DJORGOVSKI: We know that there's plenty of right building blocks out there in interstellar clouds. And there's water-- there are other solvents like methane. There are many different organic molecules including very complex ones, all the way up to the amino acids. And so that material is then used to make planets in protoplanetary disks. So there's is plenty of right chemistry.

Now, what happens is once you have a planet with liquid water, which is called a primordial soup, and was a famous experiment by a guy named Miller, where they combined the type of compounds they expect to see in proper Earth's oceans and put some electric sparks to make the electric discharge and everything else. And lo and behold, out of a relatively simple mix of compounds, they started creating very complex organic molecules.

So if you can do this in a lab-- certainly a planet-sized lab-- waiting for a couple billion years, you can do it even better. So it's very natural to expect that you will be forming at least basic material for life if you're in habitable zone. There is liquid water. Everything else is kind of provided.

So there is no whole field of astrobiology, which is dedicated to learn about life in the universe and where it's possible, how is it possible, and so on. And they concern themselves with extreme environments on planet Earth that can be used as proxy for some of the harder environments out there. And so for example, there's-- deep in the bottom of the ocean-- there are these vents called smokers, which are of volcanic origin. There's a lot of sulfur compounds. There is no light down there, it's so deep. And there are bacteria.

Now those bacteria actually use sulfur instead of oxygen for their metabolism because it's not quite as efficient as oxidizing agent, but it can be still used. So this is a very different, obviously related to the rest of life on our planet, but functions in a very different way. Likewise, bacteria have been found in hot, volcanic lakes. They're just saturated with all kinds of minerals, including arsenic, and they thrive.

So the life in planet Earth can adopt to some extremely harsh environments. There are even bacteria found inside rocks that have been dormant for a long time.

And the bottom set the pictures is actual microphotographs of microorganisms found in Lake Vostok, which is a lake in Antarctica, and there's a few kilometers of ice. So that lake was enclosed by the Antarctic ice many millions of years ago. And, in some sense, it could be a model of what life on Europa, or the Enceladus could be.

So, sure enough, they found that unlike organisms, they think all fish died a long time ago. But there are these, and they don't have any light down there. So presumably they're getting their energy from somewhere else and they're not yet classified. So we know that's possible, too.

So what about life in the solar system? Mars is everybody's favorite, and this is artist's impression based on the actual topographic map of Mars. That once upon a time, Mars had an ocean. There is now plenty of evidence for that from surface features, et cetera. And it's going to look like this. This was like 4 billion years ago. And, in that case, Mars probably did develop some kind of life. So one of the major goals of Mars missions is to actually look for signatures of that chemically or even fossilized bacteria or things like that.

But for my money, the best place to go would be moons of Jupiter and Saturn. Because some of them have oceans under the ice. Europa and Enceladus for sure, probably some others. Others have enough geotectonic activity, like Io has volcanoes with sulfur, plenty of energy. And Jupiter has radiation belts, and that radiation actually can serve positive purpose of mutating molecules of protocellular life. And the hardiest ones survive.

So, I would say that by far, the most likely place to discover some sort of life in the solar system would be one of those large moons of Jupiter or Saturn. Maybe more of them. We'll see.

But what about beyond our solar system? Well that, of course, has been the

territory of science fiction forever, and people have been trying to find extraterrestrial civilizations. SETI is an acronym commonly used. And it's based on what I find highly questionable assumption that the vast civilizations will choose to communicate by the middle 20th century planet Earth acknowledged. Could just as well use smoke signals.

So what would they use? Well we don't have any idea because they're more advanced, right? But nevertheless, if they did indulge in such an eccentric thing, you could look for modulated signals, and you have to search so-called cosmic haystack space of area in the sky, flux in frequency and modulation. And very successful, in terms of actually amount of data processed, nobody's found anything.

This project, SETI@home, the crowd source computing, they just piggyback on radio signals that are collected or received on VLA and elsewhere for completely different purposes. And they show it through a program that will look for a particular modulated signals. They recover all of solar system probes, so they know it kind of works. But that's the artifacts that we created.

Another possibility is search for extraterrestrial artifacts. Have advanced civilizations visited us previously and left something for us? And it could be a black monolith, it could be something buried in the moon. Could be something you find in the Earth's orbit. And so just to return the favor, we sent them a few postcards on interstellar probes Pioneers and Voyagers that have left or are about to leave the solar system. Carl Sagan designed this, and somebody called this pornography in space.

So how many do you expect to see? Frank Drake was a pioneer of this business, started in the early '60s. Came up with following simple equation called the Drake Equation, which is a product of a whole bunch of probabilities.

How many civilizations are there in our galaxy that we can communicate with by radio? Well, first, how many stars does it make? How many of them have planets? How many have suitable planets? How many develop life? How many develop civilization? How many survive long enough to actually communicate with us?

And so some of these numbers are much better known than others at this point. Anything to do with astrophysics, like star formation, right, the numbers of planets, and even how many might be in habitable zones, we can now have pretty good estimates of those.

How many actually develop life? Nobody knows. What fraction develop intelligent life? Even less people know. In fact, you could ask whether there's intelligent life on planet Earth, but let's not f And then finally, how many of these advanced civilizations would bother to actually do this kind of Morse code type of communication.

Well, so as usual, XKCD has one of the best comments on this. Which is how many people claim to have seen UFOs. And I'll let you read this on your own in PDF of the slides online.

So one last thing is this thing called the Fermi Paradox. Which was due to Enrico Fermi, in some lunch conversation he came up this question, where are they? And the point is that, well, even if you travel at the measly speed of 1% of the speed of light, which is not too crazy to imagine for that civilization, it'll still take you 10 million years or so to cross the entire galaxy. And you can do this robotically, or actually aliens in space star ships and so on.

And so, if there is a star faring civilization, they could populate or explore the galaxy in 10, 20 billion years. And the galaxy's 12 billion years old. So we think that's plenty of time. So if there's a single one of them, they should be around here. And so the question is, why don't we see them?

Well, some people think that we do. There's been actual books about this, over 100 different proposed solutions to the Fermi Paradox. Why we don't see obvious manifestations of extraterrestrial civilizations? Because they had plenty of time to make themselves known.