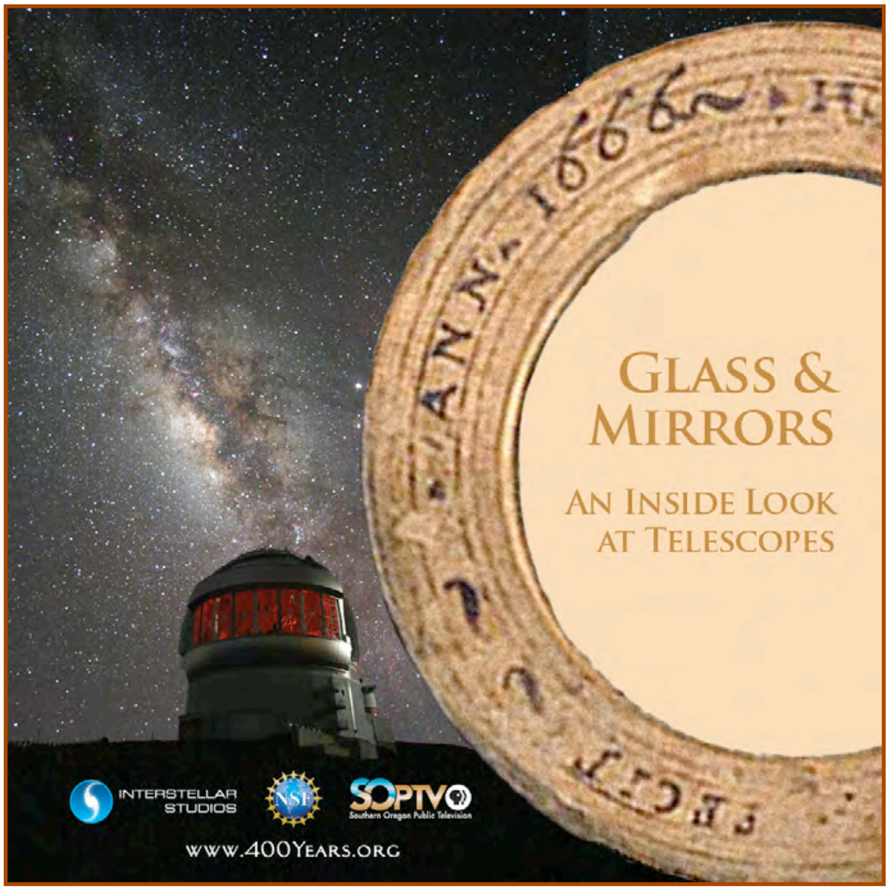

Outreach ToolKit Manual

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400 Years of the Telescope — A Journey of Science, Technology and Thought

PBS

Distributed for members of the *NASA Night Sky Network* and other ASP education networks

The Night Sky Network is sponsored and supported by:

- **400 Years of the Telescope http://www.400years.org/**
- **NASA's Kepler Discovery Mission, Grant NAG 2-6066, SETI Institute**
- **JPL's *PlanetQuest* public engagement program,**
- **NASA's *Origins Forum,***
- **NASA's *Structure and Evolution of the Universe Forum***
- **NASA's *Solar System Education Forum***

The Night Sky Network was founded by:

JPL's Navigator (*PlanetQuest*) public engagement program

NASA Night Sky Network: http://nightsky.jpl.nasa.gov/

Contacts

The non-profit Astronomical Society of the Pacific (ASP), one of the nation's leading organizations devoted to astronomy and space science education, is managing the Night Sky Network in cooperation with NASA and JPL. Learn more about the ASP at http://www.astrosociety.org.

For support contact:

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San Francisco, CA 94112
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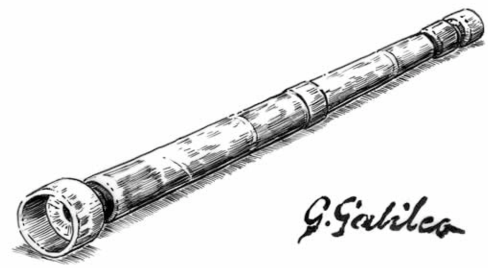
nightskyinfo@astrosociety.org

Introduction: Glass & Mirrors



Four hundred years ago, Galileo first turned a telescope to the heavens and recorded what he saw. Thus began a revolution in our understanding of the universe.

Telescopes are one of the most important instruments used to reveal the secrets of the universe. From the first reports by Galileo of the phases of Venus through the discovery of the distances to other galaxies to the evidence for planets orbiting other stars, our view of the universe and our place in it has been continually altered in our quest for understanding the phenomena observed in the night sky through our telescopes.

But how do these amazing instruments actually work? They may seem complicated and difficult to understand at first.

In reality, almost all optical telescopes are built on a very simple design – a design that was developed 400 years ago. There have been variations on the basic design, but the idea of using glass or mirrors to collect and focus light has remained the same for the last four centuries.

There are two basic types of telescopes: those that use lenses to collect light (refractors) and those that use curved mirrors to collect light (reflectors).

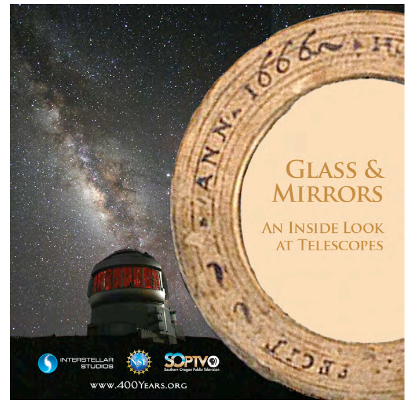
This ToolKit allows you to create a “cutaway” telescope to clearly show how both types of telescopes work.

Have fun giving your visitors an inside look at telescopes!

Acknowledgements

Some of the demonstrations in this ToolKit were adapted from materials developed for Hands-On Optics (http://www.hands-on-optics.org/resources/) by the National Optical Astronomy Observatory (NOAO) (http://www.noao.edu/) in educational collaboration with The International Society for Optical Engineering (SPIE) and The Optical Society of America (OSA) and sponsored by a grant from the National Science Foundation.

NOAO is operated by the Association of Universities for Research in Astronomy (AURA), Inc. under cooperative agreement with the National Science Foundation.



Glass & Mirrors

An Inside Look at Telescopes

What's this activity about?

Big Questions:

How do telescopes actually work?
Why are bigger telescopes better?
What's the difference between telescopes made with lenses (refractors) and telescopes made with a mirror (reflectors)?
How are the telescopes of Galileo and Newton similar to telescope designs today?

Big Activity:

Using a simple setup with lenses and mirrors, demonstrate how a telescope collects light, focuses it, then magnifies the image.

Participants:

From the club: A minimum of one person.
Visitors: Up to 10 people at a time is appropriate.

Duration:

About 15 minutes.

Contents and Topics Covered:

Where can I use this activity?

Star Party	Pre-Star Party –Outdoors	Pre-Star Party –Indoors	Girl Scouts / Youth Group Meeting	Classroom K-4	Classroom 5-8	Classroom 9-12	Club Meeting	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
√	√	√	√		√	√	√		√

What do I need to do before I use this activity?

What do I need to supply to complete the materials?	What do I need to supply to run this activity that is not included in the kit?	Do This Before Your Event
Table(s); box or book to raise the level of the flashlight; a business card or other paper with small type	*Optional:* Backup flashlight in case the batteries or the bulb in the one you are using burn out. *Optional:* Examples of telescopes.	Plan for a location with no direct sunlight and no bright lights.

Helpful Hints

This activity is best done at twilight, at night, or in a slightly darkened room. It cannot be done in full sunlight. If in a heavily shaded location, you might be able to do this outside during the day. Bright lights will wash out images on the screen.

Think of this demonstration as a cutaway telescope: a telescope your visitors can see and explore. The optics in real telescopes should not be touched to avoid ruining or smudging the elements. So, for this demonstration, encourage your visitors to hold and touch the lenses and mirror in this ToolKit. It will help them better see, feel, and understand that they are curved. Use lens paper as needed to clean them.

You may notice multiple images in the small secondary mirror – tell your visitors to direct their attention to the brightest image. There can be internal reflections in the small mirror since it is just a regular mirror and not front-silvered.

For additional help, see “Troubleshooting” on page 29.

Background Information

There are many misunderstandings about telescopes. A few are listed here.

Common <u>Misunderstandings</u> addressed by this ToolKit:

- Magnification is the most important feature of a telescope.
- Telescopes are complicated and difficult to use.
- Telescopes can see through clouds.
- Telescopes are "magic" in that most people have no idea how they work.

Additional Background Information

Why are mirrors used instead of lenses in many telescopes?
Get background information from NASA's Telescopes from the Ground Up website:
http://amazing-space.stsci.edu/resources/explorations/groundup/
Choose the section "Era of Early Refractors."

We want our telescopes to collect as much light as possible. This is done by increasing the diameter of the collecting area (also called the aperture). If the telescope uses a lens to collect light, the larger the aperture, the larger the lens must be. The rim of a lens is much thinner than the center. Lenses can only be supported around the rim since light must go through them.   As the lens becomes larger, it becomes heavier and more difficult to mount. A very large lens will also begin to sag under its own weight, distorting the image.

A telescope that uses a mirror to collect light can be designed so the mirror is fully supported across its entire expanse. This allows mirrors to be much larger than lenses, thereby allowing reflecting telescopes to collect much more light to detect the dimmer objects in the universe.

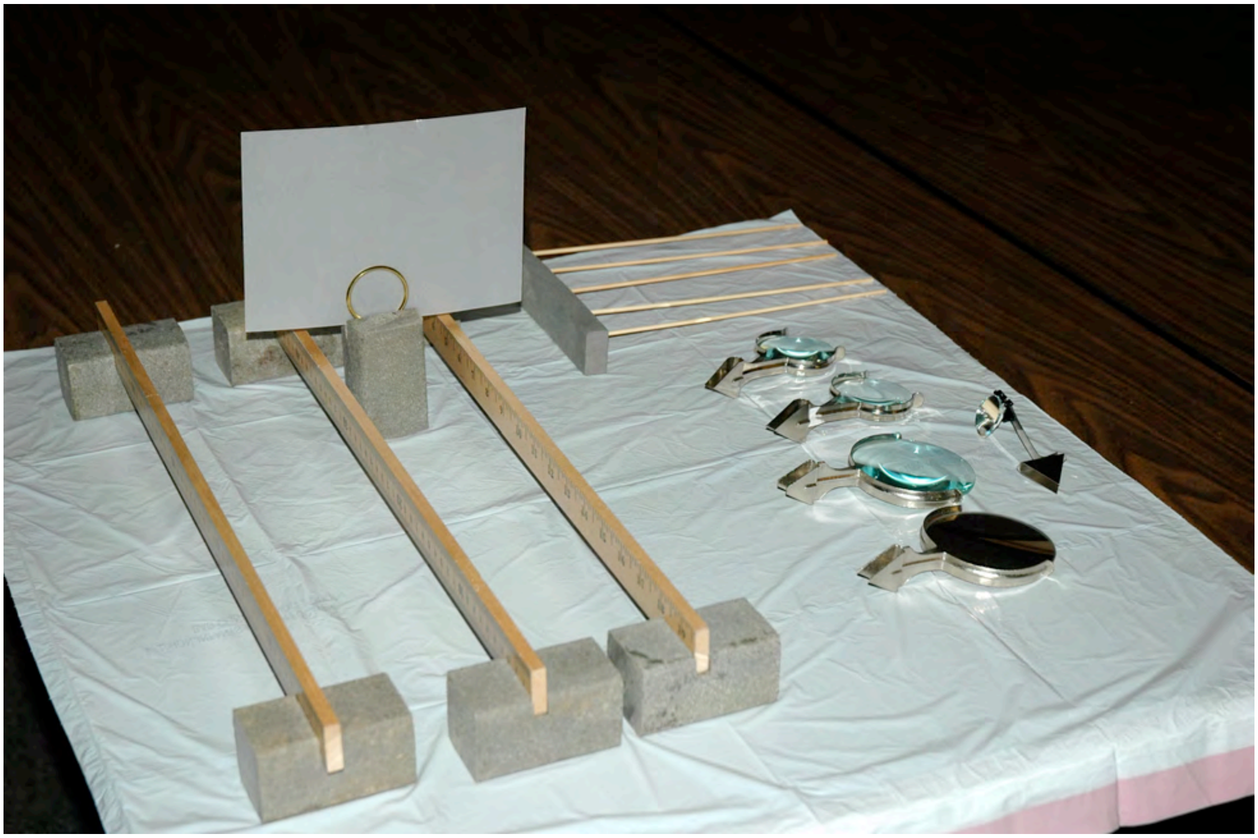
Here is more information on this topic and includes a discussion of chromatic aberration in lenses: http://astro.uchicago.edu/vtour/whyrefl.html

