Is the Universe Full of Life?

NEIL DEGRASSE TYSON: When people hear that we discover planets by the gravitational affect that planet has on its host star, they say, “you mean you don't actually see the planet?” And I say, no, gravity is as much a signature of something's existence as a direct photograph. If you live in a cabin in the woods, you come to learn what a bear footprint looks like very quickly, and if you see such a footprint outside one morning, you’ll start looking for the bear that was once there.

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ROBERT KUHN: What about all the catastrophes, the giant explosions of severe radiation in the universe, comets and asteroids flying all around all the time. I mean, it’s a hostile environment.

NEIL DEGRASSE TYSON: But before we, before we wax poetic about how bad it is, consider that the last major extinction, the one that took out the dinosaurs, enabled the tree shrew to evolve to something more ambitious than a rodent or some other small mammal, to become what we are today. So these impacts are takers away as well as givers of the diversity of life

ROBERT KUHN: Well some are not, some are radiation that I think would be destructive.

SHRI KULKARNI: Some stars die benignly like our own sun, so in another 5 billion years…

ROBERT KUHN: Not benign to us.

SHRI KULKARNI: That's true, that goes to show how much of an astronomer… The sun will just expand very gently,

NEIL DEGRASSE TYSON: We’ll be a cinder orbiting deep within the sun’s surface…

SHRI KULKARNI: But it's over 5 billion years from now so we shouldn’t be too worried. But the other stars, the more massive stars, and they do die catastrophically, and they can die super novi, which is very common. At some point runs out of fuel and then starts collapsing because gravity is the ultimate winner in this game. So it starts collapsing, and the collapse process itself releases what we call as gravitational binding energy, some of which now comes off and, in a flash and in gas coming out at very high speeds. And these super novi are not uncommon, there is one super novi in our own galaxy every hundred years. So if you’re close to one, that could be pretty bad.

ROBERT KUHN: What do you call close?

SHRI KULKARNI: Certainly a thousand light years in this definition would close by anyone's theory of what a super nova would do. And then even more exotic, but even more catastrophic things which is the gamma ray bursts, and gamma ray bursts are rare, but their sphere of influence is tremendous

ROBERT KUHN: Is that like the most powerful explosive energy in the universe?

SHRI KULKARNI: Yes, it's the most powerful directed explosive energy so they come out as basically beams of light and radiation, and we don't understand all this very well, but we are talking of thousands, many, many thousands of light years as definitely being their sphere of, you know, death.

ROBERT KUHN: Why is now such an exciting time in the search for life elsewhere in the universe?

BRUCE MURRAY:, There has been something happening to the earth which has been the discovery in mid ocean ridges, in groundwater very deep, of living systems, organisms, microorganisms, that survive in environments we never believed possible. Incredibly, they chemically process, they don't need photosynthesis, they don't need to sunlight to do it. And so I think for me personally, that is as much a reason to become optimistic, or at least less pessimistic about finding life on Mars or finding it in another planet around another star, than almost everything else.

NEIL DEGRASSE TYSON: Why didn't we know about this, it's just on the bottom of the ocean, why not 50 years ago?

BRUCE MURRAY: Just on the bottom of the ocean, these are hard to recover. I think there's two reasons, again, going back to my geological training, it wasn't in the picture, you didn't think about it.

NEIL DEGRASSE TYSON: I think, Bruce, what you left out in that whole discussion is the life at the bottom of that ocean does not require sunlight as a direct source of its energy. And once you remove the sun as a requirement, it allows you to think of other ways you might have energy to sustain life. When you teach introductory Astronomy you talk about this habitable zone around a star.

ROBERT KUHN: Describe what that is.

NEIL DEGRASSE TYSON: Let's take the sun for example, life as we know it requires liquid water, in the naive sense of this notion. If there is a planet a little too close to the host star, the water would evaporate a little too far away it's frozen, so there is this sort of Goldilocks interval where you have liquid water. And for quite a long time that concept dominated our thinking and our discussions about how and where we might look for life, around and in another star system.

ROBERT KUHN: What are some of those conditions?

SHRI KULKARNI: You need energy, that's the ultimate thing, that's the ultimate part you need to get life going, it can be tidal, it can be solar and so on.

ROBERT KUHN: How about extreme cold?

