



L-Galaxies:

A self-consistent model for the formation  
and evolution of galaxies



Millennium

Volume =  $500 h^{-1}\text{Mpc}^3$

MillenniumII

Volume =  $100 h^{-1}\text{Mpc}^3$

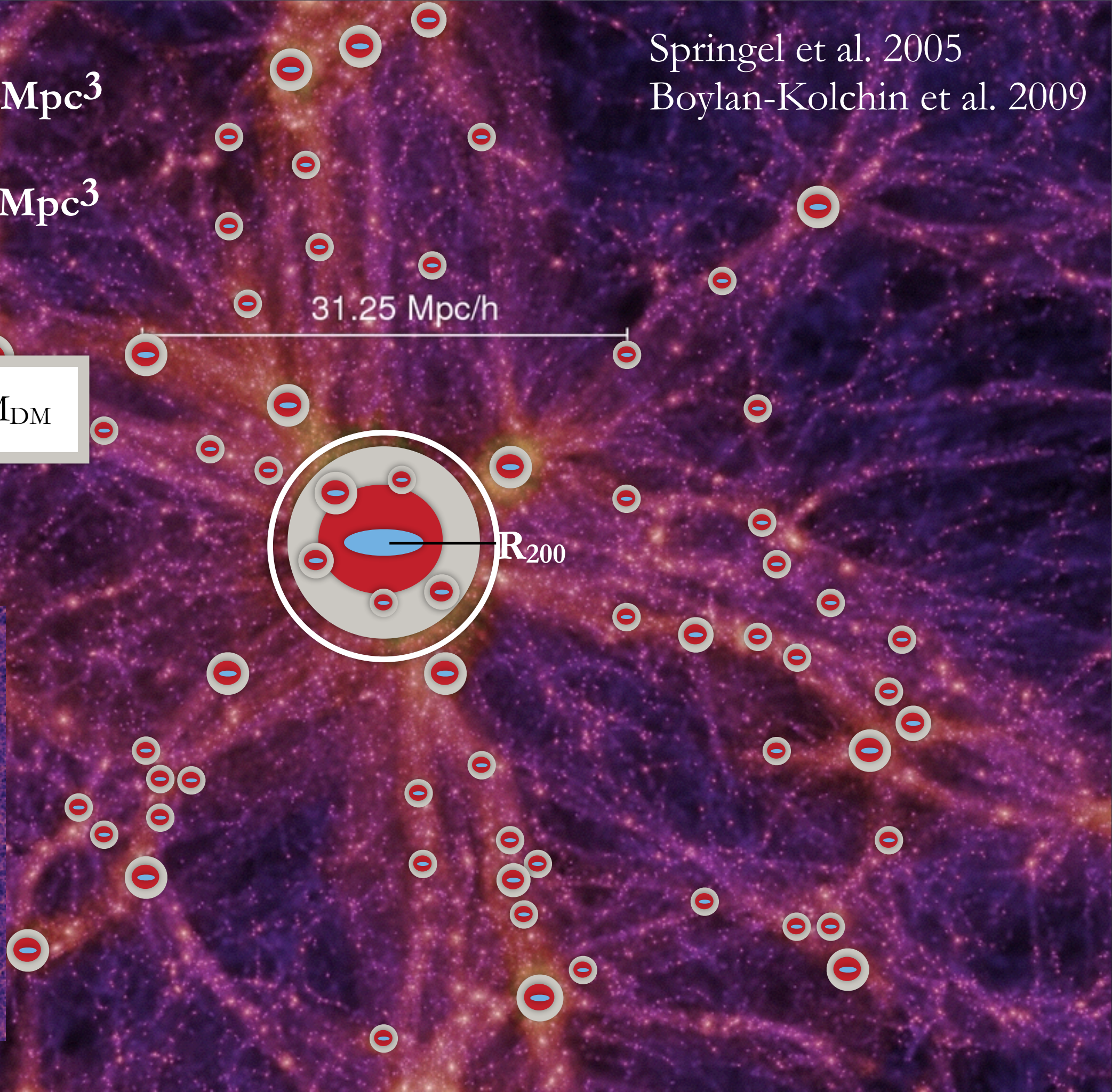
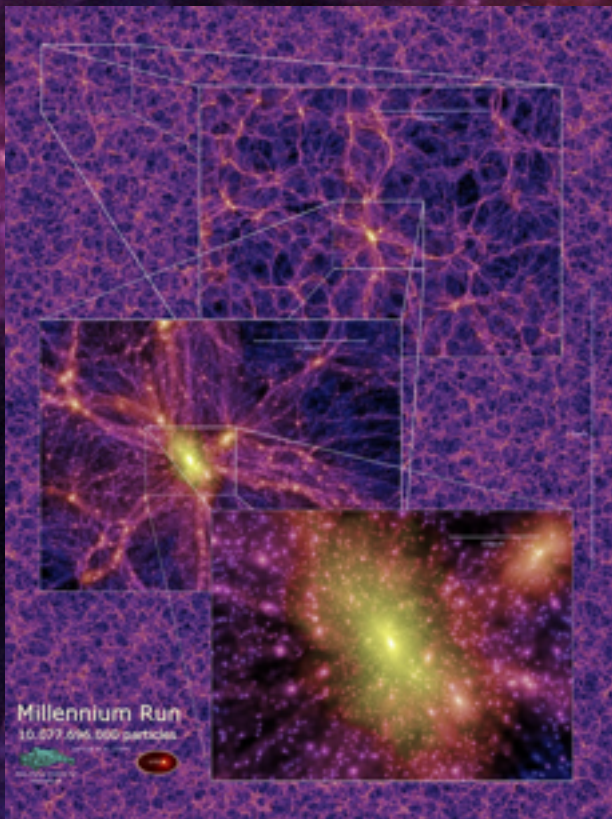
Springel et al. 2005

