Astronomy of the Solar System – Module 1: Science and the Universe Part 2

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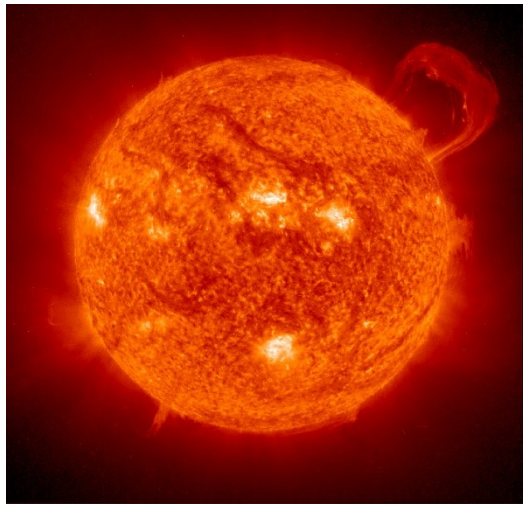
How far to zoom out to get to the Sun? OpenStax Astronomy: 1.6

- **Planet Earth – our home in the Universe**
  - Diameter: about 13,000 km
  - Surface: about 2/3 covered with liquid water, green plant life on land masses, radio/light emissions by intelligent life
- **The Moon** orbits Earth every 4 weeks
  - Diameter: about ¼ of Earth's
  - Distance: 3.8×10^5 km = 1.3 light seconds
- **The Sun**, orbited by Earth once a year
  - A star – generate energy by nuclear fusion
  - Diameter: 1.5 million km, 110 x Earth's
  - Distance: 1.5×10^8 km = 8.3 light minutes
  - average Earth-Sun distance = 1 Astronomical Unit (AU)
  - *Analogy:* Earth as apple seed, Sun as basketball 30 m (100 ft) away

Earth's western hemisphere as viewed from 35,400 kilometers up in space. (Credit: OpenStax, modification of work by R. Stockli, A. Nelson, F. Hasler, NASA/ GSFC/ NOAA/ USGS)

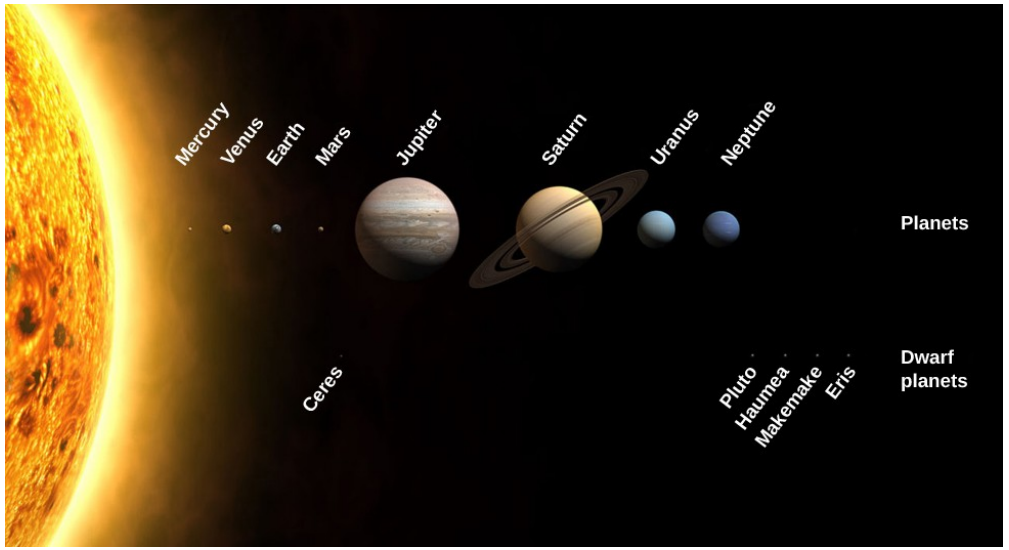
Earth-Moon distance and sizes to scale (Credit: OpenStax/NASA)