BRUCE MURRAY: That's interesting because the satellite of Jupiter called Europa has an icy crust, we know that, and probably not terribly thin, it's probably saltwater below that, so maybe that's kind of like the Arctic Ocean or the Antarctic. And there are studies that have been done that have detected organisms that really do seem to be able to live in the ice. If you stick a thermometer, it's -20 degrees Centigrade, it's below freezing, way below, and the organisms not only can survive, but they can apparently live.

NEIL DEGRASSE TYSON: But the fluid within them is still liquid, so they're not in a frozen state, solid brick.

BRUCE MURRAY: It's tougher than that because it's hard to find out if something is alive The usual test is it's got to reproduce unless you can cause it to reproduce and measure metabolism, it's very difficult to say something is alive. So, in extreme environments, do you culture those things, it's not that simple, how do you know it wasn't some contaminant from the bucket that picked the stuff up off the ground, how do you know it wasn't in your lab, how do you know it didn't come out of the air?

NEIL DEGRASSE TYSON: So now because of these extremophiles, when we think about life elsewhere in the galaxy, we no longer restrict ourselves to this Goldilocks zone because of these, how much broader our thinking has become.

ROBERT KUHN: Why is now such an exciting time in the search for life elsewhere in the universe?

SHRI KULKARNI: There are actually two reasons, one is that there is a lot of technology now that for the first time in the entire history we can address meaningfully the question of planets elsewhere, and perhaps even say something about the existence of large-scale life, by which I mean organisms and trees and so on. But the other one is probably just as important, a bit more subtle, and that's astronomers can now more or less say with confidence that every time a star has formed a bond, then planet formation is a necessary byproduct. So we know star formation is accompanied by planet formation, through observations, and we know that we have the technology to actually go look for these. So I think this is pretty much the start of a golden era in this field.

NEIL DEGRASSE TYSON: Yeah, I agree, especially in the last ten years, ever since the first discovery, the first announced discovery of a planet around a star other than the sun, and I remember distinctly the day that that planetary count exceeded the number of planets around our own sun. So we have people who are now children, for example who have only known a time where we have in our log books more planets outside of our solar system than within.

BRUCE MURRAY: We ask somebody who is 30 or older, how many planets there are and they all say, "nine." Say, no, I'm sorry, it's now 59, as far as we know right now.

NEIL DEGRASSE TYSON: We'll get a hundred any minute now.

ROBERT KUHN: So how do we know they are there?

SHRI KULKARNI: Well there are basically three techniques and in various stages of sophistication at the current time. The simplest one is where the star light itself is telling you some information, here's let's say a star, and I'll use a penny as my planet as the planet is going around. So as the planet goes around, the star is gently tugged and either you can see this…

ROBERT KUHN: By the gravitational field of the planet.

SHRI KULKARNI: Of the planet, which may be small but it's nonetheless measurable. So what you would end up seeing is, the stars undergoes a sort of a motion and astronomers detect this in two different ways, one is something called radial velocity, which is just how the motion with respect to yield let's say, that's the current technique which is producing this abundance of planets that Neil…

ROBERT KUHN: How big is that radial velocity?

SHRI KULKARNI: We are talking of meters per second, you know 10s of meters per second.

ROBERT KUHN: And, and you can detect meters per second differences at…

NEIL DEGRASSE TYSON: That's part of the technologically enabling factors of the past ten years… telescope

SHRI KULKARNI: And the way to look at this is, even a few meters per second is only one part in 10^8, that is one part in 100 million, that's a big number.

ROBERT KUHN: One part in a hundred million you're detecting.

SHRI KULKARNI: So you're going to see small variations which are delicate for one part in 100 million. And astronomers can do that quite reliably, it took awhile but we are there now.

NEIL DEGRASSE TYSON: But I would add that these Jupiter sized planets that we see around, can I make a star here with my glass too? The kind of planet you will discover first is the large planet and one that is close to the host star, which would then execute one period rather quickly, and you can get that signature in your data, and so all of the first waves of data discovered large planets close to the host star. We need a much longer baseline of time even to find a bigger planet far away.

ROBERT KUHN: Because Earth would take a year.

