Week 11

Star Clusters, Black Holes, Galaxies & Dark Matter

November 30, 2016

This Week

- Monday: Star clusters and galaxies
- Tuesday: Activity 23, Black holes, (space and time)
- **Wed: Star clusters; Cosmic Ladder; Dark matter & Dark energy, and the structure of galaxies**
- Friday: The expanding universe and the Big Bang

- Final Exam on Tuesday, December 6, 8-10 AM
  - *Cumulative: ~25% material from each midterm exam and 25% new material*
- **Review sessions:** CF 115, Thursday (10-11am) & Friday (1-2pm)

Today: Learning objectives

- Describe the difference between globular clusters and open clusters, and between “population I” and “population II” stars

- Explain what a black hole is and where they come from
- Tell where we find super-massive black holes (SMBH) and explain why they are important

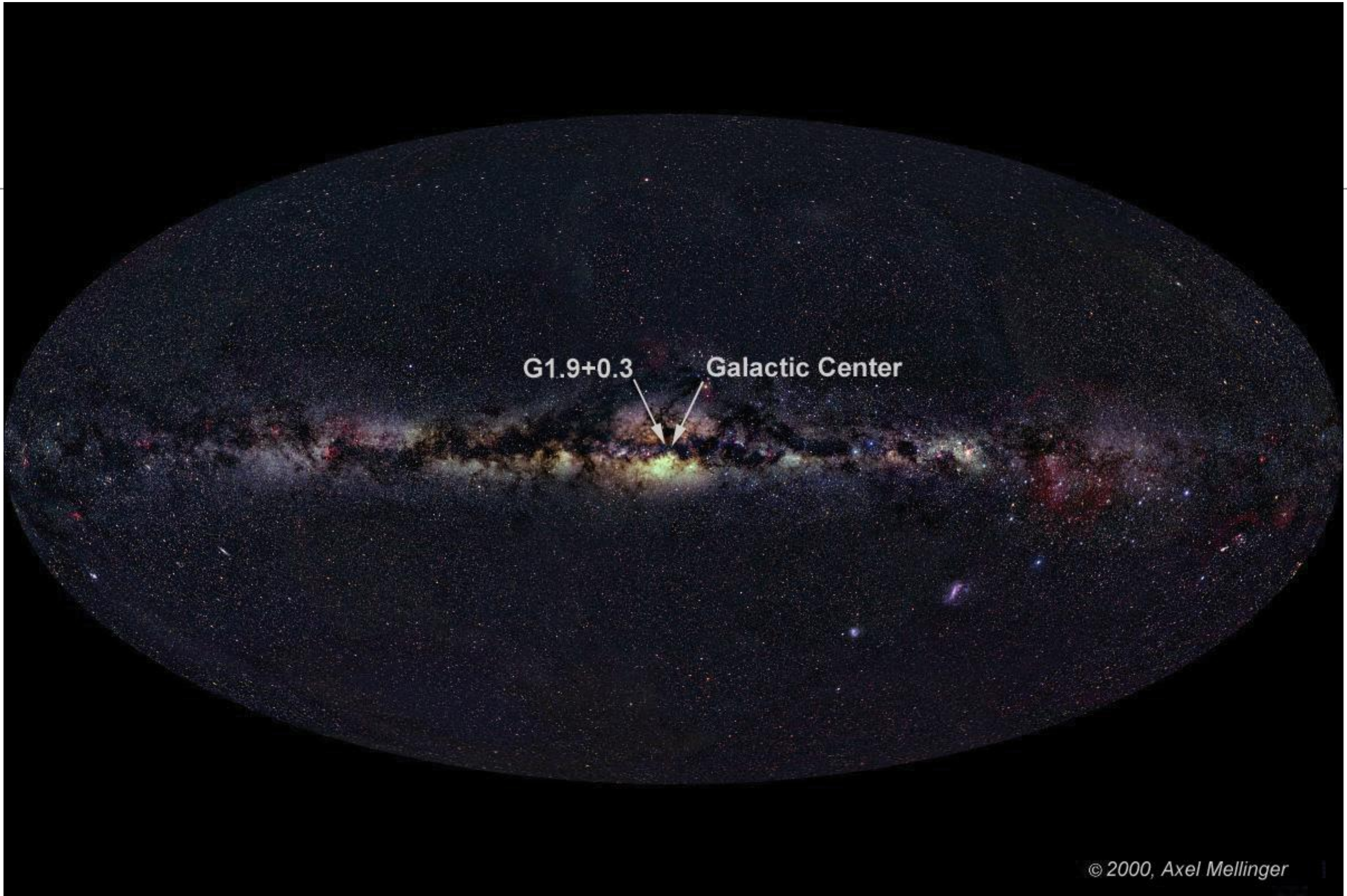
- Explain how we know distances to astronomical features, such as stars, star clusters and other galaxies

- List the types of galaxies and explain how they are related to each other

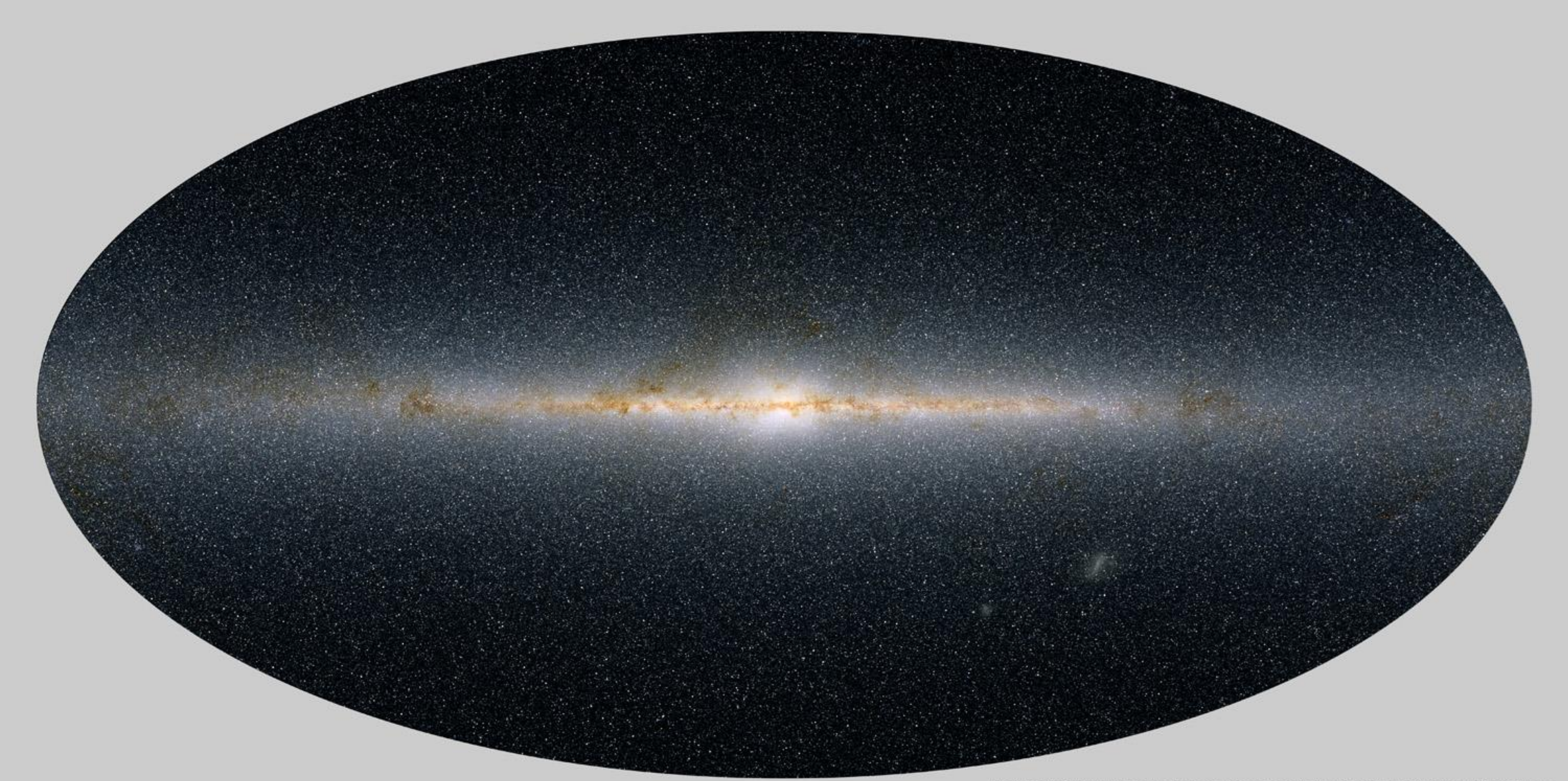
- Explain what dark matter is and how we know it is there

The Milky Way, seen one section at a time.

A complete picture of the Milky Way (in optical light)



A complete picture of the Milky Way (in infrared light)

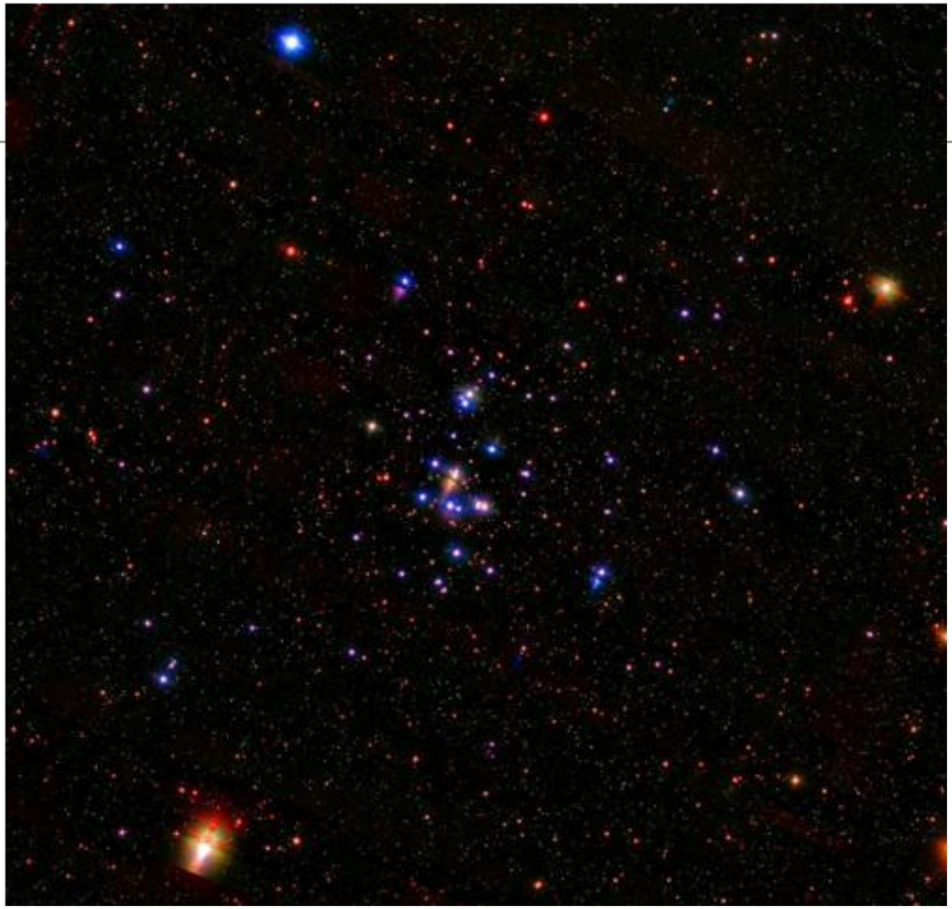


Two Micron All Sky Survey Image Mosaic: Infrared Processing and Analysis Center/Caltech & University of Massachusetts

Star clusters come in two different flavors:

Globular Clusters

Open Clusters



Rich (~10,000-100,000 stars)
Highly symmetric

Sparse (~100-10,000 star)
Asymmetric

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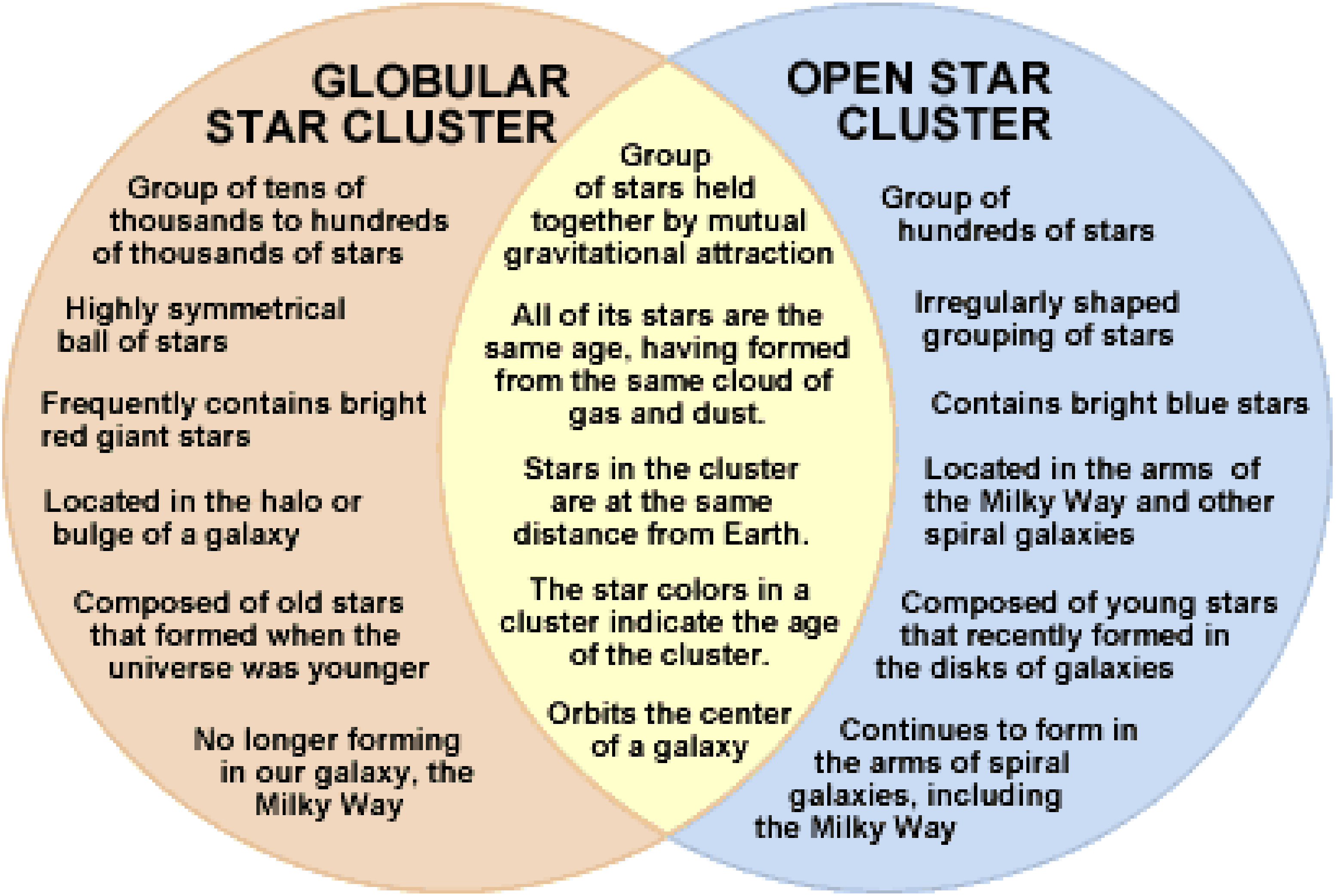
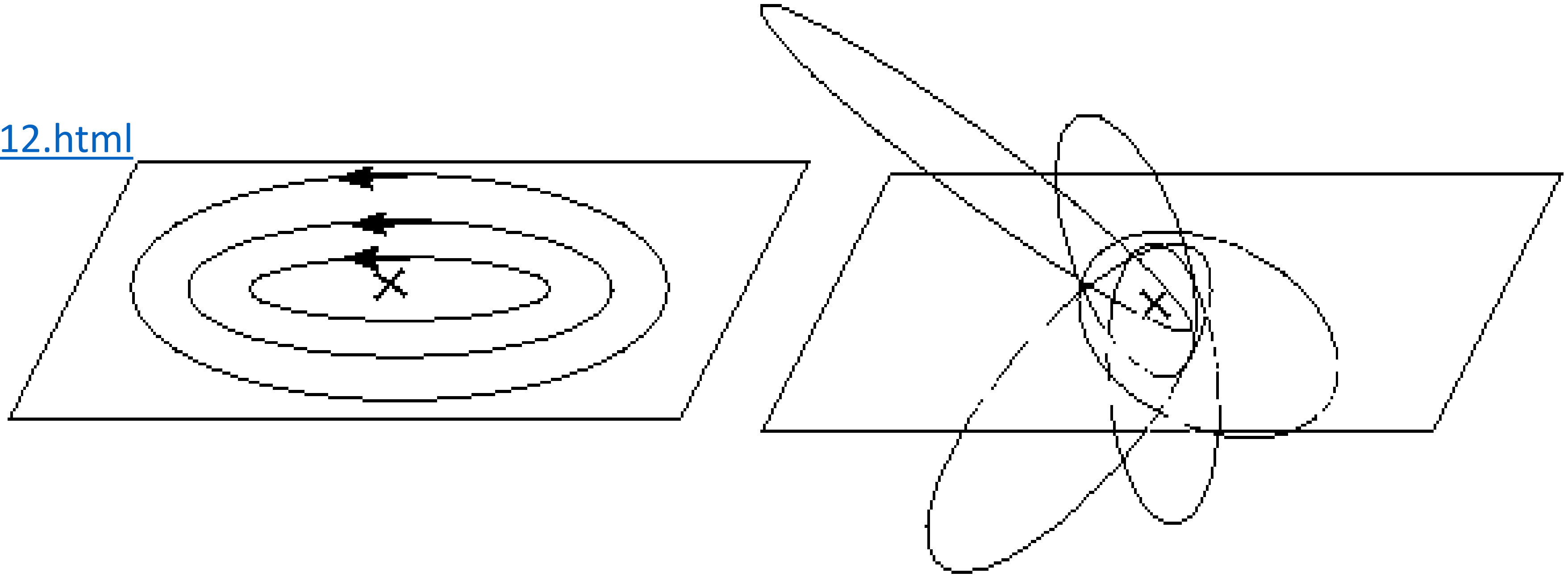


Poplulation I and Poplulation II stars

- (taken from Astronomy Notes)
- Hyperphysics

http://www.astronomynotes.com/ismnotes/starpops.gif

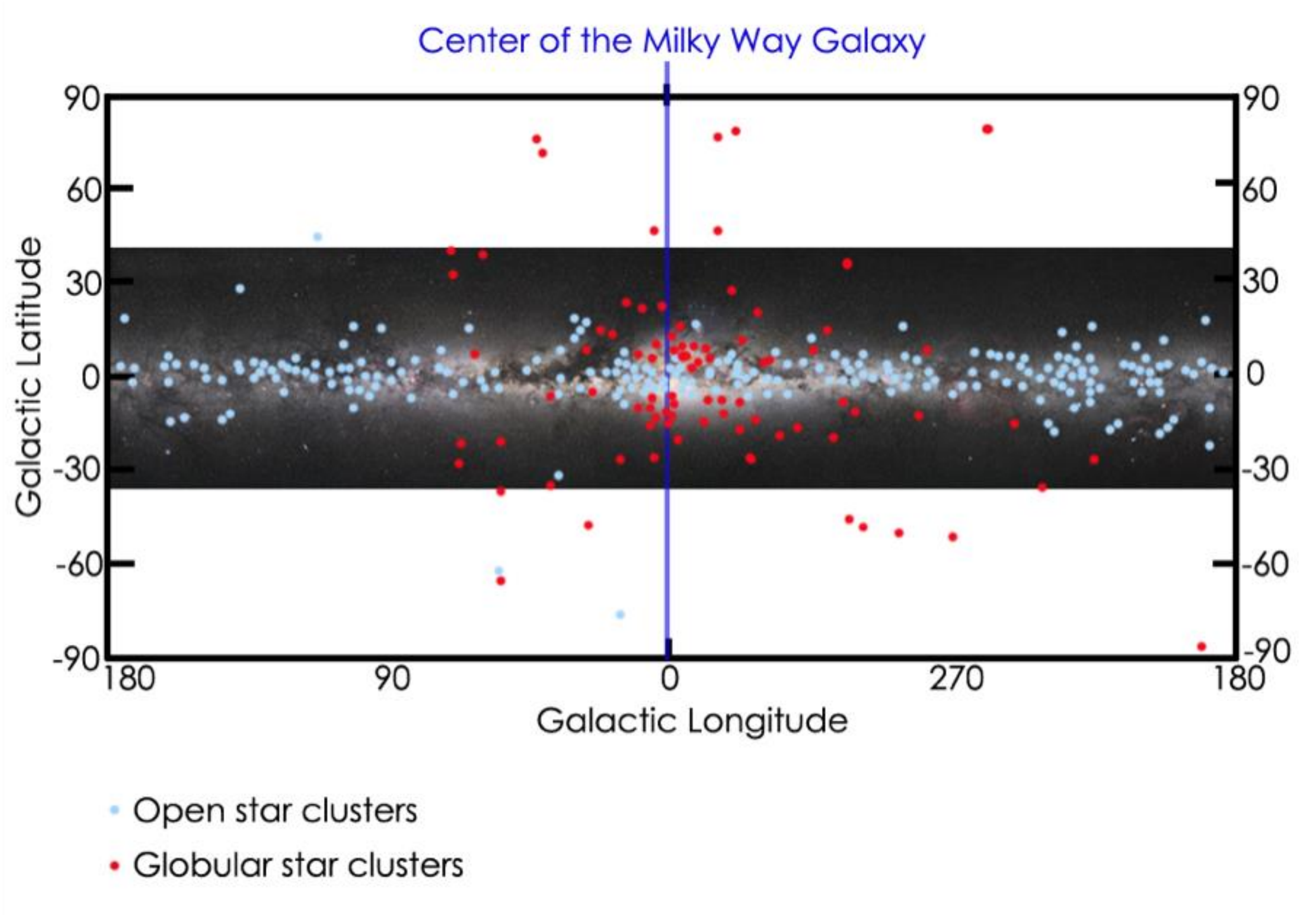
http://hyperphysics.phy-astr.gsu.edu/hbase/starlog/pop12.html



