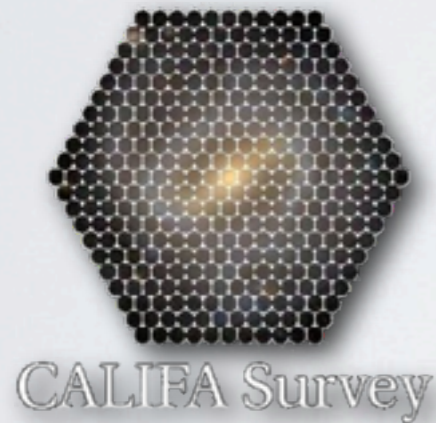


# THE RADIAL STRUCTURE OF M/L:

## CALIFA RESULTS

Rubén García-Benito  
(IAA-CSIC)

Rosa González-Delgado  
Enrique Pérez Jiménez  
Roberto Cid Fernandes (UFSC)  
&  
the CALIFA collaboration



PRELIMINARY



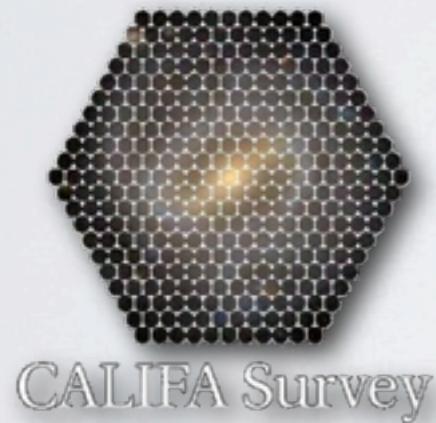
“Galaxies meet GRBs at Cabo de Gata” ◦ September 24, 2013

# THE EVOLUTION OF GALAXIES RESOLVED IN SPACE & TIME

## CALIFA RESULTS

Rubén García-Benito  
(IAA-CSIC)

Rosa González-Delgado  
Enrique Pérez Jiménez  
Roberto Cid Fernandes (UFSC)  
André Amorim (UFSC)  
Sebastián F. Sánchez (PI.)  
&  
the CALIFA collaboration



“Galaxies meet GRBs at Cabo de Gata” ◦ September 24, 2013

# **Paleontology** of galaxies

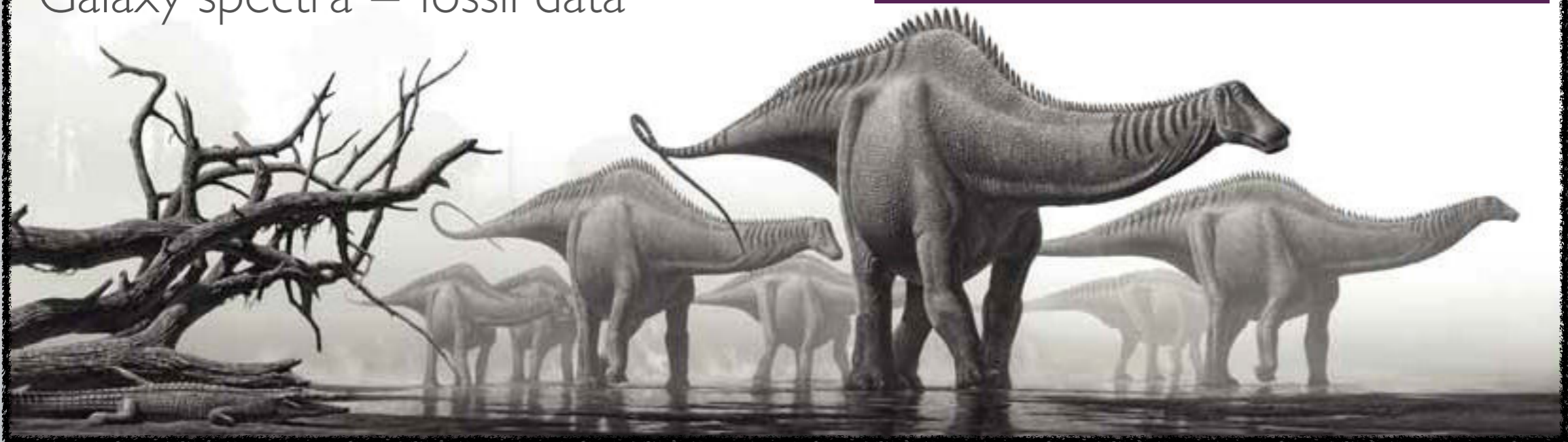
# Paleontology of galaxies

“Paleontology”?



Stars = fossil record  
Galaxy spectra = fossil data

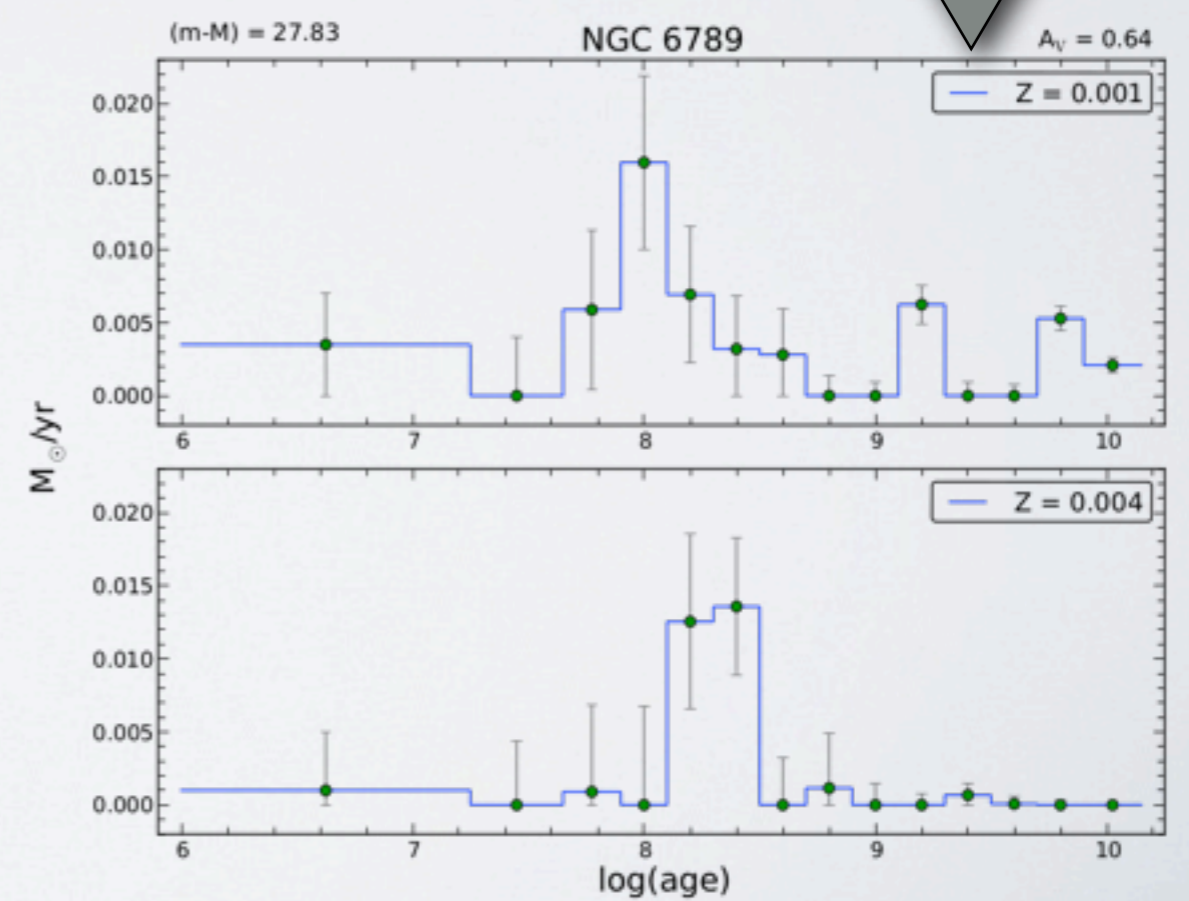
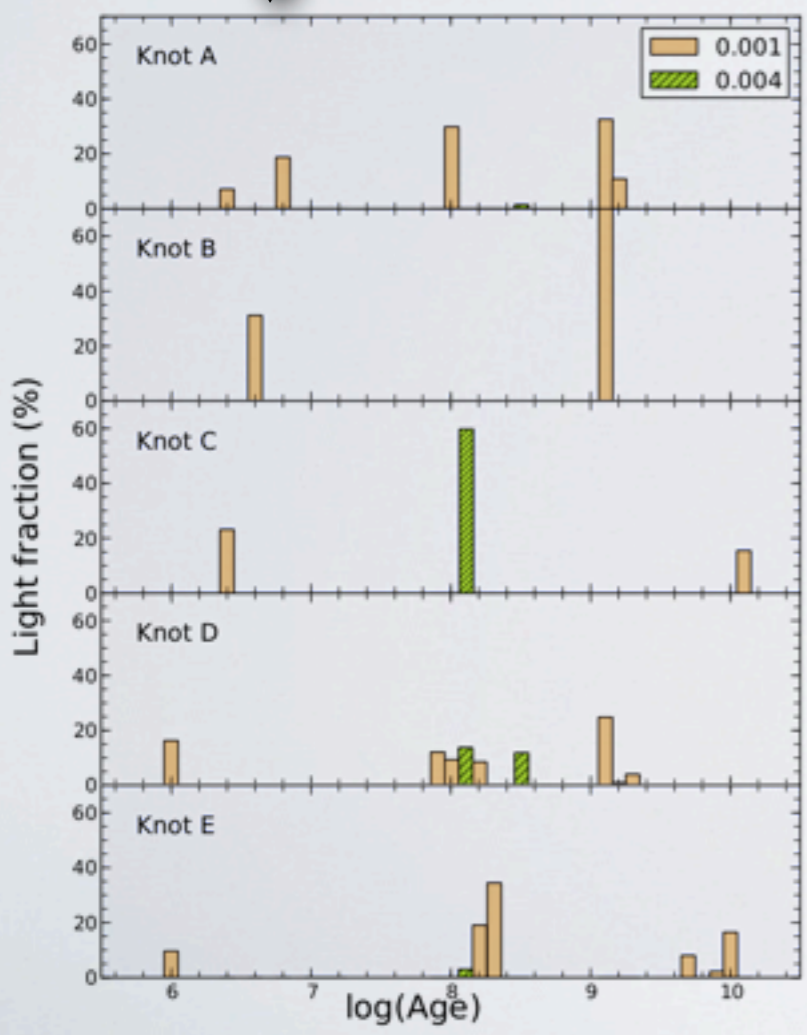
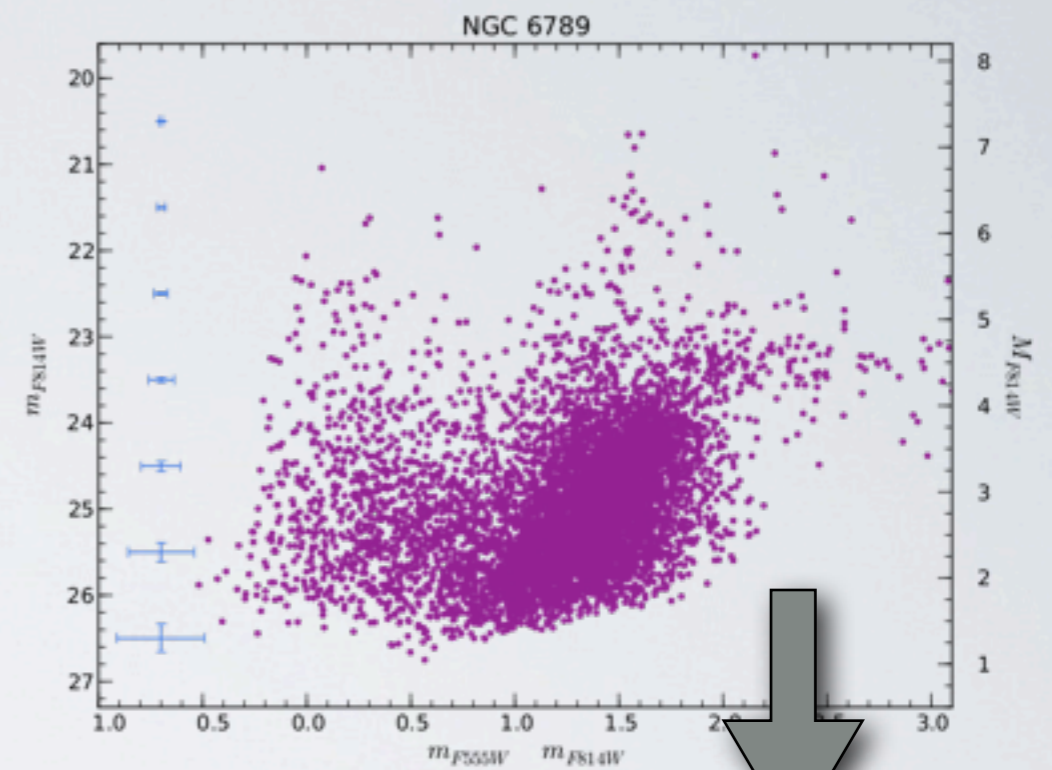
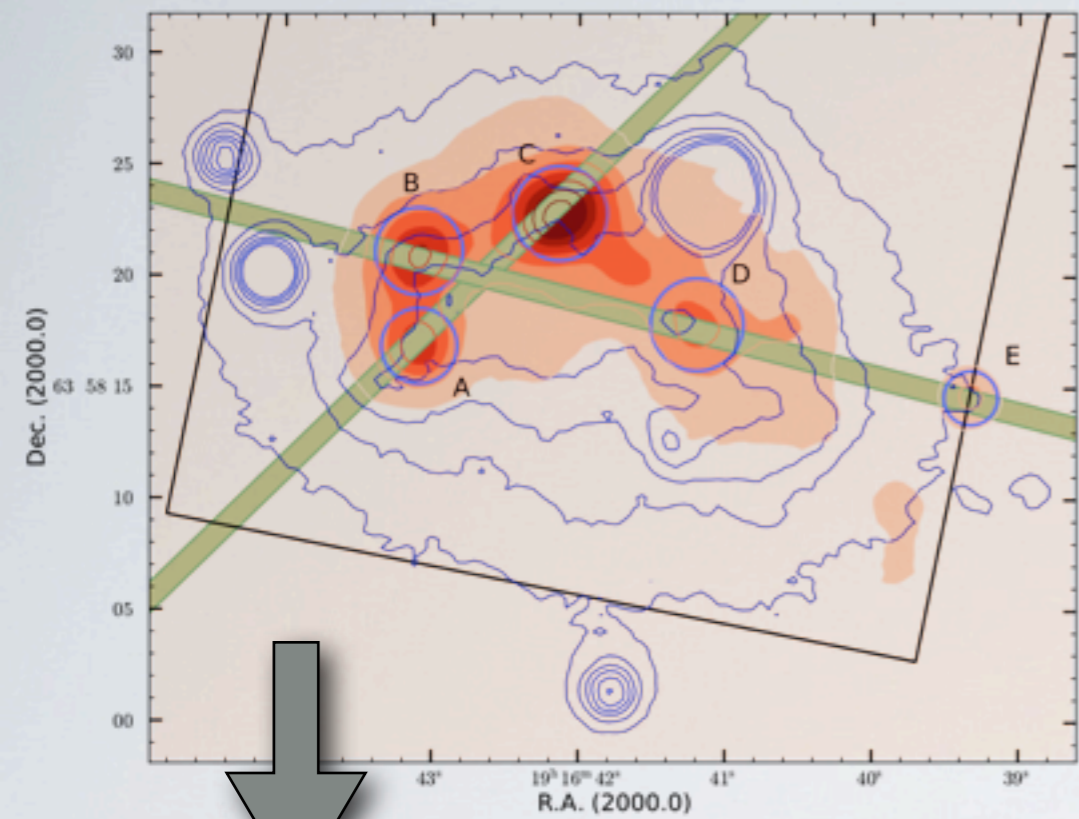
History of the Galaxy!



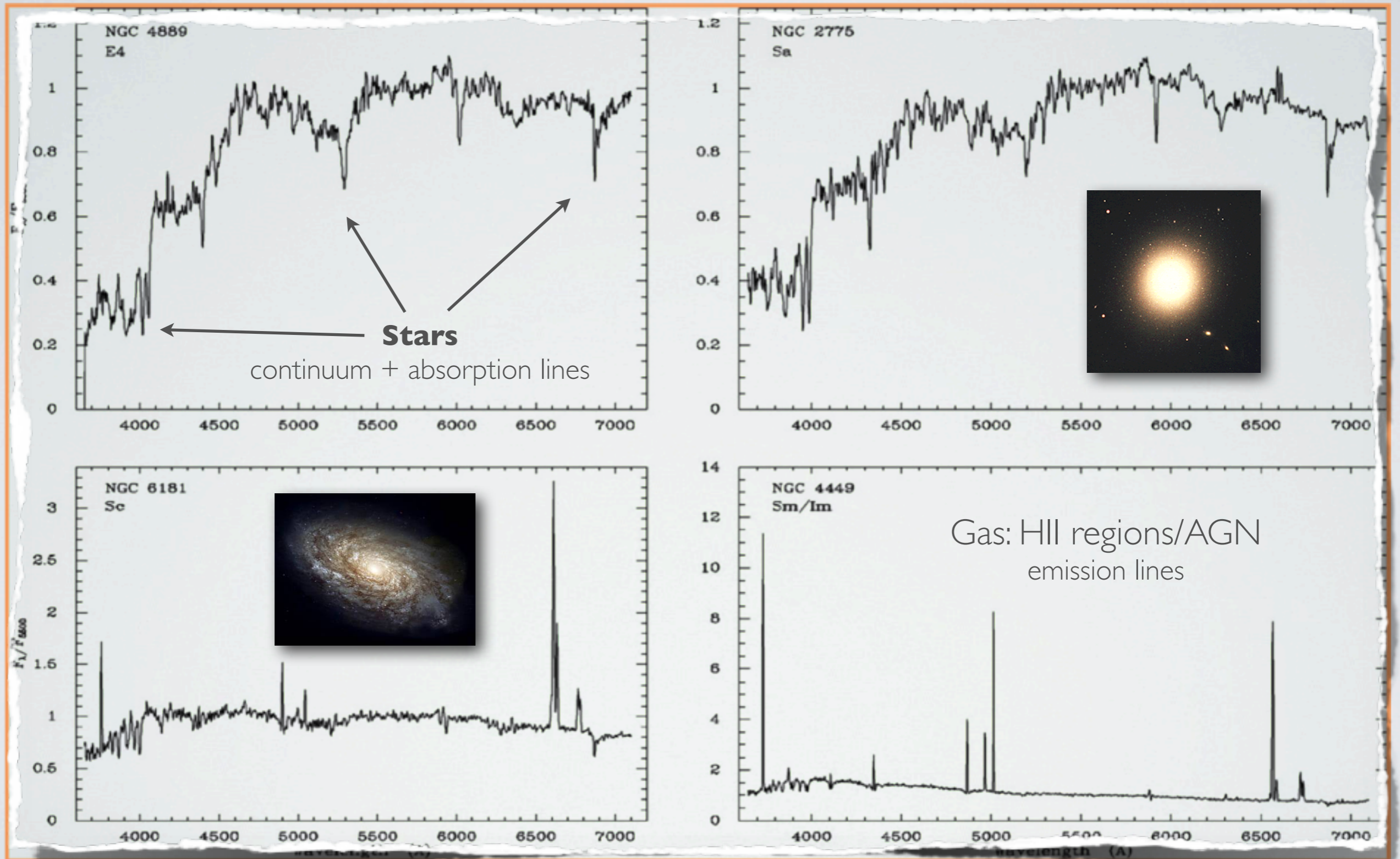
# SFH: Spectral fitting vs CMD

García-Benito & Pérez-Montero (2012)

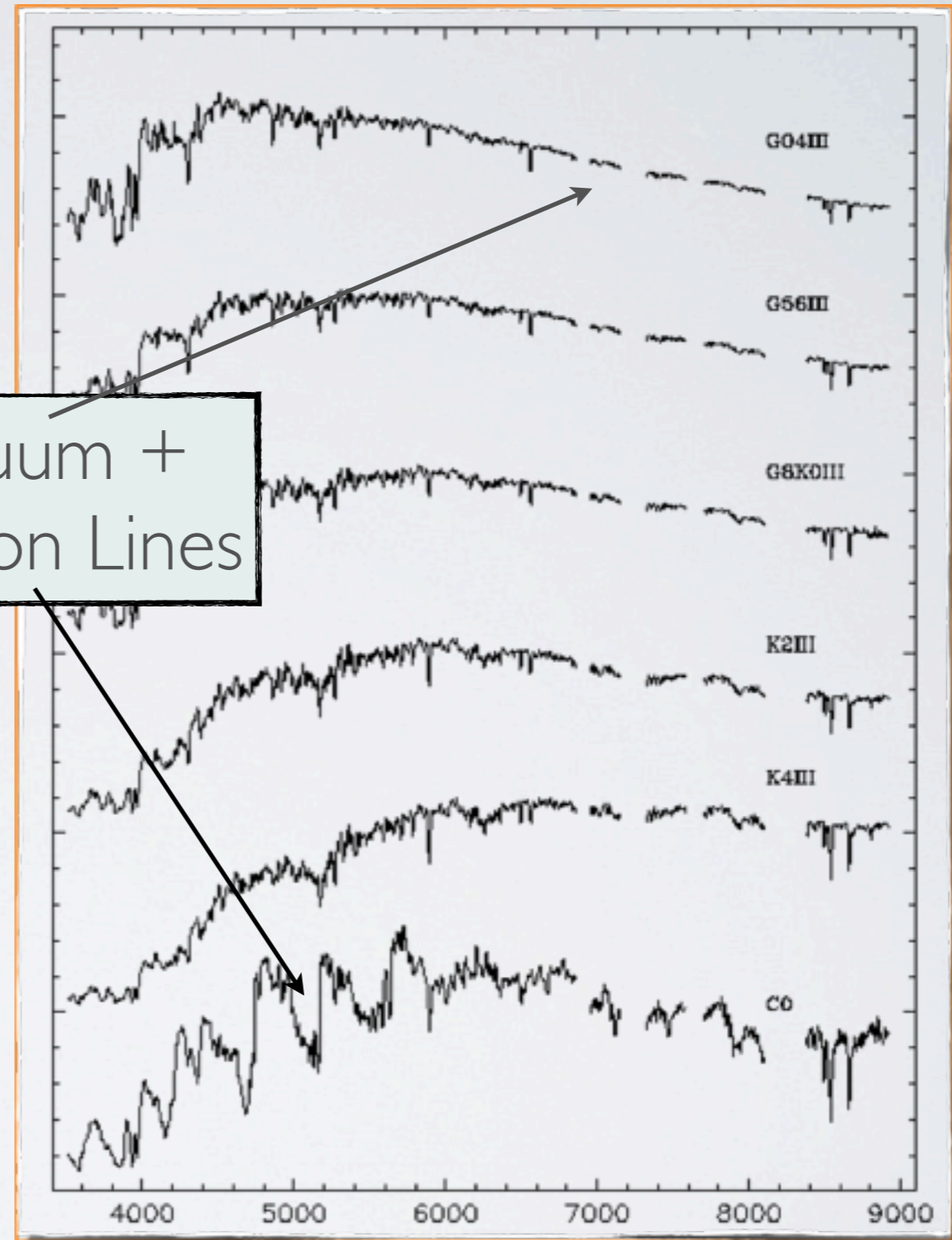
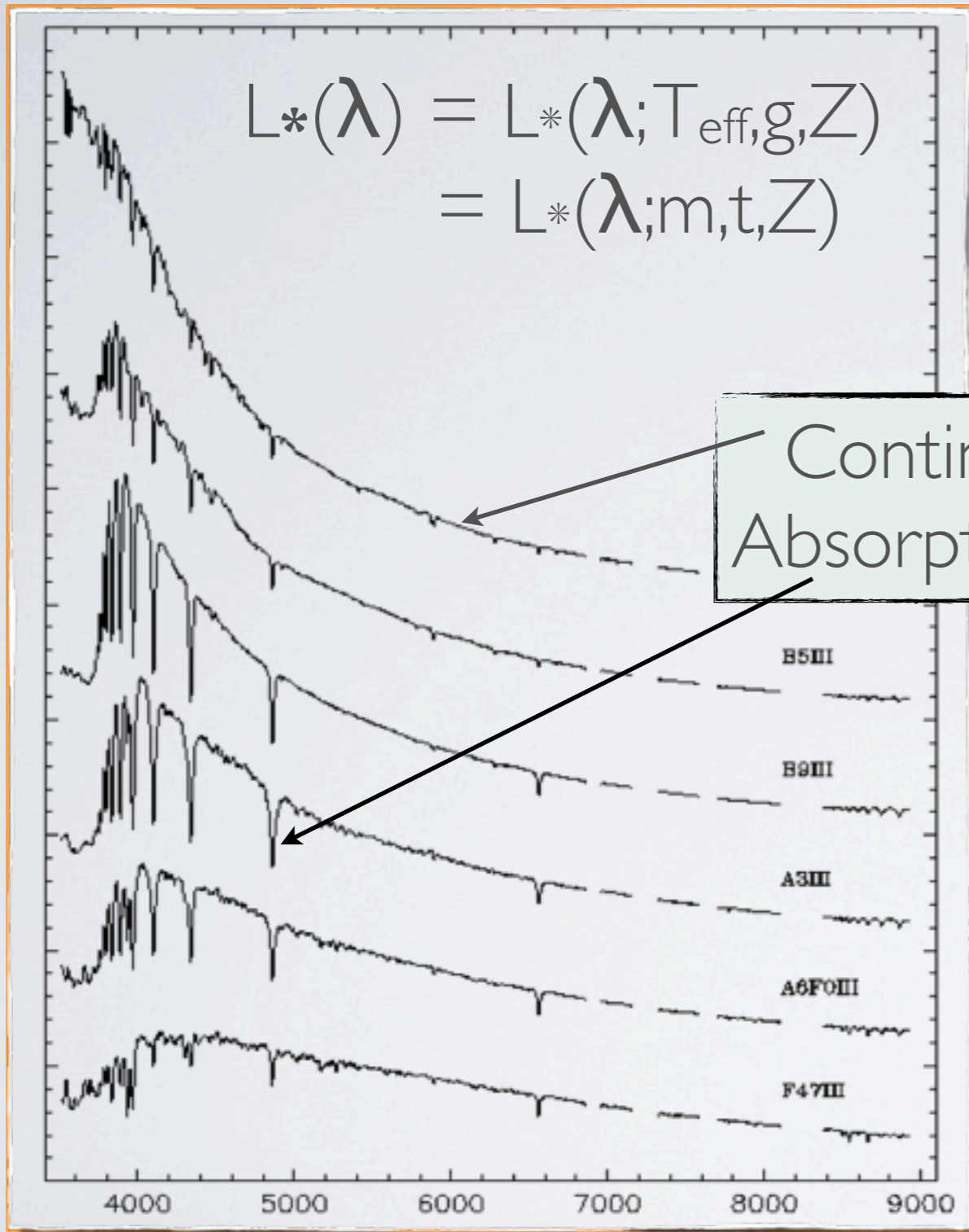
## NGC 6789



# Galaxy spectra: Stars + Gas + ...



# Stellar (optical) spectra



$$L_*(\lambda) = L_*(\lambda; T_{\text{eff}}, g, Z) \\ = L_*(\lambda; m, t, Z)$$

Continuum +  
Absorption Lines

↑  
T  
E  
M  
P  
E  
R  
A  
T  
U  
R  
E

$\lambda$  [Angstroms]

# Decomposing galaxy spectra





# Decomposing galaxy spectra



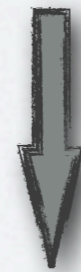
$$L_{\text{gal}}(\lambda) = \sum_{t, Z} M_{\text{SSP}}(t, Z) \times \text{SSP}(\lambda; t, Z) \times e^{-\tau(\lambda)}$$



Observables:  
*Full spectrum*



SFH:  
*Mass or  
light fractions*



Spectral Base



Dust

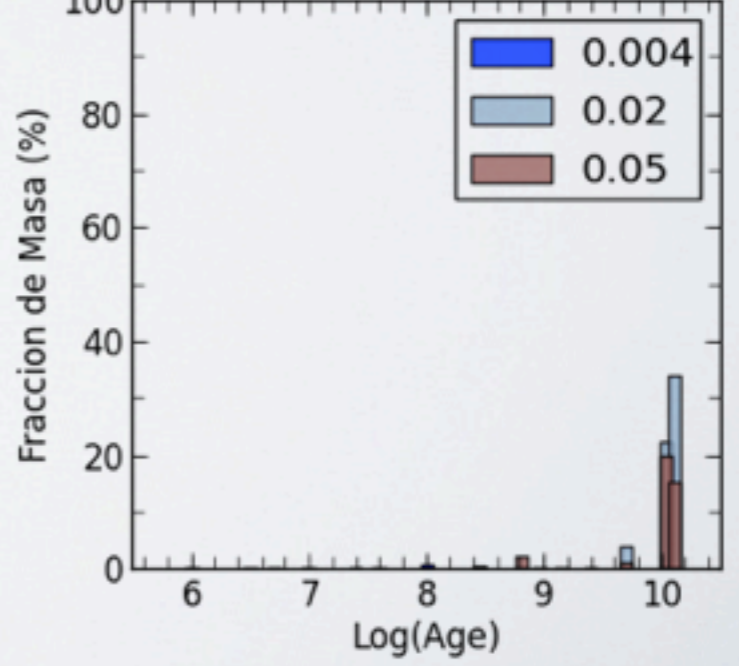
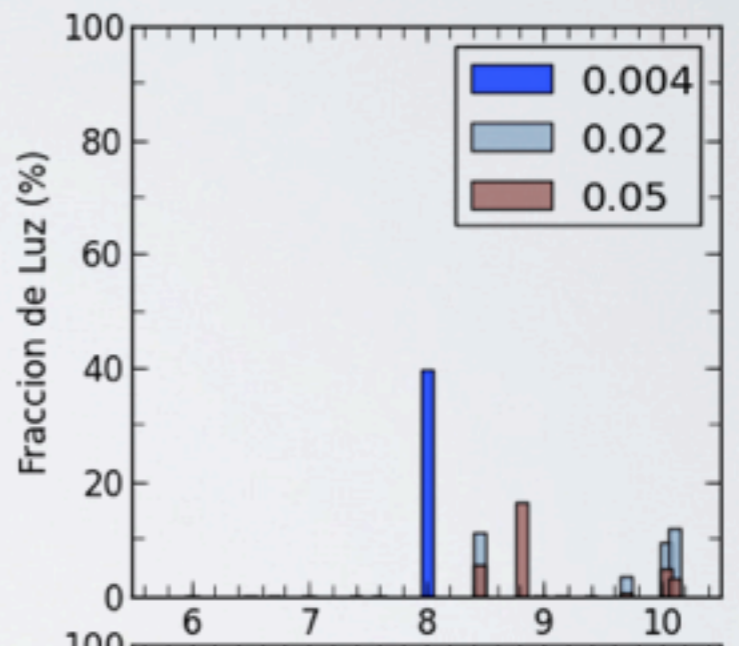
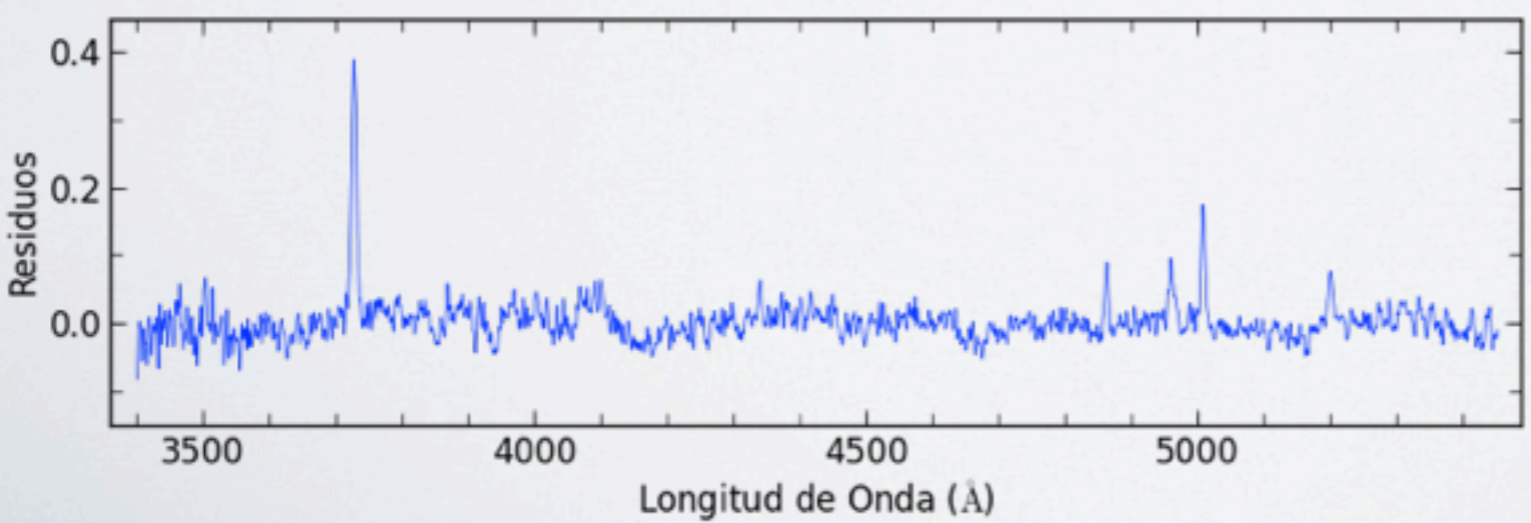
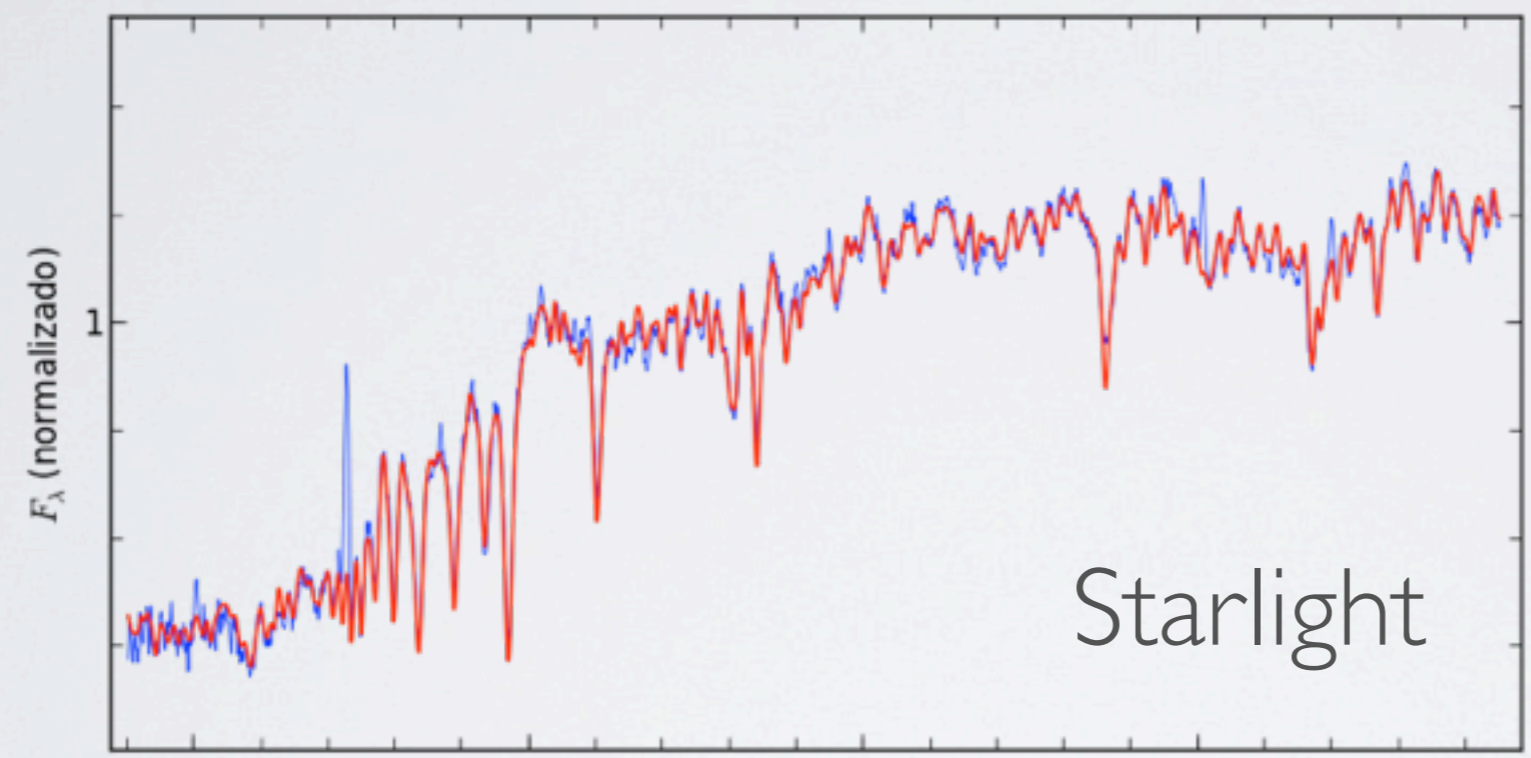
# The method

Decomposing galaxy spectra



$M_{ion} = 0.00\% \mid 0.00\%$  (10Ma|20Ma) 5377x.nuc.txt.DR.sc4.C11.gm.CAL  
 $EW(H\beta) = 0.000 \mid 0.000$   $\frac{Cont_{ion}}{Cont_{tot}}$   $\chi^2 = 0.499$   
 $M_* = 1.169e+06 \times D^2 M_{\odot}$   $Z = 0.004 \oplus 0.02 \oplus 0.05$

