APPLICATION FOR DIRECTED STUDY

Student's name (or students' names) and class year(s):

- Luke Suess (DS21)
- Sofia Mikulasek (DS22)

Term and year: Terms 3-5, Academic Year 2022-2023

Course Title: Transient Astronomy

Sponsor: Brian Hill

Pass/Fail, or graded: Graded

Credits (see section 5 of the Academic Policy): 4

Please answer the following questions and attach.

1. Attach a Long Course Description (model provided in "Curriculum and Faculty Information"). If the course is expected to earn more than two credits per semester, please attach a detailed syllabus that explains the assignment of credit.
2. What will the learning arrangement be (e.g., how many meetings with the sponsor, how many hours spent by the student(s) on project activities)?
3. How will the study be evaluated?
4. How will the proposed course contribute to the student's intellectual life at Deep Springs and to his long-term academic goals? How will it serve the sponsor's academic or professional interests? Why is this the best time and place for this course of study?

Submitted:

____Brian Hill_____ Brian Hill, Faculty Sponsor

____Luke Suess_____ Student

____Sofia Mikulasek_____ Student

Approved:

_____ Academic Dean

_____ Curriculum Committee Chair

1. Attach a Long Course Description (model provided in "Curriculum and Faculty Information"). If the course is expected to earn more than two credits per semester, please attach a detailed syllabus that explains the assignment of credit [this is spelled out in Section 3 below].

See the PDF at this URL:

https://brianhill.github.io/transient-astronomy/TransientAstronomySyllabus.pdf

Note that the above PDF is not significantly different in content than the answers to the questions below. The only significant difference is simply that the attachment is formatted as a syllabus. This is needed for the College's record-keeping, transfer credit, etc. If the committee was looking for something significantly different for this attachment than what has been provided, please inform us and we can expeditiously revise it.

2. What will the learning arrangement be (e.g., how many meetings with the sponsor, how many hours spent by the student(s) on project activities)?

This proposal is a blend of a (1) observational astronomy, (2) data-taking with research ambitions, and (3) developing a data-processing pipeline in Python. This blend fits under the model of "Research Experience for Undergraduates (REU)," as it is known at many institutions.

To carry these three activities out, we need approximately 7 meetings for theory and organization, 14 meetings for joint observation sessions, and 7 meetings for joint analysis sessions.

These numbers are intentionally aligned with how many analytical and laboratory meetings a one-semester Deep Springs course would have if half of its meetings were analytical and half were laboratory. We will necessarily need to adapt if either the analytical or laboratory work takes an unexpected amount of time, while retaining the total target of approximately the same amount of meetings as a one-semester full-load course would have.

Because we will be limited by Moon, weather conditions, and our general availability, to maximize the opportunity for joint observation sessions, we want to spread this work over three terms, rather than two. Both December and January may have quite a few weeks that are so cold that it is hard to do quality observing (although optimistically they could offer many mild weeks). Therefore the Term 3 weeks before Thanksgiving, and the Terms 4 and 5 weeks starting at the beginning of February are likely to present the best opportunities to gather high-quality images.

Project Activities

All three of us need to be fully cognizant and responsible for the results that we produce. This means that we will (outside of regular meeting times) be independently doing analyses of the data we have taken. Also, all three of us do not need to be present for all data-taking sessions, so there will be data-taking sessions consisting of just pairs of us taking additional data once the techniques have been established to all three of our satisfaction. A typical data-taking session will run from about 7pm to midnight, which includes time for setup and teardown. Some data-taking sessions will be pre-dawn instead of in the evening (e.g., from about 3am to 7am).

Three Phases

Although there is definitely not a hard delineation or progression between (1) establishing technique, (2) using that technique, and (3) analyzing and writing up results, there are nonetheless three identifiable phases.

In the first phase, we are principally establishing our experimental technique and just starting to establish our analytical technique. In the second phase, we are principally using our experimental technique while still improving our analytical technique. In the third phase, we are still getting additional data the now-established experimental technique while polishing our analytical technique, and in parallel with that we are writing up the best of the results that we were able to achieve.

Roughly speaking, these three phases will correspond to our activities in the three terms that we propose to do the work (Terms 3, 4, and 5).

Analytical Work in Python

Analytical work has frequently been referred to above. In the Spring 2022 Observational Astronomy course, this work was done in a relatively pedestrian and user-friendly tool called AstroImageJ. Most professional astronomers do similar analyses in other more versatile environments. Because Python is such a general-purpose environment and it is inexpensive, it is valuable to be familiar with it, and that will be our choice.

