

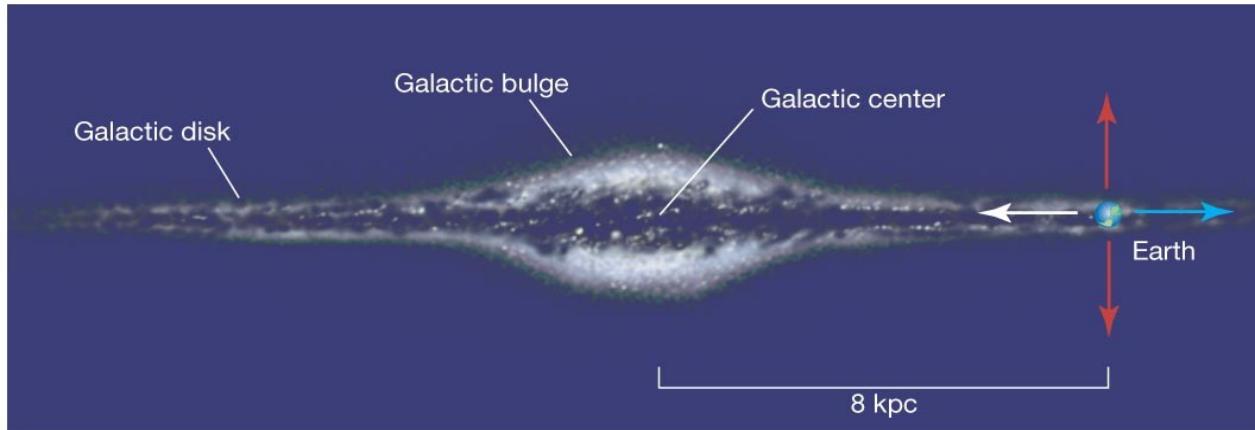
# The Milky Way Galaxy



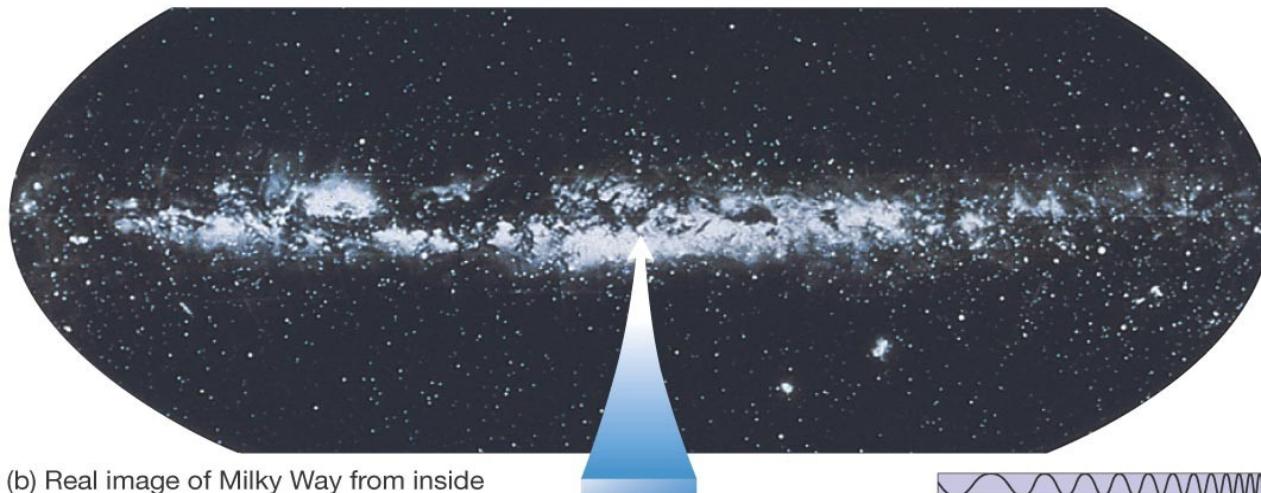
(Ch. 24)

# Our Parent Galaxy

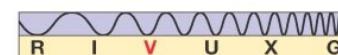
The Milky Way is what our galaxy appears as in the night sky.



(a) Artist's view of Milky Way from afar

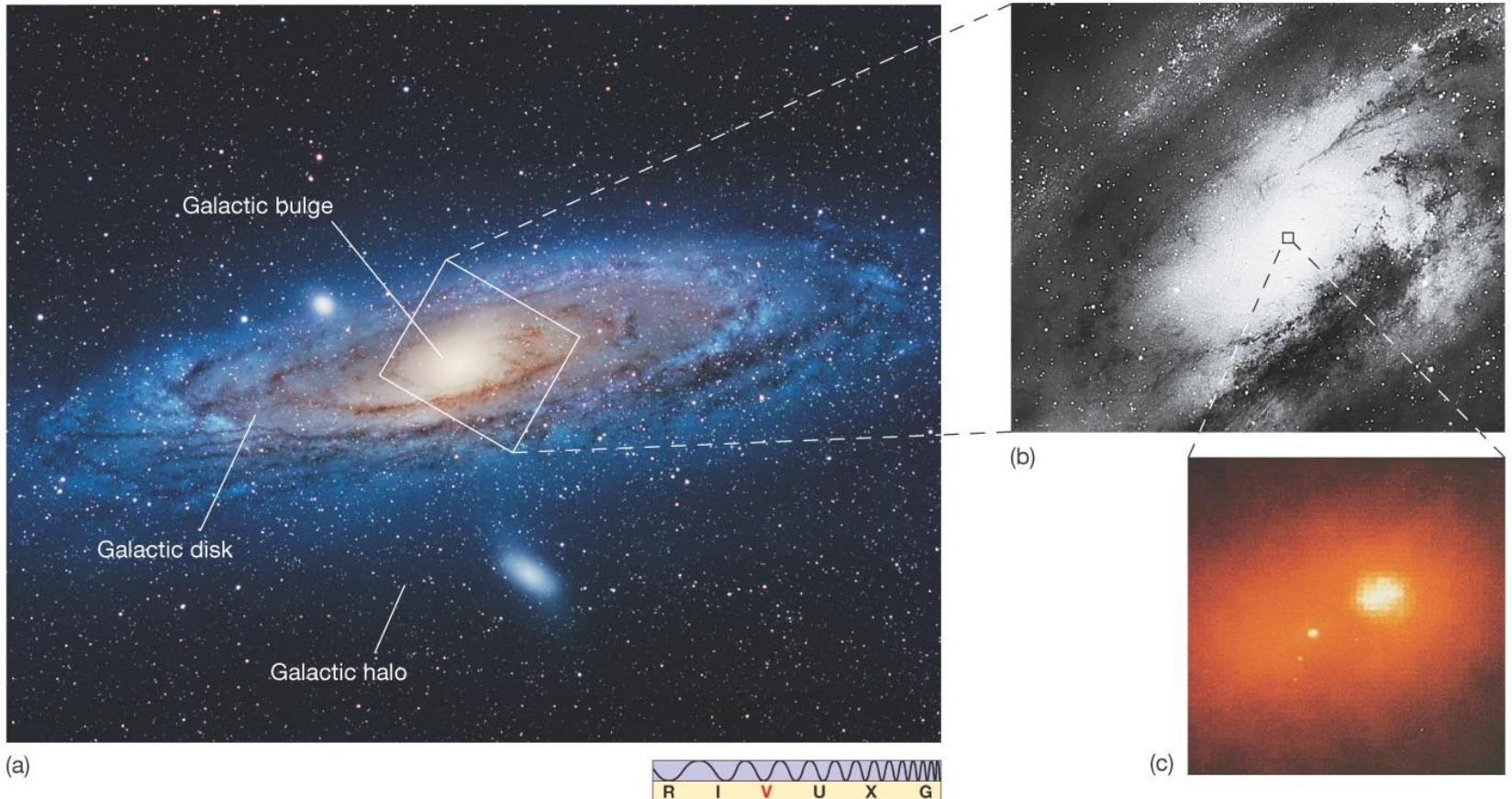


(b) Real image of Milky Way from inside



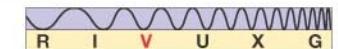
# Our Parent Galaxy

Our galaxy is a spiral galaxy. The Andromeda Galaxy, our closest spiral neighbor, probably resembles the Milky Way fairly closely.



# Our Parent Galaxy

Here are two other spiral galaxies, one viewed from the top and the other from the side:



“Face on”

“Edge on”

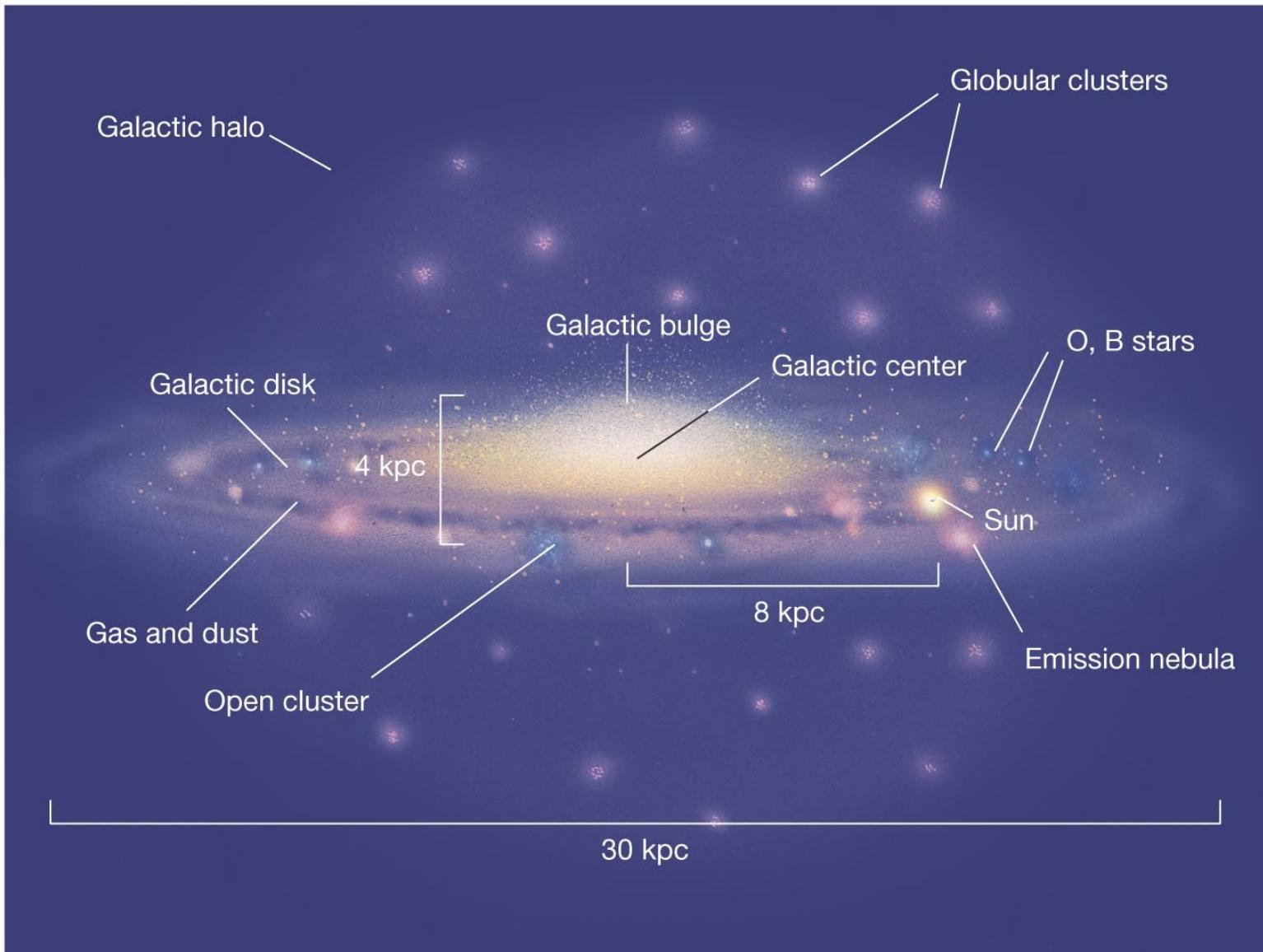
# Our Parent Galaxy

Here is a better twin to the MW, NGC 6744.  
Barred, medium-sized bulge, flocculant spiral.



