



Deep Sky Imaging Acquisition Workshop: Rig Setup

Gabe Shaughnessy

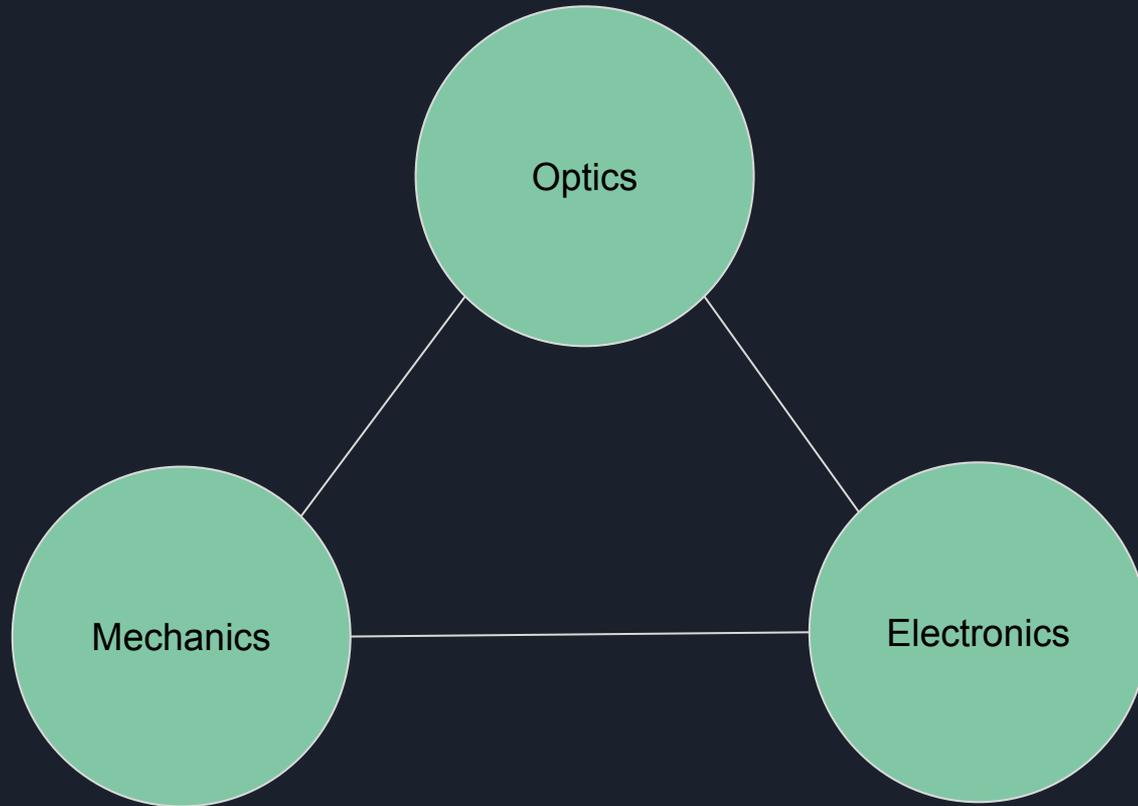
What do you want to achieve?

- Pretty pictures!
 - Color: OSC, RGB, LRGB
 - False color: HaRGB, SHO, HOO, IR-RGB
- Advance what you can image
 - First images of common targets
 - M31, M27, M57, etc.
 - More challenging targets:
 - Veil nebula
 - Dark nebula: Iris nebula, Ghost nebula, etc
 - Pushing the limits of you, your system and your skies
 - Spaghetti nebula
 - Soap bubble nebula
 - Deep integration of galaxy tails
 - IFN
 - The sky is literally the limit
- Science!
 - SN detection, Variable stars, Spectra studies, Exoplanet transit, etc.





The Trinity of Imaging



Knowing your optical system

- Aperture and focal length
- Resolving power
- F-ratio
- Aberrations
 - Spherical aberration
 - Chromatic aberration
 - Field curvature
 - Coma
- Thermal stability
- Critical Focus Zone
- Central obstructions

Celestron EdgeHD 1400



SkyWatcher Esprit 80mm



OTA Only
Mount Not Included

Knowing your electronic system

- Camera
 - Read noise
 - Dark current
 - Defects
 - Linearity
- Power management
 - Battery capacity
 - Interference
- Computer
 - USB settings
 - Entirely remote system?



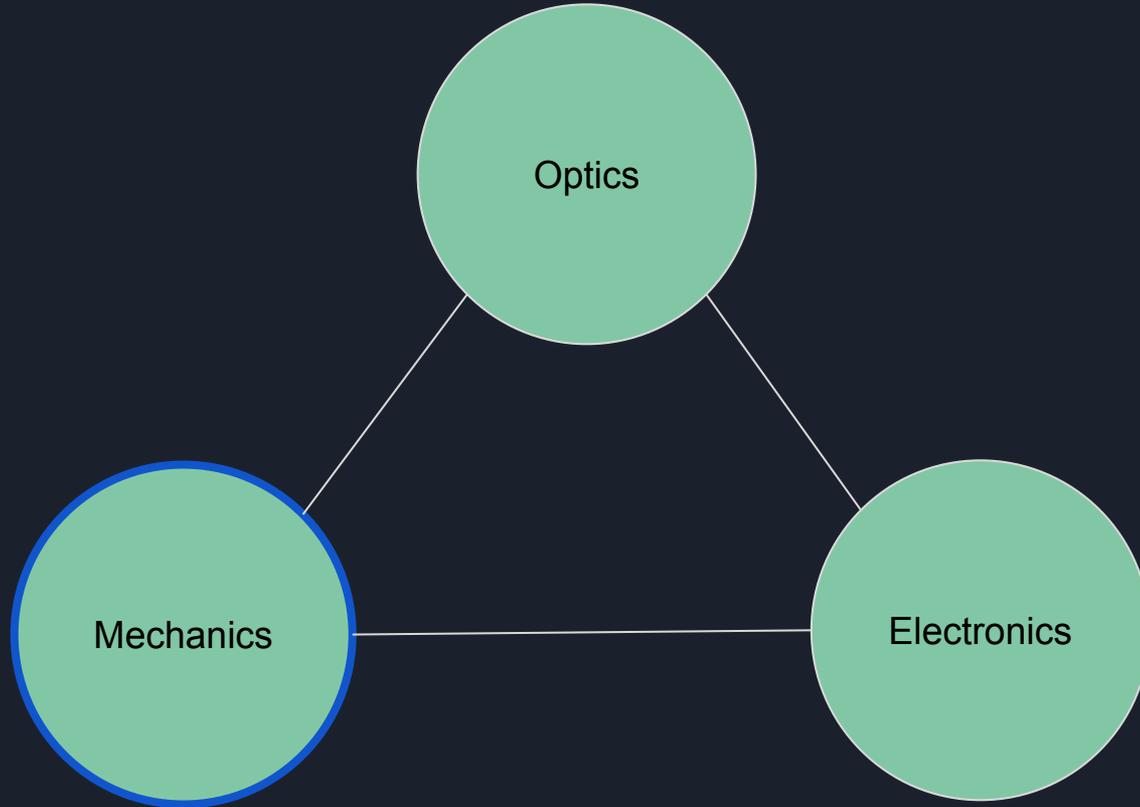
Knowing your mechanical system

- Tripod/Mount Capacity
- Periodic Error
- Telescope Balance
- Counterweight Balance
- Cable management
- Backlash
 - Mount
 - Motorized Focuser
- Wind profile
- Vibration



This will be the focus of this session

The Trinity of Imaging





The Mount

"The single most important item for the imager is the mount. Next comes the mount. Then comes the mount.... Get the picture?"

