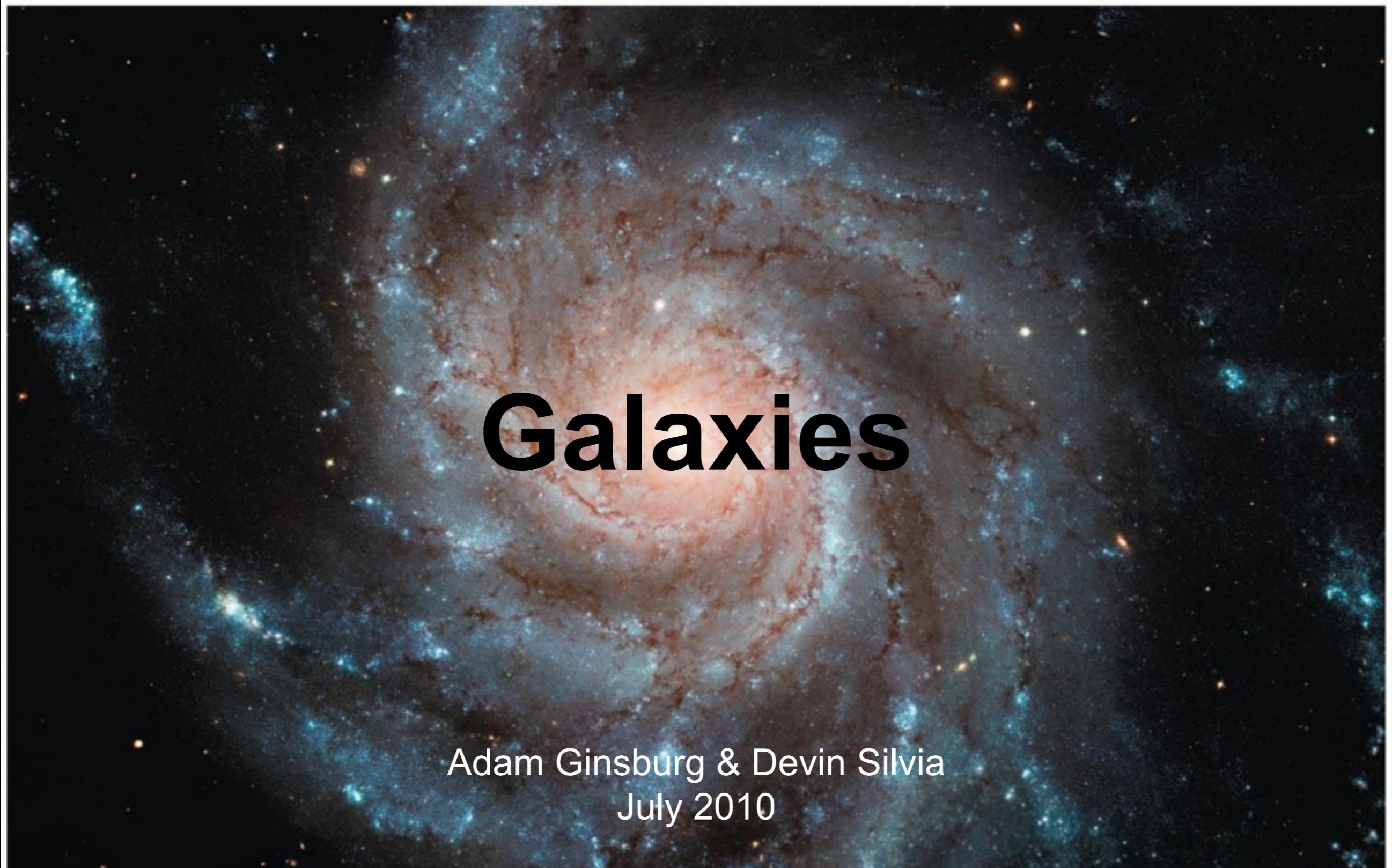


# ASTR 1120

## :: Star and Galaxies ::



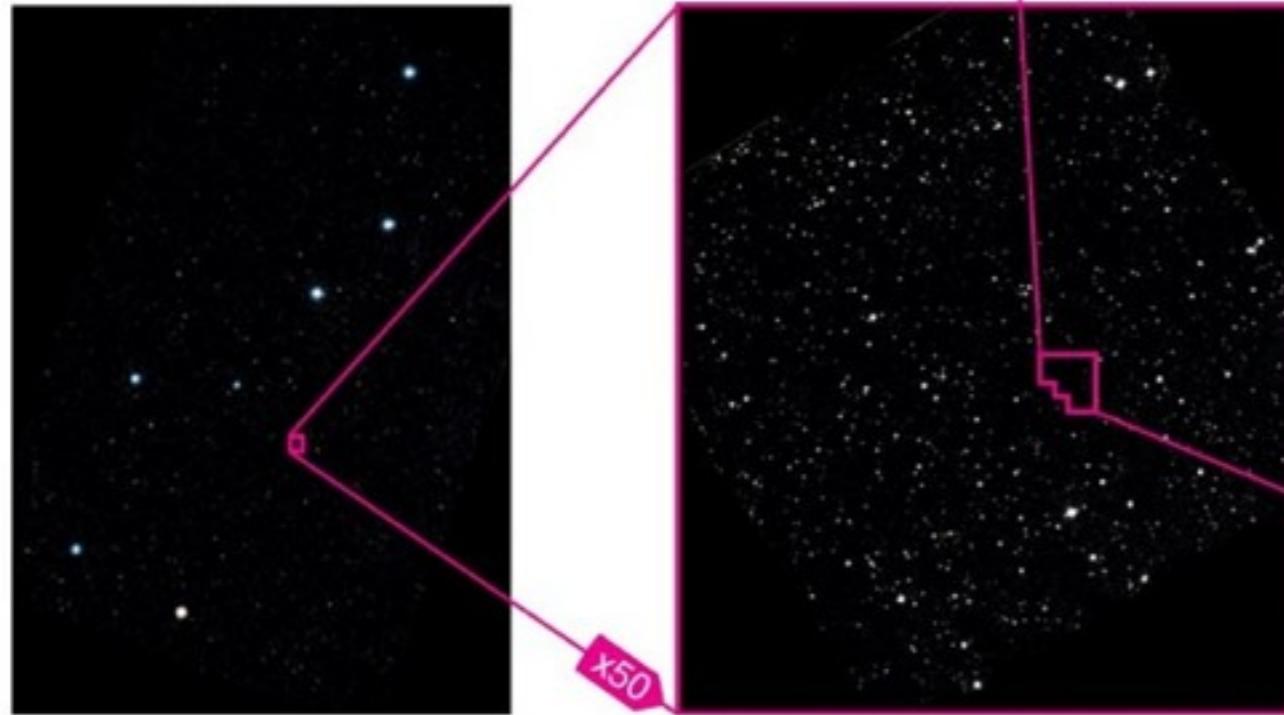
Galaxies

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...



x50

x30



Hubble Deep Field

# How many galaxies are out there?



# What types of galaxies are out there?



# What types of galaxies are out there?

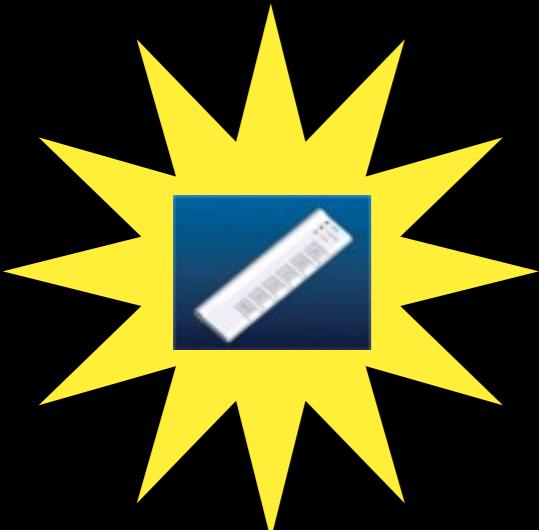


Ellipticals

Irregulars



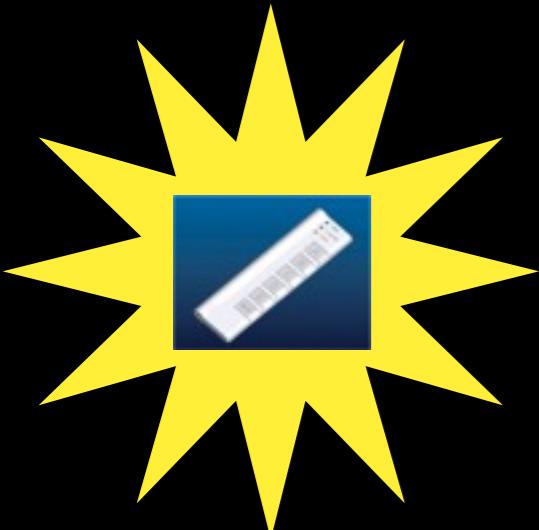
Spirals



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

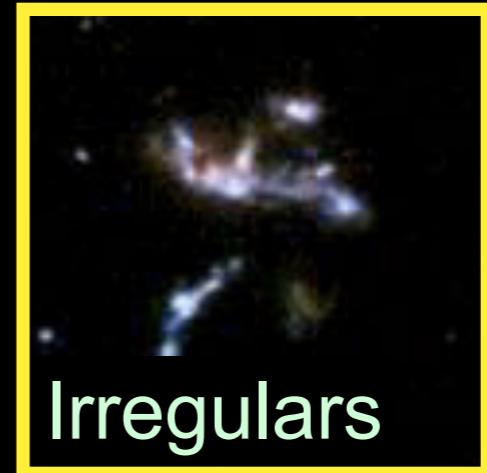
- A) Spirals
- B) Ellipticals
- C) Irregulars
- D) Spirals and Ellipticals
- E) Spirals and Irregulars





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

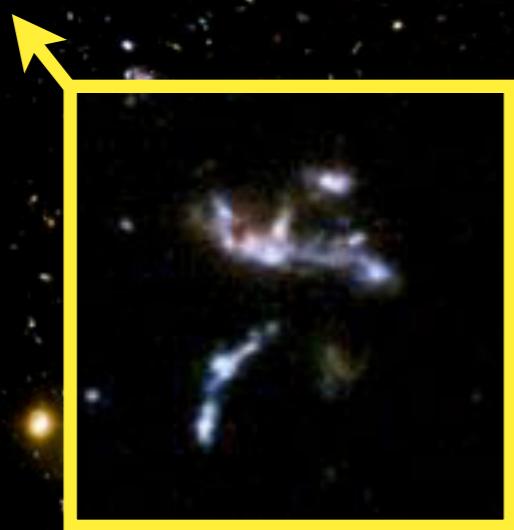


# What types of galaxies are out there?

Irregulars

Less understood.

