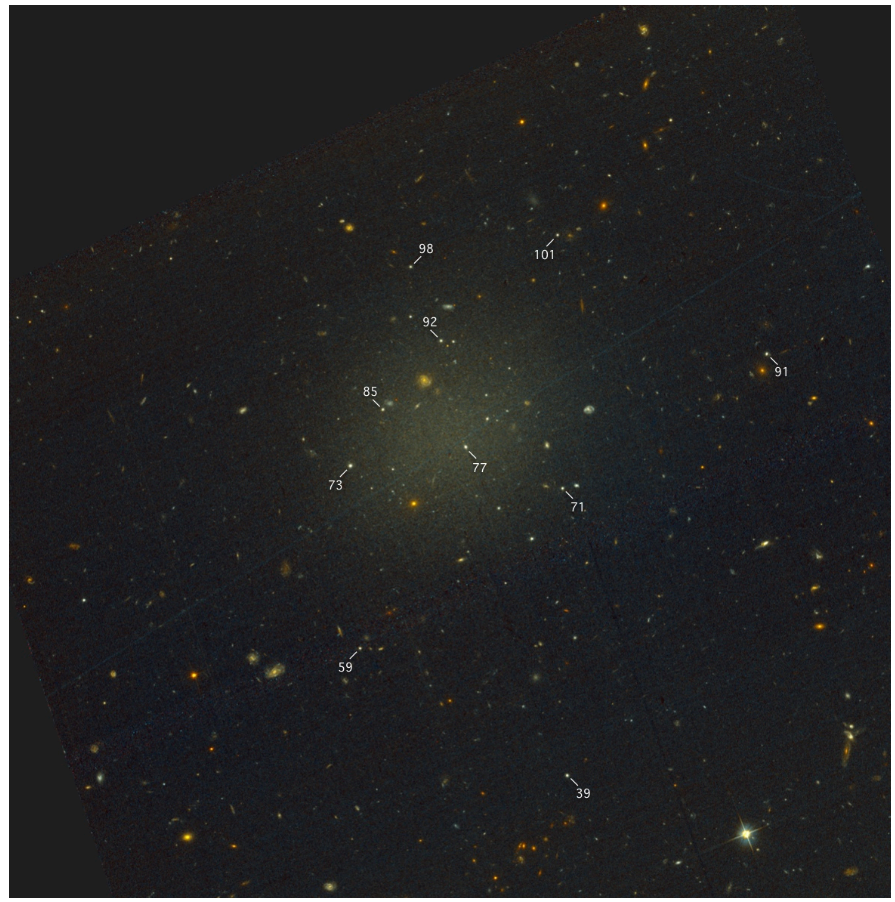
[16] Other Galaxies (3/29/18)

Upcoming Items

1. Homework #4 due on Tuesday.
2. Read Ch. 20.2 (and review the last part of Ch. 15.2 on variable stars) for next class and do the self-study quizzes.

NGC 1052-DF2

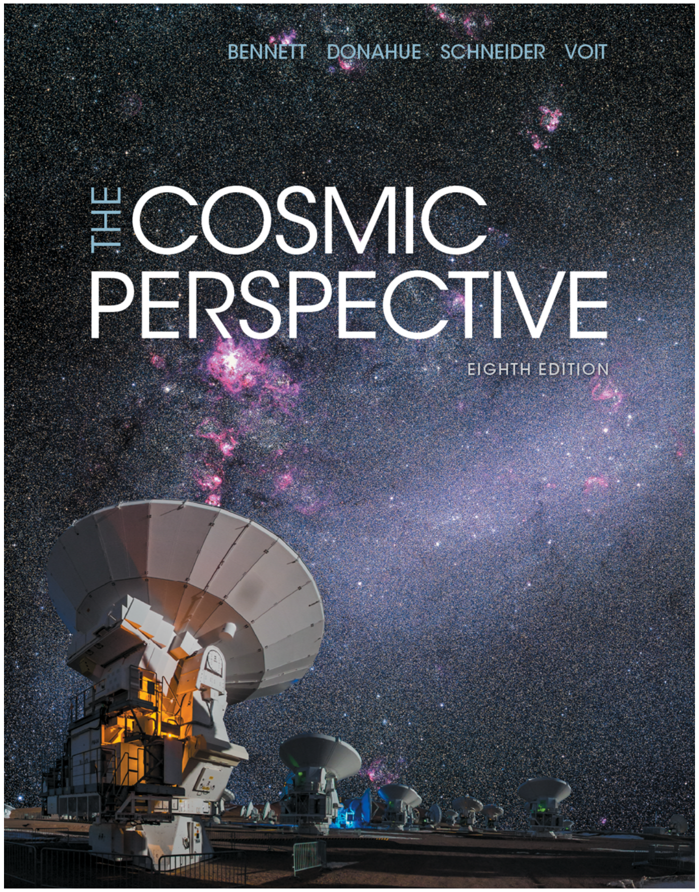


LEARNING GOALS

Ch. 20.1

For this class, you should be able to…

- … *classify a galaxy as a spiral, elliptical, or irregular based on morphology, and further estimate the subtype of spiral (barred or not, tightness of arms, etc.) or elliptical (degree of roundness);*
- … *contrast the relative proportion of gas, as well as stars of each spectral type, between galaxy types;*



Any astro questions?

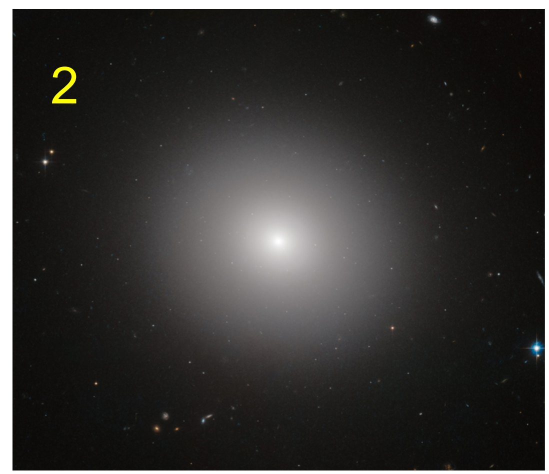
In-Class Quiz

1. Why does ongoing star formation lead to a blue-white appearance?

A. There aren't any red or yellow stars.
B. Short-lived blue stars outshine others.
C. Gas in the disk scatters blue light.

