Science AMA Series: Hi Reddit, I'm Sarah Hörst, Professor of Planetary Science at Johns Hopkins University, here to talk about the outer solar system (especially Titan). Ask me anything!

AmGeophysicalU-AMA [1] and r/Science AMAs[1]

[1]Affiliation not available

April 17, 2023

Abstract

I am Sarah Hörst, Assistant Professor in the Department of Earth and Planetary Sciences at Johns Hopkins University. I study planetary atmospheric chemistry and have spent most of my career trying to unravel the mysteries of Saturn's largest moon Titan and much of my work has been inspired. My group also studies exoplanets, Europa, Saturn, Pluto, and Venus. We are use experiments, models, and analysis of telescope and spacecraft data to improve our understanding of the role atmospheres play in the origin and evolution of life and the habitability of a planet. We are trying to answer questions like how far can organic chemistry proceed in the absence of life? You can learn more about us and our work at www.sarahhorst.com. I hope to answer lots of questions about the solar system and how we study it. I will back at 1 pm ET to answer your questions, See you all soon!

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REDDIT

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AMGEOPHYSICALU-AMA R/SCIENCE

I am Sarah Hörst, Assistant Professor in the Department of Earth and Planetary Sciences at Johns Hopkins University. I study planetary atmospheric chemistry and have spent most of my career trying to unravel the mysteries of Saturn's largest moon Titan and much of my work has been inspired. My group also studies exoplanets, Europa, Saturn, Pluto, and Venus. We are use experiments, models, and analysis of telescope and spacecraft data to improve our understanding of the role atmospheres play in the origin and evolution of life and the habitability of a planet. We are trying to answer questions like how far can organic chemistry proceed in the absence of life? You can learn more about us and our work at www.sarahhorst.com. I hope to answer lots of questions about the solar system and how we study it.
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Assuming unlimited budget and the best of current technology at your disposal, what would be your dream mission?

Lavidius

I get asked this question frequently. Of course if I had an unlimited budget I would send spacecraft everywhere :) If I had to limit it to one system, I think I would pick another Saturn system mission with multiple spacecraft elements. We've learned from both Mars exploration and from Cassini Huygens that having a landed element (or elements) and an orbital component *at the same time* is hugely powerful for understanding a world. The whole is definitely more than the sum of its parts when we have this type of opportunity. So it would be great to have a Titan boat or quadcopter or other type of landed (or quasi-landed) element at the same time as an orbiter. For Titan (and also Venus) because the atmosphere is so think, it would also be useful to have an element that is in the lower atmosphere like a balloon or any airplane because the atmospheres make it a bit more challenging (say compared to Mars) to study the surface from orbit. And of course if we are already going to the Saturn system we might as well take along an Enceladus spacecraft too (or maybe our orbiter could study both Titan and Enceladus, which is a concept that has already been studied a few times).

What solar system body do you most want a sample return mission from? And what specifically would you want to search for with it?

charonpdx

If we could do cryogenic sample return from *the liquids* of any of the ocean worlds (especially Europa, Enceladus, or Titan) that would probably be the thing that I would be most excited about in terms of sample return. I would also be really excited if we could drill a core from Titan's surface and return that as well. First and foremost I would want to search for life or evidence of life. But even if there isn't life, having samples in an Earth lab allows us to use numerous techniques that can be challenging to fly on a spacecraft.

Do you think Europa will be explored by robots in the near future? What would be the best method to explore the oceans under the crust? How do we make sure we don't contaminate any worlds that could perhaps harbor life in the future?

RV2115

The Europa Clipper team is hard at work on a spacecraft that should launch around 2022 and will orbit Jupiter, but study Europa with multiple flybys in much the same way that Cassini was a Saturn orbiter, but was able to study a large fraction of Titan's surface and atmosphere through numerous flybys. NASA is also currently studying a Europa Lander that might be a follow on to Europa Clipper and would land and search for signs of life but that concept is not as far along as Europa Clipper.

