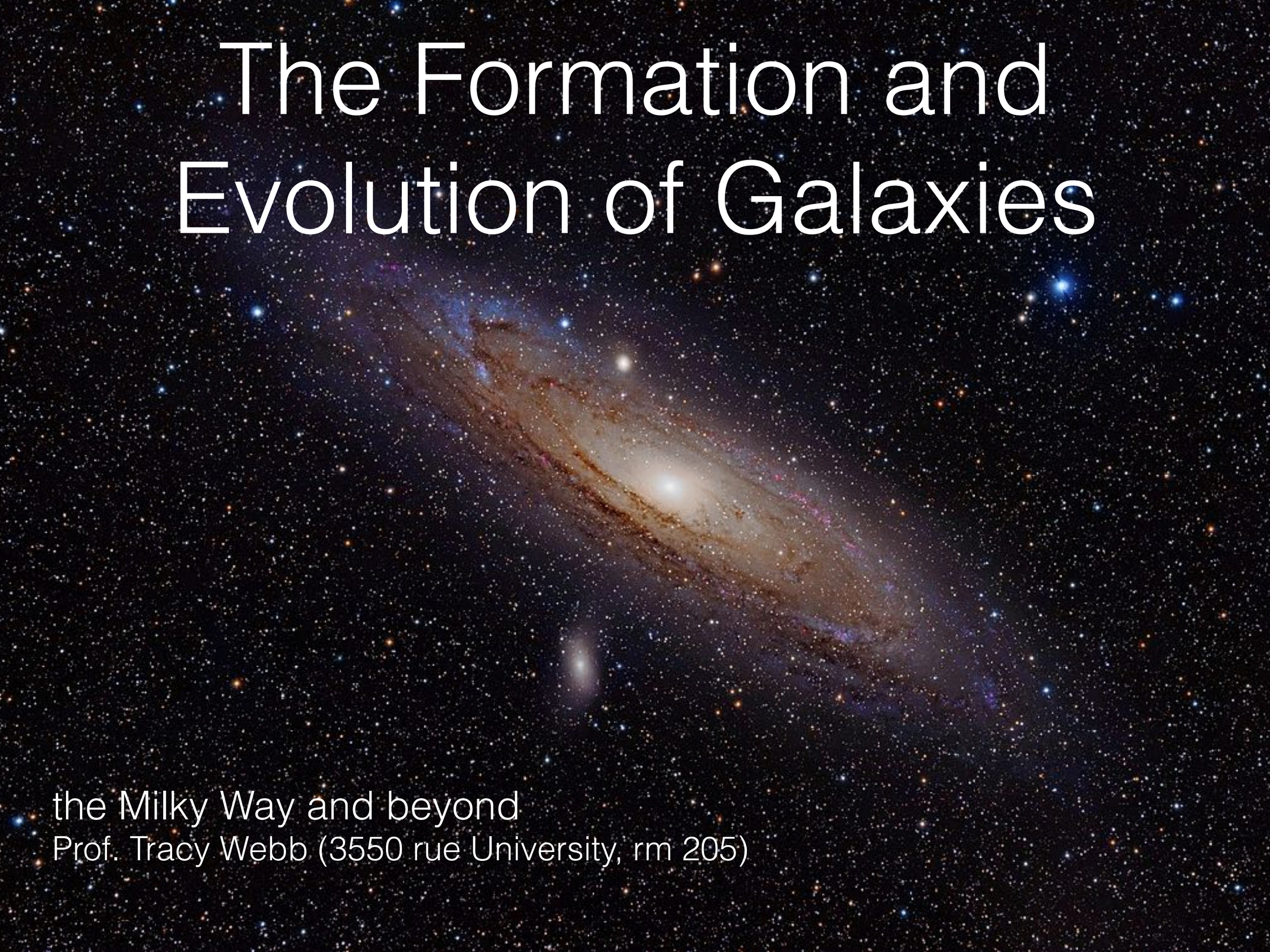
The Formation and Evolution of Galaxies

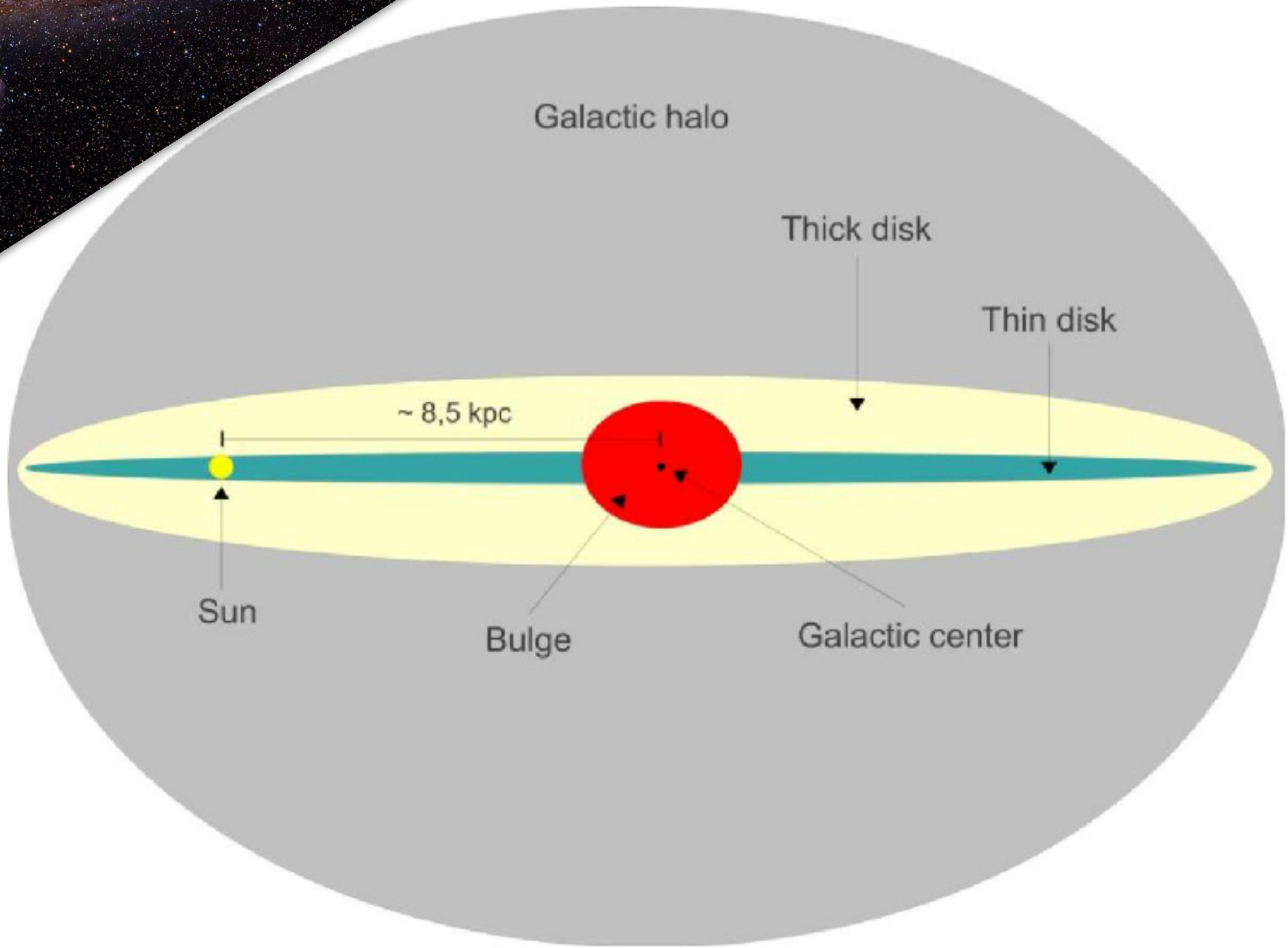


the Milky Way and beyond

Prof. Tracy Webb (3550 rue University, rm 205)

What is a galaxy?

Spiral Galaxy (Andromeda: 2.5Mlyrs)



Components of a Galaxy

Stars

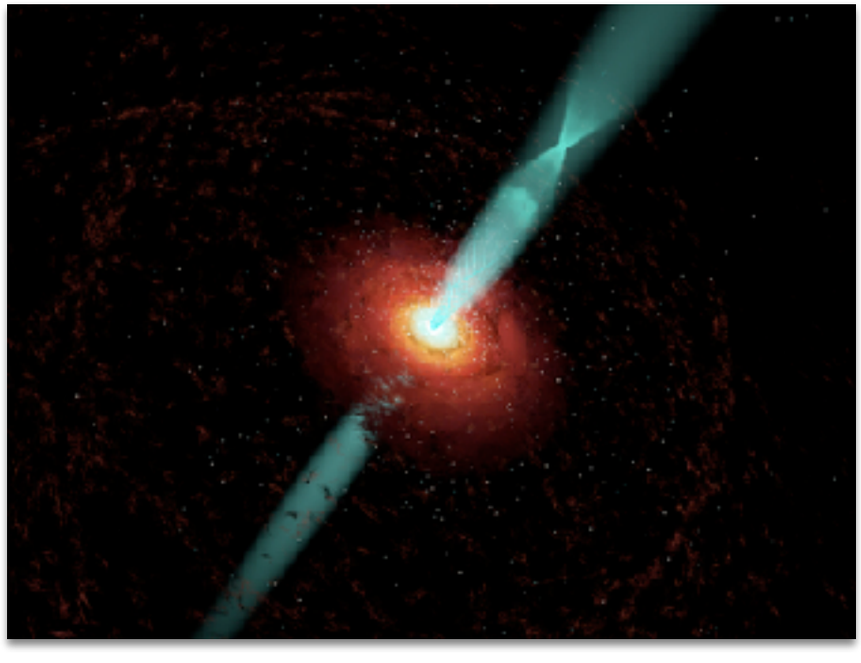
(~100 billion suns)

Gas/Dust (mostly Hydrogen)

(~ mass of stars)

A Supermassive Black Hole

(million times the mass of the sun)

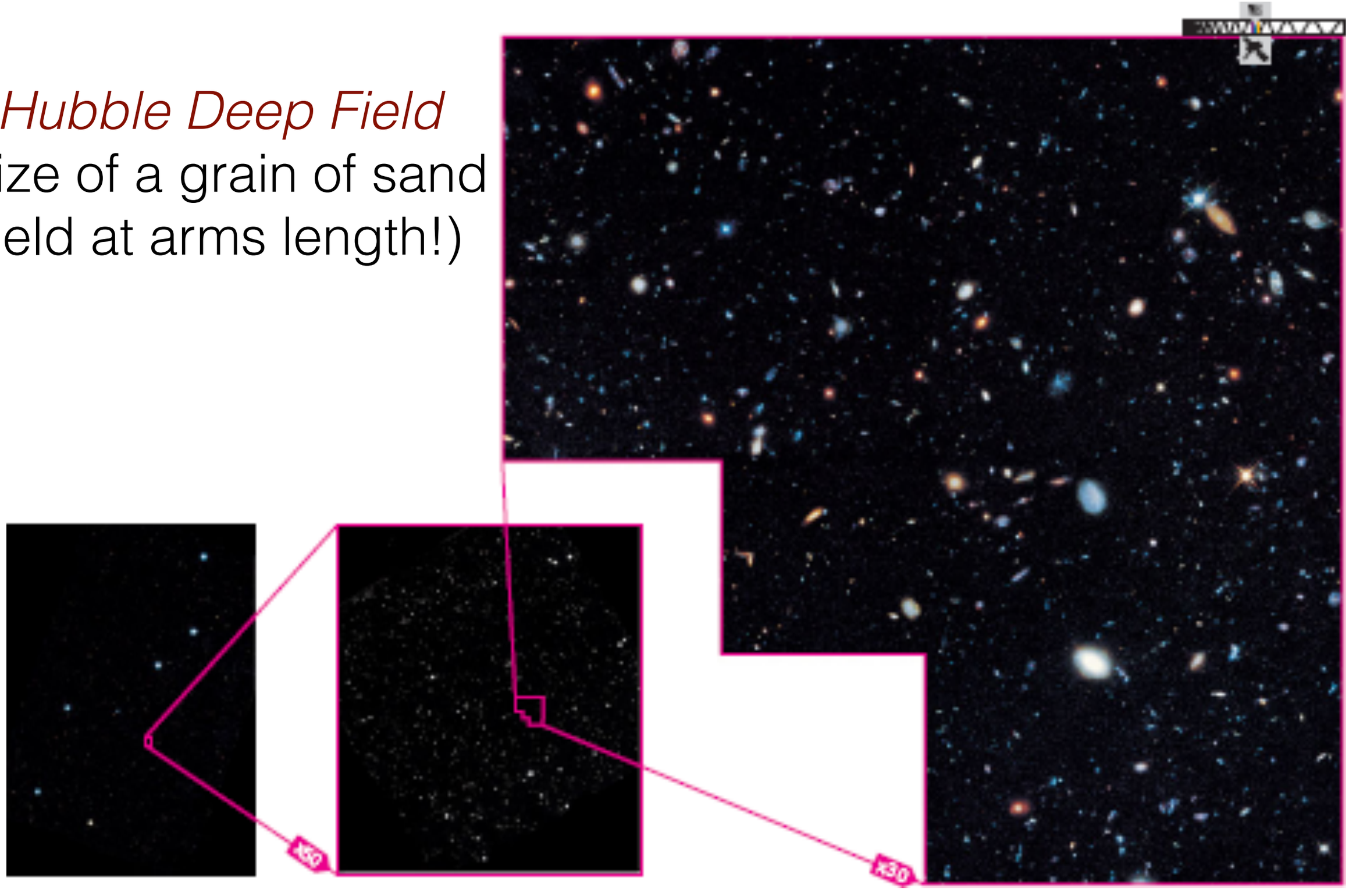


Dark Matter ?

