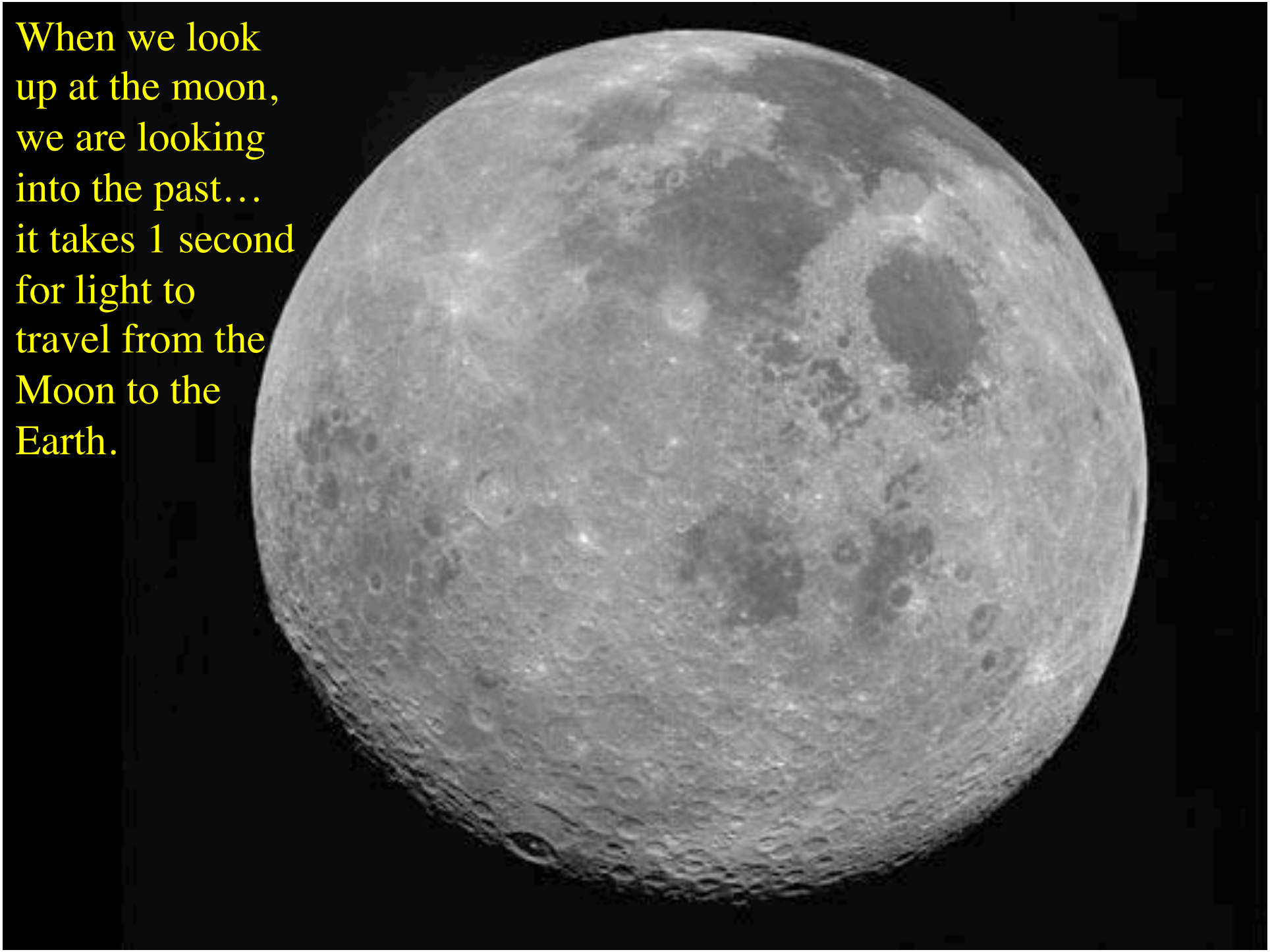
Scales of Space and Time

When we look up at the moon, we are looking into the past… it takes 1 second for light to travel from the Moon to the Earth.



How can we know what the universe was like in the past?

- Light travels at a finite speed (300,000 km/s).

Destination	Light travel time
Moon	1 second
Sun	8 minutes
Sirius	8 years
Andromeda Galaxy	2.5 million years

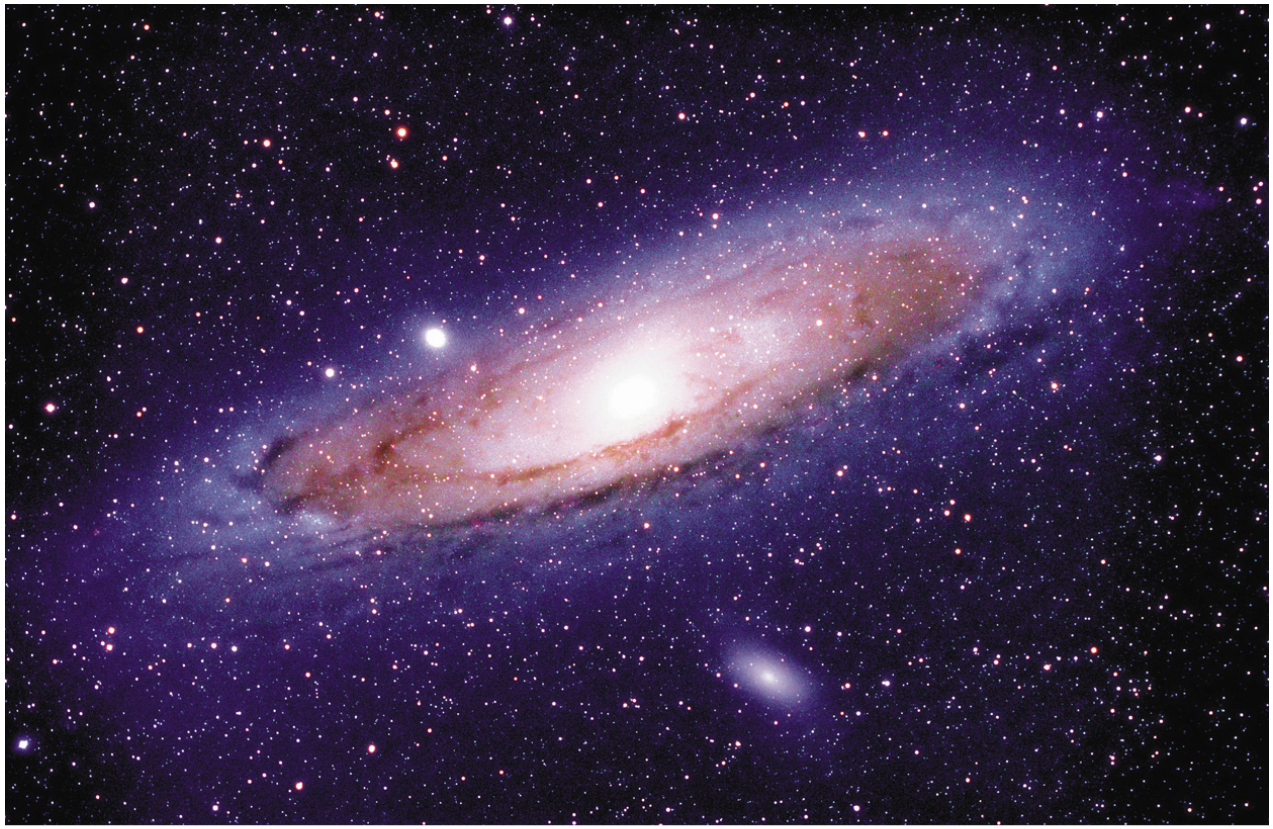
- Thus, we see objects as they were in the past:

The farther away we look in distance,
the further back we look in time.

Example:

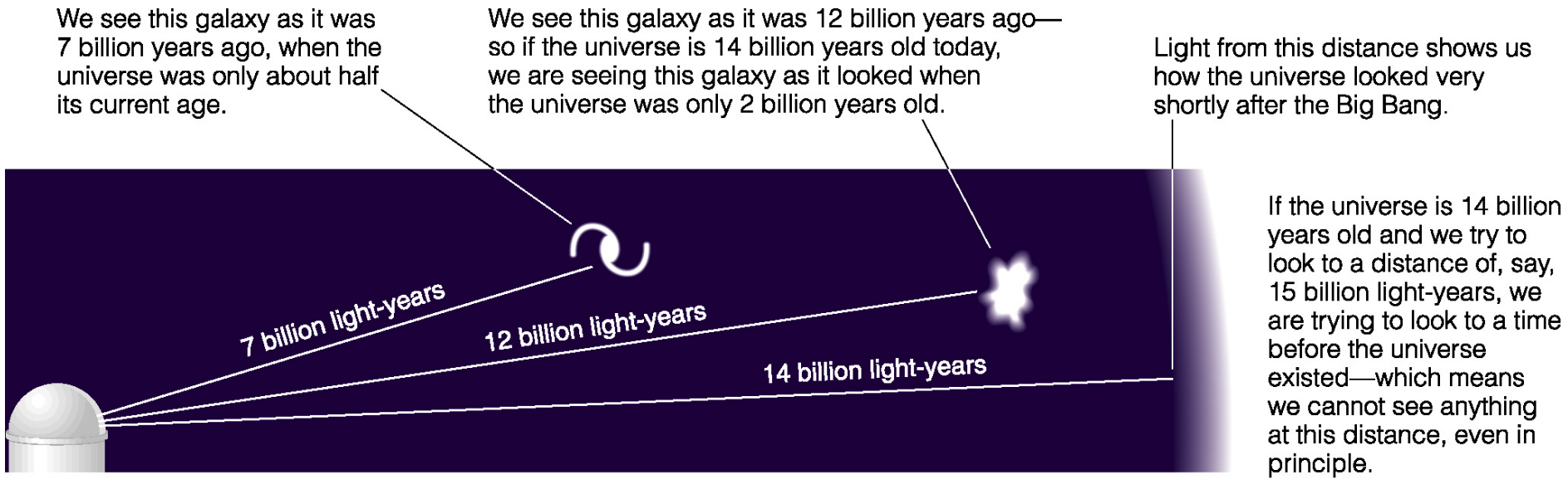
This photo shows the Andromeda Galaxy as it looked about 2 1/2 million years ago.

Question: When will be able to see what it looks like now?



Definition: a **light-year**

- The **distance** light can travel in one year
- About 10 trillion km (6 trillion miles)
- At great distances, we see objects as they *were*



A Scale Model

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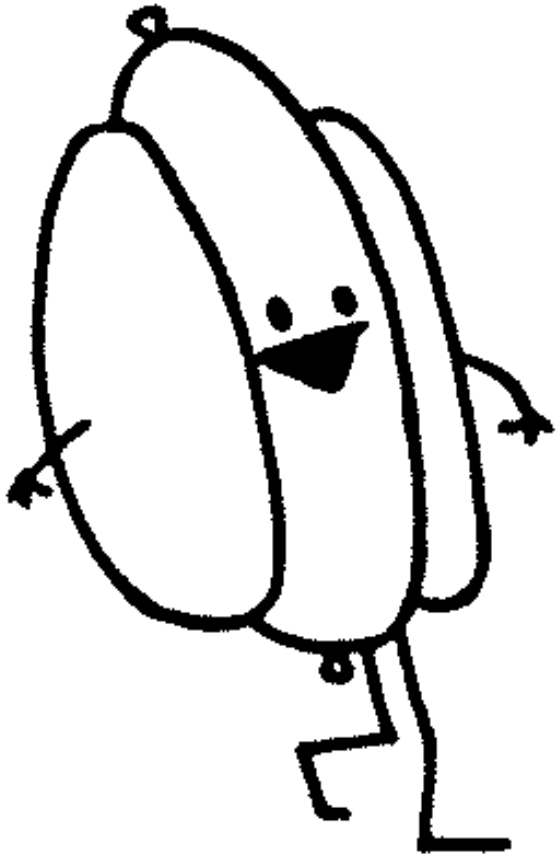
Set the Earth to a 6cm ball, or a 1:200,000,000 scale model

- The Moon is a marble at your arm span
- The Sun is a 7 m ball (about the height of Old Main) 700 m away (about the length of the UofA mall)
- The Solar System is the size of Tucson
- The nearest star is 1/2 distance to the moon!