Our analysis will involve establish a data-processing pipeline in Python probably using (i) astroalign for alignment (https://astroalign.quatrope.org/en/latest/), and (ii) photutils for aperture-annulus photometry (https://photutils.readthedocs.io/en/stable/getting_started.html). These (and other scientific) packages are most commonly accessed from Jupyter notebooks. Jupyter is an interactive scripting environment for manipulating data, making plots, and running Python code. We will produce the plots for our writeup in Jupyter notebooks.

Research Questions

We will be guided by the following over-arching questions:

1. In the dark skies and high altitude which we have at Deep Springs, what observational techniques and conditions make us the most sensitive and accurate that we can we be in detecting and estimating the changes in brightness of stars possibly as dim as magnitude 20 with our relatively modest (250mm) telescope? We fully expect to be able to get to magnitude 19. *NB: larger numbers are dimmer in the astronomical magnitude system.* Before this directed study even begins, we have obtained data that makes us confident that our equipment can easily identify magnitude 18 stars.

2. What are the best practices in the analysis of the data taken in our observations that again push the brightness limits of our setup?

3. What transient targets are of the most interest given our data-taking and analysis capability? We believe that supernovae identified by the Zwicky Transient Facility are within our grasp and that supernovae light curves taken over many nights with our gear will be of sufficient interest to the astrophysics community that we can contribute our results to refereed publications. Supernovae have various brightnesses with the brightest ones having peak luminosity brighter than magnitude 17 (see https://www.rochesterastronomy.org/supernova.html). We will pursue easier targets in the unlikely event that supernovae prove to be beyond the limit of our setup (e.g., binary star systems and transiting exoplanets).

These questions are mostly in the realm of experimental technique as our setup is, as we begin this study, mostly unproven.

3. How will the study be evaluated?

- Observational Work — 25% — This will be comprised of observatory setup and teardown work as well as approximately 10 evenings of data-taking

- Analytical Work — 25% — This will be comprised of data processing using Python packages

- Scientific Record-Keeping — 25% — Records should include: (a) Target Selection Criteria, (b) Listings of Available Targets and their properties, (c) Conditions of Data-Taking, (d) Factors in Data-Processing

- Project Report and Presentation — 25% — We will jointly produce a project report. If our results are sufficiently significant, our project report will be submitted as a paper to a refereed journal (such as the *Journal of the AAVSO* or the *Astronomical Society of the Pacific).* We will also present our results to the Deep Springs community as a standalone presentation or as a lecture in the lecture series that is under discussion by CurCom.

4. How will the proposed course contribute to the students' intellectual life at Deep Springs and to their long-term academic goals? How will it serve the sponsor's academic or professional interests? Why is this the best time and place for this particular course of study?

Brian (sponsor):

After two years of construction which began in Fall of 2020, the observatory is now fully ready for the work it was built to do, which is to provide a place to do observational astronomy under the dark skies of Deep Springs. We will select transient targets that push our equipment and use our environment to its limit. It is hoped that with dark skies, modern astronomical camera sensors, and state-of-the-art data processing techniques that we can observe transient phenomena as dim as magnitude 19 and possibly to magnitude 20. If so, we can contribute to the creation of supernova light curves. If our dark skies and equipment are not capable of that, we can certainly still do studies of transiting exoplanets.

Many students have expressed an interest in astronomy. What is special about Luke and Sofia are two things: First, they are among the most serious students I have had in any of my science courses, and second, they consistently find time in their busy schedules to help when I have needed an extra pair of hands. Two of many examples of that from Term 2 would be a heroic (but so-far unsuccessful!) attempt to re-arrange boulders around the observatory, and the construction of a custom table leg for the observatory desk.

Because of their track record of seriousness in their coursework and of making time available, I am confident that they will deliver on the sustained, quality work that a directed study in astronomy will require. Working with students like this is directly-related to my broadest and most important academic goal at Deep Springs, which is proving that a small facility with state-of-the-art equipment can do quality astronomical work that is usually in the domain of much larger colleges.

I believe I can well-manage the work of two students of this caliber. I would have difficulty managing more students or of directing the same work on a more aggressive schedule.

Luke:

Last year I took Brian's observational astronomy class and worked extensively with him during Term 4 on the construction of the observatory's control room. Working with Brian is always a great learning experience because of the high standards he holds himself to and those he works with. I believe this in addition to his ambition, expertise, enthusiasm and willingness to experiment creates great condition for research-based learning. This is the best time to take this course because our observatory just become fully operational and is ready to do research. It's like taking a car you just finished building out on a road trip.

