3

The Universal Context of Life

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LEARNING GOALS

3.1 THE UNIVERSE AND LIFE
- What major lessons does modern astronomy teach us about our place in the universe?

3.2 THE STRUCTURE, SCALE, AND HISTORY OF THE UNIVERSE
- What does modern science tell us about the structure of the universe?
- What does modern science tell us about the history of the universe?
- How big is the universe?

3.3 THE NATURE OF WORLDS
- How do other worlds in our solar system compare to Earth?
- Why do worlds come in different types?
- Should we expect habitable worlds to be common?

3.4 A UNIVERSE OF MATTER AND ENERGY
- What are the building blocks of matter?
- What is energy?
- What is light?

THE PROCESS OF SCIENCE IN ACTION

3.5 CHANGING IDEAS ABOUT THE FORMATION OF THE SOLAR SYSTEM
- How did the nebular model win out over competing models?
- Why isn't the nebular model set in stone?

You live in a cosmic ecosystem. Your planet orbits a star, which is one of 100 billion in our Galaxy, which is 1 of 100 billion in the universe. Each isolated galaxy cycles gas into stars and planets, that die and then cycle back into gas, which then cycle back into new stars and planets. These cycles take billions of years, but the universe is 13.6 billion years old, time enough so that a few generations of solar systems have come and gone in our Galaxy alone. The universe is so huge that the number of possible sights for life (as we know it) to persist is an astronomical number, on the order of the number of stars in the universe… about 1,000,000,000,000,000,000,000,000. But the distances to these places make them unreachable with today's technology.

Three ideas are especially important

in framing the universal context for everything else we will study:

- **The universe is vast and old.** Its vastness implies an enormous number of worlds on which life might possibly have arisen, and its old age means there has been plenty of time for life to begin and evolve.
- **The elements of life are wide spread.** Observations show that the basic chemical elements that make up Earth and life are present through- out the universe. Thus, at minimum, the raw ingredients of life should be found on many other worlds.
- **The laws of physics are universal.** The same physical laws that operate on Earth operate throughout the universe. Every experiment and observation made to date has given additional support to Newton's conclusion that the laws of nature are the same everywhere. In that case, it is reasonable to think that the same processes that made life possible on Earth have also made life possible on other worlds.

Together, these ideas reinforce the primary lesson of the Copernican revolution: We are not the center of the universe.

What is the cosmological setting for life in the universe?

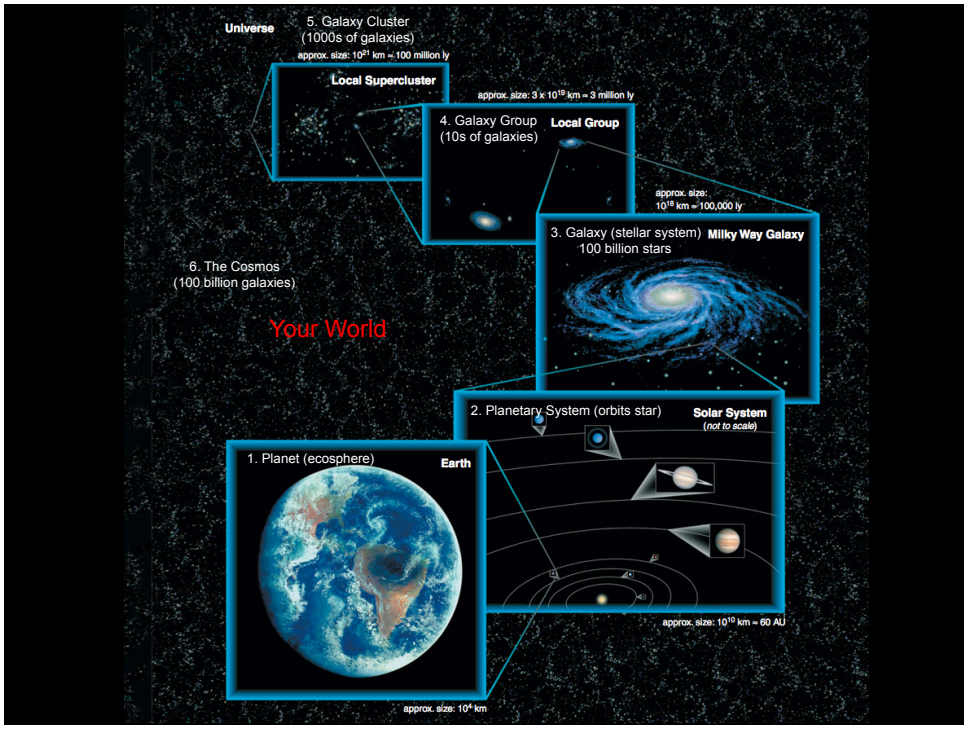
- Where (and when) do we fit in it?
- What are the main structures and how are they related?
- What are the relative sizes and locations?
- What is the cosmic ecosystem process for life?