The Sun is composed of hot hydrogen and helium gases with temperatures of 5500 °C at the surface and 15,000,000 °C in the core. (Credit: ESA/NASA)

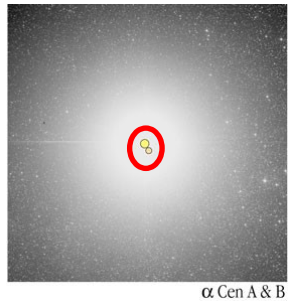
How far to the closest neighbor star? OpenStax Astronomy: 1.6

- **The Solar System -** 8 planets with moons, many dwarf planets, swarms of smaller objects orbit the Sun (a star)
  - No fusion in planets & smaller objects
  - Pluto's average orbit size = 3.2 x 10^9 km = 40 AU = 3 light hrs (not only type of boundary)
  - *Analogy:* 1.2 km from basketball Sun (3/4 mi)
- **Alpha Centauri** – the closest star system: 3 stars (2 like Sun, 1 small & red), each orbited by planets, likely more
  - Distance = 41 x 10^{12} km = 4.3 light yrs
  - *Analogy:* 7,000 km (4,300 mi) from basketball Sun = from Atlanta to Anchorage, AK



The sizes of the Sun, classical planets, some dwarf planets to scale (Credit: OpenStax modification of work by NASA)

Alpha Centauri system by European Southern Observatory (ESO). Positions of twin stars AB shown by red circle on upper right. Position of Proxima shown by white arrow inside red circle on lower right. (Source: APOD/NASA)



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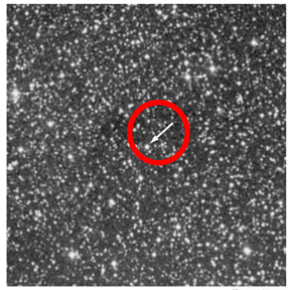


Proxima

How far to see all of our Galaxy? OpenStax Astronomy: 1.6

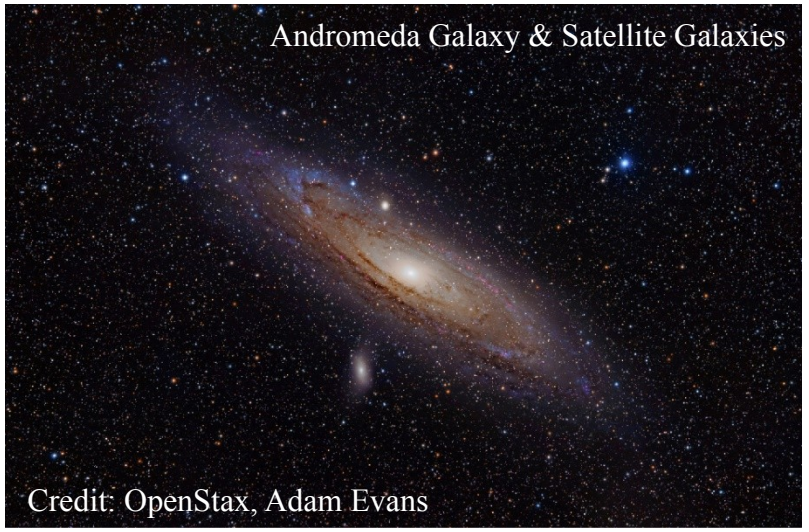
- **The Milky Way Galaxy –** 100 billion stars including Sun & Alpha Centauri, interstellar gas & dust, star clusters, super massive black hole at the center, dark matter adding unseen mass to our Galaxy
  - Gas & dust are raw material for star formation
  - Stars return their matter to gas & dust upon death – next generation forms from previous
    - *We are made from "star dust"!*
  - Diameter = 100,000 light years
  - Distance Sun-center = 30,000 light yrs
  - *Analogy:* basketball Sun 48 million km (30 million mi) to center = 1/3 real Sun to Earth
- *Structure analogy:* Solar System as house, Sun & nearby stars as neighborhood, Milky Way as city