$V_0 = -46.27$  km/s  
 $V_d = 191.58$  km/s  
 $AV = 0.5656$  mag



600  
galaxies

$0.005 < \text{redshift} < 0.03$

★ Large homogeneous sample

937 galaxies  
Mother sample

$\lambda$  range:  
3700-7000 Å

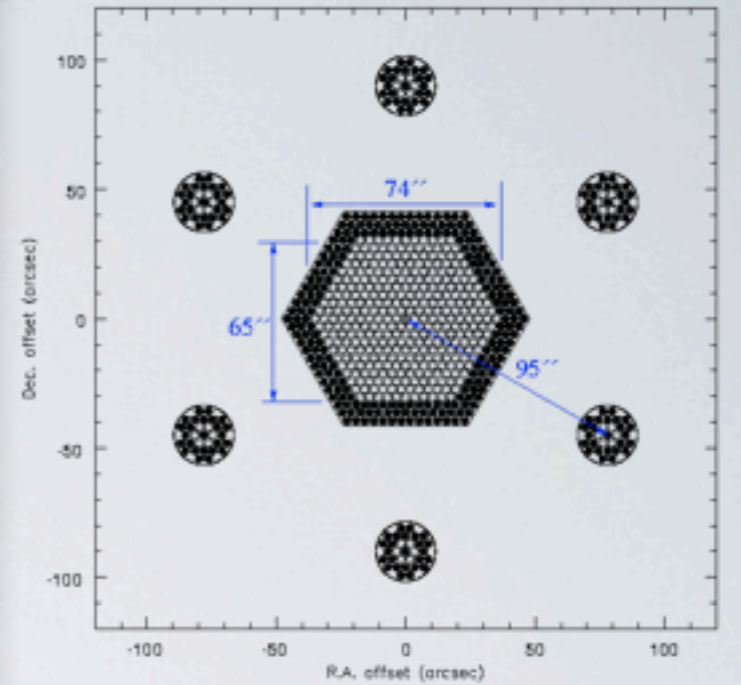
★ Cover optical  $\lambda$

V1200@R = 1650  
V500@R = 850



Fibers 2.7 arsec  
~ 0.5 - 1 kpc

★ Large FoV (1'x1')



3 dithering:  
final 1 arsec  
sampling

# Galaxy evolution studies in CALIFA:

Cosmic evolution of the stellar population properties in galaxies as a function of the galaxy mass, morphology and environment

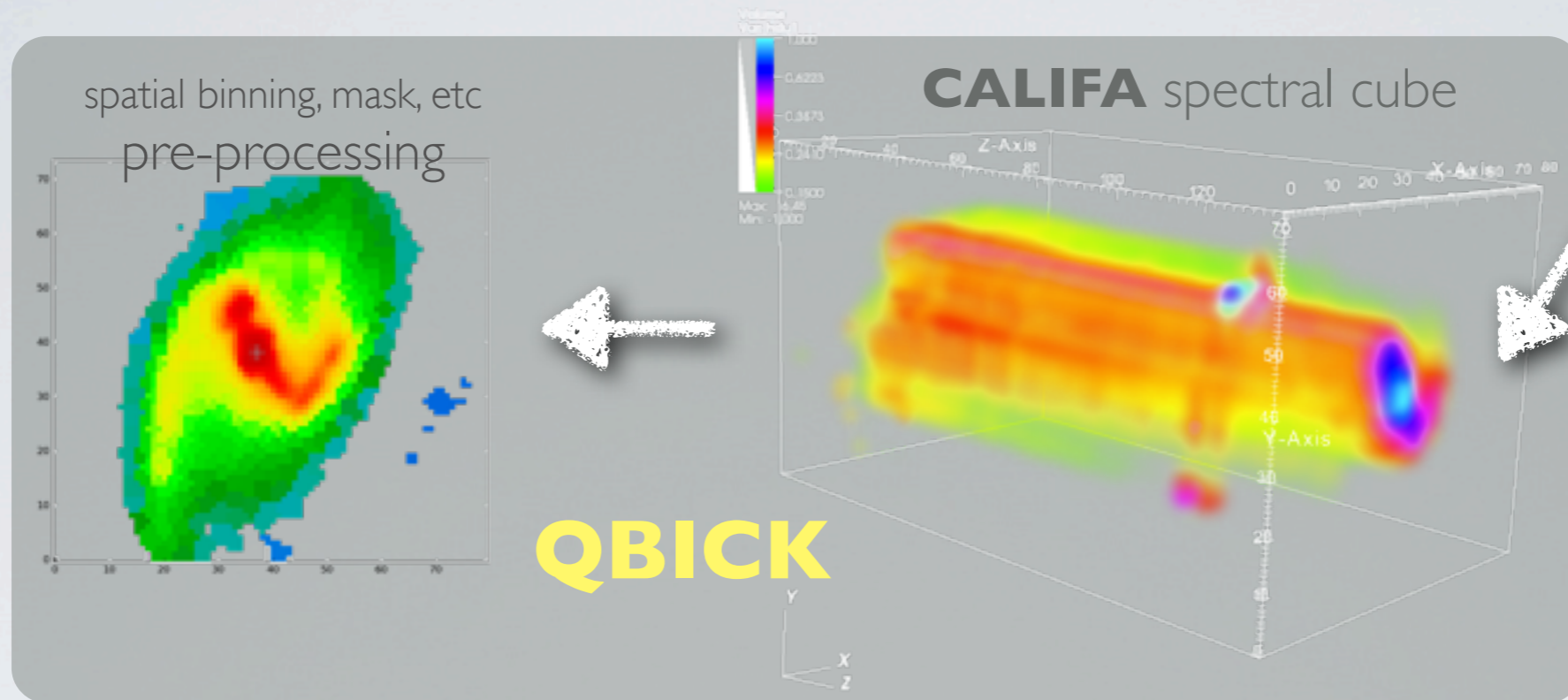
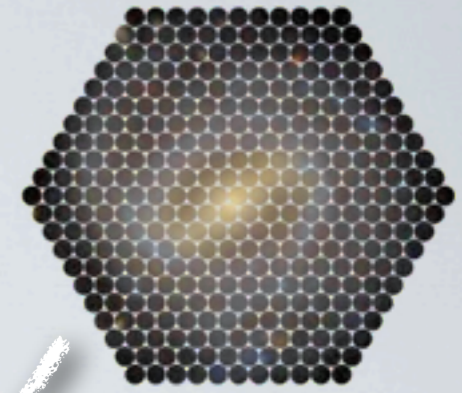
\* *The Evolution of Galaxies Resolved in Space and Time: A View of Inside-out Growth from the CALIFA Survey.* Pérez, Cid Fernandes, González Delgado García-Benito et al, 2013, ApJL, 764, L1

\* *Resolving the galaxies in time and space: I: Applying STARLIGHT to CALIFA data cubes.* Cid Fernandes, Pérez, García-Benito, González Delgado et al, 2013, A&A, 557, A86

\* *Resolving the galaxies in time and space: II: Uncertainties in the spectral synthesis of data cubes.* Cid Fernandes, González Delgado, García-Benito, Pérez, et al, 2013, A&A, accepted

\* *The spatially resolved SFH of galaxies in the CALIFA survey: The radial structure of stellar mass surface density and ages* González Delgado et al, 2013, A&A, submitted

# Processing & Analysis pipelines

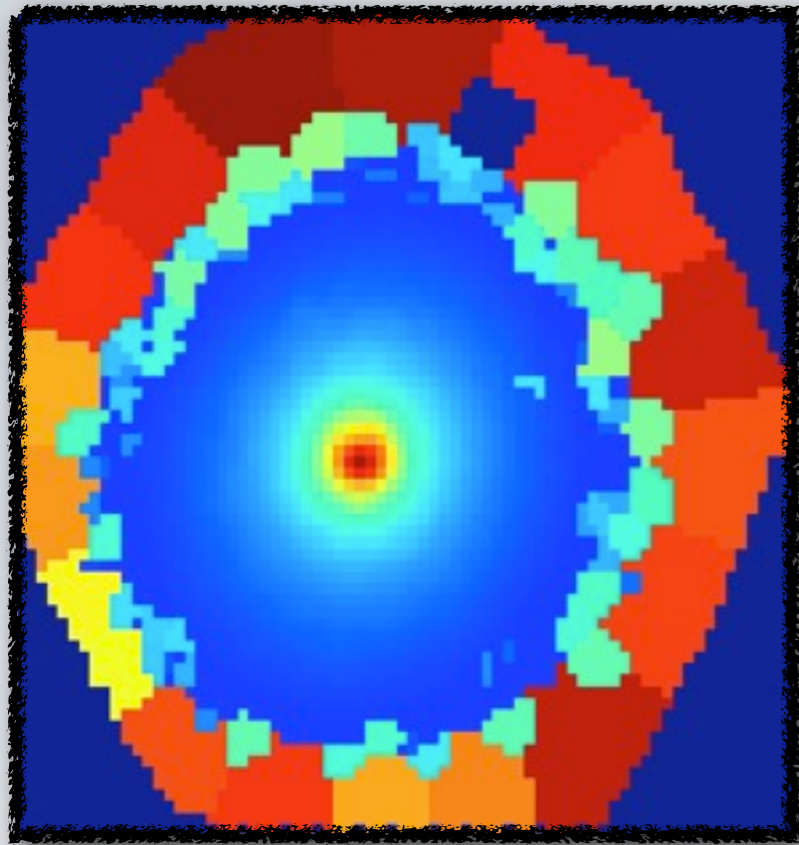


de-construct

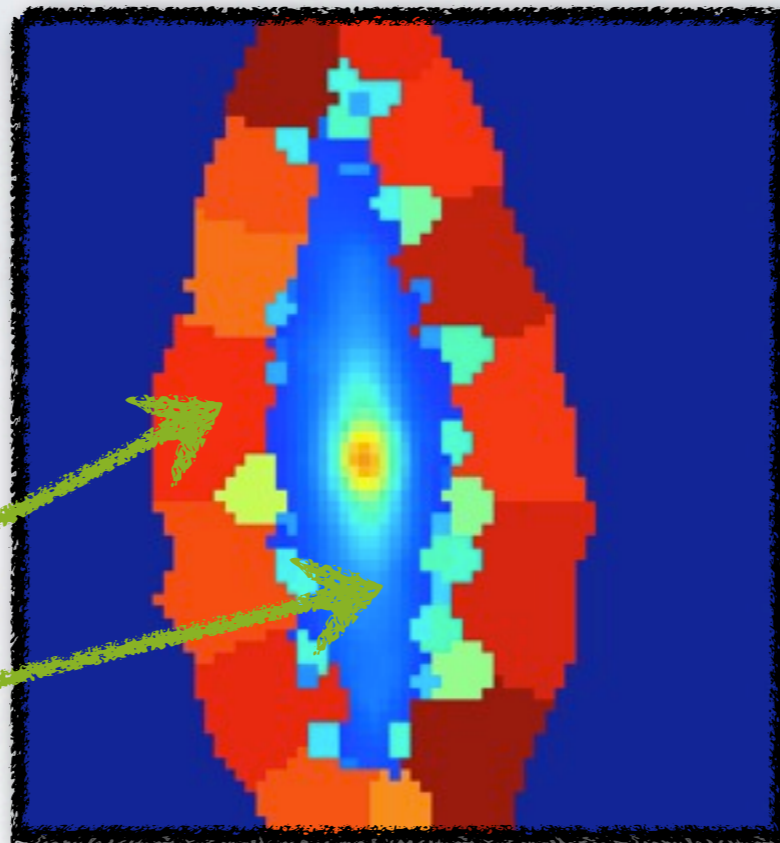


# Spatial Binning (Voronoi)

S/N  $\sim 20$

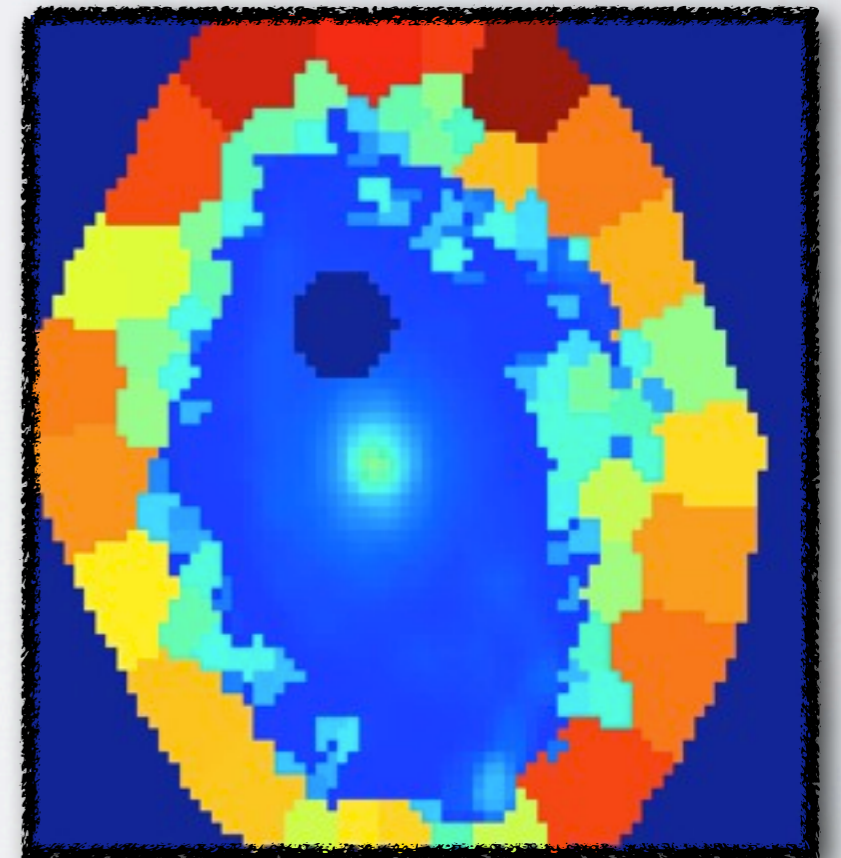


CALIFA 900

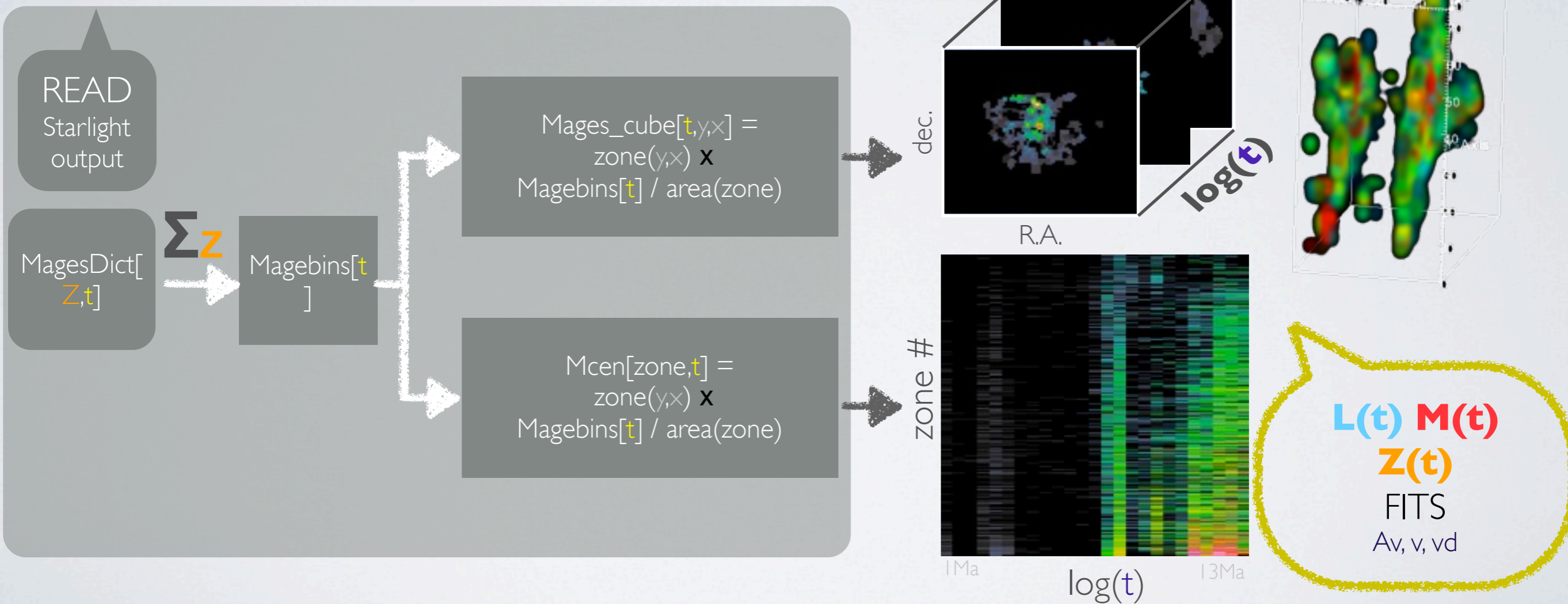
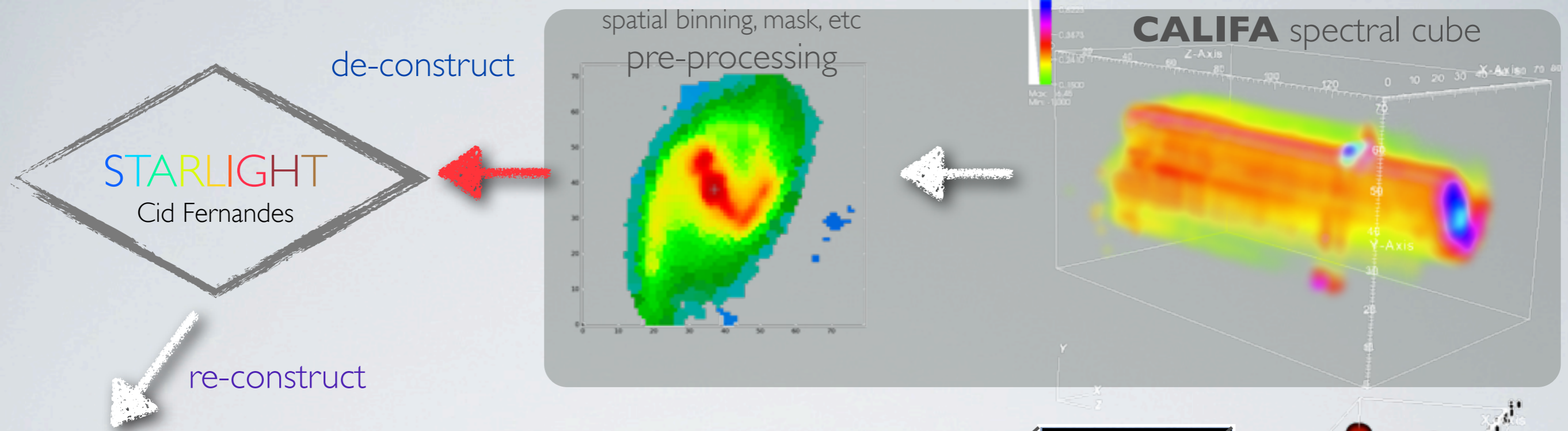


CALIFA 001

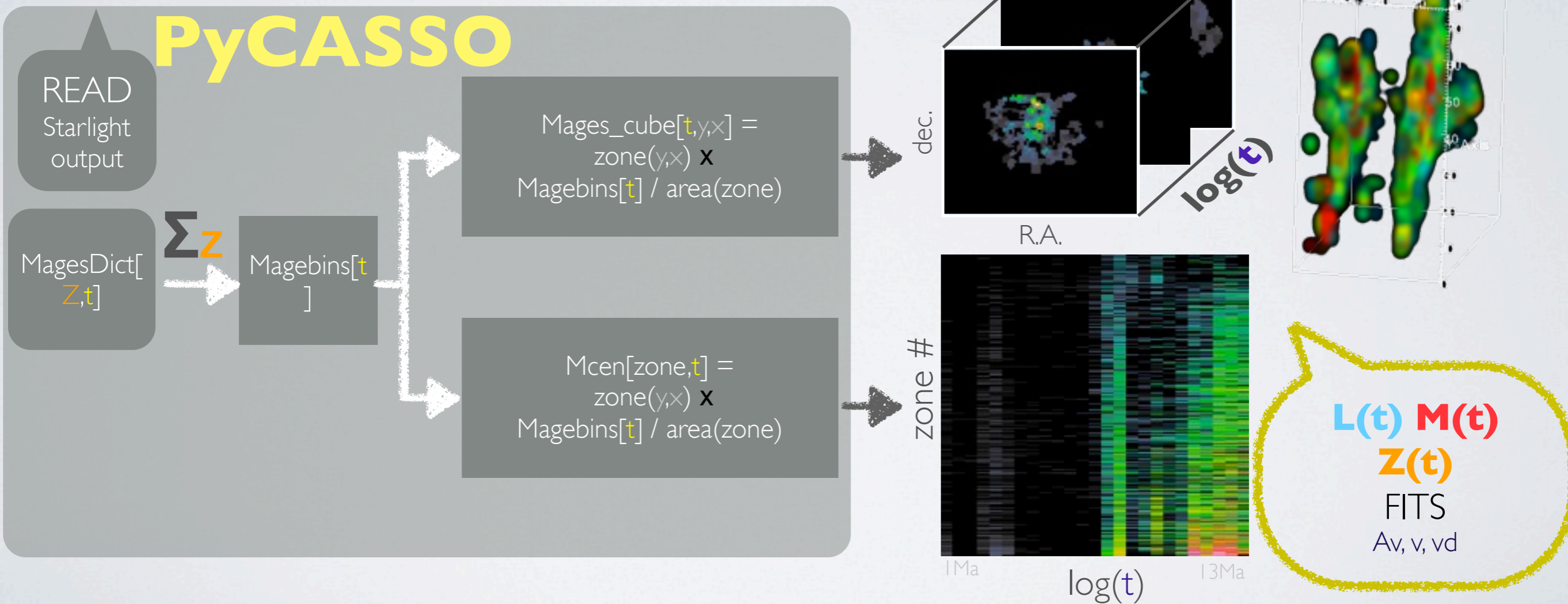
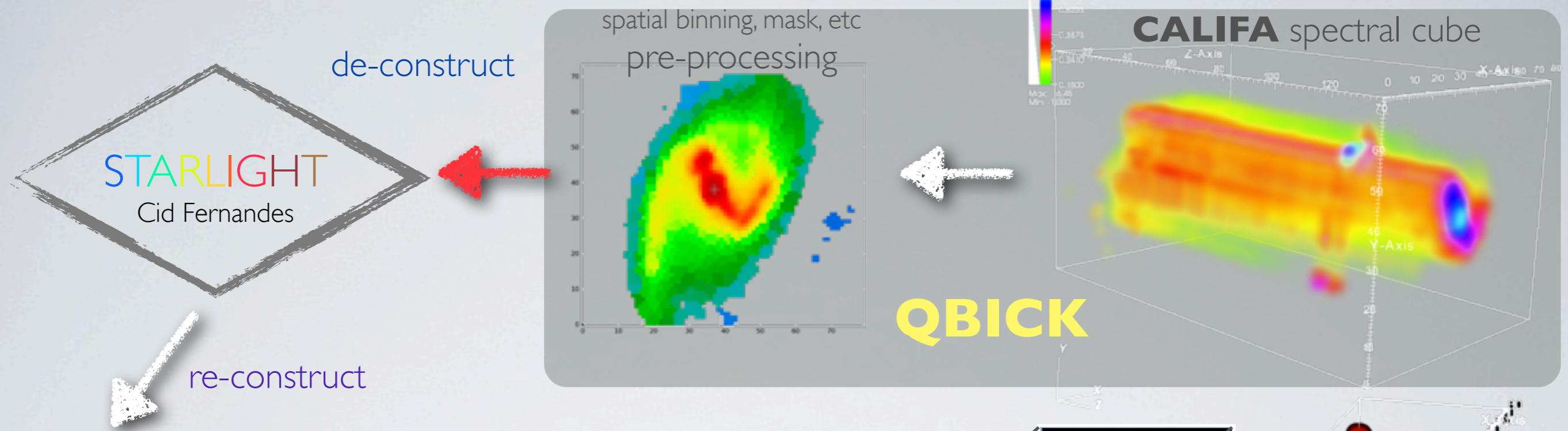
CALIFA 277



Zones



Processing & Analysis pipelines

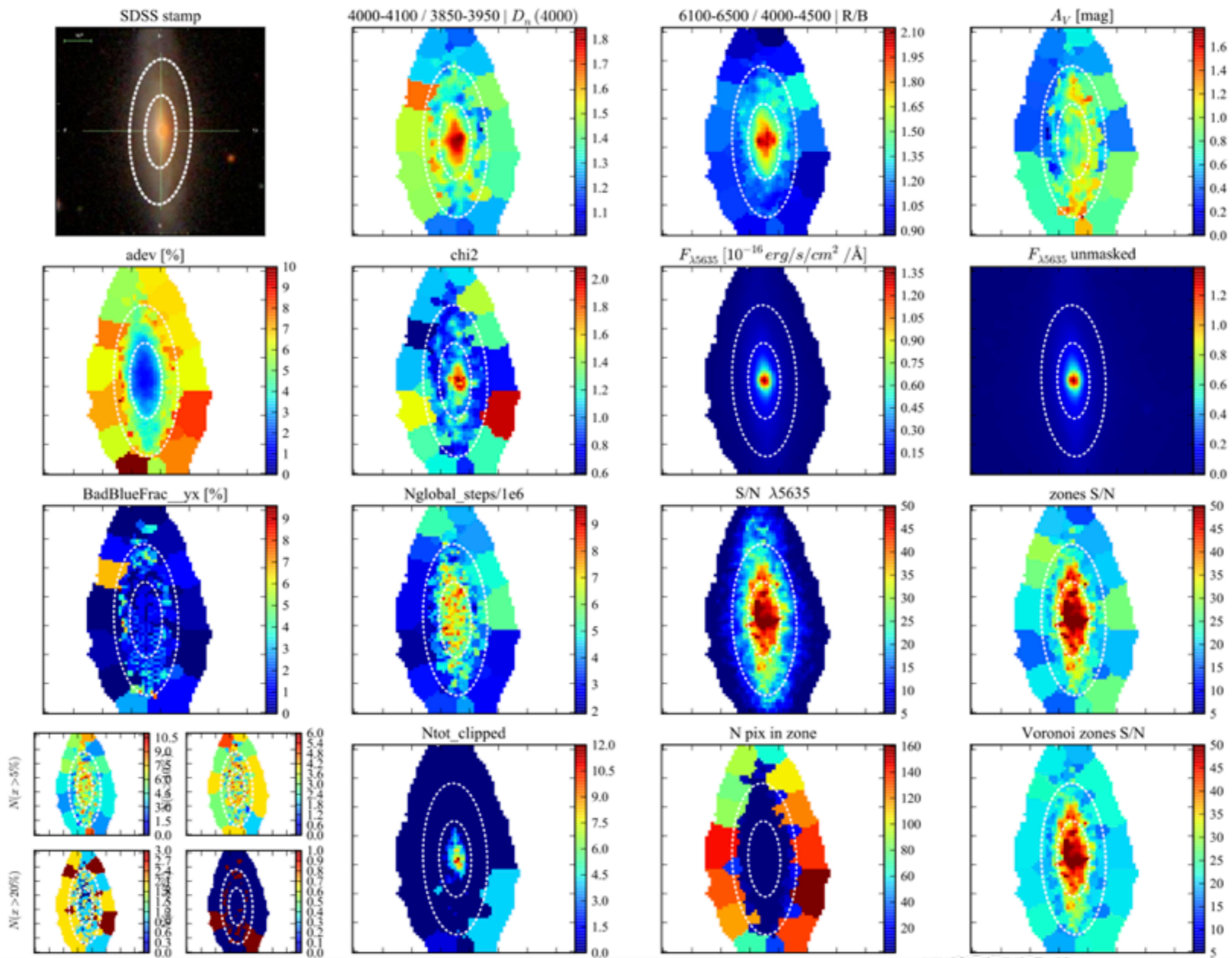


Processing & Analysis pipelines



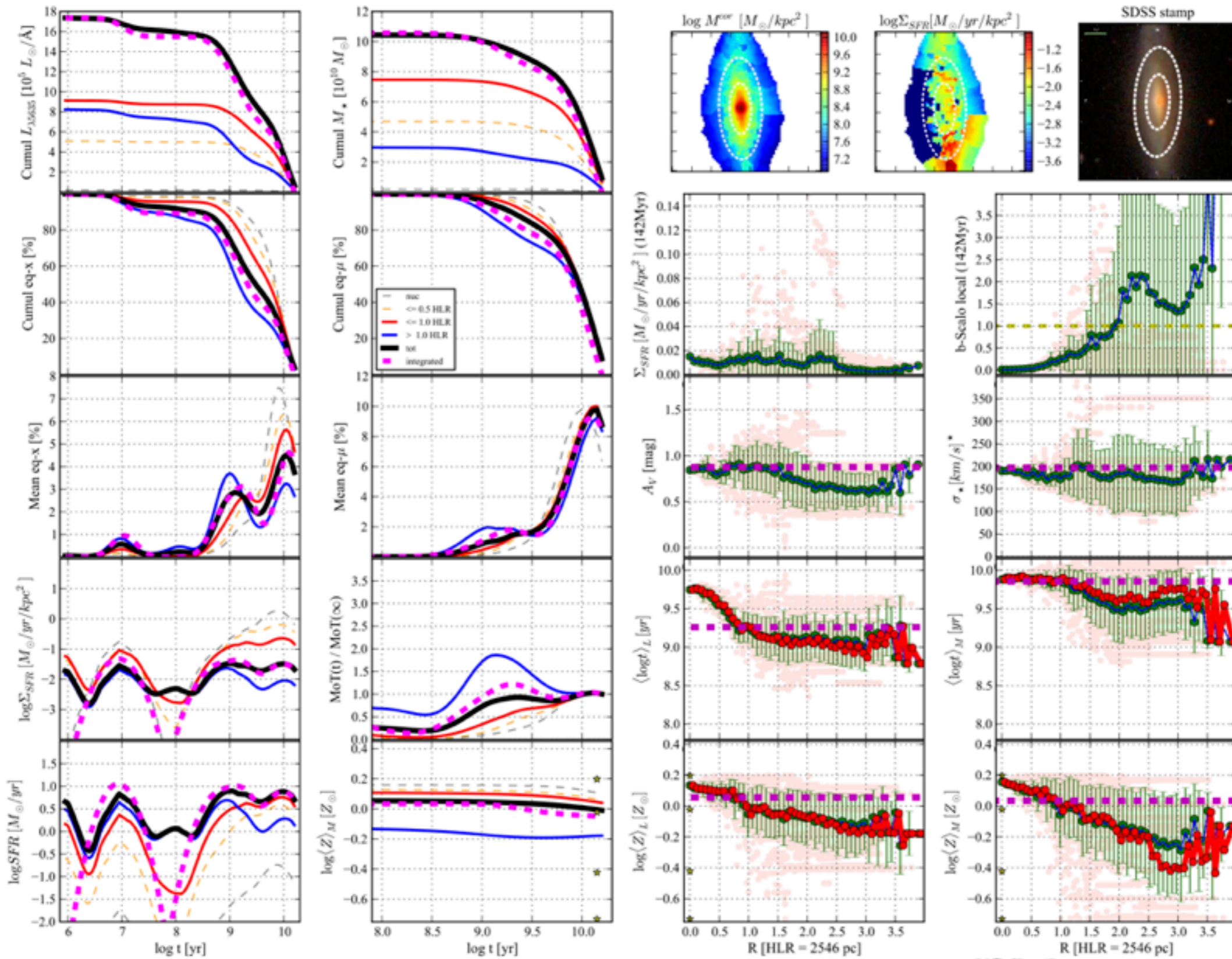
# PyCASSO Products

[Fig00] Data-&-Fit Quality || K0001 0.3.6 d13c512 w/base Bgsd01 || FWHM=0.5dex ;  $\Delta R=1.0$  pix || IC5376



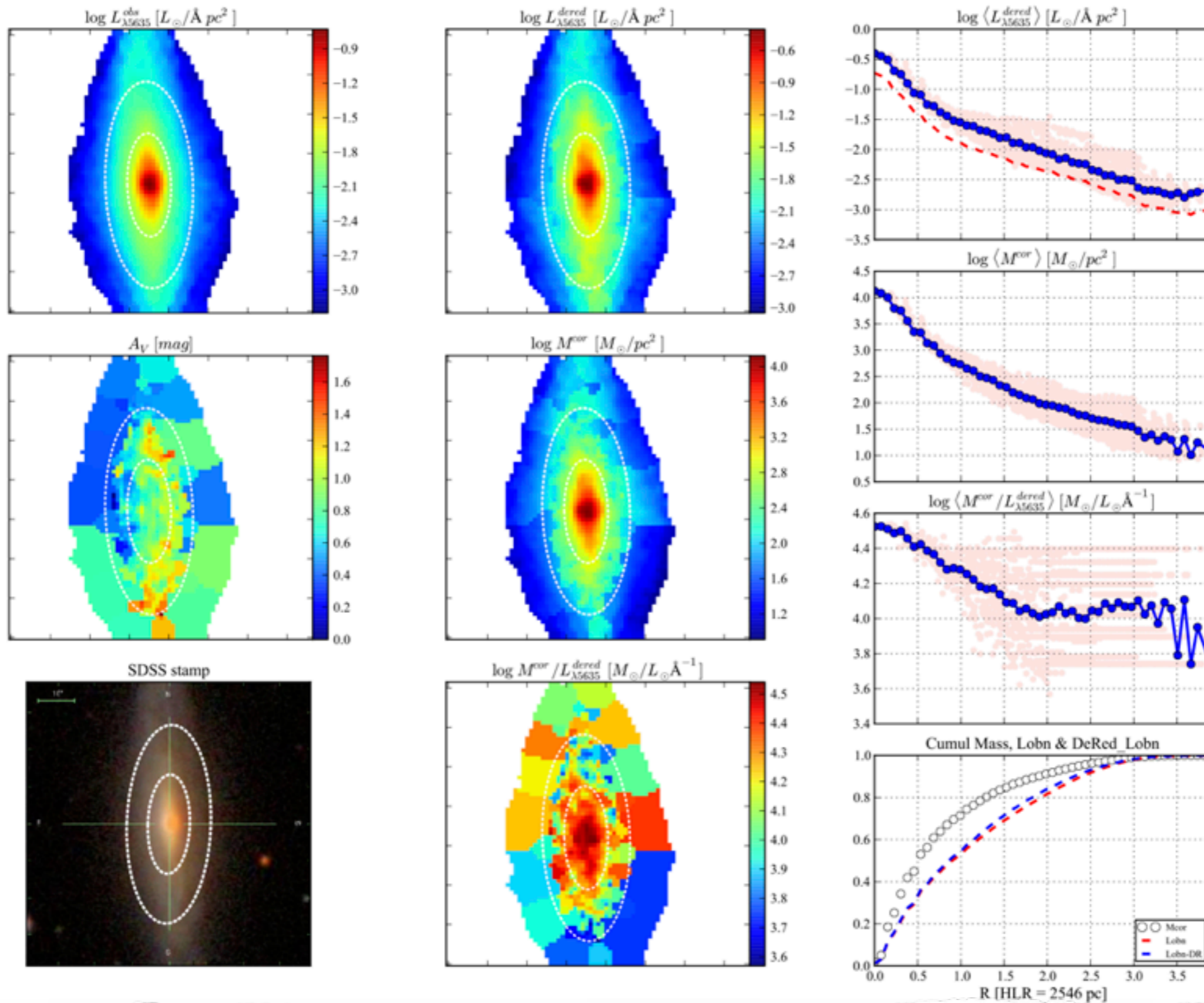
# PyCASSO Products

[Figure] 1 & 2 profiles || K0001 0.3.6 d13c512 w/base Bgsd01 || FWHM=0.5dex ;  $\Delta R=1.0$  pix || IC5376



# PyCASSO Products

[fig02] ... K0001 0.3.6 d13c512 w/base Bgsd01 || FWHM=0.5dex ;  $\Delta R=1.0$  pix || IC5376

