An Introduction To DSI Imaging

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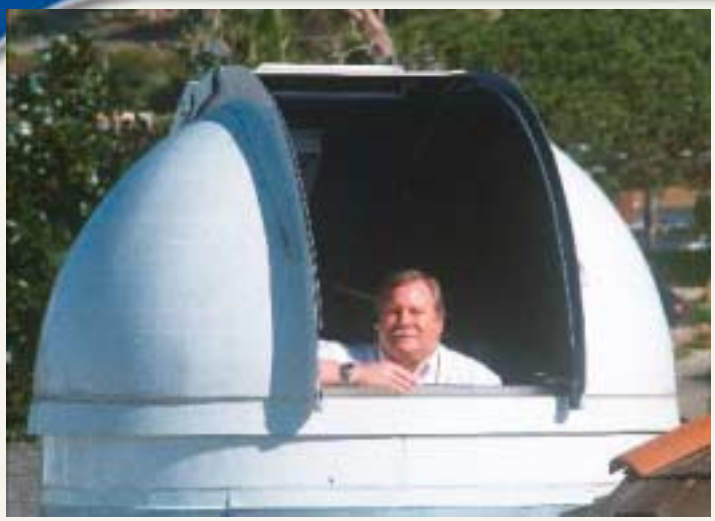

John E. Hoot

President

Software Systems Consulting

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The DSI for Autostar Suite

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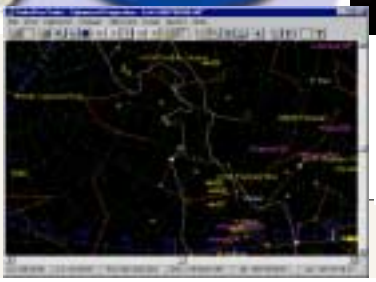

Not Just A Project, A Mission

John E. Hoot

System Architect

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DSI - Easy and Affordable CCD Imaging

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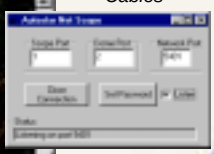
Complete! No Integration Hassles

Software

Cables



Networking

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"Turn You PC and Meade Telescope Into An Observatory"

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Network Connection

- Complete Control
- Remote Networking
- Planetarium
- Charting
- Planning
- Logging
- Catalogs
- Imaging
- Auto Guiding
- Autostar Authoring

Autostar Telescope
Imagers
Guiders

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Setup, Connect, Control And Image!!!

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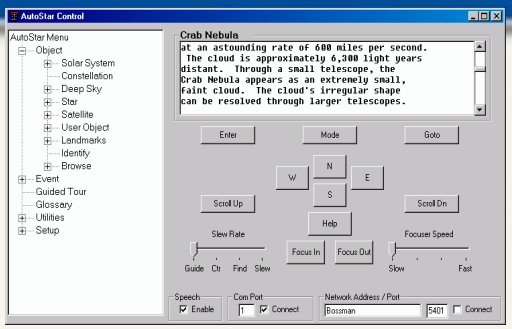
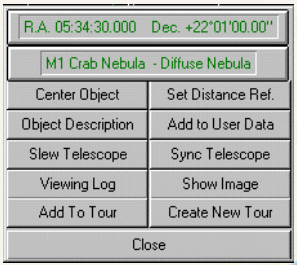


Complete Control: Show and Tell



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Comparisons

	$299	$2495	$6695	$1999	$??????
	Meade DSI	SBIG ST-7XME (*)	SBIG ST 402ME (*)	Apogee AP1E (**)	Professional Camera (Typ)
Gain (e-/ADU)	0.74	2.6	0.7	Not Specified	2.5
Read Noise (e-)	13	15	17	13-15	< 5 (10 µs/pix)
Typ. Non-Linearity (%)	<5	N.S.	N.S.	N.S.	<0.1
Full Well (e-)	50000	50000	100000	80000	120000
Dark current (e-/pix/sec)	2.8 (300 K)	1 (273 K)	1 (273 K)	50 (300 K)	0.002 (160 K)
Dynamic Range (e-), for NL < 5%	~18000	N.S.	N.S.	N.S.	~120000

(*): Specs from SBIG web page.
(**): Specs from Apogee web page
(***): we were unable to get info on the full well, and we were unable to measure it since the limitations stated on the interface (basically we were unable to saturate the array gradually to describe the saturation curve)

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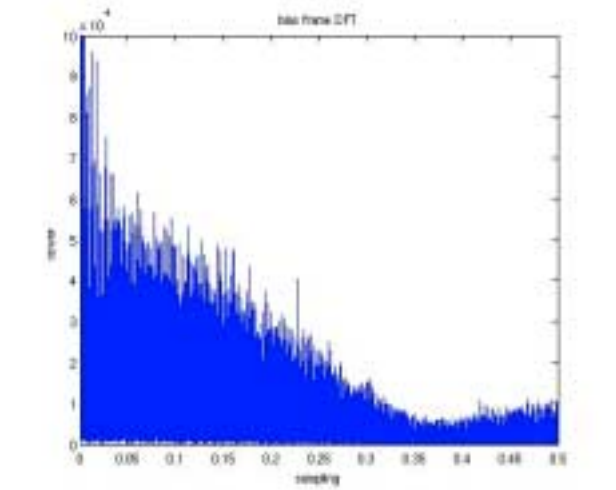
Low System Noise



Discrete Fourier Transform (DFT)

The DFT shown was done for a bias frame (minimum exp., no light) Since we do not know the sampling time (pixel read time), the X axis shows the values relative to this unknown (for us) number. The value of 1 would be the actual pixel time. The graph. shows the maximum frequency that it is possible to sample (Nyquist frequency)

The big DC component decaying with frequency is due to the CCD line transfer; basically all the noise is dominated by this. This is good in the first approach, since it is telling that there is no other dominating noise on the system. However, it is not possible to separate the controller from the Detector noise (we would need to take apart the detector and test the external electronic only, and possibly readout the detector without clocks to avoid the line transfer noise floor)

Read Noise
We did the simplest calculation for read noise: using a set of bias frames (0 exposure, no light), we applied the previously obtained gain, and calculated the rms value of the noise
RN ~ 13 e- rms

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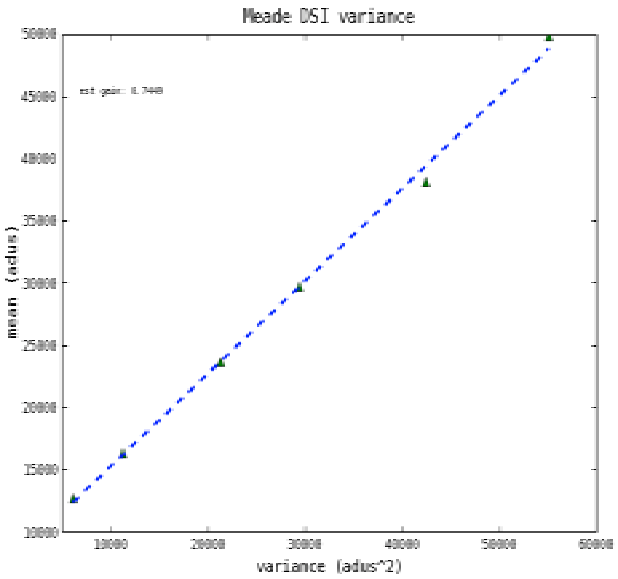
Linear Photon-Transfer Curve



Note that the maximum
flux tried was around 30000 ADUs,
(a bias frame, subtracted for zero-point correction, generated around 4000 ADUs)
At which point it may already be showing some signs of early saturation.

We were unable to get higher exposure times. The interface problems are explained at the end.

From this curve, then

Gain: **0.74 e-/ADU**

This value includes both detector and controller (external electronics) gain.

We will use this value for all the following numbers, which, unless noted, will be given on electrons (e-)

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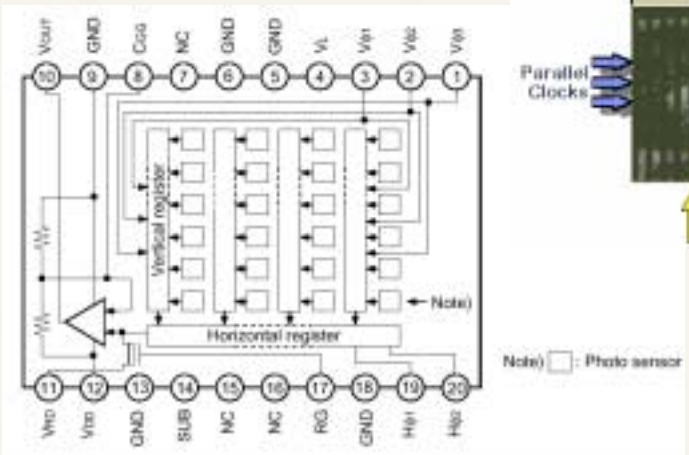
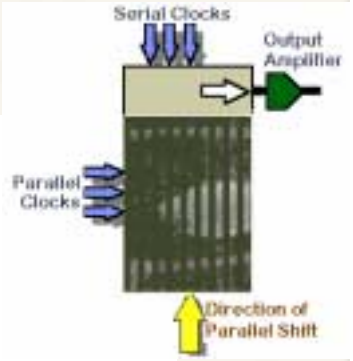
uLensed Interline CCD Chip

uLenses of High Effective QE
Simultaneous Integrate and Readout





Note) : Photo sensor

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Simple One Shot Color

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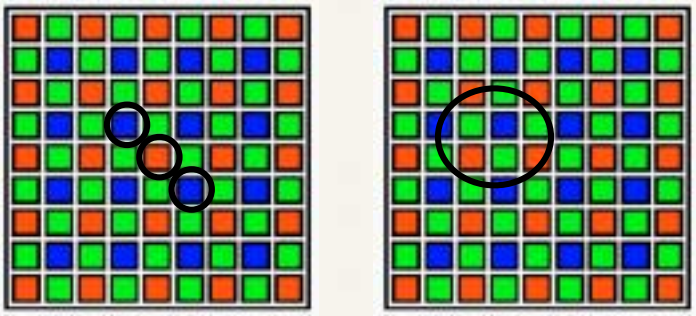
Drizzle Exploits Diversity To Double Resolution and Simplify Mosaicing



In Time

In Space

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Or Monochrome w/ Filters

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Equivalent In Performance To 2.3 Meg Pix Color Sensors Before Drizzle
9 Meg Pix w/ Drizzle

DSI Pro

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The DSI Family

DSI Family

Imager	Price	Type	Pixels	Chip Size
DSI	$299	One Shot Color	505x484	4.8mm x 3.6mm
DSI Pro	$399	Mono w/Ext IR Sensitivity	505x484	4.8mm x 3.6mm
DSI Pro w/ Filters	$499	Mono w/Ext IR Sensitivity	505x484	4.8mm x 3.6mm
DSI II	$599	One Shot Color	752x584	6.4mm x 4.8mm
DSI II Pro	$599	Mono w/Ext IR Sensitivity	752x584	6.4mm x 4.8mm
Dsi II Pro w/Filters	$699	Mono w/Ext IR Sensitivity	752x584	6.4mm x 4.8mm

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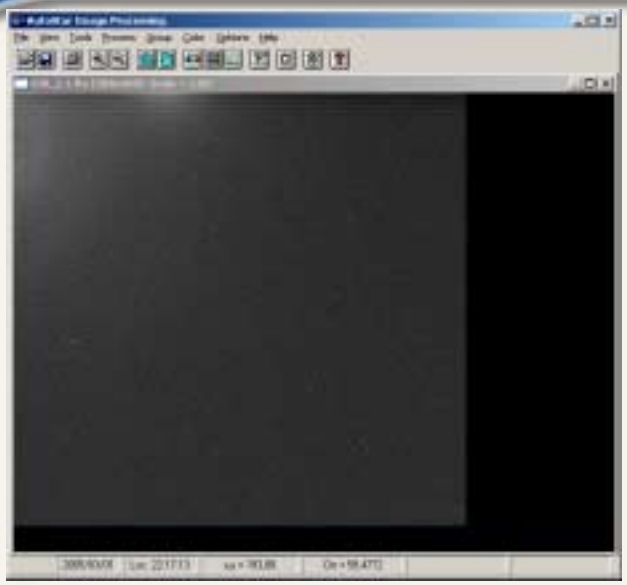
Cool Math - Not Hot Parts



Before Dark Subtraction

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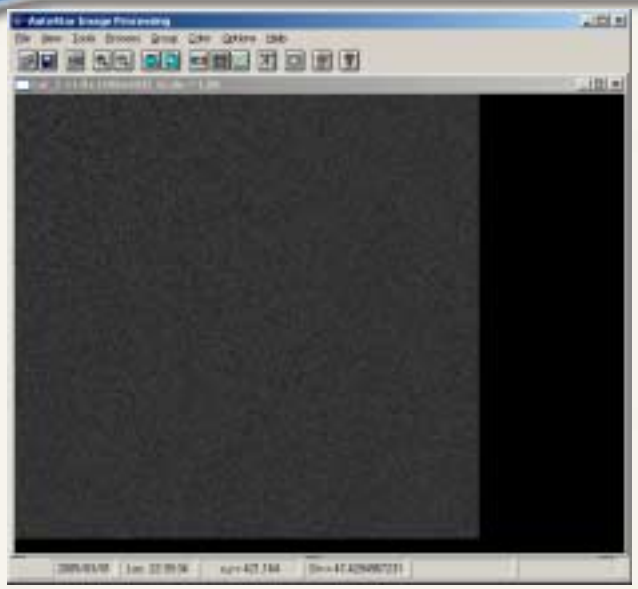
Cool Math - Not Hot Parts



After Dark Subtraction

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It Is Cool To Be Uncooled

You will hit sky limits long before dark current matters!

	DSI Camera	SBIG ST7
Full Well Capacity	50,000 electrons	50000 Electrons
Dark Rate	2.8 electrons/sec.	1.0 Electrons / sec.
Time To Fill Half The Well	148 minutes	416 minutes

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The Magic Is In The Software

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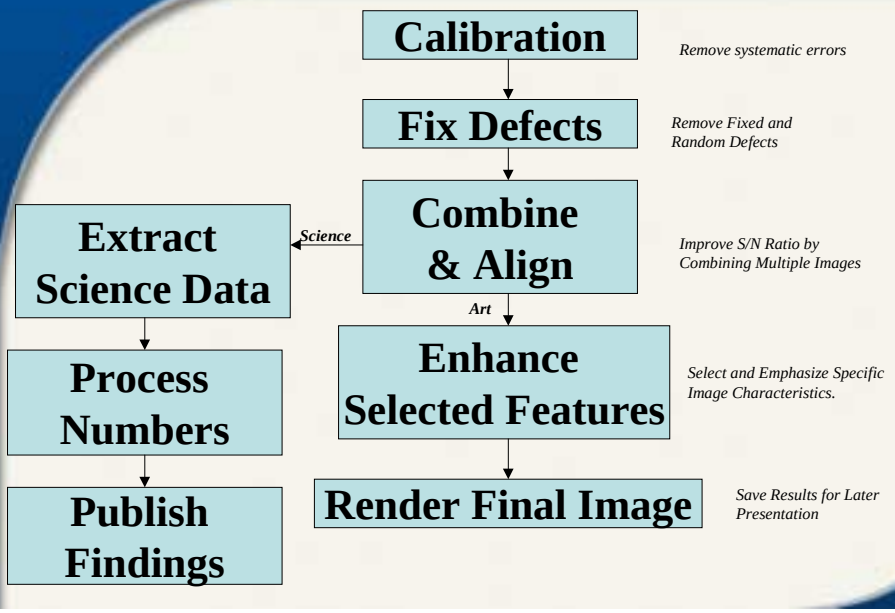
The Astro-Imaging Process



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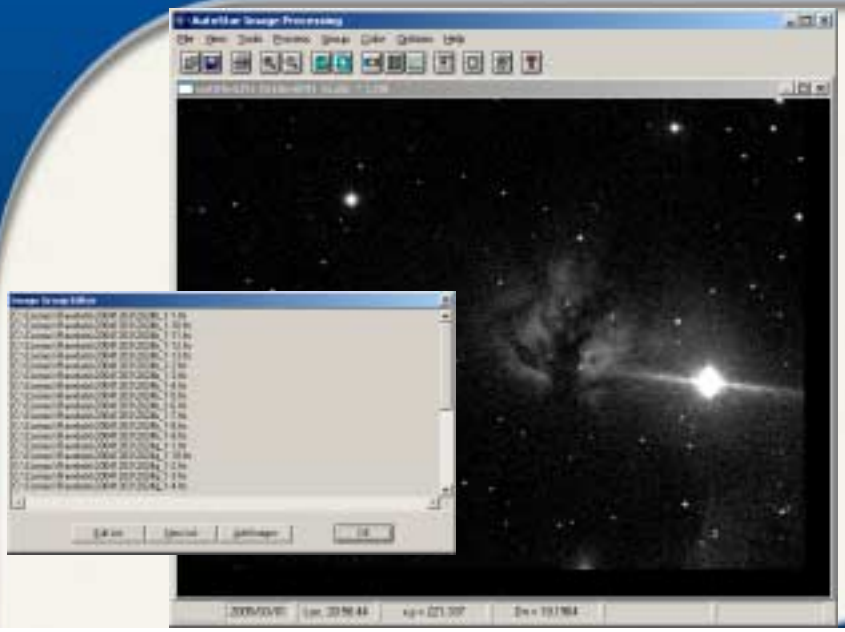
“Quantity Has A Quality All Its Own”

-Josef Stalin



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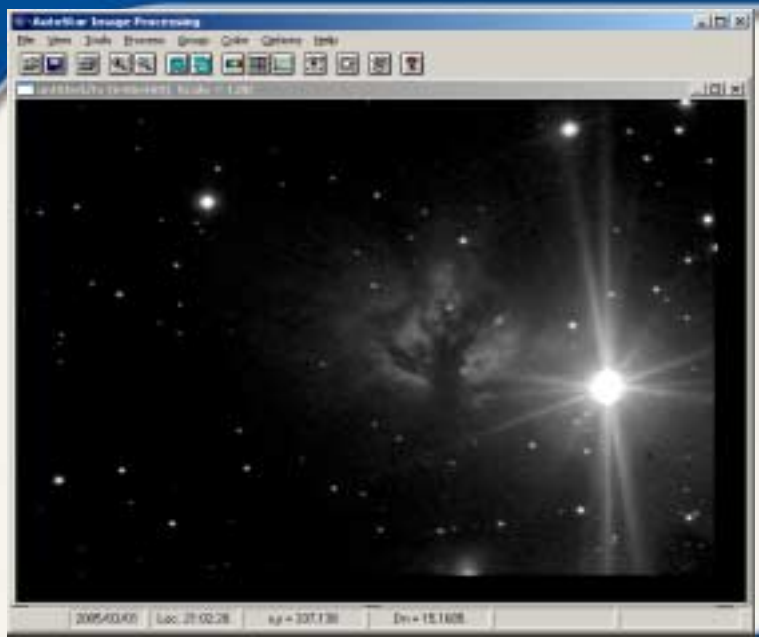
Noise Averages to 0!



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Why It Works

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Assuming all noise is from system read noise:

$$S/N(exposure(T)) = X$$

Increasing exposure time proportionately reduces noise

$$S/N(exposure(mT)) = mX$$

Dark current and limited dynamic range limit exposure time

$$S/N(m \times exposure(T)) \simeq \sqrt{m}\, X$$

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Cooled Imager Comparison

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Assume:

- •Thermal and range considerations limit your imager to 10 second maximum exposures.
- •Your QE is 1/2 the filtered cooled imager's.
- •You take 3 colors at once.
- • Read Noise Performance is Equivalent

How Many Exposures to Equal 3 One Minute Filtered Cooled Imager Exposures?

$$where \;\; S/N_{cooled}(exposure(60)) \simeq X$$

$$S/N_{uncooled}(exposure(10)) \simeq \frac{X}{12}$$

$$Time_{cooled} = \; 3 \times 60 = 180sec. = 3min.$$

$$Time_{uncooled} = \; 12^2 \times 10 = 1440sec. = 24min.$$

$$Time_{uncooled} = \; 4^2 \times 30 = 480sec. = 8min.$$

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Making Good DSI Images

- Use Fast Optical Systems (<f6)
- Focus Obsessively
- Let The Camera Temperature Stabilize
- Carefully Align Your Scope
- Train Your Drive With DSI
- Take Darks(9+) Before Beginning Imaging
- Us Auto Dark
- Use The Longest Exposure Possible
- Use the “Color Sharp/Daylight” Setting
- Pick An Unsaturated Alignment Star
- Always Save As Fits/Fits3P
- Post Process In Autostar IP

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Fields of View

DSI Fields Of View

(Arc Minutes)

Focal Len (mm)	Instrument Setup	DSI		DSI w/ Drizzle		DSI II		DSI II w/ Drizzle	
		X	Y	x	Y	X	Y	X	Y
35	Photo Lens	469	351	937	703	622	527	1243	1054
50	Photo Lens	329	247	658	494	438	370	875	740
135	Photo Lens	122	92	244	183	163	137	326	275
160	Apo w/ f.33	103	77	206	155	137	116	275	232
302	Apo w/f.63	55	41	109	82	73	61	146	123
330	LXD 75 w/f.33	50	38	100	75	67	56	133	113
630	LXD 75 w/f.63	26	20	52	39	35	29	70	59
673	LX90 8" w/f.33	25	18	49	37	33	28	65	55
1000	LXD 75 Prime Foc	17	12	33	25	22	19	44	37
1280	LX90 8" w/f.63	13	10	26	19	17	15	34	29
2032	LX90 8" Prime Foc	8	6	16	12	11	9	22	18

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M83 - Step By Step

RCX400 12” @ f2.9 27x30 Sec = 13.5min

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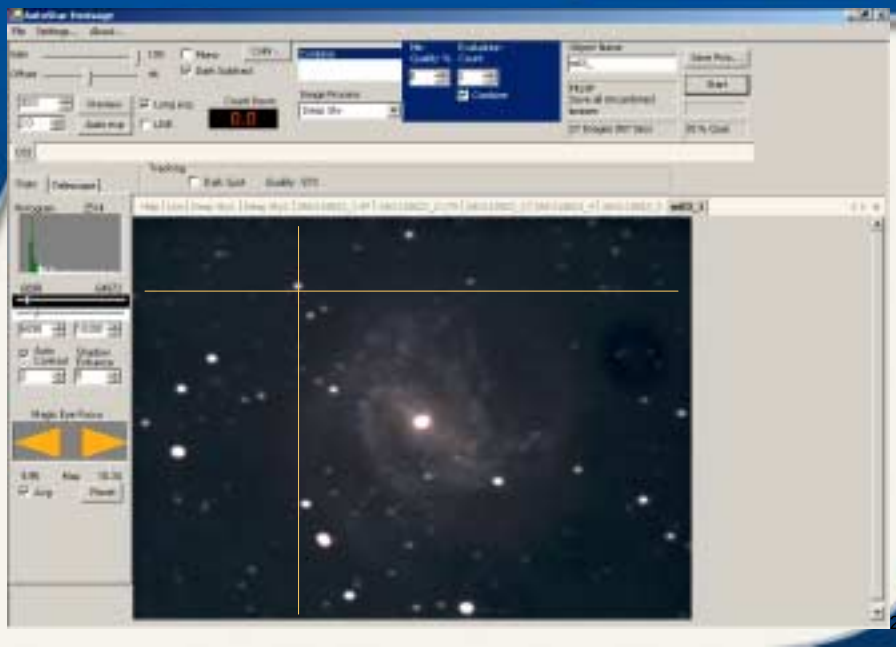
M83-Step By Step



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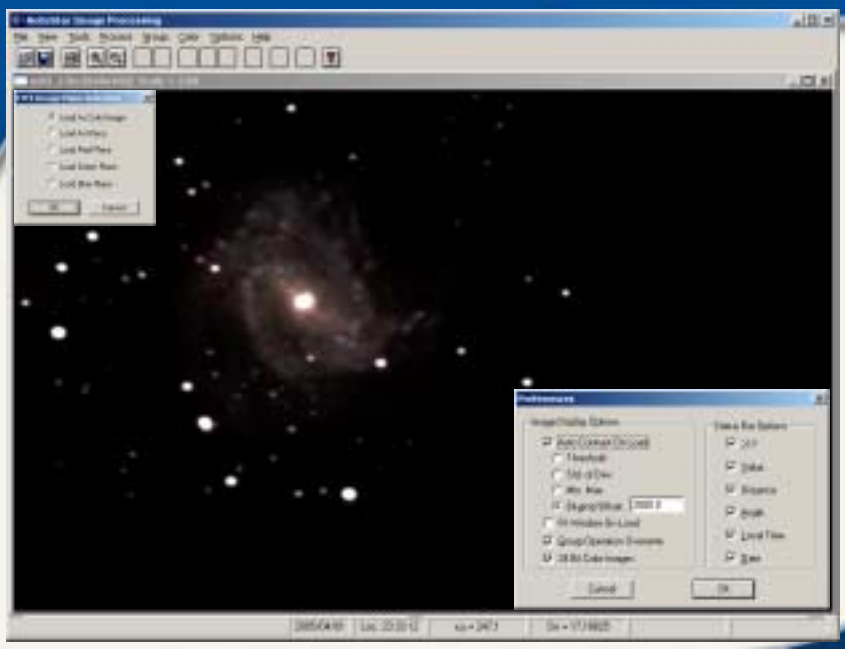
M83-Step By Step



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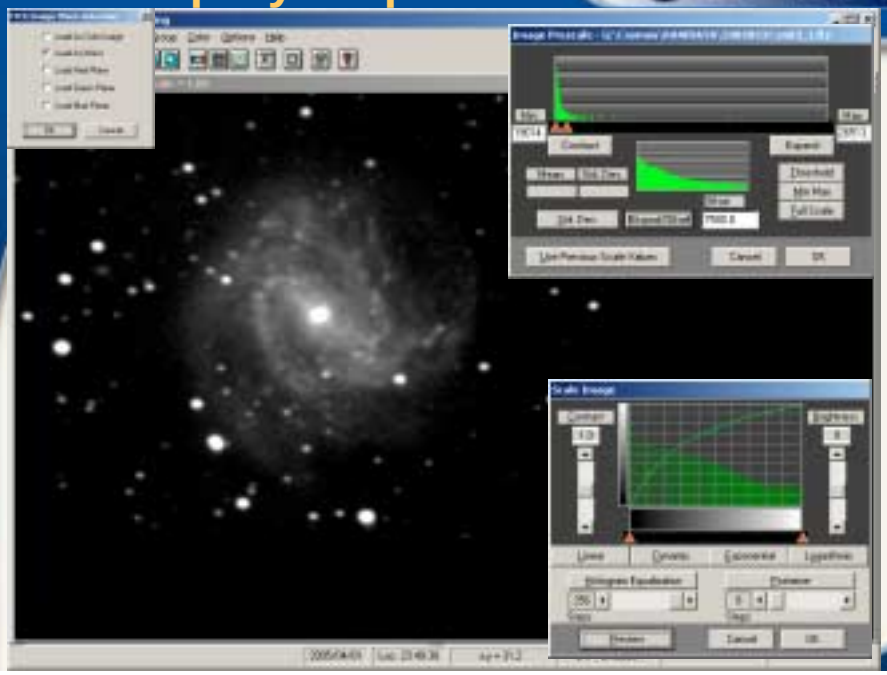
M83 - Step By Step



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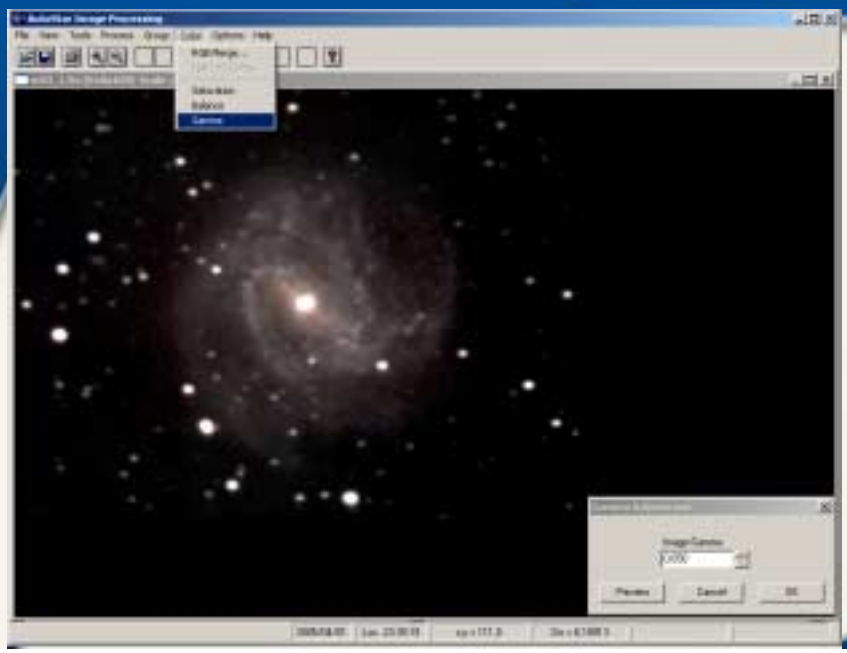
M83 - Step By Step



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M83 - Step By Step

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M83 - Step By Step

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M27 - Dumbbell Nebula

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Core Of NGC 253

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Making Great DSI Images

- Use Fast Optical Systems (<f6)
- Focus Obsessively
- Let The Camera Temperature Stabilize
- Carefully Align Your Scope
- Train Your Drive With DSI
- Take “Image” Darks Before & After Object
- Do not use “Auto Darks”
- Use The Longest Exposure Possible
- Save all “RAW” intermediate Images
- Always Save As Fits/Fits3P
- Do ALL Processing In Autostar IP w/ Groups
- Final Retouching in Photo Shop, Corel Paint...

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NGC 2237 - Rosette Nebula

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Don’t Forget Planets

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For Great Planets

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- Use Long Focal Lengths ~ 6000mm
- Focus Even More Obsessively
- Wait For Good Seeing & Light Winds/Late Evening
- Let The Camera Temperature Stabilize
- Carefully Align Your Scope
- Train Your Drive With DSI
- Do not worry too much about darks
- Watch The Histogram. Do not saturate.
- Set Balance to “Color Sharp Daylight”
- Set “Evaluation Count” & “Threshold” High
- Always Save As Fits/Fits3P
- Post Processing In Autostar IP
  - Unsharp Masking
  - Convolution Filters
  - Color Saturation
  - Color Balance
  - Dust Flats
- Final Retouching in Photo Shop, Corel Paint...

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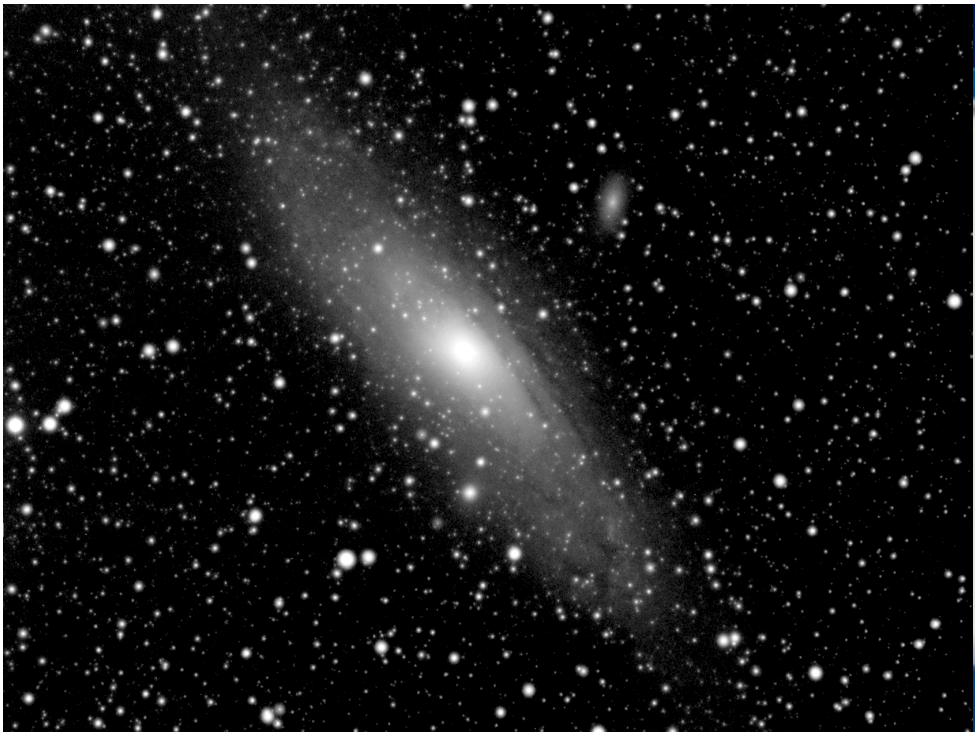

IC484 - Zeta Orionis Region

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M1 - Crab Nebula

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IC5146

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M16 - Eagle Nebula

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M17 - Swan/Omega Nebula

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M51 - Whirlpool Nebula

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M64 - Black Eye Galaxy

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M82

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M81

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M101

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