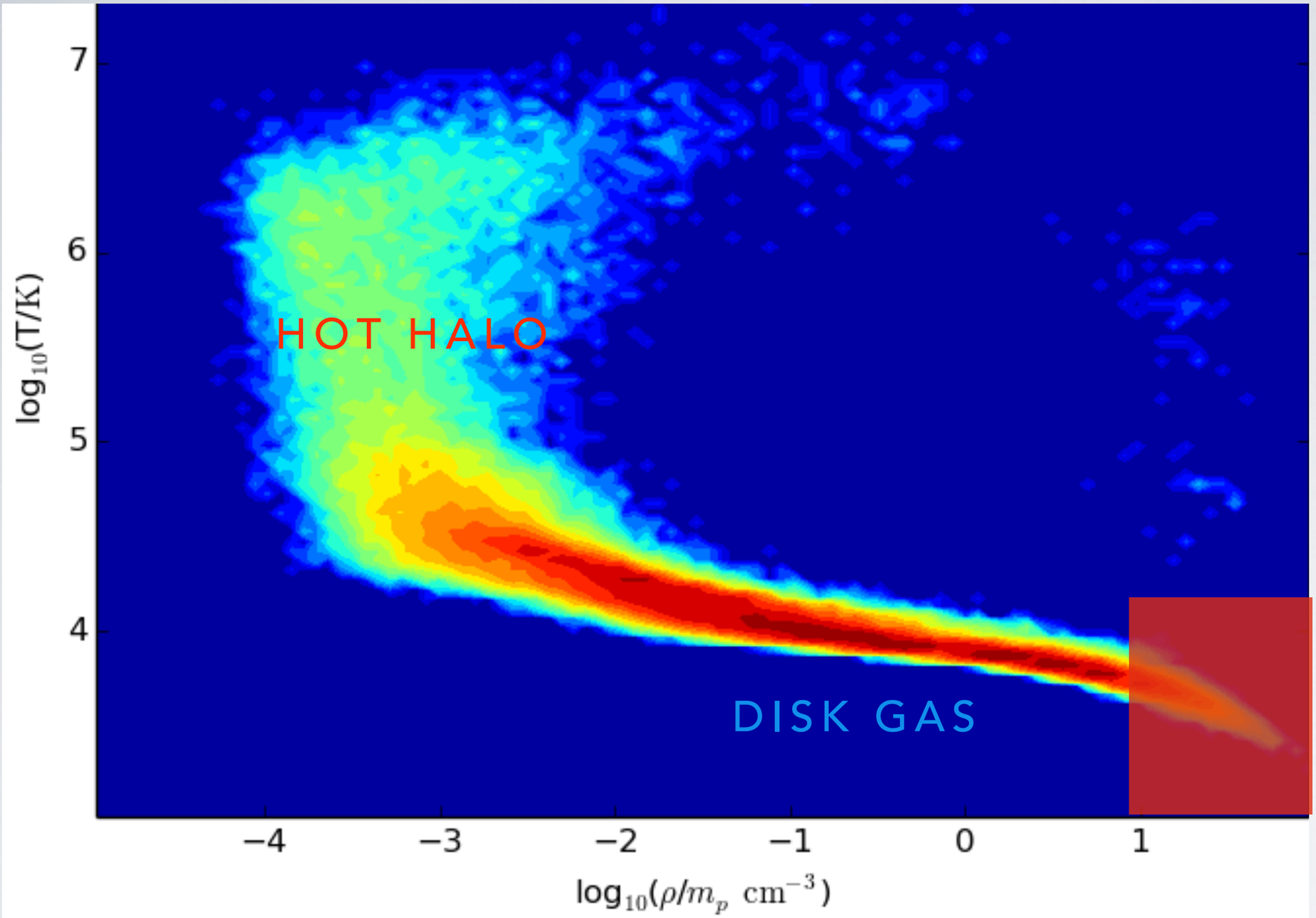
GAS MIXES

high
density

low
density

Springel
(2010)

Rayleigh-Taylor Test: High density medium starts on top of low density medium and they mix (oil+vinegar)



highest resolved density

$$n_{th} = \frac{50 \times 10^5\ M_\odot}{(310\ pc)^3}$$

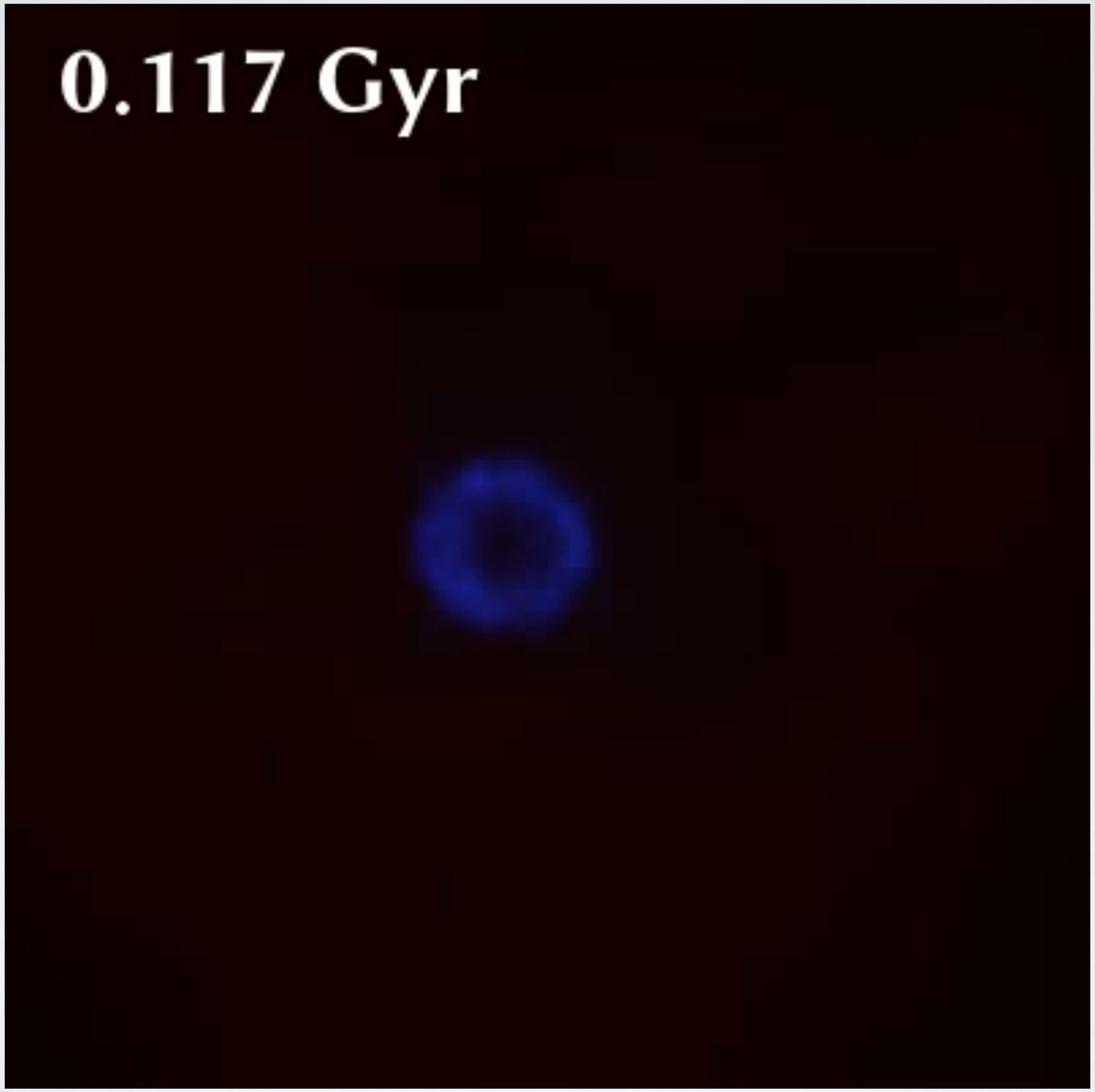
$n_{th} = 10\ cm^{-3}$

STARS FORM FROM COOL, DENSE GAS

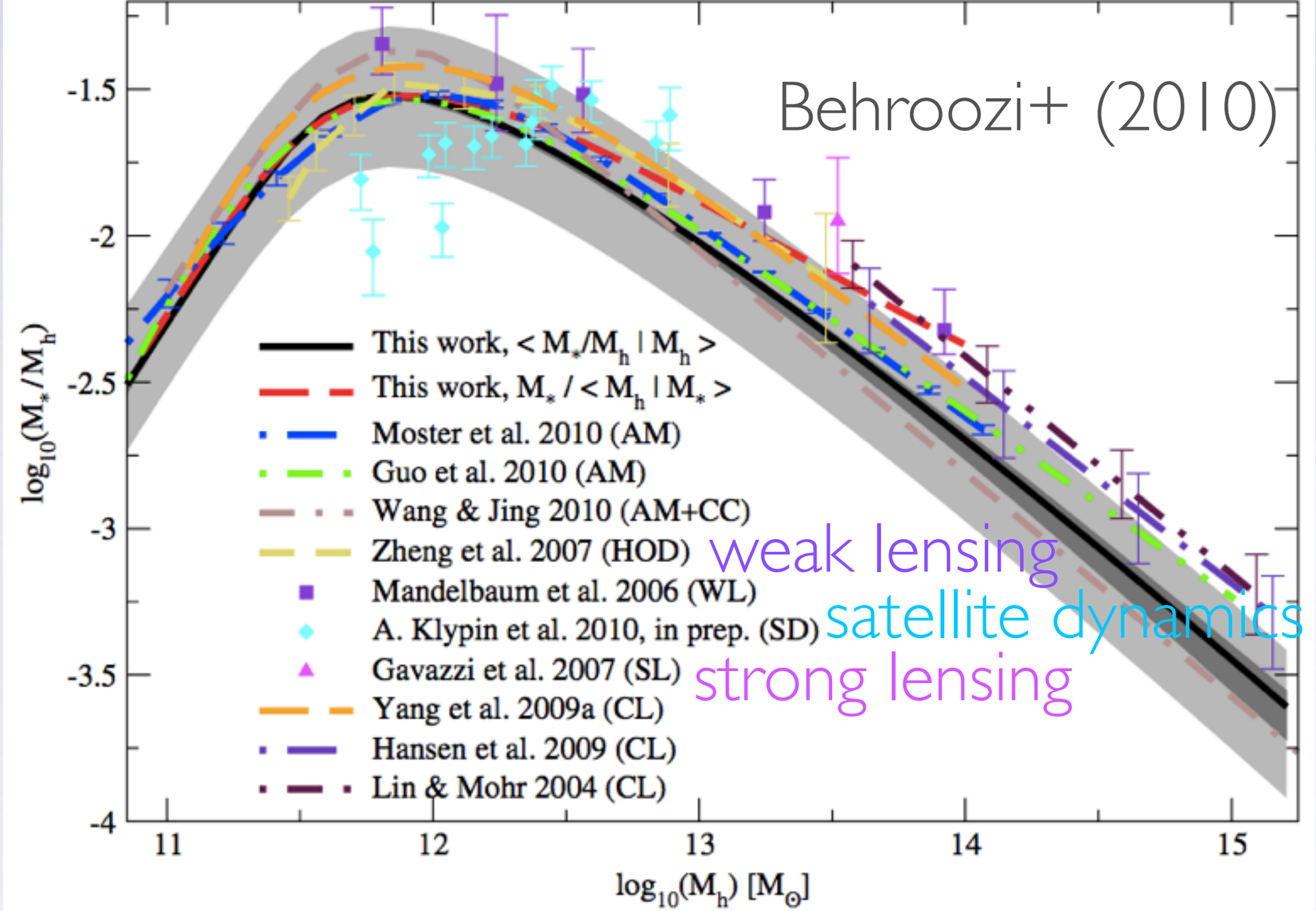
$T_{max} = 15000$ K; $n_{min} = 10$ cm-3 (resolved density)

Inherit kinematics and chemistry from parent gas

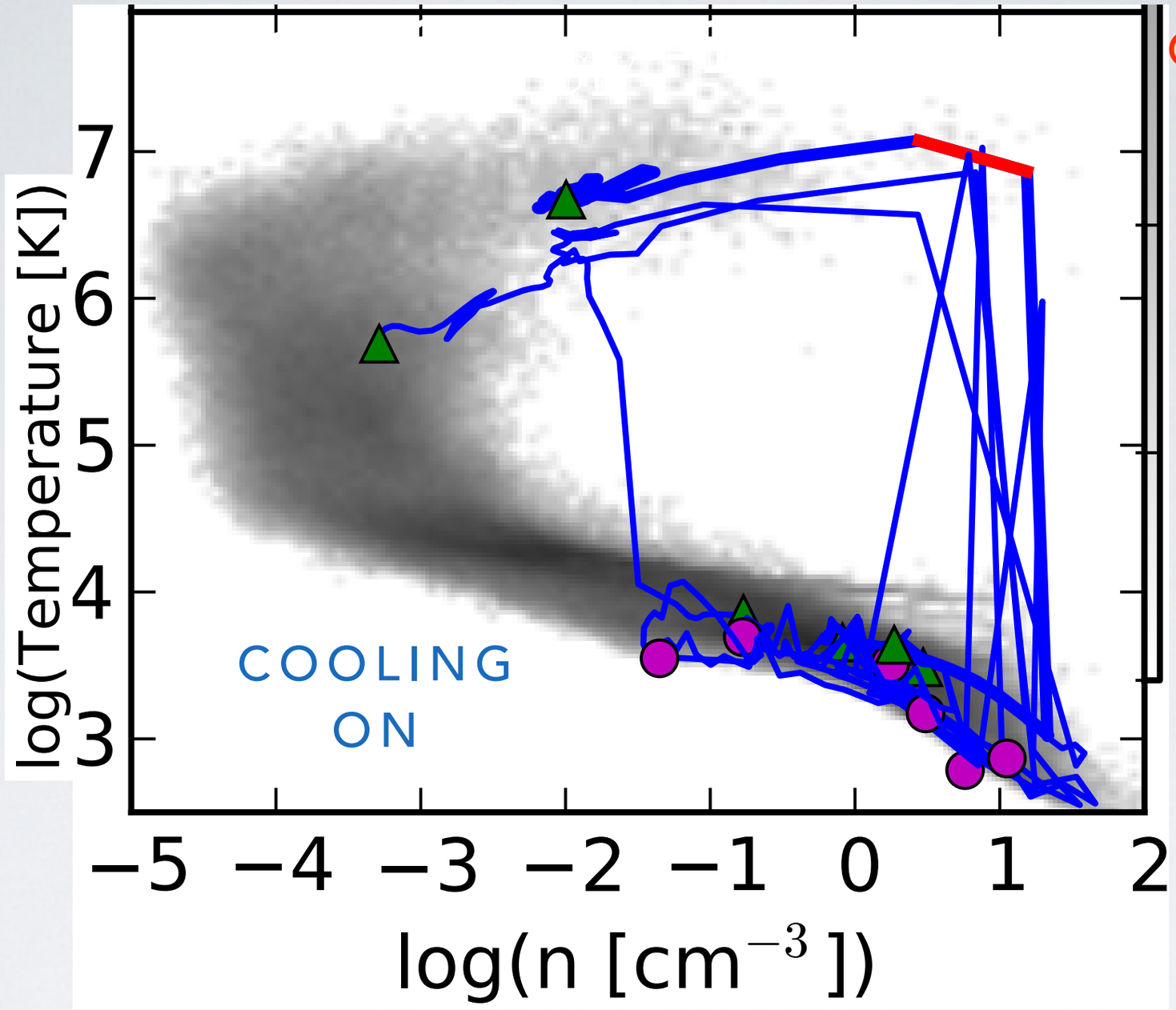
HOW DOES THAT WORK?



- Not well: Massive cooling instabilities lead to many unstable clumps



ABUNDANCE MATCHING COMPARED TO OTHER OBSERVATIONS

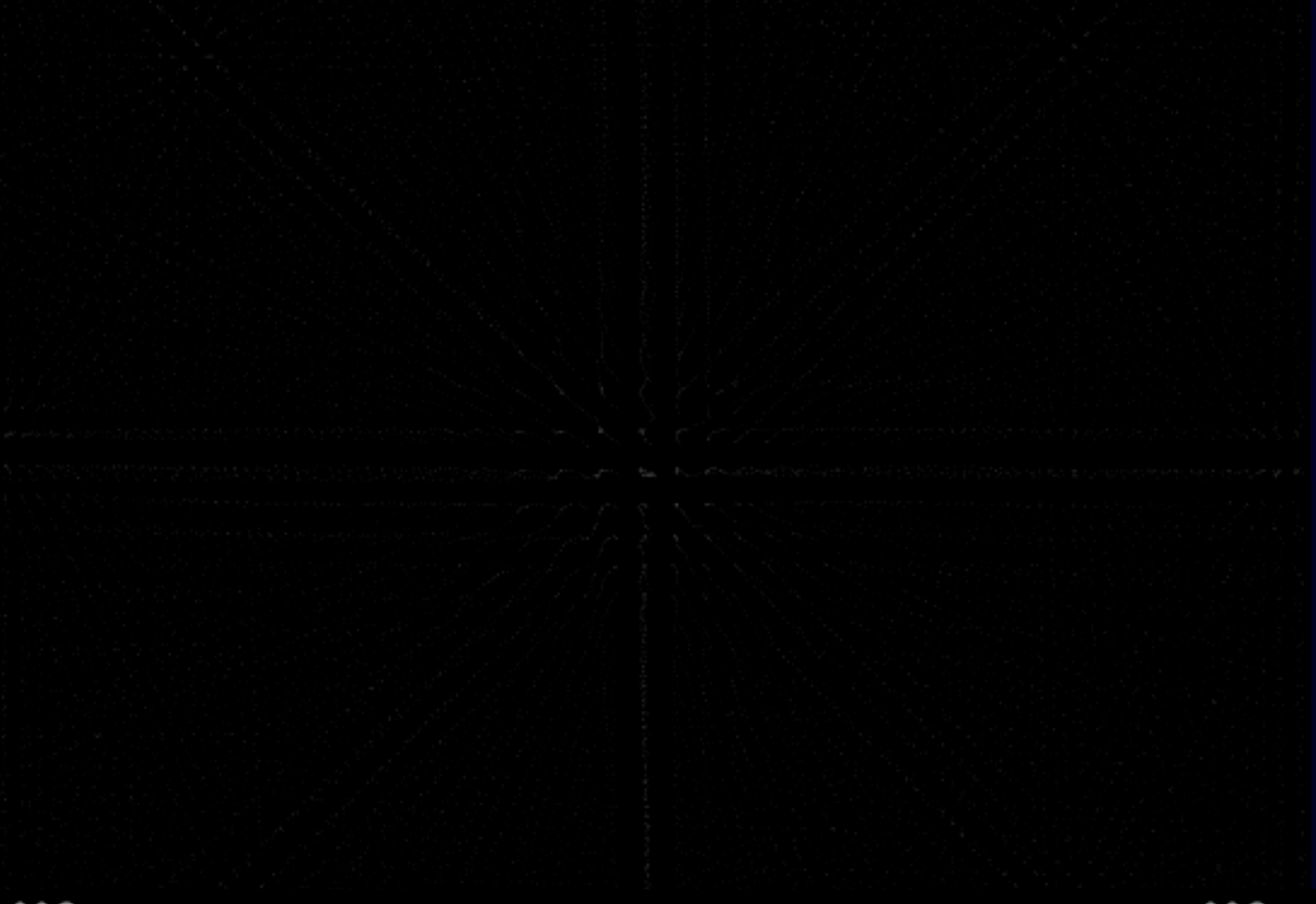


All SN energy from 1 star particle input at the same time

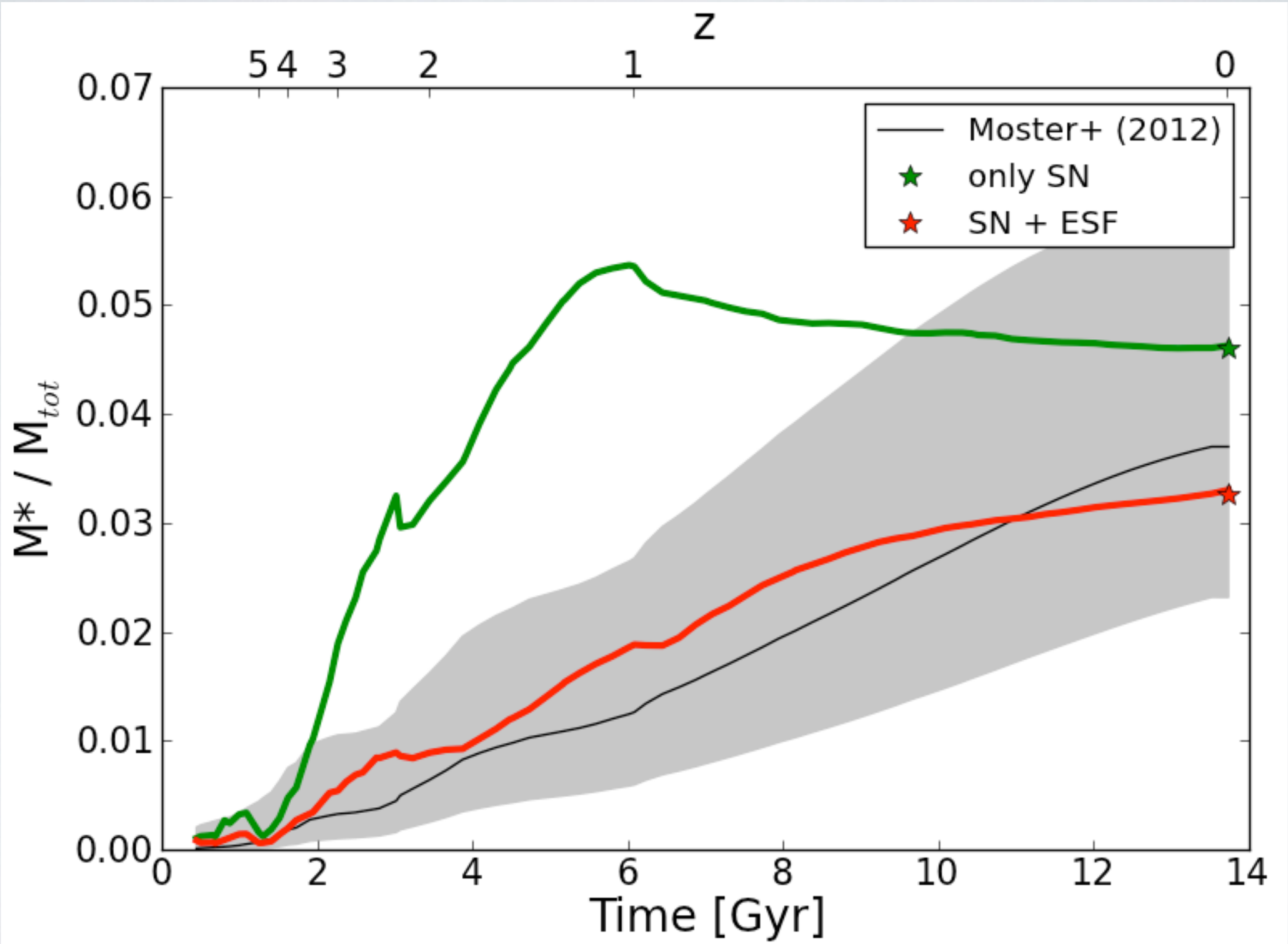
THERMAL FEEDBACK IN PHASE DIAGRAM

all SN energy packed into 1 particle at 1 time
(Dalla Vecchia & Schaye 2012)

DALLA VECCHIA & SCHAYE (2012)