Why do we need different types of telescopes to look at outer space?
http://science.nasa.gov/newhome/headlines/features/ast20apr99_1.htm

Guide for buying a telescope, including the advantages and disadvantages of each type:
http://www.astronomy.com/asy/default.aspx?c=a&id=2281

SETUP

First time out of the box, see “What do I need to prepare?” on page 38.
The activity is best done at twilight, at night, or in a slightly darkened room. This cannot be done in full sunlight. If in a heavily shaded location, you might be able to do this outside during the day.



Place the 3 lenses and 1 mirror in their respective holders lying on the table:

- 2 – 50mm diameter lenses (one has focal length (FL) of 75mm, the other 200mm FL). These are referred to as the “small thick” and “small thin” lenses. The “small thick” lens is the “magnifier” in this demonstration.
- 1 – 75mm diameter lens with 200mm FL. This is referred to as the “large lens”
- 1 – 75mm mirror with 150mm FL. This is referred to as the “large mirror”

Assemble the 3 meter-stick sections with stands side by side as shown above.
Place the screen on its stand between two of the meter-sticks, with about 4 inches (8 cm) from the end opposite the flashlight.

Set up your table so that your visitors will have easy access to the materials.

It is advisable to test your setup before you start your demonstrations – especially the height and orientation of the “secondary” mirror – the little one-inch round mirror on the flat metal holder. Make sure it is at the right height to reflect the focused image from the large mirror. See “Troubleshooting” on page 29.

Have at the ready:

- The "secondary" mirror: the small mirror attached at a 45-degree angle (approx) to the clip on the flat metal holder
- 1 business card or other paper with small type on it
- 1 set of Foam and sticks
- 1 Flashlight with the cutout image of crescent moon 5 to 8 feet (1.5 to 2.5 meters) away (If telescopes are set up near you, be sure you are set up to point the light AWAY from the telescope area). The flashlight bulb should be 5" to 8" (13 to 20 cm) above the level of the table where you have the demonstration set up (see photo at left). In other words, the center of the flashlight should be slightly above the center of the large mirror when the mirror is on the meter-stick section.
- (Optional) Extra batteries for the flashlight or an additional flashlight.

Start with the flashlight turned OFF.

There should be no lights in the area behind the flashlight – those will also be focused on the screen and cause confusion about which image to focus on.

There should be no lights shining directly on the screen. They can wash out the image projected through the lenses onto the screen.

It is advisable to setup over grass, dirt, carpet, or other soft surface. It is possible that visitors (or you!) might drop the lenses, causing them to chip or break.

Detailed Activity Descriptions

Glass & Mirrors: Introduction

Leader's Role	**Participants' Role (Anticipated)**
To Do: If you have the opportunity, have your visitors look at a number telescopes before the demonstration. *To Say:* What can you tell me about telescopes? What did you notice about how telescopes are constructed? What parts do they have?	Various comments.
To Do: Point to the lenses and mirrors on the table. *To Say:* Well, to get down to basics, telescopes are made with mirrors and lenses. *To Do:* If you have a telescope or two handy, have visitors look to see where the mirror and/or lenses are. Hold the two smaller diameter lenses (50mm) over the paper with small type. *(See Illustration #1 on page 21)* *To Say:* Let's take a look at these 2 lenses.	
Do these both magnify the same? *To Do:* Ask a few other visitors to take a look as well. *To Say:* OK – let's use that lens as our magnifier. (Set aside the small thick lens that magnifies more) Let's look at these other two lenses. *To Do:* Pick up the small, thinner lens and the large lens (50mm diameter 200mm FL lens and the 75mm diameter lens) and hold them over the paper. *(See Illustration #2 on page 21)* *To Say:* As you can see, one lens is larger than the other. But do these magnify about the same amount?	No – this one magnifies more. (indicating the thicker of the two lenses – the one with the 50mm FL) Yes, about the same

Glass & Mirrors: Light Gathering Power

Leader's Role	**Participants' Role (Anticipated)**
To Say: All right, let's use those two lenses as our light gatherers. But what do we mean by light gatherers? Do you notice that the lenses are curved? *To Do:* Pick up foam and sticks.	 Yes.
To Say: Imagine we have a clear flat piece of glass, like a window, between you and me, can you see me clearly? The light reflecting off my face goes straight through the glass with little or no change in direction. But these pieces of glass are curved, so they change the direction of the light coming through them.	 Yes.
To Do: Allow the visitors to notice that the lens is curved glass. Hold the glass near each person's face.	
To Say: Can you see me clearly through this lens? Lenses gather and concentrate light into a small area by changing the direction of the light. *To Do:* Use foam and sticks to illustrate the focal point. *(See Illustration #3 on page 21)*	 No!
To Say: Let's see what that means.	

<table>
<tr><th>Leader’s Role</th><th>Participants’ Role (Anticipated)</th></tr>
<tr><td><u>To Do:</u>
Place the two “light-gathering” lenses on two adjacent meter-stick sections.
Turn on the light with the moon image.
(See Illustration #4 on page 21)

<u>To Say:</u>
Can you see that there are a couple of fuzzy patches on the screen? Try to get those into focus by moving the lenses closer or farther away, like this.

<u>To Do:</u>
Demonstrate how to move the lens.
(See Illustration #5 on page 22)

Then pick up foam and sticks.

<u>To Say:</u>
So the light is coming through each lens and is being bent and concentrated into this small area here.

<u>To Do:</u>
Bend foam and sticks to a point with the focal length the same as the focal length of the lens.
(See Illustration #6 on page 22)</td><td>Visitor moves lenses so images are focused on screen.</td></tr>
<tr><td><u>Going further (OPTIONAL):</u>
Some may not understand why the image goes in and out of focus.

<u>To Say:</u>
Notice that if the image is projected here, in front of the focal point, the light is spread out and you get an unfocused spot.
If we move the screen here, in back of the focal point, what’s happening to the light here?
(See Illustration #7 on page 23)

So there is only one point where the image is in focus. At the focal point where all the light rays come together.</td><td>It’s spread out again.</td></tr>
<tr><td><u>To Say:</u>
Can you see a difference in the brightness of the two images?

The light coming from the moon over there is spread out all over this area.</td><td>Yes, this one is brighter (indicating the larger lens’s image).</td></tr>
</table>

Leader's Role	**Participants' Role (Anticipated)**
<u>*To Do:*</u> Next to the larger lens, bend the foam and sticks to a point with the focal length the same as the focal length of the lens. <u>*To Say:*</u> The lens is taking all the light hitting it and curving it, concentrating it like this. <u>*To Do:*</u> Next to the smaller lens, take the 3 inner sticks and hold them together at the focal point. *(See Illustration #8 on page 23)* <u>*To Say:*</u> Whereas this smaller lens is only collecting this much light and concentrating it, so it's dimmer – not as much light is being gathered. <u>*To Say:*</u> How much light does your eye gather – how big is your pupil?	Lots smaller. So my eye collects even less light.
<u>***Going further (OPTIONAL):***</u> Show that having a larger lens is like having a larger opening for your eye. <u>*To Say:*</u> Right! What happens to the pupil of your eye when you go into a dark room after being outside in the sunlight? Does that help you see better in the dark room? Sure – your eye is collecting more of what little light there is in the room. Using this lens (indicating the smaller "light-gathering lens") is like making your eye this big! *(See Illustration #9 on page 23)* And using THIS lens (indicating the larger "light-gathering lens") is like making your eye THIS big! Could you see a lot more in the dark room or at night with eyes this big? So telescopes gather light similar to the way your eyes gather light – as the opening gets larger, you can see dimmer things more easily.	It gets bigger! Yes. Yeah!

<table>
<tr><th>Leader’s Role</th><th>Participants’ Role (Anticipated)</th></tr>
<tr><td colspan="2"><u>Presentation Tip:</u>
See the “Further Exploration” Section starting on page 31. This discusses two points in more details:
1. Some people will notice that the moon image is upside down and reversed. Use the activity “Why is the image upside down?” to explain what’s happening.
2. Some people will want a better explanation about how light spreads out as it leaves its source. (“The light coming from the moon over there is spread out all over this area.”) Use the activity “Light Spreads out with Distance” to explain what’s happening.</td></tr>
</table>

Glass & Mirrors: Magnifying the Image

Leader's Role	**Participants' Role (Anticipated)**
<u>*To Do:*</u> Adjust the angle of the meter-stick section so that the image on the screen is over the meter-stick. This aligns the lens to point directly toward the moon image. *(See Illustration #10 on page 23)* <u>*To Say:*</u> Now, we've got a small image here on the screen, so let's take our magnifier (small thick lens) and see if we can make the image larger so we can see it more easily.	
<u>*To Do:*</u> Place the magnifier on the meter-stick on the opposite side of the screen of the larger lens. Lean down to look through the lens at the image on the screen. *(See Illustration #11 on page 24)*	
<u>*To Say:*</u> Does it make the image look bigger? Come take a look.	Visitors look at image through lens.
<u>*To Do:*</u> Remove the screen.	
<u>*To Say:*</u> Now, telescopes don't have screens in them, so let's take the screen away and now look through the magnifier, called the eyepiece, because it's what we look through with our eye. What do you see? *(See Illustration #12 on page 24)*	Wow! Yes, I see the image bigger and really bright. (Might also make comments on other details they see)
Now imagine placing a tube around this and what do you have?	A telescope!
And that is basically how the telescope that Galileo used worked: Using a lens to gather, then concentrate the light into an image in this little area, then using a magnifier to make the image bigger so we can see more detail.	Hey – I could make that!
400-year-old technology – still in use today!	

