Patrick Moore's Practical Astronomy Series

For other titles published in the series, go to
www.springer.com/series/3192

Deep-Sky Video Astronomy

Steve Massey and Steve Quirk

Springer

Steve Massey
Hervey Bay, QLD
Australia

Steve Quirk
Mudgee, NSW
Australia

ISBN 978-0-387-87611-5 e-ISBN 978-0-387-87612-2
DOI: 10.1007/978-0-387-87612-2

Library of Congress Control Number: 2008940645

Printed on acid-free paper

springer.com

Acknowledgements

The true rise of video as a popular and affordable, practical tool for imaging the night sky stems back to the mid-1990s, when small pockets of enthusiastic individuals around the world shared their experiences and knowledge mostly via the still early days of the Internet. Like most things in astronomy, the evolution of the technology has been spurred on by the enthusiasm and support of others combined with thousands of hours under star-filled night skies experimenting, measuring, and reporting. Either directly or indirectly, long chats by phone, at star parties, club meetings, or via e-mail, the production of this book would not have been possible without their help. First and foremost we would acknowledge the unceasing support of our life-long partners Sandra Massey and Janet Quirk. Along with friends and members of various discussion groups, such as the GSTAR-Users group, VideoAstro, and QCUAIG, our expressions of deep gratitude to Chris Wakeman, Darrin Nitschke, Rob McNaught, Gordon Garradd, Michael Clark, Allan Gould, Phillip Hinkler, Jim Ferriera, Ron Dantowitz, Albert Van Donkelaar, Dave Larkin, Mark Garrett, Jon Bradshaw, Robert Knox, Lindsay Sessions, Mike Holliday, John Sarkissian, Chris Toohey, the team at Australian Sky and Telescope Magazine, Sky Publishing USA, Tasco Australia, Steve Kerr, Dave Gault, Steve Wainwright, Dr. Andre Phillips, and Bob Balfour. Also, special thanks to Steve Chapman and John Vetter for testing our procedures for the book. We would also express our appreciation to John Watson, Maury Solomon, Peter Pushpanathan and Turpana Molina of Springer Publishers for their helpfulness, enthusiasm, and support of the project.

About the Authors

Steve Massey

Starting his journey in astronomy at the age of nine from the backyard of his family home in the early 1970s, Steve has pursued his interest on both amateur and professional levels.

In the mid-1990s he worked at the Anglo-Australian Telescope at Siding Spring Observatory and has frequently used a variety of professional telescopes (up to 1 m-class) to conduct video planetary imaging projects.

With over a hundred radio interviews and several appearances on TV, he is among a handful of pioneers that helped to popularize the use of CCD video cameras for use in astronomy and was an invited contributor on the subject for the *Oxford Astronomy Encyclopedia*.

Having numerous articles and images published in newspapers, video-camera periodicals, and astronomy magazines around the world he is also an author and co-author of six other top-selling titles, including *Video Astronomy*, *The Night Sky (A Guide to Observing the Solar System)*, *Exploring the Moon*, *How Does the Night Sky Work*, *Space-Stars and Planets*, and *Atlas of the Southern Night Sky*. He is also co-author and contributor to published scientific papers concerning the planet Mercury.

Today, he operates a successful optical supply business in Queensland Australia.

The asteroid 14420 Massey (1991 SM) was named after him.

Steve Quirk

An amateur astronomer for nearly 30 years, Steve Quirk forged his reputation for excellence in astrophotography during the 1980s and 1990s, producing many inspiring photographs of the night sky, some of which have been used in magazines and books in Australia and overseas.

Not satisfied with obtaining images of only the most famous celestial bodies, he has built up an impressive photo library of many difficult and less-frequently observed objects, using self-taught skills in star hopping and the use of setting circles. He currently uses modern CCD-based video cameras to illustrate many of the fine deep-sky objects featured in this book. Many of his images are considered among the best in the world using integrated video technology.

