

# Astrophotography CAD

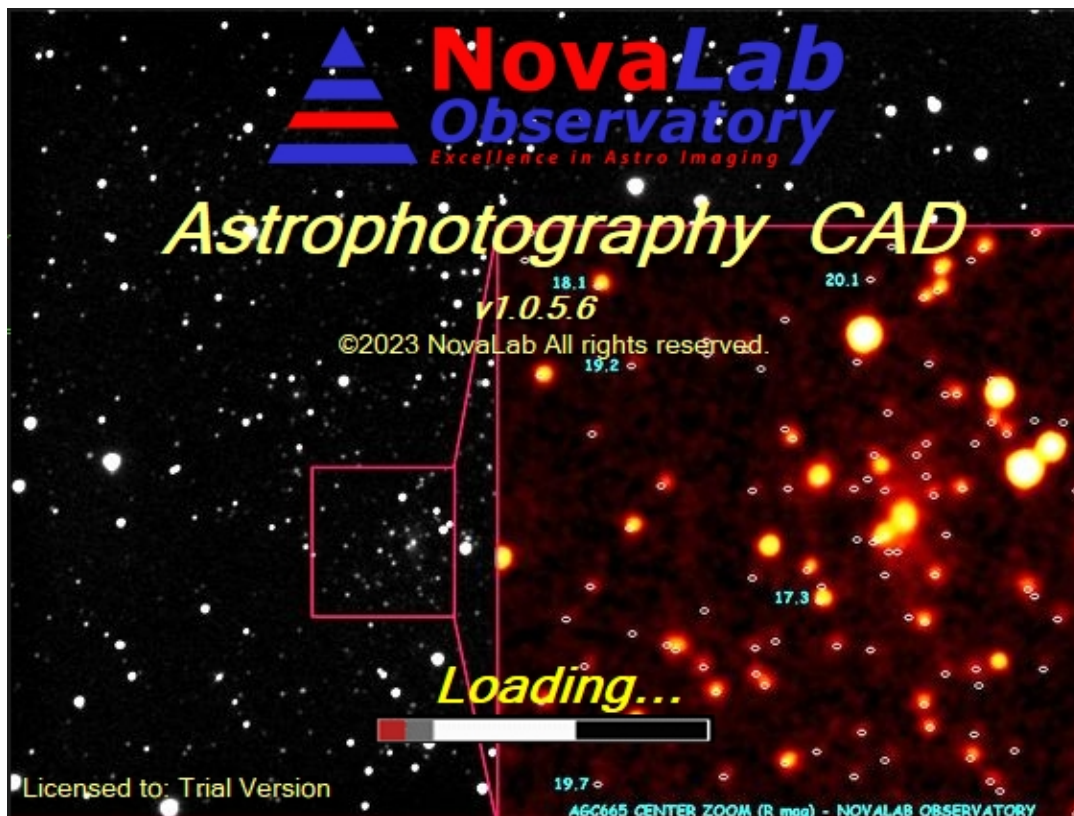
Copyright 2023 NovaLab Observatory, LLC



Software to help astronomers optimize/design astrophotography systems and plan exposure settings for superior imaging under a variety observing conditions.

## User Manual

V1.0.7.8



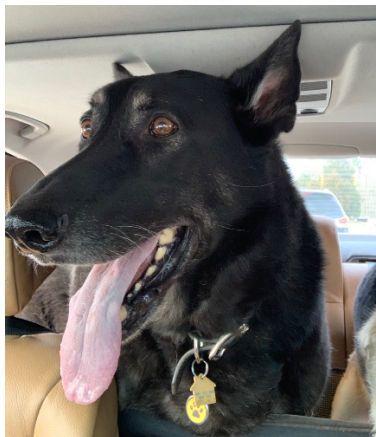
NovaLab Observatory LLC, 3 Beaugard Drive, Spencer, NC 28159

[www.NLobs.com](http://www.NLobs.com)

**The three most important questions are:**

- **Is there a God?**
- **What happens when we die?**
- **Are we alone?**

**If anyone answers any of these, it will change everything...**



***Dedicated to Magnus, a true and loyal friend, my constant companion, guard and a protector who loved me unconditionally. I shall always miss you. C.K***

## Installation:

Astrophotography CAD will run on Windows 7, Windows 8, Windows 10 and Windows 11, on both 32 and 64bit operating systems. It requires .NET Framework 4.7.2 or higher, and minimum display resolution of 1200 x 720 pixels or more (WXGA+), including 4K resolution displays.

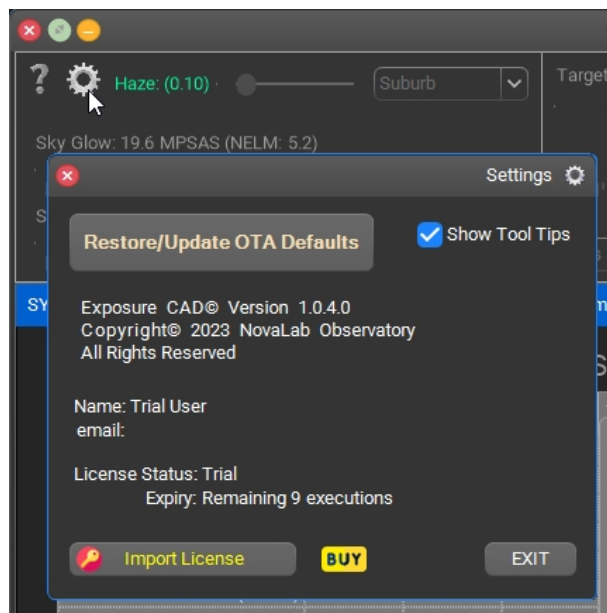
To install it, download and run *aCAD\_Setup.exe*. Installation is pretty straightforward, just follow the simple options during the install process.

Newly installed application will run in a trial mode for the first ten executions. This mode will offer all the available features, but will not allow you to change OTA or the Imager, or save / modify most of their parameters. In short, it will allow you to evaluate the functionality as it relates to your purposes. After that you must enter the license in order for application to run.

## Licensing:

In order to unlock the application, you should purchase a license from the NovaLab Observatory website ([www.NLobs.com](http://www.NLobs.com)). After the purchase, the license file will be emailed to you within minutes. The license will be tied to the name and email you used when you made the purchase. It will be automatically emailed to **that** email address.

When you receive the license, drag it onto the desktop, or save it to another handy location. Run the Astrophotography CAD application, and activate the tools icon (small gear in the upper left corner). Press the button labeled “Import License”, and the file explorer window will open. Navigate to the license file (*your\_name.license*), select it, and press “Open” button. The license will be imported, and you could delete the file you copied onto the desktop earlier, however, it is safer to save it in a safe place like a USB stick, along with the downloaded setup file, as you will need to purchase new license if you were to lose it and try to reinstall the application on a new PC. Remember, drives do crash.



In case that you have no license, and have already reached ten application executions, the Astrophotography CAD will not run, and will take you directly to the “Settings” window to enter the license. It will also open your browser to the relevant page on our website.

Note that the license is an encrypted binary file, and attempting to modify it will irreparably damage it. Please do not share the license with others, as it supports the further development and is illegal. You may install and use the application on up to two computers owned by you.

For full licensing information, please read the **License Agreement** at the end of this document.

## 1.0 Introduction and Overview

Astro images are affected by a multitude of varying parameters, some under user control and some not. There have been numerous attempts in the past to create spreadsheets and to disseminate various formulae in order to assist the user in selecting the right combination of parameters that will produce the desired result.

This application is a direct result of a failed attempt to create just such a spreadsheet. It very quickly became apparent that in order to have meaningful, all-encompassing results, it is imperative to increase the simulation granularity, and to treat the entire imaging train, from the target, thru the atmosphere, the OTA (Optical Tube Assembly) elements, filters, and finally the imaging device itself as well as the calibration parameters (darks, flats and bias frames) as a unified system. Modelling the entire system over the full range of wavelengths is the only reliable way to have precise, and meaningful results.

Astrophotography CAD was created to help users better understand how their imaging setup will perform, what are its limits, and which parameters will enhance the results. It is a result of many months of development. It's expected uses encompass:

- Helping users design their imaging system by simulating OTA/Imager combined performance and comparing it with user's stated goals. This is particularly important before significant purchases, such as telescopes and cameras. You will be reasonably assured that the system will really do what you need it to do, and may be very pleasantly surprised how little difference some very expensive features actually make to the end result.
- If you already have an existing imaging system, this application will help you optimize its optical train, and select the correct imaging parameters, such as the sub duration and total exposure length.
- If you have a particular goal in mind, this will help you determine how long of a total exposure time you need, which filters to use etc. For example, if you are studying variable stars, or doing Exo-Planet research and you need a particular photometric accuracy, this will help you decide how to get there, or just see whether you can do it at all with what you currently have.
- When purchasing or designing your own OTA from the available components, this will predict what you can expect from the end product – before you actually spend the time and money purchasing or making it.
- You can quickly compare expected performances of prospective Imaging Camera or OTA before you make a purchase, and be confident that your desired expectations will be met.

Astrophotography CAD currently comes preloaded with 151 imaging sensors and camera models, and 110 different OTAs, which you can modify or even create your own. This is supplemented by a full complement of 76 filters from various manufacturers, including LRGB, photometric, long pass and band-pass filters.

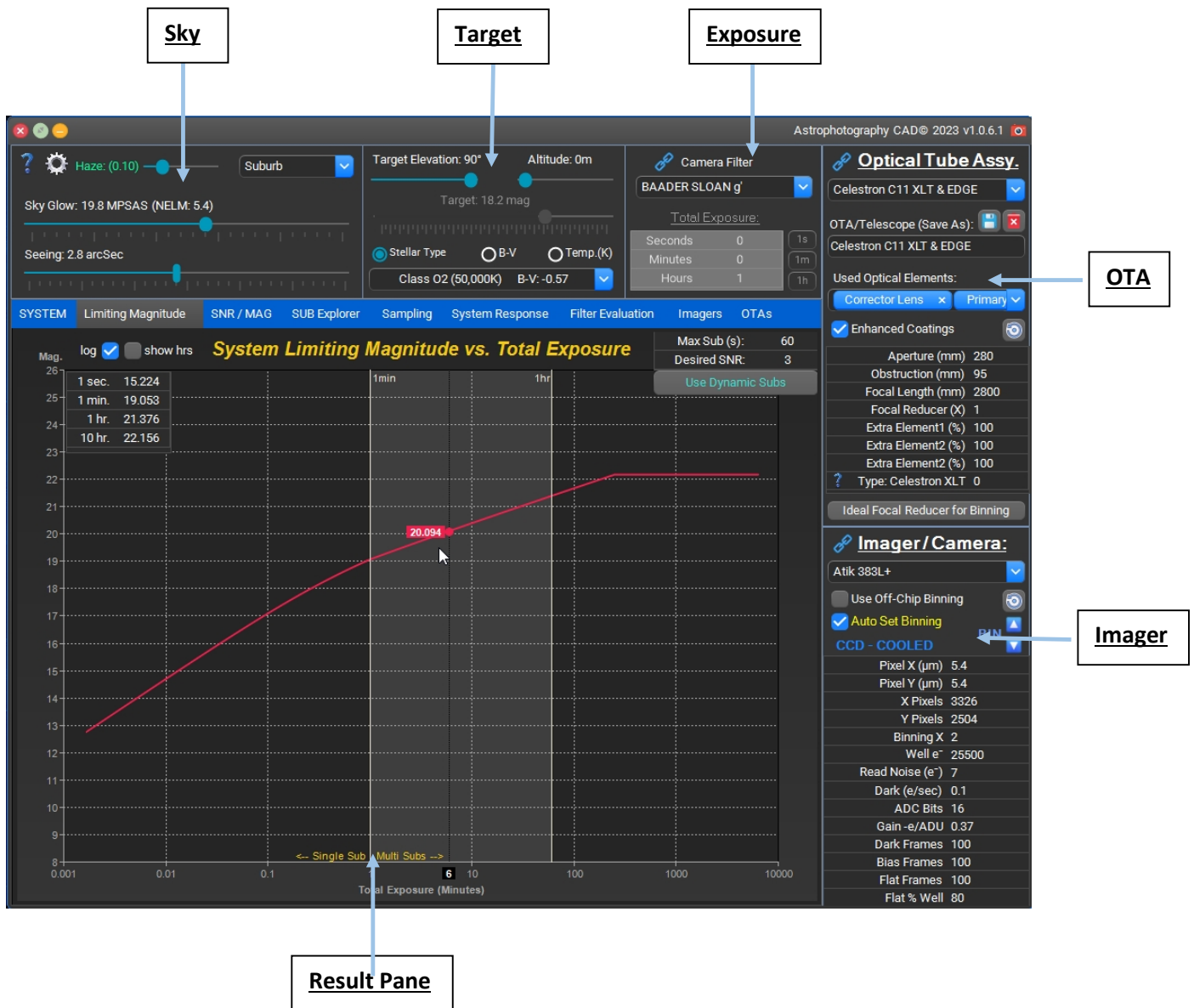
The entire system is comprehensively modeled from 350nm to 1000nm, a range covering every imager commercially available. The atmosphere is also modeled, including the Rayleigh scattering, Aerosol Scattering (haze) and Ozone extinction over the range of target elevations, and the observing site's altitude. Finally, not all the stars are made the same: Class O stars and class L have drastically different photo chromatic fluxes, and this needs to be taken into account. So, if you are specifically looking to study the Red Dwarfs, some sensors may not be your best choice.

