|  |  |
| --- | --- |
| Tiffany Kataria: | Great. Alright, well yeah, let's get started. Good afternoon everyone, I'm so excited to introduce the first of what will be five ExoExplorer Science Series talks but before we even begin with that, I first wanted to wish everyone a happy Chinese New Year. I think we can all agree in hoping that the Year of the Ox will bring good fortune, so I wanted to start off by saying that and also introducing myself. I am Tiffany Kataria, I'm the Chair of the Steering Committee for the ExoExplorer Science Series. And again, thank you so much for attending the first of what are going to be very stellar presentations. |
|  | So I wanted to start off with a brief intro explaining what the ExoExplorers Science Series is. It's sponsored by the ExoPAG Executive Committee and the NASA's Exoplanet Exploration Program, and it aims to enable the professional development of a cohort of graduate students and postdocs in exoplanet research. We're going by ExoExplorers, for short. Each member of the cohort will be featured in a webinar, such as this one, that will be live streamed to the exoplanet community, helping to increase their visibility within the field which is really important, especially during these times. The cohort will also learn from experiences of established exoplanet researchers in the field, that we've dubbed ExoGuides, via a combination of tailored presentations and small group discussions. The first cohort is currently running from January until June of this year and is comprised of 10 excellent early career scientists, that really excited for you to hear from all of them over the course of these next few months. If you want to learn more information about the programs, our Organizing Committee Chair, Vanessa Bailey, will be posting some links in the chat. |
|  | And so with that, just some ground rules. A reminder from our welcome message to behave professionally in this forum. Let's all be kind to each other and we definitely plan to save questions largely speaking until the end. So please use the chat, the Webex chat, or the raise hands tool to answer your questions at the end of each talk. You can see that by hovering over your name in the participant list, you should see the raise hand icon. And with that, let's get started. So our first speaker this afternoon is Caprice Phillips. Caprice got her B.S. from the University of Arkansas at Little Rock, M.A. at UT Austin and is currently a second year PhD at The Ohio State University. She is also the co-organizer of BlackInAstro aimed at highlighting and celebrating black scientists in space related fields, which is super important this month but every month of the year. And with that, take it away Caprice, if you want to pull up your slides and you can introduce yourself. |
| Caprice Phillips: | Okay, thank you for that introduction. Let me just start sharing my screen. Okay so, alright I think everyone can see my screen hopefully, okay thumbs up from Vanessa and Tiffany. Alright, thank you for the introduction, so she mentioned my name is Caprice and my pronouns are she/her and hers. Let's see, I'm a second year PhD student at The Ohio State University and today I am going to be talking about the research and what I'm doing at OSU involving determining whether we can detect biosignatures in the atmosphere of Gas Dwarf planets with JWST. And I just wanted to give a special thank you to the ExoExplorers program for this opportunity and all the support and help that they're providing us. |
|  | So we have a great team for this work and a pretty good subject space from the JWST proposal. I have my advisor, Ji Wang, here at OSU. There is Sarah Kendrew at the Space Telescope Sciene Institute who is a [inaudible] expert. We have Tom Greene at NASA Ames who is an expert in Near-Infrared Spectroscopy. We also have Renyu Hu at JPL who is helping out with photo chemical modeling, and we also have graduate student, Joe Schulze and Wendy Panero. Panero, who are assisting with the interior modeling of the planets along with Jeff Valenti from the STSci [inaudible]. I'm really excited to be working with all of them. |
|  | So I wanted to give an outline for my talk and the structure to have my [inaudible]. I'm going to go into the background of Gas Dwarf planets followed by [inaudible] atmospheric biosignatures, followed by Gas Dwarf atmosphere, [inaudible] having ammonia as a biosignature, detecting ammonia in the biosignature of Gas Dwarf planets, followed by [inaudible] simulation of observations detected with JWST. |
|  | So just a little bit of background on Gas Dwarf planets. So Bucchave, in 2014, published a paper distinguishing [inaudible] into three major groups based on stellar metallicities and distinguished the boundaries of those planets. Below 1.7 Earth's radii, they said they would like to do just a gassy planet and above 3.9 Earth's radii would have gas giant. There is an in between range between 1.7 and 3.9 Earth's radii which is the Gas Dwarf. We also have massive Hydrogen [inaudible] and that radii range also includes something called Super Earth and Mini-Neptunes, and so when we read lines from [inaudible] as shown here is that [inaudible] known transiting planets by size that Super Earths and Mini-Neptunes are the most abundant type of planets that we know. And we know this thanks to the crypto machine [inaudible]. And we know a little about the atmospheric composition and structure [inaudible]. |
