Engaging the Public with Live Video Observing

Sarah Burcher
Lowell Observatory
sburcher@lowell.edu

Bill McDonald
Lowell Observatory
skyhighaz@cableone.net

Keywords
observing, video astronomy, big ideas, public outreach

As part of the ongoing efforts to enhance the visitor experience at Lowell Observatory in Arizona, US, the observatory's public outreach team has established a live video observing programme. Using extremely sensitive cameras on a modest–sized telescope, we present detailed colour views of many spectacular celestial objects. With those images on a large television screen, we introduce discussions of many of the most interesting ideas of modern astronomy, supplementing the sky views with stored material to expand this exploration. This model overcomes some of the limitations of traditional visual observing with crowds and has proven to be an excellent way to engage our visitors. Here we provide specifications on our equipment and suggestions for assembling a public video observing system.

Introduction

Lowell Observatory, in addition to being an active research institution, attracts approximately 100,000 public visitors each year through our public outreach programmes. These programmes give us a unique opportunity to connect visitors from all over the world to the science of astronomy. Covering basic concepts to cutting-edge research, we offer live presentations, exhibits, and, most enticingly, sky viewing using modern and historic telescopes.

We have added live video feeds to augment traditional observing using optical telescopes in our public programming at Lowell Observatory and at smaller observing venues. This has allowed us to more actively engage our visitors with enhanced views of deep sky objects, and has provided us with opportunities to discuss those objects in groups. We can facilitate conversations that address the big ideas and discoveries of modern astronomy, leaving guests with a sense of awe at the beauty of the night sky and a deeper understanding of the universe.

Our Public Outreach Programmes in Action

Astronomy is the most visually stimulating of the sciences. For decades, stunning imagery from instruments such as the Hubble Space Telescope have been easily accessible and have captured our imaginations and formed the way we envision our universe[1].

But you don't need access to the Hubble Space Telescope to bring colorful visual appeal and scientifically interesting imagery to your public observing events. As astronomy educators, we need to find ways to combine the inherent beauty of the universe and the power of scientific ideas to create a rich environment for engaging minds.

The science of astronomy's constant groundbreaking discoveries, striking images, and big ideas inspire awe in all of us regardless of background or education level. No matter where you live, you have access to the sky. It connects us all. Those in rural or dark-sky areas undoubtedly can see and appreciate more of the night sky, but even in the largest cities you can be treated to views of the Moon and planets. The combination of concepts, images, and universal accessibility makes astronomy an ideal vehicle for introducing 21st century science.

Observing through eyepieces certainly has its appeal, and is of course the classic way to bring astronomy to your community. Nothing can compare with the grandeur of the night sky seen through a visual telescope: seeing inconceivably distant, immeasurably huge and unbelievably beautiful objects while hearing the stories they tell is not an experience anyone is likely to forget.

But there are limitations to this visual model. Depending on wait times, visitors to the Observatory or star party event may only have a few moments at the eyepiece and human vision is not optimized for speedy night-time observing. When our world is illuminated by starlight, our night vision has very little colour sensitivity[2]. This is particularly detrimental during visual observing as much of what we know about the universe has been learned by observing colour. The striking pink of hydrogen-rich star forming regions appear a murky grey through an eyepiece, and our own eyes rob us of the full-color experience. Additionally, many of the objects that we observe are extremely faint, limiting what we can see even with the largest visual telescopes. Galaxies with lower surface brightness, such as Messier 33, appear in an eyepiece with little definable structure, even through our 32" Dobsonian. When viewed through our video system with a 30 second exposure, we are able to clearly make out its core and breathtaking pinwheel structure (Figure 1).

Expanding the Conversation: Some Examples

Rather than a brief glimpse through an eyepiece, new digital cameras can rapidly produce excellent colour views of many dozens of deep sky objects with exposures of less than 30 seconds (Figure 2). Visitors are treated to full-colour images piped directly from the telescope with an attached camera.

