**Nova – Origins Part 3 – Where are the Aliens?**

**NEIL deGRASSE TYSON** (Astrophysicist)**:** A hellish, fiery wasteland, a molten planet hostile to life, yet somehow, amazingly, this is where we got our start. How? How did the universe, our planet, how did we ourselves come to be? How did the first sparks of life take hold here? Are we alone in the cosmos? Where did all the stars and galaxies come from? These questions are as ancient as human curiosity itself. And on *Origins*, a four-part NOVA mini-series, we'll hunt for the answers. This search takes unexpected twists and turns. Imagine meteors delivering Earth's oceans from outer space. Descend into a toxic underworld where bizarre creatures hold clues to how life got its start. And picture the view when the newborn moon, 200,000 miles closer to Earth than today, loomed large in the night sky. This cosmic quest takes us back in time to within moments of the Big Bang itself and retraces the events that created us, this place we call home and perhaps life elsewhere in the cosmos. Coming up tonight, *Where Are the Aliens?*

**GEOFF MARCY** (University of California, Berkeley)**:** I feel like I'm six years old when I say it. I, I feel almost embarrassed. I just want to know, "Are they out there?"

**NEIL deGRASSE TYSON:** And why do they always look so much like us?

**JACK COHEN** (University of Warwick, UK)**:** When we look at these aliens, and they've got faces with two eyes and a nose and a mouth, they can't be aliens. They must have developed on Earth. They must share that same ancestor, or they wouldn't have faces like that.

**NEIL deGRASSE TYSON:** E.T. may not be like us, but new discoveries are fueling optimism that alien life really is out there.

**GEOFF MARCY:** We're finding new planets like crazy.

**FRANK DRAKE** (SETI Institute)**:** Places where life can exist are far more extensive than we used to imagine.

**NEIL deGRASSE TYSON:** Consider this: just because a planet can support life, does that mean it will? Are we likely to encounter anything as, well, smart as you and me?

**ANDY KNOLL** (Harvard University)**:** Intelligent life, like ourselves, it's just a snap in the full history of the planet.

**NEIL deGRASSE TYSON:** Have the aliens advanced this far? And if so, are any of them willing to communicate with us? NOVA is on the hunt for alien life on this episode of *Origins*, right now.

Major funding for NOVA is provided by the Park Foundation, dedicated to education and quality television.

Science: it's given us the framework to help make wireless communications clear. Sprint is proud to support NOVA.

We see one small step on Mars. Microsoft is proud to sponsor NOVA for celebrating the potential in us all.

Major funding for *Origins* is provided by the National Science Foundation, America's investment in the future. Additional funding is provided by the NASA Office of Space Science, the Alfred P. Sloan Foundation to Enhance Public Understanding of Science and Technology, and the George D. Smith Fund.

Major funding for NOVA is also provided by the Corporation for Public Broadcasting and by PBS viewers like you. Thank you.

**NEIL deGRASSE TYSON:** Anyone who visits New York City will see all manner of different life forms. And you don't have to look far to realize that our planet is teeming with a diverse population of living creatures. And for centuries we've been asking ourselves, "How unusual is all this? What about the rest of the Universe? Is our little planet Earth the only place where the action is? Are we special?"

**AMY MANNING**(street interview)**:** I find it hard to believe the fact that we're the only people in this universe.

**OSCAR RAMIREZ**(street interview)**:** We're definitely not alone.

**GLEN TAYLOR**(street interview)**:** This is not just one universe. You know what I'm saying?

**ROBERT BURCK, AKA THE NAKED COWBOY**(street interview)**:** There's, like, a hundred thousand million galaxy, or galaxies, in the universe.

**GLEN TAYLOR:** There's trillions and billions of universes.

**ROBERT BURCK:** Whatever. The point is, it's inconceivable how big things are. To think that we're alone here is ridiculous.

**NEIL deGRASSE TYSON:** Many people are ready, even eager, to believe that we are not at all alone. And that's the view prevalent in lots of popular films and TV shows.

**WILLIAM SHATNER**(Clip from *Star Trek*)**:** These are the voyages of the Starship Enterprise.

**NEIL deGRASSE TYSON:** It's an appealing fantasy. *Star Trek*, *Star Wars*,*Men in Black*, all portray a universe filled with a multitude of intelligent life forms.

**TOMMY LEE JONES**(Clip from *Men in Black*)**:** Show us the merchandise or you're going to lose another head, dude.

**NEIL deGRASSE TYSON:** Sometimes they're friendly and sometimes they're not. Screenwriters have come up with some pretty interesting behaviors for their extraterrestrials, but they often ignore some basic principles of biology.