Galaxies in formation?  
Or transition?  
Or failed?  
Often LOTS of star birth



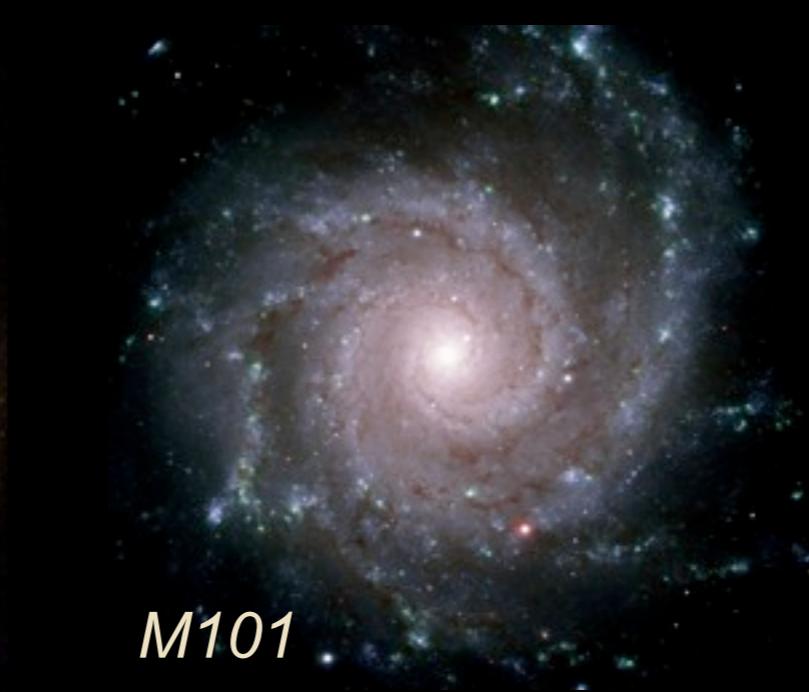
# Ellipticals



# Spirals



*NGC 4622*



*M101*



*NGC 1365*

# Lenticulars

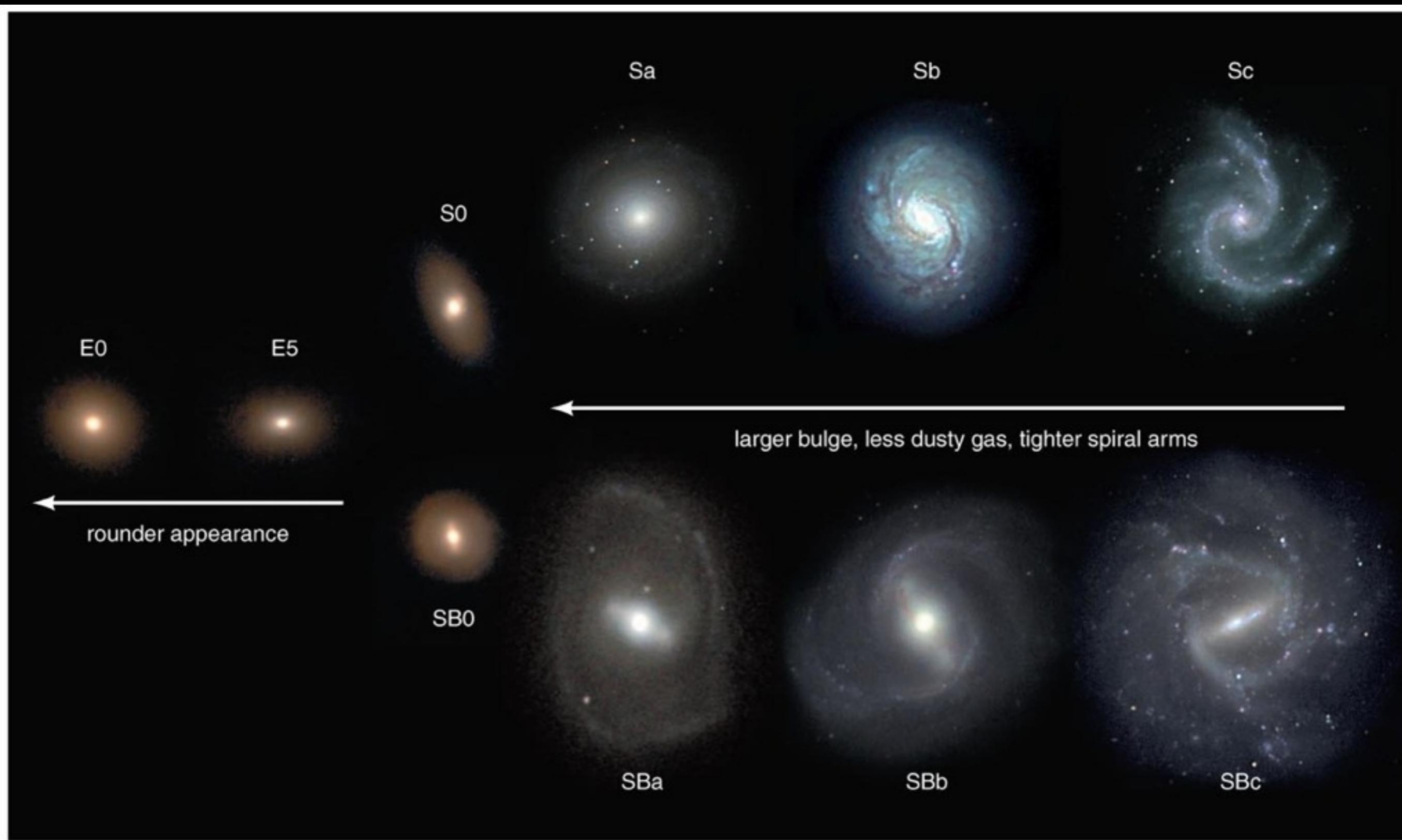


# Irregulars



UKS 17

# 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  $\mu\text{m}$ , and MIPS (the Multiband Imaging Photometer for Spitzer) at 24  $\mu\text{m}$ .

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

## Unbarred Spirals

## Intermediate Spirals

## Barred Spirals

Poster and composite images created from  
SINGS observations by Karl D. Gordon (Cox 2007)

Blue=IRAC 3.6 $\mu\text{m}$  (stars)

Green=IRAC 8 $\mu\text{m}$

(aromatic features from dust grains/molecules)

Red=MIPS 24 $\mu\text{m}$  (warm dust)

## SINGS Team

Robert Kennicutt, Jr. (Principal Investigator), Daniela Calzetti (Deputy Principal Investigator), Charles Engelbracht (Technical Contact), Lee Armus, George Bendo, Caroline Boz, 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, Maria Rieke, Helene Roussel, Kartik Sheth, J.D. Smith, Michele Thomley, Fabian Walter & George Helou



# Want to help astronomers classify galaxies?

The screenshot shows the Galaxy Zoo website. At the top, it says "EN - Galaxy Zoo is a ZOO NIVERSE project" and "...just like MOON ZOO". The main title "GALAXY ZOO" is displayed prominently with a stylized orange sun-like icon. To the right, there's a "HUBBLE" logo. Below the title is a navigation bar with links: Home, The Story So Far, The Science, How To Take Part, Classify Galaxies, Forum, Zoo Media, Blog, FAQ, and Contact Us. A large, dark background image of a star-filled galaxy field is visible. On the right side of the page, there are two sidebar boxes: one for "Classifier Log In" with a "Click here to log in" button and links for "Register" and "Forgotten Password?"; and another for "Latest News" featuring a "Happy birthday to us." post by Chris from July 11, 2010, and a list of other news items.

**Welcome to Galaxy Zoo, where you can help astronomers explore the Universe**

Galaxy Zoo: Hubble uses gorgeous Imagery of hundreds of thousands of galaxies drawn from NASA's Hubble Space Telescope archive. To understand how these galaxies, and our own, formed we need your help to classify them according to their shapes — a task at which your brain is better than even the most advanced computer. If you're quick, you may even be the first person in history to see each of the galaxies you're asked to classify.

More than 250,000 people have taken part in Galaxy Zoo so far, producing a wealth of valuable data and sending telescopes on Earth and in space chasing after their discoveries. The Images used in Galaxy Zoo: Hubble are more detailed and beautiful than ever, and will allow us to look deeper into the Universe than ever before. To begin exploring, click the 'How To Take Part' link above, or read The Story So Far to find out what Galaxy Zoo has achieved to date.

Thanks for your help, and happy classifying.

*The Galaxy Zoo team.*

**Classifier Log In**

[Click here to log in](#)

» Register  
» Forgotten Password?

**Latest News**

**Happy birthday to us.**  
by Chris - Jul 11, 2010

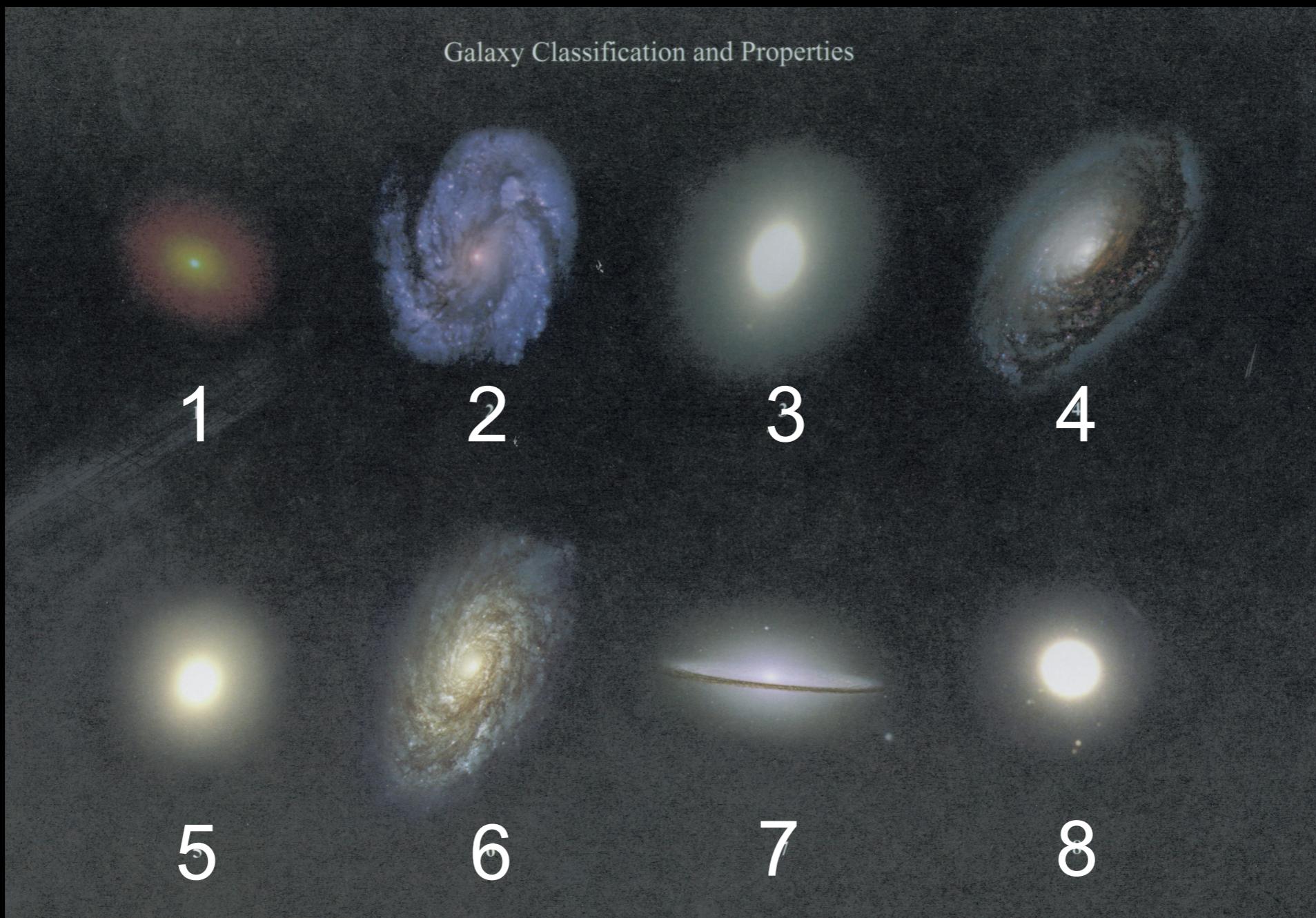
Galaxy Zoo is three years old today. Three years ago, I opened my laptop in the back of a Royal Astronomical Society meeting, ...

