The Distance Ladder I.

The Milky Way Galaxy

(Ch. 23)

Units of Chapter 23

1. Our Milky Way Galaxy

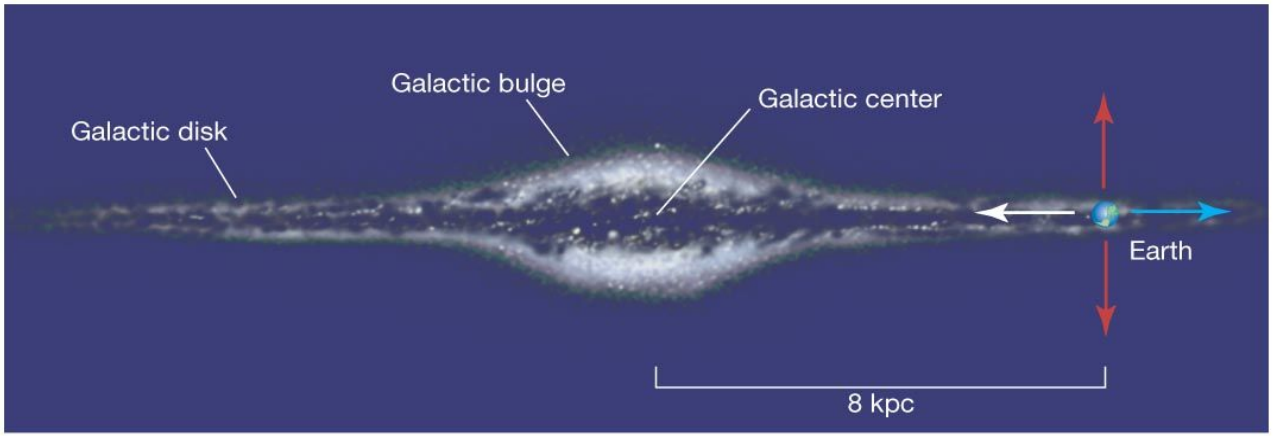
a) Dimensions and structure
b) Spiral Arms
c) Mass and Dark Matter
d) Nucleus

2. Distances within the Milky Way

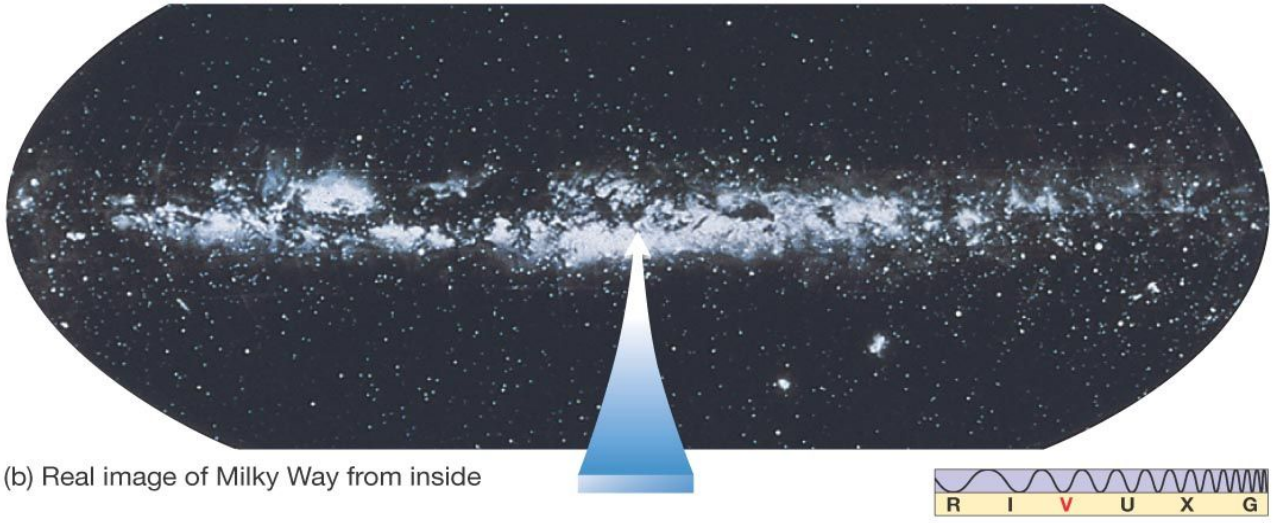
a) Stellar and spectroscopic parallax
b) “Standard Candles” or “Beasts of a kind” concept
c) Herschel's star counts
d) “Intrinsic” Variable Stars
e) Other Distance Indicators

