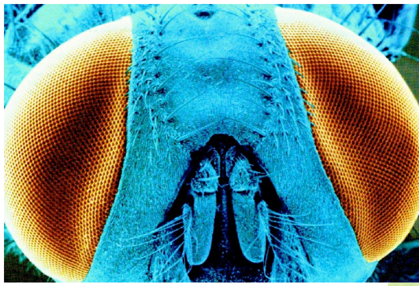
Why Study Astronomy?

Astronomy is the most ancient of sciences. It first told us about our celestial environment, the passage of time and the seasons. But astronomy on a wider scale is about our existence and our place in the universe. How did the universe begin? How did the Earth form? What keeps our life-giving sun burning? What will happen when she dies? What lies beyond our galaxy? How will the universe end?

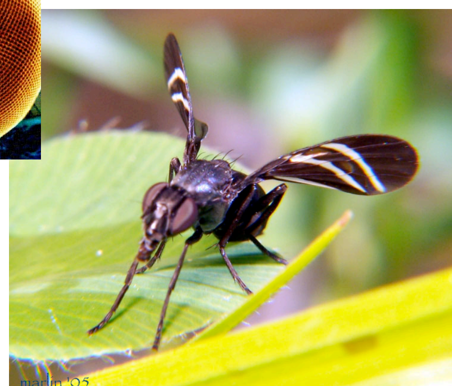
These are some of the biggest questions that we, as human beings, can ask. And astronomy has many of the answers…..

The Scale of the Cosmos

(the universe is big, really big)



1 millimetre (mm)



1 centimetre (cm)

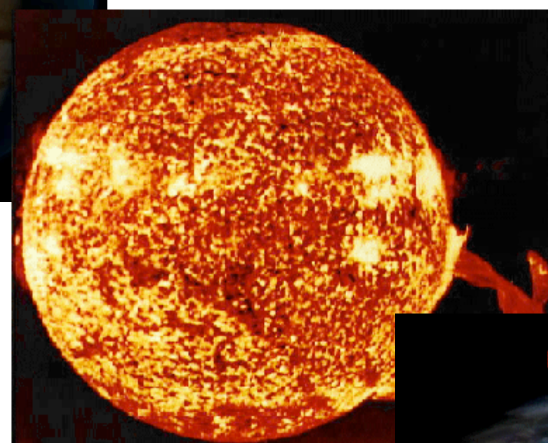
1 metre (m)

1 kilometre (km)

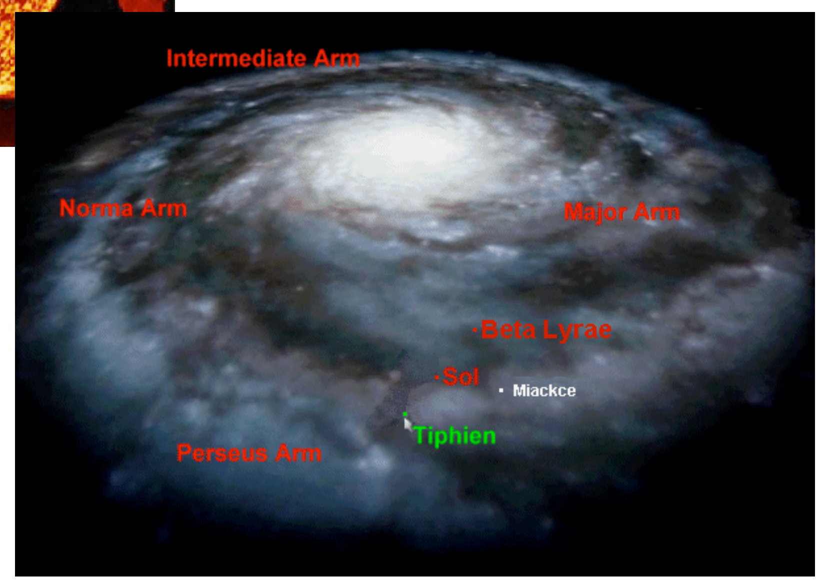
We use different units of length depending on what we're measuring. On Earth, the largest unit we tend to use is the kilometre.

