Chapter 13
Epilogue: Making a Small Telescope

An epilogue is an addition that rounds out and completes a story, and that's what we do here. For well over 300 pages, we have talked to you about building large telescopes. To round out this book—to complete the story—we show you how to build a small telescope.

This is necessary because now may not be the best time for you to build a large-aperture telescope. After all, you have to be more than a little obsessed to expend the kind of time and effort that a large telescope requires. The time, money, and skills simply aren't always available. Despite the obstacles, however, your desire to build a telescope with your own hands and use it to explore the heavens remains as strong as it ever was.

In these pages, we show how you can build an 8-inch *f*/6 Dobsonian that's a great performer. It is smaller, lighter, and less expensive than a big telescope, and to be quite frank, these features make it a lot more practical for many people. But should you ever decide to build a huge Dobsonian, you can apply the lessons you learn from building this 8-inch to the construction of your dream telescope.

Please understand that we don't want to talk you out of building a big telescope if that's what you want to do. Both of us use our own big telescopes on a regular basis, and we certainly understand and appreciate why you want a big one. For light grasp and resolution, you can't beat aperture. However, we would not be honest if we failed to point out that the deepest observing satisfaction often comes from being out under the stars with a modest telescope or pair of binoculars.

Small Dobsonians are perfect for nights when you have only a few minutes to quench your celestial thirst. If things get busy at work and you don't have the energy to observe, you'll feel a lot less guilty if your telescope is a small one than you will if it is a big one. Better yet, you can carry your 8-inch outside for ten minutes of before-bedtime skygazing, which is simply not possible with a big telescope. It's easy to use. It's easy to store. It has a wide field of view. No ladders. It's perfect for comets, Milky Way cruising, open clusters, but still big enough for celestial events like occultations, grazes and satellite transits.

Besides, even after you have built your dream telescope, you're going to

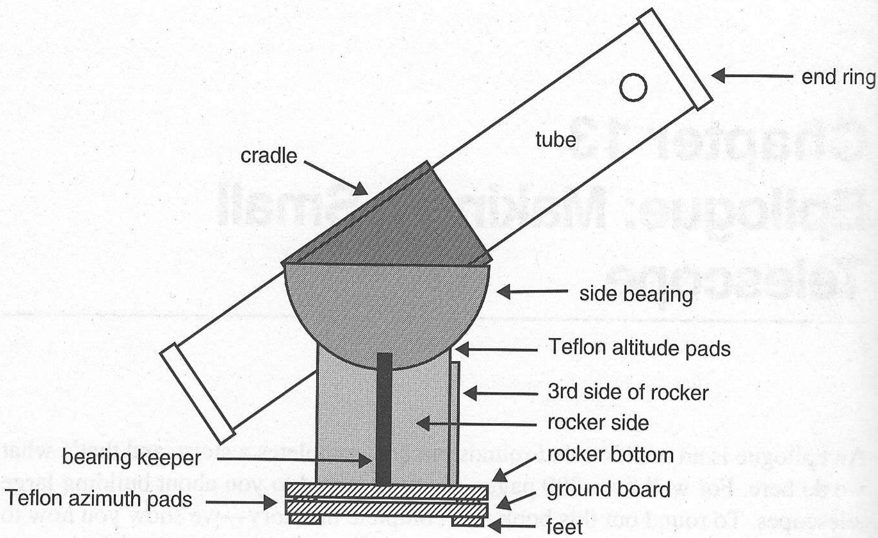

Fig. 13.1 Our small Dobsonian resembles the classic instruments of the 1980s, with a solid tube and a relatively tall rocker, but the big side bearing and low-friction laminates we recommend add up to exceptionally smooth performance.

need a small, portable instrument for the nights you don't feel like setting up a big one—so why not build the small one now? Well, enough preamble—let's talk telescopes!

13.1 Materials You Need

Collect the following parts and materials to build an 8-inch *f*/6 Dobsonian telescope:

One 8-inch *f*/6 aluminized and overcoated primary mirror. (We might add here that if the telescope-making bug has bitten you badly, you might want to consider grinding, polishing, and figuring the primary mirror. Although making a big mirror is not a task for a novice, tens of thousands of people have made an excellent 8-inch mirror on the first try.)

One 1½-inch minor-axis secondary mirror (sometimes just called a "diagonal"), aluminized and overcoated.

One commercially-made spider. The length of the spider's legs should be appropriate for the tube you are using, that is, they should be designed for a 10-inch inside tube diameter.

One commercially-made secondary-mirror holder. Be sure you order one with the same diameter as the minor axis of the secondary mirror.

One commercially-made low-profile 1¼-inch focuser. Fully racked in, it should have a maximum height of 1¾ inches. Stay away from focusers for 2-inch eyepieces; they are tempting, but eyepieces made for these are too heavy for small telescopes.

One 5-foot length of 10-inch diameter cardboard concrete form tube. This material is sold at home-improvement centers, builders supply houses, and places that sell ready-mix concrete under the trade names Sonotube, E-Z-Form, and a variety of others. It usually has a plastic or wax coating that you will have to remove.

One-half sheet of ½-inch high-quality HVHC plywood to make the mirror cell, cradle and rocker.

One half-sheet of ordinary ¾-inch plywood for the side bearings and ground board; SVSC is adequate.

One sheet of Kydex in the color of your choice. In this design, Kydex forms the outer covering of the telescope's tube, so your choice of color matters.

Ebony Star counter-top laminate. You will need enough to cut one circle 16-inches diameter and two strips 30 inches long by 1 inch wide.

