

Villa '39 Observatory

Project 'Refocus'

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Revised 29-30 August 2022

After attending a presentation on '[Secrets of Long Focal Length Imaging](#)' by John Hayes at the 2022 Advanced Imaging Conference along with a brief discussion with John afterwards I decided to optimize the focusing of my EdgeHD 14" with 16803 sensor.

To achieve this goal I permanently fixed the back focus between the OTA and imaging sensor at the Celestron specified 146.05 +/- .5 mm. An Optec Secondary Mirror Fast Focus ([SMFF](#)) system replaced the fixed secondary mirror while the primary mirror remained locked in position after initial alignment was completed. I recommend replacing the OEM primary mirror locking knobs with the more secure [Optec brass knobs](#) for this purpose as well.

What this accomplishes: The back focus distance specified by Celestron is considered the Nominal Best Focus (NBF) distance. While it is possible to achieve focus at positions slightly less than that specified, such focus comes at a cost of softer focus as one proceeds radially outward toward the perimeter of the Field of View (FOV). For smaller sensors this is not a problem since the outer portions of the FOV do not fall on the chip. However, when using a large format chip such as the 16803 it is critical that back focus be maintained at the NBF position.

Below are the calculations and test results of this configuration.

Fixed back focus computation:

To achieve NBF the following measurements were calculated and physically verified. Note that the optical path includes an Optec Gemini which is both a rotator and focuser. While I would no longer need its focuser capability, I did want to continue using the Gemini's rotator functionality. Thus, the Gemini turned into a rather accurate, albeit expensive, adjustable spacer and rotator!

Starlight Xpress SX-56 Camera (16803 sensor)	16.0 mm
Starlight Xpress Maxi Filter Wheel w/camera adapter	41.6 mm
AstroDon 50mm filter	-1.0 mm
Precise Parts adapter (Gemini <-> SX Maxi Filter Wheel)	2.3 mm
Optec Gemini Focuser / Rotator @ focuser midpoint	62.23 mm
Precise Parts adapter / spacer (effective optical distance)	<u>25.0 mm</u>

