Mass-Lifetime relation

- The lifetime of a star (on the main sequence) is longer if more fuel is available and shorter if that fuel is burned more rapidly
- The available fuel is (roughly) proportional to the mass of the star
- From the previous, we known that luminosity is much higher for higher masses
- We conclude that higher mass star live shorter lives

$$\frac{t_A}{t_B} = \frac{M_A}{M_B}\frac{L_B}{L_A} = \frac{M_A}{M_B}\frac{M_B^{3.5}}{M_A^{3.5}} = \frac{M_B^{2.5}}{M_A^{2.5}}$$

What do you think about the use of the previous equations?

A) Yuck, get that equation away from me
B) The equation confused me
C) The equation didn't help
D) The equation made things more clear
E) God reveals himself in mathematics

The level of the class is

A) Way too easy
B) Too easy
C) Just right
D) Too hard
E) Way too hard

How could lectures be improved?

A) More clicker questions and peer discussion

B) More time going over homework

C) Kaaret should walk up the aisles

D) More jokes

E) More demos with fire

I do the homework assignments

A) By myself

B) I try it on my own and then ask a friend if I have any problems

C) Together with one or more friends

D) I go to Astronomy Tutorial/Office Hours

E) There's homework?

What do you think of clicker questions?

A) Great fun! Best part of class.
B) Helps me stay awake
C) Helps me learn
D) Useless interruption of lecture
E) I'm supposed to buy a clicker?

What do you think of one-minute discussion breaks?

A) Great fun! Best part of class.

B) Helps me stay awake

C) Helps me learn

D) Useless interruption of lecture

E) I like the chance to talk, but we never talk about the question the Professor asked

Playing “Millionarie” in class is

A) Extremely useful
B) Useful
C) OK
D) Boring and a waste of time
E) I don’t attend the review sessions

Playing “Millionarie” outside class is

A) Extremely useful
B) Useful
C) OK
D) Boring and a waste of time
E) I still don’t attend the review sessions

The most interesting topic covered in the first unit was:

A) Why we have seasons and phases of the moon
B) Models of the solar system (earth vs sun centric)
C) Extrasolar planets
D) Life beyond Earth

The most interesting topic covered in the second unit was:

A) How the sun makes energy
B) Atomic models and spectra
C) Star formation
D) Evolution of stars
E) Deaths of stars

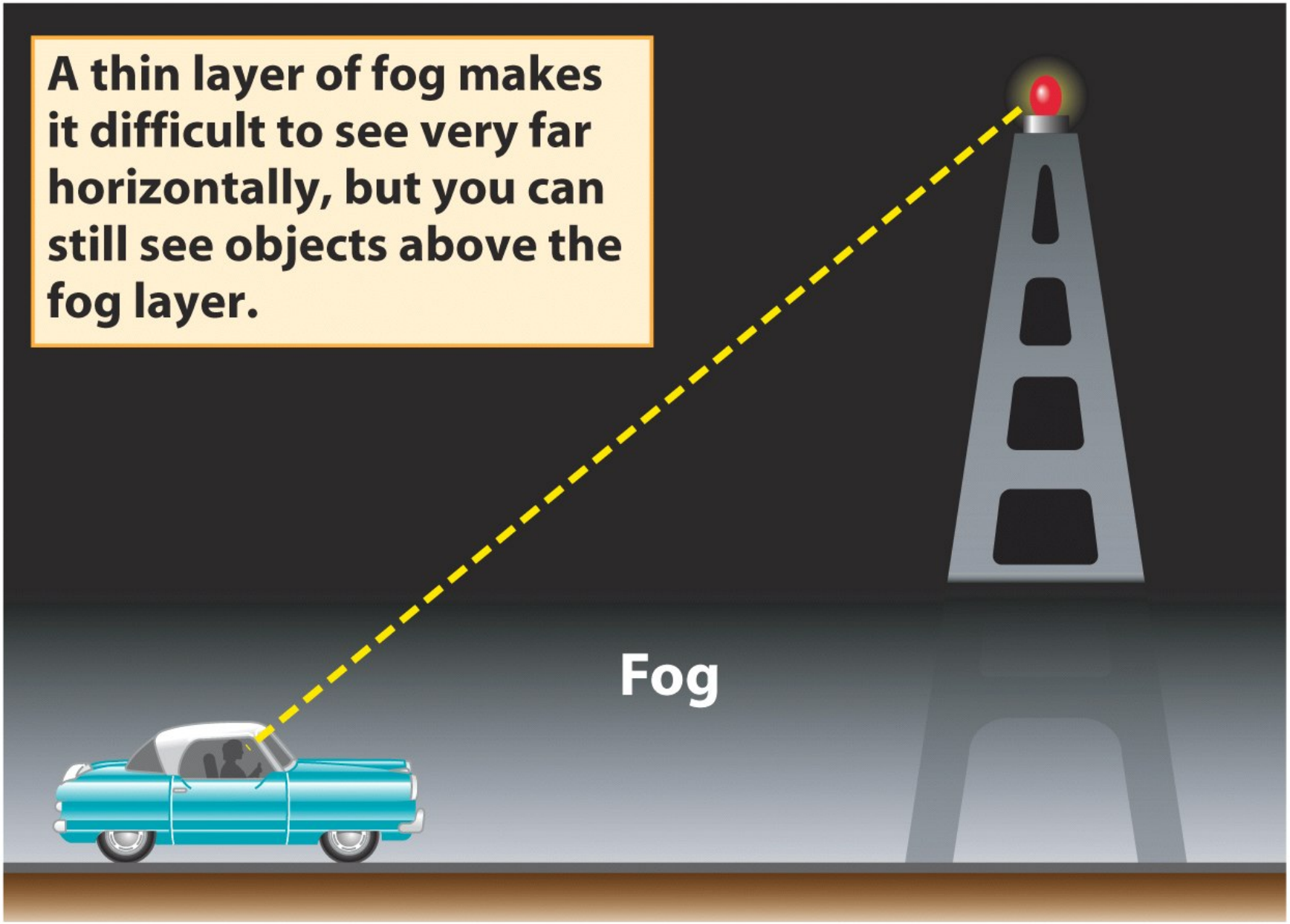
Dance Gala

- Tickets available for Thursday-Sunday, $5 for students
- Theatre Department has plays in November (Stick Fly), December (A Hamlet), February (In the Next Room or The Vibrator Play), April (Big Love)

