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Integrating the Galileoscope into the College Classroom

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Abstract. The Galileoscope is useful in addressing many of the concerns of college astronomy teachers. Many college astronomy classes struggle to incorporate telescopic observing projects into the curriculum. Scheduling observing sessions on campus at night can be problematic, particularly for students who must commute longer distances to campus. One potential solution is for students to do observing projects at home and report back the next day. In order for this model to work, each student would need a telescope at home. The Galileoscope is a low-cost, high optical quality telescope that was developed for the International Year of Astronomy (IYA) that is being used in college courses around the country. Each student in class can purchase a Galileoscope for a fraction of the cost of a typical astronomy textbook. The Galileoscope is capable of showing a wide variety of celestial sights including craters on the Moon, the phases of Venus, the Galilean Moons of Jupiter, the rings of Saturn, and a wide variety of double stars, nebulae, and star clusters.

1. Introduction

Observational astronomy plays a large role in many college-based astronomy courses for non-science majors. Astronomical observations are effectively used to address a wide variety of concerns associated with the teaching of these introductory courses. Some of these areas of emphasis include:

- identifying and addressing astronomy misconceptions in the classroom (Comins 1998, 2001);
- increasing the number of Astro 101 instructors, and providing them with research-validated curriculum and assessment instruments (Brissendon and Prather 2010);
- building a community of faculty that can assist in teacher preparation for earth and space sciences (Shupla et al. 2010);
- using laboratory exercises that simulate or supplement the observing experience (Marschall 1998);
- preparing future STEM faculty (Hooper et al. 2010); and
- using telescopes and image processing to excite students about science (Hartman et al. 2010; Dussault et al. 2010).

In discussions with college astronomy teachers in a variety of settings (state or private, large or small, 2-year or 4-year etc.), we have found that the Galileoscope provides a useful way to address many of the areas described briefly above. This workshop was designed to provide a forum for college-level instructors to share their experiences in using the Galileoscope in their programs.

2. The Galileoscope Telescope

The Galileoscope project created a small, low-cost, high optical quality refracting telescope for the International Year of Astronomy 2009 (Pompea, 2008, Pompea et al. 2008). The Galileoscope is a 50mm f/10 refractor that includes a Plössl eyepiece and a diverging lens that can be used either as a Galilean eyepiece or a 2× Barlow lens. These lenses allow the Galileoscope to be used in a variety of modes for different educational purposes. The opto-mechanical design of the Galileoscope was done in a professional way and included solid system engineering, some details of which are described elsewhere (Pompea et al. 2010).

The Galileoscope was designed for students to recreate Galileo's historic observations and college instructors have largely used the telescope to explore these objects. Students can observe craters on the Moon, the phases of Venus, track Jupiter's Galilean Moons, discover the orientation of the rings of Saturn, and many other astronomical sights. Many instructors have used the Galileoscope to enliven the history of astronomy.

Other instructors have used the Galileoscope as part of their exploration of optics and the tools of the astronomer. Of course, the optics and mechanics of the Galileoscope are much better than Galileo's original telescope. The name "Galileoscope" is used in homage to Galileo. The goal was to give students a satisfying first experience with telescopic observations, not to recreate Galileo's telescope.

There is a Galilean configuration that can be constructed with the Galileoscope. This gives the instructor the opportunity to show and explain the differences between the Keplerian and Galilean configurations. By using ray diagrams the basic concepts of focal point, magnification, and field of view can be explored. The Galilean configuration is used only after the Keplerian configuration has been explored, since its field-of-view is quite limited.

The Galileoscope project continued after IYA2009 and represents one of several important resources for science teachers developed during IYA2009 (Pompea and Isbell 2009). The NOAO educational team continues to develop new educational materials for the Galileoscope. We are also updating our existing materials such as the Galileoscope Observing Guide, which helps students understand which objects may be of the greatest interest each month. The educational materials were designed to teach the basics of optics and were derived from our Hands-On Optics program developed with the Optical Society of American and SPIE—The International Society for Optical Engineering.

All of the educational materials can be found on different parts of the *Teaching With Telescopes* Project support website,[1] run by NOAO, and is designed for teachers at all levels. *Teaching With Telescopes* is a long-term project to support college and K–12 teachers using small telescopes in the classroom. The website has a variety of

[1] `http://www.teachingwithtelescopes.org`

lesson plans, observing guides, videos, and other relevant materials. It also serves as a resource site for professional development of K–12 teachers by college instructors or professional development leaders. In the future it will host various student contests and photos taken through the Galileoscopes. As such it is a community resource.

3. Engineering Education and the Galileoscope Design

The Galileoscope was designed by a team of astronomers, optical engineers and educators to produce the best possible images at the lowest possible cost. Great care was also taken to be sure the Galileoscope was durable enough to stand up to repeated classroom use yet easy enough to be put together by young children.