(10-100x mass of stars and gas)

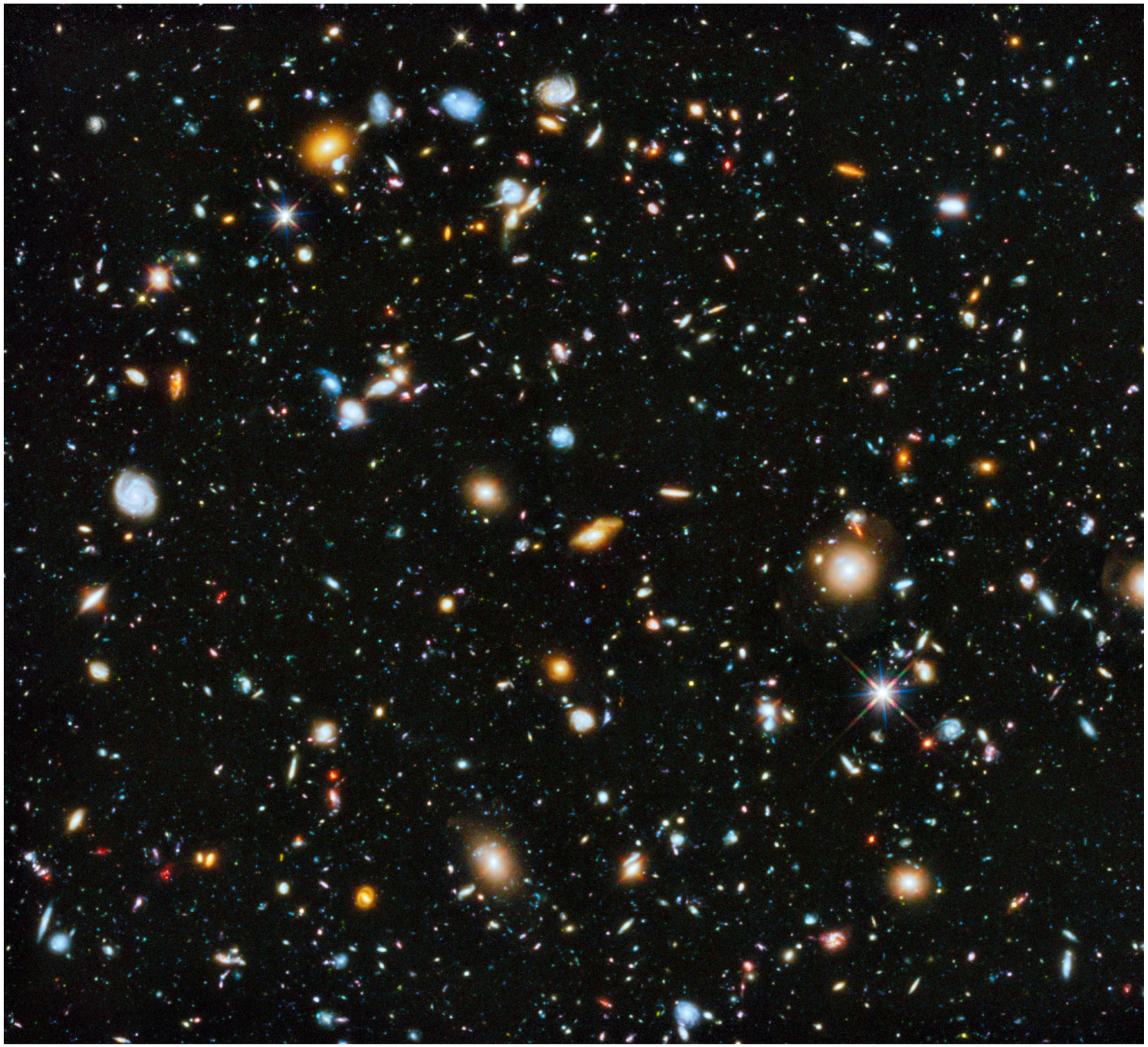
Islands of Stars

Hubble Deep Field
(size of a grain of sand held at arms length!)



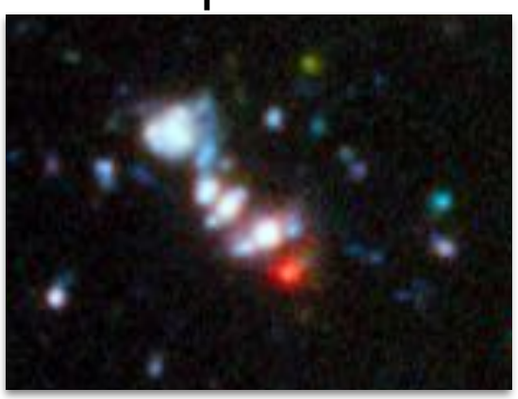
over 100 billion galaxies in the observable universe!

How do galaxies differ?



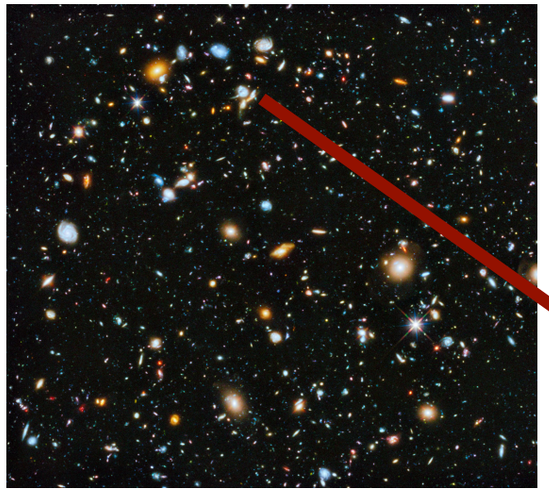
Elliptical

Spiral



Irregular

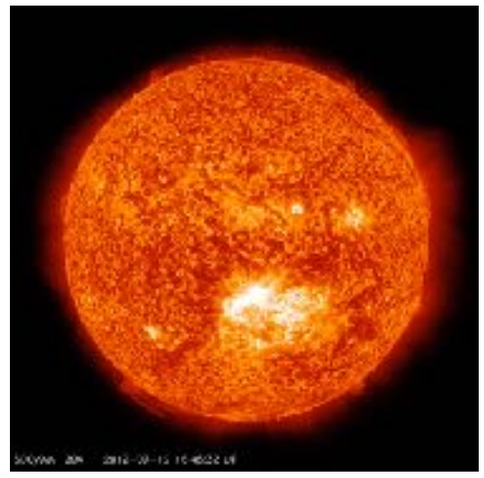
Observing galaxies: telescopes as time machines



billions - 10 billions of years

2.5 million years

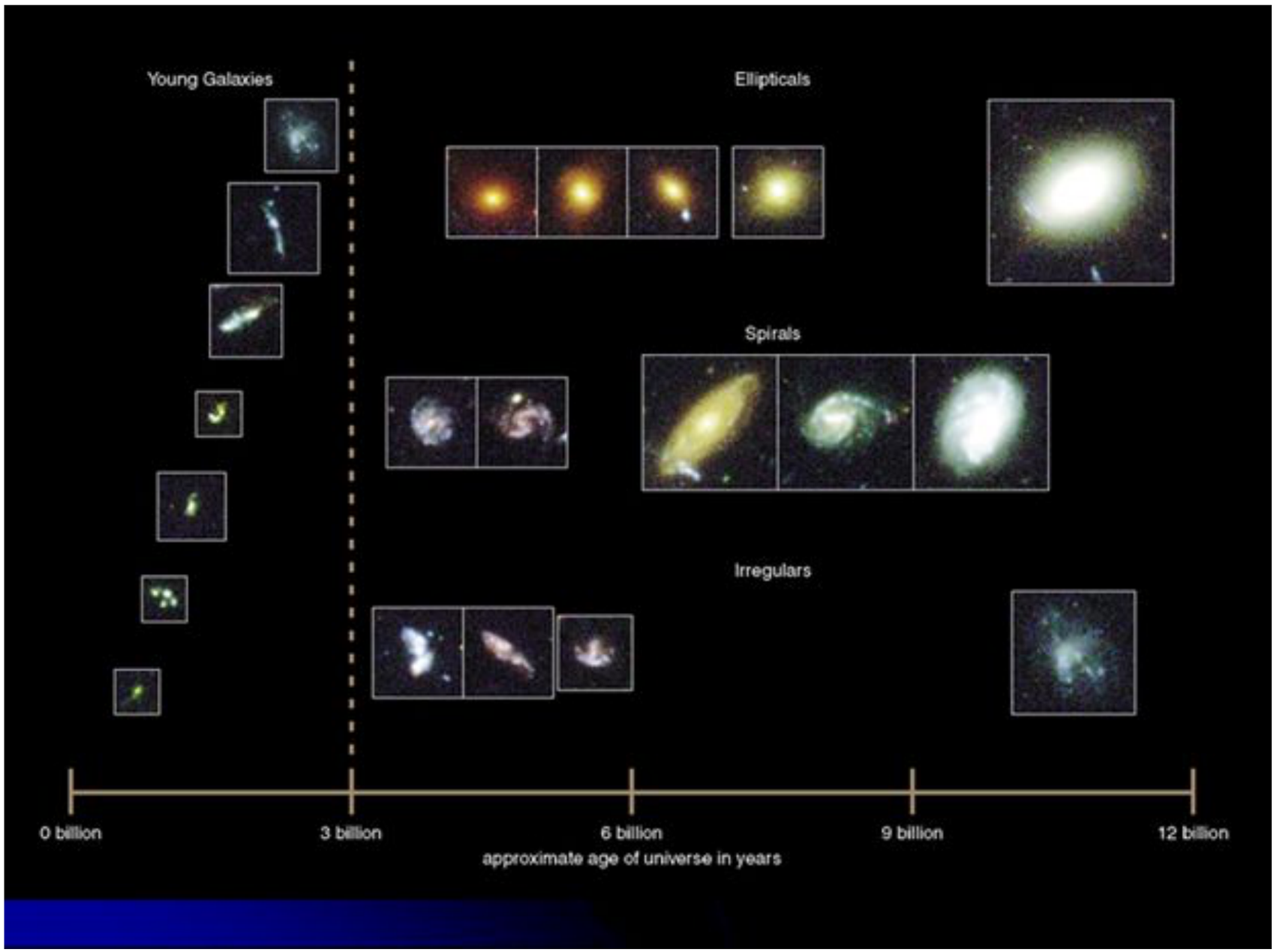
8 minutes



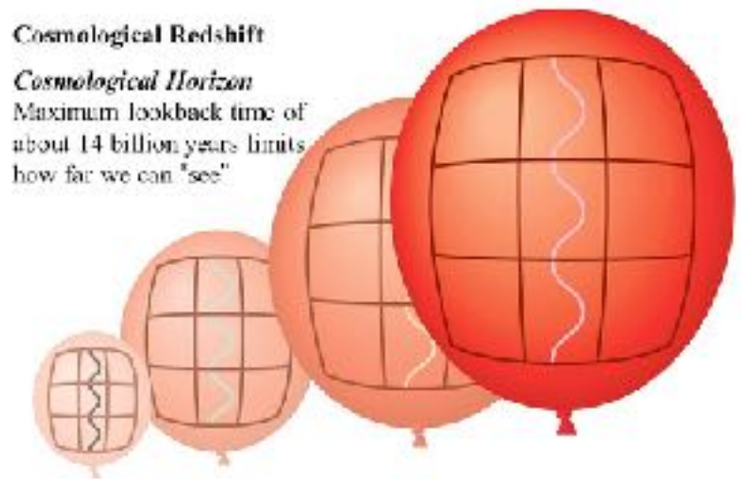
Galaxy Formation and Evolution

we cannot watch a single galaxy evolve (timescale is too long)