Teflon plastic for the bearings. You will need three pieces 1½ x 1½ inches and four ¾ x 1 inches by at least ⅛-inch thick. This is not much Teflon, so call your local plastics supplier (in the Yellow Pages under "Plastics") and ask if you can obtain scraps or cutoffs.

In addition to these components, you will need paint, a small 12-volt fan, contact adhesive, silicone adhesive, wood glue, finishing nails and assorted small bits of hardware. Read through this entire section before you do any work so you understand the whole process in advance.

13.2 Overview of Construction

The construction sequence for a small telescope is similar to building the big ones; the overall plan is to build the telescope around the optical system. Here is the construction sequence that we recommend.

Step 1. Order the mirrors, focuser and spider. Purchase the length of concrete form tube.

Step 2. Construct the primary mirror cell and install the primary mirror in it.

Step 3. Temporarily install the spider, secondary mirror, and focuser in the tube.

Step 4. Position the primary mirror cell and verify the spacing by focusing on a distant object outside.

Step 5. Trim off the excess tube behind the mirror cell.

Step 6. Remove the spider, secondary mirror, focuser and primary mirror from the tube.

Step 7. Paint the inside of the tube black and wrap Kydex around the outside of the tube.

Step 8. Construct the cradle and side bearings.

Step 9. Locate the balance point of the tube assembly. Use this value to calculate the depth of rocker.

Step 10. Construct the rocker and ground board.

Step 11. Put on the finishing touches and savor "first light" with a look at your favorite celestial objects.

13.3 Begin with the Tube

Before you order the primary and secondary mirrors, read **Chapter 5** for advice. It is almost always possible to order small mirrors "off the shelf," so you will probably receive yours in a few weeks, at most. For a primary mirror of 12 inches aperture and under, we suggest that you order a full-thickness one. Although you could argue that a thin mirror might cool faster, in the smaller sizes even full-thickness mirrors cool rapidly, and the extra weight helps to balance the tube.

Purchase a length of concrete form tube roughly 2 inches larger in diameter to keep any tube currents away from the light path. The tube should be roughly 12 inches longer than the focal length of your primary mirror. For an 8-inch *f*/6 mirror, the tube would be 10 inches diameter and 5 feet or even 6 feet long. You won't need so much, but form tube is inexpensive and the extra length means that you can select the better end and discard the extra. Concrete form tube is sold in 2-inch increments based on the inside diameter (which would be the outside diameter of the concrete casting), so 10-inch tube is available.

When you buy it, concrete form tube often looks terrible. The surface doesn't matter since you will cover it, but make sure you get a piece that hasn't been squashed out of round. If your tube has a heavy wax coating on the inside, paint may not adhere. The remedy is simple. Carefully peel away one layer of paper from the inside of the tube. The resulting surface is rough and makes an excellent light absorber when it is painted black.

With the tube in hand, order a secondary mirror, holder, and spider. We recommend a standard straight-vane spider; they are tough and don't get out of adjustment. There is nothing wrong with two-vane, three-vane, or curved-leg designs, but the four-vane types are best for portable instruments.

While you are waiting for the optics and other components to arrive, paint the inside of the tube flat black. Ordinary flat-black primer paints work the best. Attach a small paint brush to a thin wood stick at a 90° angle. Start in the middle and work out to the ends. The stick should be at least half the length of the tube.

When the components arrive, decide which is the better end of the tube. Drill holes for the focuser 8 inches from the end you have selected. There is no need to be concerned about vignetting the incoming starlight because the tube is already oversize to handle potential tube currents. Drill holes for the bolts that hold the legs of the spider; place them so that the secondary holder lies directly opposite the center of the focuser.

Refer to the manufacturer's directions to install the secondary mirror in the secondary holder, and to place the secondary holder in the spider. Next, install the focuser and spider in the tube. This installation is temporary, so don't fuss trying to make everything perfect: the purpose is for you to check the location of the optics. Double check that the secondary holder is located directly opposite the draw tube of the focuser.

13.3.1 The Primary Mirror Cell

For mirrors up to 10 inches aperture, there is little danger that the mirror will flex under its own weight. You can simply fasten the mirror to a plywood disk with three dabs of silicone adhesive. The disk that carries the mirror is called the mirror disk; it is the same diameter as the mirror.

To align the mirror, three collimation bolts opposed by stiff springs allow you to tip and tilt the mirror disk relative to a second plywood disk, the tube disk, that fits inside of the telescope tube. The tube disk will be screwed securely inside the bottom end of the telescope tube.

The collimation bolts are ¼-20 by 3-inch long carriage bolts; the springs that oppose them are stout 1 inch long by ½ inch diameter compression springs that are slipped over each bolt. Each bolt is held captive by a wing nut. By turning the wing nuts, you can tilt and tip the mirror disk to send the reflected cone of light up to the secondary mirror.

Cut the two disks out of ¾-inch plywood. The mirror disk should be the same diameter as the mirror; you can trace the outside of the mirror with a pencil. The tube disk is drawn with a compass to match the inside diameter of the tube. Cut out the disks with a saber saw or band saw, then do the final trim to round with a router or power sander. Check the fit of the tube disk. It should just slip into the tube.

Set the mirror disk on top of the tube disk and center it. Drill three ¼-inch holes 120° apart through both disks for the collimation bolts. The holes should be drilled about 1 inch in from the edge of the mirror disk. Drill the holes through both disks at the same time so they line up precisely. After you drill the holes, mark them so you know which corresponds to which. To permit the bolts to pass freely through the tube disk, redrill its three holes to 5⁄16 inches.