Roland Christen

The Mount

Specs:

- Type:
 - Equatorial
 - Alt-Az
- Payload capacity
 - Visual or imaging rated?
 - Most imaging rated typically overinflated by 2x
- Periodic Error
 - Amplitude
 - Smoothness
 - Periodic error correction
- Interface:
 - Hand paddle
 - Computer connection
 - ASCOM
 - Indi
 - Smartphone app



Periodic Error

Small inaccuracies in gear fabrication/assembly can lead to error in RA tracking

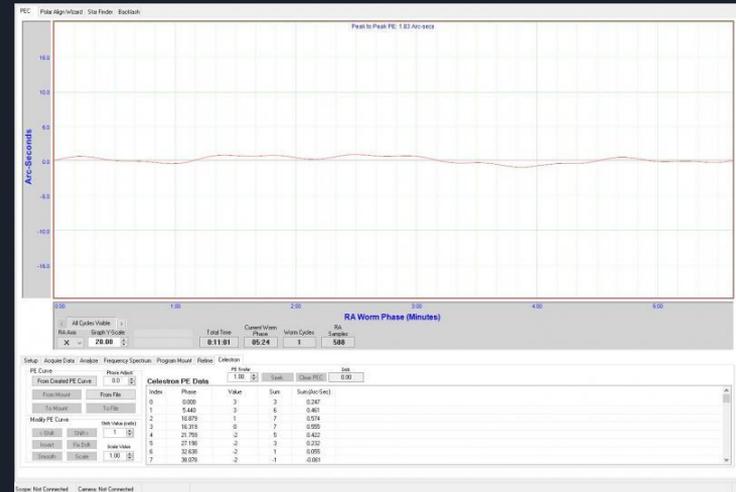
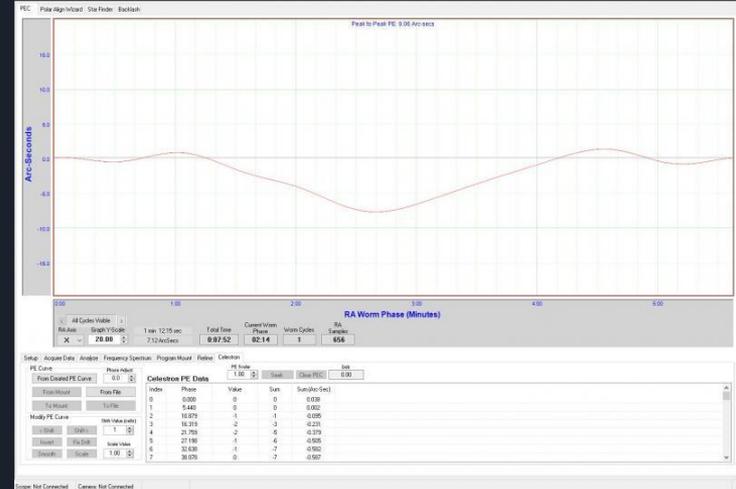
Typical PE values:

- Good mounts < 30" peak-to-peak
- Excellent < 7" peak-to-peak

Choices to get better guiding:

- If smooth enough, can sometimes ignore
- Add PE Correction

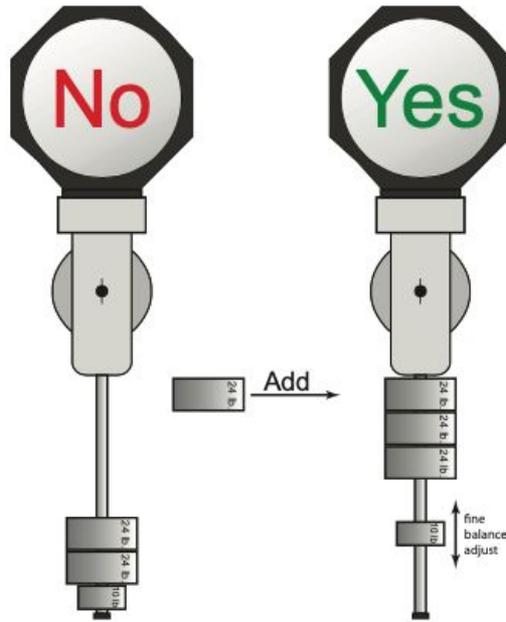
Some mounts have encoders that make PEC unnecessary



Counterweight arrangement

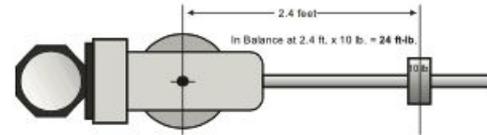
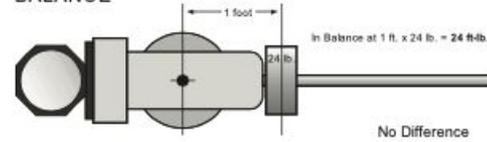
Optimizing Balance

Both examples provide balance, but the example to the left will experience a huge inertial moment arm. The examples on the following page will show the calculations.

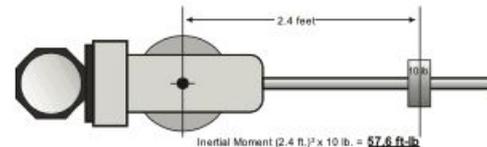
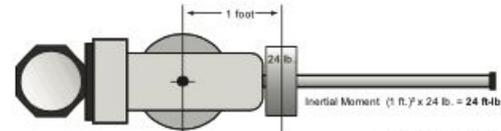


Why More Weight Higher Up the Shaft is Better!

BALANCE



INERTIAL MOMENT ARM



HUGE Difference
Distance is squared!

Why?

The balance of forces ([Newton's second law](#)) for damped harmonic oscillators is then

$$F = -kx - c \frac{dx}{dt} = m \frac{d^2 x}{dt^2}, \text{ [1][2][3]}$$

which can be rewritten into the form

$$\frac{d^2 x}{dt^2} + 2\zeta\omega_0 \frac{dx}{dt} + \omega_0^2 x = 0,$$

where

$$\omega_0 = \sqrt{\frac{k}{m}} \text{ is called the "undamped angular frequency of the oscillator",}$$

$$\zeta = \frac{c}{2\sqrt{mk}} \text{ is called the "damping ratio".}$$

The value of the damping ratio ζ critically determines the behavior of the system. A damped harmonic oscillator can be:

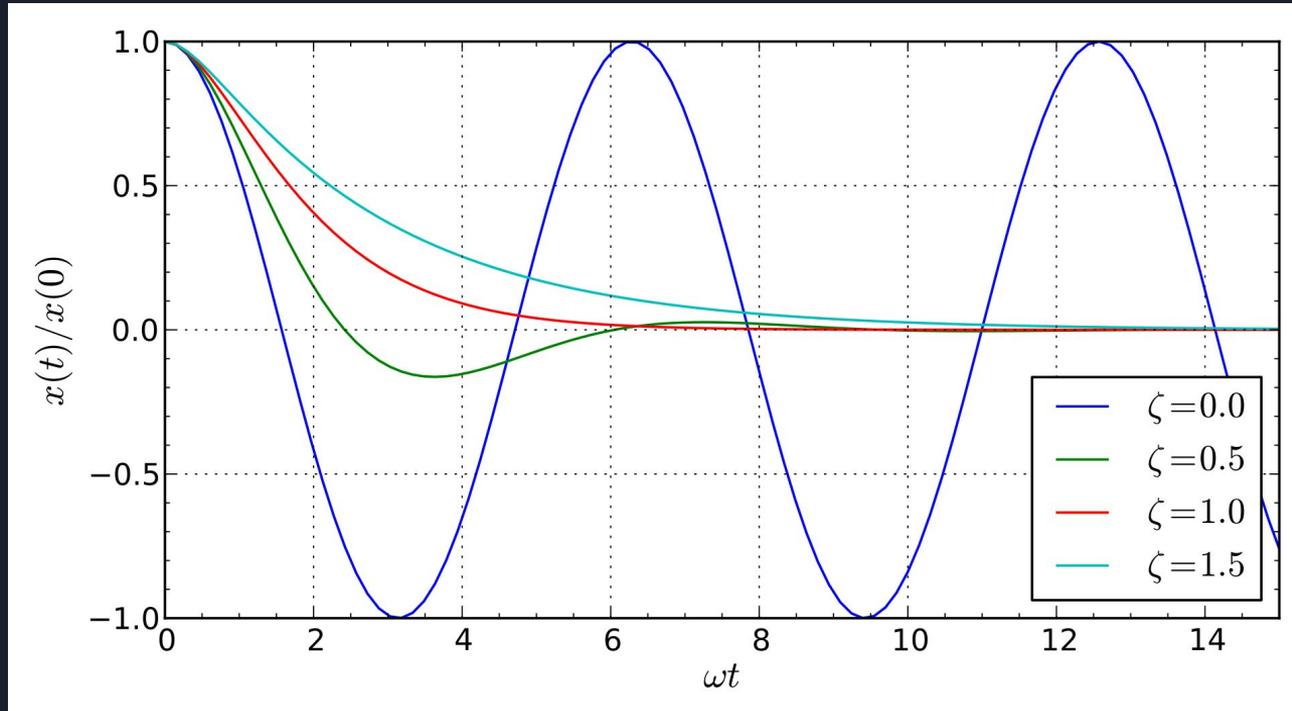
- *Overdamped* ($\zeta > 1$): The system returns ([exponentially decays](#)) to steady state without oscillating. Larger values of the damping ratio ζ return to equilibrium more slowly.
- *Critically damped* ($\zeta = 1$): The system returns to steady state as quickly as possible without oscillating (although overshoot can occur). This is often desired for the damping of systems such as doors.
- *Underdamped* ($\zeta < 1$): The system oscillates (with a slightly different frequency than the undamped case) with the amplitude gradually decreasing to zero. The [angular frequency](#) of the underdamped harmonic oscillator is given by $\omega_1 = \omega_0 \sqrt{1 - \zeta^2}$, the [exponential decay](#) of the underdamped harmonic oscillator is given by $\lambda = \omega_0 \zeta$.

