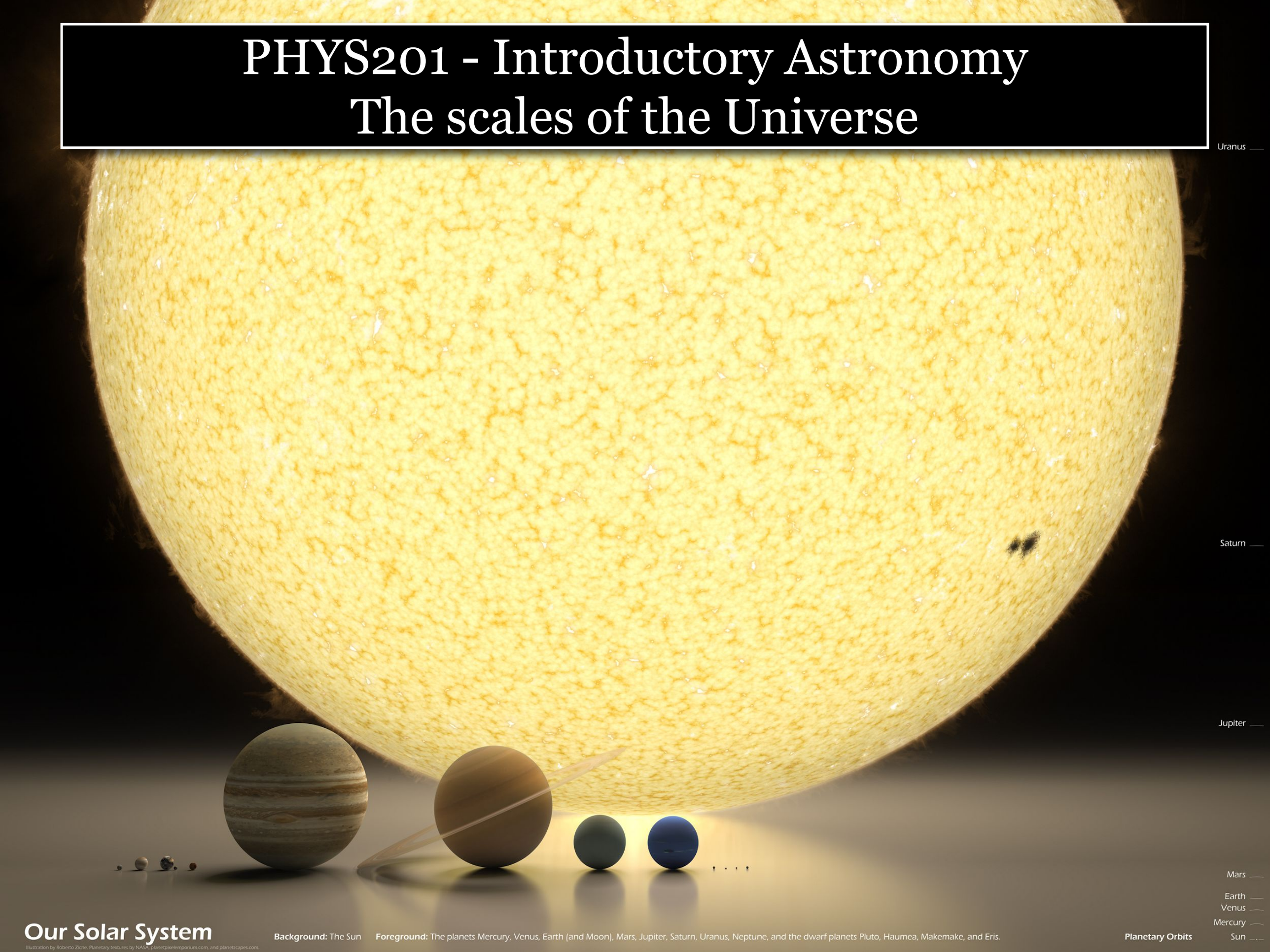
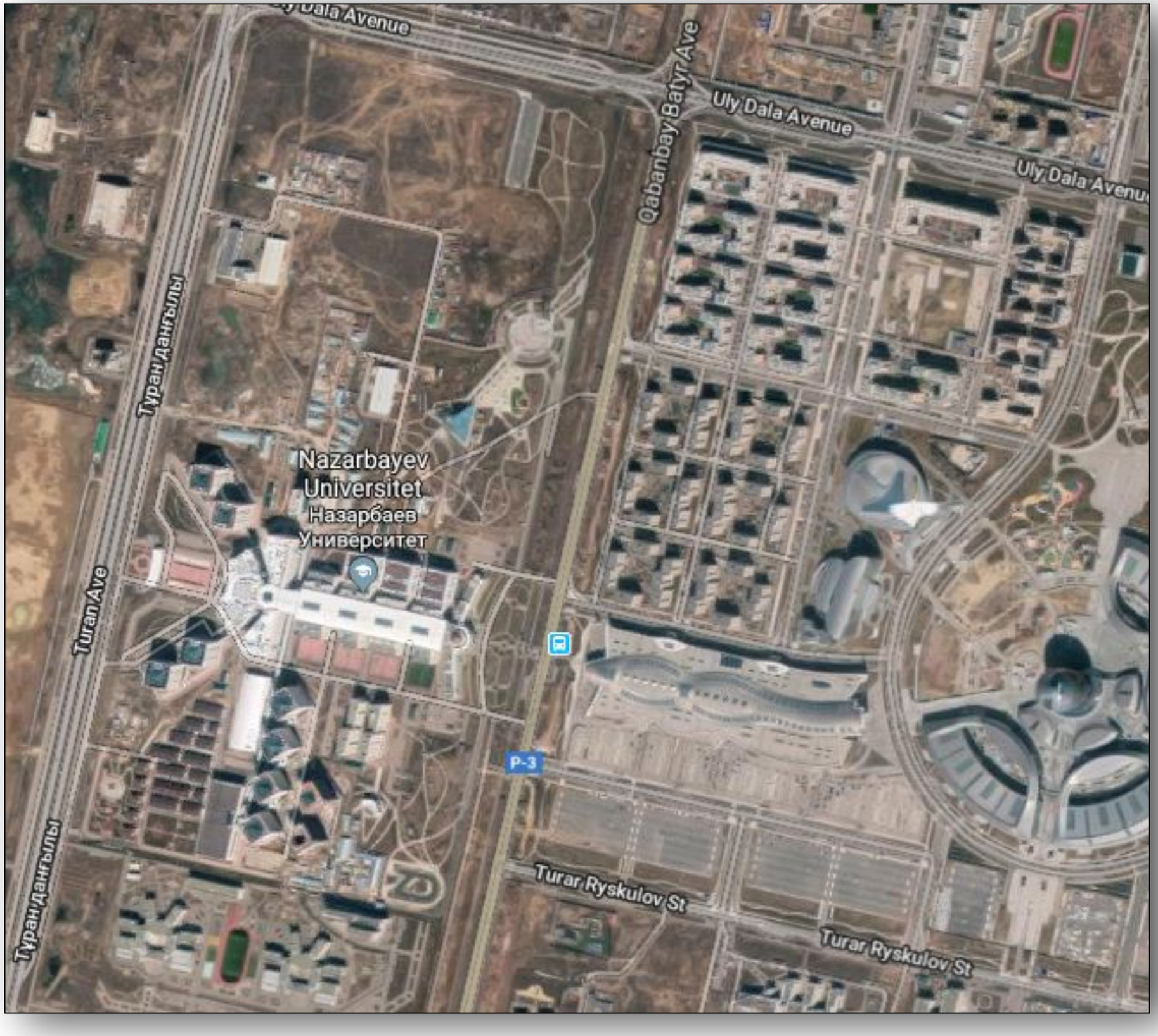
# PHYS201 - Introductory Astronomy
# The scales of the Universe



~15 m

~1.6 km

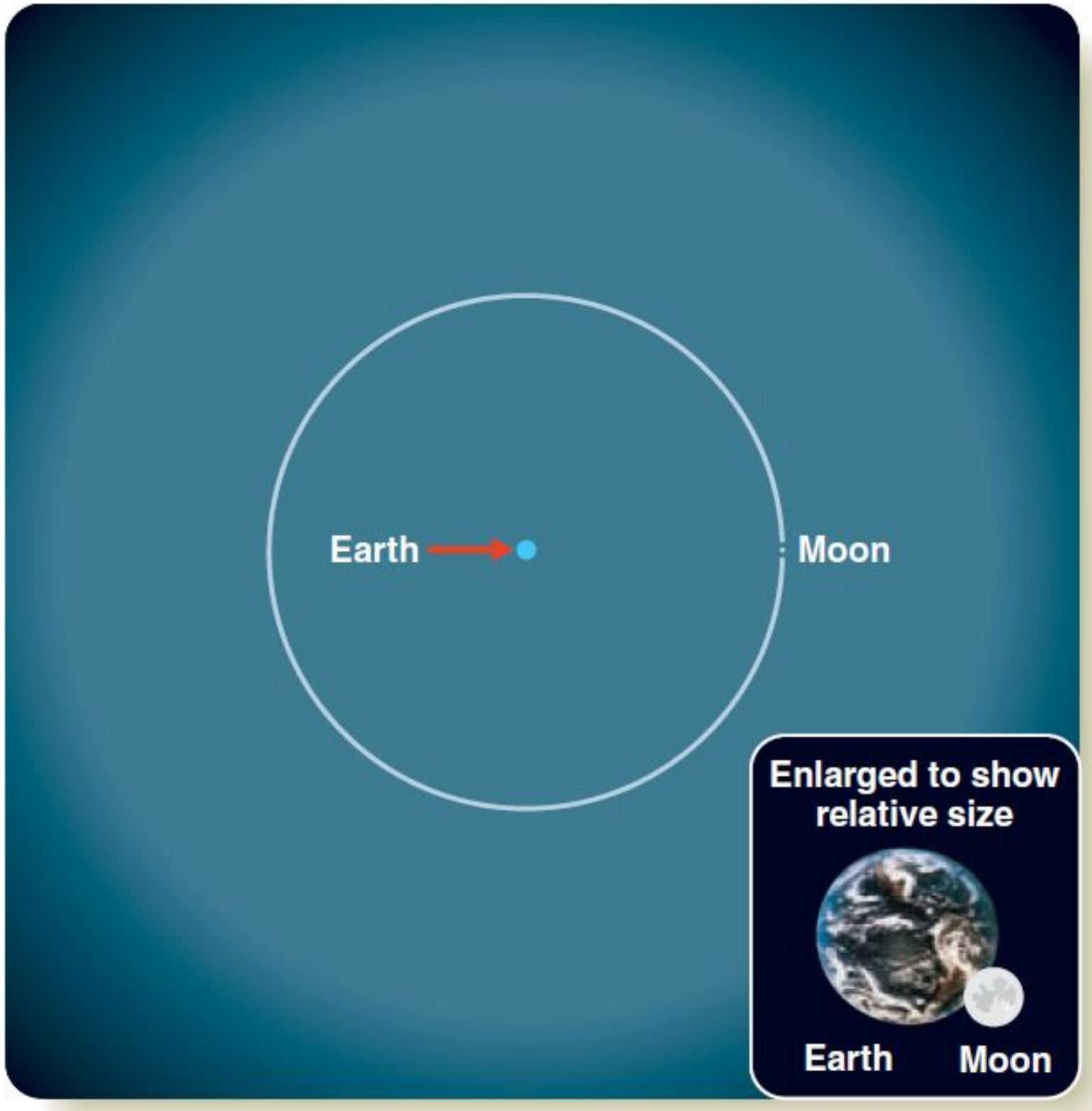

Uly Dala Avenue
Qabanbay Batyr Ave
Uly Dala Avenue
Uly Dala Avenue
Туран Данғылы
Nazarbayev
Universitet
Назарбаев
Университет
Turan Ave
Туран Данғылы
P-3
Turar Ryskulov St
Turar Ryskulov St


