

# ASTR/PHYS 1060: The Universe

## Chapter 14: Measuring Galaxies



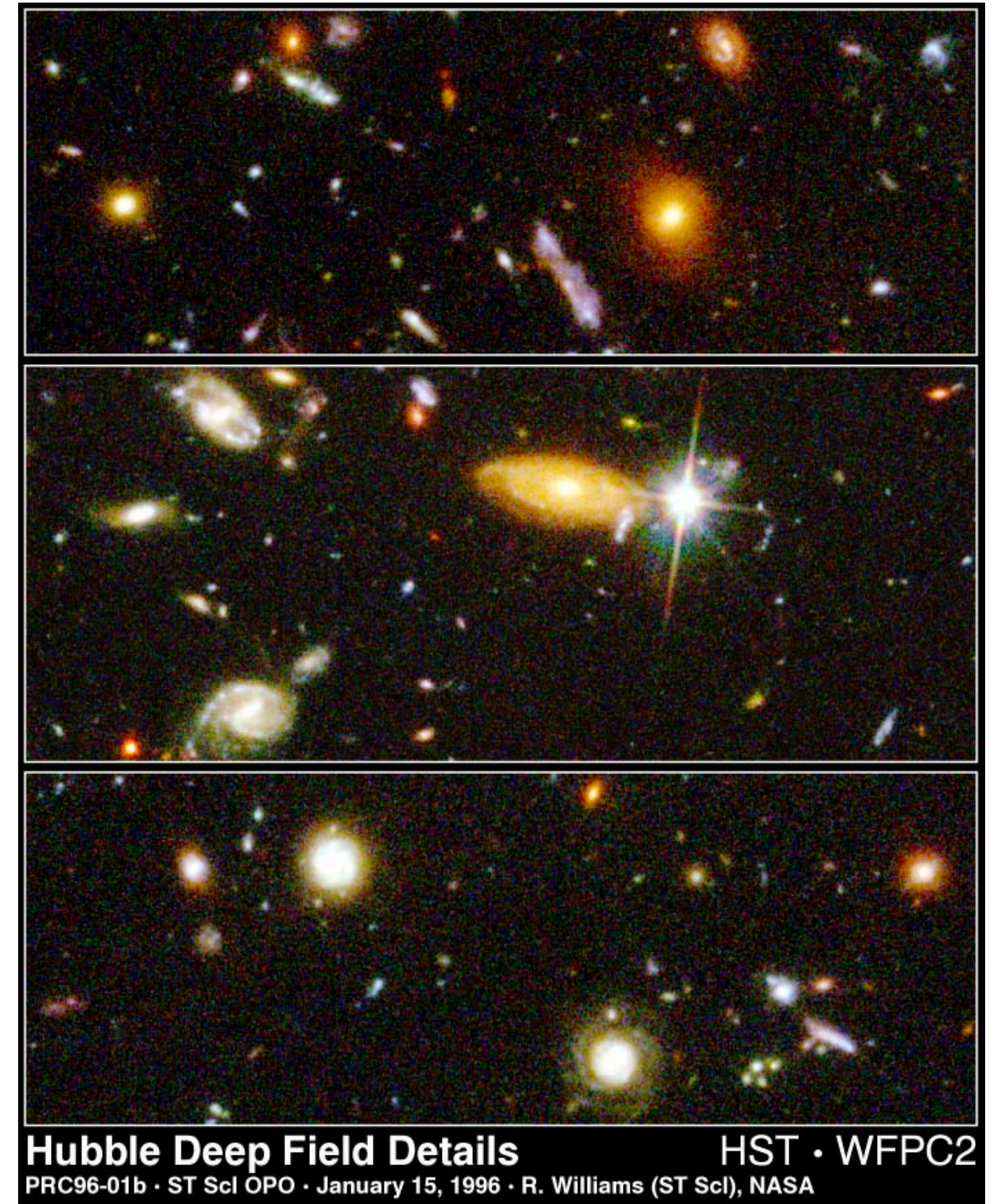
<https://apod.nasa.gov/apod/ap170510.html>



<https://www.spacetelescope.org/news/heic1919/>



# Now on to Galaxies!

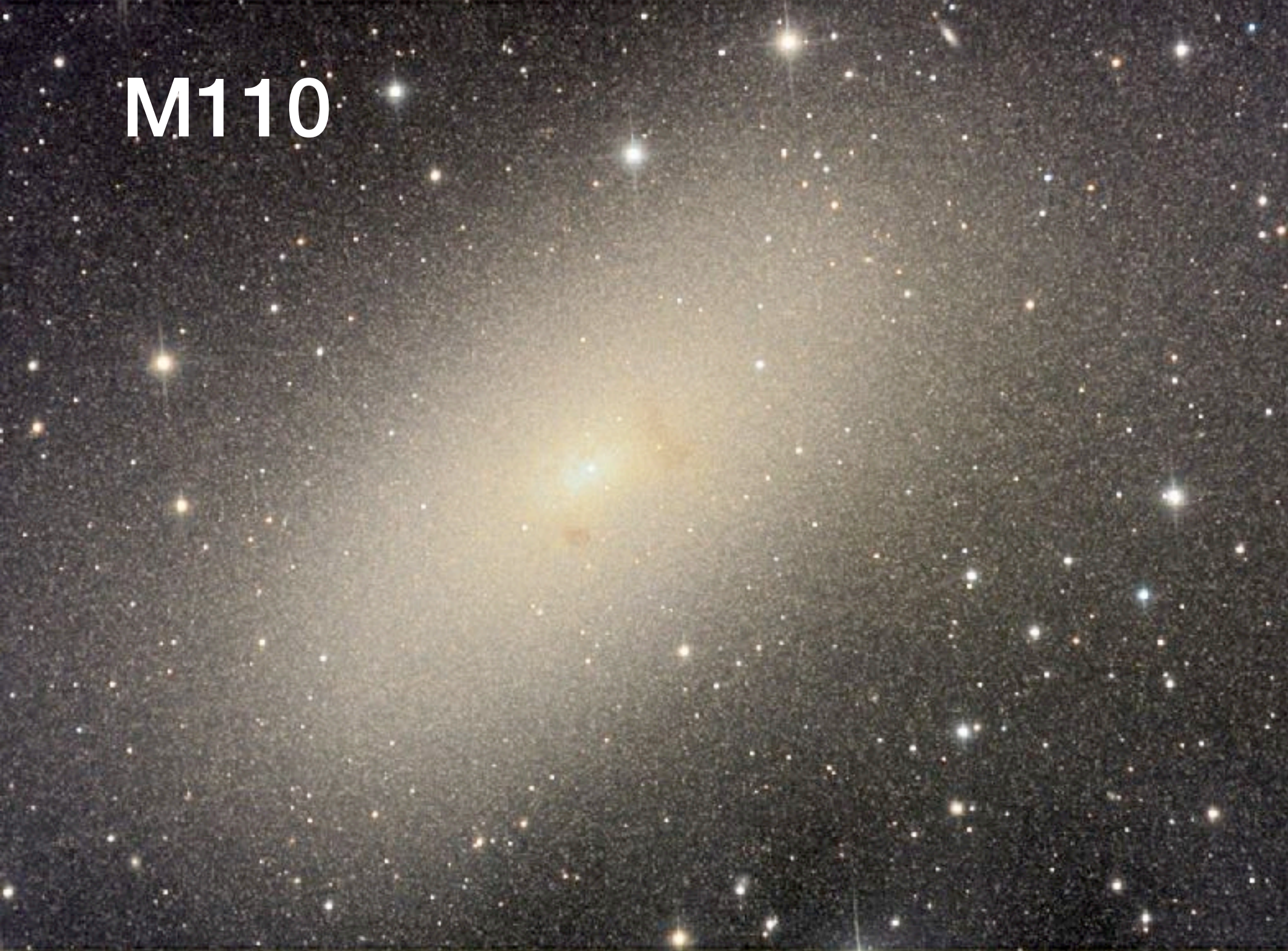




# Classifying Galaxies

- Groups of 2-4, one sheet per group
- One person from each group raise your hand (so TAs can efficiently pass out dead tree shavings)
- First step: Once I display the 8 galaxies onscreen, begin! What is the overall shape of the galaxy? Is it smooth or mottled? What else do you find notable about it?
- When finished with Questions 1-4, display your ABCD card so I know when you're done.