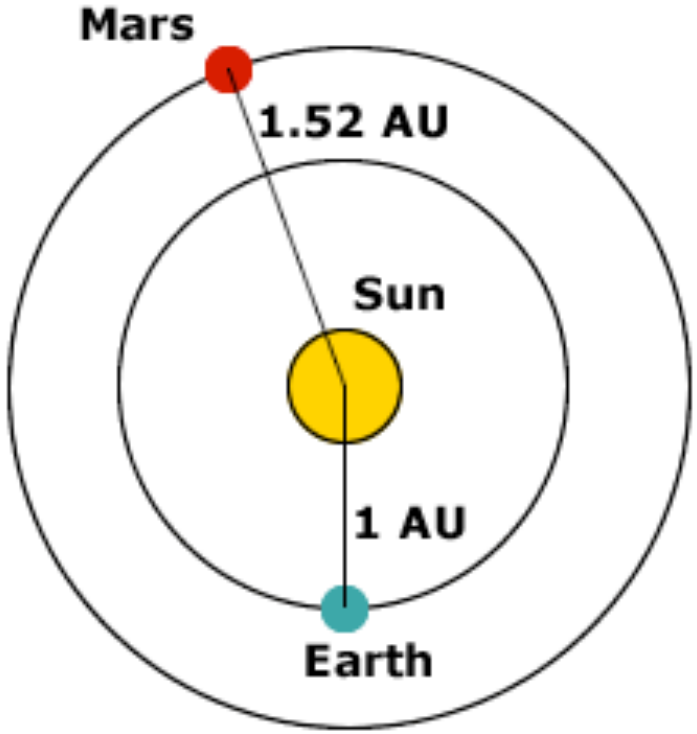


And at this scale, light is reduced to slow walking speed. There's no way information in the universe can travel any faster

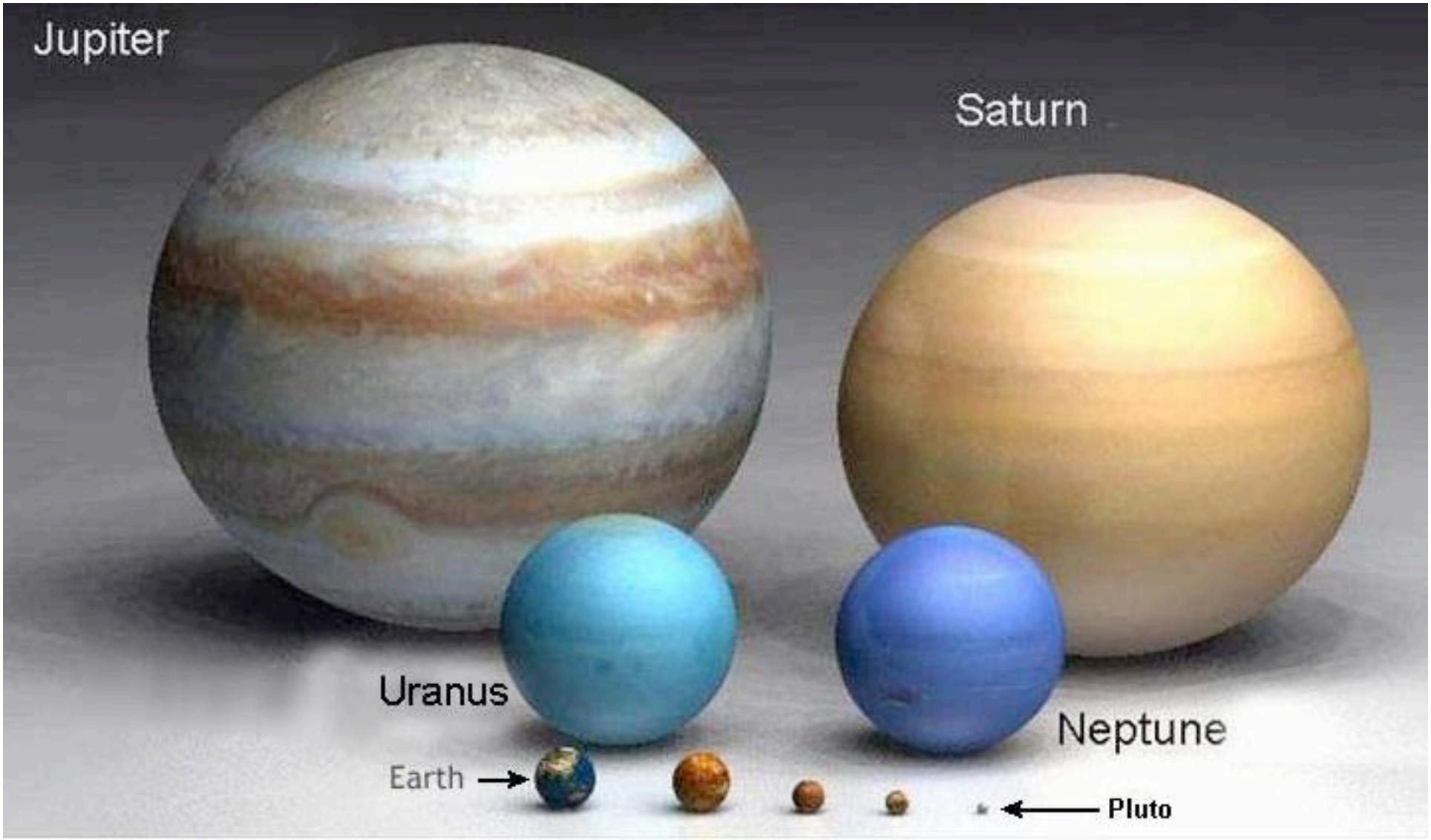
- The Moon is a seconds walk away
- The Sun is 8 minutes walk away
- 10 hours to walk the Solar System
- 4 years to walk to the nearest stars

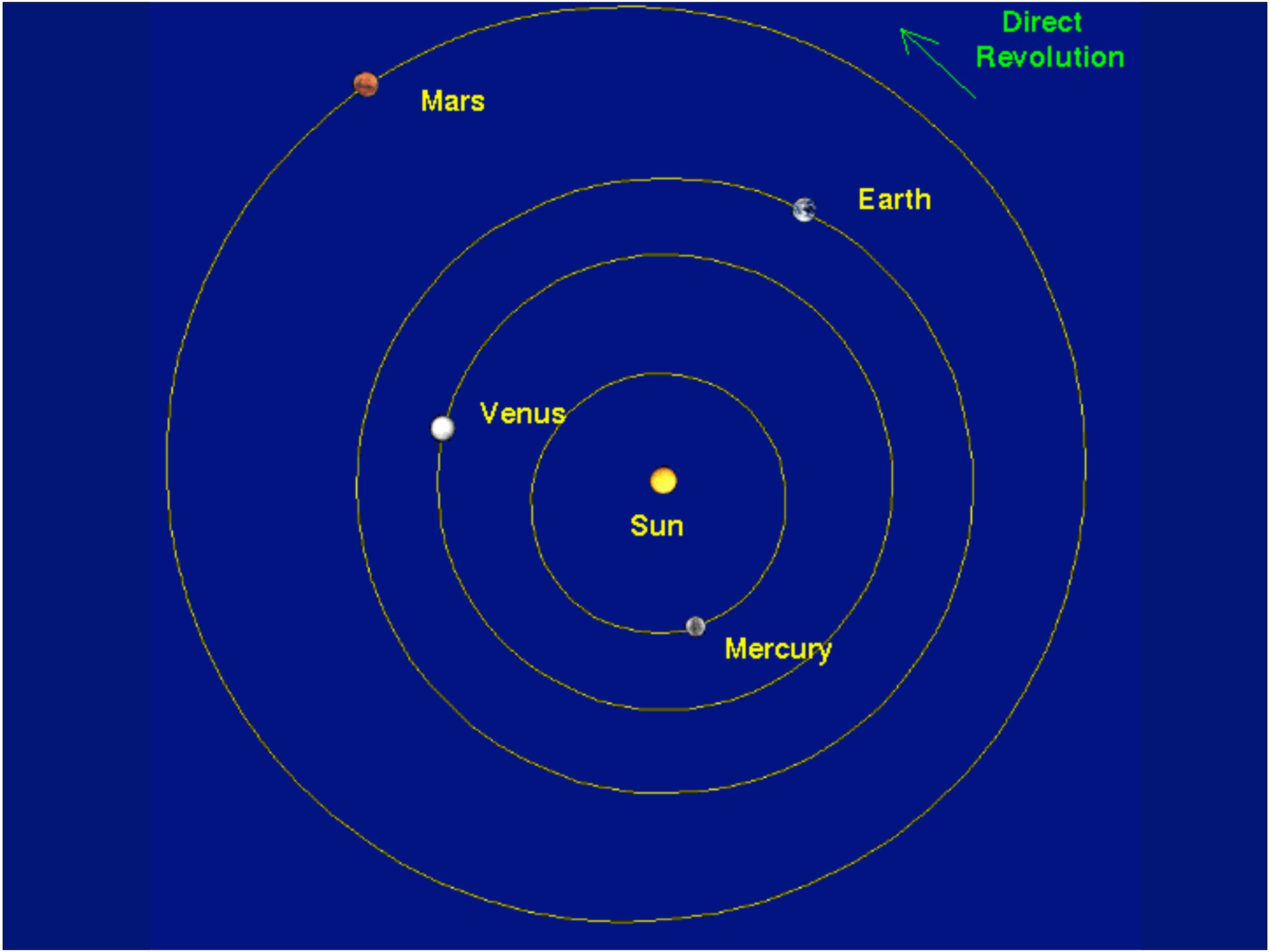
Definition: **Astronomical Unit**

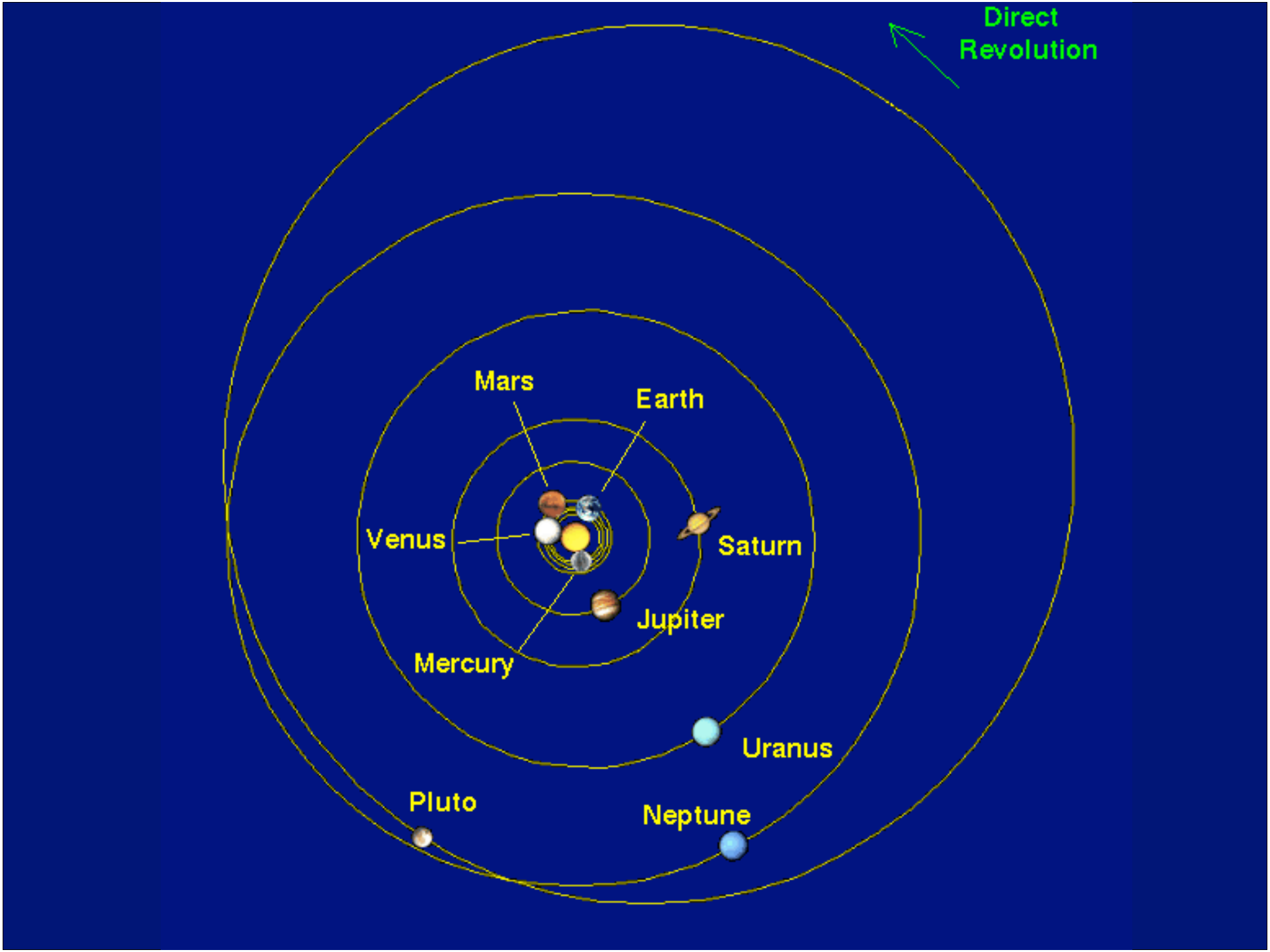
- The mean **distance** between the Earth and the Sun
- About 150 million km (93 million miles)
- Denoted as 1 “AU”

