|  |  |
| --- | --- |
| Tiffany Kataria: | All right, thanks so much, Quang. And so with that, we'll move on to our next speaker. So, while Amy is getting set up, I'd like to introduce our next speaker, Amy Glacier. Amy has received her associate's degree from Collin College, a BA from Austin College, a Master's from the UNC Chapel Hill where they're currently PhD students. And so today Amy will be talking about constraints on post super flare, Exo Auroral admission with soar and the every scope fast transit pension. That was a mouthful, but Amy will ably unpack all of that for you. So whenever you're ready, Amy take it away. Yeah, Amy, I've got you. [crosstalk]. |
| Amy Glacier: | So, yeah, as Tiffany was just saying, my title is a mouthful. I promise, I'm going to break it down. But this is some work that I'm really excited about. It's brand new work that I've just started on, which is both exciting and terrifying place to be. So to get us all on the same page about what I'm doing, and before I launch into all this stuff, let me talk a little bit about the stars I'm looking at, the actual targets I'm observing to get us all up to speed. |
|  | So the actual stars that I'm observing are M-Dwarfs. So these are some of the coolest and low mass stars, they have a math less than 60% of the sun and down to fractions of a percent of the sun. And temperatures that are less than about 3800 Kelvin. So very small, very cool. And some well known examples of stars like this are TRAPPIST-1 and Proxima Centauri. And to give you a visual for just how small these stars are, here's an artist's depiction of how they compare to our sun, where and would be the low mass star that you're seeing. And as you can see, they're not a whole lot bigger than even Jupiter, or compared to the sun. So as a consequence of their small size, it's really easy to find planets around them. Can everyone see me? I appear to be frozen. |
| Tiffany Kataria: | You're good, Amy. You're good, go ahead. |
| Amy Glacier: | Okay. So did everyone catch me? I was saying that they're small, so something about habitable zone, that’s what I was leading into. Okay, so because the stars are so small, that actually makes it easy to find on small terrestrial planets that might be in their habitable zones around them, i.e the region around a star where it's not too cold, not too warm, just right. And so for these M-Dwarfs for these really cool stars that habitable zone is really close in, you can find earth like planets really easily right, including, say TRAPPIST-1, which is an artist's concept I've shown you here of one of the planets in that star system. |
|  | So sounds great, we can detect these planets really easily. They might be earth like, they might be habitable. But of course, it's not that easy. There's complications and the complication that I really focus on is flares. And so the reason we have focused on flares with M-Dwarfs is that M-Dwarfs are really active, they're much more active than our sun. And these flares can affect planetary habitability, especially because these planets are so close into the star, they're going to get walloped all the time by a lot of powerful flares. And the more powerful the flare, the greater impact that it has on that planet. |
|  | Now, the most powerful flares are just the term for it, is super flares. And so that leads me into what I'm actually doing, which is finding “constraints on Post-Super flare Exo-Auroral Emission with SOAR and the Evryscope fast transient engine.” Yeah, let me break that down. So let's first talk about super flares for a minute. So when I say super flares, I mean, these are stellar flares that have energies greater than about 10 to the 33 [inaudible], so extremely energetic. And these are really common flare, is for M-Dwarfs. So in general they're common for them. But then these high energy flares, they're also pretty common for them compared to say, a sunlight star, our sun doesn't have super flares. |
|  | And one thing that's great about these flares, especially for me being a ground based astronomer, is that since they are the most powerful flares, their brightness, you can see this easily from Earth. And because they're the most powerful flares, they can be the most damaging for exoplanet atmospheres. Now, I've looked at [crosstalk]- |
| Tiffany Kataria: | Amy, Amy, sorry to interrupt, so sorry to interrupt, but I think they're... Oh, was there connect issues? |
| Amy Glacier: | [crosstalk] connection problem? |
| Tiffany Kataria: | Oh, your slides, I think stop sharing just now. |
| Amy Glacier: | Oh, goodness. |
| Tiffany Kataria: | Oh, yeah. This is [inaudible] the reality we live in. So maybe if you want to just try sharing again, otherwise, [crosstalk] if you want to put something [crosstalk]- |
| Amy Glacier: | WebEx has completely frozen for me. |
| Tiffany Kataria: | Okay, no problem. It happens. Okay, so, for those who are still on the line, we're just going to pause for a minute while, yeah, while Amy gets started. Amy, if you want to also email the talk, I'll put it in slack for you, but we'll pause here. I see your message, Jesse. I guess in the meantime, does anyone have any other questions for... not to put you on the spot, Quang but does anyone else have any questions for Quang while we're waiting? Oh, okay, Amy looks like she's reconnecting. But in the meantime, if anyone has any other questions, feel free to put them in the chat. Oh, Vanessa, go ahead. |
