

CCD Image Calibration Using AIP4WIN

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The purpose of image calibration is to remove unwanted errors caused by CCD camera operation. Image calibration is a very important first step in the processing of an astronomical image. Image calibration involves creating three master calibration frames: bias, dark and flat field frames. The goal is to combine multiple calibration images to create a low noise master bias, dark and flat field calibration frames. The challenge in creating these master calibration frames is to reduce noise and remove cosmic ray hits that affect the quality of these calibration frames. The high quality calibration frames applied to the astronomical image will remove or reduce unwanted errors caused by CCD camera operation. Poor quality master calibration frames will introduce additional errors in the astronomical image. The goal is to create high quality calibration frames.

First a short overview of the image taking process is covered and then the following CCD image calibration tasks are covered

- Part 1: Find Gross Defect Images
- Part 2: Organize Files
- Part 3: Create Master Dark Calibration Frame
- Part 4: Create Master Bias Calibration Frame
- Part 5: Create Master Flat Calibration Frame
- Part 6: Image Calibration, Tracking and Stacking

Image Taking Process

The astronomical images came from an all night September 23, 2000 imaging session. The imaging equipment used was a SBIG ST-237 CCD camera, Celestron C8 Fastar on a Losmandy G-11 telescope mount. MaxIm DL CCD software was used to control the ST-237 camera. The imaging location was at home on the driveway.

The imaging session started on Saturday 9/23/00 evening at 21:14 PM PST and ended on Sunday morning 9/24/00 at 5:53 AM PST. This imaging session started about half hour after twilight, which was later than usual. Normally I setup the telescope at sunset and take dark frames until the end of twilight. I start imaging objects at twilight end.

On Saturday evening 9/23/00 the Sunset was 19:04 and twilight end was at 20:46. On Sunday morning 9/24/00 the Moonrise was 2:57, twilight started at 5:19 and Sunrise was 7:00. Most of the late Sunday morning objects were low in the east to southeast just above the trees and were in the moon's sky glow. Calibration frames were taken throughout the night and during Sunday morning twilight from 4:52 AM to 5:53 AM.

The images taking process was to manually take one 30 seconds image to check dynamic range of the astronomical object to check that the important image areas did not exceed the ST-237 camera maximum 4095 level. Maximum exposure was limited to 30 seconds because all images were unguided. This night's imaging plan was to obtain a large number of Messier and selected NGC objects before the northwest cloudy weather sets in for fall and winter. Therefore, most image sequences were eight images of 30 seconds for a total of 4 minutes. Some objects were too bright for 30 seconds images. For example, M13, M92 were 16 images x 15 seconds and M42 was 30 images x 2 seconds too prevent ST-237's 4095 saturation on key parts of the astronomical object of interest.

During the imaging session 502 frames (295 Mbytes) were taken. These frames included astronomical object images, bias frames, dark frames and flat frames. All frames were stored in a single directory call Master. This Master directory was a subdirectory of the 000923 directory. The 000923 directory name was made up of the first two digits for the year, the next two digits were for the month and last two digits were for the evening day. This naming directories scheme was a hang over from using a DOS PC to control the

Cookbook CB245. The advantage of this naming technique was the directory listing sorts the order of when the images were taken and was compatible with earlier image directory names.

Part 1: Find Gross Defect Images

The first task was to copy the 000923 directory of images to the computer in the house. This was easily done by connecting a temporary 50 foot LAN 10Base-T cable between the outside ST-237 control computer and the indoor image processing computer. On the indoor computer a work in progress (WIP) directory was created in the 000923 directory and all the images in the master directory were copied to the WIP directory. The images in the master directory were never edited or processed. Only the image copies in the WIP directory were moved, edited or processed. Also, the images are kept on the outside ST-237 control computer until a CD-R ROM backup is created.