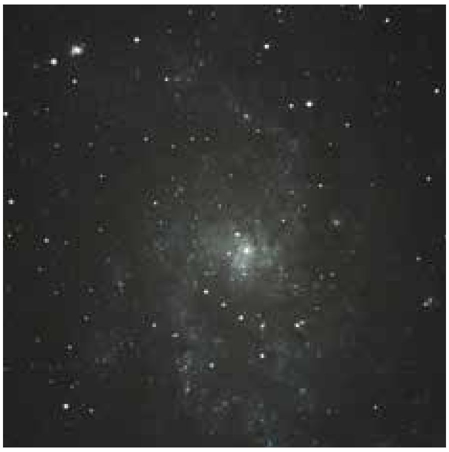

Figure 1. *An image of Messier 33 (the Triangulum Galaxy) from our system using a 14" Planewave CDK and a Mallincam DS10cTEC. Exposure time was 30 seconds. Credit: Sarah Burcher, Lowell Observatory*

For example, the Sagittarius emission nebulae, M8, M20, M16, and M17, can each be seen in exquisite detail and in full colour with an exposure time of roughly 15 seconds (Figure 2), and each can provide a wonderful platform from which to start a conversation about star formation. That conversation can then be extended to the end states of stars by moving to planetary nebulae, such as M57 and M27. The stunning colouration of M27 provides a splendid introduction to the notion of element formation (Figure 2). M97 is another option that is visible from our latitude (35° N) throughout most of the year. In winter, we can point out the Orion Nebula with a laser pointer and then show stunning views of M42 in its full spectrum of red and blue, as well as neighbours like NGC 2024 (the Flame Nebula), to illustrate the notion of star formation. Finishing with the supernova remnant M1 (the Crab Nebula) completes the story of stellar evolution and element formation.

The Moon is another excellent object to present (Figure 2). Displaying a live lunar image allows us to examine the many interesting features of our nearest celestial neighbour. Detailed views of the craters and their central peaks, the rilles, the different colours of the mare, and the Apollo landing locations are all good starting points for a wide range of discussions. It is also fun and educational to demonstrate the speed of the Earth's rotation by shutting off the telescope tracking and watching the Moon drift rapidly across the screen. Live video views of the Moon also tend to show the rippling effect caused by Earth's atmosphere, leading to discussions about the value of space telescopes.

When used with a solar telescope, the same camera used for night-time observing can produce exquisite views of the Sun, capturing sunspots, prominences, flares, and minute details of the surface granularity.

We host weekly 'Meet an Astronomer' events where Lowell astronomers lead conversations with the public using our video observing system. This allows researchers to show live views of objects they actively study, as well as images from their recent papers (Figure 3). The guests enjoy the chance to interact with 'real scientists' and learn first-hand about the process of science and recent discoveries. In the time of the COVID-19 crisis, we are able to extend this to a virtual interaction hosted on YouTube entitled 'Interactive Stargazing'. Via a live chat, viewers can interact with our hosts and request objects to be viewed live with our system.

Virtually or in-person, guests also love to ask the 'big questions' about our galaxy and beyond (Box 1). A live view of the face-on spiral galaxy M51 (the Whirlpool Galaxy) with its smaller companion, NGC 5195, provides a wonderful platform for introducing galaxies and galaxy interactions (Figure 2). The red glow at the intersection between M51's spiral arm and NGC5195 nicely demonstrates what happens when galaxies collide. Additionally, the northern hemisphere summer combination of the M51 and NGC 4565 (the Needle Galaxy) provides a three-dimensional view of spiral galaxy structure and adds depth to conversations about stellar evolution.

Increased Accessibility of Observing

Our video programme allows us to increase the accessibility of in-person observing. Our model of engaging our guests in conversations, rather than simply lecturing them, allows us to bring even the most challenging aspects of science and astronomy to any level of education or interest. The set-up provides every guest a view through a telescope regardless of mobility limitations.

The camera is operated via a laptop computer, and images are displayed on a large screen for the public. We always ensure the screen is placed a sizable distance from the visual telescopes and angled away from guests to minimise interference with guests' night vision. We also cover our screens with a translucent dark film to further reduce screen glare.

The display shows not only the view from the telescope but the interface we use to optimize the image. Visitors can watch as we adjust the exposure time, focus, and image properties. This allows us to lead a discussion about image processing and the values of different kinds of instrumentation.

Since we have access to the internet and stored resources, we can bring up pictures from the Hubble Space Telescope and other scientific sources to compare them side-by-side with our live images. We can then explain the steps of scientific observation and how many of the astronomical pictures we see are not necessarily just in the visible spectrum, but include data from other wavelengths. This can lead to discussions about the limitations of Earth-based telescopes and the value of arrays, interferometers and radio telescopes. One of the benefits of this informal setting is the ease with which conversations develop. One question begets another and that may be the best index of the effectiveness of the presentation model. Having this flexible

Box 1. Big Ideas Addressed Using Video Astronomy

- Star formation and stellar evolution
- Supernovae, planetary nebulae, and element formation
- Planet formation
- Comets, asteroids, meteors
- Big bang, expanding universe, age of the universe
- Stellar endings: dwarfs, neutron stars and black holes
- Scales of the universe
- Number and structures of galaxies (and how the Milky Way compares)
- Dark matter, dark energy

set-up allows us to touch on aspects of modern research that would be hard to explain with only an eyepiece setting.