For example, in the film *Alien*, a human being plays host to a parasitic alien until it's ready to be born. This has long bothered biologist Jack Cohen.

**JACK COHEN:** *Alien*is not concerned with the biology. You can't have a creature living in your chest which is bigger than your heart, and you don't know it's there, and your immune system isn't turned on, particularly if it's never seen a human being before. It doesn't work biologically. But it works as a film, because you see the thing coming out of the chest...aaagh...and it's exactly what they want. It's a horror film.

**SOLDIER**(Clip from *Starship Troopers*)**:**Incoming!

**NEIL deGRASSE TYSON:** Another classic horror image of extraterrestrials shows them as giant insects—the alien of choice for the film *Starship Troopers*—but according to the laws of physics, this kind of anatomy is impossible.

**JACK COHEN:** It's like bringing a mouse up to be the size of an elephant. Its little thin legs wouldn't take the weight, and they would break. You have to redesign. It's a lot easier to have a terrifying film with giant ants.

**NEIL deGRASSE TYSON:** As unscientific as the oversized insects of *Starship Troopers* are, at least they don't look like people. By far, most films, even the ones with huge special effects budgets, depict aliens that actually look like they evolved on Earth because they have faces that resemble ours.

Nearly all the vertebrates we see around us, humans included, have faces with two eyes, two nostrils, and a mouth below. This configuration came from a common ancestor who lived hundreds of millions of years ago.

**JACK COHEN:** Now, when we look at these aliens, and they've got faces with two eyes and a nose and a mouth, they can't be aliens. They must have developed on Earth. They must share that same ancestor, or they wouldn't have faces like that. We expect a living thing, a dog or a cat or even a fish, to have a face. Therefore, when we invent something for a film, we give it a face. And that really enables the people who are watching to get moved by it. Real aliens can't be like that.

**NEIL deGRASSE TYSON:** Real aliens? What are we talking about? UFO sightings and abductions that show up in tabloids?

**SAMANTHA THOMPSON**(street interview)**:** I think they have traveled to this planet.

**STEVEN BUSHMAN**(street interview)**:**They might have been here years ago, but they became extinct just like the dinosaur did.

**CHARLES LOUIS MELTON**(street interview)**:** We've been visited. Those lights in the sky aren't all weather balloons.

**NEIL deGRASSE TYSON:** Hmmm. There are some people who believe that aliens are already among us, but there's no credible evidence. There's nothing in any of these stories that can't be explained in some other, more rational way. And of course, some people are just plumb crazy!

But is it crazy to believe that somewhere, beyond our planet, life has taken root? Many scientists would say it's not only possible but likely.

One of the believers is Frank Drake.

**FRANK DRAKE:** I first believed there was life beyond Earth when I was eight years old, not for any good reason, only because my father told me there were other planets something like the Earth out there. And to my young mind that meant places just like where I lived, with houses and streets and, in fact, creatures that look just like me, which was certainly wrong. But I believed!

**NEIL deGRASSE TYSON:** Drake's childhood dreams led him to a career in radio astronomy, and he soon began wondering whether somewhere among the stars, there might exist aliens who, like us, had mastered radio.

Ever since humans learned how to broadcast radio waves, we've been leaking them out into the cosmos. Everything from Duke Ellington to *I Love Lucy* to the speeches of world leaders is, thanks to our ingenuity, now traveling across space at the speed of light.

Drake reasoned that if aliens were transmitting radio signals of their own, we might be able to detect them. And so he created the first experiment for SETI, the Search for Extraterrestrial Intelligence.

For decades, SETI astronomers have been scanning the stars of the Milky Way Galaxy, searching for signs of advanced alien civilizations. Their goal is the ultimate prize in the life-finding game: someone out there we can talk to.

**SETH SHOSTAK** (SETI Institute)**:** Nothing to do but sit here and wait for them to call. And on cue, they've called!

**NEIL deGRASSE TYSON:** SETI faces enormous challenges, not least of which is the sheer size of our galaxy. The Milky Way has hundreds of billions of stars, swirling in a giant spiral about a hundred thousand light years wide, that's 600 quadrillion miles. So what are the chances of finding intelligent aliens in all that real estate?

Early in his quest, Frank Drake came up with an equation to guide him.

