the WINNOWER

REDDIT

Science AMA Series: We're NASA Earth scientists using satellites to measure life on Earth. The more we learn, the more this question comes into focus: Maybe we're the weird one? How will our work help in the search for life on other planets? AMA!

NASAEARTHRIGHTNOW R/SCIENCE

At NASA, we use the vantage point of space to study Earth and the life it contains. And, so far, our planet is the only one with life (that we know of). The more we learn, the more this question comes into focus: Maybe Earth is the weird one? As we begin the search for alien life, the knowledge and tools NASA developed to study Earth are among our greatest assets. We will discuss how Earth science informs the search for life beyond our planet – on exoplanets and even within our own solar system. So, what do you want to know?

We will be back at 4 pm ET to answer your questions, AMA!

Morgan Cable is a NASA research scientist searching for life and interesting chemistry on ocean worlds such as Saturn's moons Enceladus and Titan.

Tony Del Genio is a NASA Earth climate scientist and planetary scientist who uses global climate models to understand the kinds of exoplanets that are most likely to be suited to the emergence of life as we know it. He once thought planets orbiting other stars wouldn't be found in his lifetime, but now he tries not to underestimate exoplanet scientists.

Shawn Domagal-Goldman is an astrobiologist at NASA who looks for ways to identify signs of life, and ways to detect those signs from far away using space-based telescopes.

Stephen Kane is a planetary astrophysicist at the University of California, Riverside, who has been researching exoplanets for more than 20 years.

Andrew Rushby is a NASA astrobiologist who uses computer simulations to try and understand those few planetary environments that could support life in the deathly cold, vacuous expanse of our galaxy.

UPDATE @ 3:24 pm ET: A new feature story and video on this topic are now posted at nasa.gov -- https://www.nasa.gov/feature/jpl/our-living-planet-shapes-the-search-for-life-beyond-earth

UPDATE @ 3:49 pm ET/1:49 pm MT: We are online and ready to start answering questions! In fact, we are all together in Laramie, Wyoming at the Habitable Worlds 2017 workshop. Looking forward to this! https://twitter.com/NASAEarth/status/930903145923989504

CORRESPONDENCE:

DATE RECEIVED:
November 16, 2017

DOI:
10.15200/winn.151075.50241

- How plausible is the plan of colonizing Mars?
- What is the most possible exoplanet that can be colonized in the future?
- Through a telescope, how can one see or determine the elements present in an exoplanet for it to be habitable by us?

cuteball

ARCHIVED:
November 15, 2017

CITATION:
NASAEarthRightNow , r/Science , Science AMA Series: We're NASA Earth scientists using satellites to measure life on Earth. The more we learn, the more this question comes into focus: Maybe we're the weird one? How will our work help in the search for life on other planets? AMA!, *The Winnower* 4:e151075.50241 , 2017 , DOI: 10.15200/winn.151075.50241

For colonizing Mars... nothing rules it out physics-wise. But it will be difficult - thin atmosphere, and the atmosphere is lost.

For an exoplanet I think we probably all have our favorite... but we really don't know enough about any of them to know they're capable of being colonized. BUT... we're trying to figure out what kinds of telescopes we would need to build to find out.

For habitability, you'd like to see surface temperature, oceans, continents, and atmospheric composition. And for atmospheric composition you want at least CO2 (for plants), O2 (for us), and N2 (for plants, too). BUT... if there's O2 on the planet that means there is *probably* already life there. And then there's a moral dilemma similar to the prime directive (do we colonize a planet with life on it already?)

--shawn

Stephen, what is the most interesting exoplanet discovered, in your opinion, and how do you believe it has changed today to the time the light took for you to be able to see it?

toomanynames1998

It's very difficult to choose a favorite exoplanet since they are all extremely diverse and intrinsically interesting. I have a natural bias towards terrestrial planets in the Habitable Zone, however, I'm particularly interested in planets for which we have no analogs in our solar system. Examples of these are giant planets in highly eccentric orbits (imagine Jupiter on an orbit like a comet) and those planets we refer to as super-Earths. The latter are particularly interesting because the large size gap we see between Earth and Neptune in our own solar system was a primary driver in planet formation theory prior to the discovery of exoplanets, but now we know that our solar system is extremely weird in this regard. If I had to choose, I would pick HD20782b, simply because it's SO different from anything in our system: http://www.ibtimes.com/meet-hd-20782-highly-eccentric-planet-may-help-scientists-understand-planetary-2340135 The system is 117 light years away so we're seeing it as it existed 117 years ago. On those timescales, not a lot would have changed, although eccentric orbits like this are intrinsically unstable and the planet will eventually fall into its star. Stephen

This is mostly directed at Morgan - Morgan, if you see this - do you honestly believe there is going to be life on those moons, when there are enough examples here on Earth to show what could be happening over there?

toomanynames1998

Great question! We have a lot of compelling evidence that the ingredients needed for life as we know it - water, chemistry and energy - exist in the oceans of moons like Enceladus and Europa. Everywhere we have found those three ingredients on Earth, we find life. Why not elsewhere too? - Morgan

Hey thanks for this ama!

1. • What is one of the most significant identifiers you have discovered that would indicate a high chance of life from afar?
2. • As someone soon to be working in the space sector once college is over, I love to learn about new achievements and findings. Is there anyway a regular person like me can contribute to your study's that doesn't involve money?
3. • What was your motivation or influence to get where you are now?

QuantumSocks

1. At the moment, our knowledge of exoplanet properties is limited to things like mass, radius, insolation flux, and various orbital properties. From here we can attempt to model planetary atmospheres, but we really need to measure the atmospheric compositions to determine if there are signatures of life.