Finally, to provide air circulation, drill a 2-inch diameter hole through the center of both disks. These holes can be bored with a spade bit or a small hole saw. After all the holes are drilled, seal both wood disks with gloss polyurethane to insure a good bonding surface for the silicone adhesive you will use shortly. Paint or varnish the outer side of the tube disk to match the finish you plan to apply to the rest of the telescope.

To assemble the mirror cell, insert the carriage bolts through the mirror disk and seat them completely by tapping their heads with a hammer. Slip a metal washer over each bolt, then the compression spring, and then another washer on top of the spring. Slip the tube disk over the bolts, place a washer on each one, then thread the wing nuts onto each bolt. Tighten the wing nuts until the springs are par-

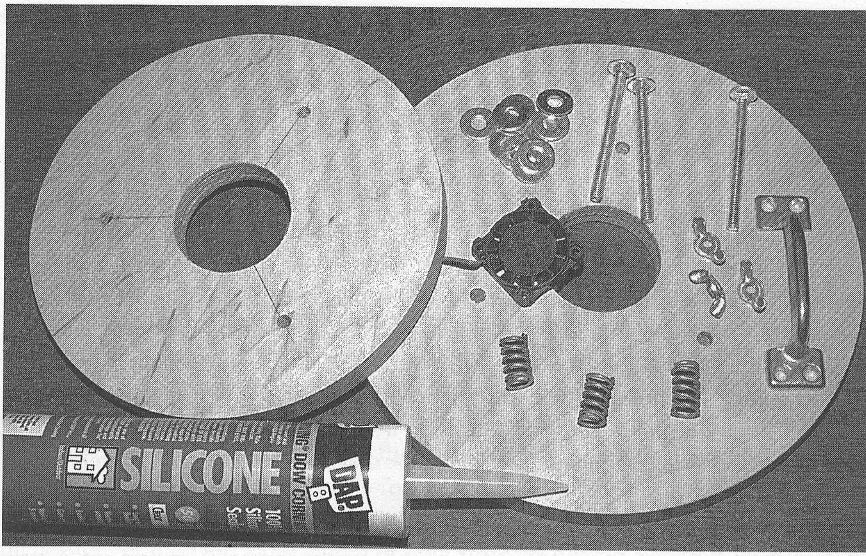

Fig. 13.2 The mirror cell is made from two plywood circles and a handful of stuff from the hardware store. The miniature fan guarantees that the tube will cool even though the bottom end is closed.

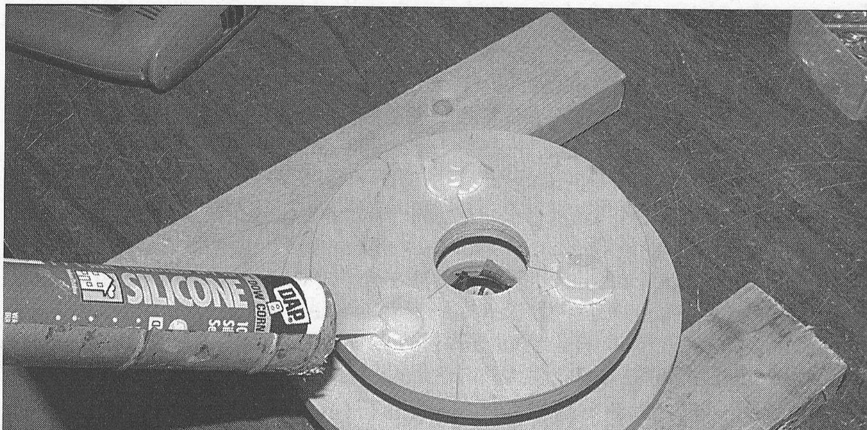

Fig. 13.3 To install the primary mirror, assemble the mirror cell and then squeeze three blobs of silicone adhesive over the heads of the collimation bolts. Center the mirror on the disc. ***Do not press it all the way down.*** *The silicone between the mirror and bolt heads has to stay about ⅛-inch thick or the mirror is distorted when the plywood changes dimensions. When the blob is thick it stays resilient. When the adhesive cures, these pads hold your mirror securely.*

tically compressed.

To aid air circulation, mount a miniature 12-volt muffin fan, the type used to cool computer chips, in the central hole of the tube disk. Orient the fan so that it will pull air from behind the mirror and blow it out the bottom end of the tube. You can leave the fan running while observing if you find that the images are better. We have never had any problem with vibration from these little fans. Finally, screw a 3-inch metal door handle to the back of the tube disk so that you will have a good grip when you install the cell in the tube.

Stop for a moment. Vacuum around your work area and the blow all the accumulated wood chips and grime off the mirror cell. From now on, you want to work clean so the aluminized mirror surface remains free of dust and dirt.

Place the cleaned mirror cell on the work surface with the mirror disk facing up. You may need to place blocks under the cell to hold it level. Squeeze blobs of silicone adhesive about 1 inch diameter and ⅜ inch thick over the head of each collimation bolt. Silicone adhesive sticks tenaciously to clean glass, metal, and polyurethane.

Align the rim of the mirror with the edges of the disk and lower it onto the silicone blob. Wiggle it slightly to get good adhesion, and gently shim the mirror until it is just ⅛ inch short of contacting the heads of the collimation bolts. This leaves about ⅛ inch open under the glass. Let the adhesive cure undisturbed for 24 hours.

Our experiments have shown that three silicone blobs will hold a mirror 8 inches diameter in complete safety for many years. However, if you are nervous, you can wrap a couple turns of duct tape over the edge of the cell. Make sure that the gummy adhesive on the tape stays well away from the aluminized surface. Frankly, we don't recommend taping because the silicone will outlast tape by many years, but if you cannot sleep worrying about your mirror, then it is best to set your mind at rest.

