Student questions: Rob Zellem colloquium on "(Small) Ground-Based Telescopes are Crucial for Space-Based Observatories"

11/09/22

In order to ensure DEI and more international collaboration, do you have any plans to expand your outreach efforts to countries/regions where astronomy/astrophysics are not studied or practiced widely?
RZ: Yes! That is something we are extremely passionate about and will be exploring ideas after our general audience launch in January 2023. If you have any ideas, please do reach out!

Does Exoplanet Watch have any hands-on training or support available for citizen scientists to maximize the potential of their science? For instance, workshops, one-on-one mentorship programs, etc.
RZ: Yes! We have online tutorials and a bi-weekly meeting, which is recorded and posted to our Slack channel, where we go over various aspects of the project, including how to use our data reduction code. We have also been thinking of starting up yearly workshops and our users themselves have been awesome in helping out other members.

How often is the pipeline updated?
RZ: The pipeline is run every other day, but the code in the pipeline is updated at least once a month, but sometimes more – depends on what we're working on.

What other characteristics does Exotic give you besides the transit dip?
RZ: EXOTIC gives the measurements of these physical properties (shamelessly copied from a recent run of EXOTIC on my computer):


```
{
    "FINAL PLANETARY PARAMETERS": {
        "Mid-Transit Time (Tmid)": "2458107.71358 +/- 0.00091
BJD_TDB",
        "Ratio of Planet to Stellar Radius (Rp/R*)": "0.1566 +/-
0.0033",
        "Transit depth (Rp/Rs)^2": "2.45 +/- 0.1 [%]",
        "Semi Major Axis/Star Radius (a/Rs)": "5.42 +/- 0.1 ",
        "Airmass coefficient 1 (a1)": "1.1626 +/- 0.0067",
        "Airmass coefficient 2 (a2)": "-0.1197 +/- 0.0024",
        "Scatter in the residuals of the lightcurve fit is":
"0.57 %",
        "Variable Reference Star": "AAVSO Label: 84, Position:
[324, 365]",
        "Best Comparison Star": "None",
        "Optimal Aperture": "4.44",
        "Optimal Annulus": "7.15",
        "Transit Duration (day)": "0.13 +/- 0.0025"
    }
}
```


We report all of these values because they are necessary to replicate our model fit to the data.

Have you observed significant growth in the number of people participating in the Exoplanet Watch program each year?
RZ: Yes! I am amazed at how large our user base is already despite not fully launching just yet. A little over 2 years ago, we had maybe 100 people, mostly in the US. Now we have ~700 participants, ~100-200 of which are very active.

What would you say is the most significant discovery that has so far been made with the use of data collected and analyzed through the Exoplanet Watch program?
RZ: I think the most significant discovery, that I can talk about right now (other work in prep!), is that we were able to refine the ephemeris on HD 80606b to save JWST an hour of uncertainty- you can read the paper here:
https://ui.adsabs.harvard.edu/abs/2022AJ....164..178P/abstract

Would location affect the transit observed by a telescope? (e.g., A telescope in North America observing transit vs. A telescope in Africa observing transit)
RZ: We take into account the differences in timings between our scopes by translating everything into a common timing. But, a user at one part of the world vs. another could observe more (or even less) of a particular transit. Also, one user might be clouded out, but another might have clear skies. So global participation is crucial for this project.

How does Exoplanet Watch ensure that citizen-submitted data is of good quality?
RZ: We use a metric called a "3 sigma significance" on the detection of the transit itself- basically, if we can say that we think that a user has detected the transit with a confidence of 99.7%, then we say that the quality of that data is good.

Since the data is collected by citizen scientists is that work checked for accuracy?
RZ: Yes! We use a metric called a "3 sigma significance" on the detection of the transit itself- basically, if we can say that we think that a user has detected the transit with a confidence of 99.7%, then we say that the quality of that data is good.

How long do these transits last, if its only for a few hours doesn't that mean the exoplanet's year is incredibly short since a year is a revolution around a star?
RZ: Exactly- most of the transiting exoplanets we're currently observing have extremely short years- most of them orbit their host stars every few days and some orbit their stars even on the order of minutes.