2. Absolutely! The latest up-to-date findings are released here: https://exoplanetarchive.ipac.caltech.edu/ and also at the NASA Exoplanet Exploration Program: https://exoplanets.nasa.gov/exep/ Direct participation can occur via programs like Planet Hunters: https://www.planethunters.org/

3. I grew up in outback Australia where I had magnificent views of the night sky. I decided to be an astronomer when I was 12 years old after a visit to a planetarium and have been having the time of my life ever since.

Stephen

Hey thanks for this ama!

1. • What is one of the most significant identifiers you have discovered that would indicate a high chance of life from afar?
2. • As someone soon to be working in the space sector once college is over, I love to learn about new achievements and findings. Is there anyway a regular person like me can contribute to your study's that doesn't involve money?
3. • What was your motivation or influence to get where you are now?

QuantumSocks

2.The best way you can contribute to our studies is by sharing our discoveries with your colleagues and friends - get us better visibility! The other thing you can do is advocate for more support of scientific research (not just NASA!). Oh! And there are plenty of ways for the community to be involved in doing REAL SCIENCE, such as SETI@home and citizen scientist programs.

3.I was always asking questions as a kid. My parents got me involved in science projects when I was pretty young, and I realized then that I could come up with a question that no one had answered yet! And that I could keep doing that, as a career, and it's called being a scientist! I absolutely love what I do, and feel so incredibly fortunate to be able to keep asking questions and then designing instruments, experiments and missions to figure out the answers!

Morgan

Hey thanks for this ama!

1. • What is one of the most significant identifiers you have discovered that would indicate a high chance of life from afar?
2. • As someone soon to be working in the space sector once college is over, I love to learn about new achievements and findings. Is there anyway a regular person like me can contribute to your study's that doesn't involve money?
3. • What was your motivation or influence to get where you are now?

QuantumSocks

1. To say a planet has life, what we would want is an observation we can explain with a model that includes biology in the model, but that we cannot explain with any model that does not include

biology. The "classic" example is oxygen + methane. Those gases are hard to keep in the atmosphere at the same time, so they have to be quickly replaced. Only life can do that effectively. So we could explain that with models that include biological activity, but not with models that do *not* include biology.
2. I'll echo the other replies about citizen science. You can also look into some of the code we write and help improve it. For example, the codes I use are on github. SPOILER ALERT: Our code is messy.
3. I was an undergrad physics major, sitting on the lawn with my brother looking at the stars during a lunar eclipse (we lived in Chicago and didn't get to see the stars that often). He asked me if I thought there was anyone out there. I said "Well, I don't know... but that sounds like a fun problem." (FWIW if he asked me today that would still be my TL;DR reply.)

--shawn

Hey thanks for this ama!

1. • What is one of the most significant identifiers you have discovered that would indicate a high chance of life from afar?
2. • As someone soon to be working in the space sector once college is over, I love to learn about new achievements and findings. Is there anyway a regular person like me can contribute to your study's that doesn't involve money?
3. • What was your motivation or influence to get where you are now?

QuantumSocks

One important thing - if you are interested in working for NASA, **do an internship**. Seriously. There are many different NASA internship programs, and all of them are awesome. That's how I got here. I came from a small college in Florida, and stumbled upon an internship at the NASA Jet Propulsion Laboratory (JPL) while I was an undergraduate (note: there are programs for all levels, from high school to graduate school and beyond, so there is probably something for you!). I totally fell in love with the work I was doing, and the NASA center where I was working, so I was able to turn that project into an entire Ph.D. thesis!

Internships are a great way to get your foot in the door, and for you to get an idea of what the work at that place is actually like day-to-day. I highly recommend it! My internship totally changed my life, and I hope it will do the same for you too!- Morgan

What's it like to tell people about your job at parties?

ReeseSlitherspoon

It's fun, and usually inspires some very interesting conversation! Protip: I usually carry some NASA stickers or other mission-related stuff with me, especially when I travel. So if we ever meet and talk about those topics you'll usually end up with something space-related to take home :) - Morgan

What's it like to tell people about your job at parties?

ReeseSlitherspoon

Telling people what I do is a lot of fun in various contexts, including parties. A common context in which this comes up is when traveling, such as sitting next to someone on a flight and striking up a conversation about science. It never ceases to impress me how interested the public is in current space science and the search for life in the universe. Stephen

What's it like to tell people about your job at parties?

ReeseSlitherspoon

I'm feel I'm always 'on call' as a scientist, so I love speaking about my job, my work, and the work of my colleagues whenever and whereever! As Stephen also notes, some of the most enjoyable conversations I've had have been on planes or when travelling. I always end up more enthused and inspired after talking to people from all walks of life who are interested in the work that NASA does. - Andrew

What's it like to tell people about your job at parties?

ReeseSlitherspoon

That all depends on the party! Lately I've had lots of fun talking to 4-year olds about looking for aliens and making spaceship telescopes at the birthday parties my 4-yo daughter gets invited to. ;-)

I remember a specific occasion - years ago - where I told some people at a party that I look for ways to look for aliens. After getting some attention for that, my "buddy" chimed in and said "He made that up. He makes that kind of stuff up all the time." There was no recovering from that...

-shawn

What's it like to tell people about your job at parties?

ReeseSlitherspoon

Tony: People are almost always excited when I tell them what I am doing now. I was amazed when a panel I was on to talk about the search for life elsewhere at a sci-fi convention a couple of years ago filled the room at 10 AM on a Saturday morning when I figured everyone would still be asleep.