The main end result calculated by this application is in almost all cases the target Signal to Noise Ratio (SNR), or its derivative, such as the Limiting Magnitude.

Why SNR? It determines what we can see (the limiting magnitude), how noisy or crisp the image is, and how accurately we can make measurements with the data we collected. Whether you are performing photometry, or doing deep sky work, the SNR is always of the uttermost importance.

## 2.0 Application Layout and Operation

The application window consists of a central pane containing the results, surrounded by segregated panes describing the Sky, the Target, the Exposure parameters, the OTA and finally the Imager/Camera.



Operation is fairly straight forward. The system parameters are changed using the Track bars or dropdown lists, and in some cases direct numeric input. The computation is performed in real-time, and there is no "Calculate Now" button.

There are guards against user errors making sure that you get correct results. For example, you will not be able to set the sub duration to longer that will saturate your imager pixels.

The "Results" pane consists of nine pages showing different aspects of your imaging system.

## 1. System Summary

This result page is typically the one most astronomers will start with. It shows you the summary of your system parameters and the expected system performance at a glance.

### SYSTEM FILTER LIMITING MAGNITUDES:

FILTER	1 min	1 hr	100 hr
BAADER LP-610nm	18.85	21.14	23.65
BAADER lp-Bessel	18.74	21.06	23.58
Astronomic LP-742nm	18.72		
AstroDon BB LP-500nm	18.65		
BAADER LP-495nm	18.64		
BAADER LP-570nm	18.64	20.92	23.42
<b>NO FILTER</b>	<b>18.60</b>	<b>20.87</b>	<b>23.38</b>
Astronomic ProPlanet	18.54	20.84	23.35
AstroDon BVRI-I	18.49	20.81	23.32
DGM Optics GCE	18.51	20.79	23.29
BAADER SLOAN i	18.45	20.77	23.28
Astronomic LP-807nm	18.42	20.75	23.27
BAADER SLOAN z-s	18.14	20.47	22.99
Astronomic LUM L-1	17.70	19.97	22.48
AstroDon BVRI-Rc	17.63	19.91	22.42
BAADER SLOAN r	17.54	19.82	22.33
Astronomic LUM L-2	17.50	19.77	22.28
Astronomic CLS-CCD	17.47	19.76	22.27
BAADER R(Old)	17.34	19.63	22.13
BAADER LUM (Old)	17.35	19.62	22.13
BAADER Rp-Bessel	17.32	19.61	22.12
Astronomic LUM-2c	17.30	19.57	22.08
BAADER LUM (CMOS)	17.27	19.55	22.05
BAADER R (CMOS)	17.26	19.55	22.06
Astronomic LUM (Old)	17.28	19.55	22.06

Note: Ref Only. Approximate, using Best SUB.

### SYSTEM PARAMETERS:

Parameter	Value	Unit
System F#	8	
System EFL	2432	mm
Clear Aperture	549.1	cm <sup>2</sup>
X FOV	25.4	arc min
Y FOV	19.1	arc min
X Resolution (Binned)	1663	Pixels
Y Resolution (Binned)	1252	Pixels
----> Focused Star Size	3.71	arc sec.
Binned Pixel	0.92	arc sec.
Binned Pixel Size	10.8	µm
Sampling Ratio	4.05	X
Airy Disk	0.91	arc sec.
Dawes Resolution	0.38	arc sec.
Critical Focus Zone	172	µm
<b>New CFZ (w. Seeing, 5% defocus)</b>	<b>363</b>	<b>µm</b>
Nyquist Binned OTA EFL	1201	mm
Nyquist Binned OTA FR	0.494	X
Nyquist Un-Binned OTA EFL	600.5	mm
Nyquist Un-Binned OTA FR	0.247	X
Max Sub (Zenith, Current Filter)	1638	Sec

Auto Binning is Set to ON!!!

On the left is a snapshot of limiting magnitudes for various filters for 1min, 1hr and 100hr (i.e. the ultimate capability) exposures. As you change the seeing, sky pollution, stellar type, filters etc., these will correspondingly change. Clicking on header columns will sort the table, so you can quickly see which filter will give you the best results. You can change the current filter if you double click on the corresponding row.

On the right are your derived system parameters. The list contains the critical parameters and help guide you towards the best focal reducer ratio, binning etc. Note the parameter “Focused Star Size”: This is the actual FWHM (full width – half maximum) size inclusive of the Seeing, and the *Diffraction properties* of your OTA. On OTAs in 8 – 12 inch range the latter has a moderate effect, but this is not so on smaller refractors. The “Focused Star Size” is used in determining the optimal binning, and to study the best OTA EFL and Focal Reducer. Please note that the best OTA FL should be determined after deciding what type seeing you expect at your site. Critical Focus Zone (CFZ) is theoretically only modified by the System F#, and it does not take into account the Seeing and the diffraction phenomena. Thus, the New CFZ exists (implemented as visually unnoticeable, 5% defocus), courtesy of GoldAstro.com. It is much more generous, and much more realistic. Why? How sharp do you want to focus the blur? Clearly, the seeing conditions will impact the focusing tolerance.

The last few rows show you the minimal Nyquist OTA EFLs and the Focal reducer needed to reach it. You see the results in the un-binned scenario or at the currently set binning. So, if you consider that the C11 - KAF8300 combination will need reducer of 0.21x when un-binned, it is clear that you need to bin or get a camera with a much larger pixel pitch. These values only take sampling into account, and the best sensitivity setting is determined on the “Sampling” page.

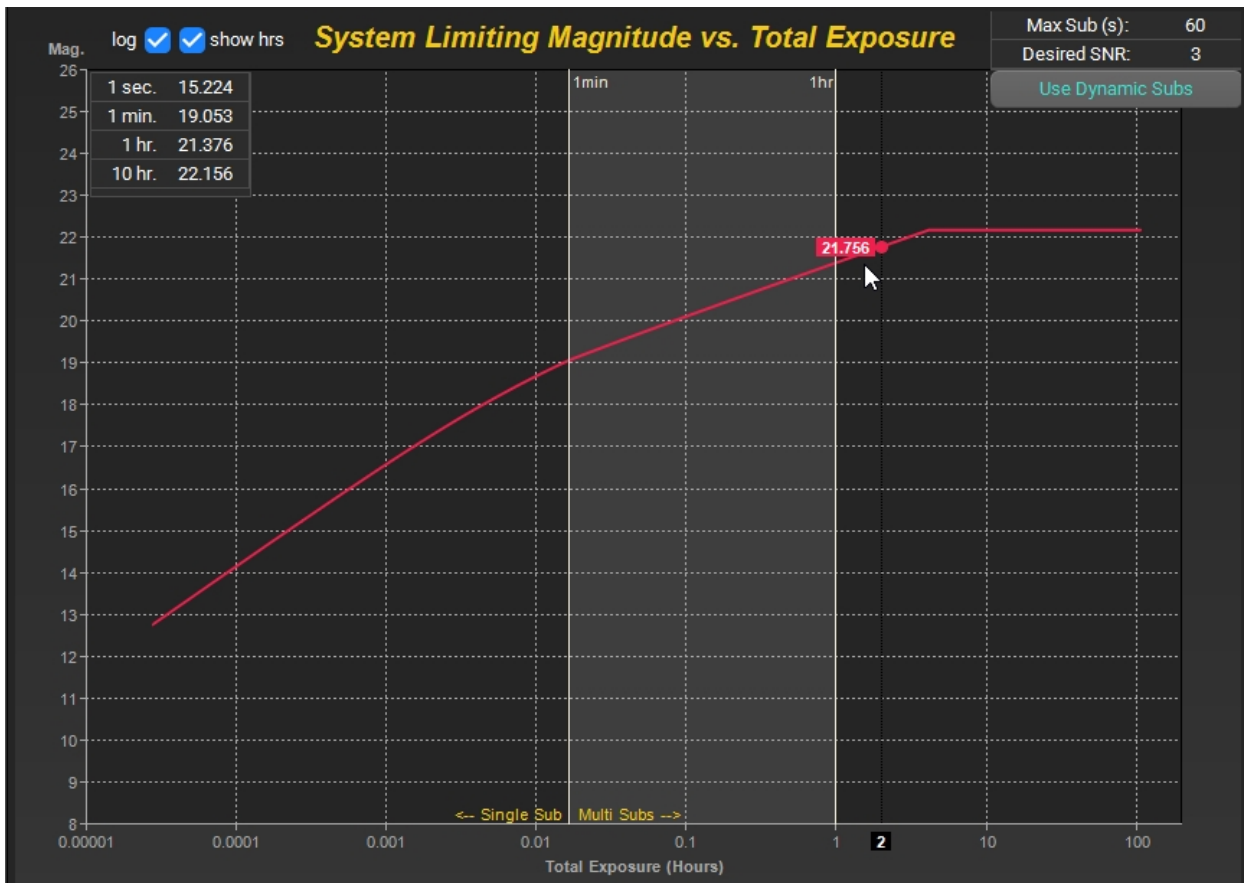


## 2. Limiting Magnitude

This page will show you the ultimate limits of your system for total exposure duration from 0.1 second to over 100 hours. You can set a fixed sub-exposure duration, or if you leave it at 0 the application will use the theoretically best (but not necessarily best for your needs) sub for your system (i.e. optimal, Dynamically variable subs). In order to show a comprehensive high dynamic range dataset, all exposures shorter than the fixed sub are always treated as dynamically optimized, variable exposures.

The boundary where the system switches to a multi sub mode is delineated on the chart. Below this is a region of dynamic subs. At the high end of the graph you may see a flat plateau. This is the artifact of ADC resolution and Camera gain – in other words, with the selected sub-exposure, the sensor does not receive enough photons from the target to fill a single ADC bit, and indicates that you need to increase the sub duration or Camera Gain (on CMOS Sensors), if you want to go deeper.

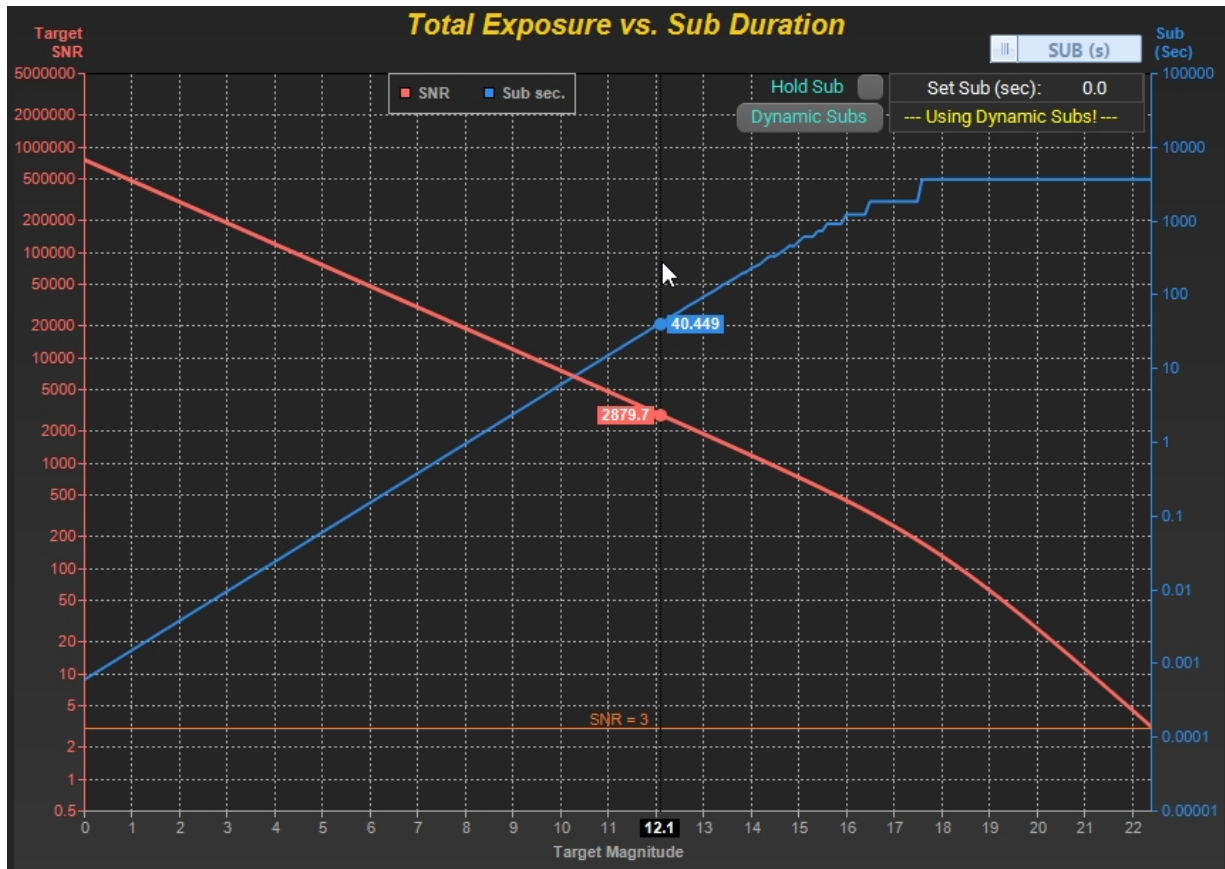
You can study the effects of the Seeing, Sky Pollution, Camera ADC resolution, Gain and other parameters on what can be achieved. If you move the mouse over the chart, the Track Cursor will be activated so you can easily see the corresponding curve values. The summary table in the upper left corner, will provide a quick overview for comparison purposes.



