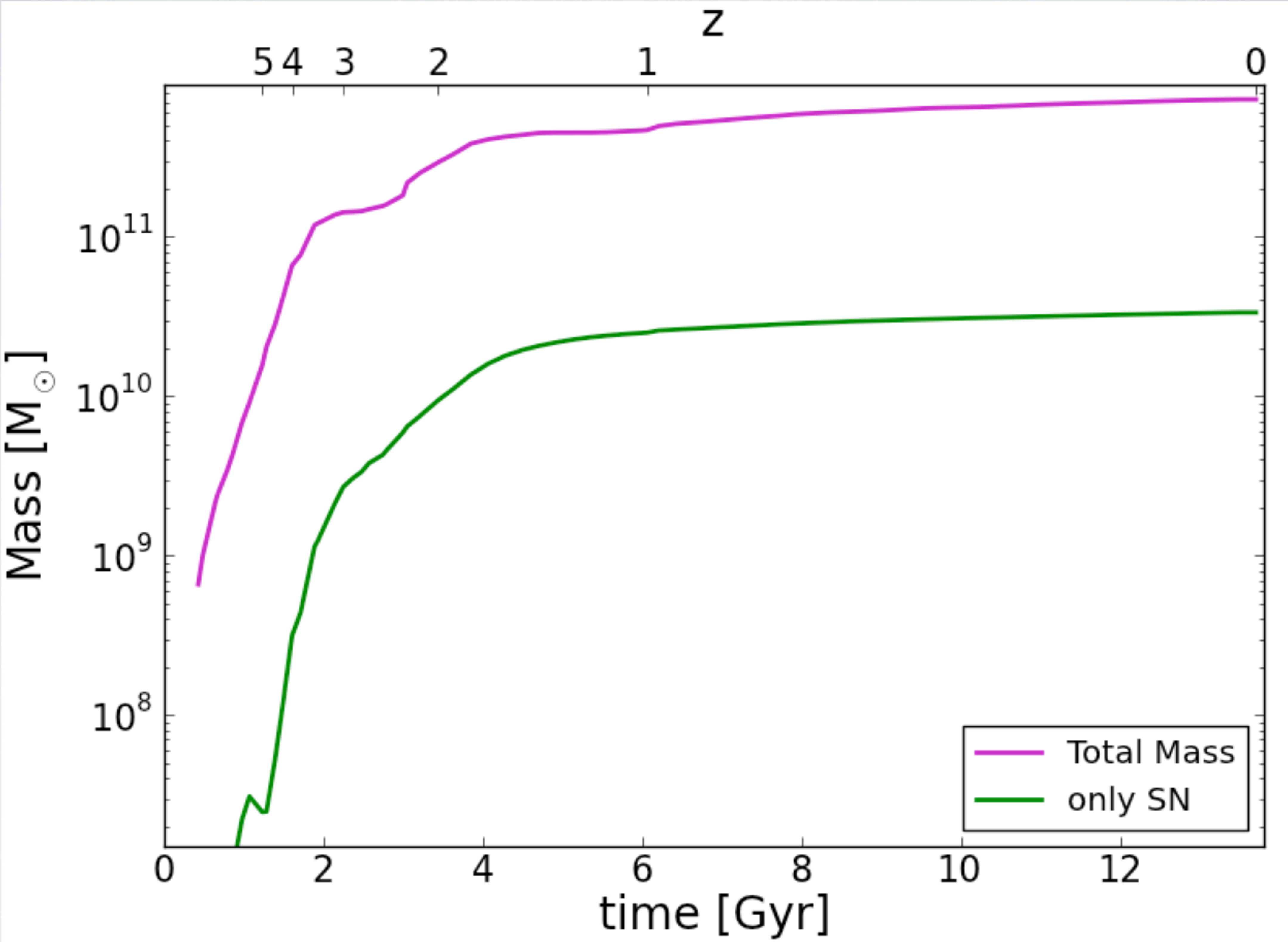
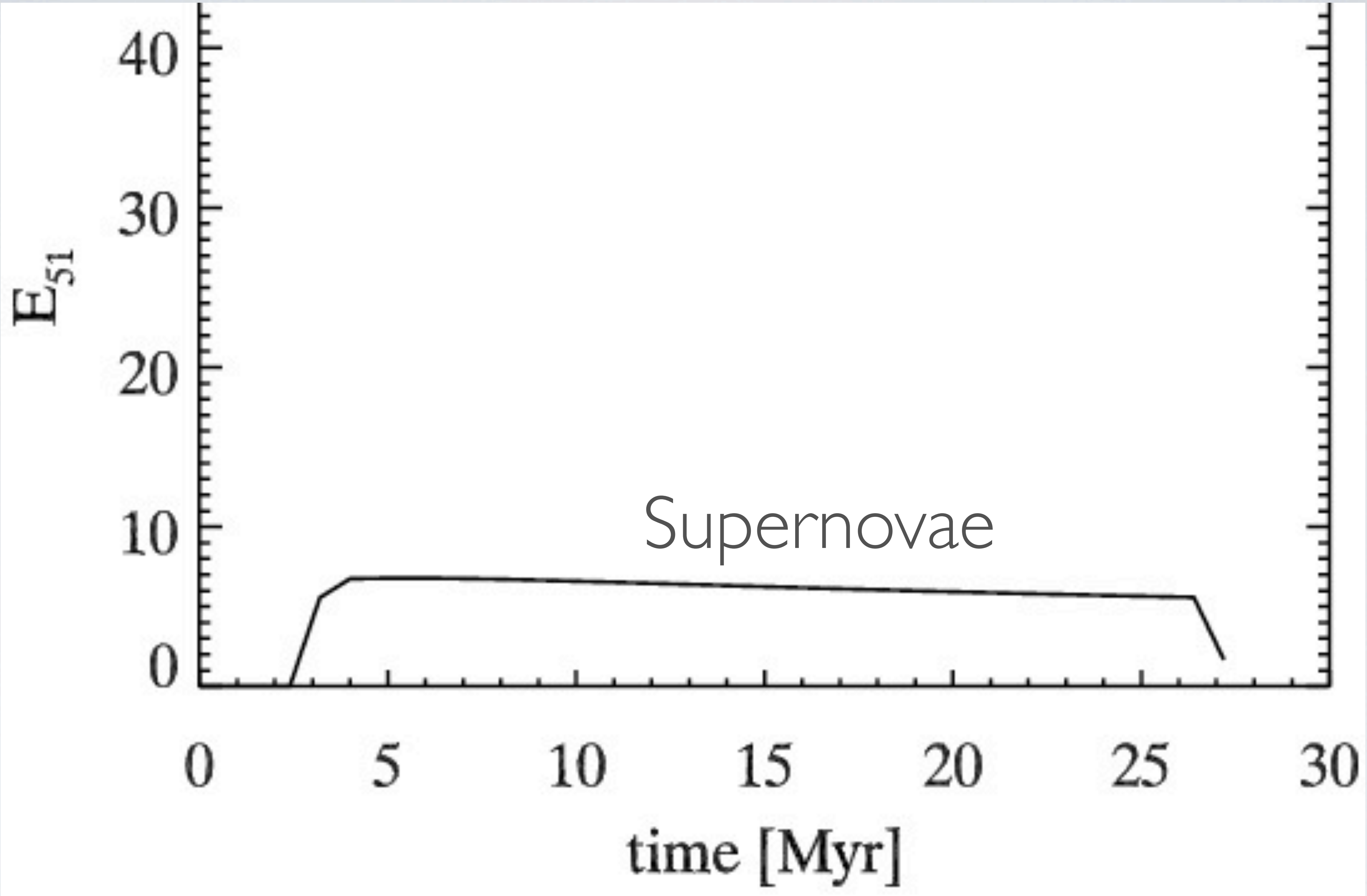


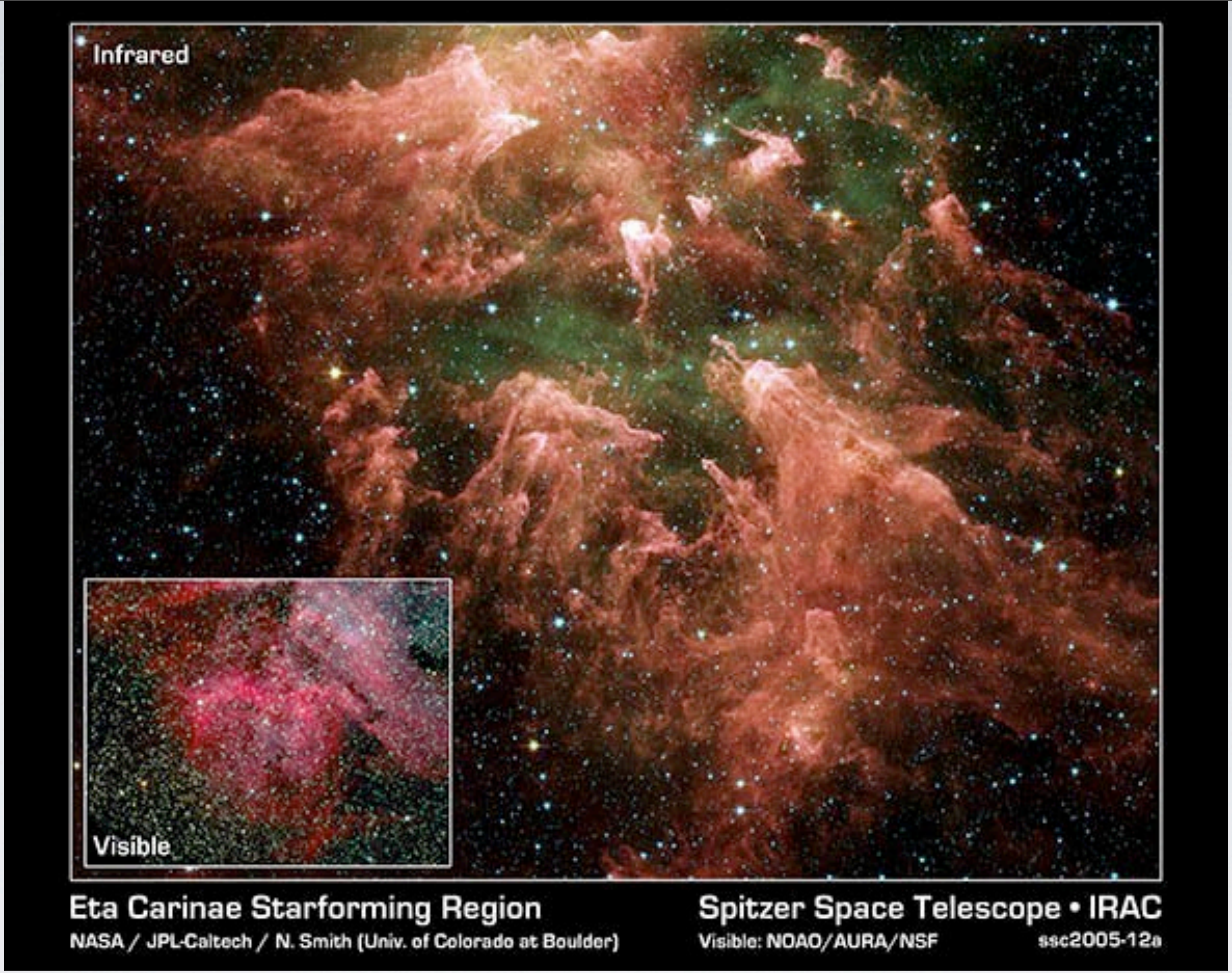
MASS EVOLUTION (SN ONLY)

