Joseph Ashley

Video Astronomy on the Go

Using Video Cameras With Small Telescopes

The Patrick Moore Practical Astronomy Series

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Springer

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Preface

Welcome to the New World of Video Astronomy!

Today video astronomy is leaving the experimental world and entering into the mainstream of amateur astronomy. There are many types of video devices used in amateur astronomy: web cameras, planetary imagers, and even DSLRs to name a few. However, none of these have excited amateur astronomers quite like video produced by low-light closed circuit television (CCTV) security cameras which can image dim nebulae or the bright Sun and do so in color and in real time.

Video Astronomy on the Go provides an orientation into the world of video astronomy. It is not a cookbook but an overview of the technology based upon relatively inexpensive, entry-level equipment. It is intended for people with little to no knowledge of video astronomy but who have a basic working knowledge of traditional visual astronomy. The book's objective is to sufficiently discuss the various aspects of video astronomy so that a beginner can reasonably have the confidence needed to assemble and use an astro-video camera with a telescope.

Just what is video astronomy? This question can often create intense debates on the Internet between advocates of different types of cameras. Web cameras, planetary imagers, DSLRs, etc. produce a video output. However, none have the wide variety of applications associated with low-light or star light CCTV security cameras.

For the past 15–20 years or so a growing group of dedicated amateur astronomers experimented with viewing the night sky with their telescopes using a variety of video cameras and associated technologies. Some of the more obvious are web cameras, DSLR movies, video recorders, Internet Protocol (IP) security cameras, planetary imagers, and closed circuit TV (CCTV) security cameras.

Initially video technology was suited only for the moon and some planets as deep space applications were hampered by the inadequate low-light sensitivity of the available cameras. In the middle of the first decade of the twenty-first century, CCTV surveillance cameras with excellent low-light sensitivities appeared on the market. These cameras were designed for no light situations where infrared painters were unacceptable for security reasons yet a high-quality image was needed. Astronomer experimenters immediately recognized the potentials of the low-light CCTV security cameras. Soon they were using them for video telescopes to view the night sky, broadcast live images over the Internet, or photograph deep space objects. The "eye" of the camera produced real-time images far deeper in space than visible in an eyepiece and could also produce the image in color. The low-light CCTV cameras produced images previously seen only in telescopes having apertures two to three times greater than the telescope used with the video camera and also restored detail and contrast to objects washed out by artificial sky glow.

Earlier experimenters purchased and personally altered their own CCTV cameras. This limited participation to people having the skills and fortitude to adapt their own camera. As the technology matured, the demand for CCTV cameras already adapted for astronomy increased. Currently, a few small, enterprising companies not only modify the better CCTV cameras but also add additional features and capabilities to them. These modified cameras are very capable, easy to use, and readily available on the commercial market. Prices start at $100 in the United States and range upwards to $2000. The introduction of commercially available CCTV cameras ready for astronomy usage was a paradigm shift and moved video astronomy from the world of the tinkerer to the mainstream of amateur astronomy.

These modified CCTV cameras are ready to use out of the box. There is no need for the astronomer to tinker with or modify one. No computer is required as they have an analog video output and can be directly connected to a television set, monitor, or DVD player. Many terms are used to identify these modified CCTV low-light, security cameras. You will see or hear them referred to as an astro-video camera, astro video camera, astrovideo camera, astronomy camera, or an astronomical camera. The term "astro-video camera" is used in this book. This choice is purely arbitrary.

Back to the question, "Just what is video astronomy?" Essentially, video astronomy is nothing more than replacing the eyepiece of a telescope with a small, lightweight television camera. At the present time the prevailing definition and the one used in this book is video produced by an astro-video camera (a low-light CCTV camera altered for astronomy that has an analog video output signal). The most basic system has a television set connected directly to the camera. To observe with this "video telescope" one simply looks at the television screen. More complex configurations exist which allow digitizing the analog signal from a video camera and feeding the signal to a computer.

