

Build a Sun Funnel for Group Viewing of Sunspots & the Transit of Venus



Richard Tresch Fienberg
American Astronomical Society



Chuck Bueter
Nightwise.org / TransitofVenus.org



Louis A. Mayo
NASA Goddard / Honeywell Tech. Solutions

This simple & inexpensive device makes it easy for many people to observe the Sun simultaneously.



Origin of the Sun Funnel: Gene Zajac and Chuck Bueter adapted (<http://bit.ly/rt16jc>) an existing design for a 2003 Great Lakes Planetarium Association Conference workshop. The rear-screen projection material, a key ingredient, is an idea borrowed from Bruce Hegerberg's Sun Gun (<http://bit.ly/q9WpYU>).



Red numbers correspond to items listed on the next two pages.

Supplies & Tools

Supplies

- 1.** Blitz Super Funnel #05034, 17.75-inch x 5-inch x 5-inch (round top), \$2 to \$5 at your local hardware or auto-parts store. Online: <http://bit.ly/ozgP07>
- 2.** Large hose clamp, 2.5-inch x 5.5-inch, e.g., Breeze #62080; \$1 to \$2 at your local hardware store. Online: <http://bit.ly/qBbvRK>
- 3.** Small hose clamp, 13/16-inch x 1.5-inch, e.g., Breeze #62016; \$0.50 to \$1 at your local hardware store. Online: <http://bit.ly/oTDjRR>
- 4.** Da-Lite High-Contrast Da-Tex rear-surface projection screen #95774, 8-inch x 8-inch; ~\$10 for 1 square foot (usually the minimum order size). Online: <http://bit.ly/nE0fTU>

Continued on next page →

Supplies, continued

5. Inexpensive (e.g., Huygens, Kellner, Plössl) telescope eyepiece, 1.25-inch barrel, focal length ~5 to ~25 mm (tips on choosing the optimum focal length are on a later page). Use one that you already have lying around. If you don't have one, they're available from numerous manufacturers and dealers, including Celestron, Sky Instruments, Meade, Orion, and Edmund Scientific. The cheapest option is Surplus Shed (<http://www.surplussed.com>).

Tools

6. Flat-head screwdriver

7. Small hacksaw

8. Medium- to fine-grit sandpaper

9. 12-inch ruler

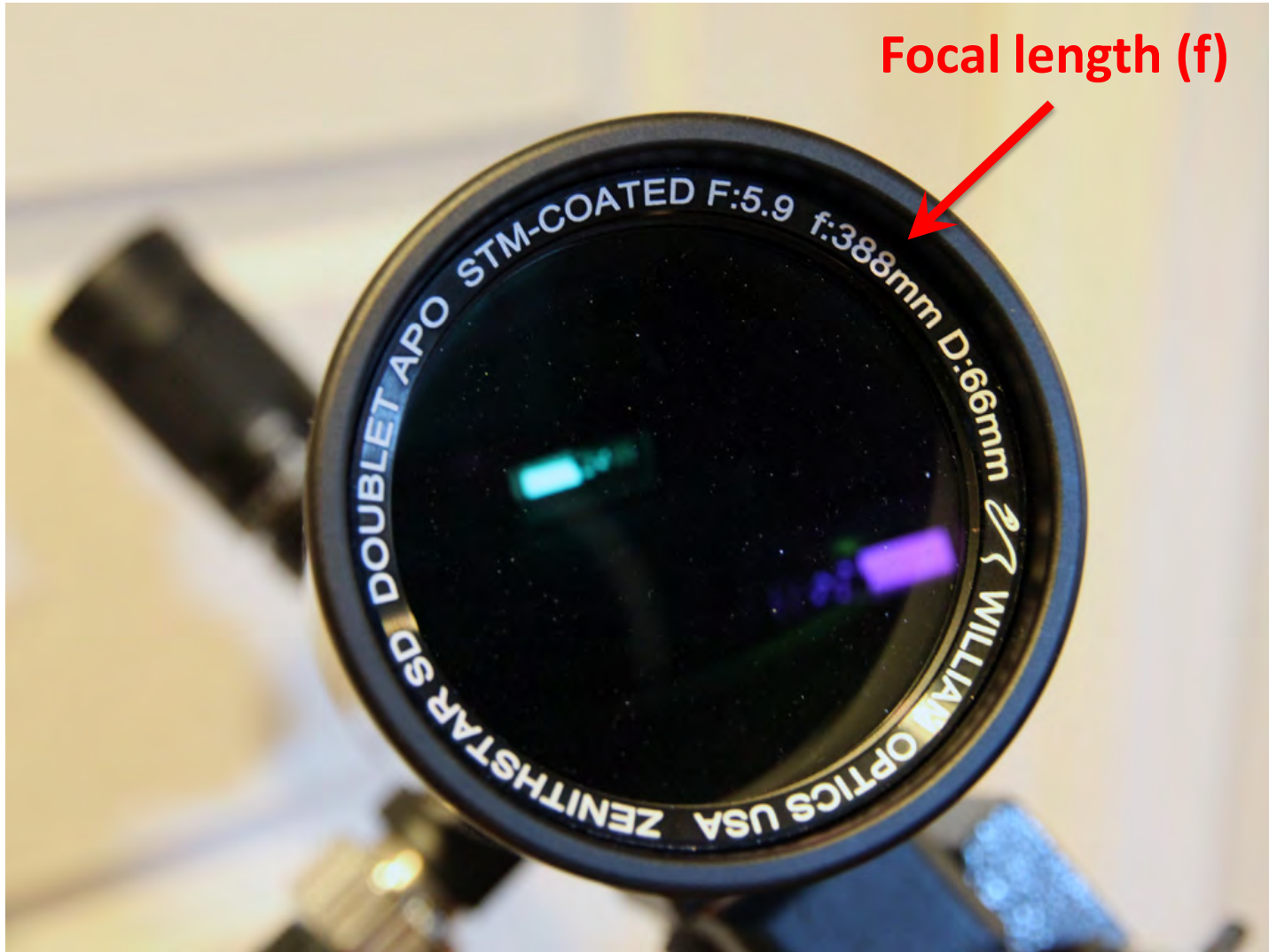
Match the Eyepiece to Your Telescope

What type of telescope? Refractor!