Let's define some **distances**:

Astronomical Unit (AU) = radius of earth's orbit
= 93 million miles (93,000,000 mi)
= 150 million kilometers (150,000,000 km)

Lightyear (lyr) = distance light travels in 1 year
= 6 trillion miles (6,000,000,000,000 mi)
= 10 trillion kilometers (10,000,000,000,000 km)

The speed of light is 180,000 mi/sec or 300,000 km/s
There are 31.5 million seconds in 1 year



Distance measured in "light time"

speed of light = 300,000 km/s = 186,000 miles/sec

Sun-Earth distance (1 AU)...	8 light minutes
Solar System diameter…….	22 light hours
Nearest Star……	4 light years
Galaxy diameter…….....	100,000 light years
Local Group diameter……	1,000,000 light years
Galaxy Cluster diameter…...	100,000,000 light years
Size of Universe……	13,600,000,000 light years

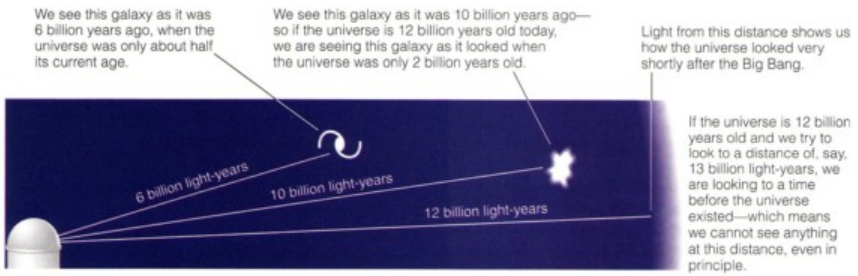
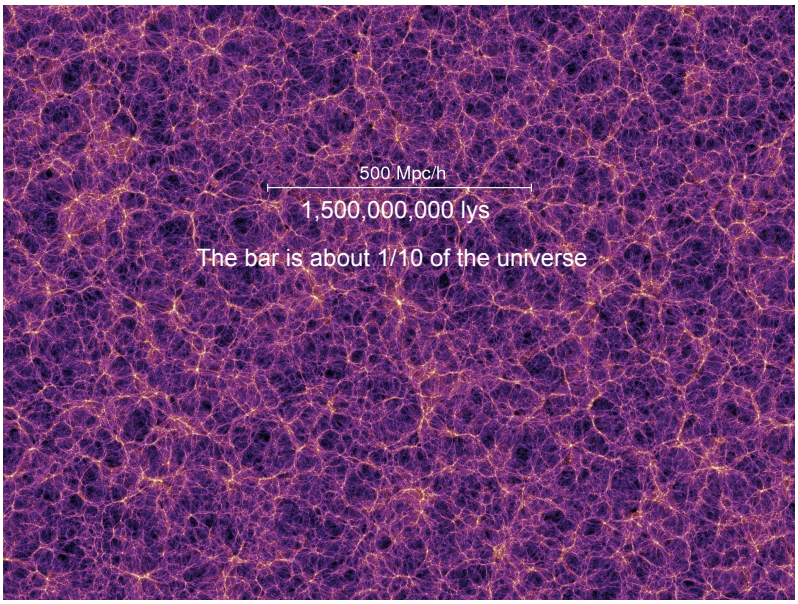
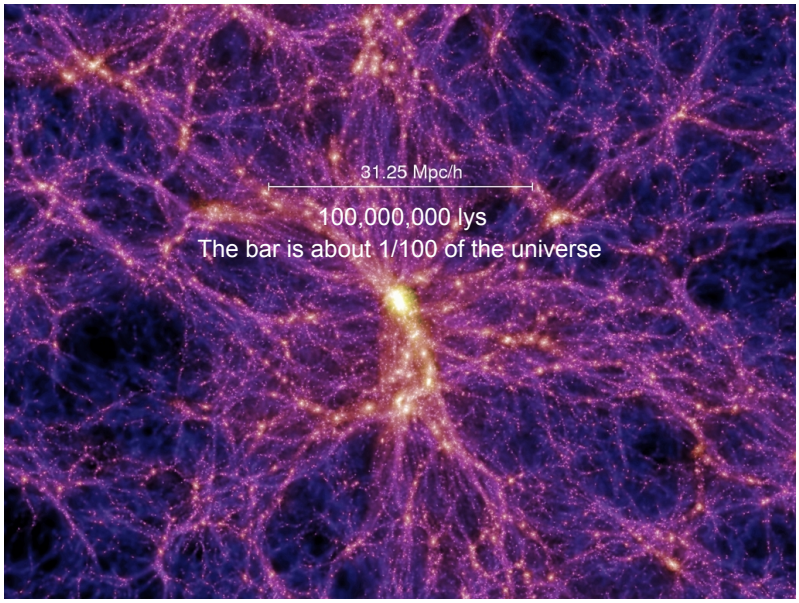


