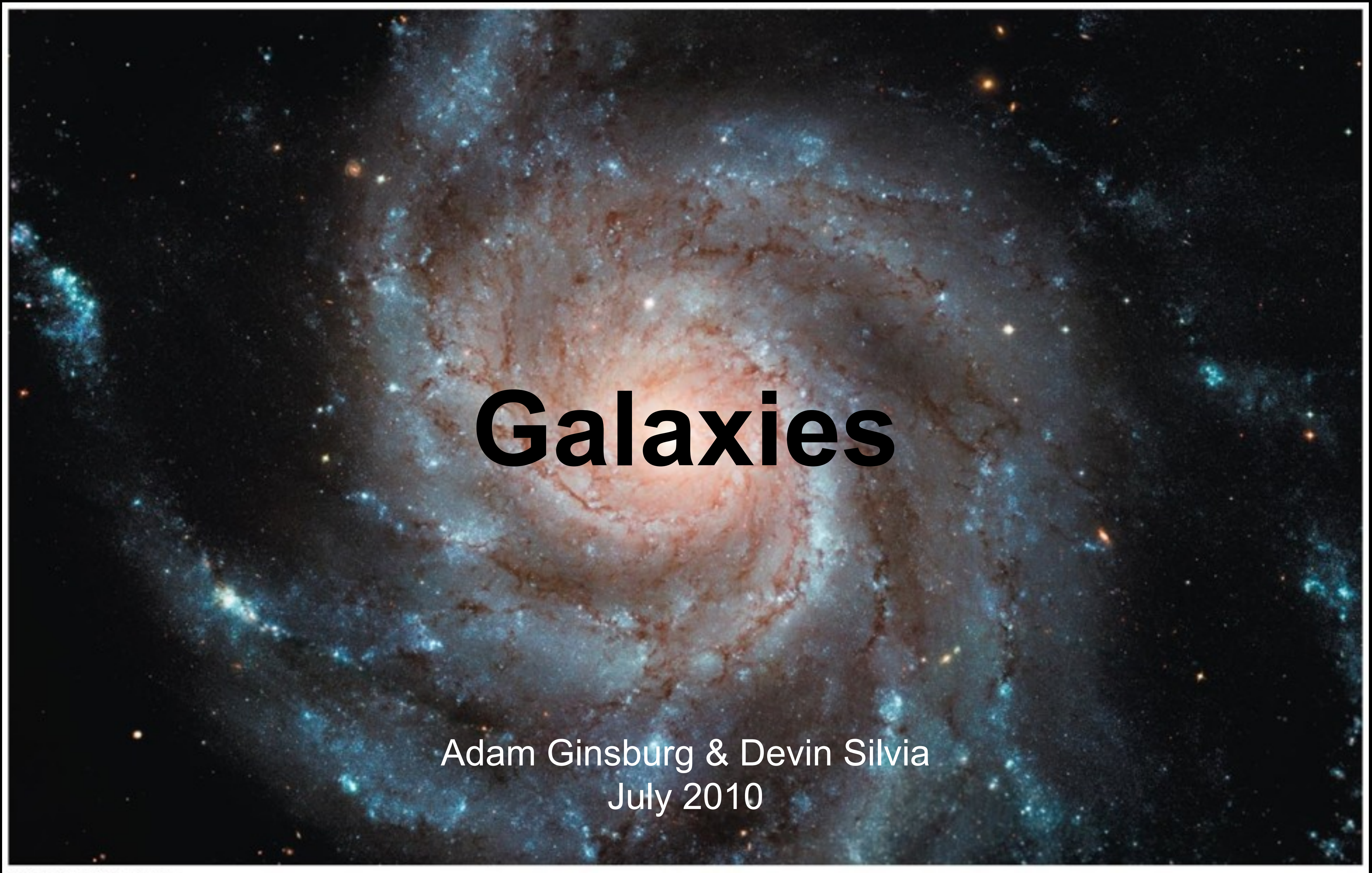
ASTR 1120
:: Star and Galaxies ::



Galaxies

Adam Ginsburg & Devin Silvia
July 2010

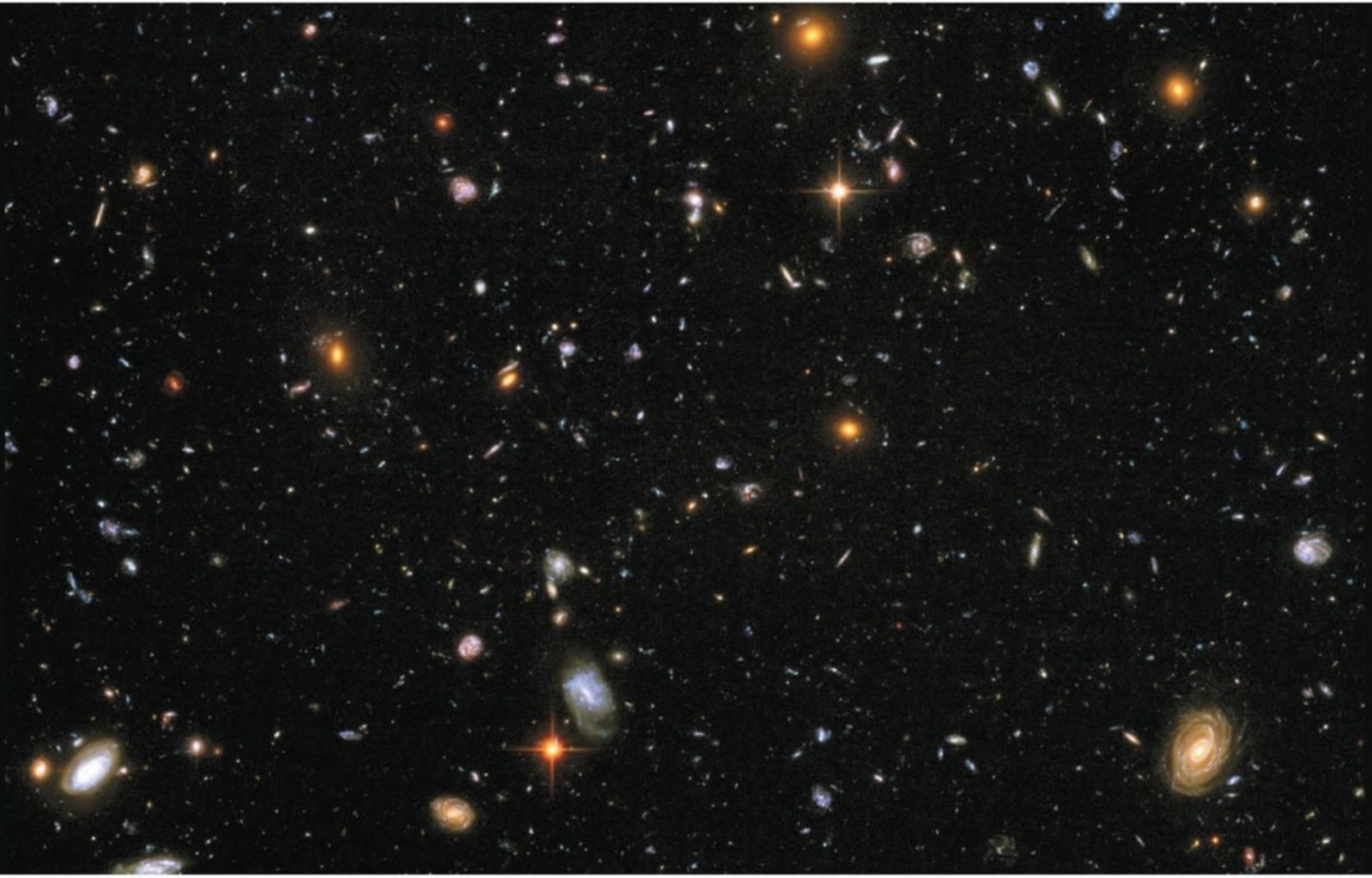
Learning Goals

- Understanding galaxy classification
  - Terms: elliptical, spiral, irregular
- How might galaxies form?
- How do we measure the distances to other galaxies?

The Milky Way is one of many...

Hubble Deep Field

How many galaxies are out there?



What types of galaxies are out there?

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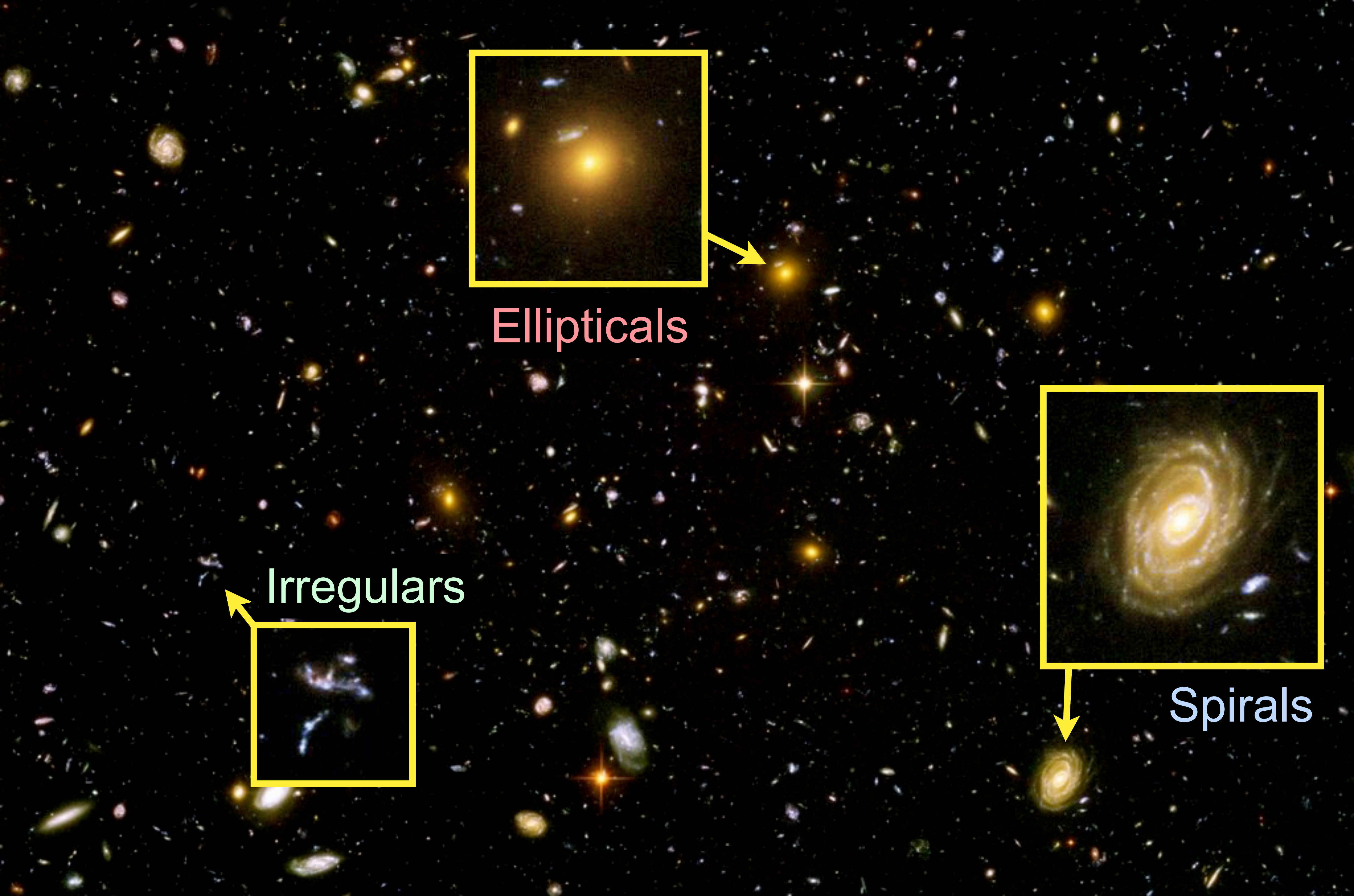


Based on their colors, which galaxies have active (current) star formation occurring?