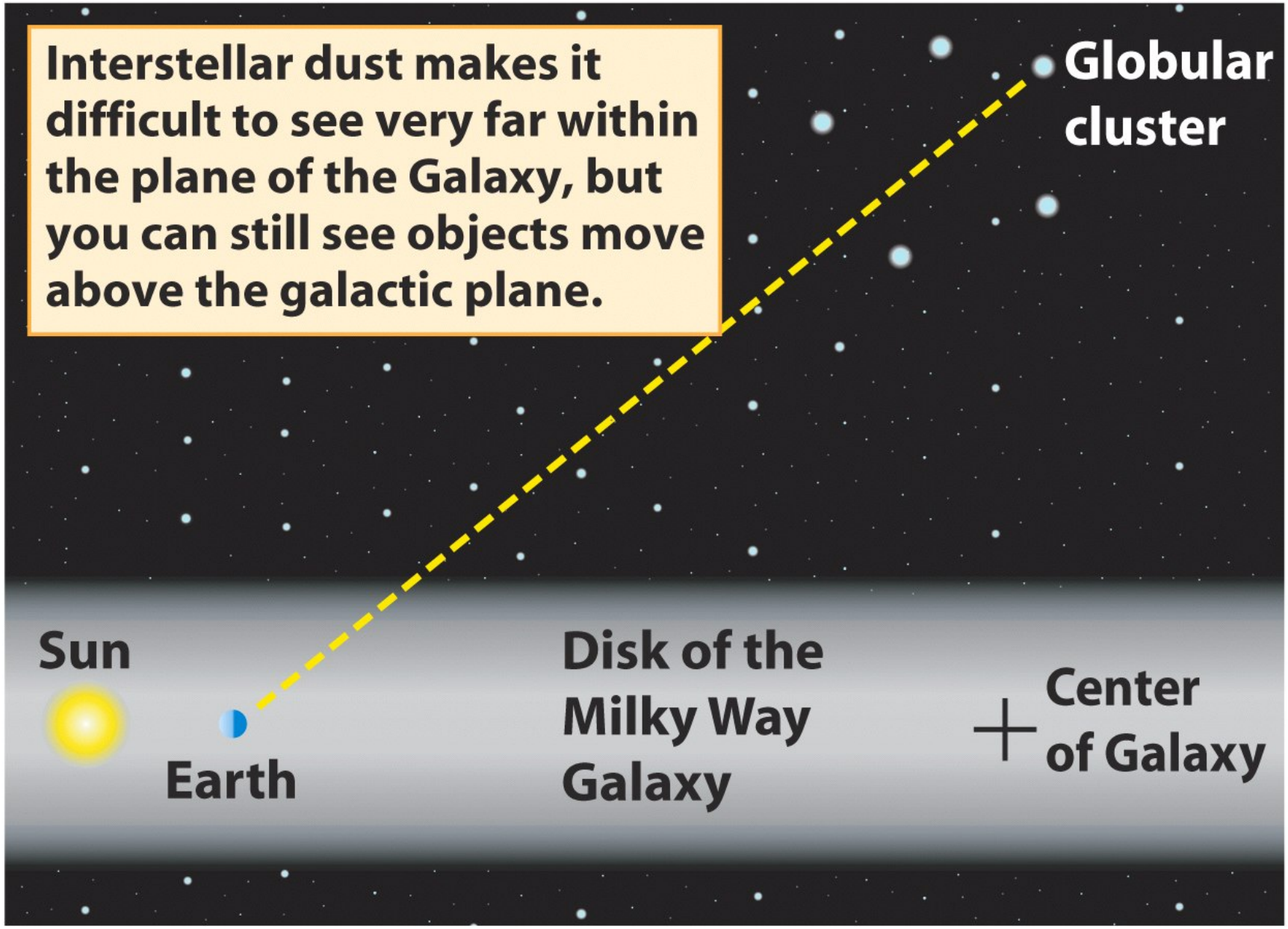
How do we locate the center of the Milky Way?

- Can’t see center directly with visible light because of obscuring clouds in the plane of the Galaxy