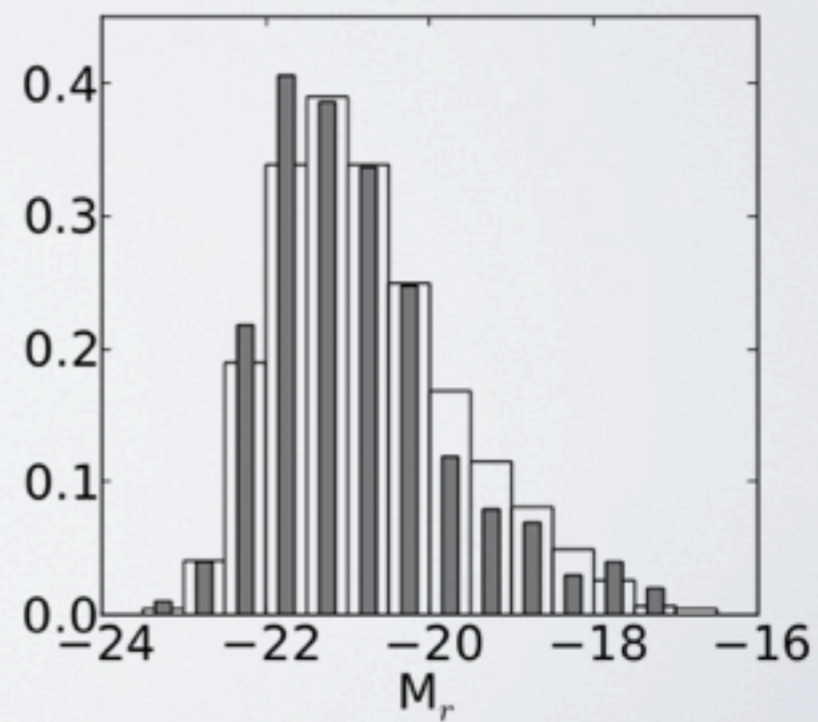
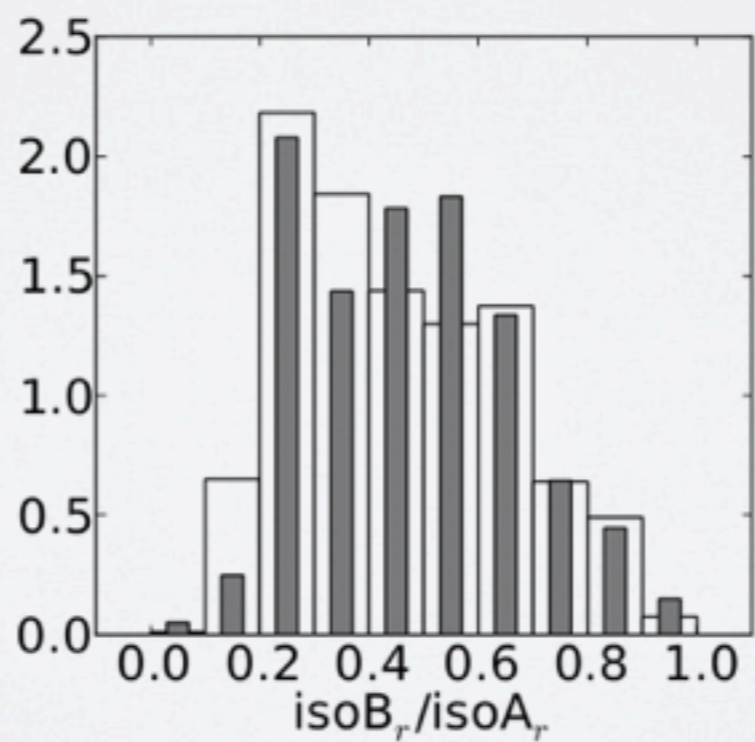
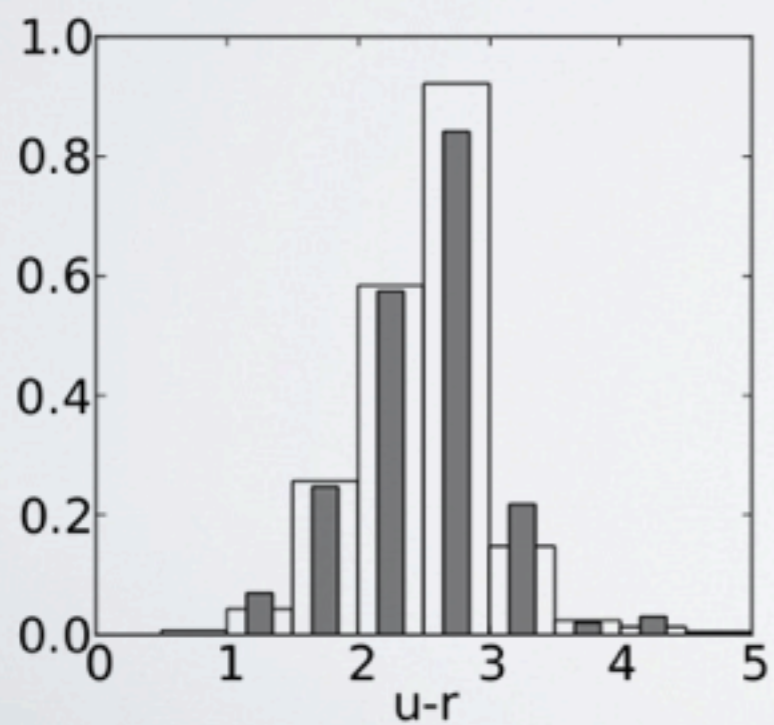
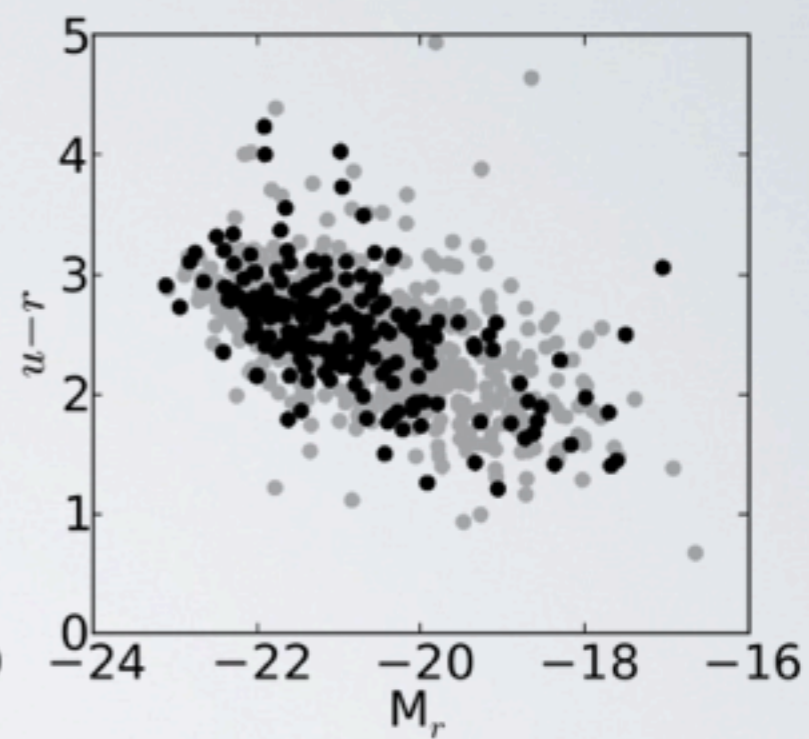
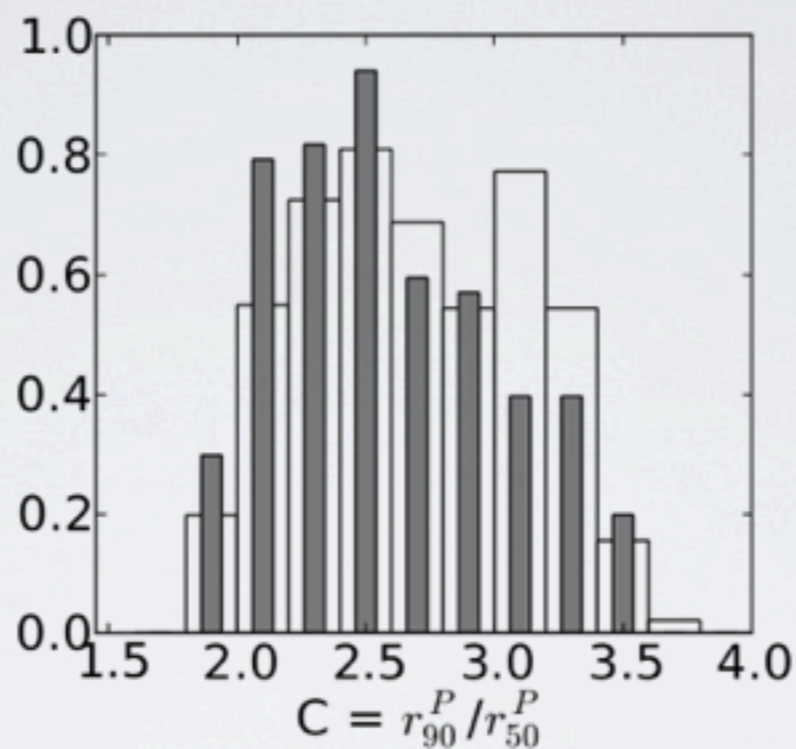
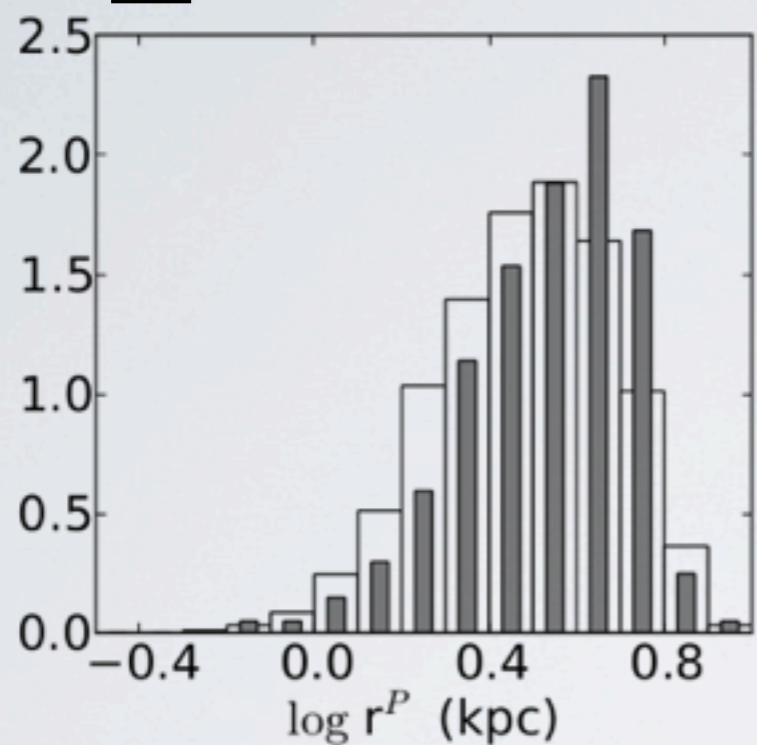


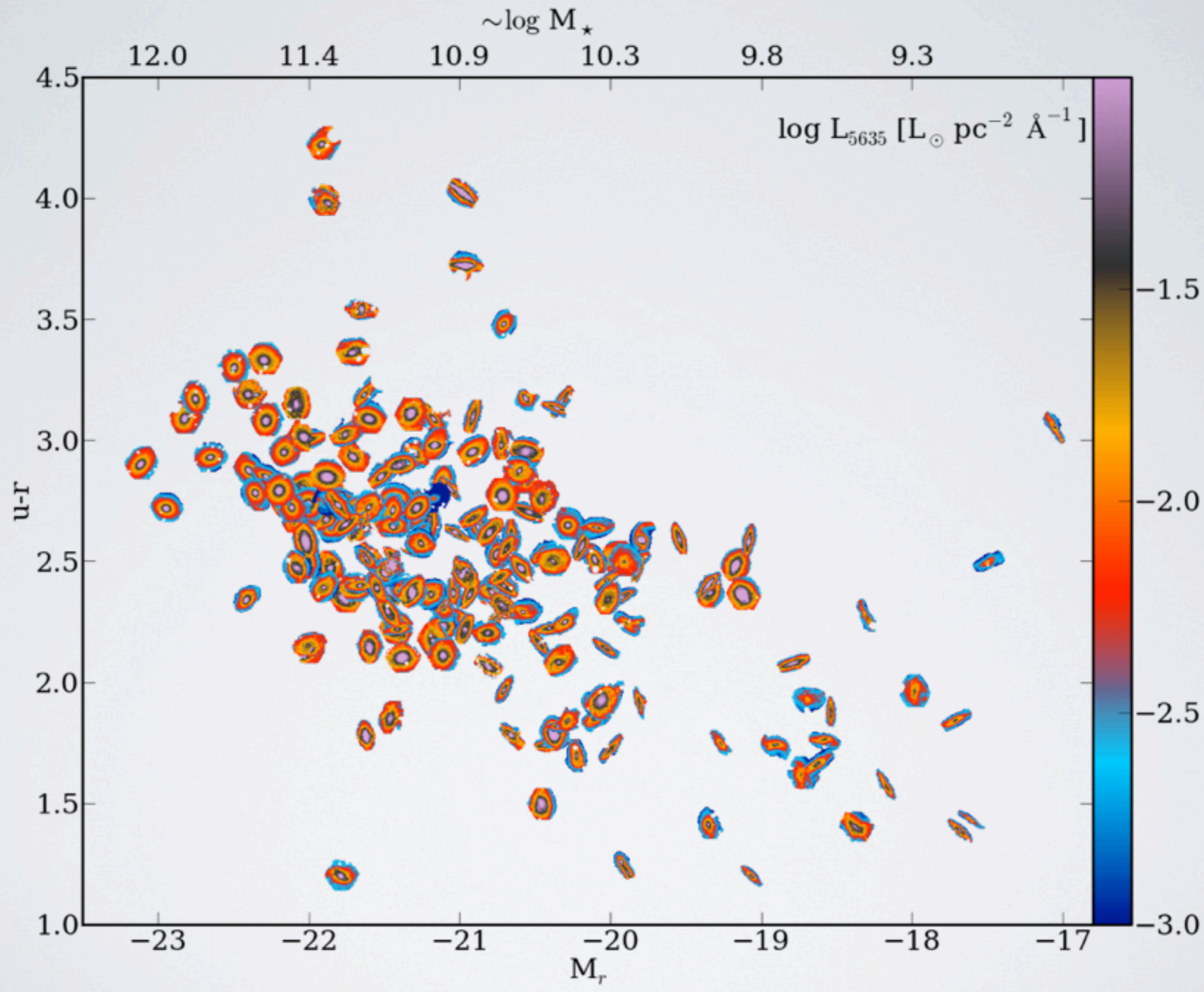


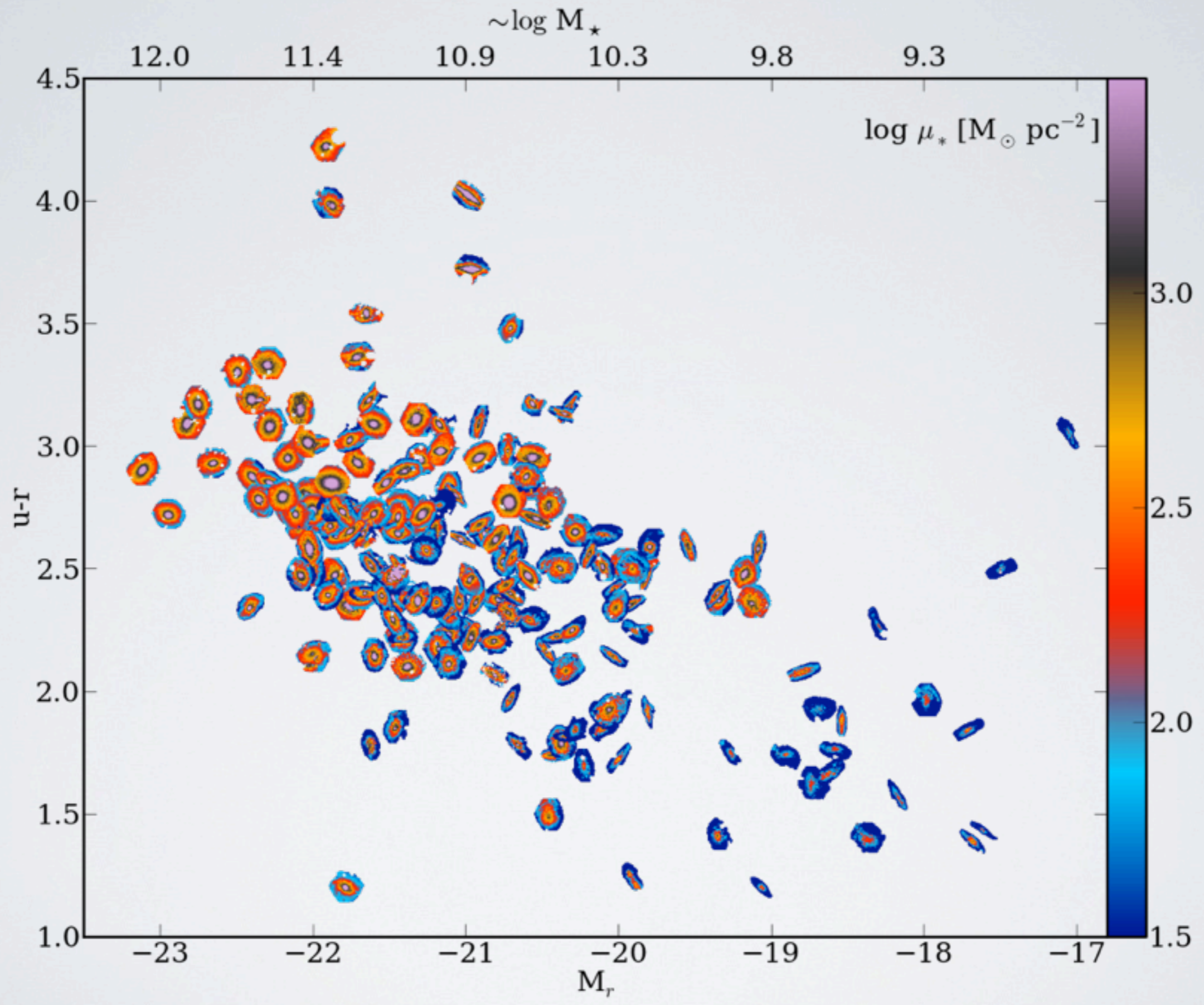
Mother sample

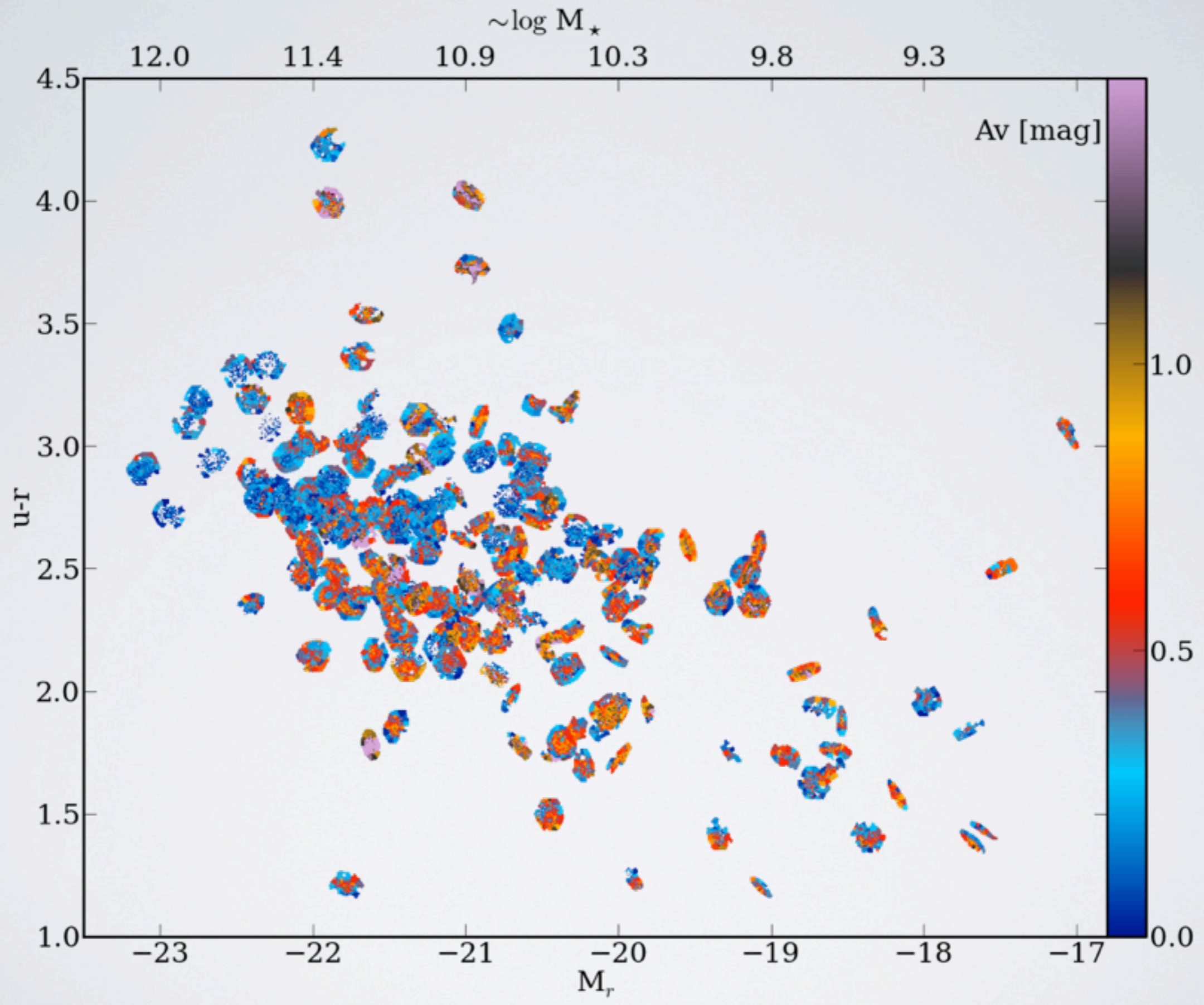


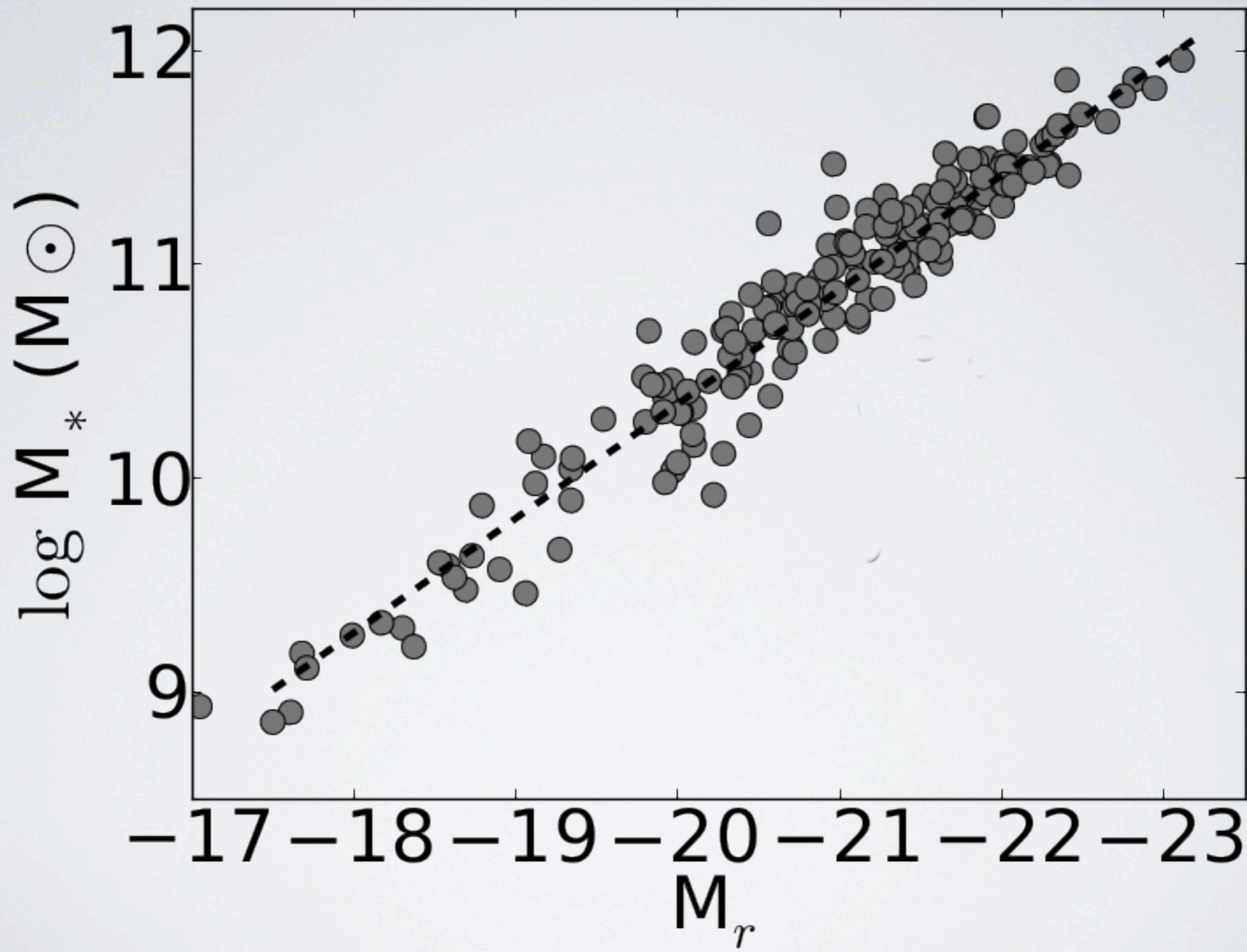
200 galaxies



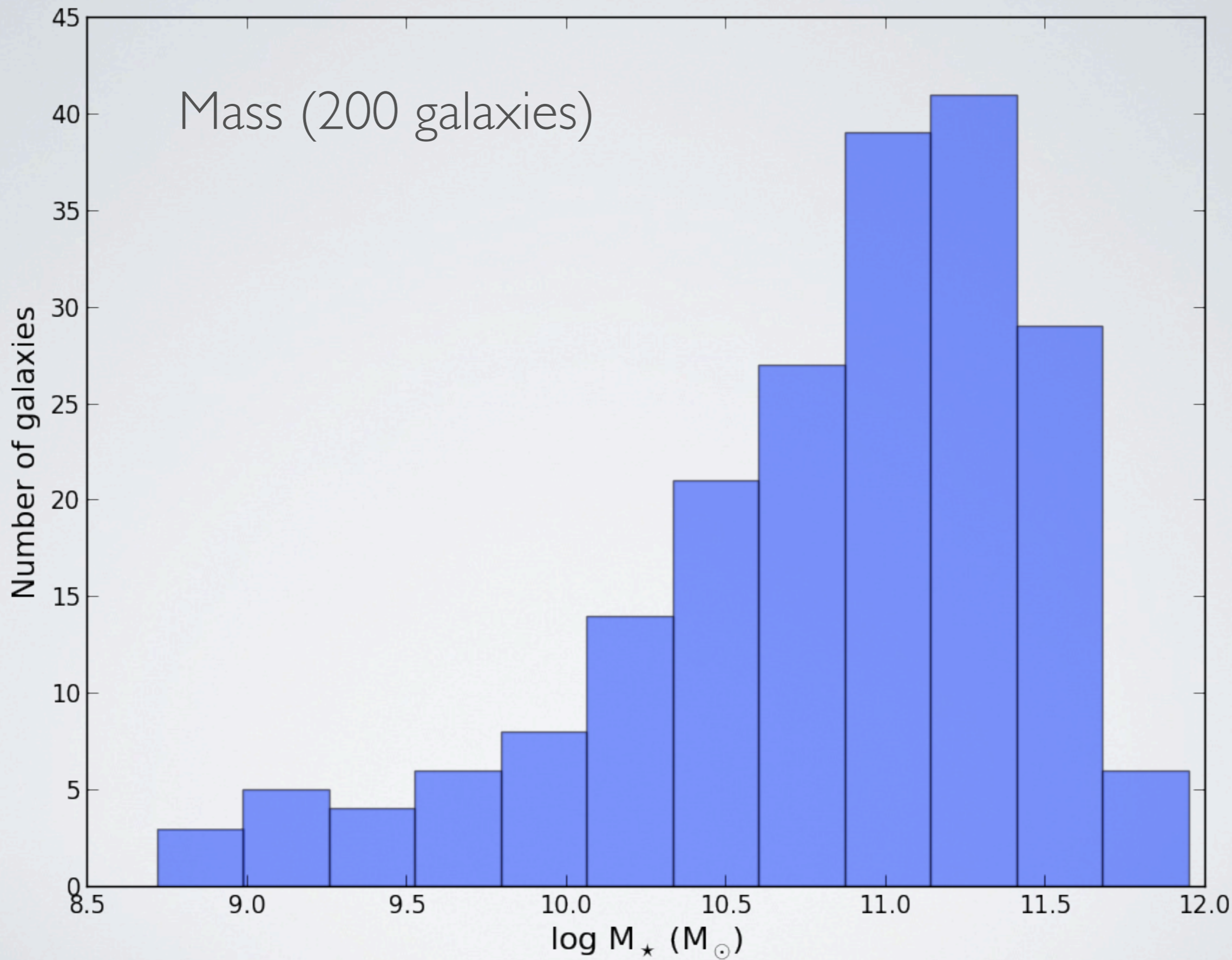


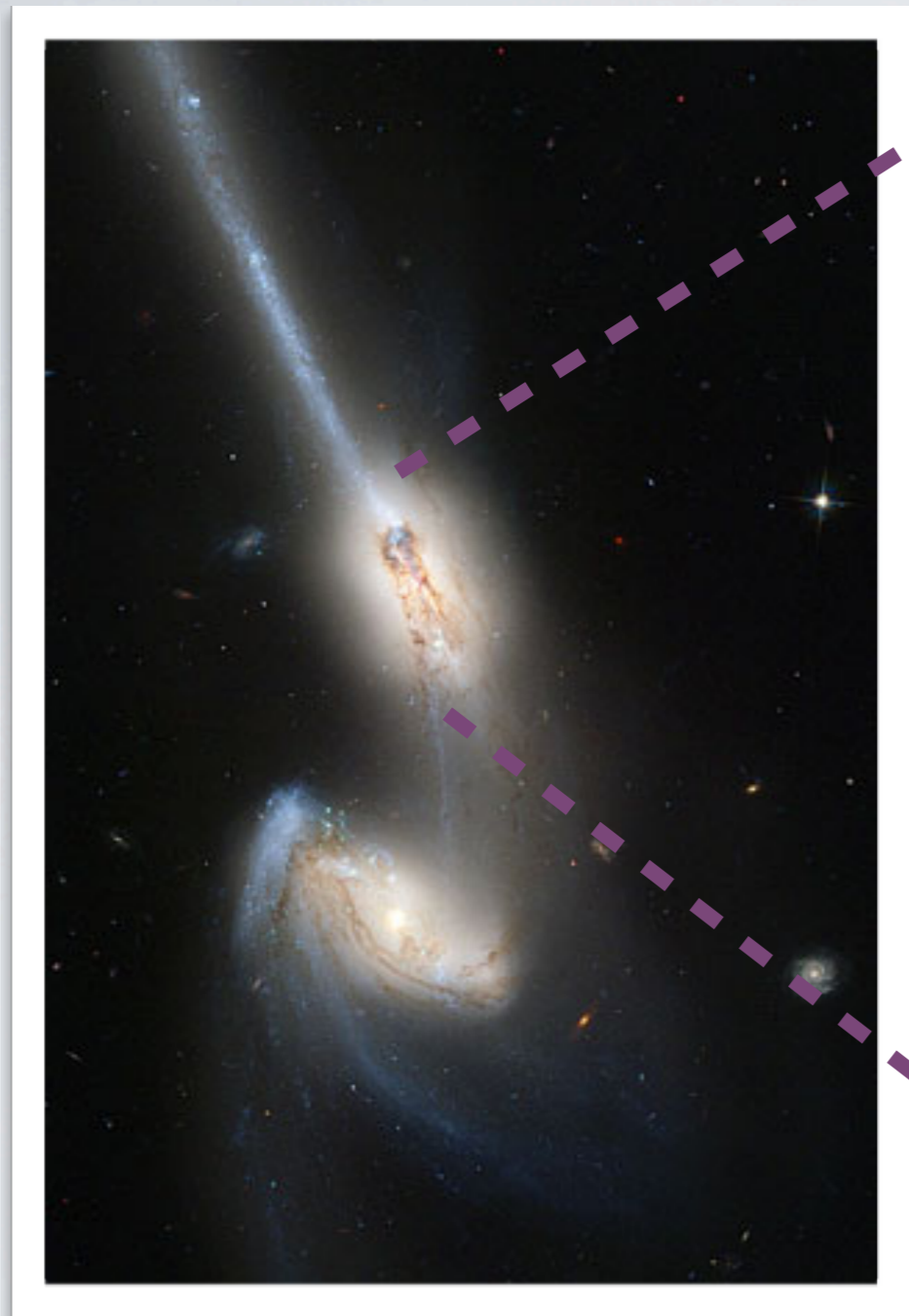




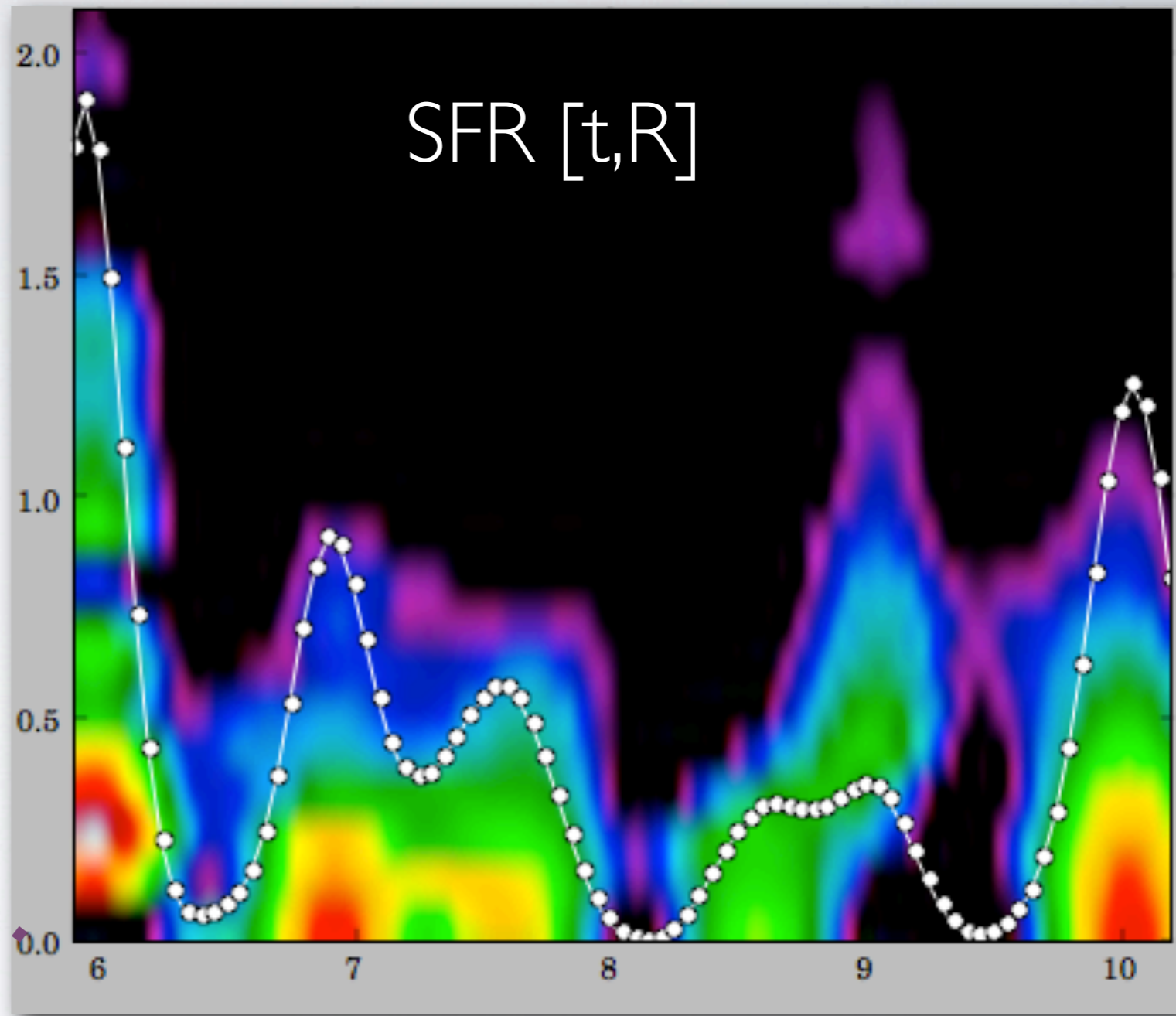




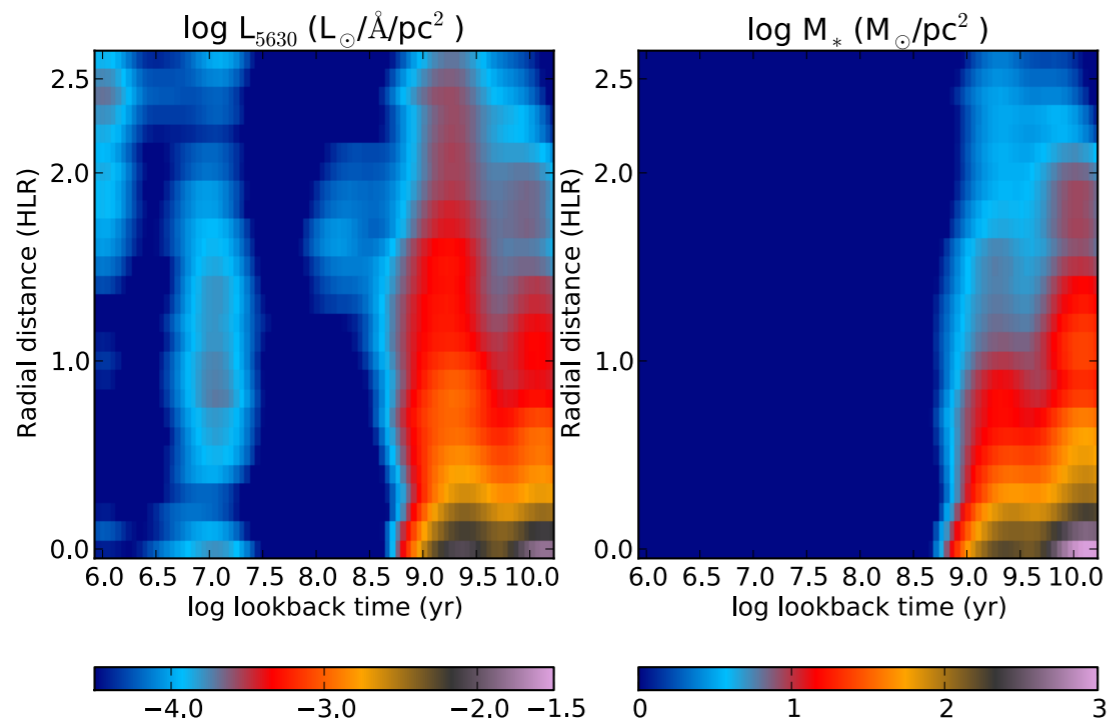




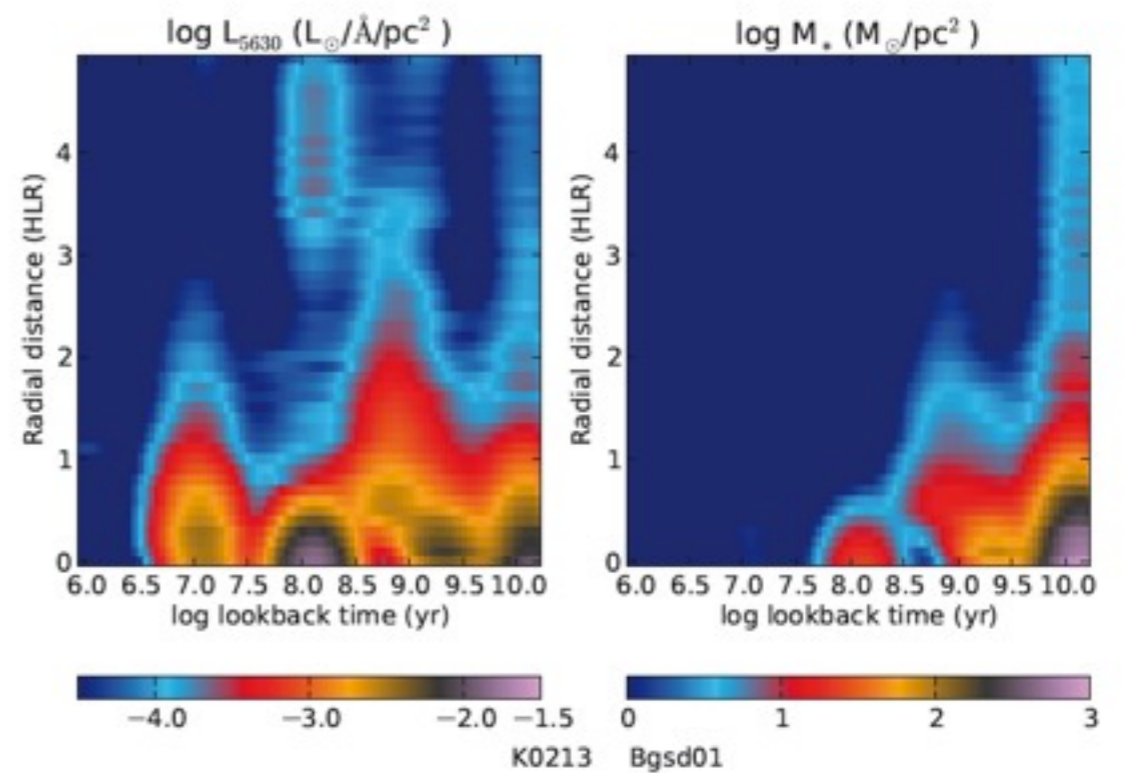
$R$  [HLLR]



