## Mr G's Little Book on

# How Big is "Big"?

## The Scale of the Solar System and the Milky Way Galaxy

**Issue 1.1**

## How Big is Big?

The sun is 1.4 million km. (865 000 miles) in diameter. Now even at our starting point, this is hard to comprehend or visualise but nevertheless let's pursue the investigation.

Let's represent the sun by a very large beach ball. One meter in diameter will suffice. Now the earth is 12.8 thousand km. in diameter (8 000 miles). The circumference calculates at a nice round 40 thousand kilometers which is how the meter was first defined.

Now back to the original thread - dividing one by the other we deduce about 100 earths could fit side by side across the sun. If we approximate the sun as a cube – well why not – then we could pack 100 x 100 x 100 inside with gaps in-between or one million. Alexa obligingly confirms this.

Now the sun is 150 million km. (93 million miles) away and that represents over 100 sun diameters. So on our scale model, we now position the earth 100 meters away from beach ball Sol.

Let's remind ourselves we building a scale model where one meter represents 1.4 million km. or 1 : 1.4 billion (a billion being a thousand million). So dividing 12.8 thousand km. by 1.4 million km. means our earth is represented by a little ball slightly less than one millimeter across.

So now we have a miniscule ball orbiting a beach ball over 100 meters away. That means space is very very empty. We'll come back to this later on.

Now let's consider Neptune – our outermost real planet. Alexa tells me it's 4.5 billion km. away. So diving by our 1.4 billion to give us a scale model length that's 3.2 km. Because we're better

working in miles for that distance that's conveniently about two miles. So Neptune is a slightly bigger ball orbiting two miles away from our one meter beach ball Sol.

Now let's build a model from the other end. Let's say our Milky Way galaxy is represented by a swirling mass of stars one kilometer in diameter. Now we start to run out of descriptive words for the true size. Alexa says it's at least one hundred thousand light years in diameter – maybe more than one hundred and fifty. For simplicity let's stick with one hundred thousand. Now light travels at 300 thousand meters per second (186 000 miles per second). The sun is about 8 light minutes away and Neptune about 4 light-hours away. However a light year is a staggering ten trillion kilometers. Multiplying those numbers together gives us a diameter of one million trillion km. or $1 \times 10^{18}$ – one followed by 18 zeros.

Now the radius of our solar system is about 10 thousand million km. So dividing one by the other we discover about one hundred million solar systems will fit edge to edge across the Milky Way. So to get our scale size if we represent our galaxy at one km. our entire solar system is smaller than the most microscopic dot - one hundredth of a millimeter across on a galaxy a kilometer wide.

We could check this calculation in "light hours" to "light-years". A year is about 10 thousand hours so we have ten thousand times one hundred thousand divided by ten (light hours diameter of our solar system) which fortunately gives us our hundred million again.

**Footnote**

We could estimate there are one hundred thousand million stars in an average galaxy and maybe one hundred thousand million galaxies in the observable universe. Wikipedia tells me that is around $10^{80}$ atoms.

Amazingly my local hero, Arthur Eddington calculated his belief in the exact number of atoms in the universe and wrote the number down. The theoretical number was $136 \times 2^{256}$ or approximately $1.57 \times 10^{79}$. He also derived results of similar scale from combining relativity with wave mechanics and also by large scale considerations on the mass of the universe - all ultimately hinging on a value of Hubble's constant plus other fundamental constants that can be derived in the laboratory.

He also first predicted the source of energy in the sun. Although critics at that time pointed out the centre of the sun was not hot enough to fuse hydrogen into helium he countered "well find me a hotter place". In fact some amazing aspects of quantum mechanics solves the problem. One proton transforms into a neutron by emitting a neutrino to give just enough time for the strong force to bind them before it converts back to a proton. So our sun will fortunately be around for a few more billion years and despite a vision of an exploding cauldron is actually more a very slow burn.

I have also calculated that if the entire universe started out at the Planck density of $5.18 \times 10^{96}$ $kg/m^3$ we can fit about 3 million compressed universes inside a hydrogen atom.

That just one example of combining the incredibly large with the phenomenally small.

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