Assuming there is intelligent life out there, what do you think is the most likely explanation for why it hasn't contacted us? (in other words, what's your favorite solution to the Fermi Paradox?)

smashleyhamer

It could be a variety of things, such as the physics required to transverse the large distances simply not existing, or that intelligent life being rare whilst basic life being common. Personally, my favorite solution is this one: https://arxiv.org/abs/1403.8146 Stephen

Assuming there is intelligent life out there, what do you think is the most likely explanation for why it hasn't contacted us? (in other words, what's your favorite solution to the Fermi Paradox?)

smashleyhamer

My favorite solution to the Fermi paradox is the "sustainability solution." This is decades old but has recently been advanced by Seth Baum and Jacob Haqq-Misra**. In order for the Fermi Paradox to truly be a paradox the civilization needs to grow exponentially forever (cue Scotty Smalls). However, that kind of growth is unsustainable and if it continues unabated then it can overpopulate a system and

cause a population crash.

So... maybe it's either: 1. Civilizations grow exponentially but doesn't last long. OR... 2. Civilizations don't grow exponentially (not for long), in which case the growth is slower and there's less of a paradox.

However, huge caveat here. 20 years ago scientists were really worried about nuclear winter, so that was a common solution to the Fermi Paradox. Now, scientists are worried about sustainability (w.r.t. our own climate), and so that's now a common solution. So my answer may be biased by our times.

--shawn

** Full disclosure, Jacob was my DM when playing D&D in grad school, so that's another source of bias in my response. ;-)

How does life impact a given planet's physical characteristics? Would Earth look the same from afar if life was taken out?

Haurihn

Tony: Without life there would be very little oxygen, so very little ozone, so no ozone layer and no stratosphere. There would probably be more carbon dioxide, which would make it warmer. But there would be much less methane, which would make it cooler. The continents would be brighter, so reflect more sunlight, which would make things a little cooler. On balance, my guess is that the planet would wind up cooler without life.

How does life impact a given planet's physical characteristics? Would Earth look the same from afar if life was taken out?

Haurihn

This is a fantastic question! As a planetary scientist I can provide some insights from the carbon-cycle at least, and one of my colleagues can add more. It's very difficult to remove life from this particular cycle as it is so involved at nearly every step along the way. For example, if we remove plant life from the land surface we would expect CO2 levels in the atmosphere to go up because plants are very effective at accelerating the weathering of the land surface, which acts as a CO2 sink. Therefore, on Earth without life, we might expect much higher levels of CO2 in the atmosphere. However, there are other impacts on the oxygen, methane, nitrogen, etc. cycles that are at play too so a definitive answer is difficult to provide. - Andrew

Does NASA have an emergency plan to send human embryos to a place in space just in case earth doesn't work out or cataclysm hits us sooner than expected? And how big of a budget do you want NASA to have that would cover all the main experiments and tests and probes you would want to do? Basically what's NASAs ideal budget for studying extraterrestrial life?

Thoriumsolution

Interesting question! Part of the reason why we study Earth is so we can be prepared for changes we know are coming. Obviously the human space exploration program is a huge part of what NASA does, and we will always be developing new technologies to expand our reach into the cosmos. Not sure if embryos are on the short list for any upcoming missions, but will let you know if they are! I think tardigrades were mentioned as a candidate for the first interstellar missions. So let's see how well they

do and go from there!

Budget discussions are always hard. Of course we'd like more funding, everyone does! The planetary science community is growing, and it would be great if we could support more of these young scientists [ahem] as they begin their careers. Some advice for those getting into this field, or interested in getting into it: if you want to do astrobiology, pick a kind of research you love (whether it's lab work, modeling, writing, building things, etc.) and pursue it. The happiest people I know at NASA continued to pursue their passion, wherever it took them. There is no right or wrong path, only your path. So make it yours!

- Morgan

If we found that the next nearest star to Earth had a planet or a planet with a moon that could possibly contain life how long would it take a craft to get close enough to verify/get there? 4.3~ly away but how close to we have to get to get an accurate scan (pretty sure this isnt the right word but im tired and couldnt think of a better one)

Tluadus

For a civilization that hasn't sent people beyond lunar orbit, an important thing to remember is that all exoplanets are at a distance of infinity for all practical travel purposes. That means that whether we hear about an exoplanet at a distance of 5 light years or 500 light years, they are both equally unattainable. For sending small nano-probes to the nearest system, there are ideas about accelerating those probes to 20% light speed so would take ~20 years to reach the Alpha Centauri system. Stephen

If we found that the next nearest star to Earth had a planet or a planet with a moon that could possibly contain life how long would it take a craft to get close enough to verify/get there? 4.3~ly away but how close to we have to get to get an accurate scan (pretty sure this isnt the right word but im tired and couldnt think of a better one)

Tluadus

One of the challenges here is communication. If we send a craft to another star system, it has to send the signal back home to tell us what it found. But it's really *really* hard to do that. The reason is it takes super precision to get the message back to Earth. Think of tossing a football through a hula hoop when the hula hoop is 1 yard away versus 100 yards away. It's the same idea - you need perfect aim to get your message all the way back to Earth AND make sure it doesn't "miss" Earth.

You could get around this by just sending the message back in a bunch of directions. But that takes a lot of power. And if you want to generate the power for that, you need a power generator (or solar panels). And that takes mass. And the mass slows down your acceleration. And then maybe it takes too long to get there.

To be clear, I'm not saying it's impossible. But the above is one of the bigger (and under-appreciated) challenges.

--shawn

Do you think our species is capable of adapting to a different planet easily once we find a sustainable way of terraforming, and in how much time could we expect to develop and try to create an oxygen based atmosphere on planets with similar sizes but without carbon based life? is it sustainable to

create a planet with a "curated" biosphere?

sprgsmnt

In the words of Jeff Goldblum: "Life ... finds a way". Stephen

What is your opinion on Panspermia Theory?