Exploring the ocean under the crust is likely to prove challenging, but it depends a lot on how thick the crust is. There is evidence that at least in some places the crust might be quite thin and that might be somewhere we decide to send a spacecraft either to get direct access to the ocean by getting through the ice (somehow) or by studying material that has come up from the ocean onto the surface relatively recently (at least on geologic timescales). We have scientists like Prof. Britney Schmidt at Georgia Tech who are testing ideas about how to explore Europa's ocean (or other ocean worlds) here on Earth in Antarctica. It will definitely be a technological challenge!

In terms of contamination, NASA has an Office of Planetary Protection and their entire job is to ensure that as we explore the solar system, we don't contaminate the places that we visit. And when we bring samples back they make sure we don't contaminate Earth. There are lots of different ways to do this and it depends on the place we are visiting and the spacecraft but a number of different sterilization techniques are employed and spacecraft are tested at every step in the process.

Titan, Enceladus, and Europa seem to be good candidates in the search for life but obviously each one presents its own unique challenges. Which do you think would be the least challenging for us to get to and begin the search?

DevinDTA

I always tell everyone that Enceladus is a very helpful moon because it is spraying the contents of its ocean out into the Saturn system for us to measure. So Enceladus certainly has the plumes in its favor. There is some evidence that Europa also has a plume (or plumes) although it is still a subject of debate within our community so we still aren't sure that Europa has plumes. Europa also suffers from the fact that the radiation environment around Jupiter is more challenging that the radiation environment at Saturn. One of the things that Titan has in its favor is a big fluffy atmosphere that makes landing there much easier than landing on Europa or Enceladus. So it depends in a lot of ways on what kind of mission you want to send, how long it needs to last, if it needs to land or not, etc.

As a scientist studying Titan, what was it like to see Cassini's mission finally come to an end? Did you use any data from that spacecraft?

shiruken

I think it will take a little while before it fully sinks in because we have so much amazing data from the mission. I will definitely miss having new data, but more than that the mission team will eventually disperse as some people retire and everyone else goes on to work on other projects. It will make it more challenging to keep the vibrant and productive scientific community we've built together and I'm more sad about that. The people who study the Saturn system are amazing and we've had this golden age of Saturn system science because of Cassini-Huygens. I was with the team for the End of Mission (EOM) and it was like this bittersweet family reunion. The last few months of the mission (the "proximal orbits" and "the plunge") provided us with amazing new data that we couldn't get during earlier phases of the mission so that's really exciting and something that could not have happened unless the mission ended in this way. In the computer modeling of Titan's atmosphere that I do, we use a lot of information that has been acquired by Cassini-Huygens and we also use Cassini measurements to test how well our model is doing. for the experiments my group runs, we also try to compare our results as often as possible to Cassini-Huygens measurements when they are relevant. Also my first job after college was analyzing Cassini imaging data of Saturn right after Saturn Orbit Insertion (SOI).

Do you see human habitation of the solar system inevitable and if so what are your opinions on how it should be done?

PS Thank you for all of the work you did with Cassini, a truly amazing job well done!

jakluesn

For me the word inevitable implies that we have no control or no choice. So I don't think it is inevitable in that sense. I think that we could choose to limit human exploration to visits rather than setting up more permanent living situations, if we decided that was what we would rather do (or should do, etc). However, I think that isn't the choice that we will make. I think eventually we will choose to do it. I really hope that when we do, we involve as many different groups and areas of expertise as possible including historians, theologians, and philosophers. Historically we haven't shown that we are very good caretakers of the Earth or humankind and I worry that our future endeavors will be just as flawed as our past. Dr. Lucianne Walkowicz is the new Astrobiology Chair for the Library of Congress and one of her projects as chair will be to look at building an inclusive framework for human exploration of Mars. I'm really looking forward to seeing the results of that project. Drs. Danielle Lee, Chanda Prescod-Weinstein, and Zuleyka Zevallos have been leading some really interesting and important discussions about human exploration as well.