Boylan-Kolchin et al. 2009

$$M_b = f_b \times M_{\text{DM}}$$

31.25 Mpc/h

$R_{200}$





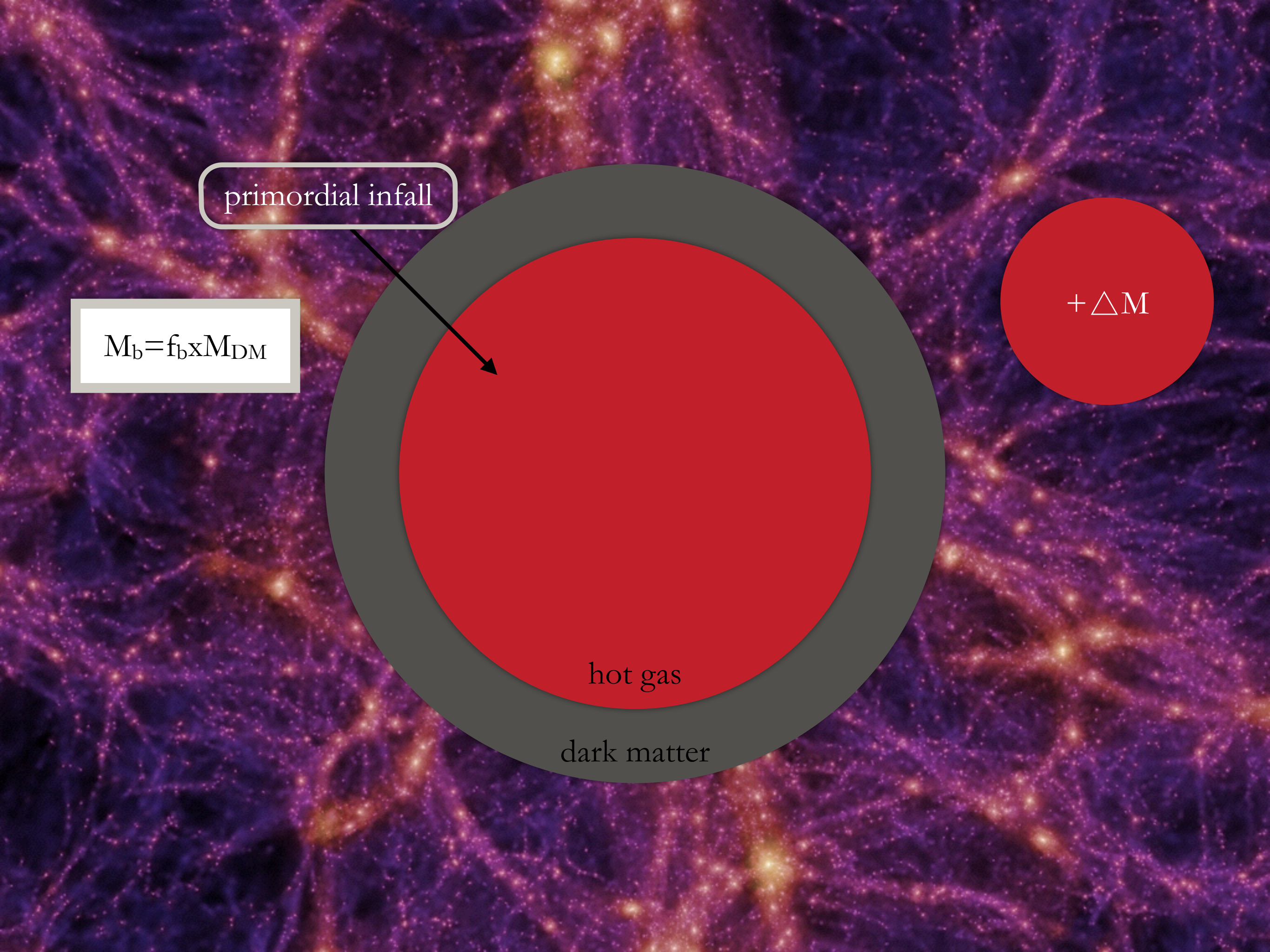
primordial infall

$$M_b = f_b \times M_{DM}$$

$+\Delta M$

hot gas

dark matter





primordial infall

cold flow -  $r_{\text{cool}} < R_{200c}$

hot mode -  $r_{\text{cool}} > R_{200c}$

cooling

cold gas

hot gas

dark matter

$-\Delta M$

$+\Delta M$

$$\Delta \vec{J}_{\text{gas}} = \frac{\vec{J}_{\text{DM}}}{M_{\text{DM}}} \dot{M}_{\text{cool}} \delta t - \frac{\vec{J}_{\text{gas}}}{M_{\text{gas}}} ((1 - R_{\text{ret}}) \dot{M}_{\star} \delta t + \Delta M_{\text{reheat}}) + \frac{\vec{J}_{\text{DM}}}{M_{\text{DM}}} M_{\text{sat,gas}}, \quad (\text{S9})$$



