Introduction to CCD Imaging

By Sam Pitts

4/2003

Revolutions in Astronomy

Telescope

Photography

CCD

CCD

(charge-couple device)

Developed by Bell Laboratories 33 years ago as a storage device

Revolutionized Astronomy as an optical detector

20-30 times more sensitive than Film

Linear-No reciprocity failure

Spectroscopy

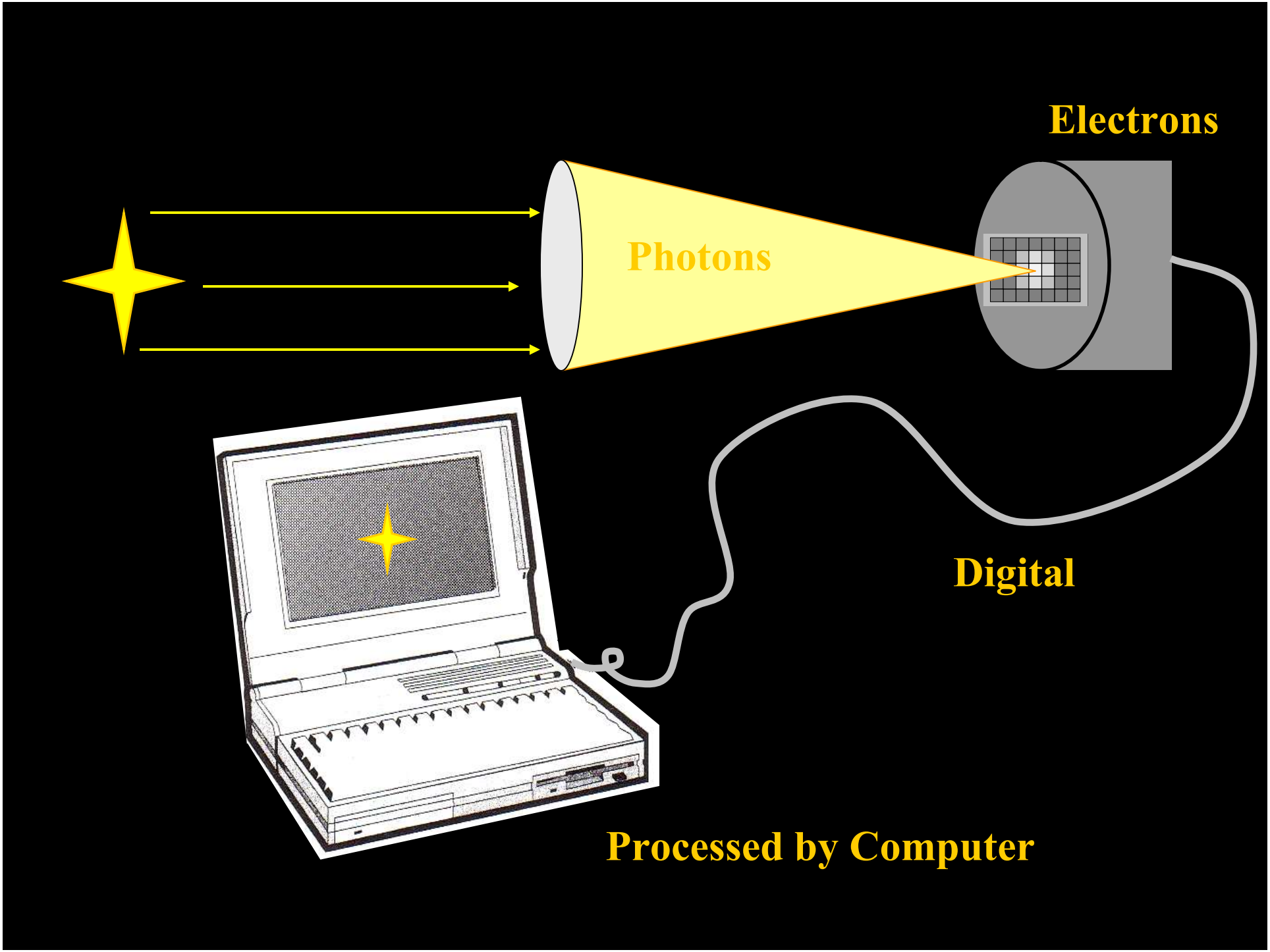
Imaging

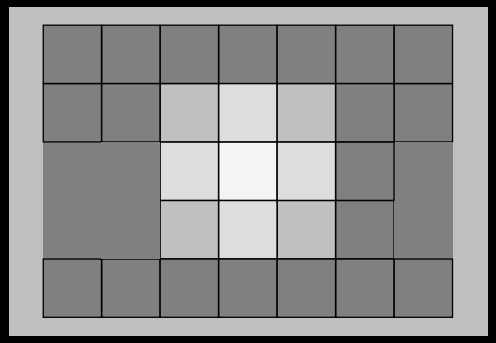
Modern Day 11”-12” Telescopes

Equipped with the Latest CCD

Can out perform a 200” Telescope

from the 1970’s & early 80’s


Electrons
Photons
Digital
Processed by Computer

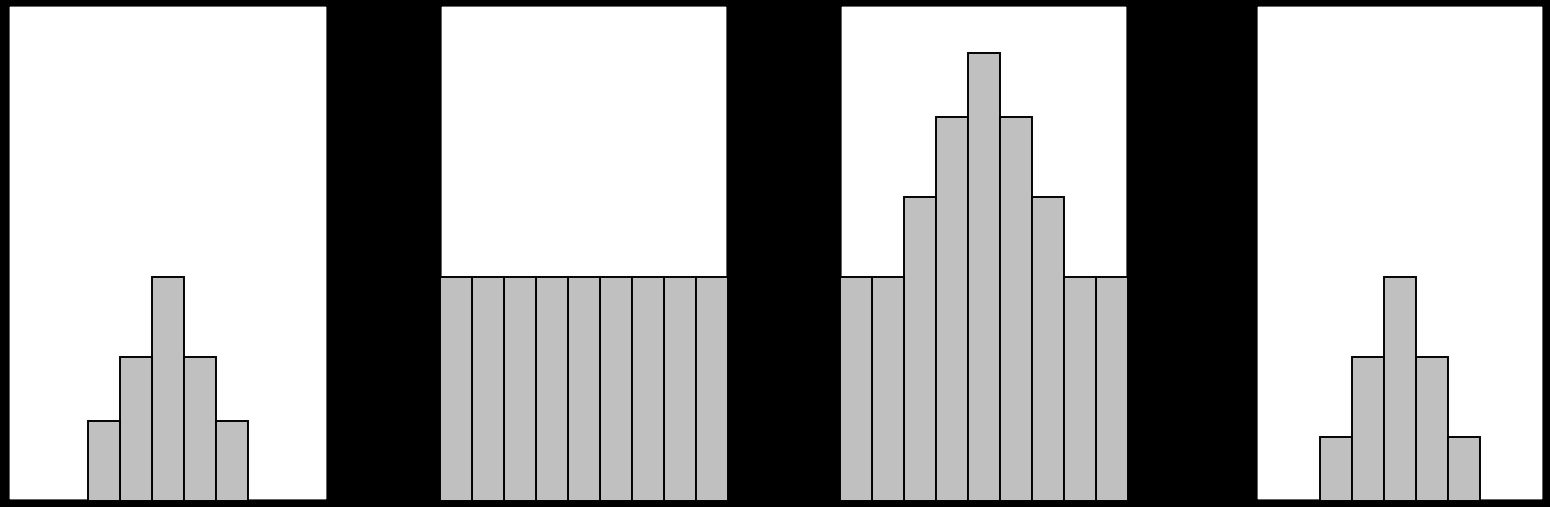


8 Bit = 256 Shades of Gray

12 Bit = 4,096 Shades of Gray

16 Bit = 65,536 Shades of Gray

Well Depth



Object + Light = Image - Background

Pollution

Noise = Grain

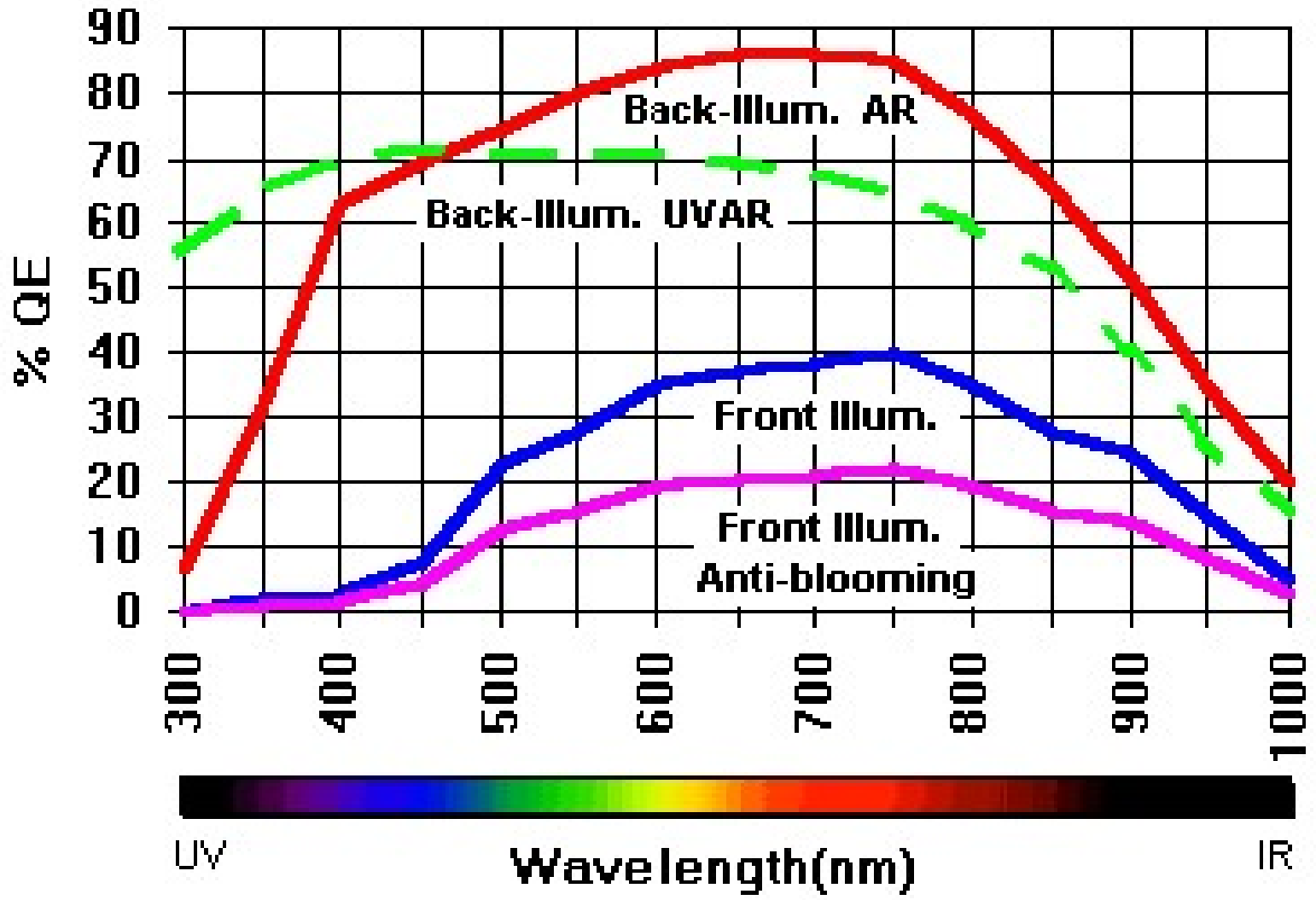
Dark Frame/Bias: Most CCD's take a bias frame and then a Dark frame these frames record noise from the electronics and camera. This is pulled out of the final image when the they are applied to the Luminous

Flat Field : Frame taken through the optical path with a flat white light. This is then applied to the final image to subtract out anomalies in the optical path, vignetting, dust, etc,

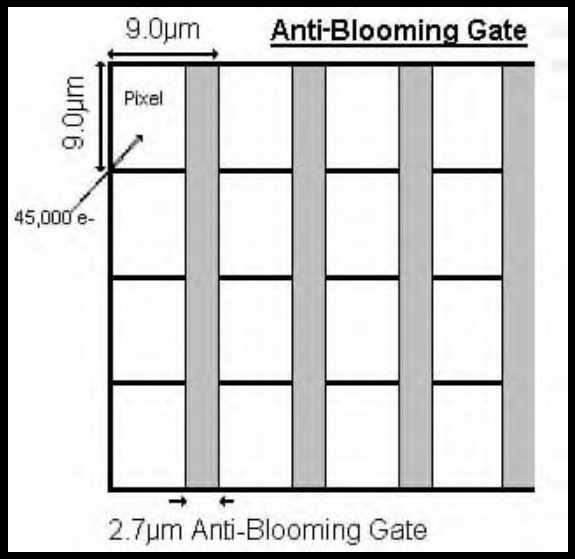
Luminous Frame: Light Frame taken through the optical path.

RBG : R=Red; B=Blue; G=Green mages are taken with Red, Blue & Green filters and then combined to form a color image.

ABG vs. NABG

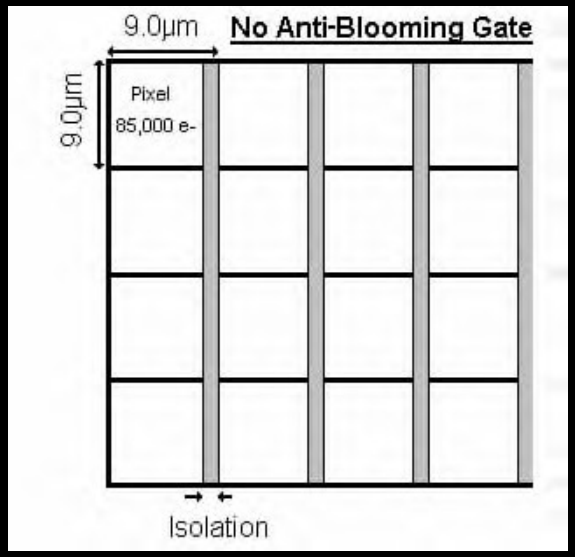

90
80
70
60
50
40
30
20
10
0
% QE
Back-Illum. AR
Back-Illum. UVAR
Front Illum.
Front Illum.
Anti-blooming
300
400
500
600
700
800
900
1000
UV
Wavelength(nm)
IR

ABG or NABG



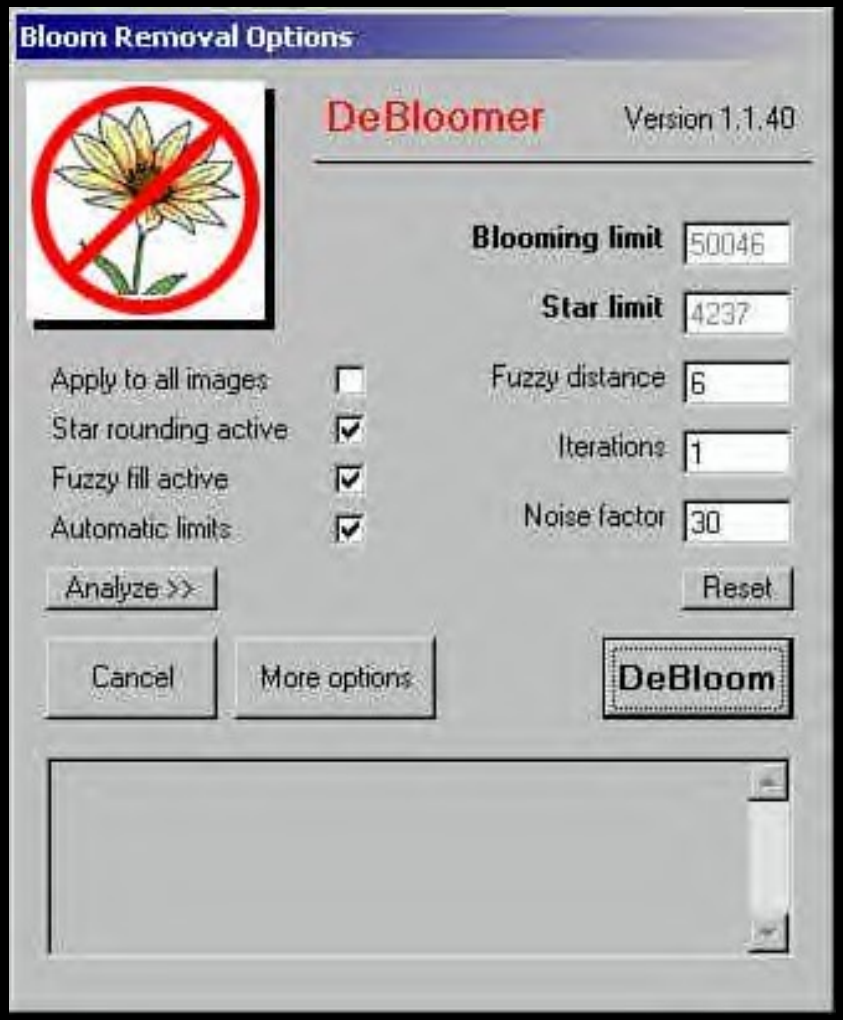
ABG

- Will allow long exposures with no Blooming
- Great for Pretty Pictures
- Lower QE/ Sensitivity
- Great for Pretty Pictures
- Will not allow Photometry, Spectroscopy, non-linear



NABG

- Will not allow long exposures "Blooming"
- Good QE, 40% or more over ABG version
- Will not allow long exposures "Blooming"
- Greater Well Depth
- Linear for Scientific research



DeBloomer - $49.95
Supports:

CCDSoft v5.0.72 or later

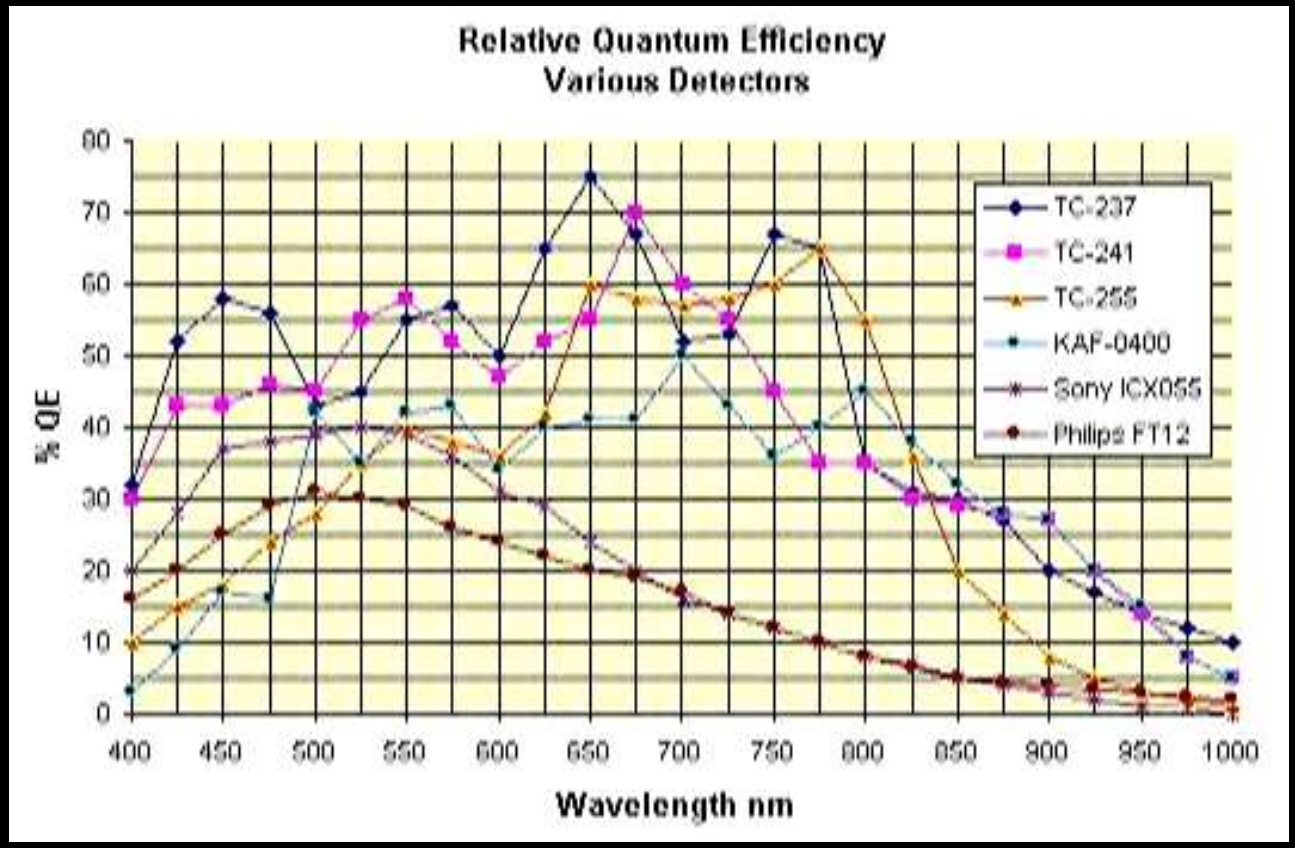
•Maxim DL 3.07 or later

. **Current version: 1.2.2.**

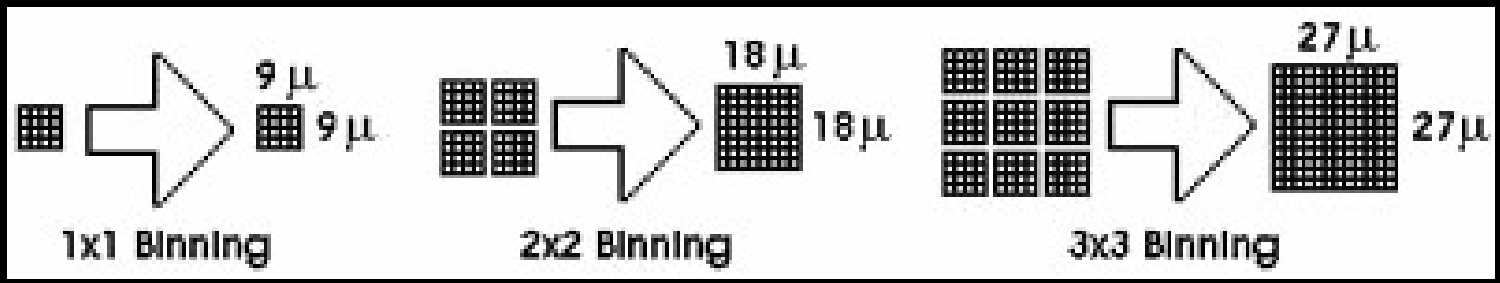
Horsehead before

Horsehead After

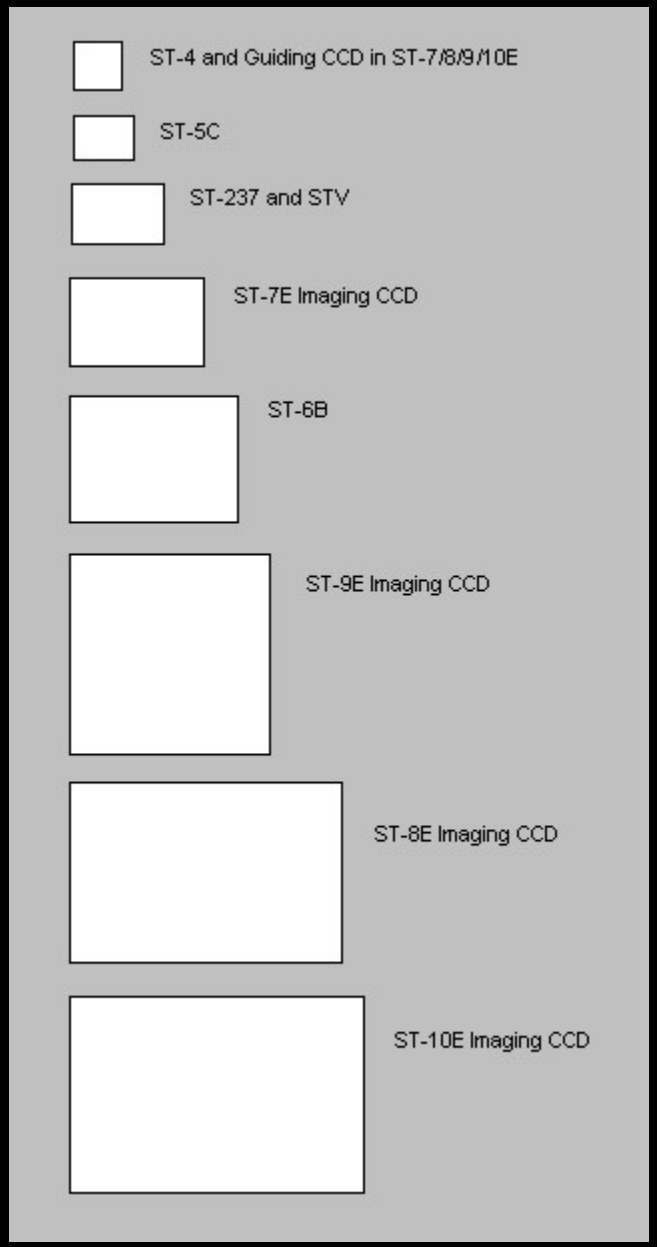
QE ?

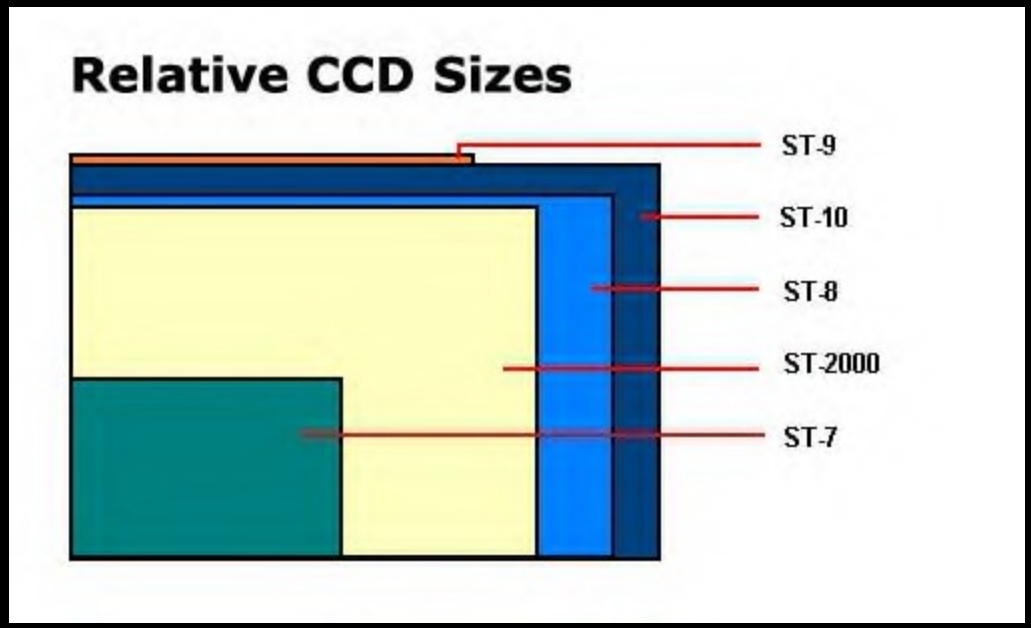

Relative Quantum Efficiency
Various Detectors
% QE
Wavelength nm
TC-237
TC-241
TC-255
KAF-0400
Sony ICX055
Philips FT12

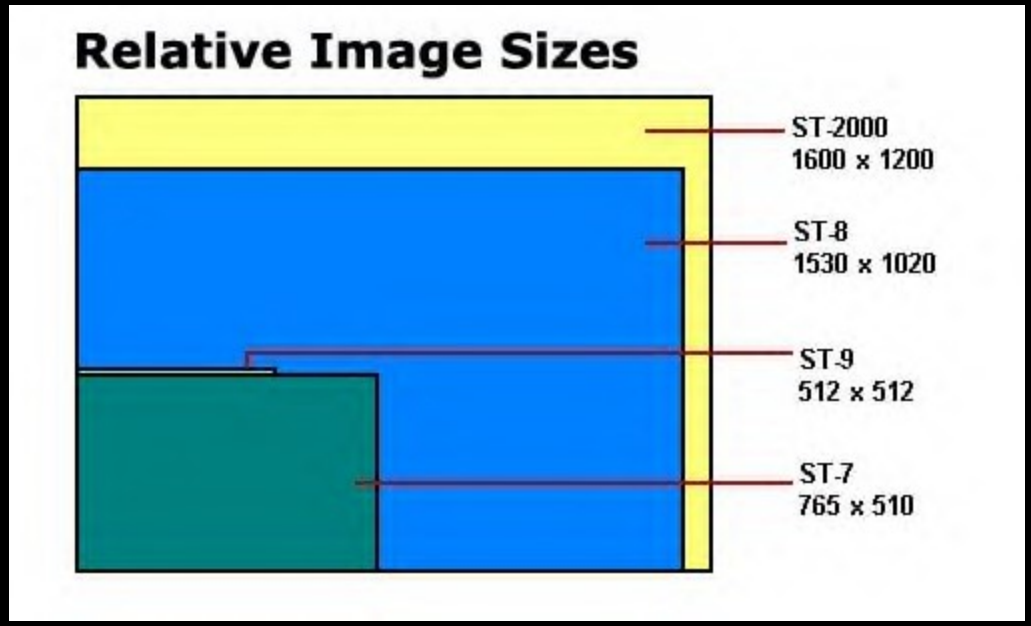
Binning


9 µ
9 µ
1x1 Binning
18 µ
18 µ
2x2 Binning
27 µ
27 µ
3x3 Binning

What Size Chip & Pixel ?

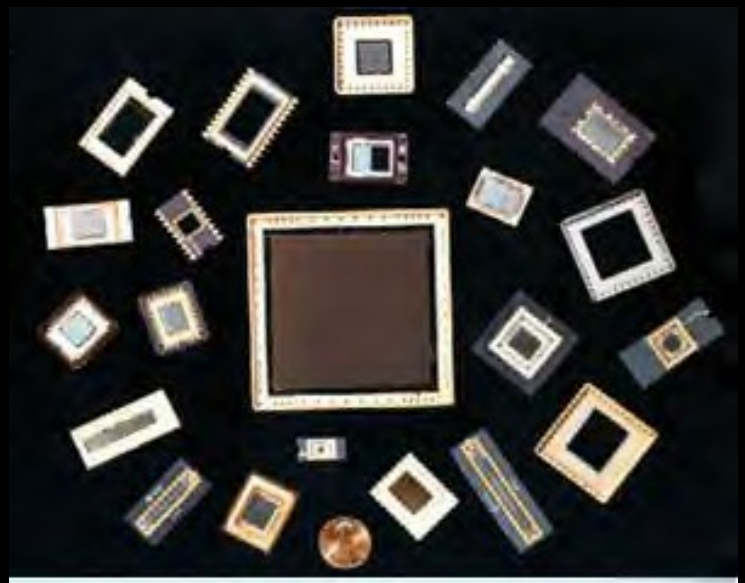


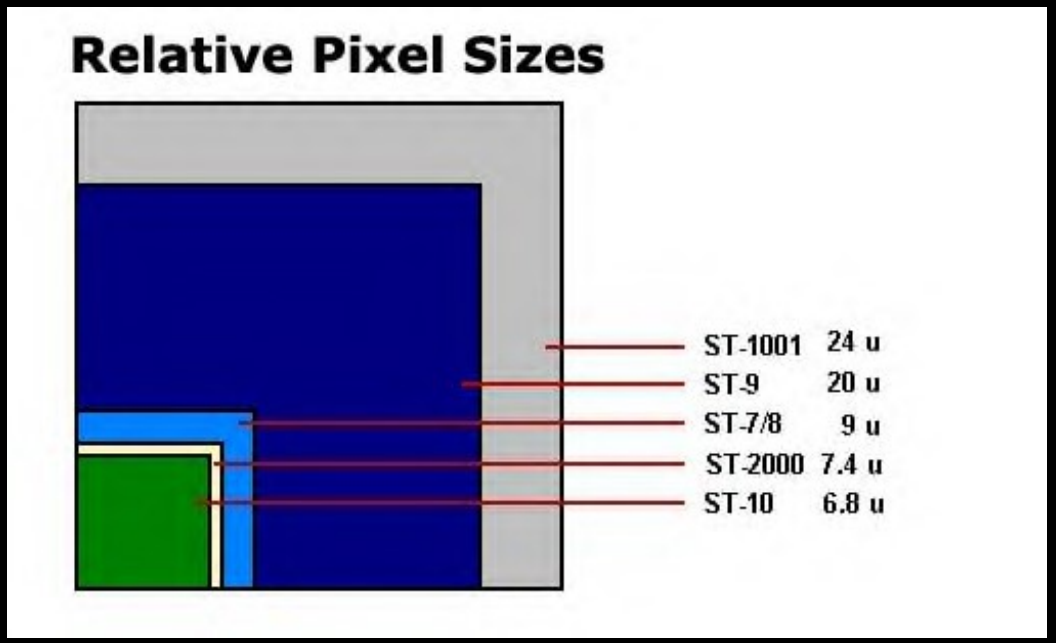




Field of View

“FOV”





1 Millimeter = 0.03937 in. or 1000 Microns (µ)

1 Micron = .00003937 in.

Field of View

FOV ST7e

Scope	Speed	FL	Width	Height	Pixel	Reducer	Mag.
FS78	F/20.25	1575	15' 1.73"	10' 1.14"	1.1787"	2.5x	32x
FS78	F/16.2	1260	18' 47.16"	12' 31.44'	1.4734"	2x	25x
FS78	F/8.1	630mm	37' 27.92"	24' 58.58"	2.9385"		13x
FS78	F/6.5	507mm	46' 41.24"	31' 07.94"	3.662"		10x
FS78	F/5.1	391mm	60' 36.02"	40' 24.00"	4.753"	0.062	8x
C11	F/25	6975	3' 23.60"	2' 15.73"	0.2661"	2.5x	140x
C11	F/20	5580	4' 14.51"	2' 49.65"	0.3326"	2x	112x
C11	F/10	2790	8' 29.02"	5' 39.33"	0.6654"		56x
C11	F/6.3	1758	13' 27.00"	8' 58.68"	1.0549"	6.3	35x
C11	F/5	1395	16' 58.07"	11' 18.70"	1.3308"	3.3	28x
C11	F/4	1116	21' 12.58"	14' 8.39"	1.6635"	3.3	22x
C11	F/3.3	921	25' 42.03"	17' 8.02"	2.0157"	3.3	18x

1 inch = 25.4 mm

Field of View

Focal length x 2 **Dived into Chip Size (Height or Width)**

Multiply by 6876 **Will Yield FOV in Arc Minutes**

Example:

C11 F/10 FL 2790 mm X 2 = 5580

5580 ÷ 6.885 (St7 width 765 pixels) = 0.0012338

0.0012338 x 6876 (radiant) = 8.4836088 Arc Minutes FOV

FOV = 8’ 29.02”

8.4836088’ x 60 = 509.017” **765 ÷ 509.017 = .6654” per Pixel**

Field of View SBIG

SBIG

Model	Resolution (pixels)	Pixel Size (microns)	Size (mm)	A/D (bit depth)	Shutter
STV	656 x 480	7.4 x 7.4	4.7 x 3.6	10 to 16	Yes
ST-237A	657 x 495	7.4 x 7.4	4.7 x 3.6	16	Yes
ST-4	192 x 164	13.75 x 16	2.5 x 2.5	8	No
ST-5C	320 x 240	10 x 10	3.2 x 2.4	16	Yes
ST-7/ST-7E	765 x 510	9 x 9	6.9 x 4.6	16	Yes
ST-8E	1530 x 1020	9 x 9	13.8 x 9.2	16	Yes
ST-9E	512 x 512	20 x 20	10.2 x 10.2	16	Yes
ST-10E	2184 x 1472	6.8 x 6.8	14.9 x 10	16	Yes
ST-1001E	1024 x 1024	24 x 24	24.6 x 24.6	16	Yes
ST-2000XM *	1600 x 1200	7.4 x 7.4	11.8 x 8.9	16	Yes

Readout Specifications

Shutters (2) 2 Position Wheel, Internal (RGB Ready)
Plus Electronic Shutter

Exposure 0.01 to 3600 seconds,
10ms resolution

Correlated Double Sampling Yes

A/D Converter 16 bits

A/D Gain 0.72

Read Noise - Typical $14e^-$

Binning Modes 1 x 1, 2 x 2, 3 x 3

Pixel Digitization Rate 30 kHz

Full Frame Download 10 seconds

Half Frame Download 3 seconds

Quarter Frame Download 1 second

Focus Frame Update Rate up to 2 frames per second
with CCDOPS for Windows
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up to 3.8 frames per second
with CCDOPS for DOS

Model ST-237A CCD

Specifications

CCD	**TI TC-237**
Pixel Array	**657 x 495 pixels**
	4.7 x 3.6 mm 4.7 x 3.6 mm
Total Pixels	**307,000**
Pixel Size	**7.4 x 7.4 microns**
Full Well Capacity	**20,000e^-**
Dark Current	**5e^-/pixel/sec at 0° C**
Antiblooming	**Fixed 100x**

$ 1295.00

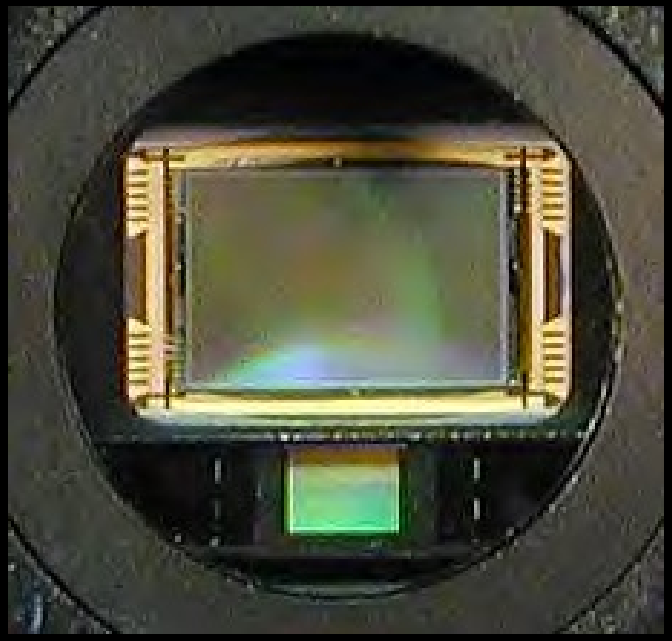
Moon. 0.1 second Model ST-237 image taken at the prime focus of a Celestron C-8. *Courtesy Nuno Costa*

Jupiter. Taken in near IR with the ST-237on 12/10/98. *Courtesy Brian Colville*

Horsehead & Flame Nebula in Orion Taken with Short Tube 80 mm Backyard, Eugene, Oregon with the ST-237a *Courtesy Sam Pitts*

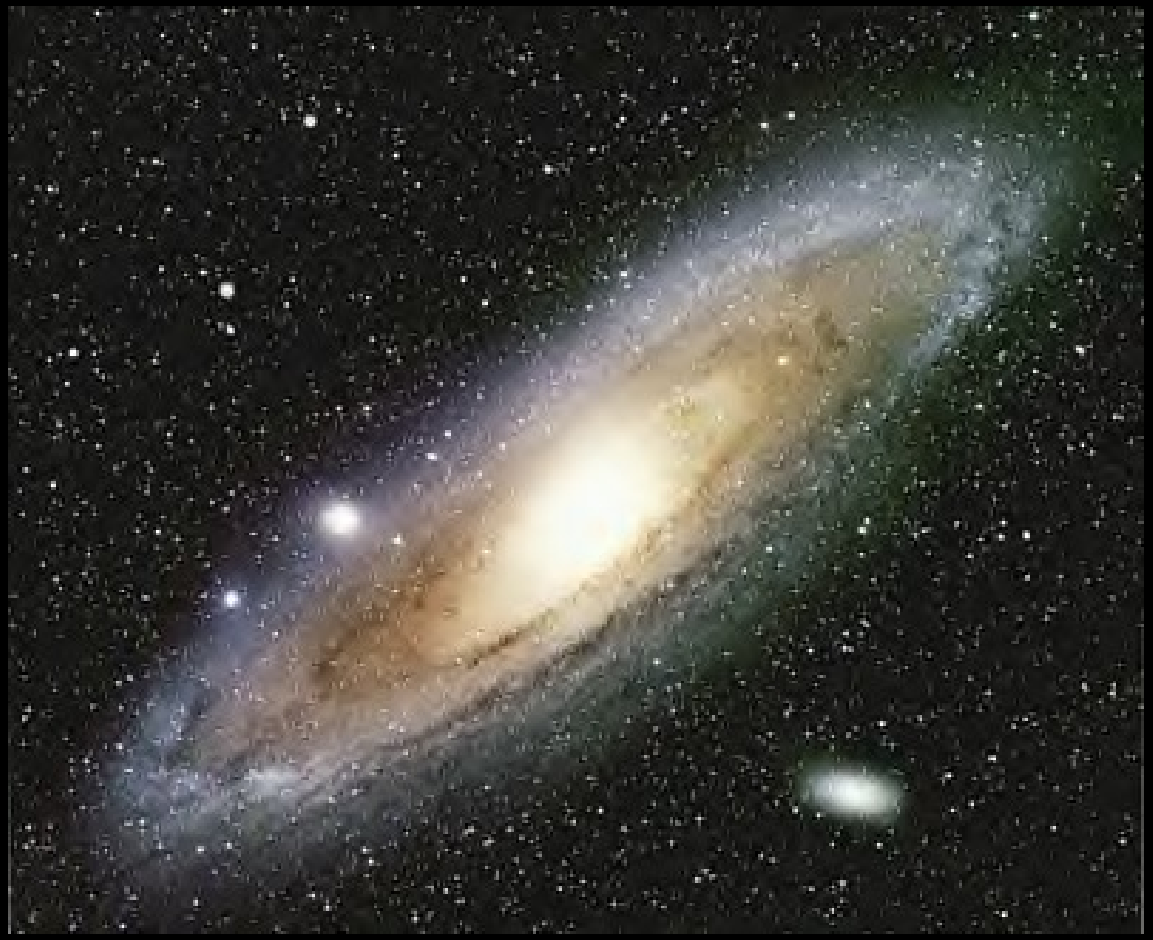
M42. Color LRGB image taken with an ST-237 camera equipped with an internal color filter wheel. Each LRGB frame is an 8 x 15 second Track & Accumulate exposure through an 8" Fastar telescope at F/1.95. *Courtesy Chris Anderson*

SBIG: ST 7E, 8E, 9E, 10E, 2000XM



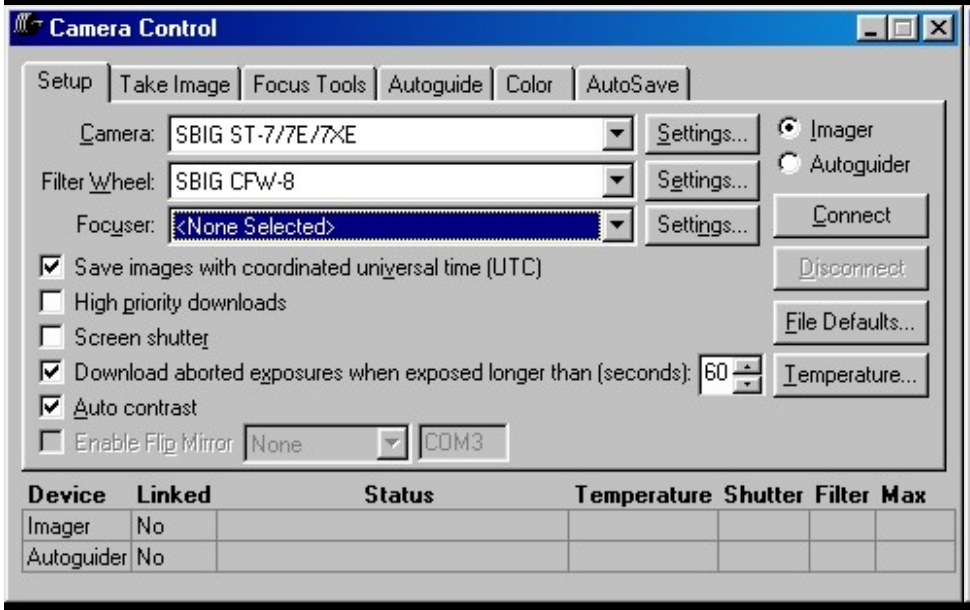
ST-7E 3.1” Refractor F/6.4

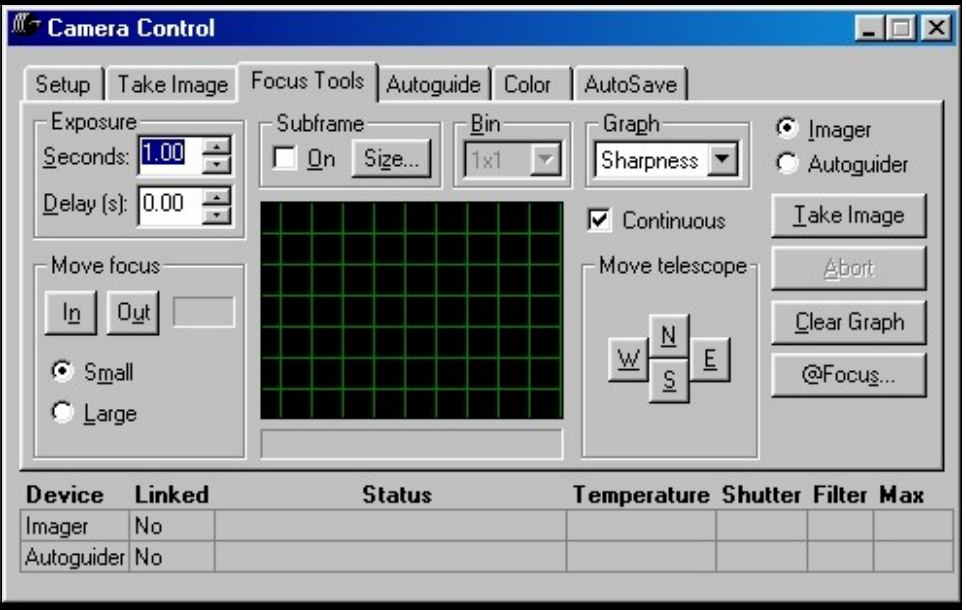
ST-8E

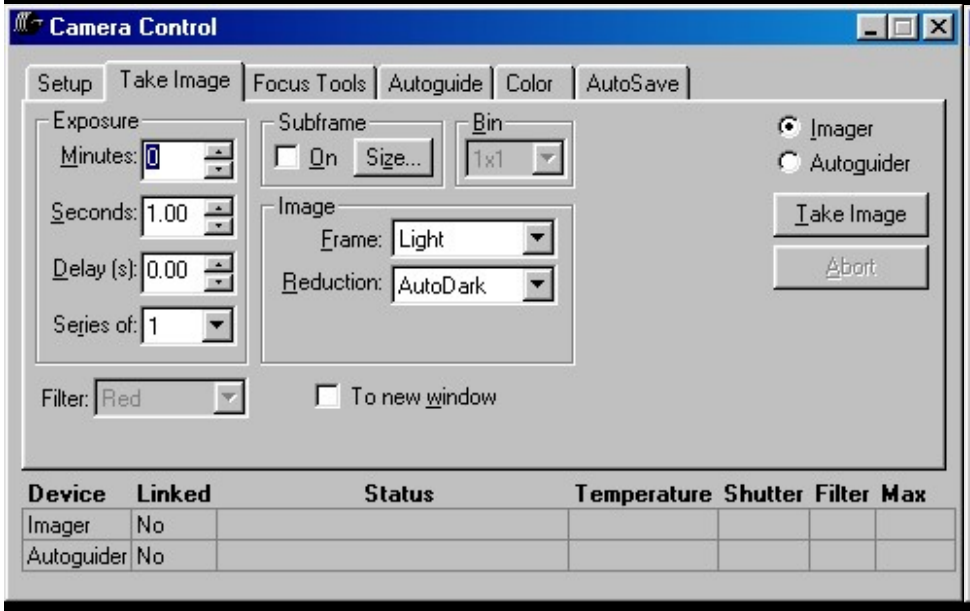


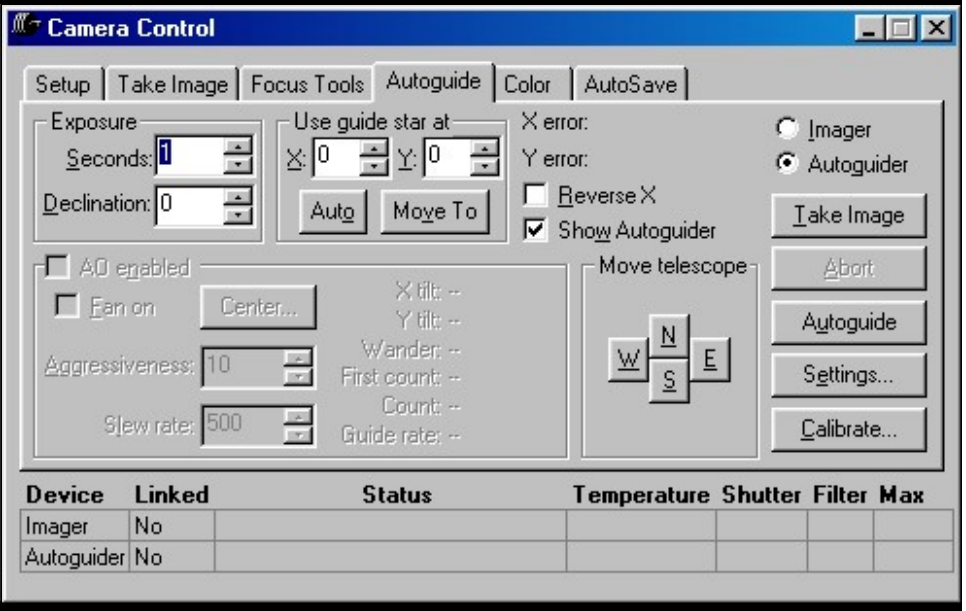
M31. ST-8E two image mosaic of Andromeda galaxy taken through a 4" refractor using a CFW8 filter wheel. ***Courtesy Robert Gendler***

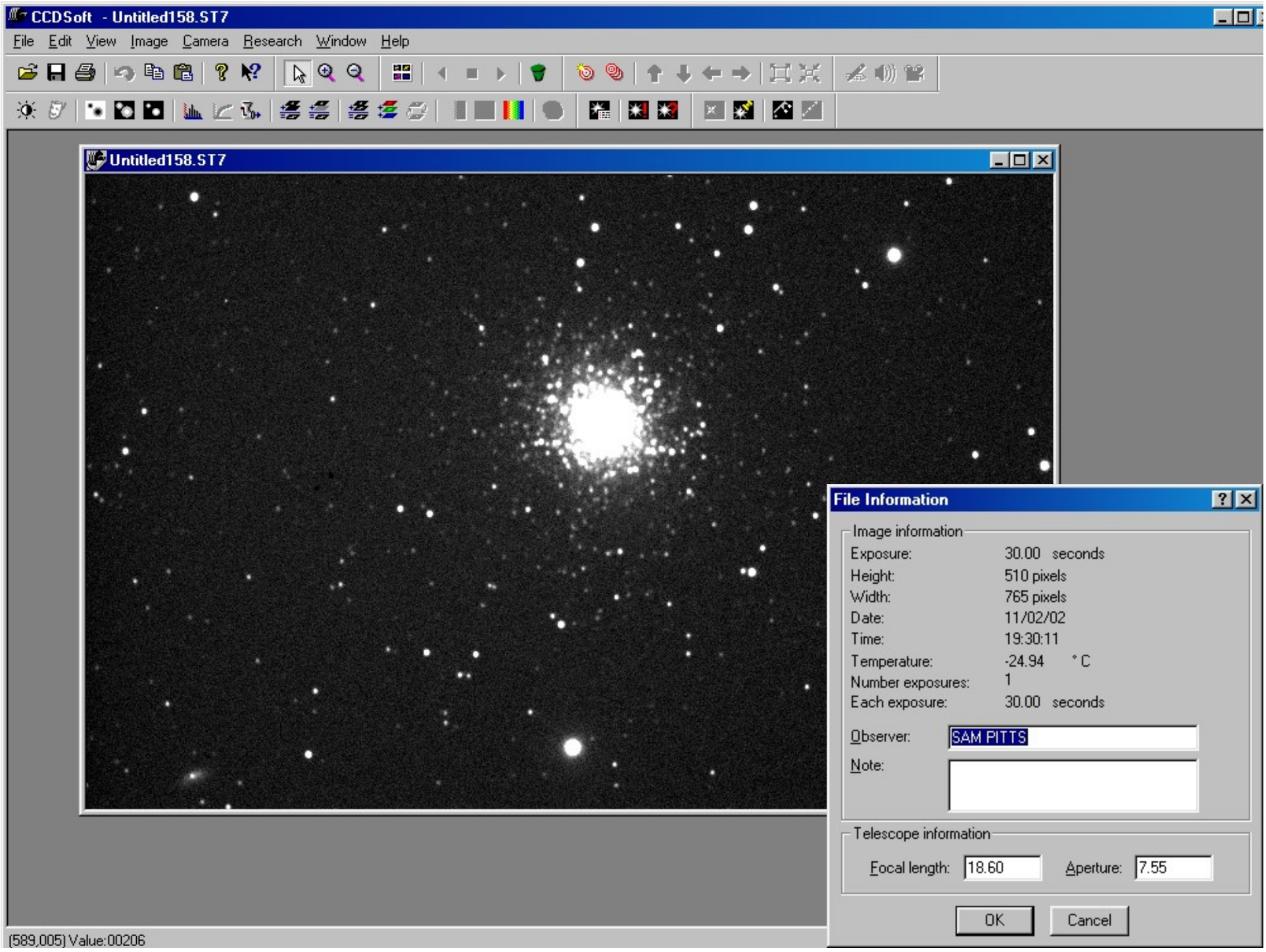
CCD Soft

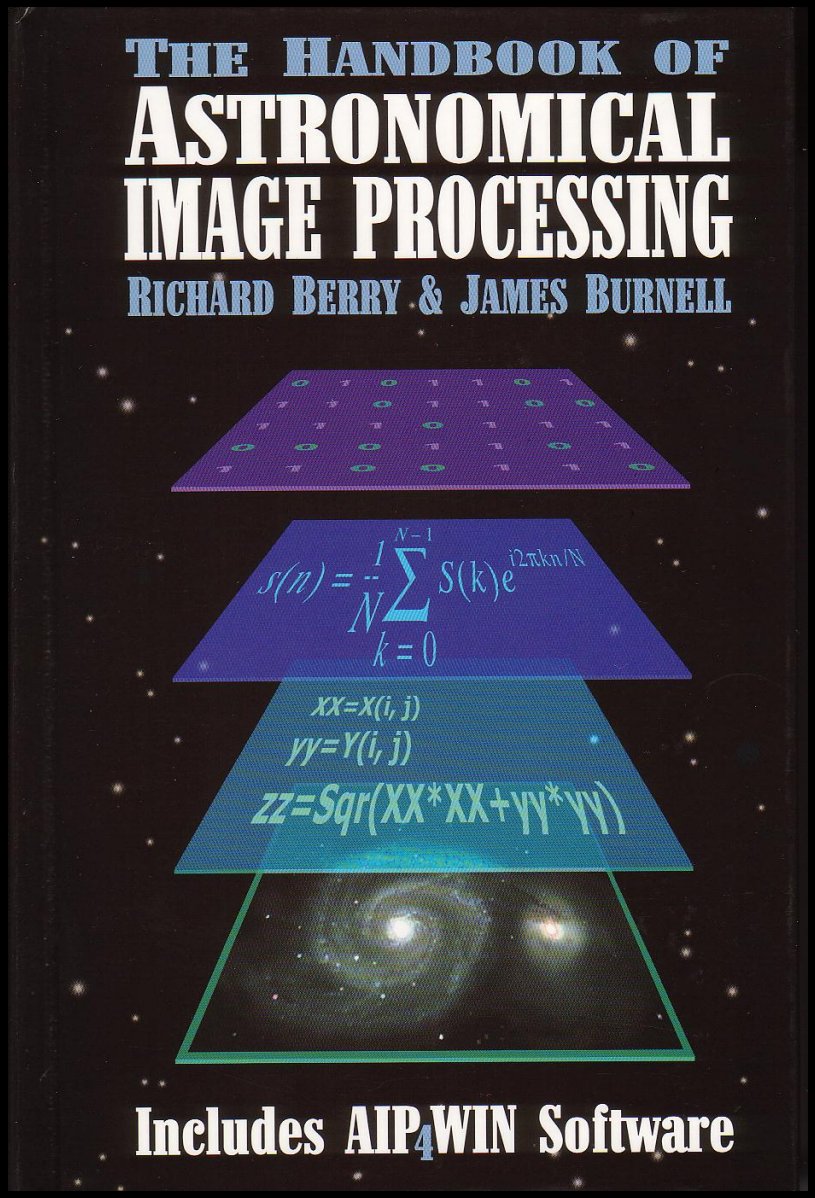

Camera Control
Setup
Take Image
Focus Tools
Autoguide
Color
AutoSave
Camera: SBIG ST-7/7E/7XE
Settings...
Filter Wheel: SBIG CFW-8
Settings...
Focuser: <None Selected>
Settings...
Imager
Autoguider
Connect
Disconnect
File Defaults...
Temperature...
Save images with coordinated universal time (UTC)
High priority downloads
Screen shutter
Download aborted exposures when exposed longer than (seconds): 60
Auto contrast
Enable Flip Mirror
None
COM3
Device Linked Status Temperature Shutter Filter Max
Imager No
Autoguider No

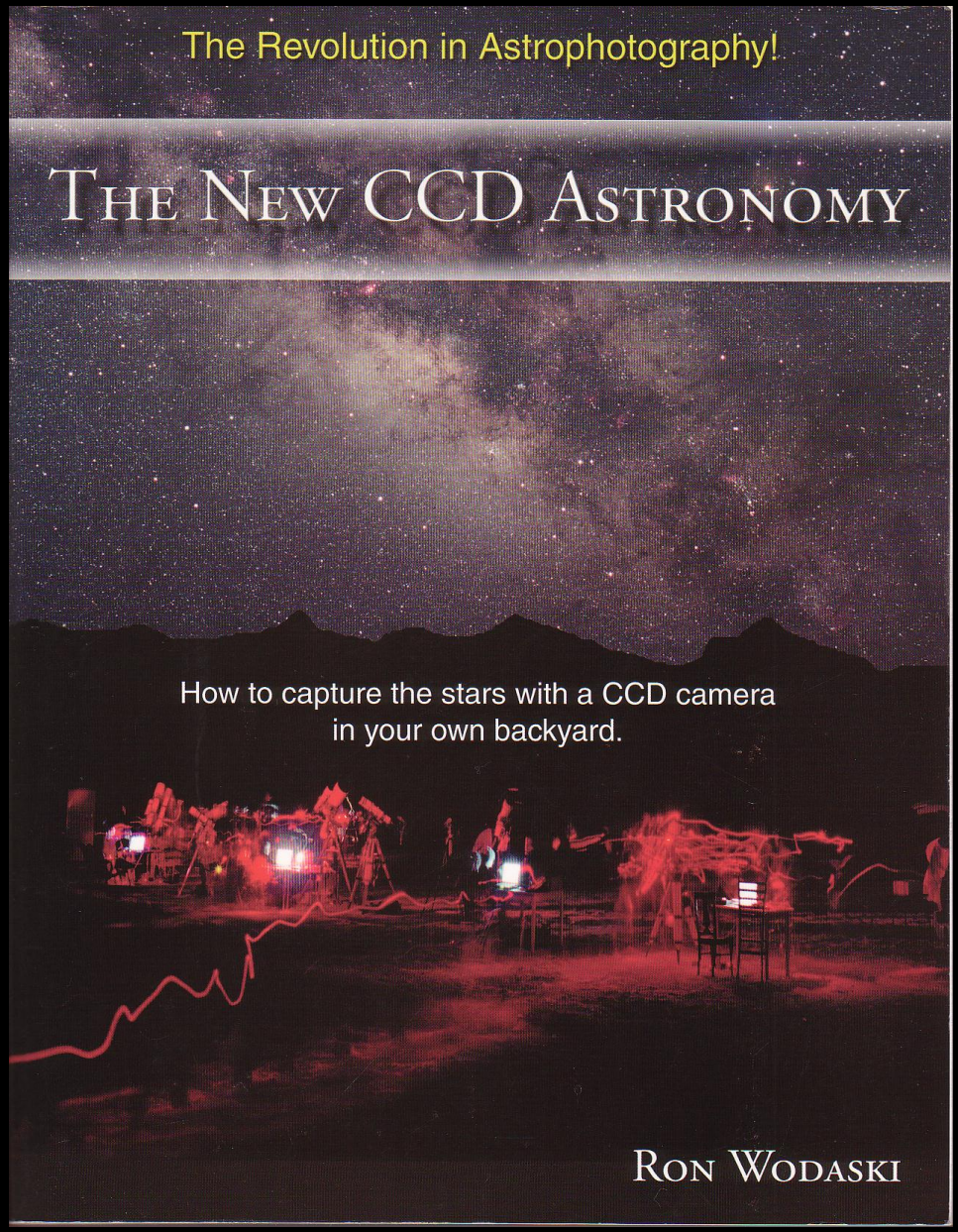

Camera Control
Setup
Take Image
Focus Tools
Autoguide
Color
AutoSave
Exposure
Seconds: 1.00
Delay (s): 0.00
Subframe
On
Size...
Bin
1x1
Graph
Sharpness
Imager
Autoguider
Continuous
Take Image
Abort
Clear Graph
@Focus...
Move focus
In
Out
Small
Large
Move telescope
N
W
E
S
Device Linked Status Temperature Shutter Filter Max
Imager No
Autoguider No


Camera Control
Setup
Take Image
Focus Tools
Autoguide
Color
AutoSave
Exposure
Minutes: 0
Seconds: 1.00
Delay (s): 0.00
Series of: 1
Subframe
On
Size...
Bin
1x1
Image
Frame: Light
Reduction: AutoDark
Imager
Autoguider
Take Image
Abort
Filter: Red
To new window
Device Linked Status Temperature Shutter Filter Max
Imager No
Autoguider No


Camera Control
Setup
Take Image
Focus Tools
Autoguide
Color
AutoSave
Exposure
Seconds: 1
Declination: 0
Use guide star at
X: 0
Y: 0
Auto
Move To
X error:
Y error:
Reverse X
Show Autoguider
Imager
Autoguider
Take Image
Abort
Autoguide
Settings...
Calibrate...
AO enabled
Fan on
Center...
Aggressiveness: 10
Slew rate: 500
X tilt: --
Y tilt: --
Wander: --
First count: --
Count: --
Guide rate: --
Move telescope
N
W
E
S
Device Linked Status Temperature Shutter Filter Max
Imager No
Autoguider No


CCDSoft - Untitled158.ST7
File Edit View Image Camera Research Window Help
Untitled158.ST7
File Information
Image information
Exposure: 30.00 seconds
Height: 510 pixels
Width: 765 pixels
Date: 11/02/02
Time: 19:30:11
Temperature: -24.94 ° C
Number exposures: 1
Each exposure: 30.00 seconds
Observer: SAM PITTS
Note:
Telescope information
Focal length: 18.60
Aperture: 7.55
OK
Cancel
(589,005) Value:00206


THE HANDBOOK OF
ASTRONOMICAL
IMAGE PROCESSING
RICHARD BERRY & JAMES BURNELL
$s(n) = \frac{1}{N}\sum_{k=0}^{N-1} S(k)e^{i2\pi kn/N}$
XX=X(i, j)
yy=Y(i, j)
zz=Sqr(XX*XX+yy*yy)
Includes AIP4WIN Software


The Revolution in Astrophotography!
THE NEW CCD ASTRONOMY
How to capture the stars with a CCD camera
in your own backyard.
RON WODASKI