So we have been looking at planets, exoplanets and moons. Then when talking about life we have certain methods to determine if there could be life but those methods are based on our life on earth what about life based on other molecules then life here on earth, no water but another dipolar molecule and maybe even not carbon but something else as the building blocks of life. Do you consider this as a possibility. And if so explain why you do/don't

ROGGOGG

We definitely think about this issue a lot. With only one example of fundamental biochemistry it is hard to know what else to look for. The strategy that many missions or mission concepts are embracing is to do sets of chemical measurements that are non-specific, that is they characterize the composition of the material (atmosphere, ice, ocean) that we are looking at completely rather than looking for specific molecules like amino acids or nucleobases. Of course we want to be able to look for those too in case there is Earth-like life somewhere else. This is a continuing area of very important discussion. We definitely don't want to miss the chance to discover extraterrestrial life because we let our biases about

what life might look like get in the way!

Hi and thanks for joining us today!

So, do you think life on Earth came about through abiogenesis or panspermia?

PHealthy

That's such a hard question. I think the idea of panspermia is really interesting (and thanks for making those link-y so other people can read about them!) but if life on Earth came about from panspermia it most likely would've come from Mars. There is still a lot of debate about what early Mars was like, but for me it is hard to imagine that early Mars was *more* habitable than Earth. If the origin of life is easy, then you could maybe imagine it arising separately on both Earth and Mars, but if that is the case then panspermia might not have been that important. So I guess that is a long way of saying right now I think abiogenesis is more likely, but I still think we have a long way to go before we truly understand how life on Earth came about.

Thanks for coming to talk to us! A lot of science fiction writes about Titan and Europa. Is there any sci fi that impresses you with its insight?

asbruckman

Although I have read a fair amount of science fiction (less now than I did as a kid) I haven't read much that is specifically about Titan or Europa (even though I know there is a lot!). I guess I've always found science fiction more interesting for the visions of the future that it provides us rather than the specific science content. Although I haven't reread it in a long time, The Sirens of Titan (Kurt Vonnegut) was one of my favorite books as a teenager. I even wrote an essay about in my junior English class in high school.

If you could spec a Cassini/Huygens 2 mission, what would you change on the spacecraft given what you've learned the first time around?

bless-you-mlud

Finally an easy (but still really great) question! If we knew then, what we know now, we would've sent a better mass spectrometer (which measures the chemical composition directly by pulling gases or particles into the instrument) with a larger mass range (to measure the very heavy molecules we now know exist in Titan's atmosphere) and better resolution to help us identify molecules. Titan's atmospheric composition is *way* more complicated than we thought it was. Cassini also had a "scan platform" that was "descoped" (removed) when Cassini ran into budget problems. The scan platform would've allowed the instruments to move more independently, rather than requiring the entire spacecraft to move to move an instrument, and that would've allowed more instruments to get optimized observations at any given time (and would probably have reduced arguments between instrument teams!).

If you could spec a Cassini/Huygens 2 mission, what would you change on the spacecraft given what you've learned the first time around?

bless-you-mlud

Also the idea of Cassini/Huygens 2 makes me unreasonably happy. :)

Can you give us an intuition of what it is like to dive into the stormy clouds of massive gas giant planets like Jupiter and Saturn? Did Cassini eventually reach a solid core and crash into it or was it simply destroyed by the storm?

RobiNoob21

I'm not sure I have much of an intuition about what that was like other than I'm pretty glad it didn't happen to me! I suspect it would be somewhat like descending through the clouds in an airplane until the part where the spacecraft started melting and vaporizing. Cassini would've vaporized before it got very deep in Saturn's atmosphere in the same way that meteors burn up in the Earth's atmosphere. It is likely that the RTG (Cassini's plutonium power supply) was the last part to vaporize, but even it didn't get very deep and definitely wouldn't have gotten all the way to the core.