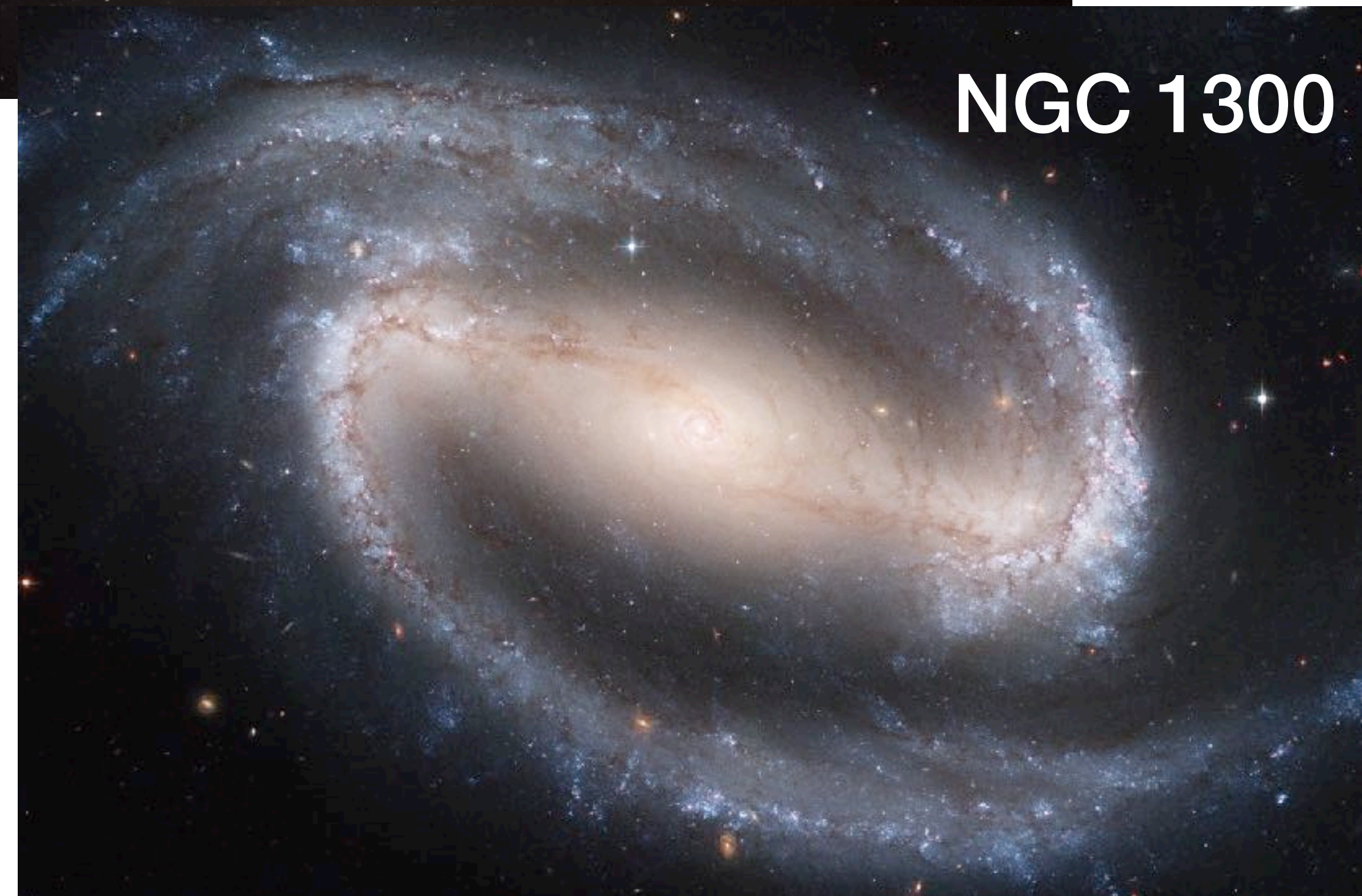




M110



M87



NGC 1300

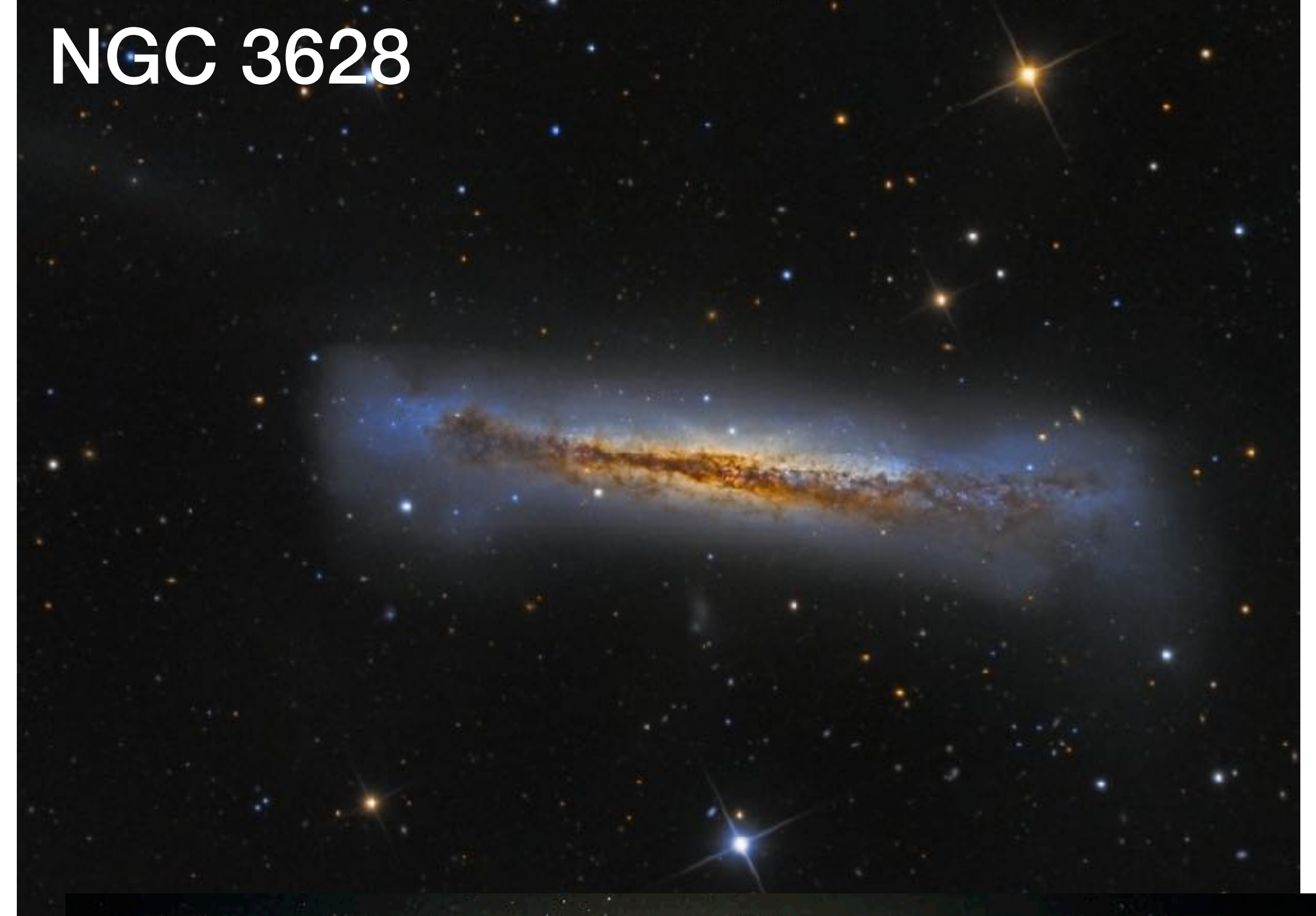


M81





NGC 4449



NGC 3628



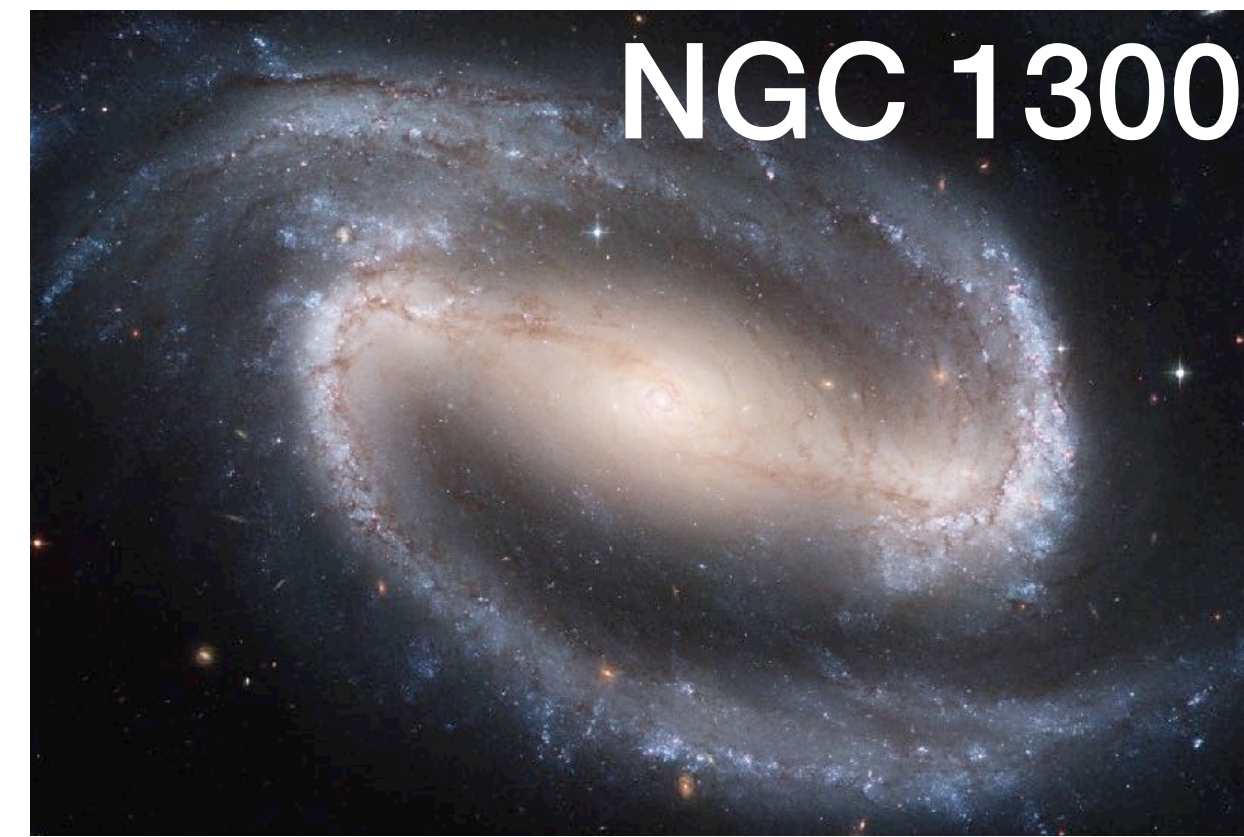
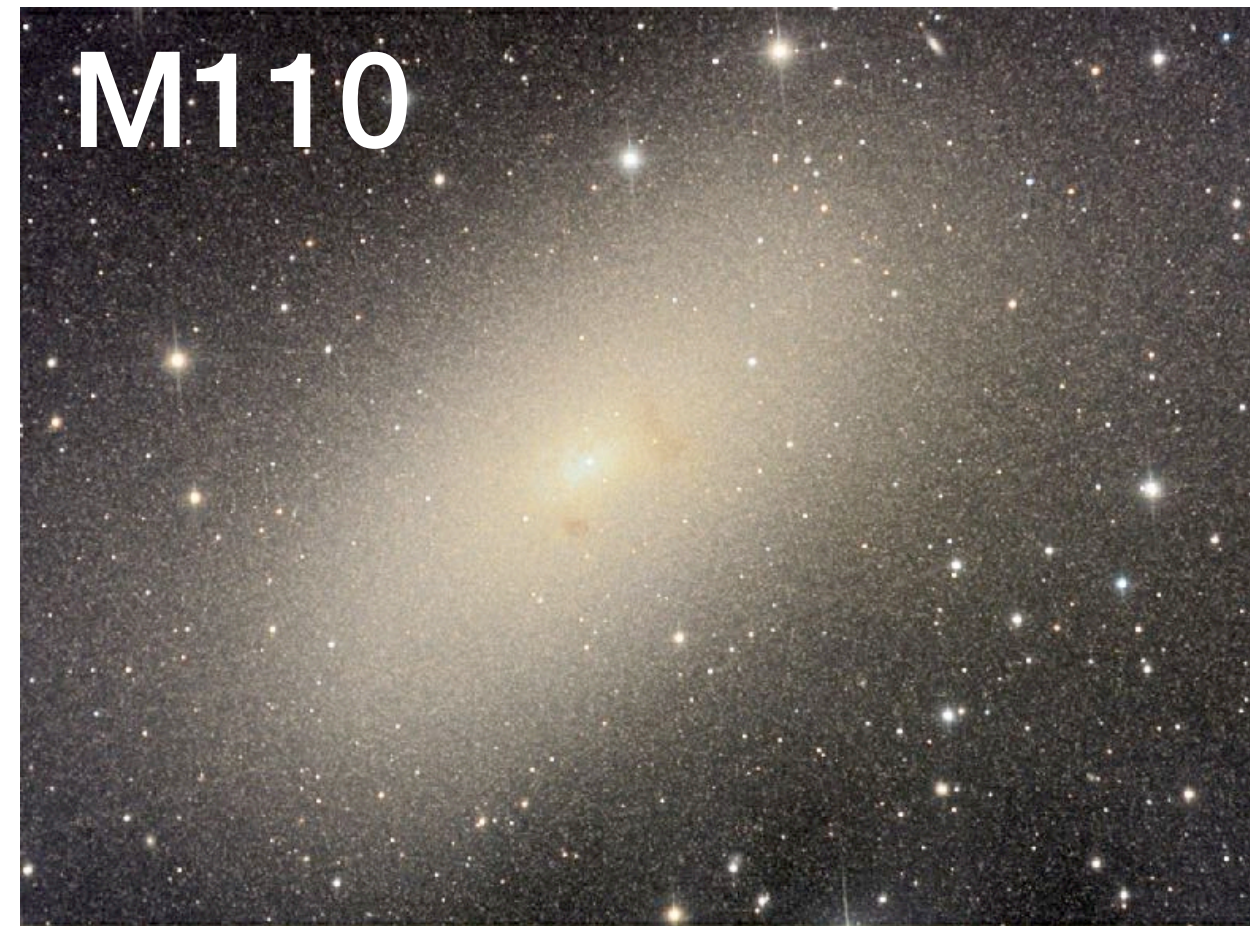
NGC 1232



Sombrero



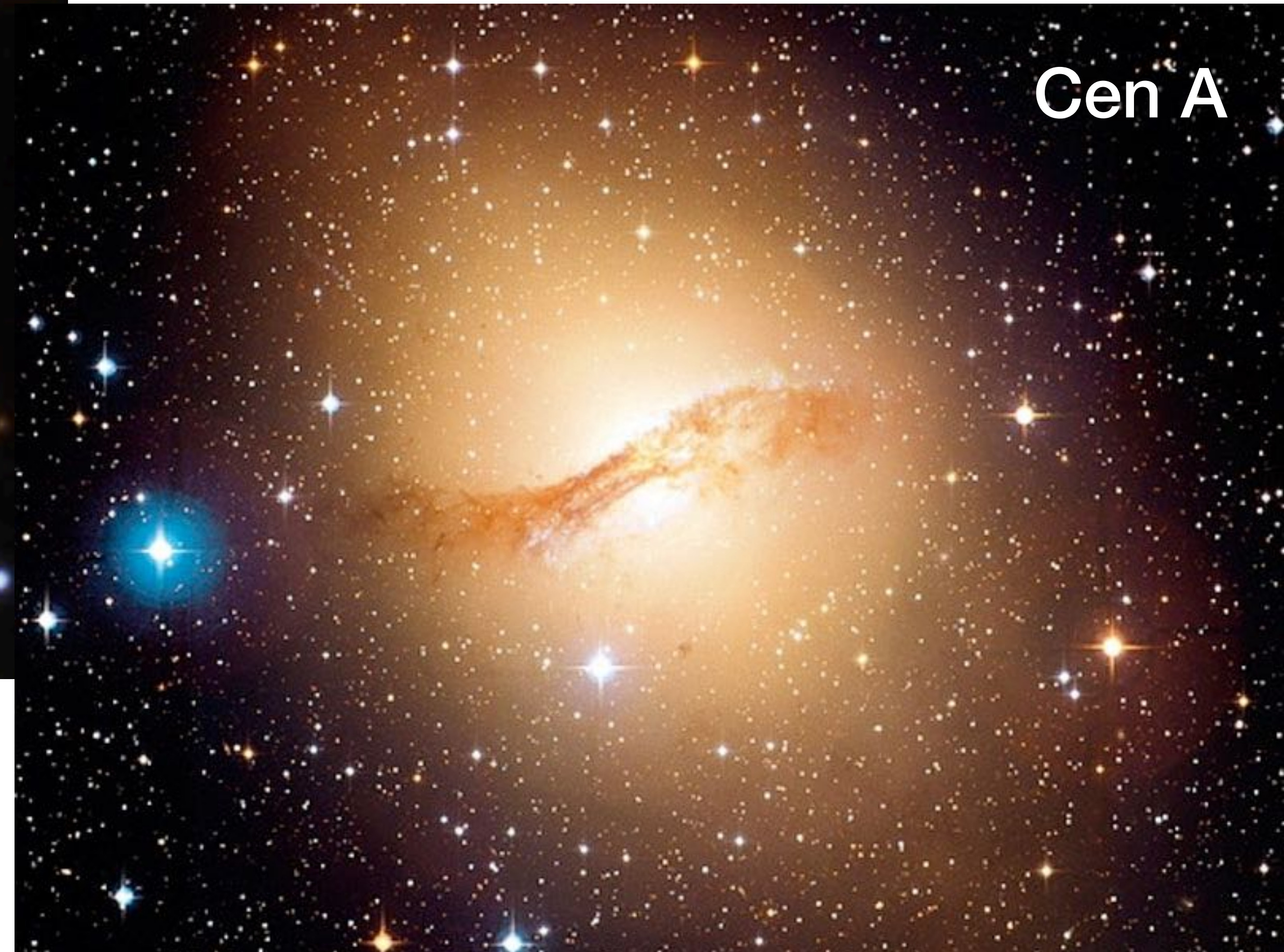
# How did you classify the galaxies?







Question 5: Try to incorporate these into your classification. Where would they go?