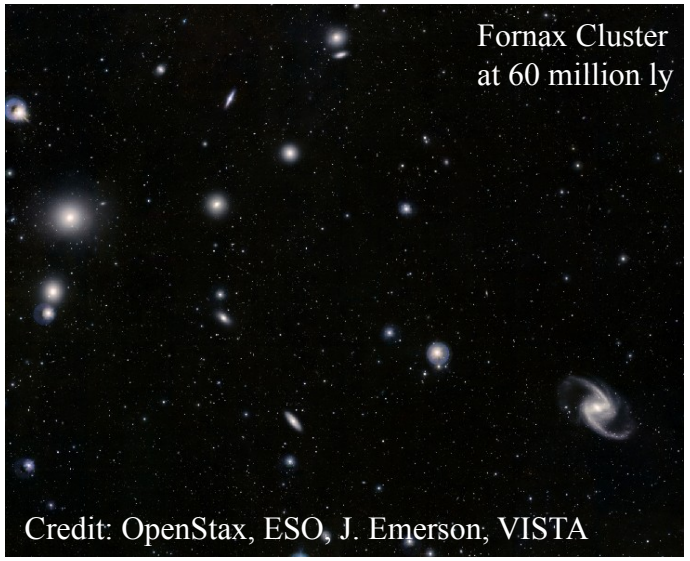
"Because we are inside the Milky Way Galaxy, we see its disk in cross-section flung across the sky like a great milky white avenue of stars with dark "rifts" of dust." Clouds of heated gas glow in different colors. (Credit: Ian Norman, OpenStax)

NGC 1073, a spiral galaxy, is thought to be similar to our own It is a giant pin wheel-shaped system with a dense bar of stars across its middle. (Credit: NASA, ESA, OpenStax)

How far to zoom out to see other galaxies? OpenStax Astronomy: 1.7

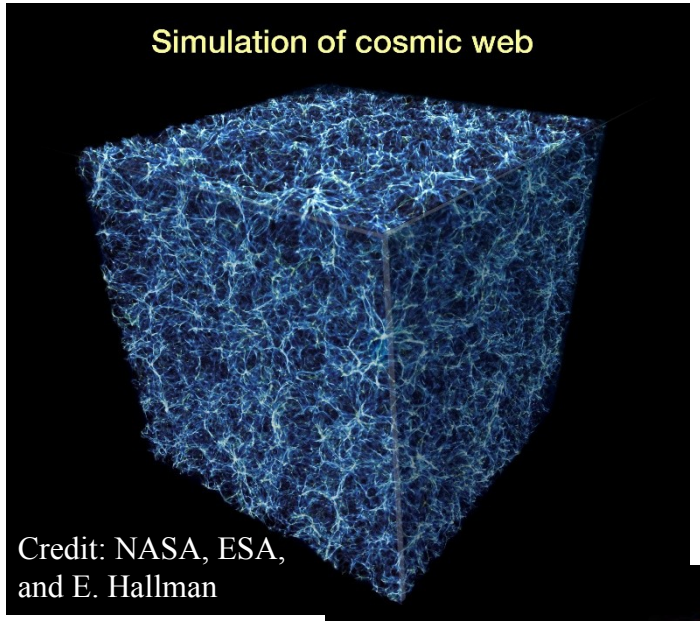
- **Milky Way has several satellite galaxies**
  - Closest: Sagittarius Dwarf Galaxy (75,000 ly)
  - Largest: Large and Small Magellanic Clouds (160,000 ly), see from Southern Hemisphere
  - *Structure analogy:* metro area with Milky Way as hub-city, satellite galaxies as close towns
- **The Andromeda Galaxy** – similar size & structure as Milky Way, also has several satellite galaxies
  - Distance about 2 million light years
- Milky Way & Andromeda with satellite galaxies form "**Local Group**" – a galaxy cluster of about 50
- *Structure analogy:* close cities and their metro areas or a state