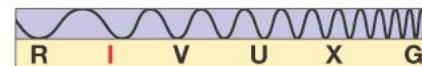
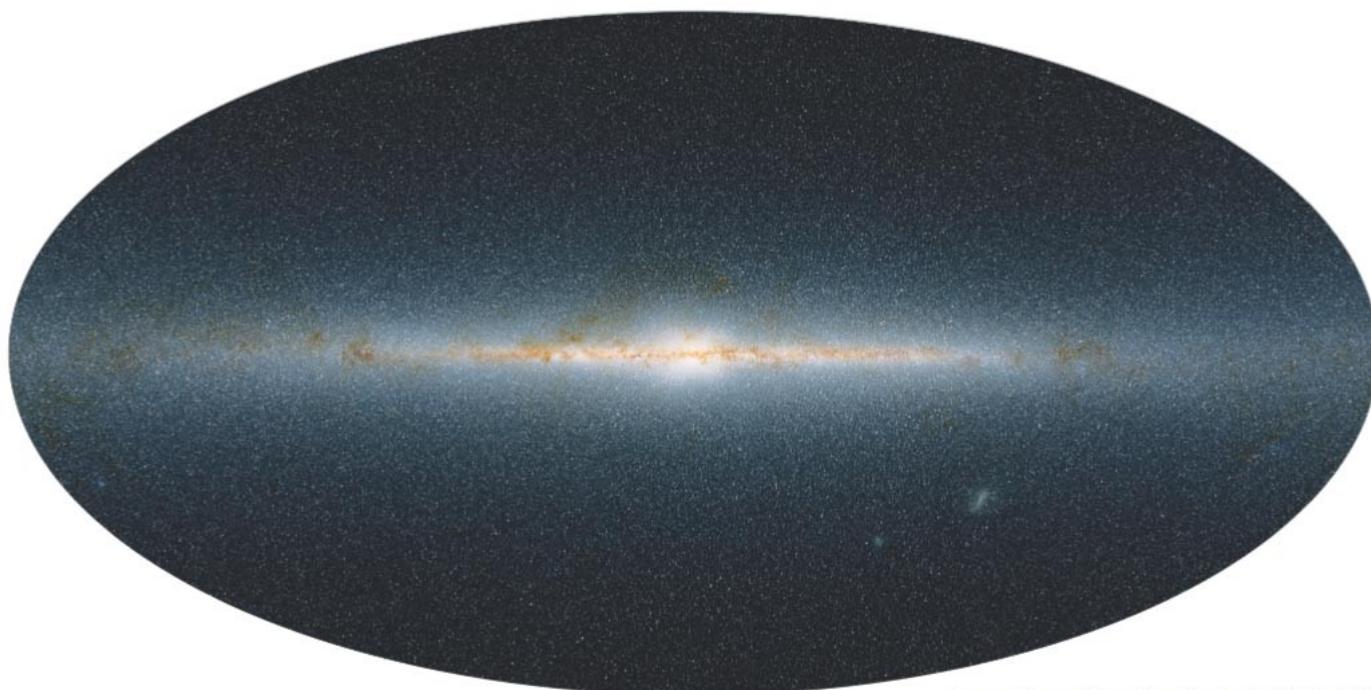
# Galactic Structure

The various parts of our galaxy:



# Galactic Structure

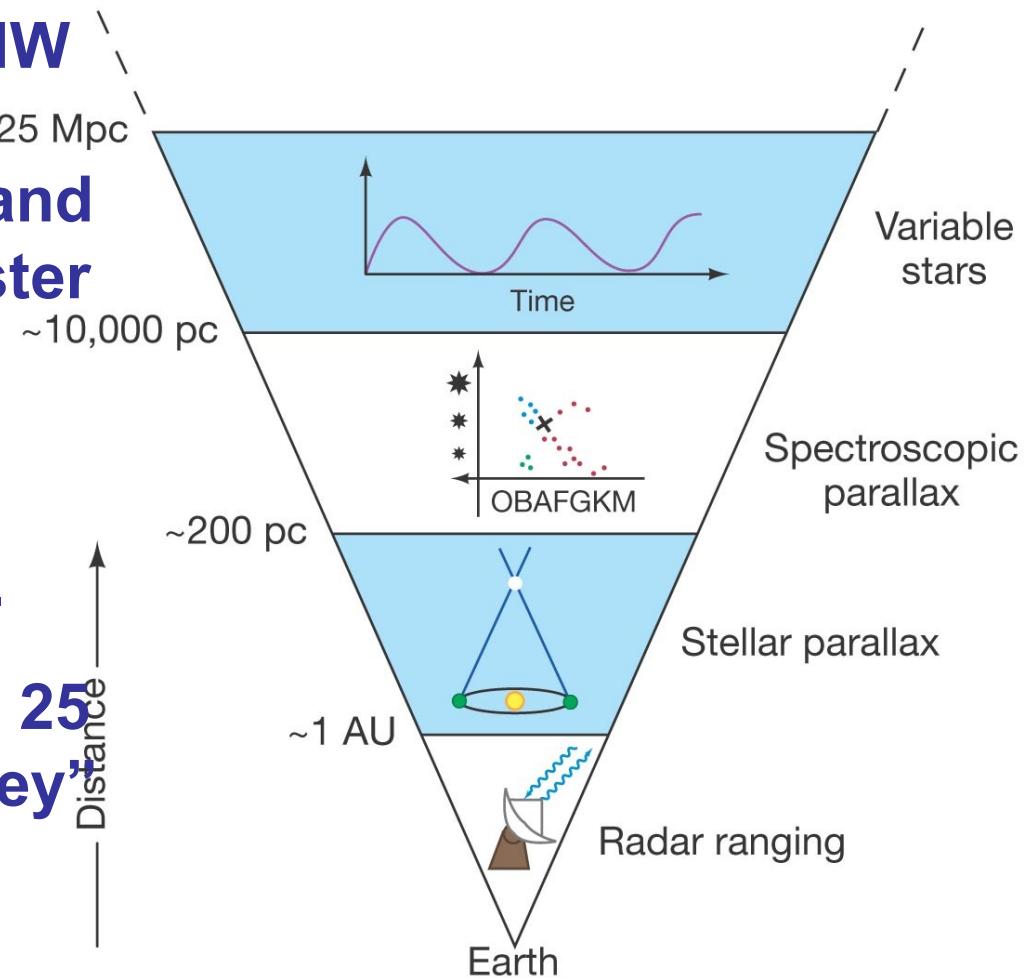
This infrared view of our galaxy shows much more detail of the galactic center than the visible-light view does, as infrared is not absorbed as much by gas and dust.



# Measuring the Milky Way

We can measure distances to (bright) parts of the MW with many techniques: ~25 Mpc spec parallax, Cepheid and RR Lyrae variables, cluster sizes, expanding photospheres, moving cluster method, stat parallax, novae, etc, etc.

Finding Cepheids out to 25 Mpc was the original “Key” project for the Hubble Space Telescope.

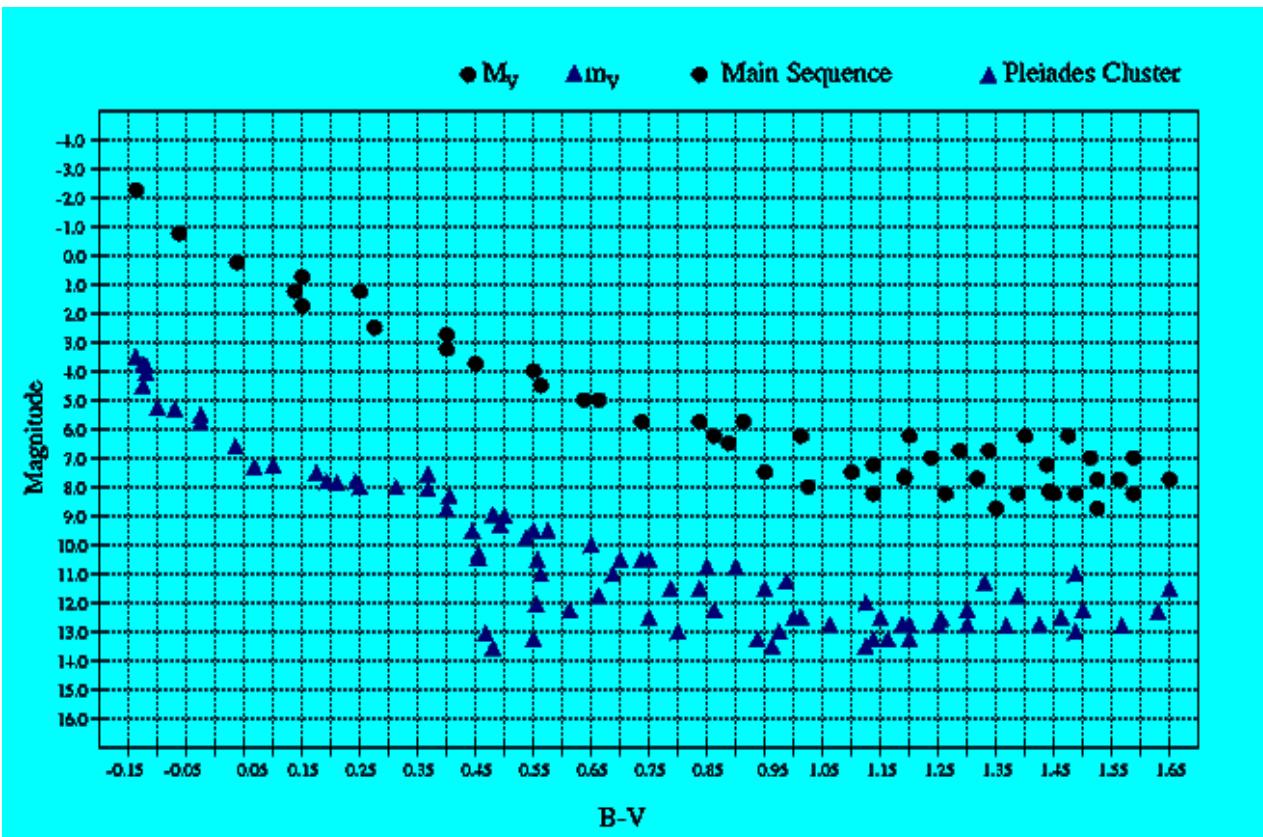


# Stellar and Spectroscopic Parallax

Stellar Parallax works out to 200pc (ground), 1000 pc (Hipparcos)

Spectroscopic Parallax works for stars for which a good spectrum can be observed (about 8 kpc), but ...