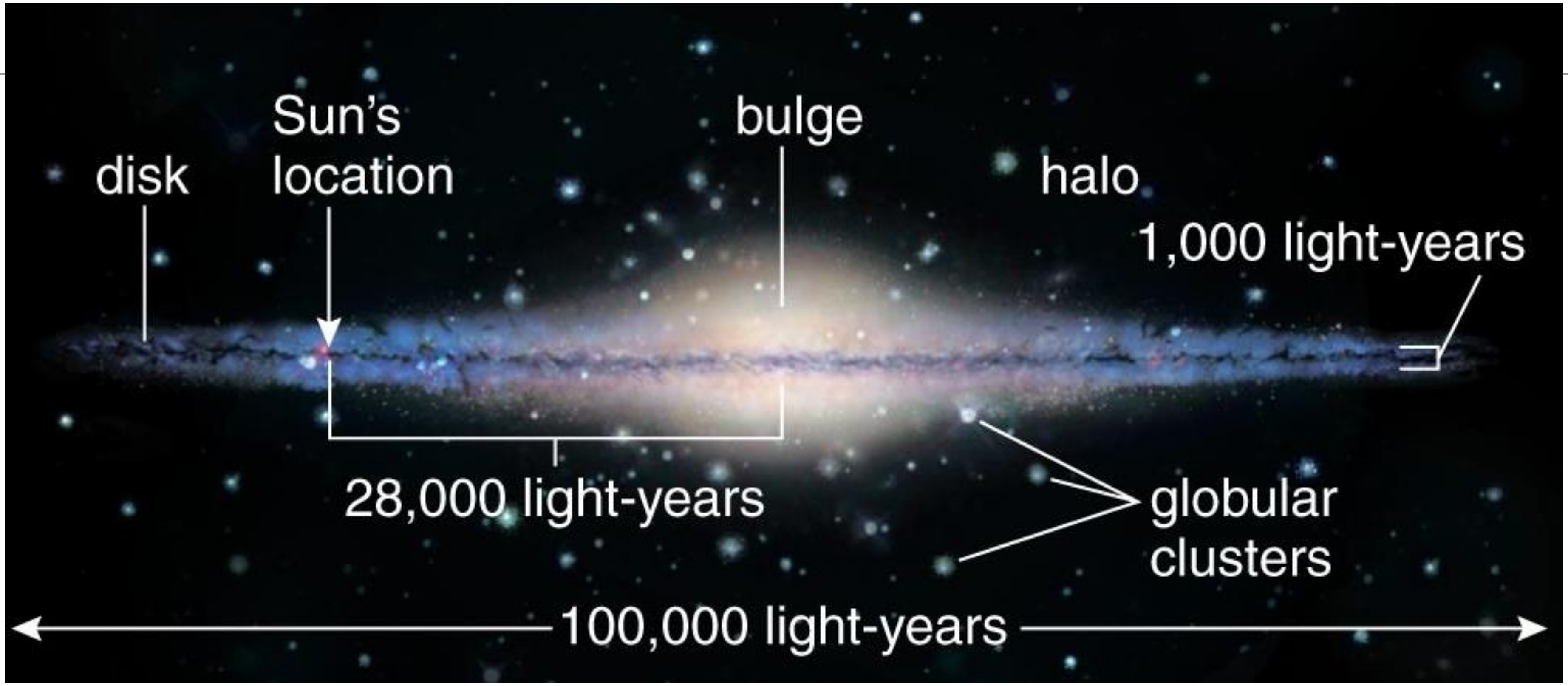
Population I stars: ordered motion. Circular orbits in the disk plane; younger, more metal-rich.

Population II stars: random motion. Eccentric orbits passing through disk plane; older, more metal-poor.

Star clusters come in two different flavors:



Star clusters gave us our first measurement of the size and age of the Milky Way.



Oldest stars & star clusters in the Milky Way: ~10 Billion years old
Youngest stars & star clusters in the Milky Way: just formed!

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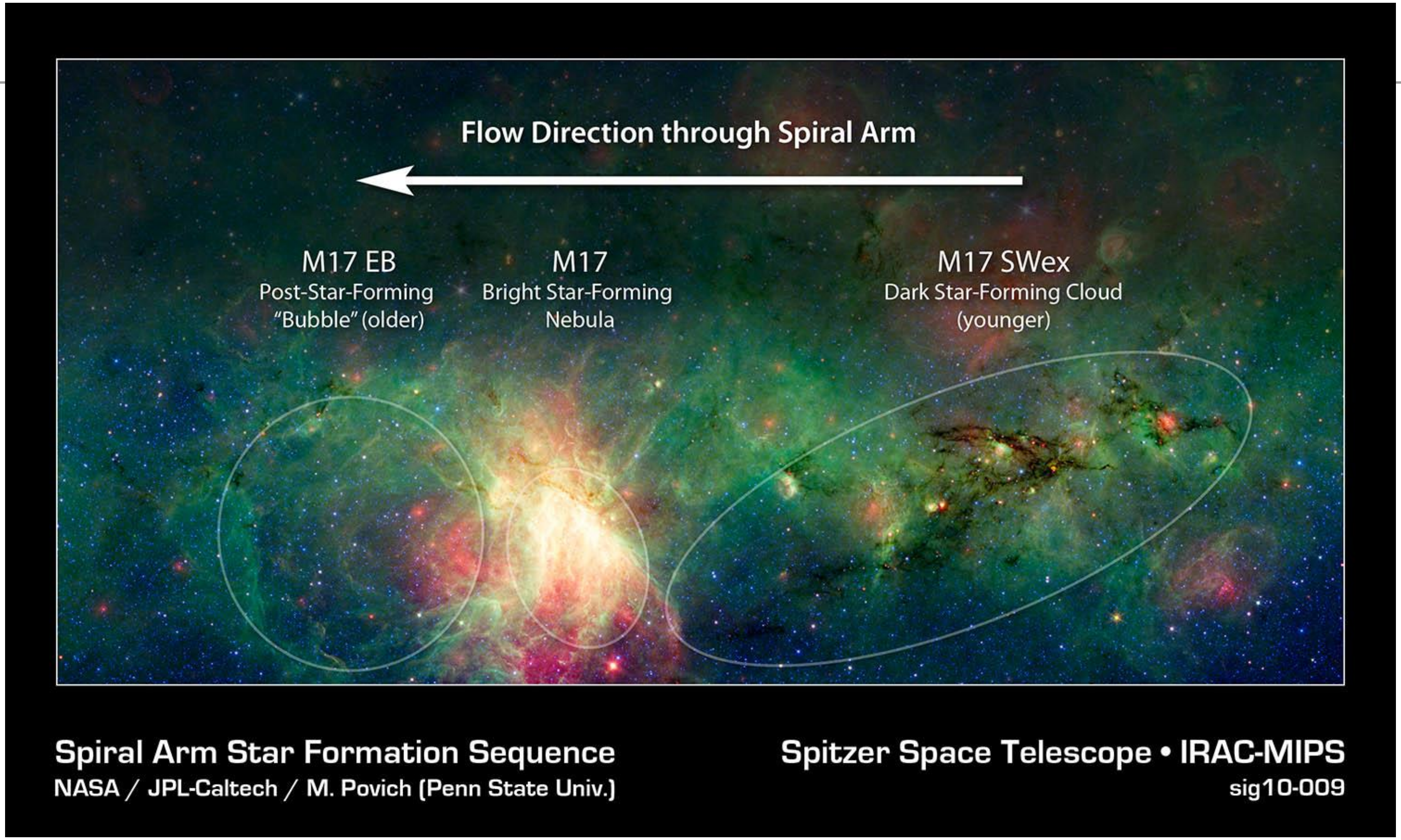

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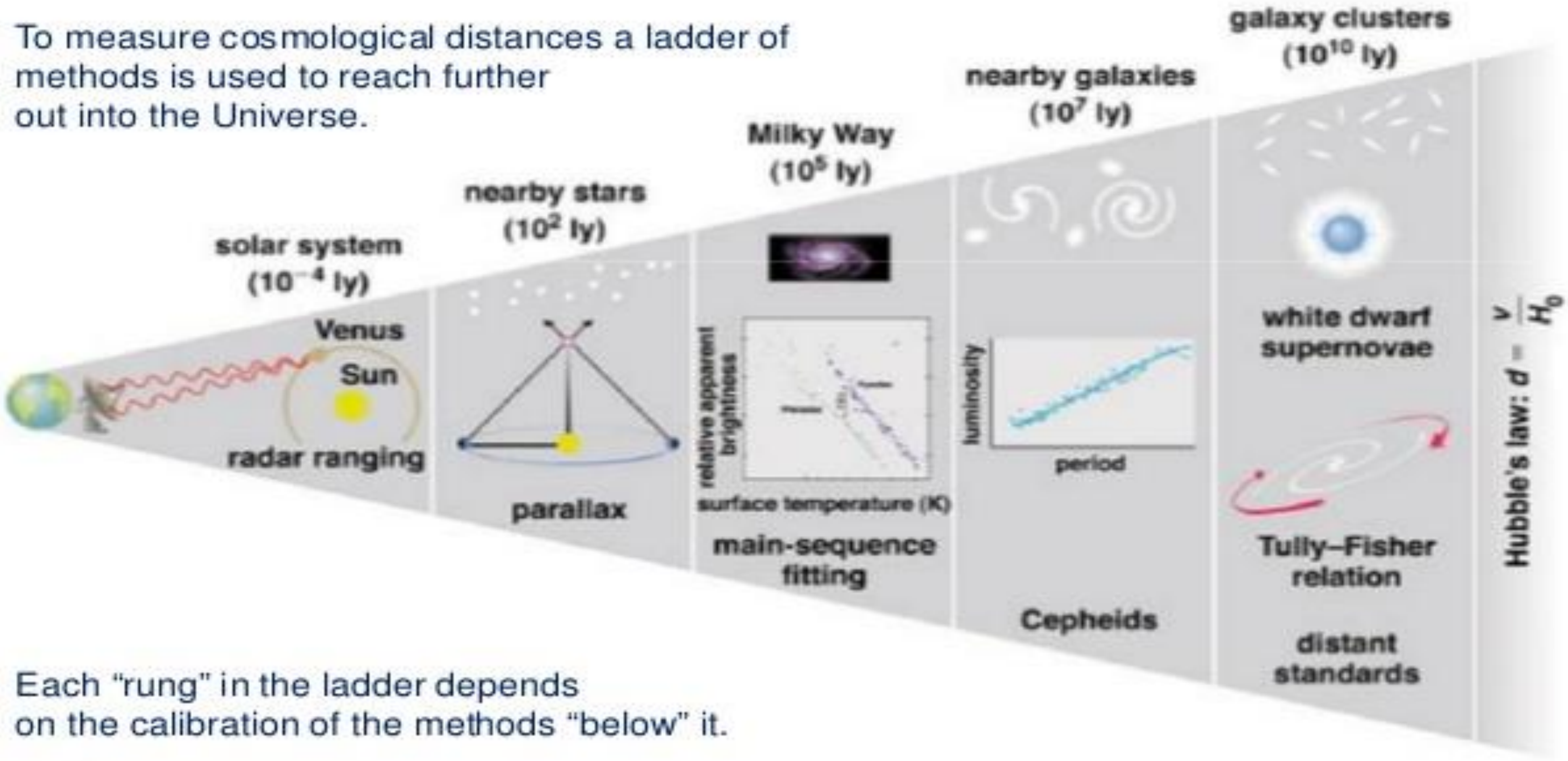
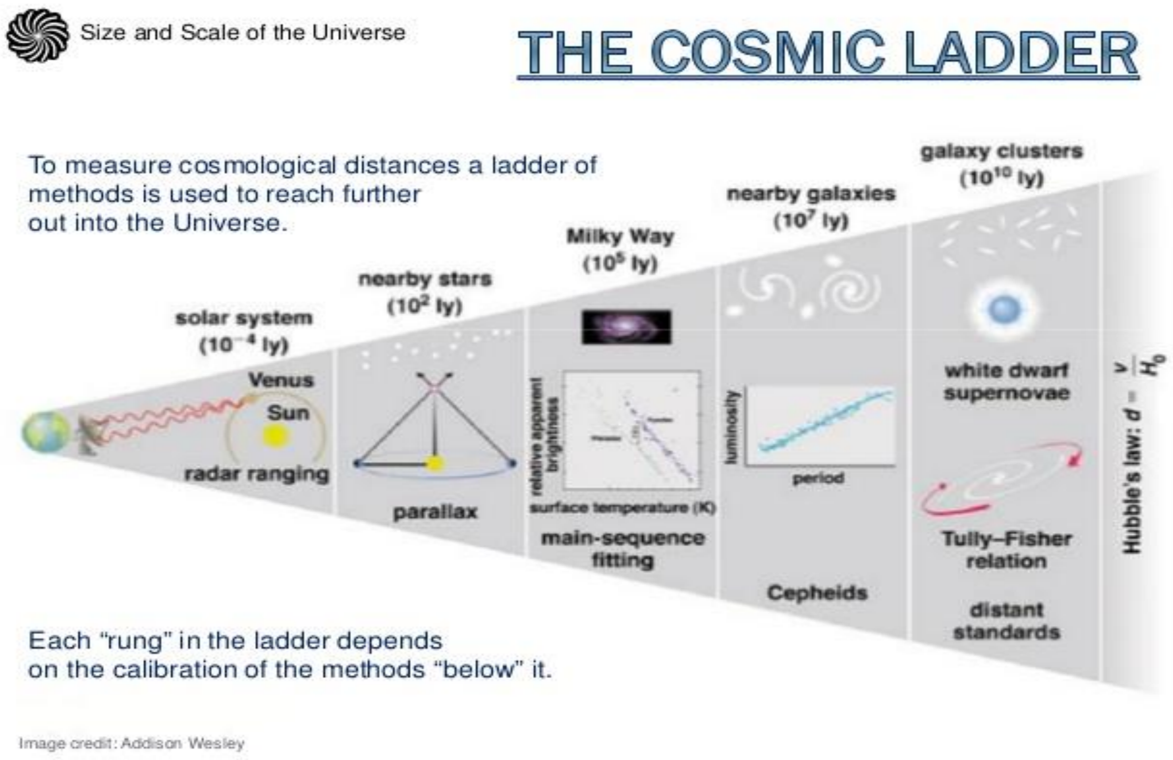
THE COSMIC LADDER