- Look above the plane of the galaxy



Determining your position in the fog



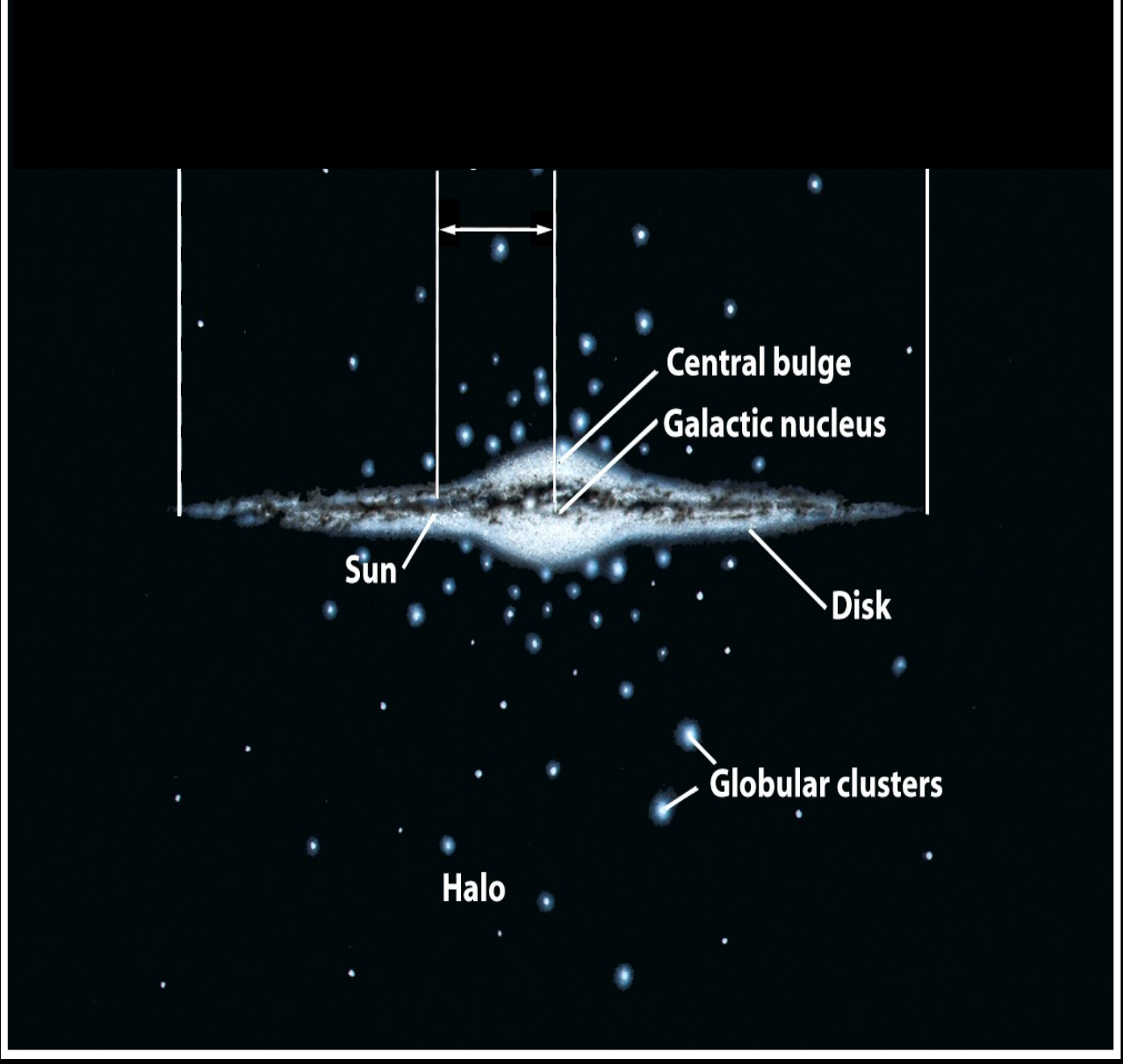
Determining your position in the Galaxy

M15

M13

Globular clusters

- Compact, spherical group of stars
- Up to several 100,000 stars
- All stars formed together, same age
- Form a halo around the Milky Way


Central bulge
Galactic nucleus
Sun
Disk
Globular clusters
Halo

Globular cluster system

- Centered on the center of the Milky Way
- Extends far above and below the plane

- By observing globular clusters, we can determine the direction to the center of the Milky Way and our distance from the center

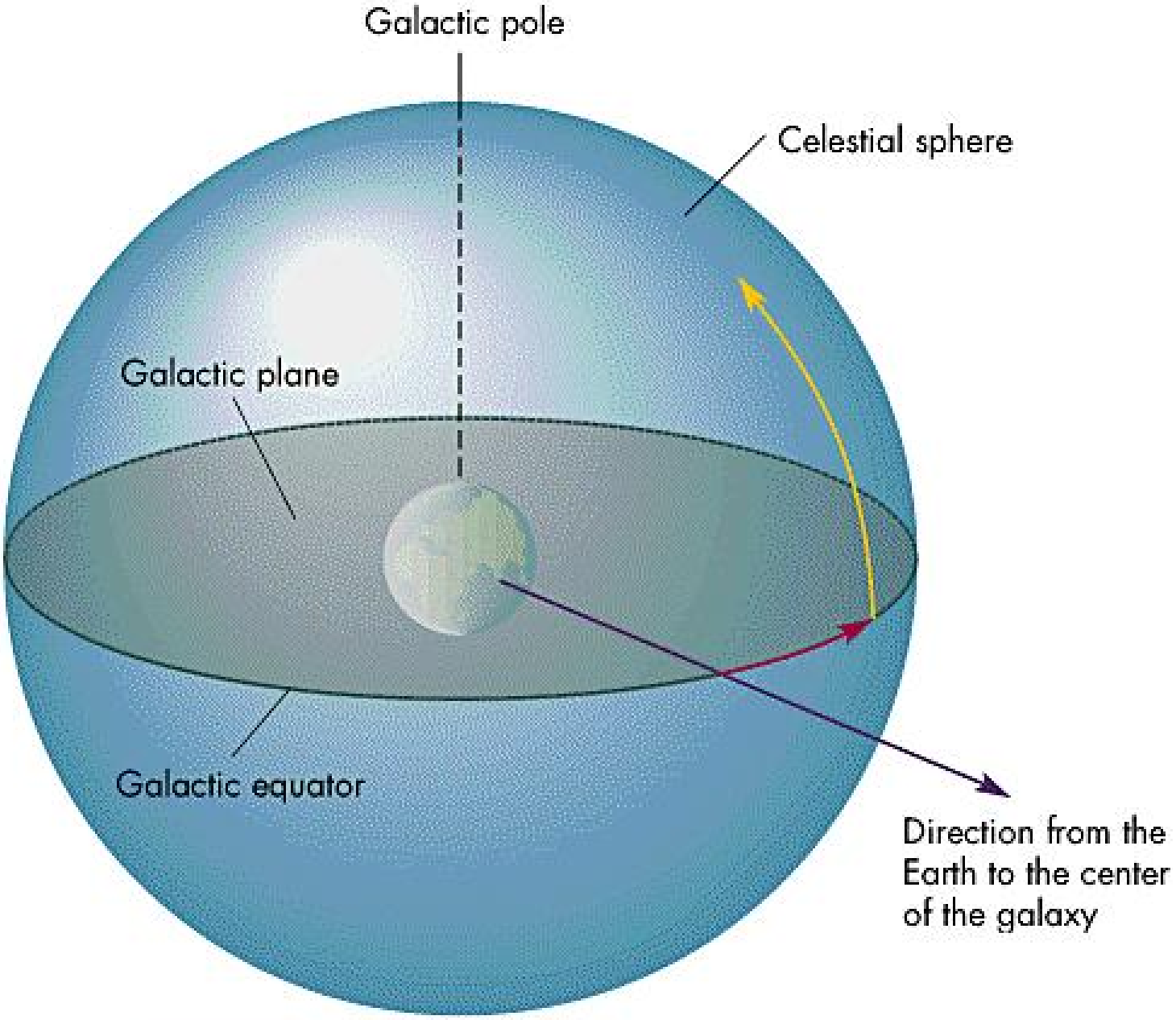
What about globular clusters allows us to determine the Sun's distance from the center of the Galaxy?

A)The clusters are confined to a thin plane.

B)The clusters are all located at the same distance from the Sun.

C)The center of the distribution of clusters is far from the Sun.

D)All of the clusters are located in a region a few parsecs across.


Galactic pole
Celestial sphere
Galactic plane
Galactic equator
Direction from the Earth to the center of the galaxy
Longitude
Latitude

How do we find the distance to the Galactic center?

- We need the distances to the globular clusters

Stars A and B have the same luminosity, but star B has 1/100 the flux of star A. How far away is star B?

A) The same distance as star A.

B) 10x farther than star A.

C) 100x farther than star A.

D) The distance to star B cannot be determined.