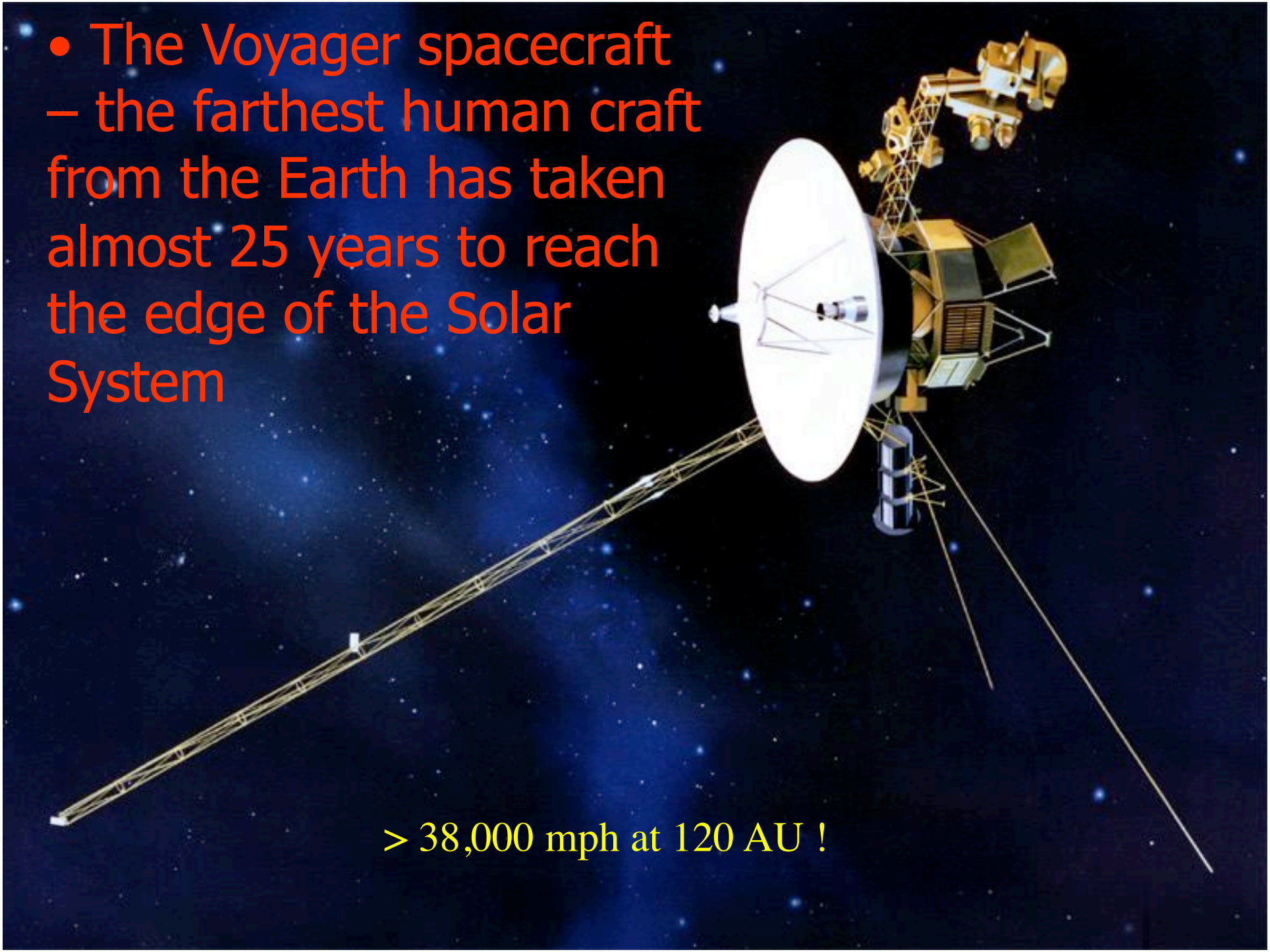


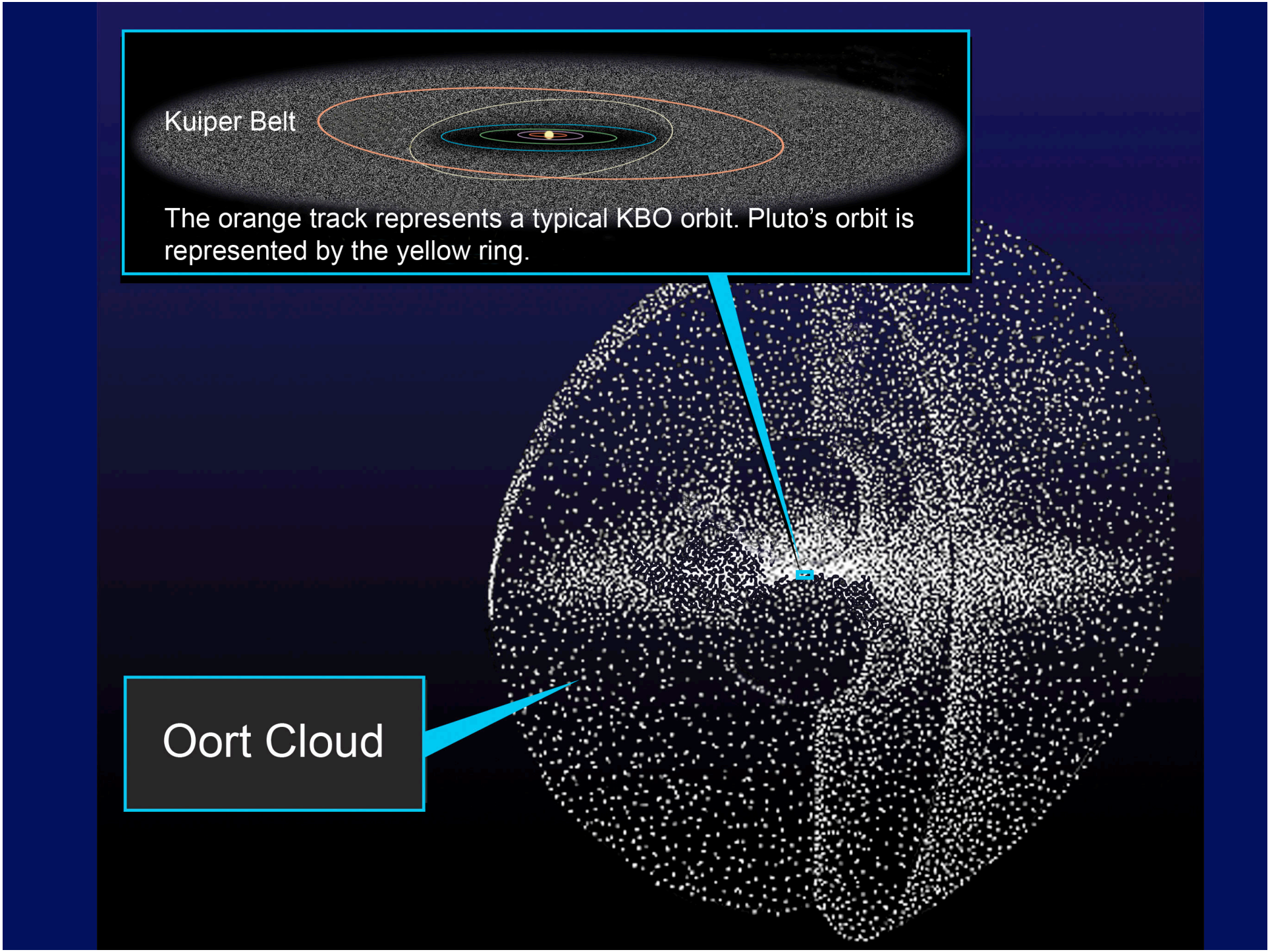
Relative Sizes of the Planets



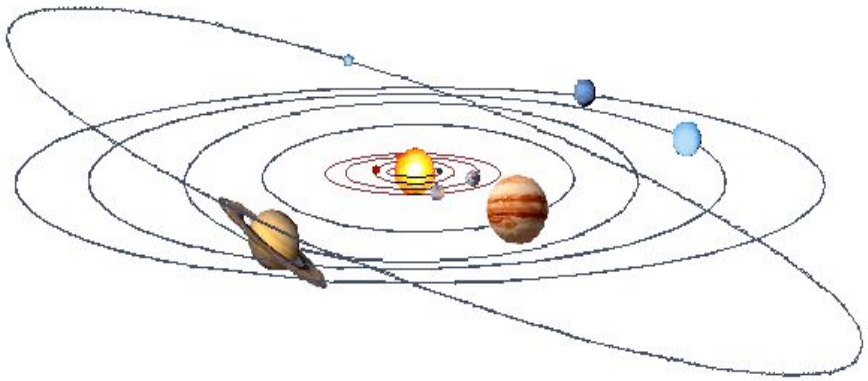

Direct
Revolution
Mars
Earth
Venus
Sun
Mercury


Direct
Revolution
Mars
Earth
Venus
Saturn
Jupiter
Mercury
Uranus
Pluto
Neptune


• The Voyager spacecraft – the farthest human craft from the Earth has taken almost 25 years to reach the edge of the Solar System
> 38,000 mph at 120 AU !


Kuiper Belt
The orange track represents a typical KBO orbit. Pluto's orbit is represented by the yellow ring.
Oort Cloud

Reduce the scale by a factor of 50,000,000



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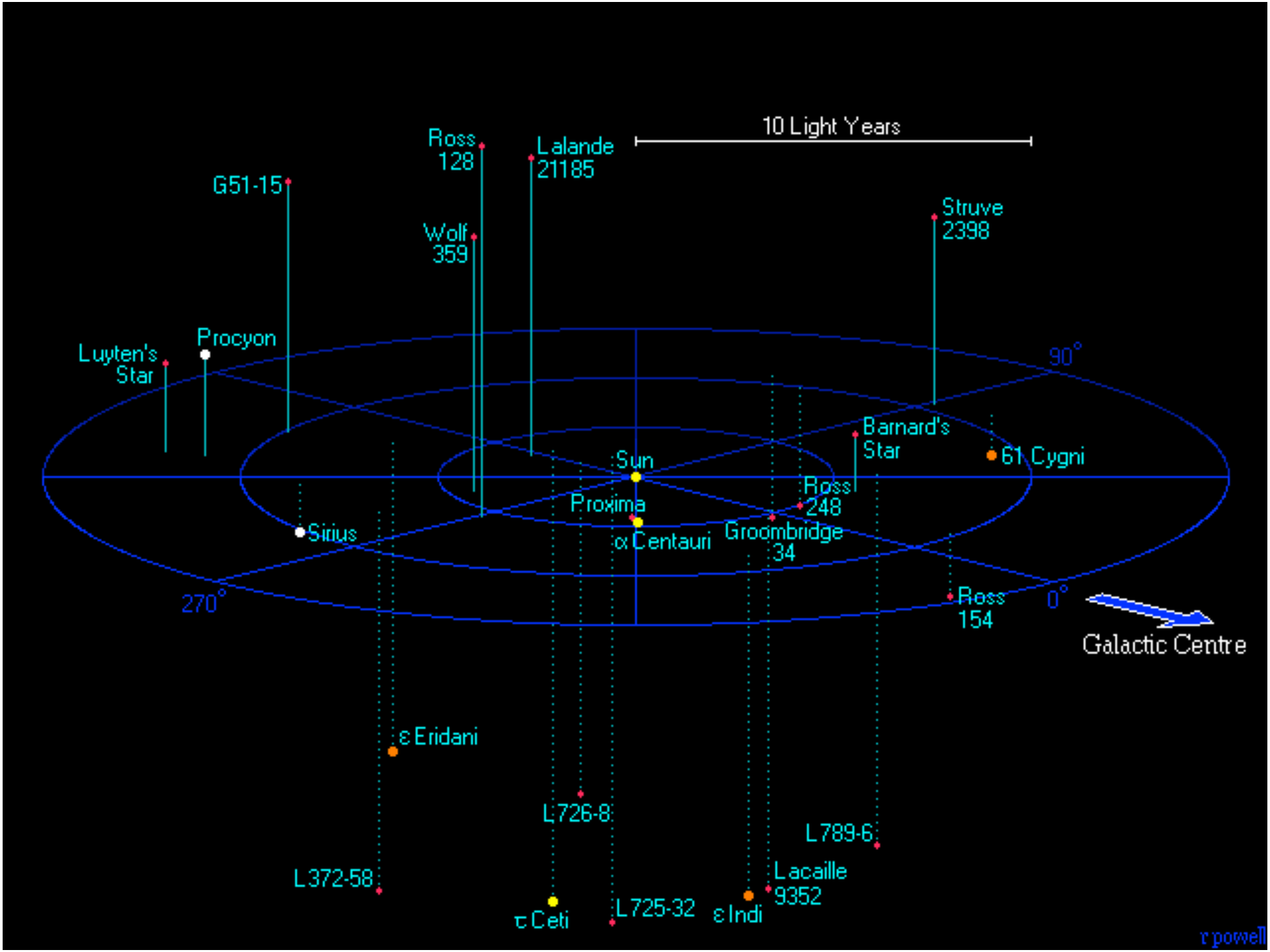
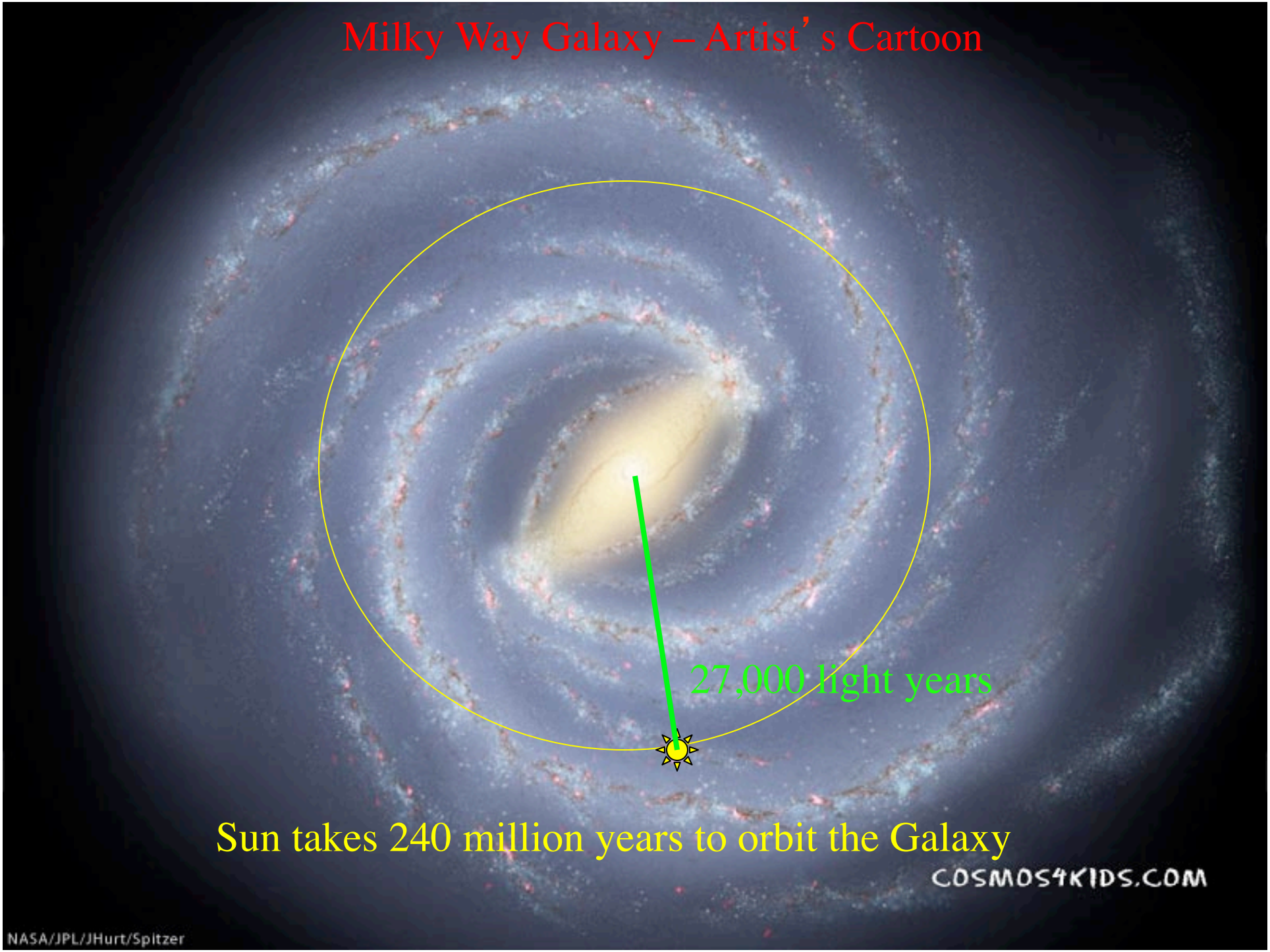
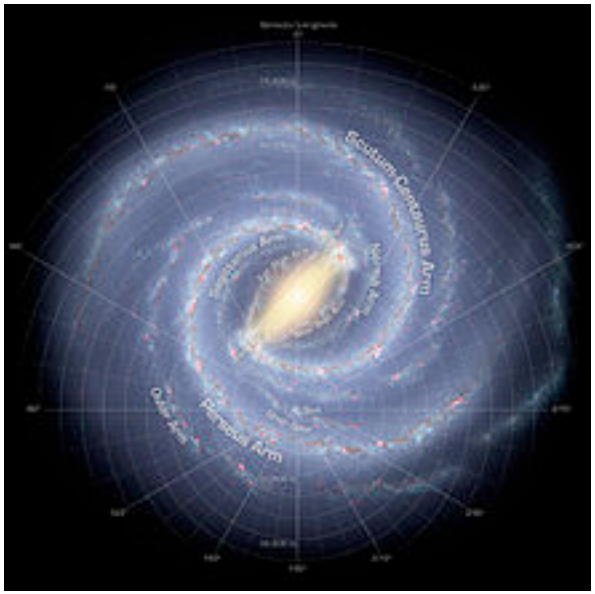
- The Solar System is a grain of sand
- The distance between stars is 10 m
- The Milky Way is the size of the U.S.
- The MW has 100,000,000,000 stars