**Note: Using Dynamic subs can be tricky when interpreting the results. The dynamic feature is only meant to help guide you towards the optimal sub duration.**

### 3. SNR vs. Magnitude

When you set the total exposure duration, it is possible to study the effects of various parameters on the SNR. You can see the attainable SNR of the target magnitudes up to the limiting magnitude. Again, you can set a fixed sub exposure, or if you leave it at 0, the system will use the Optimal (and not necessarily best for you) theoretically best subs for your system. If you set a fixed sub, only magnitudes which do not saturate pixels will be displayed. You will not be allowed to set the Sub duration greater than that which will saturate your imager pixel. The displayed photometric error is based on SNR, and includes the theoretical **scintillation** for the selected OTA aperture and the selected target elevation.



Changing the exposure will reset the Fixed Sub durations (if used). To keep the selected value while changing the exposure, check the "Hold Sub" checkbox. Moving the cursor over the chart will activate track-bars so you can quickly see corresponding values. You can use the associated slider switch to see the attainable photometric accuracy, in which case the Sigma Switch will appear allowing you to select the desired confidence level. Photometric accuracy is stated with either  $1\sigma$  (68% confidence, reporting standard) or  $3\sigma$  (95% confidence). For example, the photometric accuracy of 210mMag at  $3\sigma$  means that 95% of the readings will reside within the  $\pm 210$ mMag error band. Similarly, same target at  $1\sigma$  will yield 68% of the readings within the  $\pm 70$ mMag error band.

**Note: Using Dynamic subs can be tricky when interpreting the results. For example, it may appear that the Limiting Magnitudes increase when the binning is changed in a way that is clearly detrimental, such as when it is reduced. This is not an error, but an artifact in that the subs maximum possible duration increases as the binning is decreased (i.e. virtual pixels get smaller). This artificially increases the total exposure SNR to what you would get if you used extremely long subs. The dynamic feature is only meant to help guide you towards the optimal sub duration.**

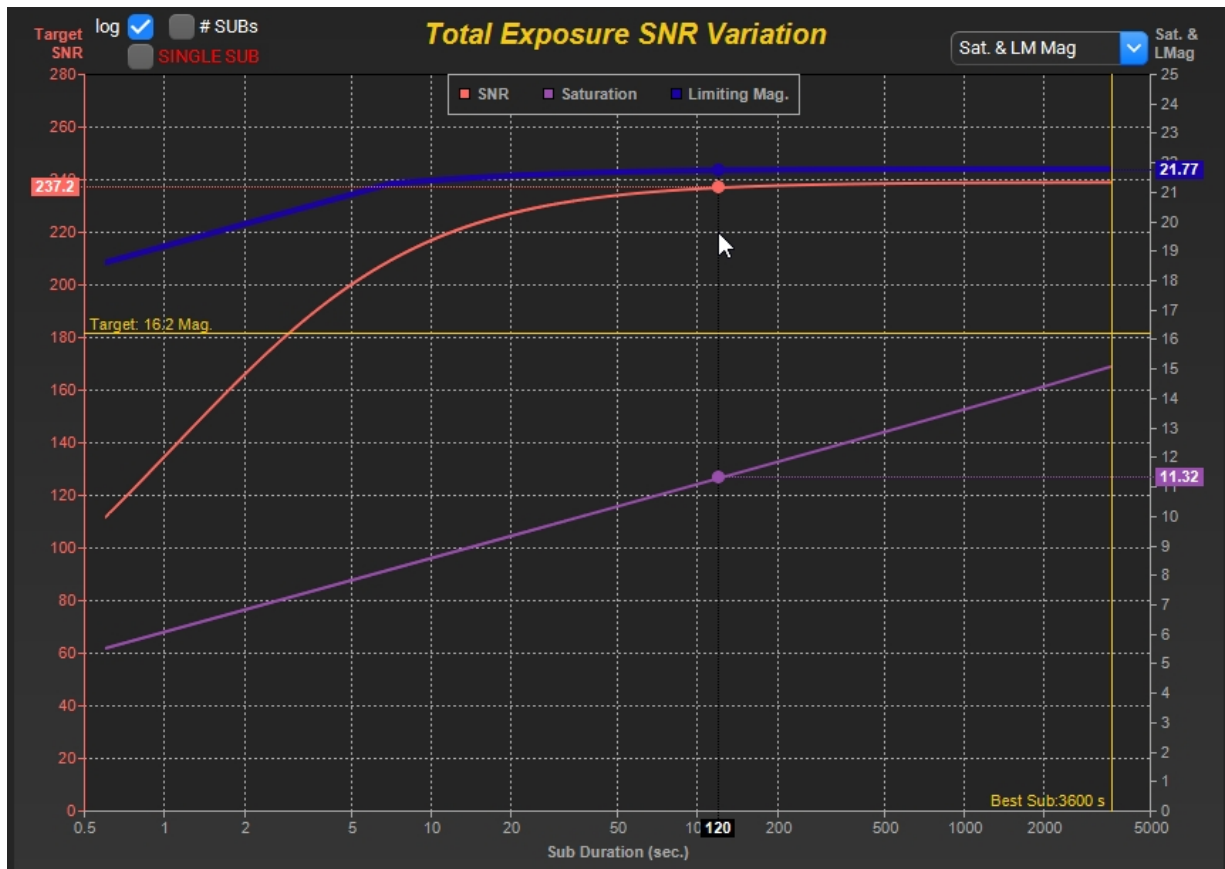


#### 4. Sub Explorer

This tab allows user to explore effects of the sub-exposure on the obtainable SNR, limiting magnitude, and photometric accuracy.

By un-checking the “SINGLE SUB” checkbox and setting the Total Exposure and the Target Magnitude slider you can study the effect of the sub duration on the total exposure’s resulting SNR. After selecting the appropriate associated drop box option, you can also see the saturation magnitude variation, and the limiting magnitude across the full range of subs (thus, the system dynamic range) as well as the Photometric Accuracy and the Well depth(s) in %. You can even see the best and worst stellar class limiting magnitudes – a feature particularly useful if imaging a star field with diverse targets. You will notice that using the OFF-Chip binning will give you a vastly improved dynamic range (if you are indeed binning), with slightly degraded SNR, and limiting magnitude eroded by perhaps 0.2 magnitudes in most cases. So, if the photometry is your goal, you should consider this option if you need more and brighter reference stars.

Some of these charts may take a bit longer to display on slower computers, on the order of one second. There is a lot of computation going behind the scenes, so even fast CPUs get pretty busy.



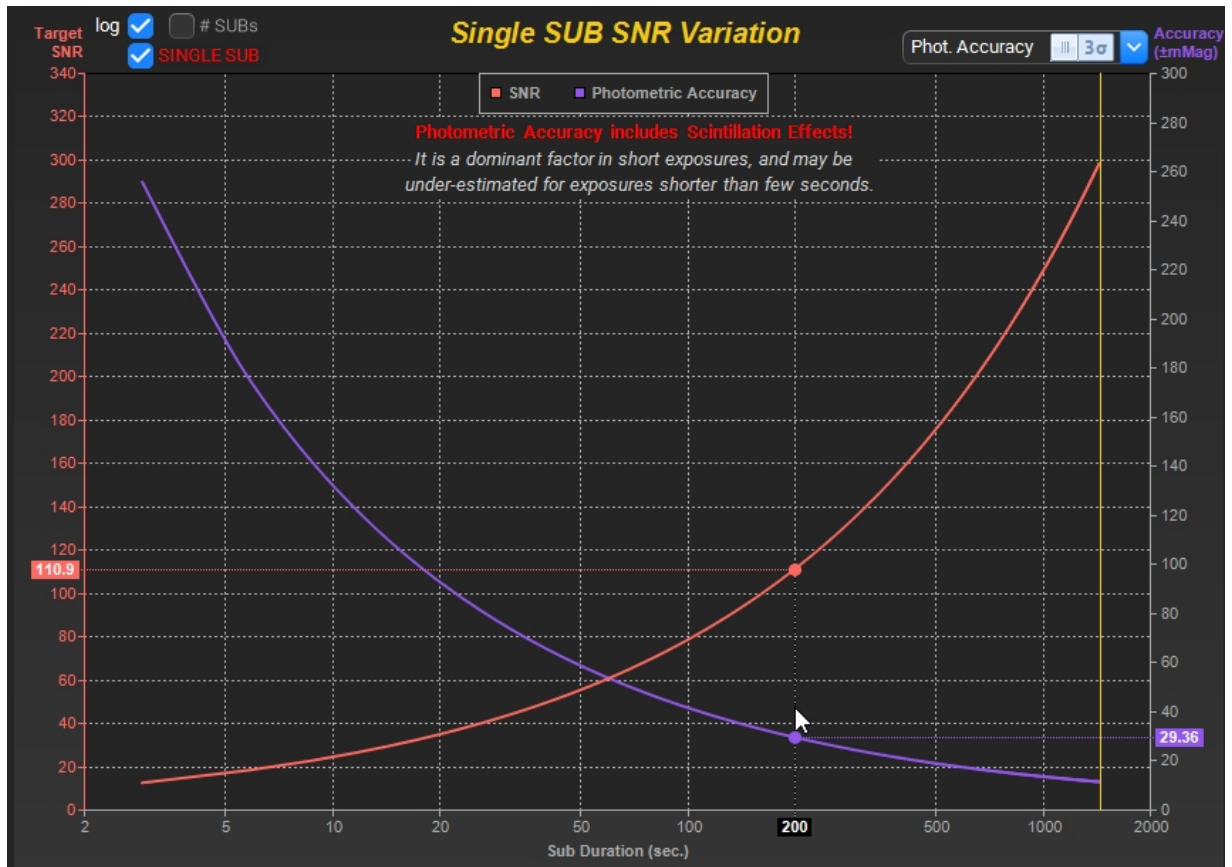
These are pretty busy charts, with lots of data, so take your time to properly study them. The displayed photometric error is based on SNR, and also includes the theoretical *scintillation* for the selected OTA aperture, total exposure time and the selected target elevation.

The best sub duration and the target magnitude markers are displayed for reference only. In most cases you will find that using a significantly shorter sub will result in only a very minor SNR degradation. You

can best gage the Sub duration inflection point by turning OFF the logarithmic display, at which point it becomes very clear which is the best Sub duration.

Checking the “SINGLE SUB” checkbox will allow to examine behavior of a single exposure. For example, when studying transient phenomena such as EXO Planet transits, or asteroid perturbations, it is important to choose shortest SUB that will yield acceptable SNR and photometric accuracy.

The chart will display selected parameter performance up to the maximum duration of the SUB duration, when the imager well is 99% full.



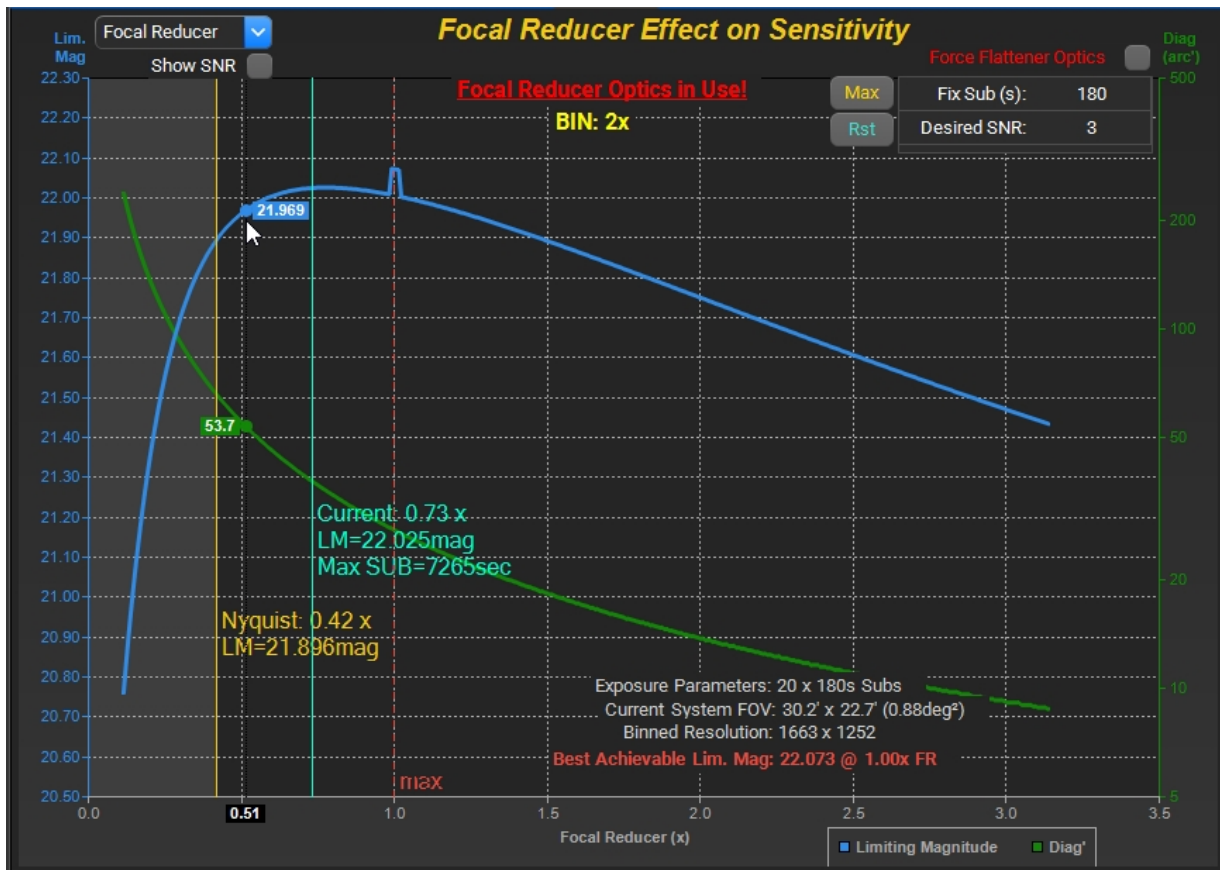
Various parameters can be studied by selecting an appropriate option in the associated drop box. If the goal is the photometric accuracy, it should be noted that the values shown also include degradation due to scintillation effects. These effects are based on Young’s estimate (1967), and is not a perfectly accurate solution, but does provide a reasonably precise estimate for general photometry work. Its accuracy is however degraded for very short exposures (less than a few seconds), in which case it may overestimate the scintillation effects, and display too high of an error.