Stepnogorsk
Степногорск
Akkol
Аққөл
Shortandy
Шортанды
hanka
канка
Astana
Астана
Koschi
Косшы
Коргалжын
Қорғалжын
Osakarovka
Осакаровка

~160 km

~16,000 km

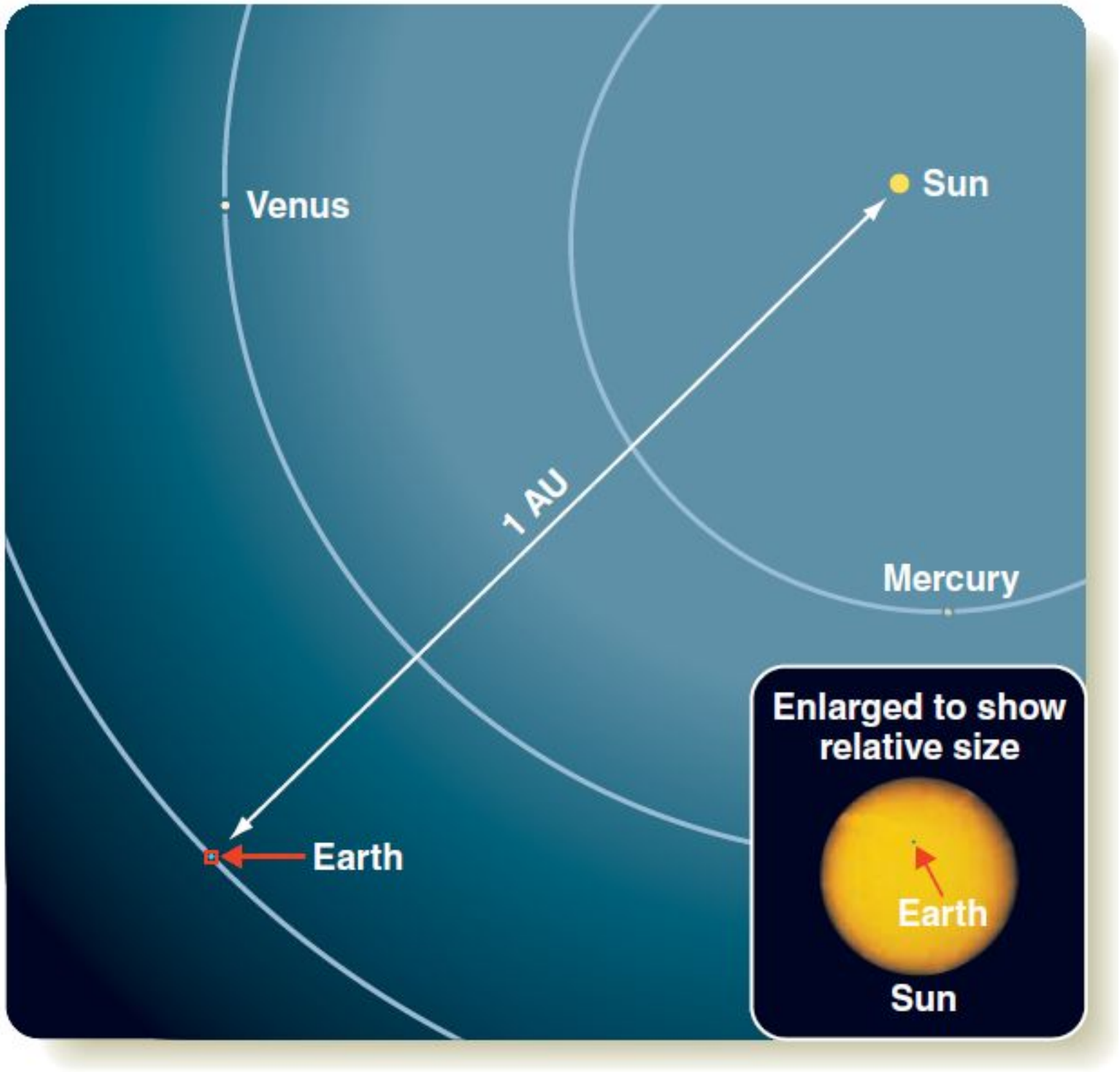
Earth diameter
~13,000 km




~1,600,000 km
$=1.6 \times 10^6$ km

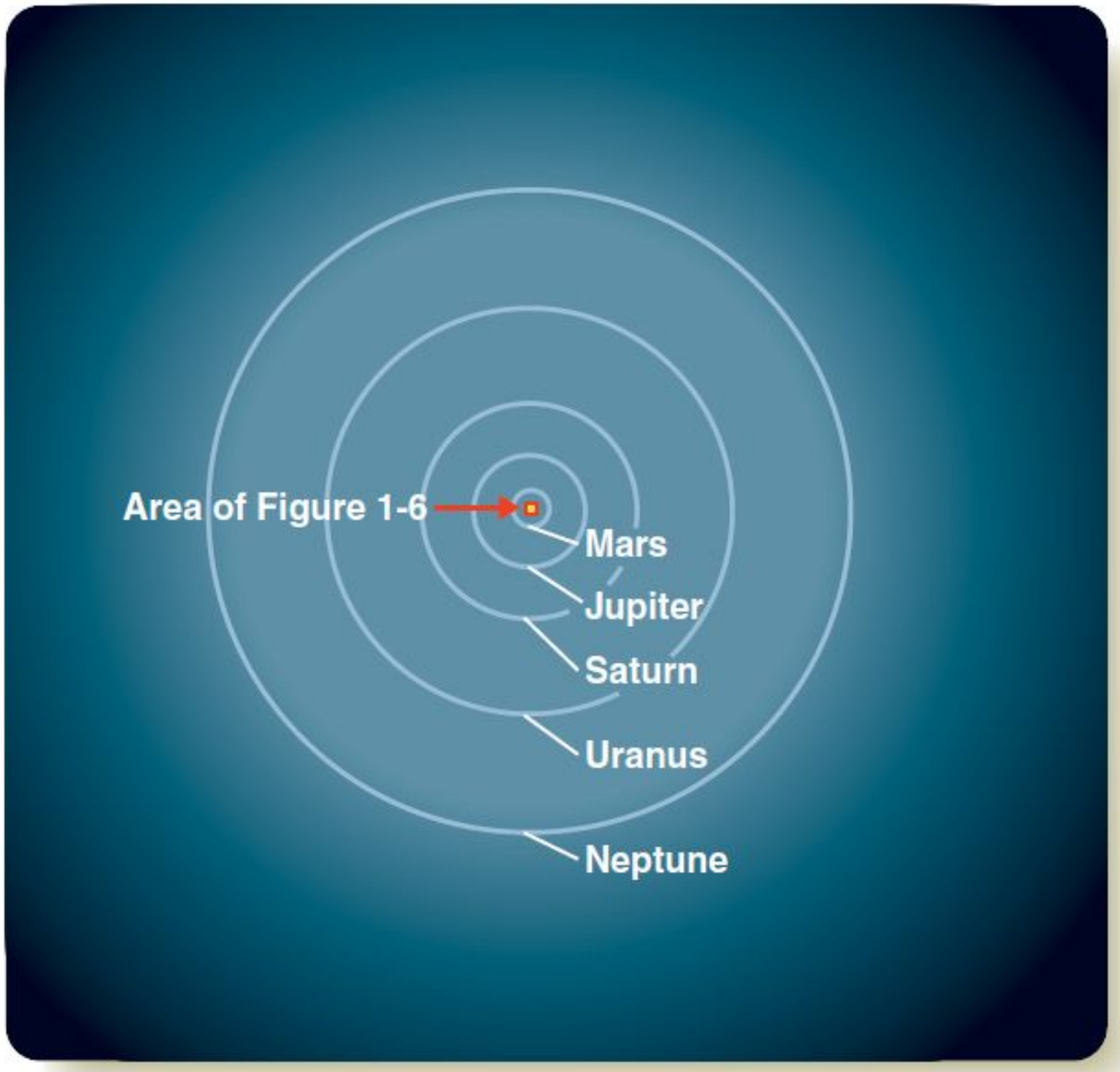
Moon orbit radius
~360,000 km
$=3.6 \times 10^5$ km

Scientific notation
$100=10^2$
$1{,}000=10^3$
...
$1{,}000{,}000=10^6$
...



