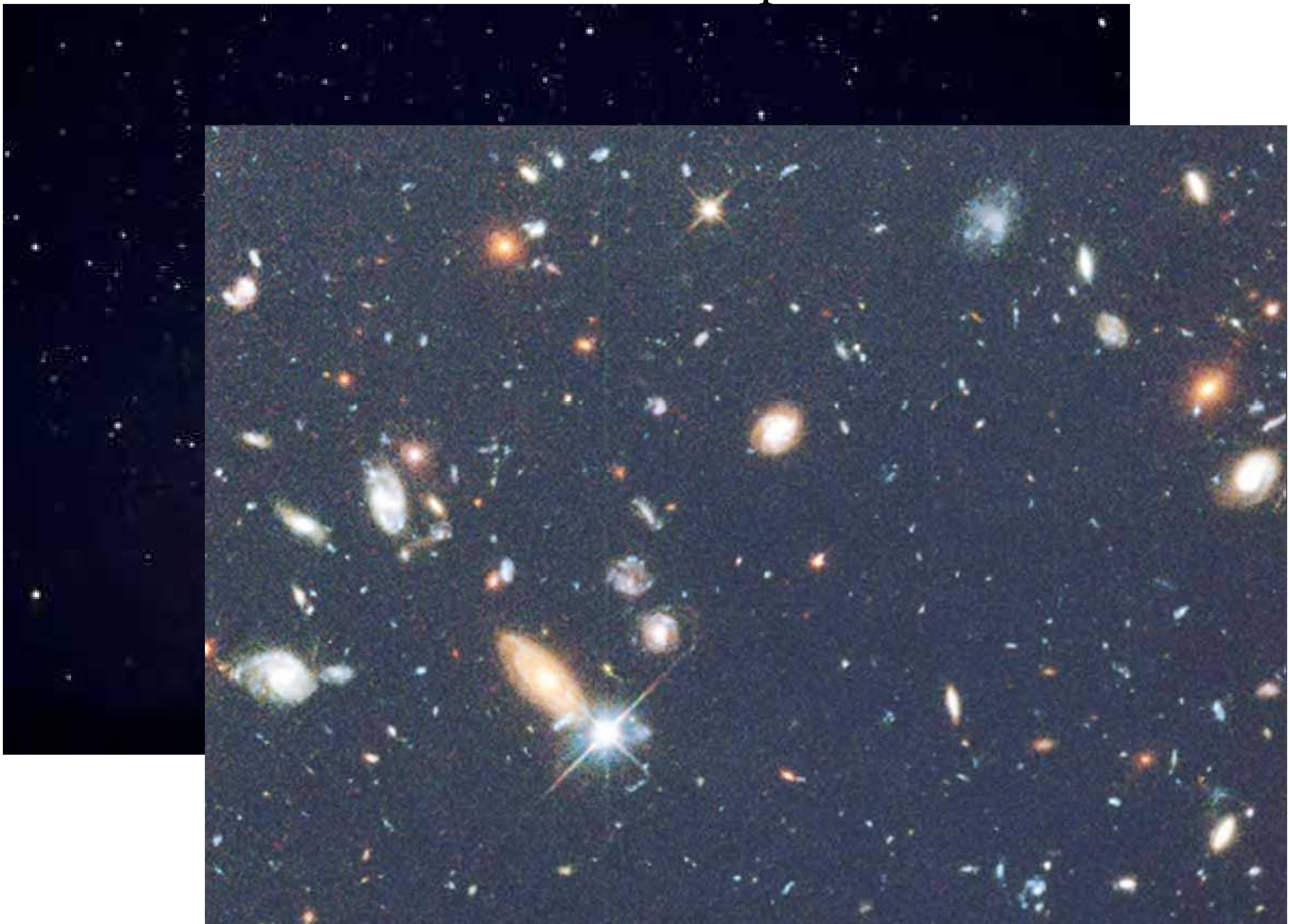
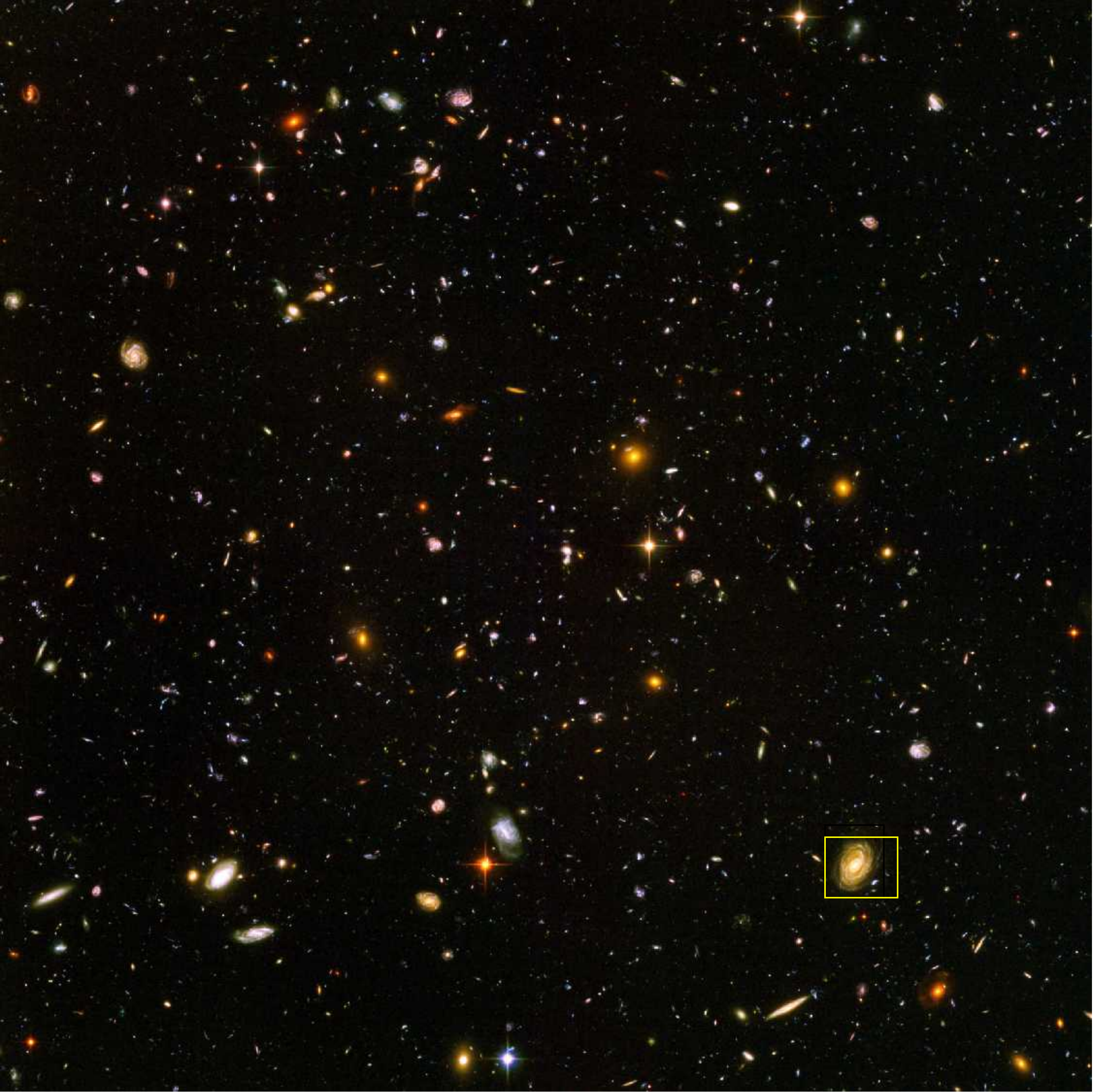
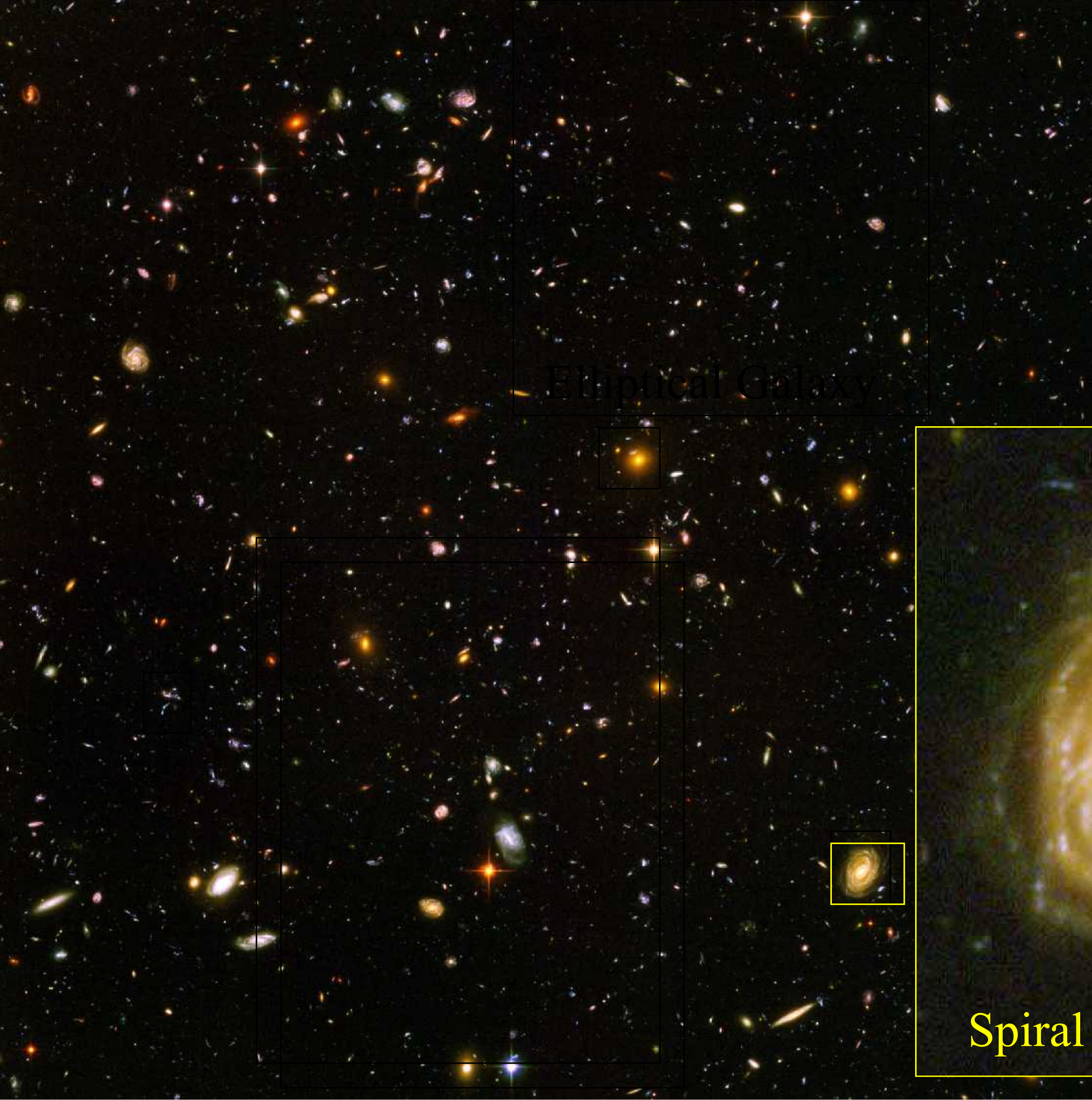
Hubble Deep Field