FIGURE 1.13 Because light travels at a finite speed, looking farther away in space means looking further back in time. This fact limits the extent of our observable universe. This figure assumes the universe is 12 billion years old; its actual age may be anywhere between about 12 and 15 billion years.

Representative Slice of the Universe

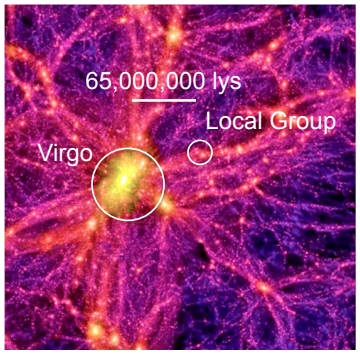


100,000,000 lys: A Cluster of Galaxies



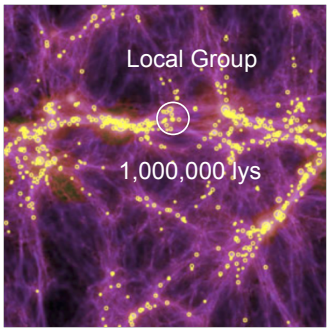
The Local Group is in the "suburbs" of the Virgo Cluster

– about 65 million light years away from the center

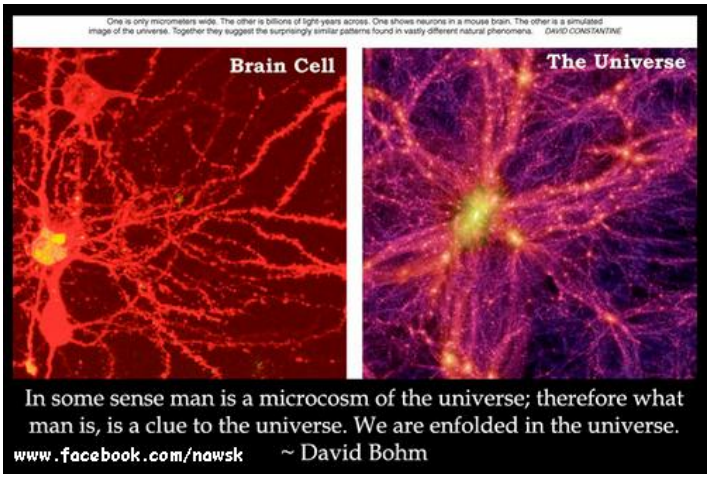


Our galaxy, The Milky Way resides in the Local Group

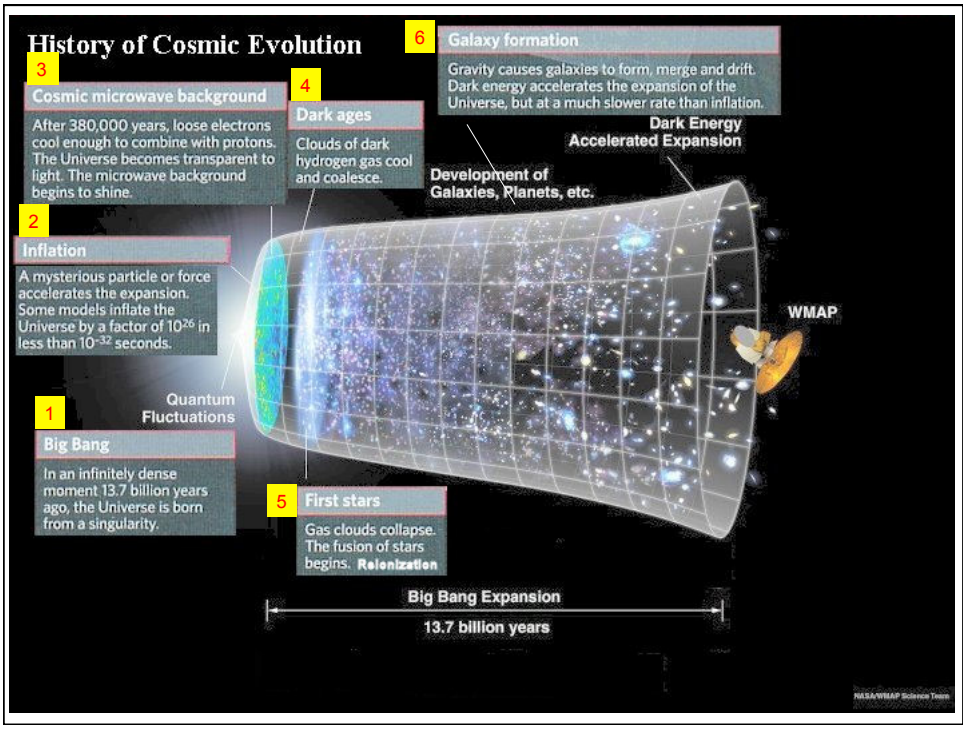
– Milky Way, 100,000 lys across, is about 1/10th the size of the Local Group