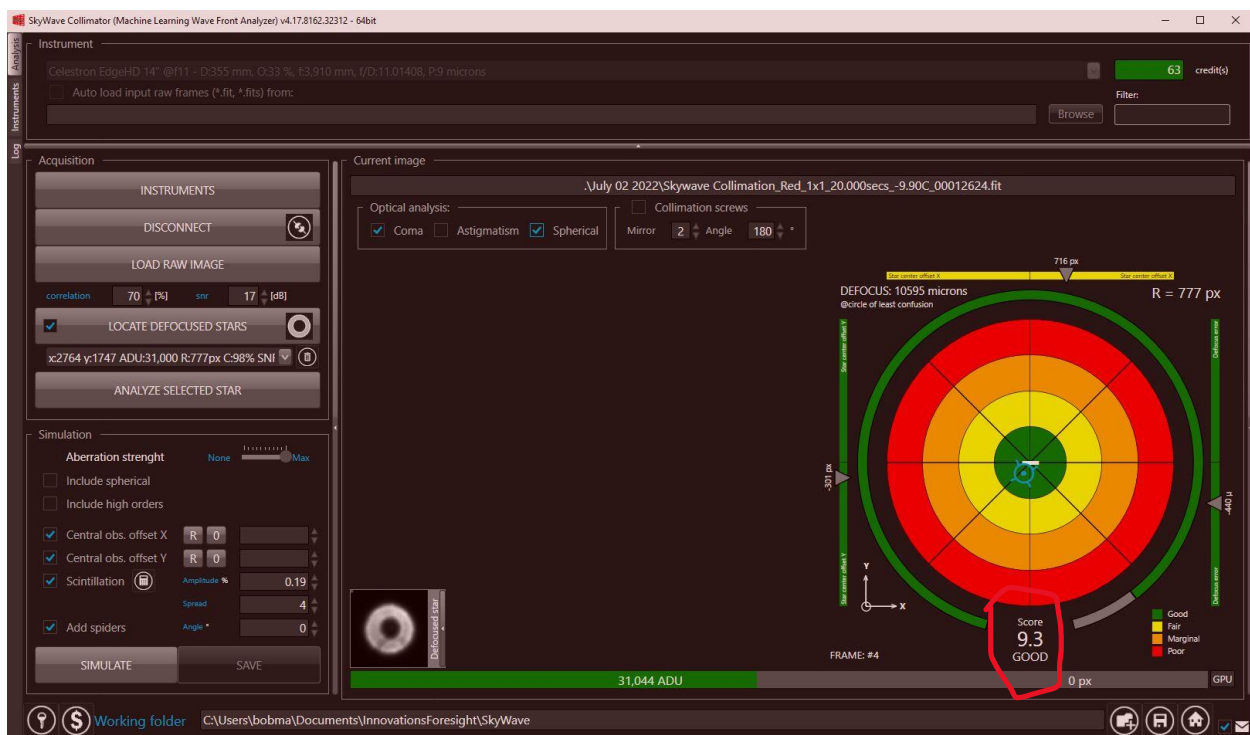
146.13 mm

Celestron Spec: 146.05 +/- .5 mm

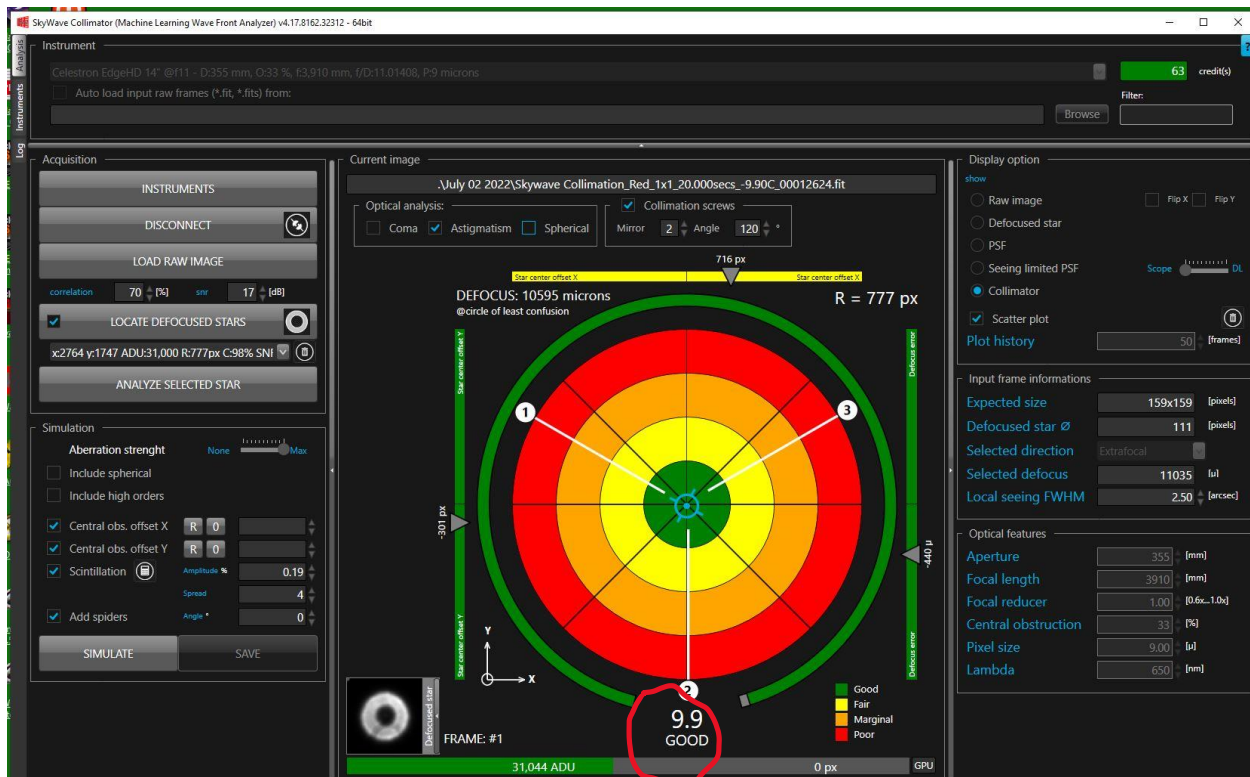
Optical collimation of the imaging path with SMFF including testing for astigmatism and mirror alignment was performed with the aid of Innovations Foresight's [SkyWave](#) software program. The results are shown below:

Basic secondary mirror collimation

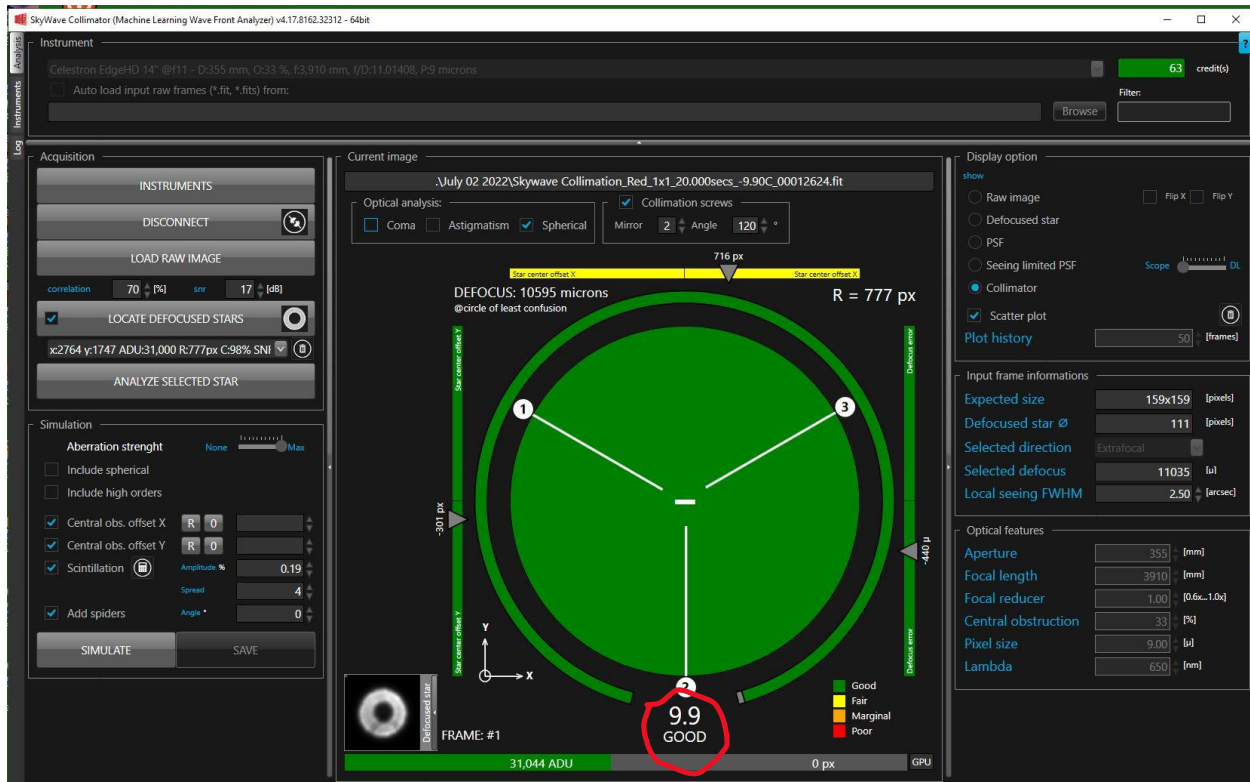
Adjustments were made to the SMFF using its unique two screw per axis system. Values greater than 8 are considered more than adequate for most applications.



Astigmatism measurement



Primary / Secondary mirror alignment



Temperature Compensation Calculation:

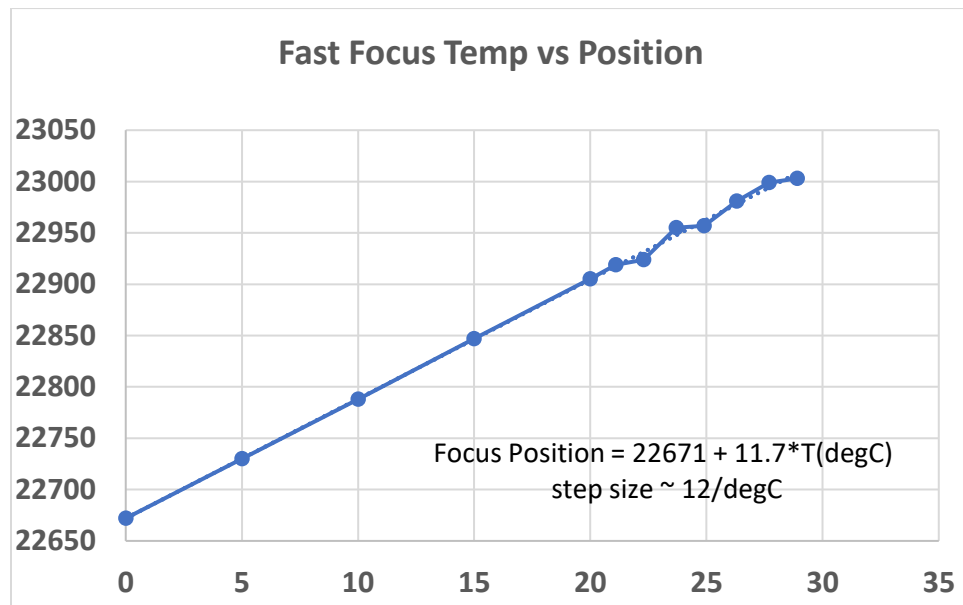
(Revised 27 Aug 2022)