23.1 Our Parent Galaxy

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



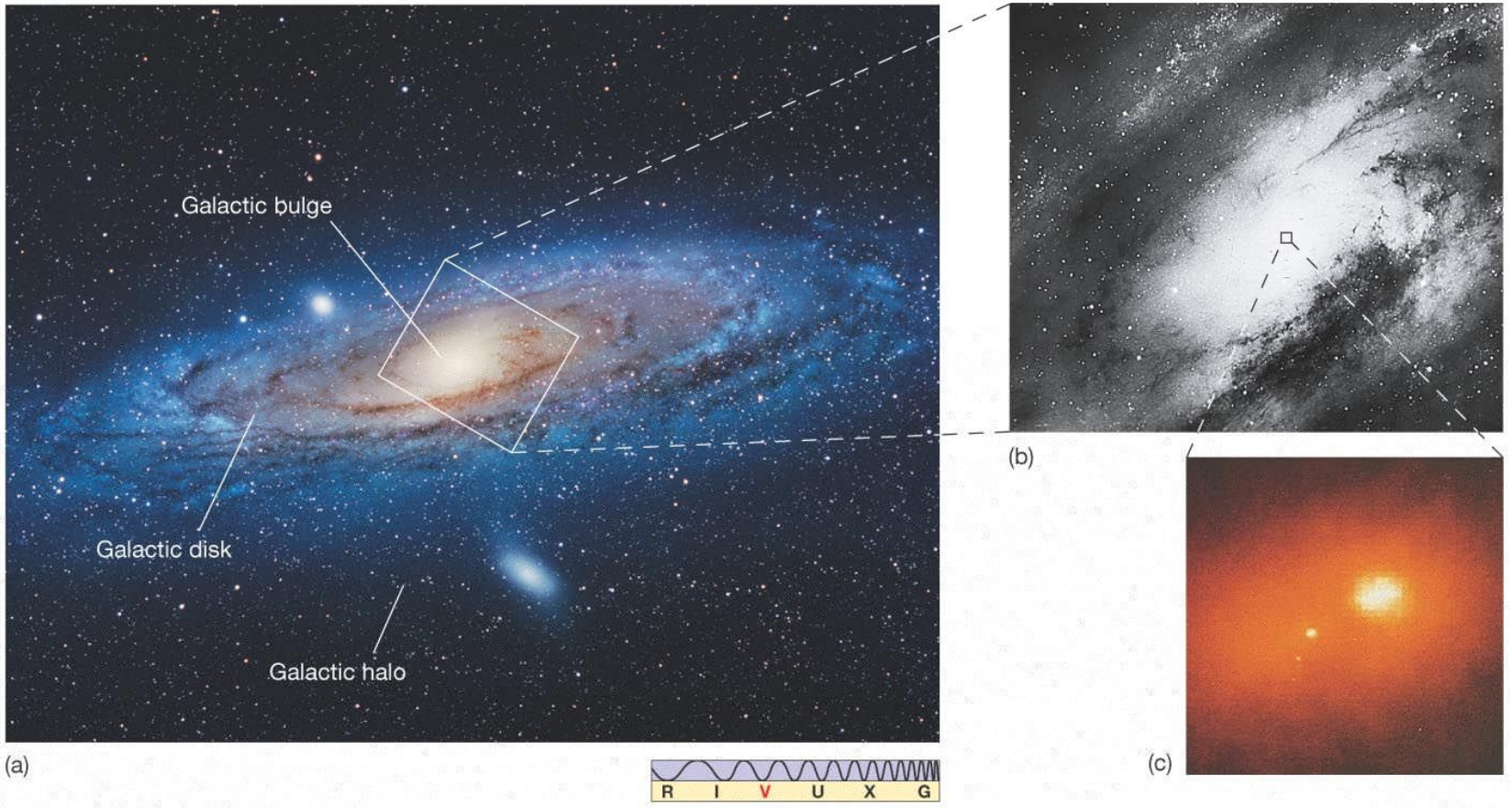
(a) Artist's view of Milky Way from afar