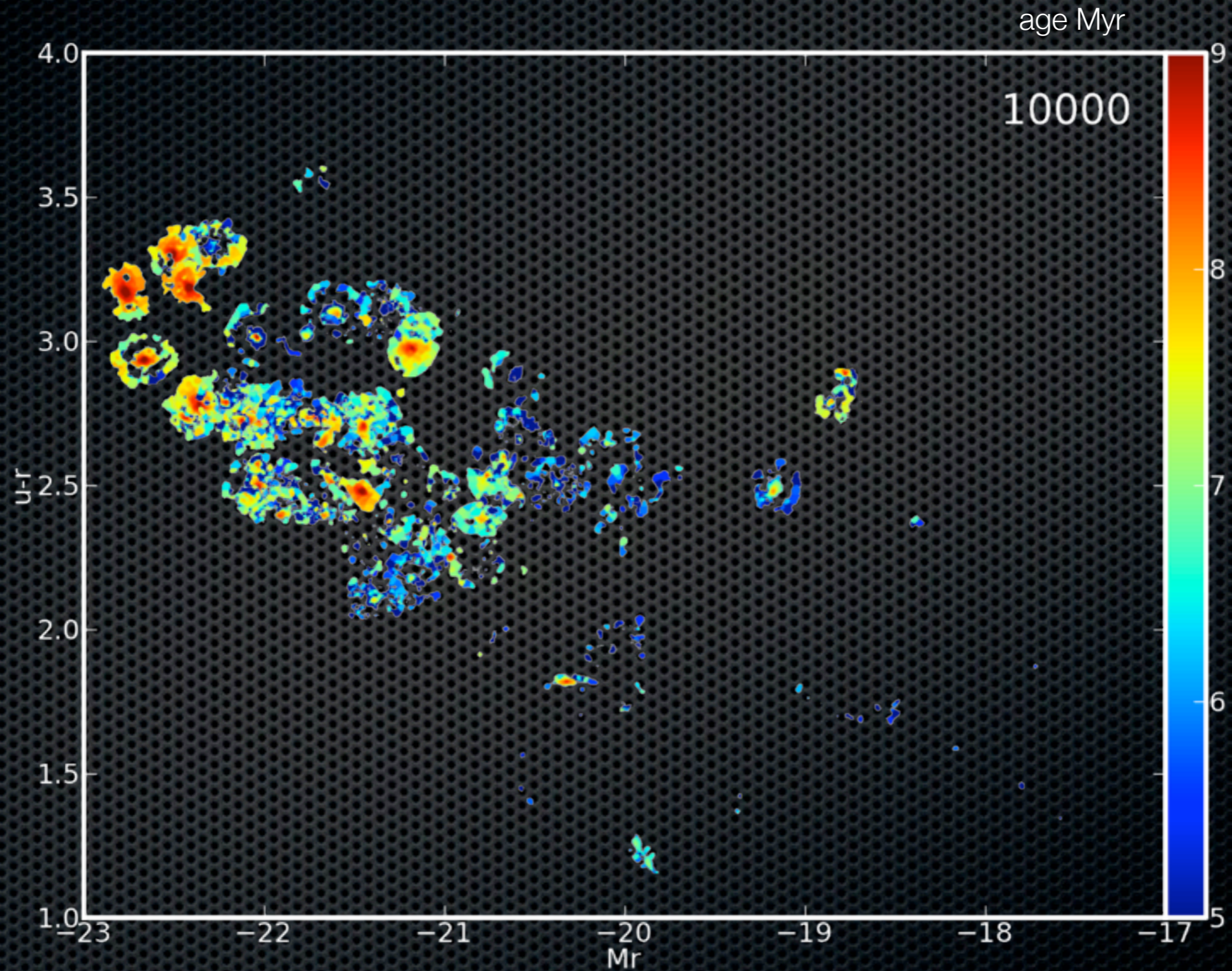
log y [yr]



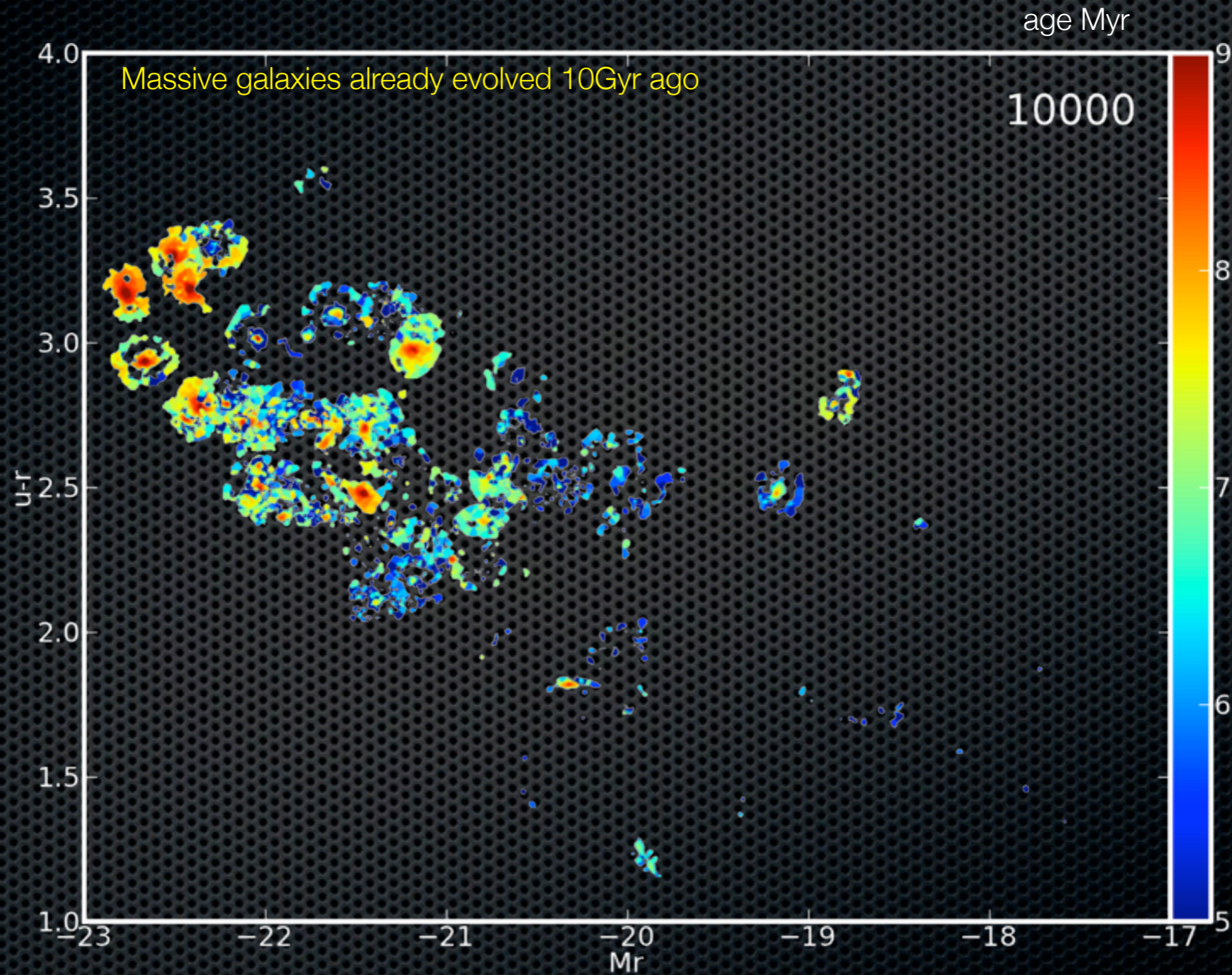
NGC 2623 (merger)