Ever heard of fractals?



Brain cells have same structural morphology as galaxy clusters and their dendrite connections form a web with the same structure as that connecting the galaxies



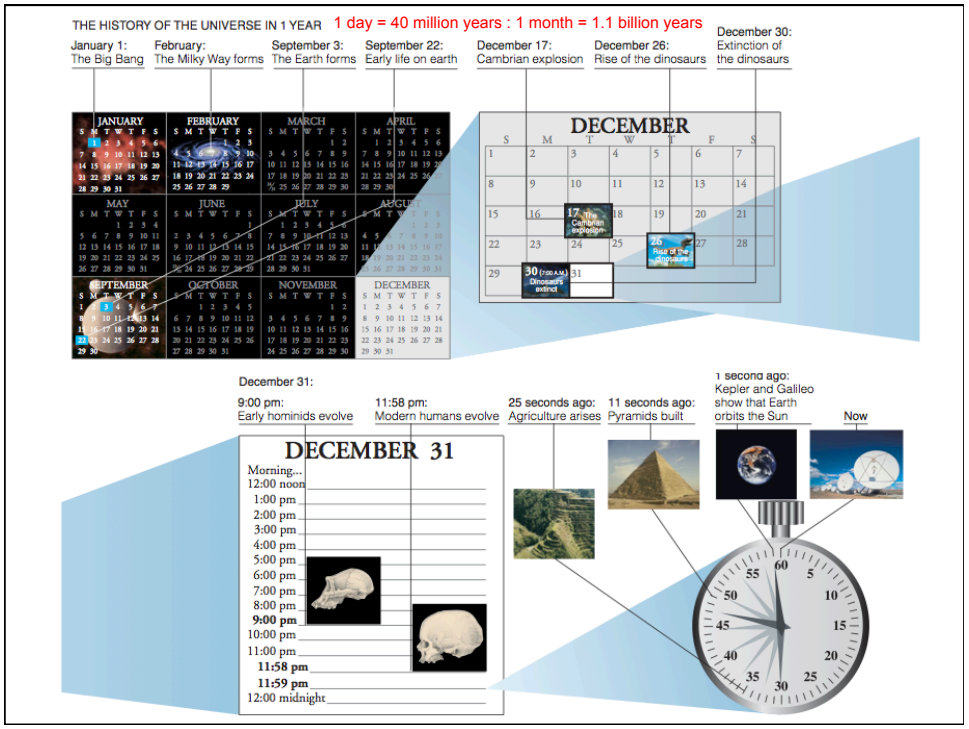
Video of the evolution of the universe in a representative 35 million light year cube (35 times the size of the Local Group; about 1/3 the size of a Galaxy Cluster (so a pretty small cube; about 1/400 of the universe itself)

This is a computer simulation; it includes

- Gravity of dark matter and regular matter
- Star formation and death, process of gas into stars and stars back into gas
- Build up of chemical elements
- Expansion of the universe based upon General Relativity

Click on the link below:

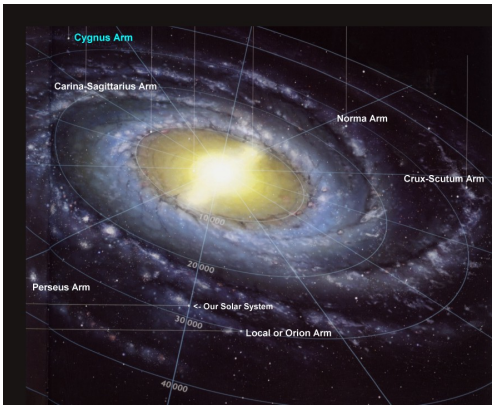
https://www.youtube.com/watch?v=jx_64y7gA_k&spfreload=10
VIDEO: Evolution of the Universe (Illustris Simulations) 2:34