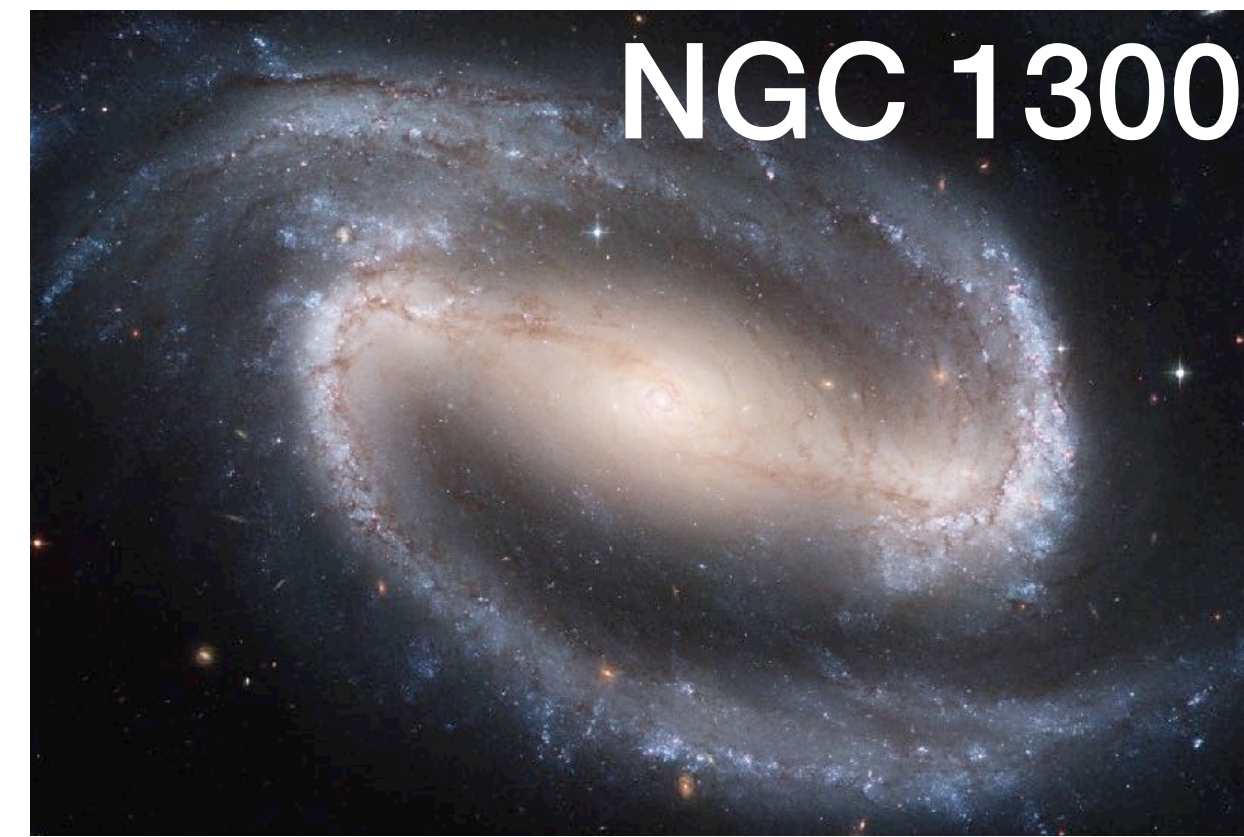
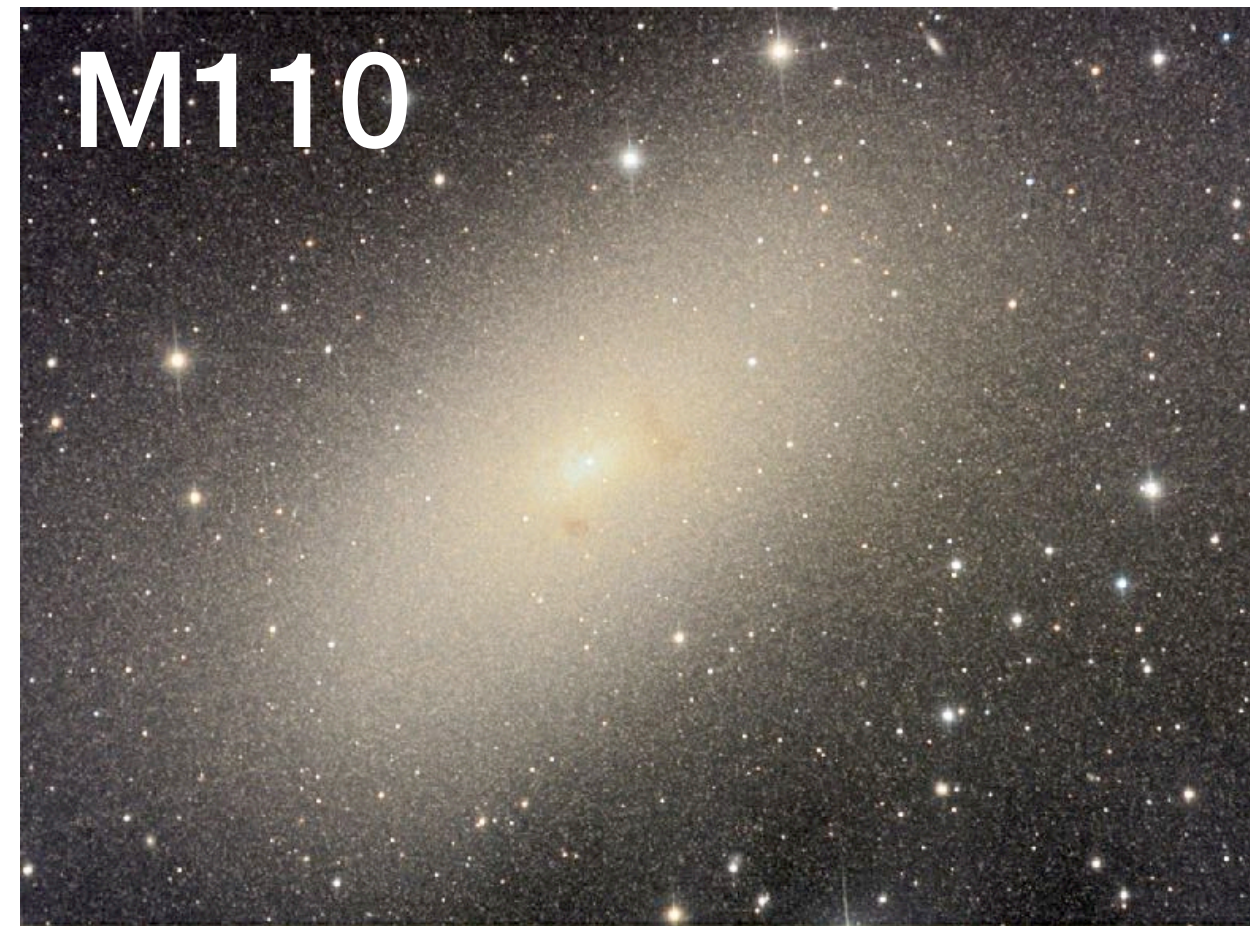


