PROJECT MOANA

Amateur built remote telescope.

Version 1.0

July 2024

Project MOANA

This book covers the following topics, from the standpoint of a dedicated amateur astronomer & ATM (Amateur Telescope Maker):

- Optical design of a well corrected catadioptric Newtonian astrograph.
- Optomechanical design of an athermal system, able to maintain collimation for extended period of time, in a wide range of temperature.
- Electrical and computer system to support remote autonomous operations.
- Remote Operation of the system.
- Results achieved with the system in the field of astro-imaging, astrometry and photometry.

Figure 1: Narrow band imaging of the Rosette nebula with the Moana system. Processing: Taras.

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Introduction

How many more telescopes do you need? *Just one more* or so goes the joke.

This section goes over the design decisions of MOANA, a carbon fiber 10″ f/4.5 corrected Newtonian Astrograph. This is my 3rd telescope build so far, and it benefited from many of the -sometime hard- lessons learned on the previous designs.

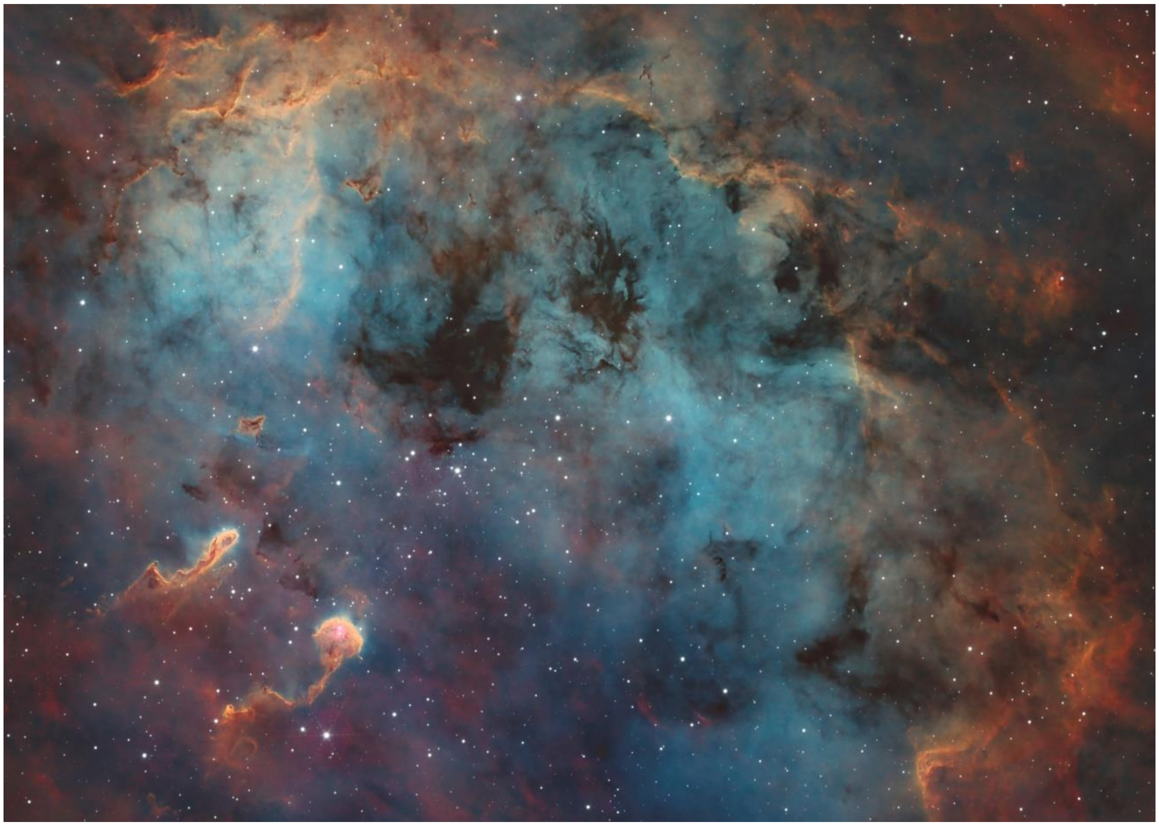


Figure 2: Tadpole Nebula, in Narrow Band, imaged with Moana. Processing Taras.

Optical design

Here are the **specifications**, as defined at the start of the project:

Optical Specifications

- A speed faster than f/5. Except for planetary/solar, I feel life is too short for anything slower than f/5.
- A focal length around 1,000-1,200mm. I already have a couple of wide or super wide field system based on telephoto lenses plus a 200mm Borg and a 600mm Hyperstar. So the next step up in focal length was in the 1,000-1,200mm range. Systems with a longer focal become either slow or big (simply because f = F/D), and increasingly more difficult to mount and guide. If one wants to maintain a reasonable speed, they also get expensive: as a general rule of thumb, the weight and price of a system increases with the power 3 of its diameter, so multiply by 2 the diameter, increase by

a factor $2^3=8$ weight and cost (we can assume in first approximation cost is proportional to mass).

- An instrument diffraction limited (or very close to it) over the sensor considered. Any instrument that does not meet this criterion (and there are still some sold commercially today) is an inexcusable optical design failure.
- Better than 90% vignetting over the sensor, a spec very often overlooked in commercial instruments. Many refractors for example boast a full frame illumination, but have over 60% vignetting at the edge of the sensor!
- Enough back focus for a filter wheel + a standard 17mm back focus camera.

Figure 3: Cocoon Nebula in RGB, imaged by Moana. Processing: Taras.

Mechanical specifications

- Weight and portability. Although MOANA is mostly designed as an observatory instrument, I wanted it to be transportable in a regular hatchback car. I also wanted the telescope to be portable enough **so a single person** could carry it and put it in station without help, and without the fear of breaking one's back or dropping the instrument. Last I wanted my mount (AP 1100 GTO) to carry it without struggling. I am not upgrading to a bigger mount any time soon.

- Very stable focus when temperature changes. Quite simple: I am not interested in refocusing every 15mn when the temperature drops with the night. A very notorious 106mm refractor with aluminum tube is very notorious for having this problem.
- Ease and stability of collimation. Collimation needs to be a quick, easy and reproducible process, that takes no more than 15mn, can be done at night or during day light. Collimation needs to remain stable for at least a night, ideally months if the instrument is not moved. Again, this is very simple: I prefer the night to be spent observing, not collimating.
- Realistic collimation tolerances for all optical parts. I have seen many commercial instruments with incredible performance on paper. However those performance can only be achieved under perfect collimation. The tolerances, which tell you how fast performance degrades when collimation quality degrades, are often not provided. This results in either chronic under-performance by the system (poor images), or a constant uphill battle and headache for the user to attain and stay within collimation tolerances. Riccardi Honders, Hyperstar, and many other systems fall into this category. I was not having any of that for MOANA: I needed the instrument to be robust enough so a slight imperfection in collimation would not have a catastrophic outcome. The instrument needs to stay in a remote observatory with wild temperature swings, and keep performing nights after nights, at all angles.
- A system realistic to build for an amateur with limited tooling, time, knowledge and skills.

Last but not least: final **cost,** and adherence to the **budget forecast**. The cost spec was simple: MOANA should not be more expensive than a high quality equivalent commercial instrument (eg: ASA Newtonian). This is a major challenge, as commercial instrument clearly benefit from an economy of scale. In particular, the cost of CNC machined part goes down dramatically as the number of part in the series increases. The other aspect is adherence to budget: it would be very easy to underestimate cost, or the amount of work involved.

Choice of the optical formula

The constraint on fabricability, tolerance, collimation and cost oriented me towards a **Corrected Newtonian**. The best Corrected Newtonian optical formula is without a doubt the **Hyperbolic Newtonian**. However, when I started the project (5 years ago) the optical correctors and main mirrors for the Hyperbolic Newtonian were, and generally still are, relatively rare (ASA makes a large professional Hyperbolic Newtonian & corrector, Hubble Optics sells mirrors and correctors for this formula to amateurs). The **Parabolic Newtonian** has the following advantages over the hyperbolic: can work or be tested on a small field without a corrector, wide range of correctors commercially available (Wynne correctors, Paracorr), can be used with a generic focal increaser (PowerMate or equivalent) for planetary or long focal work, could be used visually with the right eye pieces and without the corrector. Further many manufacturers make parabolic primaries, offering a wide choice. In the end I went for the safe, well documented and traditional Parabolic Corrected Newtonian.

The coma corrector, or corrector (as it may also help with field flattening) is central in the optical design of MOANA. In fact, the whole telescope is designed around and for the corrector. This philosophy is quite the opposite of most cheap commercial Newtonian telescopes, where the coma corrector is too often an afterthought slapped in after the owner realizes the off-axis image is unacceptable for photography.

Figure 4: crescent nebula, RGB and narrow band image, from Moana. Processing Taras.

Optimizing the choice of primary mirror – coma corrector -sensor size

Once the Newtonian has been adopted formula, this is the most important step. There are 3 elements: primary mirror, coma corrector and sensor size. Each of those elements put constraints on the other two, and an iterative process was used to optimize the system.

- for the system to remain truly portable the primary diameter needs to be at or below 10″ (25cm) -at least for me and what I am comfortable to haul.
- then to not compromise too much on the secondary mirror size and still keep low vignetting over the entire sensor, the instrument becomes limited to an APS-C sensor as the biggest sensor that can be illuminated.

Let’s pause here for a second. Full frame sensors have a huge advantage: they cover more field of view. They have a few disadvantages:

- they are expensive.

- The filters for those sensors are also extremely expensive.
- The filter wheels for those sensors are big, heavy and expensive.
- the correctors for those sensors are big (at least 3″ diameter), heavy, complex and expensive. This is because the coma increases linearly with the field angle. So correctors for bigger fields become increasingly more complex, with more glass, possibly the use of exotic glass, more extreme lens shape.
- the focuser to carry the corrector, filter wheel and sensor needs to be oversized, heavy and expensive.
- The secondary mirror, in charge of illuminating the corrector, needs to be big. It becomes heavy, makes a large obstruction which reduces the illumination, disrupt the diffraction pattern and decreases contrast.

Now on the telescope: the bigger the telescope, the bigger the field of illumination. The sensor size that can be illuminated increases linearly with the primary mirror diameter when a particular design is scaled at constant f/number.

For example, any 16″ Newtonian should effortlessly illuminate a full frame sensor, while any 10″ should effortlessly illuminate an APS-C sensor.

Notwithstanding the above statements, by making compromises (mostly an oversize secondary mirror) a particular instrument can be pushed towards some desired performance, like a wider illumination circle. For example, ASA had their 8 inch Newtonian astrograph advertised as compatible with full frame sensors. The price to pay is a very large secondary mirror for that scope (with correlative large central obstruction percentage) and some vignetting.

From those consideration, I decided MOANA would be required to illuminate an APS-C sensor only. That is, I found it was better to design a top performer on a cheaper, lighter APS-C sensor imaging train rather than an average performer compromised to illuminate a full frame sensor. The ability to make those choice eyes wide open is the huge advantage of making one’s own instrument. Also there is no right or wrong here: the question is what characteristic is most desirable, and what is an acceptable compromise to get there. From the above, it is also be clear if I ever design a 16″ Newtonian telescope, it will have at least a 3 inches Wynne corrector and will be designed to illuminate a full frame sensor: this is the natural thing to do with such diameter.

Back to the primary -corrector -sensor optimization. At this point we have a 10 inch telescope, to illuminate an APS-C sensor. A 2 inch diameter corrector minimum is required to maintain vignetting specs. What corrector should be chosen? Chapter 14.2 of the Smith-Ceragioli-Berry book (“Coma Corrector for Newtonian Telescopes”) is a highly recommended read on the question. From here there were 2 considerations. First: each corrector is optimized for a particular f/number value. Second: corrector collimation (or alignment) specs become quickly unforgiving when the f/number of the primary is fast (say faster than f/3.5) or when the corrector is also a focal reducer.

So the coma corrector and the f/number of the primary mirror are chosen together.

At this point we have chosen D the diameter of the telescope, and defined a range for F, the focal length (1,000 to 1,200mm). The focal ratio, or telescope speed, f is also f=F/D. A very important fact in optic is: focusing tolerance is proportional to f^2. This means an f/6 system, for example, would be 4 time more tolerant to focus and collimation errors than an f/3 system. This explains why fast system, very attractive on paper can be a total pain to focus and collimate. Faster primary mirrors are also more expensive (more glass needs to be removed, more time spent on parabolization) and more difficult to test.

In the end I went for f/4.5, and a corrector optimized for that focal, the Paracorr type 2.

On the **Paracorr type 2, 2 inches**: it is very wide spread in the amateur community, and has been extensively used with good results. The alignment and collimation tolerance are forgiving. I tested one on a previous telescope and knew exactly where I was going. There are drawbacks however: the optical formula is a secret of Televue so it cannot be ray traced for a particular system, the documentation coming with the corrector is a bunch of hand drawn diagrams on Televue's website (when the industry standard has been clean Zemax plots for years), and the adapters provided by Televue have back focus values inconsistent with the corrector's drawing (I think the drawing are correct and the back focus values have been mixed up with external measurement).

Figure 5: NGC 6914 in Cygnus, color imaging by Moana, processing Taras.

Conclusions

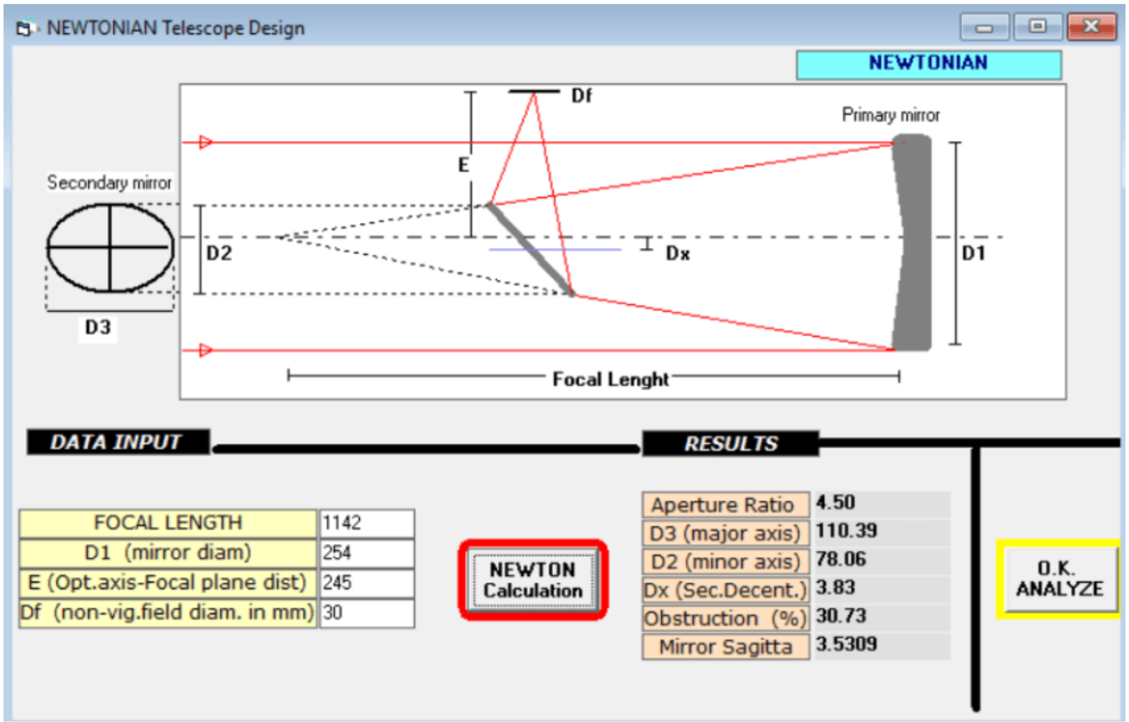
At this point the following parameters have been defined:

- the primary diameter D=10″.
- the focal ratio f/4.5.
- From the above, the focal length, F=10″*4.5=1,142mm
- the coma corrector (Paracorr type 2, 2 inches)
- the sensor to illuminate: APS-C. That is an image circle of 29mm diameter, illuminated without vignetting.

From there I used Atmos (the free version) and plugged in the above parameters. One parameter I did not have yet was the optical axis-focal plane distance. That measurement is constrained by the entry light cone diameter, and the fact I did not want the paracorr to protrude inside this light cone. It is also constrained by the secondary diameter. The secondary mirror size has discrete values, which I took from the supplier (Antares Optics).

From here I iteratively searched the values of the optical axis-focal plane distance E in Atmos, within my acceptable range, until I got out of Atmos a secondary size D2 compatible with the manufacturer specs of an existing secondary mirror (minor axis of the secondary equal to 78 mm). In scientific language, I inverted for E, knowing D2, and using Atmos as a black box. It seems complicated but it is really a 5mn process.

This iterative process lead me to an optical axis-focal plane distance of E=245 mm, fully constraining the Newtonian design, including the optimal secondary offset (Dx=3mm).



FOCAL LENGTH	1142
D1 (mirror diam)	254
E (Opt.axis-Focal plane dist)	245
Df (non-vig.field diam. in mm)	30

Aperture Ratio	4.50
D3 (major axis)	110.39
D2 (minor axis)	78.06
Dx (Sec.Decent.)	3.83
Obstruction (%)	30.73
Mirror Sagitta	3.5309

Figure 6: Moana optical formula, without corrector, in Atmos.

The last step was to ray trace the design in the free version of Oslo. The fact that the Paracorr design is secret is a problem. So for my ray tracing I used the coma corrector described in Smith-Ceragioli-Berry p389. That design is understood to be akin to the first Paracorr. The promise is that the actual ray tracing with the Paracorr type 2 would be very similar and slightly better than what I would come up with with the SCB corrector.