but we can study galaxies at different evolutionary phases

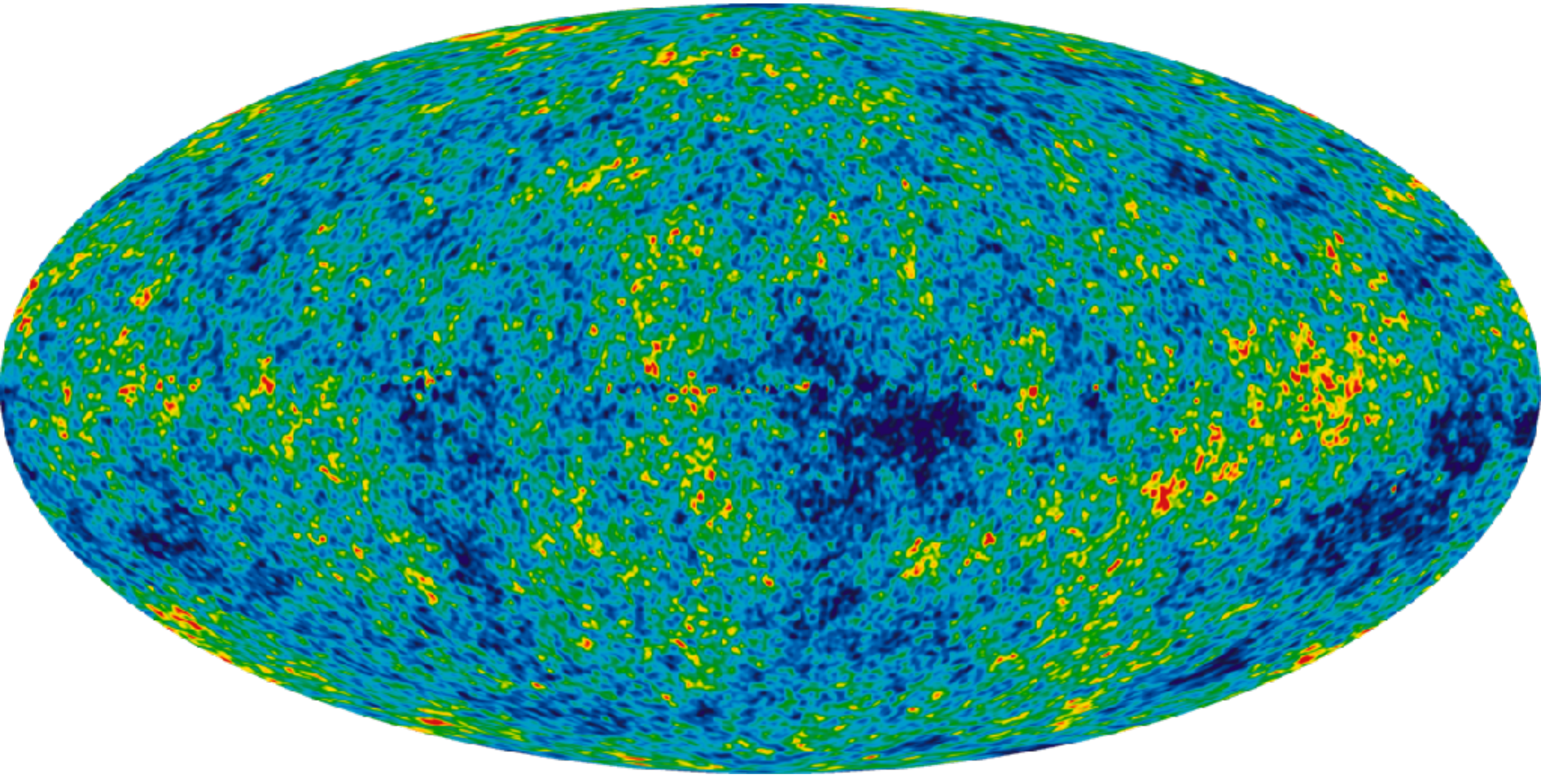


time = redshift

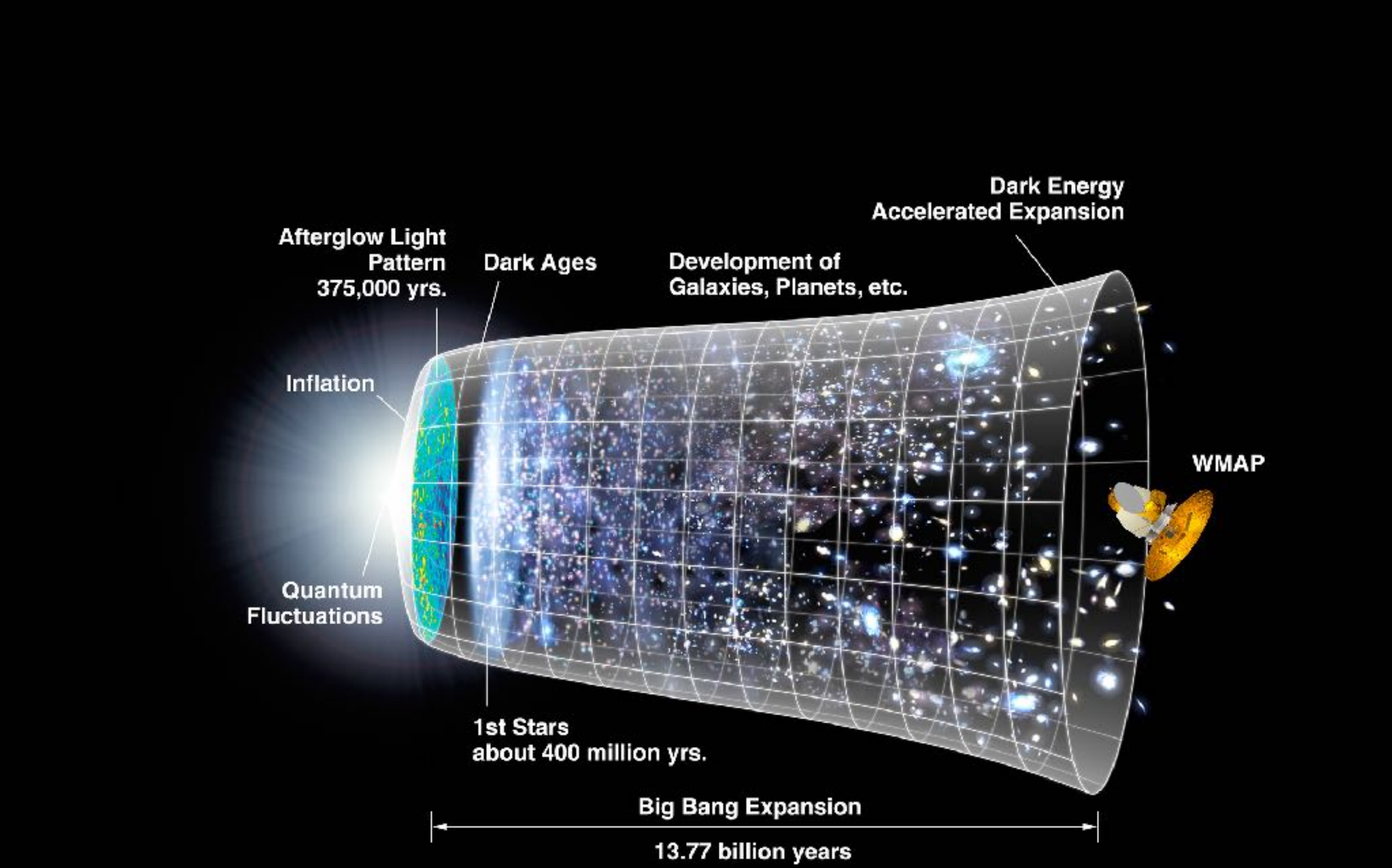


Expansion stretches photon wavelengths, causing a ***cosmological redshift*** directly related to lookback time

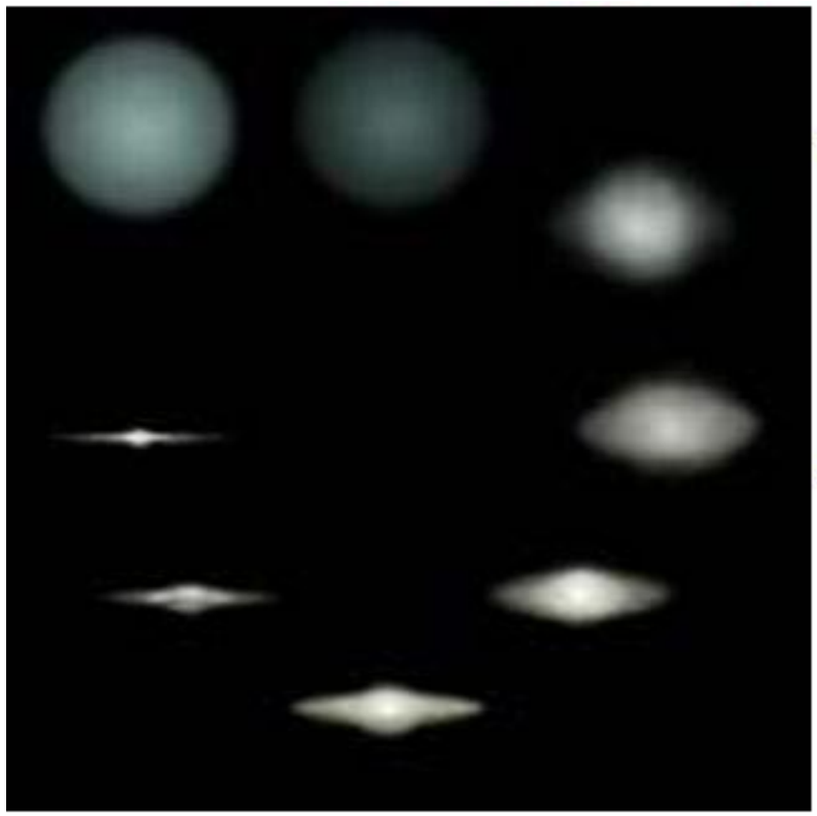
The Formation of Structure in the Universe



The Cosmic Microwave Background

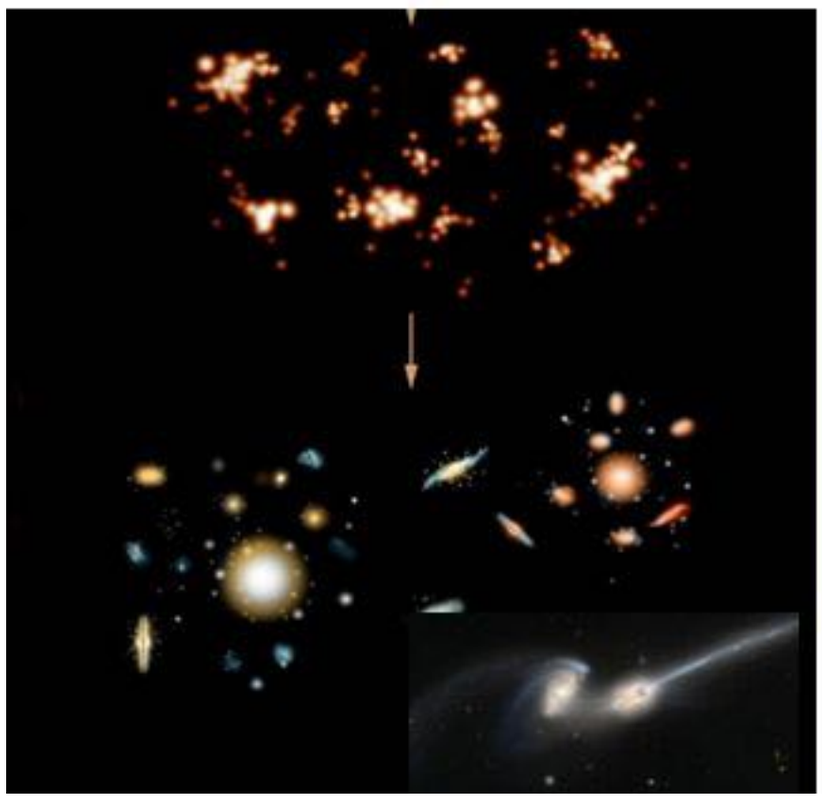

Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years

How do Galaxies Form?