Star formation follows mass accretion



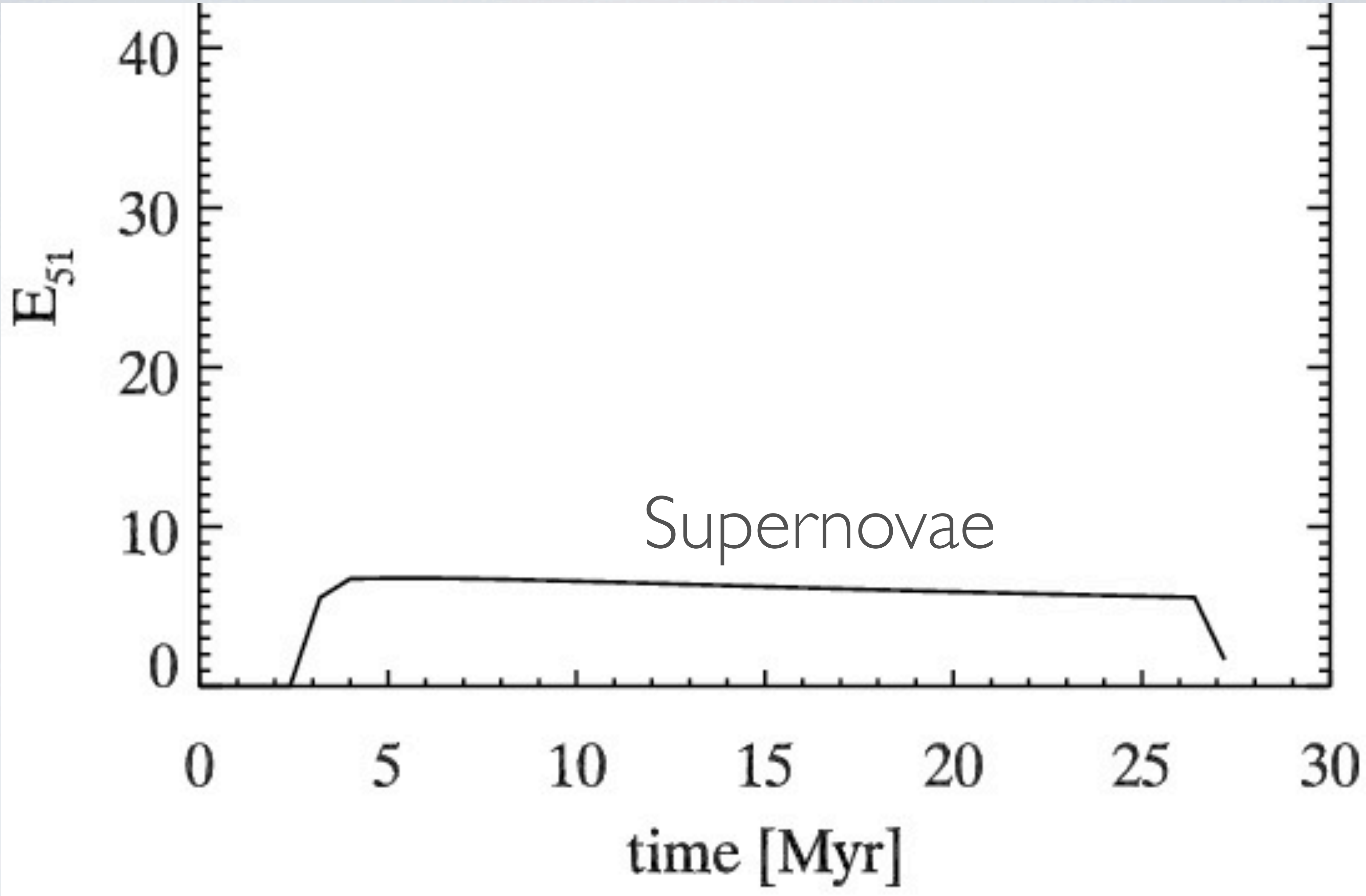
SUPERNOVA FEEDBACK

A hole



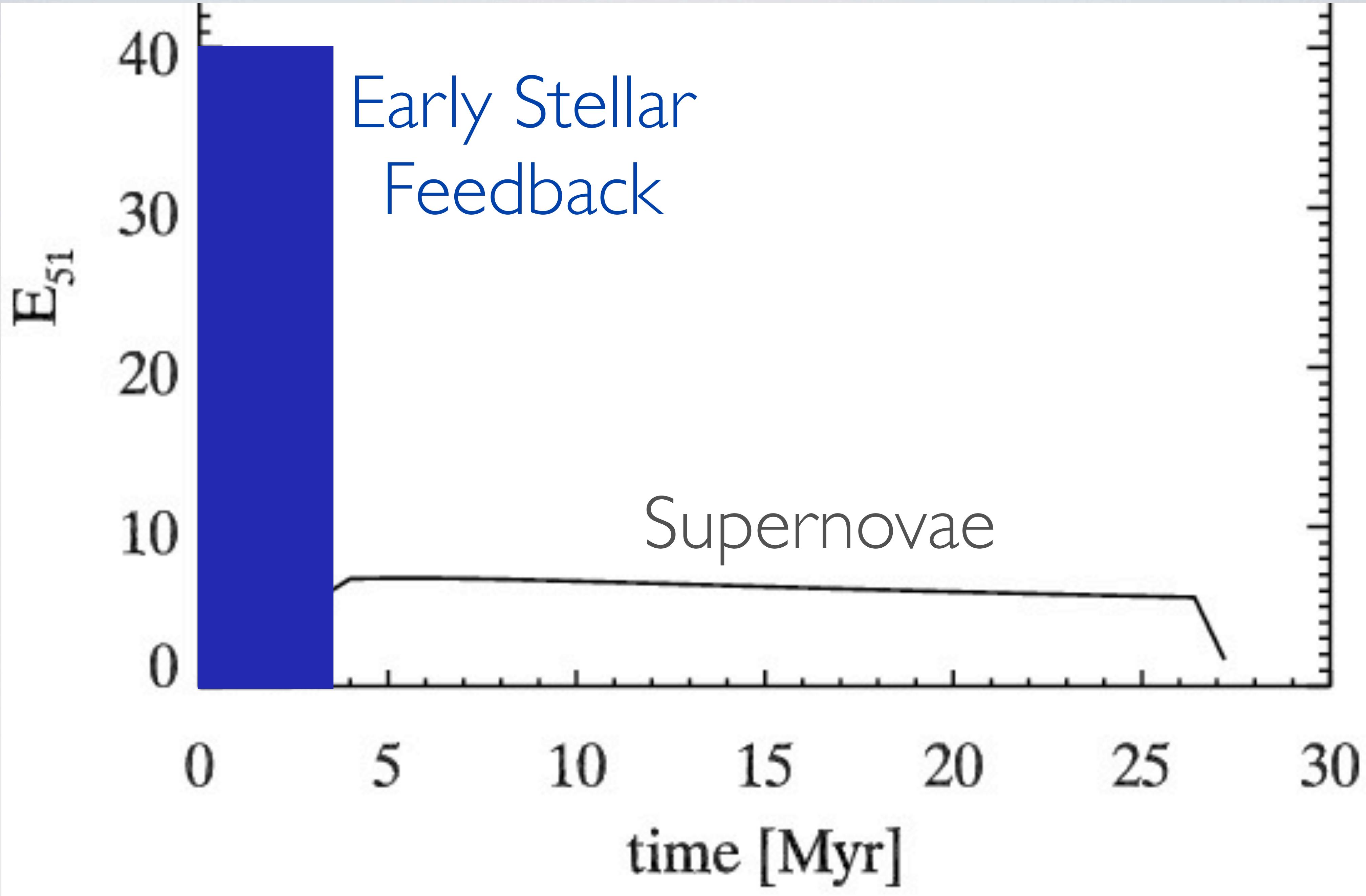
ETA CARINAE

< 3 Myr old, but stars already tearing gas apart



EARLY STELLAR FEEDBACK

A solution



EARLY STELLAR FEEDBACK

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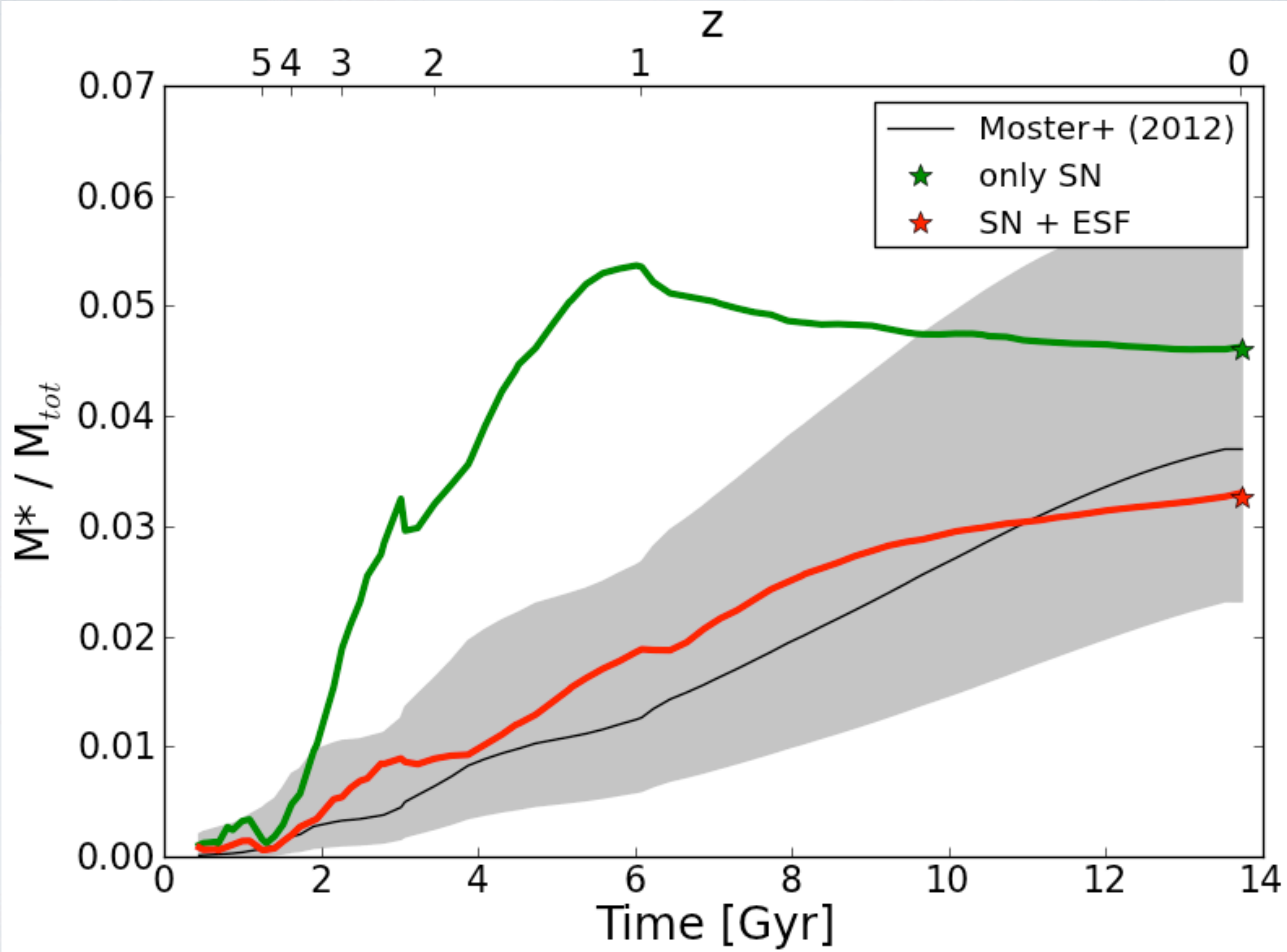
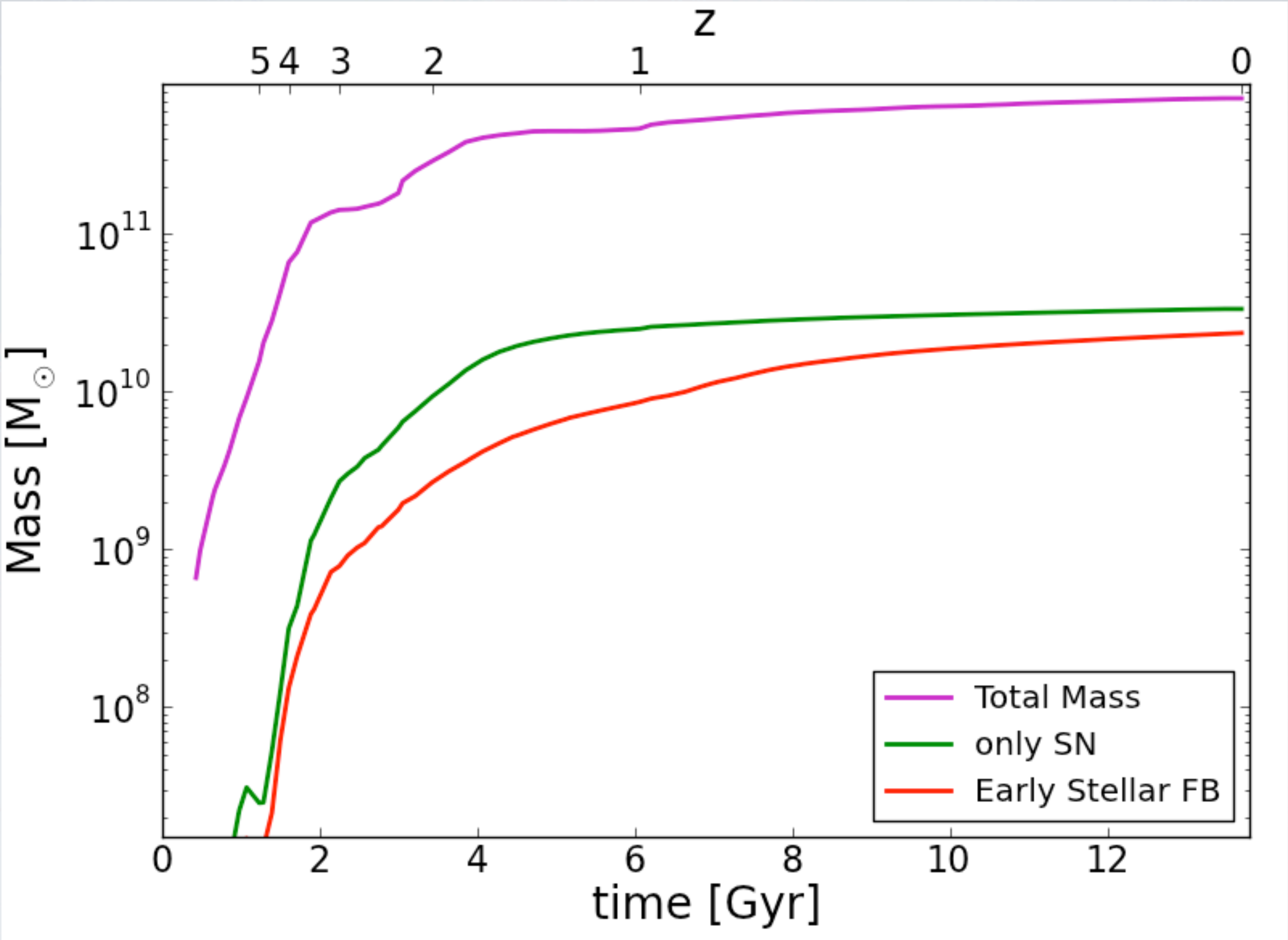


z
5 4 3 2 1 0
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
M* / M$_{tot}$
0 2 4 6 8 10 12 14
Time [Gyr]
Moster+ (2012)
only SN
SN + ESF



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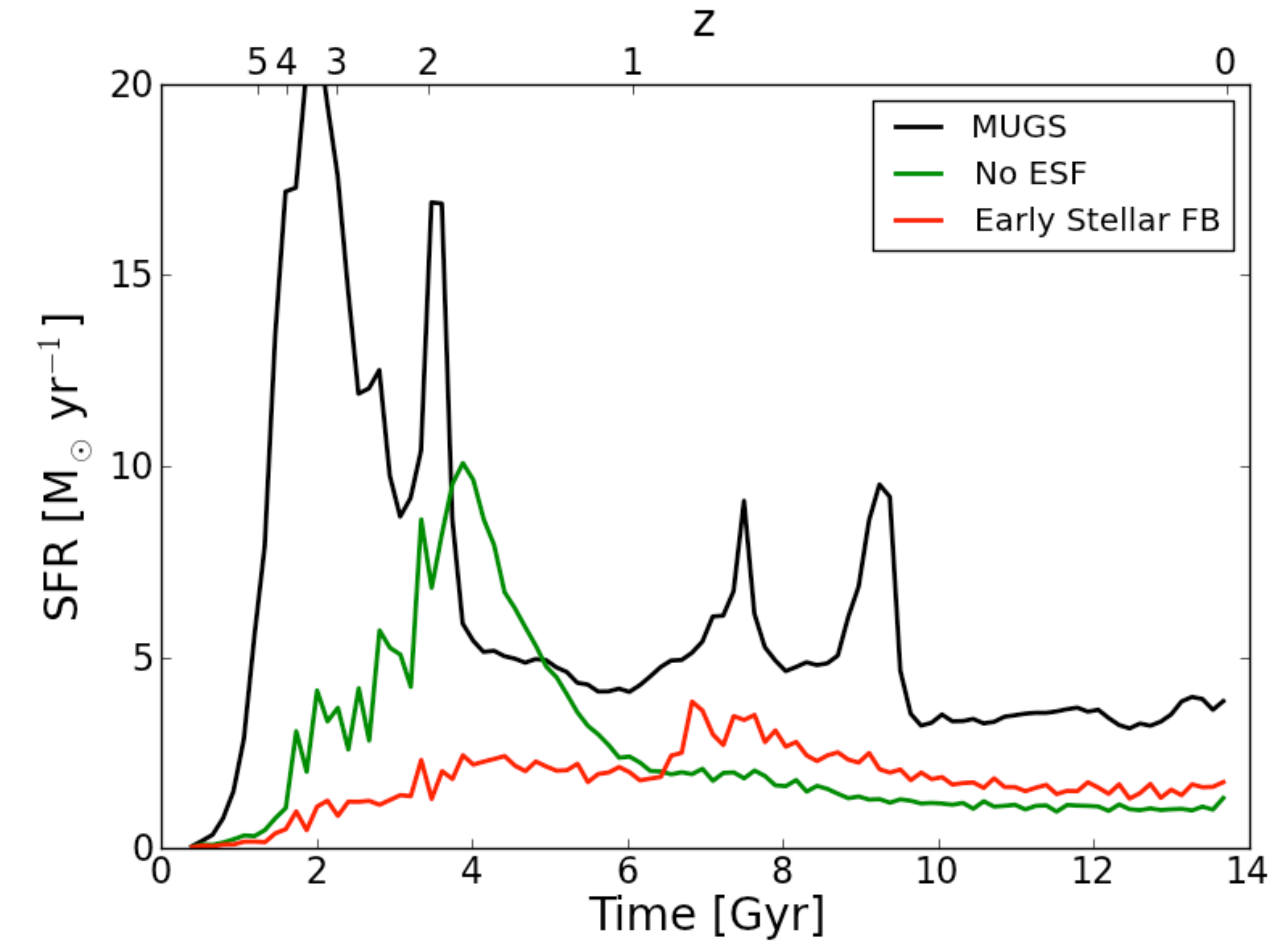
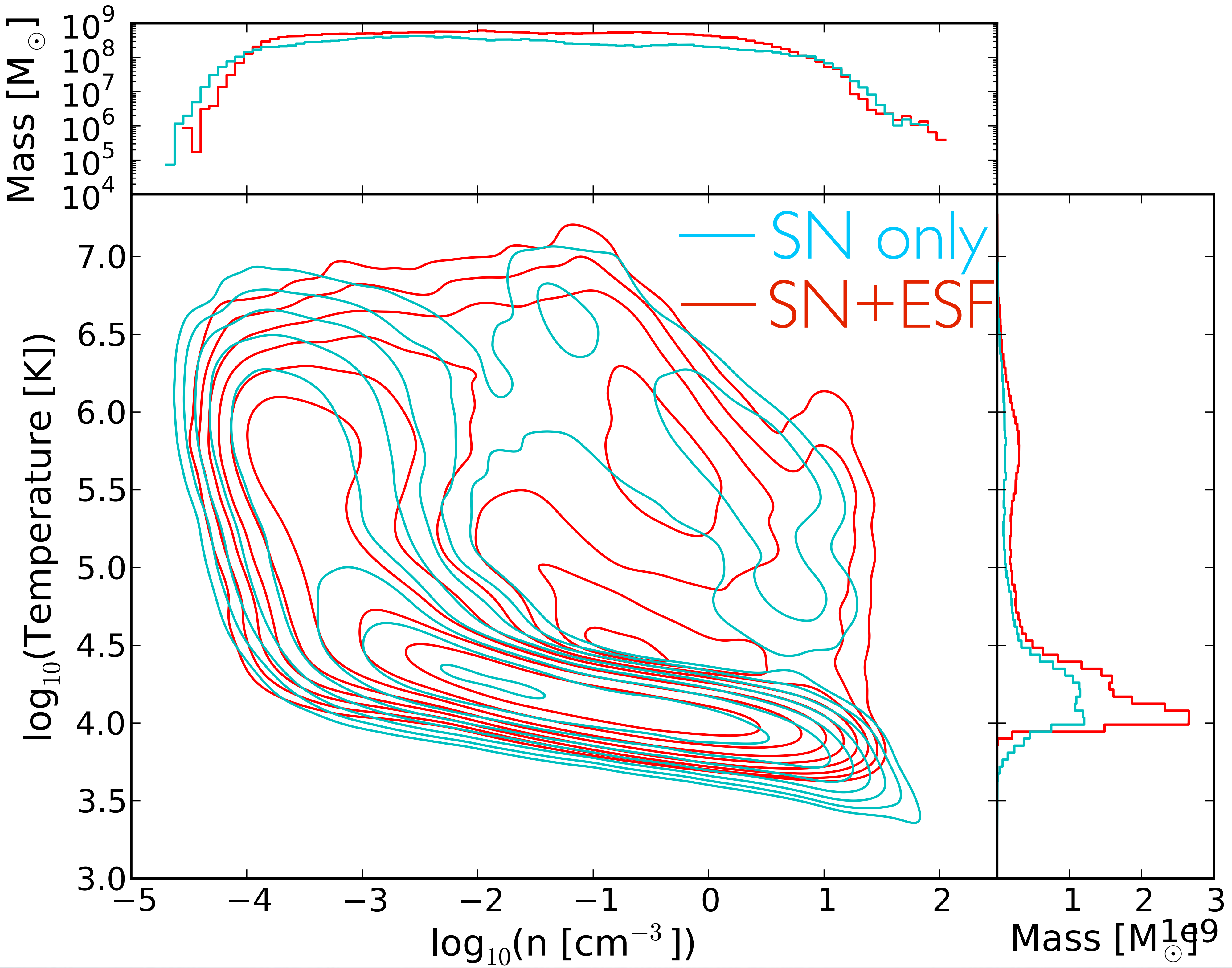