Since the tape obstructs the flow of air around the mirror, cut six slits each at least two inches long between the bottom of the glass and the disk. With the big central hole in the two plywood disks, air can circulate around the mirror.

13.3.2 Locate the Mirror Cell

At this point, the focuser, spider, secondary mirror and secondary holder should be installed in the telescope tube, and the primary mirror should be mounted on the mirror cell. Knock together a simple cradle about 18 inches long with a simple "V" block at each end. This handy device allows you to rest the tube on a surface without worrying that it will roll. Prepare a work surface—a backyard picnic table will serve—in a place outdoors where you can see some "targets" several hundred yards or more distant. Recruit someone to serve as your helper, and you're ready to go.

Place the tube on the cradle and aim the open end toward the distant target. Rack out the drawtube about ¼ inch. With a ruler, measure from the top of the fo-

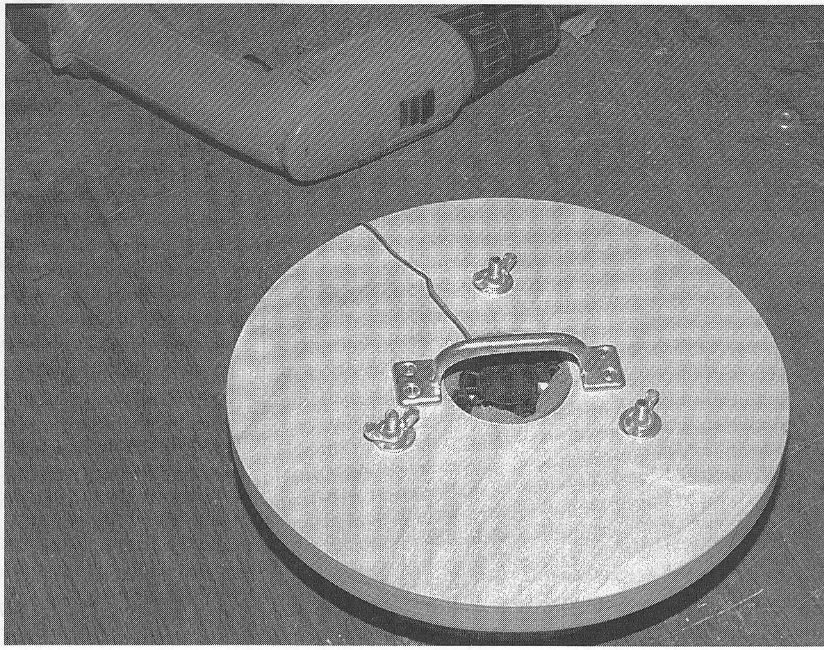

Fig. 13.4 *The handle attached to the bottom of the mirror cell makes it easier to install the cell in the telescope, and it gives you a secure place to hold the tube. Note the fan mounted under the handle.*

Fig. 13.5 *Kydex plastic makes an excellent finish for the tube: it is both tough and waterproof. Recruit a helper. Coat both surfaces with contact cement and allow the cement to dry, then slowly roll the Kydex onto the tube.*

cuser to the center of the secondary mirror. Subtract this distance from the focal length of the primary mirror. The remainder is the distance from the secondary mirror to the surface of the primary. Measure this distance from the center of the focuser along the side of the tube. Carefully insert the mirror cell with the mirror into the back end of the tube and push it forward until the front surface of the primary is roughly under the mark on the tube. (After doing this, you will appreciate the handle on the back of the cell.)

Look into the focuser and have your helper tip and tilt the cell until you see the open end of the tube reflected in the mirror. Don't worry about collimation; you just want an image. Place a low-power eyepiece in the focuser. Have your helper move the mirror cell back and forth until the image of the distant object comes into focus. Wedge the cell lightly in place with paper shims. Try all of your eyepieces to be sure that the eyepiece with most "in travel" reaches focus when the focuser is racked in. Mark the location of the back of the tube disk on the inside the tube.

If you cannot wait another moment, drill small holes and drive three small wood screws through the tube and into the side of the tube disk to hold the cell in place. Do a rough collimation, and that night prop up your telescope to do some temporary stargazing. Be careful not to let the tube fall—that would ruin your fun!

When you are satisfied that the mirror cell is correctly placed, remove the cell. Draw a line around the tube, and cut the tube to length with a hand saw or saber saw. Here's a simple way to draw the line perpendicular to the axis of the tube: wrap a large sheet of paper around the tube and adjust it so that the edge of the paper meets itself after one full turn around the tube.

13.3.3 Finish the Tube

There are lots of ways to complete the tube. You could leave the outside of the concrete form tube as is: as long as the cardboard stays dry, the images won't suffer. If you live in a humid region where dew would wet the tube, then you could seal the outside of it with varnish or paint. You'll likely have a spiral stripe down the tube, and paint tends to look at bit "hairy" on concrete form tube, but you'll have a fully functional telescope tube for very little money.

For a really good-looking job, you can wrap the tube with a sheet of Kydex plastic. Kydex is an excellent covering for cardboard tube: it is waterproof, it comes in bright colors, and it has a "hair cell" texture that hides fingerprints. If you prefer a glossy look, you can bond the textured side in and leave the smooth, shiny side out. Not only is Kydex inexpensive, it is easy to work with.

Start by removing the focuser, spider, diagonal mirror, and mirror cell. In the process of getting everything right, you may have drilled a few extra holes, but the Kydex will cover them. Sand off any bumps on the tube or protruding layers of paper around the holes.