Two 'competing' theories:

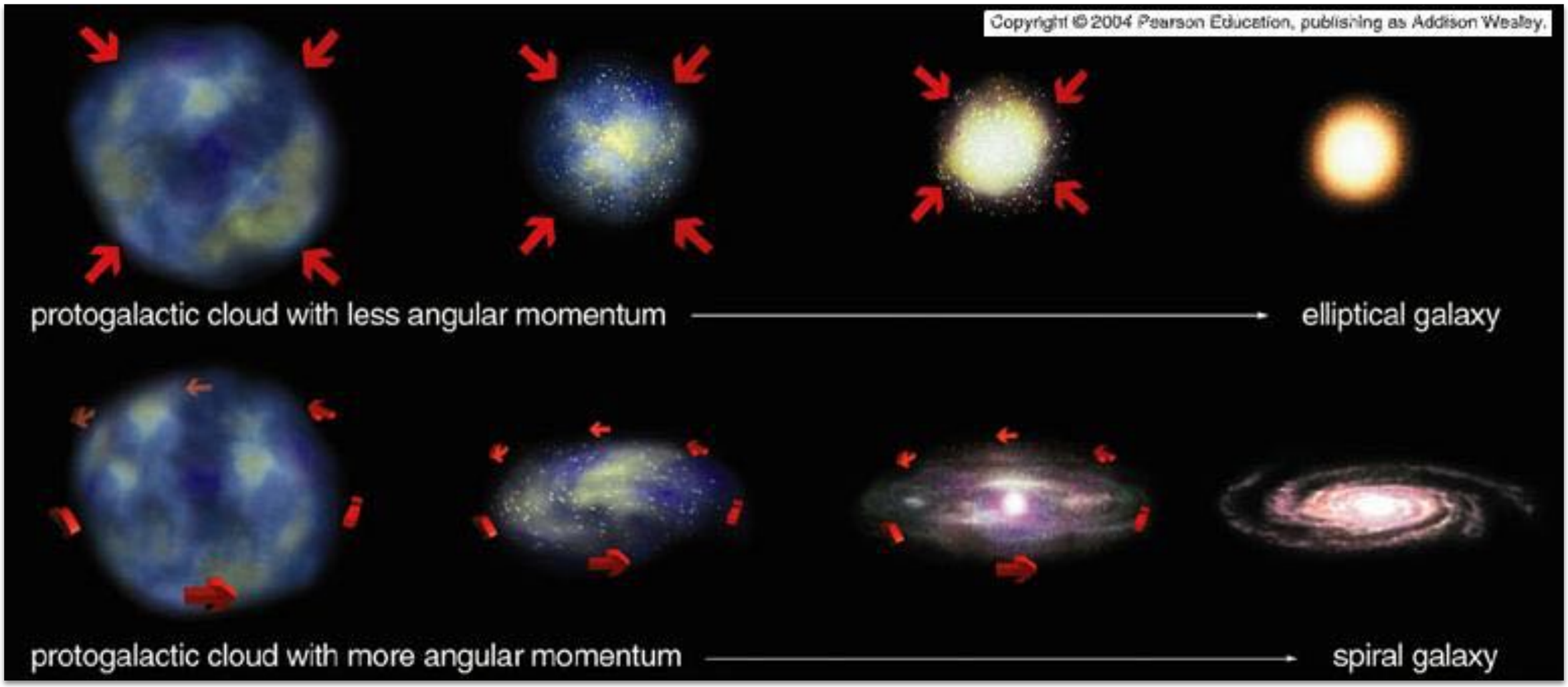
(1) Monolithic collapse



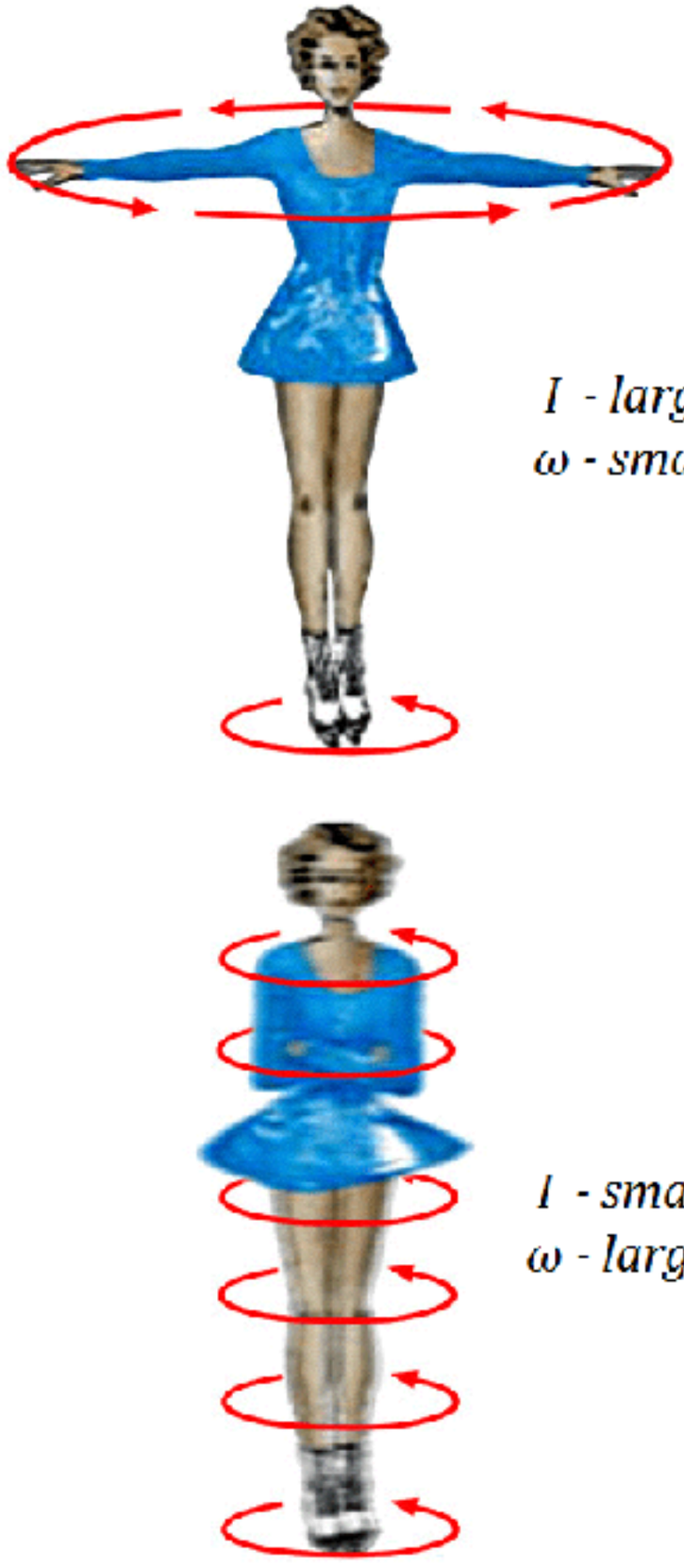
(2) Hierarchical structure formation

Monolithic Collapse

the protogalactic spin can determine what kind of galaxy is formed



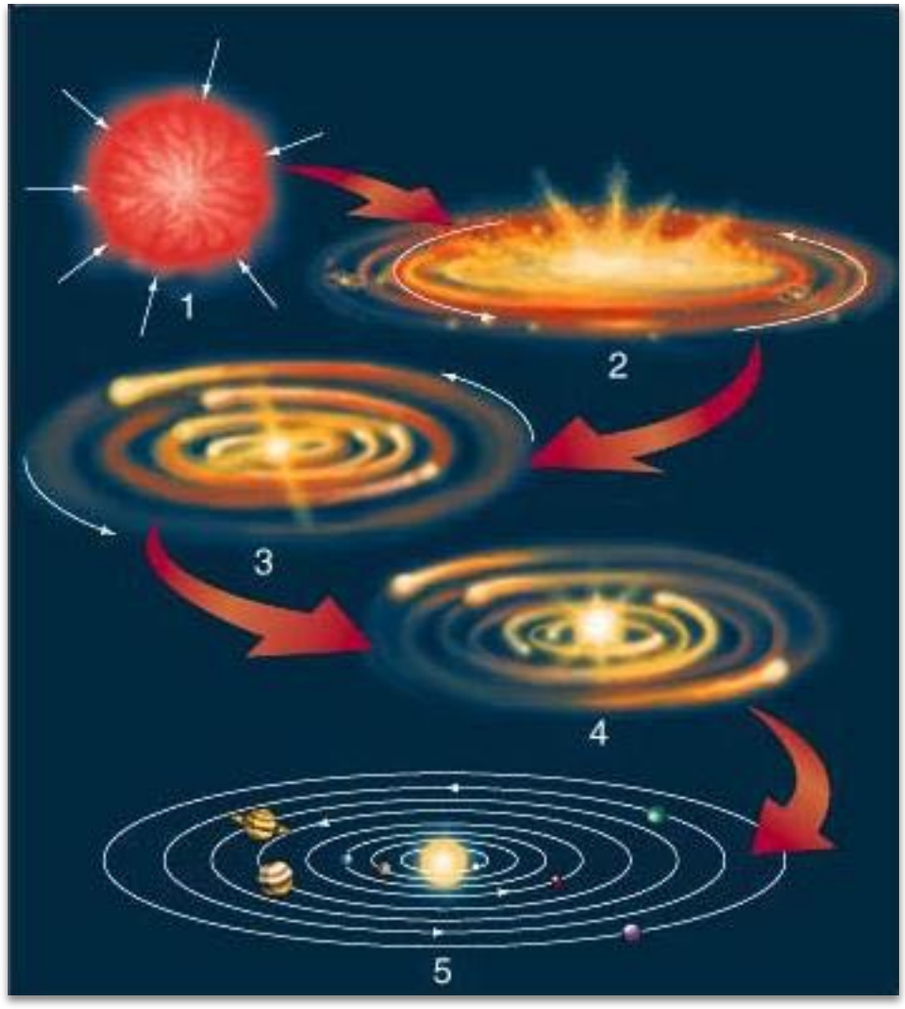
angular momentum is conserved in a closed system