0.0 Gyr

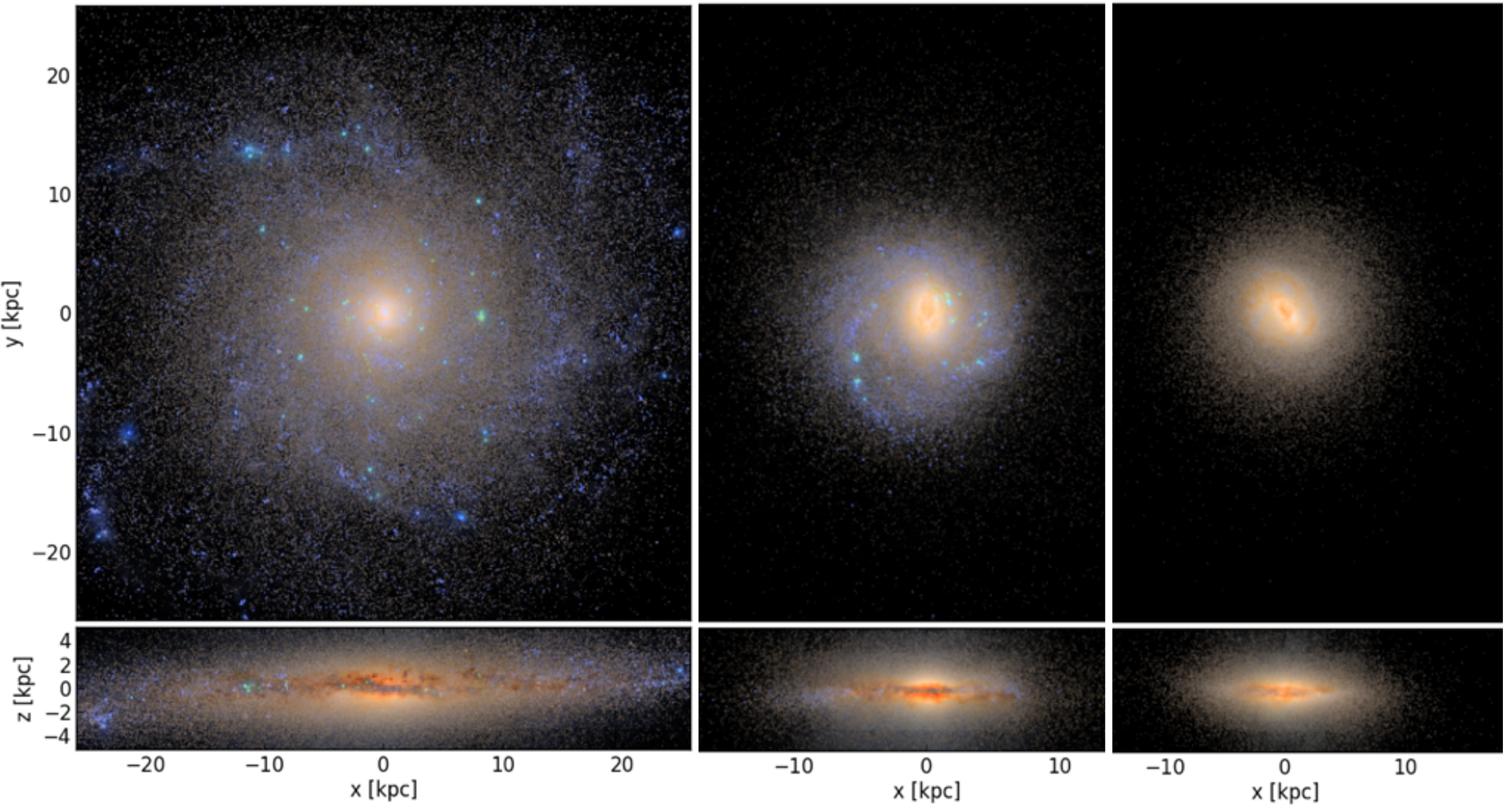

0.0 Gyr


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
Moster+ (2012)
only SN
SN + ESF
0
2
4
6
8
10
12
14
Time [Gyr]

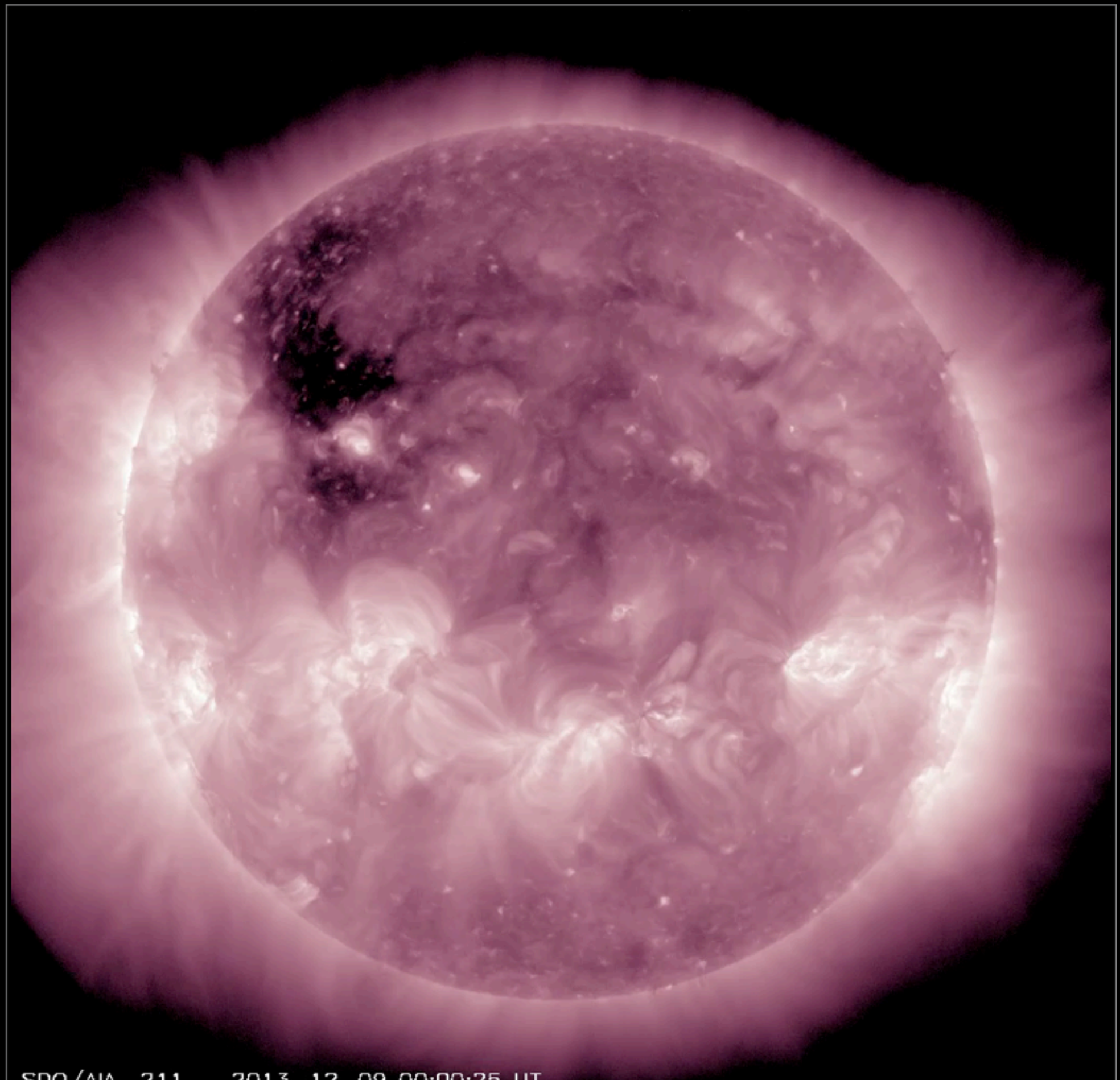
g1536:
$7 \times 10^{11}\ M_\odot$

g5664:
$5 \times 10^{11}\ M_\odot$

g511r5:
$6.5 \times 10^{11}\ M_\odot$



GREG STINSON (MPIA, HEIDELBERG)


SDO/AIA 211 2013-12-09 00:00:25 UT

p^+

H

n^0

He

p^+

n^0

γ

γ

n^0

p^+

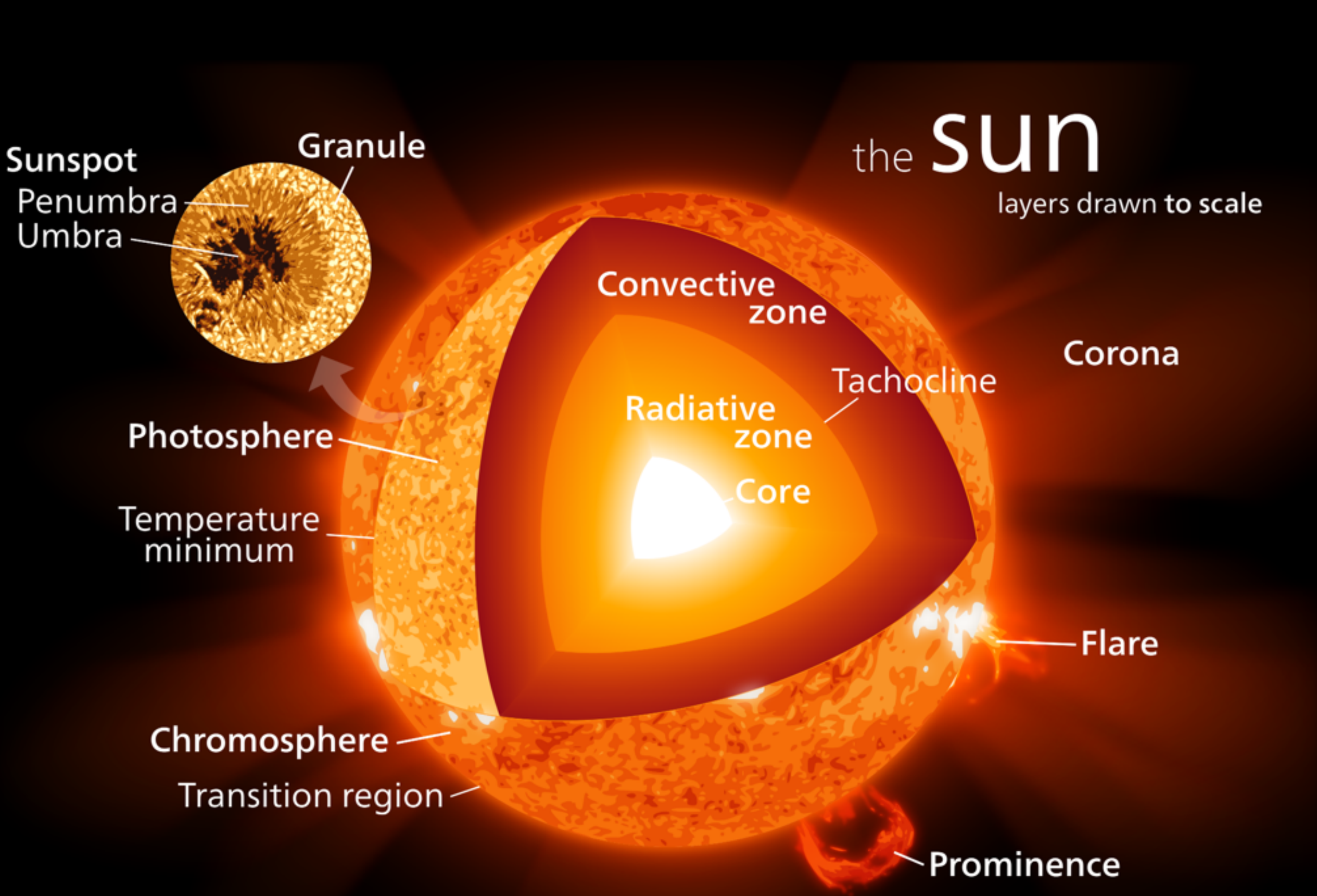
p^+

H

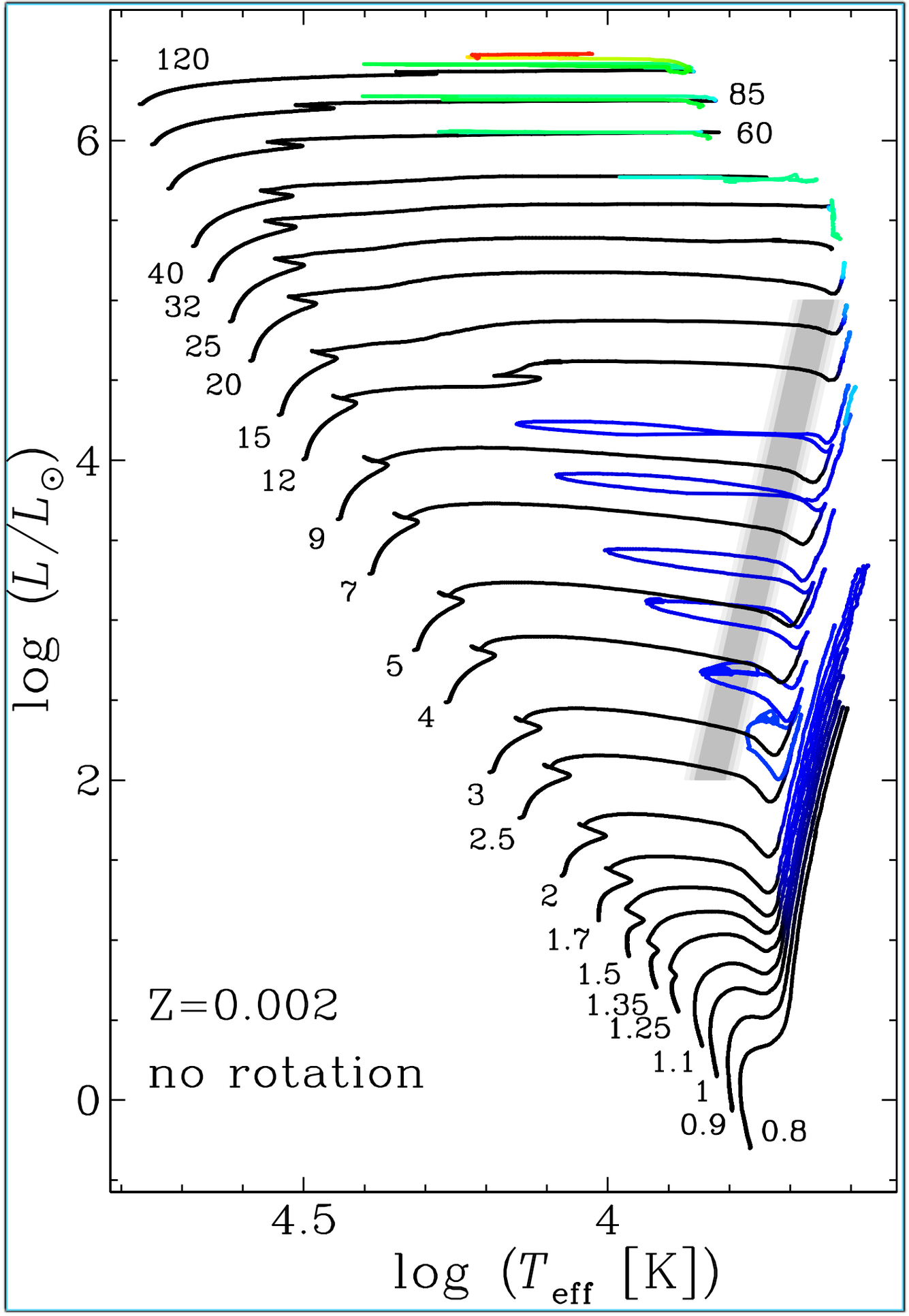
n^0

the sun

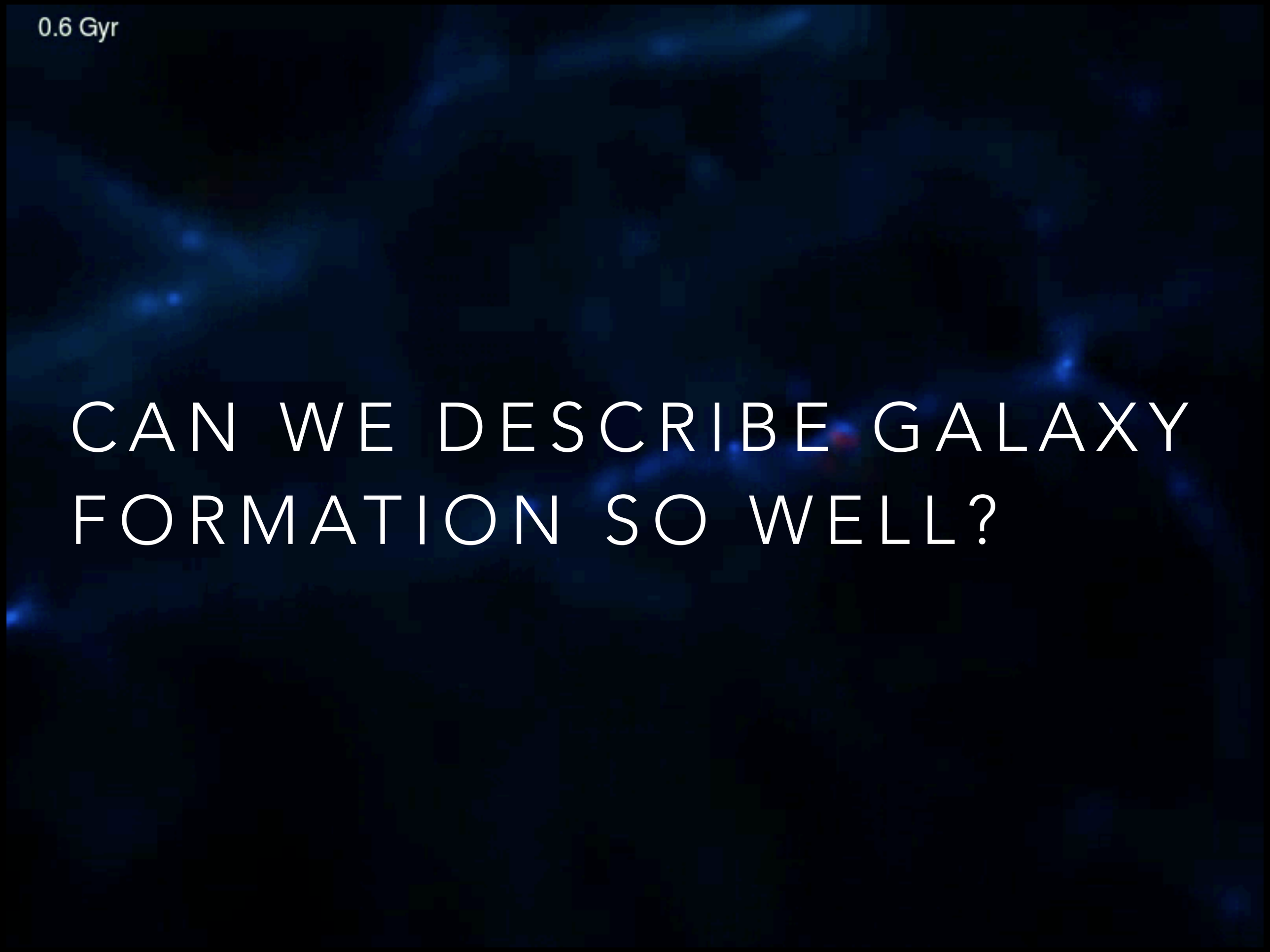
layers drawn to scale



"Sun poster" by Kelvinsong


120
85
60
40
32
25
20
15
12
9
7
5
4
3
2.5
2
1.7
1.5
1.35
1.25
1.1
1
0.9
0.8
Z=0.002
no rotation
log (L/L⊙)
log (T_eff [K])
6
4
2
0
4.5
4

GEORGY + (2013)

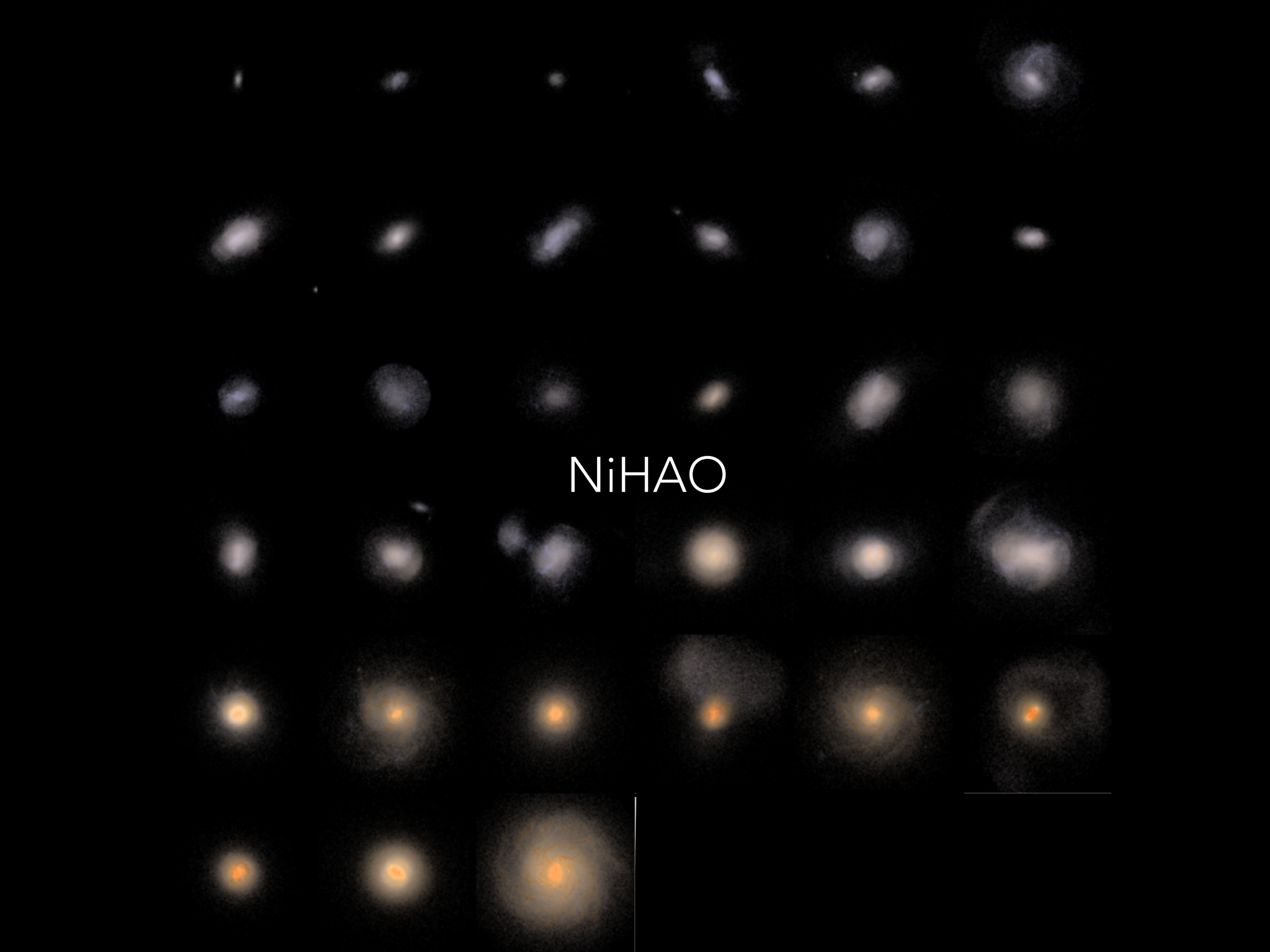


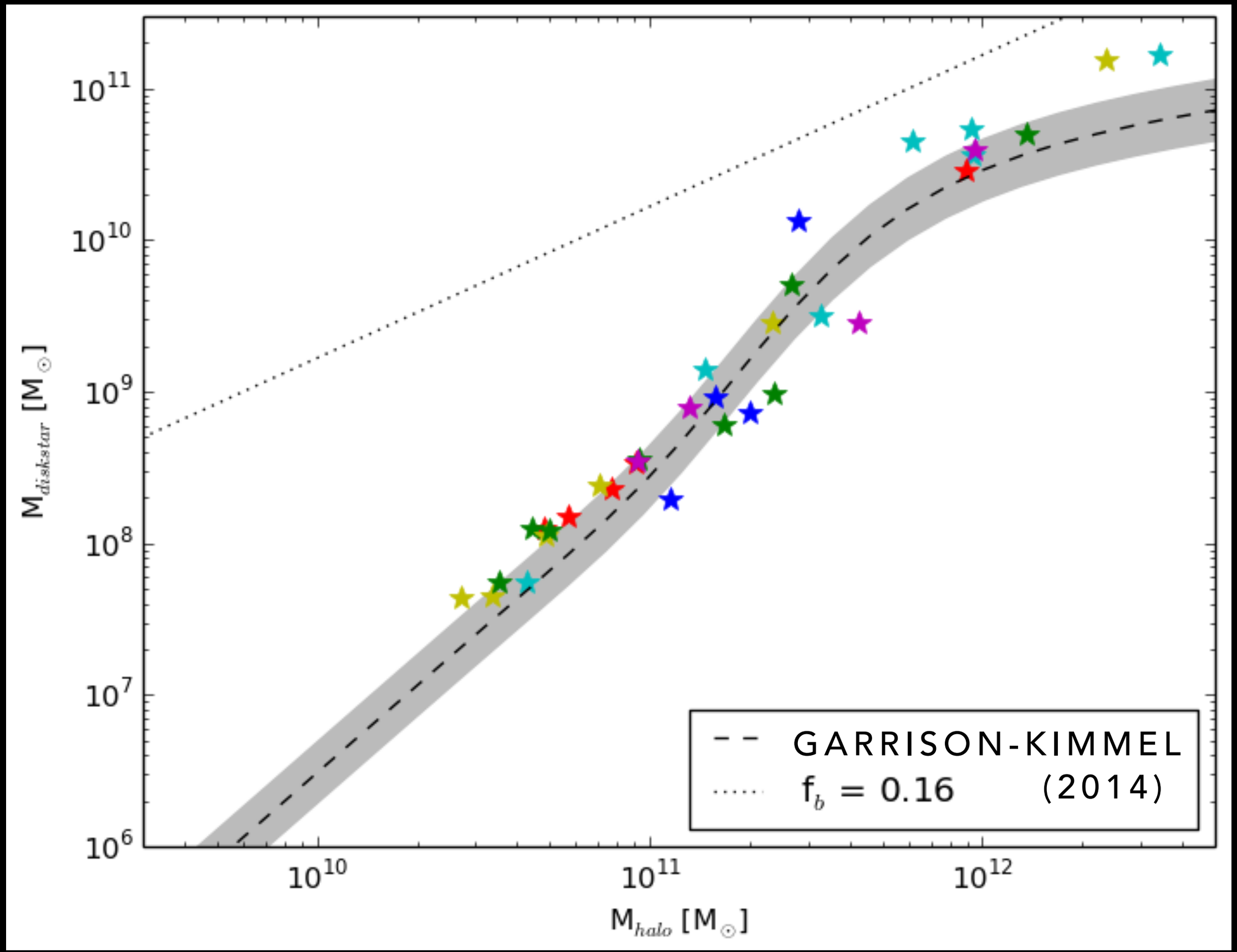
CAN WE DESCRIBE GALAXY FORMATION SO WELL?