Here is the Oslo ".len" file. 10inch_f4.5_paraboloid_para_corr Download

And here are the ray tracing results done in Oslo.

Figure 7: M33, the triangle galaxy, imaged by Moana, processing Taras.

Ray Tracing Moana

OSLO EDU is a free Windows program for optical design. It is restricted to 10 surfaces, just enough to evaluate a Newtonian with a double-doublet lens corrector. The surfaces are: entrance window, primary, secondary, 3 surfaces per doublet for 2 doublets, so 6 surfaces for the corrector and image.

The Oslo file is proposed below. The sketch shows the optical layout, and the table provides the optical prescription for Moana. 10inch_f4.5_paraboloid_para_corr Download

One remark: the actual Paracorr prescription is not public. It is very unfortunate, but Televue keeps the Paracorr prescription a trade secret. So I am using instead an analog, the coma corrector described in the Smith-Ceragioli-Berry book, p389. It is understood the actual

Paracorr type 2 is at least as good, hopefully better, than the SCB corrector shown below. From information goatherd on forums and trickled by Televue, the Paracorr Type 2 also has 1 more lens (5 lens in 3 groups I believe) than the design used here, which is more akin to the Paracorr type 1.

Another remark: when looking at the spot diagram, the black circle is 6.2 microns. It is the actual diffraction limit of the scope, given by r = 1.22λf/D. So at a wavelength of 550nm (ie green light), Moana has a 1.09 arc-second resolution, corresponding to a 6.2 micron airy disk on the sensor (2 pixels with the current CMOS camera). This is a match made in heaven between the **seeing** (rarely below 1 arc-seconds), the scope **diffraction limit** (1.09 arc-second), the **tracking precision** (around 0.5 arc second RMS, wind dependent) and the **camera pixel size** (1 arc second for two pixels).

Just keep that 6 micron scale in mind when comparing the spot diagram provided for Moana with those found on commercial websites selling telescopes, as many sales people rescale their diagrams to make the spots look smaller! A company notorious for engaging in this practice is Takahashi, sporting a 100 microns scale on their spot diagrams!

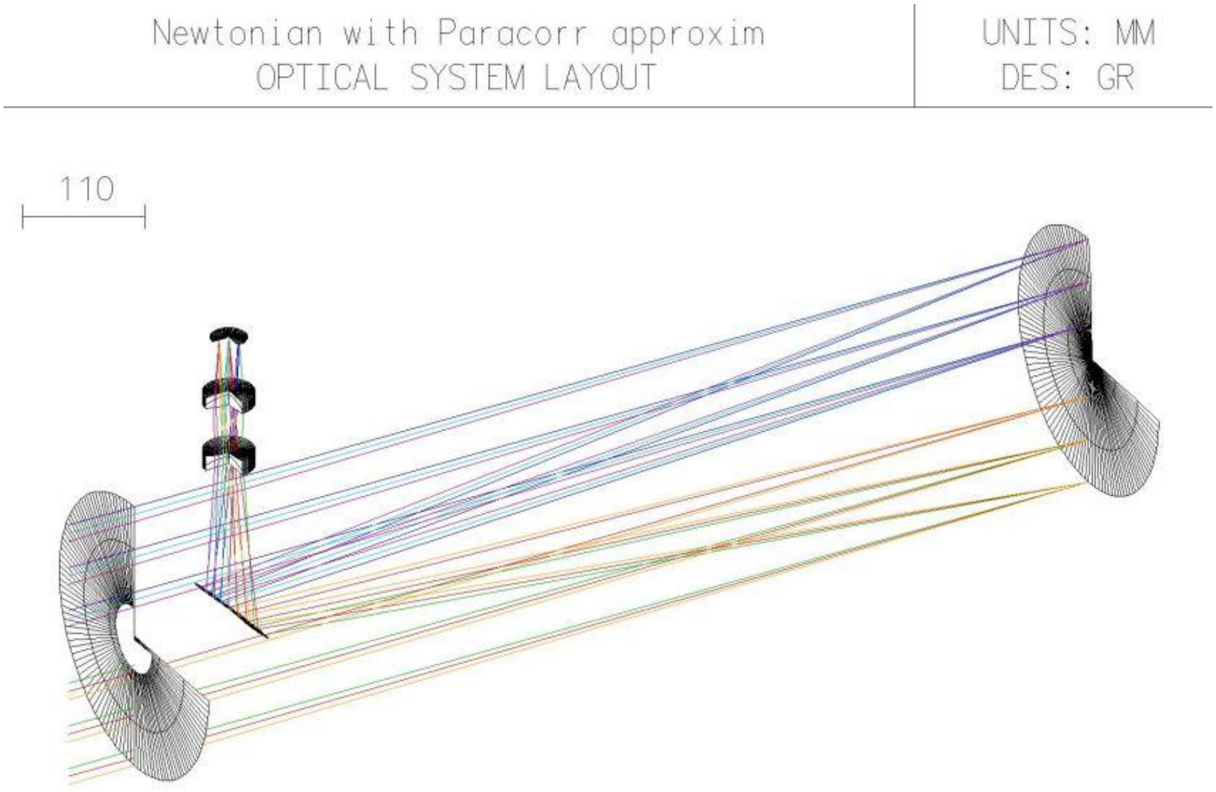
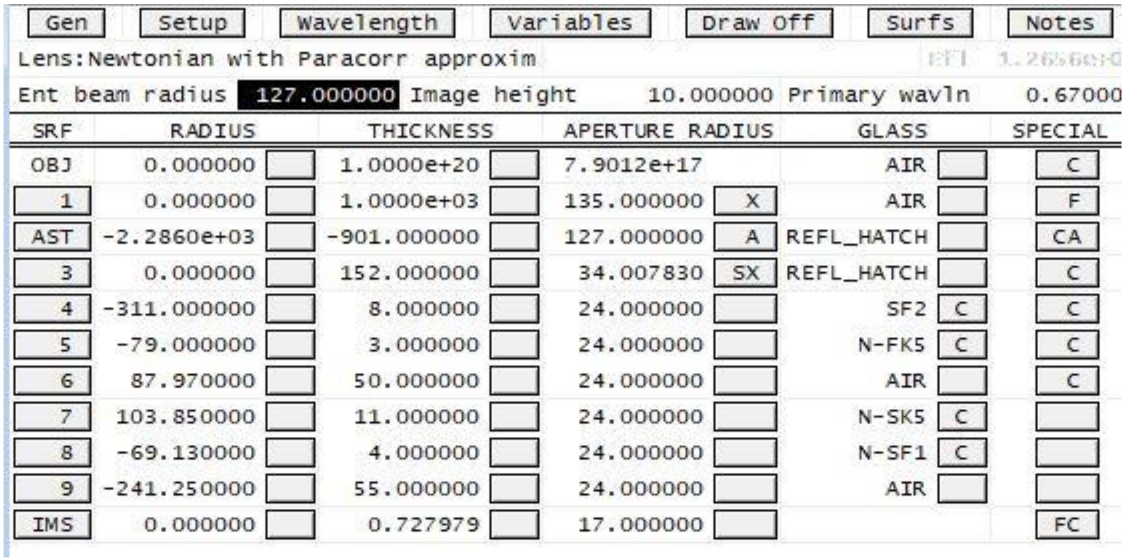


Figure 8: Moana optical layout in Oslo Edu. Note the 2 doublets of the corrector.



Lens:Newtonian with Paracorr approxim EFL 1.2656e+0

Ent beam radius 127.000000 Image height 10.000000 Primary wavln 0.67000

SRF	RADIUS		THICKNESS		APERTURE RADIUS		GLASS		SPECIAL
OBJ	0.000000		1.0000e+20		7.9012e+17		AIR		C
1	0.000000		1.0000e+03		135.000000	X	AIR		F
AST	-2.2860e+03		-901.000000		127.000000	A	REFL_HATCH		CA
3	0.000000		152.000000		34.007830	SX	REFL_HATCH		C
4	-311.000000		8.000000		24.000000		SF2	C	C
5	-79.000000		3.000000		24.000000		N-FK5	C	C
6	87.970000		50.000000		24.000000		AIR		C
7	103.850000		11.000000		24.000000		N-SK5	C	
8	-69.130000		4.000000		24.000000		N-SF1	C	
9	-241.250000		55.000000		24.000000		AIR		
IMS	0.000000		0.727979		17.000000				FC

Figure 9: optical prescription table for Moana, with the corrector.

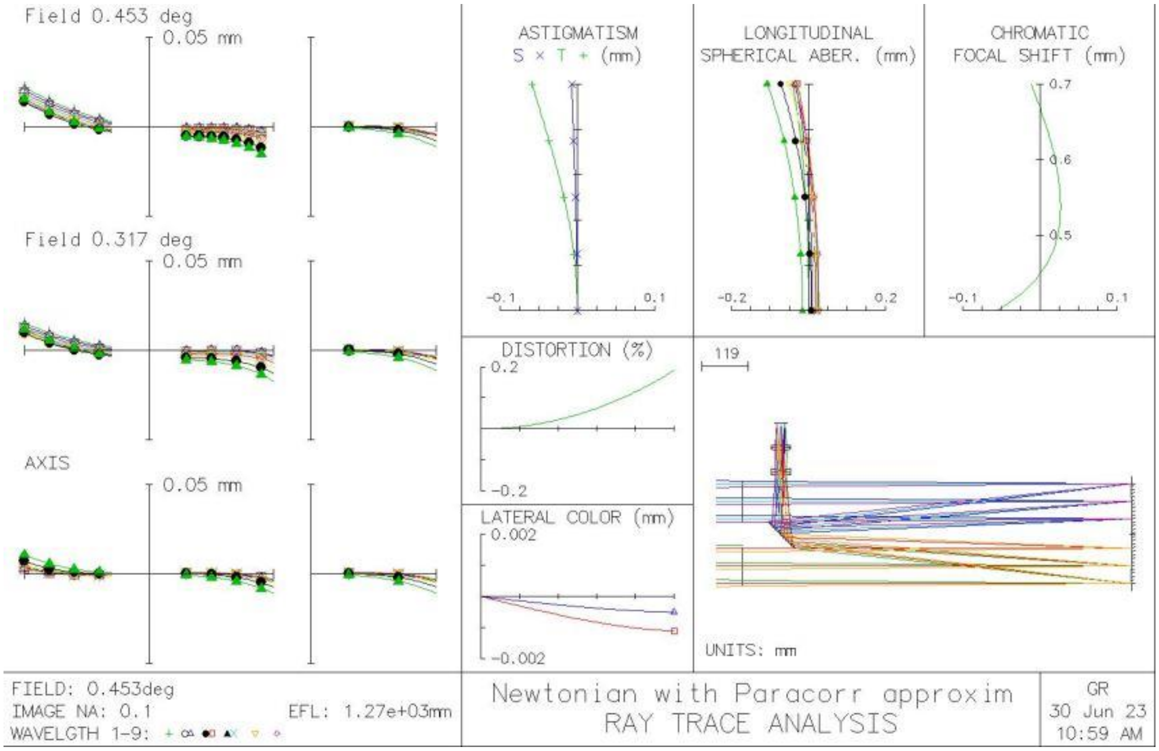


Figure 10: ray tracing analysis of Moana, with the corrector.

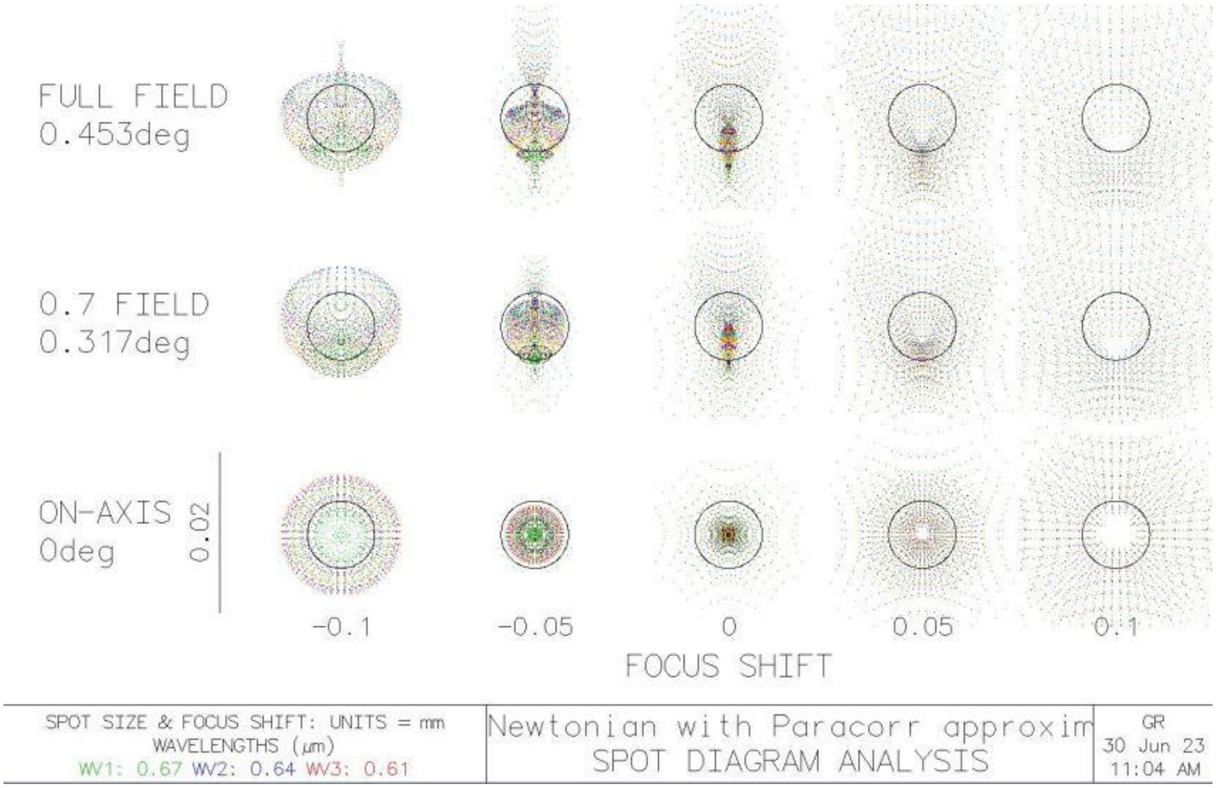


Figure 11: spot diagram for Moana.

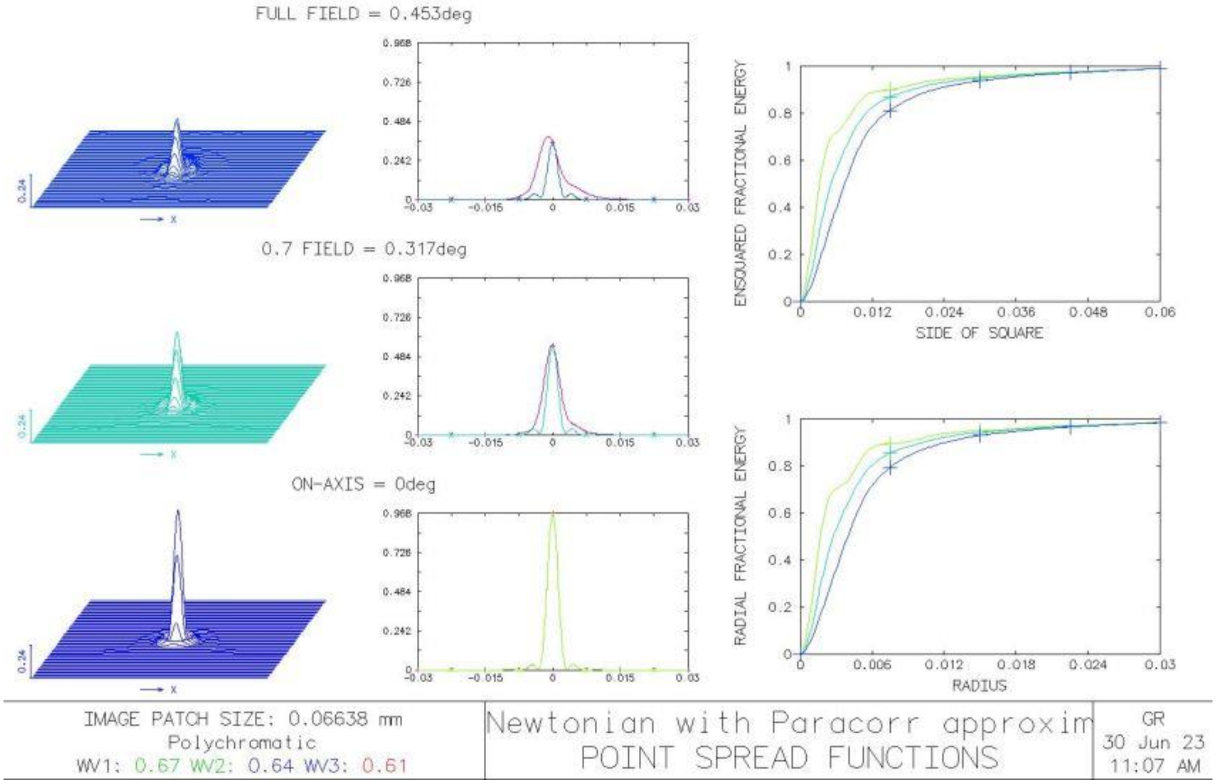


Figure 12: point spread function for Moana.