NGC 4731

Cen A

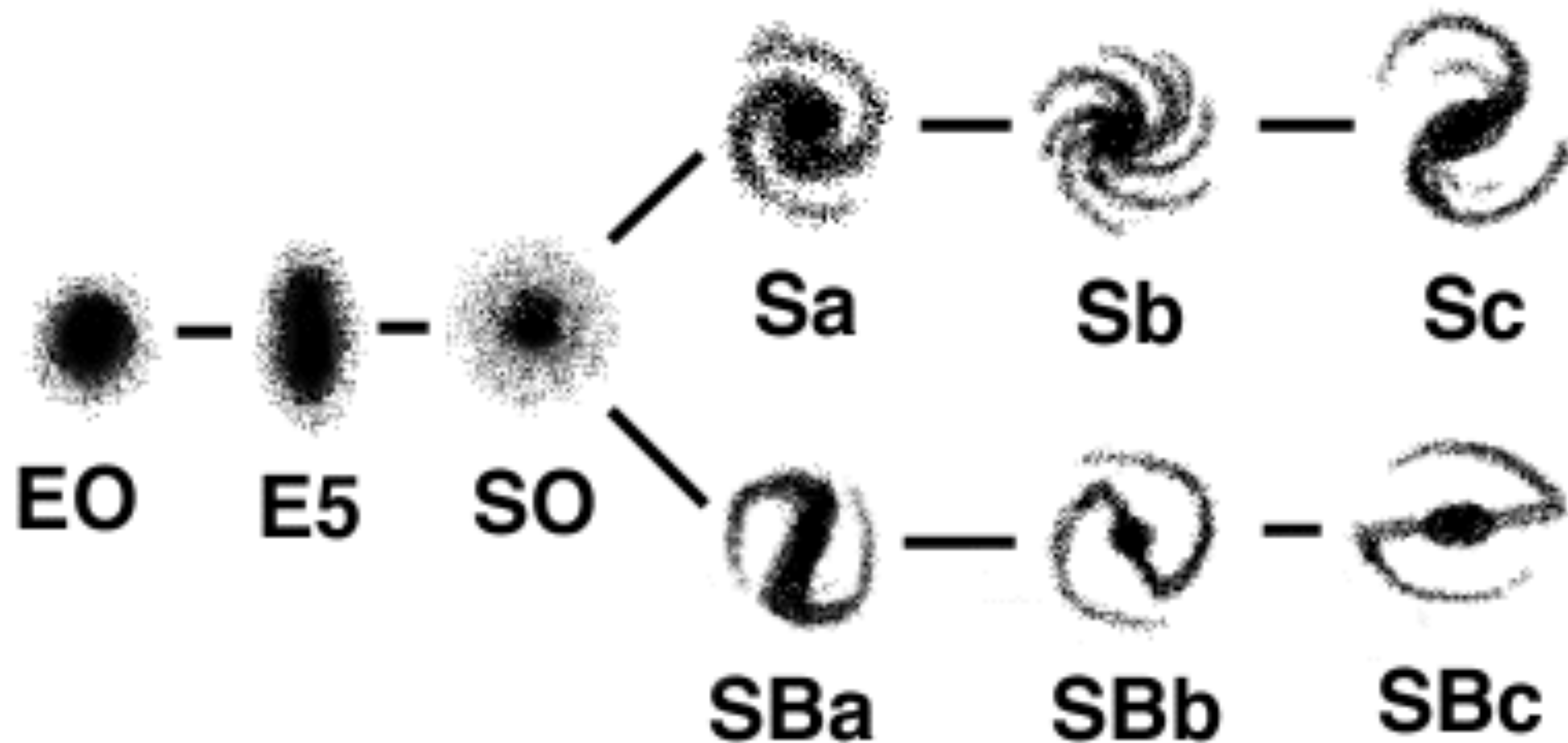


# How did you classify the galaxies?



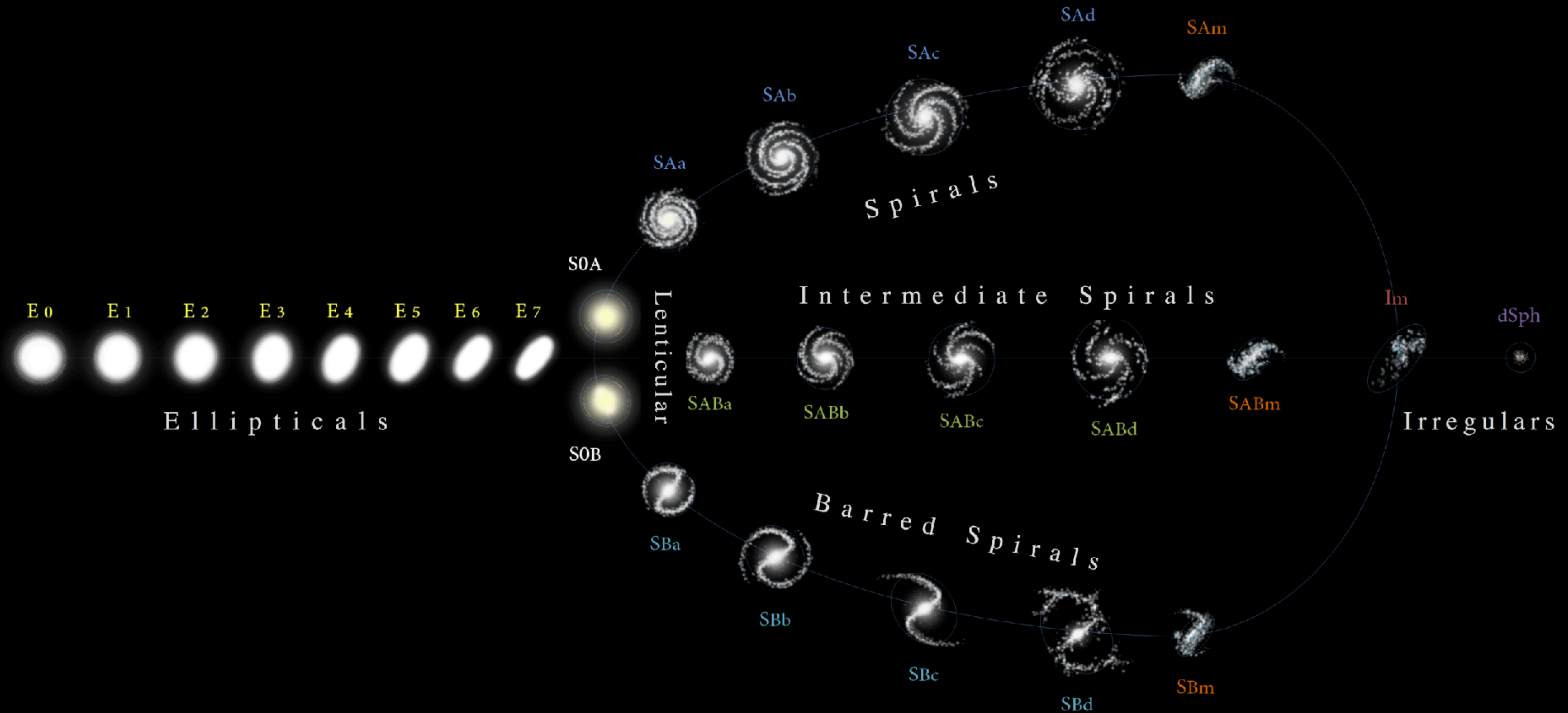


# Hubble's Classification Scheme: Tuning Fork Diagram



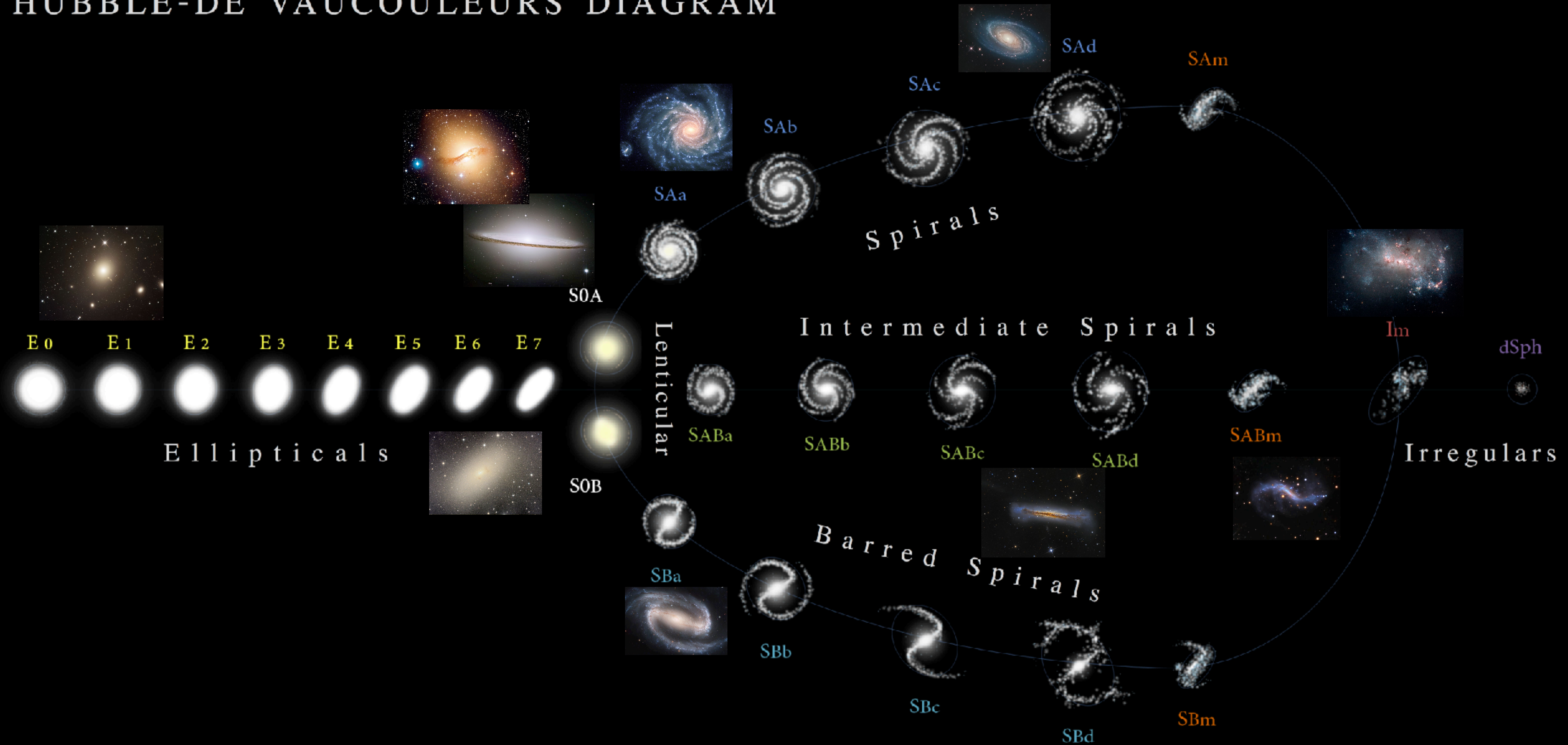


# HUBBLE-DE VAUCOULEURS DIAGRAM



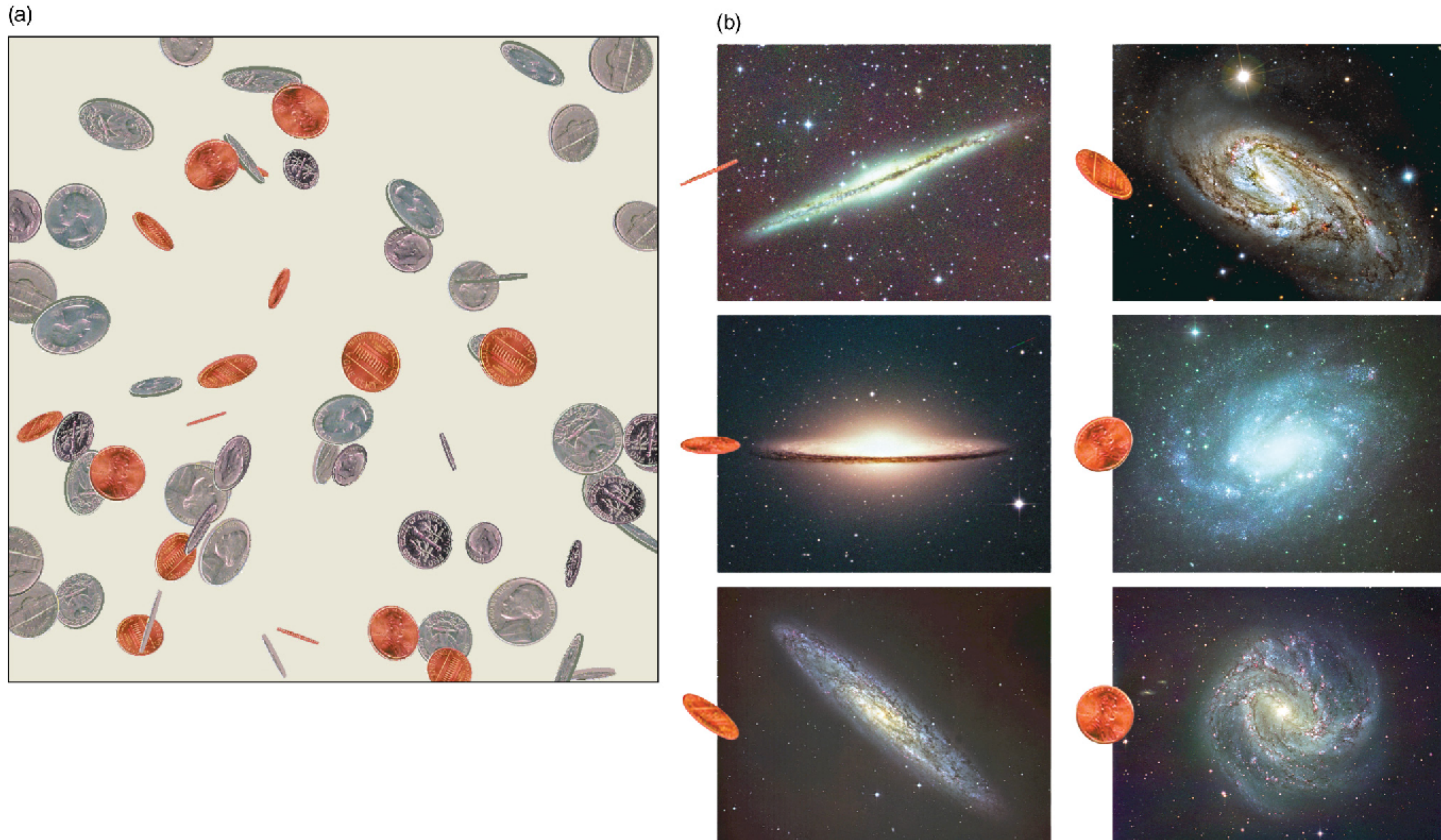


# HUBBLE-DE VAUCOULEURS DIAGRAM



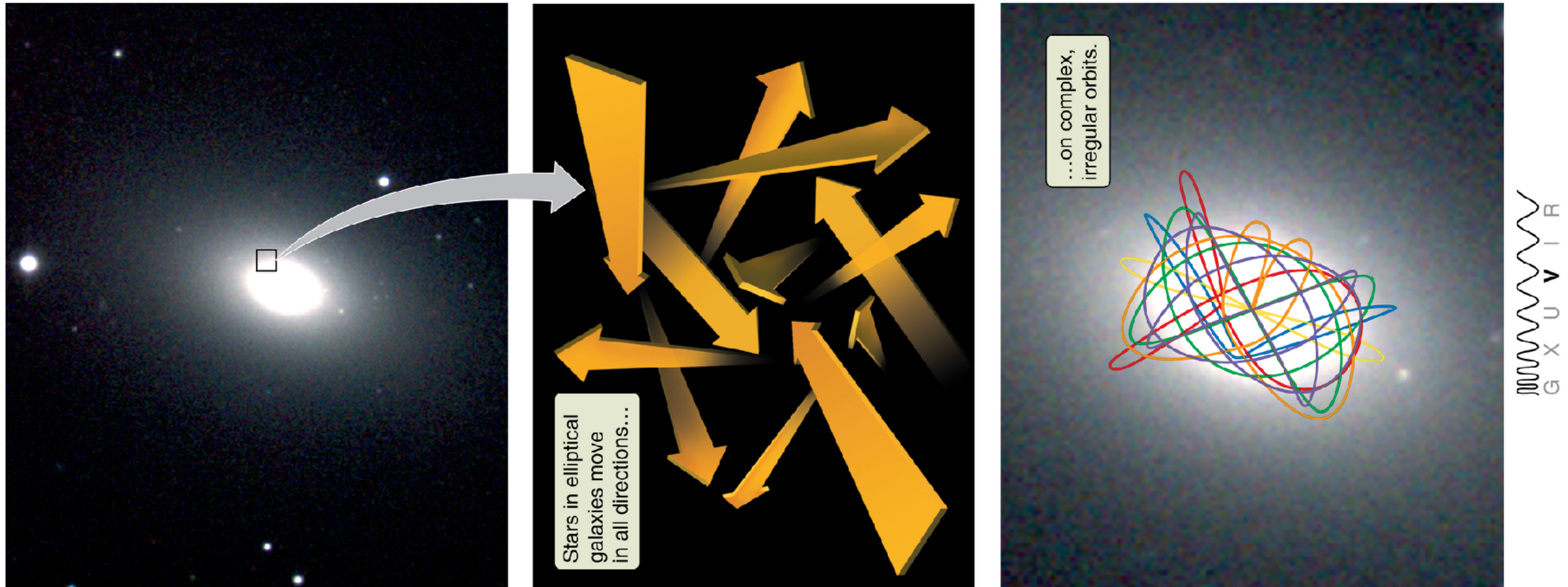


# Appearance depends on orientation...





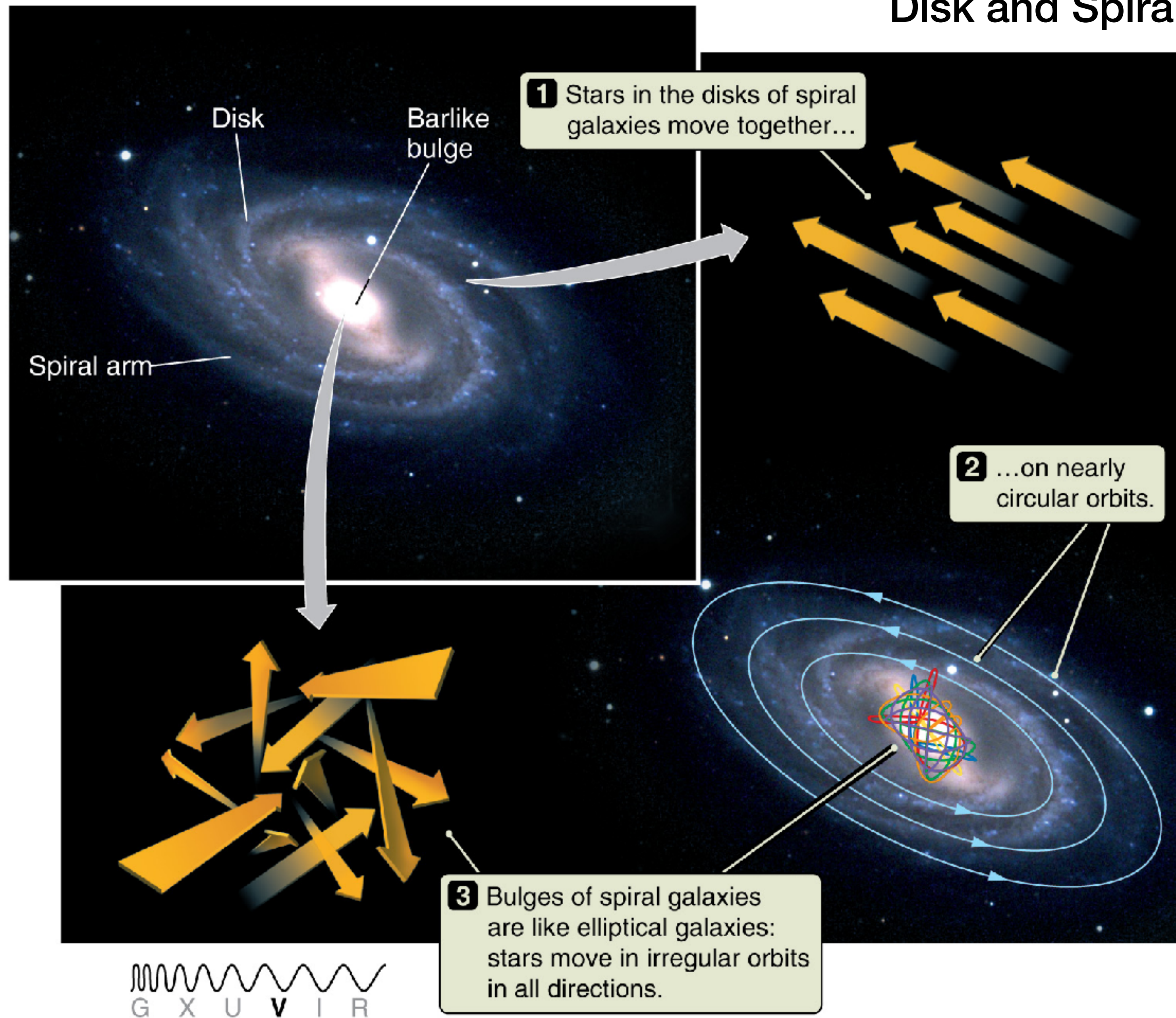
# ...and the motions of stars



Bulges and Ellipticals



# Disk and Spiral Galaxies



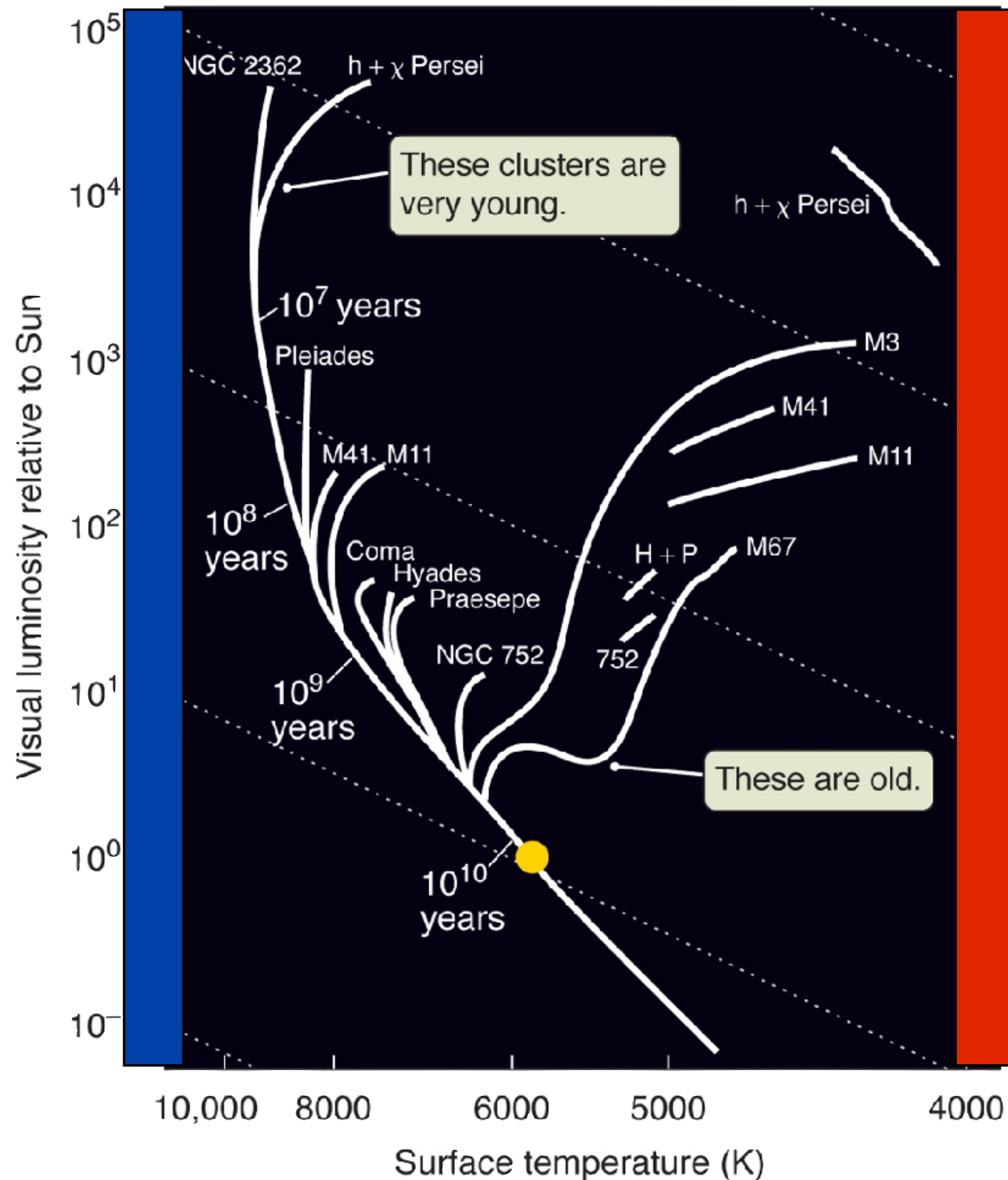
Which type of galaxy (Disk or Elliptical) is our galaxy, the Milky Way?

Why do you think so?





# Color vs stellar age



- A) Older stars have bluer colors
- B) Older stars have redder colors
- C) Stellar colors do not depend on age



A



# Which galaxy is oldest?

Which galaxy is prettiest?