Some concrete form tubes have a heavy wax coating on the outside. If yours does, remove as much as you can by peeling away the top layer of paper, or wash the tube with a paint solvent. A sure method is to evaporate the wax with a heat gun, or propane torch—but do this outside and take pains not to overheat the wax and start a fire! In the southwestern states, you can put the tube out in the hot summer sun and the wax will vaporize. If you bought a tube that was somewhat too long, experiment on the leftover piece. When you can no longer scrape away any excess wax with your fingernail, enough of the wax is gone and you are ready to begin.

For wrapping the tube, recruit a helper because it involves more than one person can easily do. Warn your helper that you expect to be crabby and snappish, but you really do need their help.

Measure and cut a sheet of the Kydex an inch longer than the tube and an inch wider than the circumference. Make sure its edges are straight and square. On the side of the tube opposite the focuser hole, draw a pencil line down the length of the tube to help you align the edge of the Kydex. Align one edge of the Kydex on this mark and do a trial wrap to make sure that the edges of the Kydex overlap slightly. If the line is not parallel to the length of the tube, you may find you have too much Kydex at one end and not enough at the other when you wrap it around the tube.

To apply contact cement, purchase several inexpensive foam brushes. You will need at least two because once contact adhesive dries, the brush is ruined. Paint a strip of contact adhesive a couple inches wide along the length of the tube beside the pencil line. Paint another strip of adhesive along the mating edge of the Kydex. Be sure you apply the adhesive to the side you want mated to the tube. Let these strips of adhesive dry to touch.

Here is where the helper comes in. Align the edge of the Kydex sheet with the pencil line on the tube. Starting in the middle, press the Kydex to the tube. Work toward both ends. You want to join the edge of the Kydex along the line parallel to the long axis of the tube. With the Kydex firmly attached to the tube this way you can control the final wrapping better.

Place the tube with the Kydex sheet attached at the end on the floor or a large table. Paint the entire outside of the tube and the mating surface of the Kydex with contact adhesive. Let both surfaces dry to touch. Carefully wrap the Kydex sheet around the tube pressing it firmly with your hands.

Go slowly. Roll and wrap only a couple inches around the tube at a time. Force out air bubbles, and make sure you have a good bond over the entire surface.

When the tube is fully wrapped, there should be about an inch of overlap. With a pencil, trace the location of the final seam on the length of the tube. Paint adhesive between the free end of the sheet and the mating surface on the tube, being careful not to go beyond the pencil line. Any adhesive applied beyond the pencil line won't be covered by the Kydex and will look bad. When the adhesive is dry to touch, press it down. Trim away the excess Kydex at the ends of the tube with a sharp knife, and then step back to admire your work. Be sure to give your helper plenty of thanks. Imagine doing the whole thing by yourself!

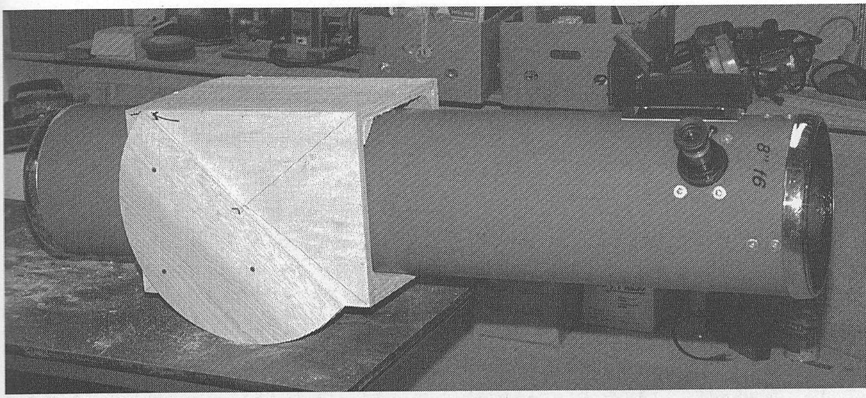

Fig. 13.6 The optical tube assembly sits on your workbench balanced on the side bearings. When you complete the rocker and ground board, your telescope will be ready for a night under the stars.

13.3.4 Add End Rings

The exposed ends of your cardboard tube need reinforcement and protection, so you have an excellent opportunity to try a little creative scrounging. You can make end rings from plywood, metal or plastic. Metal baking dishes, plastic food containers, and a wide variety of other common items like hub caps make excellent end rings. The trick is to keep looking until you find something that fits.

You may get lucky at the junk yard. The chrome-plated end rings used on the telescope in the pictures came from a pair of Ford Motor Company hub caps. They fit perfectly over the tube ends, so the centers were cut out. The front ring can be cemented permanently with silicone adhesive, but you should attach the back ring with small screws so that you can remove it. These hub cap end rings look professional and cost only a dollar apiece.

13.3.5 Assemble the Tube

Assembling the tube takes only a few minutes. Redrill the holes for the focuser and spider through the Kydex, then install the focuser, spider and diagonal at the front of the tube. Vacuum up the scraps from drilling.

To install the mirror cell, remove the bottom end ring. Drill four or five small pilot holes through the tube and into the tube disk. Secure the cell with 1 inch long drywall screws. Be careful when you drill the holes: the primary mirror is in there. Vacuum up the scraps from drilling.

With the mirror cell in place, install the bottom end ring. Use screws. You need to be able to remove this ring so you can slip the tube into the tube cradle.