The [Q factor](#) of a damped oscillator is defined as

$$Q = 2\pi \times \frac{\text{energy stored}}{\text{energy lost per cycle}}.$$

Q is related to the damping ratio by the equation $Q = \frac{1}{2\zeta}$.

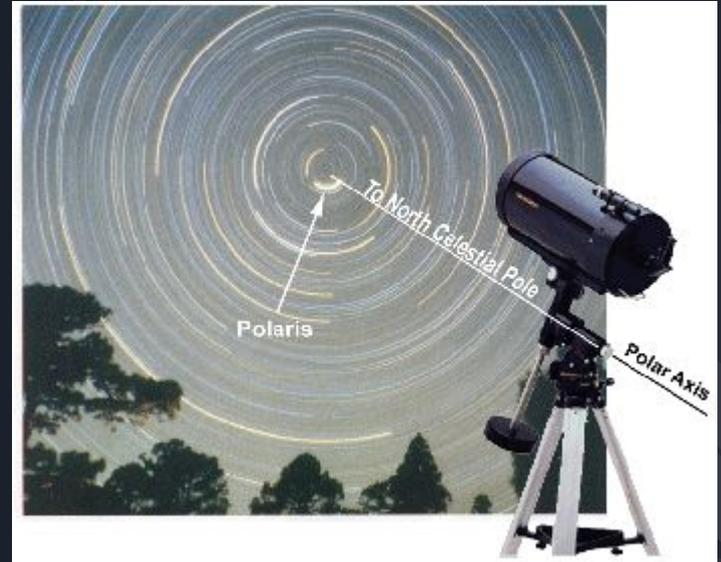
Why?



Counterweight bias

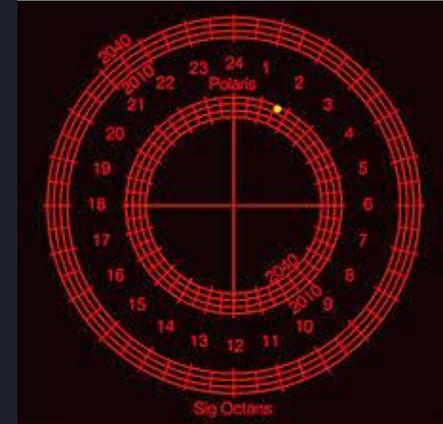
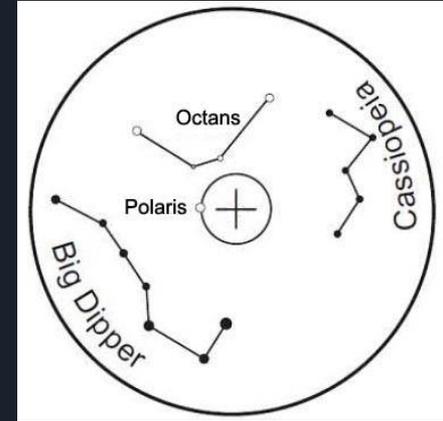


Polar Alignment



Polar alignment methods

1. Align on polaris
 - a. Polar scope: RAPAS, etc.
 - b. Polemaster
2. Drift-align methods
 - a. PHD2 has easy method
3. Model your mount
 - a. Build model of pointing/tracking inaccuracies to know polar alignment error



Direct Polaris alignment: Polemaster

Camera fixed to mount

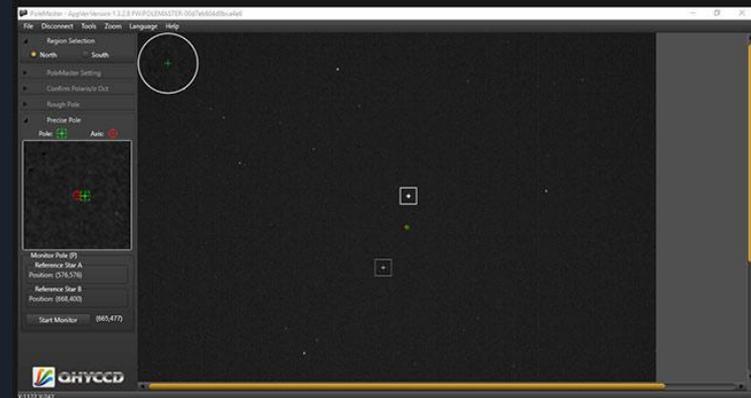
Initial alignment of stars to template

Rotation of mount in RA to fine tune alignment

Fairly fast and easy

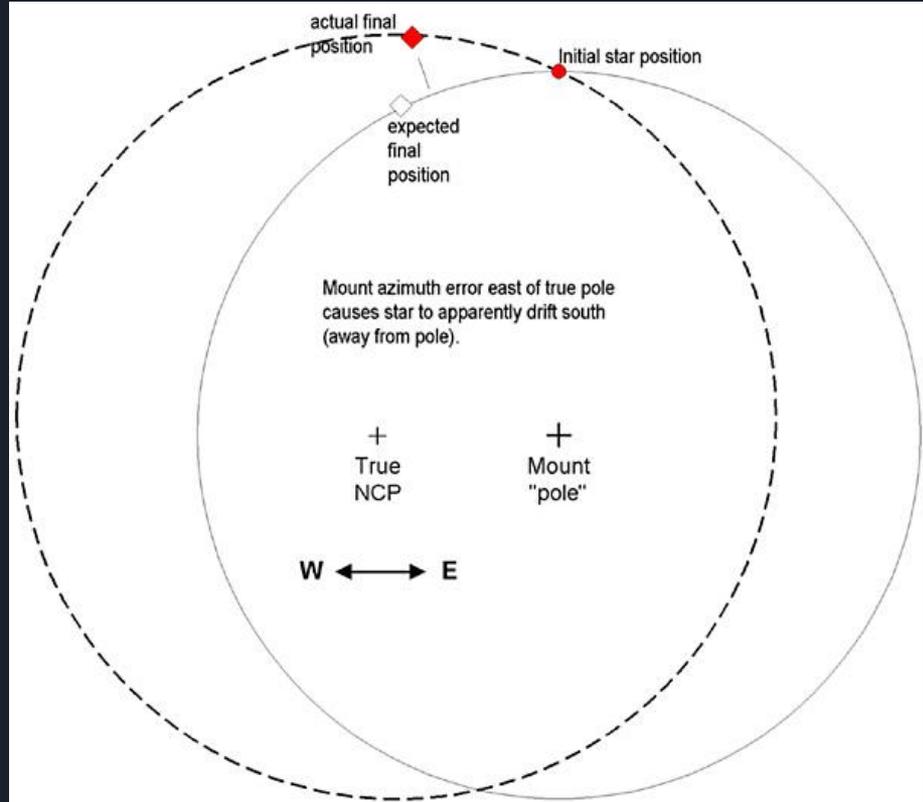
Alternative: Sharpcap

<https://www.sharpcap.co.uk/sharpcap/features/polar-alignment>



Drift alignment

Polar Alignment - Northern Hemisphere	
Star Direction	Description
Meridian	Star drifts NORTH, rotate telescope azimuth EAST Star drifts SOUTH, rotate telescope azimuth WEST
Eastern Horizon	Star drifts NORTH, adjust telescope altitude LOWER Star drifts SOUTH, adjust telescope altitude HIGHER
Western Horizon	Star drifts NORTH, adjust telescope altitude HIGHER Star drifts SOUTH, adjust telescope altitude LOWER