**FRANK DRAKE:** Actually, I first invented the equation as the agenda for a meeting. It seemed pretty obvious. It was a meeting about life in space, and I asked the question, "What do we need to know about?" And I realized if you multiply them all together, you get the number N.

**NEIL deGRASSE TYSON:** The now-famous Drake Equation lists the different factors we'd need to know to predict "N," the number of intelligent, detectable civilizations in our own Milky Way galaxy. It includes factors like, "How many stars have planets?" And, "How often will life become intelligent?" And how long a technologically advanced civilization might last.

**FRANK DRAKE:** And if you put in scientists' judgment the most plausible values for the factors in this equation, N equals 10,000 detectable civilizations in our galaxy—10,000 intelligent civilizations, just in the Milky Way alone!

**NEIL deGRASSE TYSON:** That's Frank Drake's best bet, but it's far from conclusive. If you plug different values into the equation, then it's easy to come up with other results, anything from a billion civilizations all the way down to one: ours.

For a long time, the values for most of these terms were unknown. The Drake Equation was something of a list of mysteries, leaving the equation unsolvable. But in the last few years, our knowledge of cosmic origins has been growing exponentially, and we're on our way to solving at least some of these mysteries.

Take just one term in the Drake Equation: the percentage of stars—other suns—that have planets orbiting them. If alien life is anything like us, it needs some solid ground to call home, and so we want to know how many planets are out there.

Depending on who you talk to, our sun's got eight, maybe nine planets circling around, including Earth.

Until recently, we haven't been able to see any planets beyond our own solar system, none at all. The problem is planets in deep space are rendered practically invisible by the blinding light of their suns. That's the challenge for the handful of scientists trying to track them down.

The team of Paul Butler and Geoff Marcy started their quest in the 1980s with little more than their own enthusiasm.

**GEOFF MARCY:** We started off with virtually no money at all. The first proposal I wrote for a grant to fund our planet search was for $930 for the whole year.

**PAUL BUTLER** (Carnegie Institution of Washington)**:** When Geoff and I started the planet search, back in the fall of 1986, at San Francisco State University, we were...to say we were "unknown" is to overstate it. We were sub-unknown.

**NEIL deGRASSE TYSON:** The young astronomers were banking on an experimental technique they believed could scope out planets by focusing on the stars they orbit.

**GEOFF MARCY:** As a planet orbits a star, the planet pulls gravitationally on the star, making the star wobble. You can tell a star has a planet, or more than one planet, just by the motion of the star, which ought to be stationary but wobbles due to the pull on it by the planet.

**NEIL deGRASSE TYSON:** The star's wobble, created by the gravity of orbiting planets, is so subtle, Marcy and Butler can't see it directly, so they use a special technique.

**GEOFF MARCY:** It's hard to detect this motion directly, so we thought we would use the Doppler Effect. As a star moves toward you, the light waves get compacted, and that means they get shifted toward bluer colors. And then, as the star wobbles away from you, the wavelengths of light get stretched out, and this is interpreted by the eyes as redder.

**NEIL deGRASSE TYSON:** Even using the Doppler Effect, the only planets we can infer would be ones with tremendous mass.

Marcy and Butler were confident they had the best method for hunting down big planets and hoped they'd be the first to succeed, when the unthinkable happened. A team of Swiss astronomers beat them to the punch. The first planet outside our solar system had been found, but by someone else.

Most astronomers were skeptical. Although the planet was massive like Jupiter, the Swiss discoverers claimed it orbited its star, 51 Pegasi, in only four days. This seemed impossible. Earth takes 365 days to orbit the sun. And Jupiter takes 12 years.

Marcy and Butler felt certain there must be some mistake.

**PAUL BUTLER:** Almost every year for the last 100 years somebody has claimed to have found the first extrasolar planet, and the one thing all those claims had in common was they were wrong.

**GEOFF MARCY:** And luckily, Paul Butler and I had telescope time the very next week. And we thought, "Well, we'll just go up and take data on this star, 51 Pegasi, and show that it probably doesn't really have a planet at all."

**PAUL BUTLER:** And when we got back and we analyzed all the data, we were stunned. We were stunned because their claim was right. There really was a Jupiter-like planet in a four-day orbit. We were stunned because this was the first legitimate, real planet ever discovered, and that furthermore that these planets could be much stranger, much more bizarre, than any theories that had ever been conjured before.

**NEIL deGRASSE TYSON:** Marcy and Butler had spent years looking for massive planets like Jupiter, far out from their stars with long, slow orbits. Now that they realized that big planets could make a complete orbit in a matter of days, they began to wonder: had they missed something?

