MARKUS KLUTE: Welcome back to 8.20, Special Relativity. In this section, we're going to build on-- we just learned about the relativistic Doppler effect and redshift. So we take on traveling through the galaxy from here, from Earth, towards the center of the galaxy. The situation is as follows.

We have Bob, who's stationary on our planet, Earth, and Alice, who makes use of a new spacecraft. This spacecraft is able to travel with a velocity of 0.99999998 times the speed of light. So that's really fast. It corresponds to a gamma factor of 15,000.

Now, the center of the galaxy is about 30,000 light years away. And in Bob's reference frame, this journey will take about 30,000 years, because velocity is about the speed of light. For Alice, however, the journey will only take two years. So it's quite doable.

The question, now, is what does Alice see? Literally, what is she going to see while she is looking out of the windows of the spacecraft? Is the picture similar to the one we see in some of the movies, where on the horizon, there's lots of stars, and once the spacecraft accelerates, you see those dots kind of blurry, coming towards us, right? Or is the situation somehow different?

The starlight has a wavelength of about 600 nanometers, and the cosmic microwave background a wavelength of 1.06 millimeters. So how is Alice going to observe those two light sources in her travel? So I invite you to work this out, but also think about the next question. How long does it take for Alice to accelerate from 0 to her velocity with an acceleration of 10 meters per second squared, which is 1g, which is very, very doable? OK. So I invite you to stop the video here and work out those numbers to get a feel and speculate a little bit about how this journey is actually going to look like.

So here's the solution. So the light's moving towards us, so it's going to be blueshifted. The velocity is given here. And with beta, we have seen that redshift or 1 plus redshift is equal to the emitted wavelength divided by the observed wavelength. And you find that that factor is 10,000. So we just have to divide our emitted wavelength by 10,000 and find that the observed starlight has a wavelength of 0.06 nanometers, which is X-ray.

So she's going to be flooded by X-rays of light coming from the stars. And similarly, the observed cosmic microwave background is going to be about 106 nanometers, which is ultraviolet light. The ultraviolet light-- there's a spectrum to this. So what she's going to see is X-rays, which she can actually not see with her eyes. But she will be able to see the ultraviolet, or some part of the spectrum, as kind of a blurry, fuzzy kind of background all over the place. So the situation is actually different from what we just saw in this picture.

A few more fun facts about the cosmic microwave background. It's actually at a temperature. So the spectrum of cosmic microwave background, those photons, they correspond to a spectrum emitted by [INAUDIBLE] which corresponds to a specific temperature of 2.7 kelvin. That is the temperature of our universe.

This temperature was about 3,000 kelvin about 380,000 years after the Big Bang, the age of the universe at the time. And so then at that time, this corresponds to visible light. But at that moment, the light stopped interacting-- well, stopped-- The likelihood for the light to interact with something out there in the universe became so low that it just stopped interacting. And then the frequency changed, because the universe was expanding. So what we are seeing today is kind of a relic of the universe at that time, at 380,000 years after the Big Bang.

And if you study the cosmic microwave background with some more precision, you see that there are actually fluctuations which can be analyzed. It turns out that you can correlate those fluctuations-- the fluctuations of the energy density 380,000 years after the Big Bang-- to this, the present of today's stars and galaxies and galaxy clusters. So those energy fluctuations, they served as seeds for the formation of galaxies and galaxy clusters. Quite interesting.

Today, we have about 400 of those photons-- microwave photons-- per square cubic centimeter. So there's quite a busy environment around here. So like, this little cube has about 400 of those photons. Now, this is a spectrum as well. It's not just a monochromatic background, but it's a spectrum which corresponds to these temperature [INAUDIBLE] All right.