Measuring astronomical distances

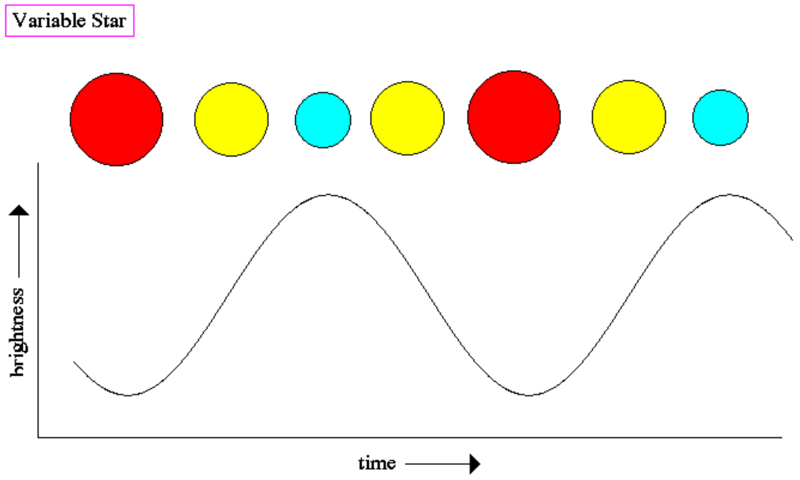
To measure cosmological distances a ladder of methods is used to reach further out into the Universe.



Each "rung" in the ladder depends on the calibration of the methods "below" it.



Cepheids: Stars periodically change luminosity
Average luminosity related to period



Type IA white dwarf supernovae: have known maximum luminosity

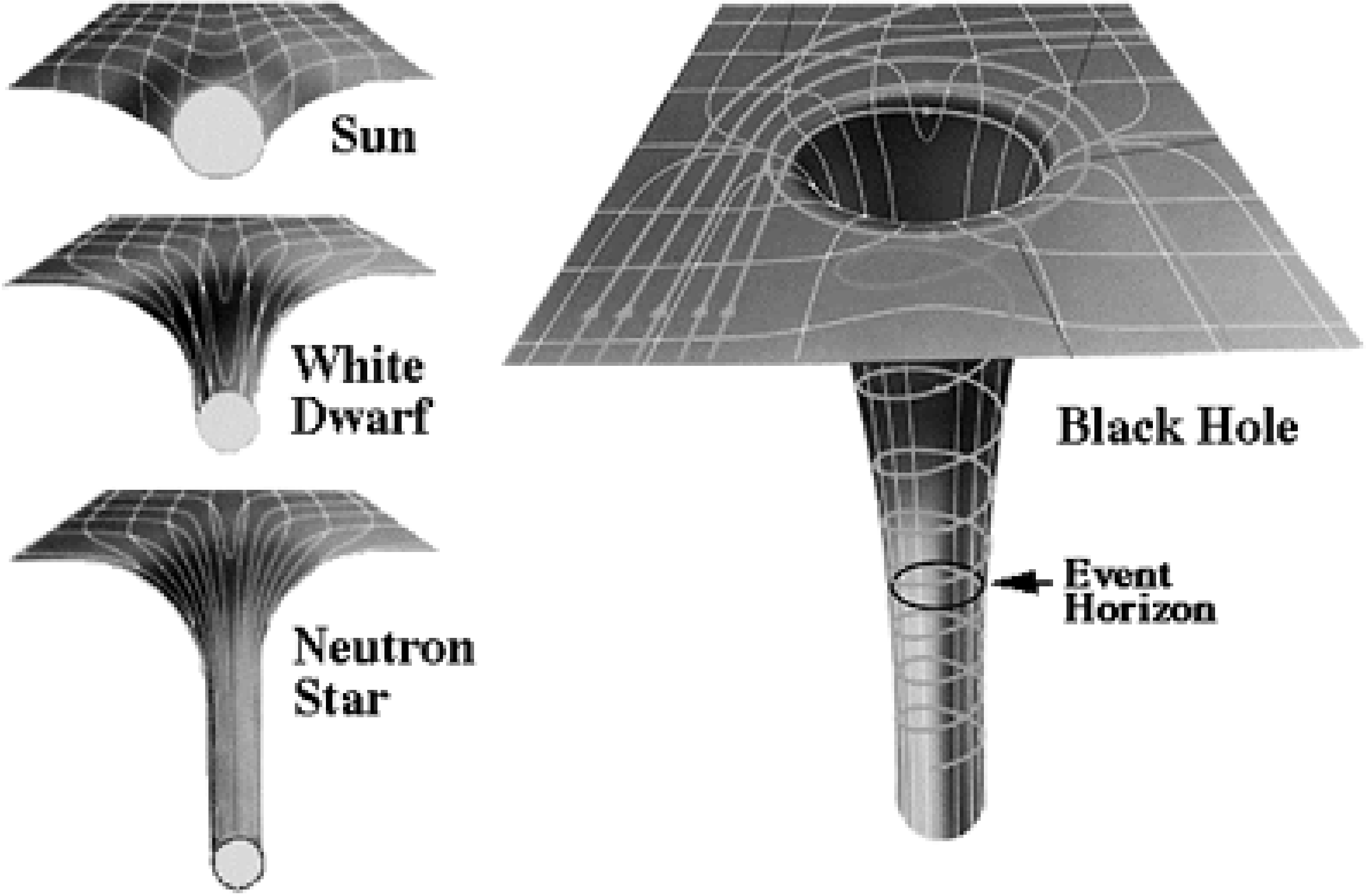
Cepheids and IA supernovae are "standard candles". We know their luminosity (actual brightness) and can get distance by measure how bright they appear to be.

$L = F_{detected} * 2\pi d^2$

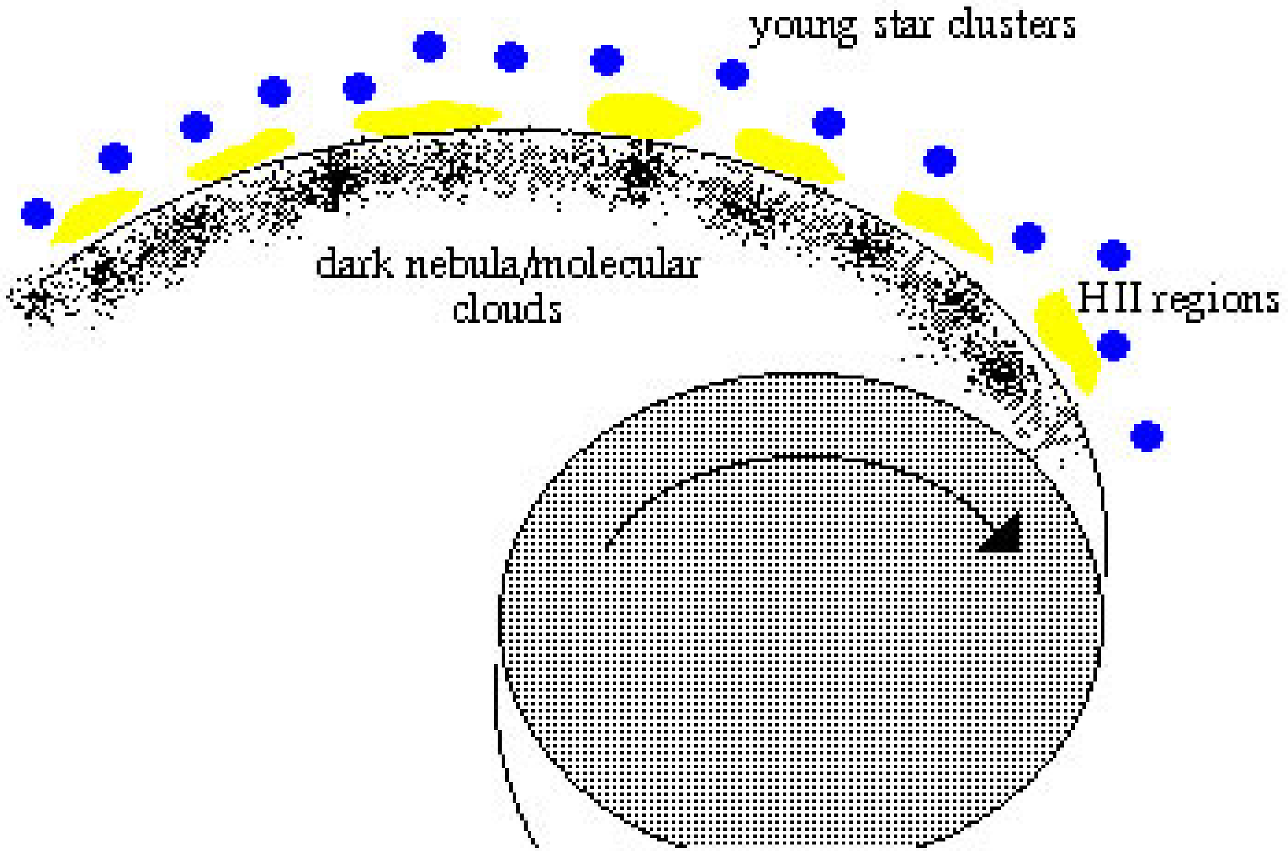
Mass distorts space and time

The greater the mass, the bigger the effect on space-time

Black hole is a mass large enough that it distorts space to the point that light cannot escape once across the event horizon

