# MIXED-METHODS STUDY THAT EXAMINES NINE SCIENCE TEACHERS' PERCEPTIONS OF SLOOH ROBOTIC TELESCOPE FOR TEACHING ASTRONOMY

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**Abstract:** Although previous studies show that robotic telescopes have the potential to enhance student learning, there is comparatively little research that focuses on teacher perceptions of this technology. This study investigates: "what is the academic merit of using SLOOH robotic telescopes to teach astronomy as perceived by science teachers?" Our sample consists of nine science teachers of students aged 13-18 years. Pre- and post-tests, interviews, and surveys were collected during two weeks of a summer online course about robotic telescopes. While pre and post-tests do not reveal a statistically significant gain in astronomy content knowledge, analysis of qualitative data reveals five themes which describe the most important aspects of using SLOOH according to participants: "Images," "Interface," "Classroom Application," "Instructor Impact," and "Logistical Issues." Analysis of these themes suggests that SLOOH can provide an interactive and social learning environment with capabilities to incorporate cross-disciplinary themes.

**Keywords:** Astronomy education research; Robotic telescopes; Education technology; Inquiry-based learning.

# MÉTODOS MISTOS DE ESTUDO QUE EXAMINAM A PERCEPÇÃO DE NOVE PROFESSORES DE CIÊNCIAS SOBRE O TELESCÓPIO ROBÓTICO *SLOOH* PARA ENSINO DE ASTRONOMIA

**Resumo:** Embora estudos anteriores mostram que os telescópios robóticos têm o potencial de melhorar a aprendizagem dos alunos, há relativamente pouca investigação focada nas percepções de professores a respeito desta tecnologia. Este estudo investiga: "qual é o mérito acadêmico da utilização de telescópios robóticos Slooh para ensinar astronomia, tal como percebido pelos professores de ciências?" Nossa amostra é composta por nove professores de ciências de estudantes com idades entre 13-18 anos pré e pós-testes, entrevistas, e levantamentos foram coletados durante duas semanas de um curso *on-line* de verão sobre telescópios robóticos. Enquanto os testes pré e pós não revelaram um ganho estatisticamente significativo no conhecimento do conteúdo astronomia, a análise de dados qualitativos revela cinco temas que descrevem os aspectos mais importantes da utilização Slooh de acordo aos participantes: "Imagens", "Interface", "Aplicação em sala de aula", "Impacto no Instrutor" e "Questões logísticas". A análise desses temas sugere que Slooh pode proporcionar um ambiente de aprendizagem interativo e social com capacidade de incorporar temas interdisciplinares.

**Palavras-chave:** Pesquisa em Educação em Astronomia; Telescópios robóticos; Tecnologia da educação; Aprendizagem baseada em investigação.

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# MÉTODOS MIXTOS DE ESTUDIO QUE EXAMINAN LA PERCEPCION DE NUEVE PROFESORES DE CIENCIAS SOBRE EL TELESCOPIO ROBÓTICO SLOOH PARA LA ENSEÑANZA DE LA ASTRONOMÍA

**Resumen:** Aunque estudios previos muostraron que los telescopios robóticos tienen el potencial de mejorar el aprendizaje del estudiante, hay relativamente poca investigación centrada en las percepciones de lós profesores respecto de esta tecnología. Este estudio investiga: "¿cuál es el mérito académico de la utilización de telescopios robóticos SLOOH para enseñar astronomía según la percepción de los profesores de ciências?" Nuestra muestra está formada por nueve profesores de ciencias de estudiantes entre 13 a 18 años pre-y post-tests, entrevistas, y. encuestas se recogieron durante dos semanas de un curso *on-line* de verano sobre los telescopios robóticos. Si bien lós tests antes y después de las pruebas no revelaron un aumento estadísticamente significativo en el conocimiento de contenido astronómico, el análisis de lós datos cualitativos reveló cinco temas que describen los aspectos más importantes de la utilización de SLOOH de acuerdo con los participantes:. "Imágenes", "Interface", "aplicación en el aula", "Impacto en el Instructor" y "problemas logísticos" . El análisis de estos temas sugiere que SLOOH puede proporcionar un ambiente de aprendizaje interactivo y social, con capacidad para incorporar temas transversales.

**Palabras clave:** Investigación en educación en astronomia; Telescopios robóticos; Tecnología de la educación; Aprendizaje basado en investigación.

## 1. Introduction

### 1.1. Motivation

With wide-spread public access of the Internet in the late 1990s and continually improving technology, telescopes have become more flexible in their requirement for in-person interaction. No longer does one have to travel to remote locations—often atop mountains with potentially adverse weather—in order to benefit from a science-grade telescope. Such a situation holds great potential for students who want to study astronomy, but cannot travel to use a telescope.

When outfitted with robotic controls, telescopes can be controlled from any location with an Internet connection, or it can be fully automated with a script for minimal human interaction, giving observers greater flexibility and ease for gathering data. The Sonoma State University Observatory designates three levels of robotic telescopes based on the amount of human interactivity required:

> *A simple robotic telescope has an integrated computer environment for controlling a telescope and CCD camera. A robotic telescope with remote accessibility can be controlled by a remote observer (at least at some level). A robotic telescope with real time control allows a remote observer to interactively control the telescope and camera.*[4]

For consistency, we use the term “robotic telescope" (henceforth, *RT*) to refer to any telescope which may be controlled over the internet, regardless of features or level of interaction.

Just as in the scientific community, robotic telescopes are becoming more and more present in the science education community as an emerging classroom technology

[4] http://gtn.sonoma.edu/resources/telescope_resources

for teaching (see University of Göttingen Observatory[5] for a list of robotic telescopes around the world). The availability of robotic telescopes in education can change how we can present scientific inquiry to students, shifting from static information and data that is given to the student, to a more dynamic, real-time, and consequence-based learning environment where students hold more responsibility for collecting data and are more deeply immersed in the learning process. However, the mere existence of such tools does not guarantee a successful learning environment, as both students and teachers have certain prerequisite needs when utilizing any technology. This paper examines the perceptions of science education teachers that learn to use SLOOH robotic telescope.

### 1.2. About the SLOOH Network

SLOOH is a network of three ground-based robotic telescopes available for public use. The name *SLOOH* is a play on words that combines "slew" which describes when a telescope is moving and "ooh," a word used to express excitment. It was the first system which allowed users to observe night-sky objects in near real-time. Two of the telescopes are located on Mt. Teide in the Canary Islands and the other is in La Dehesa, Chile--both of which take advantage of minimal light pollution. All three telescopes are outfitted with science-grade digital cameras and appropriate filters[6]. Users purchase prepaid minutes and then reserve available ten-minute observing timeslots. During observation, users can save up to three images of their object or they may join other user's observations and take pictures of their object. The main website also includes features for retrieving and sharing photos, chatting with other SLOOH users, and viewing occasional live video feeds of various astronomical events such as transits, aurorae, and most recently, coverage of the Mars Curiosity landing.

## 2. Literature Review

One of the first widely recognized applications of a robotic telescope used in education is the Hands-On Universe project (HoU), first developed at Lawrence Berkeley Laboratory in the early 1990's (FERLET; PENNYPACKER, 2006). Now a global effort, this program enables students to request and download pictures, and also manipulate the images with software developed by HoU personnel. Support from National Science Foundation, Department of Defense and Department of Energy grants has allowed continual development of curriculum, digital software, instructor training and other educational resources.

Another early pioneer of the educational use of remote telescopes has been the Telescopes in Education program, collaboratively developed through Jet Propulsion Laboratory at Caltech, Mount Wilson Observatory, and other volunteers. Students and educators can make reservations to control a 24-inch reflecting telescope in real-time over the Internet. This program is currently no longer active through Mt. Wilson Observatory.

[5] http://www.uni-sw.gwdg.de/~hessman/MONET/links.html
[6] http://www.SLOOH.com/specs.php

Preliminary research at the Charles Sturt University (MCKINNON; MAINWARING, 2000) found evidence that RTs significantly impact elementary school student attitudes towards astronomy and science. A qualitative follow-up by McKinnon and Geissinger (2002) evaluated five classes of grade five and six students who participated in a new curriculum program, "Journey Through Space and Time," that utilizes an RT in Bathurst, Australia. They found that the experience engages students to the curriculum objectives and provides a hands-on experience that is primarily student-driven.