Figure 1. Exploded view of an early prototype design done in SolidWorks 3DCAD and used to assess tolerances and to minimize the number of parts. The final design was far superior to this early concept. (S. Rath, NOAO)

This makes the design of the telescope of interest to college instructors in engineering, including human factors engineering.

The optical and mechanical design went through a number of prototyping and testing stages. Extensive testing was done by Doug Arion and his students at Carthage College and other testing was done by Rick Fienberg and at NOAO. The mechanical design was simplified in a variety of ways and an extensive analysis was done to ensure proper manufacturing tolerances. In particular, the focus tube needed to be cleverly engineered to achieve the right level of movement (friction) without excessive slippage when holding an eyepiece. Similarly the optical design evolved to meet an extensive set of requirements, which have been described elsewhere (see Pompea et al. 2010).

The Galileoscope was designed to be durable but easy to assemble. The optical quality of the instrument was the main design driver. In order to be durable enough for repeated assembly, no tools or glue were required for assembly. Similarly the design does not use any tabs or other plastic components that are likely to break under extended use. We have demonstrated that the Galileoscope can be assembled and taken apart over 100 times without damage. This makes ideal for use in a college classroom where each student assembles a telescope.

The achromatic objective and eyepiece lenses are designed to give a sharp image over a large field-of-view. Stray light is controlled in the telescope, making it suitable for urban use. This is done by a combination of baffles in the tube, a field stop in the eyepiece, and a rough interior surface to diffusely reflect light from a source like a streetlamp. A 1/4-20 nut allows the Galileoscope to easily attach to any standard camera tripod, since this is a universal size for the attachment. Significant effort went into strengthening the area of the tube around the tripod nut to allow it to be attached tightly to any tripod without fear of breakage of the plastic. In general, college instructors have not encountered durability issues with the telescope.

The Galileoscope is a 50mm f/10 refractor. The f ratio was chosen for ease of optical manufacturing. The objective lens is an achromatic doublet to reduce chromatic aberration. The included eyepiece is a 20mm Plössl (using plastic lenses to reduce the total cost). This eyepiece give a magnification of 25× with good eye relief for people who wear glasses. A Barlow lens is included to give a 50× magnification. The Barlow lens can be also used to make a Galilean eyepiece with a magnification of 17× (although with a very small field of view!). This observing mode is more illustrative than practical. The Galileoscope accepts the standard 1.25-inch eyepiece allowing even greater observing flexibility or the use of the highest quality eyepieces. A glass eyepiece of the same focal length will generally provide a wider field of view.

4. Galileoscope Assembly and Daytime Usage

We have used the Galileoscope with a variety of audiences ranging from early grade school to college students and instructors. We have worked with groups ranging from a handful of students to large audiences of up to 500 eighth graders. Although the assembly of large numbers of Galileoscopes in a college lecture hall might seem to be an impossible task, the NOAO team has done something similar with as many as 500 middle school students at one time. However, in this case, each student was situated at a flat table where the parts could be spread out. It would be much harder to do an assembly en masse if there is no flat space to spread out the pieces.

Each audience has some unique challenges building the Galileoscope. We continually refine how we lead people through the construction process based on our experiences and update our presentations and instructions accordingly. The most recent versions of the presentations and assembly instructions are available on the *Teaching With Telescopes* website.

Although the Galileoscope can be assembled in less than five minutes by the college instructor (with some practice), leading a group of people through building Galileoscopes for the first time takes at least an hour to an hour and a half depending on the age and skill level of the participants. When building Galileoscopes, you need several people circulating around the room to help with the assembly. These people also inspect the Galileoscopes as they are being constructed in order to ensure proper assembly.

The most difficult part of building a Galileoscope is the eyepiece assembly. Handling the small lenses can be challenging as the lenses must not be lost and must each be examined to allow it to be assembled correctly. For groups of very young children (below fifth grade), we sometimes pre-build the eyepieces and let the students build the rest of the Galileoscope. Young students have a difficult time handling the small lenses and getting them in the proper orientation, although they can assemble the rest of Galileoscope with proper instruction. For college students, they generally do not have a problem building the eyepiece or Barlow lens assembly. Assembling the Galileoscope gives students an important sense of ownership, so we encourage all users to build their own telescope, if possible.

Once the Galileoscope is assembled, students need practice focusing the telescope. The Galileoscope has a near focus point of about 20 feet so students can practice in most classrooms. One key area that causes confusion is which way the focuser tube should move for nearer objects. In this case the focusing tube should be pulled all of the way out. For focusing on infinity the focuser tube should be pulled out a distance of about 3 adult fingers from the end of the barrel. Without this advice, students tend to aim randomly at objects of different distances and then try to focus in a similarly random way. They rarely achieve focus quickly, on any object, and this can be frustrating.

