Hyperboloid Astro Camera

ε-160ED

Instruction Manual

TAKAHASHI

Thank you for purchasing the ε-160ED hyperbolic astrograph. While on paper the specifications of the ε-160ED look very similar to the older ε-160, the optical performance is completely different. Through improved design and exciting manufacturing precision, the correction of aberrations has allowed Takahashi to achieve a diffraction limited spot size of 3 microns over a 44mm image circle. This helps make the ε-160ED the ultimate telescope for astrophotography.

Please read this instruction manual thoroughly prior to use. This will help you get the most out of your telescope. All products are shipped only after a thorough inspection, but if you find any defects, please notify your Takahashi distributor immediately.

Warning & Caution

Please be mindful of the following safety precautions.

⚠ WARNING

Never look at the sun with an astronomical telescope. The intense light and heat present on the optical surfaces and at the focal point can damage the telescope and may result in a fire.
Looking at the sun through a telescope will cause instant and permanent blindness.



⚠ CAUTION

- When mounting the telescope on an equatorial mount be careful not to drop the telescope or pinch your fingers or other body parts. Injury may result.
- When setting the telescope down, be careful not to set the telescope on an unstable surface. The telescope could fall, resulting in damage to the telescope or bodily injury.
- Do not place the product in direct sunlight. Accidentally pointing the telescope at the sun can result in intense heat at the focal point and possible fire.
- Be careful not to pinch fingers when using the focuser.
- The telescope contains small parts that can be harmful if swallowed. Do not allow small children to be around the telescope unsupervised.
- The packaging contains flammable materials. Keep away from heat or fire. Do not allow children to play with the plastic shipping bag. Suffocation could result.

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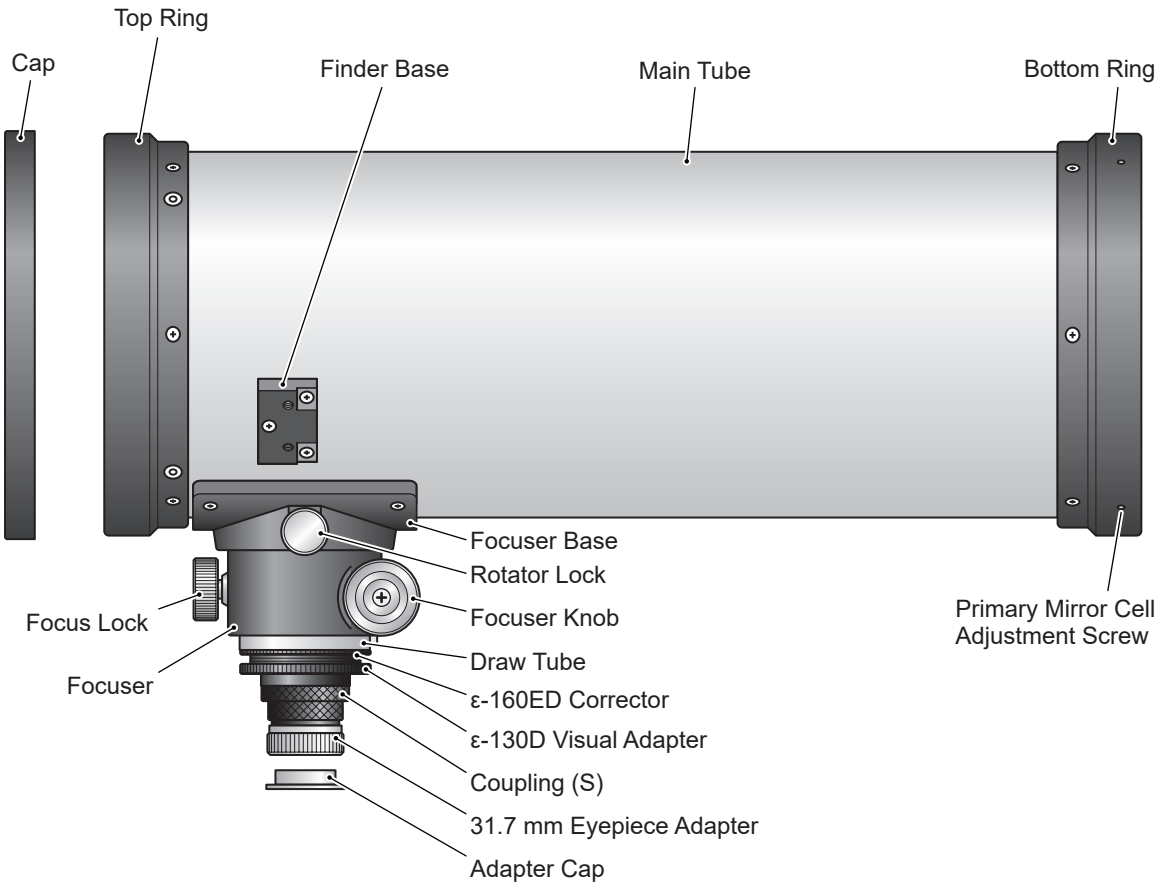
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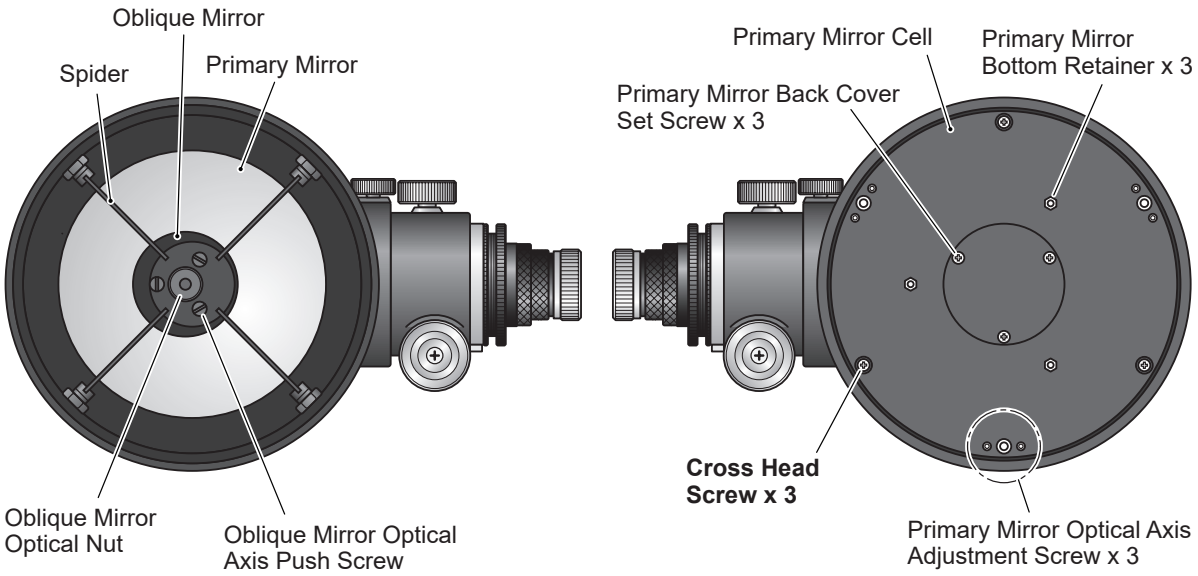
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Specifications

Optical System	Hyperboloidal Catadioptric
Effective Diameter	160mm
Effective Focal Length	530mm
Effective Focal Ratio	1:3.3
Secondary Mirror Diameter	63mm
Corrector Lens	2 elements in 2 groups
Image Circle	ϕ44mm
Photographic Field	4.8 degrees
Metal Back	56.2mm
Diameter of Main Tube	204mm
Length of Main Tube Assembly	580mm
Weight of Main Tube Assembly	approximately 6.9kg
Finder Scope	optional accessory
Focusing System	Rack & Pinion (MEF-3 compatible)
Included	Instruction Manual, Warranty Card, 3 Screws for primary mirror Installation, Hex Wrench (2mm, 2.5mm, 3mm, 4mm)

Tube Assembly Layout





About the Optical System

The revolutionary Epsilon optical system uses a hyperbolic surface for the primary mirror, coupled with a corrector in the focuser body. By combining a concave mirror and a convex lens reducer system, the Petzval condition is achieved, resulting in a flattened image plane. Takahashi's unique Epsilon optical system corrects the spherical aberrations and coma for outstanding image quality.

◆ Epsilon Performance

The Epsilon ε-160ED is a new product that further evolves Takahashi's unique Epsilon optical system. The newly designed double-lens correction lens is a new type that pursues the aberration correction required for modern imaging sensors, and a diffraction-limited spot image is achieved with a star image of 3 microns out to the edge of a full frame sensor. The smallest star image is about 1/10 the size of the older ε-160. In addition, the distortion aberration (distortion), which was a drawback of the old correction lens, has been corrected to less than half, which makes image mosaics easier to compose. The ε-160ED's 530mm (f/3.3) specification, which has the highest level of optical performance, combined with the lightweight and compact body, make it an astrophotography instrument that allows you to enjoy the very best in Epsilon performance.

◆ Takahashi Mirrors

Although it is generally considered very difficult to polish hyperbolic primary mirrors, Takahashi has developed this technology and evolved the production into this modern style.

◆ Diagonal Offset

In order to achieve maximum illumination, the secondary must be offset from the center of the optical axis to produce the best possible illumination for the image. As the speed of the optical system increases, so does the offset. The oversized secondary has been offset to produce the maximum illumination for the image.

Setup

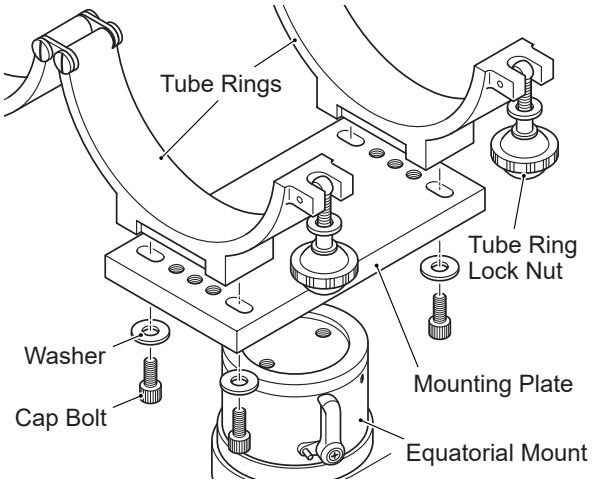
◆ Attaching the Tube holder

(Tube holder and Plate are sold separately)

Attaching the telescope to an equatorial mount will require the tube rings and mounting plate. First, attach the tube rings to the mounting, but do not tighten the mounting bolts completely. This will provide some play in the position of the tube rings. Then, attach the bridge plate to the tube rings, connecting the two tube rings on the top. After the bridge plate is attached, tighten the tube ring mounting bolts to the mounting plate. Secure the mounting plate to the Takahashi mount using the two provide cap bolts.