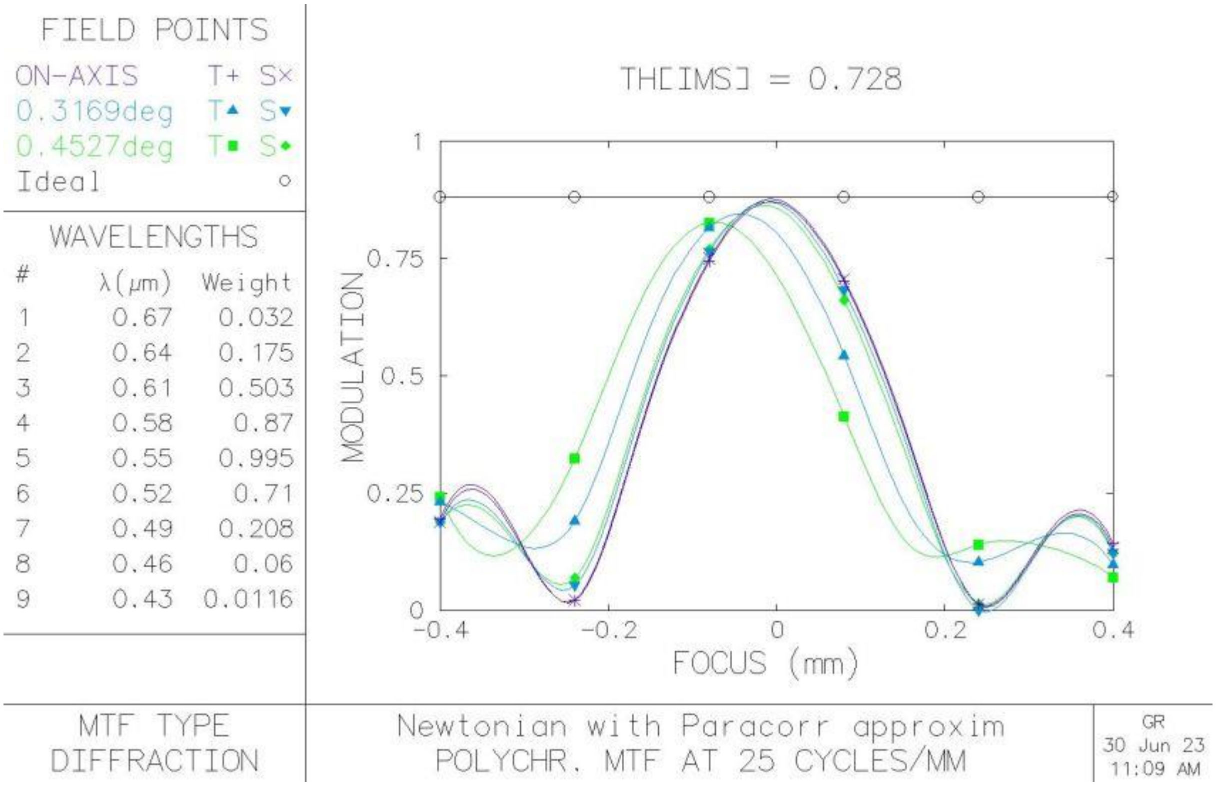


Figure 13: Moana Modulation Transfer Function analysis with focus.

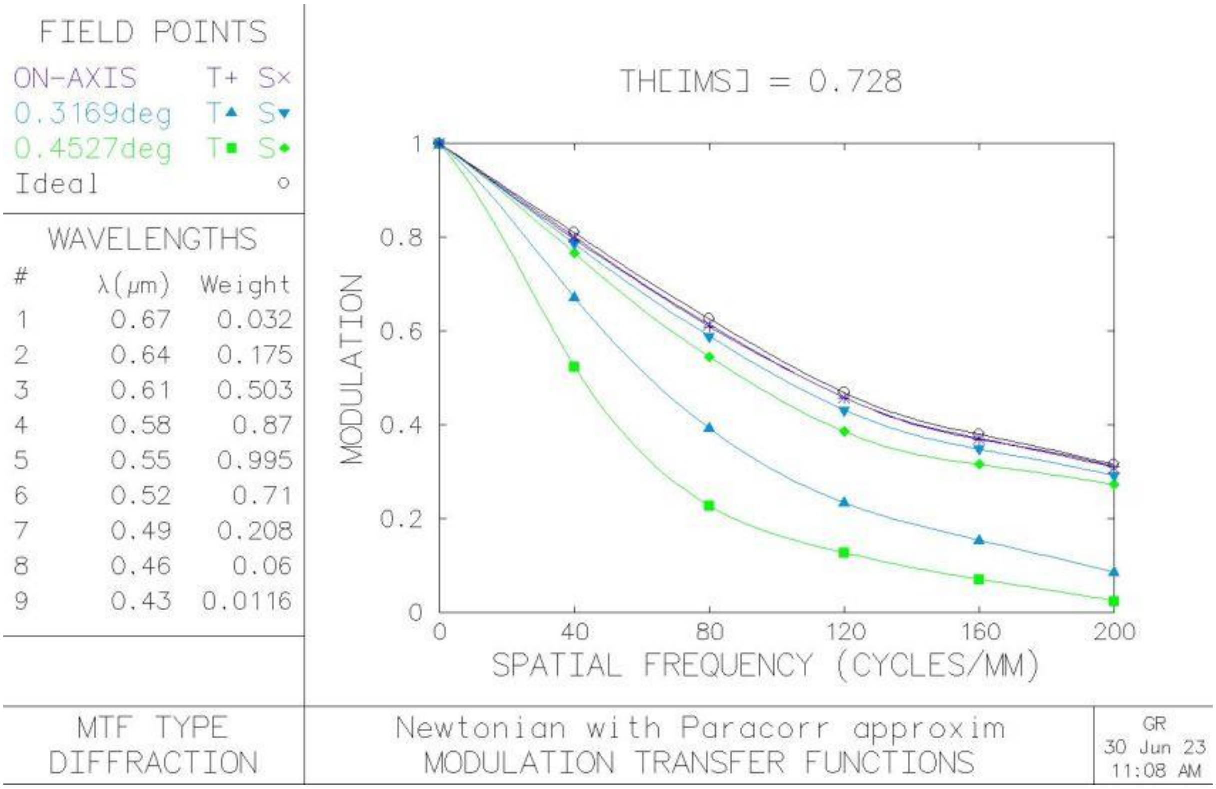


Figure 14:Moana Modulation Transfer Function (spatial frequency).

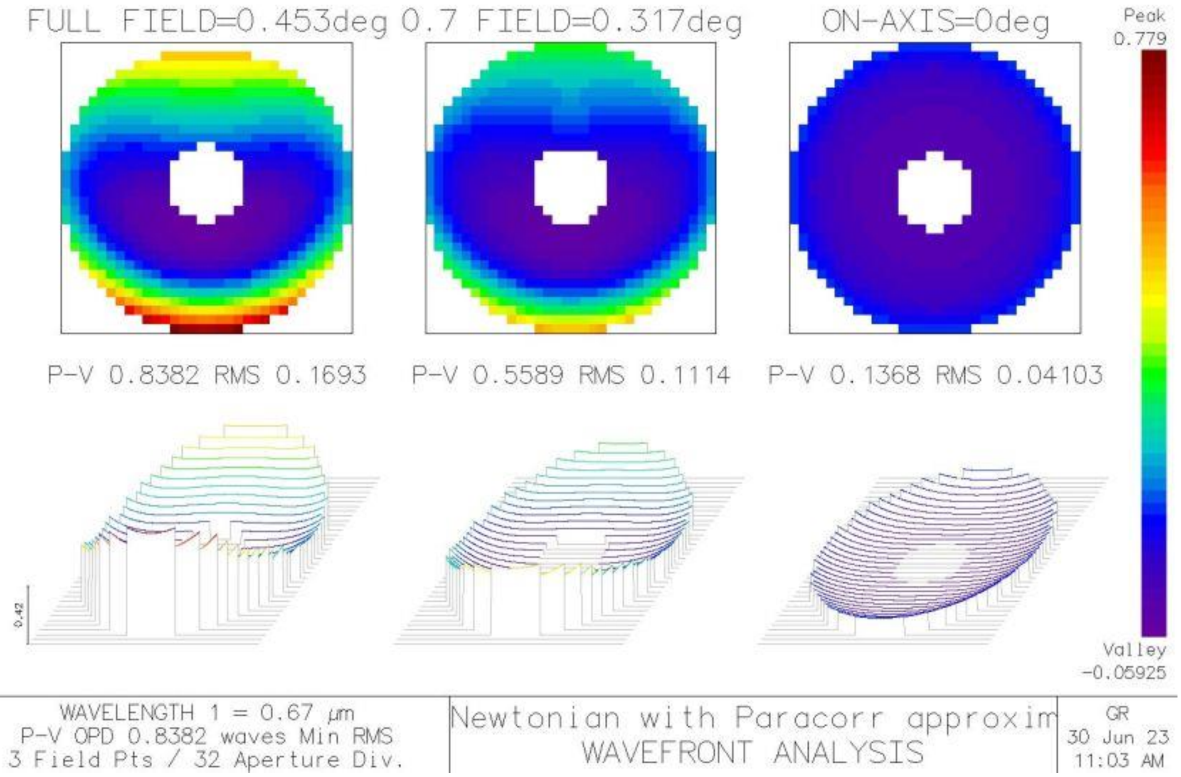
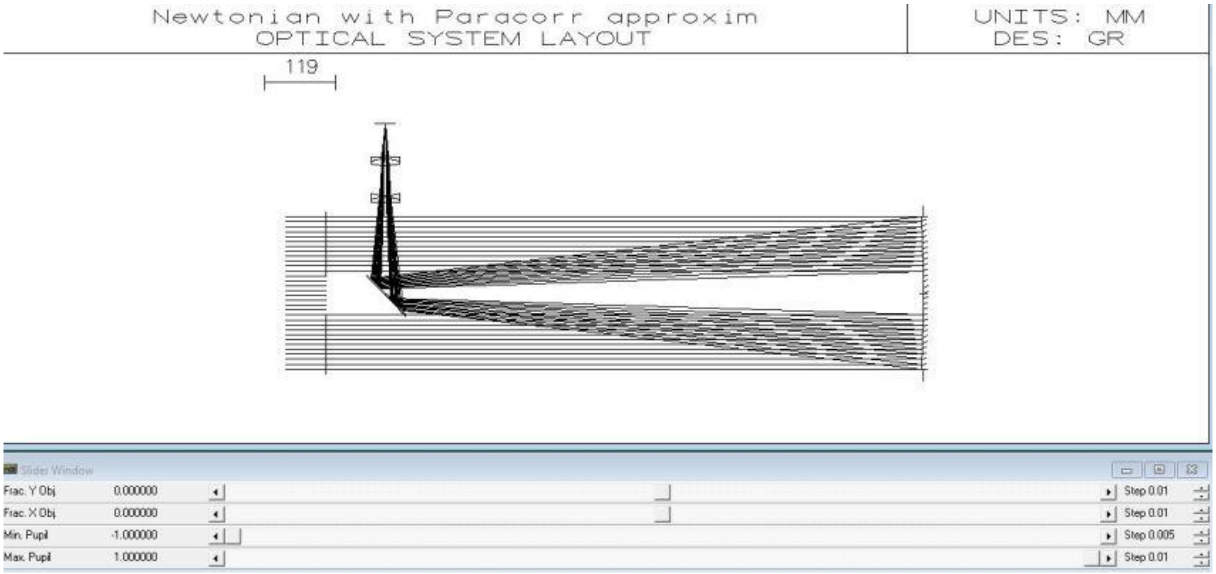


Figure 15: Moana Wavefront analysis.



Frac. Y Obj 0.000000 Step 0.01
Frac. X Obj 0.000000 Step 0.01
Min. Pupil -1.000000 Step 0.005
Max. Pupil 1.000000 Step 0.01

Figure 16: Moana system layout.

MOANA: Mechanical design

Design principles

The mechanical design of MOANA was guided by the following principles:

- **Try to not reinvent the wheel**: since 1668, when Newton built the first telescope now bearing his name, every variant of the design has been tried, and the solutions that have imposed themselves over 350 years of trial and error are now probably close to optimal.
- **Try not to overengineer**: mechanical engineering is not biology, and simplicity is a virtue. Performing the same function, the simplest design is often the most robust and reliable, and usually the simplest to build. Overengineering is often lazy and lacking vision. Elon Musk is quoted saying: The best part is no part, and the less parts the better".
- **If you can buy it, don't build it.** Buying a quality part (say a mirror cell) can be expensive. But engineering and building a better one can be an order of magnitude more expensive! Each prototype needs to be built (with a cost often comparable to the final product), tested and improved. Then for the final production, machining a one-off part is always much more expensive or time consuming (per unit) than machining a batch.
- **Build so the telescope will outlive you.**

Figure 17: flat panel test.

Tube or Truss?

The first decision to make was: **truss or tube**? One way to answer this question is to review the existing commercial instruments in the category considered. For an f/4.5 10″ Newtonian, we find many tubes (ASA, ONTC) and very few truss (AstroTech). This quick surveys through a telescope catalog seems to indicated instruments with a diameter at or smaller than 10 inches are mostly tubes, while instruments with a diameter larger than 14 inches are mostly truss.

Another way to answer the question is to use physics. Let's look at the formula for the "second moment of area" of a tube. It informs us on the stiffness of the tube in cantilever applications. It can be calculated as follows:

$I=E\,\pi / 64\,(D_e^4 - D_i^4)$ with D_e exterior diameter and D_i interior diameter of the tube. I is the second moment of area and E the extensional modulus and π is Pi.

We can substitute the external diameter with the wall thickness w, using: $D_e= D_i +w$. It then becomes apparent that the tube rigidity increases as the power 3 of the tube diameter and the power 4 of the wall thickness.

Those considerations should convince you well-built large tubes offer an incredible rigidity. Further tubes are mechanically simple, and can be rotated if supported by rings.

Figure 18: Messier 104, the sombrero galaxy, as imaged by Moana. Processing Taras.

The advantages of the truss are:

- access inside the telescope is much easier than inside a tube, which can be essential for the collimation (Richey-Chretien, Corrected Dall-Kirkham),
- formulas like a serrurier truss may deform while maintaining collimation,

- can be disassembled,
- for big structures, lighter and easier to manufacture than a tube.

For MOANA, access through the tube for collimation is not required (Newtonian) and the overall size makes tube a possible option. So due to the rigidity and simplicity consideration exposed above, this is what I chose.

Figure 19: M13 globular cluster in RGB, from Moana. Processing: Taras.

Tube

I did not consider legacy materials (sonotubes), steel (has to be too thin to be light) or exotic materials I could not source (Astro Physics for example uses on the RH scope a tube made of an exotic alloy probably similar to Invar, with near zero thermal expansion).

I considered 2 types of material for the tube: **aluminum and composite**. I had made one comparable instrument in the past out of an aluminum tube, sourced from Parallax Instrument. I found the tube heavy, very susceptible to thermal expansion (altering the length of the tube, hence the focus while temperature drops with the night), and all the aluminum tubes I have come across (from Parallax or other sources) were slightly deformed. Bending those tubes back into shape is an uphill battle. So, I decided to go for a composite tube considering the low weight, low thermal expansion, high rigidity and the absence of plastic deformation (the tube would arrive to me with its original shape -or cracked, but not bent). The drawback of composite, versus aluminum, are: high price and low machinability (you can for example tap an aluminum tube, while a carbon tube would require some form of insert).

If I was going the composite way, I figured I may also go all the way and use Carbone fiber (due to its rigidity) over other composite types, like fiber glass.

From there I considered 4 suppliers:

- Carbone Scope Tubes
- Dragon plate
- Dream Scope
- Klaus Helmerichs

I hesitated between a solid wall and a honey combed wall tube. I ended up with a solid wall tube: less expensive, more resistant to dings, easier to make holes without compromising the structure and sufficiently rigid for the task. Maybe going for a honey comb tube would have save a few grams, added some rigidity and be more glorious…

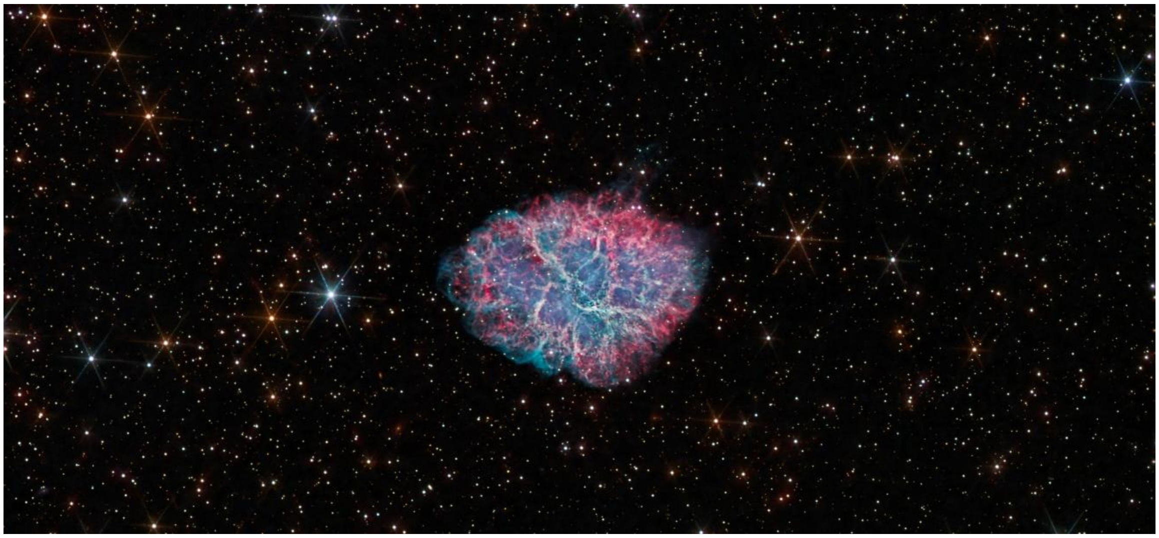


Figure 20: M1, the crab nebula, imaged by Moana.