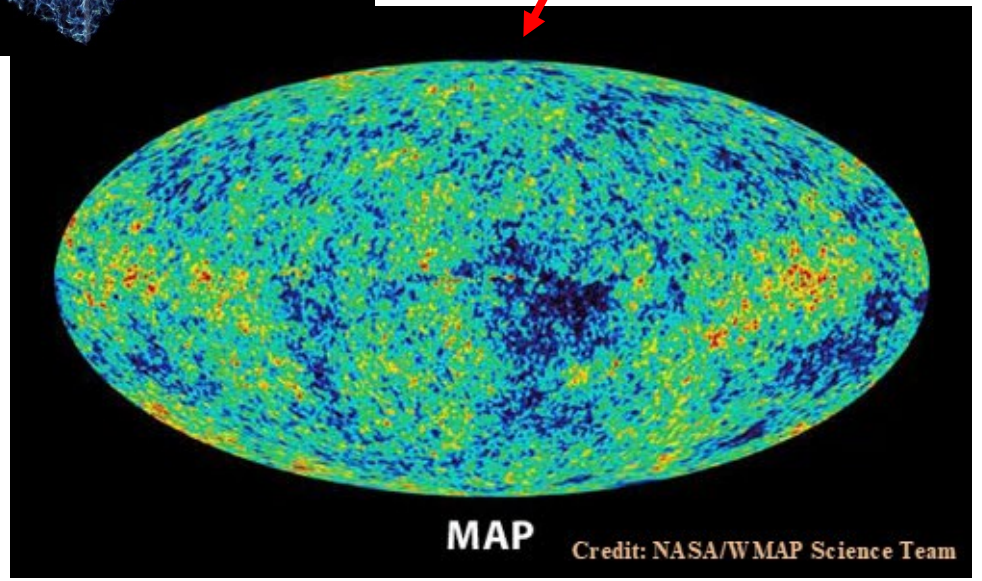


How far to see the edge of the universe? OpenStax Astronomy: 1.7

- **Virgo Cluster = a super cluster,** Local Group and other galaxy clusters
  - Diameter: 110 million ly
  - *Structure Analogy:* country of several large & small states
- **Cosmic Web –** 3D-web of large and small clusters and super clusters with large voids in between
  - *Structure Analogy:* continent
- Distant structure = *past structure* – regular galaxies too dim to see
  - See **Quasars** = galactic cores with extremely powerful emissions of hot gas falling into super massive black hole
  - Distances about 10 billion ly *(also in past!)*
- Furthest/oldest – **Afterglow of Big Bang** at 13.4 billion ly *(start of our universe & everything in it)*