C



B





# Why is there a connection between shape & stellar age?

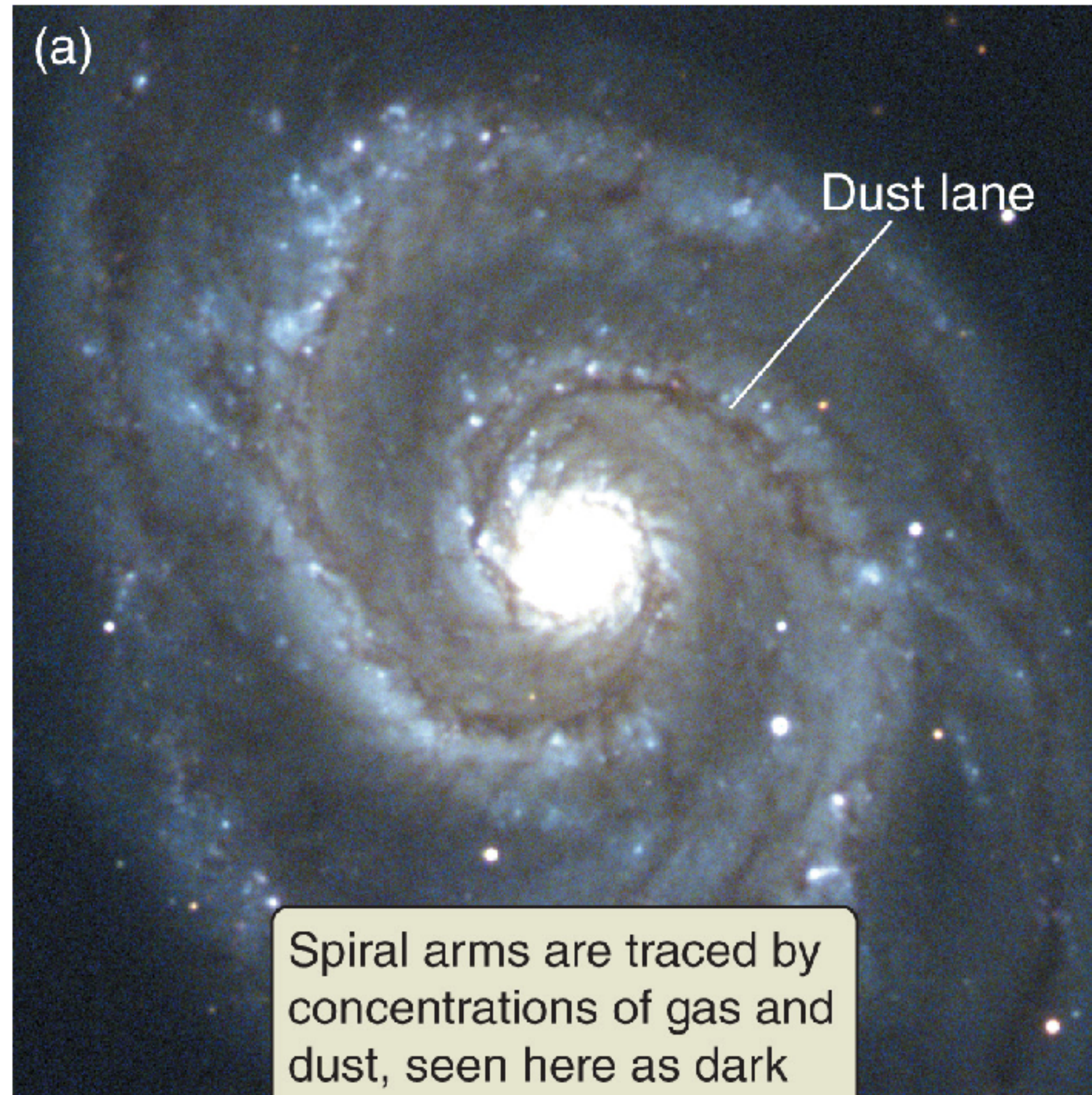
Hint: it's analogous to planets in star systems



Stars form from gas — gas settles into a disk due to angular momentum conservation!

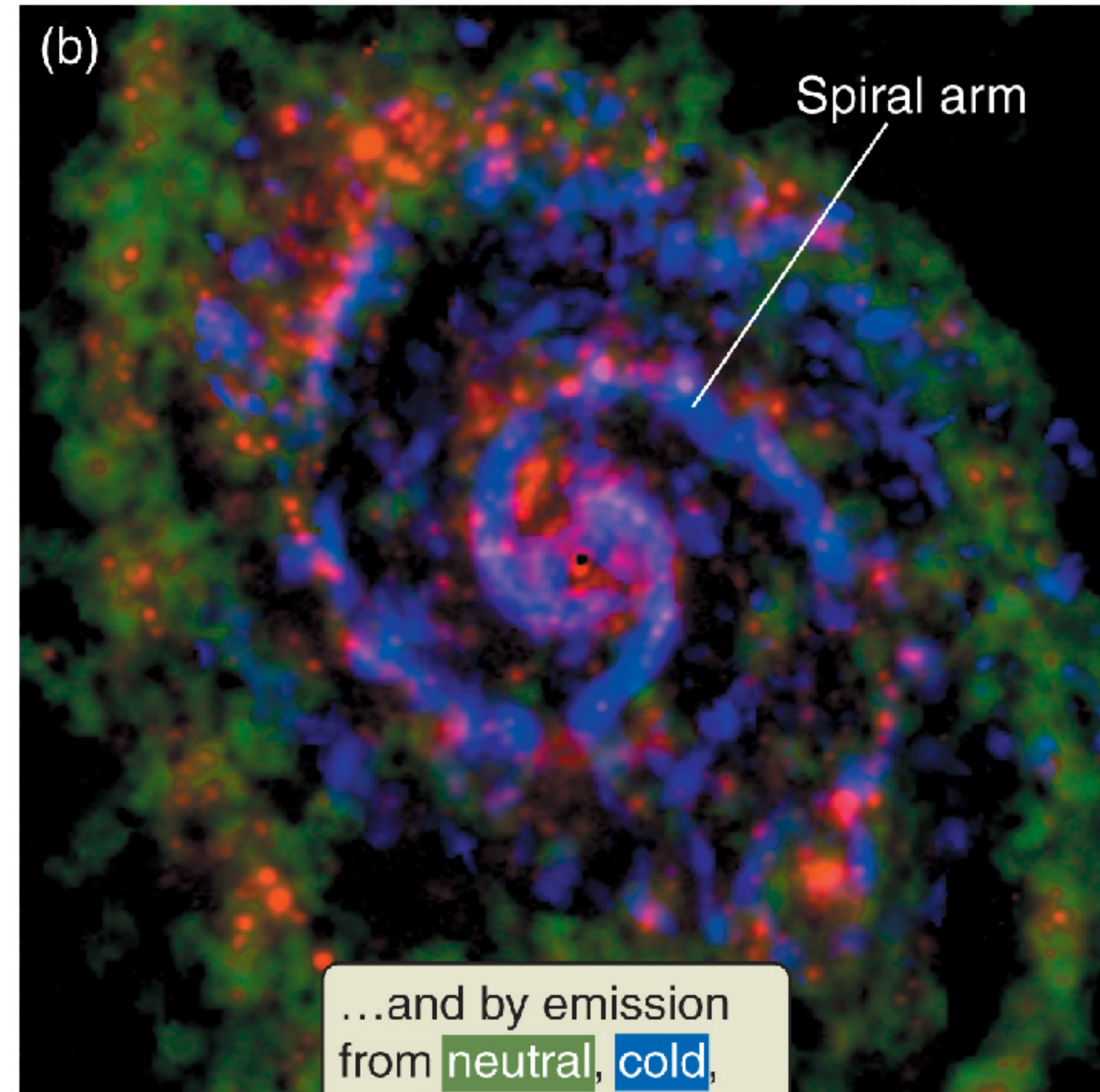


# Spiral arms are density waves (like sound waves)



Spiral arms are traced by concentrations of gas and dust, seen here as dark absorbing lanes...

G X U **V** I R



...and by emission from neutral, cold, and ionized gas.

G X U **V** I R



# Galaxies are not isolated









## Sideways Stellar Motions Suggest Shell in Milky Way Halo

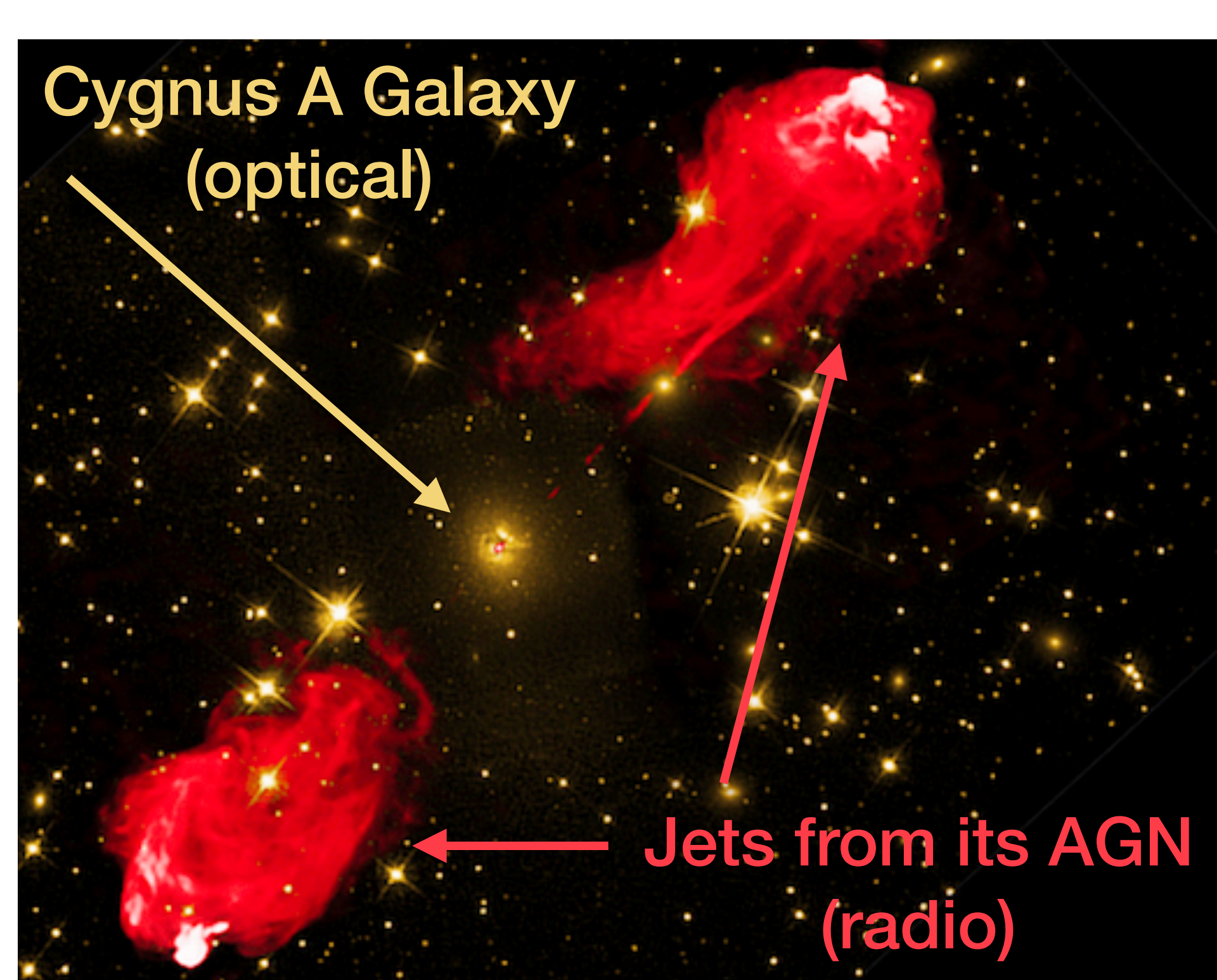


<https://www.youtube.com/watch?v=52k-VryS1hs>



# Active Galactic Nuclei (AGN) $\longleftrightarrow$ Supermassive Black Holes (SMBHs)

more or less all galaxies have an SMBH, and its mass is proportional to the mass of its bulge



M87



Centaurus A

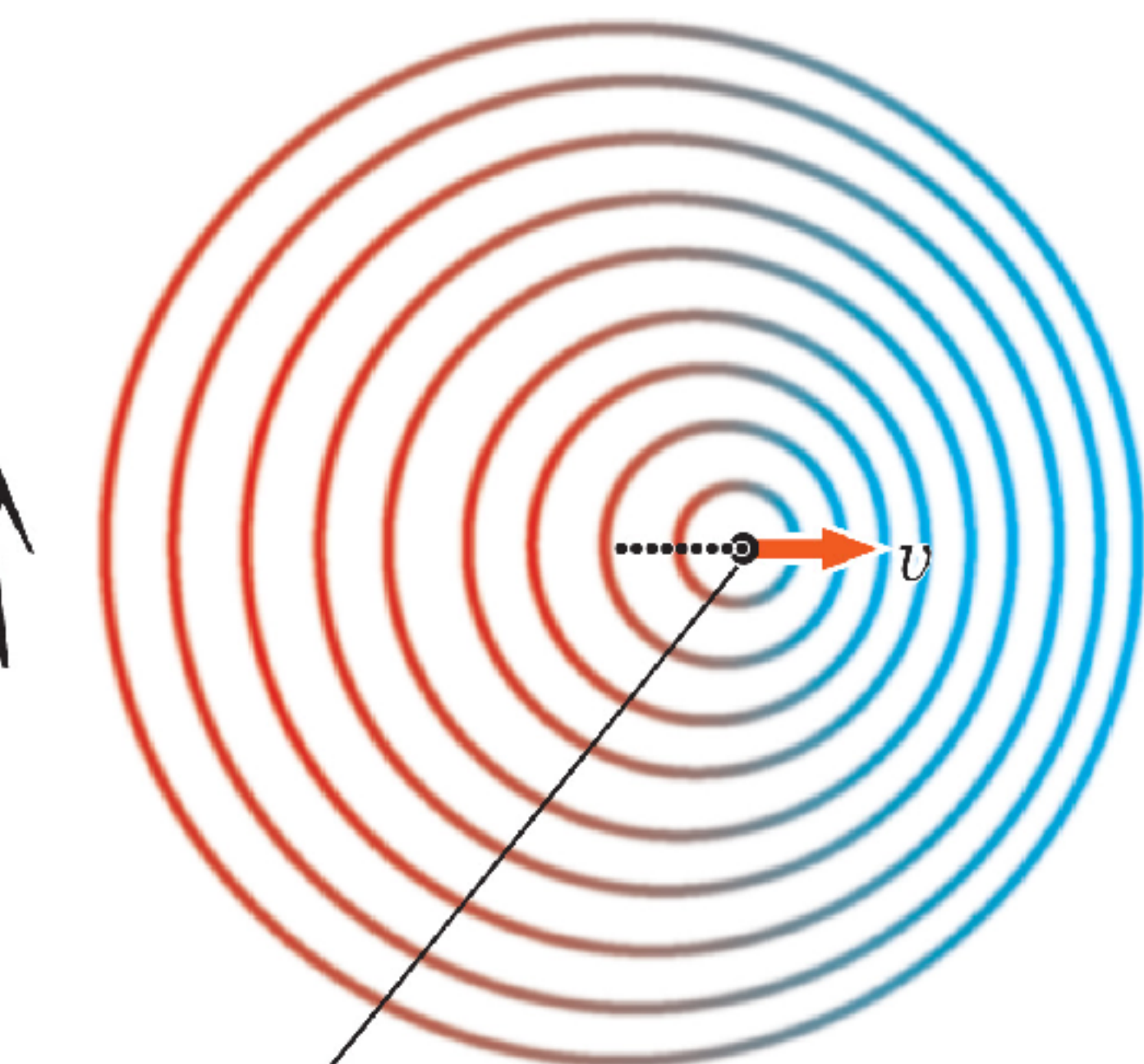


# But how are galaxies moving?



Waves that reach this observer are spread out to longer, redder wavelengths (lower frequency).