The MicroObservatory network was developed in 2000 at the Harvard-Smithsonian Center for Astrophysics (SADLER *et al.*, 2001). Gould, Dussault, and Sadler (2007) evaluated data from 475 middle-school and high school student projects through pre- and post-testing as well as student/teacher evaluations to determine the educational importance of RTs. They observed several advantages of using RTs in the classroom, including noticeable increases in student involvement, interest, and understanding of content, among others. Authors also note that with RTs being such a heavily computer-driven technology, teachers are concerned that students may rely too much on the computer component, and are not being exposed as much to naked-eye observing of the night sky.

Gehret, Winters, and Coberly (2005) evaluated a prep-school (ages 13-18 years) in urban Chicago that makes use of a robotic telescope from a facility in Mayhill, New Mexico. Besides the benefit of being able to image a dark night sky from the light-polluted city of Chicago, the authors argue that through using RTs, students are able to apply knowledge learned in class in a unique and meaningful way, and feel personally invested and satisfied with gathering their own data.

In addition to research which aims to determine the most salient features of robotic telescopes, there is also a host of published articles that evaluate discrete scientific units, activities, or entire curricula which expose students to STEM topics while utilizing robotic telescopes, requesting observations, as well as gathering and reducing data. Topics include exoplanets (GOULD; SUNBURY and KRUMHANSL, 2012), variable stars[7] and Near Earth Objects[8]. McKinnon et al. (2012) overviews the "Space To Grow" curriculum program in Australia. A partnership between the Australian Research Council and the US-based Las Cumbres Observatory Global Telescope Network (LCOGTN) enables teachers and students to request observing time on one of the LCOGTN robotic telescopes.

## 3. Research Question

While there is a clear picture that robotic telescopes have the potential to enhance student learning, there is comparatively little research that focuses on teachers' perceptions of this technology. To address this issue, researchers at the University of Wyoming and CAPER Center for Astronomy and Physics Education Research[9] have

[7] http://www.aavso.org/education
[8] http://www.ll.mit.edu/mission/space/linear/
[9] www.caperteam.com

designed a study to systematically investigate the perceptions of science teachers when learning to use SLOOH robotic telescopes.

***Main research question***:

What is the academic merit of using SLOOH robotic telescopes to teach astronomy as perceived by science teachers?

***Sub questions***:

1. What is the incoming and outgoing astronomy content knowledge of science teachers who use SLOOH robotic telescopes?
2. What do science teachers find to be the most important features of SLOOH robotic telescopes?

## 4. Methodology & Design

### 4.1. Research Methodology

We developed a mixed-methods approach, where the qualitative aspects reflect both phenomenology and grounded-theory. In this case, an interpretive approach addresses the direct descriptions of the SLOOH experience, and grounded-theory places those descriptions into the broader framework of the student-teacher environment which, "[...] helps develop a deeper understanding about the features of the phenomenon." (CRESWELL, 2007, p. 61).

### 4.2. Research Design

The participants consisted of four male and five female science teachers of students aged 13-17 years. These teachers were also science education graduate students enrolled in an eight-week online summer class from a four-year western university in the United States. The syllabus describes the class as:

> [...] a problem-based application course in how to use robotic telescopes to conduct astronomy observations...this course teaches learners how to use Internet-controlled, robotic telescopes to conduct astronomy observations with their students and how to reduce scientific data for use in scientific inquiry investigations.

These participants were selected because they were judged to have the experience necessary to provide meaningful perspectives about SLOOH. Participants range in location (Hawaii to U.S. East Coast), age (late 20's-mid 50's), chosen science discipline, as well as level and amount of teaching experience. This study focuses on weeks three and four of the class, during which, participants learned to use SLOOH robotic telescope. Data was gathered in the form of pre- and post-testing of astronomy content knowledge, focus group transcripts, surveys, and field-notes gathered by the lead researcher.

### 4.2.1. Intervention Protocol

Research participants began by signing an Institutional Review Board consent form (see Appendix A) which informed them of the research, what is to be expected of them, and that their participation is completely voluntary and has no effect on their class grade. Before the first day of class, participants attended a focus group prior to taking a pre-test. The focus group aimed to elicit any prior knowledge or experiences that participants may have had concerning astronomy, robotic telescopes, and general classroom technology. See Appendix B for a complete list of questions asked. Participants and the lead researcher all met in a secure online video chat room at a predetermined time and date prior to week one. It was ensured that a safe and respectful environment was presented so that participants would not hesitate to share any thoughts or opinions. All focus groups were audio-recorded for transcription purposes.

Immediately after attending the first focus group, participants were given forty-eight hours to complete a fourteen question pre-test (Appendix C) which was emailed to them in .pdf and .doc formats. Questions pertain to general astronomy knowledge that one might require when using a remote telescope and includes one specific question from the Test Of Astronomy Standards (SLATER *et al*. 2011, p.77-87). The purpose of this testing instrument was to gauge the incoming knowledge of participants so that we could measure whether the intervention of using SLOOH robotic telescope had any significant effect on their astronomy content knowledge. Participants completed this pre-test before the first day of class to ensure that results from this test truly reflected incoming knowledge prior to any exposure related to the class.

Weeks three and four of class marked the intervention of our research. During week three, participants were given a worksheet (see Appendix D) designed to walk them through navigating the SLOOH website, how to choose an object, reserve available ten-minute observing slots, and how to take and view images from SLOOH. The worksheet also included exercises which required participants to apply concepts related to using robotic telescopes. Participants kept a detailed log that chronicled their observations with SLOOH. This log included object name, time of observation, weather conditions, and other notes. Participants were introduced to SLOOH's unique image capture process by comparing the appearance of images after 60 seconds, 300 seconds, and 830 seconds of exposure. (refer to subsection 5.2.1, *Images*, for explanation of SLOOH's image capture process). Participants estimated the true size of an observed object by using angular size information gathered from their SLOOH observations in conjunction with an online database that reports the object's distance from Earth. During week four, participants continued to use SLOOH but also started learning how to how to acquire and process images from the MicroObservatory network of robotic telescopes. As a final culmination, participants created a portfolio of their favorite images from either SLOOH or MicroObservatory, and shared them with the entire class at the end of week four. Given the nature of the online class, participants had the freedom to complete and submit the worksheet on their own time.

### 4.3. Data Analysis Procedure

Pre- and post-tests were evaluated using a predetermined scoring rubric. Data was analyzed to determine the average participant score and resulting standard deviation. Qualitative data was manually reviewed through a process of horizontalization and clustering (CRESWELL, 2007, p.159) to determine the most pertinent themes relating to the research questions. After reading through all focus group transcripts once, the author reread the transcripts and underlined any participant comments, descriptions, or phrases (regardless of context), which seemed relevant to the research sub-question. The author collected all these quotes on a single page (horizontalization of data), noting whether the comment was positive, negative, or impartial. Each quote represents a single unit of data. The author then determined what theme would best suit each data unit and grouped data by theme. Each theme contains one or more data unit. It was noted when a theme had repeated instances of the same general quote. Final themes were based upon both frequency of mention as well as overall significance in being able to recreate participants' experiences.

## 5. Results & Discussion

Data consists of nine pre-tests, five post-tests, transcriptions from three pre-focus groups and three post-focus groups, notes and comments from the discussion boards, nine responses to an end-of-class survey, and field notes from the lead researcher. The following subsections discuss analysis of data with respect to the two research sub-questions and then address the main research question.

### 5.1. Sub-question 1: What is the incoming and outgoing astronomy content knowledge of science teachers who use SLOOH robotic telescopes?

