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| Tiffany Kataria: | Yeah, alright. So I'm pleased to introduce our next speaker, Samson Johnson. Samson has dual B.A.s from the University of Montana and is currently a fifth year PhD at the OSU. He'll be talking today about science enabled by the Roman Galactic exoplanet survey. So Samson, take it away. |
| Samson Johnson: | Sorry, I lost my ability to unmute myself. So I'm not used to Webex, I'm a Zoom user, it takes a while. But yeah, thank you so much Tiffany. I'm very excited for the opportunity to speak to you'll today. I appreciate everybody coming out on what could be the last thing for your Friday. So yeah, today I'm excited to talk about the Nancy Grace Roman Space Telescope, Galactic Exoplanet survey. I'd like to especially thank Matthew Penny and Scott Gaudi, my advisor as well as everyone else on the Roman Galactic Exoplanet Survey Science Investigation committee. |
|  | So to start off, just a quick overview of what I'm going to be talking about today. First I'm going to give an overview of the survey and how microlensing works and how microlensing is going to be able to teach us so much about exoplanets and I'll look at two specific populations of planets that I've been doing simulations on to predict what Roman [inaudible] thinks about them. The first is going to be Earth-analogs. So small terrestrial planets in habitable zones of some light stars. And then also Free-floating planets, planetary mass objects unbound from any host star. Let's first start with that overview. |
|  | [inaudible] the name. So those of you who might have known or have heard of WFIRST, which is the initial name for the Roman Space Telescope. It got renamed sometime last year after Nancy Grace Roman who was the first Chief of Astronomy at NASA, she's actually one of the pioneers of space astronomy and really one of the reasons we have a space astronomy program and was foundational in the creation of the Hubble Space Telescope. So it's a big honor to be working on a mission named after her. So what is Roman? |
|  | Roman is a relatively simple telescope compared to something like JWST. It's just a big monolithic mirror. It's about 2.4 meters and it has two main instruments on it. The first is the Wide Field Imager, the WFI, which is a collection of 18 infrared chips that's going to have a field of view, a hundred times that of Hubble. So very wide field of view for doing large scale photometric surveys. The other instrument it has is a chronographic instrument which is right now, a technology demonstration that is going to be vital for testing and demonstrating instrumentation for the next generation of k-space chart imaging telescopes. |
|  | So right now, just a quick mission update, the mission is in Phase C of the five mission phases, phase A through to phase E, and this phase is really the final design and fabrication and entered that phase in March of 2020. It's currently passing its design reviews because there's a majority of flight detectors selected for the wide field instrument and right now it's on tack to launch in late 2026. The program for Roman is a little bit different than a typical NASA fly action mission in that we're conducting three core community surveys. Two of those surveys are going to be for cosmological purposes, studying the expansion of the universe while there's also the exoplanets survey, that's conducted using microlensing. There's also a general observing program that will be coming, some 20% at a time I think, will be for general observing. And keep a note though, to keep in mind that all core community surveys are going to be open to community input up until, as the mission evolves and launches. So there still will be room for input for those four surveys. |
|  | So yeah, today I'm going to be talking about the Roman Galactic Exoplanet Survey. It is the first space-based microlensing survey of the Galactic Bulge. When I was once at a conference, I overheard from a senior NASA scientist, I heard them say that this was the exoplanet mission that nobody asked for. I'll talk about why in a second but first, let's get some background on my [inaudible]. So what Roman is going to do to detect microlensing events, is that it's going to sit and look at the center of the galaxy. So here, we can see in this little animation, or in this animation from the NASA Conceptual Image Lab, we have Roman that's going to sit at where the Earth is in the galaxy, staring towards the galactic center. |
|  | So in a microlensing event, you're waiting for the chance alignment, you're literally waiting for the stars to align. Once they become very well aligned, the [inaudible] is going to act as a lensing object magnifying the background belonging. So, this is a very rare occurrence, she will have to look at as many stars as possible, that's why we're looking for the galactic center. So in this animation, this is going to be a side view of the microlensing that happens. So we need to worry about three spatial points in a microlensing event. |
