QHY5III290MM Review

This is a review after 6 months of use, overall i'm very pleased.
This camera allows number of things that would be impossible to acheive with anything else, and i hope improvements will continue in that direction.
Thanks to QHY that made me a betatester.

The camera i'm talking about is the QHY5III290, using the IMX290 sony sensor. You will find some information here on QHY's website : http://www.qhyccd.com/QHY5III290.html

As this will be a bit long, I'll organize it in 4 parts, so if you are interested only in one of them, feel free to go there directly :)

1 - Read noise tests

2 - Anti Amp-glow tests

3 - Sky surveilance tests

4 - Test behind the scope

First of all, some noise tests. The domain i'm the most interested in is "lucky imaging" for deep sky objects, and read noise is the crucial part of it ; the lower the better.

The read noise measured by qhy was the lowest on every camera available, except for qhy224, but since it is only a color sensor, it is less interesting for my main purpose. Furthermore, it suffers from other problems such as the "amp-glow", that makes the sensor bad in medium to long exposures - more than a few seconds.

For testing i'm using only sharpcap, the software provided by QHY. I tried firecapture once as well, camera seems to work fine with it.

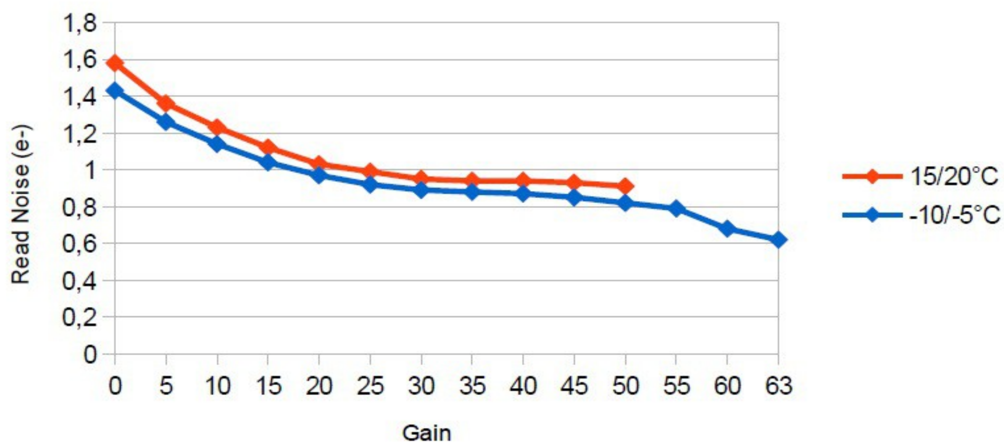
After a few experiments, I noticed something a bit strange ; read noise seemed to be very unstable, sometimes higher than expected. I noticed for example that read noise was a bit higher after, say, 1h of use than right after I plugged the camera in.

And then I suspected that read noise could be linked in some way to temperature.

Since I'm interested mostly in "lucky imaging", I did all my tests in 12-Bit mode, or "HGC Mode" as QHY calls it on their website. "LGC Mode" (8-Bit) has more read noise but is better for planetary imaging as it offers the possibility to go at a faster frame rate.

So here is some results I got from offset measurment at 1/16000s at 15/20°C and at -5/-10°C :

Gain	Read Noise (e-)	
	15/20°C	-10/-5°C
0	1,58	1,43
5	1,36	1,26
10	1,23	1,14
15	1,12	1,04
20	1,03	0,97
25	0,99	0,92
30	0,95	0,89
35	0,94	0,88
40	0,94	0,87
45	0,93	0,85
50	0,91	0,82
55		0,79
60		0,68
63		0,62



The difference might seem insignificant, but as read noise is the main limitation in lucky imaging, a decreasing value of 10% might lead to a sensitivity 20% higher, which is far from nothing.
Lucky for us astronomers, we often operate at such low temperatures, but you could say that it is a valid reason to take a cooled version of that camera ; you would have a base noise as low as possible in every situation.
The bad thing about that, is that we probably can't get any reliable master offset to do a complete preprocessing if we don't have controlon temperature. Once again, the cooled version seems to give an advantage there.