Diphyidae

I think it's very interesting! We do know that material is transferred between all of the bodies in our solar system, and that certain forms of life (bacterial spores, tardigrades) can survive in space for extended periods of time. So it's certainly possible that life may have been transferred between planets/moons. Life could have started on Mars and then moved to Earth via meteorite. We could all be Martians! - Morgan

What is your opinion on Panspermia Theory?

Diphyidae

I agree with the others - Panspermia is a cool theory! But it's also not *required* to explain the origins of life on Earth. Its one of many valid theories though.

--shawn

What exactly are the reasons that planets with earth-like conditions haven't developed life on their own?

If we end up with the technology to colonize them, can we settle immediately or will some terraforming be required?

Osheco

We don't know for sure that they haven't! I don't believe that we've found an exoplanet with very Earth-like conditions yet, or at least not one that we can be very confident about. We've discovered some very interesting exoplanets, some of which are almost certainly rocky, but these same planets could have very different atmospheres, oceans, or continental characteristics if we assume a slightly different composition to that of the Earth. Future space and ground-based telescopes, investigating our beautiful planet and how its geochemical processes operate over time, and exploring our friendly solar system neighbors will help us to better understand planets in general, which may shed more light on why some planets can host life and others cannot.

In terms of terraforming, and assuming we can master FtL travel, I believe that any planet we find will differ from the Earth in *some* way, and that degrees of terraforming may be required to produce a habitable environment. However, there are ethical and planetary protection issues to consider too; can and/or should we terraform planets that have extant life on them? Can we ever be sure that the planet we're considering for terraforming definitely has no life? Does it matter if we alter a lifeless planet, or does it have some intrinsic value beyond supporting a biosphere? These questions may be relevant for Mars in the near future. -Andrew

What exactly are the reasons that planets with earth-like conditions haven't developed life on their

own?

If we end up with the technology to colonize them, can we settle immediately or will some terraforming be required?

Osheco

Tony: We don't know yet whether any of the planets that have been discovered have Earth-like conditions or not. Some planets that have been discovered might be at the right distance from their star that liquid water could survive on the surface without freezing or evaporating, IF they have water at all. Detecting whether any of these planets actually do have any water is one of the goals of future observations. The presence of water by itself would not tell us whether there is life or not, but it's a first step. Since Earth is the only planet we know of with life right now, we don't yet know the odds of whether a planet develops life if the conditions are right. But I'll sign on to Stephen's Jeff Goldblum quote.

Is life on other planets neccessarily going to have the same basic chemistry as life on Earth? Why couldn't life in another system use different molecules for, say, genetic material, than life on Earth? I ask because I understand that sometimes, scientists are looking for things like nucleic acids (or the components to form them) on other planets, but it seems to me that that would only make sense for life that is *related to* our life. So what am I missing, exobiologists?

Thanks so much for doing this!

ReeseSlitherspoon

Thanks for the great question! You are absolutely right, life elsewhere could be completely different from life as we know it! The universe is a big place, so chances are, if you can dream it up (and it doesn't violate the laws of physics), it probably exists somewhere out there. But there are some basic assumptions we can make. If, for example, we are looking for life in a place with liquid water (as opposed to the liquid methane/ethane lakes of Titan or possibly liquid ammonia or CO2 on another world somewhere else), we can assume that it will utilize chemistry that happens in water. So that narrows things down. Then we look at the basic building blocks that are around. In our solar system, and many others we are discovering, the most abundant elements are H, C, N, O, P, S, etc. While it's possible that silicon-based or arsenic-based life could exist (though there are some chemical reasons why it would be difficult, I can get into that too if you want), it's less likely because that life would have more trouble finding the building blocks it would need to make the molecules it needs to stay alive.

So we look at what's around - amino acids, for example. There are tons of amino acids in meteorites (abiotically produced, so not made by life), and these are falling down on planets and moons all the time. So it makes sense that life might use these. This 'alien' life might use different amino acids than we do, and make different proteins (which are what you make when you string a lot of amino acids together), but it will probably leave a signature behind that we can find. When life isn't around, the most common amino acids you find are the ones that are easiest to make - glycine and alanine. But you can't make many interesting proteins from just these 2 amino acids. So if life is around, it will make and use more complex amino acids, things like maybe histidine, phenylalanine or others. Maybe different amino acids than what Earth life uses, but there will be a pattern. So we can look at the relative amounts of amino acids and, if some of these more complex amino acids are more abundant than we might expect, that would be a biosignature.

We also find nucleotides (the building blocks of nucleic acids, like amino acids are the building blocks for proteins) in meteorites too! So again, assuming life would use whatever's around, it might string nucleotides together to make it's own nucleic acids. While alien DNA or RNA may look very different from Earth life, the basic building blocks may very well be the same.

Sorry for the long answer, this is a hugely interesting topic and can't be encompassed well in a TL;DR! - Morgan

That's all well and good, but are you guys even asking the real questions here?! Like why is the meaning of life, universe and everything, 42?

Also, love NASA, and on a more serious note, what is the approach you guys are taking here? I can't wrap my head around "using satellites to measure life on Earth".