|  | We need someone to watch the event that's going to be [inaudible] Wellman. We need a star that's going to be magnified, that's the source star. Remember, the center of the galaxy is some 44 000 light years away and then there's a lensing object. Now this lensing object is just any object that has mass, and that mass is going to deflect the path of light causing the background start to split into two images and form [inaudible] magnet copies. So here in this animation, we will watch it play out as the lens, your brown dwarf, moves in between her line of sight. We see that the source power is brighter as the two images of the source star get brighter than you would expect from the star just by itself. |
|  | Some basics for a single lens event. So here, on the left side is a look at the geometry of the events while on the right side it looks at the magnification for [inaudible] microlensing events. So here, this is now looking baseline towards the source through the lens. There's a lensing object here, the source object here and then this large gas string [inaudible] called the Einstein ring. The way to think about this or another way to think about this is that whenever the source star is within the Einstein ring, it is being magnified. And the size of the Einstein ring is proportional to the mass of the lens. |
|  | So the source star is going to move along one of these trajectories from left to right and if it goes through the Einstein ring without some corresponding ramifications. But note that when it's close to the lens, at closest approach, that's where the peak magnification occurs. And then the duration of the event is equal to the radius of the Einstein ring, the angular radiant is theta e divided by the relative proper motion. You can figure out that it's just the distance over velocity. So if it's moving quickly the event is going to last longer. |
|  | So how are we going to find bound planets and find the host stars. So here's another animation of a [inaudible] view or lens star here in the center and we go a planet sphere up near the Einstein ring. We're going to see the source star move from left to right. And then as the images pass by the planet, we see that there's a perturbation on top of the broad [inaudible] that occurs from the host star. So remember, the large magnification is from the, and the magnification process is from the host star. This perturbation is due to the [inaudible]. So not all microlensing events will look alike, almost no microlensing events look alike. |
|  | So there is actually a few notable variety of what you can observe during a microlensing event. Here are a couple of examples of binary lens events, so starting with planets that have come out, some of the earliest ones. So here is similar to the picture we just saw. Broad magnification that comes from the star and then a small perturbation due to the planet. A lot of variety appears, when the lensing geometry gets more complex. You get some very interesting shapes in a magnification like this [inaudible] more average time. Now but the key thing to keep in mind is that you're most sensitive to planets that have orbital separations near the Einstein ring of the host star. This is for your sensitivity peaks. You can find planets that are either further or closer orbits but that's just for your sensitivity. |
|  | So back to that probe that I had at the beginning of the talk, a lot of people aren't huge fans of microlensing or they don't necessarily see the light yet. So I'd like to address some of the very common questions I get at conferences or concerns that I get. The first that I hear of the most, well definitely by far the most is that microlensing events are transient signals and they don't repeat. And I think that it's definitely true. It's sort of the fact of nature that we are literally waiting for stars to align for the 1 in 10 million event. In Astronomy, we are used to transient events. For example, supernovas, we don't ask for stars to explode again and we don't ask for black holes to emerge to try and take their gravitational waves from them. What it means is that we have to have as good as data as we can get and as much data as we can get during the events to be able to characterize and model those events. |
|  | The next one is that microlensing planets can't be followed up or characterized. Again, that's completely true. That's not quite the strength of microlensing, where microlensing is to build strong statistics and demographic information for extra planet population. These planets can be 7000 parsecs away but we will never really be able to follow it up but we won't be able to find those planets no matter what. |
|  | And the last one is that microlensing is either hard or too complicated or too steep of a learning curve. Most interesting problems aren't easy. If some guy from Montana, who's gone to public schools his entire life, could figure it out, I think almost anybody can or really anybody can. |
|  | So what are the strengths of microlensing? So one of the main ones is that microlensing is sensitive to planets with extremely large orbits. And also not even just that, it's a wide range of planet masses. These planets are harder to detect otherwise so having a way to access this grammar of space, is extremely important. The second point is that it can detect planets throughout the galaxy. Microlensing is essentially sensitive to planets from where the Earth is. The galaxy to the galactic center, so being able to use microlensing to say the radial distribution are of planets throughout the galaxy is an extremely important one. Finally, microlensing surveys are able to produce very robust statistics by virtue that microlensing events are so rare. If we understand the sensitivity of events, then we can really start to grow the composition of planets. |