I ended up with the following **solid wall tube**, from Carbone Scope tube:

- Inside Diameter: ID=12.61″
- Outside Diameter: OD=12.88″
- wall thickness=0.135″. This corresponds to the thickest wall available from this manufacturer
- tube length 50″
- focuser hole center at 40″ of one extremity and 10″ of the other.
- Clearcoat finish exterior, flat black interior.
- focuser hole diameter: it is a Starlight 2″ focuser with OD of 2.54″, so the focuser hole needs to be between 2.6″ and 2.75″ diameter.

Tube Ring

Three options there: find and buy a commercial ring corresponding exactly to your tube specifications, manufacture your own ring, or get a set from Parallax instrument. Joe at Parallax makes rings for scopes from 3 to 26 inches of diameters, fine stepping with many intermediate sizes. Because the rings are made of molded aluminum which is quite thick, intermediate sizes can be achieved by grinding the inside of a ring of the closest inferior size. For example, for my 12.88″ OD tube, a 12.7″ standard size ring was enlarged, grinding the interior, removing 0.09″ (2mm) everywhere in the inside of the ring. Molded aluminum is quite soft compared to the 6061 aluminum used for other parts of the scope, and the grinding process is quick and easy.

My opinion now: if one is used to the tolerance of CNC machining, molding is quite crude, and I had to rework the rings quite a bit to make them work. In particular the hinges were both out of tolerance and I had to grind the rings along the hinges to ensure no part would scratch the tube in the pivot movement consecutive to opening the ring. I also had six 1/4-20 holes taped by Joe into each ring to fixate the dove tails, and 2 of the holes were out of tolerance (not positioned to spec on the ring). The ring are also quite heavy, and painted (rather than anodized). With some effort, everything worked, and I now have a solid system. However, at some point I plan to design parametric rings, and have that CNC machined and anodized to replace the current solution.

Primary collimation cell

Teleskop-Express in Germany and Aurora Precision in Washington state have high quality collimation cells. Building, testing, and iterating to get a product comparable to or better than the Aurora AZ cell would certainly be very time consuming and expensive. Although I may end up going down that route and make my own Carbone fiber collimation cell someday, for now I am using one of Aurora Precision AZ cell. The cell is in aluminum, the collimation screws are standard 1/4-20 screws. The design is of the “floating” type, with the mirror cell floating on springs. The golden knobs are used to collimate (pull) and the red knobs are used to lock the cell (push).

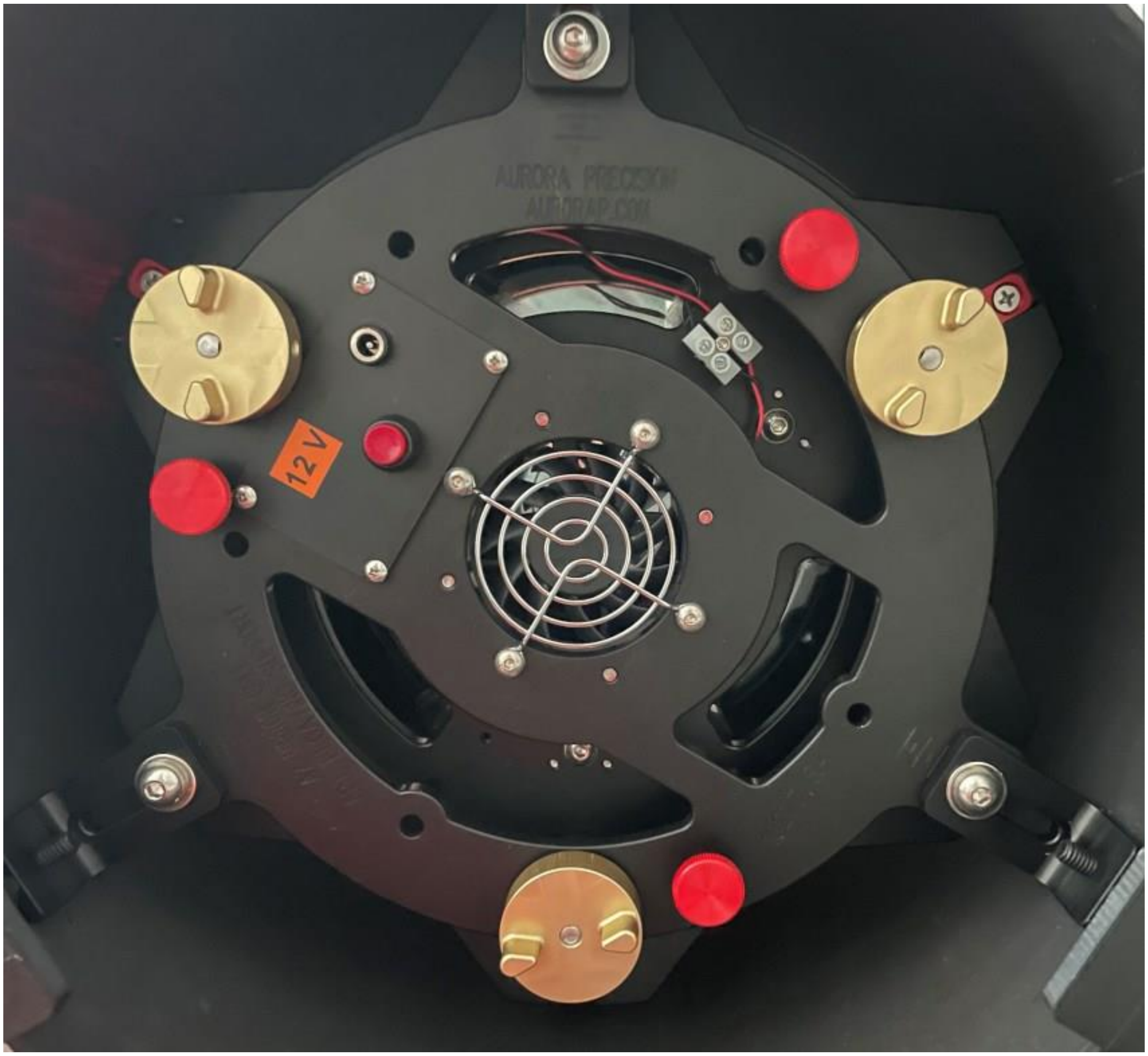


Figure 21: Aurora collimation cell.

Secondary assembly

On this front I was unable to find any commercial solution sturdy enough for my need, so I designed my own. I wanted a system that would be extremely rigid, precisely made of CNC machined aluminum, with micrometric screws (rather than standard screws), fully adjustable, mechanically insulated from the carbon tube to tolerate differential thermal expansion, and with a 120 degree symmetry for easier collimation with 3 sets of screw. And with 12v supplied through the vanes. This is a very stable and sturdy system, which has performed flawlessly, and give Moana its signature diffraction patter. Many hours of engineering, CAD design and prototyping were invested here, and this system has a potential to interest other ATM. All CAD files and drawing are opensource. The system is adjustable along the radial axis of each vane (if the 2 screws are tensioned together) of tiltable with a differential tension on the screws.

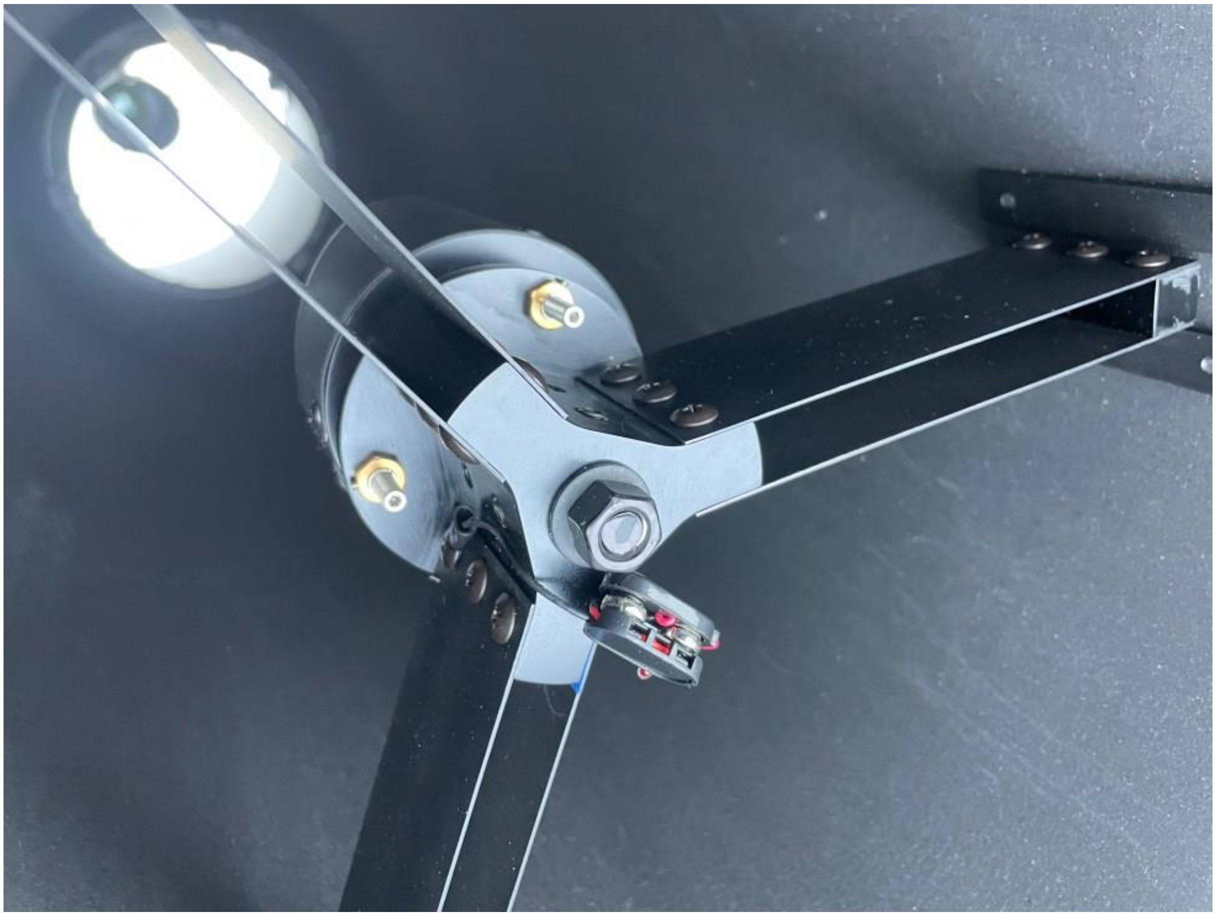


Figure 22: double van spider and secondary assembly.

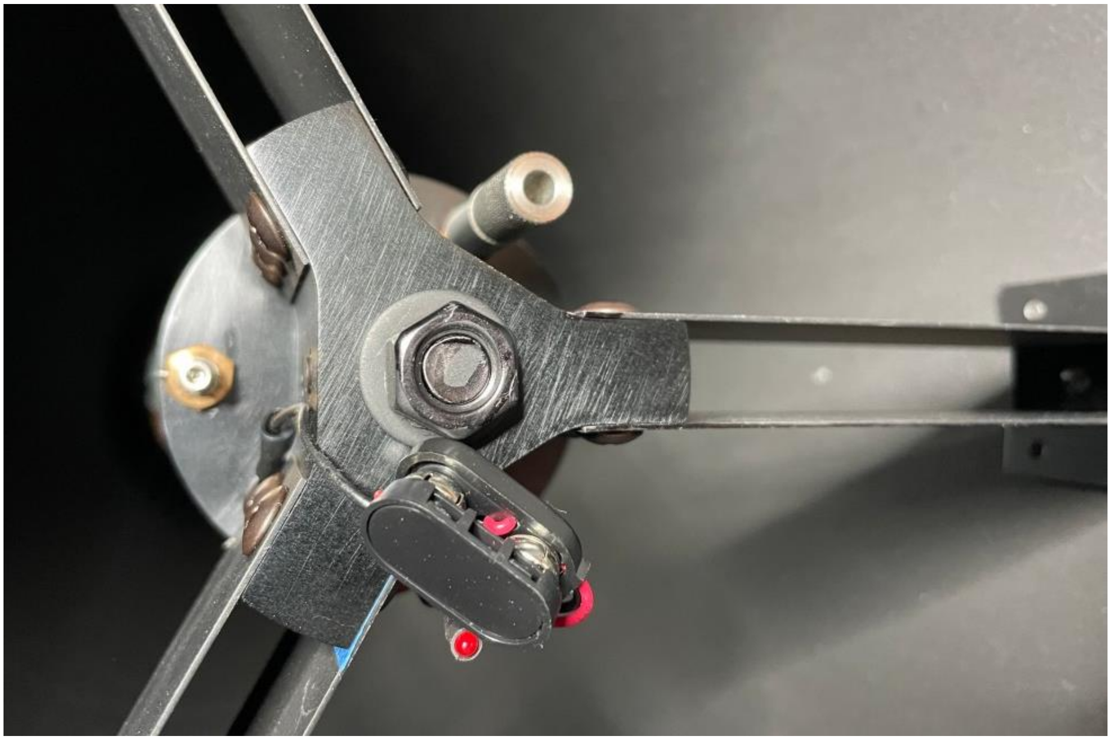


Figure 23: detail of the secondary assembly.

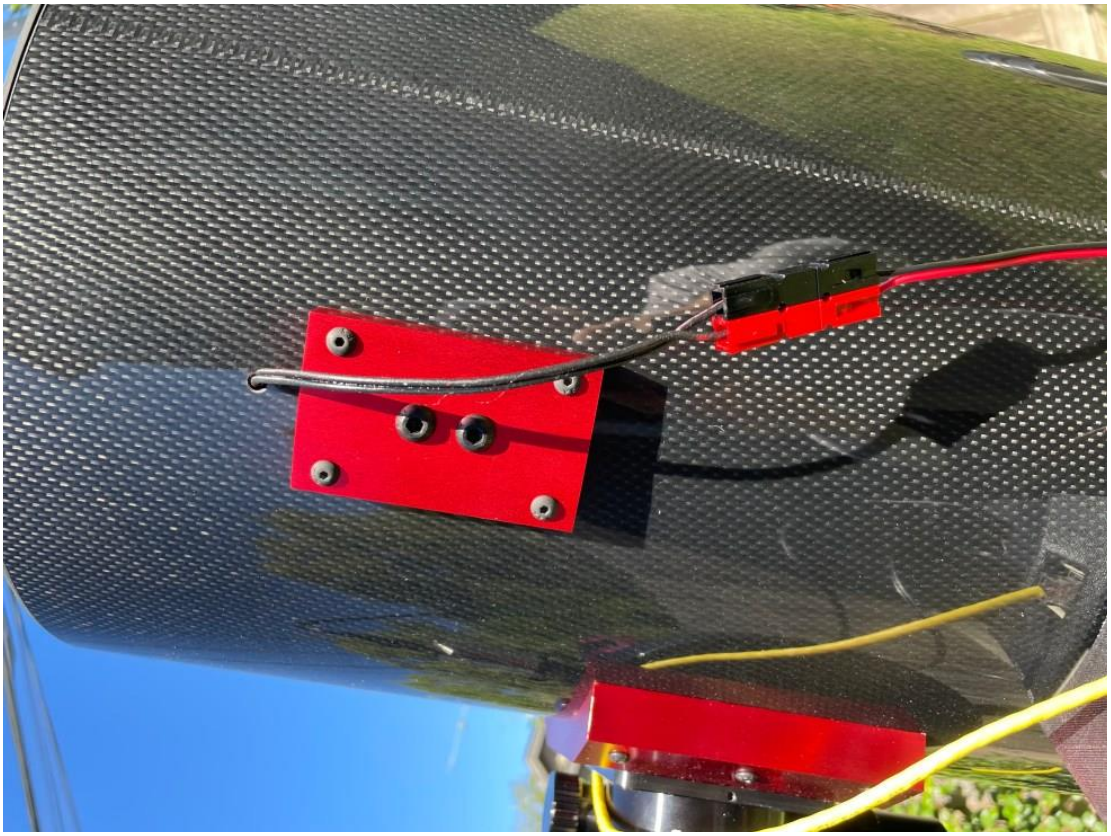


Figure 24: load spreader clamp on the outer side of the Optical Tube Assembly.

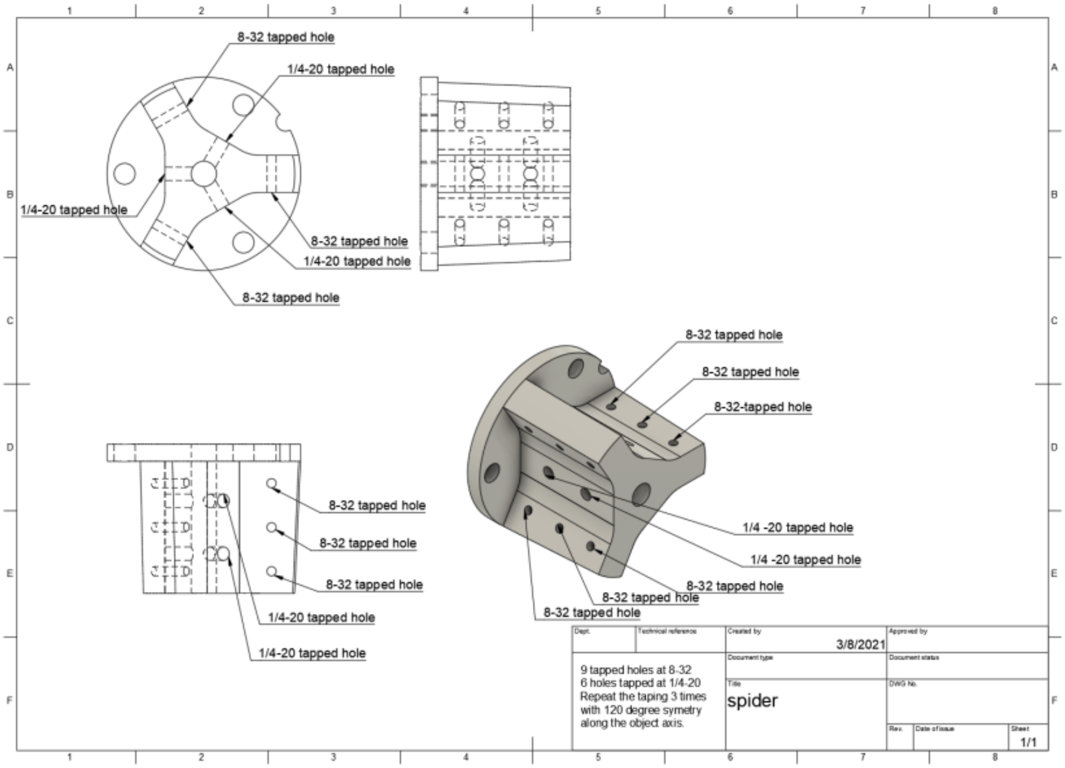


Figure 25: spider assembly central part.