Some stars pulsate and we can use their pulsations to figure out their luminosity

If a star is neither expanding nor contracting, we may assume that throughout the star there is a balance between pressure and

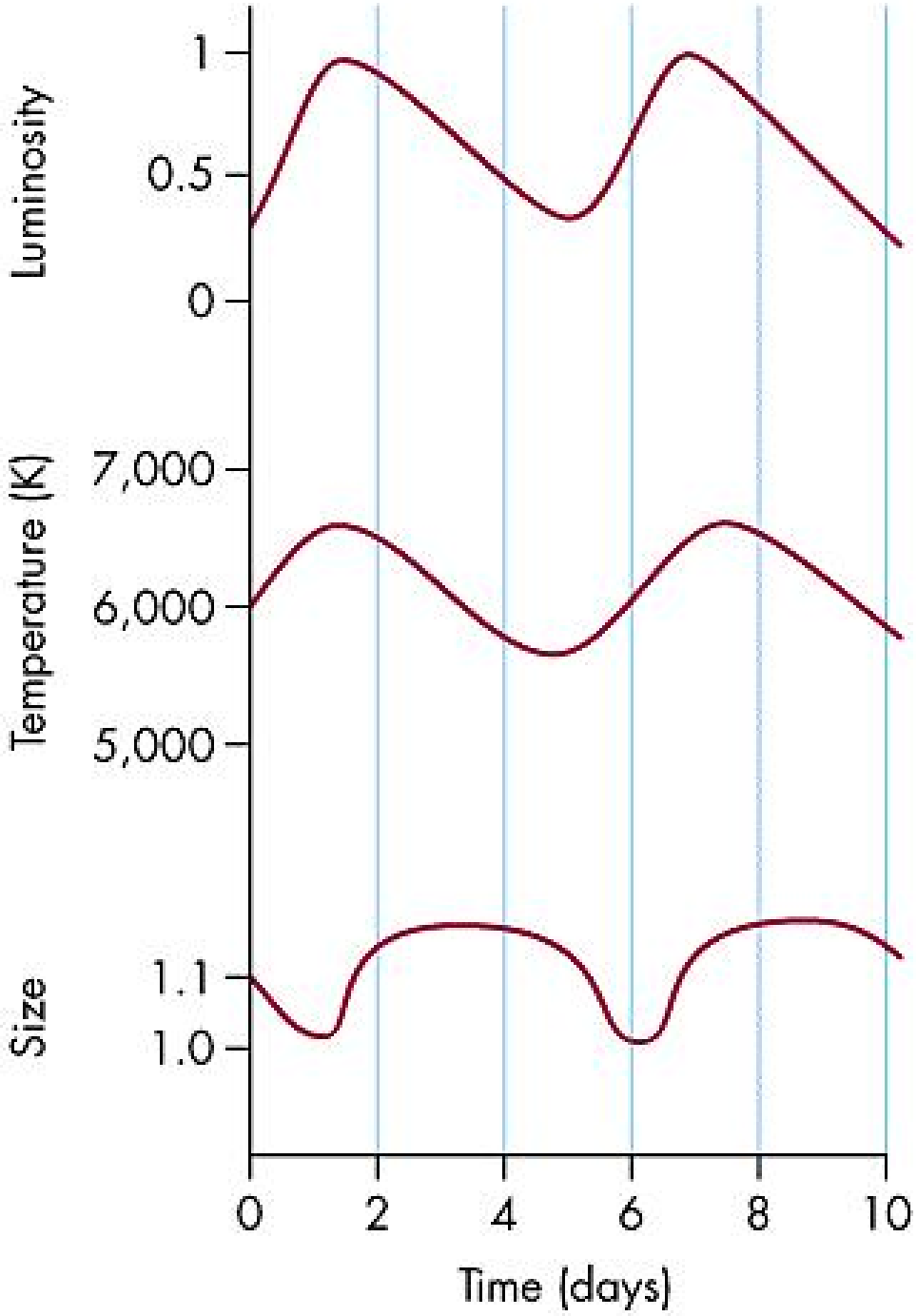
A) temperature
B) density
C) luminosity
D) gravity