| Vanessa: | [inaudible]. Oh, [inaudible], looks like Amy's back, so [inaudible] for my questions, asked you whenever, Quang. |
| Amy Glacier: | It looks like it wasn't my connection, but that WebEx completely stopped responding. Not sure why. New? |
| Tiffany Kataria: | I'm not sure why either, so it goes. Why don't you try sharing again? Let's hopefully that will work this time. |
| Amy Glacier: | Let me pick up from... what was the last slide that you remember seeing? |
| Tiffany Kataria: | It was the slide on end work. So we didn't make it to the estimates of super flare rates. |
| Amy Glacier: | Okay, then I'll start from that slide. Let me start sharing [crosstalk] again. |
| Tiffany Kataria: | ... patience. |
| Amy Glacier: | Yes. Thank you all for being here and for not giving up. But this is new, I've never had this happen before. Let me start playing this. Okay, [crosstalk] in my perspective, I'm still moving, and everyone can see my slides. |
| Tiffany Kataria: | Yeah. |
| Amy Glacier: | Okay. Let's pretend like that did not just happen [crosstalk]. |
| Tiffany Kataria: | I think we talked through most of this. So just in the interest of time, if you want to... so I think you have to slide forward, which was estimates on rates. Am I remembering correctly? |
| Amy Glacier: | So up to here? |
| Tiffany Kataria: | Yes. Yes, yes. |
| Amy Glacier: | Okay, excellent. Take [crosstalk], super flares, they're extremely high energy flare, they're calling for M-Dwarfs, they're bright enough that we can see them easily from Earth, which helps me because I'm a ground based observer. And these flares, because it's the most powerful, they're some of the most damaging for exoplanets if they impact exoplanets in a stellar system. And so previous work I've done has looked at the impact of the actual light flare itself on the habitability of planets in terms of its ultraviolet flux, and so on. |
|  | But there's another thing, it's not just the ultraviolet, and the electromagnetic effects of flares that we can think about. You can also have high energy particles following these super flares, like a coronal mass ejection, and these particles as well interact with planetary atmospheres. Now, these interactions can be catastrophic, like you can see in this lovely artist concept, I've got one of my favorite ones in this talk. You can see here, these particles as they interact within atmosphere. They can actually strip off that atmosphere completely, which is not what you want if you're living on that planet. But there is something else that these particles can do as they interact with atmosphere. And that brings me to my next piece. |
|  | I'm using super flares as a proxy for particle events to search for Exo-Auroral Emission from affected exoplanets. And so what that means is just as how on earth when the sun has a flare, and that's accompanied by a coronal mass ejection. When that coronal mass ejection hits our atmosphere, we get these gorgeous Auroral displays that are even prettier from space, it turns out. And so the characteristic color they see in an Aurora, there is red, there is pink, but it's mostly that green there that you see it's really bright. And that's due to oxygen in our atmosphere. |
|  | And so the idea that I'm taking here is, if I'm looking at M-Dwarfs in the hours after a flare after the particles, any particle outflow has had time to reach planets in that system. If I'm looking at M-Dwarfs within hours after a flare, and I see a really bright emission, at the specific line, 5577 angstroms, where oxygen and emits, that could be a sign not from the star, but an Exo-Auroral of light being emitted from the planet as these particles impact it's atmosphere, if it's got an Earth, like atmosphere, and so forth. |
|  | Now that might seem out there, and I agree, it totally is. But there's actually been some work that pretty recently that shown that Exo-Auroral from M-Dwarf planets might be detectable, depending on the geometry of where the planet is that and the actual characteristics of the atmosphere, and so forth. The star contrast planet ratio can actually get better by an order of magnitude or so in some Auroral lines. For example, this figure that I've taken from this leaguer at all paper that really does great at explaining this idea. It shows you a typical spectrum in M-Dwarf. When I say typical, it's Proxima Centauri specifically. And based on data from their simulations, they've superimposed a line at 5577 angstroms. That is the intensity that you'd expect from a planet with a certain terawatt edge of Exo-Auroral Emission and so forth. |
|  | Now, of course, what you actually see is going to depend a lot on the resolution of your instrument. This figure does not take into account specific instrumentation. But the idea is still there that this might be detectable if we just can go looking for it. And that's the challenge, actually finding events like this, actually finding flares and getting on them with spectroscopy soon enough so that you can look for signs of the rural emission. |
