PROFESSOR: Have you ever wondered how all the chemical elements are made? Then join me as we are lifting all this data secrets to understand the cosmic origin of the chemical elements. Why do stars shine? Why do we have sunlight every day? Well, it's because of nuclear fusion.

Nuclear fusion is going on in the core of the sun. Hydrogen to helium gets converted there. And that gives the sun enough energy to sustain its luminosity for billions of years.

How does this work? Let's have a look. So we want to reproduce what is going on in the sun.

And what's basically happening is that four protons, which also are just four hydrogen atoms, come together in a series of steps that we're going to leave out for now. And they form a helium atom. And that's made from two protons and two neutrons. So we have some conversion of protons here into neutrons. --one helium.

This actually works only because there is quantum mechanical tunneling going on. That's a really cool thing. Ordinarily, these positively charged protons would actually repel themselves. But in the sun, it's really quite hot, not quite hot enough for them to all fuse straight up. But because of this tunneling effect, it's hot enough, just hot enough, so that these protons can combine to eventually form a helium nucleus.

This kind of tunneling effect is important for all subsequent fusion processes, namely if we have another helium here and another one-- so we'll put all of those together-- we're going to get the carbon nucleus. This is the carbon nucleus. And if we're going to add another helium to that, we're going to get oxygen. And if we add more so-called alpha particles-- helium nuclei are often called alpha particles-- then eventually we're going to get to iron.

Now, how does this help us understanding why the sun shines? As it turns out, these lightest nuclei here, they're less tightly bound than the big ones like iron. And that means we're going to get a little bit more energy out of this than that. Now, let's look at some details and then come back to this.

So if we're going to look at the constituents here for protons, which make up one helium nucleus, and then we know a helium nucleus consists of two neutrons and two protons, and if we make a little experiment and we weigh one helium nucleus, and then we weigh two neutrons and two protons separately, we're going to find out that the helium nucleus actually weighs a little bit less than my initial constituents here.

And actually, it's 0.73%. That our final helium nucleus here weighs less than these constituents. And that's really fantastic. So this is called a mass defect.

And you've all seen the equation E equals mc squared, usually with a picture of Einstein attached. And this here, this is a little mass, a little mass difference. And if you stick that in here, you multiply it with the speed of light, c squared-- which is just a constant, so just a number-- you're going to get out energy. And that is the energy that the sun is using to shine every day. So this is the nuclear energy that stars produce.

Now, this amount of energy that gets out become successively less if you go to heavier and heavier nuclei. And if you were to try to fuse to iron atoms together, you're not going to get out anything. So iron atoms will not give you any fusion energy with this here, because this is zero. Actually, you would need to put energy in if you wanted to fuse two iron atoms.

So obviously, the star is going to have a big problem. Because it doesn't want to put energy in. It wants to get to energy out. And that's why, in the end, the star ends up with an iron core. So this is an iron core here.

These fusion processes have been going on in the center and growing larger and larger as more and more elements are being made. And eventually, there is a big, fat iron core sitting there. And since it can't get any energy out anymore, the star has a big problem. Because it needs to have an energy source. And so without that, it explodes as a supernova.