Leader's Role	**Participants' Role (Anticipated)**
<u>Going further (OPTIONAL):</u> Show that the concentrated image is still there in the space between the lenses, even though we can't see it unless we look through the eyepiece (or magnifier). <u>*To Say:*</u> Now, is that little image still hovering here in space (pointing to the general vicinity of the concentrated image)? Put your finger in there – can you see the focused image on your finger? *(See Illustration #13 on page 24)* So the image the magnifier is magnifying is this little image right here. This might be clearer using the mirror as our light-gatherer.	 Various answers. Wow – yes!

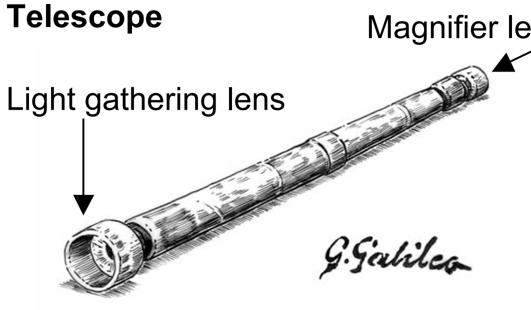
Glass & Mirrors: Mirrors for Gathering Light

Leader's Role	**Participants' Role (Anticipated)**
<u>To Do:</u> Pick up the mirror in its holder. <u>To Say:</u> But most astronomers use mirrors in their telescopes as light gatherers instead of lenses. (See "Background Information" on page 7 for further explanation.) Here's a mirror – notice that it is curved?	Yes.
<u>To Do:</u> Use foam & sticks to illustrate the following. <u>To Say:</u> If we have a flat mirror, the light hits the mirror and reflects straight back out, but with a curved mirror, the light hitting the mirror is bent and concentrated again. Like this. *(See Illustration #14 on page 25)* <u>To Do:</u> Bend foam. Place mirror on third meter-stick section at the end farthest from the flashlight and facing the flashlight. *(See Illustration #15 on page 25)* <u>To Say:</u> Let's put the mirror here. Now remember that the light is coming in on this side and reflecting back out, so where will we look for the concentrated image? In front of the mirror or in back of it?	Out here, in front of the mirror.
<u>To Do:</u> Place screen in front of mirror, completely blocking the light from the flashlight. *(See Illustration #16 on page 25)* <u>To Say:</u> Right! Let's see if we can find it. Here's the screen. If we place it here, what have we done – can any of the light from the moon hit the mirror?	No, you've blocked all the light.
<u>To Say:</u> OK, so let's move it off to the side so that at least some of the light is hitting the mirror (moving the screen to the side). See – there's the light on the edge of the screen. *(See Illustration #17 on page 25)* Go ahead and bring that image to a focus.	Visitor moves screen so image is focused.

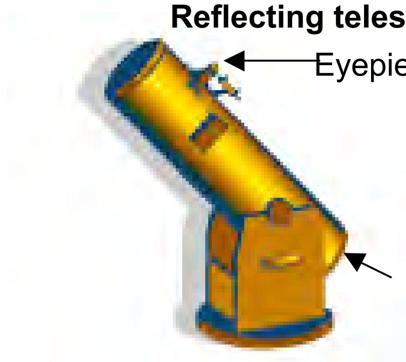
Leader's Role	**Participants' Role (Anticipated)**
<u>*To Do:*</u> Adjust the angle of the meter-stick section so that the image on the screen is over the meter-stick. This aligns the mirror to point directly toward the moon image. This way the image is more likely to appear in the little mirror you will be using next. *(See Illustration #18 on page 26)* <u>*To Say:*</u> OK. Now let's take the lens again and try to magnify the image.	
<u>*To Do:*</u> Place the lens in front of the screen. Bend down and look through the lens. *(See Illustration #19 on page 26)* (The image disappears – your head is in the way!) <u>*To Say:*</u> But if I put my head here, what have I done?	Blocked the light again!
<u>*To Do:*</u> Stand up and place the lens on the table.	
<u>*To Say:*</u>  So we have to move the little image to one side or the other so we can see the image. (Pick up the small mirror – see photo at the left) Do you think if we use this, we might be able to reflect the image off to the side?	Yes – it's a small mirror.
<u>*To Do:*</u> Place the small mirror on the meter-stick and slide it into the place where the screen image was, making sure the height of the mirror matches the height of the image on the screen. Tilt the large mirror's holder forward or backward as needed to adjust the height of the image *(See Illustration #20 on page 26).*	
<u>*To Say:*</u> If we take this little mirror and place it right where that image is, we can reflect that image off to the side, like this.	
Now the image is being reflected off over here. Remember that when light comes into a mirror at an angle, it's going to reflect back out at the same angle (point to the path the light is taking). So we need to look out here for the image. Move over here and look into the mirror from this side, can you see the moon image now? *(See Illustration #21 on page 27)*	Visitor looks for the image in the small mirror. There it is!

Leader's Role	Participants' Role (Anticipated)
Presentation Tip: You may notice multiple images in the small secondary mirror – tell your visitors to direct their attention to the brightest of the images. There can be internal reflections in the small mirror since it is just a regular mirror and not front-silvered.	
To Do: Hand the lens you are using as a magnifier to the visitor. (Some people, especially children, find it easier to use the small thinner lens as your "magnifier", but you may use the thicker lens. Use the one that's easier for your visitors.) *To Say:* Right – now look at the image again, then hold the magnifier between your eye and the moon image. See if you can get everything lined up so you can see the moon through the magnifier, which we call the eyepiece. Remember to hold the eyepiece so the image is focused. *(See Illustration #22 on page 28)*	Visitor takes lens and views the image in the little mirror. I see it!
To Say: Now, once again, imagine a tube here extending away from the mirror and a short tube sticking out the side with the eyepiece in it. You have a basic reflector telescope – a telescope that reflects the light off a mirror and concentrates it to make a bright image.	
How long do you think telescopes have been made THIS way – with a large mirror?	The last 50 years?
Isaac Newton designed the basics of this type of telescope over 300 years ago (in 1680's). And the design idea was so elegant and effective that it has not changed very much in all that time. The Hubble Space Telescope uses this basic technology – using a mirror to gather and concentrate light.	
Have fun tonight looking through instruments made of glass and mirrors whose origins go back 400 years!	Yeah!

Galileo's Refractor Telescope



Reflecting telescope



Presentation Tip:
Many backyard telescopes are of a Cassegrain design that has a secondary mirror which reflects the light back through a hole in the middle of the primary mirror to reach the eyepiece.

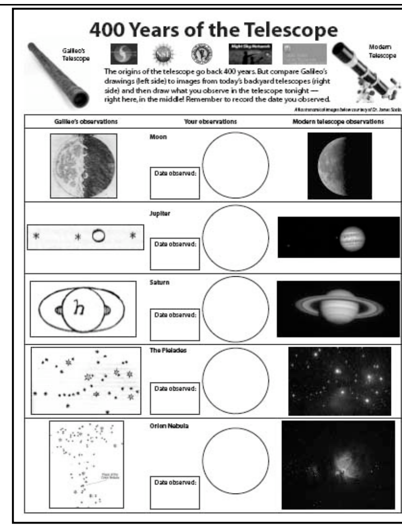
You can just explain to visitors who ask about this different design that the smaller mirror just reflects the light back through a hole in the large mirror. This is instead of reflecting the light off to the side.

The smaller mirror is already blocking some of the light that would reach the center of the large mirror. So having a hole there will not reduce the effectiveness of the telescope.   There is still plenty of light reflecting off the rest of the large mirror.

Glass & Mirrors: Handout "400 Years of the Telescope"

Leader's Role

<u>*To Do:*</u>
Pass around the "400 Years of the Telescope" handout to your visitors. This gives them a tool to view and sketch the same objects Galileo observed 400 years ago. As an extension activity for use with telescopes, show how Galileo's drawings compared to what we see through a modern backyard telescope. Then have your visitors draw what they see tonight.



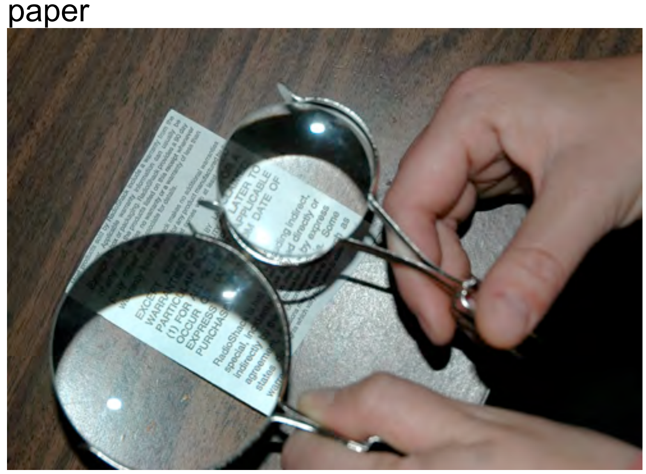
Note that all objects will not be visible at all times. Encourage visitors to come back when you know that Saturn, for example, will be visible. Use this as an opportunity to talk about how planets "wander" across the permanent patterns of background stars. Or about how different stars are visible at different times of year.

Galileo's telescope was not nearly as powerful as telescopes we use today and the glass he used was of very poor quality, but he had the benefits of very dark skies and a good dose of patience to help him.

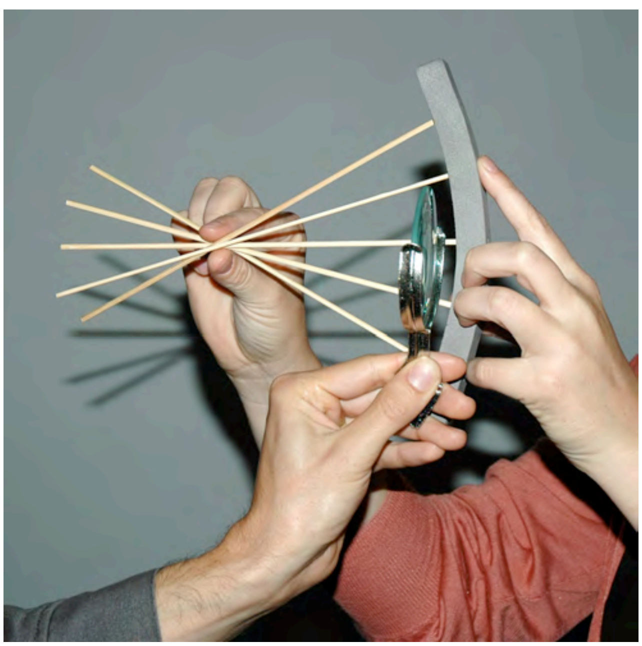
ILLUSTRATIONS

#1: Hold the two 50mm (smaller) diameter lenses over the paper with small type.