Sigma Switch: Photometric accuracy is stated with either 1σ (68% confidence, reporting standard) or 3σ (95% confidence), selectable by the toggle switch. For example, the photometric accuracy of 210mMag at 3σ means that 95% of the readings will reside within the ±210mMag error band. Similarly, same target at 1σ will yield 68% of the readings within the ±70mMag error band.

Very bright targets may require exposures too short for your camera. Using a neutral density filter is one solution that may allow you to perform photometry on such targets. If stopping down the aperture, make sure to reduce it in the telescope table fields in order to get accurate results.

## 5. Sampling Effects

Image sampling is a critical factor in Astro Imaging. Choosing the right sampling will permit a discrete sequence of pixelated samples to capture all the information available to the target. This is described by the **Nyquist-Shannon** sampling theorem, that everyone should be familiar with. Simply stated, in our case it says that the angular size of the pixel must be at least 2X smaller than the combined effects of the seeing and that of the telescope diffraction effects.



This does not necessarily translate to the best Limiting Magnitude or the best SNR, for a particular target. As the matter of fact, best Limiting Magnitude will almost always be reached at an EFL significantly greater than that dictated by Nyquist minimum, and you will find that the EFL is very sensitive to the imager read noise. Users proficient in photometry know that the best SNR is usually obtained at around 3 x FWHM, but you will notice that the target magnitude also has a profound effect on EFL at which the best SNR is attained. This is in many aspects similar to, and emanates from the same theoretical roots, and these effects can be studied on the “Sampling Effects” simulation results page.

The chart will show you the Nyquist frequency marker, as well as marker showing how your system currently is currently configured. The gray area covers the under-sampled image condition. You can view the results with OTA EFL, OTA F# or the Focal Reducer ratios shown on the X-axis. You can also quickly change the binning by means of two BIN up/down icons in the Imager area.

Note the little kink on the graph: The software takes into account that at FR=1x, there is no light loss due to the lack of reducer optics. You will find that in most cases the best setting will be at this kink. You may opt to use a reducer in order to increase the field of view, or to flatten the image plane and sacrifice some sensitivity. In that case the graph will help you find how that decision will affect the sensitivity, and decide

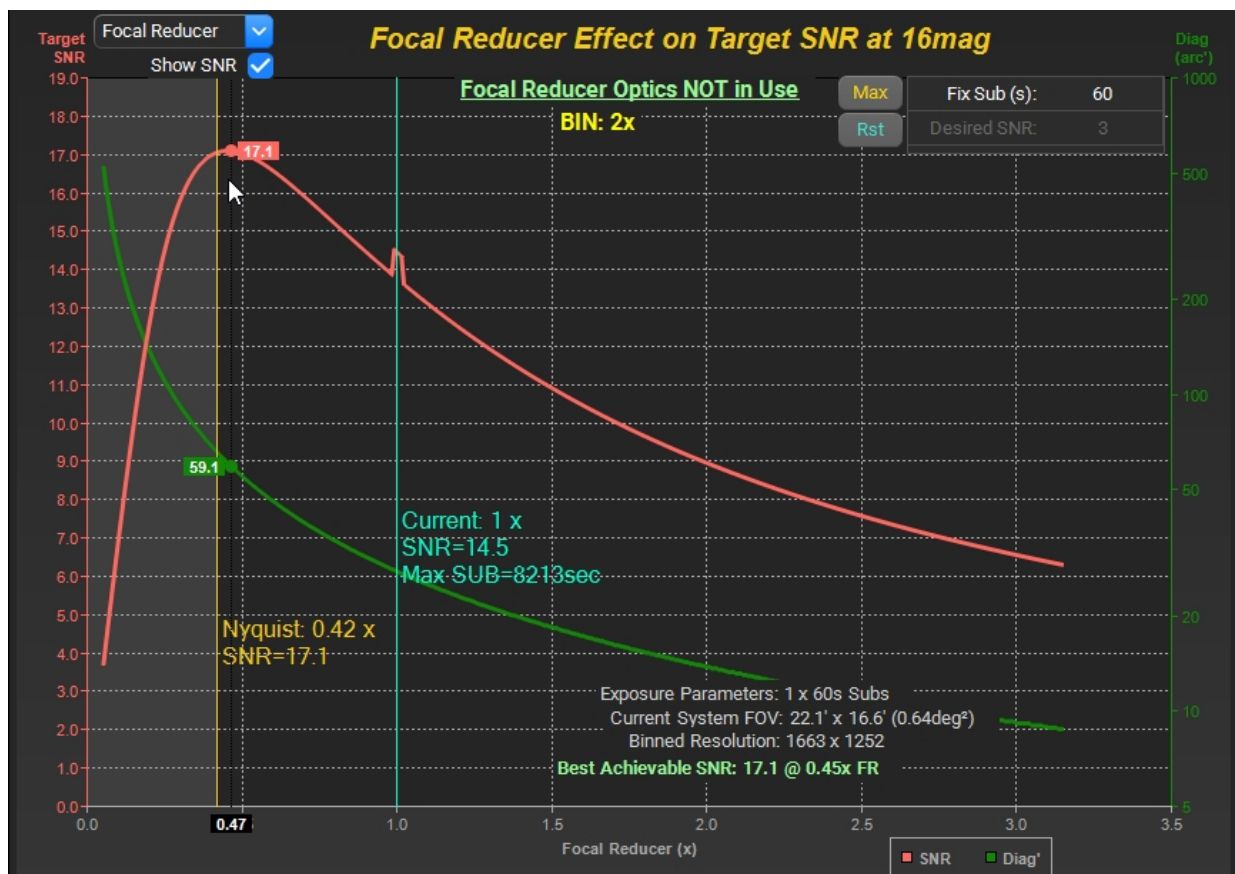
on a reasonable compromise. You can also force the Reducer/flattener optics loss by checking appropriate box.

You can either examine effects on the Limiting Magnitude or the selected target's magnitude SNR. The selection is made using the "Show SNR" checkbox.

In both instances the imager FOV diagonal in arc-minutes is also shown on the secondary axis, as this is also an important consideration when designing the system.

After the total exposure is selected, you should decide on how long your sub should be, and enter it into the "Fix SUB" box. If it does not divide equally into your total exposure, the software will automatically make the correction for you to the nearest possible sub duration.

Although counterintuitive, you will notice that the best SNR depends on the target magnitude, and the EFL at which it occurs is always shorter than that of the best Limiting magnitude. As the target star gets brighter, the SNR will increase, but the required EFL will get shorter. For very bright targets, the best SNR EFL can actually be shorter than that needed to satisfy the Nyquist sampling, but this mostly happens if you have Off-Chip binning enabled. As you increase the star magnitude, you will see that the SNR curve maximum will move towards that of the Limiting Magnitude curve, and will overlap for very dim objects.



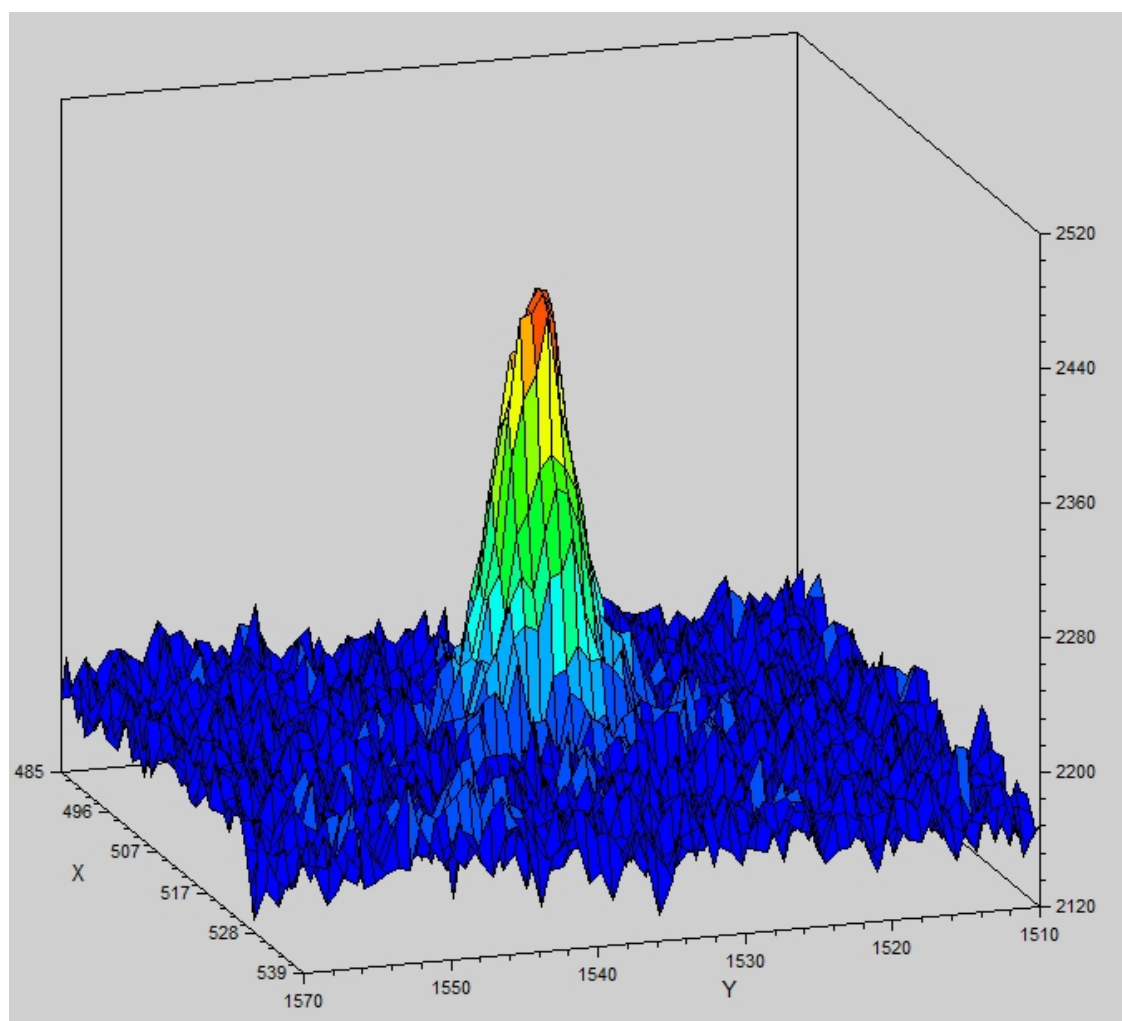
Our recommendation is to push the system towards achieving the best Limiting magnitude. The SNR of the bright targets will be a bit lower, but only by a few percent, and should not matter for very bright targets as it will already be pretty high.

The sampling effects page will let you determine the best combination of Binning, Focal Reducer, image size and resolution that will best suit your needs. It will always be a compromise, since your limitation will

be the available Reducer/Corrector/Flattener ratios. This is why it is best to carefully consider the prospective OTA native focal length before any purchase, and not only consider the telescope aperture. For example, you can quite easily lose 0.2 to 0.3 Limiting Magnitudes (or more) in a typical SCT system if you do not do things correctly, and trial and error do not always give the best results.

Only non-saturated results will be shown: In case of the star saturating the pixels for all chart variations, you will be notified that no solution can be found. You can then reduce the sub duration, or try to turn on the Off-Chip binning (if binning > 1x).

You may wonder why the limiting magnitude improves with increasing EFL. The star imaging profile is brightest in the center, but the sky pollution is constant across the sky. As you oversample the image, the center portion luminosity ratio to the background signal increases disproportionately as you take smaller and smaller slices. This only works so far, as both signals eventually diminish, with the read noise starting to dominate the SNR, and other factors also eventually take over.