What is the advantage of a video telescope over the simplicity of using an eyepiece? This is a valid question. The telescope is outside with the cold of winter and insects of summer. The television monitor can be inside and the telescope is easily remotely controlled. The observer can sit inside in comfort and tour the night sky. By having the image on a television screen, several people can see the view in the telescope at the same time. This is ideal for public outreach programs or for mom, dad, and the kids viewing the cosmos together. The output from the television camera is easily converted into a digital signal and amateur astronomers can use the Internet to share the view in their telescopes with others around the globe. Initially, these attributes (viewing in comfort and sharing images) were two primary drivers for using video technology. Later we will discuss the third driver—astrophotography.

As CCTV camera technology advanced, the importance of viewing in comfort and the sharing of images was surpassed by the "ability to view." Some CCTV cameras became so sensitive that objects too faint to see through an eyepiece were easily visible on the television screen. This essentially meant that the effective aperture of a telescope was doubled to tripled. The view through a 102 mm video telescope rivaled the view in the eyepiece of a 200–300 mm aperture telescope. But there was an added bonus. Not only could previously invisible objects be seen, the new advances in camera technology provided the views in color.

Recently some enterprising amateurs connected a 3D converter and a 3D television set to the output of their video telescopes. The few people who have viewed through a 3D video telescope report the views of nebulae are almost like a religious experience. This aspect of video astronomy is in its infancy but has a bright promise for the future.

Earlier mention was made that astrophotography was also one of the original reasons why amateur astronomers experimented with video cameras. Here too, advances in camera technology are to the point where small inexpensive television cameras can produce images of a wide variety of deep space objects that rival many images made using dedicated astronomical CCD cameras or digital single lens reflex cameras.

As amateurs experimented using astro-video cameras for astrophotography, another interesting attribute became readily apparent. With the proper camera settings, the artificial sky glow of large metropolitan areas no longer drowned out objects in deep space. Previously invisible nebulae and galaxies became visible and faintly visible objects now had details. While nothing beats a dark sky, the video telescope provides a tool to help mitigate the impact of the artificial sky glow so prevalent in our modern society.

So, What Is *Video Astronomy on the Go* All About?

Video Astronomy on the Go is about using cameras that are available on the commercial astronomy market as "branded" astro-video cameras. These cameras are ready to use out of the box. There is no need for the astronomer to tinker with or modify a camera. They have an analog video output and can be directly connected to a television set, TV monitor, or DVD player. This is not to say that the book is not usable by someone who buys and modifies a CCTV security camera or any other television camera, only that the mechanics of the needed modifications are not discussed.

The term "astronomical CCD" camera is used to define the typical CCD camera used by astrophotographers to take long exposure images of deep space objects.

Video Astronomy on the Go is especially about using astro-video cameras with small lightweight telescopes that are easily transported by foot, on public transportation, or private automobile.

Video Astronomy on the Go is intended for amateur astronomers of all skill and knowledge levels who wish to enter the world of video astronomy. The major aspects of video astronomy are explored using an inexpensive, commercially available, astro-video camera with an entry level, goto alt-azimuth telescope so a newcomer to astronomy will understand the capabilities of a basic system. As with many aspects of amateur astronomy, the equipment used for video astronomy can be basic or advanced, simple or complex, moderately priced, or astronomically expensive. One can view from their backyard or from an observatory. One interesting aspect of video astronomy is that the capabilities of basic, moderately priced, systems can compete with the more advanced and costly systems over a wide range of activities. The major differences between the two are how deep in space one can go and the amount of noise in the images produced.

Video Astronomy on the Go is an excellent book for existing amateur astronomers and beginners who live in large metropolitan or urban areas with significant levels of artificial sky glow. The ability of a video telescope to penetrate artificial sky glow presents a paradigm shift for urban observing. The downtown city dweller now has the tools needed to see deep space with a kit that is easily stored in a small city apartment and transported on city buses and subways. This is true for both experienced astronomers and beginners to astronomy as well.

No longer is video astronomy the world of the tinkerer and the experimenter. It has matured into a powerful tool available for amateur astronomers to view and study the night sky. Video astronomy is now "prime time." Other than a few forums and discussion groups, few sources of information exist to help the amateur seeking to enter the world of video astronomy. This book, *Video Astronomy on the Go*, is meant to fill the current information void.

