

The Shape of the Universe

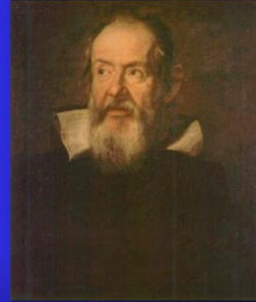
Questions:

1. What was different between Herschel's and Kapteyn's stellar distance measurements?
2. What was the Kapteyn/Shapley debate about?
3. Who was the "most" correct?
4. What did they *both* get wrong?

The Shape of the Universe



Galileo



The Milky Way is composed of
innumerable stars

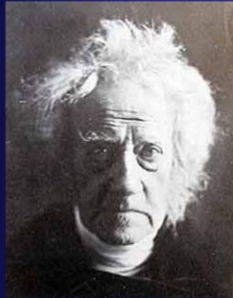
The Shape of the Universe

We need to measure
distances!

$$F_E = \frac{L}{4\pi d^2}$$

We will get the distances to objects by “knowing” their Luminosity and solving this equation

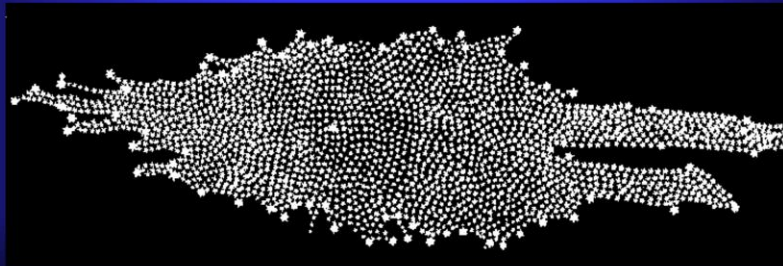
The Shape of the Universe



William Herschel

Assumes $L=1$ for all stars

The “Universe” is a flat disk 5
times wider than thick

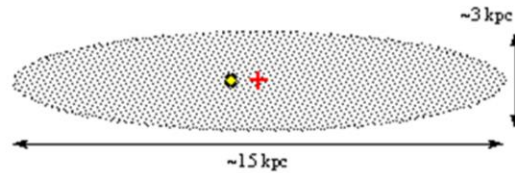


The Shape of the “Universe”



Kapteyn

Kapteyn Model (1922)



kpc = kiloparsec = 1000 pc

- Short and squat (Lentil)
- Sun is near the center
- 40,000 lyr across

Kapteyn measured the distance to stars in many different directions using main sequence stars as standard candles.

Using Newton's laws, Shapley measured the orbits of globular clusters to find the center of mass of the galaxy.

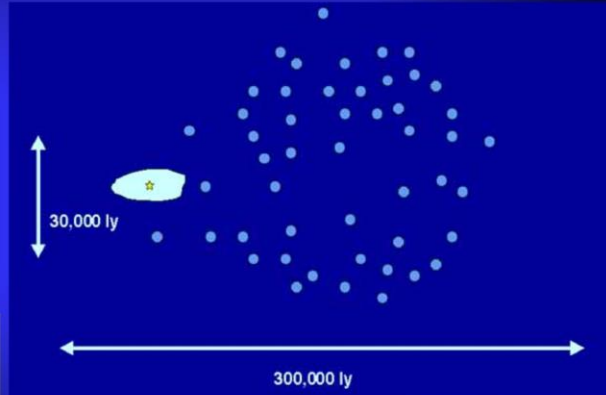
Kapteyn underestimated the obscuring effects of interstellar dust.
He imagined a lens shaped galaxy.