I - large
ω - small

I - small
ω - large

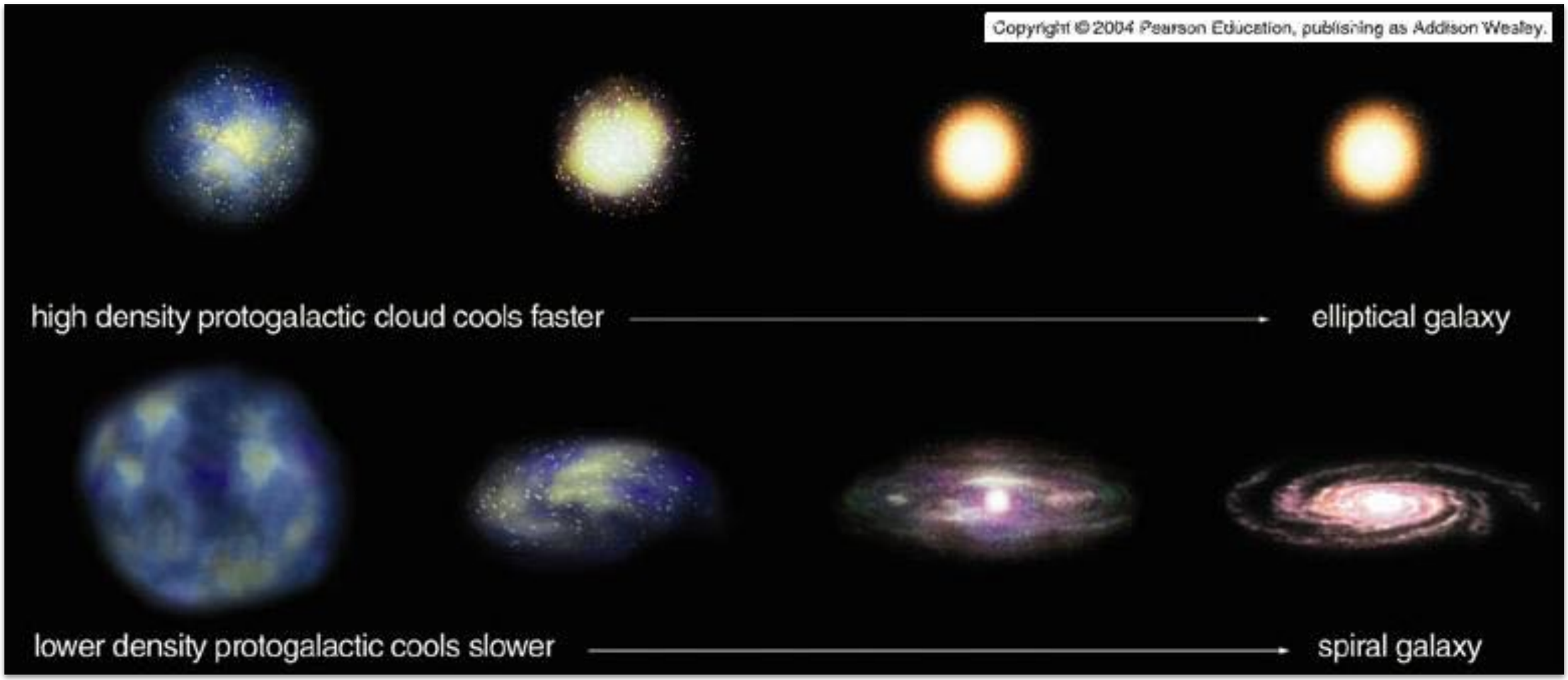
Angular Momentum	=	Moment of Inertia	x	Angular Velocity
L	=	I	x	ω



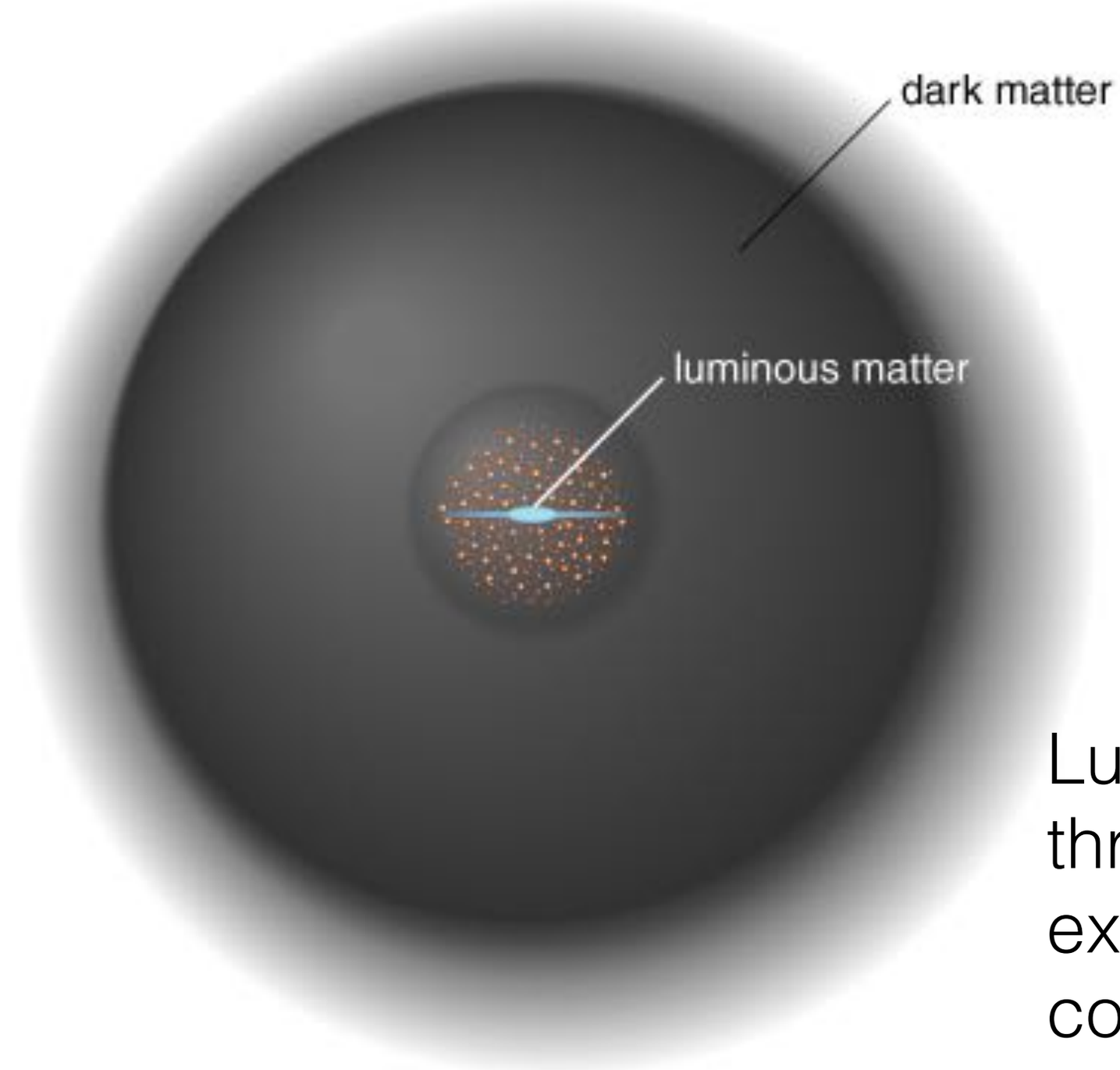
we see this in the formation of the solar system as well

Monolithic Collapse

… or the protogalactic density



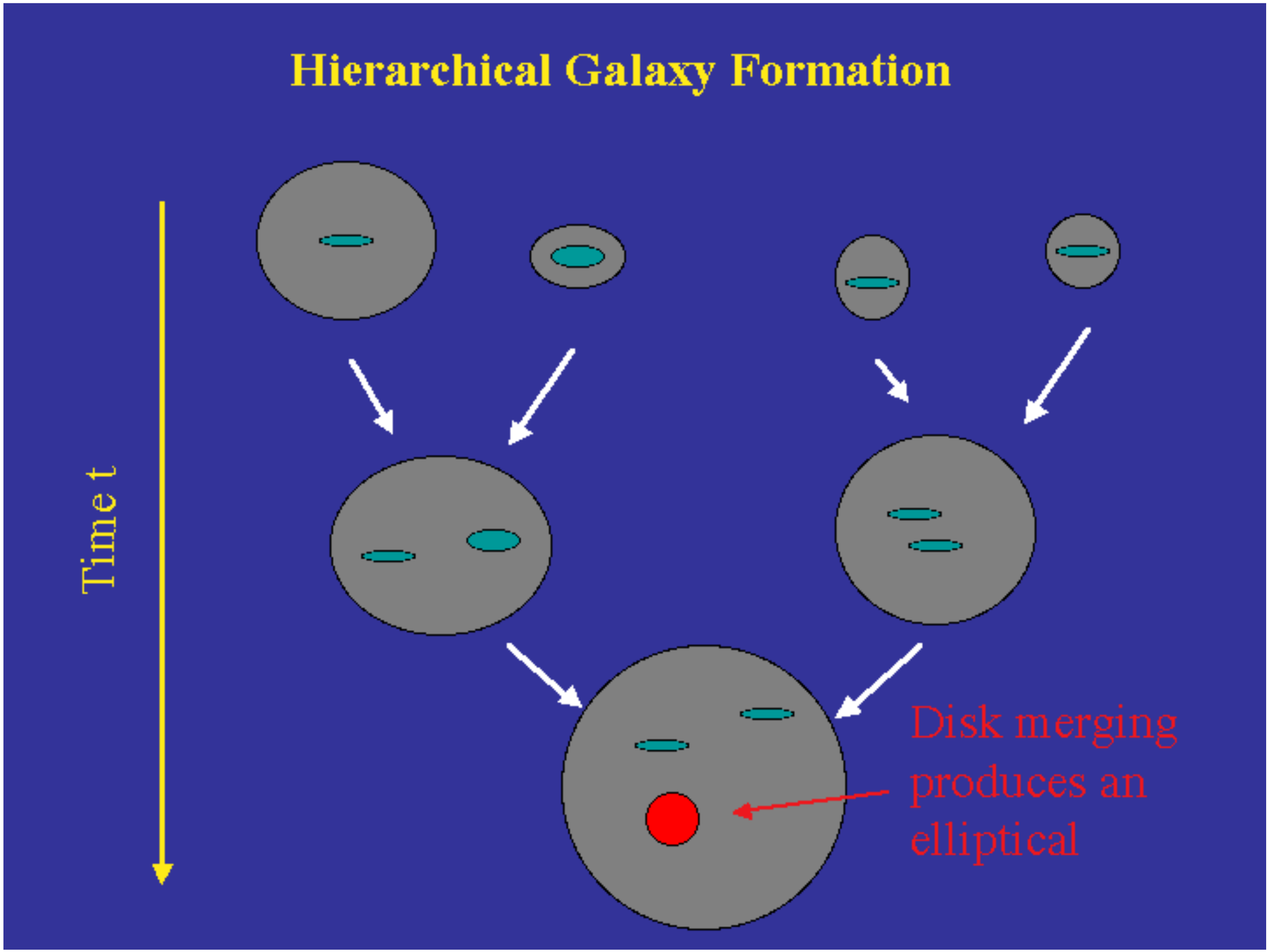
aside on dark matter distribution:



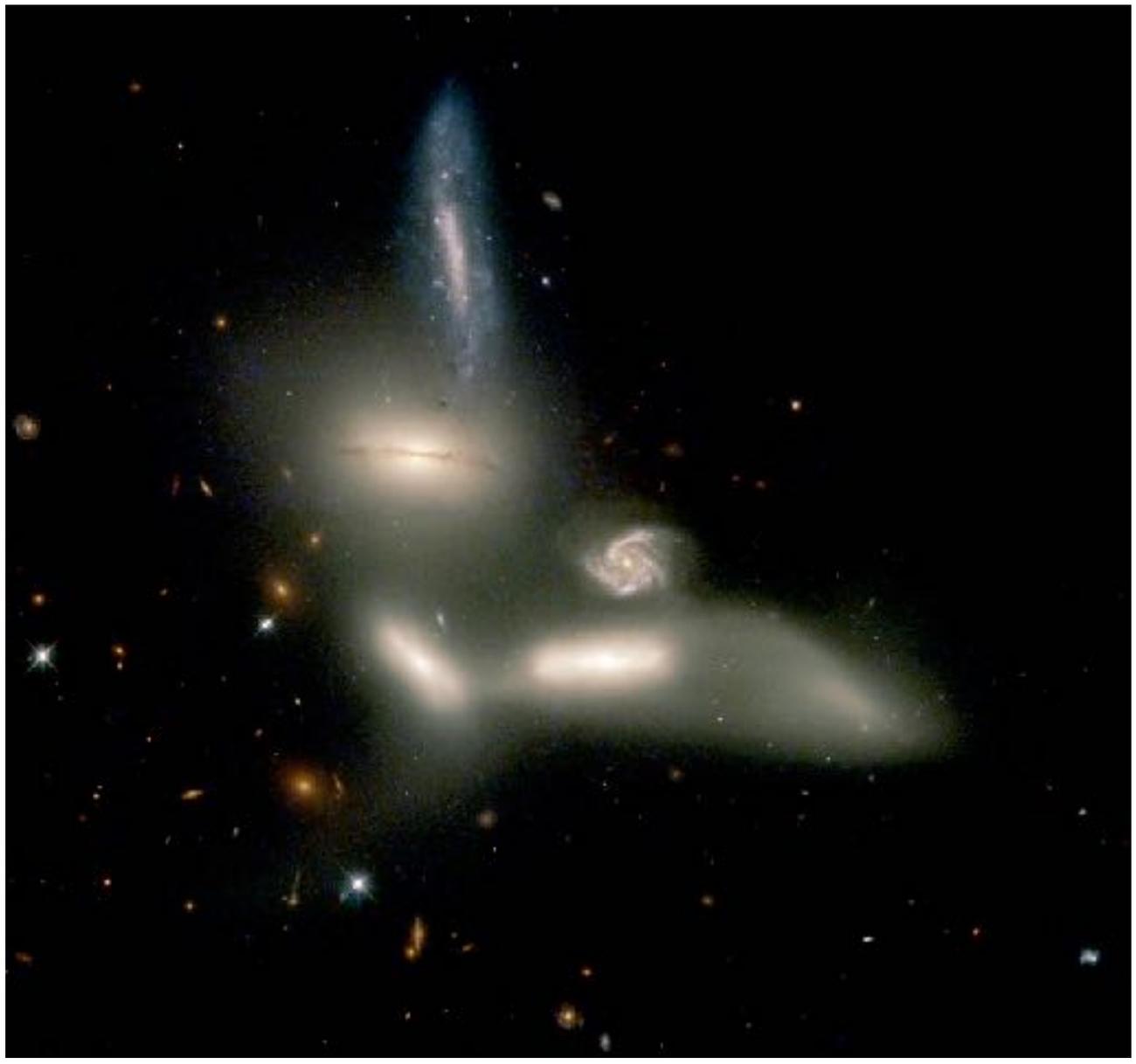
Luminous matter can cool through collisional de-excitation - and can thus collapse.

Dark matter cannot.

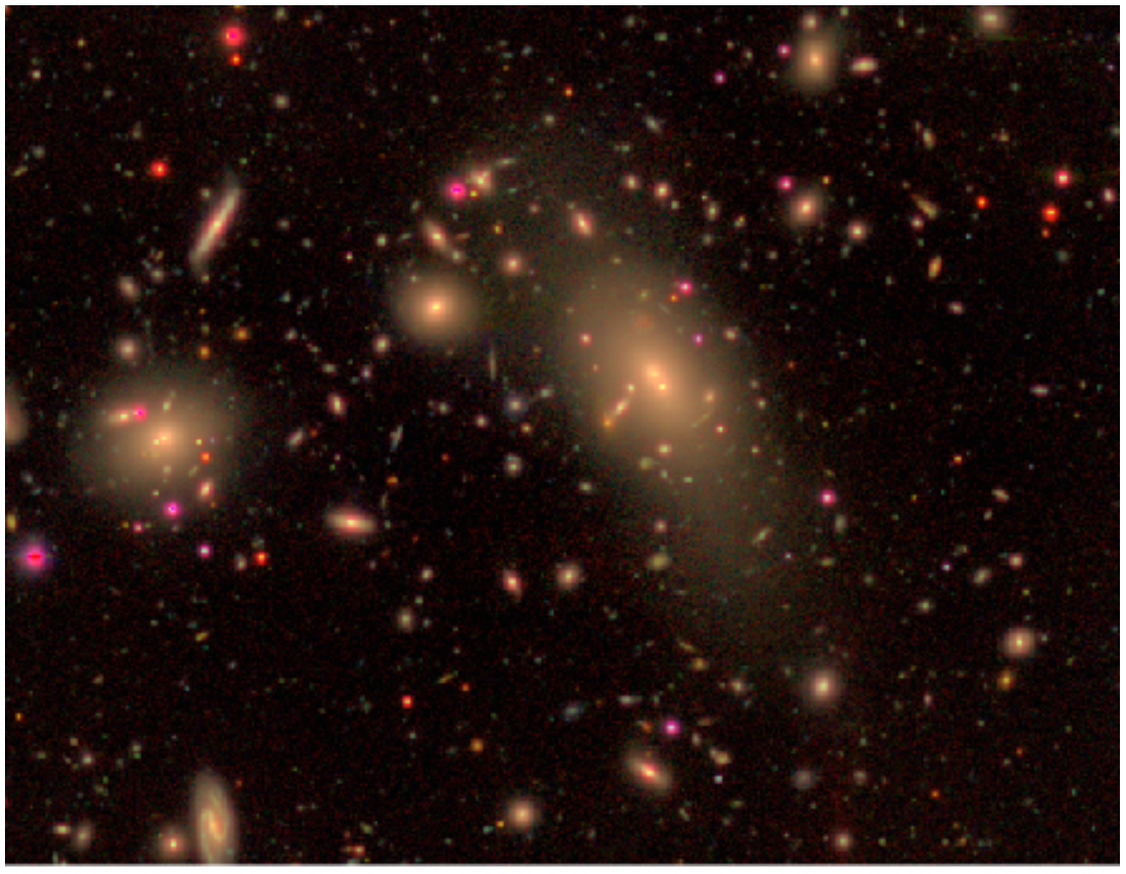
Hierarchical Growth



Merging Galaxies

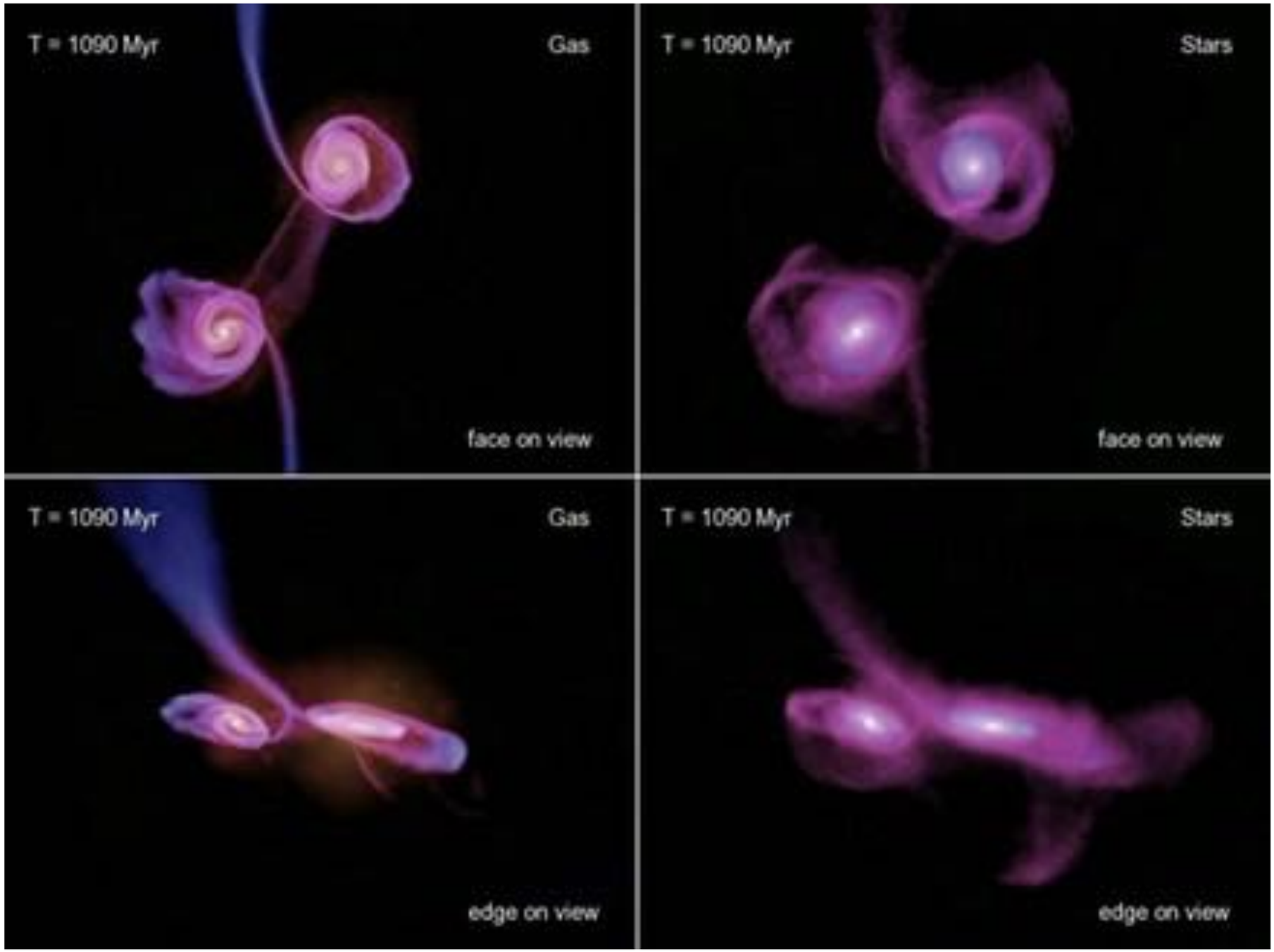


Milky Way-like groups



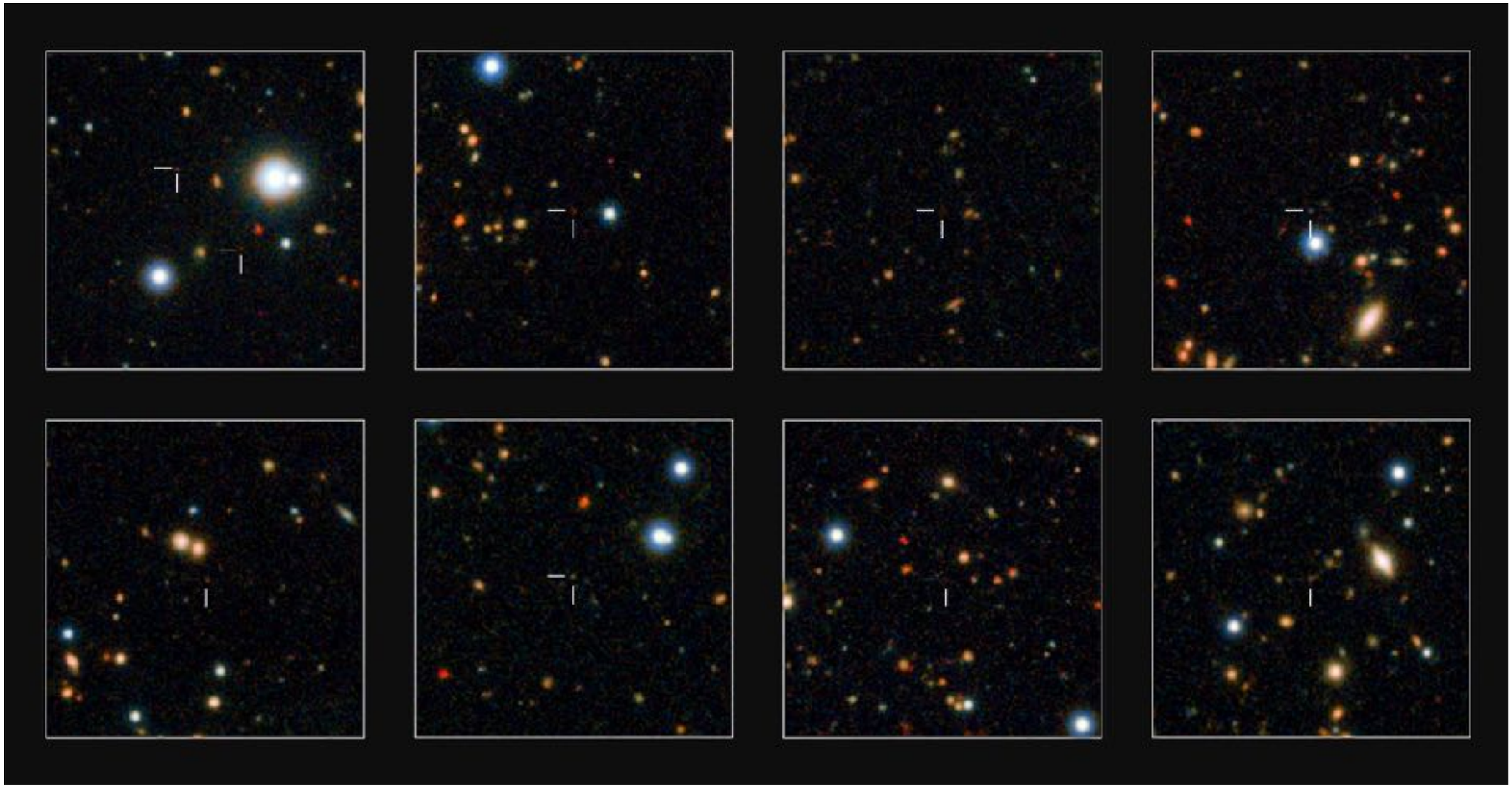
Galaxy Clusters

this process has been well-simulated - see youtube



Two spiral galaxies merge to create an elliptical
(and form an irregular along the way)