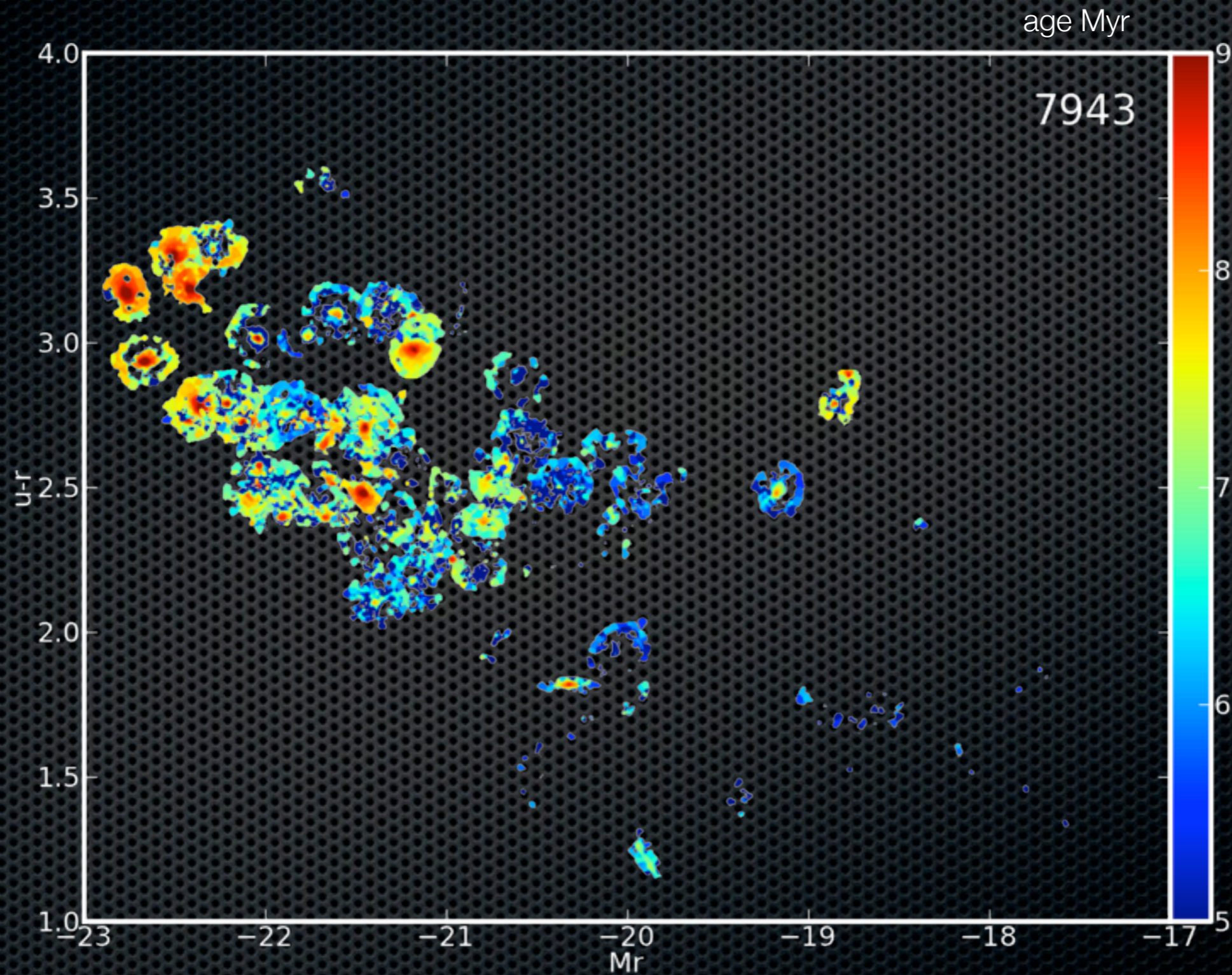
# How Mass builds up in time



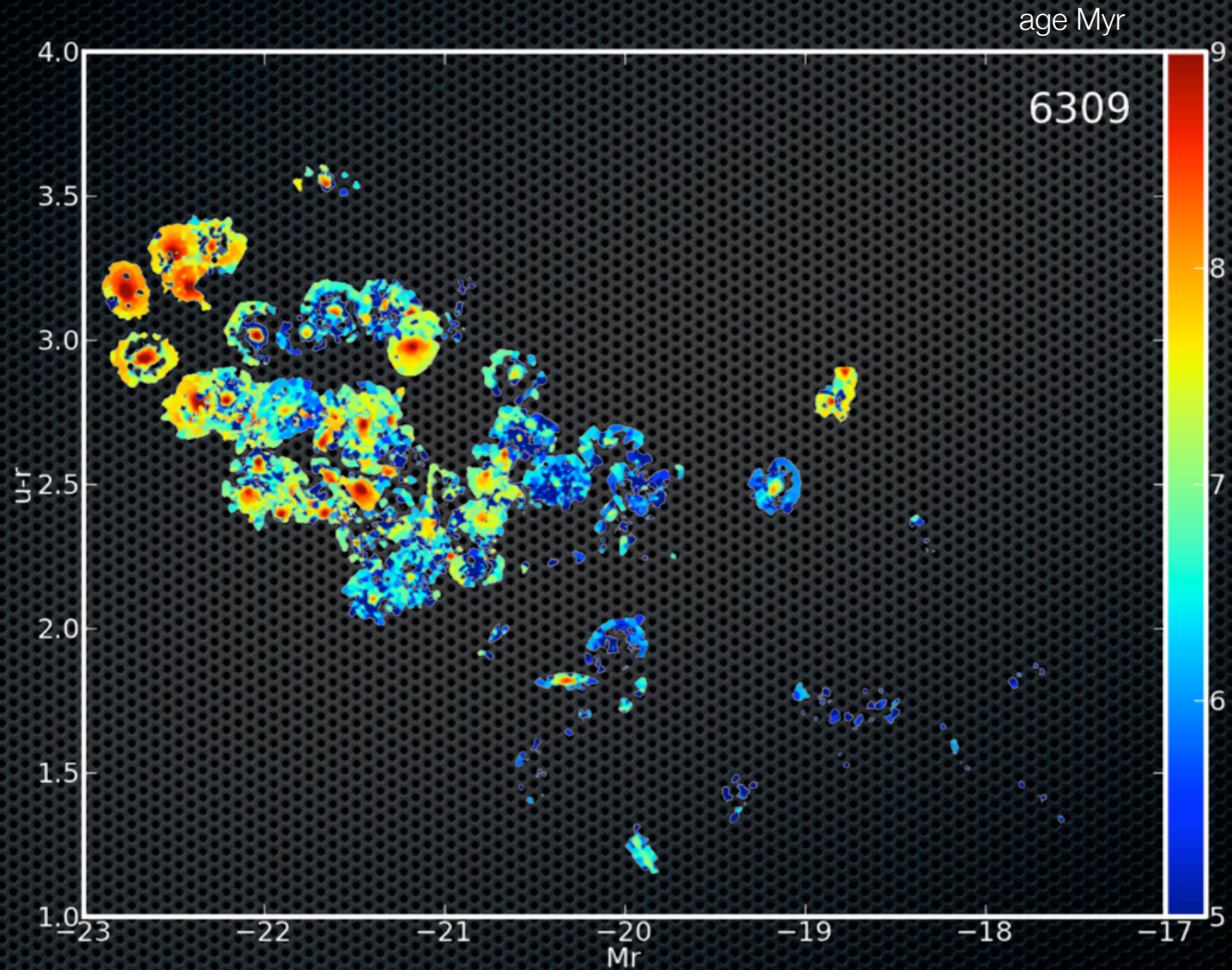
# How Mass builds up in time



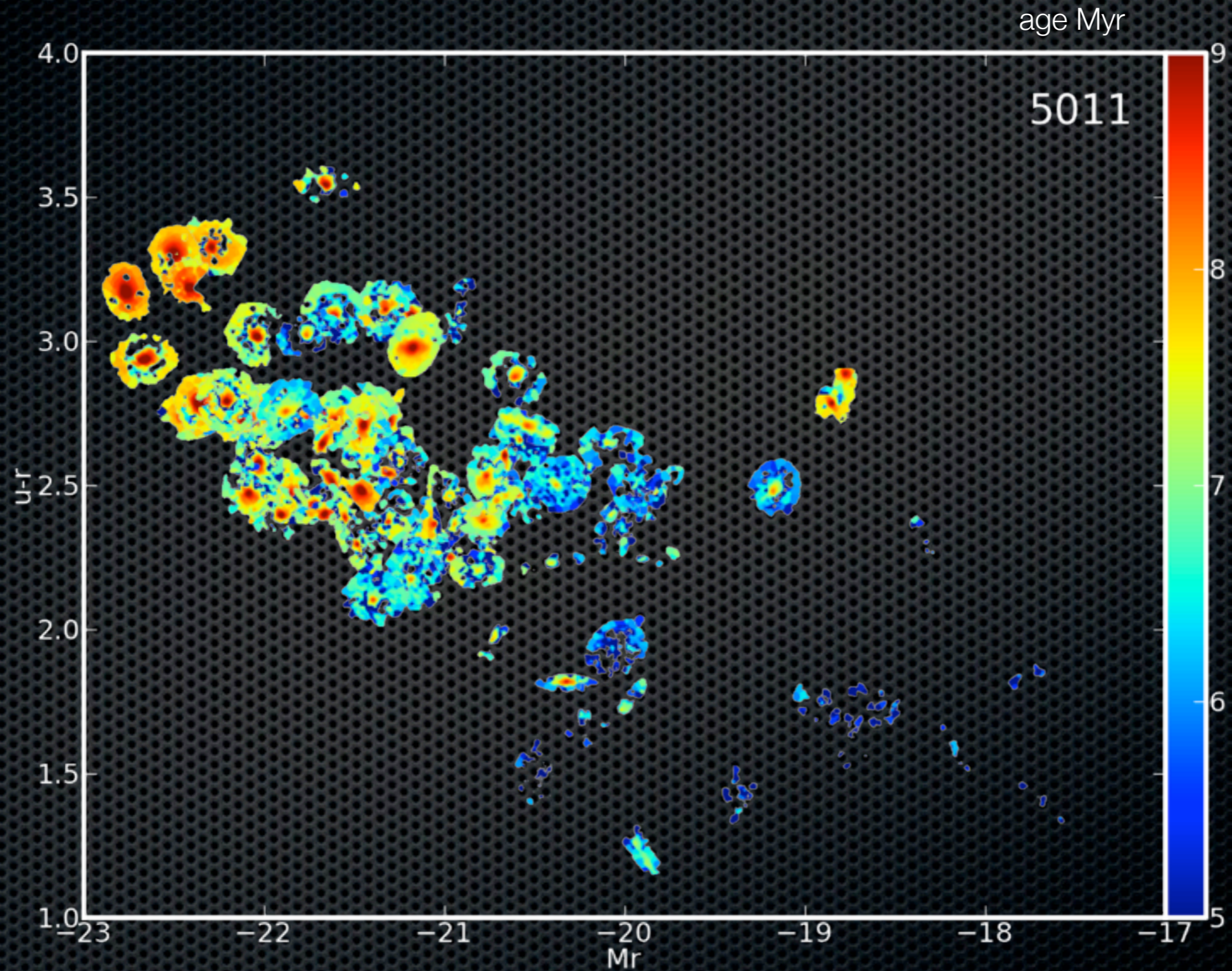
# How Mass builds up in time



# How Mass builds up in time

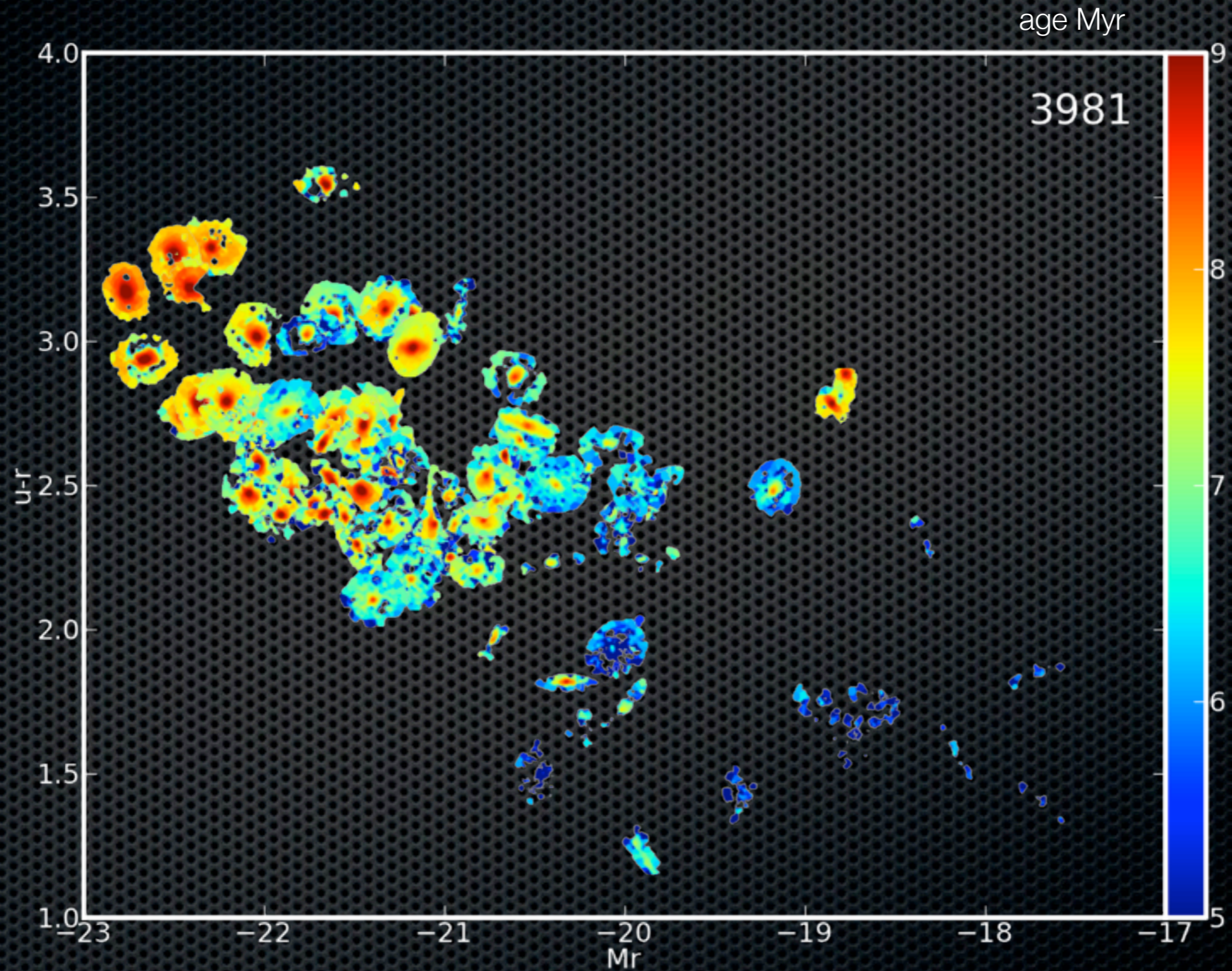


# How Mass builds up in time

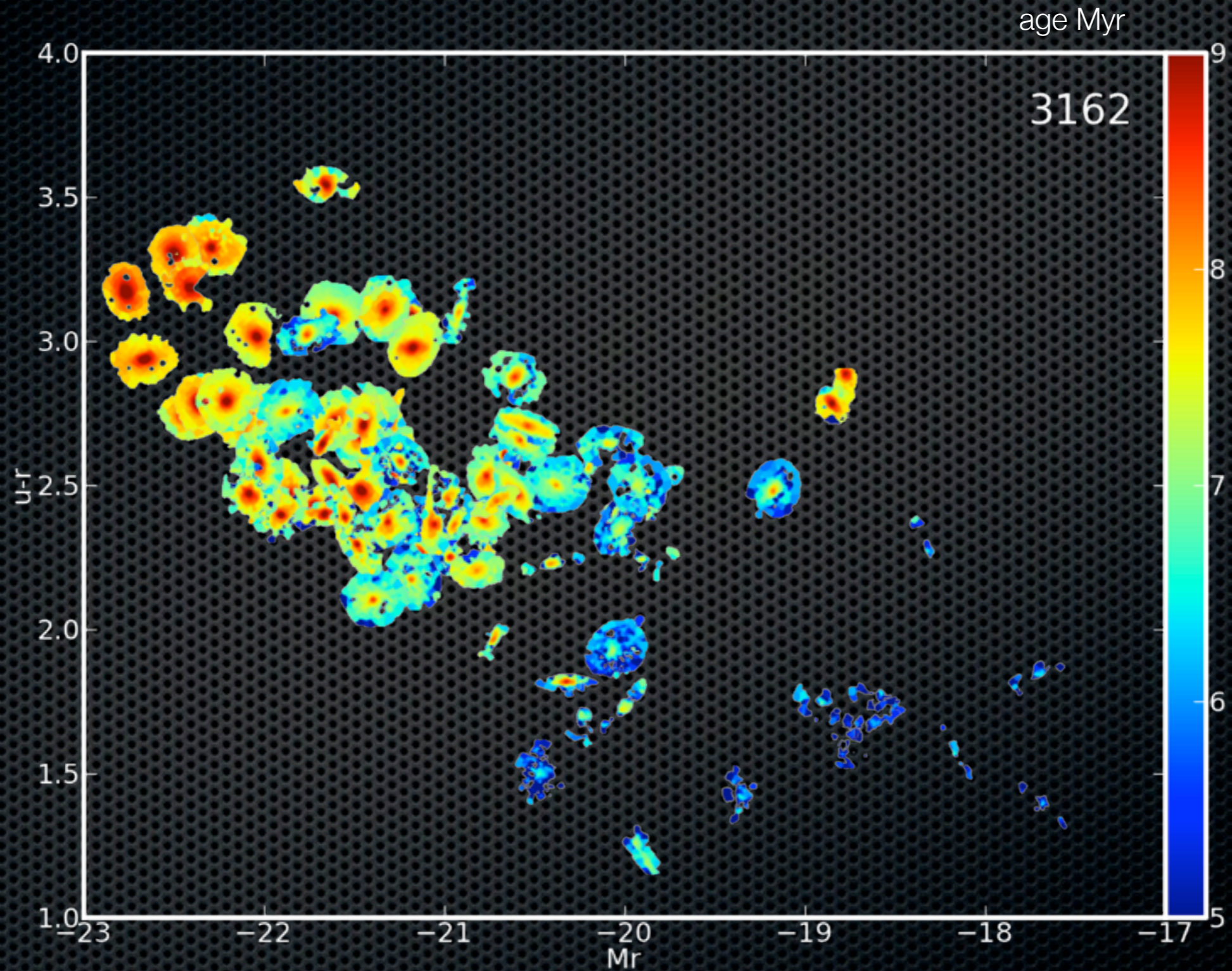




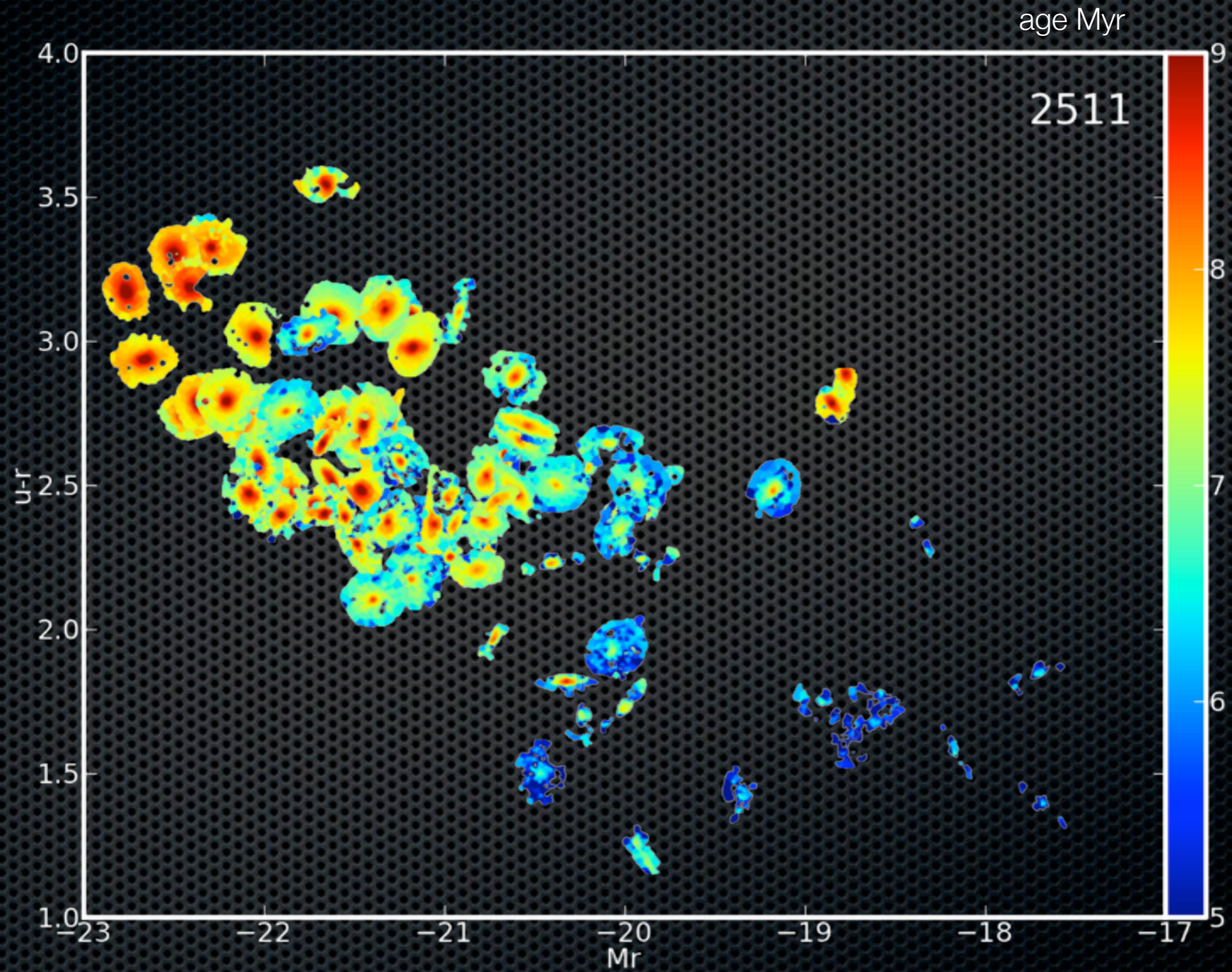
# How Mass builds up in time



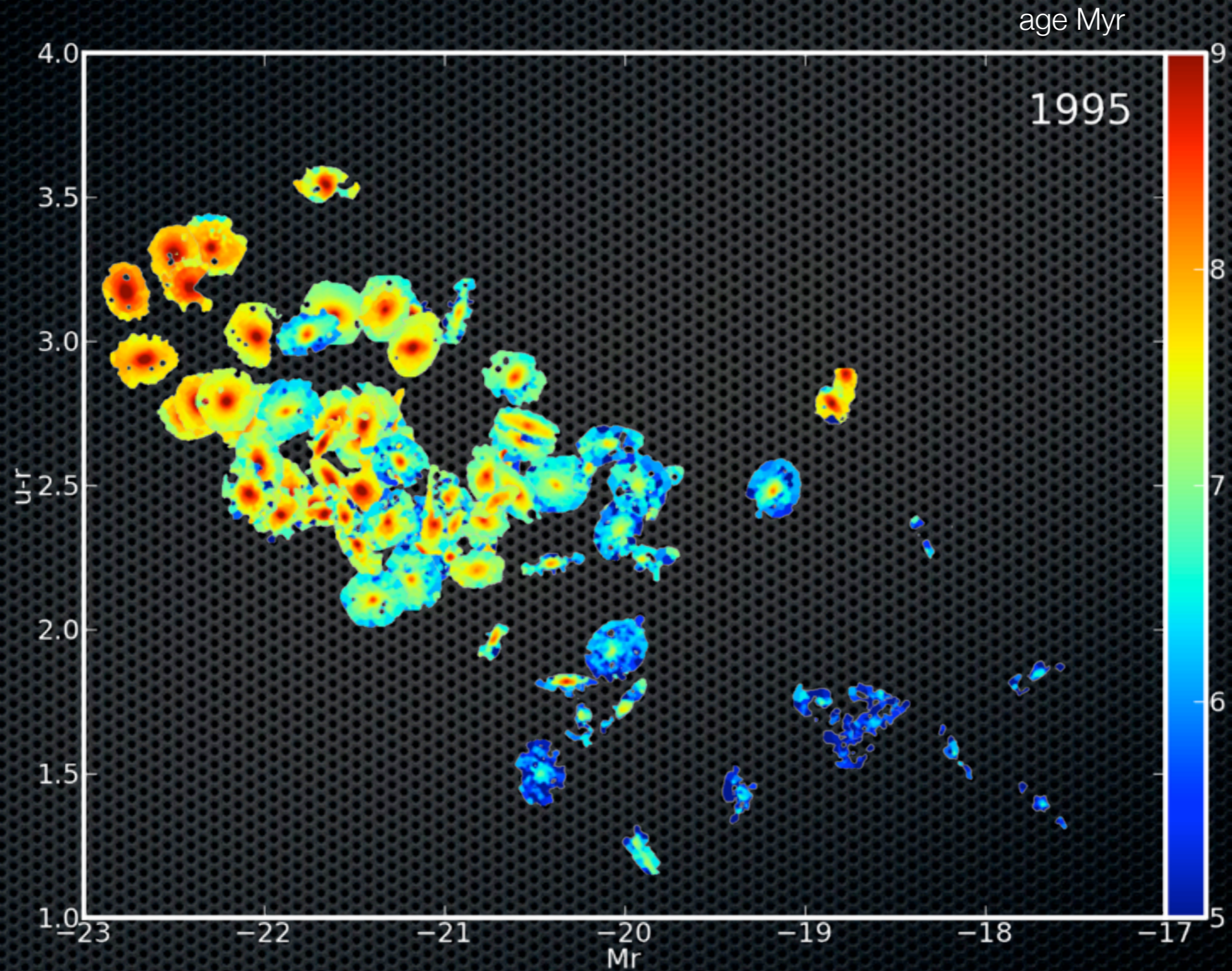
# How Mass builds up in time



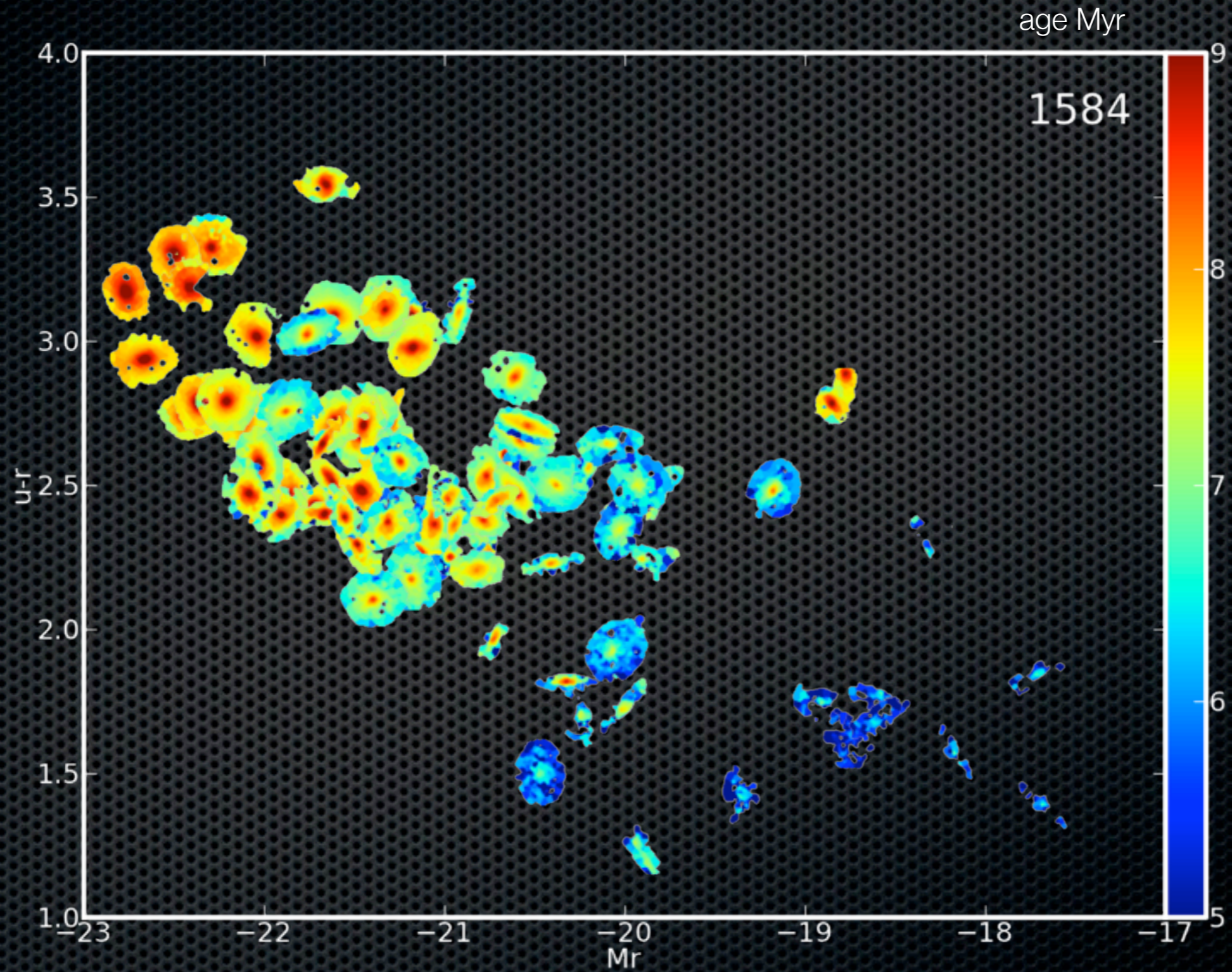
# How Mass builds up in time



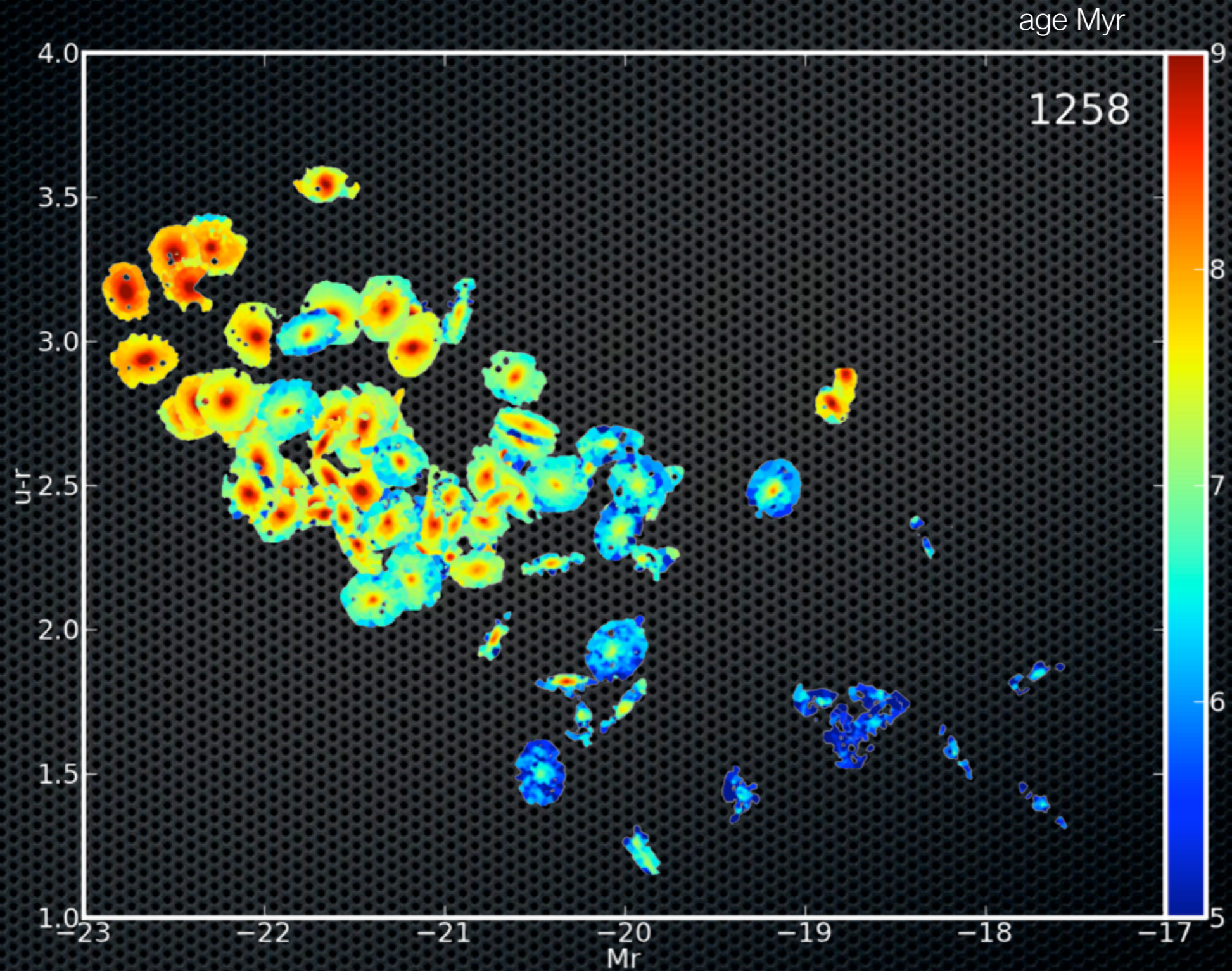
# How Mass builds up in time



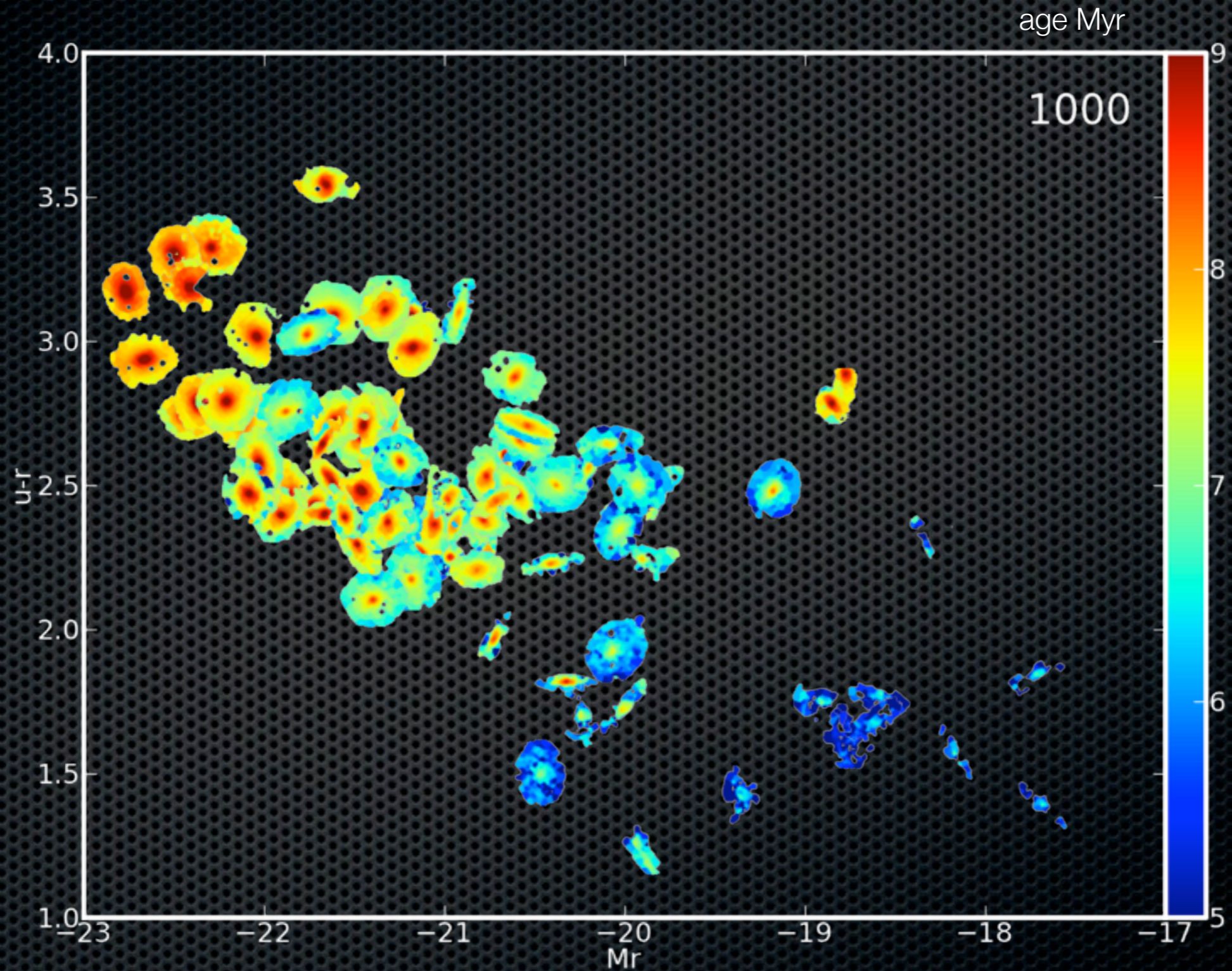
# How Mass builds up in time



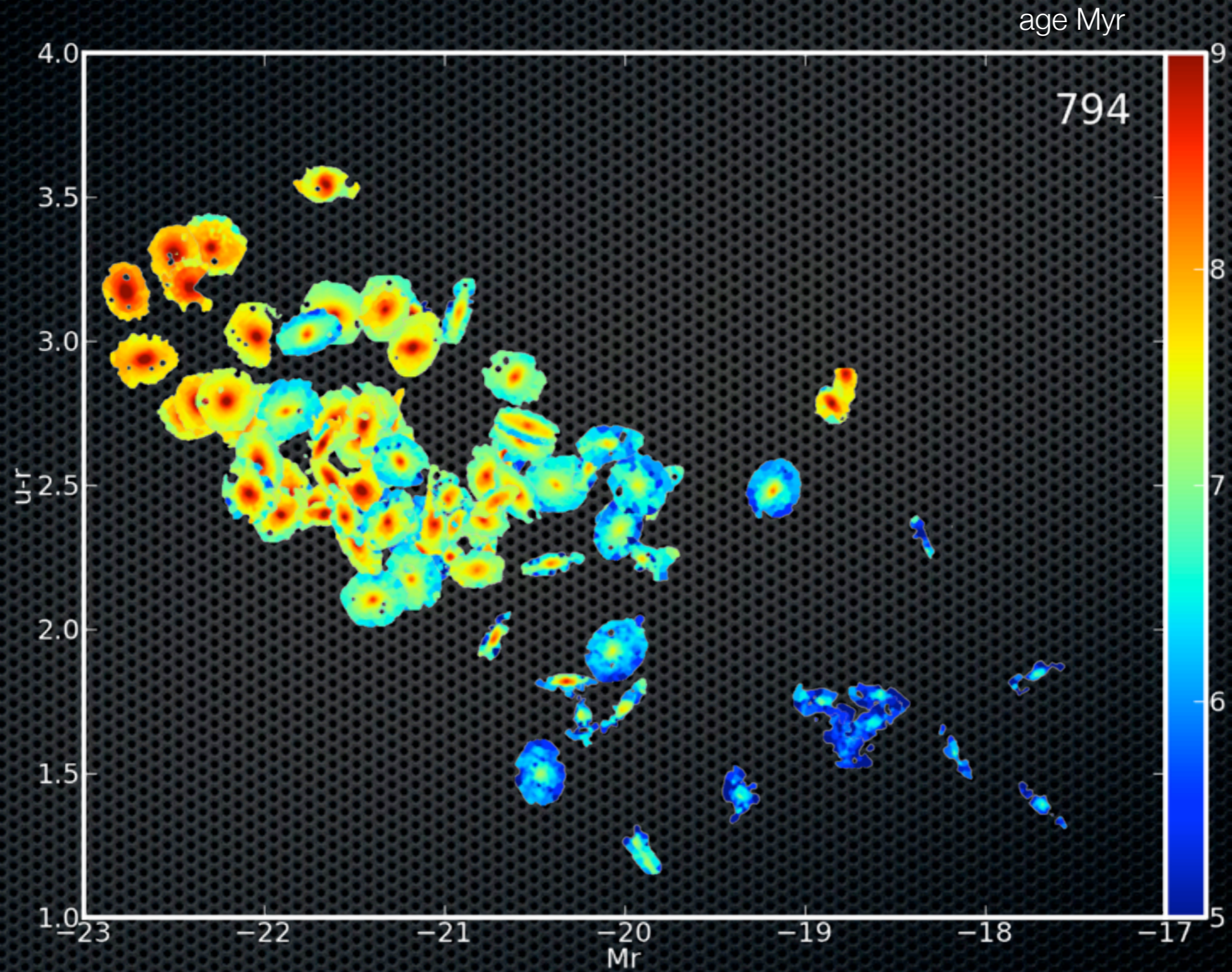
# How Mass builds up in time



# How Mass builds up in time

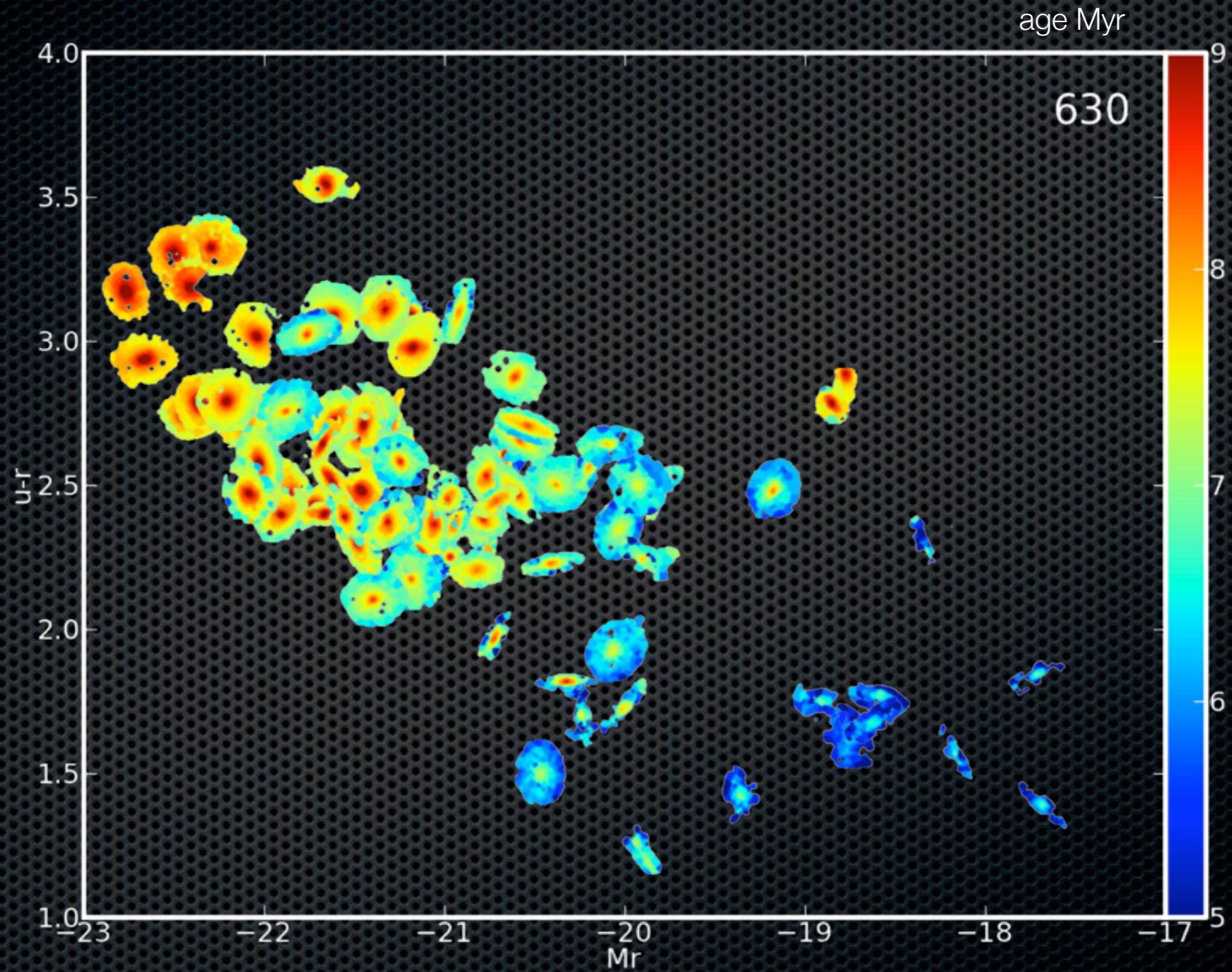


# How Mass builds up in time

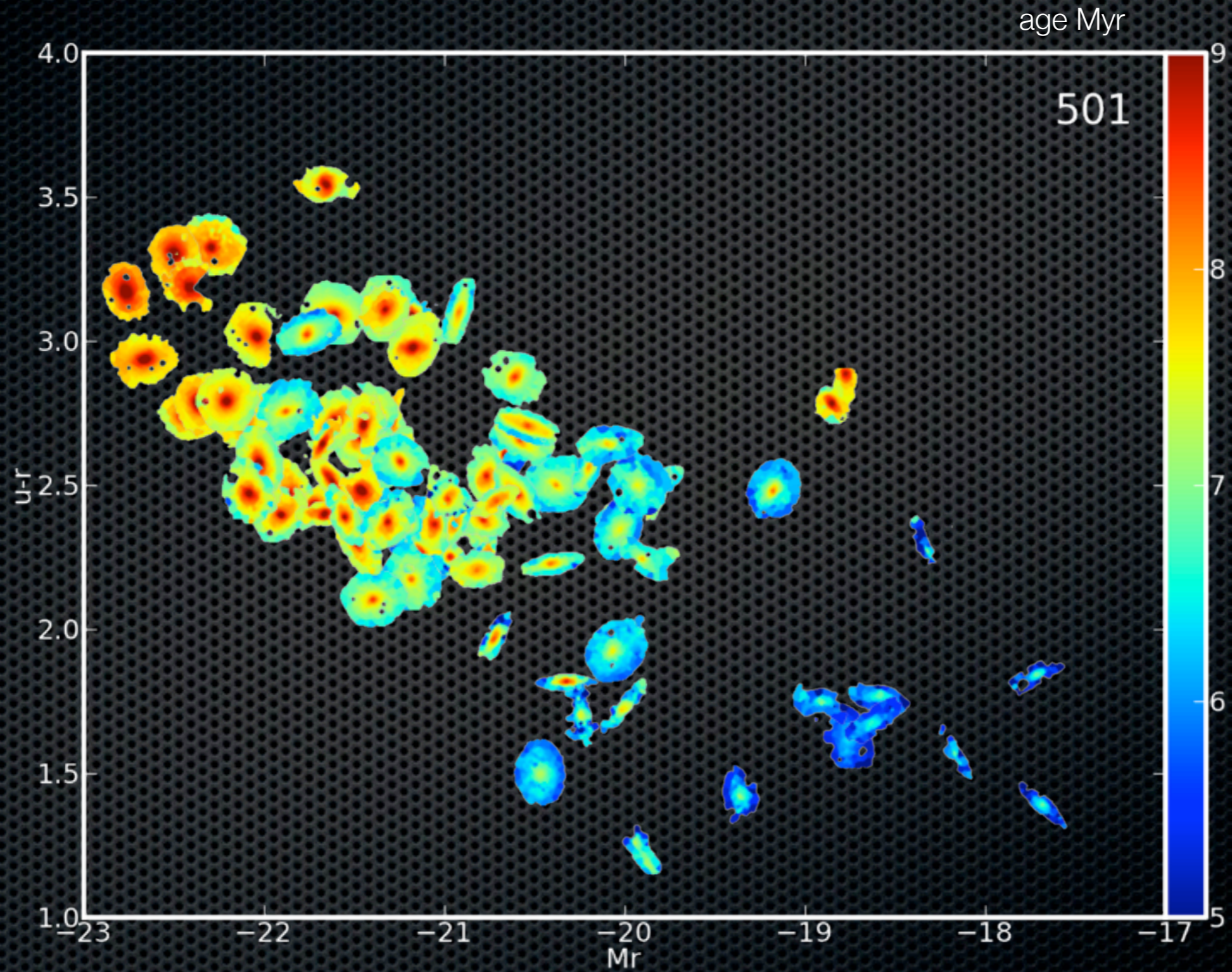




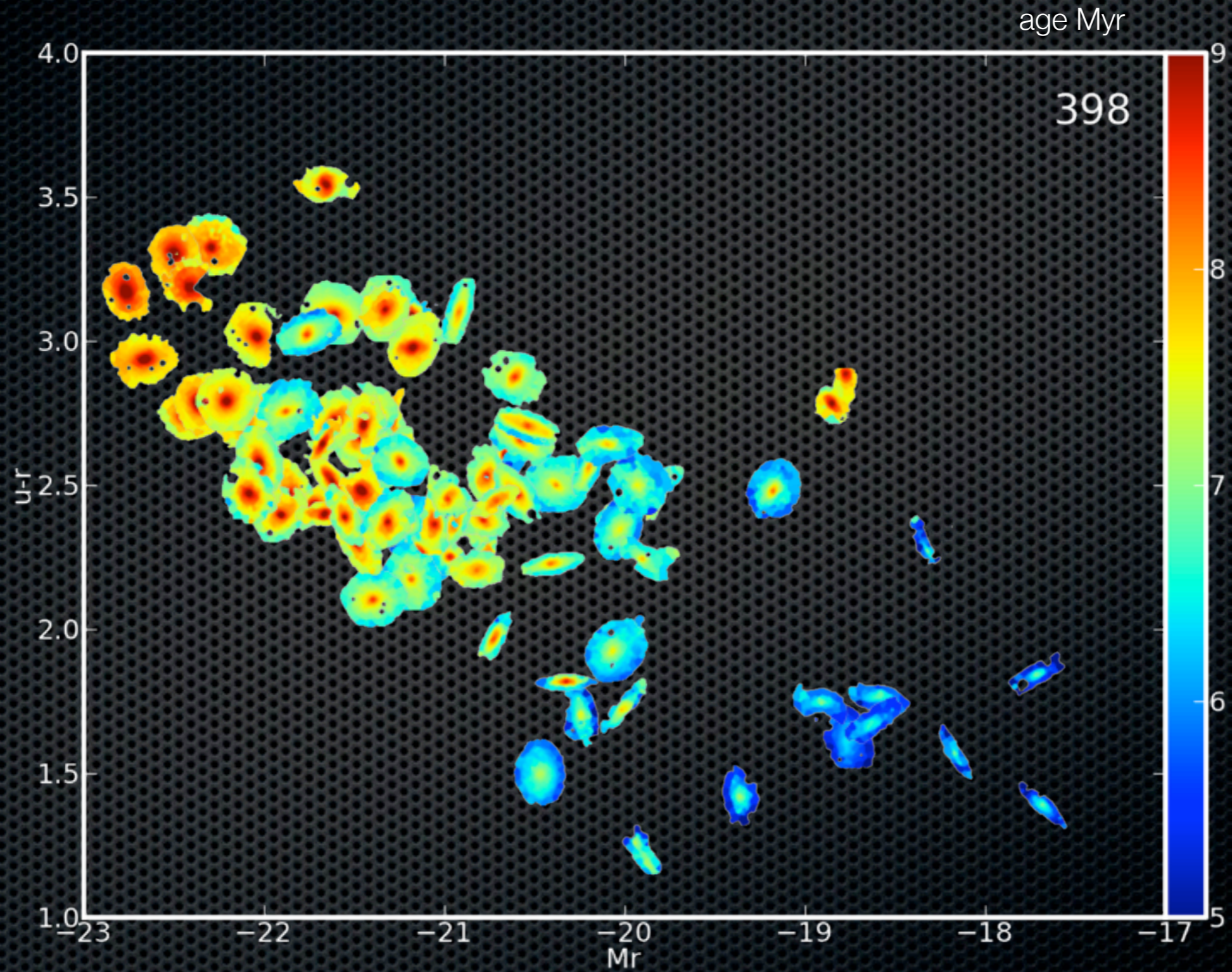
# How Mass builds up in time



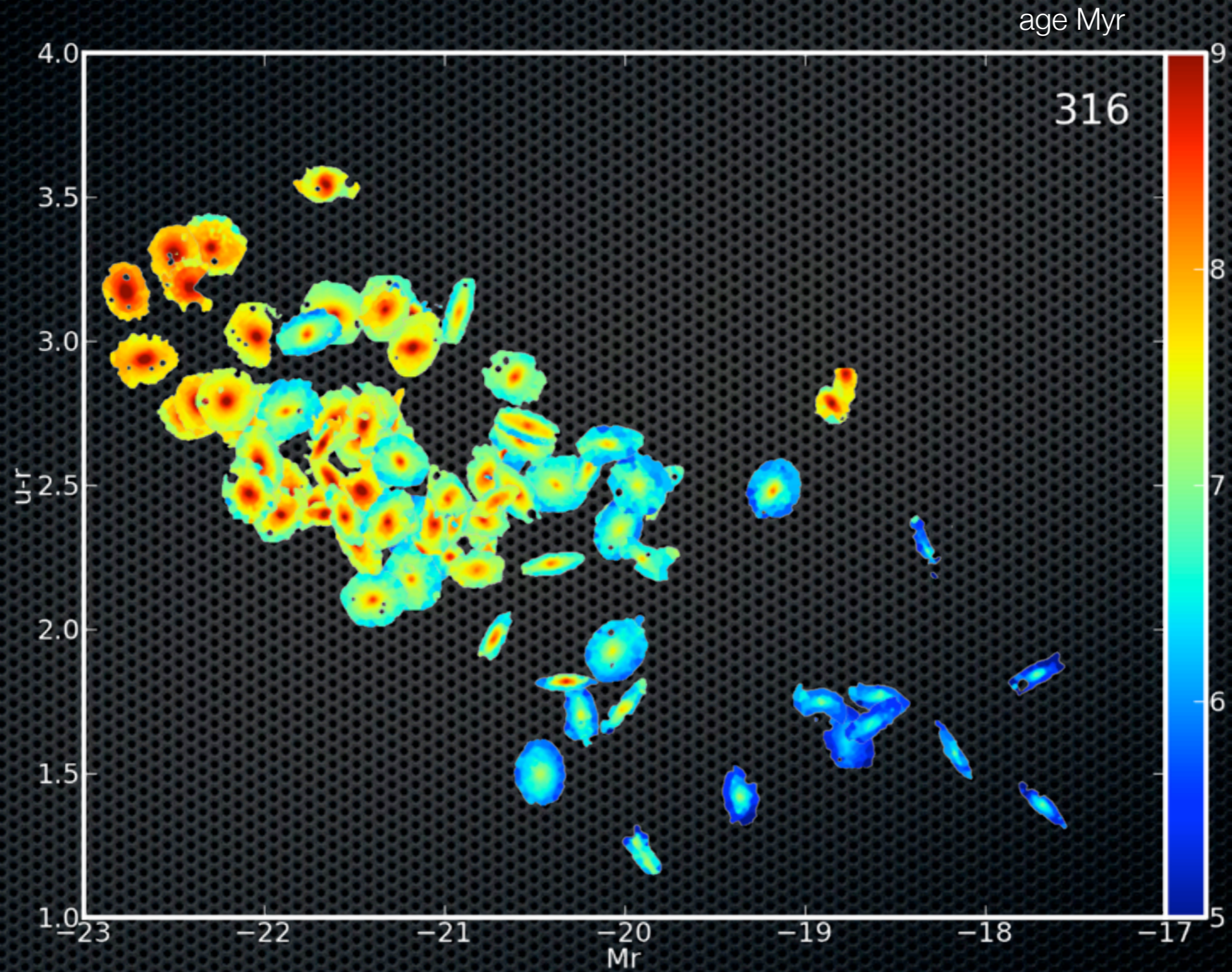
# How Mass builds up in time



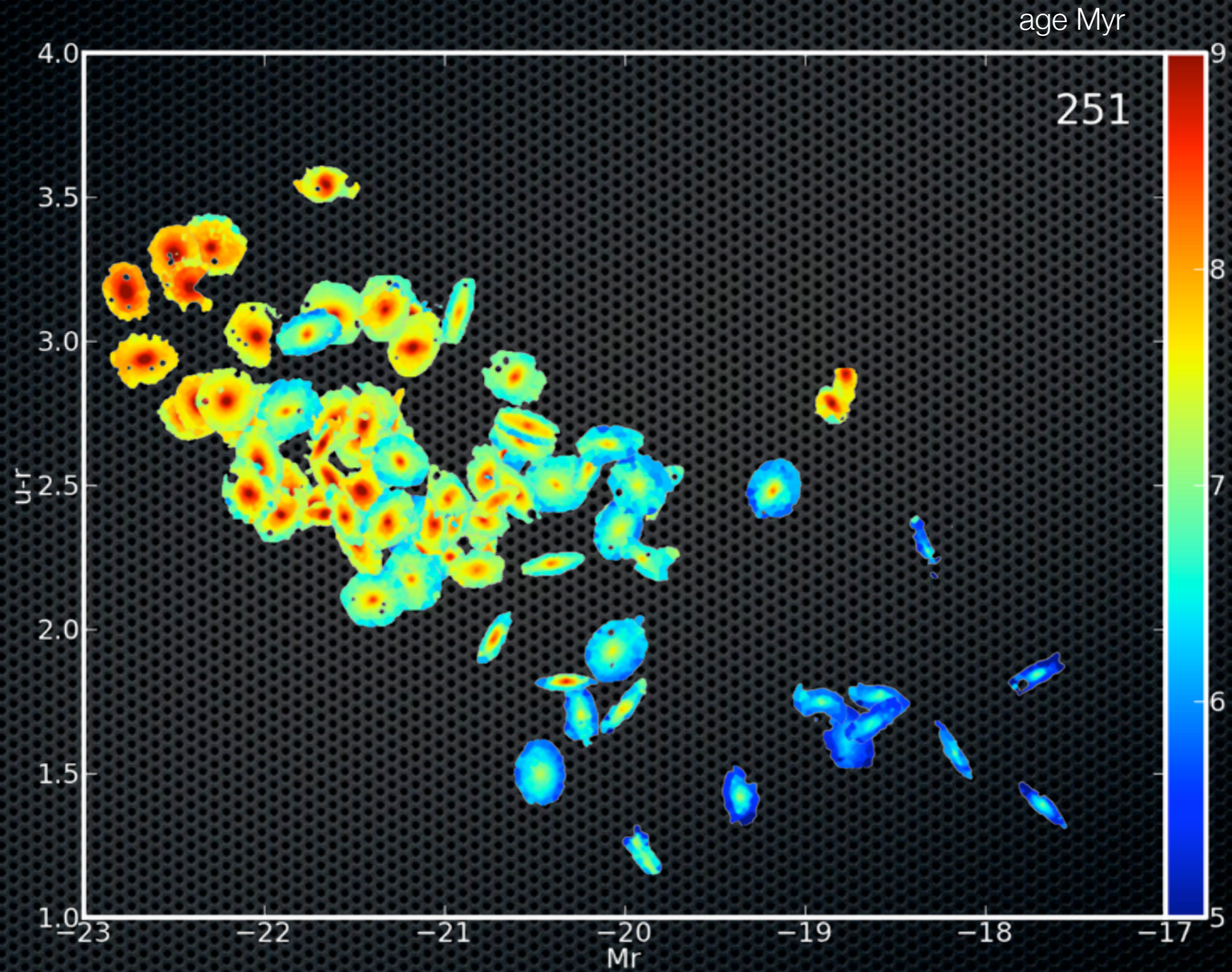