Using a Newtonian reflector or a catadioptric (mirror-lens) telescope is strongly discouraged, as concentrated sunlight can destroy such instruments' secondary-mirror holders.

A refractor's focal length is usually indicated on the barrel of the objective (front) lens.



Or, you can calculate the focal length of your telescope from its diameter (D) and focal ratio (f/ratio or f/number):

$$FL_{\text{telescope}} = D_{\text{telescope}} \times f/\text{ratio}$$

Example: For the 66-mm f/5.9 refractor shown on the previous page,
 $FL_{\text{telescope}} = 66 \text{ mm} \times 5.9 = 389 \text{ mm}$ (close enough; round-off error!)

Best eyepiece for a full-disk (~100 mm diameter) solar image:

$$FL_{\text{eyepiece}} \text{ (mm)} \approx FL_{\text{telescope}} \text{ (mm)} \div 43$$

(The derivation of this formula appears later in this document.)

Example: For the Galileoscope, a 50-mm f/10 refractor ($FL_{\text{telescope}} = 500 \text{ mm}$), the eyepiece that will produce a full-disk solar image has a focal length of $FL_{\text{eyepiece}} = 500 \div 43 = 11.6 \text{ mm}$. There are many inexpensive 12.5-mm eyepieces available; any would make a good choice.

An eyepiece with a *shorter* focal length will produce a *larger* Sun image; an eyepiece with a longer focal length will produce a smaller Sun image.

Sample Pairs of Telescope & Eyepiece Focal Lengths for a Full-Disk Image of the Sun on the Sun Funnel

Telescope ($FL_{\text{telescope}}$)	Eyepiece (FL_{eyepiece})
300 mm	7 mm
400 mm	9 mm
500 mm	12 mm
600 mm	14 mm
700 mm	16 mm
800 mm	19 mm
900 mm	21 mm
1000 mm	23 mm

Don't worry about getting the eyepiece focal length "exactly right." Depending on what you have available or what you can buy cheaply, aim to get an eyepiece whose focal length is within $\pm 10\%$ of the "ideal" value of $FL_{\text{telescope}} \div 43$.

Step 1. The funnel has a sharp little piece of plastic protruding from the side about halfway down its length.



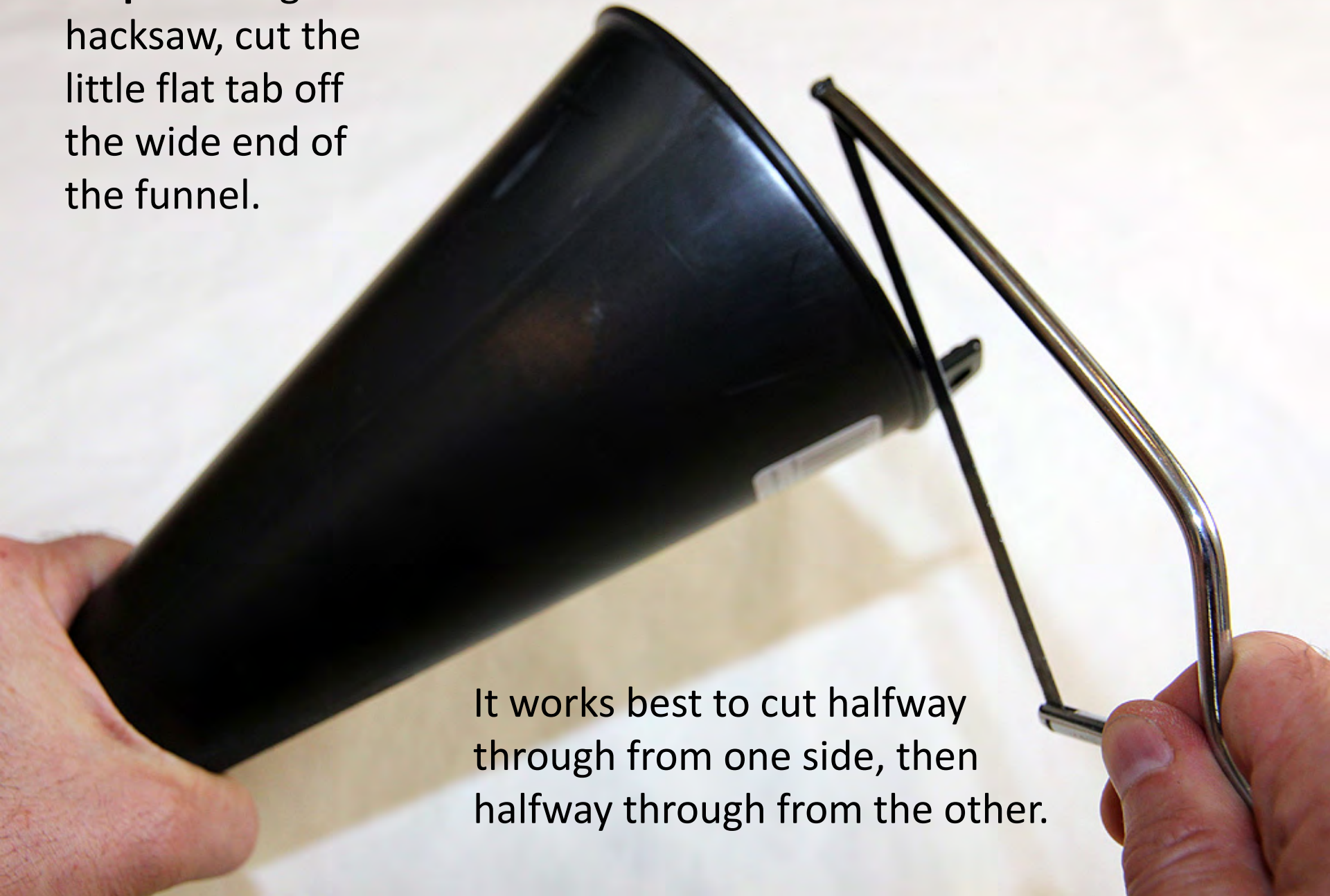
Using the sandpaper, grind it smooth so it doesn't scratch your hands.