Do mass on spring demo

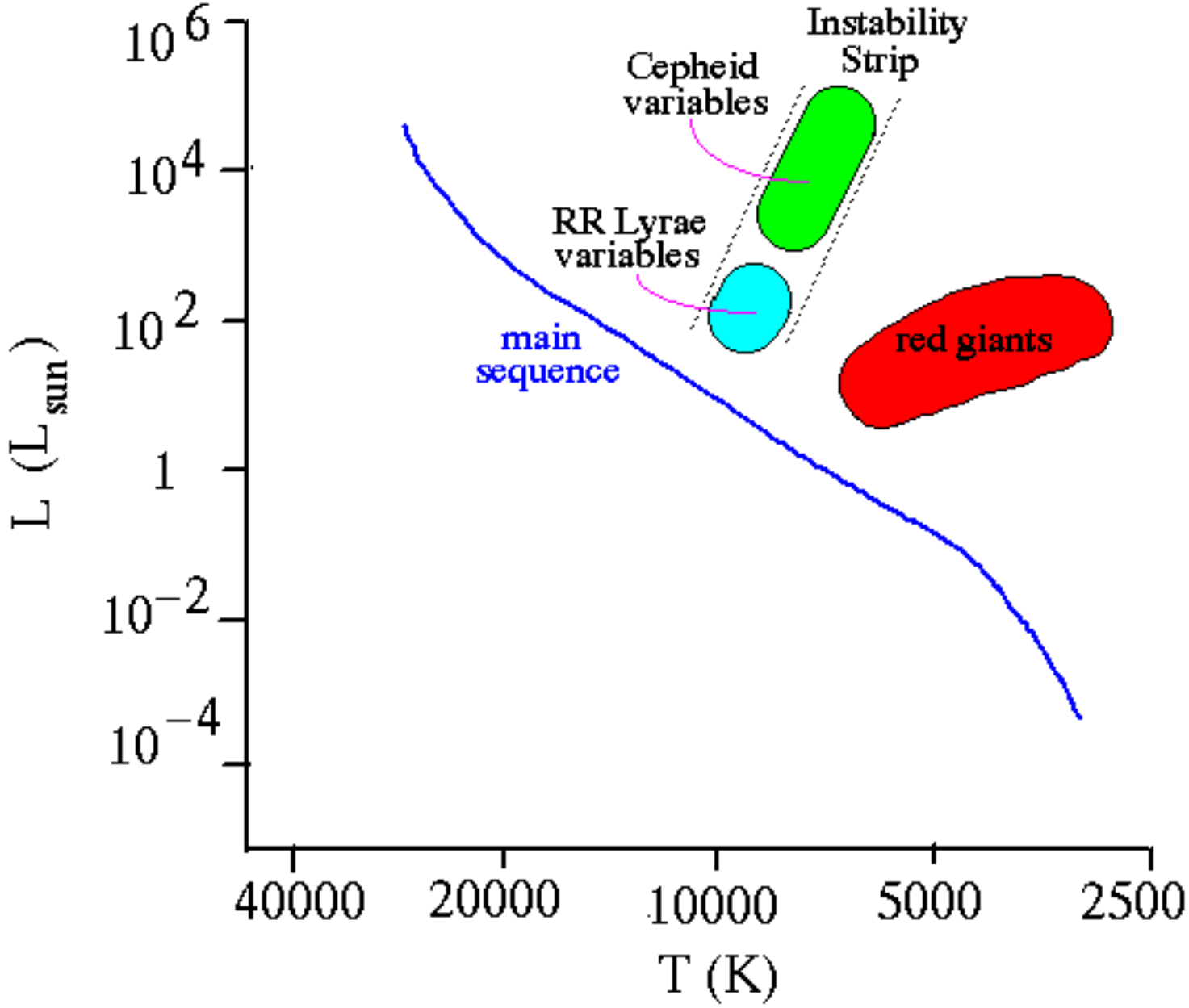
Pulsation cycle

Rate of fusion in the core stays constant.

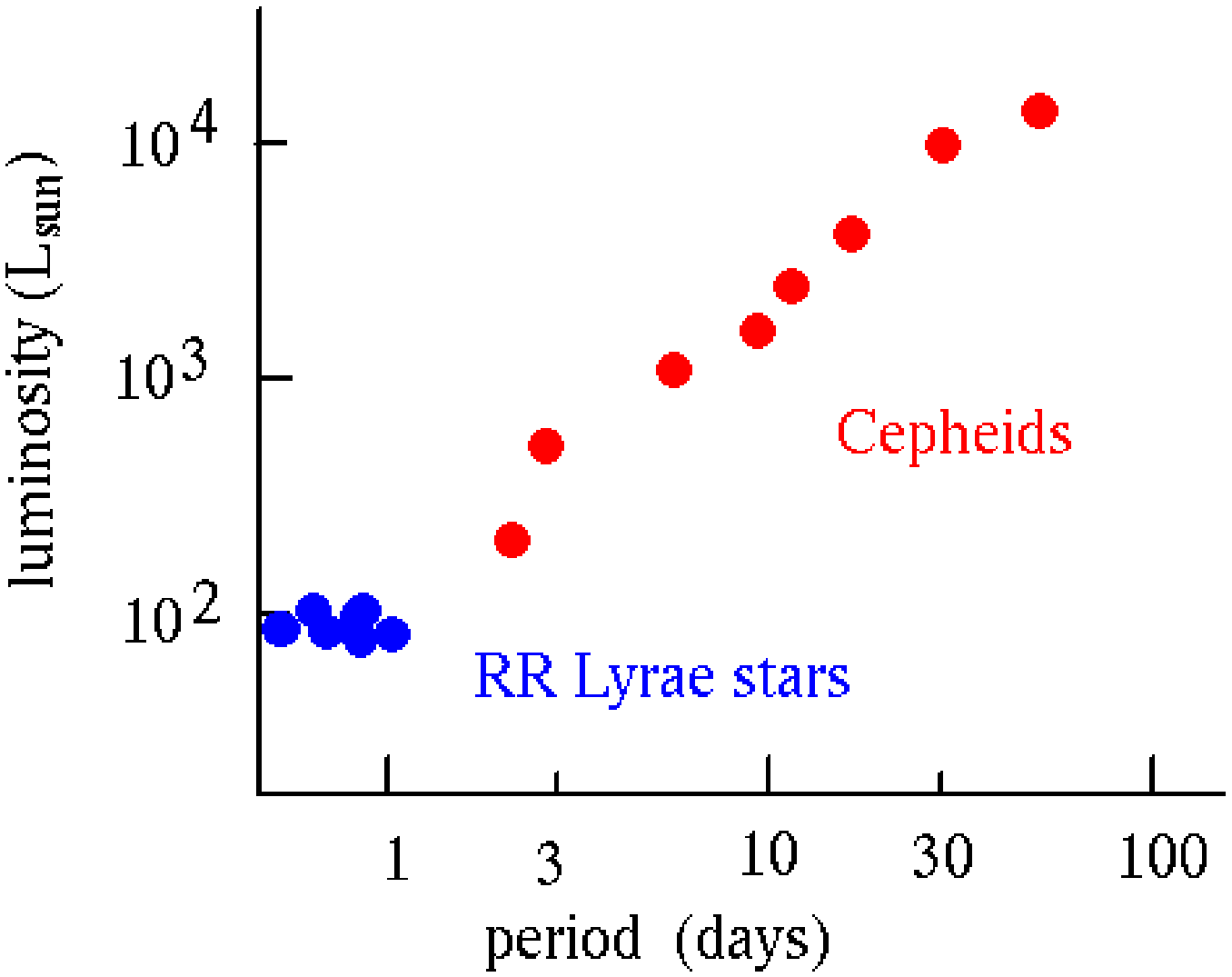
Transport of energy through outer layers of star oscillates.