- Not precise for individual stars, especially giants
- Entire clusters of stars works better! (“main-sequence fitting”)

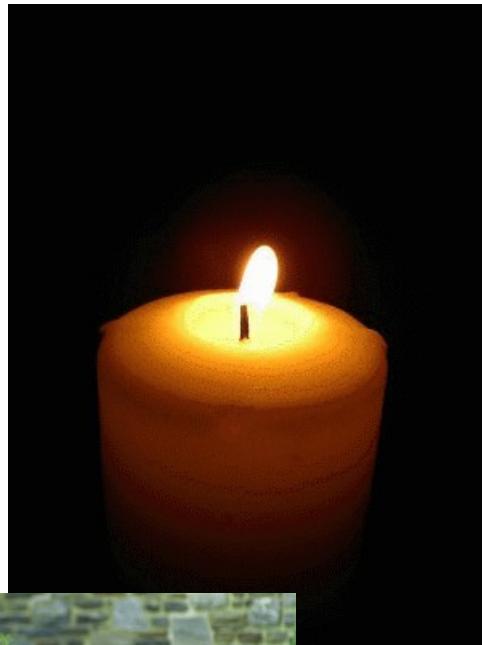


$$m-M=5\log(d/10)$$

Spec Parallax assumes, for example, that all A0V stars have the same  $M$ . That makes A0V stars “standard candles”.

# Beasts of a kind: standard candles/yardsticks

Nearby

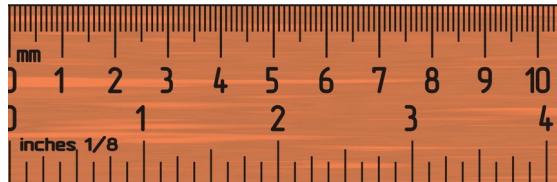


Far away



Flux,  $I \sim 1/d^2$

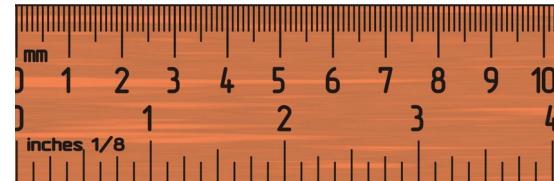
Nearby



Far away

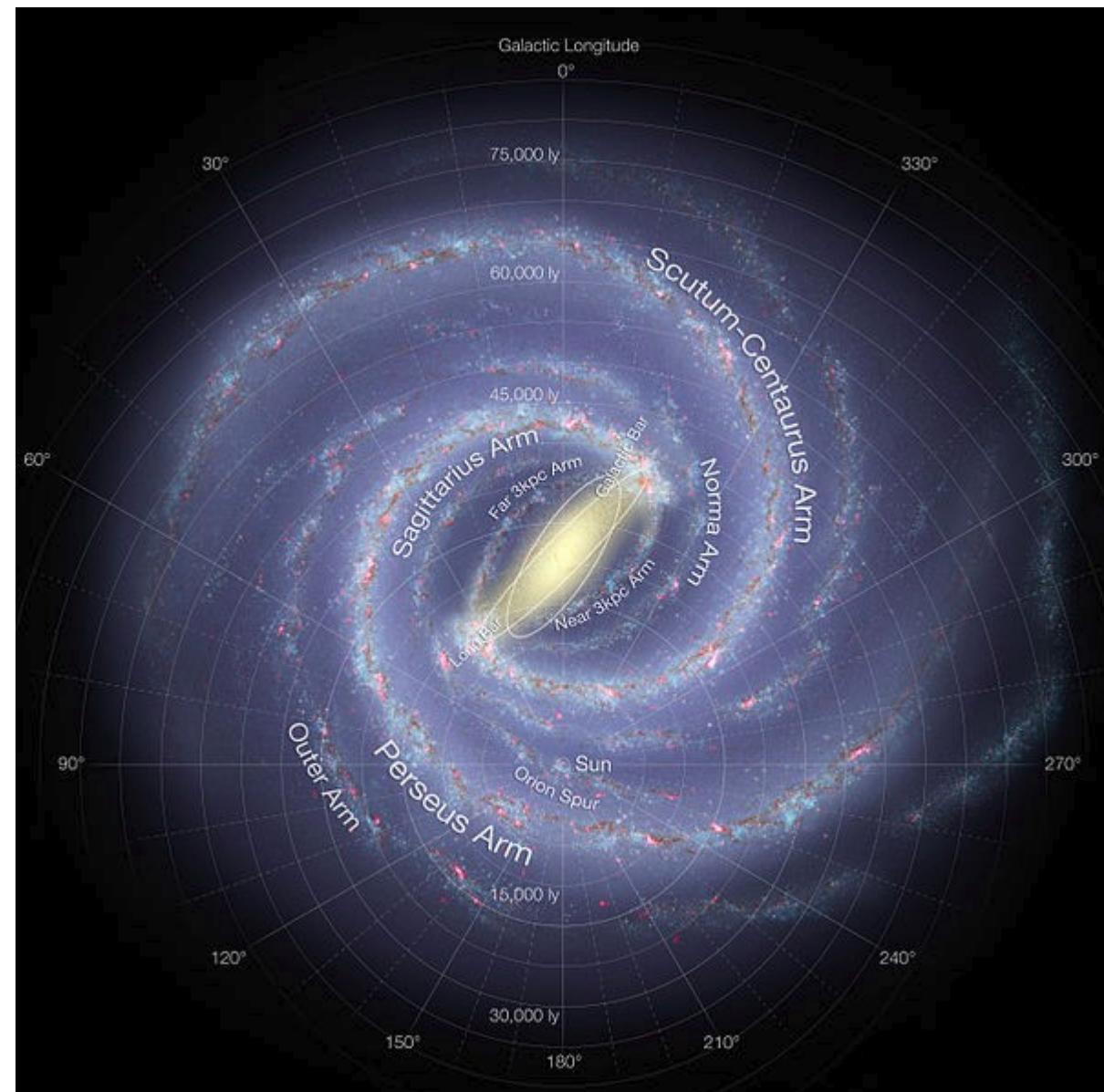


Angle,  $\theta \sim 1/d$



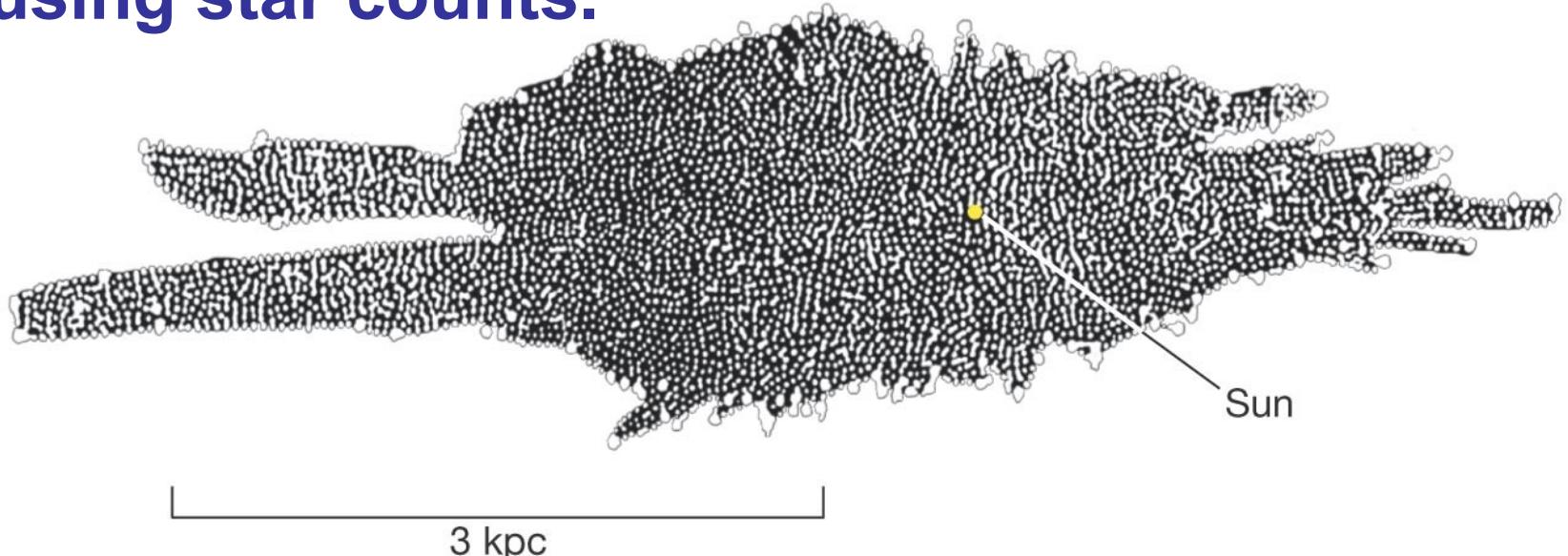
# Measuring the Milky Way

Modern mapping of the M.W. Has relied on a variety of observations, especially 20 cm radio observations of the HI gas.



# Measuring the Milky Way

One of the first attempts to measure the Milky Way was done by W. Herschel (1738-1822) using star counts.



## Problems:

1. patchy dust blocked view! (extinction)
2. all stars do not have the same luminosity!!
3. density is not uniform

# Measuring the Milky Way

A model based on non-uniform densities and photographic data was made by Jacobus Kapteyn (1850-1922).

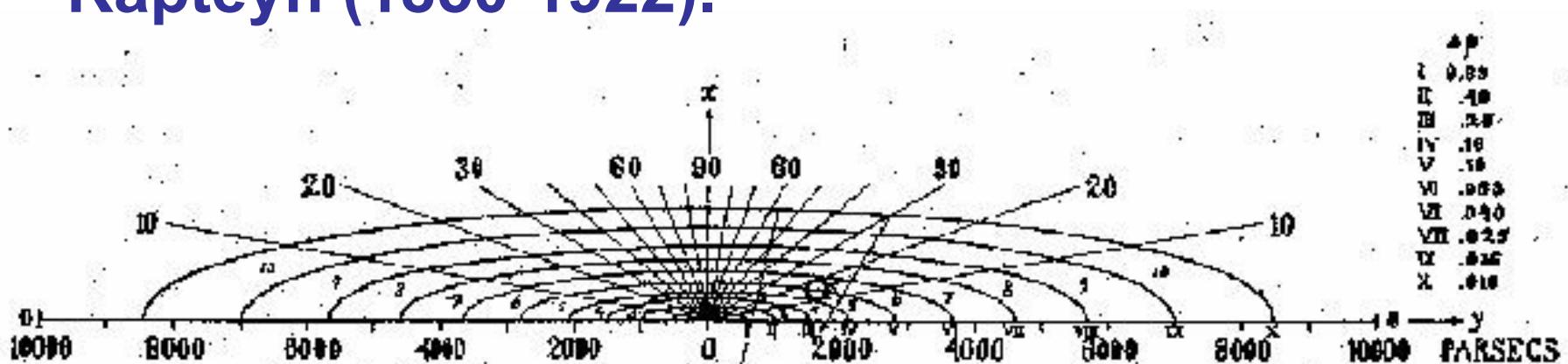
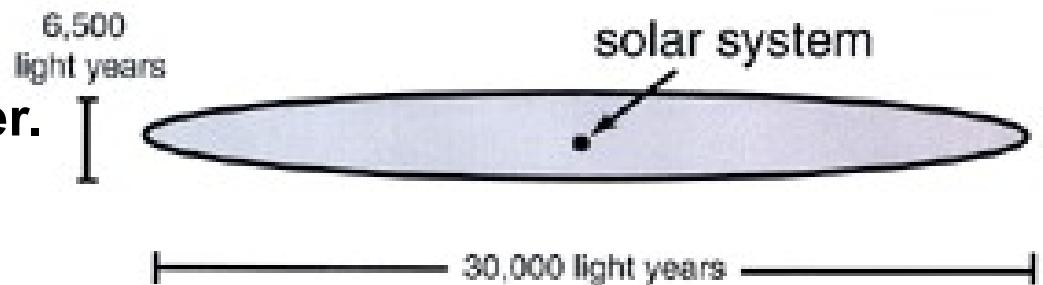


FIG. I

Still lacked corrections for extinction, although JK was aware of it.