» Happy birthday to us.  
» Announcing the Galaxy Zoo iPhone App  
» Galaktyczne Zoo Hubble po polsku!  
» Classification tree tweaks

- Check out [www.galaxyzoo.org](http://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?

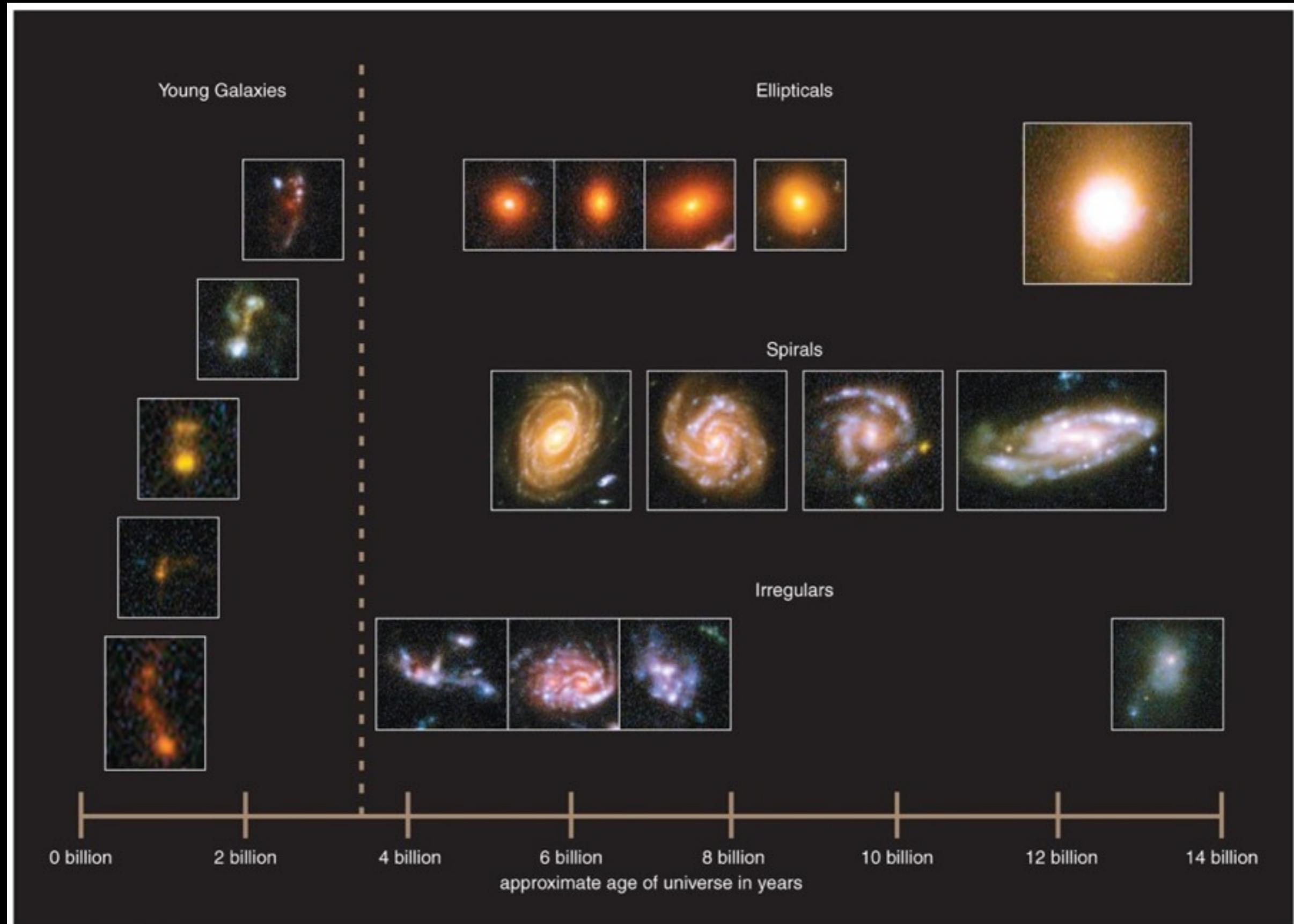
# Looking back in time

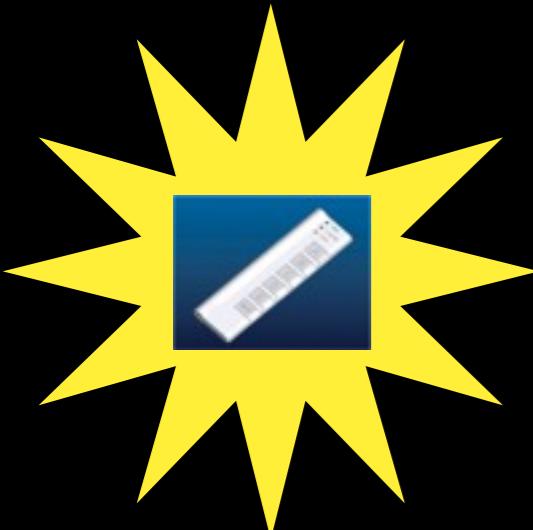
- Timescales for galaxy evolution are long
- Nearby galaxies formed in the distant past
- Given this, how can we study galaxy formation?

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





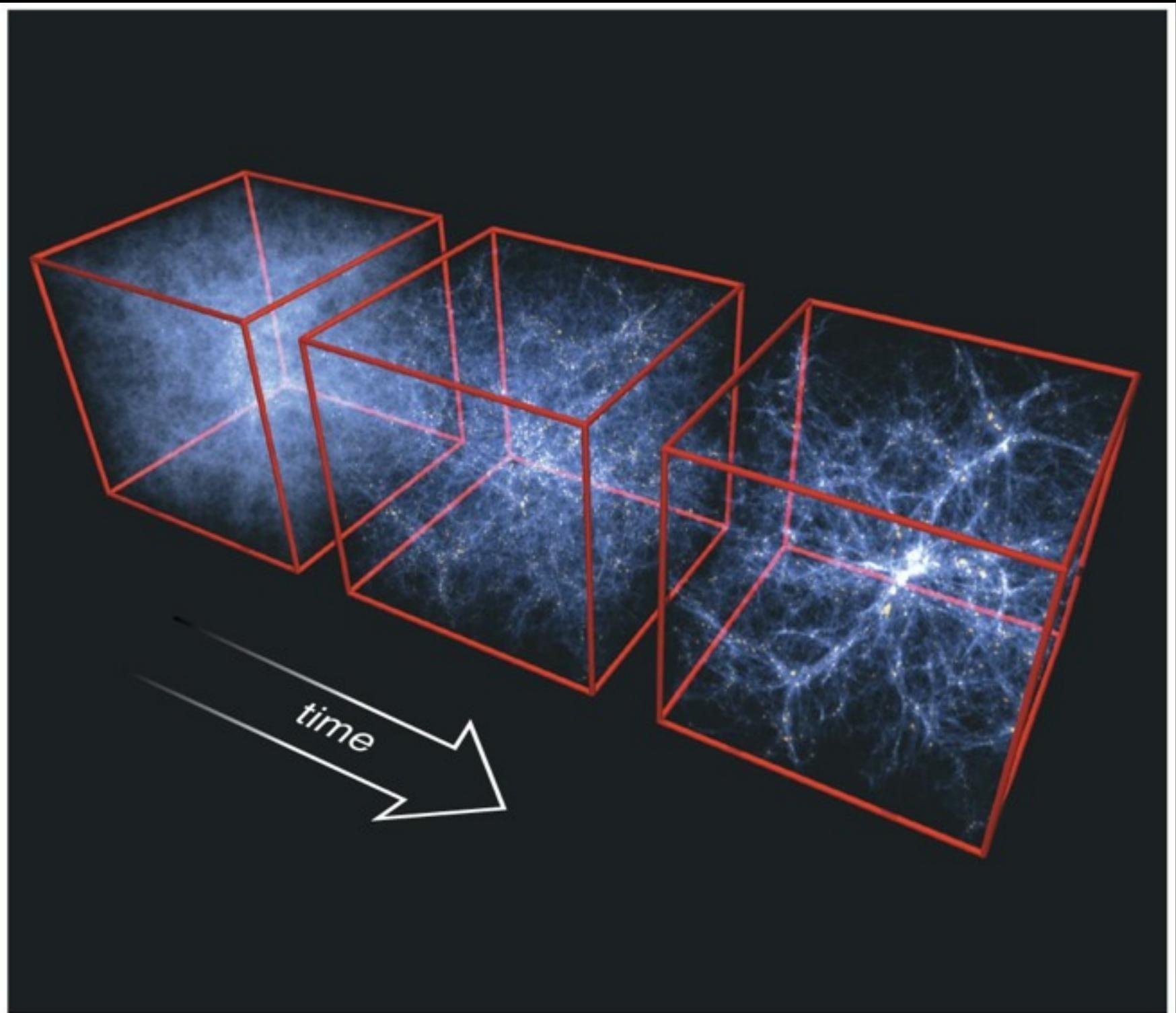
Which galaxy is more likely to  
be seen when the universe  
was 1 billion years old?