Pulsating stars



Pulsating stars

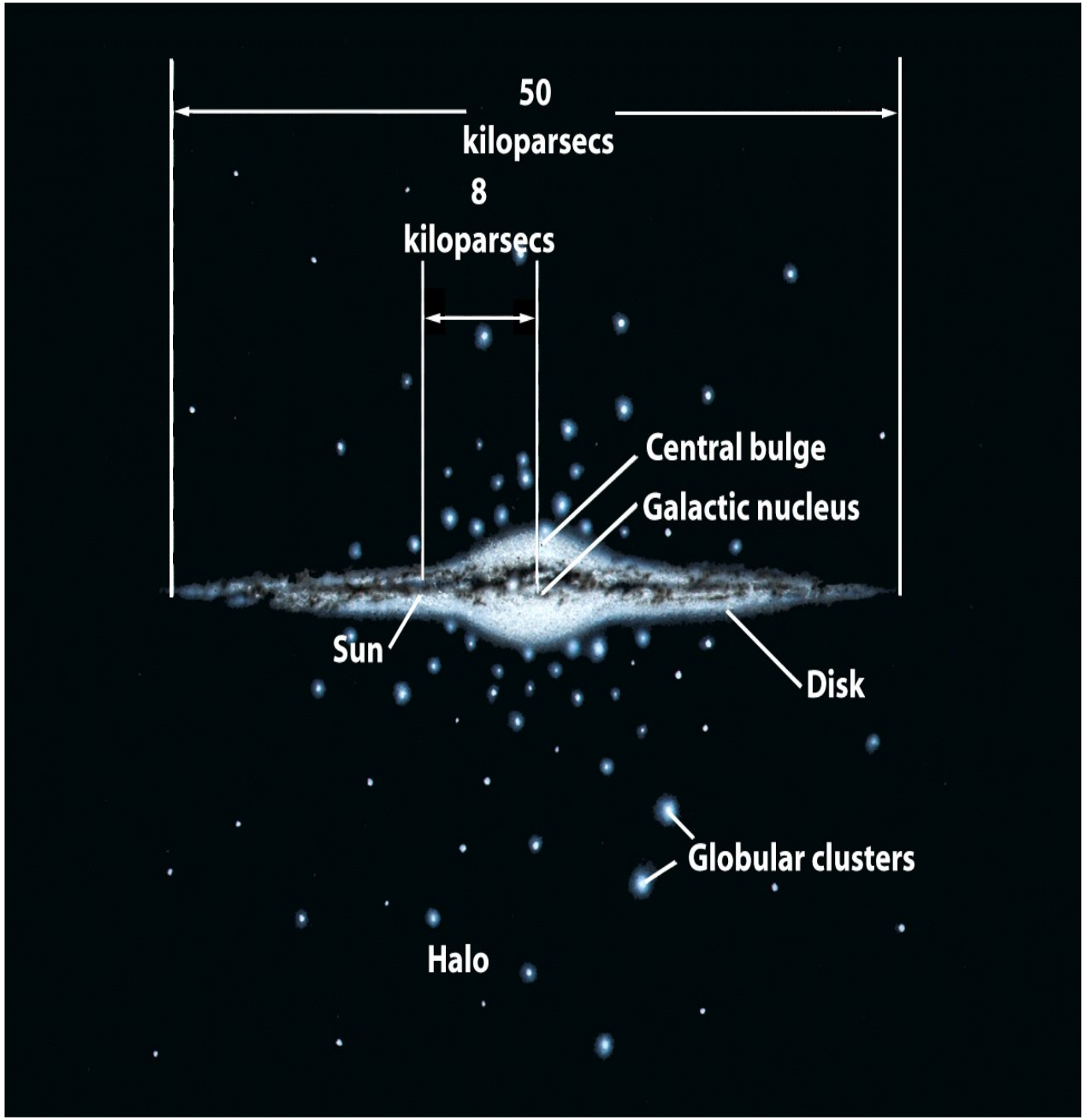


Why is this useful?

Flux versus luminosity relation

$$\frac{\text{Flux}_A}{\text{Flux}_B} = \frac{\text{Luminosity}_A}{\text{Luminosity}_B}\left(\frac{\text{Distance}_B}{\text{Distance}_A}\right)^2$$

We can figure out the luminosity of a pulsating star by timing the pulsations. Since, we can measure its flux, we can then find the distance to the star.


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

What causes Cepheid variables to vary in brightness?

A) Eclipses

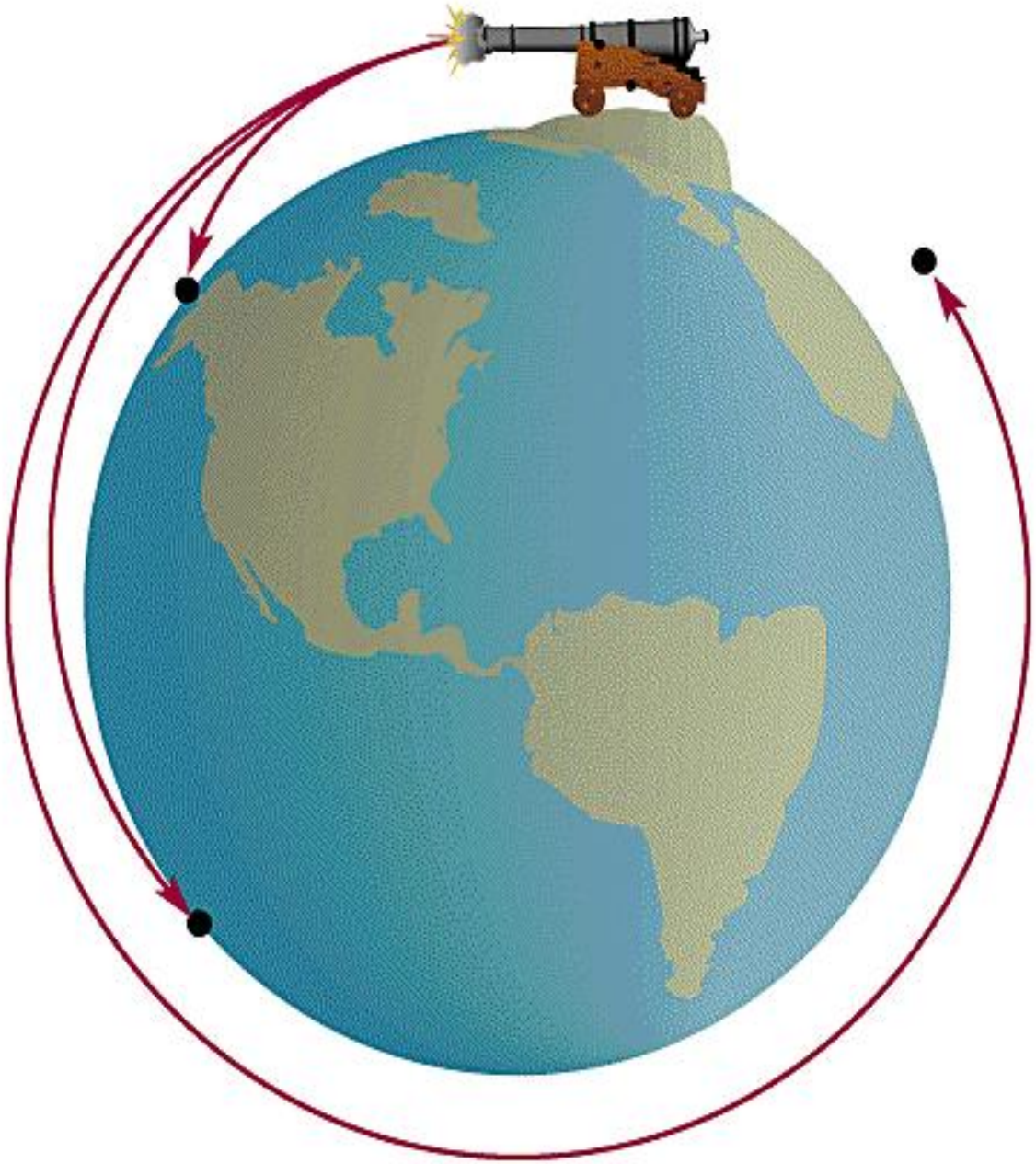
B) Changes in nuclear energy generation rate

C) Periodic changes in radius

D) Obscuration by clouds of dust

What keeps the planets in orbit around the Sun?