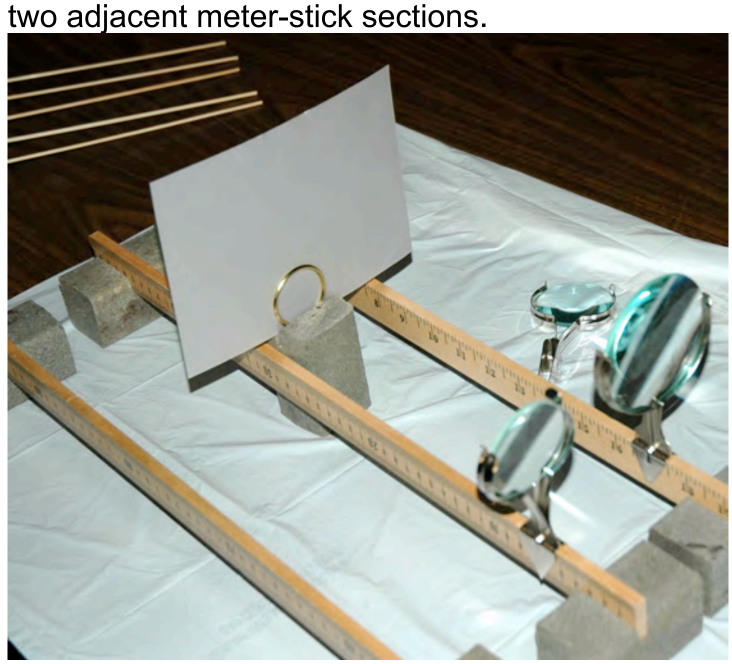
#2: Hold the 50mm diameter 200mm FL lens (thinner) and the 75mm diameter lens over the paper



#3: Use foam and sticks to illustrate the focal point.

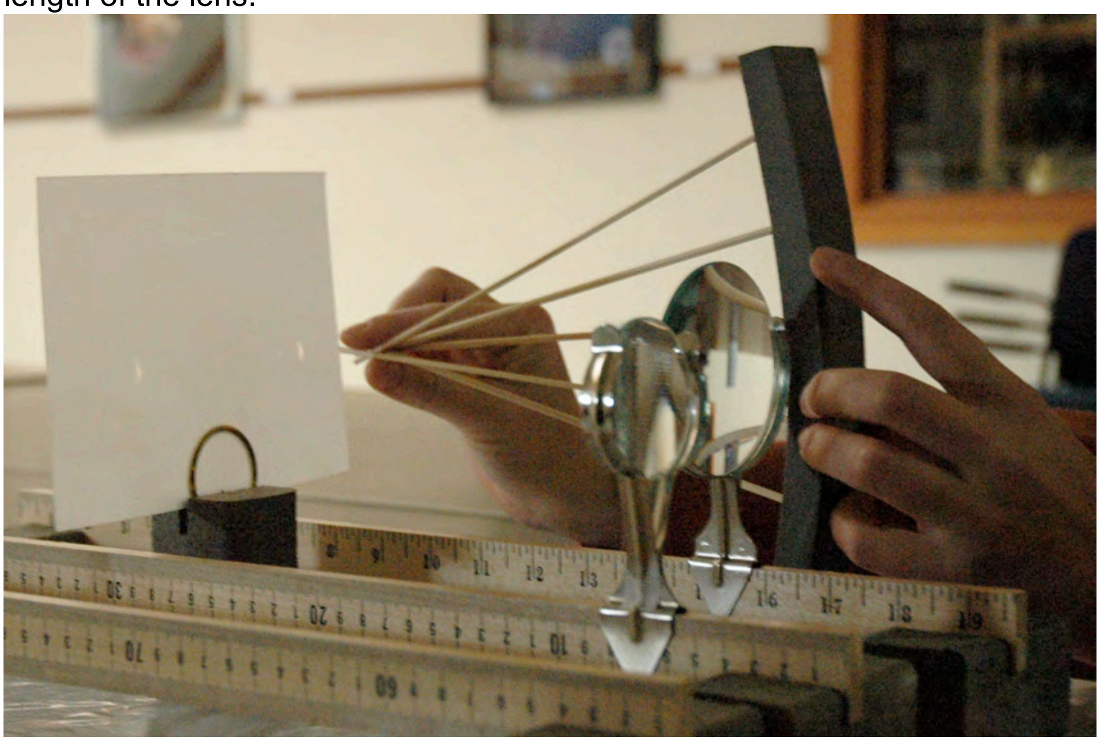


#4: Place the two "light-gathering" lenses on two adjacent meter-stick sections.

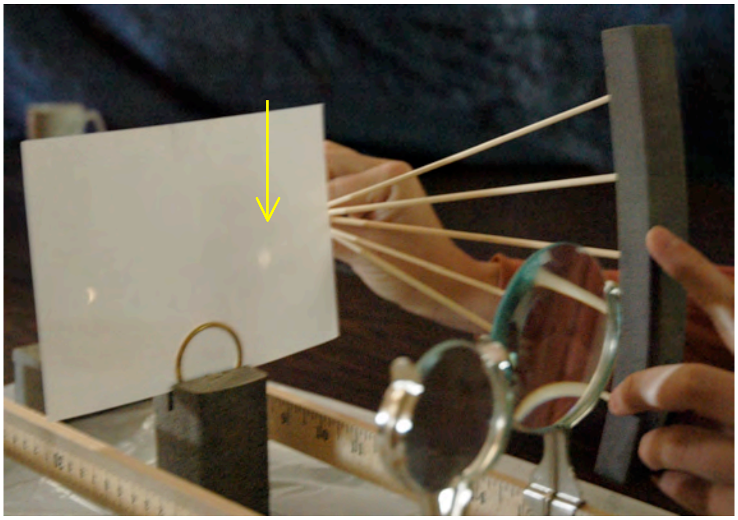


#5: Demonstrate how to move the lens.

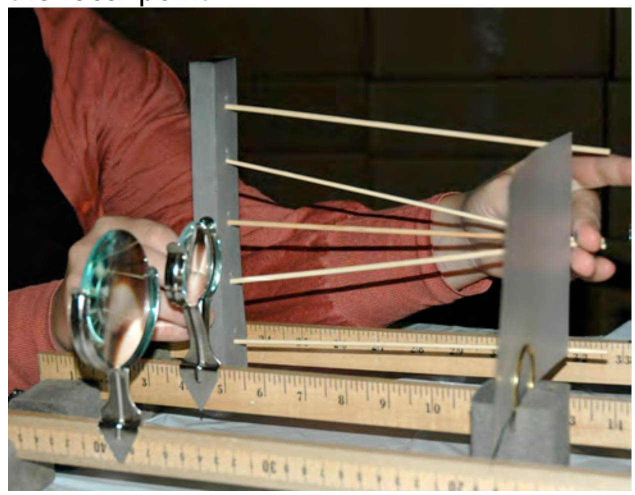
#6: Bend foam and sticks to a point with the focal length the same as the focal length of the lens.



#7: Some may not understand why the image goes in and out of focus. Notice that if the image is projected here, in back of the focal point, the light is spread out and you get an unfocused spot (see arrow below).

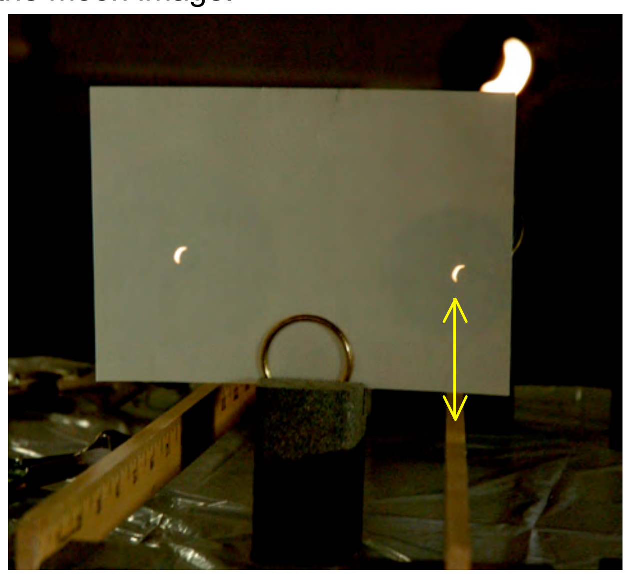


#8: Next to the smaller lens, take the 3 inner sticks and hold them together at the focal point.



#9: Using the smaller "light-gathering lens" is like making your eye this big!

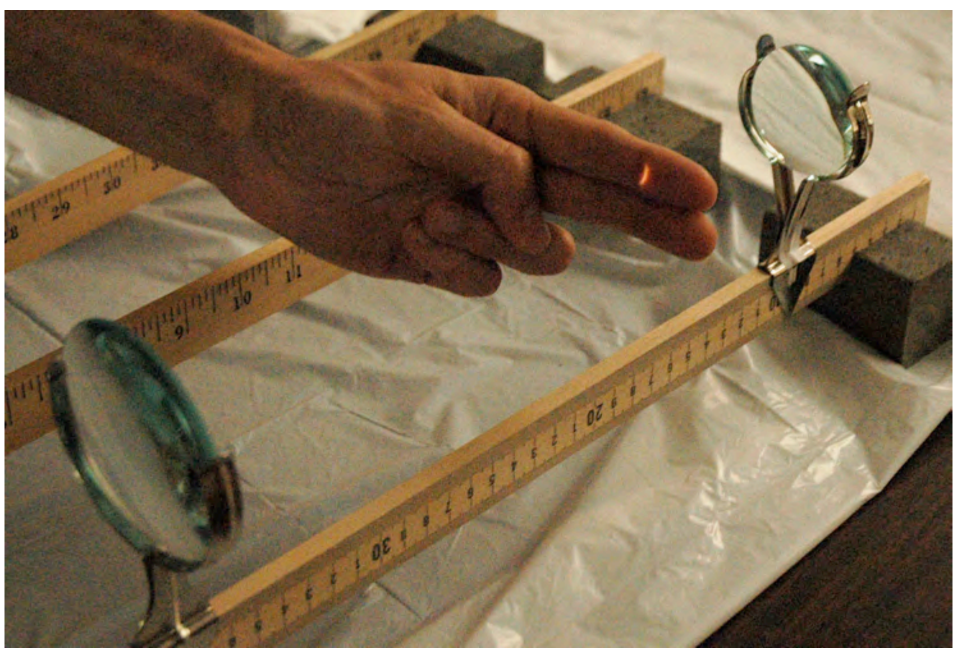
#10: Adjust the angle of the meter-stick so that the image on the screen is over the meter-stick (see arrow below). This aligns the lens to point directly toward the moon image.



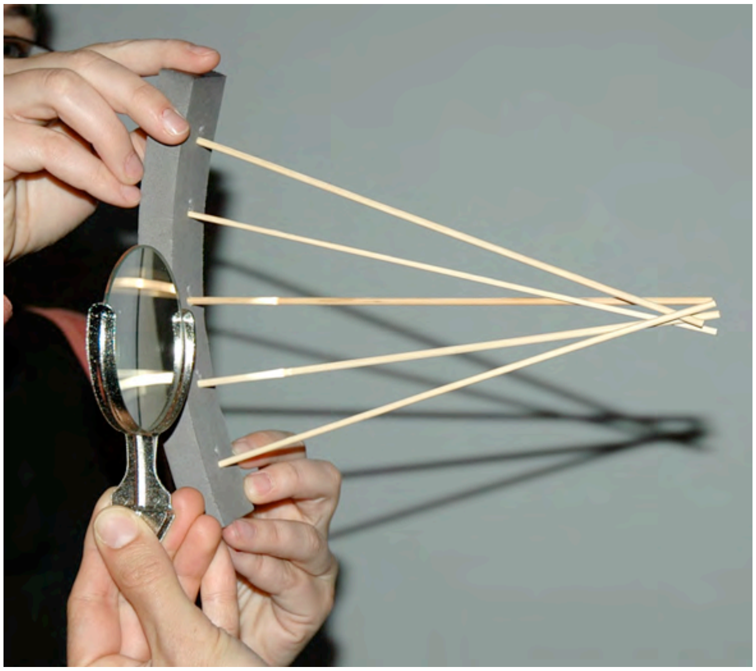
#11: Place the magnifier on the meter-stick section on the opposite side of the screen of the larger lens. Lean down to look through the lens at the image on the screen.