2. In which object would you expect to find K stars?

A. Object 1 only.
B. Object 2 only.
C. Both object 1 and object 2.
D. Neither object 1 nor object 2.



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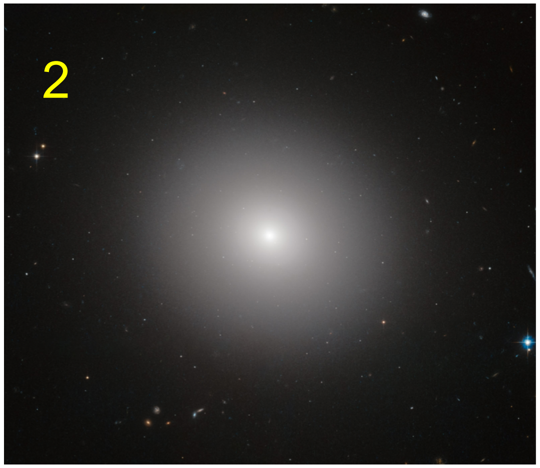
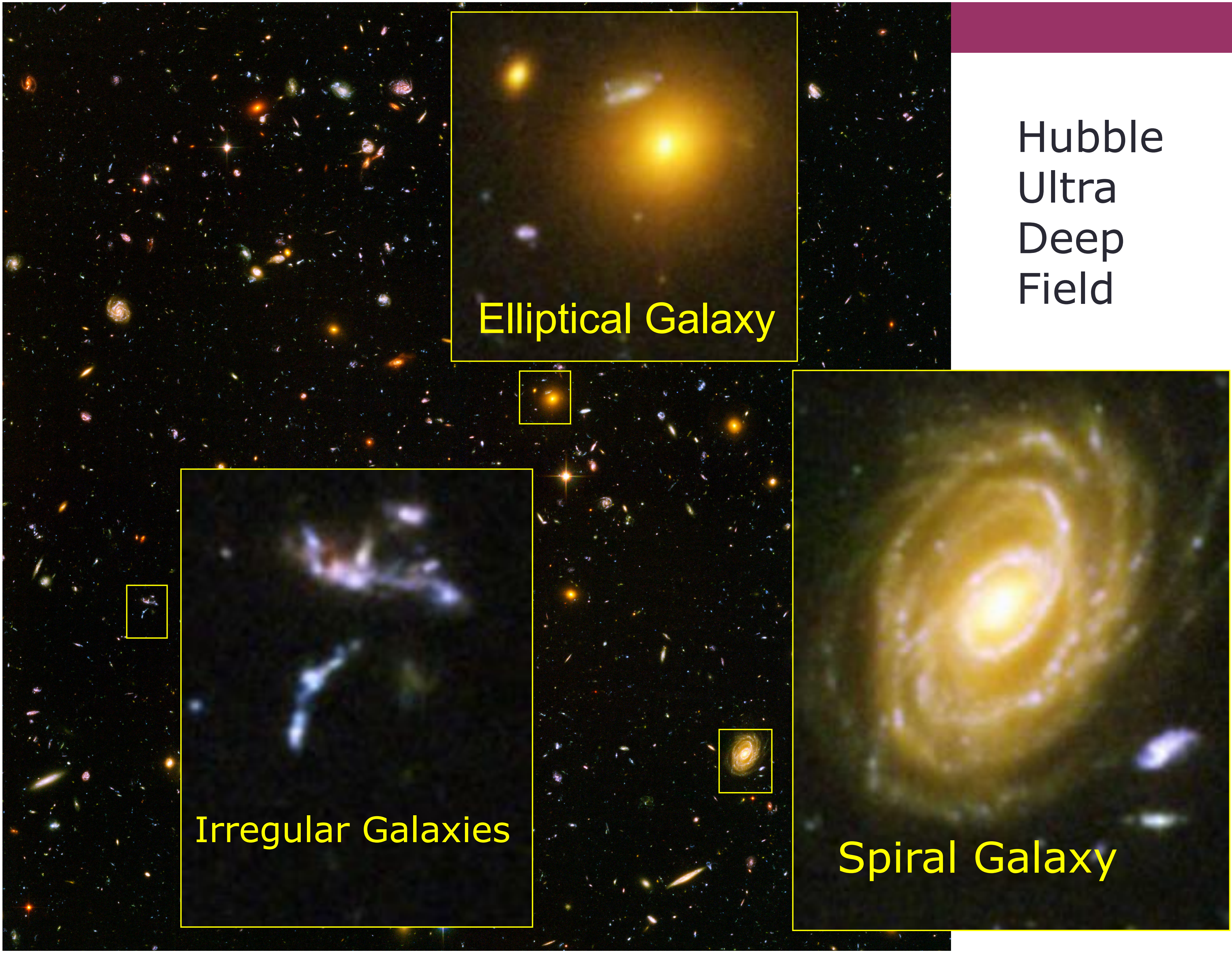