primordial infall

cooling

stars

cold gas

hot gas

dark matter

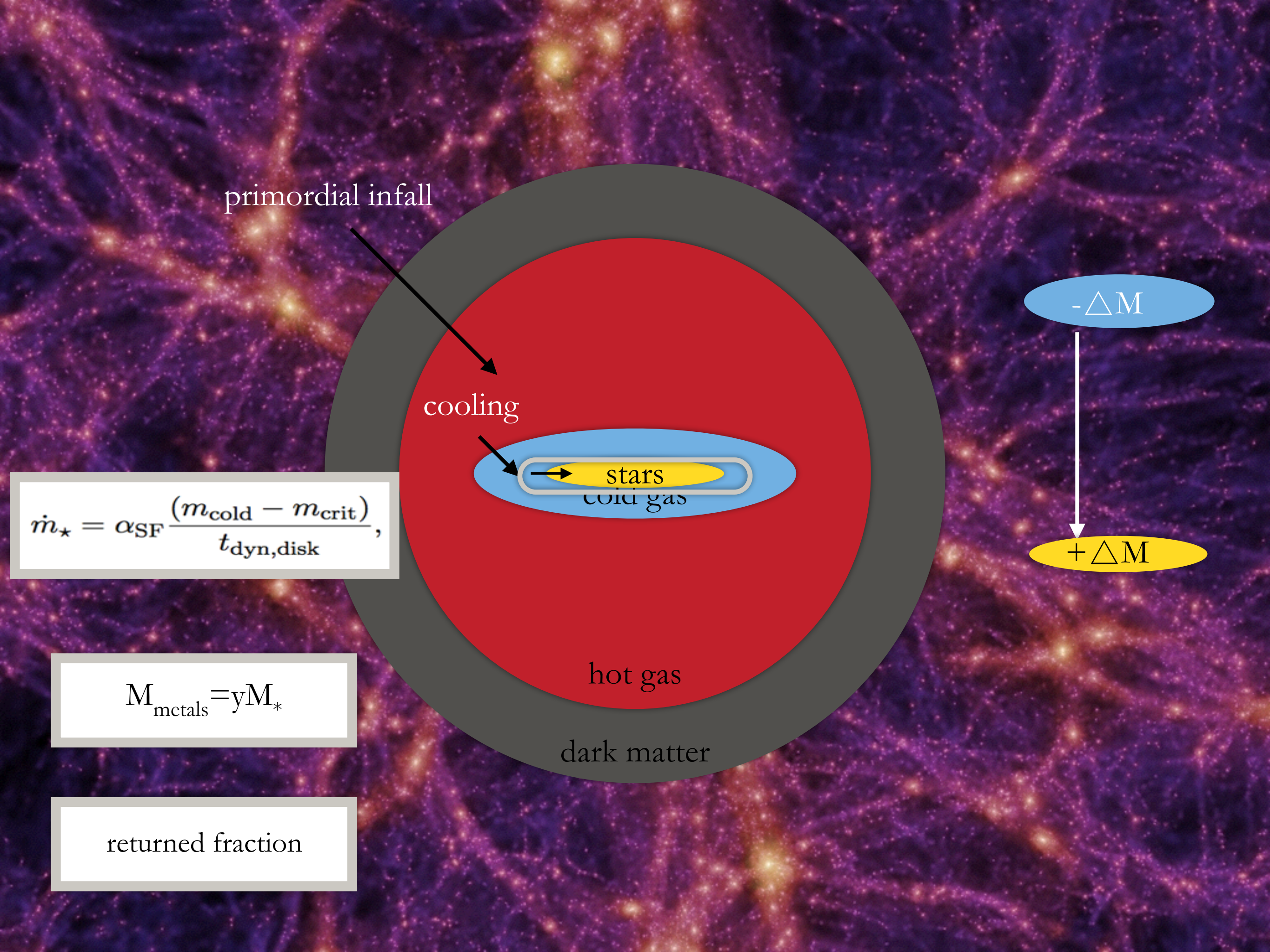
$-\Delta M$

$+\Delta M$

$$\dot{m}_* = \alpha_{\text{SF}} \frac{(m_{\text{cold}} - m_{\text{crit}})}{t_{\text{dyn,disk}}},$$