I may have an explanation for that. Since it's a rolling shutter sensor, in fact, the sensor is turning on for a way longer period of time than 1/16000s... Then, the overall noise is higher because thermal noise is no longer negligible. But I may be wrong on that one ;)

Overall, I'm close to values QHY provided on their website at low temperatures. Since then, they expanded max gain available to 63, and I measured read noise until that value : (-5/-10°C, 1/16000s)

Despite numbers showing some improvement going further in gain value, I think there is not.
To measure read noise, you have to take two offset, with no pixel with a value too close to minimum or to maximum. To do that, you can set the offset higher in the capture menu, but there is a limit ; and when you go up to 45/50 in gain, that's where some pixels begin to be set to black or to white. Then, no information can get through them, and measurement is broken.
Furthermore, lower the gain, better the dynamic. So I don't think there is any advantage in setting the gain too high - at Gain=63, the all image dynamic contains only around 15 electrons ! But a real test on the sky could prove me wrong. It is, however, very useful when you are looking for objects with camera behind a scope, or try to focus with it ; everything appears immediatly on the screen.

So in conclusion, and regarding the values I got, setting the gain above 30 seems counter-productive, because of the rapid dynamic range drop. So, I think I found there the sweet spot for lucky imaging.
In my following tests, I didn't use that value because I used an old version of sharpcap back then ; Gain was usually set at 100 which is probably equivalent to 40 right now.

With a minimal usable value around 0.85e-, that camera is definitely the best camera for lucky imaging purpose.

Then I wanted to test the amp-glow in very long exposures ; Even if 30s is enough in most cases in large band, for someone who would want to do some narrowband, that could be useful. QHY added an anti-amp-glow device that works... in some way.
If you shoot at ambient temperature, thermal noise is dominant everywhere ; so every test below was done at a temperature around -10°C, thanks to my freezer ^^

Here are some links towards 2 samples of each test I made

10s, Anti Amp-Glow on, Gain=30

https://www.dropbox.com/s/7lxjb8x05bu6ru2/Capture_0001.fits?dl=0

https://www.dropbox.com/s/qjca28mgjw0z3r8/Capture_0002.fits?dl=0

60s, Anti Amp-Glow on, Gain=30

https://www.dropbox.com/s/da88diex4043e96/Capture_0003.fits?dl=0

https://www.dropbox.com/s/dww9kndm8vmnved/Capture_0004.fits?dl=0

900s, Anti Amp-Glow on, Gain=30

https://www.dropbox.com/s/z1awd1pw63ohefy/Capture_0005.fits?dl=0

https://www.dropbox.com/s/pfnl70ganrc7dhf/Capture_0006.fits?dl=0

60s, Anti Amp-Glow off, Gain=30

https://www.dropbox.com/s/uyzh7ue91w2loae/Capture_0007.fits?dl=0

https://www.dropbox.com/s/ex65l8nxtgdjn29/Capture_0008.fits?dl=0

900s, Anti Amp-Glow off, Gain=30

https://www.dropbox.com/s/r3pomcj5s3hp1ft/Capture_0009.fits?dl=0 https://www.dropbox.com/s/v0v44e8atmy32bp/Capture_0010.fits?dl=0

As you can see, what we call "Amp glow" is still there whatever you turn on the function or not. However, in first case, the background looks way nicer. (especially visible on 900s frames)
If you substract one image to the other in each case, you can evaluate the overall noise because all redundant signal will be gone. And it is way lower when our anti Amp-glow function is on, which is a good sign. I don't know how that function works, so it might come with a counterpart, but overall i think it's a good idea to let it active at any time, as I'll show in my sky-testing later.

You can remove the Amp-glow signal by substracting dark frames, as you can see however, the noise is way higher in the Amp-glow zone, which induces a sensitivity drop.