A) Spirals

B) Ellipticals

C) Irregulars

D) Spirals and Ellipticals

E) Spirals and Irregulars

Based on your answer to the previous question, which galaxies have little dust & gas?

A) Spirals

B) Ellipticals

C) Irregulars

D) Spirals and Ellipticals

E) Spirals and Irregulars

What types of galaxies are out there?

Ellipticals

Appearance: All bulge/halo, No disk

Properties: Very little young stars, Very little cool gas/dust

Reddish color = old stars (red giants, red main sequence)

What types of galaxies are out there?

Spirals

Appearance: Disks (with spiral arms) + Spheroids (bulges+halos)

Properties: Lots of gas and dust in Disk (active star formation), Little gas or dust in Spheroid

What types of galaxies are out there?

Lenticulars (lens-shaped)

Appearance: Disks (without spiral arms) + Spheroids (bulges+halos)

Properties: Less cool gas and dust (less star formation), but more than ellipticals

What types of galaxies are out there?

Irregulars

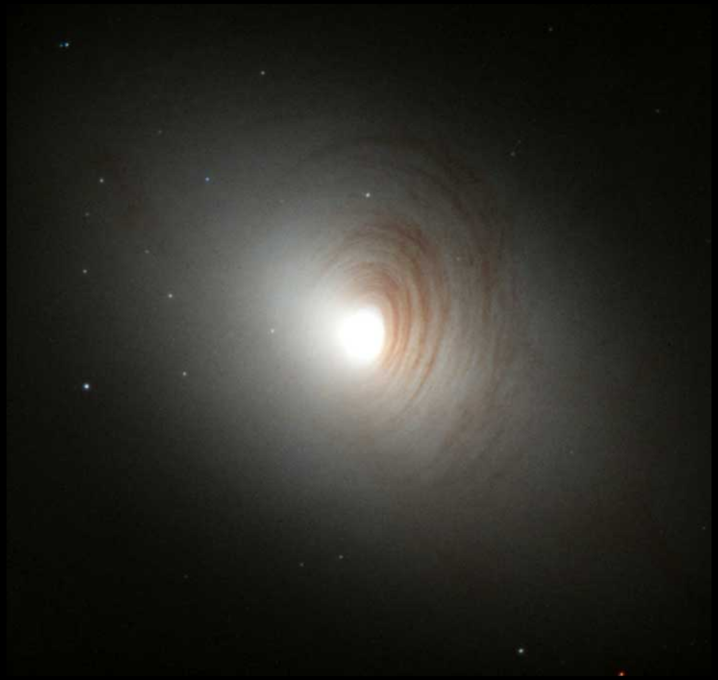
Less understood.

Galaxies in <u>formation</u>?
Or <u>transition</u>?
Or <u>failed</u>?
Often LOTS of star birth