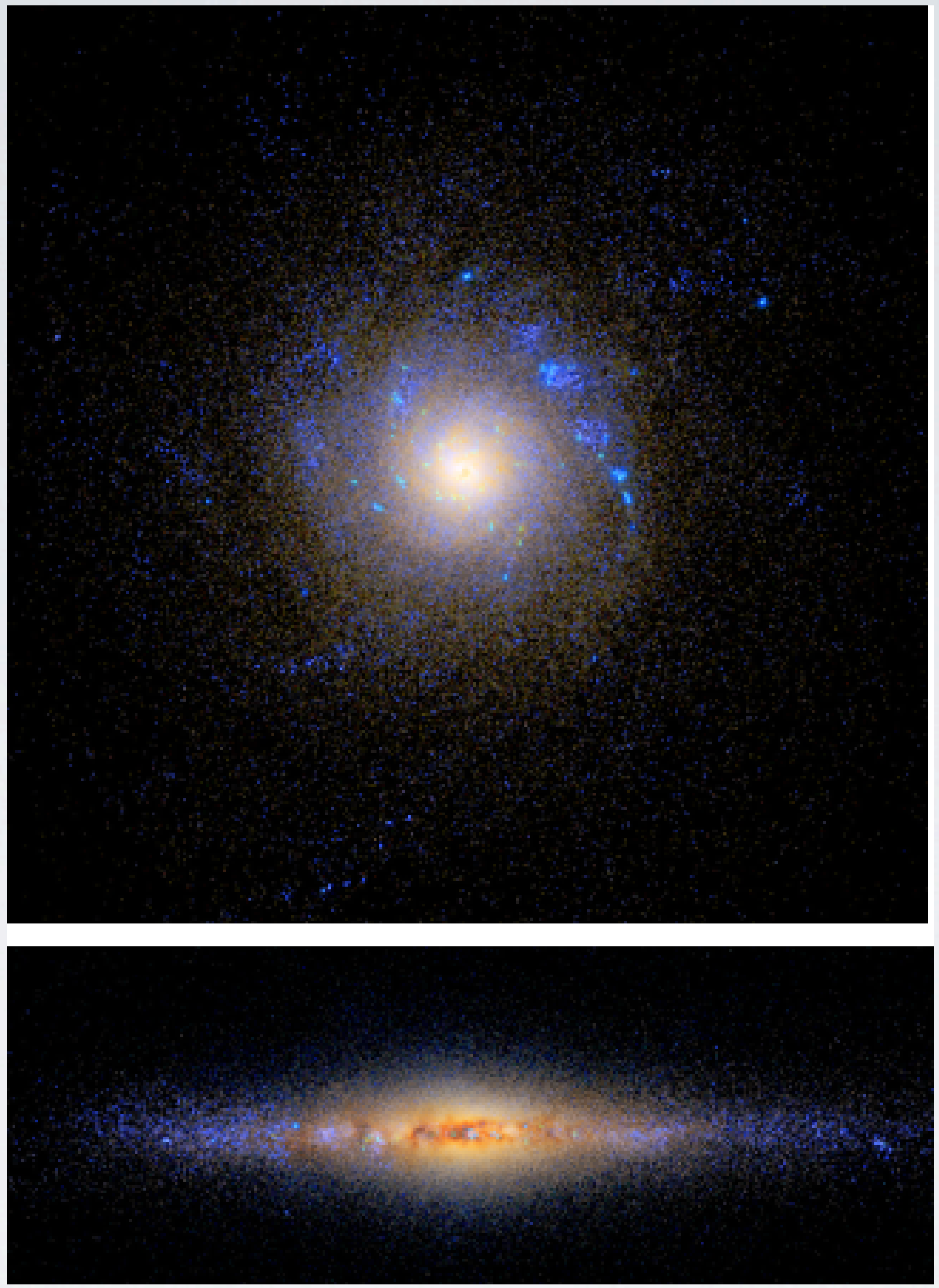
STAR FORMATION HISTORY

COMPARE **SN** WITH **SN+ESF** PHASE DIAGRAMS



WHAT KIND OF GALAXIES ARE PRODUCED?

50 kpc

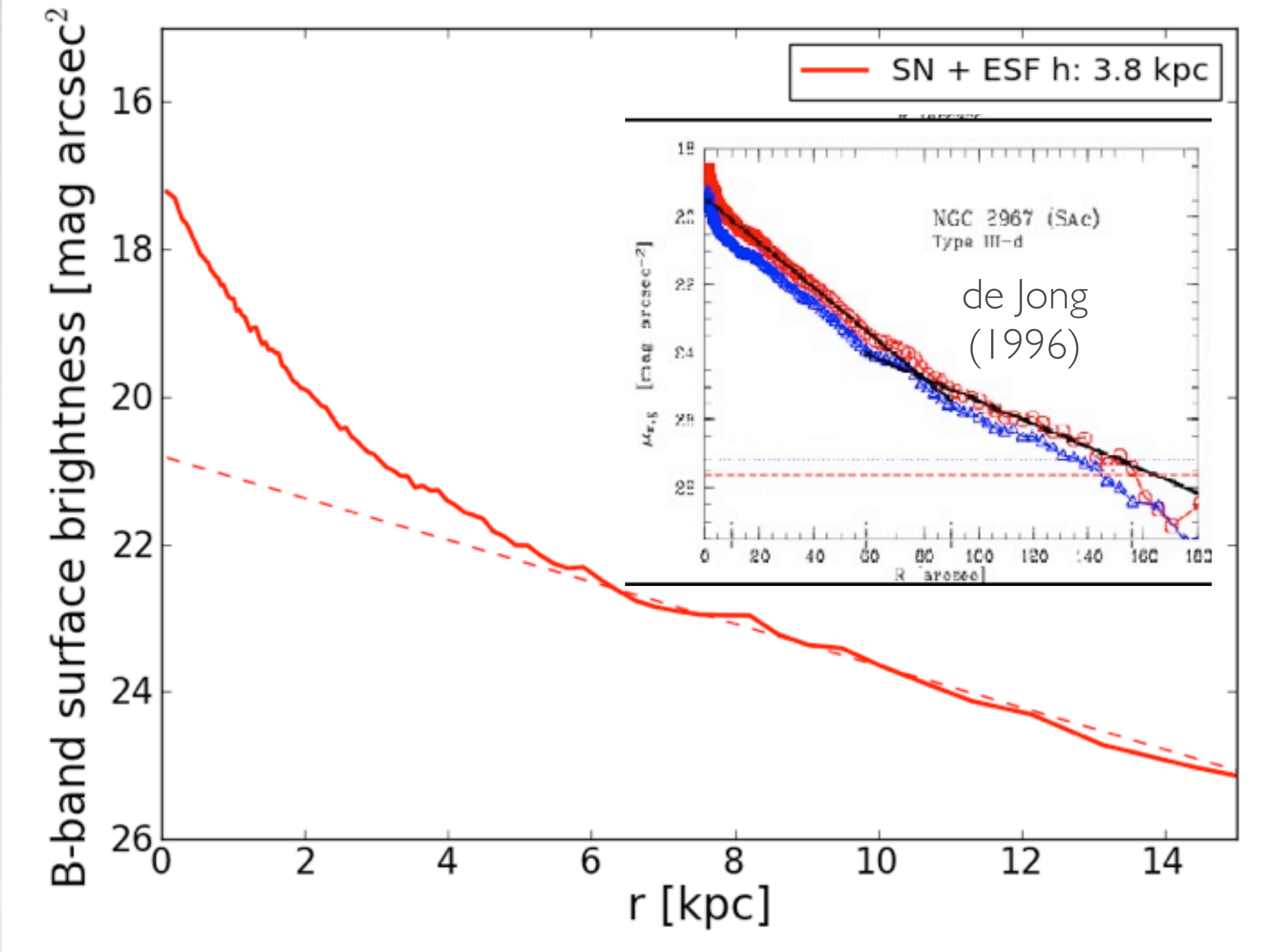


Movies at www.mpia.de/~stinson/magicc

THE MAGICC GALAXY

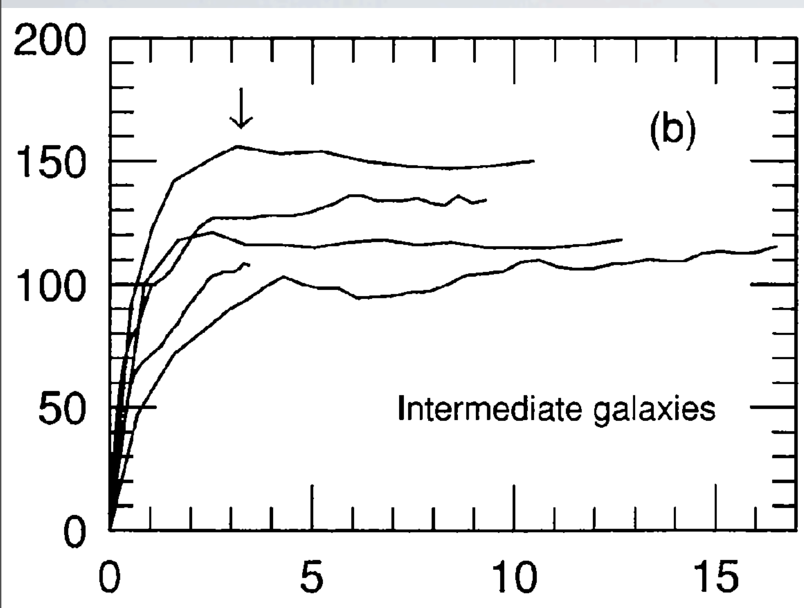
Match $M_\star$-M_{halo} and see what happens

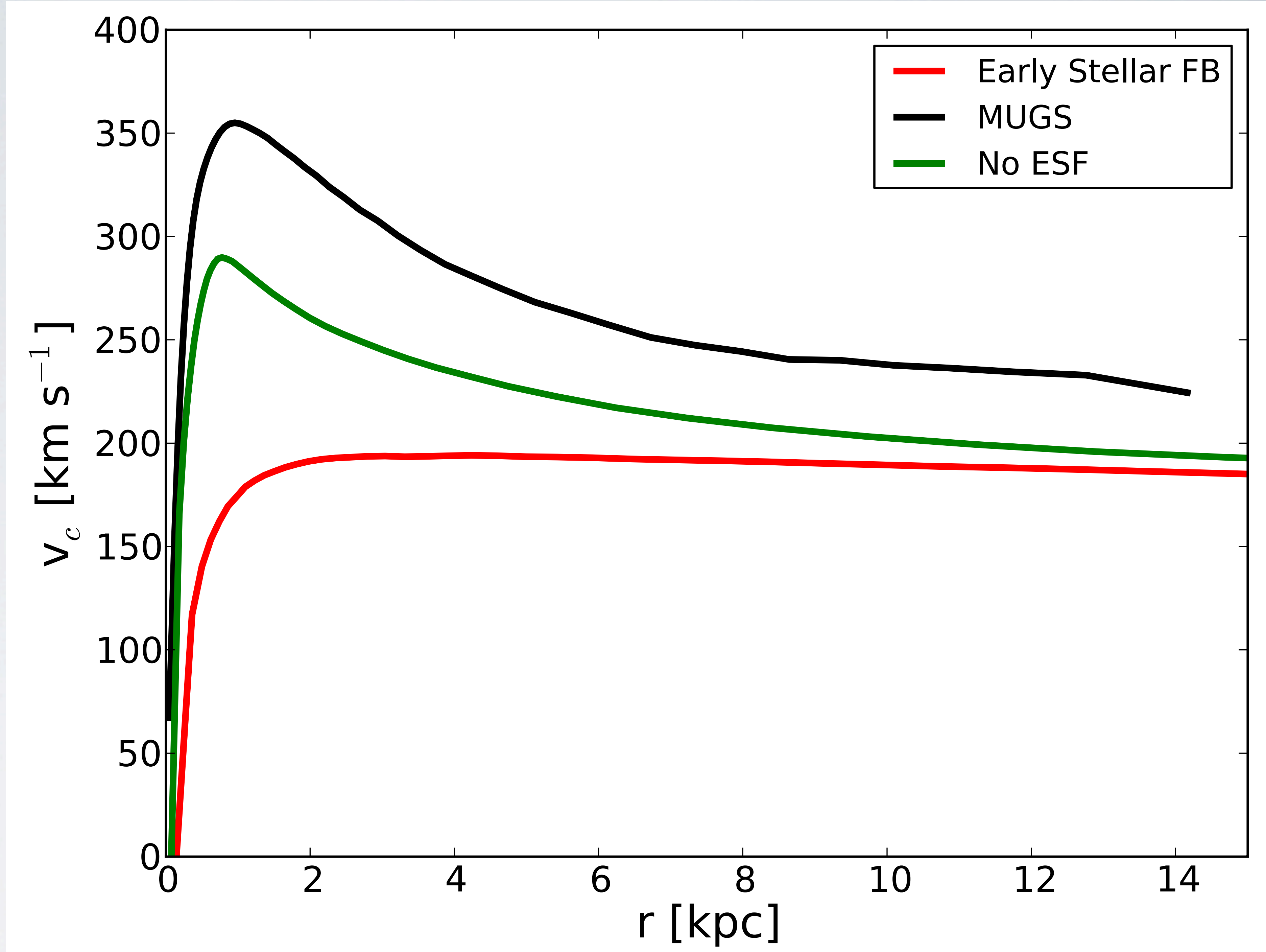
Stinson+ (2012b)