|  | So Gas Dwarfs like Super Earths and sub-Neptunes are very interesting because they aren't analogous in our solar system. We have, what we have found is a very structured system. We have the inner-rocky planets like Mercury, Venus, Earth and Mars, followed by the gas giants, Jupiter and Saturn, followed by ice-giants. So we don't have analogs [inaudible] in the solar system. So it begs the question of, are they still that version, are they inner-rocky planets or round versions of the gas giants, how do we distinguish between Super Earths and sub-Neptunes just under the ongoing questions. |
| Tiffany Kataria: | And what do their atmospheric compositions look like? |
| Caprice Phillips: | So as I mentioned, my Gas Dwarfs are unique exoplanets to characterize and search for biosignatures. Because they have a massive atmospheric composition, they look different than what we are used to such as Earth and so there might be different types of biosignatures. One of them that we are going to talk about is ammonia and so hopefully we can use upcoming instruments. There is JWST [inaudible] to probe into the atmospheres of Super Earths. |
|  | So also I just wanted to mention that the successor to Kepler, TESS, is providing great targets for follow-up observations with JWST. TESS recently celebrated its 100th exoplanet confirmation and so that's really exciting. It found really temperic [inaudible] Earths, Super Earths and sub-Neptunes that are great follow-up observations with JWST. And one of the examples of this is the TOI 270 system. It has a Super Earth and 2 sub-Neptunes that cling to the gassy planets that I described [inaudible]. |
|  | So switching gears a little bit, I wanted to start talking about what exactly is atmospheric biosignature. So essentially an atmospheric biosignature is a gas whose presence in an atmosphere indicates that the planet likely harbors life. In 2013, Meadows and Seager defined kind of three main criteria here. The first one is that it is generated by life, the second one is that it can build up in the planetary atmosphere to be detectable and the third being that it's present or active in wavelength range being observed. |
|  | Alright so when we're considering whether a biosignature [inaudible] satisfies the criteria shown in the previous slide, we want to add whether or not this biosignature is ideal and [inaudible] to ask does it not naturally occur in the atmosphere at certain pressures and pressures, is it not created by geophysical properties like volcanic activity. Is it not produced by photochemistry or easily destroyed by photochemistry and again does it have a strong spectral feature. So, for example, say we consider Earth's atmosphere which is made up of primarily nitrogen, about 78% and although this feature has strong biological sources, it doesn't have rotational vibrational transitions, there are no features present and visible or it would need this kind of criteria for being an ideal biosignature. |
|  | So in 2013, Serry Seager, had two papers describing ammonia as a biosignature in a hydrogen dominated atmosphere. So ammonia was described as one of the strongest biosignature candidates in the atmosphere of a hydrogen dominated Super Earth and the idea is that ammonia would be produced by an atmosphere rich in hydrogen and nitrogen and so microbial life could catalyze the breaking of the hydrogen and nitrogen bonds and capture the energy released and hopefully would provide an excess in atmosphere that would build up to possibly detectable levels. And so these reaction of spontaneously [inaudible] happen, under a temperature is about 1300 kelvin and needs a catalyst. |
|  | So, when I mentioned ammonia, those who aren't familiar with the idea, ammonia is a biosignature in the atmospheres of Gas Dwarfs or Super Earths. I initially associate ammonia with things such as Brown Dwarfs where the dominant form of nitrogen is ammonia and it's often present in cool [inaudible] and also it can be naturally occurring in Jupiter, really higher pressures. So I just wanted to give some background context [inaudible] heard about ammonia before, these might be the contents that you're used to hearing about it. |
|  | So in the series of papers, modeling biosignatures and biomass models, Seager experimented with something called Cold Haber World. So the idea is that it models the Haber process on Earth, which you need an iron catalyst and high temperatures to produce ammonia. So they experimented with creating this kind of synthetic Super Earth, what we want to see, we can detect, ammonia in the atmosphere of this planet. So what we have here is a planetary irradiance followed by the wavelength range and the [inaudible]. So they experimented with a 75% nitrogen and 25% hydrogen, which should be a high mean molecular weight atmosphere. And they showed that we can see in the blue here, 0.4 ppm and also they experimented with 4.0 ppm, a higher concentration and we have of course, deeper absorption features with more ammonia present in the atmosphere and this is a start of the basis for our work by looking at the foundation. |