The next task was to organize the 502 files and to identify gross image problems. At this point AIP4WIN Measure Statistics File was used to measure statistics on the image files. AIP4WIN version 1.2 includes a new feature to measure statistics on files, which was a very good time saver on checking for gross image problems. Using AIP4WIN Measure Statistics File 16 bad or problem images were found in the 502 images. Also, AIP4WIN Measure Statistics File was very help in organizing the image files by type and exposure time.

Using AIP4WIN Measure Statistics File I found all 502 files could not be measured at once because of a Microsoft limitation. AIP4WIN Measure Statistics File was used twice to create two statistics.txt files to cover the all 502 image files because of the 294 files limit. The two statistics.txt files were loaded into Microsoft Excel and combined into one spreadsheet. The spreadsheet was sorted by date/time and printed out as an over all image worksheet summary.

Most of the images were part of an eight image sequence group that was automatically taken by MaxIm DL CCD camera control sequence mode. MaxIm DL CCD takes an image sequence automatically saving each image with a three digit number at the end of image file name. In most imaging sessions I let the sequence number continue to increment throughout the imaging session. This provides an easy reference locator for any sequence image with the other sequence images. Images with less than a three digit number at the end of the file name were manually taken images used to check astronomical object centering or exposure time. In most cases these manually taken images are not used in the imaging processing, only the sequence images are calibrated, combined and processed.

Image file naming convections:

- m for Messier objects
- n for NGC objects
- dk for dark frames
- bias for bias frames
- flat for flat frames
- a, b, c, ...etc. letters after the above codes indicate a different sequence or some change in the image (object position, exposure time, etc.).

A few errors were easily seen using AIP4WIN Measure Statistics File summary table. These errors are found by checking the values for the Min PV, Max PV, Mean, Median, Mode and Std Dev for each sequence or each similar type of sequence like the 30 seconds dark frames. The following images errors were found because they had significantly different values than the other similar types of images.

Errors Frames Set 1

This sequence was to be 2 second dark frames for the M42 images, most of the values were too large. Inspecting the dark frames showed that they were star fields. The error was not correctly controlling the ST-237 CCD camera to take dark frames during the sequence.

File Name	Date	Time	Exp	Wid	Hght	Min	Max	Mean	Med	Mode	Std	Dev
dk2s445.fit	9/24/00	11:52:51	2	640	480	0	4095	4	0	0	91.103	
dk2s446.fit	9/24/00	11:53:04	2	640	480	0	4095	4	0	0	90.743	
dk2s447.fit	9/24/00	11:53:16	2	640	480	0	4095	4	0	0	99.309	
dk2s448.fit	9/24/00	11:53:29	2	640	480	0	4095	4	0	0	91.654	
dk2s449.fit	9/24/00	11:53:42	2	640	480	0	4095	4	0	0	90.462	
dk2s450.fit	9/24/00	11:53:55	2	640	480	0	4095	4	0	0	89.557	
dk2s451.fit	9/24/00	11:54:07	2	640	480	0	1399	3	0	0	39.567	
dk2s452.fit	9/24/00	11:54:20	2	640	480	0	2007	3	0	0	47.352	

Errors Frames Set 2

This sequence was to be 30 seconds dark frames, most of the values were too large as compared to other 30 seconds dark frames. Inspecting the dark frames showed that they were star fields. The error was not correctly controlling the ST-237 CCD camera to take dark frames during the sequence.

File Name	Date	Time	Exp	Wid	Hght	Min	Max	Mean	Med	Mode	Std	Dev
dkl453.fit	9/24/00	11:55:23	30	640	480	77	4095	209	206	218	265.215	
dkl454.fit	9/24/00	11:56:03	30	640	480	80	4095	209	207	216	259.703	
dkl455.fit	9/24/00	11:56:42	30	640	480	81	4095	210	207	216	264.854	
dkl456.fit	9/24/00	11:57:24	30	640	480	84	4095	209	207	217	259.022	
dkl457.fit	9/24/00	11:58:04	30	640	480	80	4095	208	206	216	264.672	
dkl458.fit	9/24/00	11:58:43	30	640	480	84	4095	208	206	215	266.940	

Error Frame 3

This error image was a flat frame named as a bias frame. This was easy seen with the statistics of the flat frames taken after this image and the bias frame taken before this image. The error was in file naming.

