NJAA AstroPhotography TechNote # 01

Topic: Value of Stacking Frames (aka sub frames)

It's generally understood that to create a high quality image you need lots of data (signal). Without getting into details of each and every ccd sensor's quantum efficiency for a spectral range, I thought it would be much more helpful to talk about the "Value" (literally) of stacking frames as I am asked many times "how many frames should I take?"

There is a standard formula for calculating the value of the increased signal (gain) for every frame that you add to your stack. It's simply the square root of (n). "n" is the number of frames that you are stacking. Therefore each additional frame that you stack adds more "signal" to the resulting image.

So now you thinking 15 minutes could save you 15% (Geico commercial). Or, hey Jim we all know this. Yes of course, however:

At what point does adding more frames have a noticeable diminishing effect on the Signal To Noise Ratio (SNR)?

That is the purpose of this TechNote - to talk about when to "STOP" taking frames.

Frameology (NJAA new astronomy term):

Light Frame = shutter on your camera is open (fixed exposure time) and collecting photons.

Dark Frame = shutter is closed for an "equivalent exposure time" as the Light Frame and collecting "noise" that is accumulated over that time.

Bias Frame = shutter is closed and the camera takes the ***"fastest exposure possible"*** which will show fixed pattern read-out noise, hot pixels etc. Note that each light frame also includes this same data in its exposure.

Flat Frame = shutter is open and the telescope is pointed to a ***"highly uniform"*** light source. The exposure time is such that it yields no more than 30-40% of the maximum ADU (analog digital units) value across the entire sensor. This frame will show the optical characteristics (impurities) of your imaging train. That is vignetting (dimming on sensor corners), dust spots, uneven light patterns across the sensor, etc.

So all things considered regarding your exposure time (future TechNote) you go about taking the longest exposure possible to get the most faint detail. So if they are 10-minute subs and you take 6, you've got one hour of combined light.

Now, how many dark or bias frames do I take to complement the light frame? First lets look at the theoretical gain with each additional frame gives you.

Subs(n)	SQR(n) Gain
1	1.000
2	1.414
3	1.732
4	2.000
5	2.236
6	2.449
7	2.646
8	2.828
9	3.000
10	3.162

As I stated before, the theoretical signal gain is a function of the square root of the number of frames that you are stacking. So just by stacking 2 frames you get a 1.4 gain increase in signal. NICE … 4 frames doubles the SNR, 9 frames triples the SNR and on we go.

That's interesting; I had to go to 9 frames to gat a 1X increase in gain again. To further illustrate that fact, below is a table extended up to 225 frames.

Sub(n)	SQR(n) Gain
1	1.0
4	2.0
9	3.0
16	4.0
25	5.0
36	6.0
49	7.0
64	8.0
81	9.0
100	10.0
121	11.0
144	12.0
169	13.0
196	14.0
225	15.0

Well it seems that it takes a huge number of frames to keep getting that 1X increase in gain. The reason for this is as you add more frames the "Value" of the signal gain contribution gets smaller and smaller. It does so mathematically with this revised formula: SNR = (SQR(n) – SQR(n-1)). In other words as you add frames, the difference (delta) in gain gets increasingly smaller and smaller.

To a point in fact that adding more frames will NOT make a noticeable difference in your processed image.