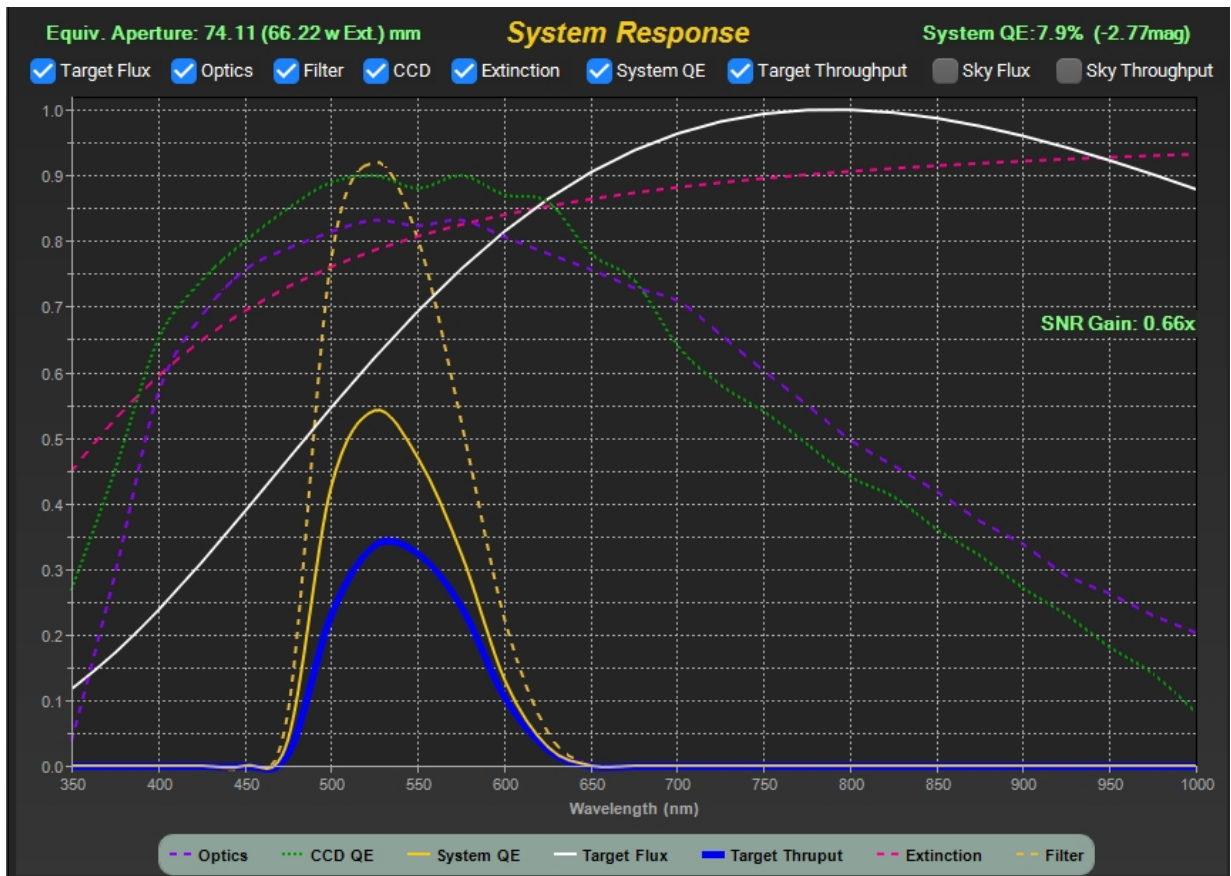
For example, if you turn on the Off-Chip binning, and play with the imager read noise values, you will see that noise of 0 produces the best result at very large EFL. Increasing the noise will produce a hump in the curve, producing a clear maximum which will vary with the amount of noise applied. More read noise you apply, the more pronounced the hump becomes. So, “quiet” cameras are a good thing to look for...



Note that the Sky conditions, and in particular the Seeing, the Light Pollution, as well as the binning parameters have a profound effect on the above results, so you should know your prevailing site sky conditions when designing the system.

## 6. System Response

Have ever wondered how much light, and what kind actually reaches your imager chip? Look no further, as this result page addresses this in full, like never before.



The chart shows the spectral responses of the entire system, as well as that of the Target Stellar Type, Extinction, Filters, Imager chip and Sky Pollution contribution. You can select what is shown by checking the available options.

At the top of the chart there is a parameter called Equivalent Aperture. Basically, this is a comparison to a perfect OTA-Imager combination. Expressed in mm, the number tells you what aperture a perfect system would need to accomplish the same light gathering result, for that particular target. For example, K0 Star, Celestron C11 OTA with Starbright optics and KAF8300 sensor behaves as a 131mm perfect system, from purely light collection aspect, neglecting the diffraction effects. Therefore, you would expect the same result using a perfect 5" refractor and a perfect camera combination, and thus your system's total efficiency is 25% (i.e. system QE). The System QE is also expressed in magnitudes, showing you how much your "imperfect system" attenuates the detected photons (25% = -1.51 mag in the stated example).

Finally, the SNR gain parameter is a relative measure of how much improved the total filtered system starlight/sky glow ratio is improved over that that actually reaches the front of your telescope. If you live in an area with heavy LED street lighting, and are using a red filter, expect to see an improvement, but at a longer exposure multiplier.



## 7. Filter Evaluation

To filter, or not to filter, and how? This is a very important decision often presented to astro-photographers, and is based on the end goal. Clearly, if you are making an LRGB image you need filters, but how much longer should a Blue exposure be compared to the Luminosity? This page will provide you with an answer to this question, and more.



The chart on the left shows you the exposure multiplier with respect to the best performing filter for the selected Target. In the case presented above the system performs the best with no filter. To see the exact multiplier values, hover a cursor over the filter respective bar. The associated Drop Box above will let you choose how those values are derived. The options are Light Grasp and SNR; both produce very similar results, but not in all cases, and your choice depends on what you are trying to do. The last option shows you the filtered System gain for each filter (expressed in  $\text{cm}^2$ , and inclusive of your camera performance, the gain number tells you what aperture area a perfect system would need to accomplish the same result).

Note that the exposure multiplier results are approximate since the very substance of the SNR will depend on many factors, such as the sub duration. In order to provide a normalized dataset, the application seeks a sub duration that will work for every filter, even as the target photon flux changes by factor of 1000x – a sub duration that is almost always not what one would use in real life.

The right chart has four options to select from: The Exposure Quality Index is a ratio of SNR gain and Exposure multiplier. This is an empirical value, intended to guide you in selecting the right filter. You may find that “No Filter” option has the shortest exposure, but that the LUM filter has a better Quality index, meaning that for few percent longer exposure the theoretical SNR will be better. System QE and Signal to Sky Glow ratio are self-explanatory. The last option is very interesting. It shows you the individual Filter attenuations in Magnitudes – for the selected target Spectral star type.

## 8. Imagers/Cameras Comparison and Overview

This page lists all the Imaging Sensors (bracketed blue labels) and Cameras (yellow labels) available in the application's library, with the most important parameters shown. Uncooled imager types are shown in Red.

Imager	Type	$\mu\text{m}$	avg QE%	Well $e^-$	Nr $e^-$	ADC bits	Pixels	Bin	Focal Reducer	Diag. (mm)	System 1hr.LM
<IMX290>	CMOS	2.90	53	14600	3.5	12	1936 x 1096	4	1.00x	6.5	21.64
<IMX304>	CMOS	3.45	37	11000	2.2	12	4096 x 3000	3	1.00x	17.5	21.65
<IMX428>	CMOS	4.50	44	25000	3.0	12	3208 x 2208	3	1.00x	17.5	21.74
<IMX432>	CMOS	9.00	48	97000	21.0	16	1608 x 1104	2	1.00x	17.6	21.23
<IMX455>	CMOS	3.76	42	85000	7.6	16	9576 x 6388	4	1.00x	43.3	21.76
<IMX461>	CMOS	3.76	48	80000	5.5	16	11656x8750	3	1.00x	54.8	21.84
<IMX492>	CMOS	4.63	56	61000	6.2	14	4144 x 2796	3	1.00x	23.1	21.79
<IMX533M>	CMOS	3.76	49	50000	3.8	14	3008 x 3028	3	1.00x	16.0	21.88
<IMX571M>	CMOS	3.76	48	95000	6.0	16	6280 x 4210	3	1.00x	28.4	21.84
<IMX991>	CMOS	5.00	65	127000	151.0	12	656 x 520	5	1.00x	4.2	19.90
<GSENSE4040FSI>	CMOS	9.00	50	74000	3.7	16	4096 x 4096	1	1.00x	52.1	21.68
<GSENSE4040BSI>	CMOS	9.00	65	56600	3.9	16	4096 x 4096	1	1.00x	52.1	21.78
<GSENSE2020BSI>	CMOS	6.50	66	55000	1.6	16	2048 x 2048	1	1.00x	18.8	21.84
<PERFECTA-20K>	CCD	2.50	100	1000000	0.0	20	20000x20000	2	1.00x	70.7	22.04
Atik ChemiMOS	CMOS	3.76	49	56000	3.8	14	3008 x 3028	3	1.00x	16.0	21.88
Atik ACIS 7.1	CMOS	4.50	44	25000	3.0	12	3208 x 2208	3	1.00x	17.5	21.74
Atik ACIS 2.4	CMOS	5.86	44	33000	3.0	12	1920 x 1200	3	1.00x	13.3	21.68
Atik ACIS 12.3	CMOS	3.45	37	11000	3.0	12	4096 x 3000	3	1.00x	17.5	21.64
Atik One 9.0	CCD	3.69	46	12000	5.0	16	3388 x 2712	3	1.00x	16.0	21.77
Atik One 6.0	CCD	4.54	38	18000	5.0	16	2758 x 2208	3	1.00x	16.0	21.69
Atik 16200	CCD	6.00	35	40000	9.0	16			1.00x	34.6	21.36
Atik 383L+	CCD	5.40	34	25500	7.0	16			1.00x	22.5	21.41
Atik 4120EX	CCD	3.10	46	9000	5.0	16			1.00x	15.8	21.66
Atik 490EX	CCD	3.69	46	12500	5.0	16			1.00x	16.0	21.77
Atik VS825	CCD	6.45	35	18000	5.5	16	1391 x 1039	2	1.00x	11.2	21.54
Atik 460EX	CCD	4.54	38	18000	3.1	16	2758 x 2208	2	1.00x	16.0	21.74

Some headers contain small red/green marks. Clicking them will cycle different parameters for that column, usually switching from physical to angular units. You can also see image FOV and diagonal in arc minutes, as well as recommended image binned resolution and the Focal Reducer. System selected imager is highlighted in red. Double clicking a table row will switch the system to that particular imager.

The 1-hour Limiting magnitude (1hr.LM) is the estimate for each Imager, using the currently selected OTA, Focal Reducer, Filter and Sky parameters. The binning is automatically calculated for each Imager to reach the best sensitivity above the Nyquist minimum limit. Note that the sub duration has been fixed to 60s for this computation. Best Limiting magnitude is presented in two ways: Best in your System, as specified, or the Best Limiting Magnitude with Focal Reducer. The latter forces the focal reducer optics (even if 1X as in case of a corrector), computes the theoretical best focal reducer ratio for your system, and reports Limiting Magnitude using it in the system, whereas the former is limited to commercially available values and takes into account if reducer optics is not present. The under sampled imagers default to theoretical reducer values greater than 1.0. Do not be surprised if the FR is almost always set to 1x. The software takes into account the reducer losses, and at FR=1x, the Limiting Magnitude will be about 0.1mag higher without additional optics. Finally, one of the cameras, Perfecta 20K, is a perfect camera with 100% QE, and no read noise. It is provided as a guide to the ultimate system capability.

To aid in Imager/Camera comparisons, the table can be sorted by any column. Repeatedly clicking on the header will sort by the column's parameter in ascending and descending order. Thus you can easily see which Camera has the best sensitivity for your OTA, which satisfies your resolution needs, FOV etc.

## 9. Optical Tube Assembly (OTA) Comparison and Overview

This page lists all the OTAs in the library, with the most essential parameters shown. In addition, it estimates the expected performance using currently enabled Camera, Seeing, Sky, filters etc.

OTA	Aperture (mm)	FL mm	F#	Dawes (arc <sup>''</sup> )	Star (arc <sup>''</sup> )	BIN	FR	avg T%	equivArea (cm <sup>2</sup> )	Best LM 1hr.LM
ASTRO-TECH 6" RC	152.0	1370	9.0	0.8	4.6	2	1.00	82	120.4	21.06
ASTRO-TECH 8" RC	203.0	1625	8.0	0.6	4.2	2	1.00	82	208.1	21.48
ASTRO-TECH 10" RC	250.0	2000	8.0	0.5	3.9	2	1.00	82	325.9	21.81
ASTRO-TECH 12" Truss RC	304.0	2432	8.0	0.4	3.7	2	1.00	82	452.1	22.05
ASTRO-TECH 14" Truss RC	356.0	2848	8.0	0.3	3.6	2	1.00	82	641.4	22.29
ASTRO-TECH 16" Truss RC	406.0	3250	8.0	0.3	3.5	2	1.00	82	835.0	22.47
ASTRO-TECH 20" Truss RC	508.0	4064	8.0	0.2	3.3	3	1.00	82	1308.7	22.77
ASTRO-TECH 6" Newt.	150.0	600	4.0	0.8	4.6	1	1.00	82	120.2	21.04
ASTRO-TECH 8" Newt.	200.0	800	4.0	0.6	4.2	1	1.00	82	227.0	21.53
ASTRO-TECH 10" Newt.	250.0	1016	4.1	0.5	3.9	1	1.00	82	360.7	21.87
ASTRO-TECH 12" Newt.	300.0	1220	4.1	0.4	3.7	1	1.00	82	533.1	22.15
Celestron C8 XLT & EDGE	203.0	2032	10.0	0.6	4.2	2	1.00	73	200.3	21.47
Celestron C9.25 XLT & EDGE	235.0	2350	10.0	0.5	4.0	2	1.00	73	276.3	21.70
Celestron C11 XLT & EDGE	280.0	2800	10.0	0.4	3.8	3	1.00	73	399.3	21.96
Celestron C14 XLT & EDGE	355.6	3910	11.0	0.3	3.6	3	1.00	73	653.0	22.31
Celestron 8" F2.0 RASA	203.0	400	2.0	0.6	4.2	1	1.00	73	187.4	21.28
Celestron 11" F2.2 RASA	279.0	620	2.2	0.4	3.8	1	1.00	73	373.2	21.87
Celestron 14" F2.2 RASA	355.6	790	2.2	0.3	3.6	1	1.00	73	584.1	22.21
Celestron C6 Starbright	150.0	1500	10.0	0.8	4.6	2	1.00	59	82.3	20.86
Celestron C8 Starbright	203.0	2032	10.0	0.6	4.2	2	1.00	59	161.5	21.36
Celestron C9.25 Starbright	235.0	2350	10.0	0.5	4.0	2	1.00	59	222.6	21.59
Celestron C11 Starbright	280.0	2800	10.0	0.4	3.8	3	1.00	59	321.8	21.86
Celestron C14 Starbright	355.6	3910	11.0	0.3	3.6	3	1.00	59	526.2	22.21
Celestron SLT102	102.0	660	6.5	1.1	5.5	1	1.00	83	67.9	20.54
Exp. Sci. 8" F3.9 Newt.	208.0	819	3.9	0.6	4.1	1	1.00	74	221.1	21.52
Exp. Sci. ES127 Triplet APO	127.0	952	7.5	0.9	5.0	1	1.00	83	105.3	20.88

**Star arc''** parameter shows the apparent size of a perfectly focused star based on the Seeing and OTA's diffraction parameters. The average transmission is computed for the stand-alone OTA from 350nm to 1000nm, excluding the effects of the Camera, Focal Reducer, Seeing, Filters etc., i.e. OTA only. Equivalent Area (**equivArea**) is the product of the average transmission and the OTA's open aperture area, and shows the area which the perfect OTA would have for equivalent light gathering/throughput capacity.

The systems Best 1-hour Limiting magnitude (**1hr.LM**) is the computed for each OTA, using the currently selected System, Camera, Filter and Sky parameters at the best binning for each OTA along with best Focal Reducer ratio, to reach the best sensitivity. Clicking again will switch the parameters to show the best sensitivity when using a Perfect camera in combination with an optically ideal, theoretically best reducer ratio. This index assumes Atmospheric Seeing of 2 arc seconds, Rural Type Sky of 21.6MPAS (IAU Recommendation), Elevation or 90, no Haze, Altitude of 0m, and KO Stellar object. OTA Index is our standardized measure of the OTA's Standalone performance. Note that the sub duration has been fixed to 60s for this computation.

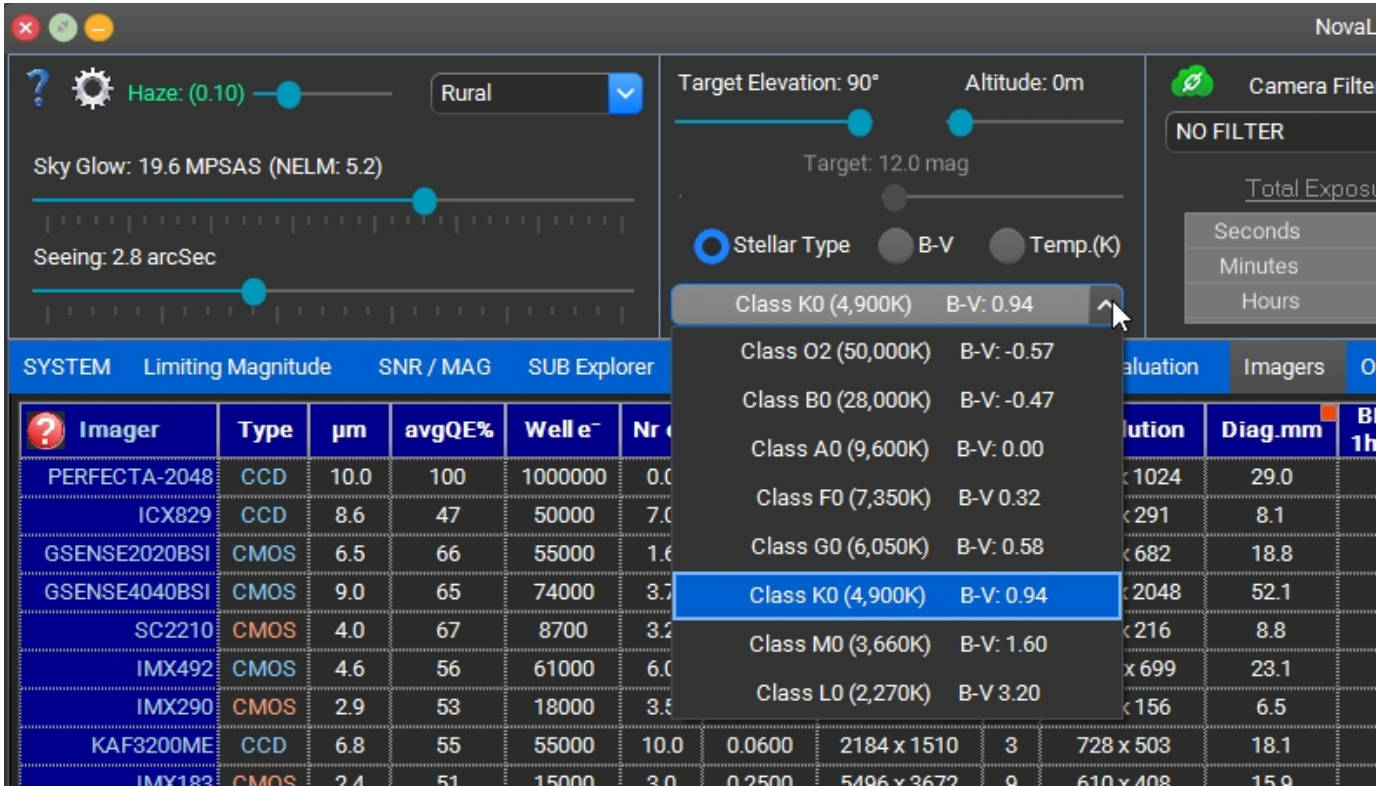
To aid in OTA comparisons, the table can be sorted by any column. Repeatedly clicking on the header will sort by the column's parameter in ascending and descending order. Thus you can easily see which OTA has the best sensitivity for your camera, which has the best overall transmission etc. Finally, the Refractors are shown in Red, and reflector OTAs are sky blue.

The currently selected OTA's row is highlighted in red. Double clicking any table row will switch the system to that particular OTA. System selected OTA is highlighted in red.



### 3.0 Input Parameters

As previously mentioned, the input parameters are segregated by function into separate panels. Note: Some controls will become unavailable for certain operations, as they are not relevant. This was done to avoid the confusion. For example, there is no point to specify the target magnitude and the exposure, when computing the limiting magnitude variation over varying exposure time.



The top-most panels contain the Sky Quality, Target and Exposure inputs.

You should specify Sky-Glow in Magnitudes/arcsec<sup>2</sup>, but if you do not know it, just move the slider to adjust the NELM value to that at your location. The seeing slider is self-explanatory, and ranges from 0 to 5 arc-sec. If your focusing is not perfect, you should include the estimated defocusing blur.

It is somewhat important to specify the type of sky pollution at your site. It does make a difference whether you have predominantly bluish LED street lighting or HPS (High Pressure Sodium) yellowish lights. For example, if imaging with the blue filter, HPS will be mostly filtered out resulting in superior SNR, and a shorter exposure for the same quality image than that with the LED street lights. The available sky emission spectra densities have been normalized to standard SQM 350-700nm readings, and you can see them on the System Response page. This data has been collected by observing typical sky emission spectra at number of locations on the East Coast of the USA. There are 5 scenarios to choose from:

1. Rural / Dark – pristine, nice and clean skies;
2. Suburb – typical, balanced mix of LED and HPS lights;
3. Suburb (+LED) – choose this if your area has predominantly LED street lighting
4. Suburb (+HPS) – choose this if you live in the area with mostly HPS lighting
5. Urban – If you are unlucky and must image from a city, both pollution types will be present, and in much larger proportion than outside the city.

The Haze is actually the Aerosol Optical Depth parameter (AOD), and is an of secondary importance. You probably noticed that the sky is not as crispy on a muggy summer night, and this is why. The typical Haze values are in 0.05 to 0.15 for a good night. This value will rise in the summer, in most parts of the world. Some examples in the USA are listed below:

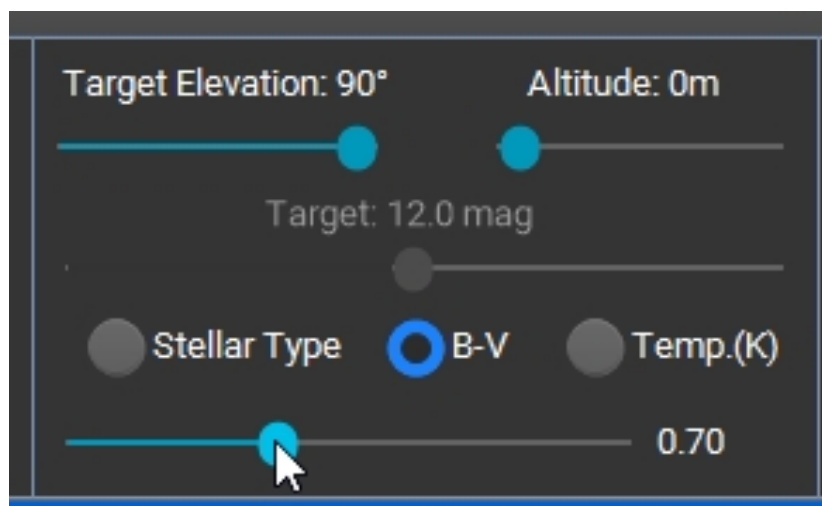
<b>Relative Transparency</b>	<b>New England</b>	<b>OH Valley/Mid-Atlantic/Southeast*</b>	<b>South Florida</b>	<b>Plains States</b>	<b>Desert SW/Pacific NW</b>	<b>Hawaii (Sea Level)</b>
<i>Winter Avg.</i>	0.06	0.09	0.10	0.06	0.04	0.08
<i>Annual Average</i>	0.13	0.19	0.13	0.13	0.07	0.08
<i>Summer Avg.</i>	0.22	0.38	0.16	0.19	0.10	0.08

Haze, Target Elevation and Site Altitude are used to compute the atmospheric extinction over the entire spectral range. The Stellar Extinction model includes Rayleigh scattering, the Aerosol Extinction, and the Ozone Extinction. The actual effects and variations can be clearly seen on the System Response page, and produce greatest effects on shorter wavelengths.

Site elevation (in m) also has an effect on transparency, but not as much as one may expect. Getting higher really results in better seeing, which does have a big effect on the sensitivity and resolution.

The target magnitude can be adjusted (when called for) in range of 0 to 25 magnitude using its slider.

In the drop-box below it, you can select from the target Stellar classes, based on Star black body radiation models. Note that those imaging distant galactic clusters should probably use class K0.




You can also specify the star by its B=V index (-0.6 to 3.0), or by the color temperature (2000K to 100,000K). In those cases, the drop down selection box will be replaced with a slider.

The (total) exposure is self-explanatory. It is acceptable to enter values such as 1.5 hours etc., as they will be automatically changed to 1hr and 30 min. The 3 nearby buttons allow you to quickly clear the exposure fields, and preset them to 1 sec, 1 minute and 1 hour.

Likewise, the filter selection is straight forward. Simply select the appropriate filter from the drop-down list.

There is a large and growing number of OTAs to choose from. Upon the selection, the required parameters will be shown in the list below it. They can be modified as need be, and the current OTA can be permanently updated by pressing the save button next to it (for example to set your preferred focal reducer). To create a new OTA, modify the list to contain new Aperture Focal length etc., enter the name for your new OTA in the textbox “OTA/Telescope (Save As)”, and then press Save button. To permanently delete the **currently selected** OTA, press the delete button.