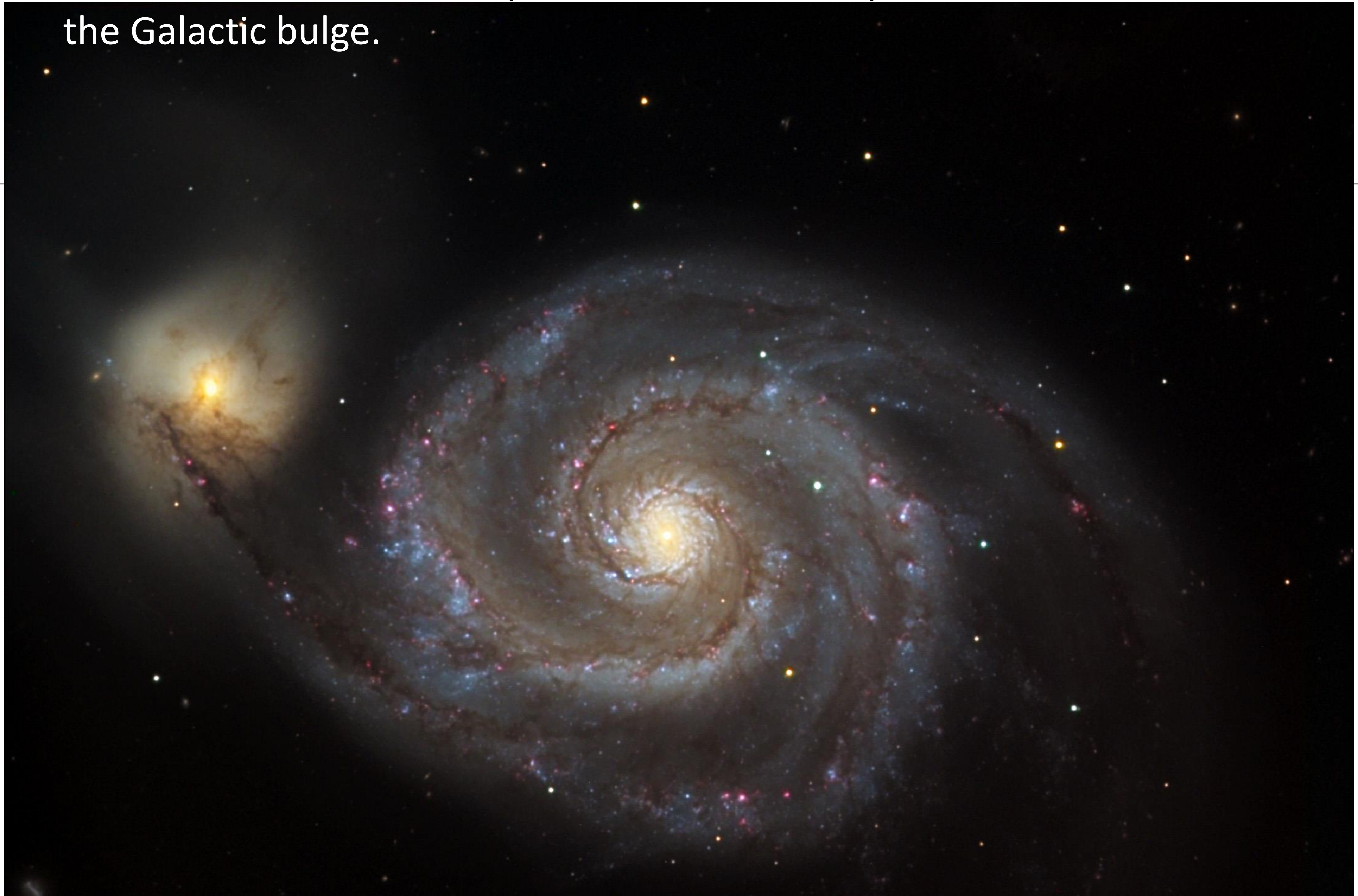


The spiral pattern collects gas and dust as it sweeps across the Galaxy disk. The gas is compressed into forming stars which develop first as HII regions then young clusters.

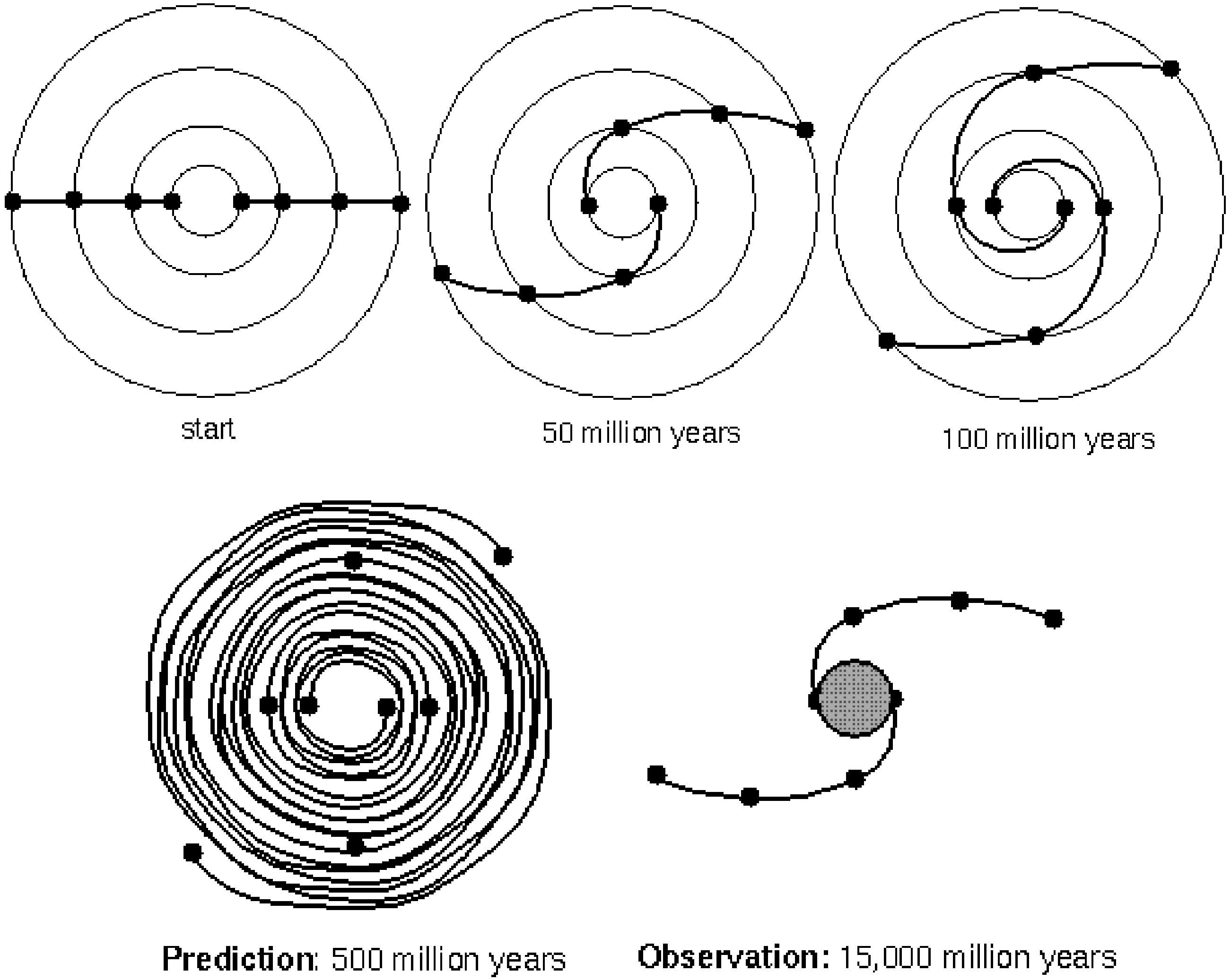


Notice that the spiral pattern moves slower than the rotation of the stars and gas. So stars form and move out from the spiral arms.

The bluest, and thus youngest, stars in other spiral galaxies are also located near dust, in the spiral arms; the older yellow stars are the Galactic bulge.

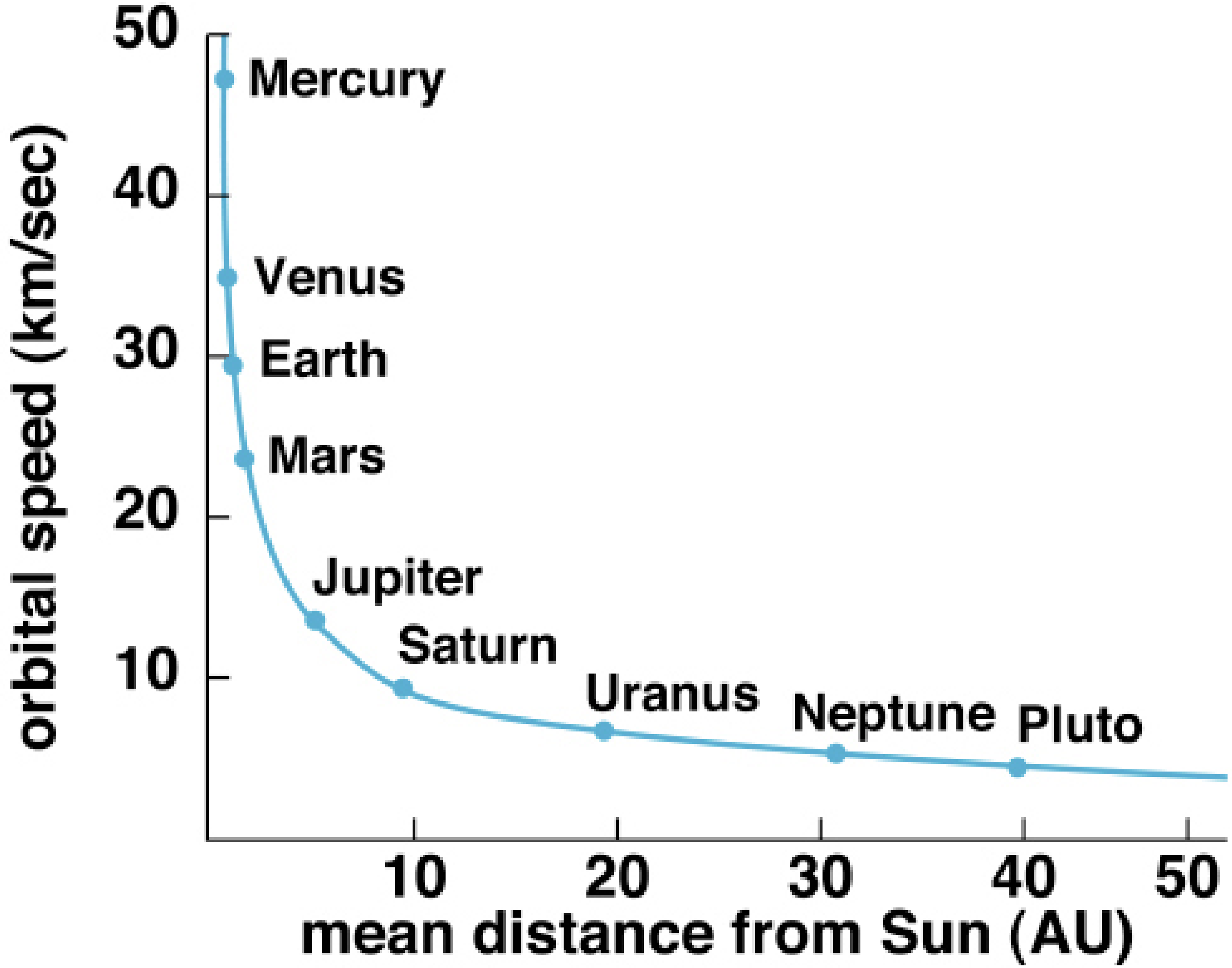


Why spiral arms?
Not simply ‘wrapping up’ due to rotation: would lead to much more tightly wound arms than we see.

