Announcements

- Study Guide now available for Midterm 3
  - Angel ➔ Syllabus ➔ Study guide 3 (next to April 3)
- Missouri Club: 7:45-8:45 tonight, this room.
- Who am I?
  - Jack Baldwin
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    - (517) 355-9200 x2415
    - Office: BPS 3270
    - Office hours: 3-4 M, 2:30-3:30 Tu, 11-12 Th

The Milky Way

Galileo first showed that it is made up of stars.

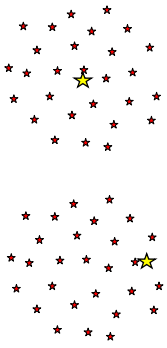
Lots of Stars

Clicker Question: *What can we conclude about the Milky Way from just the fact that we see a thin band of stars stretching across the sky?*

A. It's a sphere of stars that wraps all around us.
B. It's a disk that includes the Sun.
C. It's a disk with the Sun at the center.
D. It's a disk with the Sun 2/3 of the way to the edge.
E. It's a disk with us looking down from the top.

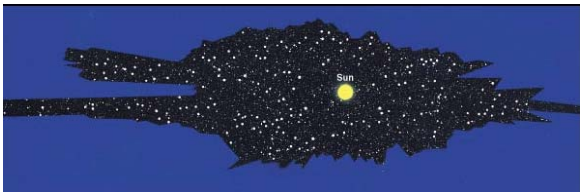
The Milky Way

- It's a disk
- But where are we located within that disk?



Mapping our Galaxy up until ~1920

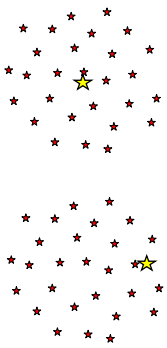
Counting Stars:



Sun near center of small universe.

(Herschel, 1784 ➔ Kapteyn, early 1900's)

Lick 36" Refractor 1888



Clicker Question:

Why did Herschel & Kapteyn get the wrong answer?

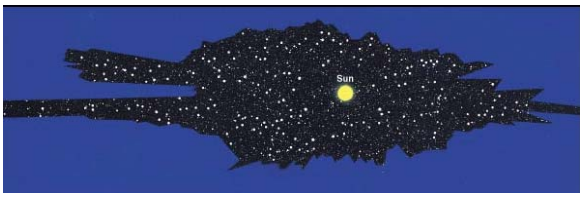
A. The hundreds of thousands of stars in Kapteyn's sample were not enough.

B. The method would only work for a spherical distribution of stars, not for a disk.

C. They did not realize that their calculator used Reverse Polish Notation.

D. They were looking into the equivalent of a fog bank.

Counting Stars:

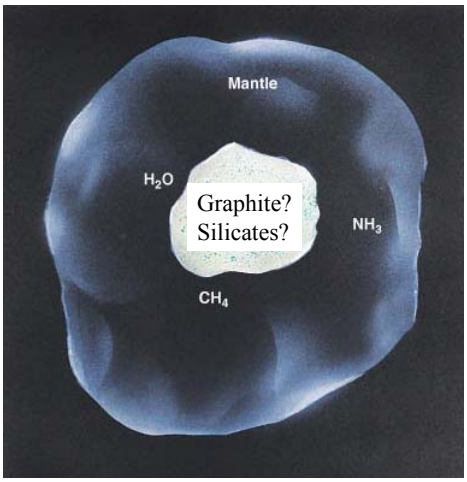


Sun near center of small universe.

(Herschel, 1784 ➔ Kapteyn, early 1900's)

Dust

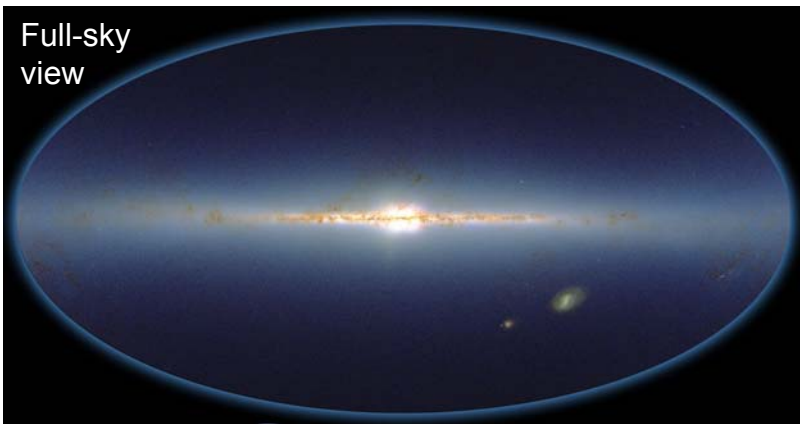
- Dust = tiny grains
  - 10^{-8} to 10^{-7} m.
- Formed in outer layers of coolest stars.
- Built up of molecules of most common elements after hydrogen and helium.
- Absorb light
  - Absorb strongest in blue, less in infra-red.