What are the difficulties of studying the possibility of extraterrestrial life, if the origin of life is not known yet?

Also, how excited are you for the James Webb Space Telescope? How will it possibly impact your research?

missle636

If you can see the creatures moving around or building cities etc then it is a lot more obvious that life of some kind exists somewhere. If we are talking about just looking for chemical signatures (which we are when we are talking about looking at exoplanets with James Webb) you have to know *a lot* about the place to convince yourself that the signatures you are seeing aren't just the result of naturally occurring processes. I think this is one of the biggest challenges. Even with decades of study at Titan and 13 years of Cassini in orbit around Saturn, there is chemistry we don't understand happening on Titan that could be interpreted as evidence of life if one was inclined to interpret it that way (and some are) so we have to be really careful that we have ruled out every other possible explanation....extraordinary claims require extraordinary evidence etc. For James Webb, we are doing a lot of atmosphere simulation experiments right now in support of James Webb with the hope that we can help them choose what kinds of atmospheres they might want to look at and also help them understand their data after they are acquired. I'm sure once the data start coming back we'll have even more questions that we can hopefully help answer with more target experiments.

Thanks so much for taking the time to do this!! This is really cool. 1)What is the current research on vinyl cyanide on Titan and it's ability to form membranes? If there is life on Titan, do you think it is likely that it involves vinyl cyanide or is it too soon to tell? 2) Are there going to be any missions in the future to Titan to take samples of the actual matter on the moon? 3) Do you think people will soon be able to go to Titan? 4) What do you think are the requirements for life?

astrogorl

(1) I'm not sure anyone is actively doing any more work on understanding the ability of vinyl cyanide to form membranes on Titan. The most obvious next step would be to investigate it with experiments but those experiments aren't easy and I'm not sure anyone is planning to do them at the moment. I think it is way too soon to tell what chemistry life on Titan would use. The interesting thing IMHO about the vinyl cyanide work is that it shows it might be possible to make membranes on Titan, but it is just one example, it might not be the way life would do it, if it exists. (2) Right now there aren't any missions on

the books for any space agencies to go back to the Saturn system, but there are two missions (out of 12 total) to Titan currently proposed to NASA's New Frontiers Program (and also two missions proposed to Enceladus). One of those *proposed* Titan missions, called Dragonfly, would sample material on the surface (and the near surface atmosphere) and help us determine its composition. The other one, Oceanus, would measure atmospheric material (high in the atmosphere) directly. (3) I don't know if people will ever go to Titan, but I don't think it will be soon (or at least not in the way that people think about "soon") (4) We believe the big picture requirements for life are a liquid solvent (like water for example), an energy source (could be chemical, could be light), building blocks (like organic molecules such as amino acids), and time. We still don't know if water is the only solvent that would work or if maybe the methane in Titan's lakes (for example) would also be an acceptable solvent. We still have so much to learn!

Besides simply for the purpose of understanding the universe, what do you think is the main impetus behind studying/exploring space?

astrogorl

I mean, I think understanding the universe is a pretty good reason. But one of the reasons we study planets is because Earth is a planet that is incredibly important to our survival. Studying Earth is incredibly important but to understand how Earth works, it is important to study other planets as well. Other plants provide us the opportunity to test our understanding. If we think we know how Earth's climate works, we should be able to apply that knowledge to the climate of Venus or Titan. So planetary science in particular is really important for building a fundamental understanding of how planets work remembering that Earth is a planet too.

What can we learn about Polar Stratospheric Clouds on Earth from Titan? Thanks!