Hubble Ultra Deep Field

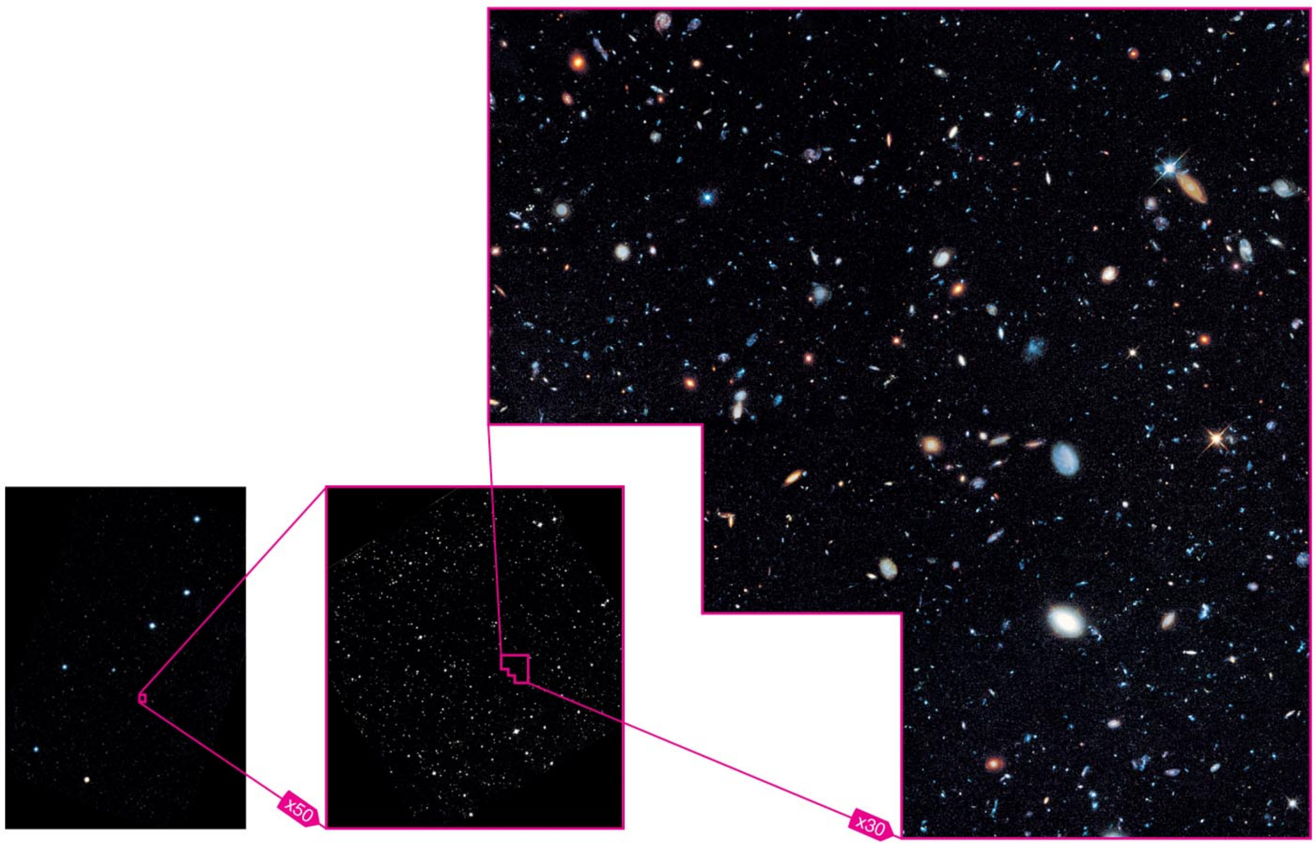


Other Galaxies

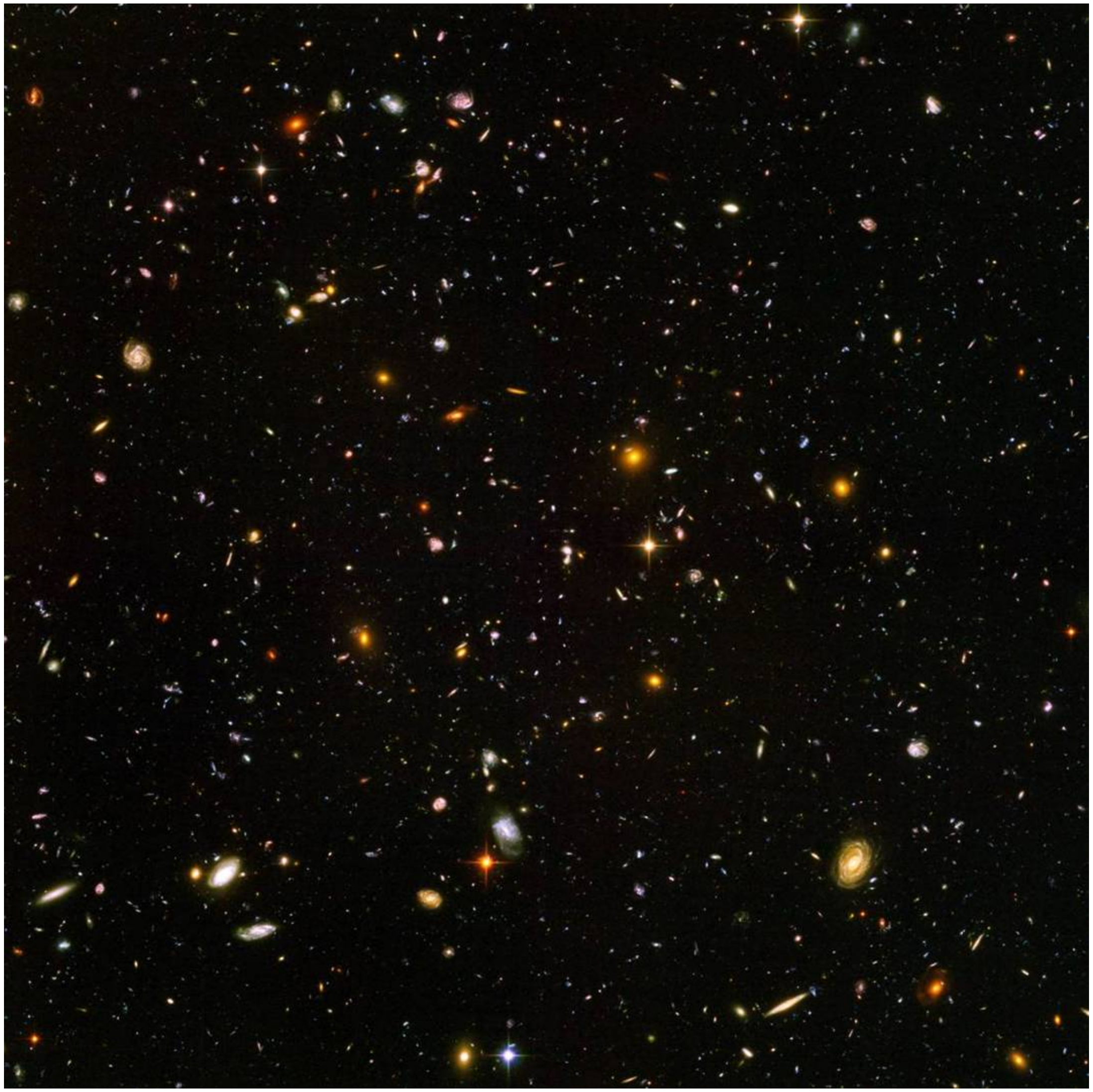
- Spirals (e.g., Milky Way).
  - Have disk and spheroid components, often a central bar.
  - Generally massive ($M \sim 10^{9–12}\ \mathrm{M}_\odot$), have ISM in disk.
  - Contain both old and young stars: overall blue-white appearance.
- Ellipticals (e.g., M87).
  - All spheroid, no disk, huge range of masses ($M \sim 10^{5–13}\ \mathrm{M}_\odot$).
  - Very little dust or cool gas, mostly old red stars: *red and dead*.
  - Biggest are usually in large clusters.
- Irregulars are in between (e.g., Small Magellanic Cloud).
  - Irregular shape, intermediate masses ($M \sim 10^{8–10}\ \mathrm{M}_\odot$), Pop I stars.
- Use Hubble's classification scheme for galaxies.
- Galaxies often come in groups.

Hubble Deep Field

- Our deepest images of the universe show a great variety of galaxies, some of them billions of light-years away.



