Student Technology Fee Advisory Committee
Request for One-Time Funding Worksheet

1. Project or Program Name: Enhanced Active Learning in Astronomy Labs

2. Department or Unit: Physics and Astronomy ________________________________

3. Department Contact Name and E-Mail: Inseok Song, song@uga.edu ___________

4. Brief description of request:

Astronomy labs (e.g., ASTR 1010L/1020L and ASTR 1110L/2030L) at UGA and other major universities and colleges have incorporated a minimal level of nighttime observation (one or two sessions per semester). Even during rare nighttime observation opportunities, more than 10 students often need to share one expensive, department-owned telescope, significantly limiting active learning opportunities. With advances in relevant technology and manufacturing, good quality optics have become affordable, and very low-cost telescopes (under $100, e.g., Celestron's FirstScope Telescope) are now readily available.

With support from the Office of Active Learning, we have purchased 50 sets of FirstScope telescopes and smartphone adapters. A pilot test project was conducted with approximately 20 students enrolled in ASTR 3010 ("Observational Astronomy") during Fall 2024. Each student checked out a 4-inch telescope and a smartphone adapter at the beginning of the semester. Using their own smartphones as digital detectors, they carried out observation projects in their own backyards. Students' reactions have been very positive, and they appreciated the hands-on experiments. More detailed information about this project can be found additional supporting material at the end of this document or from this link. However, almost all students expressed difficulties in aligning their smartphone cameras with the eyepiece's small pupil using the smartphone adapter. This has been a major distraction in an otherwise overwhelmingly positive experience.

With FY25 Student Tech Fee support, we propose to purchase a set of 40 entry-level astronomical detectors that can be directly attached to the telescope's eyepiece, eliminating the need for smartphone adapters. These entry-level astronomy cameras, dubbed planetary cameras, are sold at approximately $150 each. With these telescopes, students can readily embark on observational projects without being distracted by the alignment issues.

5. Evidence of student need, starting with number or percentage of students or courses served:

Generally, 10-15 students share one telescope in a rare observation session for any given semester at UGA. They need to come at night for astronomy labs which poses a potential security concern (no one else in the building other than students and one

TA). The need to share a telescope by a large group of students essentially eliminate any chance of providing active learning environment.

In each Fall and Spring semester, we offer two astronomy labs (ASTR 1010/1020L and ASTR 1110L/2030L) and about 40 students have enrolled in each lab. The telescope + planetary camera can be used for upper-level course such as ASTR 3010 and a cross-listed “Astrophotography” course in development by Franklin College and Lamar Dodd School of Art faculty.

6. What instructional goals are associated with this request?

Provide a greatly enhanced active and experiential learning environment. This new astronomy lab curriculum has the potential to revolutionize astronomy education in the USA.

7. Describe how this project will be accessible to students with disabilities and comply with Section 508 Electronic and Information Technology Standards.

Each student carries out assigned observation tasks at their own place during their preferred time. This greatly increases accessibility compared to the traditional approach of a dedicated nighttime session with a shared telescope.

8. Detailed Budget – Include **all items** required for this project or program:

We request to purchase 42 planetary cameras (2 as spares).

Item requested	**Number requested**	**Unit Cost**
Planetary Camera (e.g., ZWO ASI662MC)	42	$150 (before tax)

Use additional pages as necessary.

9. Total Amount Requested from STF ($2,500 Minimum): $6,500 (with estimated tax) _

10. Briefly describe additional funds available for this project, if any:

The support from the Office of Active Learning ($18,500) was able to initiate this project with the purchase of 50 telescopes and faculty summer salaries for the initial curriculum design. We plan to submit an NSF/IUSE proposal to support this project including the detailed astronomy lab curriculum development, collecting and analyzing student data, and publish the result in a research journal.

Please attach any other supporting information regarding this request.

Click here to see the list of admin stuffs

Active & Experiential Learning with Low-cost Telescopes

Project Lead: I. Song

At first, students are attracted to astronomy mainly because of the awes and beauties of celestial objects. However, students rarely have opportunities to see celestial objects with their eyes using telescopes even if they take astronomy courses. Even for astronomy majors, course activities using a telescope are greatly limited because of (1) using the department-owned, centralized large telescopes, (2) the need for night-time gathering at the campus for astronomical observations, and (3) weather limitations including the light pollution at the campus site. Traditionally, night-time observations are done with expensive telescopes (8 inches to 14 inches in size with a price tag of up to a few thousand dollars) owned by the department, and such observations require students to be gathered at a campus at night which can cause a security issue. Ability to deploy a telescope to an individual student or a small (N<3) group of students can alleviate these problems.

With the advance of relevant technology & manufacturing, good quality optics become cheap and a very low-cost telescope (under \$100, e.g., Celestron's Firstscope Telescope) is readily available currently. In addition, one can build a small (~11 cm primary mirror) reflecting telescope from parts (mirrors, focuser, eyepieces, other material) and the total cost of such a DIY telescope is about \$100 per telescope. The DIY telescope can have many “teachable” moments.