The average participant test score and corresponding uncertainty are shown in Table 1, below. The average pre-test score is 55% and this increases to 69% for the post-test. No individual participant scored lower on the post-test than they did on the pre-test. Due to the nature of such a low sample size, the resulting standard deviations are too large to conclude that this apparent increase in content knowledge is statistically significant. In addition, there is a decrease in the number of respondents from pre- to post-test that further adds to the uncertainty. Although this result is not surprising given such a small sample size, it does agree with trends found within focus group data which suggest that simply using SLOOH for less than two weeks did not work to sufficiently reinforce content knowledge, insofar as the testing instrument could measure those abilities.

| Average Participant Test Score | | | |
|---|---|---|---|
| | Sample Size | Score (%) | s.d. (%-points) |
| Pre-test | 9 | 51 | 26 |
| Post-test | 5 | 69 | 24 |

**Table 1: Average participant test score. Due to small sample size and decrease in respondents from pre- to post-test, the increase in test scores is not statistically significant.**

### 5.2. Sub-question 2: What do science teachers find to be the most important features of SLOOH robotic telescopes?

After analysis of qualitative data, the following five themes emerge as best describing the SLOOH experience according to participant comments. They are: “Images," “Interface," “Classroom Application," “Impact on the Instructor," and “Logistical Issues." It should be noted that although there are five separate themes, descriptions found within one particular theme are not necessarily isolated from another theme. Figure 1 and Table 2, in the following pages, are offered to the reader as a visual aid to help situate the findings.

**Table 2: Themes and Quote Frequency**

| Theme | Quote relates to... | Frequency of Occurrence | Positive (+) or Negative (-) |
|---|---|---|---|
| Images | ...image-capture or ability to process image | 2 | + |
| | | 1 | - |
| | ...image quality | 3 | + |
| | ...will students believe images are real? | 1 | - |
| | Totals | 5 | + |
| | | 2 | - |
| Interface | ...ability to join other user's observing sessions | 2 | + |
| | ...auto-snap feature | 1 | + |
| | ...ease of use | 4 | + |
| | ...issues with images and storage | 2 | - |
| | ...no option to process images | 1 | - |
| | Totals | 7 | + |
| | | 3 | - |
| Classroom Application | ...image ownership | 1 | + |
| | | 1 | - |
| | ...used to show images in real-time | 1 | + |
| | ...hands-on/interactive experience | 3 | + |
| | ...provides artistic perspective | 1 | + |
| | Totals | 6 | + |
| | | 1 | - |
| Impact on the Instructor | ...knowledge/awarness of technology and skills | 3 | + |
| | ...would use SLOOH in the classroom | 3 | + |
| | ...unsure how to incorporate SLOOH in the classroom | 2 | - |
| | Totals | 6 | + |
| | | 2 | - |
| Logistical Issues | ...must pay for use | 1 | - |
| | ...timing of U.S. school day | 1 | + |
| | | 1 | - |
| | ...weather | 1 | - |
| | Totals | 1 | + |
| | | 3 | - |

**Table 2: Themes and frequency of occurrence. Describes types of participant quotes, how many times each quote was mentioned, and whether the quote was positive or negative.**

#### 5.2.1. Images

“*...I was really impressed with everyone's images from SLOOH...*"

The images rendered from a robotic telescope represent the primary connection to the night sky for any user. It is not surprising then, that many participants emphasized the quality of SLOOH images. "*I really liked the image quality...some of them are just really nice looking*." Those who have experienced other similar remote telescopes also voiced that SLOOH's image quality was better. "*..the difference between those* [SLOOH's images] *and MicroObservatory was like night and day*." One participant anticipated that this could bring an artistic perspective to science class. Figure 2 shows several examples of participant images taken from SLOOH.

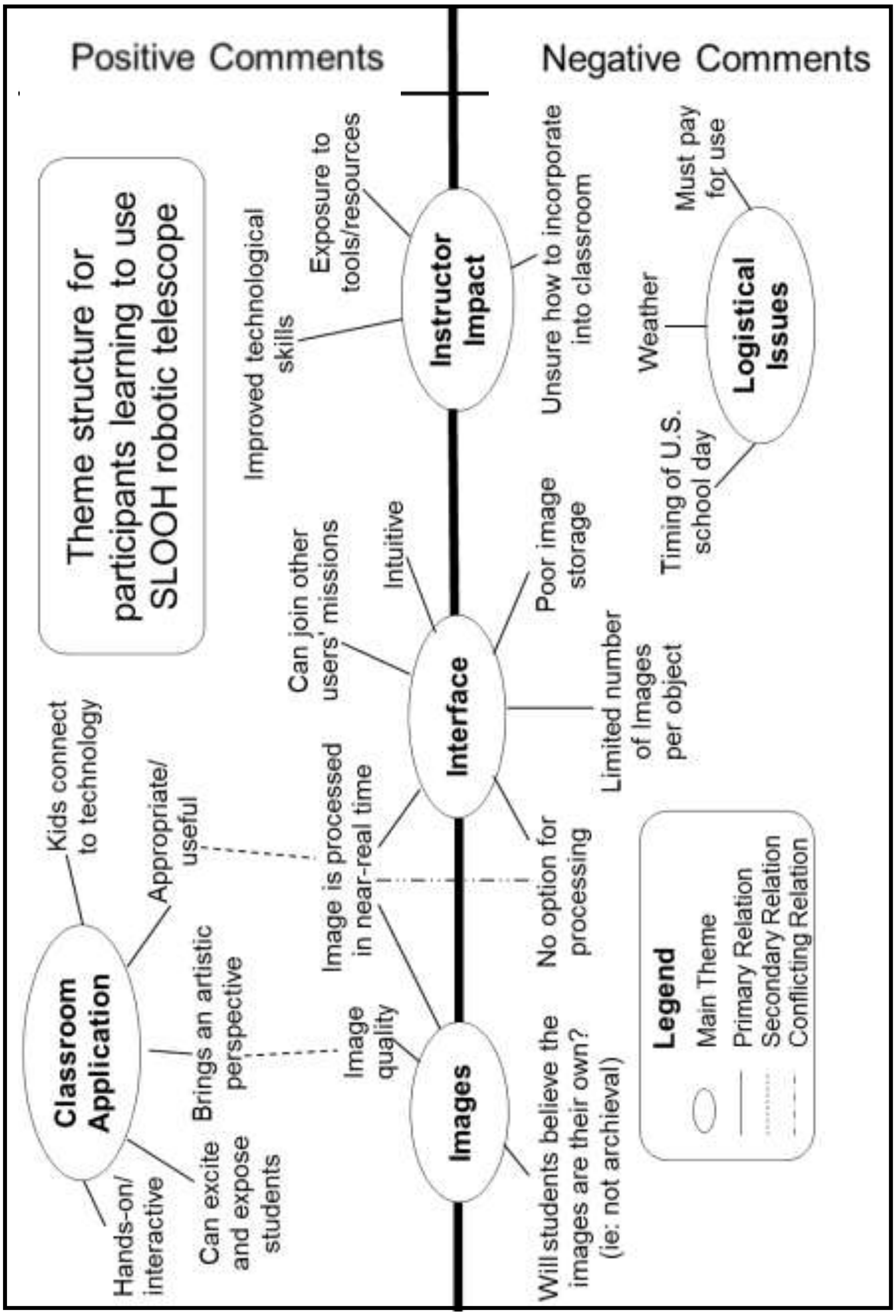


**Figure 1: A concept web that shows interrelation among the five themes and examples of participant comments. The web is split into two halves that indicate whether the comments were positive or negative as to the overall enjoyment of SLOOH.**

The importance of image quality for participants could be attributed to SLOOH's unique image capture process. Briefly, the telescope not only exposes for the user, it also *simultaneously* processes the image on screen, and the user is able to witness this gradual processing in near real-time. Images start off dim and monochrome, and slowly brighten and increase in color (see Figure 2, below, for examples). “*It's kinda fun to look at the image as the exposure time goes up and watch the image change*." Participants noted both the advantages and disadvantages of this feature. For those who are not familiar with, or do not want to deal with the intricacies of proper image processing, this works to their advantage, and educators can still offer discussions about light and color, although some users may prefer more control over their image processing. [Authors’ note: shortly after completing this research, SLOOH implemented a “FITS Pilot Program” where they gave users the option to download a calibrated FITS file of their object].