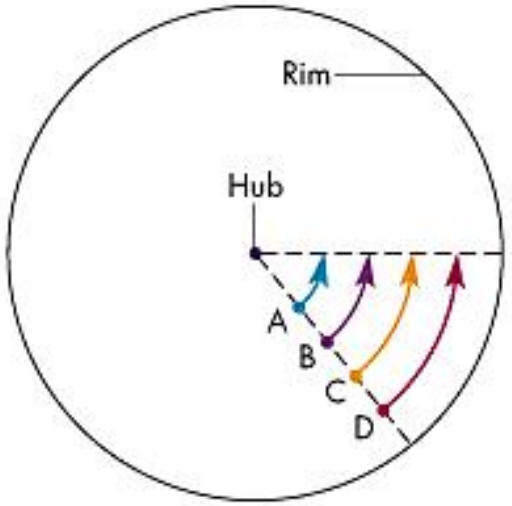
- The force of gravity from the Sun
- To orbit, a planet at a particular distance from the Sun must have a particular orbital speed.



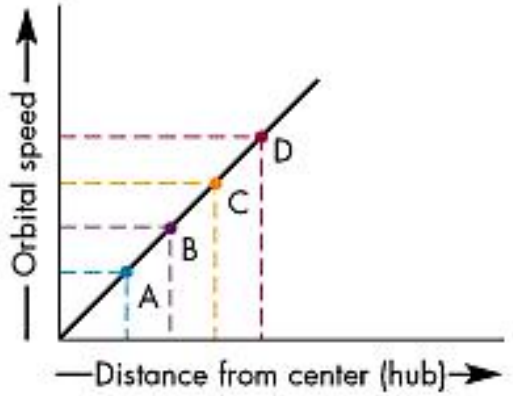
Orbits of stars in the Milky Way

- The orbit of a star is determined by the total mass lying inside the orbit
- By measuring the speed of the star's orbit and its distance from the center, we can figure out the total mass lying inside the orbit of the star