$$M_{\text{metals}} = y M_*$$

returned fraction

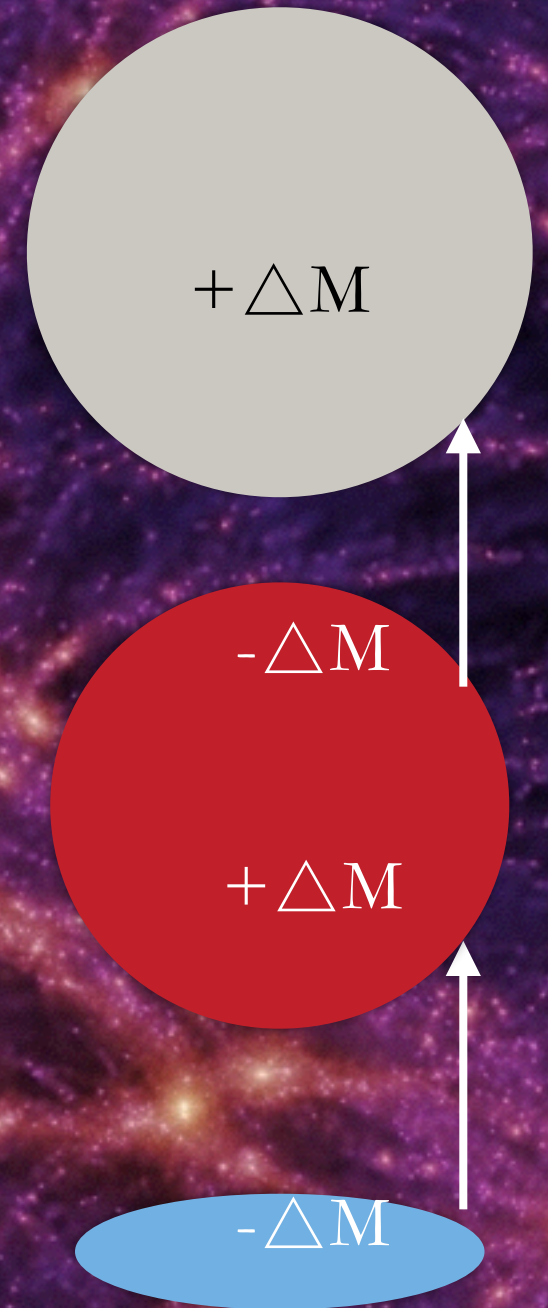
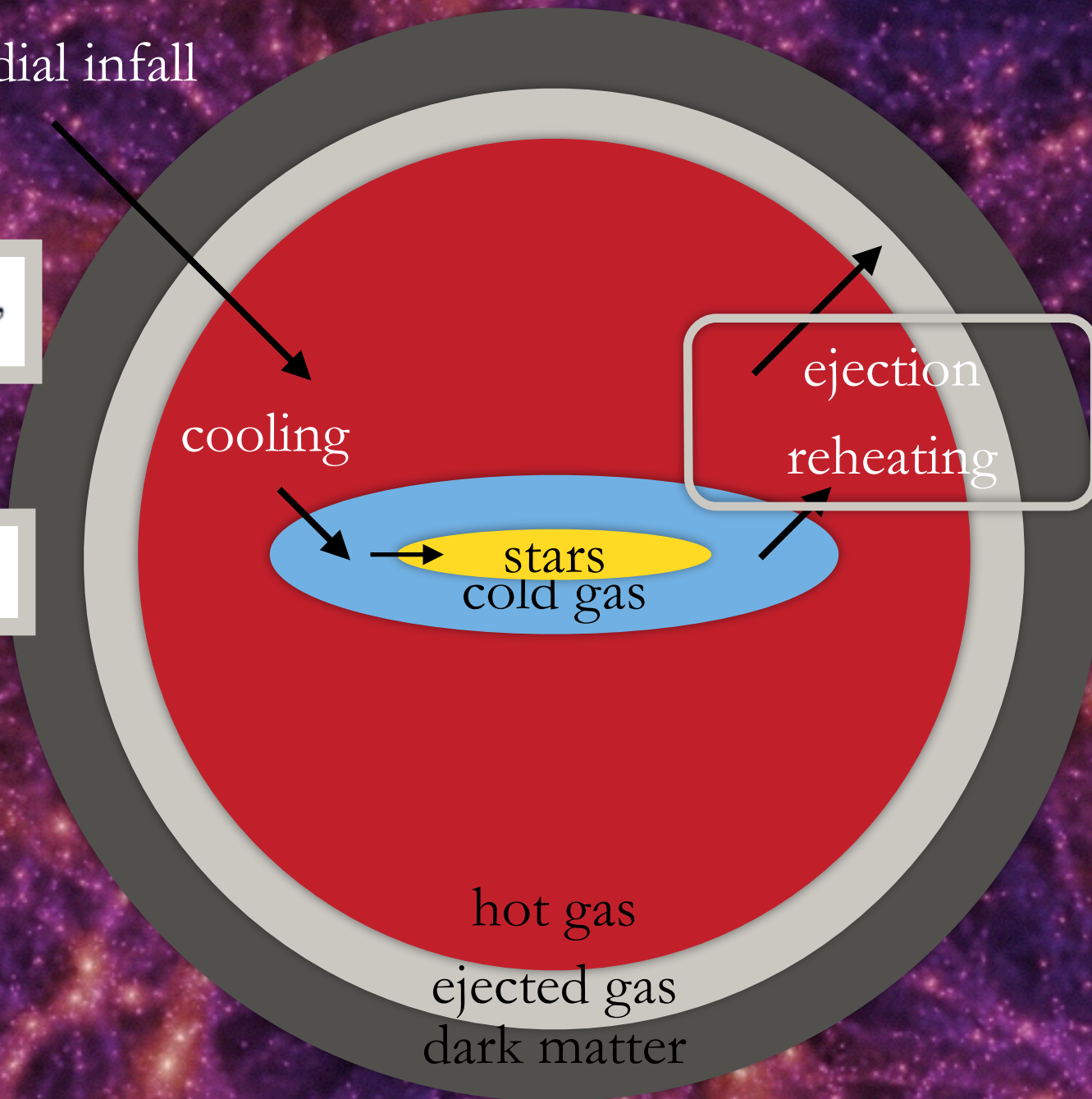




primordial infall

$$\Delta E_{\text{SN}} = \epsilon_{\text{halo}} \times \frac{1}{2} \Delta m_{\star} V_{\text{SN}}^2,$$

$$\Delta m_{\text{reheated}} = \epsilon_{\text{disk}} \Delta m_{\star},$$



How much energy/velocity in each particle?  
A lot in a few particles, a little in a lot of particles?