Nevertheless, keep in mind that I took those frames at gain=30, and when you want to shoot in such long exposures, you probably want the highest dynamic possible and therefore shoot at Gain=0, in which amp-glow is way less noticeable.
And one last point : 900s is CRAZY long for such a camera ; I can't think of any situation where it would really be useful. But even then, you can get good looking images...just don't put your main target in that specific corner.

So in conclusion, "Anti Amp-Glow" function doesn't affect amp glow, but overall thermal noise, which is dominant over read noise at such long exposures. And it "cleans" background thermal signal. I didn't find any counterpart to it... I hope there is not ;)

That anti amp-glow function is, for now, only available on QHY cameras. So it is probably a real advantage, and even in shorter exposures as i found out.

QHY provided me as well some lenses to test the camera. I had at my disposal some lenses for surveilance cameras : a 1.25mm F2 fisheye, a 8mm F1, a 24mm F2, a 50mm F1.4 and a more expensive (and probably very good) 16mm f2 for µ4/3 camera. Most of them were as well labeled "IR", except for the 50mm, which is probably important with such a sensor.
I had however two major issues trying to use those lenses.

First one is very stupid : no way to fix the all damn thing ! if you shoot with the fisheye lens, it's not really a problem, you just put it on the ground somewhere, but at 50mm (which is a long focal with such a small sensor) it's just impossible without a stable tripod. And neither the camera nor the lens have a socket for it !

So after a bit of thinking, I came up with the most stupid design you'll ever see :

Yes, the camera has a lens on it and is fixed downwards in the scope, which has the USB cable passing through, and my Neq5 mount is just there to give a way to aim... barely because as I found out, in that configuration, you can't even shoot where you want ^^

I still managed to do some tests, in a dark site. Here are some links towards video samples, shoot at 0.5 FPS, and shown here at 8 FPS (time x16)
I uploaded them on youtube, but compression is very destructive, sorry about that. If you want to see the .avi file, I can provide it somewhere maybe.
At that time, anti Amp-Glow was not available on short exposures.

I can see that youtube is not very nice with my videos ;

1.25mm F2 : https://www.youtube.com/watch?v=70j0DgszNvs&list=PLpAPnYKQcZIfEqoro9HL8Yv_0Xd07j2mj&index=1

8mm F1 : https://www.youtube.com/watch?v=UtWFDUypQwc&list=PLpAPnYKQcZIfEqoro9HL8Yv_0Xd07j2mj&index=4

16mm F2 : https://www.youtube.com/watch?v=esk6O8zdByA&list=PLpAPnYKQcZIfEqoro9HL8Yv_0Xd07j2mj&index=5

24mm F2 : https://www.youtube.com/watch?v=Sy1BUxNzEM8&index=6&list=PLpAPnYKQcZIfEqoro9HL8Yv_0Xd07j2mj

50mm F1.4 : https://www.youtube.com/watch?v=UB4pd9QVZX4&list=PLpAPnYKQcZIfEqoro9HL8Yv_0Xd07j2mj&index=7

And a bonus one, 8mm at 2 FPS, in real time : https://www.youtube.com/watch?v=ZVibXOqT6GU&index=2&list=PLpAPnYKQcZIfEqoro9HL8Yv_0Xd07j2mj

As you can see, sensitivity is crazy good (a bit hidden behint youtube quality) ; we reach mag 9 easily with the 8mm lens and a half-second exposure time, and mag 13 (!!) with the 50mm f1.4 lens in only two seconds.

However, those images can't be used to be stacked and produce some nice sky images, because it requires a much better lens quality. I tried, and even the expensive one is not good enough in my opinion.
Even without the stacking, as you can see, the 1.25mm and 8mm are only good on the center, the 24mm seems good in the bottom left corner but not in the upper right, the 50mm has some sort of blurry aspect, probably due to the fact it is not an "IR" lens, and even the 16mm shows some coma on the left side.