This time of year (Summer) makes it difficult to measure for temperature compensation. In this instance over an entire night the temperature often varies < 5 degC. The following focus results were obtained on 25 Aug 2022 using @Focus3:

Filter: Luminance

Time	Temperature (degC)	Focuser Position
20:56	28.9	23003
21:57	27.7	22999
22:46	26.3	22981
23:35	24.9	22957
00:06	23.7	22955
01:18	22.3	22924
02:03	21.1	22919

From the above table we can plot and derive a least squares equation yielding an appropriate slope (step size) for our specific OTA configuration:



Least Squares Equation: SMFF Position = 11.7 * Temperature (deg C) + 22671

Critical Focus Zone (CFZ):

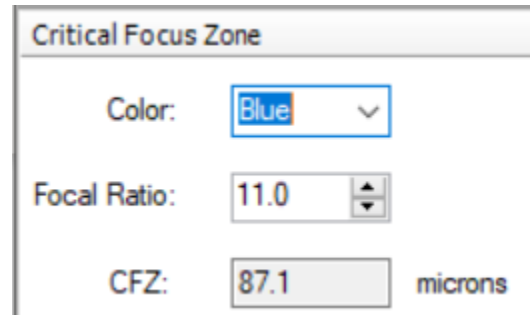
From Mark Crossley's [Critical Focus Zone calculator](#) using the most restrictive filter (Blue) we get a classic CFZ of:

Light Colour	Blue
Wavelength of light	475
Focal Ratio	11
Camera pixel size (microns)	9
Pixel binning	2x2
Calculate Reset	
Critical Focus Zone	280 microns
CCD Focus Zone	280 microns

The SMFF micron/step = .19 microns. Therefore CFZ = 280 microns = 1473.7 steps. With a temperature coefficient (TC) of 12 steps per degC a temperature change of approximately 122 degC would be necessary to deviate outside of the CFZ!

In January 2010 Don Goldman and Barry Megdal published a paper [‘Get Focused!’](#) which concluded that a more accurate CFZ is closer to 1/3 that of the classic CFZ. See the section ‘Discussion’ in the paper for the rationale.

And indeed, the CFZ calculator provided in John Smith’s CCDAutopilot5 appears to reflect this:



The image shows a software window titled "Critical Focus Zone". It contains three input fields: "Color:" with a dropdown menu showing "Blue", "Focal Ratio:" with a numeric input field showing "11.0", and "CFZ:" with a numeric input field showing "87.1". To the right of the CFZ field is the unit "microns".

Using this more restrictive CFZ of ~458 steps ($87.1/.19$) would suggest a need to refocus only after a temperature change of 39 degC well within the range of all but the most extreme nightly temperature changes.

But wait there is more! If one assumes that upon achieving focus the CFZ is centered on that focus position, then the allowable ‘in focus’ position would be $\frac{1}{2}$ of the calculated CFZ. In the above example a temperature shift of 20 degC would in turn require a shift in focus position of 229 steps which would shift focus out of the CFZ.

20 degC is still an outlier temperature change for most of us in a given evening. But even this can easily be mitigated by changing the focus automatically as the temperature changes. This is typically done either through imaging capture and control software programs or in this instance within the Optec FocusLync Hub which is distributed with the Optec SMFF. With this function enabled the SMFF will continuously adjust the step count to maintain the center of the CFZ as the temperature varies.

Summary and Conclusions

For Schmidt Cassegrain Telescopes (SCT) best / flat focus across the entire focal plane is met when the back focus is fixed to the manufacturer’s specification. This leaves focus changes due to OTA and optic contraction / expansion fluctuations to be accomplished via movement of either the primary or secondary mirror. The primary mirror is typically problematic as the necessity to allow it to move free enough when used with a focuser can also result in the dreaded mirror flop during slews, meridian flips, etc.

The Optec SMFF is an elegant solution to secondary mirror focusing. It is easy to install, collimate and use. Adjusting the focus at the secondary mirror results in having a very wide CFZ.

In practice it is now effective to perform an initial focus at the beginning of an imaging session and then let the focuser be automatically adjusted to maintain center CFZ position as temperature changes. No pause in exposure sequence to perform an external refocus is required for the duration of the session. If multiple filters are used, it is likely their focus will be within the original CFZ even if they are not

parfocal. But one still has the option to refocus at the start of each new filter or simply use precomputed filter offsets.