SURFACE BRIGHTNESS PROFILE

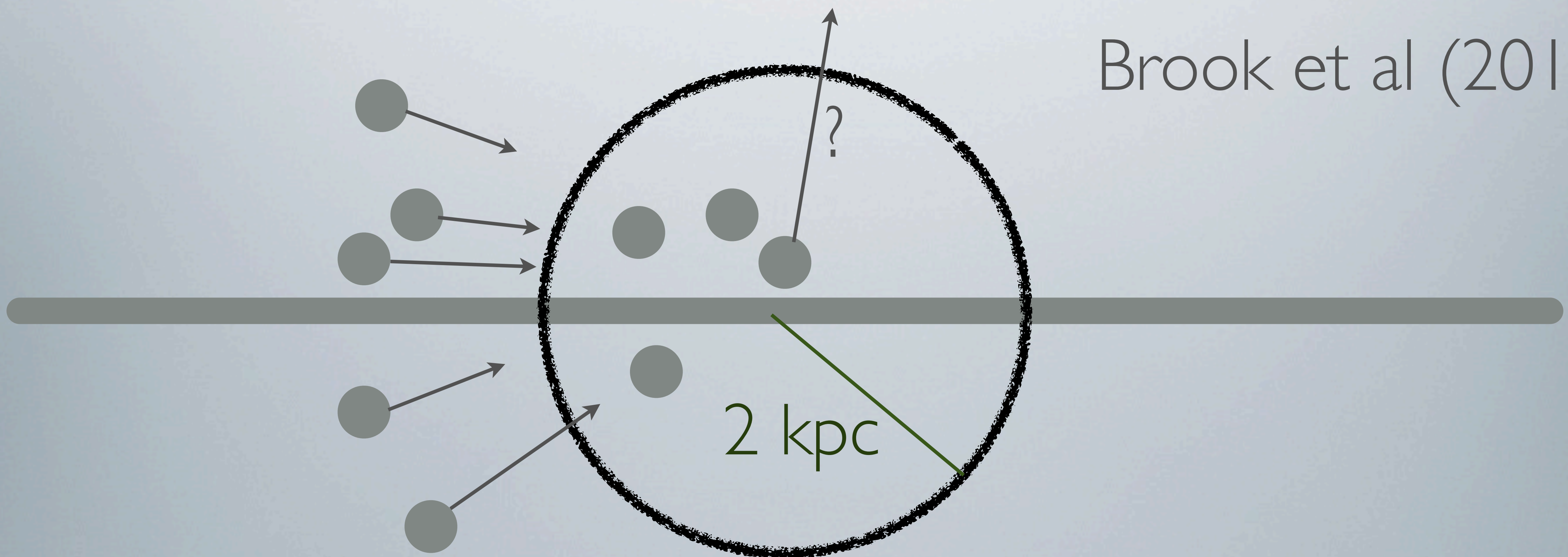
Exponential + Limited Bulge





ROTATION CURVE

Flat

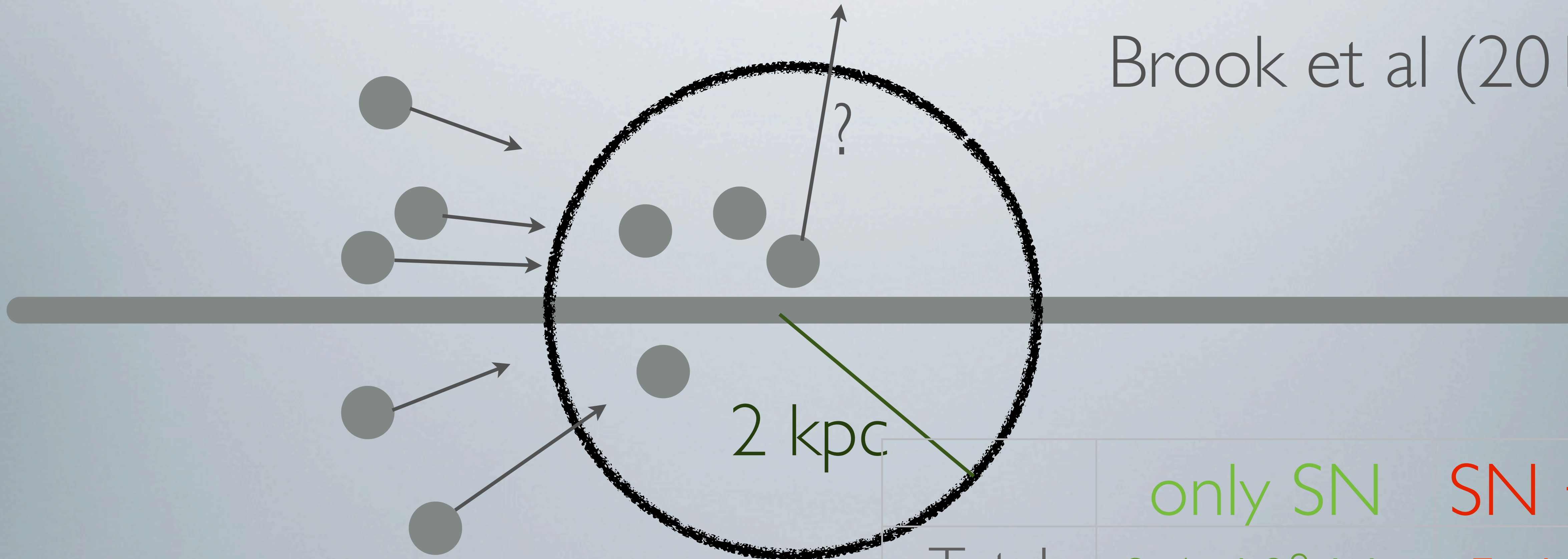


Brook et al (2012a)

WHAT HAPPENS TO LOW J_Z GAS?

Trace any particles that come within 2 kpc of center between $5.5 < z < 1.75$ to where they are at $z=0$

Brook et al (2012a)



	only SN	SN + ESF
Total	$8.4\times10^9\ M_\odot$	$5\times10^9\ M_\odot$
Stars	$5.6\times10^9\ M_\odot$	$1.8\times10^9\ M_\odot$
In Halo	$1.5\times10^9\ M_\odot$	$1.8\times10^9\ M_\odot$
In Disk	$0.7\times10^9\ M_\odot$	$1.3\times10^9\ M_\odot$

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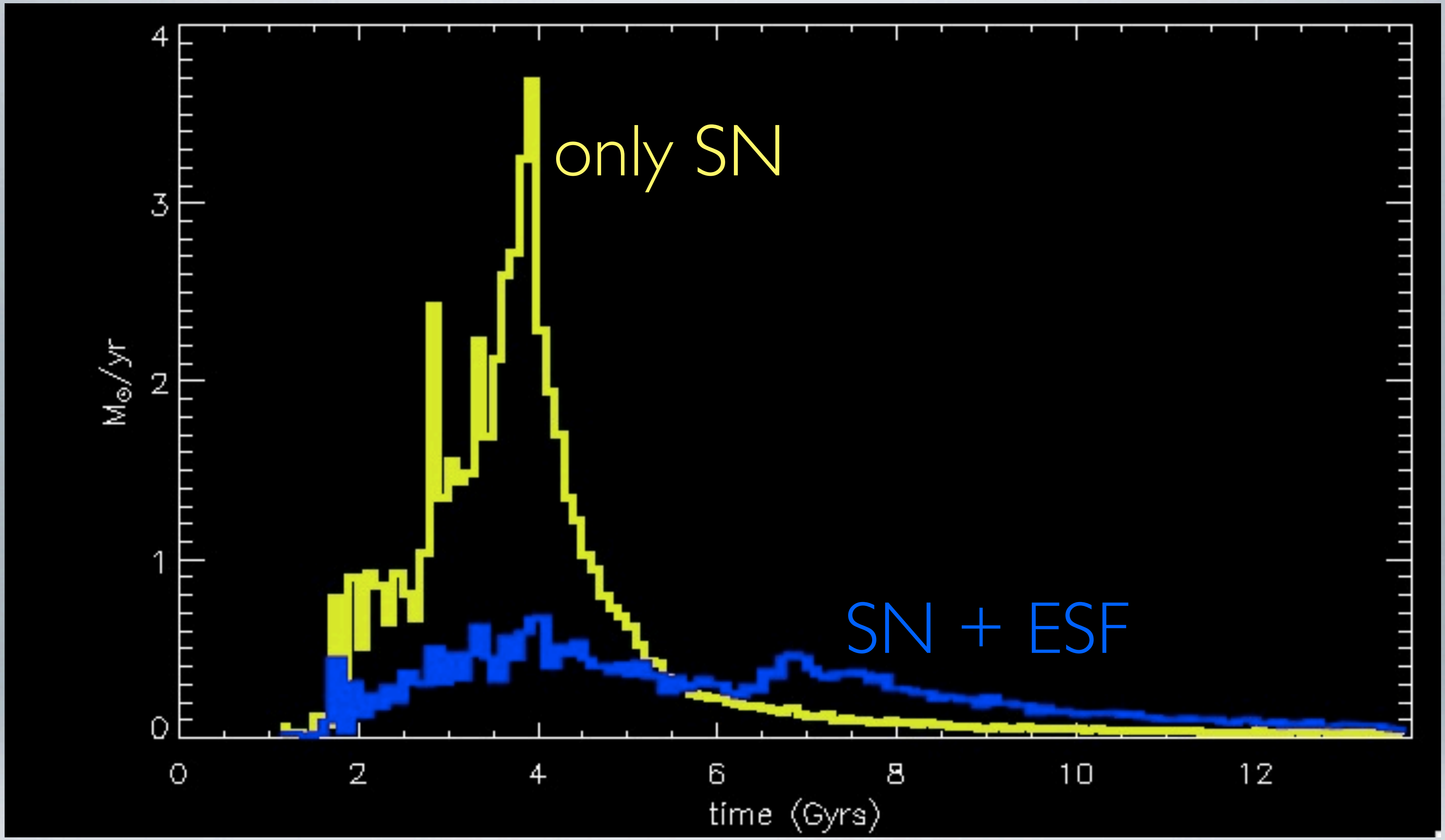
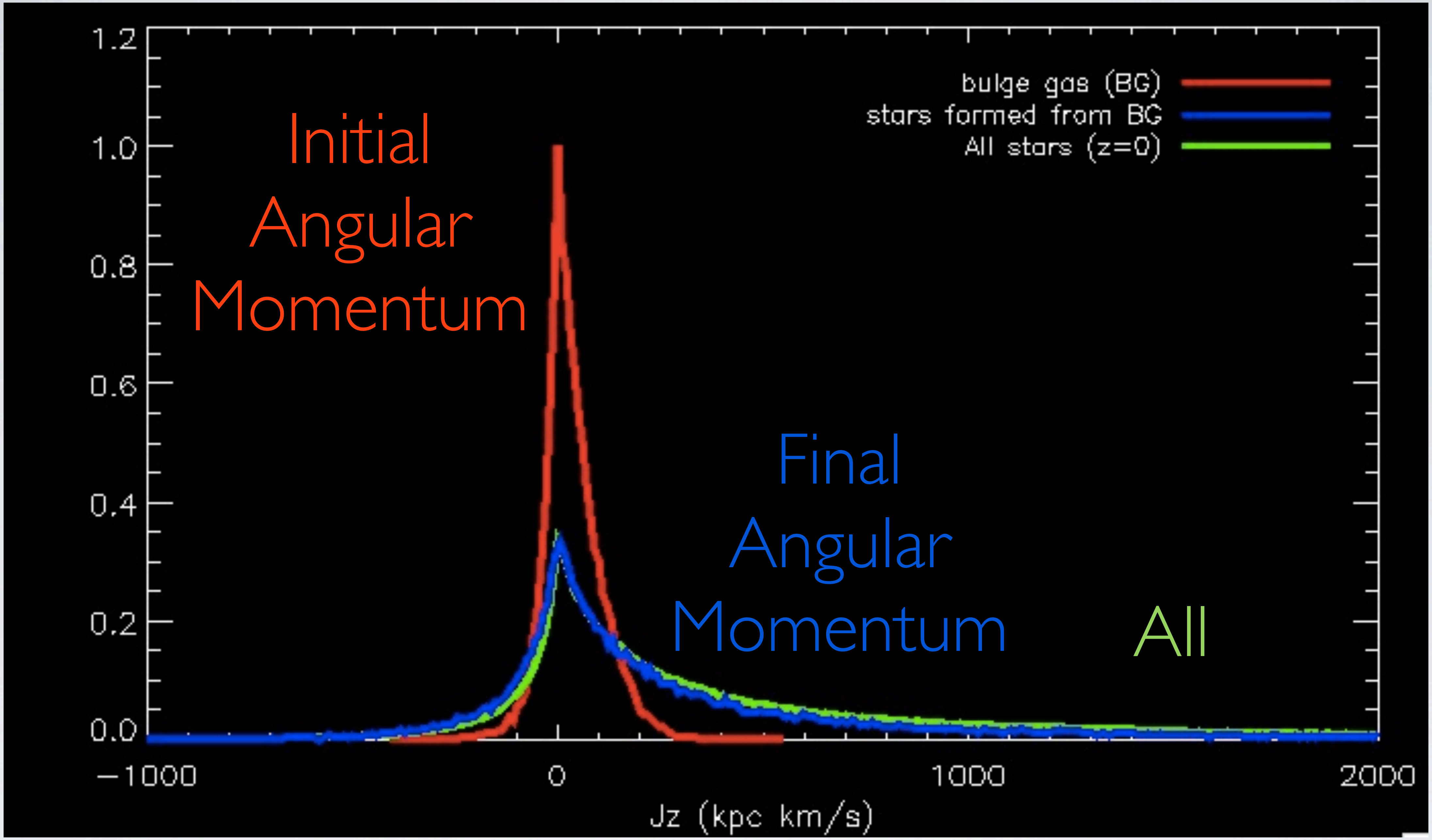


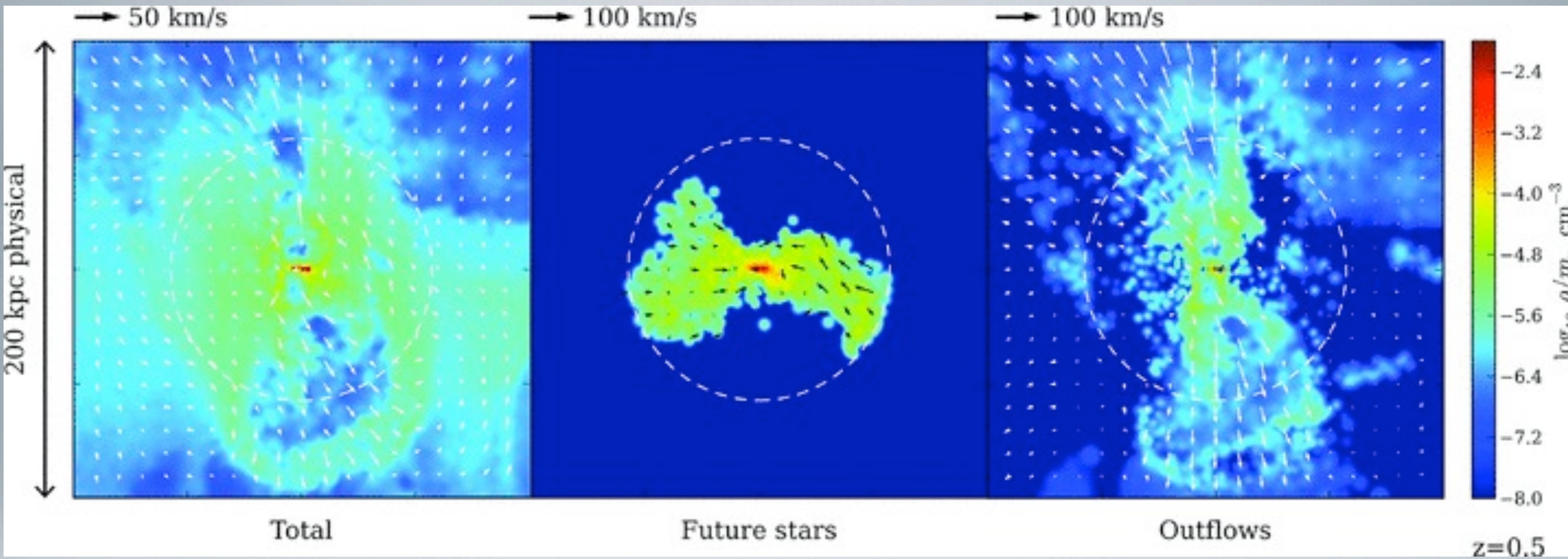
LOW ANGULAR MOMENTUM STAR FORMATION

Gas that entered bulge between $5.5 < z < 1.75$



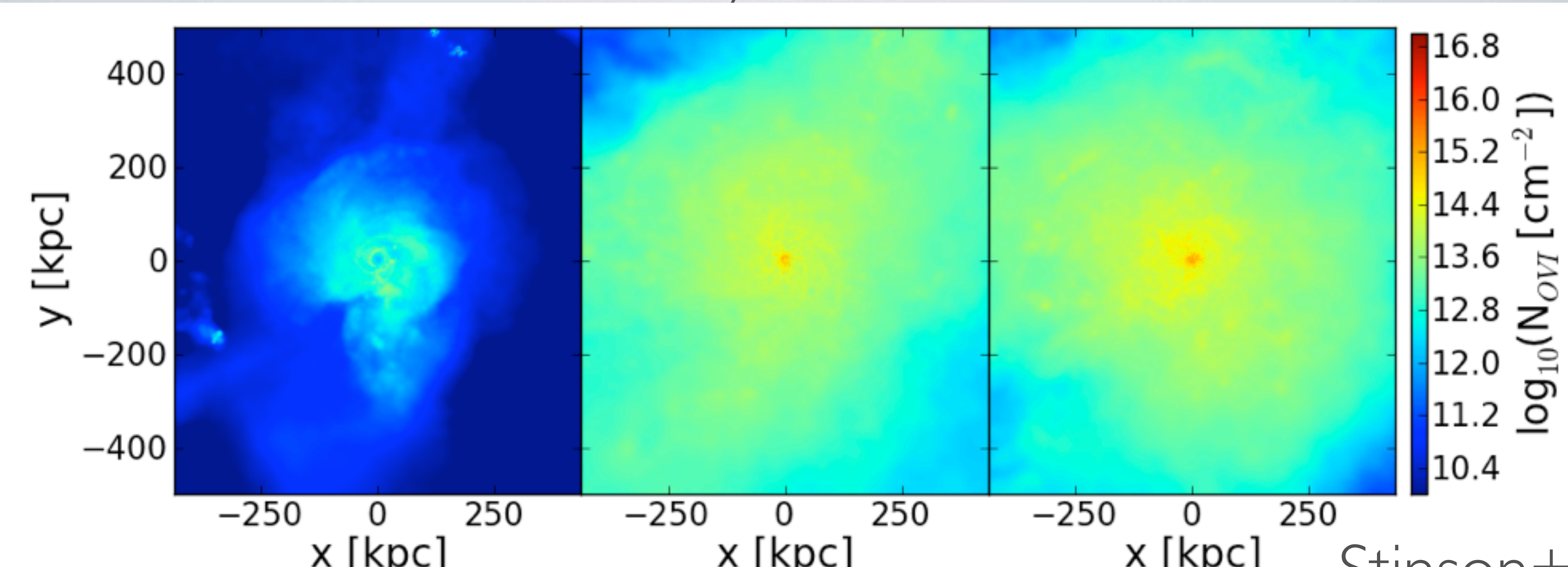
ANGULAR MOMENTUM REDISTRIBUTION

Brook et al (2011)



