# The Milky Way (Our Galaxy)

- Objectives

# The Milky Way Galaxy

- We live in a spiral arm of a thin disk
- massive collection of stars, gas and dust called *The Milky Way Galaxy*

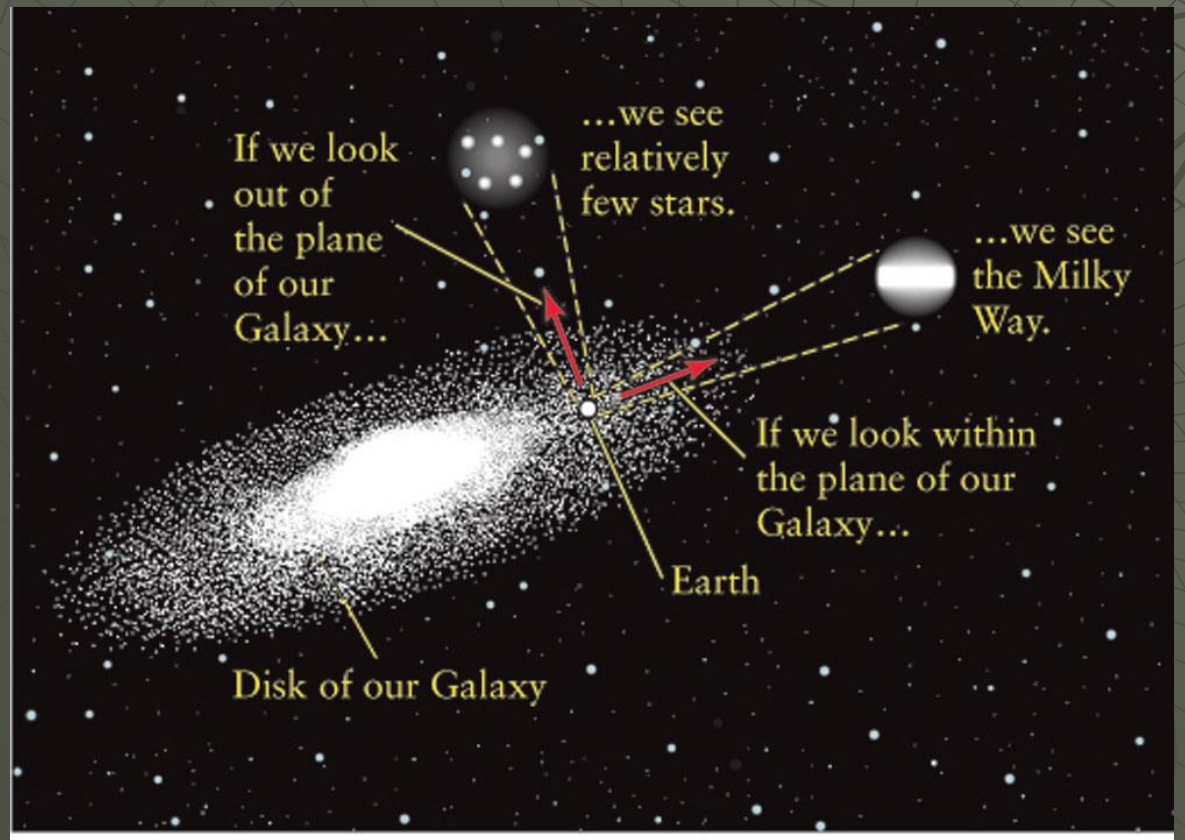
- ~200 billion stars
  - star clusters
  - Binary, triple, quadruple star systems, etc…

- Immense clouds of diffuse gas, molecular clouds, dark (dust) clouds, etc…

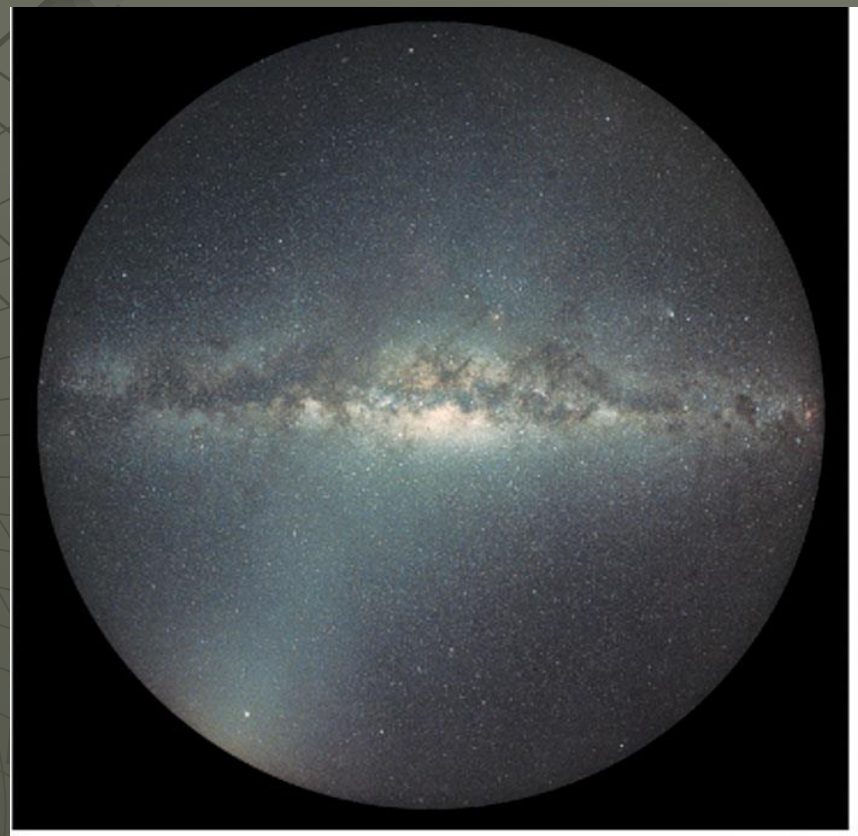
- Stellar corpses (white dwarf stars, supernova remnants, neutron stars, black holes, etc.)

# The Milky Way Galaxy

- We know the Milky Way is a disk because of how it appears in the sky
- where exactly are we in this disk???



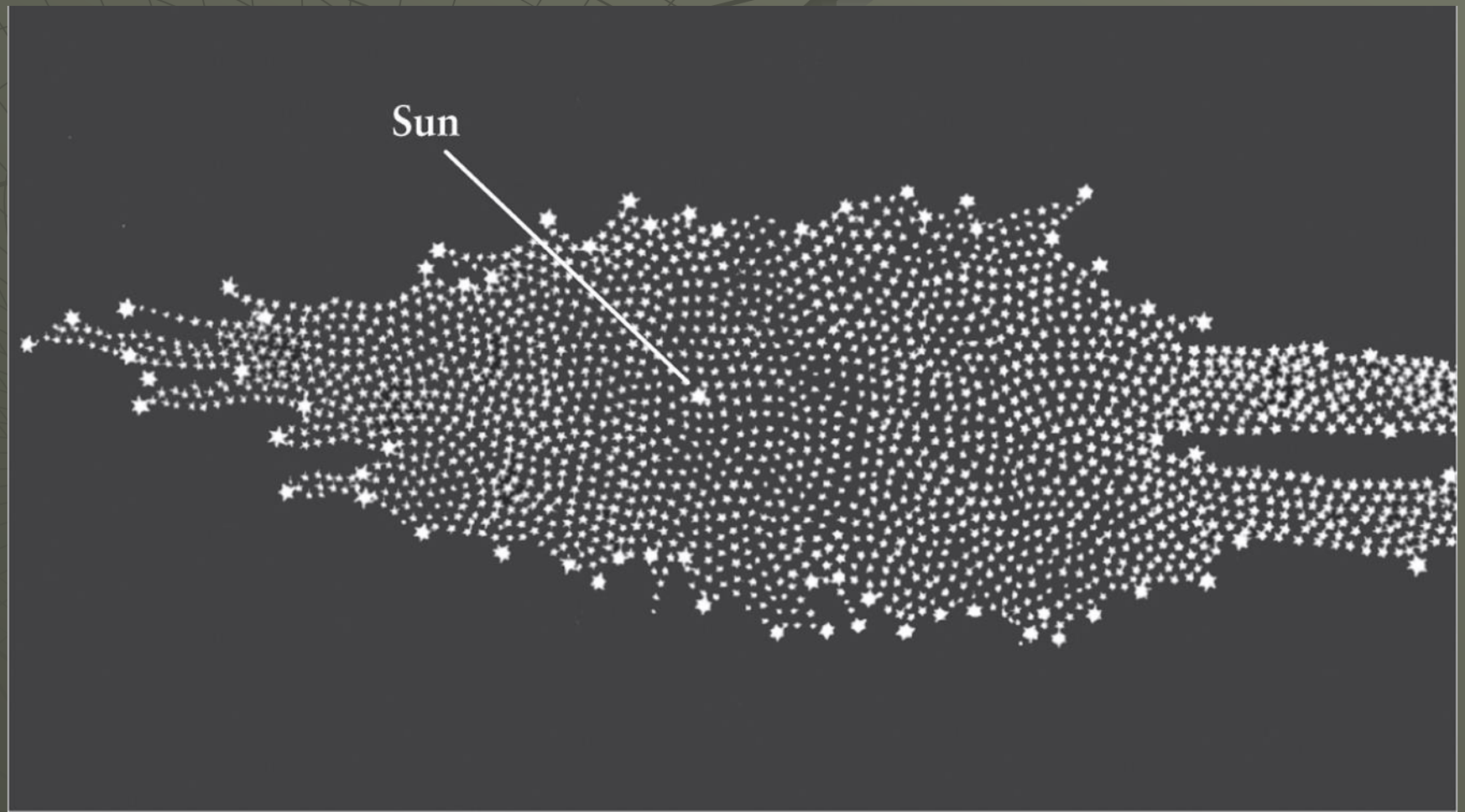

(a)




(b)

# Are We at the Center??? Really?

- Early star count densities led to the conclusion that we are at the center of the galaxy.



- Why did early astronomers see roughly the same number density of stars in all directions in the disk?