# How Mass builds up in time



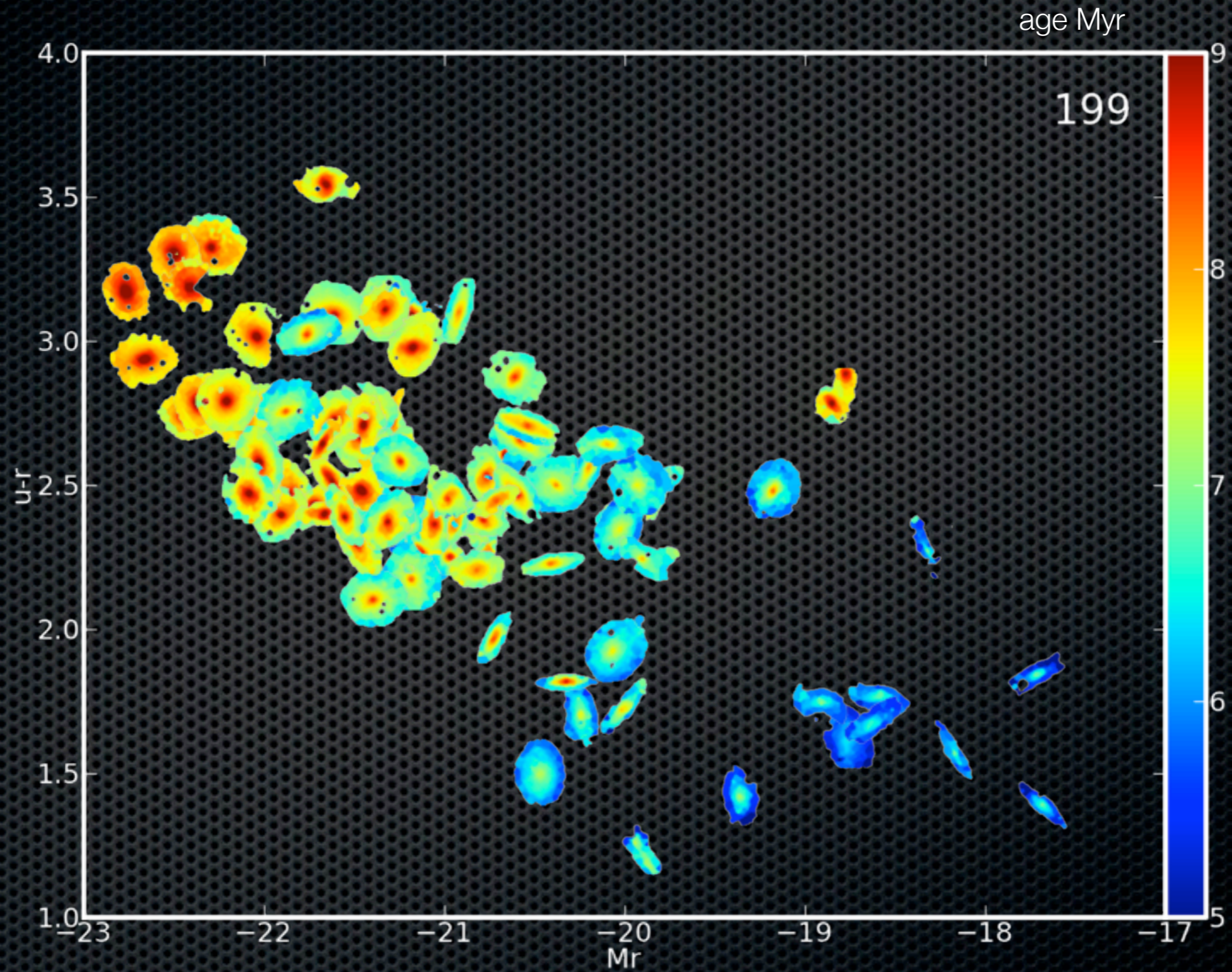
# How Mass builds up in time



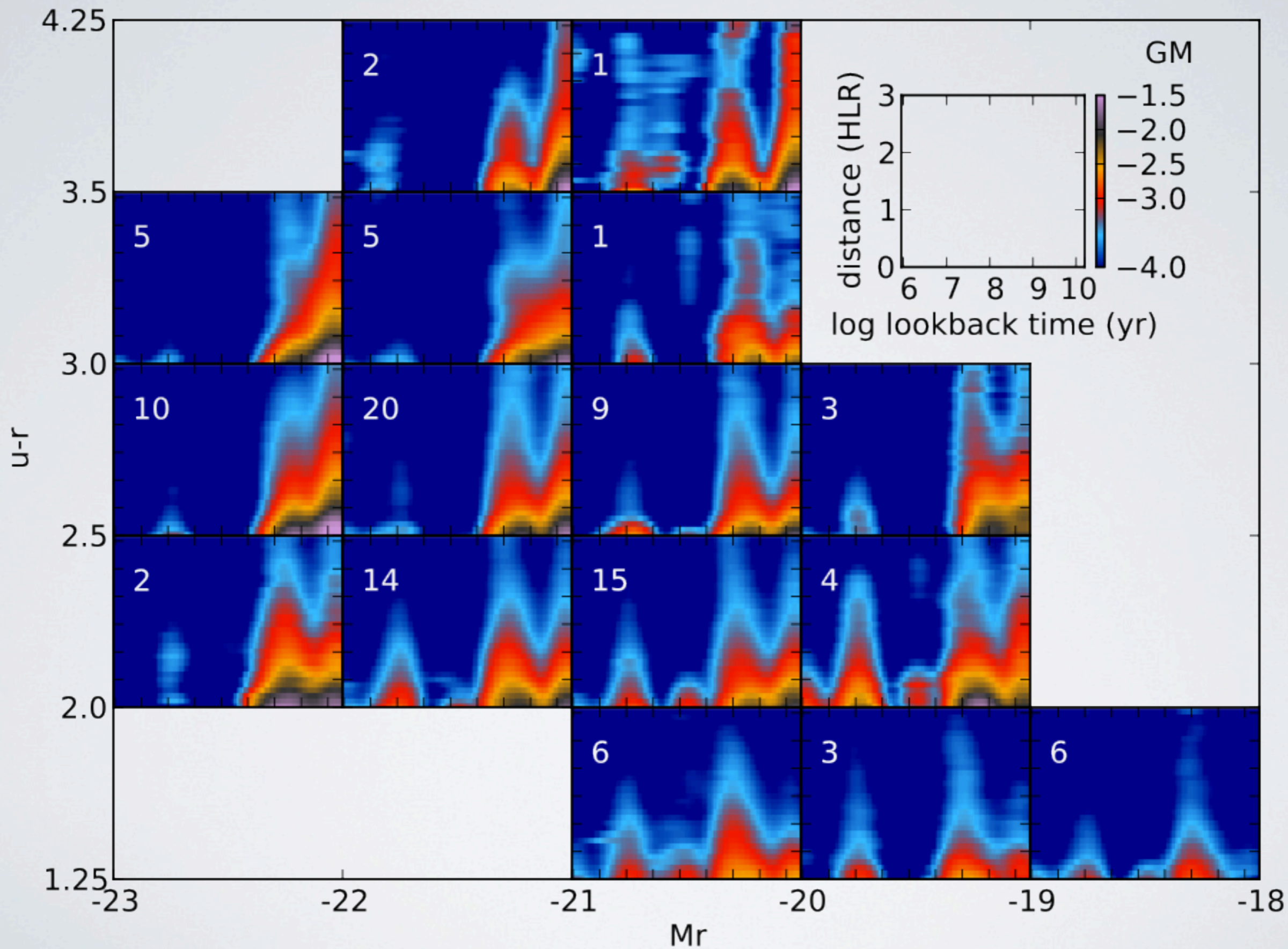
# How Mass builds up in time



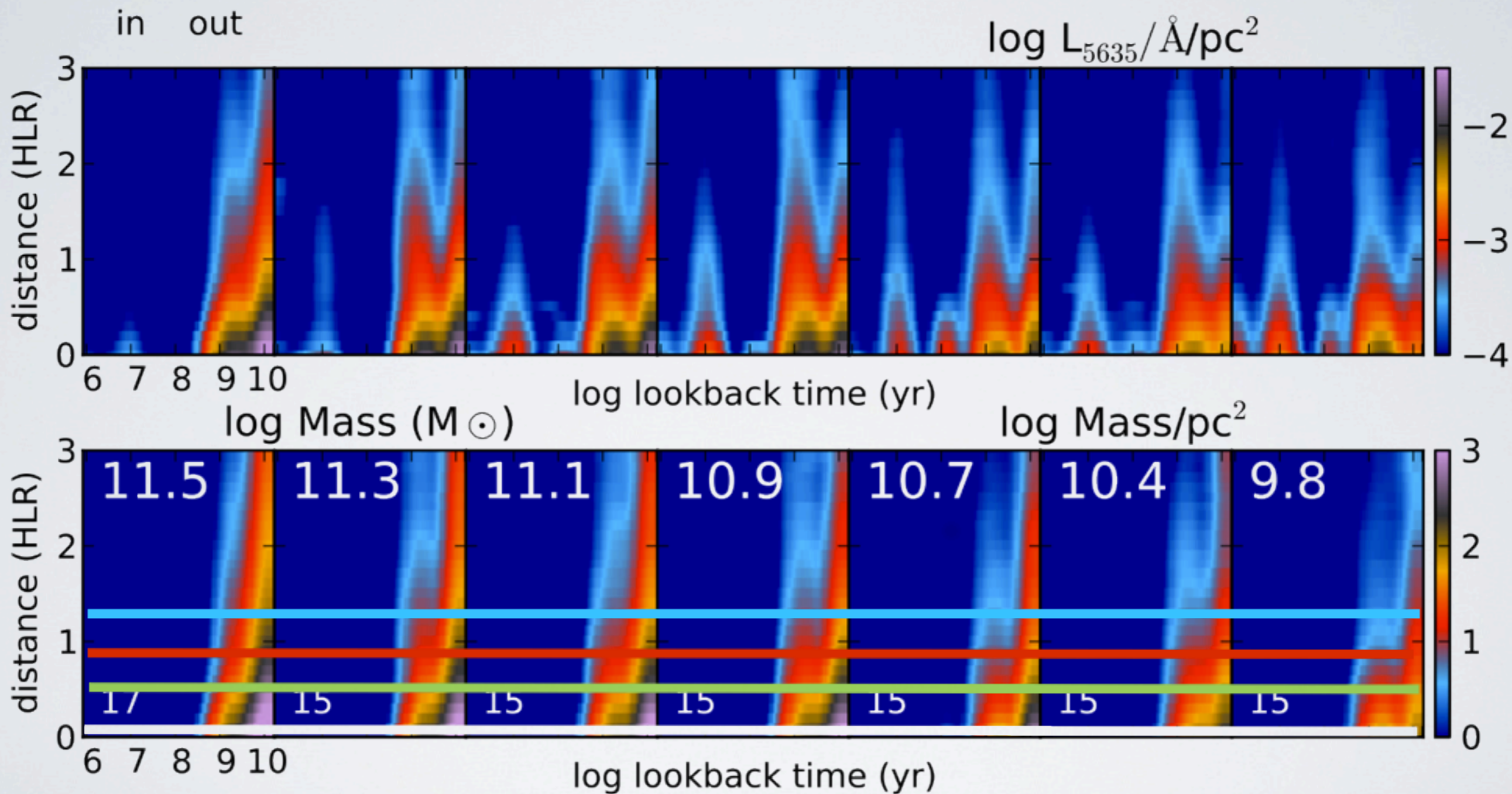
# How Mass builds up in time



# Stacking spectra

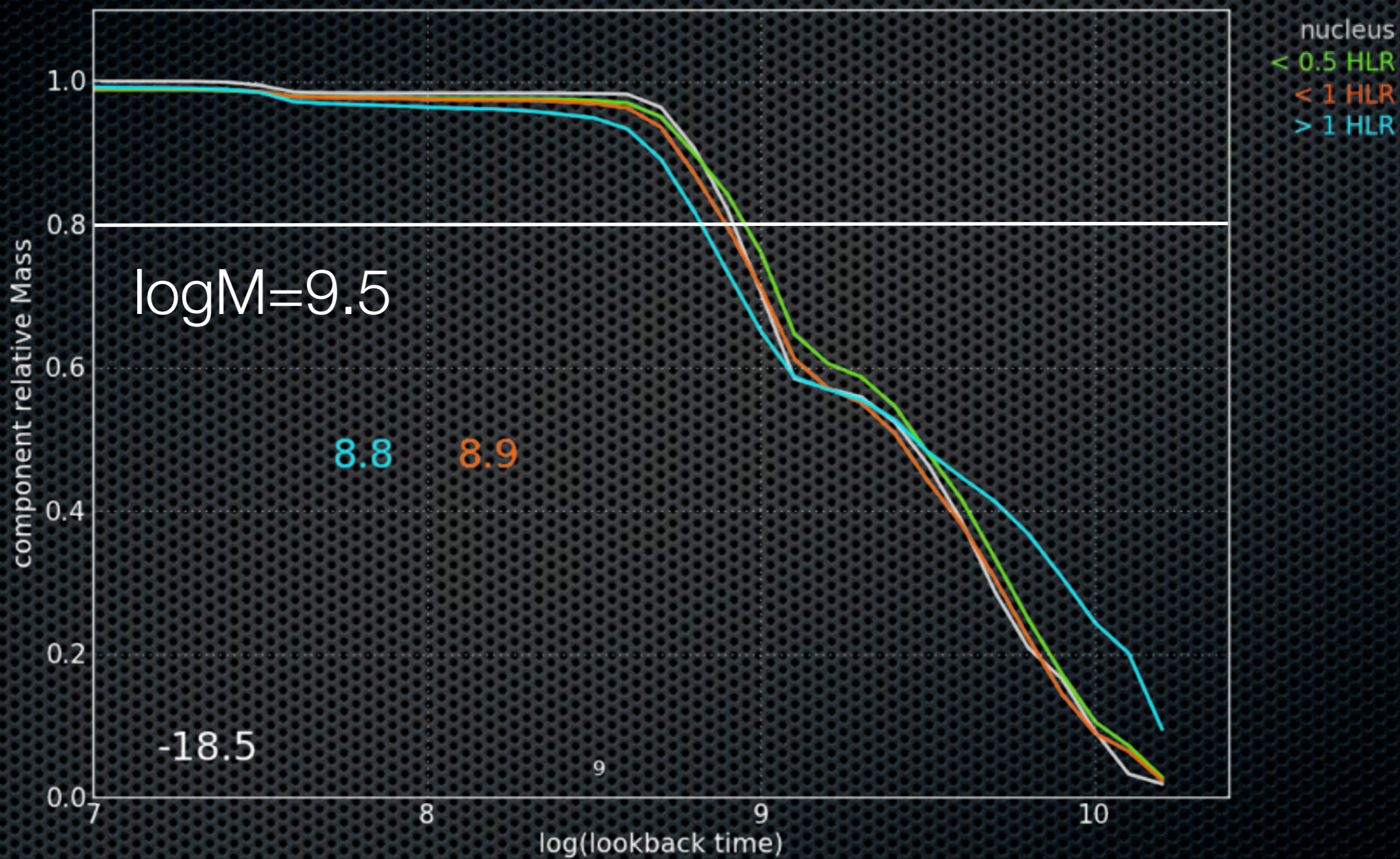


# Stacking by galaxy mass

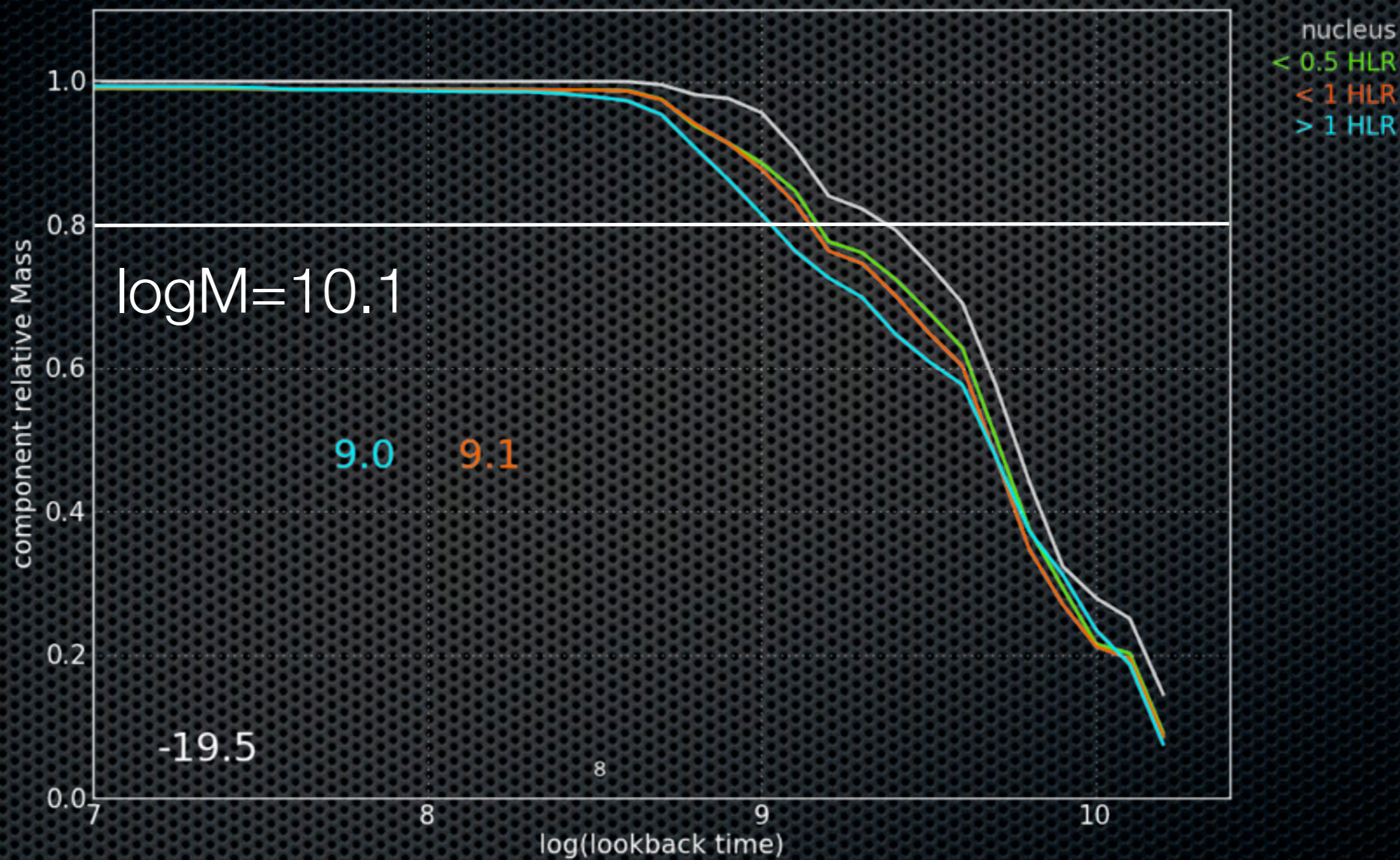




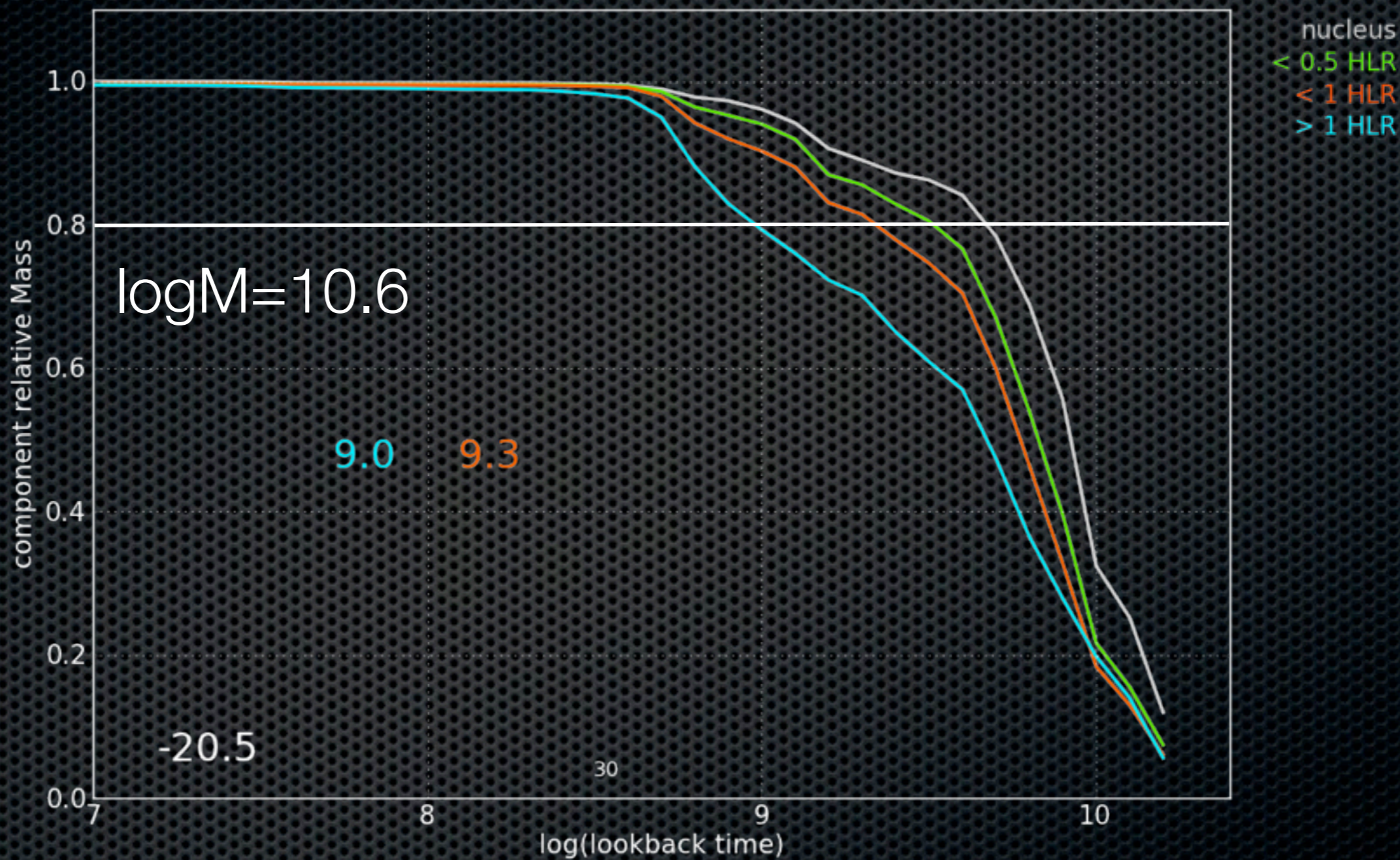
# Mass growth curve



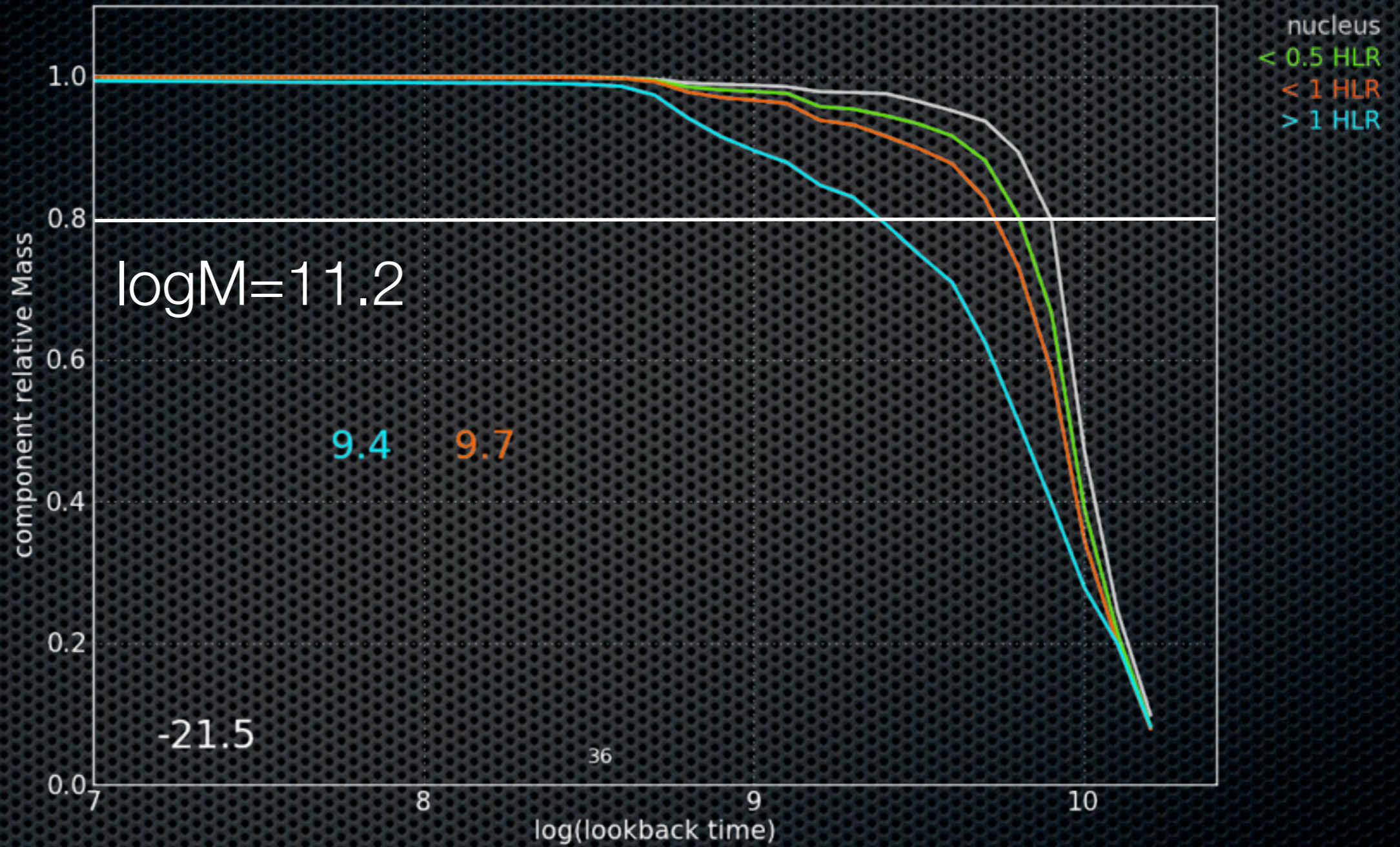
# Mass growth curve



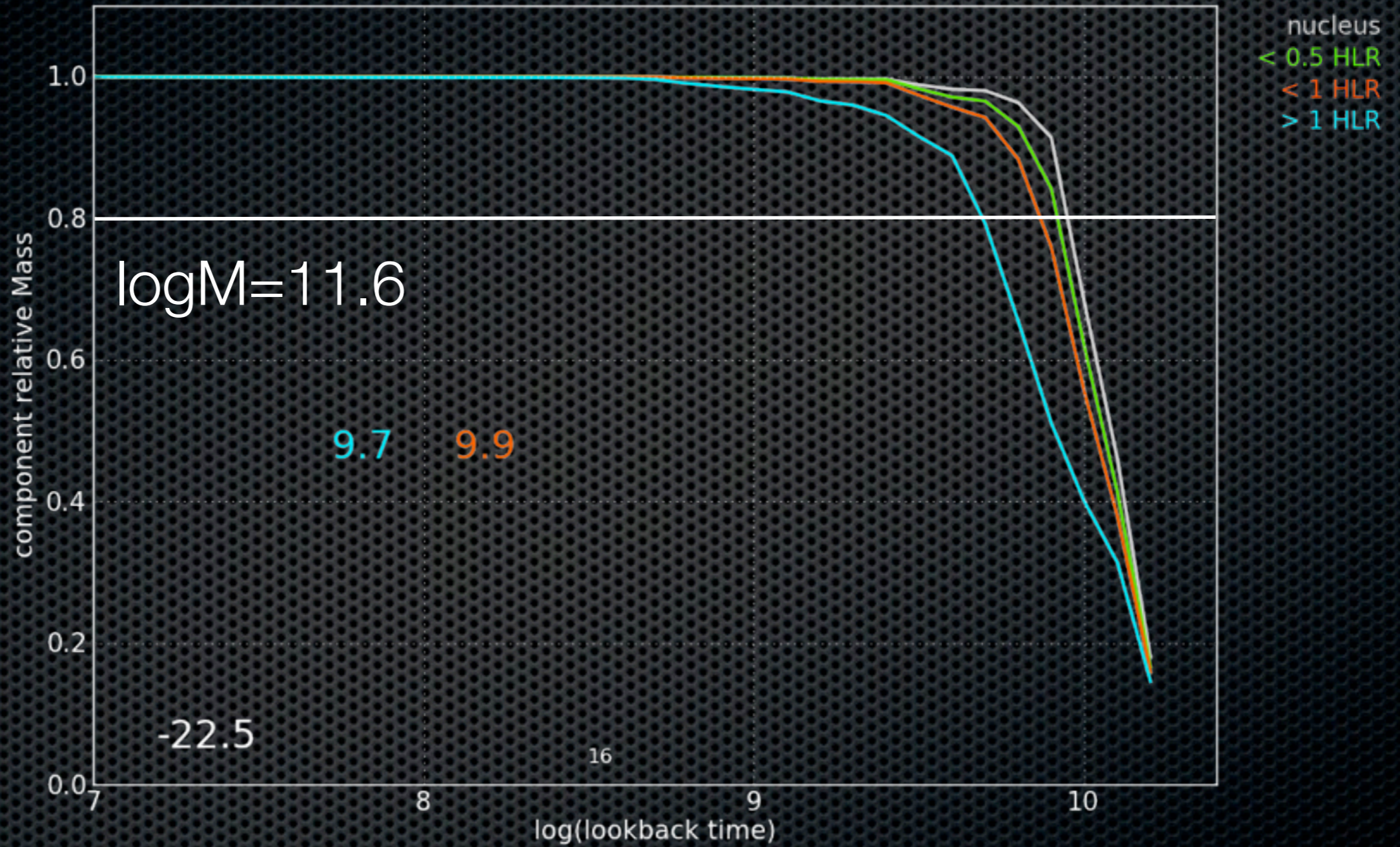
# Mass growth curve



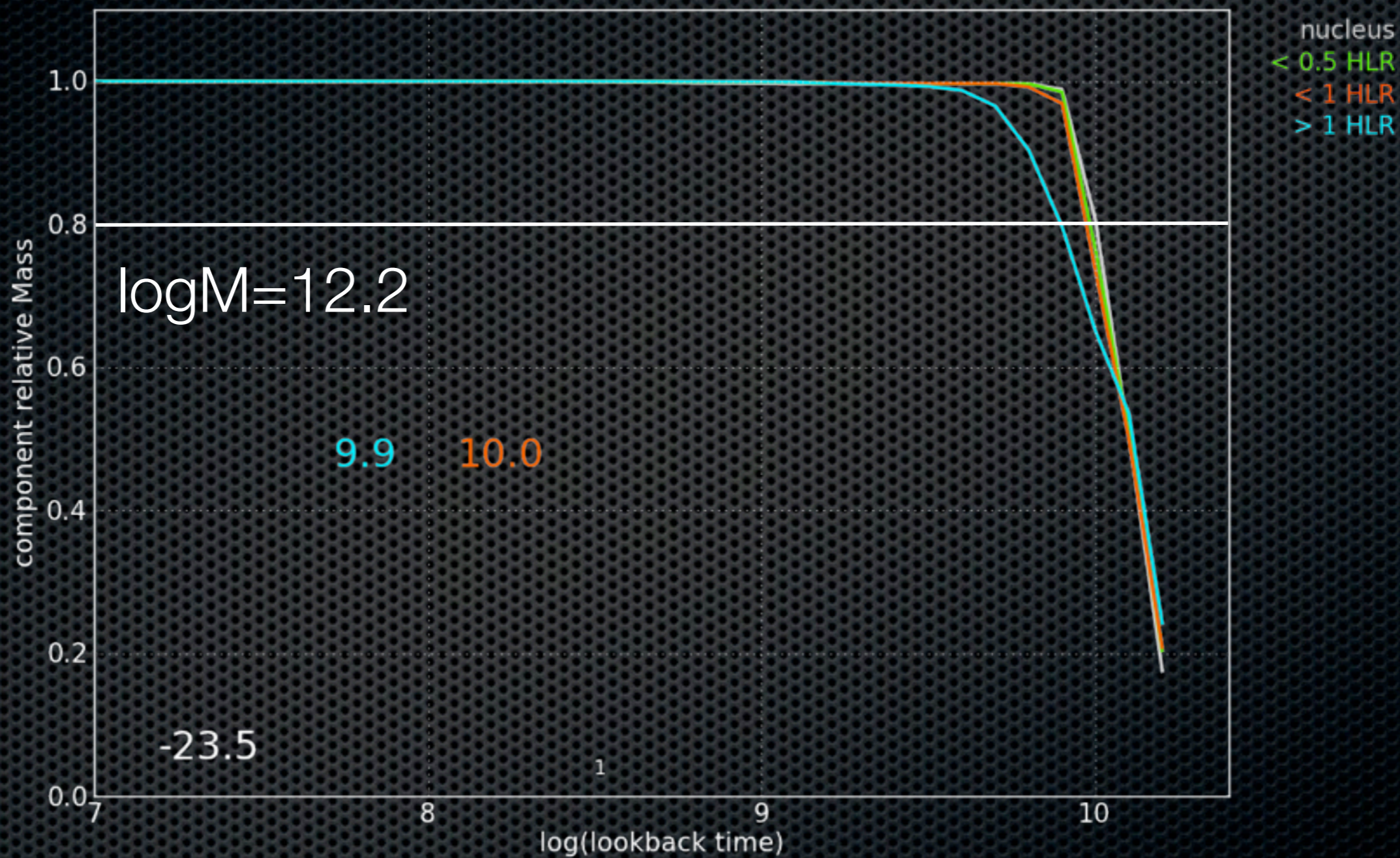
# Mass growth curve



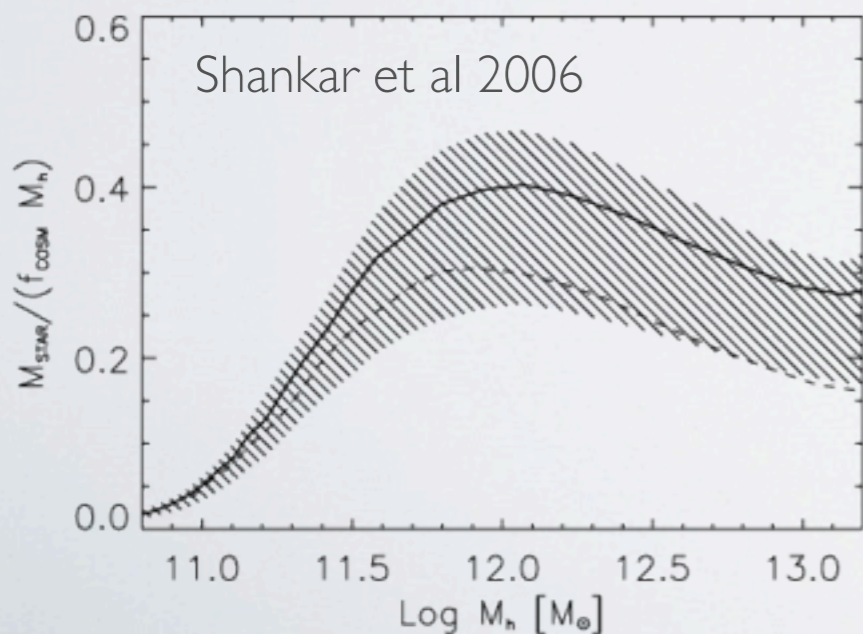
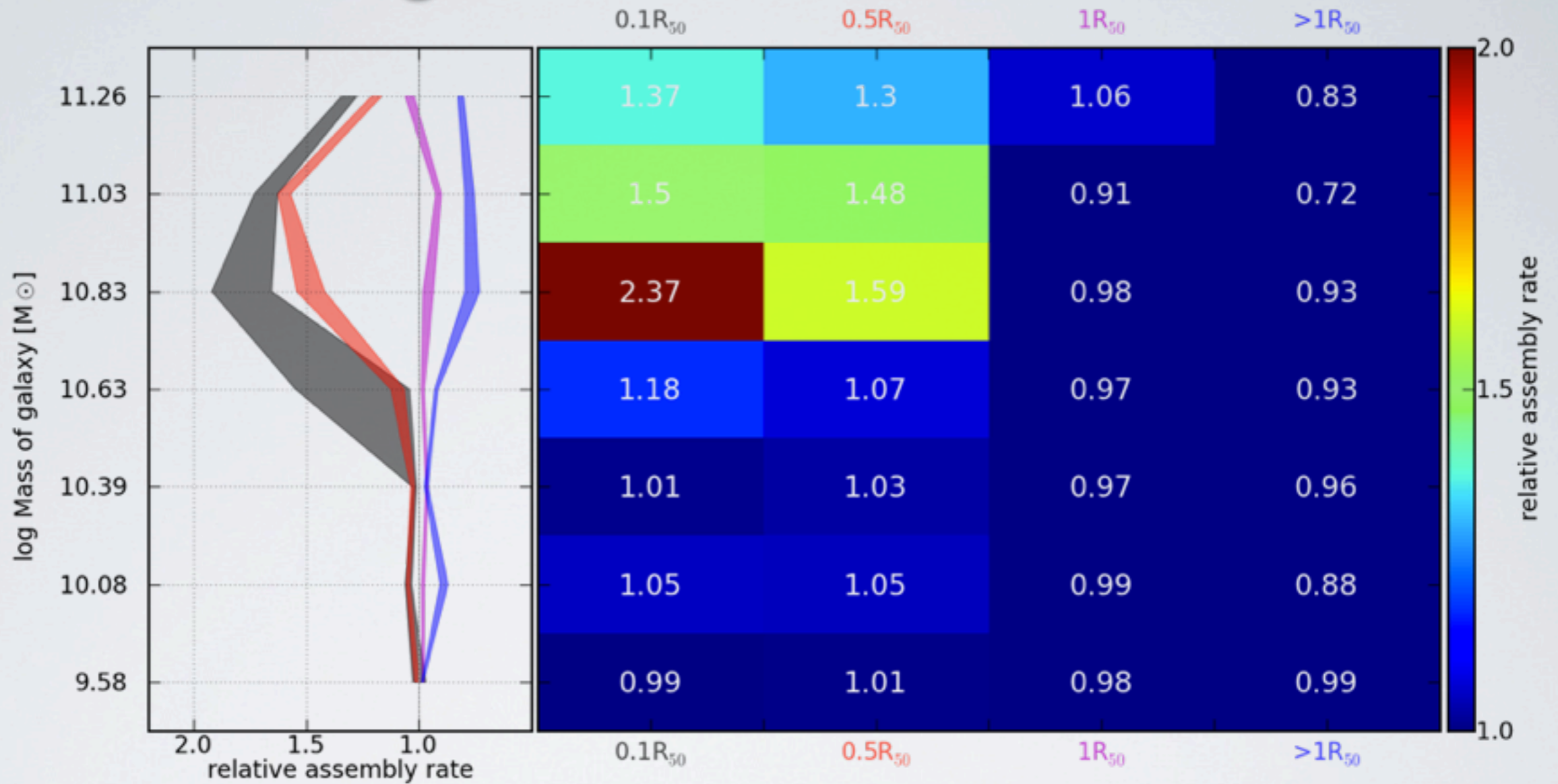
# Mass growth curve



# Mass growth curve



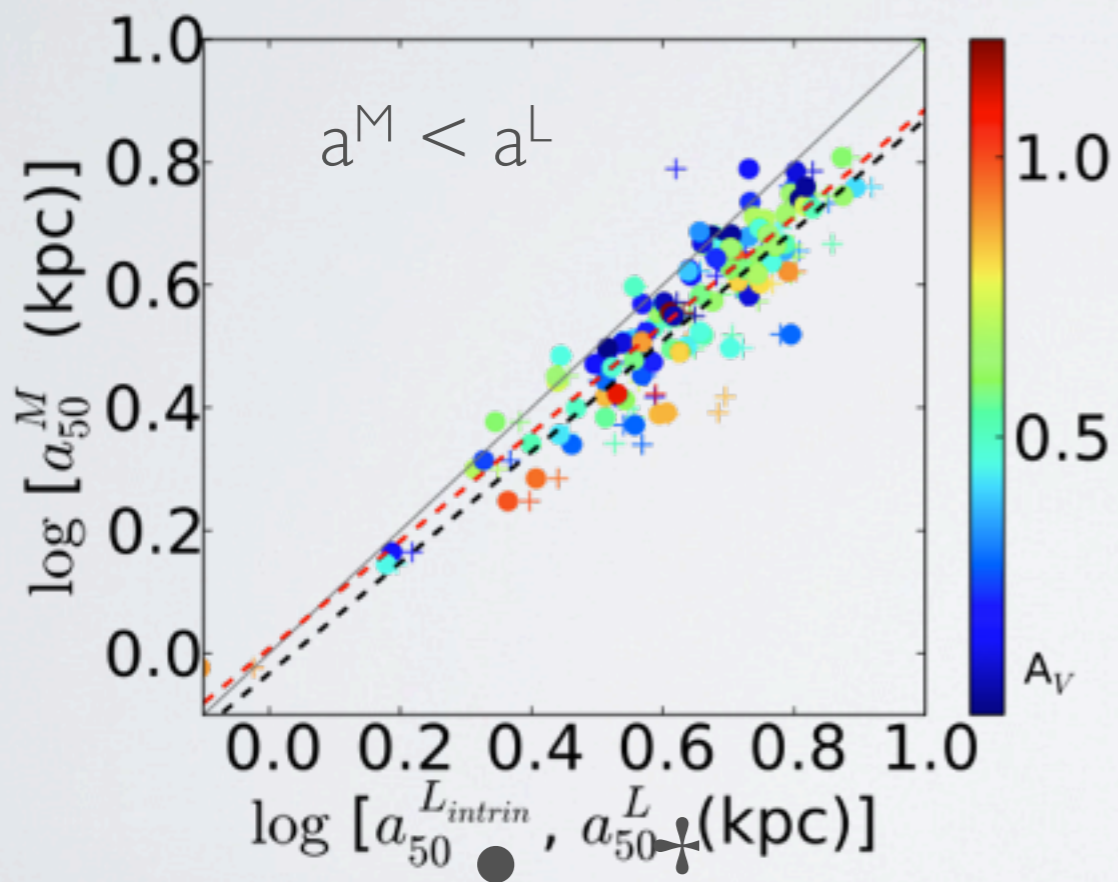
# Inside-out mass growth



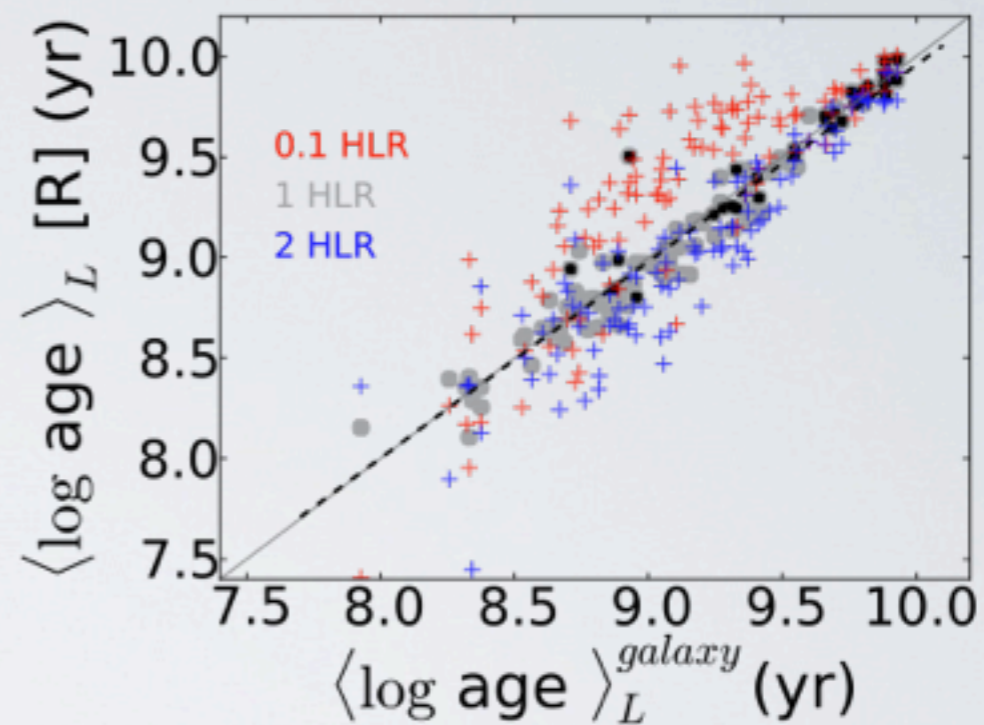
Central core of galaxies (present) stellar mass of  $\sim 7 \times 10^{10} M_{\text{sun}}$   $\rightarrow$  maximum relative assembly rate

Critical mass at which the conversion of the mass halo into star is maximum (occurs when the feedback effects by AGN and star formation are less efficient)