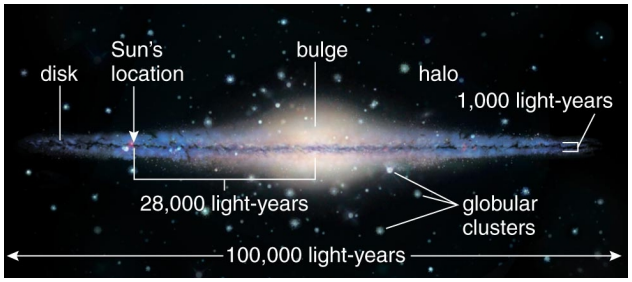


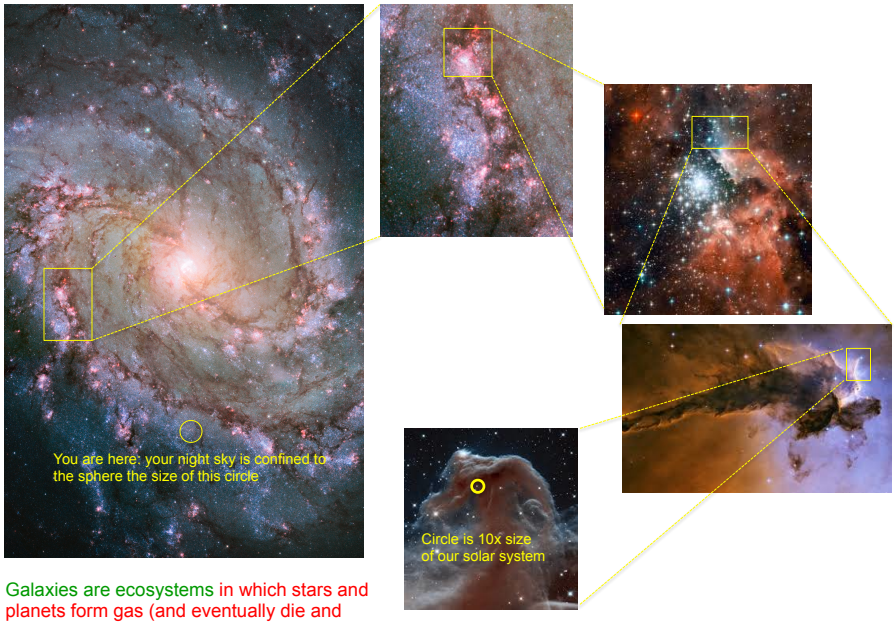
Anatomy of our Galaxy

It take about 250,000,000 years for one rotation

The sun has orbited the Milky Way about 20 times since its birth

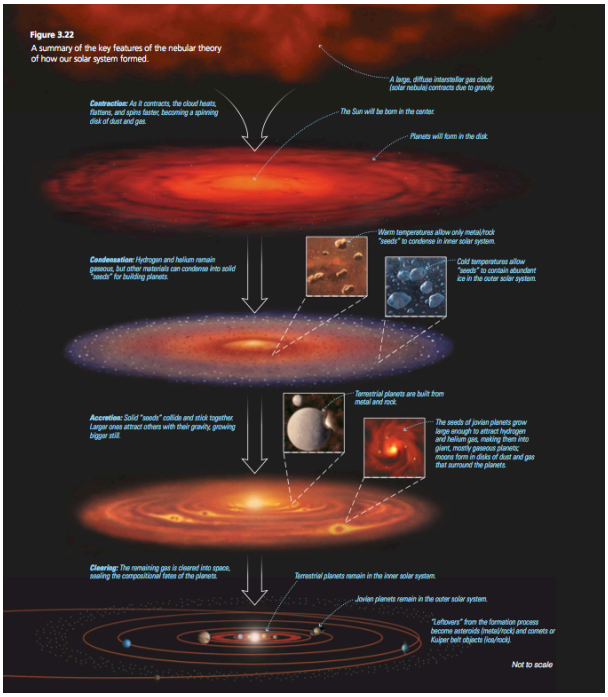






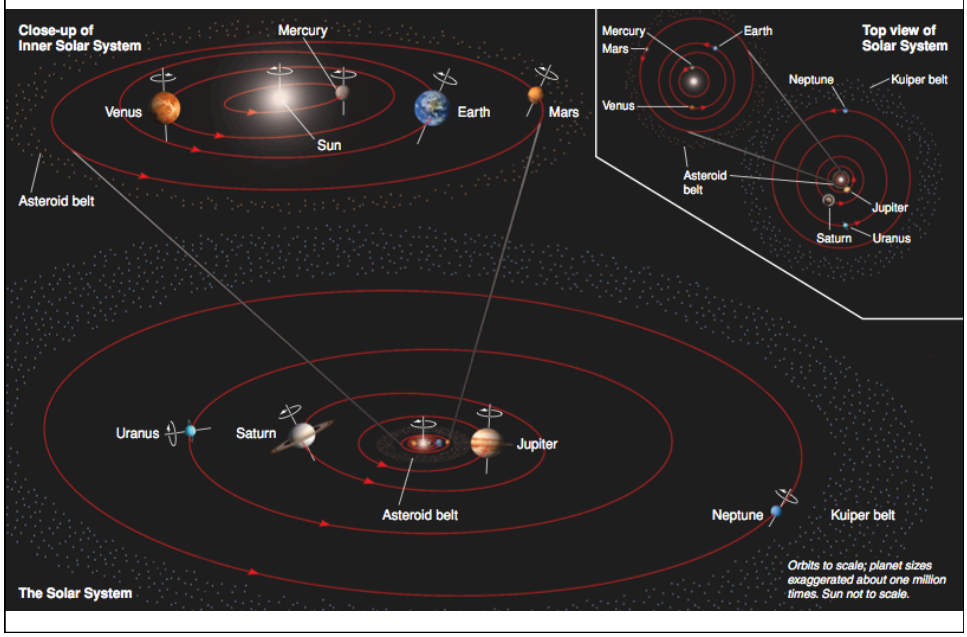