He is a member of the Central West Astronomical Society (Australia) and has been a long-time assistant in a video meteor surveillance program run by Robert McNaught at Siding Spring Observatory.

Quirk was the winner of the 1988 Skywatch Bicentennial Astrophotographic Competition and received recognition at the Central West Astronomical Society's AstroFest David Malin Awards in 2005 for a 20-year-long sequence of images showing the movement of the star Proxima Centauri.

He has written several articles on astrophotography for (Australian) magazines and is co-author of *Atlas of the Southern Night Sky* with Steve Massey.

Today he spends most of his time imaging with video from his observatory in central west NSW Australia.

The asteroid 18376 Quirk (1991 SQ) was named after him.

Contents

Introduction

Deep-Sky Video Astronomy

Welcome to the wonderful world of video deep-sky imaging!

For hundreds of years after the first telescopes were pointed skyward, our only record of the celestial realm was limited to what our eyes could see. With careful interpretation observers shared their views in sketches or paintings.

When chemical-based plate and film photographic tools became available, things began to change rapidly in the world of astronomy, but it was not until the development of greatly improved sensitivity to faint light that astronomers could efficiently record those well-traveled photons from distant stars, nebula, and galaxies. This truly opened the doors to wider scientific analysis and understanding of the universe around us.

In the decades that followed, developments in practical electronics soon ushered in a new picture medium – television. The enormous studio cameras that once beamed pictures into our homes were, like television, also based on a cathode-ray vacuum tube (CRT) design. CRT televisions and computer monitors are still used today.

As the rising bell curve of technological improvements continued, electronic components were being dramatically miniaturized, and the valves in our radios and televisions were soon replaced with small silicon semiconductor transistors. In a few short years, engineers figured out how to make them even smaller allowing them to pack thousands of these transistors together into tiny arrays called an integrated circuit (IC), and the possibilities were endless. In 1969, Bell Laboratories in the United States developed a light-sensitive array called a CCD, which is an acronym

Fig. 1. The "Trifid Nebula" (Messier 20) in Sagittarius. A fine example of what modern video technology can produce.

for charge-coupled device, and combined with powerful modern microcomputing; this amazing invention revolutionized astronomical imaging on many levels.

In general consumer goods, the CCD has rendered almost completely redundant the use of film-based cameras for taking snapshots and making movies. CCD technology lies at the heart of all professional and domestic camcorders, pocket cameras, scientific imagers, single-lens reflex (SLR) cameras, and webcams. Even cell phones take pictures and movies!

Today, the backyard astronomer can not only produce amazing images but also yield scientifically useful data with compact, lightweight, low light-sensitive cameras. Moreover, taking a great portrait of the night sky is no longer limited to the once elite amateur astrophotographer. But CCD imaging still has its elite few who well understand the rules for getting the most out of a camera and how to extract more from the final picture using advanced image manipulation software. Video imaging is no different.

Like the old film movie camera, a modern CCD video camera simply takes a rapid sequence of short, individual exposures and when viewed live on the screen or in playback mode, gives the illusion of motion. The benefits of multiple rapid exposures has long been known to astronomers as a useful means of capturing random moments of exceptional atmospheric seeing in the constantly moving air mass that surrounds our planet. By selectively plucking out individual exposures, astronomers have been able to produce diffraction limited portraits of the moon and planets to create images with amazingly sharp detail.

Delineating the differences between "conventional" analog cameras and those that can only function by computer interface (a webcam for example) has become somewhat clouded over the years and some incorrectly refer to closed-circuit television (CCTV) cameras as a webcam. Indeed, there have been recent developments whereby the best of both technologies now exists. But since both systems produce a stream of rapid exposure pictures that can be recorded as a movie file, we prefer to call them image streaming cameras (ISC). At the end of the day, whether the source is a cell phone, camcorder, webcam, or other ISC, the moving pictures they create is referred to as video and its use for imaging the celestial wonders aptly called video astronomy.

