1 How many nucleons are in the visible universe?

Nuclei consist of protons and neutrons. Protons and neutrons are called nucleons. In our Solar System, the mass of then sun is more than 99.8% of the mass of the whole system. Assuming that this essentially the case everywhere, the mass of the visible matter is to a very good approximation the mass of the stars in the universe. One way to calculate the mass of the visible matter, is to determine the number of stars and multiply this by the average mass of a star. The univers seems to have no net change. So the number of its electrons should be equal to the number of its protons. As each proton is roughly 2000 times more massive than an electron, again to a good approximation one can neglect the fraction of the mass of the universe which comes from the electrons. So, as far as the mass of the visible matter is concerned, it essentially comes from the protons and the neutrons. These have roughly the same mass. So the mass of the visible universe is equal to the number of nucleons times the mass of a nucleon.

So this is what to do. One has to count the number of stars and multiply it by the average mass of a star to arrive at the total mass. Then divide this by the mass of a nucleon to find the number of nucleons. Alternatively, one could divide the average mass of a star by the mass of a nucleon to obtain the number of nucleons in an average star, and then multiply this by the number of the stars to find the number of the nucleons.

To find the number of the stars, one way is the find the number of the stars in a typical galaxy, and then multiply this by the number of the galaxies.

Let's begin with the number of stars in a typical galaxy. This can be done with our own galaxy (the milky way), assuming that it is a typical one.

The distance between the sun and its nearest star is 4 light years. Assuming that this distance is typical, the volume corresponding to a star is of the order of 4^3 cubic light years. Of course this is not the volume of the star itself. 4^3 is 64, and is rounded to 100. So the volume corresponding to a star is about 100 cubic light years.

Our galaxy is like a disk with a diameter of about 10^5 light years and a thickness of about 10^3 light years. The volume of our galaxy is then about 10^{13} cubic light years. Dividing this by the volume corresponding to a star, one arrives at 10^{11} for the number of the stars in a galaxy.

The age of the universe is estimated to be about 10 billion years. A more exact figure is 13.8 billion light years, but for the approximate calculation performed here, the order of magnitude is sufficient. A rough estimate for the size of the visible universe the this age times the speed of light: the light of regions which are further has not reached us yet. So the size of the visible universe is about 10 billion light years (10^{10} light years). This gives the volume of the universe to be of the order 10^{30} cubic light years.

Similar to the method used to find the number of stars in a galaxy, one could estimate the volume corresponding to a galaxy, using the typical distance

between the galaxies. Then the number of the galaxies would be the volume of the universe divided by the volume corresponding to a galaxy. To find the latter, consider our nearest ordinary (non-dwarf) galaxy. This is Andromeda, at a distance of about 2 million light years, that is (2×10^6) light years from us. Assuming this distance to be typical, the volume corresponding to a typical galaxy is (8×10^{18}) cubic light years, roughly 10^{19} cubic light years. So the number of galaxies in the visible universe is about 10^{11}.

What remains is to estimate the number of nucleons in a typical star. Again it is assumed that our star (the sun) is a typical star. The mass of the sun is $(2\,times 10^{30}\,\mathrm{k\,g})$. The mass of a nucleon is equal to $(1\,\mathrm{g})$ (the mass of one mole of hydrogen atoms) divided the Avogadro number N_A. The reason is that a hydrogen atom has just one proton (and of course one electron, but the mass of the latter is negligible compared to that of the proton). So the mass of one mole hydrogen atoms is equal to the mass of one hydrogen atom times the number of atoms per mole, and the latter is the Avogadro number. The avogadro number is equal to (6×10^{23}) per mole. So the mass of one nucleon is about $(2 \times 10^{-24}\,\mathrm{g})$, or $(2 \times 10^{-27}\,\mathrm{k\,g})$. That gives the number of nucleons in the sun to be of the order 10^{57}.

So, there are 10^{11} galaxies per visible universe, 10^{11} stars per galaxy, and 10^{57} nucleons per star, resulting in 10^{79} nucleons per visible universe.