No more sharp
piece of plastic!

Step 2. Using the hacksaw, cut the little flat tab off the wide end of the funnel.

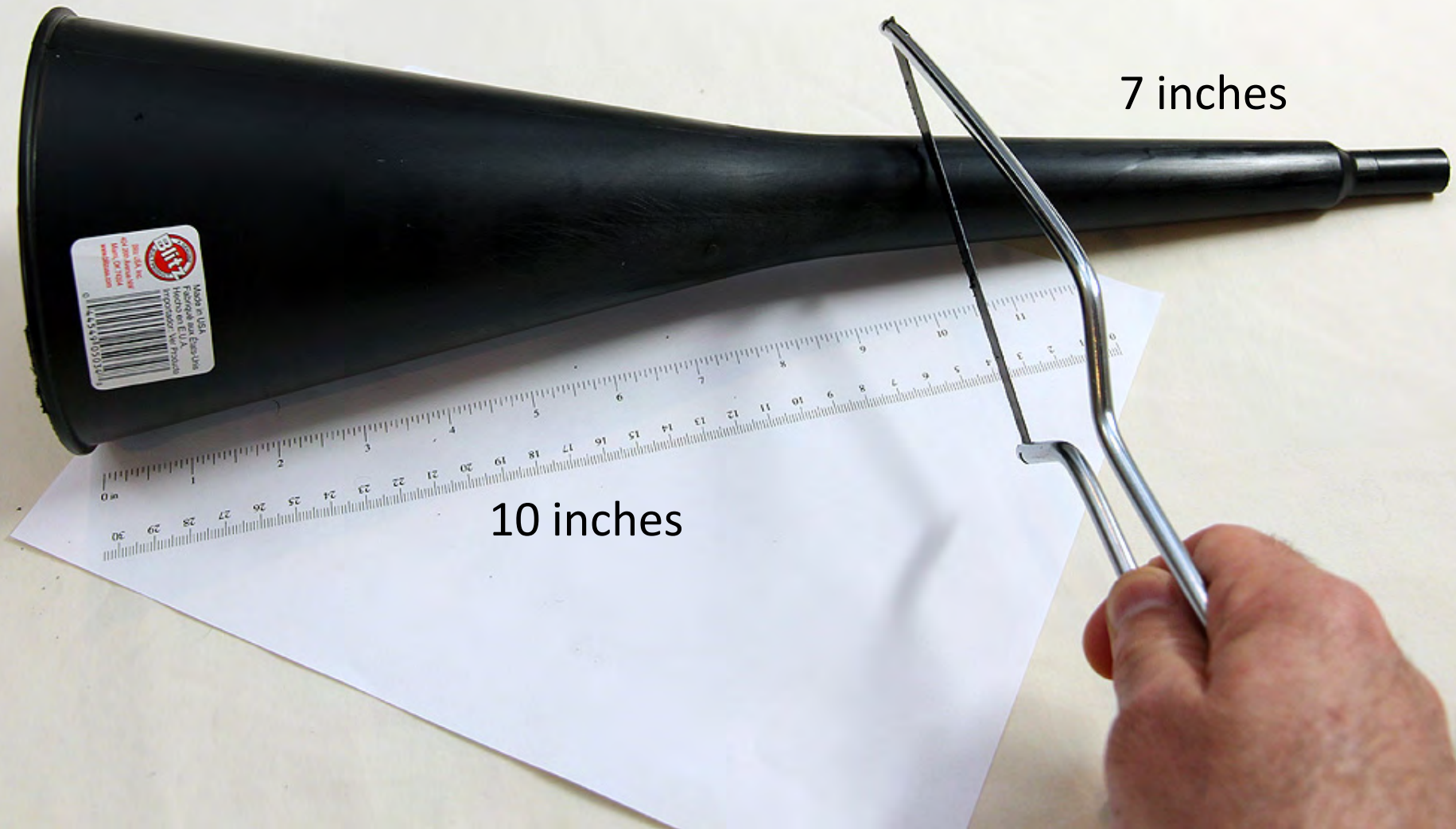


It works best to cut halfway through from one side, then halfway through from the other.

Rough edge!
Sand it smooth
now or in step 5.



Step 3. Using the hacksaw, cut about 7 inches off the narrow end of the funnel so that what's left measures about 10 inches long (use the ruler).



Try to make the cut perpendicular to the axis of the funnel, but don't panic if it ends up slightly tilted. Rotate the funnel as needed to complete the cut.