|  | So that leads into how I'm doing this, how I'm seeking out Exo-Auroral Emission with SOAR. Now, SOAR is Southern Astrophysical Research Telescope. It's down in Chile, it's about 4.1 meters and it's covered some optical through near infrared. And the primary instrument that I use on it is the Goodman High-Throughput spectrograph, and there's lots to know about it. So I alluded to the paper by Chris Clemens et al, who is a faculty member at UNC. He and his group designed the instrument. UNC, in fact, as a founding partner force, we've got a big role in it. And the main things if you want details, check out the paper, but the main things that I want to focus on are the resolution of the spectrograph, it can give us low resolution spectra for just identifying what star we're looking at, and then higher resolution spectra that I can use for looking for Exo-Auroral. |
|  | And with its wavelength coverage too, the 5577 angstrom lines specifically, it's the simplest, that's a green line, and the star overall is red. So since Goodman wavelength coverage covers that line, that line will stand out against the overall spectrum of the star, so I should be able to it. |
|  | Here's a quick bit about how observing with SOAR works. And so, SOAR nights are allocated to UNC and then split among research groups. So there's a few per group per term. I think we've got some four or five this term. And we get to observe a variety of targets not just for my science, but for science being done by others in my group. I've got some of the core group pictures here. This is us in the before times at a remote observing session with SOAR. It's all done completely remotely, we don't have to go down CTIO to do this. The operators, if you can see in the background of that image of that television screen, we have a web link open to the operators and they help us maneuver the telescope. |
|  | And so we've got everything set up, we don't have to go to CTIO to do this. We have access to SOAR. So if we can just find the flares, if we find them while we're observing on SOAR, while we have a four night, so we can just go straight to them and take spectra. Of course, the challenge is, again, you have to find the flares. That's where the next bit comes in the Evryscope Fast Transient Engine. That itself is a lot to unpack. So let me tell you what every scope is before we get into the Evryscope Fast Transient Engine. |
|  | So these are the Evryscope. These were designed and constructed by my research group at UNC, run by Nicolas Law, he's NTI. And the first of these, Evryscope stealth, it lives down in Chile, right across some SOAR. And it's been observing since 2015. Evryscope-North, we deployed more recently out in California at Mount Laguna Observatory. And so since I have access to SOAR from my spectra, I primarily use the Evryscope to go looking for flares [inaudible] Evryscope. Well, I use Evryscope house specifically to go looking for flares since it's in the hemisphere that I need. But theoretically, if you have a spectrograph in the Northern Hemisphere that you have access to, you could totally use Evryscope more through this as well. I just focus on Evryscope-South because this is what I have. |
|  | Let me give you a little bit more about the Evryscope. So it looks like this, it looks like a mushroom. And the reason it looks like a mushroom is... I see Quang laugh, I guess it has an effect on people. So all of these black circles that you see on it, each of those holds its own camera, and there's total of about 22, it can hold more than that, but there's about 22 in it at the moment. And each of those cameras has a plate scale of 13 arc seconds per pixel. So we can get pretty good separation between stars as long as the field isn't super, super crowded. |
|  | And so the way this works is this cameras are arranged to cover the entire sky. And so as the night goes on, the Evryscope will pick one pointing and then track it, so it ratchets across the sky and then ratchets back to a new pointing and then tracks and then ratchets back to a new pointing and so forth, rather than sitting still. And it does the cycle several times per night so that we can observe the entire sky as it goes on, and we're not as limited and field of view as we would be if it were just sitting still. So it's really cool. |
|  | And when I say it images the whole sky, it images the whole sky every two minutes. That's a limiting magnitude of about 16th in Sloane G. And I've got the exact number for the field of view here, but let me show you what that looks like. Before I do that, I want to call attention to... and to just wrap off, one of the people in... my other grad students in my lab, he's pictured here building the Evryscope, so there's a bit more details on it. He's one of the main constructors of the Evryscope. So it's really him that we have to thank for it. But so what Evryscope image looks like? This is what it looks like. There's a lot, and this isn't even an entire image. This is a zoomed in portion just on the galactic center. |