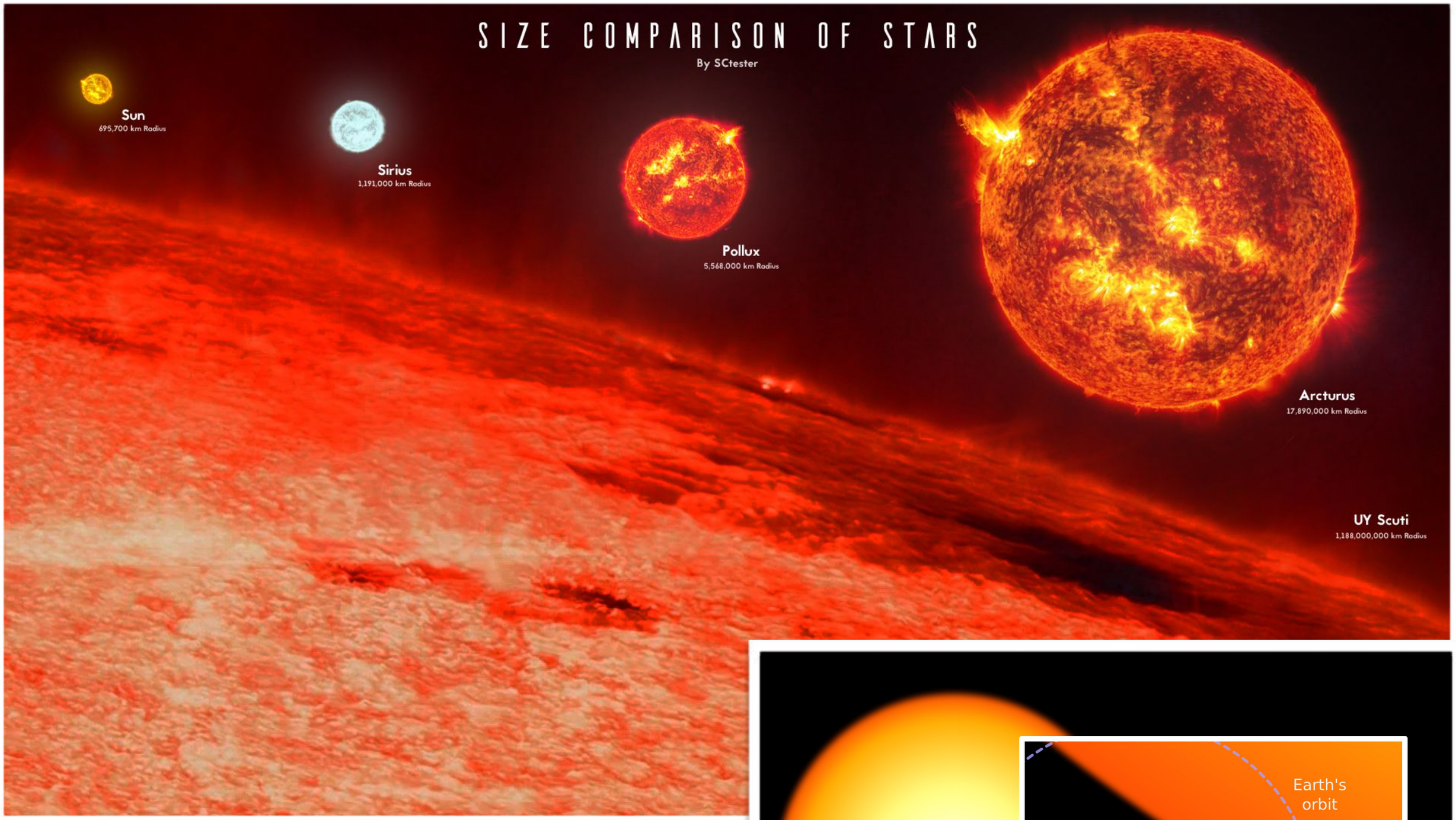

~1.6x10$^8$ km

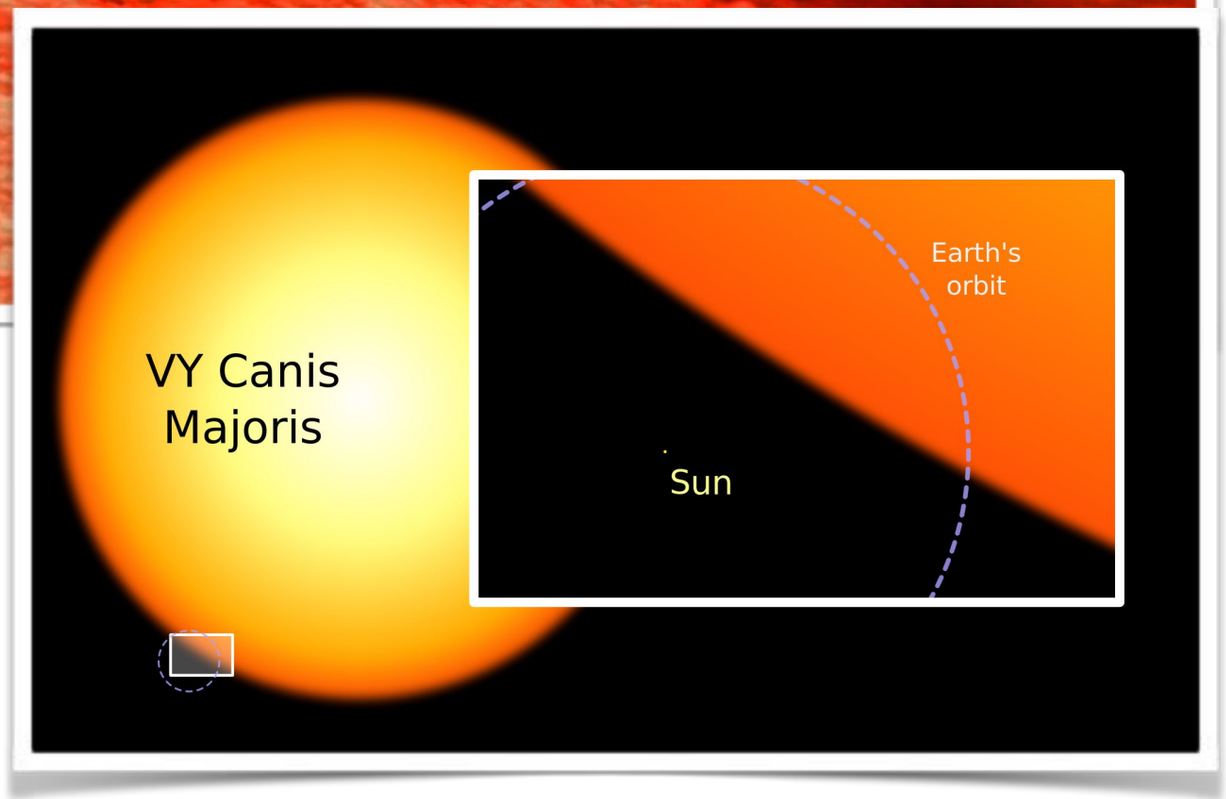
Astronomical unit (AU)
1AU~1.5x10$^8$ km



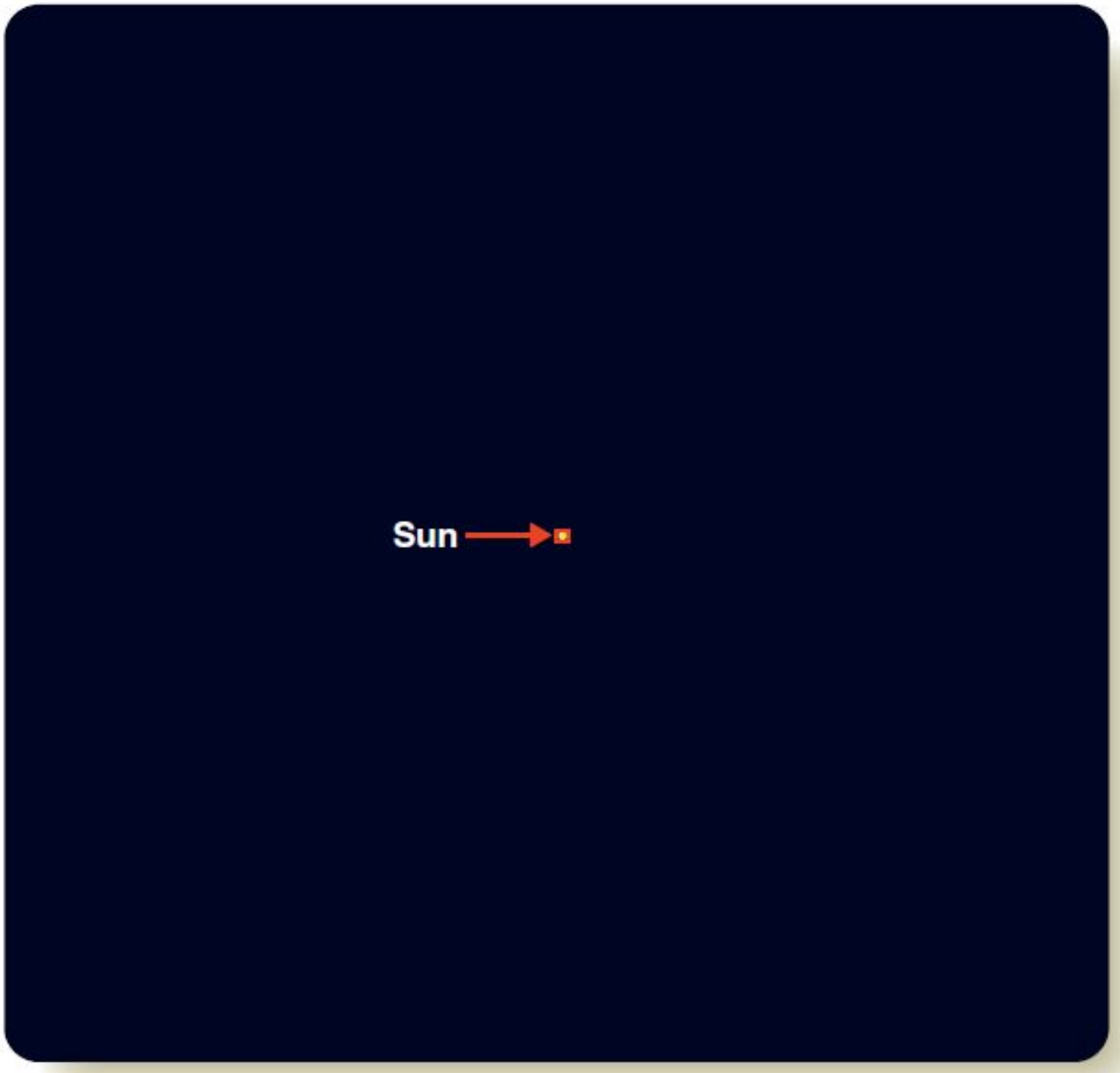

Neptune orbit radius
$4.5 \times 10^9$ km
=30.1 AU

**M**y
**V**ery
**E**ducated
**M**other
**J**ust
**S**erved
**U**s
**N**oodles




- Smallest star: 75,000 Km radius
- Sun: 700,000 Km radius
- Largest star: 990,000,000 Km radius