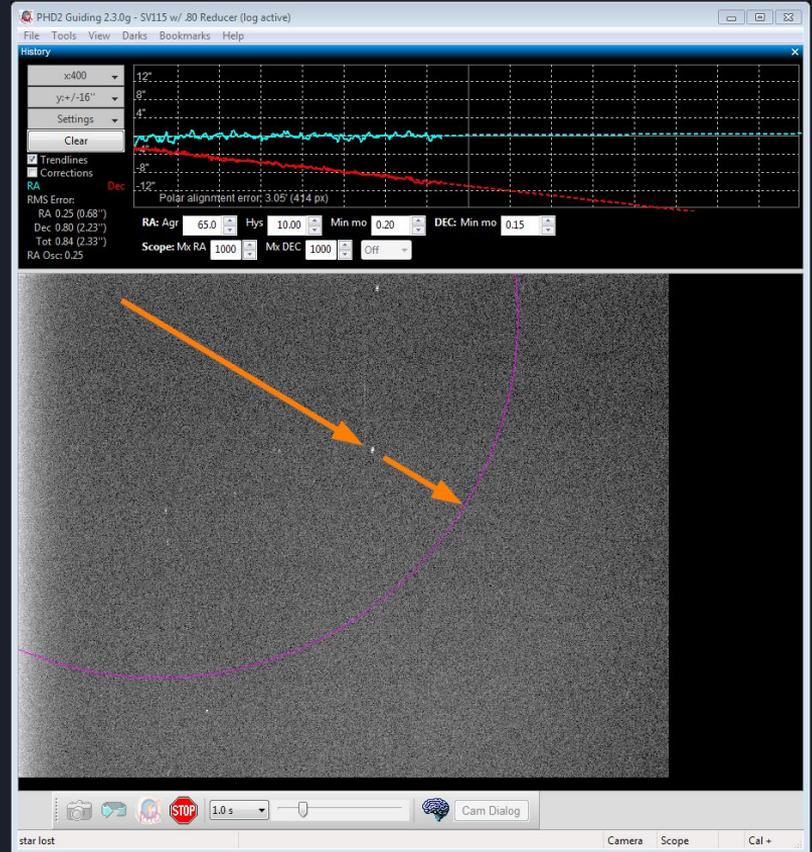


PHD2: drift align

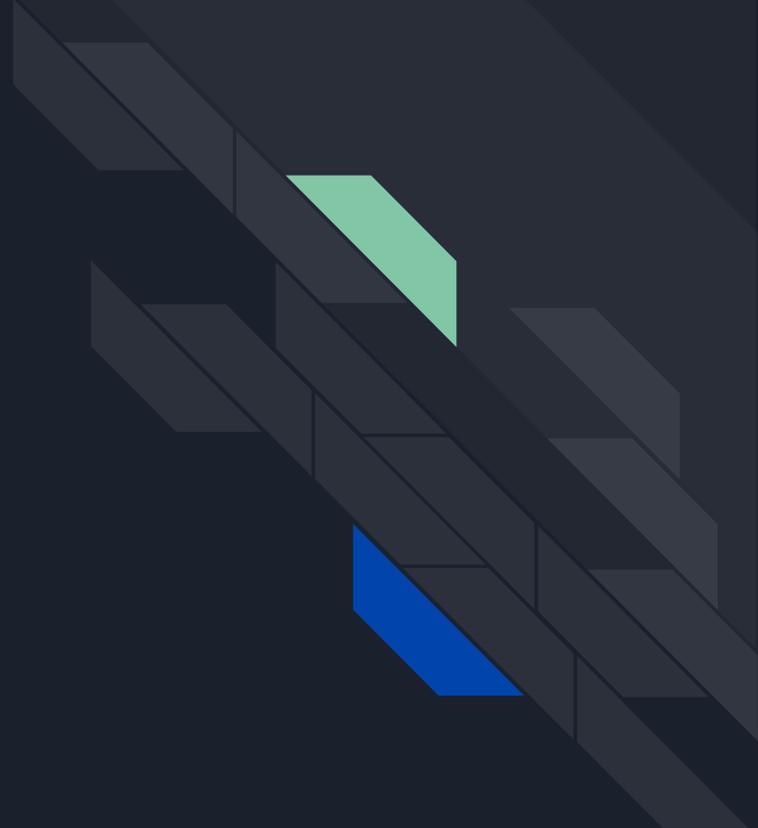
Faster than it sounds!

Very accurate with current camera sensors

I use this method to calibrate my RAPAS

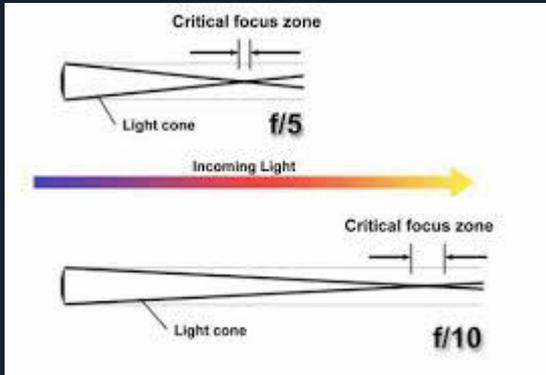


Nailing Focus



Nailing Focus - The Critical Focus Zone

- Describes how accurate focus position must be to be within acceptable focus
- Highly dependent on focal-ratio
- Very tight for fast optical systems
-



Critical Focus Zone

Calculate the length of the zone in which the focused image of a star is smaller than the size of its Airy disk.

$$\text{critical focus zone} = 2 \times \text{focal_ratio} \times \text{Airy_disk}$$

which simplifies to:

$$\text{critical focus zone} = 4.88 \times \text{focal_ratio}^2 \times \lambda$$

For CCD cameras, if we take a 2x sampling ratio:

$$\text{ccd focus zone} = \text{focal_ratio} \times \text{pixel_size}$$

where:

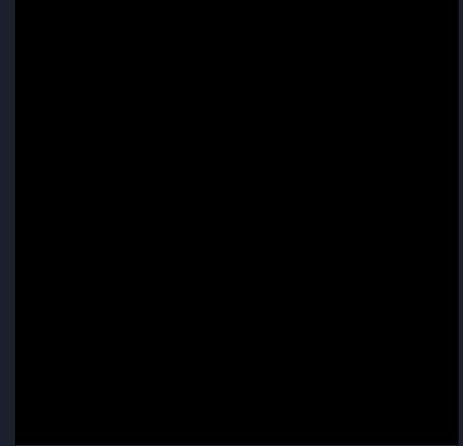
λ = wavelength of light

Light Colour	Green
Wavelength of light	510
Focal Ratio	4.6
Camera pixel size (microns)	3.69
Pixel binning	1x1
<input type="button" value="Calculate"/>	<input type="button" value="Reset"/>
Critical Focus Zone	53 microns
CCD Focus Zone	53 microns

Note that because at low f/ratios the size of the Airy disk becomes significantly smaller than typical CCD pixels sizes I have introduced a value for the CCD Focus Zone. The value for the CCD focus zone takes the larger value of the CFZ, or where the Airy disk is half the effective pixel size (2x under sampling ratio) the CCD focus zone value defined above. For small focal ratios the CFZ gives a misleadingly small figure for imagers.

Nailing Focus - A Manual Method

- As night cools, optical properties change - need to refocus
 - OTA contraction
 - Lens deformation
- Need some way to monitor changes
 - FWHM
 - Number of stars in image
 - Mask
- Bahtinov Masks



The Bahtinov Mask - How does it work?