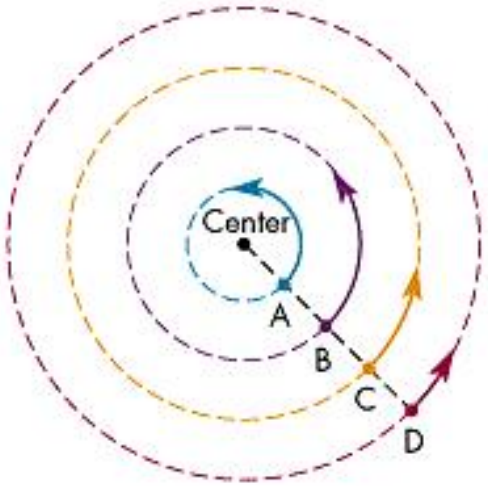
Rotation curves



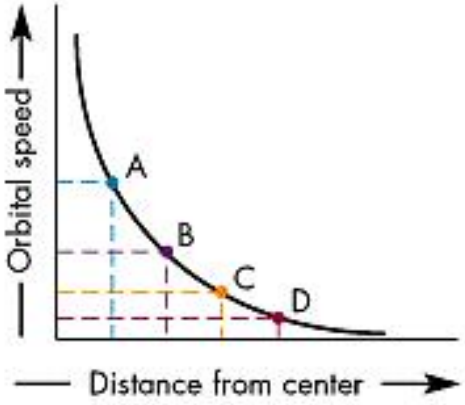
A **Wheel-like rotation**



Rotation curve for wheel-like rotation

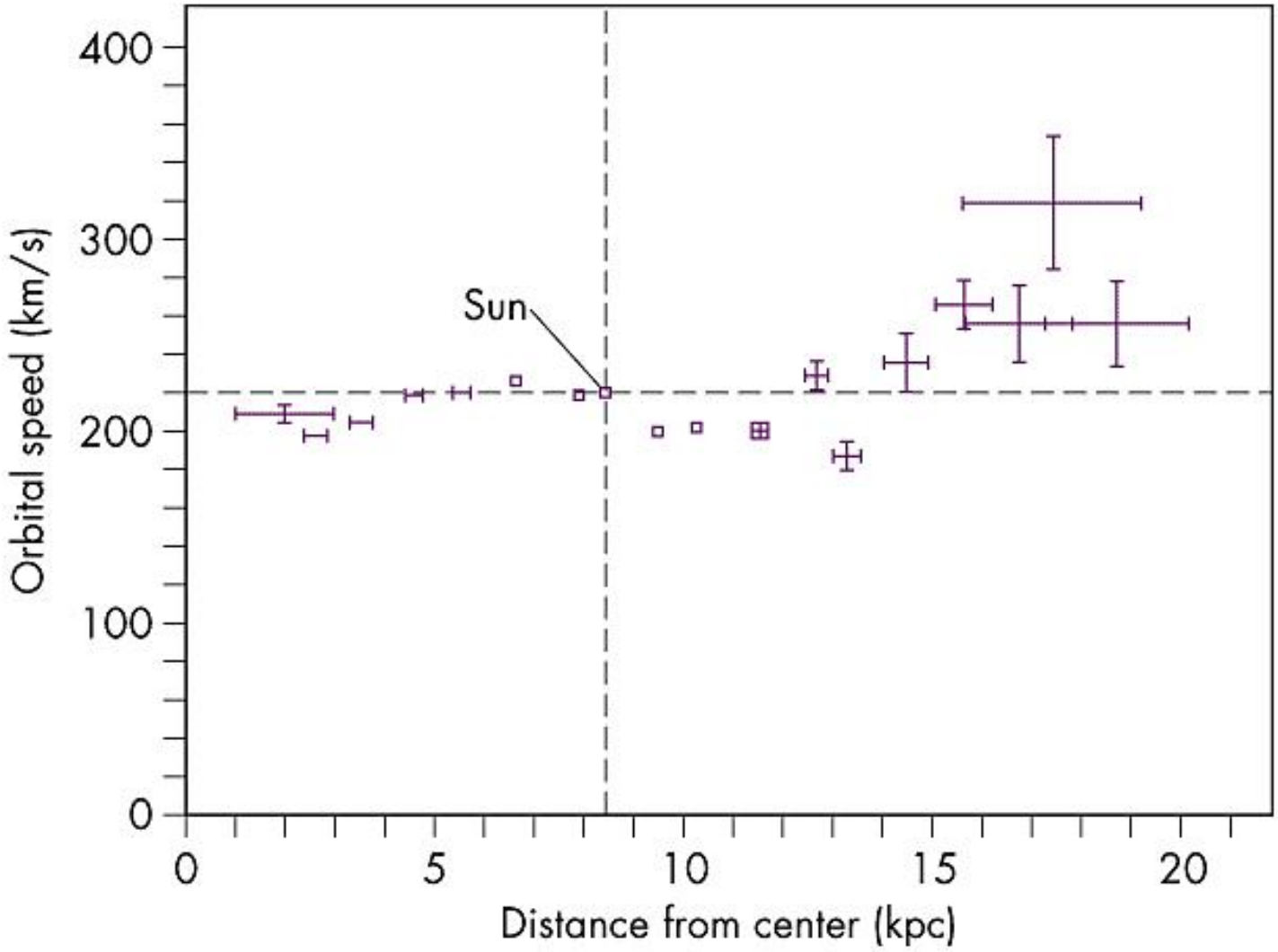


B **Planet-like rotation**

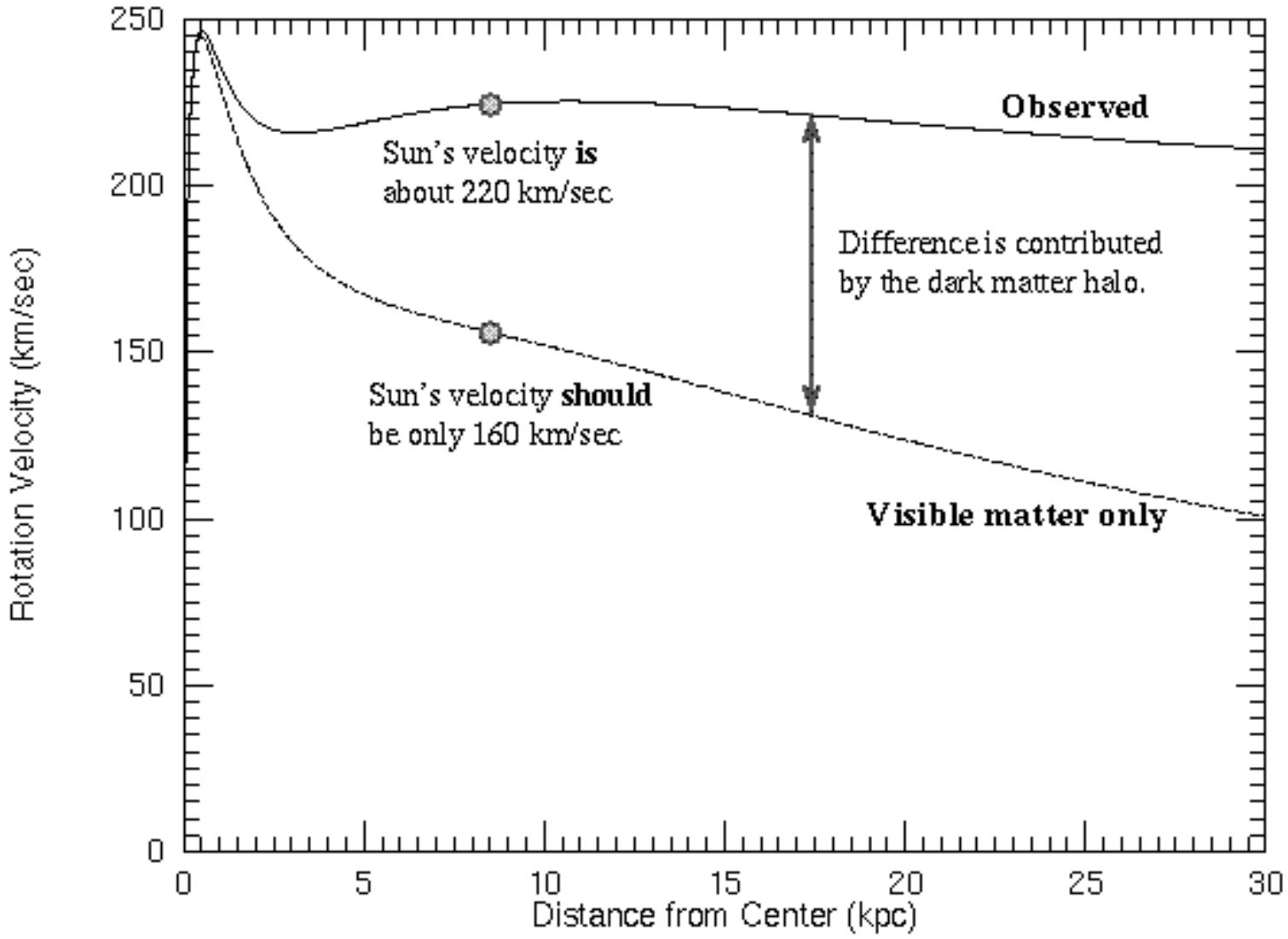


Rotation curve for planet-like rotation

Rotation curve of the Milky Way



Rotation curve of Milky Way



Dark Matter

- Dark – it doesn't produce light (any kind)
- Does have mass, produces gravity
- Nature is unknown
- Might be normal matter in a form that doesn't emit much light – very small and dim star, little black holes
- More likely it is elementary particles other than normal matter

What properties of the sun could be used to measure the total mass enclosed within the sun's orbit?

A) mass and orbital speed
B) mass and distance from the center
C) mass and age
D) orbital speed and distance from the center

If the orbital velocities of stars in the Milky Way were found to be half of what they are now measured to be

A) Our estimate of the mass of the Milky Way would decrease
B) Our estimate of the diameter of the Milky Way would decrease
C) Our estimate of the mass of the Milky Way would increase
D) Our estimate of the diameter of the Milky Way would increase

Review Questions

- What are globular clusters? How are they distributed in the Galaxy?
- What are Galactic coordinates?
- Why do some stars pulsate? Why are pulsating stars useful in measuring distances?
- What is the size and shape of the Milky Way?
- What properties of a star's orbit around the Galaxy enable one to measure the mass inside its orbit?
- What is the shape of the rotation curve of the Milky Way and why is was it unexpected?