~11,000 AU


~$10^6$ AU=17 ly

Light year
1ly=$10^{13}$ km
=63,000 AU

Dot size represents stellar brightness

# INTERSTELLAR NEIGHBORHOOD

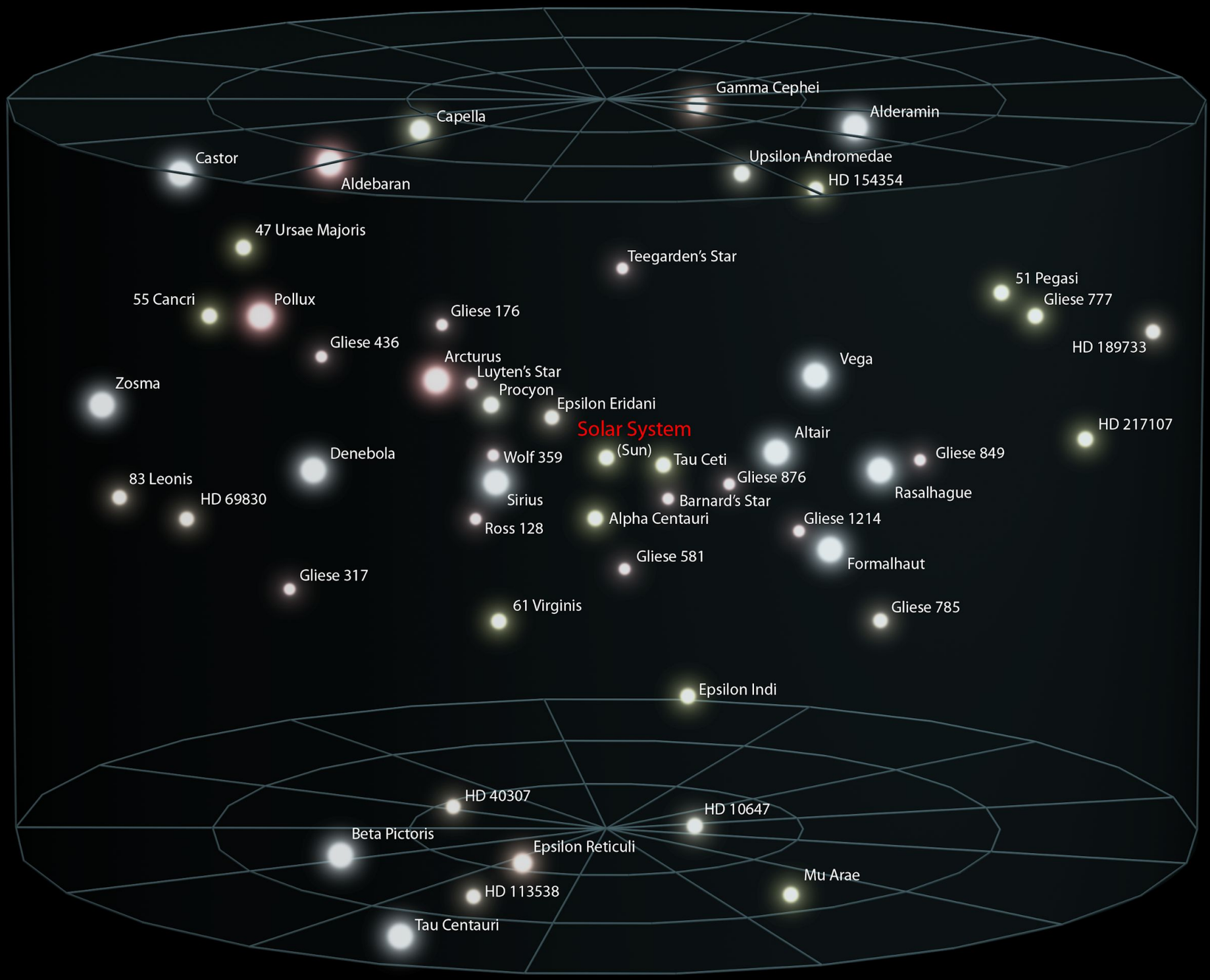



**Figure 1-10**

*This ■ box represents the relative size of the previous frame.* (NOAO)

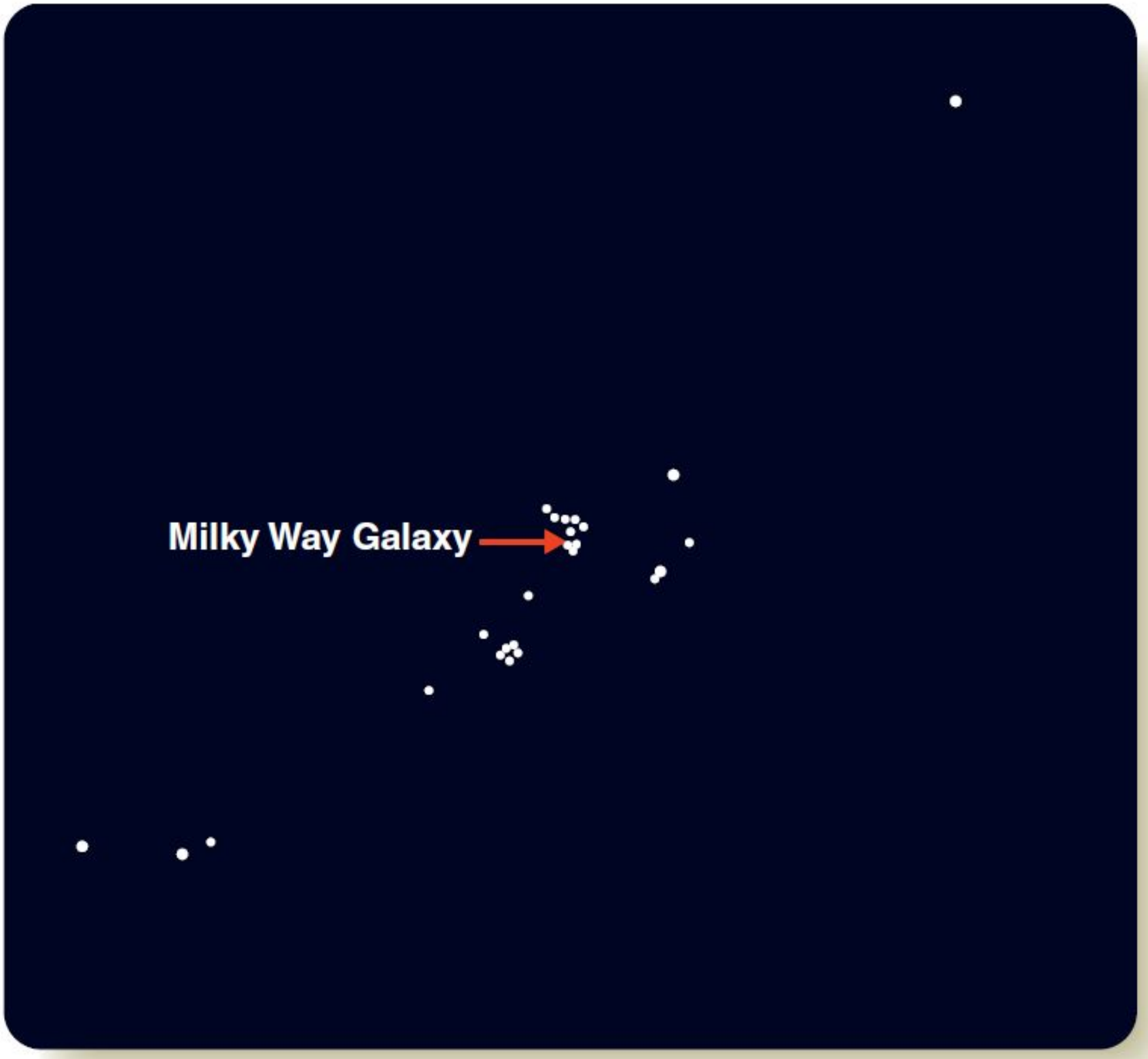
~80,000 ly

# Galaxies

- Range: 1,000 - 300,000 ly.
- Contain up to trillion stars.
- Many galaxies have spiral arms. Regions of star formation. Our sun was born in one of these arms.
- In the night sky, our galaxy can be seen as great, cloudy wheel of stars ringing the sky, aka the Milky Way.
- Only one century ago astronomers thought that our galaxy was the entire universe. Now we know that it is one of many.

Not real photo. Composition of two different photos with different exposure time.

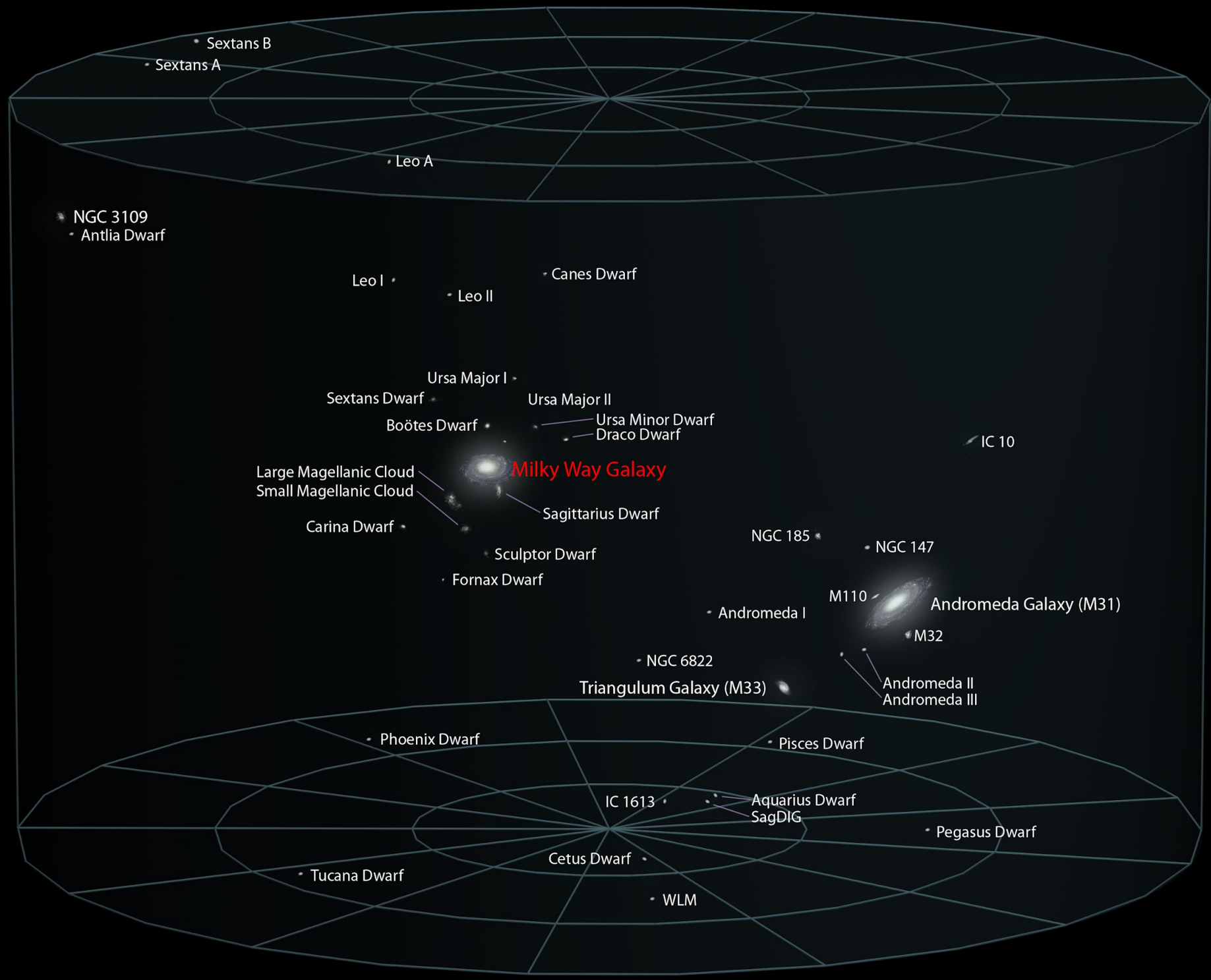
Andromeda is the nearest galaxy to the Milky Way.
It is 2.4 million light years away.
It is 3 degrees in the night sky (but too faint to be seen).
The Moon is 0.5 degrees.