These observations support the broader notion in education that visual aids can serve as an important enhancement to the learning process when used properly. Although participants in this study had a positive experience, several did express concern about whether or not their students would be convinced that the images were actually their own and not just archival data. Overall, participants described that the resulting images from SLOOH played a significant role in their robotic telescope experience.

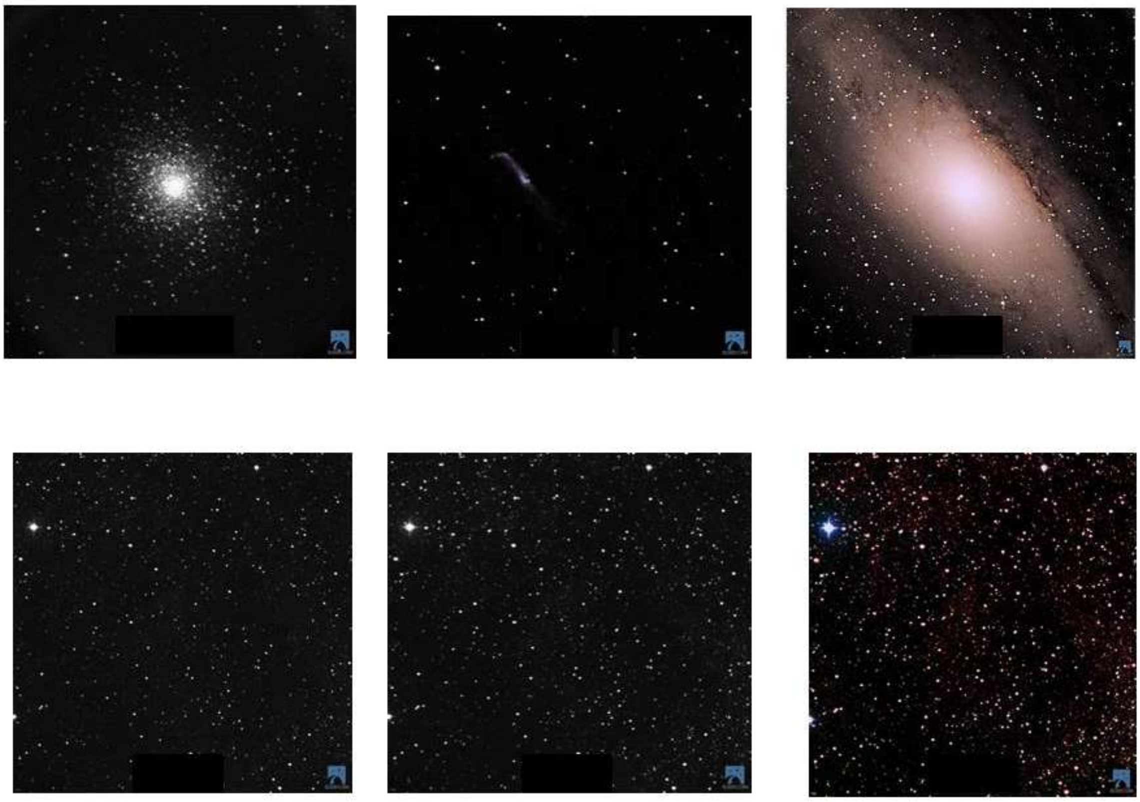

**Figure 2: Examples of SLOOH images taken by participants. Top row from left to right: Globular cluster M5, Crowbar Galaxy NGC4656, Andromeda Galaxy M31. One participant included three different images of a single object (568 Cheruskia) which shows the progression of a single exposure after 60 seconds, 300 seconds, and 570 seconds (shown at bottom row, left to right, respectively).**

### 5.2.2. Interface

"*...there's just a lot of freedom, how you can hop into different missions and check out what's going on. It seems like a fun environment to be in*."

The interface of SLOOH refers to any interaction that occurs between the user and SLOOH website, as well as any particular limitations or settings unique to SLOOH. The most general reference to SLOOH's interface pertains to the relatively minimal degree of effort required to use SLOOH as well as navigating the website. It was described as 'easy to use' [navigating and requesting a mission], 'intuitive' [the website, compared to MicroObservatory], and '...not too tough to navigate.' One feature in particular that participants mentioned is the ability to join another user's observing session and take pictures of their object. If participants were pressed on time or realized they could not attend their own reserved observation, they could simply join another user's ten-minute observing run.

One participant described that the maximum number of images able to be saved during any one observing run was "*...a drawback*." Others expressed some dissatisfaction with the manner in which image are archived and retrieved, "[it was] *Really hard to scroll through your images. I didn't really like* [that particular] *interface*."

Whereas images provide a visual connection to any robotic telescope, participants' comments indicate that the interface provides more of a personal/social connection to the telescope and other users. SLOOH's flexible interface encourages users to interact with one another. While several participants were having trouble with retrieving photos, one was able to find a solution on the SLOOH message boards. Such an interface promotes a community atmosphere and is reflected in SLOOH being described as "*...a fun environment to be in*." Although no program is without flaws, comments from participants show that interfaces which are more 'intuitive' and reflect a 'community environment,' contribute to a more enjoyable overall experience.

### 5.2.3. Classroom Application

"*I could see how it [SLOOH] could really be useful and appropriate in the classroom*."

After using SLOOH for nearly two weeks, participants were able to articulate how they think SLOOH could apply to a classroom setting. One participant drew from personal experience to say that "*...I think that the kids connect--especially with the technology; they like using the computers and stuff*." Another mentioned that it could be useful, "*because I can show pictures of things as the pictures are being exposed*." Another participant suggested that using a remote telescope to capture images would, "*...bring more of an artistic aspect to a class...hopefully* [it will] *increase interest level*." Other words used to describe how SLOOH would impact the classroom are, "*expose and excite*," as well as "*hands-on and interactive*."

These perspectives offered by participants for how SLOOH might fit into the classroom illustrates how a robotic telescope may be thought of as an educational tool. Some of the words previously used to describe SLOOH (excite, hands-on, interactive), all lend themselves to a student-centered and inquiry-based learning environment

(SLATER and ADAMS, 2004). Studies have continually shown the benefits of an active learning environment over the less engaging pure-lecture approach (UDOVIC *et al.*, 2002; KNIGHT and WOOD, 2005). Participants' comments indicate that SLOOH has the potential to benefit student learning by placing students' minds out of a text book, and giving them the power and tools to personally construct their reality in creative and meaningful ways.

### 5.2.4. Impact on the Instructor

"*...it's a nice extra resource that I'm going to have in my back pocket*."

Robotic telescopes such as SLOOH not only affect the students who use them, but also the instructors who incorporate them into the classroom. Nearly all participants who used SLOOH expressed appreciation for the skills and resources that come with learning to use a robotic telescope such as SLOOH. "*I think I have more tools to refer to, to show them* [students] *what's out there*." These tools may be as simple as the awareness of a new technology, or the confidence in being able to apply new technologies in a classroom. "*...I do feel a little bit better about...knowing a bit more about these options for remote-controlled telescopes*, [which] *I wasn't really aware of at all*."

Despite all the discussion that learning to use SLOOH had a positive impact on participants' attitudes towards classroom technology, many still described a lack of confidence in turning a technology into an effective classroom tool. "*I could see it being a take home extra credit or an extension activity, but I'm not sure how I could incorporate it* [in the classroom]." Another participant thought that SLOOH would be useful in an "elective-style" class but followed up with, "*I think I would struggle with it if I were trying to teach an astronomy class*... ." This participant did not believe that SLOOH could be robust enough to apply in a science classroom.

SLOOH robotic telescope has been shown to affect participants in both a positive and negative manner, according to analysis of their comments. Participants appreciate both the knowledge and awareness that comes with learning to use SLOOH robotic telescopes. However, several participants ultimately expressed that if they were given an opportunity to use SLOOH in their classroom, they were still unsure how to specifically incorporate it. These results reflect numerous studies that examine teacher confidence with classroom technology (ERTMER, OTTENBREIT-LEFTWICH 2010; ERTMER 2006).