(b) Real image of Milky Way from inside

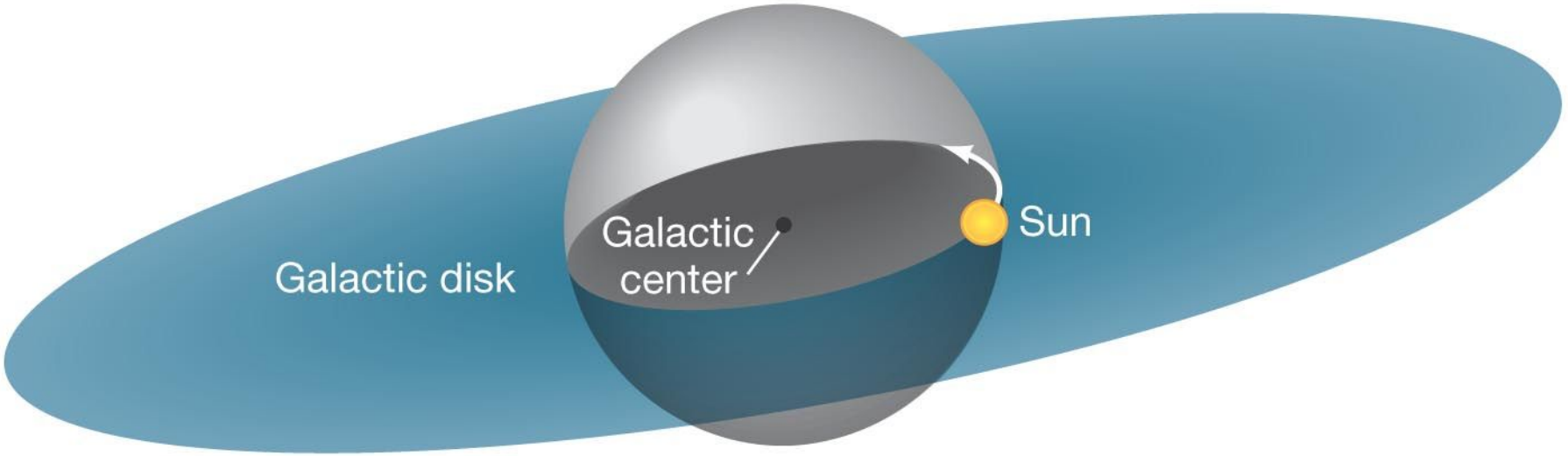
23.1 Our Parent Galaxy

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



23.6 The Mass of the Milky Way Galaxy

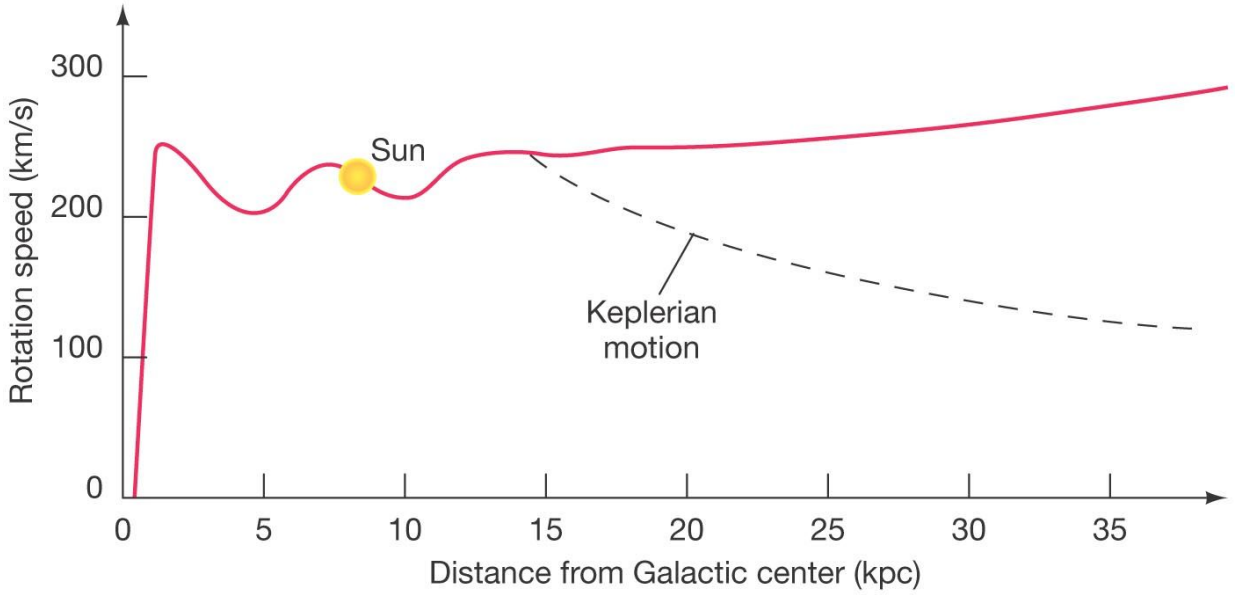
The orbital speed of an object depends only on the amount of mass between it and the galactic center:



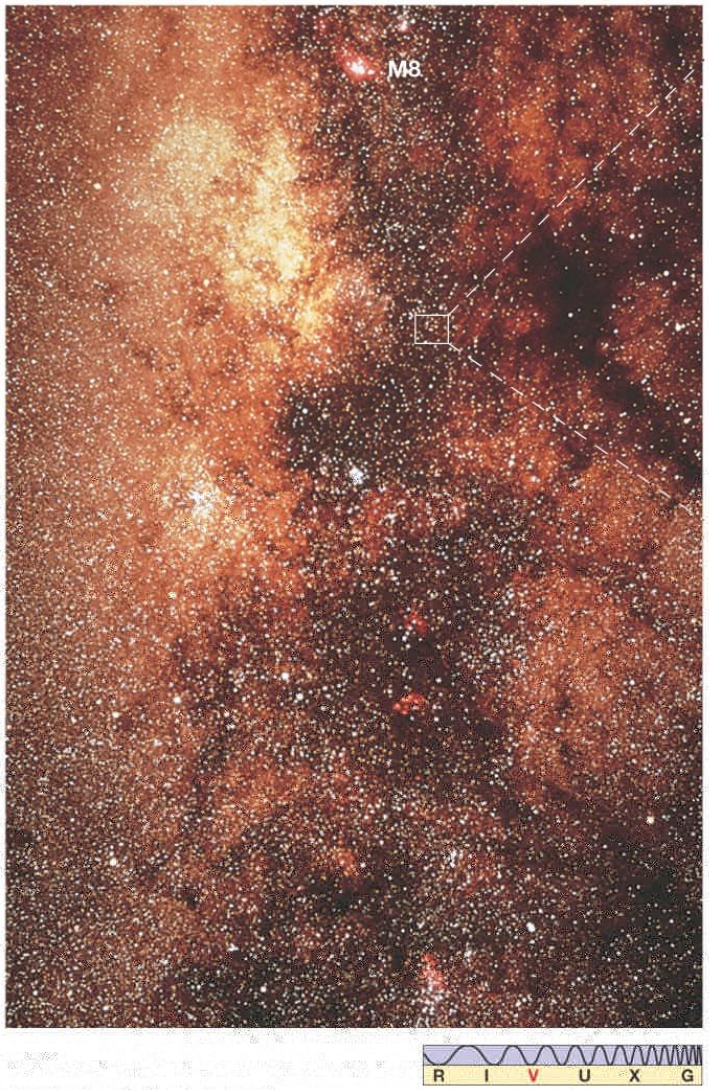
23.6 The Mass of the Milky Way Galaxy

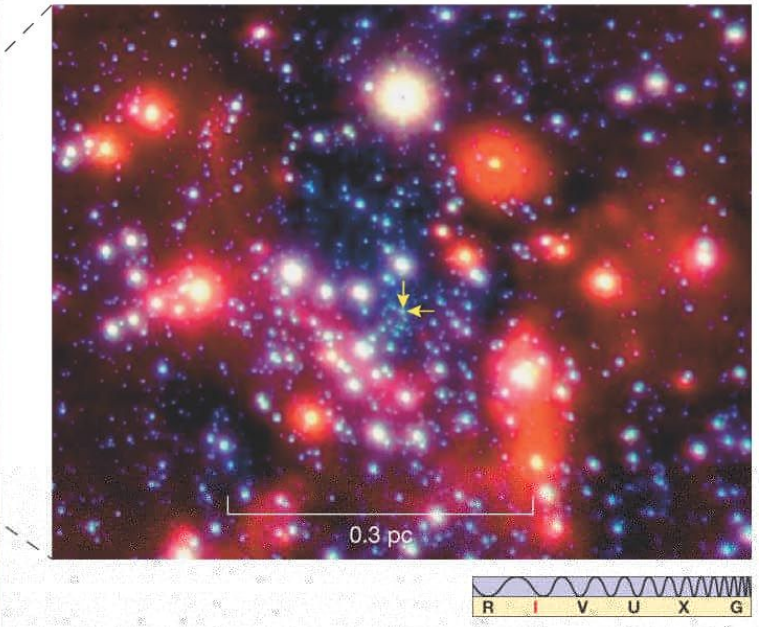
Once all the galaxy is within an orbit, the velocity should diminish with distance, as the dashed curve shows.

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



23.7 The Galactic Center

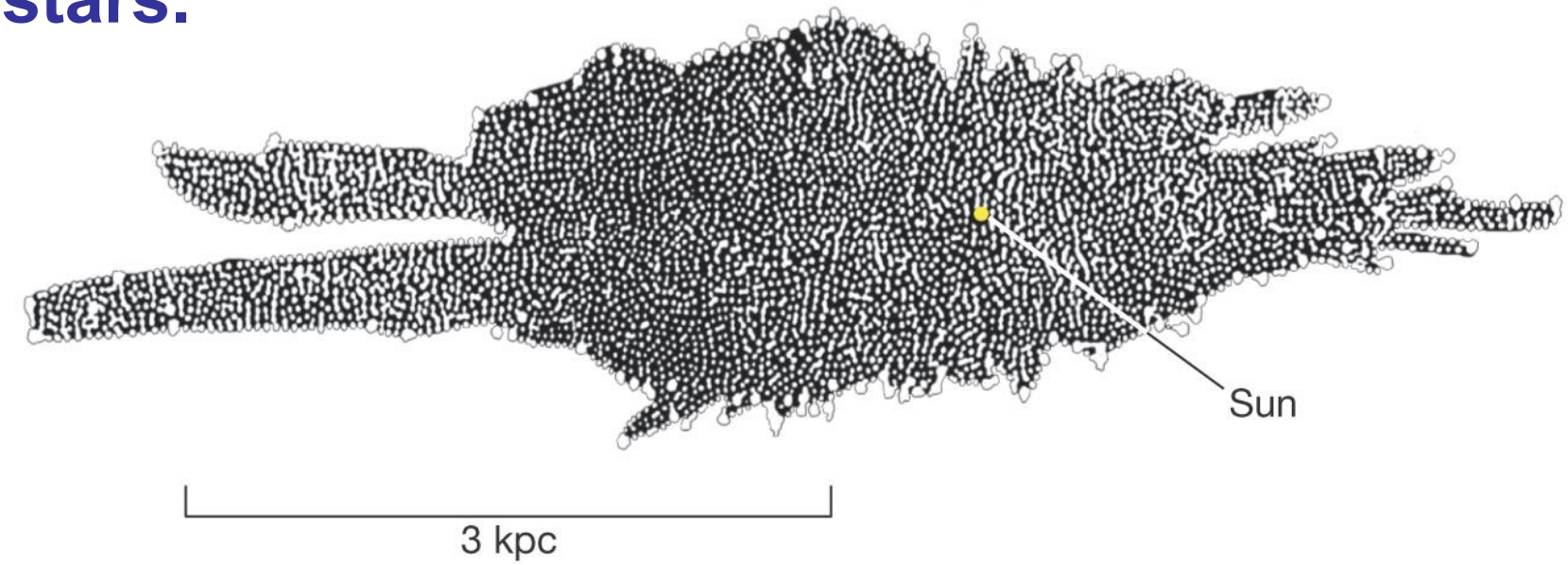




Two views toward the galactic center.

23.2 Measuring the Milky Way

One of the first attempts to measure the Milky Way was done by W. Herschel using visible stars.



Problems:

1. **patchy dust blocked view! (extinction)**
2. **all stars do not have the same luminosity!!**

23.2 Measuring the Milky Way

A model based on star brightnesses, types, & motions was done by Jacobus Kapteyn (1850-1922).