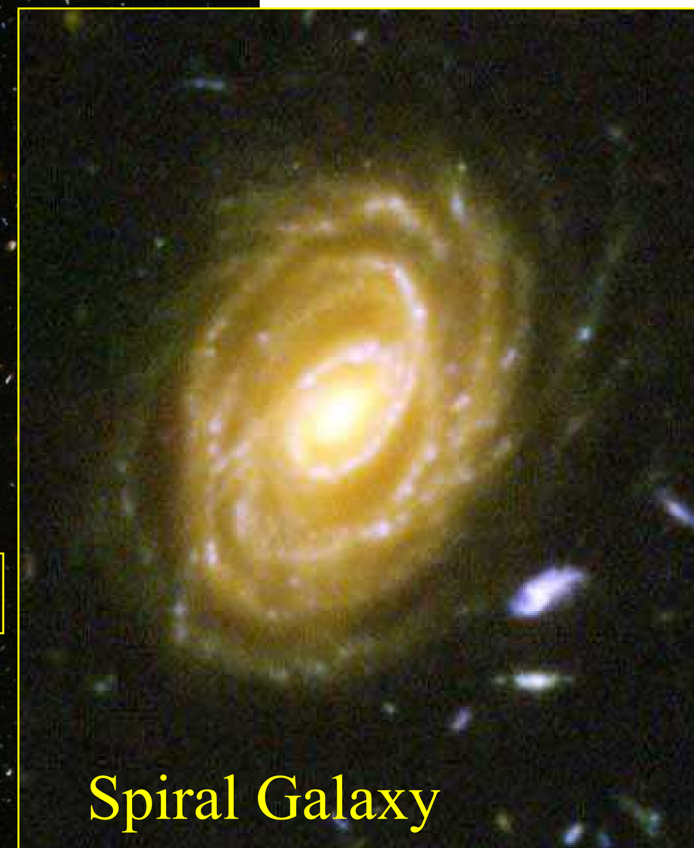




Hubble
Ultra
Deep
Field

Hubble Ultra Deep Field





Hubble
Ultra
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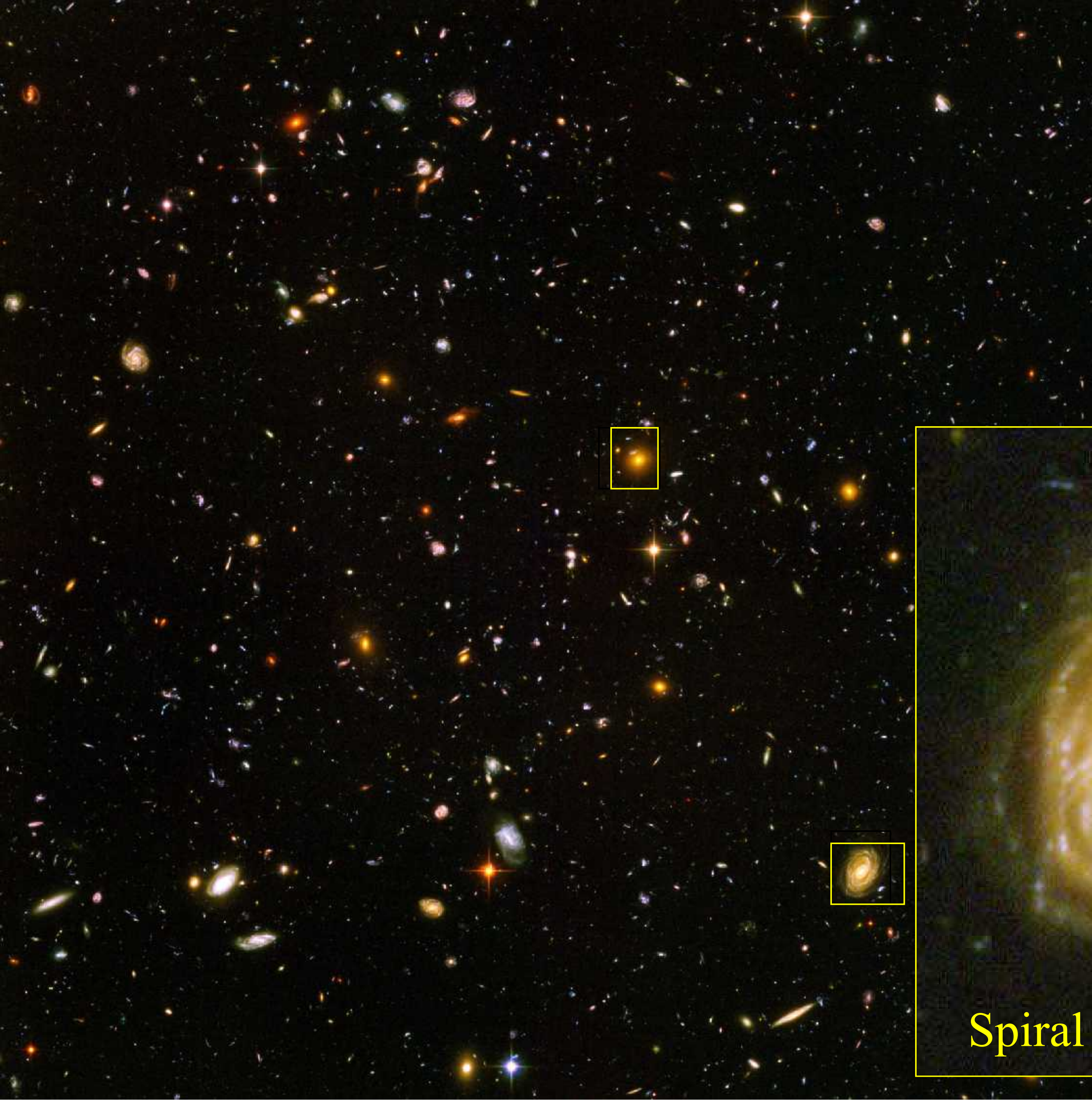

