

Formation of Galaxies

- Spiral versus elliptical
- Young Universe
- Collisions and Interactions
- Starbursts
- Elliptical galaxies

How was Hubble able to determine the distances of nearby galaxies?

- A) by measuring trigonometric parallaxes
- B) by observing Cepheid variables in them
- C) by measuring the expansion speeds of supernova shells
- D) by measuring their radial velocities

The Magellanic clouds are

- A) regions of star formation in the Andromeda galaxy
- B) closeby clusters of galaxies about 10 Mpc away
- C) regions of dust in the plane of the galaxy
- D) nearby irregular galaxies gravitationally bound to the Milky Way

Formation of a Spiral Galaxy

1. Stars form gradually within a protogalaxy.

2. Gas not involved in star formation collapses to form a disk.

3. A spiral galaxy results.



Formation of an Elliptical Galaxy

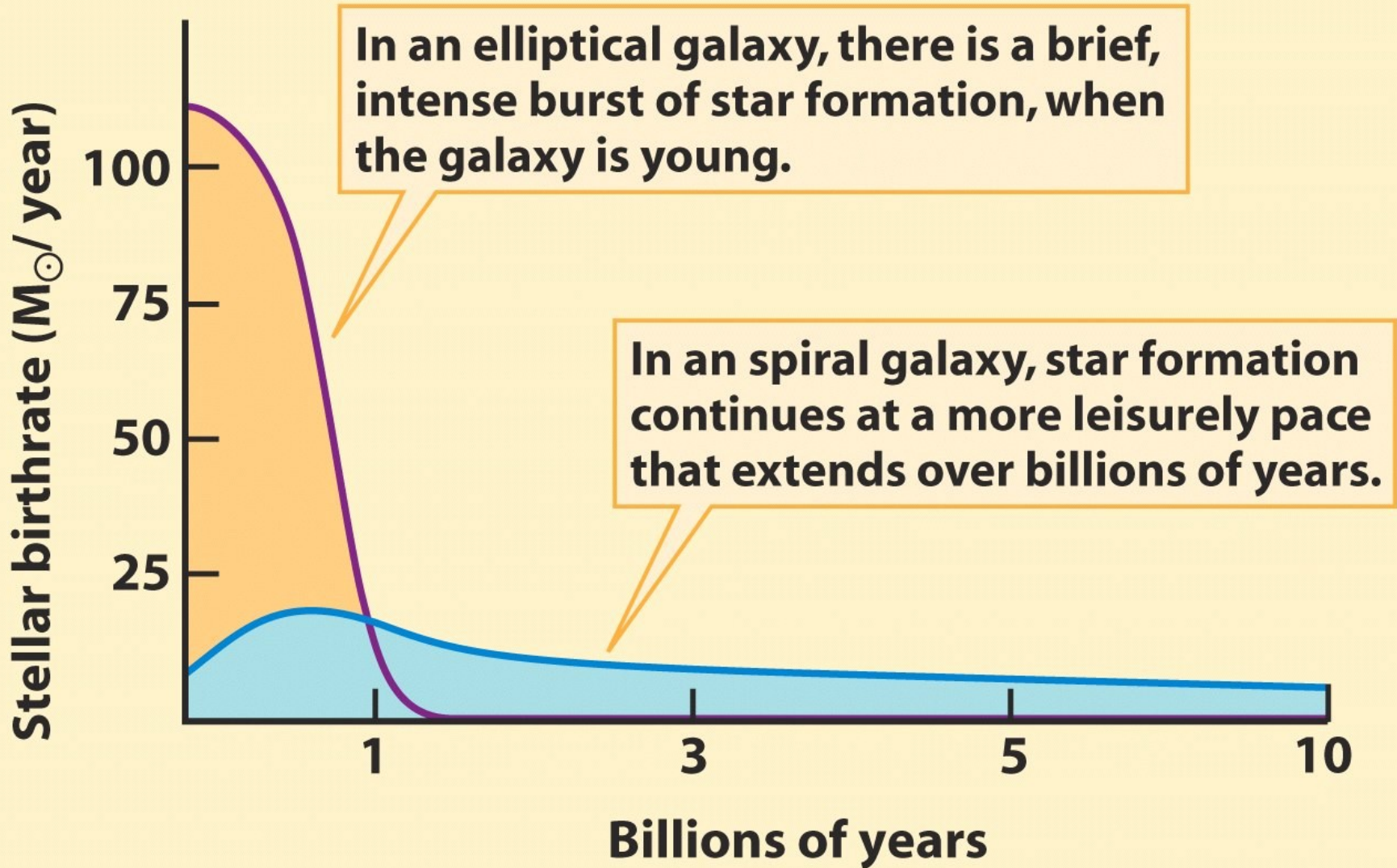
1. Stars form rapidly within a protogalaxy.