Sun only 2000 LY from center.

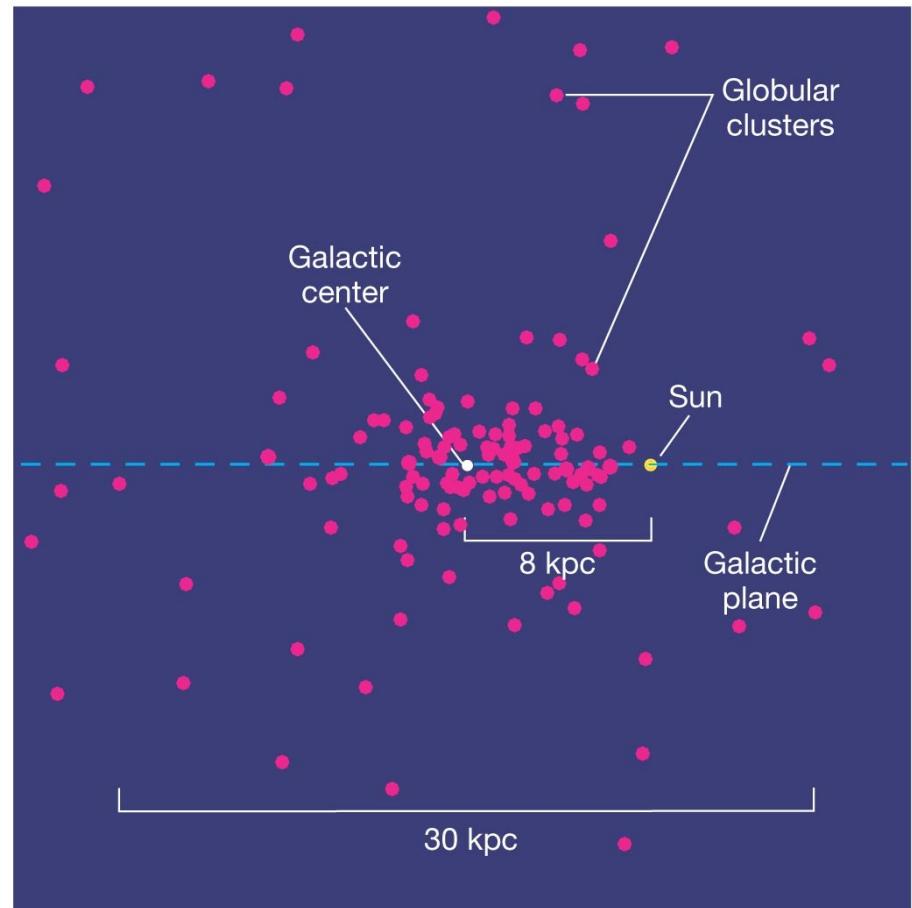
Kapteyn Universe (circa 1920)



# Measuring the Milky Way

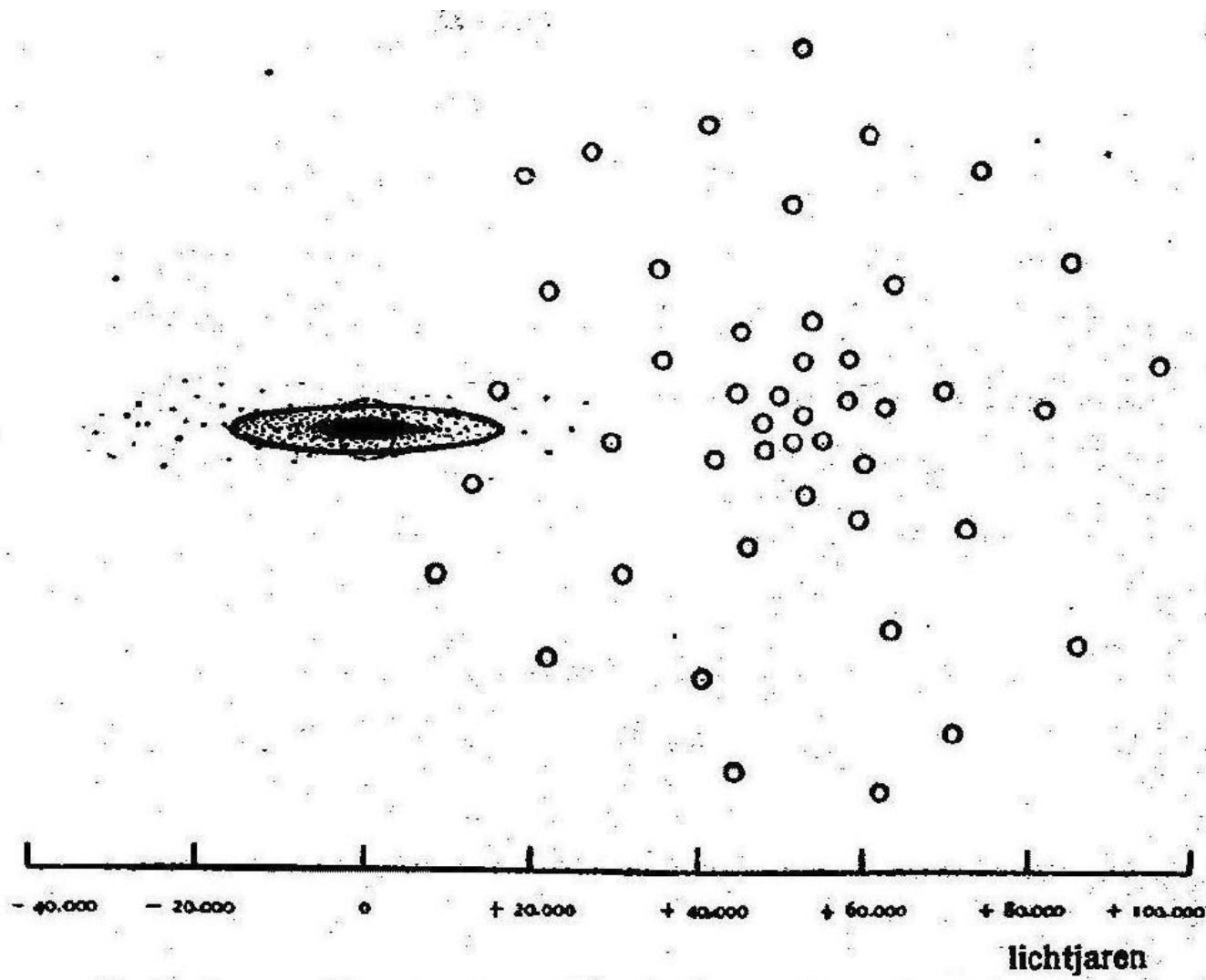
Many RR Lyrae stars are found in globular clusters. Harlow Shapley used these to estimate the size of the M.W.

He correctly determined that we were far from the center. But he overestimated the size.