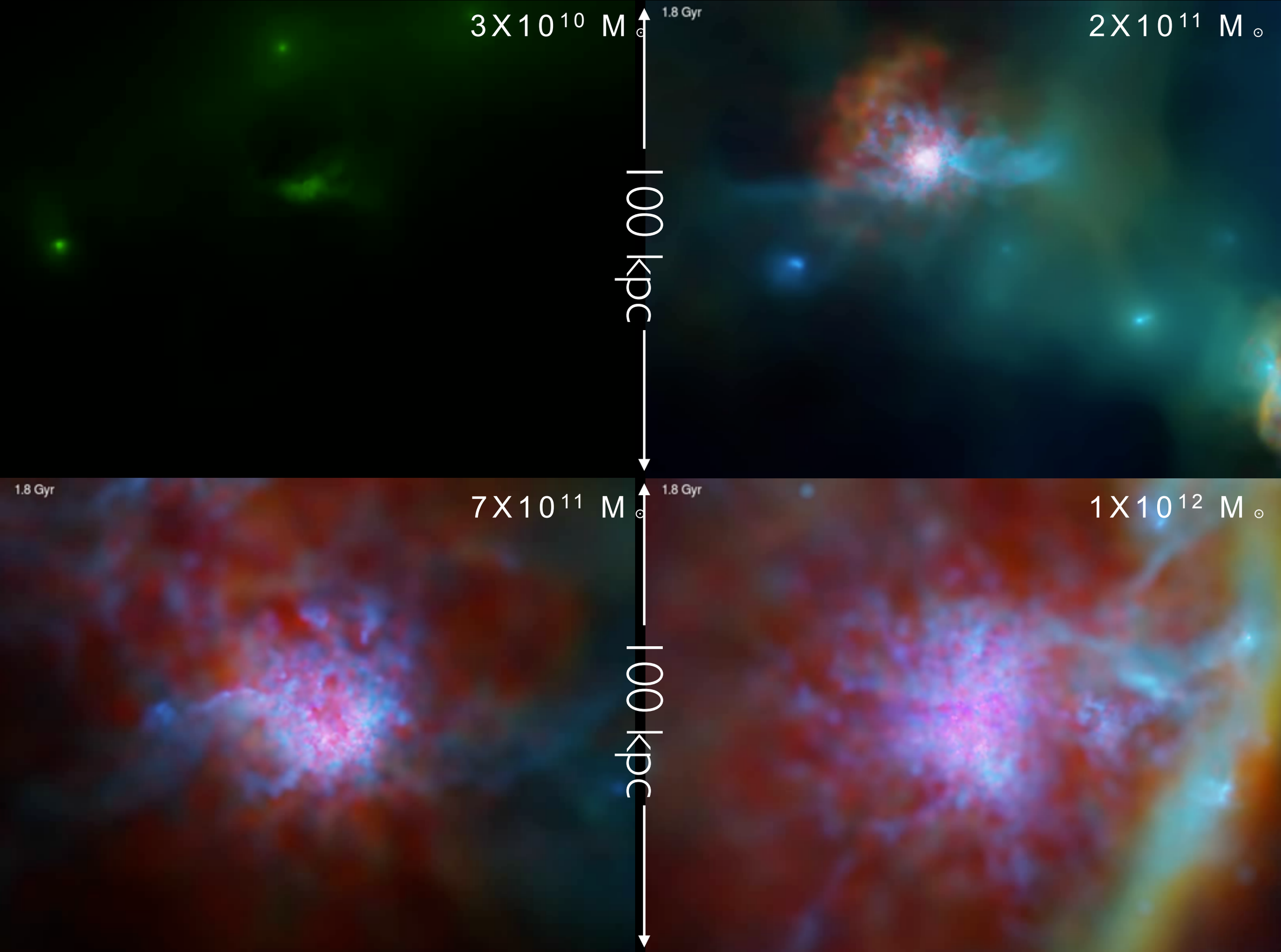
TIMESCALES

$$T_{DYN} = \frac{1}{\sqrt{4\pi G\rho}} = 26.8 \text{ Myr } \left(\frac{n}{cm^{-3}}\right)^{-1/2}$$

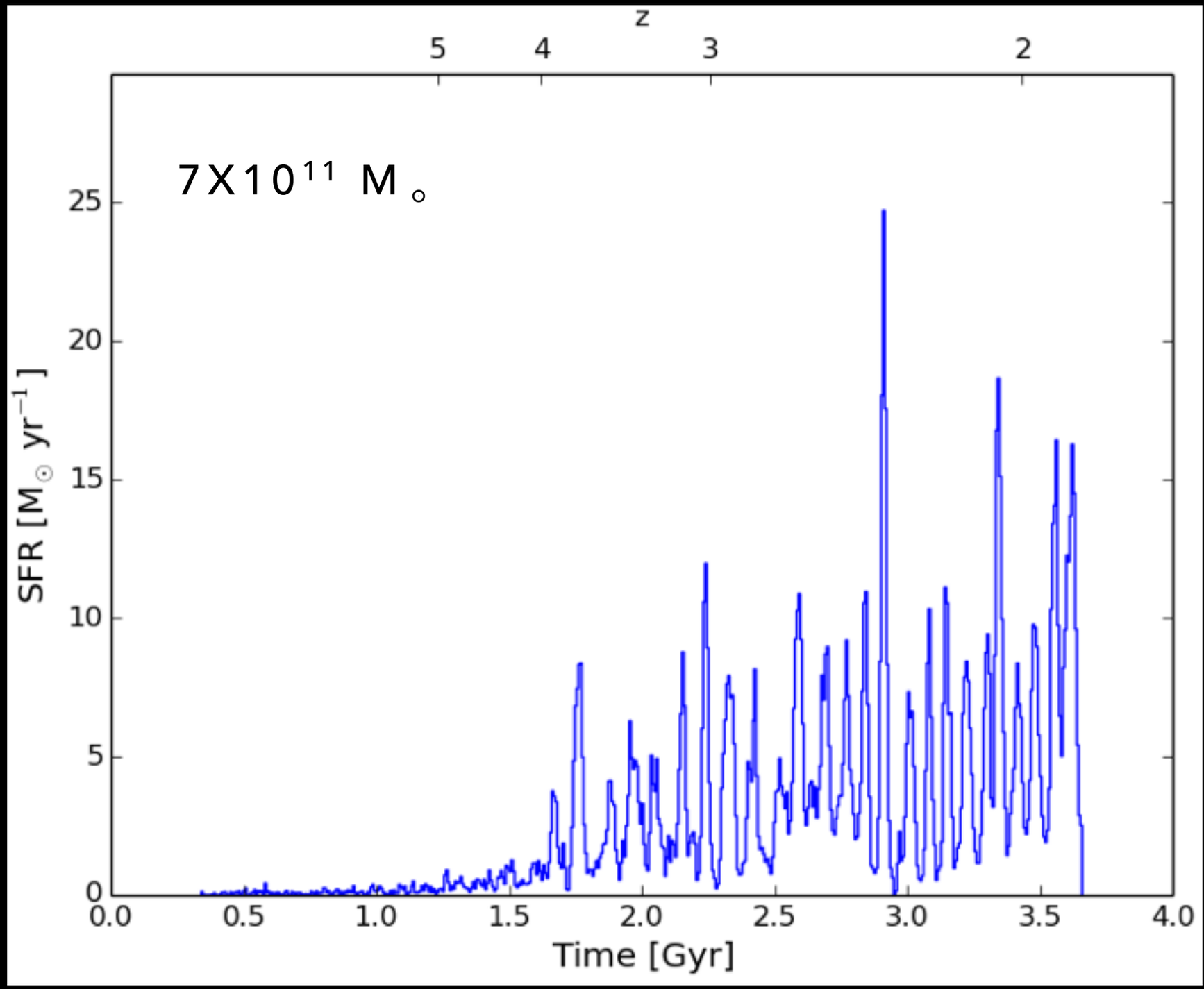
- Typical density of a star: 1 g / cc
  - t_{dyn} = 15 minutes
- Typical density of a galaxy: 0.1 m_p / cc
  - t_{dyn} = 100 Myr

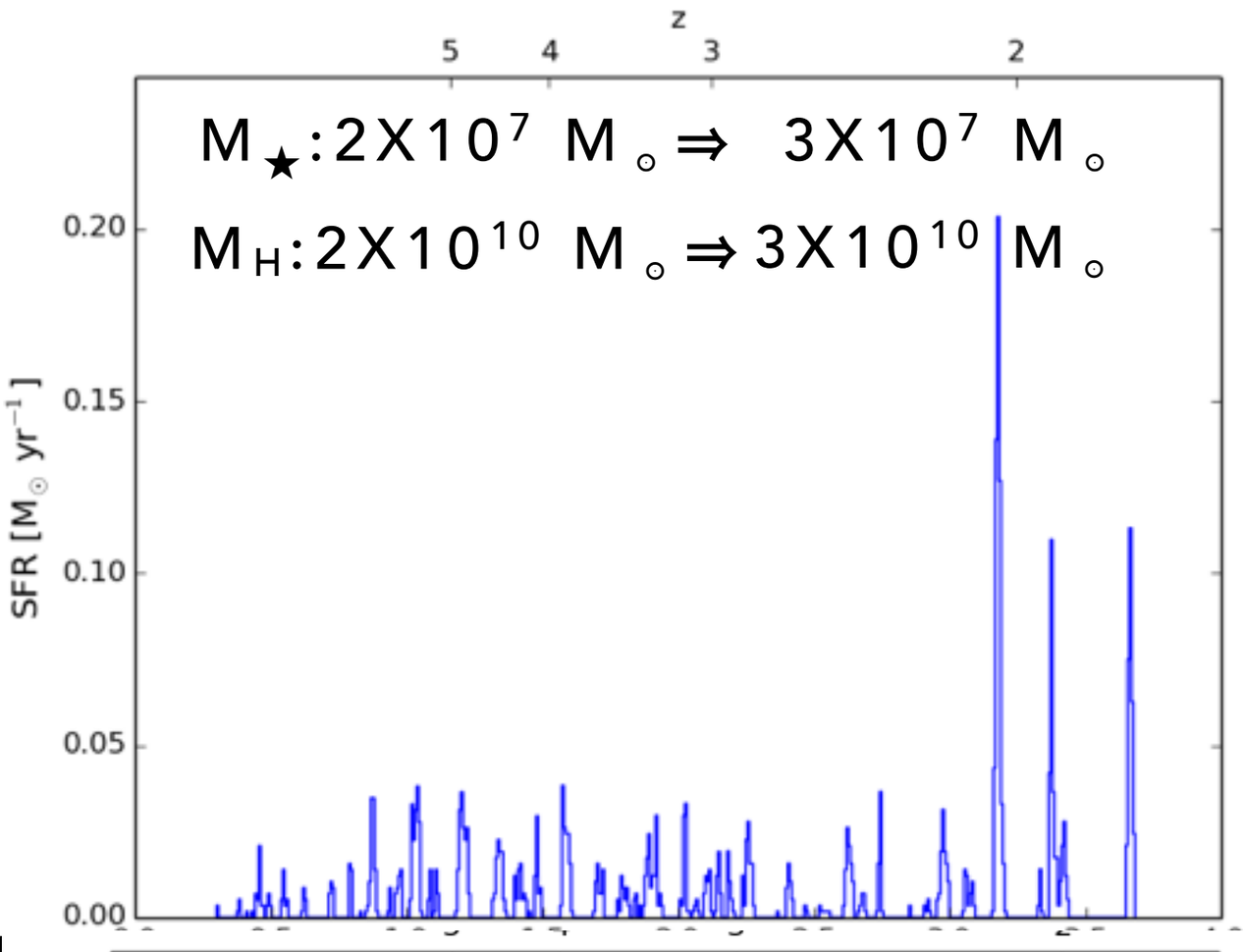

NiHAO

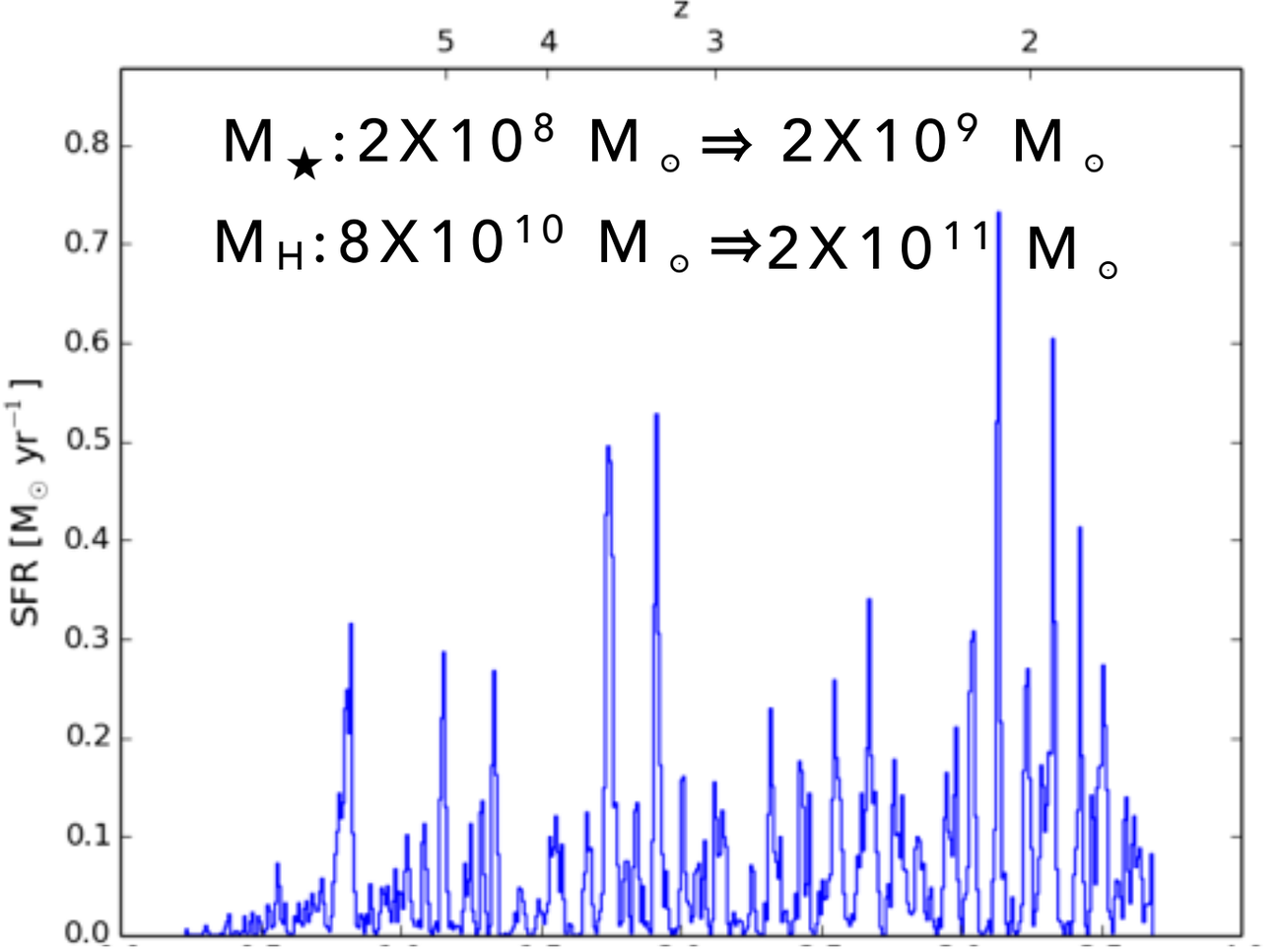

10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
$M_{diskstar}$ [$M_\odot$]
10^{10}
10^{11}
10^{12}
M_{halo} [$M_\odot$]
GARRISON-KIMMEL
f_b = 0.16 (2014)

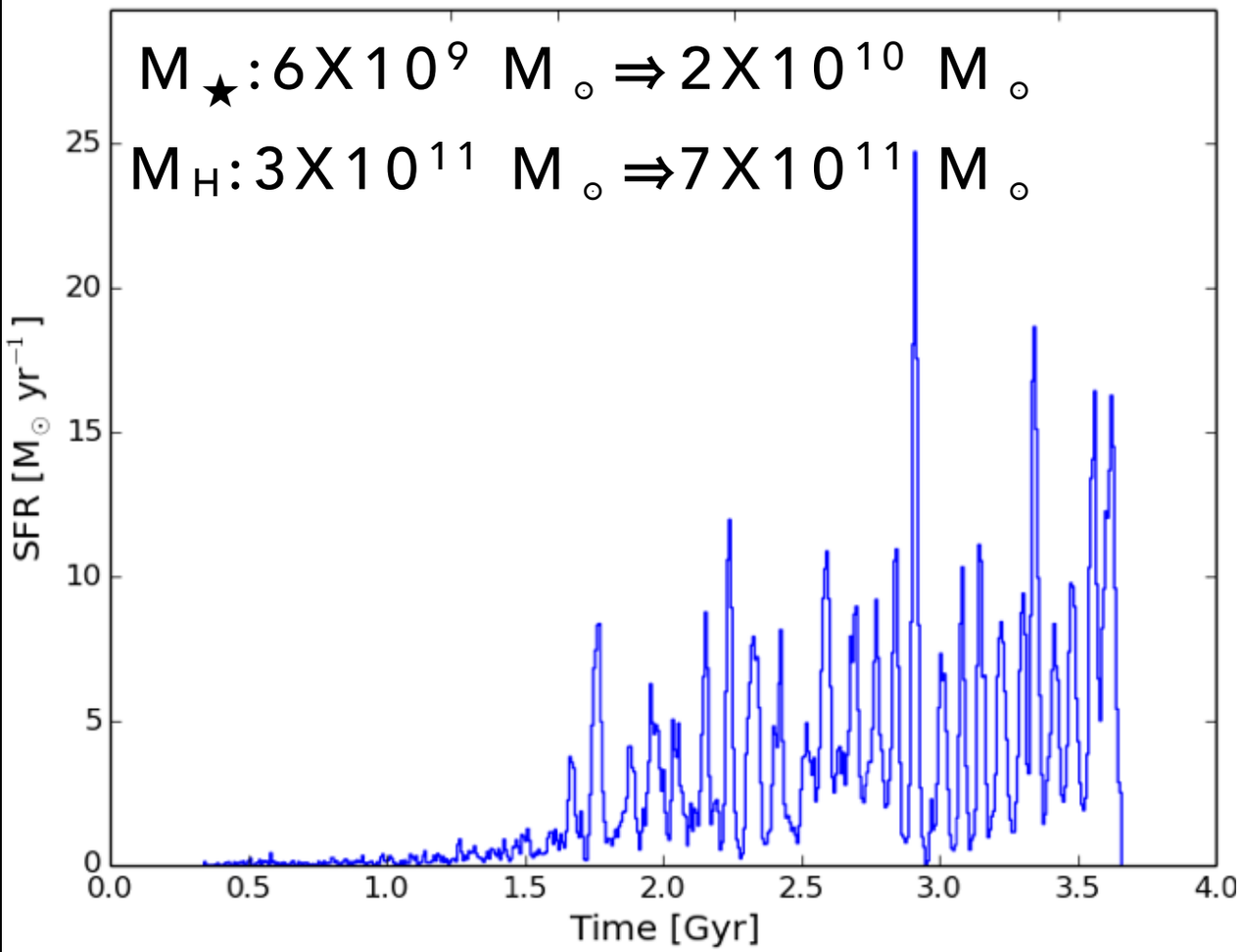

3X10^10 M⊙
1.8 Gyr
2X10^11 M⊙
100 kpc
1.8 Gyr
7X10^11 M⊙
1.8 Gyr
1X10^12 M⊙
100 kpc

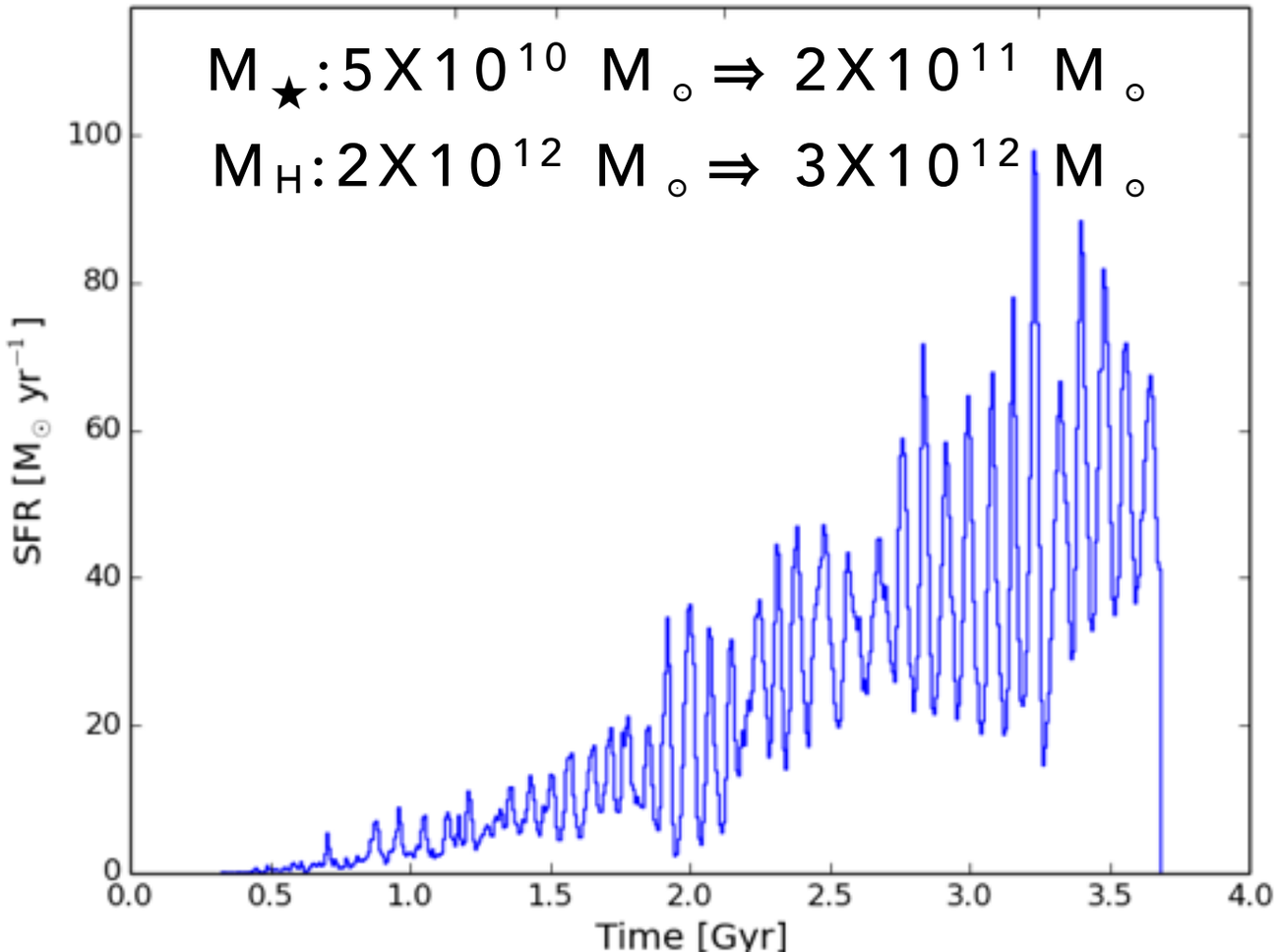
BURSTY STAR FORMATION




z
5
4
3
2
$M_\star$:2X10^7 M$_\odot$⇒ 3X10^7 M$_\odot$
M_H:2X10^{10} M$_\odot$⇒3X10^{10} M$_\odot$
SFR [M$_\odot$ yr^{-1}]
0.20
0.15
0.10
0.05
0.00


z
5
4
3
2
$M_\star$:2X10^8 M$_\odot$⇒ 2X10^9 M$_\odot$
M_H:8X10^{10} M$_\odot$⇒2X10^{11} M$_\odot$
SFR [M$_\odot$ yr^{-1}]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0