But can these short-exposure cameras be used to reveal dim objects such as galaxies and nebulae? In the past, when even the most-sensitive camera used for general surveillance work in low-light situations was applied to a telescope, the answer was simply "No," unless it was combined with an inordinately expensive, military-grade image intensifier.

Some adventurous amateurs sought a more affordable approach and turned to modifying basic webcams to perform way beyond their intended design. With a little circuit tampering to enable extended exposure times combined with some basic thermal cooling, they produced quite good results. When used in conjunction with creatively designed software such as COAA's AstroVideo, which co-adds a predefined number of images output by a camera on the fly, the result is a final image revealing vastly amplified detail.

However, today it is indeed a reality that we can now view deep sky wonders in virtual real-time as well as create the equivalent of a long-exposure photograph using off-the-shelf frame-accumulating video cameras. With the ability to internally accumulate tens or hundreds of short exposures, these cameras make viewing and photography of star clusters, nebulae, and galaxies (even from light-polluted suburbs) a breeze. Like any other CCD camera image, postprocessing at the computer is the ultimate key to producing a true, aesthetically pleasing result, and many images, when taken from near-city regions, often surpass film work done from dark country skies.

Sometimes referred to as integrating video cameras, whether they are analog or digital output, these frame-accumulating video devices are available from several specialist astronomy product vendors worldwide. Supplied with various modifications, supporting software, or other features they are packaged specifically for use in astronomy. Frame-accumulation cameras are the perfect tool for sharing the wonders of the night sky with the public, friends, and family. No need for climbing stepladders to peer into the eyepiece of a giant Newtonian, and no need to refocus an object for each individual. Viewed on a TV monitor they offer outstanding contrast with ultimate eye relief that it is second to none.

As sad as it may sound to purist visual observers, stories of star parties where visitors have been seen cueing to view a deep-sky object on a video monitor, is becoming more commonplace, especially in the case of super aperture scopes 16 inches and larger. Deep-sky capable video cameras breathe new life back into those old, unused, small telescopes that have been relegated to the back shed and collecting dust. These specialized video cameras can now enable views of fainter objects normally only within the visual limits of much larger aperture instruments.

We have personally experienced the excitement and utter amazement of seeing deep-sky objects in real time through our telescopes that were either on or beyond the visual limit for that scope, even with fully dark-adapted eyes. Every time a search is made for those faint new objects, they are found with relative ease and a great deal of satisfaction. The stars that can be seen live on a monitor are around 1–1.5 magnitudes deeper than the best visual limit for a given telescope, effectively doubling the aperture. So, for an extremely cheap telescope upgrade, it is simple, get your hands on a deep-sky capable video camera!

Our goal in this practical guide is to explain the essentials about viewing and imaging with frame-accumulation cameras. From the main camera features to setting up for use at the telescope, we cover the image-capture process with practical steps and the most important basic post-processing techniques you can use to create wonderful deep-sky portraits.

Deep-sky videography is a fun, convenient, and often very practical low-cost imaging alternative with a diverse range of applications in amateur and professional astronomy. It is our sincere hope that we will pass onto you, through this book, the amazing benefits and knowledge of our experiences and others to ensure you gain the most from this wonderful and simple-to-use imaging medium.

Fig. 2. An image of videographers at work and play, illuminated only by star and moonlight, recorded with a GSTAR-EX video camera and 135-mm lens. Courtesy of Darrin Nitschke.

CHAPTER ONE

Using Video for Astronomy

Video cameras today are being used for a wide and diverse range of activities in astronomy. A few are listed here.

- The imaging of planets, moons, asteroids, and comets
- Occultation imaging and timings
- Solar imaging
- Meteor and fireball patrols
- All-sky monitoring for observatories
- Supernova searching and confirmation
- Deep-sky imaging

The most alluring features of video are the lightning-fast exposures and long recording times. In fact, fast-exposure, image streaming cameras make it possible to record detail on the space shuttle and the International Space Station (ISS) as they pass quickly overhead. Today, specialized video cameras have the ability to record very faint objects, and with some post-processing at the computer, the results can often rival more expensive single-image, cooled astronomy cameras (Fig. 1.1).