|  | So I told you that I want to go looking for flares, but if I'm looking for flares, and I'm looking at this image, I'm just a human, I can't see if something happens on one end of the image. I'm looking at the other, I'm not going to see it. So it'd be great if we had a way of automatically detecting flares as they happen without a human having to have to comb through images. And recently we have that, I think [inaudible], but one of my colleagues, he's a brilliant programmer and he has been working on the Evryscope Fast Transient Engine. We call it FT for short because that's a mouthful. |
|  | And so what FT does, it takes images from Evryscope, images that are taken on the same pointing. So as I said, the Evryscope will do one pointing and then track it, then go back and track again. If we're looking at images within the same pointing, what FT does is it takes an image from the beginning of the pointing, that would be the reference image that I've got here at the top of this figure. Later on as the pointing other images come in, and so the second image is some image from later on in the pointing, we can call it the science image. And what happens is FT will automatically take those images and subtract them in real time as they're coming in. We don't have to worry about doing any PSF fitting or anything because our PSS are pretty stable as long as we're taking images within the same pointing on the same night and subtracting them. So, that's the key that makes this work. |
|  | And so when FT does the subtraction, it will automatically identify any transit candidates that it sees. And it literally it sends a slack message, it pings all of us on slack so that we know it's down to something. And some of the things that it finds are, for example, are like trails, tons of those. But we have a variable star down here in this image. And then over on the right, we have a super flare, which is what I'm looking for. |
|  | And so the idea here is that as flares are going off across the sky, I can find them immediately because of FT automatically looking for flares, taking differences between images to find them and just pinging me on slack. The way you would traditionally look for flares, the way you would traditionally do something like this is you'd have to fit on an active flare star and just wait for it to flare, but because of FT and because of the Evryscope huge field of view, it makes it that we can find the biggest flares across the entire sky so we don't have to wait. And that's really powerful, because since they are the brightest flares especially what that means is, I'm going to find not only flares all the time, but since they're the brightest ones, I'll find the flares that have the highest proton impact. So they'll have the most intense Aurorae, and therefore they'll be the ones that I have a chance of detecting. |
|  | So that being said, direct detection is still unlikely partly because of the numbers. There's a lot of ifs that come into play of like if the planet has an earth like atmosphere, if there's even a planet in that system for me to see, if, if, if, but because we're looking at so many stars, even a rare event is going to happen sometime. If I have the best possible chance of finding these events that they do happen. And so because of that, if they do happen I'm going to get it's not a direct detection of Aurorae, at least upper limits to inform future surveys on say how bright an Aurora could have been instilled an undetectable. And perhaps even the atmosphere composition [inaudible], I'm being big because there's lots is not yet known here, but it'll be a good start to have data. |
|  | So let me go ahead and summarize the workflow since I went through that a little quick. We have a star, it erupts in a flare, is that flare is accompanied by a CME that is going to hit the atmosphere. If there's a habitable planet, it's going to hit the atmosphere of that planet and spark an Aurora, then the Evryscope sees that flare, and then with SOAR, while I'm observing on SOAR, I can turn it to that star and look for signs of Exo Aurorae. |
|  | Few key things that I want to mention before I go into some of the first results that we thought, is this strategy isn't limited to known planet hosts and that we're looking for flares to happen all the time. So just if there's a flare, we'll go to it. We can prioritize by if there is one that's a known planet host that flare, we haven't had that happen yet, but if it does, and we'll definitely prioritize and go straight to that one over any other. Another great thing about this is that the planets don't have to be transiting in order for you to catch Aurorae, which means that normally things like transit spectroscopy to characterize a planet, and that's only possible if the planet is transiting. You don't need a transiting planet for this, which makes it really powerful if it works. |