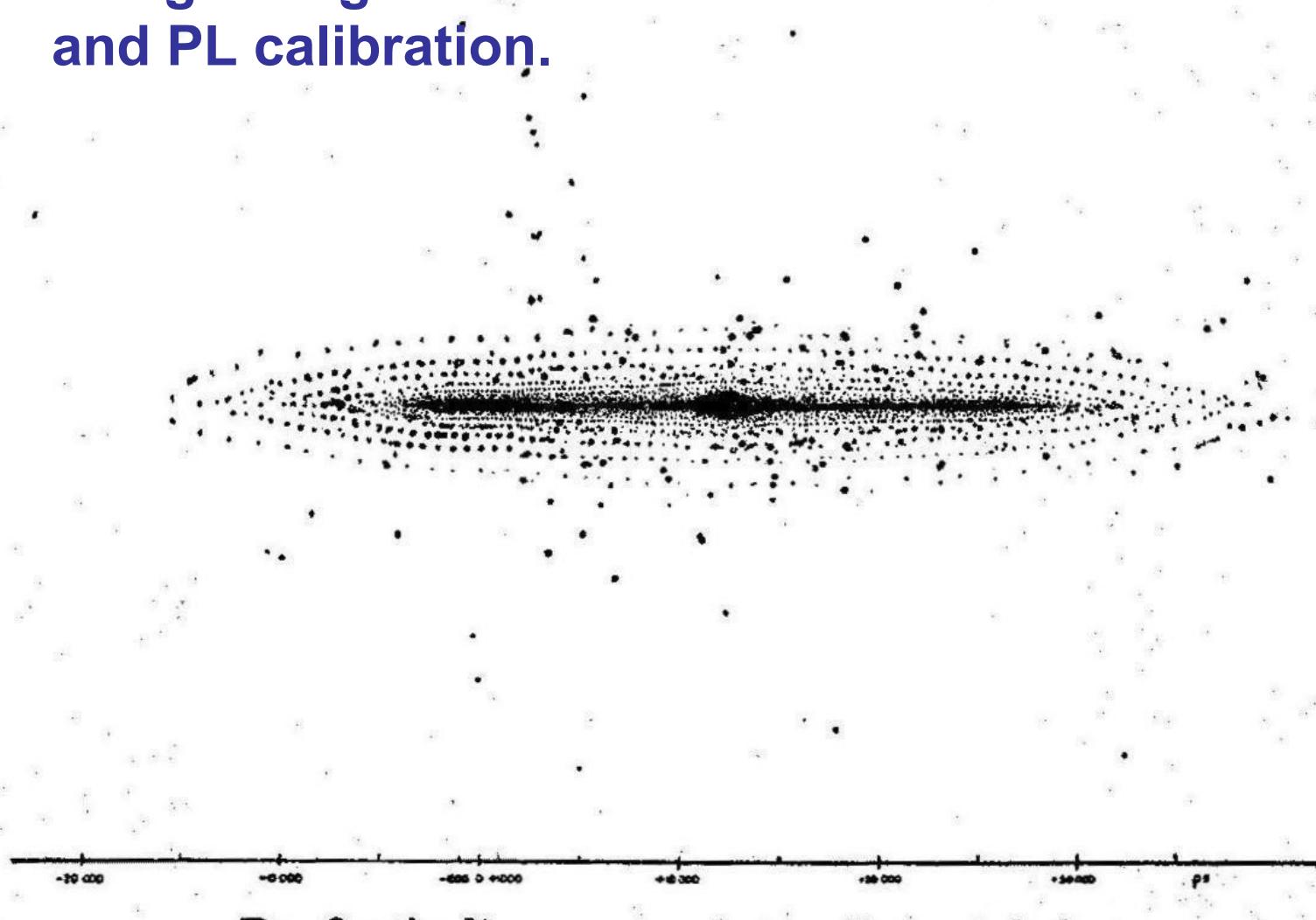
# Measuring the Milky Way

## Compare Kapteyn's universe to Shapley's.



# Measuring the Milky Way

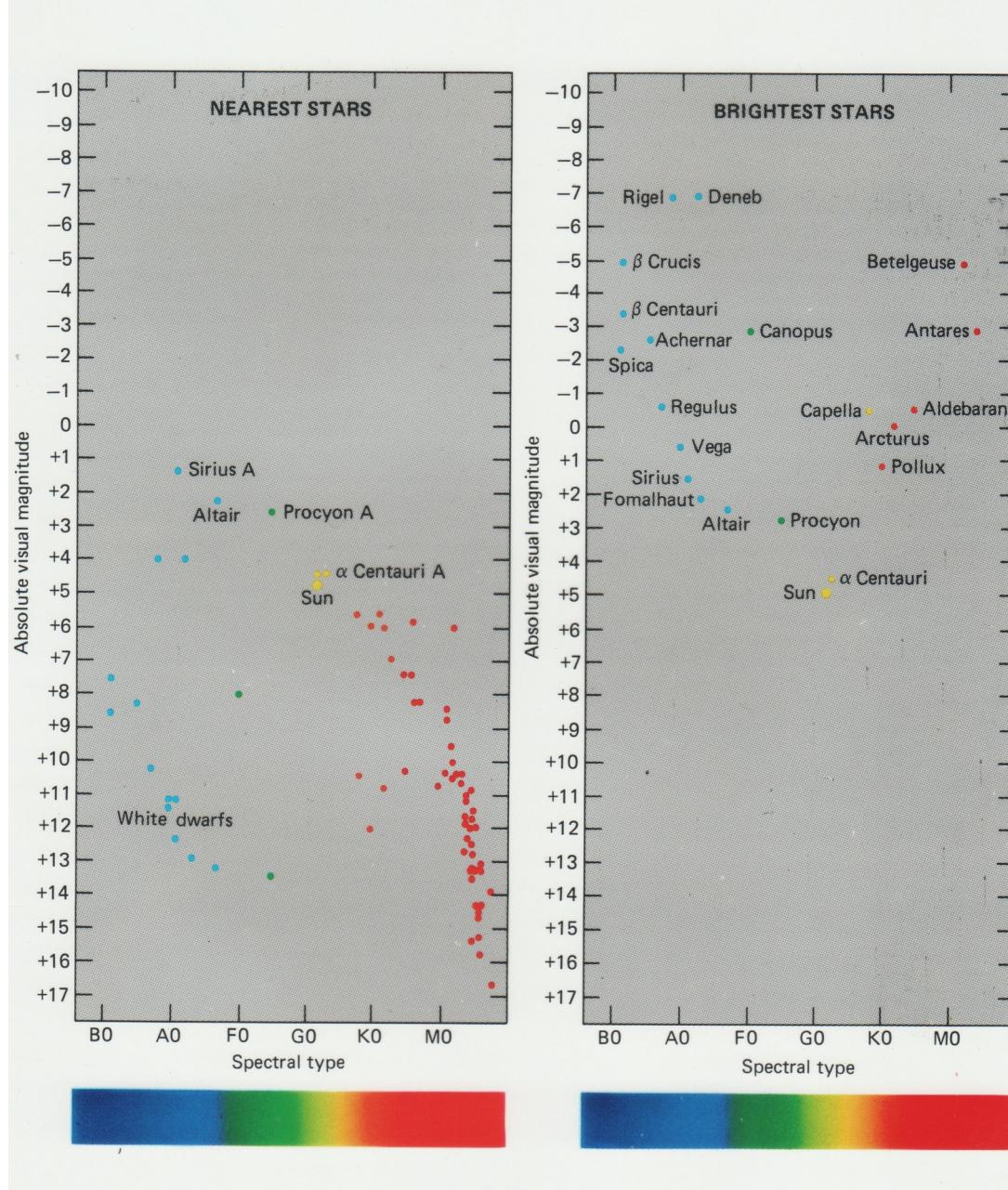
Oort showed that Shapley and Kapteyn's results can give a good match if corrected for extinction and PL calibration.



# Measuring the Milky Way

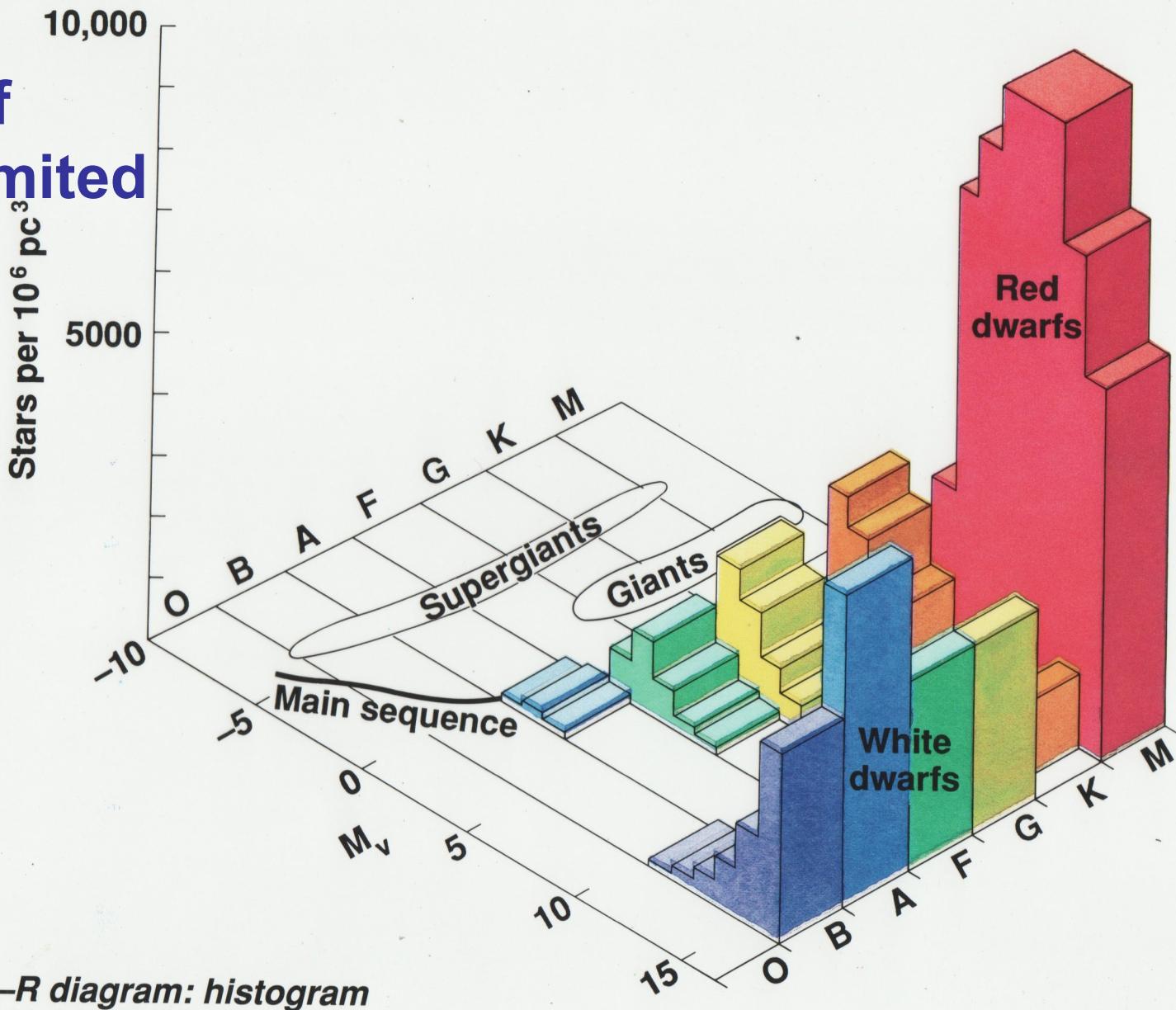
If we want to use stars to probe the geometry of the MW, we need to know about their demography.

Near stars:  
faint.  
Brightest:  
luminous.

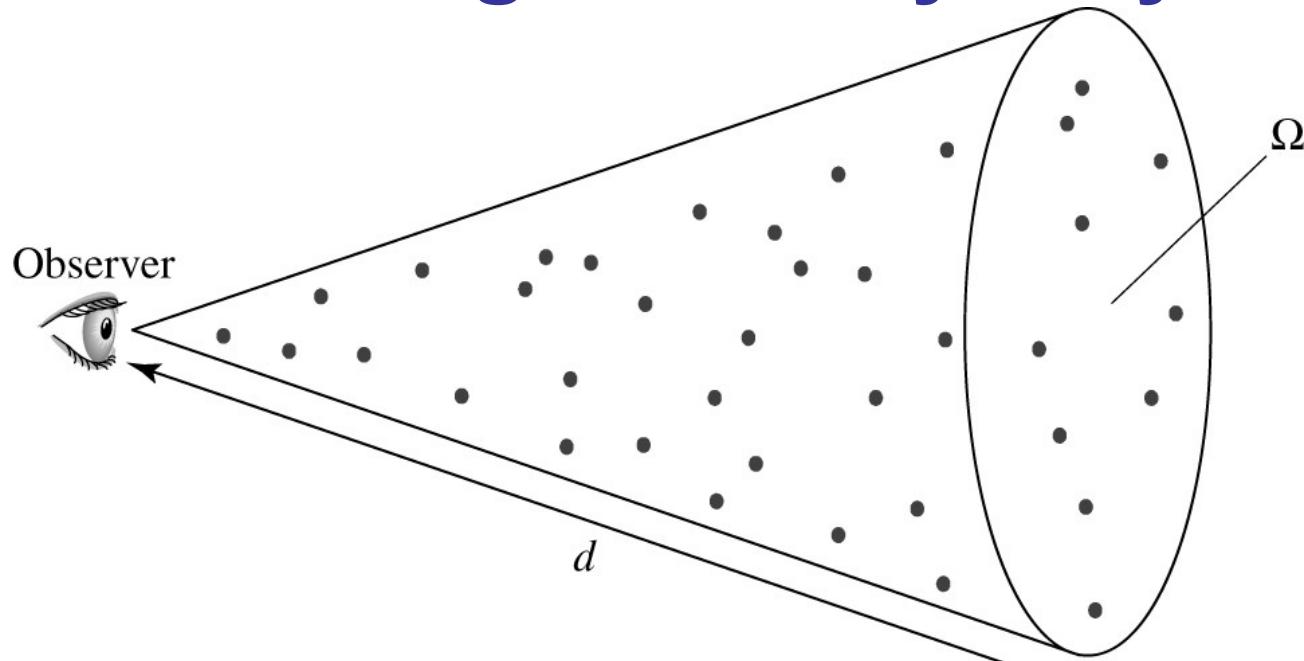


# Measuring the Milky Way

Studies of  
volume-limited  
samples  
reveal the  
rarity of  
luminous  
stars.



# Measuring the Milky Way



Star counts can be imagined out to a limiting distance,  $d$  (as above). These are integrated stars counts represented by  $N$ .