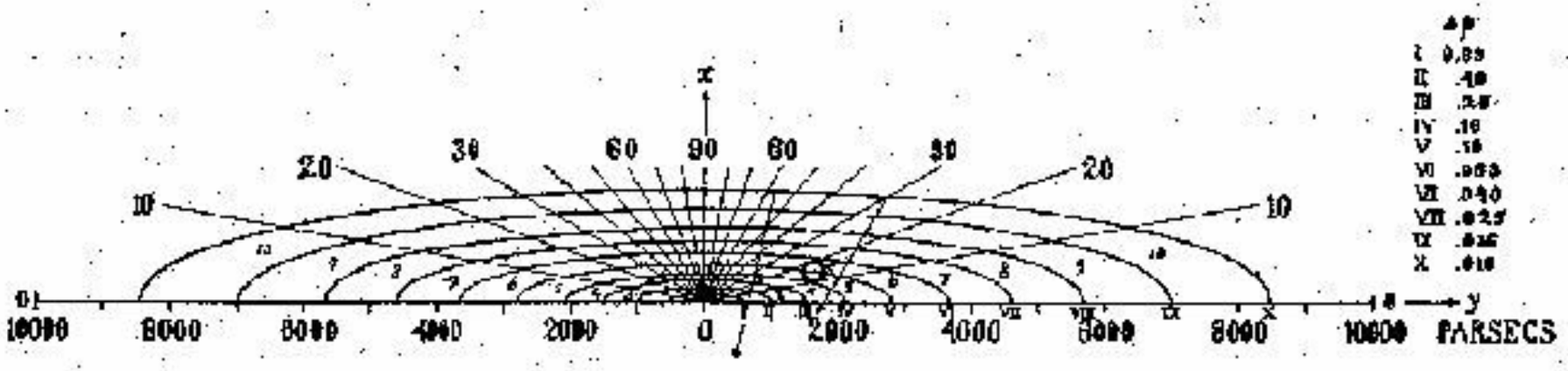
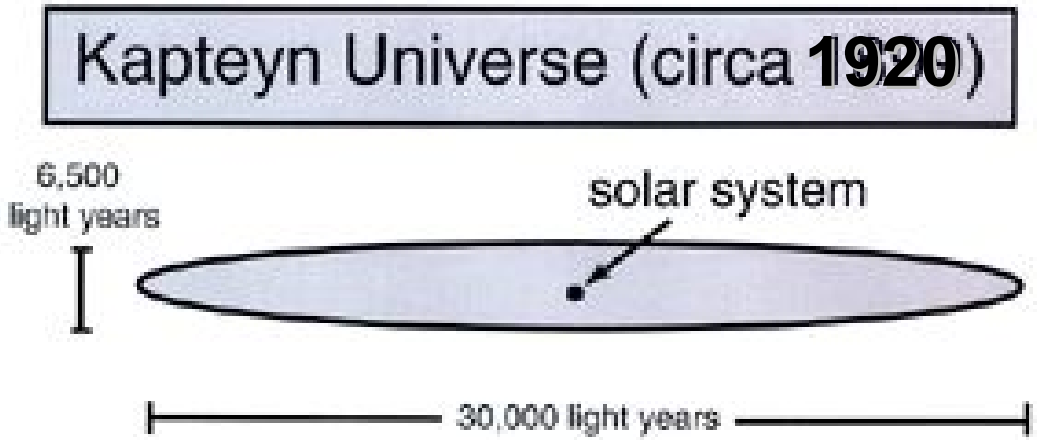


FIG. 1

Still lacked corrections for extinction.
Sun 2000 LY from center.



23.2 Variable stars & distances

Extrinsic variables: eclipsing binaries

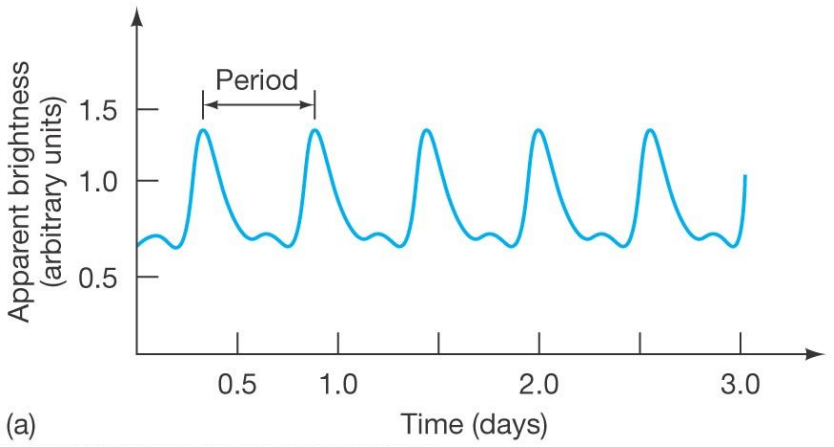
Cataclysmic variables: novae, supernovae.

``Intrinsic variables'' - pulsating regularly: RR Lyrae stars and Cepheids. - very good for distances!