**Optical Tube Assy.**

Celestron C11 XLT & EDGE

OTA/Telescope (Save As): Celestron C11 XLT & EDGE

Used Optical Elements:

- Corrector Lens
- Primary

Enhanced Coatings

Aperture (mm) 280

Obstruction (mm) 95

Focal Length (mm) 2800

Focal Reducer (X) 1

Extra Element1 (%) 100

Extra Element2 (%) 100

Extra Element2 (%) 100

Type: Celestron XLT 0

Ideal Focal Reducer for Binning

---

**Imager / Camera:**

QHY268M

Use Off-Chip Binning

Auto Set Binning

CMOS - COOLED

Pixel X (μm) 3.76

Pixel Y (μm) 3.76

X Pixels 6280

Y Pixels 4210

Binning 3

Well e<sup>-</sup> 95000

Read Noise (e<sup>-</sup>) 6

Dark (e/sec) 0.001

ADC Bits 16

Gain (e/ADU) 1.4

Dark Frames 100

Bias Frames 100

Flat Frames 100

Flats Well (%) 80



Used Optical Elements:

- Primary Mirror
- Second

Corrector Lens

Primary Mirror

Secondary Mirror

Extra Mirror

Focal Reducer

Objective Lens

Extra Lens

Camera Window

The transmission properties of any optical system are defined by the optical elements it uses. The drop down list “Used Optical Elements” will let you choose the used optics. For example, a typical SCT setup will have a Corrector, Primary and Secondary mirrors, possibly a Focal Reducer – and a *Camera Window*, an item almost never included in response performance by the camera manufacturers. You can check or uncheck any or all elements to see the effects. Not checking any elements means that you have a perfect OTA. If you enter Focal Reducer ratio different from 1x, the reducer optic element will be automatically selected for you. The default OTAs already have all relevant elements preset for you.

There are 3 extra elements for which you can specify the transmission in %, to account for extra losses etc. Additionally, if you have an older telescope you can account for mirror aging, dust etc. So, if you estimate that your mirrors are at, say, 90% (transmission) of the brand new condition, and have an SCT (which has two mirrors), you would enter 81% ( $0.9 \times 0.9 = 0.81$ , or 81%). Alternatively, you can consider them separately, and enter 90% on two of the 3 provided lines.

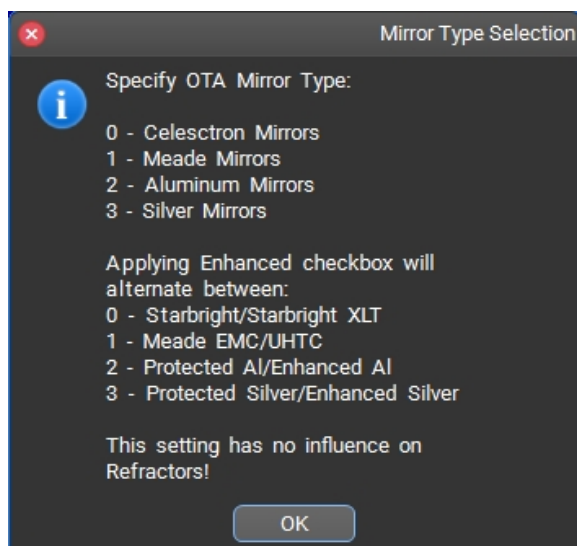
Since not all optics are made the same, and some have better coatings than others, there is a checkbox “Enhanced Coatings”. If your OTA has Celestron StarBright XLT coatings, Meade UHTC coatings (or similar manufacturer equivalents) check this box. If you are using plain old StarBright, Meade EMC mirrors on your classic LX200, a cheap mirror from AliExpress.com, or are just not sure leave it unchecked. Since most of these systems are two mirror OTAs, you will see a significant difference on the System Response charts, but not so significant in the actual limiting magnitudes, perhaps little over 0.1 magnitude difference between the C11 Starbright and XLT.

The application has built in transmission and reflection curves (based on published data) for various manufacturer optics, primarily Celestron and Meade. Other manufacturers are assumed to use Protected Aluminum or Enhanced Aluminum mirror coatings. This is an approximation, and may change in the future if this data becomes available, but



in reality any impact on the end result will be very minor. The Focal Reducer is always assumed to have a standard MgF<sub>2</sub> coating.

The above mentioned Optics Type is set as a parameter in the last row of the OTA parameters. It only impacts Reflector type OTAs. You can change it to see the effects, or if you are contemplating recoating your mirrors or building your own system. It is educational to see the difference Silver coated mirror would make, and help you make the right choice. The Mirror Type parameters can be obtained by clicking on the associated “?” icon:



A large button directly under the OTA parameters, allows you to quickly set the OTA’s Focal Reducer to value needed to reach the best system sensitivity. Note that this will be dependent on the binning specified in the Imager section.

The button “Ideal Focal Reducer for Binning” is enabled when the “Sampling” tab is selected. It will set the focal reducer to a ratio providing best sensitivity for the currently set binning. This will take into account that focal reducer has transmission losses, shown as a small kink on the curve. If you must use field flattener, check the corresponding check box, and the algorithm will honor it.

Finally, in the Camera panel you can select your imaging sensor or manufacturer camera model. Additionally, since many cameras from various manufacturers use same sensors, there is a large selection of sensor chips – in case we missed any cameras. For example, Atik ChemiMOS, ASI533MM and QHY533M all use the IMX533 sensor, and have similar performance, the difference being basically the manufacturer’s specsmanship. Any differences will be very minor. When selecting a camera for purchase, it is important to select the imaging chip first, and then look at the options in the market place of cameras for best price, reliability and features you like. To save you from looking up individual camera specifications, a number of participating manufacturer’s camera models are also included, and can be reached by clicking on an associated link icon. The camera data presented originate from the participating manufacturers, however, we compare (moderate) them to the used imager performance to ensure you are presented with a true performance picture.

In case of CMOS APS (Active Pixel Sensor) cameras it may be necessary to change the camera Gain from the default. The CMOS Camera Gain setting has an impact on the Well depth as well as the Read Noise. If you are using gain different from that shown in the Camera panel you can enter its value. However, you must also change the Well depth and the Read noise to the values provided by the Camera manufacturer. Failing to do so will not provide you with the correct analysis results.

This application does not directly support **Color** imaging chips. Most astro-photographers chose mono versions of sensors because the external interference filters have far better transmission than the dyes used on the chips.

However, the fact remains that there are many color cameras in use by the enthusiasts. To help you gauge how well they will perform, there are 3 additional filters that will simulate their transmission properties: Sony-R, Sony-G, and Sony-B. When comparing the responses of various imaging chips from various manufacturers, it was discovered that they all provide very similar filtering effect, which allows for this approximation. The actual transmission curves used are from the Sony CMOS imagers. So, if you have a color version of one of the supported imager chips, select the color of interest.

Most camera drivers and pretty much all imaging software allow you to perform the OFF-Chip binning (almost always used on CMOS Cameras): each pixel is separately read un-binned, and the binning is subsequently done by the driver software mathematically. This approach results in slightly degraded SNR ratio, but it is minimal with low read noise typical since the advent of KAF generation CCDs. With read noise of about 10-e you will see about 0.2 magnitude deterioration in limiting magnitudes (depending on the binning factor), and the SNR differences will be mostly pronounced for shorter exposures. Externally binned pixels do have one big advantage: the increased dynamic range. Imaging sensors have limited size readout wells, which are quickly filled up when On-Chip adding up, say 9 pixels from a 3x3 bin into a single readout register. You can see the effects on the "SNR explorer" page, by examining the saturation magnitude, a point at which the readout well is fully filled by the object. The typical difference will be about 2 magnitudes of dynamic range, very important if you are doing photometry and need good reference stars! However, do have in mind that reading out un-binned sensors takes longer.

Unlike CCDs, CMOS sensors do not have the ability to bin ON-chip. For that reason, when switching to a CMOS imager the OFF-Chip binning checkbox will be automatically turned on for you. You may change it to examine "what if scenarios". The external binning can be done by the camera firmware in the camera itself, or by the device driver or software such as Maxim DL™. It is important to ascertain whether the binning actually adds the pixels thus growing the apparent well depth, or simply averages the pixel values (as in case of some lower cost cameras), since this will have a profound difference on the well depth.

Similarly, for CCD sensors, this checkbox will be automatically unchecked for you, but you are free to change it in case you decide to extend the well depth externally. If "ON-Chip" binning bear in mind that device drivers limit the maximum binning ratios, and some higher bin combinations may not be available to you.

By checking the "Set Binning Automatically" you will let the application change the binning to best possible to get best sensitivity (up to 15x15), based on the OTA EFL - in other words including the used focal reducer. This enables you to quickly compare vastly different optical systems by simply scrolling thru them. A note of caution: if Auto Binning box is checked you will not be able to manually change imager Binning and Well parameters. This is the artifact of how the processing is performed, as you would be asking for things in opposition to each other in some cases.

At the bottom of the imager parameters are the calibration inputs. You can enter how many darks, flats and bias frames you take, as well as % well of the flat frame, and see how it impacts the image SNR. I used to take 100 of each, which takes a very long time with 10+ filters. Now, I drastically reduced this number, without seeing much difference, but note that the %well on the flats should be as always be reasonably high (we recommend 50%), as it does have a more significant impact.

The binning can be change by typing in the new value into the appropriate field, or by clicking the up down blue icons above the imager list. If the "Auto Set Binning" is checked, clicking the up/down icons will clear it.

While you can freely change OTA or Imager parameters while investigating possibilities, you may eventually want to return to reality. To help you restore current OTA and Imager to starting parameters, there are two small buttons, right above the parameter lists. Pressing them will restore the parameters. Imager parameter changes are not permanent, and will be restored next time you run the application.

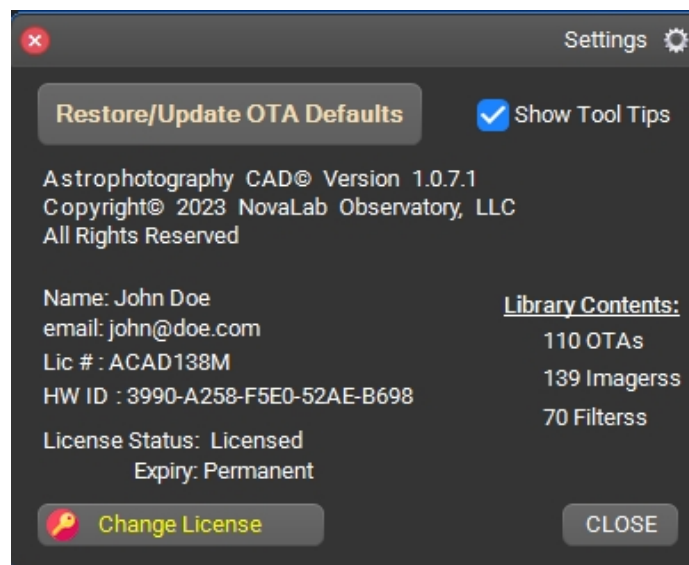


There may be small “link” icons displayed directly next to the OTA, Imager and Filter selection dropdown lists. Clicking on them will open the default browser to a relevant participating manufacturer or a distributor web page. This will allow you to check on the current item pricing, features, purchase it, or simply get some more details about the item.



The link icon appearance is governed by the agreements with individual suppliers, so, they will not always be shown. They will certainly NOT be shown for any user created OTAs. The links are geolocation sensitive, so if you live in Europe you will not be sent to a US based distributor. If you live in a region without supported distributor you may be directed directly to the manufacturer’s website instead.

## Setup Window



To access this window, click on the tools icon (small gear in the upper left corner). Here you can input or change your license. After you become proficient with the application, the tooltips may become too bothersome, and you can turn them off by unchecking the corresponding check box.

In the event that you completely mangle the OTA library settings, you can reset them to the initial defaults by pressing the “Restore OTA Defaults” button. The list and the parameters will be reset, and any custom OTAs that you may have created will be lost. This is also useful after an update, as the new OTAs may not be shown unless you do this.

## **4.0 Other Features**

Extensive tool-tip help is available by hovering the cursor over any control. If you find it undesirable, this feature can be turned off when you get a grasp of the application. Simply click on the “Settings” icon in the top left corner (a little gear) which will open a new window, and uncheck the “Show Tool Tips”. Below that can see more information about the application, as well as licensing info.

To display the help pdf (this file), click on a question mark icon in the top left corner. This application has a built in pdf viewer, but the file link is also available in Program Files, if you wish to use Adobe Acrobat™.

## **5.0 Automatic Updates**

The application will check whether there is an update available every time it starts. You must be connected to the internet in order to update. You will be given an option to update only if there is an update available. Some updates are critical and mandatory, as the application will not be able to support further upgrades without it. Updates are quick, automatic, and do not require you to visit our website in person. In case you run into problems, the update can be also done by downloading the latest setup file from our website, and running the setup again. Updating will bring new features, and skipping too many updates may require you to reinstall the application from the latest downloaded from our website. Your license will be honored in case of the reinstallation.