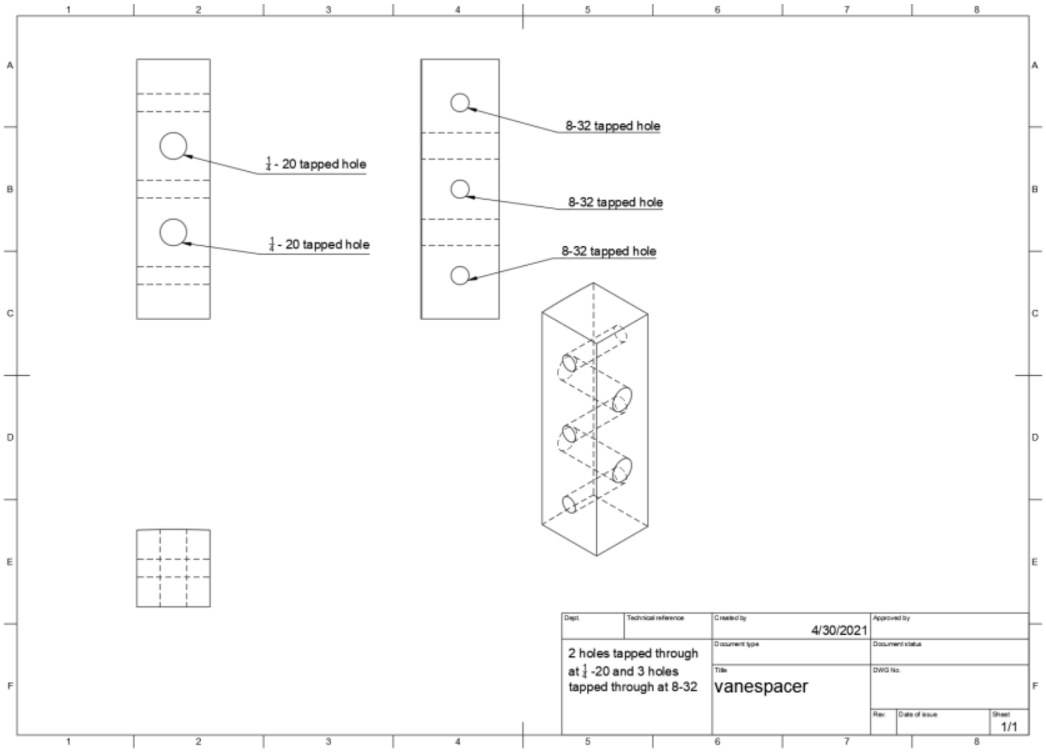


Figure 26:Dual vane spaces and outer attachment attachment.

Figure 27: front view of the telescope during collimation (secondary centering).

Focuser

The focuser is a Feather Touch® FTF2015BCR Rotatable 2.0″ with a BA20FL Flat Base 2.0″ screwed on a custom-made CNC curved adapter. This allows very precise collimation of the focuser. The outside diameter of the Feather Touch 2” focusers is 2.54” so the opening of the telescope tube needs to be bored between 2.54” and 2.75”. Drawings of the focuser support. CAD file are opensource. The image shows the focuser, racked out, on its curved base (red), with a collimation laser inserted.

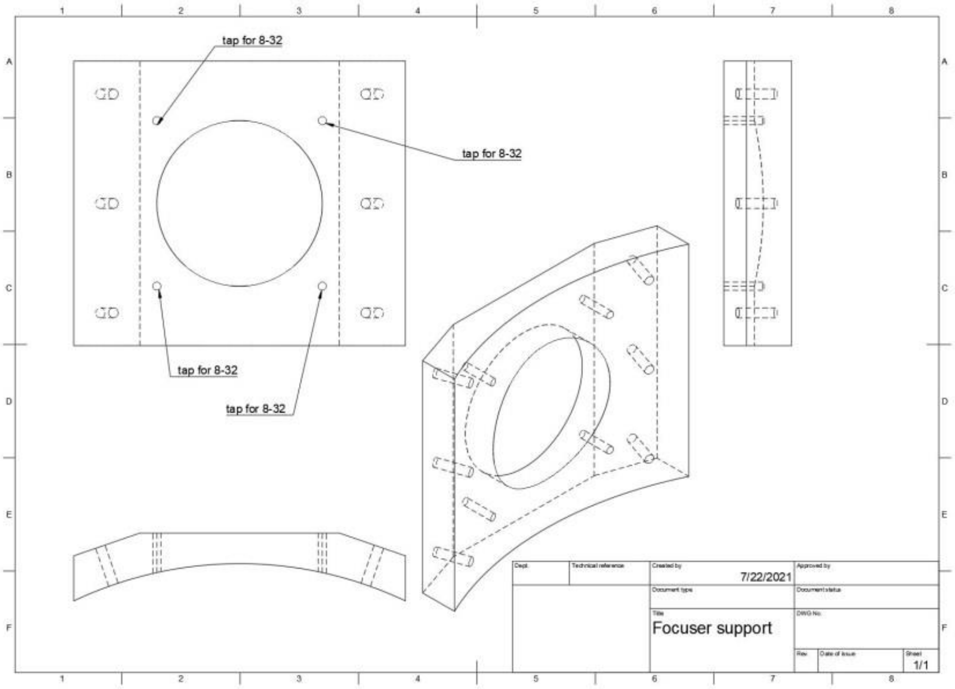


Figure 28: focuser base load spreading clamp. Provides focuser tilt and centering.

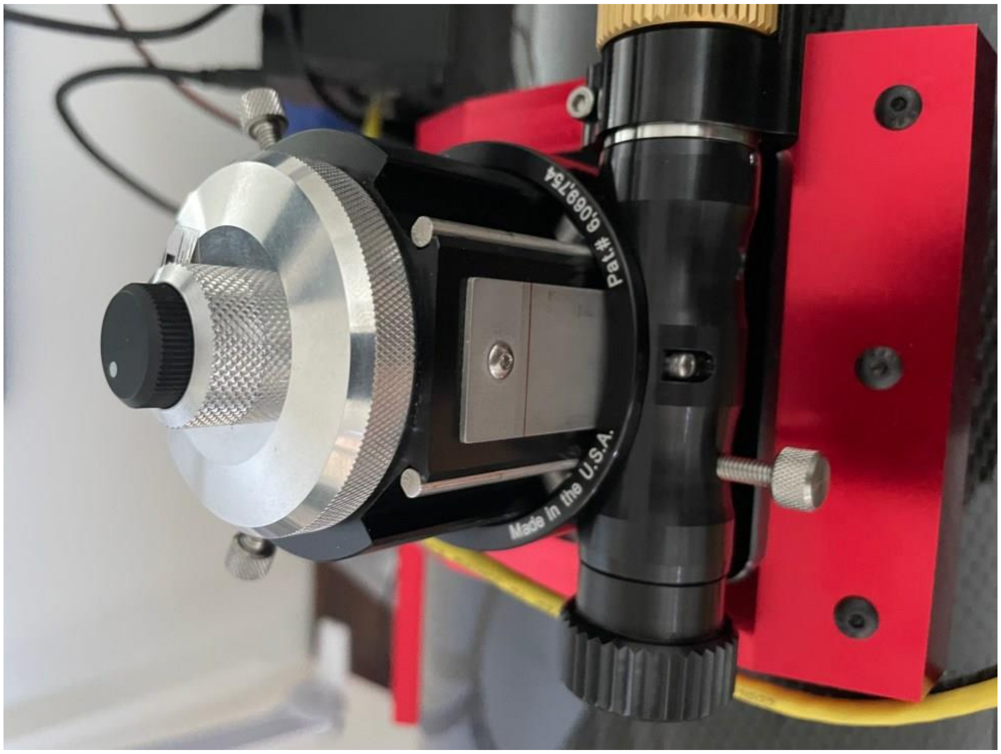


Figure 29: focuser on its base, with collimation laser inserted.

Corrector assembly

I use a Televue Paracorr, with its M54 adapter (Televue M54-1073, from the Paracorr 2.4″ to standard male 54), then an SXF54A female M54 adapter to my SFX Midi filter wheel. Corrector to camera assembly.

Figure 30: focuser, filter wheel, guide and imaging camera.

The back of the telescope is a ring of flat fiber carbon, with a screw top filter box 3D printed in black PetG. The CAD files are distributed as well. The back of the scope has a standard vacuum cleaner air filter, to allow flow of clean air and thermal equilibrium of the primary mirror.

Figure 31: back plate of Moana, with the air filter housing.

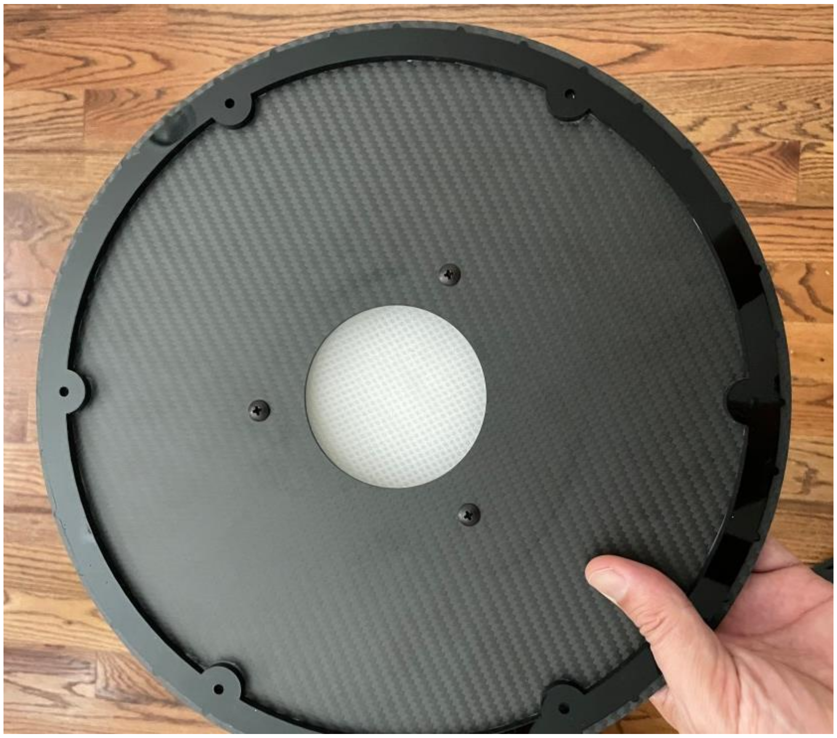


Figure 32: back plate of Moana, inside side, showing the coupling mechanism fitting the inside of the OTA.

The parts cad models and drawings can be downloaded from the erellaz.com website. The step files are what is used by the machinist to program the CNC. The parts with taped holes have additional drawing defining the taps.

MOANA: computer set up, Moana's brain

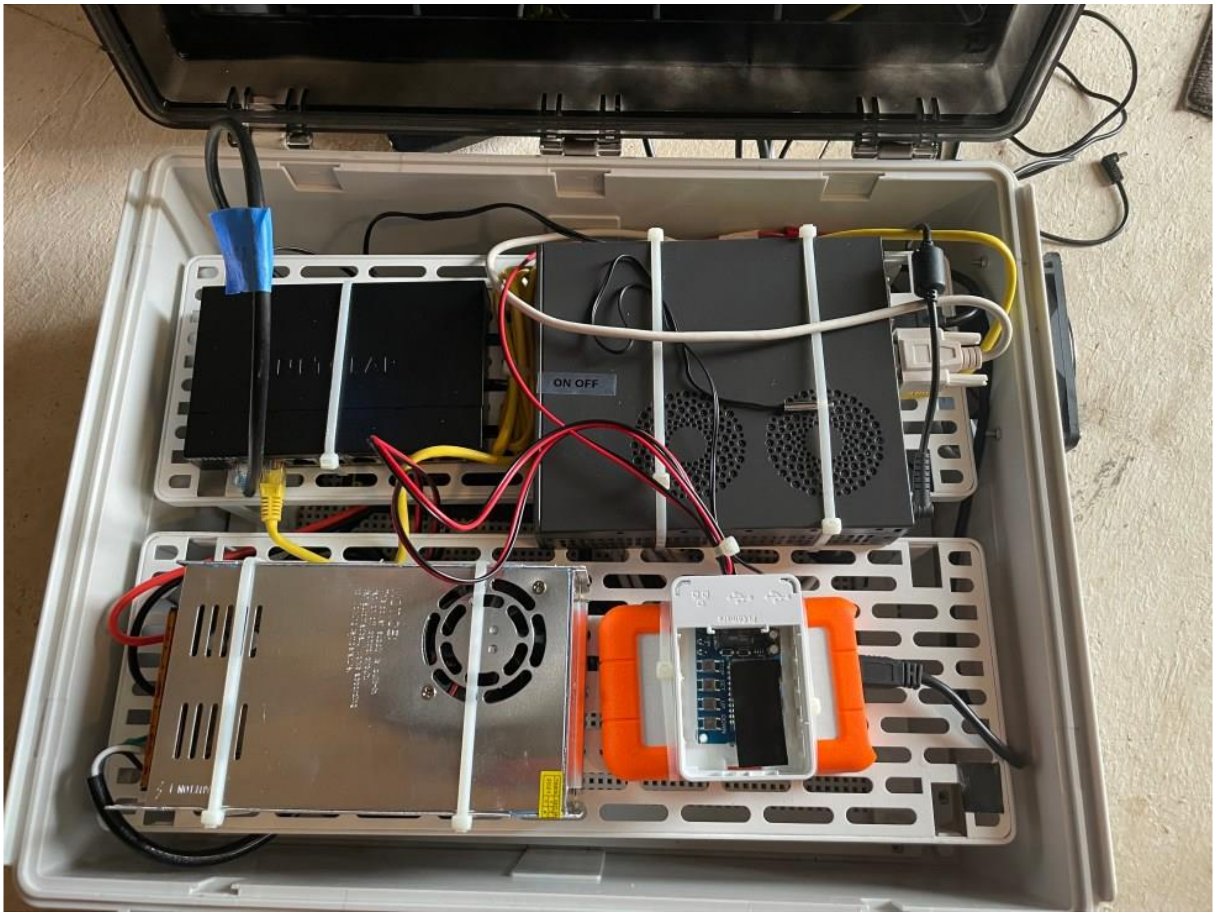


Figure 33: dust proof box with the electronic to ruun the system remote.

Here are my notes for Moana's computer setup, for remote astronomy.

The remote computer is a shuttle. It has 2 com ports, allowing robust connection to the mount (and over a longer distance than USB).

A first step was to get in the BIOS (F2 or Del) and disable the EUP (Energy Using Product) power management, then, still in the BIOS, to allow the device to boot once powered, so in essence the computer power on and shut down is controlled by the Switched PDU (WebPowerSwitch) rather than by the on/off button.

The second step was to prevent the computer from going to sleep, adjusting Windows setting > Power and sleep > Never sleep. Indeed if the computer goes to sleep, it cannot be waken up remotely, as one needs to physically hit a keyboard key.

Then I updated Windows.

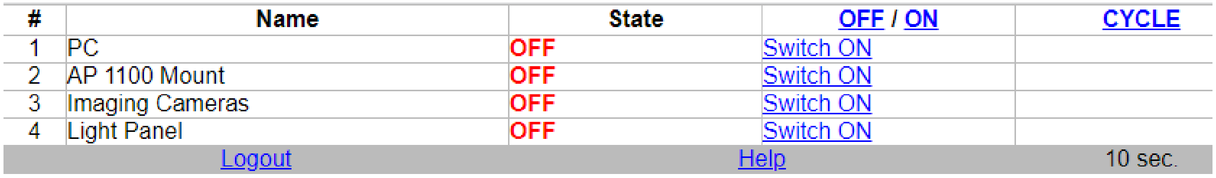
Then I installed 2 remote desktop applications, Chrome Desktop (Free) and RemotePC (Affordable using the ever going discount). Two apps are mandatory, so if one updates automatically or needs to be updated manually, the process can be seen through with the other app. With one app, one would likely loose connection at the first update.

Then I installed the gear drivers, Ascom platform, the Ascom drivers, the star catalogs for plate solving, Carte du ciel, Phd Pro, the collimation tools, Voyager, NINA and SGP, then Pixinsight for on premise processing and data volume reduction.

My Switched PDU controls 4 items:

- The computer.
- The mount 12v power supply.
- The "rest of the gear" 12v power supply: 2 cameras, 2 focusers, 1 filter wheel, the dew heaters. This does not allow too much granularity in terms of switching gear on and off. Most remote imagers have a Pegasus Power box to switch and control all electronic separately. I don't and so far it has work well to control both the main scope and the piggy back.
- The light panel.