2. Gas is quickly consumed to make stars.

3. A elliptical galaxy results.



Stellar Birthrate in Galaxies



Formation of Galaxies

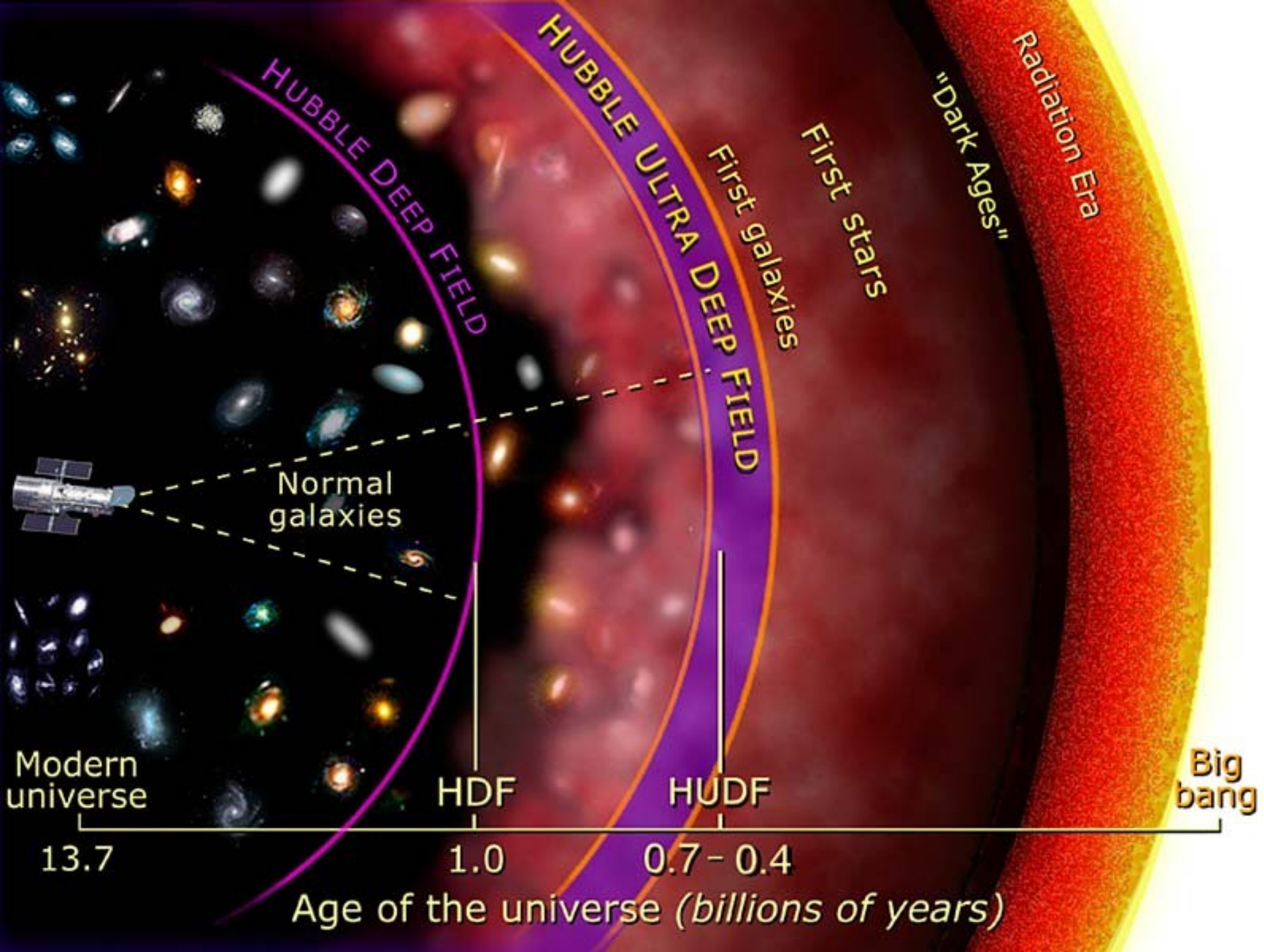
- This picture of galaxy formation is incomplete
- Mergers, collisions, and interactions between galaxies are very important in their formation, particularly in the early stages of the Universe (why?)