|  | Excuse me. In another paper, they also, Seager in 2013, also looked at planetary radius and theoretical transmission spectra for Cold Haber World. And she also experimented with varying the concentration of ammonia in the atmosphere from 0 to 0.5,5 ppm, 50 ppm and 500 ppm, showing there are lots of ammonia features present and of course with a higher concentration of ammonia, shown in red here versus the blue then we get a higher transmission signal. This is just some more background for the foundation [inaudible] development. Excuse me. |
|  | So Seager also made sure to emphasize that there is a caution for false positives for ammonia. The first would be a rocky world with a hot surface temperature of around 100, I mean sorry 820 kelvin but we are not interested in targets that would be this hot. And also there is as I mentioned, the naturally occurring ammonia in the atmospheres of gas giants and some mini Neptunes. And then the last one would be, planets with outgassed ammonia, as a planet form, gas fully vented from the interior during evolution but she also mentioned that we need to treat planets on a case by case basis. So the boundaries for these conditions that these things happen is very uncertain and we are still very much learning about these practices in general. |
|  | Alright so we'll be able to peek into the atmosphere using the transit method of detection, so we first have transmission spectroscopy where we have the [inaudible] host star and the planet goes in front of it and we can peek into the atmosphere, that way and we can use different instruments like NIRSpec and NIRISS and then we also have secondary eclipse or thermal emission where if the planet is [inaudible] currently blocked, then we can peek into the atmosphere that way as well, using different instruments too. |
|  | So JWST will provide unprecedented collection, varied collection and wavelength coverage. The wavelength range for JWST is about 0.6 to 28 microns. And just in comparison, we can see that the Hubble Space Telescope observes at 0.1 to 2.5 microns at ultraviolet to the near infrared. So shown here is a schematic showing the wavelength coverage for JWST with respect to HST and Spitzer and also showing that there is larger wavelength coverage for this telescope compared to HST [inaudible] it's very exciting. |
|  | So of course, things like NIRspec and NIRISS aren't the only instruments aboard JWST. There are other ones like NIRCAM whose primary focus is imaging but it has a spectroscopy mode. So, NIRCAM has a lower efficiency than NIRSpec and NIRISS, so we don't consider this instrument for the study. |
|  | So kind of switching gears again. So getting into the methodology and the overall way in which this project functions is shown in this schematic here. So first, we're interested in seeing whether can we detect ammonia. So we choose an amount ammonia in the atmosphere and we go with 4.0 ppm and then step 2 is to choose an instrument. So with thermal emission or secondary eclipse, we will pick the MIRI LRS instrument which covers about 5 to 11 microns. And then step 3, we choose a varying amount of hydrogen in the atmosphere so we vary the mean molecular weights of the low molecular weights that's about 90% hydrogen, 10% nitrogen based atmosphere and high mean molecular weights is about 25% to 75% nitrogen and 25% hydrogen in the atmosphere. And for the last step for MIRI LRS, we want to add if we can detect the ammonia base on the [inaudible] flux ratio of the planet in the hopes that we meet above the sensitivity threshold for MIRI. |
|  | And so we kind of follow the same steps coming down here in the blue. NIRSpec for transmission spectroscopy. Again we vary the amount of hydrogen in the atmosphere, it would be low versus high. Mean molecular weights varying from 90% and 25% base hydrogen and then for the low mean molecular weight, we often experimented with determining if there were cloud decks to see the effec that they would have on spectral as well. Then we add, if its statistically significant, if it is greater than or equal to 3 sigma so. |
|  | So before we can start any of this, we have to select targets for this study. So we have three main target selection criteria, the first being equilibrium temperature, less than 450 kelvin, is the size between 1.7 and 3.4 Earth radii and is it less than 50 parsecs away. So the temperature criterion is based on where [inaudible] exists at about ten bar atmosphere and so the range for the Earth radii of 1.7 is to ensure that it has a core-envelope and a cutoff point of 3.4 is to make sure that it doesn't have high enough surface pressure to produce ammonia abiotically. And of course, less than 50 parsecs is going to make sure that adequate [inaudible] from the planet and the host star [inaudible]. |