Earth ~ 13,000 km

Jupiter ~ 143,000 km

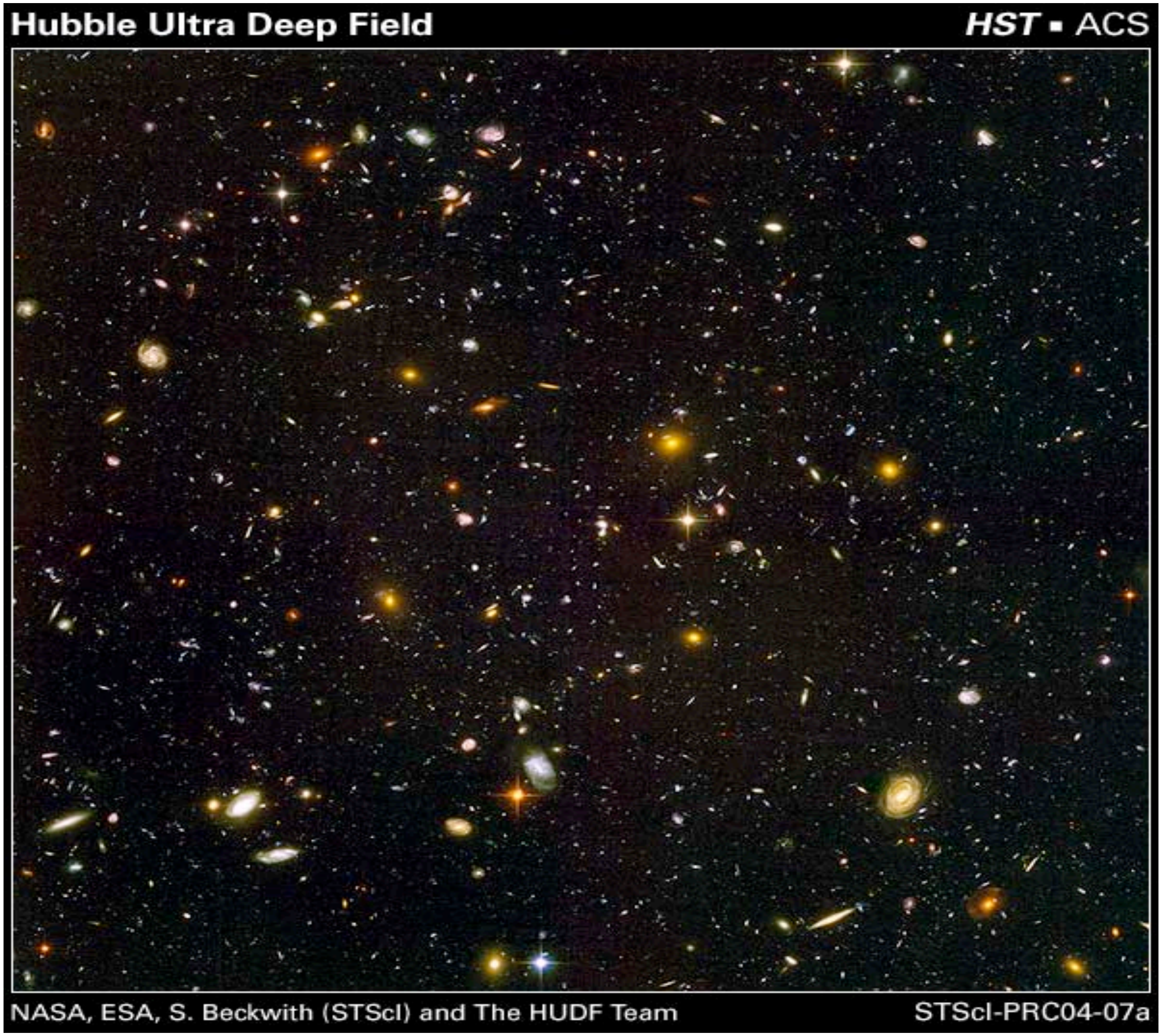


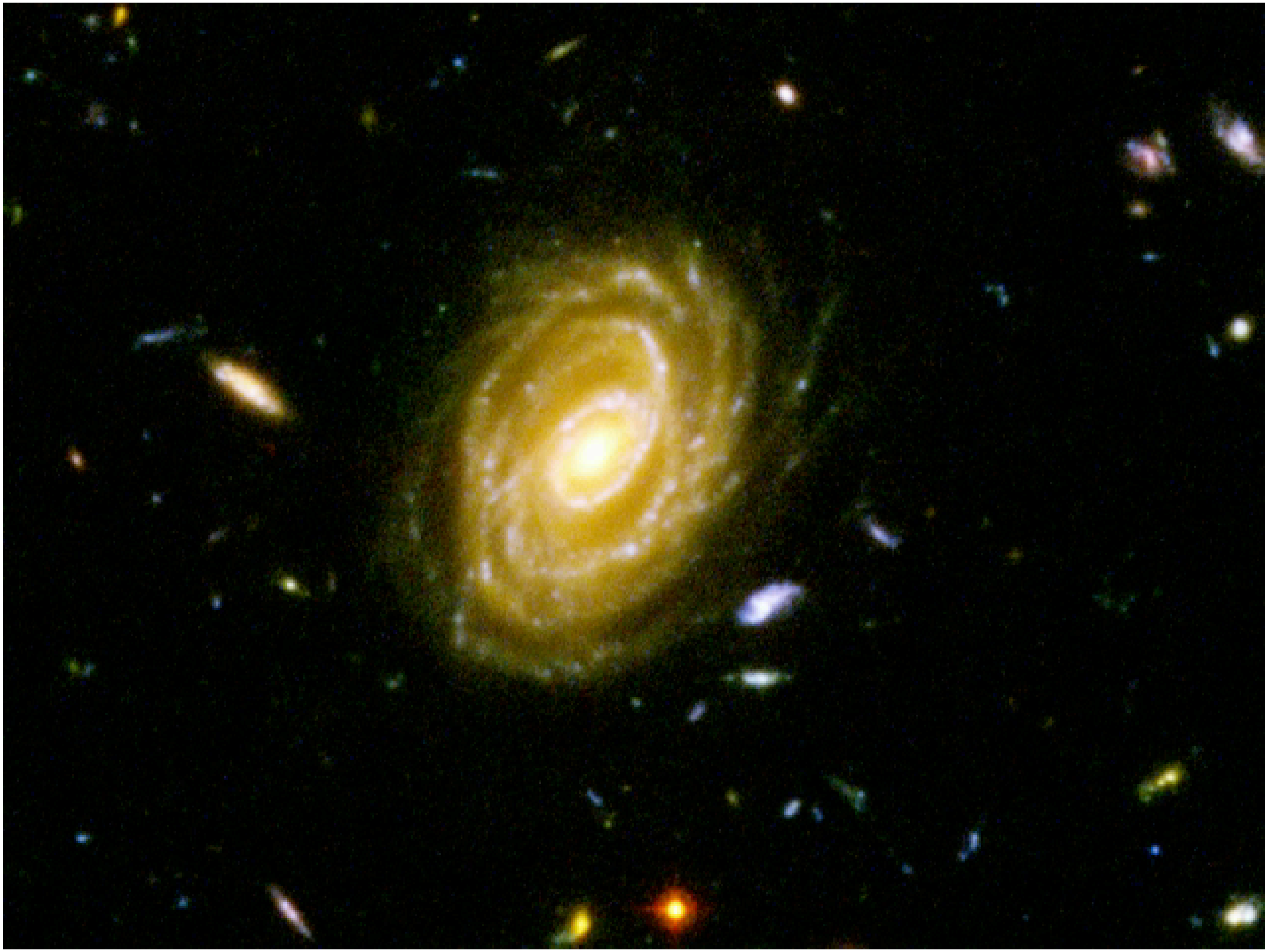
Sun ~ 1.4 million km



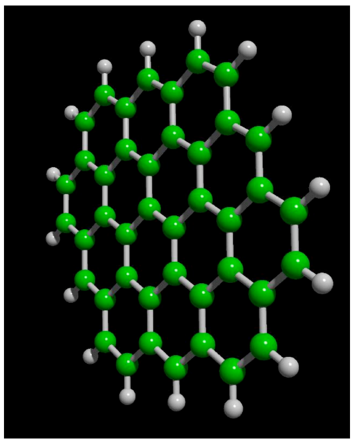
Milky Way galaxy ~ 1000 million, million, million km.

10,000 galaxies in a patch of sky the size of half a rice grain

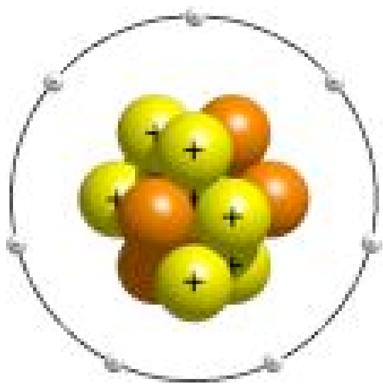




Astronomers also need to deal also with very small numbers

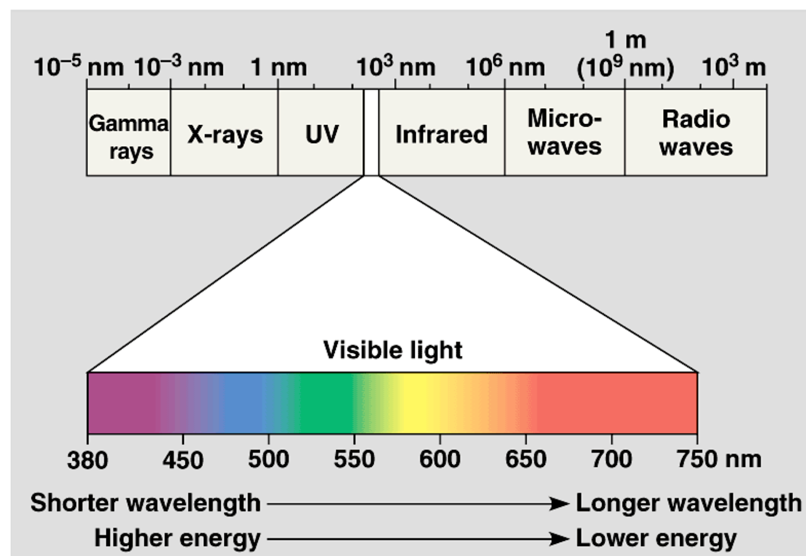


Complex carbon molecules = 1 millionth of a metre



Atom = 1 thousand millionth of a metre

Wavelengths of light, from 1 billionth of a metre, to 1 kilometre



How do astronomers deal with such extremes of scale?

1. We introduce different units that are more convenient for describing very small and very large objects. We'll introduce these as we go along through the course.

2. We use a special way of writing small and large numbers called "scientific notation".

You don't have to remember all the units and numbers in this course, most of the important ones (e.g. mass of the sun, radius of the earth) are in the appendices of your text book.

How can we write down very large numbers, or type them into our calculators? We use the power of powers!

A “power” is just multiplying a number by itself. For example, powers of 2 involve doubling numbers. Numbers get big very fast when you do this!

Folding a piece of paper in half 37 times (doubling its thickness a 37 times) would result in a wadge of paper the thickness of Earth’s diameter (about 14,000 km)! After 100 folds, the thickness is about the size of the universe.

Mathematically we write this number (2x2x2x2…100 times) as simply 2^{100} or “two to the power of a hundred”.

Scientific Notation (powers of 10)

For convenience, we usually use powers of ten.

