All galaxies great and small

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Populations of stars

Stars in galaxies can be divided into two populations:

- Population I
- Population II

Population I stars are in the *disk.* They are younger, bluer and contain more *metals.*

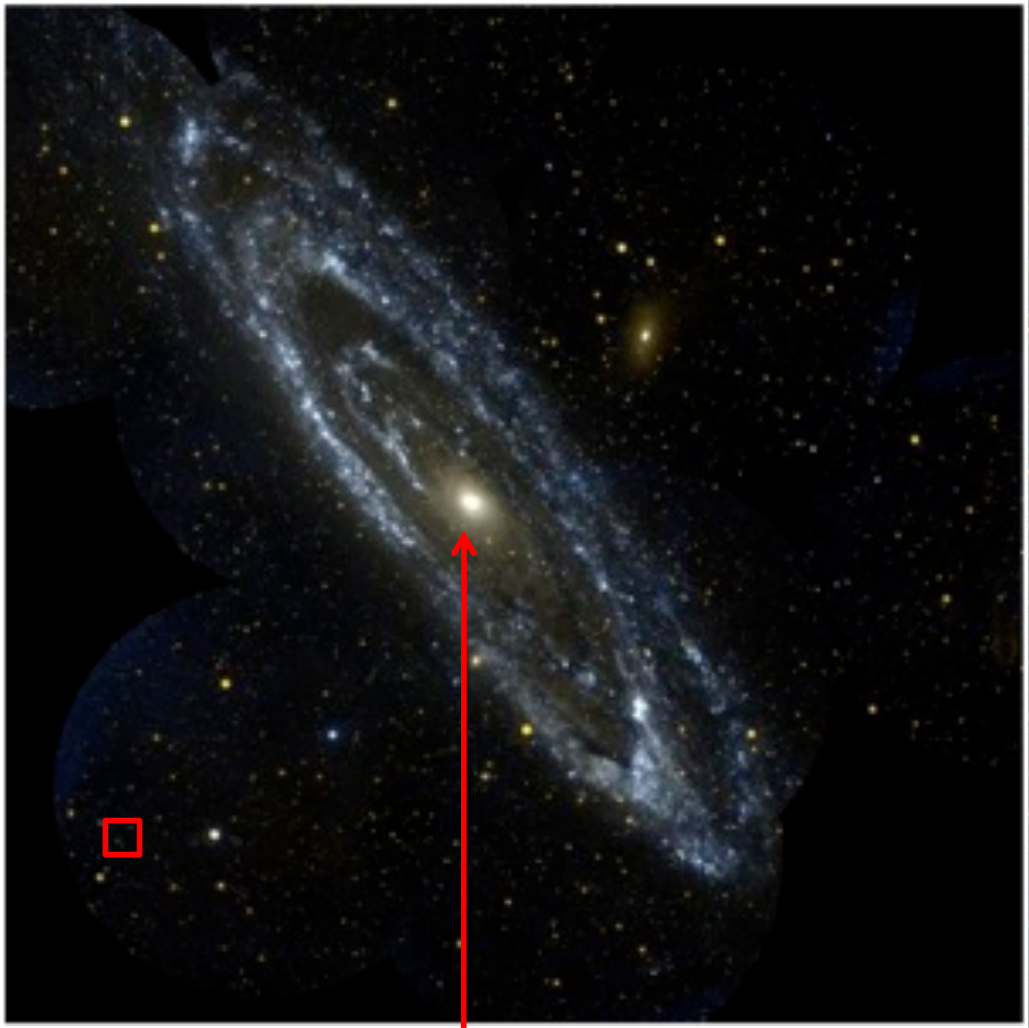
Population II stars are in the *halo* and *bulge*. They are older, redder, and contain fewer metals.

For the bulge & halo:

Are they red or blue?

Are the stars lower or higher mass than the disk?

Are the stars younger or older than the disk stars?



Bulge

Halo stars

Milky Way Structure

- Disk
  - diameter of 30 kpc and 1 kpc thick near the Sun
  - Sun is located 8.5 kpc from center of Milky Way in the disk
  - active star formation in disk
- Bulge
  - diameter of 4 kpc located at the center of the galaxy
  - more spherical than disk
  - supermassive black hole at the center (in nucleus)
- Bar
  - seen in stars and dust, extends 6 kpc through center of galaxy
- Halo
  - 100s of kpc in diameter, only contains 2% of stars in galaxy
  - includes globular clusters and *dark matter* composing most of the mass of galaxy.