$M_\star$:6X10^9 M$_\odot$⇒2X10^{10} M$_\odot$
M_H:3X10^{11} M$_\odot$⇒7X10^{11} M$_\odot$
SFR [M$_\odot$ yr^{-1}]
25
20
15
10
5
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time [Gyr]

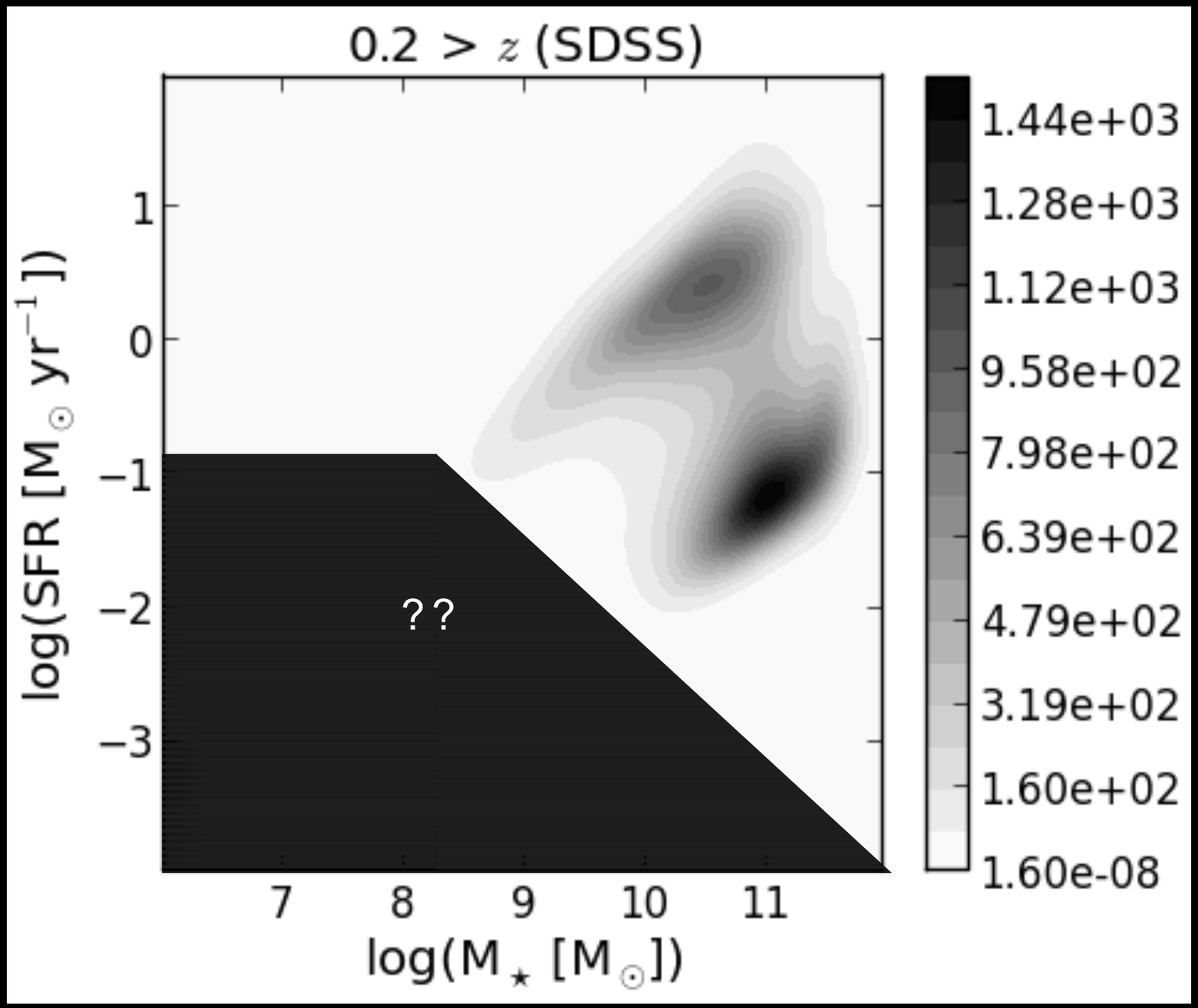

$M_\star$:5X10^{10} M$_\odot$⇒ 2X10^{11} M$_\odot$
M_H:2X10^{12} M$_\odot$⇒ 3X10^{12} M$_\odot$
SFR [M$_\odot$ yr^{-1}]
100
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time [Gyr]

BURST FREQUENCY $T_{DYN} = 26.8\ \mathrm{Myr}\ \left(\frac{n}{\mathrm{cm}^{-3}}\right)^{-1/2}$

- 6 / 500 Myr ~ 1 / 100 Myr $\Rightarrow n \sim 0.1\ \mathrm{cm}^{-3}$
  - This is closest to the ISM density
  - It takes the ISM this long to recollapse
- Are the burst amplitudes crazy?

ARE BURSTS OBSERVED?

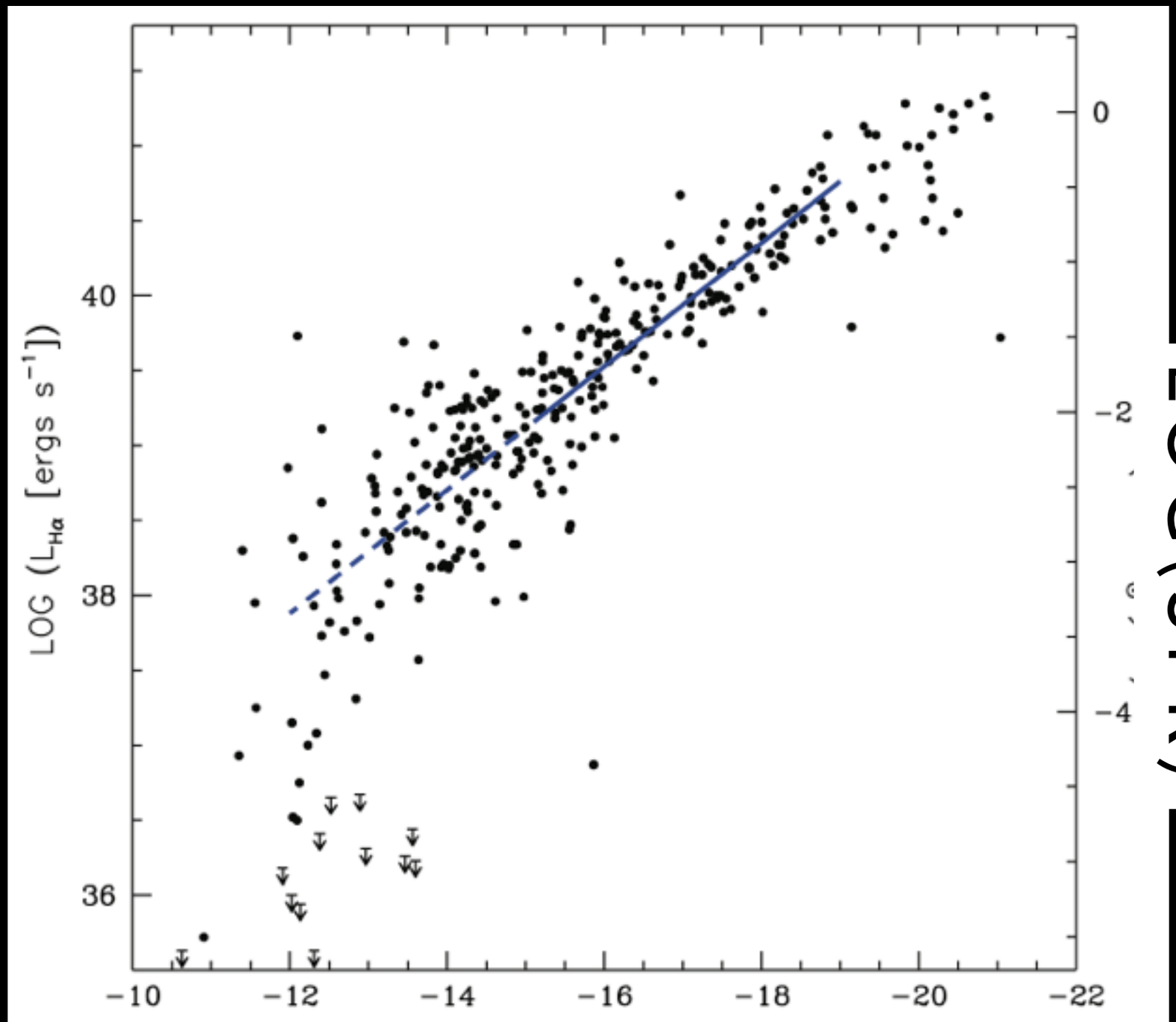
GALAXY STAR FORMING "MAIN SEQUENCE"



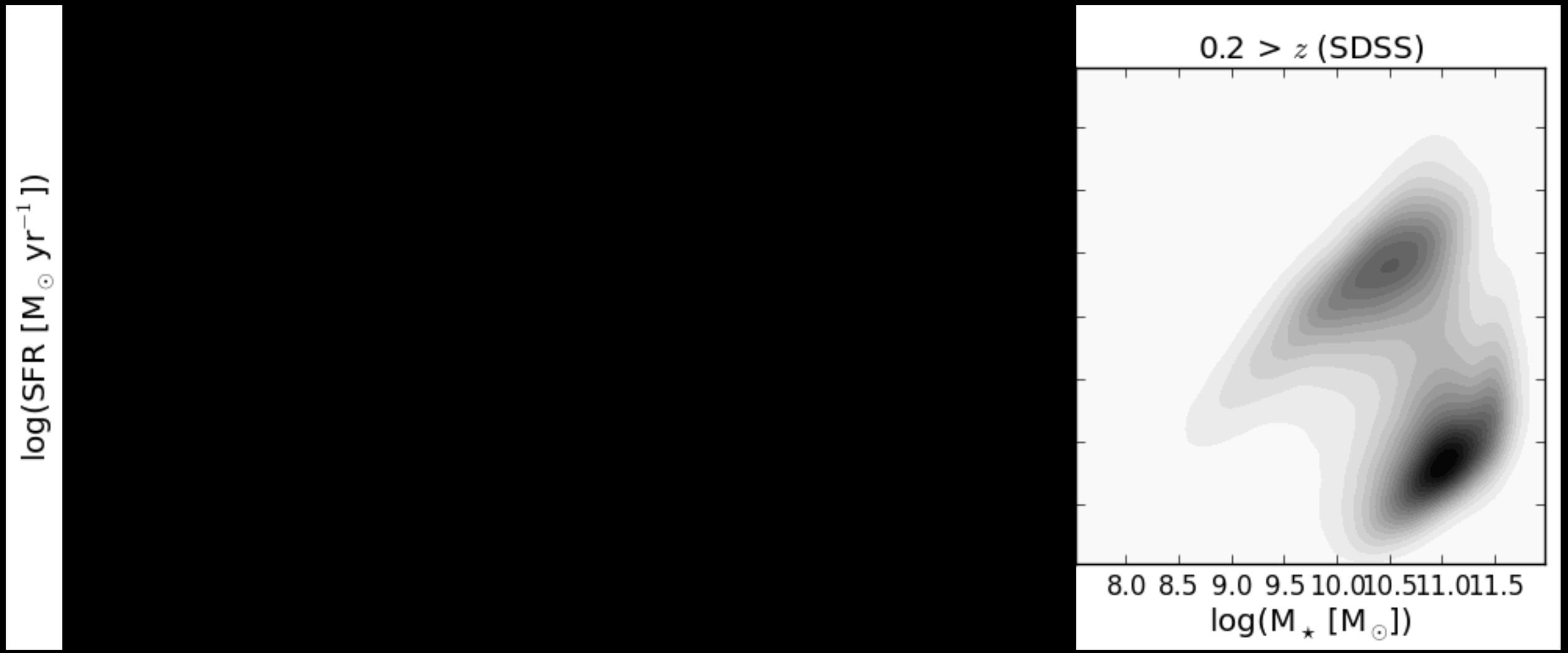
BRINCHMANN+ (2004)

Hα-UV GALAXY SURVEY 11 MPC LOCAL VOLUME SURVEY

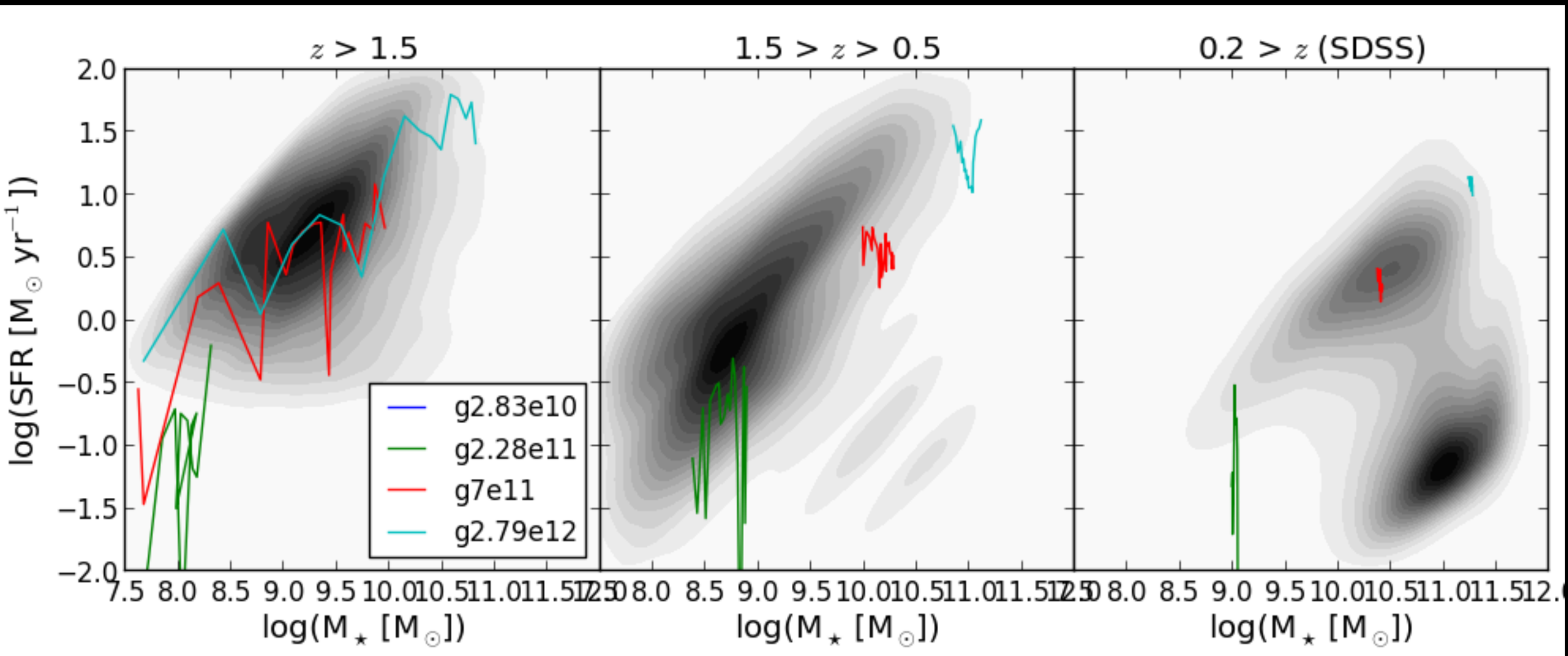
LEE, KENNICUTT ET AL (2008)



GALAXY STAR FORMING "MAIN SEQUENCE"

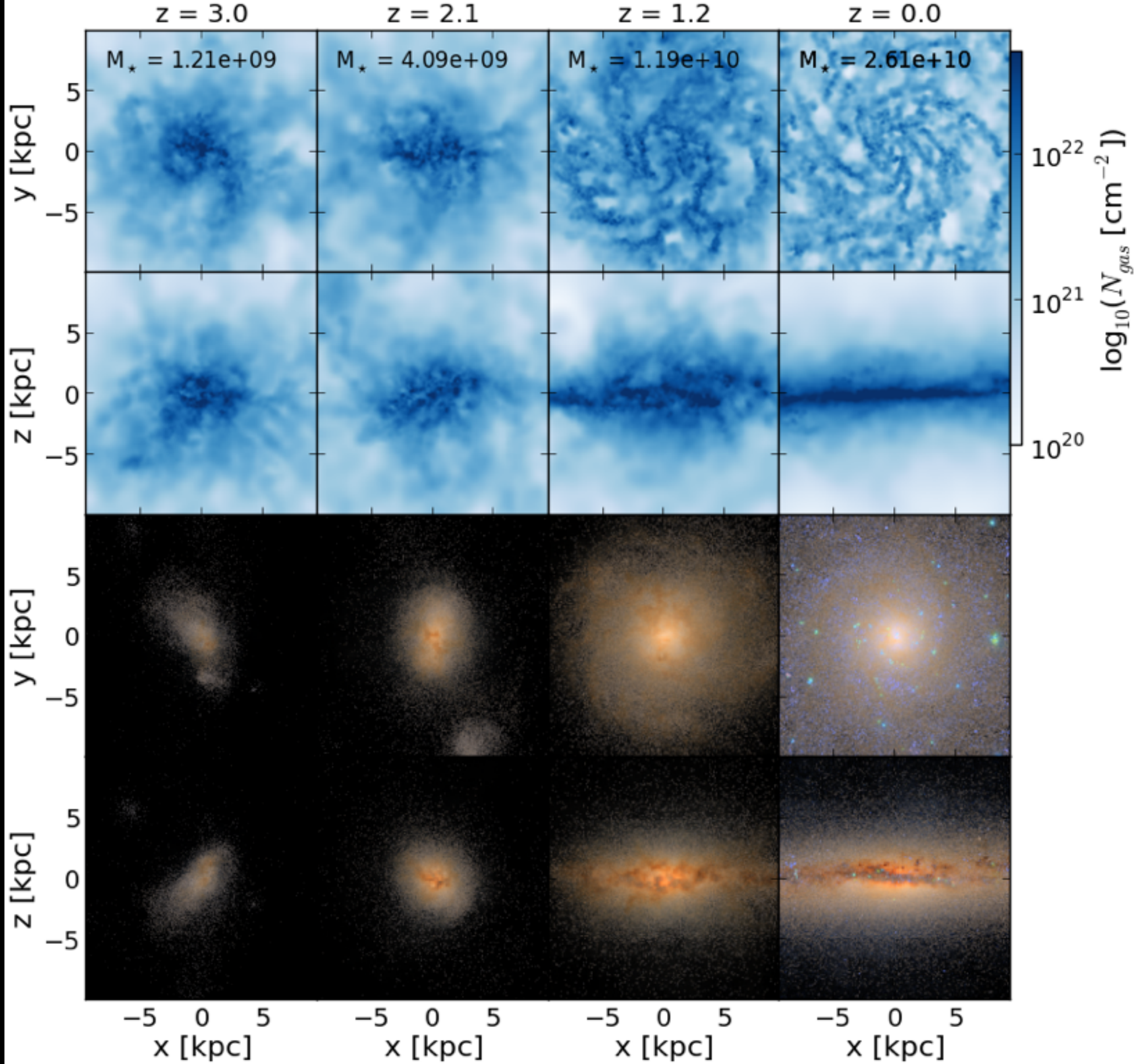


GALAXY STAR FORMING "MAIN SEQUENCE"