But before we leap head first into the practical side of things, you may find it interesting and perhaps beneficial to understand a little of how a CCD works and its application in a video camera to produce the images we want to obtain with a telescope.

S. Massey and S. Quirk, *Deep-Sky Video Astronomy*,
DOI: 10.1007/978-0-387-87612-2_1, © Springer Science + Business Media, LLC 2009

Fig. 1.1. An example of the high-speed exposures possible with video cameras and their ability to record random events.

1.1 The Image Sensor

The heart of the modern camera is its image sensor, or light-sensitive detector. Called a CCD, this solid state analog device consists of an oxide silicon substrate and an array or a matrix of vertical and horizontal light-sensitive electrodes (detectors) on the surface called pixels (short for *picture elements*). The size of each pixel is measured in microns (μm) and varies from one manufacturer's design to another. In most quality video cameras these days, pixels typically range from 6 to 10 μm, and the array is protected from undesirable elements, such as moisture and dust, by a thin glass window.

Light falling onto each pixel is converted proportionately into an electronic charge, and a combined pattern of the exposed pixels is read via electronic encoders and decoders, forming a digital interpretation of the image. The image produced is comprised of a discrete range of numerically defined values of light intensity or shades of gray from pure black to white, which our eyes perceive on a video monitor as different amounts of shadow and light.

Important to astronomy have been the continued developments in low-light sensitivity performance. Companies such as Sony Corporation developed improved CCDs that can be used in virtual "no-light" situations to meet the high demand of the growing security surveillance industry. One innovation, which is found in Sony's ExView HAD series, is the placement of microscopic lenses over each pixel, thereby more efficiently focusing photons on each detector across the entire array. This CCD boasts extremely low dark current qualities.

Depending on design for a given purpose, not all CCDs have the same inherent characteristics. Some are manufactured to respond more or less efficiently over a specific spectral range. For most domestic cameras, this is centered typically around the 550 nm yellow part of the visual spectrum, which replicates the strongest area of responsiveness we can detect with our eyes. The cameras generally range in spectral sensitivity from 350 nm to 1,100 nm but are often rated as 400–1,000 nm. Being quite sensitive in the infrared, it is also considered very beneficial in some astronomical applications (Figs. 1.2 and 1.3).

An image sensor efficiency rating for the detection and conversion of photons is known as detector quantum efficiency. The higher the rating, the better the sensor is for deep-sky imaging. A rating of 100% is considered a perfect detector, but most of the highly sensitive and affordable video cameras we find today have typical quantum efficiency ratings of around 50% or slightly better. Sony's ExView HAD series, used in many deep-sky video cameras today, boasts a quantum efficiency improvement of 18–20% above what is typical.

Fig. 1.2. At the heart of all modern digital cameras, the *CCD* collects photons and converts them into an electrical charge to create an image.