File Name	Date	Time	Exp	Wid	Hght	Min	Max	Mean	Med	Mode	Std	Dev
biasd483.fit	9/24/00	12:47:22	30	640	480	297	4039	446	453	477	97.791	

Error Frame 4

Flat frames were taken at morning twilight; this last flat frame was higher than the previous seven flats. This flat frame was not used in the calibration. The error was the twilight was changing too fast.

File Name	Date	Time	Exp	Wid	Hght	Min	Max	Mean	Med	Mode	Std	Dev
lata491.fit	9/24/00	12:53:36	30	640	480	378	4095	536	543	565	99.463	

Side Note

For the C8 Fastar telescope configuration all the images that were taken at 30 seconds have stars or astronomical objects bright enough to saturate the ST-237 at its maximum 4095 level. For example, the M31 core was max out at the 4095 in 0.1 seconds as shown in the following images statistics.

File Name	Date	Time	Exp	Wid	Hght	Min	Max	Mean	Med	Mode	Std	Dev
m31d236.fit	9/24/00	8:59:32	0.1	640	480	0	4095	2	0	0	198.141	
m31d237.fit	9/24/00	8:59:42	0.1	640	480	0	4095	2	0	0	192.776	

Part 2: Organize Files

The next task was to organize files by creating directories for each object and each set of calibration frames. Also, using AIP4WIN statistics summary table it was easy to check the exposure time for each image sequence.

A calibration directory called DK Bias Flat was created for all the bias, flat and dark frames. Subdirectories in the DK Bias Flat directory were created for each sequence of calibration frames. Each directory starts with its sequence number range, 001-008. This makes it easier to list the directories in order in which they were taken. Next part of the directory name was the type of calibration frame, DK for dark frames, Bias for Bias frames and Flat for flat frames. Next part of the directory name was the exposure length and sometimes includes the temperature. Last part of the directory name was a note like error for the sequence images 445 to 458. The calibration frames were copied from the work in progress (WIP) directory to the appropriate named directory.

Directory of H:\000923\DK Bias Flat

001-008 DK 30s
057-072 DK 15s
105-115 DK 30s
172-179 DK 30s
246-261 DK 30s
262-277 Bias 0s
278-293 DK 30s
294-309 Bias 0s
310-325 DK 30s
445-452 Stars 2s error
453-458 Stars 30s error
459-466 DK 30s
467-474 DK 2s
475-482 Bias 0s
483-491 Flat 30s

The files left in the work in progress (WIP) directory were all astronomical image files. Directories were created for the following objects: B33, M01, M103, M110, M13, M27, M29, M31, M33, M34, M35, M36, M37, M38, M39, M42, M45, M50, M52, M56, M57, M71, M74, M76, M77, M78, M92, N2024, N7635, N891, and SATURN. The images were copied from the work in progress (WIP) directory to the appropriate named directory. Now the WIP directory was empty and was deleted.

Part 3: Create Master Dark Calibration Frame

This process step was to combine multiple dark frame images together to create a low noise master dark calibration frame. The challenge was to remove the gross errors and cosmic ray hits that add noise to the dark frame and affect the calibrated image quality.

AIP4WIN Multi-Image Average Combine and Median Combine were used for each set of dark calibration frames in a sequence subdirectory. For the seven dark sequence subdirectories there were seven average images and seven median images. These dark sequence averages and medians were copied into a temporary directory and AIP4WIN Measure Statistics File was performed on the 14 files. Notice in the below statistics file how the dark sequences 001-008 and 105-115 have a higher Std Dev than the other dark sequences.