Galaxies are ecosystems in which stars and planets form gas (and eventually die and turn back into gas) It's a cycle.

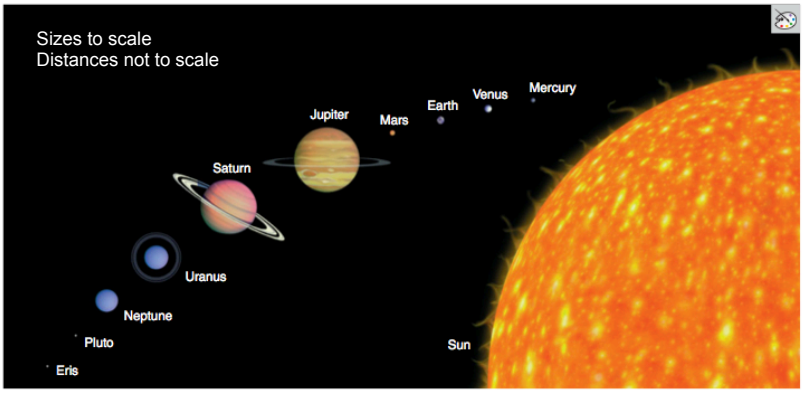
Formation Scenario



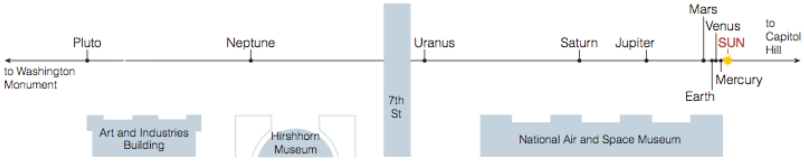
Hubble Space Telescope Images of Forming Star and Their Planets