I would like to try my 135mmF2 samyang one day (best lens ever for astronomy in my opinion) but can't figure the way to attach it for now.

So there is only one purpose left that comes in my mind : sky surveilance / shooting stars detection. For that purpose, I think the 1.25mm lens and the 8mm lens are both very good choices, one because it covers the all sky, and the other one because of its crazy f1 aperture and a still big enough field coverage.

And then I run in my second issue : how to analyse properly all the data you get ?

I'm sure for example that I got a shooting star on my 8mm sample (I saw it on a frame during the capture) but I didn't take note of it, and it was impossible to find it afterwards. And that was only a very short portion of the all night. I could as well make the exposure time shorter, but I would run into the same problem... too much data.

Here is another sample I took, in the darkest site I ever visited ; however, transparency was far from perfect that night. Furthermore, I was on a balcony and could not shoot very far above the horizon. Due to a bad camera positioning, the upper left corner is missing. Gain was lower (maybe 30), and I took 8s exposures. Again, I reach mag 10 on single frames :)

It might be 1 or 2 shootings stars just a little bit after the beginning.

With the 8mm f1, time x16 (2FPS) : https://www.youtube.com/watch?v=Tmd__Y5mwg8&index=8&list=PLpAPnYKQcZIfEqoro9HL8Yv_0Xd07j2mj

So if some people have some ideas to improve all this, I'm open to it :)

One other thing I'd like to test with all that stuff is digiscopy, but i'm not very well equipped for that at the moment.

And finally, the tests on telescope.

For now, I'm using a SkyWatcher 150/750 newtonian on NEQ5 mount. You can't really speak of "lucky imaging" at this point, since the turbulence is not really a problem with such a small diameter. However, I think of what i'm doing as a preparation for future days, and i'm having tons of fun doing it :)
The camera is very easy to set up, with a nice plus on that little ring that you can adjust to keep the focus when you want to take the camera out.

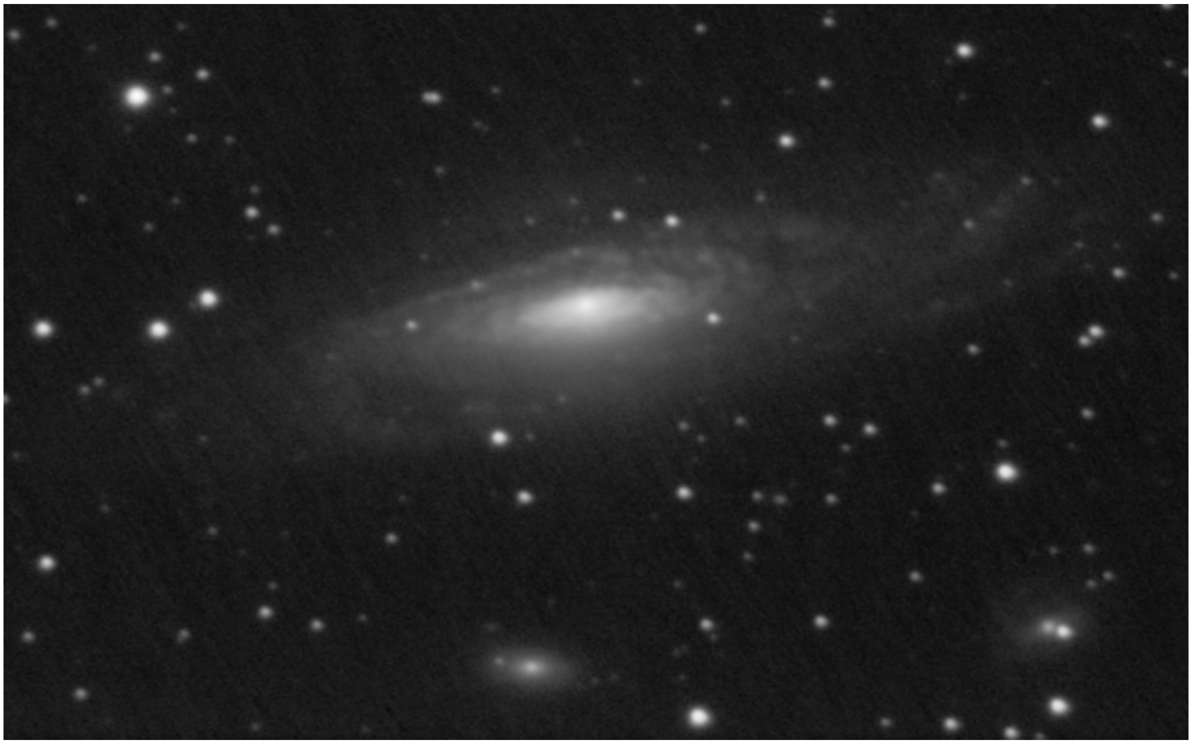
If you want to capture very bright objects, such as planetary nebulaes, you can shorten exposures a lot. But if you prefer fainter objects, like galaxies, you have to find the best compromise between resolution and light.