10 Light Years
Ross 128
Lalande 21185
G51-15
Wolf 359
Struve 2398
Luyten's Star
Procyon
90°
Barnard's Star
61 Cygni
Sun
Ross 248
Proxima
Sirius
α Centauri
Groombridge 34
270°
0°
Ross 154
Galactic Centre
ε Eridani
L 726-8
L 789-6
L 372-58
Lacaille 9352
τ Ceti
L 725-32
ε Indi
r powell


Wally Pacholka / AstroPics.com


Milky Way Galaxy – Artist's Cartoon
27,000 light years
Sun takes 240 million years to orbit the Galaxy
COSMOS4KIDS.COM
NASA/JPL/JHurt/Spitzer

Now reduce by another factor of 100,000,000



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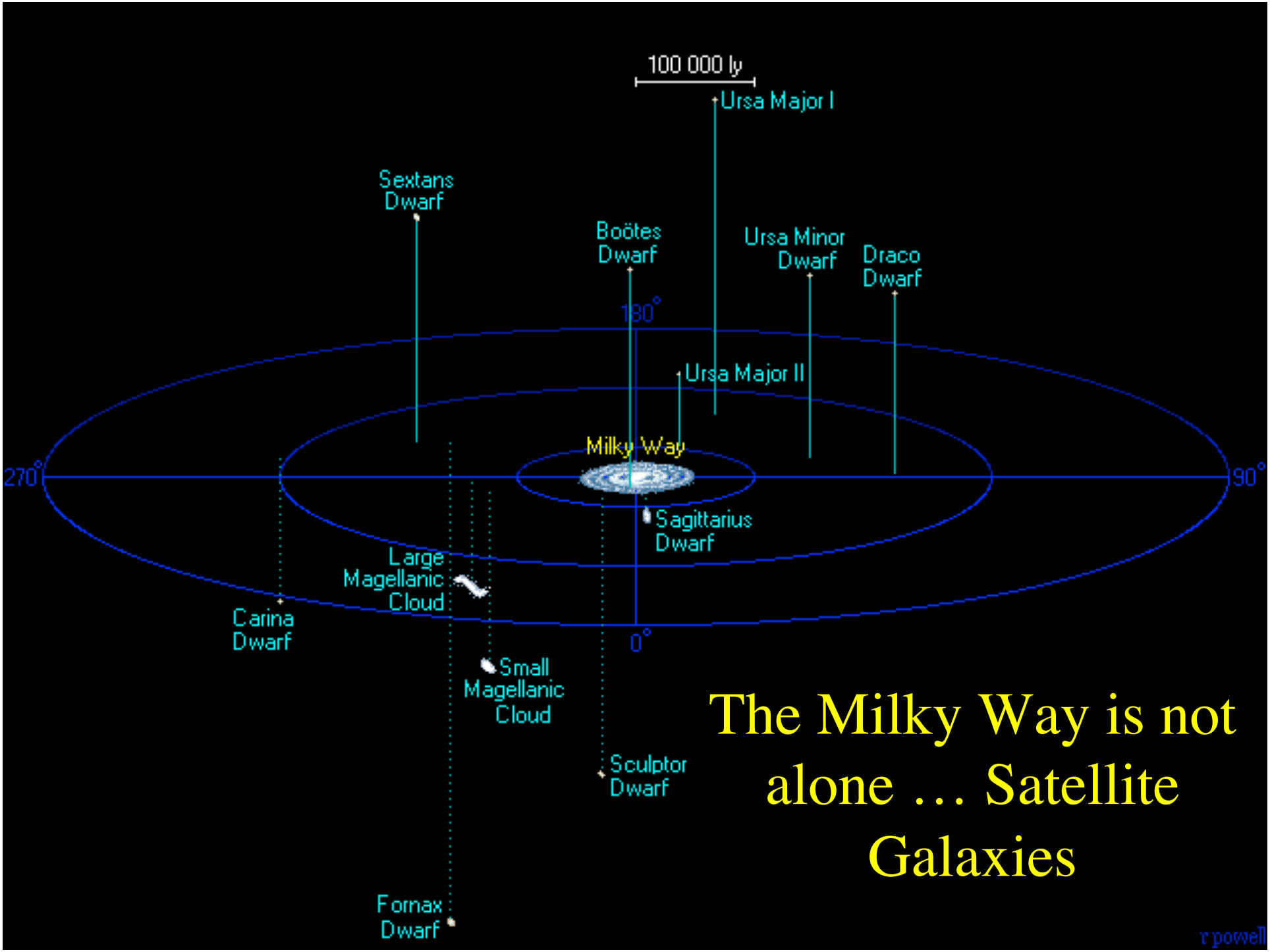
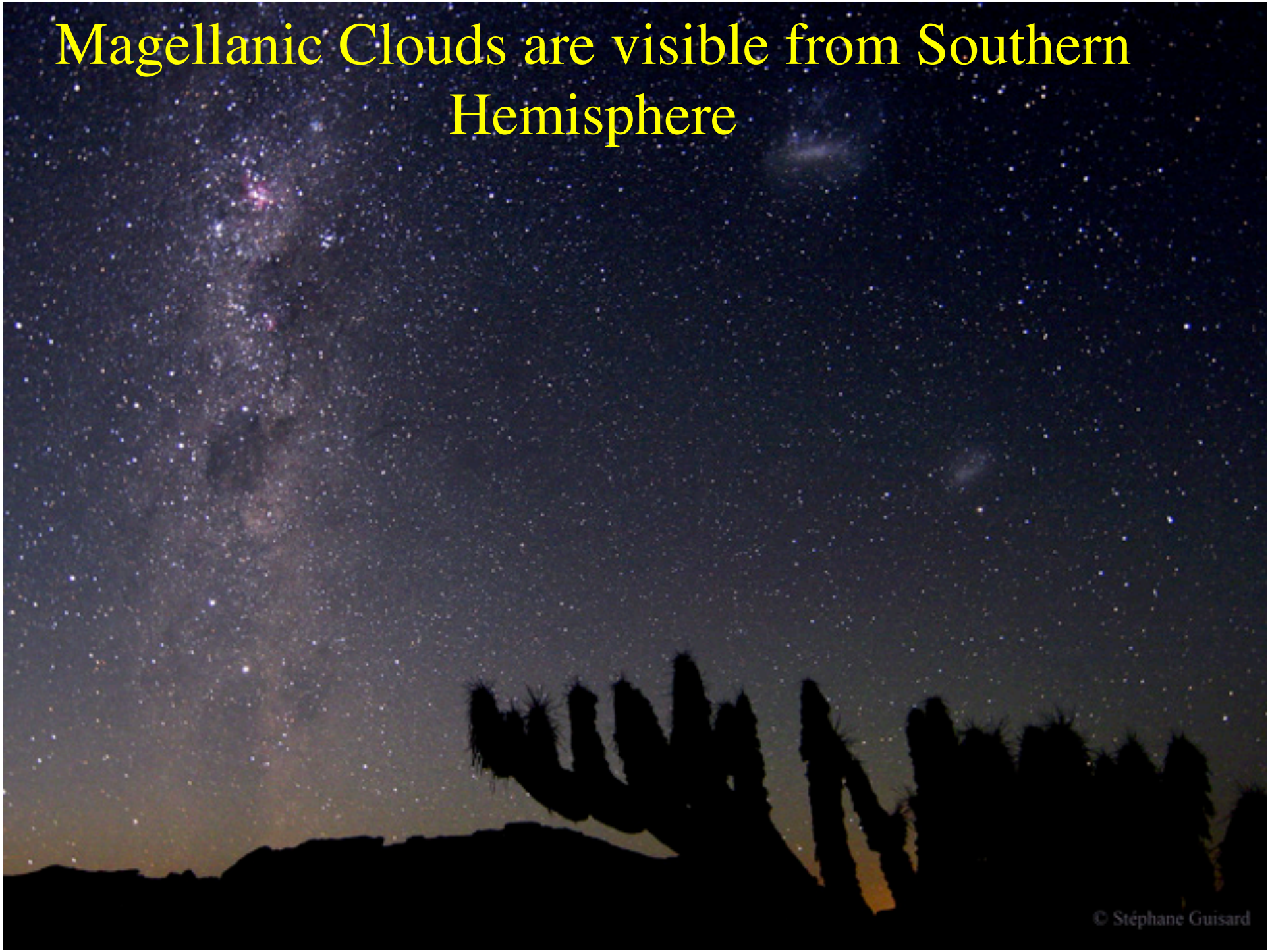
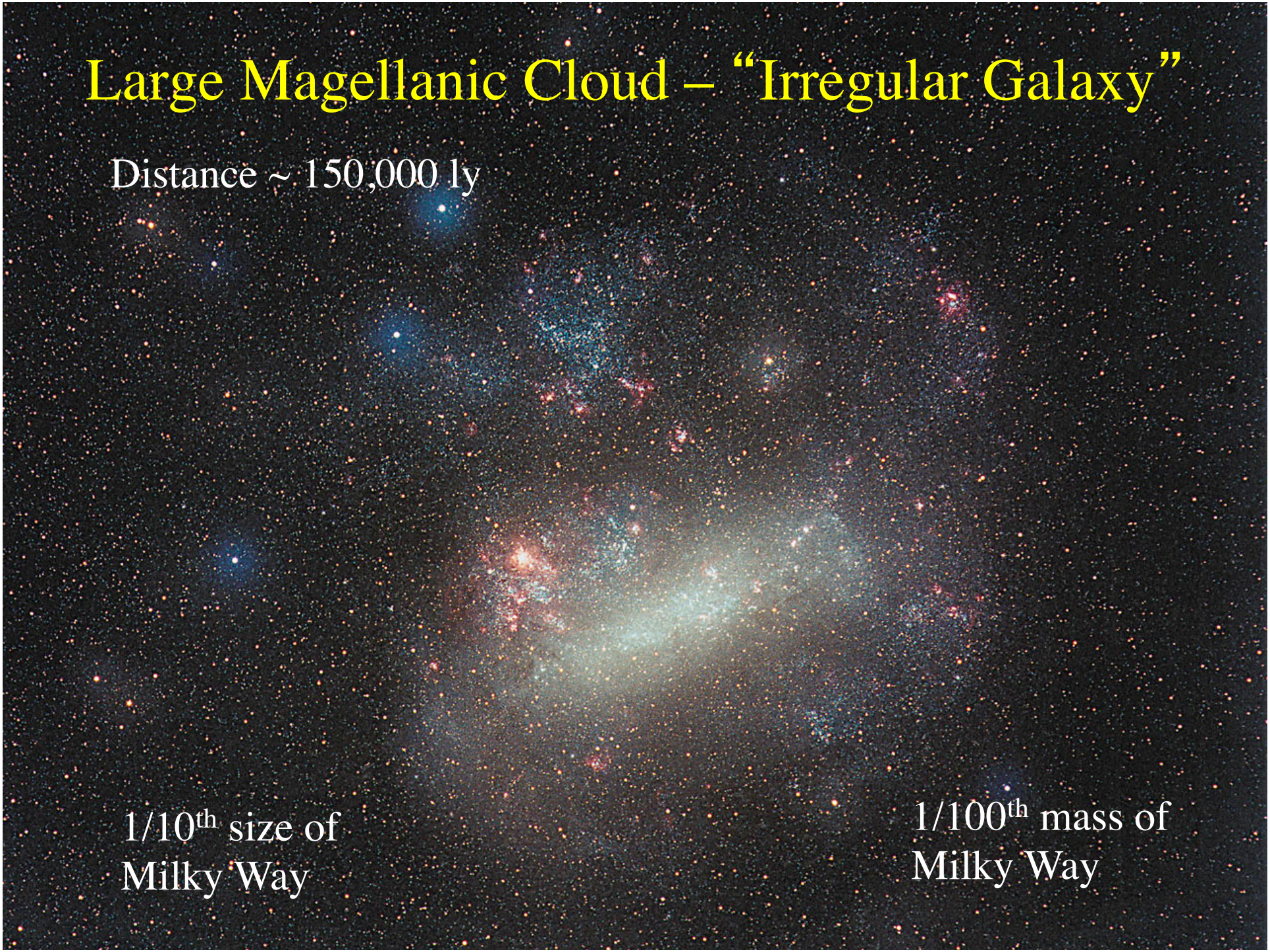
- The Milky Way is the size of a frisbee
- The nearest galaxy is 10 m away
- The visible universe is the size of the U.S.
- Billions of galaxies within this space

