Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Sunshine*.

The Sun is kind of big – 1.4 million kilometers in diameter, which is 109 times Earth's – and it makes up about 98.6% of the mass of the solar system. People may tell you it's a big ball of gas, but don't believe them. It's a big ball of plasma.

If you heat a solid it becomes liquid, heat that and it becomes gas and if you heat a gas enough it becomes plasma, often referred to as the fourth state of matter. In a plasma, the electrons normally associated with atoms begin to move about freely, carrying negative charges while the ionized atomic nuclei they have been stripped off are left with a positive charge. So a big ball of hydrogen plasma, like the Sun, is surprisingly electrically conductive and responds strongly to electromagnetic fields – in the form of sun spots, solar prominences and solar mass ejections.

You don't want to go calling the Sun average either. It's brighter than 85% of stars in our galaxy, which are mostly red dwarfs. Also, it's on its own, unlike most stars – which are most often found in binary pairs, or even larger groups.

It's formally titled a G2 type star meaning that it has a surface temperature of around 5,700 K and is a white star, although the scattering of blue light by our atmosphere could make it look a bit yellow – not that anyone should be looking at it.

All that light – and about 6 billion tonnes per hour of sub-atomic particles – getting pumped out by the Sun is the result of a form of hydrogen to helium fusion known as the proton–proton chain.

Since we are dealing with subatomic particles, we can bring quantum mechanics into the mix and say that fusing hydrogen is a chancy business. There always exists a vanishingly small probability that two hydrogen atoms could occasionally collide and fuse. As Douglas Adams once said – a virtual impossibility is a finite improbability.

You can bump up the odds a bit if you turn the hydrogen into a plasma so that you remove all the atoms' electron shells, leaving naked hydrogen nuclei bouncing around. These hydrogen nuclei are just single protons, but without their electrons they carry a positive charge so are still going to repel each other.

However, if you apply heat to a collection of single protons they will begin to vibrate so wildly that collisions between them become more frequent and the probability of fusion becomes much more likely. Outside a star you would need to heat your collection of protons to over 40 million Kelvin to initiate a significant amount of fusion.

However, inside a star the very high particle densities resulting from compression of the humungous mass of a star means that significant amounts of fusion can take place at lower temperatures because everything is jammed so tightly together.

Significant rates of fusion take place in the Sun's core at a mere 15 million Kelvin. However, even under these conditions, the probability of fusion isn't that high – which is why it will take the Sun about 10 billion years to burn through most of its fuel.

The rate of fusion in the Sun's core is also self-limiting, since a minor rate increase raises the core's temperature, making it expand slightly. This expansion reduces how closely the protons are packed together which makes their rate of fusion drop back again.

In really big stars, this carefully balanced arrangement goes out the window. The higher internal densities and hotter temperatures make the probability of fusion much more likely and the core has very little capacity to expand against the crushing force of its star's larger mass. Big stars live fast and die young – generally within a few million years.

Anyway, back to the Sun. The Sun's core extends to about 20% of its radius. It is the only region where significant rates of fusion take place and the rest of the Sun's structure is a broth of broiling plasma superheated by all the fusion activity beneath it.

Remembering that fusion is an unlikely event – just now and again in the Sun's core two protons smack together and transmute into a deuterium nucleus – with the release of a positron and a neutrino. Another proton then combines with the deuterium nucleus making an intermediate thing and releasing a high energy photon. Finally two of these intermediate things combine to form a helium nucleus, along with the release of two brand new protons.

To put it another way, you put in six protons, get two new ones back and end up with two new helium nuclei, along the way releasing two neutrinos, two positrons and two photons. In terms of mass, a nett four protons went in and two helium nuclei came out. The combined mass of the new helium is lighter than the four protons, the unaccounted mass having been turned into energy, in accordance with $e=mc^2$ – representing the principle that a tiny amount of mass is equivalent to a truckload of energy.

This energy includes the two photons produced and the additional kinetic energy in the highly energised particles that are shot out during the reaction.

Well, when I say shot out, that's not quite how it works. The two positrons annihilate themselves almost immediately by colliding with their antiparticle, the electron – which, remembering that the Sun is a big ball of plasma, are present in abundance. This represents yet more mass being turned into energy in the form of yet another photon.

The two neutrinos are almost massless and carry no charge and are therefore capable of shooting straight out of the Sun at close to the speed of light – which is just what they do. There are trillions of solar neutrinos passing through your body every second of the day and night since they can pass straight through the Earth as well.

The photons carrying all that light and heat of the Sun’s fusion reactions have a more difficult time of it. Created in the Sun’s core, they are almost immediately absorbed by all the particles crammed together in the Sun and the energy they carry can only move outwards from the core in fits and starts. Firstly through the radiative zone of the Sun and then through the convective zone, the last 30% of its radius – where this energy can move outwards more quickly by virtue of the broiling movement of plasma it is interacting with.

Finally – up to ten million years after the fusion reactions that created them – new photons emerge from the Sun’s surface and fly off at the speed of light, perhaps delivering a little ray of sunshine to you on Earth about eight minutes later.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website helping you get more big bang for your buck. No ads, no profit, just good science. Bye.