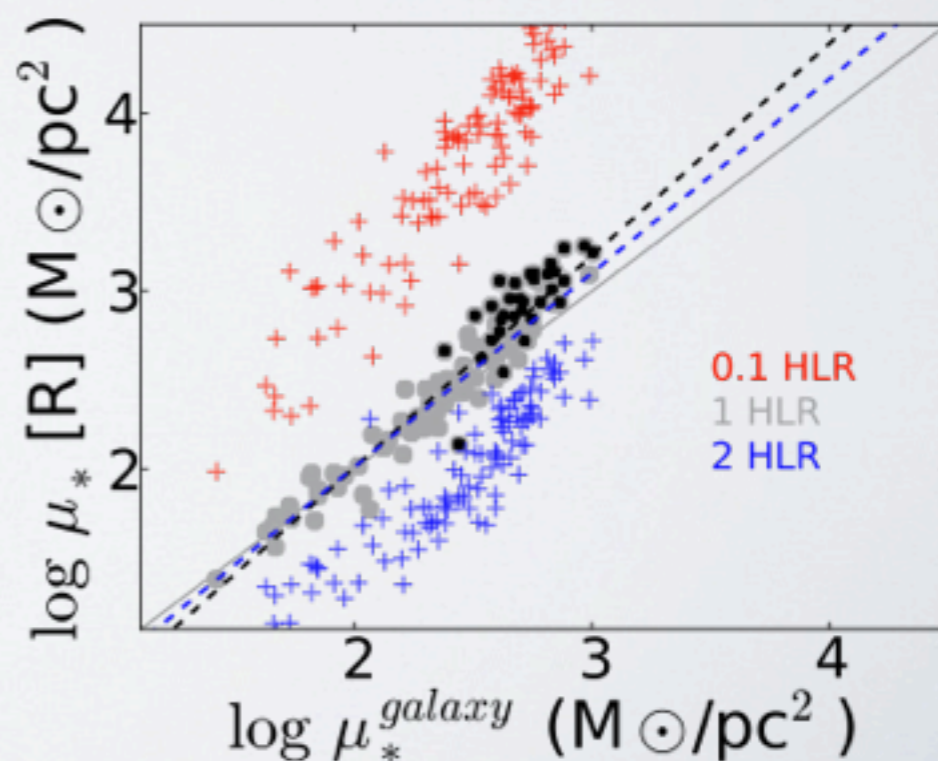
# Mass Radius vs Light Radius



# Averaged vs properties at HLR

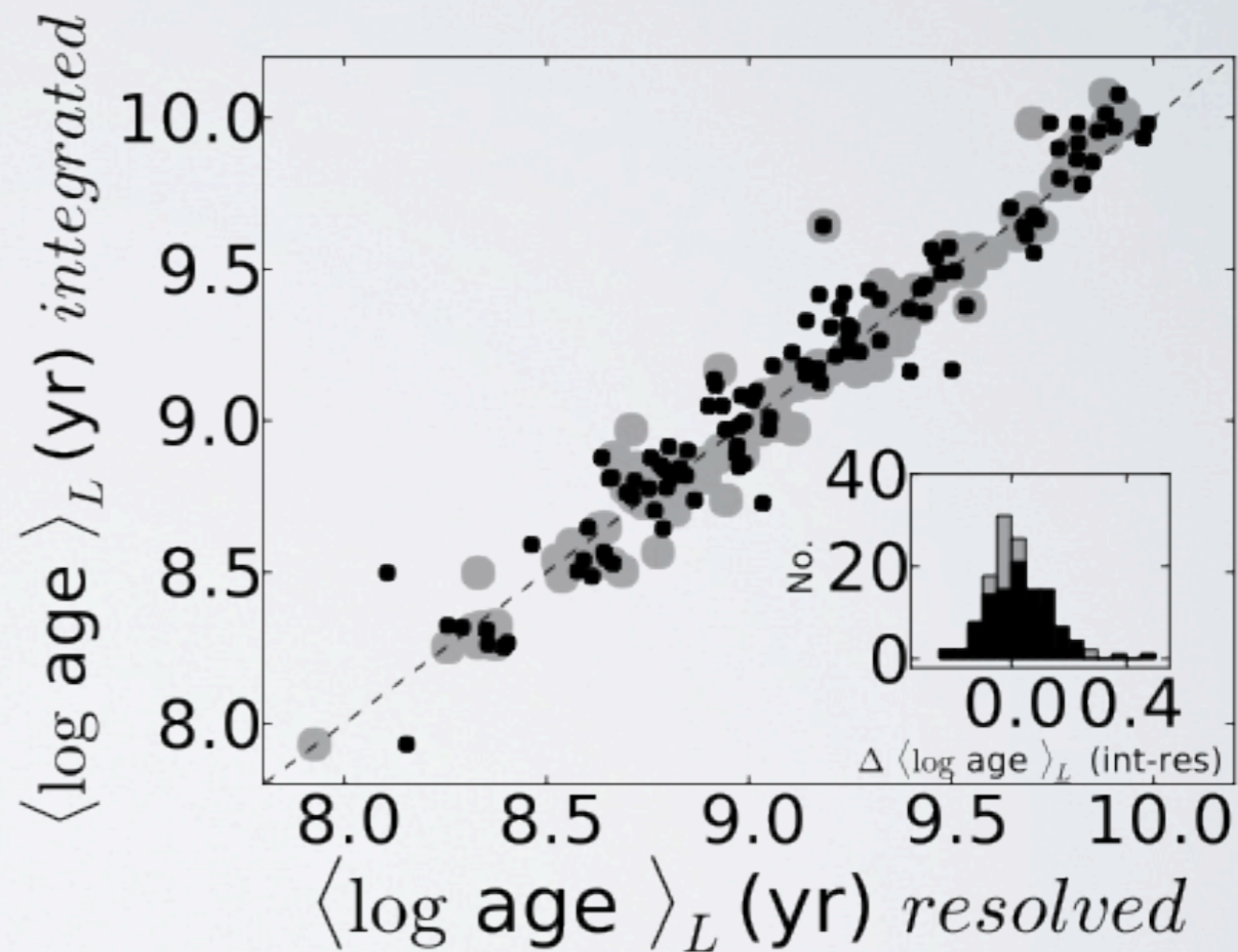
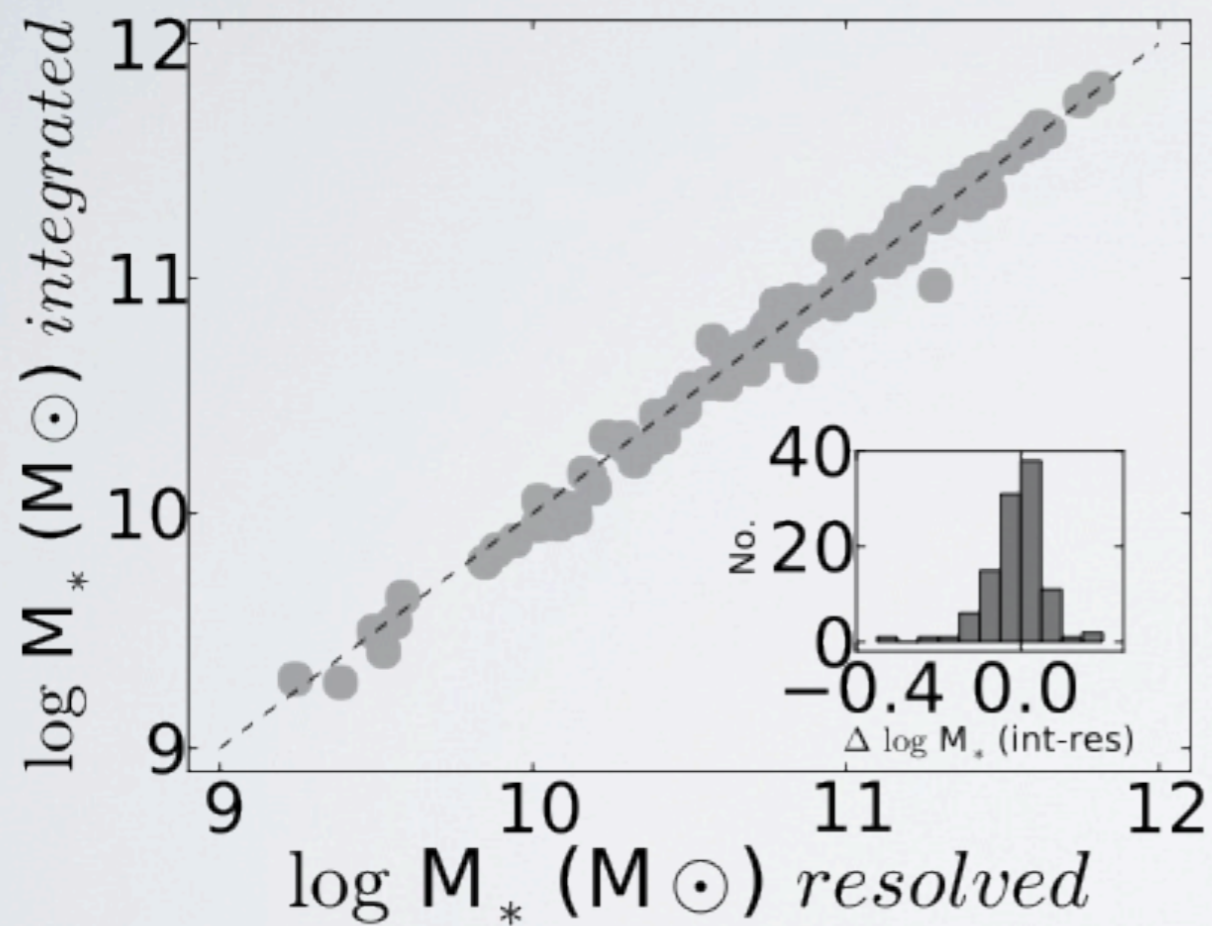


Effective radius are really “effective”

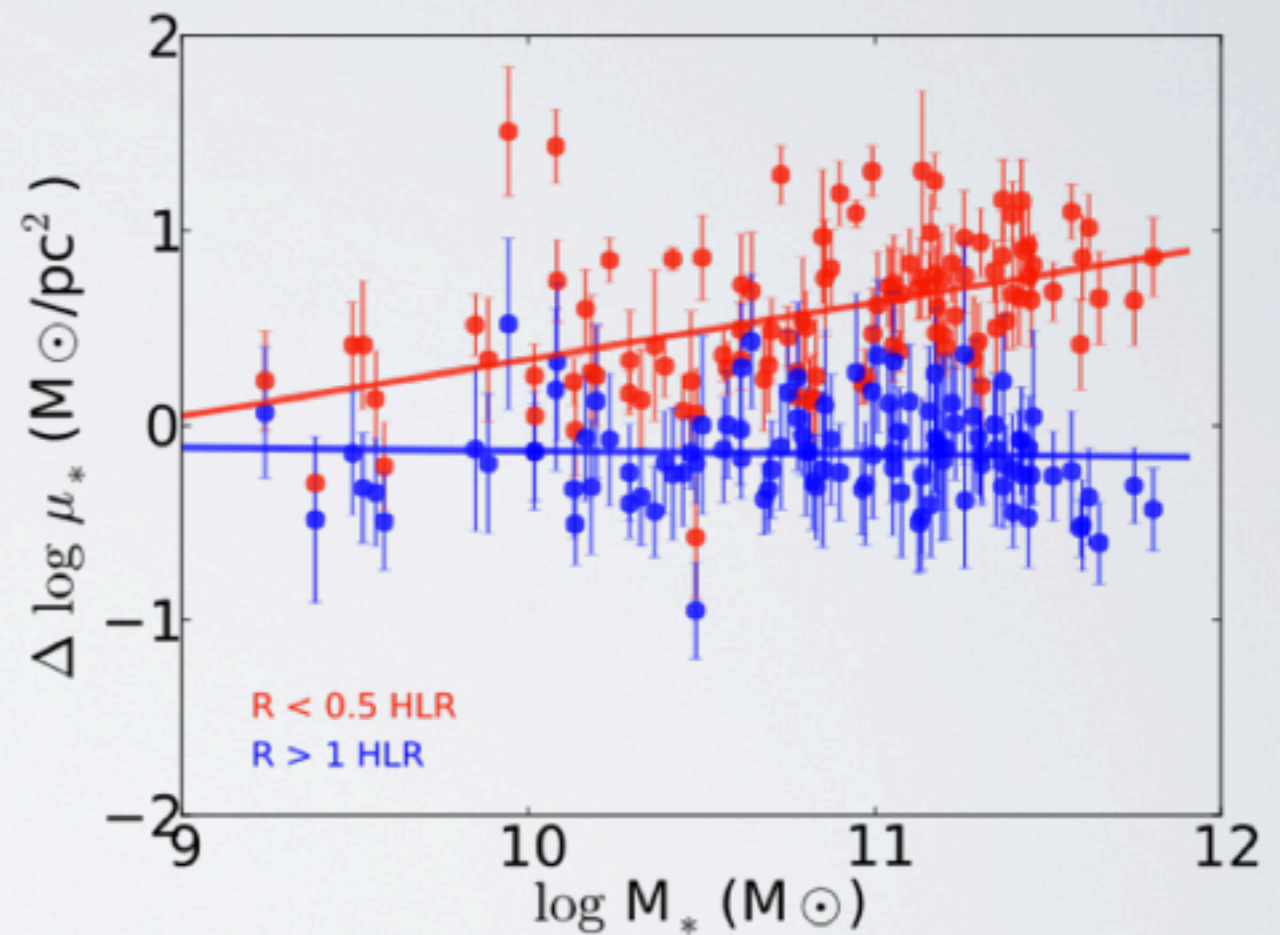
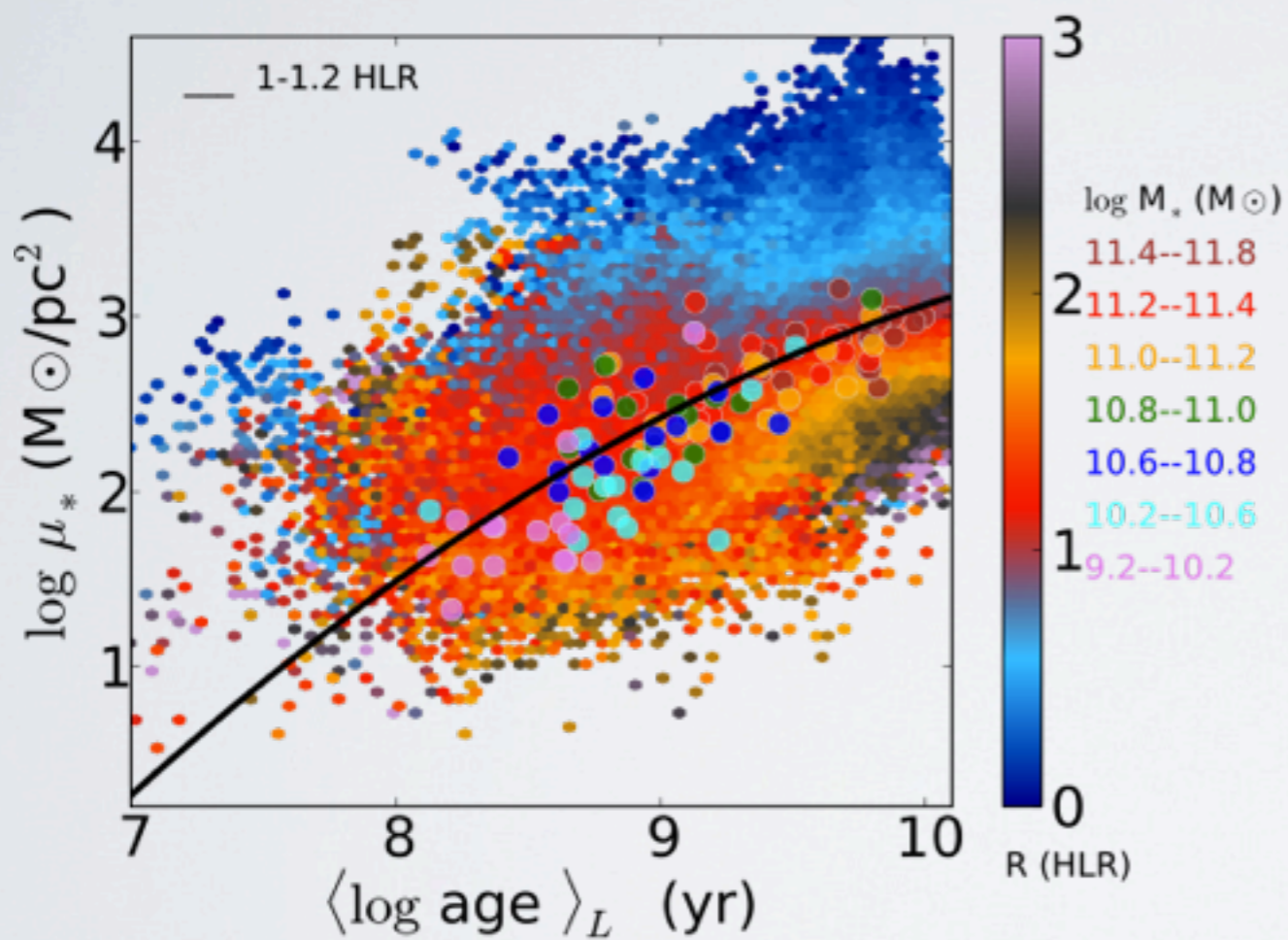




# Integrated vs resolved stellar properties



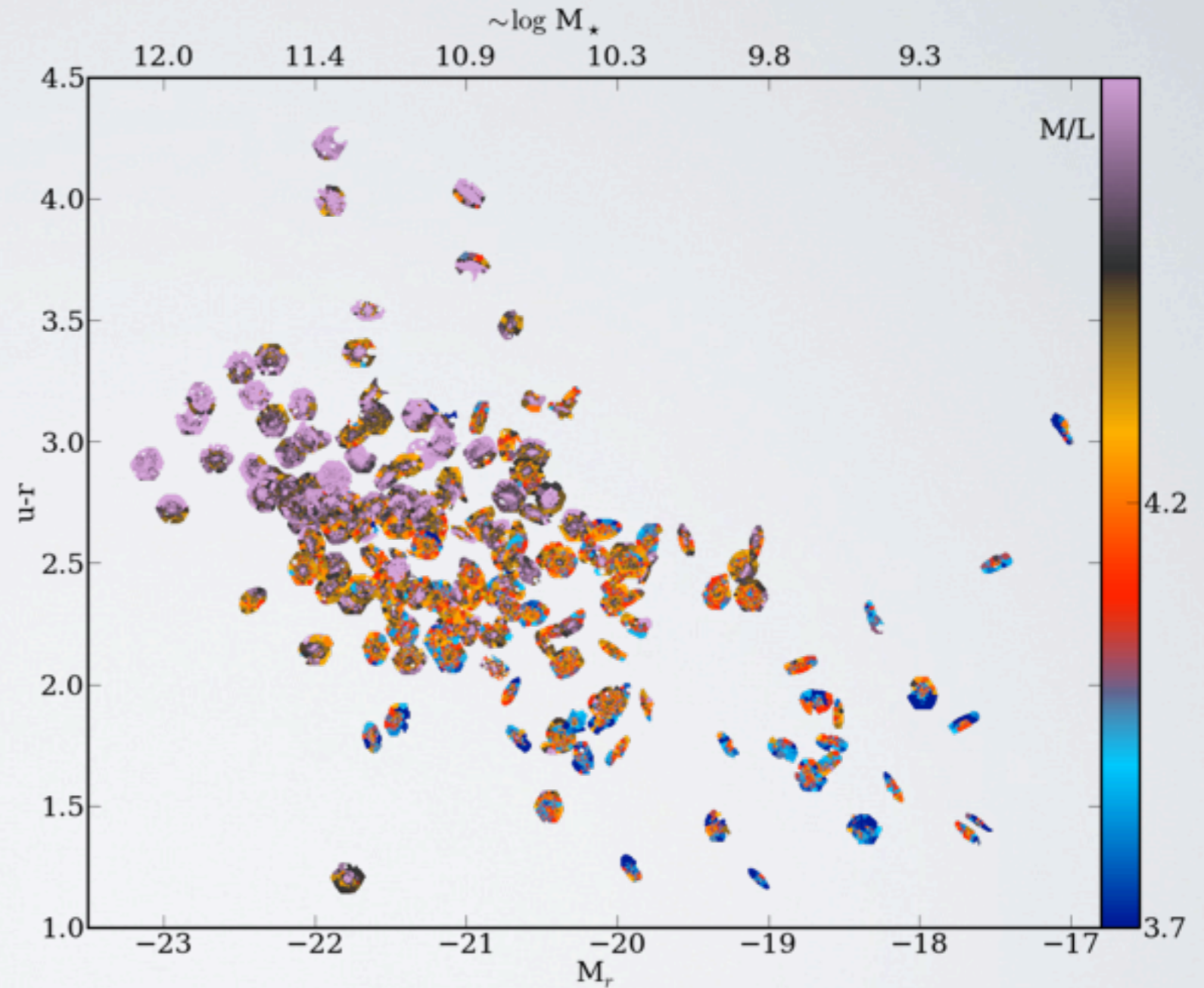
Is SFH driven by mass or local stellar mass surface density?



# Why M/L with CALIFA?

Observers: L  M

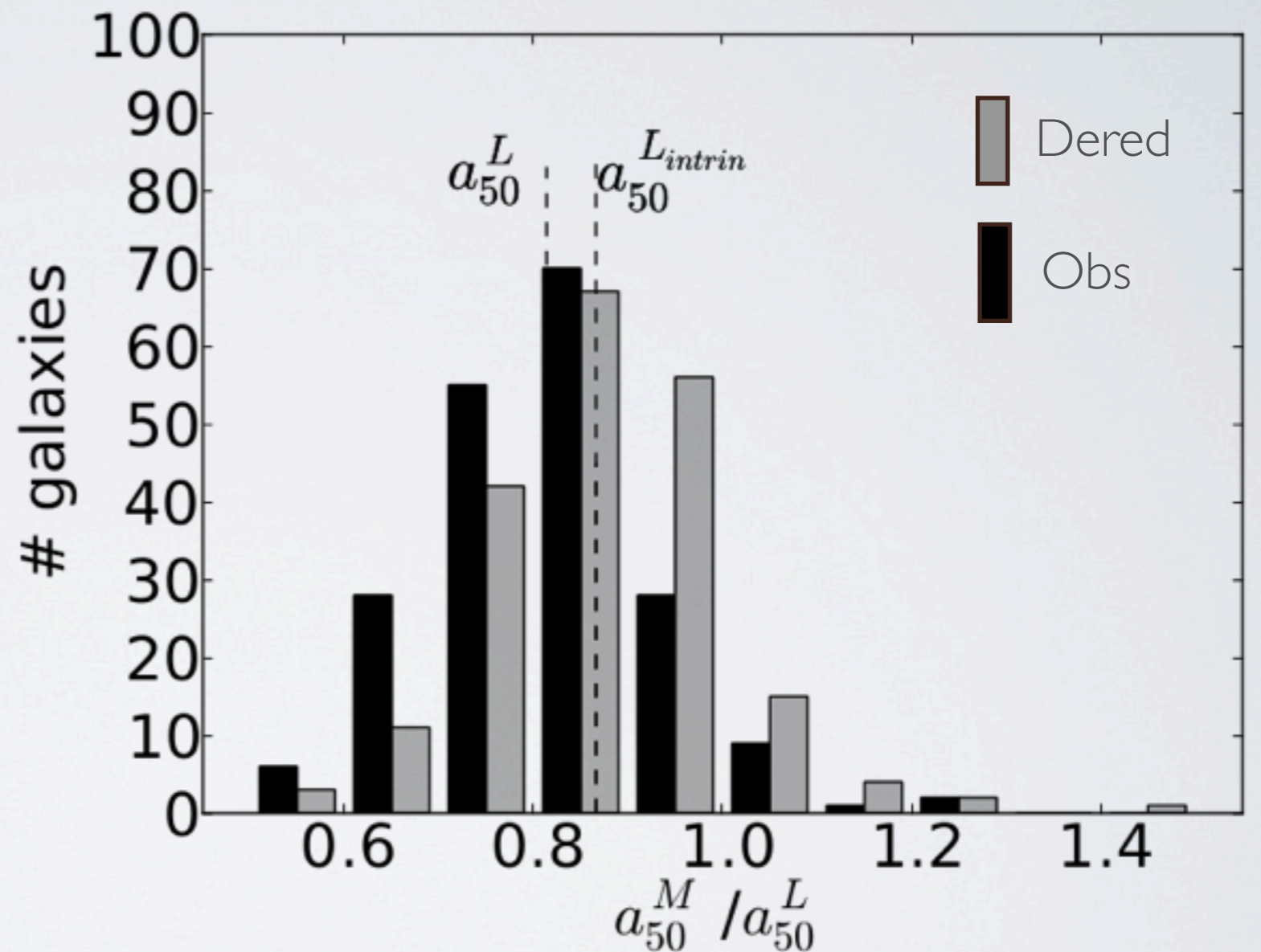
Theoreticians: M  L



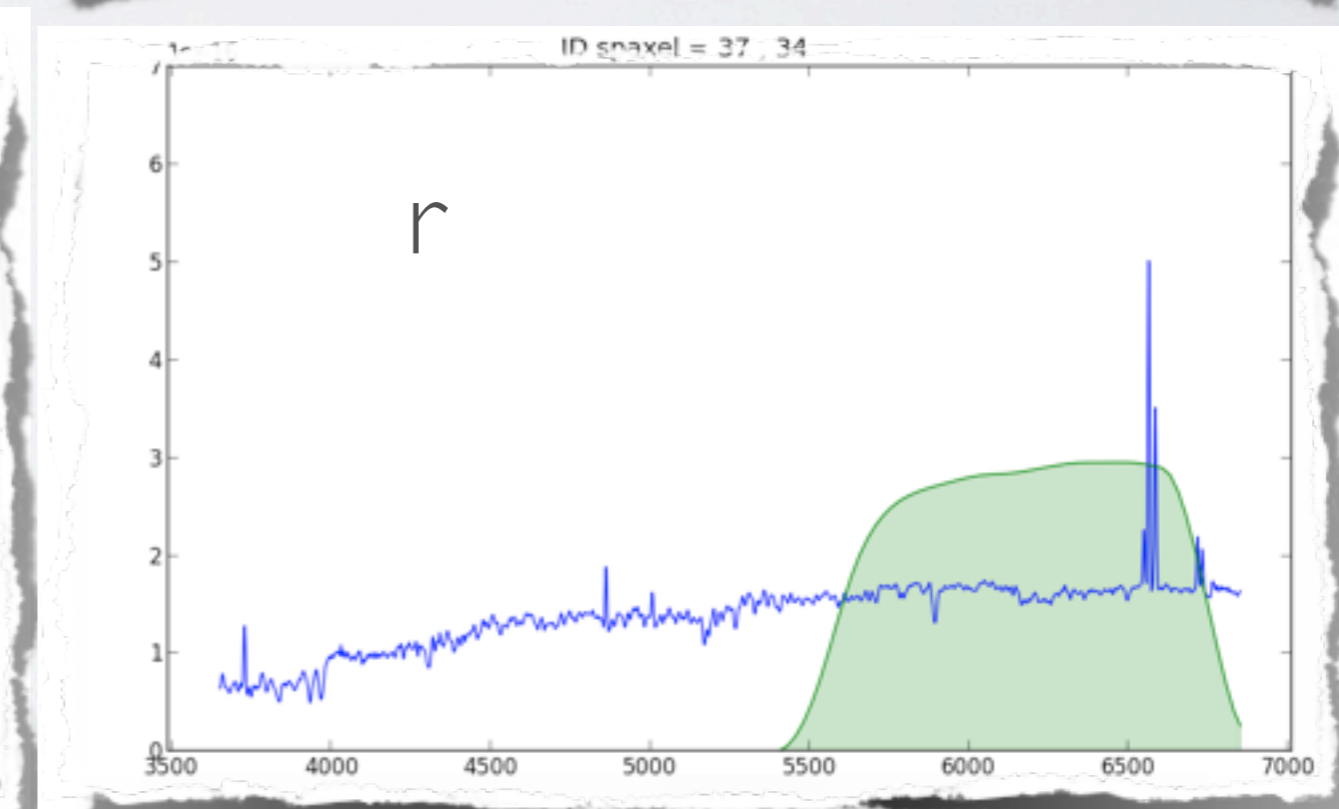
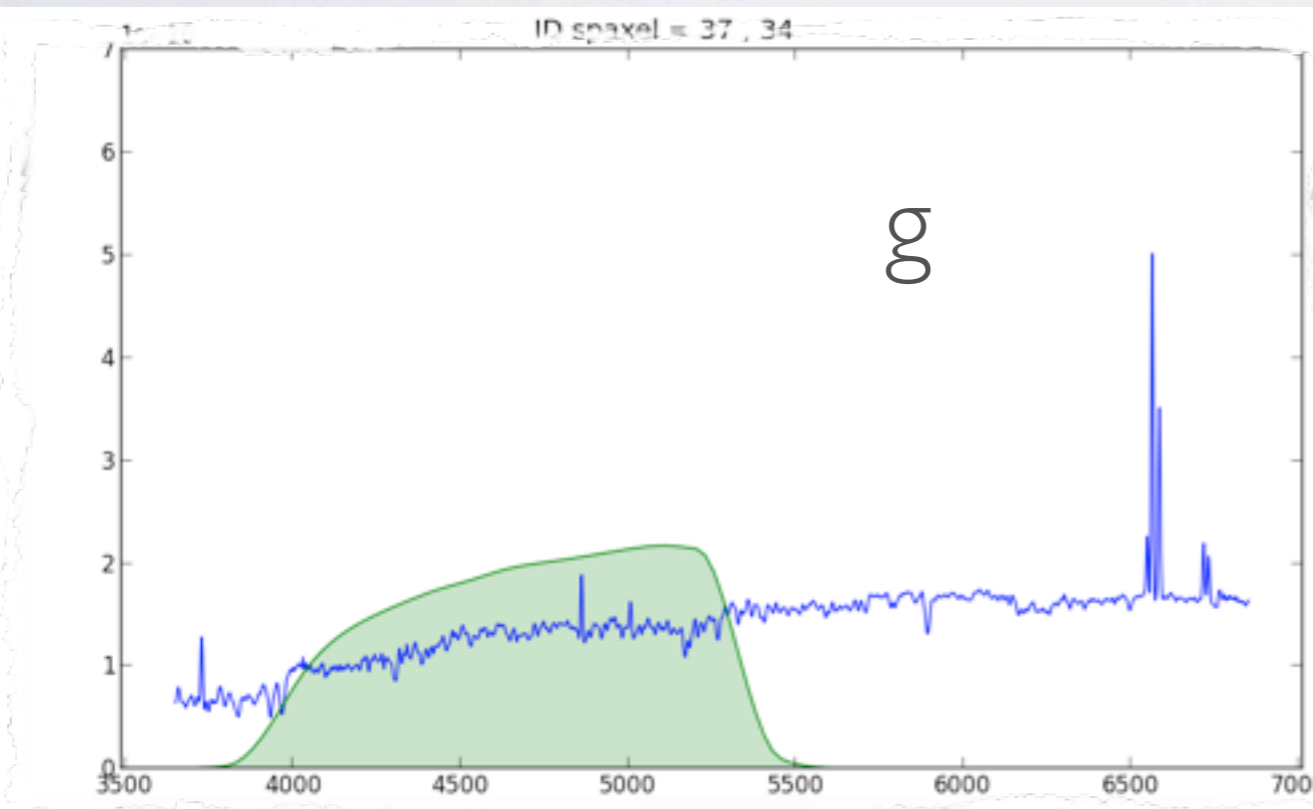
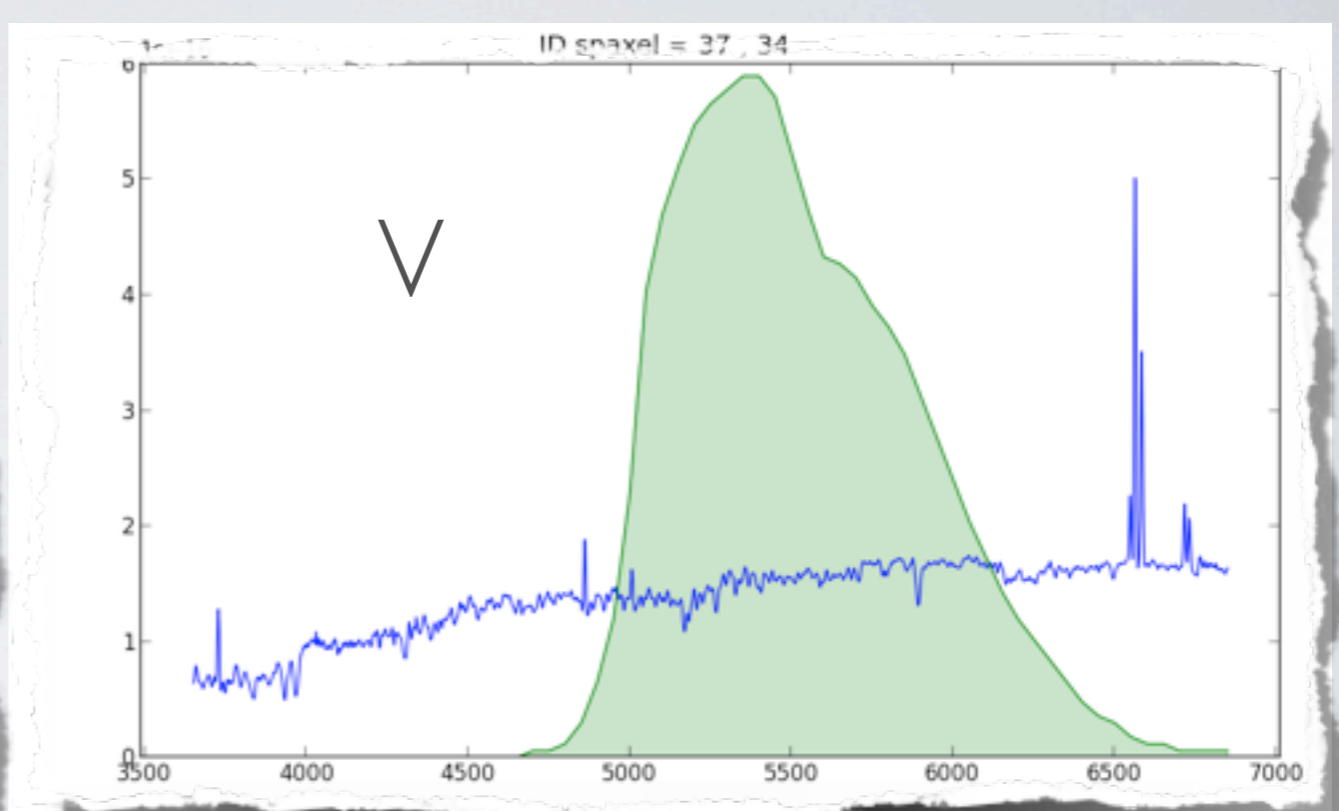
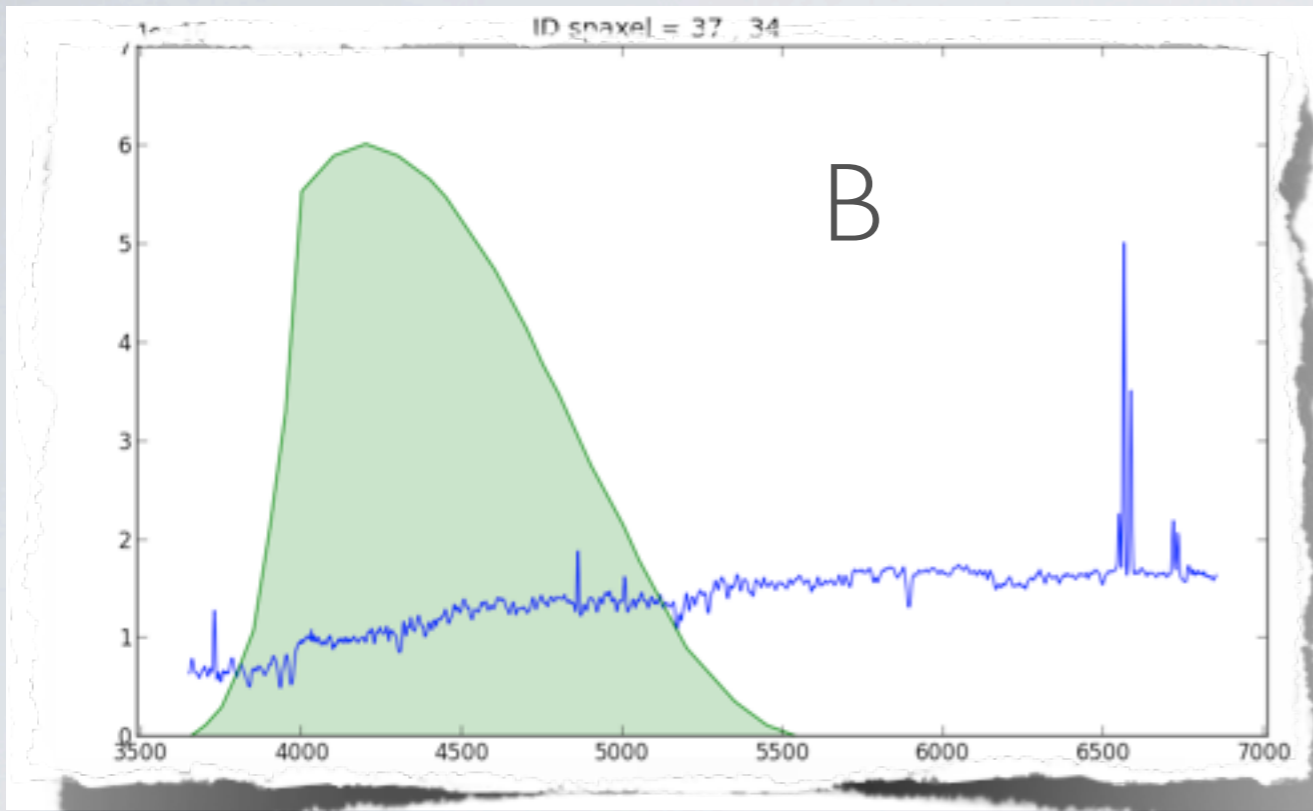
# Why M/L with CALIFA?

Lots (type) of galaxies!

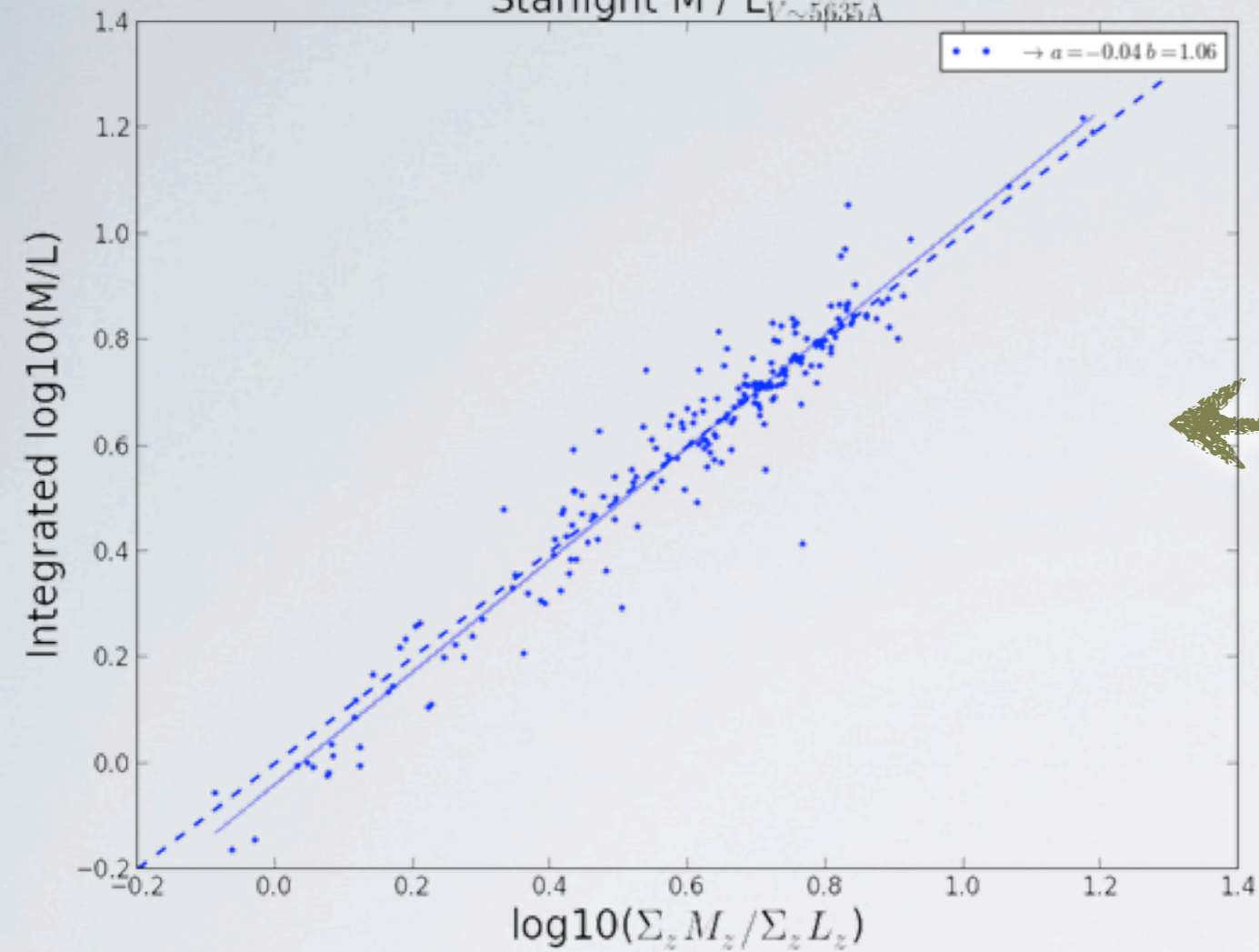
Spatially resolved!