The Milky Way

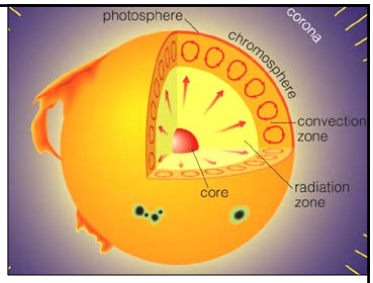
- Visible light:

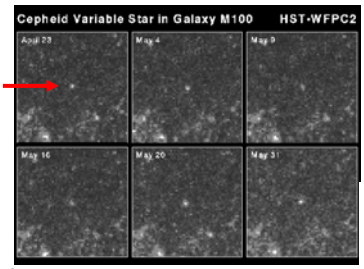
- Infrared:

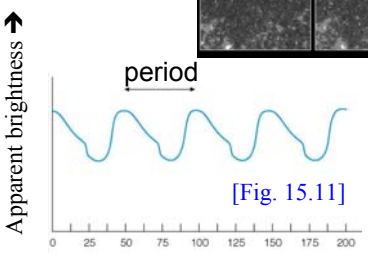


Pulsating Variable Stars [15.2]

- These stars regularly expand & contract.
- Like a big spring.
- Change in size ➔
  - change in temperature
  - change in luminosity

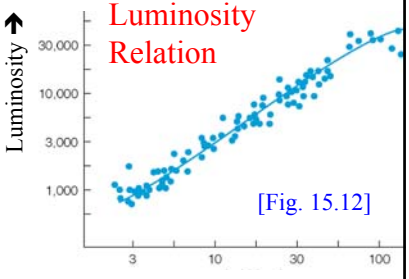




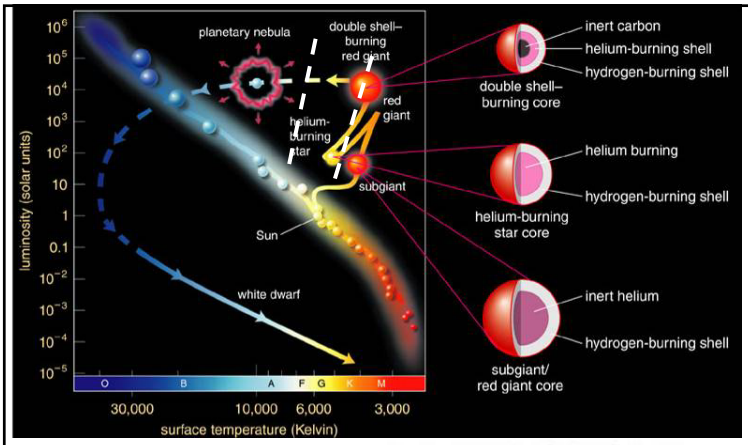


[Fig. 15.11]

Period-Luminosity Relation



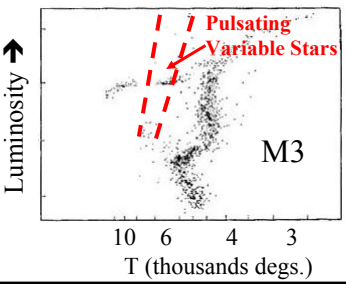
[Fig. 15.12]



[Fig 12.10]

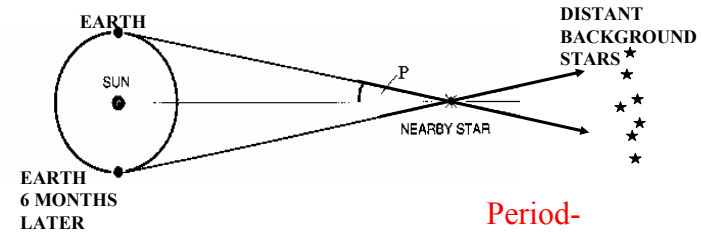
The Instability Strip

- In populations of old stars.
- For example, Globular Clusters
- Occurs during He burning