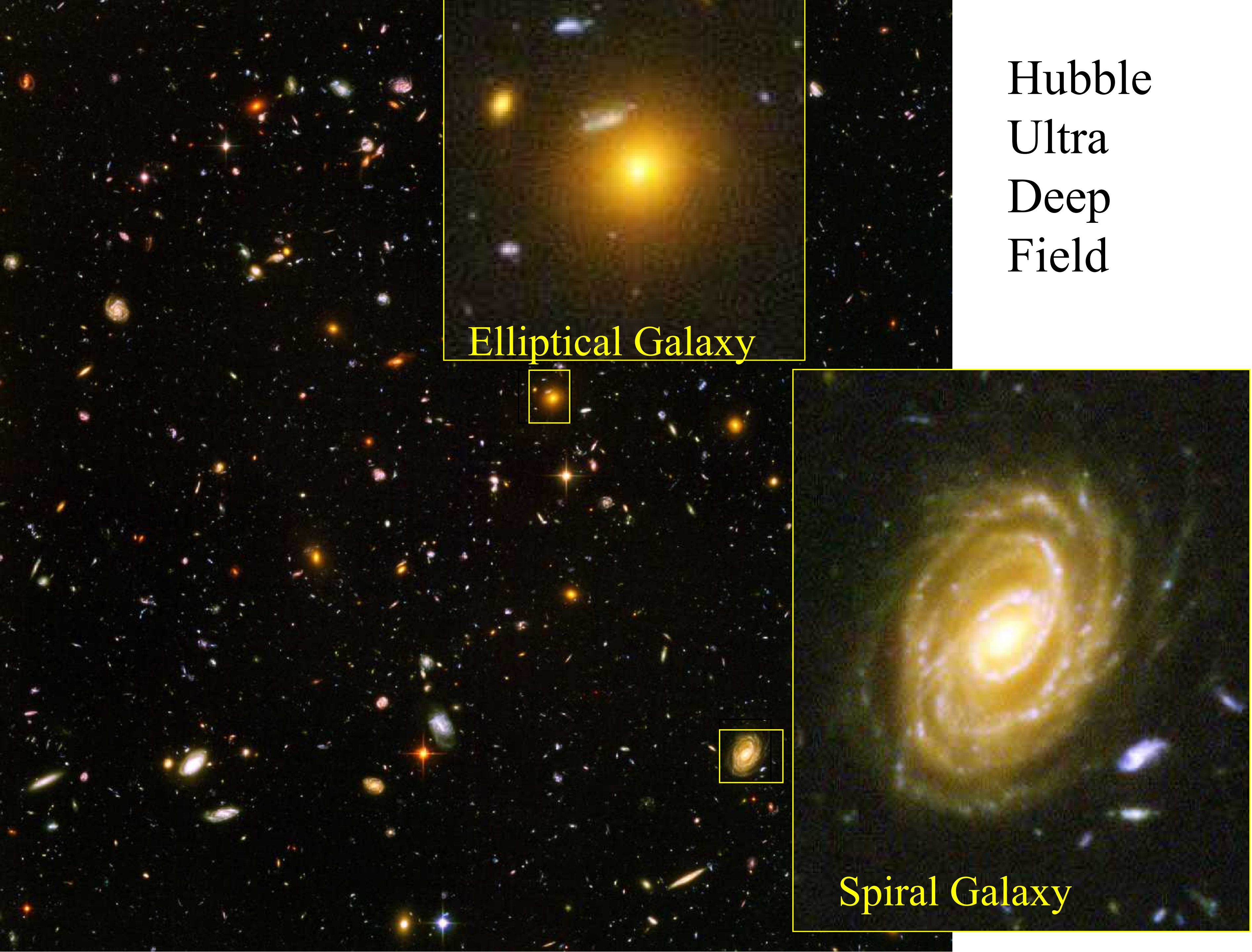

Hubble
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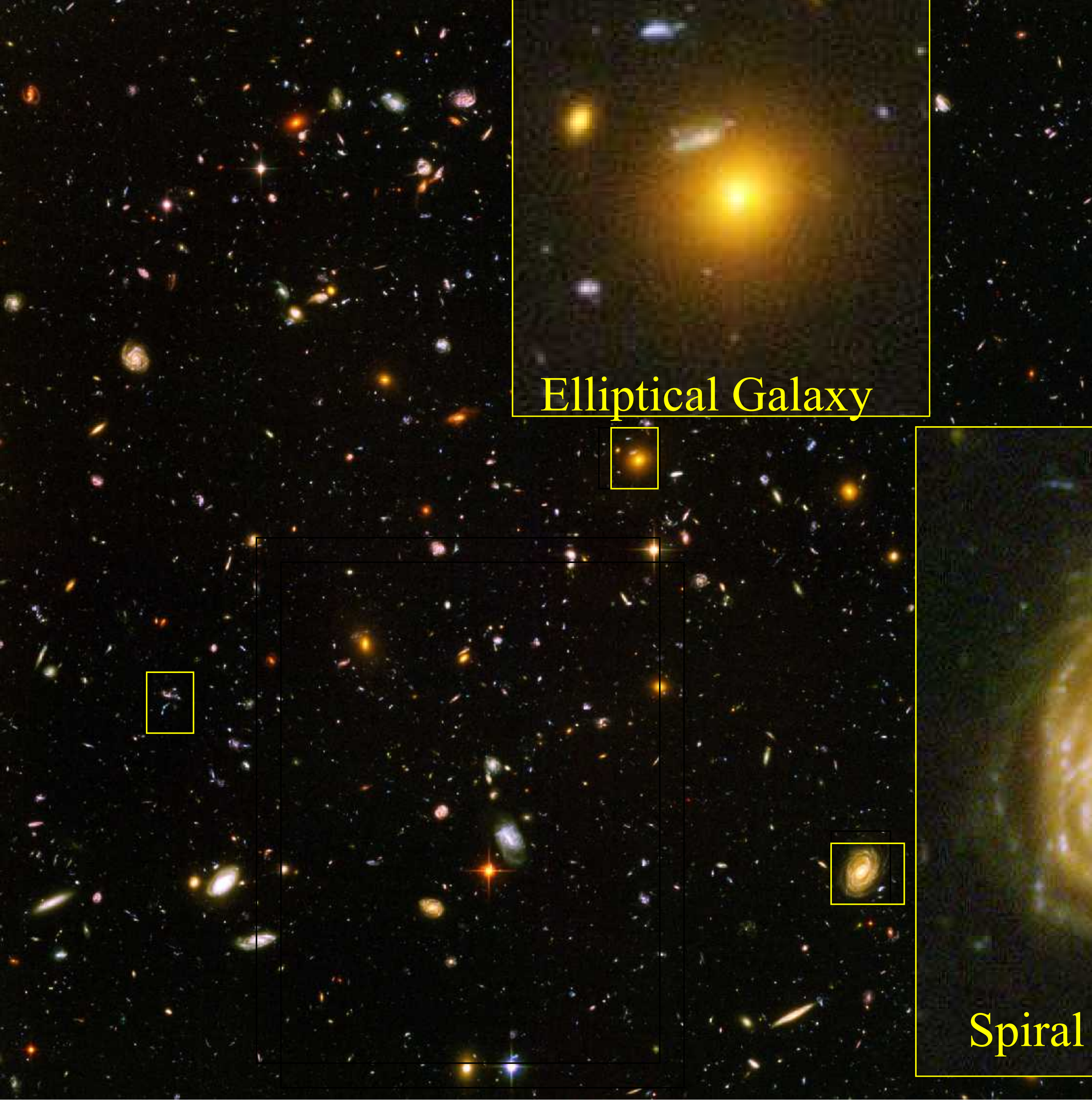
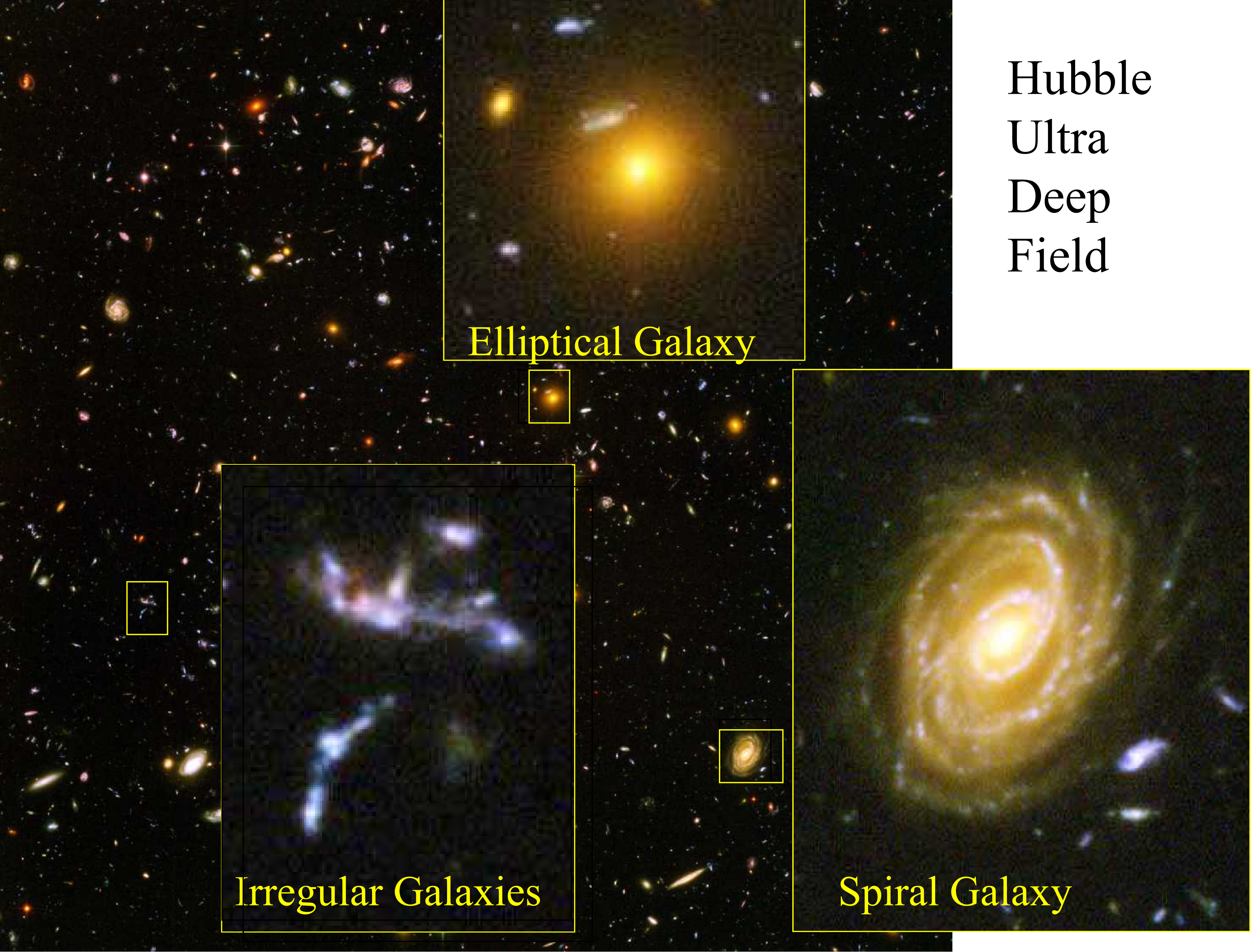
Hubble Ultra Deep Field