## APPENDIX: SUPORTED DEVICES / EQUIPMENT:

OTAs	CAMERAS	FILTERS
ASTRO-TECH 6" RC	Atik ChemiMOS	NO FILTER
ASTRO-TECH 8" RC	Atik ACIS 7.1	Astronomic LUM (Old)
ASTRO-TECH 10" RC	Atik ACIS 2.4	Astronomic LUM-2c
ASTRO-TECH 12" Truss RC	Atik ACIS 12.3	Astronomic LUM L-1
ASTRO-TECH 14" Truss RC	Atik One 9.0	Astronomic LUM L-2
ASTRO-TECH 16" Truss RC	Atik One 6.0	Astronomic LUM L-3
ASTRO-TECH 20" Truss RC	Atik 16200	Astronomic R(Old)
ASTRO-TECH 6" Newt.	Atik 383L+	Astronomic G(Old)
ASTRO-TECH 8" Newt.	Atik 4120EX	Astronomic B(Old)
ASTRO-TECH 10" Newt.	Atik 490EX	Astronomic R-Dsky
ASTRO-TECH 12" Newt.	Atik VS825	Astronomic G-Dsky
ASTRO-TECH AT60ED F6	Atik 460EX	Astronomic B-Dsky
ASTRO-TECH AT60EDP F5 ED	Atik 414EX	Astronomic R-2c
ASTRO-TECH AT70ED F6 ED	Atik Infinity	Astronomic G-2c
ASTRO-TECH AT72EDII F6	Atik VS60	Astronomic B-2c
ASTRO-TECH AT80EDT F6 ED	Altair Gpcam2 290M	Astronomic CLS-CCD
ASTRO-TECH AT80ED F7 ED	Altair Gpcam3 178M	Astronomic LP-742nm
ASTRO-TECH AT80EDL	Altair Gpcam3 290M	Astronomic LP-807nm
ASTRO-TECH AT90CFT F6 APO	Altair Hycam 115M	Astronomic ProPlanet
ASTRO-TECH AT92 F5.5	Altair Hycam 174M	AstroDon BVRI-B
ASTRO-TECH AT102EDL F7 ED	Altair Hycam 183M	AstroDon BVRI-V
ASTRO-TECH AT102ED F7 ED	Altair Hycam 26M	AstroDon BVRI-Rc
ASTRO-TECH 110EDA F4.8 APO	FLI PL16803	AstroDon BVRI-I
ASTRO-TECH AT115EDT F7 ED	Meade DSI Pro	AstroDon Sloan u'2
ASTRO-TECH AT125EDL F7.8	MI C5A-100M	AstroDon Sloan g'2
ASTRO-TECH AT130 EDT F7 ED	MI C4-16000	AstroDon Sloan r'2
ASTRO-TECH AT152EDT F8 APO	MI C3-26000	AstroDon Sloan i'2
Astro-Physics 92mm 92F665	MI C3-61000	AstroDon Sloan z_s'2
Astro-Physics 110mm 110GTX	MI C2-5000	AstroDon Sloan z'2
Astro-Physics 130mm 130GTX	MI C2-12000A	AstroDon BB LP-500nm
Astro-Physics 254mm 254F145MC	MI C1x26000	BAADER LUM (Old)
Celestron C8 XLT & EDGE	MI C1x61000	BAADER R(Old)
Celestron C9.25 XLT & EDGE	PlayerOne Poseidon-M	BAADER G(Old)
Celestron C11 XLT & EDGE	PlayerOne Artemis-M Pro	BAADER B(Old)
Celestron C14 XLT & EDGE	PlayerOne Ares-M Pro	BAADER LUM (CMOS)
Celestron 8" F2.0 RASA	PlayerOne Xena-M	BAADER R (CMOS)
Celestron 11" F2.2 RASA	PlayerOne Sedna-M	BAADER G (CMOS)
Celestron 14" F2.2 RASA	PlayerOne Ceres-M	BAADER B (CMOS)
Celestron C6 Starbright	PlayerOne Saturn-M	BAADER Bp-Bessel
Celestron C8 Starbright	PlayerOne Neptune-M	BAADER Vp-Bessel
Celestron C9.25 Starbright	PlayerOne Mars-M	BAADER Rp-Bessel
Celestron C11 Starbright	PlayerOne Apollo-M MAX	BAADER Ip-Bessel
Celestron C14 Starbright	PlayerOne Apollo-M	BAADER SLOAN g'
Celestron SLT102	QHY163M	BAADER SLOAN r'
Exp. Sci. 8" F3.9 Newt.	QHY5L-II M	BAADER SLOAN i'
Exp. Sci. ES127 Triplet APO	QHY5III200M	BAADER SLOAN z-s'
GSO 6" RC	QHY5III174M	BAADER SLOAN y'
GSO 8" RC	QSI 6162	BAADER LP-495nm
GSO 8" Classic Cass.	QSI 683	BAADER LP-570nm
KSON 80mm APO	QSI 6120	BAADER LP-610nm
Meade ETX-90 M-Cass	QSI 660	Celestron UHC/LPR
Meade ETX-125 M-Cass	QSI 690	Celestron LPS (RASA)
Meade 2040 F10 EMC	QSI 632	Chroma LUM
Meade LX90-8" F10 EMC	SBIG AC4040BSI	Chroma R

Meade LX200-8" F10 EMC	SBIG AC4040FSI	Chroma G
Meade LX200-10" F10 EMC	SBIG AC2020BSI	Chroma B
Meade LX200-12" F10 EMC	SBIG STC-428	Chroma Sloan u'
Meade LX200-14" F10 EMC	SBIG CCD694	Chroma Sloan g'
Meade LX200-16" F10 EMC	SBIG CCD814	Chroma Sloan r'
Meade LX200-8" F10 ACF	SBIG CCD8300	Chroma Sloan i'
Meade LX200-10" F10 ACF	SBIG CCD3200	Chroma Sloan z'
Meade LX200-12" F10 ACF	SBIG CCD47-10(mb)	Chroma Bessel U
Meade LX200-14" F10 ACF	SBIG CCD77-00(mb)	Chroma Bessel B
Meade LX850-10" F8 ACF	SBIG STXL-16200M	Chroma Bessel V
Meade LX850-12" F8 ACF	SBIG STXL-6303	Chroma Bessel R
Meade LX850-14" F8 ACF	SBIG STX-16803	Chroma Bessel I
Meade LX850-16" F8 ACF	SBIG ST/STF8300	Chroma Bessel Clas. U
Meade LX85-6" F4 Astrograph	SBIG STF-3200W	Chroma Bessel Clas. B
Meade LX85-8" F4 Astrograph	SBIG STC-7	Chroma Bessel Clas. V
Meade LX75 SN-6AT EMC	SBIG ST-7XE	Chroma Bessel Clas. R
Meade LX75 SN-8AT EMC	SBIG ST-8XE	Chroma Bessel Clas. I
Meade LX75 SN-10AT EMC	SBIG ST-9XE	Chroma Jov-Methane
ORION 80mm GuiderScope	SBIG ST-10XE(XME)	DGM Optics GCE
Orion EON 70mm ED F/5.0	StarShoot Pro AG	Sony Chip R
Orion EON 85mm EDX2 F/6.6	StarShoot G4	Sony Chip G
Orion EON 104mm EDX2 F/6.25	StarShoot G10-M	Sony Chip B
Orion EON 110mm ED F/6.0	StarShoot G16-M	
Orion EON 115mm ED	StarShoot G26-M	
Orion EON 130mm ED	StarShoot 2MP AG	
Orion 180mm Mak	StarShoot 6.3MP-M	
Orion 190mm F/5.3 Mak-Newt	SX TRIUS PRO-674	
Orion 8" F4 Newt. Astrograph	SX TRIUS PRO-694	
Orion 10" F4 Newt. Astrograph	SX TRIUS PRO-814	
Orion 6" F9 RC Astrograph	SX TRIUS PRO-825	
Orion 8" F8 RC Astrograph	SX TRIUS PRO-834	
Orion 10" F8 RC Astrograph	SX TRIUS SX-46	
Orion 10" F8 Truss RC	SX ULTRASTAR PRO	
Orion 12" F8 Truss RC	SX LODEST PRO/X2	
Orion 14" F8 Truss RC	ZWO ASI461MM-P	
Orion 16" F8 Truss RC	ZWO ASI990MM-P	
Planewave DeltaRho 350 CDK	ZWO ASI991MM-P	
Planewave CDK12.5 F8	ZWO ASI533MM-P	
Planewave CDK14 F7.2	ZWO ASI2600MM-P	
Planewave CDK17 F6.8	ZWO ASI294MM-P	
Planewave CDK20 F7.77	ZWO ASI6200MM-P	
Planewave CDK20 F6.8	ZWO ASI183MM-P	
Planewave CDK24 F6.5	ZWO ASI1600MM-P	
Planewave 24" RC	ZWO ASI220MM MN	
SKY-WATCHER 8" QUATTRO	ZWO ASI120MM MN	
SKY-WATCHER 10" QUATTRO	ZWO ASI174MM MN	
SKY-WATCHER 12" QUATTRO	ZWO ASI290MM MN	
TAKAHASHI FSQ-85EDX	ZWO ASI178MM-CL	
TAKAHASHI FC-100DF	ZWO ASI174MM-CL	
TAKAHASHI TSA-120	ZWO ASI120MM	
TAKAHASHI TOA-130NFB	<KAF8300M>	
DIY: GuiderScope - 60mm	<KAF16200>	
DIY: 93mm Wide Field Refractor	<KAF3200ME>	
DIY: 3"-F5 Refractor	<KAF6303E>	
DIY: 3"-F10 Refractor	<ICX419ALL>	
DIY: 5"-F5 Refractor	<ICX254AL>	
	<ICX674>	



	<ICX694>	
	<ICX695>	
	<ICX814>	
	<ICX825>	
	<ICX829>	
	<ICX834>	
	<MT9M034>	
	<SC2210>	
	<AR130CS>	
	<MN34230>	
	<IMX174>	
	<IMX178>	
	<IMX183>	
	<IMX249>	
	<IMX250>	
	<IMX290>	
	<IMX304>	
	<IMX428>	
	<IMX432>	
	<IMX455>	
	<IMX461>	
	<IMX492>	
	<IMX533M>	
	<IMX571M>	
	<IMX991>	
	<GSENSE4040FSI>	
	<GSENSE4040BSI>	
	<GSENSE2020BSI>	
	<CCD77-00>	
	<CCD47-10>	
	<KAF0261E>	
	<KAF401E>	
	<KAF1602E>	
	<KAF16803>	
	<PERFECTA-20K>	

*\*Note: Bracketed items in the camera column are standalone imager chips.*

## License Agreement

IMPORTANT: This agreement (the Agreement) is a legal agreement between you and NovaLab Observatory, LLC for this software product, including the software and associated media and printed documentation (the Product). By installing, copying, or otherwise using the Product, you agree to be bound by the terms of this Agreement. If you do not agree to be bound by the terms of this Agreement, immediately remove it from your computers.

### PRODUCT LICENSE

This Product is licensed, not sold. The Product is the property of NovaLab Observatory, LLC or its licensors and is protected by copyright law. This Agreement grants you the following rights:

1. You may install the Product on up to two computers; however, you may only use it on one computer at a time;
2. You may make one copy of the Product for archival purposes;
3. You may use the Product on a network provided that you have a licensed copy of the Product for each computer that can access the Product over that network;
4. You may permanently transfer the Product and all of your rights under this license on a permanent basis to another person or entity, provided that you retain no copies of the Product, that you transfer all of the product including any components, updates, media, and manuals, that you provide NovaLab Observatory, LLC with the name, company, and address of the person to whom you are transferring the rights granted herein, and the recipient agrees in writing to all terms of this Agreement. Please note that technical support and upgrades are available only to the original customer.

#### You may not:

1. Sublicense, share, rent or lease all or any portion of the Product;
2. Reverse engineer, decompile, disassemble, modify, translate, or create derivative works from the Product;
3. Use a previous version of the Product if you have received or obtained an upgrade version as a replacement for the previous version.
4. Use your license on two or more computers simultaneously.

For clarity, the above rules permit you to install the Product on two computers for the purpose of supporting both imaging and session planning operations, which are often performed on different computers. You are not permitted to use the same license on two computers simultaneously.

### TERMINATION

If you fail to comply with the terms of this Agreement, NovaLab Observatory, LLC may terminate the Agreement at its discretion. Upon termination, you must return or destroy all copies of the Product including all of its component parts. This does not restrict the rights of NovaLab Observatory, LLC to other remedies.

### JURISDICTION

This Agreement is governed by the laws of the State of North Carolina, USA. Each of the parties hereto irrevocably agrees to the jurisdiction of the courts of the State of North Carolina, USA.

### LIMITED WARRANTY

NovaLab Observatory, LLC warrants that the media upon which the Product is distributed will be free of defects for a period of thirty (30) days from the date the Product is delivered to you. In the event of a breach of this warranty NovaLab Observatory, LLC will, at the discretion of NovaLab Observatory, LLC, either replace the defective media or accept the return of the Product accompanied by proof of purchase for a refund. NovaLab Observatory, LLC does not warrant that the software in this Product will be defect-free or meet your requirements.

THIS WARRANTY IS EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES, WHETHER EXPRESS OR IMPLIED, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR USE, AND NON-INFRINGEMENT. This warranty gives you specific rights. You may have other rights that vary from jurisdiction to jurisdiction.

### DISCLAIMER

IN NO EVENT SHALL NOVALAB OBSERVATORY, LLC BE LIABLE TO YOU FOR ANY SPECIAL, CONSEQUENTIAL, INDIRECT, OR SIMILAR DAMAGES, INCLUDING ANY LOST PROFITS OR LOST DATA ARISING OUT OF THE USE OR INABILITY TO USE THIS PRODUCT EVEN IF NOVALAB OBSERVATORY, LLC HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. SOME JURISDICTIONS DO NOT ALLOW THE LIMITATION OR EXCLUSION OF LIABILITY FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES SO THE ABOVE LIMITATION MAY NOT APPLY TO YOU. IN NO CASE SHALL NOVALAB OBSERVATORY, LLC 'S LIABILITY EXCEED THE PURCHASE PRICE FOR THE PRODUCT.