Smartphone Astrophotography: A Useful Approach for Outreach and Education

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Abstract In this article, I describe my experiences with a somewhat neglected method of variable star observation: smartphone images. I outline the potential of smartphone images as a tool for astronomy education and argue that they are a uniquely effective way to draw in beginner observers (especially younger observers, amongst whom high-level smartphone usage is ubiquitous). I describe my methods in collecting images of two variable stars (δ Cephei and β Persei) with my smartphone, and how I used these data to make magnitude estimates and phase diagrams. I conclude with a note on the potential of smartphones as an educational tool, and outline some of the aspects that contribute to their appeal and usefulness.

1. Introduction

This past year, I have been working on a student project focused on making variable star observing more easily accessible. Like many outreach projects, it is, at heart, concerned with one question: how can astronomy (or, science in general) be made easy? In many ways, this is the million dollar question, and the many attempts to answer it have prominently featured across a variety of subjects, such as the philosophy of citizen science and the epistemology of science. One can almost convince oneself that making science "easy" is the missing piece required to solve many of the quandaries that plague those of us concerned with science outreach and related social issues; we can dream that it will promote the establishment of a scientifically literate and engaged public, which will, in turn, lead to a more effective and just society.

The question of whether easy and accessible science is indeed the solution to our ills is impossible to answer, but it nonetheless remains an intoxicating idea. It was the pursuit of this question that first introduced me to the ample history of amateur astronomers and variable star observing, and to the wealth of work done by organizations such as the AAVSO in connection to this same goal. Variable star astronomy seems to tick all the boxes for drawing in non-scientists; it incorporates the glamour and beauty of the stars, while genuinely providing a meaningful opportunity for amateurs to contribute to the greater enterprise of astronomy. In this article, I'll talk about my experiences with creating an "easy" astronomy resource for beginners, and how I believe smartphone camera photometry may be a more effective entry point to the field than the more commonly used methods of visual observing or DSLR camera observing.

2. The case for smartphone images

The project I previously mentioned involved the creation of a standalone tutorial for variable star observing in the form of an interactive and gamified app (this app is still in development and will be made available on the Google Play Store by August 2020, under the title "Variable Astronomy: A Do-It-Yourself Experiment"). Created in UNITY, a platform often used for video game development, the application was created with high school and university students in mind as the target audience, users who would most likely begin their intellectual journeys into astronomy by looking for resources online. On a basic level, the idea of the project was to guide people with absolutely no prior knowledge of astronomy through the process of a simple yet useful experiment in variable star observing. It began by teaching users how to collect data and make magnitude observations and concluded with a guide to creating phase diagrams from their data. It also informed users about how they could share their observations and engage with the wider astronomical community. My hope was that this application would be an effective way to create new amateur astronomers. As such, much of its success relied on it being, to put it simply, easy. Thus, while working on creating this resource, I imagined myself in the role of a salesman trying to recruit new clients into variable star observing.

In trying to find the easiest and fastest way to observe stars, I began by putting myself in the shoes of my target users, and experimented with various methods of observing. Of these, I reasoned that the most accessible (and least intimidating) is visual observing. After that, DSLR photometry is probably the second most appealing to complete beginners, with DSLR cameras being a reasonably common and familiar device. I also tried taking pictures with the camera on my smartphone, with little hope that the quality would be high enough to be able to make magnitude estimates.

To my surprise, these smartphone images ended up being the most convenient and effective method for a rough and tumble introduction to variable stars. As more experienced observers would have been able to tell me, there are certain hidden difficulties in visual observing that are easy to forget until you find yourself outside in your chosen observing spot, unsure of where to look and what to do next (Gaskell 1991). For example, after you've settled on a target star, you must use star maps, or planetarium apps to actually find it in the sky. This is sometimes easier said than done, especially in areas with high light pollution; you must allow your eyes to adjust to the night sky, and wait a while until you can accurately guess at the magnitude of your star. You also need to have memorized the positions and magnitudes of your reference stars–otherwise, you will have to refer back and forth between the sky and your star chart, running the risk of losing the position of your star and wasting time as your eyes become disaccustomed. In addition, in harsher weather conditions, being outside for longer periods of time is quite difficult. For dedicated, passionate observers, these inconveniences are minor, and do not strongly affect the quality of the experience. But for complete beginners with little emotional attachment to or stake in the enterprise, the slightest difficulty may be enough to put them off the idea completely.