$$\epsilon_{\text{disk}} = \epsilon \times \left[ 0.5 + \left( \frac{V_{\text{max}}}{V_{\text{reheat}}} \right)^{-\beta_1} \right]$$



primordial infall

reincorporation

ejection

cooling

reheating

stars

cold gas

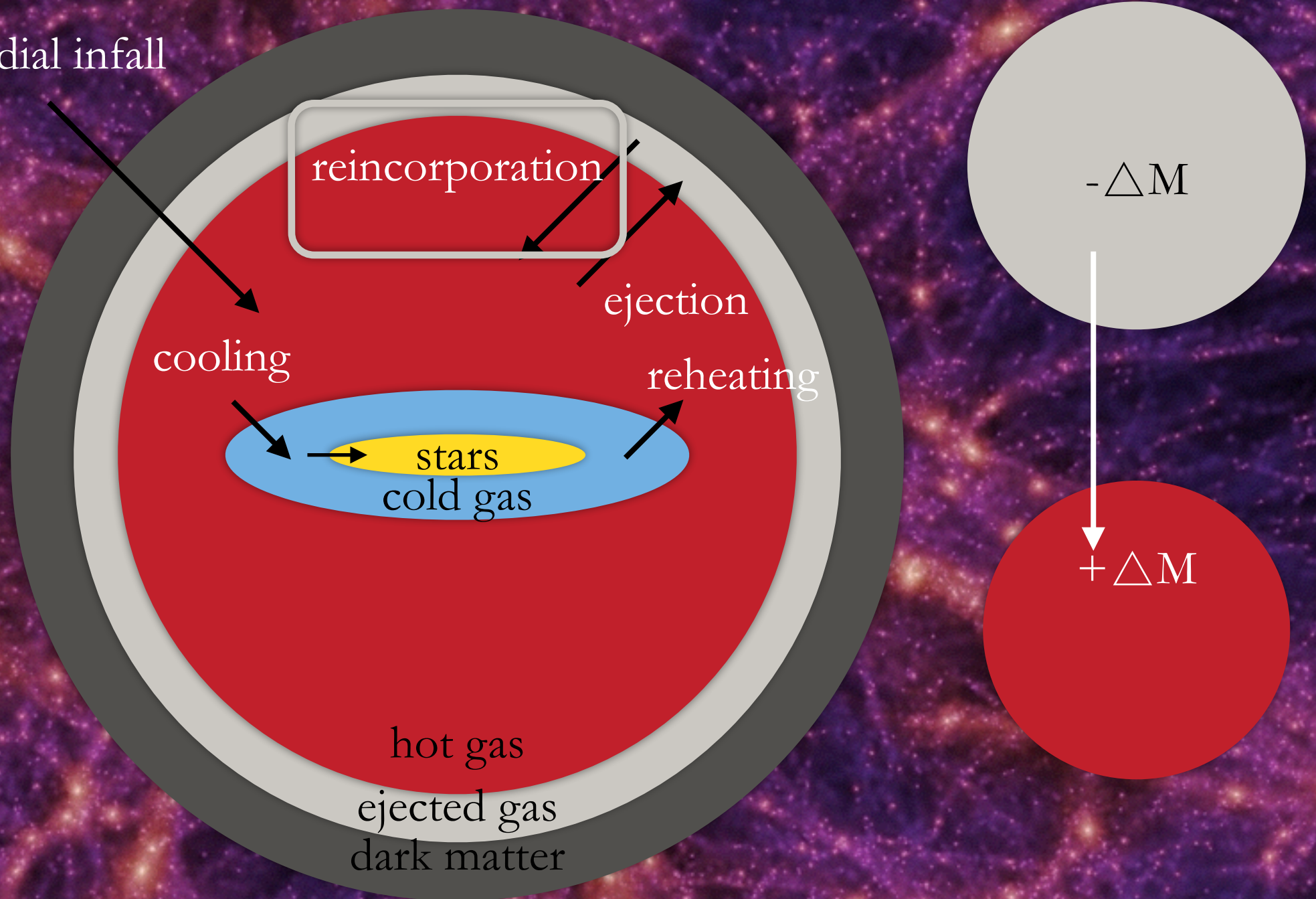
hot gas

ejected gas  
dark matter

