Video Astronomy

Curtis V. Macchioni

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June 15, 2012

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Outline

- Historical Development of Video Astronomy
- Dedicated Astro-Video Equipment
- Applications Overview
- Live Viewing with a Video Camera
- Solar System Imaging
- DSO Viewing and Imaging
- Video Astronomy Resources

Camcorders Usher in the Era of Video Astronomy

- Common Attributes
  - The first consumer camcorder was introduced by Sony in 1983
    - Zoom lens, CMOS Image sensor(CCD today)
    - Integral Recorder, LCD Monitor, Rechargeable Battery
    - Analogue recording on magnetic tape, switched to digital in the 90s
  - Optical zoom
  - Frame grabber or Firewire is required to transfer images to a computer
  - Only option for video astronomy until webcams were introduced

- Limitations
  - Exposures of 1/60 sec or less limits use to bright objects
  - Lenses usually cannot be removed … must be used in an afocal mode
  - Require specialized mounting bracket or tripod …heavy, may require CW

- Applications
  - High frame rate imaging of Sun, moon & planets for stacking & processing
  - Records video … Occultation timing

The Webcam Makes Solar Systems Imaging Easy

- Common Attributes
  - QuickCam was 1st commercial webcam , introduced in 1994 ~$100
    - Recorded 60fps with 4 bit grey scale with 320x240 pixels
  - CMOS sensor, Plastic Lens, Electronics, USB Connection (Power, Output)
  - Inexpensive , Lightweight, Color, Available in HD
- Limitations
  - Need to remove the lens and attach a 1 ½" nosepiece
  - Requires a PC to display an image
  - Limited to bright objects unless user modified for longer exposures
- Dedicated Astronomy Webcams … No mods needed
  - Orion Starshoot Solar System Color Camera IV ($99.99)
  - Celestron NexImage 5 ($199.95)

- Applications
  - Ideal for bright objects, Sun, Moon, Planets
  - Records fine detail with small pixels (2.2, 3.6mm square)
  - 1.3, 5 MP CMOS
  - Still only 1/30sec exposure maximum unless modified

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Video Security Cameras Bring DSOs into Sight

- Common Attributes
  - Designed for low light
  - Initially 1/3" Format Sony CCD
    - Supercircuits PC-23C (B/W) or PC-33C (Color) ~1998-1999
    - PC-164C introduced in 2002 (Sony ExView HAD CCD w/micro lenses) higher sensitivity
  - Removable lenses with C-Mount for easy attachment to telescopes
  - Electronic shutter
  - Composite (BNC) analogue video connector for output to monitor or tape
  - Inexpensive $90 - $170

- Limitation
  - Lacks manual shutter & gain - Minimize background area to avoid over exposure
  - Maximum exposure of 1/30sec - Good for bright objects but not DSOs
  - Small, 1/3" format, chip

- Modern Day Security Cameras like the Samsung SCB 4000 $377
  - ½" Format Sony ExView HAD Color CCD (ICX428AKL)
  - Good spectral response at both visible and IR
  - Increased exposures up 8.5sec
  - Pos/Neg Image, Mirror Flip, Digital Zoom
  - Many additional models available in Color or B/W for ~$100 or more
  - DSOs within reach

Dedicated Astro-Video Cameras Go Deep

- 1st dedicated Astro-Video cameras were introduced ~ 2000 – 2001

- Common Attributes
  - Typically ½" format Sony ExView HAD (Hole Accumulation Diode) CCD
    - Micro lenses at each pixel for higher sensitivity
    - ~8.4 x 9.8µm pixel size, 768 x 494 active pixels
    - Color or B/W
    - Interline Transfer
  - Electronic shutter
  - Composite (BNC) analogue video connector
    - Analogue output easily displayed on TV monitor
    - Requires a frame grabber for image capture to PC

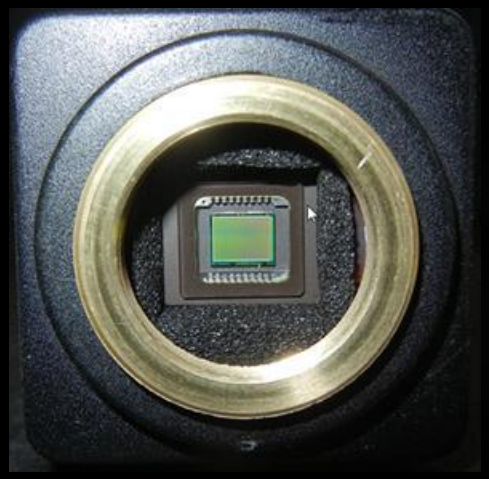
  - Removable lenses with C-Mount for easy attachment to telescopes
  - Versatile exposure range (varies by camera)
    - Short ~1/100,000 sec for Solar, Lunar, Planetary
    - Long ~2sec to infinity in the frame accumulation mode for DSOs
  - Automatic Gain Control - Increases sensitivity at the expense of noise
  - Gamma corrections 1 / 0.45 / 0.35 for grey stretching (varies)
  - Peltier Thermoelectric cooler on some to minimize hot/warm pixels
  - Higher grade CCD chips