I think a good compromise is to try to get as much background noise than read noise in your image. Basically, it allows you to get half the maximal sensitivity you could get doing longer exposures, but by doing so you reduce a LOT the exposing time needed by frame. It depends on your sky quality and the aperture of your instrument ; in my case and at my usual astronomical spot, that time is around 2.5s per frame.

However, my mount doesn't allow me to take exposures longer than 2s with such a small field ; i'm down to 0.8arcsec by pixel, which is very little for a 150mm telescope ; therefore I used mostly that exposure length except on some cases I'll explain later.

First test was NGC7331. As you can see, probably due to a bad collimating, the image is quite blurry. But it showed some banding as well, which scared me a little... the amp-glow reducer was not avilaible at this time for such short eposures.

NGC7331 ; 5500x0,5s (37min total)



Afterwards, that option came available, and I used iton my next target : stephen's quintet. The image was already sharper than the previous one, but still not pinpoint. However, no banding at all ! I still don't know if that is linked to the amp-glow reducer, but I think it might be, since banding never came back.
I managed to get above the 20th magnitude, a decent score for a 150mm in my opinion.

Stephen's quintet ; 2450x2s (1h22 total)

Two months later, I finally managed to get some pinpoint images. In my enthusiasm, instead on focusing on one target, I tried a bit of everything :

