RBI Considerations for a KAF series camera

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Look at slide #22 of this: http://www.narrowbandimaging.com/incoming/RBI_CMOS_Crisp_2018.pdf

There is a plot of families of curves of Dark Shot noise (electron units) versus time and Thermal Charge Leakage (dark signal) (in electron units) vs time using Log Log Plots for various temperatures

This is for DARK data of varying length for various temperatures.

The horizontal line at 5.4 electrons represents the measured read noise of the camera, a Proline 3200ME

The Thermal Charge Leakage is the cumulative dark signal in electrons. It has a slope of +1 since it grows linearly with time

Since the dark shot noise = Sqrt (cumulative dark signal) the slope of the dark shot noise curve = ½ when plotted using Log Log axes.

That's a cross check from theory to show you that your empirical data is good (stable temperature, no light leaks, no trapped charge)

You can operate at -15C and expose 6600 seconds before the dark shot noise passes the read noise. Usually that's referred to as the maximum practical exposure limit in the professional literature. To run longer you cool more. So there's a concept of longer exposures mean deeper cooling is required. That's an important concept.

The KAF series of sensors has a charge trapping problem (RBI) that is presented when operating at chilled temperatures

On the one hand we like to operate at chilled temperatures to minimize dark shot noise and we also like the cosmetic performance benefits
http://www.narrowbandimaging.com/incoming/cooling_cosmetics.pdf

On the other hand, it leads to charge trapping/image lag issues.

One of the biggest issue is the patterns left in images from trap charge decay from a sensor that's been exposed to uniform light such as used in flat fielding: see slide 12 of
http://www.narrowbandimaging.com/incoming/RBI_CMOS_Crisp_2018.pdf

If you use light flood to fill the traps completely before any light or any dark exposure (match temperatures and lengths) then these patterns are removed by dark subtraction: they are classic dark fixed pattern noise (DFPN)

If you don’t use light flood and ignore the RBI then you can get these patterns in your images and you cannot subtract them because you can’t match a partially filled trap’s pattern. If fully filled, no problem. If empty, no problem. If partially filled: BIG PROBLEM.

Other problems caused by Image Lag/Charge Trapping (aka RBI)

Besides the swirling patterns, you also get ghost stars in images: you dither between shots and the brighter stars from the last images reappear in the next image and then those two sets of offset star fields (from the dithering) now appear as ghost stars in the third image and so on.

Then you can get ghost galaxies too. (see page 3, 4 & 5 of http://www.narrowbandimaging.com/incoming/RBI_CMOS_Crisp_2018.pdf)

In nights with high levels of solar activity when radiation hits are more common, those hits get trapped too so your image frames get noisier as the night goes on

So you need to light flood

Now the only problem is the traps leak a lot of charge fast unless you cool them much heavier than without the light flood. On the one hand you completely solve the problems from Image Lag (ghosting) and from the non-uniform DFPN, on the other hand you have a new source adding to the Dark Shot Noise.

Dark Shot noise ultimately limits your exposure time as I mentioned above. When you light flood the initial leakage rate is about 10x the thermal charge leakage rate so it is a huge increase in dark shot noise. That’s the bad news.

The good news is that is completely addressed by cooling. But you need to know how much cooling for what exposure length

Now look at page 25 of http://www.narrowbandimaging.com/incoming/RBI_CMOS_Crisp_2018.pdf

It is a plot like on Page 22 we examined at the beginning. But this one has a difference: it was light flooded before taking each data point.

Notice how the dark signal no longer is a straight line with a slope of +1. That’s because it isn’t a steady signal like thermally generated charge. It is a lot more charge than we saw in the thermal case.

The dark shot noise is also no longer a straight line with a slope of +1/2. It is completely dominated by the trapped charge leakage which is significantly greater than the thermally generated case.

Let’s see what happens at -15C; this time the dark shot noise crosses the read noise after only 120seconds: two minutes instead of one hour and 33 minutes.

To expose for 15 minutes like I do, you need to operate at -40C

That isn’t a 40C DELTA T from ambient, that means a SENSOR temperature of -40C.

If your ambient temperature is 10C and you can get 55C of cooling you can reach -45C which gives you some margin

The trouble is most camera makers cannot do that.

So the question is what to do?