7 inches

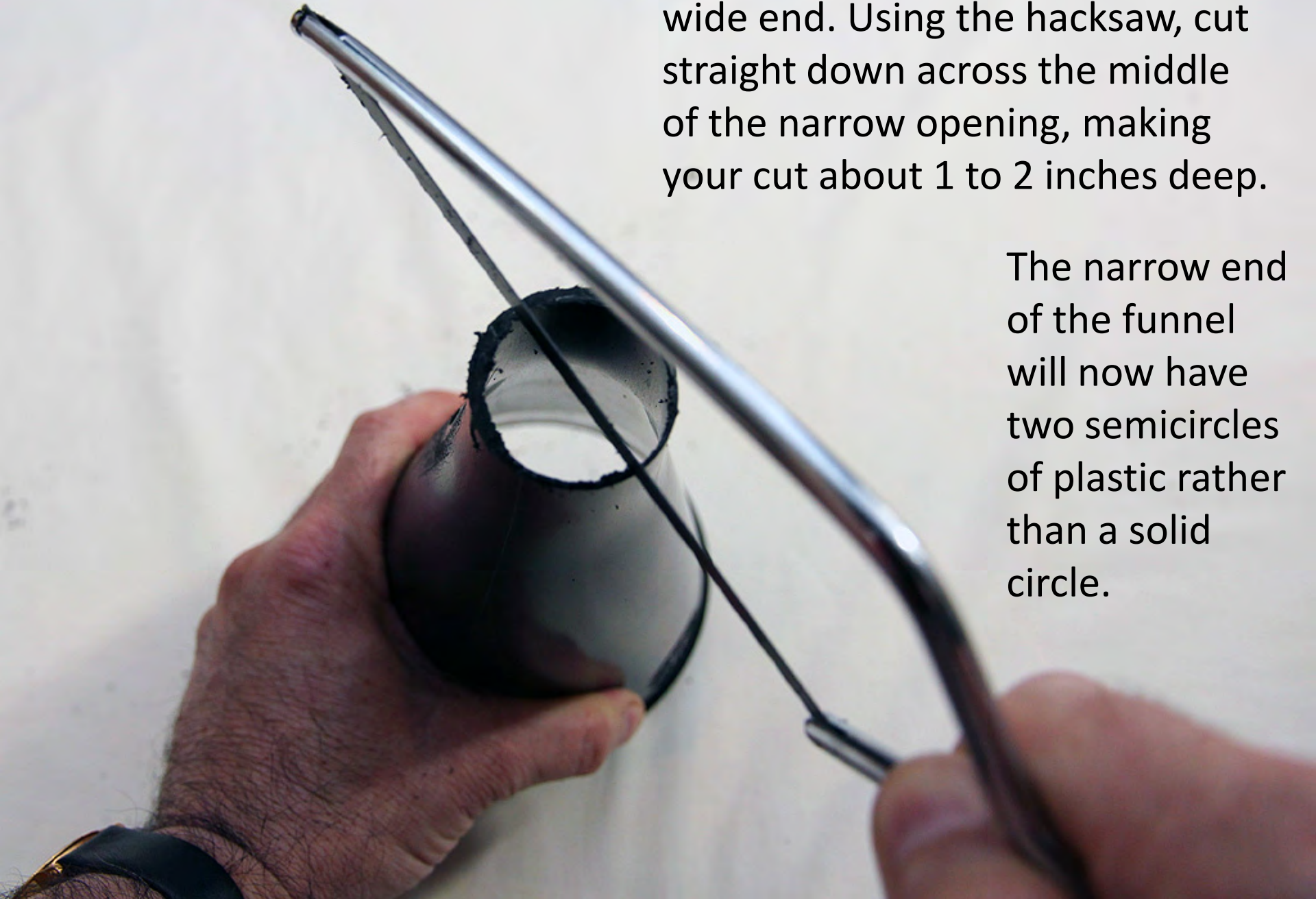
Don't bother sanding
this rough edge yet.



Discard this piece of plastic.

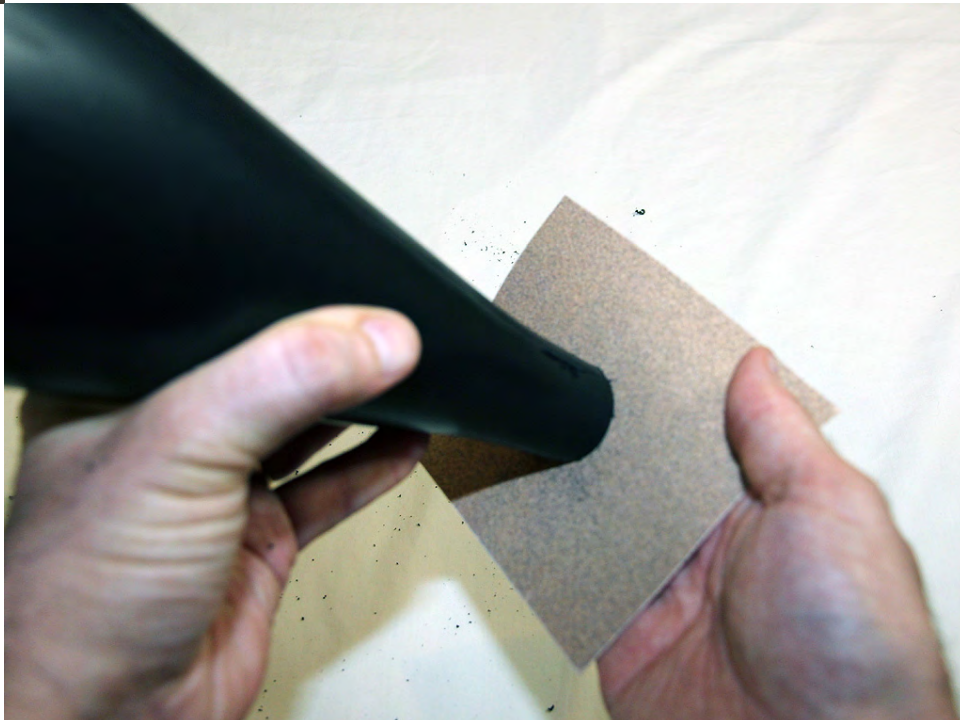
Step 4. Stand the funnel on its wide end. Using the hacksaw, cut straight down across the middle of the narrow opening, making your cut about 1 to 2 inches deep.