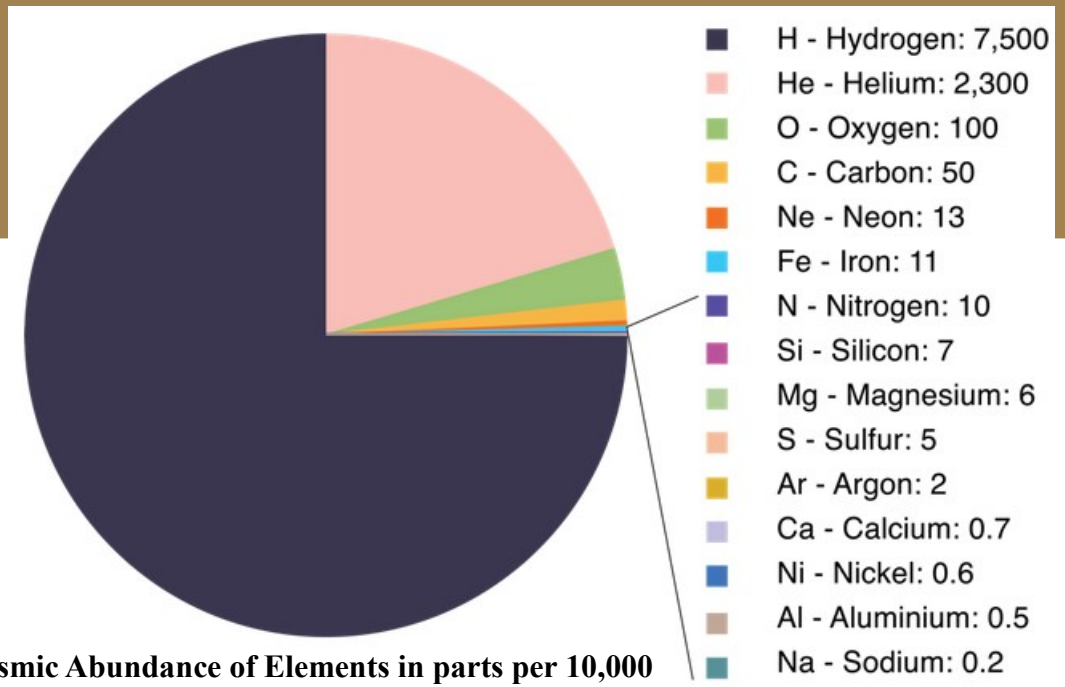
Baby picture of the Universe, 380,000 years after Big Bang. False colors: "red" means warmer "blue" means colder. Oval projection of whole sky.



What chemical particles are we made of?

OpenStax Astronomy: 1.8

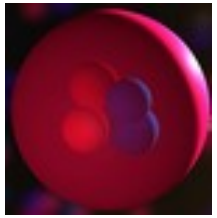
- **Molecule –** the smallest particle of a substance that retain its chemical properties
  - Can be broken down into atoms – smaller particles with unique chemical properties
- **Atom** – smallest particle of a chemical element that can still be identified as that element
  - Cannot be broken down into other elements
  - Size range: 0.3 – 3 x 10^{-10} m
- **Element** – simplest substance composed of atoms that all react the same chemically
- ***Example:*** Substance = Water; Molecule = H_2O; Atoms = H, H, O; Elements = Hydrogen, Oxygen
- All matter made of about 100 elements listed in Periodic Table
- Not equally common! Only a few make up 99% of substances of everyday life



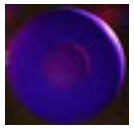
Cosmic Abundance of Elements in parts per 10,000

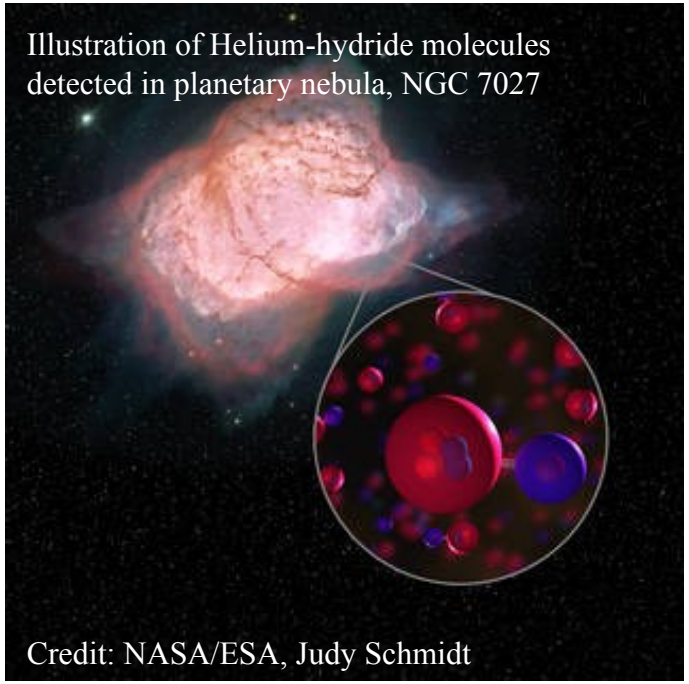
Credit: NASA/CXC/K.DiVona

Red = Helium atom



Blue = Hydrogen atom





Can atoms be broken down into smaller units? OpenStax Astronomy: 1.8

Atom break into smaller, unequal parts:

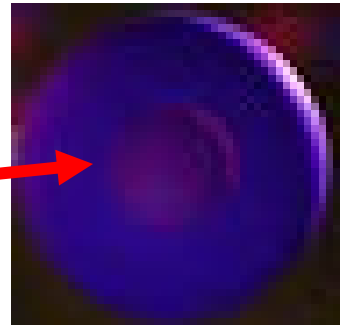
- **Atomic nucleus** – unique "+" electric charge defines element
  - Made of positive protons (mass, + charge), neutral neutrons (mass, 0 charge) in tight space
  - Size: about 1 x 10^{-16}m, 100,000 smaller than size of atom! Atom ***mostly empty!***
- **Electrons** in space around nucleus – have "-" charge, as many in atom as "+" charge of nucleus
  - Size: effectively 0 (- charge only)
  - Range of motion determines size of atom

Matter, energy, space, time ruled by the **4 basic forces: gravity, electromagnetism, weak nuclear, strong nuclear** (stay tuned …)

Examples of Atoms And Their Interior

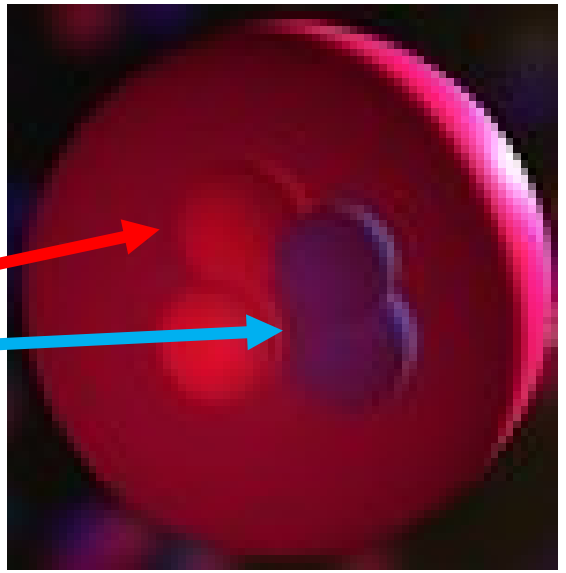
Hydrogen atom (not to scale)

- Nucleus = **1 proton**



Helium atom (not to scale)