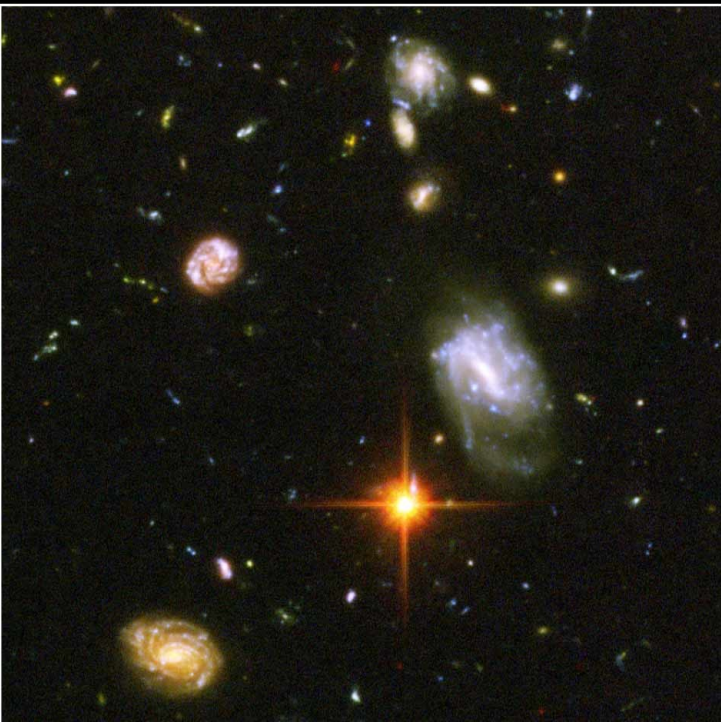
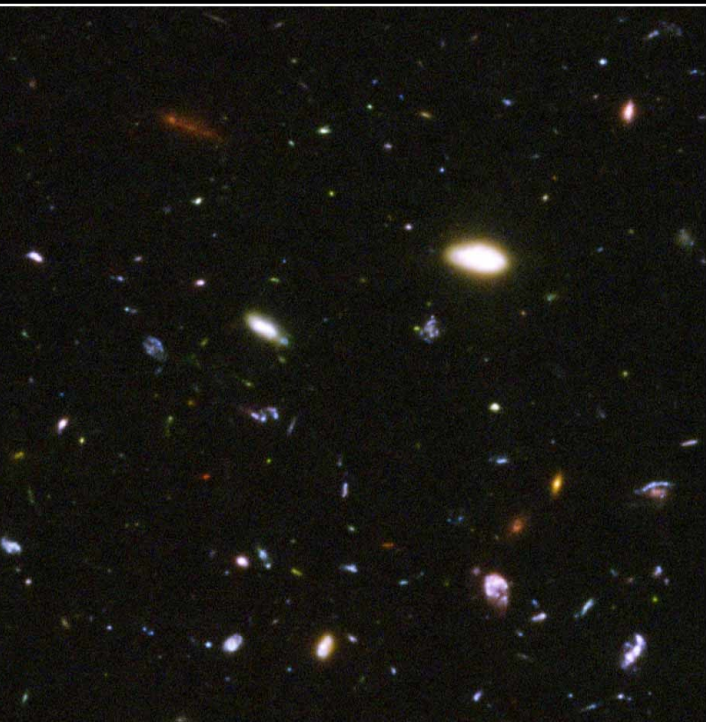
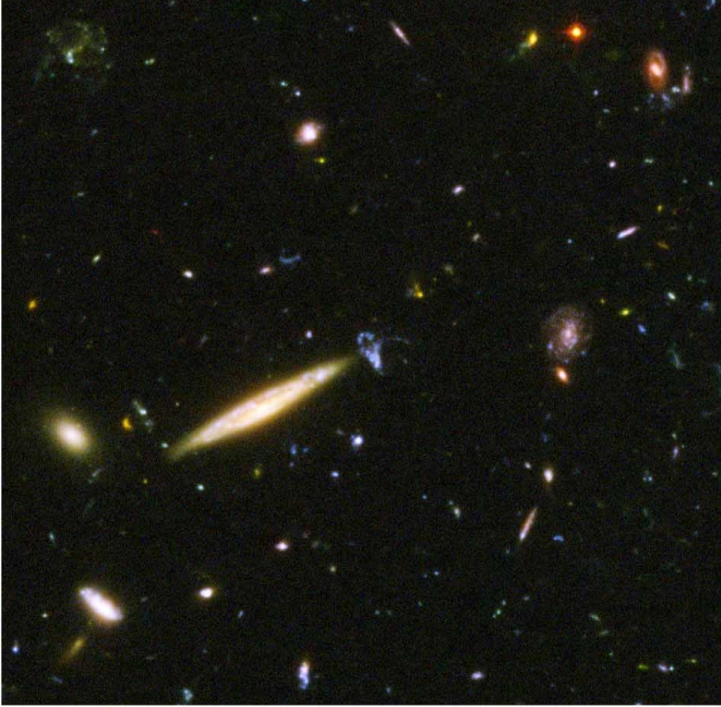
Expansion of the Universe