Galaxies and Cosmology



- A galaxy’s age, its distance, and the age of the universe are all closely related.
- The study of galaxies is thus intimately connected with **cosmology**—the study of the structure and evolution of the universe.

Group Q: Why do Spirals have Gas?

- You know that spirals have gas and significant ongoing star formation; ellipticals have little gas and little ongoing star formation
- But why do the spirals still have lots of gas?
- In particular, if we asked how long it would take for existing gas to cool, contract, and form stars, it is ***way*** shorter than the ages of the galaxies
- Thus almost all the gas in spirals should have formed stars, billions of years ago
- What might have prevented that?

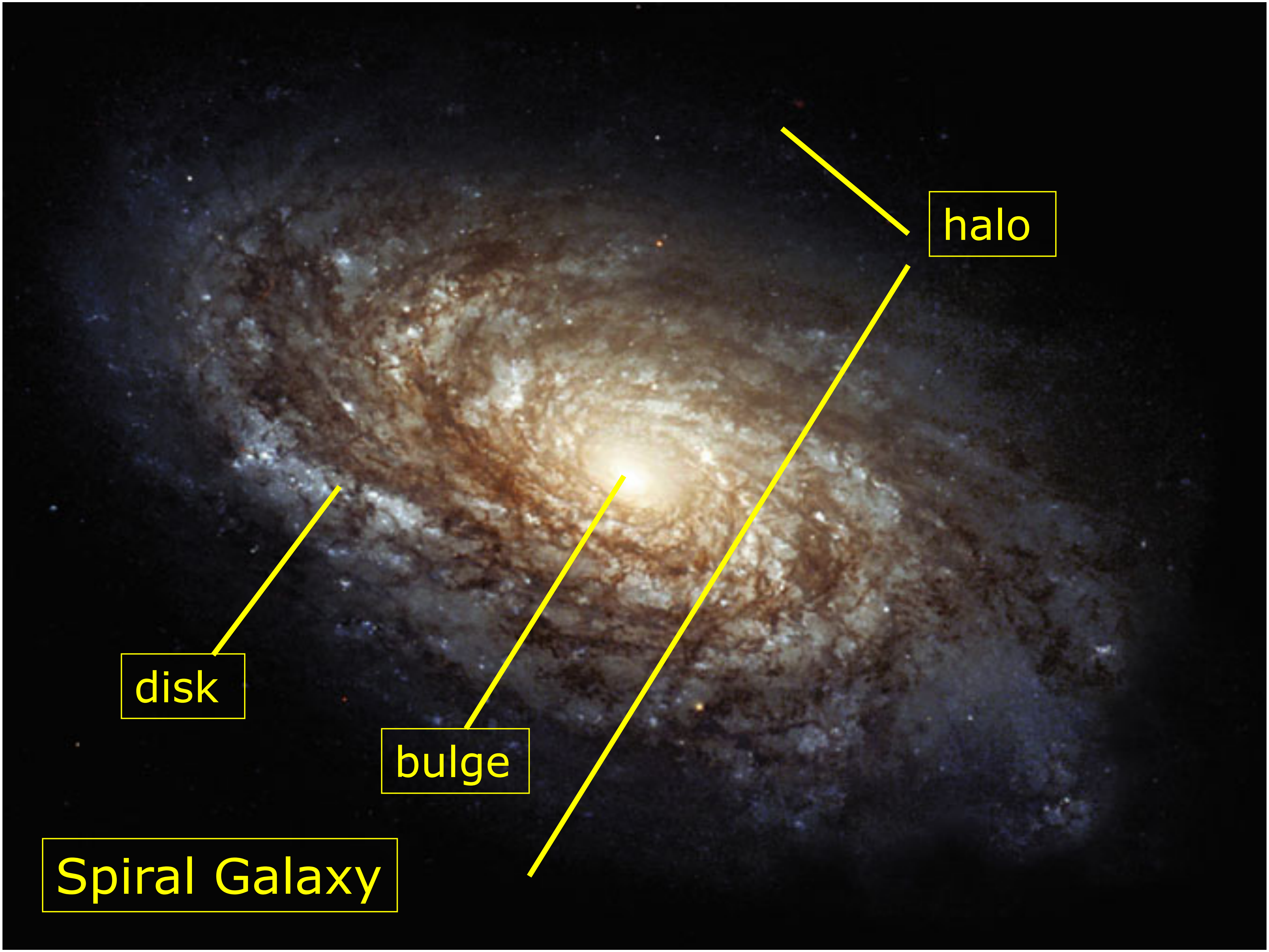
Galaxy Types

- There are three basic varieties of galaxies:
  1. Disk/spiral galaxies (e.g., Milky Way).
  2. Elliptical galaxies (e.g., M87).
  3. Irregular galaxies (e.g., Small Magellanic Cloud, M82).

- We start by discussing the general properties of each type.

Properties of Disk (Spiral) Galaxies

- We have already discussed the Milky Way.
- More generally, spirals possess two main components:
  1. **Disk component**: Flattened structure orbiting center with organized rotation. Contains old and young stars, as well as cold gas and dust.
     - Coldest gas & youngest stars found near spiral arms (density waves).
  2. **Spheroidal component**: spheroidal distribution of old stars on random orbits with little dust or gas in between.
     - Includes the bulge and halo.
     - Like mini elliptical galaxies…
- Spiral galaxies can be *barred* or *unbarred*.



halo
disk
bulge
Spiral Galaxy

Disk component:
stars of all ages, many gas clouds.

Spheroidal component:
bulge and halo, old stars, few gas clouds.