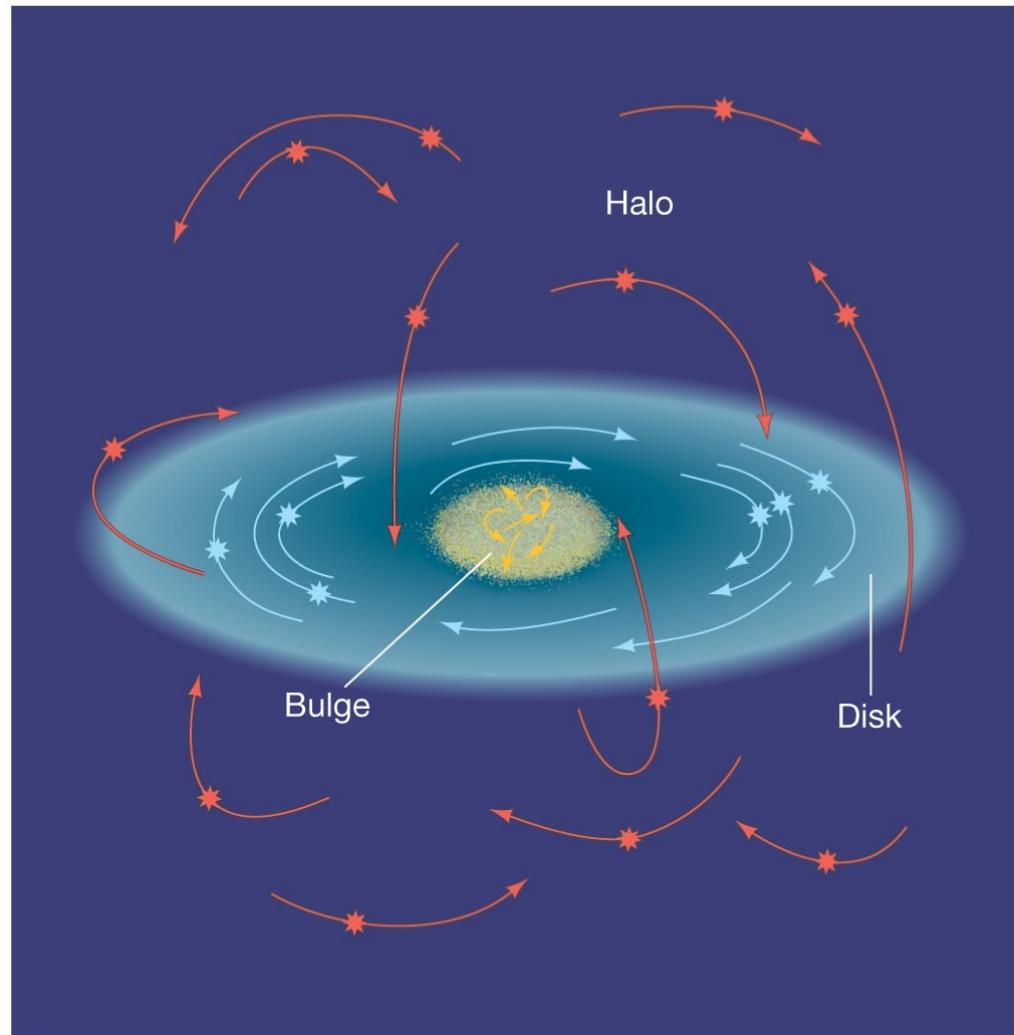
However, it is easier to measure magnitudes than distances, so usually star counts are done down to a limiting magnitude (integrated star count,  $\bar{N}$ ), or in magnitude bins (differential star count,  $A$ ).

Note that the distance corresponding to a limiting magnitude,  $m$ , will be greater for more luminous stars (with lower  $M$ ).

# Galactic Structure - kinematics

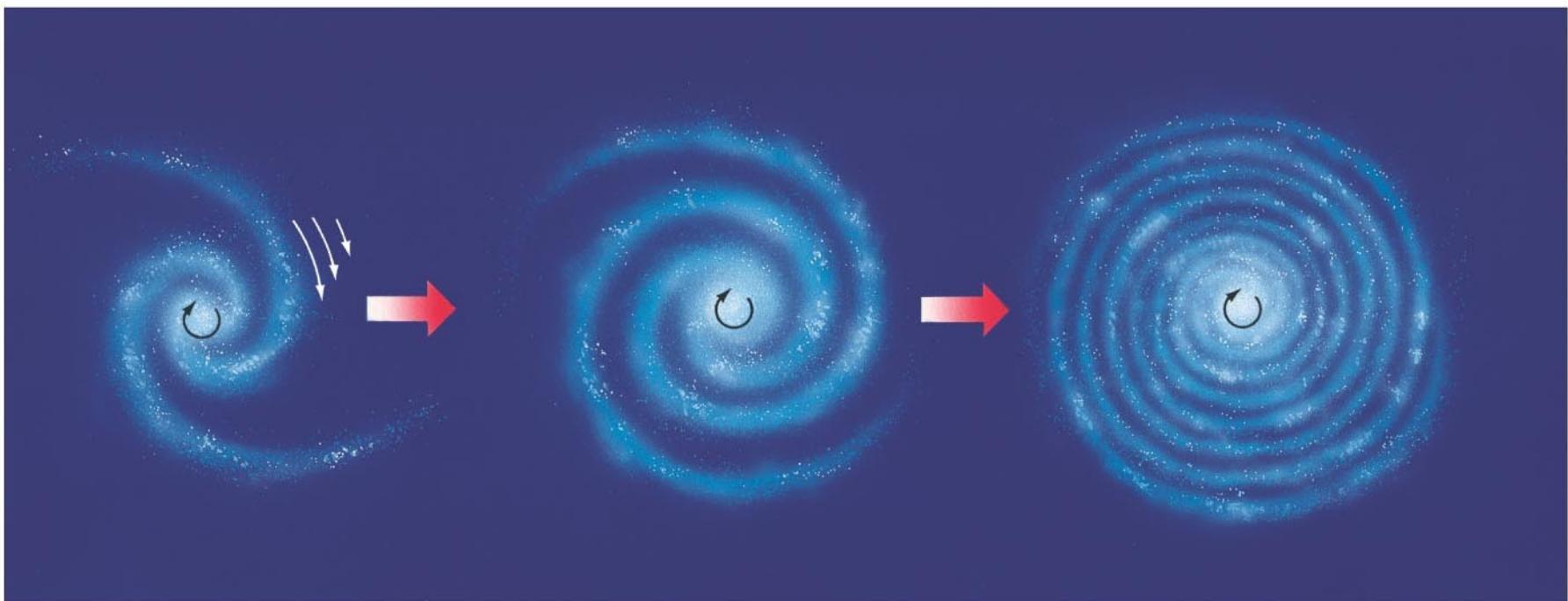
**Stellar orbits in the disk move in a common plane (*co-planar*) and in the same direction.**

**The orbits in the halo and bulge are much more random (*isotropic*).**



# Galactic Spiral Arms

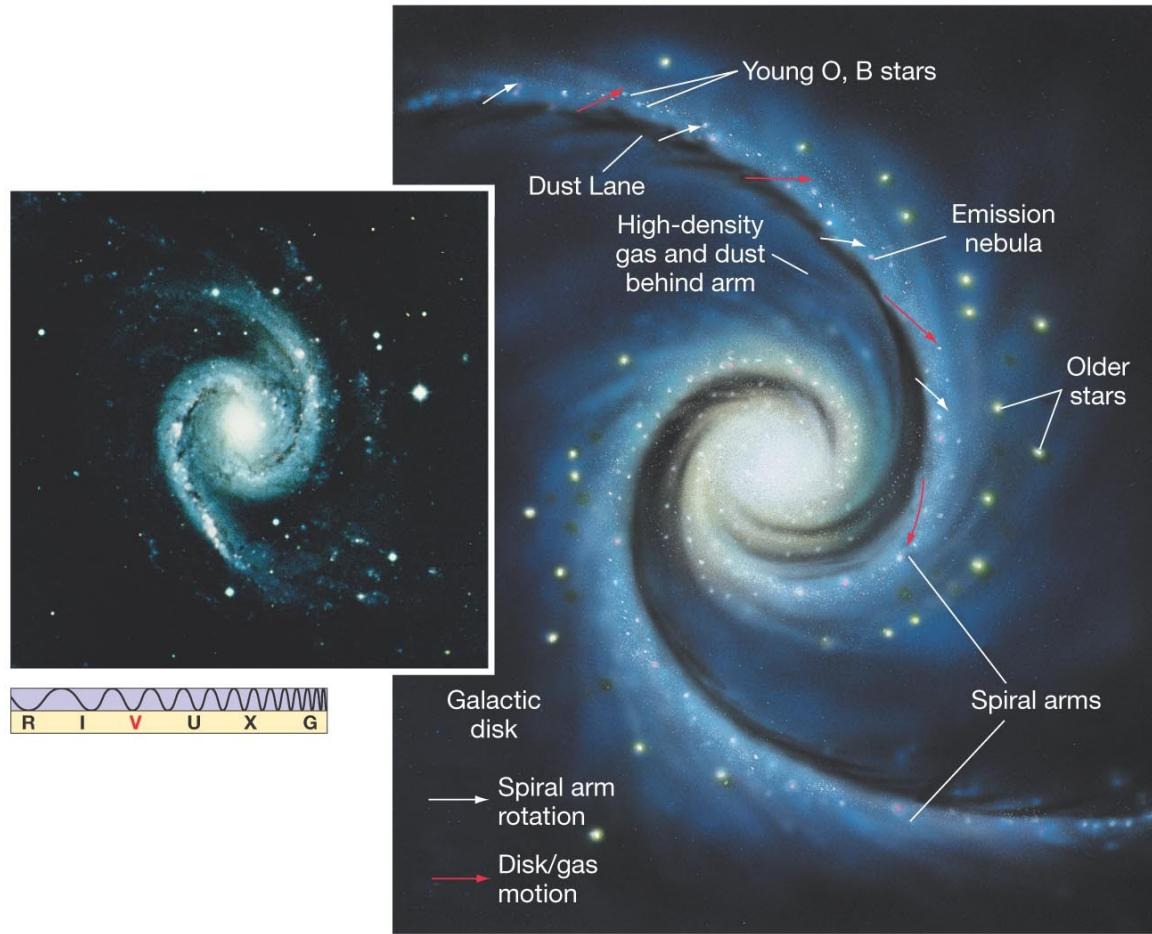
The spiral arms cannot rotate exactly as the stars do; they would “wind up”.  
(The “winding problem”.)



The speed of the stars is almost constant with radius, so inner stars make it around in less time than outer stars. The period is ~240 Myrs. MW formed ~50 rotations ago.

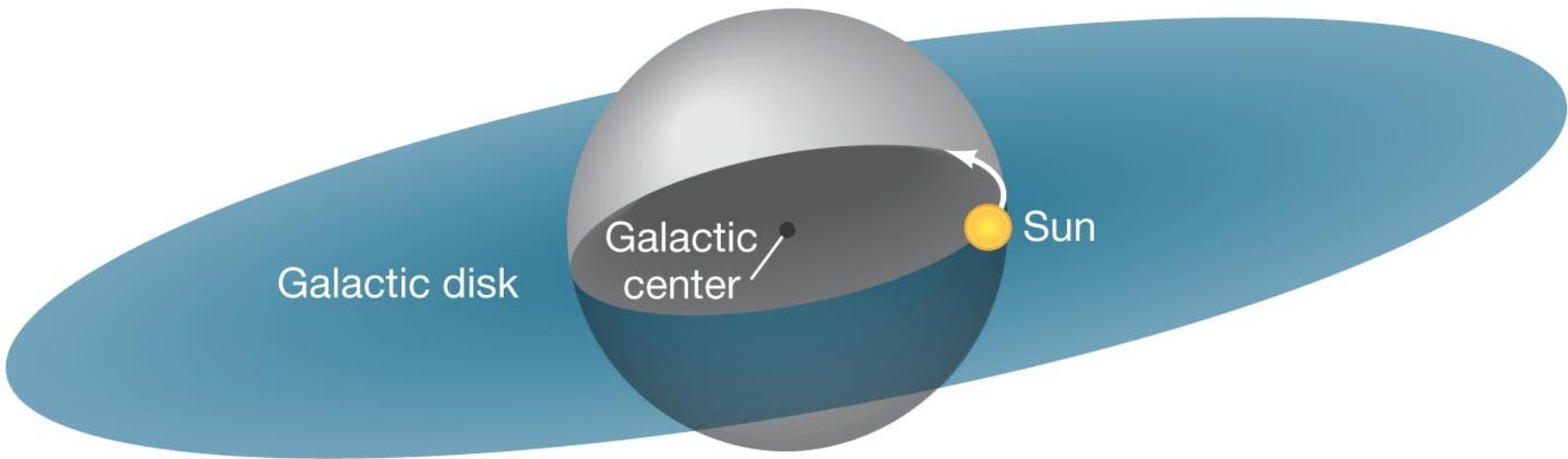
# Galactic Spiral Arms

Rather, they appear to be density waves, with stars moving in and out of them such as cars move in and out of a traffic jam:



# The Mass of the Milky Way Galaxy

The orbital speed of an object depends only/mainly on the amount of mass between it and the galactic center for a spherical/cylindrical mass distribution.