- The Universe is expanding
- This means that the Universe used to be smaller
- In the early stages of the Universe galaxies were closer together, therefore, they interacted more
- Since galaxies can merge, there were also more galaxies in the past



Young Universe







In which type of galaxy are star's orbits distributed in random directions?

- A) elliptical galaxies
- B) spiral galaxies
- C) barred spiral galaxies
- D) blue galaxies

Early in the history of the universe, which
was NOT true?

- A) galaxies were closer together
- B) there were more galaxies
- C) galaxies interacted more frequently
- D) there were more elliptical galaxies

Colliding galaxies



The Mice



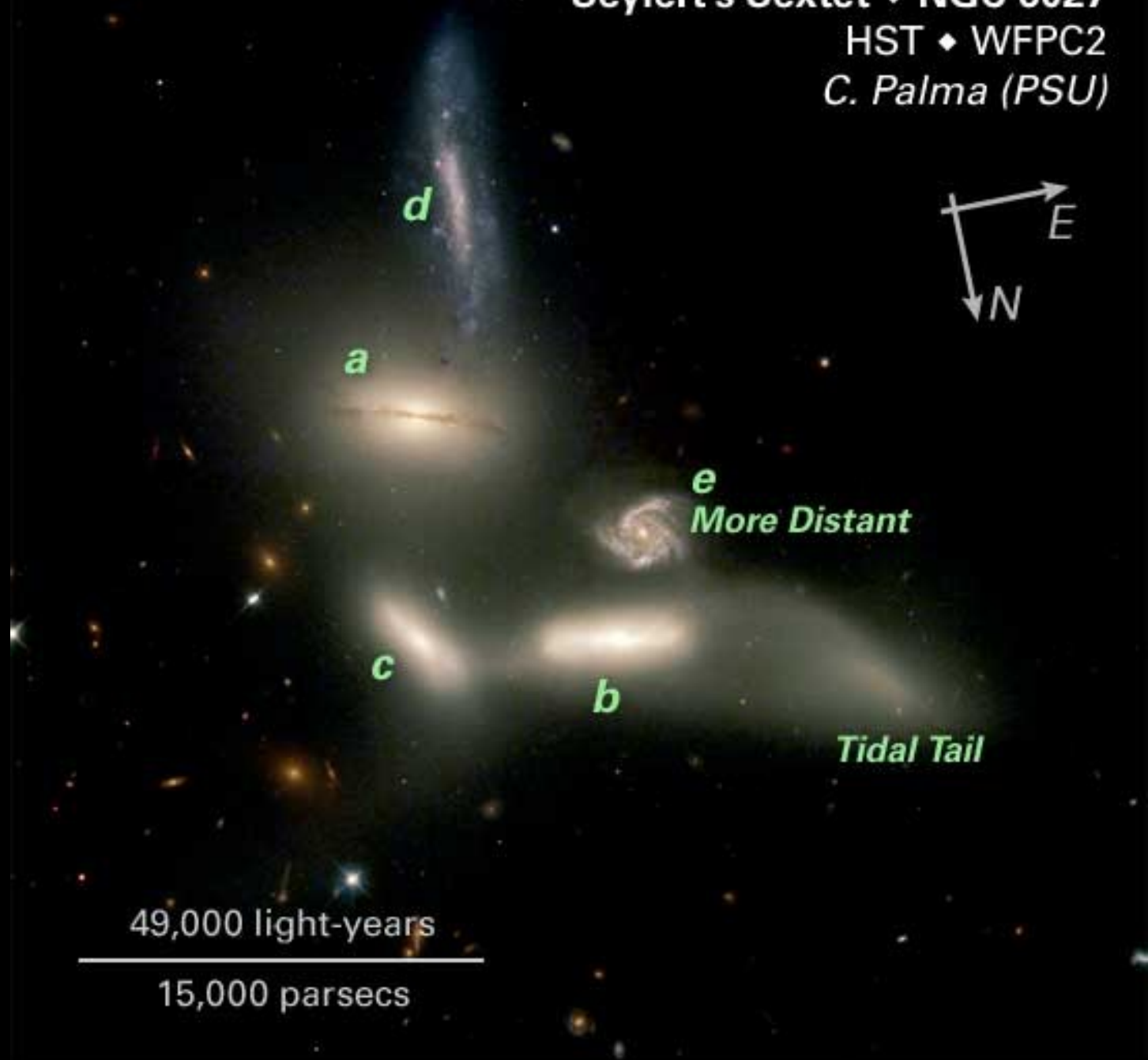
Cartwheel galaxy



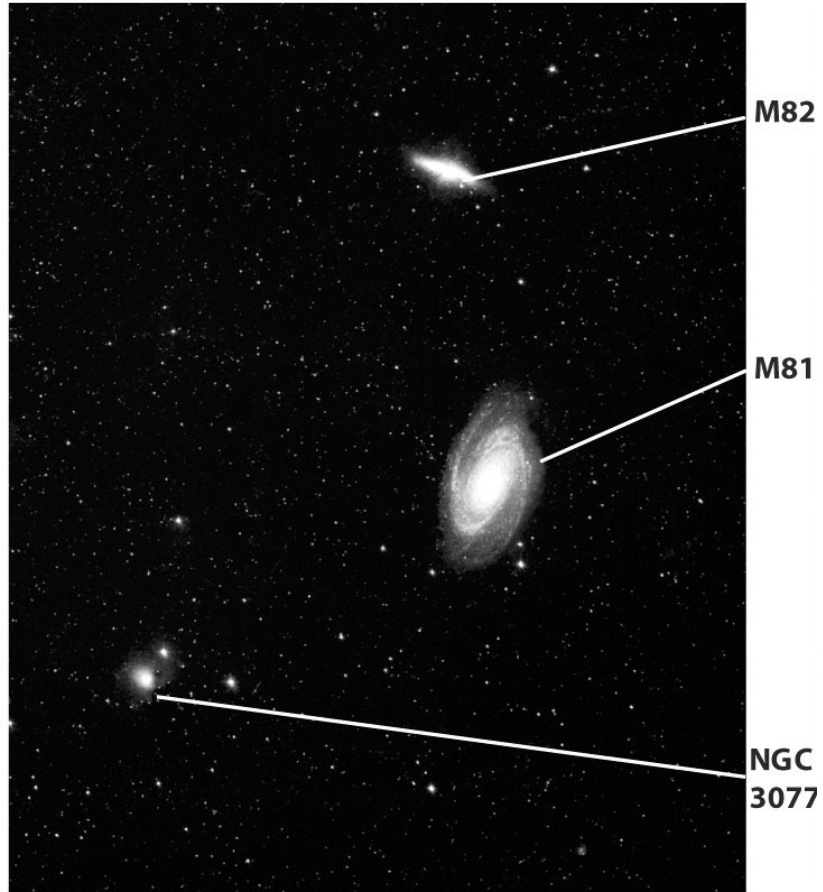
Seyfert's Sextet ♦ NGC 6027

HST ♦ WFPC2

C. Palma (PSU)

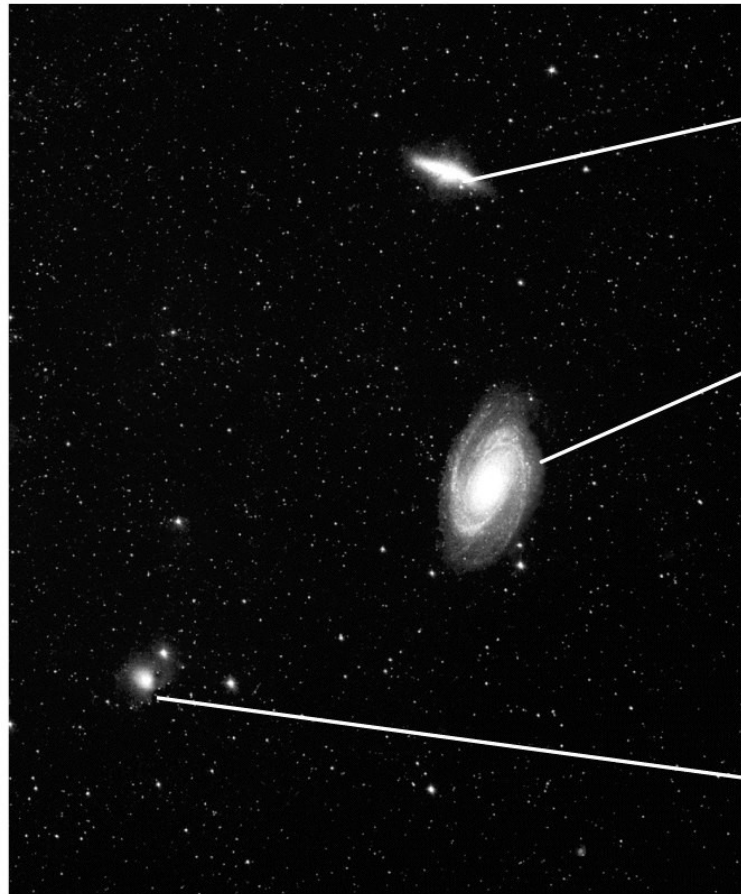


Interacting galaxies

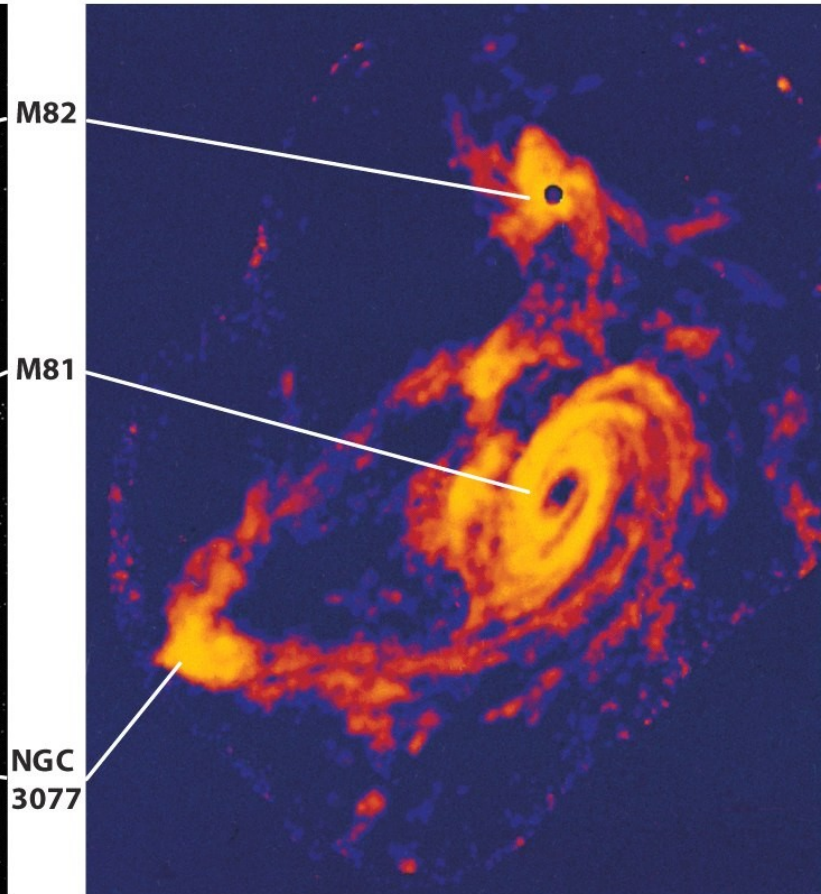


(a)

Interacting galaxies



(a)



(b)