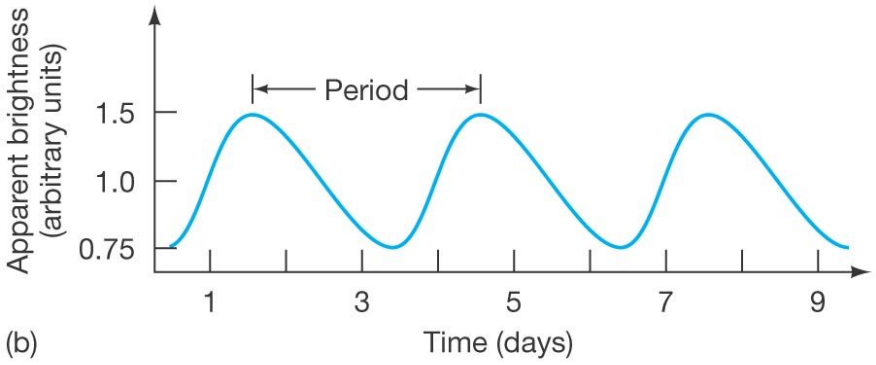
Long period, semi-regular variables (like Mira) – not good for distances

23.2 Variable stars & distances

The upper plot is an **RR Lyrae** star. All such stars have essentially the same luminosity curve with periods from **0.5** to **1** day.



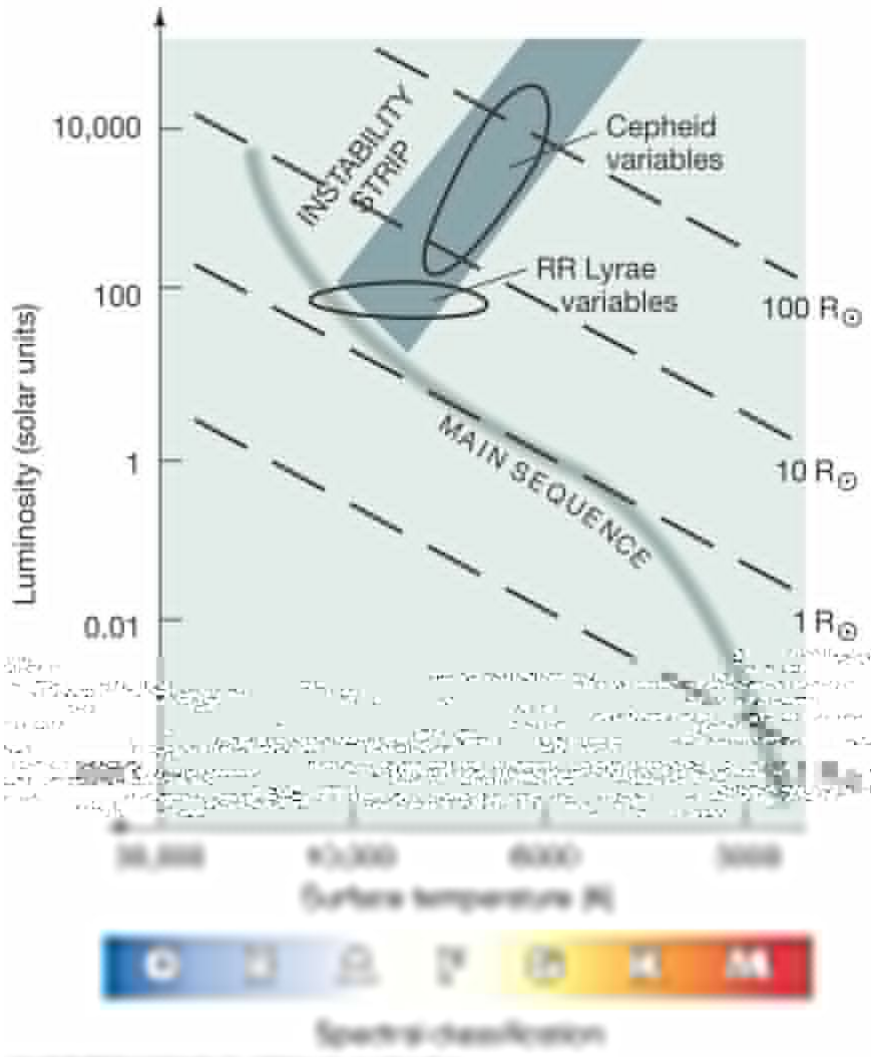
The lower plot is a **Cepheid** variable; Cepheid periods range from about **1** to **100** days.