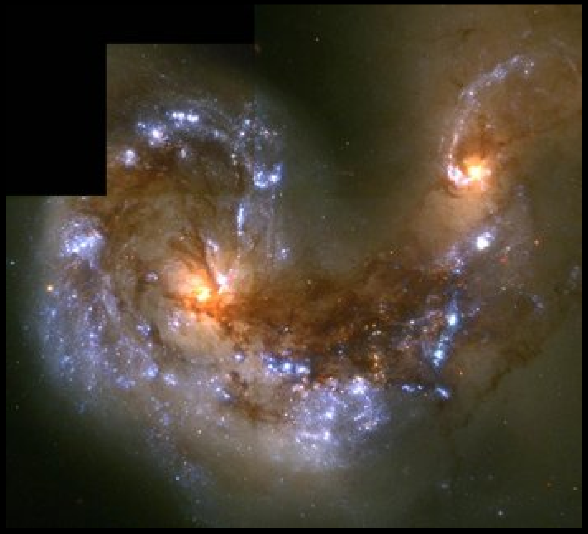
Ellipticals

Spirals

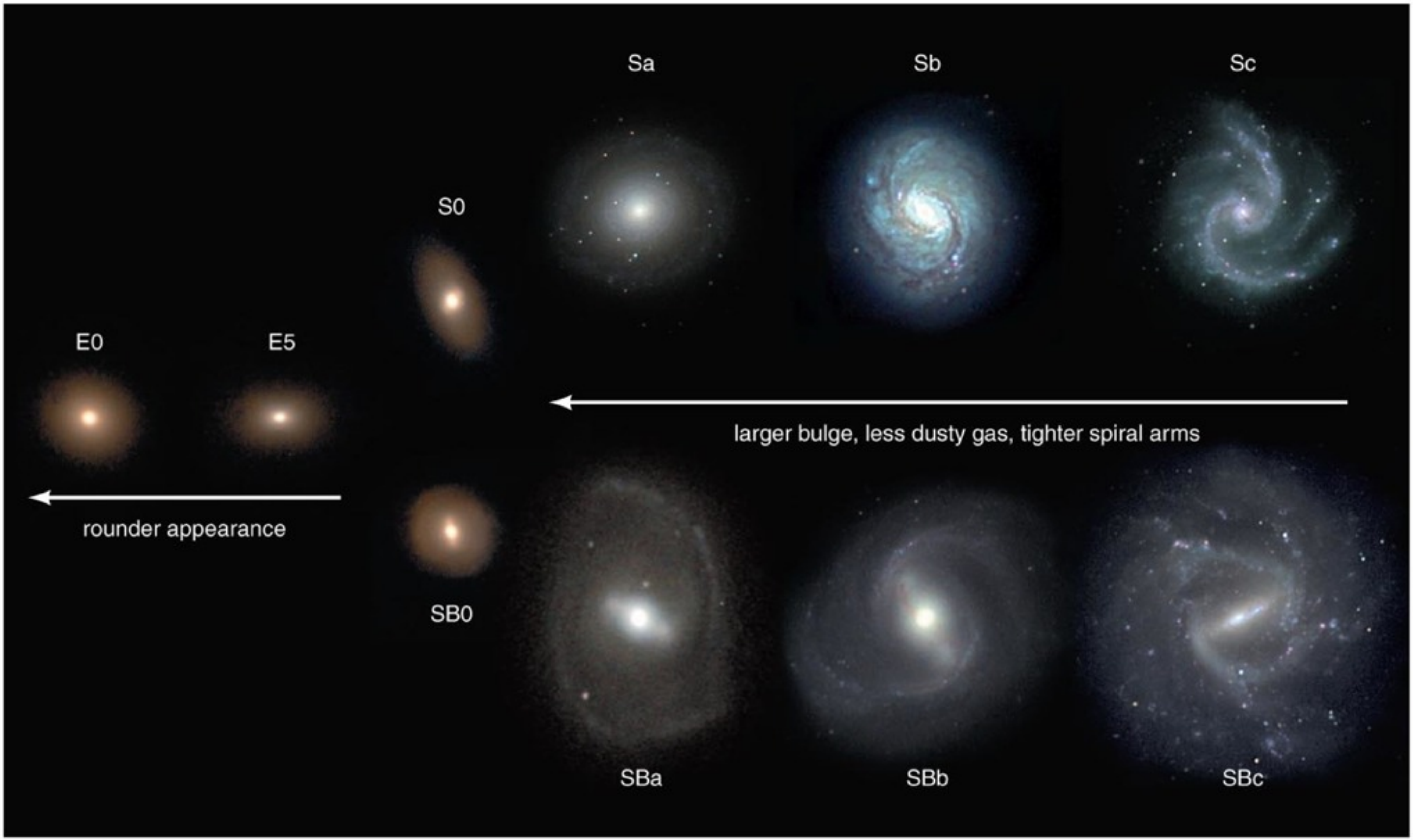
Lenticulars

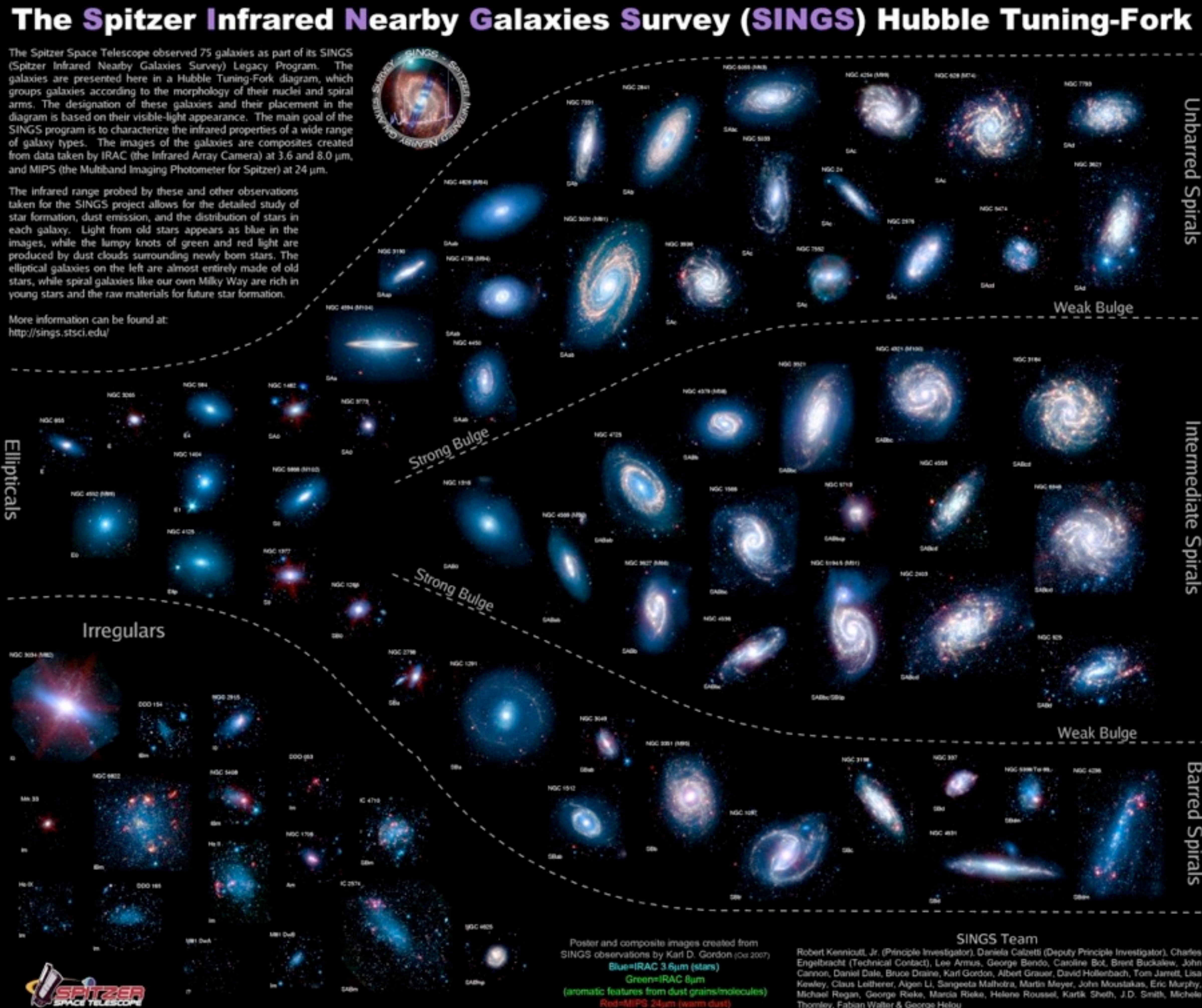


Irregulars



Hubble's Galaxy Tuning Fork



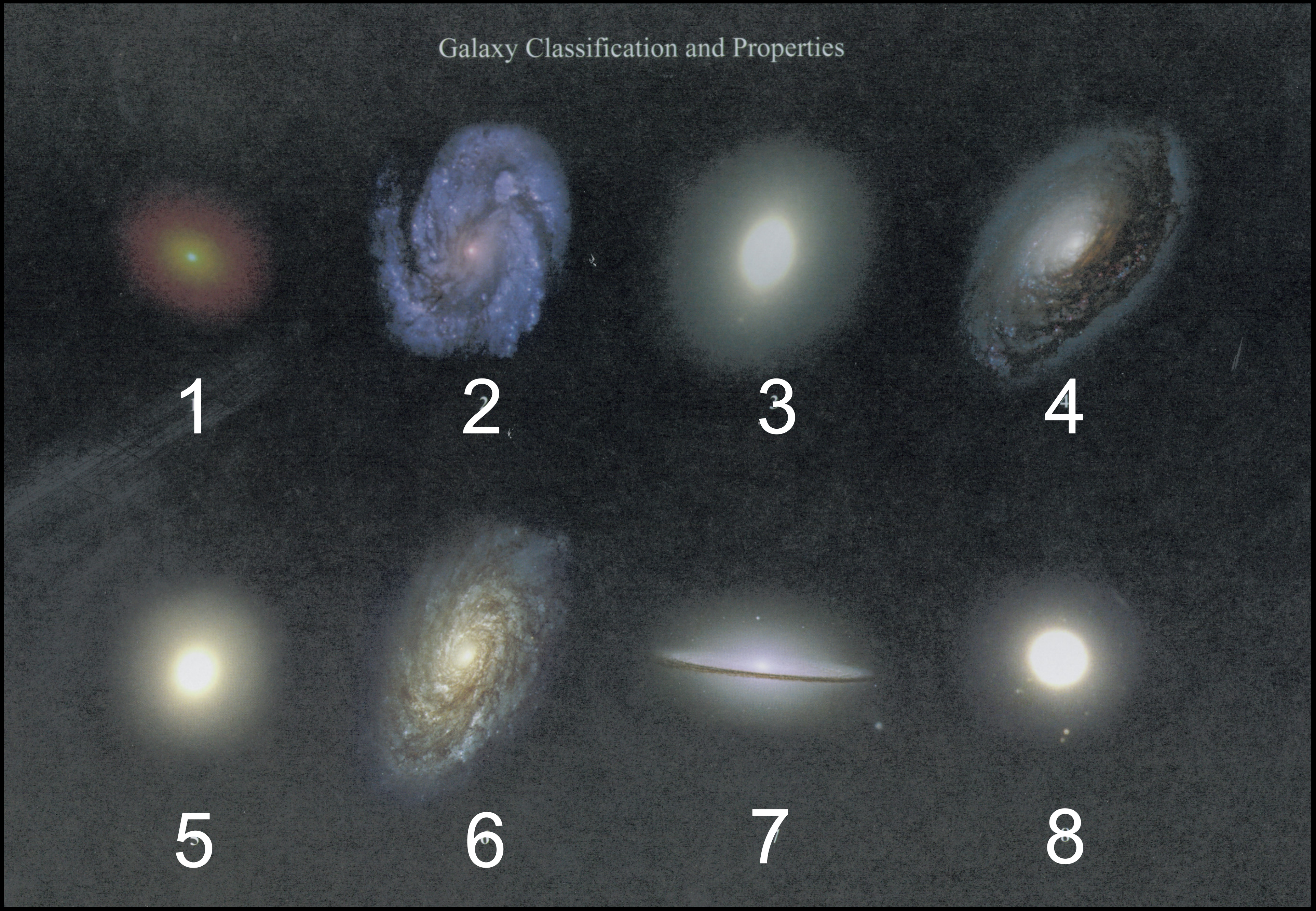

The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork
The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 µm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 µm.
The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.
More information can be found at:
http://sings.stsci.edu/
Ellipticals
Irregulars
Strong Bulge
Strong Bulge
Weak Bulge
Weak Bulge
Unbarred Spirals
Intermediate Spirals
Barred Spirals
Poster and composite images created from SINGS observations by Karl D. Gordon (Oct 2007)
Blue=IRAC 3.6µm (stars)
Green=IRAC 8µm
(aromatic features from dust grains/molecules)
Red=MIPS 24µm (warm dust)
SINGS Team
Robert Kennicutt, Jr. (Principle Investigator), Daniela Calzetti (Deputy Principle Investigator), Charles Engelbracht (Technical Contact), Lee Armus, George Bendo, Caroline Bot, Brent Buckalew, John Cannon, Daniel Dale, Bruce Draine, Karl Gordon, Albert Grauer, David Hollenbach, Tom Jarrett, Lisa Kewley, Claus Leitherer, Aigen Li, Sangeeta Malhotra, Martin Meyer, John Moustakas, Eric Murphy, Michael Regan, George Rieke, Marcia Rieke, Helene Roussel, Kartik Sheth, J.D. Smith, Michele Thornley, Fabian Walter & George Helou
SPITZER
SPACE TELESCOPE

Want to help astronomers classify galaxies?

- Check out www.galaxyzoo.org

Tutorial Time!

- Galaxy Classification, pg. 127



Galaxy Evolution

Now that we know what they look like, how did they end up that way?

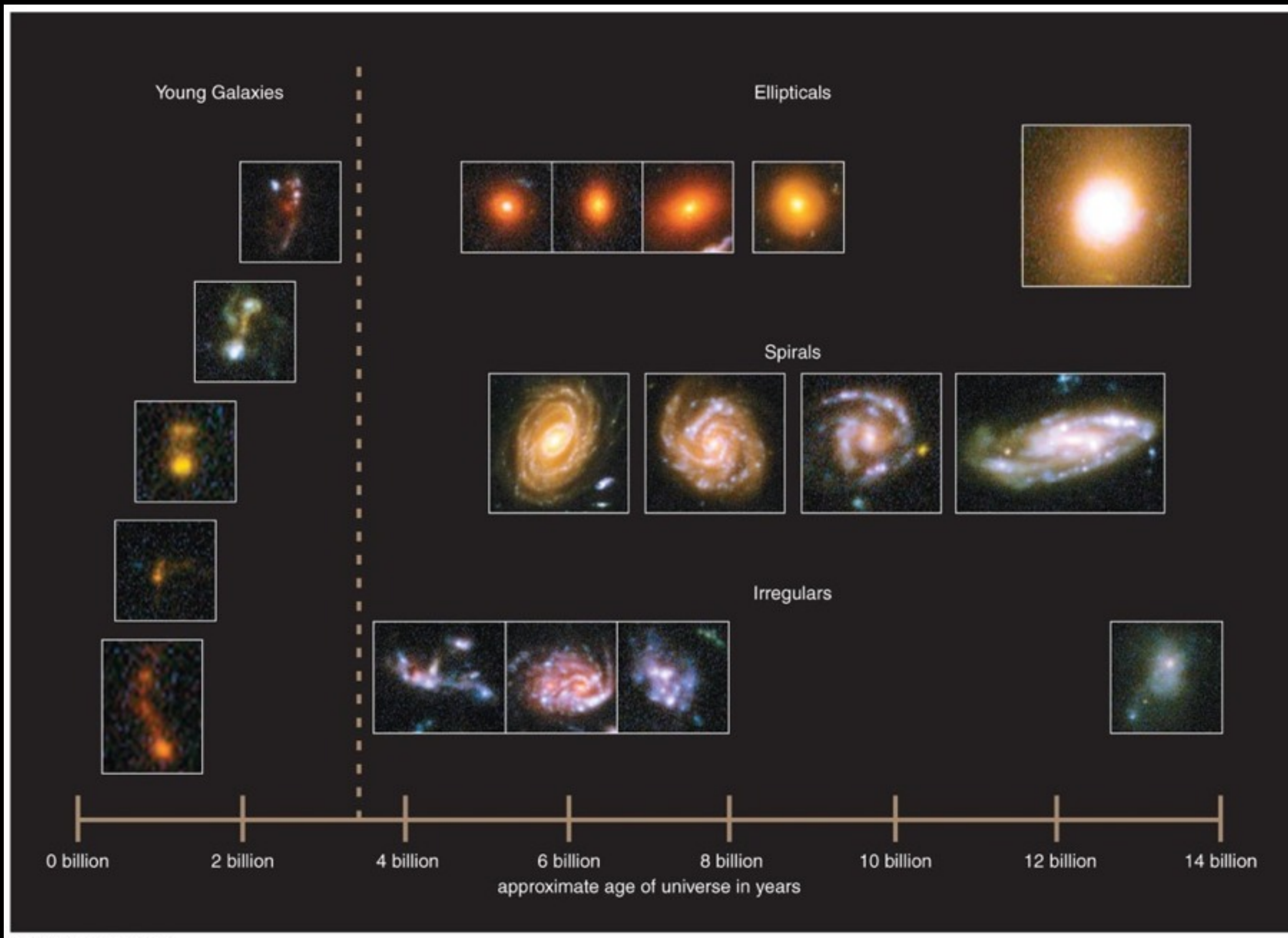
Looking back in time

- Timescales for galaxy evolution are long
- Nearby galaxies formed in the distant past
- Given this, how can we study galaxy formation?

By looking at very distant galaxies, we see them as they were a long time ago

Unfortunately, far away galaxies are not easy to see!

A Galactic Family Album



Which galaxy is more likely to be seen when the universe was 1 billion years old?