Klekociuk

We now know that Titan's winter pole (the north pole when Cassini arrived at Saturn, the south pole now) possesses a vortex like many other planetary poles in the solar system (for example Earth, Venus, and Mars all have polar vortices as well). About five years ago as the polar vortex was forming at Titan's south pole a giant hydrogen cyanide (HCN) ice cloud appeared at Titan's south pole in the stratosphere. One of the interesting things about Titan is that it seems to have a number of different ices in its atmosphere so it provides us the chance to test our ideas about how atmospheric ice clouds form and the role that they play in atmospheric chemistry, radiation transfer, and dynamics. We're very early in these studies but there is some really interesting Titan ice work being done by Dr. Carrie Anderson and her group at NASA Goddard. I think polar vortices in general and PSCs in particular are one of many areas where the comparative planetology that we are now able to do will really help us understand what is going on.

Hello Sarah! Is there any chance of a subsurface ocean on Titan (H2O or otherwise) as there is on Europa, Enceladus etc? Would surface liquid seas of methane necessarily preclude that? Thanks--

Curiousful

Yes! We always forget to tell people this because we are so busy talking about all of the other interesting things about Titan, but we have evidence from a number of different measurements and models that Titan has a subsurface liquid water ocean in addition to is large lakes/seas of hydrocarbons on the surface. The crust is likely much thicker than on Europa or Enceladus, but it seems very likely that it has a subsurface liquid water ocean too! This means that Titan provides us to

search for life as we know it and life as we don't know it!

Do we see evidence of Rossby waves in the atmosphere of Titan? Orographic gravity waves too? Hi to Darren Waugh at JHU!

Klekociuk

The mountains on Titan aren't very tall. Although we do see evidence of gravity waves I think the general consensus is that at least those waves are not orographic. Some of the cloud features on Titan have been attributed to Rossby waves. I'll tell Darryn you say hello!

I learned embarrassingly recently that most gas giants have cores. Are the cores of gas giants made up of the same material as the gas that surrounds it? Are the cores slowly growing with time due to its gravitational effect on the surrounding gas?

I also know that gas giants formed because of faster cooling in that area in space causing the formation of ice particles that allowed matter to group together faster than the hotter places where rocky planets formed. So my question is, how were the moons of these gaseous planets able to form as solid objects instead of gaseous objects? Are moons rocky (made of metals)?

astrogorl

We think the cores are probably some combination of ice and rock so in some ways they are kind of like big terrestrial planets surrounded by a ton of gas. Then we think there is a transition region between the ice/rock cores and the atmosphere where metallic hydrogen exists. We still have A LOT of questions about the interiors of planets in general and especially the interiors of giant planets. The Juno mission currently at Jupiter was designed to try to answer a lot of those questions for Jupiter and hopefully some of the end of mission data for Cassini will help us get closer to answer some questions about Saturn's interior. The giant planet moons are a combination of ice and rock (Titan is about half and half based on its density) and they likely formed out of the cloud of material that surrounded the giant planets as they formed (we call these clouds the subjovian and subsaturnian nebulae for Jupiter and Saturn). We still have A LOT of questions about how giant planets and their moons form. Hopefully studying exoplanets will help us provide some of the puzzle pieces necessary answer some of these questions

Is it possible that human space exploration has been spreading micro organisms throughout the solar system? Does Voyager contain any cellular life from Earth? Say our probes and vehicles do carry these organisms, what conditions would be required on a planet to allow Earth organisms to grow and multiply?

Purgatory_Dog

As I mentioned in another answer here, NASA has an office of Planetary protection that is very concerned with these issues. Here is the relevant part of that answer copied and pasted "In terms of contamination, NASA has an Office of Planetary Protection and their entire job is to ensure that as we explore the solar system, we don't contaminate the places that we visit. And when we bring samples back they make sure we don't contaminate Earth. There are lots of different ways to do this and it depends on the place we are visiting and the spacecraft but a number of different sterilization techniques are employed and spacecraft are tested at every step in the process" We try very hard to minimize the number of organisms carried by our vehicles. It would depend on the organism what is required (liquid water might be required for example, so we are extra careful with places that have

water) but this is still an ongoing area of research as we learn more about organisms that can survive in extreme environments ("extremophiles").

With Cassini gone, how will that impact how you study Titan?