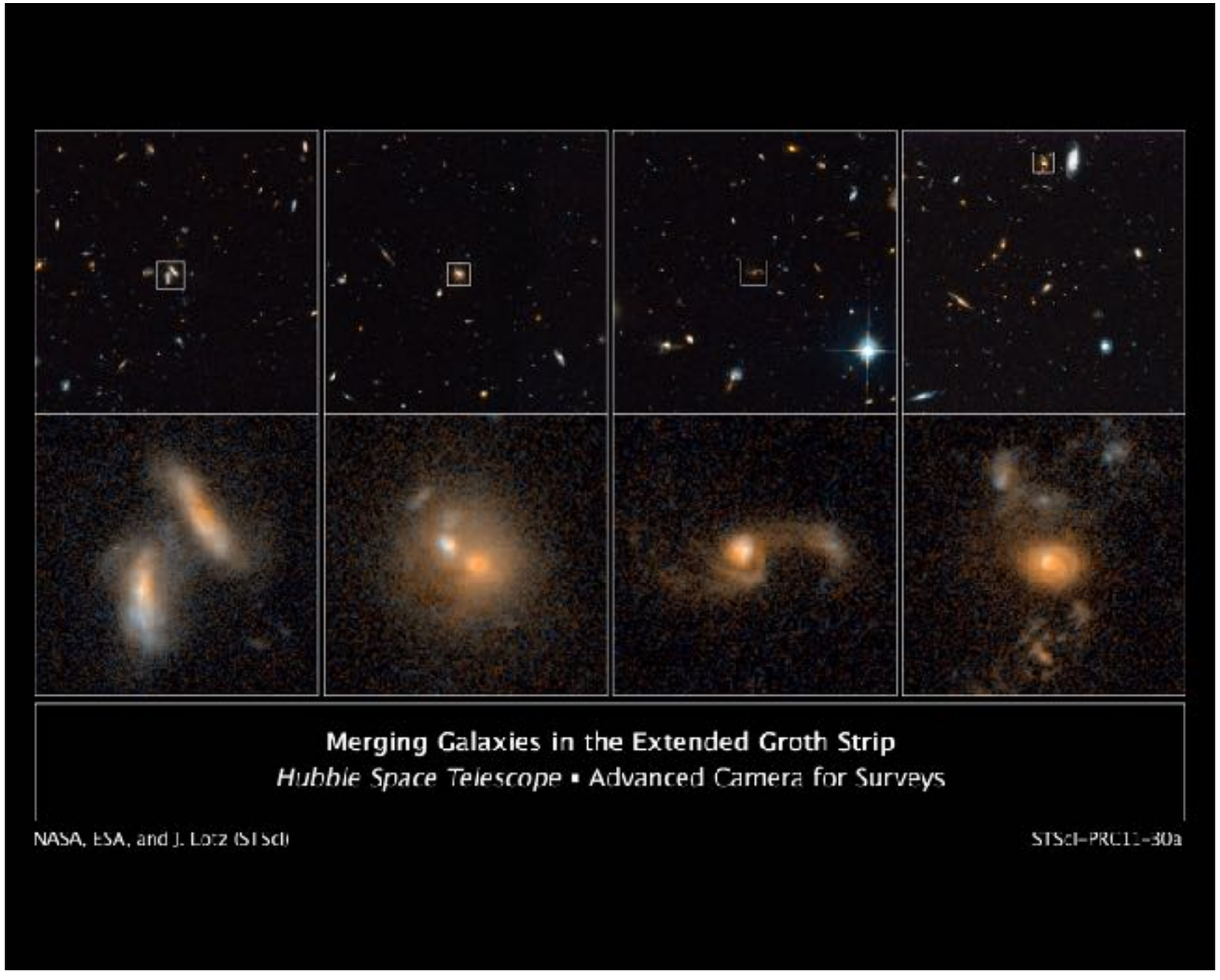
What is the evidence?



we have discovered massive elliptical galaxies at very early times (~ 1 billion years post BB)

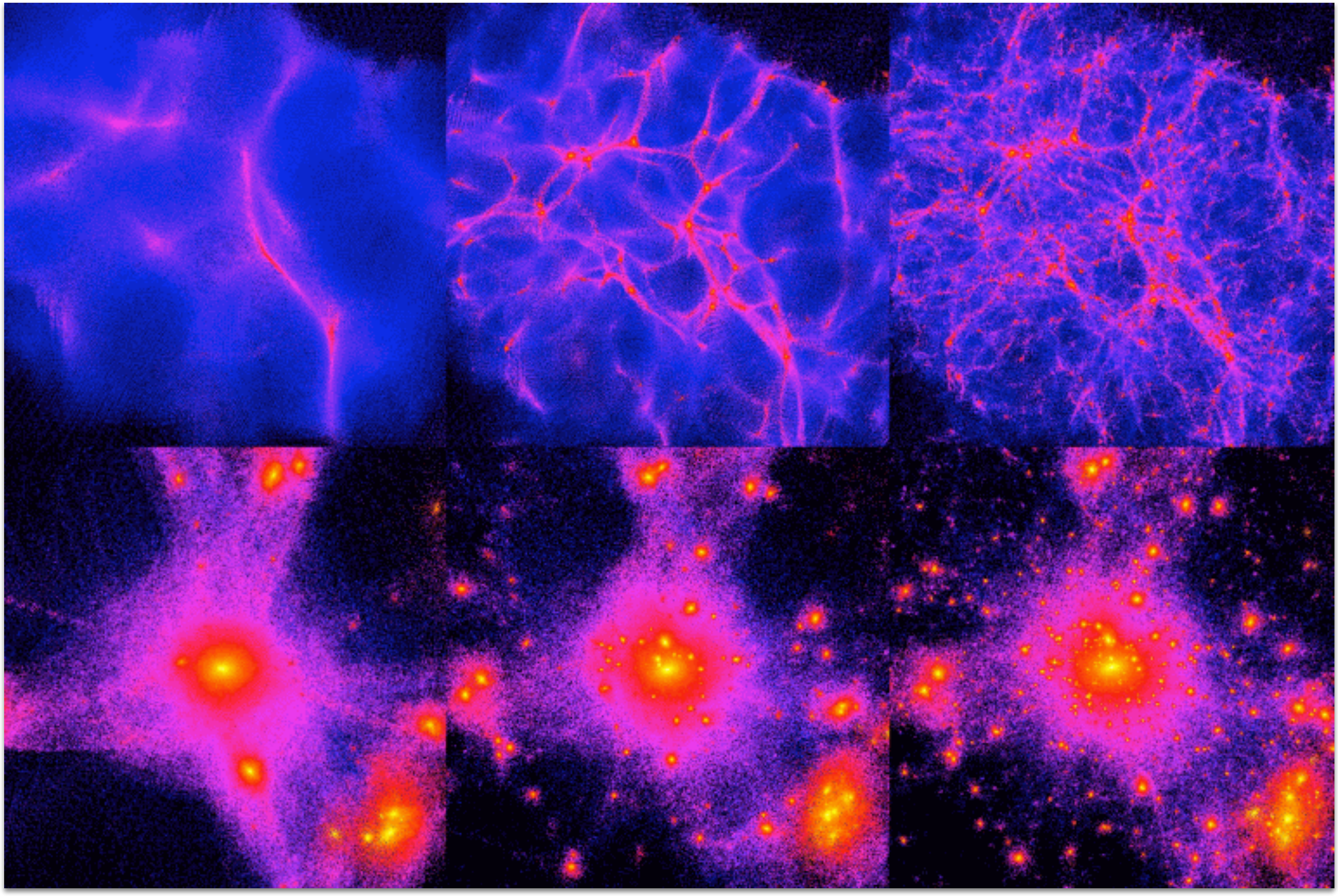
rapid monolithic collapse??

But strong evidence of hierarchical growth too!



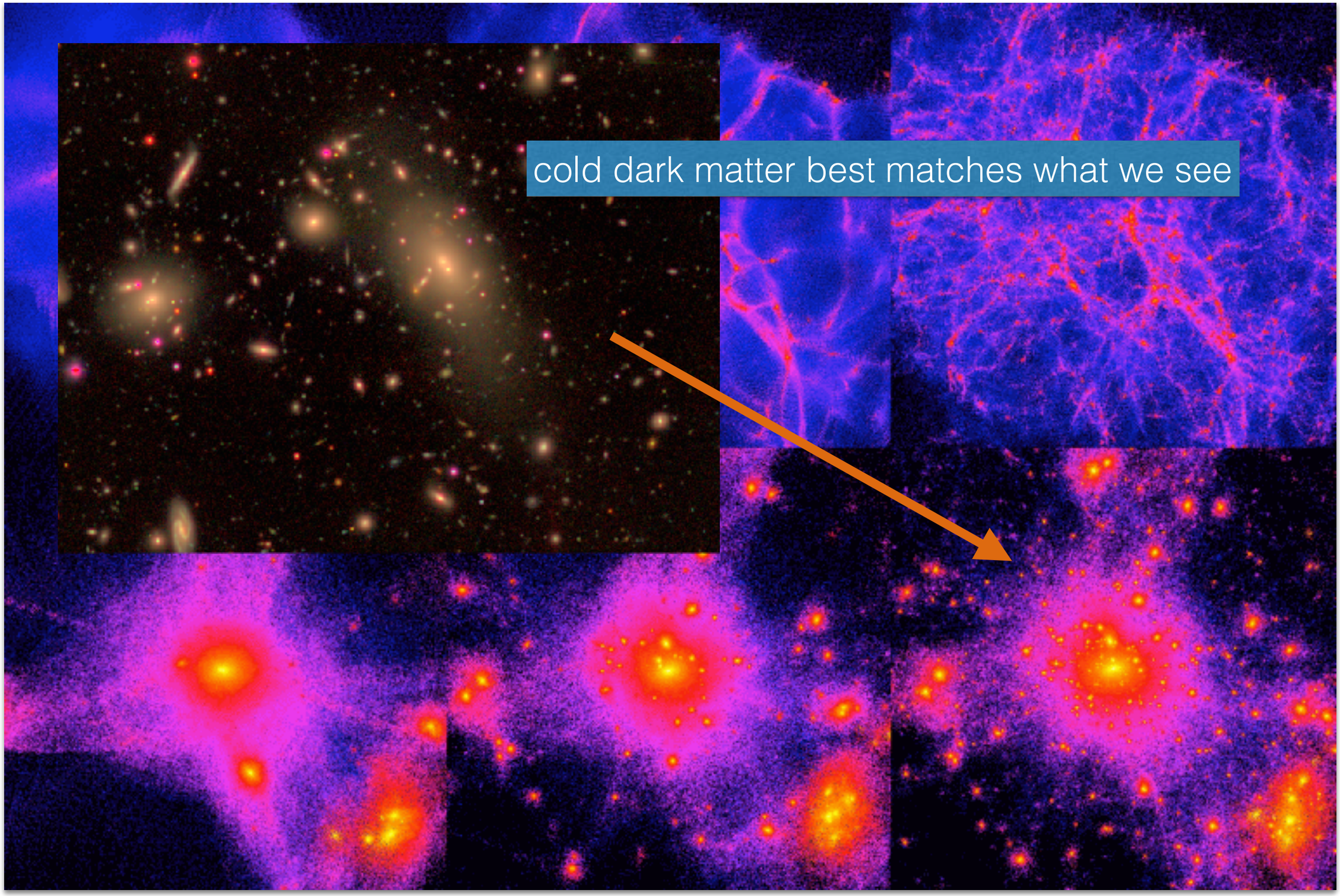
merger rates increase with decreasing universe age