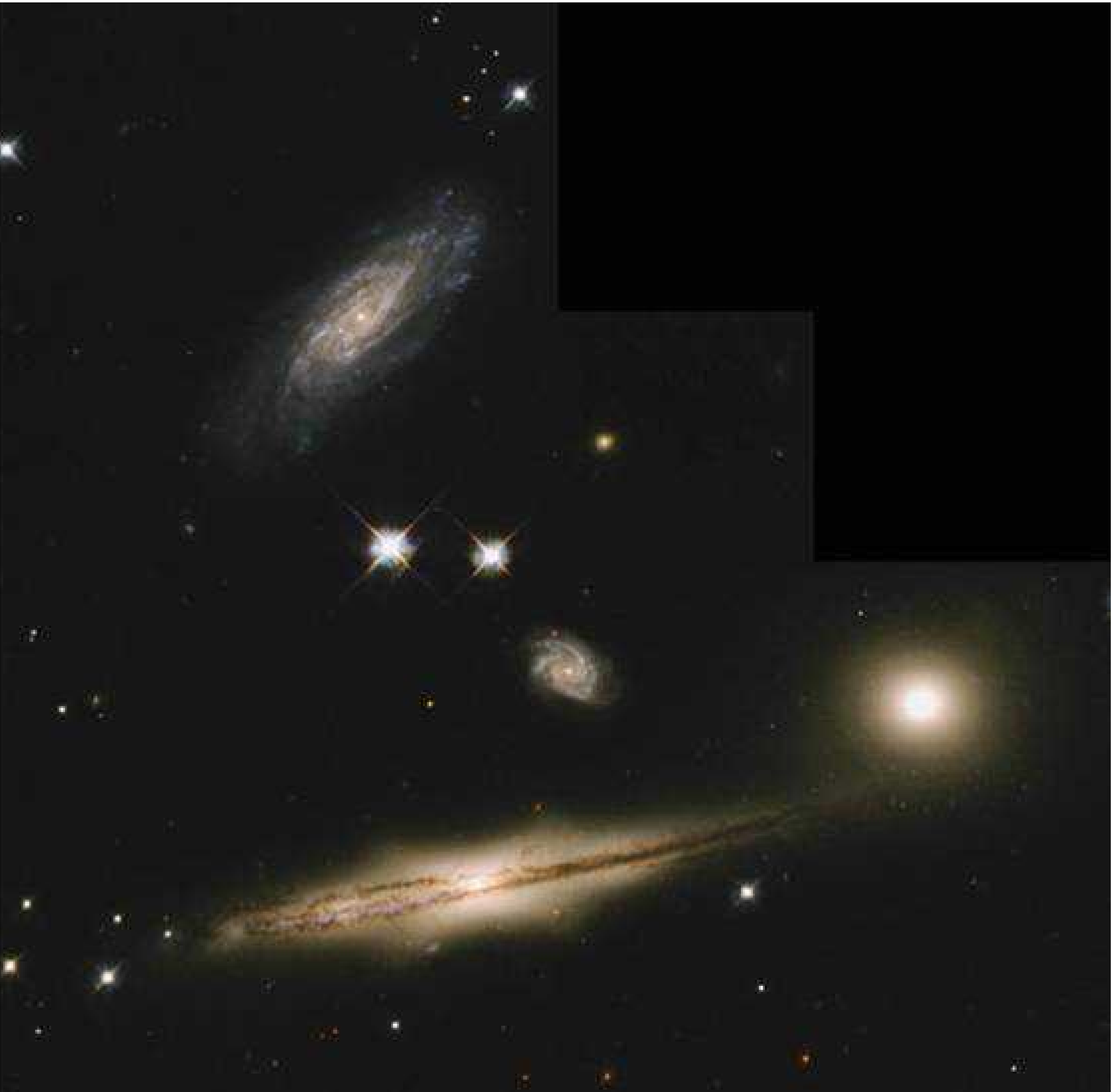


Hubble Ultra Deep Field



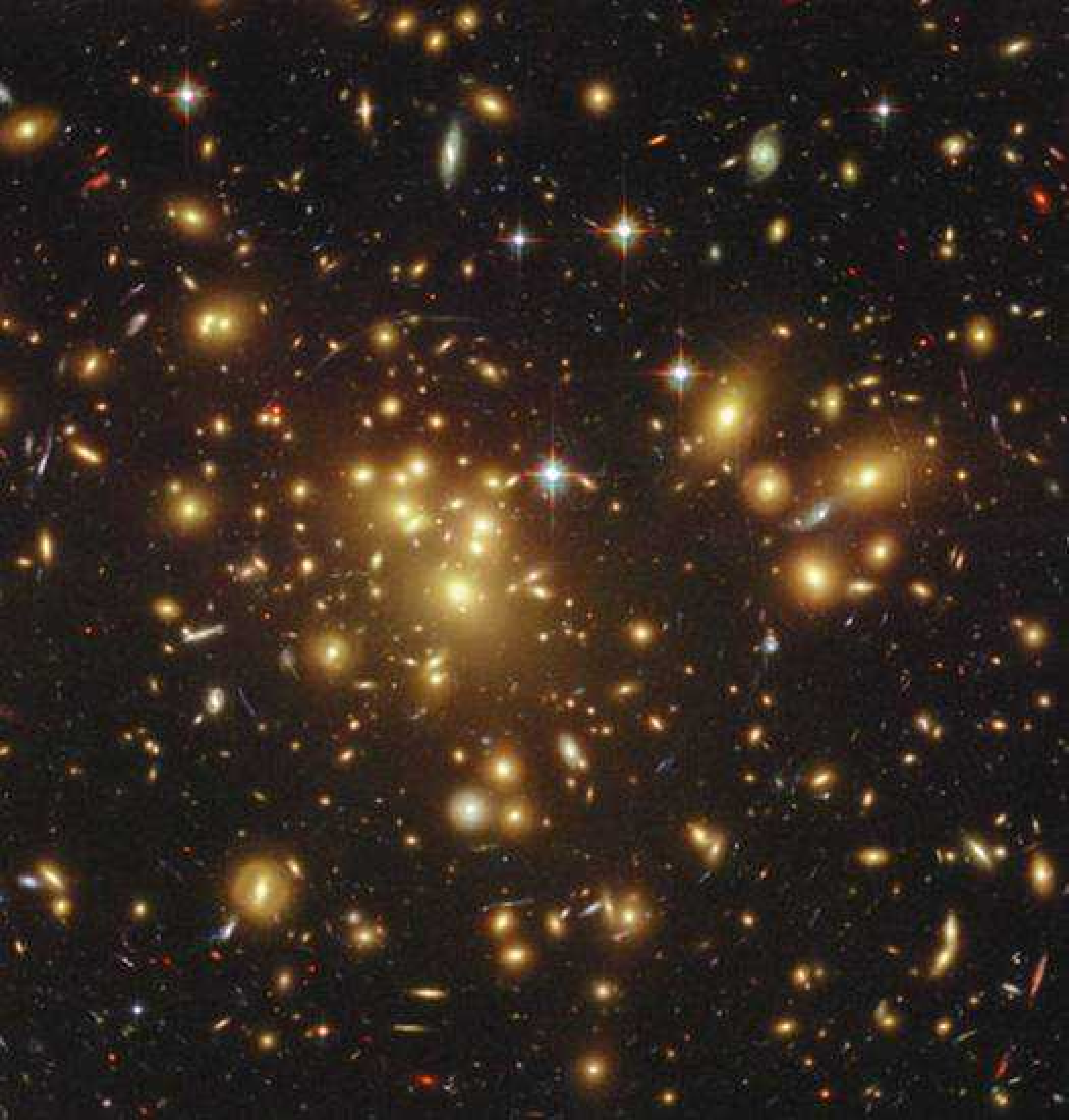
Cosmology questions

How are galaxies grouped together?



Spiral galaxies are often found in ***groups*** of galaxies

(up to a few dozen galaxies)

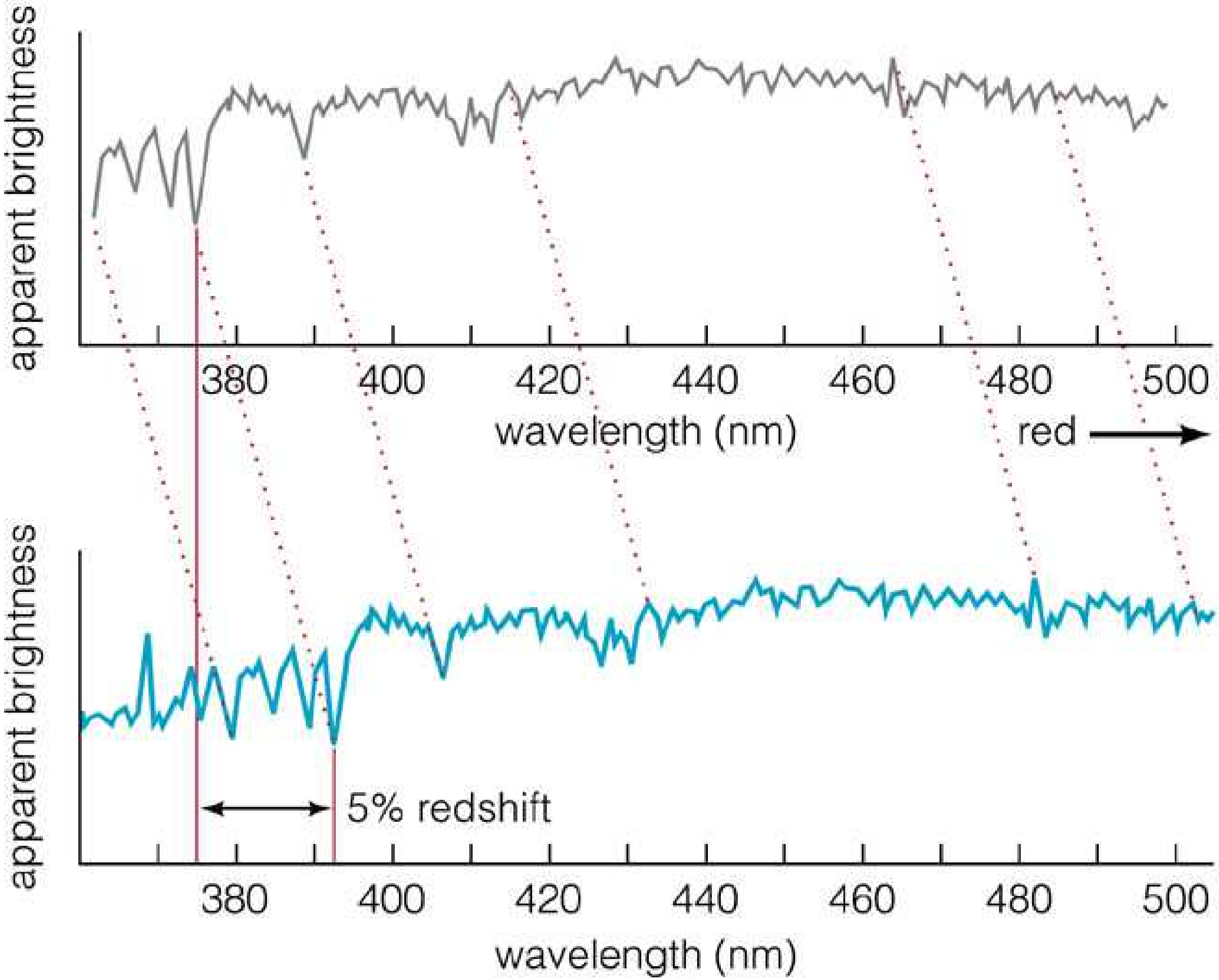


Elliptical galaxies are much more common in huge ***clusters*** of galaxies

(hundreds to thousands of galaxies)

Cosmology questions

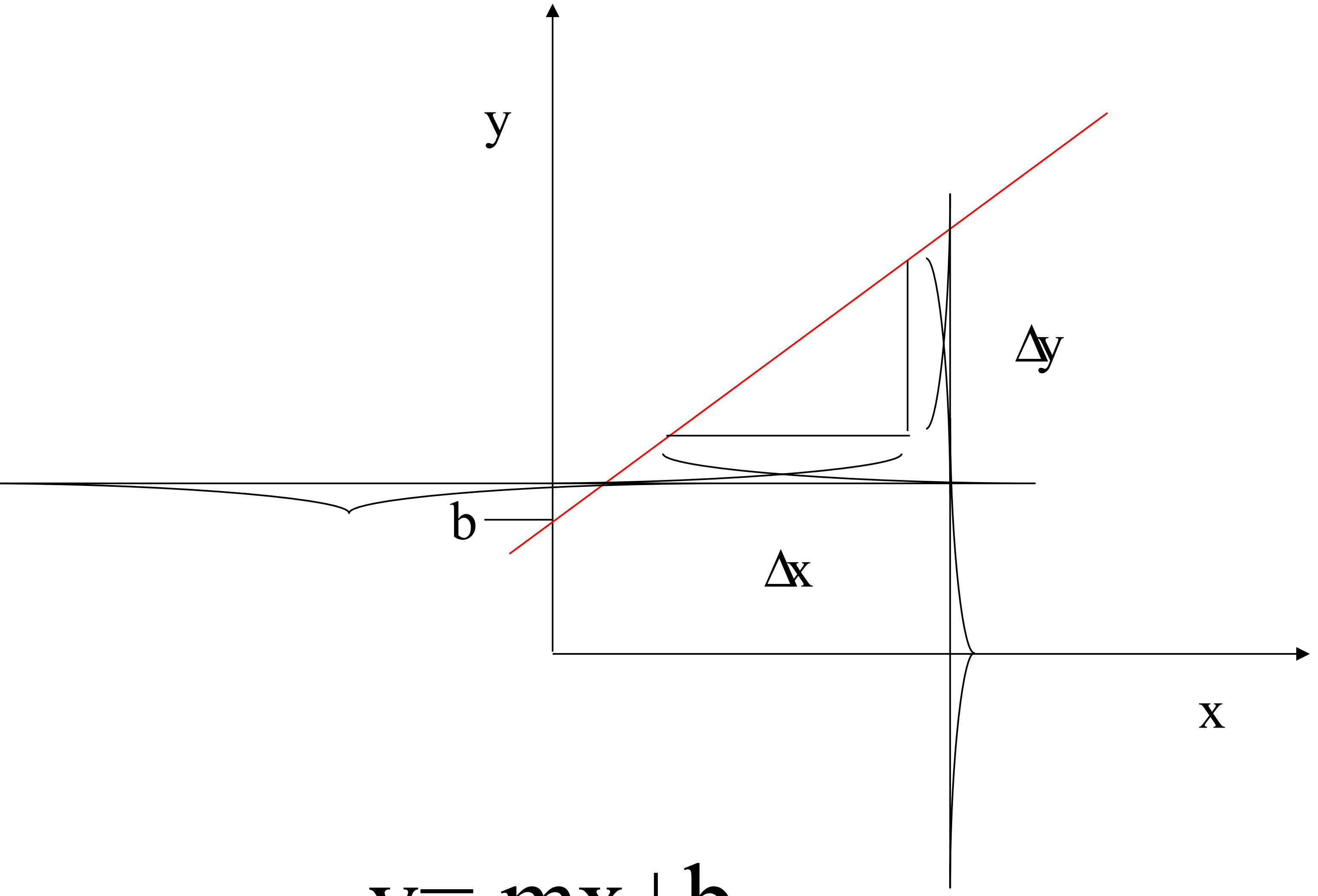
Are galaxies doing anything peculiar?