Cosmos3110

Because my group primarily does modeling and experiments, we can keep doing that work even without Cassini (or new data from Cassini). There is so much Cassini data though that people will be analyzing it for decades to come. So right now there won't be a huge impact on how we study Titan. We have plenty of questions that we can continue to work on answer for a number of years to come.

Potential contamination of Saturn's moons has been a topic brought up by the end of the Cassini mission. Were any special precautions taken with respect to the Huygens probe landing on Titan?

MKellyISU

Yes. All spacecraft undergo planetary protection protocols to make sure that we are as careful as possible. I don't know the specific details of the planetary protection protocols that Huygens underwent, but since we were already *very* interested in the astrobiological potential of Titan (which is one of the reasons we sent the Huygens probe in the first place) this was definitely considered carefully. (I talk a bit about planetary protection in some of the answers here as well. A hot topic today!)

In light of today's OSIRIS-Rex flyby, how important is sample return for any Saturnian or Jovian planet/moon data? Can probes and orbiters get the job done if we are talking about finding extremophiles? Mars samples seem easier (proximity) but how will we ultimately make the big breakthrough?

Huge fan, thanks for all your work esp sharing on Twitter!

bradpatrick

Of course having samples is really great because it allows us to use all of our very powerful Earth laboratory techniques, some of which can be somewhere between very challenging and basically impossible to do with a spacecraft. I do think that robotic spacecraft can get the job done if there are any but I think it is also time to start considering cryogenic sample return from a number of these bodies and indeed people are already starting to study how to do that. You are very welcome!

This is incredible! Your research is *exactly* my dream job. (Okay, maybe a little less atmospheric chemistry, a little more subplanetary structural geo, but I've always loved organic chem also!!)

I'm in my second year of college, math+geology. I'm trying to as involved in my department as possible and get into all the research opportunities I can, but I'm not always seeing the long-term goal. Do you have any advice? Especially for grad?

Thank you so much! It's amazing that you're doing an AMA: I wasn't ever even 100% sure that people did what I was always dreaming of doing!

roidsinspace

I think it is perfectly normal in your second year of college to not always (or maybe ever occasionally)

to see the long term goal. Right now it is important to learn as much as you can and take advantage of as many opportunities as you can. Getting involved in research early is a great start because it will help you figure out what types of research you like (experiments, field work, computer modeling, data analysis) and what content areas you find particularly interesting (or completely boring). Just keep asking questions and learning and eventually you will find the way forward!

What's the current understanding of the tectonic/atmospheric cycles on Titan? How much do we know about them?

Bowgentle

The connection between Titan's interior, surface, and atmosphere is still a really active area of research. For example, much to everyone's consternation, despite 13 years in orbit around Saturn we still don't understand the origin of Titan's atmospheric methane, which should be destroyed by solar photons in much less time than the age of the solar system unless it is being resupplied somehow. The general assumption is that it is coming from the surface and/or interior somehow but we still aren't really sure how. Hopefully the answer is still hiding in the Cassini-Huygens data somewhere or maybe in data we can acquire from an Earth based telescope, otherwise this decades old question is going to continue to plague our community for many years to come.

Life often has to use trace elements in enzymes, usually metals. Have you found any metals on Titan? Could there be life without iron, copper, magnesium, etc?

rahendric

We didn't have a good way of detecting them from Cassini but there will definitely at least be some from impacts of small bodies like comets and meteorites. We don't really know what life requires, could life invent a way to provide the functions of some of those metals from other molecules? I'm not sure. This is one of the reasons we should find out!

What have we discovered about Pluto's atmosphere from the New Horizons' data?

sagareshwar

A lot! Some of the biggest surprises are that it doesn't seem to be escaping at the rate that we thought it would be. Also although there had been evidence of haze (kind of like smog) in Pluto's atmosphere before New Horizons I think most (if not all) of us didn't think we would be able to SEE it in the imaging data so I think those iconic images of Pluto's haze were a big (pleasant) surprise for a lot of people.