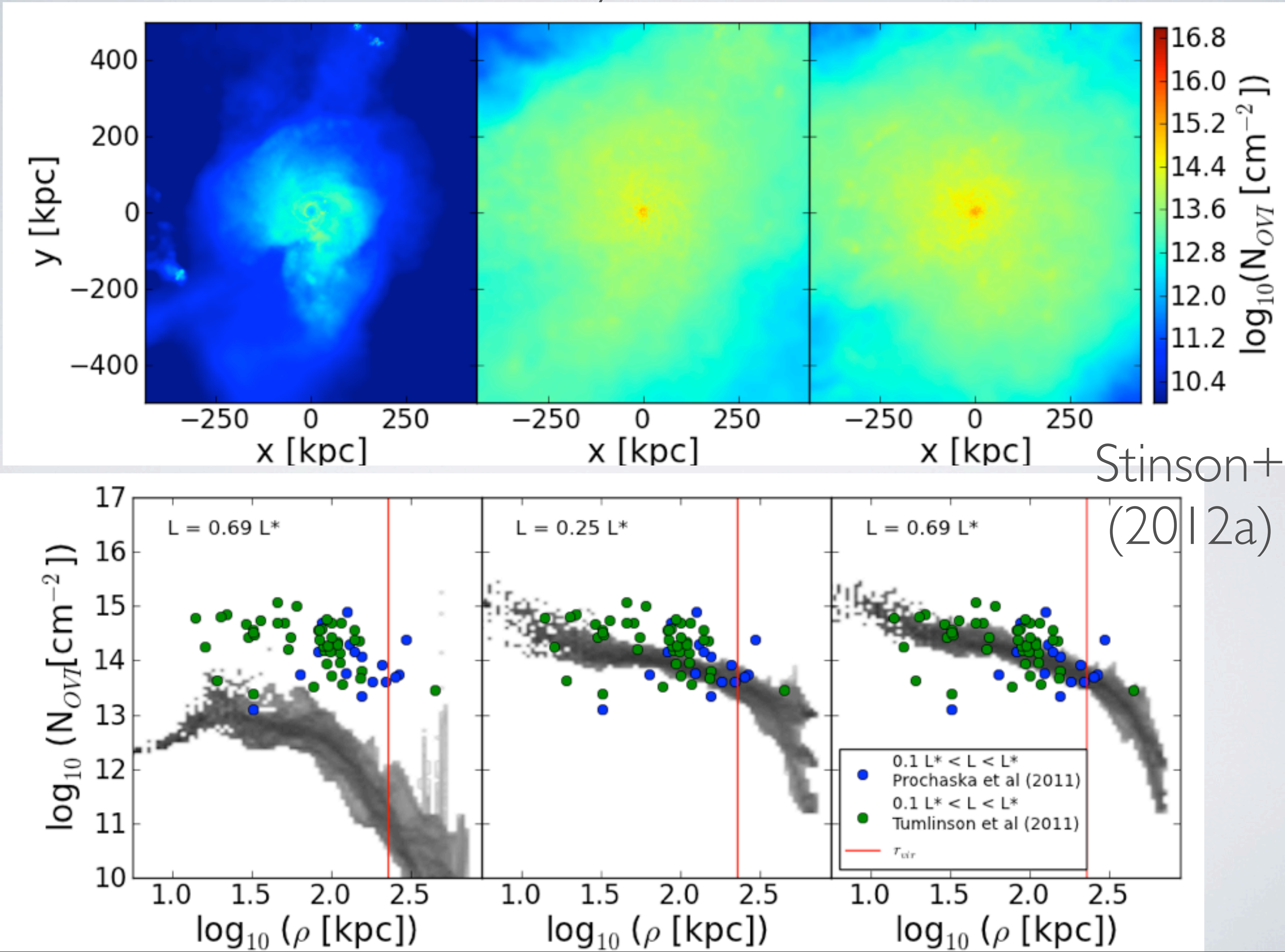
SIMULATED BARYON CYCLE

MUGS   only SN   SN+ESF

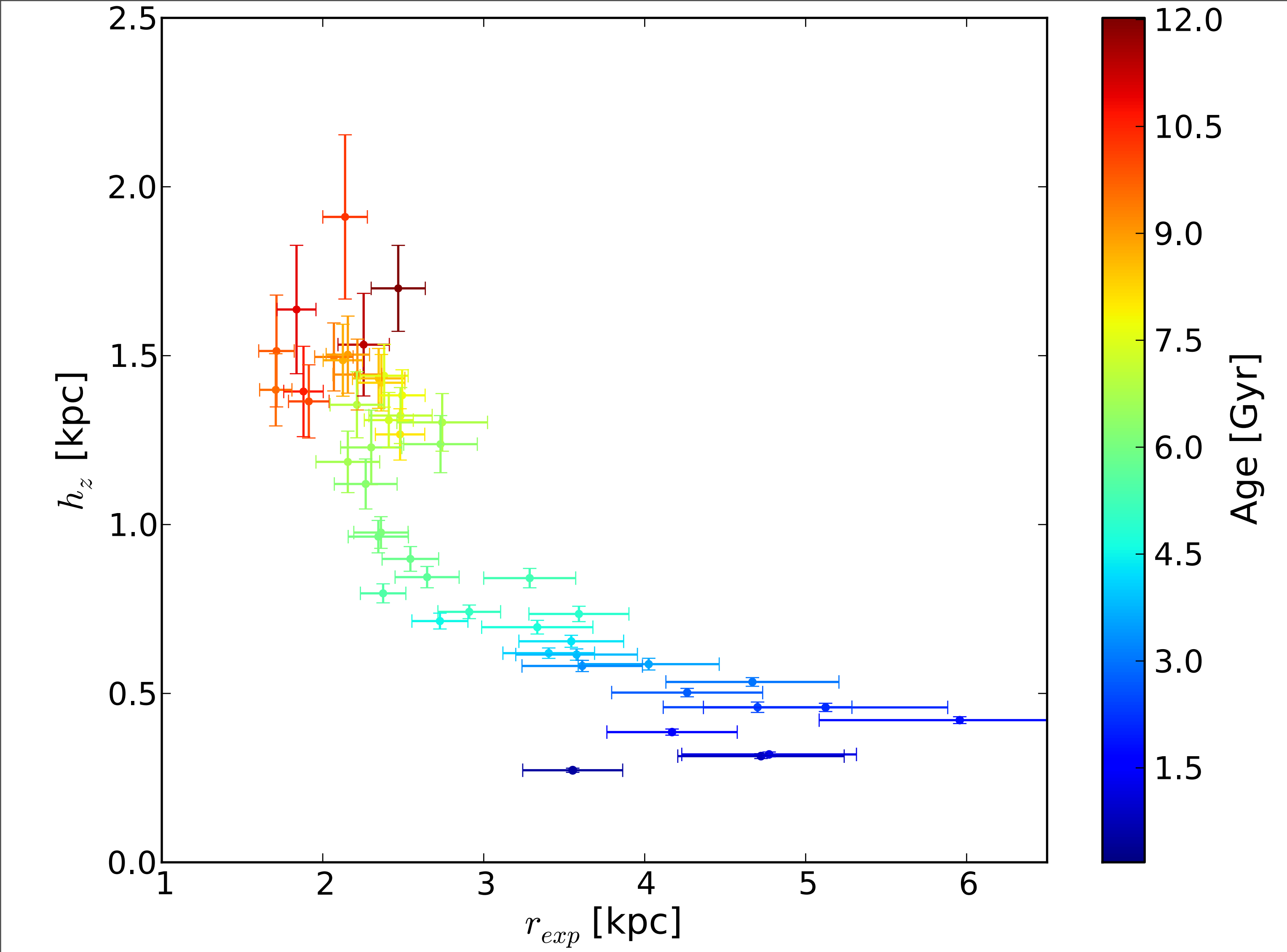


Stinson+ (2012a)

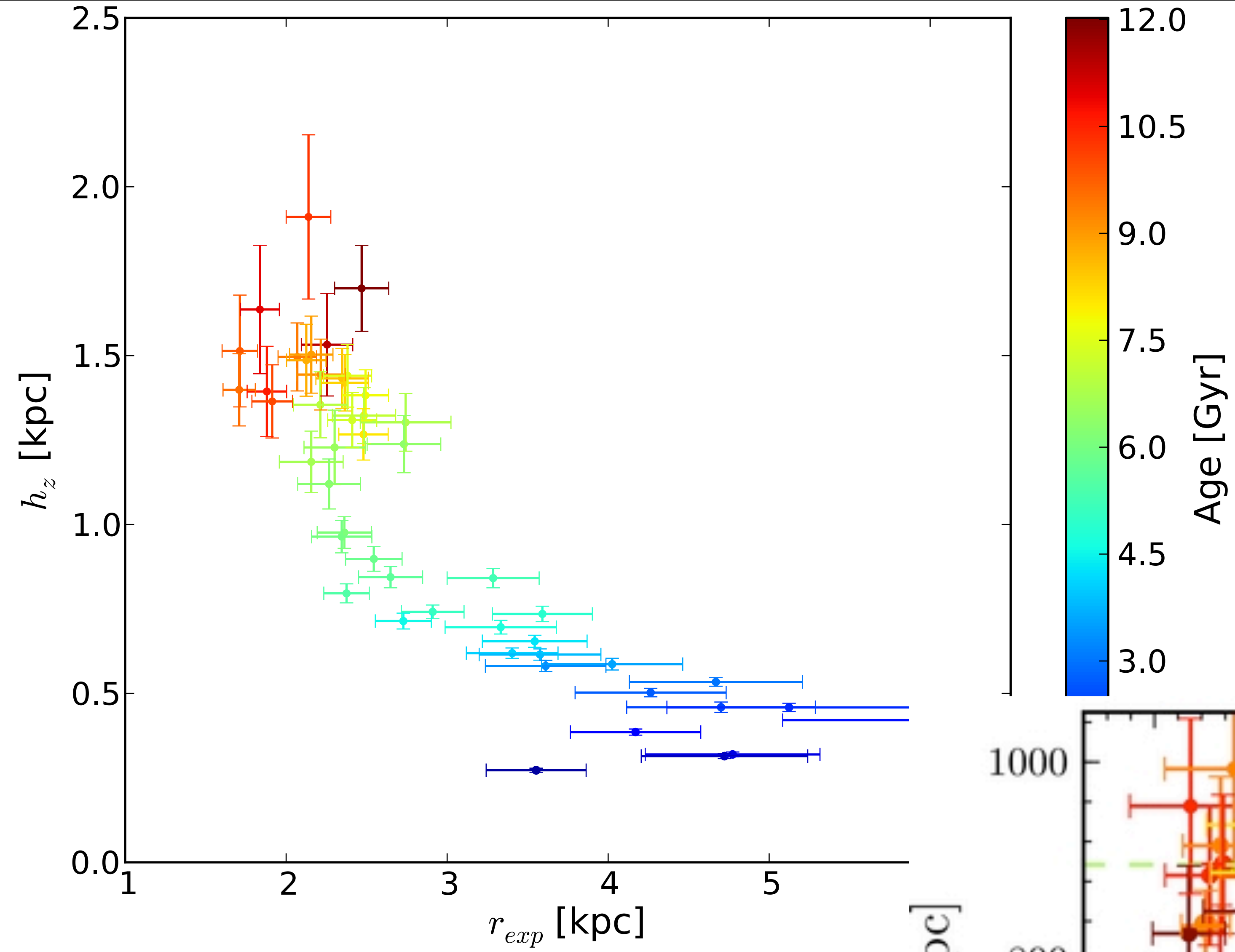
MUGS only SN SN+ESF



Stinson+ (2012a)



- Thick Disk Formation
- Stinson+ (in prep)



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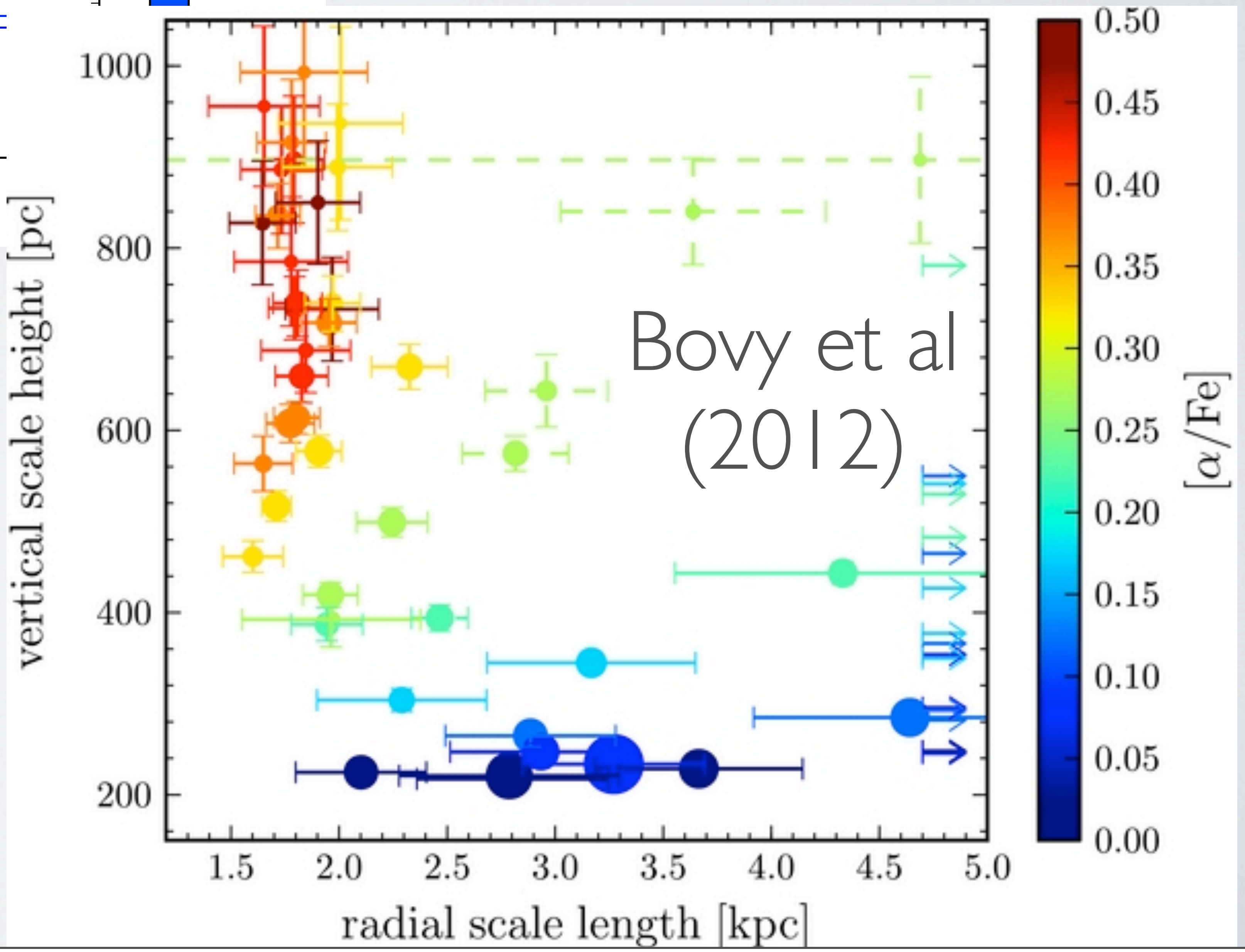