$-\Delta M$

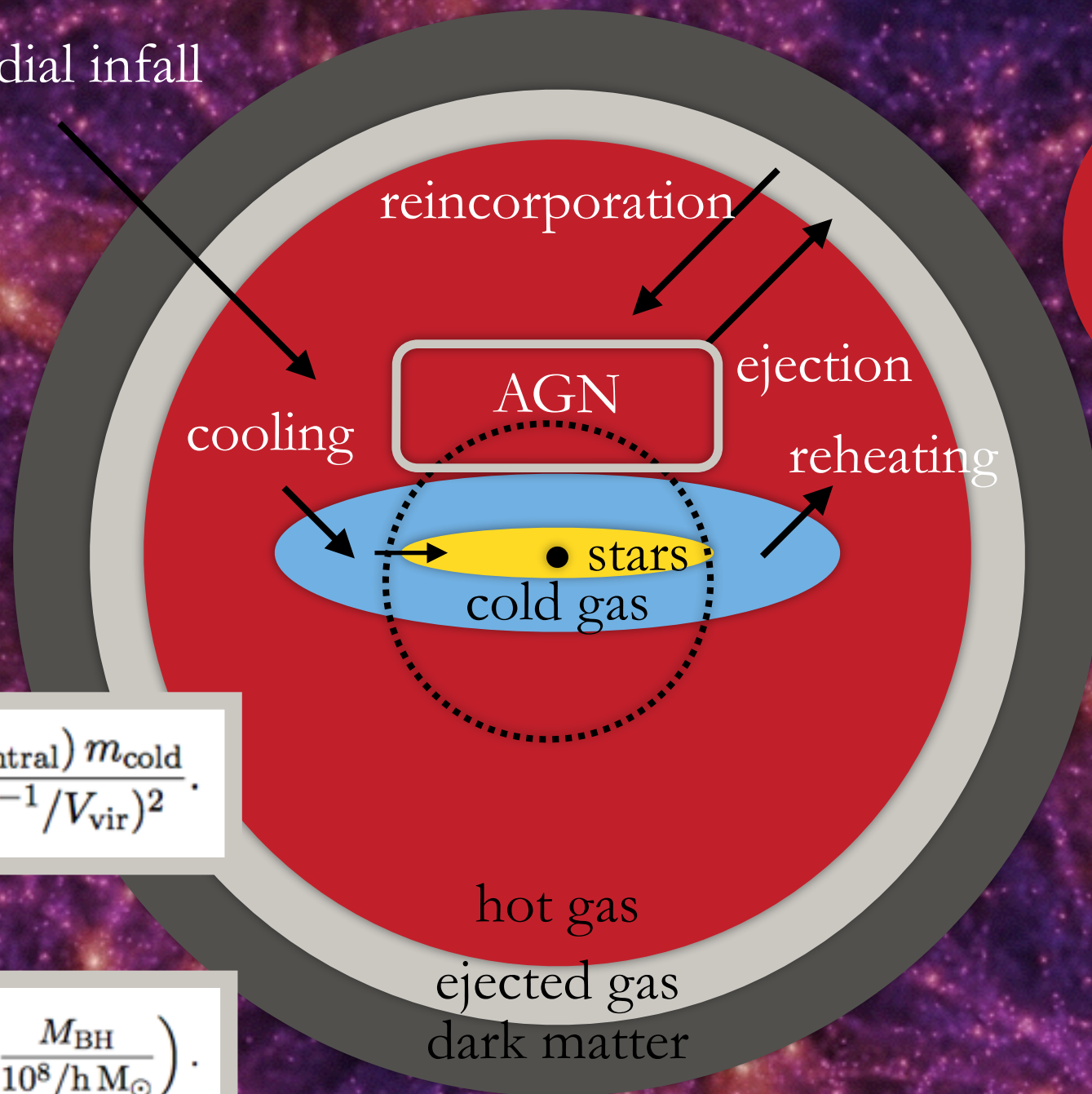
$+\Delta M$

$$t_{\text{reinc}} = -\gamma' \frac{10^{10} M_{\odot}}{M_{\text{vir}}},$$





primordial infall



$-\Delta M$

$-\Delta M$

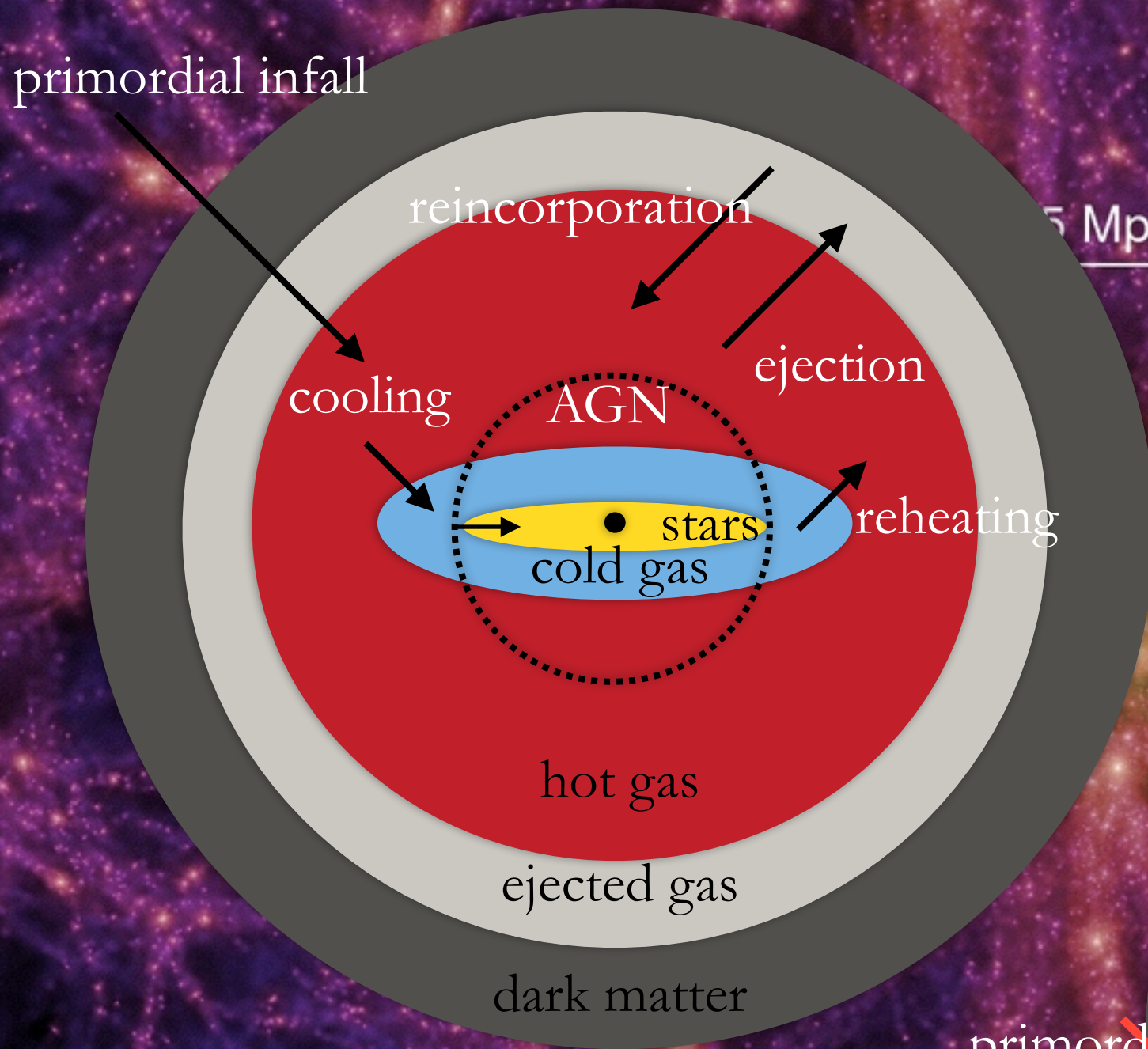
$+\Delta M$

$$\Delta m_{\text{BH,Q}} = \frac{f_{\text{BH}}(m_{\text{sat}}/m_{\text{central}}) m_{\text{cold}}}{1 + (V_{\text{BH}} \text{ km s}^{-1} / V_{\text{vir}})^2}$$

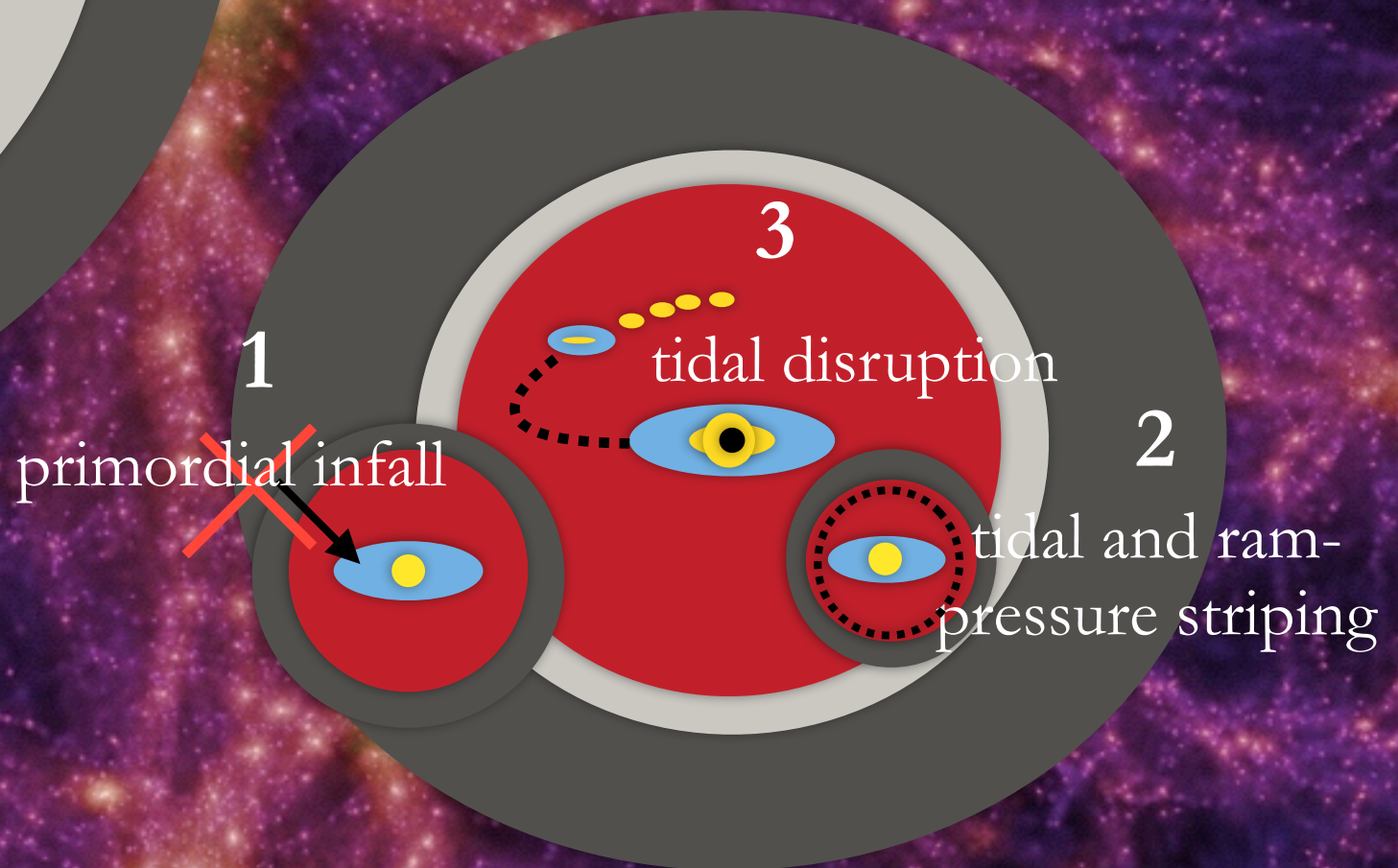
$$\dot{M}_{\text{BH}} = k_{\text{AGN}} \left( \frac{M_{\text{hot}}}{10^{11} / h M_{\odot}} \right) \left( \frac{M_{\text{BH}}}{10^8 / h M_{\odot}} \right)$$