Thanks for the AMA!

nrj224

Tony: On Earth there are many ways that we can see life, or the consequences of life, from space. We can detect vegetation by looking at sunlight reflected from Earth's surface at different wavelengths. Vegetation on Earth absorbs red light but reflects light at wavelengths slight longer than the human eye can see. By comparing what we see at those two wavelengths with the satellite instrument MODIS we can tell that vegetation is there. More importantly by seeing how that changes with time we can identify whether vegetation is stressed or dying (e.g., due to heat stress or drought). NASA monitors this continuously, using what they call NDVI (the normalized difference vegetation index). We monitor carbon dioxide with the OCO-2 satellite and can see the seasonal decrease and increase of CO2 as plants grow (photosynthesis) and decay (respiration) in spring and fall. Most of the oxygen and methane in our atmosphere is due to life. And of course images of Earth at night show the bright lights of civilization.

That's all well and good, but are you guys even asking the real questions here?! Like why is the meaning of life, universe and everything, 42?

Also, love NASA, and on a more serious note, what is the approach you guys are taking here? I can't wrap my head around "using satellites to measure life on Earth".

Thanks for the AMA!

nrj224

The Earth will always be our best studied case of a habitable exoplanet. That means studying life on Earth directly feeds in to our search for life elsewhere. An example of this is using climate satellites, like DSCOVR: https://epic.gsfc.nasa.gov/ to model the Earth as an exoplanet. In this case, we are taking the beautiful images of the Earth and collapsing them down to a single pixel, and adding noise to the data that is expected from an exoplanet imaging mission. From these data we can determine the requirements needed to recover the Earth's rotation rate and the tilt of the Earth's axis. Since these are critical pieces of the Earth's long-term habitability, it is very important that we study how to measure these properties for other planets. Stephen

GREAT TOPIC. I once read a book called "Rare Earth," basically postulating that life in the universe may be common, but that "complex" life (beyond microbes) is likely rare. Do you think this might be the case? And if so, how might we detect the presence of "simple," microbial-based ecosystems from a distance? What are the challenges in trying to detect signs of single-celled life in an exoplanet (or moon like Europa) by passive means?

kiri-kin-tha

This is what is so *fun* about this field right now. We can take hypotheses like the "Rare Earth Hypothesis" and turn it into one we can test with observation (as all hypotheses should be tested).

Most of what we think about when we think about biosignatures is actually focused on the microbial signatures. That's because they dominate our planet, and have dominated it for billions of years. You can thank them for that oxygen you're breathing right now. (Plants too but the microbes figured it out first.) So that's an emphatic yes - we know how to see the signs of microbial-based ecosystems from a distance. But we wouldn't be looking for those individual cells, we'd be looking for the collective impact they have had on the planet.

So if we saw, for example, oxygen in a planet's atmosphere, along with water and methane, we'd have a pretty good idea *some living thing* was making that oxygen. Then the question is whether its microbes or plants or something else. Plants have their own signatures - they are really reflective at some wavelengths due to leaf structures. So if you saw the oxygen and the methane and the water all together but not that reflective feature that would be a hint (but probably not conclusive) that only simple life is on that world.

--shawn

GREAT TOPIC. I once read a book called "Rare Earth," basically postulating that life in the universe may be common, but that "complex" life (beyond microbes) is likely rare. Do you think this might be the case? And if so, how might we detect the presence of "simple," microbial-based ecosystems from a distance? What are the challenges in trying to detect signs of single-celled life in an exoplanet (or moon like Europa) by passive means?

kiri-kin-tha

Rare Earth is a great book that raises lots of interesting points. It's very difficult to answer this question definitively, but there may be some evidence to support the fact that 'simple' life may be common but complex life is more difficult. There may be a 'bottleneck' or 'critical step' in evolution en route from single celled life to more complex organisms that is just so fantastically unlikely to occur that it may never happen in the time that the planet on which that life emerged remains habitable. Therefore, the amount of time a planet can remain habitable for is really a important factor in considering the evolution of its biosphere!

In terms of detecting life from afar, we're becoming more aware of just how effective life is at altering the atmosphere of a planet, *especially* the smallest organisms like cyanobacteria on the Earth. Therefore, by studying the atmosphere of an exoplanet using techniques like spectroscopy we can determine whether or not life exists on that world if we can detect a particular gas or mixture of gases that is produced by that life. However, even using these techniques, there are still potential false positives and false negatives that might cloud our picture of these biosignatures. This is a popular area of research at the moment as our future space telescopes (like JSWT) will help us to answer this question, if we're able to interpret the results properly. - Andrew

How likely is it that we will find an intelligent species beyond our solar system that will require humans to band together to fight for our survival? How soon can we make this happen? Humans don't seem to care too much about destroying the world themselves but maybe if it's presented as an outside party creating the destruction of the planet more people will want to fight for it.

upvoatsforall

The Drake Equation is a good place to start when looking at the possible distribution of life (including intelligent species) throughout the Universe. Long story short, space is big. Really big. And humanity

has only been around, and transmitting radio signals and other evidence of our existence into space, for a very short period of time. The probability is nonzero (meaning it could happen) but it's really unlikely. - Morgan

Who has been there the longest out of you guys?

MastaCan

I think I'm probably the most junior scientist here! I've been working at NASA for the past 18 months. - Andrew

Who has been there the longest out of you guys?

MastaCan

Tony: I'm sure I'm the winner. I've worked for NASA for 32 years.

Who has been there the longest out of you guys?

MastaCan

I don't work for NASA and am a professor instead, so it's 0 years for me. I've been working on exoplanet discovery and habitability since 1995 though. Stephen

Who has been there the longest out of you guys?

MastaCan

I've been doing work at a NASA center since I was a graduate student, so 12 years. But I've only been a real, card-carrying NASA scientist for 4. - Morgan

The somewhat recent announcement about evidence of hydrothermal vents on Enceladus is very exciting. In the potential instance that life may have bloomed in these areas, how likely is it to have proliferated throughout the ocean as opposed to staying in these isolated hot spots?