At an eyepiece, guests can feel pressured by the line of others behind them waiting to view, and can be reluctant to engage the operator with their questions. We have found that in these larger groups gathered around our screen, guests feel more engaged in our conversation than as an individual at an eyepiece. They are welcome to stay as long as they like, and listen to the questions of others around them. It becomes a community learning opportunity. Guests learn what we have to teach about astronomy, but also – and possibly more importantly – learn that everyone has questions about our universe.

In these large groups, we often find visitors with mixed levels of education and astronomy knowledge. In these instances, we strive to find ways to captivate the entire audience. We do appreciate when learned guests come to us with their complicated technical questions, and the best educators are adept at using these questions as a stepping stone to a larger conversation with the whole group. We try to avoid technical jargon and focus on bringing the ideas to a level everyone can understand. We strive to explain concepts simply but completely by using analogies, stories, and even hand motions to bring tough material to an understandable level. A notable example is when guests ask about dark matter. In this instance, we would bring up live images of a few select galaxies, especially face-on galaxies with clear disk structure. We would then lead the guests along a conversation about the rotation of galaxies, and how we would expect them to rotate like solar systems, with the objects closer to the center moving faster. We then explain that galaxies move instead like records on a record player – with every point making revolutions at the same rate. We've then laid the foundation for delving into the history of the discovery of dark matter and, for example, Vera Rubin's work on the predicted versus angular motion of galaxies (some of which was done at Lowell Observatory)[3].

The large screen gives visitors who normally have trouble viewing through eyepieces, like the elderly, children, and individuals in wheelchairs, access to a live telescope experience. When we use video to observe we do not need to coach each guest as he or she approaches the scope. Rather, our time is spent examining the objects before us in much greater detail than we could with purely visual tools. Eyes vary substantially; with our video feed, focus is not an issue. By accumulating light, the camera allows us to see faint objects in greater detail than purely visual observing would permit. That said, we always operate the video system alongside visual scopes, including the 24-inch Clark refractor that Vesto Slipher used to gather the first evidence of the expansion of the universe.

The large display also addresses the issue of queues. Time spent waiting in a queue to see celestial objects is time wasted. We should optimize use of people's time