Ages of stars in the Milky Way

- Disk stars: 0-10 billion years old, metal-rich (Population I)
  - Spiral arms have stars < 100 million years old
  - stars in the rest of the disk, 0.2-10 billion years old
- Bulge stars: 2-10 billion years old, metal-poor (Population II)
- Halo stars: 10-13 billion years old, very metal-poor (Population II)

So what about other galaxies?

The Milky Way is just one of billions of galaxies…

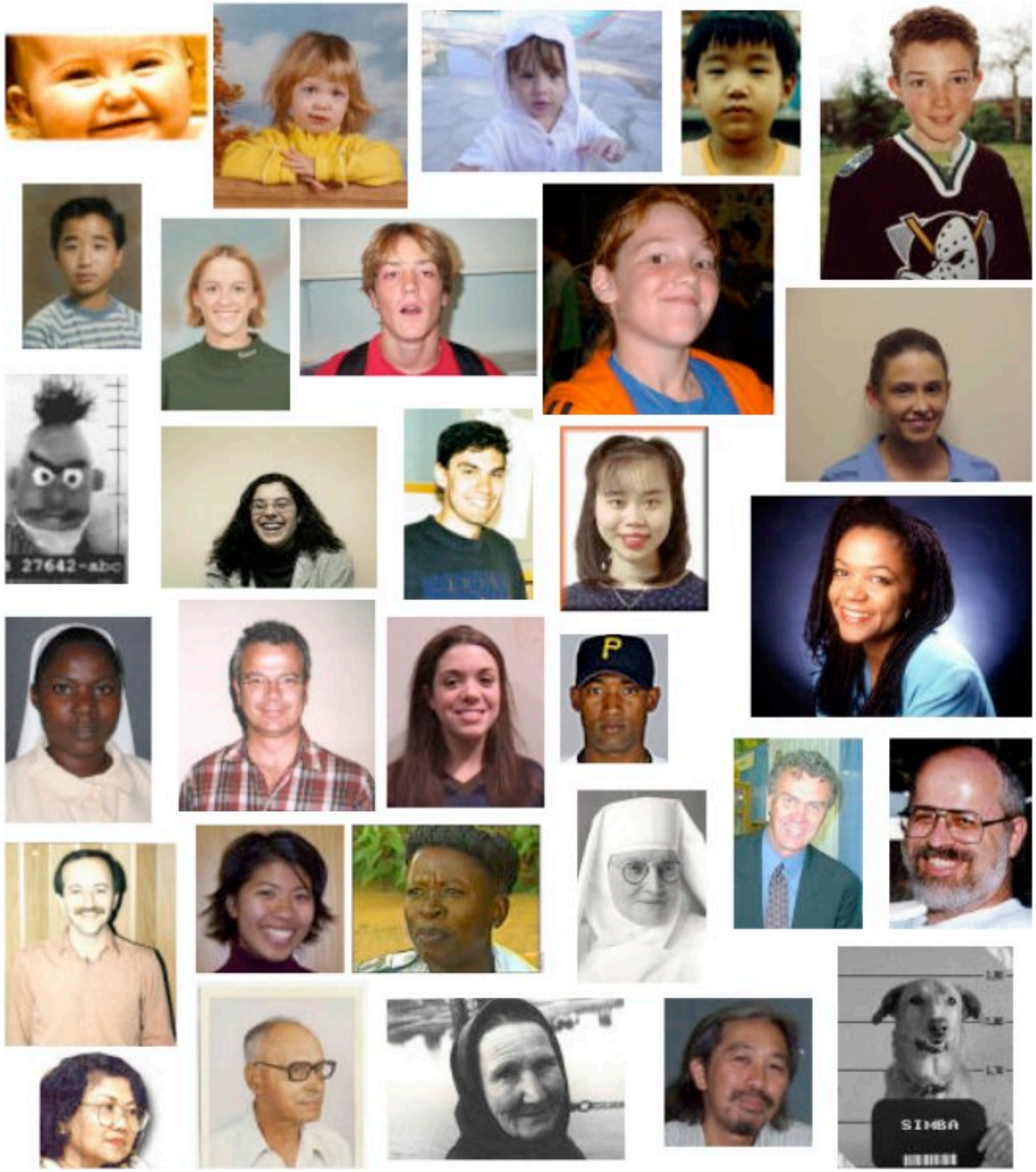

The Galaxy Zoo
Galaxies come in all shapes and sizes. To make sense of them, astronomers classify them based on their appearance.