The Galileoscope has a boresight on the top of the Galileoscope to be used as a finder. It is important to practice inside during the day before taking the Galileoscope outside under the stars. An important part of the workshop is teaching students how to mount the Galileoscope on a tripod. A steady mount is essential for viewing at 25×. We have tested many models of inexpensive tripods and have found several to work well. Even with the best tripod, it is difficult to observe objects near the zenith. The Galileoscope will not accept a star diagonal. Using a chair or setting the Galileoscope on a table often works to make it easier to observe objects at higher elevations.

5. Observing at Night with the Galileoscope

Most of the college instructors we have worked with have integrated the Galileoscope into their nighttime observing program. In many cases the Galileoscope is used in conjunction with other telescopes at a campus observatory or remote observing site. In some cases the Galileoscope is loaned the student for home-based observations. Both strategies seem to be highly effective.

Most of our Galileoscope workshops (including this one) take place during the day and we do not usually have time to observe with the Galileoscope at night. In an optimal workshop, there would be sufficient time to observe with the Galileoscopes in the day and then use and improve those acquired skills that night. We have hosted many star parties that feature the Galileoscope where the students who built it are using it for the first-time at night. They have all been successful if the setup of the telescope occurs before it gets dark. One of these star parties (the Flagstaff star party of October 2010) had over 300 people observing with Galileoscopes they had built that week.

Prime observing targets for the Galileoscope are the planets and the Moon. Using a software program such as the *Virtual Moon Atlas*, you can plan an observing session that lets you track down many named Maria and craters on the surface on the visible portion of the Moon. We try to schedule star parties around the first quarter Moon for

Figure 2. Galileoscope on a small tripod.

the best observing conditions. This also allows the setup of the star party to take place before sunset. Observations of the Moon can begin before or during sunset as well.

Saturn and Jupiter are the prime targets for planetary observing. The rings of Saturn are easily visible and Titan can be observed as well. Jupiter's four Galilean Moons are easy targets and their movement can be observed over the course of a few hours. The phases of Venus are also visible through the Galileoscope although no surface features are visible. The phase of Venus (or occasionally Mercury) can be effectively connected to the history of astronomy.

There are many double stars that are good Galileoscope targets. These include Abireo, Eta Cassiopeiae (Achird), Epsilon Lyrae, and Mizar. The Galileoscope can resolve all three components of Mizar. The color contrast of double stars such as Albireo always makes them a pleasing target.

Star clusters such as the Pleaides, the Wild Duck Cluster in Scutum (M11, or NGC 6705), the Coathanger cluster (Collinder 399 in Vulpecula), and M7 in Scorpius (NGC 6475) are good Galileoscope targets. The Galileoscope has a generous 1.5-degree field of view that takes in bright open clusters better than larger telescopes that have a narrow field of view. Globular clusters such as M13, M4 (NGC 6121 in Scorpius), and M5 NGC 5904 in Serpens) are also good observing targets.

Nebulas and galaxies are trickier targets but there are several that are easily visible with the Galileoscope. The Orion Nebula is perhaps the most famous and a very pleasing site through the Galileoscope. The Andromeda Galaxy is the best extragalactic target (with the possible exception of the Magellanic Clouds which are only visible from the southern hemisphere) and is easily visible.

There are many fainter objects that are visible with the Galileoscope that may not be suitable for a beginning student observer. This is primarily because the student may not be able to navigate to the object. In some cases (with various considerations), the instructor will use a green laser to help students in pointing at the object of interest. Most of the Messier catalog is in reach and many brighter NGC objects are as well. Uranus and Neptune can be seen with the Galileoscope although no surface detail is visible. Locating them can also be difficult, unless there are near a star that can be located.

6. Planning Observing Sessions

For most of the objects described, it is helpful NOT to observe them near the zenith. Although this is contrary to how most college astronomy instructors think, the Galileoscope is somewhat frustrating in observing zenith objects. To help plan observing sessions, we use and recommend the free planetarium program *Stellarium*.[2] *Stellarium* is an open-source program available for Windows, Mac, and Linux operating systems that permits users to see what is visible from any location on Earth at any date and time. Another free program called *Virtual Moon Atlas*[3] helps observers identify hundreds of different features on the surface of the Moon.

On the *Teaching With Telescopes* website, we have put together a Galileoscope Observing guide. The observing guide contains tips on using the Galileoscope, a list of planets and when they are visible (this is updated yearly), interesting conjunctions, eclipses, and other interesting objects. Updates will be posted on the *Teaching With Telescopes* website for events such as comets that are not always predictable but can be easily observed with the Galileoscope.

7. Conclusion

The Galileoscope is a long-term legacy project for the International Year of Astronomy 2009. We will continue to develop and support the *Teaching With Telescopes* website and provide professional development workshops for educational professionals around the country. We are constantly exploring new avenues to increase the reach of the Galileoscope education programs. College instructors from many different programs have used the Galileoscope successfully in their teaching. Some have integrated it with the history of astronomy while others use it for teaching basic optics concepts. Nearly all have used it to give students an opportunity to make and record their own telescopic observations.

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[2] `http://www.stellarium.org`

[3] `http://www.ap-i.net/avl/en/start`

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