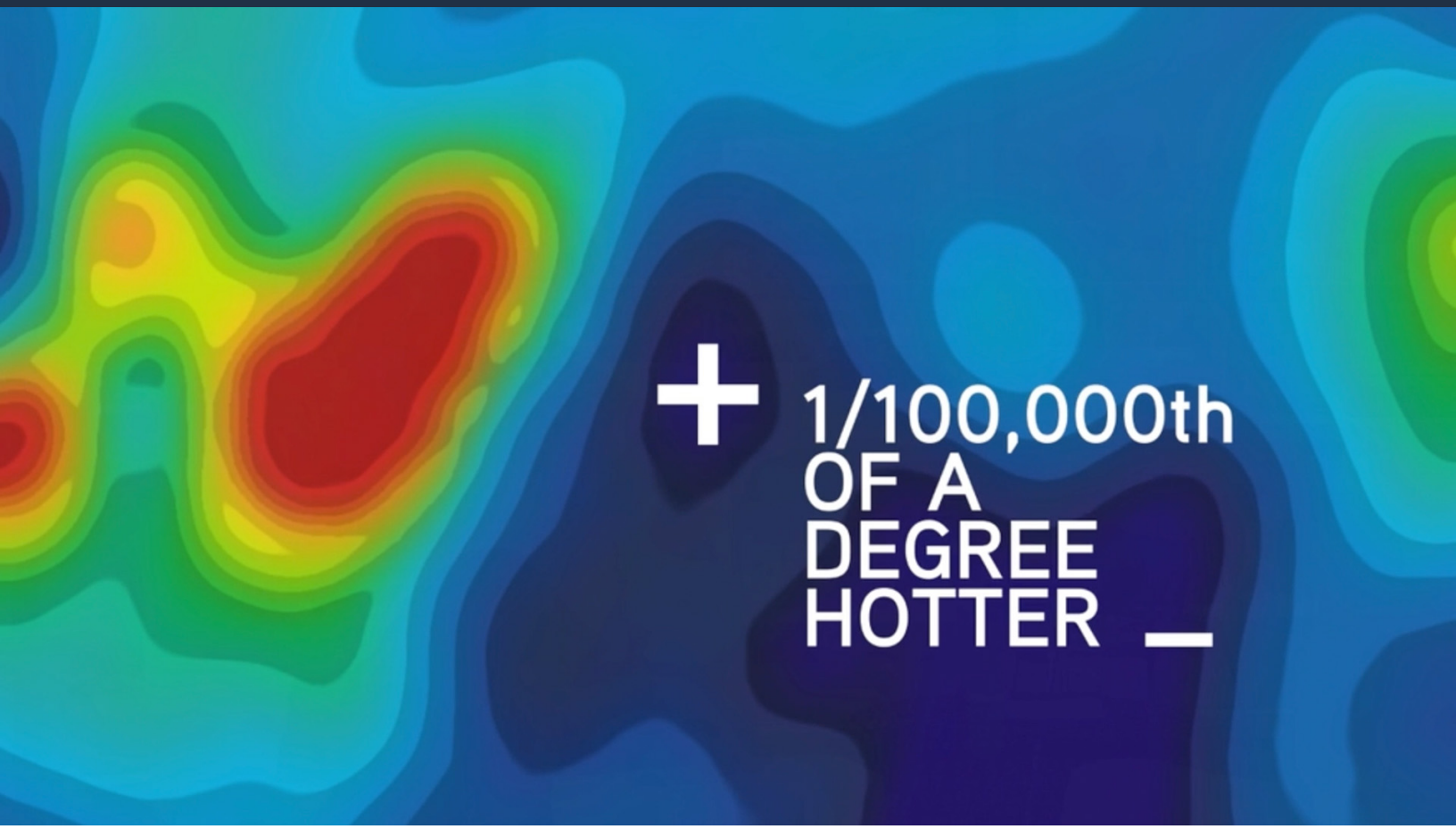

How Were Stars Formed?

Stars are formed from massive clouds of gas and dust in space, called nebulae. Gravity pulls the gas and dust together, and as the material gets tighter, it heats up. When the core becomes hot and dense enough, nuclear fusion starts, and the star begins to shine.