Video Astronomy on the Go had a rocky road to travel along the way to its birth. With the encouragement of John Watson of Springer and Sophia, my wife for some 50+ years, I was able to struggle through government collapses, a flash flood through our home, bank failures with their long lines in the heat of the summer just to get a few Euros from a teller machine, and a mass migration from the middle east into Europe. Thanks John. Thanks Sophia. We do live in interesting times.

Marathon, Greece Joseph Ashley

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About the Author

An American by birth, Joseph Ashley currently lives in Greece. He has a BS in Physics, an MS in Mechanical Engineering, and a Doctorate in Public Administration. His short career in the US Navy included the recovery of astronauts Conrad and Cooper and their Gemini V spaceship from the sea; from there he began an engineering and research career involving submarine noise, chemical warfare defense, and energy conservation. Now retired, he completed his career as the Program Manager for the US Department of the Navy and Marine Corps Energy Conservation Program. He purchased his first telescope, a Meade 2045LX3, in 1987 and still uses the little 102 mm SCT, along with other scopes, until this day including his favorite, a C6S (150 mm SCT) on a lightweight alt-azimuth GOTO mount. After retirement, Ashley participated in online astronomy forums, primarily the Astronomy Forum, but does drop by the Stargazers Lounge from time to time. In late 2009 he became a moderator on The Astronomy Forum. Parallel with that, he pitched into what he calls "the dark side of astronomy"—astrophotography—concentrating on getting the best possible images from simple lightweight equipment. That took him into the world of video astronomy where today he is evaluating the advantages that small portable tablets bring to video astronomy. Previously, he published *Astrophotography on the Go; Using Short Exposures on Light Mounts* in Patrick Moore's Practical Astronomy Series.

Chapter 1

Astronomy from a Video Perspective

What Is an Astro-Video Camera?

Just what is an astro-video camera, and how does it work? Unfortunately, video astronomy is not well defined. Movie files and video clips can be made by a wide variety of cameras, including digital single lens reflex cameras. For the purposes of this book, an astro-video camera is a small television camera that displays its image using either a NTSC or PAL Television Standard analog television signal.

Video astronomy is actually nothing more than substituting the eyepiece of a telescope with an astro-video camera. To simplify matters for future discussion, we will call this combination, that of a telescope with an astro-video camera, a "video telescope." The camera provides a live, analog, video signal to a television monitor, DVD player, etc., that can be shared by more than one person. More complex configurations involving analog to digital converters, computers, Internet access, etc., are also used dependent upon exactly what the astronomer wants to accomplish.

A varied selection of astro-video cameras are on today's market. This book focuses upon entry-level cameras that typically cost about $200 with accessories (cables, remote camera controls, etc.). This does not mean that the information in it is not applicable to other astro-video cameras that have higher performance levels, only that the examples in the book as well as the other topics covered in the book are derived around the entry-level camera.

One major difference between viewing through the eyepiece with the human eye and viewing on a monitor connected to a camera is that the camera can integrate a signal over time while the human eye cannot. This ability of a camera to integrate over time has a major impact. It allows a camera to capture objects far

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fainter than the human eye can detect. This is a well known attribute and is why astrophotographs are far more detailed than any view seen with the naked eye.

However, video astronomy is more than just making an image, as is done with an astronomical CCD camera or a digital single lens reflex camera. These images are static and typically require an extensive amount of image processing. Video astronomy is different. Like viewing through an eyepiece with your eye, video astronomy is live (real time). These two aspects, the ability to integrate over time and the ability to view real time, allows video astronomy to perform functions not possible with the human eye through a telescope's eyepiece. Actually, viewing with an astro-video camera is near real time as there can be a lag of a few milliseconds to a couple of minutes dependent upon how the camera is used.

Just what can video astronomy do that makes it worthwhile using? Here is a list giving a few applications for video astronomy. More exist and are also discussed in this book:

- penetrate light pollution
- see deeper into space
- see deep space in color
- share images real time with others
- remote viewing
- astrophotography.

How Does Video Astronomy Work?

