From sub-atomic to Universal, the range of scale tends towards infinity - in both directions. It could be argued that the small can be imagined as our minds can attempt to grapple with the concept of nothing and then it is only a case of imagining something getting infinitesimally closer to that limit. Yet with large scale we become stuck - viewing from or within a constricted radius of planet Earth it is difficult to put scale into perspective. We quickly lose our ability to compare the large with the larger which soon appear to be both insignificantly small in comparison to the larger still. This article helps rebalance scale. What you once thought big, you’ll think big no longer.

Do you ever find yourself looking at people and thinking how short or tall they are? Do you ever think that the building in front of you is huge, while the grains of sand on the beach are tiny? If you call a person big, a building huge, a planet gigantic...how long until you run out of words? Just how big do things get, and how far away are those dots in the night sky?

Our minds can only readily comprehend what is in our usual experience; many quantum phenomena seem unintuitive to us even though they are perfectly natural, whilst a computer interface is non-natural but familiar, and therefore, we can understand it. The tallest freestanding structure, the Burj Khalifa, is 818m tall and this is just about as large as we can easily imagine. The Great Wall of China, the longest man-made structure, is 8,852km from tip to tip (it is one thousand times as long as Mt Everest is tall). By volume, the now closed Fresh Kills Landfill was the largest man made structure, but this was only 12 square kilometres (although at its most full it was just 25m shorter than the torch on the Statue of Liberty). Contrary to popular belief, The Great Wall cannot be seen from the moon; for a sense of scale, if one were standing on the moon, the Great Wall of China (at an average of 384,393km away) can be compared to a 2cm thick cable does 1000km away – not at all.[1]

So let us say that the largest man-made structure is on a scale of around 10^7m (10,000,000m or 10,000km). Currently the largest proposed structure with any level of plausibility is a space elevator, and rough ideas of the length for this put it at around 100,000km [2] (Earth is 13,000km in diameter), which would mean it would go a quarter of the way to the moon. So for planned structures, the current upper limit is 10^8m.

Beyond this, we start to get to what most people would consider to be “unimaginable scales”. Jupiter, the largest planet orbiting the sun and that which consists of 71% of the mass of all the planets in the solar system combined is 143,000km in diameter. This means you could fit around 1,300 Earths inside the volume of Jupiter! The planet with the largest confirmed size is TrES-4 at 260,000km wide [3], although the more recently discovered (11-08-09) WASP-17b may be the largest known planet but this is yet to be confirmed. It is estimated to have a radius 1.5-2.1 times that of Jupiter. Also of interest is that it is the
least dense planet at 0.14g/cm³ [4] (compared to 1.33g/cm³ for Jupiter) and was the first discovered planet with a retrograde orbit – which is in the opposite direction of the rotation of its host star. The physical upper mass limit for a planet is roughly 13 times the mass of Jupiter; [5] this is because beyond this mass, threshold deuterium will fuse and a star is born. Thus, objects with a mass more than 13 times that of Jupiter are stars, failed (like brown dwarfs) or otherwise.

But failed stars are not the smallest type of star; this honour belongs to neutron stars. Between 20 and 40km in diameter (which is less than the width of some cities), they are so dense that they are almost at the limit for how dense something can be before collapsing into a black hole. If all of humanity were compacted to the size of a sugar cube, this would have the approximate density of a neutron star.[6] Most stars, however, are significantly bigger than this; even dwarf stars, assumed to be small, can have a diameter many hundred times greater than that of the Earth. The Sun, a yellow dwarf (which is in fact white, only appearing yellow through the Earth’s atmosphere), consists of 99.86% of the mass in the whole Solar System and is a near perfect sphere (its polar and equatorial diameters differ by only about 10km – considering the diameter is roughly 1,392,000km, this is fairly negligible.). Nonetheless, our Sun does have issues: not only is it currently going through an extended period of sunspot minimums, but its magnetic field is less than half of the minimum recorded 22 years ago, and the Solar Wind has cooled by 13% in the last two decades. [7] Our next step up takes us to subgiant stars. These stars are in the process of swelling up to giant stars, which usually takes a few tens or hundreds of millions of years. Subgiants normally start at just a few times the diameter of the Sun, but by the time they are fully converted to giant stars are between 10 and 100 times the diameter. Some giant stars are many hundred times larger than the Sun. For a sense of scale, if the Sun expanded to just over 100 times its current size, Earth would be inside it. Giant stars can be up to 1,000 times more luminous than the Sun, and the brightest of these are known as bright giants, not quite massive or luminous enough to be included in the next category up, but too luminous (and often too massive) to be a giant star.