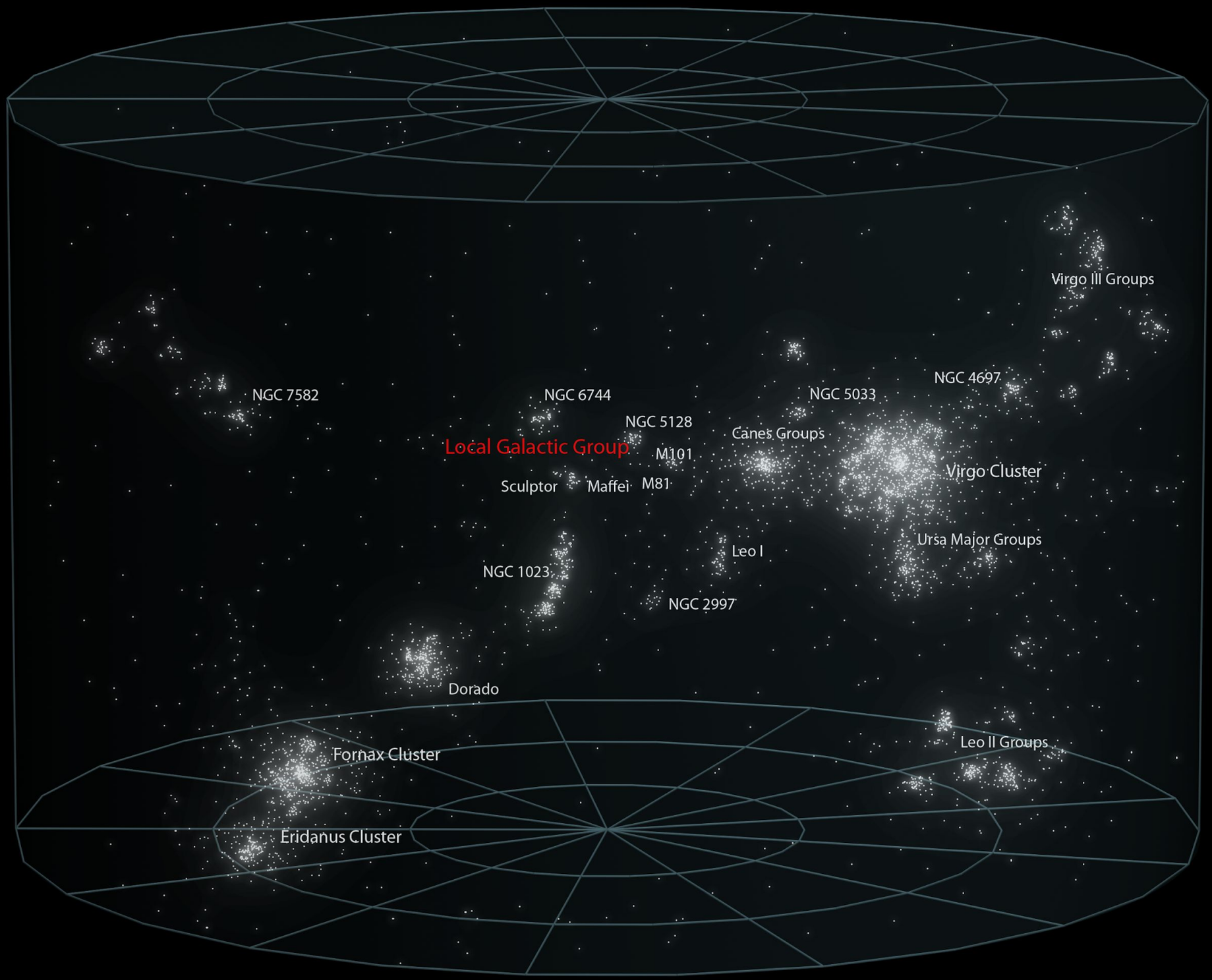

~1.7x10$^{7}$ ly

Cluster of galaxies. Many galaxies are located in clusters, which in turn are located in superclusters.

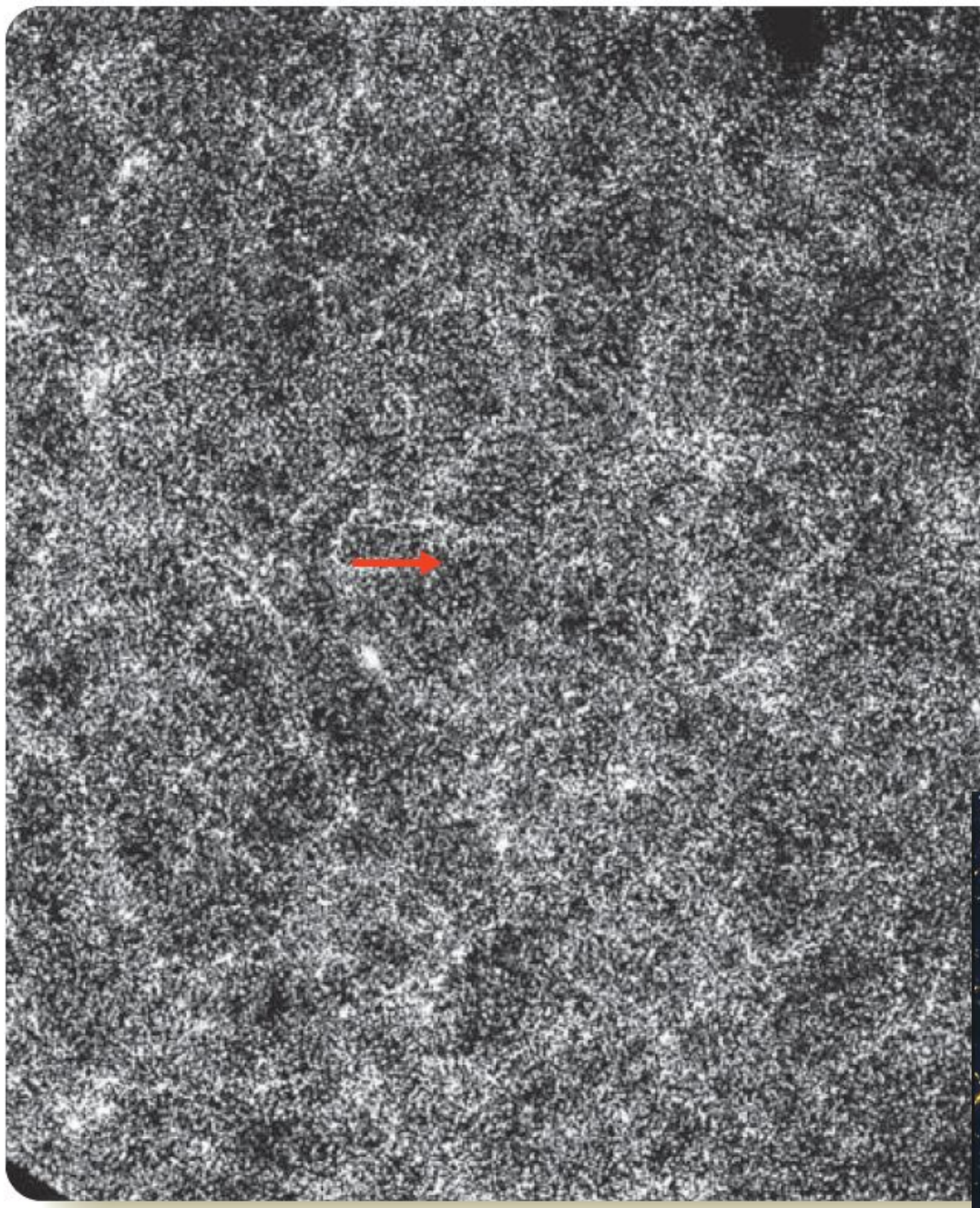
# LOCAL GALACTIC GROUP



# VIRGO SUPERCLUSTER



Large scale structure of the Universe.
Filaments, walls, and voids.



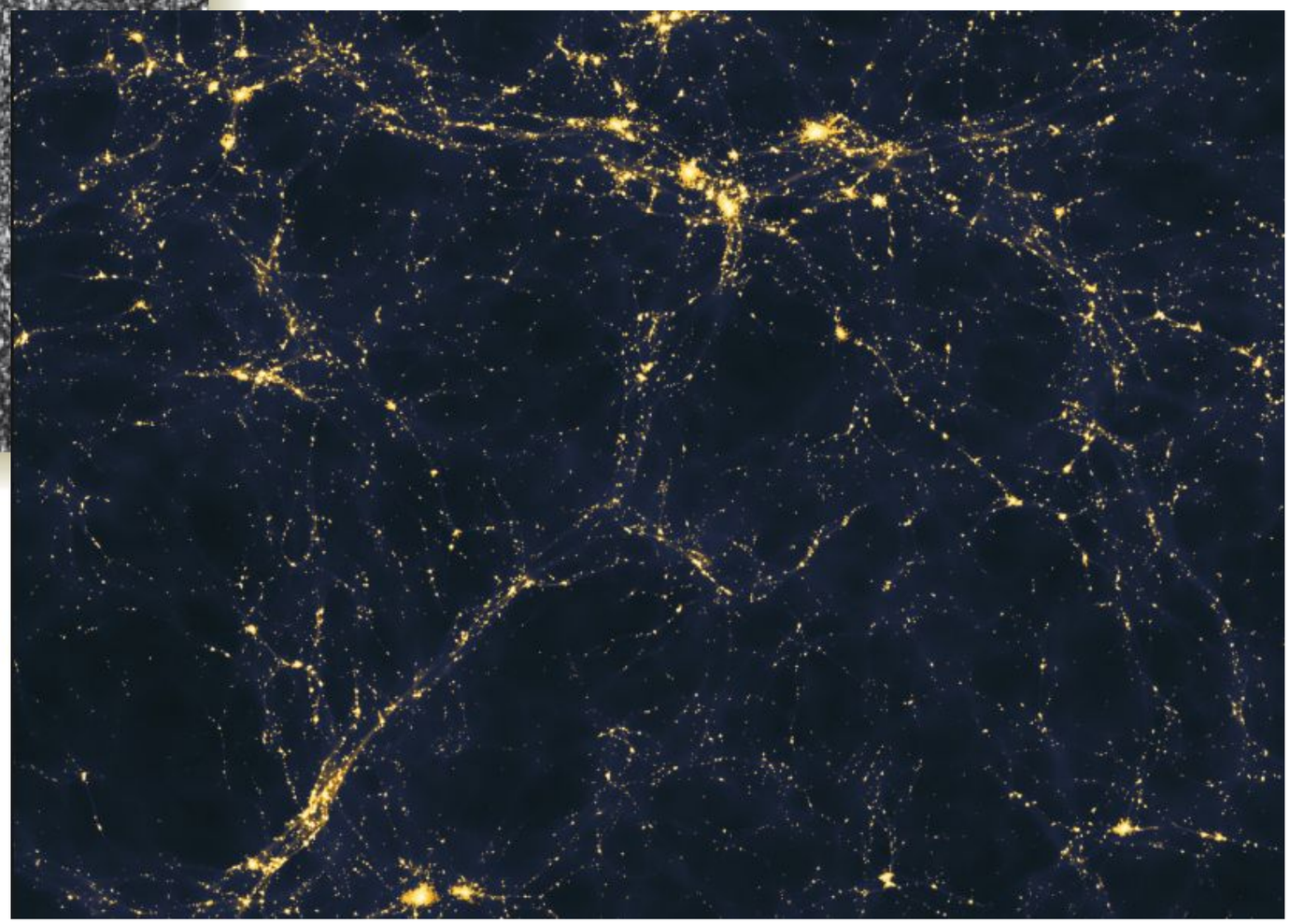
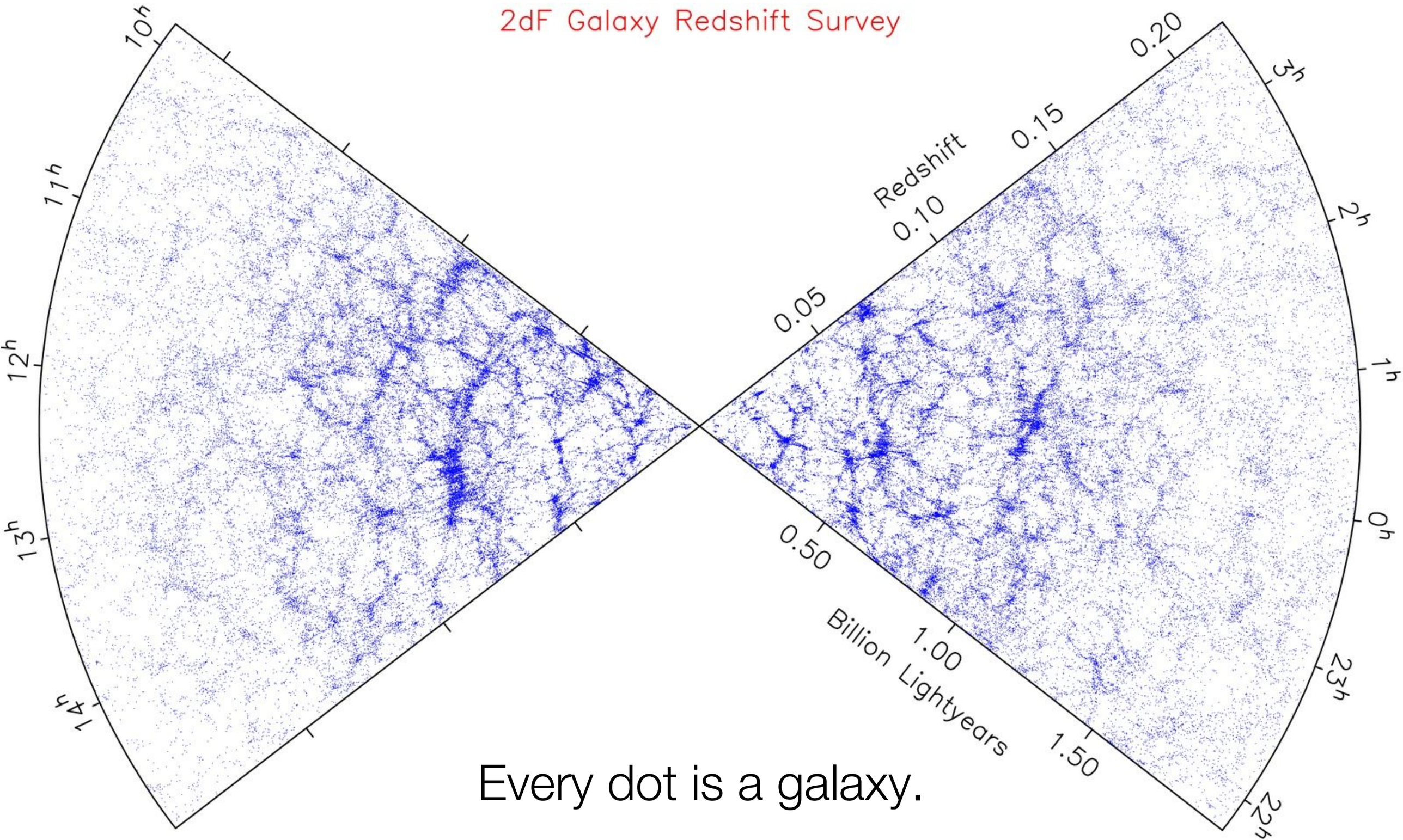