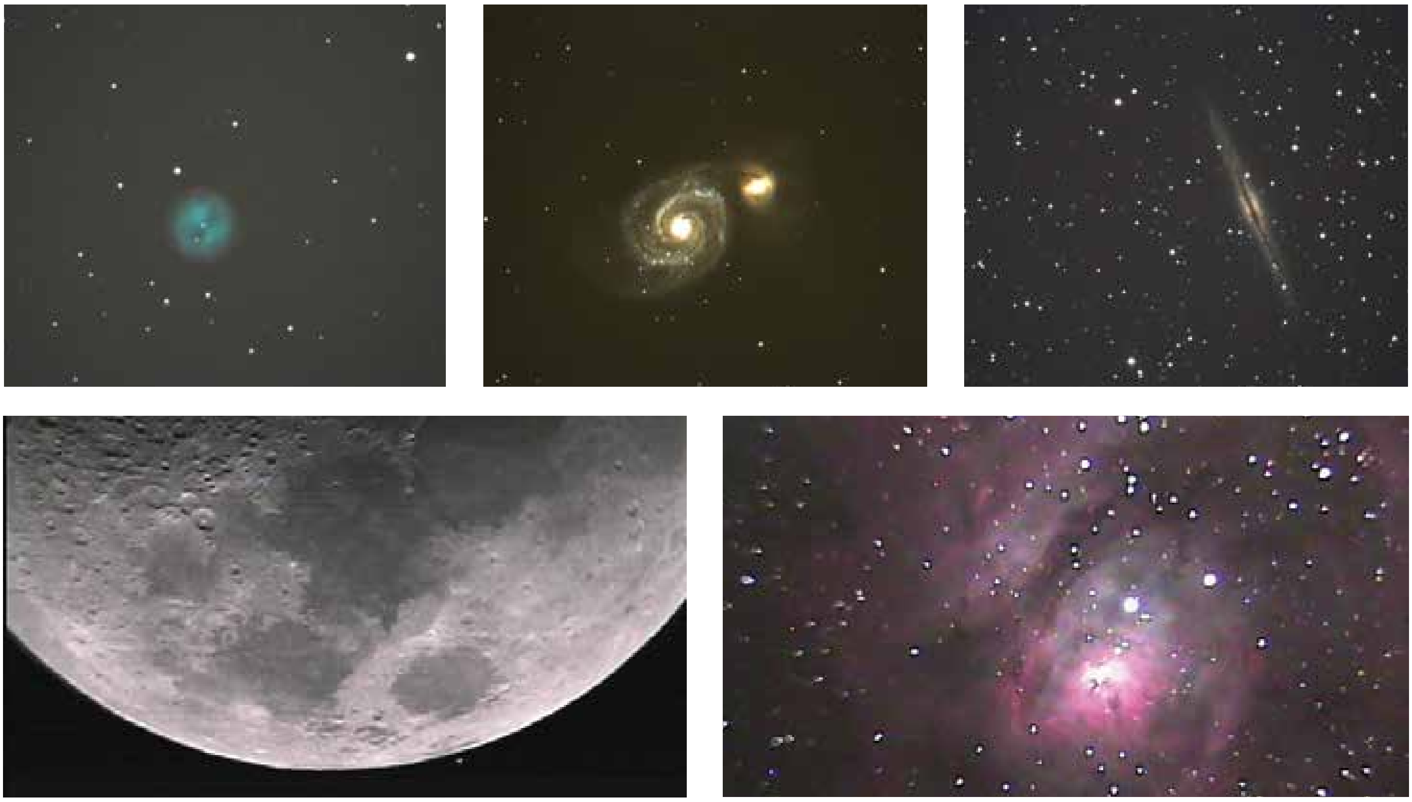

Figure 2. *A sampling of images taken with our systems. All pictures have less than 30 seconds exposure time, and are presented here (like they would be live to the public) with only minimal editing of brightness and contrast. Objects shown clockwise from the upper left:* ***a)*** *Messier 97 (the Owl Nebula).* ***b)*** *Messier 51 (the Whirlpool Galaxy).* ***c)*** *NGC 891.* ***d)*** *Messier 8 (the Lagoon Nebula).* ***e)*** *The Moon after occulting Aldebaran. The images on the top row were taken with a Mallincam DS10cTEC and the images on the bottom row were taken with a Mallincam Xterminator. Credit: Sarah Burcher, Lowell Observatory*