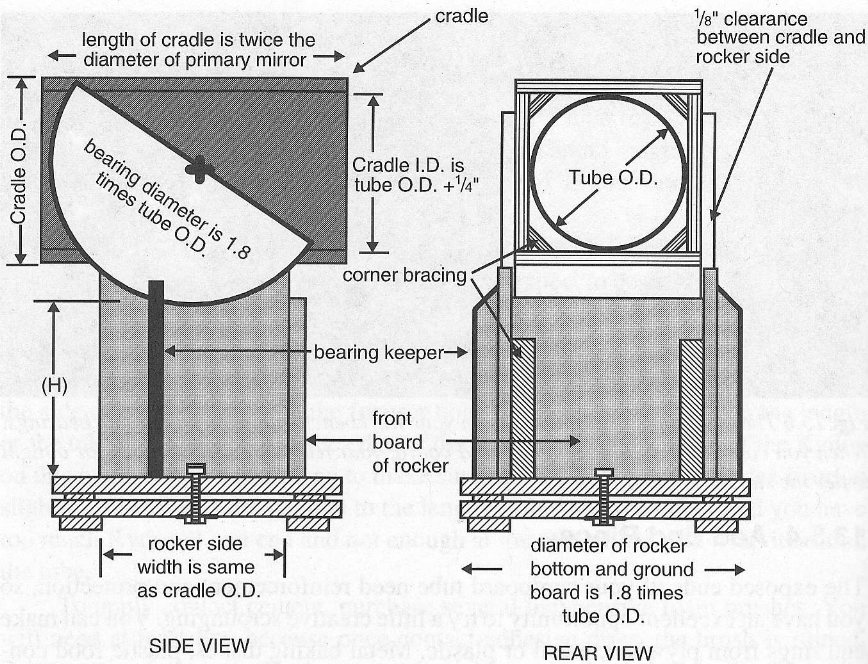

Fig 13.7 The mounting is constructed from ½-inch hardwood plywood. The tube cradle is sized to fit the optical tube assembly; the large side bearings are attached directly to it. This mounting is quite compact: the rocker stands only about a foot high.

13.4 The Mounting

Compared to building a large telescope, mounting a small Dobsonian is a cinch. The mounting consists of four easy-to-build plywood components:

1. tube cradle,
2. side bearings,
3. rocker, and
4. ground board.

The tube cradle is a squarish box that holds the tube; the side bearings are mounted on the sides of the tube cradle. The rocker is a three-sided box that supports the tube in the cradle on Teflon bearings, and the ground board is the flat piece on the ground that everything turns on.

13.4.1 Build the Tube Cradle

Because the optical tube assembly of your telescope has a round cross section, it needs a foundation with flat sides where you can attach side bearings. That's the job of the tube cradle, a four-sided structure that goes around the tube. You will

Fig. 13.8 Use a carpenter's framing square to check that the rocker box is precisely square before you put it aside for the glue to set. If the rocker is out of square, the tube cradle may bind against the rocker.

use high-quality ½-inch HVHC plywood for the cradle.

Begin by accurately measuring the outside diameter of the tube. The inside dimension of the tube cradle should be ¼-inch larger than the outside diameter of the finished tube. It can then be inserted easily into the cradle and held firmly with cardboard shims. The length of the cradle is relatively arbitrary. We recommend a 16-inch long cradle for an 8-inch telescope with a cardboard tube.

Since your tube may be a bit larger or smaller, be sure to figure your own dimensions. As an example, however, an 8-inch *f*/6 Dobsonian with a tube 10 inches outside diameter would have a cradle 10¼ by 10¼ inches inside by 16 inches long. Because two of the cradle sides must overlap at the corners, two of the sides must be 11¼ inches wide and the other two must be 10¼ inches wide.

Lay out the four sides on a sheet of ½-inch HVHC plywood and cut them out. Be as accurate as you can when sawing. Each pair of opposing sides should have exactly the same dimensions and should be perfectly square. Bond the corners of the cradle with wood glue and a few small finishing nails. Clamp or set heavy weights on it to improve the strength of the joint. The finishing nails serve to keep the pieces aligned on the slippery glue while it sets; they add little to the strength

Fig. 13.9 Finish the rocker and ground board with a pleasing wood stain and several coats of polyurethane varnish. This mounting is remarkably compact considering that it carries an 8-inch telescope.

of the joint. Wipe off any excess glue with a damp rag.

Before the glue sets, double-check the corners with a framing square. If the cradle isn't square, the tube will get squashed out of round, the side bearings will not be aligned so that the scope will wobble in the rocker, and the bottom end of the tube will scrape the inside of the rocker when you try to aim the telescope at the zenith.

After the glue sets, reinforce the corner joints with corner braces that run the length of the rocker and are an inch or two wide. If your cradle is square, the 45° saw cuts on the braces will mate perfectly in each corner. Glue them in by wedging scrap sticks of wood between opposite braces. Be careful that you don't push the cradle out of square.

Install a metal door handle on the top of the cradle to make it easy to carry the cradle-tube assembly out to your back yard. Insert the telescope tube into the cradle. Rotate the tube so the focuser is at a 45° angle from vertical. This is the most comfortable all around viewing position. Press cardboard shims between the tube and the cradle to secure the tube firmly.

Congratulations. The optical tube assembly of your telescope is ready for photons.

13.4.2 Side Bearings

The side bearings are large semicircular disks cut from ¾-inch ordinary SVSC plywood. For a 10-inch diameter tube, we recommend bearings 18 inches in diameter. Note that the side bearings are ¾ inch thick but that the rocker sides are ½ inch thick. The greater thickness of the bearing spans the ⅛-inch clearance between the inside of the rocker and the outside of the cradle.