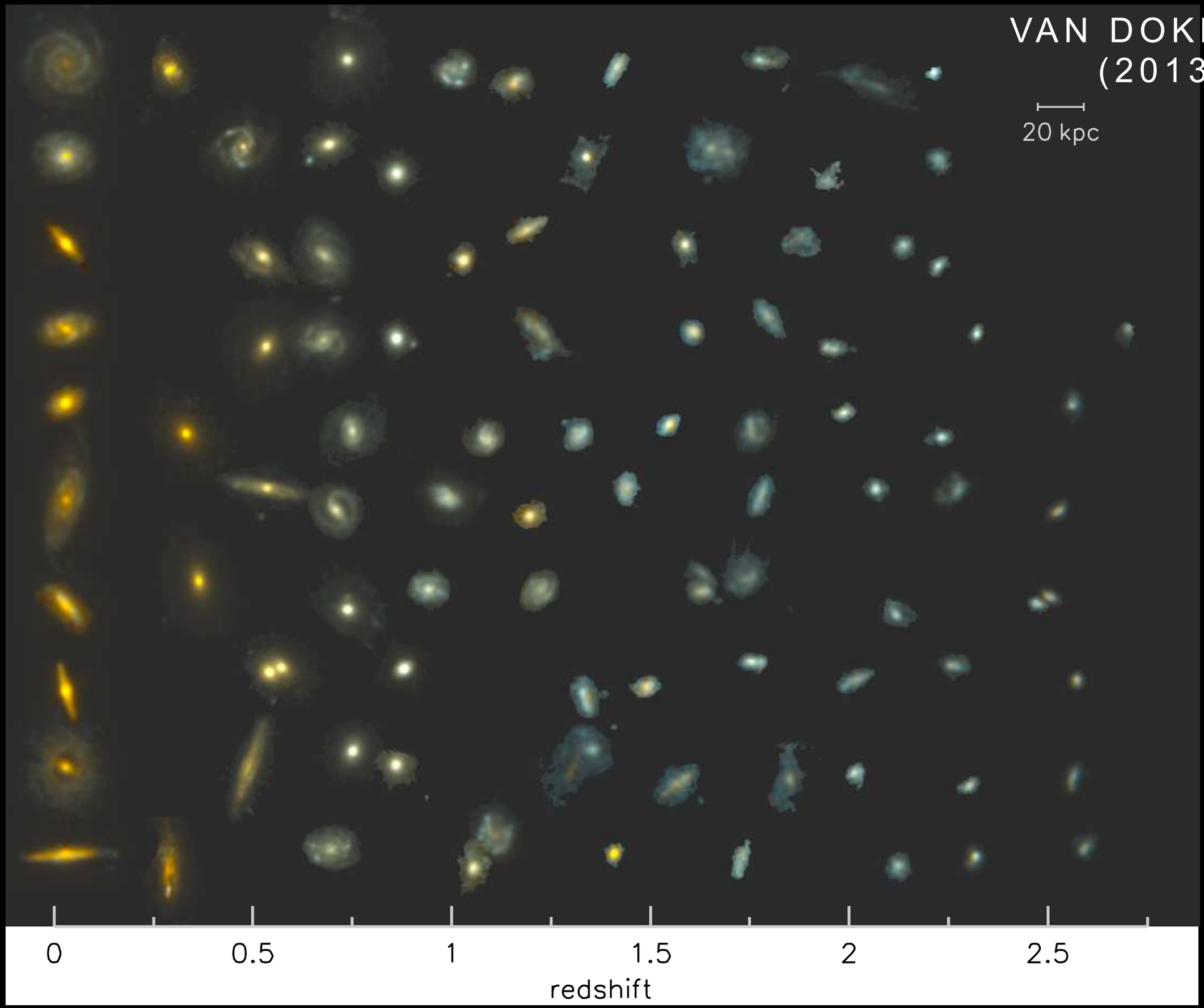


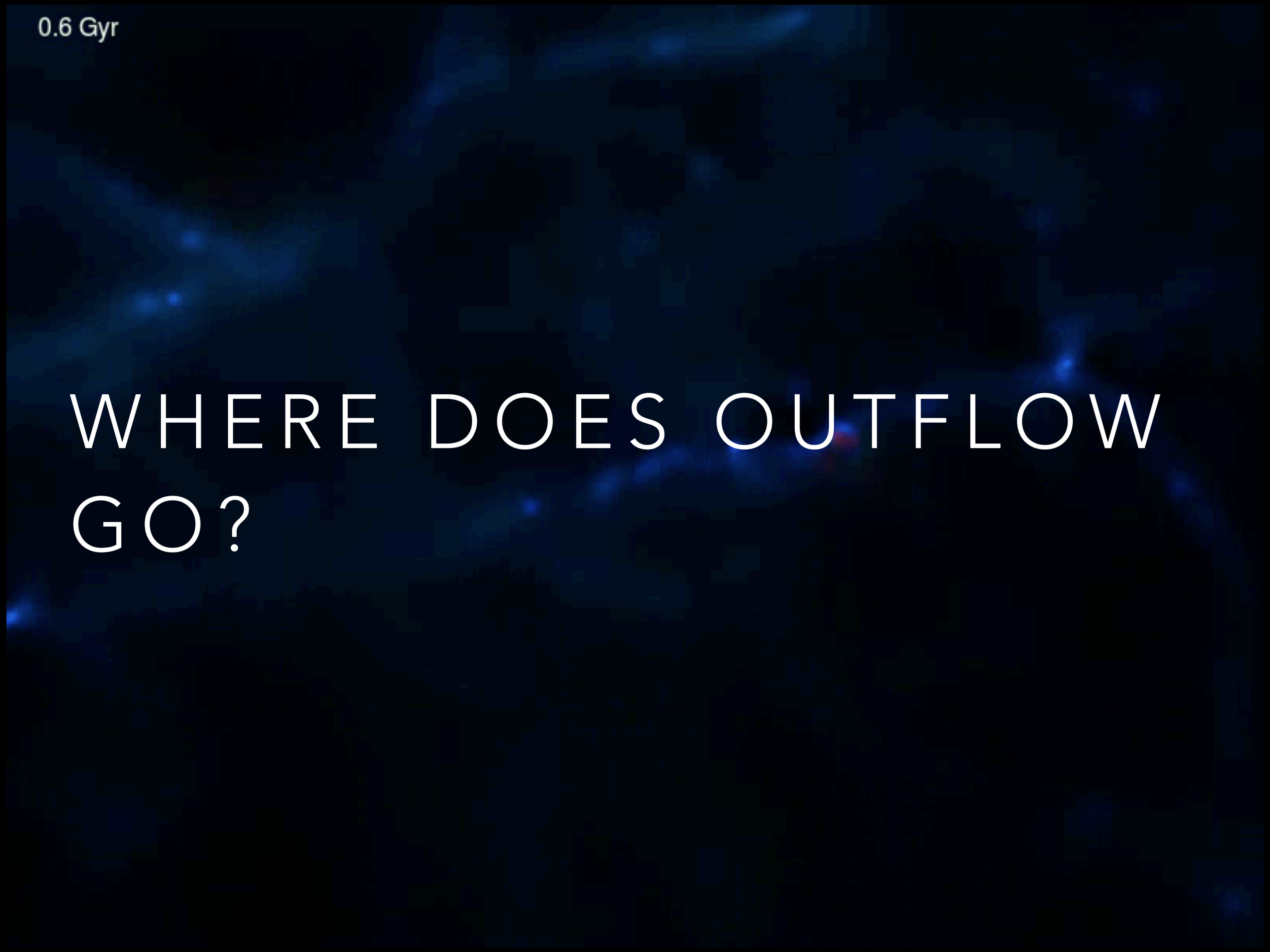
SIMULATED SFR IS MEAN OF PREVIOUS 15 MYR

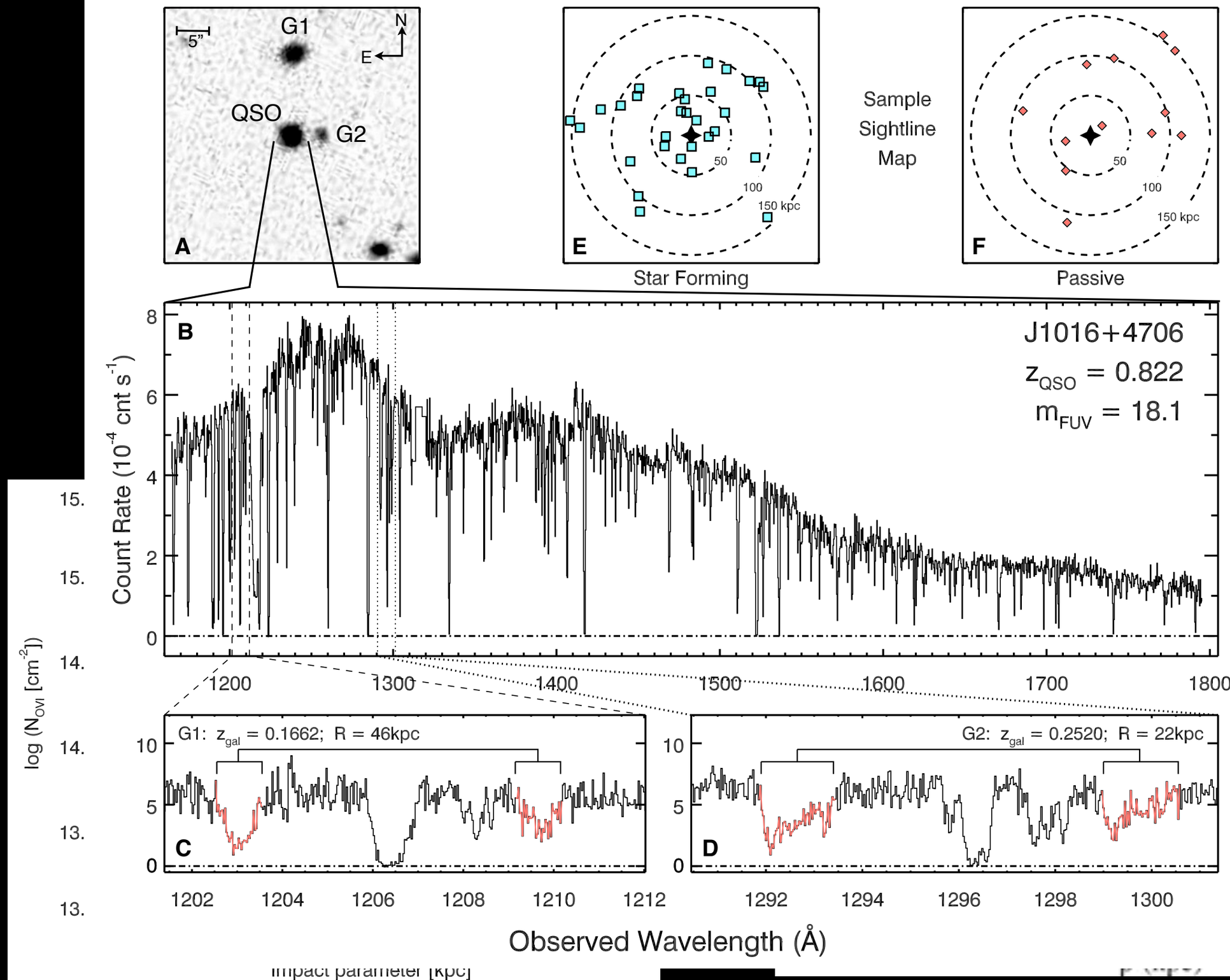
IMPACT ON DISK STRUCTURE



MILKY WAY PROGENITORS

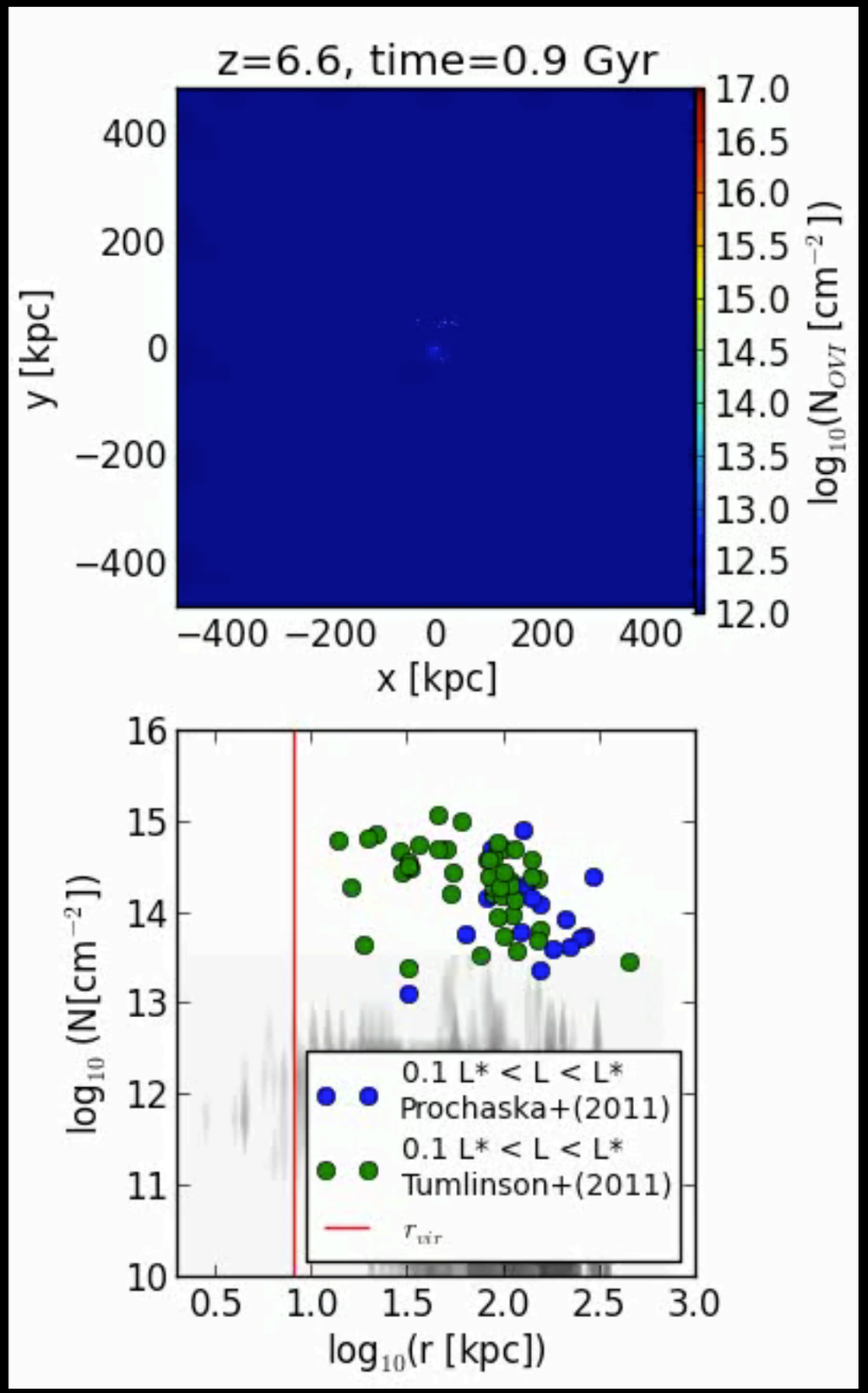


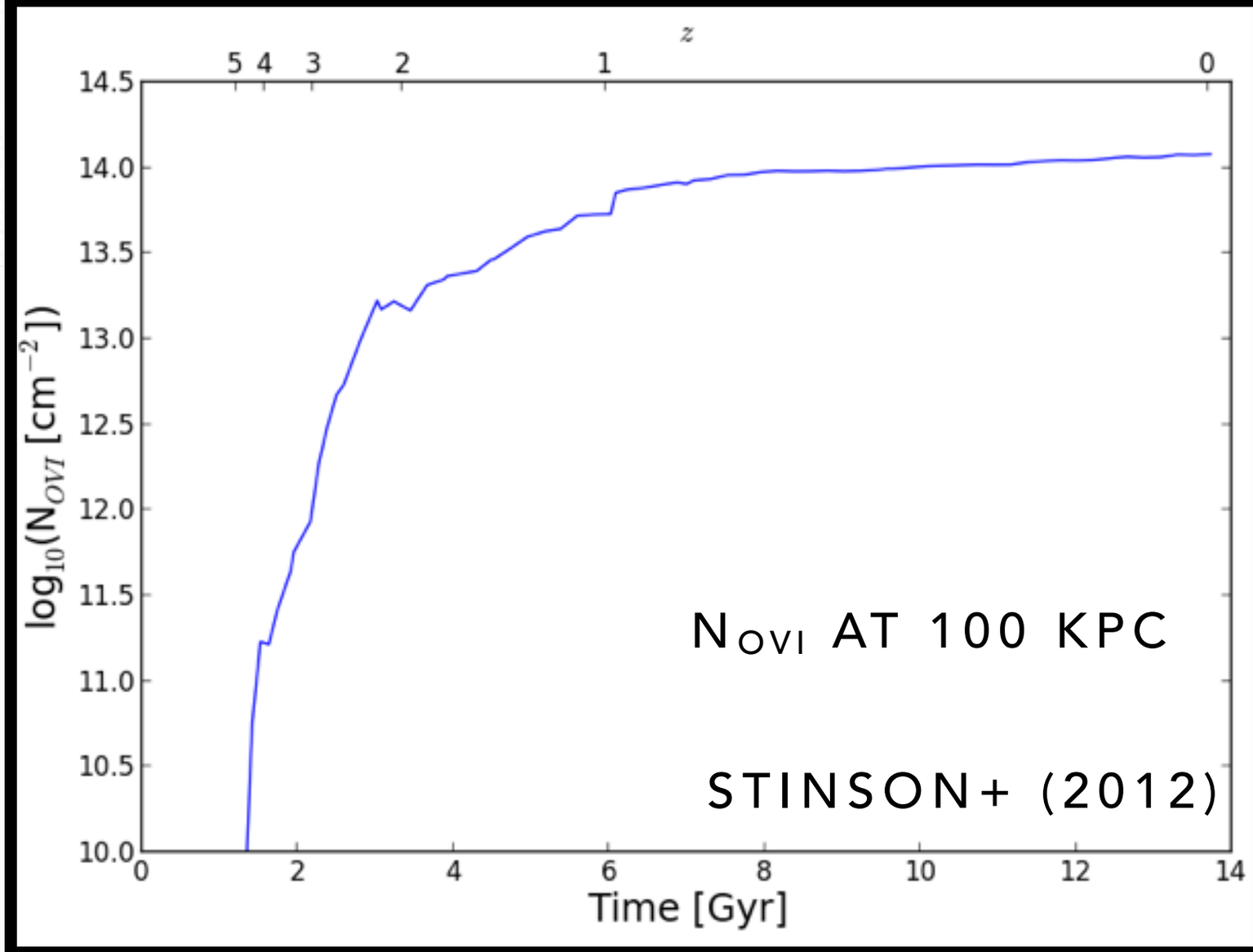

0.6 Gyr
WHERE DOES OUTFLOW
GO?

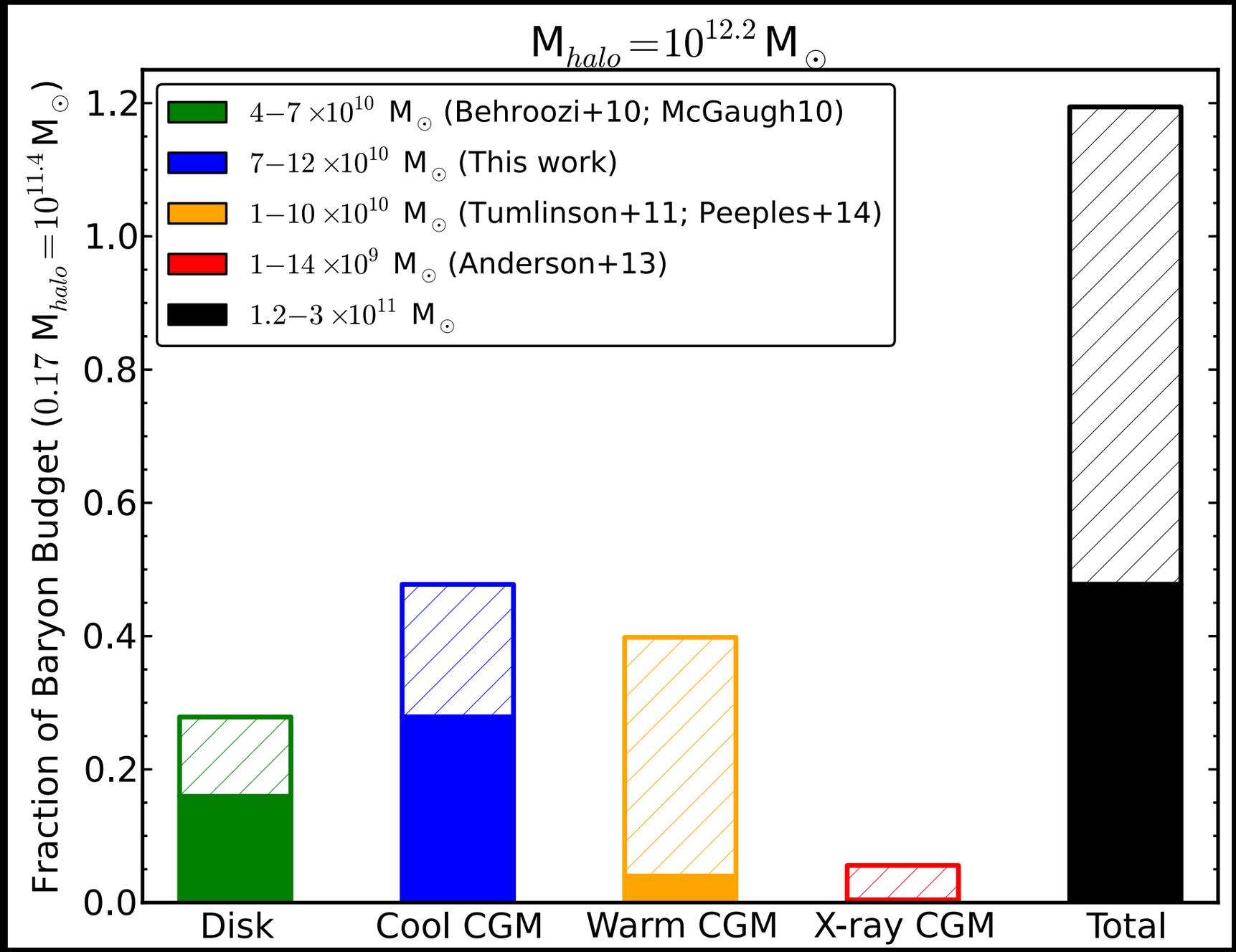


COS HALOS OVI OBSERVATIONS

TUMLINSON+ (2011)


z=6.6, time=0.9 Gyr
y [kpc]
x [kpc]
$\log_{10}(N_{OVI}\ [cm^{-2}])$
$\log_{10}$ (N[cm^{-2}])
$\log_{10}$(r [kpc])
0.1 L* < L < L*
Prochaska+(2011)
0.1 L* < L < L*
Tumlinson+(2011)
r_{vir}


z
$\log_{10}(N_{OVI}\ [cm^{-2}])$
Time [Gyr]
N_{OVI} AT 100 KPC
STINSON+ (2012)



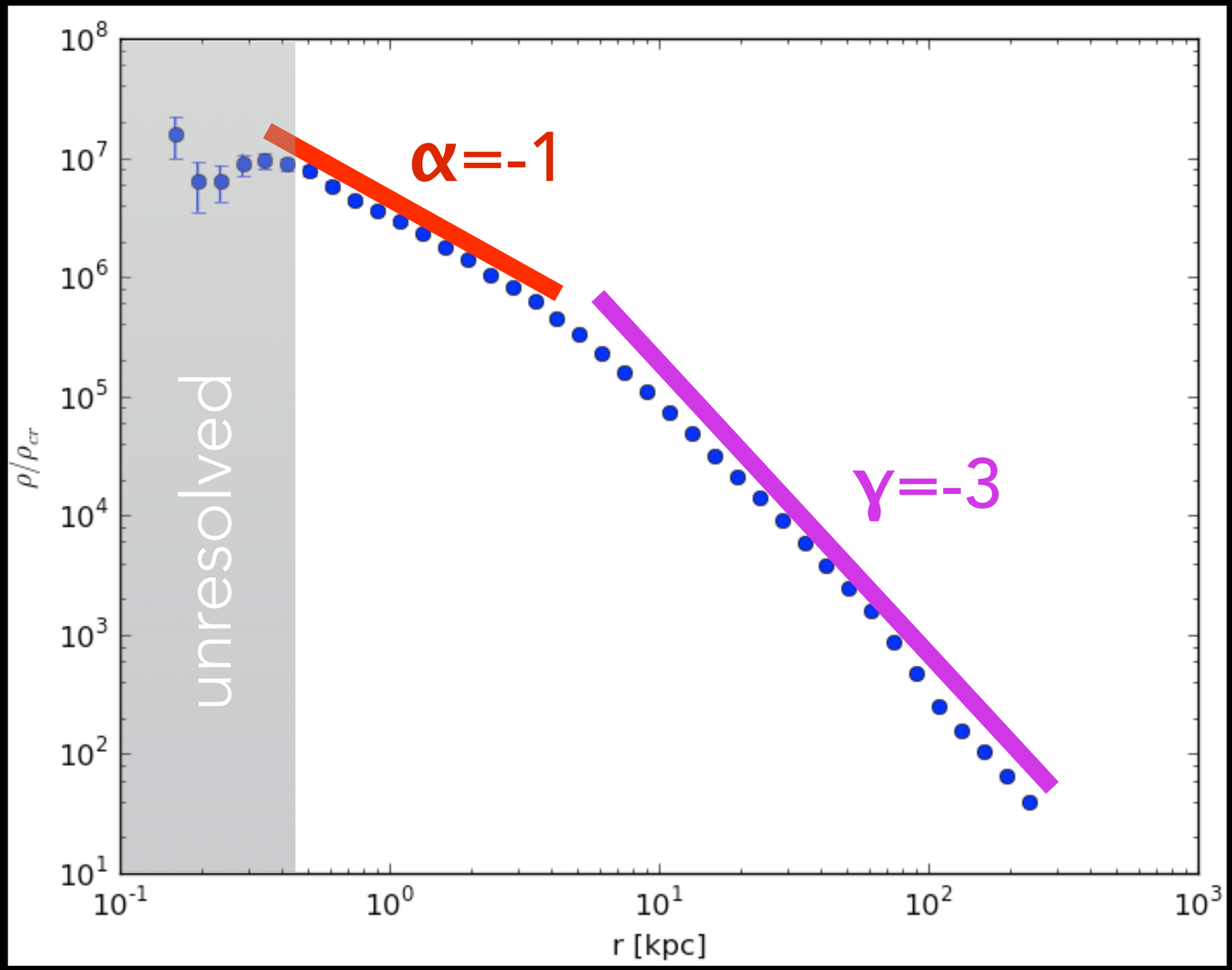
WERK+ (2014)

MISSING BARYONS?

CORE OR CUSP?