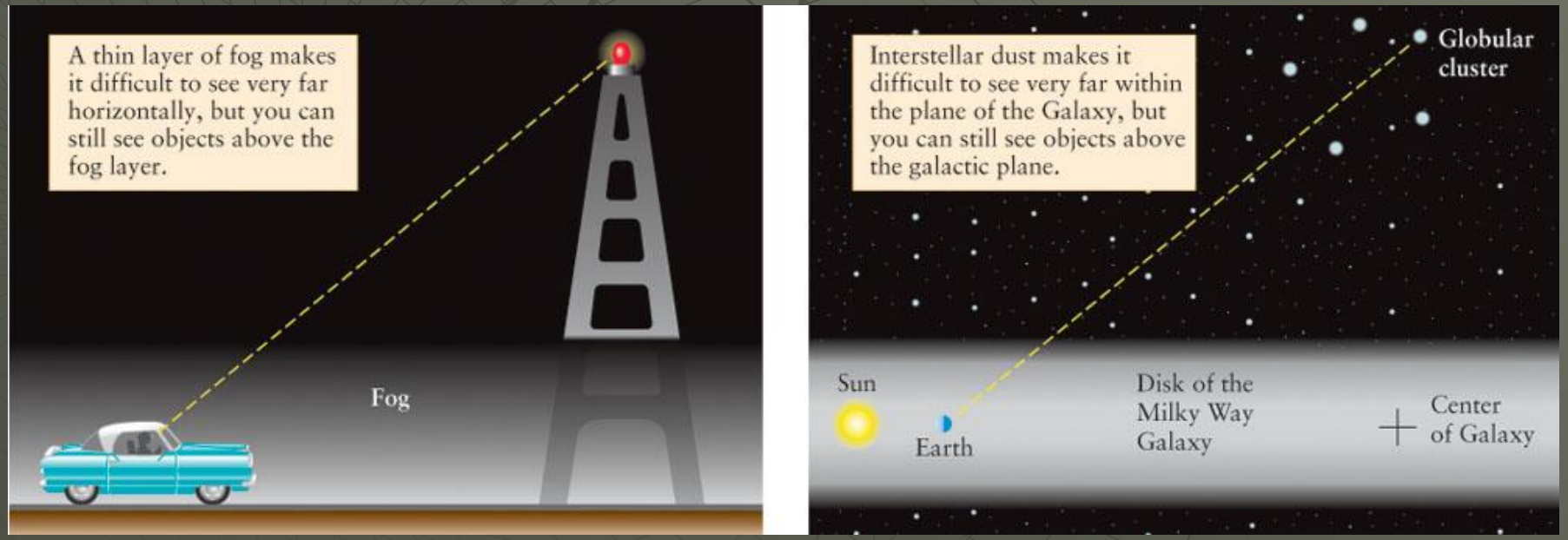
A. We really are at the center of the galaxy
B. Gas and dust blocks all visible light at the same distance away from the earth
C. Far away stars are too dim to see
D. Chuck Norris said so (last one I swear)

# The Milky Way Galaxy

- The large amounts of gas and dust filling the disk of our galaxy make it difficult to observe very far through the disk

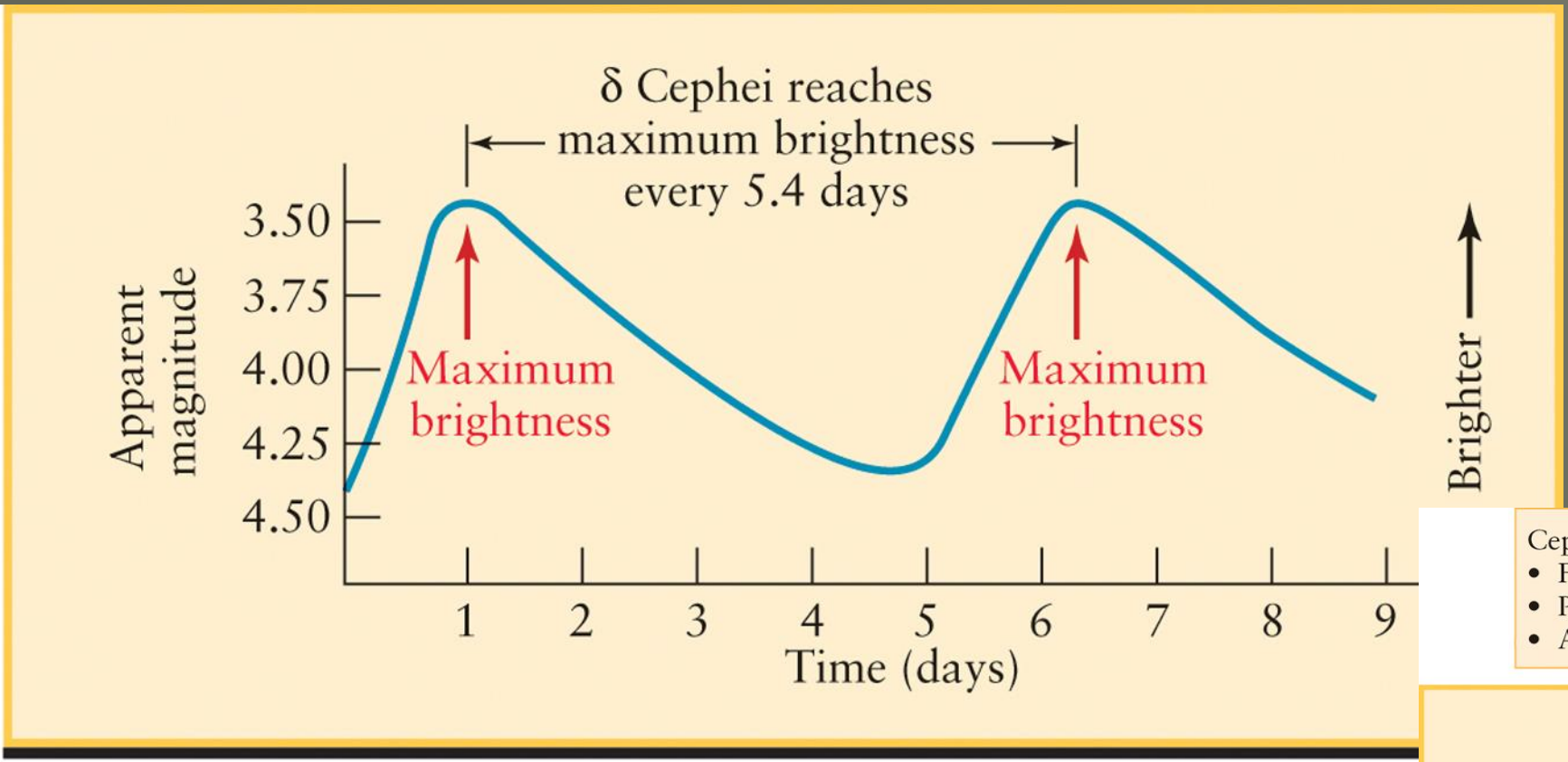
- Dust and gas tend to absorb and scatter light, leading to interstellar extinction

- We need to observe objects outside of the disk → star clusters!!!

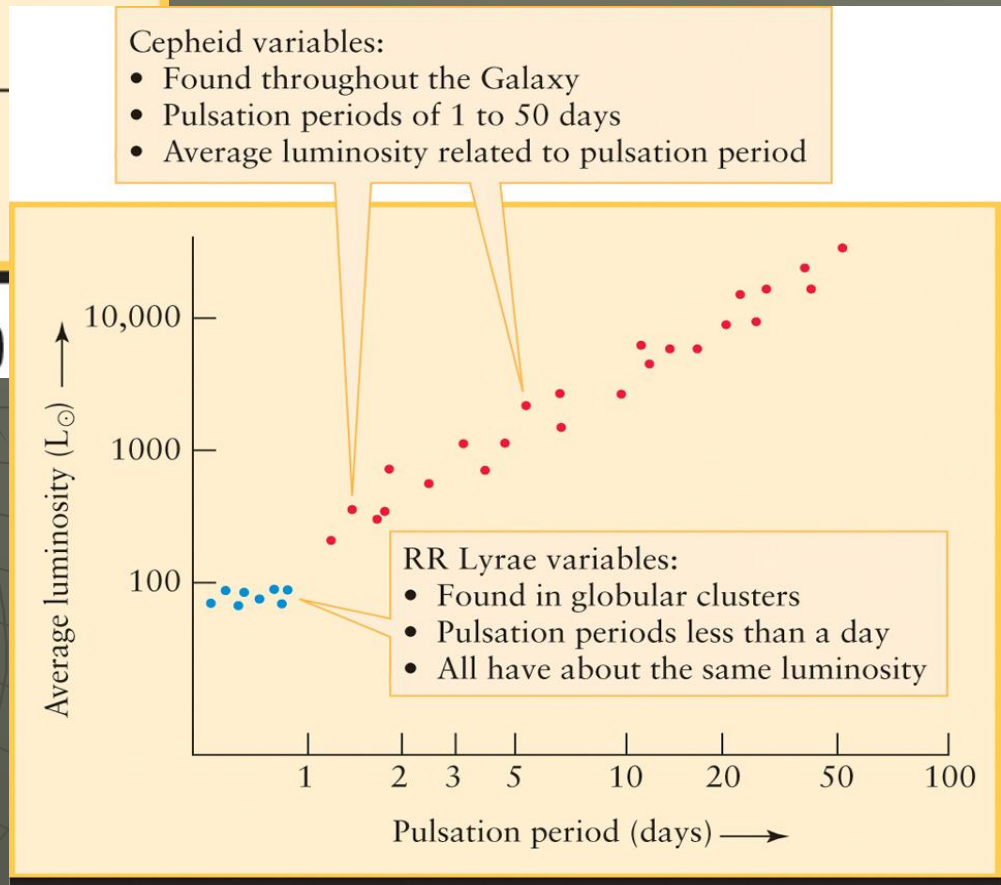


# Cepheid Stars

- In addition to HR diagram methods
- Multiple sources = more accurate data




(a) The light curve of δ Cephei (a graph of brightness versus time)