hierarchical structure formation with different kinds of Dark Matter



Hot Warm Cold

hierarchical structure formation with different kinds of Dark Matter



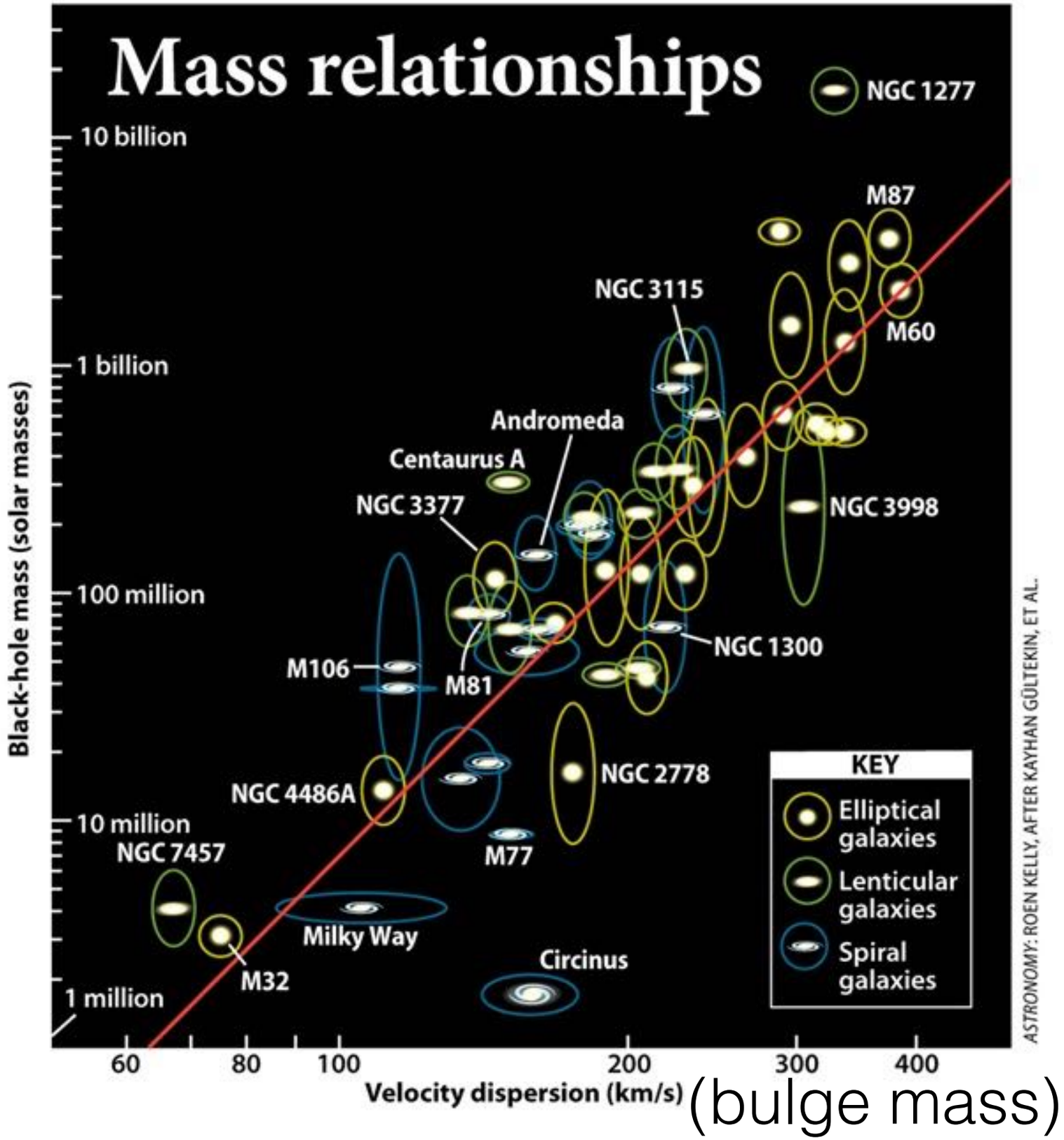
Hot Warm Cold

an open question in galaxy evolution

- all massive galaxies house a supermassive black hole at their centre

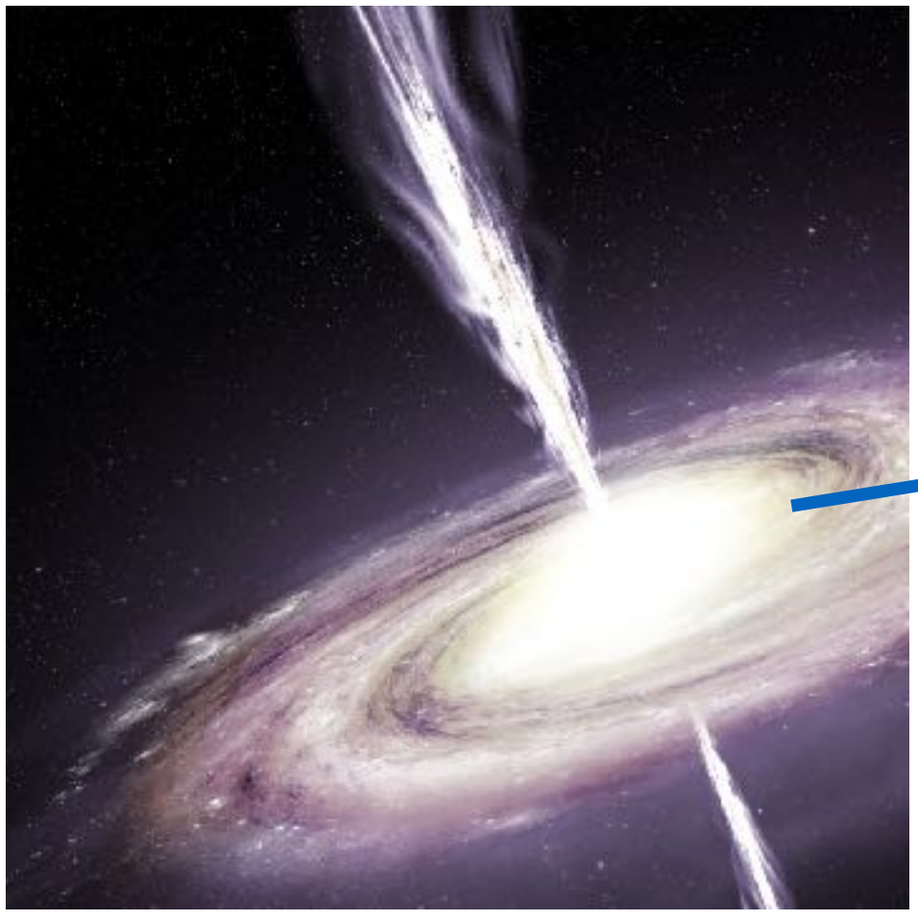
- the mass of the black hole is correlated with the mass of the galaxy

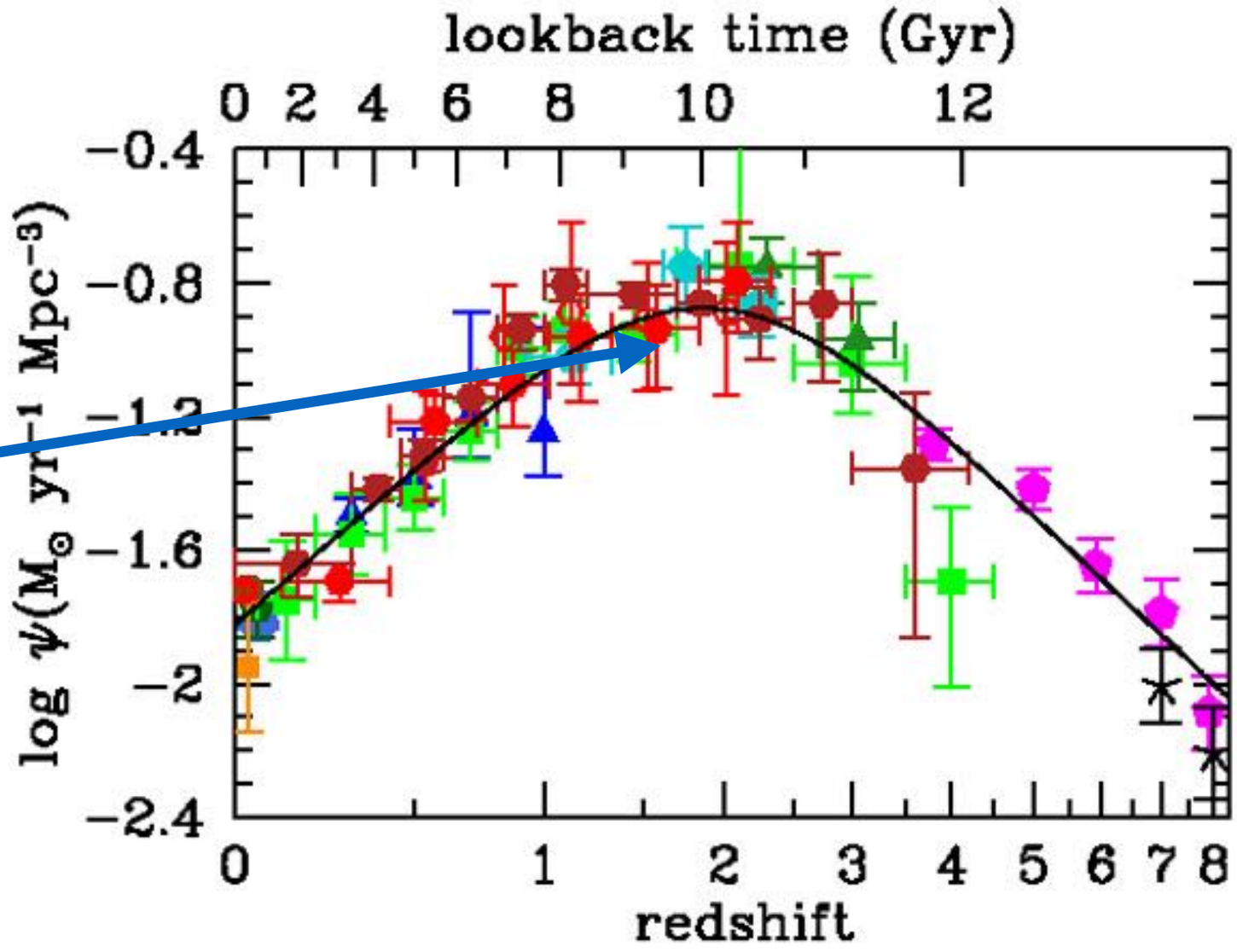
- scales are 1000x different - so *why*?



(bulge mass)

supermassive black holes peak in growth at the same time as star formation does (in a global sense)





indicative of a feed-back mechanism?

We see evidence for feedback on galaxy cluster scales

X-ray image of a galaxy cluster (Perseus)