The narrow end of the funnel will now have two semicircles of plastic rather than a solid circle.





Step 5. Using the sandpaper, smooth all the cut surfaces on both ends of the funnel.



Step 6. If your eyepiece has a rubber eyecup and/or rubber grip, remove it/them.



Note that if you have a yellow thread-in eyepiece filter, you can screw it into the eyepiece barrel to produce a yellow Sun. But note, too, that the true color of the Sun is . . . white!

Step 7. Insert the eyepiece into the narrow end of the funnel: lens in, chrome barrel out. You may need to pry apart the two semicircular halves of the funnel's opening.



If the eyepiece still won't go in, cut away a little more of the funnel to widen the opening, then try again.

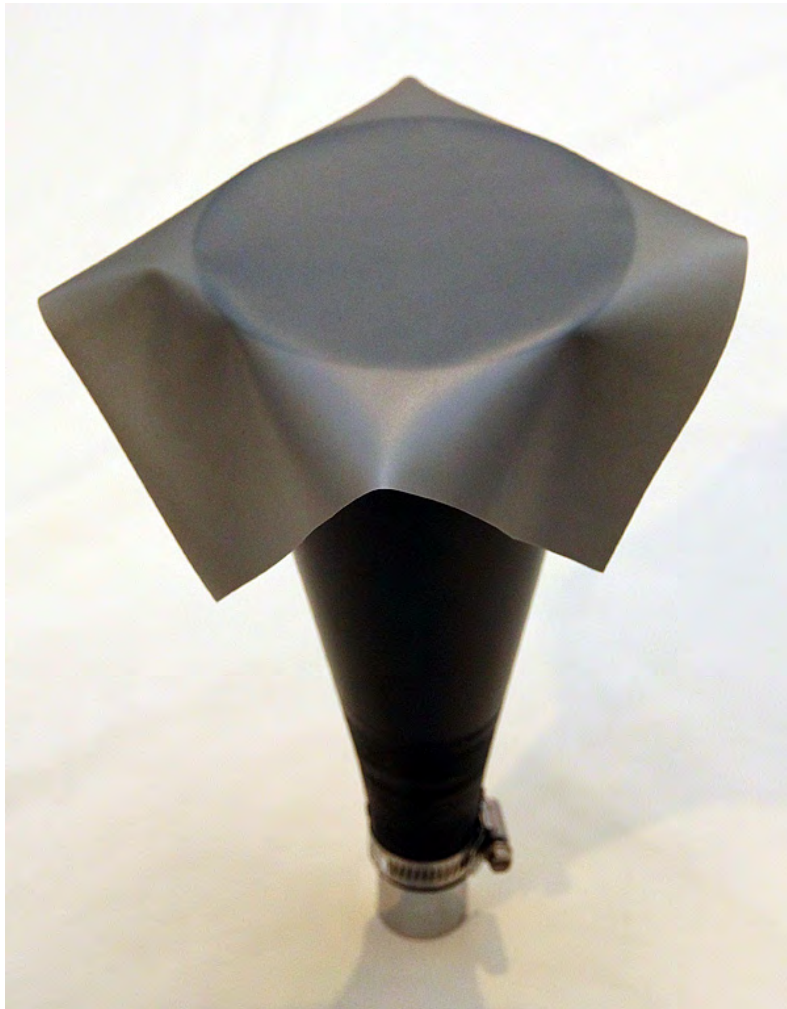


Aim to get at least a half inch of the length of the eyepiece into the funnel.

Step 8. Place the small hose clamp over the narrow end of the funnel and, using the screwdriver, tighten it around the funnel to securely hold the eyepiece.



