**DJORGOVSKI:** Well, let's first talk about energy balance of planets. And you would know what's going to happen to this polar bear, right? Why is this happening?

Well, let's look at the simple physics of what goes on as planets are being illuminated by different stars. So a star has certain luminosity, illuminates a planet at a certain distance, say a. And the disk of the planet intercepts the lights.

Now, it should radiate out as much energy as it actually accepts from the Sun. Some of it will be reflected obviously. And that's called albedo.

And for Earth, that's about 1/3. 1/3 of all incident sunlight on Earth is being reflected away into space and does not participate in warming of the planet. That number varies-- depends on the season, clouds, snow, and what have you.

So the radiation is absorbed. And then Earth has some finite temperature and is going to emit more or less like a black body of that temperature. And the question is, what's the temperature?

So first, how do we compute this? Well, it's very easy. All right, you ask, what fraction of the sphere at the distance from the Earth to the Sun is covered by the Earth's disk? And so that's a simple ratio of the areas.

Now, the absorbed luminosity would be fraction that's not reflected. That's 1 minus alpha, the albedo, times the ratio of the surfaces. That's the same amount of energy that has to be then radiated away.

And assuming that Earth is a black body, there's our Stefan-Boltzmann formula, and it's right in here. So you can solve this simple equation. And you have the expression for the temperature of a planet at the distance a, albedo alpha, from its star with luminosity, L.

Notice that there is no radius involved. If you know a star's luminosity, if you know how a planet is and have a good guess of albedo, you can figure out its temperature. So this makes life a lot simpler.

Now let's see how it works for the Earth. So plug in the number. You have to trust me that albedo really is about 1/3.

And we know how far it is. It's 1 astronomical unit, or Stefan-Boltzmann constant stellar luminosity. And we come up with 253 Kelvin, give or take-- in other words, 20 degrees centigrade below freezing. Well-- and that's supposed to be the average temperature of planet Earth.

So clearly, this was not the case. The actual average temperature of the Earth is more like 287 Kelvin. So there's 33, 34 degrees difference.

So where does that come from? And the answer is, it's the so-called greenhouse effect. That we have a blanket, and the blanket's called the atmosphere.

So you can start thinking about this and say, why is an oven getting hot? If the oven was radiating perfectly to get in thermal equilibrium with the kitchen, kitchen and the oven will be the same temperature, which is somewhat warm kitchen and not much can be cooked. But there is isolation that tends to preclude the heat diffusing from the enclosed oven. And that's why ovens get hot.

Well, at the planetary scale, this is what happens to plants. There is atmosphere that retains some heat and then planets get a little warmer. So atmosphere is not perfectly transparent. And certainly, at some frequencies, it's not transparent at all.

And in the region that matters here, which is thermal infrared, it's so-called greenhouse gases. And chief among them is carbon dioxide. So these gases trap any thermal radiation that goes away from the Earth.

And so in a sense, it is as if you had an additional source of luminosity. In addition to what you get from the Sun, there is this extra piece that should have been erased away, but it hasn't. And so the planet will get hotter.

And if you're 100% efficient in retaining this heat, you have a runaway greenhouse effect. But in reality, at some temperature the cooling becomes efficient again and things stabilize. But at the temperature that's different, higher than the one that will happen if everything was perfect black body and absorption into nothing.

So here is a simple illustration of what happens. And we can go through the numbers. But to explain really what's going on, we have to look at the spectra. And what's shown here on the top is a normalized transmission of Earth's atmosphere as a function of labeling in infared. And the visible light, most of it goes through, right?

And so you can see that there are all these bands and lines for molecular absorption. And the biggest one is from carbon dioxide. And then there is water vapor and such.

Now, if you look at the black body curves below, which I stretched and shifted so the wavelength scale is pretty much the same, and so you look at the bottom one, 260 Kelvin, that would be roughly what the temperature of the Earth ought to be. Well, a big chunk of that is going to be missing both on the Wein side of water vapor and also Jean's side because of the carbon dioxide. And that is the part of the black body radiation that will be retained and reused to reheat some more.

But now, as the Earth heats up, what happens to the plank curve? It shifts towards the lower wavelengths. This is the Wein's Law. And that means that relatively smaller fraction of the flux will be absorbed, because the bulk of the thermal emitted radiation is now moving further away from the absorption band of carbon dioxide.

And so at some point then the cooling catches up. And this is where the greenhouse effect saturates. Now, if you keep pouring more and more greenhouse gases in the Earth's atmosphere, you're going to make this process a lot more efficient. And as you do so, the temperature keeps going up and up.