$10^1 = 10$

$10^2 = 10 \times 10 = 100$

$10^3 = 10 \times 10 \times 10 = 1{,}000$ = 1 thousand

$10^4 = 10 \times 10 \times 10 \times 10 = 10{,}000$

$10^5 = 10 \times 10 \times 10 \times 10 \times 10 = 100{,}000$

$10^6 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1000{,}000$ = 1 million

Of course, we often want to have something other than "1" of something (e.g. 6.2 million rather than 1 million).

$6.2 \times 10^6 = 6{,}200{,}000$ = 6.2 million

We'll be seeing scientific notation a lot, so let's do some more examples. Write the following numbers in scientific notation:

$920 = 9.2 \times 10^2$
$3,452 = 3.452 \times 10^3$
$78,900,000 = 7.89 \times 10^7$

Now write these numbers out long-hand:

$5.8 \times 10^1 = 58$
$6.7 \times 10^4 = 67,000$ (67 thousand)
$3.1 \times 10^6 = 3,100,000$ (3.1 million)

In order to enter these numbers into your calculator, use the "exp" button, which means x 10 to the power of something. This is different for different calculators, but normally for 3.1×10^6 you would type: 3.1 exp 6.

Scientific notation can be used also for very small numbers using same principle as for large numbers

10^{-1} = 1 / 10 = 0.1 = 1 tenth

10^{-2} = 1 / 10 x 10 = 1/100

10^{-3} = 1 / 10 x 10 x 10 = 1/1,000 = 1 thousandth

10^{-4} = 1 / 10 x 10 x 10 x 10 = 1/10,000

10^{-5} = 1 / 10 x 10 x 10 x 10 x 10 = 1/100,000

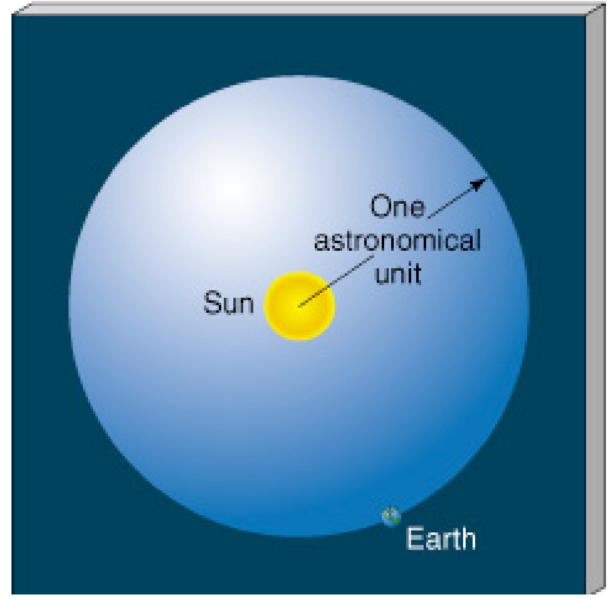
10^{-6} = 1 / 10 x 10 x 10 x10x10x10 =1/1000,000 =1 millionth

We will use small numbers a lot when talking about the size of atoms and the wavelength of light. In particular, we introduce a new unit of length: the nanometre (nm).
1 nm = 1 billionth of a metre = 1 x 10^{-9} m.