The Shape of the “Universe”



Shapley

- Globulars are in a spherical “halo”
- Center is 45,000 lyr away

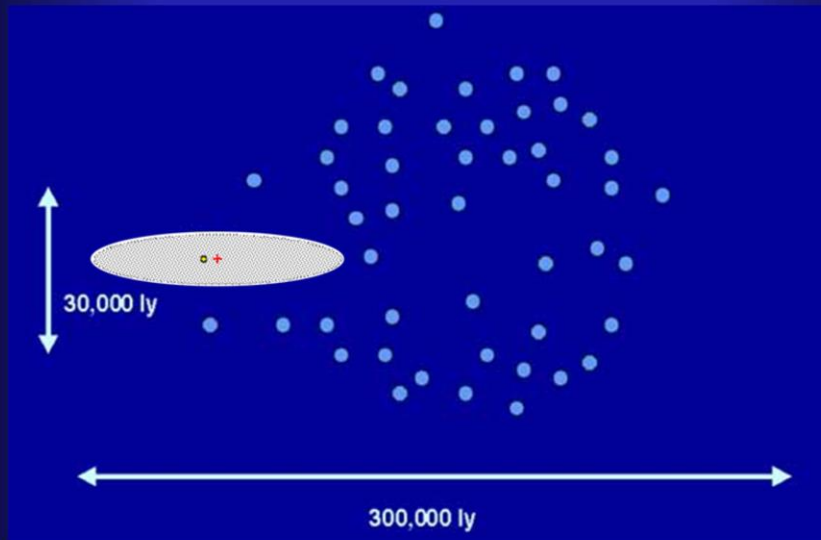


Kapteyn measured the distance to stars in many different directions using main sequence stars as standard candles.

Using Newton’s laws, Shapley measured the orbits of globular clusters to find the center of mass of the galaxy.

Kapteyn underestimated the obscuring effects of interstellar dust.
He imagined a lens shaped galaxy.

What's going on?



The Kapteyn and Shapley Universes superimposed on one another.

Kapteyn and Shapley disagree about nearly everything...

- The overall size.

- The shape

- The distance to the "center"

What's going on?

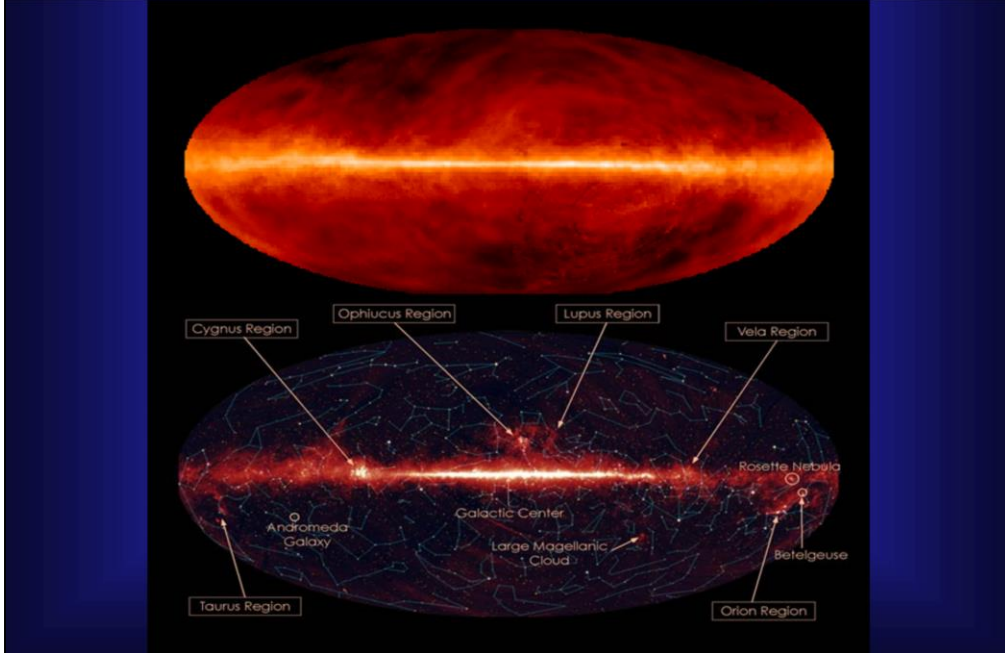
Facts

- Kapteyn is looking at *resolvable* stars.
- Shapley is looking at Globular Clusters
- They disagree about the size by a factor of 10
- They disagree about the location of the Sun
- The dust is concentrated in the midplane of both Kapteyn's and Shapley's distributions.

Questions

- Why is Kapteyn's Universe so small?
- Why can Shapley see so far?
- Why is Kapteyn's disk so thick and why does it extend so far "behind" us?