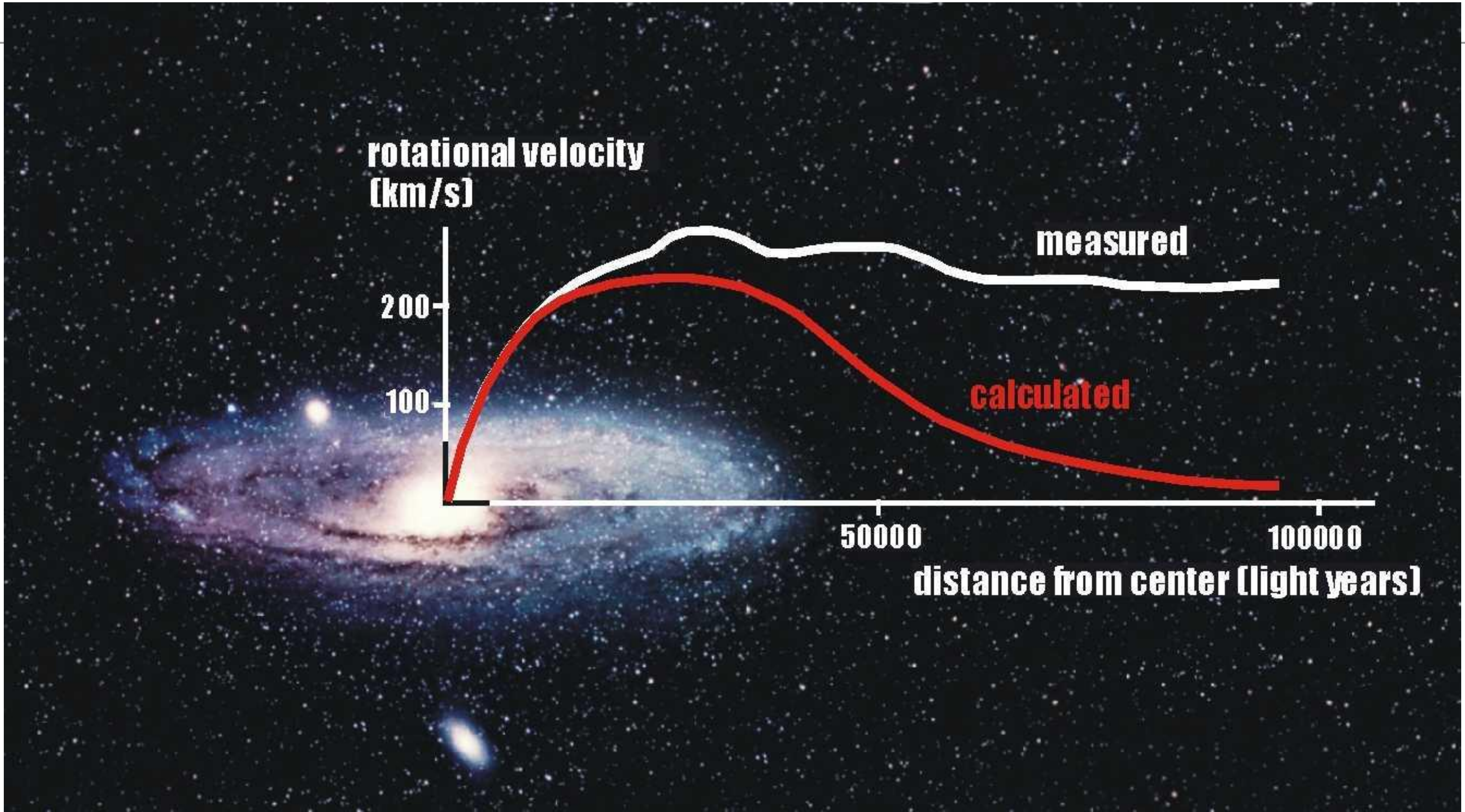


Handy Spiral Galaxy image for estimating light -> mass

Planets' orbital velocities drop off with distance, because the mass enclosed by their orbits is effectively constant.



Orbital velocities of stars (& gas) in the Milky Way & external galaxies don't drop off like we'd expect given how their brightness (and thus stellar mass) declines with radius.



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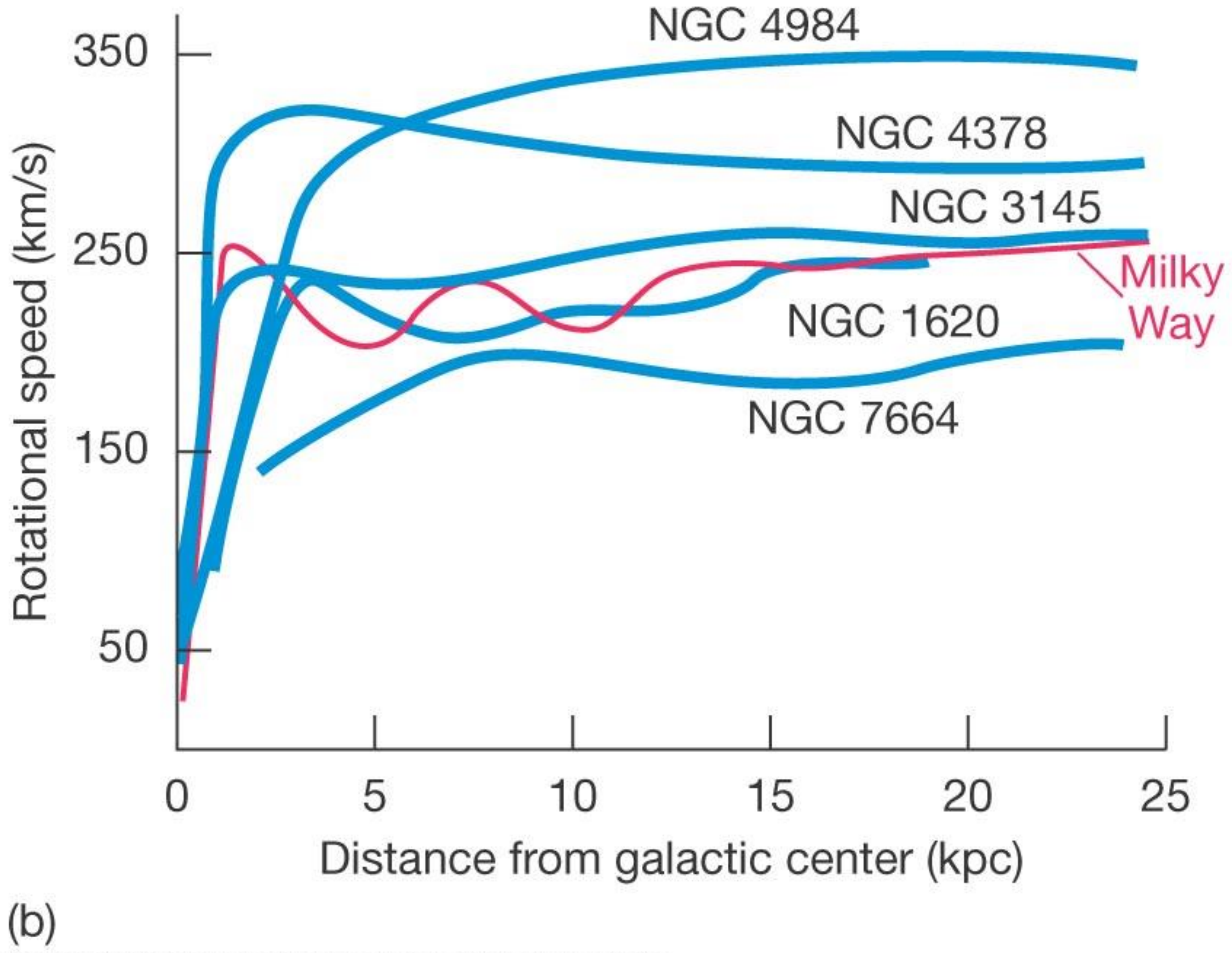

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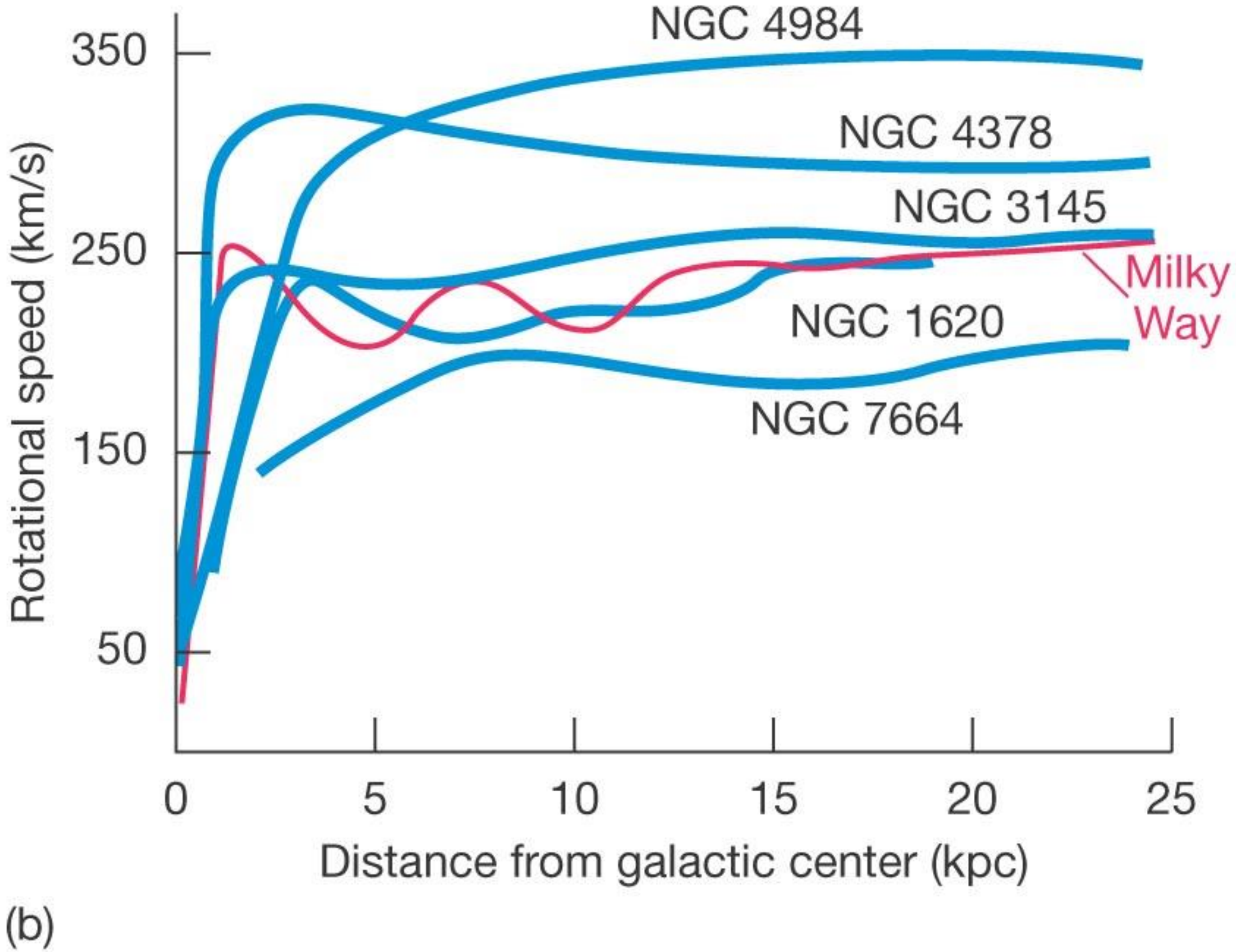
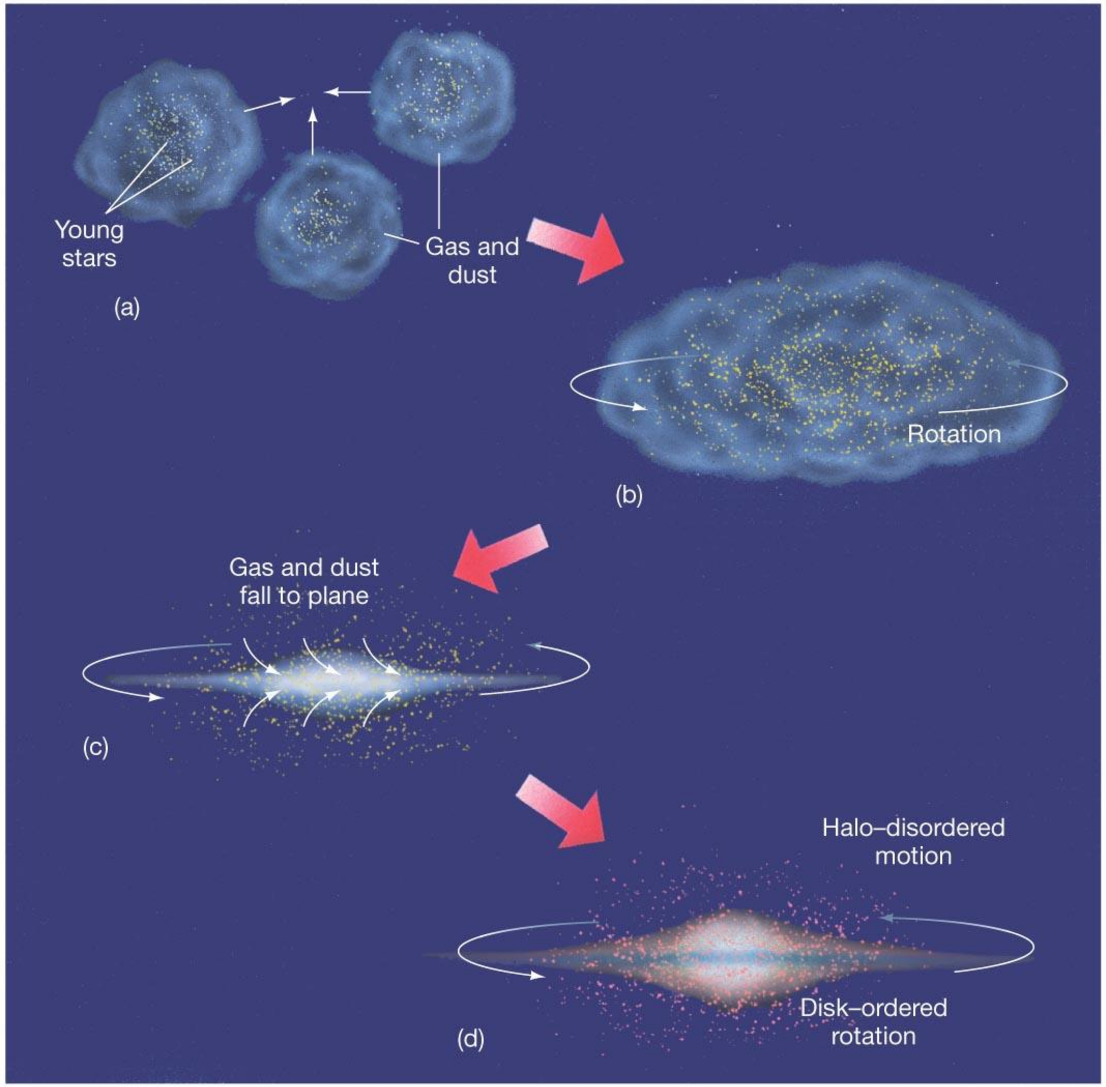