NEIL DEGRASSE TYSON: Take a year. Jupiter in our solar system takes 10, 12 years to go around, and so we've all been taking data for 12 years, so we would not have even seen a full orbit of Jupiter by now. I'm often asked, when we people hear we discover planets by the gravitational affect that planet has on its host star, they say, "you mean you don't actually see the planet?" And I say, no, we measure the gravity. And people get worried, well if you can't see it, how do you know it's there? And I simply say that gravity is as much a signature of something's existence as a direct photograph of it, we have many ways we can measure something is there. Just as you do if you live in a cabin in the woods, you come to learn what a bear footprint looks like very quickly, and if you see such a footprint outside one morning, you'll start looking for the bear that was once there. You're not going to say, "oh, I didn't see the bear, therefore it couldn't have existed." So it's that kind of inferences we make that have been very powerful throughout the history of astronomy. It's how we first even expected there to be the planet Neptune, from its gravitational effect on the planet Uranus, no one knew what was causing that, so the gravity tells us there is an object out there.

SHRI KULKARNI: The other technique that's been in development for sometime now, and it's also coming of age with ground based facilities at Keck in Hawaii, this is called interferometry, when you have more than one telescope and you have combined the light, and by combining the light you get more synergism basically, and the technical word for that is interferometry.

ROBERT KUHN: It's as if the telescope was much bigger than either one of those.

SHRI KULKARNI: Absolutely. With that technique, as well as the next mission that NASA has already funded, called the Space Interferometry Mission, astronomers will be able to go after more distant Jupiters as well as get, for the first time, our normal stars we will be able to look at.

BRUCE MURRAY: Can I have my glass back?

SHRI KULKARNI: So let's imagine this, this quarter is a star, and of course this is back, my penny, it's a planet, so here's a star, and you're seeing the star, both ways, and as this planet is going around a star and is, at some point it comes and occults it, so from that…

ROBERT KUHN: Occults meaning it crosses its face.

SHRI KULKARNI: It eclipses it. So, if there's not planet, if the planet is not eclipsing it, you get all the light from the star, but when it is in front of it, then you get a little less light.

ROBERT KUHN: And some of the planets have been detected with that occulting technique?

SHRI KULKARNI: Yes, one planet has been detected, first identified through this radial velocity technique and then followed up.

ROBERT KUHN: Let's talk about Europa and Mars, because that's close and that's real.

NEIL DEGRASSE TYSON: It's in our backyard, if we have evidence for life ever, whether or not it's there now, but dig down in the surface of Mars, Mars we know had running water, they're dried river beds that meandered, floodplains, river deltas, all this tantalizing evidence that it was once an oasis and wherever we know an oasis is on earth, it's got life. So, if life ever existed on Mars that's our backyard, right there.

BRUCE MURRAY: There's a problem.

NEIL DEGRASSE TYSON: What's the problem?

BRUCE MURRAY: Astronomers don't appreciate, nor biologists I might imagine, when they talk about it. The surface of Mars is self-sterilizing, the ultraviolet radiation reaches the surface.

NEIL DEGRASSE TYSON: Today, in some stars.

BRUCE MURRAY: It's really self-sterilizing.

NEIL DEGRASSE TYSON: Today!

BRUCE MURRAY: Down for maybe a meter, who knows, ten meters, we don't know.

NEIL DEGRASSE TYSON: Today!

BRUCE MURRAY: There's no organic material on it.

NEIL DEGRASSE TYSON: Today!

BRUCE MURRAY: Today, you're right. So that means that whatever life did form…

ROBERT KUHN: Might have formed.

BRUCE MURRAY: Did or might, depending on which side of NASA you are on. But that means that it had to either evolve or be subterranean life, like in the groundwater of the earth.

NEIL DEGRASSE TYSON: So you go out digging and you find it, and if you find it, it means one of our nearest planets has life, that's good!

BRUCE MURRAY: You're glossing over the problem, how far do we have to dig? I'm trying to say it's a much more difficult task, it could in extreme case require the equivalent of a human expedition with great big drills

NEIL DEGRASSE TYSON: I'm not worried about how big our shovel is when we get there, if it's got life, it's got life.

BRUCE MURRAY: So I think that's important. Europa is a different kind problem because Europa is not self sterilizing, it's in the field of, of Jupiter's radiation belts, it's lethal for anything that we want to send, including many robots, so you have to build, the same kind of technology used in a nuclear weapon, or that you…

NEIL DEGRASSE TYSON: Hardened electronics.

BRUCE MURRAY: Hardened electronics, so again, it's not easy. The extremophile, the thing we are looking for, lives in an area that not just humans can't take, but even robots can't. So it's, again, it's a challenge, we'll do it, I agree, we've got to do it, and both of those are good targets.