# “Observed” bands



Starlight M / L<sub>V~5635A</sub>

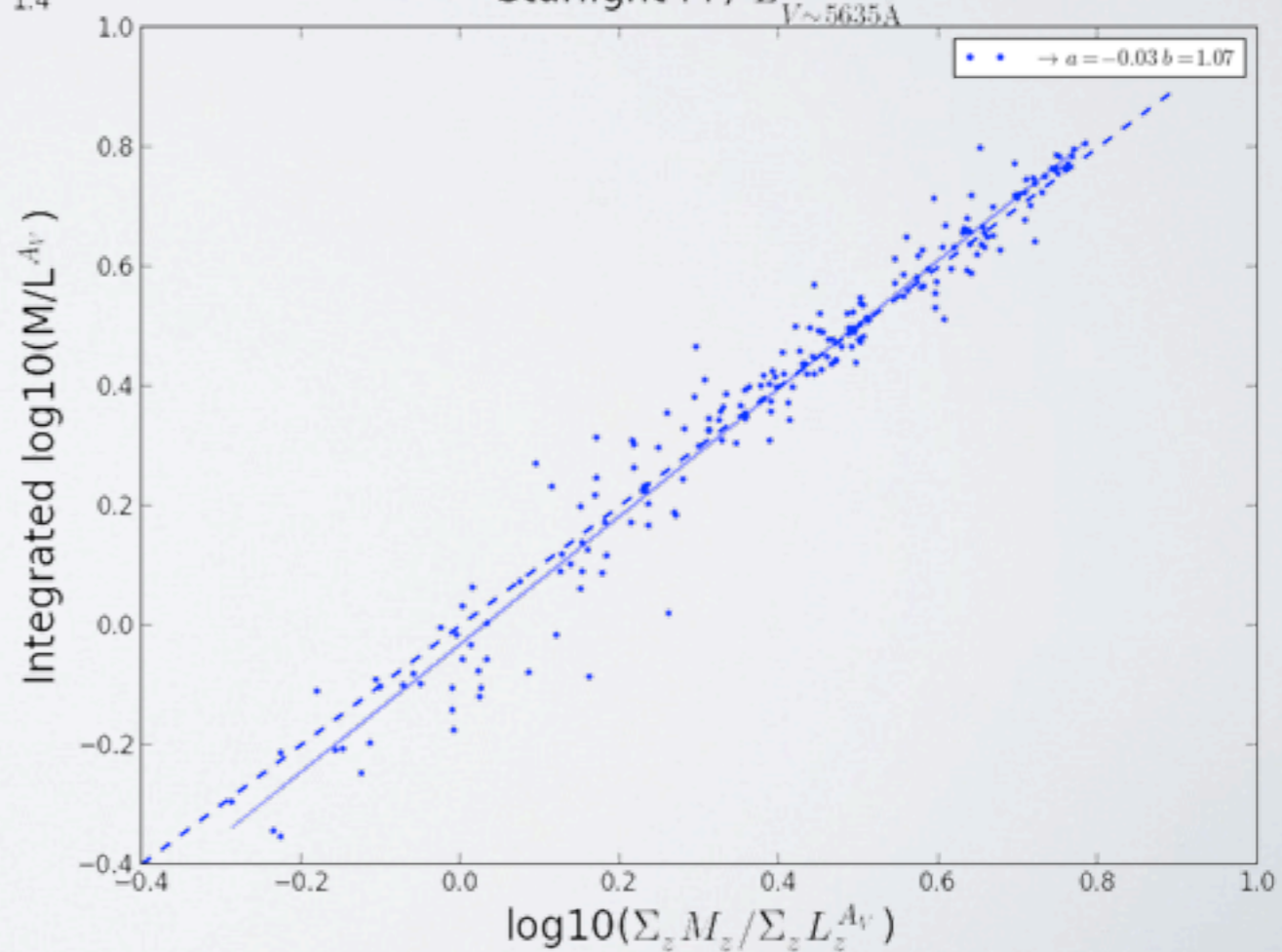


Integrated M/L  
vs  
ΣM/ΣL Zones

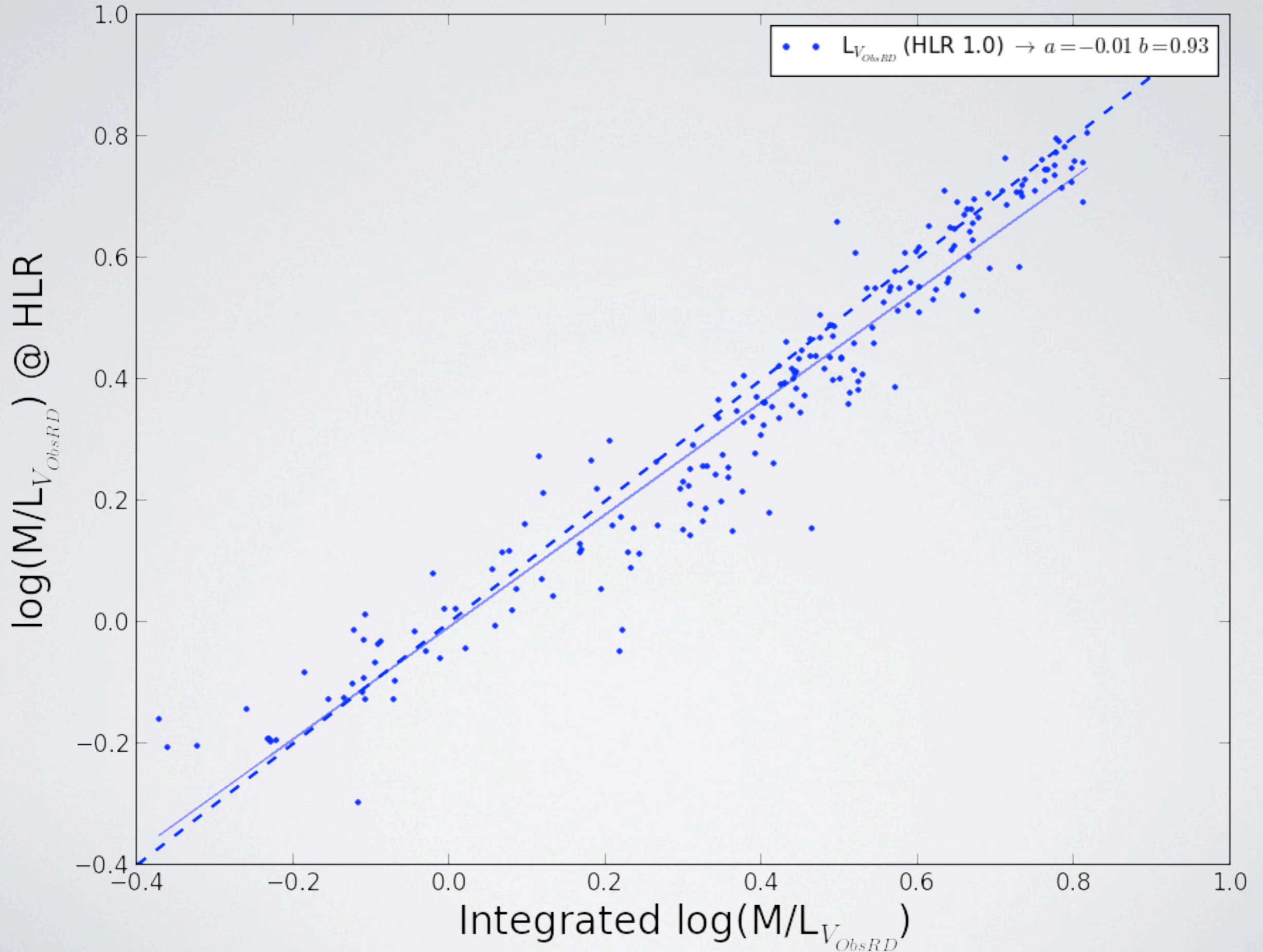
Integrated M/L<sub>AV</sub>  
vs  
ΣM/ΣL<sub>AV</sub> Zones

(Deredden)

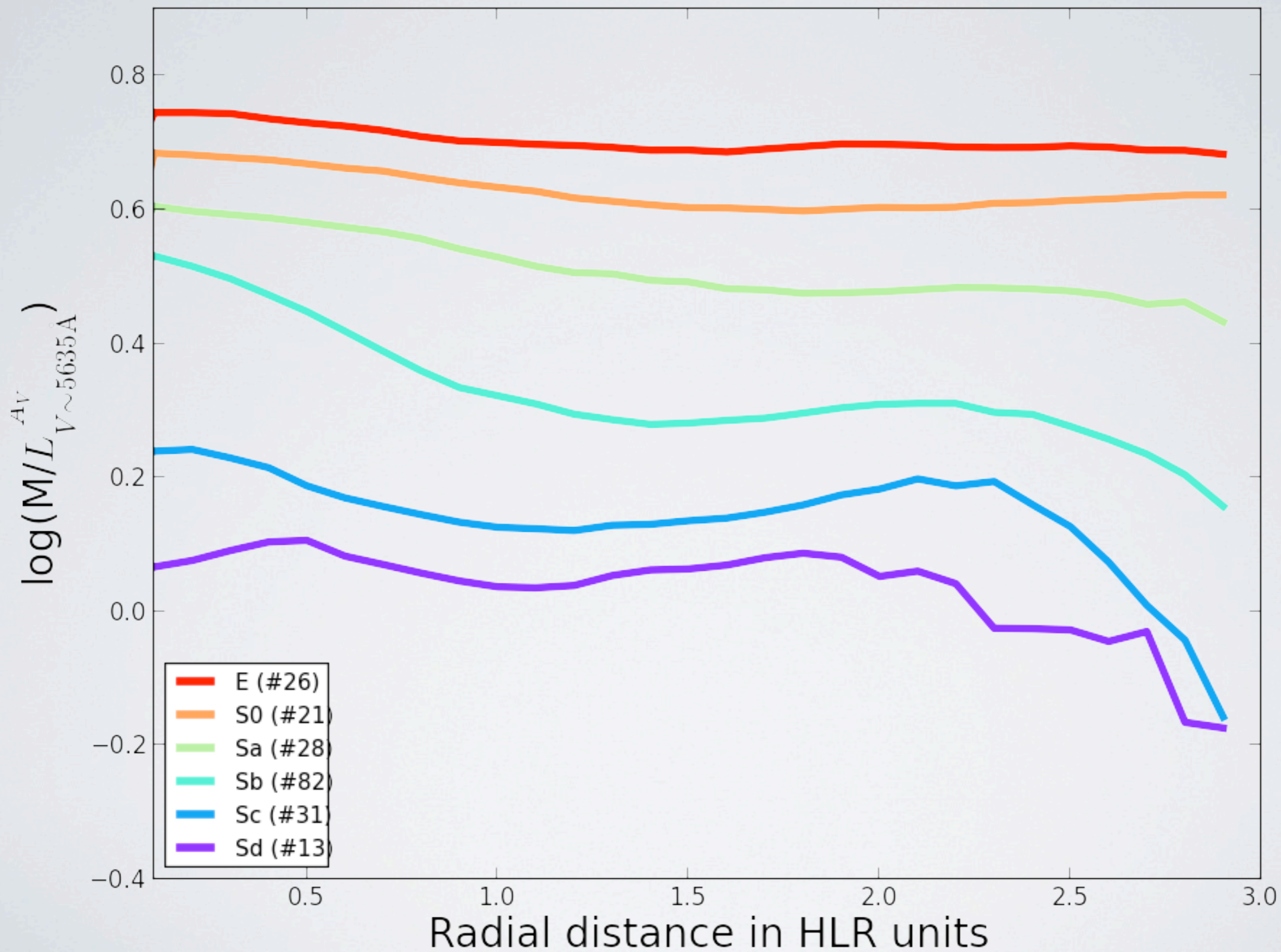
Starlight M / L<sub>V~5635A</sub><sup>AV</sup>



# M/L<sub>V</sub>-Dered @ HLR vs Integrated M/L<sub>V</sub>-Dered

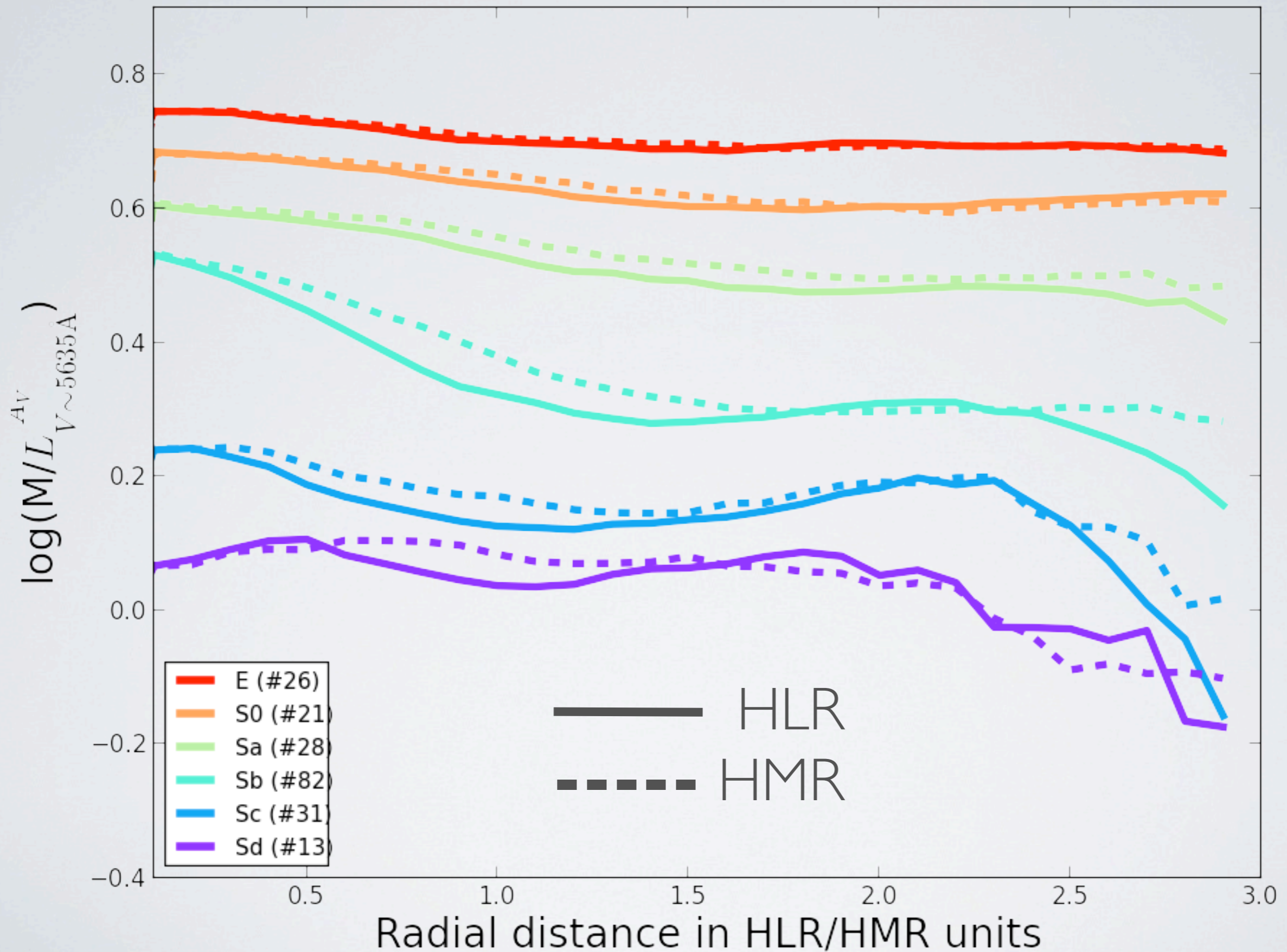


# Radial $M/L_{\text{Dered}}$ - Morphology

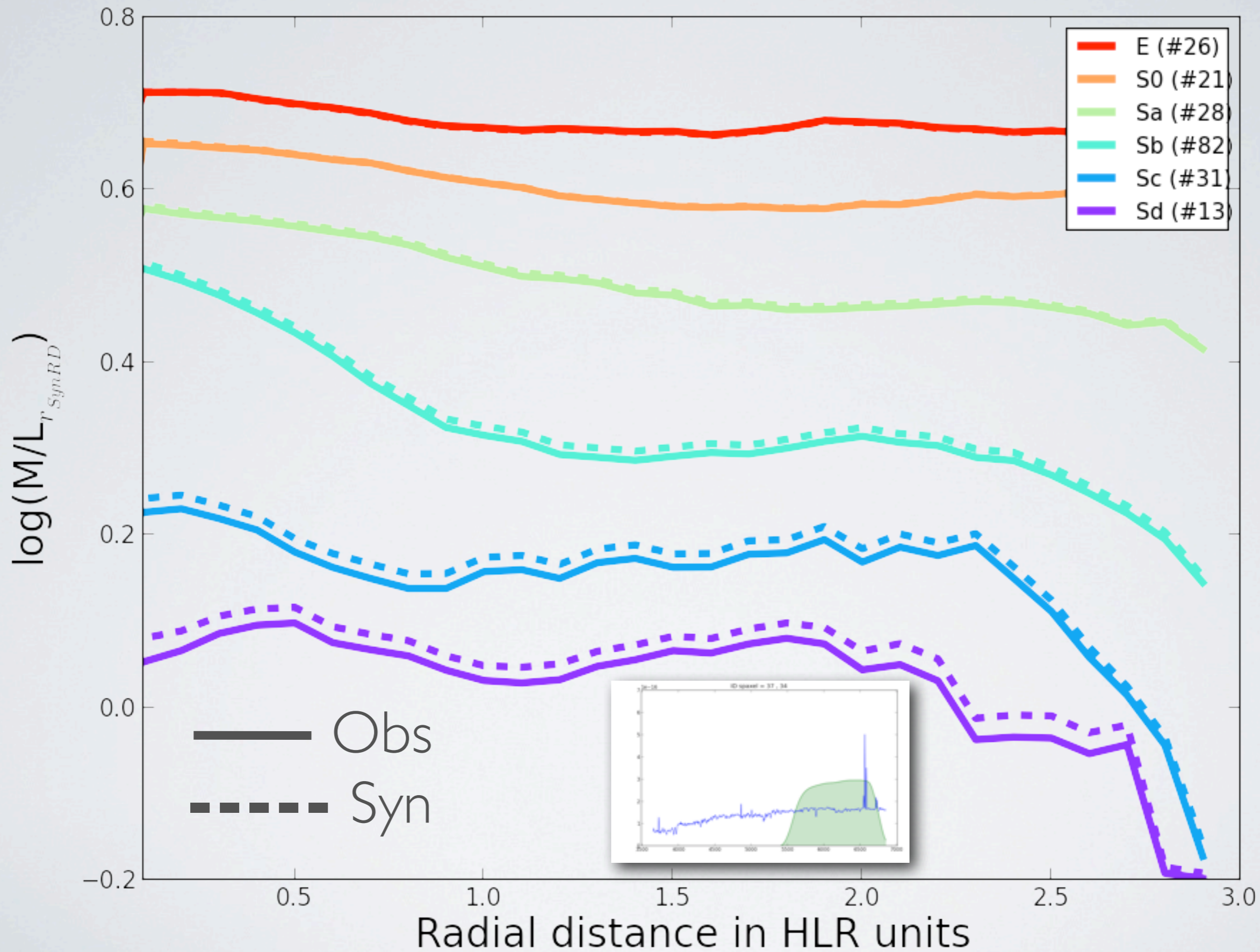




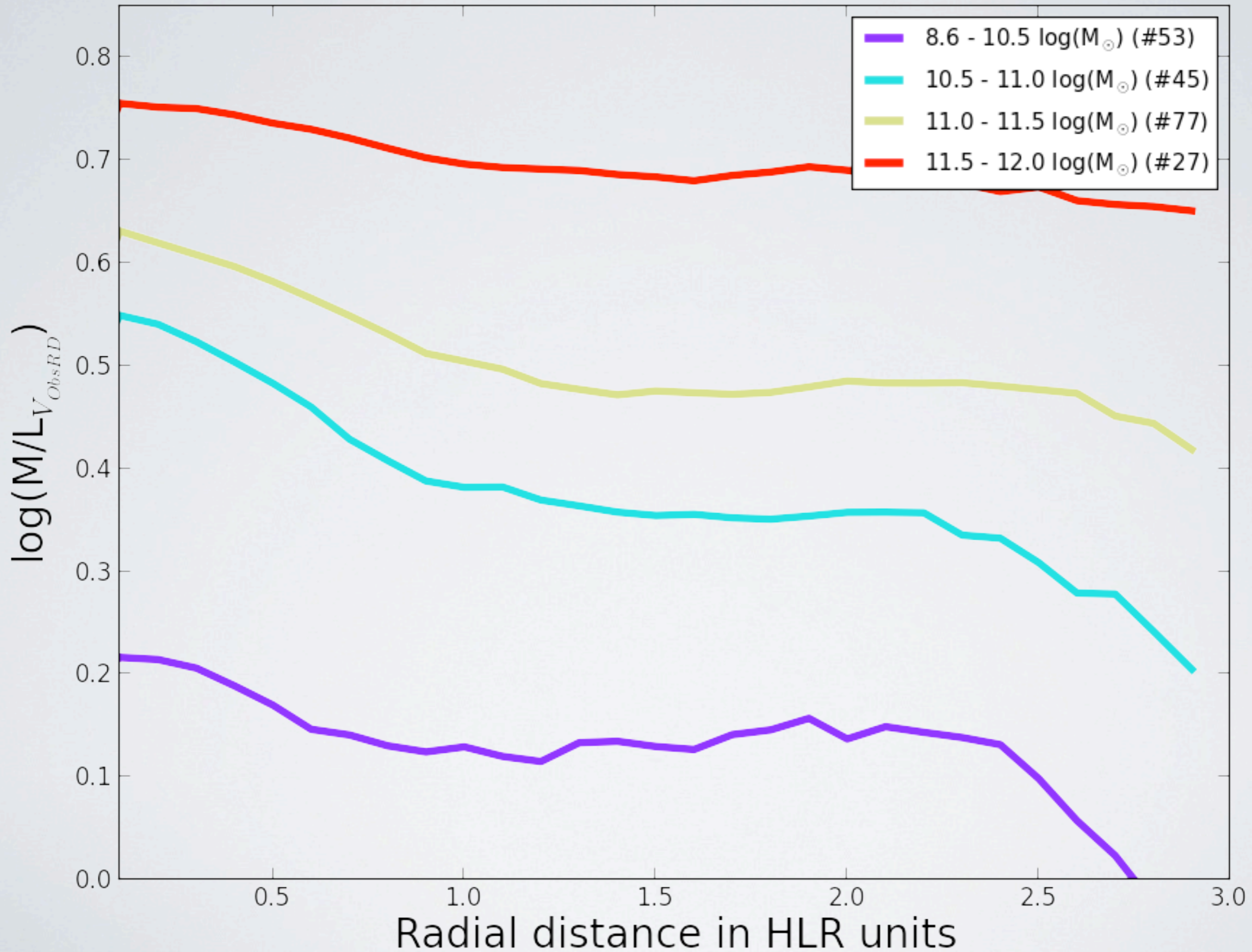
# Radial $M/L_{\text{Dered}}$ - Morphology - HLR vs HMR



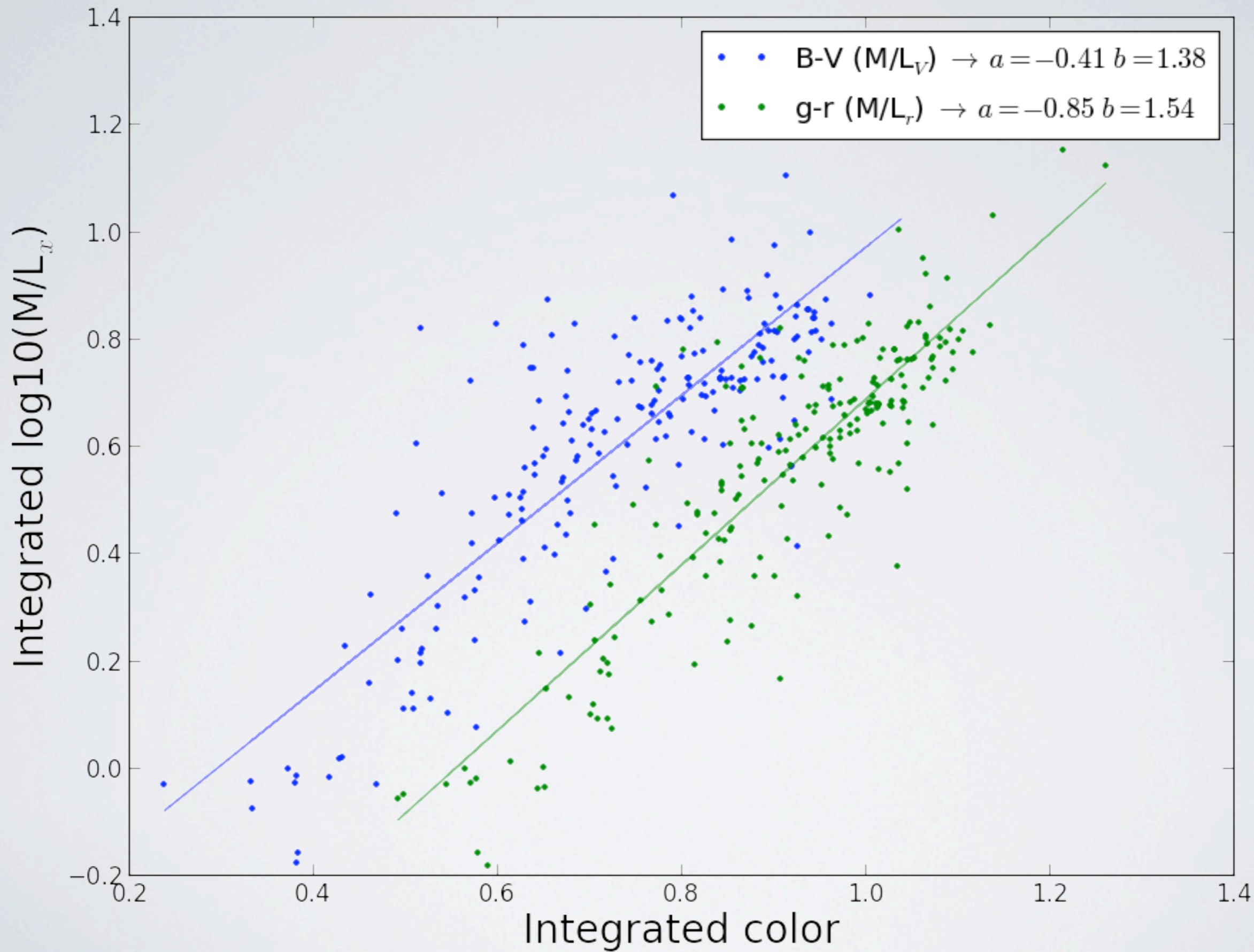
# Radial M/L<sub>Dered</sub> - Morphology - Obs vs Syn

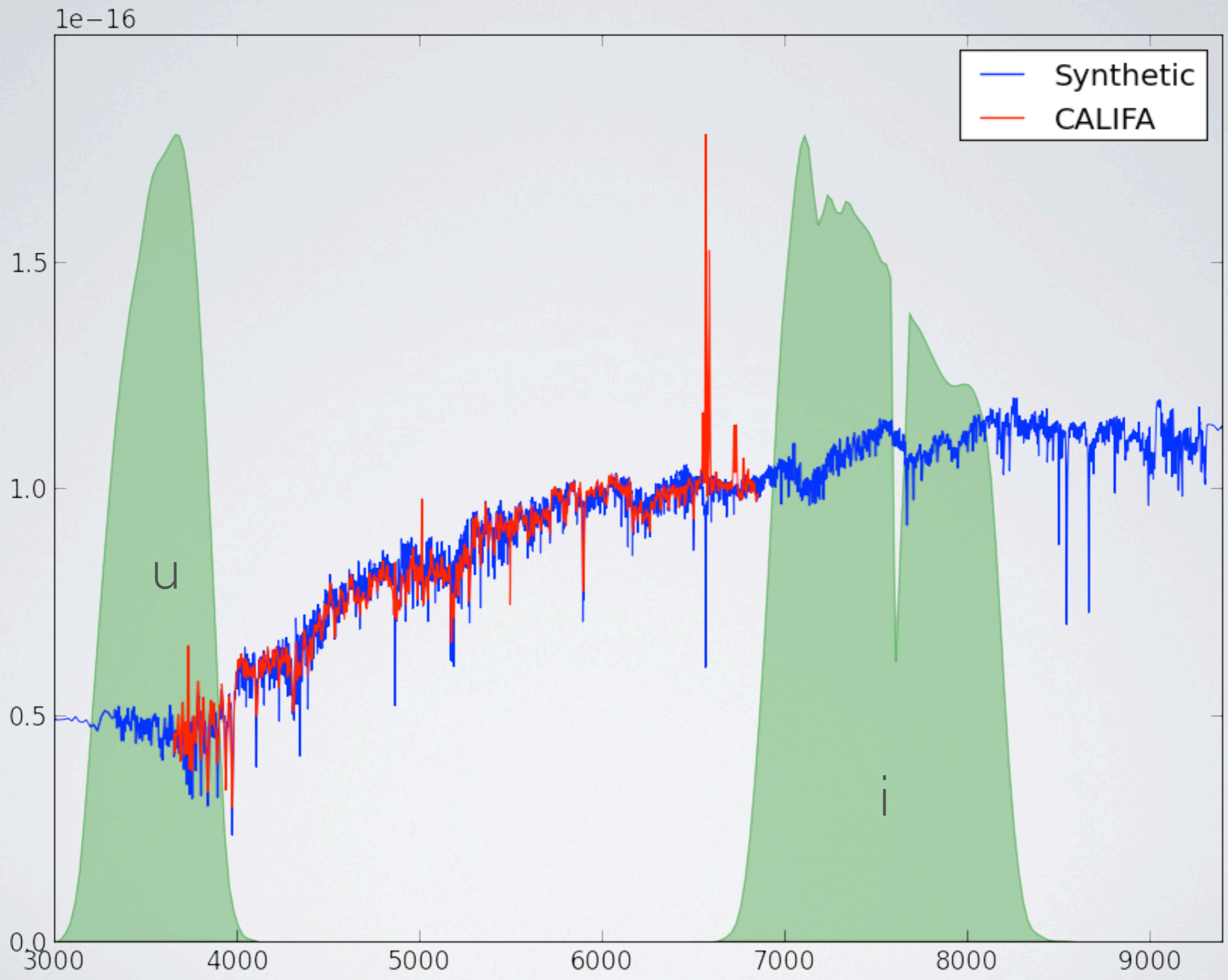


# Radial $M/L_{\text{Dered}}$ - Mass



# M/L - Color





# Summary & Conclusions

- \* We have analyzed  $\sim 200$  CALIFA galaxies, which is so far the largest integral field data set of complete galaxies that are well distributed in the color magnitude diagram, from the blue (disk) to the red (bulge) sequence
- \* Radial profiles of ages, metallicities, and mass assembled growth curves suggest that galaxies with  $\text{Mass} > 10^{10} (M_{\odot})$  grow inside-out
  - \* There is a critical mass at which the conversion of the mass halo into star is maximum, it occurs when the feedback effects by AGN and star formation are less efficient
- \* The local stellar mass surface density drives the SFH of galaxies disks, but in bulge dominated galaxies total stellar mass is a more fundamental property.
- \* Averaged and integrated galaxies properties are well correlated and are well represented by the galaxy properties at 1 HLR

THE EVOLUTION OF GALAXIES  
RESOLVED IN SPACE & TIME  
+  
THE RADIAL STRUCTURE OF M/L  
CALIFA RESULTS

THANKS!

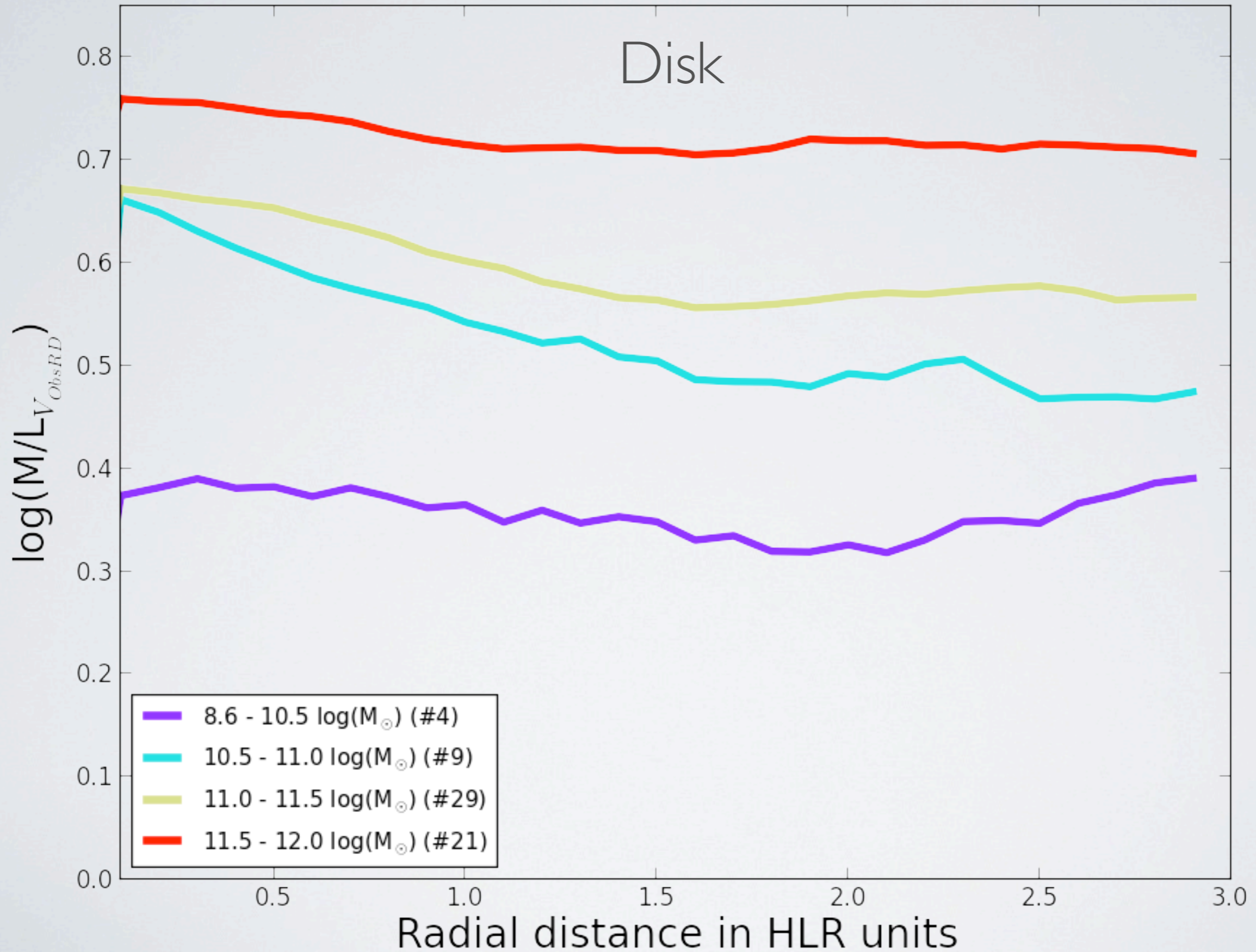
Rubén García-Benito

“Galaxies meet GRBs at Cabo de Gata” ◦ September 24, 2013

# Radial $M/L_{\text{Dered}}$ - Mass & C

$$C = r_{90}^P / r_{50}^P$$

$C \geq 2.8$

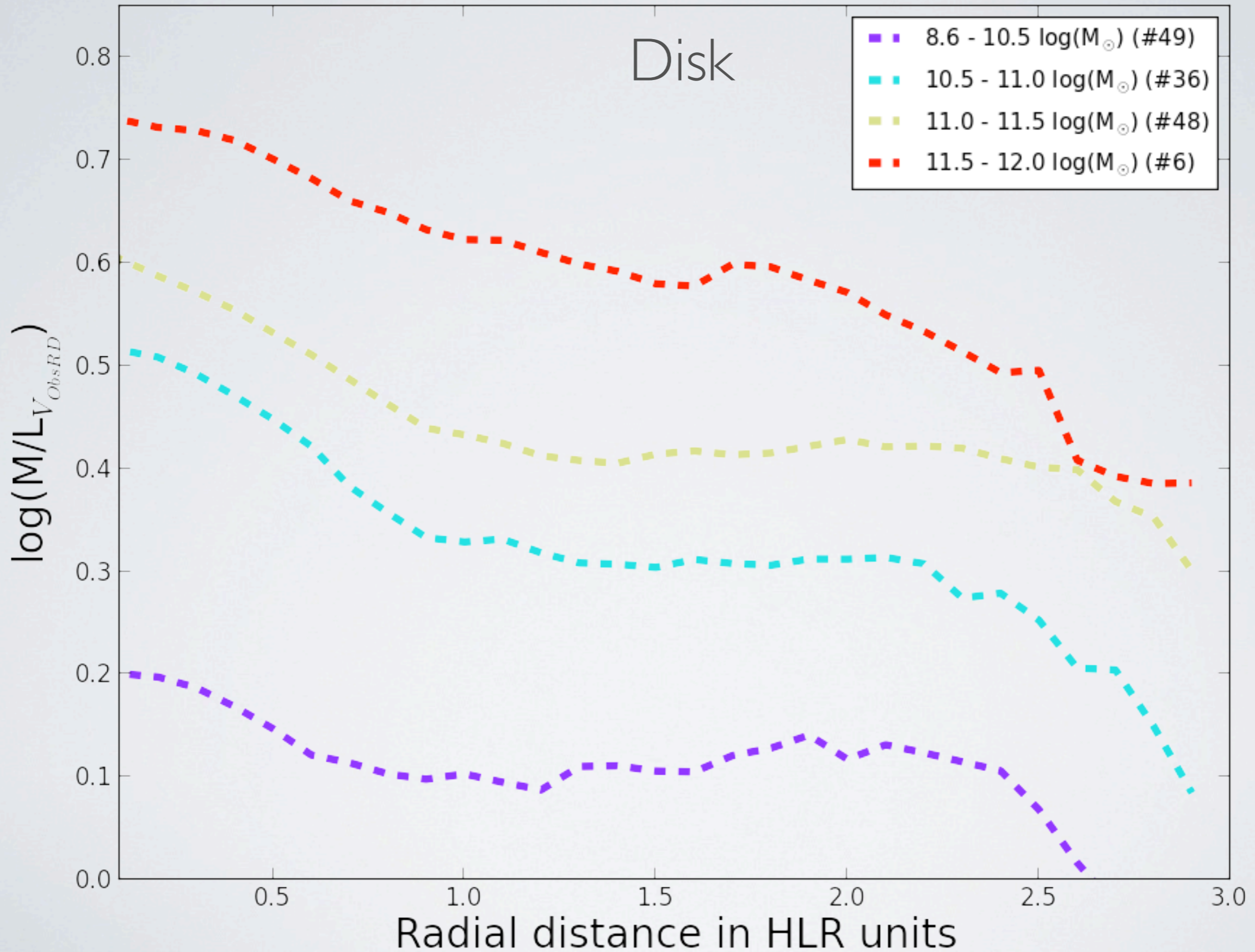




# Radial $M/L_{\text{Dered}}$ - Mass & C

$$C = r_{90}^P / r_{50}^P$$

$C < 2.8$



# Radial $M/L_{\text{Dered}}$ - Mass & C

$$C = r_{90}^P / r_{50}^P$$