**Figure 1-13**

This box ■ represents the relative size of the previous frame.

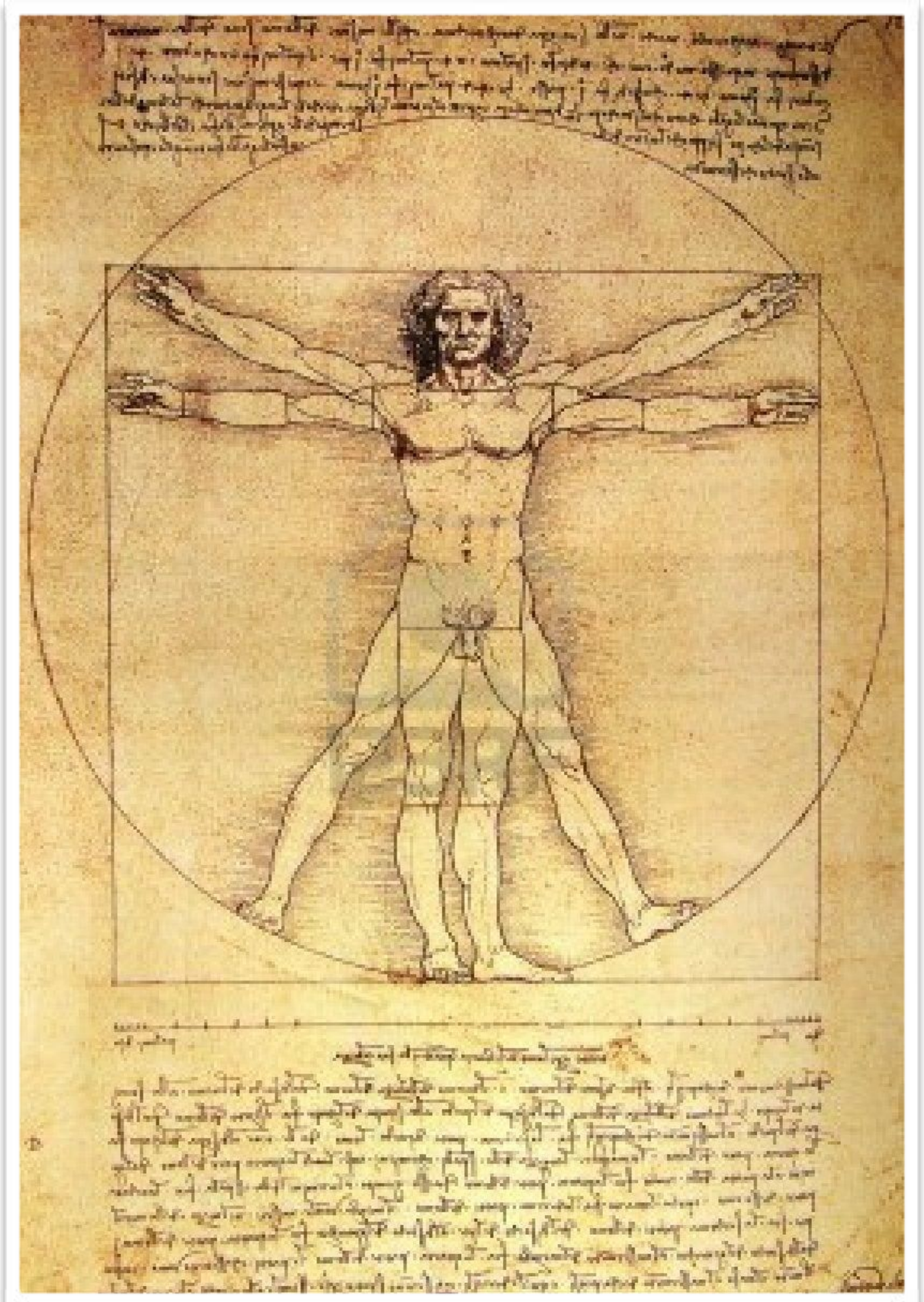
# Large scale structure




Every dot is a galaxy.

# Cosmic Voyage

# The scales of the universe (time)



# Human life
# ~80 years

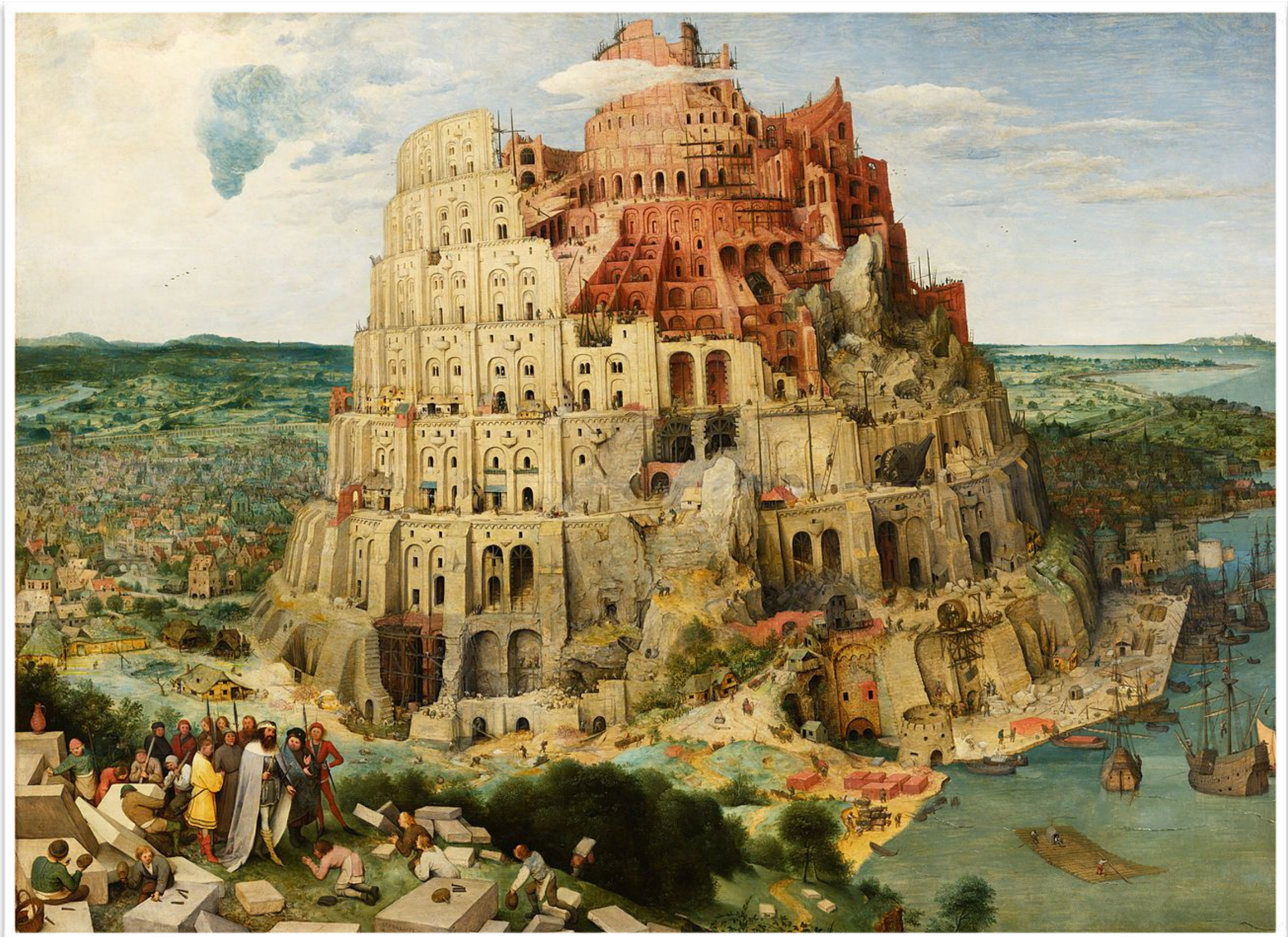
Humans rarely start any enterprise that will require longer than a lifetime to complete:

- James Webb Telescope: 19 years
  Funded in 2002, expected to launch in 2020.
- LIGO: 31 years
  Started in 1984, detected gravitational waves in 2015.
- Apollo program: 8 years
  Started in 1961, landed men on the Moon in 1969.
- Sagrada Familia: More than 100 years
  Started in 1882, still not finished (expected 2026).
- York Minster Cathedral: 252 years
  Started in 1220AD and finished in 1472AD.
- Great pyramid: Around 20 years
  Construction began around 258BC.