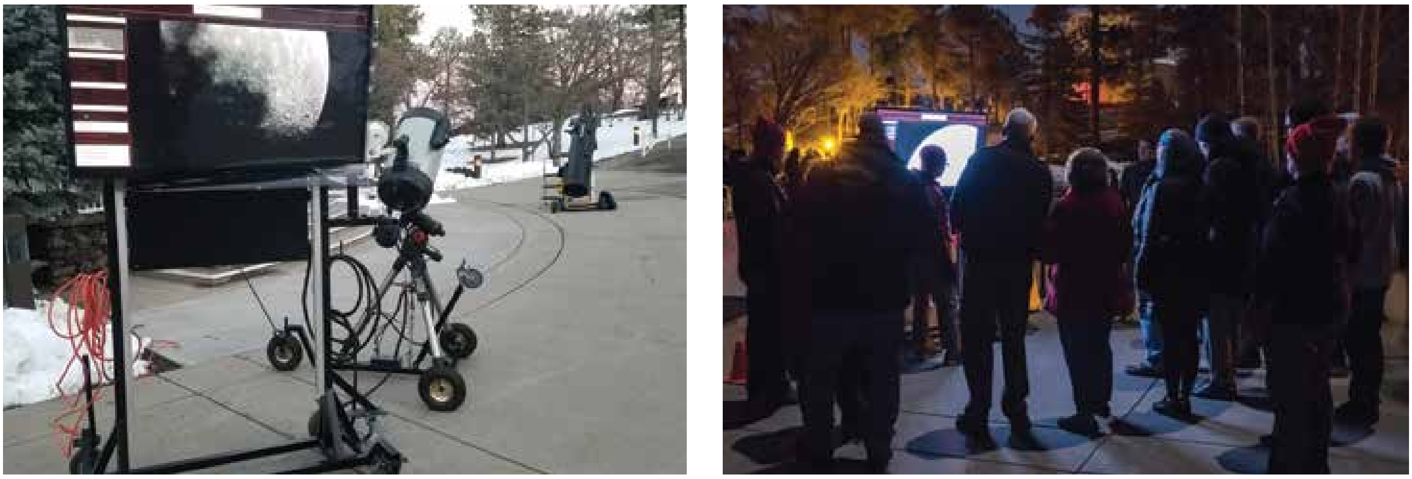

Figure 3. *Our system incorporated an 11-inch Celestron telescope, a Mallincam Xterminator camera, and a large-screen television to display images directly to the public (left). We used live images from the telescope to entertain large crowds on busy evenings at Lowell Observatory and during our always popular 'Meet an Astronomer' evenings (right). Please note that the live television display of the Moon is overexposed in the right photograph, but clearly visible in the left. Credit: Sarah Burcher, Lowell Observatory (left); Jim Cole, Lowell Observatory (right)*

by actually seeing and considering those objects. Video observing serves this goal well by allowing us to engage a dozen or more people at once. The camera's view is also much less compromised by a bright Moon or light pollution than a person's visual view. That allows us to provide good images of many reasonably bright objects at any time during the lunar cycle or even in heavily populated areas.

Tools and Tips

Live video observing is only possible because extremely sensitive cameras have become available[4], allowing us to present viable images of deep sky objects in exposures of 5-30 seconds. Astronomical images like those seen in astronomy magazines generally require much longer exposures, often many hours in length. With our system there are hundreds of objects that we can use in our programmes with exposures under 30 seconds.

There is a substantial range of equipment available to implement a video observing programme. Lowell Observatory added a new observing plaza, the Giovale Open-Deck Observatory (GODO), for its public programmes. Our video observing system includes a Mallincam DS10cTEC video camera attached to a 14-inch Planewave CDK (f/7.2) optical tube. This model is not mobile, and we know that this may not be a financially-viable option for many public observing ventures.

We thus invite you to consider the system that we formerly used at Lowell Observatory. Our less expensive, mobile set-up included a Celestron CGEM GoTo German equatorial mount with a StarSense automatic alignment system, a Celestron 11-inch Schmidt-Cassegrain optical tube with a 0.33 focal reducer, and a Mallincam Xterminator CCD video camera. We used a laptop with a video frame grabber to control the camera and display the images on a 27-inch plasma television screen (Figure 3).

The first thing to do if you are contemplating setting up a live observing system is to study the state-of-the-art camera technology. There has been rapid growth in the availability of cameras for live observing, some with the high sensitivity needed for outreach projects like ours, and others requiring substantially longer exposures[5,6]. The latter are useful for applications like private observing where the time requirement is more relaxed. Often these cameras require an order-of-magnitude more time to image an object. Until recently, only CCD cameras were suitable for outreach, but developing a camera that can produce images in dozens of seconds requires some tradeoffs. Our CCD camera, for example, sacrifices resolution by using large sensor elements and small sensor arrays. However, recent advancements in CMOS technology have yielded camera chips that have very low noise levels allowing higher sensitivity and resolution than earlier cameras.

There are excellent resources to learn how to evaluate a camera. The Cloudy Nights EAA (Electronically Assisted Astronomy) forum[5] is a good place to explore the technology and ask questions. Their 'Astro Video Image Gallery' archive provides a good measure of what can be done now with a camera and a way to trace the evolution of the technology over the last 11 years. Two night skies websites[7] broadcast live observing sessions with a wide range of equipment and afford an opportunity to chat with the presenters during webcasts.

To set up a video observing system you can begin with any optical tube (we are familiar with set-ups from 2 to 27 inches) and any mount with reasonably accurate tracking. The scope should be reduced to f3 – f4 to accelerate image acquisition. Suitable cameras are available for 300 USD.

Broadcasting events in a time of crisis

Our programmes as described above were established as local events with in person visitors. When the COVID-19 pandemic forced the suspension of our public programmes we introduced broadcast observing events to allow us to continue our outreach. The broadcast programmes differ significantly from our local programs. There is, of course, some loss of intimacy, and the loss of feeling as one with the universe. There are also advantages. Our broadcast programmes have reached wide audiences. We have generally attracted audiences of 500 to several thousand for these "Interactive Stargazing" programmes including significant numbers from around the Earth. Clearly there is the potential to reach very large numbers of people. One extreme example was an extended programme that we did on the occasion of the recent Saturn / Jupiter conjunction. That event attracted over 2 million views on YouTube.

There is extraordinary potential here. We can do basic programs, or much more rigorous programmes or anything in between. These programmes are broadcast on YouTube and are archived and available for viewing later. They also have chat options so that viewers can ask to see specific objects or ask questions.

We are in the planning stages of online observing events for private groups that range from astronomy clubs to organisations that serve persons with special needs, and will tailor each program to fit the audience.

We will welcome the opportunity to get back to local guests, but the opportunity to address vast and diverse audiences via the internet programmes is clear.

Conclusions

We have found that augmenting traditional telescope observations with video observing systems at public astronomy events substantially adds to the quality of our presentations. Visitors can see distant galaxies, planetary and emission nebulae, and many other objects in full colour and higher detail than they would using only optical telescopes.

We do not endeavor to replace the observing experience that occurs at an eyepiece. Viewing the wonders of space with your own eyes, while breathing in the chill of the night, with the heavens glistening above you, remains an experience that cannot be outdone, regardless of technological advances in imaging. A major benefit of our video astronomy programme is that it can reach global audiences when streamed online. This allows us to provide a genuine astronomy experience when in-person programmes are not accessible.

Though either can stand alone, we believe that visual and video programmes work best in tandem. We draw on the awe that occurs at the eyepiece and use that experience to further engage our guests with our on-screen full-color imagery.

Our video observing format allows us to present information in many ways, generate detailed conversations with our guests, and address the needs of the old, the young, and most visitors with physical and visual limitations. We are able to reduce the waiting time to observe and provide excellent views of bright celestial objects despite factors such as a bright moon or light pollution. Based on our experience, it is hard to imagine a better platform to introduce visitors to the ideas of science.

Notes

[1] 'An article about the cultural impact of Hubble Imagery: https://mag.uchicago.edu/arts-humanities/astronomical-sublime#

[2] A good reference on the limitations of human eyesight in low-light situations: Hood DC, Finkelstein MA. Sensitivity to light. In: Boff KR, Kaufman L, Thomas JP, editors. The handbook of perception and human performance, vol. 1. Sensory processes and perception. New York: John Wiley; 1986.

[3] Here are two sites where people webcast live video observations including opportunities to discuss objects and tools with the presenters:NSNLive.com and https://www.nightskiesnetwork.com/

[4] An article from the Arizona Daily sun concerning Vera Rubin's work at Lowell Observatory: https://azdailysun.com/news/opinion/columnists/view-from-mars-hill-vera-rubin-broke-new-ground-in-astronomy/article_f2639329-39d9-5f8c-8805-31cab3fe1c13.html

[5] Observing with Astrovideo Cameras' by Rob Mollise is an article in the February 2013 issue of Sky and Telescope. It gives a good overview of video astronomy and includes set-up tips as well as background information on the differences in versatility between astronomical video cameras and traditional cameras for observing: https://www.mallincam.net/uploads/2/6/9/1/26913006/observingwithastrovideocameras_feb2013snt.pdf

[6] There is an excellent discussion group at Cloudy Nights EAA forum. It is a good place to familiarise yourself with the possibilities of electronically assisted astronomy (EAA): https://www.cloudynights.com/forum/73-eaa-observation-and-equipment/

[7] Another resource is the Electronically Assisted Astronomy EAA Discussion and Images Facebook group. Images using a wide range of cameras and telescopes, accompanied by guidance and assistance, can be found there: https://www.facebook.com/groups/289077791456944

Acknowledgements

We would like to acknowledge the contributions of Kevin Schindler, who first welcomed the video observing project to Lowell, as well as Jamie Money, Ian Avilez, Jason Sanborn, Rock Mallin, Jack Huerkamp, Michael West, Travis Brown, Jim Cole, and Shyanne Dustrud, all of whom made substantial contributions to the development of the video project.

Biographies

Sarah Burcher has a Master's degree in biomechanics from Northern Arizona University, and fell in love with astronomy when she became an educator at Lowell Observatory. She now works full-time in the observatory's outreach department facilitating observing experiences for the public.

Bill McDonald started his engineering career at a geophysical observatory, developing seismic instruments to install on the Moon and the ocean floor, then ended it at another university lab. He retired to Arizona, US where he discovered the night sky and began to explore ways to optimise the way astronomy is presented to the public.