23.2 Variable stars & distances

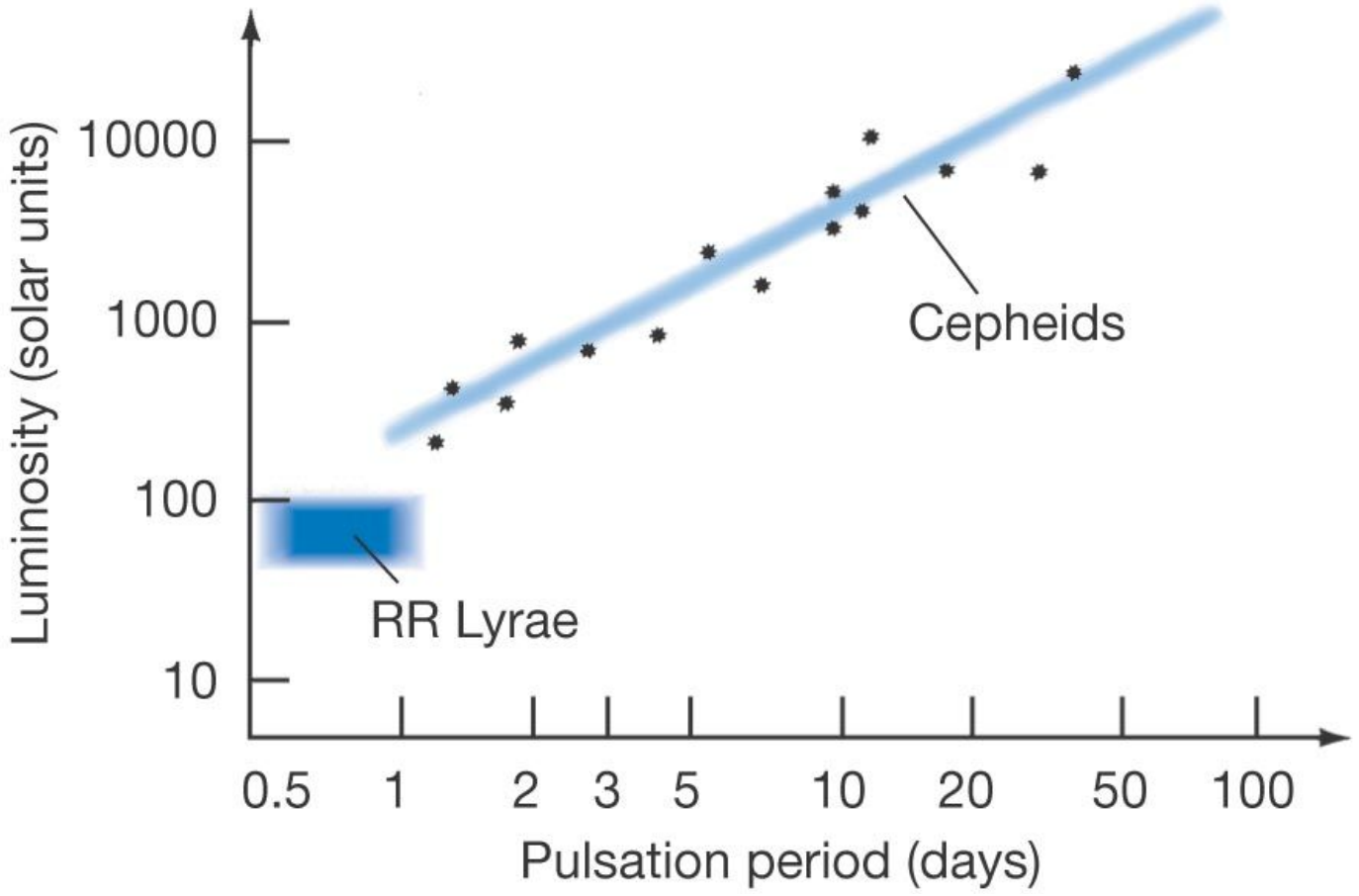
The variability of these stars comes from a dynamic balance between gravity and pressure—they have large oscillations around stability.

- Helll opacity-



23.2 Variable stars & distances

The usefulness of these stars comes from their period–luminosity relation:



23.2 Variable stars & distances

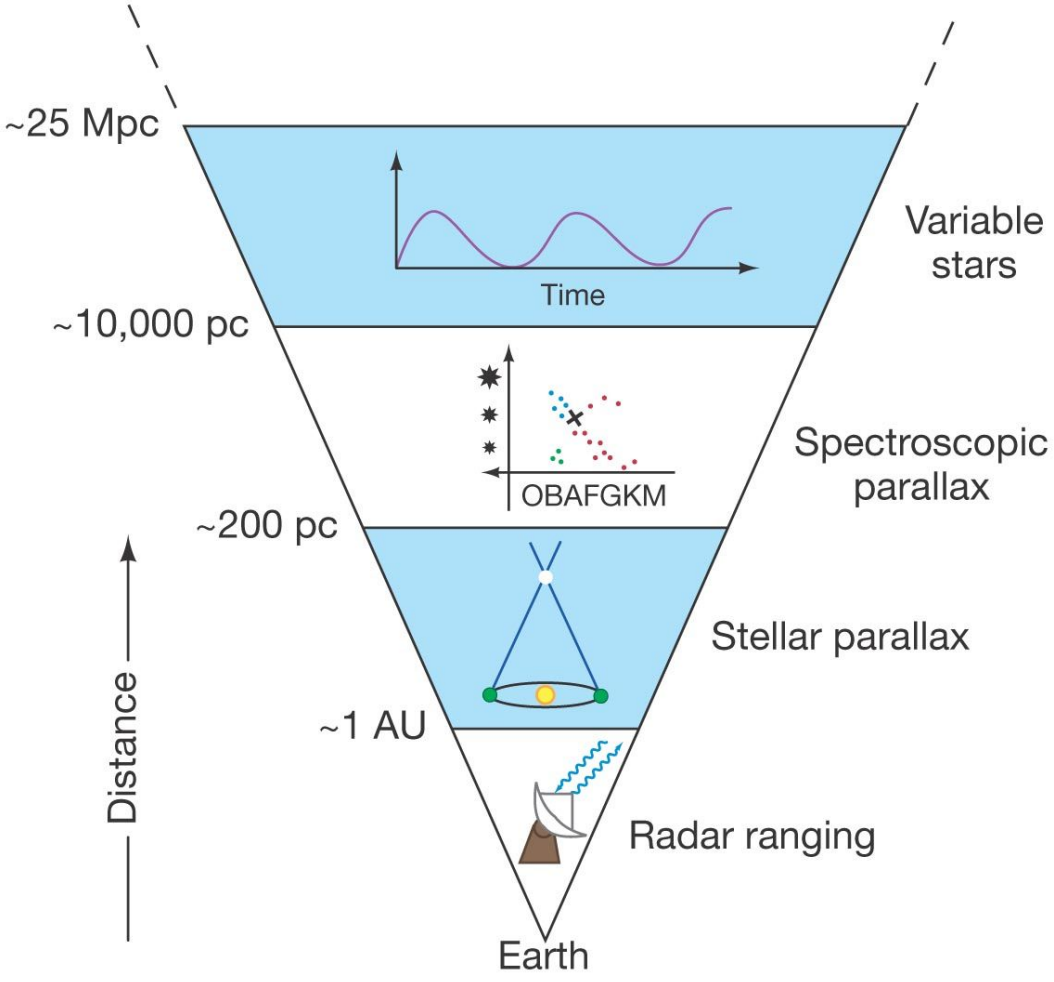
This allows us to measure the **distances** to these stars:

- **RR Lyrae** stars all have about the same **luminosity**; knowing their **apparent magnitude** allows us to calculate the **distance**.

- **Cepheids** have a **luminosity** that is strongly correlated with the **period** of their oscillations; once the period is measured, the luminosity is known and we can proceed as above.

23.2 Measuring the Milky Way

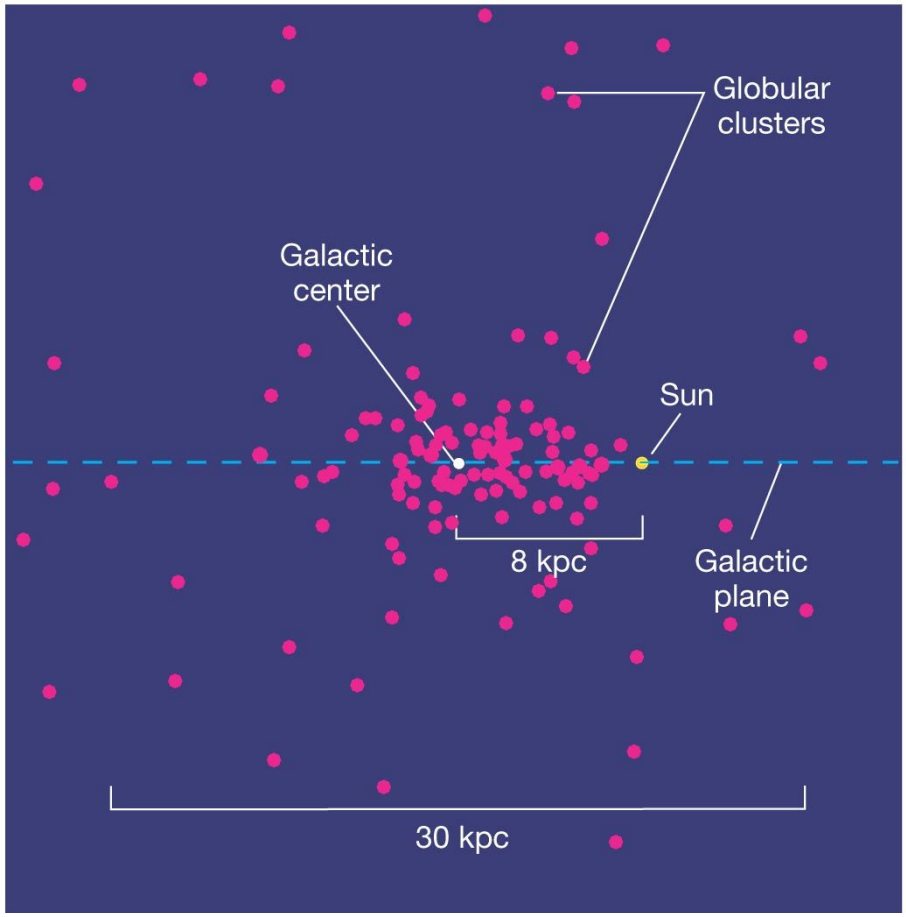
We have now expanded our cosmic distance ladder one more step:



23.2 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.

This yields a much more **accurate** picture of the extent of our galaxy and our place within it.



23.2 Distance indicators

So Far:

Novae, supernovae, cepheids, RR Lyrae

Other Standard Candles:

Brightest blue stars, Brightest red stars

Tip of the red giant branch (TRGB)

Planetary nebula luminosity function (PNLF)

globular cluster luminosity function (GCLF)

Standard Yardsticks:

Open Clusters, Globular Clusters, HII regions,

Size of galaxies of specific types

Other techniques:

Eclipsing Binaries, spectro. parallax, stel. Parallax,

Globular cluster spatial distribution

Trig parallax using radio interferometry! (2009)

Summary

- A good “standard candle” is luminous
- Variable stars can be used for distance measurement through the period–luminosity relationship.
- The extent of the Galaxy can be determined using globular clusters.
- Modern mapping of the MW is done with radio interferometry of gas clouds.

Summary of Chapter 23 (cont.)

- Spiral arms may be density waves.
- The galactic rotation curve shows large amounts of undetectable mass at large radii called dark matter.
- Activity near galactic center suggests presence of a 2 to 3 million solar-mass black hole