### 5.2.5. Logistical Issues

The theme "Logistical Issues" encompass matters relating to SLOOH and its use which concerned participants but were entirely out of their control. Several participants mentioned that SLOOH does cost money to use, although followed up with, "*I still think it's worth it*." Inclement weather was also mentioned by one participant when describing his experience, "*...the faults dealt with the sandstorms. Night after night I was trying to do things and couldn't get it*."

Perhaps the single logistic that participants considered most significant was that of coordinating observations during school hours. For instance, if observers in the United States wanted to use the SLOOH telescope in the Canary Islands during the fall or winter months, they could start at the earliest 19:30 UTC, which is equivalent to 5:30 pm on the U.S. east coast and 2:30 pm on the U.S. west coast. Participants emphasized the difficulty of observing with SLOOH during the school day, "*...you can't do it* [observe with SLOOH] *when you're in class because missions don't start until later in the day*." For the one participant living in Hawaii, "*...it would actually work for us, as things start around lunch time*, however this participant did follow up with, "*It would be nice if they set up some other sites that would work for the main land in the United States...during the school day*." These comments from participants all represented elements of the SLOOH experience which impacted them during their two weeks of using SLOOH, but were completely out of their control.

### 5.3. Limitations of Study

There are two general features which makes this research unique compared to other studies. One is that all participants learned to use the telescope through an *online* format, as opposed to an in-person group setting. Participants were connected, however, through an online discussion forum and video chats. Therefore, any data collected does not stem from direct observation of the participant-telescope experience, but from verbal testimony which was self-reported by participants and survey data. Second, our data is based on a much shorter time span of telescope use, whereas much of the literature is based on classrooms and afterschool programs that integrate a robotic telescope into the learning experience ranging from months to a full school year.

## 6. Conclusions: What is the academic merit of SLOOH robotic telescopes to teach astronomy as perceived by science teachers?

After considering both quantitative and qualitative results, the most useful conclusions are drawn from the qualitative portions. By far the single aspect of SLOOH that resonates with other studies is that of images (see subsection 5.2.1, *Images*). The importance of capturing one's own images has been phrased by some researchers as "image ownership" (SADLER *et al.*, 2007), whereby students who capture their own images through a robotic telescope are more likely to be excited and engaged in learning. SLOOH is currently the only robotic telescope that enables users to view their object simultaneously on the screen as the object is being exposed. In other systems, the user will either have to wait until the end of the exposure period or must wait until the next day to be emailed the image file. SLOOH's unique format enables students to immediately access images and begin using them in class. The use of images with SLOOH can also act as a way to incorporate cross-disciplinary themes within the curriculum that extend to Science, Technology, Engineering, and Mathematics (STEM) and non-STEM disciplines. Using SLOOH can complement a student's exposure to topics within astronomy as well as related math concepts. Technology and engineering are also deeply interrelated to robotic telescopes and can be included through discussions of telescope optics and how camera sensors function. Outside STEM, the nature of taking digital astrophotos provides opportunities for students to exercise visually creativity. In addition, processing the photos (adjusting contrast, stacking multiple images, etc.) can provide students with valuable experience using image software or programming in a computer language.

Participants' descriptions of SLOOH such as ‘hands-on,' ‘engaging,' and [eliciting] ‘excitement,' indicate the potential for a telescope which is interactive in nature. The Hands-On Universe Project similarly base their goals and objectives on the fact that students “...should as much as possible directly participate through observing, arguing, sharing, discussing, and interpreting}..." (FERLET and PENNYPACKER, 2006). In addition to providing a more interactive and hands-on learning experience (MCKINNON *et al.*, 2002; COWARD *et al.*, 2011; SADLER *et al*., 2007), participants' comments indicate that SLOOH robotic telescopes show potential for creating a social learning environment. SLOOH's design not only allows students to take pictures but also connects them to a social network of telescope users. This includes the ability to join other users' observations or communicate and share photos on the message boards with other SLOOH members. Even things which can go wrong with a robotic telescope such as bad weather or hardware malfunctions can be used as a positive learning experience. These opportunities provide students with examples of how to deal with and learn from failures in a controlled environment of the classroom.

## 7. Summary

We evaluated the educational potential of the SLOOH network of robotic telescopes based on qualitative and quantitative data from nine science teachers who used SLOOH during two weeks of an eight week summer online course. Although analysis of pre- and post-tests showed no statistically significant difference in the learning gains of participants, interviews, surveys and general observations revealed aspects of the SLOOH experience that most affected participants. The themes were, “Images," “Interface," “Classroom Application," “Instructor Impact," and “Logistical Issues." SLOOH does exhibit potential as a successful classroom tool such as real-time image processing, a social learning environment in which to interact with other users, as well potential to incorporate both STEM and non-STEM themes.

### 7.1. Future research

Although the study of robotic telescopes for educational purposes is still a nascent domain, future research can help develop understanding of robotic telescopes in a two-fold manner. More large-scale studies (on the order of Sadler et al., 2007) that track student learning in a meticulous and scientific manner will provide policy-makers with definitive evidence for the importance of robotic telescopes. Similar studies can also provide a clearer picture as to what influences a teacher's confidence particularly when using robotic telescopes. Second, educators and researchers alike must continue to contribute and publish practical ideas for how to meaningfully integrate robotic telescopes into the classroom (such as Gould, Sunbury, and Krumhansl, 2012). Future research which addresses these two issues will provide the education and research community with insight to both the phenomena of robotic telescopes and how it can be effectively implemented in the classroom.

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## APPENDIX A - Consent Form

### I. General purpose of the study:

The research study that you (here on out known as 'subject') may choose to participate in will help educators at the university of Wyoming determine what are the educational benefits of using SLOOH Space Camera and if is appropriate to be introduced in the curriculum. Your participation is important because it will help us gauge the potential for using SLOOH as an educational tool.

### II. Procedure:

This study will take place over the online class interface and will be conducted by graduate student, Daniel Gershun. In addition to the normal course work, subjects will be asked to complete the following: Subjects will be tested and interviewed at the beginning of the SLOOH unit. They will be introduced to the SLOOH Space Camera and asked to perform several assignments that will not be graded. At the end of the SLOOH unit, subjects will retake the same test, participate in another focus group and have the chance to leave any comments. The extent of your participation in this research will last only during the meeting hours of class (weeks 2 and 3).

### III. Disclosure of risks

Minimal risk is anticipated for participants in this study. In the highly unlikely event that subjects feel personal discomfort or anxiety during the focus groups, subjects will be allowed to leave at any time and be referred to the University Counseling Center. Due to the nature of focus groups, there is a risk of breach of confidentiality for participants. Although measures have been implemented by the researchers to ensure participant confidentiality, the researchers cannot guarantee what the other individuals in the focus group may do following the meeting.

### IV. Description of benefits:

There are no direct benefits to subjects who participate.

### V. Confidentiality:

The tests that you will complete over the course of this research will not be linked to any personal information. Conversation from the focus group will be transcribed and not names will be used. This data will only be accessible to certified investigators and graduate student researchers. All data will be stored on a password-protected external hard-drive and stored in the Physical Sciences Building, room 112, for the duration of three years, after which, it will be destroyed**.**

## VI. Freedom of consent:

*My participation is voluntary and my refusal to participate will not involve penalty or loss of benefits to which I am otherwise entitled, and I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled. I understand that my refusal to participate or my withdrawal at any point will not affect my course grade or class standing.*

If after consenting to participate in this research, the subject deems it necessary to withdrawal his/her participation, he/she may do so at any time during the research process by means of verbal request.

## VII. Questions about the research:

Requests for information or any concerns can be directed to the principal investigator, Daniel Gershun, dgershun@uwyo.edu or (781) 572-2590 during normal business hours. If you have any questions about your rights as a human subject, please contact the University of Wyoming IRB Administrator at 307-766-5320.

## VIII. Consent to participate:

______________________________________________

Printed name of participant

______________________________________________ ________________

Participant signature Date

## APPENDIX B - Question Prompts for Focus Group

(Beginning of SLOOH unit)

- What kind of experience(s) have you had with telescopes before? What was the impact of those experiences?
- What do you know about remote telescopes?
- What do you hope to gain from using robotic telescopes?
- Teachers often debate the pros/cons of dissecting real frogs in the lab versus virtual frogs over the internet. How can this be compared to controlling a telescope in-person versus over the internet? Explain
- Do you think there are any reasons to use robotic telescopes in the classroom? Why/Why not?