With the tube rings open, carefully mount the telescope in the tube rings. Once the telescope is in place, close the tube rings and secure them with the tube ring lock nuts. With the lock nuts in place but not fully tightened, balance the telescope on the mount. Once proper balance is achieved, tighten the lock nuts (Please see next section on for more details on balancing).

(Note) The Takahashi mounting plate can be used with the EM-11, EM-200 and EM-400 mounts. If a third-party mount is used, a proper mounting plate will need to be obtained.

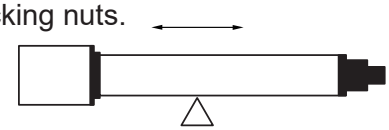


◆ Balancing

Attach any additional equipment, such as camera and adapters, to the optical tube assembly before balancing. It is best to have the focuser pointing skyward when balancing. Proper balance is important to avoid damage to the telescope and to reduce the strain on the mount gears and motors when slewing and tracking.

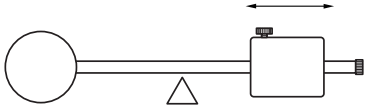
▼ Balance around the Declination Axis

1. Loosen the R.A. clamp and rotate the tube so that it is in the horizonal position. If the R.A. balance is too far off, the telescope may be difficult to move. In this case, balance the R.A. axis first.
2. While holding the telescope firmly, loosen the declination clamp slightly and check the balance around the declination axis.
3. If the balance is not correct, loosen the tube ring locking nuts and slide the telescope back and forth within the tube rings until proper balance is achieved. Once balance is achieved, tighten the tube ring locking nuts.



▼Balance around the R.A. Axis

1. With the declination axis balanced, firmly tighten the declination clamp.
2. Loosen the R.A. clamp and check the balance around the R.A. axis.
3. If the balance is not correct, move the mount balance weight up or down to achieve proper balance.
4. If balance cannot be achieved with the weight at the extreme end (bottom) of the shaft, additional weight may need to be added.



◆ Focusing System

▼ Focuser

ε-160ED adopts a rack and pinion system that allows the focusing mechanism to achieve best focus and enables speedy operation. To focus, loosen the focus lock and rotate the focusing knob until focus is achieved. Please note that if you attempt to focus with the focus lock engaged, you may cause damage to the focusing gear or draw tube.

(Note)

- Please also refer to the section on imaging for more information on focusing.
- The size of the focus lock has been increased to ensure that the draw tube does not move during imaging. Therefore, the distance between the rotator lock and the drawtube lock is narrow. Use caution when using to avoid pinching injuries to fingers.

▼ Corrector

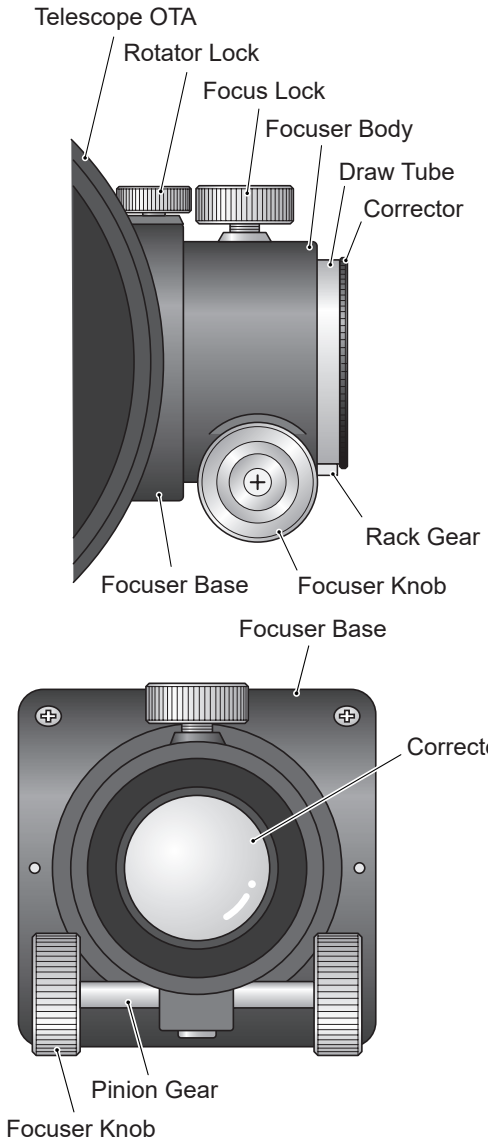
The Epsilon optical system is designed so that a good image can be obtained by combining the primary mirror and a corrector lens. These are meant to work together, and the telescope should not be used without the corrector. However, when adjusting the optical axis, it is difficult to make adjustments with the corrector in place, so the corrector should be removed to adjust the optical axis. When reattaching the corrector after adjusting the optical axis, be sure that it is screwed completely in, so it does not come loose during imaging.

(Note)

- The corrector for the ε-160ED is for the ε-160ED only. It cannot be used with other models such as the older model ε-160 because the aspherical coefficient of the primary mirror is different.

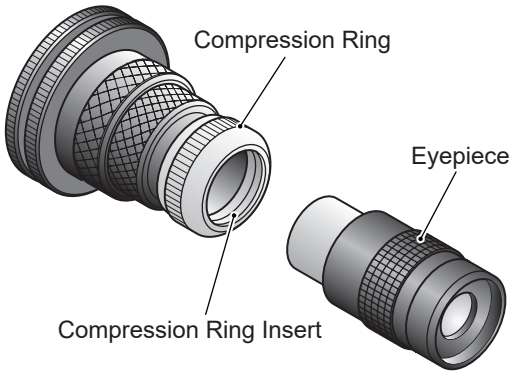
▼ Camera Angle Adjuster (CAA)

On the ε-160ED, the camera angle adjuster is built into the focuser, allowing rotation of the camera, making for easy composition adjustments. To change the image composition, loosen the rotator lock and rotate the camera. When the image is composed properly, tighten the rotator lock. When rotating the camera, be sure to hold the focuser body when turning so that the threads attaching the corrector and camera mount do not loosen. The rotator is designed so that the focus does not change due to this rotation, but this should be confirmed after each rotation.



◆ Visual Use

While the ε-160ED is designed for astrophotography, you can attach an eyepiece and enjoy it as a wide-field telescope for visual observation. To attach an eyepiece, loosen the compression ring and remove the eyepiece cap. Then insert an eyepiece into the eyepiece adapter and tighten the compression ring. If the eyepiece cannot be inserted even after loosening the compression ring, push the plastic ring inside the compression ring with your fingers to expand it. While all Takahashi eyepieces have been confirmed to reach focus with the ε-160ED, third party brands have not been tested to confirm focus.



◆ Eyepieces

Takahashi sells the following types of eyepieces. Each series is designed with different features and capabilities so that you can choose the eyepiece that is best for your needs.

▼ LE

LE eyepieces are high-quality eyepieces that provide a wide field of view and a wide variety of types from low to high magnification. Available sizes: LE5 to LE30 in a 31.7 mm style, and LE40 and LE50 in 50.8 mm style. Note that 50.8 mm eyepieces cannot be used with the ε-160ED.

▼ ABBE

While the construction of Abbe eyepieces has a short apparent eye-relief when compared to more modern designs, they provide good contrast and high performance at a low cost. All Abbe eyepieces are a 31.7 mm style.

▼ TOE

TOE eyepieces take full advantage of the performance of the objective lens, and are designed with priority to magnifications and field of view suitable for observing the moon and planets at high magnification. All TOE eyepieces are a 31.7 mm style.

▼ TAK-UW

TAK-UW are a series of ultra-wide-angle eyepieces with an apparent field of view of 90 degrees, while prioritizing the sharpness of the star image. All TAK-UW eyepieces are a 31.7 mm style.

◆ Focusing

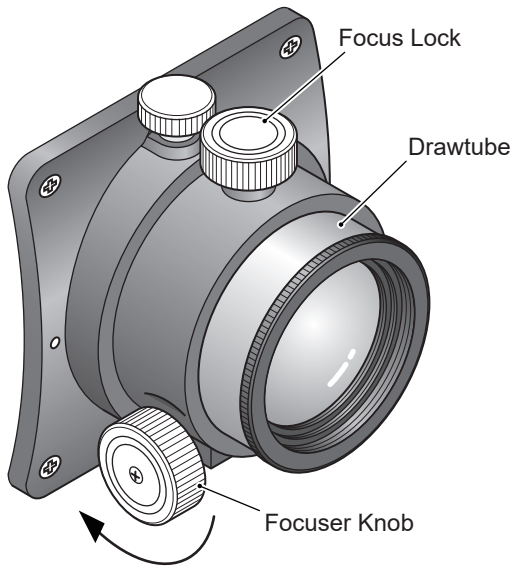
After attaching the eyepiece to the telescope, it is necessary to align it with an object in the field of view. Especially when looking at a star, if it is out of focus, you may not be able to see anything even if the star is caught in the field of view. Also, if you do not focus accurately, you will not be able to bring out the optimum performance of the telescope. In astrophotography, accurate focusing is the deciding factor for taking good pictures. Please try to observe with the best possible focus, as follows.

▼ Focusing System

The telescope uses a rack-and-pinion focusing system. This system permits rapid and accurate focus adjustment. By turning the focusing knob clockwise, the drawtube will move out of the telescope tube. By turning the focusing knob counter-clockwise, the drawtube will move into the telescope tube.

▼ Adjusting the focus point

Focusing is performed by moving the rack gear attached to the Drawtube and the pinion gear directly connected to the Focuser knob to move the Drawtube in and out. This rack and pinion system make it easy to adjust the speed at which the focusing knob is turned, and precise focus is easy to quickly achieve. Turn the focuser knob in the direction of the arrow in the figure to move the drawtube out, and turn it in the opposite direction move the drawtube in.



Rotating in this direction moves the draw tube outward

▼ Focusing

First, attach the eyepiece to the eyepiece adapter, and check that the focus lock is loose. Next, slowly turn the focus knob. The telescope is shipped with the drawtube in its fully retracted position, so when using the telescope for the first time, you will gradually need to extend the draw tube to achieve focus. Prior to observing celestial bodies, focus on a distant terrestrial object during the daytime (note that the landscape will appear upside down) and mark the focus position on the drawtube. If you perform this with distant objects, the position of the focuser should be close to that needed to see a celestial body. As a guide, you can get good focus from that position with a slight focus adjustment. When you look at a star at high magnification, the star image may be greatly blurred or not visible at all if the focus is even slightly off. First focus at low magnification and then replace with a high magnification eyepiece to focus. When you switch magnification you may need to adjust focus again.

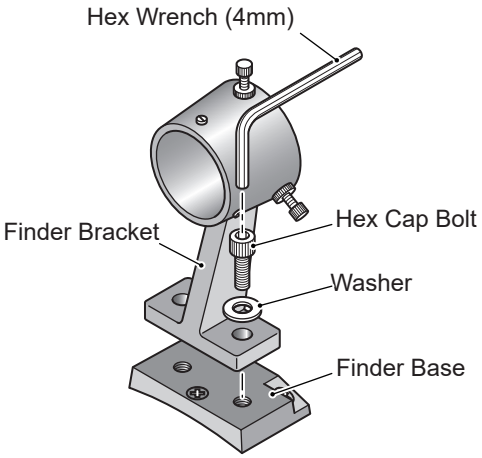
▼ Focus Lock

The Focus lock is not generally required for visual observation, but when taking an image, the weight of the camera attached to the eyepiece may cause the Drawtube to move, resulting in a change in focus. To avoid this, tighten the Focus lock to fix the draw tube firmly in place. When moving the Drawtube again, be sure to loosen the Focus lock. Forcibly turning the Focus knob while the focus lock is tightened may damage the gear or cause play in the focuser.

◆ Mounting the Finder Scope

The ε-160ED can be used with the Takahashi 6x30 or 7x50 finder scope and finder scope bracket (sold separately).

Place the finder bracket in on the finder pedestal as shown in the figure below. Securely fix the Finder bracket to the Finder base with the cap bolts and washers included with the Finder bracket. Use the included Hex Wrench (4 mm) to tighten the bolts. If you install and tighten these bolts without attaching the Finder bracket, they will come into contact with the telescope tube and may cause damage.



▼ Attaching the Finder Scope
(requires a flathead screwdriver)

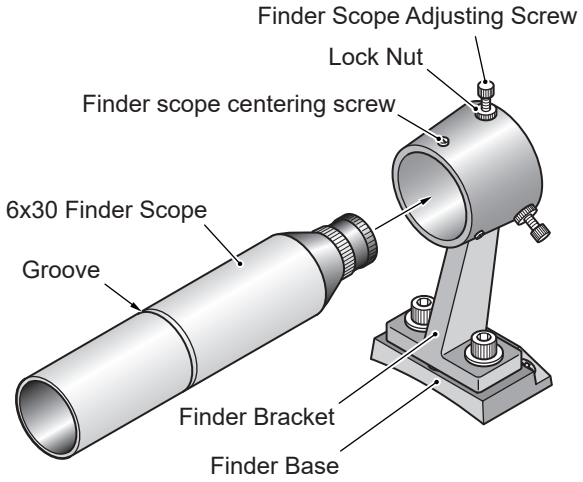
If the Finder scope adjustment screws and the end of the Finder scope centering screws are too far inside the Finder bracket, they will hinder the insertion of the Finder scope. To back out the centering screws, back off the Lock nut of the Finder scope adjustment screw and back out the adjustment screw. To back out the Finder scope centering screws, use a flathead screwdriver to back out the screws.

(Note)

To prevent small scratches on the Finder scope, you may wish to use clear tape (3 layers) to protect the Finder scope where it meets the Finder bracket screws.

▼ 6 x 30 Finder scope

Insert the 6x30 mm Finder scope into the Finder bracket as shown in the upper right figure and adjust the position so that the Finder scope centering screw presses the groove on the Finder scope. Adjust the Finder scope adjustment screw and the Finder scope centering screw so that the gap between the inner circumference of the Finder bracket and the Finder scope itself is even, and fix with the Lock nuts.



⚠ Caution

Never use the Finder scope and Finder bracket as a handle to lift the ε-160ED. This can damage the Finder bracket and the Optical tube assembly, creating alignment problems.

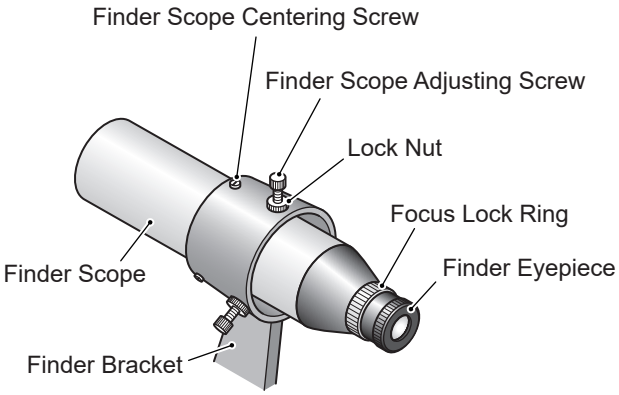
◆ Adjusting the Finder Scope

Since the telescope has a high magnification and relatively narrow field of view, locating and centering celestial bodies can be difficult. Also, when taking an image of a star with a camera, the image can be very dark, further complicating the proper centering of the object.

To help with centering objects, the finder scope is used. The finder scope is a small telescope with a low magnification and a wide field of view. If the finder scope is properly aligned with the telescope, objects centered in the finder scope will be in the field of view of the telescope. To properly align the finder with the telescope, use the following procedures.

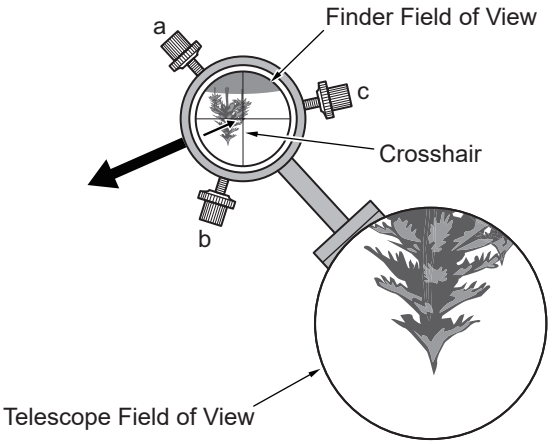
▼ Focus Adjustment of the Finder

1. Loosen the focus lock ring.
2. Using the finder, while viewing a distant object on land, rotate the finder eyepiece until sharp focus is achieved.
3. Tighten the focus lock ring.



▼ Adjusting the Finder Alignment

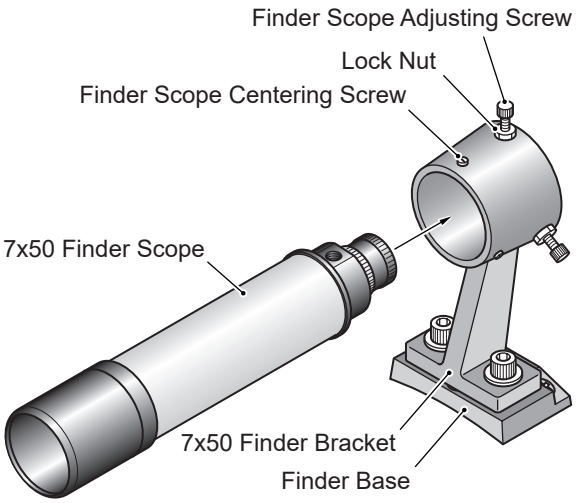
1. Set up the telescope for visual use according to the system chart and attach a lower power eyepiece. Then, select a clearly visible distant object and center it in the field of view. This is most easily done during the daytime.
2. Exchange the lower power eyepiece for a higher power eyepiece, and again focus on the distant object.
3. Looking through the finder, move the finder with the following procedure and adjust it so the object is centered in on the crosshair.
4. To adjust the finder, turn all lock nuts until they reach the head of the adjusting screws.
5. Referring to the diagram, in order to move the crosshair in the direction of the arrow, first loosen screw (a) and tighten (push) the finder with screw (c). Next loosen screw (b) and tighten the finder with screw (c). This procedure will move the crosshair in the desired direction. The end of the finder will move in the opposite direction and the object will move in the direction of the small arrow. When the finder is properly aligned, lock the finder by tightening the lock nuts.



▼ 7 x 50 Finder scope

Insert the 7x50 Finder scope into the Finder bracket, as shown in the figure below. Evenly tighten the 3 Finder centering screws at appropriate positions with a flathead screwdriver. Adjust the finder screws so that the gap between the inner circumference of the bracket and the Finder scope is even. Then, tighten the Finder scope adjustment screws evenly and lock them with the locking nut. Finally, position the Finder Scope and the Optical Tube Assembly (telescope) as parallel as possible. Adjust as necessary to complete alignment.

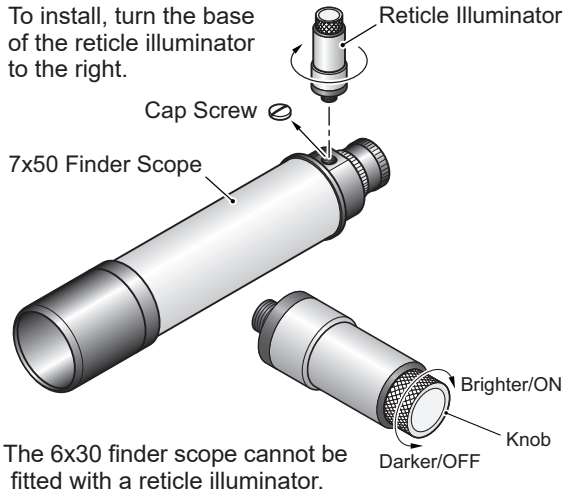
The 7x50 Finder scope can be equipped with an optional lighting unit called a Reticle Illuminator (sold separately). With the reticle illuminator, the crosshairs in the finder will appear red, even in a dark starlit sky. This optional accessory is very convenient to center dark celestial bodies, etc.



◆ Reticle Illuminator

The Reticle Illuminator (sold separately) can be attached to the 7x50 Finder scope. With the reticle illuminator, the crosshairs of the finder scope are illuminated in red, making it easy to center celestial bodies.

When the illuminator is not attached to the finder, a screw is attached at the position where the illuminator is attached. To install

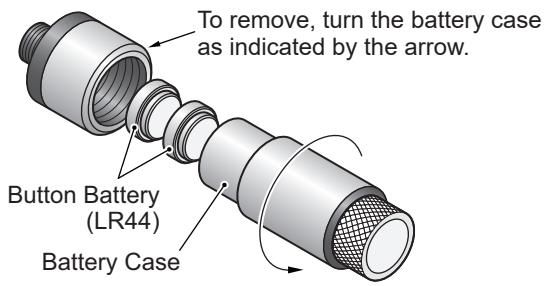


* The 6x30 finder scope cannot be fitted with a reticle illuminator.

the reticle illuminator, first remove the screw with a flathead screwdriver. Then, screw the reticle illuminator into the finder scope. Turn the knurled knob on the end of the illuminator to activate and adjust the light intensity. When turned, the knob will make a clicking sound to indicate is in the on position. If you continue to turn the knob in the same direction, the light intensity will increase. If you turn the knob in the opposite direction, the light intensity will decrease until the light turns off with a clicking sound. Adjust the brightness of the light so that you can easily see both the stars and the crosshairs while looking through the finder scope.

▼ Replacing the Battery

When replacing the batter, remove the battery case as shown in the figure. Wipe the terminal surface of the new battery thoroughly and install the battery. Use care not to make a mistake in the polarity. The battery uses a button battery (LR44).



Observation

◆ Preparations Before Observation

The ε-160ED has a mirror diameter of 160 mm, and when used in low temperatures may take some time to stabilize. Taking the telescope outside an hour before observing will allow it to equalize with the colder air.

◆ Visual Applications

▼ Determining Magnification

This unit is designed for astrophotography. It is not ideal for planetary observations but can be used for deep space.

The magnification of any eyepiece used with the telescope can be calculated by using the following formula:

(Focal Distance of the Telescope) / (Focal Distance of the Eyepiece)

Example: Utilizing the LE-18mm
530mm / 18mm = 29.44x

Therefore, the shorter the focal length of the eyepiece, the higher the magnification, and the longer the focal length, the lower the magnification.

Please use Takahashi eyepieces. Due to the short range of movement of the drawtube, eyepieces from other manufacturers may not focus. Also, with a low magnification eyepiece with a focal length of 24 mm or more, it will be less than the minimum effective magnification, and the shadow of an oblique mirror will appear in the field of view, obstructing the view.

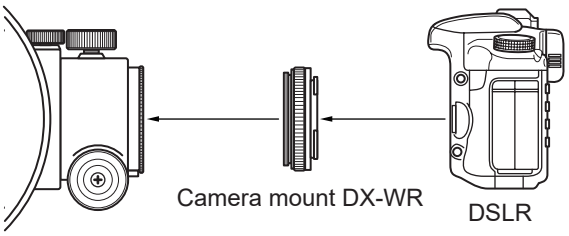
◆ Astro Imaging

The ε-160ED is designed as an astrophotography telescope for deep space imaging.

▼ Prime Focus Imaging

When imaging with a telescope, focusing is one of the most critical elements of making great images. To achieve proper focus, it is important to place the camera sensor at the focal point of the telescope. Because the focal length of the telescope is large, it is also important to use a high quality equatorial mount. Any unwanted movement or error in tracking can ruin an imaging session.

To produce images using the telescope, one can use either a digital SLR, or a specialized CCD or CMOS camera. Takahashi system charts show the adapters and connections needed to attach a DSLR. Standard adapters are generally available for Nikon, Canon and Sony cameras. These cameras utilize the CA-35 and a DX-WR camera ring for the specific camera. To attach dedicated astrophotography cameras, some specialized adapters are needed. Please consult with your Takahashi dealer for further details.



Due to the specialized nature of the ε-160ED optical system, image degredation can occur when using 3rd party extenders. Therefore, we have developed the Epsilon Extender 1.5x, which can extend the focal length by 1.5 times while maintaining the same optical performance (release date TBD).

▼ Filters

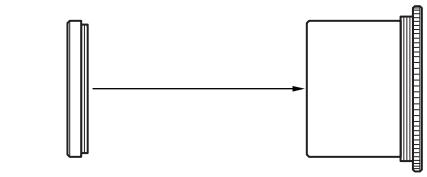
The ε-160ED can be used with filters. However, please note that some filters have a large mounting frame, and not all filters can be mounted even if the screw diameter is the same. Also, using a filter may cause ghosting.

- A 48mm filter can be attached to the camera mount DX-WR. A filter with a large mounting frame cannot be used, because it will cause interference when the camera mount DX-WR is attached to the telescope.



ϕ48mm Filter Camera Mount DX-WR

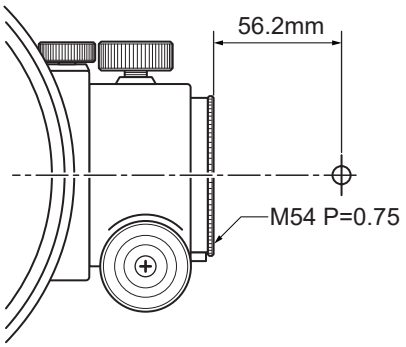
- A 55 mm filter can be attached to the correction lens of the ε-160ED. A filter with a large mounting frame cannot be used because it will not fit in the drawtube.



ϕ55mm Filter Correction Lens

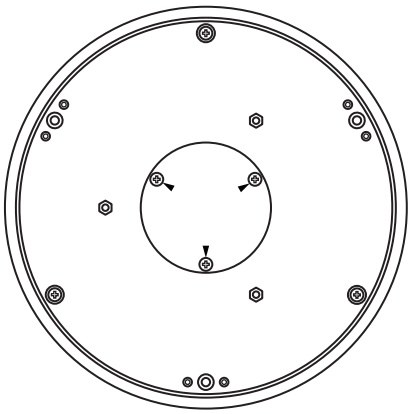
▼ Back focus

This ε-160ED has a back focus measured from the correction lens to the focal plane. When specifying a camera system, it is important that the camera sensor be located at the focal point as defined by the back focus. If this is not observed, the optical performance as designed cannot be achieved. When using accessories, connect according to the system chart or follow the dimensions from the end of the correction lens.



◆ Primary mirror

The back side of the primary mirror can be exposed so that the temperature of the mirror can acclimate to the outside air temperature in a shorter time, quickly eliminating the influence of the airflow. If you remove the three primary mirror cell back cover set screws (▼marks), the primary mirror cell back cover will come off and the back side of the primary mirror will be exposed to the outside air.

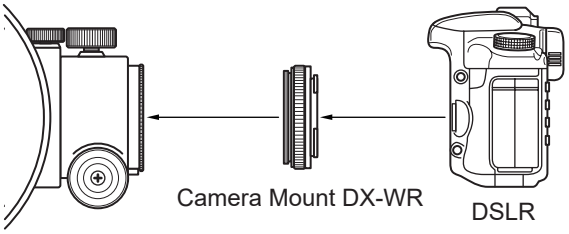


Accessories

Takahashi has special accessories for imaging with the ε-160ED.

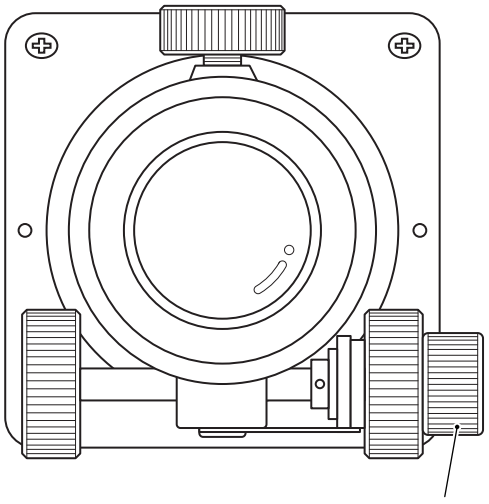
◆ Camera mount DX-WR

Use the camera mount DX-WR to attach a DSLR camera. This mount is available in (EOS) for Canon EF mount and (Nikon) for Nikon F mount. If using a mirrorless Canon or Nikon camera, an adapter will be needed to convert the mirrorless camara to either and EF or F mount. Contact your Takahashi distributor for details on other cameras.



◆ MEF-3

The optional MEF-3, Micro Edge Focuser, is an accessory (sold separately) exclusively for Takahashi. It is designed to move the focuser at a fine speed of 8 to 1 ratio (smaller knob) while the larger knob moves the focuser at 1 to 1 ratio. It can be easily attached to the ε-160ED.



Optical Alignment

The ε-160ED is collimated before shipment. Both the primary mirror and the secondary mirror have a structure that prevents the optical axis from shifting, but if there is a strong impact during transportation or use, the optics could lose collimation. In addition, the cell may be removed for mirror cleaning, etc., and this will require collimation of the instrument. In shortfocus, catadioptric systems, slight misalignment of the optics will adversely affect the image. For optimal imaging, it is important to keep the scope collimated. Be sure to master the collimation procedure so that you can always use the scope to its fullest. Also, make it a habit to check the collimation before use.

◆ Collimating Tools

In order to collimate the scope correctly, prepare the following accessories and tools.

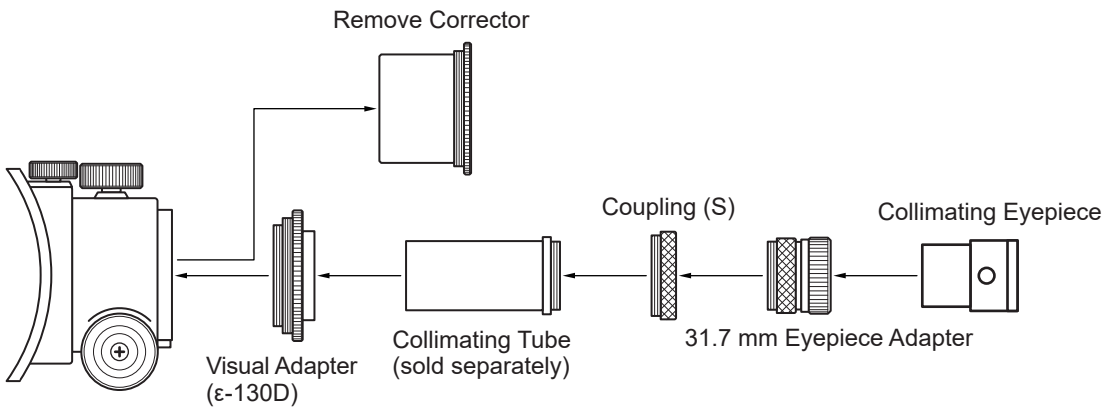
Accessories: Visual adapter (ε-130D),
Eyepiece adapter,
Connection ring (short),
31.7 Eyepiece adapter
Sold Separately: Collimating tube,
Centering eyepiece 31.7
Tools: Hex wrench, Flathead screwdriver,
Spanner (14mm)

◆ Connection

First, remove the corrector. After confirming that the camera angle adjuster is tightened, turn the corrector body counterclockwise until the thread fully disengages. Then carefully pull the corrector from the drawtube. The corrector lens is heavy, so be careful not to drop it when removing.

Screw the Visual adapter (ε-130D) into the focuser where the corrector was located, and connect the other parts as shown in the figure below.

(Note)
The collimating tube (sold separately) comes with an instruction manual that explains in detail how to make adjustments, so please refer to that as well.



Using the collimating eyepiece and collimating tube will be a great help in collimating the ε-160ED, and are used in the instructions below.

When collimation is necessary, complete the process during the day in a brightly lit room. The telescope can be pointed at a brightly lit white wall, or at a translucent white sheet placed across a window. Place the tube with the focuser to the left, facing the light source, as illustrated in the figure. If you lose your orientation to the movement of the secondary, place your finger over the opening of the tube to regain the orientation. The directions of the field of view correspond to the numbers 1 through 4 on the illustration.

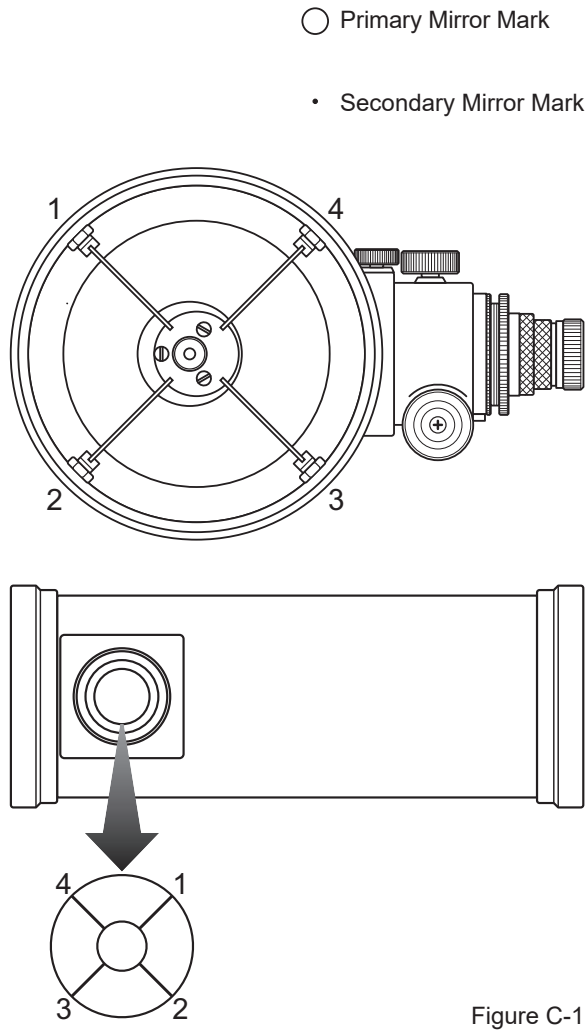


Figure C-1

◆ Adjusting the Secondary Mirror

The secondary can be adjusted by loosening the large nut at the center to turn it and the three small sets of screws to tilt it.

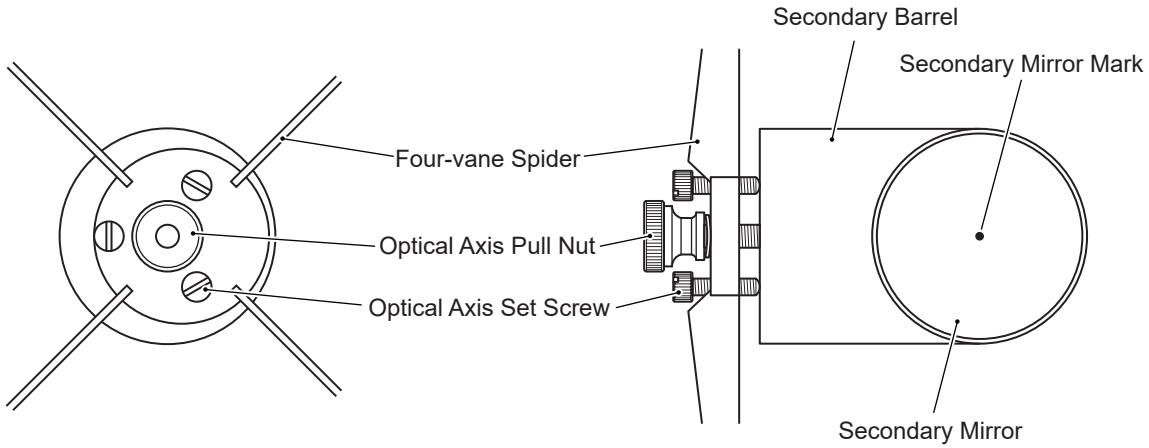


Figure C-2

1. Turning the mirror
   Loosen the large knurled nut that holds the secondary assembly to the spider slightly by turning it counterclockwise. This will allow the secondary to be turned in either direction. The secondary mirror assembly is tightened by turning the nut clockwise. When the securing nut is loosened, loosen the nut very sparingly to allow the secondary to be turned, but not too loose.
2. Moving the secondary mirror
   Loosening the large knurled knob some distance will allow the secondary to be moved up or down in a parallel fashion for better collimation.
3. Tilting the secondary mirror
   There are three screws with locking nuts provided to allow the secondary mirror to be tilted for collimation. In order to tilt the secondary, it is necessary to loosen the lock nuts. Loosen each slightly to prevent the secondary from moving too much. Refer to Fig. C-3.

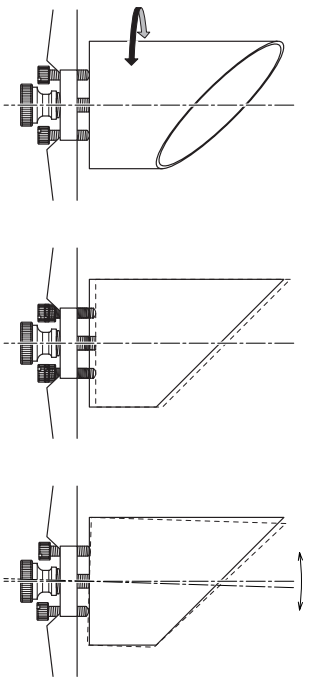


Figure C-3

◆ Aligning the Secondary Mirror

1. Turn the crosshair of the collimating eyepiece so that the lines are horizontal and vertical. Make certain that the telescope is pointing at the bright area. Make certain that the telescope is pointing at a white card or a window covered with a translucent sheet.
2. If the optical axis is off, as shown in Fig. C-5A, loosen the secondary mirror securing nut and rotate the secondary as shown in Fig. C-4.
3. Rotate the secondary until the reflection of your eye is centered in the crosshair. Slightly tighten the securing nut. Refer to Fig. C-5B.

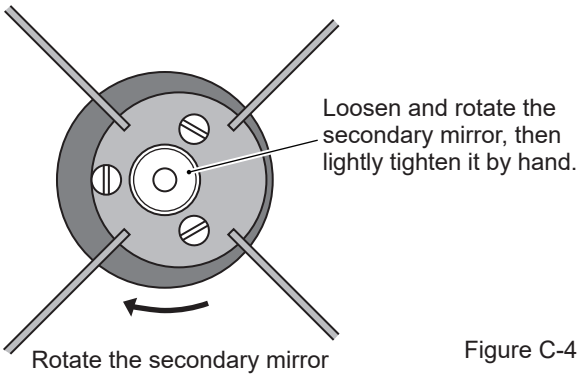


Figure C-4

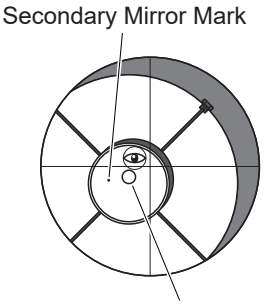


Figure C-5A

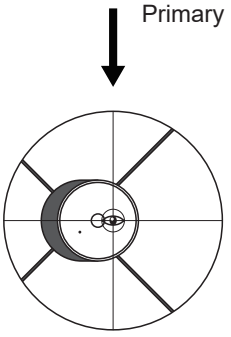


Figure C-5B

4. Insert the collimating eyepiece and adjust the tilt of the secondary mirror with the set screws until the secondary mirror mark coincides with the center of the crosshairs. In the illustration Fig. C-7, the center of the collimating eyepiece matches the center of the crosshair, but the secondary dot is located low and to the left. The secondary must now be tilted toward the primary mirror mark, and the primary mirror mark must be moved upwards. Slightly loosen the push screws A, B and C after backing off the lock nuts. Loosen the large knurled nut and then tighten the push screws A, B and C.

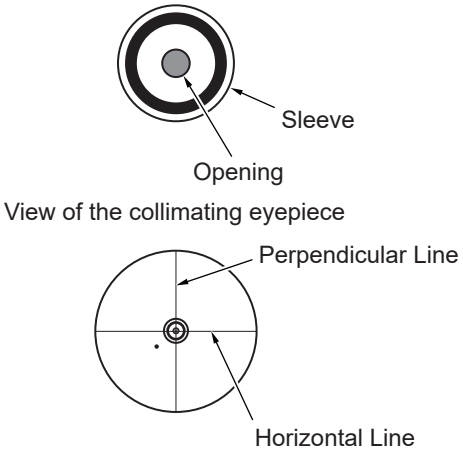


Figure C-7

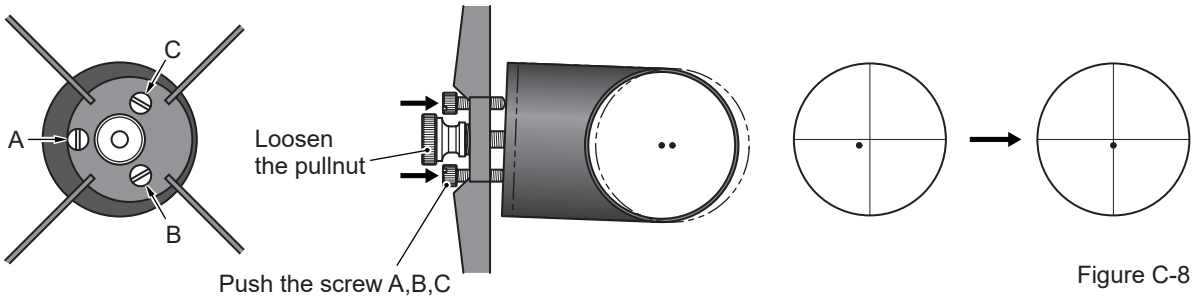


Figure C-8

Now the center of the secondary dot has been shifted below the center of the crosshairs. It then becomes necessary to tilt the secondary using screws A, B and C to center the dot on the secondary with the center of the crosshairs.
Refer to figures C-8 and C-9

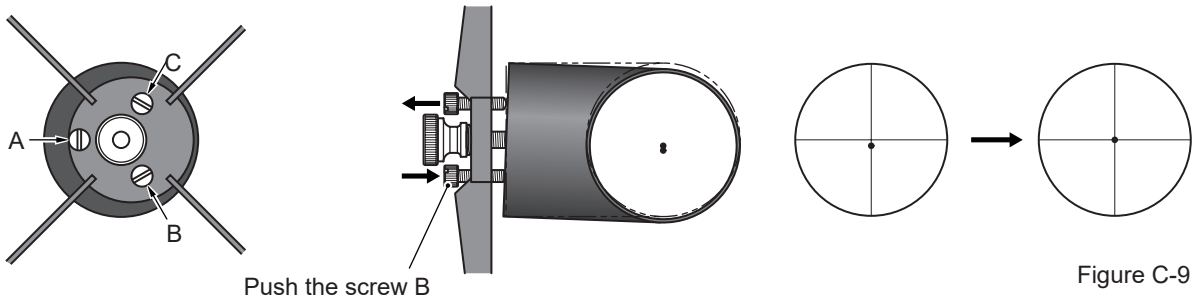
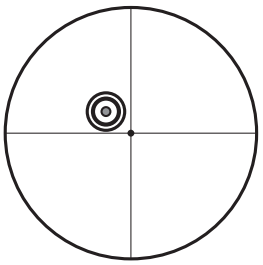
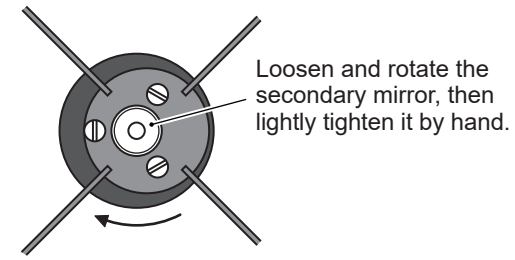


Figure C-9

5. In this process the center of the reflection of the collimating eyepiece has been shifted off center as seen in Figure C-10. It then is necessary to rotate and tilt the secondary mirror so that the center of the reflection of the collimating eyepiece is centered on the crosshairs. In figure C-10 the secondary is rotated so that the reflection is on the crosshair and in figure C-11 the secondary is tilted so that the center reflection of the collimating eyepiece is centered in on the crosshairs by adjusting screw A.





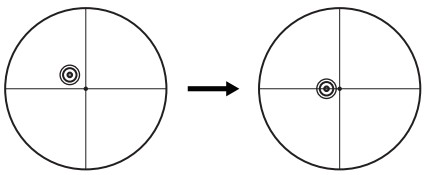
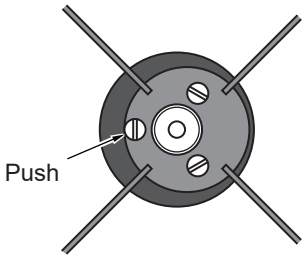


Figure C-10



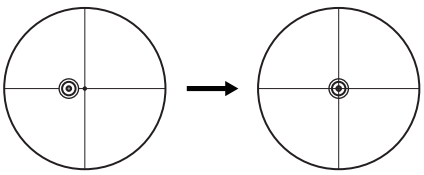
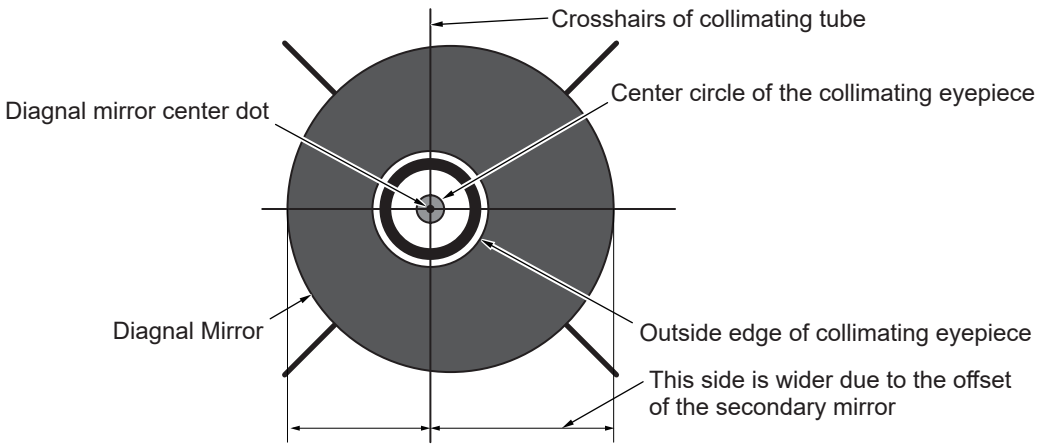


Figure C-11

6. The secondary mirror mark and the collimating eyepiece reflection should now align with the crosshairs as shown in figure C-12.



[This figure illustrates the collimation of the correct secondary mirror.]
(Note) In this illustration the circle on the primary mirror has been left out.

Figure C-12

When the optical axis of the secondary mirror is aligned (the primary mirror mark is omitted in this figure), but if the eyepiece is rotated, the crosshair may shift with respect to the secondary mirror mark. See Fig. C-13. In that case, a correction is necessary.

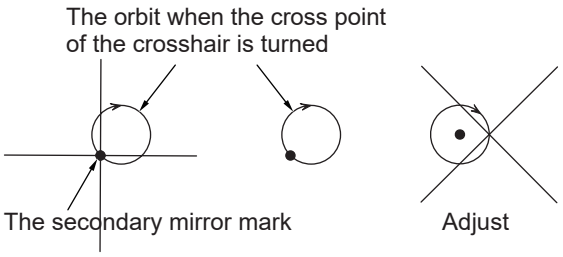


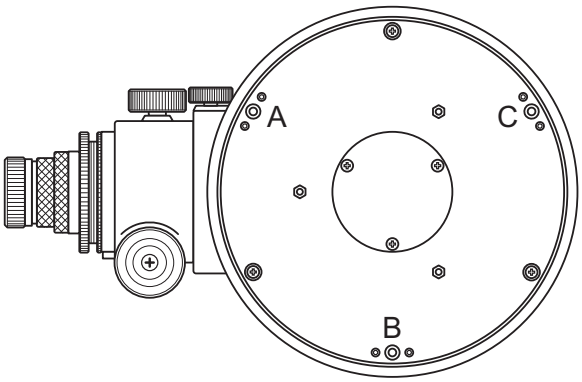
Figure C-13

▼ Correction

Adjust the set screw so that the crosshair moves around the mark as shown in Fig. C-13. Then, the opening of the collimating eyepiece deviates from the secondary mirror mark. Next, loosen the pull screw as in step 6 and rotate the secondary mirror so that the collimating eyepiece is on the horizontal line. Adjust with set screws to match.

◆ Collimating the Primary

To collimate the primary mirror, simply align the primary mirror mark with the secondary mirror mark. The primary mirror is adjusted by pushing and pulling the three collimating screw sets. Moving only one will deform the mirror and adversely affect its shape, so loosen the other two screw sets simultaneously. First, loosen the primary mirror collimating screws (3) on the side of the bottom ring. After adjusting the optical axis of the oblique mirror, if the primary mirror mark is off as shown in Fig. C-15, press the screw on the A side. While adjusting the other screws, adjust so that the primary mirror mark, the secondary mirror mark, and the collimating eyepiece are concentric as shown in Fig. C-16.



3 primary mirror adjustment screws (A, B, C)

Figure C-14

After collimating the primary mirror, tighten the primary mirror adjustment screws. These screws double as the centering of the primary mirror cell and the locking of the cell.

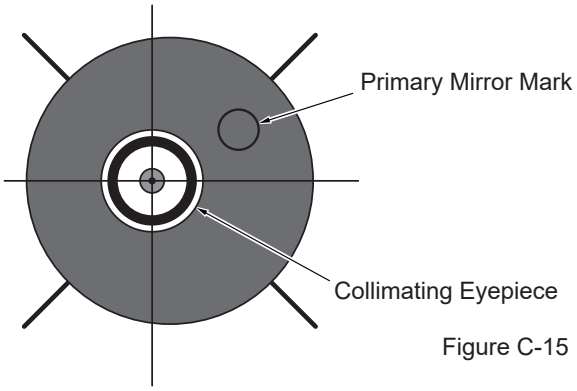


Figure C-15

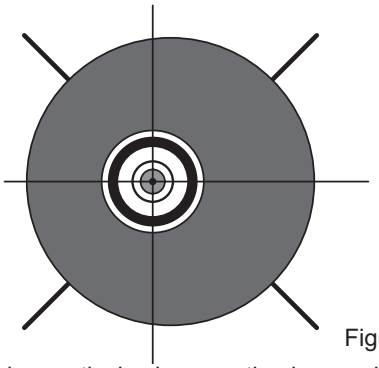


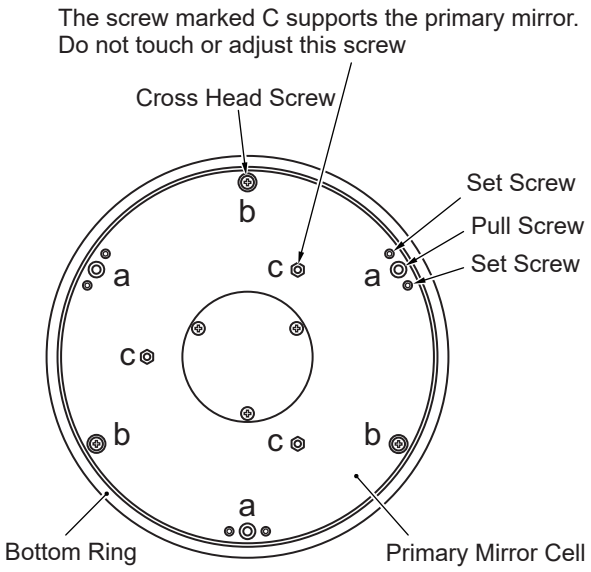
Figure C-16

View when optical axis correction is completed

◆ Structure of the optical axis adjustment screws

a. Optical axis adjustment screw set
Adjust the optical axis with three adjustment screws. Of the three, the cap bolt in the middle is the pull screw, and the two screws on the left and right are the set screws.

b. Cross head screw
When removing the primary mirror for maintenance, remove these three screws and attached the primary mirror cell attachment/detachment screw to remove the mirror.



◆ Adjusting the spider

The spider is adjusted at the time of product shipment. If you haven't adjusted the spider, no further action is required.

1. Remove the parts (corrector and visual adapters) attached to the drawtube, and look from the top side of the focuser, and then from the bottom side of the focuser.

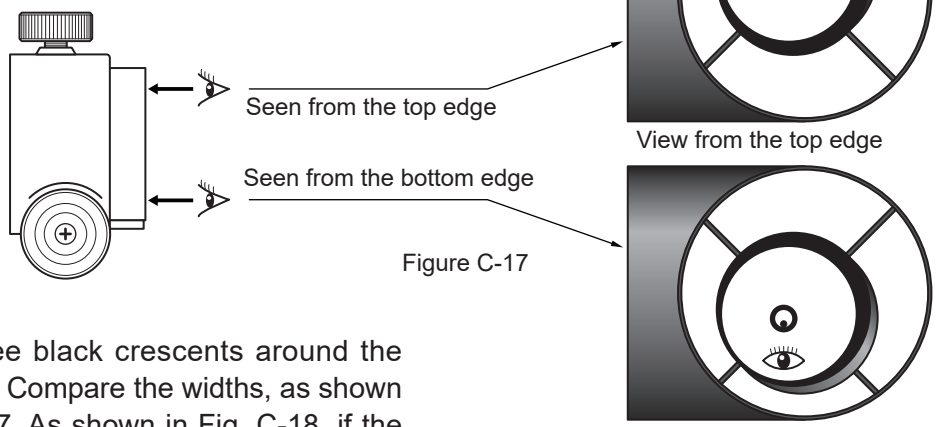


Figure C-17

You will see black crescents around the secondary. Compare the widths, as shown in Fig. C-17. As shown in Fig. C-18, if the upper part appears wider, the secondary should be lowered. If the upper and lower parts appear to be the same width, there is no need to adjust the spider.

2. In a case like Fig. C-18, loosen the adjustment screw C as in Fig. C-20 and the width of the secondary holder as seen from above and below becomes uniform.

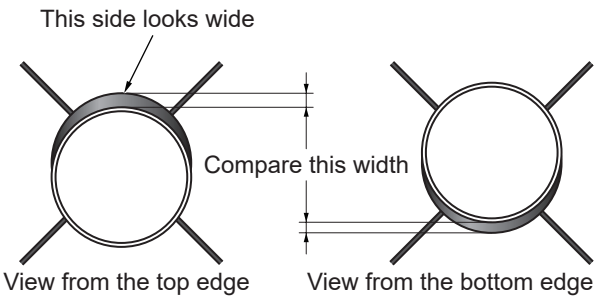


Figure C-18

3. Next, when you check the position of the secondary mirror mark again, it should be above the intersection of the crosshairs as shown in Fig. C-21. In this case, loosen 1 and 4 in Fig. C-19 and tighten the screws 2 and 3. The secondary mirror mark approaches the intersection of the crosshairs, so when you come to the horizontal line, look up and down again to check the widths, firmly squeeze the spider pull screw, and set the lock nut with a spanner. Perform adjustments as necessary until it becomes as shown in Fig. C-16.

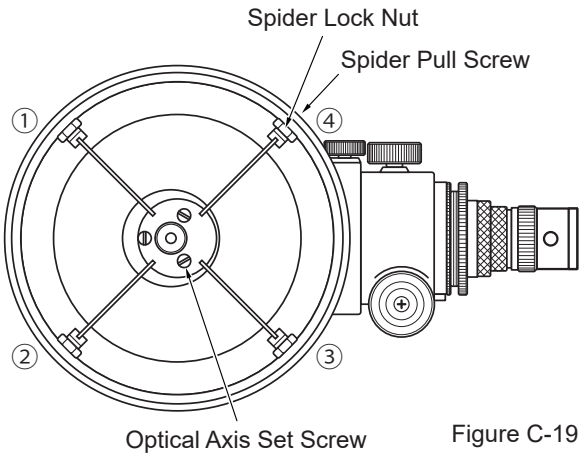


Figure C-19

Check the following:

- Secondary mirror: the intersection of the crosshairs and the secondary mark overlap, and that point is at the center of the collimating eyepiece.
- Primary mirror: the mark of the primary mirror is at the intersection on the extension line of the spider blade.
- The sides of the spider / secondary mirror outer cylinder have the same width when viewed from above and below.

If these are confirmed, the adjustments are complete.

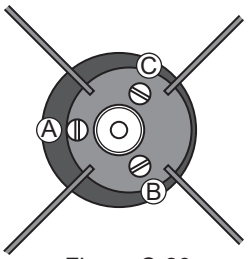
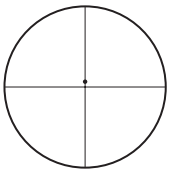


Figure C-20


Figure C-21

◆ Star image test

▼ Photo test

After adjusting the optical axis with the centering eyepiece, the in-focus and out-of-focus airy disks are checked visually, but since the ε-160ED is an astro camera, it is better to evaluate a test image. That way, you can detect a deviation of the optical axis from the edge of the image.

For this test, select an image which has the sharpest central image from the previewed images. Enlarge the edge of the image to check the quality of the stars.

- The star image is elongated
- The star image is bloated

If any of the issue above are present, it could be caused by the misalignment of the optical axis. By repeating the image test while recording the changes in edge of the image, you will be able to obtain consistently good results.

▼ Visual test

Since the diagonal mirror of the ε-160ED is off-set to produce a fully illuminated image circle, when the visual image is defocused the diffraction ring will appear eccentric. This is perfectly normal. This is not an indication of decollimation.

Precautions for Photography

When imaging with a DSLR, it is sometimes difficult to focus using the LCD screen. Choose a star on the screen that is not too bright or too dim – the best choice is typically a 3rd or 4th magnitude star. Most DSLR viewfinders do not have sufficient resolution to accurately focus, so it is best to use “live mode” and the LCD screen. The image on the LCD screen can usually be enlarged sufficiently to achieve accurate focus.

◆ Test shots

We recommend completing test shots at home before taking your equipment to a dark site. If you use a digital camera, you can take short exposures, so follow the focusing procedure to check the system. A Bahtinov mask can be helpful and may be obtained through your local telescope store.

◆ Guiding

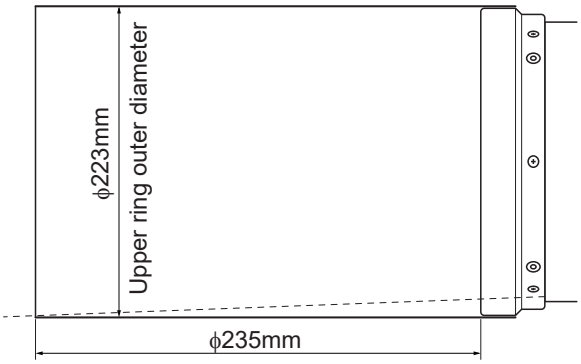
In an optical system with a sharp star image such as the Epsilon, the star image will blur even with a slight guide error. Precise guiding is required. In particular, since this unit has a low focal ratio, a momentary error will appear as a blur, so if there is play or deflection around the guide mirror, accurate tracking will not be possible. Securely fix the guide mirror. For long exposures, it is convenient to use the GT-40, a guide-only telescope, and the auto guider.

◆ Focus Considerations

Be sure to tighten the camera rotator so that the camera cannot move during shooting. When attaching a camera to the telescope, be sure to connect the camera according to the system chart. If the connection method is not done correctly, the image may not be in focus and the expected performance may not be assured. A bright star in the field may cause ghosting.

◆ Dew Shield

Attaching a dew shield to the end of the optical tube assembly will help to prevent both stray light and dew condensation. Thick paper can be used as a DIY dew shield. For dew shields with an inner diameter that matches the diameter of the upper ring (223 mm), 235 mm is the maximum length of the hood. If a longer hood is used, vignetting will occur.



◆ Star Images

Since light acts as a wave, it causes a phenomenon called diffraction. Diffraction also occurs when light from a star enters or travels through a telescope, and this is unavoidable. When shooting celestial bodies, the light from diffraction is also imaged and scattered by the telescope together with the light of the stars, so it appears in the form of bright lines and flares around the stellar image. However, since diffraction occurs not only in the spider by also in various parts of the telescope and imaging system, it acts in a complex manner, including the influence of the telescope’s own optical system. As a result, it may disturb the bright lines and flares, or appear as an unexpected deterioration of the star image. Also, since stars are the ultimate point source, this effect can be particularly noticeable. Please note that this is not a defect of the product, but rather an unavoidable phenomenon.

Care & Maintenance

Regular maintenance is very important to ensure the best use and longevity of your telescope.

⚠ PRECAUTIONS

Do not disassemble excessively. Please refrain from removing the primary mirror and secondary mirror from the cell as much as possible. It is stored so that there is no play or pressure, so if you take it out carefully, even if you can put it in the cell without any damage, the star image will often deteriorate. In addition, Takahashi is not responsible for any damage or deterioration of the image when the correction lens is disassembled outside of the authorized service facility.

Please feel free to contact your authorized service facility for cleaning and collimation.

◆ Primary mirror and secondary mirror

Dew/condensation can form on the mirror. Be certain that the mirror surface has dried well before capping. To remove dust from the mirror or lens element, use a blower (as described on the next page). Moisture and dust can cause significant problems, shortening the life of the mirror coating.

The ε-160ED is precisely collimated at the factory prior to shipment. However, the alignment can be impacted by transportation or other rough movements. Check the star image, and if the appearance is abnormal, please contact us as soon as possible. Alternatively, see the collimation instructions from page 18 to make adjustments.

The Mirror coating has a durability of 10 years or more, but if mold or rust occurs, please ask us to re-coat. (Note: we cannot accept requests for coating other companies' products or selfmade mirrors.) If the entire mirror surface becomes whitish and dim, it is possible that rust has occurred, but it may be cleaned by cleaning the mirror surface. Please contact us before requesting re-coating.

◆ Correction lens

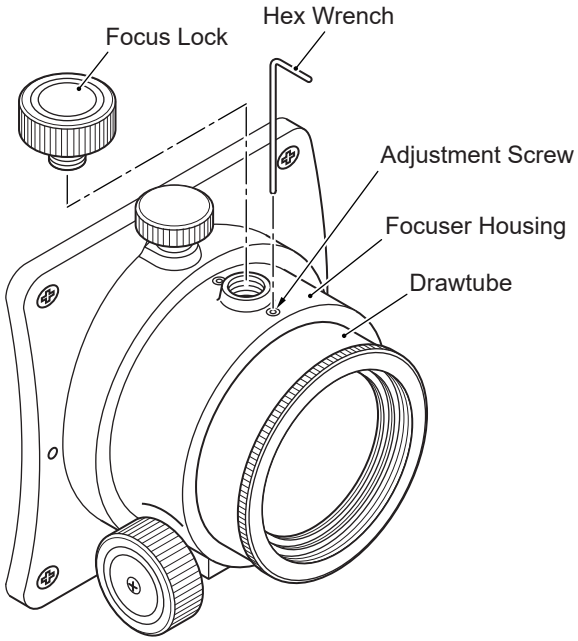
Before observing, remove the correction lens from the drawtube and blow off the dust on the surface with a hand blower. If it is extremely dirty or has fingerprints, moisten a commercially available lens cleaning solution on a soft, oil-free cloth and wipe it gently in a spiral from the center of the lens to the periphery. Please note that if you wipe it with dust on it, or with strong pressure, it may cause scratches.

◆ Optical tube assembly

For cleaning the optical tube assembly, use a damp (tightly squeezed) cloth. Dirt that is difficult to remove can be cleaned by wiping it off with car wax.

◆ Focuser

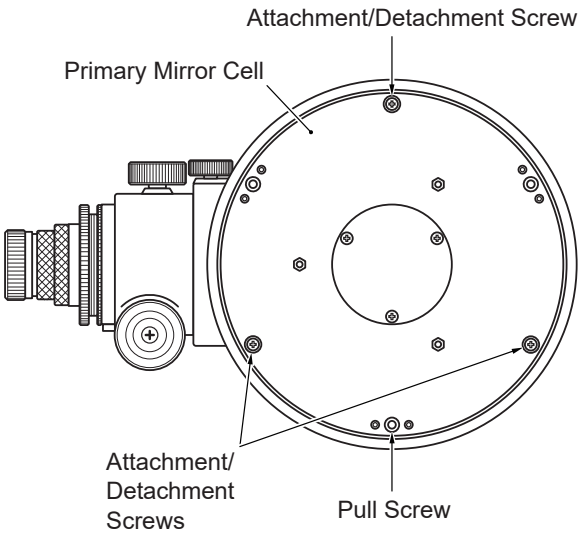
The drawtube may rattle during long-term use. If there is play, turn the adjustment screws in two places with the hex wrench and adjust so that the drawtube moves smoothly with the least amount of backlash.



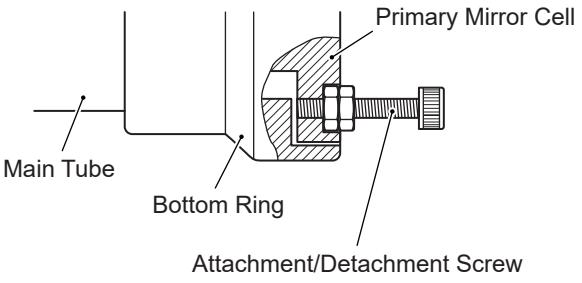
- Since it is adjusted to the best position at the factory, do not touch this screw more than necessary.
- Special grease is used for the drawtube and rotating body, so it can be used for a long time without grease replacement. If you put machine oil on it, this grease will flow and may slow down the movement. If you believe the instrument has run out of grease, contact us with a request to overhaul it.

◆ Detachment of the primary mirror cell

When cleaning the primary mirror, first remove the primary mirror cell from the optical tube assembly. Since there is no place to touch the primary mirror cell as it is, remove the cross head screw and screw in the primary mirror cell attachment/detachment screw to make it a handle. Attach the primary mirror cell attachment/detachment screws at least in two places so that you can hold it with both hands and it will not drop. If your return the primary mirror cell to the same position, the optical axis will not be misaligned, so if you mark it so that you can see the positional relationship between the screw hole of the lower ring and the pull screw hole of the primary mirror cell, the subsequent work will be easier. First, loosen the three primary mirror cell adjustment screws, and then remove the three pull screws to remove the primary mirror cell from the lower ring. Hold the set primary mirror cell attachment/detachment screw and do not hit the lower ring. Carefully pull it straight out.

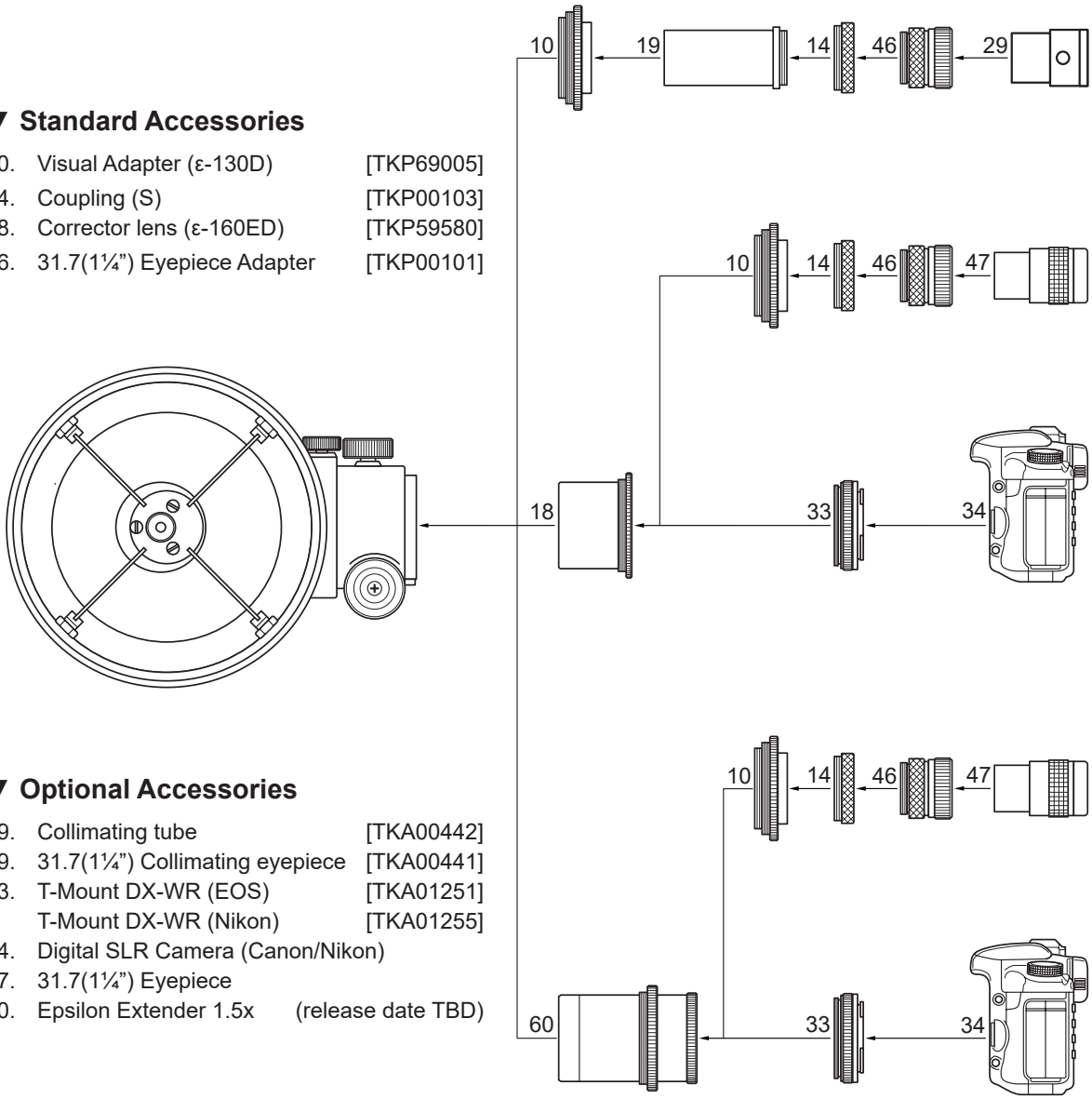


When attaching or detaching the primary mirror cell, be sure to use the attached primary mirror cell attachment/detachment screw.



System Charts

◆ Visual/Imaging System Chart



▼ Standard Accessories

10. Visual Adapter (ε-130D) [TKP69005]
14. Coupling (S) [TKP00103]
18. Corrector lens (ε-160ED) [TKP59580]
46. 31.7(1¼") Eyepiece Adapter [TKP00101]

▼ Optional Accessories

19. Collimating tube [TKA00442]
29. 31.7(1¼") Collimating eyepiece [TKA00441]
33. T-Mount DX-WR (EOS) [TKA01251]
    T-Mount DX-WR (Nikon) [TKA01255]
34. Digital SLR Camera (Canon/Nikon)
47. 31.7(1¼") Eyepiece
60. Epsilon Extender 1.5x (release date TBD)

(Note)

Parts Nos. 10, 14, 18 and 46 are standard with the tube assembly.
Some DSLR can not be attached.

MEMO

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