# Model of Galaxy Formation



Environmental effects on satellite galaxies





White & Rees 1978

White & Frenk 1991

Kauffmann et al 1999

Croton et al 2006

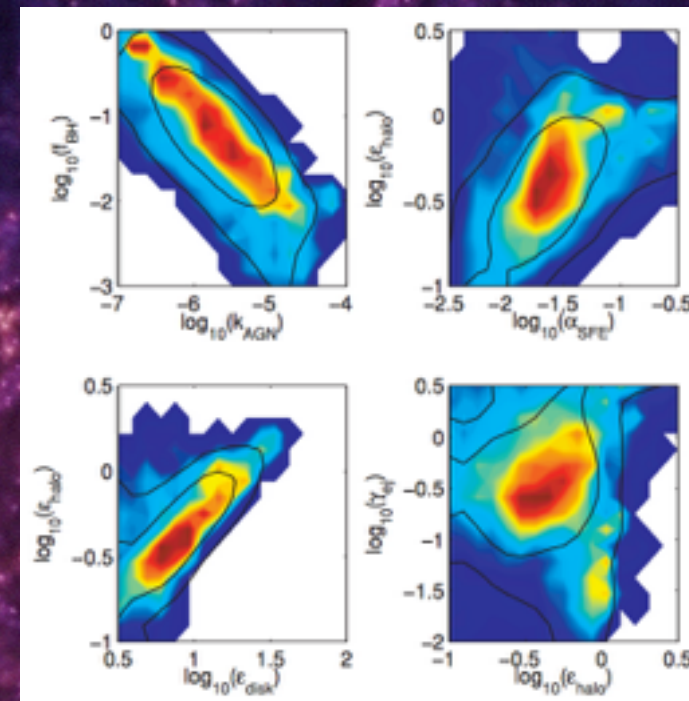
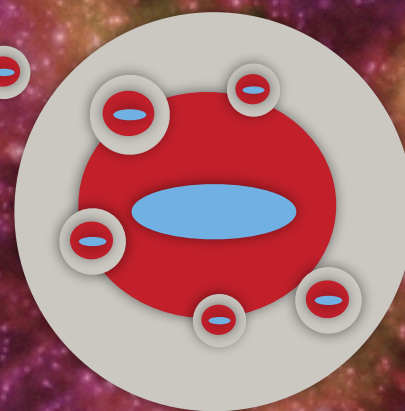
DeLucia & Blaizot 2007

Guo et al 2011

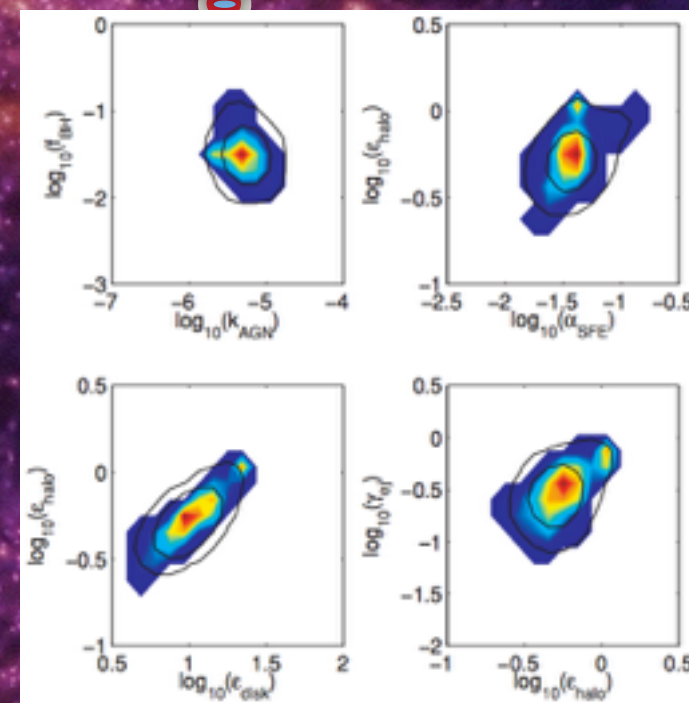
Henriques et al. 2015

- large degeneracies between parameters?
- models fail because of wrong assumptions or wrong parameter values?

31.25 Mpc/h



MCMC



Henriques, Thomas et al. (2009), Henriques & Thomas (2010),  
Henriques et al. (2013), Henriques et al. (2015)