The evidence for new planets might be buried in their old data, but to find it, they'd need hundreds of hours of computer time.

**GEOFF MARCY:** And we only had two little computers. So we ran around madly trying to borrow, and in some cases subverting, our colleagues and stealing their computers so that we could analyze all of this backlog of data.

**NEIL deGRASSE TYSON:** They worked furiously around the clock for weeks, re-crunching eight years of data.

**PAUL BUTLER:** I was literally in my office 24 hours a day for about six months, reducing data.

**GEOFF MARCY:** Some nights, you know, hardly sleeping at all, and just making sure the computers were all running. God forbid the computers should sit idle when we could've been finding planets with them.

**NEIL deGRASSE TYSON:** But the marathon was worth it.

**GEOFF MARCY:** Within a month and a half of the discovery of the planet around 51 Peg, we found two planets sitting in our own data, right there on our computers: the planet around 47 Ursae Majoris—spectacular—and then the other planet around 70 Virginis.

**NEIL deGRASSE TYSON:** Planets were finally being found, but they were huge gas monsters, circling close to their stars, often in highly elliptical orbits. Scorching hot or with unstable climates, they were friendly to neither life nor other Earthlike planets.

**GEOFF MARCY:** Any poor Earth that got in the way would be slammed to death. I mean, a little Earth anywhere nearby a Jupiter would get slingshot out of the system, or maybe the Jupiter would hit that Earth and probably spell doom for any life on any terrestrial planets in those systems. And it really begs the question, "Is our solar system with its nice neat, phonograph groove-like orbits, some kind of wacky weirdo in the universe or are there others like ours?"

**NEIL deGRASSE TYSON:** In addition to its neat, round orbits, our solar system provides particular shelter for Earth, thanks to the presence and position of Jupiter. Jupiter's enormous gravity throws asteroids and comets off course, slingshotting them out of the solar system. Without this protection, these cosmic missiles would frequently smash into Earth and destroy life as we know it.

So, if Marcy and Butler want to find Earthlike planets, first they need to find Jupiters more like our own.

**GEOFF MARCY:** The Holy Grail, for us, is to find a sunlike star that has a Jupiter as far from it as our own Jupiter is from the sun. That Jupiter would protect any Earths that were in there. And of course the real super Holy Grail is to find a system that has, not only such a Jupiter, but also the Earth itself.

**NEIL deGRASSE TYSON:** After almost twenty years of searching, things are looking up.

**GEOFF MARCY:** We're finding new planets like crazy, all the time. Every week or two we find another new one, on average.

**PAUL BUTLER:** Lookie at that one. That's a beauty. Let's see how that corrects up. That's a planet.

We have about 700 stars on our program, and I'd say the thing that's really most amazing to us is how many of them appeared, like they have planetary signals imbedded in them.

**NEIL deGRASSE TYSON:** The team is tracking several stars that appear to have Jupiters right where they want them, far out from their host stars and in perfect position to shield life-friendly planets like Earth.

**GEOFF MARCY:** We're always following some exciting Jupiters. We don't tell anybody about them, but at any given time we have a half a dozen Jupiters that look like our own Jupiter.

**NEIL deGRASSE TYSON:** If their hunches are confirmed, then not only are there other solar systems that look like ours, there may be lots of them.

**GEOFF MARCY:** Ninety percent of the stars show no close-in Jupiters. Those are stars that could easily have an Earth in an Earth-like orbit. I think of the 700 stars we're following, I would bet at least half of them have rocky Earth-sized planets going around them.

**NEIL deGRASSE TYSON:** Just a decade ago astronomers could not be sure if there were any planets beyond our solar system. Today, we have a much better picture of our galaxy. And Geoff Marcy estimates that of the several hundred billion stars in the Milky Way, about five percent have small, rocky planets that might harbor life. If he's right, that could mean 10 billion Earthlike planets.

But before you start packing your bags to visit an extraterrestrial neighbor, consider this: just because a planet can support life, does that mean it will?

It's a crucial factor in the Drake Equation: the percentage of planets where life does arise. On a planet where no life exists, like our own early Earth, how does life suddenly come into being? Is the spark of life rare or common?

**ANDY KNOLL:** Twenty-five years ago, most people, when they thought about the origin of life, thought in terms of inherently improbable reactions that would actually occur because of the fullness of time.

**NEIL deGRASSE TYSON:** Andy Knoll is a paleontologist who studies fossils for clues to how early life evolved on Earth.