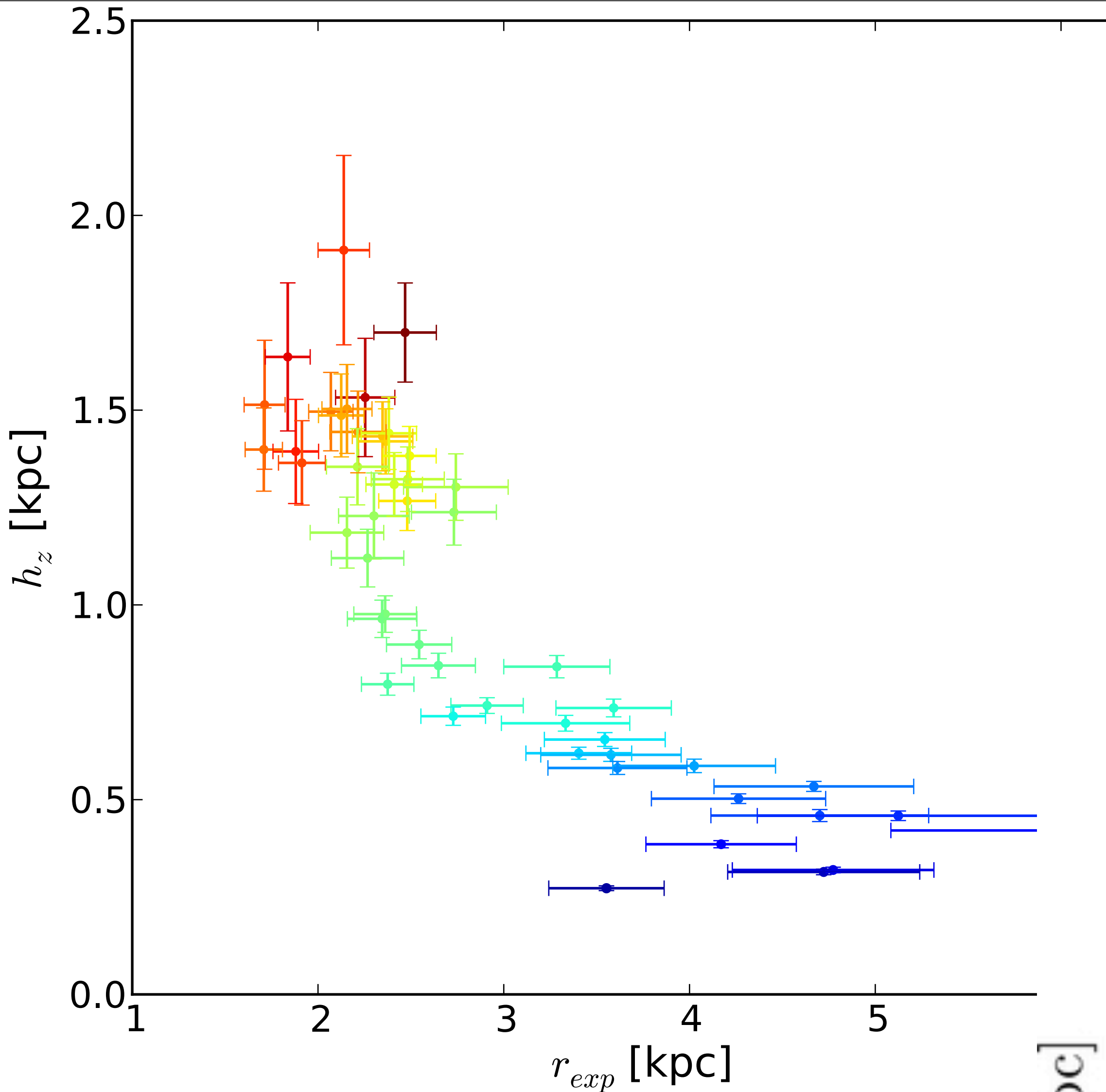

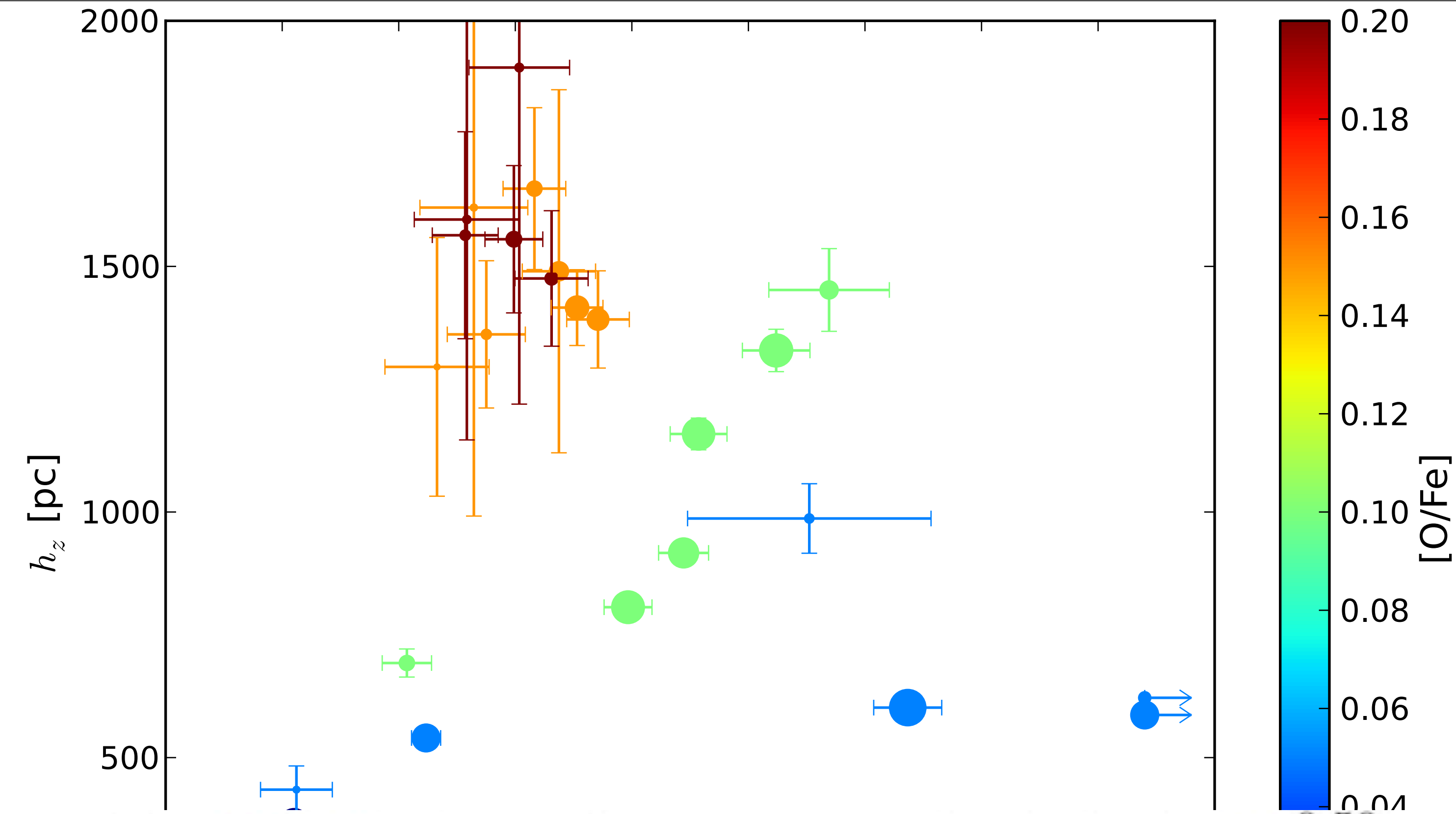

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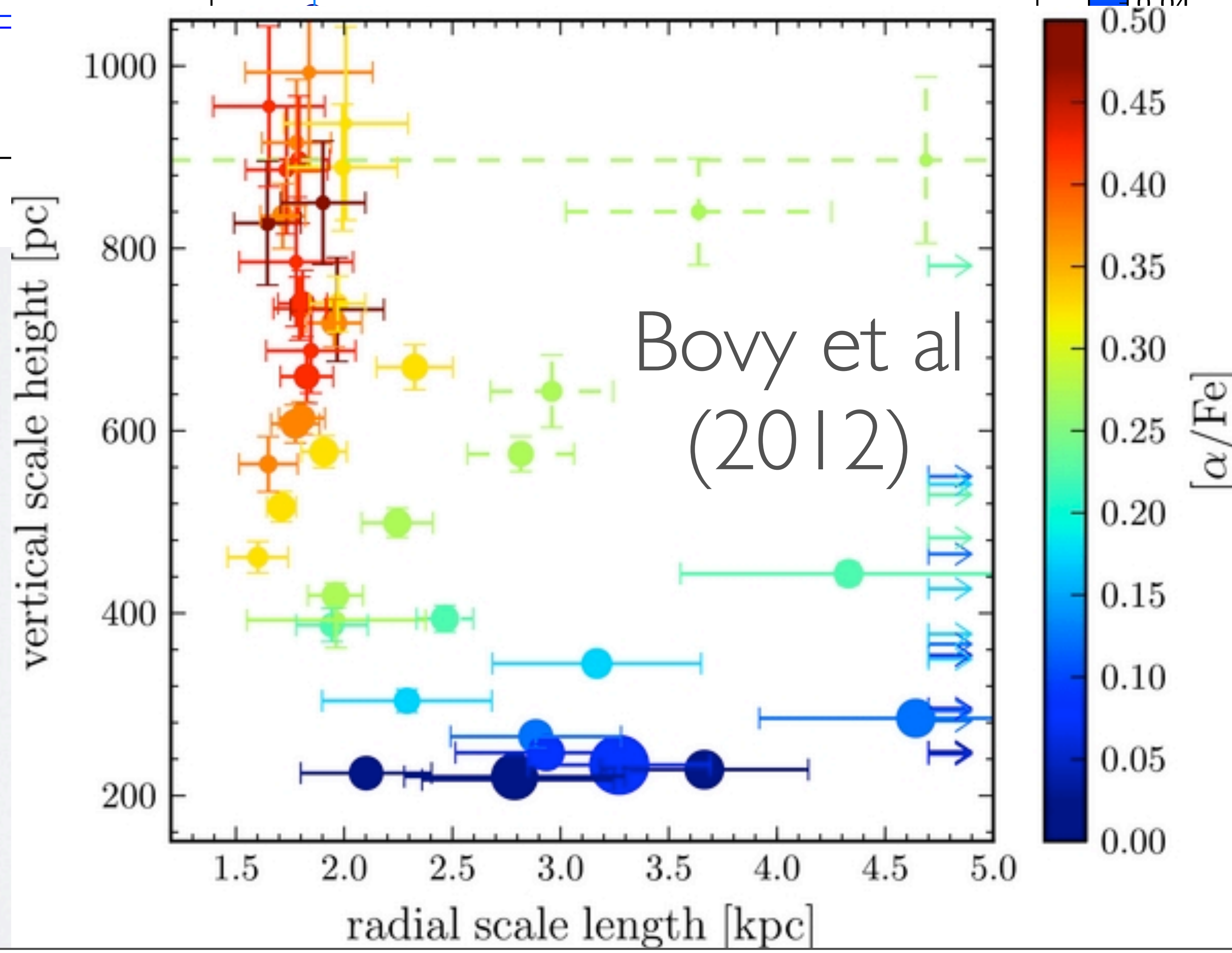
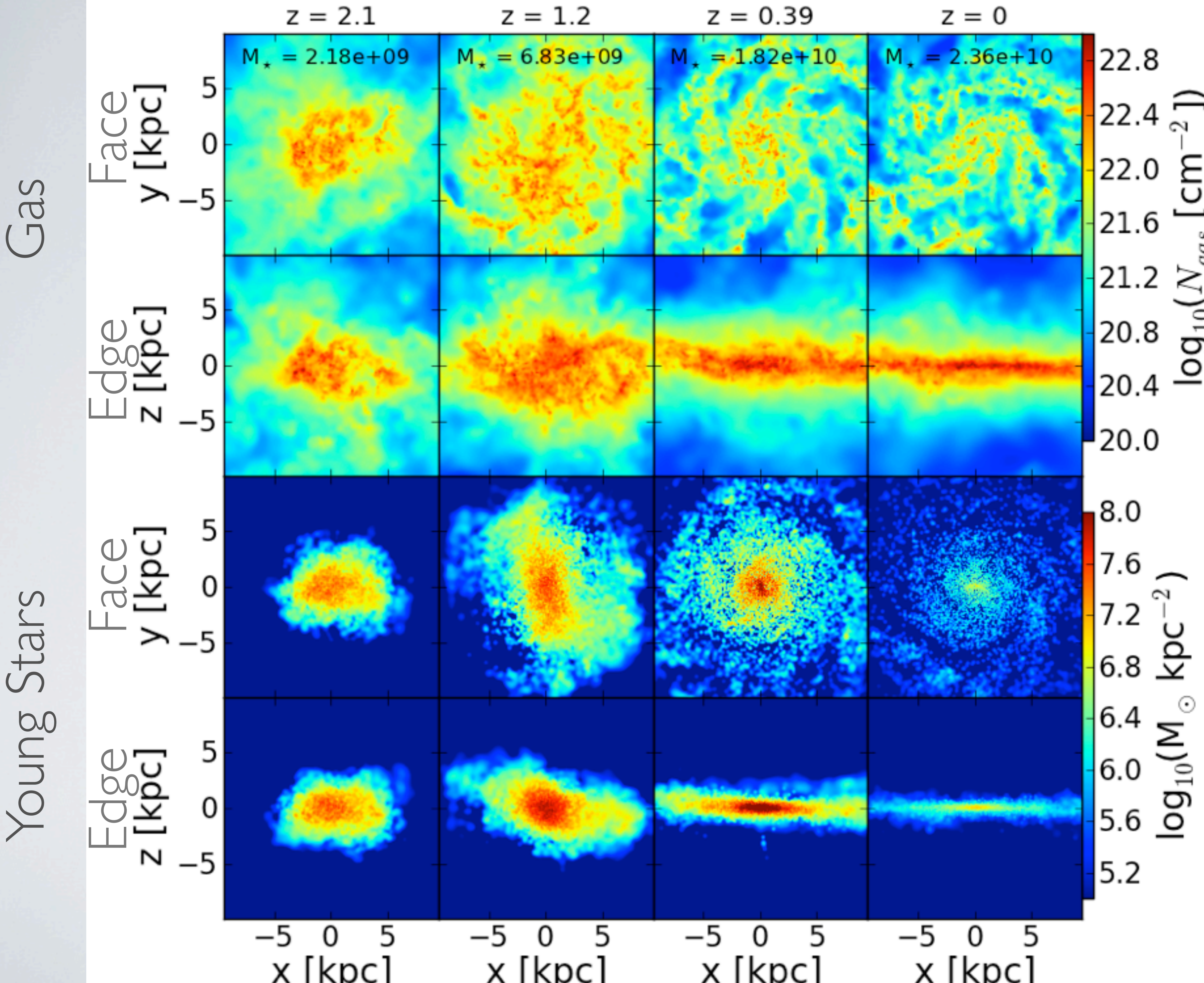
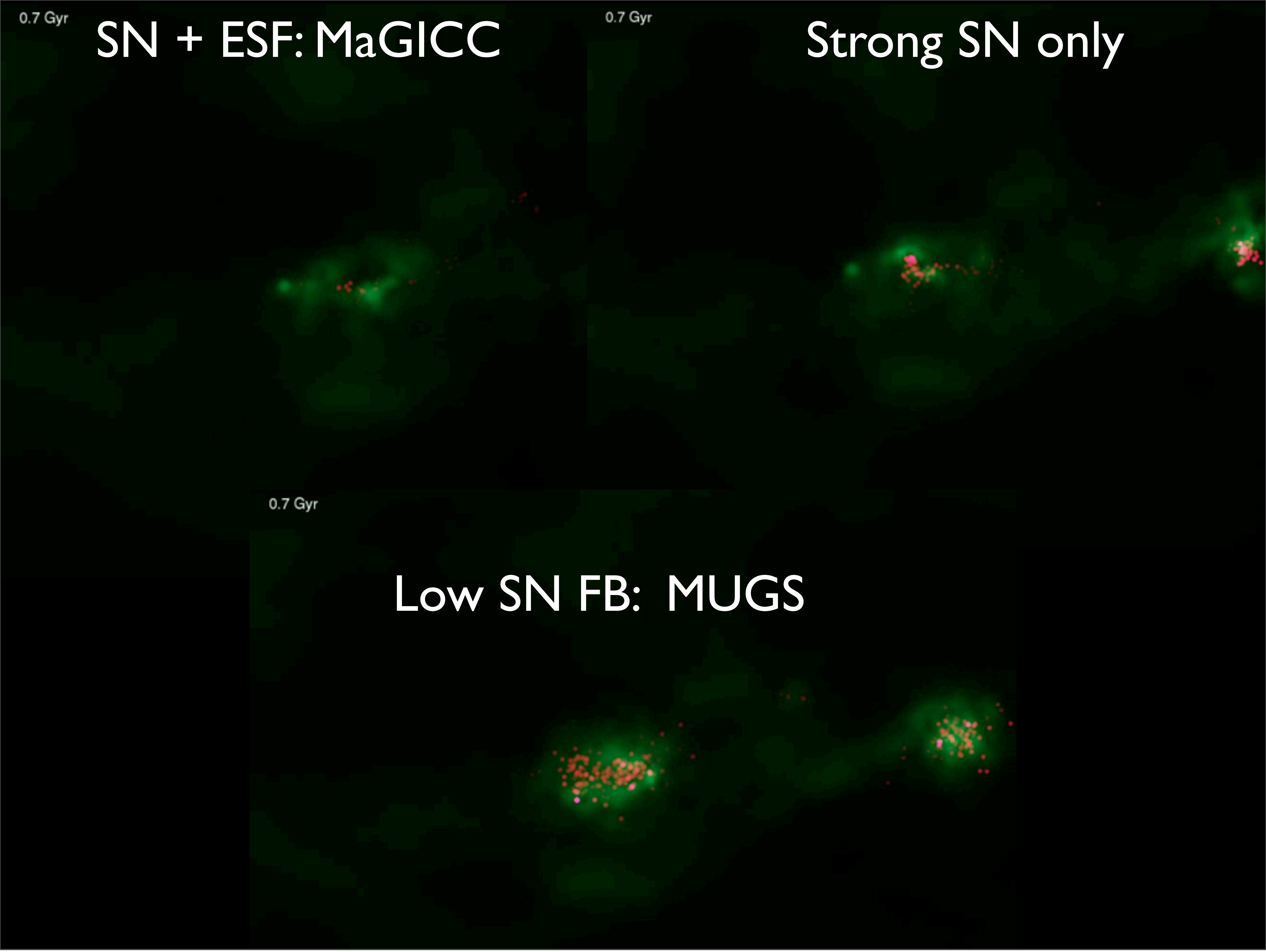
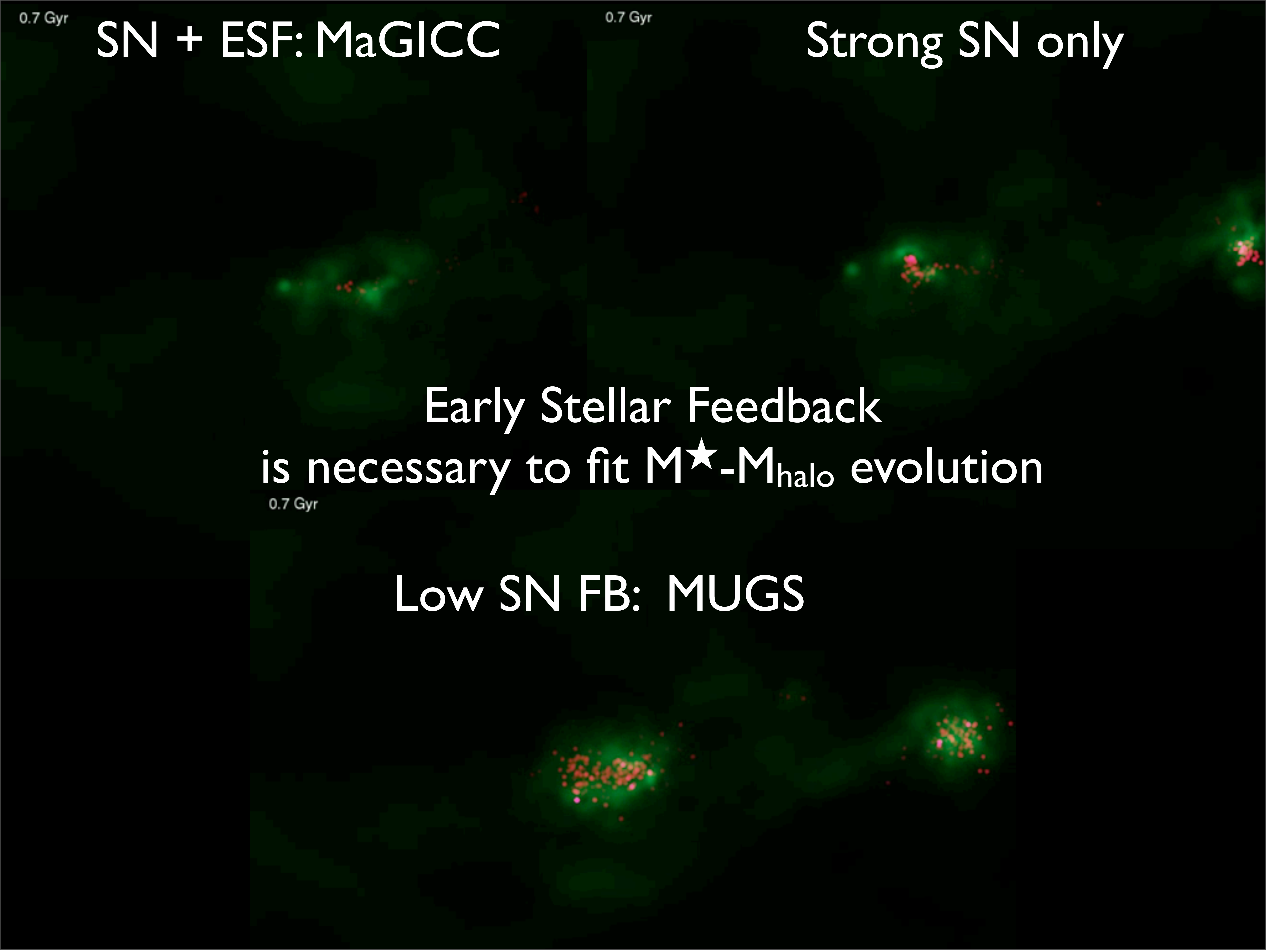
