APPLICATION FOR DIRECTED STUDY 2024-01-10

REVISED 2024-01-15 WITH ADDED "SECTION 4. CONTINGENCIES"

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

- Ethan Liao (DS22)
- Hexi Jin (DS23)

Term and year: Terms 4-5 (Spring Semester) 2024

Course Title: Supernova Observation

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

____Ethan Liao_____ Student

____Hexi Jin_____ 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/supernova-observation/SupernovaObservationSyllabus.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 processes, etc.

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 builds on the Academic Year 2022-2023 work of Luke Suess and Sofia Mikulasek. It is a blend of (1) learning the basics of observational astronomy, (2) performing data-taking with research ambitions, and (3) analyzing data 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 1 ½ hours in length for theory and organization, 10-14 meetings 4 to 5 hours in length for joint observation sessions, and 7 meetings 1 ½ hours in length to coordinate analysis.

These numbers are intentionally aligned with how many analytical and laboratory contact hours 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, our 10-14 meetings for observation sessions will be opportunistically (rather than uniformly) spaced through the spring semester.

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 results, there are nonetheless three identifiable phases.

In the first phase, we are principally establishing our experimental technique. A lot of the hard work on this was done in the prior academic year, so in this academic year, we will have the luxury of building on an established technique. Our contribution will be to dramatically increase the accessibility of the passover so that future students have even less wrong turns and debugging to do.

Our idea for increasing the accessibility is to create a video passover which should make the many dozens of steps more digestible than they are in their current printed form. Furthermore in the first phase we may want to document the use of a new telescope, to be purchased with funds just gifted to the College.

In the second phase, we are principally using our experimental technique to get one or more excellent datasets. Among the ways that we have to be opportunistic is that supernovae are regularly discovered, but only occasionally (ever few weeks) is one discovered that is suitable for observation with our equipment at our location.

In the third phase, we will be focused on analyzing the best data we have obtained.

Analytical Work in Python

Our analysis will involve 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 overarching 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 least as dim as magnitude 18 with our relatively modest (250mm) telescope? *NB: larger numbers are dimmer in the astronomical magnitude system.* We have plenty of data that makes us confident that our equipment can identify magnitude 18 stars in isolation, but supernovae have the added complexity that they are almost always sitting directly on top of a fuzzy background (the galaxy in which they inhabit), and the methods for subtracting background are tricky.
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).
4. How does this work inform preparation for the Vera C. Rubin Observatory which is now just one year from its initial large-scale synoptic surveys?

3. How will the study be evaluated?

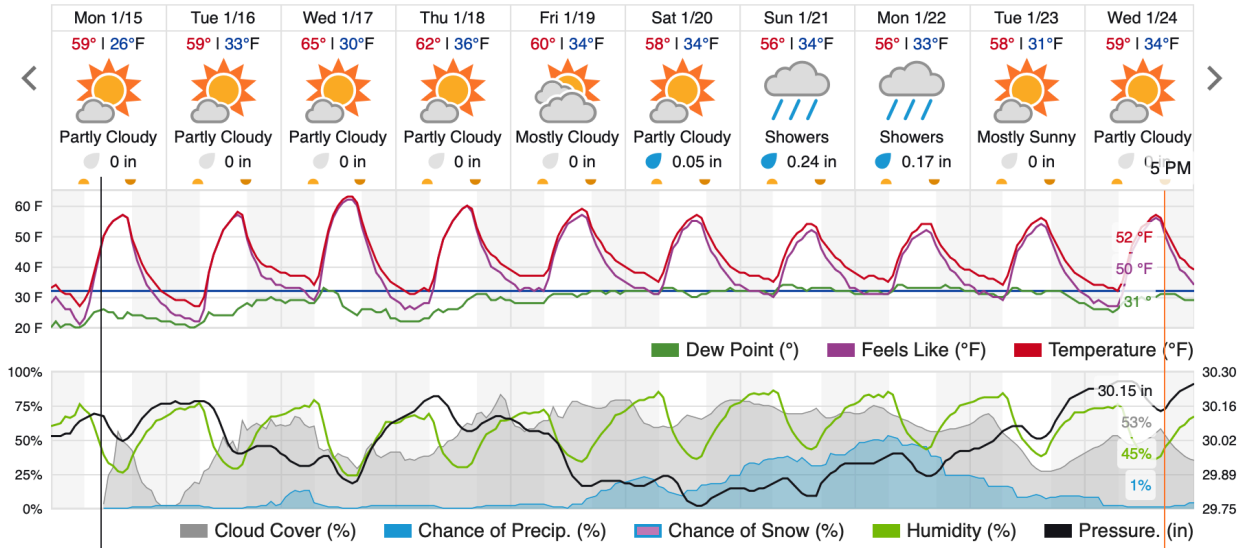
- Observational Work — 35% — This will be comprised of observatory setup and teardown work as well as 10-14 evenings of data-taking
- Analytical Work — 20% — This will be comprised of data processing using Python packages
- Scientific Record-Keeping — 20% — Records should include: (a) Target Selection 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 and an expanded (hopefully multimedia!) passover. If our results are sufficiently significant, our project report will be submitted as a paper to a refereed journal.