The spectral features of virtually all galaxies are ***redshifted*** They're all moving away from us

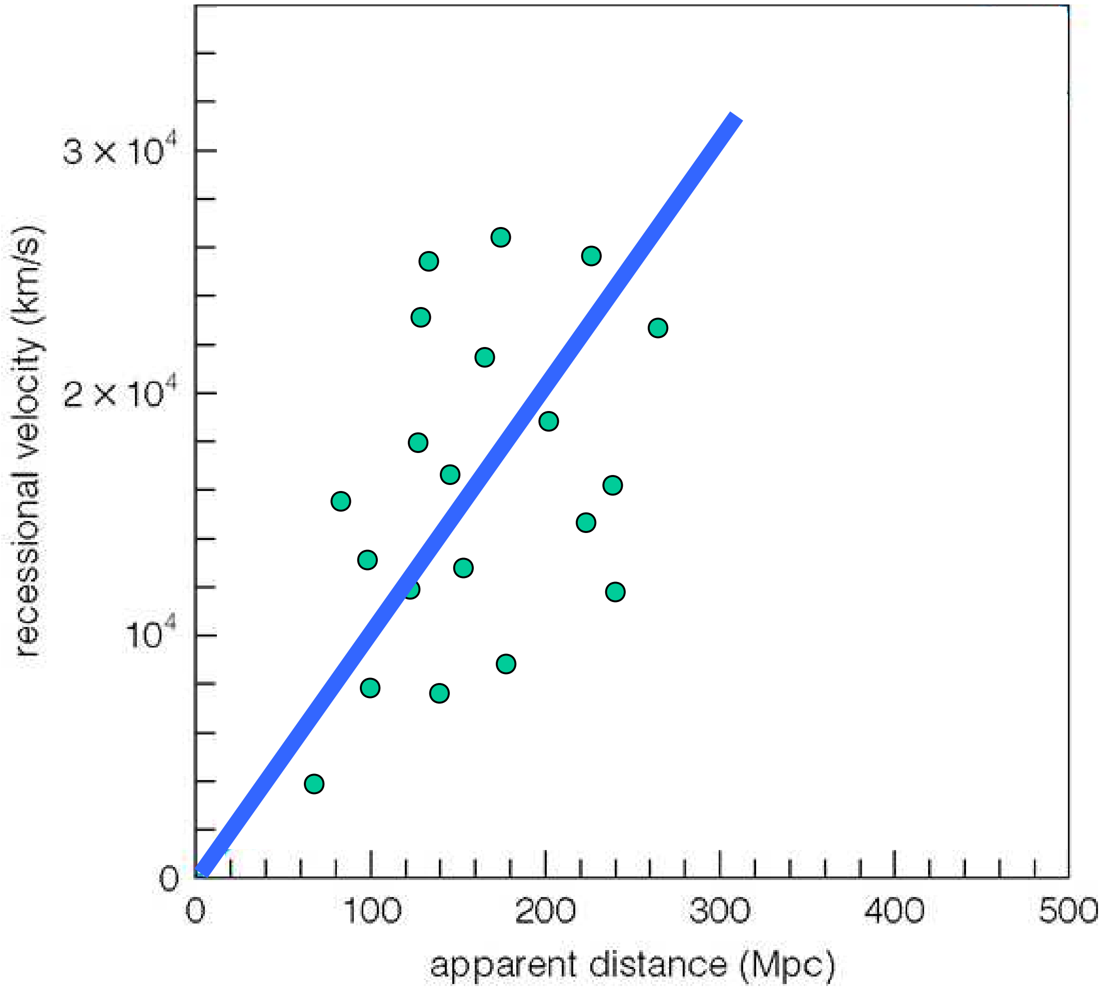
Edwin Hubble, using Cepheids as standard candles, was one of the first to measure distances to other galaxies

By measuring distances to galaxies, Hubble found that redshift and distance are related in a special way