Waves that reach this observer are squeezed to shorter, bluer wavelengths (higher frequency).



Moving source of light

This observer sees no Doppler shift.





# Doppler Shift of Light



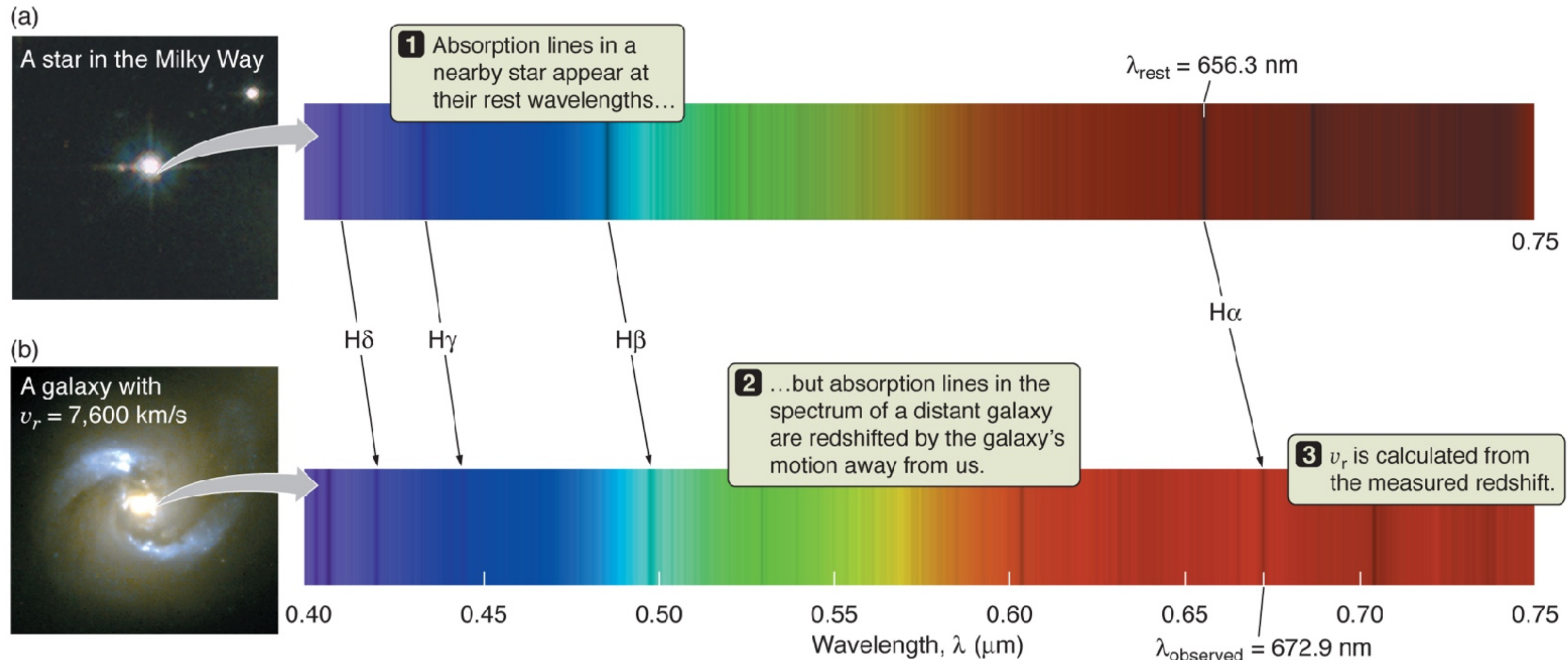
$$\frac{\lambda_{observed} - \lambda_{emitted}}{\lambda_{emitted}} = \frac{v}{c}$$

Which spectrum is moving away from us the fastest?



Almost all galaxies are moving away from us.

$$\frac{\lambda_{observed} - \lambda_{emitted}}{\lambda_{emitted}} = \frac{v}{c}$$





# We live in an expanding “balloon universe”





# What are the spiral nebulae?

The great debate of 1920



Harlow Shapley



Herber Curtis

**MW is whole Universe**

- ✓ • Sun is in outer part of the MW
- ✗ • M31 would have to be at an insane distance to be similar
- ✗ • we can see rotation in the Pinwheel
- ✓✗ • this one nova in M31 would have been impossibly bright

**MW is one of many galaxies**

- ✗ • Sun is at the center of MW
- ✓ • M31 has too many novae to be just a galactic nebula
- ✓ • we see dust lanes in other nebulae, like the MW's



