

White Balancing RGB Filters with a G2V Star

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Why White Balance?

Because “true color” requires balanced RGB signal-to-noise ratios

- Non-flat CCD quantum efficiency (QE) curves result in uneven RGB filter responses to white light, unless the RGB filter transmittances are specifically tailored to a chip's QE curve
- Uneven RGB responses mean imbalanced signal-to-noise ratios (SNRs) from white-light sources when equal exposure times are used for RGB data acquisition
- “Truer,” more esthetic RGB color composites derive from balanced RGB SNRs, so we need a method to determine RGB exposure times which provide that balance

Balanced RGB SNRs are important! Following are RGB composites of globular cluster M56 made from an imaging system where R:G:B transmittance = 0.6 : 1.0 : 0.75; that is, 5 units of red, 3 units of green, and 4 units of blue are required for white balance.

NOTE: All layers in each image were stretched equally, with a gamma of 10. Backgrounds were balanced.



R:G:B = 2:3:4 minutes

Low red SNR results in stars that are too cyan



R:G:B = 4:3:2 minutes

Low blue SNR results in stars that are too red/yellow



R:G:B = 5:3:4 minutes
Balanced SNR star color is "true"

Applying a simple pixel value multiplier to a layer to offset its low QE position in the R:G:B ratio does not change the SNR deficit:

R:G:B = 2:3:4



R:G:B = 2:3:4, R x 2.5

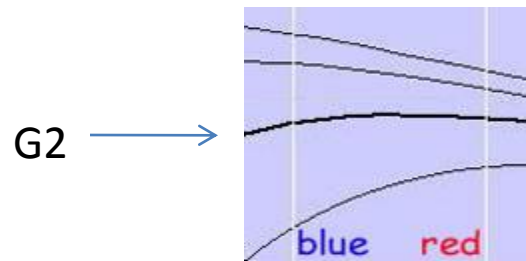


Nonlinear stretches of gamma=10 were applied to all layers of each image. Backgrounds were equalized.

Balanced SNRs are key to a white-balanced result

Why use G2V Stars for White Balancing?

1. Our sun is a G2V star and is our reference for white light
2. Although the sun is often seen as a yellow star, this is primarily due to atmospheric extinction, which scatters blue wavelengths more than red wavelengths, making the sun look yellow to red, depending on the sun's altitude, atmospheric contaminants, and water vapor content
3. The sun's black-body radiation curve does peak in the light-yellow (which is why it is called a yellow star in astronomy), but it best represents an even distribution of wavelengths across the visible spectrum:



“The vertical lines represent the range of visible light, from blue and violet (on the left) to red (on the right). The curves, from lowest to highest, represent temperatures of 3000, 5780, 12000 and 24000 Kelvins. Cooler bodies radiate more in the red and infrared, and hotter bodies in the violet and ultraviolet.”

Graph and caption from: <http://cseligman.com/text/sun/blackbody.htm>

Although there are relatively small percentage differences in the R:G:B ratios derived from extinction-corrected photometry of stars with photospheric temperatures from about 4500K to 8000K, a G2 star is the best standard for our purposes.

Acquiring and applying proper G2 calibration data for RGB filters is quick and easy with the following procedure:

1. Use a sky that is nicely transparent. Seeing isn't critical, but steady transparency is!



This



Not this

2. Select a G2 star with a low zenith angle; that is, high in the sky, at least 50 degrees or so above the horizon. Although extinction corrections can be made for stars at any zenith angle, it is best to keep visibility good and corrections small

Example	Solar	Analog	Stars	
Right Ascension	Declination	Magnitude	Spectral Type	Name
00h 18m 40s	-08° 03' 04"	6.5	G3	SAO 128690
00h 22m 52s	-12° 12' 34"	6.4	G2.5	9 Cet
01h 41m 47s	+42° 36' 48"	5.0	G1.5	SAO 37434
01h 53m 18s	+00° 22' 25"	9.7	G5	SAO 110202
03h 19m 02s	-02° 50' 36"	7.1	G1.5	SAO 130415
04h 26m 40s	+16° 44' 49"	8.1	G2	SAO 93936
06h 24m 44s	-28° 46' 48"	6.4	G2	SAO 171711
08h 54m 18s	-05° 26' 04"	6.0	G2	SAO 136389
10h 01m 01s	+31° 55' 25"	5.4	G3	20 LMi
11h 18m 11s	+31° 31' 45"	4.9	G2	Xi UMa
13h 38m 42s	-01° 14' 14"	10.0	G5	SAO 139464
15h 37m 18s	-00° 09' 50"	8.4	G3	SAO 121093
15h 44m 02s	+02° 30' 54"	5.9	G2.5	Psi Ser
15h 53m 12s	+13° 11' 48"	6.1	G1	39 Ser
16h 07m 04s	-14° 04' 16"	6.3	G2	SAO 159706
16h 15m 37s	-08° 22' 10"	5.5	G2	18 Sco
19h 41m 49s	+50° 31' 31"	6.0	G1.5	16 Cyg A
19h 41m 52s	+50° 31' 03"	6.2	G3	16 Cyg B
20h 43m 12s	+00° 26' 15"	10.0	G2	SAO 126133
21h 42m 27s	+00° 26' 20"	9.1	G5	SAO 127005
23h 12m 39s	+02° 41' 10"	7.7	G1	SAO 128034

Extinction Correction Factors

EL	ZA	Air Mass	Rxc	Gxc	Bxc
90	00	1.000	1.000	1.000	1.000
80	10	1.015	1.001	1.002	1.003
70	20	1.064	1.005	1.010	1.014
60	30	1.155	1.013	1.025	1.035
55	35	1.221	1.018	1.036	1.050
50	40	1.305	1.025	1.050	1.070
45	45	1.414	1.034	1.068	1.097
40	50	1.555	1.046	1.092	1.132
35	55	1.743	1.063	1.125	1.180
30	60	2.000	1.085	1.172	1.249
25	65	2.365	1.118	1.242	1.356
20	70	2.923	1.170	1.356	1.535
15	75	3.862	1.263	1.574	1.892

3. Make several short, equal-duration exposures through each filter, making sure that no pixel saturation occurs (same as in taking flats)

The screenshot displays the 'Astronomical Image Processing for Windows' software interface. The main window shows a dark image of a star, identified as 'sa062484blue005.fit'. The 'Image Display Control' panel on the left includes a histogram, 'User Black/White' sliders (3432.66 to 3467.99), and gamma/zoom controls. The 'Image Status' panel on the right provides metadata for the image, including exposure time, date, and coordinates. The 'Star Image Tool' panel at the bottom right shows detailed star parameters.

Image Status

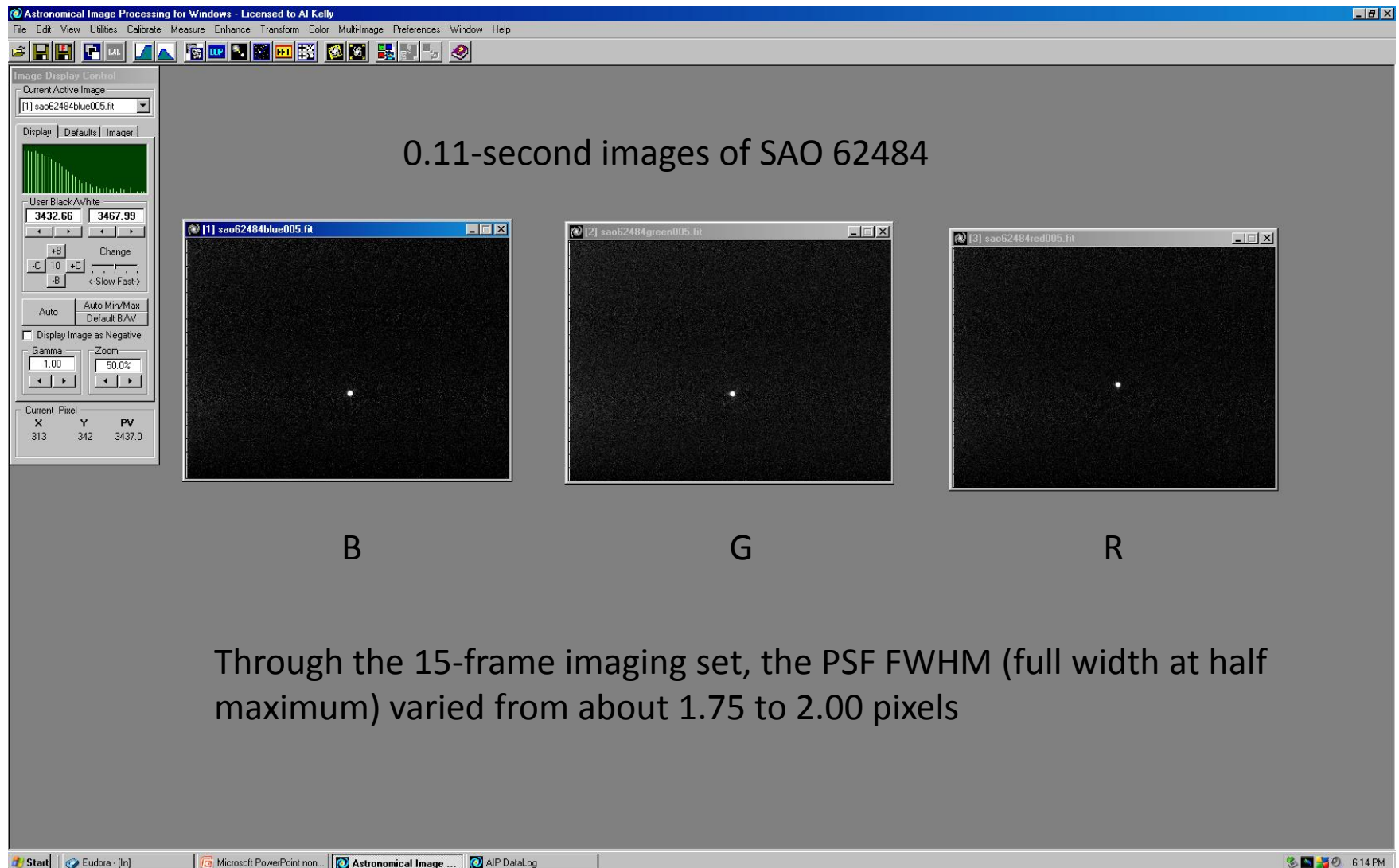
Statistics	Document	Display	Camera	Header
SIMPLE	=	T		
BITPIX	=	16		
NAXIS	=	2		
NAXIS1	=	752		
NAXIS2	=	580		
BZERO	=	32768.0		
EXPOSURE	=	0.11000000000000000		
TEMPERAT	=	0.0		
DATE-OBS	=	'2010-02-16T05:27:28.2' / UT		
JD	=	2455243.72741000000		
DATE-LOC	=	'2010-02-16T00:27:28.2' / LT		
AVISUMIN	=	3427.0		
AVISUMAX	=	3443.0		
AVISUTYP	=	0.0		
END				

Star Image Tool

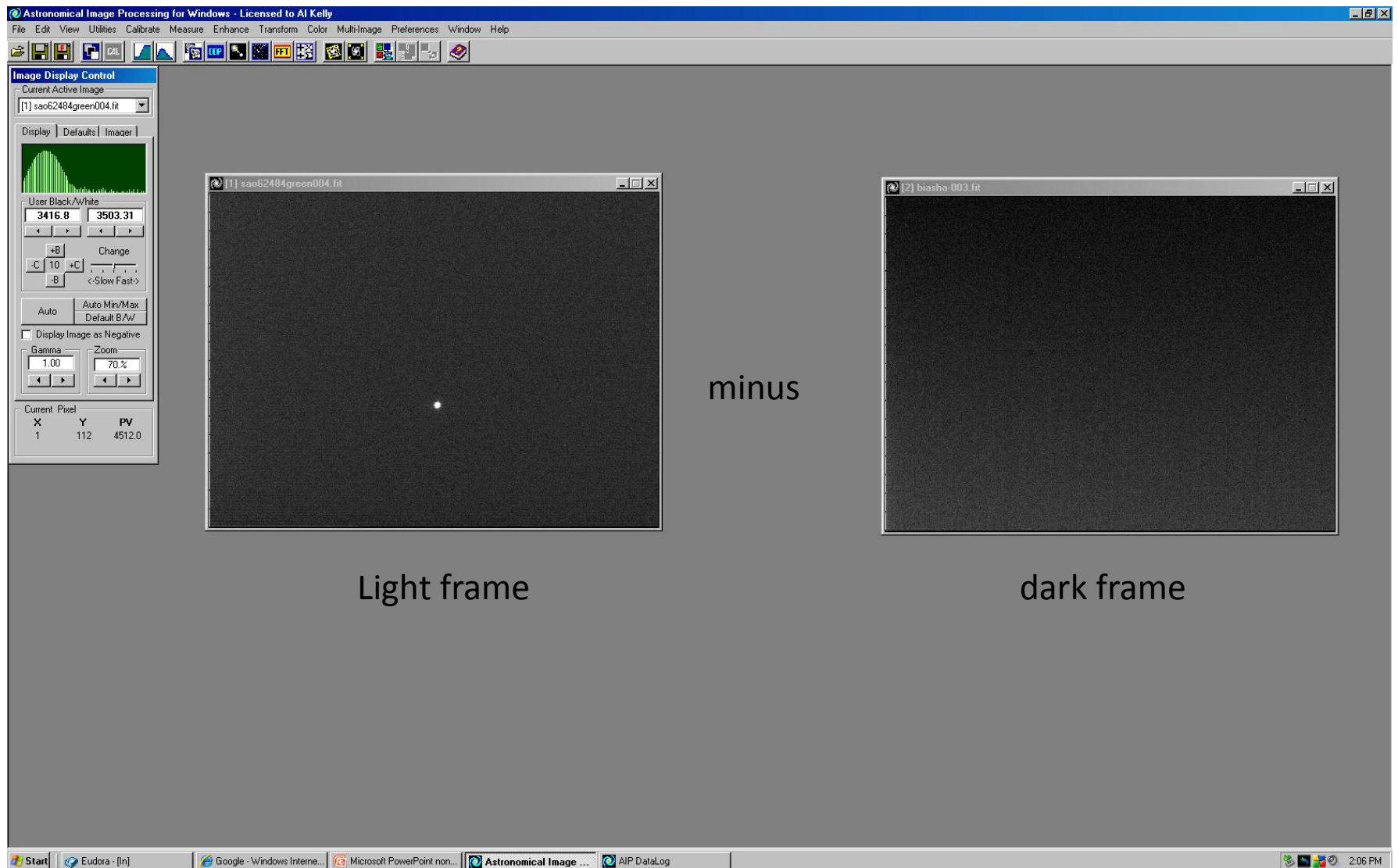
Result	Shape	Settings
Position		
Star X:	381.648	
Star Y:	373.072	
Size (in pixels)		
Sigma:	0.74	
FWHM:	1.74	
Peak Pixel Value		
PV max:	42552.0	
Brightness (in ADUs)		
Star - Sky:	179351.7	
Sky:	3433.93	
Close		

This is the last of five 0.11-second blue exposures of SAO 62484. 0.01-second precision was used to assure equal exposure durations.

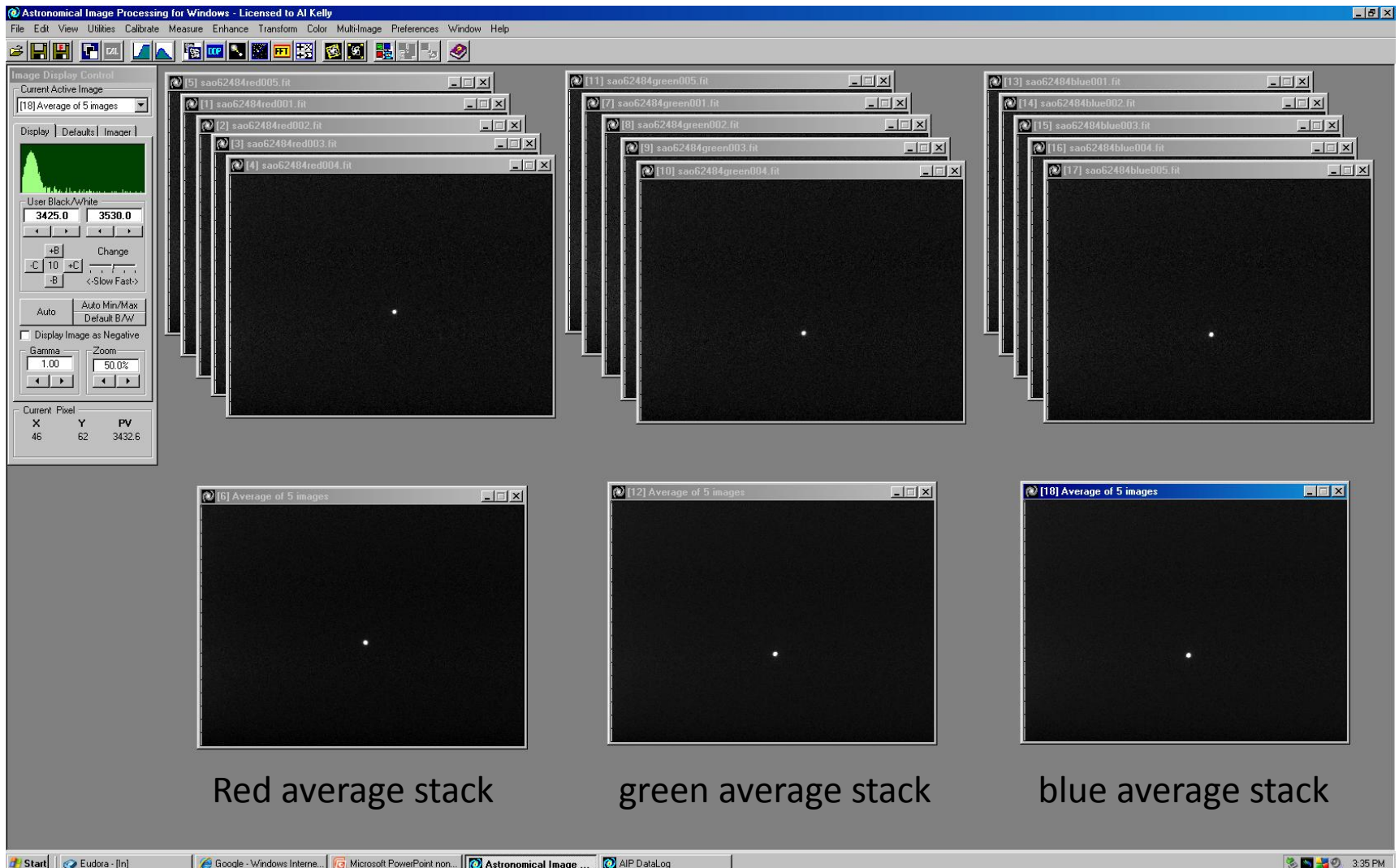
4. Focus is not critical, but keep star point spread functions (PSFs) relatively consistent



5. Calibrate the images to remove bias and hot pixels



6. Carefully register the images and create averaged RGB stacks for photometric sampling



7. Determine the photometric flux for the target star in the RGB stacks

The screenshot displays the 'Astronomical Image Processing for Windows' software interface. The main window, titled '[13]Track & Stack: Average of 5 images', shows a dark image with a single star highlighted by a yellow circle. On the left, the 'Image Display Control' panel includes a histogram, 'User Black/White' sliders (3.511 and 184.256), and a 'Current Pixel' display showing X=758, Y=371, and PV=17.5185. On the right, the 'Single Star Photometry' window is open, showing the following data:

Position	
Star X:	395.508
Star Y:	366.355

Peak Pixel Value	
PV max:	19097.77

Signal (in ADUs)	
Star - Sky:	163644.2
Sky:	19.05305

Raw Instrumental Magnitude	
9.569 ±0.003	
Z= 25.0 / Integration= 0.11 s.	

The 'Single Star Photometry' window also includes a 'Show Analysis' checkbox and a 'Close' button.

8. Correct the flux for extinction and calculate the R:G:B sensitivity ratio

Color Calculator

	Ref. Star Flux	Weight
Red	94867.70	0.571
Green	163347.70	0.988
Blue	164393.40	1.000
Cyan		
Magenta		
Yellow		

G2V Photometry - Reference Star Select

Red **Green** **Blue**

Calculate Weights Save Weights Close

Based on these calculated weights, the R:G:B imaging duration ratio for equalized SNR at the zenith would be ~ 1.75:1:1

9. Use the calculated ratio to guide the amount of total exposure time required through each filter for white-balanced color composites

KEEP IN MIND:

***Ratio numbers within ~5% are close enough
For SNR balancing purposes.***

***When imaging far from the zenith, make
adjustments to your RGB imaging times to
maintain relatively equal SNRs. For example,
imaging at 35 degrees above the horizon means
that the calculated R:G:B imaging times of 1.75:1:1
are closer to 1.6:1:1.***

***Either imaging method is valid: 1) making equal
numbers of unequal R:G:B subexposure durations
or 2) making unequal numbers of equal R:G:B
subexposure durations. The latter may be easier.***

Extinction Correction Factors

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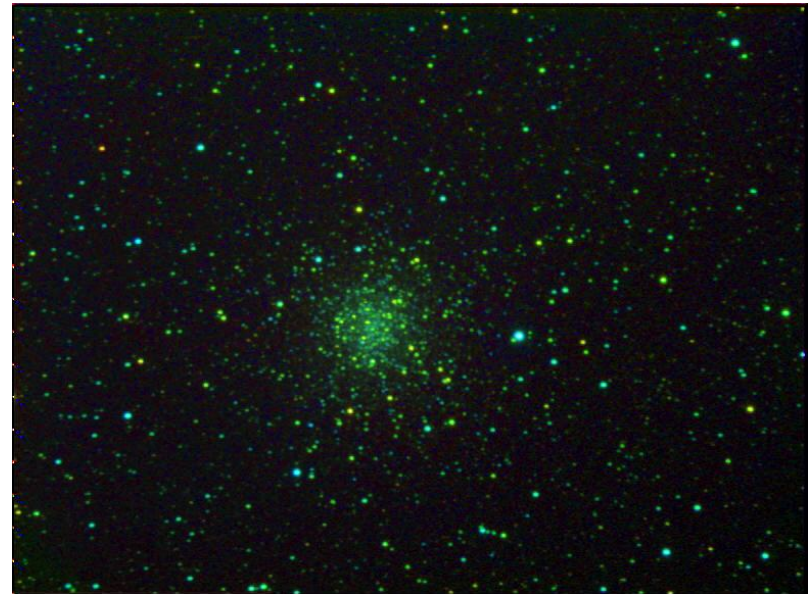
The importance of equalized nonlinear stretching and background neutralization

When RGB exposures of white-balanced durations are combined, “true color” composites will naturally fall out....right? WRONG!

Without equalized nonlinear stretching to balance the histograms and sky background neutralization, even RGBs with equal SNRs can produce ghastly results:



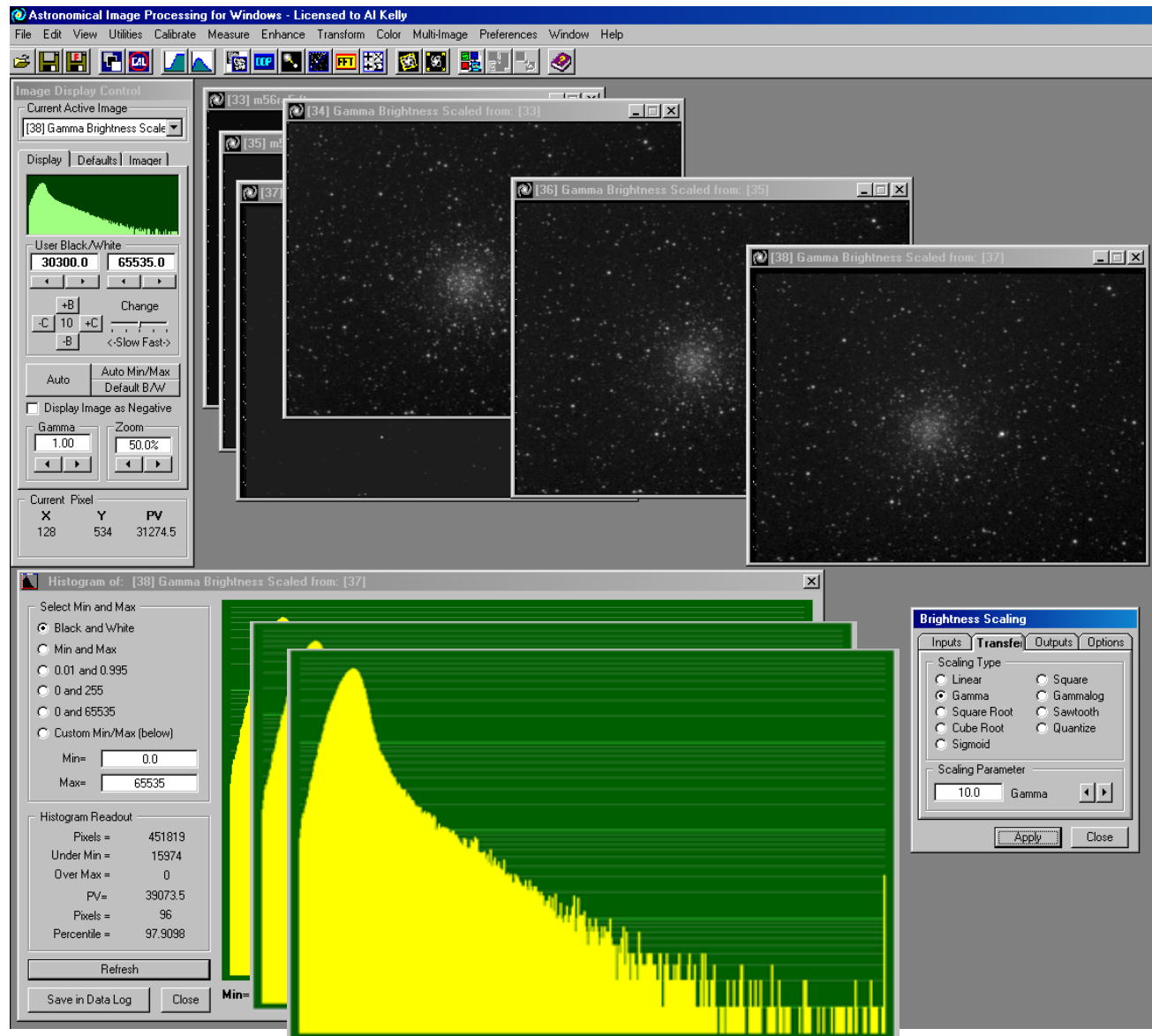
Red gamma10, green gamma10, blue gamma10



red gamma5, green gamma12, blue gamma8

M56 data with equal RGB SNRs -- $R:G:B = 5:3:4$

Equal nonlinear stretching and background neutralization of RGB frames with equal SNRs yields balanced histograms:



And true color results!