Before about 600 million years ago, all life on earth was tiny, single-celled creatures, so small that Knoll and his colleagues do most of their work with microscopes or in chemistry labs. The big surprise is that no matter where they look for signs of ancient life, they find it.

**ANDY KNOLL:** Our planet is about four and a half billion years old. We have evidence from the oldest rocks that we know of, at least the oldest sedimentary rocks we know of, that by about 3.8 billion years ago, life had already gained a foothold on our planet.

**NEIL deGRASSE TYSON:** Scientists haven't figured out exactly how that first spark of life happened, but since it seems to have sparked early on, then maybe it isn't so hard.

**ANDY KNOLL:** Most people think that whether or not we understand what the chemistry that leads to life is, that it's a chemistry that under the right conditions will pretty much go and...and is a fairly probable chemistry, and that therefore, life doesn't take billions of years to unfold on a planet. It might unfold in thousands of years or a million years. A lot of people think if you can't do it in a million years, you probably can't do it at all.

**NEIL deGRASSE TYSON:** So, what is required to get it all started? Here on Earth, the chemistry of life relies heavily on the element carbon. Carbon is one of the most versatile elements, each carbon atom can hook up with one, two, or three or four other atoms. It can even link up with other carbon atoms creating long chains or rings. Throw in a few other elements, and you've got amino acids, the ingredients of proteins, the building blocks of life as we know it.

**JACK COHEN:** Carbon is a very useful element to sit at the center of life's chemistry. There's a lot of it in the universe. It's made very easily in stars. It makes very complicated, meshed-together compounds which have the possibility of changing each other's properties. You can have a really complicated, complex setup with carbon. I'd expect that very nearly all life forms we come across that are matter-based are going to be carbon-based.

**NEIL deGRASSE TYSON:** If carbon helps make life happen, then there might be a lot of life out there. Carbon is one of the most common elements in the universe. So if it's got carbon, what else does life need? Lots of oxygen in the air? Seventy-two degrees? We tend to think life belongs in a place that's, well, comfortable for us. But is that really true?

In the last few years, we've been finding life practically everywhere on Earth, and not just the obvious spots. Microbes are thriving under rocks in the driest, hottest deserts. Life's doing just fine in the dark bottom of the oceans, warmed by deep sea vents. And now, life is turning up in some of the coldest, bleakest conditions imaginable, including the ice sheets of Antarctica and Greenland.

So now that we've found life not just surviving, but thriving just about everywhere on Earth, suddenly it's looking more likely that life might thrive in lots of places beyond Earth, even if we would find them a bit uncomfortable.

If life is common, then we should be able to find signs of it beyond our own little planet. Unfortunately, the evidence has been elusive. It's seems as if one crucial ingredient has been missing.

**CHRIS McKAY** (NASA Ames Research Center)**:** The most important requirement for life is liquid water, and that's the defining requirement for life in terms of our solar system. There's plenty of energy, there's plenty of carbon, there's plenty of other elements on all the planets in our solar system. What's rare, and which, as far as we know, only occurs now on Earth, is liquid water.

**NEIL deGRASSE TYSON:** Liquid water is crucial because it's an ideal solvent. Molecules can easily move around in it and react with one another, allowing the complex chemistry of life to do its thing.

For years, it seemed that Earth, with its oceans of liquid water, was an oddball and perhaps the only, place in the solar system where life had ever thrived. Then we started to look more closely at our neighbors.

In recent years, NASA spacecraft have sent back images of Mars with stunning detail, and there are clear signs of a watery past.

**CHRIS McKAY:** From orbit around Mars we can see ancient rivers that are now dry, canyons which look like they had lakes in the middle of them, even what looks like an ancient ocean floor in the northern hemisphere. We see unmistakable signs that Mars was a wet place.

**NEIL deGRASSE TYSON:** And now there's even more information from NASA's twin rovers that roamed the Red Planet, taking pictures and probing the rocks for their chemical makeup. The photos reveal clear sedimentary layers in the Martian rocks, and chemical analysis shows they must have been laid down in the presence of water.

Mars might be too cold and dry to harbor life today, but if water was once there, then perhaps life was, too. And now, there's hope that life may thrive even farther out in the solar system.

**CHRIS McKAY:** I think Mars is the number one candidate for the search for life beyond the Earth, especially if we're going to find it soon. But we do have a backup plan, and in this case the back up plan is Europa, one of the moons of Jupiter.