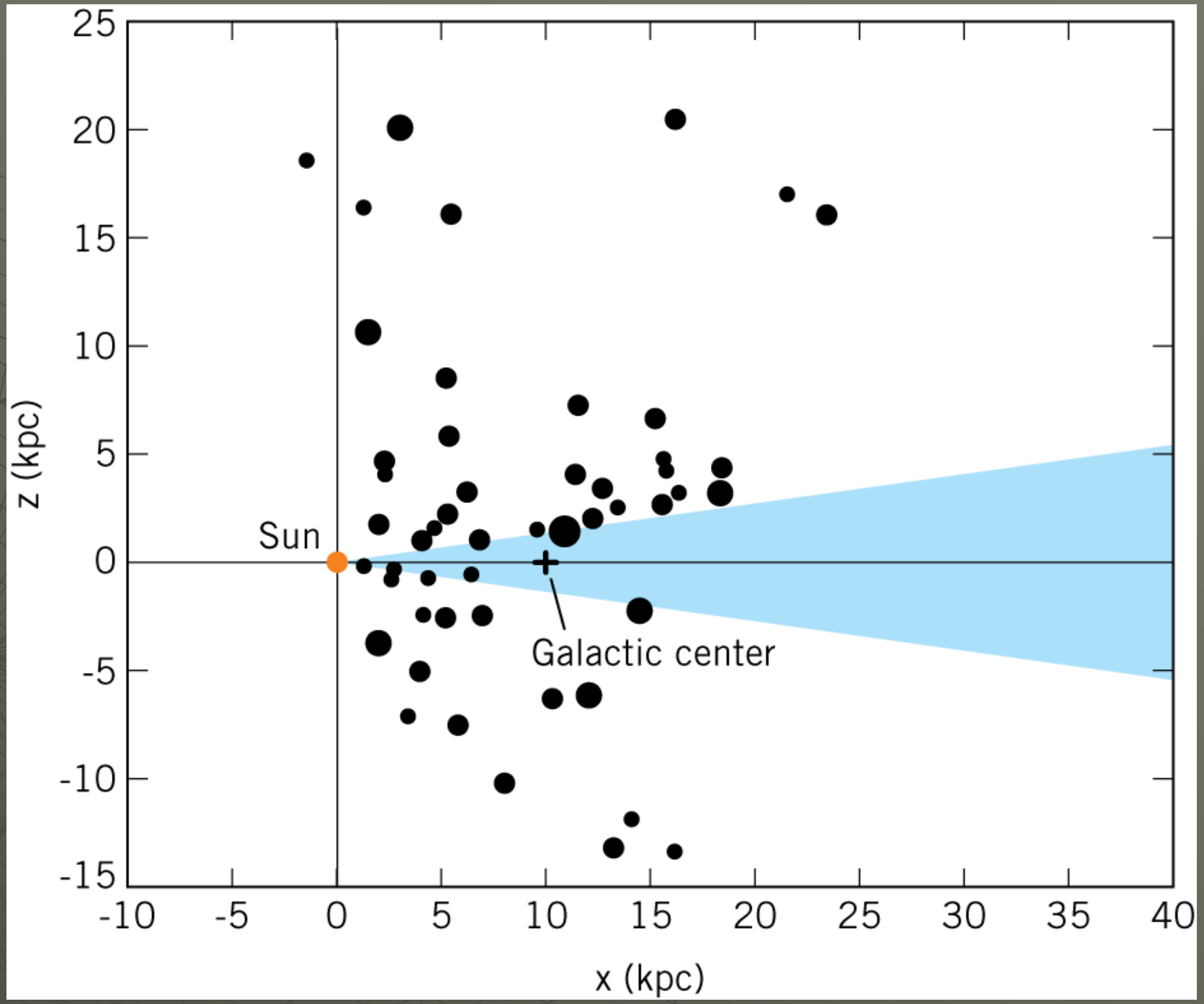


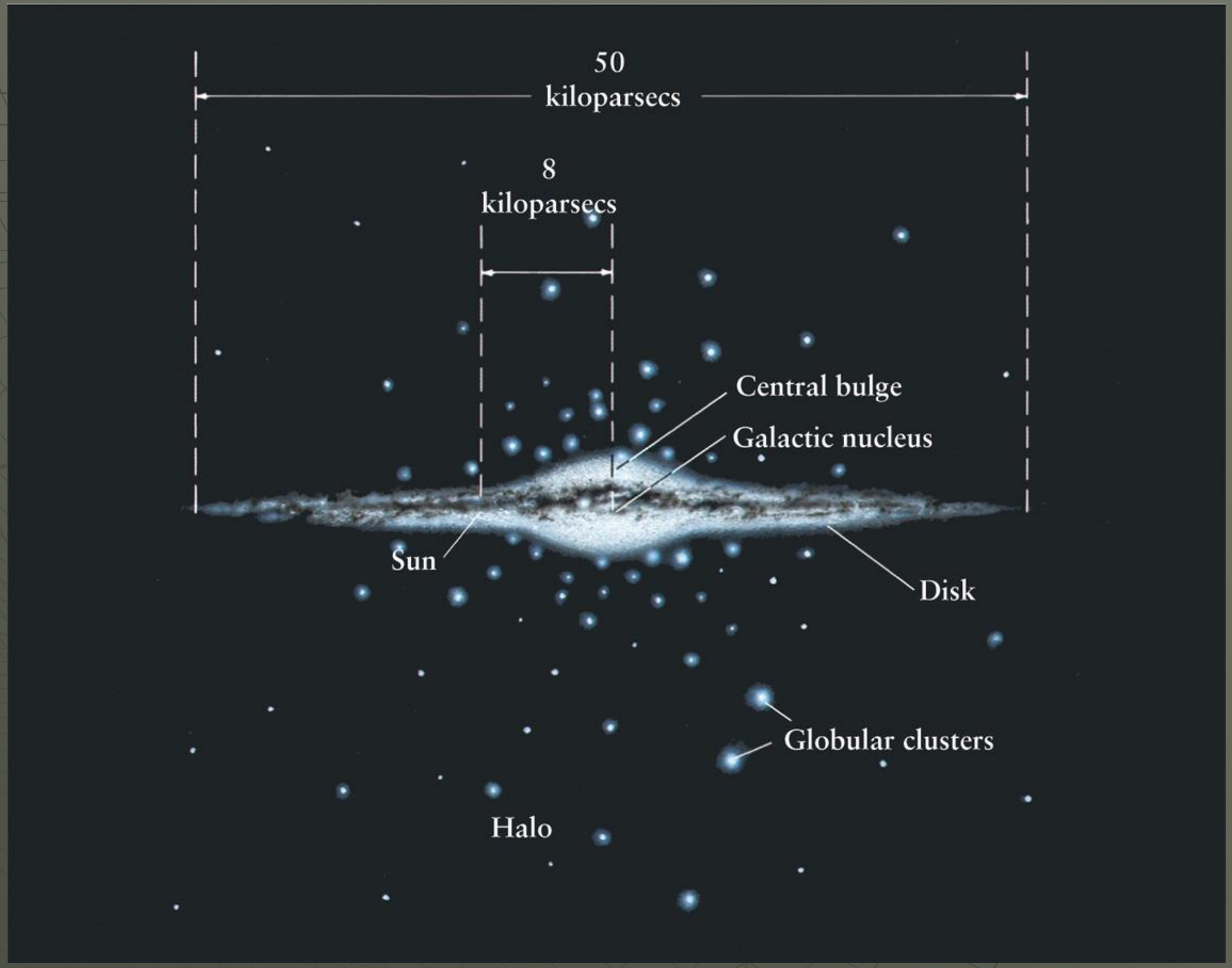

- Red Giant stars that are pulsating
- Period of pulsation correlates with absolute brightness
- Gives us a distance!

# Finding the Center of the Galaxy

We can use the distribution of globular clusters to approximate the center.

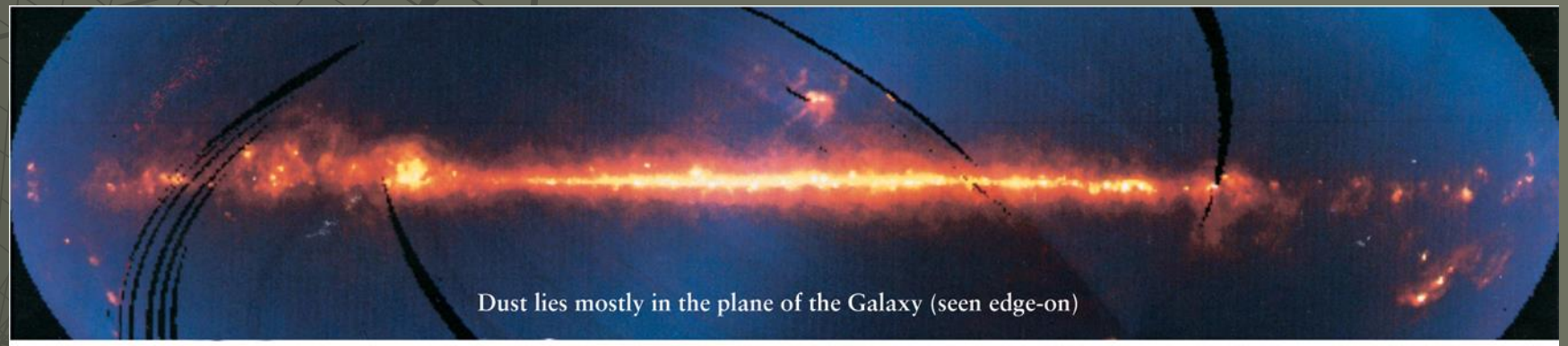
- Center of MW = center of star cluster distribution
- Center = 8 kpc from us



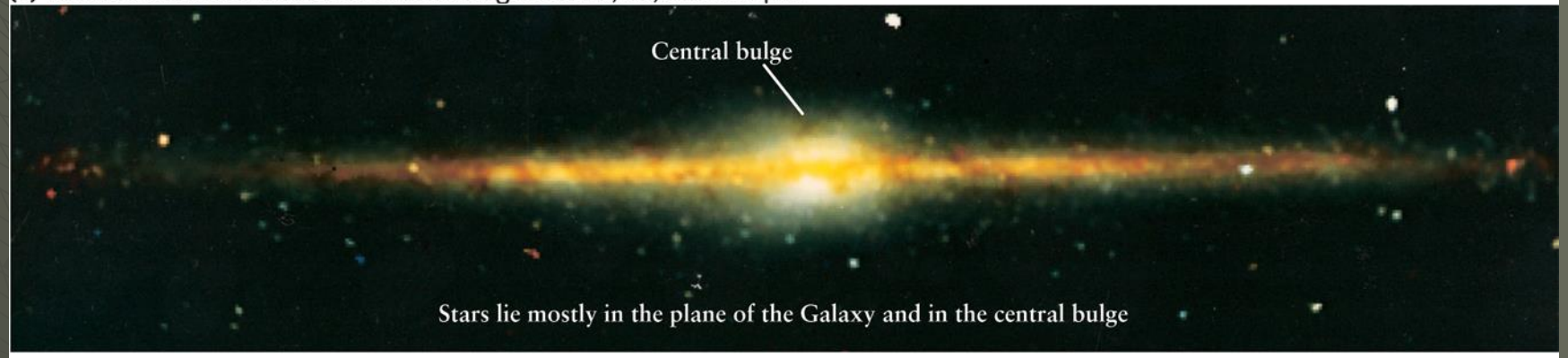

50
kiloparsecs
8
kiloparsecs
Central bulge
Galactic nucleus
Sun
Disk
Globular clusters
Halo

# IR Observations

- Infra-Red wavelengths are not obscured as much as visible light
- Cold gas clouds (T~ 100 K) have a blackbody peak in the IR
- Blackbody curve gives Flux, which gives a total luminosity, which gives a distance!