What kind of equipment would you recommend using to be able to get decent data to be able to participate in the project?
RZ: Folks have been using scopes as small as 4.5 inches (10 cm) to get great data that they contribute to this project. Based on our 2020 study, I might recommend a slightly larger telescope – a 6 inch – as it does give access to more targets.

What kind of work would the internship entail?
RZ: TBD, honestly. We're just thinking about interns right now, but probably a bunch of coding in Python3 and potentially some outreach opportunities.

Have you looked at the effect of using Exoplanet Watch on student's self efficacy, within a classroom environment?
RZ: Yes- this is an amazing part of Exoplanet Watch that I am super proud of. We have had a few student groups promote the project, and even start their own virtual "summer school" on Exoplanet Watch that had ~100 high school participants. I cannot, due to some weird NASA rules, make products specifically for school settings. So I am extremely happy that folks have taken our existing products and altered them to include them at their schools and in their curricula.

What are the next steps/goals for Exoplanet Watch, specifically any plans to expand?
RZ: Our next immediate goal is gearing up for our public launch in January 2023- we are looking forward to making Exoplanet Watch truly for "everyone and anyone". Hopefully we will get hundreds, if not thousands, of new users.

What is the best format/software to compile data in before attempting to use the database?
RZ: All of our code is written in Python3.

Do you have suggestions for students to get involved without a traditional data science background?
RZ: That's a great question, and admittedly one that I am not sure I have a great answer for. I know Dr. Simon has a few of these students in her virtual astronomy major class. I would recommend to just keep at it – it seems like the folks who have a ton of drive typically manage to find, and make, success.

Looking at the locations of participant telescopes for ExoWatch, do you have any specific plan to increase coverage in Africa and South America?
RZ: Yes- we definitely want to increase our participation in these parts of the world. We're actively figuring that out, so if you have some ideas, please reach out and let us know!

As a scientist working both with space telescopes and ground observatories, do you feel like the current collaborative network is optimized in its current shape and dynamics?
RZ: I am extremely proud of our network of citizen scientists. That being said, a few places where we could do better is getting more participants in Asia, Africa, and South America. I would also love participation from more small colleges/universities to hopefully help inspire the next generation of astronomers.

Acknowledging the usefulness of small ground-based telescopes, how useful would small cube-sat sized telescopes be in a similar role?
RZ: This is actually an idea I've been kicking around- the difficult part, in my opinion, is convincing NASA that a cubesat is needed, despite us having such a large user network. They could very likely say "why spend a few million dollars on a cubesat to do this work, when you're already doing it with Exoplanet Watch?". If you have any ideas, though, please reach out!

Given your expertise: How useful would networked groups of smallsat and/or cubesat telescopes be, and are there circumstances where their performance could compete with larger telescopes?
RZ: This network would be extremely helpful to 'plug up the gaps' in our network coverage and to all but guarantee that we could observe a high priority transit any given night.

It seems that current long baselines campaigns have been done mostly with small telescopes in the Northern Hemisphere. Have there been efforts to expand this to the southern hemisphere?
RZ: Yes- we definitely want to increase our participation in these parts of the world. We're actively figuring that out, so if you have some ideas, please reach out and let us know!

Do you plan to have any workshops for people intereseted to contribute to the Exoplanet watch program on the topic of techniques and strategies for good astronomical observations?
RZ: Yes! We have online tutorials and a bi-weekly meeting, which is recorded and posted to our Slack channel, where we go over various aspects of the project, including how to use our data reduction code. We have also been thinking of starting up yearly workshops and our users themselves have been awesome in helping out other members.

How do small telescope networks work to measure planetary mass?
RZ: Our network mostly cannot – you typically need larger telescopes (~1 meter and larger). But if you can measure transit timing variations (https://en.wikipedia.org/wiki/Transit-timing_variation#:~:text=Transit%2Dtiming%20variation%20is%20a,small%20as%20that%20of%20Earth.) you can actually back out the mass of an external planet by monitoring the movement of the inner planet (due to the gravitational pull on it from the outer planet).

In the case of discovering new stars and exoplanets, how effective is this network of small telescopes?
RZ: So far, it has been awesome. But honestly, we're just getting off of the ground, so TBD!