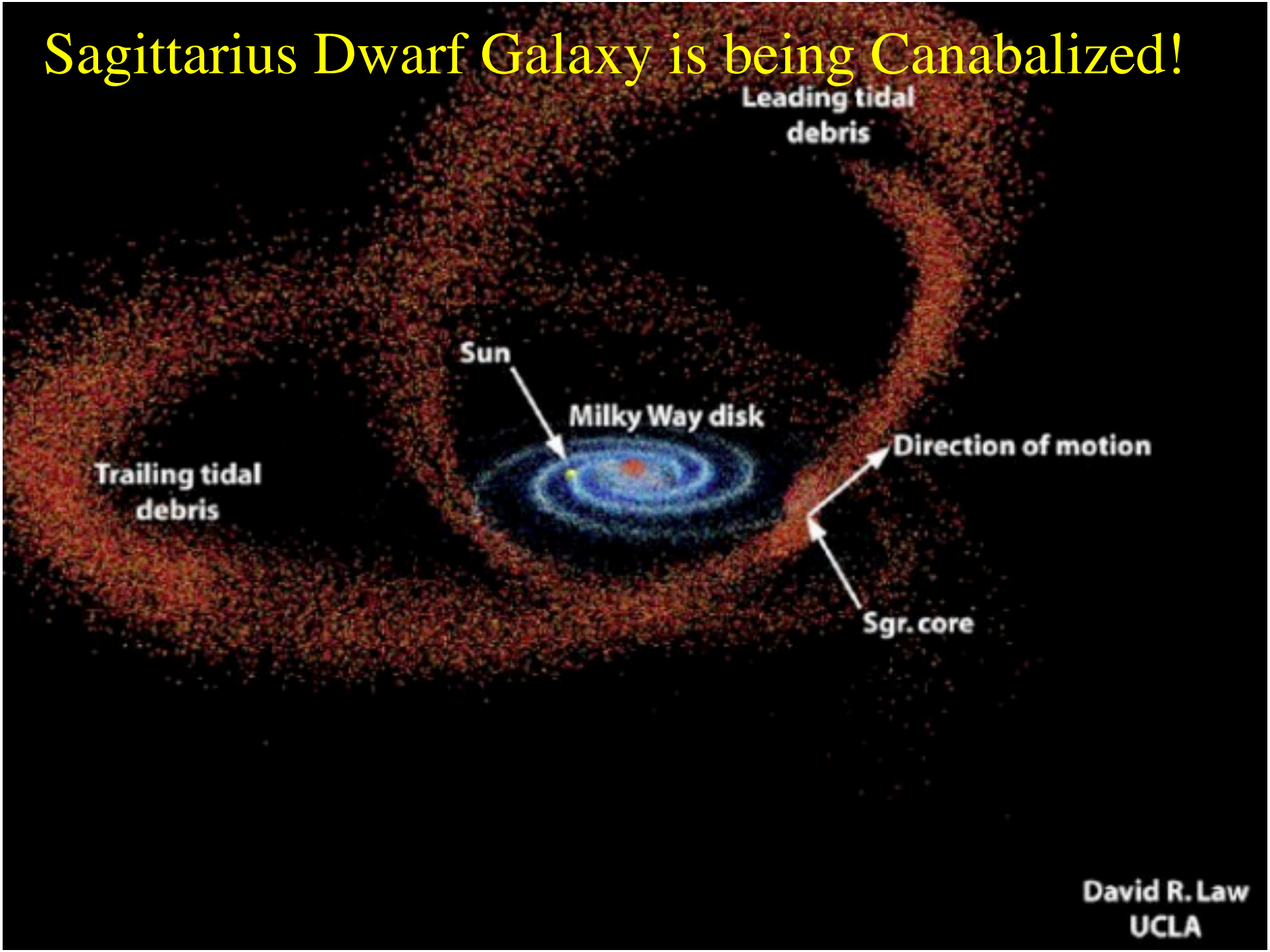


The Milky Way is not alone … Satellite Galaxies

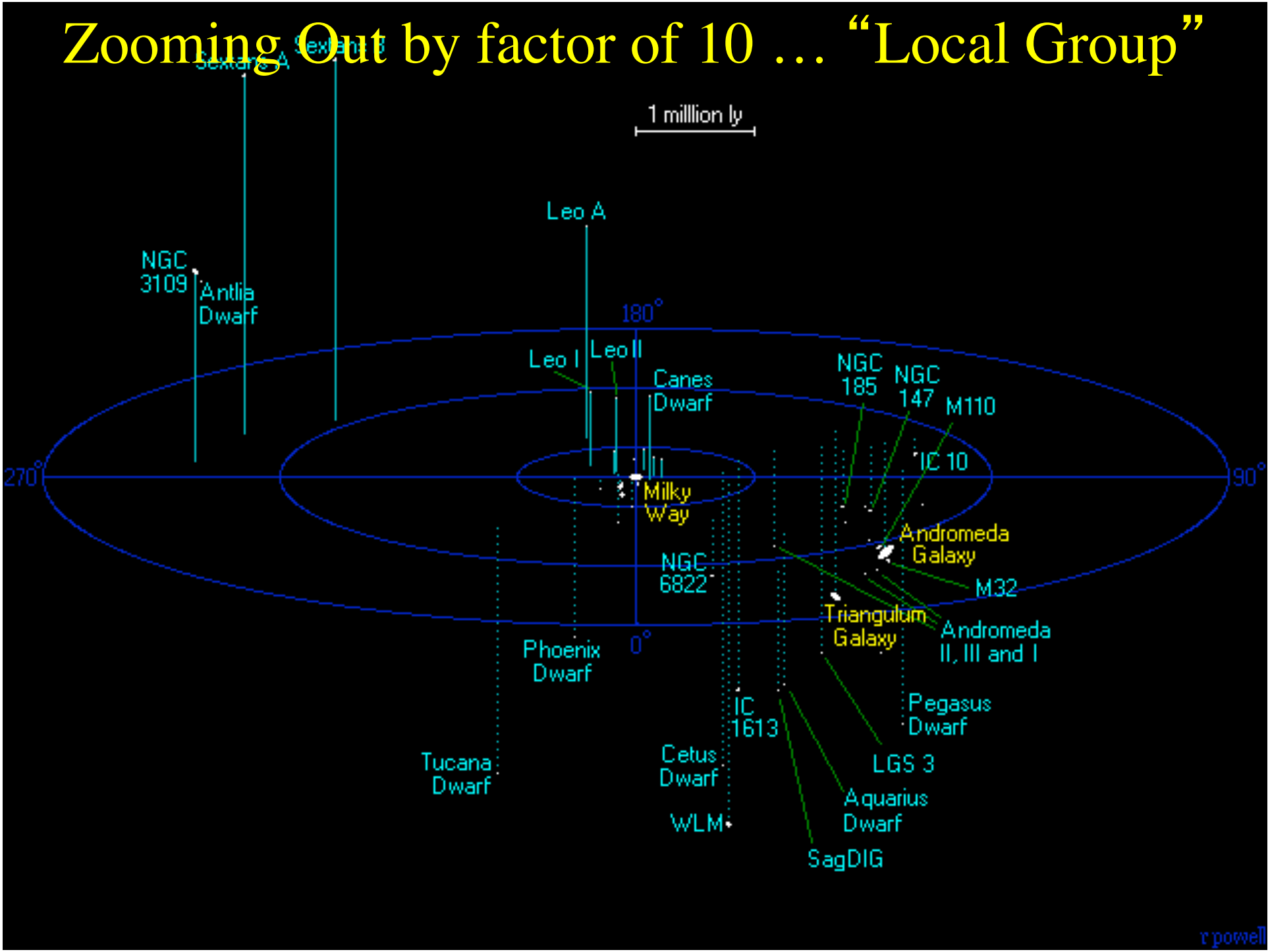

Magellanic Clouds are visible from Southern Hemisphere
© Stéphane Guisard


Large Magellanic Cloud – "Irregular Galaxy"
Distance ~ 150,000 ly
1/10th size of Milky Way
1/100th mass of Milky Way

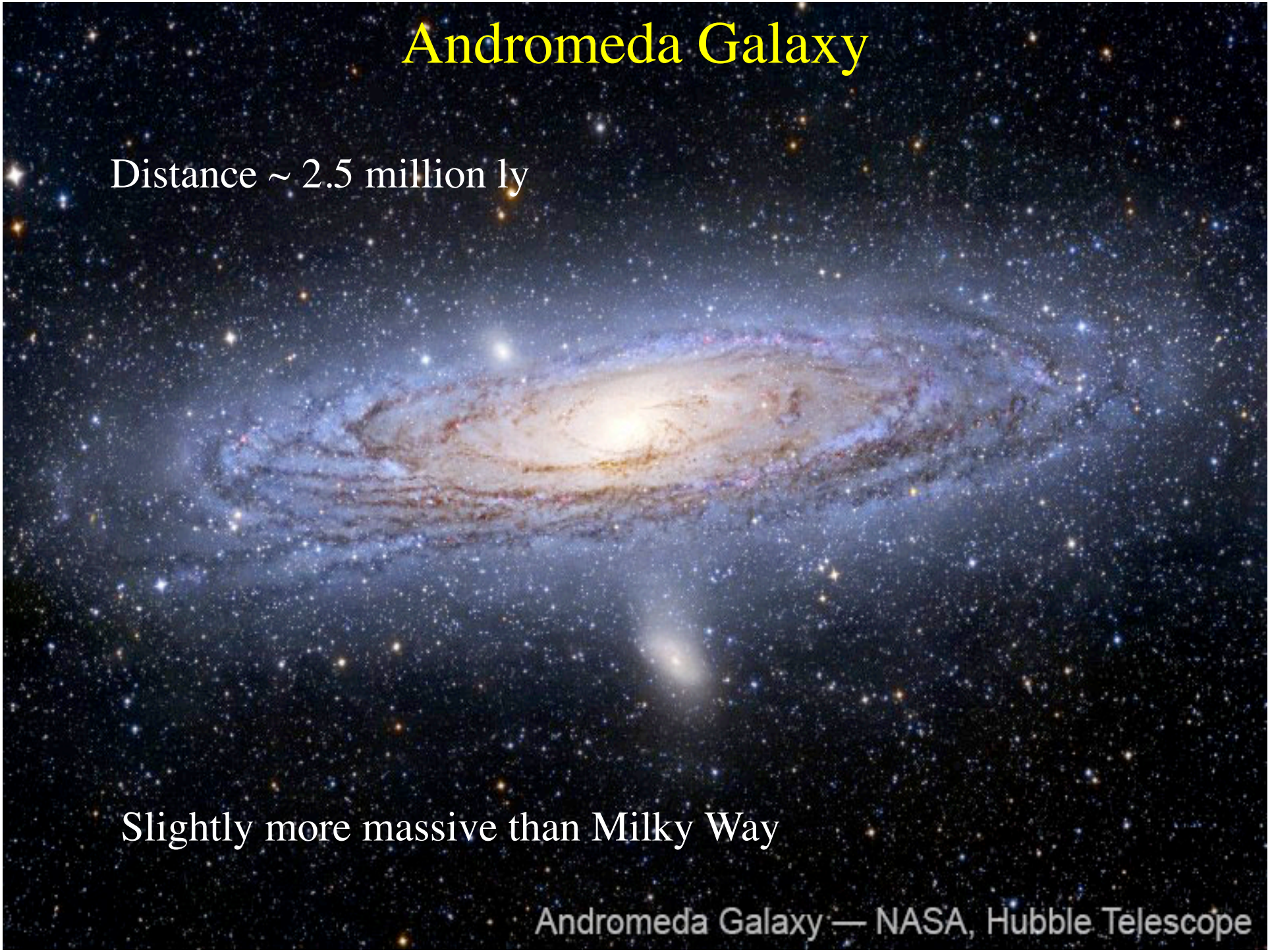
Sagittarius Dwarf Galaxy is being Canabalized!