$$y = mx + b$$

where $m = \Delta y / \Delta x$

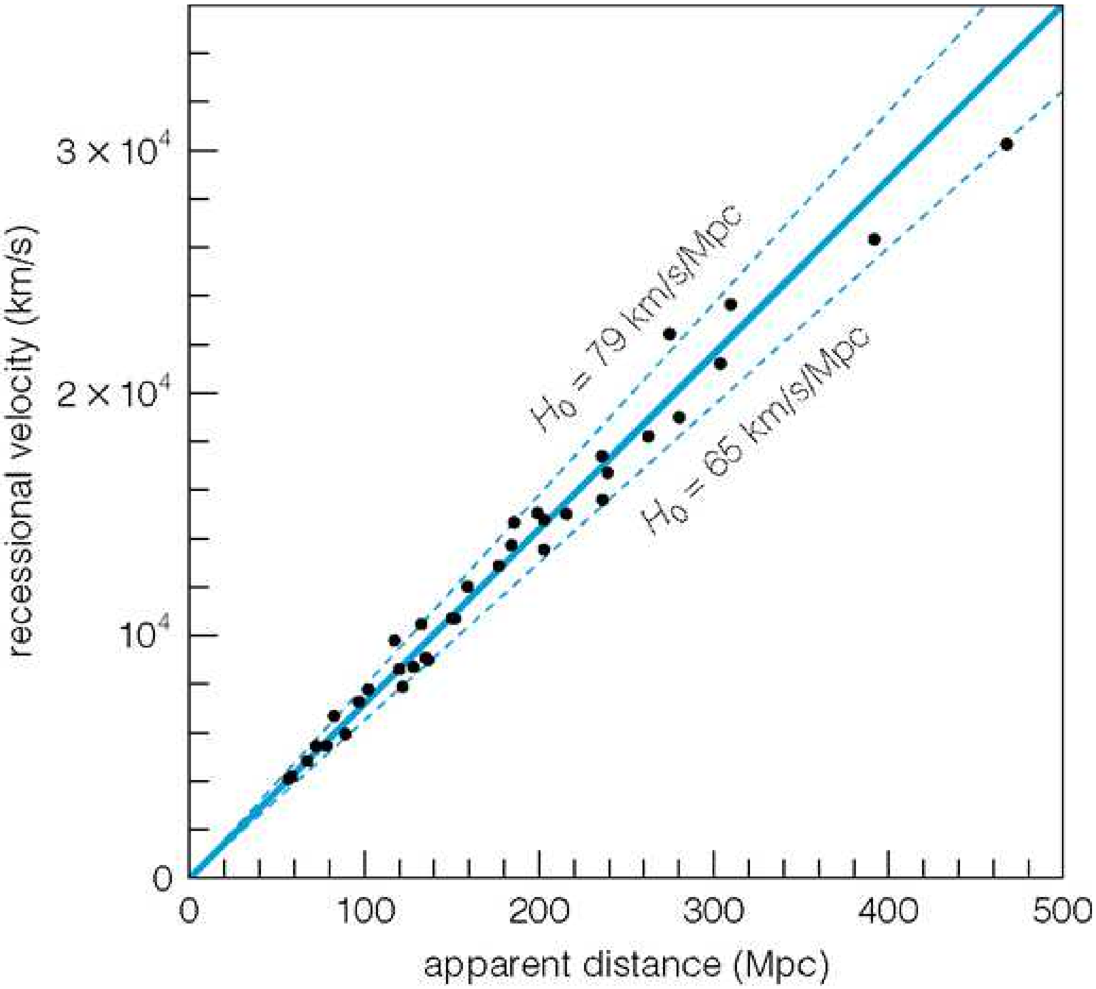


$$y \quad = \quad mx + b$$

velocity = (H0)i(distance) + 0

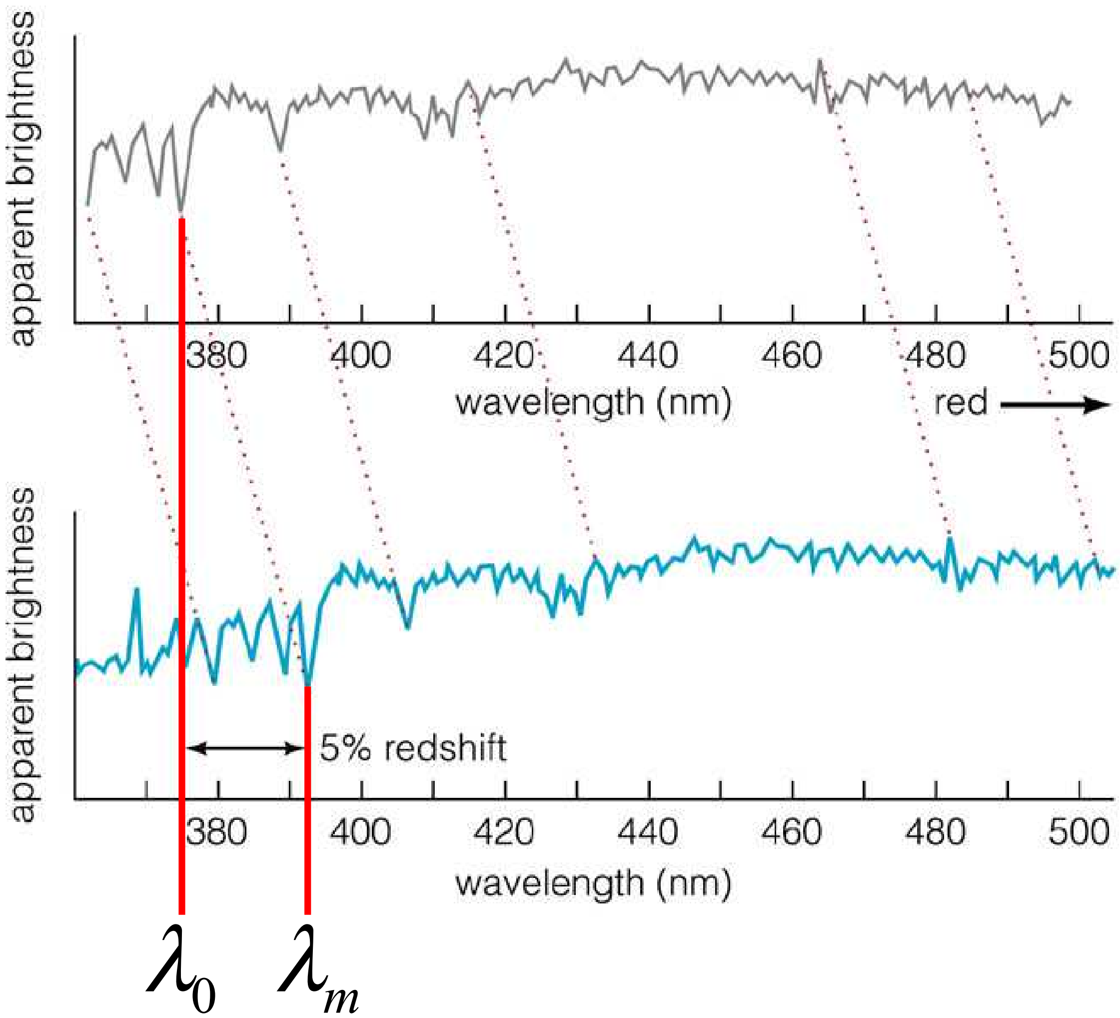
The Hubble Law

H0 is the 'Hubble constant'



The Hubble Law:

velocity = (H0)i(distance)



Redshift of a galaxy tells us its distance through Hubble's Law:

$$\text{distance} = \frac{\text{velocity}}{H0}$$

redshift (z) is defined:

$$z = \frac{\lambda_m - \lambda_0}{\lambda_0} \cong \frac{velocity}{c}$$

Homework #11

1. Hubble originally got 250 km/s Mpc for the Hubble constant. How old is the universe with that value of H0?

3. If a galaxy has a redshift of 0.02, how fast is it traveling away from us?

4. How far away is the galaxy?

Homework #11

1. Hubble originally got … for the Hubble constant. How is the universe with that value of H0?

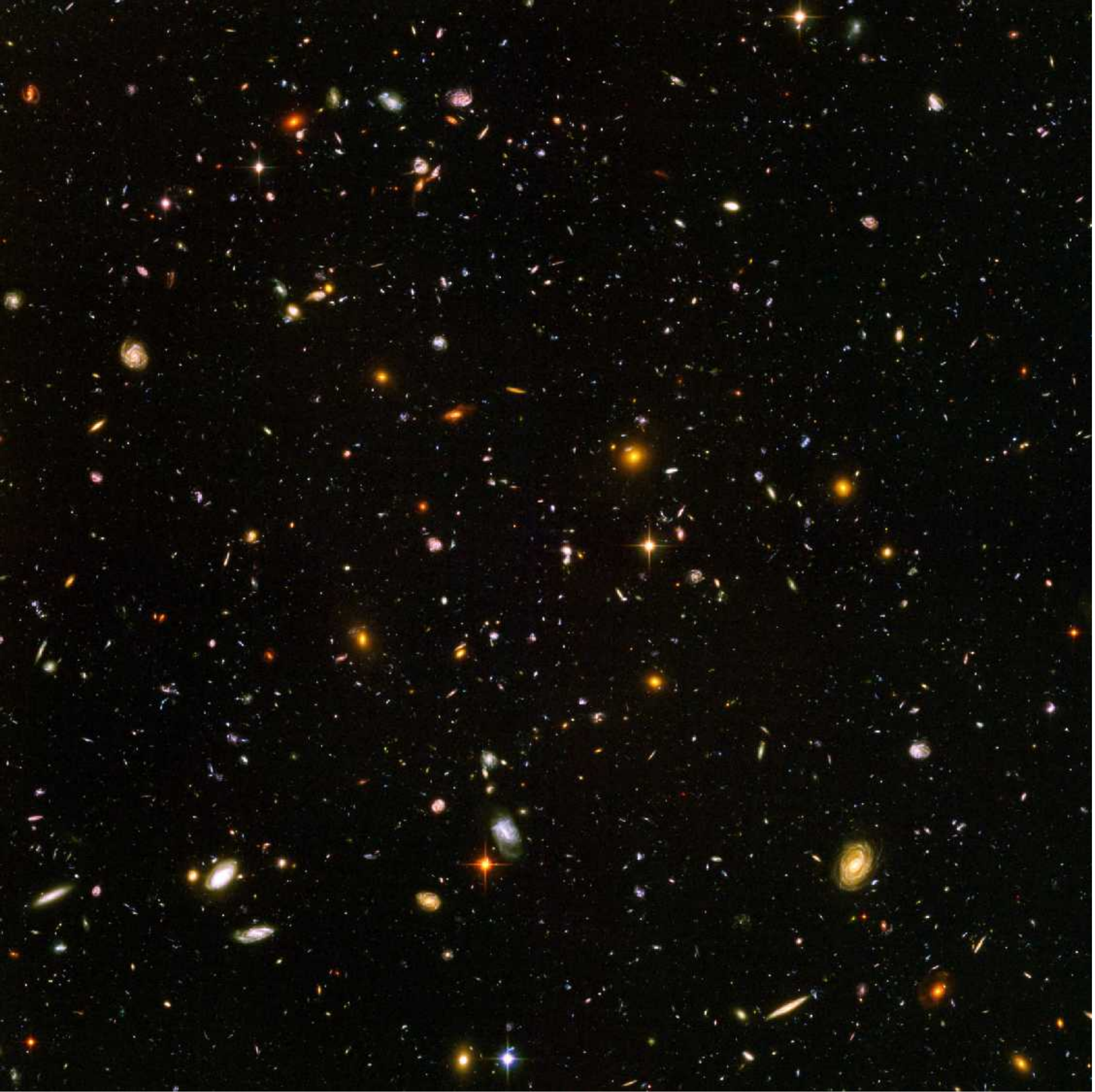
$$v_{esc} \quad \sqrt{\frac{2GM}{r}} \quad \sqrt{\frac{2(6.67 \quad 10 \quad ^{11})(6 \quad 10^{24})}{6.4 \quad 10^{6}}} \quad 1.1 \quad 10^{4}\, m/s$$

3. If a galaxy has a redshift of 0.02, how fast is it going?

4. How far away is it?

$$v_{esc} \quad \sqrt{\frac{2GM_{*}}{r_{*}}} \quad \sqrt{\frac{2(6.67 \quad 10 \quad ^{11})(2 \quad 10^{30})}{6.96 \quad 10^{8}}} \quad 6.2 \quad 10^{5}\, m/s$$

$$c^{2} = \frac{2GM_{e}}{r} \qquad r \quad = \frac{2GM_{e}}{c^{2}} = \frac{2(6.67 \quad 10^{-11})(2 \quad 10^{30})}{(3 \quad 10^{8})^{2}} = 2.96 \quad 10^{3}\, m$$



Distances of farthest galaxies are measured from redshifts

Cosmology questions

How do distance measurements tell us the age of the universe?

Thought Question

Your friend leaves your house. She later calls you on her cell phone, saying that she's been driving at 60 miles an hour directly away from you the whole time and is now 60 miles away. How long has she been gone?

A. 1 minute

B. 30 minutes

C. 60 minutes

D. 120 minutes

Thought Question

Your friend leaves your house. She later calls you on her cell phone, saying that she's been driving at 60 miles an hour directly away from you the whole time and is now 60 miles away. How long has she been gone?

A. 1 minute

B. 30 minutes

C. 60 minutes

D. 120 minutes

$$\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{60 \text{ miles}}{60 \text{ miles/hour}} = 1 \text{ hour}$$

Thought Question

Your observe a galaxy moving away from you at 0.1 light-years per year, and it is now 1.4 billion light-years away from you. How long has it taken to get there?

A. 1 million years

B. 14 million years

C. 10 billion years

D. 14 billion years

Thought Question

Your observe a galaxy moving away from you at 0.1 light-years per year, and it is now 1.4 billion light-years away from you. How long has it taken to get there?