A little smaller than our moon, Europa is covered with ice, but there are cracks in its surface, perhaps signs of ice sheets floating on a deep ocean of liquid water. What might be melting the ice is internal friction created by the gravity of Jupiter and its other moons. Europa's ocean is suddenly considered a potential home for life.

**FRANK DRAKE:** The places where life can live and exist are far more extensive than we used to imagine. We used to think a life-bearing planet would be just like the Earth, and a little closer to the sun it would be too hot, a little farther away it would be too cold. And now we realize, "Oh, gosh, there's a place which has an ocean with three times as much water as the ocean of Earth, and the water is warm." And that's way out in the solar system where we used to think the temperatures were ridiculously low; there could never be life there. So the likelihood of life existing on planets in space has just gone up enormously.

**NEIL deGRASSE TYSON:** So, even though we've yet to find life elsewhere in the solar system or beyond, we're getting more optimistic that life may be widespread.

But if life is common in the galaxy, what kind of life would it be? Is it merely the kind of life we had here for about three billion years, microorganisms happily brewing away with nothing bigger or more interesting than bacteria? Or is it the complex plant and animal life we find in our oceans, of all shapes and sizes? Or could it be what SETI is banking on: intelligent life that builds cities, computers and radio transmitters?

We now know that the way we got to this, from something like this, was through evolution. Does that mean evolution would work the same way wherever life appears? Frank Drake thinks so.

**FRANK DRAKE:** Once you have life, evolution goes to work. Life is very opportunistic. It expands. It finds ways to survive. It finds ways to cope with changing environments. And in the process it becomes more intelligent, and in the long run you end up with something like us, exploiting technology to live in even more inhospitable habitats.

**NEIL deGRASSE TYSON:** Drake's optimism shows up in the estimates he's plugged into his own equation. His guess is that wherever life arises, it will evolve into intelligent life 10 percent of the time. Not quite inevitable, but a fairly common outcome.

It's hard to know how likely or common intelligence is, when it's shown up so recently in Earth's history.

**ANDY KNOLL:** So the short history goes like this: life early, but the familiar life that we think of, plants and animals, that is really a relatively recent development on this planet. And intelligent life, people like ourselves, technologically competent humans, that's just a snap in the full history of the planet.

**NEIL deGRASSE TYSON:** After about three billion years with only microscopic life, Earth finally became home to true plants and animals. And after another five or six hundred million years, we came along.

One of the major mechanisms for all these changes has been DNA, the long chain of molecules that carries the blue-print for every living thing. Every time a cell divides, its DNA makes a copy of itself, and in that copy, there are always some mistakes. Sometimes those mistakes result in an animal or plant that's more successful than its parents. It's these kinds of mistakes that have allowed the tree of life to branch out in so many directions, creating the great diversity we see on our planet.

So, if there's life on other planets does it have to have DNA?

**JACK COHEN:** Would aliens have DNA? Well, I would be surprised to find aliens with DNA as their heredity, because DNA is a useful molecule, it can replicate, it can do the mirror image bit, it can do the...It's a very useful trick, but other chemicals can do that, and I'd be surprised if aliens latched onto the same one that we did.

**NEIL deGRASSE TYSON:** To get from microbes to complex animals and intelligent life, you might not need DNA, but there's one ingredient that could be absolutely crucial for the evolution of intelligence, and it may be the rarest of all: time.

Some scientists say that the key to our evolution was Earth's long and relatively peaceful history.

Among them is paleontologist Peter Ward. In this big galaxy of ours—hundreds of billions of stars—surely earth is repeated many places, many times. Why not?

**PETER WARD** (University of Washington)**:** Well, I think the question is, "How much time do we have?" For instance, we got to intelligent organisms on this planet after 500 million years of animal life. So you've got a long period of time. Now that doesn't say you couldn't get it sooner at other places, but you still need finite periods of time. And to me that is the major argument against there being intelligent civilizations. You can't go from a bacterium to an intelligence in a million years, maybe not even ten million years, probably not even in a hundred million years. How many other planets are going to have such long periods of time? Not many, I think.

**NEIL deGRASSE TYSON:** In the half a billion years when intelligence was evolving, Earth's plant and animal life might have been pushed back to square one, single-celled organisms, with one catastrophic event. At least a couple of times, we came pretty close.

This crater, about a mile across, was made by a meteor that plunged to Earth nearly 50,000 years ago. As violent as that event must have been, it was nothing compared with earlier catastrophes. Just ask the dinosaurs.