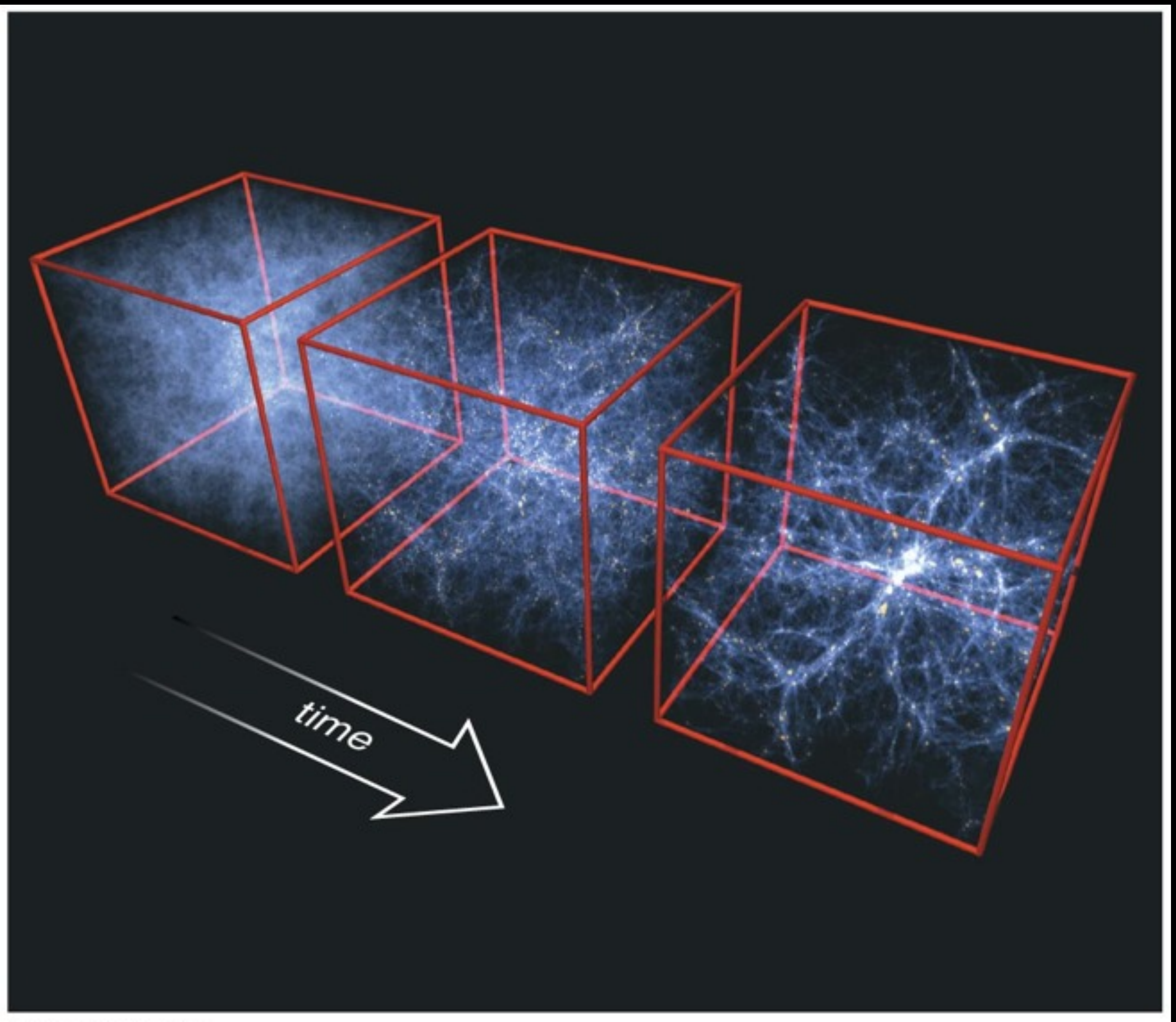
A) A

B) B

C) Don’t know

Modeling Galaxy Birth

- The basic idea:



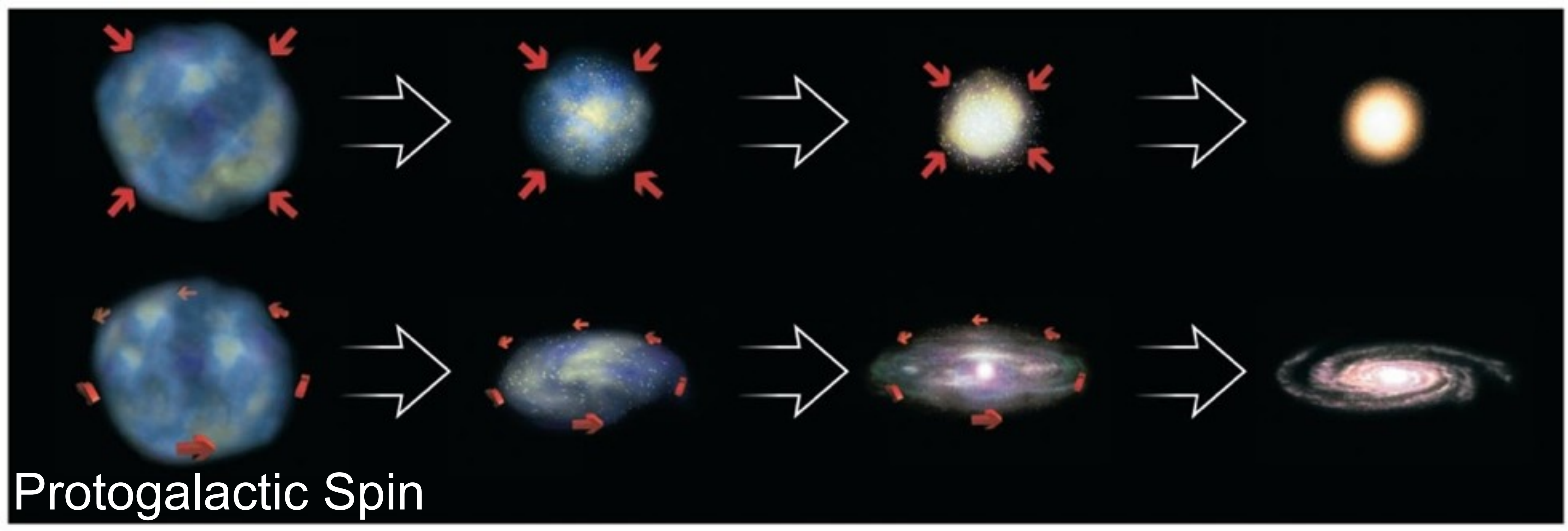
  - The universe was nearly uniformly full of hydrogen and helium
  - Slight over-densities in the universe start collapsing
  - These collapsed regions serve as the formation sites for galaxies

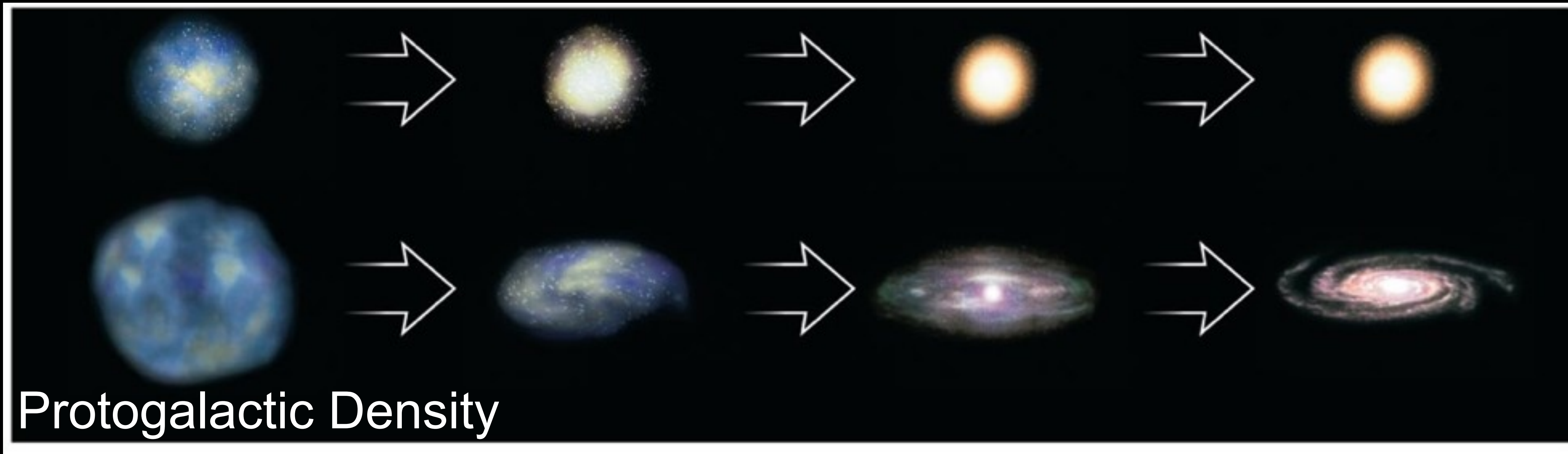
Why don’t all galaxies look the same?

- Two possibilities:

1. Different initial conditions led to different final results
2. Initial conditions may have been similar, but interactions with other galaxies altered them