We can develop several active-learning and experiential learning opportunities by using low-cost telescopes or DIY telescopes.

- Create a new course, e.g., “Observational Astronomy II”, to be offered as an elective for astrophysics majors. This course will provide two active learning activities: (1) build a DIY telescope using components and (2) carry out an astronomical observation project using the telescope built in the first half of the semester.
- First-Year Odyssey Seminar (FYOS) scourses: (1) we can offer an astrophotography class using a commercial low-cost telescope during a fall semester and (2) a course during a spring semester tailored toward the creation/usage of a DIY telescope.
- PHYS 1252 / Advanced Lab: (1) Using optics parts, machine shop prepared materials, and 3-D printed parts → make a telescope, (2) create a spectroscope (using a simple grating), (3) use a smartphone as a camera or add a lost-cost CCD with relevant electronics, (4) obtain and measure gas emission lines to calibrate the spectroscope, (5) carry out a simple, astronomical photometric and/or spectroscopic observation project.
- Dylan Valin (department's lab specialist) agrees to join as a team member, and he can mentor “assembly of telescope” activities including (1) 3-D printing of parts, (2) CNC milling of base plates, etc. Small Satellite Research Lab (SSRL) in the basement of the Physics building has a CNC milling machine and we may be able to use it through a contract.
- Check the following site for manufacturing a telescope using cheap optics parts (mirrors etc.) and 3-D printed components: https://www.printables.com/model/224383-astronomical-telescope-hadley-an-easy-assembly-hig

To use a smartphone as a digital detector for astronomical observations, we need a special camera app that allows a much longer exposure time than possible. Use one of the following apps depending on your phone type.

- Android, DeepSkyCamera (free): https://www.deepskycamera.de/manual/DeepSkyCamera_manual_en.pdf
- Apple, NightCap ($2.99): https://apps.apple.com/us/app/nightcap-camera/id754105884

Things to consider It would be beneficial to adopt a similar approach to the one showcased in the poster below when it comes to sharing lab instructions with students. Not only does this method help us utilize lab time more efficiently, but it also ensures that instructions are delivered clearly to students. Additionally, it presents an excellent opportunity for TAs to practice science communication skills. NJW had implemented this approach in his PHYS 1251/52 courses, and it was proven to be very effective.

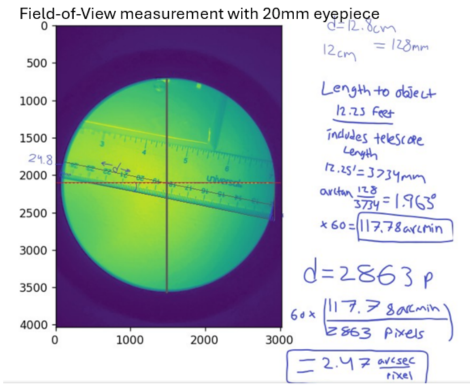
- https://www.researchgate.net/publication/375632481_Laboratory_Instruction_Enhancement_Utilizing_QR_Codes_and_Digital_Resources_in_Introductory_STEM_Courses
- https://www.researchgate.net/publication/369588986_Re-Engineer_the_Way_We_Introduce_Introductory-Level_STEM_Lab_Activities

Quick demonstration of the Telescope + Smartphone setup

Here is the quick display on the setup of the telescope + smartphone and some sample images.

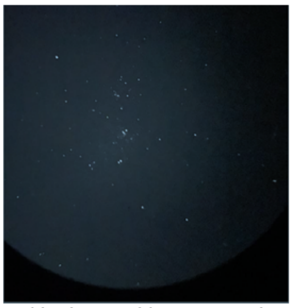
Telescope Setup

Some Example Pictures

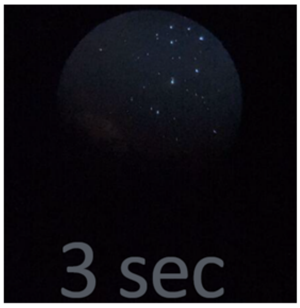


Preliminary works from ASTR 3010 students (2024 Fall)


Moon, with 20mm eyepiece, 1/30 sec


Double Cluster, with 15mm eyepiece


Saturn+Titan, 4mm eyepiece



Pleiades


Messier 25, with 20mm eyepiece


Jupiter + 3 Jovian Moons, 4mm eyepiece

Lab Topics suitable with Low-Cost Telescopes

1. Introduction to the telescope + smartphone
2. Collimation of telescope mirrors
3. Camera operation (ISO, exposure, repeat, etc.)
4. Data analysis (preprocessing + stacking)
5. Image enhancement (photoshop etc.)