This is what happened to our sister planet Venus, where atmosphere is largely composed of greenhouse gases. So Venus's atmosphere is extremely efficient at retaining the heat and sort of preventing the outward diffusion of the heat. And so the consequence of that is that Venus could have molten lighter methyls on its surface. And it would not be a very pleasant place to go and visit.

There was only one landing on Venus by a Soviet probe, Venera- something. And it was one picture, and that was it. The best knowledge we have of Venus is from flyby probes and radar images.

So what happens on Venus is exactly the same thing that happens here, only to a different degree. But if we're to say, replace all of oxygen and nitrogen with carbon dioxide, we will be almost like Venus. So this is what causes global warming.

And here are some measurements. The one on the top left is the measurement of the concentration of carbon dioxide from top of Mount Ola middle of the Pacific Ocean, spanning about 50-odd years. And the zigzag line is due to the annual variation. The concentration goes up and down depending on the seasons. But it goes up and up and up.

And the net result of that is that the average temperature of the planet Earth has been going up. And these are actual measurements. Now, they're fluctuations. This is not a perfect process. The weather fluctuates and so on. But the overall trend is pretty clear.

And this is now being confirmed again and again and again from the ground, from space, and so on. Here is just one of the maps that can be obtained from space-based data. This is the difference between average temperature over a 10-year period. So you can average over all the weather and seasonal effects and so on versus another 10-- being of 30 years, some time earlier.

And the red means positive. Blue means negative. And aside from a little old area near the Antarctica, all the rest of the world has warmed up on average. And most of the warming happens in the northern hemisphere.

Part of the reason for this is that you start melting arctic ice. Ice has a great reflection, a good albedo. So as you remove ice, you're making it more efficient for the Earth to absorb the heat.

So just like you can have runaway global warming, you can have runaway global cooling. And that's happened in the past too. Because say, for whatever reasons, the Earth's orbit gets colder, you get more area covered by ice and snow, that means albedo will go up.

That means less sun will be accepted-- will be absorbed. And so it'll get even colder. And so you can have so-called Snowball Earth. This presumably happened in the past as well.

Well, there is a natural cycle to this, but we have added to it by releasing much more carbon dioxide in the atmosphere than occurs there naturally. Earth's atmosphere and climate are a very complex system. And so it's a delicate equilibrium.

And so endless amounts of simulations were done. And there are three consequences of this process. First, as the name said, global warming temperature increases. If the arctic ice melts, that doesn't matter, because it's floating on the water, so the level of the water will stay the same.

But if ice that's on ground, like in Antarctica or Greenland, melts, that water then goes in the ocean and will increase the average level. And so here is the artist's conception of what Manhattan might look like if the level of the ocean goes up by a few meters. The second thing that again everybody agrees among the climate scientists is that the climate zones expand from the equator towards the poll.

So the tropical belt is a little wider. The subtropical belt, the desert moves further north and so on. And what that will do, it will disrupt agriculture everywhere and make California water crisis look like child's play. So both of these are obvious direct things-- what happens when you start increasing the temperature.

And millions and millions of people will die because of this, never mind polar bears. They are cute. But many, many people will die because of this. And something that's not widely appreciated but I think maybe even deadlier is that it's not just the mean that goes up but the variance as well.

The variations in the temperature and climate also increase in the amplitude. So now we are in a regime where what used to be called 100-year storms happen every 10 years. And what used to be 10-year storms happen every year.

And you may have gotten the impression, there is more and more extreme weather events. And you're right. There is. You can't attribute any one of them to the overall process. But statistically, this is what you expect.

So in many natural and also technological systems, if you take them out of dynamic equilibrium, they start to oscillate. And that can go nonlinear and disrupt the whole thing. I think we might be at the beginning of that process with Earth's climate.

So in other words, we screwed up your planet for you and your grandchildren. Sorry about that. Hope you don't mind.

So this is physics. This is science. This is not a matter of opinion. Fortunately, there is an alternative theory. And he actually did say that.

So your choice. Do you believe physics or what this authority has to say? OK, well, back to the universe.

So since for a given star, given luminosity, the temperature will depend on how far it is from the star. Albedo doesn't come into the equation very strongly. That defines a belt called the habitability zone.

On the cold end, where water freezes, it's called frost line. On the hot end, where water boils, it's called steam line. And so if you require liquid water on the surface of your world-- say, it's a good thing to have life. It's hard to maintain life in boiling water or in ice. That defines a belt within which you could have life. So if planets in that regime would, in principle, be able to develop life.

In our solar system Earth is the only one that sits in this belt. Mars, almost. And in the past, Mars had the atmosphere, which helped nudged it temperature up. This is why it had the ocean.

But right now this is where we are. And so it will depend on the star. And as we talk about extrasolar planets, people look for earth-like planets that are within the habitability zone of their parents are.