A. 1 million years

B. 14 million years

C. 10 billion years

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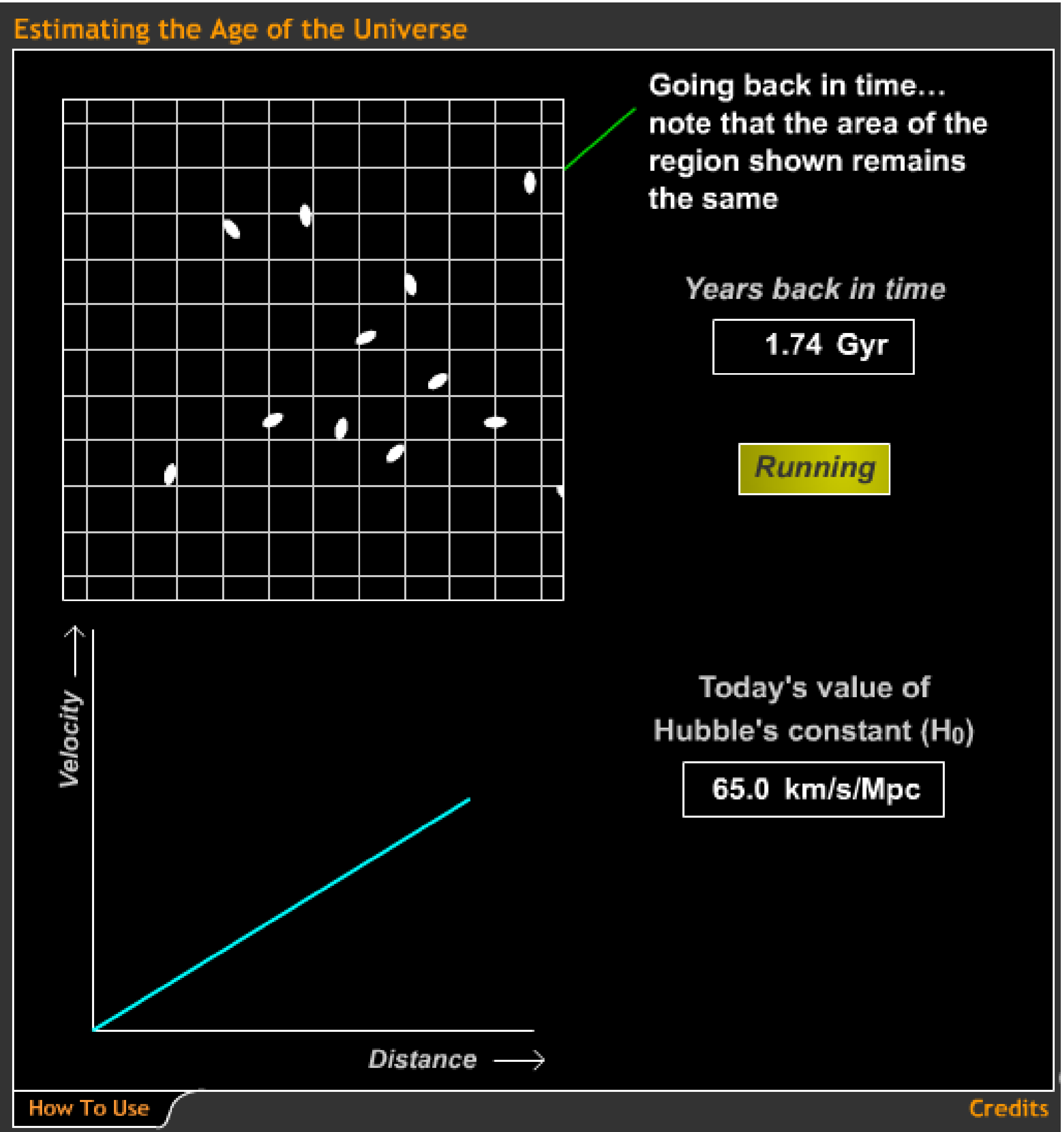
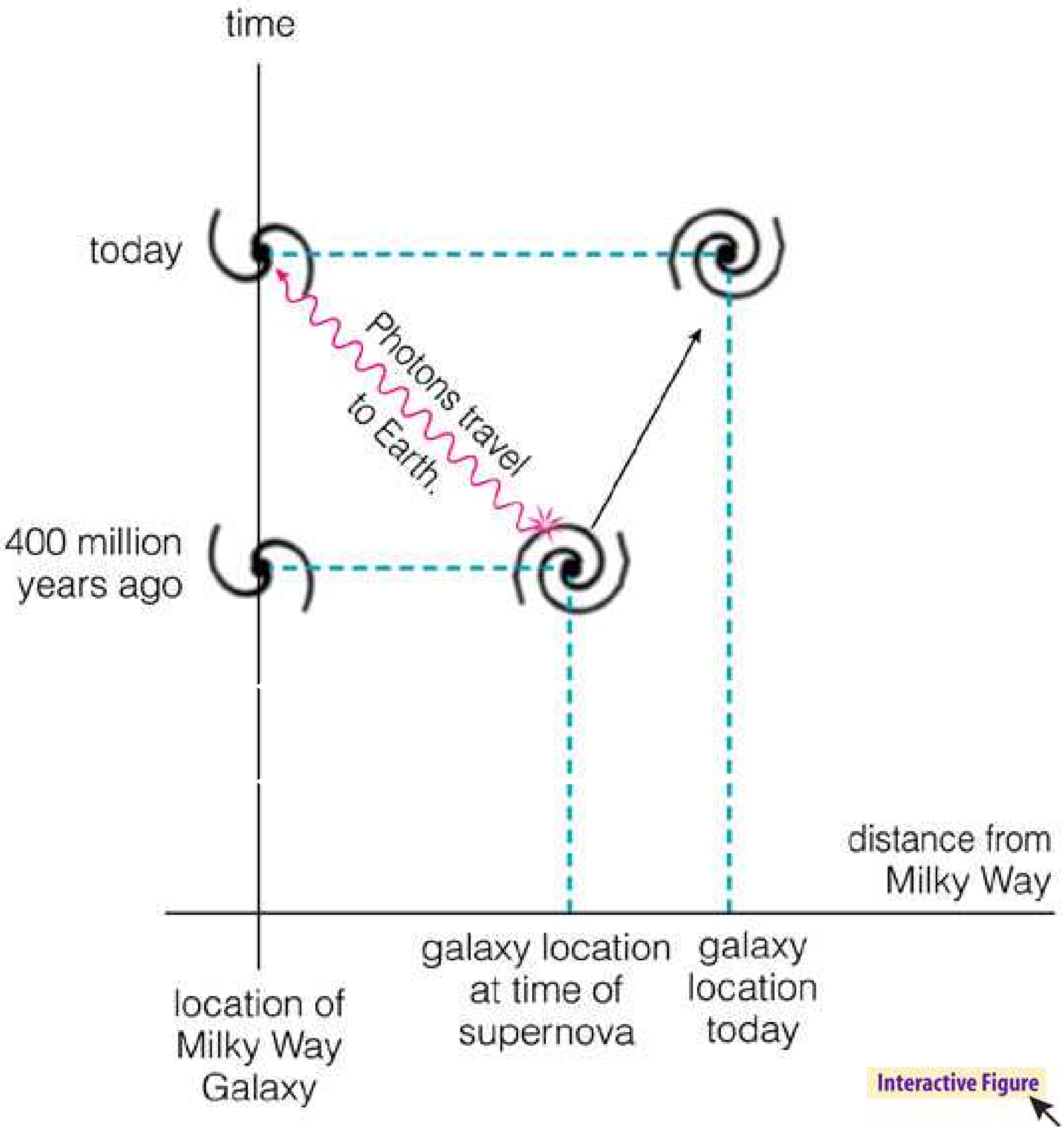
$$\text{time} = \frac{1.4 \text{ billion ly}}{0.1 \text{ ly/year}} = 14 \text{ billion years}$$



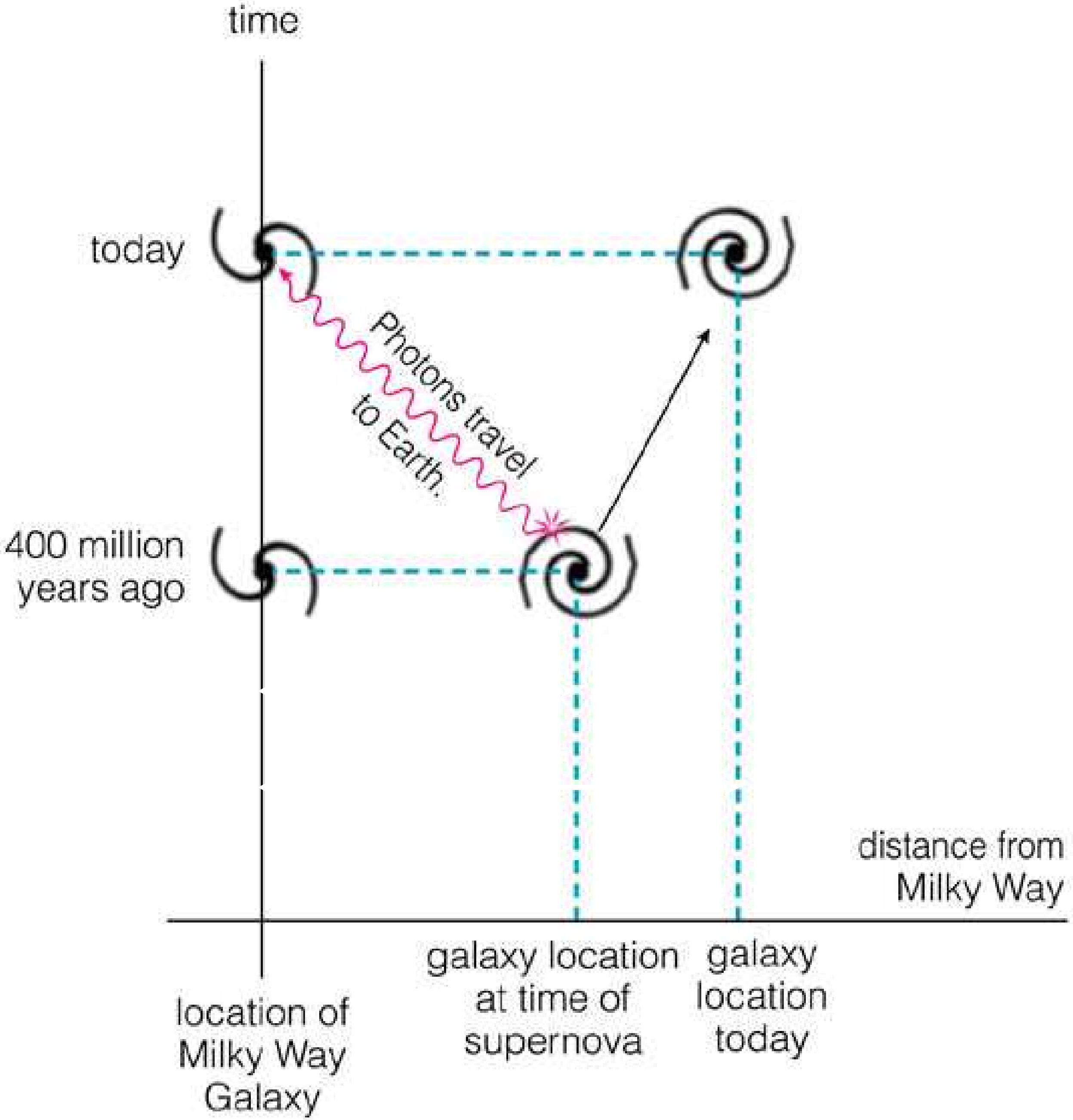
Hubble's constant tells us age of universe because it relates velocities and distances of all galaxies