A video telescope is a typical optical tube assembly (OTA) often adapted for video by adjusting its focal length with a focal reducer and inserting an astro-video camera in the telescope's focuser. Unlike astrophotography using DSLRs (digital single lens reflex cameras), just about any telescope will do, including Newtonians.

The astro-video camera with its analog output makes remote locating of the TV monitor or computer screen far from the telescope and camera something that is easily done. Unlike the digital signals from web cameras and astronomical CCD (charge coupled device) cameras that are so often limited by their cabling to about 4.5 m (15 feet), the analog signal from a video camera can travel upwards of 30 m (100 feet) and much more. This provides a lot of flexibility concerning the location of the viewing and recording equipment.

The actual dimensions of astro-video camera sensors are small, while the focal lengths of popular telescopes can be quite long. The combination of a small sensor and long focal length results in a small field of view with a large image size. With the exception of short focal length telescopes, such as an 80-mm f/5 short tube refractor, the image sizes are large. This creates a problem. Finding and tracking objects in the sky using an astro-video camera and a typical telescope is rather difficult. These two issues are addressed by (1) Using a focal reducer to reduce the focal length of a telescope, and (2) Using a GOTO mount to locate and track objects in space.

Although not a hard and fast rule, for video astronomy a focal length less than around 800–1000 mm works very well for the deep space objects typically observed by amateur astronomers. A 0.5x focal reducer improves the situation considerably for telescopes having a focal length longer than 1000 mm. The Meade 0.33x focal reducer is popular for many owners of SCTs as are Celestron SCTs having the Celestron/Starizona HyperStar/FastStar setup.

Finding objects without a GOTO mount is difficult but doable if you have the skills. However, you will need a tracking capability to keep the object in view once you do find it. For most people using a GOTO mount is the best, perhaps only, option for both finding and tracking objects. As far as what kind of mount to use; unless you plan to use your video telescope for astrophotography, an alt-azimuth GOTO mount works very well, almost as well as an equatorial GOTO mount in most situations.

Summing up, a typical video telescope for viewing deep space will have the following characteristics:

- an astro-video camera
- any size aperture
- focal length of less than 800 and 1000 mm either with or without using a focal reducer
- GOTO alt-azimuth or GOTO equatorial mount.

Notes Video telescope and camera characteristics will be discussed in more detail in Chaps. 2 and 3. If you are having difficulty with terms used in this discussion you may want to check out Appendix A in this book, "Glossary of Terms."

Telescope Mounts

As mentioned earlier, a GOTO mount is essentially a necessity for most video astronomy applications. The small sensor sizes of astro-video cameras produce a rather small field of view. Any mount or tripod vibration is amplified. The implication of this is that a sturdy tripod is required. However, as discussed later, this is not necessarily the case for all video astronomy applications.

A small field of view and large image size means that star hopping is by and large not possible, especially for dim objects. Setting circles are not much better. Locating and tracking objects is often tedious and frustrating. Furthermore, if you live in an urban area, artificial skyglow often makes star hopping essentially impossible. A GOTO telescope solves these issues.

Using a manually operated mount such as a Dobsonian or a German equatorial mount is technically possible but very difficult. You can easily do a test before buying a camera to see if such a setup is suited for you and your conditions. Go out at night with your telescope and only a 6-mm eyepiece. If you have difficulty locating and then viewing objects, you may seriously want to consider a GOTO telescope mount.

One advantage of video astronomy is that the observer can view from inside the comforts of home and remotely control the video telescope. Here again, an accurate GOTO mount, alt-azimuth or equatorial, is required.

Alt-azimuth or equatorial mount? Whenever an alt-azimuth mount is used with a camera, the impact of field rotation must be considered. In the past, for visual work, the issues associated with field rotation and an alt-azimuth mount were not significant. However, with the current integrating cameras having total integrated exposure times of several minutes, an equatorial mount undoubtedly produces the best images. Another issue related to an alt-azimuth mount is that many have difficulty with objects very near the zenith (tube strikes or tracking). An alt-azimuth mount on a wedge or a German equatorial mount, if precisely polar aligned, can counter the impact of field rotation. No constraints exist near the zenith, but you may have to deal with meridian flipping.