The Nature of Worlds

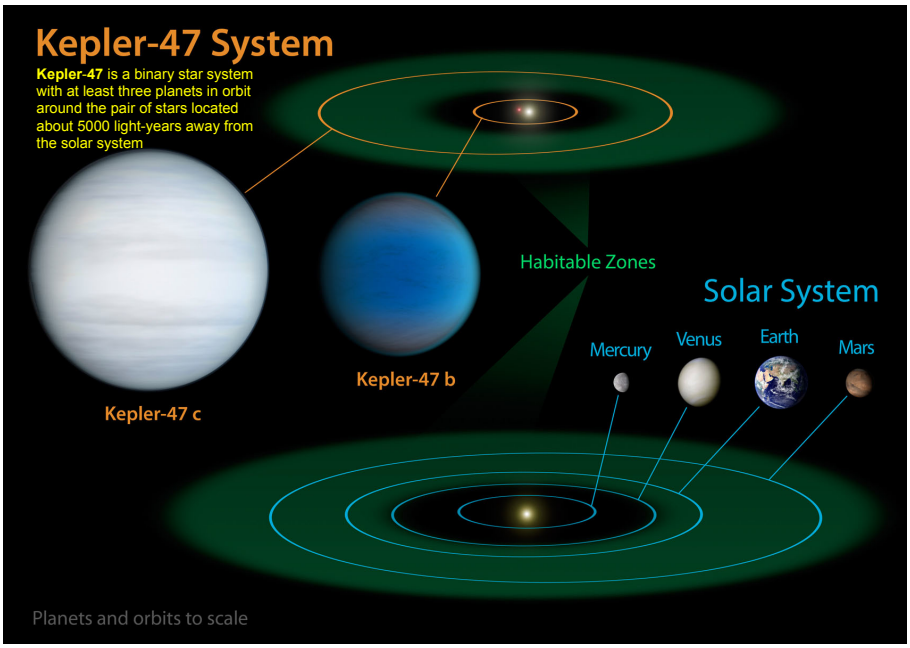




Distances to scale. 1 AU = 7.5 meters (shrunk by 10 billion times)

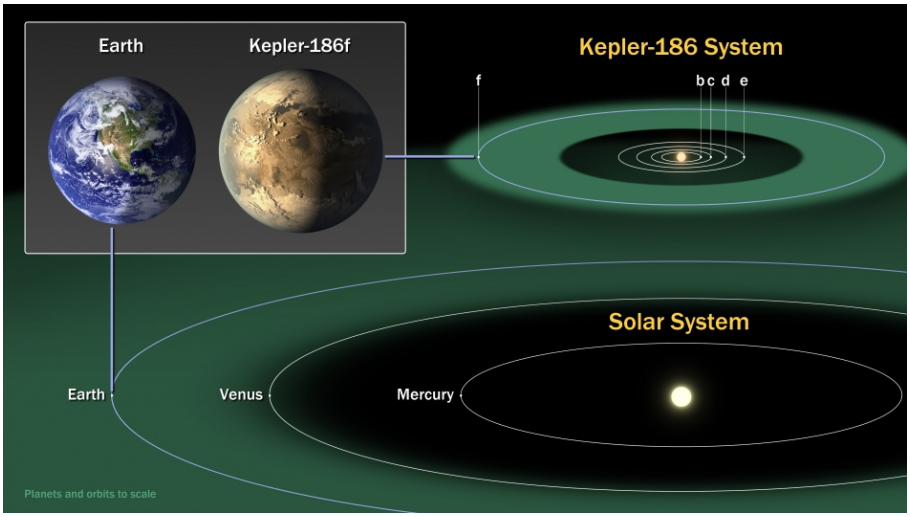


A brief tour of other solar systems….



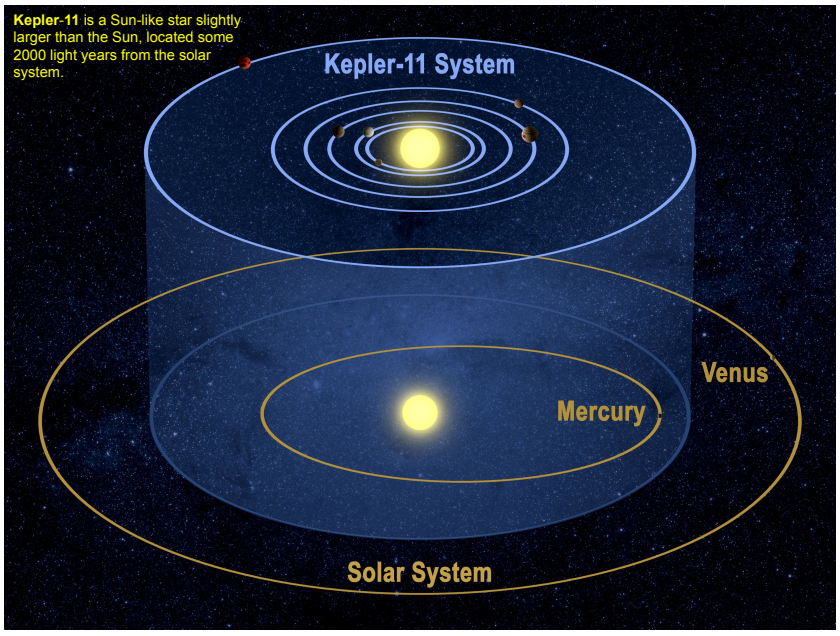
A brief tour of other solar systems….

Kepler-186 is a main-sequence M1-type dwarf star, located about 500 light years from the solar system.



A brief tour of other solar systems….

Kepler-11 is a Sun-like star slightly larger than the Sun, located some 2000 light years from the solar system.