#12: Now look through the magnifier, called the eyepiece, because it's what we look through with our eye. What do you see?

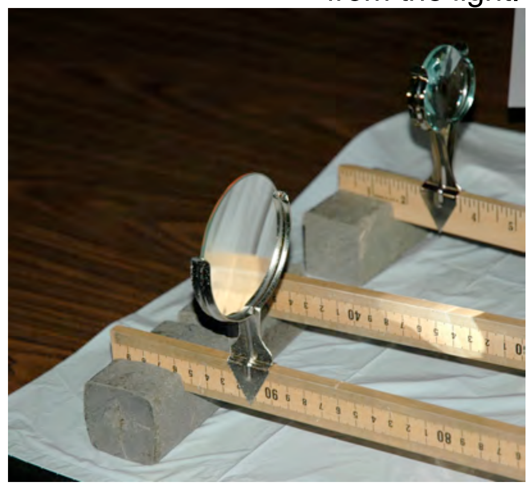
#13: Show that the concentrated image is still there in the space between the lenses. Put your finger in there – can you see the focused image on your finger?



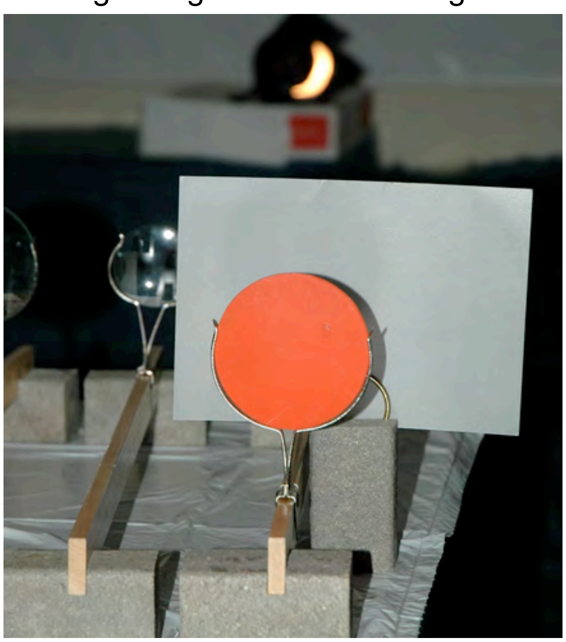
#14: If we have a flat mirror, the light hits the mirror and reflects straight back out, but with a curved mirror, the light hitting the mirror is bent and concentrated again.



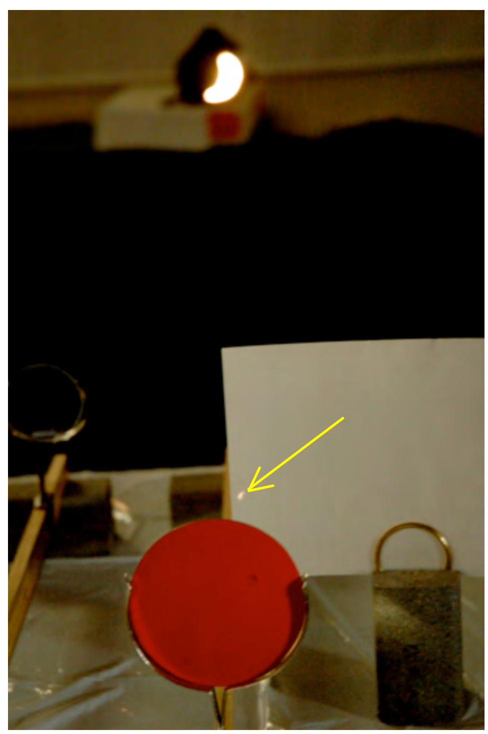
#15: Place mirror on third meter-stick section at the end farthest from the light.



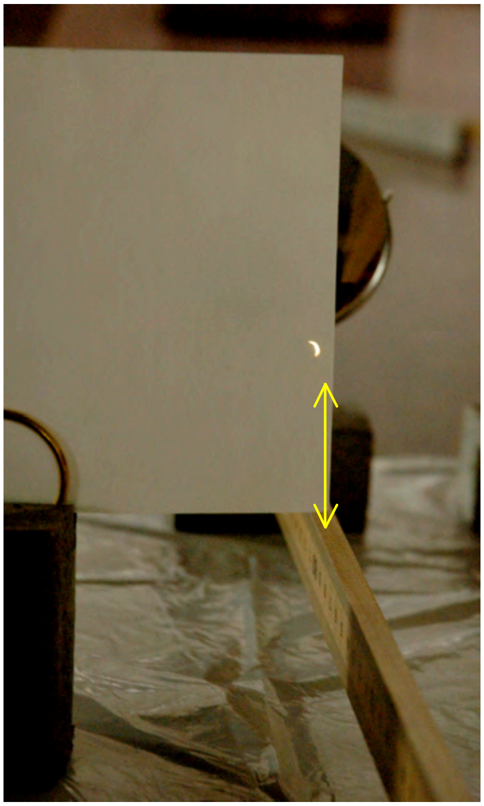
#16
Place screen in front of mirror, completely blocking the light from the flashlight.



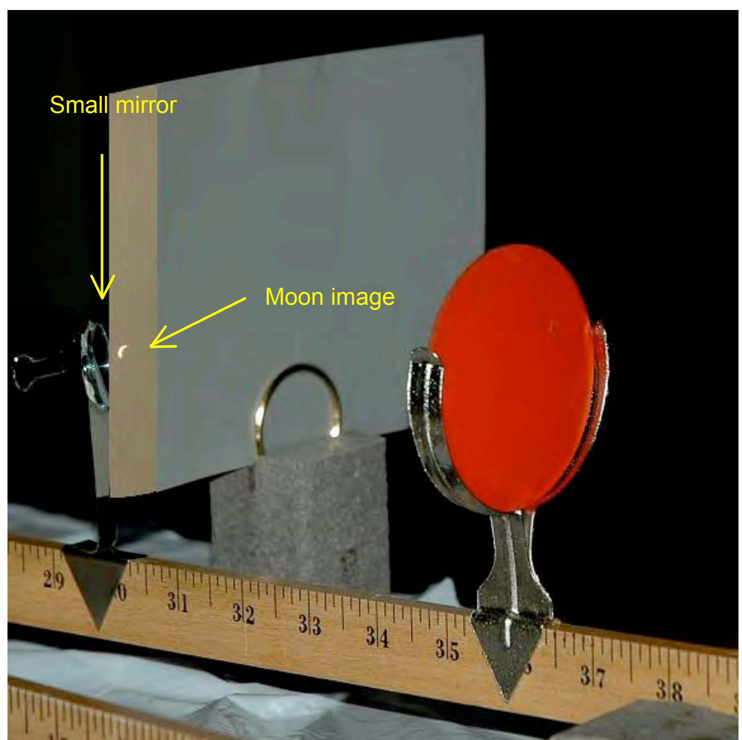
#17
Move the screen to the side so that at least some of the light is hitting the mirror and an image forms (see arrow).



#18: Adjust the angle of the meter-stick so that the image on the screen is over the meter-stick (see arrow below). This aligns the mirror to point directly toward the moon image.



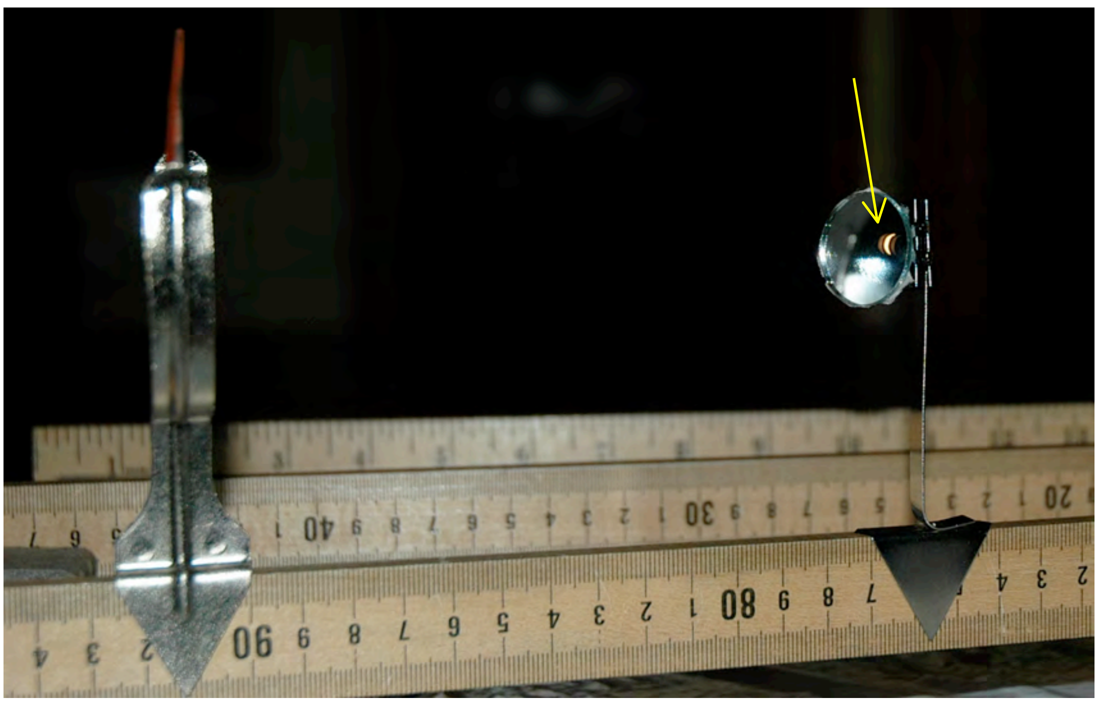
#19: Place the lens in front of the screen. Bend down and look through the lens. The moon image disappears – your head is in the way!



#20: Place the small mirror on the meter-stick and slide it into the place where the screen image was, adjusting the height of the mirror as needed to match the height of the moon image on the screen.

#21: Remember that when light comes into a mirror at an angle, it's going to reflect back out at the same angle. Move over here and look into the mirror from this side, can you see the moon image now?

(See below) What the visitor sees – the arrow is pointing to the moon image.



#22: Take the lens and see if you can get everything lined up so you can see the moon through the magnifier, or eyepiece. Remember to hold the eyepiece so the image is focused.

Troubleshooting

The images on the screen are too high or too low.