Classifying objects

Before we try classifying galaxies, let's start with something more down-to-Earth:

Imagine that you are an alien visiting Earth and want to learn about the human lifecycle, but you only have 10 minutes to do so. So you take a bunch of pictures to sort it out.

What conclusions can you divine just from looking at the following photos?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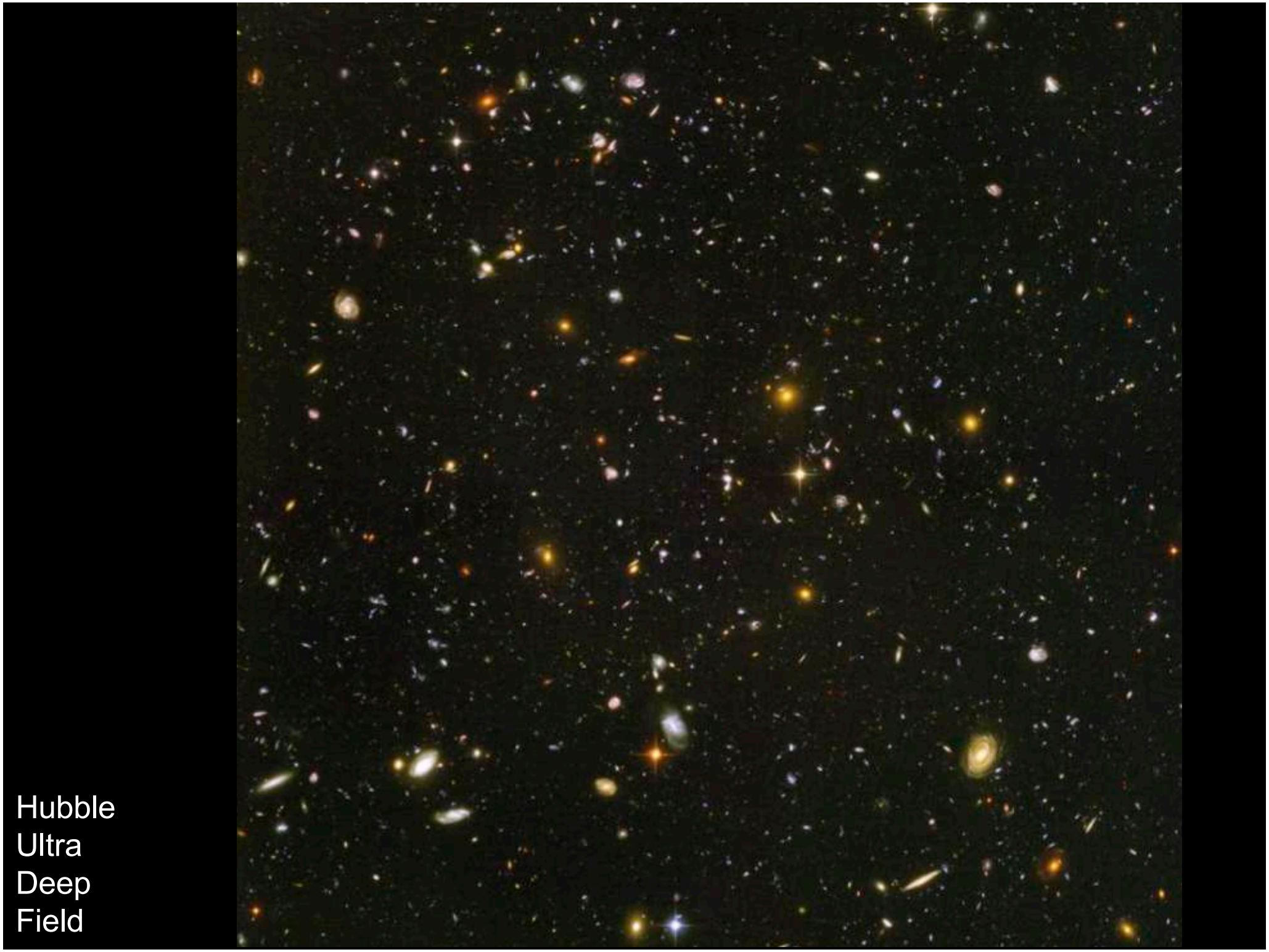
Classifying Galaxies

What did you notice about the galaxies you looked at?