DENSITY PROFILES

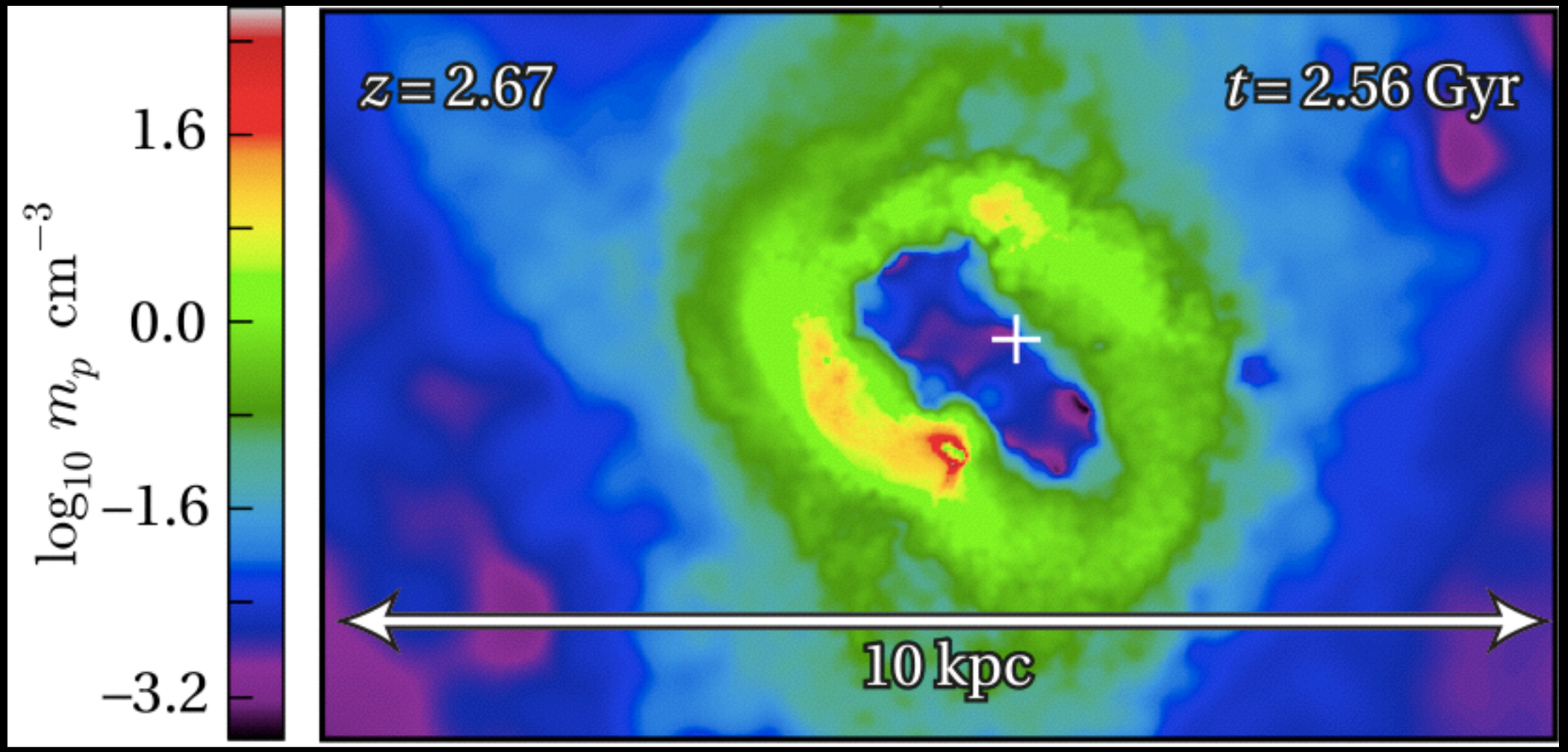
NFW DENSITY PROFILE



Density profile of dark matter

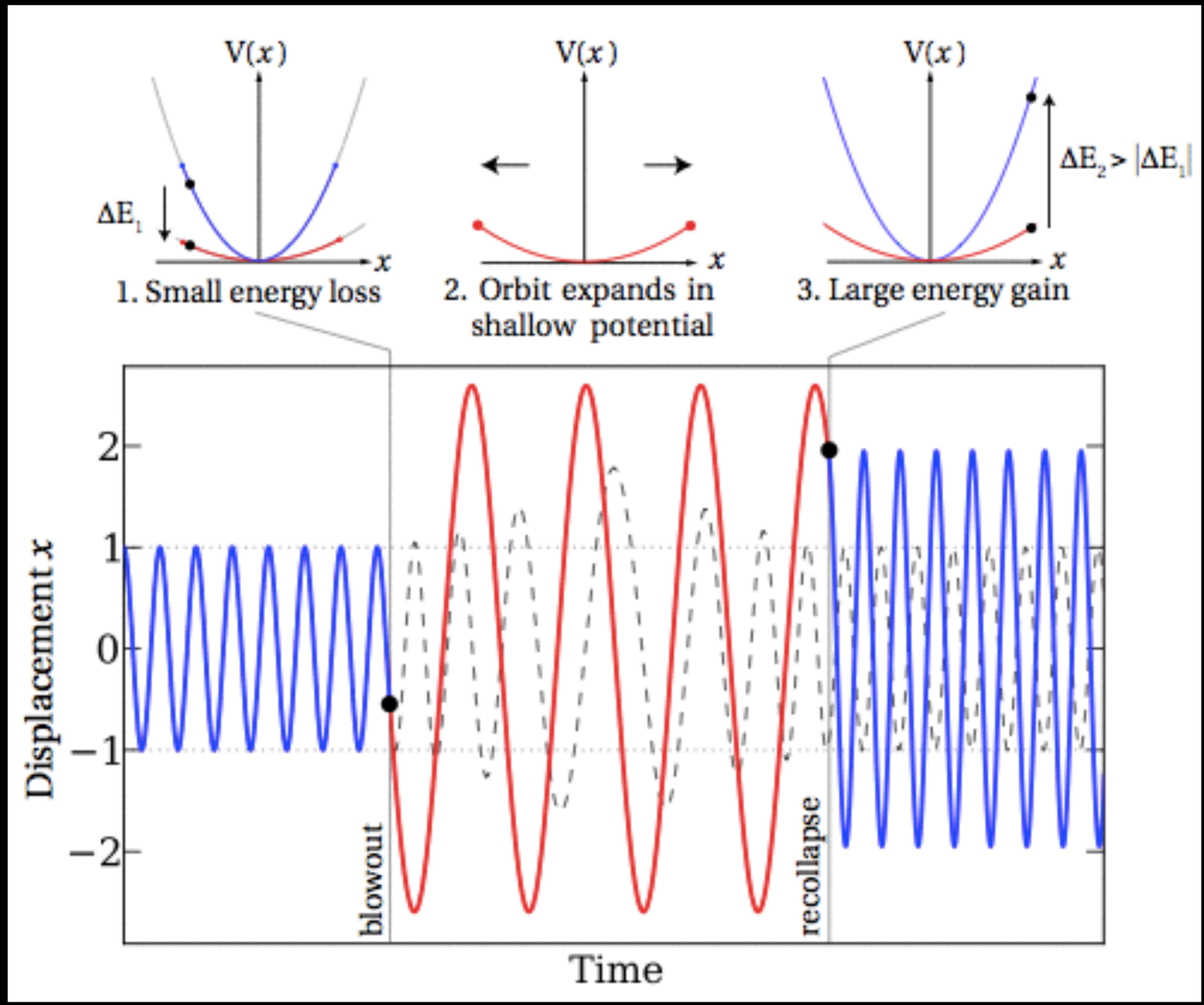
PONTZEN & GOVERNATO (2012)

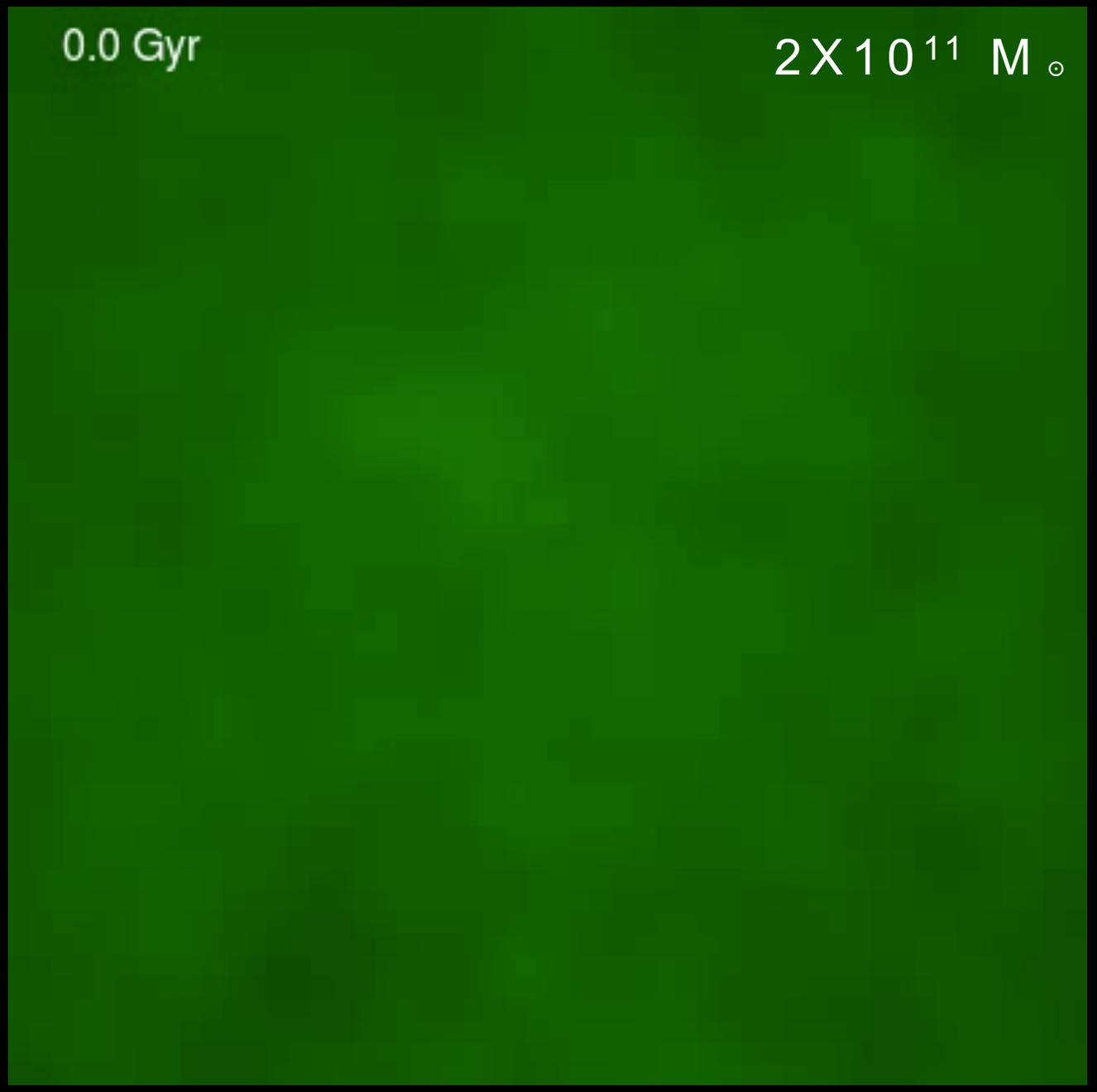
FLATTENING CUSPS



VARYING POTENTIAL

- Changes in potential change the orbits of particles





ALSO SEE PONTZEN & GOVERNATO (2012)

DO BURSTS AFFECT THE GALAXY'S SHAPE?

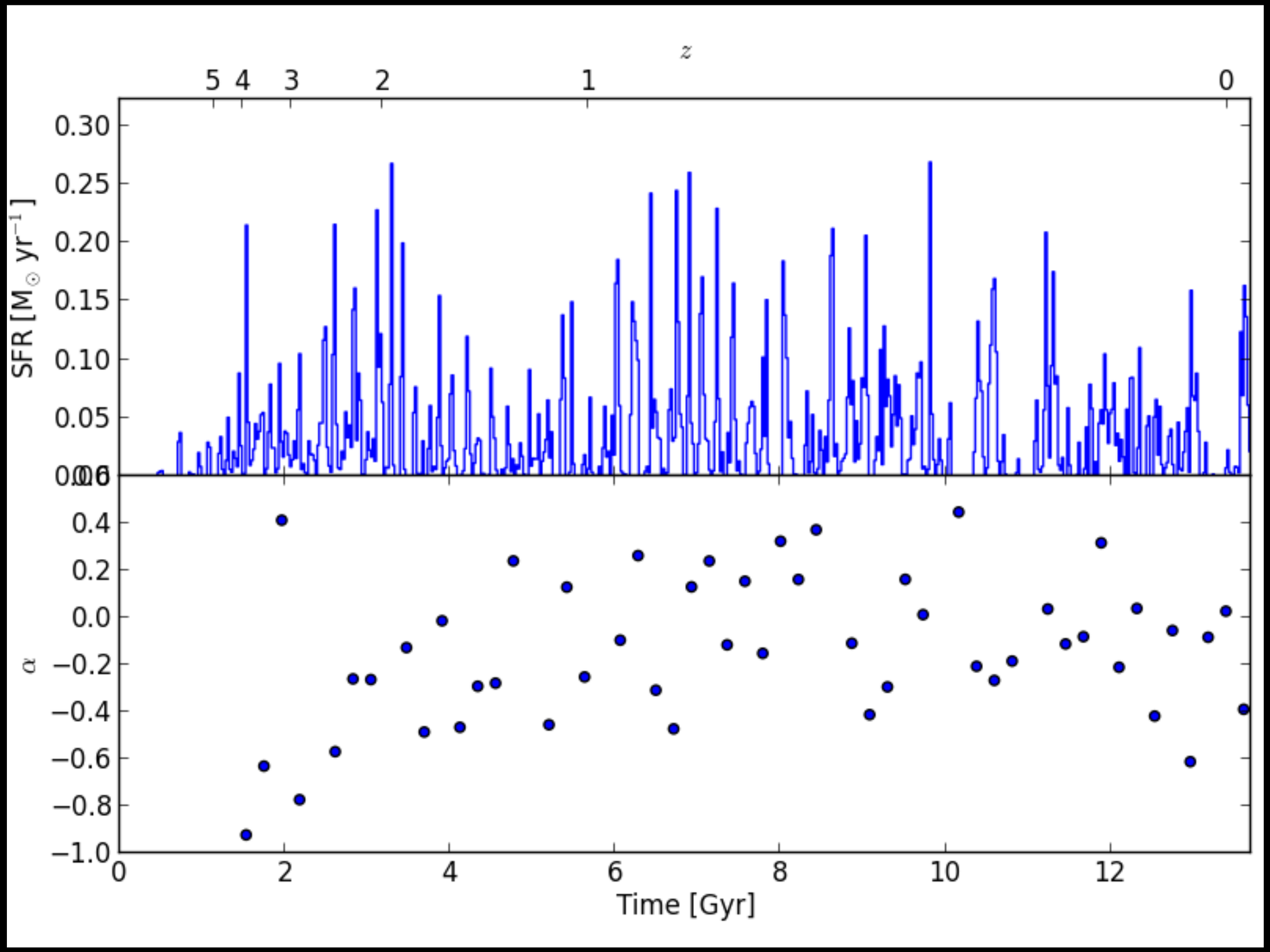
THERE IS NO CENTER SINCE STELLAR FEEDBACK KEEPS MOVING ENOUGH GAS TO AFFECT POTENTIAL