1. Astrophotography → imaging of the brightest galaxy. any significant scientific gains?
2. Phase of the Moon, Libration Movie → Specifics of scientific activities? **Can be done on non-photometric nights**
3. Phase of Venus; phase-size dependency → Specifics of scientific activities? **Can be done on non-photometric nights**
4. Movement of Uranus → estimate its “circular” speed and estimate its distance (Uranus is 6th mag). Uranus moves about 0.7 arcmin per day.
5. Mapping the light pollution in your area
6. Color-scale of your camera: measure the relationship b/w RGB color and Teff
7. Asteroid observation: (1) known asteroid and recover its orbit or (2) blind hunting for asteroids
8. Any oppotunistic objects such as comets
9. Observe Galilean Moons (or Titan) → create a movie → and measure periods → calculate distances from the central planet (max angular sep of Io/…/Callisto is b/w 2 and 10 arcmin and Io's period is 1.77 days. Titan's max angular sep from Saturn is 0.3 arcmin with an orbital period of 16 days).
10. Obtain the limit of the deep observation → how deep one can go with this setup? Related to the light pollution mapping
11. Color-Magnitude diagram of bright, nearby clusters (Pleiades, Hyades, Beehive, etc.) → **Need**

photometric nights

12. Observations of short-period variables (Cepheids, Eclipsing binaries, etc.) → recover known periods. **Can be done on non-photometric nights**
13. Standard transformation of your smartphone camera

1. Engineering projects: creating ESP32 camera holder, creating a finderscope, spectrograph, etc.
2. Post Image processing (by Marni Shindelman)

DIY telescopes & Digital Detectors

Parts

- Mirrors: \$29
- Eye pieces (x3): \$29
- DIY Focuser: here
- Other materials (from hardware stores and 3D printing): ~\$20?

- Check also this site: Hadley Telescope

- Check also this “Monolithic Telescope” made of a single block of glass: https://hackaday.com/2022/04/21/watch-a-complete-reflector-telescope-machined-from-a-single-block-of-glass/. How much does it cost to create one?

Low-Cost Digital Detector or Camera

ESP32-CAM

As a start, we can use the smartphone as a digital detector. However, controlling the phone in terms of image output (full-frame, subsampling, well-depth, etc.) is greatly limited. We can build a DIY digital detector using a low-cost CMOS image sensor (e.g., OV2640 [\$9.99 in Amazon]) controlled by an Arduino ESP32 (three for \$15.99 in Amazon). However, this may require in-depth knowledge of electronics. We can build a course aiming to develop such a digital imaging detector (ASTR 3020?). In addition, we can also consider manufacturing a DIY spectrograph. There is a GitHub repo for controlling ESP32 camera board: ESP32 Camera Control

WiFi Telescope Eyepiece

Alternatively, we can use an eyepiece camera that can be attached over the eyepiece and images can be captured through wifi-connected smartphones. It is listed at \$73 in amazon (search for “WiFi Telescope Eyepiece Camera” on Amazon). **I tested out this eyepiece, and it should be used on top of an eyepiece and the aligning the camera over an eyepiece still needs to be done carefully. Other then providing a convenient WiFi connection, there seems to be not much of additional benefits.** Furthermore, image/video can only be seen and obtained via a dedicated smartphone app.

Other low-cost "planetary cameras"

There are some cheap (<\$100) CMOS cameras on the market labeled as “planetary cameras”. These cameras have a max exposure of 1 sec. Some examples are:

- SVBony camera → supported by SharpCap → SV105=\$47, SV205=\$90, SV305=\$114
- FIBONAX camera → not sure if usable with SharpCap ⇒ Nova200 = \$55
- Player One Mars-C (IMX462) = \$169
- ToupTek G3M662C = \$149
- ZWO ASI662MC = \$149

Software

Camera Software

Some camera manufacturers provide their own software such as Celestron or ZWO. Otherwise, most commonly recognized cameras can be supported in **SharpCap** or APT (Astro Photography Tool; non-free). SharpCap runs only on Windows machine.

firecapture is an alternative to SharpCap and it runs on Windows, Mac, Linux, and Raspberry PI.

Image Analysis software

DeepSkyStacker, a free software available for Windows/Linux/MacOS, can do:

- pre-processing (bias, dark, flat, and bad pixel corrections)
- registering (i.e., centroiding + shifting) images
- stacking (i.e., combining images) images

Another software (Siril), available for Windows/Linux/MacOS, can do similar tasks as well. It also provide a photometry tool.

A Potentially Useful Combination

SharpCap allows a user to use a webcam as the imaging device. With the free app called iriun, a smartphone can be used as a webcam which can be controlled from a computer (Windows, Linux, or MacOS). Then, without replying on the use of an external camera app (e.g., NightCap or DeepSkyCam), a student can take night sky images via SharpCap.

Image Analysis

Quick Image Check

Check http://deepskystacker.free.fr/english/index.html for quick registering and stacking of images.

Status of the Project

— *Inseok Song 2024/05/03 15:36*

- Check this page for the progress made by an undergraduate team member, Anna Dmitrieff, using the FirstScope from Celestron.