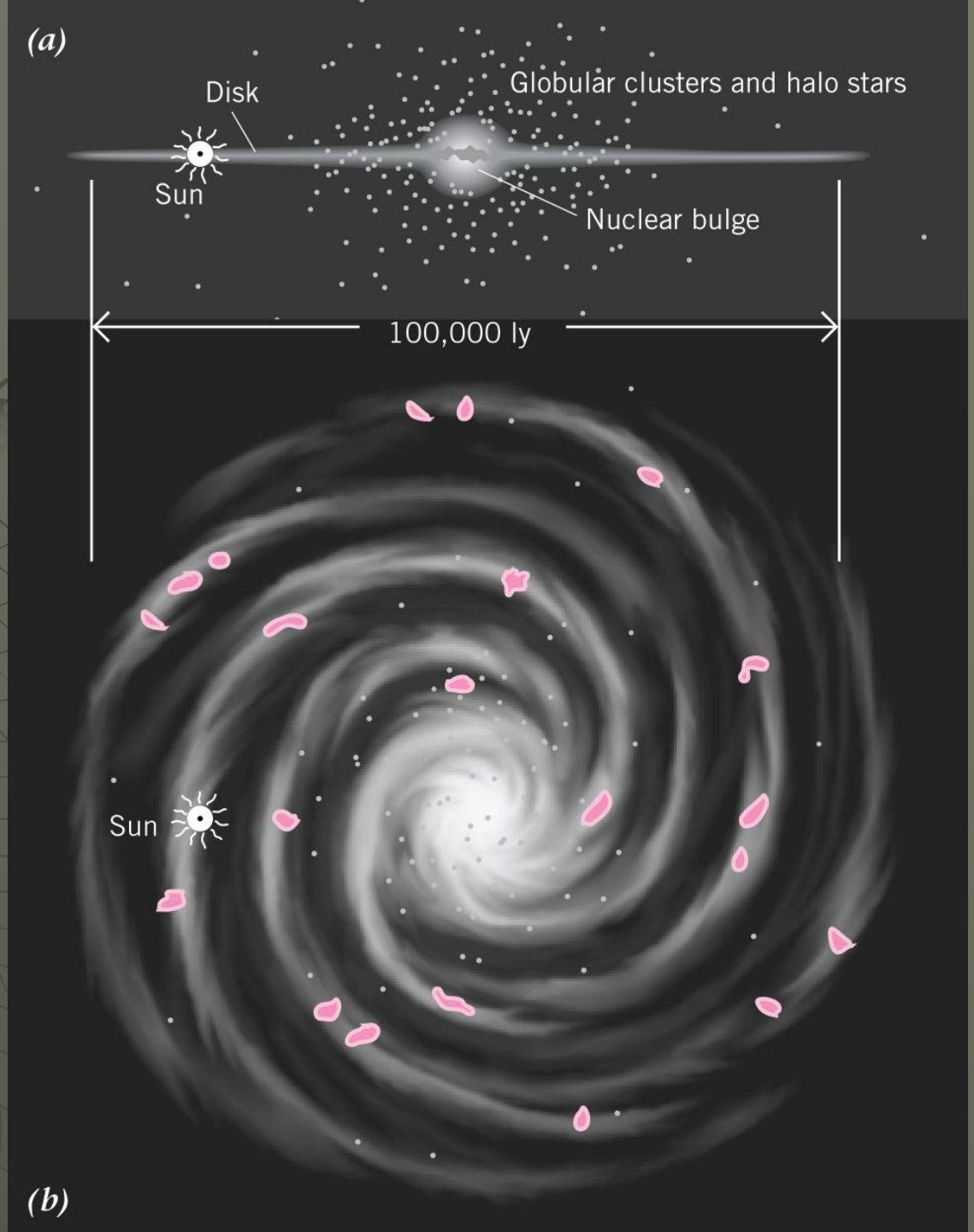

(a) Infrared emission from dust at wavelengths of 25, 60, and 100 μm




(b) Infrared emission from dust at wavelengths of 1.2, 2.2, and 3.4 μm

# Structure

- Buldge
  - The Center
- Halo
  - Old stars
- Disk
  - Young stars
  - Spiral arms



- The fact that most globular clusters are in the same direction suggested that

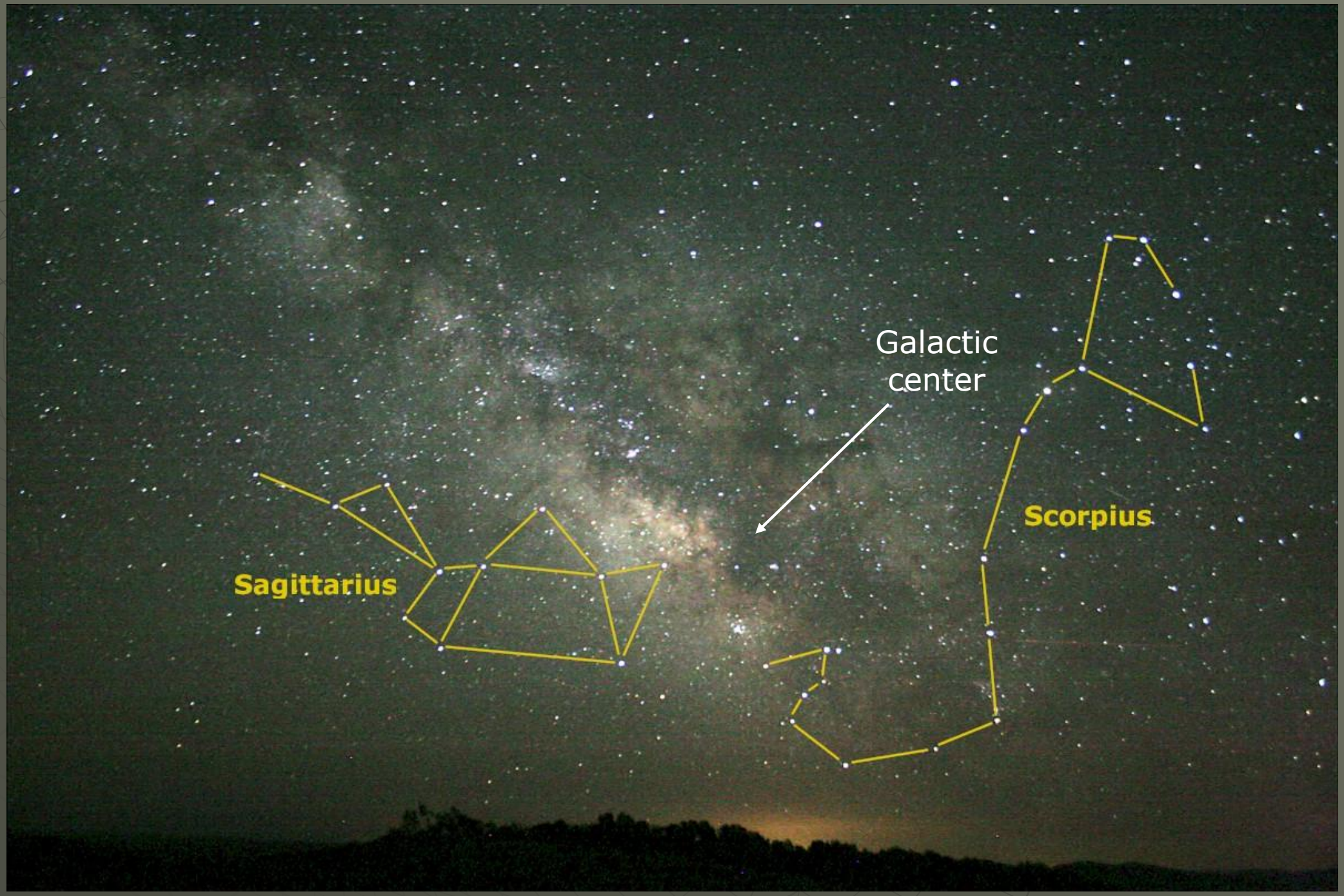
A. more globular clusters formed on one side of the Galaxy than the other.
B. there is more dust obscuring our view of the Galaxy in one direction than in the other.
C. we are not at the center of our Galaxy
D. a massive object on the other side of the Galaxy has pulled many of the globular clusters to that side.

- Two Cepheid variables have the same average apparent brightness, but Cepheid A has a period of 10 days while Cepheid B has a period of 5 days. Which Cepheid is closer?