File Name	Max PV	Std Dev
average001-008.fts	3752	43.052
average105-115.fts	3814	44.125
average172-179.fts	3649	41.975
average246-261.fts	3588	41.304
average278-293.fts	3602	41.565
average310-325.fts	3601	41.563
average459-466.fts	3553	40.962
median001-008.fts	3743	42.928
median105-115.fts	3819	44.063
median172-179.fts	3659	41.903
median246-261.fts	3586	41.256
median278-293.fts	3602	41.526
median310-325.fts	3599	41.520
median459-466.fts	3539	40.843

The span of 001-466 files contained 84 dark frames of 30 seconds.
The span of 172-466 files contained 64 dark frames of 30 seconds.

The next step was to copy all 30 seconds dark frames into one directory. AIP4WIN Multi-Image Average Combine and Median Combine were used to create the following four dark frames based on all 84 frames and on selected 64 frames that exclude the dark sequences of 001-008 and 105-115.

Statistics for average and median show that the median of 172-466 has the lowest Max PV and Std Dev.

File Name	Max PV	Std Dev
average001-466.fts	3643	41.996 contains 84 frames
average172-466.fts	3598	41.469 contains 64 frames
median001-466.fts	3611	41.764 contains 84 frames
median172-466.fts	3595	41.463 contains 64 frames

The below calculations using AIP4WIN Multi-Image Image Math showed interesting results that the median is within 3-4 values being the lowest value. It would seem that cosmic rays or some other additive signal was becoming the primary noise component. At this point the median172-466.fts file is the best dark frame with the average172-466.fts file being the second best dark frame.

average001-466.fts minus average172-466.fts Max Pixel Value = 45
average172-466.fts minus average001-466.fts Max Pixel Value = 2
Analysis: average001-466.fts contains much higher values than average172-466.fts

median001-466.fts minus median172-466.fts Max Pixel Value = 16
median172-466.fts minus median001-466.fts Max Pixel Value = 4
Analysis: median001-466.fts contains much higher values than median172-466.fts

The median and average 172-466 files were lower values than 001-466 files.

Next compare the average versus median files of the same image frames.

average001-466.fts minus median001-466.fts Max Pixel Value = 32
median001-466.fts minus average001-466.fts Max Pixel Value = 3

average172-466.fts minus median172-466.fts Max Pixel Value = 12
median172-466.fts minus average172-466.fts Max Pixel Value = 3

Analysis: median files were lower than the average files for the same set of darks frames.

One may be tempted to use only median459-466.fts with its Std Dev 40.843 for 8 darks. Comparing median459-466.fts with the median172-466.fts shows a large difference. This would be expected with a median of a small set of 8 frames versus a median of 64 frames.

median172-466.fts minus median459-466.fts Max Pixel Value = 56
median459-466.fts minus median172-466.fts Max Pixel Value = 12

Summary: median172-466.fts was the best master dark frame.

Side Note: The Std Dev of a median or average image is not the best way to compare the quality of two calibration frame with each other. The Std Dev of an image is giving a measure of how spread out the pixels values are from the average pixel value of the image.

Part 4: Create Master Bias Calibration Frame

Creating a master bias calibration frame was a similar process to creating a master dark frame. AIP4WIN Multi-Image Average Combine and Median Combine were used to create an average and median bias calibration frames for each bias frame subdirectory. AIP4WIN Measure Statistics File was used to measure each average and median bias calibration frame for each bias frame subdirectory. Analysis: no obvious problems were identified.

Average and median bias calibration frames for the bias frame sequence subdirectories.