Cellphone photometry alleviates these inconveniences to a degree that may be enough to keep the more fickle observers interested. To begin with, when taking cell phone pictures, observers do not need to pinpoint the exact location of their target star. Knowing the vague position, perhaps guided by a general constellation that may be easier to immediately identify, is often good enough if several pictures in that field of view are taken. Observers can avoid staying outside for long periods of time, as well as preparing star charts and memorizing reference stars, by pulling their pictures up once in the comfort of their own homes and making their magnitude estimates in their own time, aided by any other resources they may find helpful. Furthermore, some of the urgency involved in making accurate estimates is eliminated by the fact that observers can just go out and take another cell phone picture if their first attempts do not go as planned. In this way, visual observing can be "tamed" enough for beginner observers to gain an entry into the science of variable star observing.

DSLR pictures offer some of these advantages, and also allow for observers to make magnitude estimate in their own time (Loughney 2010). However, in my experience, DSLR cameras are a more intimidating animal, and observers may be confused as to how exactly to adjust their cameras for optimal quality. Smartphone cameras tend to have less customizable settings, and as such are less daunting to beginners. Changing the ISO, white balance, and aperture is just a matter of tapping some icons on a screen.

DSLRs are also more cumbersome and thus more difficult to transport to your observing location, while many observers will already be carrying their cellphones with them wherever they go. DSLRs will also need a tripod, whereas you can get away with not using one for smartphone pictures (you may look silly resting your phone on nearby benches or walls to stabilize it, but the pictures will turn out well!) (Loughney 2010). Furthermore, when it comes to disseminating pictures, DSLRs must be hooked up to a computer and files must be transferred, whereas most smartphones will have built-in options for easily sharing pictures (Loughney 2010). This affects the social nature of observing: much of the fun of the experience comes from sharing findings with a wider community, or bragging to friends about how cool your pictures are. Smartphones lend themselves to this aspect of the activity, and are conducive to creating a sense of community.

While the quality of the smartphone photographs may not be good enough to do advanced photometry or highly accurate estimating, it is more than adequate to capture magnitude fluctuations in the more popular beginner stars (see Figure 1). For new observers, simply being able to see some kind of change in a star is a pivotal and impactful moment,

Figure 1. Image of the constellation Cepheus taken on at 8:13:00 p.m., February 19, 2019, in Toronto, Canada. δ Cephei, ζ Cephei, and ε Cephei are outlined by a black box. δ Cephei is the topmost star within this box. By using comparison stars, I estimated δ Cephei to have a visual magnitude of approximately 3.5.

as it can feel like a shift from passively stargazing to actually "doing science."

3. Method and results

I took my pictures in light-polluted downtown Toronto, and was able to capture fluctuations in δ Cephei and β Persei with my Samsung Galaxy S9. Newer Samsung series phones like mine often have a "pro" mode on their built-in cameras; while regular settings aren't sensitive enough for astrophotography, pro mode allows users to adjust their ISO, aperture, and shutter speed, focus settings, and white balance, similar to how one might on a DSLR camera (Samsung 2020). I used an ISO of 800 (the highest setting available on my phone), an aperture of f/1.5, and a shutter speed of 8 seconds, while setting my focus to manual mode and my white balance to 5500 K. While different types of phones vary in camera quality and level of modifiability, many will offer at least some of these advanced features. In order to ensure that my results could be achieved with a variety of smartphone models, I did some research into other popular phone models. iPhones, for example, don't have the "pro" function available on Samsungs, but can be tweaked with the help of third party applications that adjust these camera settings for you.

I took my pictures over a range of dates from October 2018 to March 2019, usually from a nearby schoolyard which offered some respite from the bright lights of the city. Despite poor seeing and frequent cloud coverage, my cell phone was able to capture stars as dim as 5.2 magnitude (I suspect that under more amenable conditions, even dimmer stars could be photographed).