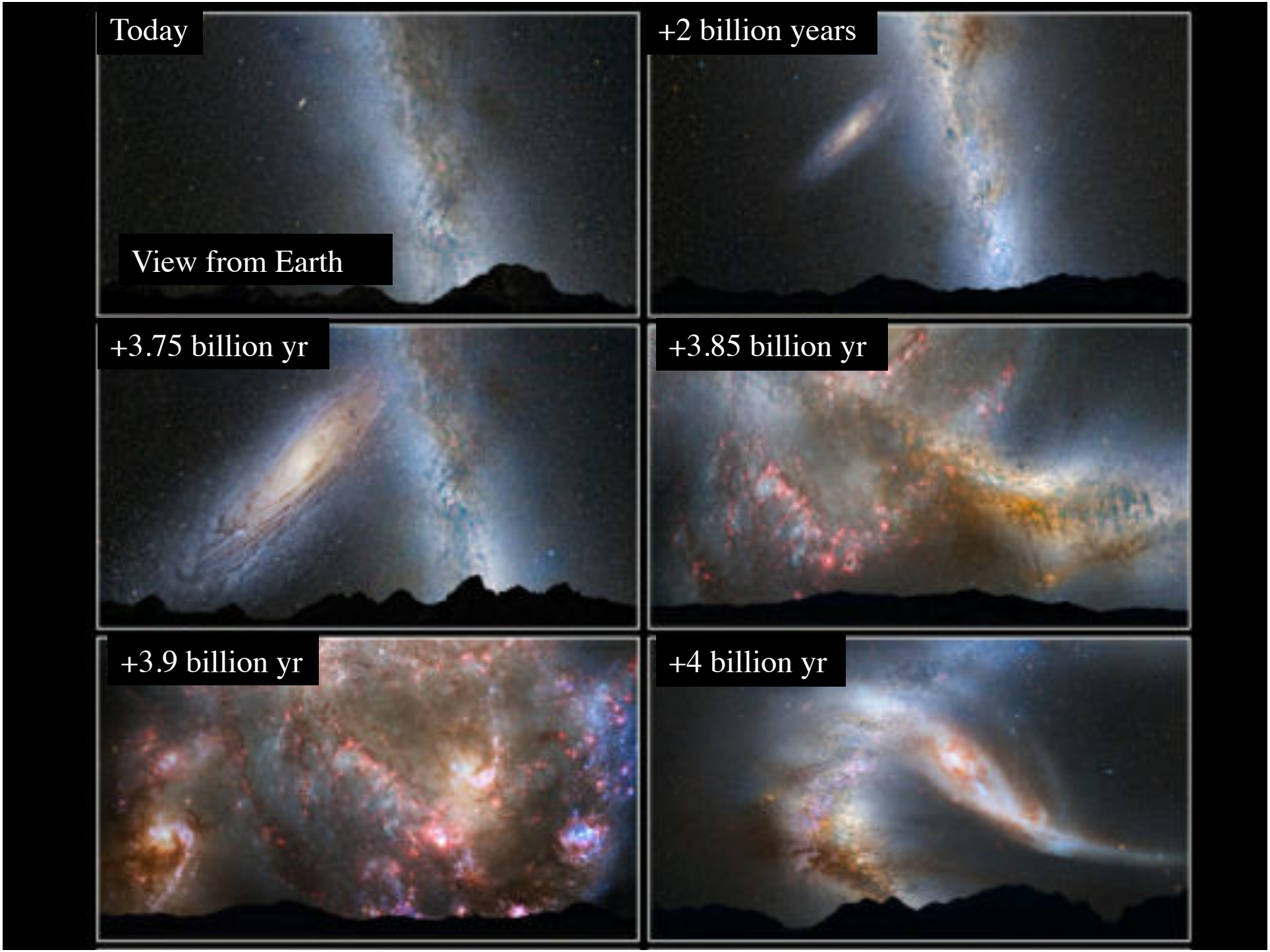


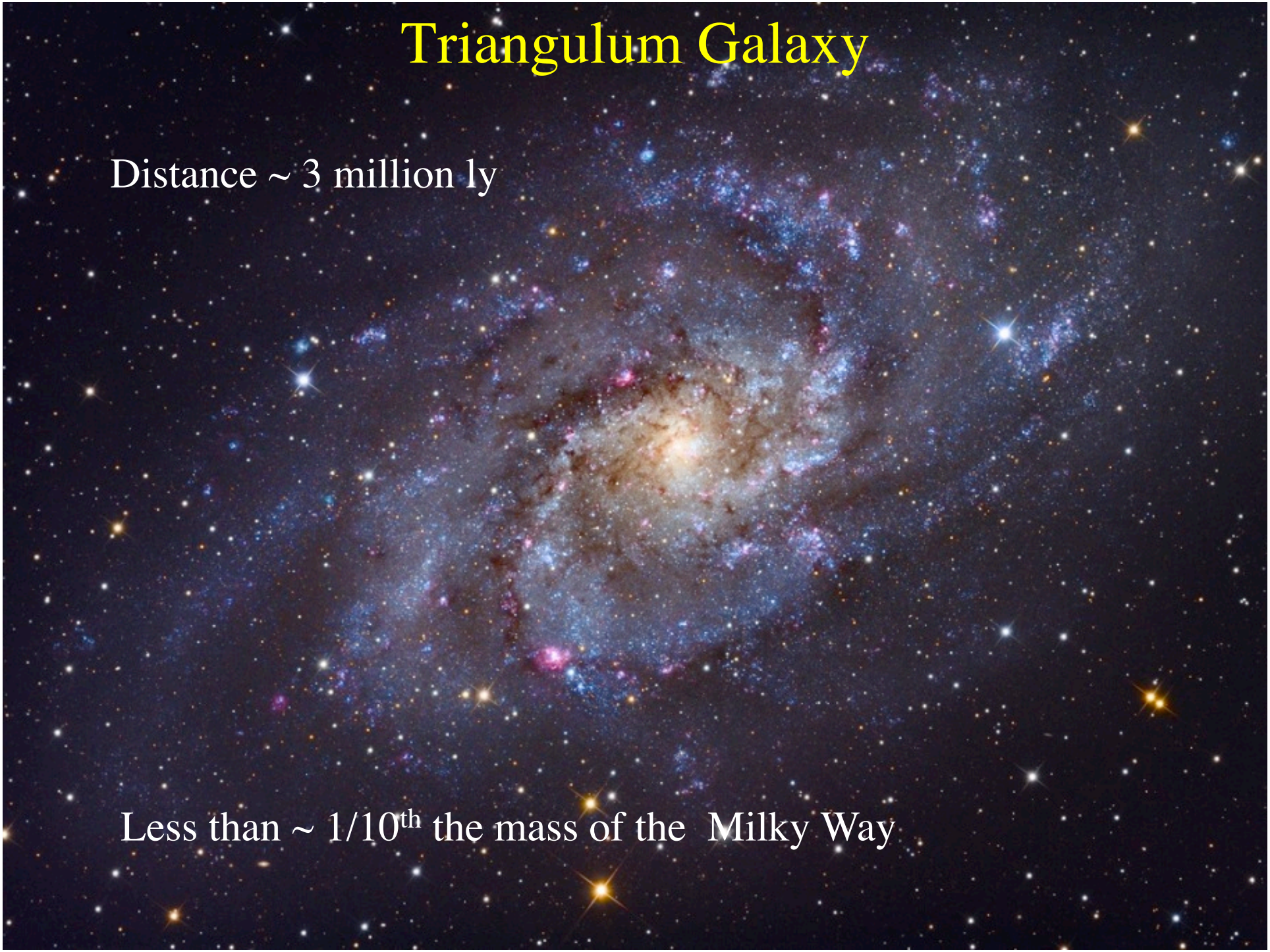
Zooming Out by factor of 10 … "Local Group"



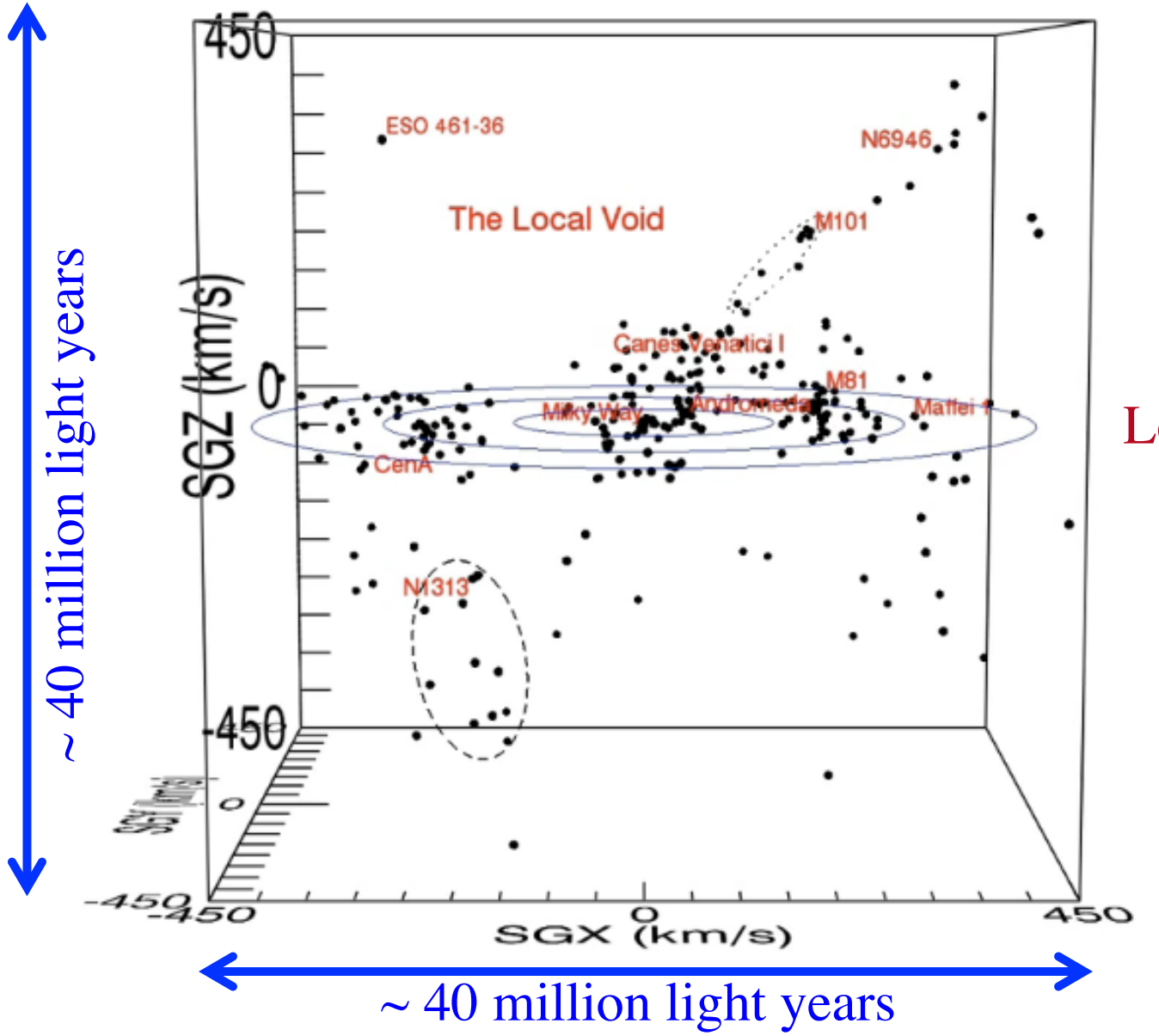
Andromeda Galaxy




Today
View from Earth
+2 billion years
+3.75 billion yr
+3.85 billion yr
+3.9 billion yr
+4 billion yr