Using a stick compass, draw an 18-inch circle on the plywood. Mark the center where the nail in the stick compass pricked the wood so you can recover the center later. Cut the disk with a saber saw or band saw, staying as close to the pencil line as possible without crossing inside it. Trim the disk to final dimensions with a router.

Draw a line parallel to the face grain of the plywood across the disk through the center point. The direction is important because the plywood is stiffer along the grain, and the bearings will look more attractive too. Then with a square, draw a short line perpendicular to the diameter at the center point so that you can locate the center of rotation of the bearing after you cut the disk in two.

Cut the disk in half along the pencil line to yield the two side bearings. Apply a ¾-inch strip of Ebony Star laminate to the outside circumference of each side bearing with contact adhesive. File or sand the edges of the laminate smooth.

The two side bearings must lie exactly opposite each other on the tube cradle. On each of the opposite sides of the cradle, draw a pair of pencil lines from opposite corners. These lines cross at the exact center of the cradle. Place the exact center of the bearing at this point and then rotate it until one end is flush with the top surface of the cradle. Recheck that the center of the bearing is still at the center of the cradle, and then attach the bearing to the cradle with a couple of wood screws. Flip the cradle over and attach the other bearing the same way.

Do not glue the bearings to the cradle. If they wobble in the rocker when you assemble the telescope, you can readjust them.

13.4.3 Locate the Tube Balance Point

Balancing the tube is much easier on a small scope than it is on the big one, but to do it right, everything that you plan to attach to the tube assembly should be attached now. The optics must be in place, your heaviest eyepiece, your finder or Telrad, and miscellaneous things like dew heaters must all be installed. Slip the

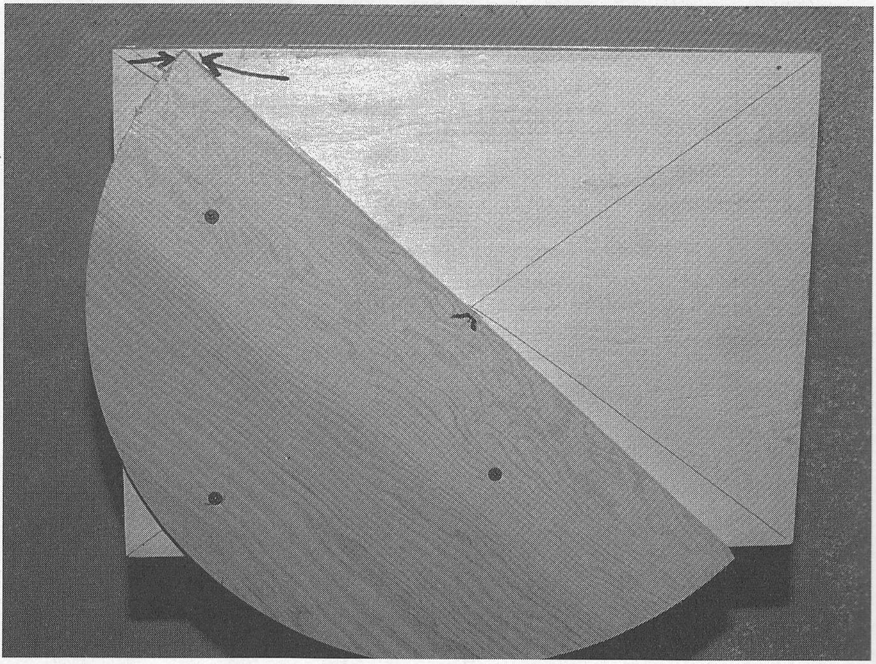

Fig. 13.10 *The center of the side bearing coincides with the center of the tube cradle, and the ends of the flat side of the side bearing cross from one side of the tube cradle to the other.*

completed tube into the cradle, removing the bottom end ring if necessary, and then reattach the bottom end ring.

Place the assembly on the floor. The telescope will rest on the side bearings. Slide the tube back and forth in the cradle until it sits level on the bearings. The balance point is then precisely at the center of the cradle and tube assembly and at the center of radius of the side bearings. Balancing is easy; the hard part was attaching all the extras.

To secure the tube, slip in cardboard shims. Do not glue the tube into the cradle because you may need to rebalance it in the future.

13.4.4 Construct the Rocker

Before you build the rocker, the optics must be installed in the optical tube assembly, the cradle and side bearings must be finished, and the balance point of the whole system must be determined. The reason is that before you can build the rocker, you need to determine how tall it should be.

With stick or ruler, measure from the center of the side bearing circles to the bottom of the tube. Just to be on the safe side, add two inches to the bottom length. The two inches give you an extra bit of clearance if you need to find a different balance point to accommodate a new 3-pound eyepiece that you couldn't resist. The height of the rocker sides is this height minus the radius of the side bearings.

Fig. 13.11 The best reasons for building a small Dobsonian are its portability and ease of use. Long after you have built the enormous telescope of your dreams, you'll still use "The Little One" often.

For example, if the tube balances 18 inches from the bottom end, add 2 inches clearance for a total of 20 inches. With side bearings 18 inches in diameter, the radius is 9 inches, so 20 minus 9 equals 11 inches. The height of the rocker sides to the bottom of the arc should be 11 inches.

The rocker sides should be the same width as the tube cradle, 11¼ inches. Cut out two pieces of ½-inch HVHC plywood 11¼ inches wide and longer by the radius of your side bearings than height to the bottom of the rocker arc; this would be 11 plus 9 inches, for a total of 20 inches. You need the extra length to locate the point of a compass so that you can draw an arc that matches the side bearings.