BRUCE MURRAY: Let me come back to my earth centered, solar centered view. I think it's quite relevant, which the overriding question about us, philosophical, and it's really a religious question, is, are we something special here in this solar system, and therefore our earth is kind of special, and therefore the fact we are sitting here talking is special. Or is that really very common throughout the galaxy? That's probably about as important a question as I know how to formulate scientifically that could be answered with science. Or are we the freak, because my hunch, personally watching this happen, is, when you find Jupiter at the distance of Mercury, which is what some of these places have, if that's the typical thing, and we here are unusual, that's got tremendous implications about the abundance of life, and especially the abundance of human, or at least intelligent life, I think.

NEIL DEGRASSE TYSON: I'm quite confident that life is not only hardy, given how many environments we find on earth, it's also easier than we know to form. First, even if earth, at our distance from the sun is rare, you bring nearby Jupiter to the sun, and that Jupiter might have 40 moons or 50 moons, some of which then would possibly harbor life. So that doesn't scare me that perhaps earth at the Goldilocks distance is somehow rare. But the two points that need to be reckoned with, typically when people ask how soon did life appear on earth, they take the age of the earth and subtract the age of the oldest fossil, and if you do that, you get 4.6 billion minus 3.8 billion, and you get 800 million years. And you say, well that's pretty quick, but it's better than that, because earth spent about 600 million years in a period of heavy bombardment vacuuming up the remains of the solar system, and the earth's surface was basically sterilized because of the deposited energy and the heat, it was basically molten for 600 million years. It's not fair to start your stopwatch at the beginning of that because complex molecules can't survive it. Wait till we cool down, then start your stop watch? 200 million years - [SNAPS FINGER] that's [SNAPS FINGER] nothing in a cosmic time scale. It seems to me if life were something hard, it would have taken earth a little longer than 200 million years, maybe several billion years. And one final point, you learn in your biology it's water, you break apart water you have hydrogen and oxygen, take hydrogen, oxygen, carbon, nitrogen, that's what we're made of, the chemistry of these ingredients is the chemistry of life. And you look in the universe, there they are in the universe, hydrogen, it's also got helium, but that's inert - oxygen, carbon, in the same order. If we were made of some isotope of plutonium you could argue that we were rare. So I have high confidence in this, I'm not just dreaming here.

SHRI KULKARNI: It seems to me planet formation just empirically is very common, and we just know our planetary system well. And we know nothing about the remaining 90, 95 percent, which is why you need these missions, these other techniques.

ROBERT KUHN: How many years do you think it will take to get sufficient amount of information as we are doing it now, to be able to make an informed opinion about some generalities about what we can know in the immediate future?

NEIL DEGRASSE TYSON: I think it's just money at this point, it's not like we're not smart enough to know what the questions are at this point. By the way, the questions we're asking, just as a caveat here, a lot of the answers we'll be finding may be as a result because we're looking for our car keys under the lamppost where the light is illuminating it. There may be systems that in fact are unlike earth that are just perfectly happy making life that we have yet to think of. And science is <u>full</u> of examples like this. But it's just a matter of funding, funding the Kepler mission, the Space Interferometry Mission, so I put it 10, 20 years.

SHRI KULKARNI: Also the main, the one that will really fill this gap between the radial velocity techniques and the occultation, which have similar sort of biases or similar sort of systems they'll find, is really the Space Interferometry Mission and interferometry in general. So I would say by about 2015, because SIM will get launched in 2009, we'll have a fairly good idea of an inventory of planetary systems.

NEIL DEGRASSE TYSON: Looking for oxygen.

SHRI KULKARNI: So the next step really is, how to do more detailed analysis. Occultation as I said is a relatively inexpensive here and now technique. But it requires very favorable orientations, if you find evidence of planets, let's say around Alpha Centauri, then you can't expect it to be all nicely lined up for you. We don't know how to make this mission, we don't know whether it should be in the infra red or optical, and this is something that astronomers are more actually thinking right now.

ROBERT KUHN: Are they talking about putting telescopes at opposite ends of the solar system?

NEIL DEGRASSE TYSON: People dream that. We gotta work our way.

SHRI KULKARNI: They will be like, you know, tens of meters to perhaps hundreds of meters depending on exactly what they end up, which wave length we'll operate. And this sort of a mission which is called Terrestrial Planet Finder, TPF, it's being talked about, it will be expensive, but again my own guess is this will happen roughly about 2015.