4. Contingencies

During academic years 2020-2021 and 2021-2022 we had lots of clear skies. Drought was the Valley's problem, not excessive clouds, rain, or snowfall. In Spring of 2023, this changed significantly. Cold, clouds and wind were frequent in January and February, culminating in the storm that dropped 4' of snow on Feb. 25, 2023. That storm cut the campus off from civilization for 6 days, and digging out greatly affected operations for another week. In all, we completely lost three weeks of observing opportunity, at a time in the schedule (early March) when observing was meant to be peaking.

It behooves us to have some contingency plan if spring of 2024 is more like spring of 2023 than 2020 or 2021.

Indeed, some need for this is already apparent. The last week has been cloudy except for one day, and the 10-day forecast is currently mild but mostly cloudy!



Bishop forecast as of 1/15/2024

So our contingencies are to rearrange as follows:

(1) The passover that we had proposed to augment after meeting with David Schisgall, we will begin with immediately. The idea is to do a high-quality video passover. The upside is that creating a video passover allows us to review all aspects of the equipment setup and we are hopeful that a video passover will be more digestible.

(2) If we are forecast to be persistently clouded out for another couple of weeks beyond the current cloudy forecast, we will focus on analysis of previously taken data rather than taking new data. The upside of this is that the previously taken data (which was meant to be analyzed last May and last summer) has only been cursorily examined. Moving the analysis of it up rather than taking additional data is actually a big win for the overall goals even if it isn't fully satisfying to have to put off new data-taking.

5. 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 construction which began in Fall of 2020 and completed in Fall of 2022, and then improvements undertaken in by Luke Suess, Sofia Mikulasek, and myself in Spring of 2023 (the permanent pier!) the observatory is proven and ready to do additional observational work.

My highest priority in calendar year 2024 is to use the observatory for what it was originally designed to do. For this reason, I have chosen (and been approved) to spread my sabbatical semester over calendar year 2024. Working with strong science students on observational astronomy directly aligns with my professional interests.

Ethan and Hexi both have demonstrated themselves to be top students in the science courses. They are conscientious, prepared, and ambitious. Working with them will push me to do the kind of work I want to be doing.

Ethan:

During my interview to come to Deep Springs, ApCom asked me what classes I would like to take. I'm guessing they asked it because they saw a potential conflict in my interest in deep STEM research and the current composition of the curriculum. My answer was that I was excited to study the natural world right at the valley, citing how Sue's rivers class discussed the Owens river or Brian's observational astronomy class studied stars that could be seen clearly here.

In part because the lab was defunct and in part because of the classes on selection, I haven't had any classes that quite fit that bill. Perhaps Ben Holtzman's geology class Term 6 will do it, but it is only a one-term long class and at the end of my academic path at DS. In observing supernovae, I look forward to a mixture of practical work with equipment and software and theoretical understanding behind the bodies we are observing. I am excited to make full use of Deep Spring's unique location for scientific study.

Intellectually and academically, this class would complement my past and future experiences. Cosmology taught me about space on a very grand scale, but this directed study would help concretize it by studying particular celestial bodies. Linear Algebra made me realize that my main gap in STEM knowledge is in data analysis and programming, something that I'd want to practice before heading into STEM classes in a four-year college.

Hexi:

I took two classes offered by Brian last semester: Modern Introductory Physics and Ancient Astronomy. For the Ancient Astronomy class, we did several observations with the naked eye, binoculars, and telescopes. Observing the stars has always been a wonderful experience for me. I am interested in learning about more advanced astronomical knowledge and conducting more professional observations.

My primary academic interests are astronomy, classics, and physics. I am considering pursuing a degree in either classics or astrophysics in the future. Nevertheless, I did not consider pursuing a degree in science until last semester. I do not have much scientific research experience, which hindered me from applying for short-term scientific research programs outside of Deep Springs. I took several science classes in high school. My mathematical and physical knowledge is decent. I am enthusiastic about developing scientific research skills through this opportunity.

I am constantly amazed by the starry sky here. The physical conditions of the college, such as the isolation and altitude, provides an excellent opportunity for astronomical observations. Partially for this reason, we have a college observatory in good condition. The construction and maintenance of the college observatory took a tremendous amount of effort from Brian and some students. Currently, there is no class or research using the observatory. The College is also going to purchase a new, high-quality telescope soon. This directed study would utilize the resources of the College well.

I went to the observatory with Brian multiple times last term. I volunteered for maintaining the place, using the telescopes, and collecting data once. We went up late at night or early in the morning a few times. I am aware of the potentially demanding schedule and the tedious work. I am confident about committing myself to this project.