= Evidence for DARK MATTER:

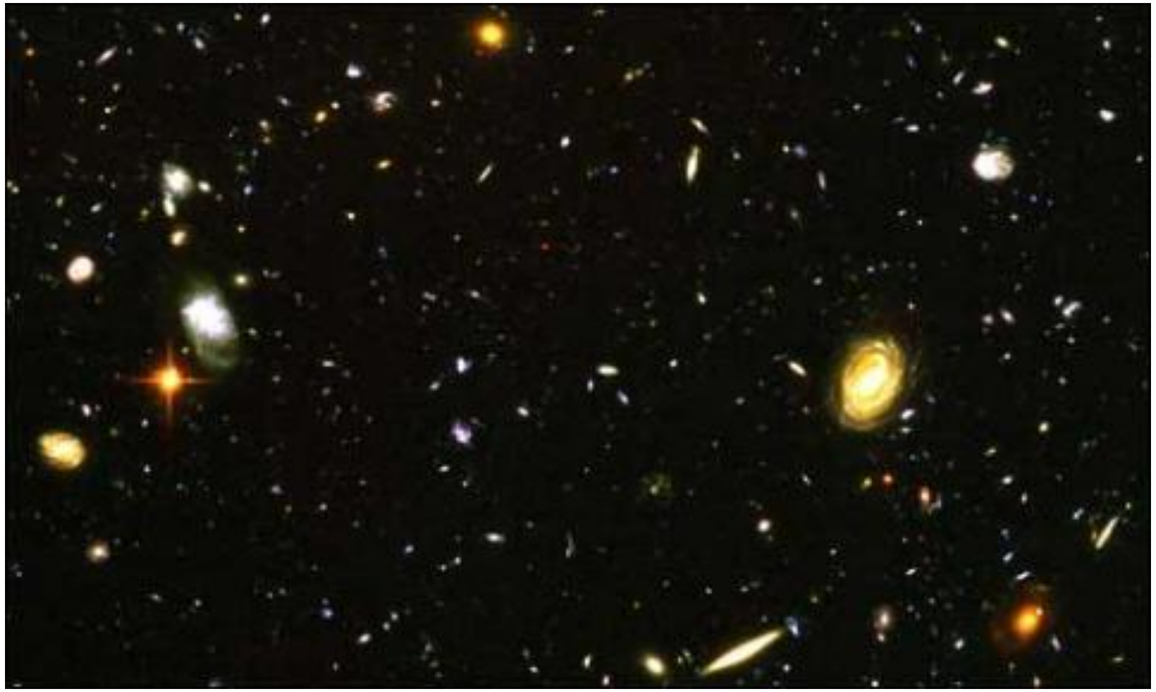
- We see gravitational effects of a mass (matter)
- We do not see interaction of light with the mass (its dark)

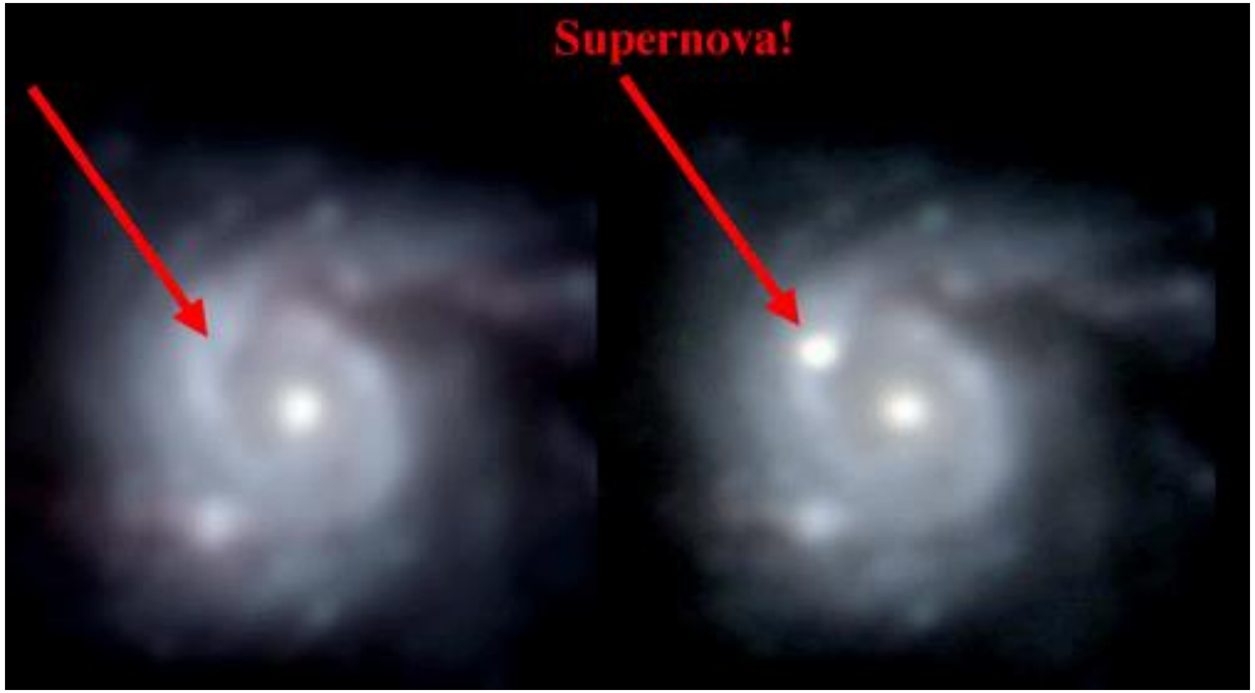
Computer simulation of the formation of a galaxy like the Milky Way:
https://www.youtube.com/watch?v=MncUDWhPB_E
Or
https://www.youtube.com/watch?v=n0jRObc7_xo&spfreload=1

Galaxies appear to be built up by the collisions of smaller dwarf galaxies (like the Sagittarius dwarf and the Large Magellanic cloud).



How do we know there are other galaxies?

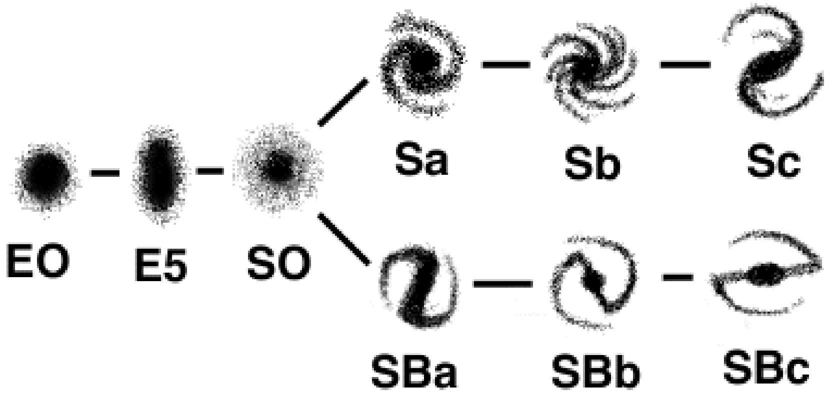


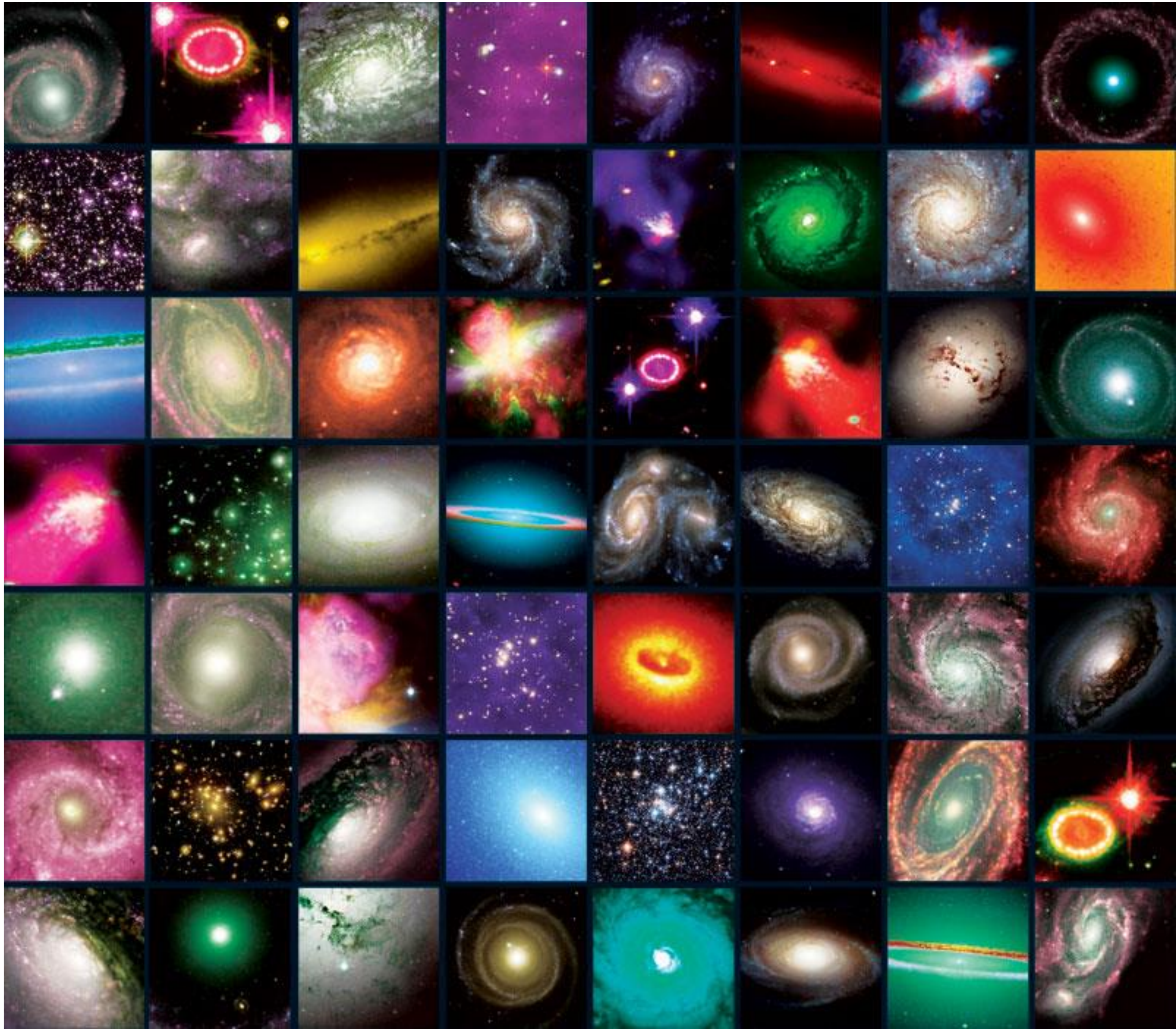


Galaxies

There are different ways to categorize them.