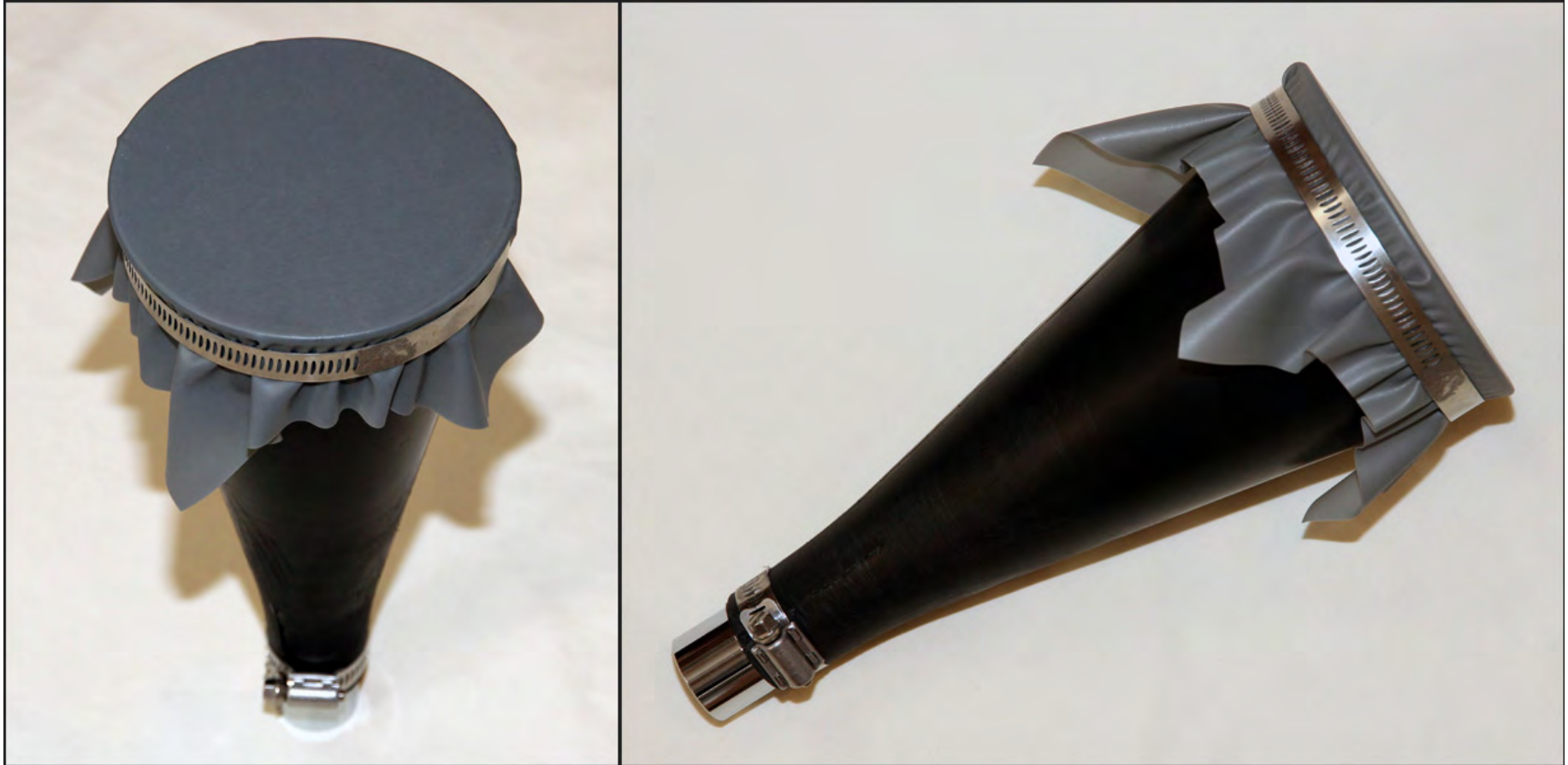
Step 9. Turn the funnel wide end up (you might find it easiest to sit down and hold the funnel between your knees). Place the Da-Tex screen over the wide opening; it doesn't matter which side faces down. Lower the large hose clamp over the wide end of the funnel...



...and, using the screwdriver, tighten it around the funnel to securely hold the screen; as the clamp begins to get purchase on the funnel and screen, gently pull down all around the loose edge of the material so that the screen ends up flat and taut over the funnel's wide opening. This is an iterative process; you'll need to pull down on the material after each turn of the screw to keep it taut.



The Sun Funnel



Congratulations! You have successfully built a Sun Funnel!

Step 10. Insert the eyepiece barrel into your telescope's 1¼-inch eyepiece holder, secure it with the thumbscrew(s), aim your telescope at the Sun (first taking care to cover your finder scope, if any), focus, and enjoy group viewing with your Sun Funnel!

WARNING! ALWAYS SUPERVISE USE OF THE SUN FUNNEL. NEVER POINT AN UNFILTERED TELESCOPE AT THE SUN. SEVERE EYE DAMAGE MAY OCCUR!

How to Aim a Telescope at the Sun

How do you aim a telescope at the Sun when you're not supposed to look through it, and when you're supposed to remove or cover your finder so that you don't look through that either (and so that bright sunlight doesn't melt its crosshairs)?!

One solution is to watch your telescope's shadow on the ground and adjust the aim until the tube's shadow is as small and as round as you can get it.

Another solution is to add a special-purpose Sun finder that projects a shadow or a spot of sunlight onto a target. There are several commercial units available, including these:

- Far Laboratories Helio Pod: <http://bit.ly/pcLOW>
- Tele Vue Sol-Searcher: <http://bit.ly/nkhyOk>
- Coronado Sol Ranger: <http://bit.ly/phOnds>

Yet another solution is to make something yourself based on the design of one of these products.