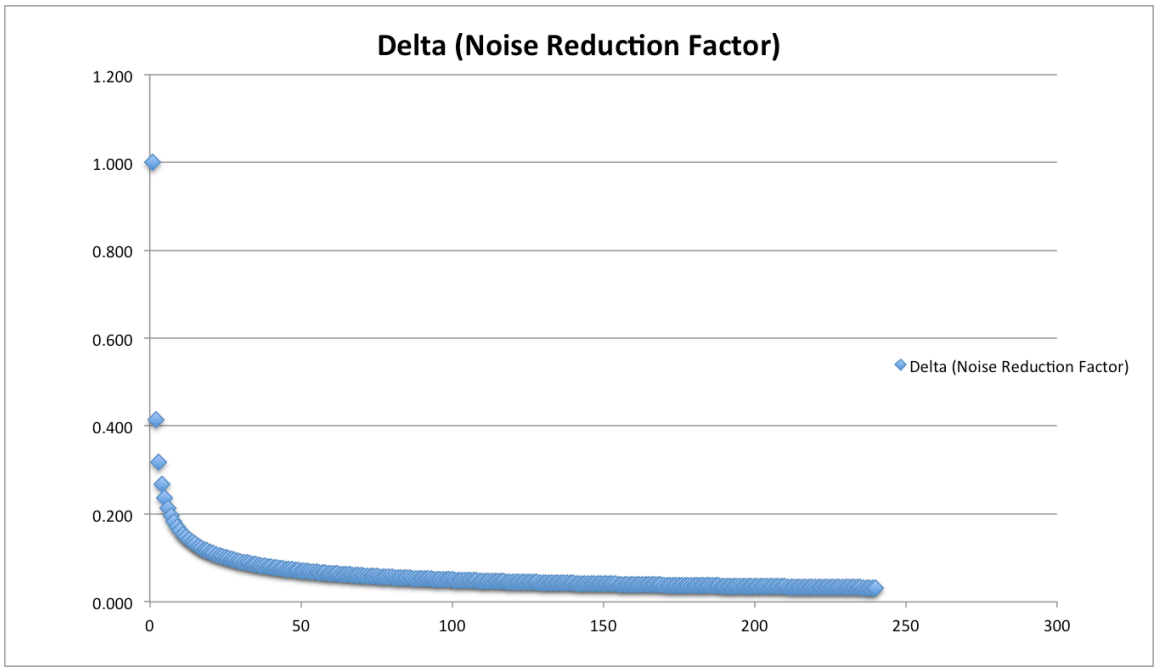
So, at what point is that? First a few more numbers that show the gain difference (delta):

Subs(n)	SQR(n) Gain	SQR(n-1) Gain Increase	Delta Gain Diff
1	1.000	0.000	1.000
2	1.414	1.000	0.414
3	1.732	1.414	0.318
4	2.000	1.732	0.268
5	2.236	2.000	0.236
6	2.449	2.236	0.213
7	2.646	2.449	0.196
8	2.828	2.646	0.183
9	3.000	2.828	0.172
10	3.162	3.000	0.162

The key on this is the diminishing gain delta. As you add more frames, that delta gets smaller and smaller. Below is the delta expressed over 240 frames sampled at various points.

Subs(n)	Delta
1	1
20	0.113
40	0.080
60	0.065
80	0.056
100	0.050
120	0.046
140	0.042
160	0.040
180	0.037
200	0.035
220	0.034
240	0.032

Now you're saying wonderful, lots of numbers and still no answer on when to stop taking subs. Ok, below is a graph that illustrates "ALL" the above and holds that answer to the question.



As you can clearly see, there is a huge benefit from stacking anywhere from 1 to 50 sub frames. After that, the benefit is extremely small. So small in fact, that more subs will not make a noticeable difference in your processed image!

So what's the recommendation Jim?

Looking again at the numbers below, this is why I always recommend a minimum of 20 subs for the light frames.

This gets you a massive increase in SNR. At 30 subs, the delta is .092. Now we're talking about the delta being in the thousands and diminishing from there.

Subs(n)	Delta
1	1
20	0.113
40	0.080
60	0.065
80	0.056
100	0.050
120	0.046
140	0.042
160	0.040

180	0.037
200	0.035
220	0.034
240	0.032

Summary:

So we have not talked about exposure times here. That's correct because the formula is not time dependent. Your exposures will vary by object brightness; mount capabilities and the dozens of other factors that go into acquiring a perfect set of subs.

The above information is relevant for light, dark, bias and flat frames. Obviously taking 20, 30 or more light & dark frames can become a multi-hour undertaking. But we all know that it's required to create a successful Astronomical Photograph. Well, at least the bias frames will go quickly!

I hope that this information is helpful.
Clear Skies.
Jim Roselli

P.S. If you would like the accompanying spreadsheet that I created to support this artcile, send me an email (jim@jimroselli.com) and I will forward it to you.