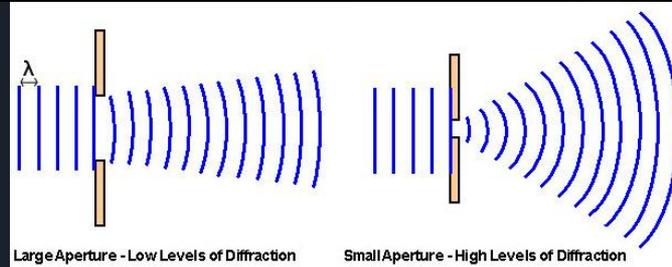
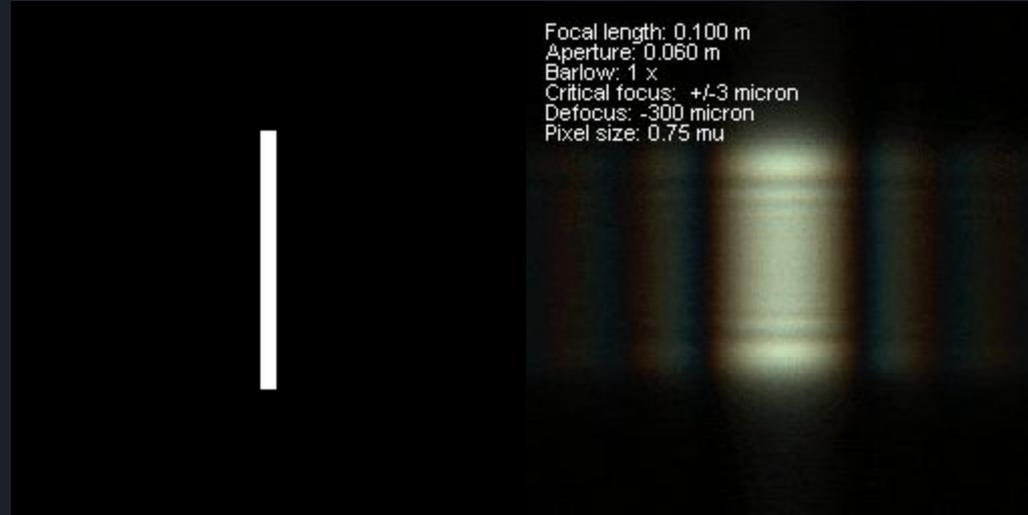
Credit [cprobertson1](#):

<https://www.pentaxforums.com/forums/groups/135-astrophotography/9078-bahtinov-masks-basic-visual-guide-how-they-work.html>

The Bahtinov Mask - How does it work?



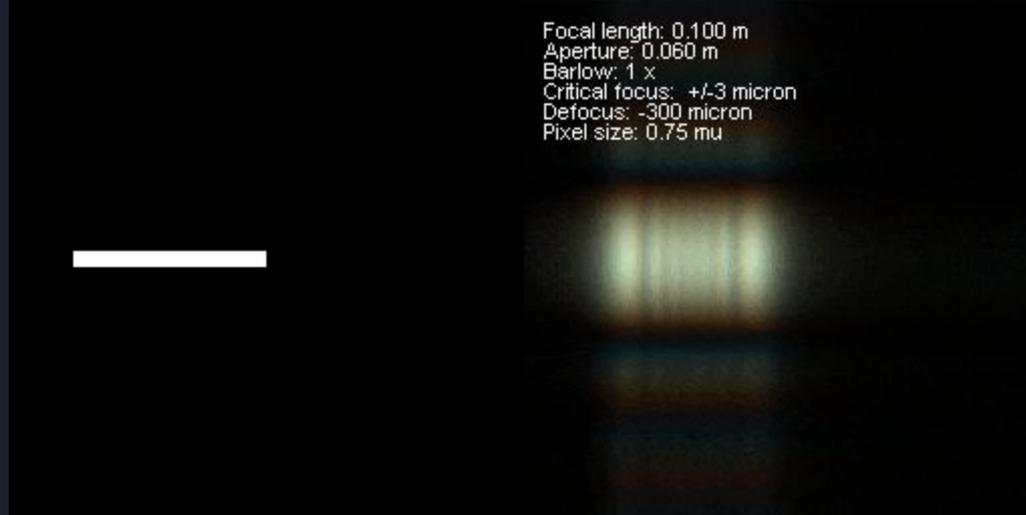
The Bahtinov Mask - How does it work?



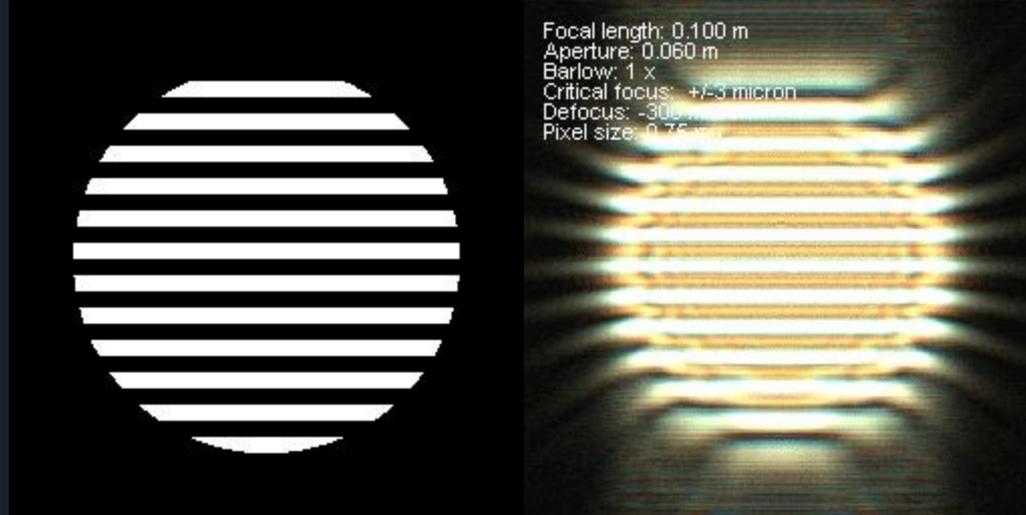
The Bahtinov Mask - How does it work?



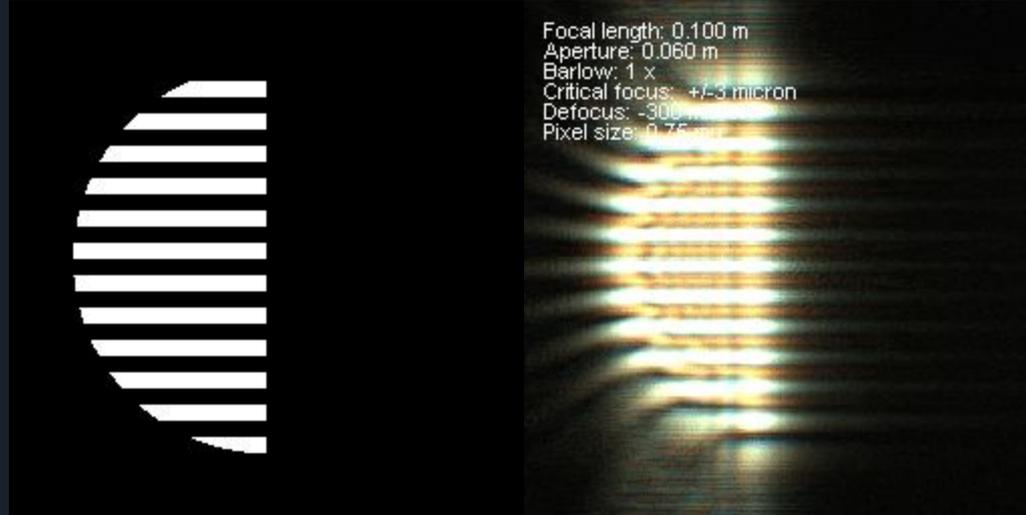
The Bahtinov Mask - How does it work?



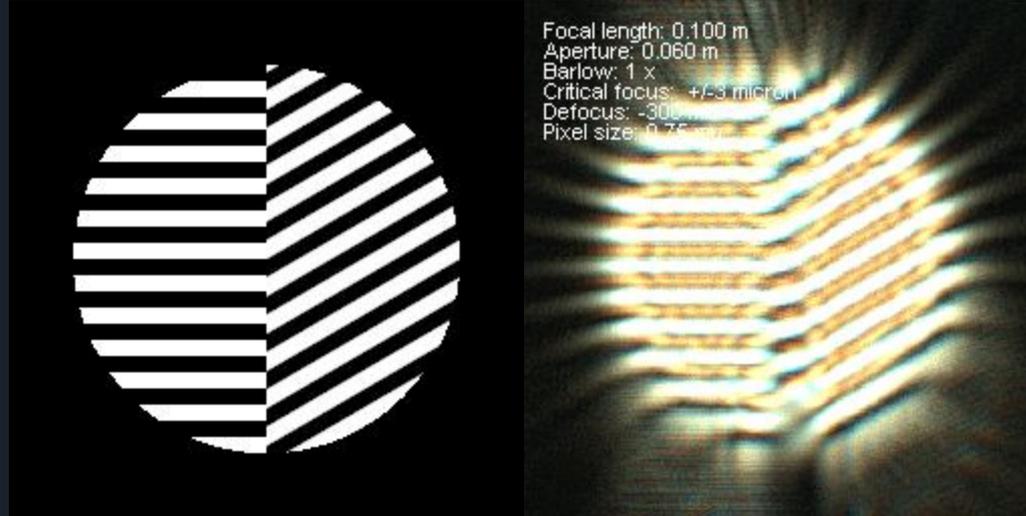
The Bahtinov Mask - How does it work?