WARNING: PRELIMINARY ANALYSIS

FLATTENING DEPENDS ON MASS

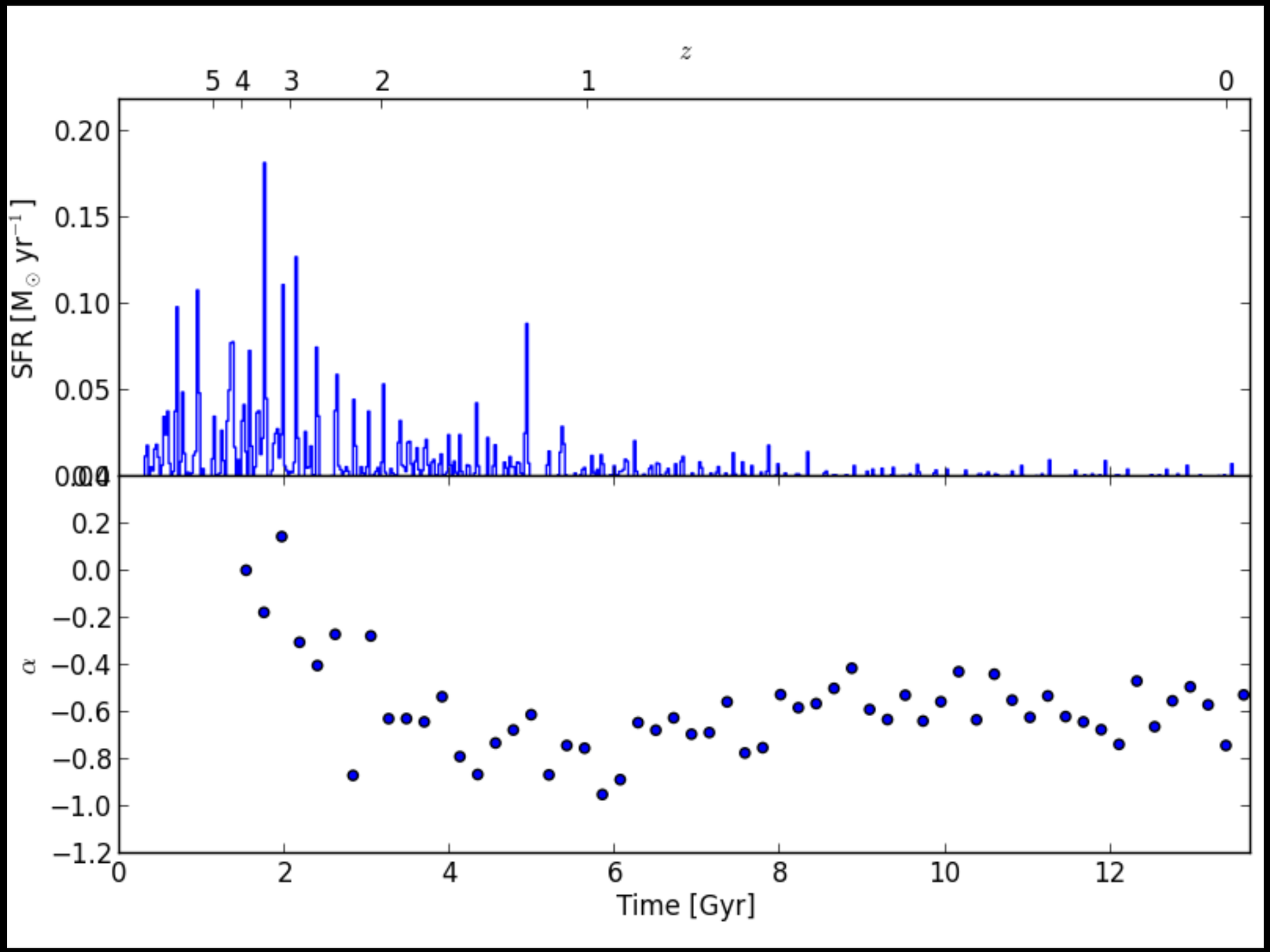
MEDIUM MASS

$M_{halo}=10^{11}\,M_{\odot}$

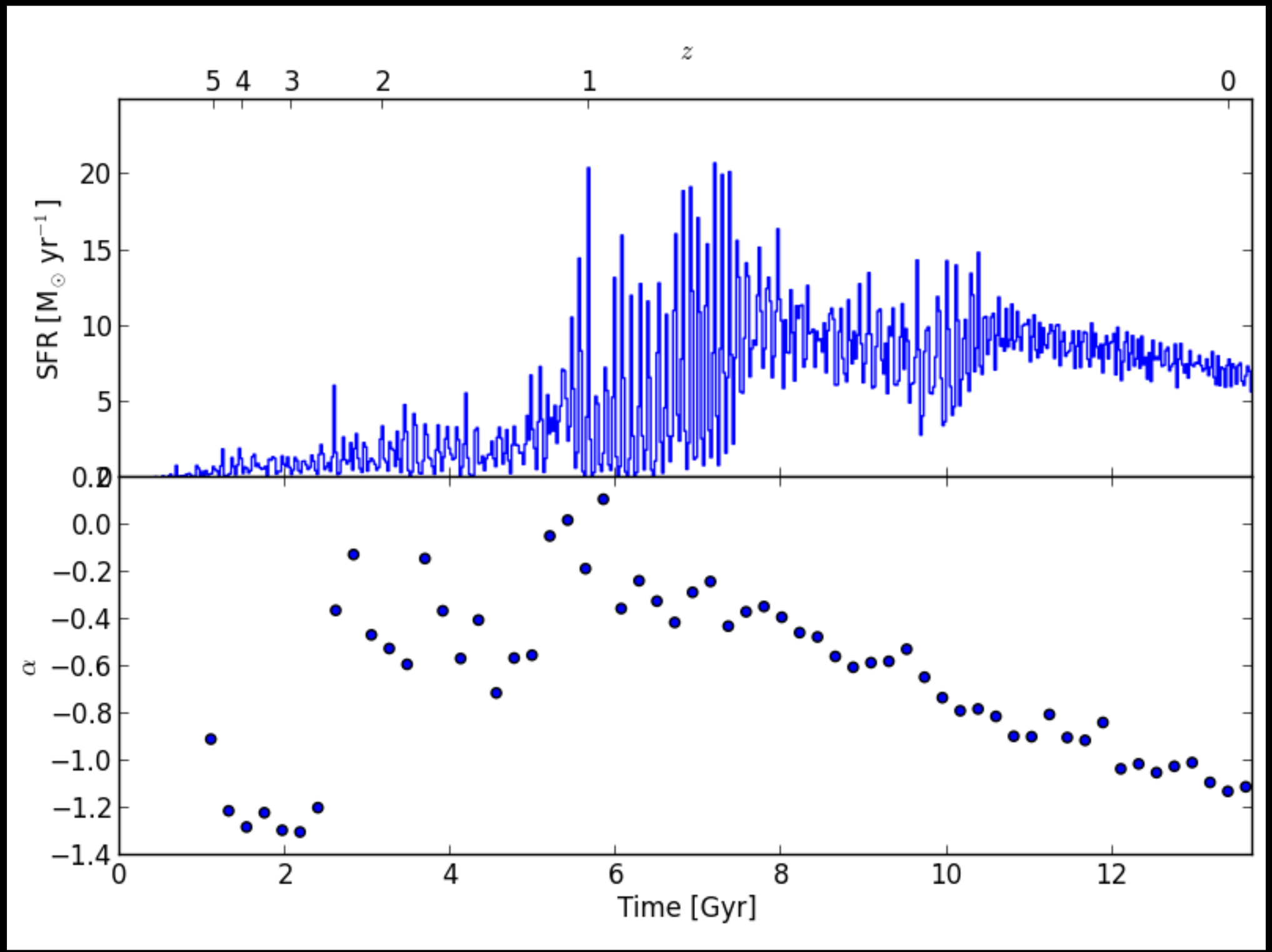


LOW MASS

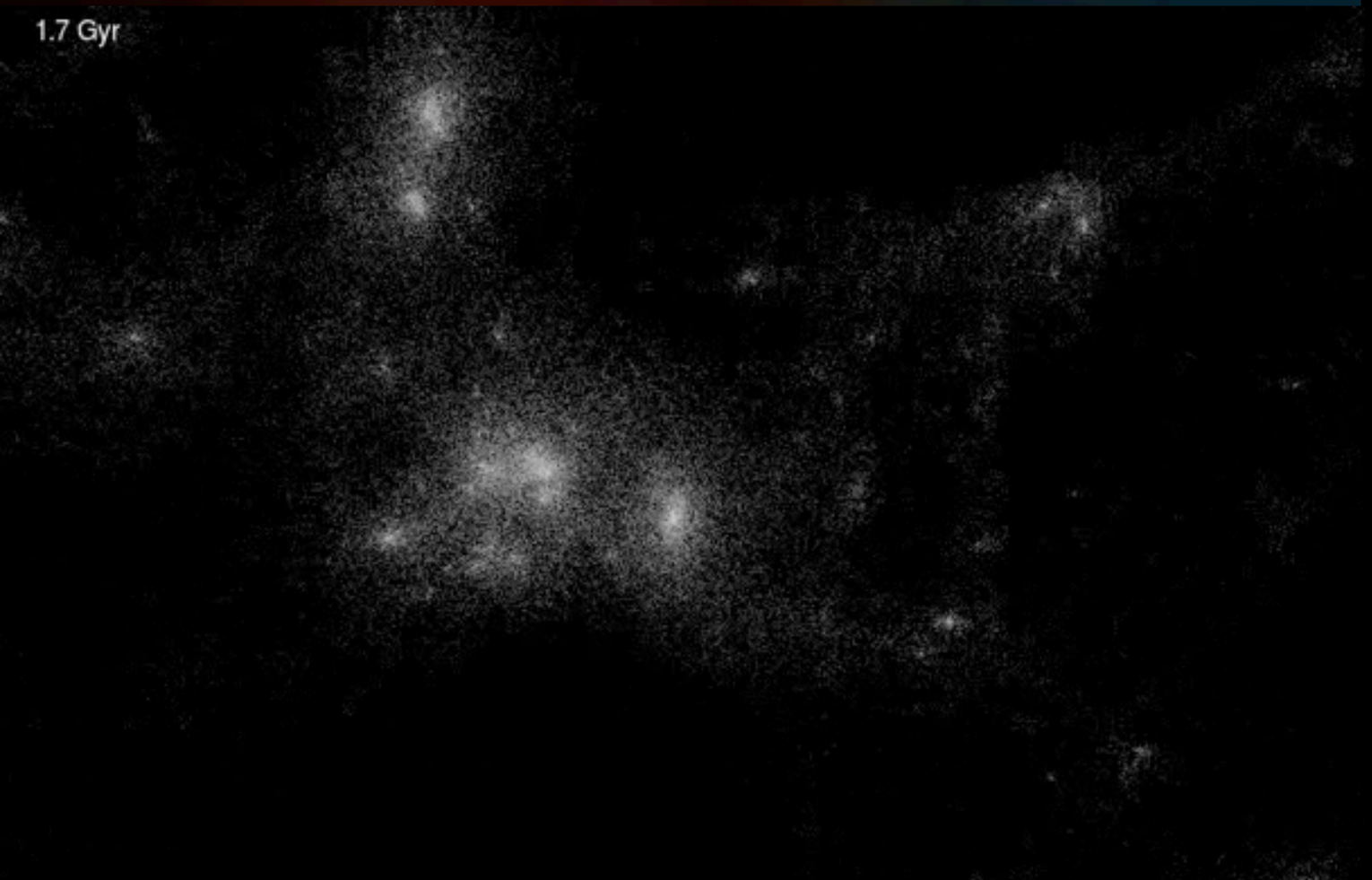
$M_{halo}=3x10^{10}\,M_{\odot}$

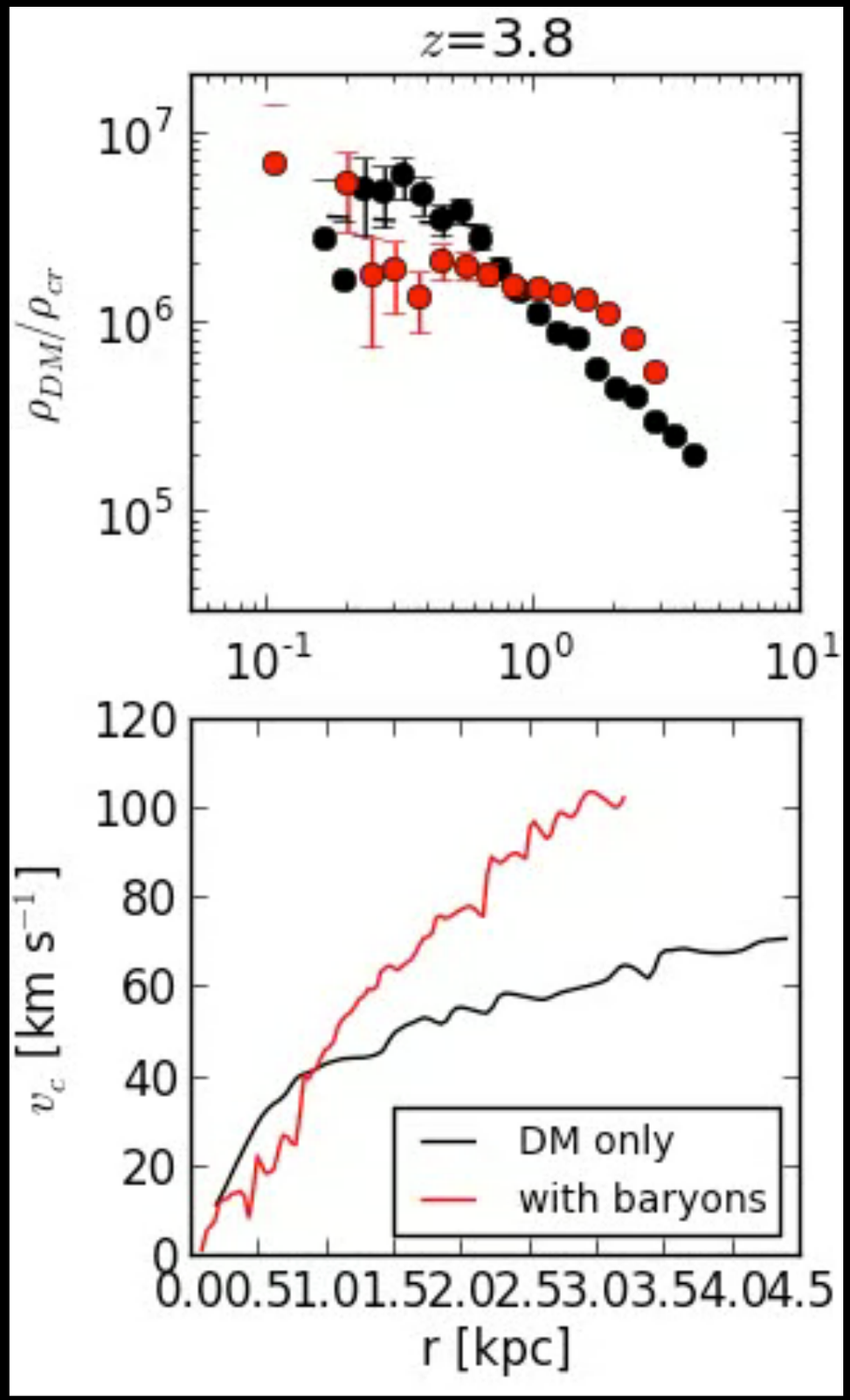


HIGH MASS (MILKY WAY) $M_{halo}=10^{12}\,M_{\odot}$



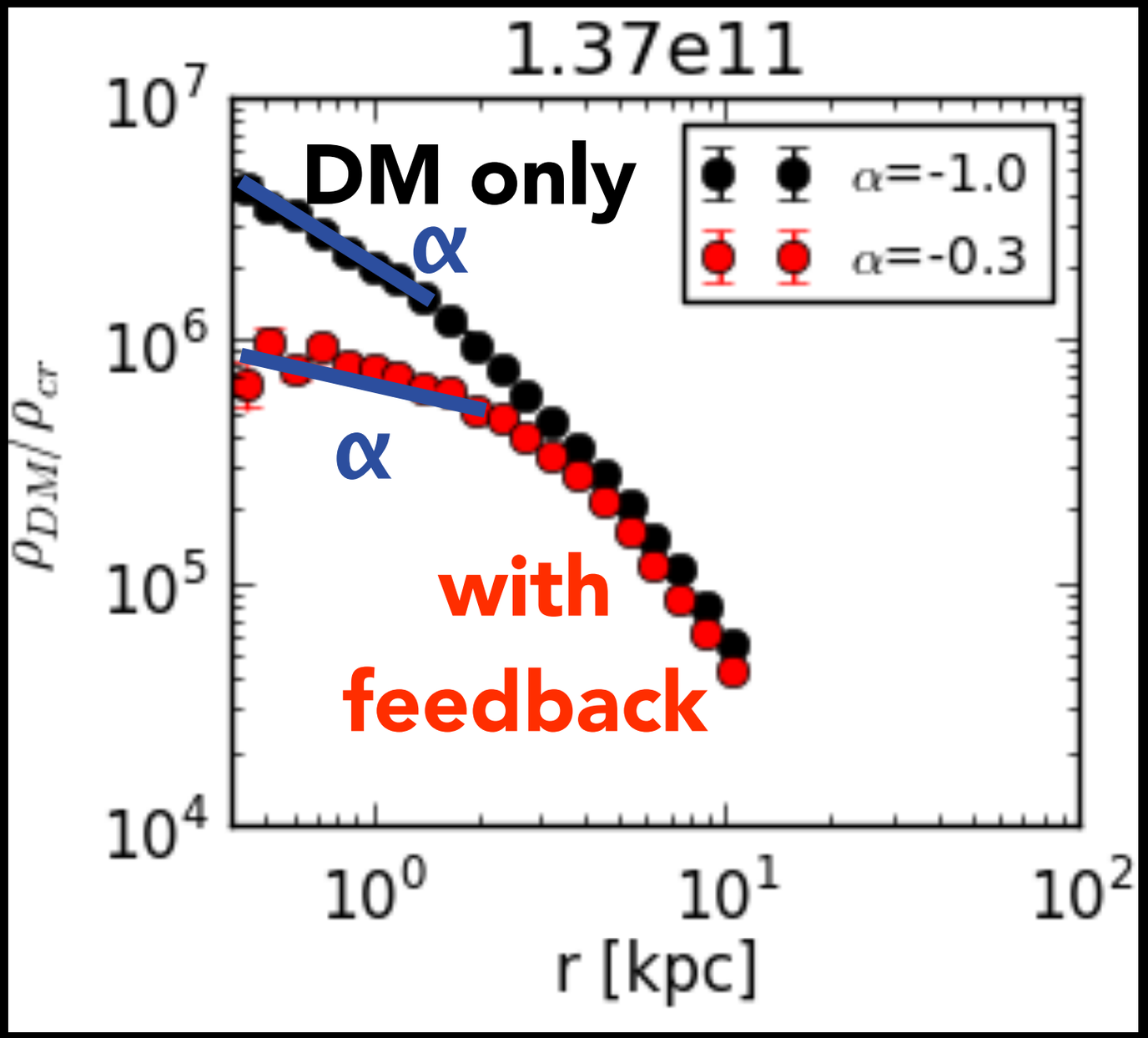

1.7 Gyr


1.7 Gyr


z=3.8
ρ_{DM}/ρ_{cr}
10^7
10^6
10^5
10^{-1}
10^0
10^1
120
100
80
60
40
20
0
v_c [km s^{-1}]
DM only
with baryons
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5
r [kpc]

α IS PROFILE'S INNER SLOPE

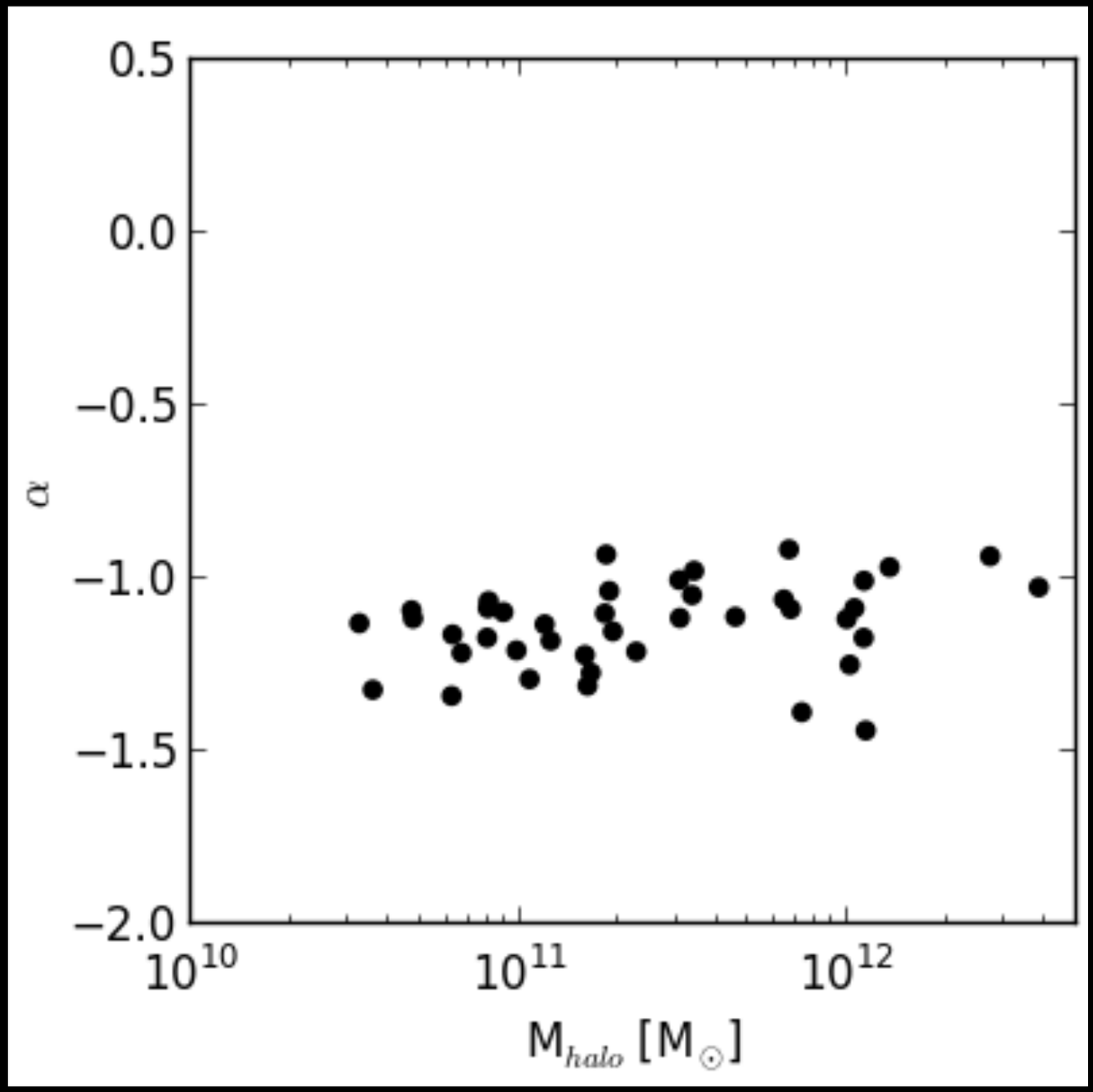
DARK MATTER PROFILES



at z=0

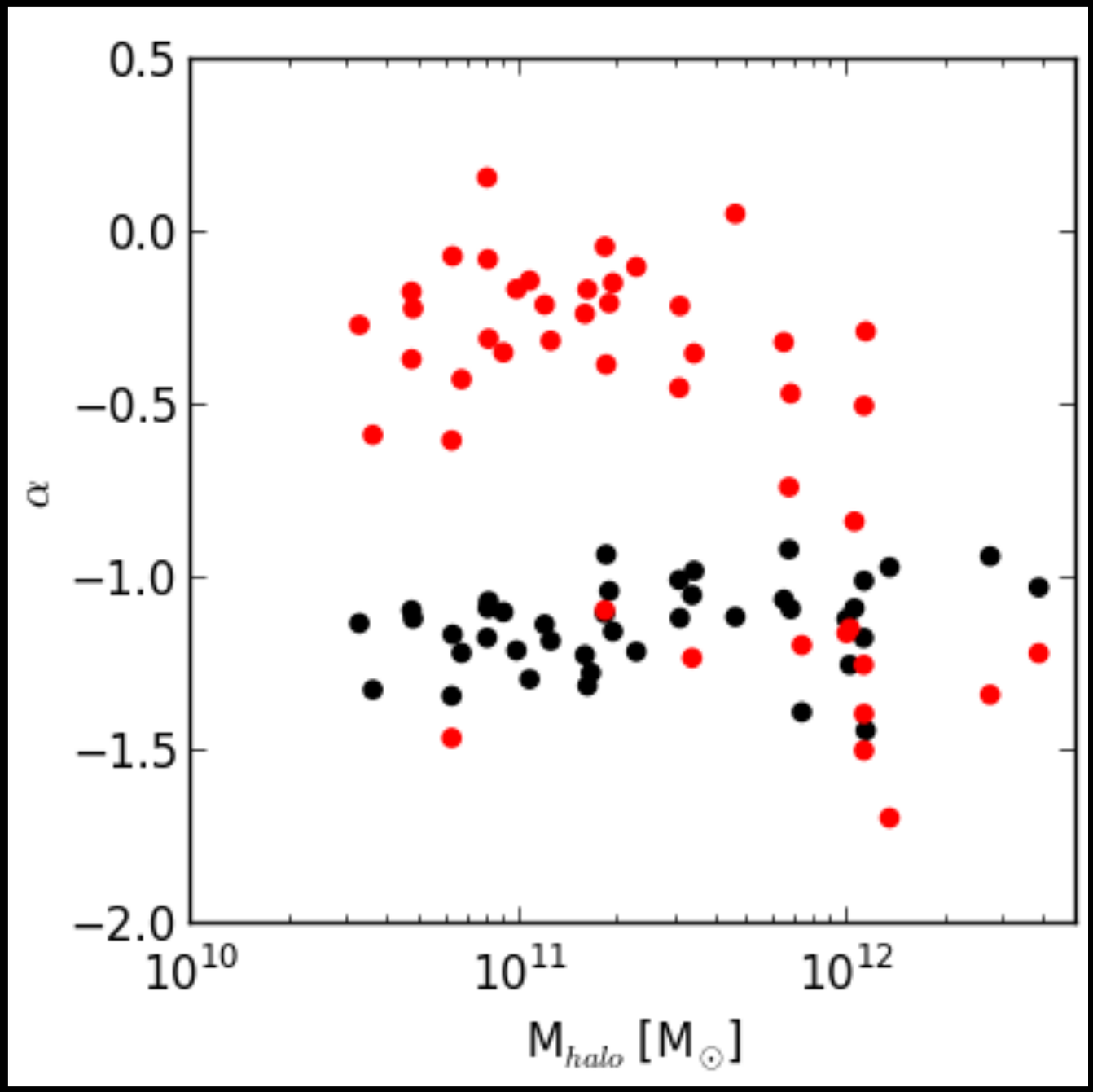
DARK MATTER ONLY

- Fairly constant independent of mass



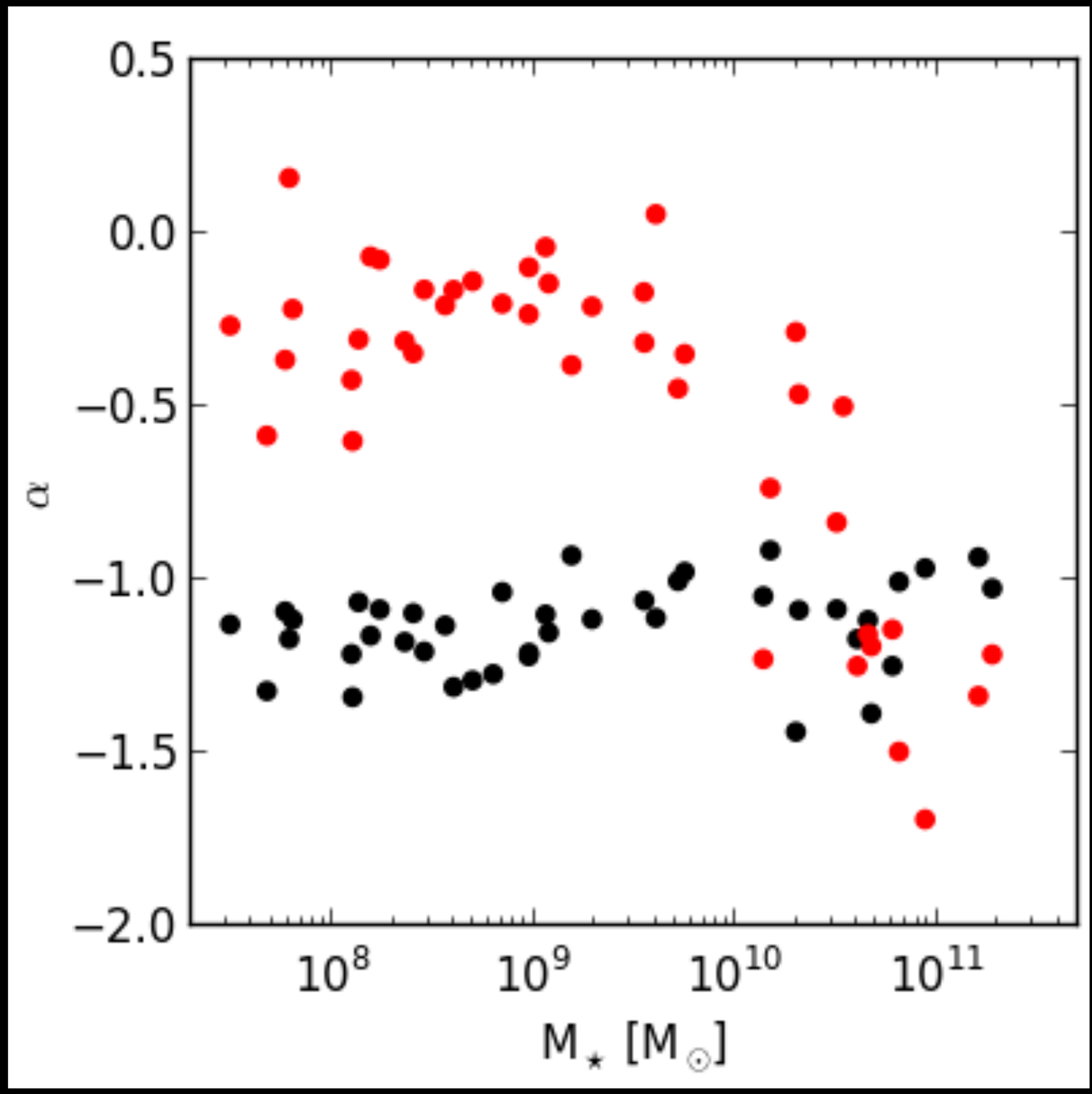
WITH STELLAR FEEDBACK

- trend with mass
- lots of scatter



AS FUNCTION OF STELLAR MASS

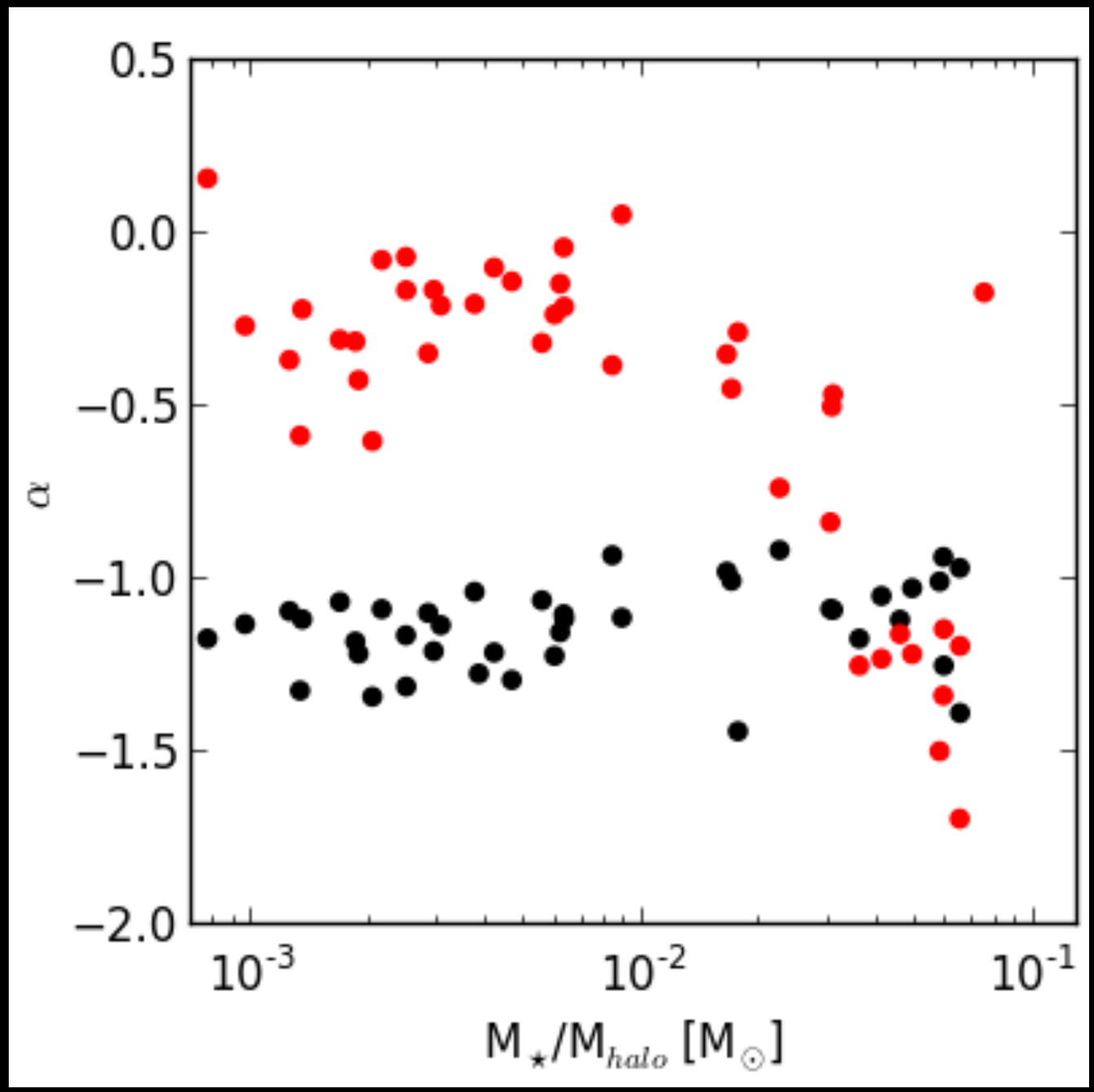
- same trend
- maybe less scatter?