Additional question I'm not sure can be answered: Would extremophiles that came to live in that environment be at all similar to those that live on Earth?

Thanks for doing this AMA!

Tartuffe

I'm super excited about this discovery too! The amount of life that could subsist in the Enceladus ocean is a topic of intense study right now. We have analogue environments on Earth that we can use as examples - places like the Lost City hydrothermal vents at the ocean floor, subglacial lakes in the Arctic and Antarctic, and deep polar ocean environments. These places are cold, energy-constrained and isolated from sunlight. While the cell densities and levels of organic carbon (and other biosignatures) are reduced compared to other environments, they are still detectable by modern instruments. I encourage taking a look at the Europa Lander Science Definition Team report, which goes into a lot of detail about these analogue environments (granted in the context of Europa instead

of Enceladus, but given these environments are similar to first order you can extend the biosignature detection strategy to both). The link to the report is here.

I think that, if extremophiles exist in the Enceladus ocean, they may look different from Earth life, but will most likely use the same chemistry. Life in this system will probably use the building blocks around it, meaning carbon, hydrogen, nitrogen, oxygen, etc., as Earth life does. They would have to survive in liquid water, which means they would probably have some kind of nonpolar carbon chains (like lipids or phospholipid fatty acids) to encase their molecular machinery and separate it from the environment (meaning: a cell membrane). They will probably use energy sources that are readily available - in hydrothermal systems, this is usually what we call 'redox chemistry'. Basically some molecules have too many electrons (they are reduced, the 'red' in 'redox') and some have too few (oxidized, the 'ox'), and life can take advantage of this by helping to move those electrons around, gaining some energy as a 'thank you' along the way. So we can look for evidence of life in these systems by searching for patterns in these basic building blocks and key indicators of life taking advantage of redox chemistry! - Morgan

1. How is it possible to prove that life exists on some of these planets light-years away? For instance Ross 128 b was recently discovered 11 light-years away. It could be full of simple single celled organisms or even plant life. These organisms would be incapable of communicating with us. Even if we found evidence of intelligent life so far away how would we go about trying to establish contact?

2. Enceladus may be the best hope for life in our solar system (besides earth of course). Are there currently any plans in the works to put a rover on it?

McGluvs

For number 2, yes we are developing mission concepts for Enceladus right now! Enceladus was added to the list of potential targets for a New Frontiers Mission (more information on the New Frontiers Program here), so if NASA selects an Enceladus mission to move forward we could start building a spacecraft to return there in the next few years. The concepts I've seen so far range from orbiters that fly through the plume, to landers, to cave-climbing robots that would get down into the vents, to even submersibles to explore the ocean itself! I hope to see one, some or all of these architectures explore Enceladus one day! Morgan

1. How is it possible to prove that life exists on some of these planets light-years away? For instance Ross 128 b was recently discovered 11 light-years away. It could be full of simple single celled organisms or even plant life. These organisms would be incapable of communicating with us. Even if we found evidence of intelligent life so far away how would we go about trying to establish contact?

2. Enceladus may be the best hope for life in our solar system (besides earth of course). Are there currently any plans in the works to put a rover on it?

McGluvs

For part 1, proving the existence of life on another planet is something that we will need to do indirectly, at least for the foreseeable future. That means even if we cannot travel there and take a ground sample like we do on Mars, we can still infer the presence of life due to the interaction life has with the atmosphere. For example, the Earth's biosphere has had a profound impact on our atmosphere as a function of time, such as the production of molecular oxygen and methane. The difficulty comes when we consider non-biological (geological) processes that can also produce these gas species, so proving

the presence of life on an exoplanet includes a careful ruling out of such false alarms. Stephen

1. How is it possible to prove that life exists on some of these planets light-years away? For instance Ross 128 b was recently discovered 11 light-years away. It could be full of simple single celled organisms or even plant life. These organisms would be incapable of communicating with us. Even if we found evidence of intelligent life so far away how would we go about trying to establish contact?

2. Enceladus may be the best hope for life in our solar system (besides earth of course). Are there currently any plans in the works to put a rover on it?

McGluvs

Tony: For #1, we will be looking for signs that there is water there, at least in vapor form (humidity). In a couple of decades it may be possible to detect an ocean om the surface. Then we look for as many of the gases that life produces as possible - oxygen (and ozone, which is made from oxygen), methane, and so on. If we're lucky we may some day be able to detect vegetation on the surface too, although vegetation on a planet orbiting a cool red star may not be green, might be red instead. About Ross 128 b: Given how close it is to its star, it gets 38% more starlight than the sunlight that Earth gets. So it's bound to be pretty hot, my guess is that it's too hot to be inhabited. If it spun on its axis more slowly than the 9.9 days orbit period implies, it might have a better chance. We assume that a lot of planets this close to their star have the same side facing the star all the time (as the Moon does with the Earth). If that happens, and if the planet has water, our climate models predict that a big thick cloud deck will form on the dayside and block the light like a sun umbrella and keep things from getting too hot. But the chances of that happening would be better if Ross 128 b took a longer time to orbit its star. But never say never... as people study it more we could learn something that we didn't expect. If there is life there, even simple life or plant life, we eventually might detect it by the gases that life produces, see many other comments in this AMA.

Which countries do you believe will be inhabitable byvthe end of this century?

landymud

Tony: Most countries will still be habitable by the end of the century. There are some small low-lying nations in the tropical Pacific that may be under water by then, depending on how fast sea level rises. Same for some coastal areas of the U.S. Some tropical countries that have been harmed by drought in the past may find conditions for living even more difficult as drought intensifies. Drought will be a problem too in already dry areas of the southwest U.S. BUT....that's if we continue on the path we're on now. It's up to us whether we ever get to that point.