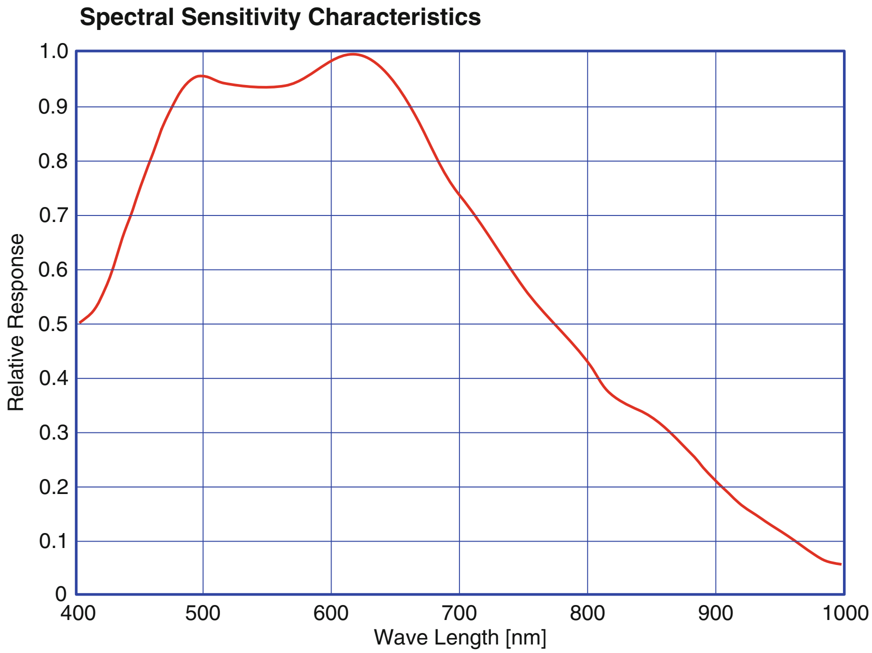

Fig. 1.3. This graph represents the spectral response of an unfiltered *CCD* image sensor found in most commercial cameras.

1.2 Efficiency in Astrophotography

Like the long exposures needed to record deep-sky objects with film, CCD cameras are also capable of storing or integrating a single image for extended periods but can achieve similar, if not far better, results in only a fraction of the time. Also, because we live on a constantly turning world, long-exposure astrophotography requires a well-aligned mount and accurate guiding to achieve those aesthetically desired round or pinpoint stars. Depending on the optical magnification, alignment, and tracking accuracy, short-duration exposures, like a subsecond snapshot, are far less demanding.

Whether producing digital USB, Firewire, or an analog signal output, webcams, camcorders, or CCTV-specific cameras are inherently short-exposure devices that pump out "still images" in rapid succession. Viewed on a monitor or recorded and played back, this series of fast-changing pictures give the illusion of real-time motion.

Short exposures mean less time for photons to build up a significant enough charge in the CCD for it to reveal faint structure in deep-sky objects. However, since the advent of frame accumulation short-exposure cameras, even the smallest amount of charge detected by a highly sensitive CCD, can be revealed as though the exposure time were much longer. This is achieved by electronically co-adding numerous exposures using an internal image memory buffer.

There are essentially two different video picture output techniques used by a CCD to read out the image we eventually see on a monitor or display. These techniques are known as progressive scan and interline transfer. The latter produces an interlaced TV picture (Fig. 1.4).

1.3 Progressive Scan

Webcams and all modern consumer digital camcorders generally use progressive scan technology, which outputs the image recorded across the entire active pixel array at once. This technique is very effective in situations of high-speed motion, offering less smeared recordings of things like a car race or in astronomy, for freezing out the sharpest moments from rapidly changing optical distortions caused by air turbulence in our atmosphere. Progressive scan cameras are particularly useful for high magnification work, such as lunar and planetary imaging.

1.4 Interlaced TV Images

The foundation of the interlaced picture at basic TV standard dates back to the days of early TV and still has a governing influence over much of the new digital standards, for reasons including backward compatibility for digital conversion and aspect ratios. The picture we see on a conventional 4:3 aspect TV monitor, for example,