|  | The rapid follow-up that we can do like a CNC, Evryscope detects a flare, we can get around that pretty quick. That means that we're not limited to just looking for Aurorae, we can also capture the flare astrophysics that happened in the early stages of the flare, and that can help us really nail down the temperature evolution of the flare over time for example. And because of how for and the Goodman spectrograph are built, it's flexible enough that we can switch from low resolution at the beginning of an observation to get the flare astrophysics at the very beginning of the flare, then switch to high resolution for my science, which looks for Aurorae. So, that's how a typical night goes on. One of my colleagues works on flare astrophysics, we'll start with low resolution as soon as the flares goes off, then switch to higher resolution as the flares goes on so that I can look for Aurorae in the ensuing hours. |
|  | So how am I doing on time? Okay, so let me show you one of our very strong [crosstalk]. Okay, I figured it was about time, but I wanted to make sure since we're interrupted. So here is one of our first flares that we caught this way. What I've shown here in this image is, in the first column on the left, you've got the reference image, that would be an image from the start of appointing the start of an observing cycle. And you can see there's not really anything in the center, because the star that made this flare is real doom, we can't see it with the Evryscope when it's KSN. But then in the science image, then you can see that, oh, wow, something is definitely there. There's a flare there where there was nothing before. And then the difference image that FT takes really shows that okay, there's definitely something here. And the reason this is a square, and not just a line is that the flares appeared in multiple cameras, which is one of the checks that we run to make sure that we're seeing actual astrophysics, actual stars doing stuff, not say cosmic rays hitting one of the cameras, for example. |
|  | And so this flare, this is from Valentine's Day, last year, right before the pandemic shut things down. And this is from an early to mid M-Dwarf, FT automatically cross reference catalogs to check if this was from a known source or if it didn't correlate to a known source. And so in the time that it took from the first pane of FT on slack to up being able to communicate to the operator at the telescope what we're doing, and to get the telescope slewed on target, and then getting the target in the spectrograph actually start taking data, the whole process happened within 15 minutes. And that's not even the fastest time that we've had so far, and so on. Whereas like my science for the Aurora, it can hold off for a few hours into the flares. This really helps us get additional data, additional science done seeing how the flight revolves in the first minutes afterward. |
|  | So let me show you what the floor looks like. I find it easier to understand if I put it in motion. So I'm going to do that. What I'm showing you here is a spectrum. So on the X axis, I've got the wavelength, on the Y axis, I've got the intensity of the source. And so maybe it's playing as on time, we thought we were able to get a lot of exposure of this flares rapidly. And so at the beginning of the flare, you can see that it's bluer, it's more intense on the blue end of the spectrum. And that's because flares are hotter than when the star is just KSN, chilling being a star being red. And so as you can see, looking closely as the flare goes on, that blue shift down and becomes less intense as you'd expect. And then the emission lines get stronger as the flare goes on. So it starts with more on continuum shifts toward blue, and then the emission lines get stronger. |
|  | And so this is the whole flare. Zooming in on the lines that I'm interested in, we took this in the low resolution mode, because this is one of our first flares to verify that we could do this whole project, we could do this whole process. So we didn't switch to high resolution yet. Reason low resolution, you can see how the spectrum is changing over time. In this specific start, not a lot is going on and the line that I'm interested in. But I've demonstrated that I can see it, that I can get there fast enough, quite ahead of when I would expect particles to impact the planet anyway, and to just watch the star and wait to see next Aurora. |
|  | But since it is lower resolution, I have on my list after that, of course is to move into higher resolution so that I can really see what's going on and really detect any emission that's present since you do need higher resolution to get that final line. Now the moon hasn't been cooperating with me otherwise, I would hopefully have a plot of overall emission. But since the moon hasn't been cooperating with me, I do have for you a binary star that we observed as a standard to see what it would look like in high resolution. And again, I'll play it, so that you can see. And there's definitely on the higher resolution helps, I can get more detail around that lines I'm looking at. I may need to go to even higher resolution, we'll see once I can catch a flare. We're currently awaiting dark nights, good moonless night so that I can continue searching for flares. |