Mathematical Underpinnings of the Sun Funnel Design

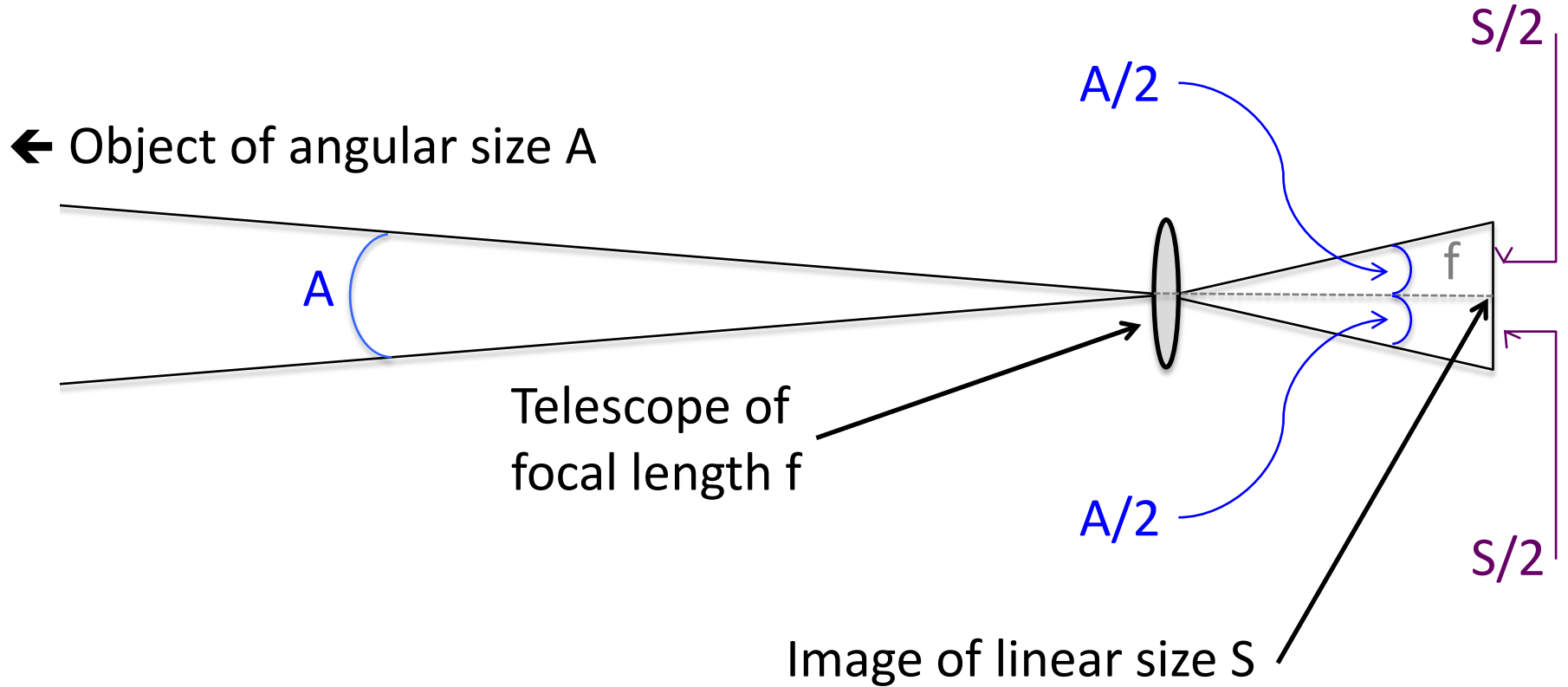
On the following pages we go through the (relatively simple) math behind the Sun Funnel. It relates the following quantities over which we have some measure of control:

- Telescope focal length
- Eyepiece focal length
- Projection distance
- Projected image diameter

and the following quantity over which we have absolutely no control:

- Sun's angular diameter

Telescope of focal length f (mm) produces image of linear size S (mm) of object with angular size A (radians).



Relationship between these quantities:

$$\tan (A/2) = (S/2) / f$$

Rearrange $\tan (A/2) = (S/2) / f$

to get $f \tan (A/2) = S/2$

and finally $S = 2f \tan (A/2)$

Note that for the very small angles we typically encounter in astronomy,

$$\tan (A/2) \approx A/2$$

so we have $S = 2fA/2$

which reduces to $S = fA$ (S, f in mm; A in radians)

We need to know the size of the Sun image produced by the telescope, since that's what we plan to project onto the Sun Funnel screen. Do you know the Sun's angular size, A , in radians? Probably not, so let's tweak our formula to put A into degrees instead.

There are 180° in π radians (the arc of a semicircle), so

$$S = fA \times (180^\circ/\pi)$$

or
$$S = fA/57.3 \quad (A \text{ in degrees})$$

The Sun's average angular size is just over $\frac{1}{2}^\circ$ (you knew that, right?), i.e., $A \approx 0.533^\circ$.