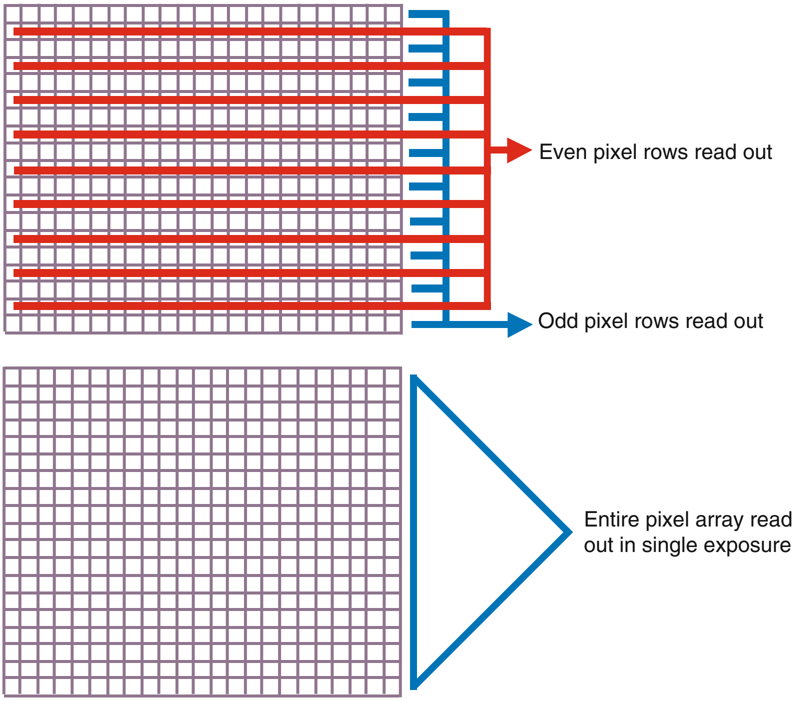

Fig. 1.4. Two *CCD* readout formats. *Above*, interline transfer CCD and *below*, a progressive scan CCD.

is produced by an electronic gun attached to the back of a phosphorous-coated vacuum-tube display (also known as a cathode ray tube, or CRT), which is illuminated when struck by electrons. As it traces out an image from the top of the screen to the bottom, phosphors illuminate with varying levels of brightness, according to the intensity of the electron beam.

Each line traced out across the screen takes around 64 microseconds (μs) to complete and is called a scan line. The duration between successive scans while the gun is off and returning to a point just below the starting point of the previous scan is known as horizontal line blanking time. A full TV picture (a single frame of video) is made up of two interlaced sets of these completed traces from top to bottom, called odd and even scan line fields.

In the case of the phase alternating line (PAL) television standard, the odd scan lines are traced from left to right and top to bottom of the CRT in about 1/50 of a second (20 ms), creating the odd field, which is comprised of 312.5 lines. The off time for the electron gun to move to the top of the screen again is the vertical blanking period, after which a series of even scan lines are then sprayed to fill in the blank even rows of the picture from top to bottom. This occurs within the next 1/50 of a second and makes up the even field. Each field, therefore, represents only half of the complete picture (Table 1.1 and Fig. 1.5).

Table 1.1. Basic PAL and NTSC characteristics[a].

TV system	PAL 625/50	NTSC 525/59.94
Scan lines per video frame	625	525
Video frame display rate/s	25	30 (29.97)
Scan lines per field	312.5	262.5
Field frequency (Hz)	50	60 (59.94)
Field display time (ms)	20	16.68
Active lines (containing image) per field	287.5	242.5
Total active lines per video frame	575 (576)	475 (476)
Line trace time (μs)	64	63.55
Vertical blanking lines	25	20
Horizontal line blanking time (μs)	12	~10
Active (picture display) line trace time (μs)	52	52.65