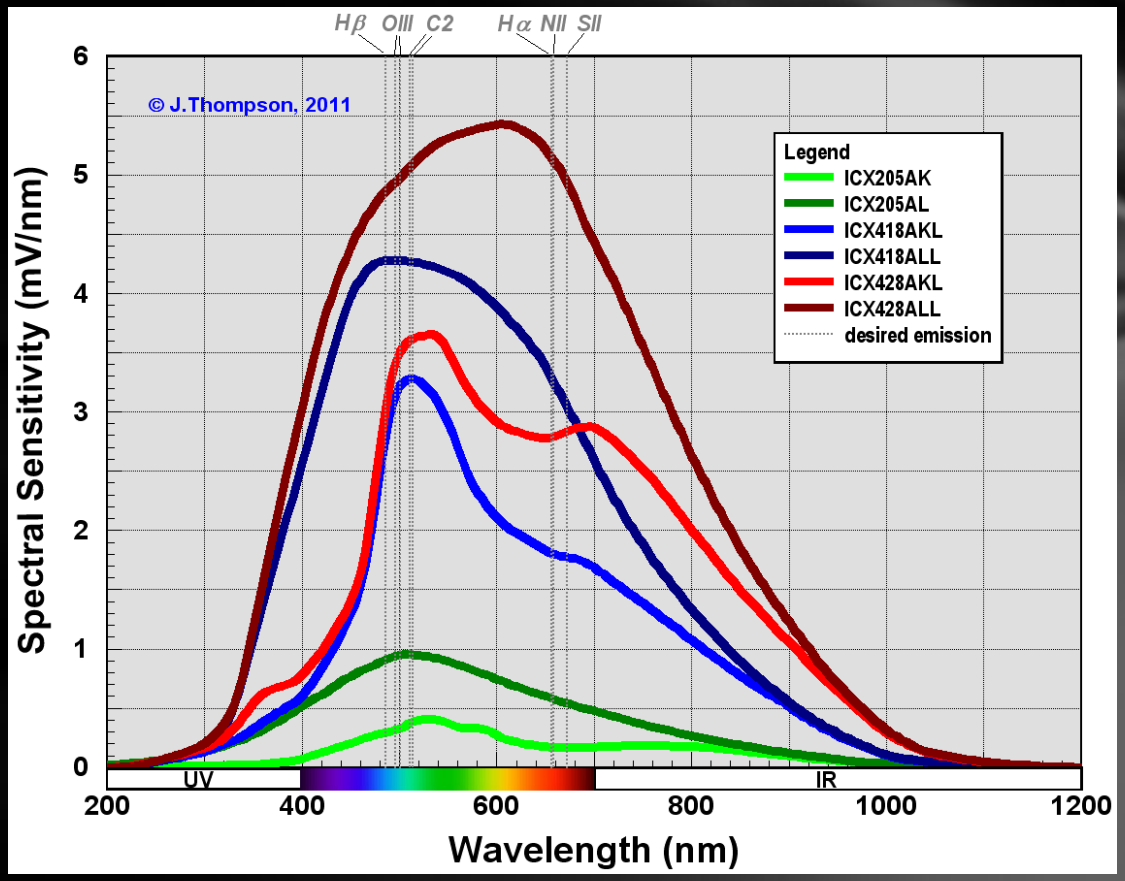
- Longer exposures, AGC make it fairly easy to view/image DSOs

Typical Dedicated Astro-Video Cameras

Camera	Format	Chip	Color	Pixels	Pixel Size	Exp Range	TEC	Outputs	Other	Cost
MC Extreme	½"	Sony ICX418AKL-A	Yes-YCMG	768 x 494	8.4µm x 9.8µm	1/12,000 - 100min	Yes	S-Video Composite	Opt. Wireless Remote $249.95	$1499.95
		Sony ICX428AKL-A ExView HAD								$1699.90
MC Hyper Plus	½"	Sony ICX418AKL-A	Yes-YCMG	768 x 494	8.4mm x 9.8mm	1/12,000 – 56sec	Yes	S-Video Composite		$1199.95
		Sony ICX428ALL-A EXView HAD	No							$1099.95
MC Jr	½"	Sony ICX428ALL-A ExView HAD	Yes - YCMG	768 x 494	8.4µm x 9.8µm	1/10,000 – 4sec	No	S-Video Composite	3D SDNR	$495.95
Orion StarShoot Deep Space Video Camera II	½"	Mintron 72S85HN-EX-R	Yes	768 x 494	8.4µm x 9.8µm	1/10,000 – 4sec	No	Composite	Includes Capture Device & SW	$549
Astrovid StellaCam3 (Watec 120N, N+)	½"	Sony ICX418ALL	No	768 x 494	8.4µm x 9.8µm	1/2,000 - Infinity	No	Composite	Wired Remote	$895
							Yes w/Fan		Opt. Wireless Remote $395	$1245

Relative Sensitivities of Video CCDs





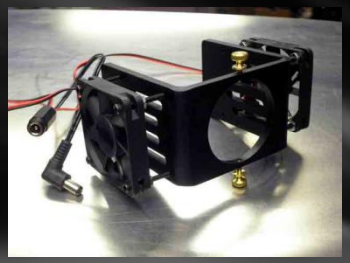
- CCD sensitivity spans from the visible through the near IR
- B/W sensors have higher sensitivity than their Color versions across the spectrum
- ICX428 sensor has ~30% higher sensitivity and has its peaked shifter to the near IR

Additional Features to Differentiate AstroVideo Cameras

- Rear panel camera control & on-screen display (OSD)
- Remote Control (Wired and/or Wireless)
- Color Bars to adjust monitor settings
- Cross-Hairs for easier and more accurate alignment
- Digital Magnification – up to 2X – provides close up views and can help with focus
- Mirror Image - Horizontal/ Vertical axes
- Positive/Negative Image – Adds contrast to bring out faint stars
- Title Text – useful for Public Outreach or labeling images
- Coronograph – combined with a solar filter, reduces the light level to bring out solar corona
- APC **(Advanced Pixel Control) adjusts DSP to** enhances detail … can cause halos around stars.

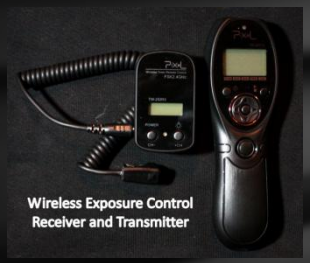
Camera	OSD	Remote	Color Bars	Cross Hairs	Digital Mag	Mirror	Neg.	Title	Corono graph	Freeze Frame	APC
Mallincam	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Orion StarShoot DSV Camera II	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No	No
Astrovid StellaCam3 (Watec 120N, N+)	No	Yes	No	No	No	No	No	No	No	Yes	No

Optional Accessories



- Cooling Fans … especially helpful to minimize hot/warm pixels during long exposures or with high gain applied

- Remote Control … Wired/Wireless camera control without a computer



- Focal Reducers … Increased FOV & camera speed for shorter expsoures
  - Celestron f/6.3, Meade f/3.3, Mallincam (MFR6 f/0.8, MFR5 f/4-3.3, f/0.49, MFR3 f/3.3)

- Small LCD Monitor …
  - Mount on scope for polar alignment/collimation/focus
  - Watec WAT-LCD35 3.5inch Color TFT Monitor
  - Orion DVD Recorder/2.5"LCD Monitor & DVD Recorder

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My Typical Camera Configuration C9.25"

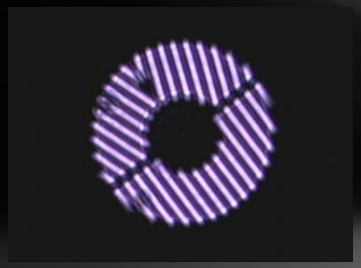
- Straight through 1 ½" C-Mount adaptor
  - f/25 with Televue 2.5 barlow for planets
  - f/10 for small DSOs
  - ~f/4.5 with the MC MFR5 (2 lens elements with a 5 or 10mm spacer between)
  - ~ f/2.5 with the Celestron f/6.3 + MFR5 for wider field and shorter exposure times
  - Astronomic CLS-CCD filter for light pollution
  - Astronomic IR filter to minimize star bloating
  - Astronomic Ha
  - Astronomic OIII

Application Overview

- Helpful Telescope Setup Applications
- Live Viewing & Public Outreach
- Solar, Lunar and Planetary Imaging
- Deep Sky Viewing and Imaging

Helpful Telescope Setup Applications

- Focusing
  - On-screen image facilitates focusing with a Bahtinov mask. I use ~2sec exposure of a bright star (Arcturus) to get close and then switch to 7sec exposure to fine tune.

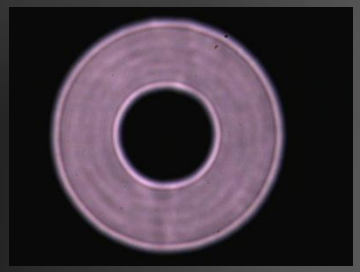


- Mount Alignment

  Cross hairs and cross hatch takes the guesswork out of judging when a star is centered

- Collimation

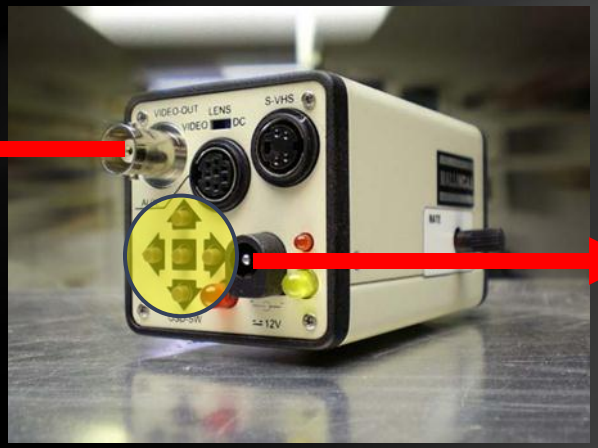
  Can view the out of focus image comfortably on a monitor while adjusting the collimation screws.
  No need to run back and forth between the EP and the front mirror of my SCT.



Typical Live Viewing Session on a Video Monitor

- Extremely Simple setup
  - Attach 1 ½" C-Mount adaptor to the camera along with any focal reducer and filters as required
  - Attach the camera to the telescope
  - Supply 12V DC power (battery or AC transformer)
  - Connect BNC – RCA video or S-Video cable to a monitor
- Adjust camera settings as needed via 5 buttons on back panel using the OSD or a remote control
- Presto … the Universe appears on your monitor!

NC-RCA



12VDC (Battery or AC Transformer

What Can One Expect to See Virtually Live: 1st Light with the Mallincam VSS

2-4-2011 Livermore, CA M42 and M1

C 9.25" + MC VSS w/MFR5 (5mmspacer) focal reducer ~f/4.5+ Astronomic CLS-CCD
Single frames, 1min M42 and 2min for M1

Images are unprocessed screen captures from an AVI file

2nd Light with the Mallincam VSS

2-10-2011 Livermore, CA Horsehead Nebula & NGC2024 (Flame Nebula)

Orion ED80 + MC VSS w/MFR5 (5mmspacer) focal reducer + Astronomic Ha filter
Single 2min frame with AGC = 4 (midpoint)

Image is an unprocessed screen captures from an AVI file

Advantages of a Video Camera for Live Viewing

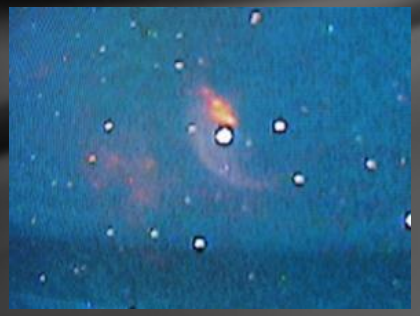
- Advantages of a Video Camera
  - No need for dark adaptation
  - Detailed high contrast images of galaxies, nebulae & star clusters in virtual real time (seconds)
  - Extends the observable limiting magnitude ~1 – 1.5 magnitudes, effectively doubling a telescope's aperture - inexpensive telescope upgrade
  - Observe in color instead of black and white (with a color video camera)
  - Excellent eye relief - readily accommodates eyeglass wearers - less eye strain
  - View in comfort - Sitting in a chair inside a warm room or house – Not perched on a ladder

- Ideal for Public Outreach
  - Accommodate many viewers at once - no waiting in lines
  - No need to re-focus for each person
  - Easier to point to features in the object being viewed
  - Avoids possible wear and tear on the telescope

Video Monitors

SpongeBob 14" TV

Philips 7" LCD Monitor



Speco VM905C 9" Color Monitor

- Old TV like my 14" SpongeBob Square Pants
  - Inexpensive, large screen , bulky/heavy, power hog,
- Philips 7" LCD Monitor - $89 @ Best Buy (includes 2nd LCD & DVD player)
  - Small , lightweight, 480 x 284i, 1.5lbs, attach to the scope for focusing, collimation
- Dedicated CRT Monitor -$236 Speco VM905C 9" Monitor
  - Flat tube, 500 lines, front panel controls, 40 watts

Solar System Applications for Video Cameras

- Solar, Lunar and Planetary Viewing and Imaging
  - Exposures <1/60 sec facilitate image capture during moments of excellent seeing
  - Frame rates of 30-60 fps capture thousands of frames in short order
  - Post processing software (Registax)
    - Grade and select the best frames, then align & stack for sharp detailed images
  - Sensors with small square pixels are best to obtain sharp detail
    - Sensitivity is reduced but made up by stacking many frames
    - MC Signature (3.45μm)
    - Celestron NexImage5 (2.2μm)
    - Orion StarshootIV (3.6μm)
    - DFK41AU02.AS (4.7μm)

- Capturing AVI. Files of Occultations and Transits

Jupiter 10-2-2011, Uranus 11-9-2011

MC Xtreme Single Frame 1/160 sec C9.25" f/25

MC Xtreme 200 Frames in Registax
1/160 sec C9.25" f/25

MC Xtreme Single Frame C9.25" f/25

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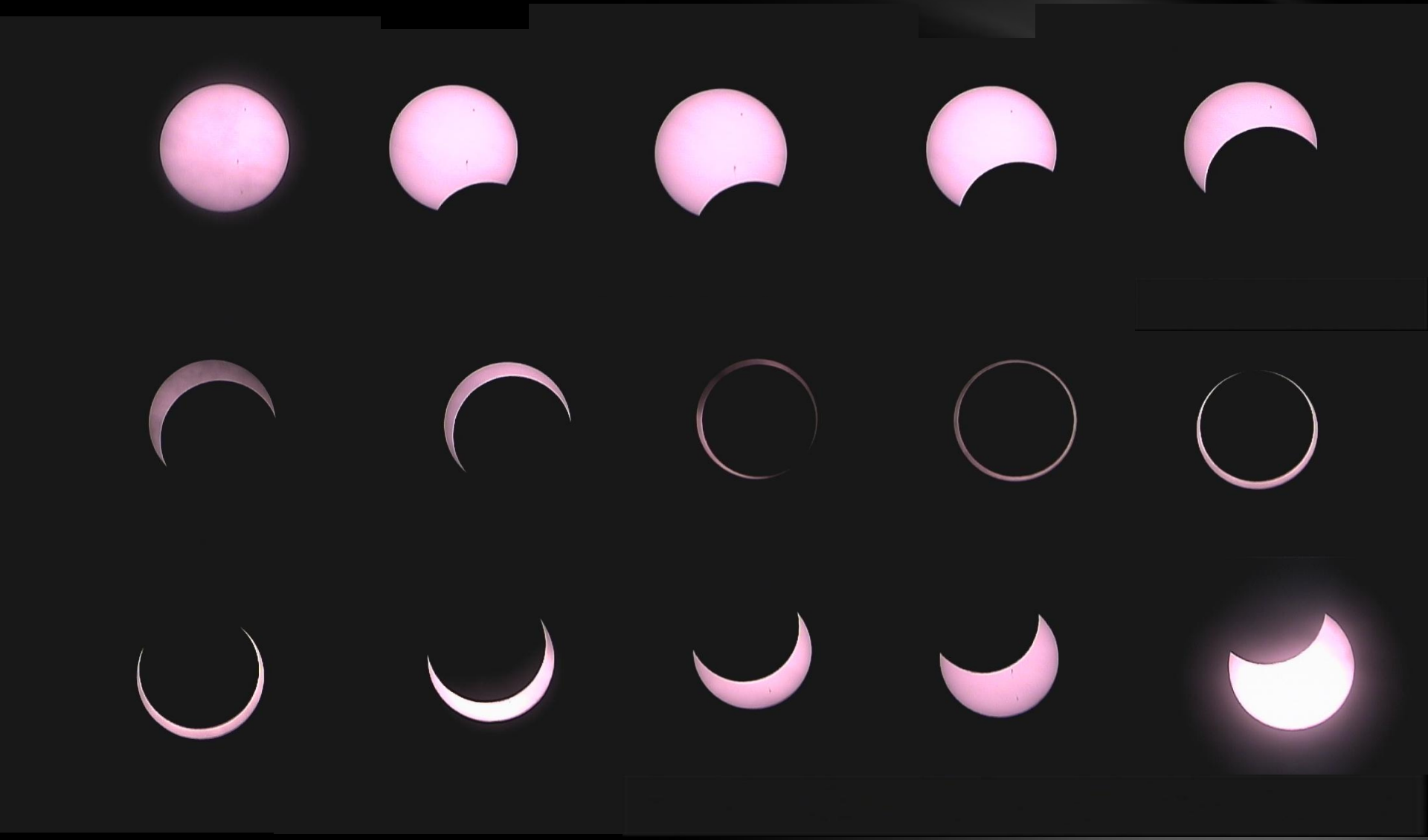
Annular Eclipse, May 20, 2012 Redding, CA



MC Xtreme, Single Frames @ 1/12,000sec, Orion ED80mm w/Orion Glass Solar Filter

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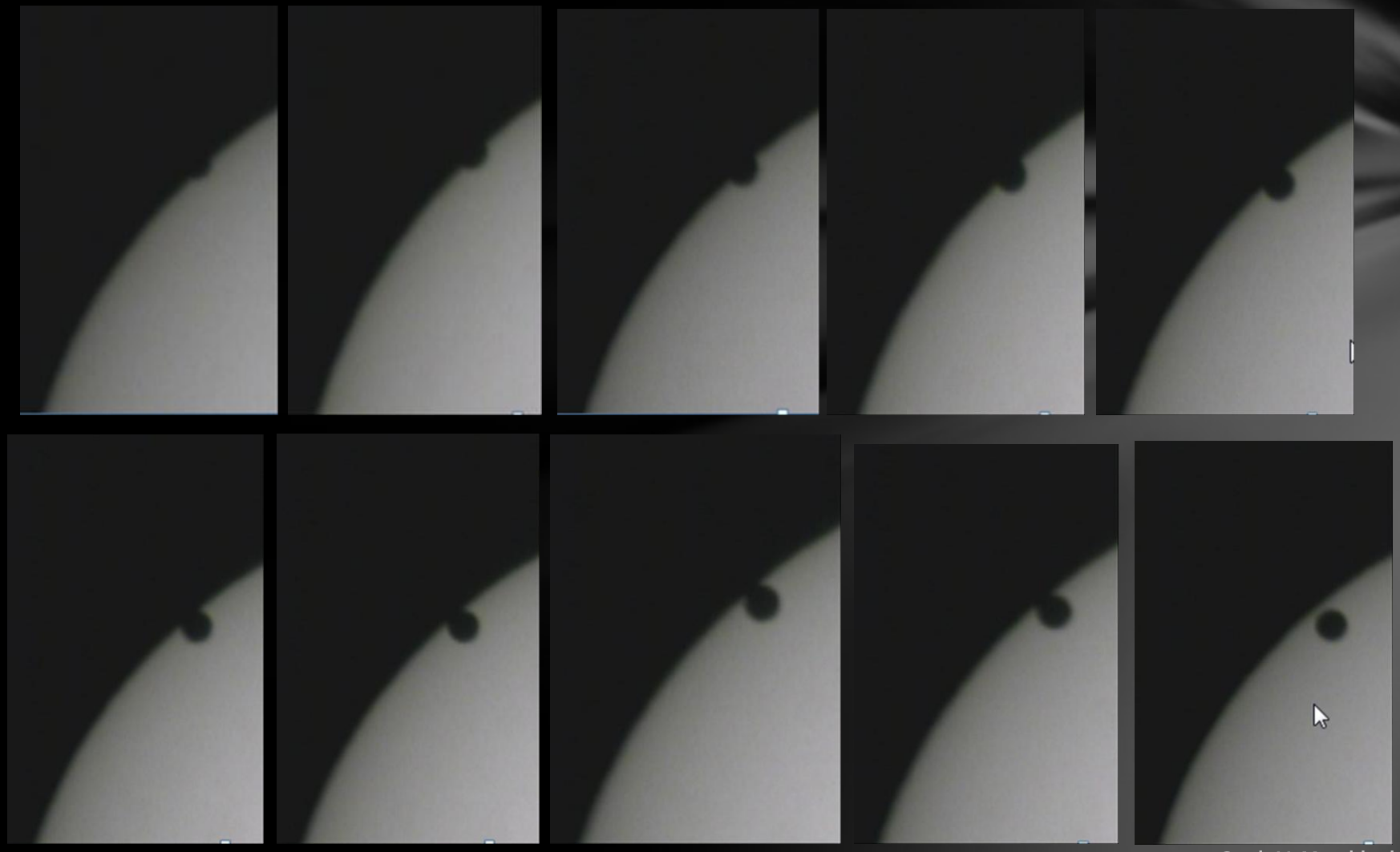
Venus Transit June 5, 2012, Livermore, CA Celestron CGE 9.25, 3" Off-Axis Homemade Solar Filter, 2X Digital Zoom



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Comet Garrard 9-20-2011 Livermore, CA

C9.25 ~f/4.5 2min unguided CLS CCD + IR Filters

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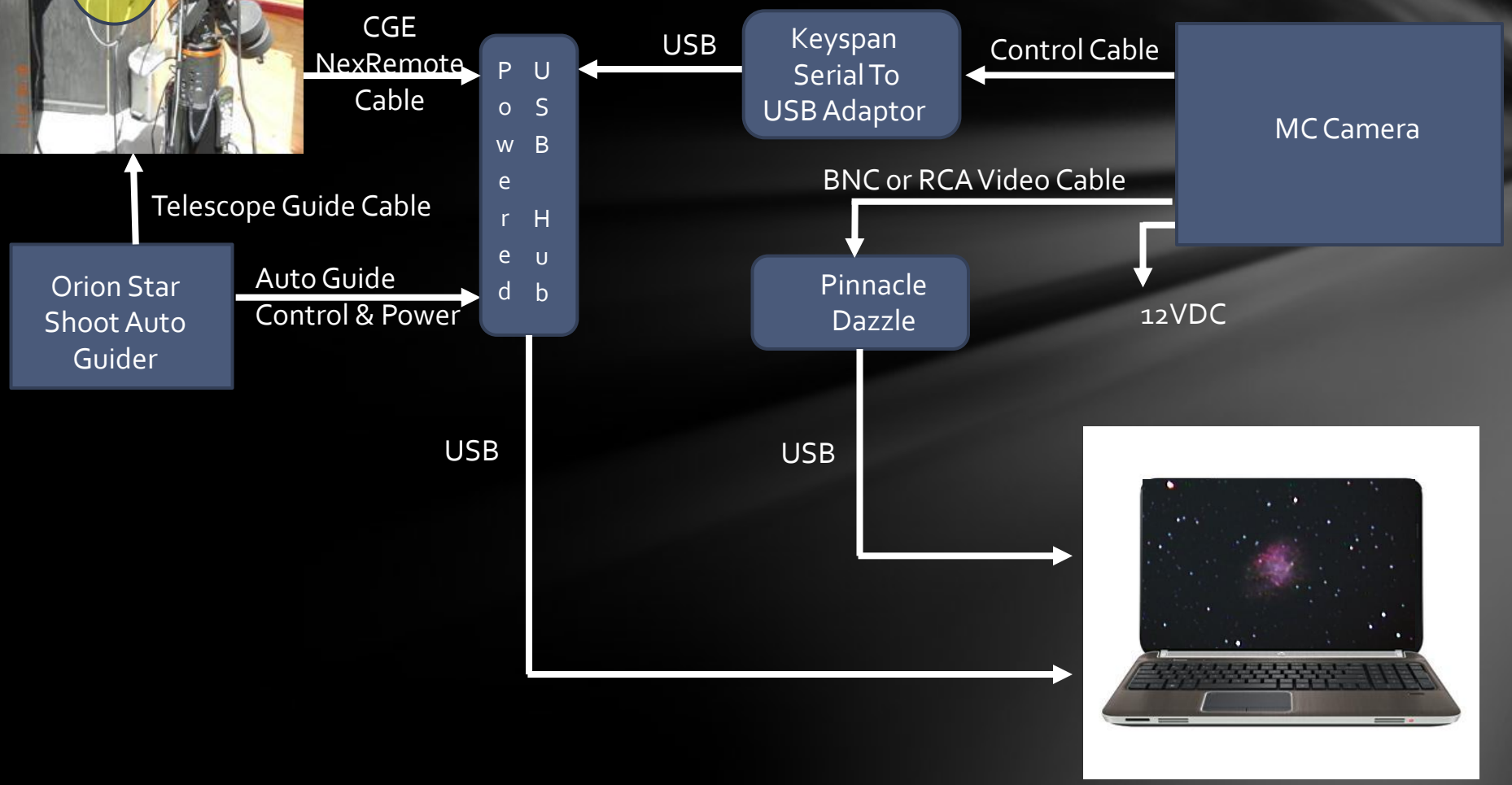
Viewing & Imaging DSOs with a Video Camera

- Deep Sky Viewing and Imaging
  - Frame accumulation, or image integration allows exposures of 2 sec to infinity
  - Able to see detail in galaxies, nebulae and star clusters not possible with an EP
  - As with EPs, broad-band and line filters can improve contrast
  - Can use AGC to provide gain to the CCD output to see more detail
    - Tends to lighten background and increases Amp Glo
    - AGC off is best for CCD-like images and absolutely required for planets, lunar
  - Can take dark and flat frames for post processing same as traditional CCD imaging
  - Can use full range of filters, broad-band, line, color (with B/W cameras)

  - Messier Project
    - Capture single frame images of all the Messier Objects with the MC from my backyard
      - Captured 93 to date

My Image Capture & Telescope Control Configuration



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Video Capture Devices (Frame Grabber)

Frame Grabber: Digitizes each frame of the analogue video output into a single bitmapped still image and passes it to the computer. Can be a stand-alone device connected between the camera and the computer, or built into the video capture board or display adaptor in the computer.

A frame grabber is required for image capture, but not for live viewing on a monitor.

Device	Inputs			Output	Cost
	RCA	S-Video	Component	USB 2.0	
Pinnacle Dazzle DVC 100	Yes	Yes	No	Yes	$39.99
Orion Video Capture Device	Yes	Yes	Yes	Yes	$39.99
Roxio Video Capture USB	Yes	Yes	No	Yes	$44.99
MCV-1	Yes	Yes	Yes	Yes	$79.99
MCV-1-VDVE	Yes	Yes	Yes	Yes	$149.99

MCV-1-VDE has and added control to increase image contrast/dynamic range by ~60%

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Video Capture & Camera Control Software

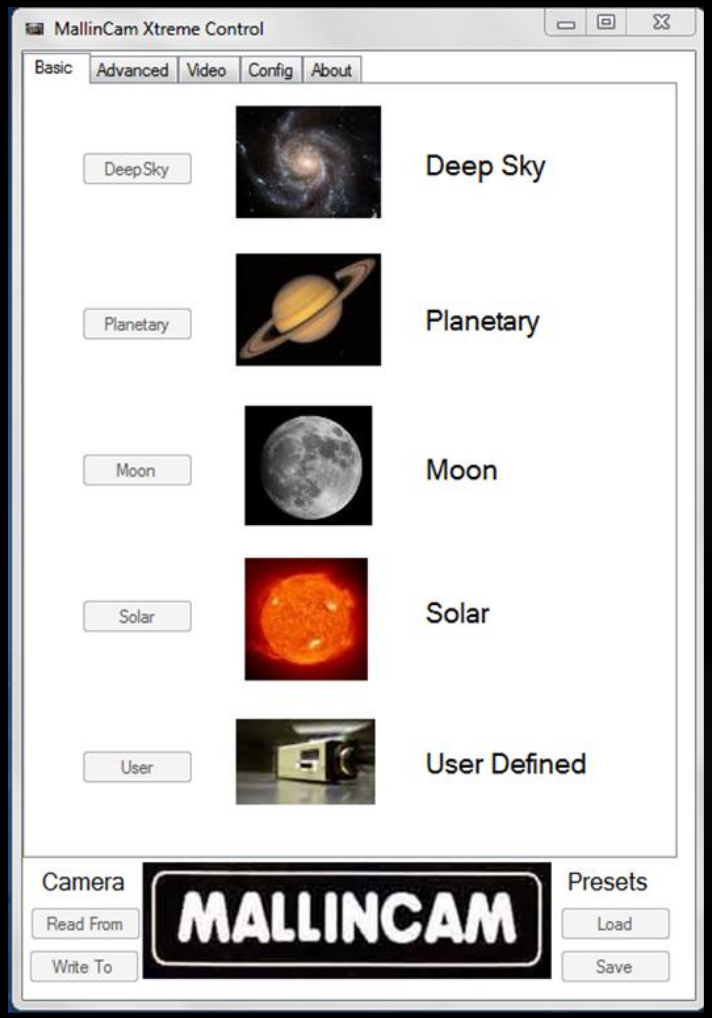
Software is necessary to capture either video (AVI or MPEG files) or single frame images, (TIFF, JPEG, BMP).

Software is available for several Asrro-video cameras to control all camera settings.