Scientific research opportunities are something which Deep Springs cannot often supply its students and is a noticeable gap in the curriculum. Coming from a research-focused high school, I have experience in working on extended science projects and am intimately aware of the extremes of hours, the tedious work, and the glowing satisfaction seeing data transform into an answer of a question. Research is something I both valued and miss from my high school education. Deep Springs is uniquely suited for astronomy research. I don't foresee pursuing astronomy in particular in my future, but the experience of doing quality scientific research of any sort comes with translatable skills and often gives students an edge when applying to graduate programs.

In high school, I produced two science fair projects that competed at the state level and one of those that went on to compete in the International Science and Engineering Fair. I worked with the same partner for both of these projects and in doing so developed the particular skill of doing research with a small team as well as learning the value of having partners in which to bounce ideas off of and catch each other's mistakes. Sofia and I have worked successfully together as mechanical assistants and in CurCom subcommittee work. I am confident that under the guidance of Brian Hill we will be able to do high-quality research.

In addition to a general interest in astronomy that grew from Brian's class last year, I am fascinated by the idea of seeing as a fundamental way of learning. Seeing is simply trying to make sense of a perceptual array of data. Without the power of the human brain behind our eyes seeing would be meaningless. During this project we will not be seeing with our eyes but rather using super-sensitive sensors to detect minute changes in light intensity. Throughout the project I hope to develop the skills both of careful observing in setting up and using our precision equipment, and the skill of data analysis. These skills are something we do almost every minute of our lives, but taking the time to focus so closely on seeing and understanding perceived information is something that will undoubtedly translate to other areas of study.

Lastly, my dad had interest in stars and constellations and we would often go out and try to identify constellations and occasionally make camping trips to see meteor showers. Doing this research project will give me an opportunity to carefully examine and study an interest that we shared.

Overall, I am excited to have this rare opportunity to do serious research with a motivated and focused team at Deep Springs. In addition to producing good results, I hope we can figure out a successful model for conducting research at Deep Springs for future years.

Sofia:

I spent the first few years of high school insisting I would never pursue laboratory science of any kind. This attitude came from a place of general disdain for the exacting demands of the sciences, which I once saw as antithetical to my own development as a creative thinker. That thinking was eventually reformed my junior and senior years, when I took physics for the first time as a serious class and began to understand the underlying pedagogical and philosophical value of operating within certain constraints of 'right' and 'wrong.' What does convincing evidence look like? What can we glean from statistics—and what can we not? What is the nature of certainty? Even as these epistemological questions have set answers in the context of this directed study, learning how to operate within them is a skill I want to pursue for the sake of better understanding what science is and what place it has in our understanding of the world. In other words, I want to earn my "climbing the ladder of asking 'why'" by developing a deeper understanding of one rung of the ladders—seeing where it begins and where its limits are.

My primary interests are in metaphysics, epistemology, and the philosophy of science, and I see this directed study being a natural extension of these ideas, exploring their applications in a very practical light. Someone once commented to me that one couldn't be a serious philosopher without being a physicist. This is, essentially, the other version of a philosopher-citizen, whose political thinking must necessarily have some basis in their experience of politics. I am confident a deeper understanding of how physics is done will contribute to my understanding of metaphysics and deepen how I think about the nature of the world and truth.

Despite my used-to-be-disdain for the sciences, I took the most advanced science classes my school had to offer, all of which involved serious lab work that required consistently working with others. I always found a lot of satisfaction in finding answers to questions through meticulous data collecting, and is something I would like to continue doing. Luke and I work well together, both as laborers and in our Newton

class, where we are able to challenge each other on our understandings of problems and proofs. I am also confident in Brian's ability to lead a team, based both on his general enthusiasm for what he does and a few experiences of working with him on the observatory.

Though I do not see myself, as of now, pursuing astronomy past Deep Springs, I am interested in pursuing a degree in Philosophy and Physics, which would require some laboratory research. By doing this directed study, I would be learning skills that would certainly be important to have later, and would be getting some familiarity with the research process at a level more rigorous than high school labs.

I am excited to do this directed study now because I know it will set me up with a deep knowledge of the observatory and the sky that I hope to further during my time at Deep Springs. Doing this as a first year, I will have the chance to expand upon the skills I'll develop over the course of the directed study in my second year, where I hope to be able to pursue more independent projects and perhaps write a passover for the next year's class about the observatory that will outlast my and Brian's time here. Though I didn't take the Observational Astronomy course, the small number of us means I'll get plenty of time to catch up, and I'm confident in my own ability to do so at a reasonable pace.

It's worth mentioning that for the next term, this directed study will put me at just the upper limit of the course credits of a 'regular' load. I know this will take more time management on my part, but I think I have done a good job this past term of managing my work—I have yet to turn in an assignment, or even eval, late, and haven't taken any time off labor to do so—and feel up to the task of adding this commitment to my schedule.