Would involving citizen scientists be more advantageous than using AI-led techniques while analyzing ground-based observations (after the observations have been made)?
RZ: Kyle Pearson, our Deputy Science Lead, uses AI a lot. However, we haven't used it just yet because we haven't needed it (yet). But…I could definitely see that changing as we get more data in the coming months.

What are the limits on transit depths for ground-based telescope observations?
RZ: It depends honestly on the brightness of the host star- the brighter the star, the more signal you can get, and the small transits you can measure. But typically, small scopes are best at getting transit signals as small as ~1%.

How do you think the data from citizen scientists will be affected when/if professional astronomers are involved?
RZ: I am hoping that professional astronomers will continue to make requests to our users and also contribute data to our pipeline as well. Professional astronomers, who might have institutional access to larger scopes, could help us push to smaller planets around dimmer stars. But there will always be a need for our amateurs- there's simply too many planets to follow up and not enough "professional" observatories to do this effort. The amateurs are crucial (I probably should have made more of a big deal about this during my talk, in hindsight…).

Are there resources available to help citizen scientists carry out and publish their own surveys?
RZ: Yes- any of our users are more than welcome to grab any of our data off of our website, and a few have done their own surveys using our robotic telescopes.

What was the driving motivation for making exoplanet watch?
RZ: Seeing the need for monitoring of currently-known planets and knowing that the numbers of planets that needed follow-up was overwhelming for "professional" observatories.

What have been the largest complications in regards to integrating citizen scientist within the academic publication system?
RZ: Unfortunately, there still seems to be some elitism within the field so that observations taken by amateur astronomers are automatically seen as dubious. I am actively fighting against this, but if you have any ideas, please reach out!

Knowing what you do now, what would you change?
RZ: Starting this project earlier. Applying for more grants for more funding to increase our small team.

Is there any way to make observing time more efficient and less time consuming?
RZ: Unfortunately there's not much one can do- you need to observe, ideally, the full transit (which is typically ~3-5 hours) and also some time before and afterwards (another ~1-2 hours). However, some folks have gotten some awesome partial transits, so perhaps that's a way to decrease the observing time.

Do you have any initiatives to encourage involvement from students who are from groups typically unrepresented in STEM?
RZ: I am hoping that the ability to publish papers will actively do this. If you have any ideas, please reach out!

Has there been any interest from telescope companies like Celestron to help promote Exoplanet Watch alongside their telescope sales?
RZ: We have Unistellar's eVscopes participating in our project. But we cannot actively promote a private company due to NASA rules.

How can these small telescopes make planetary science and/or astronomy more accessible, both for researchers in lower-income countries and regular citizens interested in the field?
RZ: By lowering the bar for participation. You do not need a large scope or dark skies to make meaningful, science-grade observations. So you don't need an extremely expensive setup. So you can use your smaller scope to do awesome observations and do your own research and get some publications out of it.

How is the research based on data from these small telescopes viewed by the research community (in terms of reliability, etc.) compared to studies with data from larger ground telescopes or JWST?
RZ: Unfortunately, there still seems to be some elitism within the field so that observations taken by amateur astronomers are automatically seen as dubious. I am actively fighting against this, but if you have any ideas, please reach out! But JWST will always do better than our amateurs- but we're enabling observations of JWST by doing "pre-observations" of these targets to ensure that we use JWST efficiently.

I'm aware of moons of planets displaying orbital resonances; is this the same concept that is applied when searching for previously unknown exterior exoplanets?
RZ: Yes, exactly! And we can look for these resonances to help us discover new exoplanets.

What are your thoughts about a hypothetical ninth solar system planet causing some of the odd orbital trajectories of Kuiper Belt Objects?
RZ: Seems interesting- but I know a bunch of folks who have tried to observe it and haven't yet. So maybe it is still lurking out there somewhere?

You mentioned using perturbations in a known exoplanet's orbit to find another exoplanet, so would you be able to determine if a system has 2 vs more than 2 exoplanets?
RZ: Yes exactly- we can actually start looking for higher-ordered signals (which look like multiple sine waves stacked up on top of each other) to deduce that there's more than 2 planets.

Do you know the demographics of your citizen scientists and do you anticipate that there will more diversity in contributors after you roll out the telescope loaning program?
RZ: We are restricted due to US and NASA privacy rules how much information we can collect. However, I know offhand that most of our users are older, white, and priveledged (those who can afford their own telescopes). We have been able to increase our userbase to more diverse high school and college groups, however, by loaning them data from our robotic telescopes.