File Name	Max PV	Std Dev
median475-482.fts	239	1.812
median262-277.fts	250	1.862
median294-309.fts	249	1.881
average475-482.fts	242	1.923
average262-277.fts	248	1.930
average294-309.fts	250	1.945

An All Bias directory was created and all 40 bias frames were copy into it. AIP4WIN Measure Statistics File was used on all 40 bias files. The bias file statistics summary was loaded into Excel and sorted by Std Dev. Then the top three highest Std Dev bias files (biasa267.fit, biasa268.fit and biasd476.fit) were removed which left a total of 37 bias frames. AIP4WIN Multi-Image Average Combine and Median Combine were used to create a master average37 and median37 bias calibration frames for the remaining 37 bias frames.

File Name	Max PV	Std Dev
biasa267.fit	465	3.074
biasa268.fit	330	3.068
biasd476.fit	245	2.504
biasb299.fit	249	2.392

biasb302.fit	262	2.329
biasd477.fit	237	2.297
biasb300.fit	252	2.291
biasa271.fit	264	2.285
biasb295.fit	259	2.280
biasd479.fit	239	2.280
biasa262.fit	253	2.276
biasb296.fit	251	2.276
biasb304.fit	246	2.274
biasd480.fit	243	2.267
biasb301.fit	244	2.263
biasd478.fit	248	2.263
biasa273.fit	255	2.262
biasb306.fit	247	2.260
biasa270.fit	253	2.259
biasb297.fit	258	2.259
biasa266.fit	261	2.251
biasb298.fit	240	2.248
biasb309.fit	268	2.244
biasb307.fit	249	2.241
biasa263.fit	230	2.240
biasa276.fit	246	2.239
biasa277.fit	233	2.237
biasb305.fit	245	2.233
biasd482.fit	260	2.233
biasa274.fit	253	2.232
biasb303.fit	255	2.222
biasa265.fit	253	2.220
biasa269.fit	250	2.218
biasa275.fit	258	2.217
biasd481.fit	236	2.211
biasa272.fit	247	2.201
biasb294.fit	241	2.200
biasd475.fit	234	2.200
biasa264.fit	237	2.198
biasb308.fit	243	2.188

The resulting median and average statistics of the 37 bias frames.

File Name	Max PV	Std Dev
median37.fts	249	1.876
average37.fts	248	1.913

average37.fts minus median37.fts Max Pixel Value = 5

median37.fts minus average37.fts Max Pixel Value = 2

Analysis: median file was lower than the average file for the same set of bias frames.

Summary: median37.fts was the best master bias frame.

Part 5: Create Master Flat Calibration Frame

AIP4WIN Multi-Image Auto-Process Deep Sky was used to create a master flat calibration frame. First, AIP4WIN Measure Statistics File was used to measure each flat frame. Analysis: no obvious problems were identified with the flat frames.

Flat frames

File Name	Date	Time	Exp	Wid	Hght	Min	Max	Mean	Med	Mode	Std Dev
flata484.fit	9/24/00	12:48:51	30	640	480	307	4003	459	466	489	98.736
flata485.fit	9/24/00	12:49:31	30	640	480	286	4026	443	450	470	96.949
flata486.fit	9/24/00	12:50:12	30	640	480	254	3978	394	400	416	95.693
flata487.fit	9/24/00	12:50:53	30	640	480	239	3975	381	386	408	94.131
flata488.fit	9/24/00	12:51:34	30	640	480	275	4002	419	425	441	96.943
flata489.fit	9/24/00	12:52:15	30	640	480	287	4066	432	439	464	96.989
flata490.fit	9/24/00	12:52:55	30	640	480	286	4054	435	441	464	96.452

AIP4WIN Calibrate Setup Advanced menu settings were:

- use bias frame, median37.fts for bias frame,
- create master bias
- median172-466.ft for dark frame
- automatic dark matching
- create master dark
- applied flatfield correction
- select the above seven flatfield files
- normalize median combine since they were twilight flats
- subtract flat dark
- median172-466.ft for flat dark frame
- create master flat
- Save master flat as flatmaster7.fts

Close Advanced Calibration menu

AIP4WIN Calibrate Master Frames was used to verify the Master Dark Contents, Master Flat Contents and Master Bias Contents.