Hi! Thank you for doing this AMA!

How can you consider our biosphere as the weird one, since we don't have anything else to help us do the comparison?

Hafornin

We try to not be 'Earth-centric' when we search for life elsewhere. In our own solar system, we have a great example of a completely different potential biosphere - Titan! This moon of Saturn has liquid hydrocarbon lakes, made of mostly methane and ethane. Any life that might exist in this environment would have to be very, very different from water-based life. So we are trying to figure out what kind of

'weird' life might exist in places like this, especially because there may be more Titans than Earths out there in the Universe! Statistically, the most common star out there is the red dwarf. Any planet in a stable orbit around a red dwarf is going to get about the same amount of light/heat from the star as Titan does from our sun. So chances are, there are more Titan-like worlds in the Universe than Earth-like worlds (making Earth the 'weird' exception to the rule). Meaning if we can find life on Titan, or chemistry that might lead to life there, it has truly 'Universal' implications! - Morgan

Shawn, what do you think the future of astrobiology will be for the next few decades? Do you have any predictions for new techniques that might arise or techniques that are difficult to use now but may become better refined?

LameJames1618

I think there are a few things on the horizon. For exoplanets, there's a lot of talk about machine learning being used for analysis of the data we get back. Tons of awesome stuff to do there. For in-situ (Mars and icy worlds) then whatever is "cutting edge" in biology, astrobiology tends to use a few years later. So... CRISPR stuff is hot right now in biology. My guess is we'll see a lot of that in the future. --shawn

How effective is the James Webb telescope going to be at determining the atmospheric composition for earth-sized exoplanets?

silence7

I love this question because my answer has changed recently. A year ago I would have said that Webb can do this... in theory, but not in practice, because it can only do it for darn-near-perfect targets.

But with the discovery of planets like those in the TRAPPIST 1 system, we have *darn-near-perfect* targets. So it can do this, at least for some atmospheric compositions. It will still be expensive (it will take a relatively large amount of telescope time). But it's possible! Stay tuned...

--shawn

What are 2--3 things you think the general public should know about Astrobiology that we may not at the moment?

onopau

Something I'll add to Shawn's response is that we often think of astrobiology being about the merging of astronomy and biology, but it has a much broader meaning. The discovery of terrestrial planets around other stars is forcing a remarkable merging of many scientific disciplines, including astronomy and biology but also geology and Earth sciences. This shared expertise forging new scientific directions is a large part of the exciting nature of the field. Stephen

What are 2--3 things you think the general public should know about Astrobiology that we may not at the moment?

onopau

1. Astrobiology is more than just "looking for aliens." Its also about looking at life here on Earth to better understand *how* and *where* to look for aliens.

2. Astrobiology has a bright future. Most of the "search for life" missions are 10-20 years away. So that means if you're a high school student now, by the time we fly these missions you could be me, sitting on a Reddit AMA answering questions about the mission's results.
3. Astrobiology has lots of targets to search for life on! Mars, Europa, Enceladus, Ceres, Titan, and billions of exoplanets. --shawn

What are the possibilities of non-carbon based life forms forming?

Do you think we will ever create a craft able to go to other systems in order to observe other life in a reasonable timeframe?

What are you looking for on exoplanets to see if life has already formed beyond just looking for planets in the habitable zone?

Is there any real evidence for the habitable zone beyond earth's distance? I imagine that there is math involved, but considering everything, like atmospheric composition, rotation, size of revolution, etc, how do we know that the habitable zone is truly accurate?

Wesus

On the habitable zone test... we don't have any explicit ones yet. We've found some planets in the habitable zones of other stars. But so far we just know about the sizes of these worlds, their orbits (how far they are from their star), and how hot their star is. But this just tells us which planets have the *potential* to harbor oceans. It doesn't tell us if any of these planets*actually have* oceans. For that we'd need to get spectral information on the planet itself. And that's what we're designing the next generation of space telescopes (and ground telescopes) to do!

Those future telescopes would also be able to look for signs of life in the planet's atmosphere or on the planet's surface. Like the oxygen you're breathing - that wouldn't be in our atmosphere if life wasn't producing it in massive quantities.

--shawn

What are the possibilities of non-carbon based life forms forming?

Do you think we will ever create a craft able to go to other systems in order to observe other life in a reasonable timeframe?

What are you looking for on exoplanets to see if life has already formed beyond just looking for planets in the habitable zone?

Is there any real evidence for the habitable zone beyond earth's distance? I imagine that there is math involved, but considering everything, like atmospheric composition, rotation, size of revolution, etc, how do we know that the habitable zone is truly accurate?

Wesus

Non-carbon based life forms - so carbon is actually really unique as an atom. It can form a variety of bonds (single, double, triple) with a lot of different other atoms. It can form long chains with itself and other atoms (important for creating large molecules capable of storing information, like DNA). Importantly, the bonds it forms are not too strong and not too weak (so they can be used to do chemistry important for life, or store and transfer energy, like in ATP). Other atoms can behave in similar ways, but not quite like carbon. Silicon, for example, can also form multiple bonds, but long chains tend to not be stable for long. Also while CO2 is a gas at biologically-relevant temperatures and

pressures, SiO2 is a solid. That makes it difficult to obtain or get rid of if you're a cell. I think the most telling aspect of silicon is that, although it is almost 1000 times more abundant on the Earth than carbon, life on Earth still evolved to use carbon. So life as we know it thinks carbon is pretty special.