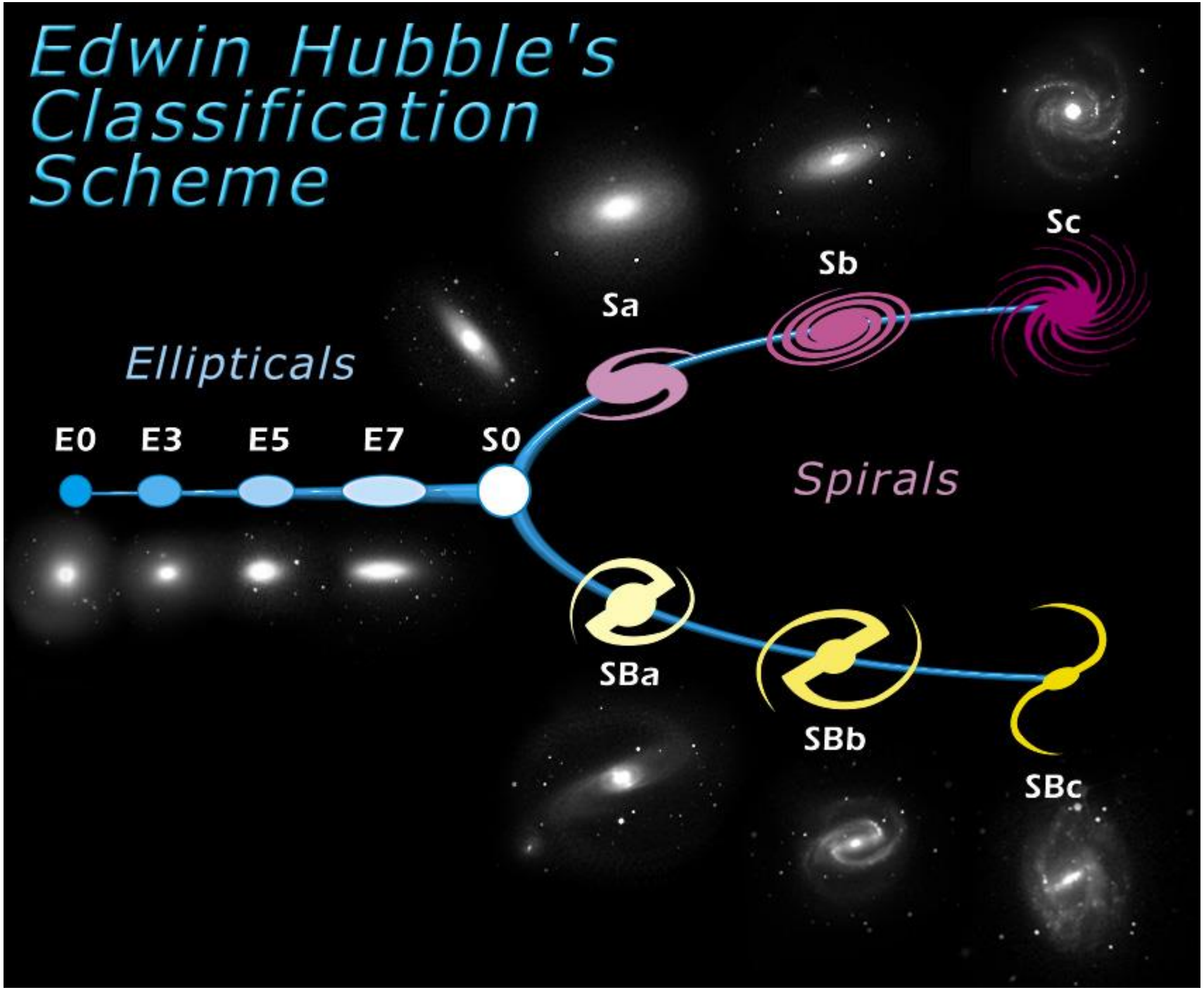
Edwin Hubble did so like so



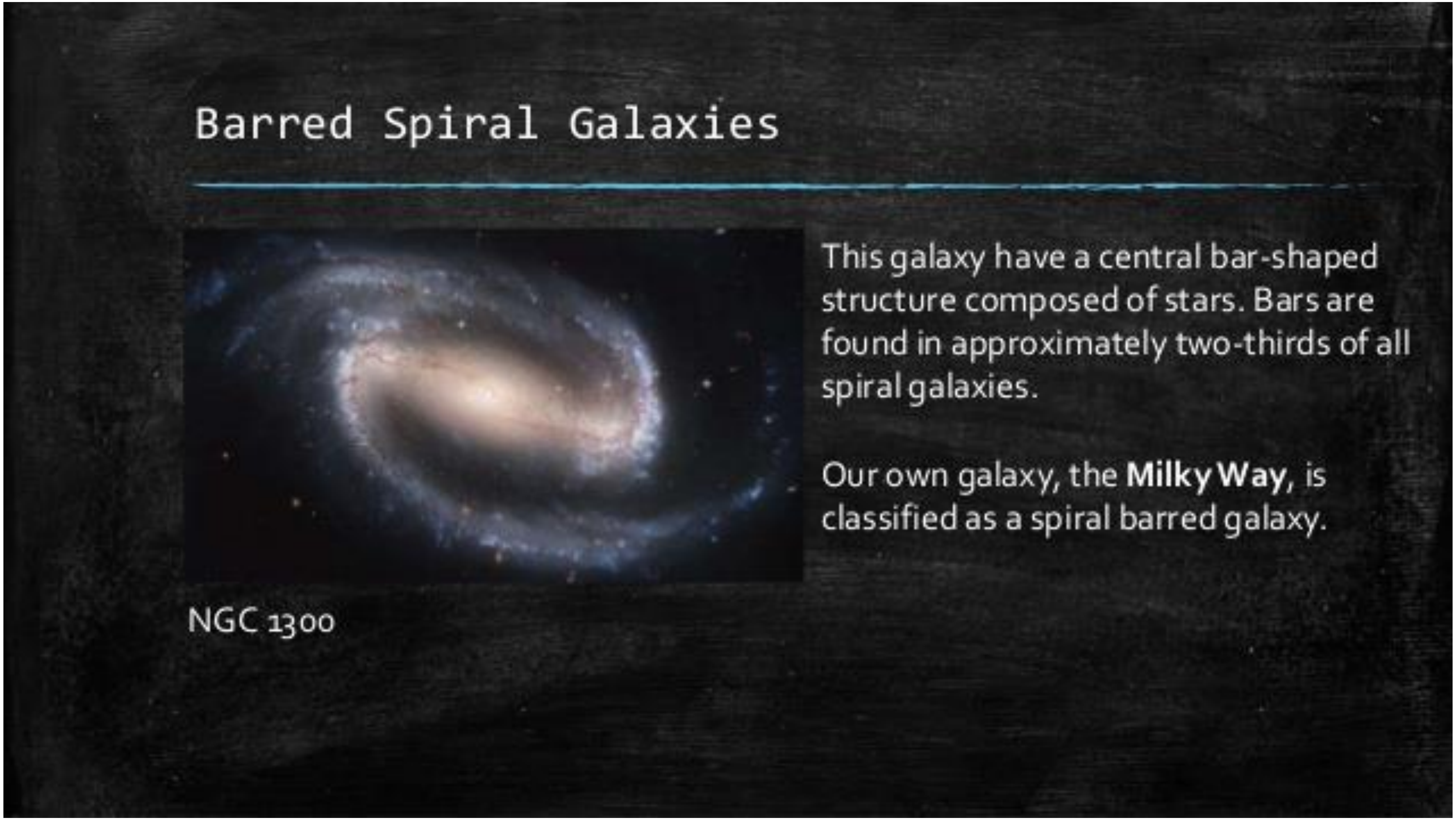


Different types of galaxies

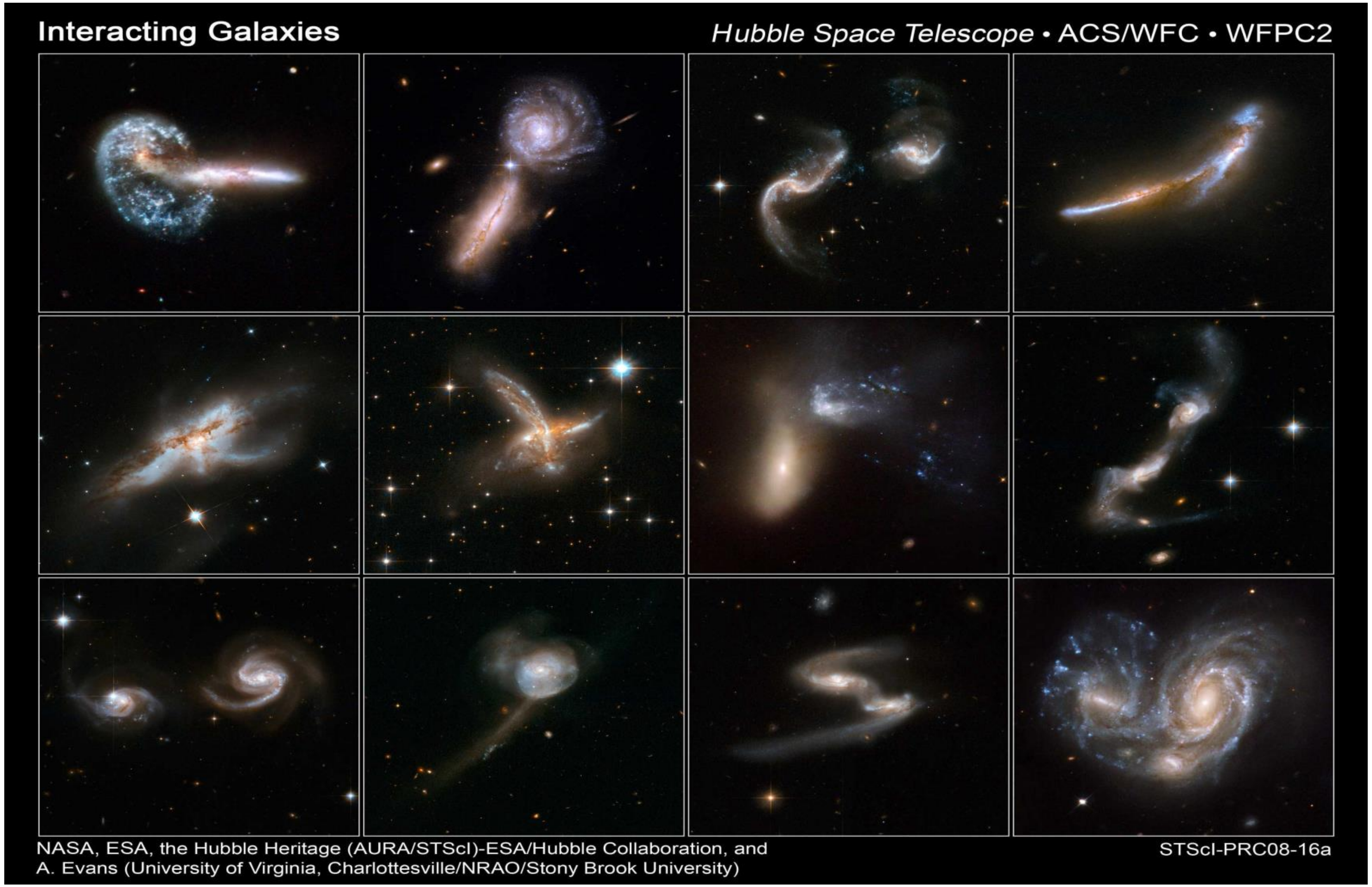
- Elliptical
- Spiral
- Barred spiral



OUR MILKY WAY GALAXY



Mergers can create Ellipticals



http://www.youtube.com/watch?v=C0XNyTp5brM&feature=youtu.be