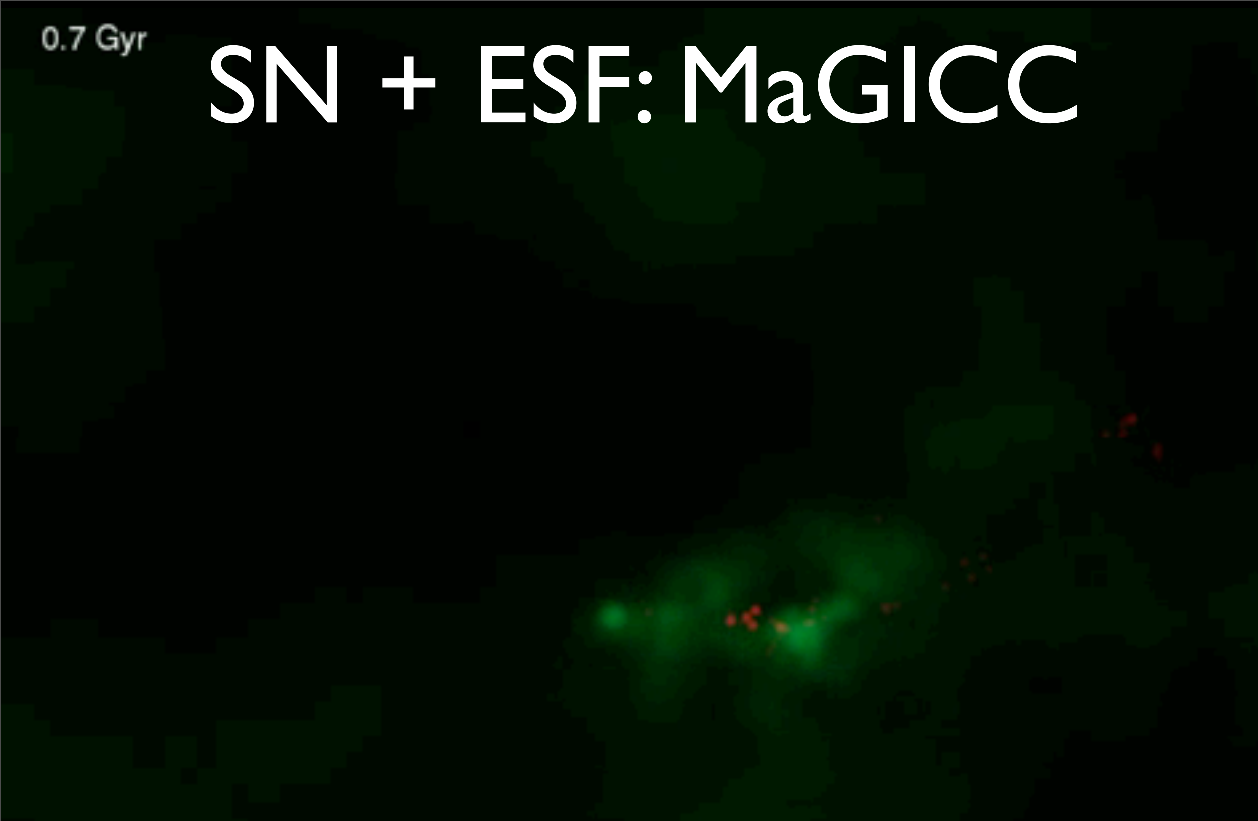




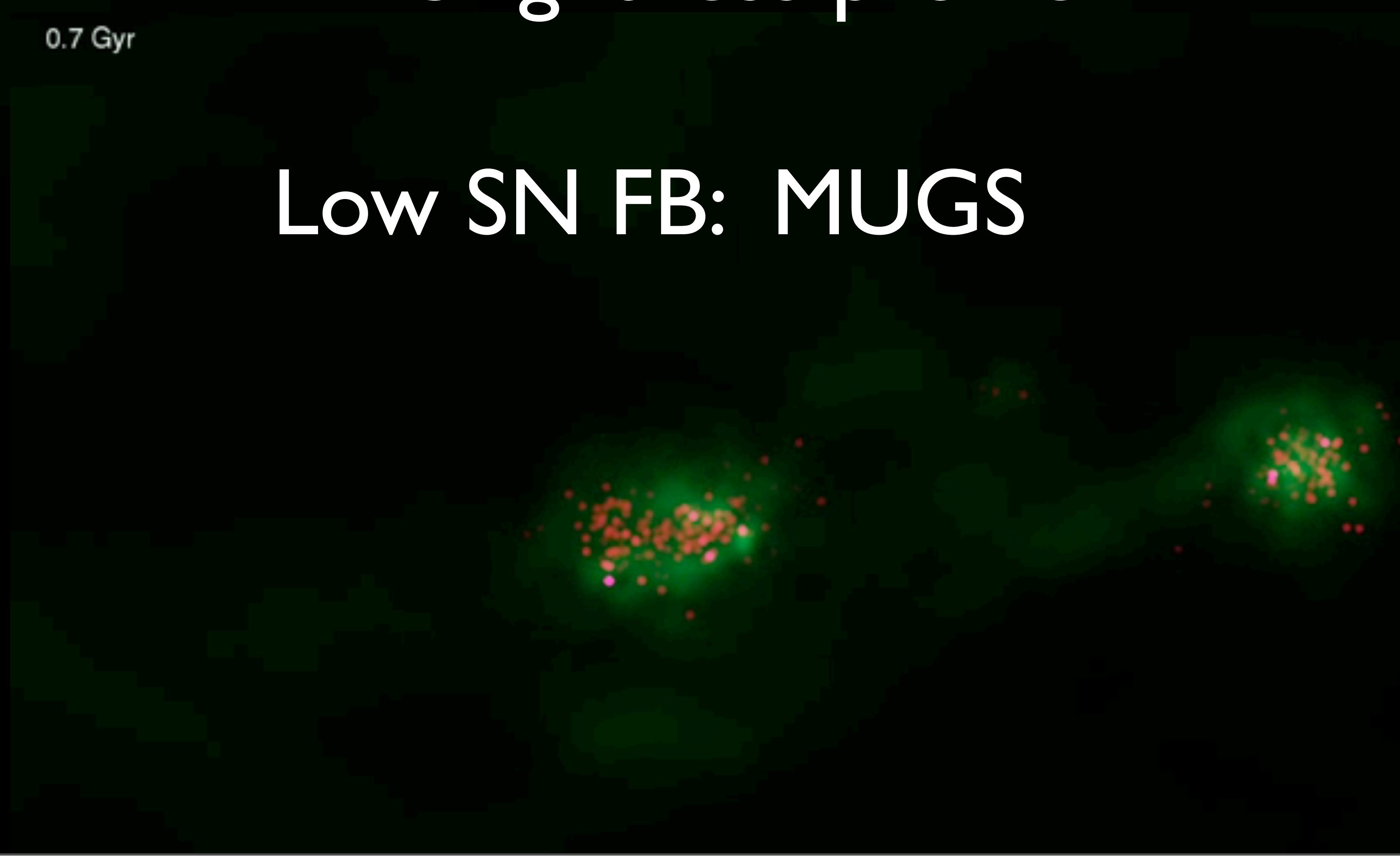
Gas
Young Stars
Face
Edge
Face
Edge
z = 2.1
z = 1.2
z = 0.39
z = 0
M⋆ = 2.18e+09
M⋆ = 6.83e+09
M⋆ = 1.82e+10
M⋆ = 2.36e+10
y [kpc]
z [kpc]
x [kpc]
$\log_{10}(N_{gas}\ [\mathrm{cm}^{-2}])$
$\log_{10}(\mathrm{M}_\odot\ \mathrm{kpc}^{-2})$