What properties of galaxies can we see in the following slide that would be helpful to classify them?

Which properties are *intrinsic* and which are *extrinsic* to the galaxy?



Hubble
Ultra
Deep
Field

Galaxy Properties

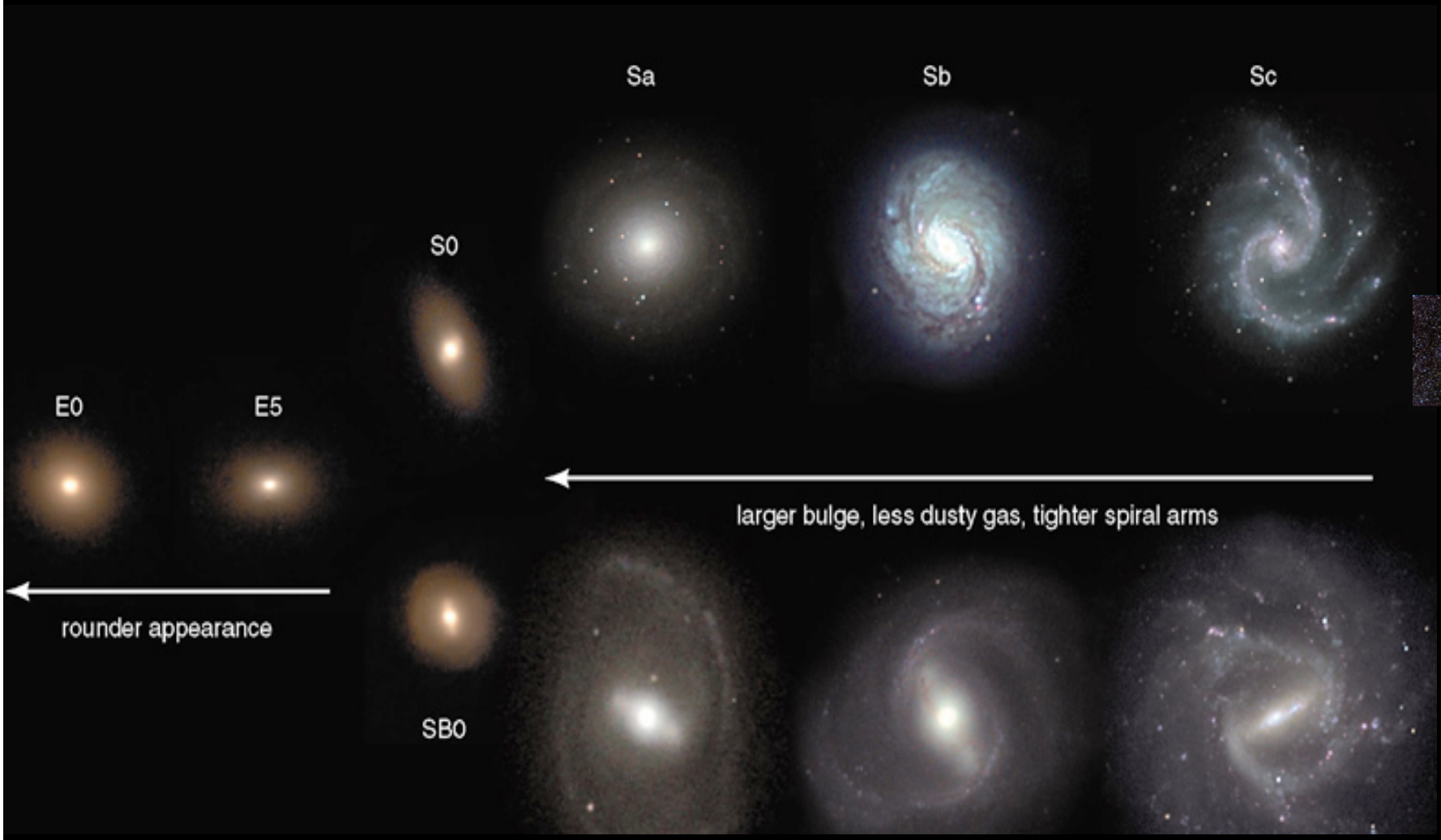
Intrinsic:

- Luminosity
- Physical size
- morphology
- color
- mass
- others?