Different initial conditions

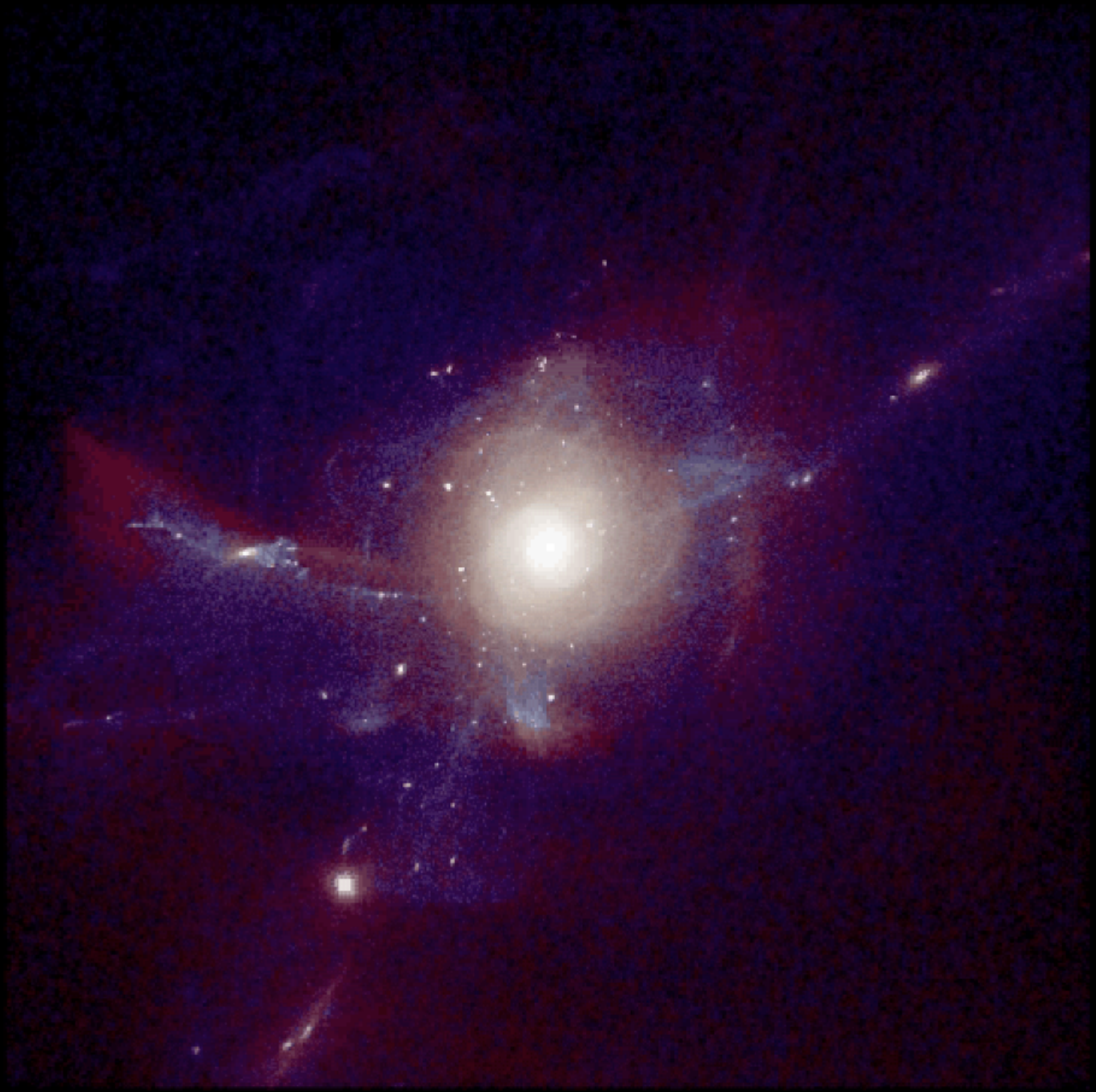




Galactic Collisions

A collision and merger of two spirals could result in an elliptical

Galactic Collisions

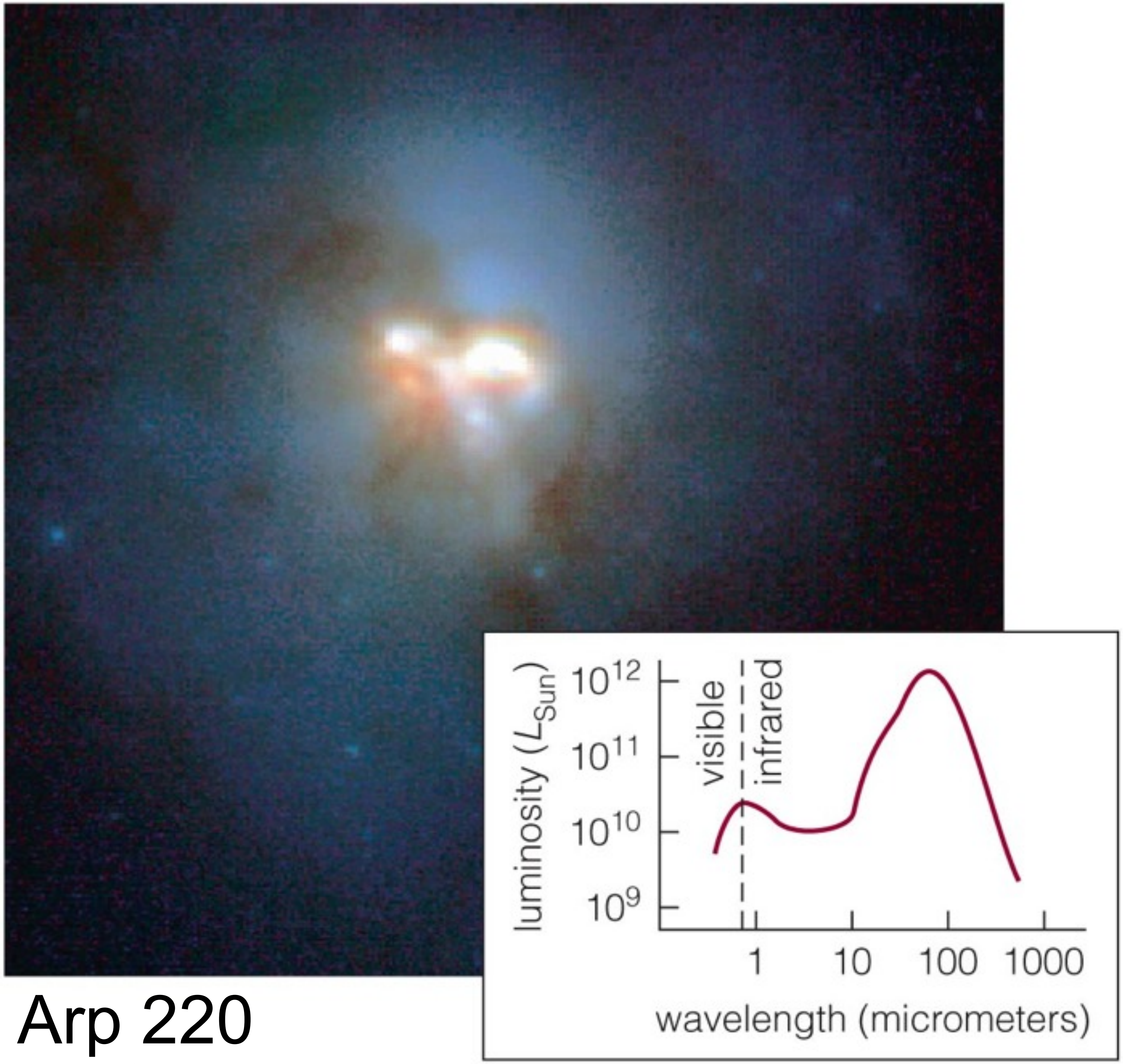


A collision and merger of two spirals could result in an elliptical

Galactic Activity
“Starburst Galaxies”

- A small percentage of galaxies are producing stars at an accelerated rate
- Normal galaxy: 1 star per year
- Starburst Galaxy: 100 stars per year
- These rates are unsustainable -- if they continued, the galaxy would run out of interstellar gas in a few hundred million years

What do they look like?



Arp 220

Due to dust and gas blocking visible light, they aren't much brighter than normal galaxies at such wavelengths

However, they are nearly 100 times brighter in the infrared!

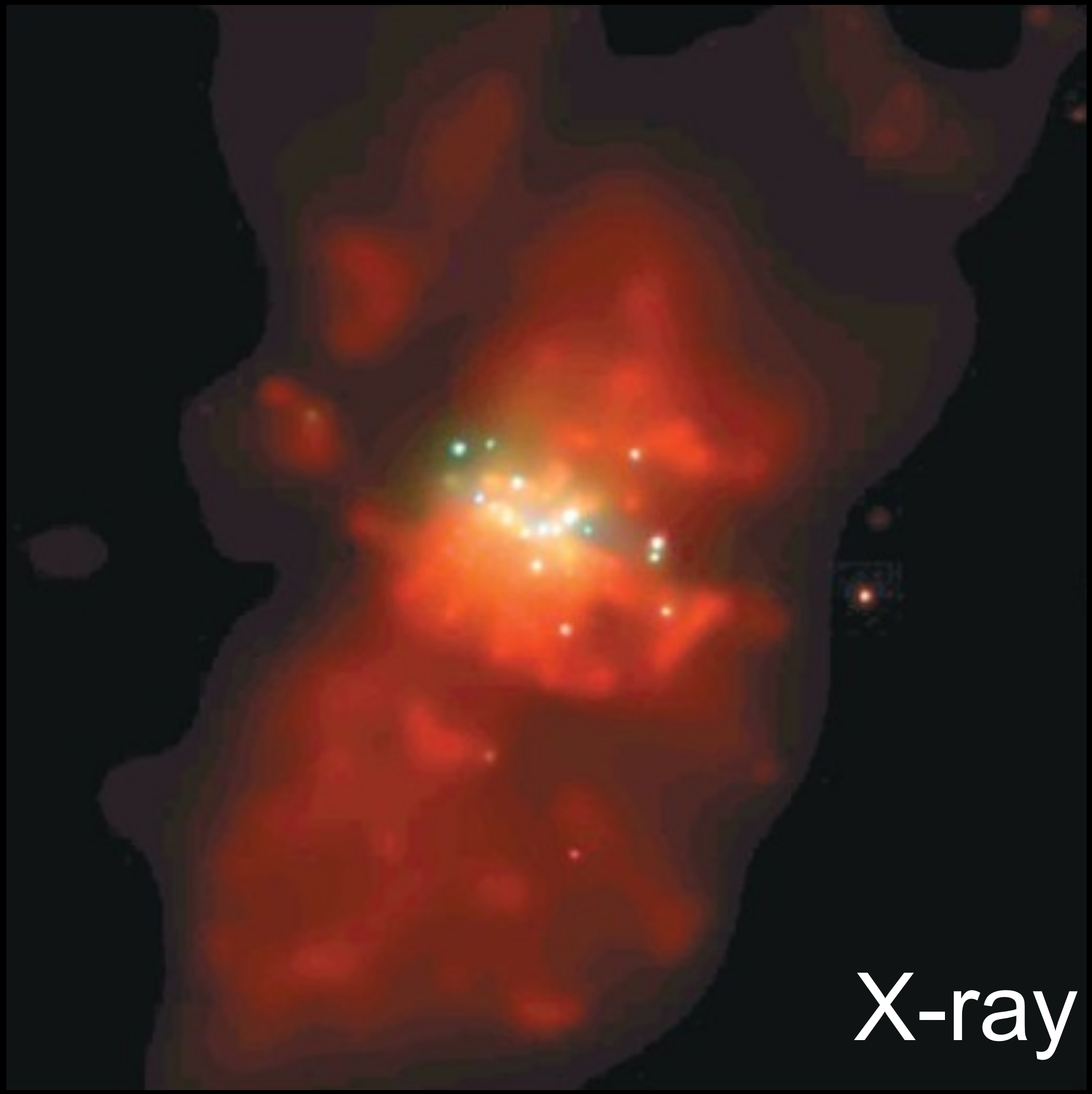
Infrared light is from heated dust grains

Other effect: galactic winds!

- A factor of 100 increase in star formation rate means a factor of 100 increase in supernova rate
  -- super-powered super bubbles!
- Winds consist of low-density, extremely hot gas (10-100 million K) -- this generates lots of x-ray emission
- These winds can push lots of material out of small galaxies -- can shut off star formation