|  | So the main things that I want to highlight here for my takeaways are super flares, the effect of more planets, habitability, a lot of work has shown that and then the associated particle events beyond the flare, those can induce Exo Aurorae, and that can give us a way to potentially detect or characterize these planets. And with the Evryscope being able to detect super flares, and then for being able to get on them that fast, that really unlocks our whole ability to detect Exo Aurorae to get on them quickly enough to find them. Instead of having to wait for a star to go off, we can just go straight to the flares. And that's really exciting, and I am looking forward to seeing where this project takes me and sharing it with the community. |
|  | And with that I'll close. And I think we still have time for questions inside of WebEx. So yes, please feel free to ask. |
| Tiffany Kataria: | Yeah, thanks so much, Amy. Yes, and we will take time for questions. I know folks may have to dial off I already see 2 hands. But I just wanted to say for those who do have to dial off, that Amy has her left her email there. So obviously feel free to get in touch with her directly. [crosstalk]. I see a question from Nora Bailey. Nora, go ahead. |
| Nora Bailey: | Hi. Thanks so much, this was really interesting. I was curious, you were talking about habitability and how you might see these Exo Aurorae from planets in the habitable zone of the M-Dwarf. But my assumption would be that there's no necessary tie between the atmosphere and the habitable zone for this Aurorae, so how far out do you think you would be able to detect one of these Exo Aurorae? Would you be able to detect it for a planet that was beyond the habitable zone, I guess? |
| Amy Glacier: | Oh, that's a good question. We should be able to, I can't think of any reason why not. Obviously, I'm very focused on habitable zone planets, because I really want to find another Earth. But yeah, if you've got a planet that's got oxygen in the atmosphere, if that's further out, then you could totally detect it outside the habitable zone. That would be totally doable. |
| Nora Bailey: | Thanks. |
| Tiffany Kataria: | Thanks. I see another hand from David Wilson. David, go ahead. |
| David Wilson: | Hi, Amy. Sorry. Did you allow my [inaudible]. Yeah, great talk, that's really cool project. You're using flares to link, assuming the flares meaning coronal mass ejections, I was wondering how well established that link is between flares and hostile events? In particular, can we tell anything about the intensity of the particular events and the intensity of the flare? |
| Amy Glacier: | It is not necessarily. That's a great question. So with some stars, more powerful flares tend to give you more CMEs and more powerful CMEs. But that relationship has not been established for M-Dwarf stars yet, or if that relationship even exists, we don't know. It's not necessarily a yet thing, and so we don't know yet thing. So, that's still an open question that we've got that... I'm hoping that with this work I can help answer too, because if I find evidence for CMEs by doing this work, then that will help with that question. |
| David Wilson: | Okay, thank you. |
| Tiffany Kataria: | Thanks. And maybe just one more. I see Neal Turner puts on in the chat. Neil, do you want to unmute yourself and ask your question? Oh, maybe Neal [inaudible] go off. Okay. [crosstalk]. Sorry? |
| Amy Glacier: | There's a question from Eric in the chat as well, [crosstalk]- |
| Tiffany Kataria: | Yes. I was just going to get to that. Yeah, yeah. So yeah, Eric, I think you're still on. So go ahead, I'm so sorry about [crosstalk]- |
| Eric: | I can read my own writing quickly. Are there theoretical predictions or simulations to how bright to 5577 mission should be? |
| Amy Glacier: | I'm sorry, can you repeat that? I didn't catch the first part. |
| Eric: | Is there any predictions of how bright the emission could be for an optimal flare pointed right into the very reflect planet? |
| Amy Glacier: | Yes, that's most mostly comes from the Luger paper that I alluded to, the simulations that they've done in there. And yes, if that means figures, that gives you a good visual of it. The trouble is, there's a lot of ifs that go into that again, because the actual intensity you can expect depends on whether the planet has magnetic field, whether the composition of the planet's atmosphere. And I'm sure that there are other characteristics that I can't think of off the top of my head, too. But so as a consequence of all the variables in there, like, you could get up to say, 0.1 terawatts of emission, and that would be about, I believe, it's about 1000 times what Earth Aurorae... I think that it's 1000 times what Earth Aurorae can do, I would need to double check that number. But yeah, to really constrain the range of a bit more, we would need to do more work. |
| Eric: | [inaudible]. |
| Tiffany Kataria: | Yeah, thanks, Eric. Okay. With that, so we'll copy... There was a question from Neal Turner, we'll relay that to Amy later on. But yes, thank you, everyone, for attending our second of ExoExplorers talks. Our next event is on April 16, where we'll be hearing from David Coria from the University of Kansas and from Jason Williams, who's at USC Carnegie. And so thanks, everyone, thanks to Amy and to Quang, and I'll see you next month. Take care everyone. |
| Amy Glacier: | Thank you. |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |