ONAG®

Patent Pending

Astronomy

Innovations Foresight, LLC

Revision 4.0

Innovations Foresight, LLC

ONAG®

Standard and XT

ON Axis Guider

User Manual

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http://InnovationsForesight.com

Introduction

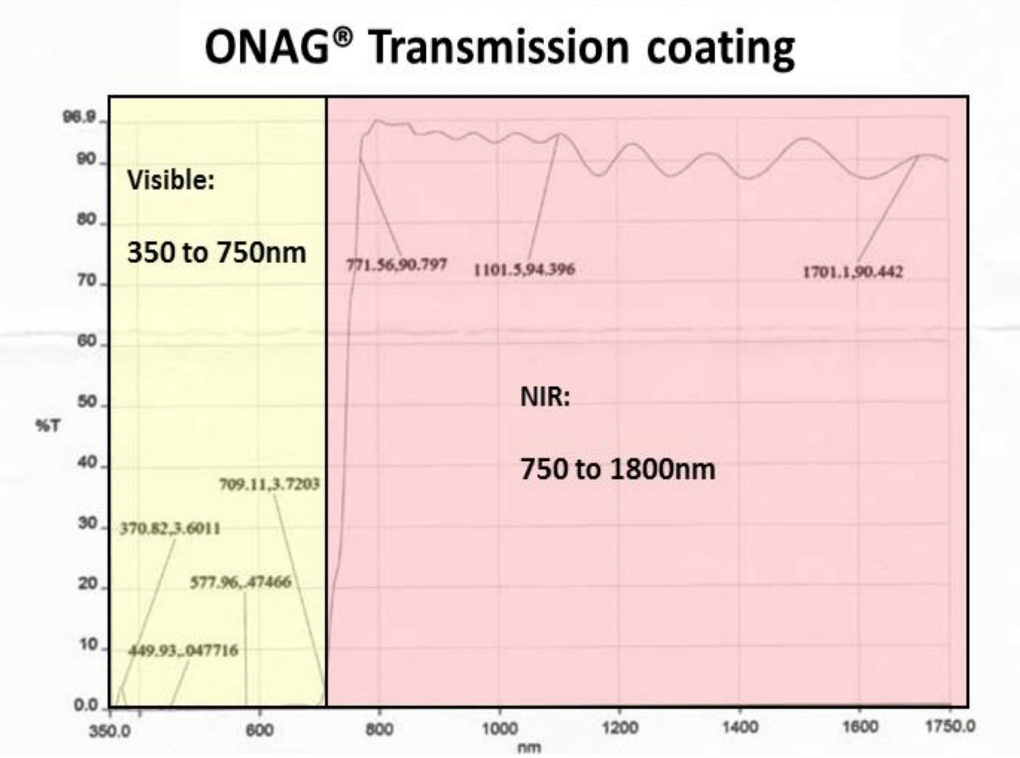
Thank you for purchasing our patent pending on-axis guider ONAG®. This product has been designed with care to give its user the highest level of experience and satisfaction. Take a moment to read this manual in order to get the most of your ONAG®, refer to section 7 for pictures of the ONAG® and its parts. See section 9 for the ONAG® XT specifics.
Please note this product was not designed, or intended by the manufacturer for use by child 12 years of age, or younger. The ONAG® comes in two versions. The standard ONAG® uses a M42 thread system and has been optimized for CCD imagers using large format APS-C chips (up to 28mm in diagonal). The ONAG® XT supports full frame CCD, such as the 24mm x 36mm format, and uses a dovetail system. Searching for a suitable guide star has never been easier thanks to its wide field of view and convenient quick set-up X/Y stage, providing an exploration circle up to 46 mm (1.8") in diameter. This is more than 1.3 arc-degrees for a two meters focal length scope.
Because it uses the same scope and optical train as your imager there is no differential flexure.
The ONAG® shares the same focal ratio (F-number) as your scope set-up, providing maximum light to the guider camera. Since filters and filter wheels are placed in the imager optical path, they will not interfere with the guider camera. Therefore even narrow band imaging will not make the guide star(s) too dim to use anymore. Although the ONAG® will work well with any scope, provided you have the necessary back focus (see section 3), it excels with

Schmidt Cassegrain type of scopes (SCT), as well as long focal. The ONAG® is made of high quality aluminum, and stainless steel, therefore there is no risk of any rust. The optical beam splitter is fully multi-coated and protected with a transparent layer of quartz for a long life.
This document describes the standard and XT versions of the ONAG®. Most of the functions and concepts are the same and therefore are presented on a standard ONAG®. Specific information on the XT version can be found at the end of this document in the section ONAG® XT specific (section 9).

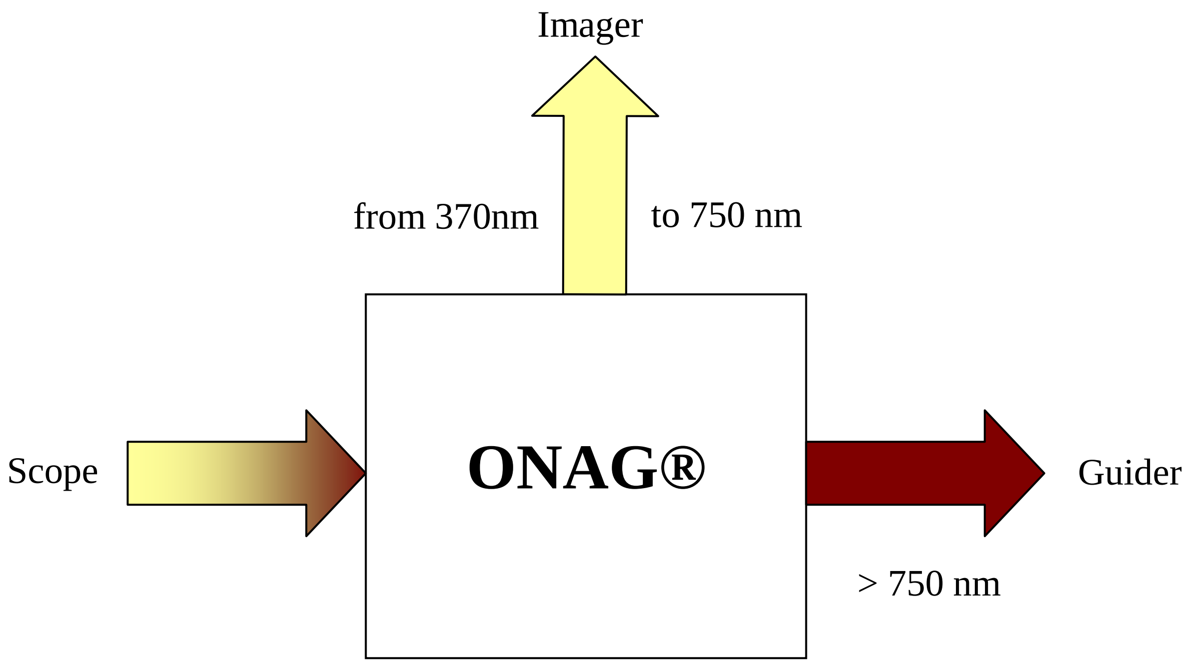
<u>Description</u>

The ONAG® is composed of 7 fundamental elements:

(1) A fully multicoated dichroic beam splitter (DBS), or “cold mirror”. The DBS reflects more than 95% of the visible light (typically > 98%), from 370nm to 750nm, toward your imager.
More than 90% of the near infrared (NIR) portion of the light, from 750nm to 1800nm, goes through the DBS to be used by your guider camera. Because the visible light is reflected, there is no optical aberration involved here. The guide star may look a bit elongated, but since the DBS is only few millimeters thick this effect is minimized. It has no impact on popular auto-guider software, like Maxim DL, GuideDog, PHD guiding…, or software using centroid algorithms to track the guide star(s). The ONAG® XT features an integrated corrective optics inside the guider drawtube to remove any guide star distortion.



ONAG® spectral response



ONAG® basic principle

(2) A scope port (SP). The SP allows the ONAG® to be attached to any scope using a standard T-threaded female connection (M42 x 0.75), or a 59mm dovetail system for the XT version.
The ONAG® comes standard with a 2” tube adapter, and a low profile SCT female adapter.
If you own an adaptive optic module, such as the Orion SteadyStar™, or the Starlight Xpress SXV, you can mount them directly between the SP and your scope. Use the ONAG® for guiding and controlling the AO unit then.
Since the off-axis ports of both products are not used they should be covered to avoid parasitic light. We offer an adapter plate for the SBIG AO8 adaptive optic module. This allows you to mount the AO8 in front of the ONAG®.
Other adapter for any ONAG® can be made by our partner *preciseparts* (www.preciseparts.com). The SBIG AO-L is only supported by the ONAG® XT.

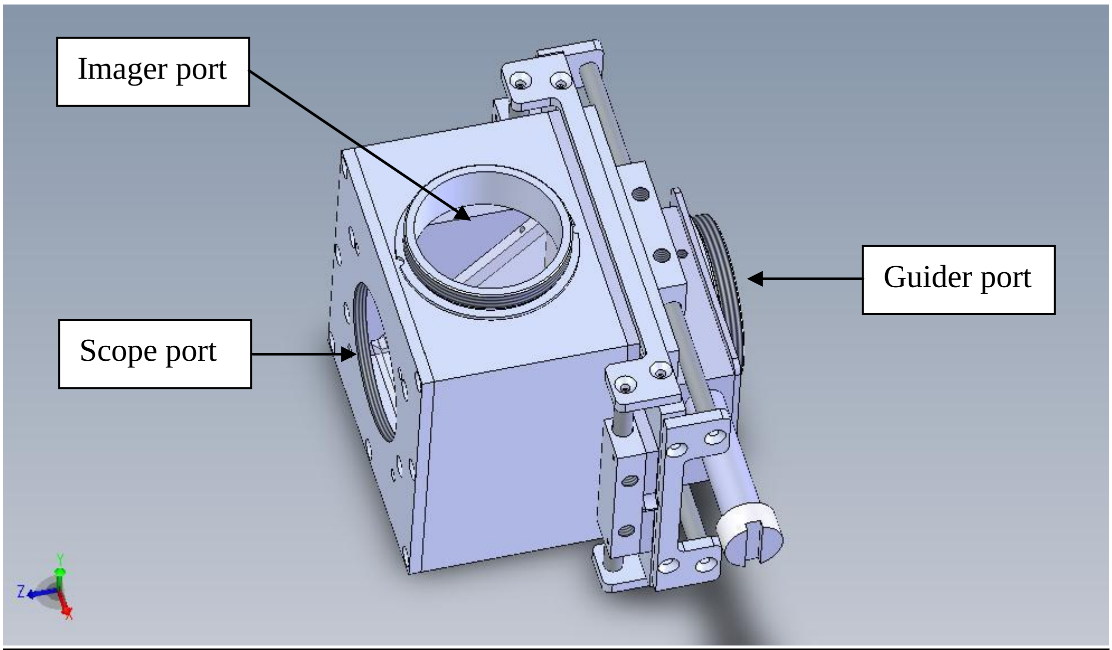
(3) An imager port (IP). The IP is used to attach the imager camera and related accessories, such as a filter wheel, to the ONAG® using a standard male T-thread (M42 x 0.75), or a 59mm dovetail system for the XT version.

(4) A guider port (GP). The GP is used to attach the guider camera to the ONAG®, including the XT version, using a male T-thread (M42 x 0.75). A low profile T-threaded ring is provided to secure the camera at the desired position. The GP is also the guider focuser drawtube (see the element 5 below).

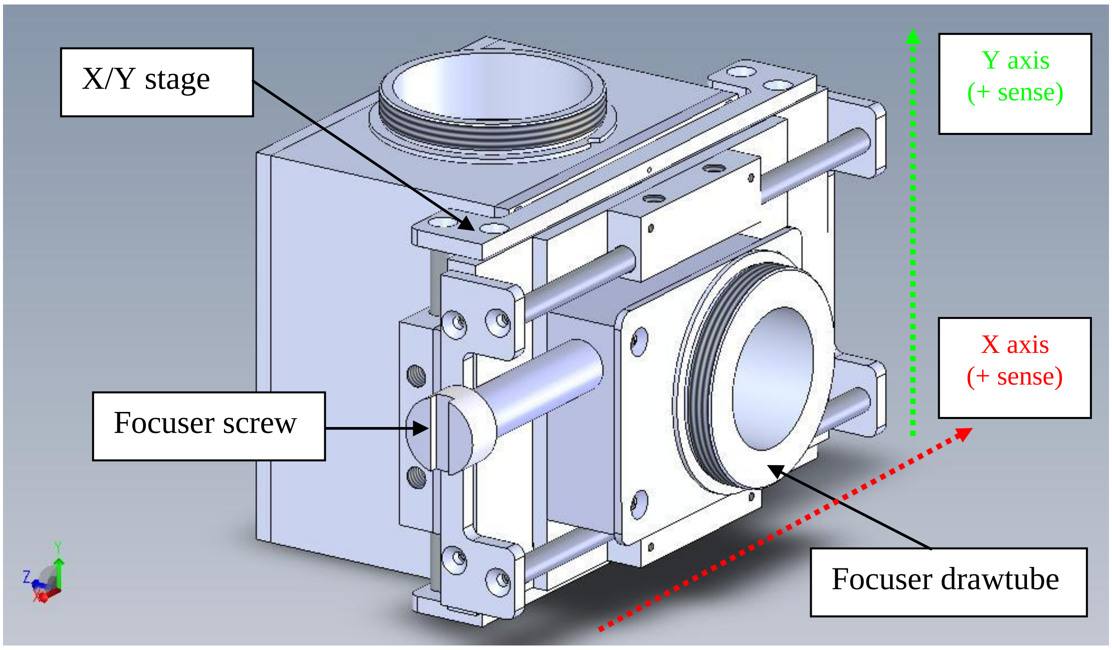
(5) A guider focuser (GF). The GF provides up to 9 mm of travel to adjust the guider focus. The focuser uses a heavy duty compressing ring to insure a 360 degrees grip on the drawtube. This design eliminates any flexure. Since the drawtube is 1¼" in diameter and can be removed, this allows the use of any standard 1¼" accessories. Very handy if your guide camera nosepiece does not come off. In such configuration you may need an extra 1¼" extension tube to reach focus (see section 7). The ONAG® XT features an integrated corrective optics to compensate for any dichroic mirror distortion, leading to seeing limited guide stars.

(6) A X/Y stage (XYS). The XYS allows easy and quick search for a suitable guide star. It is attached to the ONAG® body on one end, while it supports the guider focuser on the other end. The XYS slides in both directions (X, Y axis) using two stainless steel shafts; each axis can be secured with 4 nylon screws (two screws and two thumbscrews) when you have settled on your guide star. For convenience the screws can be tightened to provide any level of friction and comfort, while moving the stage. In normal operation only the two nylon thumbscrews for each axis need to be touched. The other 2 slotted nylon screws are tighten only once using a screwdriver to insure proper smooth motion and remove any play. Do not over tighten them.

(7) A collection of three T-threaded (M42 x 0.75) extension tubes. The ONAG® XT also comes in standard with three dovetail extension tubes of the same lengths. Those tubes are 8 mm, 16 mm and 24 mm long. They can be used in any of the standard ONAG® optical ports (SP, IP, and GP). The XT dovetail extension tubes are used for the SP and IP, however both ONAG® versions use a M42 connection for the GP. With the proper combination they allow a wide range of imager (including DSLR) and guider to reach focus simultaneous (see set-up section 3 for further information). Alternatively they can be used to extend the ONAG® back focus when necessary.



ONAG® optical ports



ONAG® guider focuser and X/Y stage

1. Set-up

For proper operation it is required that cameras, imager and guider, reach focus simultaneously. The three T-threaded extension tubes (8 mm, 16 mm, and 24 mm) are used to conveniently spaced, when needed, the cameras from the ONAG® body.

There are two low profile T-rings for rotating the cameras to the desired positions. Alternatively the ONAG® XT dovetail system offers a total freedom of rotation for the IP and S.
Since the IP and GP male T-threads are longer than the extension tube threads, it is recommended to use the T-ring at those ports. Although they could be used with extension tubes as well, you may run out of thread length to safely secure the cameras.
The ONAG® is connected to your scope using the SP. It is highly recommended to use a rigid assembly, such as the T-thread, the SCT adapter, or a 2" adapter with a compression ring on the scope side. Alternatively you can get custom adapters (for both ONAG®) from our partner *preciseparts* (www.preciseparts.com).
The ONAG® DBS has been laser aligned with care and precision for providing the best results, however an inappropriate user set up could impact significantly the image quality.
Thumb screen set ups may result on poor optical alignment leading to tilt of the camera focal plane and distorted star across the image. Therefore they are not encouraged.
The ONAG® XT features a user tilt/tip mirror adjustment mechanism, see ONAG® XT specific section 9 for further information.
The standard ONAG® does not offer such user adjustment, therefore please do not try to do so, you will upset the factory adjustment and void the warranty.

1.1. Differential back focus

The ONAG® has 66 mm (2.6”) of optical back focus from the SP (front plate) to the IP (T-thread), and 90 mm (3.54”) from the SP to the GP, when the GF drawtube is half way extended.
The ONAG® XT has two more millimeters of back focus, respectively 68mm and 92mm. This document and following examples assumes a standard ONAG®, for the XT version just add an extra 2mm. The DBF table and related calculations are valid for both versions.
This 24 mm (0.98”) difference on back focus, associated with the three extension tubes, allows for a wide range of imager and guider pairs, including DSLR. The XT version comes also with three extra dovetail extensions tubes (same lengths) for the GP and IP. The key factor here is the differential back focus (DBF), which is defined as the difference between the imager back focus (IBF) and guider back (GBF) focus:

$$DBF = IBF - GBF$$

Most of the time this number is greater than zero, but in some configurations it could be negative.

Of course both back focus values must include any related accessories mounted in series with either camera, such as a filter wheel. Should you have a focal reducer FR, see sections 5 and 6 below.
The table below guides you by providing the recommended selection of extension tube (8, 16, and 24 mm) for a correct set-up.
All you need is your imager (including the filter wheel, if any) and guider back focus values, see your product specification, or contact the relevant manufacturer or reseller.
With those two numbers, compute the DBF, and refer to the table.
The table here provides solutions only when using the three extension tubes included with the product.
Should you use your own set up and hardware (extension tubes) here is the equation to compute the necessary extension value.
Positive values mean the guider must be moved away from the ONAG®, negative values the imager must be moved away from the ONAG®.

$$\text{Extension value} = DBF + IXT - 24 \quad \text{(in millimeters)}$$

Where IXT is the length of the imager extension tube used (in mm), if any.
IXT values lower than 16mm will reduce the upper Y axis travel of the XYS leading to a low profile configuration (see 3.2.2).
This equation assumes, like the table, that the guider focuser drawtube is

extended half way (~4.5mm).

DBF [mm]	IP Extension Tube(s) [mm]	GP Extension Tube(s) [mm]	IP Back Focus (IPBF) [mm]	Comment
-24	24 + 16 + 8	None	114	DBF < 0
-16	24 + 16	None	106	DBF < 0
-8	24 + 8	None	98	DBF < 0
0	24	None	90	
8	24	8	90	
8	16	None	82	
16	24	16	90	
16	16	8	82	
16	8	None	74	Low profile
24	24	8 + 16	90	
24	None	None	66	Low profile
32	16	24	82	
32	8	16	74	Low profile
32	None	8	66	Low profile
40	16	24 + 8	82	
40	8	24	74	Low profile
40	None	16	66	Low profile
48	8	24 + 8	74	Low profile
48	None	24	66	Low profile
56	8	24 + 16	74	Low profile
56	None	24 + 8	66	Low profile
64	None	24 + 16	66	Low profile
72	None	24 + 16 + 8	66	Low profile

Recommended extension tube v.s. differential back focus (DBF)

Although the table provides a good indication for selecting the extension tubes, it is only a recommendation. Actual device back focus values from manufactures may deviate from their specification, or may vary over time without warning. Other elements, such as filter thickness and mechanical connections could impact the final set-up as well.
Since most likely your DBF will not be in the table, the normal course of action is to look in the table for the closest DBF, yet some time the one below, or above could be necessary.

For some DBF values there are several options. Either of them will allow both cameras to reach focus simultaneously, however some may require using the ONAG® low profile configuration (see section 3.2).
They also differ on IP back focuses (IPBF). For an optical train and scope point of view, the total optical back (TOBF) focus, including the ONAG® and the imager + its accessories (filter wheel, if any), is the right figure of merit. The TOBF will eventually limit the scope focusing mechanism ability to reach focus. The TOBF, not including accessories before the ONAG® such as a focuser and/or AO unit, can be estimated with the following formula:

$$TOBF = IPBF + IBF$$

The choice of the right option is a function of the scope performance and requirement. In some situations one may want to minimize the TOBF, but there are many cases where we may need a larger back focus.
Most scopes, such as SCT, are designed for some optimal back focus distances, for which they reach their nominal specifications (such as focal length, F number, field of view).
For instance the Celestron EdgeHD SCT series have a built-in corrector, and they will provide optimal performance if the focal plane is at, or near, a predefined distance from the scope visual back. According to Celestron (http://www.celestron.com/c3/support3/index.php?_m=knowledgebase&_a=viewarticle&kbarticleid=2260):

133.35 mm for 8” EdgeHD SCT
146.00 mm for 9.24”, 11”, and 14” EdgeHD SCT

In such case you may even add spare extension tube(s) on the SP to reach the right distance.

<u>Example #1:</u>

Imager SBIG ST-4000 XCM

IBF = 23 mm back focus

Guider SBIG Remote guider head

GBF = 17.53 mm back focus

Differential back focus DBF = 23 – 17.53 = 5.47 mm

The closet DBF option from the table above is 8 mm of DBF. This means either, a 24 mm extension tube on the IP with a 8 mm extension tube on the GP (IPBF = 90 mm), or a 16 mm extension tube on the IP with no extension on the GP (IPBF = 82 mm).

This gives us two possible values of TOBF:

a) IPBF = 90 mm

TOBF = 90 + 23 = 113 mm (4.45”)

b) IPBF = 82 mm

TOBF = 82 + 23 = 105 mm (4.13”)

Option b) will provide the smallest optical back focus.

If used with a Celestron EdgeHD 8” SCT (without any other accessory in the optical train) you may want to use option a) and add the 16 mm extension tube between the SP and the provided low profile SCT adapter (7.5 mm back focus). This will place the imager focal plane at:

113 + 16 + 7.5 = 136.5 mm

Only 3.15 mm (1/8”) too far . This is close enough.

<u>Example #2:</u>

Imager DSLR Canon EOS (EF and EF-S mounts)
Flange back focus distance = 44 mm
T-ring adapter for EF/EF-S mount back focus = 8 mm

IBF = 44 + 8 = 52 mm back focus

Guider ORION StarShoot autoguider

GBF = 15 mm back focus

Differential back focus DBF = 52 – 15 = 37 mm

The DBF closest option from the table is 40 mm. The three possible options lead to:

a) IPBF = 82 mm

TOBF = 82 + 52 = 134 mm (5.28”)

b) IPBF = 74 mm   low profile configuration, see 3.2

TOBF = 74 + 52 = 126 mm (4.96”)

c) IPBF = 66 mm   low profile configuration, see 3.2

TOBF = 66 + 52 = 118 mm (4.65”)

Be aware that option c) could prohibit access to some DSLR functions and interface, if its body is too close to the ONAG®.

1.2. Standard versus low profile configuration

The ONAG® has three effective degrees of freedom for exploring the field of view in search for a guide star.
The X/Y stage (XYS) provides two orthogonal axis X and Y (see section 2), while the rotation of the ONAG® body adds a third degree for freedom. This gives an overall exploration circle up to 46 mm in diameter and allows the ONAG® to be used in different and flexible ways.
There are two fundamental configurations, standard and low profile, which can be used to optimize the set-up.
While the X stage axis can always be used at full range, there are may be travel limitations for the Y axis, please see the section below.

1.2.1. Standard profile configuration

In the standard configuration the XYS can be fully extended in the upper Y axis portion (positive sense, toward the IP, see section 2). This is possible only if a 16 mm, or more, extension tube(s) is attached on the IP. Otherwise the XYS will experience limited Y travel toward the IP (see low profile section 3.2.2 below).
With the standard configuration the XYS can be used alone to search for a guide star across the full field of view. When used in conjunction with ONAG® body rotation you can achieve up to 23 mm of off-axis offset (both X and Y axis at travel ends)!

However this configuration leads to more total optical back focus (TOBF).

1.2.2. Low profile configuration

In low profile configuration the Y axis travel is limited, as follow:

With a 8 mm extension tube there is 16 – 8 = 8 mm reduction of Y axis upper portion travel.
With no extension tube there is no travel on the upper Y axis portion anymore. Any configuration below 16 mm will restrict the travel by:

$$\text{Travel restriction [mm]} = 16 - X$$

Where X is the length (X<16 mm) of the extension used in mm. In the low profile configuration the lower portion of the Y axis travel, and all the X axis travel range, are fully usable.
Therefore a rotation of the ONAG® up to 180 degrees will allow access to the full field of view when searching a guide star. What is left of Y axis travel combined with the X axis and the ONAG® rotation provides again an exploration circle up to 46 mm in diameter. The low profile configuration is recommended if a short TOBF is desired (see table on section 3.1).

2. Using the ONAG®

The use of the ONAG® is quite simple. First focus both cameras, next you select a guide star and then you are ready for a normal imaging session using your usual auto-guiding hardware and software.
If you are not using an automatic tracking calibration procedure, you do not have to be concerned by the inversion effect of the dichroic mirror in your manual entry. The guider uses the light coming straight through the DBS, there is no reflection involved here.
The recommended focusing procedure, assuming you have the right extension tube set-up, see section 3 above, is as follow:
Center the XYS using the two yellow rulers (position at 0). Gently tight the nylon screws to insure an easy slide of any axis in any direction when displaced by hand, while the stage does not move under its own weight.
Tighten the GF stainless steel focuser screw just enough allowing a smooth travel of the drawtube with a minimum of play.
Select a bright star near your target (do not over expose), or the zenith, and center it on the imager. Then focus the imager using the scope focusing

mechanism, as usual. Using the XYS, center the same star and focus it using the GF, tighten, by hand, the GF screw (never use a tool.)
If you can not do so you may have to reconsider your extension tube selection.
When you move the ONAG® guider focuser drawtube all the way, the guide star should change form from a vertical ellipsoidal shape to a horizontal ellipsoidal shape, or the opposite in function of your CCD reference frame position. The optimal focus point is achieved when both ellipsoid collapse becoming a spot, or a little cross. This is normal and not a source of concern. This feature becomes handy when manually seeking for best focus. The ONAG® XT has an integrated corrective optics and therefore does not exhibit such effect, the guide star is round and seeing limited.
Since most scopes and optical components are not optimized for the near infrared (NIR) there is maybe small distortion involved.
Autoguider algorithms are mainly based on centroid algorithms and are not sensitive to this. They average pixels from the all guide star area, so the maximum pixel value or FWHM are not much relevant in this case, unlike for imaging. If you use computer assisted focusing software, such has Maxim DL, the right figure of merit should be the half flux diameter (HFD), or ½ FD. The half-flux diameter is the diameter in pixels that contains half the energy in a star image. In other words, if you add up the pixel values (less the background) inside the diameter, and outside the diameter, you will get the same number. This measurement gives a very similar answer to FWHM, but it is much more robust in the presence of seeing, noise, and can handle non circular distorted images, even out-of-focus like "donuts". The HFD varies linearly with focus position making it reliable to locate the best focus regardless the star shape.
If you use the PHD guiding software watch the SNR value, you should seek for its maximum. If you do not use any software, the best focus will be achieved when the guide star cross like shape is minimized and symmetric.
The two images below show the same guide star seen from the imager (IP) on the left or from the guider (GP) on the right at best focus, same camera, set-up, and cropping.

Guide star seen from IP
HFD=6.0px, FWHM=3.4px

Guide star seen from GP
HFD=6.2px, FWHM=5.2px

The cross like shape of the guide star viewed from the GP is clearly visible. Yet as far as the energy budget is concerned both cases have almost the same HFD. The GP larger FWHM is due to the star non-circular shape.

During this focusing process avoid to over exposing the guide star. Doing so will bias the HFD values, and make the star shape more difficult to guess for accurate focus.
Bright over expose stars may result in ghost images offset by few millimeters (hundreds of pixels). Those are reflections from the DBS and nearby surfaces, such as the CCD/camera windows. Most optic are not coated for NIR. The reflections are out of focus and will look like faint stars with "donuts" like shapes. This is not issue.
When you reached the desired focus, hand tight the ONAG® focuser screw (stainless steel) to avoid any motion or flexure.
Now you are ready to come back to your target. Center and fine focus it on the imager. Then it is time to locate and center your guide star on the guider camera using the XYS. If necessary adjust the guider focus with the GF.
Now tighten by hand all 4 nylon thumbscrews to avoid any flexure (never use a tool.)
Proceed with your imaging session.
Should you keep your cameras attached to the ONAG® for the next session, there is no need to focus the guider again (if you did not touch the GF).
You will just need to focus the imager and use the XYS to locate the guide star, which will be automatically on focus, saving time.

Although if the DBS has a high efficiency broad band antireflection (AR) coating on its back, if you overexpose bright star(s) you may experience dimmed ghost images of them offset by few hundred pixels, unless your imager has a near infrared (NIR) cutting filter.
Most, if not all, one-shot color cameras and DSLR have UV + NIR blocking filters. Monochrome ones usually do not, however the associated filters, such as LRGB should take care of this, cutting the NIR, typically above 700 nm.
If not you may have to consider adding a UV-NIR filter in front of the imager. Alternatively should you want to image in NIR, avoid overexposing your target. For scientific and research purpose a ghost image may not be much an issue since it is dimmed and offset from its source by about 3 mm.
In any case **never place any NIR filter, or any other filters blocking the NIR, in front of the ONAG®**, otherwise you will not have any image of

any star on your guider camera!

3. Focal reducers

Focal reducers FR can be used with the ONAG®. Those reducers should be located at a specific distance DFR from the imager focal plane, please refer to your reducer specification and user manual. There are two options available:

You can place the FR in front of the ONAG®, at the SP, if your TOBF associated with your set-up matched the FR required back focus.
Most popular 0.63x focal reducer/correctors (such as Meade or Celestron) can be used in a range of +/-1" (+/- 25mm) to their nominal DFR values without any significant alternation of their correction performances.
However the actual reduction factor h is a function of the distance q from the focuser to the imager focal plane.
If q is different from its nominal DFR value, so h. In first approximation we have:

h=1-q/f   and   q=f (1-h)

Where f is the reducer effective focal length.

For instance the Celestron 0.63x corrector/reducer has a focal of 235mm, therefore its nominal DFR value is:

$DFR_{0.63x}$=235 (1-0.63)=87mm, or 3.42"

If placed one inch further away from the imager focal plane its reduction factor $h_{+1"}$ becomes:

$q_{+1"}=DFR_{0.63x}+25.4=112.4$mm

$h_{+1"}=1-112.4/235=0.52$x instead of 0.63x, a 17% decrease.

FR in front of ONAG® example #1:

Reducer Starizona SCT corrector 0.75x

DFR = 90mm

Imager SBIG ST-8300C

IBF = 17.5mm

ONAG® in low profile mode

Back focus = 66m.

You will need an extension tube of 90-66-17.5=6.5mm to meet the Starizona DFR value of 90mm.

<u>FR in front of ONAG® example #2:</u>

Reducer Celestron 0.63x (f=235mm)

DFR = 87mm

Imager QSI-683ws

IBF = 35.5mm (1.4")

ONAG® in low profile mode

Back focus = 66mm

q=66+35.5=101.5mm leading to a reduction factor:

h=1-101.5/235=0.57x 9% larger.

The second option is to place the FR at the ONAG® IP, before the imager. In this case the ONAG® back focus does not play any role anymore. We are here in the classical situation.
However you will have to find the right spacing for reaching focus with your guider by trial and error, since the table from section 3.1 above will not be correct anymore. Most likely you will need to use extra extension tubes to move the guider further away from the ONAG® body.
The following relation is useful to guide you through this process:

p=q/h

Assuming you are in focus at the imager focal plane with the FR in place then p is the distance from the FR to the scope focal plane. This is the distance where you would be in-focus if the FR is removed and the scope focus is left untouched. In short with a FR you have to focus your scope at a plane behind the FR located at the distance p from the FR. This is also the distance you need to consider for the guider, since in this configuration FR is not part of its optical path. For instance with a Celestron 0.63x focal reducer (f=235mm, DFR=87mm) p should be:

p=87/0.63=138mm

It is worth to mention that the calculation of the effective focal reduction factor h is more complex with a SCT since those scopes require moving the principal mirror forward, which in return changes the scope effective focal length f.

For most SCT the focal length increases roughly 3 to 4 times faster than the back focus. Let's use an average value of 3.5 times.

The nominal SCT focal length $f_{nominal}$ is reached around 100mm (4") of back focus (from the visual back). This allows for a star diagonal and eye piece room.

For instance with a C11 at f/10 we have $f_{nominal}$=2800mm. Therefore if we use a Celestron 0.63x FR in front of the ONAG®, in low profile mode, the effective focal f becomes:

p=138mm

ONAG® back focus=66mm

$f_{0.63x}$ = 2800+3.5 (138+66-100)=3164mm

And the resulting effective reduction factor h is:

h=0.63 (3164/2800)=0.71x

About 13% larger which means a reduced focal length of 1993mm instead of 1764mm. You effectively use this C11 at f/7.1.

The Celestron FR 0.63x, or other ones for that matter, will still correct for the SCT field curvature as before, with a slight change in h.

In short the FR does reduce the SCT focal length f and does retain any of its optical correction capability, when applicable. However due to the FR back focus f is larger than $f_{nominal}$ leading to a larger reduction factor h relative to $f_{nominal}$.

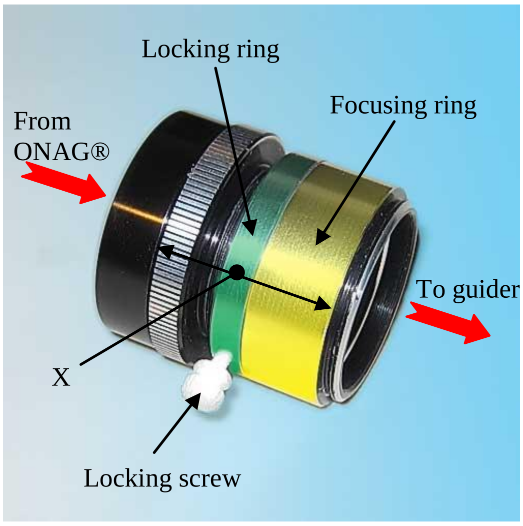
4. Adjustable focal reducer AFR

In order to minimize the resulting guider optical path associated with a FR in front of the imager (ONAG® IP) IF offers an adjustable FR (AFR) for your guider.
The AFR works with almost any FRs as well as most guiders. It has been optimized for NIR imaging using fully multi-coated aspheric optics.

AFR adjustable FR for NIR

ONAG® mounted on C8 with AFR

The normal procedure with the AFR will be to place your imager FR directly at the ONAG® IP. You may need adaptors for your FR to interface with the ONAG® T-thread IP. IF offers a low profile female T-thread to male SCT adaptor for popular 0.63x FR.



AFR parts and nomenclature

Then place the AFR at the ONAG® GP in one end and connect with your guider in the other end.
Now position the ONAG® guider focuser half way out (about 4mm), this will give you some room for fine focus later.

Search for a bright star, but do not over expose, and place it at the center of the imager, carefully focus your scope. Center the ONAG® X/Y stage (zeros on the yellow rulers).

For the next step you need to estimate the AFR extension value X (see the AFR parts and nomenclature figure above). The required X value is given by the following relation:

$X=q_{AFR}-GBF$

With GBF your guider back focus and

$q_{AFR}=q/h\ (102/(q/h+102))$

the required AFR back focus.

Where q (in mm) and h are your imager FR back focus, most likely q=DFR, and its reduction factor respectively. See your FR specifications and user manual for those values. By the way the above SCT comment does not apply here.
By adding, when necessary, one or more ONAG® T-threaded extension tubes (8, 16, 24mm) you have access to a large range of AFR extension value X listed in the table below:

X Minimum [mm]	X Maximum [mm]	Extension Tube(s) [mm]
26	36	None
34	44	8
42	52	16
50	60	24
58	68	24+8
66	76	24+16
74	84	24+16+8

AFR extension value ranges v.s. extension tubes

Select a suitable range from the table and adjust the AFR focusing ring to bring the AFR extension length close to the selected X value with the extension tube(s), if any. You can use a ruler to help.

Now focus the guider using the AFR focusing ring, you may have to adjust the ONAG® X/Y stage to center the star. When done, secure the AFR focusing ring using its locking ring and the associated screw.

Fine focus can be achieved with the ONAG® guider focuser if necessary. Now you are ready to use your ONAG® with your FR and the IF AFR.

<u>Example #1:</u>

Reducer Celestron 0.63x

DFR = 87mm and h = 0.63x

Guider Orion StarShoot autoguider

GBF = 15mm

q_{AFR} =87/0.63 (102/(87/0.63+102)) = 58.7mm

X=58.7-15=43.7mm

From the table above we have two options, adding a 8mm, or a 16mm T-threaded tube.

<u>Example #2:</u>

Reducer Starizona SCT corrector 0.75x

DFR = 90mm and h = 0.75x

Guider SBIG Remote guider head

GBF = 17.5mm

q_{AFR} =90/0.75 (102/(90/0.75+102)) = 55.1mm

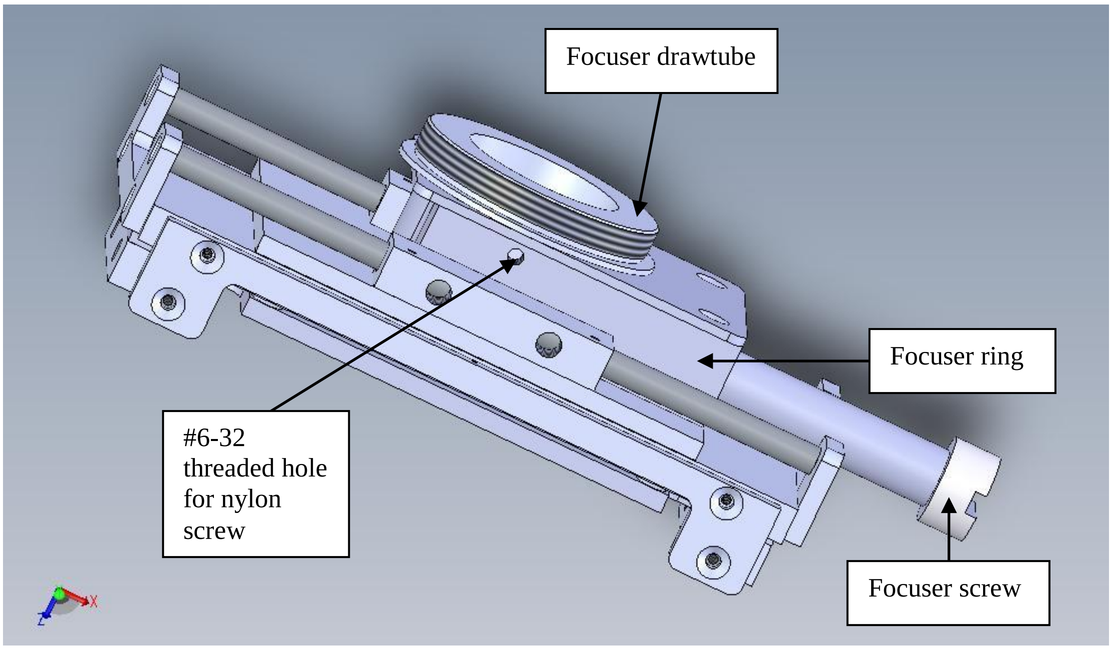
X=55.1-17.5=37.6mm

From the table above we need to add a 8mm T-threaded extension tube to reach focus with our guider and the Starizona FR attached to the imager.

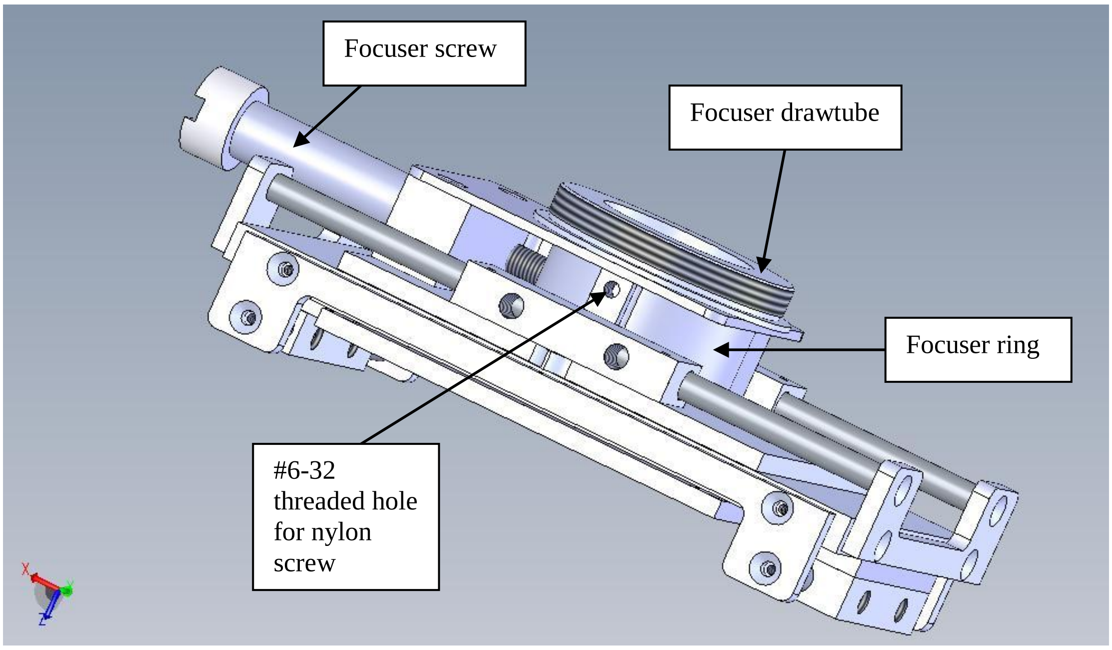
5. Removing the GF drawtube, use of a 1¼" nosepiece

Use a 1¼" nosepiece instead of the GF drawtube, first you will need to remove the drawtube.
There are two #6-32 nylon screws on each side of the focuser compression ring. Those screws slide in two key slots, or groves, stopping the drawtube for leaving the focuser compression ring.
Remove and save the two screws, now slide the drawtube away, and then place your 1¼" nosepiece instead.
You can use the compression ring to lock it at the desired position. However, remember there **is nothing stopping the nosepiece and your guider camera from falling** anymore if the compressing ring screw is not tightened!

Be careful, Innovations Foresight cannot be held responsible for the consequence of such an accident. This ONAG® GF mode of use is provided for convenience only, and it is the sole responsibility of the user to take the necessary precautions.



XY stage and guider focuser, top view



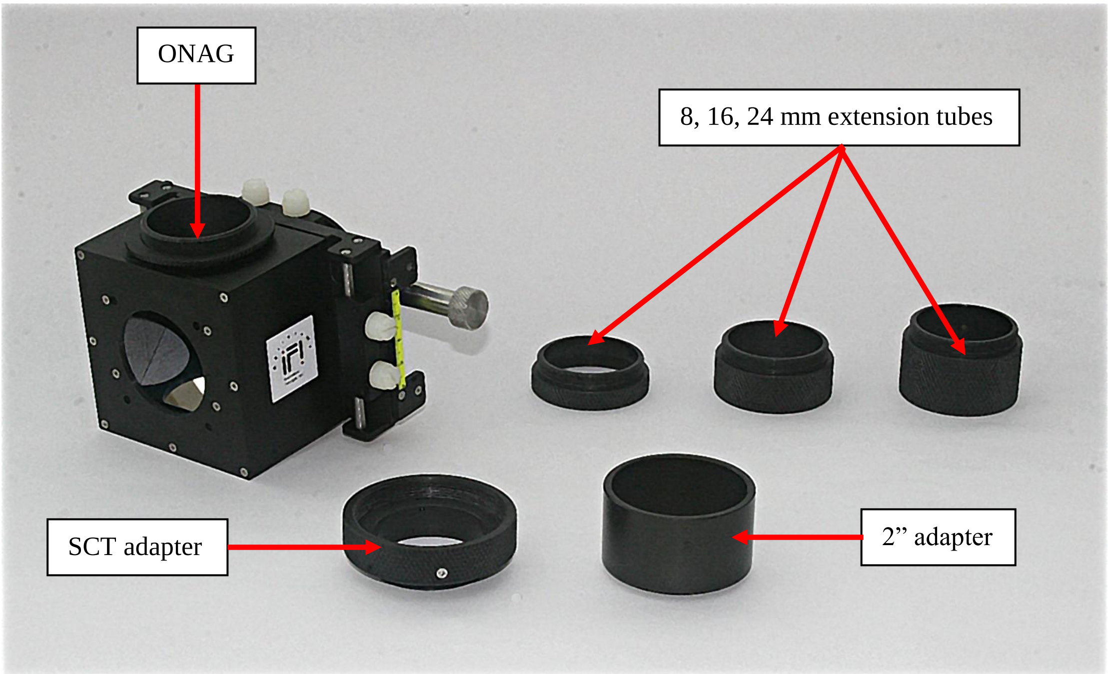
XY stage and guider focuser, bottom view

Note that in such configuration T-treaded extension tubes are not an option anymore and you will have to use 1¼" extension tubes, if any, instead. Those are readily available from many sources.
When you put the drawtube back in place**, do not forget to replace the two nylon screws and to check** that they will prevent the drawtube from falling. The drawtube comes lubricated with grease for easy tube travel. Should You have to add some, use just a bit of grease to avoid any spillage on the DBS and ONAG® inside body. Grease for aluminum alloys with a large temperature range is recommended. **Never use oil**.

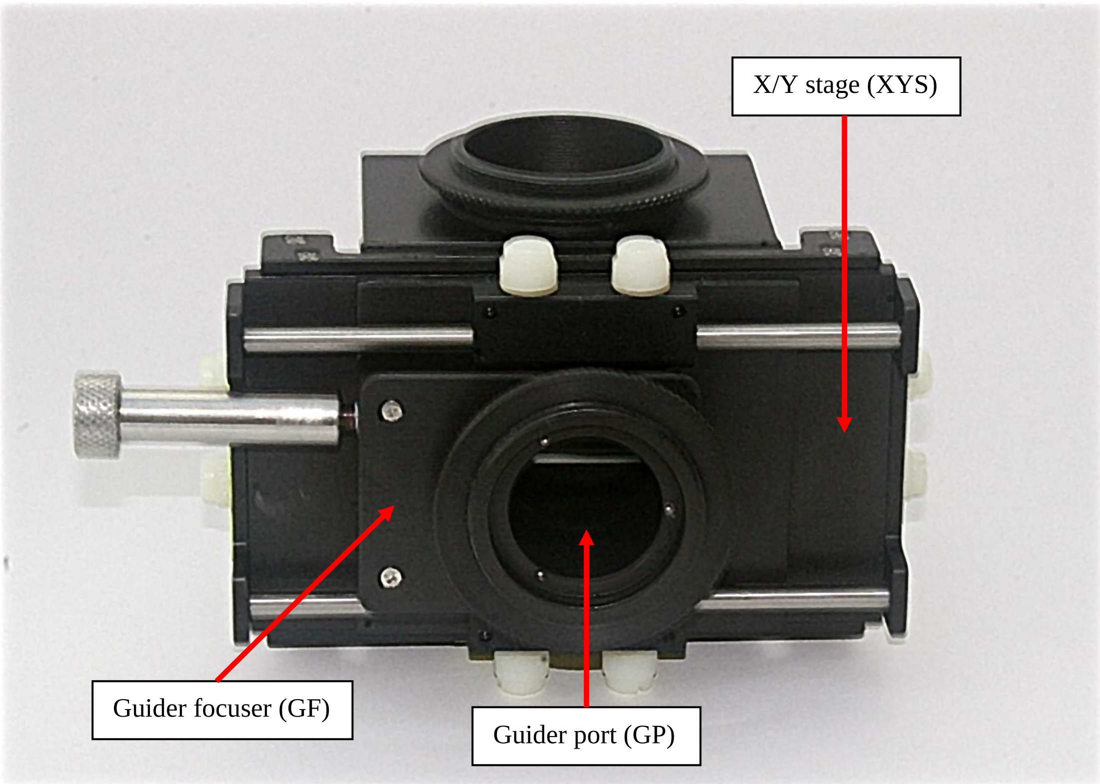
6. Low profile SCT adapter

The provided low profile SCT adapter allows the ONAG® to be attached to a standard SCT male thread (2" 24 tpi) with a minimum of back focus (7.5 mm, about 1/3").
The adapter comes mounted with Phillips stainless steel screws to secure the SCT female ring with the T-thread core. First screw the adapter to the ONAG® SP, or any T-threaded accessories mounted in front of the ONAG®, such as AO unit, tighten it.
If you want to freely rotate the SCT female ring, remove and save the screws with a Phillips screwdriver. To remove the adapter from the ONAG® SP, or other accessories, put the screws back in place and then unscrew the adapter.

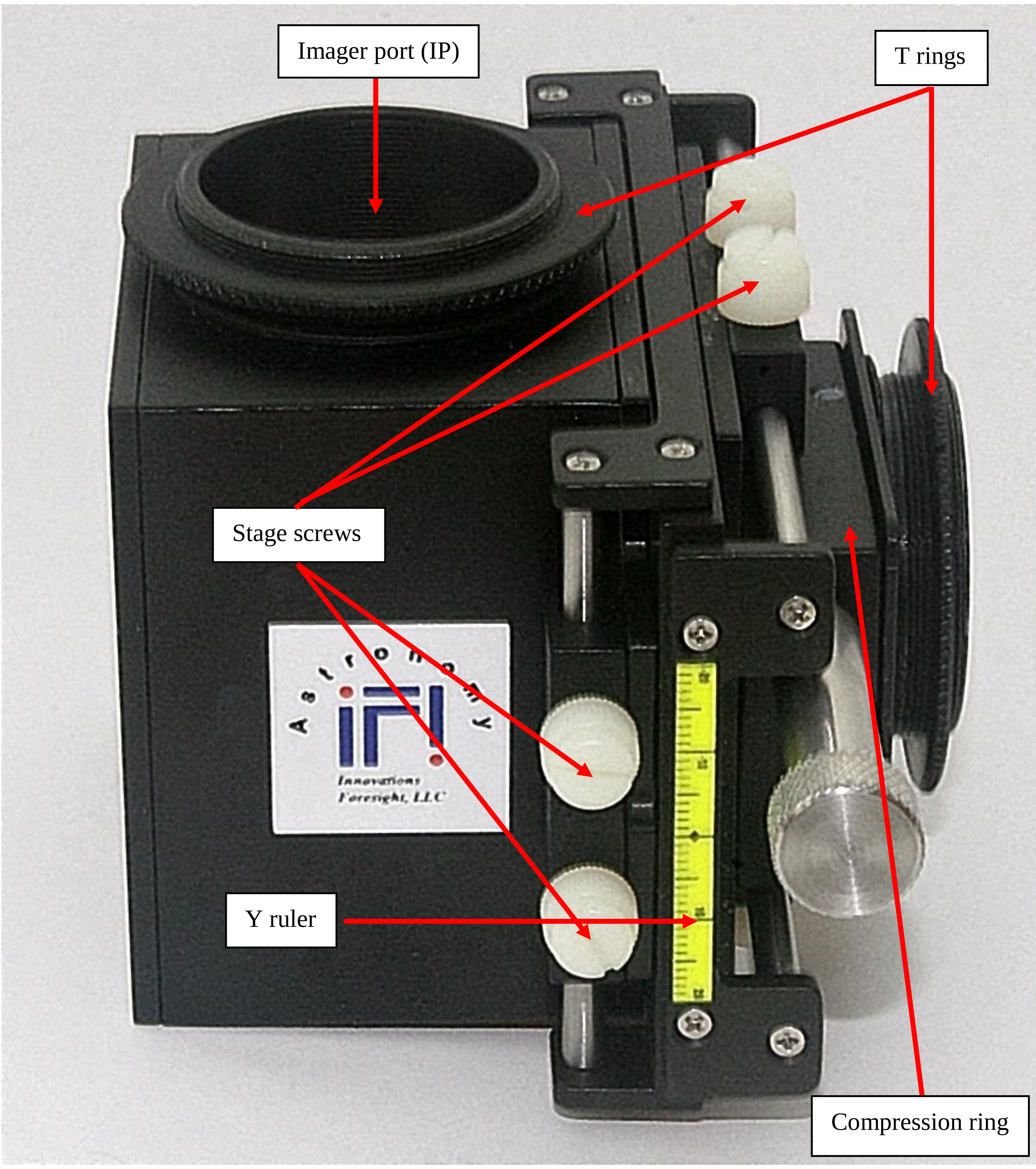
7. ONAG® and its parts



ONAG® and its parts

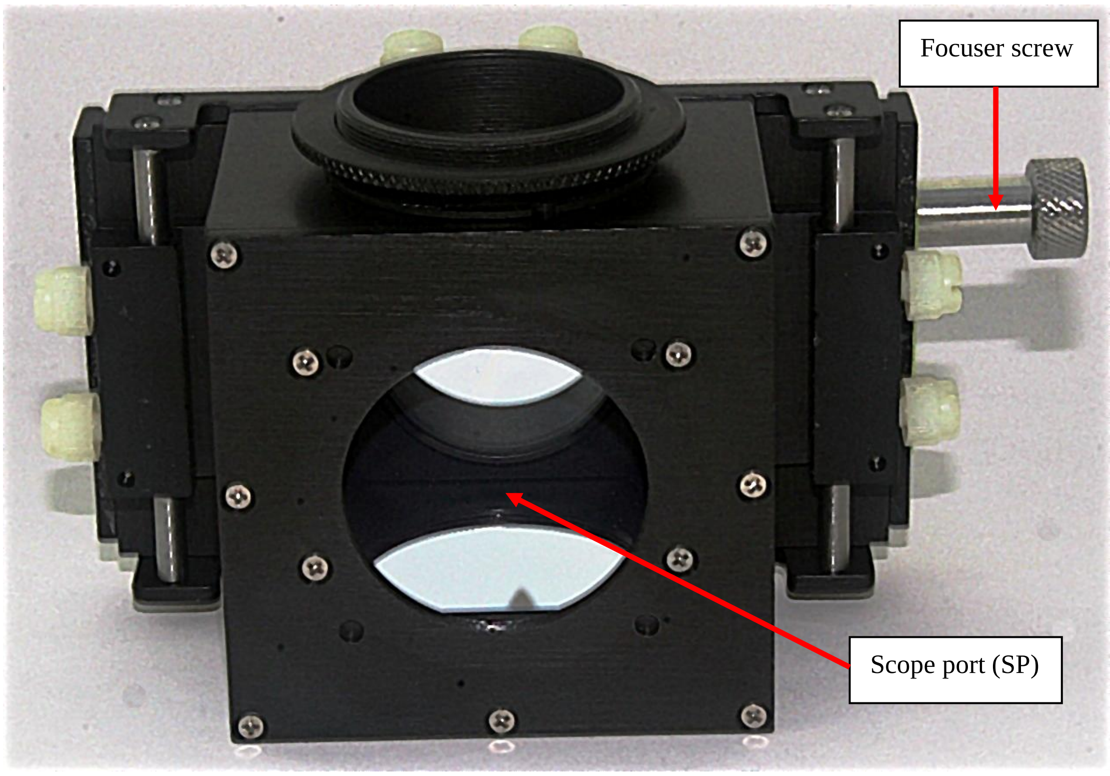


ONAG® back view

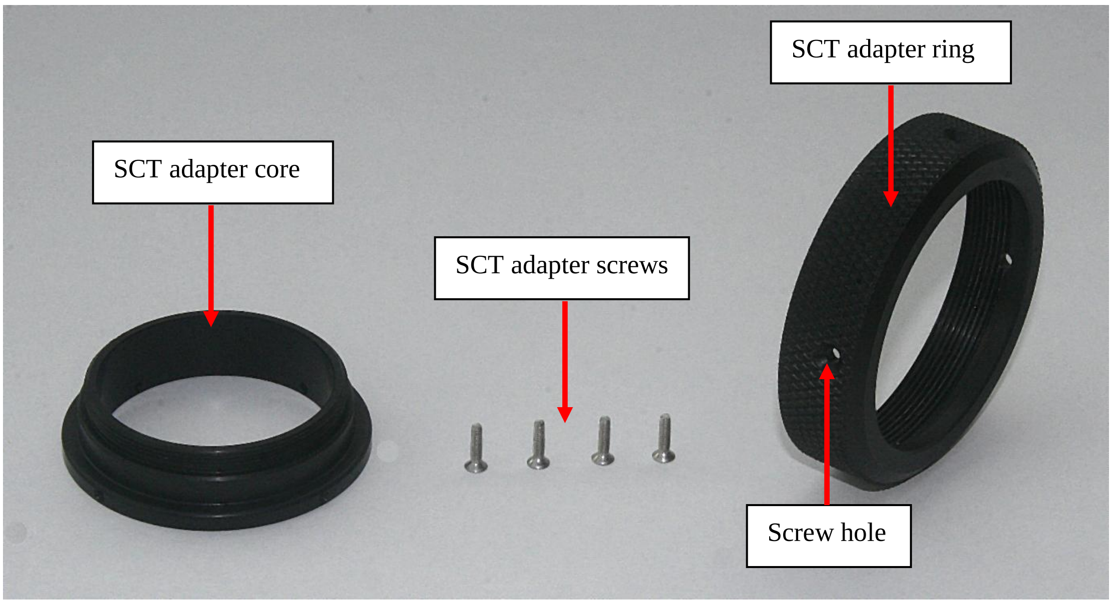


ONAG® side view

Notice: New ONAG® (serial number 4000 and above) and the XT version have 4 nylon thumbscrews only. The four others are nylon slotted screws which may be adjusted to insure easy smooth stage motion. Usually this is done once, than the four thumbscrews are more than enough to insure a rigid, play free stage, when hand tighten.



ONAG® front view



SCT lower profile adapter

ONAG® mounted on Celestron 8" ("orange" tube) with SBIG ST2000XCM imager and Orion StarShoot autoguide

8. ONAG® and tracking software, some considerations

Although the ONAG® solves differential flexure problems while featuring a wide field of view to locate a suitable guide star, the tracking software is also a key element in the all process of auto-guiding.
It is paramount to understand its basic operation and choose the right software settings to achieve good image quality.
There are many tracking software available, such as Maxim DL, PHD guiding, GuideDog to name few. They typically use centroid algorithms averaging pixel values all around the guide star area to estimate its position with sub-pixel accuracy. The guide star shape does not matter much, as long as it is not clip, consistent across frames and is not too much spread or fain.
For that matter the little cross shape of the guide star seen from the ONAG® GP in NIR does not impact the software tracking capability.
Guiding with the ONAG® means using the same focal length than imaging, and unlike guide scopes, this translates most of the time to a small field of view, especially for long focal scopes. Meaning for each guide star frame we may expect having more seeing effect and other short term perturbation contributions. Therefore most of the time it is recommended to bin the guider image by 2x or 3x, which will average nearby pixels, unless the guider pixel size is much great than the imager one, 4x or above.
This can be seen as a low pass filter operation, limiting seeing and chasing the noise like guide star motion at each frame.
Yet the most important single parameter of any tracking software is the aggressiveness, which is the level of correction the algorithm will apply to the mount after each new guide star frame. In control system theory (close loop systems) this is known as the feedback gain G_f.
If it is too low the correction is not enough to compensate for the mount drift. In the other hand if G_f is too large the correction will become instable and erratic. The later is the most problematic and common issue in tracking leading to elongated star in the images even with near perfection optics.
From the above considerations we recommend you start with a low aggressiveness (1/2 or 50%, or less) to begin with, and increase it slowly only if you have to. For instance for Maxim DL this means 5, in PHD guiding this would translate to 50, for both cases it is half way to full scale correction (1, or 100%), or less.
A common figure of merit for the tracking error quality evaluation is the rms (root mean square) error value over a time window. However even with a low error value you still may experience elongated stars.
Very often bright stars are much brighter than the target under consideration for your imaging session, such as galaxy, or nebulas.
During several minute of exposure a short extreme erratic tracking correction during a second or so way above the rms value will be enough to distort the

bright stars. Those outliers are more likely if G_f is large. They may also come from some mechanical problems, such as over compensated backlash by the mount software.

If your mount is equipped with a periodic error correction (PEC) you should use it. We also recommend unbalancing just a little your mount in AR, making it "East heavy" to avoid any backlash on the RA axis. Be aware this must be done differently for both meridians on equatorial mounts.

Backlash compensation done by most mount software may result, if too large, in bumping the mount, especially on DEC axis (equatorial mounts) for which the drive motor can reversed it direction. Yet too little backlash compensation leads to lag in the correction and erratic tracking. If you have difficulties to solve this DEC problem you can use a simple technique:

Just disturb a little bit the mount polar alignment, this will result in a single direction DEC drift, the DEC drive motor does not need to reverse anymore avoiding backlash issues.

Most software allows disabling either correction direction in AR and DEC, use this feature when available. You need just a very little polar alignment error to accomplish this trick.

Do not misalign your mount too much otherwise long exposures may exhibit field rotation.

If this is your first experience with guiding at the same focus than imaging, you will need some time to find the right settings most likely, but the reward will be huge in term of image quality. Should you need more support or advise please feel free to contact us we will be glad to help.

9. <u>ONAG® XT specific</u>

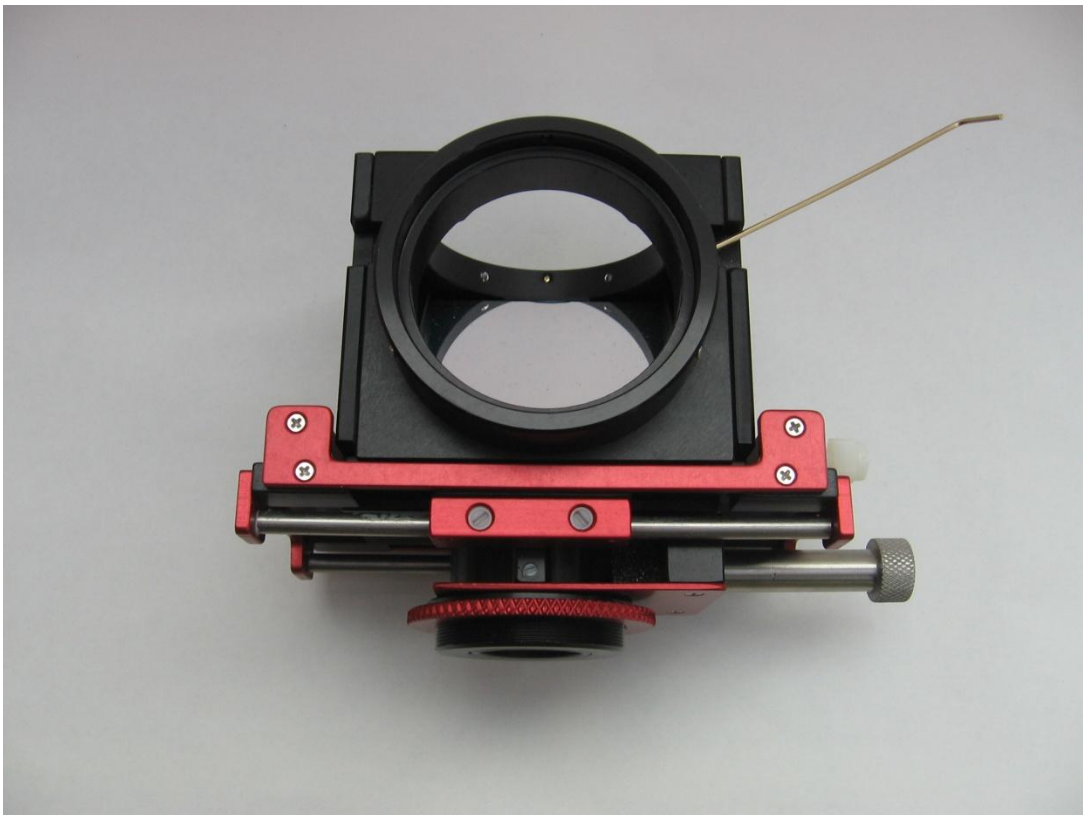
This section describes the ONAG® XT specifically features and procedures. Please read the above sections carefully first.

Below an image of the ONAG® XT with its included accessories.

ONAG® XT and its accessories

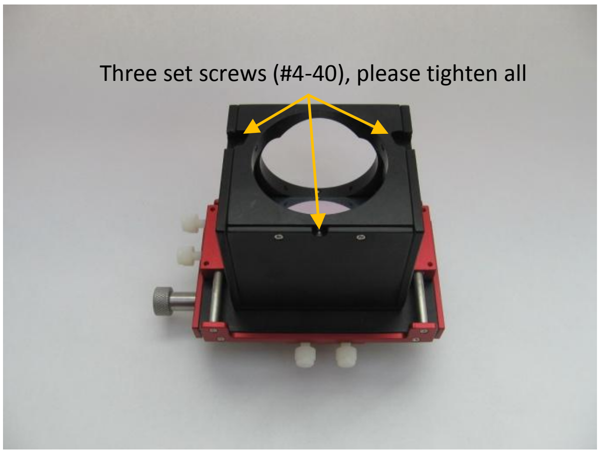
There are three M42 (T-thread) and three male/female dovetail (59mm) extension tubes of length, 8mm, 16mm, and 24mm. Also provided female and male adapters for 2" and STC connections.
The provided 2" female adapter has a stainless steel thumbscrew for the compression ring (full body), as well as a second thumbscrew to secure any nosepiece in place (usually using a nosepiece grove). We do recommend that you use it to avoid any accidental drop of equipment due to the scope/mount motion.
Please do not over tighten this screw, it is made in stainless steel and will mark the nosepiece if excessive force is used. Although the compressing ring provides a very rigid connection accident may happen and it is a good practice to have this back system to lock in place your equipment.
This female adapter has a 30mm depth which is more than enough for most nosepieces. Be carefully not to exceed this length otherwise you may touch and damage the dichotic mirror. Innovations Foresight would not be responsible for product (ONAG®, ONAG® XT and associated accessories) and equipment damages due to failure to follow proper procedures, recommended care, and good practice.

The ONAG® XT uses a 59mm dovetail system for the IP and SP. This insures a rigid, squared, and secure connection, as well as provides minimum back focus solutions. Each female dovetail is equipped with three #4-40 UNC stainless steel set screws. They **must all be tightening** to insure a secure attachment using a 0.05" Allen (hex-key) wrench (one is provided with the ONAG® XT). The set screw tips are made of either brass of nylon to protect the aluminum surface of the male dovetail part. Only limited force is needed to lock in position the dovetails, please do not over tighten the set screws. We do recommend that you use the long side of the Allen wrench, as shown in the image below, resist using the short side which may lead to excessive torque.



Allen wrench recommended procedure to use with the dovetail set screws

The two images below show the location of the set screws on the ONAG® XT body. Accessing the third dovetail IP set screw requires moving down the X/Y stage toward the negative direction of its Y axis.



ONAG® XT IP set screw locations *ONAG® XT SP set screw locations*

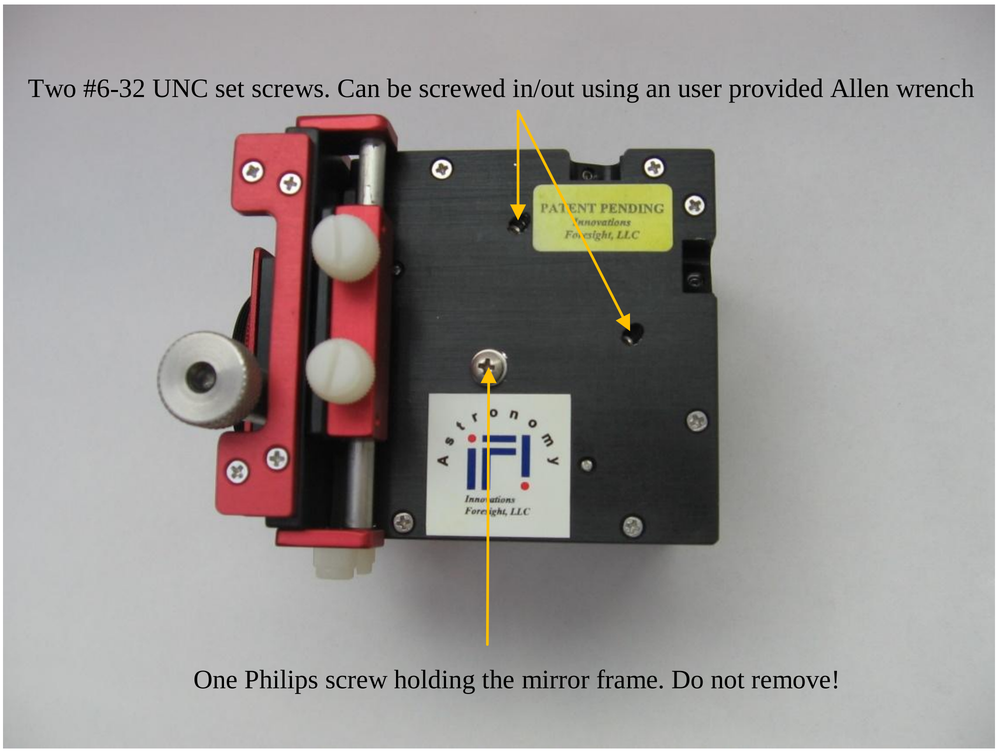
The ONAG® XT features a user dichroic mirror tilt/tip adjustment mechanism. The product is laser aligned at factory, however tilts/tips in the optical train are common issues and are especially of a concern for large CCD ships.
Those problems could comes from various sources, such as focuser and adapters not squared, thread plays and tolerances, …

We recommend first that you have a well collimated scope before adjusting the ONAG® XT dichroic mirror, if any.
First a good collimation should be achieved in accordance with scope manufacturing recommendations and procedures.
Most of the time the optical train length should be kept at minimum by removing un-necessary piece of equipment, including the ONAG® XT at least for the first time, during collimation.

Trying to adjust the ONAG® XT dichroic mirror, while the scope is out of collimation, will most likely results in failure to reach a good collimation leading to poor images. It is important to understand that he ONAG® XT dichroic mirror tilt/tip adjustment does not replace the scope collimation mechanism.

The mirror adjustment is based on two sets of three screws, one for the left and on for the right side of the ONAG® XT body.
The mirror is supported, from below, with four spring loaded balls.

The image below shows those 3 screws for the ONAG® XT left side.



ONAG® XT dichroic mirror tilt/tip screws

The Philips central screws keep the mirror holding frame in place and they should not be removed in any condition. Doing so will void the warranty.
We recommend that you do not touch them (left and right sides) unless it is absolutely necessary. Most of the time you should not need to do so since the necessary tilt/tip correction, if any, should be very small. Keep in mind moving the mirror by any amount will translate to the double of light angle deflection amount of change.
The primary procedure is based on very small corrections. The two set screws #6-32 UNC are set at 45 degrees and can be screwed in/out with a user provided Allen wrench (do not use excessive torque and/or use electric tools).

The procedure is quite simple and can be applied iteratively:

If you thigh by the same amount the two (left and right sides) bottom set screws in same time the image on your imager camera will move up/down accordingly (up or down is relative to, and function of, the camera and software set up of course).
If you thigh by the same amount the two (left and right sides) top set screws in same time the image on your imager camera will move down/up accordingly.

The same mechanism and approach is valid for left and right scenarios.

If you thigh the two set screws (top and bottom) on the left side the same amount together the image on your imager camera will move right/left accordingly (right or left is relative to, and function of, the camera and software set up of course).

If you thigh the two set screws (top and bottom) on the right side the same amount together the image on your imager camera will move left/right accordingly.

For small tilt/tip corrections, which you should usually expect, we suggest you only tight the set screws.

Should you run out of correction range with the set screws (you cannot thigh them further), then you could un-screw the two Philips screws just enough for the spring mechanism to push the mirror up. Then use the set screws has before, but now you can also un-screw them. When close to the correct position tighten the two Philips screws again and do the final fine adjustment using the above procedure.

Remember moving the mirror will change the image twice faster. Do only incremental tiny corrections. Try first with very little motion to learn how your image changes, this will give you the necessary feedback for the actual adjustments.
Do not over tighten the set screws. If you cannot screw them further, or need to apply excessive torque chance is you are fully screw in and you need to lose a bit the two Philips screws then.

10. Specifications (no extension tube or adapter attached)

In between […] for XT version.

Over all dimensions:	123 x 92 [110] x 83 [70] mm
ONAG® weight:	770 [800] g
Imager back focus:	66 [68] mm
Guider back focus, half way extended:	90 [92] mm
X/Y stage, full X travel:	37 mm
X/Y stage, full Y travel (excepted low profile):	28 [24] mm
X/Y stage, maximum off-axis offset:	23 [22] mm
X/Y stage maximum exploration circle:	46 [44] mm
Low profile SCT adapter thread:	2” 24 tpi
Low profile SCT adapter ring inner depth:	12.5 mm [male 11, female 8]
Low profile SCT adapter back focus:	7.5 mm [male 2, female 4]
2” tube adapter outside length:	30 mm
2” tube adapter back focus:	0 mm [male 2, female 30]
Guider focuser type:	Compression ring
Guider focuser travel:	9 mm
Scope port:	T-thread (M42) [dovetail]
Imager port:	T-thread (M42) [dovetail]
Guider port:	T-thread (M42)
T-threaded tubes outside:	Fully knurled
T-threaded/dovetail tube useful lengths:	8, 16, 24 mm
Dichroic beam splitter coating:	Fully multi-coated
Dichroic beam splitter protection (both sides):	Optical grade quartz
Dichroic beam splitter reflection (visible):	> 95%
Dichroic beam splitter visible range:	> 370 nm to 750 nm
Dichroic beam splitter transmission (NIR):	> 90%
Dichroic beam splitter NIR range:	> 750 nm to 1800 nm
Anodizing:	Black, low reflection

11. Warnings, maintenance and care

As with any high quality optical device, the ONAG® should be handled with care. Do not drop the ONAG® or submit it to excess vibrations or temperature.

The ONAG® has been assembled with precision to insure accurate alignment of the dichotic beam splitter (DBS) in relation with all the optical ports, therefore resist disassembling the ONAG® body.
Doing so may result in image distortion due to misalignments, but also will void the warranty. The ONAG® XT provides a user tilt/tip mirror adjustment, the classical ONAG® **does not**.

The scope port (SP) provides a standard female T-thread for mounting the standard ONAG® to a scope or another device, be sure when you screw any equipment there that the associated male T-thread length will not interfere with the dichroic beam splitter (DBS). Failure to do so may scratch the DBS surface. As guidance only you may want the male T-thread no longer than 5mm. If longer, then consider using a T-ring to control the thread penetration depth. The ONAG® XT female 2" adapter as a usable 30mm depth, be sure that you **do not exceed this length**, otherwise you may touch and damage the dichroic mirror.
The guider focuser (GF) drawtube has two grooves and there are two associated nylon screws #6-32 (see section 6) on the focuser compressing ring outside perimeter to stop it for moving away.
Those screws should be checked on a regular basis, and each time a guider camera is attached. They should be in place, good condition, and screwed deep enough to secure the drawtube, while allowing it to move freely for focusing. Check by moving the drawtube gently back and forth, and verifying it cannot leave the focuser ring. The maximum drawtube travel is about 9mm. The guider focuser screw (see section 6) as well as the X/Y stage eight nylon screws should always be tight before using the ONAG® for an astrophotography session, moving the telescope, or slewing its mount. Failure to do so may result in significant damage due to the abrupt part and camera motions or falls.
The 4 nylon thumbscrews of the X/Y stage, as well as guider focuser screw (stainless steel) should be tightened by hand, never use a tool, such as a screwdriver. Use only a screwdriver for the 4 slotted nylon screws when doing initial adjustment. Please do not over tighten them.
We also recommend, as good practice, that each camera has a backup mean to stop it for falling, should the primary mechanical interface fails for any reason. A string could be used for this, see what your camera user guide may suggest.

Should you need to clean the DBS, first remove any dust using optical grade compressed air, or brush. Do gently to avoid scratching the DBS coatings. If necessary, and only if, you could use a cleaning product for multi-coating optical elements. Never apply such product directly to the DBS surface, instead use an optical grade soft tissue and gently clean the surface with the minimum of force and pressure as possible.

If needed the X/Y stage shafts and guider focuser can be lubricated, time to time, with light aluminium and stainless steel compatible grease for extended temperature range. **Never use oil.**
Use a minimum of grease and be sure it will not find its way inside the ONAG® body, nor spill on the DBS and cameras.

Never look at the sun, or any bright sources with the ONAG®, from any optical ports. Doing so could result in serious injuries.
Products performances, specifications and features can be changed without warning.

12. Limited Warranty

This Innovations Foresight (IF) on-axis guider device (ONAG®) is warranted against defects in materials or workmanship for a period of one year from the date of purchase. This warranty is for the benefit of the original retail purchaser only. During this warranty IF will repair or replace, at IF's discretion, any warranted device that proves to be defective, provided it is returned postage paid to IF at 225 Cadwalader Avenue, Elkins Park, PA 19027.
If the product is not registered, proof of purchase (such as a copy of the original invoice) is required.
This warranty does not apply if, in IF's judgment, the instrument has been abused, mishandled, not properly cared of, or modified, nor does it apply to normal wear and tear. This warranty gives you specific legal rights, and you may also have other rights, which vary from state to state. For further warranty service information, contact IF (http://InnovationsForesight.com, or +1.215.885.3330).

13. Registration

Product name: ……………………………….……………..

Serial Number: ………………………………………………..

Date of purchase: ………………………………………………...

Where did you buy it?: ………………………………………………..

Have you registered with us before? YES NO

First name: ……………………………………………………

Last name: ……………………………………………………

Address: ……………………………………………………

City: ……………………………………………………

State/Prov.: ……………………………………………………

ZIP code: ……………………………………………………

Country: ……………………………………………………

Phone (day time): ……………………………………………………

email: ……………………………………………………

Please take a moment to answer the following questions.

How did you hear about us?

On which equipment do you plan to use our product?

Any comments?

Please copy and send this form to:

Innovations Foresight

225 Cadwalader Avenue

Elkins Park, PA 19027

United State of America

14. Glossary

AFR	Adjustable focal reducer
DBF	Differential back focus
DBS	Dichroic beam splitter
FR	Focal reducer
GBF	Guider back focus
GF	Guider focuser
GP	Guider port
IBF	Imager back focus
IP	Imager port
IPBF	Imager port back focus
IXT	Imager extension tube
NIR	Near infrared
ONAG®	On axis guider
SCT	Schmidt Cassegrain telescope
SP	Scope port
TOBF	Total optical back focus
XYS	X/Y stage

15. Table of Content

16. Notes