|  | So based on this, we had seven targets for this study and on the right here, there is a plot sign of planetary radius versus equilibrium temperature and our targets are highlighted in color. Circles here, so we have targets like LHS 1140b, two of the planets in the TOI 270 systems c and d, K2-18b, GJ 143b, K2-3c and LP 791-18c. And so in comparison, and the little grey dots here are those planets that meet the equilibrium temperature requirement and our radius requirement must be less than 50 parsecs away. |
|  | So we simulate the transmission and emission spectra of these targets using an open source radiated transfer code by Mollhere et al 2019 called the petitRadtrans. So what the user can do is, you can change things like the abundances, the pressure temperature profiles, surface gravity, radius, equilibrium temperature and mean molecular weights. You can also set the pressure bar and determine if you want cloud decks or not. And so it gives you out either a simulated transmission spectra shown here on the left where on the y axis, the transit radius versus the near infrared coverage here. And then for an emission spectra we have the frequency unit on the y axis with respect to the wavelength frames [inaudible] 25 for example. |
|  | So given the planet's distance and size, the planetary flux, what we have received is incredibly low which should make atmospheric characterization challenging. So shown here in this part here, the planetary flux and [inaudible] and the wavelength range covering the MIRI LRS instrument. So again there's that around 10 micron ammonia feature and so this part, is showing just the planetary flux for our target spikes. The one with the highest equilibrium temperature has the higher planetary flux and we see it decreasing planetary flux as the equilibrium temperature goes down. |
|  | So we also calculate the flux ratio of our targets to determine whether we can detect ammonia and again the sensitivity threshold for MIRI LRS is around 10 to the -4 flux ratio contrast. So we plot the flux of the planet over the flux of the star versus the wavelength range for MIRI LRS. We're interested in this 10 micron feature here and shown here that there is only about one target that even's kind of close or just a little bit above the sensitivity threshold so that marks that it will be very difficult to detect the ammonia feature given the sensitivity constraints for this instrument, for MIRI LRS. |
|  | But alas, ammonia has many features in the NIR infrared, so turned to that with transmission spectroscopy to explore and we can detect ammonia in this range. So we use Pandexo, which is a mock observation and noise stimulant of JWST to determine whether we can detect ammonia features. So shown here, is the radius of the planet versus the radius of the star squared. And in color here, is the simulated spectral from fatigue, one of the examples, LP 791-18c, and this is showing the simulation for JWST as shown by either the black filled in circles or the open circles with a cross is for the different instrument, NIRISS, and two different modes for NIRSpec. |
|  | And at the bottom here is the corresponding signal-to-noise for a certain feature. So, for example, around 1.5, there is an ammonia feature around 1.5 microns and the corresponding signal-to-noise would be around 5 sigma, so that will be a good indication that we can detect that specific feature where versus the fuller micron feature which doesn't have a very high signal-to-noise, so it will be very difficult to detect the ammonia feature around this one. We also know that the signal-to-noise scale is inversely proportional to 1 over the mean molecular weight. |
|  | So I mentioned that it shows in the receiver [inaudible] that the mean molecular weight. So I forgot to mention before about that atmosphere was a 90% hydrogen based and 10% nitrogen based atmosphere, so we experimented with a higher mean molecular weight, showing a 25% hydrogen based atmosphere and 75% nitrogen atmospheric composition, shows weaker signal-to-noise. So again, our specter has shown in the color here and the Pandexo mark observation. And NIRISS simulation is shown with circled in or open circled with a cross markers. Again, for example, like the 1.5 ammonia feature, the signal-to-noise is almost half that of the one with the lower mean molecular weight, more hydrogen based atmosphere. |
|  | So we wanted to test how different factors can affect the amount of ammonia in the atmosphere and whether we could detect it and the effect of the transmission signal on it. So one of the other things that we varied would be the concentration of ammonia in the atmosphere. So again we have a plot here showing the radius of the planet over the radius of the star squared, in ppm, versus the wavelength micron range for the different MIRI LRS instruments like NIRSpec and NIRISS. So we see here in the black, from the 0 ppm and we vary it from 0, 0.4, 4, 40 and 400 ppm and we see that there is a stronger transmission signal as there is a higher concentration of ammonia in the atmosphere. And with some places, we see a difference of about 400 to 600 ppm based on that. |
| Tiffany Kataria: | Hey Caprice, you have three minutes. |