Some software does both camera control and video capture, such as the MC Control Xtreme

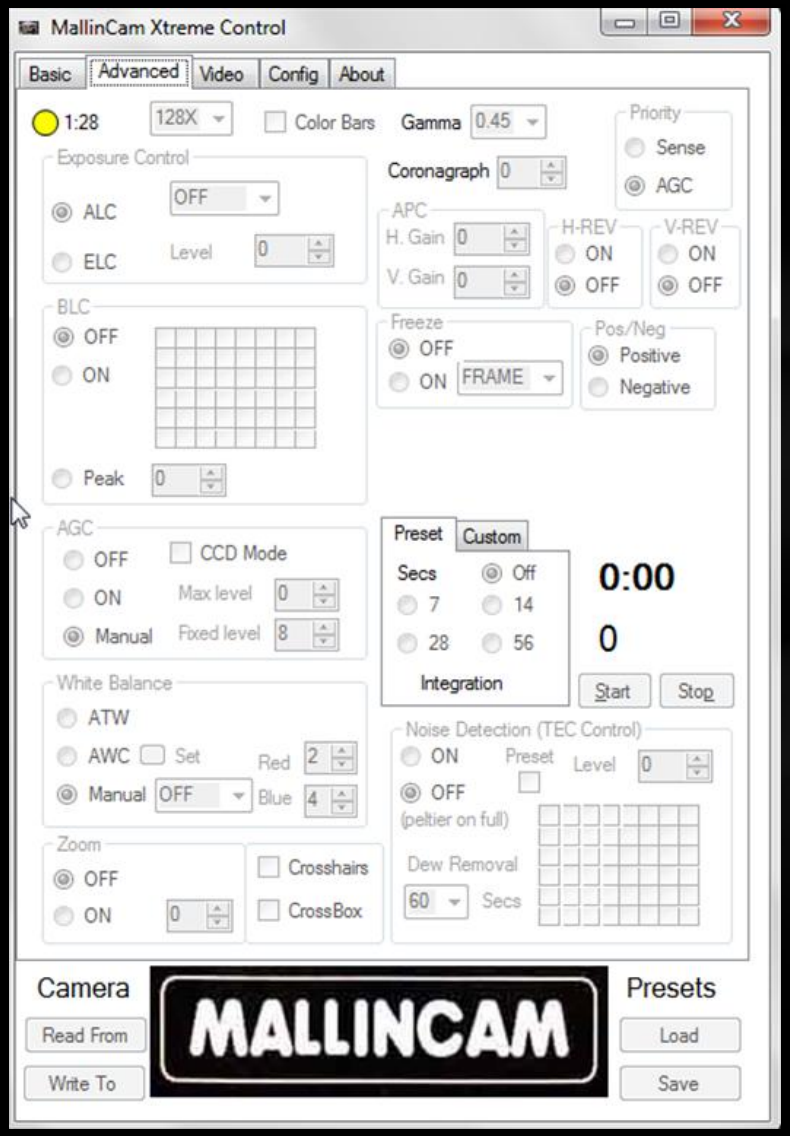
Software	Single Frame Capture (TIFF, JPEG)	Video Capture (AVI)	Automated Capture	Preview	Camera Control	Other	Cost
MallinCam Control Extreme	Yes	Yes	Yes	Yes	Yes (MC)	For MC Xtreme	Freeware
Orion StarShoot Deep Space Video Camera II Computer Control			No	Yes	Yes (Orion)	Includes 50" Serial Cable & RS232-USB Adaptor	$59.99
AmCap	Yes	Yes	No	Yes	No		Freeware
Deep Sky Imager	Yes	Yes	Yes	Yes	No		$34.99

MC Xtreme Control Software



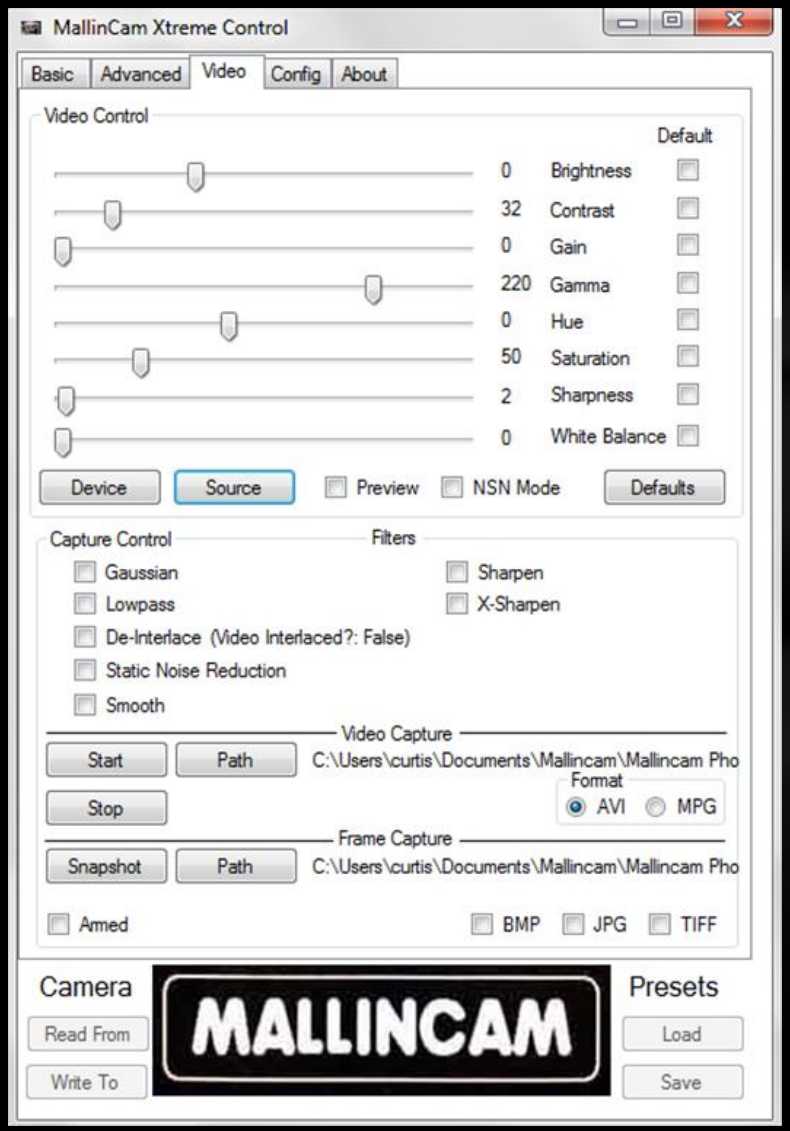
- Freeware written by Stephan Lelonde
- Remote Computer control of all camera settings
  - Preset conditions for DSOs & Solar System
  - User Defined Presets can be stored
  - Adjust on the fly