---

(End of SLOOH unit)

- Describe your experience using SLOOH. What aspects did you like? Dislike?
- What are your perceptions of using robotic telescopes in the classroom? Have they changed at all over the course of this unit? Why/Why not?
- How did the online nature of this class affect your learning to use a robotic telescope?
- Did you learn anything or develop any new skills over the course of this unit? How so?
- Would you use SLOOH in your classroom? Why/Why not?

## APPENDIX C - SLOOH Space Camera Evaluation: Pre-Test and Post-Test

Requests for information or any concerns can be directed to the principal investigator, Daniel Gershun, dgershun@uwyo.edu or (781) 572-2590 during normal business hours. If you have any questions about your rights as a human subject, please contact the University of Wyoming IRB Administrator at 307-766-5320.

1. Would you rather have control over a small telescope to take an astronomical image, or just simply download a detailed image of that same object from Hubble or other observatory?

2. What factors might negatively impact a night of telescope observing?

3. Imagine you see Mars rise in the east at 6:30 pm. Six hours later what direction would you face (look) to see Mars when it is highest in the sky? (choose one)
    a. Toward the north
    b. Toward the south
    c. Toward the east
    d. Toward the west

4. Define/explain the following as best as you are able:

    a. Zenith
    b. Meridian
    c. Azimuth
    d. Focal Length Altitude
    e. Hour Angle
    f. Right Ascension
    g. Declination

5. Describe how Earth's motions result in the motion of the heavens and the different seasons of constellations.

6.
    a. What do astronomers use CCDs (Charge Coupled Devices) for?

    b. If you were to look at 2 digital photographs of the same galaxy, one of which is a 2-minute exposure, and the other a 200-minute (3hr 20min) exposure, describe what would be different about each picture and why.

7. During the northern hemisphere summer months Laramie, WY, USA is -6:00

UTC. Melbourne, AUS is +10:00 UTC. A celestial object is located according to Figure A.

a. Assuming the object is visible in both hemispheres, which location will see the celestial object cross the meridian first?

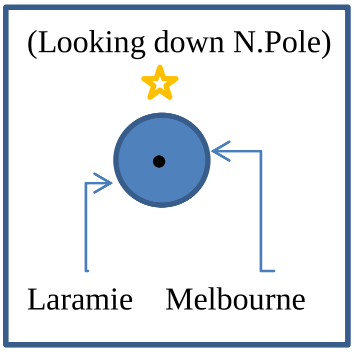



*Figure A*

b. What is the difference between the time that the object crosses the meridian in Melbourne and Laramie?

c. If it is currently sunset (sunrise) in Laramie, what is the corresponding local time in Melbourne? (Assume Laramie experiences night from 8pm-6am, MDT)

8. Explain why observers in the United States see different constellations throughout the year.-

9. What range of Right Ascensions are visible at midnight on…

   a. March 21st (Vernal Equinox)

   b. June 21st (Summer Solstice)

   c. September 21st (Autumnal Equinox)

   d. December 21st (Winter Solstice)

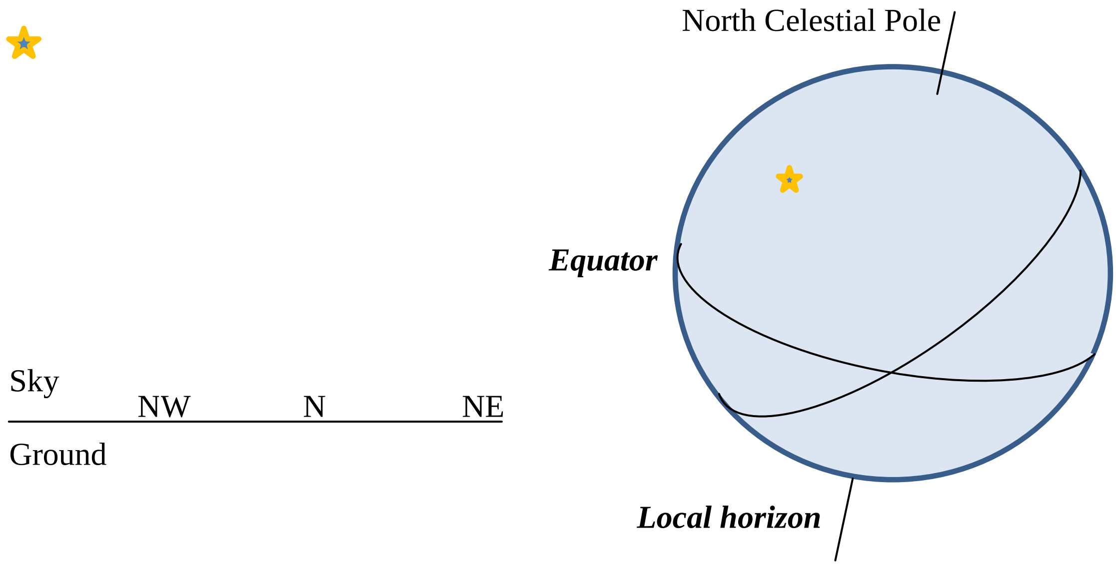
10. What defines a Right Ascension of 0h?

11. What is your current 'local time' (indicate time zone)? What is your current 'local sidereal time?'

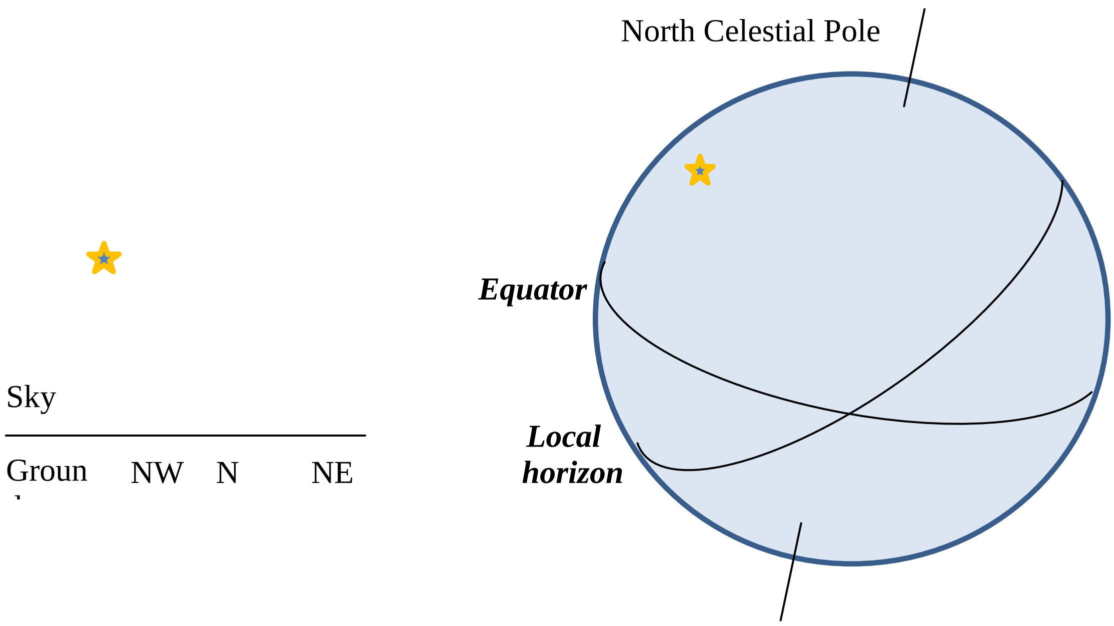
12. Name two astronomical catalogues and their similarities/differences.
13. On the left is a drawing of the horizon looking north. On the right is depiction of

the celestial sphere, with the equator and local horizon noted. Draw in the Alt-Az and RA-Dec coordinate systems for the following stars. Label the zero-points and which direction is increasing.