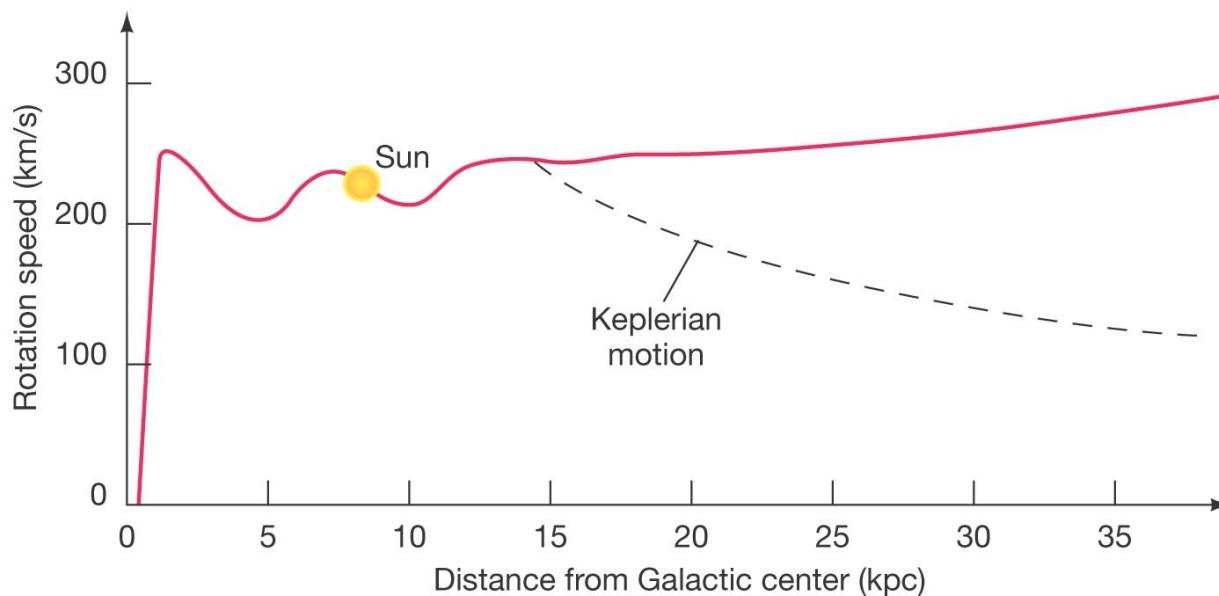


(Newton's shell theorem applies strictly to spherical mass distributions.)

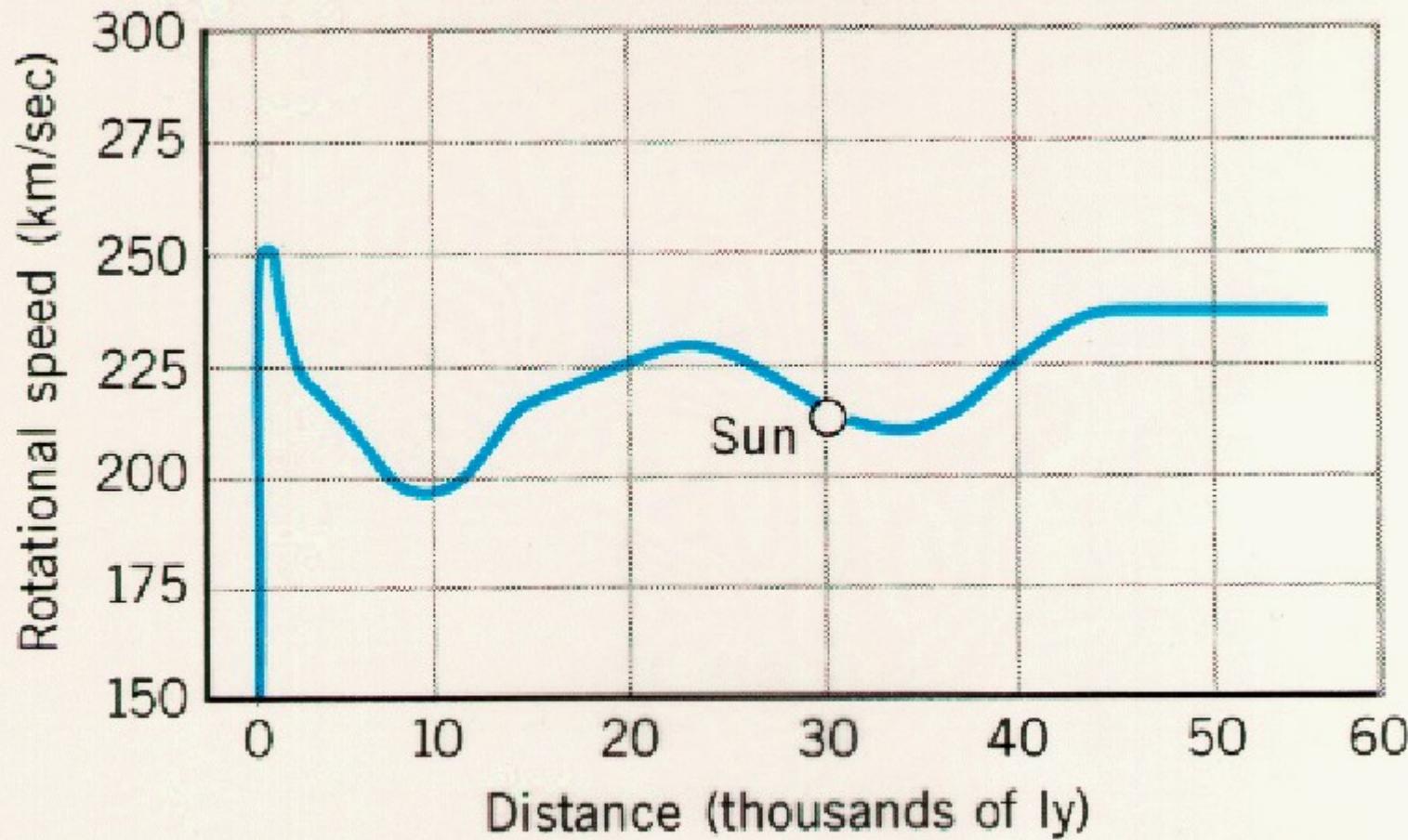
# The Mass of the Milky Way Galaxy

Beyond the limits of the visible galaxy, the velocity should diminish with distance, as the dashed curve shows.

It doesn't; more than twice the mass of the galaxy would have to be outside the visible part to reproduce the observed curve.



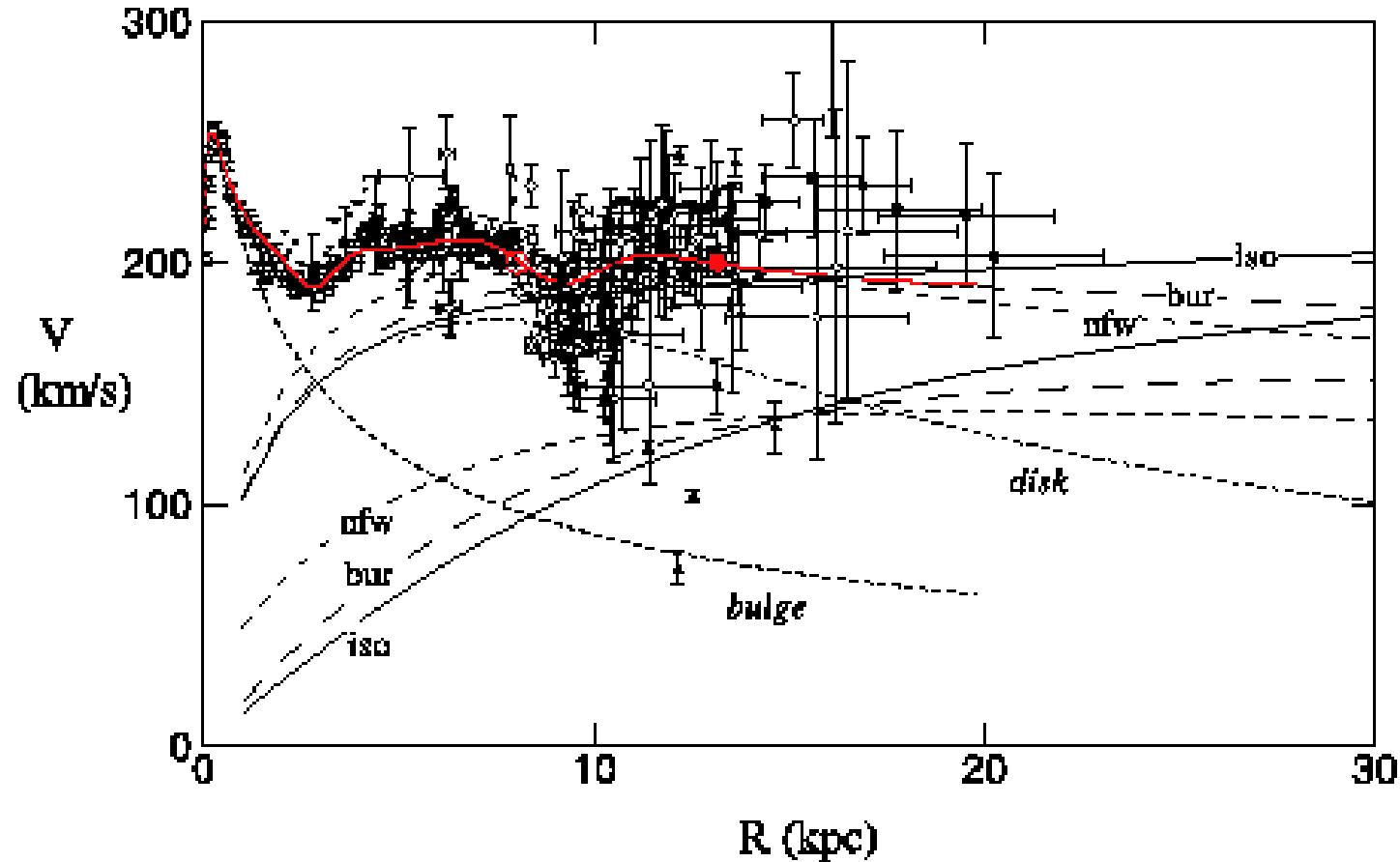
# The Mass of the Milky Way Galaxy



Galactic rotation curve, based on carbon monoxide and hydrogen observations; the sun's speed is 220 km/s and its distance is 30,000 ly.

Another smoothed, simplified view.

# The Mass of the Milky Way Galaxy

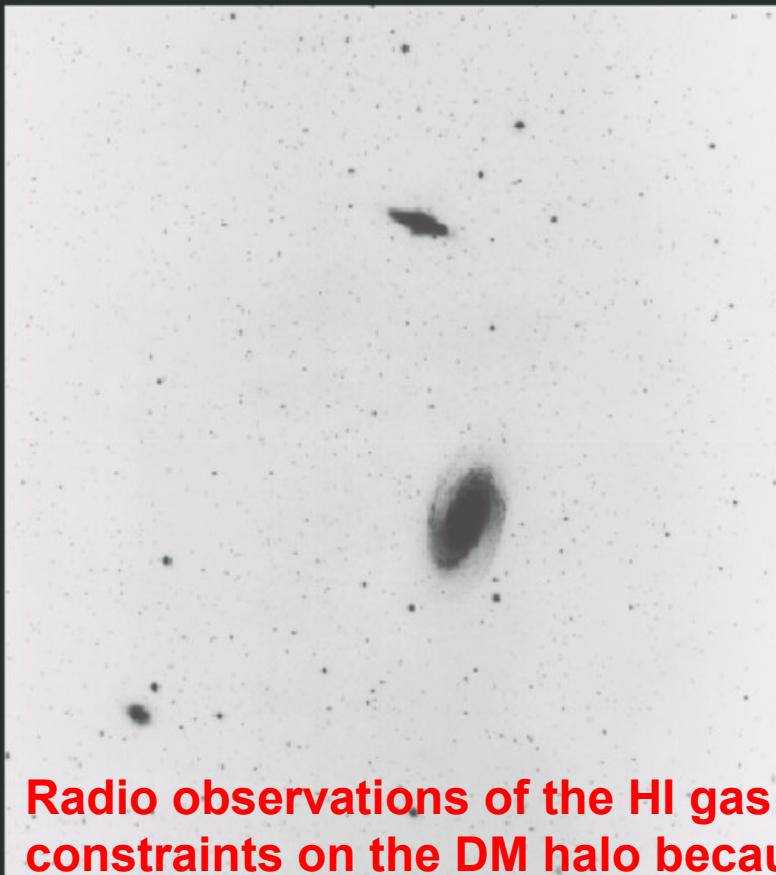


Data from Sofue (2006) with contributions from model components shown.