- Nucleus = **2 protons** + **2 neutrons**

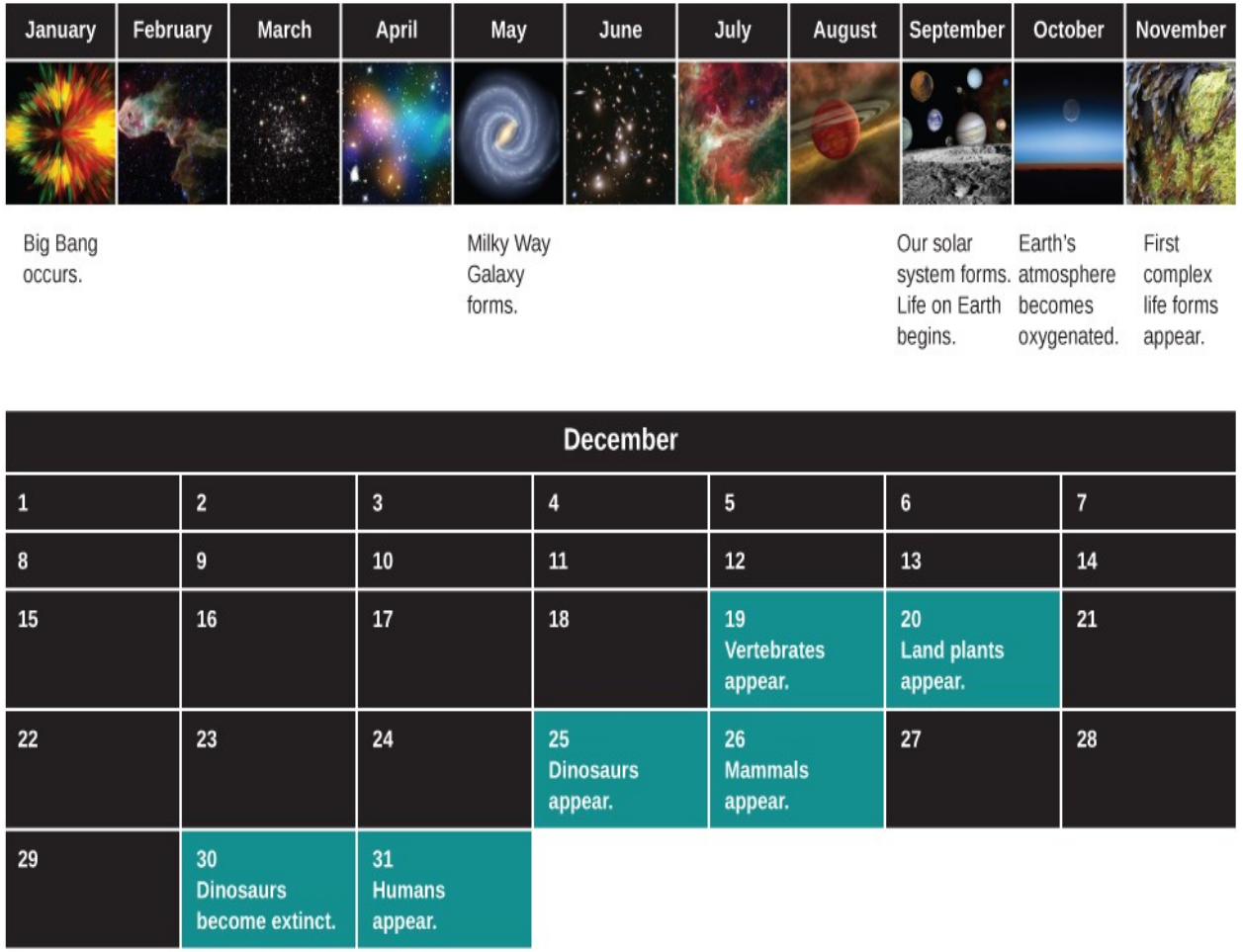


Illustrations of hydrogen and helium atoms, modification of work from NASA/ESA, Judy Schmidt

What about the "size" of time in the Universe? OpenStax Astronomy: 1.9

Age of the Universe (most current) = **13.77 billion years** = 13.77 x 10^9 years – inconceivably old!

- Carl Sagan's Cosmic Year Analogy
  - ***Big Bang:*** 00:00 hour on January 1
  - ***Birth of Solar System:*** September 10
  - ***Oldest Rock/Simple Life:*** 3rd week of September
  - ***Complex Life:*** 1st week of November
  - ***Land Plants:*** December 20
  - ***Dinosaurs:*** December 25
  - ***Mammals:*** December 26
  - ***Dinosaurs die out:*** December 30
  - ***Humans appear:*** evening of Dec. 31
  - ***Alphabet:*** Dec. 31, 11:59 pm, 50th second
  - ***Modern Astronomy:*** 12/31, 11:59 pm, **fraction of second before midnight!**



Cosmic time mapped onto Earth year (credit: OpenStax, Carl Sagan, NASA, ESA, JPL, U of CA, CalTech, Harvard-Smithsonian, et al.)