**Label Alt-Az Here**




**Label RA-Dec Here**



**APPENDIX D – Welcome to the SLOOH Space Camera!**

To be completed by Friday, June 22

This document will walk you through how to use SLOOH Space Camera (sections 1-6) and also includes some Tasks to answer after you are comfortable with using SLOOH (section 7).

Due to the late-night nature of astronomy, I will make myself available on Elluminate from the hours of 8pm-9pm MDT, except Saturdays. You may also contact me any time at dgershun@uwyo.edu. Lastly, the online discussion forum is at your diposal to contact your classmates, ask questions, provide assistance etc. (slaterclass_AstroForEducators@yahoogroups.com)

# 1 Activating Your Minutes and Logging On

Set up an account on slooh.com by going to slooh.com, select LOGIN and then hit the REDEEM button to enter in the number on the back of your card you obtained. (150-200 minutes costs about $20 and unlimited for a year costs about $40.) Then, log in to the site:

NOTE ABOUT USING YOUR MINUTES: Don't worry about running out of minutes - yet. You only spend MINUTES when you click the green JOIN MISSION button (another window will open) and when you close the window, your time stops.

# 2 Acquainting Yourself With the Launch Pad

When you first logon, you are directed to the main menu, aka: the 'SLOOH Launch Pad' (see Figure 1, next page). At the left side of the Launch Pad, there are three small boxes which you can click to connect yourself to one of three SLOOH Observatories. There are two observatories in the Cannary

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Islands, Spain (CI1, CI2) and one observatory in La Dehesa, Chile (CL). NOTE: Chances are, only CI1 will be operational by the time you begin week 3. That's fine, you should still be able to make several reservations throughout the week. Note that when you switch between SLOOH Observatories, the the circular picture at the left and the Mission Boxes will also change to reflect this switch.


Figure 1: The SLOOH Launch Pad

The right side of the Launch Pad shows three rows. The top row shows what RESERVATIONS you have requested, and how many you have remaining (you may reserve up to 5 time-slots in a 24 hour period). The next row shows you the UPCOMING MISSIONS, what object they are and what time they start. The bottom row shows you what PICTURES you have captured recently. Click on this to see all your pictures which are categorized by object type.

Finally, in the very upper-left of the Launch Pad is a button WEATHER CONDITIONS which provides you with information about weather, moon phase, sun rise/set and other useful bits. If ever you are confused about why Missions are not online, check here for current weather and forcast.

### 2.1 HELP Menu

The HELP menu is located at the top right of the Launch Pad. This drop-down menu contains information about general astronomy knowledge, how to use SLOOH, and information about UTC time.

## 3 A Brief Word About Keeping Time

Astronomers record their events in Universal Time, abbreviated 'UTC.' You will see this method of time-keeping a lot in SLOOH and in other remote telescopes. It is also referred to as 'Greenwich Mean Time' or 'Zulu Time.' UTC is the current local time along Earth's $0^o$ meridian which passes through Greenwich, England. For instance, 22:30 UTC implies that it is 22:30 (11:30pm) in Greenwich, England. Consult the 'What Is UTC?' pdf under the help menu in order to convert from UTC to your local time in the United States. For example, I live in Laramie, WY which is 6 hours BEHIND UTC (-6UTC) during the summer. When it is 22:30 UTC (*10:30*pm in Greenwich), it is 16:30 (4:30pm) in Laramie. If your home location is not in the United States, consult this website to find out what time-zone you live in. The SLOOH camera in the Canary Islands is one hour AHEAD of UTC (+1UTC) during the summer.

## 4 Joining a Mission or Reserving a Time-slot

The one good feature about SLOOH is that you don't *have* to reserve a time-slot in order to observe an object and take pictures. I will show you both methods:

### 4.1 Join Another Member's Mission

When Missions are online for a particular dome, you will see a green button that says JOIN MISSION. Otherwise that button will be red and says MISSIONS OFFLINE (probably due to weather or technical issues). At any

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point in the night you may join another member's mission by clicking the green JOIN MISSION button. Jump to Section 5: Let's take Some Pictures!

## 4.2 Reserve Your Own Mission

If you want to make absolute sure that SLOOH will look at a particular object during the night, you may want to reserve your own time-slot. Starting from the Launch Pad, click on MY RESERVATIONS which takes you to today's reservations. Brown and Black slots are already taken, and Green ones are available. If you don't see any open slots, you may advance up to 7 days in the future to see if there are any available slots. Once you find a desireable time, click on it and it will promt you to choose an object. This can be done in four ways, also shown in Figure 2, next page.

- QUICK PICK: Chooses an object for you...LAME! Let's skip this one.
- CHOOSE ITEM FROM LIST: This option provides you with a list of popular objects that are currently visible from your chosen observatory. Objects are listed by catalog number (e.g.: IC, NGC, M). If you are unfamiliar with catalogs, the following website contains information about the history and nomenclature of astronomical catalogs. After choosing, go to section 5.

  http://spiff.rit.edu/classes/phys445/lectures/catalogs/catalogs.html
  *DO NOT complete the exercises at the bottom of the webpage**
- ENTER CATALOG NUMBER: Allows you to enter the objects catalog and the corresponding number. Beware: Make sure that whatever object you choose, it is visible from your chosen observatory at the time-slot which you have chosen. When in doubt, STELLARIUM is your friend. Typically, objects that have just risen above the horizon will not be seen by the telescope. Look for objects that are at least $15^o$ above the horizon. After choosing, go to section 5.
- ENTER COORDINATES: This option gives you the freedom to point *anywhere* in the sky! Once you decide upon an object, determine the object's coordinates (Right Ascension, Declination) and enter them accordingly. Coordinates are almost always included in a catalog, but if you can't find them, search on the NASA Extragalactic Database (http://ned.ipac.caltech.edu/forms/byname.html). Or, you can search for an object on Stellarium by pressing F3. Look for the information,