Measuring distances inside the Galaxy

- Parallax: to 300 pc = 1000 LY

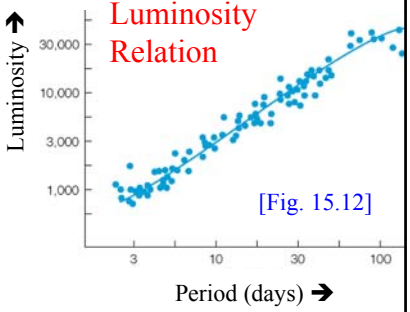


- Then… Pulsating variables (Cepheids, RR Lyraes)

$$F = L/(4\pi r^2)$$

$$r = \sqrt{L/(4\pi F)}$$

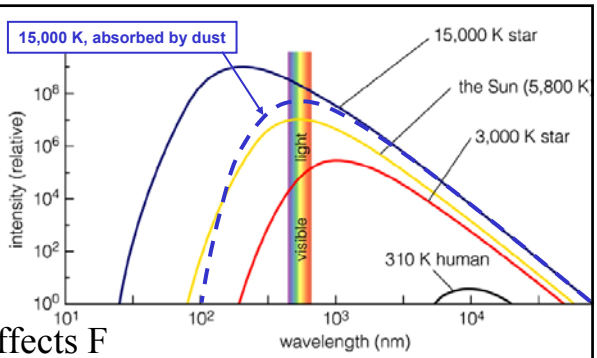
Period-Luminosity Relation



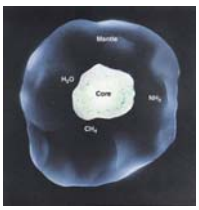
[Fig. 15.12]

Need to correct for absorption by dust.

- $F = L/4\pi r^2$



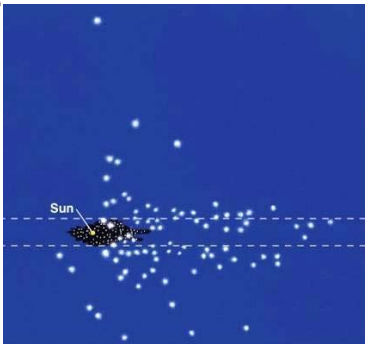
- But absorption also affects F
  - Absorption, or larger r ?



- Dust absorbs more in blue than in red.
- Changes shape of thermal radiation curve

  ➔ amount of absorption at each wavelength.

Mapping our Galaxy with globular clusters



- Globular Clusters offer key breakthrough (in ~1920).
  - Distances from pulsating variables.
  - Spherical distribution in space.
  - Sun very far away from center.

The Great Debate: *The Size of the Universe* (1920)

Heber Curtis

- Our Galaxy is rather small, with Sun near the center.
  - 30,000 LY diameter.
  - Kapteyn's result.
- Universe composed of many separate galaxies
  - Spiral nebulae = "island universes"

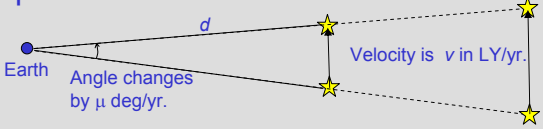
The Judges?

Harlow Shapley

- Our Galaxy is very large, with Sun far from center.
  - 300,000 LY diameter.
  - Sun 60,000 LY from center.
  - Based on distribution of globular clusters,
    - Pulsating variables.
- Spiral Nebulae are inside our galaxy.
  - "Proper motion" measured.

The Great Debate: *The Size of the Universe*

Proper Motion:



For a measured proper motion μ, what sets the upper limit on the distance *d*?

v cannot be greater than 1 LY/yr.

Shapley

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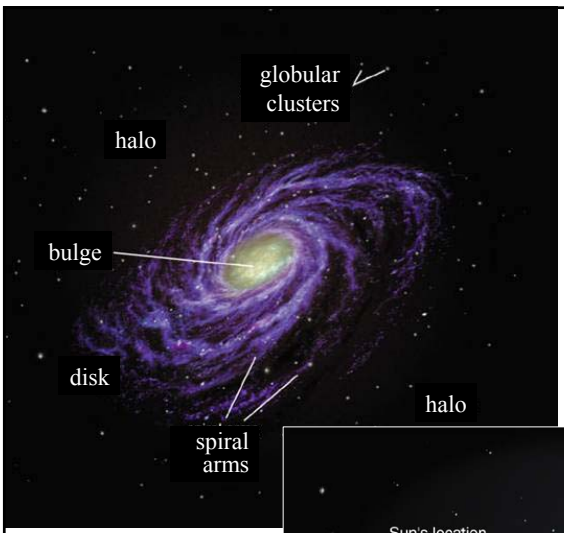
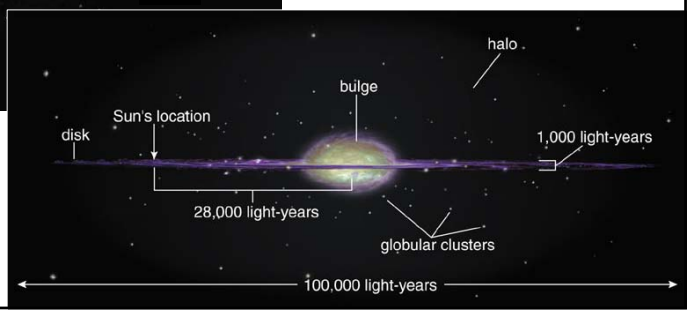