Advanced Camera Settings



- Main Features
  - Exposure Settings for Solar System Objects:
    - Short : 1/12,000 to 1/100 15 levels
    - Fixed: 2.1, 7, 14, 28, 56 sec
    - Custom: 3 sec to 100min
  - AGC
    - OFF: No electronic gain
    - ON: 1-8 steps of gain
  - White Balance
    - Auto: 2 modes ATW , AWC
    - Manual: Set Red and Blue Levels
  - Gamma: 1.0 or 0.45
  - TEC
    - On full time
    - Noise Detection activated (Level, Time)

Video Camera Settings



- Main Features
  - Device – Frame Grabber
  - Source – BNC or S-Video
  - Display Settings
    - Brightness, Contrast, etc.
  - Preview
    - Opens a preview window which displays the current video frame
  - Video Capture
    - AVI, MPEG
    - BMP, JPG, TIFF
    - Set Capture Folder
    - Snapshot – Single Frame
    - Armed – Continuous capture synced to exposure time

Examples of DSO Images Captured with Different Settings & Conditions

M42 Impact of Exposure on Visible Detail

C9.25 ~f/4.5 with Astronomic CLS-CCD + IR 2/16/2012 Livermore

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M42 Effect of Gamma on Visible Detail & Background

C9.25 ~f/4.5 with Astronomic CLS-CCD + IR 2/16/2012 Livermore

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M42 3 x 1min 2/23/2012 Orion EON ED80

Orion ED 80 f/6.25 with Astronomic CLS-CCD

2/23/2012 Livermore

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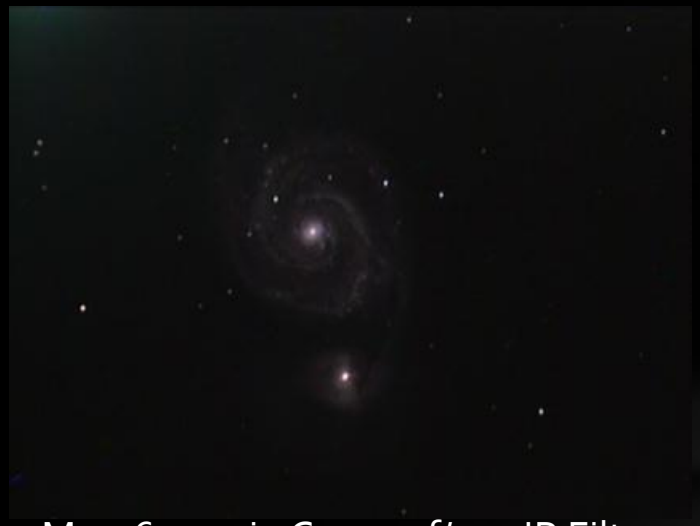
NGC7635 Bubble Nebula Effect of AGC on Visible Detail & Background

AGC OFF

AGC =4 (Mid-Point)

2min C9.25 ~f/4.5 with Astronomic CLS-CCD + IR 9/4/2011 Livermore

Galaxies



M51 6 x 2min C9.25 ~ f/4.5 IR Filter
GSSP 7-2-2011

M81 14 x 4min C9.25 ~ f/4.5 Guided
2-18-2012 Livermore, CA

M82 7 x 4min C9.25 ~f/4.5 Guided
2-18-2012 Livermore, CA

NGC4565 2min C9.25 ~ f/4.5 IR Filter
7-2-2011 GSSP

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M31 & M110

4X 1min γ =0.45 Orion ED80 Astronomic CLS-CCD + IR
8/27/2011 Livermore, CA

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Nebulae from GSSP 7-2-2011

M16 2min C9.25 ~ f/4.5 IR Filter

M20 2min AGC 3C9.25 ~ f/4.5 IR Filter

NGC 6960 Veil Nebula
2min γ =0.45AGC4 3C9.25 ~ f/4.5 IR Filter

M27 2min
AGC 3 C9.25 ~ f/6.3 UV-IR Filter

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Super Nova Remnant & Planetary Nebula

M1
7 x 2min C9.25 ~f/2.6 Astro. CLS-CCD
2-21-2011 Livermore, CA

M57
2min C9.25 f/6.3 Baader UV-IR
7-1-2011 GSSP

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Globular Clusters

M5
2min C9.25 f/4.5 CLS-CCD
6-25-2011 Livermore, CA

M13
2min C9.25 f/4.5 CLS-CCD
6-25-2011 Livermore, CA

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M3 Suburban vs Dark Site Comparison

M3
2min C9.25 f/4.5 CLS-CCD
6-25-2011 Livermore, CA

M3
2min C9.25 f/4.5 CLS-CCD
7-3-2011 GSSP

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Images from Fellow MC'rs

Bubble Nebula 14ACF 3min Guided Astro UHC
Brian Alspaugh, Indianapolis, IN

Running Man Nexstar 11 ~10 Stacked
Hyperstar f/2, Chris Bernardi Mt Diablo, CA

Eagle Nebula f/3.5, Chris Appleton, Toronto, Canada

Leo Triplet CPC 800 50 x 4sec
John Scholl, Louisiana

Additional Resources

- ***Deep Sky Video Astronomy*** by Steve Massey & Steve Quirk, Springer 2009
- Yahoo Video Astro Group
- Yahoo Mallincam Group
- Night Skies Network http://www.nightskiesnetwork.com/