$$\text{Age} = \frac{\text{Distance}}{\text{Velocity}}$$

$$\sim 1 / H0$$

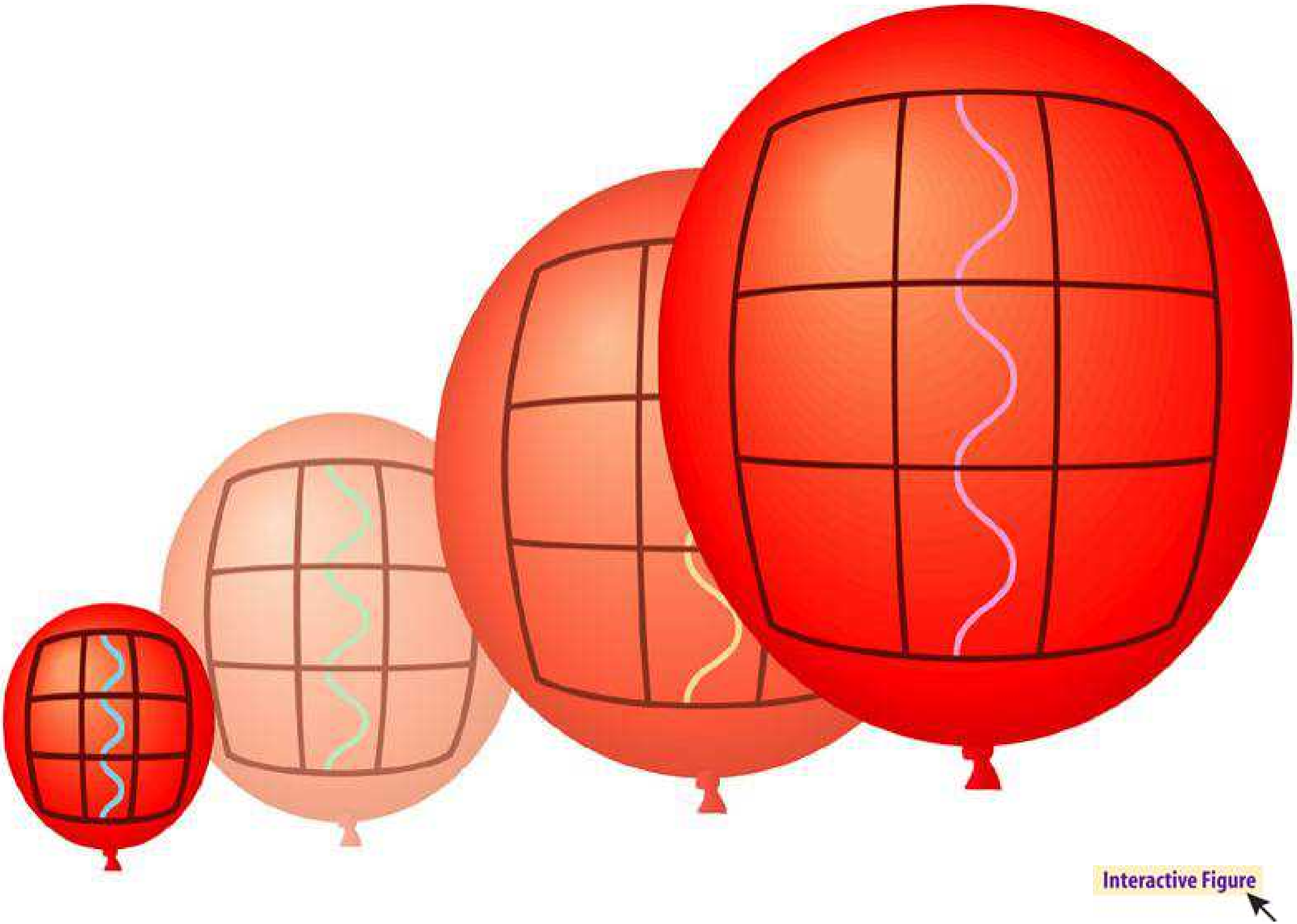


Distances between faraway galaxies change while light travels

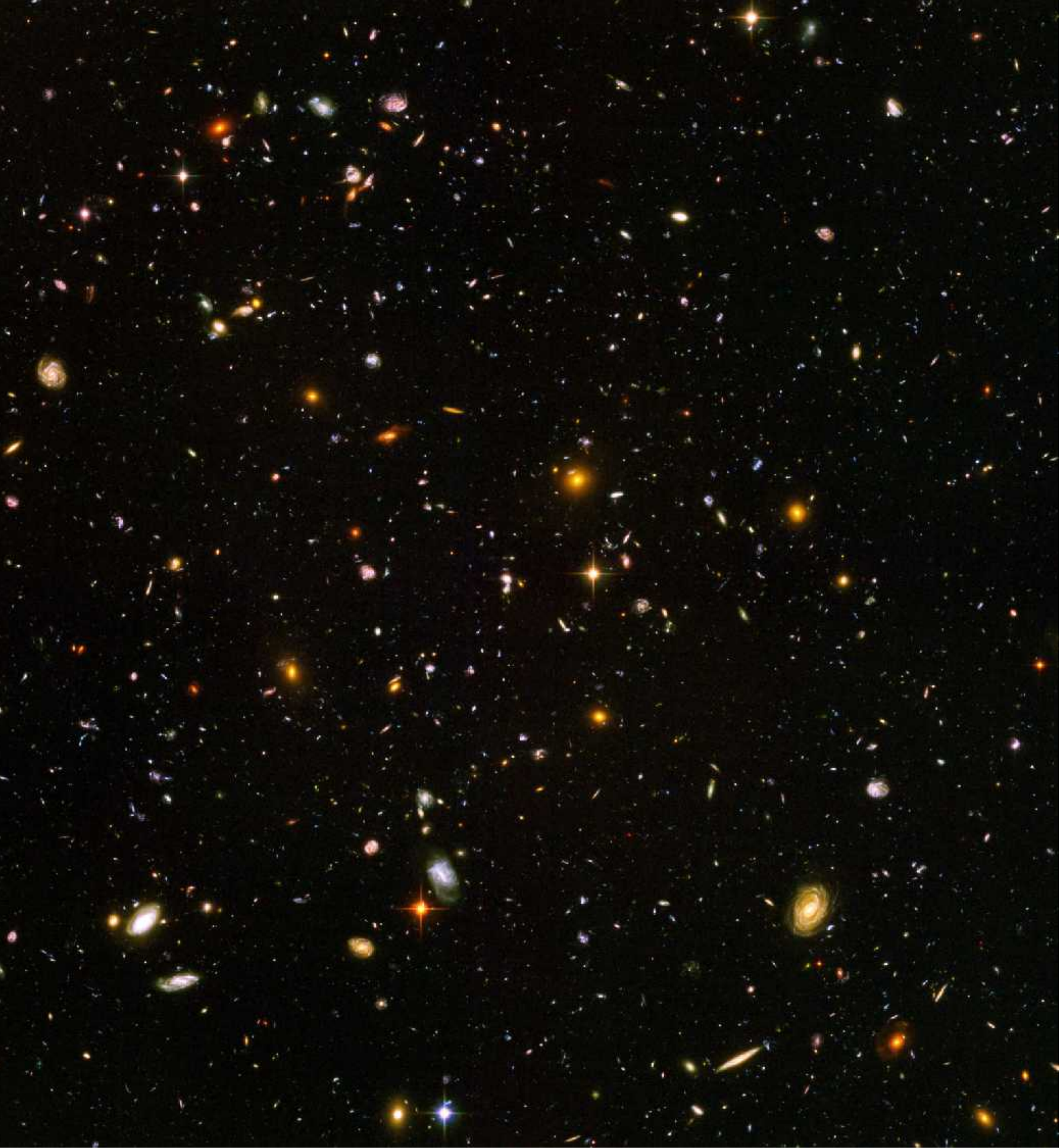


Distances between faraway galaxies change while light travels

Astronomers think in terms of ***lookback time*** rather than distance



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



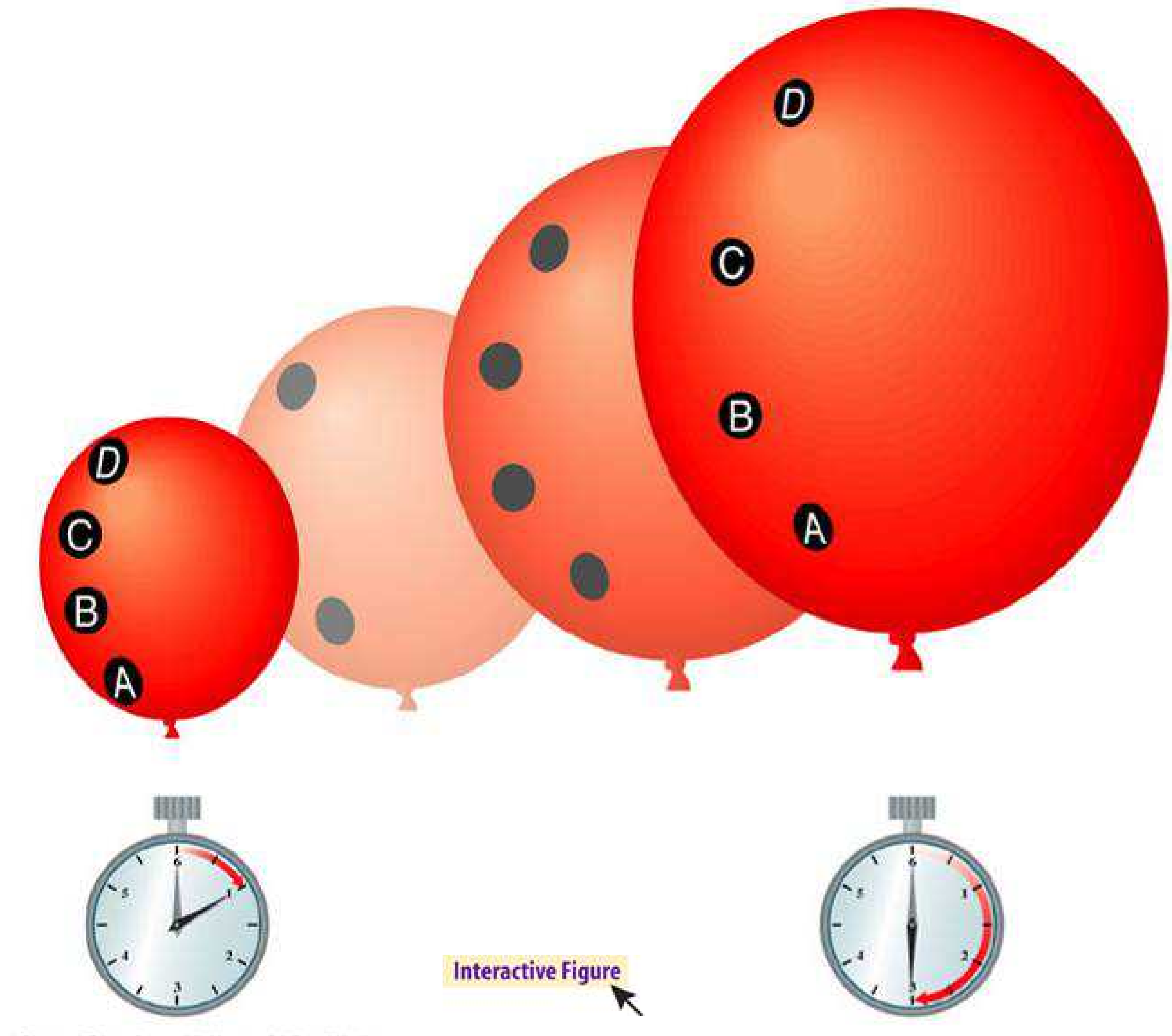
Cosmological Horizon

Maximum lookback time of 14 billion years limits how far we can see

Cosmological Principle

The universe looks about the same no matter where you are within it

- Matter is evenly distributed on very large scales in the universe
- No center & no edges



Surface of a balloon expands but has no center or edge

Cosmological Principle

The universe looks about the same no matter where you are within it

- Matter is evenly distributed on very large scales in the universe
- No center & no edges
- Not proven but consistent with all observations to date

Cosmology questions

Has the Universe changed?