Gas and dust maps

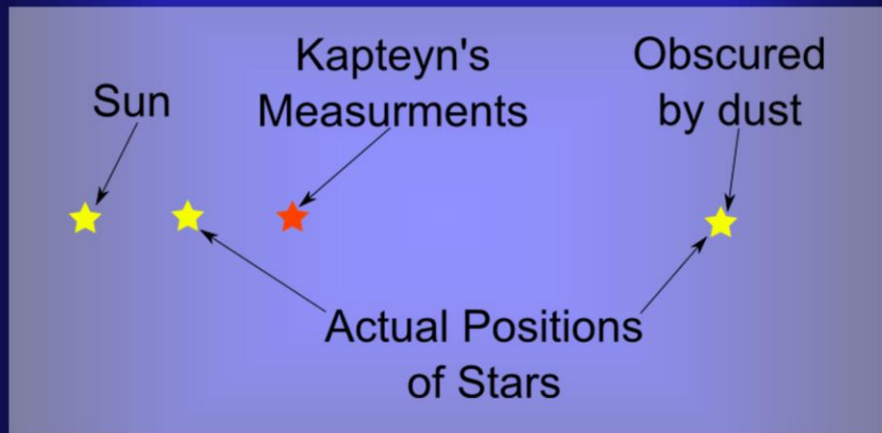


In modern times, we have built all sky maps that trace out the dust in the galaxy.

We have noticed that the dust is concentrated in a narrow band and is the most dense towards the constellation of Sagittarius.

Both Kapteyn AND Shapley found that the galactic center lies in the direction of Sagittarius.

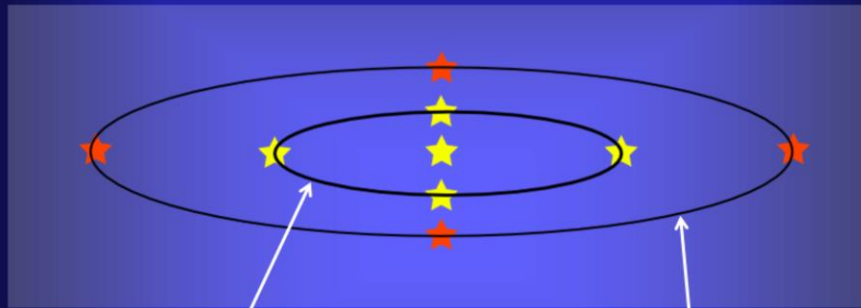
Why so small?



Kapteyn couldn't SEE all of the stars in the galaxy because of dust in the galactic plane.

The most distant star in this image would have been blocked from his view. The nearby star that he COULD see was dimmed by dust causing him to get the wrong distance.

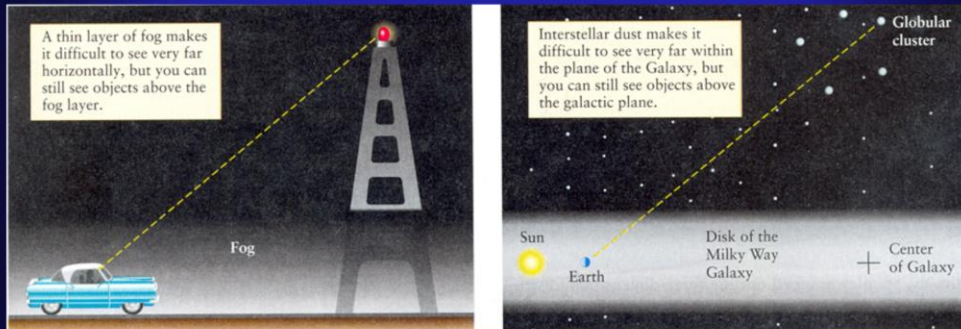
Why is the disk too thick?