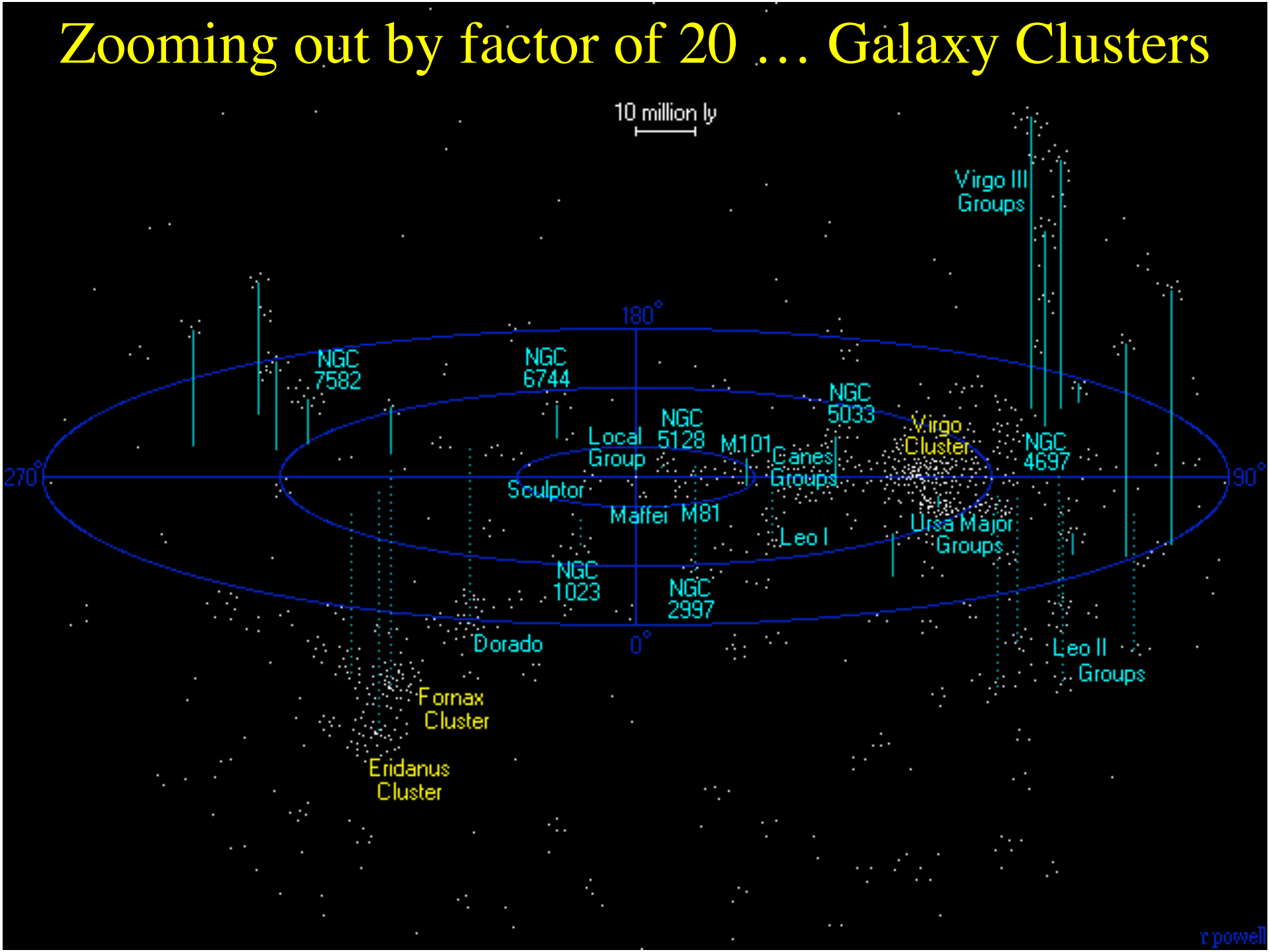

Triangulum Galaxy
Distance ~ 3 million ly
Less than ~ 1/10th the mass of the Milky Way

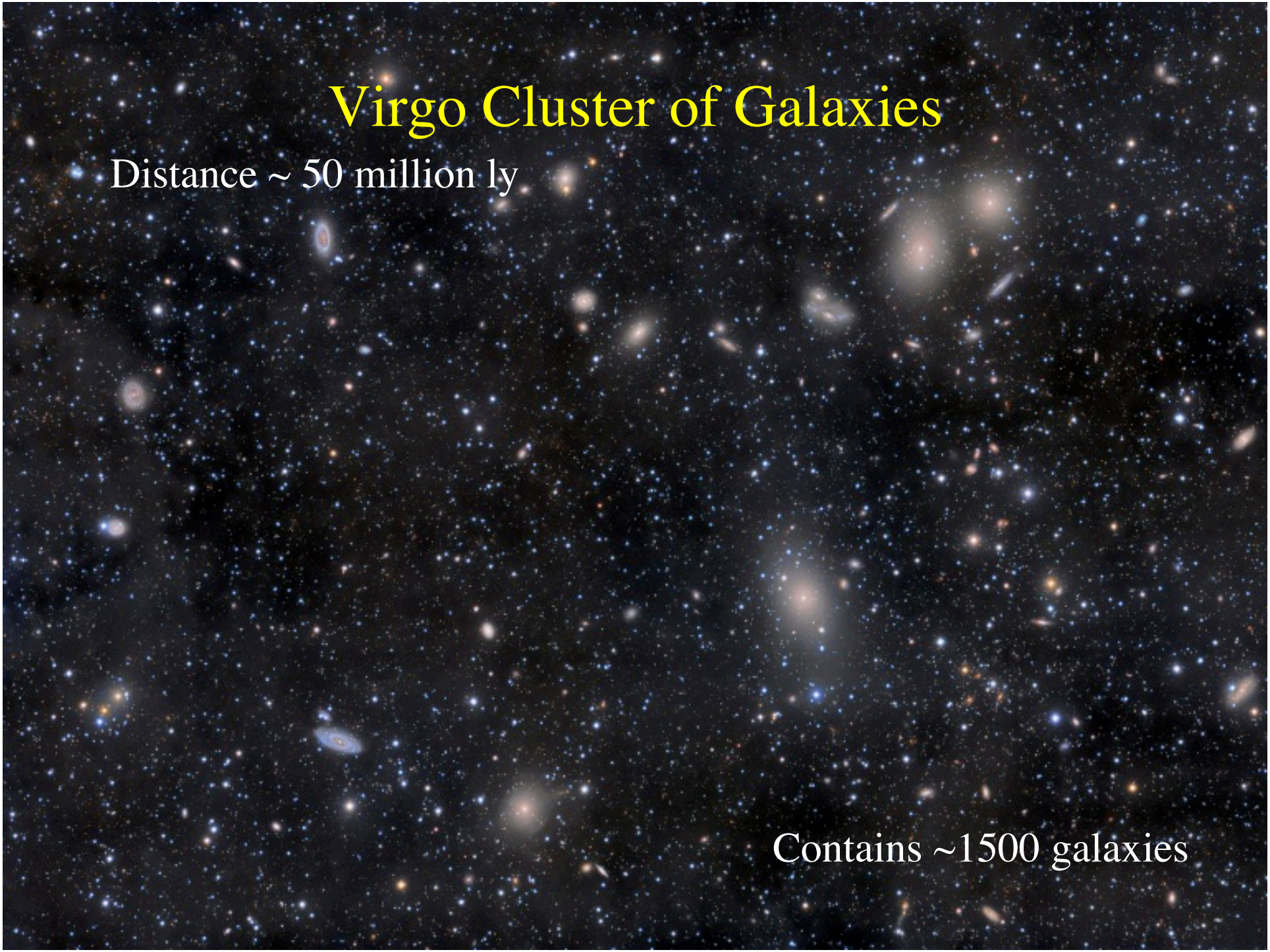
Many galaxies near us lie mostly along a plane called the Local Sheet

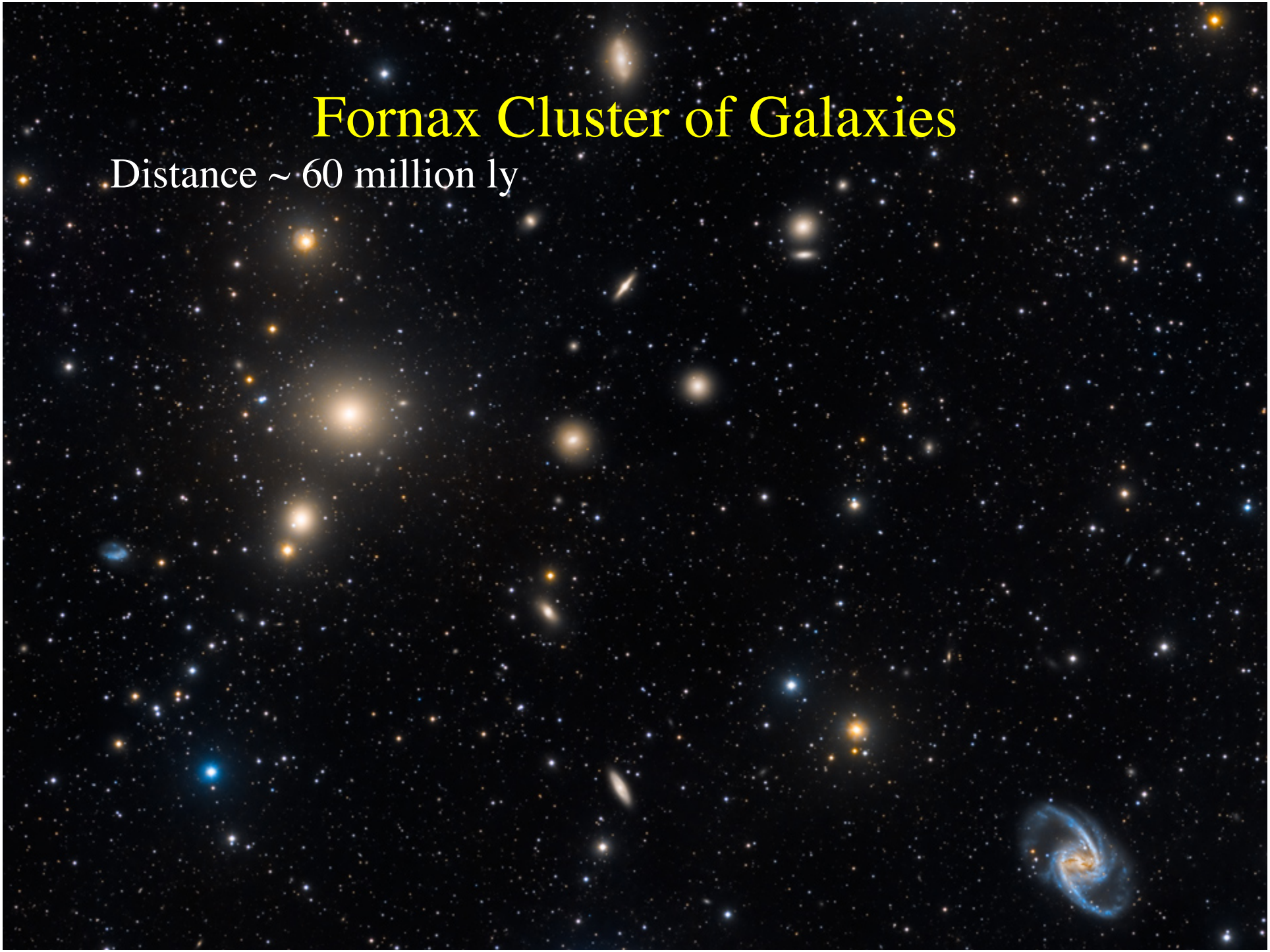


Local Sheet

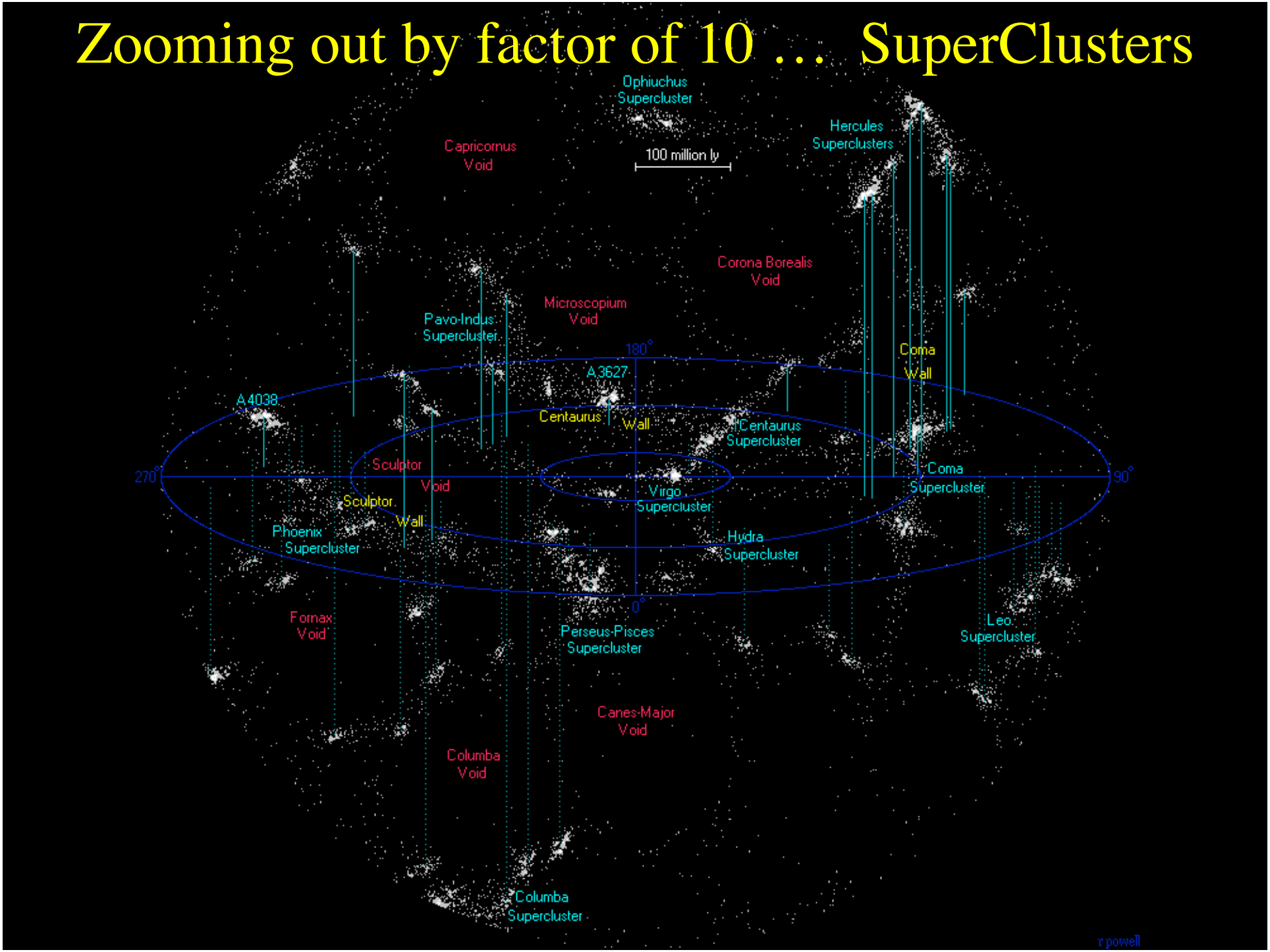
Zooming out by factor of 20 … Galaxy Clusters