AIP4WIN Measure Statistics File was used on the flatmaster7.fts file. This data cannot be compared to the above seven flats because it was normalize and dark subtracted.

File Name	Date	Time	Exp	Wid	Hght	Min	Max	Mean	Med	Mode	Std Dev
flatmaster7.fts	9/24/00	7:47:36	30	640	480	298	539	422	430	459	81.023

Image calibration setup was now competed.

Part 6: Image Calibration, Tracking and Stacking

AIP4WIN Multi-Image Auto-Process Deep Sky was used to calibration, tracking and stack NGC 891 deep sky image. First the NGC 891 statistics on file summary table were check for abnormal readings between the eight 30 second images. None were found. Next AIP4WIN Multi-Image Auto-Process Deep Sky was used to calibrate, track and stack eight 30 second NGC 891 images.

AIP4WIN Multi-Image Auto-Process Deep Sky menu settings were

- Select files: n891a148.fit, n891a149.fit, n891a150.fit, n891a151.fit, n891a152.fit, n891a153.fit, n891a154.fit and n891a155.fit
- Stack
- Calibrate image
- 2X resample
- Prescale, prescale factor 16
- Nose Filter, deviation 1
- Select Master Frame n891a148.fit
- 2 star alignment, track radius 6
- Slave alignment, Star selection automatic
- No enhancement

Save n891 calibrated, tracked and stacked image as n891cal.fits.

Appendix A

Improving the Master Dark Frame

Cosmic ray hits add unwanted light to the dark frames. Cosmic ray hits can be seen by comparing/blinking the dark frames. AIP4WIN Measure Statistics File provides a quick visual multiple file blink feature. It opens an image, displays the image in the same window location, closes the image and gets the next image. This is very handy to see major cosmic ray hits and other defects that cause it to be different than the other dark frames. This section looks at ways to identify cosmic ray hits on dark frames based on analysis and not rely on visual interpretation.

Use AIP4WIN Multi-Image Image Math to take the absolute differences between median172-466.fts and each dark frame, save the absolute differences file. I used file name letter d plus the sequence number. This is a very, very slow and manual process for 84 dark frames.

Next use AIP4WIN statistics files on all of the absolute differences files d001.fts to d466.fts. Load the statistics file in to Excel and delete all columns except File Name, Max PV and Std Dev. Sort the data by Max PV. The dark frames with cosmic ray hits stand out with Max PV's greater than 1,000. Other candidates are any Max PV's greater than 500. Create a Cosmic Ray Hits directory and move the dark files that correspond to these absolute differences files to the Cosmic Ray Hits directory.

File Name	Max PV	Std Dev
d007.fts	3652	42.163
d311.fts	3604	41.586
d278.fts	3579	41.536
d105.fts	1983	9.332
d001x.fts	1428	6.805
d111.fts	877	4.707
d315.fts	688	3.891
d003.fts	679	3.429
d465.fts	589	4.382
d463.fts	509	2.959
d466.fts	341	3.417
d251.fts	303	2.332
d108c.fts	278	3.378
d255.fts	277	2.265
d110.fts	264	3.373
d323.fts	261	2.177
d108d.fts	243	3.462
d283.fts	242	2.718
d460.fts	240	2.310
d114.fts	239	3.049
d109.fts	236	3.305
d112.fts	234	3.208
d106.fts	224	3.188
d282.fts	200	2.149
d006.fts	199	2.254
d280.fts	199	2.133
d314.fts	195	2.122
d115.fts	192	3.115
d107.fts	184	3.097
d113.fts	184	3.088
d281.fts	173	2.085