| Caprice Phillips: | Okay, thank you. So we also wanted to explore the effects that clouds have so we varied between 0.01 bar, the 0.1 bar and the 1.0 bar, we answered exactly where clouds could just be present in the atmosphere so we wanted to experiment with different ones. So we see here that a 0.01 cloud would produce some near a feature list, spectrum as well, so just showing the effects that clouds do indeed weaken the spectral features and where we could detect ammonia. |
|  | So one of the last ways, that we wanted to test, was again varying atmospheric composition. How it affects the transmission signal, so we experimented with that base of 90%, in the black here, hydrogen based atmosphere comparing it with a 75% hydrogen based atmosphere compared to if you only had about a 1% hydrogen based. So we see the 1%, barely any hydrogen with not producing strong spectral features and almost near flat like signals which barely have hydrogen present and then we also compared it to a near 100%, like kind of a water world planet shown in the blue here. |
|  | So based on this, we have a ranked list of targets and I just wanted to highlight a couple, LHS 1140b and K2-18b. These are some of the target we proposed during the JWST proposal and what's interesting about these two are that they have more precise math and radii measurement than any of the other targets, so I wouldn't worry about it and just focus on these two. |
|  | So I just wanted to put up my last two slides showing that Gas Dwarfs are more massive and common than Earth and are promising sites to look for signs of life. And ammonia is an exotic biosignature unique to hydrogen dominated atmospheres of gas dwarfs including Super Earths and we found that NIRSpec is a better instrument than MIRI LRS to detect ammonia. And ammonia detectability is affected by concentration of ammonia in the atmosphere, the mean molecular weight and the presence of clouds. |
|  | With that I put up my last slide. I just wanted to again give a shout-out to the ExoExplorers program and also to BlackInAstro to further support and follow them on Twitter to further support black astronomers, in the field, we're here so. Thank you so much. |
| Tiffany Kataria: | Thanks very much, Caprice. Alright, so if you have questions please put them in the Webex chat and we'll do our best to moderate. And so I see, first up a question from Johanne Kathy who says, "Nice talk Caprice. Did you consider different host star spectral types and your target selection? Why or why not. Are all of the host stars similar temperature?" |
| Caprice Phillips: | So most of them, the host star is Gas Dwarfs or there is one that. Okay, maybe I think I must have messed that up. But not all of them are Gas Dwarfs. But it's more ideal to look for transmissions in Gas Dwarfs and so, as part of the reasoning. |
| Tiffany Kataria: | Do you need extra help? |
| Caprice Phillips: | Uh-huh. |
| Tiffany Kataria: | I heard a hand from, it only says Webex chat [inaudible]. Rob, if you want to go ahead and ask your question. |
| Rob: | Hey Caprice, you were a great talk. So what's the next steps on your study? |
| Caprice Phillips: | So I think, sorry excuse me, double take. But I mean the next step that I am working on is a paper. And then B, I think the next thing that I'm going to be getting into is, atmospheric retrievals and seeing whether OSU is one of the founding members of the Twinkle mission. So kind of trying to take this work, that I've done here and helping make a pipeline and just some things like Twinkle and different things like that and continue testing different atmospheric compositions and different things like that and it would be interesting. |
| Tiffany Kataria: | Great. I see a hand also from Ellenora. I hope I pronounced your name correctly. |
| Ellenora: | Yeah, perfectly actually. Thank you. So first of, it was amazing to see that you were using petitRadtrans, because I am one of the devs of petitRadtrans right now so, yay, it’s nice to see it being used. Another question, generally when you talk about biosignatures you tend to find at least a couple of them when you study a section, especially due to the fact that they could be produced abiotically. So have you figured out what other biosignatures you would find in addition to ammonia, when you look for signatures on a planet. |
| Caprice Phillips: | Yeah so I can't, I don't now like the other names offhand but we based, from a Seager paper. I don't know, ATN, I don't know if that's the one and I don't want to lie to you but, she kind of had, like we based things in the atmosphere based on volume mixing ratio that she had for different types of planets. So there were other features that maybe you could look at but right now the focus should be on ammonia. It would be interesting to look at something like that in the future, that's a really great kind of interesting route. |
| Ellenora: | Alright, cool. Thank you.[crosstalk] |
| Tiffany Kataria: | Yeah, thanks. For the purposes of time, I think we're going to move to the next speaker but thank you again for an excellent talk.  |
|  |  |