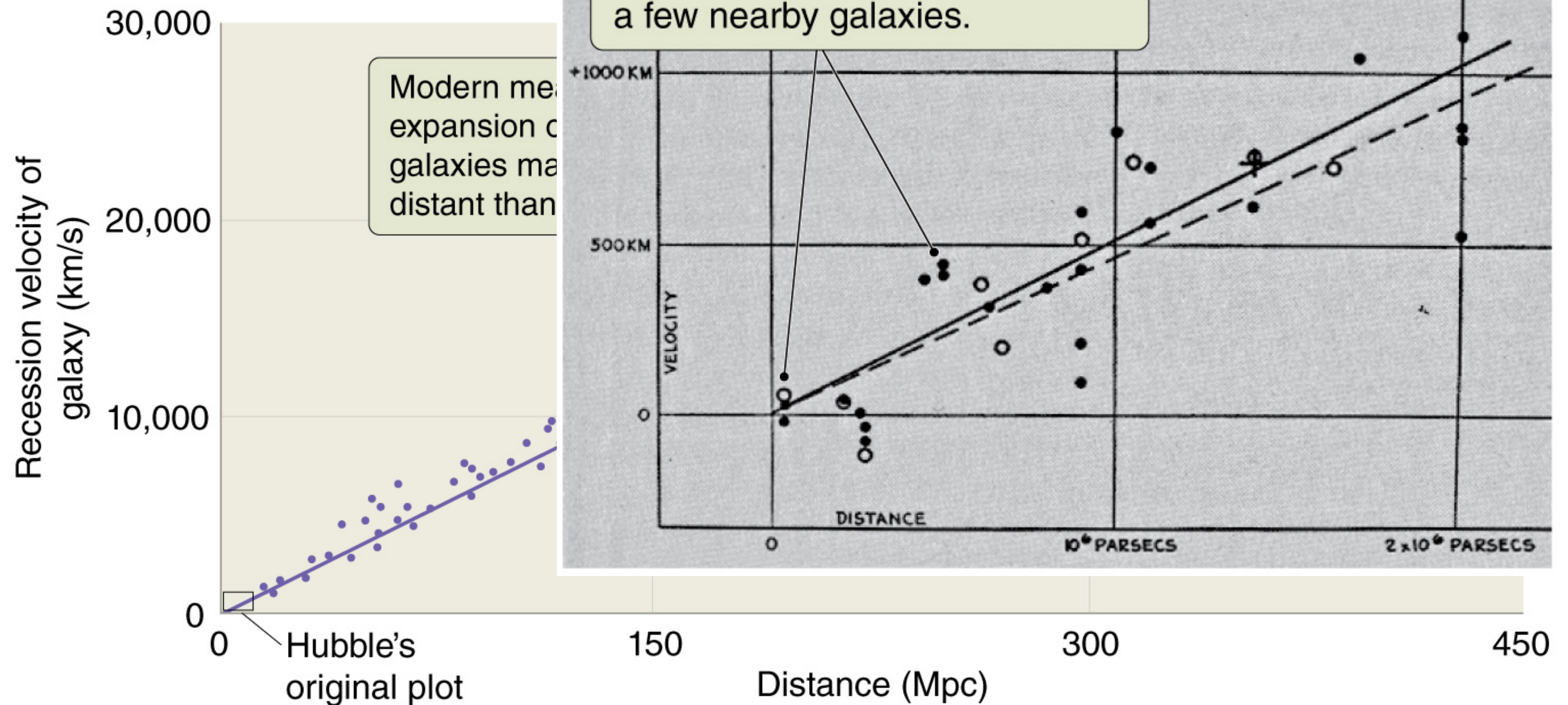
# Edwin Hubble settles the debate



M31: Andromeda Galaxy

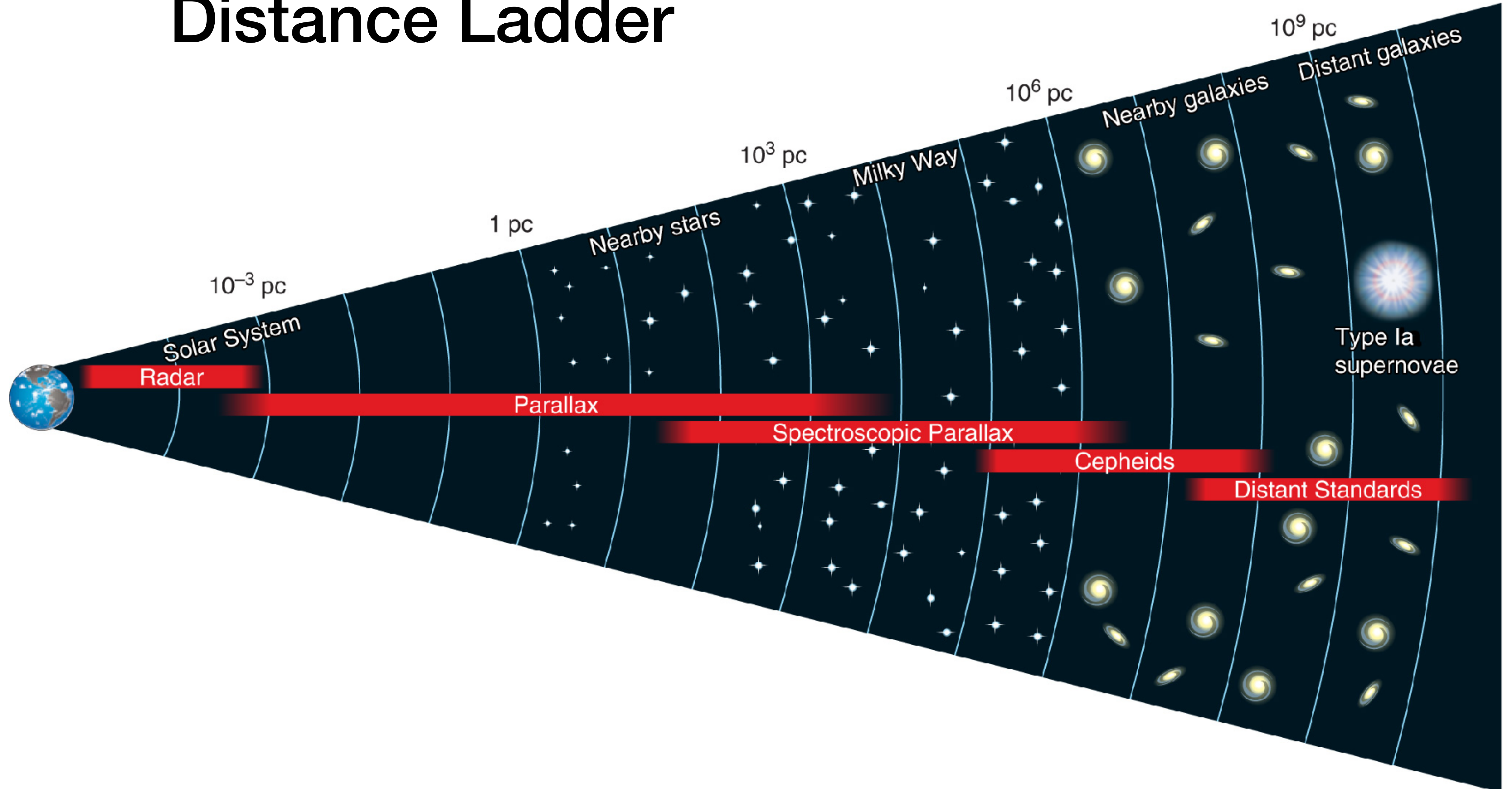


# Hubble's Law



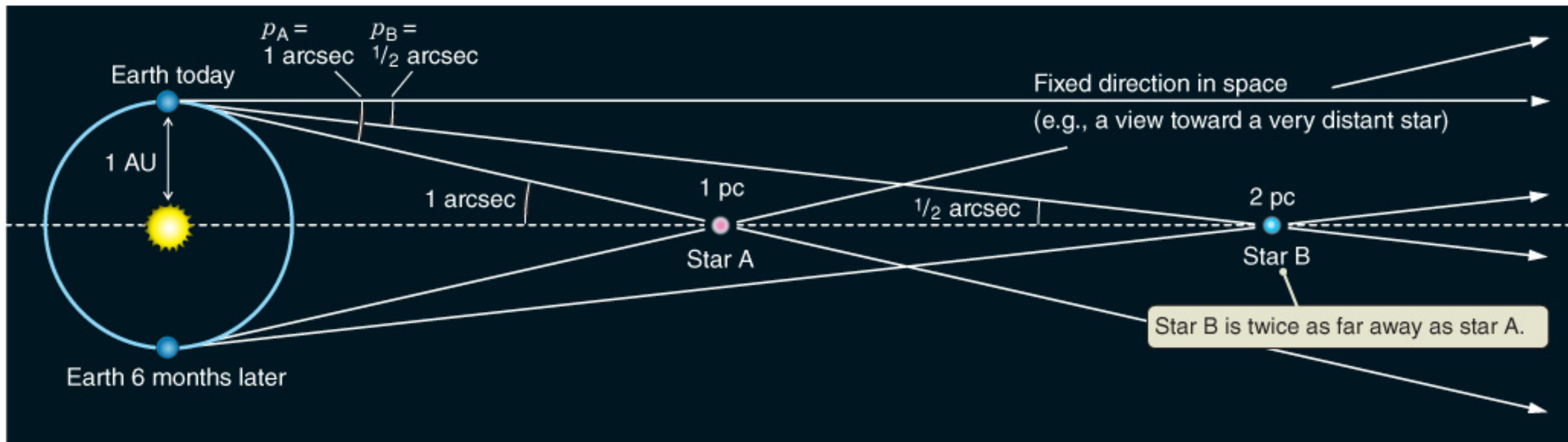


# Distance Ladder

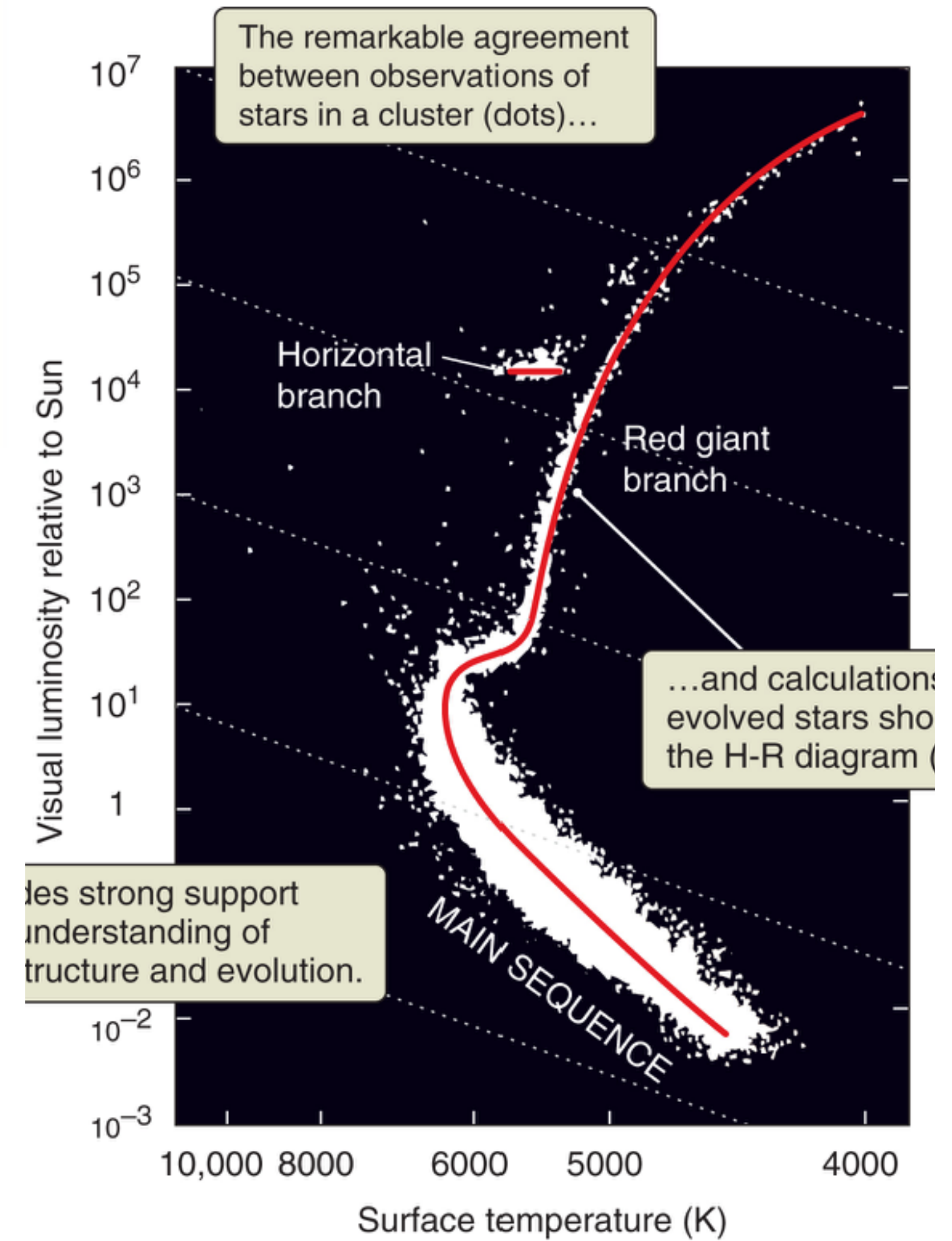




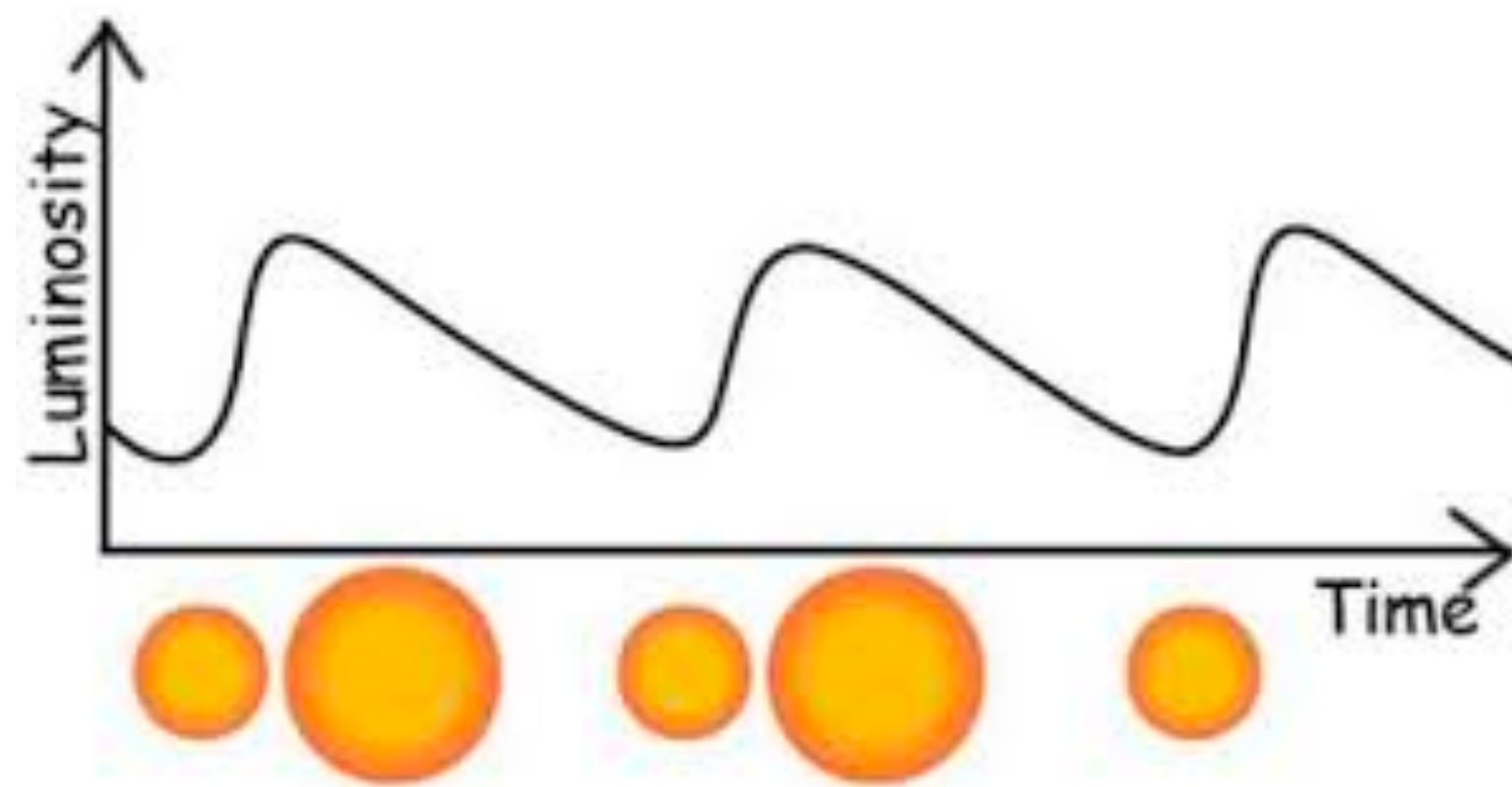
## Parallax



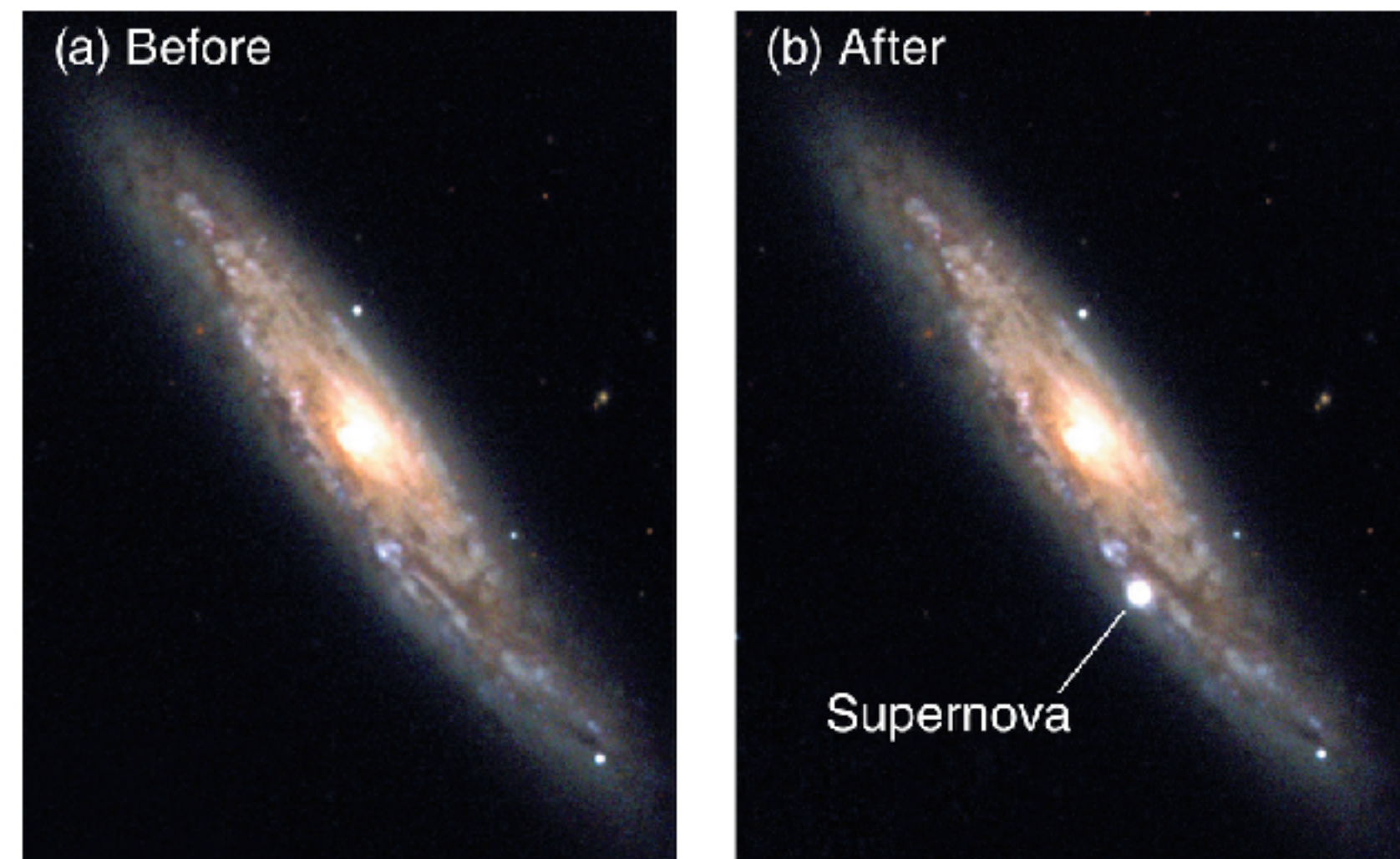
## Spectroscopic Parallax



## Cepheid Variables

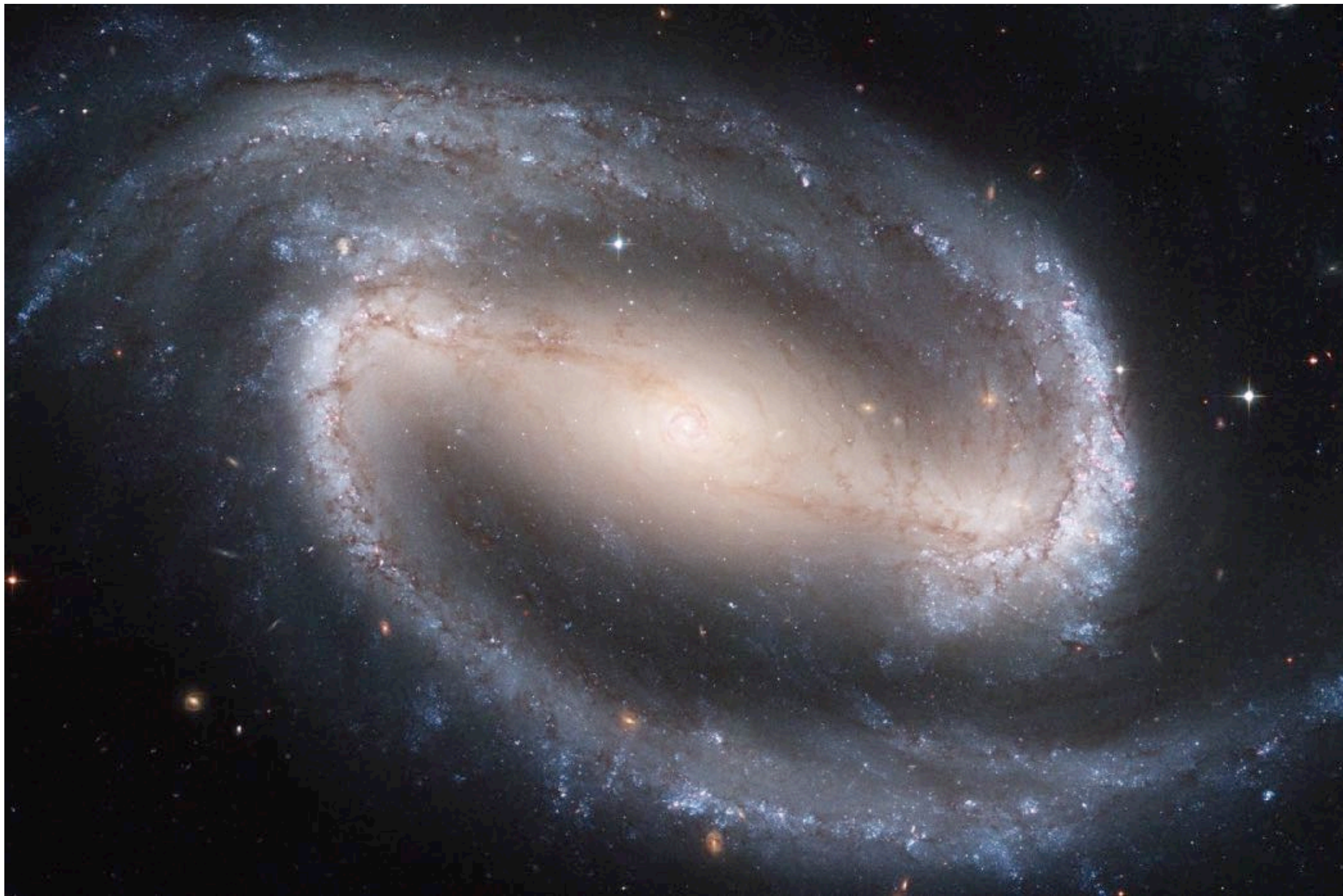


## Type Ia SNe





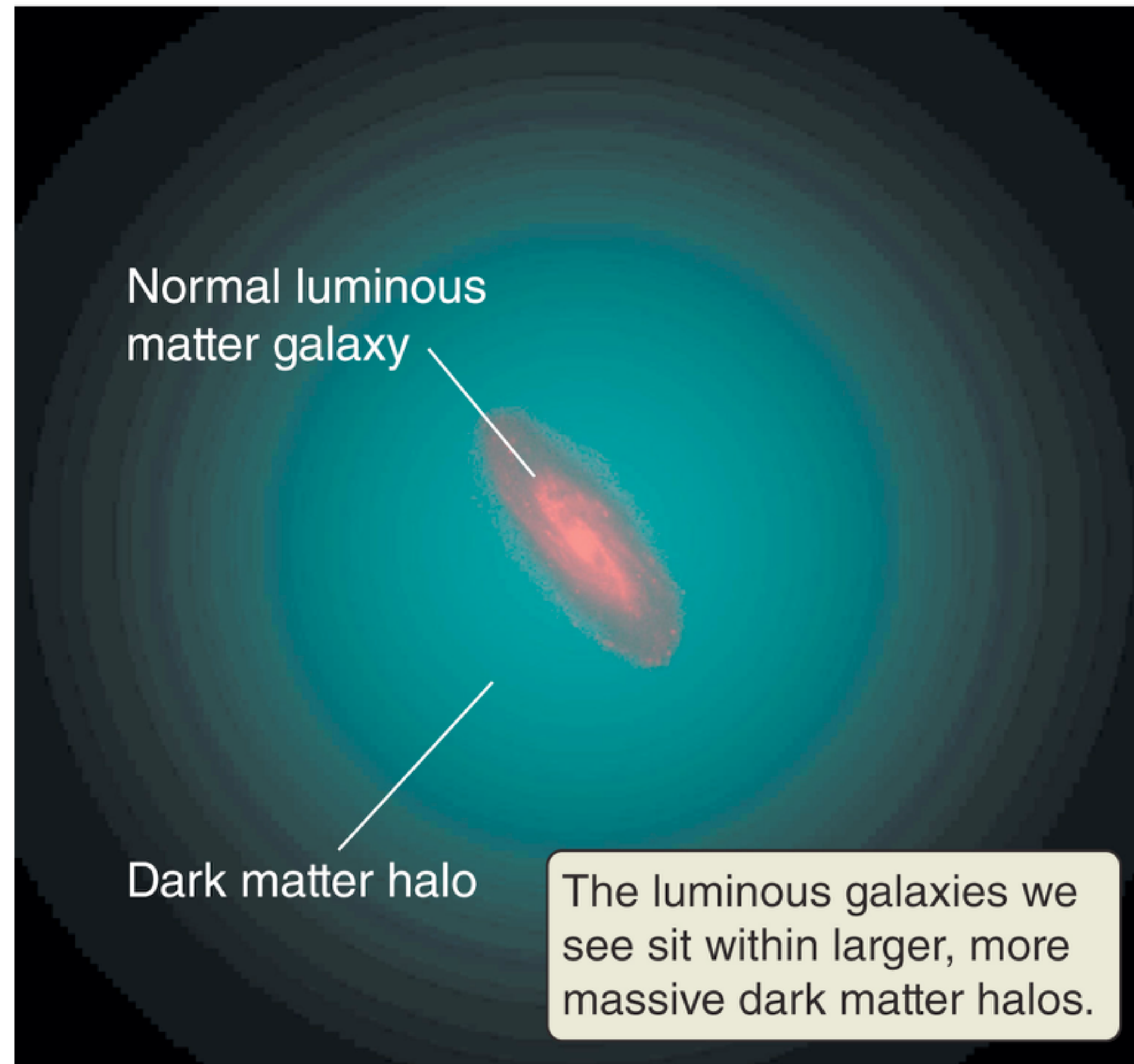
# What is the dominant factor that determines a galaxy's appearance?



- A) Total Mass
- B) Age of stars