- A) A
- B) B
- C) Don't know



# Modeling Galaxy Birth

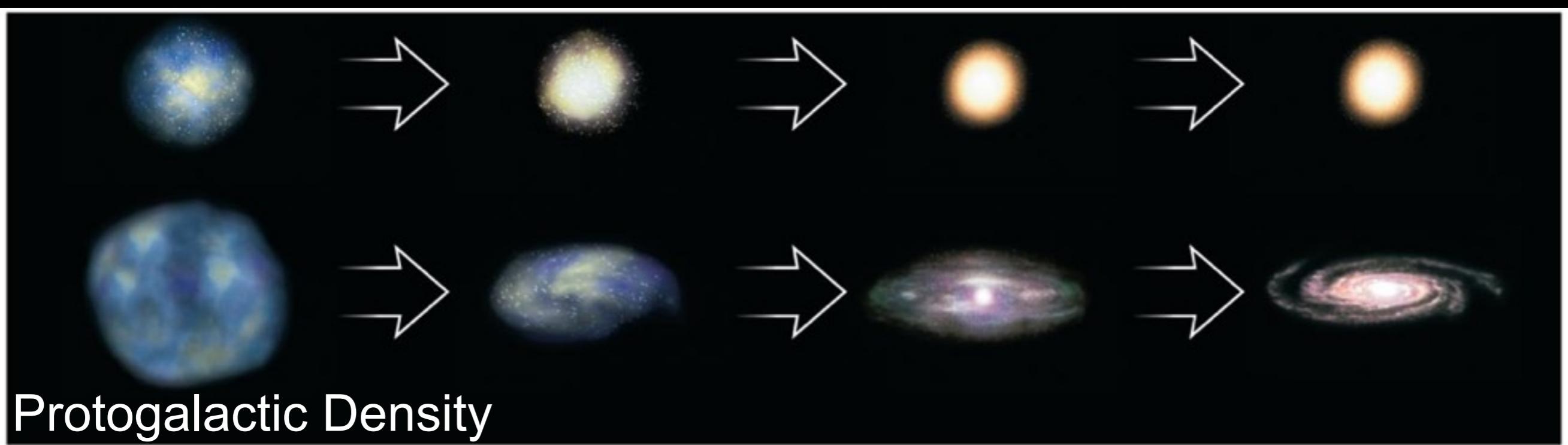
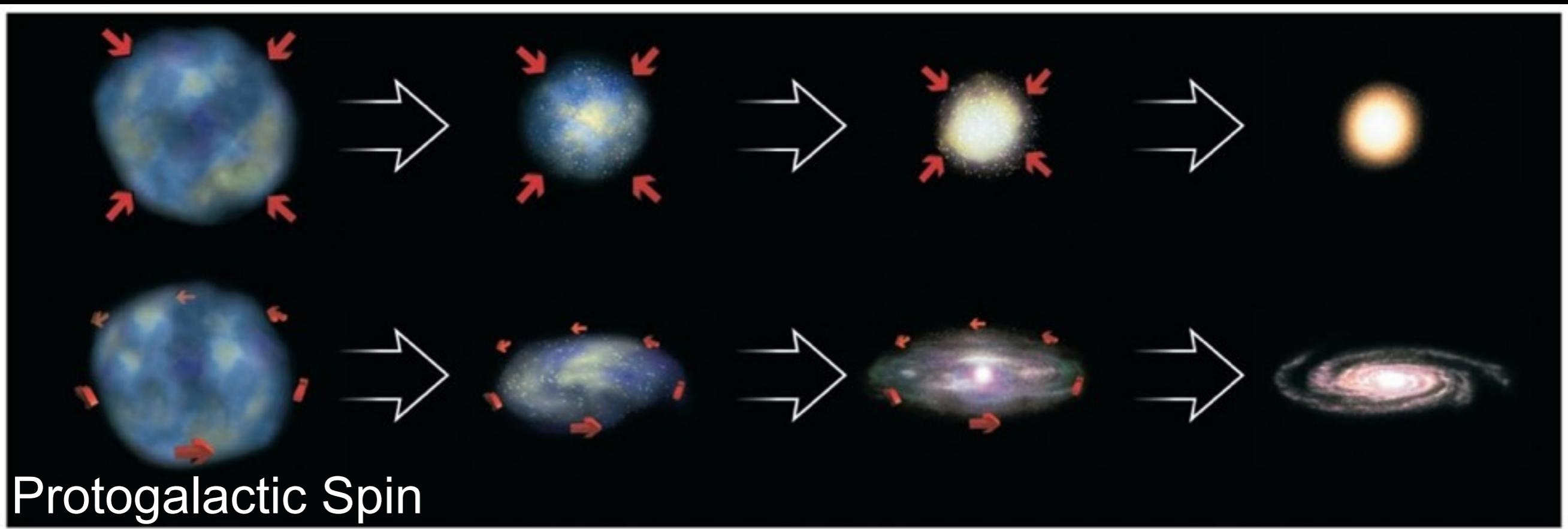
- The basic idea:
  - The universe was nearly uniformly full of hydrogen and helium
  - Slight over-densities in the universe start collapsing
  - These collapsed regions serve as the formation sites for galaxies



# 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

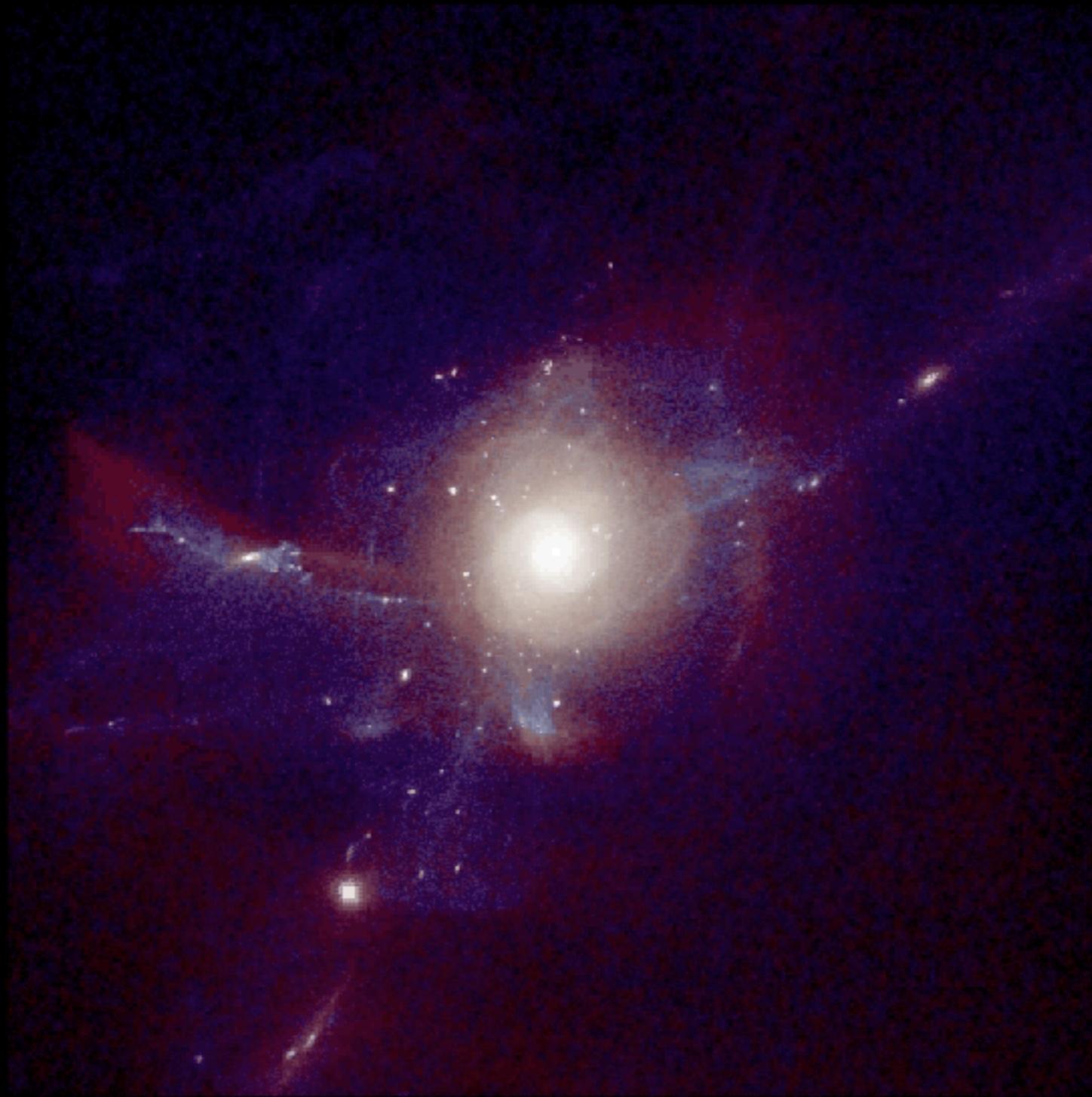


# Galactic Collisions



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

# Galactic Collisions



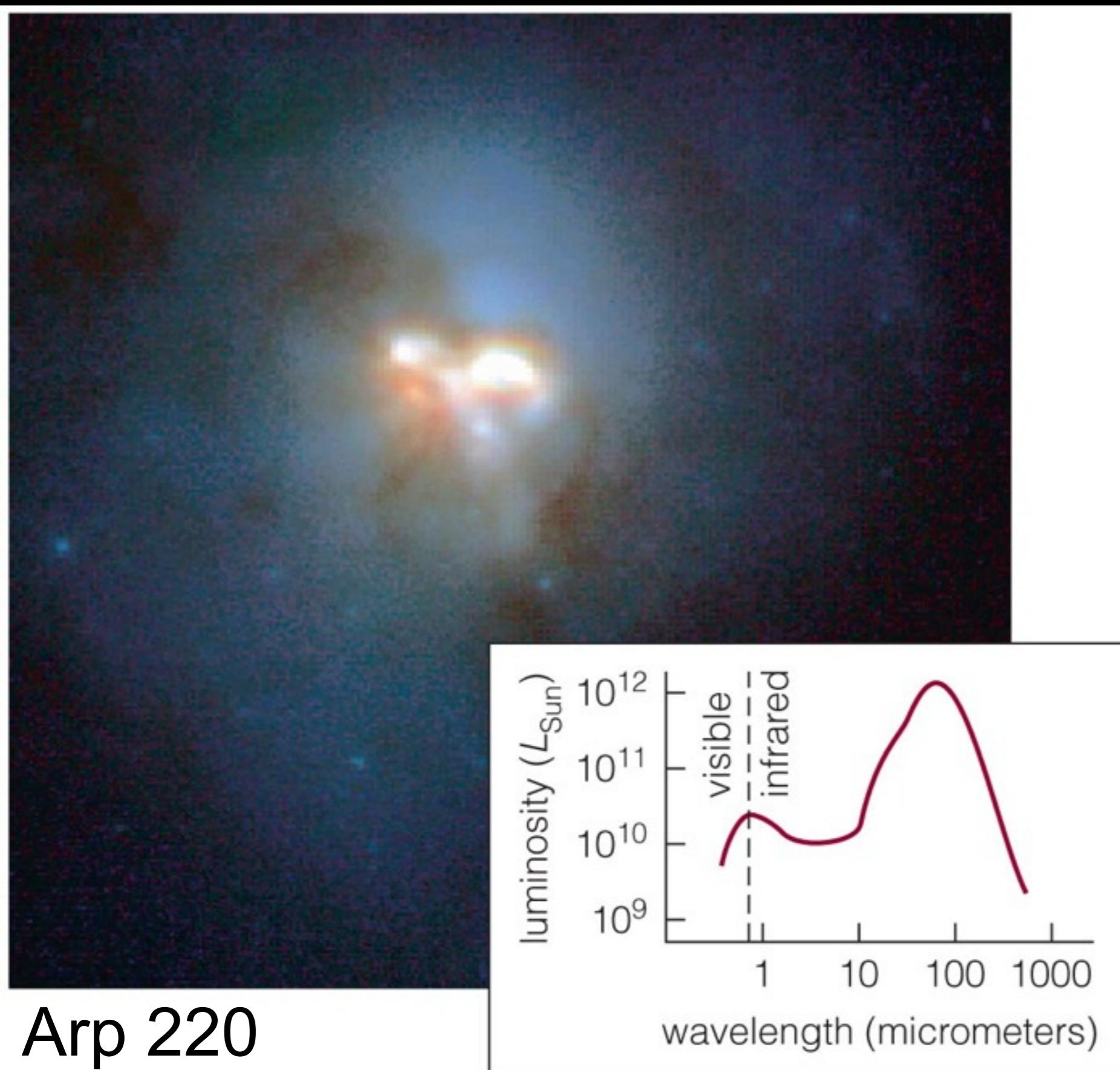
A collision and merger of two spirals could result in an elliptical

# 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?



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!