|  | So how is Roman going to find my transient events. That really comes down to the survey parameters. So right now Roman is set to look at 2 squared degree field of view that's just South and a little left of the galactic center. And that is made up of 7 separate fields that are shown here on the left. We are going to moderate those fields in six separate 72 day seasons and those six seasons are going to be spread out over the 5 year mission baseline. During the season, it will have a high 15 minutes cadence in wide infrared bandpass using that Wide Field Imager. But they would also use a bluer filter that has a much stronger cadence which is going to be essential for microlensing events and really characterizing those events. Overall, Roman will produce ten to the eight light stars and in fact more than 30,000 microlensing events. |
|  | Of those, as you'll see here, that there would be a significant number of microlensing planets. Here the plot is from Penny et al. 2019, on the vertical axis, I have planet Earth, they have planet mass and on the horizontal is the orbital separation, the semi major axis. These red points are the planets discovered by the Kepler Kansas survey and then the black points are essentially planets discovered from the ground. And then a number of solar system objects have their [inaudible] hots photos taken. So here we can see, we found a lot of planets in the inner parts of the stellar planetary system. There's a lot of open space for widely separated planets. In fact, we actually know a few solar system analog objects such as Neptune, Uranus, Saturn so being able to understand more and exoplanetary systems is very important. There's a lot of predictions from planet formation theory that can be estimated. |
|  | So here is a predicted simulated yield of what Roman could detect and then we see, immediately a large cloud of blue points, comparable to that Kepler discovered and we all know that Kepler has constitutionally cut through to exoplanet science. So here tho, we can see that it complements Kepler extremely well and that Kepler is very sensitive to planets with small orbits whereas Roman is going to be sensitive to planets with much large orbits. So here there is going to be a wealth of information gained by Roman but I start to add salt to sand where I've been doing what Roman can teach us about two specific populations of planets. |
|  | So the first I'm going to talk about is Roman's ability to constrain the frequency of Earth like planets in the Habitable Zone of sunlight stars. Right now what we know about that comes from, the statistics is current rate is actually very important in it's own right but it is also very important for the design of future direct imaging missions by looking to detect biosignatures or look for habitable conditions in the planets nearby. So here, right now, currently our best estimates are coming from the Kepler survey where Earth-analogs on edge of Kepler's sensitivity. And so what you necessarily have to extrapolate from shorter period and larger radii planets should constrain that frequently. And here in the plot of current rate as a function of time, there's a pretty large variance in the estimates of occurrence rates and is starting to converge but there's still a fair amount of uncertainty in that number and so any other handle we can get on it is extremely important. |
|  | So most people might have some notion of microlensing that when they think microlensing, they think pole Jupiter is around Dwarfs. That's not the only thing you can do with microlensing and in fact I have to try and convince you otherwise. So here when we're worried about the habitable zone, the microns have to worry about two scales, there's the habitable zone distance so for that I've chosen a prescription from showing the inner and outer edge of the habitable zone for the function of stellar mass and distance from the stars. |
|  | You can see that is massive and pushes the habitable zone further and further out. Remember for you're most sensitive to planets that have separation comparable to Einstein ring radius and that's a function of the mass of the whole star so we see it, pushing out a little bit slower than the habitable zone but the distance is also a factor in calculating the size of the Einstein ring. And so here for this perturbation that I chose, one had 5 kilo parsecs and one had 7.5 kilo parsecs, the one that's further away, this one actually begins to intersect with the habitable zone for solar maps' host stars. There is a possibility for detecting [inaudible]. |
|  | So we're doing a more detailed simulation on this region of parameter space. So for a simulated yield in here, I've got a separate plot where I've taken the planet mass on the vertical axis over here, and I have translated that using a mass-radius relationship on the opposing axis. And then for the horizontal, I've scaled the semi-major axis by the bold metric luminosity of the host star. So that has the effect of, if you're orbiting a cooler star that will push further out, into a further orbit. Here in the simulated planets, I've also put a background that you'd expect to have planets with significant hydrogen or helium envelopes in the blue region, and in the green region is where you would expect [inaudible]. |