Check the seating of the lenses or mirror in their holders. Sometimes, during handling or transporting, the lens may have tilted slightly and no longer be vertical in the holder.

I can't see any images on the screen.

Make sure you've aligned the meter-sticks to point at the light.

Check the location of your light-gathering lenses – they need to be between the light and the screen.

Make sure you are using the thinner of the two smaller lenses as one of your light-gathering lenses.

If you are using the large mirror, make sure the screen is between the light and the mirror. Check that the screen is pulled off to the side so the screen is not blocking all the light from hitting the large mirror. *(See Illustration #17 on page 25)*

I can't get a clear image in the small round mirror OR I can't see ANY image in the small mirror.

Be sure the holder of the small mirror is placed on the meter-stick *at the focal point of the large mirror* – about 6 inches (15 cm) from the large mirror.

Make sure the small mirror is adjusted to the height of the image that you saw on the screen.

Try tilting the holder of the large mirror slightly backward to raise the level of the focused image or slightly forward to lower the focused image.

For additional help, see "Helpful Hints" on page 6.

Presentation Summary List

This summarizes the steps in the Glass & Mirrors demonstrations. Use this list to prompt your presentation.

Introduction: Difference between Magnifier and Light-gatherer

1. Test 2 smaller lenses for magnification.
2. Test thinner small lens and large lens for magnification.

Light Gathering Power

3. (Large lens & small thin lens) Which image is brighter?
4. Use foam & sticks to illustrate why larger lens has brighter image.

Magnifying the Image

5. Place MAGNIFIER lens on meter-stick behind the screen to have visitors view the image.
6. "Now image placing a tube around this and what do you have?"
7. 400-year old technology.

Mirrors for Gathering Light

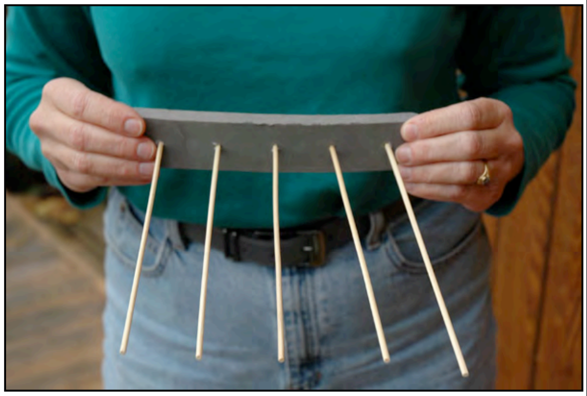
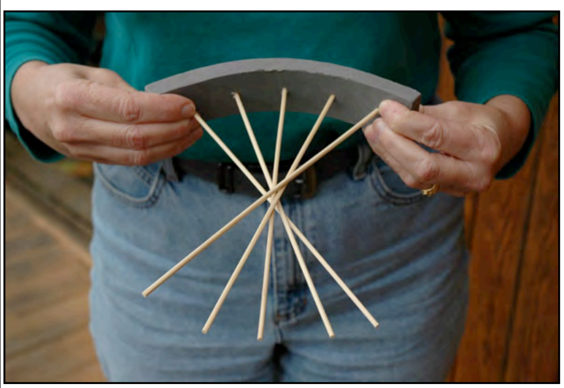
8. Flat mirror vs. curved mirror. Use foam & sticks to illustrate light path.
9. Have visitors focus image and line up image on screen over meter-stick.
10. Place small round mirror at location of focused image (at the focal point) to re-direct the image to the side.
11. "Now imagine a tube here extending away from the mirror and a short tube sticking out the side with the eyepiece in it." Newton's telescope design.
12. Technology over 300 years old.

Further Exploration

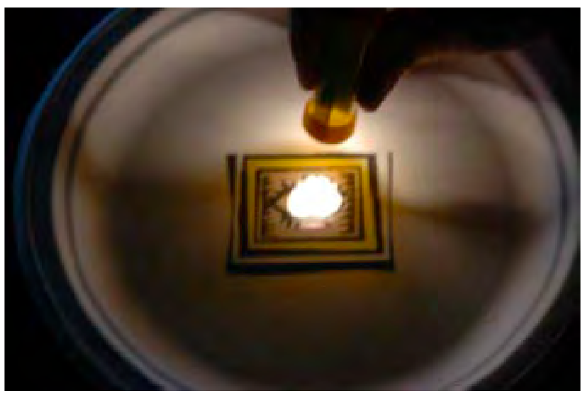
Glass & Mirrors: Why is the image upside down?

Leader's Role	**Participants' Roles (Anticipated)**
Key message for your visitors to take home: Many telescopes invert the image. The telescope may also flip the image right for left. These are effects of a curved mirror or lens.	
Materials: Spoon, foam with sticks. Use a shiny spoon that reflects your image well. You must be able to see yourself in the bowl of the spoon. Stainless steel usually works well.	
Presentation Tip: The only time you probably get this question is when you are looking at the Moon or at a terrestrial object.	
Question from visitor: The Moon doesn't look right. It looks upside down. *To Do:* Hand the visitor the spoon and, if it is too dark to otherwise see their reflection, shine a red light indirectly toward their face. *To Say:* Hold this spoon a couple feet from your face. 	
Alternate way, using telescope: If it is still daylight and you have a reflector telescope, ask them to stand about 5 to 8 feet in front of the telescope and look down the barrel – they may have to look off center.	
To Say: How do you look? 	Upside-down!
Why is your image upside-down?	I don't know.

To Do: Hold up foam and sticks. *To Say:* This telescope has a curved mirror in it to collect the light. When you look in a flat mirror, the light comes straight back out at you. The top spoke is where your forehead is and the bottom spoke is where your chin is. But a spoon is curved -- so is the telescope mirror. 	
To do: Curve the foam strip.  *To Say:* NOW where is your forehead and where is your chin?	Reversed!
That's the difference between astronomical telescopes and spotting scopes you might use to find birds. You could put one more mirror or lens in the path of the light in the telescope to turn the image right side up again, but with each additional element (lens or mirror), some light is lost. For astronomers it's more important not to lose that dim light than it is to have it the image "right" side up.	

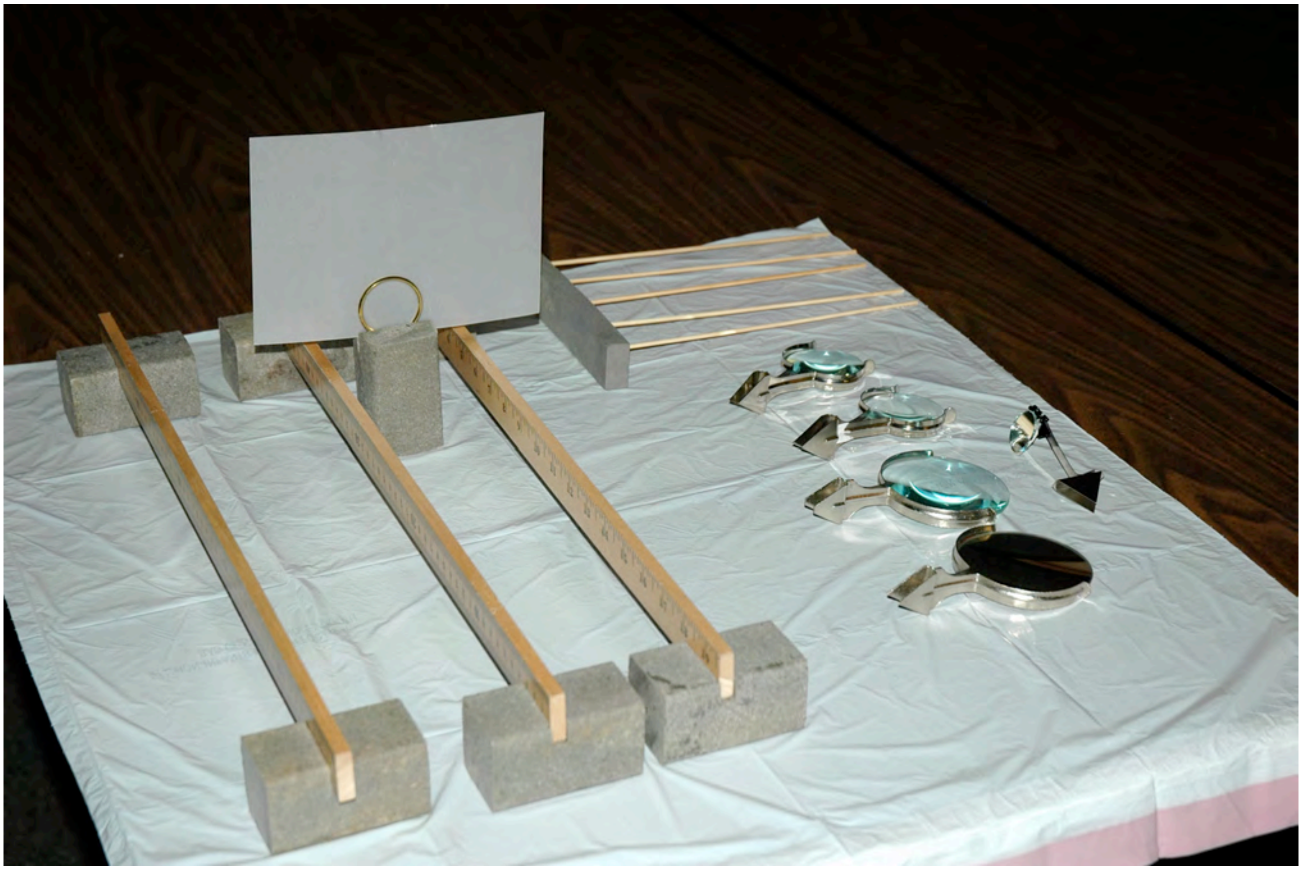
Leader's Role	Participants' Roles (Anticipated)
Presentation Tip: Many visitors might notice when looking in the spoon that when they raise their right hand, the opposite hand of their upside down reflection is raised.	
<u>*Question from visitor:*</u> Wait a second – when I raise my hand, the opposite hand is raised in my reflection. <u>*To Do*</u>: Hold foam and sticks horizontally.  Hand the foam and sticks to the visitor and ask them to figure it out or talk them through it while they bend the foam. <u>*To Say:*</u> Once again, when you look in a flat mirror, the light comes straight back out at you. Here's your right hand and here's your left. But a spoon is curved -- so is the telescope mirror. <u>*To Do:*</u> Curve the foam strip.  <u>*To Say:*</u> NOW where is your right hand?	

Glass & Mirrors: Light Spreads out with Distance

Leader's Role	Participants' Roles (Anticipated)
Key message for your visitors to take home: Although other telescope characteristics, like magnification, are sometimes referred to as the telescope's "power", the most important power of a telescope is its ability to collect a lot of light, determined by the aperture (i.e., the diameter of the telescope's large lens or mirror).	
Materials: Drawing of an eye on a paper plate, a small flashlight.	
To Say: By the time light from the universe reaches Earth, the light is very dim. The farther the light-emitting object is away from us, the dimmer its light appears to us here on Earth. Why? Light radiates. It spreads out as it leaves its source. Let's see what that means.	Answers
To Do: Draw an image of eye onto paper plate. Hold a small flashlight very near the eye.   Start very close to the eye then move the light away and watch how the light spreads out and dims.	
To Say: How much light is coming in here (indicating the pupil of the eye)?	Just that little amount.
(Refer to a circular plate representing a telescope mirror). "How much light is this one collecting?"	A lot more.