The dinosaurs ruled Earth for about a hundred and fifty million years. They had the size. They had the power. It seemed that nothing could stop them. Then, sixty-five million years ago, an asteroid about six miles across headed toward Earth. In the aftermath of a collision of epic proportions and widespread volcanic eruptions, as many as two thirds of all living species were wiped out. The big guys didn't stand a chance.

Among the survivors were little mammals, and with the dinosaurs conveniently out of the picture, they thrived. Over the eons, their descendents evolved into lots of different animals, including primates, including us. That's how we got our start.

But what if you turned back the clock? What if that asteroid had taken a slightly different course and missed Earth completely? Little mammals may never have gotten their chance because the dinosaurs could still be in charge today. And instead of me, one of them would be hosting this show!

**DINOSAUR**(animation)**:** Thank you, thank you very much!

**NEIL deGRASSE TYSON:** In some ways, we owe our existence to serendipity, and some argue that this makes the evolution of intelligence far less likely. Our brains evolved through many stages: the little rodents, the early primates, and later on we branched from the apes.

This worked for us, but is it the only route to intelligence? Would an alien species have to go through the same steps? There's no way to know for sure, but on our planet, lots of animals have remarkable brains and behavior, including some that are very distant from us on the evolutionary tree. Among them are the cephalopods, including octopus, squid and cuttlefish.

**ROGER HANLON**(Marine Biological Laboratory)**:** Cephalopods are mollusks. They're related to clams and oysters, but they don't look much like them at all. And in evolutionary terms, they've evolved in a very different way.

**NEIL deGRASSE TYSON:** Roger Hanlon has spent the last 30 years studying the behavior of these animals, behavior that is their main defense from ending up as dinner.

**ROGER HANLON:** These animals are a yummy hunk of protein swimming around in the ocean, and once they're caught, they have no defenses. So they have to have a good primary defense. That's camouflage: don't be seen.

**NEIL deGRASSE TYSON:** In the lab, Hanlon and his team study how cephalopods, like this cuttlefish, control and change their skin patterns.

**ROGER HANLON:** It's taking that visual information and translating it to the skin on the back.

This is beautiful. Look at that perfect white square.

**NEIL deGRASSE TYSON:** To see how they apply their tricks in their natural habitat, Hanlon tails them with his underwater camera. His biggest challenge? Finding them in the first place. Octopus and cuttlefish have an uncanny ability to completely disappear into the background.

**ROGER HANLON:** We all think of the chameleon as sort of the king or queen of color change, but that's not true. A cephalopod can show many more patterns and can show them instantaneously. An octopus can be so camouflaged you literally cannot see it. So every place they go, they are morphing into something that looks a lot like that environment.

So here's the scene. You've got a rock with algae all over it. There appears to be nothing there except the swimming fish going by. Okay, so take a look here and just watch for a moment.

There it is. Whoa! Isn't that amazing? This animal was completely camouflaged on that rock, and suddenly it was there.

This remarkable camouflage, changing both pattern and three-dimensional texture, is performed by skin unlike any other animal's. It's an amazing skin, because there are up to 20 million of these chromatofore pigment cells, and to control 20 million of anything is going to take a lot of processing power. We call it a computer. Animals have brains. These animals have extraordinarily large, complicated brains to make all this work.

**NEIL deGRASSE TYSON:** For Hanlon, the brains and sophisticated behavior of these animals suggest that there's more than just one way to get smart.

**ROGER HANLON:** Even an invertebrate animal related to a clam or a snail can develop an incredibly complicated brain. This is one of the true wonders of nature. It's hard to explain why, but it's everywhere. And what does this mean about the universe and other intelligent life? The building blocks are potentially there and complexity will arise. Evolution is the force that's pushing that. I would expect, personally, a lot of diversity and a lot of complicated structures. It may not look like us, but my personal view is that there is intelligent life out there.

**NEIL deGRASSE TYSON:** But intelligent life is not necessarily life we can talk to across the depths of space. For that, you need technology. As smart as an octopus or a dolphin is, neither one of them is going to build a radio transmitter or a space ship.

When paleontologist Peter Ward looks at Earth's track record, the odds for technological aliens don't seem very promising.

**PETER WARD:** There's maybe 30 million species on the planet today. And if we look at the fossils, there's hundreds of millions of species in the past, but only one of them which has risen to technology. It's happened one time out of hundreds of millions of possibilities on planet Earth—one time, one time only. So, that's an astronomically small number.