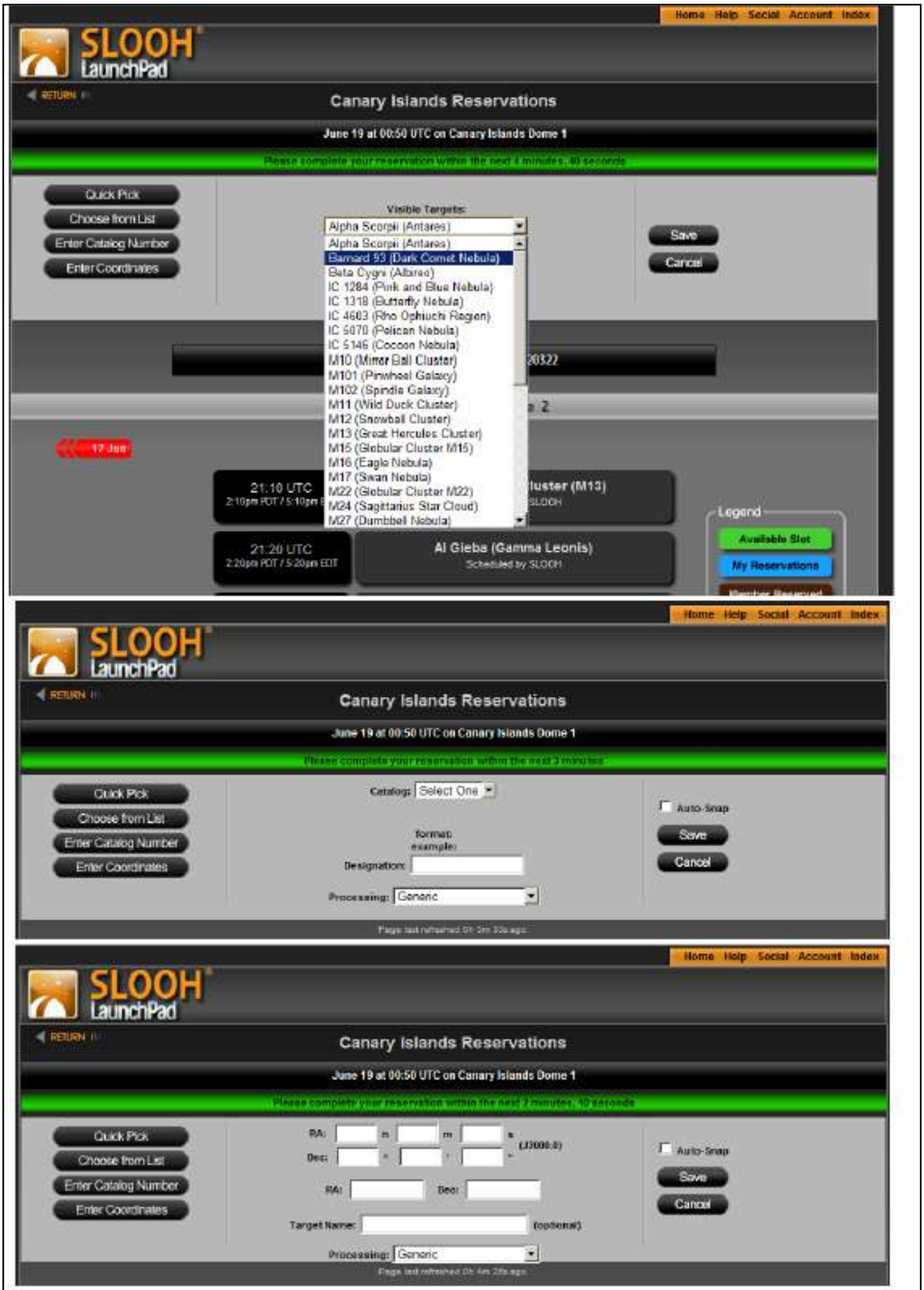


Figure 2: Ways to reserve a time-slot. Top: Choose From List; Middle: Catalog Number; Bottom: Enter Coordinates

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'RA/DE (J2000).' Again, make sure that your chosen object is visible during the time-slot. After choosing, go to section 5.

Each method of requesting an object is different and has its advantages and disadvantages. Play around and see what works best for you.

## 5 Let's Take Some Pictures!

You've finally reserved a time-slot and chosen an object that is visible (or joined someone's mission). Now it's time to take some pictures! When you click on the green JOIN MISSION button, a separate window will pop up. Once this window opens, YOUR MINUTES WILL START DEPLEATING. The left side of this window provides information about what you are looking at. In addition, there are other buttons at the bottom which you can explore. If you are ever stuck, the HELP button will guide you through many of the features.

The right side shows you the the field of view (FOV), or what the telescope can see. At about 2 o'clock, are three round buttons (small, medium, and large). These buttons controll the views: wide-field (small button), narrow-field (medium), and high-magnification (large). The middle button is not available in the CI1 Dome, so you should always use the high-magnification button to see your object.

At about 11 o'clock, there is a zoom slide which magnifies your FOV even more. This does not provide any detail, in fact, the quality gets more grainy as you zoom with this. But it is yours to play with and tinker.

At 3 o'clock is the image meter. This shows you the how far along (in %) your are in your 10-minute exposure. SLOOH is unique in the sense that it chooses filters and processes the image for you as it is exposing. Notice how the image changes as the 10 minutes progresses...

Lastly, at about 4 o'clock, is what you've been waiting for: The SNAP PICTURE button!! At any point during the 10 minutes while the picture is exposing, you may take a picture which will show up in MY PICTURES. You may only take THREE pictures during a mission. If you don't like one of them, you may select it (one of the three white circles) and press DELETE PICTURE.

## 6 Retrieving Your Pictures

Go to MY PICTURES to find your most recent pictures. They are also organized by object type. Clicking on a particular picture it brings you to


Figure 3:

a new window. You can add optional information to the picture as well as upload it to Facebook or Twitter, delete it, or download it to your hard drive. I suggest downloading it.

## 6.1 Processing

Any pictures that come through a telescope are rarely perfect and often need to be improved. You can insert your picture into MS Word or MS PowerPoint and go to the FORMAT tab and select CORRECTIONS to make it just right! You can change the contrast and the color to highlight important features. This important and required step is called IMAGE PROCESSING.

To do even more than can be done with Word or PowerPoint, you can use any picture program, such as PAINT on a PC or Gimp on a Mac. You can put multiple images on a single WORD page or PPT slide to showcase all of the different images youve taken with a telescope.

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$$s = \theta d, \tag{1}$$

where 's' is the objects TRUE SIZE, '$\theta$' is the objects apparent size, and 'd' is the distance from Earth to the object. Refer to Figure 4 for a diagram of this relation. This phenomena is the same reason that mountains look smaller when they are on the horizon (far away), than when they are close to you.

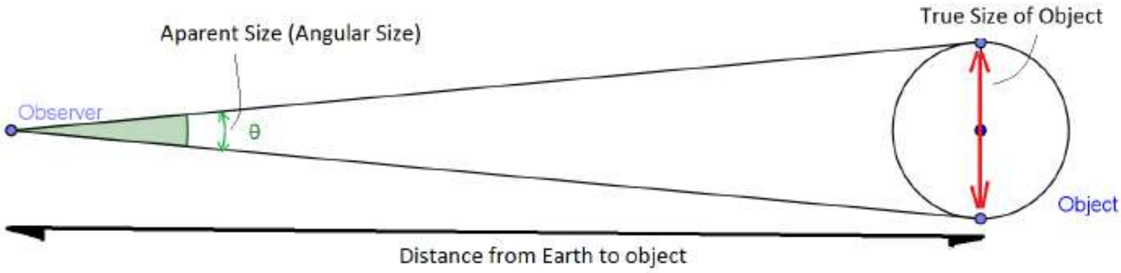


Figure 4: Relation among true size, aparent size, and distance of a far away object.

The only thing you need to remember is that your angular size MUST be in units of radians (r). Also, whatever units you use for 'd,' you will come out with the same units in 's.'

TASK: Join a mission which is looking at a galaxy. What is the galaxy's apparent size and distance? Determine the true size of the galaxy using equation (1). Compare your value to one which can be found in the Nasa Extragalactic Database (NED). See example below for details.

#### 7.3.1 Example

For instance, last night, I observed NGC 3938, a face-on spiral galaxy. The apparent size of this galaxy is 300" (arcseconds is noted as "), and the distance from Earth is 54 Mly (million light years). My first job is to convert the angular size ($\theta$) to radians, which is a unit of angle.

$$\theta = 300'' \frac{1^r}{206264''} = 0.001454^r \tag{2}$$

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Now that the angular size is converted to the proper units, I can use this in equation (1):

$$s = (0.001454^r)(54Mly) = 0.0785Mly = \underline{\underline{24.3kpc}} \qquad (3)$$

Therefore, I calculate the true diameter of NGC 3938 to be 24.3 kpc (1pc = 3.26 ly). I can now compare this to values in the literature. The NASA Extragalactic Database (NED), has all sorts of data for thousands of deep-space objects.

http://ned.ipac.caltech.edu/forms/byname.html

I type in my object name 'NGC 3938' where it prompts for object name. After searching, I look for the second box down, 'INDEX for NGC3938.' There should be a link, 'Quick-Look Angular and Physical Size.' Click that, and I am looking for the column, 'Physical Major Axis (2a) [kpc]. If there is more than one entry, take the average. I find that NGC 3938 has an average diameter of 30 kpc. Compare this to my calculated value of 24.3 kpc. Pretty good, considering that this method is just a rough estimate!

### 7.4 Showcase Portfolio

To show off all the hard work you have spent leanring how to use SLOOH and take pictures, I would like you to choose 5-8 of your favorite photos that you captured using SLOOH.
Organize the pictures into a portfolio (Flickr, powerpoint, poster, etc.) and also prepare an expository piece (poem, short story, video, 3-5minute talk, etc.) which describes interesting facts about your objects. We will show our portfolios in class on Elluminate at the end of Week4 MicroObservatory unit, Friday, 6/29, time TBD. Be as creative as you want with your portfolio and your expository piece! Just make sure that you will be able to submit your final product electronically. Contact me if you have any questions about format.

(NOTE: you will also make another portfolio for week 4, MicroObservatory, but you will only choose ONE to present on 6/29)

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