It should be noted that the PDU is always on, and so is the Internet switch (which I do not really need, since the computer is the only thing on it -maybe one day the mount will be connected there too). The pier has 2 internet cables: one for the PDU, and one for the internet switch. Here is what the web interface of my Switched PDU looks like.



#	Name	State	OFF / ON	CYCLE
1	PC	OFF	Switch ON	
2	AP 1100 Mount	OFF	Switch ON	
3	Imaging Cameras	OFF	Switch ON	
4	Light Panel	OFF	Switch ON	
	Logout		Help	10 sec.

Figure 34: PDU landing page.

I can connect from anywhere in the world to the PDU, by just typing the static IP of the observatory followed by the port name my PDU is listening on.

The light panel is a cheap but large led drawing panel, slightly modified and controlled with Pulse Width Modulation from a Pegasus Pocked box. Light intensity change is achieved through PWM by wiring the panel like if it was a dew heater. This is cheap and effective.

Open datasets

All datasets acquired with Moana from DSO (Dark Sky remote Observatory), near Fort Davis, TX, USA.

Figure 35: remote observatory at dusk.

The data distributed here is under Creative Commons license, attribution: “Moana Project”. If you feel like it, feel free to tag BlackRig on Astrobin so I can see your results.

The potential of what can be achieved on Moana’s Data with is showcased on this collaborative Astrobin page. Some updates of the telescope are here.

The datasets are free, this page has no publicity, and I do not collect any user data. Feel free to support the project through the buy me a coffee link at the bottom right corner of this page. My goal use the community support for hosting this site & cover the data storage fee.

After 15 months of almost daily imaging, the MOANA project concluded in January 2024. I picked up the scope in Fort Davis, and I am in the process of doing some cleaning and upgrades. Then I would like to resume this open & free project on a long term basis with some partners.

Data:

Imaging:

This section covers long exposure datasets in color and narrow band to illustrate the beauty of the night sky.

- Horse Head nebula of Orion in SHORGB.
- Virgo Cluster around M86 in RGB.
- Flaming Star Nebula in SHO.

- Sculptor Galaxy in color.
- Pelican nebula in SHO.
- Tadpole nebula in SHO.
- M2, globular cluster in RGB.
- M45, the Pleiades in RGB.
- IC 443 in RGB and SHO.
- Baby Eagle Nebula in RGB.
- NGC 7000, North America in SHO.
- NGC 6946, the Firework Galaxy in RGB.
- NGC 6960 in Cygnus: the Western Veil in RGB and SHO.
- NGC 6914 in Cygnus in RGB and SHO.
- SH2 101 the Tulip nebula in Cygnus, RGB and SHO.
- The Wizard nebula, RGB.
- M8, the lagoon nebula. LRGB and SHO, 2 panels mosaic.
- The wing of the bat (NGC 6995) in Cygnus in RGB and SHO, for mosaic.
- Trifid Nebula in LRGB.
- Cluster Galore: M5, M13 and M92 in RGB.
- M27, the Dumbbell nebula in SHO. 16 hours.
- NGC6995, the bat nebula in SHO.
- M57 the ring nebula in RGB and SHO.
- M101 with Super Nova 2023ixf in RGB.
- NGC 4565, the Needle galaxy in Coma Berenices.
- Pickering's triangle, a detail of the veil nebula in Cygnus.
- Messier 104, the Sombrero Galaxy.
- Messier 97, the Owl nebula.
- Messier 94, beautiful spiral galaxy .
- Messier 105's group.
- M51, the Whirlpool Galaxy. Over 15 hours to go after the faint nebulosity, RGB and Ha.
- Details of the Rosette Nebula (going deep, 27 hours)
- M1 planetary nebula. 20 hours of color and narrow band high resolution data.
- Galaxy M77, RGB HA dataset.
- M33 Mosaic. RGB and Ha.
- Running Man of Orion. 10 hours of RGB data, bright nebula.
- Dark structure in the California Nebula, narrow band only, Ha and SII, with dark nebula.
- Thor's Helmet, RGB and Narrow Band.
- M16 dataset: RGB, and narrow band.
- Helix nebula dataset, about 8 hours of integration, RGB and narrow band.
- Crescent Nebula, in RGB and narrow band. About 20 hours of integration.
- Cocoon Nebula, RGB and narrow band, in Cygnus.
- M78 in Orion, RGB dataset.
- M15 and Pease 1 in Pegasus, RGB dataset.
- Horse head nebula in Orion, Ha only.
- M74, a face on spiral galaxy, in RGB and Ha.Back to datasetsBack to Moana

Photometry:

Datasets suitable for training, education and research in astrometry and photometry.

- Super Nova 2022wpy: dataset covering over two months of regular follow up observations for photometry.
- Super Nova 2022zut: an RGB dataset and photometry follow up.
- Wasp 36 b exoplanet transit. 98 frames of 1mn, a clean exoplanet transit dataset.
- Wasp-10 b exoplanet transit. Photometry set, 157 frames of 1mn, a clean exoplanet transit dataset.
- Wasp 107b exoplanet transit. Light curve only, as the data is a bit noisy.
- Main belt asteroid 349 Dembowska at opposition. Datasets for light curve and rotation period determination.
- Minor planet Haumea at opposition. Dataset for light curve of this very fast rotator. At magnitude 17.3, one of my dimmest object for light curve so far.

Comets:

- Comet 29P, imaging and photometry sets.
- Comet 2022 E3 ZTF, multiple datasets.
- Comet Nishimura.

Sun:

Eclipse datasets.Back to datasetsBack to Moana

Planets:

Various tests and endeavors not to be taken too seriously. Like doing planetary imaging with a scope optimized for deep sky, failures with interesting lessons, etc…

- Pluto (is a planet!). Single 2mn frame.
- Planetary dataset, moon and Jupiter in RGB.

Other:

- Difficulties, defects and disappointment.

About the data:

The files have been curated (PixInsight SubFrame Selector working in conjunction with this script, and visual QC) then stripped of private information (like observatory exact coordinates) with this script. The frames are otherwise raw from acquisition.

The image parameters are as follow:
Resolution: 0.591 arcsec/px
Field of view: 45′ x 35′
Focal distance: 1325 mm
Pixel size: 3.80 um
Aperture: 254mm -10 inches
F number: f/5.3
Guiding: Off Axis Guider with QHY 5L2M

The camera is currently an ASI 1600MM, soon to be replaced by a QHY268M. The mount is an AP1100 GTO.

For imagery I use mostly gain 90 and 5mn exposure for Narrow Band, between 1 and 5mn exposure for RBG. 5mn seems to be a good compromise between minimizing the amount of disk used each night, collecting enough light, but also be short enough to avoid too many satellite trails, cloud interference or a guiding mishap ruining the frame.

For photometry, given the wide variety of target brightness, anything goes (gain, exposure time and filter) to achieve the correct exposure.

In all cases gain and exposure shall be verified from the fits header, to ensure the use of the correct calibration masters.

The filters are Baader CMOS-Optimized RGB-R Bandpass Filter and Baader 6.5nm Narrowband Ha, OIII and SII. All 36mm round, unmounted

Remote operation

Moana at DSO.

Installation:

Road trip:

I installed the system in my back yard, on a tripod, and got it running for a last test. Once I was satisfied the system was complete and running, I packed everything to boxes that I sealed with tape. The OTA went into plastic bags (big “contractor bags”) then into a thick sleeping bag to be protected during transportation. The sleeping bag is much lighter and easier to manage than making a large and heavy plywood box for transport – I have one of those and it is a giant hassle to transport and store. I also packed my collimation tools and a very complete toolbox, plus some clothes.

For the trip I remove the primary mirror from the OTA and transported it, still in its cell, in a protected box, laying horizontally.

The day before the trip I packed everything in the back of my car, ready to go. On the big day I left just before rush hour, around 6am. I arrived at DSO at about 4pm, after a long but uneventful trip. The last mile of the dirt road had been destroyed by heavy rains, and it was pretty bad, even to my loose standards.

Mount and scope setup:

Although I arrived late, I decided to install the scope and engaged in a race against the clock to be done before night. The install was much like installing on my tripod in the back yard, except I put oil on all the screw taps, so at the end of the lease when I remove the gear, the screws won’t get solid rusted in their sockets. I had the mount set up, the scope on the mount, and the balancing done within one hour and a half of intense work. Note: if you mess with oil and optics on the same day, have some latex gloves.

Collimation:

After the trip on the bumpy dirt road and the reinstallation of the primary mirror, I had to go through a full collimation. I usually proceed with my Howie Glatter laser. It is fairly straight forward. Then P., who was installing a dual FSQ106 on the next pier, passed me his Takahashi collimation tool, to check my primary centering. The results from the laser and the collimation tool were widely different, which left me completely baffled. The 2 tools were perfectly self consistent, gave perfectly reproducible results, but those result were not identical, and by quite a big margin.

Polar alignment:

At that point the sun had set and it was getting dark. I then proceeded with polar alignment. I had expected to use the Rapas (AP's Right Angle Polar Alignment Scope), which usually gets me to a few arc minutes of alignment in less than 1mn of work. However Polaris is not visible from my Pier (obscured by the rolling roof). That was a giant bummer. From there there was many other options (NINA's 3 star align is one), but the one I was most familiar with at that point was to use drift align. So I used Phd 2 drift align routine and aligned with my wide angle guide scope. Although I was widely off at startup, this did not take too much time, and I was decently aligned in about 35 minutes. At that point the clouds rolled in and that was it for the night.

Computer set up:

The following day, I came back and proceeded with installing the remote computer (all operations from the previous night were done from my laptop), the Switched PDU, flat panel and took some flats consistent with the new collimation. I was a little afraid of the configuration of the Switched PDU (because all remote operations depends on it) but it turned out to be super easy and uneventful -maybe because P. did all the work for me on that one.

After that, the weather turned to rain and it was clear I would not be able to refine my collimation nor my alignment that night. So I went back to fort Davis and tested my remote set up from my hotel room, confirming that everything was OK.

I finally drove back home the following day, without the possibility to fully check collimation and alignment on stars.

Conclusions:

Once back home, I ran a very complete drift align remotely, and determined alignment was 1.6 arc minutes off. I also built a pointing model, to confirm the value, and know in which direction I needed to correct. Note: I should have taken notes during the initial drift align procedure on site to record, for each side of the pier, the correspondence between a positive or negative drift and an East or West correction -but I did not, and use the pointing model estimate instead. On the AP1100, the azimuth knob has 18 divisions, and each division is 2 arcminutes. So I called P. who was still at DSO and asked him to unlock my azimuth axis and turn the azimuth knob a little less than 1 division. I knew the direction (East or West) though the pointing model error result, and next time I should get it from my notes. He did the correction and I was basically aligned in Azimuth. Regarding the error in elevation, the pointing model tells me I have a positive error on one side of the pier and a negative error on the other side. I will at some point fiddle with it, so the errors are equal in magnitude and opposite in sign. But for now I have let go, and the pointing model takes care of it.

Conclusions

Here I reflect on the learning after over 1000 hours of observing and over 6 months at DSO operating remotely.

- The **computer system,** remote switch and all the electronic has worked flawlessly, 100% availability. Remote update of Windows, software… have also been painless. I have used Google Remote Desktop exclusively, without any worry.
- I have had one **mount loss**, and recovered manually in about 30mn. The fact the mount has no encoder (absolute or otherwise) is a total non issue, and for future remote setup, I do not think I will need absolute encoders unless I get into asteroid/satellite tracking, which would, by the way, also necessitate a fork mount (to do away with the meridian flip). To the specific of the mount loss: it is due to a bug in APCC Pro. APCC Pro should just be extra features on APCC. However those are 2 different software than can (but should never) coexist on the same computer. I had been using Pro for a while, but one evening I had not started the mount software before hand, so when I launched NINA it auto started APCC (rather than APCC Pro). As those 2 software do not share the mount position file, APCC used an old and incorrect mount position file, not consistent with physical reality. To regain internal consistency, APCC then proceeded to corrupt every possible setting: time, observatory position, scope position, etc.. without any warning. Even the side of the pier was incorrect. To recover, I moved the scope using manual controls, looking at it on surveillance camera. This is dangerous thing to do as this can lead to a pier collision and possibly twisting of the cables going through the mount. However I managed to move the scope to the sky, without collision and without inducing twists (I checked months later). Then once looking at the sky again I blind solved and resync the mount. The irony is that then APCC Pro's safety checks (which had left me down in the first place during the crash) kicked in and prevented the recovery (error between solved and expected position too big). The quick solution is to iteratively add a series of corrections, all under the safety threshold, then do one last plate solve. A major problem with this procedure is that the mount can be told its true pointing position (Dec, RA), but not the physical side of the pier it is on (and each pointing direction has 2 sides of pier possible). The solution to this second layer of problem is to move to Park 3 (ie: looking at Polaris in the Northern Hemisphere) and cycle the mount, restarting from Park 3. Since I have uninstalled APCC and things have been going well – no more lost mounts.
- **Mount**: tracks below 1 arc sec most of the time. The added counterweight to reduce the inertial moment helped a lot. Read this if you need the full explanation.
- **Data sharing**: I use syncthing, a very light and efficient system. This works flawlessly.

- **Collimation**: for the longest time I could not decide if I was more a laser “Glatter” or Catseyes kind of guy. I am now definitely on the Catseyes Autocollimator side, and I follow instruction on the highly recommended Vic Menard “New Perspectives on Newtonian Collimation“. My rational for this is: if anything anywhere is wrong, you do not get an autocollimator read – so at least you know. Correlatively if you get a good autocollimator read, you are aligned. By day and by night.
- **Wind:** big Newtonian tubes are very sensitive to high wind pushing on the tube and messing with guiding. It is just a fact of life and maybe I did not fully measure this drawback when getting into the project.
- **Camera**: My current 1600MM is just not doing justice to the scope and the observatory conditions. I am moving to a QHY 168M.
- **Collimation stability.** This has been the main problem I experienced on my setting. I indulged some musing on the topic on CN forum , and here is the gist of it: *I have a Newtonian Astrograph using a thin (.78 inch) Zambuto 10" fused quartz parabolic f/4.5 mirror. The mirror is supported by an Aurora Precision EQ cell. The astrograph is located at DSO, operating remotely every clear night, all night. I have over 1000 hours of observing on that scope, in a wild variety of conditions. The imaging results from that scope can be seen here, while I discuss the optical design of the astrograph here and the mechanical design here. Further I distribute all the observation raw data open source here. Because everything is available open source for that scope, from CAD design files to the raw fits images taken every night, what I say can be verified with actual available data, and if I err, people can call me on that (and some certainly have). For completeness: I collimate with Catseyes autocollimator using the Vic Menard “New Perspective” book. So to the topic at hand: currently my mirror is not glued to the cell. If I let the mirror pretty loose in the cell, I experience movements of the mirror (with an effect akin to a mirror flop in a SCT) when I track low on the horizon or when I park the scope head down. If I keep the mirror tight in the cell, I experience astigmatism -lots of it. If temperature was constant, there might be a sweet spot where the cell is tight enough to maintain collimation but without excess that would warp the optical surface. However, temperature at the observatory ranges from 0 F in the dead of winter to 100 F in the Texas desert heat, so this sweet spot does not exist. So for me thin mirror + EQ Aluminum cell + not gluing is not working. To be fair, if you do not park the telescope inverted, do not track low on the horizon and have access to the scope to tweak collimation every evening before your observation run, it probably works just fine. Another problem with the cell & not gluing is the need for clips to the front of the mirror which degrades the image, as documented here. Maybe not an issue for visual, but definitely a problem for imaging. A solution may be to do away with* ***thin*** *mirrors, but then I would suggest to go all the way down that road with “conical” mirrors like Royce used to make for Newtonians. After all this is how Planewave does it for this size of mirror (photo here) on their astrographs and those are very stable in all positions. Now let’s say you already own one of those thin mirrors and want to support it properly. This is a very difficult problem I am afraid. Currently I am building a new carbon fiber cell, and will silicon the mirror to it. The mirror will also be siliconed to the edge support, and there will be no front clip. I plan to post the CAD design when done and tested. The rational for Carbon fiber comes from the CTE comparison (Coefficient of Thermal Expansion): Carbon Fiber (30 × 10−7/K) Fused quartz (5.5 × 10−7/K) Aluminum (240 × 10−7/K). For CTE calculation of Carbon Fiber and anisotropy discussion, see here. I am also exploring the possibility to glue a conical piece of glass to the back of the mirror, so it could be supported like a conical mirror.*

Moana for Pilots

I am more and more moving to the NINA **scheduler,** where no interaction may be needed for days. However, running interactive with the NINA **sequencer** is still needed to test new parameters, evaluate some target, check the gear & behavior of routines, use the Exopolanet & Neo containers, track satellites, work in marginal weather or just enjoy the magic. So this page shows the interactive routine with the telescope, for use with the **NINA sequencer**.

If you are more interested by automatic routine with the NINA **scheduler**, check this.