Extrinsic:

- apparent brightness
- apparent size
- distance
- environment
- color?
- morphology?
- others?

Hubble Tuning Fork

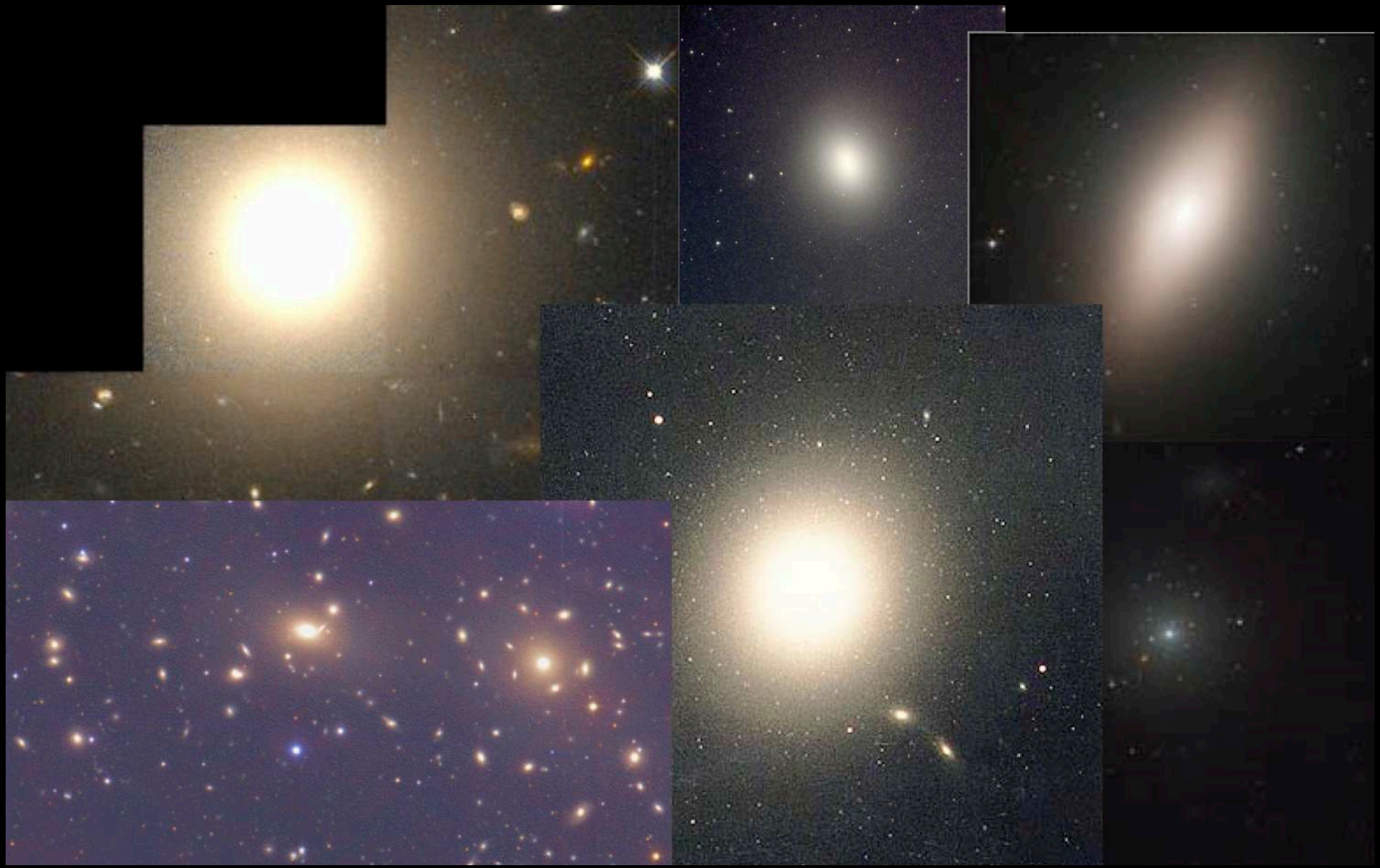


Ellipticals

Spirals

Irregulars

Elliptical Galaxies



Elliptical Galaxies

- Spherical, Football-shaped (oblong), or flattened football (triaxial) collections of stars.
- Very little gas or dust. Many have lots of X-ray emitting hot gas. Mostly old stars.
- Most reside in galaxy clusters
- Luminosities ≥ 10^{12} $L_{\odot}$, Mass ≥ 10^{12} $M_{\odot}$. These represent the most massive, luminous galaxies in the Universe.
- However, some are *dwarfs* (much smaller than Milky Way).