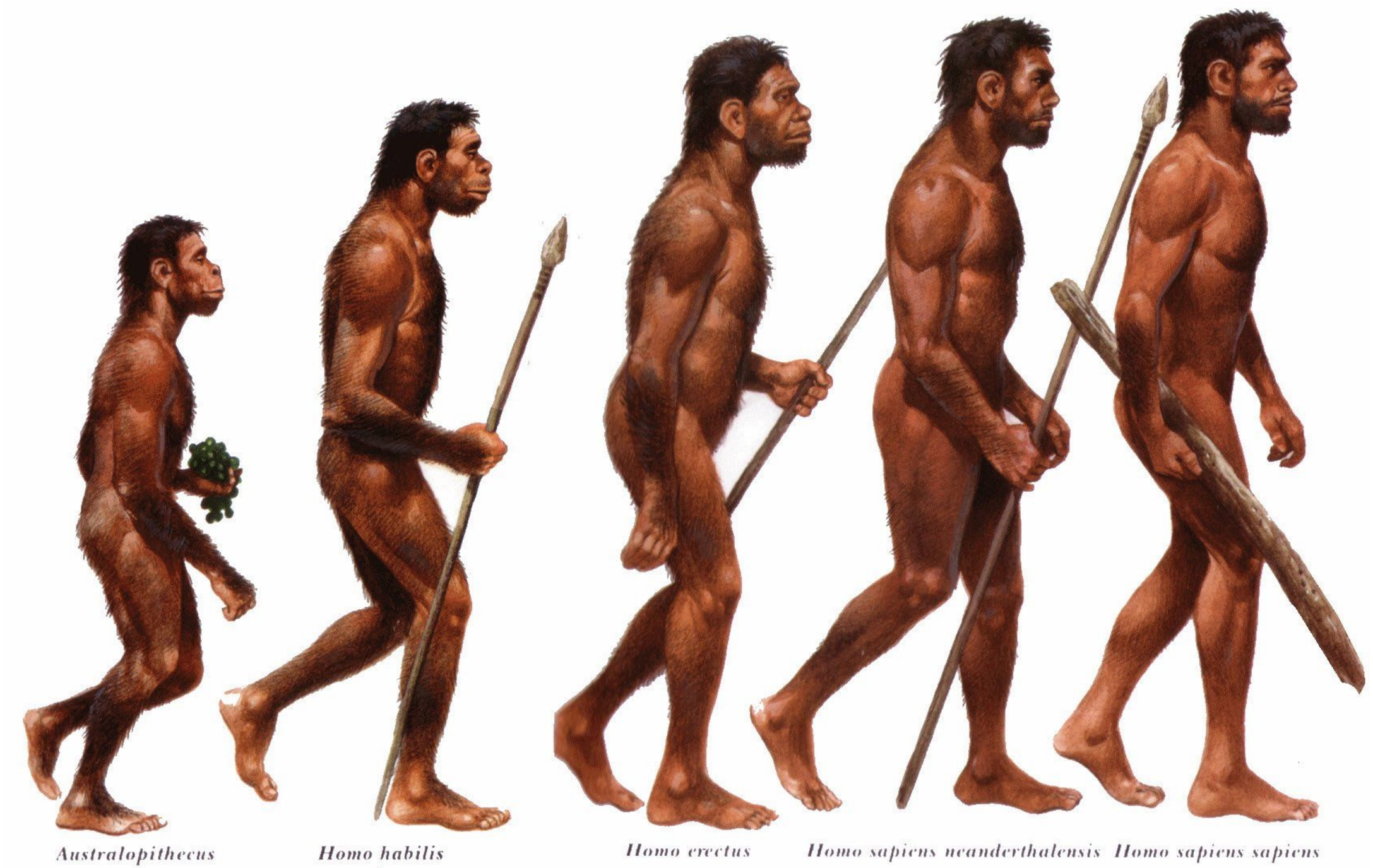
Sedentarization
~12,000 years

Earliest civilizations
~8,000 years

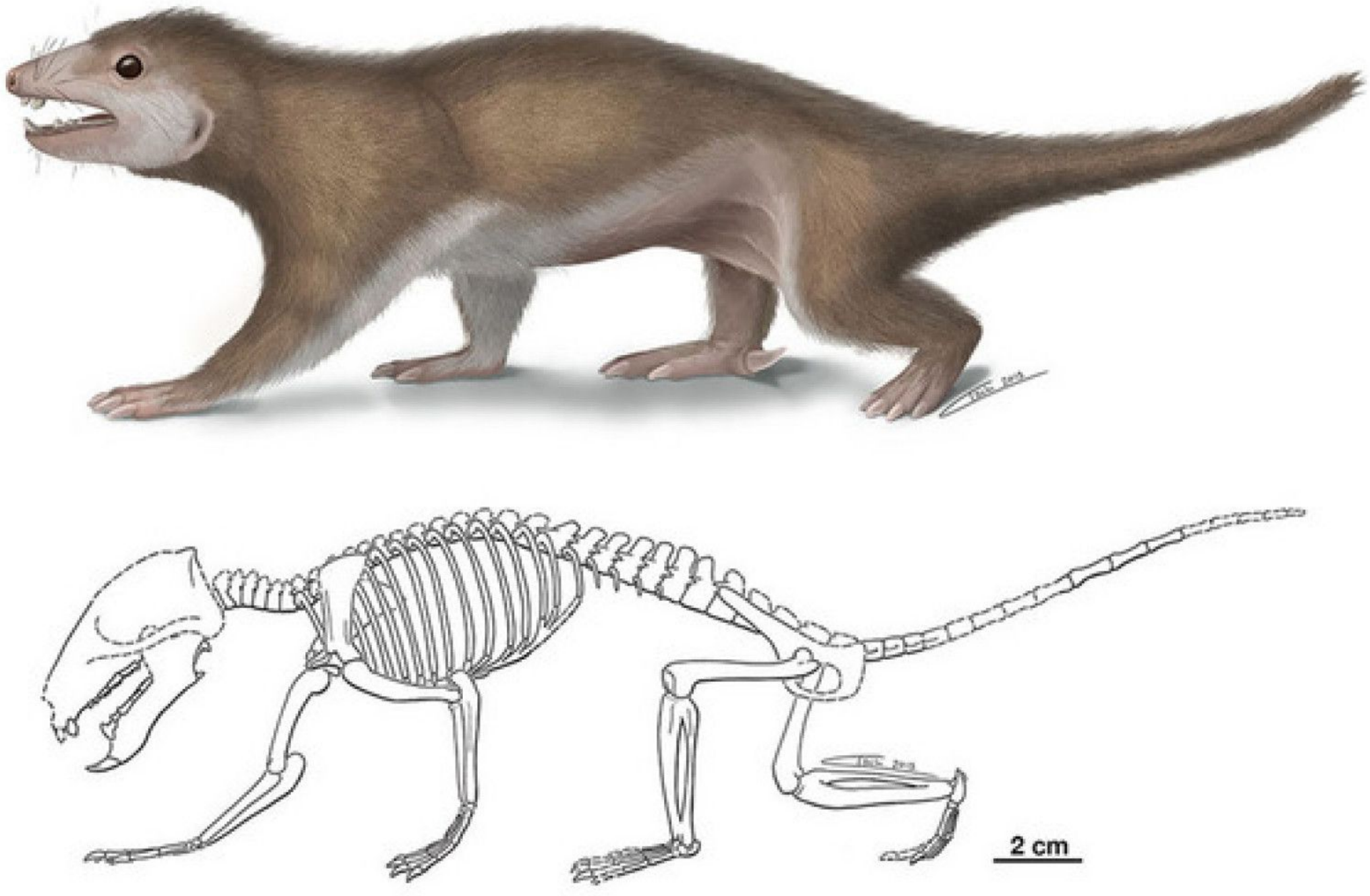
Written history
~5,000 years



Homo sapiens
~200,000 years

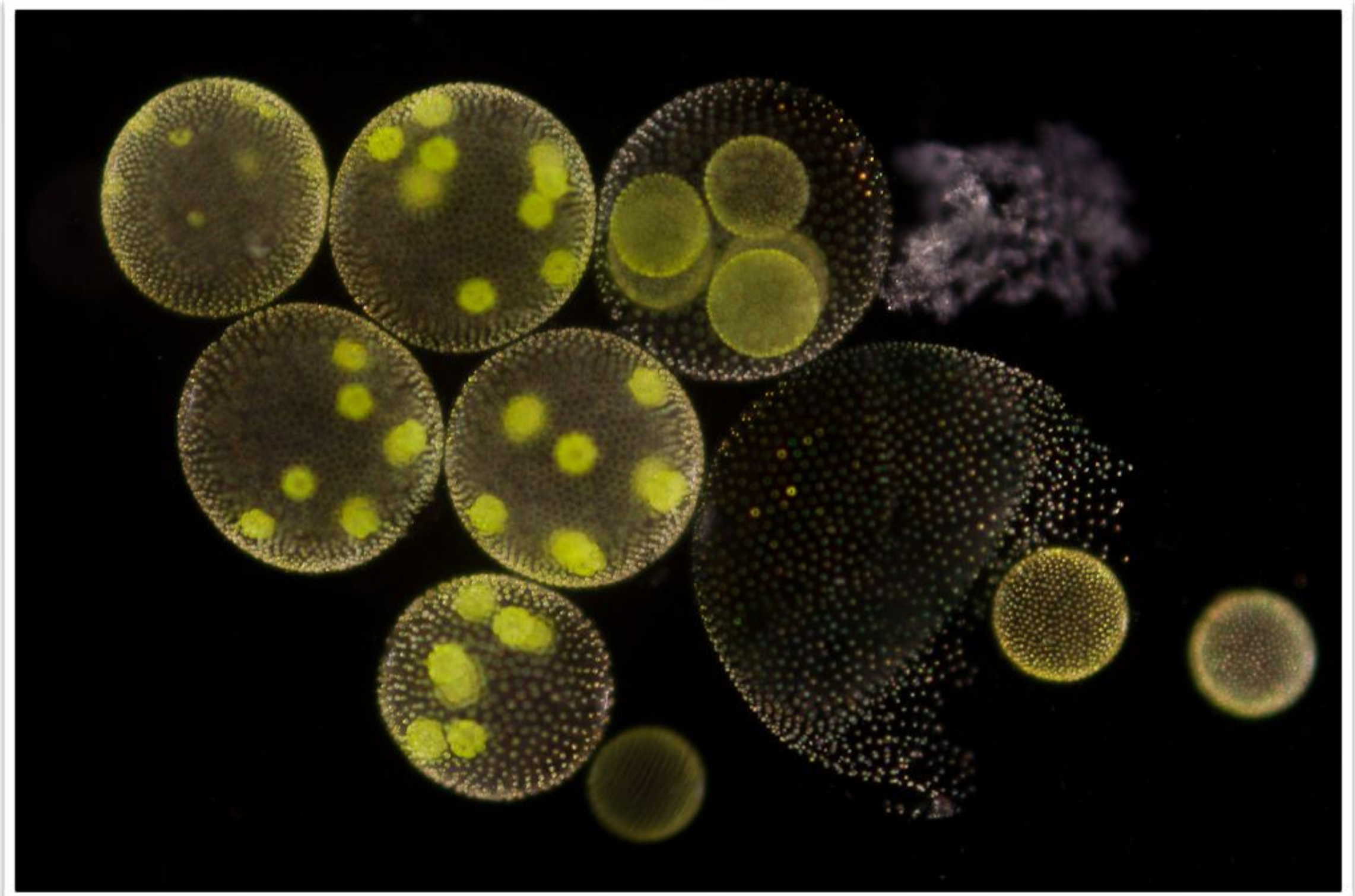


Mammals
~200 million years




Reconstructions by April Isch of The University of Chicago

# Multicellular life ~600 million years

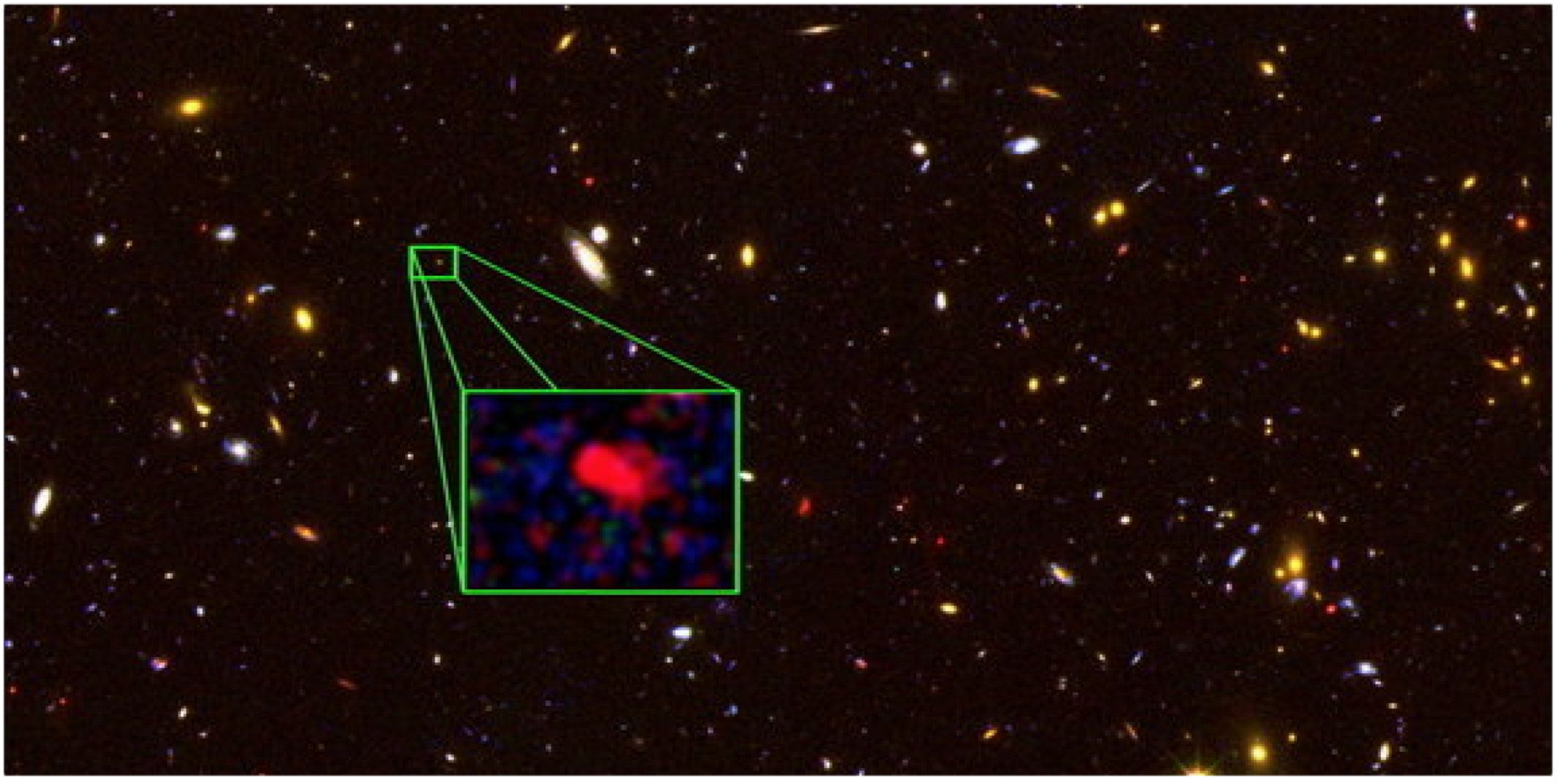


Life appeared 3,5 billion years ago

Earth
~4.5 billion years

The solar system is just a bit older.

# Oldest galaxy ~13.4 billion years



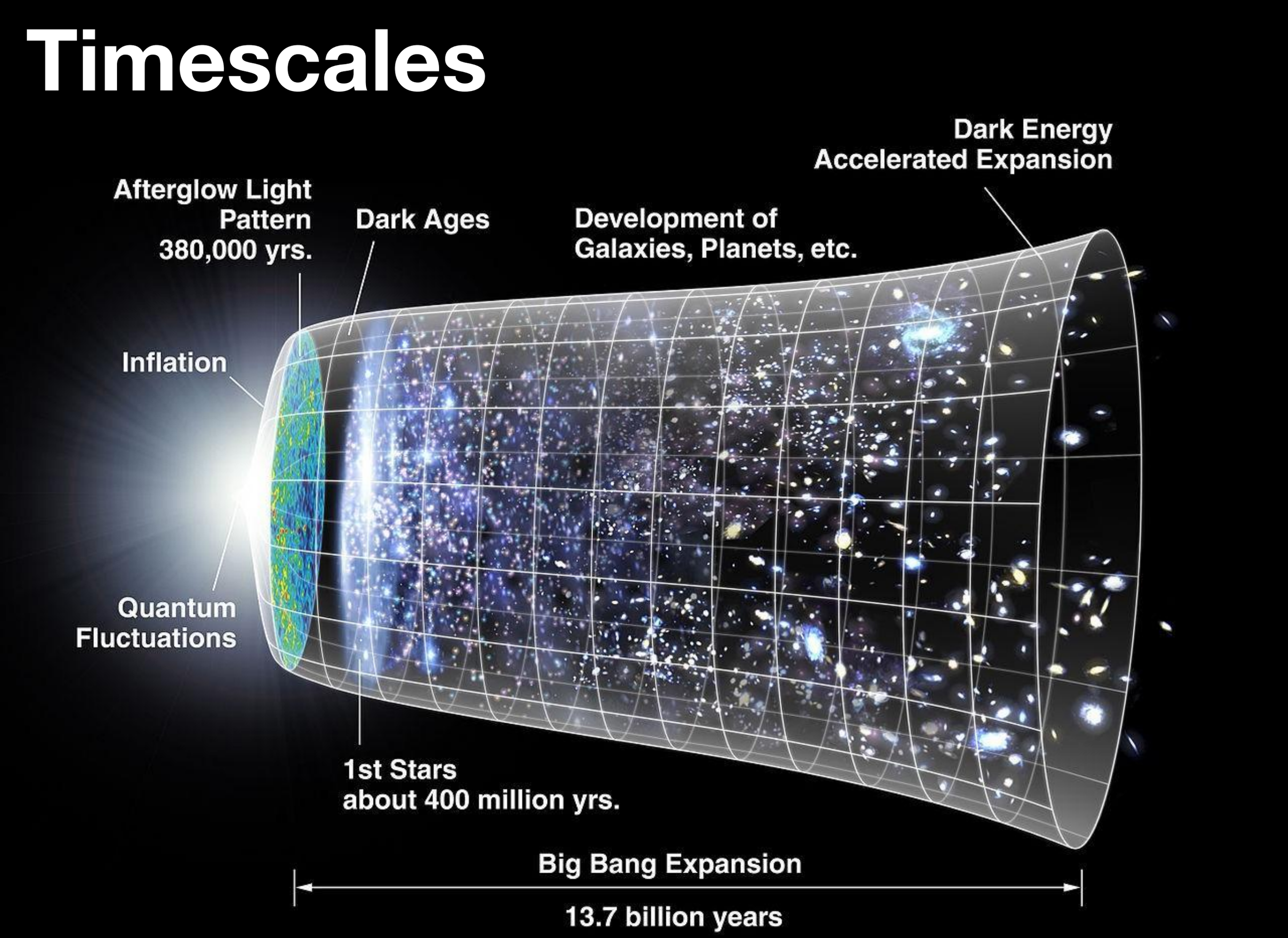
The oldest star observed in the Milky Way
is 13.2 billion years old.

# Age of the Universe

Estimated 13.772 billion years

- Big bang: $10^{-45}$ seconds after t=0.
- Until 400,000 years after the Big bang the universe was too dense for light to propagate.
- Gravity pulls gas together to form the first stars around 150,000,000 years after the big bang.
- Our solar system forms after 9 billion years from big bang, around 4.6 billion years ago.

# Timescales


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

# The scales of the universe (Mass)

- Hydrogen atom: ~1.6X10^-27 Kg