Video Astronomy and Celestial Observing, or the True Armchair Astronomer

One reason for the development of video astronomy over the years was the ability to view the night sky from inside the comfort of home; in other words, the ability to be the ultimate armchair observer (see Fig. 1.1). The system needed to do this is rather simple, requiring nothing more than an astro-video camera, a GOTO telescope, some long cables, and a television set. This basic setup requires that the observer venture outside into the elements of winter and the insects of summer to align the telescope mount and to focus the camera. If the distance is not too far, say around 100 feet (30 m), an extension can be added to the hand controller cable and the telescope controlled from inside. For longer distances, the GOTO mount can be controlled inside using a laptop computer and remote controls used for the camera settings and telescope focus.

Regardless of whether you set up your system to view the night sky from inside the comfort of your home or you sit outside in a comfortable chair holding a small television monitor in your hand, video astronomy will give you the same view of the night sky. You will see objects in depth and details not possible using an eyepiece with your telescope. In addition you will see the objects in color. An astro-video camera will take you two to three magnitudes deeper than your eyepiece. In effect, it is a multiplier that effectively increases the aperture of your telescope by up to a factor of three.

Like most things in astronomy, video astronomy loves a dark sky. However, if you are viewing from light-polluted skies, you will be pleasantly surprised. Add a light-pollution filter such as a CLS filter and objects invisible in the eyepiece are easily seen with details and color on your television screen. How deep can you penetrate artificial skyglow is dependent upon your equipment, but be prepared to see details in nebulae and galaxies and see them in color.

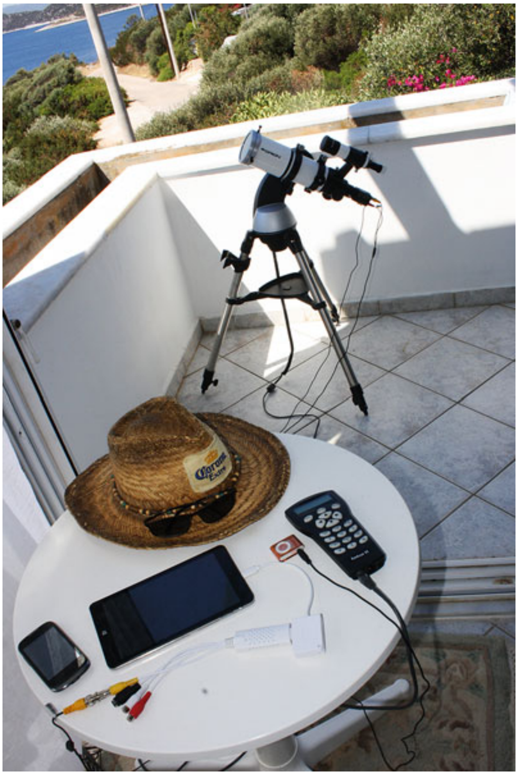

Fig. 1.1 Remote viewing

Video Astronomy and Outreach

Video astronomy is especially useful for outreach activities. Here, all that is required is an astro-video camera, a telescope, and an appropriately sized television set for the number of people expected. Video astronomy also requires a different way of thinking concerning outreach activities. No longer do the bright planets and a couple of deep space objects hold an outreach activity hostage. There is no need to have a long line of people waiting for a few seconds to gaze at the Moon or a planet. With a large screen television, many people can simultaneously see what the telescope sees. With video astronomy, an educational program incorporating a tour of the various kinds of objects in the night sky is possible in synchronization with a lecture on the objects being observed. Such activities are not practical with folks lined up to individually view one object at the time in the eyepiece of a telescope.

However, there is a dark side, so to speak, associated with using video astronomy for outreach activities. A television set produces a large amount of light. If the outreach event is at a star party, then the video setup must be either shielded from or located remotely from the traditional telescopes. Electrical power is also another issue, as a large television will need its share.

Video Astronomy and Astrophotography

Astrophotography requires converting the analog signal from the astro-video camera into a digital signal and then storing the image or video into the memory of a computer for processing. A video capture device (also known as a frame grabber) is used to convert the analog signal to a digital signal. Operation is simple; just plug the analog video cable into one end of the frame grabber, and it converts the analog signal into a digital signal formatted for an USB port. Your computer now sees a camera attached. Then, if you wish, a computer program stores and displays the signal from your camera.