- First check the weather for Fort Davis.
- If the weather is promising, log in to the Switched PDU (Power Distribution Unit) using the observatory static IP and the port the S-PDU is on.
- On the SPDU web page, switch on the computer, 12v bus for the mount and 12v bus for the camera, filter wheel, focuser and guider.
- Once the remote computer is on, remote log in to it (usually with Chrome Remote Desktop), and start the following programs, in that order: APCC (the program that manages the AP mount, and in particular enforces meridian and horizon limit, to avoid a pier crash), Nina, and a browser window to access, on the observatory LAN the following items: the observatory surveillance cameras, observatory weather station, as well as Nina's web session plugin, to monitor the session.
- Check the computer's clock. It should have correct date and time (or disaster will ensue).
- Check on surveillance cameras the scope looks good, and is parked in the expected position, and nobody has moved stuff in the vicinity of the scope (like a chair). Check the roof is open and look at the sky on the surveillance camera, looking for clouds.
- Connect APCC to the mount, but leave the mount parked. (Just press the green "connect" button). Also initialize the mount when that menu pops up.
- In Nina, refresh the imaging pan, load the sequence to execute in the advanced sequencer. Connect all equipment. Check the equipment does connect. The Starlite Express filter wheel in particular has a buggy ASCOM driver, and it sometimes need to more than 1 try. Worst case reset the 12v bus and reconnect all. This automatically starts PHD2. Do not start PHD2 manually, let Nina launch it and connect to the PHD2 server.
- Hit run in the Nina advanced sequencer, and go on with life. In time, automatically, camera will cool, mount unpark, slew to target, plate solve, sync the mount to the sky if necessary, autofocus in L filter, switch to the correct imaging filter, apply filter offset and start imaging.
- Later, while the session is running, if still awake, come back to the computer and control the following: CPU temperature of the computer, camera sensor temperature, electronic box temperature. Check autofocus curve for the last few autofocus, check image overall quality, check the corners. Check guiding curves and RMS guiding error. Check scope position, in APCC and on camera for consistency.

In the morning, once the sequence is finished: go back to the surveillance cameras and check the mount is in the expected parked position. Check in APCC the mount is also in parked state, and the position is consistent with reality, as seen on camera. "Disconnect all" in Nina. Disconnect APCC from the mount. Log in to the SPDU and switch off the 12v bus for mount and imaging train. Check the result from the night in the web browser (Nina Web plugin).

Save the session in Nina, close Nina. Optionally start Syncthing to download the data. Shut down the computer from Windows, then shut down the computer's power supply from the SPDU. If at shut down Windows is pushing an update, use the "update and restart", and log back in, then shut down again. Only switch off the SPDU after certainty of a positive complete software shutdown.

Moana without a pilot

In this section I detail how I run Moana fully automated, without intervention for multiple nights in a row, with NINA.

Prerequisite

The following items, although not mandatory make things easy and safer:

- **Safety monitor**: at the observatory, the *roof scheduler* (ie: the device responsible for opening and closing the roof) writes the roof status (open or closed) in a text file accessible on the network. Every computer in the observatory has read access to this shared file. Then, the ASCOM Generic File Safety Monitor can be installed and configured to read roof status from that text file. From there, NINA connects to the safety monitor, and knows the roof status. It is then easy to program triggers, for example stop imaging and park, if the roof suddenly closes. Here is my config file for the safety monitor.
- Web Power Switch ASCOM driver: most people doing remote imaging use a **PDU** from "Digital Loggers, Inc.". The huge advantage of this particular device versus other is it has an ASCOM driver. The PDU can be used to remotely switch on/off 110v AC outlets. I have been using 3 ways to interact with the PDU. The first is via the aforementioned ASCOM driver, so once connect to the driver in NINA, it is easy to switch on the various devices at start up (mount, camera train, etc…) and switch them off at the end of the session, via NINA Switches. The 2nd way to interact with the device is via http, simply in a web browser. The observatory has a static IP, and the router of the observatory is configured so that accessing this IP on a particular port forwards to my PDU. With this, the PDU is accessible from anywhere in the world, at any time, even from a cell phone. I typically use this for manual start up and manual shut down. In case a static IP is not possible, one could configure a service like DynDns. The 3rd way to interact with the PDU is via Python script. At the end of each session, I run a script, which, amongst many things, checks the status of the various PDU outlets and performs hard shut down if needed (this is the last layer of safety if everything else has failed). A few notes: rather than using the PDU over ASCOM, many people use a Pegasus Power Box. The PDU switches 110v AC, while the PPB switches 12v DC. I believe ASCOM allows at this point only 1 Switch at a time. So to use both, I interact with the Pegasus box via ASCOM, and with the PDU via "run script", and run a Python script for each specific action. Here are the switch on and switch off scripts. This work around allows to use 2 different set of Switches in NINA, when only one set is possible with ASCOM.
- **Weather service**: I have a weather service configured in ASCOM as well. At the very least it updates the images' fit headers with weather info. In some case it could be used to trigger a particular behavior. In practice I rely on the roof scheduler for that, the roof scheduler relying in turn on the local weather station.

NINA sequence

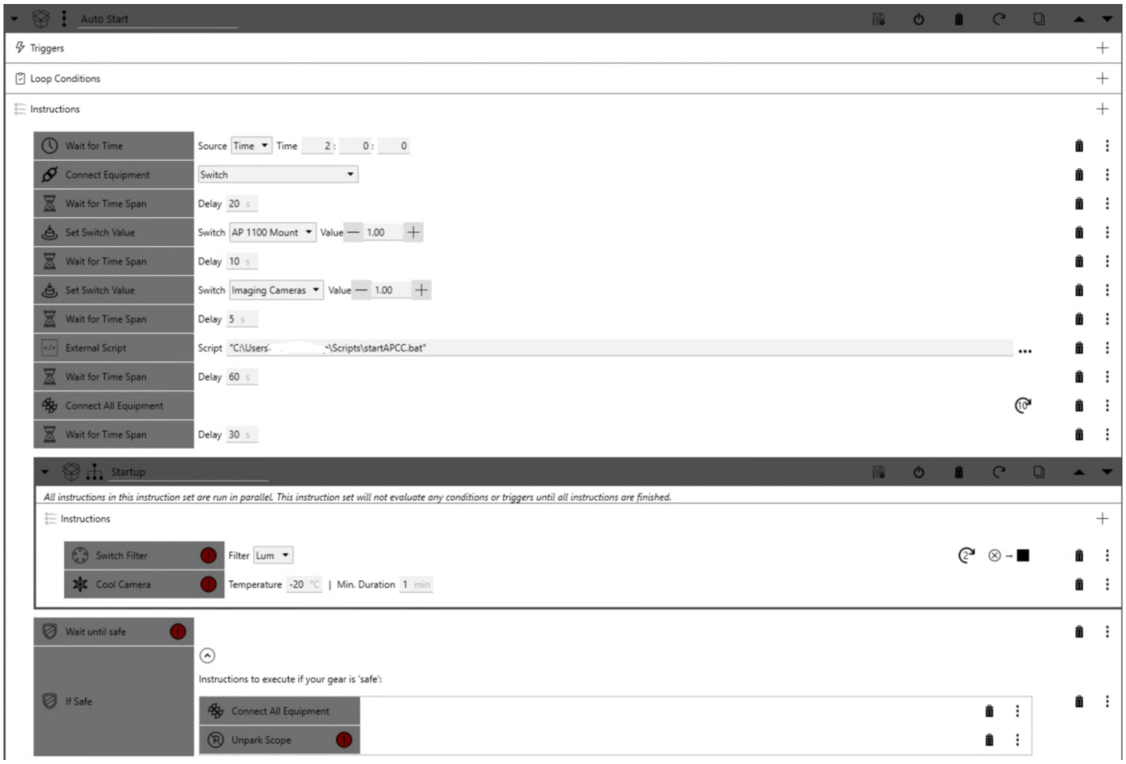
The NINA sequence (availble to download from the link below) is structured with an infinite loop, one iteration every day.SequenceAutoDownload

In the loop:

- a startup sequence,
- some imaging (either with the Scheduler or the Sequencer),
- a shut down sequence, and
- a “handle transition to next day” sequence.

Let’s review each part:

- The **start up** is pretty straight forward: connect to the switch, wait 20s, and power up the mount, then the camera. Then start the mount software (APCC), here via a script (as I do not care paying a subscription just to have the NINA “start APCC” module). Then connect all equipment (imaging camera, guider, filter wheel, mount and focuser) in ASCOM. Then set the filter to Luminance, for the first plate solve and focusing of the night and cool the camera. After that, if conditions are safe (roof open), move to imaging.



Auto Start

Wait for Time: Source Time, Time 2 : 0 : 0
Connect Equipment: Switch
Wait for Time Span: Delay 20 s
Set Switch Value: Switch AP 1100 Mount, Value 1.00
Wait for Time Span: Delay 10 s
Set Switch Value: Switch Imaging Cameras, Value 1.00
Wait for Time Span: Delay 5 s
External Script: Script "C:\Users[redacted]\Scripts\startAPCC.bat"
Wait for Time Span: Delay 60 s
Connect All Equipment
Wait for Time Span: Delay 30 s

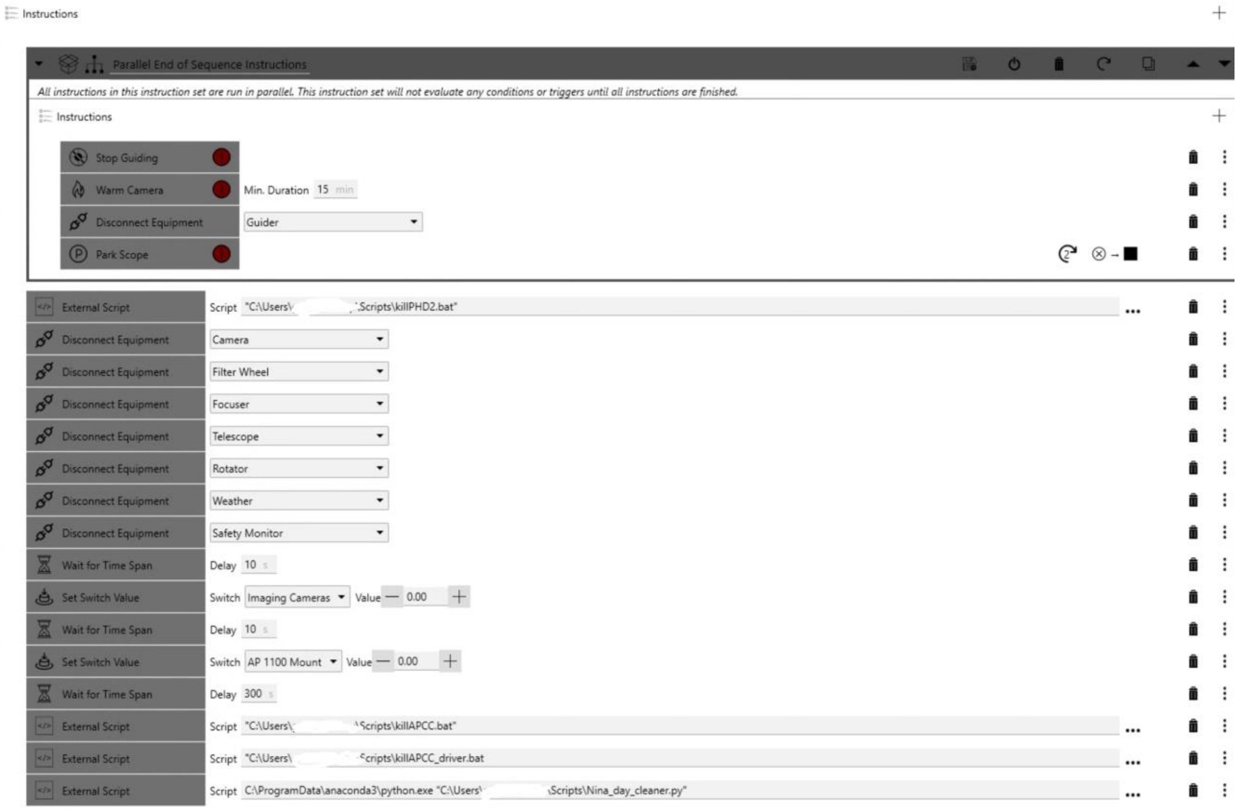
Startup

All instructions in this instruction set are run in parallel. This instruction set will not evaluate any conditions or triggers until all instructions are finished.

Switch Filter: Filter Lum
Cool Camera: Temperature -20 °C | Min. Duration 1 min

Wait until safe
If Safe: Instructions to execute if your gear is 'safe':
Connect All Equipment
Unpark Scope

- The **shut down** is pretty simple as well. In parallel stop guiding, warm the camera, disconnect the guider and park the scope. Then shut down the guide software (I just kill PHD2, as it seems there is no graceful exit). Then we need to disconnect the equipment. A “disconnect all” would not work, as it would disconnect the PDU as well, making it impossible to shut down the power to the equipment. So unfortunately each ASCOM driver must be shut down individually. Once the ASCOM drivers have been disconnected, one can power off each individual component and kill the mount software via script. The last script, written in Python, automatically detects and remove bad frames (based on the optional NINA log), in particular eliminating frames with bad guiding, no stars or poor seeing/focus solution (large FWHM). Then that scripts performs clean up, back up, move files and start synchronization with the remote server. Last it performs watch dog functions and forcibly kills or hard shut down any equipment still up at that point.



Instructions

Parallel End of Sequence Instructions

All instructions in this instruction set are run in parallel. This instruction set will not evaluate any conditions or triggers until all instructions are finished.

Instructions

Stop Guiding	
Warm Camera	Min. Duration 15 min
Disconnect Equipment	Guider
Park Scope	

External Script	Script "C:\Users\[redacted]\Scripts\killPHD2.bat"
Disconnect Equipment	Camera
Disconnect Equipment	Filter Wheel
Disconnect Equipment	Focuser
Disconnect Equipment	Telescope
Disconnect Equipment	Rotator
Disconnect Equipment	Weather
Disconnect Equipment	Safety Monitor
Wait for Time Span	Delay 10 s
Set Switch Value	Switch Imaging Cameras Value 0.00
Wait for Time Span	Delay 10 s
Set Switch Value	Switch AP 1100 Mount Value 0.00
Wait for Time Span	Delay 300 s
External Script	Script "C:\Users\[redacted]\Scripts\killAPCC.bat"
External Script	Script "C:\Users\[redacted]Scripts\killAPCC_driver.bat
External Script	Script C:\ProgramData\anaconda3\python.exe "C:\Users\[redacted]\Scripts\Nina_day_cleaner.py"

- The next item is to wait until NINA **transitions to the next day**. The definition of "day" has changed in NINA a few times, so you would have to see what works with your version.

Remote operation

Moana at DSO.

Installation:

Road trip:

I installed the system in my back yard, on a tripod, and got it running for a last test. Once I was satisfied the system was complete and running, I packed everything to boxes that I sealed with tape. The OTA went into plastic bags (big "contractor bags") then into a thick sleeping bag to be protected during transportation. The sleeping bag is much lighter and easier to manage than making a large and heavy plywood box for transport – I have one of those and it is a giant hassle to transport and store. I also packed my collimation tools and a very complete toolbox, plus some clothes.

For the trip I remove the primary mirror from the OTA and transported it, still in its cell, in a protected box, laying horizontally.

The day before the trip I packed everything in the back of my car, ready to go. On the big day I left just before rush hour, around 6am. I arrived at DSO at about 4pm, after a long but uneventful trip. The last mile of the dirt road had been destroyed by heavy rains, and it was pretty bad, even to my loose standards.

Mount and scope setup:

Although I arrived late, I decided to install the scope and engaged in a race against the clock to be done before night. The install was much like installing on my tripod in the back yard, except I put oil on all the screw taps, so at the end of the lease when I remove the gear, the screws won't get solid rusted in their sockets. I had the mount set up, the scope on the mount, and the balancing done within one hour and a half of intense work. Note: if you mess with oil and optics on the same day, have some latex gloves.

Collimation:

After the trip on the bumpy dirt road and the reinstallation of the primary mirror, I had to go through a full collimation. I usually proceed with my Howie Glatter laser. It is fairly straight forward. Then P., who was installing a dual FSQ106 on the next pier, passed me his Takahashi collimation tool, to check my primary centering. The results from the laser and the collimation tool were widely different, which left me completely baffled. The 2 tools were perfectly self consistent, gave perfectly reproducible results, but those result were not identical, and by quite a big margin.

Polar alignment:

At that point the sun had set and it was getting dark. I then proceeded with polar alignment. I had expected to use the Rapas (AP's Right Angle Polar Alignment Scope), which usually gets me to a few arc minutes of alignment in less than 1mn of work. However Polaris is not visible from my Pier (obscured by the rolling roof). That was a giant bummer. From there there was many other options (NINA's 3 star align is one), but the one I was most familiar with at that point was to use drift align. So I used Phd 2 drift align routine and aligned with my wide angle guide scope. Although I was widely off at startup, this did not take too much time, and I was decently aligned in about 35 minutes. At that point the clouds rolled in and that was it for the night.

Computer set up:

The following day, I came back and proceeded with installing the remote computer (all operations from the previous night were done from my laptop), the Switched PDU, flat panel and took some flats consistent with the new collimation. I was a little afraid of the configuration of the Switched PDU (because all remote operations depends on it) but it turned out to be super easy and uneventful -maybe because P. did all the work for me on that one.

After that, the weather turned to rain and it was clear I would not be able to refine my collimation nor my alignment that night. So I went back to fort Davis and tested my remote set up from my hotel room, confirming that everything was OK.

I finally drove back home the following day, without the possibility to fully check collimation and alignment on stars.

Conclusions:

Once back home, I ran a very complete drift align remotely, and determined alignment was 1.6 arc minutes off. I also built a pointing model, to confirm the value, and know in which direction I needed to correct. Note: I should have taken notes during the initial drift align procedure on site to record, for each side of the pier, the correspondence between a positive or negative drift and an East or West correction -but I did not, and use the pointing model estimate instead. On the AP1100, the azimuth knob has 18 divisions, and each division is 2 arcminutes. So I called P. who was still at DSO and asked him to unlock my azimuth axis and turn the azimuth knob a little less than 1 division. I knew the direction (East or West) though the pointing model error result, and next time I should get it from my notes. He did the correction and I was basically aligned in Azimuth. Regarding the error in elevation, the pointing model tells me I have a positive error on one side of the pier and a negative error on the other side. I will at some point fiddle with it, so the errors are equal in magnitude and opposite in sign. But for now I have let go, and the pointing model takes care of it.