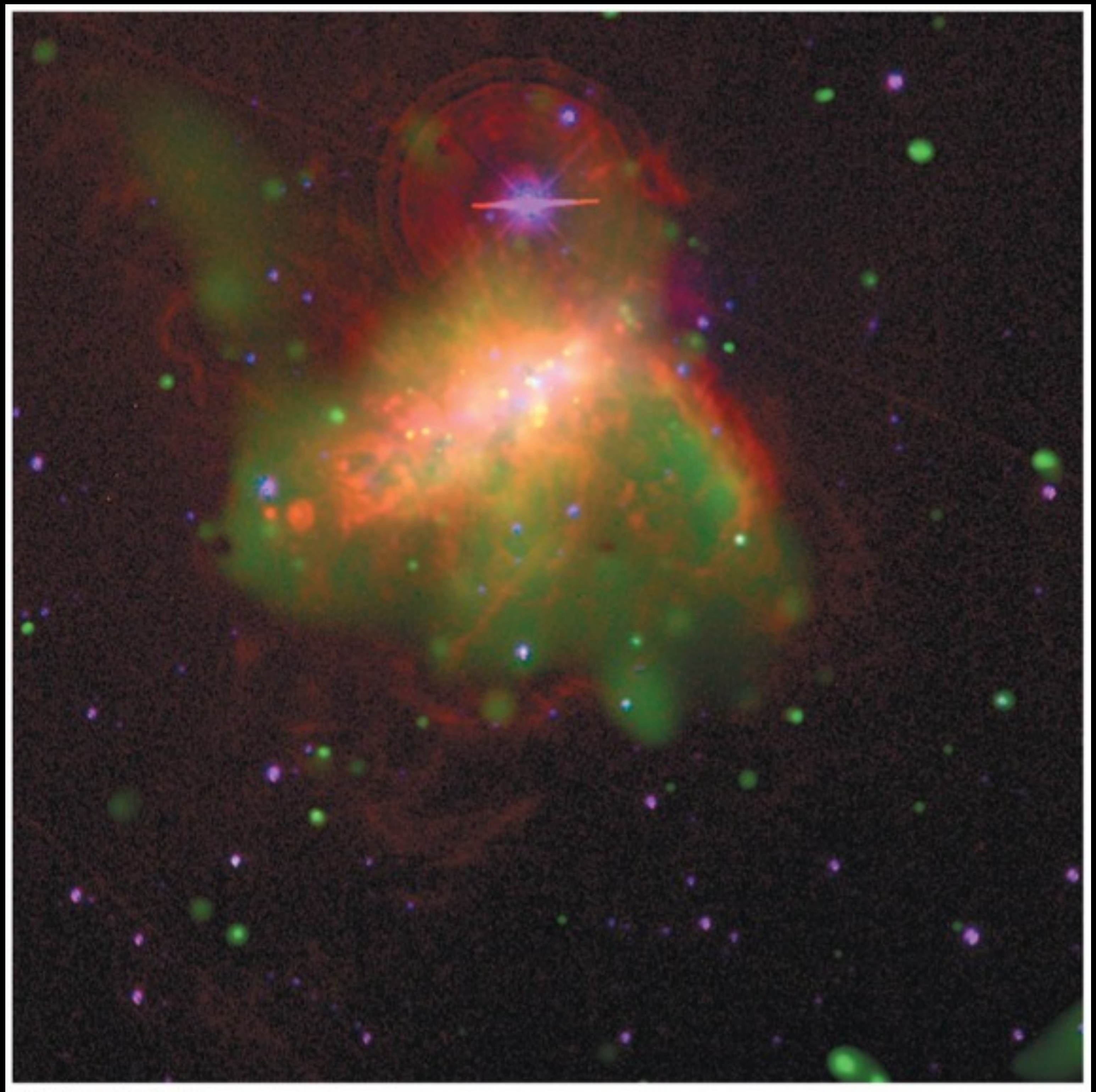
Visual Evidence

M82



Visual Evidence

NGC 1569 -- Dwarf starburst galaxy



Causes for starbursts?

- Collisions?
- Close encounters? (Large Magellanic Cloud)

We know what they look like, we know why they might look that way, but how far away are they?

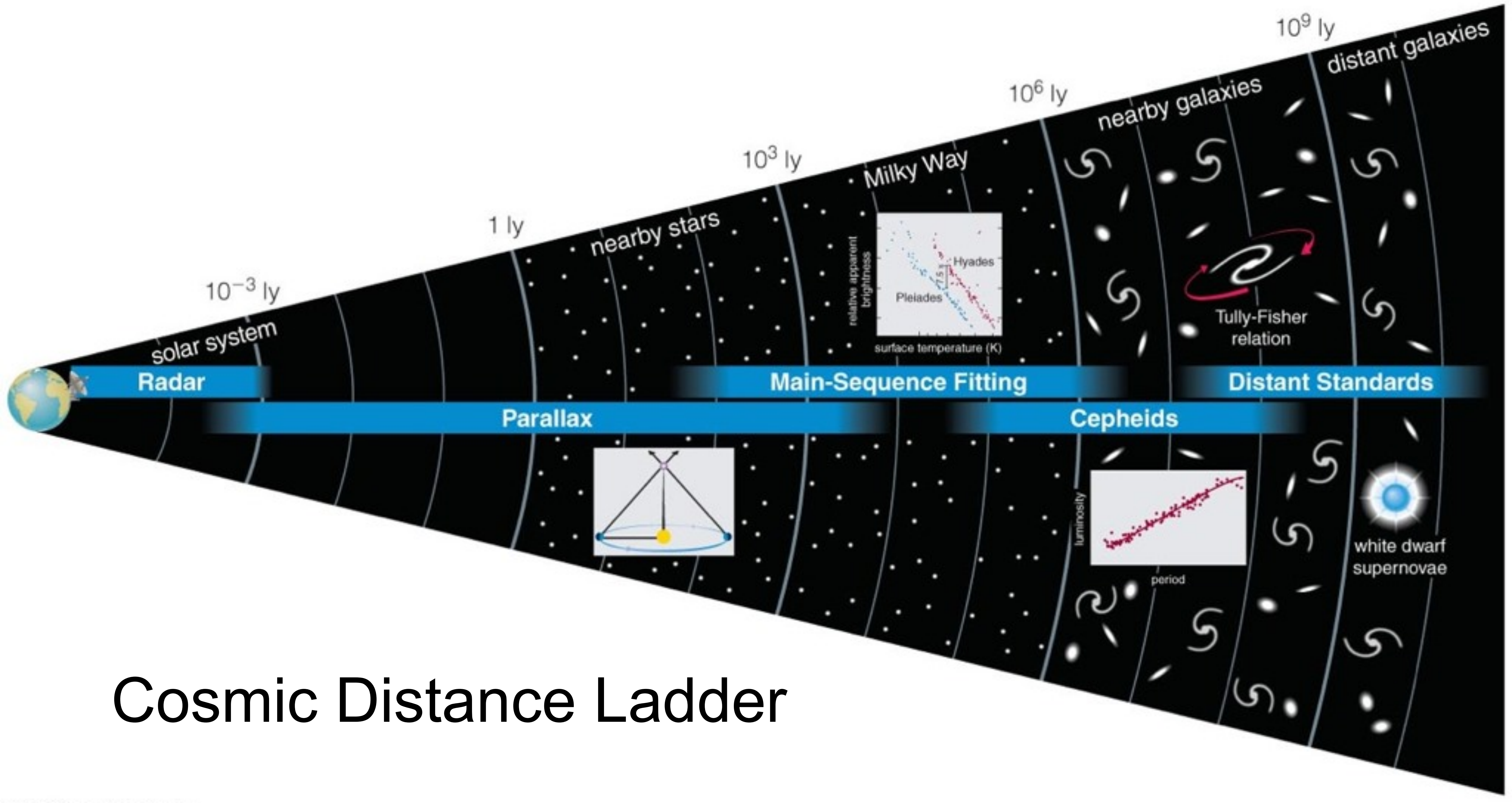
How do we measure galactic distances?

Why do we care about distances?

- Estimating distances gives us an idea about the size of the observable Universe.

- Distances give us look-back times
  - How old are we?
  - What do ‘young’ galaxies look like?
  - When did galaxies first start forming?

No one method is good enough for all distances



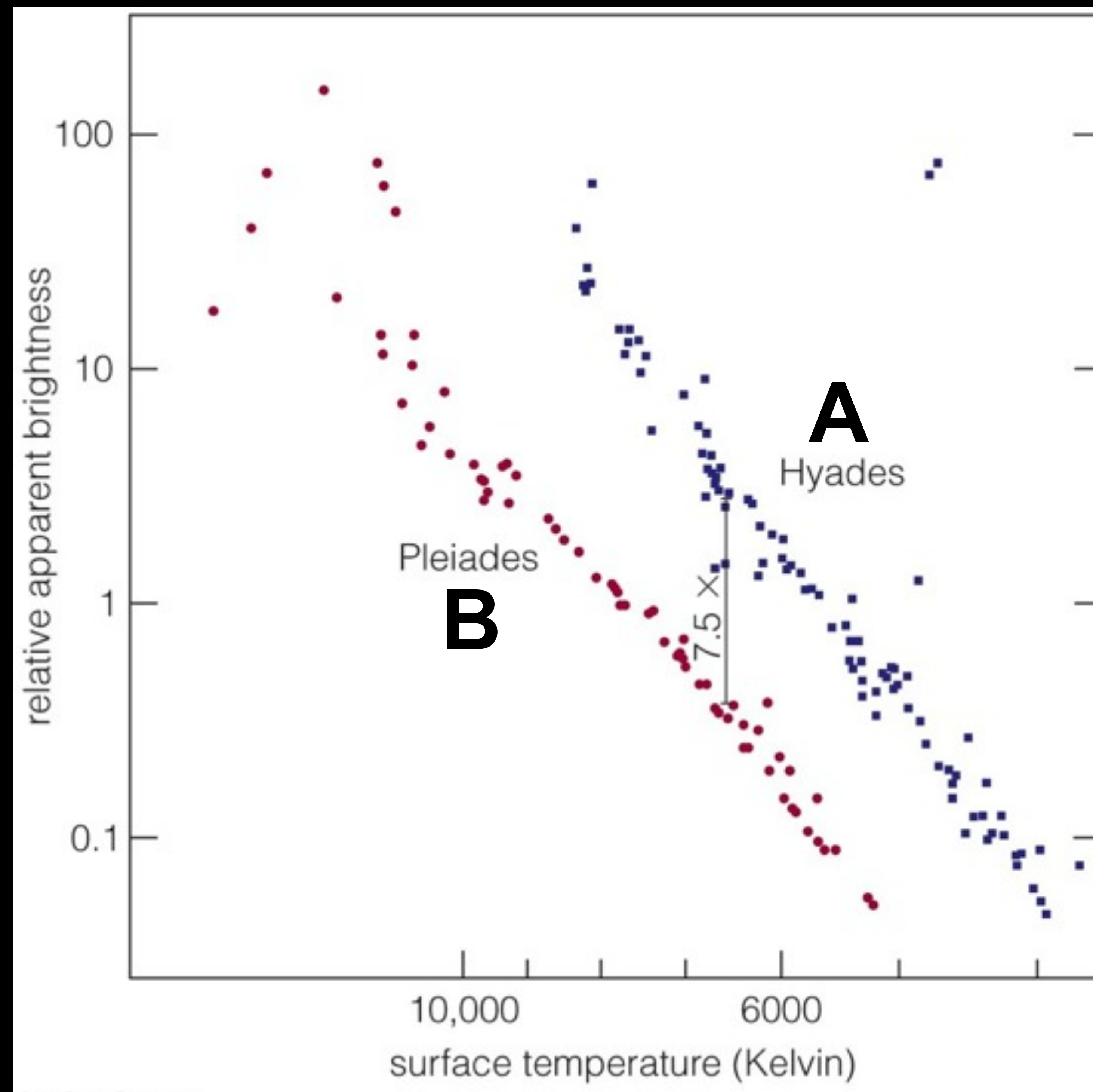
Cosmic Distance Ladder

Shown is the main sequence for two stellar clusters. Which cluster is closer?