- Virus: ~10^-19 Kg
- Human cell: ~10^-12 Kg
- Eyelash: ~10^-8 Kg
- Mosquito: ~10^-6 Kg
- Apple: ~0.1 Kg
- Human: ~70 Kg
- Elephant: ~1000Kg
- Dinosaur: ~10^4 Kg
- International Space Station: ~4x10^5 Kg
- Great pyramid of Giza: ~6x10^9 Kg

# The scales of the universe (Mass)

- Moon: ~7x10^22 Kg
- Earth: ~6x10^24 Kg
- Jupiter: ~2x10^27 Kg
- Brown dwarf: 2x18^28 Kg
- Sun: ~2x10^30 Kg (1 Solar mass)
- Most massive star: ~7x10^32 Kg (350 Solar masses)
- Sagittarius A*: ~8x10^36 Kg (4 million solar masses)
- Most massive black hole: ~4x10^40 Kg (20 billion solar masses)
- Milky way: ~10^42 Kg (5.8x10^11 solar masses)
- Observable universe: ~5x10^52 Kg

# The scales of the universe (Energy)

- Kinetic energy of one apple falling from 1 meter: ~1J
- Kinetic energy by world record hammer throw: ~1000J
- Human food intake daily: ~10MJ (10^7J)
- Human heart over a lifetime: ~1GJ (10^9J)
- Atomic bomb (Little boy): ~10TJ (10^13J)
- World's energy consumption in 2010: ~10^20J
- Sunlight hitting earth every day: ~10^22J
- Sun (every day): ~10^31J
- Sun (lifetime): ~10^44J (over around 10 billion years)
- Supernovae: ~10^44J (in a few days)
- Most powerful Gamma Ray Burst: 8.8x10^47J