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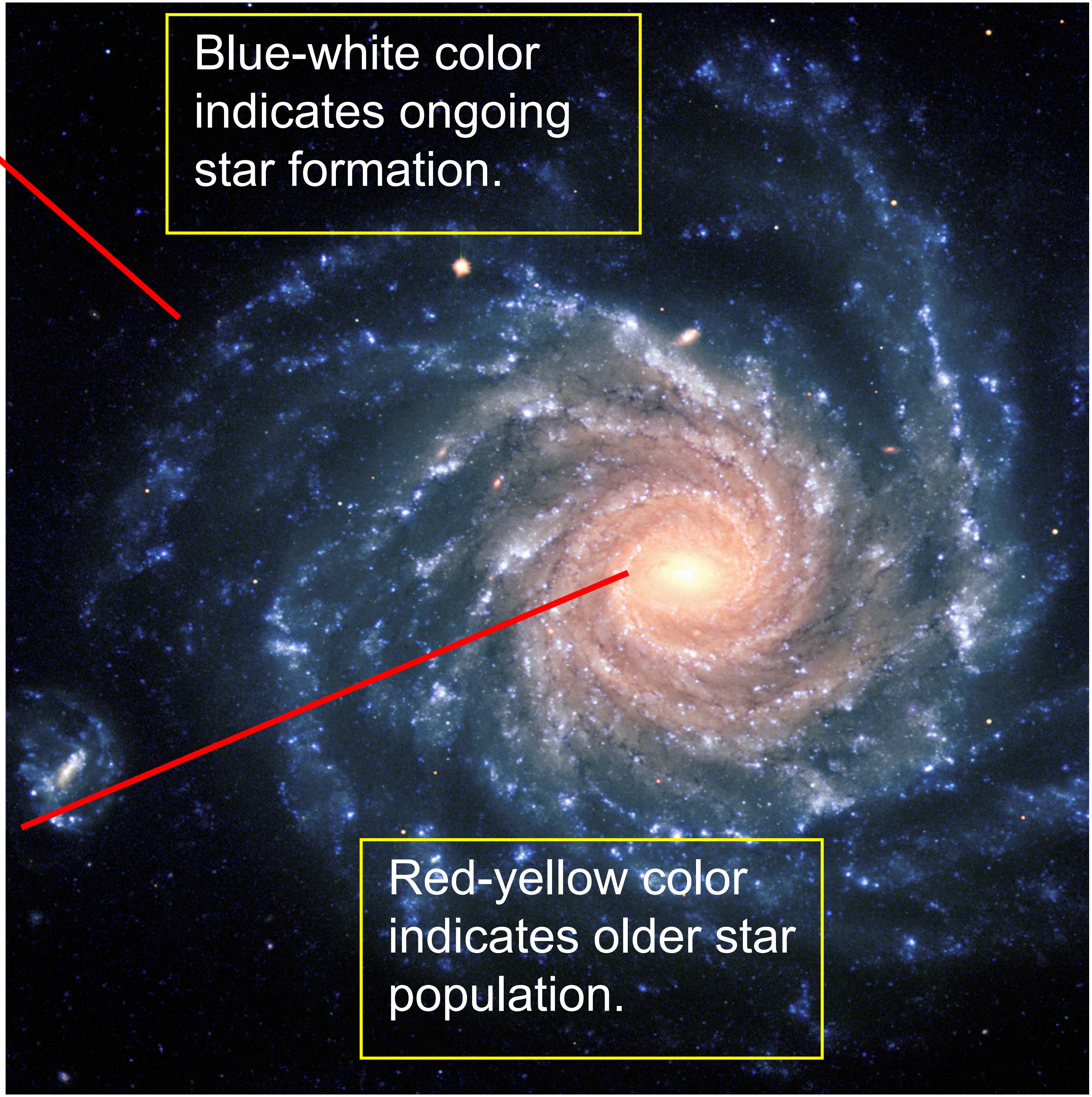
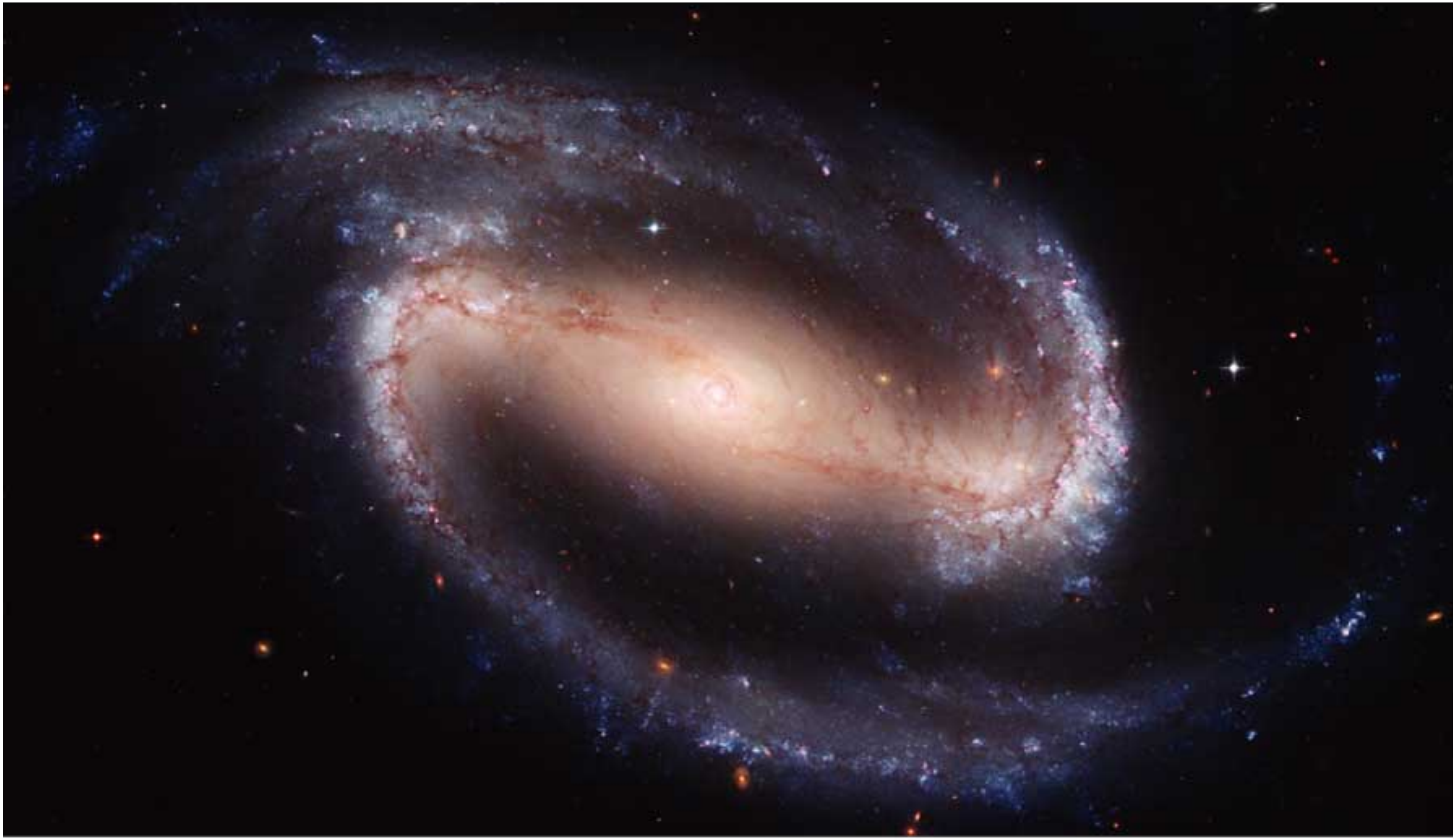




Barred Spiral Galaxy:
Has a bar of stars across the bulge.