Entry level astro-video cameras have shutter speeds that are selectable, from as short as 1/100,000 of a second to as long as 17 seconds for the NTSC standard or 20 seconds for the PAL standard. They also have the ability to reduce noise by internally digitally combining (stacking) up to five images. With a 17-second exposure, this means that a our entry-level NTSC camera can produce an image having a total integrated exposure time of 85 seconds, and a PAL camera can produce an image having a total integrated exposure time of 100 seconds. Keep in mind that a typical alt-azimuth mount can support exposure times of 20–30 seconds, which is long enough to cover most areas of the night sky before field rotation creates star trailing and blurring of the image. Also, as an object approaches the zenith, exposure times rapidly decrease, and only a couple of seconds are allowable near the zenith (See Appendix B). On the other hand, a precisely aligned equatorial mount can image the entire night sky.

The images made with an astro-video camera can be digitized and then stacked like any other image. Unless a focal reducer is used, the field of view with an astro-video camera is very small, implying a very large image size. Some stacking programs cannot adjust for field rotation, and their images may be blurred if an alt-azimuth mount is used. Other stacking programs adjust for field rotation but need a minimum number of stars common to all the images to successfully stack the image. For example, *DeepSkyStacker* requires eight stars common to all light frames. Due to the large image size and small field of view, the images of many objects do not contain eight common stars, and the program will not work. Field rotation is not an issue with a precisely aligned equatorial mount, and the probability of successfully stacking an image is far greater. More on imaging with a video telescope is discussed in Chap. 7.

Video Astronomy and Broadcasting

With video astronomy you can broadcast the view in your telescope to almost any place on our planet. All that is needed is a decent Internet connection. The easiest way to broadcast is to use a website such as Night Skies Network. With this site, which is very popular with astronomers, all you need do is establish a free account. When you log onto the site, it will establish communications with your computer, and then, after selecting a few options, you will be broadcasting live on the Night Skies Network. Anyone who wishes to see your broadcast only needs to go to the site's directory, find your name, and right click on it. In addition to the video, you also have two-way voice as well as Instant Messenger communications with anyone viewing your video stream.

Another variation is to set up your own personal site for broadcasting the signal. There are many sites on the Internet that host broadcasting sites; some offer free services, but most charge a monthly fee.

Video Astronomy and Other Applications

If you add a 3D signal converter to the output of an astro-video camera and feed the signal to a 3D television set, you will see a 3D image of the object you are viewing. People who have experienced 3D astronomy report that seeing nebulae in 3D is almost akin to a religious experience. 3D astronomy as well as substituting inexpensive tablets for laptop computers are two areas currently being explored by many amateurs.

Chapter 2

The Anatomy of a Video Camera

How Astro-Video Cameras Work

Current popular entry-level astro-video cameras as well as many advanced cameras are adaptations of closed-circuit television (CCTV) security camera technology that was designed for use in very low light situations. One such security application requires the covert production of high quality monochrome or color images or the imaging of moving targets without blurring in low light situations. This covert requirement, among other things, means that infrared painting is not allowed, as the infrared source betrays the presence of the security camera.

For this application, only the natural light from the night sky is used—approximately 0.001 lux or less for a dark sky with no Moon. These low light security cameras, or starlight cameras as they are often called, have excellent sensitivities with a minimum illumination as low as 0.0001 lux for monochrome and 0.001 lux for color. It is this starlight security camera technology that is used by current introductory level and more advanced astro-video cameras.

Video astronomy is still in its formative stage and is considered by a large segment of astronomers as wholly an amateur activity. At one time amateurs purchased CCTV security cameras and used them to explore deep space, and many still do. Today, a few very small companies, all started by amateur astronomers, produce astro-video cameras that are available on the commercial market. These cameras use the technology developed for starlight security cameras but modified to varying degrees to adapt the technology for astronomy. Recall from Chap. 1 that this book is written around the typical entry-level astro-video camera currently costing about $200 for the camera, an adapter, a video cable, a power cable, a remote controller, and a remote control cable.

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