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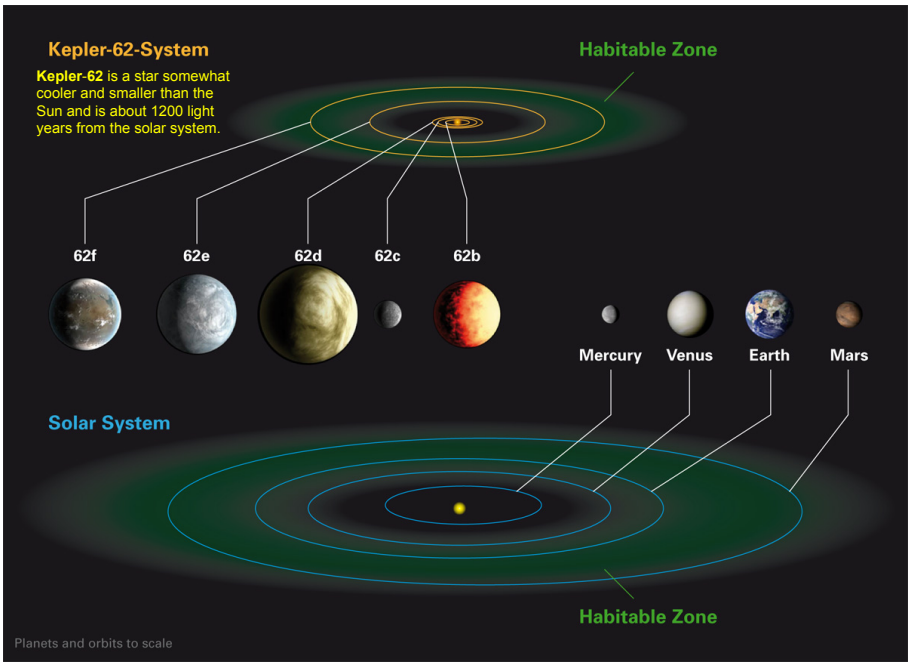

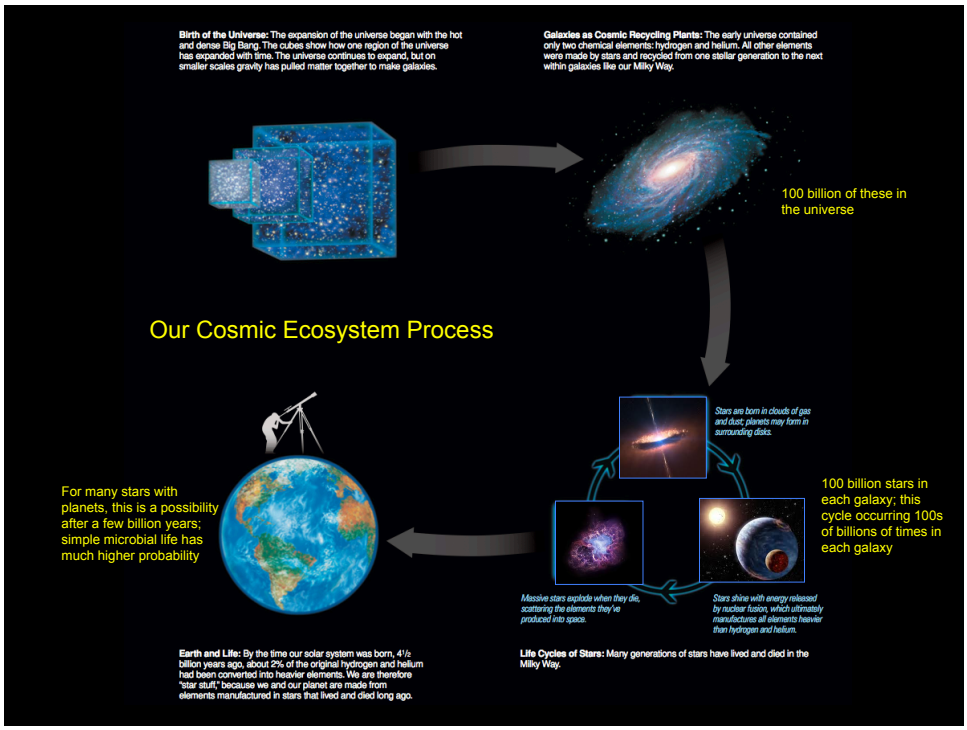

Just released (January 2015) *Hubble Space Telescope* images of the deepest ever pictures resolving the individual stars in the galaxy of Andromeda.

Another Galaxy has NEVER been seen like this before.

https://www.youtube.com/watch?v=udAL48P5NJU
VIDEO: Gigapixels of Andromeda 3.28