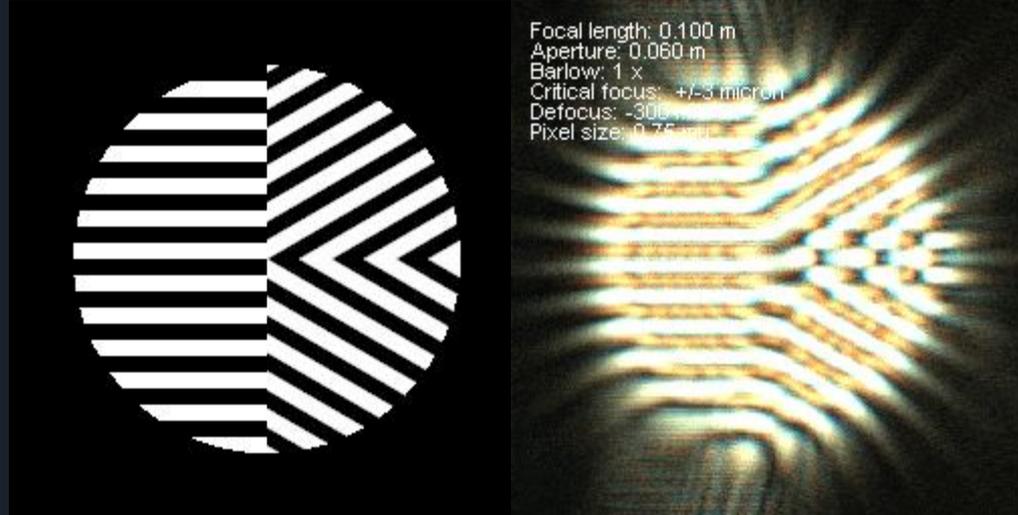
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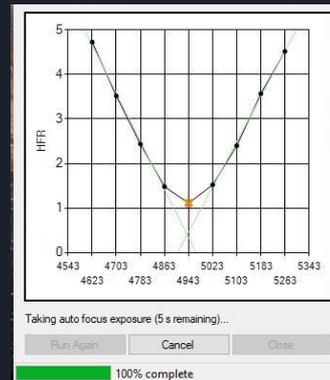
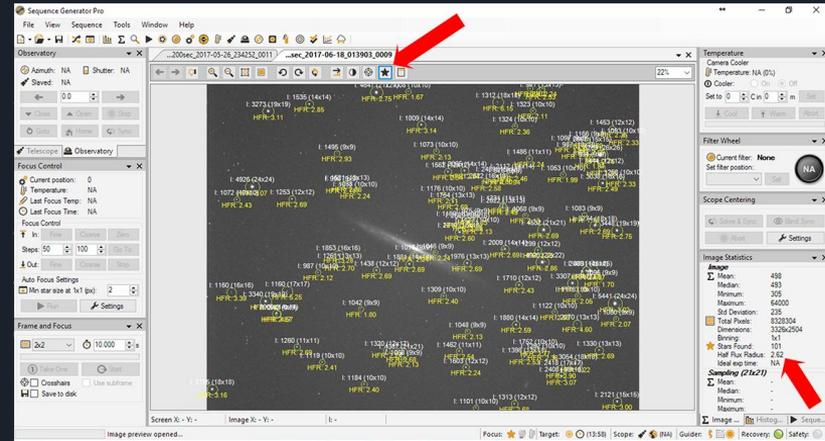
Autofocus

- Need focus motor and controller
 - Feathertouch
 - Moonlite
 - Pegasus Astro
 - Robofocus
- Telescope systems
 - High accuracy
- Camera lens system
 - Belt driven
 - Can have significant backlash
 - Can pull lens laterally



Autofocus

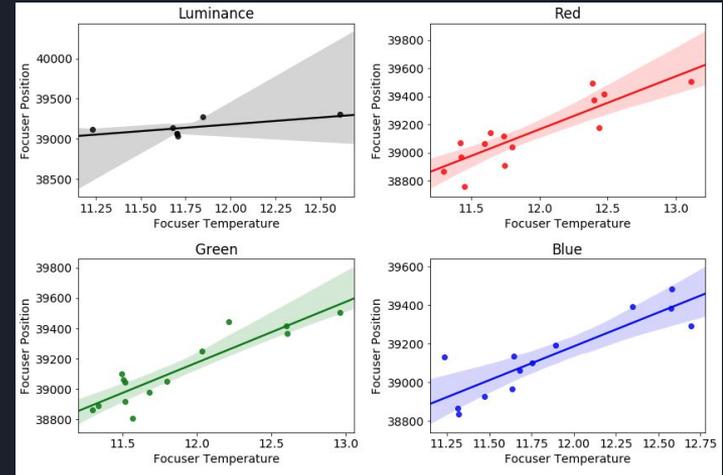
- Single star method:
 - Fast if using ROI
 - V-curve is intuitive
 - Only one portion of FOV - bad for field with high curvature
 - Great for optically flat systems
- Multi star method:
 - Can be slower - full frame download
 - Good for systems w/ some curvature
 - Method used in SGP



Keeping focus

Some telescopes are more susceptible to focus drift with changing environment temperatures

- May depend on tube construction, optical design, speed of optics
- I refocus every 0.5C change in ambient temp
- Temperature compensation another option **



Cable Management



Cable Management

Why?

- Better guiding/tracking
- No cable snags
- Less impact from wind gusts

How?

- Bundle cables together
 - Cord Wrap
- Provide enough slack to slew to all parts of sky
- Attach bundle to low-moment arm areas of mount
 - I often use saddle plate



Cable Management: Side vs. Top mount

Side mount (my preference)

- + Less weight
- + Forces better cord management
- Longer cables

Top Mount

- + Fewer cables running up (sometimes just power and mount)
- + Shorter cable runs to peripherals
- More weight and moment arm



Cable Management

- Bundle cables together
 - Cord Wrap
 - Zip ties
- Crucial: Provide enough slack to slew to all points in the sky
- Be aware of pinch-points
 - Cable pinching can cause tracking inaccuracies at best, damaged cables or even mount at worst



Chengsi Cable Organizer Coiled Tube Sleeve Cable Cable Management Sleeve (Black Length 118.1inches Diameter 0.62inches)
Brand: chengsi
★☆☆☆ 134 ratings | 20 answered questions
Price: \$10.99 ✓prime & FREE Returns
Size: 59inch*1.1inch | **118.1inch*0.62inch**
Color: **Black**

- INSTANT SOLUTION THAT LASTS. Easy installation, no other tools needed. Wrap the cable management sleeves around your cords and within a minute you can enjoy a tidy and lovable living/working environment.
- Safety, protect wires from the wear and tear, prevent electric leakage
- Easy to install with the thread guide and can be cut to custom lengths
- Ideal for home or office use.SIZE:118.1inch*0.62inch=3m*16mm (Length: 118.1" Diameter: 0.62")
- MONEY BACK GUARANTEE: If you're not 100% SATISFIED, let us know and we will make things right: full refund or a free replacement, whichever you would prefer.

Roll over image to zoom in

Report incorrect product information.

\$10.99
✓prime & FREE Returns
FREE delivery: **Tuesday** Details
53058
Deliver to Gabe - Nashotah 53058
In Stock.
Qty: 1
Add to Cart
Buy Now
Sold by chengsi us and Fulfilled by Amazon.
Add to List
Add to your Dash Buttons



Alex Tech 10ft - 1 inch Cord Protector Wire Loom Tubing Cable Sleeve Split Sleaving for USB Charger Cable Power Cord Audio Video Cable - Protect Cat from Chewing Cords - BlackRed
Brand: Alex Tech
★☆☆☆ 1,974 ratings
1 Best Seller in Cable Sleeves

Price: \$12.99 ✓prime FREE One-Day & FREE Returns
Pay \$12.99 \$0.00 after using available Amazon Rewards Visa Card Points.

Size: **1"-10ft**
1/2"-10ft | 1/2"-25ft | 1/4"-10ft | 1/4"-25ft | 1/8"-10ft
1/8"-25ft | **1"-10ft** | 1"-25ft | 3/4"-10ft | 3/4"-25ft
3/8"-10ft | 3/8"-25ft

Color: **Blackred**

- Size: Diameter: 1" Length: 10 Feet | Color: Blackred. Our wire loom is split and easy to load wires. Once loaded, our cable sleeve will close on itself and perfect wire wrap
- Operating temp (Degree F):3-105 to 257(Melt temp: 446. Our cable management sleeve is used for HiFi speaker Mini automotive wires
- Our cord protector keeps cat from chewing cables. Our cable protector is insulated
- Our wire sleeve: UL Recognized
- Our cable organizer keeps the cords organized with no more messy cables in your home and office

Roll over image to zoom in

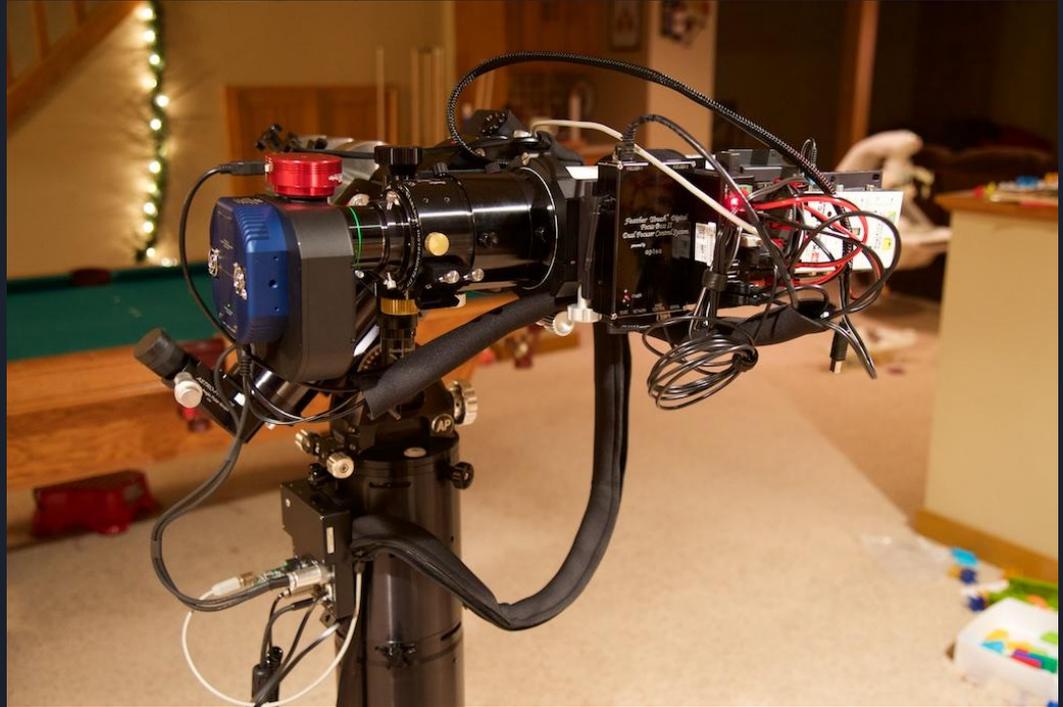
See more product details

\$12.99
✓prime FREE One-Day & FREE Returns
FREE delivery: **Tomorrow**
Order within 50 mins Details
53058
Deliver to Gabe - Nashotah 53058
In Stock.
Qty: 1
Add to Cart
Buy Now
Sold by San-mart and Fulfilled by Amazon.
Add to List
Add to your Dash Buttons
Share
Have one to sell? Sell on Amazon

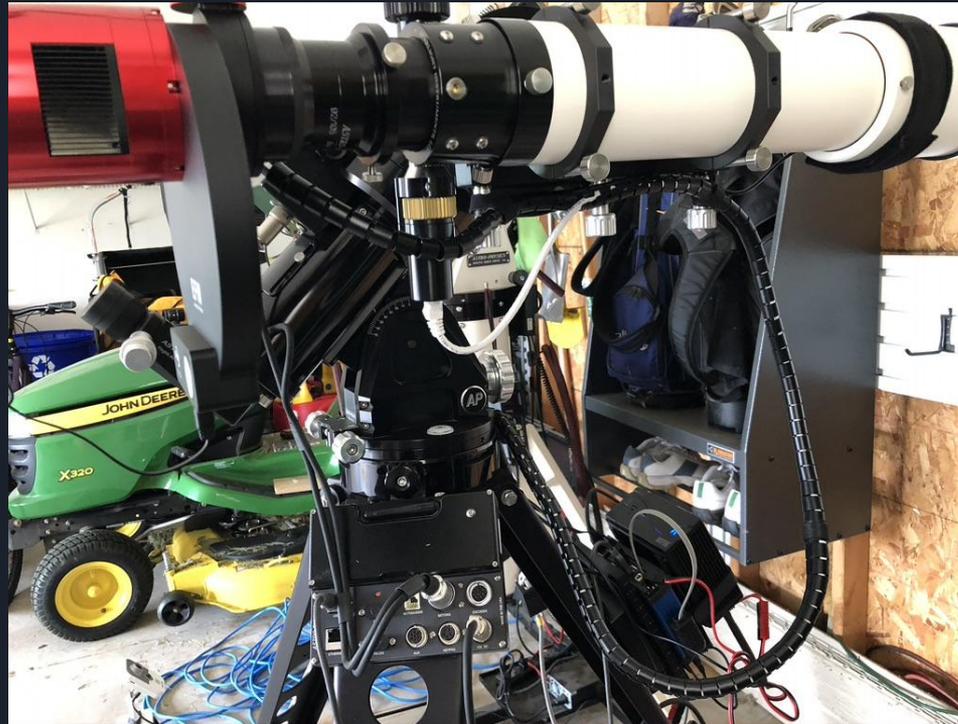
Cable Management examples



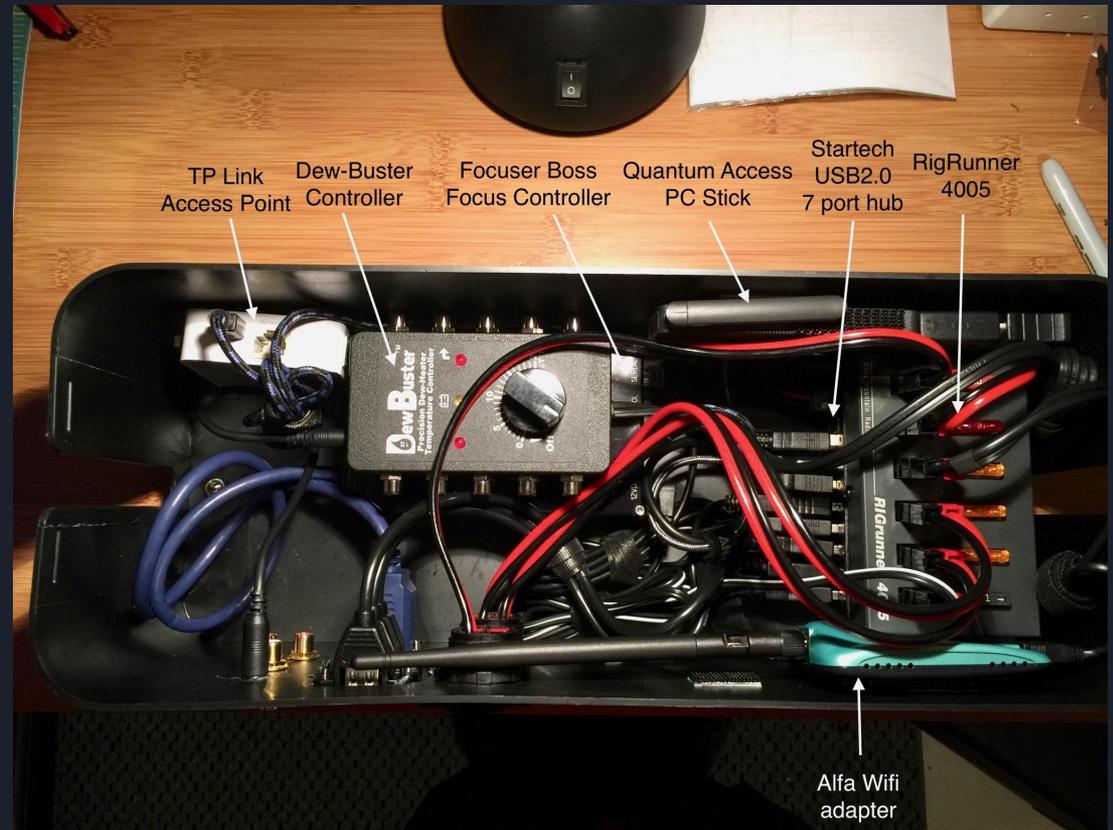
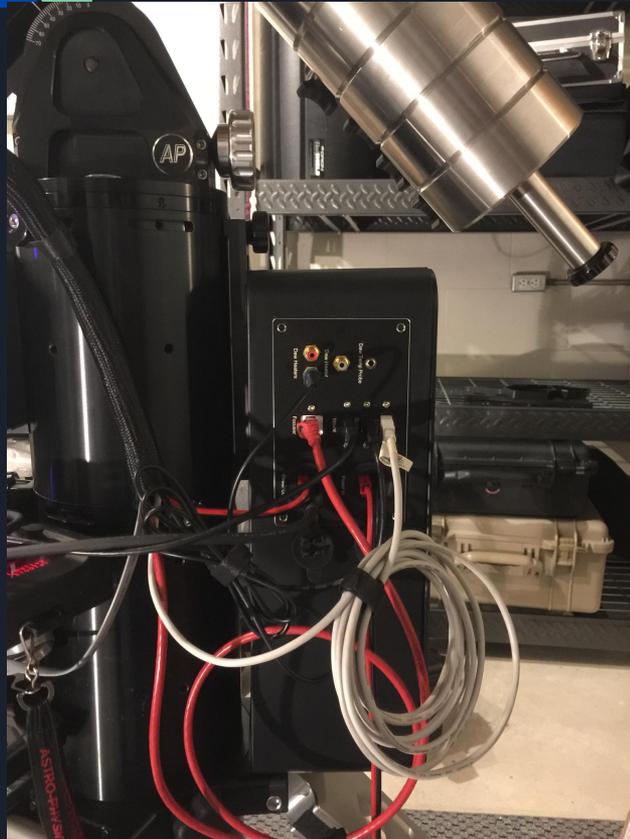
Cable Management examples