Leader's Role	Participants' Roles (Anticipated)
To Say: If I was to take this light to {that mountain top, over to that city, on top of that building} would you still be able to see it?	Probably not.
Right, less of its light is reaching us, because it is spreading out – a bit like water spraying out of your showerhead – the farther from the showerhead, the more the water is spread out.	
If you place a bottle cap in your tub to collect the water, are you going to collect much?	No.
How about if you had a pie pan? Would you collect more water?	Lots more.
The bottle cap represents how much light your eye can collect and the pie pan represents how much light a telescope mirror could collect.	
There is only so much light coming from an object each second. Little packets of light called photons. The farther you are away, the more the photons of light are spread out.	
A galaxy outside of the Milky Way is tremendously far away and its light is spread out in all directions, all over the universe. So only a little of its light, or photons, hits the surface of the Earth. But the light is spread out all over the side of the Earth facing that galaxy. The more of its photons we can collect, the more likely we are to see it. Telescopes have big mirrors to collect as much light as possible.	

Materials



<u>What materials from the ToolKit do I need?</u>

- Foam strip
- Skewer sticks
- Glue
- Concave mirror - 75 mm diameter x 150mmFL
- Lens: dbl convex 50mm diam x 200mm FL
- Lens: dbl convex 50mm diam x 75mm FL
- Lens: dbl convex 75mm diam x 200mm FL
- Lens paper pack of 50 sheets
- 2 - Lens Holder - 75mm lens
- 2 - Lens Holder - 38mm lens (for 50mm lenses)
- 3 – Meter-Stick sections
- Optic Bench Object Marker
- Screen Support
- Key ring for screen holder
- Optical Bench supports
- 1" round glass mirror
- Binder Clip
- 2 - Screens - Laminated Vellum
- 5 – Tyvek® Envelopes

- Labels (small) for each lens and mirror to put on the Tyvek® envelopes
- Black plastic sheeting square
- Crescent moon shape
- Wax paper square
- Flashlight & batteries
- Rubber band - to attach moon cutout to flashlight

What must I Supply:

- Scissors
- Tape
- Pencil
- Business card, book, magazine, or other paper with small writing on it.
- Box or books to raise flashlight to appropriate height.
- Table(s)
- Backup Batteries for lantern flashlight (optional)

For the "Further Exploration" Activities:

- Stainless steel spoon – you must be able to see yourself in the bowl of the spoon.
- 8" paper plate
- Drawing of an eye
- Small flashlight

What do I need to prepare?

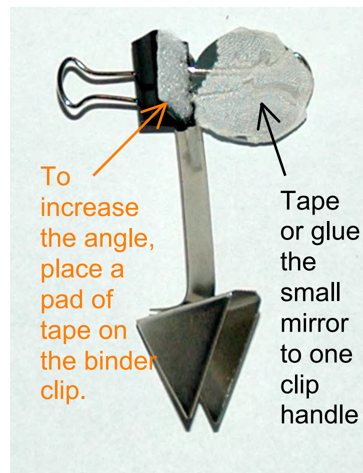
Mirrors and Lenses:

- Insert the three lenses and one mirror into the lens holders that fit them.
- Notice that the lens holders are two different sizes. Use the larger ones for the large lens and the mirror.
- Optional: Place labels on the Tyvek® envelopes for each lens or mirror.
- For storage, leave the lenses and mirror in their holders and insert them into the Tyvek® envelopes.

"Secondary" mirror assembly:

1. Tape or glue the flat one-inch round mirror to the binder clip as shown at right.
2. Attach the clip to the metal pointer.

3. The mirror should be roughly at a 45-degree angle to the meter-stick. If the mirror is at too narrow an angle, roll a small piece of tape into a pad and place it on the clip as shown. You may instead cut a small wedge from the holder's blue protective pad and attach that to the clip.
4. Store in a Tyvek® envelope.



Screen Assembly:

- If the key ring has a small metal ring attached it, remove the small ring and dispose of it.
- Press the key ring into the slot on the screen holder.
- Insert the screen into the key ring as shown.

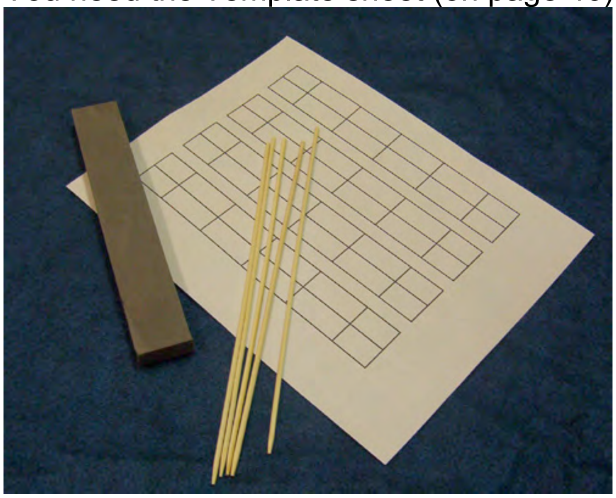
Moon-on-flashlight assembly:

- Use the square of black plastic sheeting.
- Draw or trace a 2" to 2.5" long crescent shape onto the middle of the plastic square.
- Using scissors (or a matte or X-acto® knife), cut out just the crescent shape: **DO NOT cut from the edge of the plastic.** If using scissors, you can fold the plastic in half, cut out a half-crescent, then unfold it to reveal the whole crescent.
- Spread a thin film of glue around the edge of the crescent opening and press the sheet of wax paper onto it. Allow to dry.
- Wrap the moon assembly over the front of the flashlight, positioning the moon shape so it is near the edge of the light.
- Secure with a rubber band.

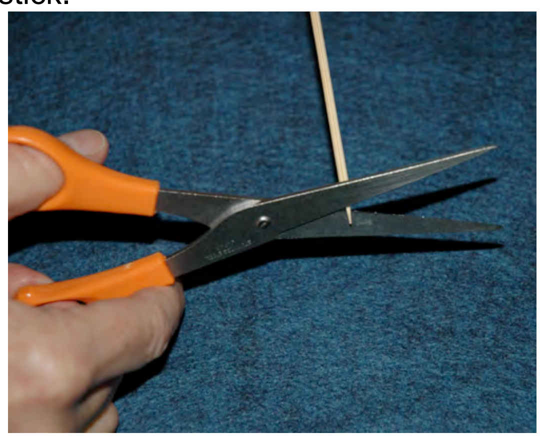
There are enough materials in the ToolKit to make two sets of the foam and sticks.

1. **To make the foam and sticks:**

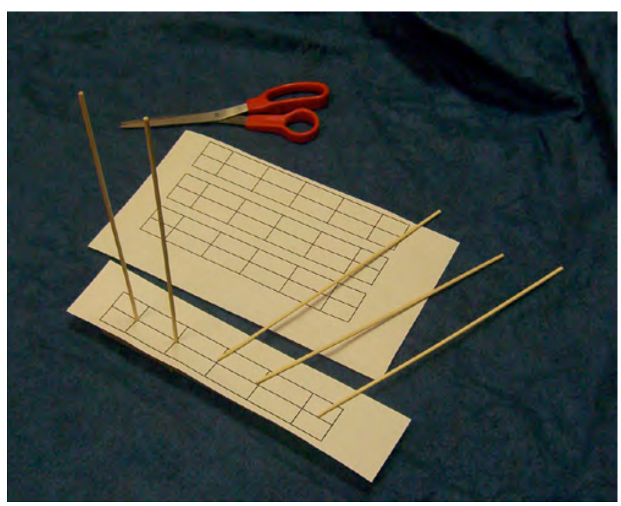
   a) You need the Template sheet (on page 46), five skewer sticks, and a foam strip.

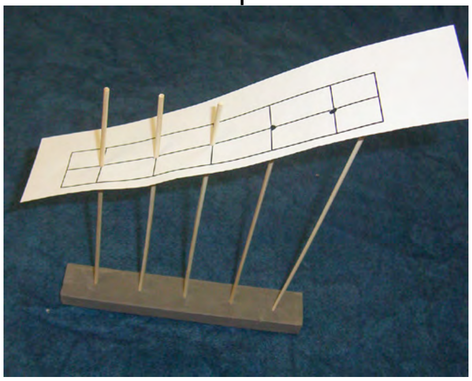
   b) With scissors you supply, trim about 1/4 inch off the sharp end of each skewer stick.

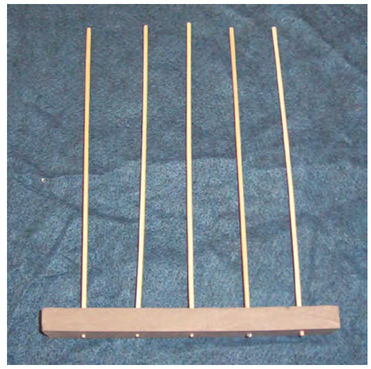
   

   c) Place one foam strip template on one of the foam strips and insert the skewer sticks into foam strip at the marks – try to make them as vertical and parallel as possible.

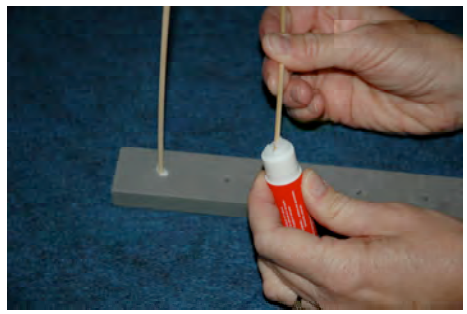
d) Remove the template.





e) **Loose sticks?** If the sticks in the foam get loose after several uses, you can either:

- glue them into the holes by using white glue or by wiping the end of each stick over a glue stick (see photo to the right)



Or move each stick just to the right or left and make a new hole. This option will only work for 3 or 4 relocations of the stick before you'll need a new piece of foam.

Where do I get additional materials?

Websites listed here are where the materials in the ToolKit were obtained. You may choose to acquire the materials from other sources.