Get out your trusty stick compass and set it to the radius of the side bearings (9 inches) plus the thickness of the Teflon pads you are going to use. If the pads are ⅛-inch thick, then set the compass to a radius of 9⅛ inches.

Next, locate the center of the arc at the top of each of the rocker sides. From the center of the bottom edge of the rocker side, measure up 20⅛ inches and mark a point exactly in the center of each rocker side, that is, 5⅝ inches in from both sides. Place the compass at this point and draw an arc across the face of the plywood. Check the line against your side bearings to confirm it falls inside the arc by the thickness of the Teflon pads. Cut out the arcs on each side. The center should be the same you used for your compass point. If you don't have a router, then cut the arc with a saber saw. After you make both rocker sides, set them on top of each other and check that the length, width, and arcs match perfectly.

Cut the front board of the rocker from ½-inch HVHC plywood. The front board connects the sides that support the side bearings, and substantially reinforces the rocker. To make the rocker as rigid as possible, the front board should reach the top of the rocker arcs; measure this directly off the rocker sides. Its width should equal the distance between the outer surfaces of the side bearings plus a small clearance. Since the cradle is 11¼ inches wide and the side bearings are each ¾ inches thick, the total is 12¾ inches. Allowing another ⅛ inch for clearance between the outside of the cradle and the inside of the rocker sides, the front board should be 13 inches wide by at least 11 inches tall. Cut it out and check that your cuts are accurately square.

Begin assembling the rocker by gluing the rocker sides to the front board. Tap in a few finishing nails to hold the assembly together. While the glue sets, place the assembly on the flat surface of your work bench and check that the bottom edges contact the bench evenly. If they do not, twist the assembled sides until they do, and then recheck the squareness of the three sides with a framing square. When the assembly is both square and rests flat on the bench, clamp the joints until the glue sets.

Reinforce the inside corners of the rocker with braces as you did for the cradle. Be sure these braces do not interfere with complete rotation of the tube assembly. If they extend too high, the cradle may hit them and prevent you from aiming the scope straight up.

The three-sided rocker box sits atop the round rocker bottom, a disk of ½-inch HVHC or ¾-inch SVSC plywood. We recommend that you make the rocker bottom 1.8 times the tube diameter. For a 10-inch tube, this would be 18 inches. Since the ground board should be the same diameter, when you cut and trim the rocker bottom, make two disks. One of them can serve as the ground board. For a good-looking telescope, use the better-looking face of the better-looking disk for the top of the rocker bottom.

Place the three-sided rocker assembly atop the rocker bottom disk so that the sides are equidistant from the center. To help, draw two lines across the disk through the center. After you draw the first line, use a framing square to draw a second line perpendicular to it. These lines are a good visual aid to centering the rocker sides. The three sides should just fit onto the bottom disk.

Mark the location of the rocker box on the bottom disk, then remove the box and drill two pilot holes per side through the disk. Replace the box and run 1½-inch long drywall screws through the bottom of the disk and into the end grain of the sides. If you set the telescope on the box, you should be able to swing it from vertical to horizontal without its binding or striking anything.

When you are confident the fit is good, remove the screws, apply wood glue to the bottom edges of the sides, and reassemble the rocker. Tighten the drywall screws until the heads are flush with the bottom of the disk. If any screw head protrudes from the surface of the underside of the disk you will need to file it flat or remove it after the glue has set.

With contact cement, attach the Ebony Star laminate to the bottom of the rocker assembly. Brush the cement on both surfaces, allow it to dry until it is no longer tacky, and then bring the surfaces together. They will bond instantly and permanently. Trim off any excess with a router and a laminate trimming bit.

Drill a ½-inch hole through the center of the rocker bottom for the pivot bolt.

Cut out four Teflon rectangles for the altitude pads. They should be ½ inch wide and 1 inch long. Attach the pads to the ends of the rocker arcs using tiny finishing nails. Use a nail set to recess the heads of the nails halfway through the Teflon so they will not score the laminate bearing.

Set the tube-cradle assembly on the rocker and check the movement. Note that the side bearings tend to slide sideways off the rocker pads. To prevent this, attach a short wood strip 1 inch wide and ¾ inches thick to each rocker side. These "keepers" should rise 1 inch above the bottom of the rocker arc. Glue a felt covering on their inside surface to prevent scratches on the faces of the side bearings.

13.4.5 Make the Ground Board

The ground board is easy to make since you have already cut out the disk. Make three feet each 2 inches square by ¾ inch thick from a hardwood and glue them to the bottom of the ground board 120° apart. Their outer edges should lie about ¼ inch from the outside edge of the ground board.

Drill a ½-inch hole through the center of the ground board for the pivot bolt. Construct a ½-inch welded nut-and-plate as described in **Section 10.3.2**, and attach the plate to the underside of the ground board.

At this point, all of the construction is done. Stain, varnish, or paint the rocker and ground board top and bottom, inside and outside. Allow the finish materials to dry thoroughly before you continue.

Cut three pieces of Teflon 1½ inches square; attach them to the ground board directly over the feet using tiny finishing nails. Recess the heads so they cannot scratch the bottom bearing. Wax the bearings with car wax.

Connect the ground board to the rocker with a ½-inch hex-head machine bolt. Don't tighten this bolt; leave about 1/16 inch clearance under the washer so that the rocker is free to rotate.

If you have not done so already, slip the tube into the tube cradle. Turn the tube so that the focuser is 45° above horizontal, and then shim the tube securely into the tube cradle with pieces of cardboard.

Finally, set the tube-cradle assembly into the rocker and, come nightfall, enjoy "first light" on the star of your choice.