A) Hyades

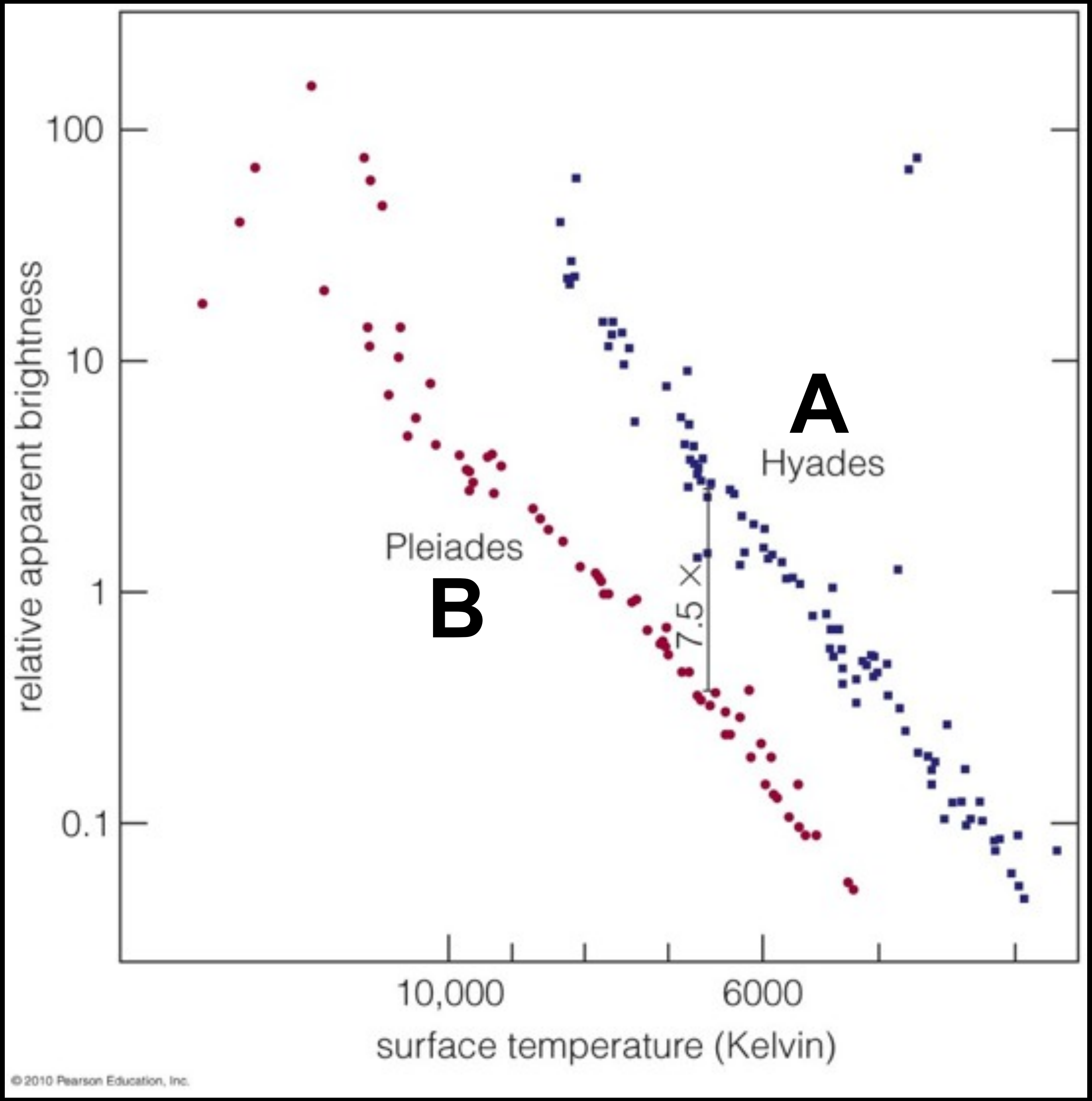
B) Pleiades

C) Not enough information to tell



Main-sequence Fitting

- Start with a cluster whose distance is known via parallax (A)
- Compare to another cluster (B)
- Calculate the distance to B based on brightness difference



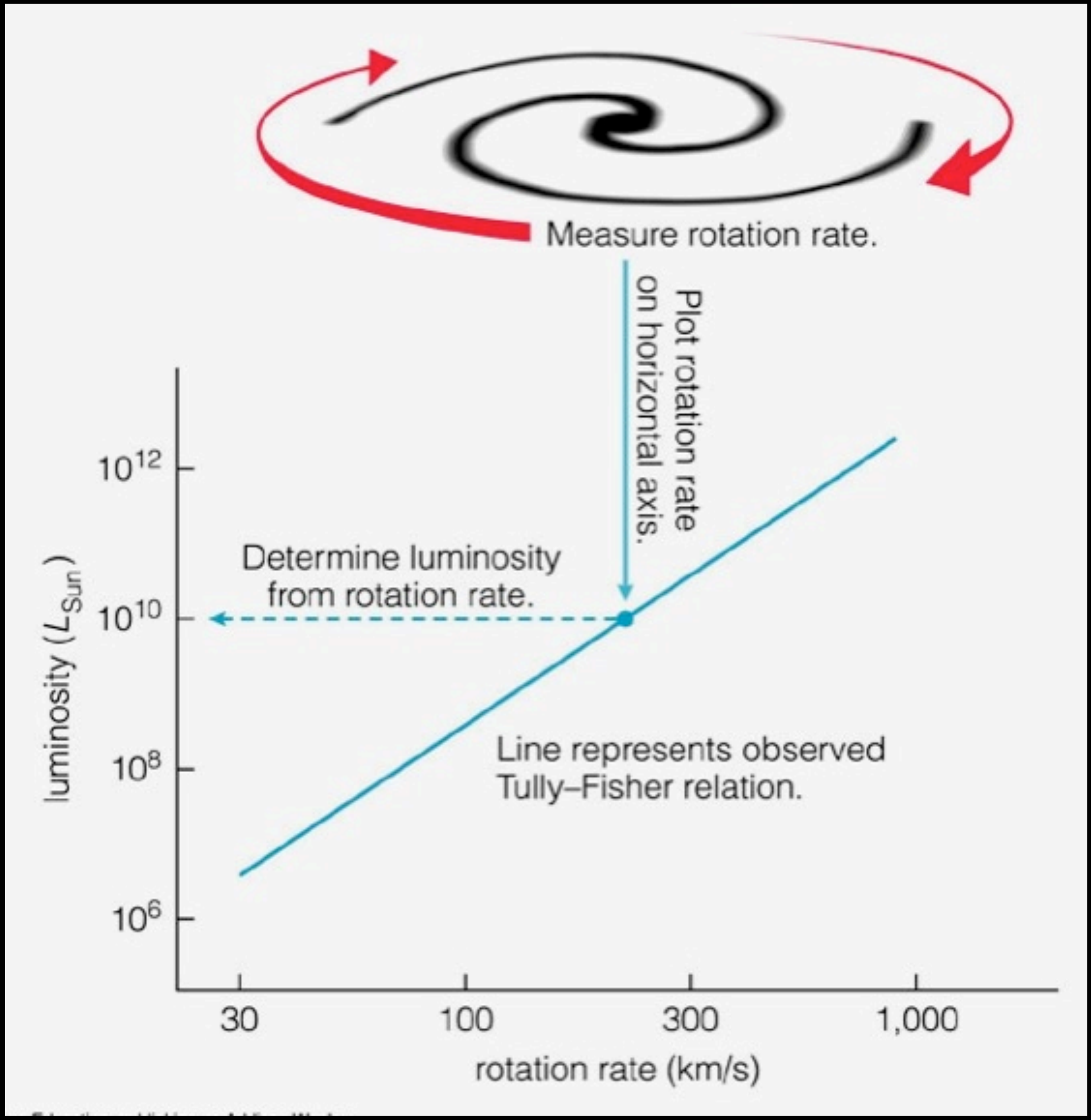
Distances good to about 200,000 ly

Hyades Cluster

- Popular cluster for main-sequence fitting
- Only ~150 ly away
- Can get distances to nearly all the cluster members using parallax

Tully-Fisher Relation

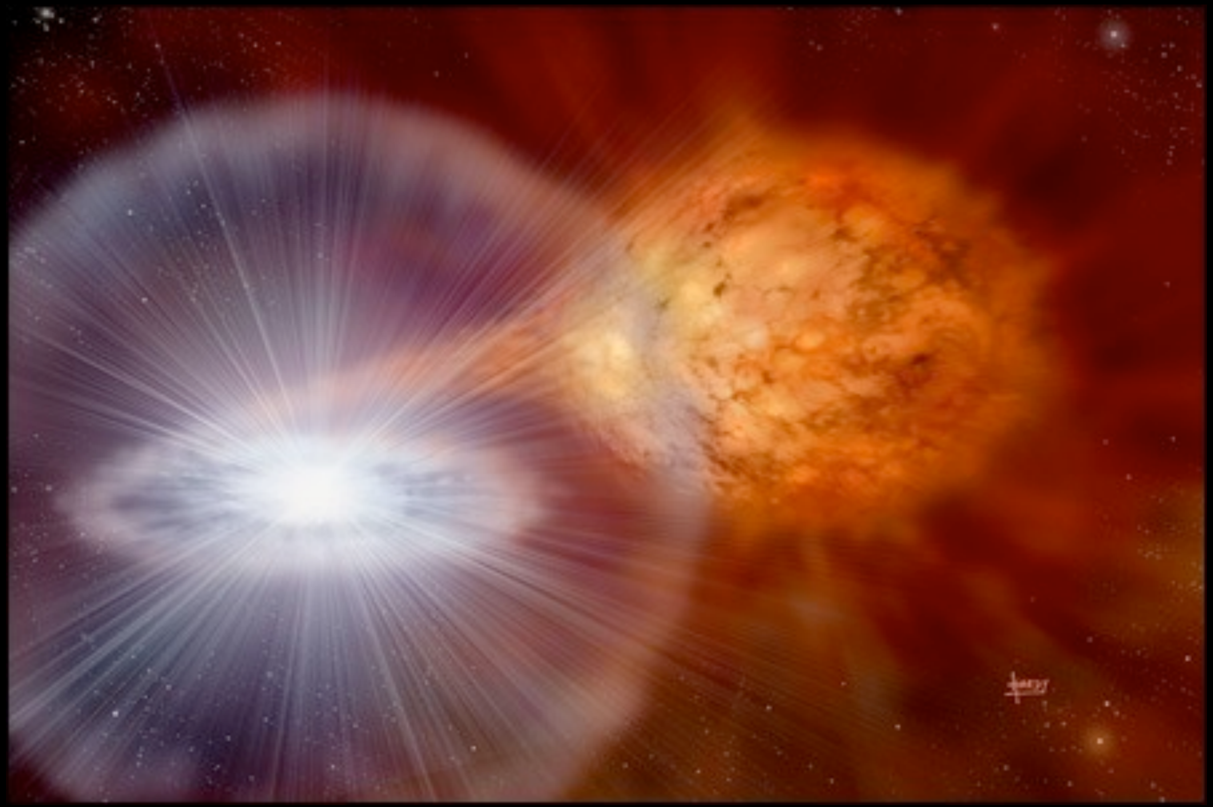
- Fast rotation speeds in spiral galaxies
  - more mass in galaxy
  - higher luminosity
- Measure rotation speeds to infer luminosity
- Need bright "edge-on" spirals, estimate tilt