|  | And then finally, there is this grey region that denotes some range of the habitable zone for a star. And then finally, I fully predicted planet detections, I've coded them by their symbol, where the large circles are for planets that have hosts similar to the sun, those that have greater than a solar or have a solar mass. And then the diamonds, small diamonds are those that have more host stars. So here, we see that Roman does find a few planets in the habitable zone but the real power is going to be coming from the logistic Kepler, gonna extrapolate from longer periods and higher mass. But the other thing to note too, is that this information does not have to exist in a vacuum and the real power is gonna come from a combined constrained Kepler and Roman. Kepler's planets are all gonna sit on basically this side of the diagram, so we can extrapolate and try and estimate the frequency within this range. That's where the real power. There could be a lot of good information. |
|  | So, for the last inspection, I would like to talk to you about free floating planets that Roman kept. So what I mean by free floating planets, are free floating planets are really free floating planetary mass objects that are not bound to any host star. So where there are couple origins of such objects, The first is that they could form similar stars and they could condense out of dry molecular clouds, that are really low mass Brown Dwarfs. So we potentially have masses in the ranges of like three to five Jupiter masses or maybe a little bit lower, but they're sort of gas giants. |
|  | An alternative pathway is that they could they form disks bound to host stars initially or liberated through either dynamical interactions or through post main sequence evolution of the host. And now it tends to produce lower mass objects, currently Eath mass or lower. So but the common thing between these two pathways is that you catch these young stars on the left very early on when they're still hot, they're going to be admitting almost no life. And the same thing with very low mass objects, there's almost no way to take them photometrically. |
|  | So what we're going to do is use microlensing, because microlensing is only sensitive to the mass of a lens. So, if we have a free floating planet lens then we could potentially take those events and characterize them and try to constrain this population. So where do free floating planets lie on this diagram, I already said it a few times, but they're not on this diagram. They have basically an infinite orbital separation from host stars because they don't have a host star. Just wanted to drive that point home. So- |
| Tiffany Kataria: | Samson, you got about. Sorry to interrupt, 5 minute warning. |
| Samson Johnson: | Perfect, thank you Tiffany. So what evidence do we have for free floating planets in our galaxy right now? So that actually comes from looking at this time scale distribution of microlensing events. So the timescale of microlensing events, remember is equal to the size of the Einstein ring divided by that relative proper motion. This is really a proxy for the lens of the earth, the mass of the lens. So, longer time scale events typically have a higher mass lens. So apart from Shamec Mroz in 2017, there is a plot of the time scale distribution, so really its sort of a histogram number put in as a function of events rather than a function of time scale. |
|  | So here in this broad peak, this is just coming from stars in our galaxy, Kepler understood, we're not worried about stars, we want the low mass stuff. But what they do see, that is very interesting is that there is a tentative signal for a potentially large population of free floating planets, here in green. And this is consistent with order of five to ten Earth mass planets per star in our galaxy, that should be a very large number of objects. When in fact over there's been over the past couple years, Shamec Mroz and have been reporting fairly several events that are candidly free floating planets events. One of the most interesting is, came out last year, here we see the shortest time scale microlensing event ever detected. That lens is consistent with that being invert mass free floating planet. So there is a lot to understand here, and it is very hard to do this on the ground, so Roman is especially poised to teach us about free floating things. Especially give us the sensitivity we need in this short time scale portion of the event time scale distribution. |
|  | So what would free floating planets look like to Roman, so here are some simulated events, this is all real fake data. On the left here is a microlensing event for a two Jupiter mass free floating planet. And here we see a normal looking microlensing event, Watford data throughout it, so Roman is trying to hit this one out of the park. Easy to detect, fairly good to model, should be easy. But on the right hand side here, is a much lower mass planet. So this one is a half earth mass planet, roughly half earth mass planet. We see a definite change in the morphology of the event, and it looks almost like a top hat or a box cart. This is some very interesting microlensing phenomenology that we are putting out a paper on soon that could be, both help and hinders the detection of these very low mass lenses. I would be happy to talk about that a bit more, if there's time in the questions section. |