Cable Management examples



Cable Management: Assemble an Astro-box



Guiding setup: to OAG or not to OAG

To OAG (my preference)

- If significant flexure/mirror flop
- Sensitive guide CCD
 - Pick off prism can give small FOV
- Simpler focus
 - Set and forget



No OAG

- Mount can handle extra guide scope
- No flexure
- Not enough backfocus to get OAG
- Large FOV



Environmental Sensors

Tracking environmental conditions

- Temperature
 - Proactive tracking for focus changes: can be in focus motor on scope
 - How much to push TEC for camera
- Humidity
 - Sense level of dew prevention needed
- Wind
 - Knowing if the wind is too much for your rig
- Rain sensors
- Cloud sensors

ASCOM drivers available to also connect with OpenWeather or other sources to get local conditions

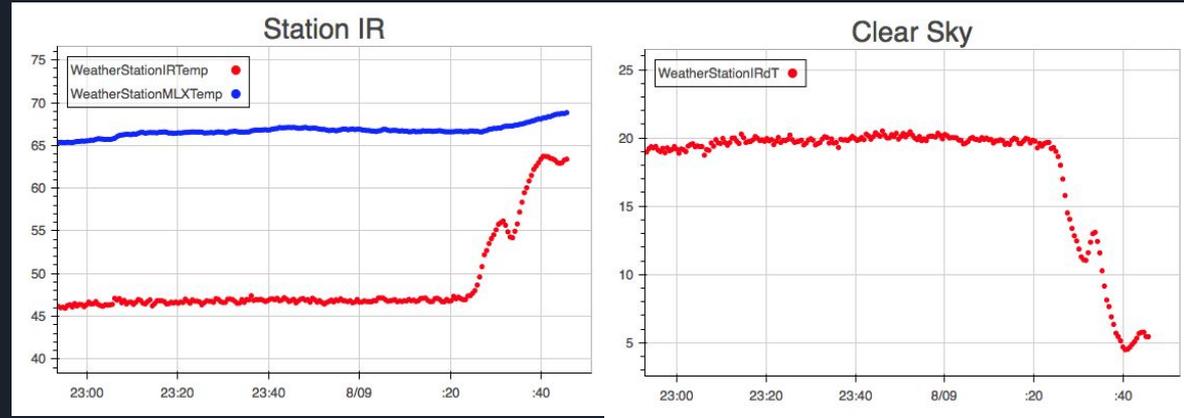


Cloud sensors

Main method of detection

- IR signature of cloud vs. open sky

Can alert to clear skies or when conditions are deteriorating



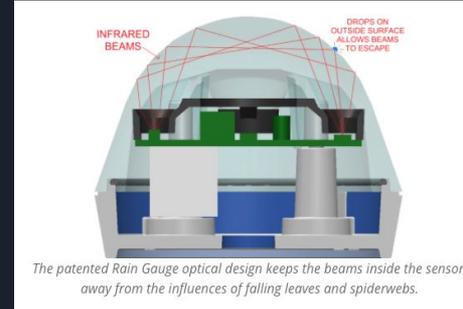
Rain sensors

Hydreon RG11

- Uses IR light to measure beads of water on transparent cover
- Configurable sensitivity

Tip-bucket

- Typically 0.01" increments



Tipping Bucket

Replace your tipping bucket with a low maintenance alternative

[Learn More](#)

"It's Raining"

Close a skylight at the first sign of rain, and open it when it stops

[Learn More](#)

Drop Detection

Provide drop detection for your own external data interpretation

[Learn More](#)

Wiper Control

Control a wiper system on boat, ship, locomotive, and more

[Learn More](#)

Irrigation Control

Measure both rain accumulation and rain intensity

[Learn More](#)

Condensation Sensing

Reliably detect condensation or frost

[Learn More](#)

Dew Control

Need a heater to put on objective to keep dew away on humid nights

PWM of some controllers can affect electronics

Last resort: hairdryer



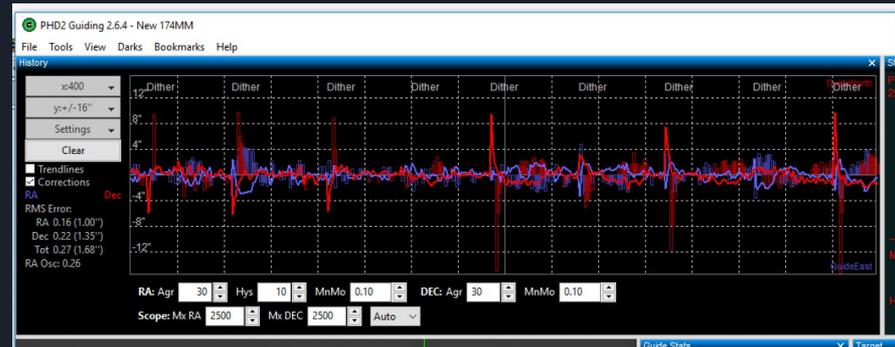
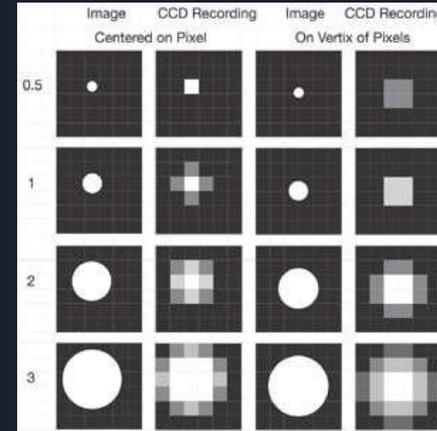
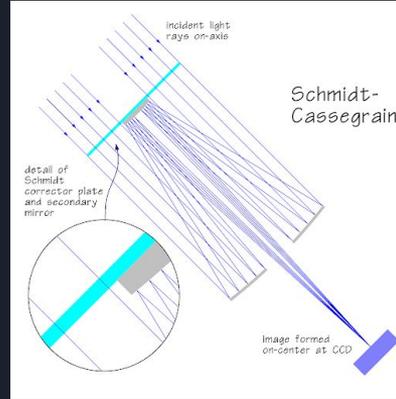
Next time:

Me (September 9):

- Optical system
- Electronic system

Jeff (October 14):

- All about guiding



Down the road

- Cameras and settings
- Calibration frames
- Acquisition software (SGP, etc.)
- Target planning/sequencing
- Data management
- Weather resources
- Observatory topics
- More processing topics
 - PS/PI



Looking for volunteers for some of these topics