A. Cepheid A
B. Cepheid B
C. They are the same distance away.
D. More information is needed to make this determination.

# LT

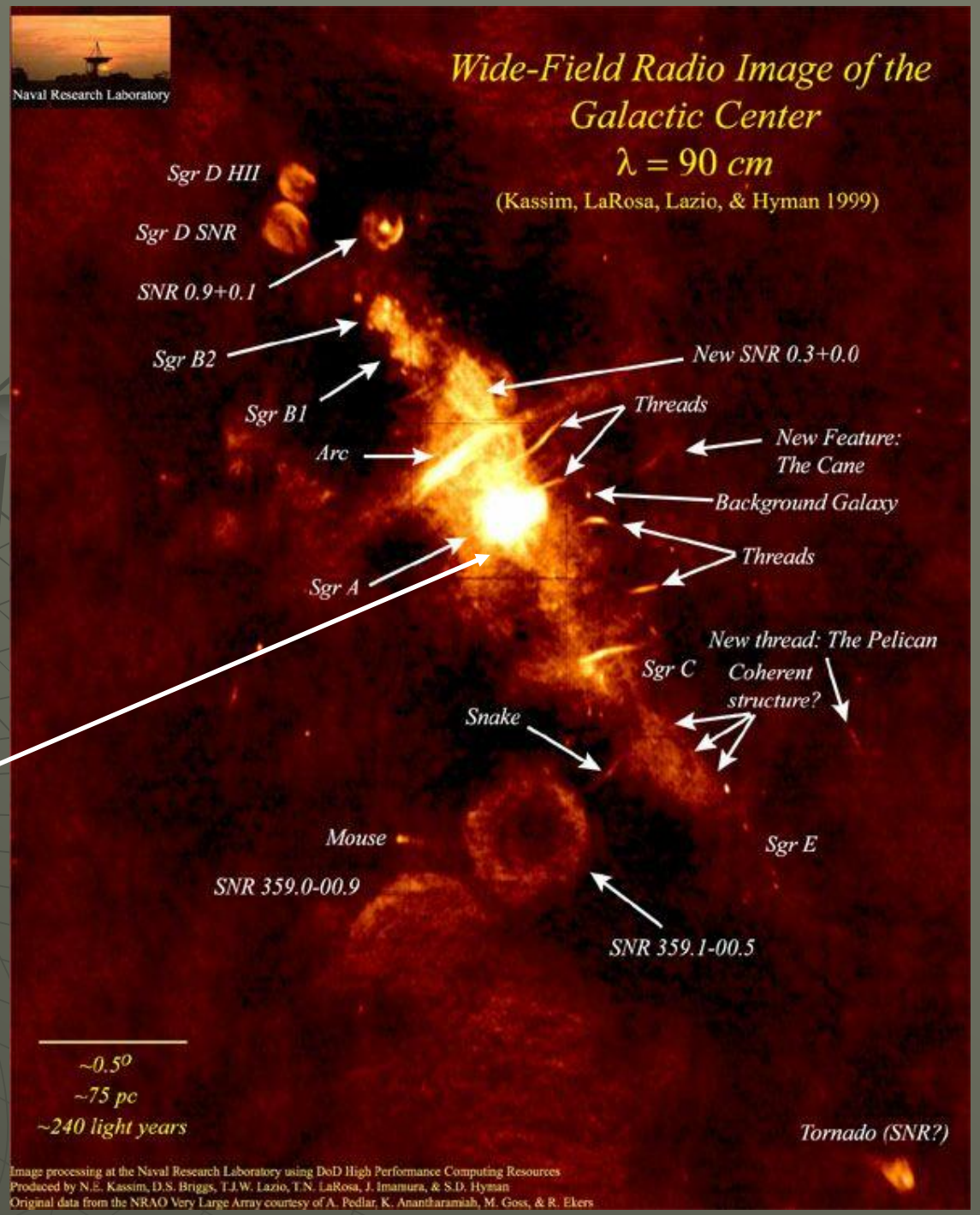
- Milky Way Scales
  - Pg 135


Galactic
center
Scorpius
Sagittarius

# Center is Crowded!

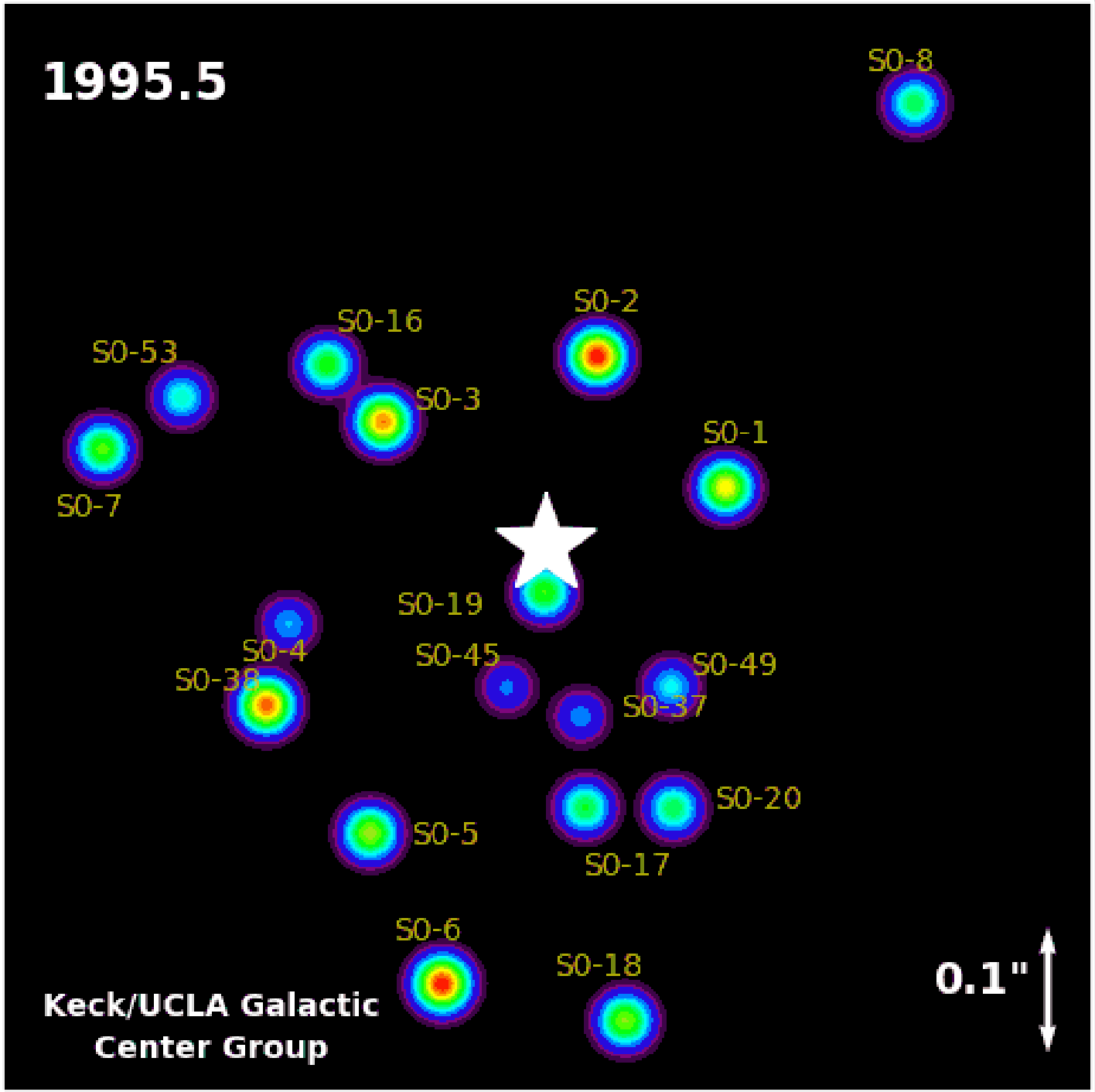
- Radio image
  - Able to see light through dense clouds
- Star clusters
- Giant gas clouds
  - Spherical
  - Threads
  - SN remnants

- Super Massive black hole
  - Sagittarius A (sgr A)



# Physics!

- S0-2 → period of 15 years
- S0-16 → 90 AU away!
- Super massive black hole
  - Kepler's 3rd Law
  - Newton's Gravity
  - 4 million times $M_{sun}$

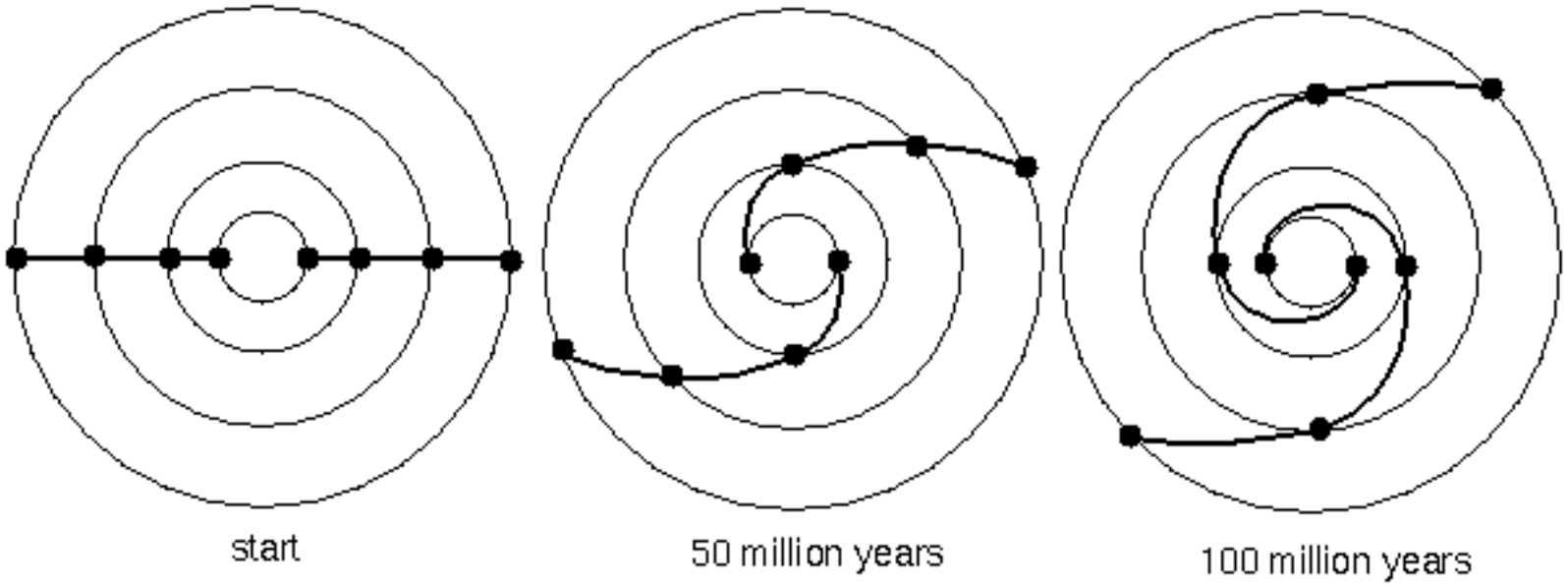


# Spiral Arms

- Explaining the disk shape of the galaxy is easy- it is due to the same processes that are involved in forming the solar system

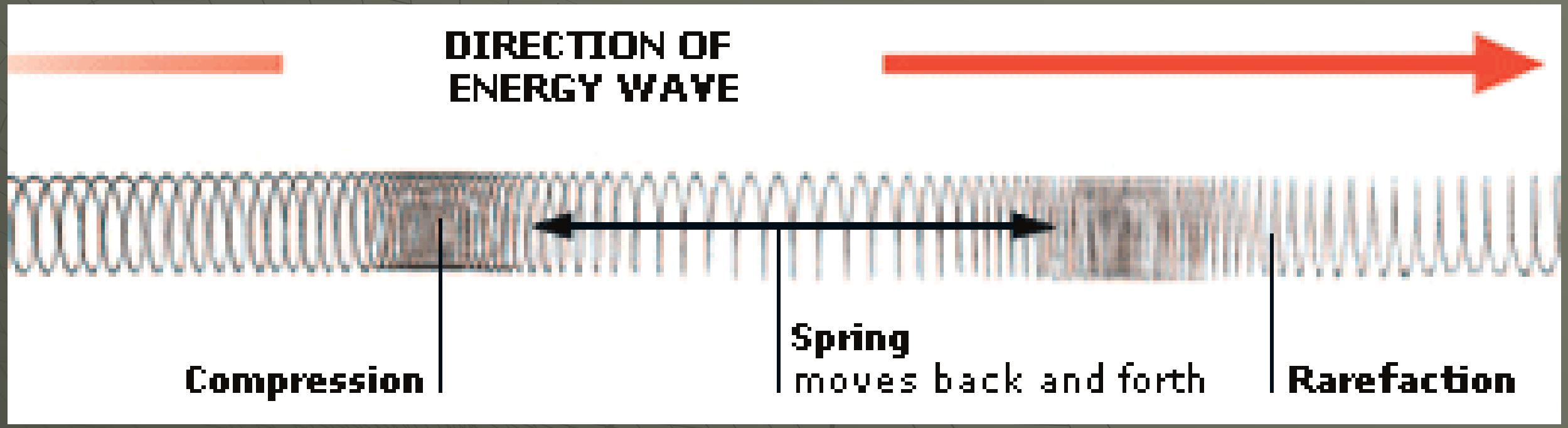
- But why are there spiral arms?
- For the pattern to remain fixed, the galaxy would have to rotate as a rigid object- this isn't true

- Since it is not rigid, the spiral arms should Continually wind up into a tighter and tighter spiral, eventually Disappearing
- This doesn't happen either




*Differential rotation*: stars near the center take less time to orbit the center than those farther from the center. Differential rotation can create a spiral pattern in the disk in a short time.