|  | But we are sensitive to very low mass lenses which just shows that there is a plot of the limit Roman will be able to place on the number of such objects in our galaxy. This is a busy plot but just to describe it really quickly, on the vertical axis this is the total mass of free floating objects of mass, M, per star where that mass, M, is the horizontal axis. So, if there were say ten free floating earth mass planets per star in our galaxy, that means we would have ten one earth mass planets, so that's ten and one. So this point would be that where ten earth mass planets in our galaxy per star. |
|  | So here these dash lines are previous limits set by Michael in surveys from the ground. And so these black points are observational results related to free falling planets specific. And as we can see, Roman has a 95% upper limit, if it doesn't detect any upset objects, is going to order the magnitudes lower than previous observational [inaudible]. And in fact it's going to be low enough to be able to test predictions from planet prediction theories, looking at objects ejected during planet formation and so on. |
|  | So and we don't know anything really about the mass function of such objects but right now we assume, [inaudible] something to do with the mass function, we will predict that Roman is going to find roughly 250 of these events. And really start to help us understand what the low mass scale of our galaxy looks like. |
|  | So for the key takeaways from my talk, definitely that Roman will be conducting the first microlensing survey and that survey is actually going to, hopefully a good deal about exoplanet demographics and statistics we would be able to attain, any other way. As I said Roman doesn't exist in a vacuum and it's going to be a great compliment to our picture of planets in our galaxy that are like Kepler and all the other surveys and detection techniques. And so understanding how it fits into that bigger picture, is going to be a very important [inaudible]. With that out of the way, thank you and I'd be happy to take any questions. |
| Tiffany Kataria: | Alright, great. Yeah, thanks again Samson. As before if you have any questions please put them either in the chat or use the raise hand tool and we'll monitor those. I already see one question from Shaun Kerry. Do you think Roman Ground Paralex measurements will be useful for free floating planets? Is there enough overlap that we can detect from the ground in Roman? |
| Samson Johnson: | That's a really good question, and a number of people have looked into that especially in terms of LSST but I think it would be hard because these events could be very faint and very short. It would have to be a pretty conservative effort for it to be able to do that, the short way to put it. I might have a better answer for you some other day, it's also Friday, 5 PM for me too. |
| Tiffany Kataria: | Certainly, yeah. I mean it sounds like more telescopes were request, than are in order. Alright, another question from Tai Smolders. Nice talk, will we know the host ser-masses of the detected exoplanets? And the related follow up question, your plot was predicted and had its own exoplanet showed solar equivalent for me to access on the x axis. Are these on planets on lower masstards, higher masstards or both? |
| Samson Johnson: | Okay so for the first one, Roman so, this question comes from the fact that for bound planets you are typically sensitive. One of the main observables of the microns in the event are the mass ratio between the planet and the host star. So we need to get the map to the host star to be able to get the true mass of the planet. And actually Roman is going to be able to detect or measure the masses of a large number of the planet it detects. I'll point to you towards [inaudible] is doing. I might have a slide somewhere and it might take a little bit to explain but there is a method by trying to measure the relative proper motion to train the Einstein ring of these planet hosts to get towards their mass and the true masses for those planets. [inaudible]. |
|  | And then the second one was, I can't remember the exact masses at this point but they're greater than half a solar mass, so they're more solar [inaudible] tied in or something like that. I think that answers your seconds question, I actually don't remember what it was. |
| Tiffany Kataria: | Fine, alright we've got one last question but I'll let you handle that offline since we're now at the top of the hour. And so in an effort to thank both speakers, we're going to try something, if you all want to unmute and applaud, that would be great and we'll see how that happens with seven to eight people. But thank you again. Again for your attendance and your attention. The next set of ExoExplorer talks takes place on March 12th and Vanessa if you could chime in on the next speakers, I should have pulled that up. |
| Vanessa: | So next month will be Quang Tran and Amy Glazier, so be on the lookout of announcements. I think they're both on the line, so look forward to seeing you then. Alright, thanks again everyone. Take care, happy weekend. |
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