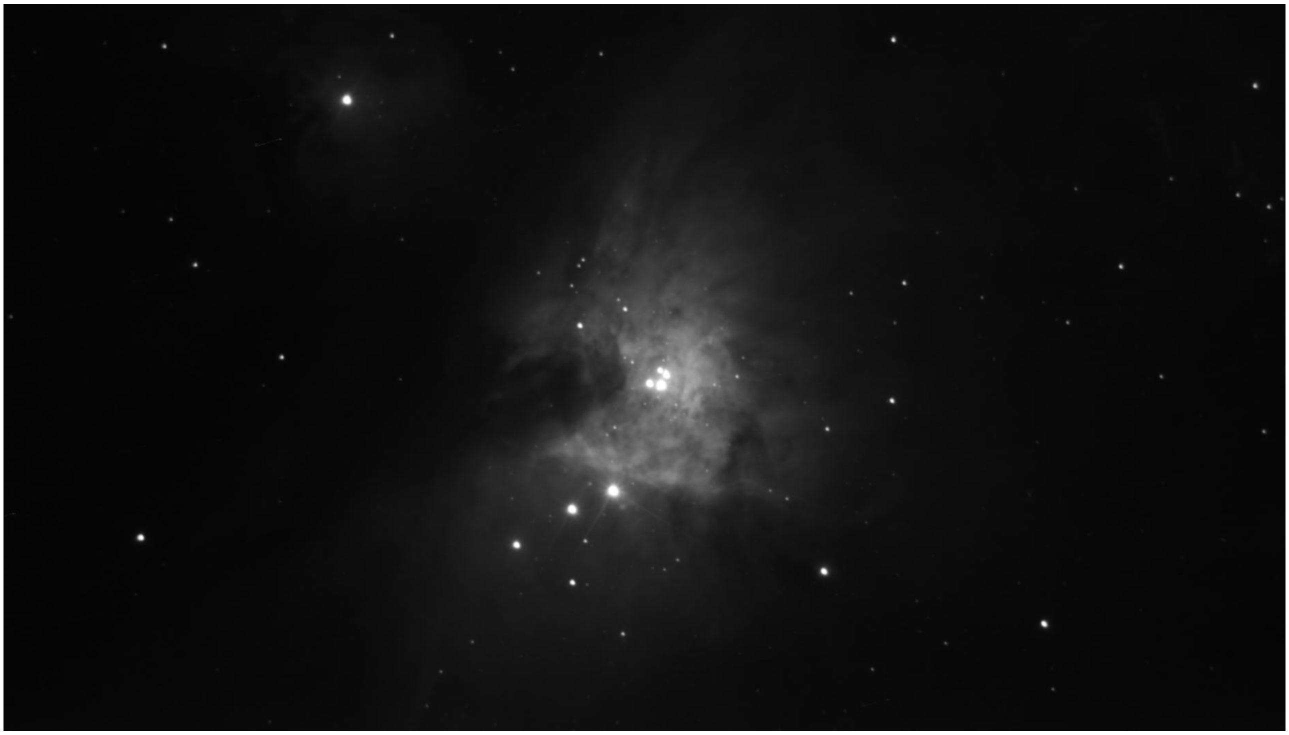
M82 ; 17min total with 4s frames

M33 (+ NGC604) ; 12min total with 2s frames

Flame Nebula ; 20min total with 2s frames

Horsehead Nebula ; 27min total with 2s frames

Core of M42 ; 4min total with 250ms frames



A bit later, I tried the Horsehead once again, with longer total time, but I was in a much worse place (closer to Paris, lot of light pollution) so I didn't get a very much better result than I got before, even with a total exposure 4 times longer :

And last but not least, I wanted to try some longer exposures to see if the camera was good in that domain as well. Since my mount holds only 2s on a normal target, the solution was to take a target as close as possible to north pole. So I came up with this image of NGC2276, my favorite image so far.

NGC2276 ; 2h total with 15s frames

In bonus, I got a supernova in it, and broke my own record going above 21st magnitude ;)

If you compare my result to some others found on the web, i'm on the level of images taken with a way larger diameter in resolution AND sensitivity, which proves (at least to me) that this camera is way more than a planetary camera, despite its moderate price.
We don't have any info on Quantum Efficiency of that sensor, but I think it's on a very high level, maybe higher than any CCD camera out there ; thanks to BSI technology.

Can't wait to go out again :)

About the processing, it might seem tedious with such a big amount of files, but keep in mind your images are 2Mp monochrome, so any computer will process them fast. Furthermore, with such a small field, you probably don't need flat fields, and I find offsets useless as well. Taking darks is still needed though.
Again, you probably don't need a powerful alignment algorithm, a "one point" is enough for me. I tested with some more powerful stuff, didn't change anything on the result.
The only step you want to spend time on is the image selection. I'm still searching for the perfect tool which could sort my images from the best to the worst, but it seems that the naked eye is still the best in that

domain. I keep usually around 2/3rd of all the images, but again, turbulence is not yet a problem for me. So I could see a world where you keep only the 30% best, or even less, just to improve resolution...

I have numerous other ideas and tests to do (messing with filters, planetary imaging, coma correcting, guiding while imaging...) I'll test that as soon as possible and maybe add some data to this.

Sorry if my writing is not top notch, as a french guy I tried my best, and thanks if you made it to that point ^^

Clear skies

Romain Chauvet