That being said, the Universe is HUGE, and if there was some weird pocket of the Universe that was depleted in carbon, it's entirely possible that life would evolve without this element. It's just that, due to the abundance of carbon in the Universe, this is pretty unlikely. - Morgan

Is there even a tiny possibility the sun is one of the stars that are being absorbed by the Milky Way from the Sagittarius dwarf galaxy?

pr-mth-s

Current evidence regarding the composition of the Sun and its movement around the center of the Milky Way galaxy indicates that our sun is native to our galaxy and will remain so for a long time to come. Stephen

Young professional with degrees in Geography and GIS looking to use satellite imagery and remote sensing to work on amazing things like you guys. Any suggestions on how to bridge the gap to get where you are?

rhinogirl2

Two general ways: 1. You can try to leverage the skills you already have and find a job or research project that uses those skills. (It may be your coding chops, even if it's not GIS-specific.) 2. You can go back to school and get a degree in something else related to astrobiology and the search for life.

But whatever it is, you gotta love it. We work our tails off but that's a lot easier when you love the work.

--shawn

Young professional with degrees in Geography and GIS looking to use satellite imagery and remote sensing to work on amazing things like you guys. Any suggestions on how to bridge the gap to get where you are?

rhinogirl2

A lot of what NASA does is studying our own Earth, and your background fits perfectly here. I recommend looking into some of NASA's remote sensing work like the airborne and orbital imaging spectrometers. If you find it fascinating, apply for a position at NASA centers working on these, or **do an internship** (see details in the other comment I made on this thread about that!). Also check out the NASA Postdoctoral Program if you've got a Ph.D.

The best piece of advice someone ever gave me when it came to jobs was to push outside of my comfort zone. You might not find a position that perfectly fits your background, and that's okay - **apply anyway**. NASA won't hire you if they don't think you're right for the job, and if they do hire you, you are bound to learn something new! Best of luck in your next adventure! - Morgan

So, for us to inhabit a new plant like Mars, what things would we need to bring for plants or something that Mars doesn't have. Like what are the essentials that we need to provide to colonize?

Lupterns

Here's one answer, from the guy that used to be my boss's boss's boss:

https://astrobiology.nasa.gov/news/how-to-give-mars-an-atmosphere-maybe/

--shawn

What is your guy's view on the Fermi Paradox? Thank you ! :)

inzane772

Tony: See Stephen's comment to an earlier question about this. Intelligent civilizations may be a lot rarer than simple life forms. They may be too far away to realize yet that we're here. They may think we're too primitive to be interesting yet. Or there is the South Park theory that "Earth" is just an alien reality show.

Can you bring back the worm logo please? Thanks.

ieGod

That's above my pay grade, but I'll see what I can do. I really like the worm logo too! - Morgan

Hi team, thanks for doing this AMA!

- What would be your best guess to the types of animals (assuming they exist) on a given exoplanet with the available resources?
- Have we developed an earth based telescope strong enough to as tangible proof the moon landing wasn't a staged? (tired of the same arguments)
- What do you all enjoy doing on your downtime?

Boldly go!

Redditor_404

Animals: No idea. I think it would vary widely depending on the environment of that exoplanet. The key driver would be energy availability. If there is a lot of energy available (on Earth, for example, the majority of the energy we receive is from the sun, as opposed to geothermal energy or other sources), you could have huge organisms like we do (elephants, whales, etc.). If there is little energy, life may be limited in size to single-celled organisms or other forms that are very energy-efficient.

Moon landing: Turns out you don't even need a telescope to prove that - you can fire a laser and it will reflect off of mirrors the Apollo missions left behind. Okay, due to dispersion of the laser beam you still need a telescope to do that, but I think it's really cool.

Downtime: I enjoy a lot of things, from reading and surfing to some more unusual sports like mountain unicycling (google it, you won't be disappointed). I think it's important to have balance, and it's something I'm still working on achieving. One thing I have noticed about my colleagues is we all seem to pursue our hobbies with the same passion as our work. So if you ask a NASA scientist what they like to do for fun, you are bound to get an interesting story! - Morgan

Would NASA ever consider using mining of asteroids to fund its projects? Also Gnorts Mr Alien.

BertnErnie32

NASA is funded completely by you - the taxpayers. I think that's what makes our work so great, since we're motivated purely by our drive to learn more about the Universe and our place in it. I dream of the day when traveling to space is commonplace, and commercial interest and investment in things like asteroid mining is an important step in that direction. - Elbacnagrom

Would NASA ever consider using mining of asteroids to fund its projects? Also Gnorts Mr Alien.

BertnErnie32

If NASA did head to asteroids our primary mission there would to be prove that we**can**, because this is what we do best! NASA dares the mighty things and leads the way to enable, in this case, commercial space companies to follow. - ybhsurwerdna

Would NASA ever consider using mining of asteroids to fund its projects? Also Gnorts Mr Alien.

BertnErnie32

There's been lots of talk about this in a broad sense. But it's usually w.r.t. private enterprise doing the mining, not NASA. But NASA is helping pave the way for things like that with the technologies we are developing.

-- Nam Dlog-Lag Amod N. Wahs

Would NASA ever consider using mining of asteroids to fund its projects? Also Gnorts Mr Alien.

BertnErnie32

I don't believe that NASA mining asteroids for funding is any more likely than NASA mining Earth for funding. That's more of a commercial enterprise. If we found oil on Titan however ... - Enak Nehpets

Are there any more of Megalodon near surface sightings as seen some time ago on... I think it was Shark week on Discovery that I saw it on ?

CyberAssassinSRB

Not that I'm aware of. It would be so incredible to find something like that on Europa or Enceladus! - Morgan