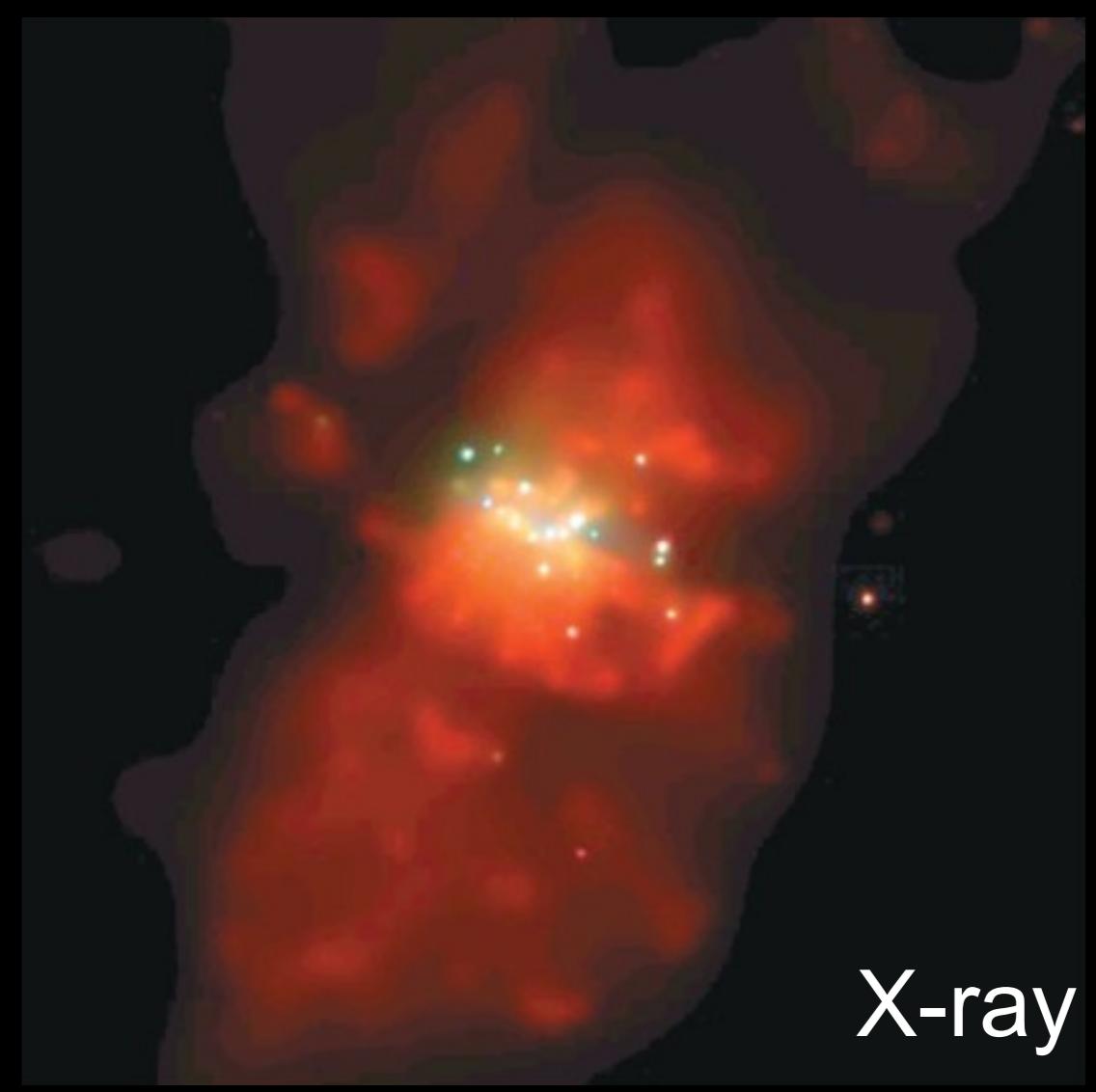
- A factor of 100 increase in star formation rate means a factor of 100 increase in supernova rate
  - super-powered super bubbles!
- Winds consist of low-density, extremely hot gas (10-100 million K) -- this generates lots of x-ray emission
- These winds can push lots of material out of small galaxies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

# Visual Evidence

M82



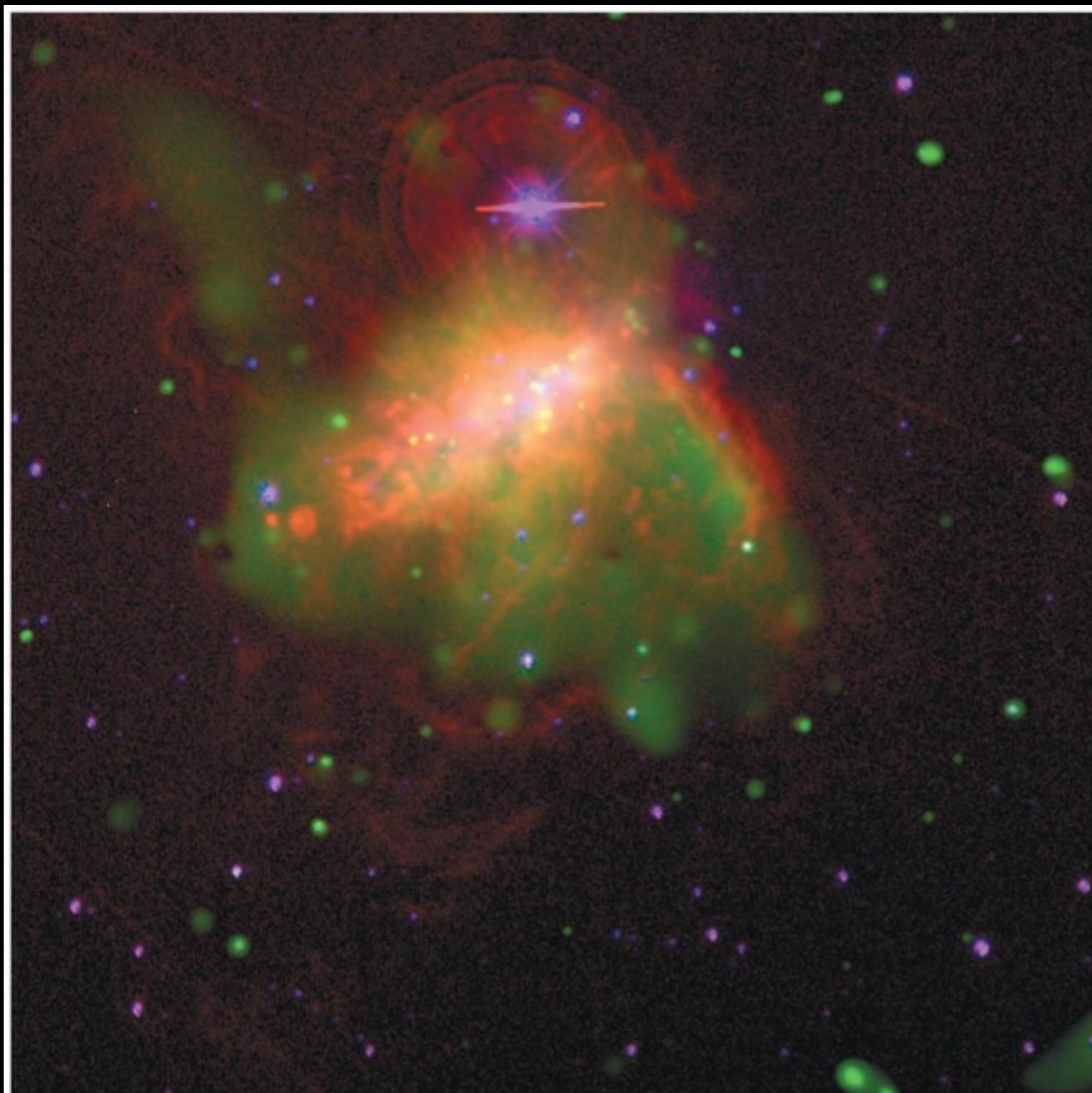
Visible



X-ray

# 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?

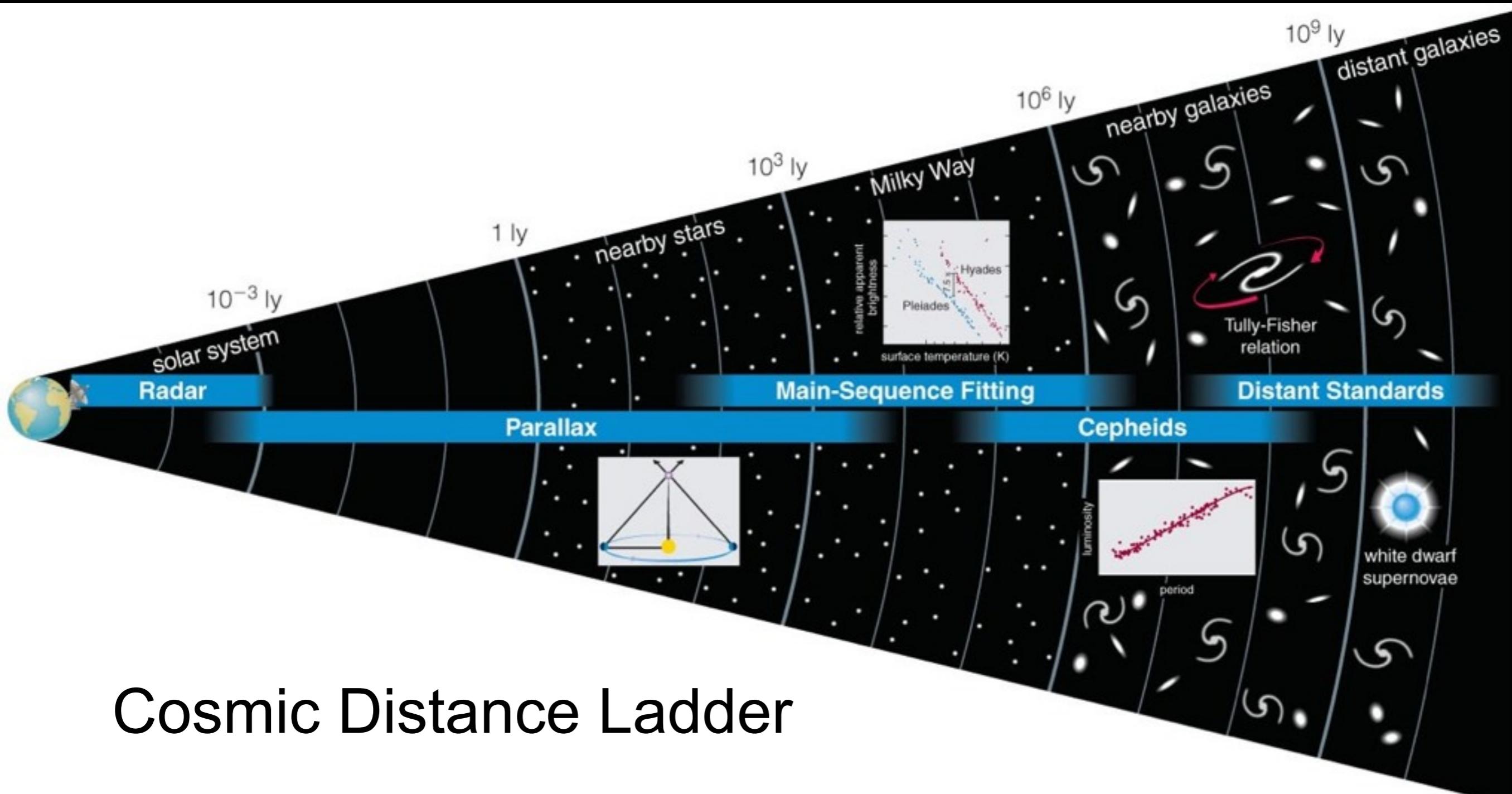
# How do we measure galactic distances?