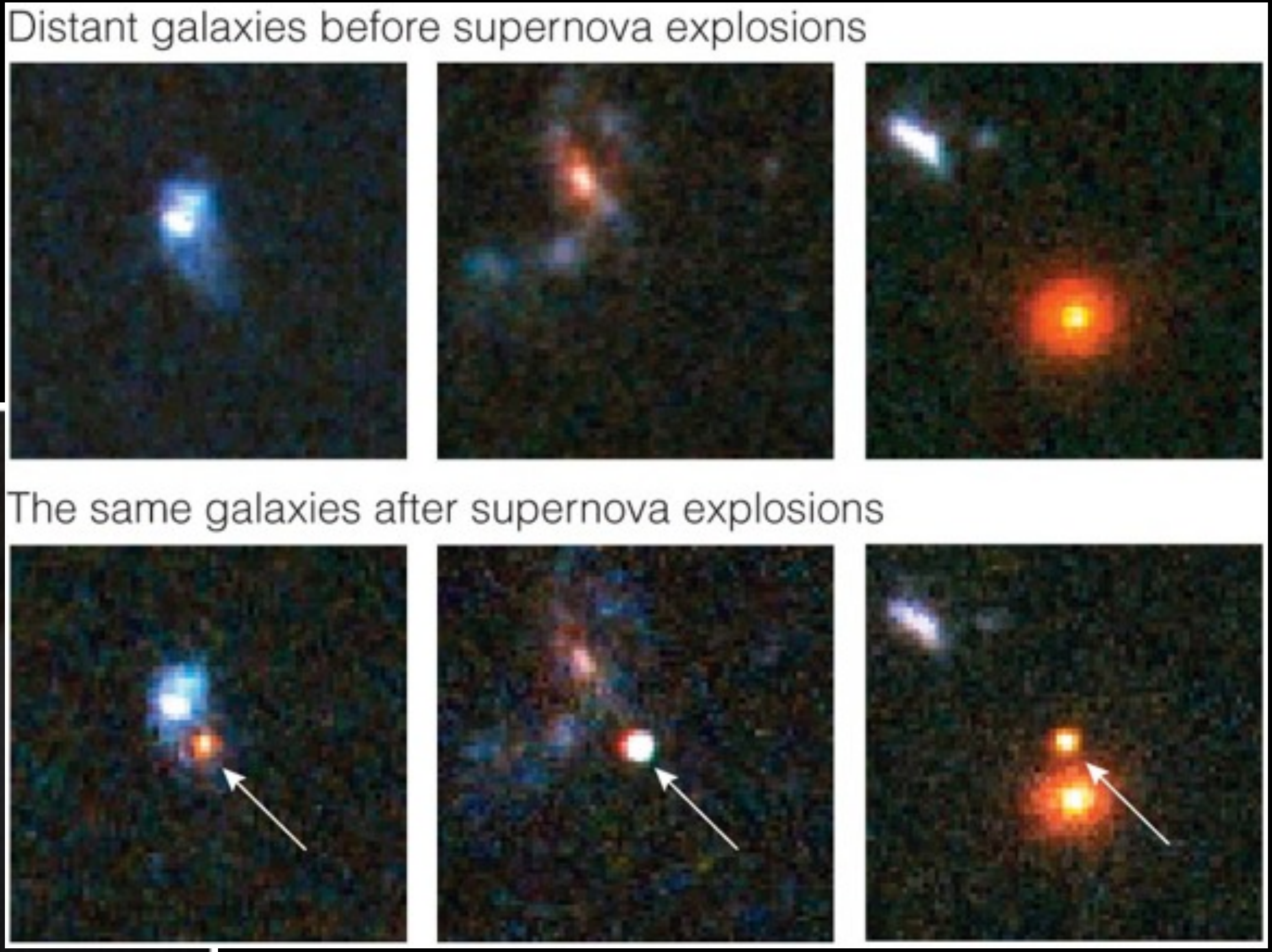
Distances good to about 10 billion ly

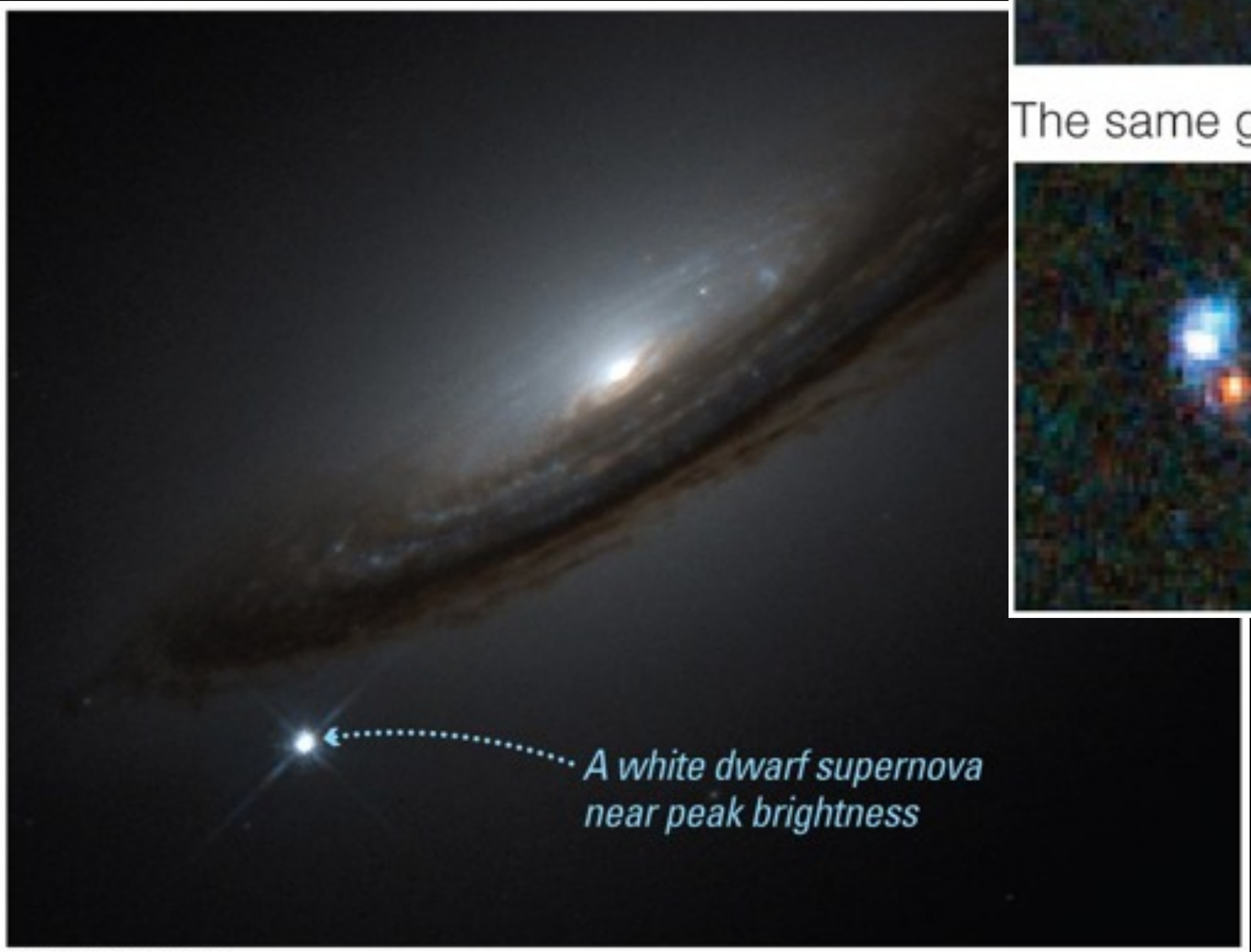
White dwarf supernova

- Nearly the same amount of energy released every time (why?)
- "Standard explosion" = fusion of 1.4 solar masses of material



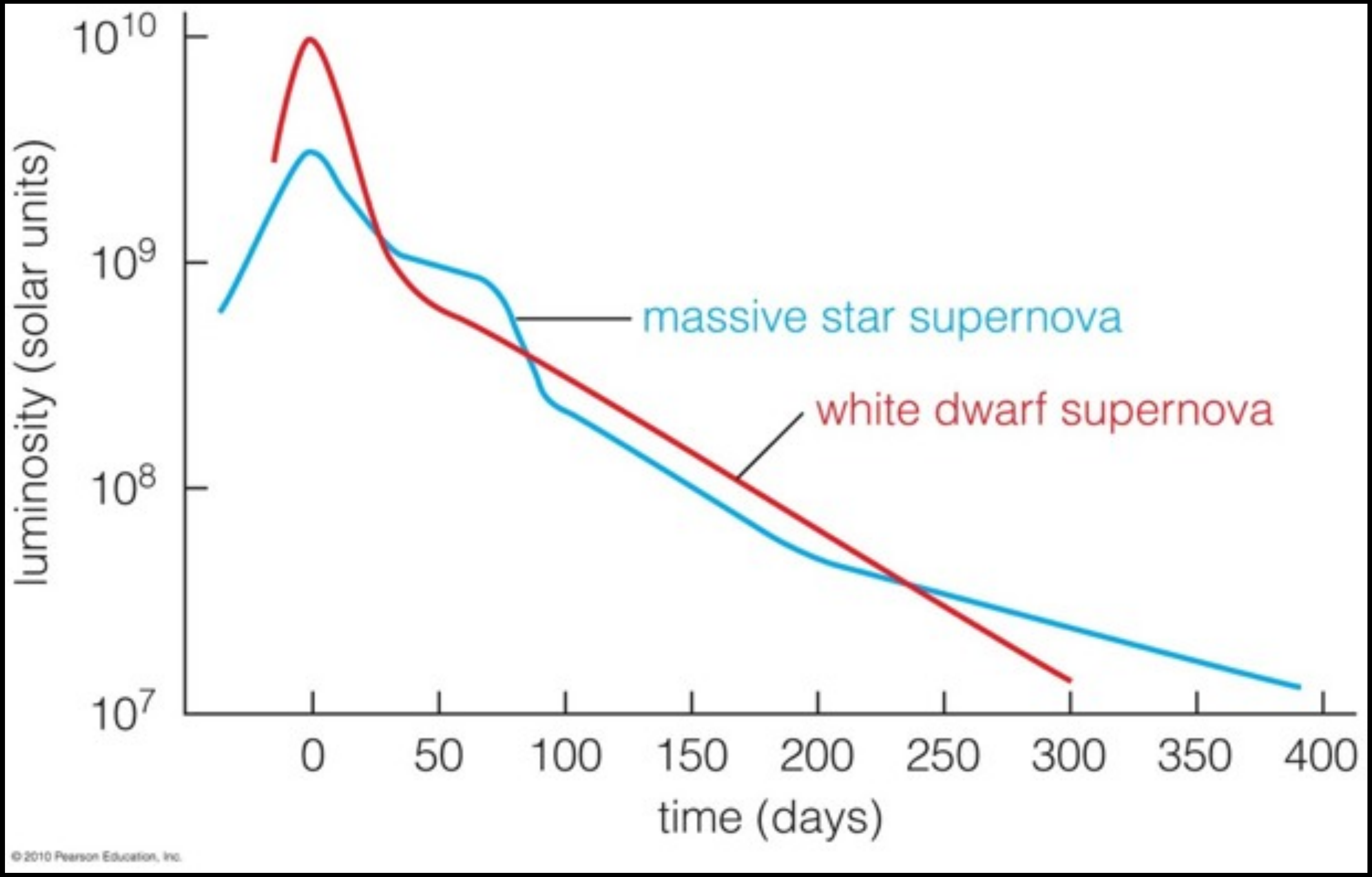
Bright enough to be seen in the far reaches of the observable universe





Useful for mapping the universe
to the largest distances

But there is a catch...



- Need to catch them within a day or two of the explosion
- About 1 per galaxy per century
- Need to monitor thousands of galaxies to catch a few per year

"Standard Candles"

- Objects whose absolute luminosity can be figured out through other means

1. Main-sequence fitting
2. Cepheid variables
3. Tully-Fisher relation
4. White dwarf supernovae

$$\text{Brightness} \propto \text{Luminosity} / \text{Distance}^2$$

Summary

- Three main type of galaxies: elliptical, spiral, irregular
- Galaxy formation is not a solved problem
  - Could be a direct result of initial conditions
  - Could be the result of galaxy interactions
- Measuring galactic distances tells us information about the size of the universe and a means of making galactic “family albums”