Events log

2023-09-20: Flake event

See the detail of the Flake event here.

2023-07-14: Chasing tilt – wide field scope

I have been working on the wide field refractor set to replace Moana during her overhaul. However there is some tilt in the new wide field system. I believe the tilt is mostly between the rotator and the scope, with possible low residual tilt after the rotator (sensor tilt) and low to very low miss collimation of the triplet. To be definitive on the triplet collimation I need to use my Takahashi collimating scope, but the adapter for it (Tak S coupling to 2″) has been out of stack for 2 years and there is no sign it will be produced any time soon (I called Tak America), so I eventually bought the Rap adapter instead, which is much cheaper and can connect to M48 thread. Once I get that, I shall answer the triplet collimation question with a high degree of certainty (hopefully).

On the focuser tilt, I have been using stars and Nina's aberration inspector, from my back yard in the big city, in the midst of light pollution. That requires stars (obviously), so good weather, and staying up pretty late as it is summer and I do not get darkness before past 10pm. Of course, before I work the tilt I first need to align and all that good stuff, delaying the actual useful work even more. So progress has been very slow, as I have other things to do at night, like running Moana or sleeping. If somebody knows a better way to chase focuser tilt, feel free to pm me on Astrobin.

Moana has been performing OK, the electronic box is running warm in the desert heat, so I am cooling it using the exhaust fan, which kicks a lot of dust in the observatory (the floor there is super dusty, as there has been many visitors going in and out, and seemingly all ignoring the door mat). So Moana's optics are getting dirty, and I should be doing new flats to fix that, but I am slightly worried that if I remotely put the scope head down looking at the flat panel, I may experience movement of the primary mirror again (hanging by the clips in its cell) and mess up the collimation. So, at this point I just keep going and monitor the situation. This is for sure an interesting chain of un-intended consequences.

Last, weather has been pretty cloudy at DSO and the summer nights are shorts. So less frames per night, and a lot of the acquired frames did not pass the bar due to atmospheric nebulosity. An then of course we just had full moon.

None the less, I managed to add RGB to M27 and NGC 6995 and shoot a few star clusters. I will update that soon.

2023-06-16: preparing a trip to DSO

I plan to get to the observatory during the next full moon, unmount MOANA and bring her back for a complete cleaning and overall. In particular: new vanes to reduce diffraction spikes, new carbon fiber primary cell to increase mirror stability without pinching the mirror, so I can get rid of that pesky astigmatism at last, new main camera to enter the modern era (overdue), and new guide camera. Possibly a remote dust cap/light panel and a Pegasus box V3. I want to take my time to test the upgraded setup, and the new mirror cell is still just a concept on the drawing board (but I have been thinking about it for 2 years now). So Moana will be out for some time, at least the whole summer, maybe more.

Meanwhile I will have a wide field refractor on the mount, so I do not miss a beat. Of course I still plan to continue distributing the data, till I run out of storage here, and hopefully beyond.

2023-05-24: A photogenic supernova in a nearby galaxy

This year (2023) has been particularly good for transient events: a great comet (E3 ZTF) reaching magnitude 8, and now a bright (magnitude 10) supernova, 2023ixf, in a nearby photogenic galaxy, M101, well positioned for Northern Hemisphere observing. I had waited for that for almost 10 years! As soon as the weather cleared I updated my sequences to image M101. The SN is so bright it even has diffraction spikes! See a raw frame below, which will be part of an upcoming RGB imaging dataset. The SN is outlined in red.M101 and SN2023ixf, on a raw blue frame.

2023-04-25: Camera cooling properly after all

Well, last night the camera did cool without a hitch. Not sure what was going on. I will keep an eye on it. On the imaging side, I finished M94 and started acquiring luminance on M104, to see if it improves my usual RGB workflow.

2023-04-23: Camera not cooling properly

I have a feeling the fan on the main camera quit working, as cooling is very slow and the sensor does not reach -20C as it should. The good news is I finally got the QHY 268M camera, intended to replace the current camera. I have to see how I'll go about this one. I may bring Moana back home and put a wide field setting on the pier, although it is a little earlier than I anticipated to do the switch: the milky way does not rise before 3am.

2023-04-19: Accumulating data

I have slowed down the rate of data posting. First because there was quiet a bit of bad weather in the last 2 months. Second because spring being “galaxy season” I am doing less narrow band and more RGB, becoming less tolerant to moon glow. Third because I want to focus on quality: deeper datasets (ideally 30 hours per target), image taken only very close to transit (so no more than a few hours of imaging per object per night), and discarding more of the questionable frames (gradients, soft focus/bad seeing, high clouds, tracking perturbed by wind). And Fourth the nights are just getting shorter.

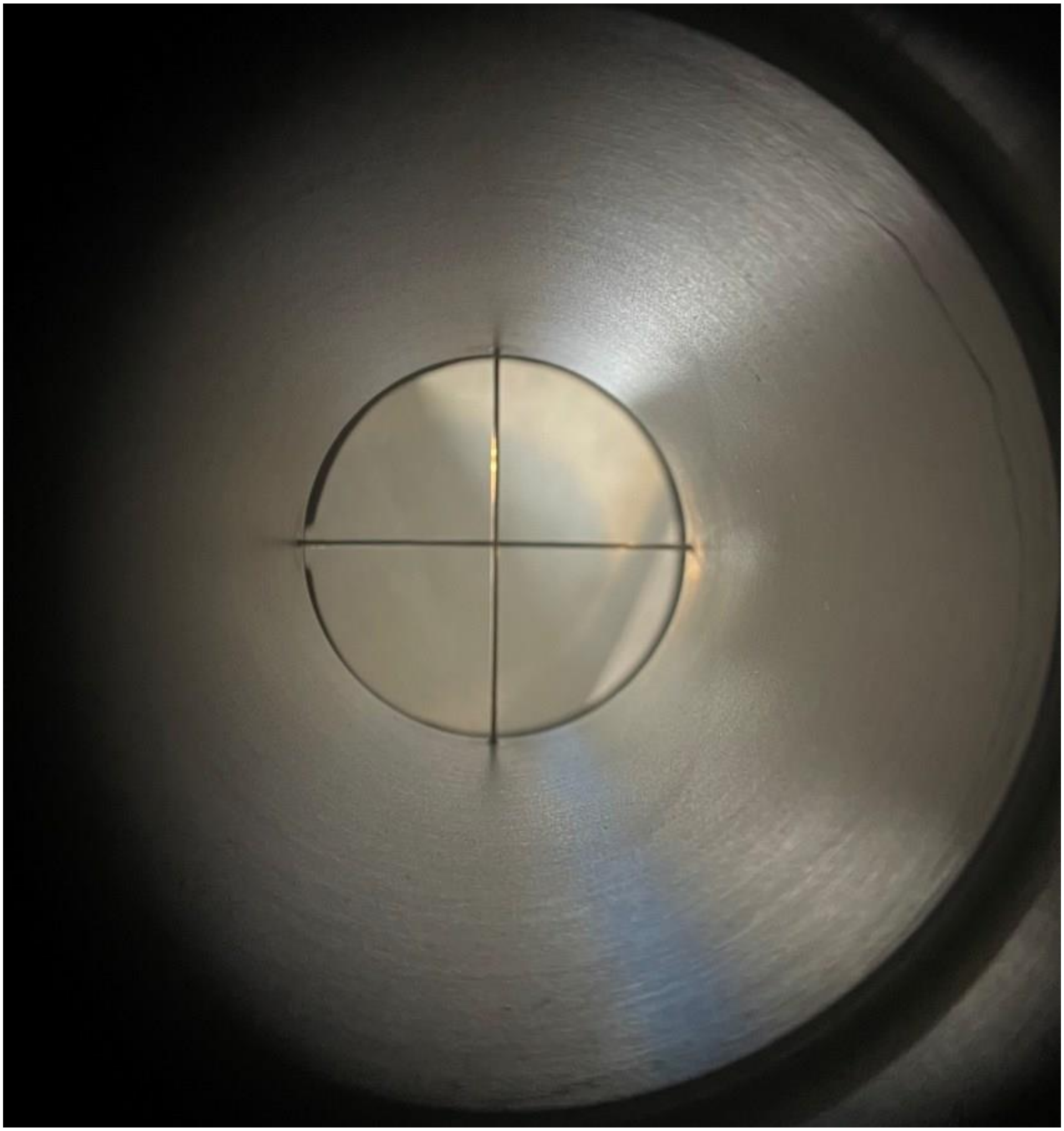
In the meantime I just posted a photometric dataset for Haumea, which is at opposition about now (April 20, 2023).

2023-02-27: Bad weather streak, some imaging

The weather in West Texas has been horrendous, with clouds, rain and winds up to 60mph!! Only 3 nights of imaging in 3 weeks. The new moon has basically been wasted! But here are some updates:

- Guiding has improved incredibly with the added mass on the counterweight. I was surprised to see such a measurable improvement. When seeing is good I am now below 1 arc second RMS consistently, on every session. I said it below, but I guess I have to say it again. This was a very welcome surprise.Decreased inertial moment arm on the counterweight shaft.

- Collimation is holding well. I stopped parking the telescope head down: although it is better to avoid collecting dust on the primary, I think the mirror, not being glued, does not like too much being suspended by its edges and possibly its clips. This leads to the mirror moving in its cell and decollimation. I am working on a new cell, made of carbone fiber to better match the thermal expansion of the borosilicate. The mirror will be glued on it.Sight tube view of the centered secondary mirror.



- Looking at the corner of my images, it is pretty good, but I think it is possible to improve. My guess is that the primary is slightly pinched in its cell.
- Still some slight astigmatism when out of focus, small, but very consistent. Not sure if it is the primary being pinched, or the secondary, or some misalignment.

2023-02-16: Star test and imaging

Clear sky at last! Star tested Moana, resumed imaging. Tested Mico and started imaging. It is great to have 2 NINA instances running and 2 cameras churning images in parallel.

Also managed to run LRGBLRGB… on NINA without triggering autofocus, which is the correct way to image comets.

The added weight to the mount (18lbs) to decrease the inertial moment arm must be working wonders: for the first time (ever!) I started guiding below 1 arc second RMS in both RA and Dec! The low wind and good seeing were also helping.

2023-02-12: Upgrades and collimation

The following updates were performed:

- Added counterweight 18lbs.
- Fixed the light panel PWM power supply.
- Added a second 12v bus for the piggy back imager.
- Routed a new 12v power line through the mount for the piggyback electrical bus. For that I had to remove the scope and disassemble the top of the mount. I also checked that the USB and the main 12v line were not twisted. They were not: after 4 months of remote operations including 1 mount lost + manual remote recovery, I had no twists!
- Turned the camera so the sensor frame is squared with the spider. Also turned the scope in its ring so the camera is closest to the equatorial axis to reduce the moment of inertia.
- Installed a color camera on the piggyback, for dual imaging. The piggy back is a 200mm Borg 55FL Fluorite (some kind of Petzval Refractor from Borg in Japan), with an APSC color camera (ASI 071). The Borg is OK for 4/3 sensors, but exhibits coma for anything bigger, so this system is far from perfect, but since I have the camera and refractor, I may as well use them. I decided to nickname the Mini Color system “MiCo”. The Borg will eventually go and be replaced by a Canon-compatible telephoto lens (maybe the Sigma 180) with an Astromechanic focuser.
- Disassembled secondary and primary, dry cleaned them all (as well as the coma corrector), reassembled, and collimated with Catseyes autocollimator. This should have been easy, quick and smooth. But it was at the end of a very long day after driving 9 hours and working on the scope for another 6 hours, and somehow I botched the collimation. The scope started to exhibit terrible astigmatism. I initially tough the astigmatism was due to a pinched primary, or a pinched secondary or both. This seemed plausible, as I had just tightened the primary cell vigorously. So now I had a bad collimation and a bad diagnostic. I finally went to bed, and the mystery was not resolved until the following morning, with daylight, some coffee and a clear brain. The astigmatism was due to focuser axial error -with the daylight I saw the focuser axial shift clearly in the Telecat. Having found a likely cause I could precisely research my predicament, and found the following, in Vic Menard’s words, talking about Newtonians. “An oblique optical axis may indeed deliver an astigmatic image (ref.: Amateur Astronomer’s Handbook, J.B.Sidgwick). Furthermore, the aberration is more pronounced in larger apertures. (page 79, Astigmatism and Field Curvature). In the field, I’ve noted astigmatic defects caused by errors in both axes (focuser and primary) that smear the entire field of view unless the eye is very carefully centered on the exit pupil. The astigmatism was most pronounced with a significant focuser axial error combined with a minimal primary mirror axial error. The aberrations can be resolved with proper axial collimation, and the sensitivity of the pupil disappears as well.” With this new knowledge, I eventually fixed the

problem to a good autocollimator read. Then, of course, the clouds rolled in. Although I was pretty sure the problem was solved, I could not star test. So I had to eventually leave DSO without the certainty I had solved my astigmatism problem.
- Last but not least, I saw one of the wild donkey who inhabits the Davis Mountain. Pretty cool!

2023-02-03: decollimation

Collimation had started to drift slightly in the previous months, so I knew something in the optical train was not stable. Some time ago, tracking low on the Western horizon I experienced a defocusing and decollimating event, which I strongly suspect was due to the primary starting to have some play in its cell: while tracking low, the primary is on its side, and not supported by the whiffle tree. The event felt akin to an SCT mirror flop. I remotely moved the telescope vertical (looking at the zenith) then leaning Eastward, and managed to unflop the mirror, but from hereon I knew I was due to a road trip. The only question was: could I keep it together a couple weeks until I received the new camera I have to install and do only 1 road trip for all the fixes and upgrades or … was it game over already?

Well, today I had another flop event, and from this one I did not recover. I managed to refocus (and therefore measure the mirror movement on axis by converting focus steps to microns), but I did not managed to unflop the mirror and the scope is out of collimation. I did not try too hard to unflop either: the right thing to do is to go to the observatory, tighten the mirror cell, carefully collimate and do the other upgrades.

Upgrades todo list. Those are my notes for the first trip back to the observatory since installation 4 months ago. I added a few comments & explanation as some people (considering remote imaging) may find it useful.

- Mark focus position on focuser, mark scope position in its rings.
- Remove the primary, clean it, secure it in the cell. Possibly glue it to the pads.
- Clean the secondary.
- Reassemble the system, recollimate. Follow the Vic Menard collimation book. Use the Glatter laser to get in the ballpark quickly, but finely collimate with the catseye tools (autocollimator). If time allows during day, investigate why the Takahashi collimating scope gives results so different from the other tools for centering the center of the primary. At night, star test & fine tune collimatin with the x4 Powermate. Once the scope is collimated and the Powermate still on, indulge some planetary imaging if the night is long enough. Put the coma corrector back and check the camera tilt with NINA, ASTAP and CDD inspector – should all be the same, but who knows!
- See if coma corrector and filters need blowing.
- Mark focus position. Calibrate the zero position of the feather touch focuser to the almost fully racked position. This will allow large defocus for the Pixinsight wave front analyzer (or the Innovation Foresight wave front analyzer). If time allows record the defocused images and check collimation with the wave front analyzer.
- Connect the secondary heater and add a an electrical fuse to protect it.
- Remove the Guide Scope piggy back: I never use it, as 100% of operations have been Off Axis Guided. That will reduce weight on the scope side, reduce overall inertial

moment arm and reduce electrical load on the 12v bus. Possibly add a weight to preserve Dec balance. If rebalancing Dec by moving the scope in its ring redo the meridian limit procedure. Here and here.

- Add a new 18lbs counterweight to the shaft. The goal is to increase weight on the counterweight side, so the weights can ride closer to the polar axis and thus decrease inertial moment arm. You can read this if you need the full explanation. The second goal is to increase the frequency of the mount's harmonic oscillations. This should help guiding in high wind (above 12mph). Follow AP's recommendation: "we recommend a slightly heavy RA balance towards the counterweights and a slightly heavy Dec balance toward the back end of the scope when imaging."
- Rise the flat panel.
- Change the flat panel power supply to the Pegasus Pocket box to have functional variable illumination of the panel using PWM.
- Change the power supply of the exhaust fan of the electronic cabinet to the Pegasus Box, so I can remote control the fan according to temperature inside the electronic cabinet, rather than having a thermostat-only activated fan.
- Add a new 12v power supply and power bus, route additional 12v cable through mount. Check any twisting of cables already in the mount. This is installed in prevision of a future wide field piggy back.
- Remove the network switch and direct connect to computer instead.
- Install the new camera if I get it by then. If not, redo the dark and flat library for current camera. Add 3mn darks. Also add higher gain.
- Redo the flats as collimation has changed.
- Square camera sensor to diffraction pattern for esthetic reasons. Achieve by rotating the coma corrector (and the rest of the imaging train attached to it). Recalibrate guider after rotation.

2023-01-28

I checked the images from the telescope icing night, and they look just fine. Maybe just a bit soft at the coldest point of the night, just before dawn. But I do not think I had any significant icing on the primary, secondary, corrector or sensor. That's good as I imagine it could not be positive for the coating of those various surfaces!

2023-01-26

This morning I check the observatory cameras before doing the usual mount park, with the instrument head down (to protect from dust accumulation in the tube & mirrors). I found the telescope was marbled with frost , at least on the outside. Low temperature combined with 80% humidity resulted in the formation of a thin ice layer on the carbon fiber tube. The electronic, camera and mount still worked perfectly. I will look at the pictures and see if the ice affected the optics.