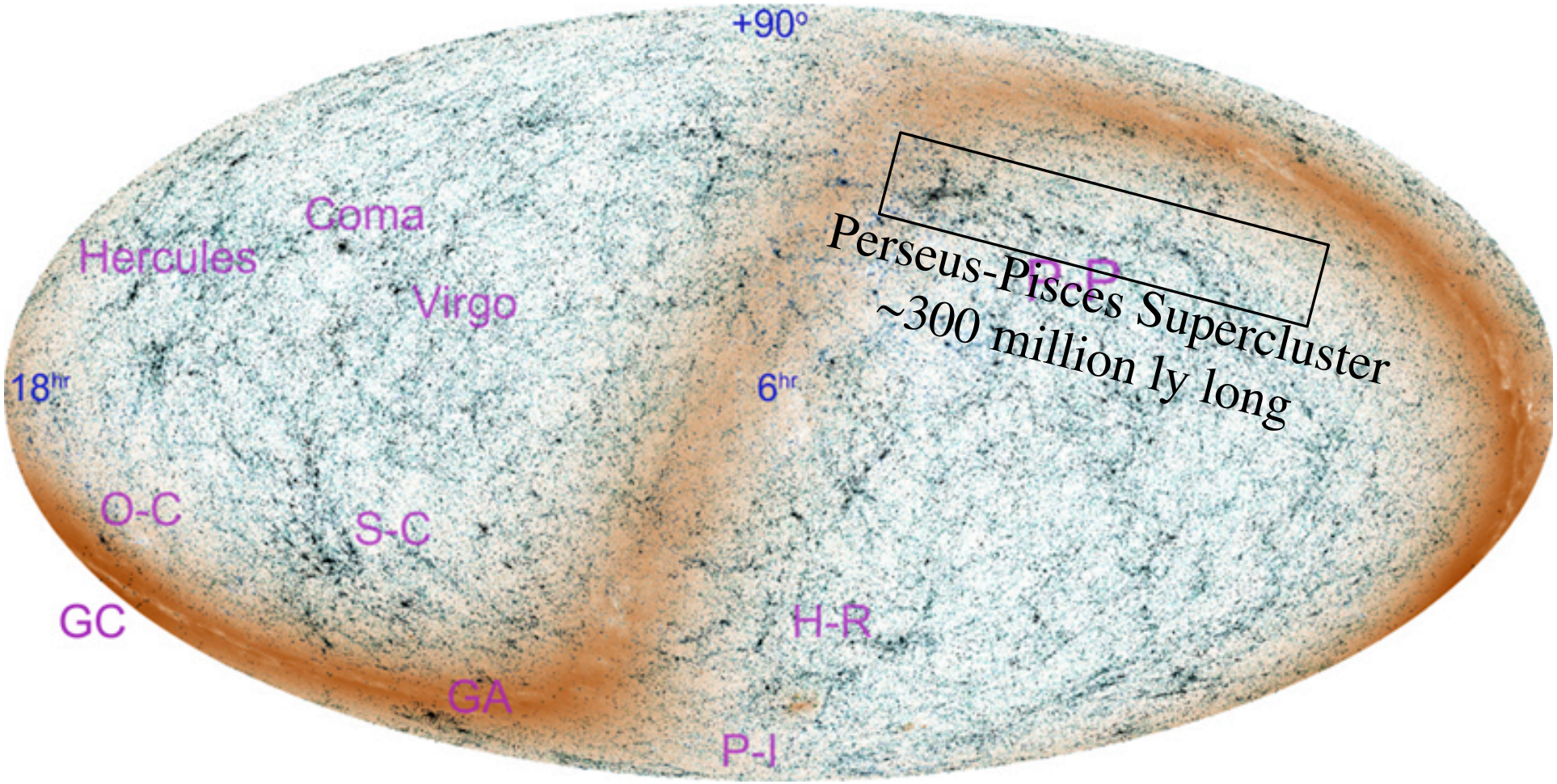

Virgo Cluster of Galaxies
Distance ~ 50 million ly
Contains ~1500 galaxies


Fornax Cluster of Galaxies
Distance ~ 60 million ly

Zooming out by factor of 10 … SuperClusters

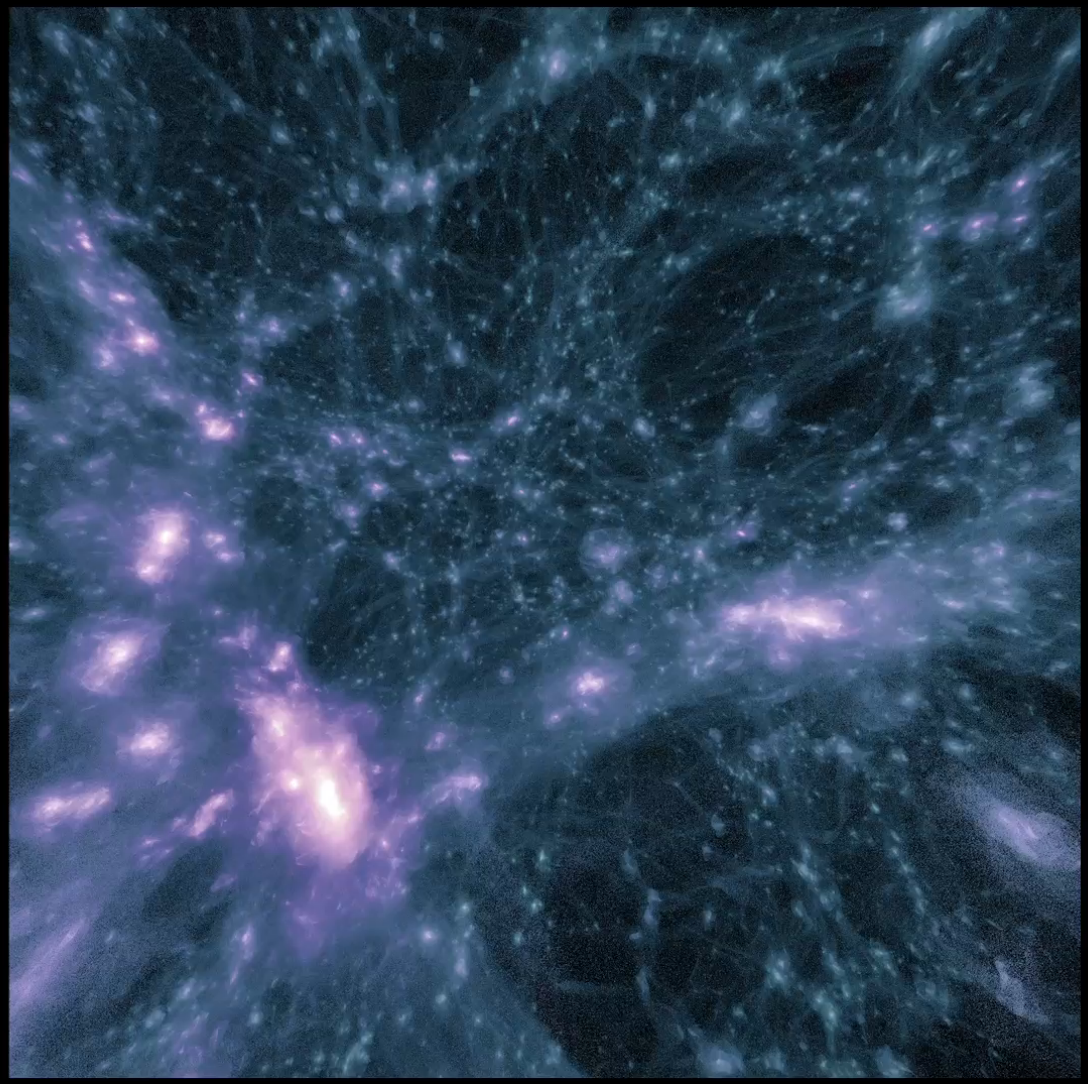


All Sky Distribution of Galaxies



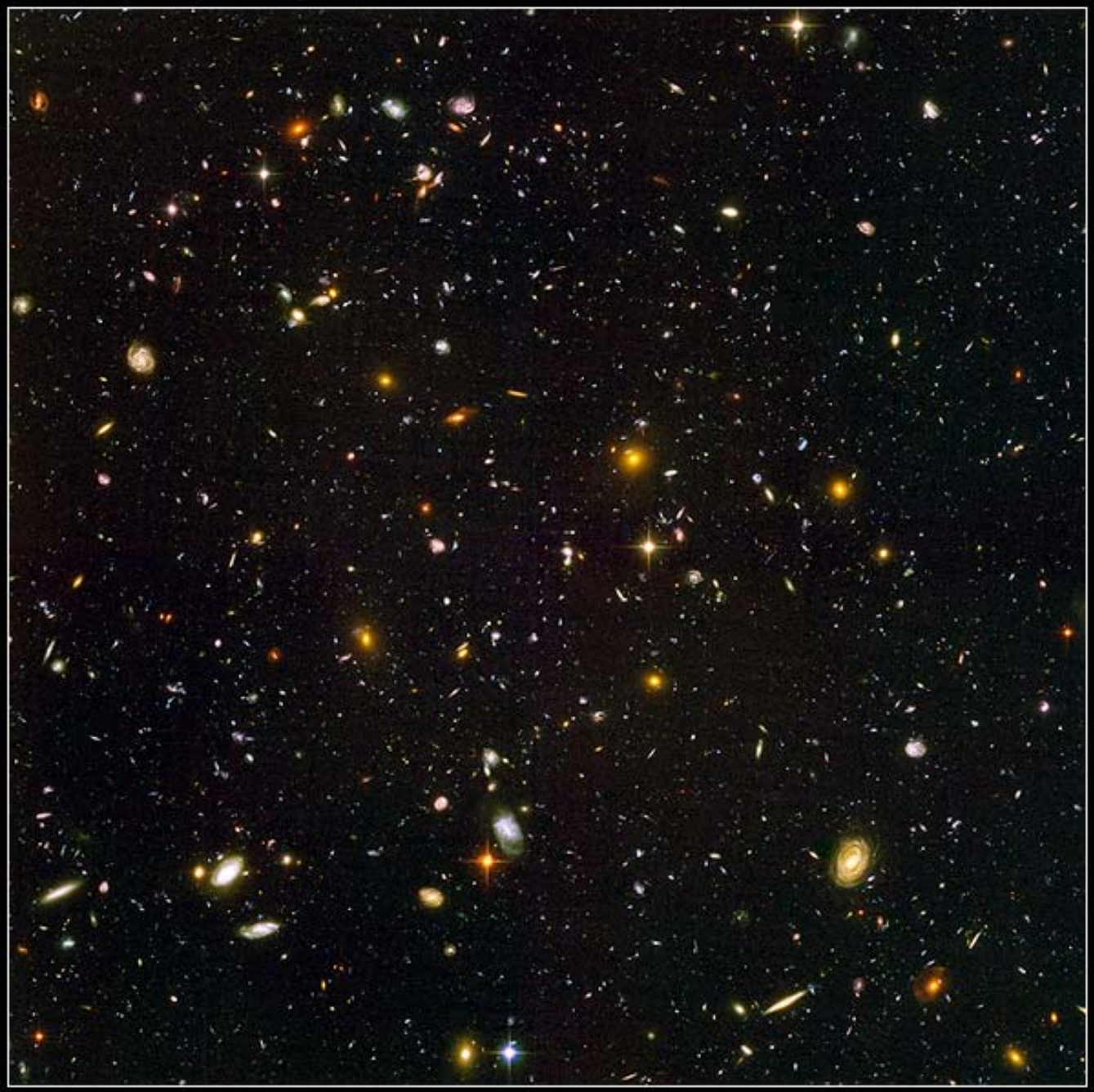
Credit: 2MASS

On largest scales **Gravity** has organized galaxies into filaments 100s of millions light years long



Simulation courtesy Dr. Brant Robertson (Arizona)

Hubble Ultra Deep Field ***HST*** ▪ ACS



NASA, ESA, S. Beckwith (STScI) and The HUDF Team STScI-PRC04-07a

90% of the volume or look-back time is probed by deep field

- **Number of galaxies in the observable universe: ~ 60 billion**
- **Number of stars in the observable universe: ~ 10^{22}**

WHOAAAAA!

How many stars is that?

- The Milky Way is one of about 60 billion galaxies.
- 10^{11} stars/galaxy x 10^{11} galaxies = 10^{22} stars

As many stars as grains of (dry) sand on *all* Earth's beaches…
Counting galaxies at one/second, ~2000 years
At this rate, it would take longer than the lifetime of universe to count all the stars

Cosmic Microwave Background: The farthest we can see back…

Radiation signature from 300,000 years after the Big Bang