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ALMOST NOTHING

Ken Tapping, 17th May, 2016

Every material object in the observable universe is made up of atoms. Each atom consists of two main parts: a nucleus in the centre, and a system of orbiting electrons. The simplest and most common atom is that of hydrogen, which has a nucleus consisting of one proton. This is orbited by a single electron. If we represent the proton by a golf ball, the electron would be a bit bigger. In this case our hydrogen atom would be almost 2km in diameter. Atoms are almost totally made up of empty space. Other atoms contain more particles, but in all cases they are mostly empty space. Most of the volume of physical objects, including the Sun, the Earth and us is filled with nothing.

However, even so, atoms are very resistant to compression, which is why our mountains and buildings stay up, and our planet does not implode. They are not however immune to compression; it's just to make that happen we need a lot of force.

Imagine we are making a huge pile of atoms, adding more and more material. Initially nothing much happens. We know that we can make planets out of atoms. However as we continue to add more material, getting to star-sized lumps, the atoms compress a bit. Their electrons move closer to the nucleus. Imagine an apartment block. Some apartments are occupied, and some aren't. The unoccupied apartments are scattered around the building. If we were to move tenants from upper floors to unoccupied apartments on lower floors, we could maybe remove a floor or two from the building, making it smaller. Similarly, if all the electrons in an atom were pushed into locations closer to the nucleus, the atom would become quite a lot smaller. We could reduce the Sun to the size of the Earth. Matter in this condition is called "degenerate". It occurs in the cores of stars, and a teaspoonful of it would weigh about a tonne.

If we keep piling on more and more material, nothing much will happen for a long time, because degenerate matter is extremely resistant to

compression. However, eventually it does collapse. The electrons are pushed right into the nucleus, where they combine with the protons to make neutrons. So we end up with a very small, extremely heavy lump of neutrons. The core of a star compressed to this point would be a few kilometres in diameter but still weighing as much as a star. A teaspoonful would now weigh about a billion tonnes. Predictably, we call these objects neutron stars. We have now discovered quite a few of these scattered around our galaxy.

If we continue to add material, the situation becomes really strange. As an object gets more compressed, its surface gravity rises. The object also becomes more resistant to compression. However, as shrinkage continues, the gravitational compression force rises faster than the resistance to compression. This would suggest that once pushed beyond a certain point, either by the weight of overlying mass or by the shock wave in an exploding star, our lump of material would shrink indefinitely. We're not quite clear whether shrinkage will actually continue for ever, but we do know that as the gravity gets more intense, a point is reached where the fabric of space time becomes extremely distorted. The object becomes surrounded by an envelope of curved space time where things can drop in, but nothing can get out, not even light. It has become a black hole.

Black holes are created when giant stars explode, and most large galaxies, including ours, have massive black holes in the centres, swallowing any gas, dust and stars that get too close. We have seen several stars that our galaxy's black hole is in the process of pulling in. Fortunately, our galaxy's black hole is a nice long way away.

Jupiter is high in the south after sunset. Mars and Saturn, rise around 10pm. Mars is the brighter of the two and will be at its closest to Earth on the 30th. The Moon will be Full on the 21st.

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