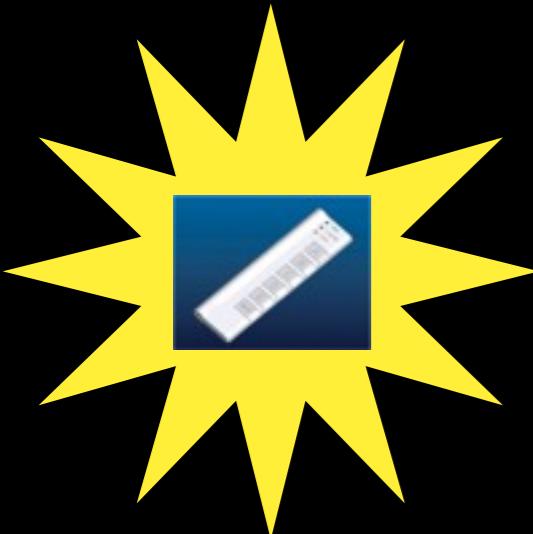


# Why do we care about distances?

- 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?

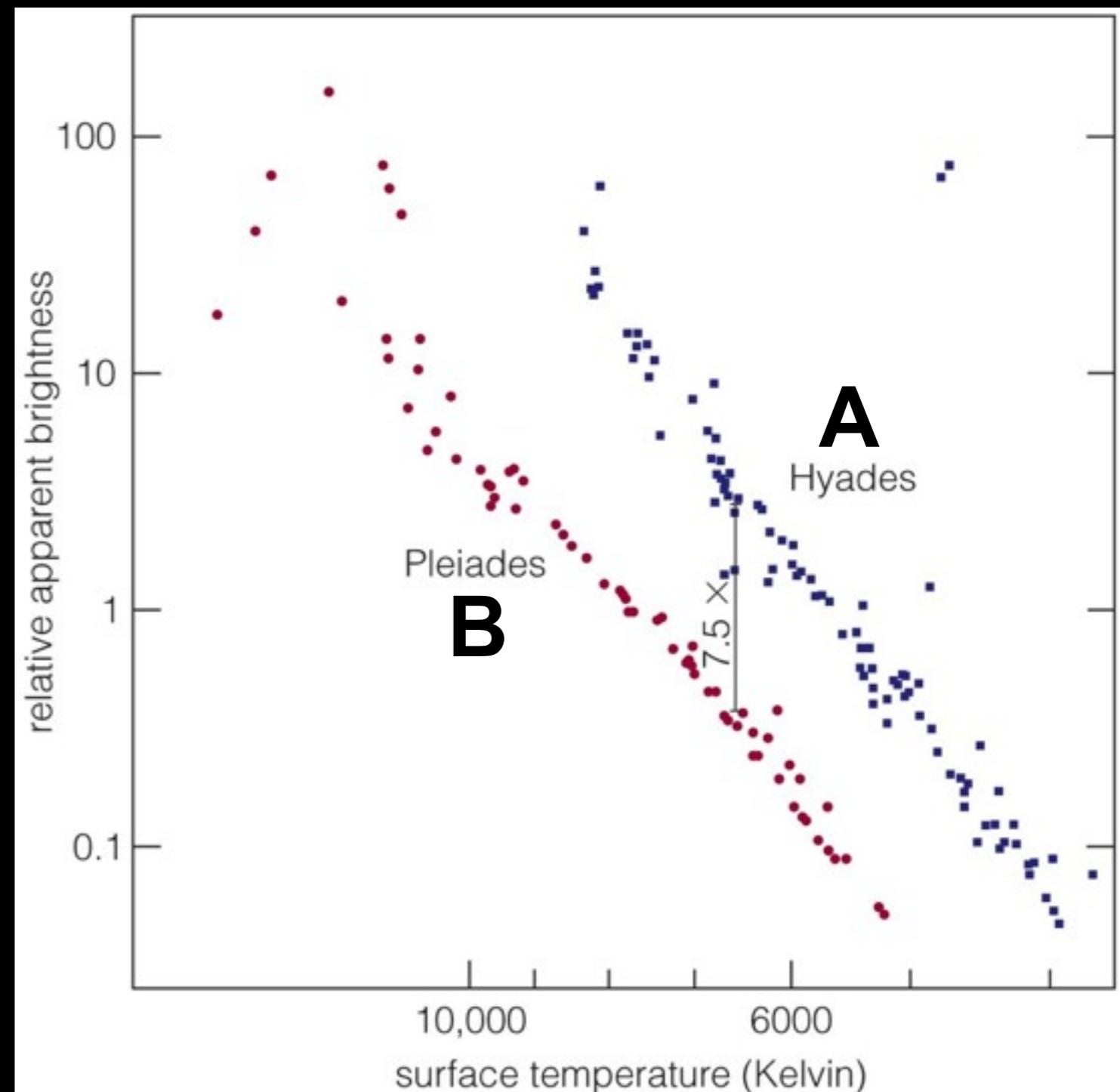
# No one method is good enough for all distances





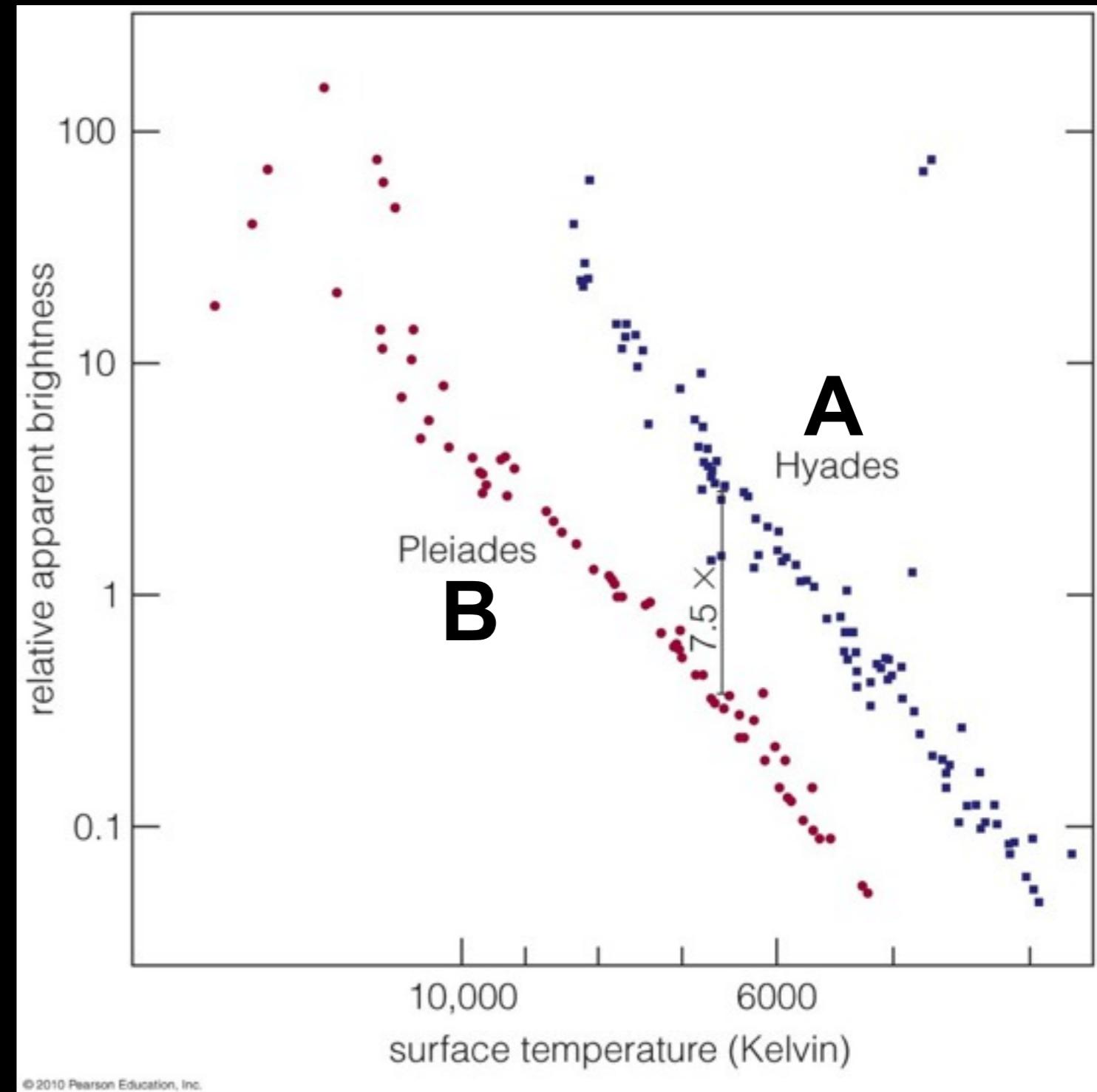
Shown is the main sequence for two stellar clusters. Which cluster is closer?