BRUCE MURRAY: Let me give you a <u>different</u> point of view. We are in a very early process of discovery in exploration, and it sounds very organized, it sounds like laboratory science, it's not, you look and you find and the trick is to look properly and broadly. We could find something next year where one of these occultations or another technique shows evidence of carbon dioxide gas, which is strongly apparent in our atmosphere, and also methane gas which is strongly apparent in Jupiter's atmosphere. What would be significant is those two are incompatible, one is an oxidized gas, carbon dioxide, one is a reduced gas, methane, and they are made of very common stuff. Now if we got lucky, and if that happens the overpowering conclusion is it's got to be a disequilibrium going on, namely life, because that's why we have that on the earth. We have exactly that situation.

NEIL DEGRASSE TYSON: Cow flatulence, giving us methane in the atmosphere.

BRUCE MURRAY: And plants giving us carbon dioxide. So we could get surprised or something comparable to this, or this powerful techniques we've described might not show that. And it's going to be very hard to prove life, or even have a high suspicion unless we get lucky with something like that. I'd rather say I think it's likely between now and 30 years it will happen, sort of a cumulative probability.

ROBERT KUHN: That's still within the lifetime of, hopefully all of us, but certainly most people.

BRUCE MURRAY: I will be disappointed personally if we don't have a strong indication that there is life, and if we don't have one, my conclusion would be maybe it isn't there, maybe in fact there's something special about this solar system.

NEIL DEGRASSE TYSON: That would be in violation of the Copernican Principle, suggesting that nothing we've ever measured about our circumstances has ever been special.

ROBERT KUHN: Either answer to the question is overwhelming. A new term has developed, "astrobiology," are you comfortable with that term?

NEIL DEGRASSE TYSON: Oh yeah, you know, astronomers cannot do it alone, you know there's certain questions we know how to ask that don't include the kinds of questions a biologist would ask if you brought them along on a mission. Same is true if you bring along a geologist. Better yet, a paleontologist, if there is some history of life buried within the soils, you need somebody who has experience rummaging through cross sections of the planet. So, there's been a realignment of effort by multiple disciplines all asking the same question, the chemist, the biologist, the astronomers, we all want to know about life elsewhere in the cosmos. And astrobiology is a nice umbrella term for that, although keep in mind that it's an entire field with no data right now. We have not one example of life off of earth, so they're anxiously awaiting their first sample for the lab.

SHRI KULKARNI: Well, I won't say it's no data in the sense, I think all these life in extreme environments is, I think…

BRUCE MURRAY: That's not astro, that's geobiology, which is a distinguished wonderful field.

NEIL DEGRASSE TYSON: Starter data, it's starter data. Practice data.

SHRI KULKARNI: What really missing here actually is, while many fields actually have a theoretical basis, astronomy has a theoretical basis, certainly physics, which is the granddaddy of all has a very scientific basis. It took a long time for the chemists to get a theoretical basis of their bonds. The problem is that biology has no, there is no such thing, at least to my knowledge, of a theory of biology, it seemed very complicated.

ROBERT KUHN: What you're almost say is that you can't make a theoretical biology unless you have more than one data point.

NEIL DEGRASSE TYSON: Unless you have more than one data point.

SHRI KULKARNI: Historically always been the case, right, I mean chemistry wasn't a discipline until you could see patterns, and so on. You gotta see patterns, you've got to classify data, you've got to do all that butterfly collecting first. And unfortunately that's why I said this is a little difficult subject because you can't do this collection in the field because the field is a bit far away.

ROBERT KUHN: Exciting because this is a unifying human quest, and all peoples, all societies, all groups have the same meaning for all-time, that's a good point.

BRUCE MURRAY: And, call it a quest, not a field, because it's not a field yet, you can't have a field without a single example, life elsewhere, so it's a quest. It is a noble…

NEIL DEGRASSE TYSON: As alchemy was a quest. I mean, there's people right in alchemy. People rag on alchemy, but consider that at least it was a, an experimental subject and it happened in laboratories, and there were important foundations from alchemy that led to chemistry. And so you have to begin somewhere, alchemy had no theoretical foundation that was working for them

BRUCE MURRAY: But it had a wonderfully compelling idea, I can take lead into gold.