- C) Environment
- D) All of the above



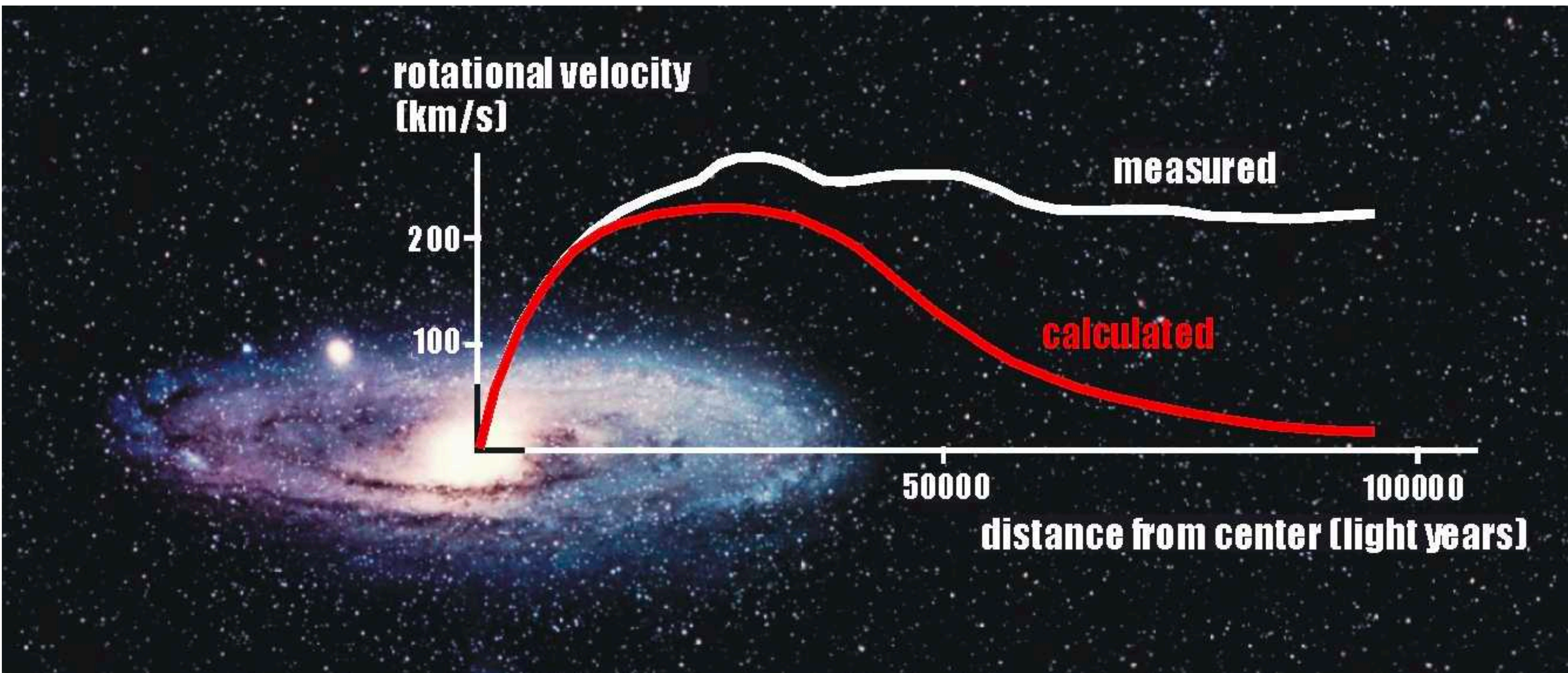
# What are galaxies mostly made of?



- A) Stars
- B) Stellar Remnants
- C) Gas
- D) Who knows?

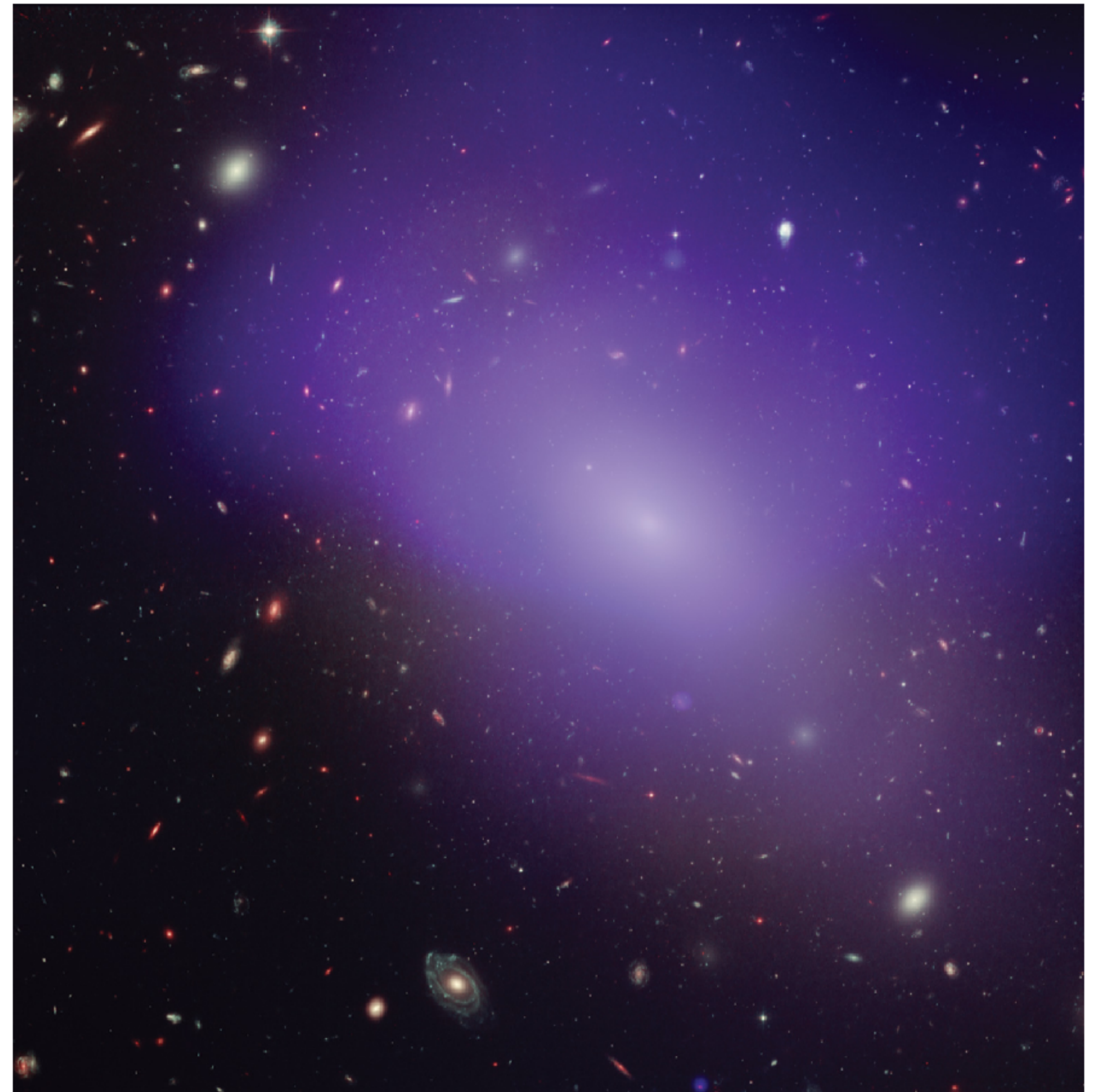


# What are galaxies mostly made of?



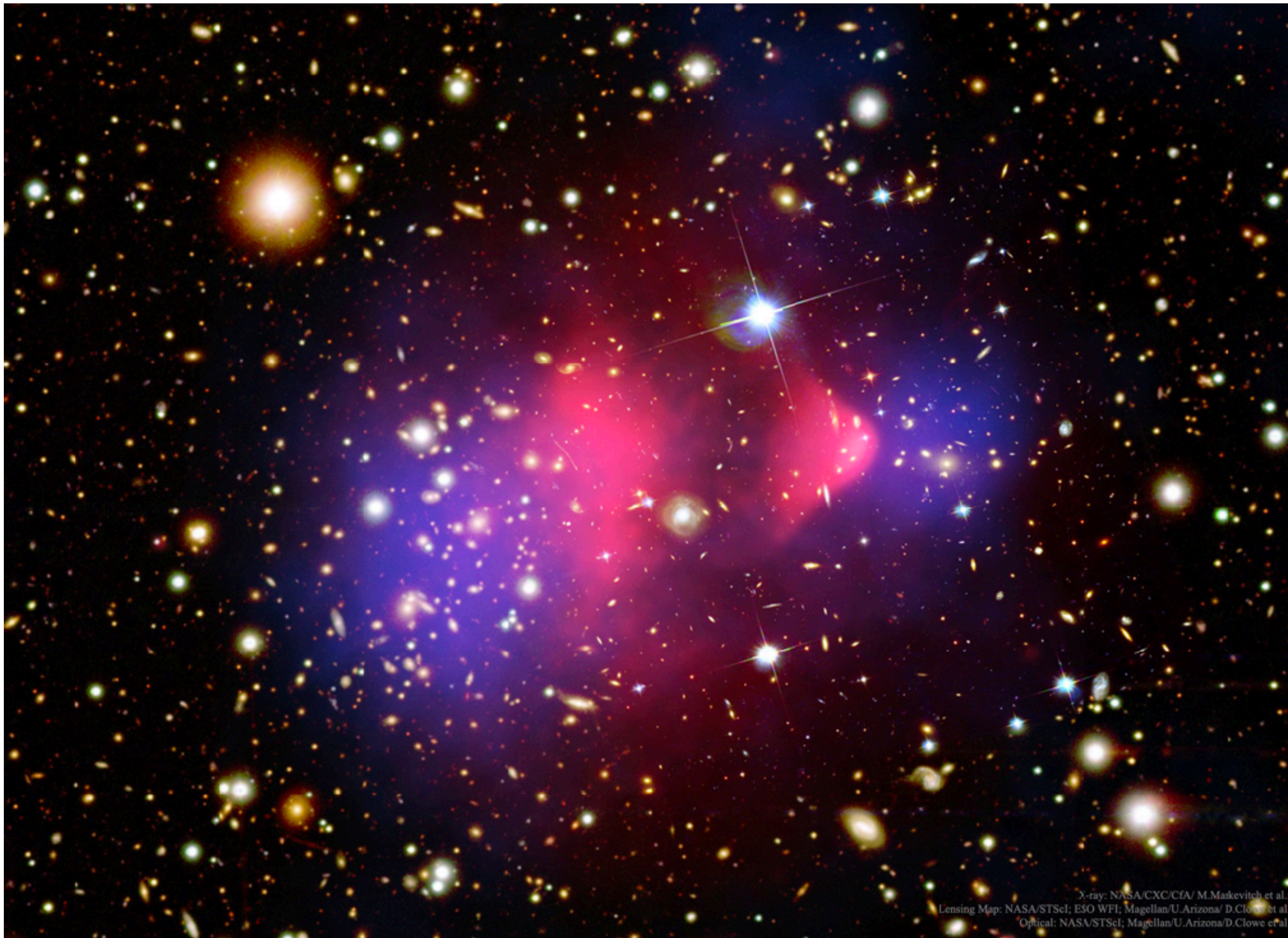


**Can estimate the  
mass of elliptical  
galaxies from its  
hot, X-ray  
emitting gas**





# What is dark matter?



- Most likely a new kind of matter (but possibly a modification to general relativity)
- Does not absorb or emit light
- Interacts very weakly, except through its gravity
- WIMP or MACHO? Axion or sterile neutrino?