- A) Hyades
- B) Pleiades
- C) Not enough information to tell



# Main-sequence Fitting

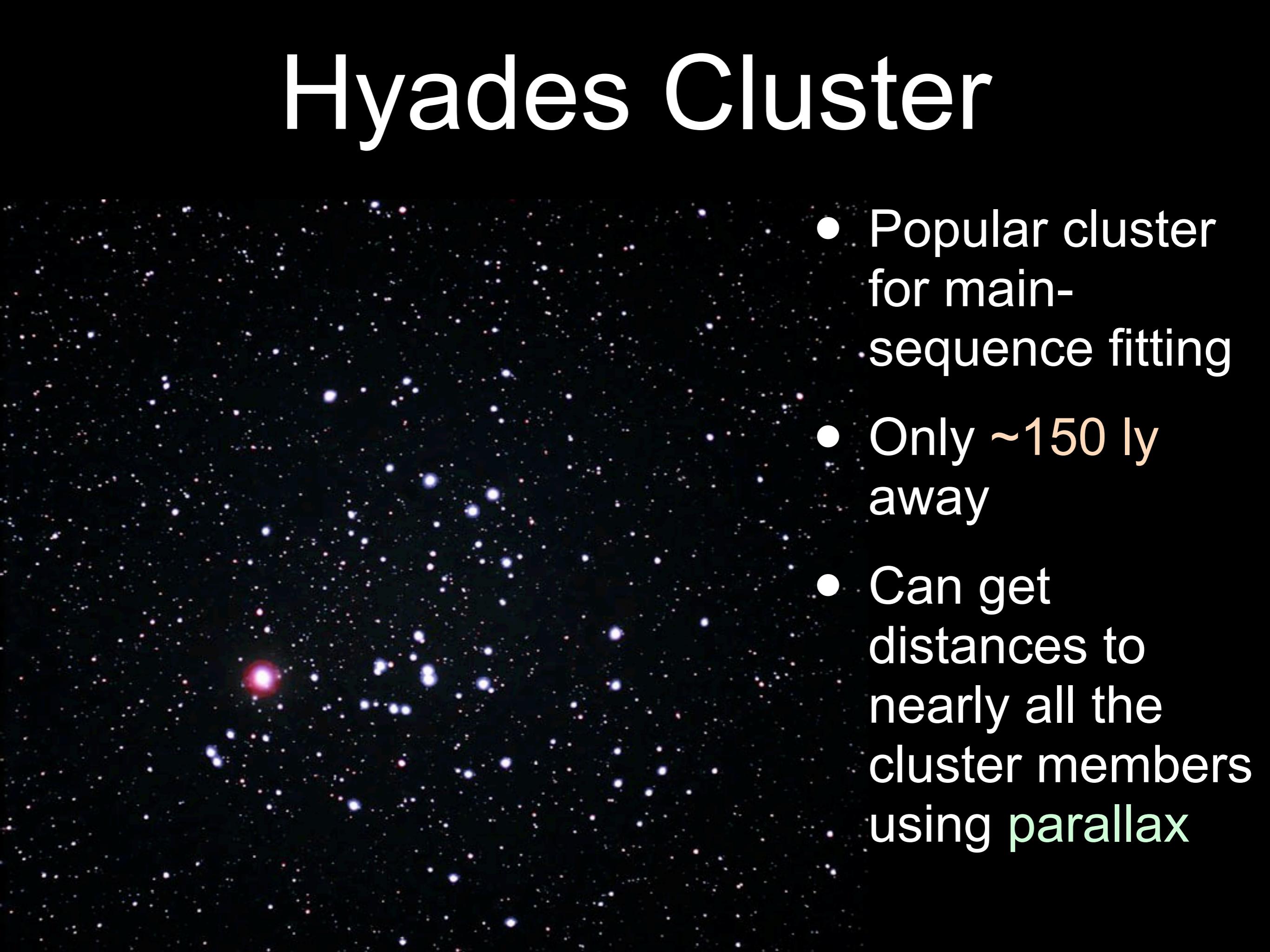
- Start with a cluster whose distance is known via **parallax** (A)
- Compare to another cluster (B)
- Calculate the distance to B based on brightness difference



Distances good to about 200,000 ly

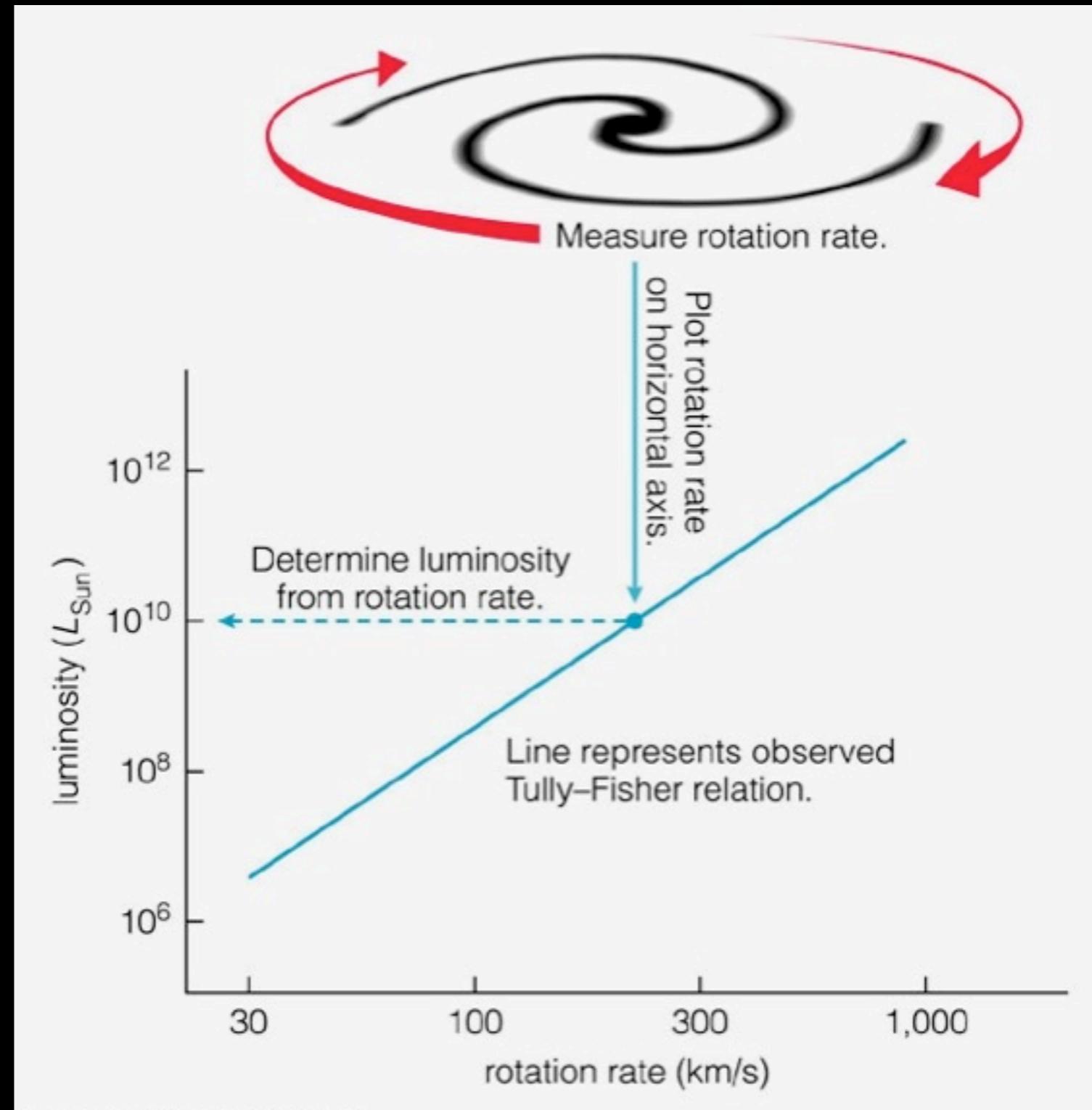
# Hyades Cluster

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



# Tully-Fisher Relation

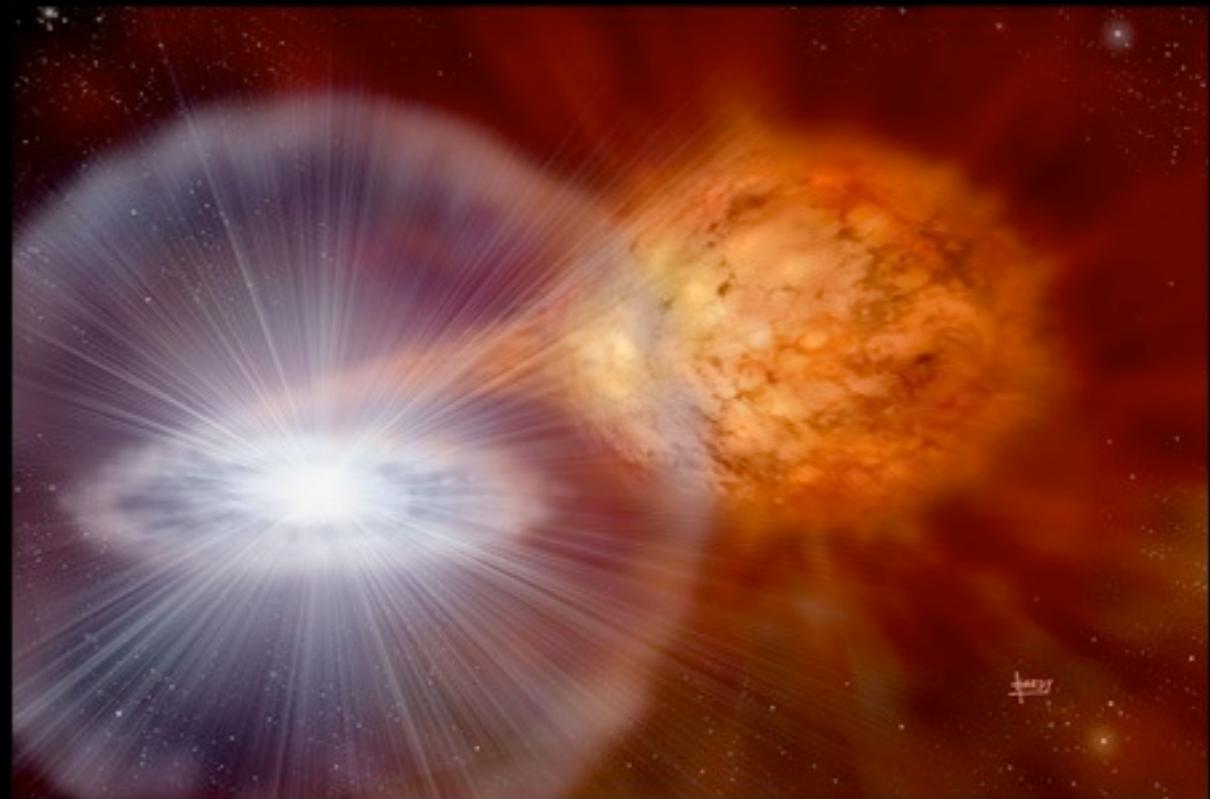
- Fast rotation speeds in spiral galaxies
  - more mass in galaxy
  - higher luminosity
- Measure rotation speeds to infer luminosity
- Need bright “edge-on” spirals, estimate tilt