What is the basis for the site selection of ground-based telescopes?
RZ: Right now, it is increasing coverage to undersampled parts of the world- for us, it is South America and Africa.

Whether the data collected by the telescope has background noise and how to remove it?
RZ: Our data reduction code, EXOTIC, will handle a bunch of this for you. But you can also take some calibration images while you're observing to help quantify, and afterwards remove, these noise sources.

How often can longer transits be observed by amateur astronomers in the US, and do longer transits have more transit time variability?
RZ: Longer transits can be observed once in a while- we've mostly discovered short-period planets because they're simply easier to observe (short period planets orbit their host star more regularly/quickly, so you can see more transits in a given timespan). I do not believe that these longer period transits have more transit time variability.

Are there any resources that you know of that could help support a community or high school astronomy club with the purchase of a telescope to contribute to Exoplanet Watch?
RZ: We unfortunately do not have it in our budget (and I'm not sure what the NASA rules are) for giving our grants to clubs. However, we can loan them one of our loaner scopes for a year. We will hopefully start this up in the first half of 2023.

How do you separate good quality amateur data from bad quality data, and what is the cutoff for "good" data?
RZ: We use a metric called a "3 sigma significance" on the detection of the transit itself- basically, if we can say that we think that a user has detected the transit with a confidence of 99.7%, then we say that the quality of that data is good.

Does EXOTIC account for any asymmetries (i.e., Rossiter-McLaughlin effects) or limb darkening, or does it treat the stellar cross section as a uniform disk?
RZ: We do model limb darkening in our code, but other than that, no. I don't think we have the precision to model Rossiter-McLaughlin effects, unfortunately- I think you need a much larger scope, like >=4 meter class, to do that. But perhaps we could bin all of our users' data together to achieve a high SNR…TBD.

What over-the-counter cameras are sufficient?
RZ: We have personally used a ZWO astronomy camera that costs $200. I know other folks have also used a digital DSLR camera to do these observations as well.

What is the tolerance on the tracking mounts? / are there any mechanical tracking mounts that don't have sufficient precision?
RZ: We recommend an equatorial mount- it is much easier to guide with. You can use a "standard" alt-az mount, but it usually needs a separate guider camera to keep the target in the field of view over the ~6 hours of observations.

Using the transit method it is possible to identify exoplanets, but are we able to determine if these exoplanets have moons?
RZ: Yep! We have a few scientists that are poking our data to see if they can see a moon in our data- it will just look like a "mini-transit".

If not all exoplanets transit in front of their star from earth's view; are you able to make inferences about such possible exoplanets based on the influence they may have on exoplanets that do transit in front of their star?
RZ: Yes- there's other folks out there that are taking the returns from transit efforts and then doing the math to estimate how many planets we're missing, and therefore the total number of planets out there.

Has anyone ever found a duel planet system using the transit method?
RZ: Yes! We have also found a Tatooine, a planet that orbits two stars! Kepler-16b: https://www.nasa.gov/mission_pages/kepler/news/kepler-16b.html

Would you ever consider building observation stations where citizens can be taught how to do their own observations?
RZ: Yes! We have online tutorials and a bi-weekly meeting, which is recorded and posted to our Slack channel, where we go over various aspects of the project, including how to use our data reduction code. We have also been thinking of starting up yearly workshops and our users themselves have been awesome in helping out other members. But with regards to building observing stations, the only reason that I've been hesitant to do this is that it typically only helps out the audience/participants local to that station. But perhaps there's a way to livestream observations from one of our remote observatories….

What types of data can transit light curves provide on exoplanet atmospheres?
RZ: Typically, they give us the elemental and molecular abundances in that planet's atmosphere as well as the thermal structure (how temperature varies with height) as well as the existence of clouds or hazes. We also can get information about a planet's climate: for example, the speed of winds on these planets.
How are exoplanet diameter and orbit calculated from a transit light curve?
RZ: I find this animation helps explain things: https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/#/2
But also this one: https://exoplanets.nasa.gov/faq/31/whats-a-transit/#:~:text=Transits%20reveal%20an%20exoplanet%20not,over%20a%20period%20of%20time.