[a]Some numbers are rounded off and serve only as a rough guide

PAL phase alternating line, *NTSC* National Television Systems Committee

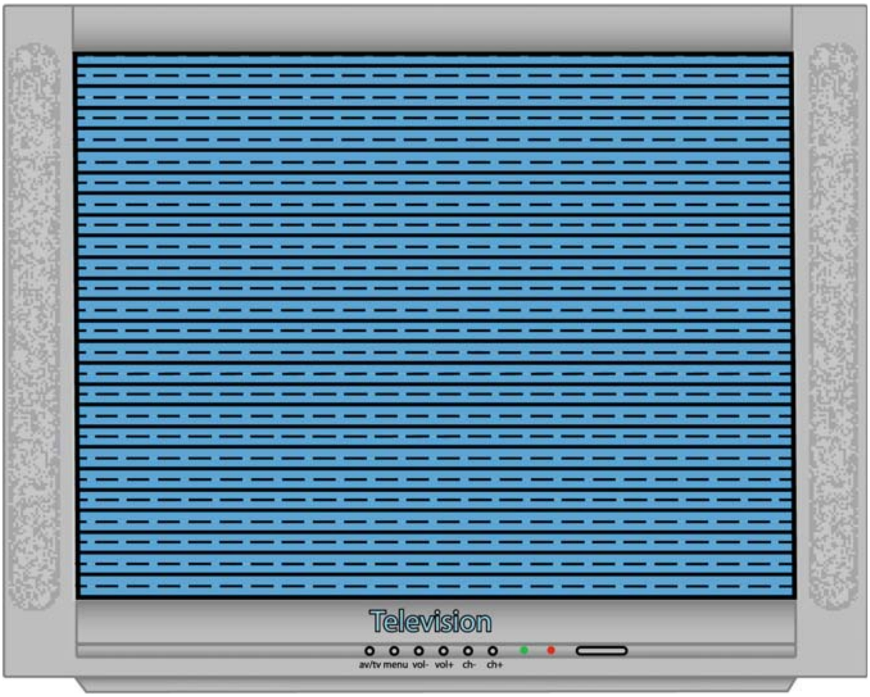

Fig. 1.5. Interlacing of odd and even scan lines on a conventional *CRT* television display.

The combination of these two fields (interlaced) produces the entire picture (a single frame of video) comprised of 625 scan lines displayed every 1/25 of a second (40 ms). The actual picture information is contained within the bulk of these scan lines (the active lines), but some of the scan lines are reserved for delimiting frame boundaries, synchronization timing, and other PAL or National Television Systems Committee (NTSC) signal carrier requirements and are cropped from the visual image displayed. Furthermore, it is interesting to note that only half of the first and last active scan lines contain picture information. For convenience purposes these lines are essentially combined into the active picture line count as making up an additional scan line, that is, 287.5 + 287.5 = 575 scan lines. When doing number rounding for simplicity in digital sampling, however, the blank part of these scan lines is taken into account, thus being considered as an additional scan line - hence, the common 576 we encounter.

Interline transfer CCD video cameras producing an encoded carrier-based analog signal output also process two sets of line-matching exposures (interlaced fields) to meet this convention by reading out successive rows of pixel data just like the alternating scan lines producing the odd and even interlaced fields on a TV monitor. Note that like the scan lines produced in a TV monitor, not all of the manufacturer-quantified pixels used in the array produce the active image, and, similarly, several are reserved for signal transfer and picture synchronization timing, etc. Therefore, you will often encounter two sets of pixel numbers defined for a given array, being total number of pixels and total active pixels.

Considering that a progressive scan CCD reads out the entire image immediately, we can see in the case of a dual exposure interline transfer camera that should the position of a subject shift dramatically between each 1/50-second exposure, the resulting full-frame image may appear slightly smeared. On close inspection of a single frame of video, this may be seen as a jagged appearance around the borders of a star or a half-lit lunar crater where differences in contrast may be dramatic. But this can be corrected using a deinterlacing filter either during postimage processing or as a real-time filter, if your video capture software allows. Either way, its application will bring both fields back into correct registration, removing the jagged scan line appearance.

1.5 Video Resolution

Since pixels are micron-sized detectors, the smaller that manufacturers can make them, the more they are able to fit into an array for producing an image of higher resolution. As any camera shop employee will tell you, the greater the number of pixels a camera has, the finer the detail revealed in the resulting picture.

By today's standards, a typical CCTV camera, like that used for astronomy, is considered a low to medium resolution device when compared to the megapixels scale images of large format CCDs in direct digital output imagers such as a DSLR or SBIG astronomical cameras, for example. A digitized frame of full resolution interlaced video is limited to 768×576 pixels at best, using an economical capture device. But it is important not to compare apples with oranges because interline transfer