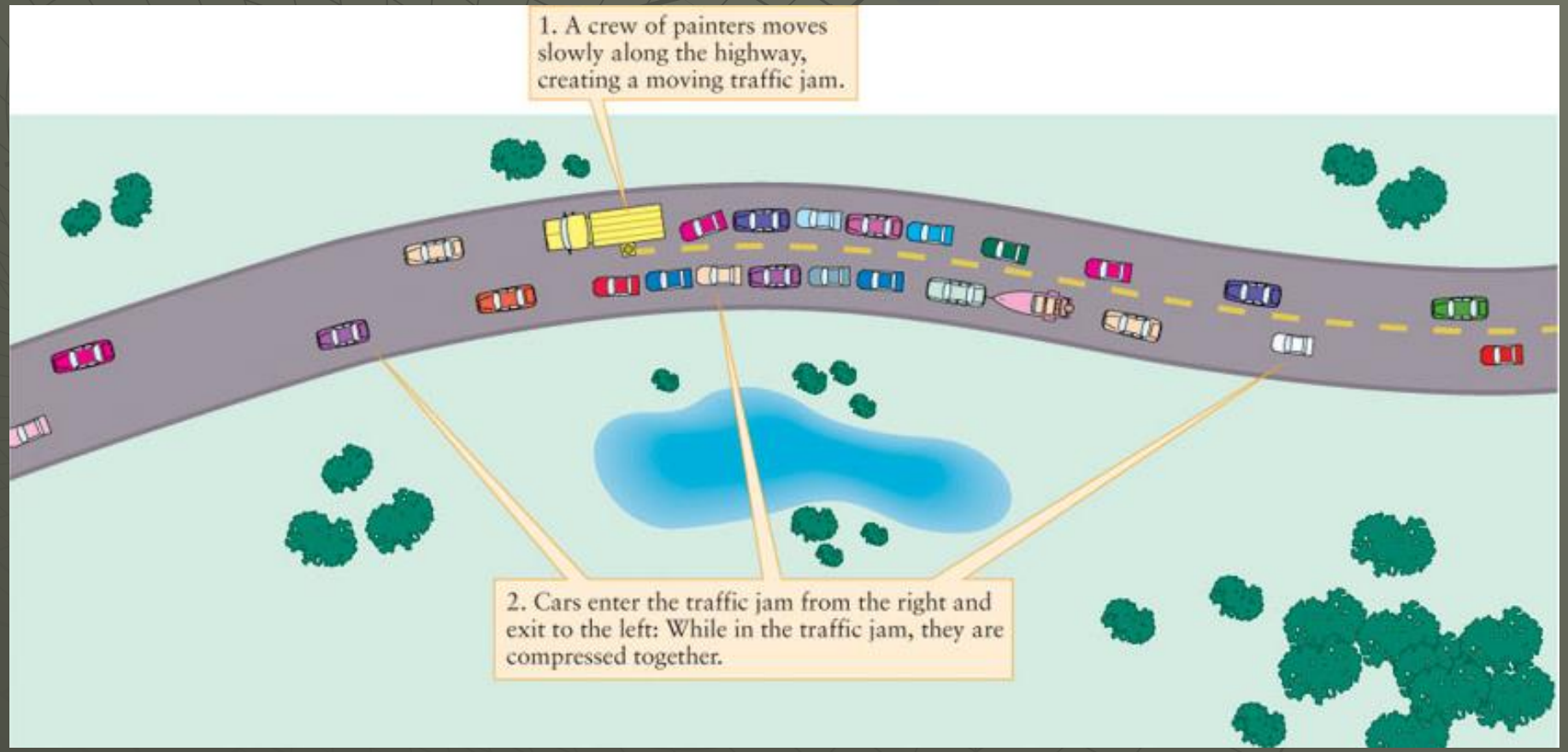
# Spiral Arms are Density Waves




- Stars and gas are also moving in the same direction as the density wave
- More like a traffic jam

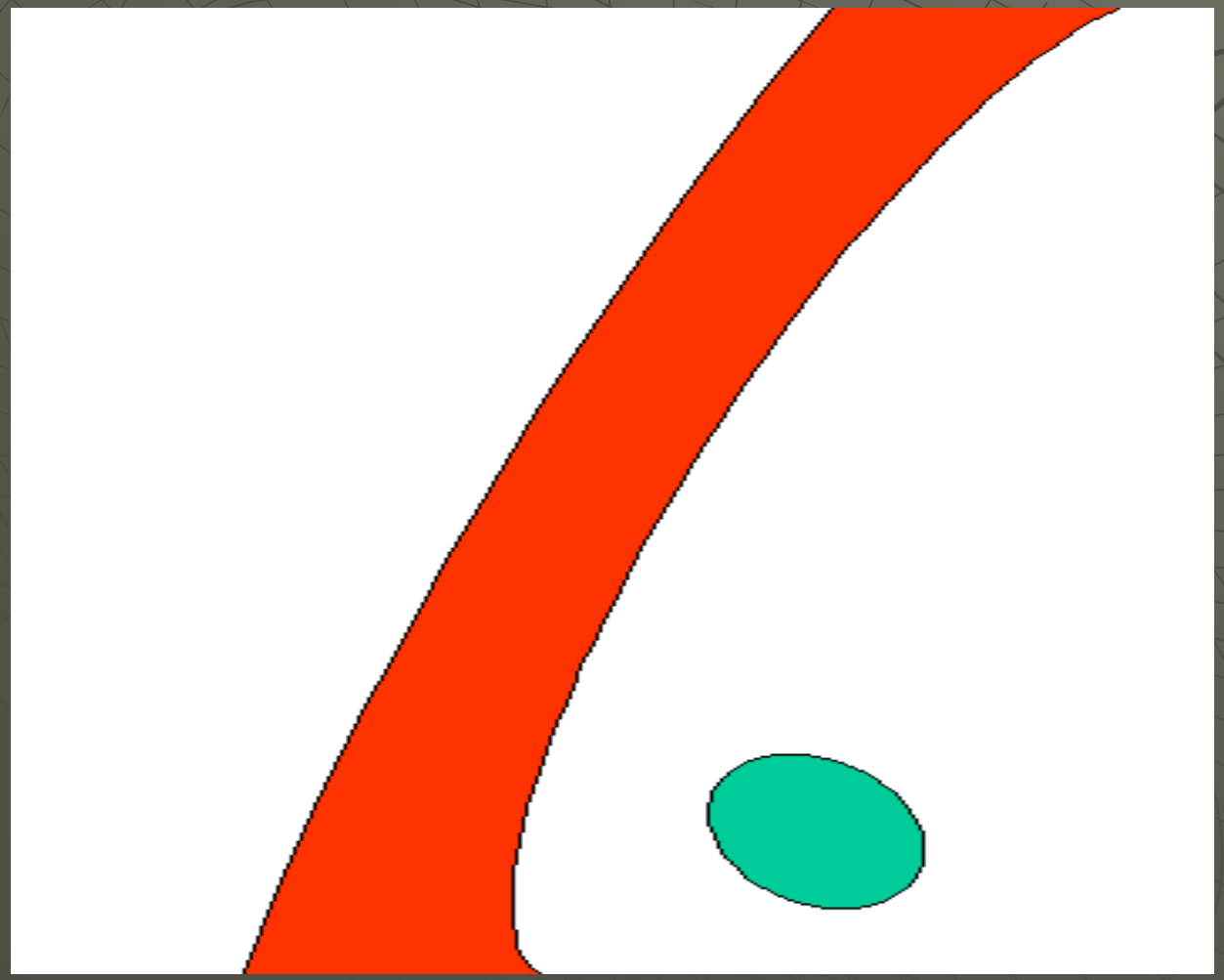
# Spiral Arms

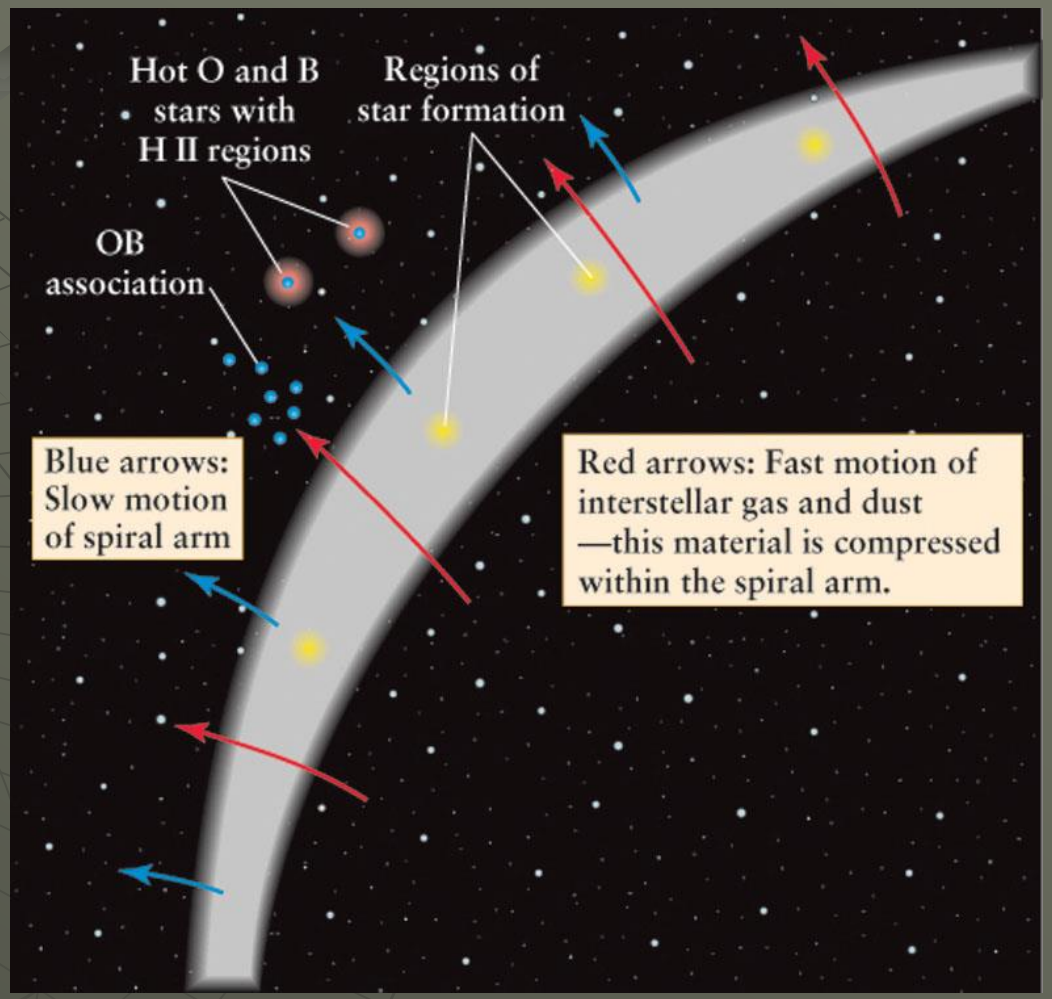
- A disturbance that move through the galaxy, like ripples in water
- Spiral arms - *density waves* traveling around the galaxy.
  - Material piles up at the crests



# Star Formation and Spiral Arms

- As wave runs into gas:  compression
- Intense star formation occurs





# Star Formation - Spirals

- Gas clouds plow into density waves:  star formation!
- Because blue stars will be formed, arms look blue
  - O and B stars are **bright**
  - O & B:  short-lived, momentarily light up spiral arms
- So O & B stars show where density wave are
  - They don’t actually get carried along with spiral arm itself!