So, with $A = 0.533^\circ$, we get

$$S = fA/57.3$$

$$S = f(0.533/57.3)$$

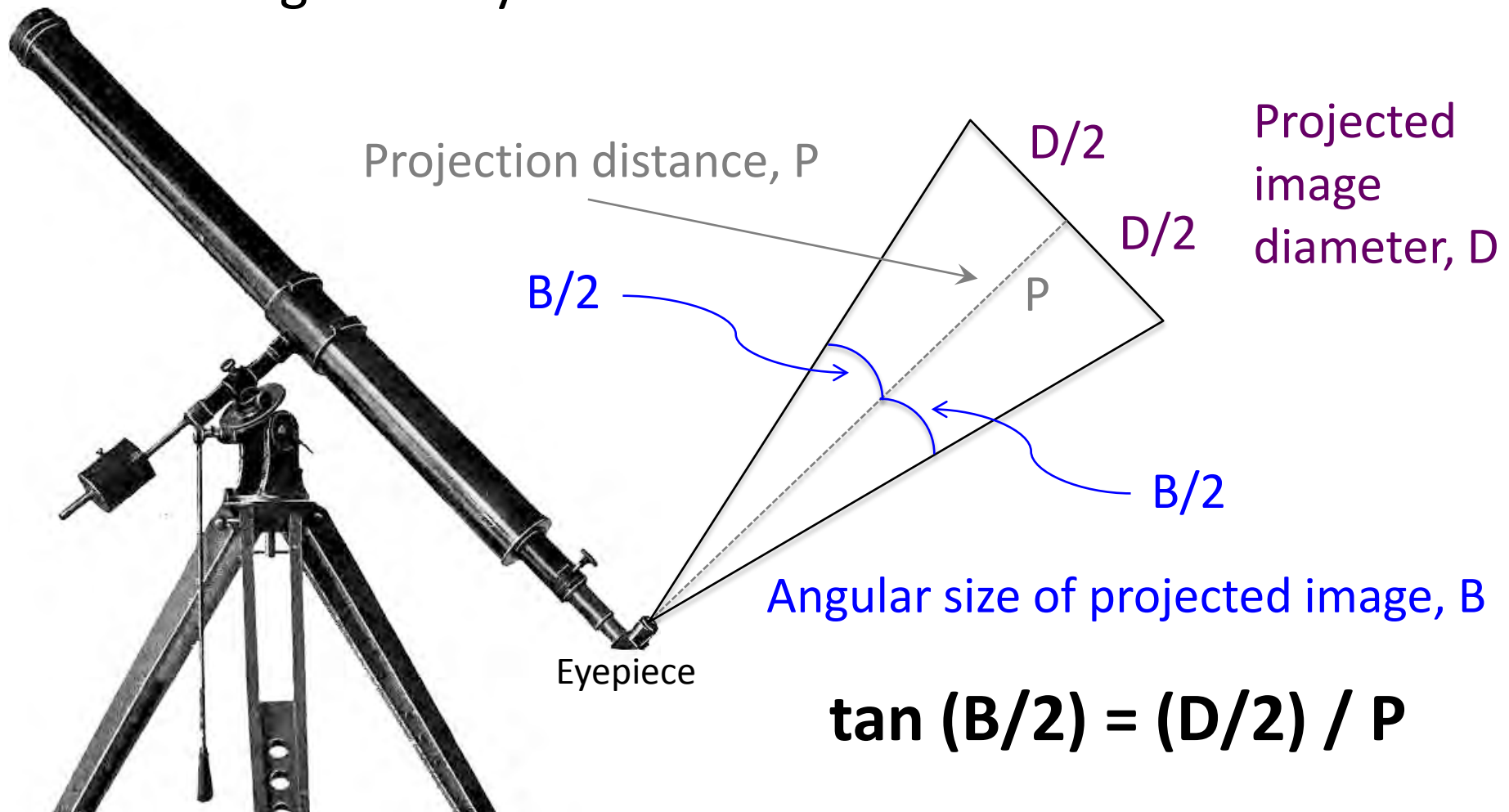
$$\mathbf{S = 0.0093f} \quad (\text{S in mm, f in mm})$$

Consider the Galileoscope, which has a focal length of 500 mm. When aimed at the Sun, it produces an image of diameter $S = 0.0093 \times 500 \text{ mm} = 4.65 \text{ mm}$.

You're not going to have much luck trying to see sunspots or Venus's silhouette on such a tiny image!

That's why we use projection, i.e., to produce a larger image on which we can more easily see sunspots and other features of interest on the Sun's disk.

The geometry is similar to what we saw earlier:



Rearrange $\tan (B/2) = (D/2) / P$

to get $P \tan (B/2) = D/2$

and finally $D = 2P \tan (B/2)$

Again, for the very small angles we typically encounter in astronomy,

$$\tan (B/2) \approx B/2$$

so we have $D = 2PB/2$

which reduces to $D = PB$ (D, P in mm; B in radians)

But what is B, exactly? Remember A? It's the angular size of the image produced by the telescope. Well, B is just that angle multiplied by the magnification produced by the telescope's eyepiece. And that, in turn, is the focal length of the telescope divided by the focal length of the eyepiece, i.e.,

$$B = A \times \text{magnification} = A \times (FL_{\text{telescope}}/FL_{\text{eyepiece}})$$

so $D = PB$

becomes $D = PA(FL_{\text{telescope}}/FL_{\text{eyepiece}})$

with D, P, and the two FL's in mm, and A in radians.

But remember, A (the Sun's angular diameter in radians) is equal to $0.533/57.3$, or 0.0093 . So our formula for the diameter of the projected image,

$$D = PA(\text{FL}_{\text{telescope}}/\text{FL}_{\text{eyepiece}})$$

becomes **$D = 0.0093P(\text{FL}_{\text{telescope}}/\text{FL}_{\text{eyepiece}})$**

with all quantities in mm. This can be rearranged to solve instead for the projection distance, P:

$$**P = 107.5D(\text{FL}_{\text{eyepiece}}/\text{FL}_{\text{telescope}})**$$

again with all quantities in mm.

Alternatively, either formula can be rearranged to solve instead for the eyepiece focal length:

$$\mathbf{FL_{eyepiece} = 0.0093P(FL_{telescope}/D)}$$

again with all quantities in mm. For the Sun Funnel as described here, $P \approx 10$ inches ≈ 250 mm, and the desired image size for a full-disk Sun is $D \approx 100$ mm (since the wide end of the funnel is about 5 inches, or 127 mm, across). Thus,

$$FL_{eyepiece} = 0.0093 \times 254 \div 100 \times FL_{telescope}$$

or
$$\mathbf{FL_{eyepiece} = 0.023 FL_{telescope} = FL_{telescope} \div 43}$$

Now that you have all the mathematical relationships between telescope focal length, eyepiece focal length, projection distance, and projected image size, you can design your own solar-projection device using materials other than those suggested here.

Questions? Comments?

You may contact the authors by email:

Rick Fienberg: rick.fienberg@aas.org

Chuck Bueter: bueter@nightwise.org

Lou Mayo: astronomer2go@verizon.net