Mass of stars

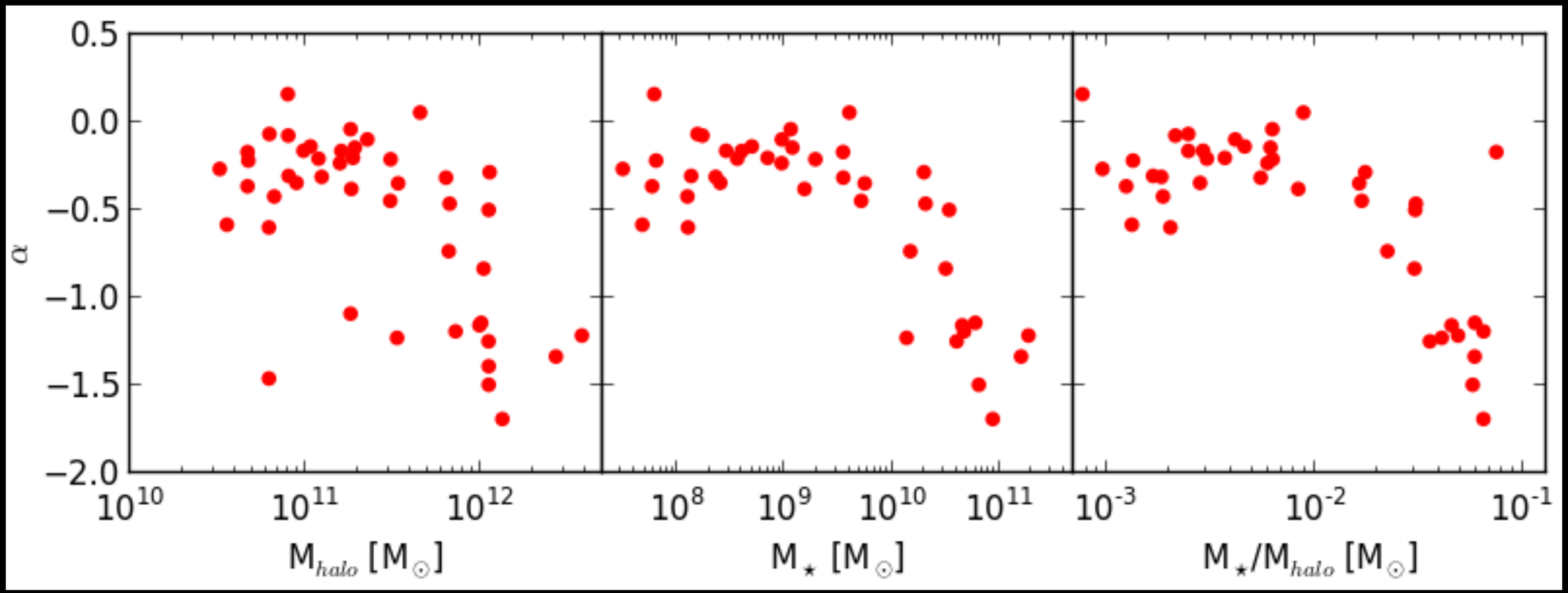
STAR FORMATION EFFICIENCY

- even less scatter?



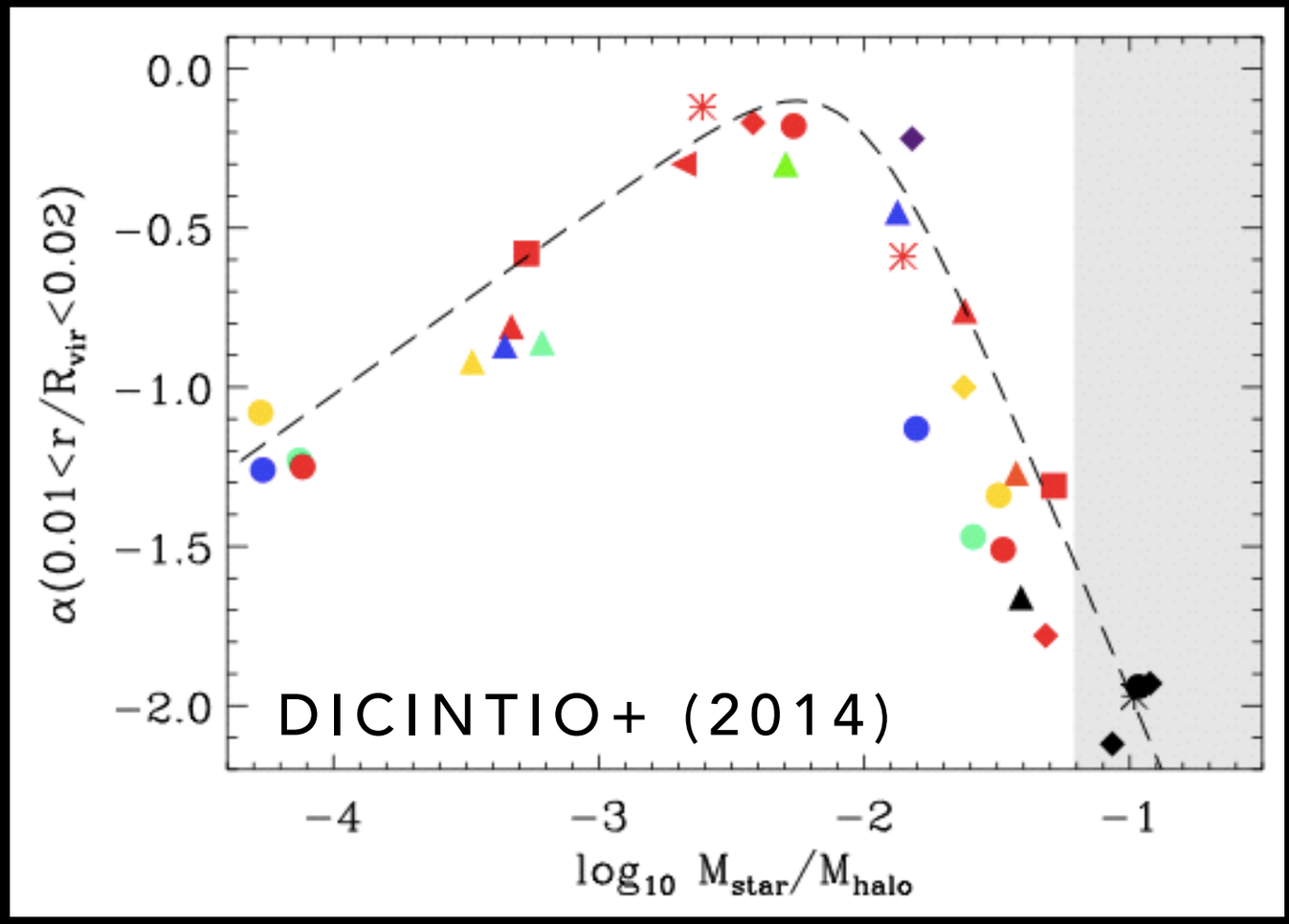
Star formation efficiency

ALL SIMULATIONS WITH FEEDBACK TOGETHER



STELLAR FEEDBACK LIMITS STAR FORMATION AND FLATTENS DM DENSITY PROFILE

LOWER STELLAR MASS HALOS HAVE FLATTER PROFILES

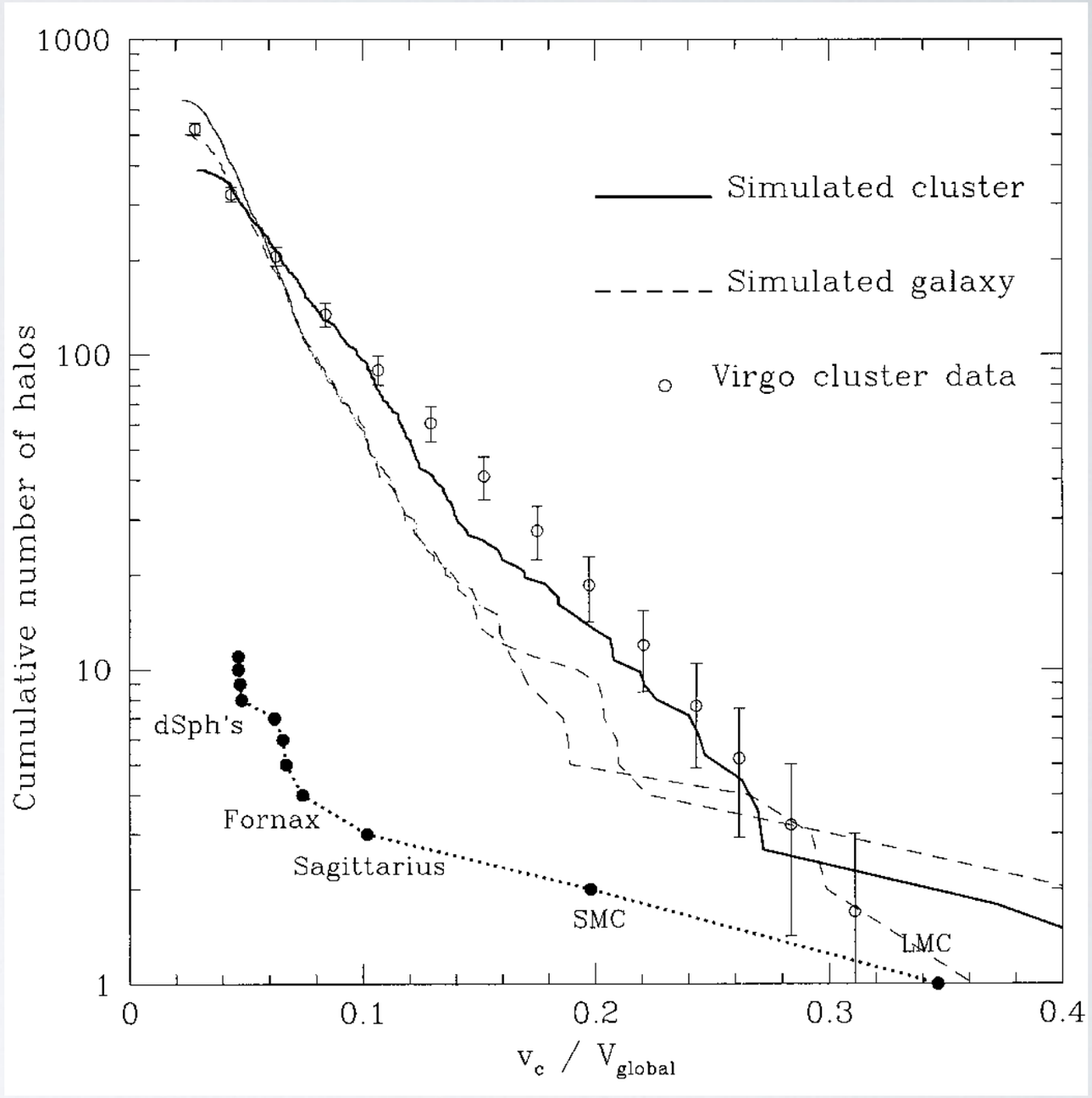


SUMMARY

- Stars drive outflows
- Bursty star formation histories
- Creates Circum-galactic medium (CGM, gas halo)
- Change DM profile cusps to cores and back again

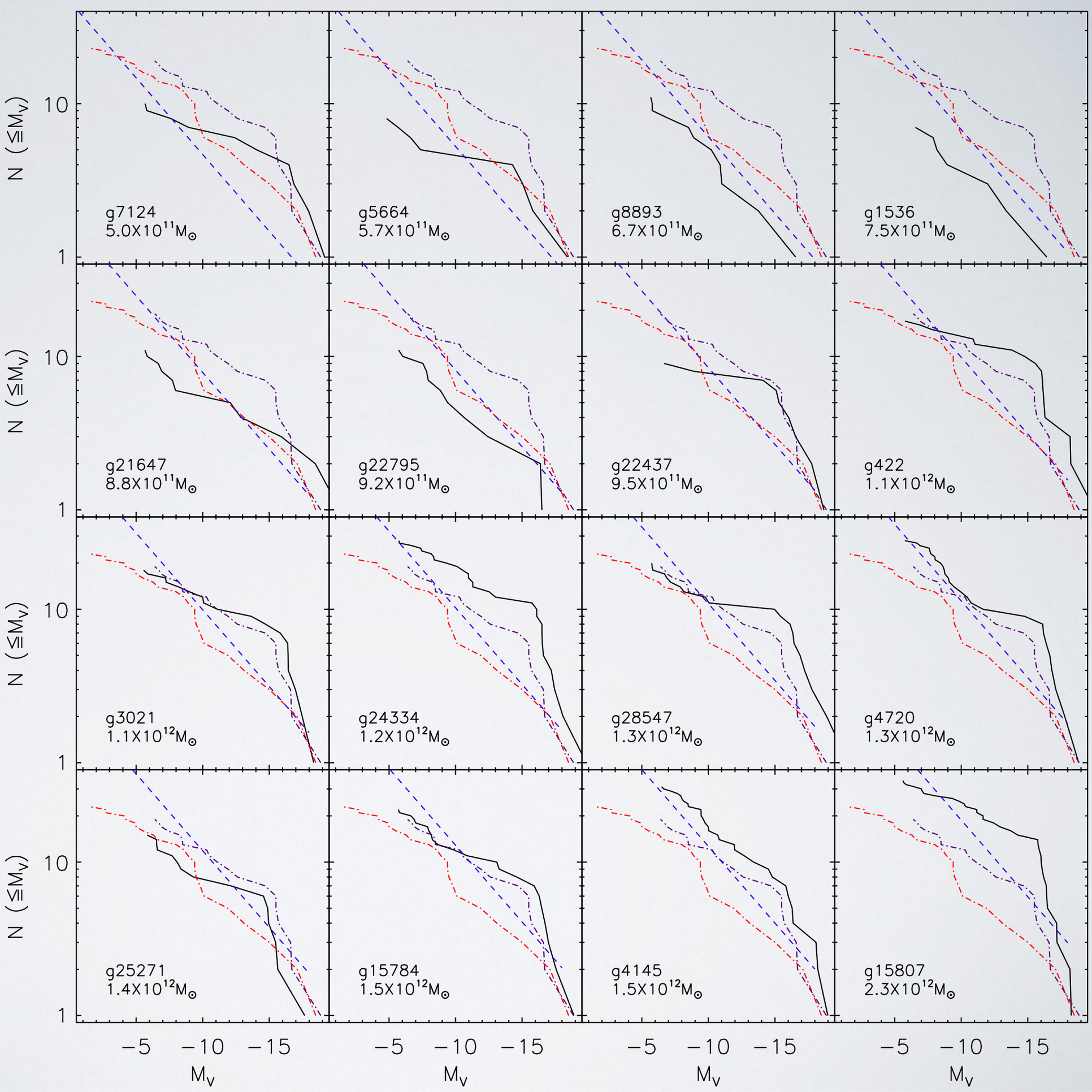
MISSING SATELLITES PROBLEM

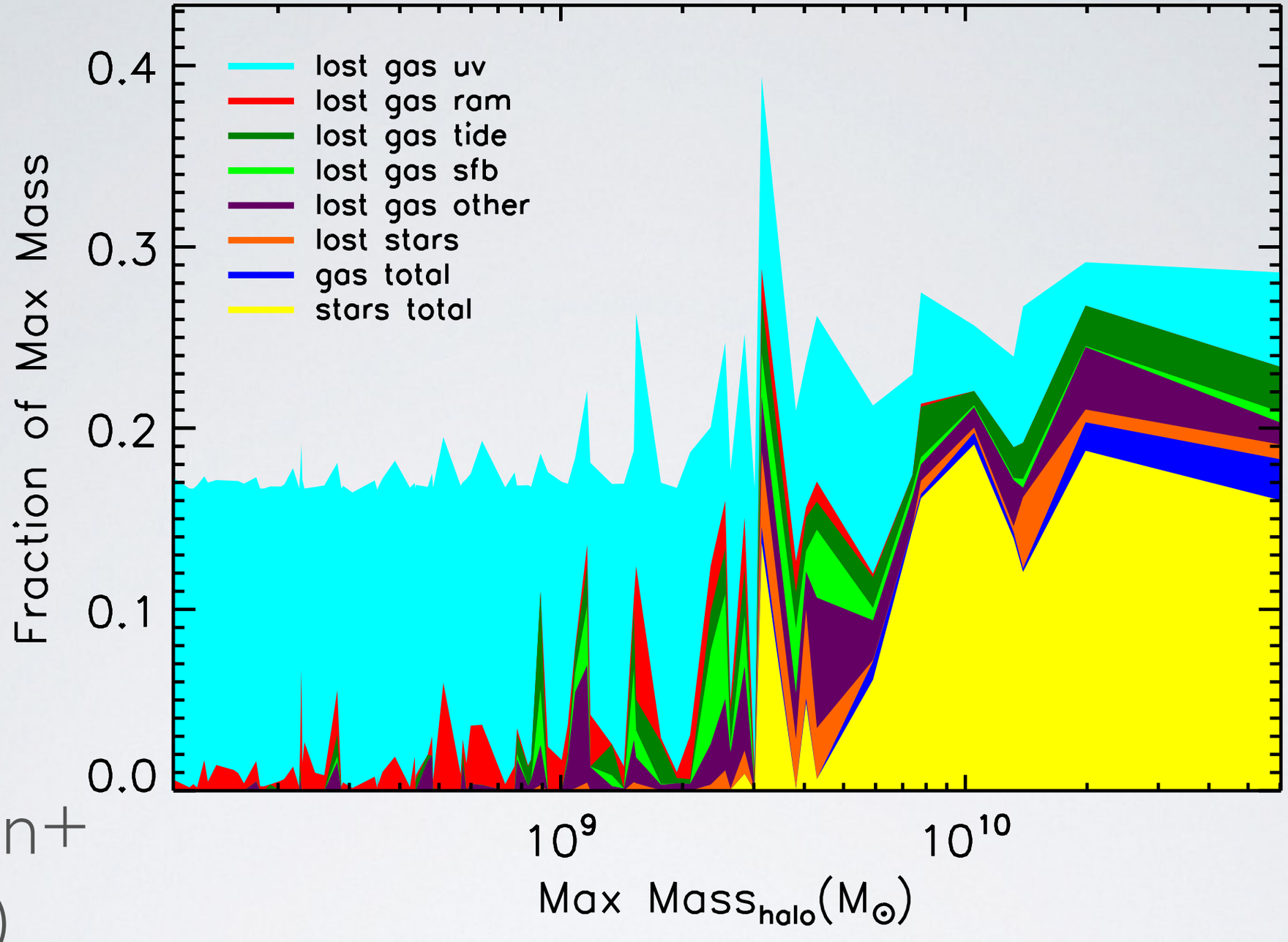
Far fewer satellite substructures found around Milky Way than CDM predicts



with MUGS overcooled

Nickerson+ (2012)



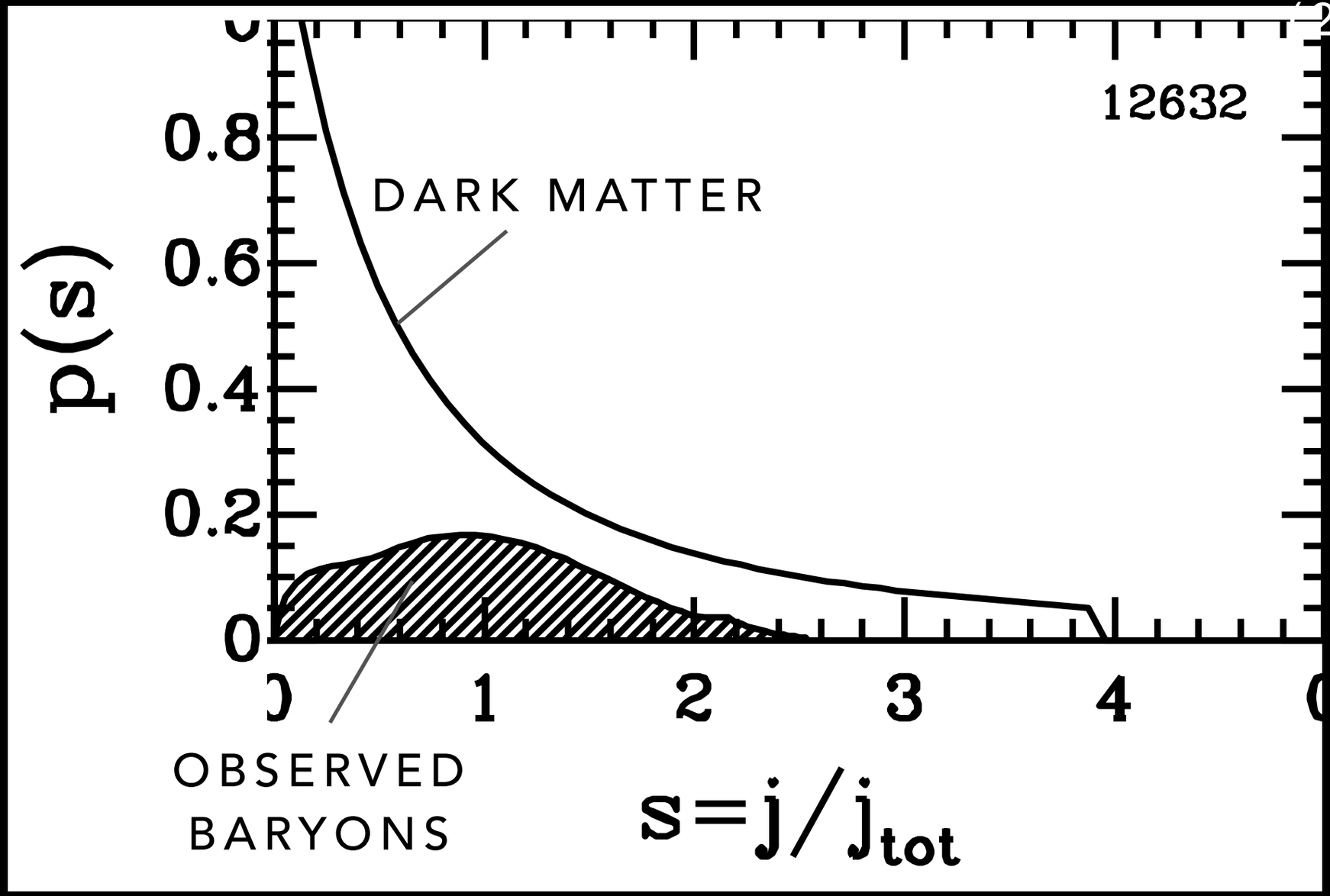


Nickerson+ (2011)

WHY SUBHALOS FAIL

Low mass potentials not deep enough to hold ionized 10^4 K gas

VAN DEN BOSCH+ (2001)



BARYONS HAVE MUCH LESS LOW ANGULAR MOMENTUM MATERIAL THAN DARK MATTER: WHERE DID IT GO?

ANGULAR MOMENTUM DISTRIBUTION