

Sizes of Things - Atoms, the Solar System and Galaxies

It is useful to gain some feeling for the sizes of extremely tiny atoms and extremely large astronomical objects. To do so, we can build scale models.

Small Things

Proton (hydrogen nucleus) is a sphere 1.75×10^{-15} meters in diameter.

Hydrogen atom is a sphere 1.1×10^{-10} meters in diameter.

Hemoglobin molecule is nearly spherical about 5.5×10^{-9} meters in diameter.

Influenza viron is a sphere 1×10^{-7} meters in diameter.

Wavelength of green light 5.5×10^{-7} meters.

Escherichia coli bacterium is a cylinder 2×10^{-6} meters in length and 0.5×10^{-6} meters in diameter.

Paramecium (single cell protozoan) about 2×10^{-4} meters in length. (barely visible to the naked eye)

Small grain of salt is a cube about 3×10^{-4} meters on each side and contains 6×10^{17} NaCl molecules.

The Superdome football stadium in New Orleans is about 210 meters in diameter.

If we were to enlarge the small grain of salt to be the size of the Superdome, we would need to magnify it by a factor of $\frac{210 \text{ meters}}{3 \times 10^{-4} \text{ meters}} = 700,000$. Enlarging the other small things by this same factor would produce

a Paramecium that is 140 meters and could just fit inside the Superdome.

an Escherichia coli bacterium that is 1.4 meters long, about the height of a person.

an influenza viron that is 0.07 meters in diameter, about the size of a fist.

a hemoglobin molecule that is 0.004 meters = 4 mm in diameter, about the size of a large bead.

a hydrogen atom that is 8×10^{-5} meters, about the size of a small paramecium.

a proton that is 1.2×10^{-9} meters in diameter, about the size of a buckminsterfullerene (C-60) molecule.

Put differently, if a salt grain were the size of two soccer fields, an atom would be a bit smaller than a grain of salt.

Solar System (orbital distances are averages around elliptical orbits)

The sun is 1.39×10^9 meters in diameter.

Mercury is 4.88×10^6 meters in diameter and is 6.4×10^{10} meters from the sun.

Venus is 1.21×10^7 meters in diameter and is 1.08×10^{11} meters from the sun.

Earth is 1.27×10^7 meters in diameter and is 1.5×10^{11} meters from the sun.

Moon is 3.47×10^6 meters in diameter and is 3.85×10^8 meters from the earth.

Mars is 6.78×10^6 meters in diameter and is 2.28×10^{11} meters from the sun.

Jupiter is 1.40×10^8 meters in diameter and is 7.79×10^{11} meters from the sun.

Saturn is 1.16×10^8 meters in diameter and is 1.43×10^{12} meters from the sun.

Uranus is 5.07×10^7 meters in diameter and is 2.88×10^{12} meters from the sun.

Neptune is 4.92×10^7 meters in diameter and is 4.50×10^{12} meters from the sun.

Light can circle the earth 24 times in one second, but sunlight requires 8 minutes and 20 seconds to reach the earth, and 4 hours 10 minutes to reach Neptune.

If the Sun were shrunk by a factor of two billion (2×10^9), it would become the size of a large beach ball (0.7 meters). Reduced by that same factor,

Mercury would be 0.00244 meters = 2.44 mm in diameter and 32 meters from the beach ball.
Venus would be 0.00605 meters = 6.05 mm in diameter and 54 meters from the beach ball.
Earth would be 0.00635 meters = 6.35 mm in diameter and 75 meters from the beach ball.
Moon would be 0.00174 meters = 1.74 mm in diameter and 0.193 meters = 193 mm from Earth.
Mars would be 0.00339 meters = 3.39 mm in diameter and 114 meters from the beach ball.
Jupiter would be 0.070 meters = 70 mm in diameter and 390 meters from the beach ball.
Saturn would be 0.058 meters = 58 mm in diameter and 715 meters from the beach ball.
Uranus would be 0.0254 meters = 25.4 mm in diameter and 1440 meters from the beach ball.
Neptune would be 0.0246 meters = 24.6 mm in diameter and 2250 meters from the beach ball.

Note that on this scale, Earth and Venus are about the size of small marbles, Moon the size of a bead, Mercury and Mars the size of peas, Jupiter the size of an apple, and Uranus and Neptune are the size of very large marbles.

Light travels at a speed of 3×10^8 meters per second. In one year, light can travel 9.5×10^{15} meters. This distance is called a light-year. Remember, it is a measure of distance, not time.

A car traveling at 100 km per hour, will require 11 billion years (twice the age of the earth) to travel one light-year.

Galactic Scale

Distance to the sun is 0.000016 light-years.
Distance to the nearest star visible with the naked eye (Alpha Centauri) is 4.36 light-years.
Distance to the center of our galaxy (Milky Way) is 26400 light-years.
Diameter of our galaxy is 110000 light-years.
Number of stars in our galaxy is about 3×10^{11} .
Distance to Andromeda galaxy is 2.54×10^6 light-years.
Distance to the most distant galaxy observed is about 1.34×10^{10} light-years.
Number of galaxies in the observable universe is about 2×10^{12} .
Number of stars in the observable universe is about 1×10^{24} .

The number of stars in our galaxy is about equal to the number of small grains of salt that could fit in a box 2 meters on a side:

$$\left(\frac{2 \text{ m}}{0.0003 \text{ m}} \right)^3 = 3 \times 10^{11}$$

If the earth's orbit around the sun were the size of a grain of salt, the nearest star would be about 70 meters away, and the center of the galaxy would be 500 km away, about the distance from San Francisco to Los Angeles.