**NEIL deGRASSE TYSON:** Here on Earth, we are the only species that has mastered technology. Since it's so rare here, should we really expect technology to be common among the aliens? Many would say "no," but the folks at SETI continue to hope.

Searching for alien signals night after night can test anyone's patience, unless, of course, you find one. Most evenings SETI will get a false alarm or two, but one night in 1997, they received a signal so strong and true, it looked as if their long search might be over.

**SETH SHOSTAK:** We were observing at another telescope in West Virginia, and we got this signal that started to pass all the automated tests that we use to determine is it really extraterrestrial, is it just more interference?

**NEIL deGRASSE TYSON:** The lead astronomer that evening was SETI director, Jill Tarter. Following standard procedure, she pointed the receiving dish away from the star where the signal appeared to originate: if the signal remained, it was just a stray transmission from Earth. But when they moved the dish, the signal went away. And when it was pointed back at the star, the signal returned. Excited, the SETI team repeated the test.

**JILL TARTER** (SETI Institute)**:** We went off in another direction, and the signal went away. And we came back and it was there. And we went off in another direction, and the signal went away. And we came back and it was there. And it was now getting very interesting.

**NEIL deGRASSE TYSON:** Interesting because the signal might actually be coming from deep space. The excitement quickly spread back to SETI headquarters in Mountain View, California.

**SETH SHOSTAK:** I was back in Mountain View. We were watching the signals on remote monitors. Well, after about four or six hours of this, still passing the tests, needless to say, our blood pressure definitely was rising.

**JILL TARTER:** And I was so excited that exactly what I was looking for was right there, staring me in the face.

**NEIL deGRASSE TYSON:** By now the star had set. The next night would tell the tale. If the signal returned, perhaps E.T. was finally on the line.

**SETH SHOSTAK:** I, for one, couldn't sit down; I was sort of pacing around. A lot of people were huddled around the computers. Nobody went home. Nobody went out for a burger. In a sense, you know, it could have been an historic moment.

**NEIL deGRASSE TYSON:** The historic moment didn't survive the night. Most of the time, SETI used a second telescope, located in Georgia, to weed out false alarms. Unfortunately, the backup antenna wasn't working. So it took a little longer than usual for the SETI team to discover the truth on their own: the signal was coming from a distant research satellite. The champagne remained unpopped.

Despite the disappointment, SETI has never lost faith. Its scientists remain convinced that our universe is capable of producing intelligent life on many different worlds.

**FRANK DRAKE:** I truly believe there are signals out there. I also recognize full well that our instruments, as powerful as they are, are hardly beginning the search. The number of stars we've looked at, the number of radio frequencies, is minuscule compared to the total inventory of combinations of stars and frequencies there are to search. So we've hardly started. We should not have succeeded. Only through a great fluke of good luck would we have succeeded by now.

**NEIL deGRASSE TYSON:** Humans have been leaking radio waves into space for most of the past century. Compared to the history of our Milky Way galaxy, about 10 billion years, that's a tiny blip. And we've been actively listening for the radio signals from distant civilizations for only about 40 years.

If the aliens are on the other side of the galaxy, any signal they send could take tens of thousands of years to reach Earth. It's as if the aliens were throwing a dart and trying to hit one tiny spot on this enormous landscape of time and space. Let's face it, the odds of our capturing that signal aren't very good.

And yet, who can blame us for trying?

**JILL TARTER:** For me, it's the most interesting question. Are we alone? What's our place in this universe? How do we fit in? Are we just run of the mill? Are we totally exceptional? Or are we somewhere in between?

**NEIL deGRASSE TYSON:** Exploring our own world and the universe beyond has been full of surprises. Just a few hundred years ago, we assumed that everything about us and our surroundings was special and unique. Now we know there are lots of stars out there; many like our sun. We're discovering other solar systems with planets.

And the chemicals of life, forged in stars, are abundant in the universe. If those common chemicals have caught the spark of life somewhere else, who knows how that life will evolve, what path it will follow, and whether we'll ever meet?

**GEOFF MARCY:** I feel like I'm six years old when I say it. I feel almost embarrassed. I just want to know, "Are they out there?" And all of my science training, and math and skills as a researcher kind of go out the door. I just feel that this is a question that is going to be so profound for us as a species, but also individually. Each one of us will have to look within ourselves and figure out what it means to us.

**NEIL deGRASSE TYSON:** Are we alone? Are we rare? Are we common? We still don't know. But perhaps someday we will. And the answer, whatever it is, will reshape our sense of ourselves and our place in the universe.