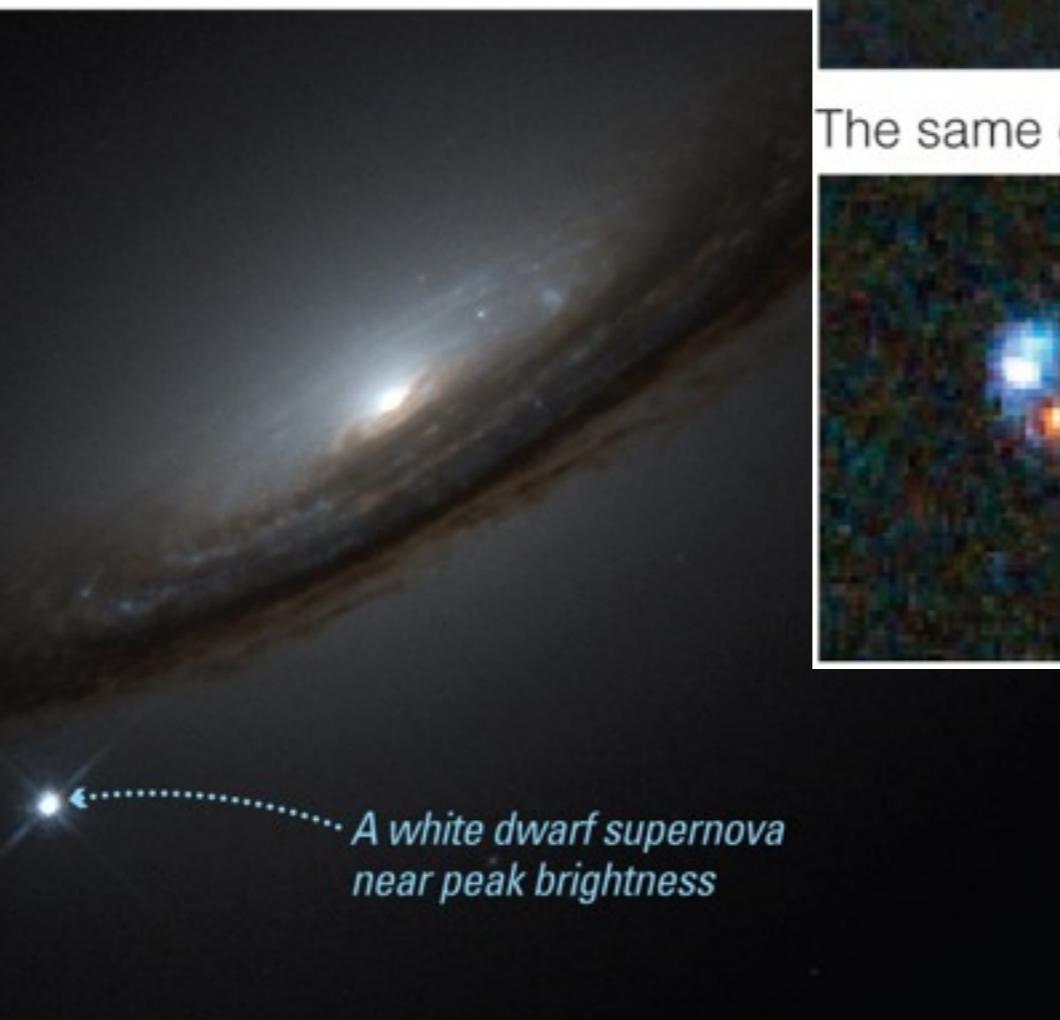
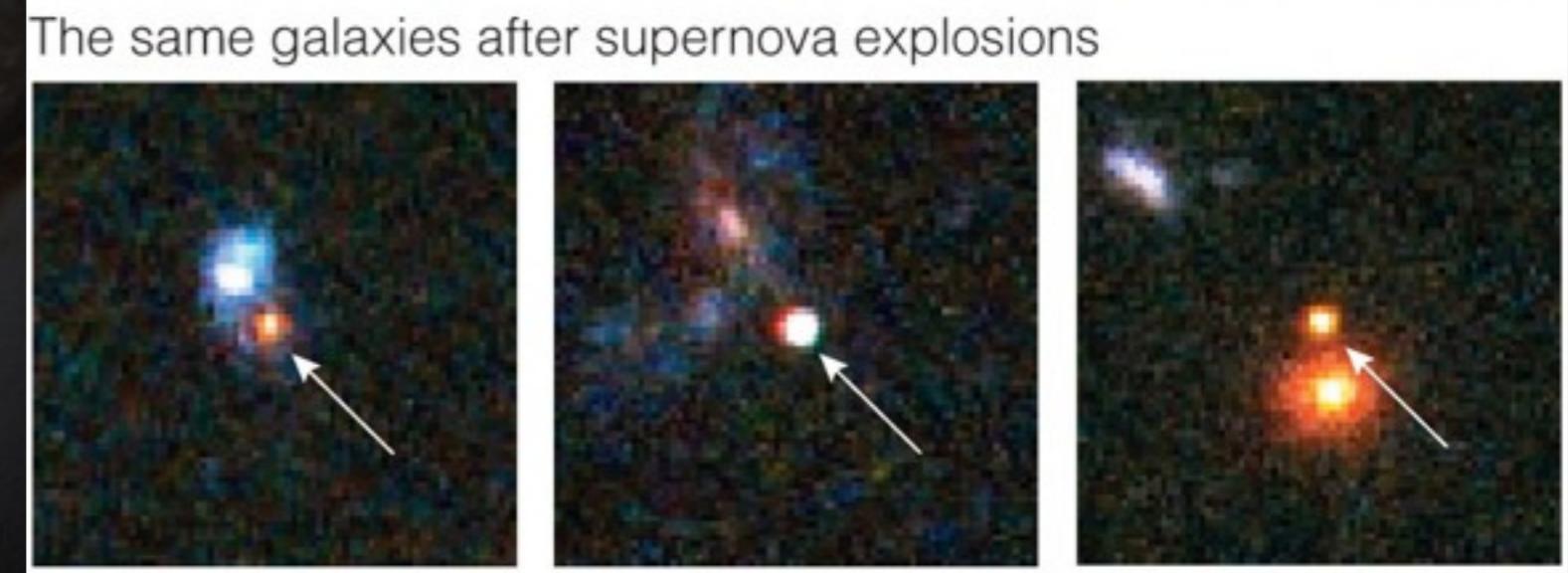
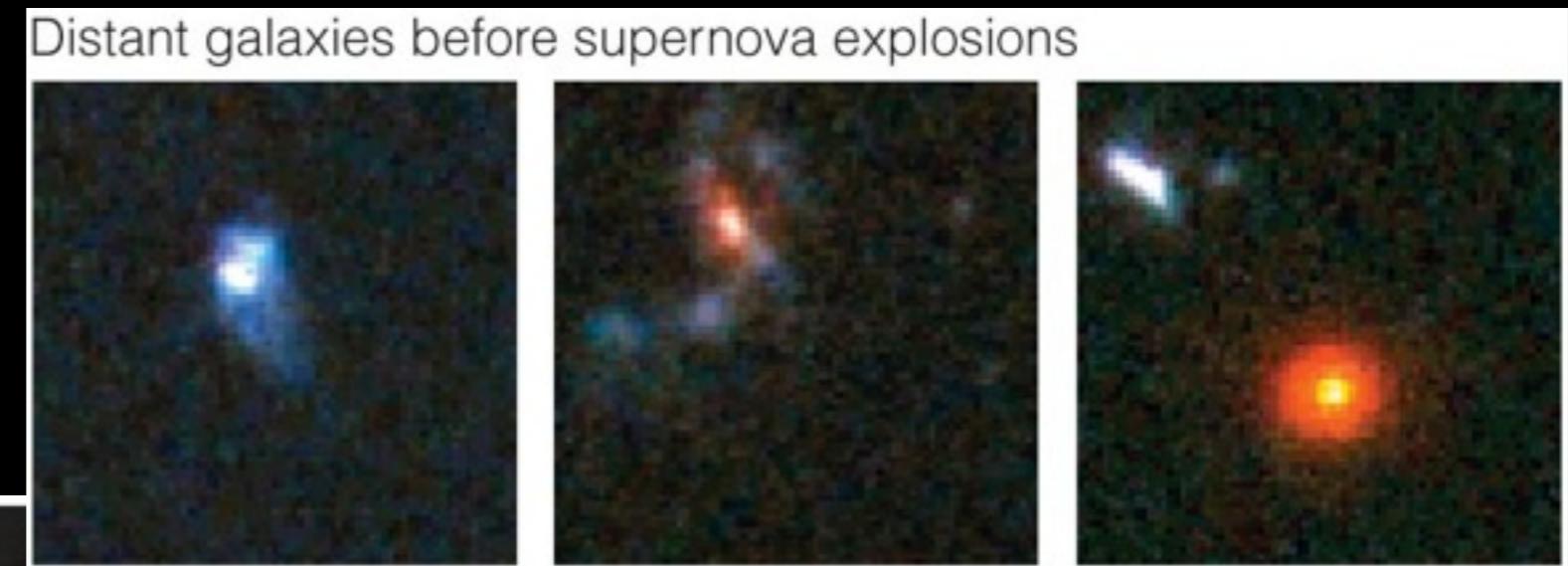
Distances good to about 10 billion ly

# White dwarf supernova

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

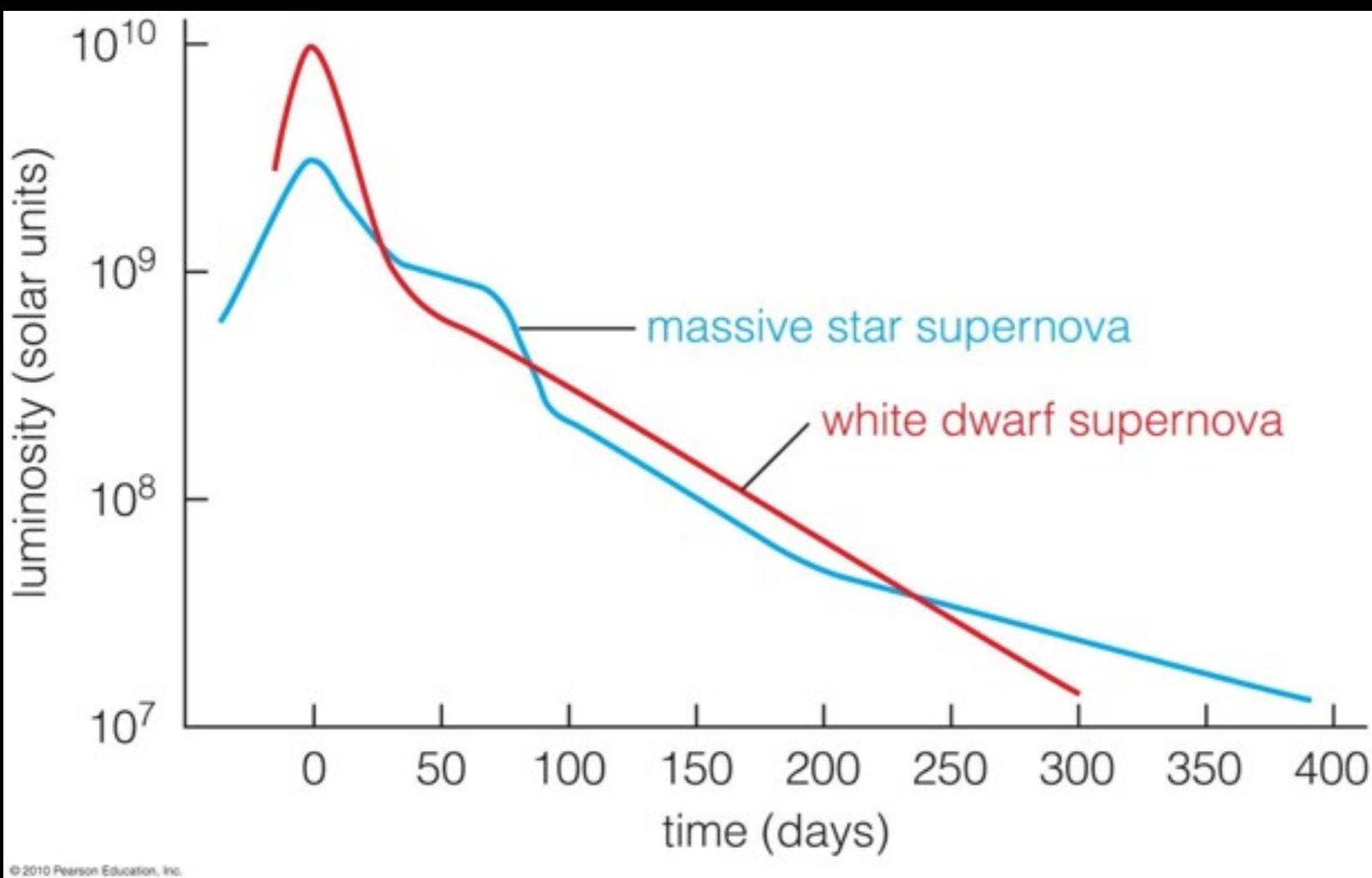


# Bright enough to be seen in the far reaches of the observable universe



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

Brightness  $\propto$  Luminosity / Distance<sup>2</sup>

# 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”