I avoided making any unaided-eye magnitude estimates, and instead reviewed my pictures only after I returned home. There, I pulled up star charts for δ Cephei and β Persei and made my estimates by comparing with the reference stars that had also been captured in my pictures. For δ Cephei, I used ε Cephei and ζ Cephei, and for β Persei I used α Persei and ρ Persei (see Table 1 and Table 2). (Note: ρ Persei is a semiregular variable with 0.7 magnitude amplitude, which is a large enough variance to potentially affect the accuracy of visual estimates. If possible, chosen reference stars should not be variables with an amplitude larger than 0.5 magnitude). After collecting enough pictures to construct a somewhat sparse light curve for both of my target stars, I checked my magnitude estimates against others during the same time period by using the AAVSO's light curve generator (LCG, see Figure 2 and Figure 3). Happily, I found that my cell phone pictures resulted in a light curve quite similar to the one compiled by the LCG, and that my resulting phase diagrams matched up with previously constructed phase diagrams (Kafka 2020). All in all, I found that cell phone pictures resulted in reasonably accurate magnitude estimates, and were a great way to conduct a simple little experiment—one that has the potential to quickly and effectively introduce new observers to many aspects of variable star observing.

4. Conclusion

Perhaps the greatest strength of smartphones as an observing tool is their ubiquity and familiarity. Especially amongst younger generations, smartphones tend to be understood as an extension of our bodies–they act as a supplement to our memory and knowledge and extend the scope of our limited human abilities (Mutchler *et al.* 2011). And more often than not, they are always on our person. Much like visual observing, smartphone camera observing feels less like an adoption of new technology for the sake of doing complicated science and more like a natural process of casual observation and discovery, with common tools that in our immediate environment and readily at our disposal. In this way, the sense of old-fashioned adventure and playful discovery experienced with visual observing is

Table 1. δ Cephei smartphone image observations.

Julian Date	*Magnitude Estimate*	*Phase*
2458410.431	3.7	0.39
2458421.313	3.7	0.36
2458426.528	3.7	0.39
2458481.326	4.1	0.2
2458482.292	4.2	0
2458490.325	3.4	0.49
2458534.343	3.5	0.69

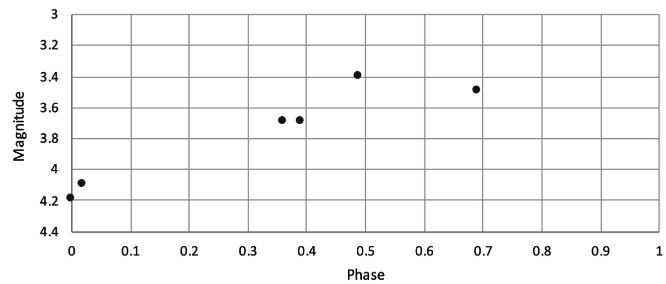

Figure 2. δ Cephei phase diagram.

Table 2. β Persei smartphone image observations.

Julian Date	*Magnitude Estimate*	*Phase*
2458410.431	2.0	0
2458421.313	2.1	0.79
2458426.528	2.0	0.6
2458481.303	3.0	0.69
2458481.354	2.5	0.71
2458482.292	2.0	1

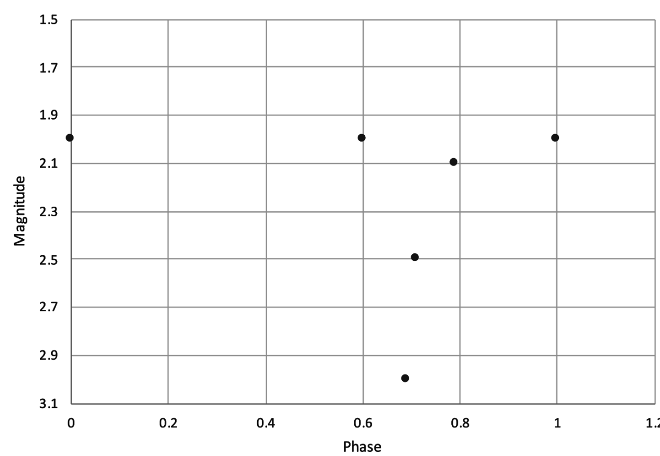

Figure 3: β Persei phase d+iagram.

preserved, with the added benefit of the higher convenience afforded by smartphones. In trying to "sell" newcomers on variable star observing and create the next generation of amateur and professional scientists, smartphones have great potential to not only briefly entice people into the world of variable astronomy, but to lay the groundwork for a deeper engagement that empowers new learners to perceive themselves as real astronomers who do real science.

Such outreach efforts are crucial in fundamentally changing the relationship between science and the public and blurring the line between experts and laypeople by democratizing access to scientific data and expertise. Through their ease of use and great potential for data collection, smartphone images make a valuable contribution to the wider project of science.

5. Acknowledgements

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