Starburst galaxy – M82



The 'Medusa' in **optical** and **X-rays**



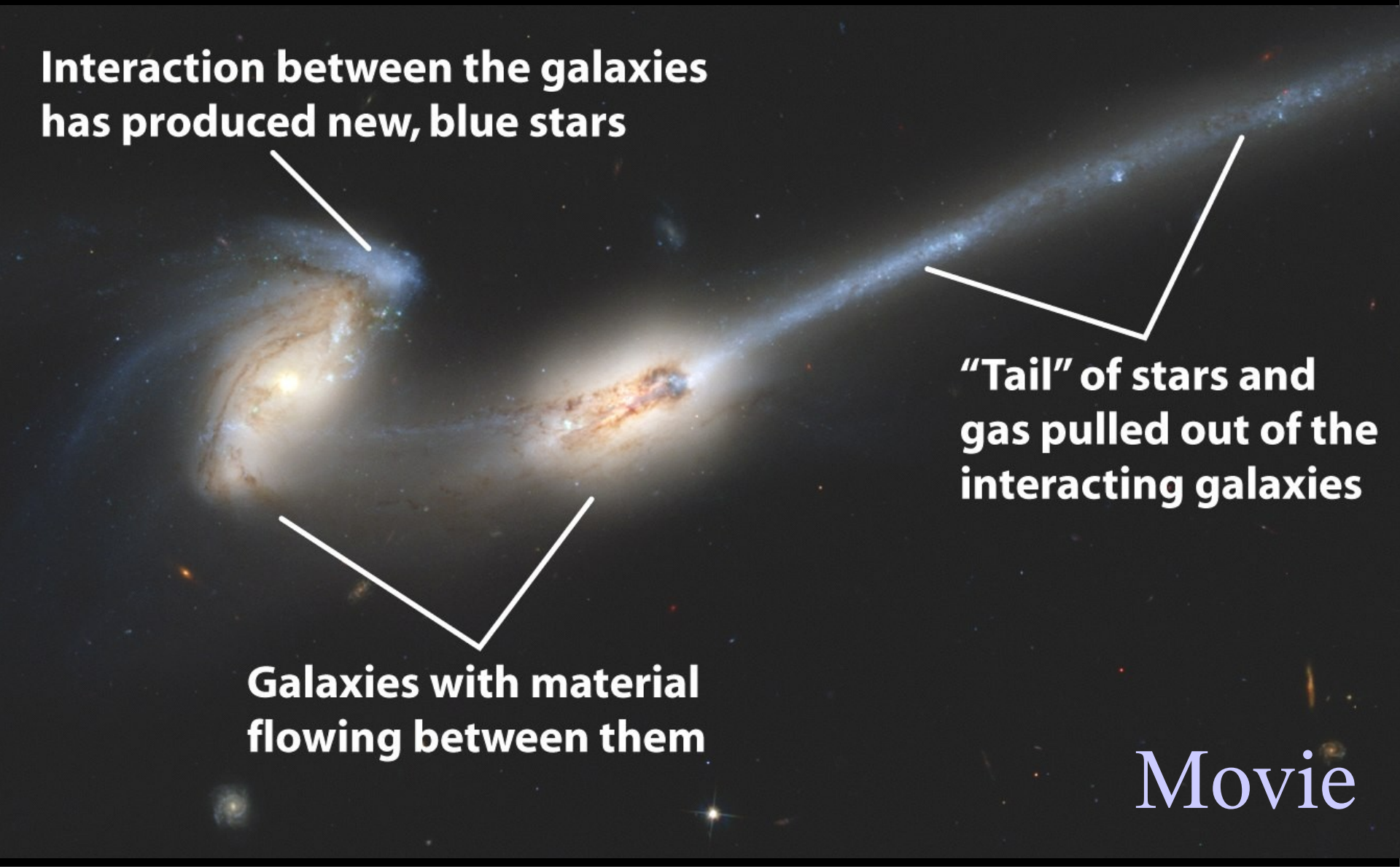
Colliding galaxies

**Interaction between the galaxies
has produced new, blue stars**

**"Tail" of stars and
gas pulled out of the
interacting galaxies**

**Galaxies with material
flowing between them**

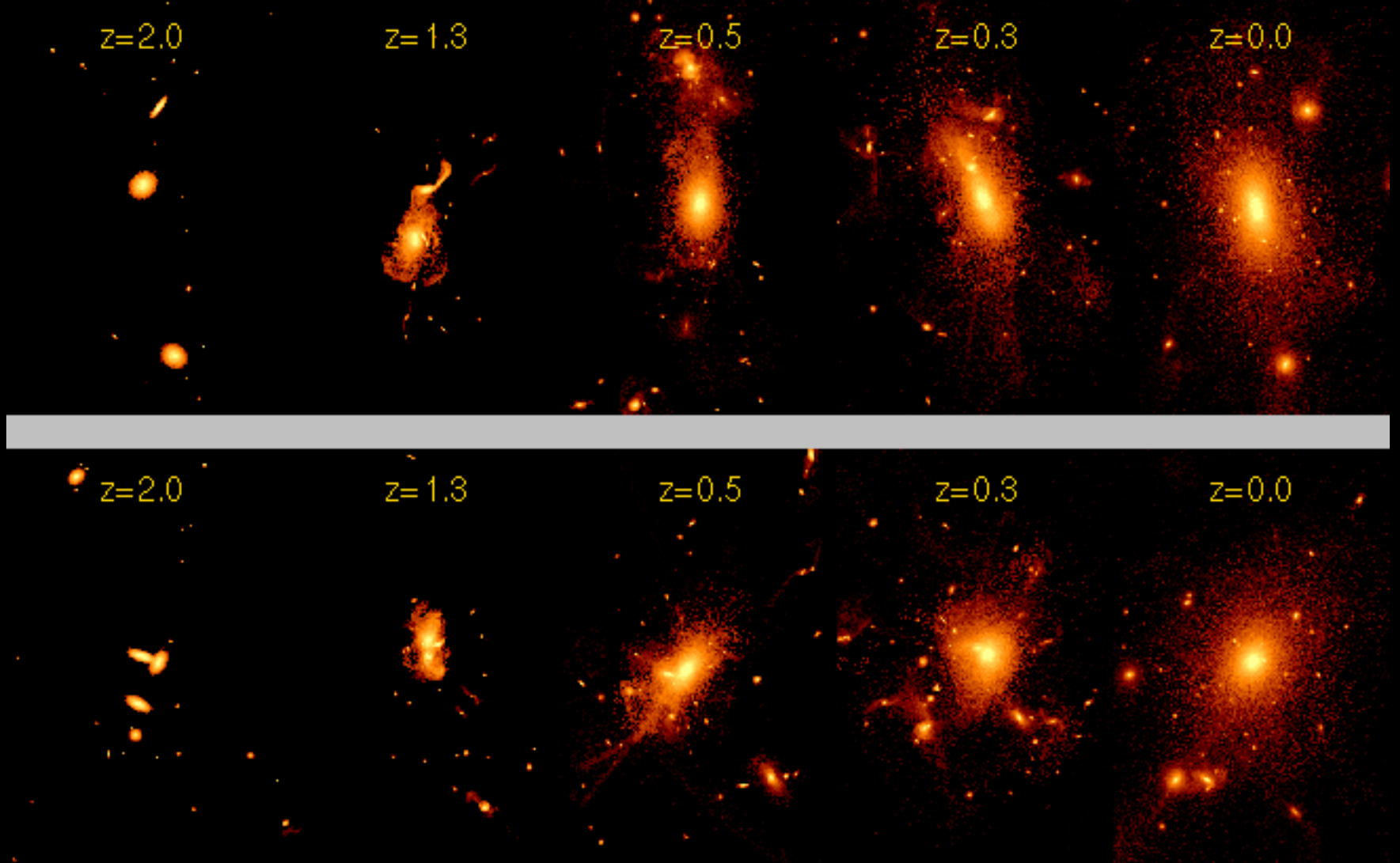
Movie



Galaxy interactions

- Interactions can rip stars out of galaxies, producing tidal tails
- Interactions can disturb gas in and between galaxies, producing starbursts
- Collisions can randomize stellar orbits leading to the formation of elliptical galaxies

Formation of an Elliptical Galaxy



Movie

Galaxy growth via interactions

- Galaxies initially form from mergers of several gas clouds
- Galaxies then are changed by interactions
- Galaxies grow gradually by galactic cannibalism
- Interactions disturb gas leading to starbursts
- Collisions can randomize stellar orbits leading to the formation of elliptical galaxies

Review Questions

- How are elliptical versus spiral versus irregular galaxies formed?
- How do the star formation histories of elliptical versus spiral galaxies differ?
- Why do galaxy interactions tend to cause star formation?
- Was the population of galaxies different in the past?