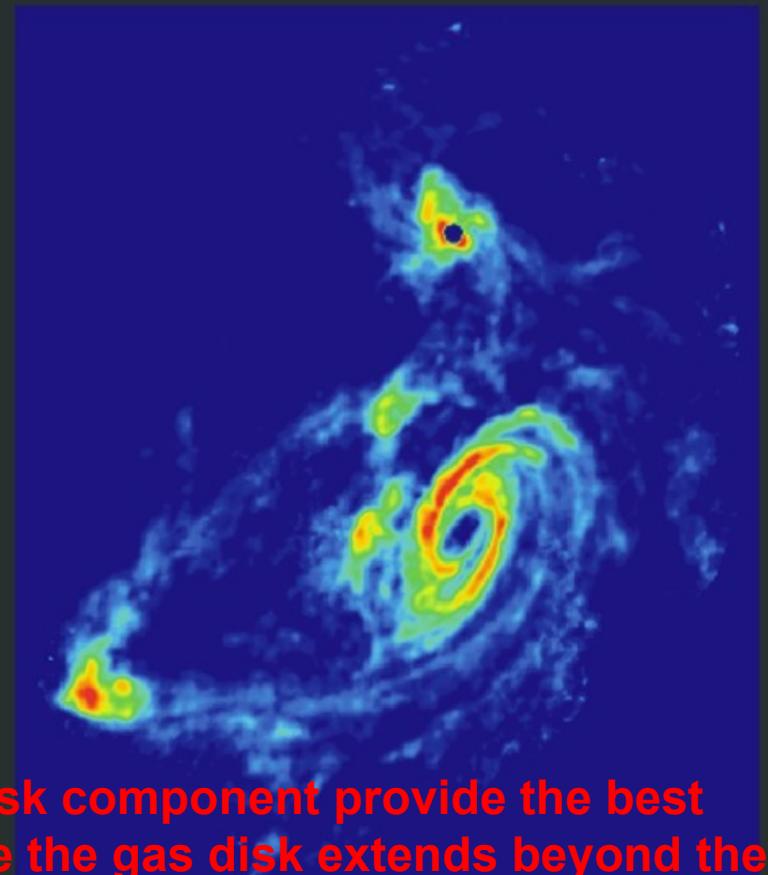
# The Mass of the Milky Way Galaxy

## TIDAL INTERACTIONS IN M81 GROUP

Stellar Light Distribution

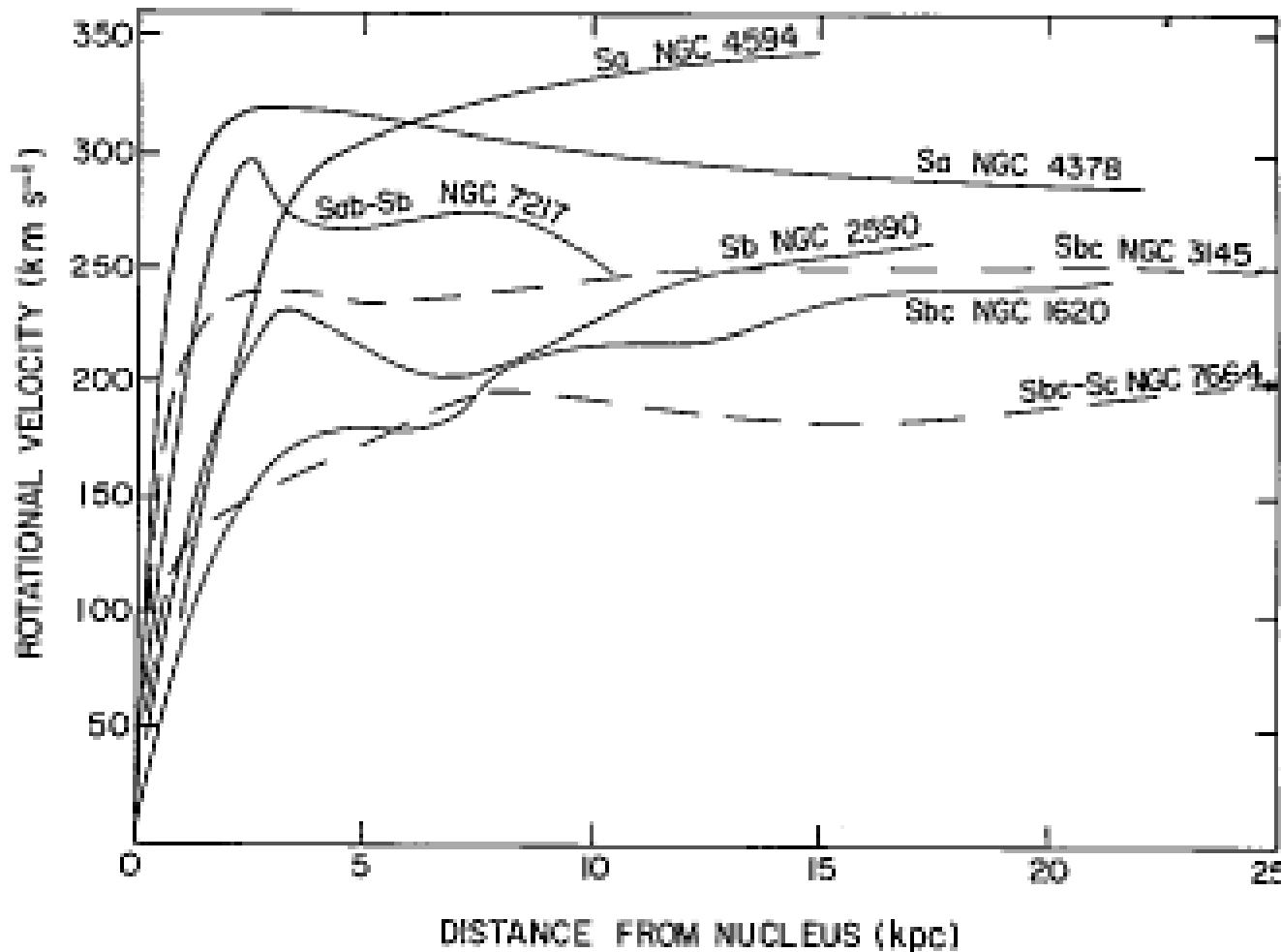


21 cm HI Distribution



Radio observations of the HI gas disk component provide the best constraints on the DM halo because the gas disk extends beyond the visible stellar disk.

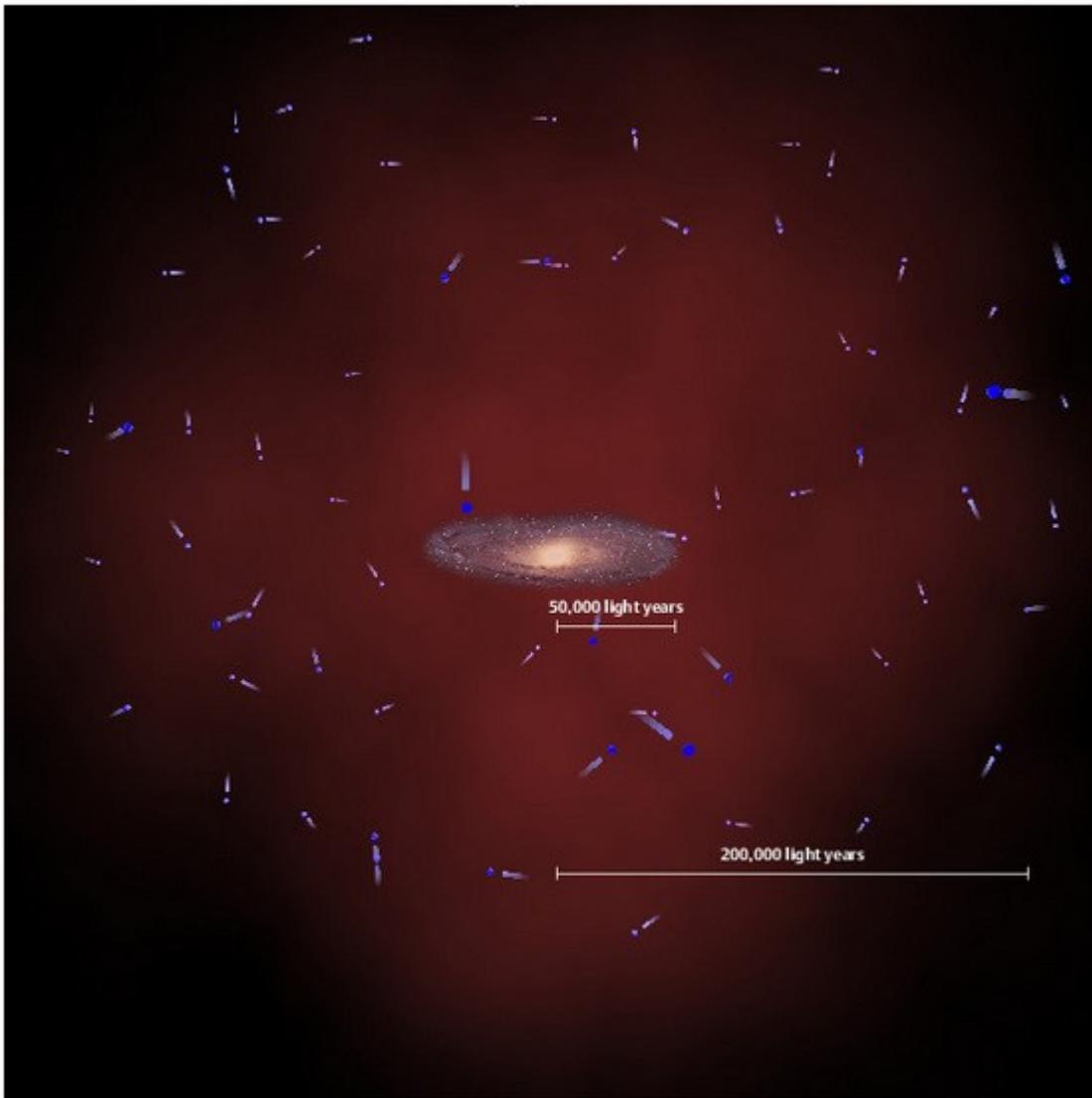
# The Mass of the Milky Way Galaxy



Rotation curves of other spiral galaxies. Rubin, Ford, and Thonnard (1978).

# The Mass of the Milky Way Galaxy

The MW has a dark matter halo.



**Candidates:**

**MACHOS:**

**Brown dwarfs**

**Red dwarfs**

**Stellar black holes**

**Neutron stars**

**WIMPS:**

**Axions, neutrinos,  
unknown**