# Dark Matter Intro

- The Sun moves around the galactic center in a circular orbit at about 220 km/s (490,000 mph)! From Globular Clusters

$$P = \frac{dist}{speed} = \frac{2\pi r}{v} = \frac{circumference\ of\ circle}{veocity}$$

- Given our distance from the galactic center, this means it takes 220 million years to go around the galaxy one time

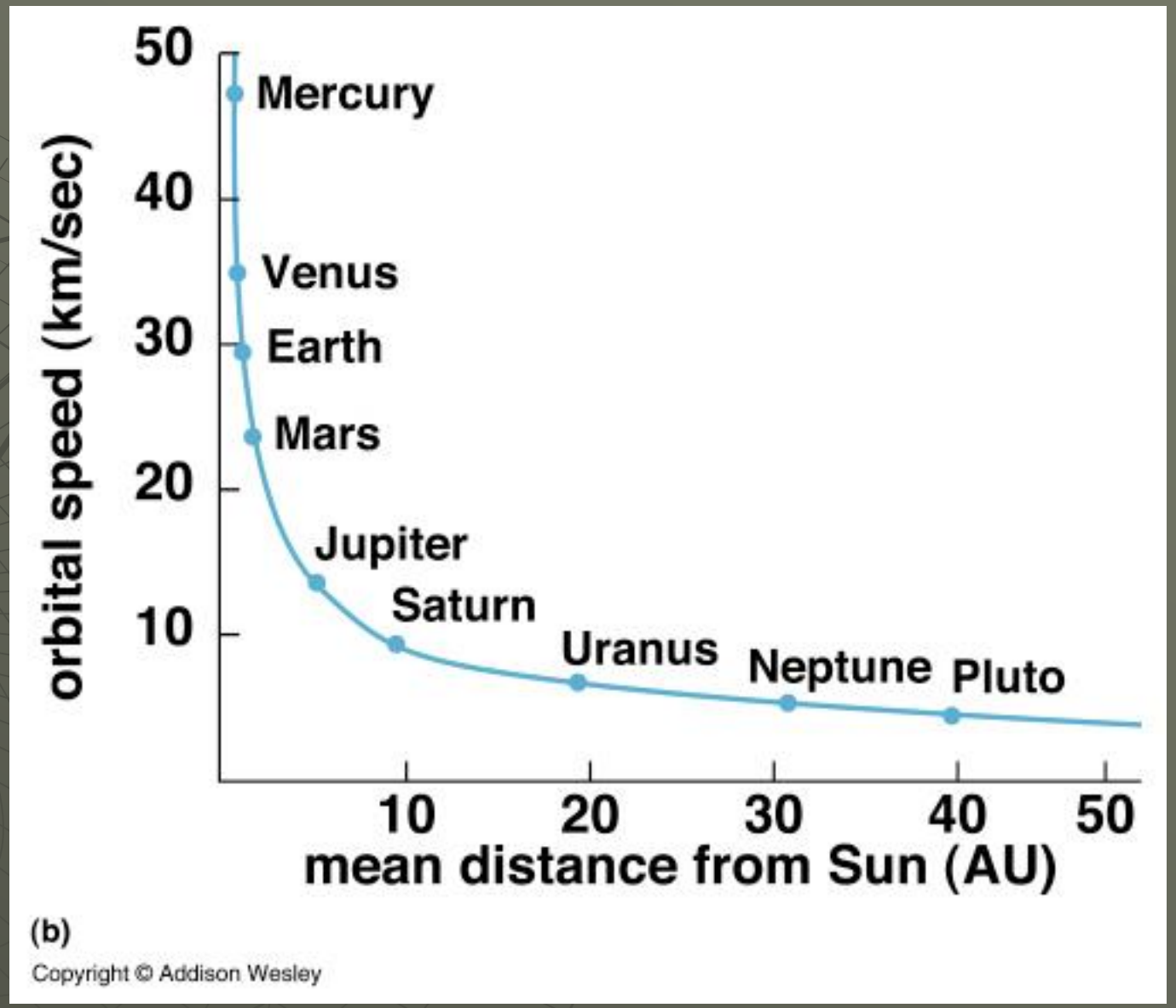
- Using Newton's form of Kepler's 3rd law, this means that there is $9 \times 10^{10}$ $M_{sun}$ of material interior to the Sun's orbit

# Rotation - Solar System vs the Galaxy

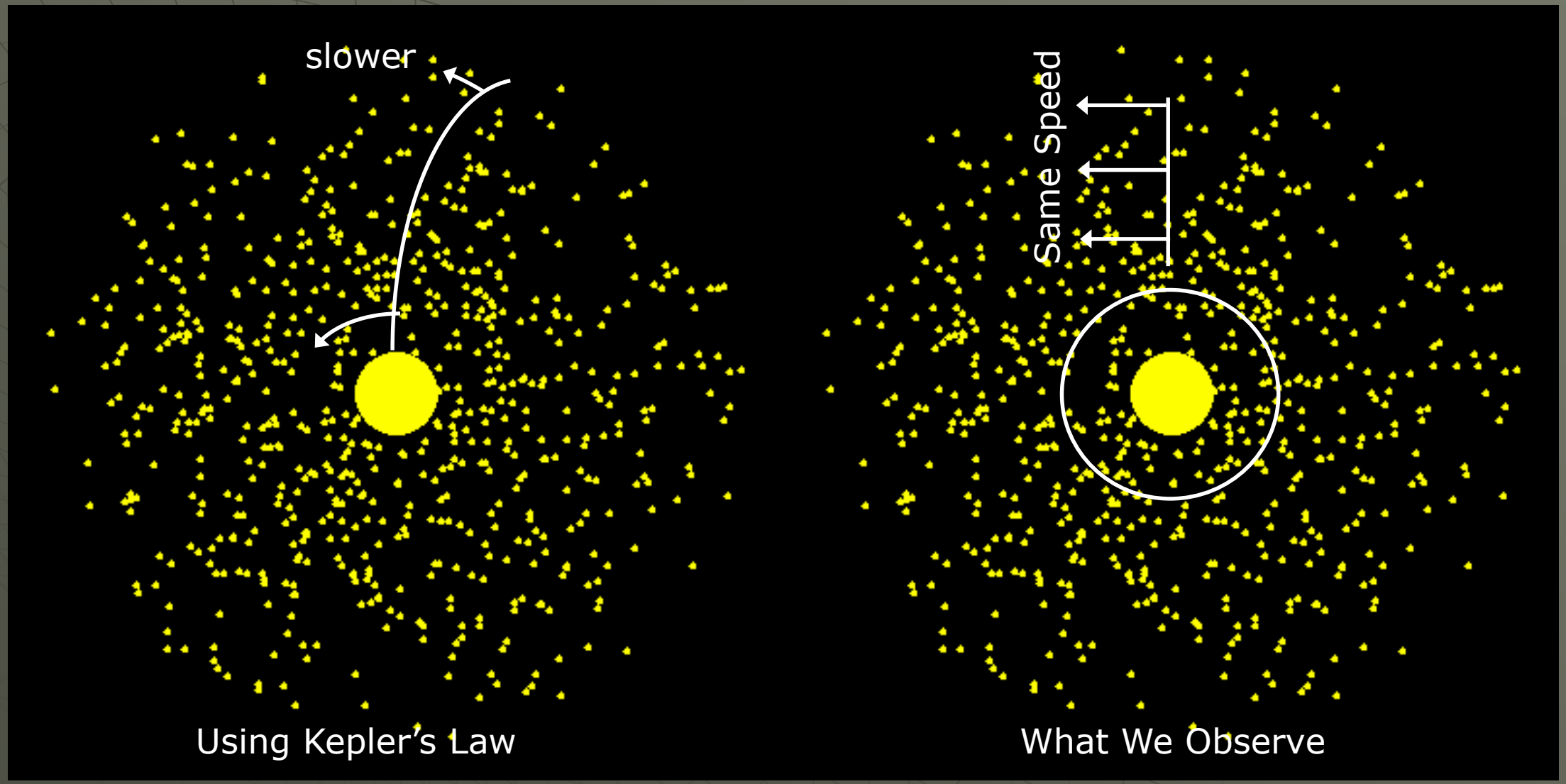
- Planets further out "feel" less gravity
  - Due to the Sun
- Less Force → less acceleration

$$P = \frac{dist}{speed} = \frac{2\pi r}{v}$$

- Stars in the MW "feel" gravity of the sum of all stars inside of it
  - Still move slower further out, but at a slower rate



# Just as Fast in the Outer Disk



# Dark Matter

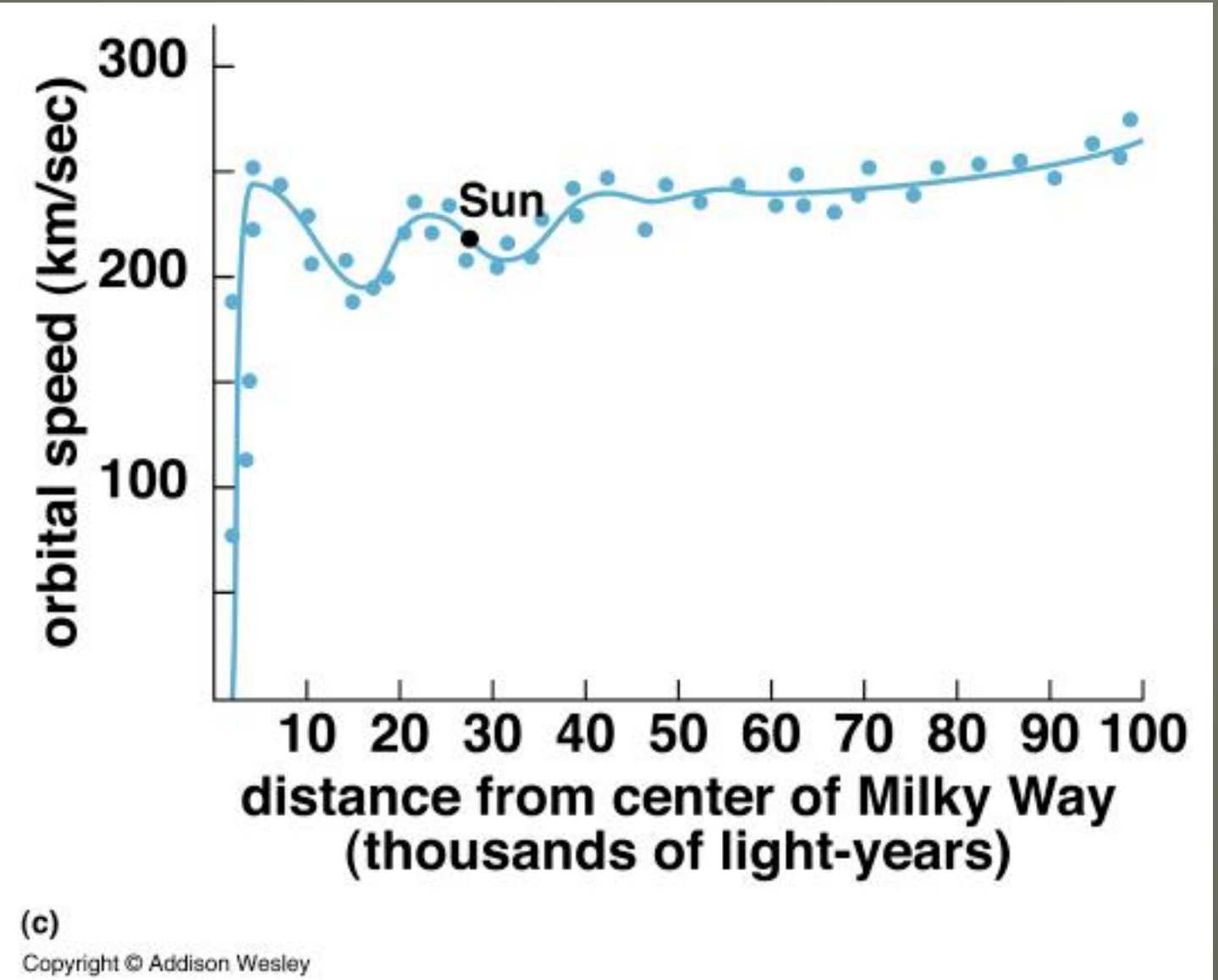
- Kepler's 3rd law:

$$P^2 = \frac{4\pi^2}{G(M+m)} a^3$$

- Period – velocity

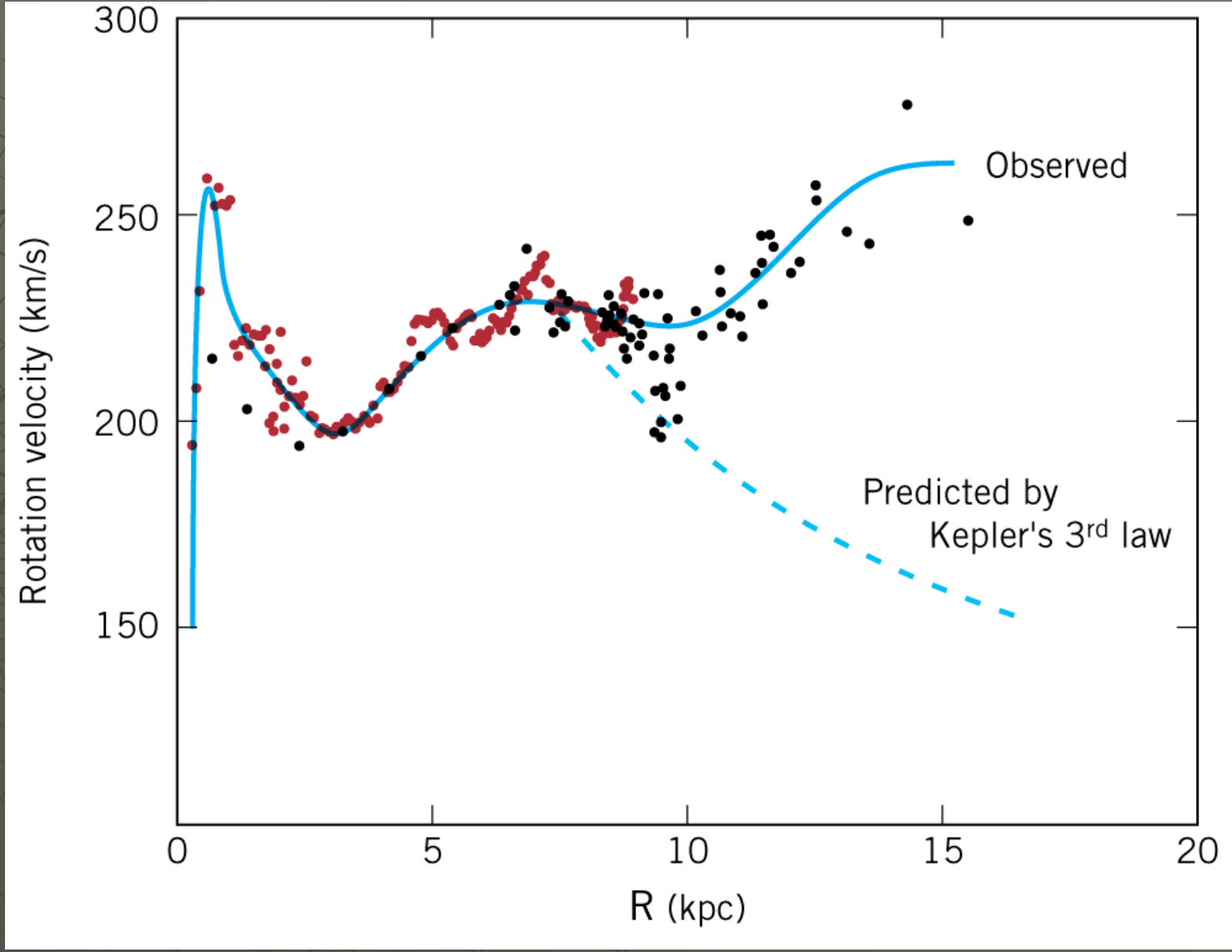
$$P = \frac{dist}{speed} = \frac{2\pi r}{v}$$

- M proportional to v
- Greater mass greater velocity



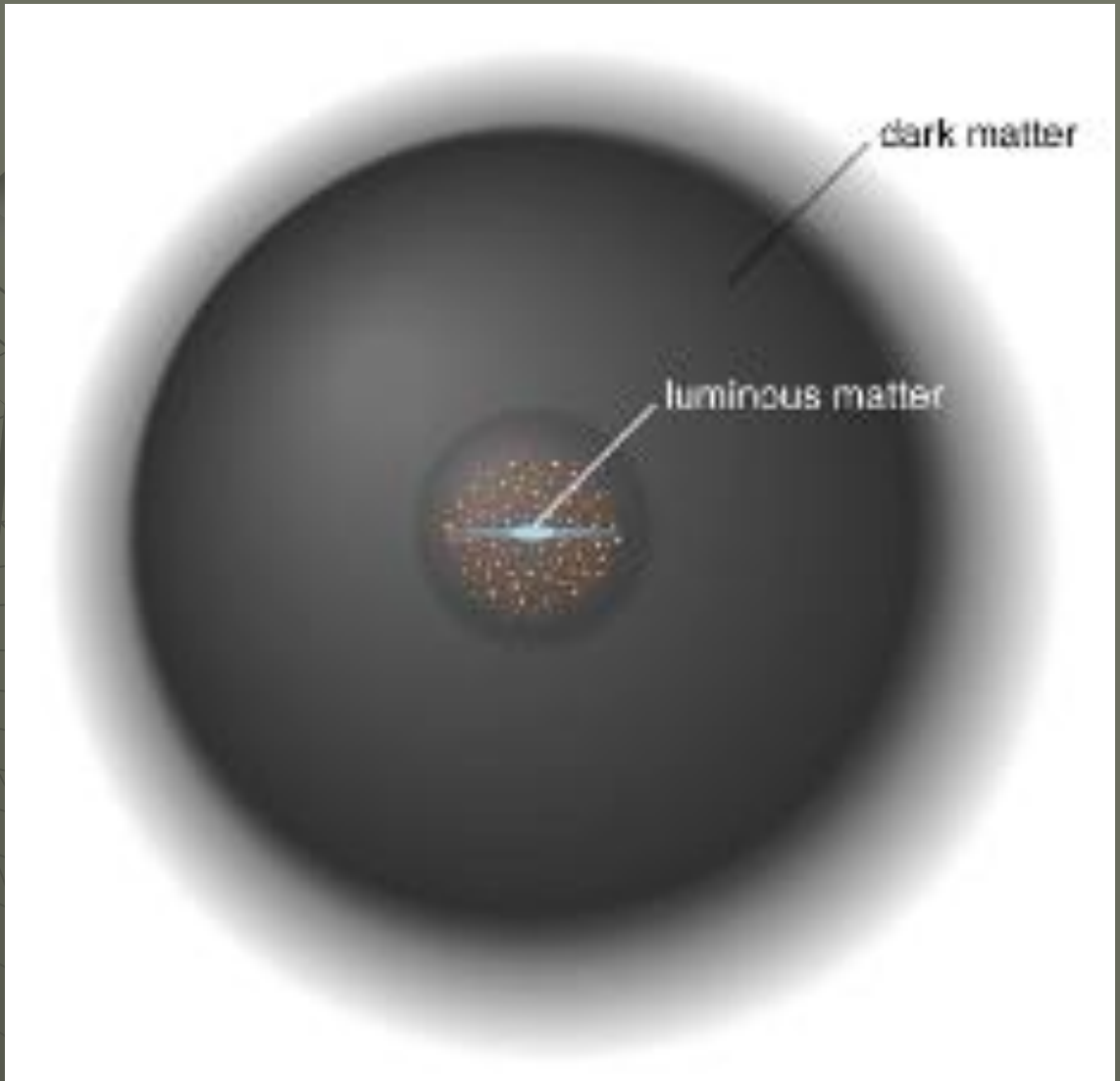
# Milky Way Real Rotation Curve

- It would take a mass of $10^{12}$ $M_{sun}$
- 1 trillion solar masses
- M of visible stars
  - ~ 0.1 trillion $M_{sun}$
- Dark Matter
  - 0.9 trillion $M_{sun}$



# Dark Matter

- A big sphere of uniform “stuff” we can’t see
- Only interacts gravitationally?
- MACHOS
  - Black holes, brown dwarfs, black dwarfs
    - Nope: 0.1%
- WIMPS
  - Similar to neutrinos???
  - Still working on it



- The fact that we find O and B stars in the disk of our Galaxy but not the halo suggests that

A. star formation still occurs in the disk, but not the halo.
B. halo stars have a higher metal content than disk stars.
C. only low-mass stars formed in the halo.
D. dust blocks our view of these stars in the halo.

- Stars farther out from the center of the Galaxy travel _____ distance over time and complete one rotation _____ we do.

A. a lesser; slower than
B. a greater; at the same rate as
C. the same; slower than
D. the same; at the same rate as

- What evidence do astronomers have that a supermassive black hole lies at the center of our Galaxy?

A. The density of stars is much higher near the center than it is in our local neighborhood.
B. Stars appear to be orbiting something at very high speeds.
C. Stars appear to be orbiting very close to something, suggesting that it is relatively small.
D. All of the above is evidence suggesting the presence of a supermassive black hole.

# LT Homework

- Dark Matter
  - Pg 143