Lenticular Galaxy:

Has a disk like a spiral galaxy but much less dusty gas (intermediate between spiral and elliptical).

Properties of Elliptical Galaxies

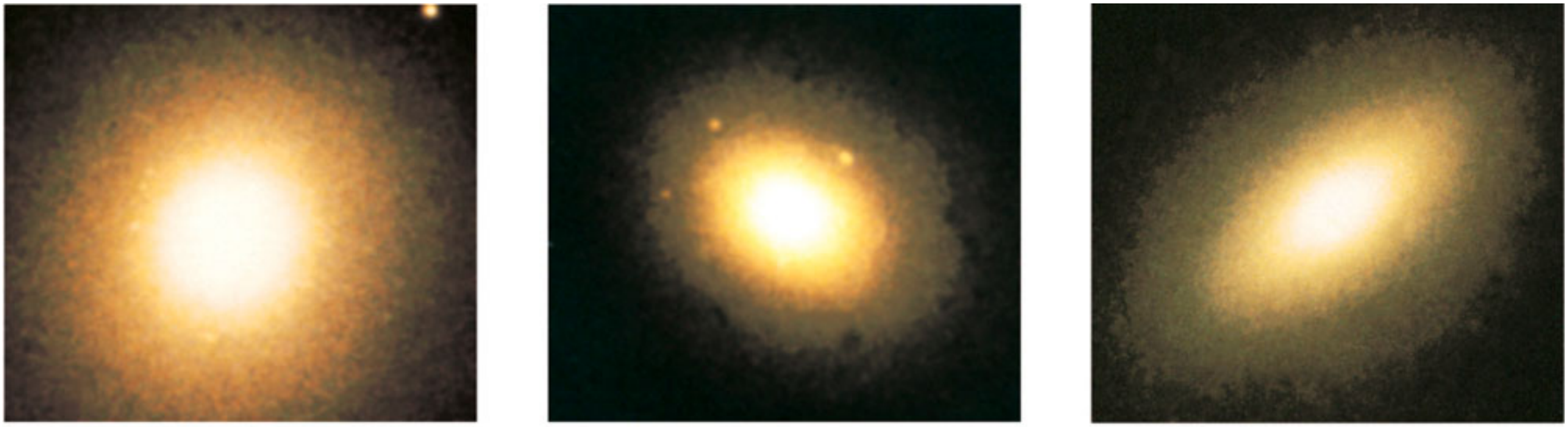
- Large “swarms” of stars orbiting with random orientations in the galaxy’s gravitational field: **spheroidal shape**.
- The randomness of the orbits means that the galaxy as a whole has **very little net rotation**.
- The **stellar population is old** (Pop. II): in general, there are no massive stars (they have all gone supernova).
- Usually **very little dust or cold gas** present… explains lack of star formation/young stars.
- Some **elliptical galaxies can be very massive** (the most massive galaxies in the universe are elliptical).
- There are also a lot of **dwarf ellipticals**… may have only a few million stars. Some of these may be the oldest galaxies (“fossils” of the first phase of galaxy formation).

a M87, a giant elliptical galaxy in the Virgo Cluster, is one of the most massive galaxies in the universe. The region shown is more than 300,000 light-years across.

Elliptical Galaxy:

All spheroidal component, virtually no disk component.

Red-yellow color indicates older star population: RED and DEAD.

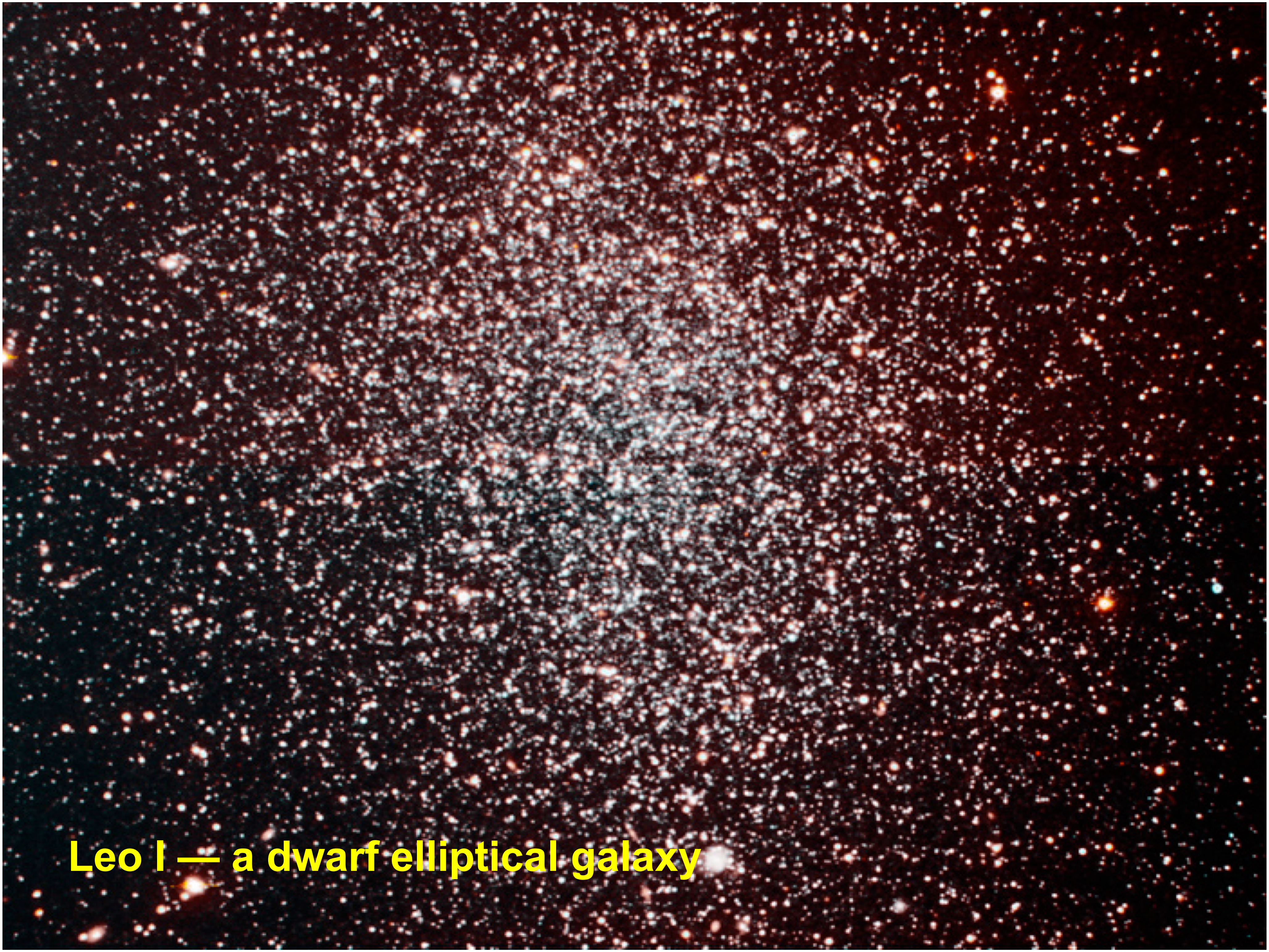


(a) E0 (M105) (b) E3 (NGC 4365) (c) E6 (NGC 3377)

Shape classification: E#, where $\# = 10 \times (1 - b / a)$; a = major axis length of image, b = minor axis.