Amongst the largest of any individual objects are the supergiant stars. These can go beyond 1000 times the diameter of the Sun as well as being hundreds of thousands of times as
bright, although blue supergiants are smaller than red ones of the same luminosity. Contrary to what one might think, hypergiants are not necessarily more massive than supergiants, as they are defined by the rate at which they burn mass. The largest of these supergiants are so bright that they approach the Eddington limit – the point at which radiation pressure outward equals gravitational pressure inward. Beyond this, the star would radiate out part of its outer layers until it fell below the Eddington limit once more. The largest known star, VY Canis Majoris, is believed to be around 2000 times as large as the Sun, meaning that if it were the star in the Solar System (replacing the Sun) then it would extend beyond the orbit of Saturn. Light travels around the Sun in 14.5 seconds; it would travel around VY in 8 hours. For a sense of scale, it would take 7,000,000,000,000,000 (7 quadrillion) Earths to fill the volume of this star, compared with just 1,300,000 to fill the Sun – this is 5.5 billion times as many!

Only a small fraction larger than VY Canis Majoris, a supermassive black hole is currently theorised to have a maximum size of 10AU (VY has diameter 9AU, where one Astronomical Unit is the distance from Earth to the Sun). However, while only a little larger, it is far more massive; although the star is estimated to be around 20 times as massive as the sun, the black hole could be tens of billions of times as massive. The largest known black hole is at the centre of the OJ 287 galaxy and has a mass estimated at 18 billion solar masses. It can be hard to imagine how large a billion is, but help is at hand; consider that a billion minutes ago the Roman Empire was thriving (1,900 years ago), a billion hours ago we were in the Stone Age (114,000 years ago), and a billion months ago dinosaurs roamed the Earth (82 million years ago).

These are, so far as we know, the largest individual astronomical objects. However, astronomical bodies range from far smaller (such as the Asteroid Belt between Mars and Jupiter) to far larger (such as intergalactic filaments, the largest structures yet known to humankind). Something everyone is familiar with, the Milky Way Galaxy is 100,000 light years across, compared to just 0.00047 light years from the Sun to Neptune. Yet galaxies are very rarely isolated, instead often forming groups or clusters of tens, hundreds or thousands of galaxies together. The Milky Way Galaxy is part of the Virgo Cluster which is 15,000,000 light years across and contains an estimated 1500 galaxies. Beyond this scale we reach Superclusters which, if you can imagine a cluster as being a group of galaxies, are equivalent to a group of clusters of galaxies. These form the largest structures known to us and the largest so far is the Great Sloan Wall (essentially a wall of galaxies, named after the Sloan Digital Sky Survey which discovered it) spanning 1.37 billion light years. Now this is truly huge, but considering that an estimate for the minimum size of the Universe is 78 billion light years, there’s still a lot of space to fill.

Unfortunately, lots of this space isn’t filled. Voids in space which span tens or hundreds of millions of light years are not too rare, and have an average density of one atom per cubic metre. These fill the distance between galaxy clusters and often contain no galaxies at all. In 2007 scientists found a void almost a billion light years wide, devoid of matter and dark matter alike, but thought it highly unlikely to be the largest void there is. Quite right too; they have now found a void over 3.5 billion light years wide. And you thought a building was big.

There are millions of galaxies “near” the Milky Way Galaxy, but there are billions of galaxies elsewhere. If there were a way to travel at the speed of light (or very near to it) it would still take hundreds of millions of years to get to most of these galaxies. That is far longer than humans have been around, and an implausible amount of time to be travelling. Even crossing our own galaxy at the speed of light would take 100,000 years, and if we consider that 100,000 years ago is when humans are estimated to have started using tools, we get a sense of scale of how large some things truly are.

References

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