d002.fts	164	2.393
d004.fts	163	2.182
d175.fts	157	1.755
d177.fts	156	1.915
d310.fts	156	2.252
d179.fts	155	1.787
d008.fts	148	2.168
d005.fts	120	2.171
d173.fts	104	1.712
d257.fts	101	2.034
d324.fts	97	1.980
d174.fts	92	1.662
d316.fts	91	1.997
d256.fts	84	1.985
d259.fts	84	1.972
d254.fts	83	2.017
d317.fts	80	1.998
d260.fts	69	2.006
d176.fts	66	1.585
d287.fts	66	1.982
d178.fts	57	1.668
d291.fts	57	1.958
d459.fts	57	2.106
d253.fts	56	1.986
d288.fts	56	1.979
d293.fts	56	1.972
d461.fts	56	2.076
d246.fts	52	2.015
d286.fts	52	1.924
d462.fts	50	2.097
d172.fts	49	1.653
d285.fts	48	1.930
d321.fts	48	1.956
d290.fts	47	1.965
d292.fts	47	1.972
d319.fts	47	1.970
d320.fts	47	1.991
d248.fts	46	2.059
d249.fts	46	2.004
d464.fts	46	2.180
d261.fts	45	1.924
d284.fts	44	1.931
d289.fts	44	1.992
d279.fts	42	1.984
d312.fts	42	1.977
d322.fts	42	1.913
d252.fts	41	1.980
d247.fts	40	2.031
d325.fts	40	1.951
d258.fts	38	1.999
d313.fts	38	1.986
d318.fts	37	1.904
d250.fts	33	1.935

All 84 absolute differences files

Median 94.500

Average 312.833

Stdeva 700.508

The bottom 74 absolute differences files

Median 81.500

Average 117.432

Stdeva 83.837

(3* Stdeva)+ Average = 368.944

Take the AIP4WIN Multi-Image Average Combine and Median Combine on the new set of 74 dark frames (84 – 10 cosmic ray hit frames).

Average74dks.fts minus median74dks.fts Max Pixel Value = 34

median74dks.fts minus Average74dks.fts Max Pixel Value = 3

Analysis: median has lower values than average.

median172-466.fts minus median74dks.fts Max Pixel Value = 4

median74dks.fts minus median172-466.fts Max Pixel Value = 11

Analysis: median172-466.fts has lower values than median74dks.fts.

median172-466.fts minus median64dks.fts Max Pixel Value = 4

median64dks.fts minus median172-466.fts Max Pixel Value = 16

Analysis: median172-466.fts has lower values than median74dks.fts.

median172-465crh.fts minus median172-466.fts Max Pixel Value = 5

median172-466.fts minus median172-465crh.fts Max Pixel Value = 4

Analysis: these two files may be similar.

average172-465crh.fts minus median172-465crh.fts Max Pixel Value = 13

median172-465crh.fts minus average172-465crh.fts Max Pixel Value = 3

Analysis: median172-465crh.fts has lower values than average172-465crh.fts.

File Name	Max PV	Std Dev
median172-466.fts	3595	41.463
average172-466.fts	3598	41.469
median172-465crh.fts	3598	41.491
average172-465crh.fts	3600	41.499
median64dks.fts	3611	41.703
median74dks.fts	3606	41.713
median001-466.fts	3611	41.764
average74dks.fts	3640	41.943
average001-466.fts	3643	41.996

According to Std Dev the median172-466.fts is the best calibration dark frame. See concerns on using Std Dev of an average or median frame to determine a merit of goodness in the below side note.

Side Note: The Std Dev of a median or average image is not the best way to compare the quality of two calibration frame with each other. The Std Dev of an image is giving a measure of how spread out the pixels values are from the average pixel value of the image. What is needed is a data set of Std Dev for each pixel against all the image frames that made up the calibration frame. For the ST-237 with 640 x 480 pixels there would be 640 x 480 Std Devs, one for each pixel location. One could average the data set of all the Std Devs and use this number to compare it to other calibration sets. The proposal is that the lower average of all pixels Std Dev is a lower noise and lower cosmic ray affected calibration frames set and will produce a higher quality calibrated image.