But note: we observe the projected shape!

Can we see an intrinsically elongated galaxy as nearly circular? Can we see an intrinsically spherical galaxy as highly elongated?


Leo I — a dwarf elliptical galaxy

Properties of Irregular Galaxies

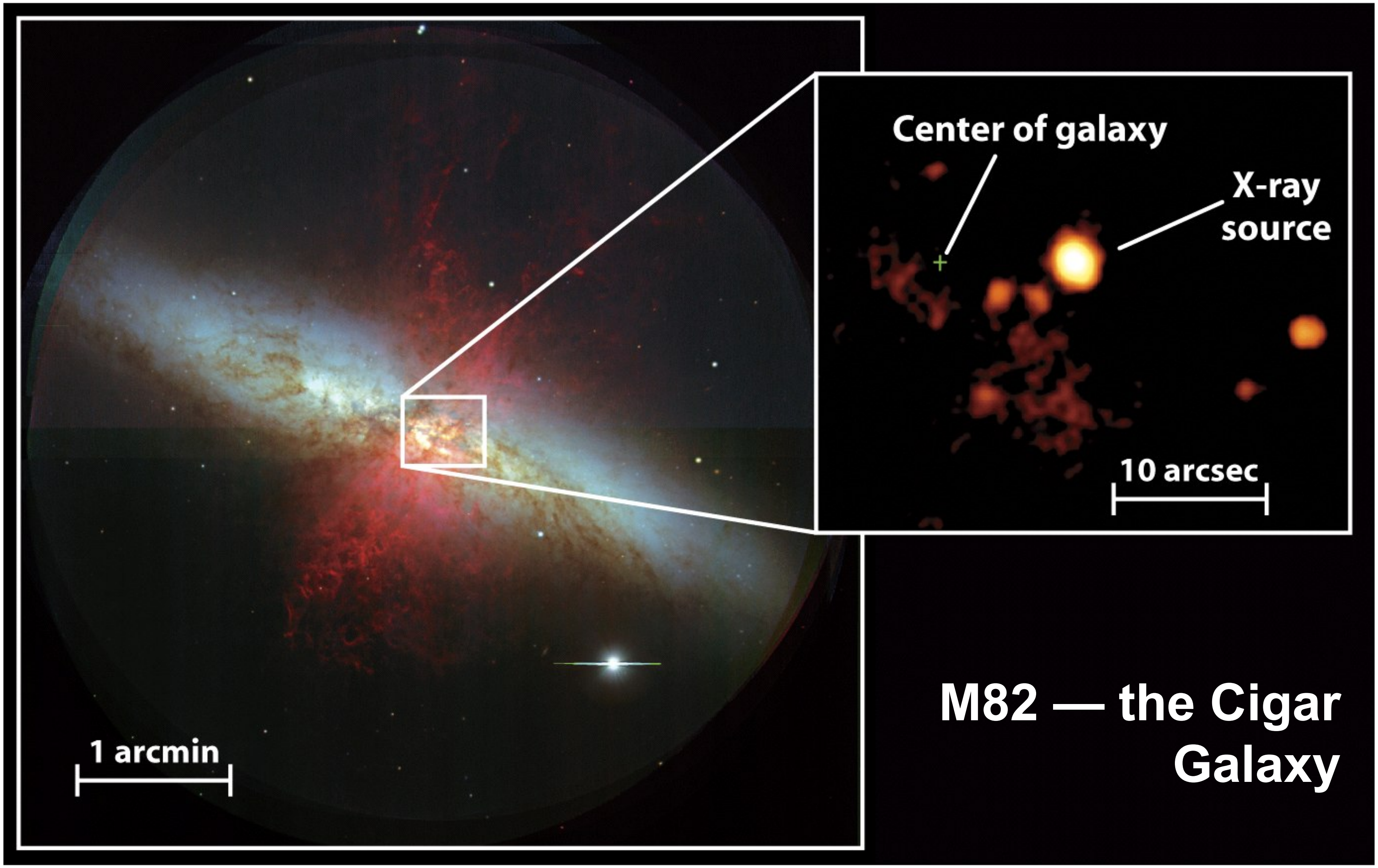
- Only hints of organized structure, or highly distorted objects caused by the collision of galaxies or violent activity in their centers.
- Often have many H II and star-forming regions.
- Examples: SMC, M82 (starburst galaxy).