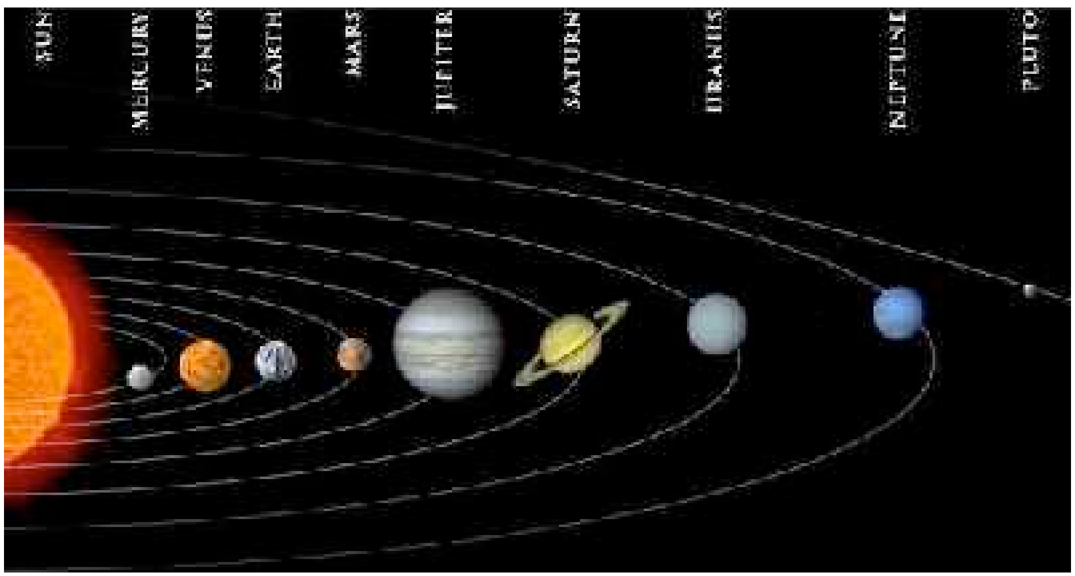
Distances in the solar system

Image not to scale - there is a lot of space between the planets!

An astronomical unit (AU) is the **average** distance between the earth and the sun.



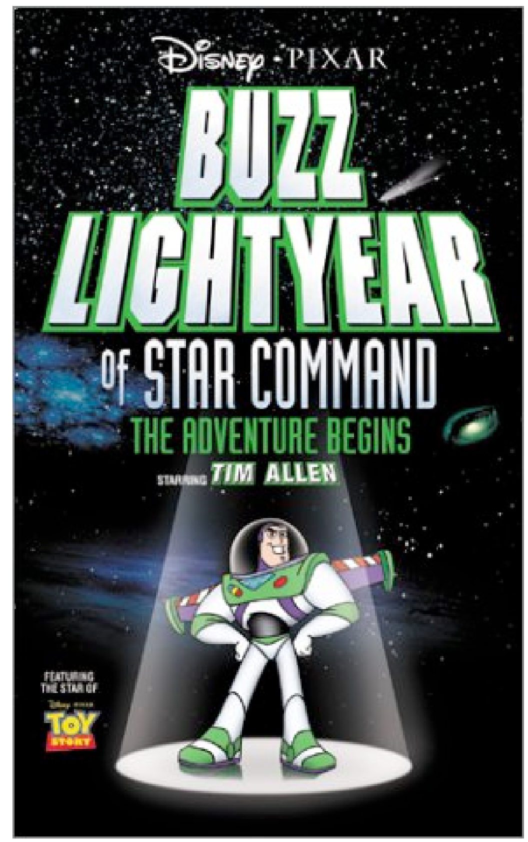
1 AU = 1.5×10^{8} km (150 million km)



Question: if Jupiter is 5 times more distant from the sun than the earth, what is the distance between the sun and Jupiter?

AU are convenient for the solar system, but what about distances to other stars?

The nearest star to the sun is Proxima Centauri at 4×10^{13} km (40 million, million km) away. How many AU is that?



$1 \text{ AU} = 1.5 \times 10^8$ km

$4 \times 10^{13} / 1.5 \times 10^8 = 2.7 \times 10^5$ AU!!

So, for distances to stars we use a different unit: the light year.

Definition: One light year is the distance that light travels in one year.

What is a light year in kilometres? Light travels at $3x\ 10^5$ km/s. First we need to calculate how many seconds in a year: $60 \times 60 \times 24 \times 365 = 3.15 \times 10^7$ seconds.

distance= speed x time = $(3x\ 10^5)\ \times (3.15 \times 10^7)$

1 light year = 9.5×10^{12} km

Let's return to Proxima Cen. which is 4×10^{13} km away. How many light years is this?

$4 \times 10^{13} / 9.5 \times 10^{12} = 4.2$ light years