Foam & Sticks

1. Skewer sticks: grocery store
2. Foam strip: You can use any fairly dense soft foam (like the material some computers come packed in) or you can order the material included in the ToolKit at: http://www.oneoceankayaks.com/ - the material is "Minicel Foam". Order the 5/8" thickness. A 20"x24" sheet will make 48 strips that are 1-1/4" x 8". You can use a utility knife to cut the foam.
3. Foam Strip Template: See page 46.
4. Glue: Office supply store

Lenses and Mirrors

5. Concave mirror - 75 mm diameter x 150mmFL www.schoolmasters.com
6. Lens: dbl convex 50mm diam x 200mm FL http://www.surplusshed.com/
7. Lens: dbl convex 50mm diam x 75mm FL http://www.surplusshed.com/
8. Lens: dbl convex 75mm diam x 200mm FL http://www.surplusshed.com/
9. Lens paper : School science materials suppliers
10. Lens Holder - 75mm lens http://www.scienceartandmore.com/
11. Lens Holder - 38mm lens (for 50mm lenses) http://www.scienceartandmore.com/
12. Tyvek® 3 1/2 x 6 1/2 Open End Coin Envelope http://papermartinc.com/

Optical Bench

13. Meter Stick - cut in half http://wardsci.com/
14. Screen Support: As a substitute, use a paper cup or Styrofoam cup with a slit cut in it. (See photo to the right)

15. Key ring for screen holder: Hardware Store
16. Optical Bench supports: These are made from a composite material called Trex®. If you have a wood shop, you can make your own out of wood and use a router or dado blade to make the groove for the meter stick. You can purchase metal supports commercially by searching the Internet for "meter stick optical bench accessories."
17. You may also want to search the Internet for "meter stick optical bench" or "meter stick optical bench accessories" to get some of the parts you need for the stick, supports for the stick, and some of the lens holders and lenses.
18. Screen - Laminated Vellum. Vellum can be purchased at an office supply store. Printing companies often have laminating services.

“Secondary” Mirror

19. 1" round glass mirror (qtys of 144): C.O.D. Wholesale (codwholesale.com) or Party supply store.
20. Binder Clip – small: Office supply store
21. Optical Bench Object Marker (holder for the small mirror) http://www.hometrainingtools.com/

Flashlight Assembly

22. Black plastic sheeting (“visqueen”): 8”x8" (20cm x 20cm). Available at hardware and construction stores. You can also use black construction paper.
23. Crescent moon shape (not available commercially). You can make your own template.
24. Wax paper: Grocery store.
25. Flashlight and batteries: Hardware Store.

Visitor Handout: “400 Years of the Telescope”

26. Visitor handouts: find the master on page 45.

Suggestions from the ToolKit Testers

The Astronomical Society of the Pacific wishes to thank the members of the astronomy clubs who reviewed and tested these activities.

- Cameron Park Rotary Community Observatory
- Eastbay Astronomical Society
- Mt. Diablo Astronomical Society
- San Mateo County Astronomical Society
- San Francisco Astronomical Association
- Sonoma County Astronomical Society

Here are their tips for a successful presentation:

- Spend some time with the ToolKit first, play "what ifs" with placement of the lenses. Explore!

- It's OK to touch the lenses in the ToolKit – they're not coated. It really does help your visitor understand their shape if you let them touch.

- Make sure your visitors know it's really hands-on:
  - Put the lenses and mirror in their hands.
  - Then tell them, "That's the last piece of glass you'll touch tonight…"

- Practice!

- The script works well for preparation, but use the Presentation Summary List on page 30 for the presentation itself.

- If you're in a new environment, be sure to try out the lighting and alignments before you start your presentation. You may need to make adjustments.

- If your audience is likely to be mostly adults, you might consider setting up on a taller table or countertop to raise the whole demo up so your visitors don't have to bend over so far to see through the lenses. As an alternative, you might provide a chair for taller people to sit on to get down to the height of the lenses.

- Leave the lenses and mirror in their holders and just store them in their envelopes. It makes setup much faster.

- Try using both the small lenses as eyepieces (or the magnifiers) to demonstrate why we use different eyepieces to magnify the image formed by the objective.

400 Years of the Telescope

PBS

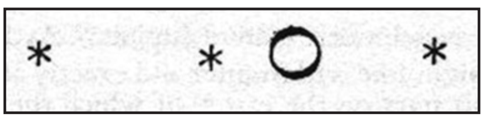
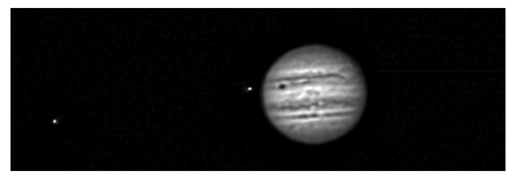
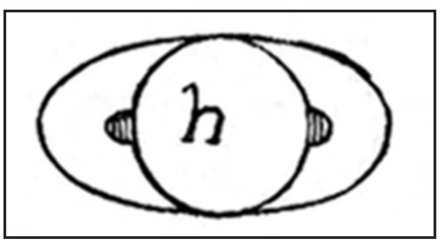
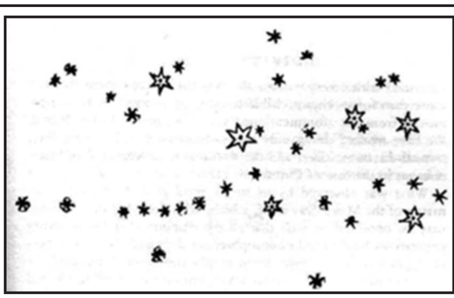
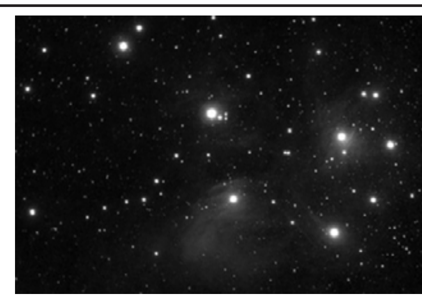
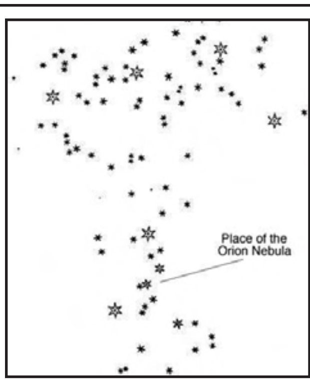
Galileo's Telescope

INTERSTELLAR STUDIOS · NSF · Astronomical Society of the Pacific · Night Sky Network · 400 Years of the Telescope

Modern Telescope

The origins of the telescope go back 400 years. But compare Galileo's drawings (left side) to images from today's backyard telescopes (right side) and then draw what you observe in the telescope tonight — right here, in the middle! Remember to record the date you observed.

All astronomical images below courtesy of Dr. James Scala.

Galileo's observations	Your observations	Modern telescope observations
	**Moon** Date observed:	
	**Jupiter** Date observed:	
	**Saturn** Date observed:	
	**The Pleiades** Date observed:	
	**Orion Nebula** Date observed:	

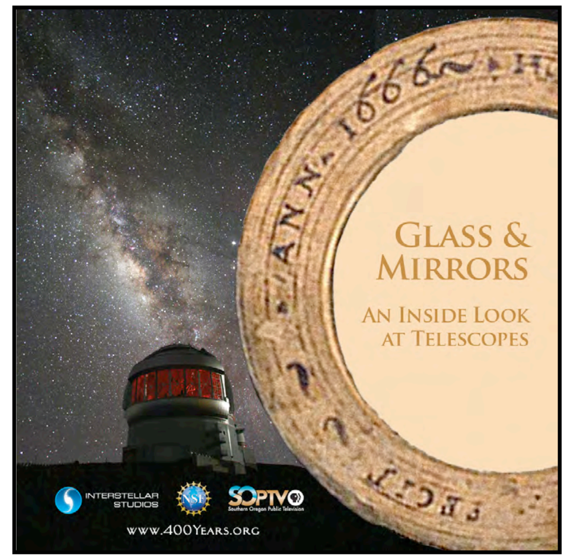
FOAM STRIP TEMPLATES

Glass & Mirrors Outreach ToolKit - Bag #1 of 2

An Inside Look at Telescopes

Telescopes are one of the most important instruments used to reveal the secrets of the universe. Our view of the universe and our place in it has been continually altered in our quest for understanding the phenomena observed in the night sky through our telescopes.

But how do these amazing instruments actually work? Almost all optical telescopes are built on a very simple design. There have been variations on the basic design, but the idea of using glass or mirrors to collect and focus light has remained the same for the last four centuries. This ToolKit allows you to create a "cutaway" telescope to clearly show how telescopes work.



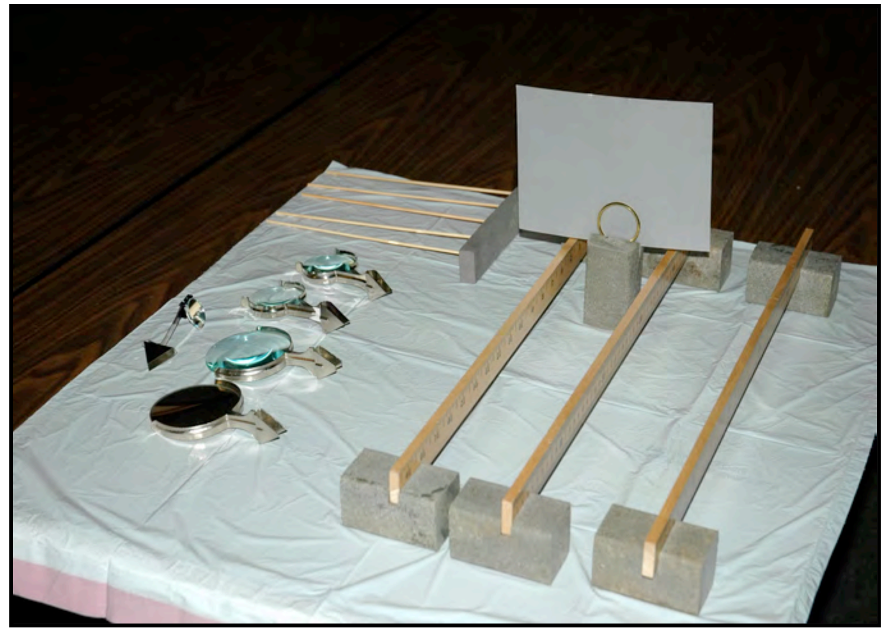
GETTING STARTED

1. **INSERT "MANUAL & RESOURCES CD" INTO YOUR COMPUTER. Click on GMManual.pdf to navigate through the ToolKit Manual. You need the free Adobe Acrobat Reader to view the manual: http://get.adobe.com/reader/.**
2. **For best results copy the entire CD onto your computer in any folder you choose.**
3. **VIEW THE TRAINING VIDEO as you review materials in the ToolKit – this is a DVD labeled "Training Video DVD." This explains how to assemble and use the materials.**
4. Questions? Contact nightskyinfo@astrosociety.org

Contents of this bag:

Manual & Resources CD
Training Video DVD
2 Foam strips
10 Skewer sticks
Template for stick placement in foam
Moon cutout
Glue
2 larger Lens Holders
2 smaller Lens Holders

Glass & Mirrors Outreach ToolKit - Bag #2 of 2



Contents of this bag:

Packed in padded Bag:

- Concave mirror: 75 mm diameter x 150mm FL
- Lens: dbl convex 50mm diameter x 200mm FL
- Lens: dbl convex 50mm diameter x 75mm FL
- Lens: dbl convex 75mm diameter x 200mm FL

2 Screens of laminated vellum
Key ring
Lens paper
5 Tyvek® Envelopes, one of them containing:
    1" round glass mirror
    Binder Clip
    Optic Bench Object Marker

Labels for each lens or mirror to put on the Tyvek® envelopes
A square of black plastic sheeting
Wax paper squares
Rubber band
Visitor handout – sample set

Loose in the box:

Flashlight & batteries
3 lengths of half Meter Sticks
6 meter-stick supports
Screen Support