Actual Positions

Kapteyn's
Measurements

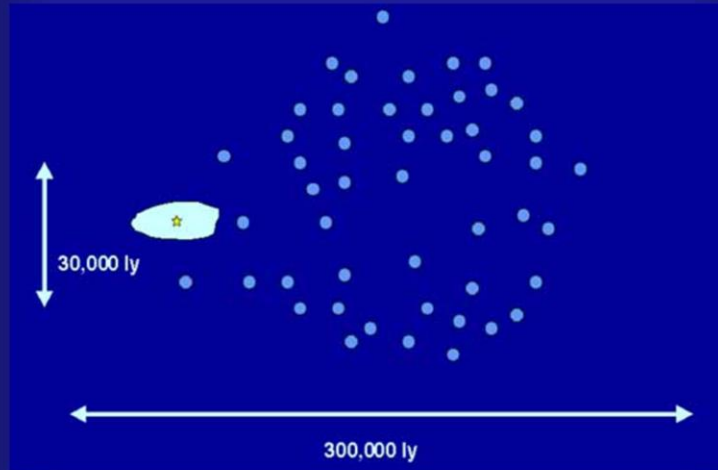
Why can Shapely see further?



Shapely's distances were ALSO too big because of dust.
But he could see further!

He could see further because he was looking through less dust AND the globulars are BRIGHT

Who's Correct?



They were both wrong, but Shapely was closer.

Milky Way Scales



Lecture Tutorial p 135

The Great Debate



Shapley

You wanna
fight about it?



Curtis

Bring it on,
whippersnapper

Shapley: The universe is one big galaxy and the spiral nebula are within it.

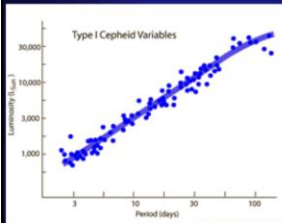
Curtis: Galaxies are island universes and the Milky Way is but one of them.

Shapley said that the Milky way is very large. In fact the entire universe is taken up by the Milky Way and the 'spiral nebula' are nearby gas clouds within the Milky Way.

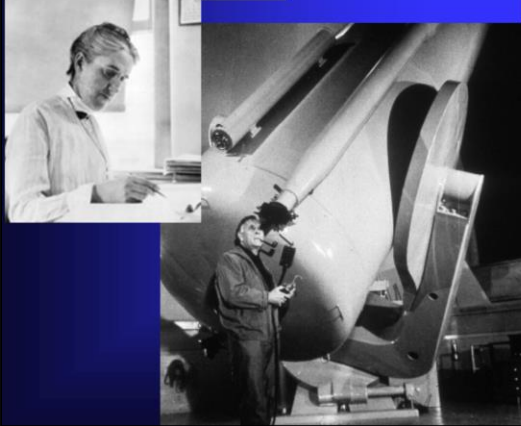
Curtis said that the Milky Way is smallish and the Sun is nearly in the center (40,000 ly across). The 'spiral nebula' are other galaxies like the Milky Way.

Note: They are BOTH wrong about one thing and right about one thing.

The Great Debate



Henrietta
Swan Leavitt
Cepheids
1912



Edwin Hubble looks at
Cepheids in the
Andromeda Galaxy 1924

Way farther away than even Shapley's estimates of the size of the galaxy!

Cepheids have a period luminosity relationship. We measure the period and derive the luminosity.

We then measure the flux and calculate the distance.

Turns out that M31 is 2.9 million light years away. This really blew their minds.

But... Shapley was right about the overall size of the Milky Way. It's much larger than Kapteyn and Curtis thought. It turns out that the Universe is a lot larger than *anyone* thought.

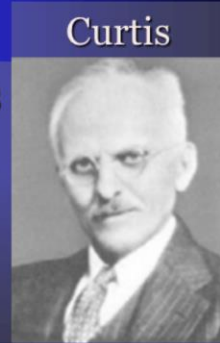
The Great Debate



Shapley

Right: Milky Way is very large & we are not at the center

Wrong: universe is one big galaxy



Curtis

Right: Galaxies are island universes and the Milky Way is but one of them.

Wrong: MW is small & sun nearly in the center

Shapley said that the Milky way is very large. In fact the entire universe is taken up by the Milky Way and the 'spiral nebula' are nearby gas clouds within the Milky Way.

Curtis said that the Milky Way is smallish and the Sun is nearly in the center (40,000 ly across). The 'spiral nebula' are other galaxies like the Milky Way.

Note: They are BOTH wrong about one thing and right about one thing.