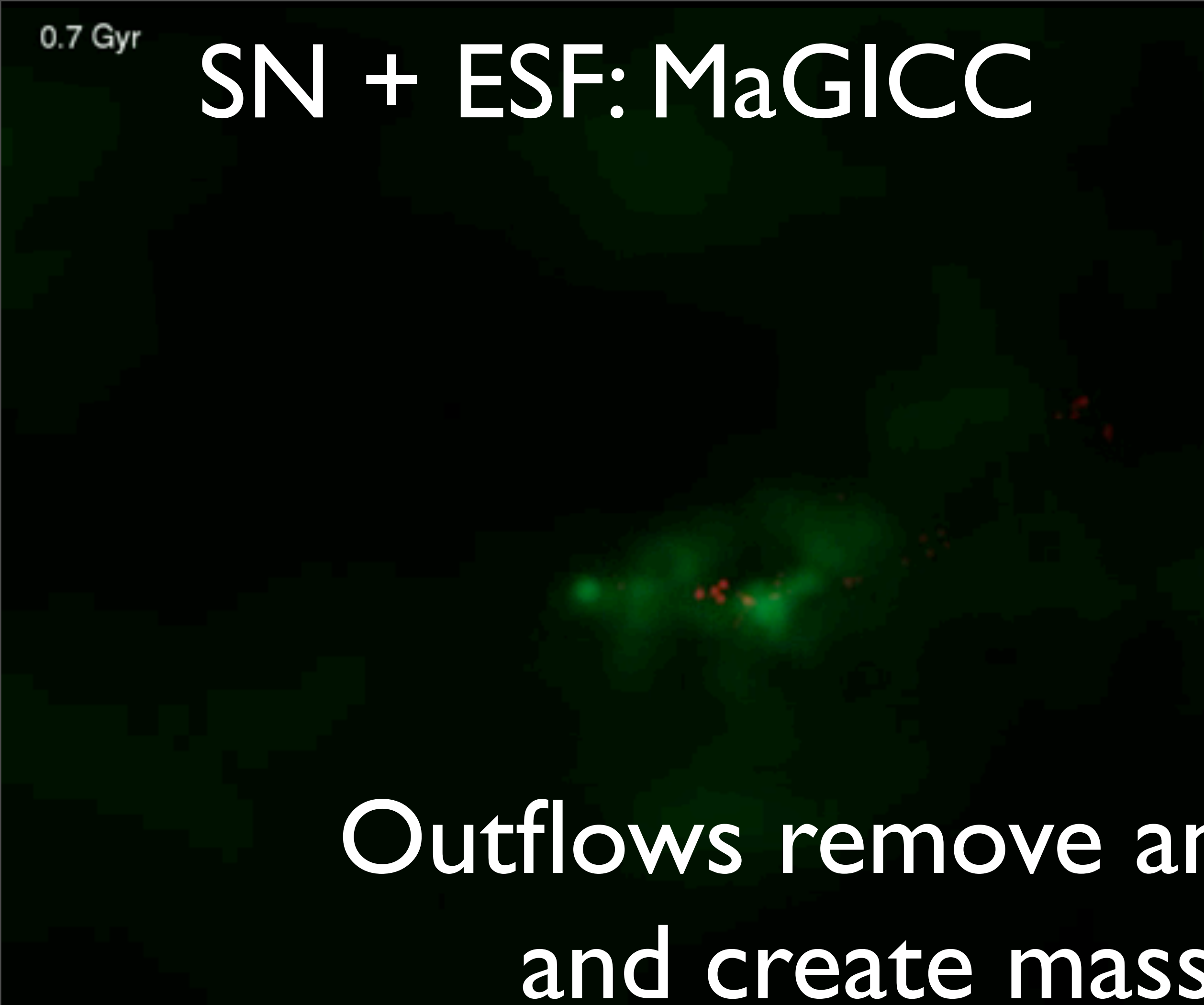

0.7 Gyr
SN + ESF: MaGICC
0.7 Gyr
Strong SN only
0.7 Gyr
Low SN FB: MUGS

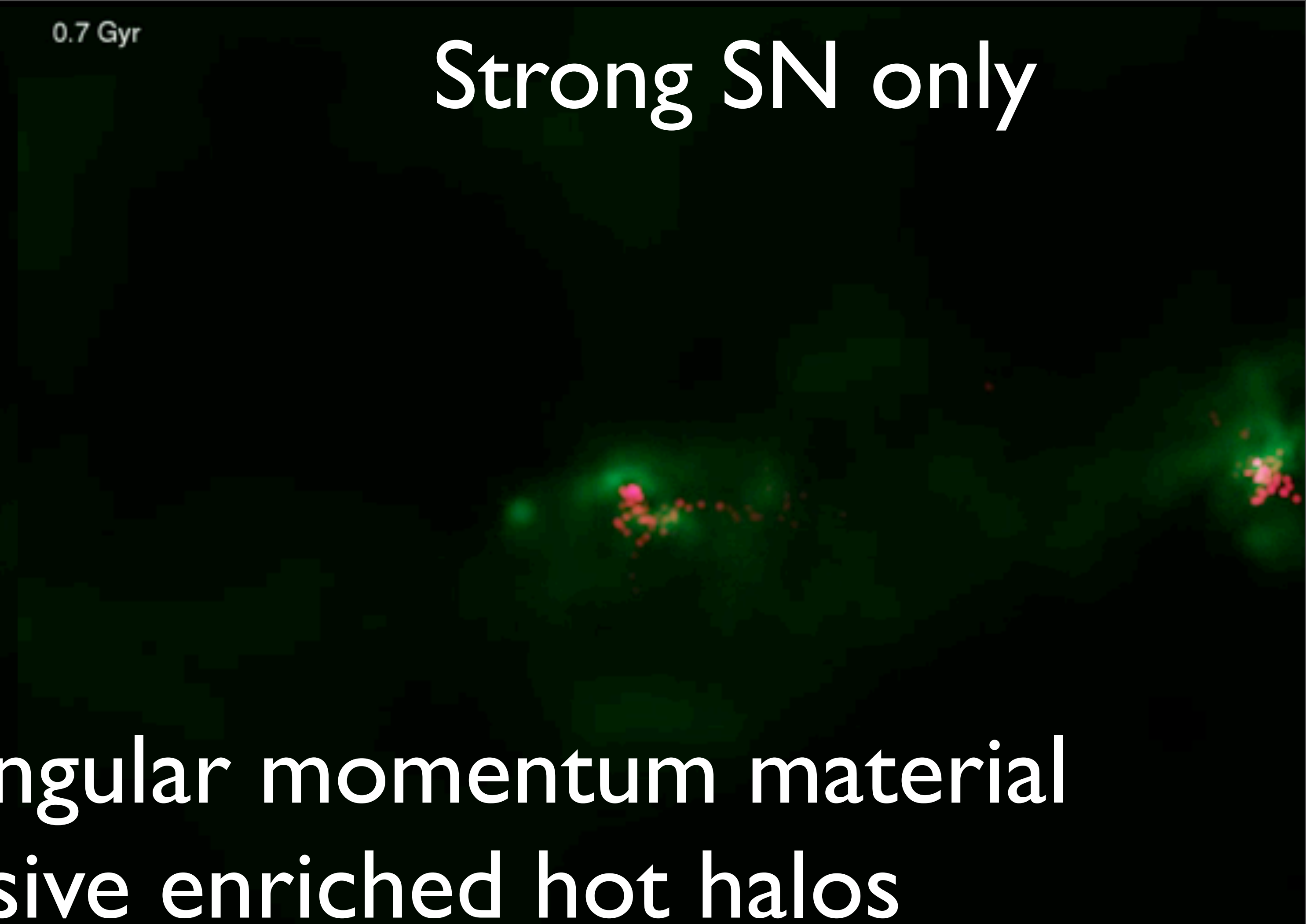

0.7 Gyr
SN + ESF: MaGICC
0.7 Gyr
Strong SN only
Early Stellar Feedback
is necessary to fit M★-Mhalo evolution
0.7 Gyr
Low SN FB: MUGS



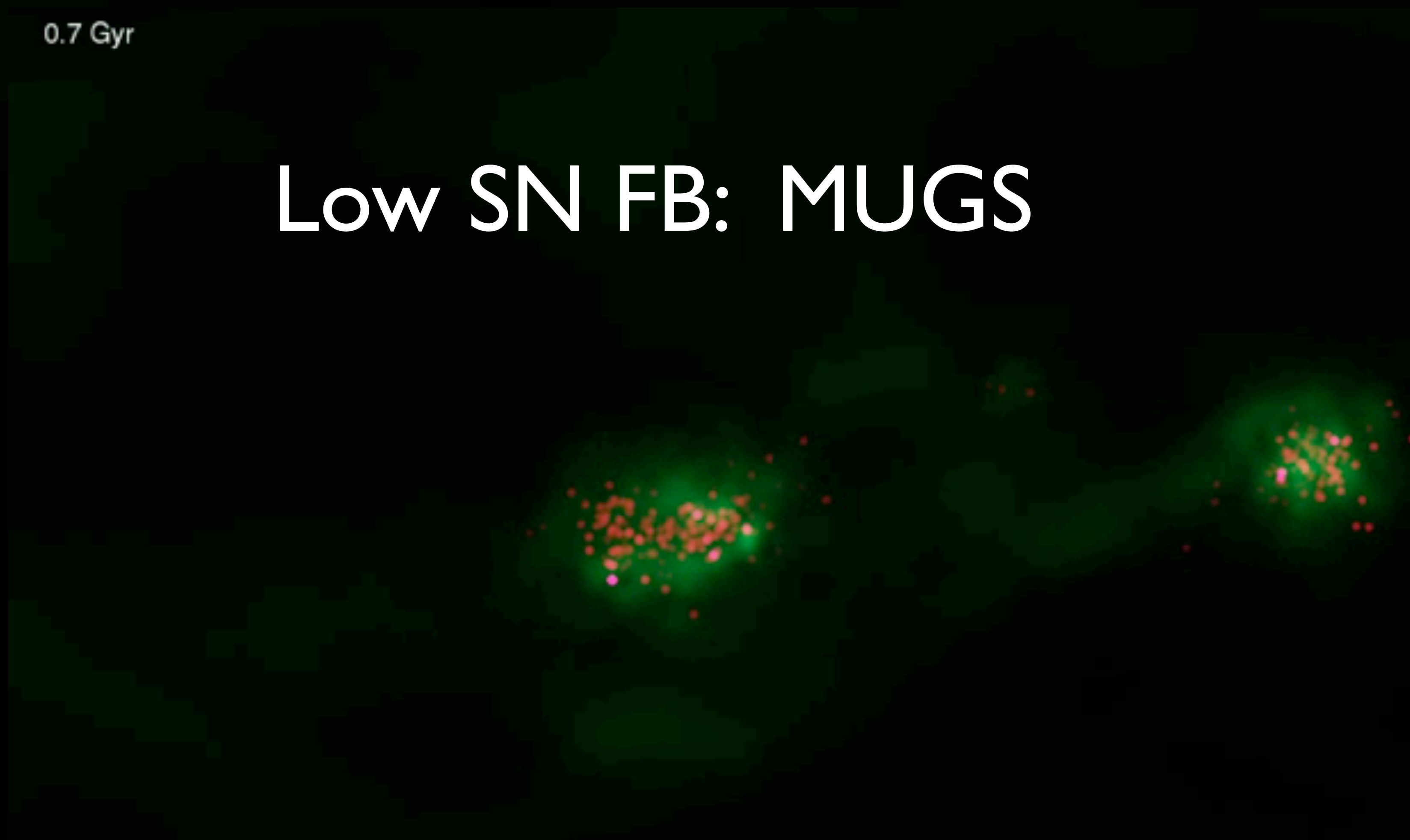
Galaxy has flat rotation curve, exponential surface brightness profile







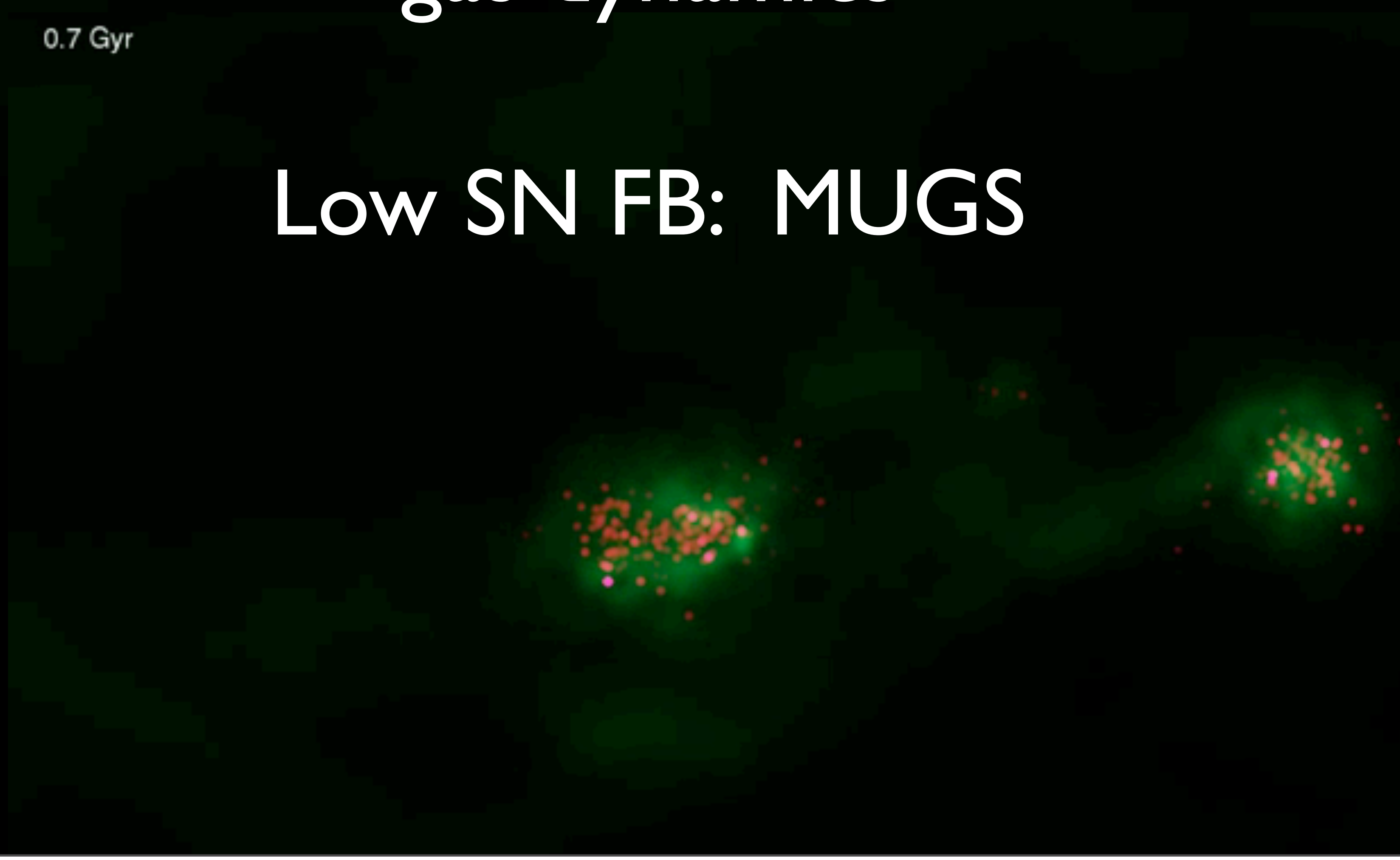
Outflows remove angular momentum material
and create massive enriched hot halos



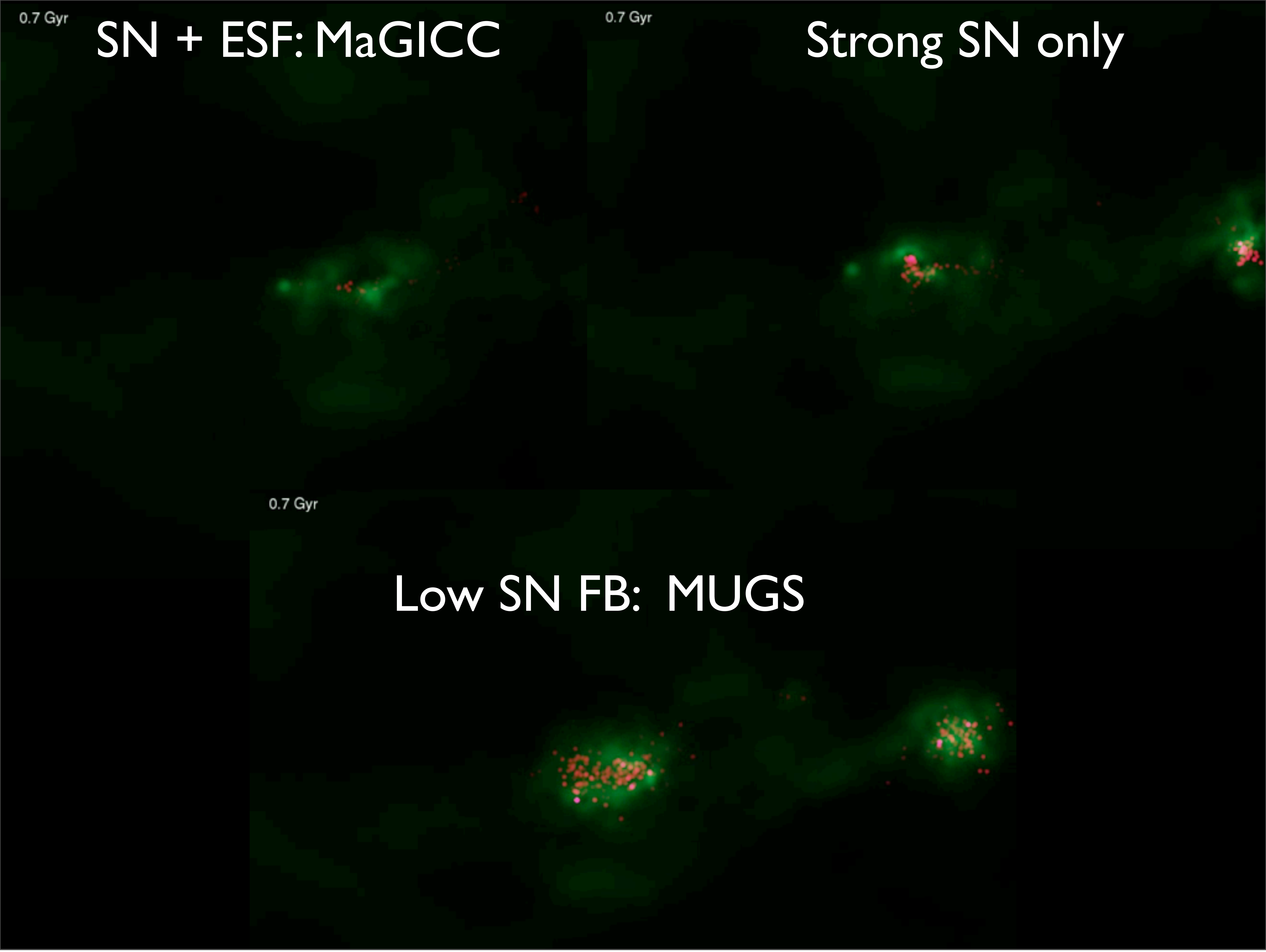
SN + ESF: MaGICC

Strong SN only

Thick and thin disk similar to MW that form based on gas dynamics



Low SN FB: MUGS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