Spiral Galaxies

Spiral Galaxies

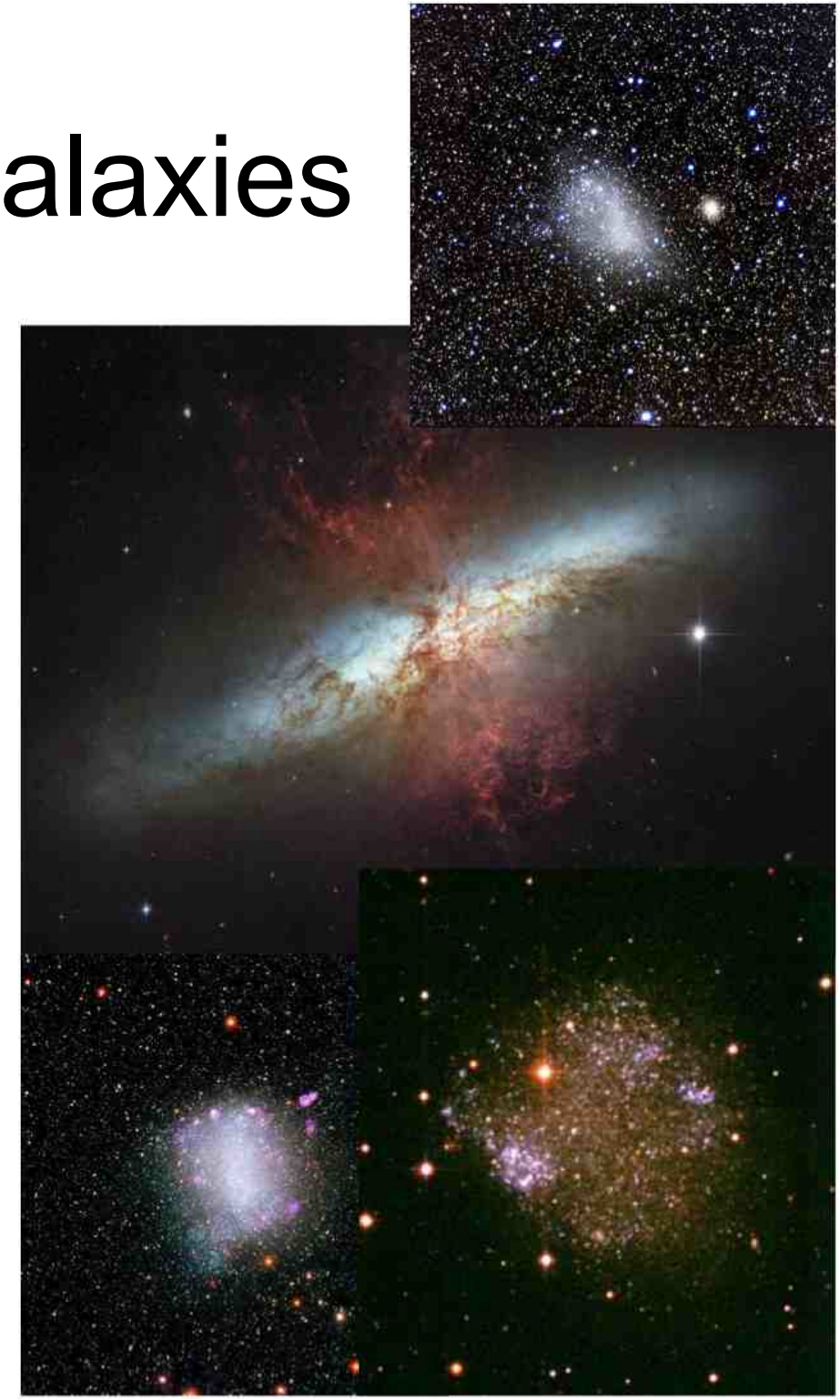
- Rotating, flattened disks of stars, gas, and dust.
- Have spiral arms and, sometimes, bars.
- Also have bulges (some small) and halos (not visible here)
- See at different angles from edge-on (left) to face-on (right).
- Contain young and old stars.
- Masses and luminosities similar to Milky Way:

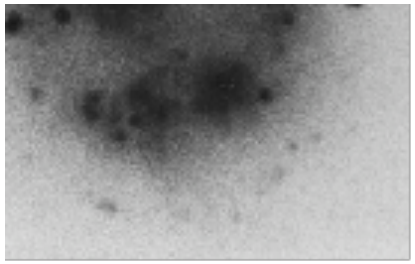
  $L \sim 10^9 – 10^{11}\ L_\odot$, $M \sim 10^8 – 10^{11}\ M_\odot$

Irregular Galaxies

- Fat-disks, but no spiral structure. No bulge.
- Dominated by young stars, some old stars, but not many.
- Often have lots of star formation (middle image).
- Along with spirals, they reside in all environments.
- Luminosities and masses lower than spirals:

  $L \leq 10^8 L_\odot$, $M \leq 10^8 M_\odot$





Dwarf galaxies

- Galaxies that are much, much smaller than *giant* galaxies.
- Luminosities as low as 10^3 $L_\odot$ (fainter than some stars)
- Masses as low as 100-1000 $M_\odot$
- Sizes of ~ 1 kpc, but some as low as 10's of parsecs (compared to 10-100 kpc for giant spirals and ellipticals)
- Found in all environments
- Dwarf irregulars may have some gas and dust and star formation (left).
- Dwarf spheroidals (or ellipticals) typically have no ongoing star formation, and have fewer young stars (right).

Which of the following is correctly ordered by increasing average mass?

A. elliptical, spiral, irregular, dwarf spheroidal
B. dwarf spheroidal, elliptical, irregular, spiral
C. dwarf irregular, spiral, irregular, elliptical
D. dwarf spheroidal, irregular, spiral, elliptical

Which of the following would appear the most red?

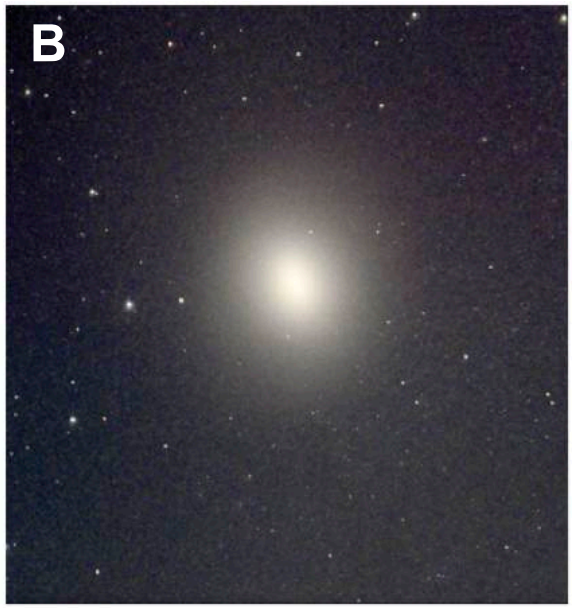
A. Irregulars
B. Spirals
C. Ellipticals
D. Dwarf irregulars
E. They are all the same.

Which of the following typically lacks young stars?

A. Irregulars
B. Spirals
C. Ellipticals
D. Dwarf irregulars
E. None of the above

Which of the following contains old stars?

A. Irregulars
B. Spirals
C. Ellipticals
D. Dwarf irregulars
E. They all contain very old stars



In which of the galaxies above would you expect to see bright, blue stars?

A. Only galaxy A
B. Only galaxy B
C. Both galaxies
D. Neither galaxy

Why are the arms of spiral galaxies typically blue in color?

A. They are usually moving towards us and are Doppler shifted to blue wavelengths.
B. The gas and dust in the arms filter out all but the blue light from stars in the arms.
C. Stars are forming in the arms, so there are high mass, hot, blue stars in the arms.
D. Almost all the stars are in the arms of the disk of the galaxy and their light makes the arms appear blue.

A galaxy that appears to be populated by mostly red stars, likely:

A. never had blue stars in the galaxy.
B. had blue stars that are no longer present.
C. has been around long enough for the blue stars to all evolve into the red main sequence stars we see.
D. never contained enough gas to have blue stars develop.
E. has blue stars that are being blocked by dust.