0:00 *Sped up video of stars in the night sky with shooting stars.*	We've all looked up at the stars at night and wondered about them, but can you imagine what it would feel like if you looked up at the stars and you saw nothing, no stars at all? Well, that's what it was like for about 200 million years after the Big Bang.
0:22 *Image of a blue timeline starting with the Big Bang in white to the Dark Ages in blue.*	As the universe expanded, it got colder and colder, and darker and darker, and frankly less and less like a place that might produce things like you and me. Astronomers call this part of the universe's history the “dark ages.”
0:45 *Clip of white atoms floating through black space followed by specific atoms with their chemical symbols.*	During the dark ages you had a lot of atoms flowing through space. You had about 75% of them were hydrogen with one proton, about 25% -most of the rest- were helium with two protons and there was a tiny sprinkling of beryllium, of lithium, lithium's got three, berylliums got four protons, and finally of boron. The whole universe was really very, very simple.
1:10 *Montage of images of the universe starting with white stars in black space, followed by red, yellow, green and blue dots, ending with an image of the universe overlayed with text.*	Everywhere you looked, you seem to have the same temperature, the same density, the same types of atoms. Really everything was uniform and that's a real problem, because it seems as if the universe was just too simple, too uniform for anything interesting to happen. How could you produce you and me from such a universe? More complex things seem to appear when you have just the right Goldilocks conditions for their appearance.
1:35 *Video of space with white stars in black space with white text on top, ending with red, yellow, green and blue dots with white text..*	So, what were the perfect goldilocks conditions for creating just a bit more complexity in the early universe? Well, it turns out that those conditions were scattered all through the universe. The crucial things you needed were, first, lots of matter, secondly gravity, and third tiny differences in the distribution of that matter. And they were all there. There are some areas that are just slightly hotter and slightly denser than others. In those areas gravity was just slightly more powerful. So, what it did was it clumped those areas together.
2:20 *Montage of rotating videos of orbs spinning on a black screen followed by a video with spinning white dots with a white thermometer on the right side.*	As they clumped together, they got denser, so the power of gravity increased, and they began to clump even further together. Gravity increases so the whole thing is clumping a bit like a runaway train, and this gets faster and faster and faster and now what happens is at the center of each of those clouds of atoms, atoms begin to bang into each other really violently and they begin to heat up. Eventually the temperature reaches about 3,000°. The temperature in the cloud keeps rising until eventually it reaches 10 million degrees and something spectacular happens at that temperature. Protons start banging together so violently that they overcome the repulsion of their positive charges, and they fuse together and are now held together by the strong nuclear force.
3:08 *Montage of videos of a star being created, a red and*	As that happens there's a huge release of energy as some of their matter is turned into pure energy. This is very similar to what happens in an H-bomb. So, now at the center of the cloud we have a sort of furnace that's pushing back against the force of

yellow star on a black screen, pink and blue cloud of particles, and a video of the galaxy with a yellow star in the center with black and brown clouds surrounding it.	gravity and that stabilizes the whole thing. And now what's happened is a star has lit up. We've now crossed our second major threshold of complexity in this course. From about 200 million years after the big bang, the universe starts filling up with stars, billions and billions and billions of them, and the universe is now a much more interesting place. Stars increased the complexity of the universe in another way. They gave it new types of structure at many different scales from the level of the stars themselves to galaxies to superclusters. Let's begin with the stars.
4:06 *Clip of a red star cut in half with white text describing the makeup of a star.*	Stars themselves have a very clear structure. At the center you've got protons that are at an extremely high temperature, as we've seen, and they're fusing to form helium nuclei just around the center, around the core you have a sort of store of protons ready to be fused eventually when they sink down into the center. Now photons of energy and light from the center slowly work their way through the plasma, taking sometimes thousands of years, until eventually they reach the surface and then they flash out into space.
4:39 *Montage of clips of the universe and super clusters overlayed with text.*	But stars themselves are gathered together by gravity into much larger structure. We call these galaxies. Our Milky Way is our galaxy, it contains perhaps a 100red billion, some say 200 billion stars, it's absolutely huge. And there may be a 100red billion galaxies in the entire universe. But structures exist at even larger scales too. Gravity gathers galaxies together into what are called clusters. Our local group is a cluster like that, it contains about 30 galaxies including Andromeda and the Mag Melanic clouds. Both of which you can see with the naked eye. Gravity can even hold clusters together to form what are called superclusters. These scatter through the universe in huge webs and sort of chains. But beyond that, gravity is too weak to hold superclusters together and it's beyond the level of superclusters that you begin to see finally what Hubble saw. You be able to see whole superclusters moving apart and there at that scale you can see the expansion of the universe.