[Fig. 14.1]

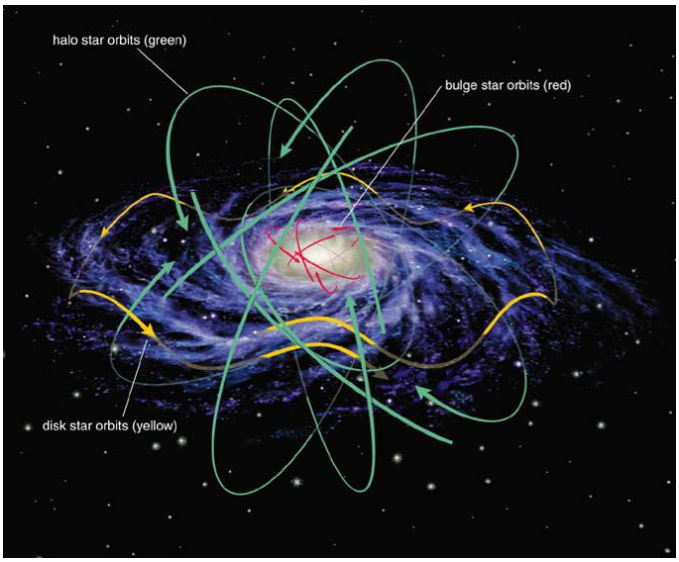
The Milky Way

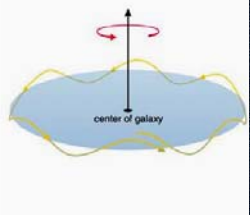
- Gas, large fraction of stars in thin disk
  - ~1000 LY thick
  - Spiral structure
- Spherical halo
  - ~150 globular clusters
  - Spherical distribution of stars
- Nuclear bulge

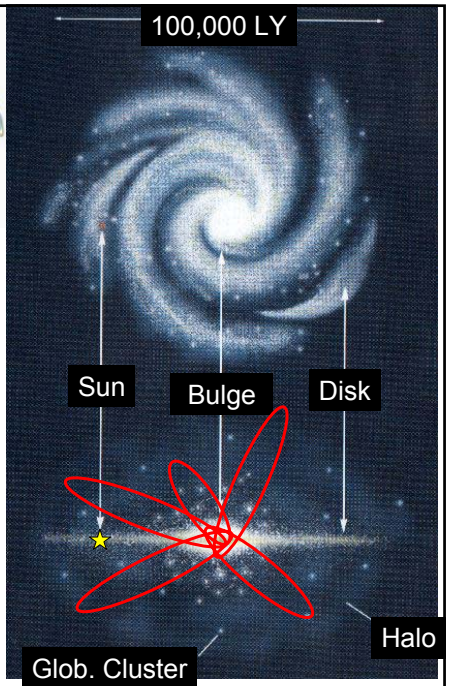


Orbits in the Galaxy

[Fig 14.2]







Disk
- gas, + young ➔ fairly old stars.
- circular orbits.

Bulge
- fairly old stars.
- elongated orbits.

Halo
- oldest stars.
- elongated orbits.

Clicker Question: *Why does all of the gas lie in a thin disk?*

A. Because the gas was expelled from stars that are arranged in a disk.

NO! It's the other way around!

B. It's a fluke of nature.

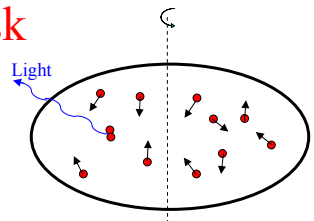
About half of all large galaxies have thin disks!

C. Because a rotating cloud of gas always does that.

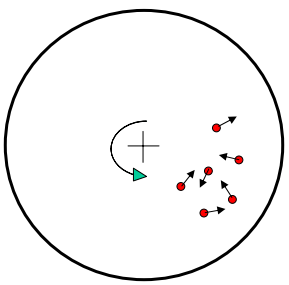
Why a collapsing gas cloud forms a spinning disk

- Collisions convert kinetic energy to light
  - Light carries away energy.
  - Nebula gets cooler
  - Contracts because of gravity.
- But angular momentum
  ➔ cannot collapse in direction perpendicular to spin axis
  ➔ disk.

See [Fig. 6.18]



Side view -- as many atoms move up as move down.



Top view -- net rotation superimposed on random motions.