SMC

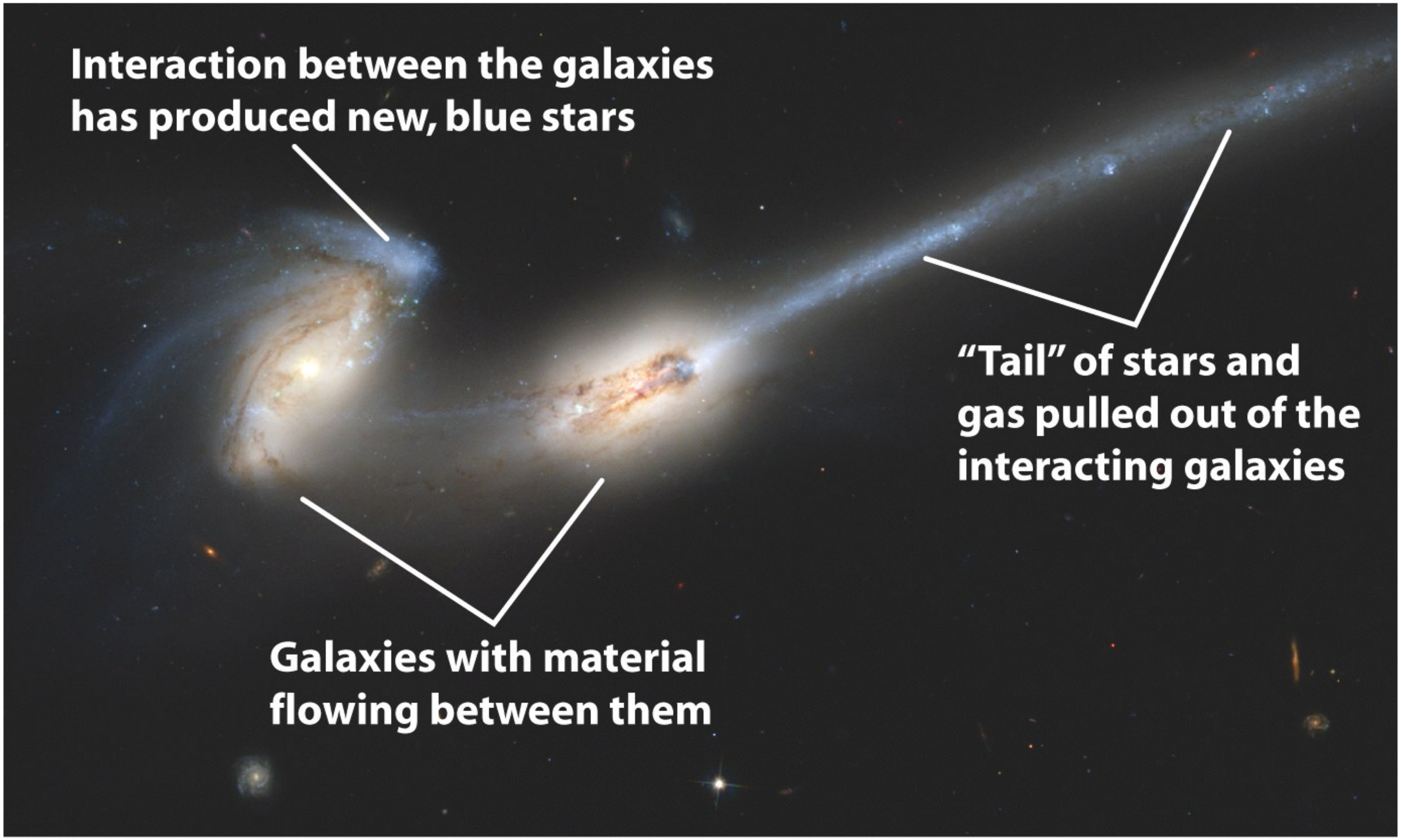
Irregular Galaxy:

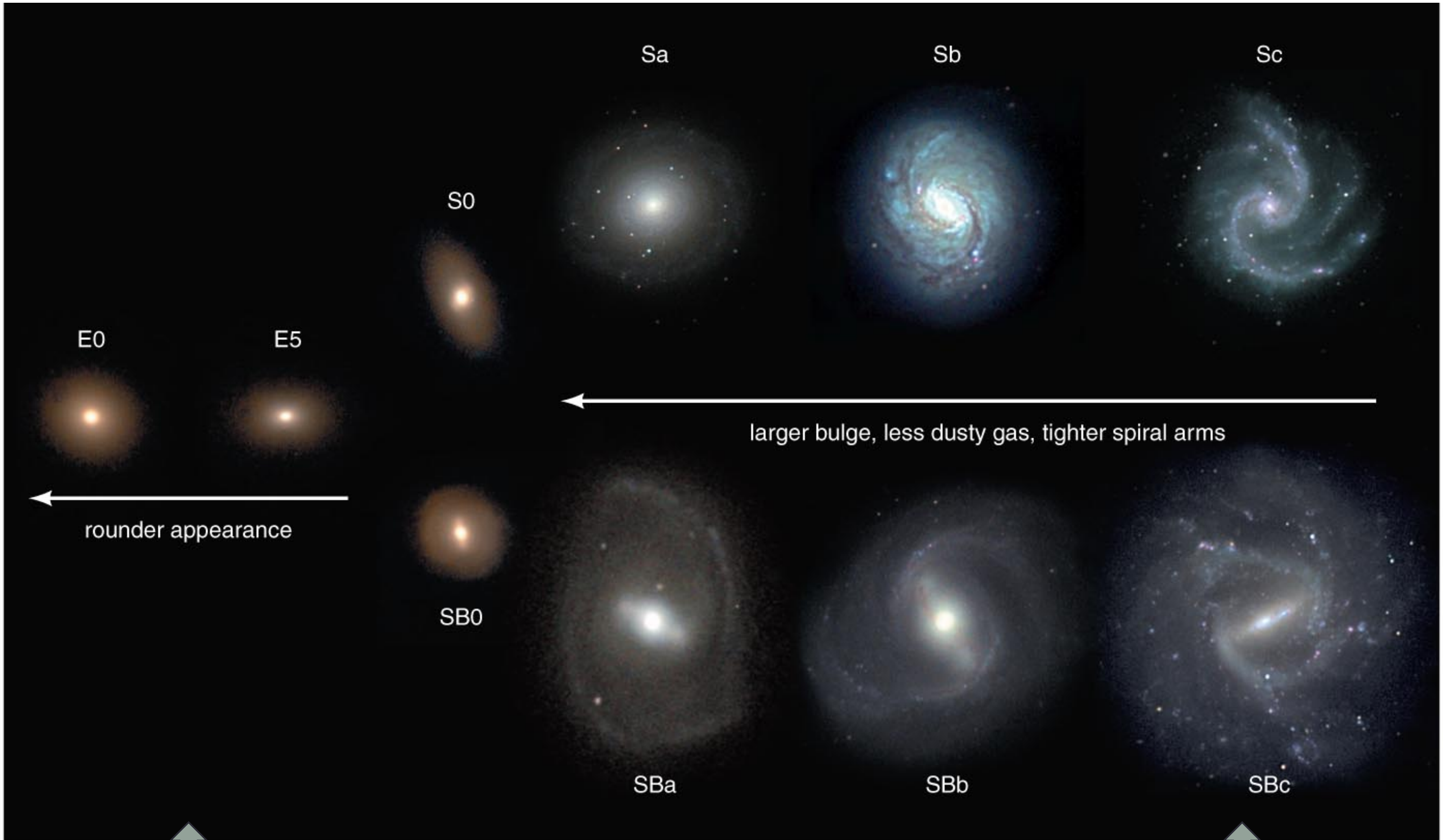
Neither spiral nor elliptical.

Blue-white color indicates ongoing star formation.



M82 — the Cigar Galaxy


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



Spheroid Dominates

Hubble's Galaxy Classes (irregulars not shown)

Disk Dominates